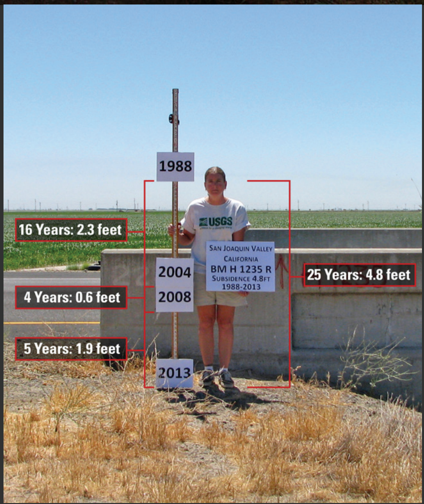
MERCED SGMA

Merced Groundwater Subbasin

GROUNDWATER SUSTAINABILITY PLAN

Image courtesy: Veronica Adrover/UC Merced



November 2019
Revised July 2022

Woodard & Curran

MERCED GROUNDWATER SUBBASIN GROUNDWATER SUSTAINABILITY PLAN

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ACRONYMS AND ABBREVIATIONS

Acronym	Definition
μg/L	micrograms per liter
AB	Assembly Bill
AF	acre-feet
AFY	acre-feet per year
As	Arsenic
ASO	Airborne Snow Observatory
AWMP	Agricultural Water Management Plan
bgs	below ground surface
BMP	Best Management Practices
CALSIMETAW	California Simulation of Evapotranspiration of Applied Water
CASGEM	California Statewide Groundwater Elevation Monitoring Program
CCR	California Code of Regulations
CDEC	California Data Exchange Center
CDFW	California Department of Fish and Wildlife
CDL	Cropland Data Layer
CDP	Census Designated Place
CDPH	California Department of Public Health
CDPR	California Department of Pesticide Regulation
CEDEN	California Environmental Data Exchange Network
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CGPF	CalSim II Generated Perturbation Factors
CGPS	continuous global positioning system
CGS	California Geological Survey
Cl	chloride
CPT	cone penetration test
Cr^6	Hexavalent Chromium
CSD	Community Services District
CVDRMP	Central Valley Dairy Representative Monitoring Program
CVGM	Central Valley Groundwater Monitoring Collaborative
CVHM	Central Valley Hydrologic Model
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
CWC	California Water Code
CWD	Chowchilla Water District

CWSRF	Clean Water State Revolving Fund
DAC	disadvantaged community
DBCP	dibromochloropropane
DDW	Division of Drinking Water
DHS	Department of Health Services
DLR	Detection Limit for Purposes of Reporting
DMS	Data Management System
DPR	Department of Pesticide Regulation
DTSC	Department of Toxic Substances Control
DWR	Department of Water Resources
DWSRF	Drinking Water State Revolving Fund
EC	electrical conductivity
EDB	ethylene dibromide
EPA	Environmental Protection Agency
ESJWQC	East San Joaquin Water Quality Coalition
ET / ETo	evapotranspiration / reference evapotranspiration
EWMP	Efficient Water Management Practices
F	Fahrenheit
Fe	iron
FEIS	Final Environmental Impact Statement
FERC	Federal Energy Regulatory Commission
Flood-MAR	Flood-Managed Aquifer Recharge
ft	feet
GAMA	Groundwater Ambient Monitoring and Assessment
GAR	Groundwater Quality Assessment Report
GCM	global climate model
GDE	Groundwater Dependent Ecosystem
GICIMA	Groundwater Elevation Monitoring Groundwater Information Center Interactive Mapping Application
GIS	Geographic Information System
GPCD	gallons per capita per day
gpm	gallons per minute
GPS	global positioning system
GQTM	Groundwater Quality Trend Monitoring
GSA	Groundwater Sustainability Agency
GSAs	MIUGSA, MSGSA, and TIWD GSA-1
GSP	Groundwater Sustainability Plan

HCM	Hydrogeologic Conceptual Model
HEC-HMS	Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center River Analysis System
HUC	Hydrologic Unit Code
HVA	high vulnerability area
IDC	IWFM Demand Calculator
ILRP	Irrigated Lands Regulatory Program
IM	interim milestone
IRWM	Integrated Regional Water Management
IRWMP	Integrated Regional Water Management Plan
IWFM	Integrated Water Flow Model
JPA	Joint Powers Authority
LGAWD	Le Grand Athlone Water District
LIDAR	Light Detection and Ranging
LOCA	local analogs method
LTMWC	Lone Tree Mutual Water Company
LUST	Leaking Underground Storage Tank
MAF	million acre-feet
MAGPI	Merced Area Groundwater Pool Interests
MCL	Maximum Contaminant Level
MCWD	Merquin County Water District
MercedWRM	Merced Water Resources Model
METRIC	Mapping Evapotranspiration at High Resolution and Internalized Calibration
mg/L	milligrams per liter
MID	Merced Irrigation District
MIDH20	Merced Irrigation District Hydrologic and Hydraulic Optimization
MIRWMA	Merced Integrated Regional Water Management Authority
MIUGSA	Merced Irrigation-Urban Groundwater Sustainability
Mn	manganese
MO	measurable objective
MOA	memorandum of agreement
MOI	memorandum of intent
MOU	Memorandum of Understanding
MSGSA	Merced Subbasin Groundwater Sustainability Agency
MSL	Mean Sea Level
MT	minimum threshold
MTBE	Methyl Tertiary Butyl Ether

N	nitrogen
NCCAG	Natural Communities Commonly Associated with Groundwater
NEPA	National Environmental Policy Act
NO_3	nitrate
NTU	Nephelometric Turbidity Unit
NWIS	National Water Information System
NWR	National Wildlife Refuge
OWTS	onsite wastewater treatment systems
PBO	Plate Boundary Observatory
PCBs	polychlorinated biphenyls
PCE	tetrachloroethylene
pCi/L	picoCuries per liter of air
PFOA	perfluorooctantoic acid
PFOS	perfluorooctanesulfonic acid
PRISM	Precipitation-Elevation Regressions on Independent Slopes Model
PRMS	Precipitation Runoff Model System
PWS	Public Water System
RCP	representative climate pathway
RTS	real time simulation model
RWQCB	Regional Water Quality Control Board
SB	Senate Bill
SCRO	DWR's South Central Region Office
SDAC	Severely Disadvantaged Community
SED	Substitute Environmental Document
SGMA	Sustainable Groundwater Management Act
SHE	Self-Help Enterprises
SJRRP	San Joaquin River Restoration Program
SMCL	secondary maximum contaminant level
SMMWC	Sandy Mush Mutual Water Company
SNMP	Salt and Nutrient Management Plan
SOI	Sphere of Influence
SRA	State Recreation Area
SSURGO	Soil Survey Geographic Database
Subbasin	Merced Subbasin
SWD	Stevinson Water District
SWRCB	State Water Resources Control Board
TCA	1,1,1-trichloroethane

TCE	trichloroethylene
TCP	1,2,3-trichloropropane
TDS	total dissolved solids
TFP	Tolladay, Fremming & Parson
TIWD	Turner Island Water District
TIWD GSA-1	Turner Island Water District Groundwater Sustainability Agency #1
TM	Technical Memorandum
TNC	The Nature Conservancy
TON	Threshold Odor Number
UCM or UC Merced	University of California Merced
umhos/cm	micromhos per centimeter
USACOE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish & Wildlife Service
USGS	United States Geological Survey
UWMP	Urban Water Management Plan
VIC	Variable Infiltration Capacity
VOC	volatile organic compound
WDL	Water Data Library
WDR	waste discharge requirements
WEAP	Water Evaluation and Planning System
WRIMS	Water Resource Integrated Modeling System (formerly CalSim II)
WY	Water Year

EXECUTIVE SUMMARY

ES-1. INTRODUCTION AND PLAN AREA

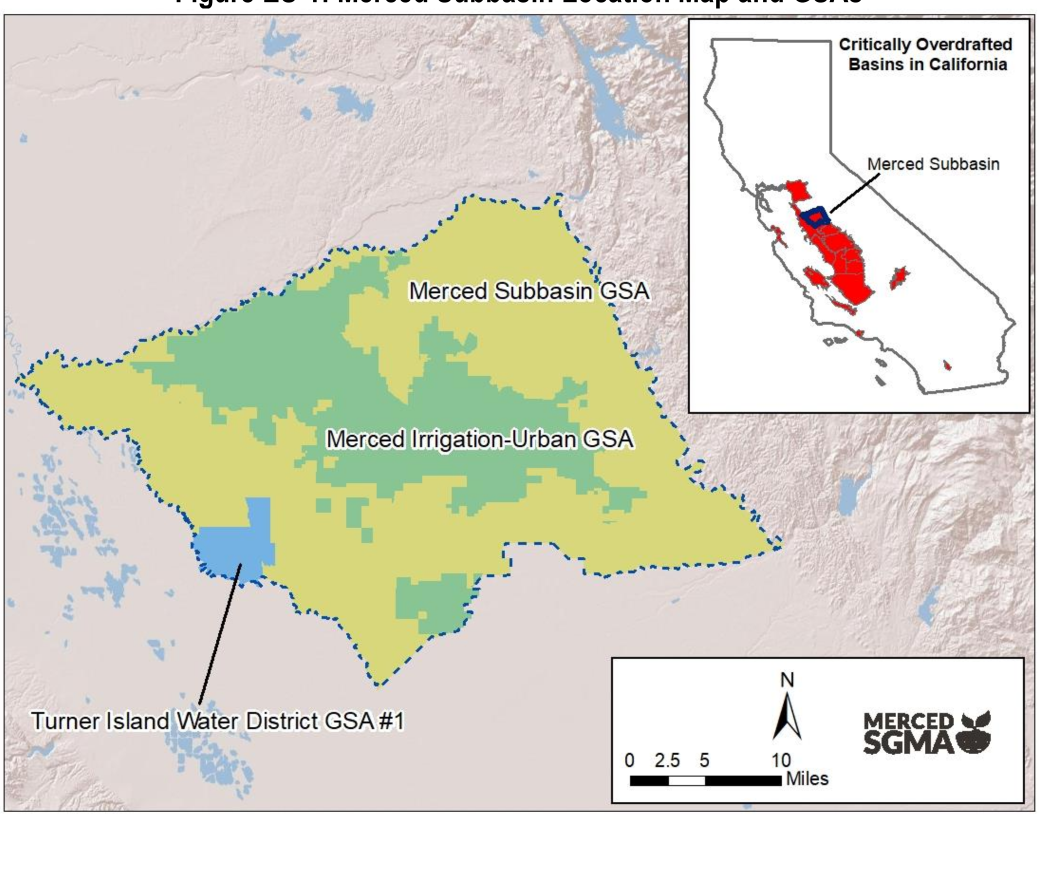
The Sustainable Groundwater Management Act (SGMA), passed in 2014, requires the formation of local Groundwater Sustainability Agencies (GSAs) to oversee the development and implementation of Groundwater Sustainability Plans (GSPs), with the ultimate goal of achieving sustainable management of California's groundwater basins. The purpose of this Groundwater Sustainability Plan is to bring the Merced Groundwater Basin (Merced Subbasin or Subbasin), a critically overdrafted basin located within the San Joaquin Valley (see Figure ES-1), into sustainable groundwater management by 2040. The Subbasin is heavily reliant on groundwater, and users recognize the basin has been in overdraft for a long period of time.

The County of Merced and water districts and cities within the Merced Subbasin formed three GSAs in accordance with SGMA: Merced Irrigation-Urban Groundwater Sustainability Agency (MIUGSA), Merced Subbasin Groundwater Sustainability Agency (MSGSA), and Turner Island Water District Groundwater Sustainability Agency #1 (TIWD GSA-1) (see Figure ES-1). The three GSAs coordinated efforts to develop this GSP for the Subbasin. With the adoption of this GSP, the GSAs will adopt the following sustainability goal for the Merced Subbasin:

> **"Achieve sustainable groundwater management on a long-term average basis by increasing recharge and/or reducing groundwater pumping, while avoiding undesirable results."**

This goal will be achieved by allocating a portion of the estimated Subbasin sustainable yield to each of the three GSAs and coordinating the implementation of programs and projects to increase both direct and in-lieu groundwater recharge, which will in turn increase the groundwater and / or surface water available in the Subbasin.

Figure ES-1: Merced Subbasin Location Map and GSAs



Development of the GSP was guided by a Coordinating Committee composed of members appointed by the GSA Boards to provide recommendations on technical and substantive basin-wide issues. The Coordinating Committee and GSA Boards were also informed by a Stakeholder Advisory Committee, which consisted of a broad group of groundwater beneficial users (also appointed by the GSA Boards) to review groundwater conditions, management issues and needs, and projects and management actions to improve sustainability in the basin. Extensive outreach was also conducted to seek input from additional beneficial users of groundwater through multiple venues including public workshops held in locations specifically selected to provide access to disadvantaged communities. Figure ES-2 illustrates the relationship among the groups described above.

Figure ES-2: Diagram of Levels of Engagement and Decision-Making

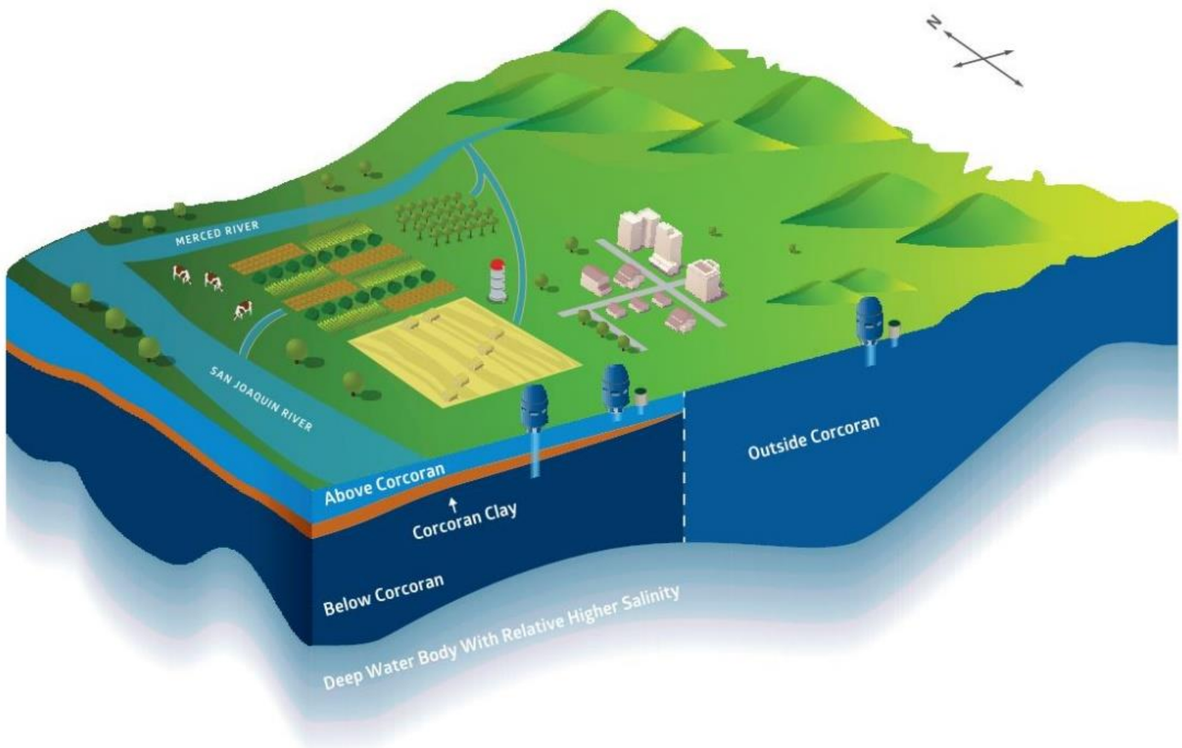
As of July 2022, the GSP has been updated in several key places to respond to comments and corrective actions contained in the *Statement of Findings Regarding the Determination of Incomplete Status of the San Joaquin Valley - Merced Subbasin Groundwater Sustainability Plan* (DWR, 2022). GSP Annual Reports submitted in April 2020, 2021, and 2022 contain more recent information on basin conditions and GSP implementation status. A redlined version of the GSP that highlights the edits can be found on MercedSGMA.org.

ES-2. BASIN SETTING

Hydrogeologic Conceptual Model

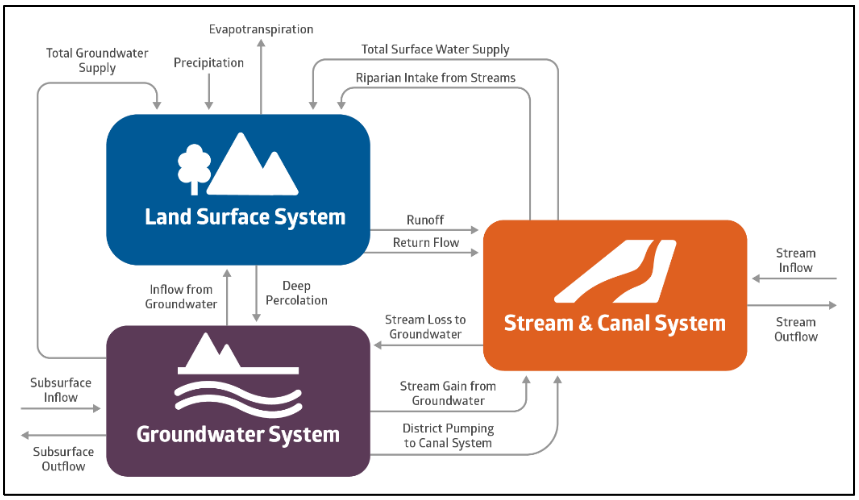
The Merced Subbasin contains three principal aquifers that are defined by their relationship to the Corcoran Clay aquitard, a laterally-extensive silt and clay layer that underlies approximately the western half of the Subbasin and acts as a significant confining layer. The **Above Corcoran Principal Aquifer** includes all aquifer units that exist above the Corcoran Clay Aquitard and generally contains moderate to large hydraulic conductivities and yields for domestic and irrigation uses. The **Below Corcoran Principal Aquifer** includes all aquifer units that exist below the Corcoran Clay Aquitard and contains hydraulic conductivities and yields ranging from small to large for irrigation as well as some domestic and municipal uses. The **Outside Corcoran Principal Aquifer** includes all aquifers that exist outside of the eastern lateral extent of the Corcoran Clay. The Outside Corcoran Principal Aquifer is connected laterally with the Above Corcoran Principal Aquifer at shallower depths and the Below Corcoran Principal Aquifer at deeper depths. Major uses of water in the Outside Corcoran Principal Aquifer include irrigation, domestic, and municipal uses. The Principal Aquifers are underlain by a deep aquifer with higher salinity relative to the principal aquifers. See Figure ES-3 for a 3D illustration demonstrating the relationship between the principal aquifers and Corcoran Clay aquitard

Figure ES-3: 3D Illustration of Merced Subbasin Principal Aquifers and Aquitard



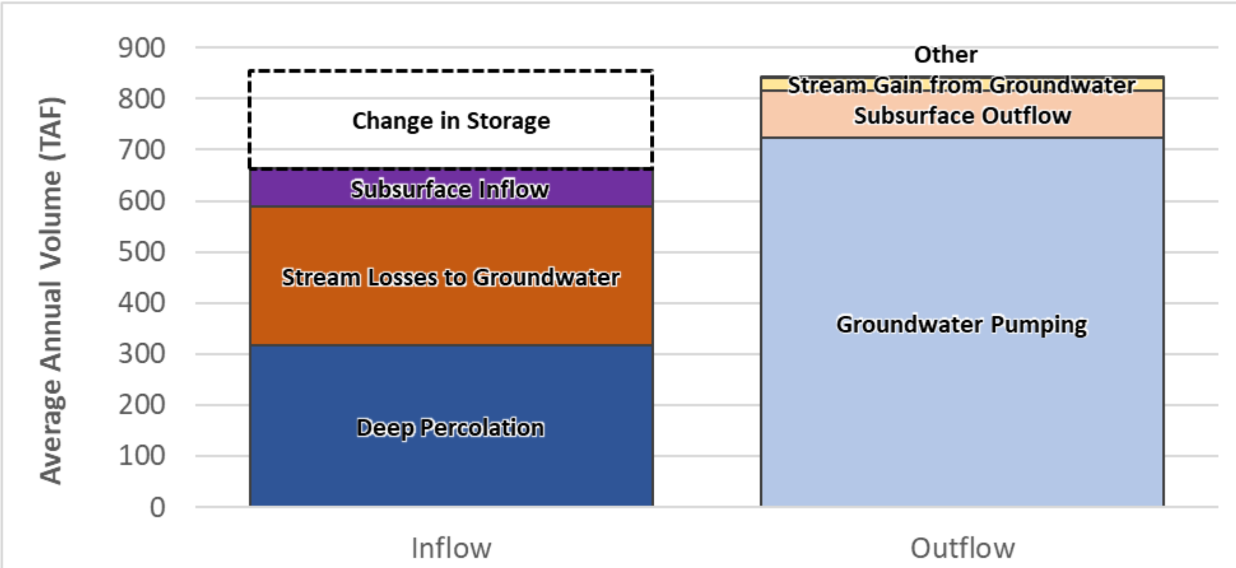
Water Budget Information

Figure ES-4: Generalized Water Budget Diagram



Water budgets provide quantitative accounting of water entering and leaving the Merced Subbasin and can be used to help estimate the extent of overdraft occurring now and in the future. Consistent with SGMA requirements, water budgets for historical, current, projected, and sustainable conditions were developed for the Merced Subbasin. These water budgets were developed using the Merced Water Resources Model (MercedWRM), a fully integrated surface and groundwater flow model developed and calibrated specifically for the Subbasin. See Figure ES-4 for a conceptual diagram of the inputs and outputs quantified by the model. The historical conditions water budget (see Figure ES-5) shows an annual average rate of overdraft ("Change in Storage") of 192,000 acre-feet per year (AFY) over water years 2006 through 2015. In this Figure, the "Change in Storage" represents the average annual decline in storage resulting from the Subbasin outflows, principally groundwater pumping.

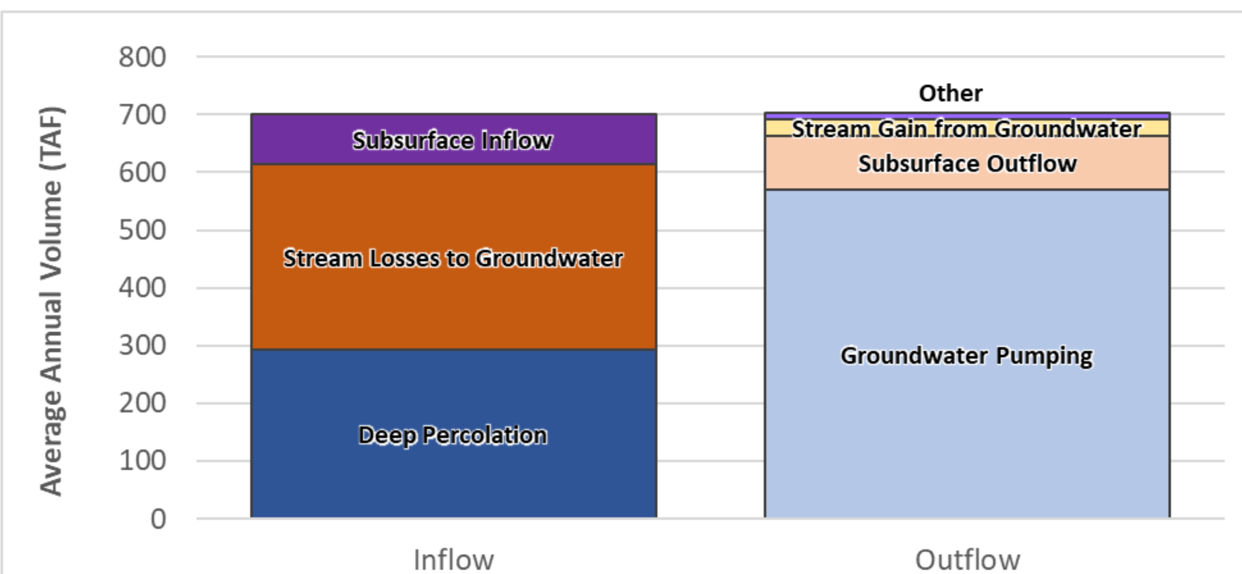
Figure ES-5: Historical Conditions Water Budget



SGMA defines sustainable yield as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result" (California Water Code §10721(w)).

For the Merced Subbasin, sustainable yield was estimated by modifying conditions in the groundwater model to balance out the change in stored water over time. In order to achieve a net-zero change in groundwater storage over a long-term average condition, current agricultural and urban groundwater demand in the Merced Subbasin would need to be reduced by approximately 10 percent, absent implementation of any new supply-side or recharge projects. Figure ES-6 illustrates the Subbasin water budget under long term sustainable conditions.

Figure ES-6: Groundwater Water Budget under Sustainable Groundwater Management Conditions Long-Term (50-Year) Average Annual



ES-3. SUSTAINABLE MANAGEMENT CRITERIA

SGMA requires consideration of six sustainability indicators. For each indicator, the GSP must define undesirable results for the basin ("significant and unreasonable" negative impacts) and determine if they could occur. For the indicators with the potential for undesirable results, the GSP must establish sustainable management criteria that are intended to prevent undesirable results from occurring and establish a monitoring network.

Sustainable management criteria were developed to be protective of beneficial uses in the Merced Subbasin and to support the Subbasin's sustainability goal. Demonstration by 2040 of meeting the sustainability management criteria and an absence of undesirable results will support a determination that the basin is operating within its sustainable yield, and thus that the sustainability goal has been achieved.

A summary of the sustainable management criteria for the Merced Subbasin is shown in Table ES-1-1.

Table ES-1-1: Summary of Sustainable Management Criteria

Sustainability Indicator	Minimum Threshold (MT)	Interim Milestone (IM)	Measurable Objective (MO)	Undesirable Result
Groundwater Levels	Fall 2015 groundwater elevation	Based on range of projected values that account for hydrologic uncertainty, more details in Section 3.3.3.	November or October 2011 groundwater elevation (measured, or estimation if historical record not available)	Greater than 25% of representative wells fall below MT in 2 consecutive years
Groundwater Storage	Not applicable - not present and not likely to occur in the Subbasin due to the significant volumes of freshwater in storage			
Seawater Intrusion	Not applicable - not present and not likely to occur due to the distance between the Subbasin and the Pacific Ocean (and Sacramento-San Joaquin Delta)			
Degraded Water Quality	1,000 mg/L TDS	1,000 mg/L TDS	500 mg/L TDS	At least 25% representative wells exceed MT for 2 consecutive years
Land Subsidence	0 ft/year, subject to uncertainty of +/-0.16 ft/year	2025: -0.75 ft/year 2030: -0.5 ft/year 2035: -0.25 ft/year	0 ft/year	Exceedance of MT at 3 or more representative sites for 2 consecutive years
Depletions of Interconnected Surface Waters	Groundwater levels used as a proxy for this sustainability indicator			

There are two sustainability indicators deemed not applicable to the Merced Subbasin. Undesirable results related to significant and unreasonable **depletions of groundwater storage** are not present and not likely to occur in the Subbasin, since historical reductions have been insignificant relative to the total volume of freshwater water storage in the Subbasin. **Seawater intrusion** is not an applicable sustainability indicator because seawater intrusion is not present and is not likely to occur due to the distance between the Subbasin and the Pacific Ocean (and Sacramento-San Joaquin Delta).

For the remaining sustainability indicators, sustainable management criteria were established to be protective of Subbasin beneficial uses as described below.

Minimum thresholds for **chronic declining groundwater levels** were developed based on the fall 2015 elevation recorded at each representative monitoring well. This threshold keeps groundwater levels generally above levels that have been experienced in the past. In this way, impacts to shallow well users and other beneficial users of groundwater will generally not exceed what has historically been experienced in the subbasin. Sustainable management criteria for declining groundwater levels were evaluated against the depths of the shallowest domestic and Public Water Supply wells in Merced County's well permitting database. Groundwater levels are also being used as a proxy indicator for depletion of interconnected surface waters.

Degraded water quality is unique among the six sustainability indicators because it is already the subject of extensive federal, state, and local regulations carried out by numerous entities, and SGMA does not directly address the role of GSAs relative to these other entities (Moran & Belin, 2019). SGMA does not specify water quality constituents that must have minimum thresholds. Groundwater management is the mechanism available to GSAs to implement SGMA. Establishing minimum thresholds for constituents that cannot be managed by increasing or decreasing pumping was deemed inappropriate by the GSAs and basin stakeholders. The major water quality issue being addressed by sustainable groundwater management is the migration of relatively higher salinity water into the freshwater principal aquifers. The nexus between water quality and water supply management exists for the pumping-induced movement of low-quality water from the west and northwest to the east. Other water quality concerns are being addressed through various water quality programs and agencies that have the authority and responsibility to address them. The selection of a groundwater level minimum threshold based on fall 2015 elevations is consistent with the avoidance of significant and unreasonable impacts to subsidence, water quality, and depletions of interconnected surface water, as described later in this Plan.

Within the Merced Subbasin, while **land subsidence** has been recognized by the GSAs as an area of concern, it is not considered to have caused a significant and unreasonable reduction in the viability of the use of infrastructure. However, it is noted that subsidence has caused a reduction in freeboard of the Middle Eastside Bypass over the last 50 years and has caused problems in neighboring subbasins, highlighting the need for ongoing monitoring and management in the Merced Subbasin and surrounding subbasins. Sustainable management criteria were established based on the long-term avoidance of land subsidence, set with the recognition that the interconnectedness of the Merced Subbasin with surrounding subbasins, and the ability to meet the sustainability management criteria is dependent on the successful management of all nearby subbasins. The criteria are also set to be consistent with the sustainable management criteria for groundwater levels which seek to keep levels above 2015 conditions. A management action has also been developed to avoid declines in storage below historical levels, further reducing the risk of subsidence.

Depletions of interconnected surface waters will be managed using groundwater levels as a proxy due to the challenges associated with directly measuring streamflow depletions and because of the significant correlation between groundwater levels and depletions.

ES-4. MONITORING NETWORKS

Consistent with SGMA requirements, the GSAs plan to establish monitoring networks for each sustainability indicator to monitor trends in the Subbasin and evaluate GSP implementation against sustainable management criteria. The groundwater level monitoring network consists of wells from the California Statewide Groundwater Elevation Monitoring (CASGEM) Program that were selected to provide representative conditions for groundwater levels across the

Subbasin. The groundwater quality monitoring network includes a combination of wells in the Subbasin that are part of the East San Joaquin Water Quality Coalition Groundwater Quality Trend Monitoring Program as well as public water system wells that report data to the Division of Drinking Water. The subsidence monitoring network relies on control points monitored by the United States Bureau of Reclamation as part of the San Joaquin River Restoration Program. While the monitoring networks reflect a robust history of monitoring Subbasin conditions, data gaps exist, and plans to fill these data gaps for each sustainability indicator are also described in this GSP.

ES-5. DATA MANAGEMENT SYSTEM

The Merced Subbasin Data Management System (DMS) was developed to serve as a data sharing portal to enable utilization of the same data and tools for visualization and analysis to support sustainable groundwater management and transparent reporting of data and results. Monitoring data can be manually input by users or batch uploaded via template and is expected to include groundwater level, groundwater quality, streamflow, and subsidence data. All monitoring locations can be viewed spatially (map or list format) and data records per site can be viewed temporally (chart or list format). Ad-hoc queries and standard reports will greatly assist in answering questions about basin characterization, providing input for decision-making, and developing reports to meet annual report submittal requirements.

ES-6. PROJECTS AND MANAGEMENT ACTIONS TO ACHIEVE SUSTAINABILITY GOAL

SGMA requires that GSPs describe the projects and management actions to be implemented as part of bringing the Subbasin into sustainability. The primary means for achieving sustainability in the basin will be reduction in groundwater pumping achieved through implementation of an allocation framework to allocate the sustainable yield of the basin to the GSAs. A water allocation framework has been the subject of much discussion during GSP development. The GSAs have agreed that they intend to allocate water to each GSA but have not yet reached agreement on allocations or how they will be implemented. Such an agreement will be developed during GSP implementation.

The GSP identifies a shortlist of 12 priority projects that met a series of screening criteria for implementation (see Table ES-1-2) as well as a longer list of possible future projects that were identified during GSP development. Projects and management actions will either increase surface water supplies to augment the sustainable groundwater yield or will increase groundwater recharge, which will in turn increase the amount of groundwater that may be sustainably used. Management actions will also include rewarding GSAs based on their extracted volumetric groundwater extraction, since 2015, proportioned to other GSAs in the basin.

Table ES-1-2: Projects Shortlist for Merced Subbasin Groundwater Sustainability Plan*

Project Name	Current Status	Expected Completion	Estimated Cost
Project 1: Planada Groundwater Recharge Basin Pilot Project	Planning, to be implemented with DWR Grant Funding	12/17/2023	$395,292
Project 2: El Nido Groundwater Monitoring Wells	Planning, to be implemented with DWR Grant Funding	12/31/2019	$400,000
Project 3: Meadowbrook Water System Intertie Feasibility Study	Planning	06/2020	$100,588
Project 4: Merquin County Water District Recharge Basin	Planning/Initial Study	12/15/2021	$1,400,000
Project 5: Merced Irrigation District to Lone Tree Mutual Water Company Conveyance Canal	Conceptual	11/2020	$3-6,000,000
Project 6: Merced IRWM Region Climate Change Modeling	Design	4/30/2021	$250,000
Project 7: Merced Region Water Use Efficiency Program	Design	12/31/2020	$500,000
Project 8: Merced Groundwater Subbasin LIDAR	Planning/Initial Study	12/2020	$150,000
Project 9: Study for Potential Water System Intertie Facilities from MID to LGAWD and CWD	Design Complete	06/01/2020	$100,000
Project 10: Vander Woude Dairy Offstream Temporary Storage	Planning/Initial Study & Conceptual Design	05/2020	$750,000
Project 11: Mini-Big Conveyance Project	Planning	06/2026	$ 6-8,000,000
Project 12: Streamlining Permitting for Replacing Sub-Corcoran Wells	Planning	1/31/2020	$75,000

*Information provided by project proponents.

ES-8. PLAN IMPLEMENTATION

Implementation of the GSP will be a substantial undertaking that will include implementation of the projects and management actions as well as GSAs administration, public outreach, implementation of the monitoring programs and filling data gaps, development of annual reports, and development of a 5-year update and report. The GSAs have developed an implementation schedule (see Table ES-1-3) and estimated costs for all activities, as well as potential funding mechanism options. Implementation of the GSP is projected to run between $1.2M and $1.6M per year. Costs for projects and management actions are estimated to be an additional $22.9M in total, with costs for individual projects or management actions ranging between $75,000 to $8M in total.

Table ES-1-3: GSP Implementation Schedule

2020 | 2025 | 2030 | 2035 | 2040

Monitoring and Reporting	Preparation for Allocations and Low Capital Outlay Projects	Prepare for Sustainability	Implement Sustainable Operations
• Establish monitoring network • Install new monitoring wells • Reduce/fill data gaps	• Conduct 5-year evaluation/update • Monitoring and reporting continue	• Conduct 5-year evaluation/update • Monitoring and reporting continue	• Conduct 5-year evaluation/update • Monitoring and reporting continue
• GSAs allocated initial allocations • GSAs establish their allocation procedures and demand reduction efforts • Develop metering program	• As-needed demand reduction to reach Sustainable Yield allocation • Metering program continues	• As-needed demand reduction to reach Sustainable Yield allocation	• Full implementation demand reduction as needed to reach Sustainable Yield allocation by 2040
• Funded and smaller projects implemented	• Planning/ design/ construction for small to medium sized projects	• Planning/ design/ construction for larger projects begins	• Project implementation completed
• Extensive public outreach regarding GSP and allocations	• Outreach regarding GSP and allocations continues	• Outreach continues	• Outreach continues

1 INTRODUCTION AND PLAN AREA

1.1 INTRODUCTION AND AUTHORITY

This July 2022 Revision includes updates to the November 2019 Groundwater Sustainability Plan (GSP) in response to the Statement of Findings issued by the California Department of Water Resources (DWR) on January 28, 2022 (DWR, 2022). The GSP has been updated in several key places to address DWR's recommendations. However, not all information was updated to reflect the most current information, and the GSP Annual Reports submitted in April 2020, 2021, and 2022 contain more recent information on basin conditions and GSP implementation status. A redlined version of the GSP that highlights the edits can be found on MercedSGMA.org.

1.1.1 Purpose of the Groundwater Sustainability Plan

The purpose of this GSP is to bring the Merced Subbasin, a DWR-designated critically overdrafted basin located within the San Joaquin Valley, into sustainable groundwater management by 2040 by meeting the regulatory requirements set forth in the three-bill legislative package Assembly Bill (AB) 1739 (Dickinson), Senate Bill (SB) 1168 (Pavley), and SB 1319 (Pavley) collectively known as the Sustainable Groundwater Management Act (SGMA), §10720 - 10737.8 of the California Water Code (CWC). Under SGMA, critically overdrafted, high- and medium-priority basins must be managed by a GSP by January 31, 2020. GSPs are prepared and implemented by Groundwater Sustainability Agencies (GSAs) that are newly formed from local and regional authorities.

SGMA defines sustainable groundwater management as "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results," which are any of the following effects caused by groundwater conditions occurring throughout the Subbasin:

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply
- Significant and unreasonable reduction of groundwater storage
- Significant and unreasonable seawater intrusion
- Significant and unreasonable degraded water quality
- Significant and unreasonable land subsidence
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water

The planning and implementation horizon is defined by SGMA as a "50-year time period over which a groundwater sustainability agency determines that plans and measures will be implemented in a basin to ensure that the basin is operated within its sustainable yield."

1.1.2 Sustainability Goal

The sustainability goal succinctly states the GSAs' objectives and desired conditions of the Merced Subbasin. The Merced Subbasin is heavily reliant on groundwater, and users recognize the Subbasin has been in overdraft for a long period of time. The sustainability goal for the Merced Subbasin is to:

Achieve sustainable groundwater management on a long-term average basis by increasing recharge and / or reducing groundwater pumping, while avoiding undesirable results.

This goal will be achieved by allocating a portion of the estimated Subbasin sustainable yield to each GSA and coordinating the implementation of programs and projects to increase both direct and in-lieu groundwater recharge, which will, in turn, increase the groundwater and / or surface water available to each GSA.

More information on the sustainability goal and sustainable management criteria is detailed in Section 3 - Sustainable Management Criteria.

1.1.3 Agency Information

This GSP for the Merced Groundwater Subbasin was developed jointly by the Merced Irrigation-Urban Groundwater Sustainability Agency (MIUGSA), the Merced Subbasin Groundwater Sustainability Agency (MSGSA), and Turner Island Water District Groundwater Sustainability Agency #1 (TIWD GSA-1). Collectively, these three GSAs will be referred to as "GSAs".

The GSAs developed a Memorandum of Understanding (MOU) that provides the basis for the agreement of the three GSAs to work together to develop and implement a GSP for the Merced Subbasin (Merced Subbasin GSA, MIUGSA, Turner Island Water District GSA-#1, 2017). The GSAs submitted an Initial Notification to jointly develop a GSP for the Merced Subbasin on January 4, 2018 (Merced Subbasin GSA, MIUGSA, Turner Island Water District GSA-#1, 2018). The MOU is provided as Appendix A to this document.

1.1.3.1 Organization and Management Structure of the GSAs

The GSAs were guided by a Coordination Committee that is composed of up to four representatives from each GSA and appointed by each respective GSA Board (Merced Subbasin GSA, MIUGSA, Turner Island Water District GSA-#1, 2017). The Coordination Committee is responsible for developing recommendations on technical and substantive Subbasin-wide issues, and then submitting the recommendations to each GSA governing board for final approval. To become fully effective, each GSA governing board must approve the Coordination Committee's recommendations. The Coordination Committee is tasked with developing actions including, but not limited to, the following:

- Budget(s) and appropriate cost sharing for any project or program that requires funding from the GSAs;
- Propose guidance and options for obtaining grant funding;
- Recommend the adoption of rules, regulations, policies, and procedures related to the MOU;
- Recommend the approval of any contracts with consultants or subcontractors that would undertake work on behalf of the GSAs and/or relate to Subbasin-wide issues and, if applicable, recommend the funding that each GSA should contribute towards the costs of such contracts;
- Report to the GSAs' respective governing boards when dispute resolution is needed to resolve an impasse or inability to make a consensus recommendation;
- Recommend action and/or approval of a GSP.

  (Merced Subbasin GSA, MIUGSA, Turner Island Water District GSA-#1, 2017)

A process for dispute resolution, including internal resolution and mediation prior to judicial or administrative remedies, is laid out in the GSAs' MOU.

The Coordinating Committee and GSA Boards were also informed by a Stakeholder Advisory Committee which consists of community representatives who review groundwater conditions, management issues and needs, and projects and management actions to improve sustainability in the basin. The committee met monthly during the development of the GSP and will meet quarterly during GSP implementation. These sessions are open to the public, providing a forum for testing ideas as well as providing information and feedback from members' respective constituencies. The committee consists of 24 members, including representatives from local cities, public and private utilities, agriculture, local nonprofits, business owners, researchers or university employees, and residents. An application to join the committee was disseminated in early 2018. More than 35 applications were received. The 23 Stakeholder Advisory Committee members were selected by the Coordinating Committee and approved by the GSAs to represent the broad interests and geography of the region (see Appendix N for a list of Stakeholder Advisory Committee members).

1.1.3.1.1 Merced Irrigation-Urban Groundwater Sustainability Agency (MIUGSA)

MIUGSA was formed by an MOU between the Merced Irrigation District, City of Merced, City of Atwater, City of Livingston, Le Grand Community Services District, Planada Community Services District, and Winton Water and Sanitary District. Decision-making is intended to be by unanimous consent of all Parties, but otherwise allows for a majority vote where MID and each of the cities is entitled to one vote and the community service districts are collectively entitled to one vote. MID is designated as the primary agent for purposes of developing technical information as well as being the point of contact and designated representative for MIUGSA for coordination with the other two GSAs in the Merced Subbasin as well as adjacent basins.

The mailing address for MIUGSA is:

Merced Irrigation-Urban Groundwater Sustainability Agency
744 W. 20th Street
Merced, CA 95340

1.1.3.1.2 Merced Subbasin Groundwater Sustainability Agency (MSGSA)

MSGSA was formed as a Joint Powers Authority (JPA), including Plainsburg Irrigation District, Le Grand-Athlone Water District, Stevinson Water District, Merquin County Water District, County of Mariposa, and County of Merced. Two mutual water companies, Lone Tree Mutual Water Company and Sandy Mush Mutual Water Company, participate in the JPA as Contracting Entities. The JPA formed a Governing Board consisting of six members:

1. An elected member of the Board of Supervisors for the County of Merced
2. One representative from the Western White Area[1] (actively and primarily engaged in agriculture, appointed by County of Merced Board of Supervisors)
3. One Representative from the Eastern White Area[2] (actively and primarily engaged in agriculture, appointed by County of Merced Board of Supervisors)
4. One member from the Board of Directors of a Contracting Entity

---

[1] "Western White Area" refers to all lands southwest of the Merced Irrigation District service area within the Merced Subbasin but outside of established water or irrigation districts, municipalities, community service districts, Contracting Entities, or other eligible local agencies as defined by the Act. (MSGSA, 2016)

[2] "Eastern White Area" refers to all lands northeast of the Merced Irrigation District service area within the Merced Subbasin but outside of established water or irrigation districts, municipalities, community service districts, Contracting Entities, or other eligible local agencies as defined by the Act. (MSGSA, 2016)

5. One member from the Board of Directors for either the Stevinson Water District or Merquin County Water District

6. One member from the Board of Directors for either the Le Grand-Athlone Water District or Plainsburg Irrigation District

Each Board Member has one vote, and decisions are made by affirmative vote of four Board Members, except in the following cases, which require five affirmative votes: decisions about initiating litigation, adoption of the GSP, incurring bond debt, and expenditures over $100,000.

The mailing address for MSGSA is:

Merced Subbasin Groundwater Sustainability Agency
Merced County
2222 M Street
Merced, CA 95340

1.1.3.1.3 Turner Island Water District Groundwater Sustainability Agency #1 (TIWD GSA-1)

TIWD GSA-1 is governed exclusively by the Turner Island Water District (TIWD), a local water agency. TIWD is comprised of several agriculture landowners that rely on groundwater for irrigation. The GSA is differentiated as #1 because TIWD also has a role as a GSA (TIWD GSA #2) in the adjacent Delta-Mendota Subbasin. The mailing address for TIWD GSA-1 is:

Turner Island Water District GSA #1
1269 W. I Street
Los Banos, CA 93535

1.1.3.1.4 Merced GSP Plan Manager

SGMA regulations require the GSP designate a plan manager to serve as a point of contact with DWR. The contact information for the Merced GSP Plan Manager is:

Hicham Eltal,
Merced Irrigation-Urban Groundwater Sustainability Agency
744 W. 20th Street
Merced, CA 95340
Phone: 209.722.5761
Email: heltal@mercedid.org

1.1.3.2 Legal Authority of the GSAs

Any local public agency that has water supply, water management, or land use responsibilities in a basin can decide to become a GSA. A single local agency can decide to become a GSA, or a combination of local agencies can decide to form a GSA by using either a JPA, a memorandum of agreement (MOA), or other legal agreement (DWR, 2016c).

MIUGSA's MOU describes the following powers in addition to authorities granted to GSAs by SGMA (MIUGSA, 2017):

- Adopt standards for measuring and reporting water use

- Adopt rules, regulations, policies and procedures to govern the adoption and implementation of the GSP, as authorized by SGMA including funding of the GSA, and the collection of fees or charges as may be applicable

- Develop and implement conservation best management practices
- Develop and implement metering, monitoring, and reporting related to groundwater pumping
- Hire consultants as determined necessary or appropriate by the GSAs
- Prepare a budget

MSGSA's JPA describes the following powers in addition to authorities granted to GSAs by SGMA (MSGSA, 2016):

- Employ agents, consultants, advisors, independent contractors, employees, and other staff members
- Enter contracts
- Acquire, hold, and convey real and personal property
- Incur debts, borrow money, accept contributions/grants/loans
- Invest money not needed for immediate necessities
- Reimburse Agency Members for expenses
- Sue and be sued

TIWD is the only local agency governing TIWD GSA-1 and has powers granted to GSAs by SGMA.

The MOU between the three GSAs describes the following collective authorities (Merced Subbasin GSA, MIUGSA, Turner Island Water District GSA-#1, 2017):

- To coordinate the implementation of SGMA among the GSAs
- To recommend the adoption of actions, rules, regulations, policies, and procedures related to the coordination of the GSAs for purposes of implementation of SGMA
- To perform all acts necessary or proper to carry out fully the purposes of the Agreement; and to exercise all other powers necessary and incidental to the implementation of the powers set forth herein.

1.1.3.3 Estimated Cost of Implementing the GSP and the GSAs' Approach to Meet Costs

Implementation of the GSP is projected to range between $1.2M and $1.6M per year. Costs for projects and management actions are estimated to be an additional $22.9M in total, with costs for individual projects or management actions ranging between $75K to $8M in total. It is anticipated that most of these projects will be implemented within the first five years of GSP implementation. Development of this GSP was substantially funded through a Proposition 1 Sustainable Groundwater Planning Grant. The implementation of the GSP and future SGMA compliance will be a substantial and costly undertaking that will likely require GSAs to collect fees as well as seek additional outside funding. The Merced GSAs will develop a financing plan for the overall implementation of the GSP. Costs for GSP project implementation will be shared based on project beneficiaries. Costs of overall GSP administration are expected to be shared by the three GSAs consistent with the cost share in the MOU. Financing options under consideration include pumping fees, assessments, loans, and grants. Prior to implementing any fee or assessment program, the GSAs would complete a rate assessment study or other analysis consistent with the regulatory requirements.

More detailed information can be found in Chapter 7 - Plan Implementation.

1.1.4 GSP Organization

This GSP is organized according to DWR's "GSP Annotated Outline" for standardized reporting (DWR, 2016d). The Preparation Checklist for GSP Submittal in DWR formatting can be found below in Table 1-1 (DWR, 2016e).

Table 1-1: DWR Preparation Checklist

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) in the GSP
Article 3. Technical and Reporting Standards				
352.2		Monitoring Protocols	• Monitoring protocols adopted by the GSA for data collection and management • Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin	GW levels: 4.5.5 GW quality: 4.8.5 Subsidence: 4.9.5 Depletions of interconnected surface waters: 4.10.5
Article 5. Plan Contents, Subarticle 1. Administrative Information				
354.4		General Information	• Executive Summary • List of references and technical studies	Executive Summary: Section ES References & technical studies: Chapter 8
354.6		Agency Information	• GSA mailing address • Organization and management structure • Contact information of Plan Manager • Legal authority of GSA • Estimate of implementation costs	1.1.3
354.8(a)	10727.2(a)(4)	Map(s)	• Area covered by GSP • Adjudicated areas, other agencies within the basin, and areas covered by an Alternative • Jurisdictional boundaries of federal or State land • Existing land use designations • Density of wells per square mile	1.2
354.8(b)		Description of the Plan Area	• Summary of jurisdictional areas and other features	1.2.1

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) in the GSP
354.8(c) 354.8(d) 354.8(e)	10727.2(g)	Water Resource Monitoring and Management Programs	• Description of water resources monitoring and management programs • Description of how the monitoring networks of those plans will be incorporated into the GSP • Description of how those plans may limit operational flexibility in the basin • Description of conjunctive use programs	1.2.2
354.8(f)	10727.2(g)	Land Use Elements or Topic Categories of Applicable General Plans	• Summary of general plans and other land use plans • Description of how implementation of the GSP may change water demands or affect achievement of sustainability and how the GSP addresses those effects • Description of how implementation of the GSP may affect the water supply assumptions of relevant land use plans • Summary of the process for permitting new or replacement wells in the basin • Information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management	1.2.3
354.8(g)	10727.4	Additional GSP Contents	**Description of Actions related to:** • Control of saline water intrusion • Wellhead protection • Migration of contaminated groundwater • Well abandonment and well destruction program • Replenishment of groundwater extractions • Conjunctive use and underground storage • Well construction policies • Addressing groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects • Efficient water management practices • Relationships with State and federal regulatory agencies	1.2.4

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) in the GSP
			• Review of land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity • Impacts on groundwater dependent ecosystems	
354.10		Notice and Communication	• Description of beneficial uses and users • List of public meetings • GSP comments and responses • Decision-making process • Public engagement • Encouraging active involvement • Informing the public on GSP implementation progress	1.2.5
Article 5. Plan Contents, Subarticle 2. Basin Setting				
354.14		Hydrogeologic Conceptual Model	• Description of the Hydrogeologic Conceptual Model • Two scaled cross-sections • Map(s) of physical characteristics: topographic information, surficial geology, soil characteristics, surface water bodies, source and point of delivery for imported water supplies	2.1
354.14(c)(4)	10727.2(a)(5)	Map of Recharge Areas	• Map delineating existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas	2.1.3.5
	10727.2(d)(4)	Recharge Areas	• Description of how recharge areas identified in the plan substantially contribute to the replenishment of the basin	2.1.3.5
354.16	10727.2(a)(1) 10727.2(a)(2)	Current and Historical Groundwater Conditions	• Groundwater elevation data • Estimate of groundwater storage • Seawater intrusion conditions • Groundwater quality issues • Land subsidence conditions • Identification of interconnected surface water systems • Identification of groundwater-dependent ecosystems	2.2

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) in the GSP
354.18	10727.2(a)(3)	Water Budget Information	• Description of inflows, outflows, and change in storage • Quantification of overdraft • Estimate of sustainable yield • Quantification of current, historical, and projected water budgets	2.3
	10727.2(d)(5)	Surface Water Supply	• Description of surface water supply used or available for use for groundwater recharge or in-lieu use	2.1.3.3 (Surface Water) 2.1.3.5 (Groundwater Recharge and Discharge Areas)
354.20		Management Areas	• Reason for creation of each management area • Minimum thresholds and measurable objectives for each management area • Level of monitoring and analysis • Explanation of how management of management areas will not cause undesirable results outside the management area • Description of management areas	3.2
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria				
354.24		Sustainability Goal	• Description of the sustainability goal	3.1
354.26		Undesirable Results	• Description of undesirable results • Cause of groundwater conditions that would lead to undesirable results • Criteria used to define undesirable results for each sustainability indicator • Potential effects of undesirable results on beneficial uses and users of groundwater	GW levels: 3.3.1 GW storage: 3.4 Seawater intrusion: 3.5 GW quality: 3.6.1 Subsidence: 3.7.1 Depletions of interconnected surface water: 3.8.1
354.28	10727.2(d)(1) 10727.2(d)(2)	Minimum Thresholds	• Description of each minimum threshold and how they were established for each sustainability indicator • Relationship for each sustainability indicator • Description of how selection of the minimum threshold may affect beneficial uses and users of groundwater • Standards related to sustainability indicators • How each minimum threshold will be quantitatively measured	GW levels: 3.3.2 GW storage: 3.4 Seawater intrusion: 3.5 GW quality: 3.6.2 Subsidence: 3.7.2 Depletions of interconnected surface water: 3.8.2

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) in the GSP
354.30	10727.2(b)(1) 10727.2(b)(2) 10727.2(d)(1) 10727.2(d)(2)	Measurable Objectives	• Description of establishment of the measurable objectives for each sustainability indicator • Description of how a reasonable margin of safety was established for each measurable objective • Description of a reasonable path to achieve and maintain the sustainability goal, including a description of interim milestones	GW levels: 3.3.3 GW storage: 3.4 Seawater intrusion: 3.5 GW quality: 3.6.3 Subsidence: 3.7.3 Depletions of interconnected surface water: 3.8.2
Article 5. Plan Contents, Subarticle 4. Monitoring Networks				
354.34	10727.2(d)(1) 10727.2(d)(2) 10727.2(e) 10727.2(f)	Monitoring Networks	• Description of monitoring network • Description of monitoring network objectives • Description of how the monitoring network is designed to: demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features; estimate the change in annual groundwater in storage; monitor seawater intrusion; determine groundwater quality trends; identify the rate and extent of land subsidence; and calculate depletions of surface water caused by groundwater extractions • Description of how the monitoring network provides adequate coverage of Sustainability Indicators • Density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends • Scientific rational (or reason) for site selection • Consistency with data and reporting standards • Corresponding sustainability indicator, minimum threshold, measurable objective, and interim milestone	Overall objectives: 4.1 GW levels: 4.5 GW storage: 4.6 Seawater intrusion: 4.7 GW quality: 4.8 Subsidence: 4.9 Depletions of interconnected surface water: 4.10
			• Location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used • Description of technical standards, data collection methods, and other procedures or protocols to ensure comparable data and methodologies	GW levels: 4.5 GW storage: 4.6 Seawater intrusion: 4.7 GW quality: 4.8 Subsidence: 4.9 Depletions of interconnected surface water: 4.10

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) in the GSP
354.36		Representative Monitoring	• Description of representative sites • Demonstration of adequacy of using groundwater elevations as proxy for other sustainability indicators • Adequate evidence demonstrating site reflects general conditions in the area	GW levels: 4.5.4 GW quality: 4.8.4 Subsidence: 4.9.4 Depletions of interconnected surface water: 4.10.4
354.38		Assessment and Improvement of Monitoring Network	• Review and evaluation of the monitoring network • Identification and description of data gaps • Description of steps to fill data gaps • Description of monitoring frequency and density of sites	GW levels: 4.5.6, 4.5.7 GW quality: 4.8.7, 4.8.8 Subsidence: 4.9.6, 4.9.7 Depletions of interconnected surface water: 4.10.6, 4.10.7
Article 5. Plan Contents, Subarticle 5. Projects and Management Actions				
354.44		Projects and Management Actions	• Description of projects and management actions that will help achieve the basin's sustainability goal • Measurable objective that is expected to benefit from each project and management action • Circumstances for implementation • Public noticing • Permitting and regulatory process • Time-table for initiation and completion, and the accrual of expected benefits • Expected benefits and how they will be evaluated • How the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included. • Legal authority required • Estimated costs and plans to meet those costs • Management of groundwater extractions and recharge	Chapter 6
354.44(b)(2)	10727.2(d)(3)		• Overdraft mitigation projects and management actions	Chapter 6
Article 8. Interagency Agreements				
357.4	10727.6	Coordination Agreements - Shall be	**Coordination Agreements shall describe the following:** • A point of contact	3.9

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) in the GSP
		submitted to the Department together with the GSPs for the basin and, if approved, shall become part of the GSP for each participating Agency.	• Responsibilities of each Agency • Procedures for the timely exchange of information between Agencies • Procedures for resolving conflicts between Agencies • How the Agencies have used the same data and methodologies to coordinate GSPs • How the GSPs implemented together satisfy the requirements of SGMA • Process for submitting all Plans, Plan amendments, supporting information, all monitoring data and other pertinent information, along with annual reports and periodic evaluations • A coordinated data management system for the basin • Coordination agreements shall identify adjudicated areas within the basin, and any local agencies that have adopted an Alternative that has been accepted by the Department	

1.2 PLAN AREA

The Description of Plan Area is a detailed description of the Merced Subbasin, including major streams and creeks, institutional entities, agricultural and urban land uses, locations of groundwater wells, and locations of state lands. The Plan Area also describes existing surface water and groundwater monitoring programs, existing water management programs, and general plans in the Plan Area.

1.2.1 Summary of Jurisdictional Areas and Other Features

The Merced Subbasin falls within the larger San Joaquin Valley Groundwater Basin (see Figure 1-1). Basin and Subbasin designations by DWR were first published in 1952, and subsequently updated in 1975, 1980, and 2003. The San Joaquin River Hydrologic Region contains 11 distinct subbasins, where the Merced Subbasin (Bulletin 118 Basin Number 5-022.04) is bordered to the north by the Turlock Subbasin (Bulletin 118 Basin Number 5-022.03), to the south by the Chowchilla Subbasin (Bulletin 118 Basin Number 5-022.05), and to the west by the Delta-Mendota Subbasin (Bulletin 118 Basin Number 5-022.07) (see Figure 1-2).

The Merced Subbasin includes lands south of the Merced River between the San Joaquin River on the west and the crystalline basement rock of the Sierra Nevada foothills on the east. The Subbasin boundary on the south stretches westerly along the Chowchilla River (Merced-Madera County boundary) and then along the northern edge of the sphere of influence boundary of Chowchilla Water District. Geologic units in the Merced Subbasin consist of consolidated rocks and unconsolidated deposits.

Figure 1-1: San Joaquin Valley Groundwater Basin

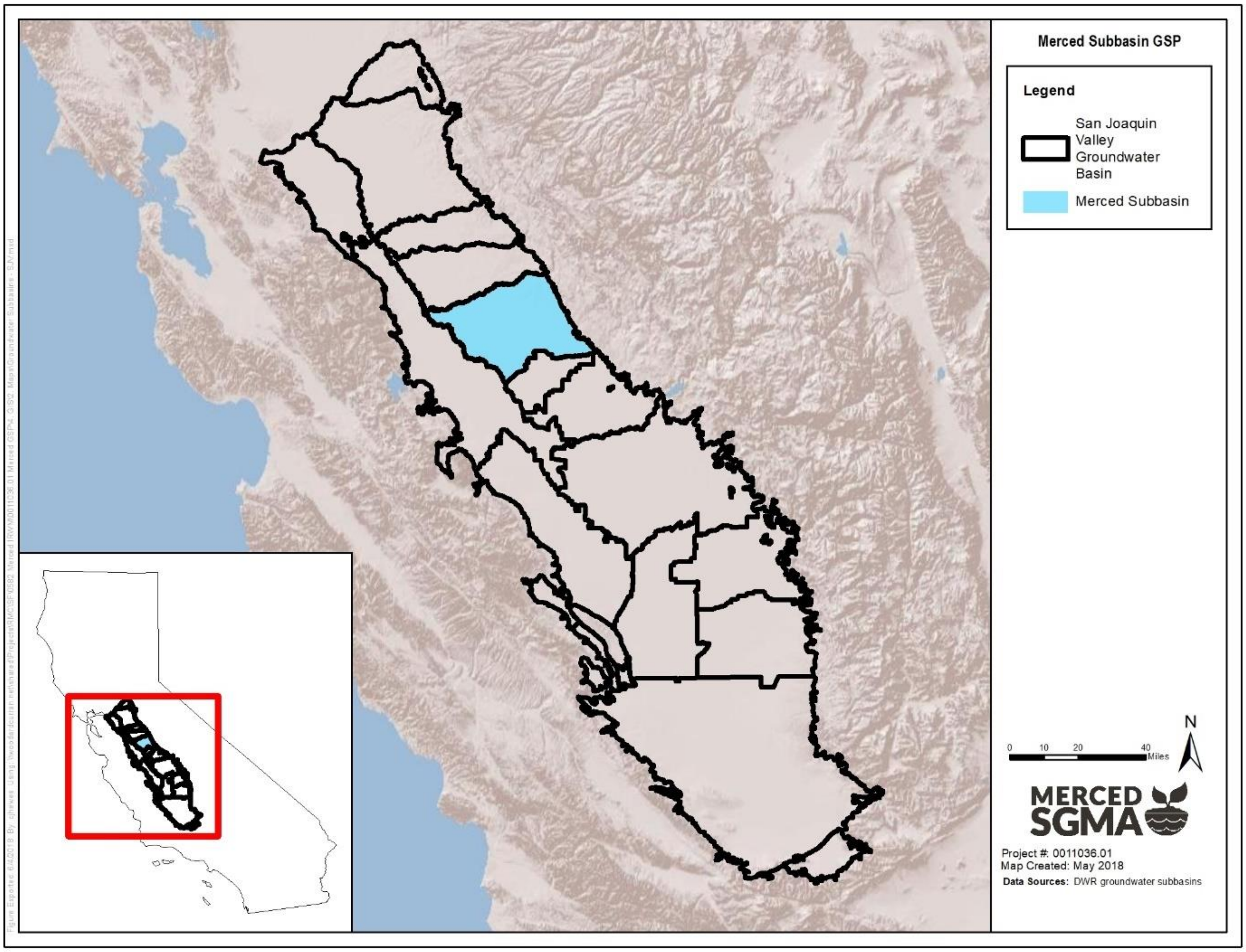


Figure 1-2: Neighboring Groundwater Subbasins

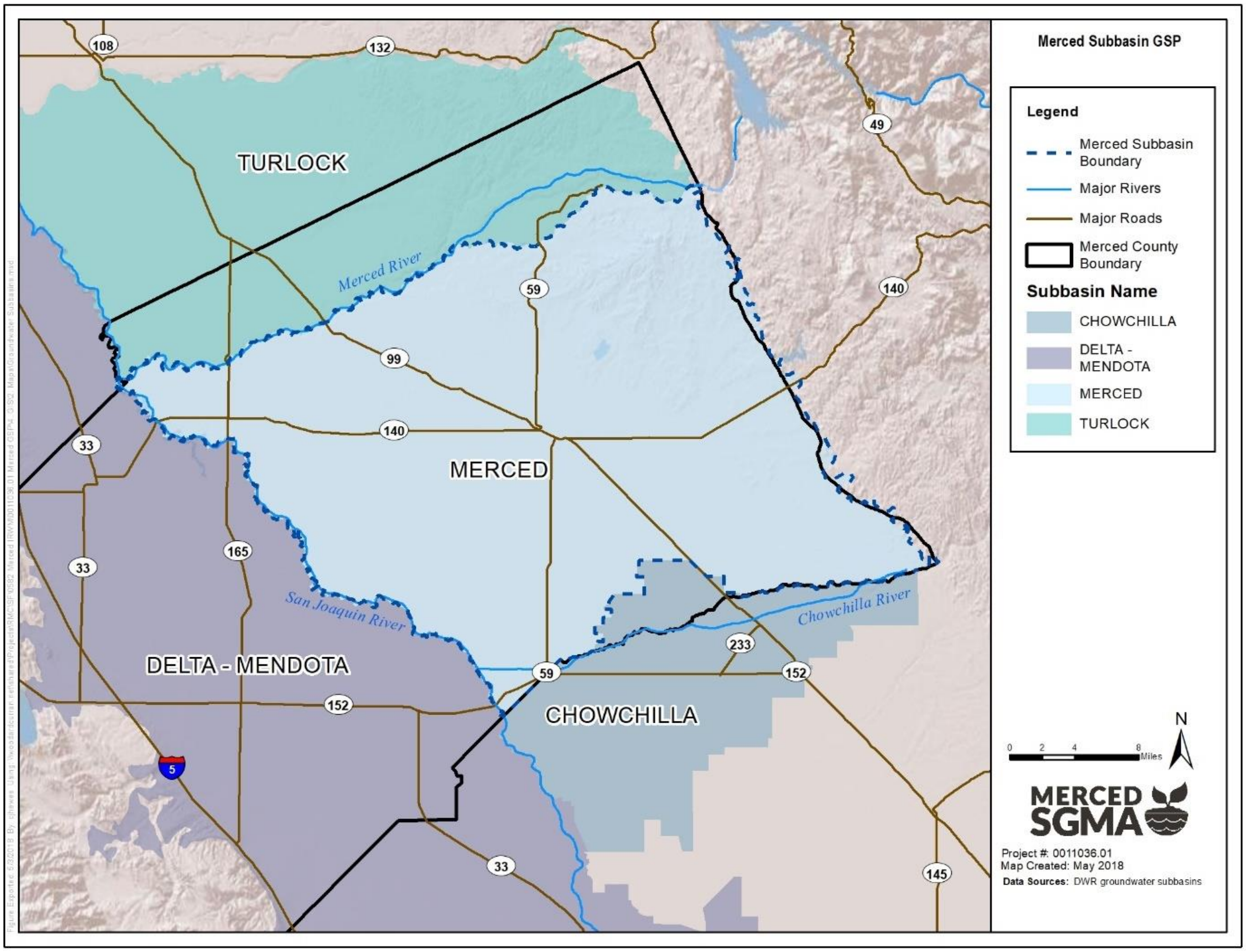


Figure 1-3 shows the location of Merced County within the State of California as well as the seven counties bordering Merced County: Tuolumne, Mariposa, Madera, Fresno, San Benito, Santa Clara, and Stanislaus.

Figure 1-3: Surrounding Counties

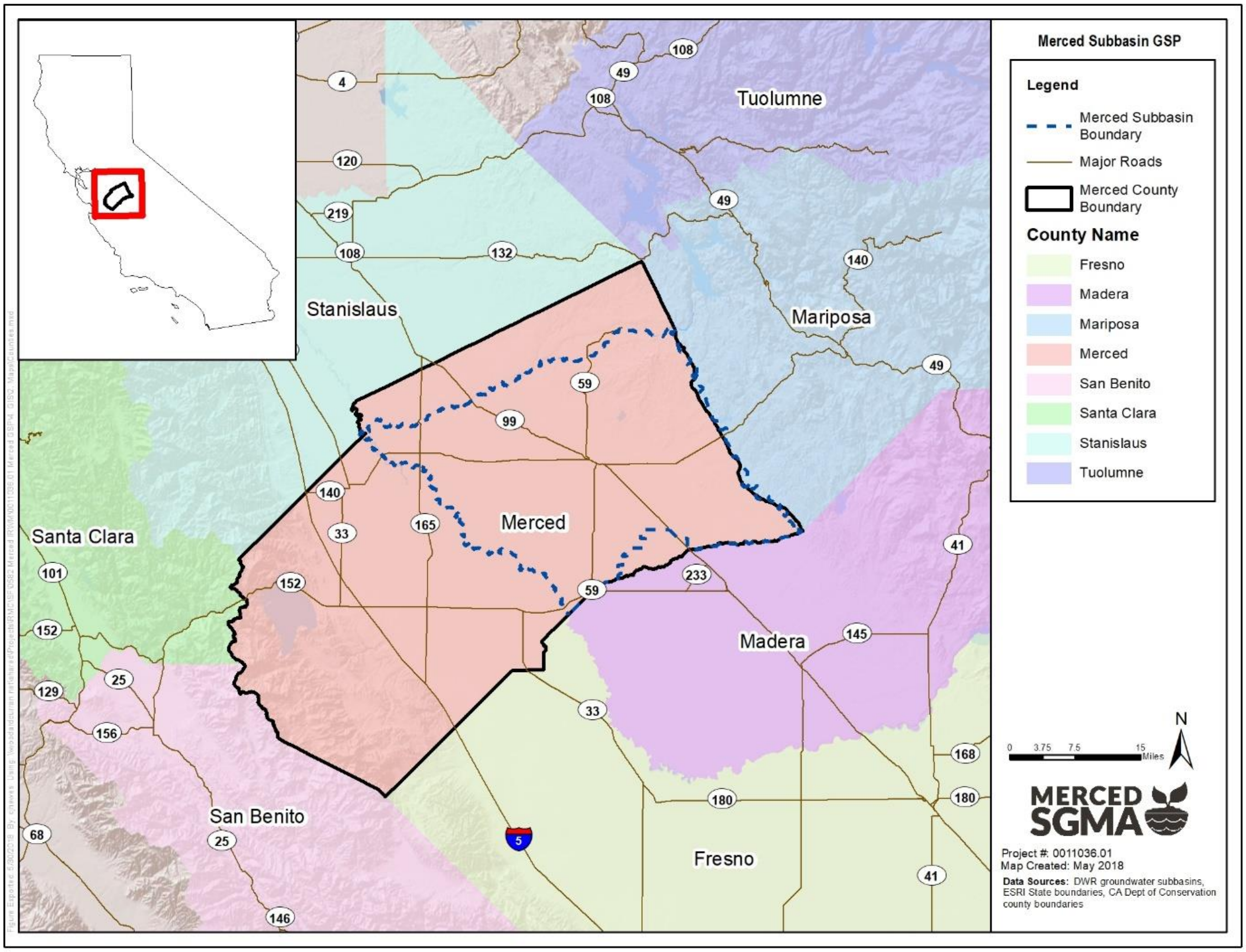


Figure 1-4 shows the Merced Subbasin and the Subbasin's key cities, communities, and major rivers. The Subbasin encompasses an area of about 801 square miles. There are five entities within the region with land use jurisdiction: the County of Merced, the City of Merced, the City of Livingston, the City of Atwater, and the University of California, Merced (UC Merced). A small portion of the Subbasin falls within the western edge of Mariposa County. The cities of Merced, Atwater, and Livingston and UC Merced are contained entirely within the Subbasin, while only part of the eastern portion of Merced County lies within the Subbasin. The Merced Subbasin encompasses the following unincorporated communities within eastern Merced County: Bear Creek (Celeste), Cressey, El Nido, Franklin/Beachwood, Le Grand, McSwain, Planada, Stevinson, Tuttle, and Winton.

Figure 1-4: City Boundaries

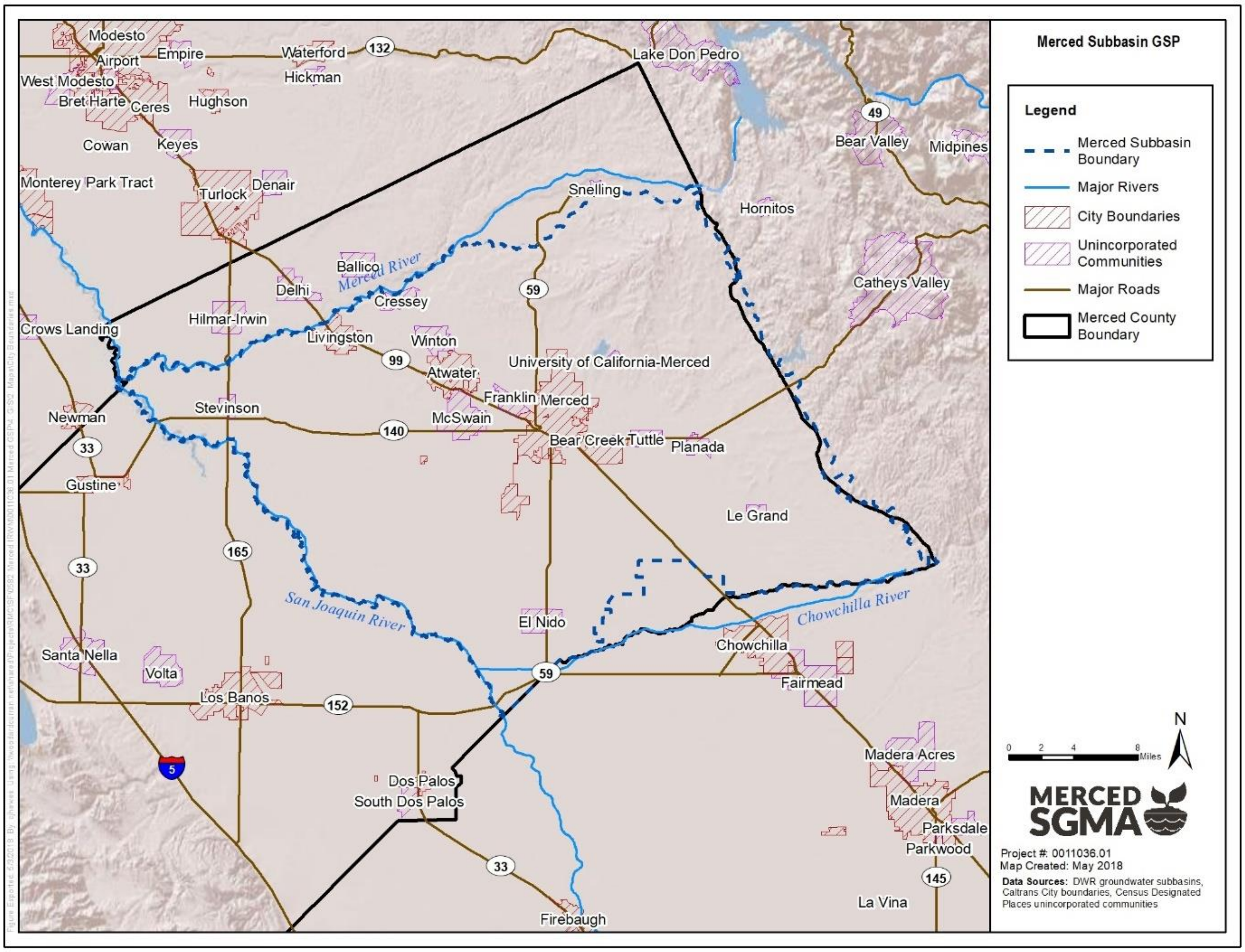


Figure 1-5 shows the extent of the three GSAs which together encompass the entire Merced Subbasin. See Section 1.1.3.1 for a description of the agencies making up each GSA.

Figure 1-5: GSA Boundaries

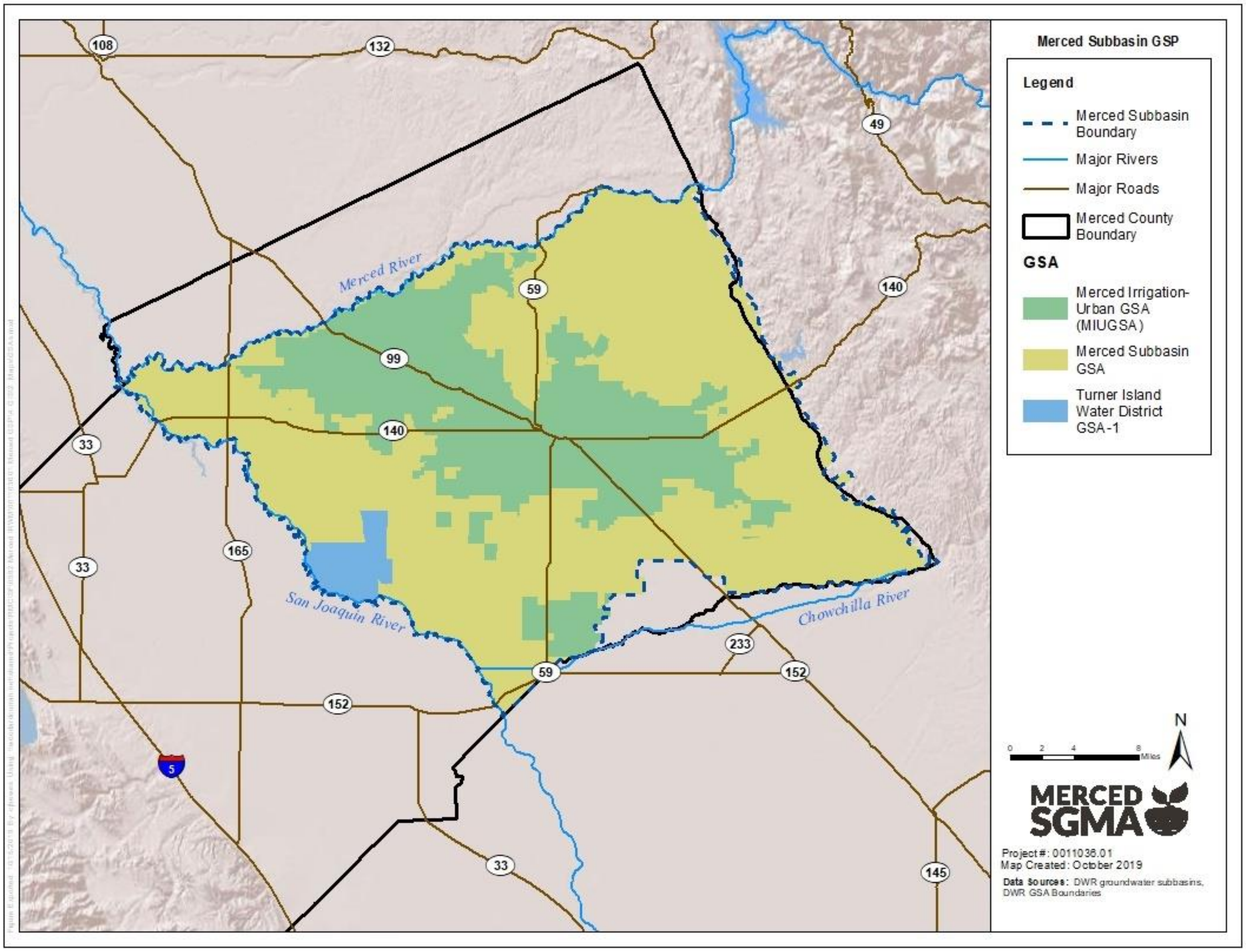


Figure 1-6 shows a map of land use in Merced County across four general categories: cropland, rangeland, undeveloped, and urban. These categories were aggregated based on categories provided by 2016 land use from the California Farmland Mapping and Monitoring Program. It is noted that these categorizations were focused on distinguishing cropland from other land uses, with less focus on specific subcategories for managed wetlands or other habitats. Areas of federal lands or state parks with managed habitats are shown in Figure 1-7. More information about groundwater dependent ecosystems can be found in Section 2.2.7.

Land use patterns in the Merced Subbasin are dominated by agricultural uses, including animal confinement (dairy and poultry), grazing, forage, row crops, vineyards, and nut and fruit trees. These uses rely heavily on purveyors/districts, private groundwater wells, and surface water sources in some areas. Urban land use relies on groundwater except for limited landscape applications. Land use is primarily controlled by local agencies. Land use patterns in the mountainous areas to the east are dominated by national forest and timber, recreation, tourism, and rangeland grazing of forested areas in the lower foothills.

Figure 1-6: Land Use

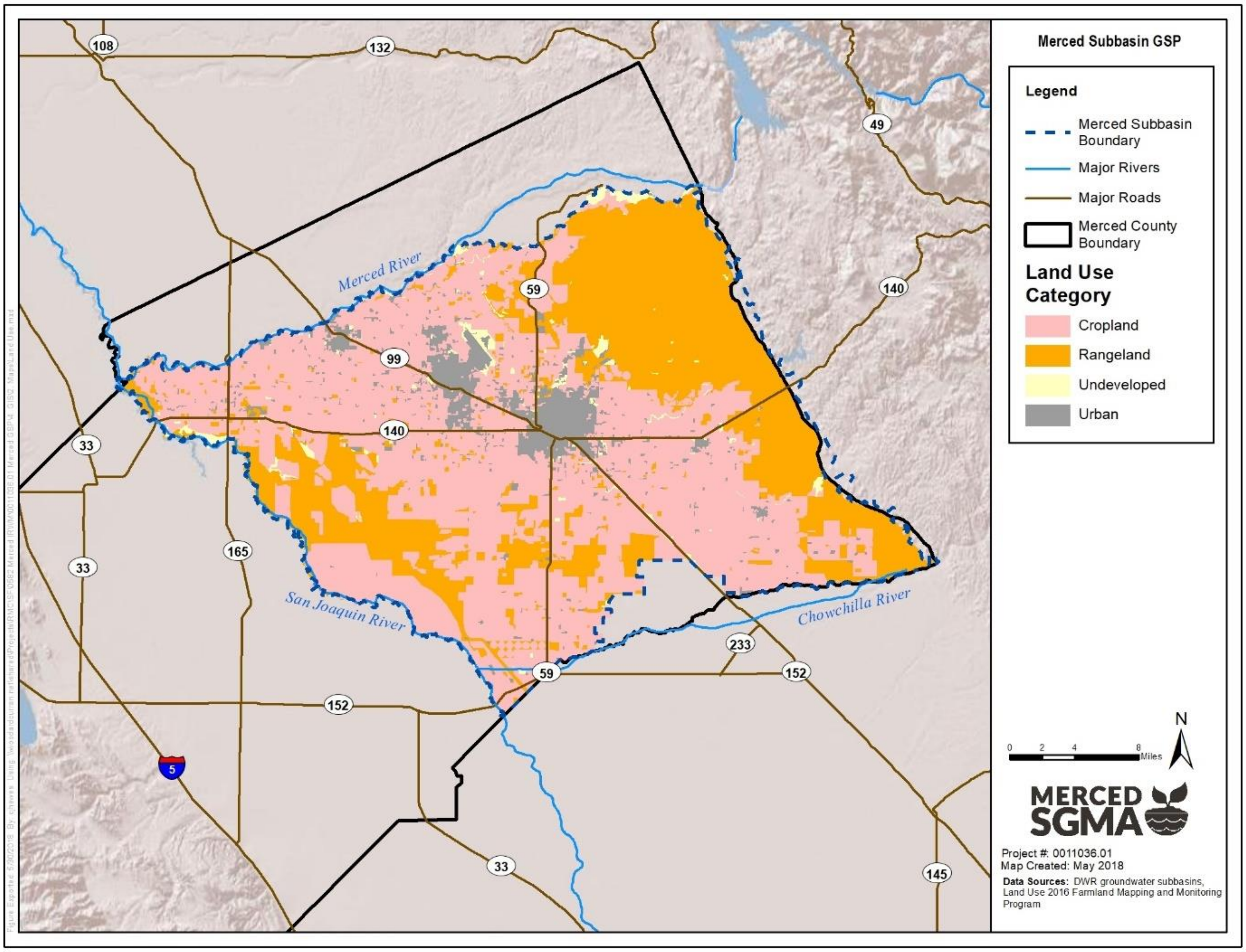


Figure 1-7 shows a map with boundaries of federal and state lands within the Merced Subbasin.

The US Fish & Wildlife Service (USFWS) has three properties at least partially within the Subbasin: San Luis National Wildlife Refuge, Merced National Wildlife Refuge, and the Grasslands Wildlife Management Area (which is composed of several fee title and easement subgroups). All properties are part of the San Luis National Wildlife Refuge Complex.

California State Parks maintains two properties that have small portions of their total area within the Subbasin: Great Valley Grasslands State Park and McConnell State Recreation Area (SRA).

Figure 1-7: Boundaries of Federal and State Lands

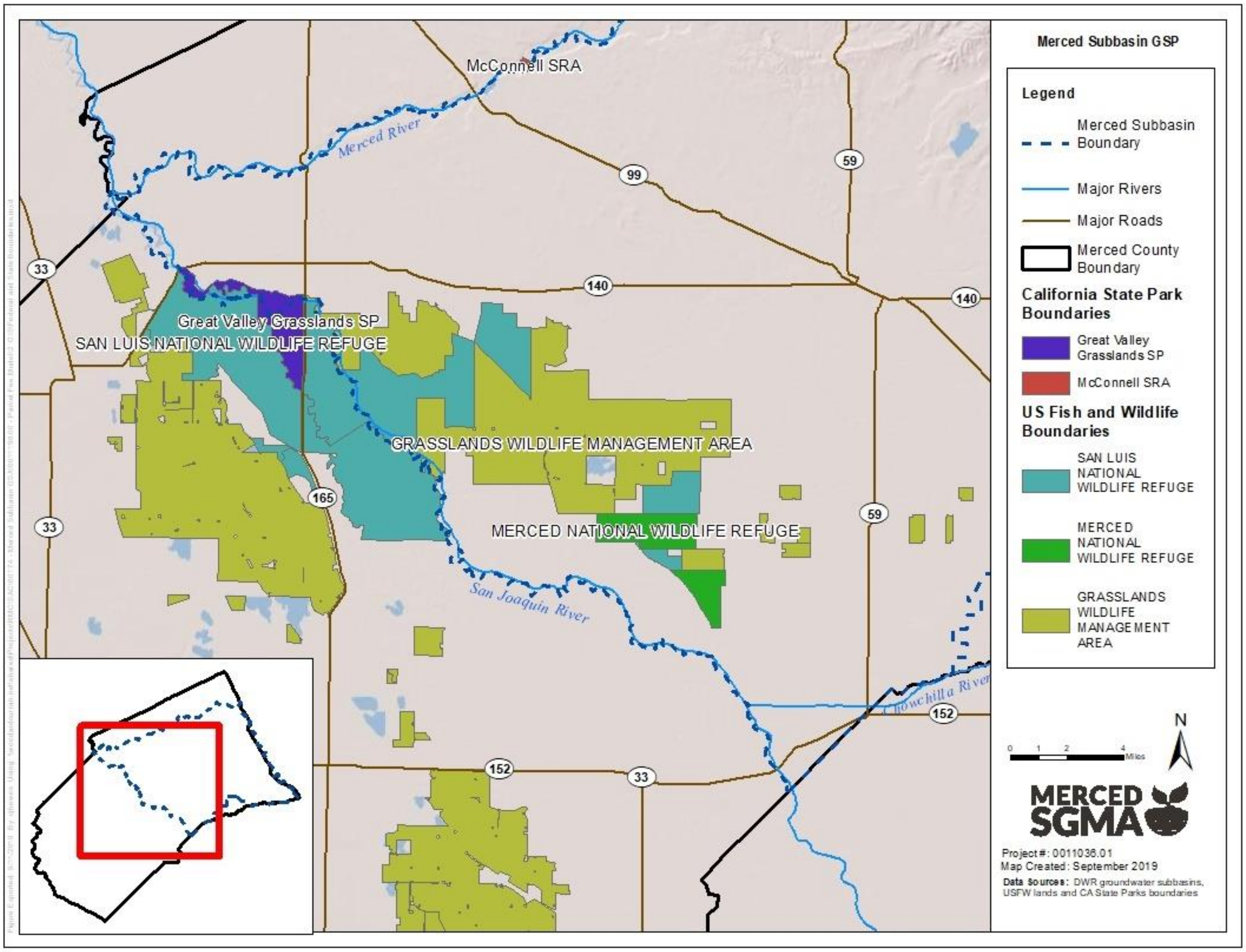


Figure 1-8 shows the density of non-domestic wells per square mile in the Merced Subbasin. This includes 887 unique wells collected primarily from DWR's Water Data Library (WDL), but also other state, regional, and local monitoring entities. Wells containing groundwater level data are described further in Section 1.2.2.1.

Figure 1-9 shows the density of domestic wells per square mile in the Merced Subbasin. This includes 2,388 active domestic wells from Merced County's electronic well database that records wells permitted in the 1990s or later.

In both figures below, city and unincorporated boundaries (from Figure 1-4) have been added for reference.

Figure 1-8: Density of Non-Domestic Wells per Square Mile

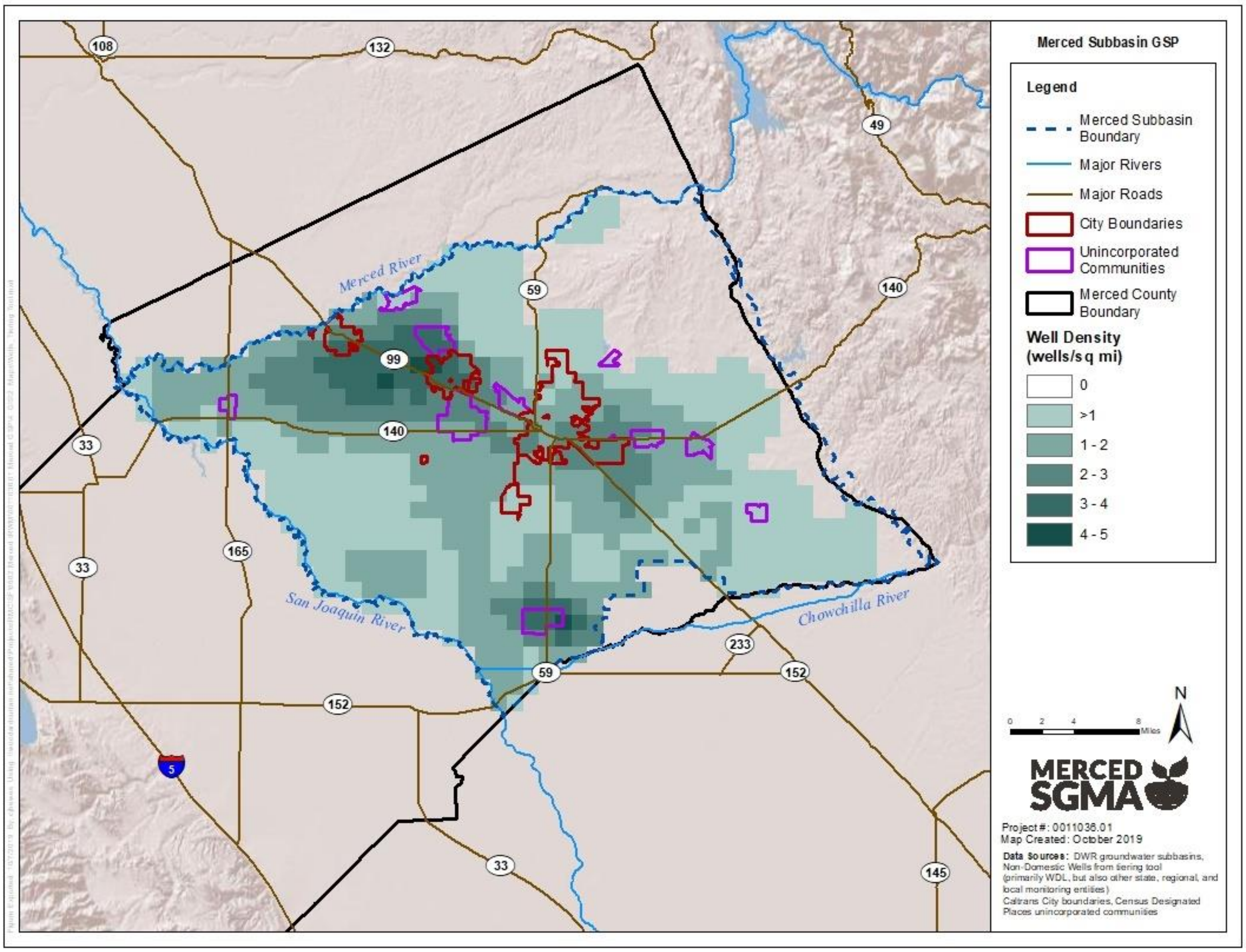
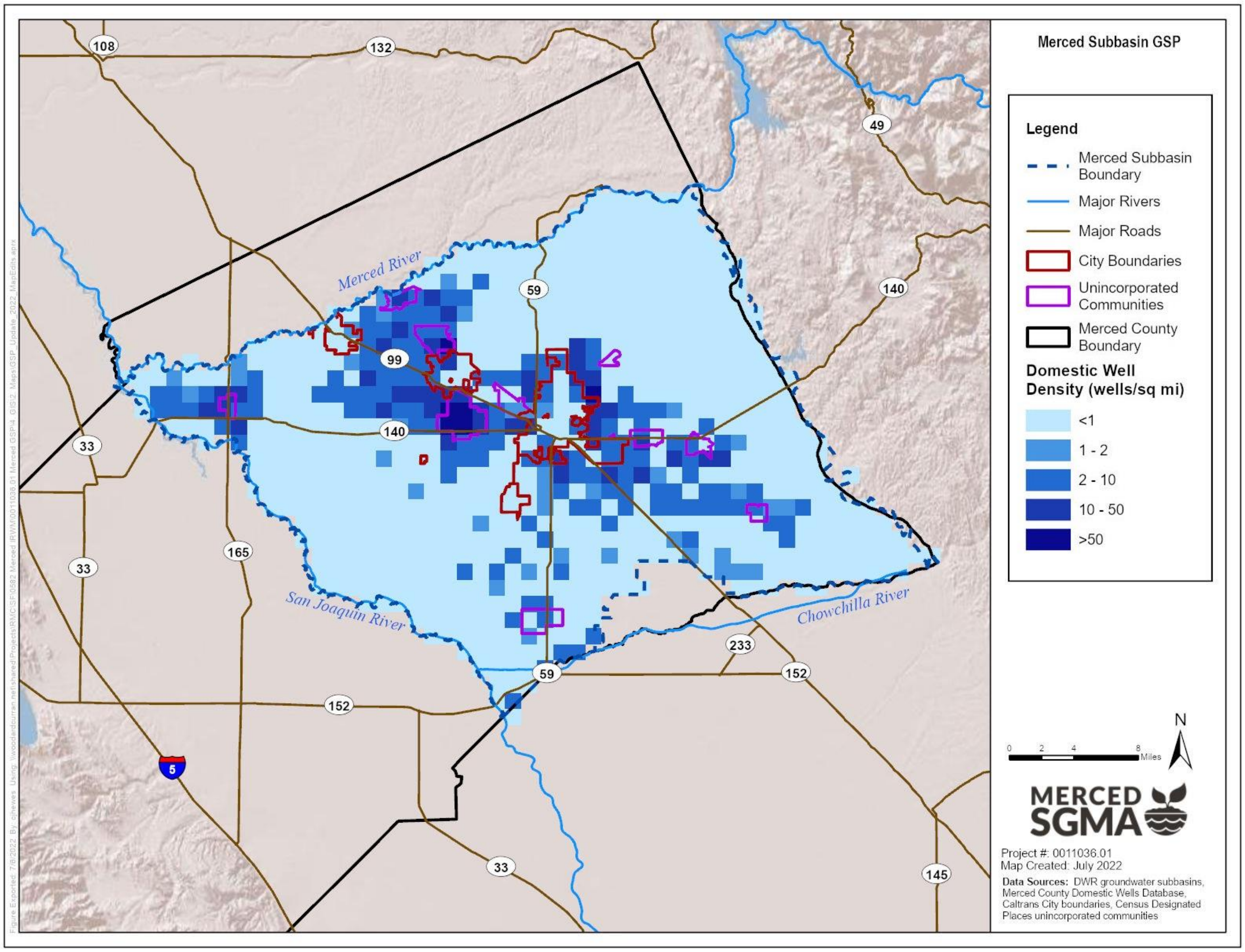


Figure 1-9: Density of Domestic Wells per Square Mile



1.2.2 Water Resources Monitoring and Management Programs

The existing monitoring and management landscape within the Merced Subbasin is a patchwork of local, regional, state, and federal programs, each serving its own specific function. This patchwork provides valuable data that has supported past needs and will assist in meeting monitoring needs under SGMA. This patchwork of programs also creates redundancies, inconsistent protocols, and inconsistent timing of monitoring that will need to be improved under SGMA.

Existing monitoring within the Merced Subbasin is extensive and complex, performed for a variety of purposes by a variety of entities. During a review of existing groundwater monitoring data and programs, data were collected from the following agencies and/or programs:

Statewide Monitoring Programs (Agencies and Databases):

- California Data Exchange Center (CDEC)

- California Department of Pesticide Regulation (CDPR)
- California Environmental Data Exchange Network (CEDEN)
- State Water Resources Control Board (SWRCB), Division of Drinking Water (DDW)
- Department of Water Resources (DWR):
  - California Statewide Groundwater Elevation Monitoring Groundwater Information Center Interactive Mapping Application (GICIMA)
  - Water Data Library (WDL)
- Groundwater Ambient Monitoring and Assessment Program (GAMA)
- UNAVCO
- United States Bureau of Reclamation (USBR)
- United States Geological Survey (USGS)

Regional Monitoring Programs:

- Groundwater Quality Trend Monitoring Program through SWRCB Irrigated Lands Regulatory Program (ILRP)
- San Joaquin River Restoration Program (SJRRP)

Local Monitoring Agencies

- City of Atwater
- City of Livingston
- Le Grand Community Service District (CSD)
- Meadowbrook Water Company
- McConnell Recreation Area
- Merced Area Groundwater Pool Interests (MAGPI)
- Merced County Department of Public Health, Division of Environmental Health
- Merced Irrigation District (MID)
- San Luis National Wildlife Refuge (NWR) Complex
- Stevinson Water District (SWD)

1.2.2.1 Groundwater Level Monitoring

1.2.2.1.1 Department of Water Resources – Water Data Library

DWR's WDL contains measurements of groundwater elevations from water supply and monitoring wells monitored by numerous entities, including local agencies, DWR, and federal agencies. Based on an export of groundwater level data requested directly from DWR on December 6, 2016, the Merced Subbasin contains 95 years of groundwater elevation measurements from 814 wells monitored between 1922 and 2016.

1.2.2.1.2 City of Livingston, Department of Public Works

The City of Livingston, Department of Public Works records depth to groundwater measurements for nine wells in their service area. Depth to groundwater readings were taken biannually from 1993 to 1994 and in 2002, and monthly from 2014 to 2017. There is a total of seven years of data for the nine wells.

1.2.2.1.3 Groundwater Information Center Interactive Mapping Application (GICIMA)

The GICIMA is an interface that displays groundwater elevations and depth to water measurements. Groundwater elevations are measured biannually, in the spring and fall, by local monitoring agencies as part of the California Statewide Groundwater Elevation Monitoring Program (CASGEM) program. Based on data downloaded from GICIMA on May 30, 2018, within the Merced Subbasin there are 67 wells with seasonal groundwater elevation and depth to groundwater data from 2011 through 2017.

1.2.2.1.4 Merced Area Groundwater Pool Interests

The Merced Area Groundwater Pool Interests was formed in 1997 and is a consortium of 15 municipal and agricultural water purveyors, one Member at Large, and two interest groups within Merced County. MAGPI selected wells from member agencies and developed a well network to form a representative groundwater profile of the Merced Subbasin. The cooperating agencies report groundwater levels to MAGPI. In total, the MAGPI monitoring network consists of 44 CASGEM wells and eight voluntary wells. Through the data request, monthly groundwater level data were received for 36 MAGPI wells for 1993 through 2014. The following specific wells from individual member agencies are reported to MAGPI:

- Black Rascal Water Company (2 wells, monthly groundwater levels from 2003-2015)
- City of Atwater – Department of Public Works (10 wells, monthly static groundwater levels)
- Le Grand CSD (3 wells, monthly static groundwater levels for 2013-2014)
- MID (310 wells, monthly static groundwater levels from 1993-2013)
- Planada CSD (5 wells, monthly static groundwater levels 2005-2015)
- Stevinson Water District (5 wells, monthly groundwater levels 1962-2008)
- Winton Water & Sanitary District (5 wells, monthly static groundwater levels 2005-2015)

1.2.2.1.5 San Luis National Wildlife Refuge Complex

The San Luis NWR Complex records groundwater elevation data for 25 wells in the Merced National Wildlife Refuge, typically only when well tests are performed by a contractor, which occurs less than once per decade on each well.

1.2.2.1.6 Merced County Department of Public Health, Division of Environmental Health

The Merced County Department of Public Health, Division of Environmental Health maintains data on 530 irrigation, domestic, and public water system wells in the Subbasin, each of which have at least one groundwater elevation measurement, but no available date.

1.2.2.2 Groundwater Quality Monitoring

Numerous agencies within Merced County collect or maintain groundwater quality data and are described in the sections below.

1.2.2.2.1 State Agencies

1.2.2.2.1.1 DWR Water Data Library (WDL)

The WDL contains water quality data recorded at 211 unique monitoring wells within the Merced Subbasin, with sampling dates from 1946 through 1988. The majority of monitoring activity took place in the 1950s and 1960s, and most wells have one to two days of sampling results, as wells are not regularly sampled. The most frequently sampled parameters (more than 1,000 sample results) are dissolved chloride, sodium, calcium, boron, magnesium, and sulfate as well as conductance, pH, and total alkalinity and hardness. Nutrients, metals, and total dissolved solids (TDS) were also sampled but have fewer sample results available.

1.2.2.2.1.2 California Department of Pesticide Regulations

The CDPR maintains a well inventory database containing data from wells sampled for pesticides by a variety of agencies, including the California Department of Public Health (prior to reporting being taken over by the SWRCB), CDPR, DWR, USGS, and SWRCB DDW. These agencies monitor a variety of wells, including monitoring, domestic, large and small water systems, irrigation, and community wells for 35 different pesticides and report measurements to the CDPR. Exact locations are not known, but based on estimation of coordinates via county, township, range, and section, there are 951 wells monitored within the Merced Subbasin with groundwater quality measurements on pesticides, such as DBCP and xylene, sampled between 1979 and 2015.

1.2.2.2.1.3 Groundwater Ambient Monitoring and Assessment Program (GAMA)

Established in 2000, the GAMA Program monitors groundwater quality throughout California. GAMA is intended to create a comprehensive groundwater monitoring program throughout the state and increase public availability and access to groundwater quality and contamination information. Agencies submit data from monitoring wells for 244 constituents including TDS, nitrates and nitrites, arsenic, and manganese. GAMA data for the Merced Subbasin contains wells monitored by the DDW, CDPR, environmental monitoring wells monitored by regulated facilities, and USGS, with sampling performed from 1930 through 2016. Most wells have one or two days with sampling results because wells are not regularly sampled. Agencies submitting data to GAMA are summarized below.

Division of Drinking Water

The SWRCB DDW monitors public water system wells for Title 22 requirements (such as organic and inorganic compounds, metals, microbial, and radiological analytes). Data are available for active and inactive drinking water sources for water systems that serve the public –defined as serving 15 or more connections or more than 25 people per day. Data are electronically transferred from certified laboratories to the DDW daily. Wells are monitored for Title 22 requirements, including pH, alkalinity, bicarbonate, calcium, magnesium, potassium, sulfate, barium, copper, iron, zinc, and nitrate. In the Merced Subbasin, DDW reported groundwater quality data for 177 wells from 1984 through 2016.

California Department of Pesticide Regulations

CDPR is described above. CDPR reports data to GAMA. Unlike data reported directly from CDPR, GAMA provides latitude and longitude coordinates for CDPR wells. In the Merced Subbasin, CDPR reported groundwater quality measurements for 170 wells with water quality data from 1981 through 2012. CDPR only monitors for pesticides and therefore does not have results on water quality constituents such as nitrates and TDS.

DWR

DWR's groundwater quality data are incorporated from the WDL, described earlier in this section.

Environmental Monitoring Wells

Environmental monitoring wells are monitored by facilities that in many cases have identified contamination but may not necessarily require an investigation and cleanup (i.e., monitoring through GeoTracker described below). Environmental monitoring wells that fall under the GAMA program typically include municipal water purveyors or small water supply systems. 355 wells were identified in the GAMA data download with water quality measurements taken from 2000 through 2016. Contaminated sites often have concentrations of constituents that are not indicative of regional groundwater quality, so environmental monitoring wells may often be excluded from water quality analysis. However, these wells and associated data may have utility in SGMA analysis related to the presence and impact of point-source contamination.

United States Geological Survey

USGS data within the GAMA database reports groundwater quality data for 173 wells within the Merced Subbasin, monitored from 1950 through 2012.

1.2.2.2.1.4 GeoTracker

GeoTracker, operated by the SWRCB, is a subset program of the GAMA program. GeoTracker GAMA does not regularly monitor for general groundwater quality constituents. GeoTracker contains records for sites that require cleanup, such as leaking underground storage tank sites, Department of Defense sites, and cleanup program sites. GeoTracker also contains records for various unregulated projects as well as permitted facilities including: Irrigated Lands Regulatory Program, oil and gas production, operating permitted underground storage tanks, and land disposal sites. GeoTracker receives records and data from SWRCB programs and other monitoring agencies. 669 are sites within Merced County, with increased density near cities such as Merced, Atwater, Livingston, Gustine, Los Banos, and Dos Palos. Of the 669 sites identified in Merced County, 80 are listed as active or open.

1.2.2.2.2 Regional Monitoring

1.2.2.2.2.1 Merced County Department of Public Health, Division of Environmental Health

Merced County Department of Public Health, Division of Environmental Health monitors 60 domestic wells in Merced County for chloride. Additionally, it has monitored nine domestic wells within the Merced Subbasin for general minerals, inorganics, dibromochloropropane (DBCP), and ethylene dibromide (EDB) since 1988 (AMEC, 2008).

1.2.2.2.2.2 Irrigated Lands Regulatory Program

The RWQCB initiated the Irrigated Lands Program in 2003, later renamed to the Irrigated Lands Regulatory Program, to regulate discharge from irrigated agriculture to surface waters and groundwater. The program monitors for a variety of pollutants found in runoff from irrigated lands, including pesticides, fertilizers, pathogens, salts, and sediment. Groundwater is required to be sampled biannually.

The Eastern San Joaquin Water Quality Coalition (ESJWQC) represents the region with waste discharge orders. ESJWQC monitors the Turlock, Merced, and Chowchilla groundwater subbasins. The ESJWQC submitted a

Groundwater Quality Assessment Report (GAR) in 2015. The GAR characterizes past and present groundwater quality (nitrates, salinity, TDS, and pesticides) and the impact of irrigated agricultural practices on groundwater quality.

1.2.2.3 Land Subsidence Monitoring

In the Merced Subbasin, subsidence monitoring is performed using continuous global positioning system (GPS) stations monitored by UNAVCO's Plate Boundary Observatory (PBO) program as well as static GPS points from the USBR's SJRRP. There are no known extensometers in the Merced Subbasin.

1.2.2.3.1 UNAVCO's Plate Boundary Observatory Program

The UNAVCO PBO network consists of a network of about 1,100 continuous global positioning system (CGPS) and meteorology stations in the western United States to measure deformation resulting from the constant motion of the Pacific and North American tectonic plates in the western United States. Information from this monitoring can support monitoring of land subsidence resulting from extraction of groundwater. There are two CGPS stations within Merced County but not within the Merced Subbasin: P303, near the City of Los Banos, and P252, near the City of Gustine. Both station P303 and P252 have subsidence data from 2005 to present (2017).

1.2.2.3.2 United States Bureau of Reclamation

The most comprehensive subsidence monitoring within Merced County comes from USBR's SJRRP. USBR has been surveying 85 static GPS points across the San Joaquin Valley biannually, in July and December of each year, to monitor ongoing subsidence since 2011. The Merced Subbasin contains 11 of the total 85 static GPS points, with an additional 9 points within Merced County and 31 additional GPS points located within 20 miles of the county boundary, primarily to the south.

1.2.2.3.3 United States Geological Survey

There are no known extensometers monitored by the USGS within Merced County. However, there are three USGS cable extensometers directly south of the county, with the closest extensometer approximately 3 miles southwest of the city of Dos Palos (the other two extensometers are 13 and 15 miles south of Dos Palos). The three extensometers have recorded data since 1958, 1961, and 1964, with periodic gaps in the data (i.e., most monitoring occurred in the 1960s through 1990s with a lapse in data until the early 2000s). Only the two farthest extensometers are currently monitoring subsidence, the third extensometer that is closer to the county boundary has been offline since a cable broke in 2012 (USGS, 2017).

1.2.2.4 Surface Water

1.2.2.4.1 Streamflow Monitoring Data

Streamflow monitoring data in the Merced Subbasin is available on the following waterbodies:

- Merced River
- San Joaquin River
- Bear Creek

Figure 4-9 in Chapter 4 (Monitoring Networks) shows a map of the streamflow gauging stations described in the sections below.

1.2.2.4.1.1 Department of Water Resources

DWR has a total of seven river discharge monitoring stations located in or along the border of the Merced Subbasin; four are co-operated with DWR's South Central Region Office (SCRO) and one station is co-operated with DWR's Flood Management Agency. Of the seven sites operated by DWR, SCRO, and Flood Management, two are located along the Merced River, one is located along Bear Creek, and four are located along the San Joaquin River. DWR monitors river stage (feet) and river discharge (cubic feet per second [cfs]) hourly. The oldest available data record is from 1984, but most stations went online in 1997 and have been monitoring since.

1.2.2.4.1.2 Merced Irrigation District

MID has three stream gages on the Merced River (one jointly operated with the USGS). Available data from MID monitoring of Merced River water diversions and flow extends back to 1998. Two monitoring stations monitor surface water diversions from dams to canals; one at the Merced Falls Dam into the Northside Canal and the second at the Crocker-Huffman Diversion Dam into the Main Canal. The third Merced River monitoring station monitors streamflow at the Shaffer Bridge.

1.2.2.4.1.3 United States Army Corps of Engineers

The United States Army Corps of Engineers (USACOE) has two streamflow gages on Bear Creek, one at the Bear Creek Dam and Reservoir and the other on Bear Creek at McKee Road. The USACOE has hourly data records on the inflow and outflow (cfs) to the Bear Creek Reservoir and streamflow (cfs) for Bear Creek at McKee Road, in addition to Bear Creek Reservoir storage (acre-feet [AF]), for water years 1995 through 2017.

1.2.2.4.1.4 United States Geological Survey

Within the Subbasin, the USGS operates three streamflow gages on the San Joaquin River and two on the Merced River. Rivers are monitored at 15- to 60-minute intervals for streamflow (cfs), gage height (feet), and change in gage height (feet). The oldest stream gage (#11270900) has 115 years of data (from 1901 through 2016) of daily streamflow and gage height changes. The other four gages in the Subbasin have a range from 105 years of data (#1127400, installed in 1912) to two years of data (#11260815, installed in 2014).

1.2.2.4.2 Surface Water Diversion

The following agencies divert surface water and record their diversions:

- Merquin County Water District
- Stevinson Water District
- Merced Irrigation District
- San Luis National Wildlife Refuge Complex (which includes the Merced National Wildlife Refuge)
- Turner Island Water District

1.2.2.5 Canal Diversions and Seepage

MID performed a study from 2010 through 2015 to monitor seepage and established that canal seepage is one of the main components of groundwater recharge in the Subbasin. Seepage and deep percolation from applied water on grower's fields varied between 133,000 AF and 313,000 AF between 2010 and 2015 (MID, 2016). Canal seepage alone contributed between 21,454 AF and 181,107 AF from 2010 through 2015 (MID, 2016). Results from this study helped characterize the seasonality and location of seepage, finding that seepage rates increase during low precipitation years and that about half of all seepage occurs in the utilized portions of creeks, sloughs and drains, as well as regulating reservoirs and off-channel inundated areas (MID, 2016).

Currently, MID does not monitor for water quality in the canals. In 2016, MID designated certain canals for water supply conveyance to future surface water treatment plants in Merced, Atwater, and Livingston, once the groundwater basin reaches a certain threshold for water quality and groundwater levels (MID, 2016).

1.2.2.6 Existing Water Management Programs

The subsections below contain descriptions of the Integrated Regional Water Management Plan, Agricultural Water Management Plan, and Urban Water Management Plans that apply to the Merced Subbasin.

1.2.2.6.1 Integrated Regional Water Management Plan

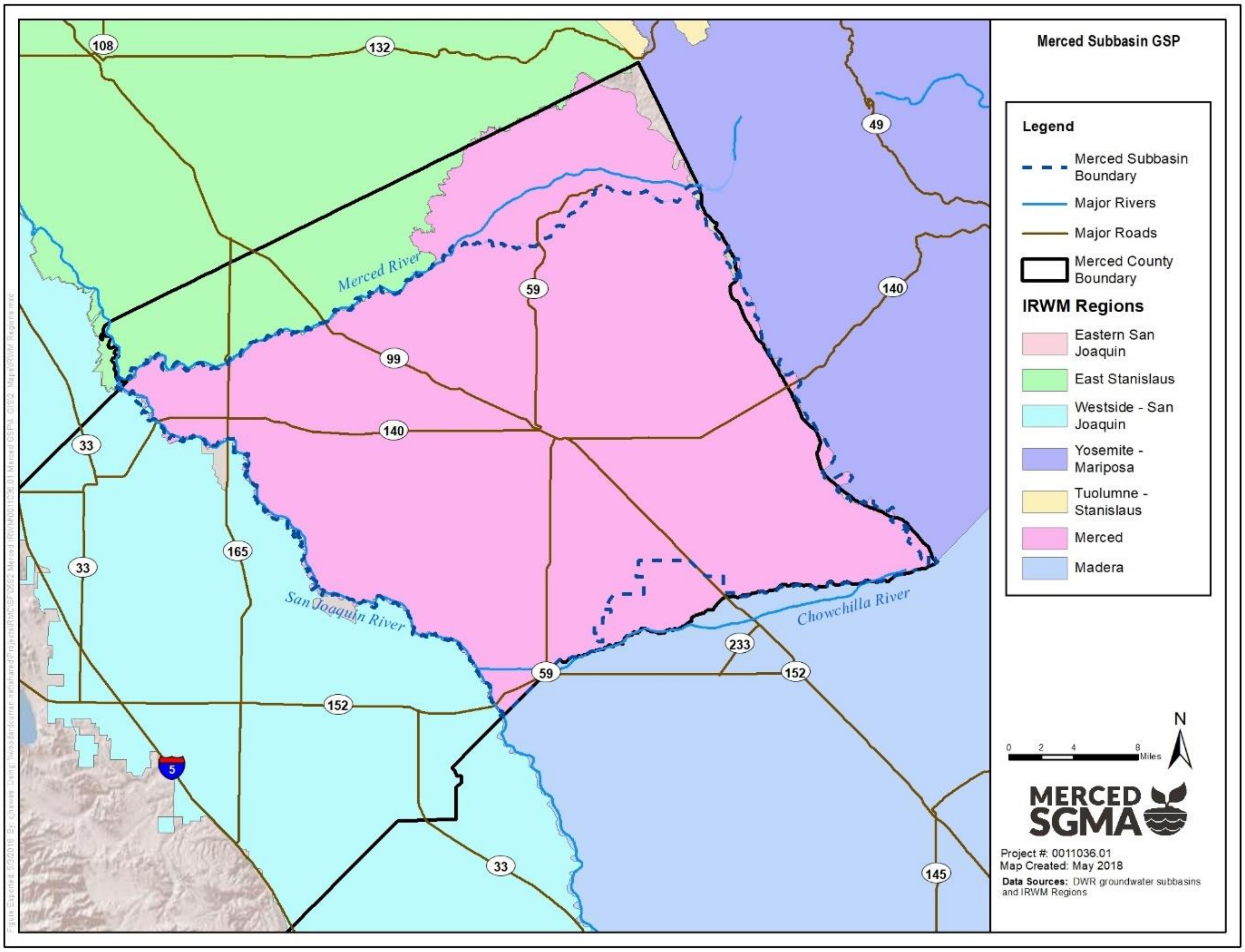
The Merced Integrated Regional Water Management Plan (Merced IRWMP) is a collaborative regional planning document that was published in August 2013. The IRWMP covers a geographic region that includes the entirety of the Merced Subbasin, and also portions of the Turlock Subbasin to the north and Chowchilla Subbasin to the south. The IRWMP boundaries are generally defined by the eastern boundary of the Merced and Turlock Groundwater Subbasins to the east, the San Joaquin River to the west, the northern boundary of the Dry Creek watershed to the north, and the Chowchilla River to the south. Low-lying areas north of the Merced River between the river's confluences with Dry Creek and the San Joaquin River are also included (RMC Water and Environment, 2013a).

The following 2013 IRWMP objectives related to groundwater use would potentially influence implementation of the GSP:

- Manage flood flows for public safety, water supply, recharge, and natural resource management
- Meet demands for all uses, including agriculture, urban, and environmental resource needs
- Correct groundwater overdraft conditions
- Protect and improve water quality for all beneficial uses, consistent with the Basin Plan

The 2013 IRWMP provides valuable resources related to potential concepts, projects, and monitoring strategies that are leveraged in this Merced GSP. See Figure 1-10 for a map of the Merced IRWM Region. An update to the 2013 Plan is currently underway.

Figure 1-10: Merced IRWM Region Setting



1.2.2.6.2 Agricultural Water Management Plan

The Agricultural Water Management Plan (AWMP) was developed and adopted by MID in 2013 in compliance with SB X7-7 of 2009 which required certain agricultural water suppliers to prepare an AWMP and implement Efficient Water Management Practices (EWMPs) (MID, 2013). The Critical EWMPs include:

- Measure the volume of water delivered to customer with sufficient accuracy
- Adopt a pricing structure based at least in part on quantity delivered (Volumetric Pricing)

Applicable Conditional EWMPs that have the benefit of less applied water or increasing system efficiency include:

- Facilitate financing of capital improvements for on-farm irrigation systems
- Implement an incentive pricing structure that promotes one or more of the goals identified in the CWC
- Expand line or pipe distribution systems, and construct regulating reservoirs to increase distribution system flexibility and capacity, decrease maintenance, and reduce seepage
- Increase flexibility in water ordering by, and delivery to, water customers within operational limits
- Construct and operate supplier spill and tailwater recovery systems
- Automate canal control structures
- Facilitate or promote customer pump testing and evaluation
- Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress report
- Provide for the availability of water management services to water users
- Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage
- Evaluate and improve the efficiencies of the supplier's pumps

The 2013 AWMP provides a framework of management practices to help meet water management goals that align with the goals of the Merced GSP.

1.2.2.6.3 City of Merced Urban Water Management Plan

The City of Merced 2015 Urban Water Management Plan (UWMP) was developed according to requirements of the CWC (City of Merced, 2017). The city's water supply comes from two sources: 79 percent from groundwater in the Merced Subbasin and 21 percent from recycled water. Year 2035 projections of water supplies include exchanges and transfers with MID, but groundwater and recycled water remain the top two sources of water supply. Total water demands are expected to increase from 22,741 AF per year (AFY) in 2015 to 37,829 AFY in 2035.

The City of Merced uses the following actions to encourage conservation and efficient use of water:

- Water Waste Prohibition Ordinance
- Fully metered distribution system
- Tiered water rates
- Public education and outreach efforts
- Free residential plumbing retrofit devices
- Washing Machine Rebate program

1.2.2.6.4 City of Livingston Urban Water Management Plan

The City of Livingston 2015 UWMP was developed according to requirements of the CWC (City of Livingston, 2016). The city's water supply comes entirely from the Merced Subbasin and is expected to remain the sole source of water through 2040. Total water demands are expected to increase from 2,190 AFY in 2015 to 2,604 AFY in 2040.

The City of Livingston uses the following actions to encourage conservation and efficient use of water:

- Water shortage contingency plan
- Majority of distribution system is metered
- Excess water use is billed at a variable rate
- Public education and outreach efforts

1.2.3 Land Use Elements or Topic Categories of Applicable General Plans

1.2.3.1 Existing General Plans

The Merced Subbasin is located almost entirely within Merced County, which has jurisdiction over land use planning for the majority of the surface area of the Subbasin. The incorporated cities of Merced, Atwater, and Livingston make up the remaining area. Implementation of the Merced GSP will be affected by the policies and regulations outlined in the Merced County General Plan, as well as the General Plans for the other three cities, given that the long-term land use planning decisions that would affect the Subbasin are under the jurisdiction of the county and respective cities.

This section describes how implementation of the various General Plans may change water demands in the basin, how the General Plans may influence the GSP's ability to achieve sustainable groundwater use, and how the GSP may affect implementation of General Plan land use policies.

1.2.3.1.1 Merced County General Plan

The Merced County General Plan describes the official County "blueprint" on the location of future land use, development preservation, and resource conservation decisions. It's five guiding principles encompass the core issues facing the community: support and protection of agriculture, expansion and diversification of economic development, protection of environmental quality, support of all essential public facilities and services, and coordination of transportation networks (Merced County, 2013).

1.2.3.1.1.1 Relevant Merced County General Plan Goals and Policies

The following Merced County General Plan Land Use Element goals and policies related to groundwater use would potentially influence implementation of the GSP:

- Goal LU-2: Preserve, promote, and expand the agricultural industry in Merced County.
- Policy LU-2.5: Agricultural Support Facilities (RDR/JP): Allow consideration of locating characteristically-specific commercial and industrial uses in rural areas in limited cases based on the unique nature of the use and for health and safety reasons, which require location on large parcels or in sparsely populated areas. In addition, consider the following criteria during the Conditional Use Permit review process:
    - h) The use shall not have a detrimental effect on surface or groundwater resources

- Policy LU-4.4: Efficient Development (RDR): Require efficient and environmentally sound development, which minimizes impacts on sensitive habitat/species, protects water quality and supply, and provides adequate circulation, within Rural Centers.
- Policy LU-5.F.1: New Urban Community Size and Location Requirements (RDR): Only accept applications for the establishment of additional new Urban Communities if they encompass a minimum area of 320 acres in order to achieve efficiencies in urban service delivery and provide for long-range growth needs. In addition, require that proposed new Urban Communities be located only in areas that:
  - b) Contain few wetlands or significant natural resources;
  - g) Are not located within areas that recharge to already compromised source water aquifers (i.e., in overdraft condition) or areas highly susceptible to groundwater contamination.
- Policy LU-5.F.4: Water Impacts (RDR): Prohibit new Urban Communities, or the expansion of existing urban communities, if they will negatively impact the water supply of existing users.

The following Merced County General Plan Agricultural Element goals and policies related to groundwater use would potentially influence implementation of the GSP:

- Goal AG-2: Ensure the long-term preservation and conservation of land used for productive agriculture, potentially-productive agricultural land, and agricultural-support facilities.
  - Note that the term “productive agriculture” is defined as: “farmland that has received water supplies in three of the prior 10 years and is classified as Prime Farmland, Farmland of Statewide Importance, or Unique Farmland on the Statewide Important Farmland map.” (Merced County, 2013)

The following Merced County General Plan Water Element goals and policies related to groundwater use would potentially influence implementation of the GSP:

- Goal W-1: Ensure a reliable water supply sufficient to meet the existing and future needs of the County.
- Policy W-1.1: Countywide Water Supply (MPSP/IGC): Ensure that continued supplies of surface and groundwater are available to serve existing and future uses by supporting water districts and agencies in groundwater management and water supply planning; requiring that new development have demonstrated long-term water supply; and assisting both urban and agricultural water districts in efforts to use water efficiently.
- Policy W-1.3: Agricultural Water Study (MPSP/IGC): In cooperation with local water agencies and districts, maintain the detailed General Plan study of countywide water use and needs for agriculture with periodic updates and with information that can be widely shared and publicized.
- Policy W-1.4: Groundwater Recharge Projects (RDR): Support implementation of groundwater recharge projects consistent with adopted Integrated Regional Water Management Plans to minimize overdraft of groundwater and ensure the long-term availability of groundwater.
- Policy W-1.5: New Well Guidelines (RDR/IGC): Coordinate with the cities and special districts in developing County-wide guidelines regarding the location and construction of new water wells.
- Policy W-1.7: Water Sufficiency Requirement (RDR): Require new developments to prepare a detailed source water sufficiency study and water supply assessment per Title 22 and SB 610, consistent with any Integrated

Regional Water Management Plan or similar water management plan. This shall include studying the effect of new development on the water supply of existing users, with public input.

- Policy W-1.8: Single User Well Consolidation (IGC): Encourage consolidation of single user wells into local water districts (with management plans) where feasible.
- Policy W-1.10: Groundwater Overdraft Protection (RDR/MPSP): Where a water supply source is nearby and accessible, encourage large water consumers to use available surface irrigation water (secondary water) for school athletic fields, sports complexes, and large landscape areas.
- Goal W-2: Protect the quality of surface and groundwater resources to meet the needs of all users.
- Policy W-2.1: Water Resource Protection (RDR): Ensure that land uses and development on or near water resources will not impair the quality or productive capacity of these water resources.
- Policy W-2.2: Development Regulations to Protect Water Quality (RDR): Prepare updated development regulations, such as best management practices, that prevent adverse effects on water resources from construction and development activities.
- Policy W-2.3: Natural Drainage Channels (RDR/MPSP): Encourage the use of natural channels for drainage and flood control to benefit water quality and other natural resource values.
- Policy W-2.4: Agricultural and Urban Practices to Minimize Water Contamination (JP): Encourage agriculture and urban practices to comply with the requirements of the Regional Water Quality Control Board for irrigated lands and confined animal facilities, which mandate agricultural practices that minimize erosion and the generation of contaminated runoff to ground or surface waters by providing assistance and incentives.
- Policy W-2.5: Septic Tank Regulation (RDR): Enforce septic tank and onsite system regulations of the Regional Water Quality Control Board to protect the water quality of surface water bodies and groundwater quality.
- Policy W-2.6: Wellhead Protection Program (MPSP): Enforce the wellhead protection program to protect the quality of existing and future groundwater supplies by monitoring the construction, deepening, and destruction of all wells within the County.
- Policy W-2.8: Water Contamination Protection (RDR/MPSP): Coordinate with the State Water Resources Control Board, Regional Water Quality Control Board, and other responsible agencies to ensure that sources of water contamination (including boron, salt, selenium and other trace element concentrations) do not enter agricultural or domestic water supplies and will be reduced where water quality is already affected.
- Policy W-3.1: Water Availability and Conservation (SO/PI): Support efforts of water agencies and districts to prevent the depletion of groundwater resources and promote the conservation and reuse of water.
- Policy W-3.2: Landscape Water Efficiency (SO/PI): Ensure the conservation of water in urban areas through the implementation of the State Model Water Efficient Landscape Ordinance as implemented in Section 18.38 (Landscaping Standards) of the County Zoning Ordinance.
- Policy W-3.4: High Water Use Processing Activities (RDR): Prohibit any processing activities with high water use practices near areas where groundwater overdraft problems exist, unless the facility uses water recycling and conservation techniques that minimize effects of water use to the groundwater table.

- Policy W-3.13: Agricultural Water Reuse (RDR): Promote and facilitate using reclaimed wastewater for agricultural irrigation, in accordance with Title 22 and guidelines published by the State Department of Public Health.
- Policy W-3.14: Agricultural Water Conservation (JP): Encourage farmers to use irrigation methods which conserve water in areas where flood irrigation is used for groundwater recharge.
- Policy W-3.15: Agricultural Water Efficiency (IGC): Coordinate with the Farm Bureau and agricultural irrigation districts to promote protection of water resources in agricultural areas by encouraging programs that assist producers to use water efficiently in agricultural operations and by promoting technology for efficient water use in agriculture.
- Goal W-4: Enhance and protect County watersheds through responsible water and land use management practices that address water bodies, open spaces, soils, recreation, habitat, vegetation, groundwater recharge, and development.
- Policy W-4.1: Water Resource Protection and Replenishment (RDR/MPSP/IGC): Protect watersheds, aquifer recharge areas, and areas susceptible to ground and surface water contamination by identifying such areas, and implementing requirements for their protection such as:
    - a) Implement zoning and development regulations to protect water resources, including aquifer recharge areas and areas susceptible to ground and surface water contamination;
    - b) For new development, and when adopting new Community Plans, require community drainage systems that incorporate on-site infiltration and contaminant control measures that are compatible with the County SWMP and NPDES regulations for post-construction runoff conditions; and
    - c) Cooperate with other agencies and entities with responsibilities for water quality and watershed protection.
- Goal W-5: Promote interagency communication and cooperation between local governments, irrigation districts, and water districts in order to optimize use of resources and provide the highest level of dependable and affordable service, while respecting individual entities water rights and interests.
- Policy W-5.1: Countywide Water Supply Study (RDR/MPSP/PSR): Prepare and regularly update a comprehensive water supply study that includes all four groundwater basins and three hydrologic zones, and takes into consideration activities in neighboring counties and the region. The plan shall consider reductions in Federal and State water deliveries in the western part of the County and anticipated reductions in water supplies due to climate change.
- Policy W-5.2: Master Plan Development (IGC): Coordinate with all agricultural and urban water districts to develop water supply master plans to guide future groundwater basin water supplies through regional solutions.
- Policy W-5.3: Water Forum (IGC/FB): Support a county-wide water forum to coordinate long-term water demand and supply programs that emphasize sustainability in the County consistent with approved IRWMPs.

1.2.3.1.1.2 Merced County General Plan's Influence on Water Demand and Groundwater Sustainability Plan

The General Plan explicitly encourages preservation of the county's groundwater resources, and states that future urban and agricultural growth should be accommodated only while ensuring that this growth occurs within the sustainable capacity of these resources. Due to the complementary nature of the General Plan and the GSP, implementation of the GSP is anticipated to be consistent with the General Plan's goals and policies.

1.2.3.1.1.3 Groundwater Sustainability Plan's Influence on Merced County General Plan's Goals and Policies

Successful implementation of the GSP will help to ensure that the Merced Subbasin's groundwater supply is managed in a sustainable manner. Given the amount of population growth projected in the county in the coming years, it is possible that changes in groundwater management by the GSP will impact the location and type of development that will occur in the Subbasin in the future. It is anticipated that GSP implementation will reinforce the General Plan's goals related to sustainable land use development in the county.

1.2.3.1.2 City of Merced General Plan

The City of Merced General Plan describes the City's 2030 vision and provides guidance for the growth needed to achieve it (City of Merced Development Services Department, 2011). The General Plan for 2030 vision was built upon the Merced Vision 2015 General Plan (adopted 1997) and was developed through a series of public forums, stakeholder and property owner meetings, and joint City Council/Planning Commission study sessions to solicit input from citizens, property owners, and decision makers.

1.2.3.1.2.1 Relevant City of Merced General Plan Goals and Policies

The following City of Merced General Plan goals and policies related to groundwater use would potentially influence implementation of the GSP:

- Policy P-3.1: Ensure that adequate water supply can be provided within the City's service area, concurrent with service expansion and population growth.
- Policy P-3.2: In cooperation with the County and the Merced Irrigation District, work to stabilize the region's aquifer.

1.2.3.1.2.2 City of Merced General Plan's Influence on Water Demand and Groundwater Sustainability Plan

The General Plan supports the efforts of the MAGPI in preservation of groundwater resources and recognizes that groundwater recharge is critical to supporting the city's future growth (City of Merced Development Services Department, 2011). Due to the complementary nature of the General Plan and the GSP, implementation of the GSP is anticipated to be consistent with the General Plan's goals and policies.

1.2.3.1.2.3 Groundwater Sustainability Plan's Influence on City of Merced General Plan's Goals and Policies

Successful implementation of the GSP will help to ensure that the Merced Subbasin's groundwater supply is managed in a sustainable manner. Given the amount of population growth projected in the city in the coming years, it is possible that changes in groundwater management by the GSP will impact the location and type of development that will occur in the city in the future. It is anticipated that GSP implementation will reinforce the General Plan's goals related to sustainable land use development in the city.

1.2.3.1.3 City of Atwater General Plan

The City of Atwater General Plan was published in 2000 and is a guide for community growth and development (Pacific Municipal Consultants, 2000). This update of the General Plan was assisted by an 18-member Technical Work Group made of representatives from various city departments, and other local public agencies. Core group input was augment by representatives from local school districts, businesses, and community organizations.

1.2.3.1.3.1 Relevant City of Atwater General Plan Goals and Policies

The following City of Atwater General Plan goals and policies related to groundwater use would potentially influence implementation of the GSP:

- Goal CO-1: Support efforts to monitor and remediate existing groundwater contamination within the planning area.
- Goal CO-2: Prevent the creation of new groundwater contamination or the spread of existing contamination.

1.2.3.1.3.2 City of Atwater General Plan's Influence on Water Demand and Groundwater Sustainability Plan

The General Plan focuses on groundwater contamination in the form of nitrates, pesticides (mainly dibromochloropropane), and other contaminants as a result of past operations at Castle Air Force Base (Pacific Municipal Consultants, 2000). Groundwater overdraft is not mentioned as an issue within this General Plan, likely due to being published in 2000, prior to more recent drought and overdraft issues. Implementation of the GSP is anticipated to be consistent with the General Plan's goals and policies related to groundwater quality monitoring.

1.2.3.1.3.3 Groundwater Sustainability Plan's Influence on City of Atwater General Plan's Goals and Policies

Successful implementation of the GSP will help to ensure that the Merced Subbasin's groundwater supply is managed in a sustainable manner. While population estimates are nearly two decades old, expected ongoing growth in the city means that it is possible that changes in groundwater management by the GSP will impact the location and type of development that will occur in the Subbasin in the future. It is anticipated that GSP implementation will reinforce the General Plan's goals related to sustainable land use development in the county. It is also likely that the GSP will influence groundwater quality monitoring and remediation described in the 2000 General Plan.

1.2.3.1.4 City of Livingston General Plan

The City of Livingston General Plan was updated and published in 1999 and is a long-term, comprehensive framework to guide physical, social, and economic development within the community (Quad Knopf, Inc., 1999). The 1999 General Plan update was developed by a General Plan consultant who worked with city staff and a General Plan Review Committee, with input from meetings with local service clubs, a workshop, and four town hall meetings. Key Issues of importance that guided policies for the General Plan were identified in these sessions and include agricultural preservation, contiguous planning, payment for expansion of public facilities by new development, and neighborhood development.

1.2.3.1.5 Relevant City of Livingston General Plan Goals and Policies

The following City of Livingston General Plan goals and policies related to groundwater use would potentially influence implementation of the GSP:

- Objective 5.2 (A): Protect natural resources including groundwater, soils, and air quality, to meet the needs of present and future generations.
- Policy 5.2 (1): Protect areas of natural groundwater recharge from land uses and disposal method[s] which would degrade groundwater quality. Promote activities, which combine stormwater control, and water recharges.

- Policy 5.2 (2): Expand programs that enhance groundwater recharge in order to maintain the groundwater supply, including the installation of detention ponds in new growth areas.
- Policy 9.1 (16): To encourage groundwater recharge, ponding basins shall be designed as detention basins. However, pumping facilities shall be included in such facilities to handle peak flows and to provide for disposal of storm water into irrigation ditches when necessary. Stormwater inflow into irrigation district canals and pipelines shall be subject to existing or future agreements by and between the City and the irrigation districts specifying maximum inflow, maximum service area boundary, and any other limitation thereto.
- Policy 9.1 (22): The City of Livingston shall cooperate with local water agencies to identify and resolve long-term water supply issues.

1.2.3.1.6 City of Livingston General Plan's Influence on Water Demand and Groundwater Sustainability Plan

The General Plan supports the efforts of preservation of groundwater supply and quality (Quad Knopf, Inc., 1999). Due to the complementary nature of the General Plan and the GSP, implementation of the GSP is anticipated to be consistent with the General Plan's goals and policies.

1.2.3.1.7 Groundwater Sustainability Plan's Influence on City of Livingston General Plan's Goals and Policies

Successful implementation of the GSP will help to ensure that the Merced Subbasin's groundwater supply is managed in a sustainable manner. While population estimates are nearly two decades old, expected ongoing growth in the city means that it is possible that changes in groundwater management by the GSP will impact the location and type of development that will occur in the Subbasin in the future. It is anticipated that GSP implementation will reinforce the General Plan's goals related to sustainable land use development in the county.

1.2.3.2 Land Use Plans Outside the Subbasin

Land use planning in the portions of the Turlock and Delta-Mendota Subbasins that are adjacent to the Merced Subbasin are located within Merced County and are thus covered by the Merced County General Plan described in Section 1.2.3.1.

A small portion of the Chowchilla Subbasin is located within Merced County, but most of the adjacent portions are located within Madera County. The Madera County General Plan is a major guiding document for land use development adjacent to the southern portion of the Merced Subbasin. It was last updated in 1995, with 17 amendments through 2015. A notable amendment in 2004 included the resolution that "The County shall implement policies and procedures stated in the County adopted "AB3030 Groundwater Management Plan" for the Chowchilla, Delta-Mendota, and Madera Basins" (Madera County, 1995).

Land use decisions in neighboring areas experiencing subsidence and overdraft are likely to effect groundwater conditions in the Merced Subbasin.

Surface water users (Merquin County Water District, Stevinson Water District, Merced Irrigation District, and San Luis National Wildlife Refuge Complex) are more likely to be impacted by land use change outside of the Subbasin, which might affect San Joaquin River or Merced River flows.

1.2.3.3 Well Permitting

In 2015, Merced County implemented a new well permitting program for any new, replacement, back-up, and De Minimis well construction. The permit program is enforced by County Municipal Code Chapter 9.27 (Groundwater Mining and Export) and 9.28 (Wells). Applicants must provide information about groundwater elevation estimates, land elevation estimates, land subsidence rate estimates, depth to Corcoran Clay, and other basic well characteristics (Merced County, 2015). Groundwater cannot be "exported", meaning used outside of the same basin from which it is extracted, without an exemption claim.

Merced County has established water well standards that define property line setbacks, casing perforations, gravel packing, well seals, backflow prevention, disinfection requirements, sampling taps, and more, as well as the requirement for installing monitoring device(s) for groundwater extraction, elevation, and/or water quality (Merced County, n.d.).

The City of Merced also enforces water well standards through Chapter 8.12 (Water Wells) in the City Code of Ordinances, under legal authority granted under CWC, Section 13801, for "Special Ground Water Protection" to minimize impacts and prevent the migration of harmful chemicals into aquifers used by the city (City of Merced, n.d.). The standards apply to all new and existing water wells, monitoring wells, cathodic protection wells, test wells and those exploratory holes deeper than twenty feet within the jurisdictional boundaries of the city. The city requires a permit for construction, rehabilitation, sealing, modification, or destruction of wells, which includes requirements for well site inspection by the city. Permittees are directed to DWR's State Water Well Standards for all standards related to location, construction, maintenance, rehabilitation, modification, abandonment, or destruction of wells.

New monitoring wells are subject to the same permitting requirements described above.

1.2.4 **Additional GSP Elements**

SGMA requires that the following topics are addressed in the GSP (CWC §10727.4). See below for references to where each topic is addressed.

- Control of saline water intrusion
    - See Section 3.5 for an explanation of why the saline water intrusion sustainability indicator does not apply to the Merced Subbasin.
- Wellhead protection
    - Details on wellhead protection are discussed in Section 1.2.3.3 (Well Permitting).
- Migration of contaminated groundwater
    - Details on migration of contaminated groundwater are discussed in Section 2.2.4.4 (Point-Source Contamination).
- Well abandonment and well destruction program
    - Details on well abandonment and well destruction are discussed in Section 1.2.3.3 (Well Permitting).
- Replenishment of groundwater extractions
    - Details on projects are discussed in Chapter 6 (Projects and Management Actions to Achieve Sustainability Goal).

- Activities implementing, opportunities for, and removing impediments to, conjunctive use and underground storage
  - Details on this topic are discussed in Chapter 6 (Projects and Management Actions to Achieve Sustainability Goal).
- Well construction policies
  - Details on well construction policies are discussed in Section 1.2.3.3 (Well Permitting).
- Measures addressing groundwater contamination cleanup, recharge, in-lieu use, diversions to storage, conservation, water recycling, conveyance, and extraction projects.
  - Details on projects are discussed in Chapter 6 (Projects and Management Actions to Achieve Sustainability Goal).
- Efficient water management practices for the delivery of water and water conservation methods to improve the efficiency of water use
  - Details on efficient water management practices are discussed in Section 1.2.2.6 (Existing Water Management Programs) and Section 1.2.3 (Land Use Elements or Topic Categories of Applicable General Plans).
- Efforts to develop relationships with State and federal regulatory agencies
  - Details on this topic can be found in Section 7 (Plan Implementation).
- Land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity
  - Details on this topic can be found in Section 1.2.3 (Land Use Elements or Topic Categories of Applicable General Plans).
- Impacts on groundwater dependent ecosystems
  - Details on groundwater dependent ecosystems are discussed in Section 2.2.7 (Groundwater-Dependent Ecosystems).

1.2.5 Notice and Communication

1.2.5.1 Beneficial Uses and Users in the Basin

The California Regional Water Quality Control Board Central Valley Region designates all ground waters in the Sacramento River Basin and San Joaquin River Basin as suitable or potentially suitable, at a minimum, for municipal and domestic water supply, agricultural supply, industrial service supply, and industrial process supply (Central Valley RWQCB, 2016).

Groundwater users in the region include municipalities, utilities, or other public water districts that provide groundwater as a drinking water supply, agricultural purveyors, individual private supply wells, and the environment. For the environment, the US Fish & Wildlife Service operates several wildlife refuges/management areas that are supported by groundwater. There are additional wetlands and other groundwater-dependent ecosystems throughout the Subbasin but are primarily concentrated in the western portion.

Merced National Wildlife Refuge is able to receive up to 15,000 AFY of water for environmental surface water flows from the beginning of April through the end of September from MID (according to 1993 settlement between MID and USFWS, recognized by the Federal Energy Regulatory Commission [FERC]). This GSP does not relieve any entity within the Subbasin of their commitments. Since 2000, Merced River releases by MID for the Vernalis Adaptive Management Plan to facilitate the migration of juvenile Chinook salmon have been approximately 60,000 AFY. During 2002 and again in 2007, MID released approximately 25,000 AF of surface water from the Merced River to the Environmental Water Account for protection and restoration of at-risk fish species listed under the Federal and California Endangered Species Acts. MID pumped an equal amount of groundwater to replace the surface water supply to growers within the District (AMEC, 2008).

Additional interests (as listed in CWC §10723.2) include, but are not limited to:

- Public water systems/municipal well operators:
    - Le Grand-Athlone Water District
    - Merquin County Water District
    - Plainsburg Irrigation District
    - Stevinson Water District
    - Lone Tree Mutual Water Company
    - Sandy Mush Mutual Water Company
    - California American Water, Meadowbrook District
    - Merced Area Groundwater Pool Interests (monitors and reports groundwater elevations in the Merced Subbasin)
    - Le Grand Community Services District
    - Planada Community Services District
- Local land use planning agencies: described in Section 1.2.3 - Land Use Elements or Topic Categories of Applicable General Plans
- State Agencies
    - California Department of Fish and Wildlife
    - Great Valley Grasslands State Park
- Federal government:
    - U.S. Fish and Wildlife: San Luis National Wildlife Refuge, Merced National Wildlife Refuge, and the Grasslands Wildlife Management Area (all are part of the San Luis National Wildlife Refuge Complex)
    - USDA Natural Resource Conservation Service, Fresno
    - USDA, Farm Service Agency

- U.S. Geological Survey, California Water Science Center, Sacramento

- Disadvantaged communities (DAC), combined list based on DWR's DAC Mapping Tool[3] and Merced County's SB244 Analysis[4]:
  - Disadvantaged: Atwater City, Le Grand Census Designated Place (CDP), Merced City, Stevinson CDP, The Grove, Tuttle CDP, Winton CDP
  - Severely Disadvantaged: Bear Creek CDP (Celeste), El Nido CDP, Franklin CDP, Planada CDP
- Environmental interests
  - Audubon California
  - East Merced Resource Conservation District / Sustainable Conservation
  - U.S. Fish and Wildlife Service
  - California Department of Fish and Wildlife
  - River Partners

Potential interests (listed in CWC §10723.2) that are not present in the Merced Subbasin include:

- California Native American tribes

1.2.5.2 Public Engagement and Active Involvement

A Merced Subbasin Stakeholder Engagement Strategy was developed (see Appendix N) to achieve the following goals:

- Conduct an inclusive outreach and education process that best supports the success of well-prepared GSP and that meets SGMA requirements.
- Offer a comprehensive, transparent outreach and education process that builds understanding and trust among the various stakeholders.
- Using a Planning Roadmap, that aligns the public engagement opportunities with the development of technical information at key points throughout the project, create an atmosphere of clear, concise, transparent, reliable information flow and opportunities for input.
- Engagement methods used will be evaluated throughout the GSP process and modified as needed.

  (Woodard & Curran, 2018a)

Active public participation was encouraged through the following opportunities for public engagement:

- Accepting public comment at GSA Board Meetings of all three GSAs.

[3] DWR DAC Mapping tool: https://gis.water.ca.gov/app/dacs/. Data is based on US Census ACS 2010-2014.

[4] Merced County SB244 report: http://www.co.merced.ca.us/DocumentCenter/View/12199. Report is dated May 2016, based on 2000 Census data.

- Accepting public comments at Coordinating Committee Meetings and Stakeholder Advisory Committee Meetings.
- Forming the Stakeholder Advisory Committee that includes community representatives of the diverse interests in the Subbasin to review and provide input on the elements of the GSP through monthly meetings open to the public.
- Conducting briefings and Public Workshops to provide opportunities for community members and interests groups to learn about, discuss, and comment on the GSP planning process before major decision milestones.
- Coordinating with Leadership Counsel and Self-Help Enterprises in their DAC outreach efforts.
- Developing a robust website with timely, pertinent information, opportunity to make comments, and sign-up for email notifications. The website houses information about SGMA, the GSP process, the Merced Subbasin GSA Boards, Coordinating Committee, Stakeholder Advisory Committee, Public Workshops, and draft GSP sections.
- Issuing news releases announcing public participation opportunities at Public Workshops.
- Providing translation services at Public Workshops.

The public comments received at GSA Board Meetings, Coordinating Committee Meetings, Stakeholder Advisory Committee Meeting and Public Workshops were used to inform the GSP team and allow the team to make adjustments to the GSP during its development. Meeting notes from the Stakeholder Advisory Committee, Coordinating Committee, and Public Workshops are included in Appendix B and capture the issues discussed during development of the GSP.

Noticing methods included:

- Website: (www.mercedsgma.org) Agendas for all committee meetings and public workshops were posted at least 48 hours ahead of meetings.
- A public email listserv was used to provide notice of GSA, CC, and SC meetings and Public Workshops.
- Informational e-newsletter articles**:** Articles that informed stakeholders about GSP planning, technical issues, and opportunities for participation and review were periodically provided to the Merced Farm Bureau, East Merced Conservation District, and the Greater Merced Area Chamber of Commerce for distribution to their constituents.
- Engagement with local and regional organizations and partners: Organizations and partners assisted in noticing Community Workshops and sharing project information. Organizations and partners included the three GSAs, Merced County, City of Merced, City of Livingston, City of Atwater, participating water and irrigation districts, Merced Farm Bureau, Greater Merced Chamber of Commerce, Hispanic Chamber of Commerce (Merced), Self-Help Enterprises (SHE), Leadership Counsel for Justice and Accountability, East Merced Resource Conservation District, and several area Municipal Advisory Councils.
- Social media channels: The County of Merced, Merced Irrigation District and McSwain Municipal Advisory Council posted information about GSP development and Community Workshops on their social media platforms.
- Press Releases: To announce opportunities for participation and input, press releases were issued to media lists maintained by the County of Merced and Merced Irrigation District.

- Display Advertisements: To announce Community Workshops, display ads were placed in the forward news section of the Merced Sun Times.
- Noticing in Disadvantaged and Severely Disadvantaged Communities: Community Workshop notices and other related GSP information were distributed by Self-Help Enterprises and the Leadership Council on behalf of the Merced Subbasin GSP team.

1.2.5.3 List of Public Meetings Where the GSP was Discussed

The following lists the public meetings held from January 2018 through June 2019.

GSA Board Meetings

The Boards of the 3 GSAs met regularly during plan development and not all meetings are listed below. The following GSA Board meetings included GSP-specific presentations:

Joint GSP Planning Workshop of the 3 GSAs (MSGSA, MIUGSA, TIWD GSA-1)
2018: January 11

MSGSA Board Meeting – Presentation on Water Budgets
2018: November 1
2019: April 11

Joint Board meeting of MIUGSA, MID, and TIWD GSA-1 – Presentation on Water Budgets
2018: December 4

Joint Board meeting of MIUGSA, MID, and TIWD GSA-1 – Draft GSP Public Comments
2019: September 18

Coordinating Committee Meetings (monthly on 4th Monday starting March 2018 – current)

2018: March 26, April 23, May 29, June 25, July 23, August 27, September 24, October 22, November 26, December 17
2019: January 28, February 25, March 25, April 22, May 29, June 24, July 22, August 26, October 28

Stakeholder Advisory Committee Meetings (monthly on 4th Monday starting May 2018 – current)

2018: May 29, June 25, July 23, August 27, September 24, October 22, November 26, December 17
2019: January 28, February 25, March 25, April 22, May 29, June 24, July 22, October 28

Public Workshops (with Spanish translation available)

2018: August 2, December 4, December 13
2019: February 25, May 29

1.2.5.4 List of Additional Public Meetings Where the July 2022 GSP Update was Discussed

The following lists the public meetings held from January 2022 through June 2022 where the July 2022 GSP Update was discussed.

GSA Board Meetings

The Boards of the three GSAs continued to meet regularly after GSP adoption, including meetings to discuss the July 2022 GSP Update in the first half of 2022.

Coordination Committee Meetings

2022: February 7, March 21, April 25, June 1, June 27

Note that additional meetings of the Coordination Committee were held in 2020 (November 2 and December 1) and 2021 (February 22, April 26, July 26, October 25, and December 22) after the adoption of the GSP in 2019 to discuss ongoing implementation activities.

Stakeholder Advisory Committee Meetings

2022: January 31, March 21, April 25, June 1, June 27

Note that additional meetings of the Stakeholder Advisory Committee were held in 2021 (April 12, July 12, and November 8) after the adoption of the GSP in 2019 to discuss ongoing implementation activities.

1.2.5.5 Comments Regarding the Plan

Meeting notes from the Stakeholder Advisory Committee, Coordinating Committee, and Public Workshops are included in Appendix B and capture the issues discussed during development of the GSP as well as the continued meetings post-adoption to discuss implementation of the GSP and the July 2022 update in response to DWR comments.

The Merced GSP Public Draft was published July 19, 2019 and written comments were collected for a 30-day period ending August 19, 2019. Additional comments were also received at a joint meeting of the three GSA Boards held on September 18, 2019. Individual comments from all letters and the public were reviewed, categorized, and addressed in Appendix O. Comment letters are included as an attachment to Appendix O. Comments from the joint boards meeting are documented in the meeting minutes and included as an attachment to Appendix O.

The Merced GSP July 2022 update was discussed at numerous public meetings (see Section 1.2.5.4) in the first half of 2022. The document was revised by the GSAs before review and adoption by the three GSA Boards in July 2022.

1.2.5.6 Communications

1.2.5.6.1 Decision-Making Processes

This GSP was developed jointly by MIUGSA, MSGSA, and TIWD GSA-1 (GSAs). The GSAs were guided by a Coordination Committee that is composed of up to four representatives from each GSA and is responsible for coming to unanimous agreement on recommendations for the technical and substantive Basin-wide issues, and then submitting the recommendations to the governing board of each GSA for final approval. To become fully effective, each GSA governing board must approve the Coordination Committee's recommendations (Merced Subbasin GSA, MIUGSA, Turner Island Water District GSA-#1, 2017). The Coordinating Committee met monthly during GSP development starting in March 2018. Meetings were open to the public with agendas posted at least 48 hours in advance. Coordinating Committee meeting agendas, presentations, and notes are posted on the Merced GSP website (www.mercedsgma.org).

The GSAs were also informed by a 23-member Stakeholder Advisory Committee which consisted of community representatives who reviewed groundwater conditions, management issues and needs, and projects and management actions to improve sustainability in the basin. The committee met monthly starting in May 2018 in sessions open to the public, providing a forum for testing ideas as well as providing information and feedback from members' respective constituencies. Agendas were posted at least 48 hours prior to meetings. The meeting agendas, presentations, and notes are posted to the website.

A more detailed description of the governing bodies of each individual GSA can be found in Section 1.1.3.1 - Organization and Management Structure of the GSAs.

1.2.5.6.2 GSP Implementation and Updates to GSP

The GSAs intend to continue public outreach and provide opportunities for engagement during GSP implementation. This will include providing opportunities for public participation, especially from beneficial users, at public meetings, providing access to GSP information online, and continued coordination with entities conducting outreach to DAC communities in the Basin. Announcements will continue to be distributed via email prior to public meetings (e.g., Stakeholder Advisory Committee meetings, Coordinating Committee meetings, public workshops, and GSA Board meetings). Emails will also be distributed as specific deliverables are finalized, when opportunities are available for stakeholder input and when this input is requested, or when items of interest to the stakeholder group arise, such as relevant funding opportunities. The Merced SGMA website, managed as part of GSP Administration, will be updated a minimum of monthly, and will house meeting agendas and materials, reports, and other program information. The website may be updated to add new pages as the program continues and additional activities are implemented. Additionally, public workshops will be held semi-annually to provide an opportunity for stakeholders and members of the public to learn about, discuss, and provide input on GSP activities, progress towards meeting the Sustainability Goals of this GSP, and the SGMA program.

2 BASIN SETTING

2.1 HYDROGEOLOGIC CONCEPTUAL MODEL

This section describes the Hydrogeologic Conceptual Model (HCM) for the Merced Subbasin. The HCM is developed to understand and convey the physical conditions by which water moves through in the basin and is used elsewhere in the Groundwater Sustainability Plan (GSP) to support the development of sustainable management criteria, monitoring networks, water budgets, projects, and programs and management actions.

Consistent with the Sustainable Groundwater Management Act (SGMA) requirements, the HCM:

- Provides an understanding of the general physical characteristics related to regional hydrology, land use, geology geologic structure, water quality, principal aquifers, and principal aquitards of the basin setting;
- Provides the context to develop water budgets, mathematical (analytical or numerical) models, and monitoring networks; and
- Provides a tool for stakeholder outreach and communication.

The HCM is based on several existing geologic and hydrogeologic studies as briefly described below:

- R.W. Page & Gary O. Balding, 1973. *Geology and Quality of Water in the Modesto-Merced Area, San Joaquin Valley, California, with a Brief Section on Hydrology*. United States Geological Survey (USGS) Water-Resources Investigations Report 73-6, prepared in cooperation with the California Department of Water Resources (DWR).
  - Provides the basis for the understanding of the underlying geology of the Merced Subbasin.
- Page, R.W., 1977. *Appraisal of Ground-Water Conditions in Merced, California, and Vicinity*. USGS Open-File Report 77-454, prepared in cooperation with DWR.
  - Provides the basis for the understanding of the five aquifer systems and the base of fresh water in the Merced Subbasin.
- Page, R.W., 1986. *Geology of the Fresh Ground-Water Basin of the Central Valley, California, with Texture Maps and Sections*. USGS professional paper 1401-C.
  - Provides basis for the understanding of surficial geology in the Merced Subbasin as well as underlying geologic structure.
- AMEC Geomatrix, Inc., 2008. *Merced Groundwater Basin Groundwater Management Plan Update*, submitted to Merced Area Groundwater Pool Interests, Merced, CA.
  - Provides a summary of previous geologic studies with more recent information on groundwater subbasin and water resources conditions.

2.1.1 Regional Geologic and Structural Setting

The Merced Subbasin is located in the San Joaquin Valley, a broad structural trough approximately 200 miles long and up to 70 miles wide. This trough is filled with up to 32,000 feet of marine and continental sediments deposited during periodic inundation by the Pacific Ocean and by erosion of the surrounding mountains. Continental deposits shed from the surrounding mountains form an alluvial wedge that thickens from the valley margins near the eastern boundary of the Subbasin toward the axis of the structural trough near the western boundary of the Subbasin. This depositional axis is below and slightly west of the series of rivers, lakes, sloughs, and marshes that mark the current and historical axis of the surface drainage of the San Joaquin Valley (DWR, 2004).

The Merced Subbasin is generally bounded by the foothills of the Sierra Nevada Mountain range in the east and other groundwater subbasins of the Central Valley to the north, south, and west (see more detail in Section 2.1.6). The southwest portion of the basin is underlain by the Corcoran Clay, a bed of laterally extensive reduced (blue/grey) silt and clay. The Corcoran Clay is a significant confining layer up to 60 feet thick.

This geologic setting is reflected throughout the HCM. The very deep sediments create a large volume of groundwater within the Merced Subbasin. At greater depths, this groundwater is saline, reflective of deposition of the deeper aquifer materials in a marine environment. Shallower depths have fresh groundwater, reflective of deposition in a non-marine environment or flushing with fresh water from higher in the system. The nature of the aquifer materials holding this groundwater is driven by the depositional environment. In higher-energy environments, such as fast-moving streams, larger materials are deposited, such as gravels and sands. In lower-energy environments, such as lakes, smaller materials are deposited, such as clays and silts. Thus, the aquifer system typically has coarser, more conductive materials along current or ancestral river courses and closer to the foothills. Finer, less-conductive materials are present farther from current or ancestral river courses and towards the axis of the valley near the San Joaquin River. In addition to spatial influences on aquifer materials, there is a time component as well. The deposition of continental deposits in alluvial fans emanating from the foothills was interrupted when the valley was inundated by Lake Corcoran, creating a low-energy depositional environment which resulted in the regional clay unit known as the Corcoran Clay. The Corcoran Clay is an important aquitard in that portion of the basin, separating the subsurface into two distinct aquifer systems, one above the clay and one below.

2.1.2 **Geologic History**

The geologic history of the Merced Subbasin is one of deposition of sediments in an environment with changing climate, changing sea levels, and tectonic movement, all of which resulted in the sediments that form today's aquifer system. A summary of the geologic history is provided below. This summary refers to the geologic time scale, which is included in Appendix C as a reference.

As with other areas on the east side of the San Joaquin Valley, the deposition of sediments occurred on a westward-tilted block of crystalline basement composed of Sierra Nevada plutonic and metamorphic rocks under the eastern part of the valley and mafic and ultramafic rocks of a presumed ophiolite of Jurassic age under the central and western parts of the valley (Bartow J. A., 1991). Thus, the bottom of the basin is a westward extension of the materials associated with the Sierra Nevada or is ophiolitic material associated with subducting oceanic crust from the west. In addition to forming the bottom of the basin, the continued tilting of the Sierran block contributed to the ability to accumulate sediments in the basin and resulted in the dipping units and angular unconformities between units.

Pre-Tertiary marine rocks are deposited at the greatest depths and in great thickness. Cretaceous Period marine rocks are as much as 20,000 feet thick in areas of the San Joaquin Valley (Page R. W., 1986).

Most of the materials relevant to groundwater management were deposited in the more recent Cenozoic Era. Near the close of the Mesozoic Era, the San Joaquin Valley area was the southern part of an extensive forearc basin (Bartow J. A., 1991). Tectonic movements elevated many Coast Range areas, including those adjacent to the Sacramento Valley and the northern San Joaquin Valley; these movements created the ancestral Tertiary San Joaquin and Sacramento basins as restricted troughs of deposition lying between the emerging Coast Ranges and the eastern Sierra Nevada (Page R. W., 1986). With significant restriction between what is now the valley and the ocean, the depositional environment varied based on sea level, tectonics, and deposition.

The Ione Formation was deposited in the middle Eocene Epoch discontinuously on pre-Tertiary rocks, dipping gently to the southwest (Bartow J. A., 1991). Overall, the formation is considered deltaic in origin, with fluvial, lacustrine, and lagoonal deposits (Page R. W., 1986). The beginning of the middle Eocene was characterized with lower eustatic sea levels resulting in a non-marine depositional environment for earlier Ione Formation materials. As eustatic sea levels rose through the middle Eocene, the depositional environment became more shoreline or shallow marine. The Merced Subbasin was generally a coastal environment with open ocean to the west. The more southwesterly portions of the Subbasin would be more likely to be shallow marine and the more northeasterly portions of the basin more likely to be non-marine. Towards the end of the middle Eocene, lower eustatic sea levels again moved the Ione to more non-marine deposition (Bartow J. A., 1991).

Deformation, driven by tectonic forces, generally resulted in west or southwest tilting. This causes the subtle angular unconformities in the Cenozoic units with discordances of generally less than 1 degree. Discordances appear to be less between Eocene and younger units compared to Eocene and older units, but there is evidence of continued tilting in the Oligocene based on differences in the gradient of depositional surfaces in the Eocene Ione and Miocene Valley Springs Formations. Currently, tilting continues to be present, likely at an accelerated rate (Bartow J. A., 1991).

The Oligocene marks a change in sedimentary history in the Merced area and the San Joaquin Valley, with a change from few, long-lasting, San Joaquin Valley-wide depositional sequences, to shorter sequences of more local extent. This is associated with a regional transition from a convergent continental margin to a transform margin (Bartow J. A., 1991).

During the Oligocene, at the time of maximum regression, the entire Subbasin was above sea level, sloping towards the south. A hiatus representing most of the Oligocene is evidence that there was negligible subsidence in the western part of the block during that interval (Bartow J. A., 1991).

The Subbasin remained above sea level during the Miocene, although uplift to the south resulted in a change in slope towards the southwest. The Valley Springs Formation was deposited in the Upper Oligocene and Lower Miocene unconformably over the Ione, dipping gently to the southwest. The Valley Springs was deposited following a period of low eustatic sea levels. While eustatic sea levels became higher during this period, the depositional environment remained non-marine, with fluvial sequences and ash deposits.

The Mehrten Formation was deposited in the Middle to Upper Miocene unconformably over the Valley Springs, dipping gently to the southwest. The Mehrten Formation is considered to have been laid down by streams carrying andesitic debris associated with the beginning of andesitic volcanism in the Sierra Nevada (Page R. W., 1986). There is no apparent angular discordance between the Mehrten and the Valley Springs, although there is an unconformity with as much as 120 meters of erosional relief in the eastern part of the outcrop area (Bartow J. A., 1991).

By the end of the Pliocene (approximately 2 million years ago), seaway connections were completely closed due to rapid filling of the San Joaquin Valley with sediment (Elam, 2012), marking the end of marine deposition and the beginning of continental deposition.

Interrupting the alluvial deposition of continental deposits, in the Pleistocene Epoch a large lake known as Lake Corcoran was impounded, filling nearly the entire valley (Bartow J. A., 1991). The period coincided with low eustatic sea levels associated with glaciation. The large lake is evidenced by the widespread deposition of the lacustrine clays today known as the Corcoran Clay. Outwash from alpine glaciers was deposited into the lake by Sierra Nevada rivers. The lake drained approximately 600,000 years ago when the present-day drainage outlet of the Carquinez Strait was carved out. However, several other smaller lakes also occupied portions of the valley later during the Quaternary Period (Bartow J. A., 1991).

More recent deposits are alluvial, aeolian, and floodplain deposits derived primarily from the Sierra Nevada (Page R. W., 1986) (Page & Balding, 1973). The presence of today's Corcoran Clay at depths of approximately 40 feet to 240 feet is indicative of rates of tectonic subsidence (not related to groundwater withdrawal) that have occurred over the past 600,000 years.

2.1.3 Surface and Near-Surface Conditions

This section describes the topography, soils, surface water, imported water supplies, and recharge areas in the basin.

2.1.3.1 Topography and Physiography

The Merced Subbasin is largely flat, with a minimum elevation of approximately 50 feet, near the confluence of the Merced and San Joaquin Rivers and a maximum elevation of 836 feet, in the foothills near the northern corner of the Subbasin. Figure 2-1 shows a map of elevation within the Subbasin.

The topography is driven by the physiography of the area. The following description of the physiography and geomorphology of the Merced Subbasin is provided to add context to the topography and is based on geomorphic descriptions and maps by the USGS (Davis, Green, Olmsted, & Brown, 1959) as referenced in the Merced Groundwater Management Plan (AMEC, 2008).

The physiographic units in the Merced Subbasin area include the Sierra Nevada, dissected uplands, low alluvial plains and fans, river floodplains and channels, and overflow lands (Page & Balding, 1973). These physiographic units are presented on Figure 2-2. The Sierra Nevada unit, which can be found along the eastern border of the Merced Subbasin, consists of metamorphic and granitic mountains that have deep river-cut canyons and highly dissected foothills.

The dissected uplands unit has a width ranging between 5 and 18 miles and covers a significant portion of the Merced Subbasin. Local relief may be up to 200 feet. Within the uplands, the Merced River has developed two terraces and a broad floodplain while the Chowchilla River is only slightly entrenched into the upland surface.

The low alluvial plains and fans unit, which consists primarily of coalescing alluvial fans, has a width ranging between 14 and 20 miles and also covers a significant portion of the Merced Subbasin. Local relief may be up to 10 feet. Between Atwater and Turlock, northwest trending sand dunes underlie the surface of the plains and fans.

The river floodplains and channels unit flank the channels of the major rivers including the Merced and Chowchilla Rivers. In the dissected uplands unit, the floodplain of the Merced River ranges in width between 0.25 and 1 mile. In the Cressey area, natural levees are present. Near the valley trough, the Merced River floodplain becomes indistinguishable from the surrounding alluvial plains. The Chowchilla River, which is entrenched about 40 feet near where it leaves the Sierra Nevada, has developed a thin floodplain through the dissected uplands. The river has deposited natural levees throughout the low alluvial plains and fans unit.

Figure 2-1: Topography

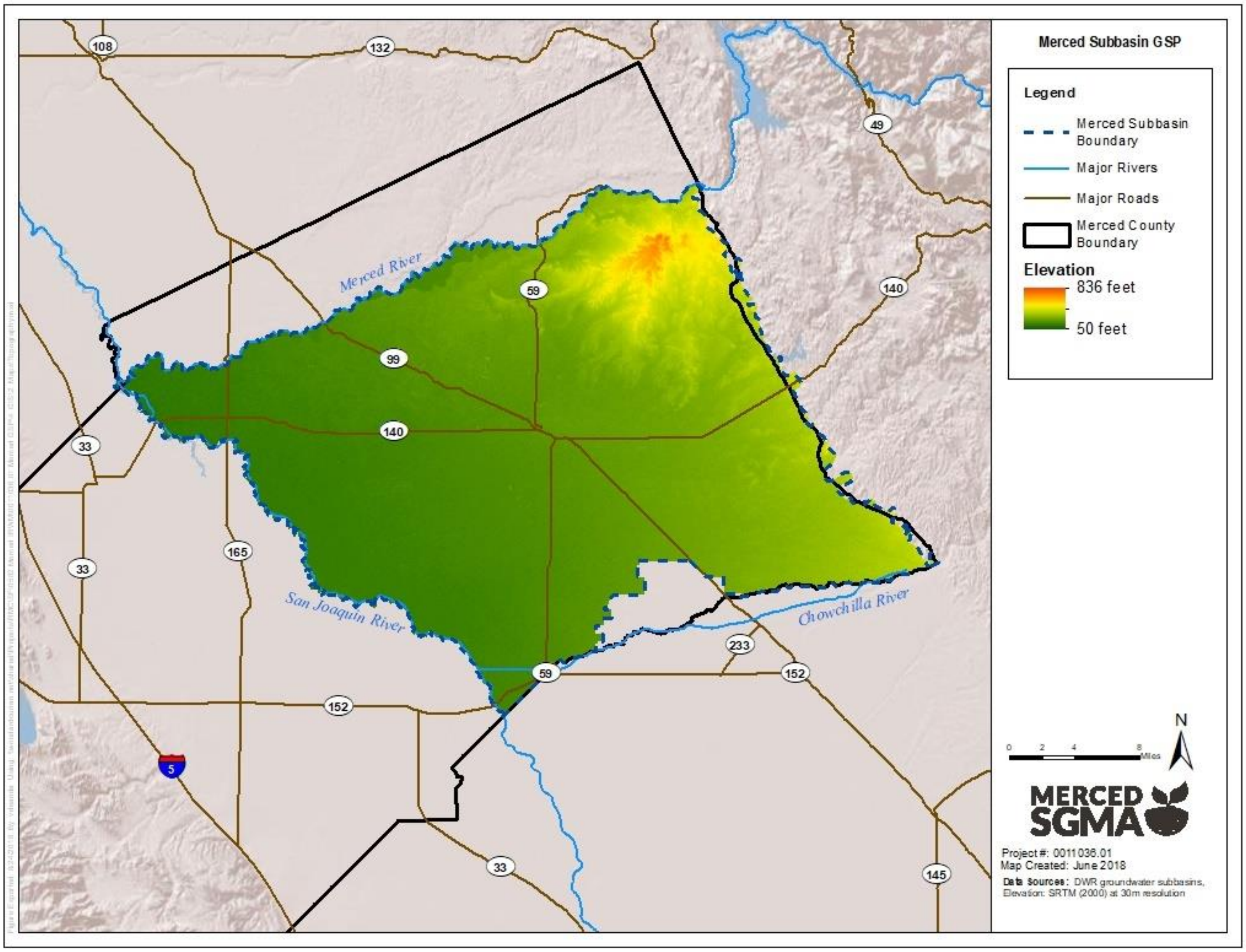
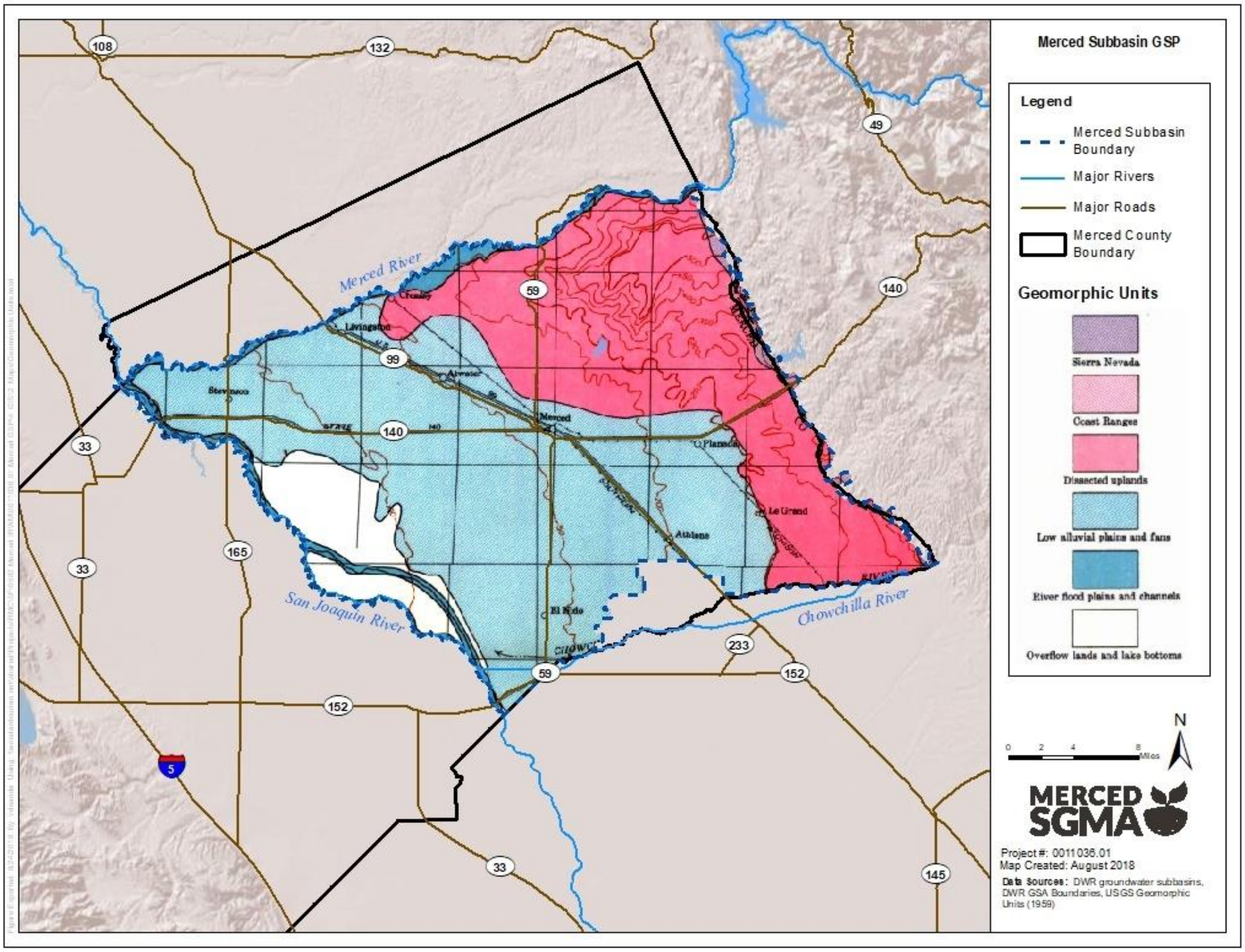


Figure 2-2: Geomorphic Units



Source: (Davis, Green, Olmsted, & Brown, 1959)

2.1.3.2 Surface Soils

The United States Department of Agriculture (USDA) Soil Conservation Service (now the USDA Natural Resource Conservation Service) conducted a soil survey in Merced County and identified more than 200 unique soil types within the Merced Subbasin. Data on soils can assist in the understanding of how water may infiltrate or run off the surface as well as how chemical constituents may interact with soils. The soil types can be grouped into 25 associations based on general soil type (Figure 2-3 and Table 2-1) and permeability (Figure 2-4), along with other characteristics identified by the USDA. Soil types and permeability were mapped using the Soil Survey Geographic (SSURGO) database last updated 2017.

Figure 2-3: Soil Types

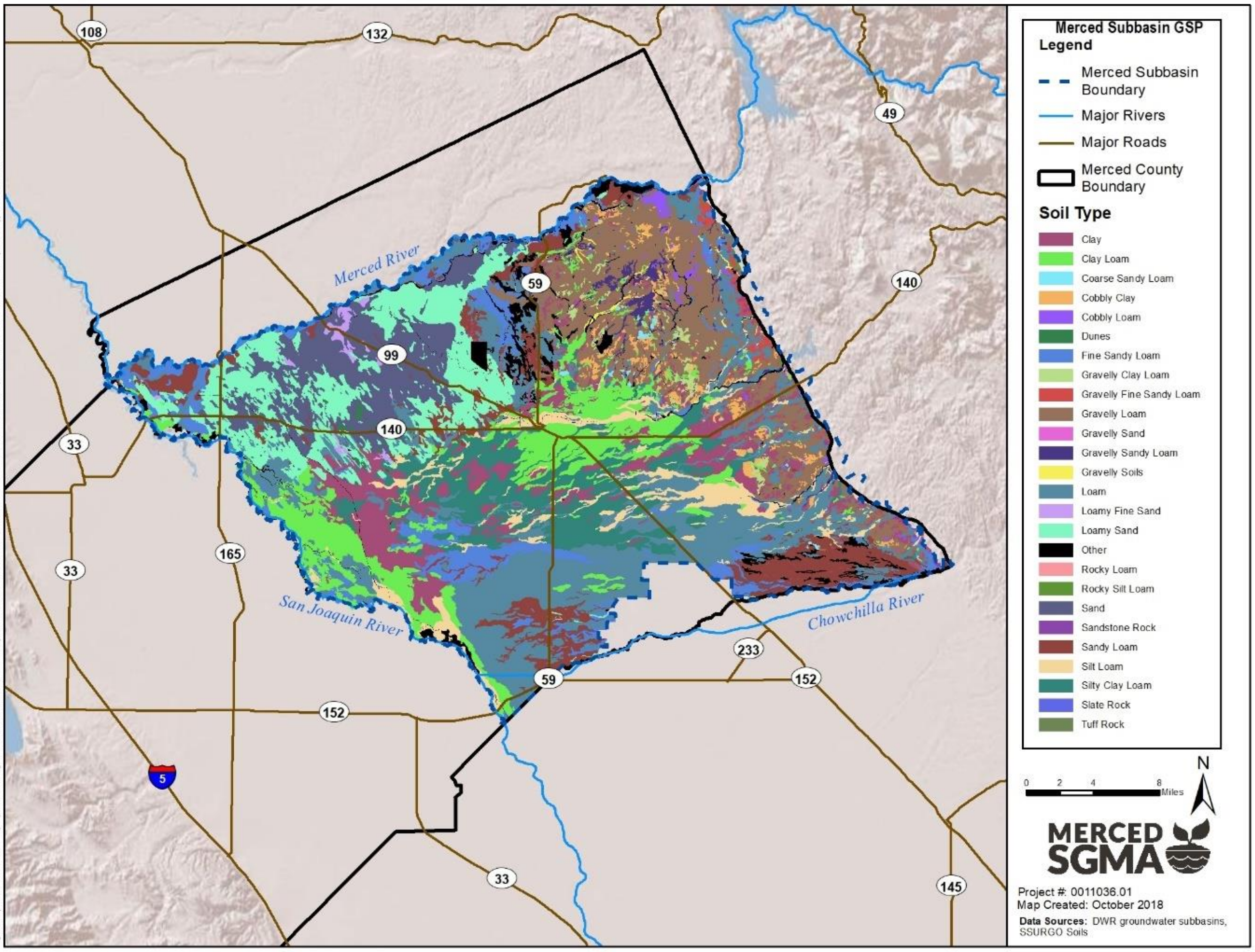
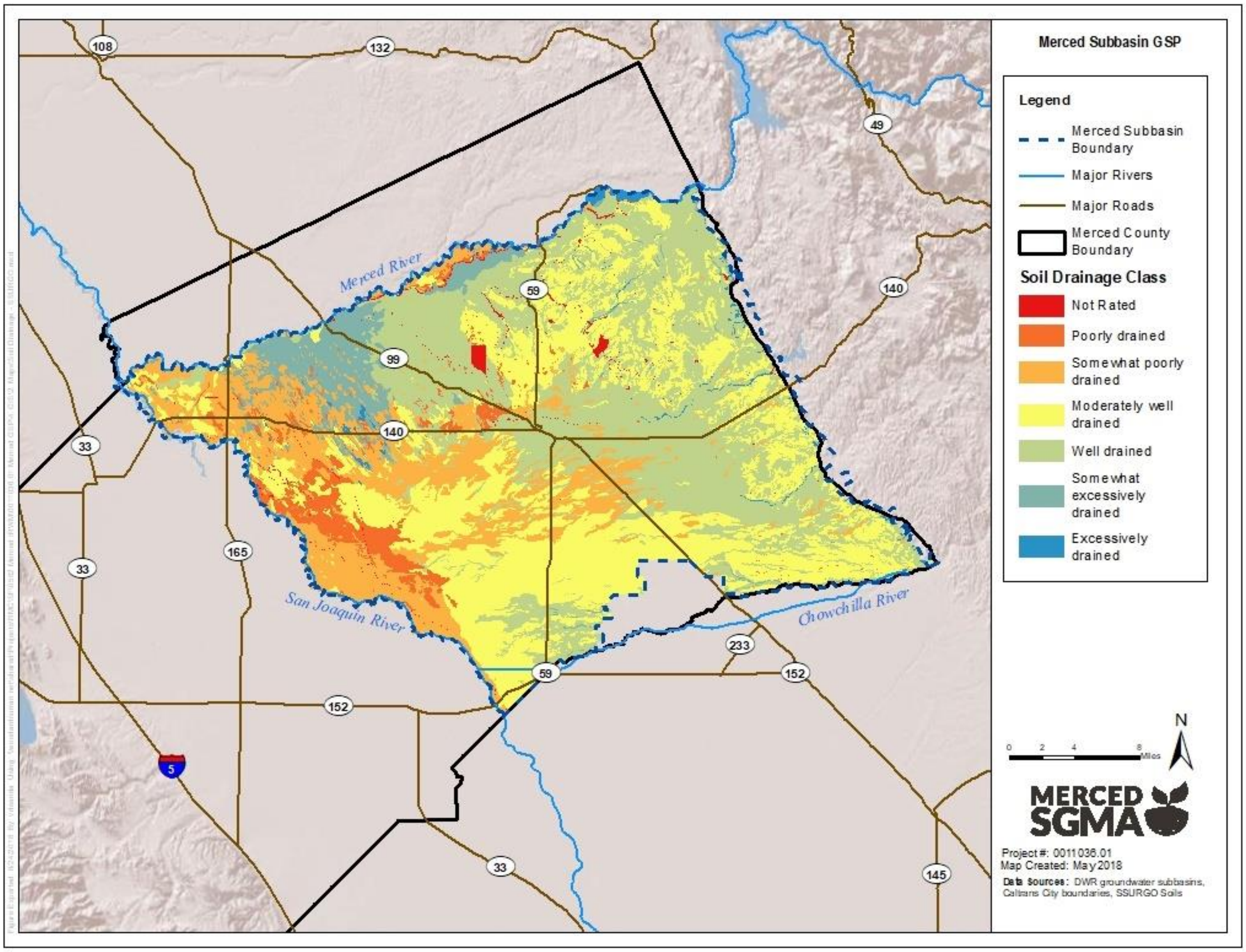


Table 2-1: Soil Type Summary

Soil Type	Area (sq miles)	% of total
Loam	145.8	18%
Gravelly Loam	96.3	12%
Clay Loam	77.8	10%
Loamy Sand	74.5	9%
Sand	66.9	8%
Silty Clay Loam	63.9	8%
Clay	62.2	8%
Sandy Loam	54.5	7%
Fine Sandy Loam	48.0	6%
Silt Loam	32.6	4%
Other (Includes Water, Fill, No Data Available)	28.2	4%
Cobbly Clay	10.9	1%
Gravelly Sandy Loam	6.7	1%
Gravelly Clay Loam	4.7	1%
Gravelly Fine Sandy Loam	4.0	1%
Loamy Fine Sand	3.8	<1%
Cobbly Loam	3.7	<1%
Coarse Sandy Loam	1.6	<1%
Gravelly Soils	1.4	<1%
Dunes	1.2	<1%
Sandstone Rock	1.1	<1%
Rocky Silt Loam	1.0	<1%
Rocky Loam	0.2	<1%
Slate Rock	0.0	<1%
Tuff Rock	0.0	<1%
Gravelly Sand	0.0	<1%
Total	**791.3**	**100%**

Figure 2-4: Soil Drainage Class

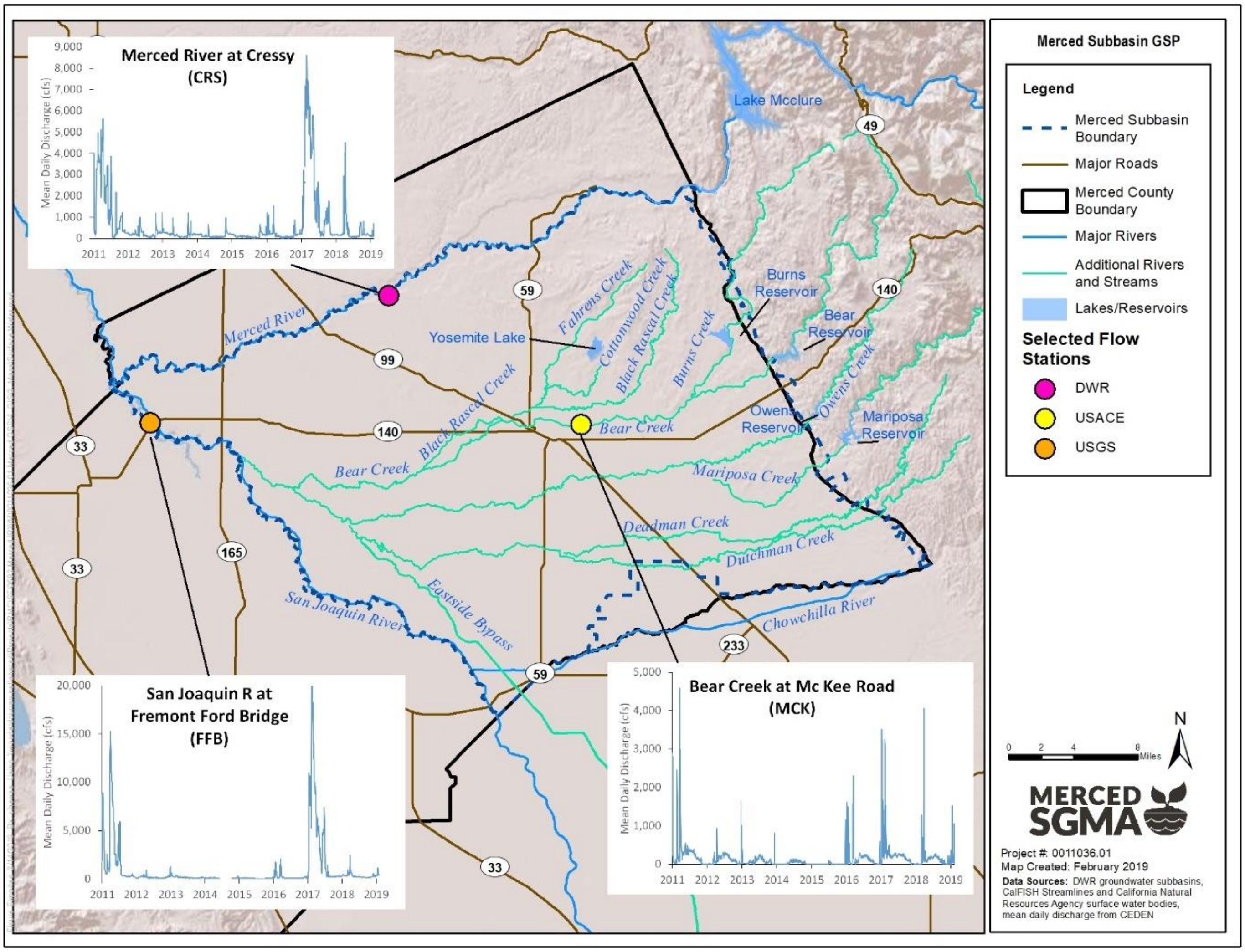


2.1.3.3 Surface Water

Many surface water courses cross the Merced Subbasin, generally flowing from the uplands in the northeast towards the San Joaquin River in the southwest. The San Joaquin River is an exception, flowing northwest towards the Sacramento-San Joaquin Delta. The San Joaquin and Merced Rivers are the largest rivers in the Subbasin. The Chowchilla River is also a significant water course.

Other surface water bodies within the Merced Subbasin include the following streams, nearly all of which are utilized for conveyance of irrigation water: Bear Creek, Black Rascal Creek, Burns Creek, Canal Creek, Cottonwood Creek, Deadman Creek, Dutchman Creek, Fahrens Creek, Little Dutchman Creek, Mariposa Creek, and Owens Creek (Figure 2-5). Figure 2-5 shows hydrographs for mean daily discharge (in cubic feet per second) at three selected gauging stations on the Merced River, San Joaquin River, and Bear Creek. The water in these surface water features is a mixture of snowpack and rainfall. No DWR, USGS, or United States Army Corps of Engineers (USACOE) stream gauges are operational on the Chowchilla River with available discharge information.

Figure 2-5: Surface Waters



Source: (DWR California Data Exchange Center)*, Hydrographs show mean daily discharge in cubic feet per second (cfs) from 2011-2018.*

The Merced River is the principal renewable surface water supply in the Merced Subbasin (see Figure 2-5). The Merced River is impounded by New Exchequer Dam, forming Lake McClure. Lake McClure has a storage capacity of over 1 million acre-feet (MAF) and is used for flood control and storage of irrigation water. Under agreement with the USACOE, each spring the storage pool in Lake McClure is reduced to a maximum of 675,000 acre-feet (AF) for flood control purposes (AMEC, 2008).

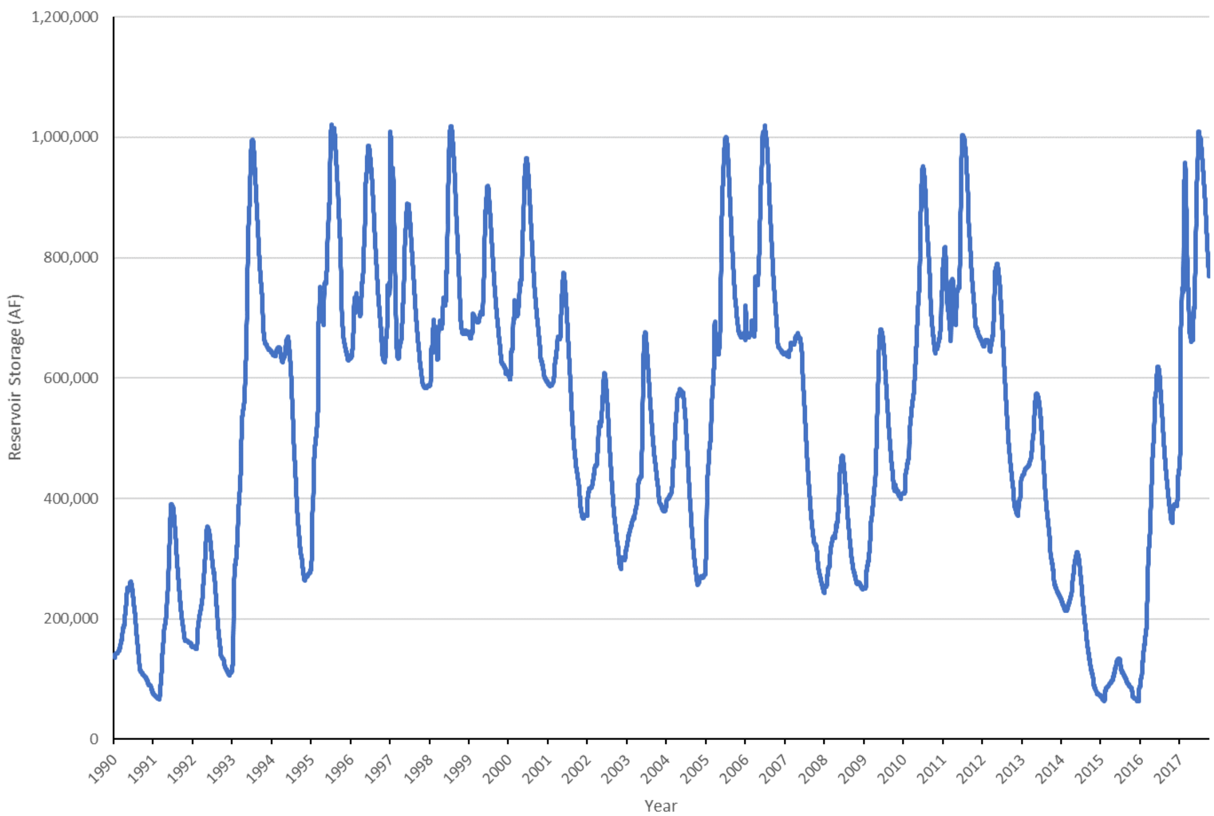
From 1990-2017, storage in Lake McClure has ranged from about 63,300 AF (February 2015) to 1,022,000 AF (July 1995) and averaged about 524,000 AF (Figure 2-6).

Diversions from the Merced River include:

- Merced Irrigation District (MID) – 430,000 acre-feet per year (AFY) (2003 - 2015 average)
- Stevinson Water District (SWD) – 18,000 AFY (2003 – 2013 average)

- Merquin County Water District (MCWD) – 16,000 AFY (2003 – 2013 average)

Figure 2-6: 1990-2017 Lake McClure Reservoir Storage



Source: USGS Data for Site 11269500 LK MCCLURE A EXCHEQUER CA

Minimum flow requirements for the Merced River downstream of Crocker-Huffman diversion dam (which is downstream of New Exchequer Dam), as measured at Shaffer Bridge, as required by MID's existing FERC license, are shown in Table 2-2. The values do not represent actual flows.

Table 2-2: Merced River Current Minimum Flow Requirements

Period	Normal Years (cfs)	Dry Years (cfs)
June 1 through October 15	25	15
October 16 through October 31	75	60
November 1 through December 31	100	75
January 1 through May 31	75	60

Source: (FERC, 2015)

The MID distribution system includes portions of natural streams (or drains), about 121 miles, that convey irrigation water, as well as 422 miles of unlined canals, and 97 miles of lined canals (MID, 2013). See Table 2-3 for details. The canals are conveyance structures that do not fall under the jurisdiction of SGMA legislation but are presented here for context of understanding the entire surface water system in the Subbasin.

Table 2-3: MID Water Conveyance and Delivery System

System Used	Number of Miles
Natural Channels (creeks and sloughs)	121
Unlined canal	422
Lined canal	97
Pipelines	177
Drains	45
Total Mileage of System	**862**

Source: (MID, 2013)

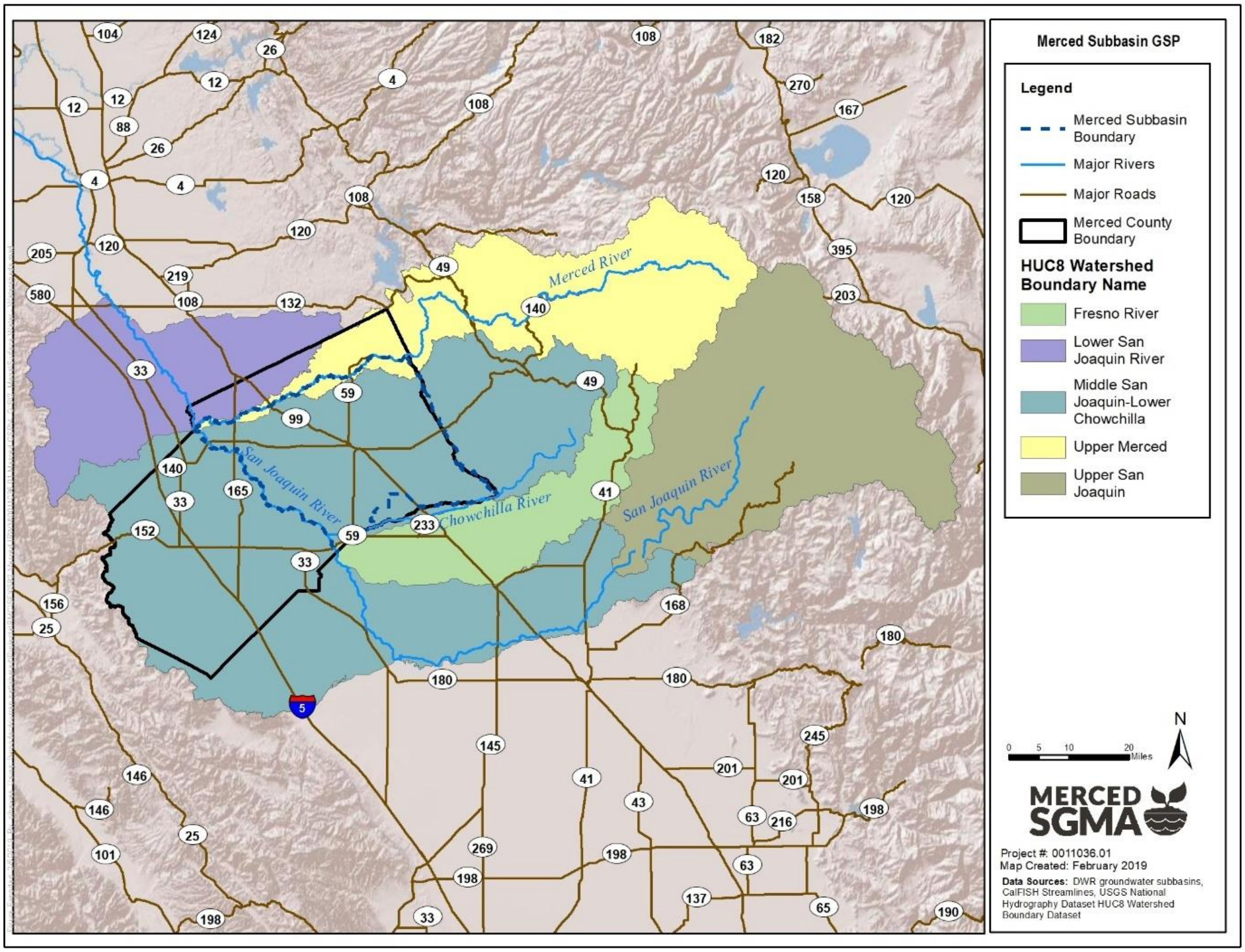
The Chowchilla River drains a 254 square-mile watershed on the western slope of the Sierra Nevada and is regulated by Buchanan Dam. Some flows downstream of the dam are diverted at Chowchilla Water District canals. Average annual natural flows from 1912 to 2008 at Buchanan Dam were approximately 70,000 AF. Chowchilla Water District has been able to take delivery of approximately 43,000 AF annually from the reservoir. The remaining 27,000 AF have been released as flood flows from the dam (RMC Water and Environment, 2015).

The San Joaquin River is regulated by Millerton Reservoir and other reservoirs on upstream tributaries. In the Merced Subbasin, the river is a source of water supplies for Turner Island Water District which diverts approximately 20,000 AFY (2003 to 2013 average) using the San Luis Canal Company conveyance. Turner Island Water District also receives periodic flood flows from the Eastside Bypass of 5,000 AFY, when available.

Based on outreach to stakeholders, there are no known active springs or seeps within the Merced Subbasin. Wetlands within the Subbasin are generally supplied supplemental water and are not dependent on shallow groundwater. Additional information on groundwater dependent ecosystems can be found in Section 2.2.7.

Figure 2-7 shows the Merced River, San Joaquin River, and Chowchilla River within their respective Hydrologic Unit Code (HUC) 8 watershed boundary, where HUC8 is a designation within the USGS Watershed Boundary Dataset. HUC's range in size from 2 (large regional systems) to 12 (small subwatersheds), with 8 being an appropriate size designation to provide some context of the size and location of the regional watersheds compared to the Merced Subbasin.

Figure 2-7: HUC8 Watershed Boundaries



2.1.3.4 Imported Water

No agencies in the Merced Subbasin benefit from imported water supplies from outside the Subbasin, such as from the Central Valley Project or State Water Project. The Turner Island Water District is split into two GSAs. Turner Island Water District GSA #1 (TIWD GSA-1) is the portion of the water district that falls within the Merced Subbasin while #2 falls within the Delta-Mendota Subbasin. There is some transfer of groundwater between the two GSAs, though the exact volume is unknown.

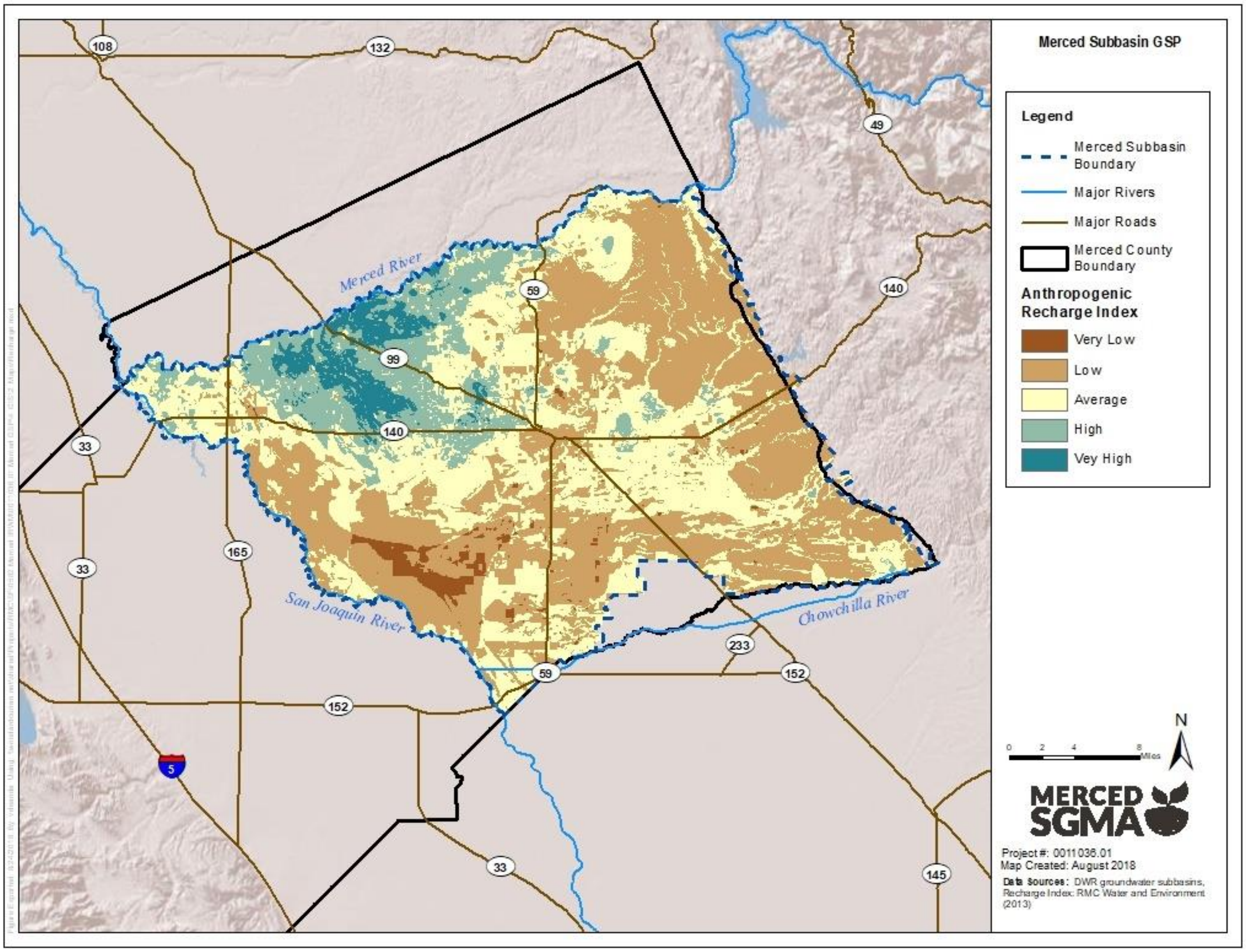
2.1.3.5 Groundwater Recharge and Discharge Areas

Groundwater recharge and discharge is driven by both natural and anthropogenic (human-influenced) factors. Areas of recharge and discharge within the Merced Subbasin are discussed below. Quantitative information about natural and anthropogenic recharge and discharge is provided in the water budget section.

2.1.3.5.1 Anthropogenic Groundwater Recharge

Anthropogenic recharge, particularly deep percolation from agricultural irrigation and earthen-lined canals, is a key source of recharge in the Merced Subbasin. A Groundwater Recharge Study was conducted as part of the Merced Integrated Regional Water Management (IRWM) Plan Development in 2013 to identify where recharge is occurring. The study used a Geographic Information System (GIS) overlay method to analyze spatial data and integrate information to interpret recharge areas (RMC Water and Environment, 2013b). The Subbasin was divided into five different categories, relating the relative amount of recharge occurring in the area (see Figure 2-8). The map shows recharge is occurring in areas with coarser materials in the upper subsurface and in areas with extensive applied water to support irrigated agriculture. The map does not show the recharge occurring from surface water courses, including rivers and canals. Estimates of the quantities of these recharge components are provided in the water budget discussion in Section 2.3.

Figure 2-8: Areas of Recharge



2.1.3.5.2 Natural Groundwater Recharge and Discharge

Groundwater discharge is primarily through groundwater production wells. However, groundwater also discharges to rivers and streams where groundwater elevations are higher than river stage. This occurs in limited areas in the lower portions of the Subbasin. Figure 2-9 shows gaining streams in red where groundwater discharges to rivers, while losing streams are shown in blue where streams recharge groundwater.

This analysis was based on modeling results from the Merced Water Resources Model (MercedWRM) for approximately 1,500 stream nodes in the Merced Subbasin. The stream nodes within the MercedWRM contain information on the quantity of stream gains and losses on a monthly basis. Using the historical simulation (see 2.3.4.1 - Historical Water Budget), the median value of monthly stream gains and losses was calculated over the 2005 to 2015 time period. Figure 2-9 indicates where these stream nodes indicate gaining conditions (groundwater contributing to streamflow, where median monthly gains were larger than losses) and where they indicate losing conditions (surface water recharging groundwater, where median monthly gains were less than losses). Any stream nodes that are disconnected from the principal aquifer (see Figure 2-10) are noted as losing. Disconnection from the principal aquifer was determined where the invert elevation of the streambed is higher than the elevation of the groundwater levels within the MercedWRM aquifer hydrogeologic structure. In areas of the Shallow Unconfined Aquifer (described later in Section 2.1.7.1 - Aquifer Systems in the Basin), conditions can result in regions of perched water tables (AMEC, 2008) which are often associated with or affected by instream flow levels and may not always be considered a full interconnection with the deeper groundwater system typically accessed by production wells.

The groundwater elevation data indicate that there is groundwater discharge along the San Joaquin River (gaining stream). There is a trough in the water table elevations that follows the San Joaquin River. Groundwater inflow to the river and surrounding areas occurs from both sides of the San Joaquin Valley. Apart from groundwater pumping, this river and the surrounding areas are the primary groundwater discharge area for the valley (AMEC, 2013).

On the north side of the Merced Subbasin west of State Highway 99, the lower reaches of the Merced River appear to be a groundwater discharge area (where the Merced River is a gaining stream). East of the highway, the river may be acting as a constant head source and supplying water to the pumping depression centered approximately 17 miles northwest of Merced. East of Oakdale Road (Township 5 South, Range 12 East, Section 36), the river is higher than the groundwater and probably provides some recharge to the groundwater (AMEC, 2013).

Comparison of Chowchilla River elevations with groundwater levels indicates that the river is higher than the groundwater. Consequently, the river probably contributes some recharge to groundwater along the reach south of the study area. The pumping depressions near the Chowchilla River do not appear to be affected by the presence of the river (AMEC, 2013).

Figure 2-9: Losing and Gaining Streams

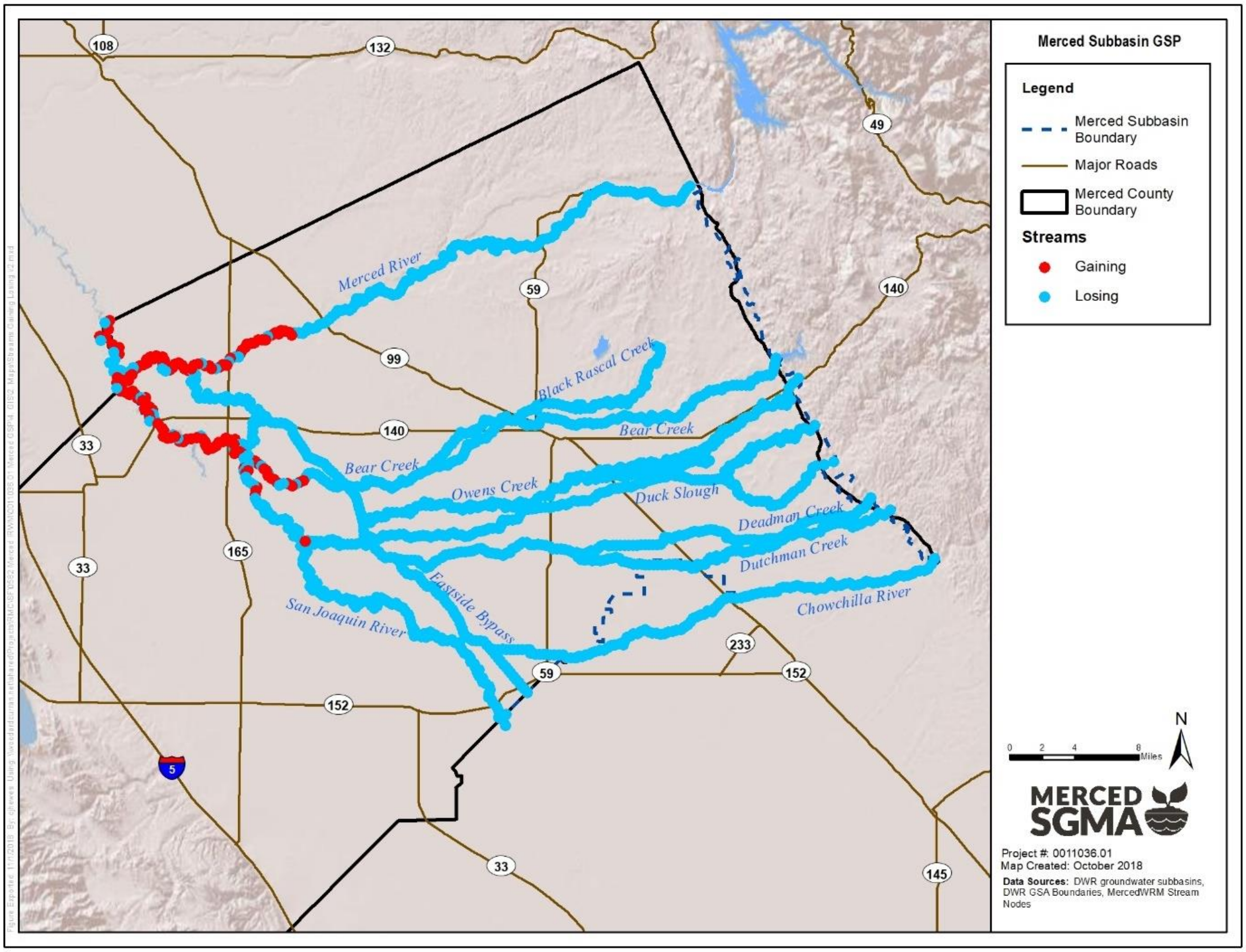
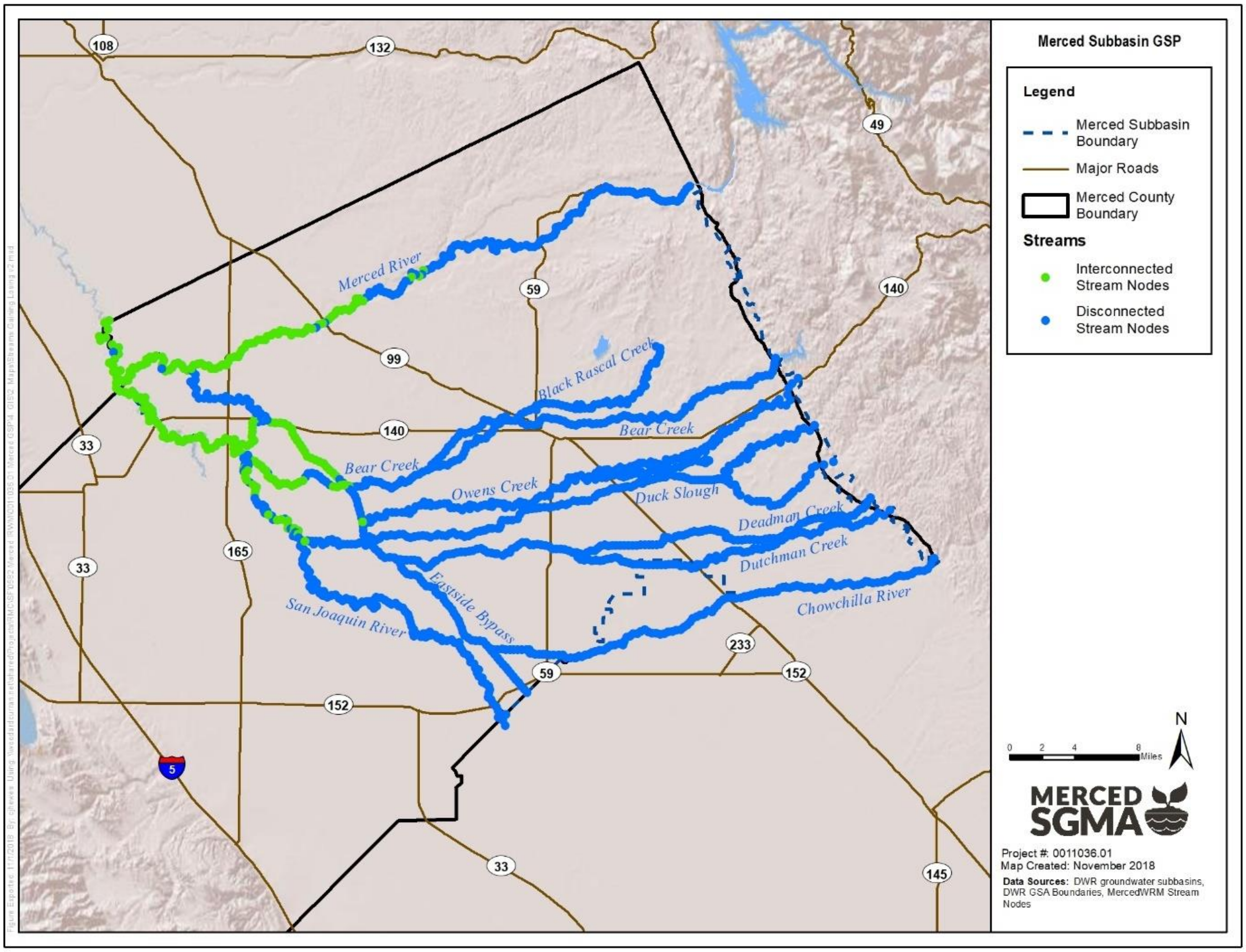


Figure 2-10: Interconnected and Disconnected Streams



2.1.4 Geologic Formations and Stratigraphy

DWR's best management practices (BMP) for the HCM suggests using California Geological Survey (CGS) or USGS data for surficial geologic mapping. For this GSP, surficial geology as well as cross-sections were developed based on detailed USGS work performed by Page & Balding (1973), Page (1977), and Page (1986).

The Merced Subbasin is underlain by consolidated rocks and unconsolidated deposits. The consolidated rocks, from bottom to top, include the Sierra Nevada basement complex, Ione Formation and other sedimentary rocks, the Valley Springs Formation, and the Mehrten Formation (Page & Balding, 1973). The unconsolidated deposits include continental deposits, lacustrine and marsh deposits, older alluvium, younger alluvium, and flood-basin deposits.

A description of the consolidated rocks and unconsolidated deposits is provided below, with a map of surficial geology shown as Figure 2-11 and a summary table of the units and their water-bearing characteristics provided as Table 2-4.

Note that the text, table, and maps are taken from different sources and use slightly different terminology. Therefore, Table 2-5 is provided to map terminology between items.

The Merced Groundwater Management Plan (AMEC, 2008) provides the following description of the Subbasin geology in the following subsections. The discussions are supported by a geologic map (Figure 2-12) and cross sections (Figure 2-13 through Figure 2-22) from several sources.

2.1.4.1 Consolidated Rocks

The consolidated rocks include the Sierra Nevada basement complex, Ione Formation and other sedimentary rocks, the Valley Springs Formation, and the Mehrten Formation.

The Sierra Nevada bedrock complex consists largely of metasedimentary and metavolcanic rock of pre-Tertiary age (Page & Balding, 1973). These rocks occur as foothill ridges along the eastern edge of the Merced Subbasin (Figure 2-11). Where the basement complex occurs near the surface, fracture sets and joints within the bedrock complex may contain sufficient groundwater for domestic or stock supplies.

The Eocene Ione Formation unconformably overlies the Sierra Nevada bedrock complex and is composed of marine to non-marine clay, sand, sandstone, and conglomerate. These rocks occur as foothill ridges along the eastern edge of the Merced Subbasin (Figure 2-11). The Ione is characterized by a white sandy clay (kaolinite) at its base and beds of conglomerate and yellow, red, and gray sandstone in its upper parts. In localized areas near the Sierra Nevada foothills, the formation contains fresh water; however, well yields are highly variable.

The Miocene Valley Springs Formation overlies the Ione Formation and is composed of a fluvial sequence of rhyolitic ash, sandy clay, and siliceous gravel in a clay matrix. These rocks occur as foothill ridges along the eastern edge of the Merced Subbasin (Figure 2-11). Because of the abundant ash and clay matrix, the Valley Springs has a relatively low groundwater yield, sufficient for domestic or stock supplies, but generally insufficient for irrigation.

The Miocene/Pliocene Mehrten Formation overlies the Valley Springs Formation and is composed of fluvial deposits of sandstone, breccia, conglomerate, luff, siltstone and claystone. It contains a large amount of andesitic material, making it easy to distinguish. The Mehrten outcrops over a large area in eastern Merced Subbasin (Figure 2-11). It forms an important aquifer in the Merced Subbasin with relatively high yields.

2.1.4.2 Unconsolidated Deposits

The unconsolidated deposits, from bottom to top, include continental deposits, lacustrine and marsh deposits, older alluvium, younger alluvium, and flood-basin deposits.

The Pliocene/Pleistocene continental deposits consist of a heterogeneous mixture of poorly sorted gravel, sand, silt and clay derived primarily from the Sierra Nevada. The sediments, which are found throughout the Merced Subbasin, dip gently to the southwest and have variable thickness up to 700 feet. The continental deposits have relatively large yields to wells and are an important part of the aquifer system.

The lacustrine and marsh deposits consist of two beds: the Corcoran Clay Member of the Pleistocene Tulare Formation and a shallow clay bed of Holocene age (Page R. W., 1977). The Corcoran Clay is a bed of laterally extensive reduced (blue/grey) silt and clay that underlies about 437 square miles in the southwest portion of the Merced Subbasin (Figure 2-37). The Corcoran Clay is a significant confining layer up to 60 feet thick. The shallow clay bed of Holocene age is composed of oxidized (brown/red) sandy clay and clay with silica cemented intervals (hardpan). It is found throughout most of the Merced Subbasin at a shallow depth (-35 feet). For more information on the Corcoran Clay, see Section 2.1.7.2: Principal Aquifers and Aquitards.

The older alluvium consists of a heterogeneous mixture of poorly sorted gravel, sand, silt and clay up to 400 feet thick derived primarily from the Sierra Nevada. The sediments, which are found throughout the Merced Subbasin, were deposited as a series of interbedded coarse-grained and fine-grained layers and form a leaky-aquifer system.

The flood-plain deposits consist of intercalated lenses of reduced to oxidized fine sand, silt, and clay. These deposits are found in the southwestern portion of the Merced Subbasin (Figure 2-11) and generally are less than 30 feet thick.

The younger alluvium consists of well-sorted gravel and sand derived primarily from the Sierra Nevada. The younger alluvium is found in a narrow band along the stream channels throughout the Merced Subbasin (Figure 2-11) (Page & Balding, 1973).

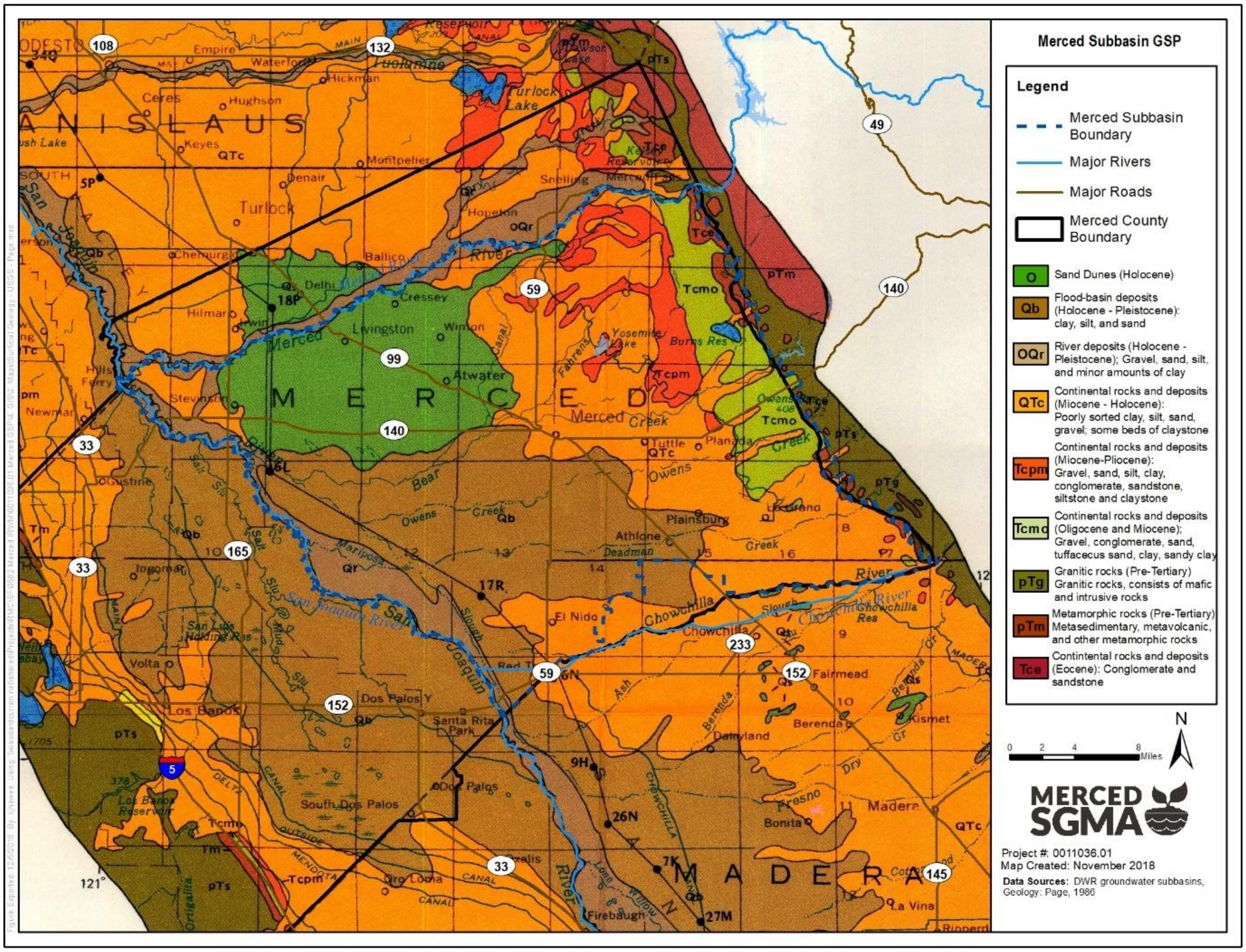
Table 2-4: Generalized Section of Geologic Units and Their Water-Bearing Characteristics

Period and Epoch		Geologic Unit	Lithologic Character	Maximum thickness (feet)	Water-Bearing Character	For Reference - Figure 2-11 Formation Name
Unconsolidated Deposits						
Quaternary	Holocene	Flood-basin deposits	Silt, clay, and fine sand, bluish-gray, brown, and reddish-brown.	100	Small hydraulic conductivities and small yields to wells.	Qb (Flood-basin deposits [Holocene-Pleistocene])
	Holocene	Younger alluvium	Gravel, sand, and find sand, some silt and clay, little or no hardpan; yellow, yellowish-brown, brown.	100	Moderate to large hydraulic conductivities, where saturated yields moderate quantities to wells. Unconfined.	Qr (River deposits [Holocene-Pleistocene])
	Pleistocene and Holocene?	Older alluvium	Gravel, sand, silt, and clay, some hardpan; brown, reddish-brown, gray, brownish-gray, white, blue, and black.	400 (in northern part of area) 700 (in southern part of area)	Moderate to large hydraulic conductivities; yields to wells reported as large as 4,451 gpm (gallons per minute); average yield to large wells (1900 gpm). North of study area transmissivities of about 11,700 ft^2/day (cubic feet per day per foot). Unconfined and confined.	QTc (Continental rocks and deposits [Miocene-Holocene])
	Pleistocene	Lacustrine and marsh deposits	Silt, silty clay, and clay, gray and blue.	100	Confining bed, very small hydraulic conductivities. (includes the Corcoran Clay)	(not pictured)
Tertiary and Quaternary?	Pliocene and Pleistocene	Continental deposits	Gravel, sand, silt, and clay; brown, yellow, gray, blue, and black.	>450 (In northern part of area) >700 (in southern part of area)	Moderate to large hydraulic conductivities; yield to wells as large as 2,102 gpm. North of study area transmissivities of about 8,000 ft^2/day. Confined beneath lacustrine and marsh deposits. In extreme western part of area, water contains in excess of 2,000 mg/l (milligrams per liter) dissolved solids.	QTc (Continental rocks and deposits [Miocene-Holocene])

Period and Epoch		Geologic Unit	Lithologic Character	Maximum thickness (feet)	Water-Bearing Character	For Reference - Figure 2-11 Formation Name
Consolidated Rocks						
Tertiary	Miocene and Pliocene	Mehrten Formation	Sandstone, breccia, conglomerate, tuff, siltstone, and claystone; brown, yellowish-brown, grayish-brown, pinkish-brown, pink, blue, yellow, green, gray, and black. Large amounts of andesitic material occur in beds.	200 (In northern part of area) >700 (In southern part of area)	Small to moderate hydraulic conductivities. North of study area ranges in hydraulic conductivity from 0.01 to 67 ft/day. Yield to wells as large as 2,102 gpm. In western part of area, water contains in excess of 2,000 mg/l dissolved solids content. Locally in eastern part of area water probably contains in excess of 2,000 mg/l dissolved solids.	Tcpm (Continental rocks and deposits [Miocene-Pliocene])
Tertiary	Miocene and Pliocene	Valley Springs Formation	Ash, sandy clay, and siliceous sand and gravel generally in clay matrix, tuff, siltstone, and claystone; yellow, yellowish-brown, brown, reddish-brown, gray, greenish-gray, white, pink, green, and blue. Rhyolitic material occurs in beds.	900 (In northern part of area) Unknown in southern part of area	Probable small hydraulic conductivities. Quality of water ranges from fair to poor.	Tcmo (Continental rocks and deposits [Oligocene and Miocene])
Tertiary	Eocene	Ione Formation and other sedimentary rocks	Conglomerate, sandstone, clay and shale; partly marine; yellow, red, gray, and white.	800 (In northern part of area) Unknown in southern part of area	Probable small to moderate hydraulic conductivities. In places reported to yield saline water.	Tce (Continental rocks and deposits [Eocene])
Cretaceous		Marine sandstone and shale	Sandstone and shale.	>9,500 (In northern part of area) Unknown in southern part of area	Unknown. Reported to yield saline water.	(not pictured)
Pre-Tertiary		Basement complex	Metamorphic and igneous rocks.		Fractures and joints locally yield small quantities of water; otherwise virtually impermeable.	pTm (Metamorphic rocks [Pre-Tertiary])

Source: (Page & Balding, 1973)

Figure 2-11: Surficial Geology



The units generally dip to the west; that is, the elevation of the units is higher in the east than in the west. Some units are not present across the entire basin. Notably, this is true of the Corcoran Clay which extends east to near Highway 99, where it is generally shallow and thin, and becomes deeper and thicker to the west where it extends beyond the western boundary of the Subbasin. Details on materials in the subsurface are provided through cross sections and a three-dimensional rendering of the basin.

Five cross sections were developed by Page & Balding (1973) across the Merced Subbasin and neighboring Turlock Subbasin. The locations of the cross-section are shown on Figure 2-12, with the cross-sections themselves shown on Figure 2-13 through Figure 2-17. The cross sections show the units dipping towards the west, highlighting the depth, thickness and extent of the Corcoran Clay as well as the depth of the base of fresh water (short dashed line). Note that these cross sections include vertical exaggeration in order to highlight the small difference in the vertical axis. Distances shown vertically are 52.8 times the horizontal distances, allowing visualization of finer detail with depth, but also resulting in dip angles appearing much steeper and the overall aquifer appearing much deeper than in reality.

Four additional cross sections were developed by Page (1977) more specifically for the City of Merced-City of Atwater area. The locations of these cross-sections are shown on Figure 2-18, with the cross sections shown on Figure 2-19 through Figure 2-22.

Figure 2-12: Location of Geologic Cross Sections (Page & Balding 1973)

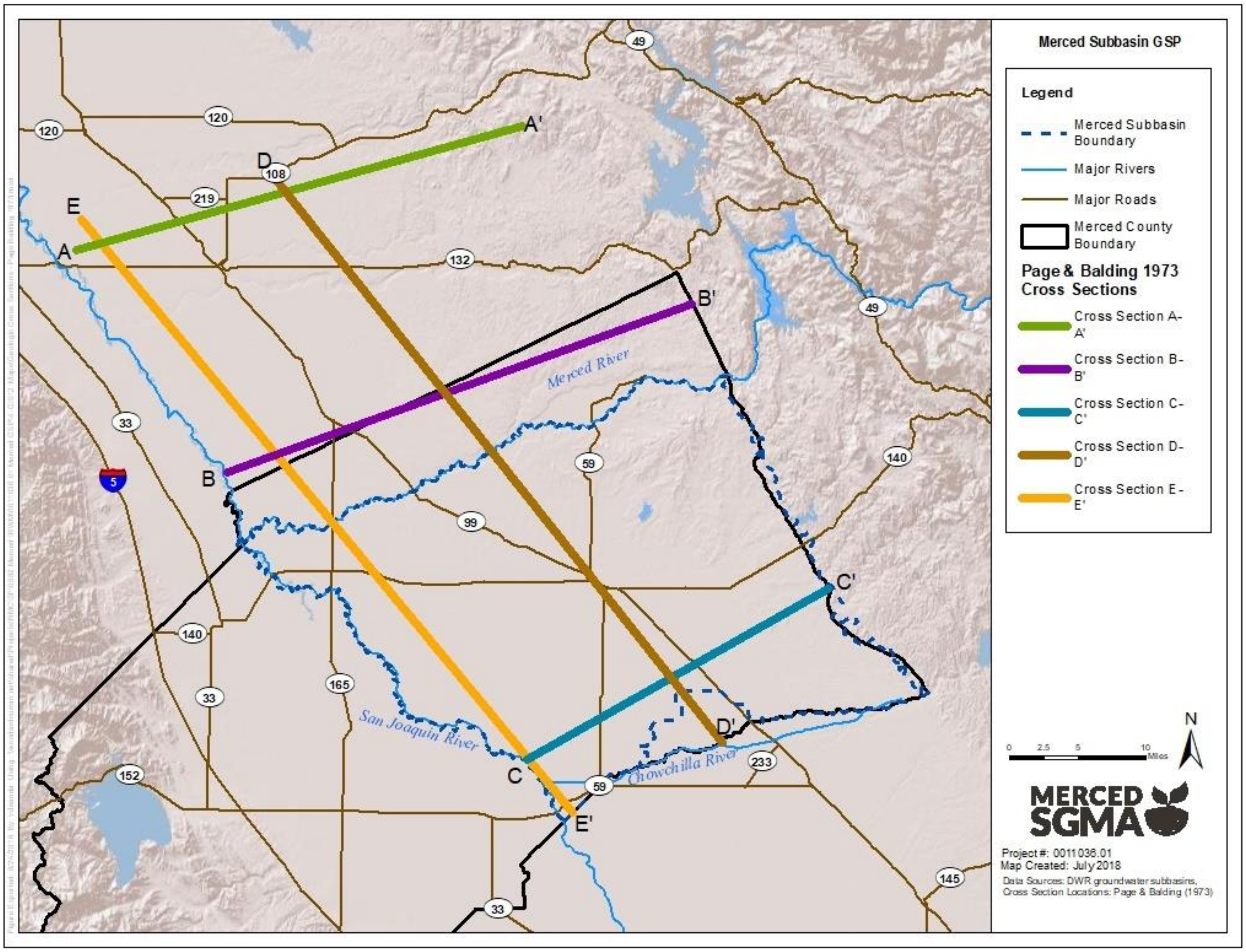
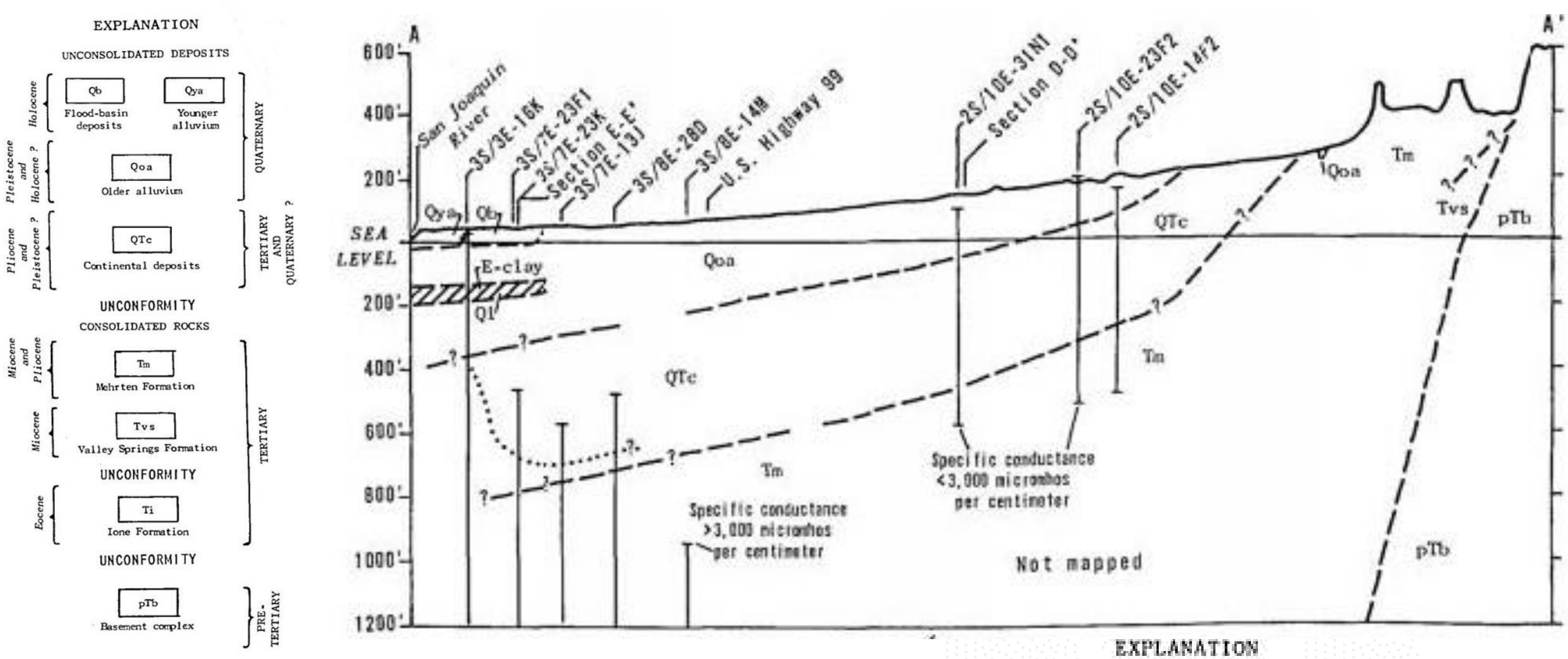
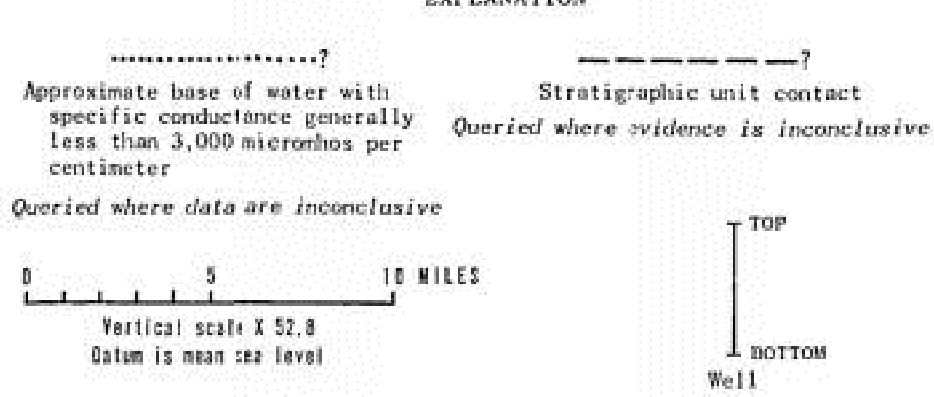


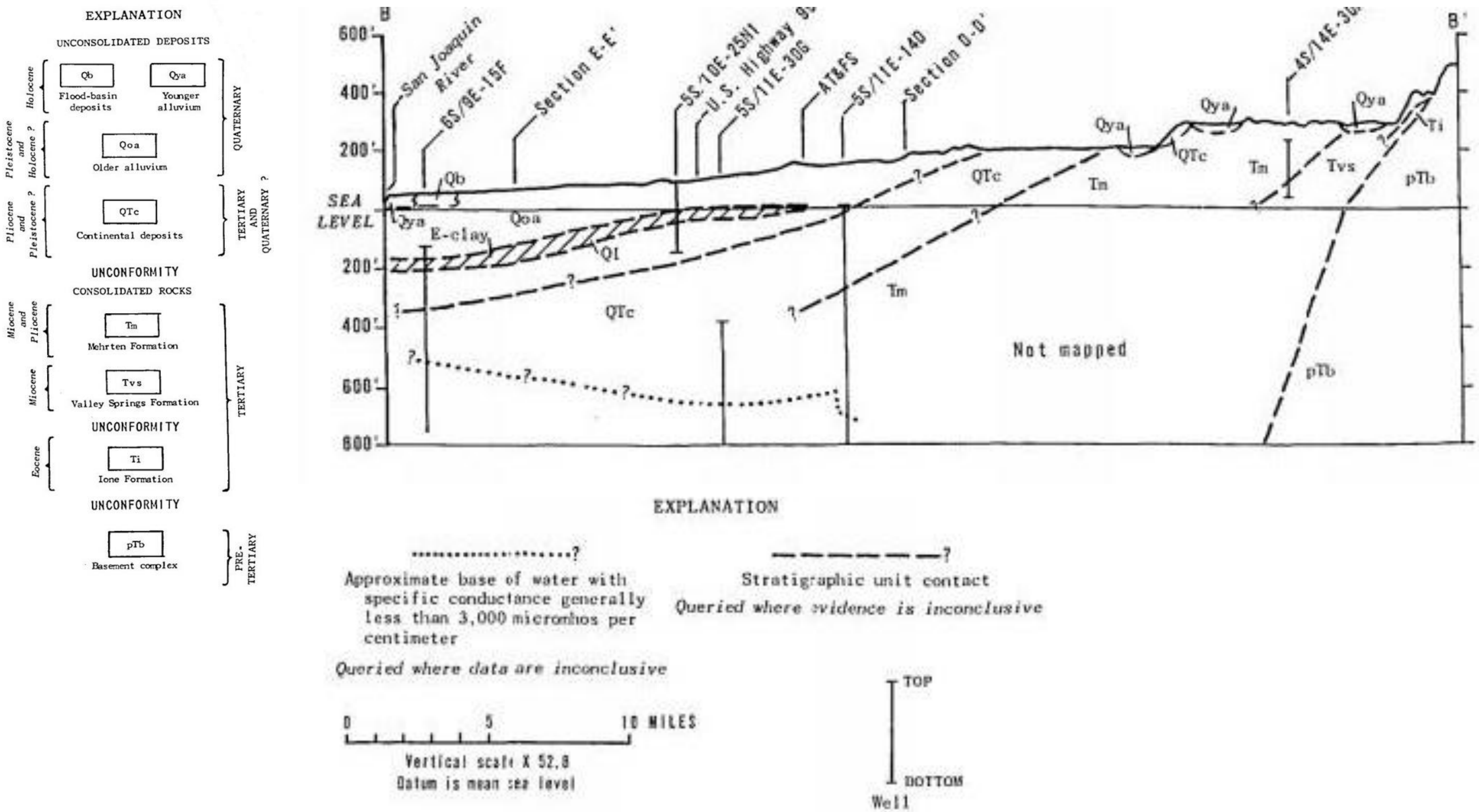
Figure 2-13: Geologic Cross-Section A (Page & Balding 1973)





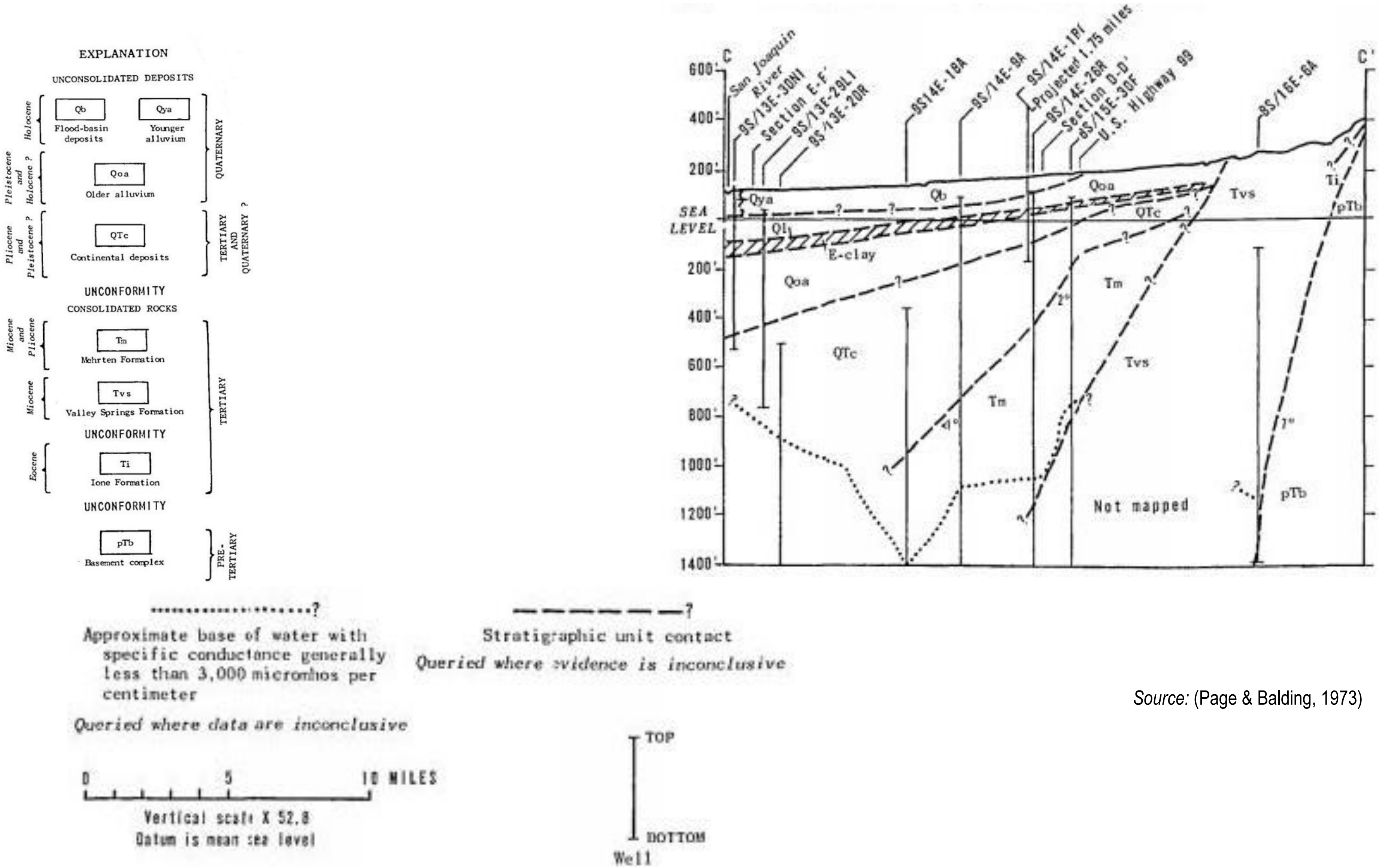
Source: (Page & Balding, 1973)

Figure 2-14: Geologic Cross-Section B (Page & Balding 1973)



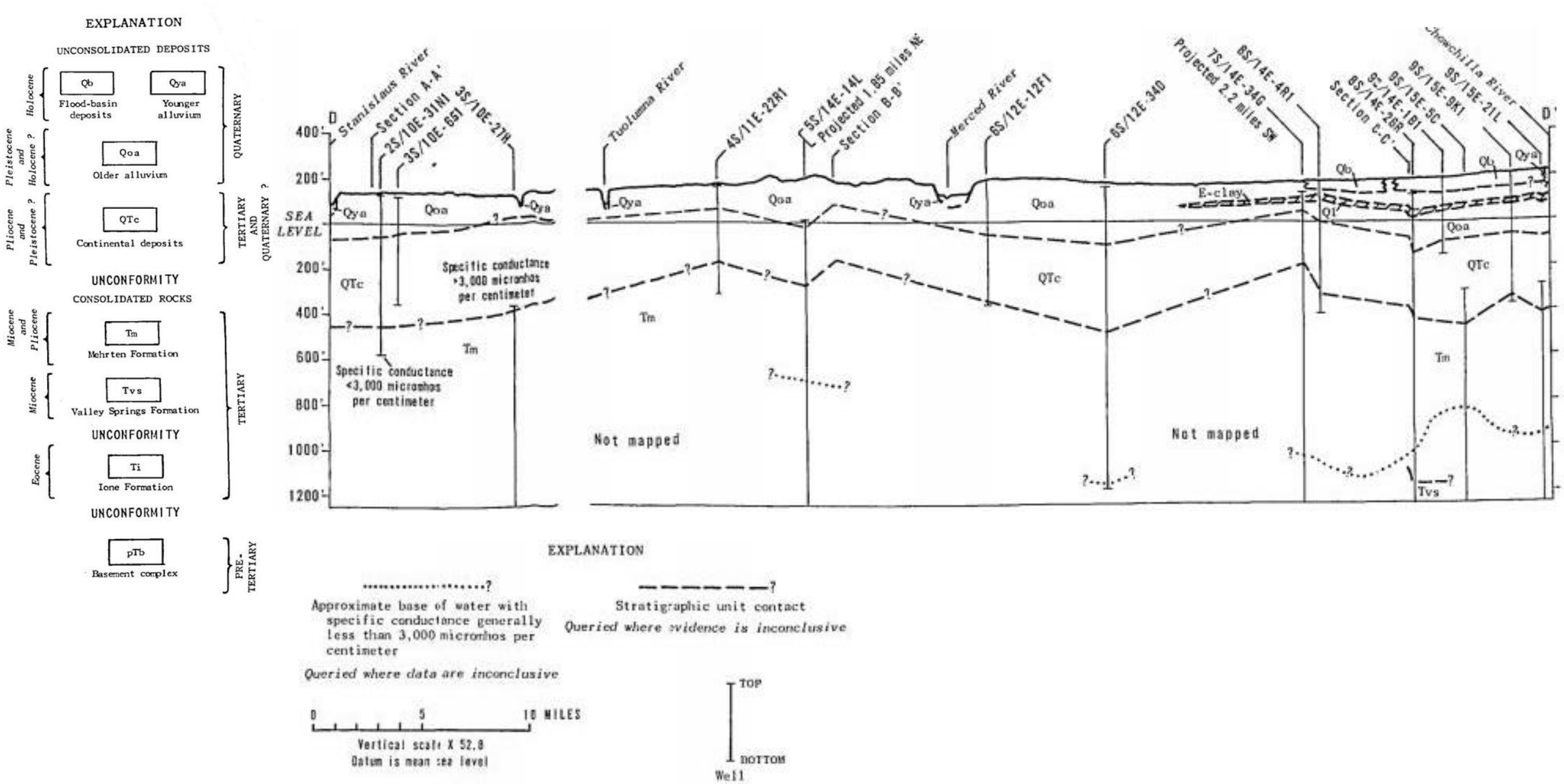
Source: (Page & Balding, 1973)

Figure 2-15: Geologic Cross-Section C (Page & Balding 1973)



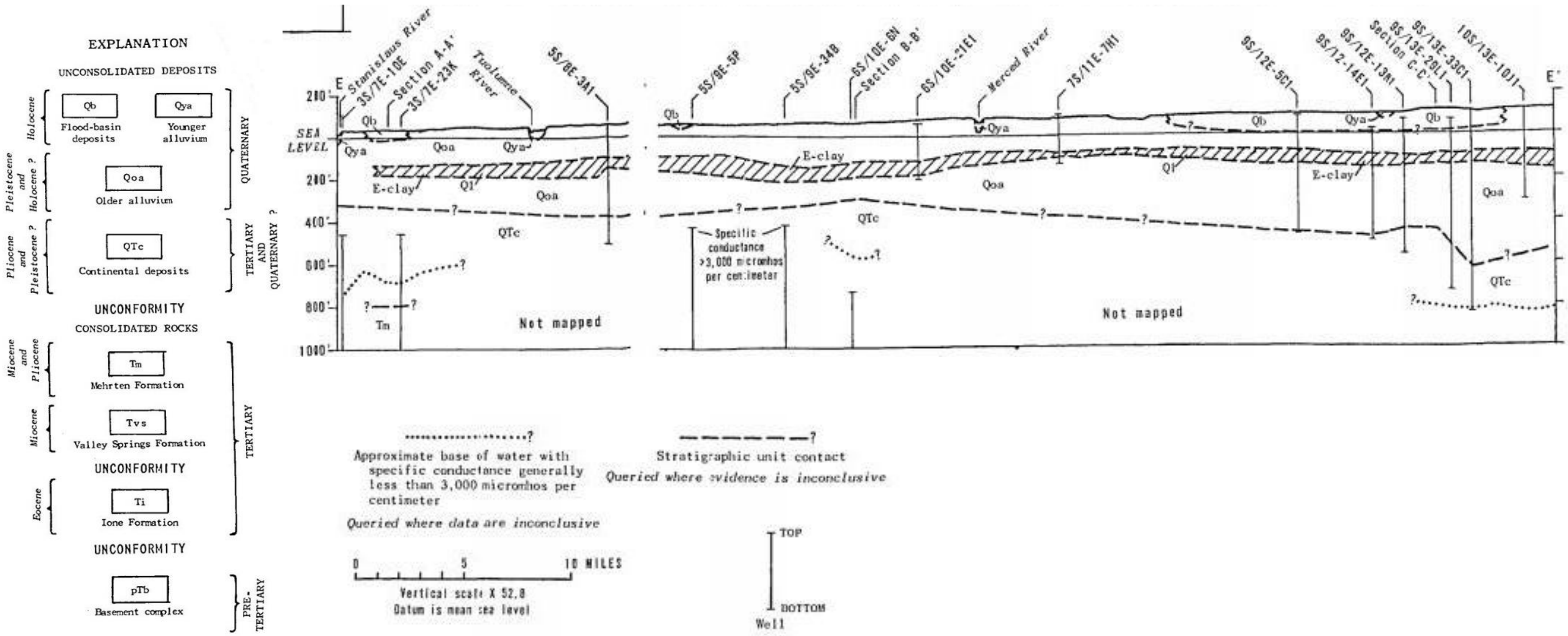
Source: (Page & Balding, 1973)

Figure 2-16: Geologic Cross-Section D (Page & Balding 1973)



Source: (Page & Balding, 1973)

Figure 2-17: Geologic Cross-Section E (Page & Balding 1973)



Source: (Page & Balding, 1973)

Figure 2-18: Location of Geologic Cross Sections (Page 1977)

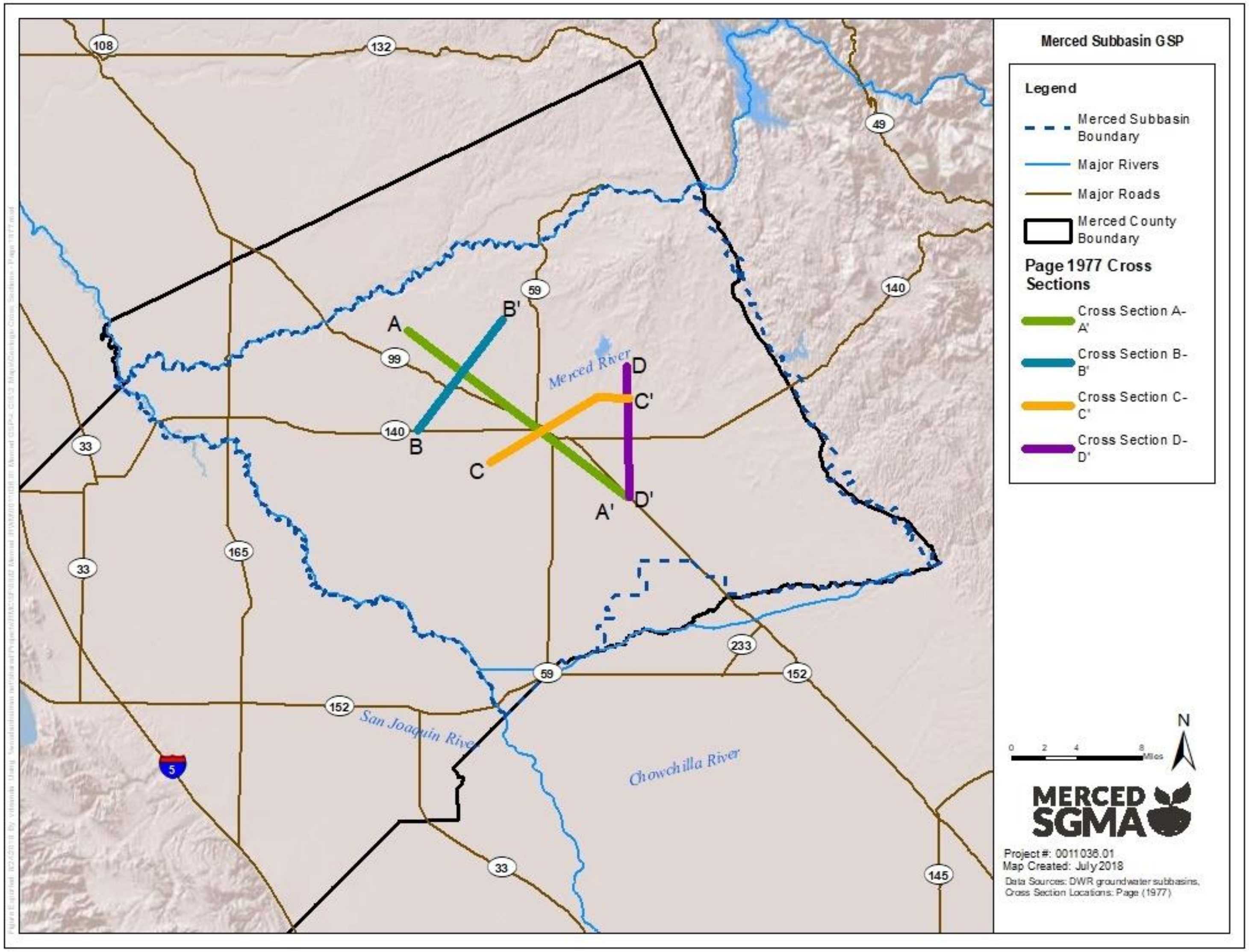
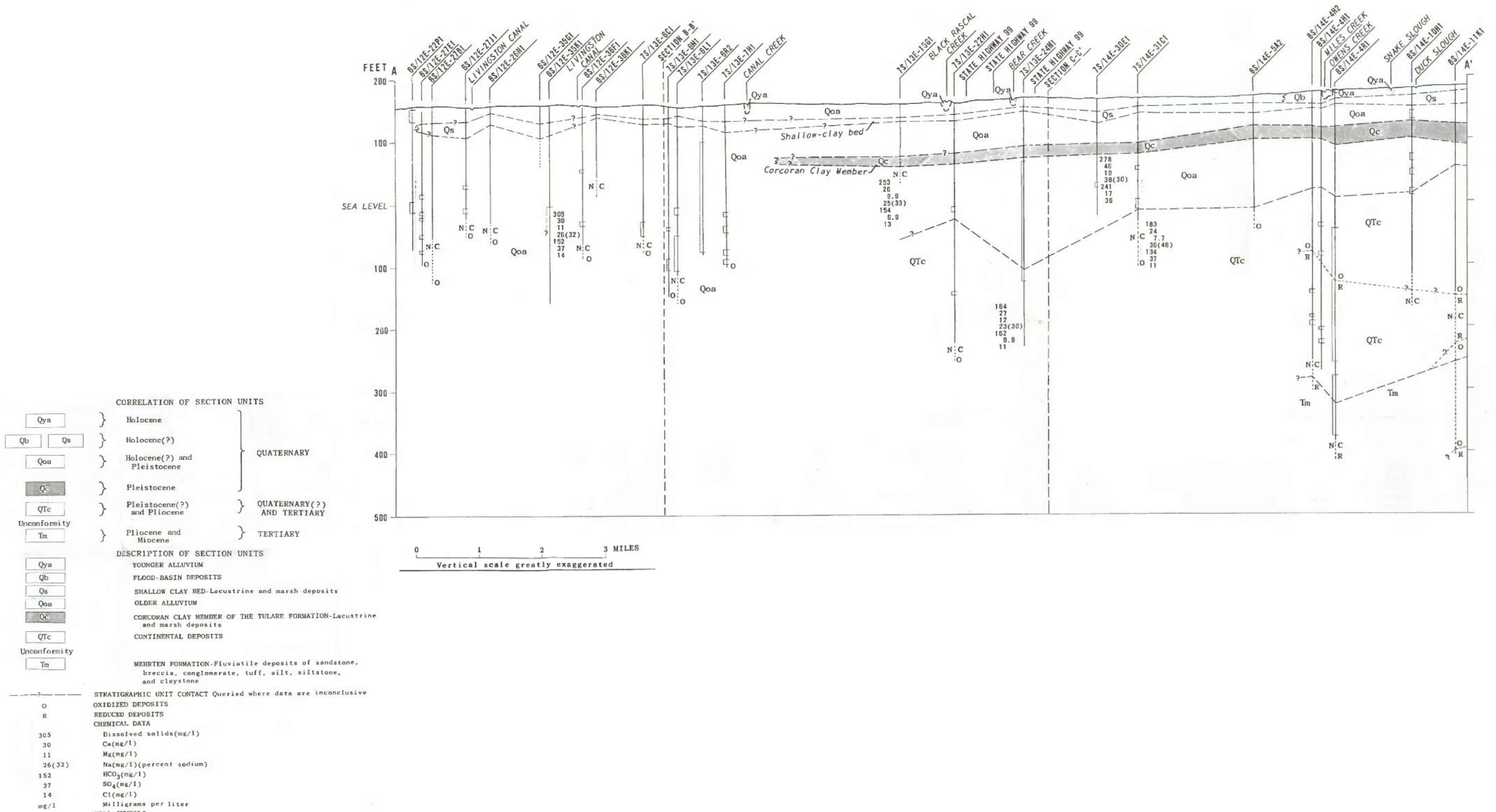
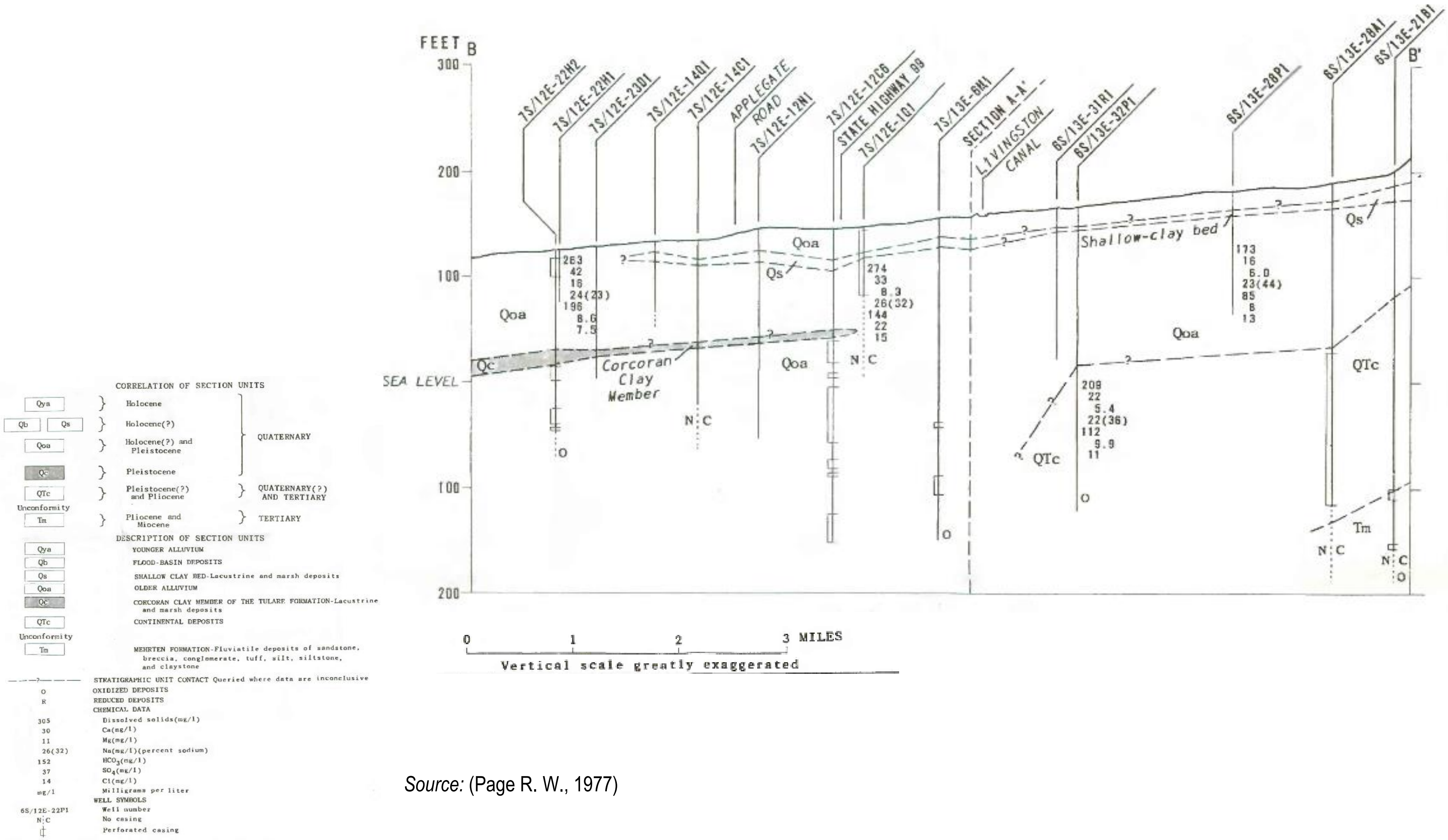


Figure 2-19: Geologic Cross-Section A (Page 1977)



Source: (Page R. W., 1977)

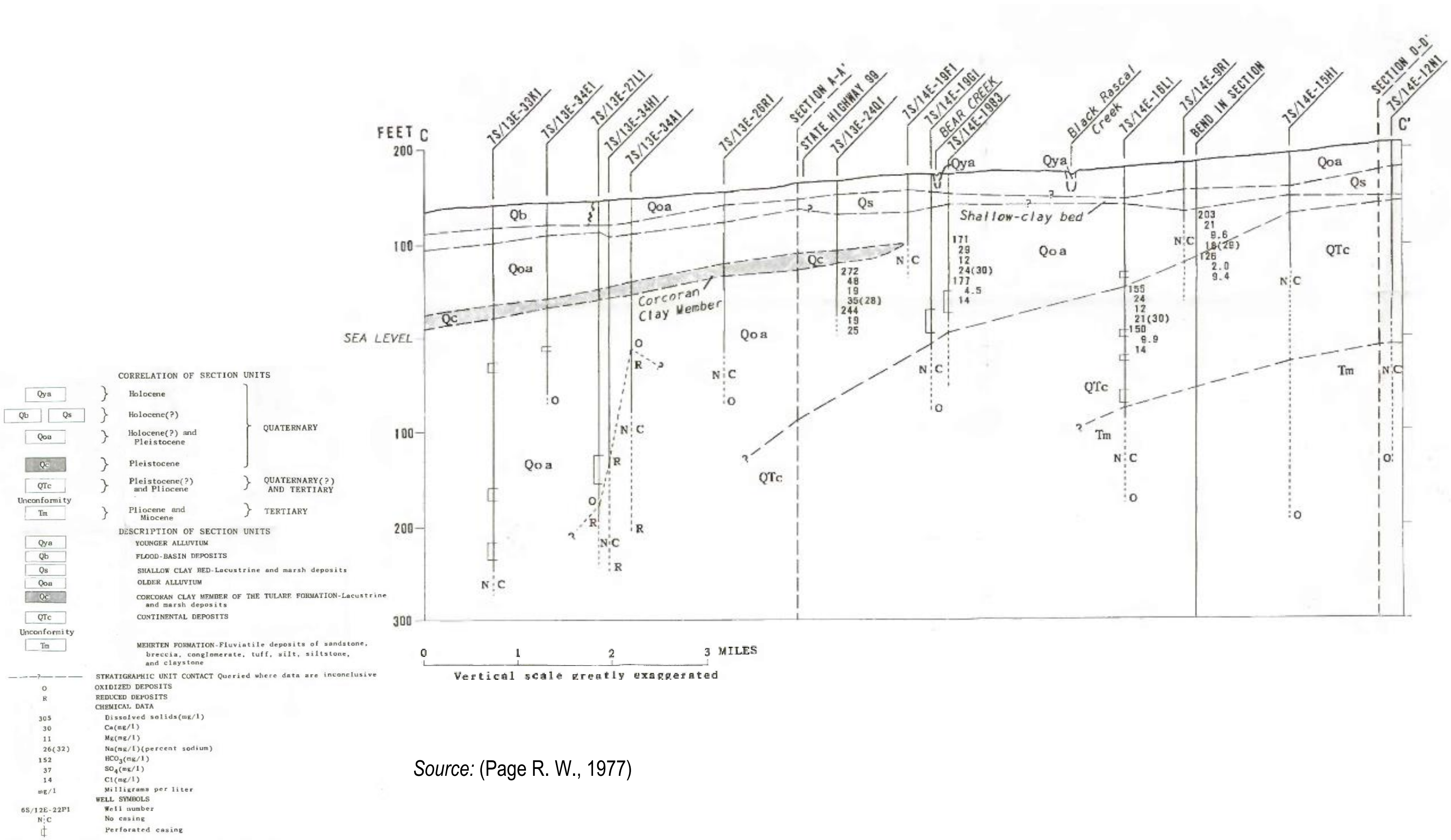
Figure 2-20: Geologic Cross-Section B (Page 1977)



Source: (Page R. W., 1977)

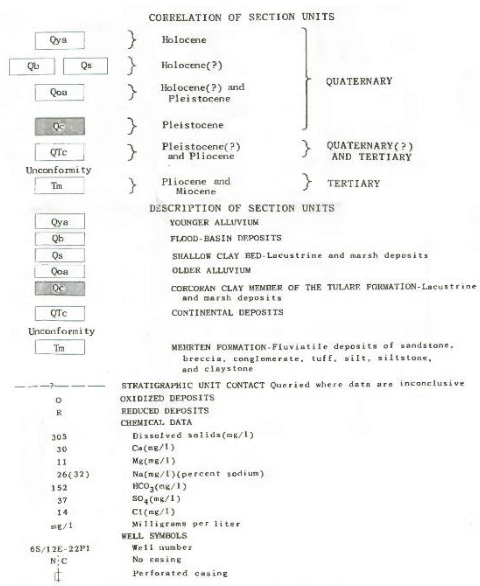
Woodard & Curran

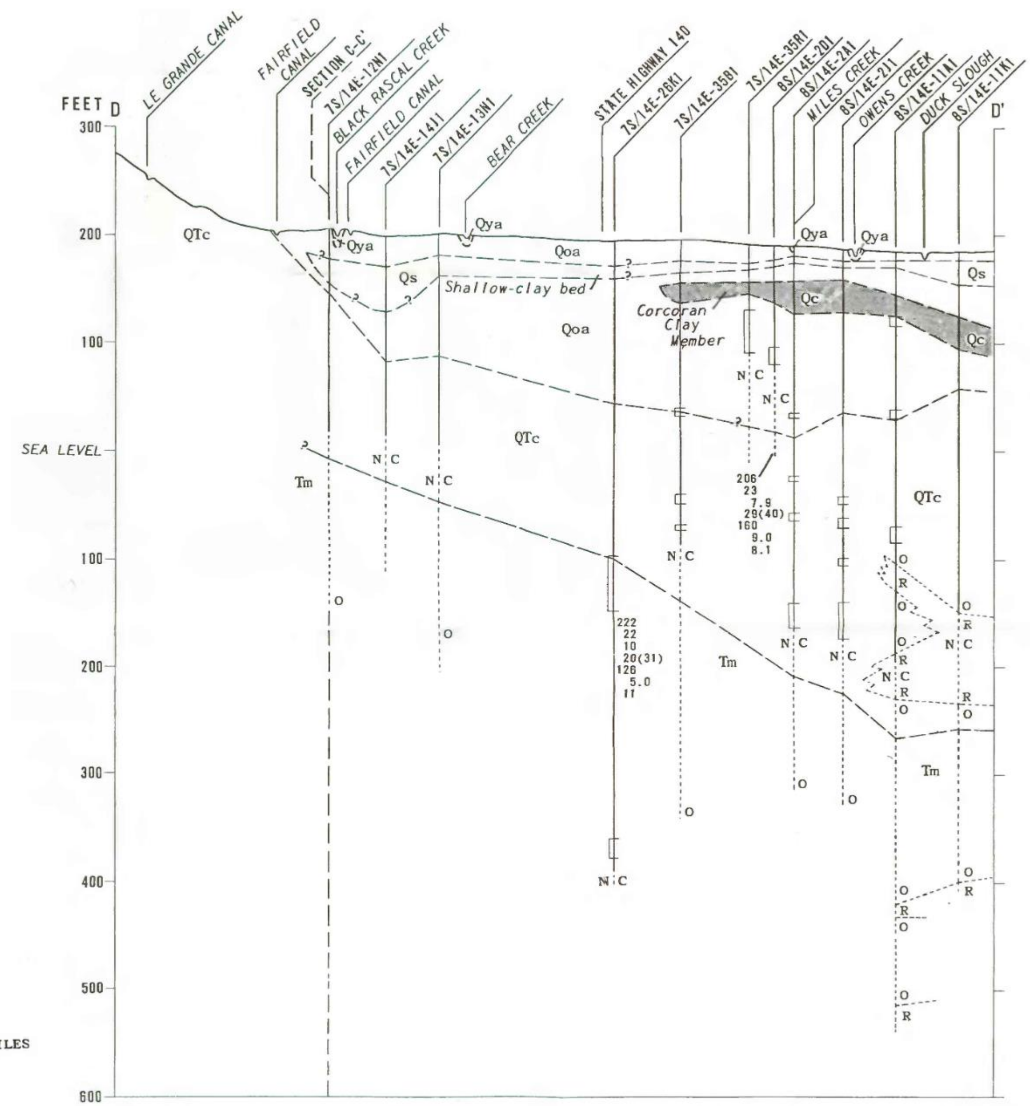
Figure 2-21: Geologic Cross-Section C (Page 1977)



Source: (Page R. W., 1977)

Figure 2-22: Geologic Cross-Section D (Page 1977)





Source: (Page R. W., 1977)

Table 2-5 provides a lookup table that links the various names used for the formations described in the earlier text of Section 2.1.3 with the cross sections shown below (Figure 2-13 through Figure 2-22).

The cross sections from Page & Balding (1973) and Page (1977) were used together with the USGS Central Valley Hydrologic Model (CVHM) texture model to develop the basis of the physical structure and hydrogeologic characteristics of the MercedWRM. The texture model was used to augment the cross sections with more recent boring log data through 2004 at a finer spatial resolution. The USGS applied data from several thousand boreholes to a geostatistical analysis to estimate the percentage of fine- and coarse-grained materials, which relates to aquifer parameters. These parameters were then adjusted and calibrated within the MercedWRM to reflect long-term trends in water levels. Additional information about incorporation of USGS CVHM Texture Model data can be found in Appendix D (MercedWRM Documentation).

Table 2-5: Formation Name Lookup for Geologic Text, Tables, and Figures

<table>
<tr><th colspan="2">Formation Name in Report Text</th><th>Formation Name in Surficial Geology Map (Page 1986)</th><th>Formation Name in Page & Balding 1973 Cross Sections</th><th>Formation Name in Page 1977 Cross Sections</th></tr>
<tr><td colspan="2">Sierra Nevada bedrock complex</td><td>pTm (Metamorphic rocks [Pre-Tertiary]) + pTg (Granitic rocks (Pre-Tertiary)]</td><td>pTb (Basement complex)</td><td>-</td></tr>
<tr><td colspan="2">Eocene Ione Formation</td><td>Tce (Continental rocks and deposits [Eocene])</td><td>Ti (Ione Formation)</td><td>-</td></tr>
<tr><td colspan="2">Miocene Valley Springs Formation</td><td>Tcmo (Continental rocks and deposits [Oligocene and Miocene])</td><td>Tvs (Valley Springs Formation)</td><td>-</td></tr>
<tr><td colspan="2">Micoene/Pliocene Mehrten Formation</td><td>Tcpm (Continental rocks and deposits [Miocene-Pliocene])</td><td>Tm (Mehrten Formation)</td><td>Tm (Mehrten Formation - Fluviatile deposits of sandstone, breccia, conglomerate, tuff, silt, siltstone, and claystone)</td></tr>
<tr><td rowspan="2">Lacustrine and marsh deposits</td><td>Corcoran Clay Member</td><td>N/A – not surficial</td><td>E-clay or Ql</td><td>Qc (Corcoran Clay Member of the Tulare Formation - Lacustrine and marsh deposits)</td></tr>
<tr><td>Shallow clay bed (Holocene age)</td><td>N/A – not surficial</td><td>-</td><td>Qs (Shallow Clay Bed - Lacustrine and marsh deposits)</td></tr>
<tr><td colspan="2">Pliocene/Pleistocene continental deposits</td><td rowspan="2">QTc (Continental rocks and deposits [Miocene-Holocene])</td><td>QTc (Continental deposits)</td><td>QTc (Continental deposits)</td></tr>
<tr><td colspan="2">Older alluvium</td><td>Qoa (Older alluvium)</td><td>Qoa (Older alluvium)</td></tr>
<tr><td colspan="2">Flood-plain deposits</td><td>Qb (Flood-basin deposits [Holocene-Pleistocene])</td><td>Qb (Flood basin deposits)</td><td>Qb (Flood basin deposits)</td></tr>
<tr><td colspan="2">Younger alluvium</td><td>Qr (River deposits [Holocene-Pleistocene])</td><td>Qya (Younger alluvium)</td><td>Qya (Younger alluvium)</td></tr>
</table>

A three-dimensional representation of the Subbasin (Figure 2-23) provides the capability to understand geologic conditions at different depths and locations throughout the Subbasin. The three-dimensional representation allows for the development of cross sections at any location, with examples shown in Figure 2-24 and Figure 2-25. Originally developed for the MercedWRM, the three-dimensional representation incorporates information from the Page & Balding (1973) cross sections and the surficial geologic map, in addition to subsurface texture data from the USGS. Model layers were aligned with the formations and are described in detail in Section 2.1.7 - Principal Aquifers and Aquitards. More information on the MercedWRM can be found in Appendix D.

Figure 2-23: 3D Rendering Cross Section Overview

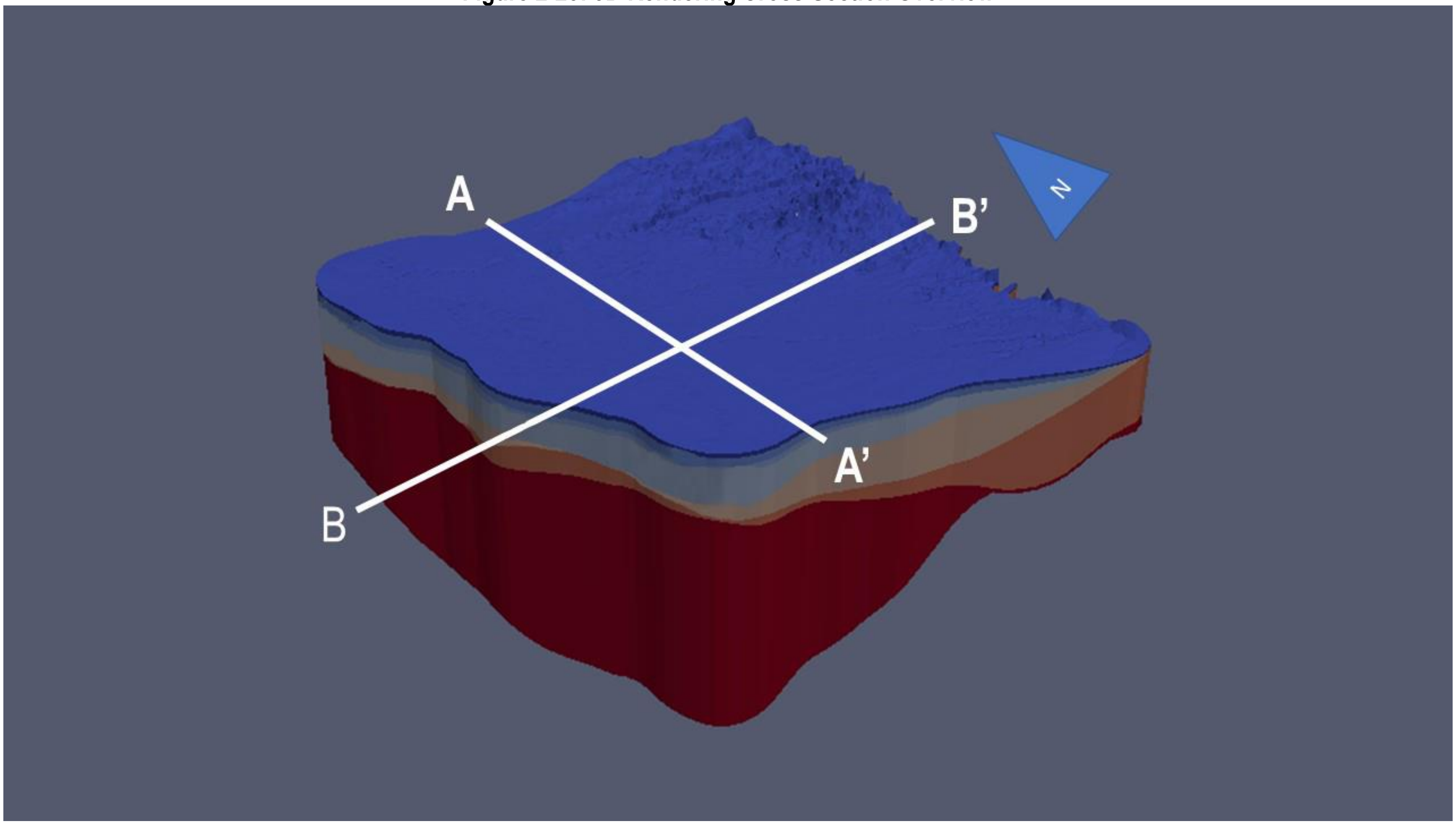


Figure 2-24: 3D Rendering A-A'

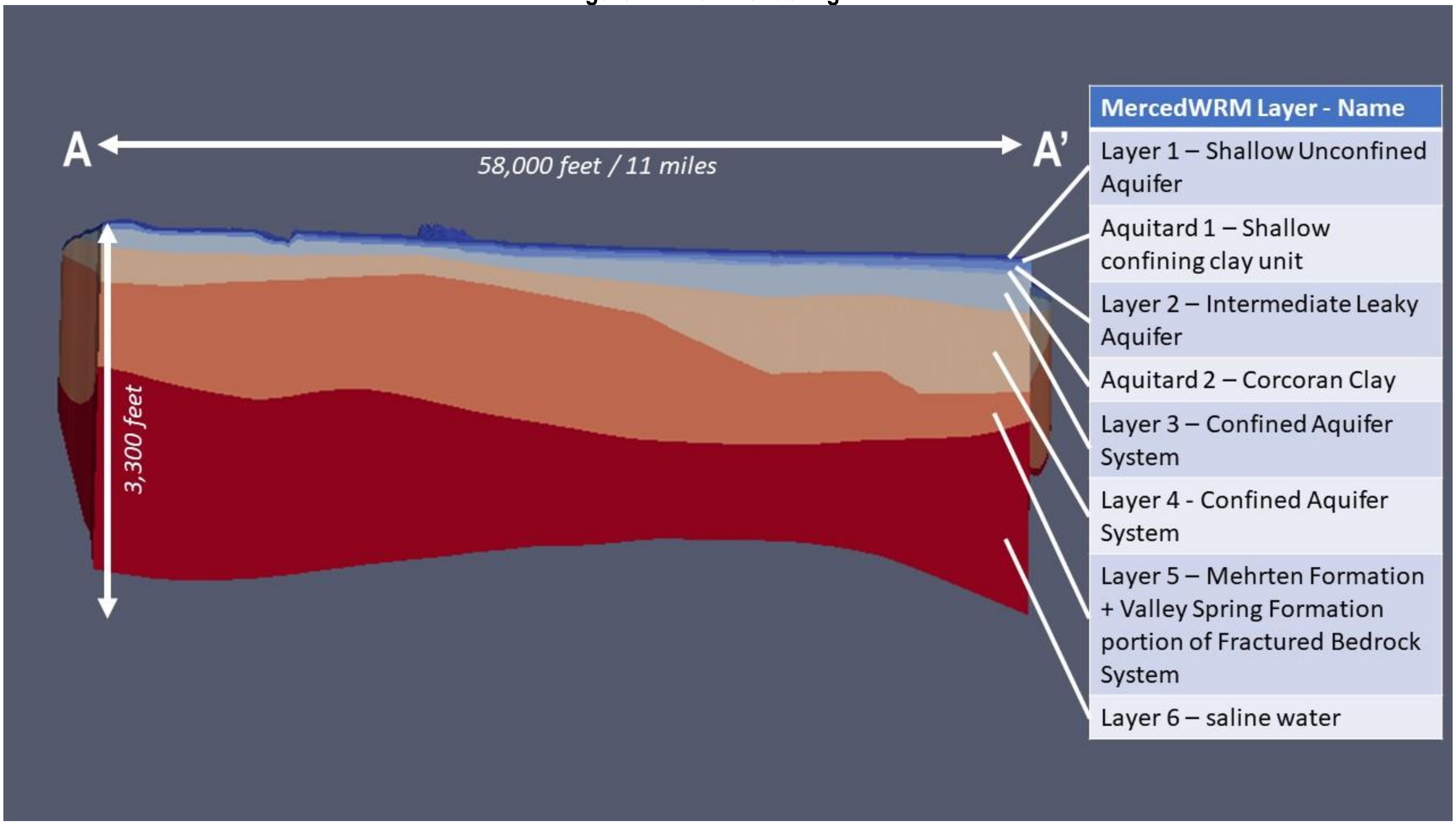
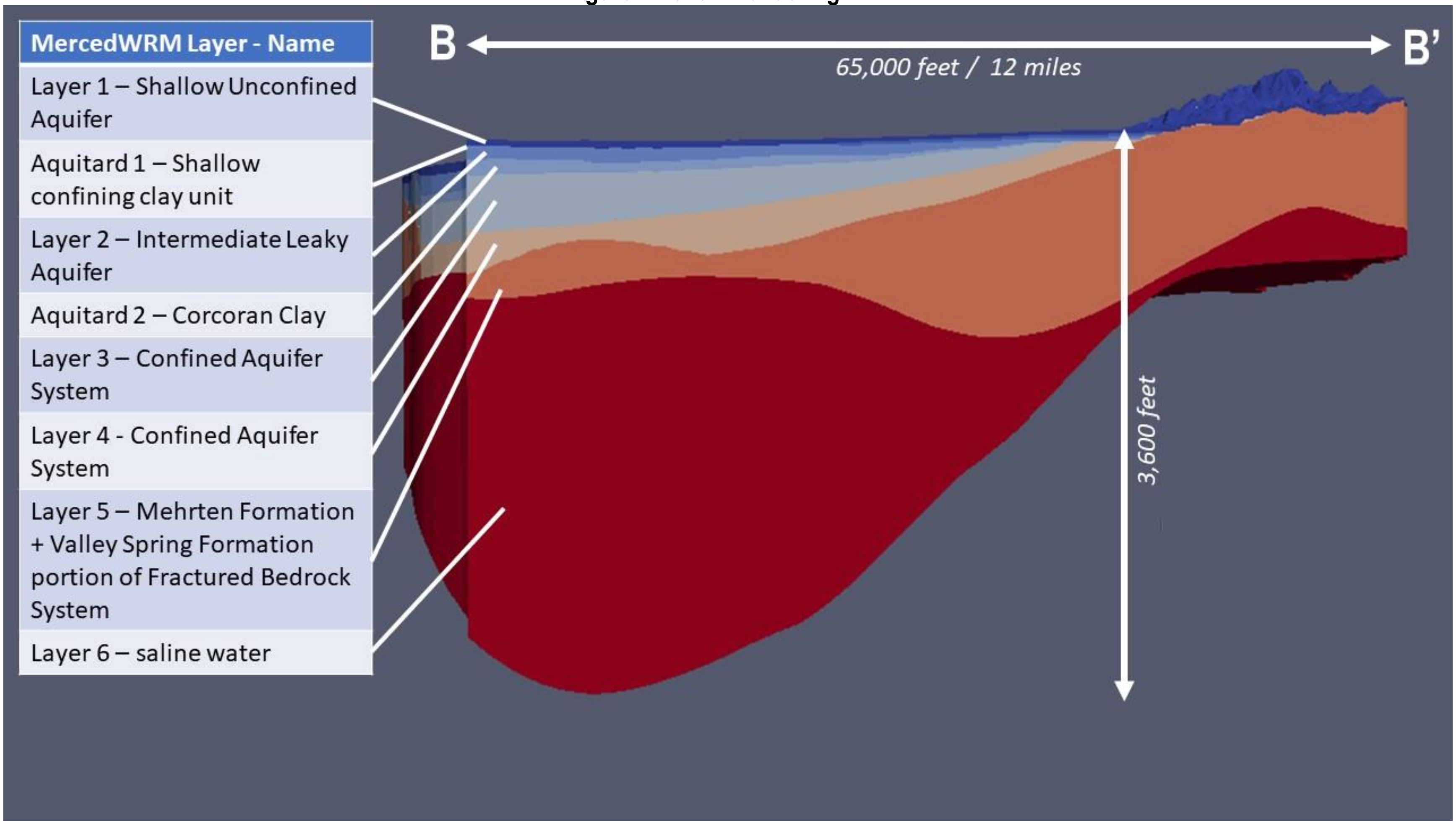


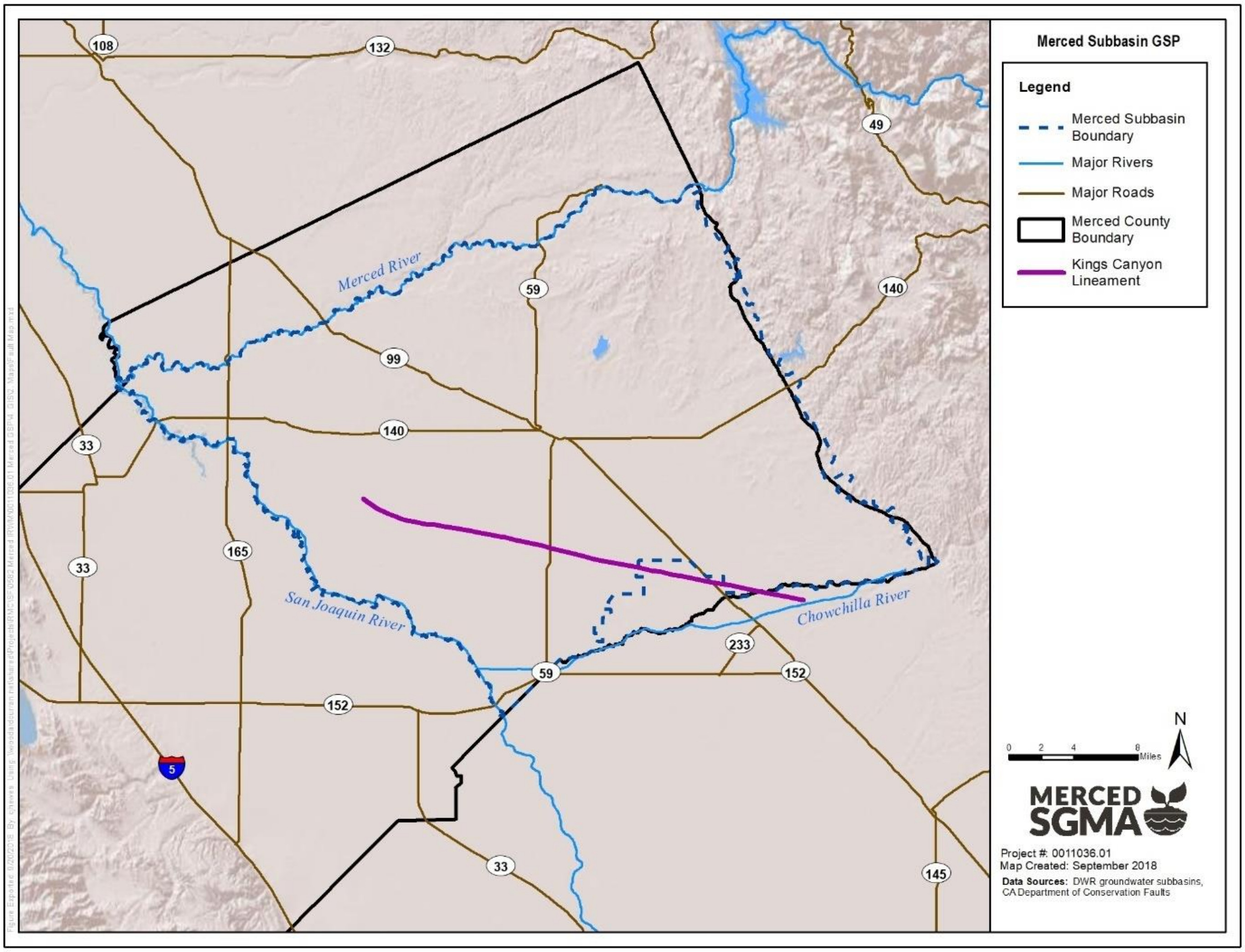
Figure 2-25: 3D Rendering B-B’



2.1.5 Faults and Structural Features

There are no major faults, anticlines, or synclines in the Merced Subbasin. The only minor feature present in the Subbasin is the Kings Canyon Lineament, shown in Figure 2-26 (California Geological Survey, 2010). This feature coincides with an unnamed inferred fault based on apparent offset of subsurface materials (Bartow J. A., 1985) and is not known to affect groundwater flow in the basin (DWR, 2004) nor is it known to affect subsidence or groundwater quality. The key geologic feature that affects groundwater flows is the Corcoran Clay, which is described previously.

Figure 2-26: Fault Map



2.1.6 Subbasin Boundaries

The horizontal and vertical boundaries of the Merced Subbasin are described below.

2.1.6.1 Lateral Boundaries and Boundaries with Neighboring Subbasins

The Merced Subbasin includes lands south of the Merced River between the San Joaquin River on the west and the crystalline basement rock of the Sierra Nevada foothills on the east. The Subbasin boundary on the south stretches westerly along the Chowchilla River (Merced-Madera County boundary) and then along the northern edge of the sphere-of-influence boundary of Chowchilla Water District.

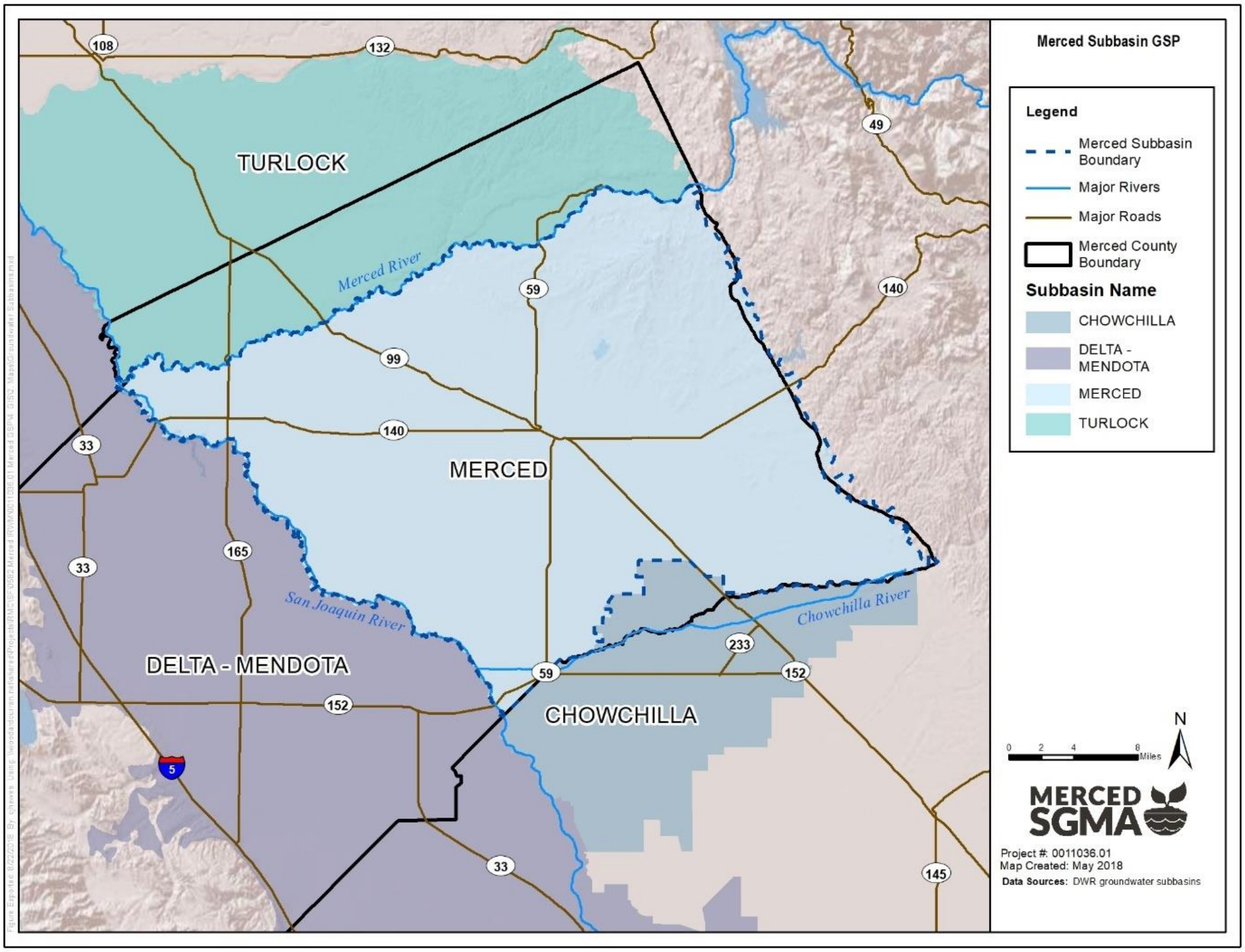
DWR defines boundaries based on the following restrictions on groundwater flow: impermeable bedrock, constructions in permeable materials, faults, low permeability zones, groundwater divides, and adjudicated basin boundaries (DWR, 2003). While boundaries divide the Merced Subbasin from surrounding subbasins of the San Joaquin Valley Groundwater Basin, groundwater within the Merced Subbasin is hydraulically connected with groundwater in the surrounding subbasins. The boundaries of the Merced Subbasin are described below in Table 2-6 based on these boundary types. Figure 2-27 shows a map of the surrounding subbasins.

Table 2-6: Basin Boundary Description and Type

Boundary	Boundary Type	DWR Definition	Boundary Description
Eastern	Impermeable Bedrock	"Impermeable bedrock with lower water yielding capacity. These include consolidated rocks of continental and marine origin and crystalline/or metamorphic rock." (DWR, 2003)	Bounded by the crystalline bedrock of the Sierra Nevada mountain range.
Northern	Groundwater Divide	"A groundwater divide is generally considered a barrier to groundwater movement from one basin to another for practical purposes. Groundwater divides have noticeably divergent groundwater flow directions on either side of the divide with the water table sloping away from the divide. The location of the divide may change as water levels in either one of the basins change, making such a "divide" less useful. Such a boundary is often used for subbasins." (DWR, 2003).	The Merced River forms northern boundary of Merced Subbasin (Bulletin 118 Basin Number 5-022.04) and divides the Subbasin from the Turlock Subbasin (Bulletin 118 Basin Number 5-022.03).
Southern (eastern side)	Groundwater Divide	(defined above)	The Chowchilla River divides the Merced Subbasin from the Chowchilla Subbasin (Bulletin 118 Basin Number 5-022.05) along the eastern edge of the southern boundary. The Chowchilla River also generally forms the boundary between Merced and Madera Counties in this area.

Boundary	Boundary Type	DWR Definition	Boundary Description
Southern (western side)	Jurisdictional Boundary	Not defined.	The boundary generally follows the sphere-of-influence boundary of Chowchilla Water District. Starting from the intersection of the Chowchilla River at the northwest corner of Section 13, Township 9 South, Range 15 East, it runs north and west along the east and north boundary of Section 11, Township 9 South, Range 15 East until it reaches the Southern Pacific Railroad tracks. Then northwesterly along the Southern Pacific Railroad tracks until it reaches the northeast corner of Section 4, Township 9 South Range 15 East. Then west along the north boundary of Sections 4, 5, and 6, Township 9 South, Range 15 East. Then southwesterly along the boundary of the Chowchilla Water District until it reaches the northern boundary of Madera County (County of Madera, 2016).
Western	Groundwater Divide	(defined above)	Based on the San Joaquin River, which divides the Merced Subbasin from the Delta-Mendota Subbasin (Bulletin 118 Basin Number 5-022.07).

Figure 2-27: Neighboring Subbasins

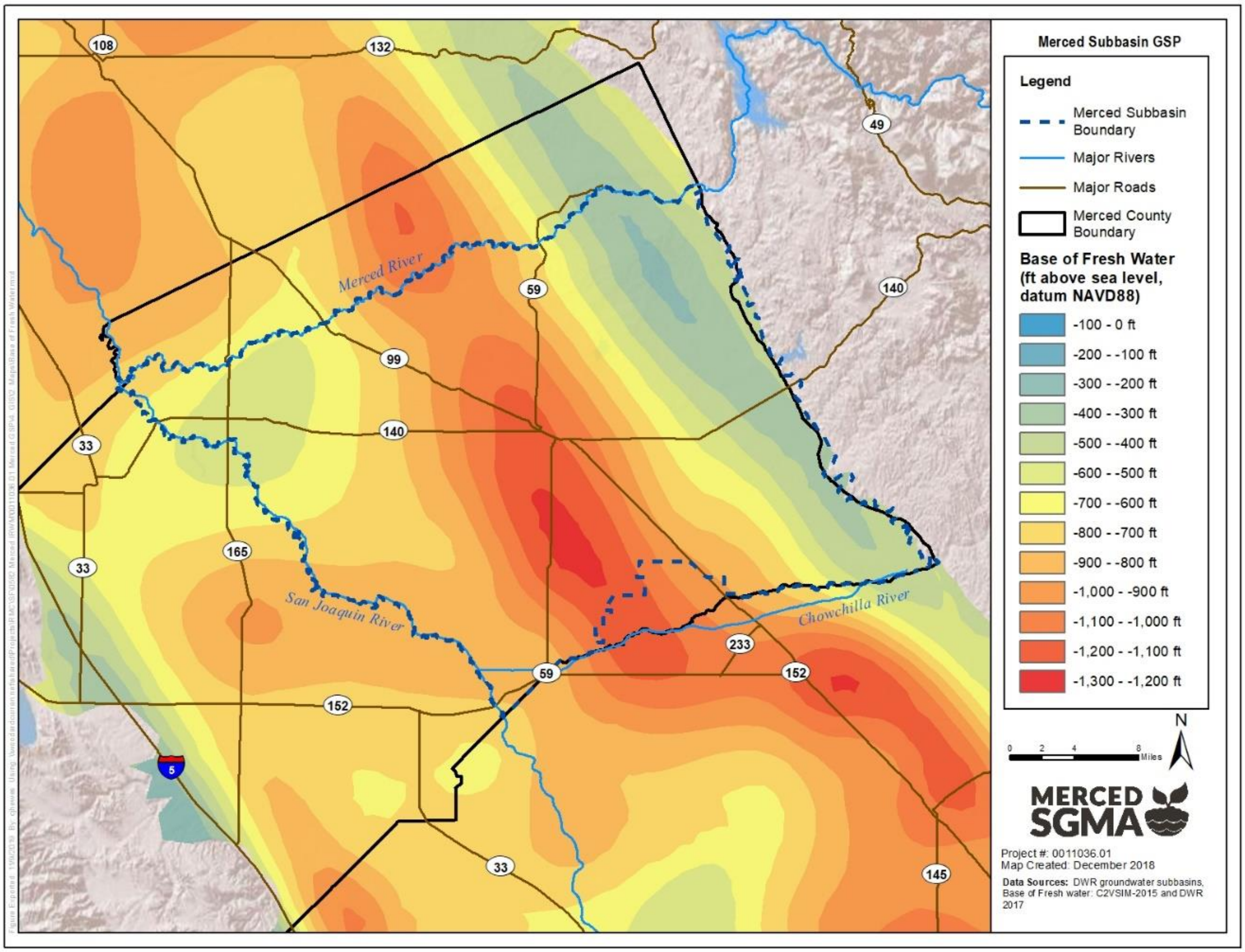


2.1.6.2 Bottom of the Merced Basin

As discussed above, the San Joaquin Valley is filled with up to 32,000 feet of marine and continental sediments. However, only the uppermost portion of these sediments are saturated with fresh groundwater. Deeper sediments contain saline groundwater. The bottom of the Merced Basin is defined as the lowest elevation of fresh water. This elevation is called the "base of fresh water" and is defined here as specific conductance of less than 3,000 micromhos per centimeter. The depth of the base of fresh water is defined by Page (1973), who mapped the base of fresh water based on measurements at wells of specific conductance of less than 3,000 micromhos per centimeter. Page's interpretation of the base of fresh water is incorporated into the California Central Valley Groundwater-Surface Water Simulation Model, which includes this information in the definition of model layers and was last updated by DWR in 2017 (see Figure 2-28 which shows elevation of the base of fresh water in feet above sea level). In most parts of the Subbasin, the base of fresh water is very deep (greater than 500 feet) which is reflected in the relatively large total storage volume described elsewhere in this GSP. The variations in the elevation of the base of fresh water are driven by underlying geology as well as locations of deeper saline groundwater.

A well depth analysis completed in March 2018 found that, based on information in Merced County's well permit database, 56 wells (approximately 4% of wells with data) extended below the bottom of the basin as defined above, primarily located along the central portion of the County just east of the San Joaquin River (Woodard & Curran, 2018b). The quality of water produced from these wells is not known, and no data are available to show that the wells are actively used.

Figure 2-28: Base of Fresh Water



2.1.7 **Principal Aquifers and Aquitards**

There are five different aquifer systems identified in the Subbasin based on their differing geologic history and hydrogeologic characteristics. These systems have been modeled in the MercedWRM. The systems interact with each other throughout the Subbasin but are separated in some areas by the presence of the confining Corcoran Clay layer. Based on these interactions and for the practical purpose of developing and implementing this GSP, the five aquifer systems have been combined into three pertinent Principal Aquifers and are described further in the sections below.

2.1.7.1 Aquifer Systems in the Basin

Five aquifer systems have been identified in the Merced Subbasin by the Merced Groundwater Management Plan (AMEC, 2008), including, in order of decreasing depth: a fractured bedrock aquifer, the Mehrten Formation, a confined aquifer, an intermediate "leaky" aquifer, and a shallow unconfined aquifer. These aquifer systems interact with each other throughout the basin, except where the Corcoran Clay exists.

In addition to the descriptive information from the Merced Groundwater Management Plan, the MercedWRM (see Appendix D) provides information on aquifer characteristics by aggregating available data and calibrating selected characteristics to closely match observed and simulated groundwater elevation and streamflows. The model uses five distinct fresh-water aquifer layers, one saline aquifer, and two confining units. The fresh water aquifer layers correspond closely with the aquifer formations described below from the Merced Groundwater Management Plan.

Hydraulic conductivity, specific storage, and specific yield are three aquifer parameters that describe physical characteristics of aquifers that are important for groundwater modeling.

Hydraulic conductivity is defined and mapped separately for each aquifer layer (Figure 2-29 through Figure 2-33

). Hydraulic conductivity is a numeric characteristic of an aquifer that describes the ease with which groundwater moves through pore spaces or fractures in soil or rock.

During a sensitivity analysis in which changes in aquifer parameters were compared against modeled groundwater level outputs, specific storage (Figure 2-34) and specific yield (Figure 2-35) were determined to not vary significantly between aquifer layers and thus are defined across the entire Subbasin for all aquifer layers (Woodard & Curran, 2019). Specific storage describes the unit volume of water released or taken into storage per unit change in hydraulic head. It is a unitless quantity. Specific storage is a more important characteristic for unconfined aquifers (i.e., above the Corcoran Clay) and has less importance for confined aquifers (i.e., below the Corcoran Clay). Specific yield describes the unit volume released from the aquifer per unit change in head under the force of gravity.

These five aquifer systems are described from deepest to shallowest, and the following Section 2.1.7.2 describes the three principal aquifers to be used in this GSP based on the interactions of the five systems described below. Table 2-7 shows the relationship between MercedWRM layer, formation name, and principal aquifer name.

Fractured Bedrock - Along the eastern edge of the Merced Subbasin, wells have been completed within the Valley Springs and Ione Formations (Page & Balding, 1973), (Page R. W., 1977). The Ione Formation unconformably overlies the Sierra Nevada bedrock complex and is composed of marine to non-marine clay, sand, sandstone, and conglomerate. The Valley Springs Formation is composed of a fluvial sequence of rhyolitic ash, sandy clay, and siliceous gravel in a clay matrix. Wells in this system appear to be completed in fractured bedrock with limited and variable yields. Because of the limited extent (and poor yields) of the fractured bedrock aquifer, the fractured aquifer is not a significant source of water in the Merced Subbasin (AMEC, 2008).

Hydraulic conductivity is shown in Figure 2-29 as part of the MercedWRM Layer 5 which contains both the Valley Springs Formation portion of the Fractured Bedrock system where it underlies the Mehrten Formation as well as the Mehrten Formation itself (described below).

The Mehrten Formation - The Mehrten Formation outcrops over a large area in the Merced Subbasin. It is composed of fluvial deposits of sandstone, breccia, conglomerate, luff, siltstone and claystone. It contains a large amount of andesitic material, making it easy to distinguish. Many water supply wells in the eastern portion of the Merced Subbasin penetrate the formation, and it is a significant source of groundwater. Where the Mehrten occurs beneath the Corcoran Clay, it is considered a confined aquifer. Where the Mehrten does not underlie the Corcoran Clay, there is insufficient data to determine the degree of confinement of the formation (AMEC, 2008).

Laboratory and field tests made by the United States Army Corps of Engineers (USACOE) and DWR in other areas indicate a range in hydraulic conductivity in the Mehrten Formation range from 0.01 to about 67 ft/day. Yields from the Mehrten, therefore, can be expected to differ greatly from place to place and at different depths. Based on another DWR regional study, the Mehrten formation has a yield of about 1,000 gallons per minute (gpm) and a horizontal transmissivity of about 9,100 ft^2/day (Page & Balding, 1973).

Hydraulic conductivity is shown in Figure 2-29 as part of the MercedWRM Layer 5 which contains both the Mehrten Formation and the Valley Springs Formation portion of the Fractured Bedrock system (described above).

Confined Aquifer - The confined aquifer occurs in older alluvium (and Mehrten Formation) deposits that underlie the Corcoran Clay (Figure 2-37). The older alluvium consists of a heterogeneous mixture of poorly sorted gravel, sand, silt and clay up to 400 feet thick derived primarily from the Sierra Nevada. Many water supply wells in the western portion of the Merced Subbasin penetrate the Corcoran Clay into the confined aquifer, and it is a significant source of groundwater (AMEC, 2008).

In the older alluvium, yields to wells were as large as 4,450 gpm with an average 1,900 gpm. The specific capacity of 101 sampled wells ranged from 8.2 gpm/ft to 134.6 gpm/ft with a mean of 41.9 gpm/ft and a median of 36.7 gpm/ft. Specific capacities in the eastern part of the area, where wells penetrate older rocks and deposits, were generally smaller than those in the west. Because specific capacity is a rough indicator of transmissivity, the pattern indicates smaller transmissivities in the eastern part of the area near where the consolidated rocks crop out (Page & Balding, 1973).

The Confined Aquifer's hydraulic conductivity is shown in both Figure 2-30 and Figure 2-31 as part of the MercedWRM Layers 3 and 4 which together describe the Confined Aquifer. Layer 3 consists of older alluvium while layer 4 consists of continental deposits.

Intermediate Leaky-Aquifer - The intermediate leaky aquifer occurs in older alluvium deposits that overlie the Corcoran Clay or are east of the Corcoran Clay. Where the Corcoran Clay is absent, the intermediate leaky aquifer extends to the Mehrten Formation. In the eastern portion of the Merced Subbasin the intermediate aquifer consists of a series of interbedded coarse-grained (gravel and sand) layers separated by fine-grained (silt and clay) layers. The fine-grained layers inhibit, but do not prevent vertical groundwater flow between layers and thus form a leaky-aquifer system. Many water supply wells in the Merced Subbasin are completed in the intermediate leaky-aquifer, and it is a significant source of groundwater (AMEC, 2008).

The intermediate leaky-aquifer is the most extensively developed aquifer in the Merced Subbasin. Measured well yields within the Merced Subbasin range from 670 to 4,000 gpm (Page & Balding, 1973). Estimates of specific capacity of supply wells throughout the Merced Subbasin range from about 20 to 40 gpm/ft of drawdown and indicate that the specific capacity increases from east to west.

Hydraulic conductivity is shown in Figure 2-32 as part of the MercedWRM Layer 2.

Shallow Unconfined Aquifer - The shallow unconfined aquifer occurs in older and younger alluvium deposited above the shallow clay bed. Because of its shallow depth, few water supply wells are completed in the shallow unconfined aquifer. Where water levels in the intermediate leaky aquifer fall below the base of the shallow clay bed, groundwater in the intermediate aquifer becomes unconfined and water in the overlying shallow aquifer becomes perched (AMEC, 2008).

Hydraulic conductivity is shown in Figure 2-33 as part of the MercedWRM Layer 1.

The sixth layer of the model (not mapped) consists of saline water below the base of fresh water (described in 2.1.6.2) and was implemented as a refinement to the water quality model and for the potential use of scenario development for the simulation of deep well production (Woodard & Curran, 2019).

Table 2-7: Formation, Aquifer Name, and MercedWRM Layer Number Lookup

Formation/Aquifer Name	Principal Aquifer for GSP	MercedWRM Layer Number
Ione Formation	N/A	6
Valley Springs Formation	Outside Corcoran Clay	5
Mehrten Formation (outside of Corcoran Clay extent)	Outside Corcoran Clay	5
Mehrten Formation (within Corcoran Clay extent)	Below Corcoran Clay	5
Confined Aquifer	Below Corcoran Clay	4 (continental deposits)
	Below Corcoran Clay	3 (older alluvium)
Intermediate Leaky-Aquifer (within Corcoran Clay extent)	Above Corcoran Clay	2
Intermediate Leaky-Aquifer (outside of Corcoran Clay extent)	Outside Corcoran Clay	2
Shallow Unconfined Aquifer (outside of Corcoran Clay extent)	Outside Corcoran Clay	1
Shallow Unconfined Aquifer (within Corcoran Clay extent)	Above Corcoran Clay	1

Figure 2-29: Hydraulic Conductivity – Mehrten Formation and Valley Springs Portion of Fractured Bedrock System (MercedWRM Layer 5)

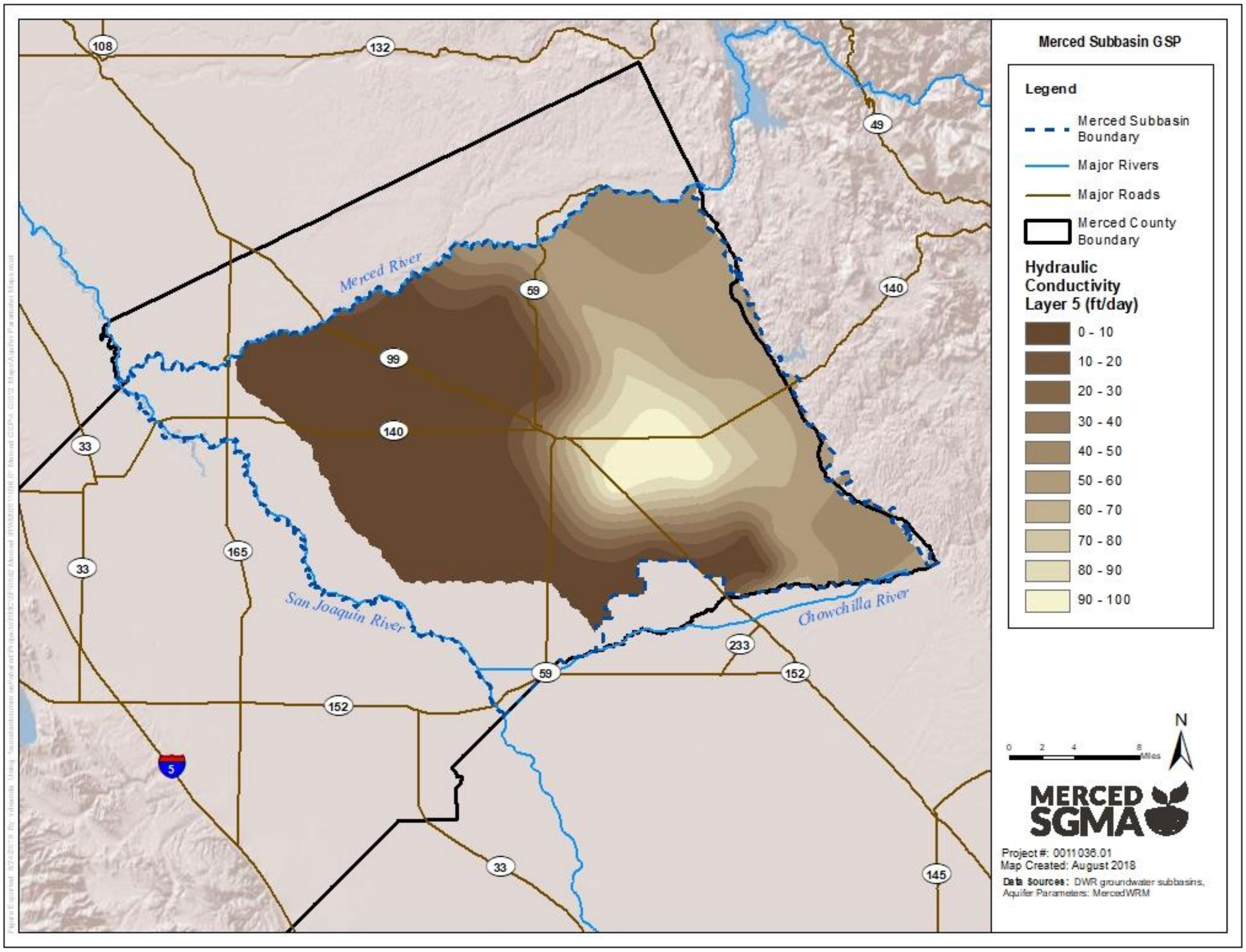


Figure 2-30: Hydraulic Conductivity – Confined Aquifer (MercedWRM Layer 4)

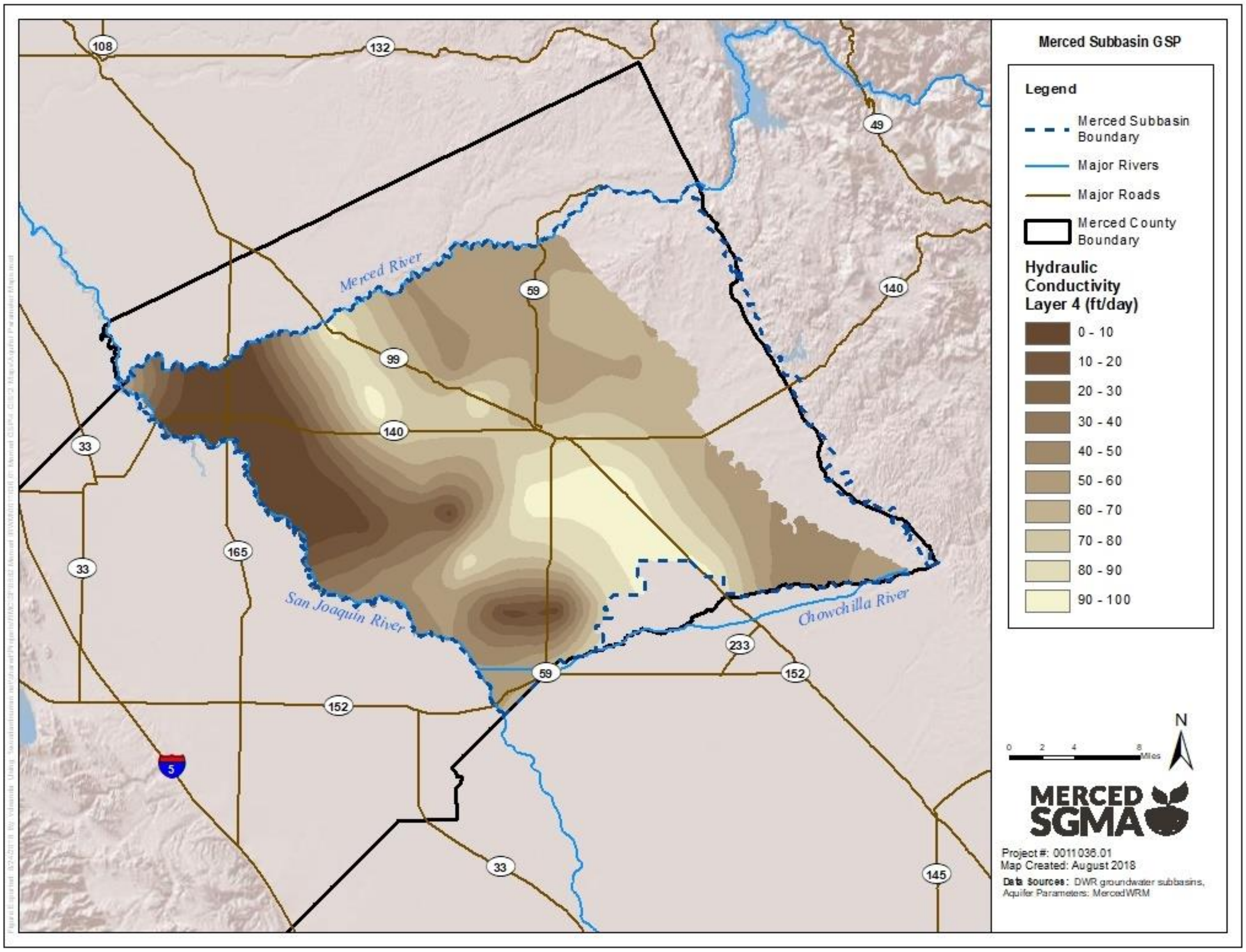


Figure 2-31: Hydraulic Conductivity – Confined Aquifer (MercedWRM Layer 3)

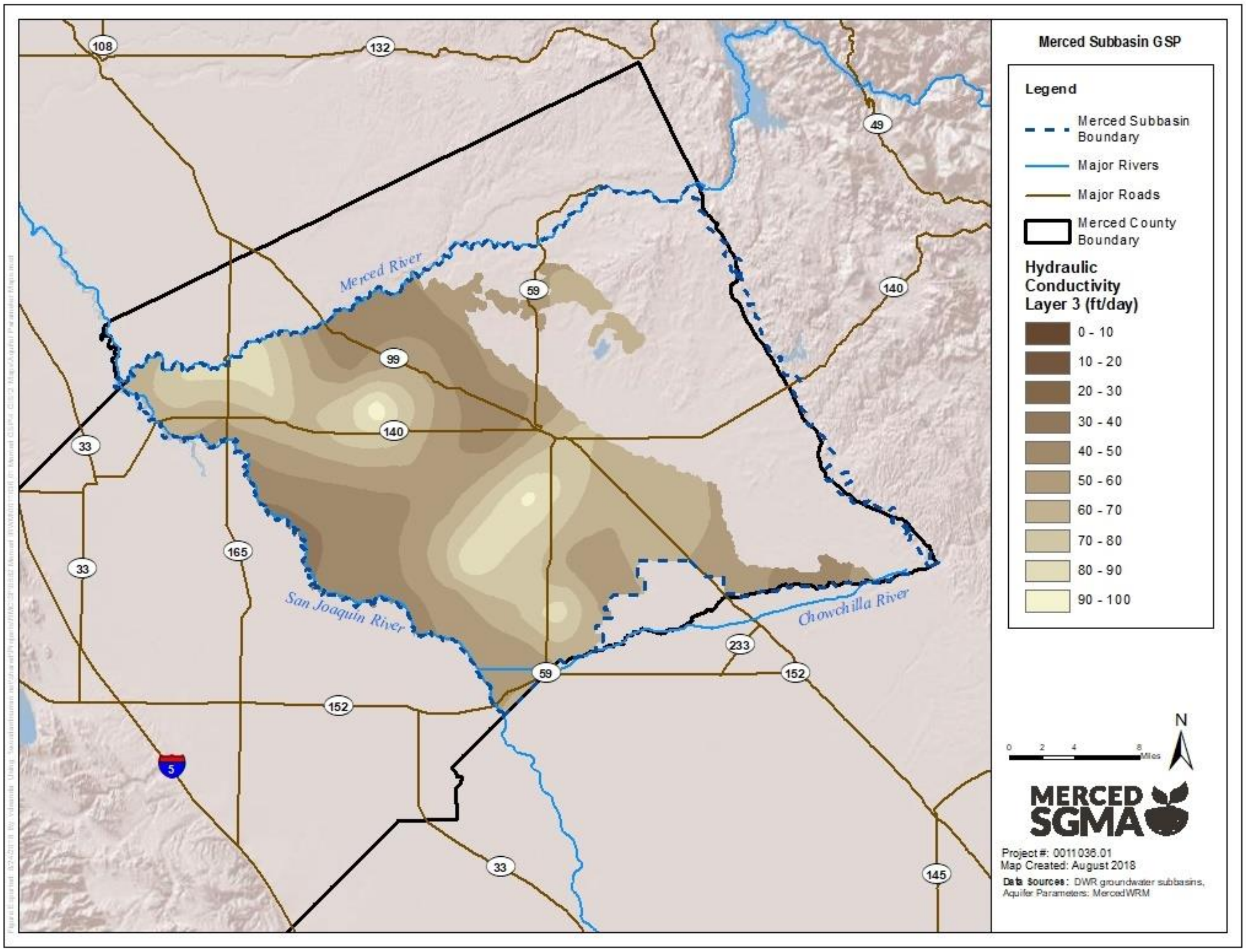


Figure 2-32: Hydraulic Conductivity – Intermediate Leaky-Aquifer (MercedWRM Layer 2)

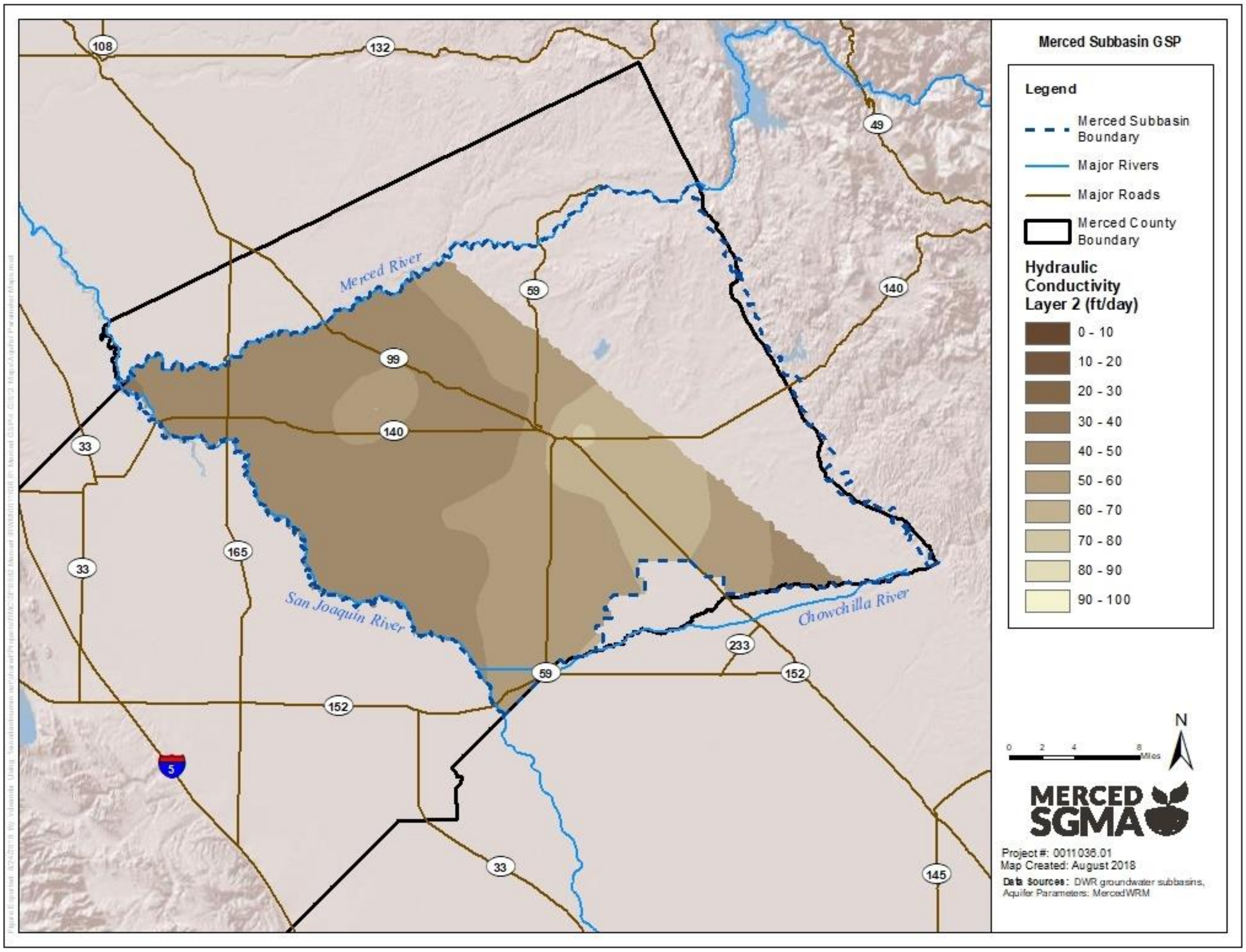


Figure 2-33: Hydraulic Conductivity – Shallow Unconfined Aquifer (MercedWRM Layer 1)

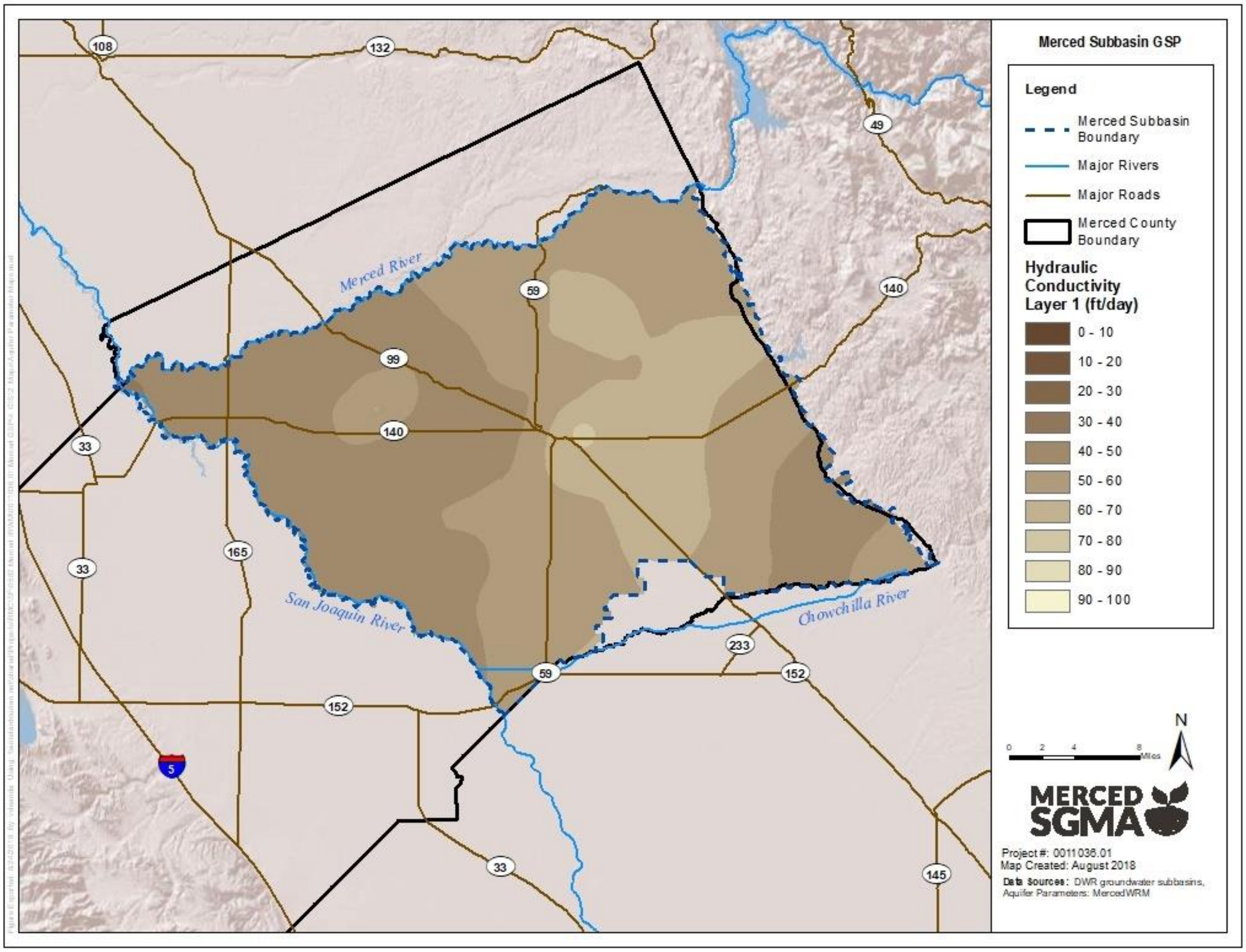
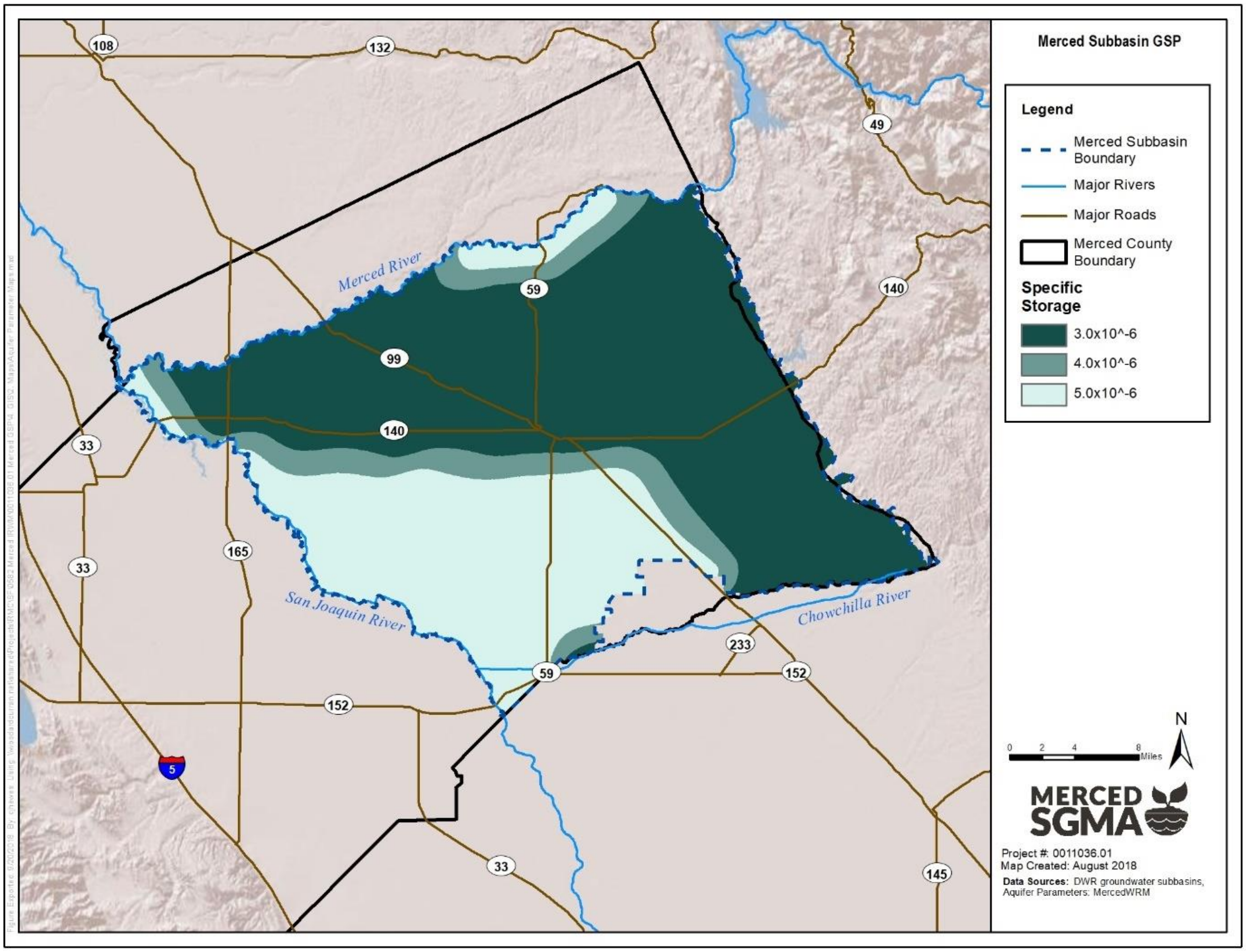
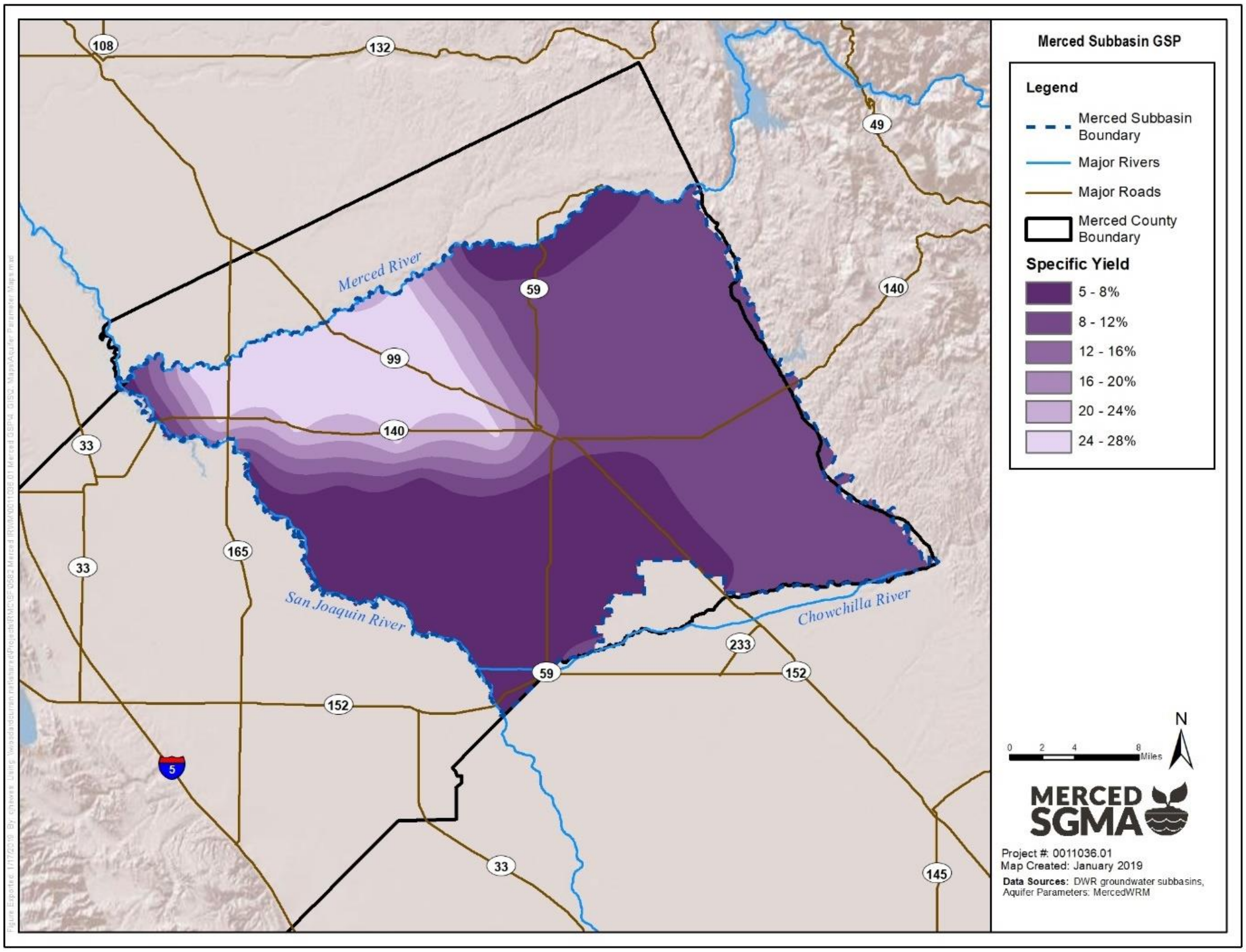


Figure 2-34: Specific Storage (all aquifer layers)



(Note that Specific Storage is a dimensionless (unitless) quantity)

Figure 2-35: Specific Yield (all aquifer layers)



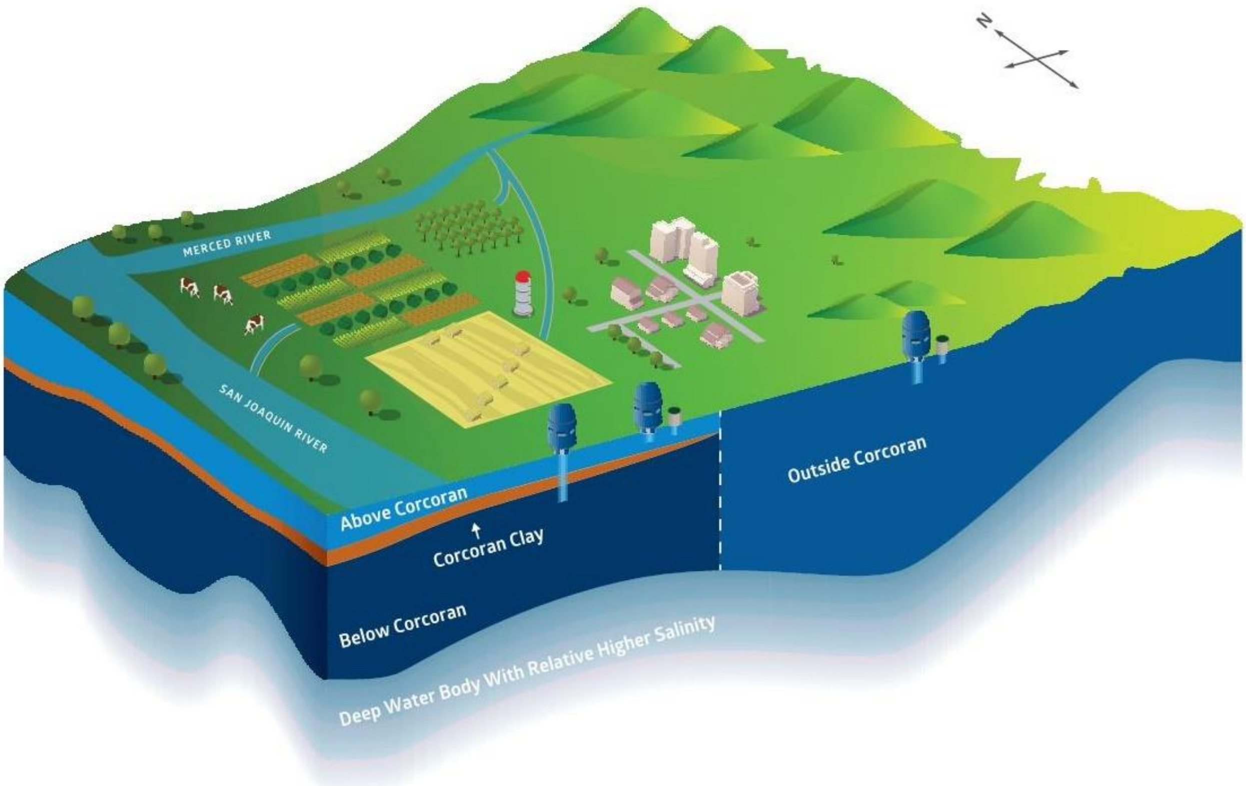
2.1.7.2 Principal Aquifers and Aquitards

The five aquifer systems described in Section 2.1.7.1 interact with each other throughout the basin, except where the Corcoran Clay exists. The three principal aquifers in the Merced Subbasin and their associated characteristics are described below by referencing the specific formations defined earlier. Included in the sections below is a description of general water quality characteristics for the principal aquifers based primarily on the work of Page & Balding (1973). Specific constituents of concern with values and spatial distributions (where applicable) are described later in Section 2.2.4 – Groundwater Quality under Section 2.2 – Current and Historical Groundwater Conditions. Table 2-8 provides a summary of key characteristics of the principal aquifers. Figure 2-36 shows a three-dimensional illustration of the three principal aquifers and the Corcoran Clay aquitard.

Table 2-8: Summary of Characteristics of Principal Aquifers

Parameter	Above Corcoran Principal Aquifer	Below Corcoran Principal Aquifer	Outside Corcoran Principal Aquifer
Aquifer System Names	Intermediate Leaky-Aquifer Shallow Unconfined Aquifer (within Corcoran Clay lateral extent)	Mehrten Formation Confined Aquifer (within Corcoran Clay lateral extent)	Fractured Bedrock Mehrten Formation Intermediate Leaky-Aquifer Shallow Unconfined Aquifer (outside of Corcoran Clay lateral extent)
Geologic Formation Names	Older Alluvium Flood-basin deposits Younger Alluvium (within Corcoran Clay lateral extent)	Valley Springs Formation Mehrten Formation Older Alluvium (within Corcoran Clay lateral extent)	Valley Springs Formation Mehrten Formation Older Alluvium Younger Alluvium (outside of Corcoran Clay lateral extent)
Vertical Extent	From the groundwater surface elevation to top of Corcoran Clay	From bottom of Corcoran Clay to base of Fresh Water	From the groundwater surface elevation to base of fresh water
Lateral Extent	Located within the lateral boundary of the Corcoran Clay	Located within the lateral boundary of the Corcoran Clay	Located outside the lateral boundary of the Corcoran Clay
Hydraulic Conductivity	Defined in Figure 2-32Figure 2-32 and Figure 2-33	Defined in Figure 2-29, Figure 2-30, and Figure 2-31	Defined in Figure 2-29, Figure 2-32, and Figure 2-33
Specific Storage & Specific Yield	Defined in Figure 2-34 and Figure 2-35		
Properties that Restrict Groundwater Flow	Corcoran Clay aquitard (below)	Corcoran Clay aquitard (above)	-
General Water Quality	Changes east to west from a calcium bicarbonate type to a calcium sodium or calcium magnesium bicarbonate type to a sodium bicarbonate type. Hardness is moderately hard to hard to very hard	Mostly a sodium or calcium bicarbonate type with hardness ranging from soft to very hard	Changes east to west from a calcium bicarbonate type to a calcium sodium or calcium magnesium bicarbonate type to a sodium bicarbonate type. Hardness is moderately hard to hard to very hard
Primary Uses	Domestic & Irrigation	Irrigation with some Domestic & Municipal	Irrigation, Domestic, & Municipal

Figure 2-36: 3D Illustration of Merced Subbasin Principal Aquifers and Aquitard



The **Above Corcoran Principal Aquifer** includes all aquifers that exist above the Corcoran Clay Aquitard, namely the Intermediate Leaky-Aquifer (where it overlies the Corcoran Clay) and the Shallow Unconfined Aquifer, both described above. This excludes areas that are located east of the extent of the Corcoran Clay. The related geologic formations are the Older Alluvium, Flood-plain deposits, and Younger Alluvium. While the flood-basin deposits have small hydraulic conductivities and small yields, the Older and Younger Alluvium deposits have moderate to large hydraulic conductivities and yields. Major uses of water in the Above Corcoran Principal Aquifer include domestic and irrigation uses.

The general chemical composition of groundwater in the unconfined aquifers (including both the Above Corcoran Clay and Outside of Corcoran Clay Principal Aquifers) changes spatially across the basin; moving downgradient from east to west, the water quality generally changes from a calcium bicarbonate type to a calcium sodium or calcium magnesium bicarbonate type to a sodium bicarbonate type. In terms of hardness, groundwater was generally moderately hard (61-120 mg/L) east of Highway 99 and hard to very hard (121-180 or >180 mg/L) west of Highway 99 (Page & Balding, 1973).

The **Corcoran Clay Principal Aquitard** is a member of the Pleistocene Tulare Formation. It is a laterally extensive reduced (blue/grey) silt and clay that underlies about 437 square miles in the southwest portion of the Merced Subbasin. The Corcoran Clay is a significant confining layer up to 60 feet thick (Page & Balding, 1973). Numerous silt and clay beds occur above and below the Corcoran Clay, but they could not be correlated over large areas and are therefore only of local importance to the confinement of groundwater (Page & Balding, 1973). The depth (and lateral extent) of the Corcoran Clay is shown on Figure 2-37. Thickness of the Corcoran Clay is shown on Figure 2-38.

The **Below Corcoran Principal Aquifer** includes all aquifers that exist below the Corcoran Clay Aquitard, namely the Confined Aquifer and any portion of the Mehrten Formation or Fractured Bedrock system that underlies the Corcoran Clay, described above. The related geologic formations are the Older Alluvium, Mehrten Formation, and Valley Springs Formation. The Valley Springs Formation has a low water-bearing character (small hydraulic conductivity), while the Mehrten Formation has small to moderate hydraulic conductivity. The Older Alluvium has a moderate to large hydraulic conductivity and yield. Major uses of water in the Below Corcoran Principal Aquifer include irrigation as well as some domestic and municipal use.

Water quality of the Below Corcoran Clay Principal Aquifer is mostly a sodium or calcium bicarbonate type. In terms of hardness, groundwater was found to range from soft (>60 mg/L) to very hard (>180 mg/L) (Page & Balding, 1973).

The **Outside Corcoran Principal Aquifer** includes all aquifers that exist outside of the eastern lateral extent of the Corcoran Clay, namely portions of the Mehrten Formation, Fractured Bedrock, Intermediate Leaky-Aquifer, and Shallow Unconfined Aquifer. This aquifer is connected laterally with the Above Corcoran Principal Aquifer at shallower depths and the Below Corcoran Principal Aquifer at deeper depths. Related geologic formations include all of the geologic formations described above in the Above and Below Corcoran Principal Aquifers with the exception of the flood-plain deposits. Major uses of water in the Outside Corcoran Principal Aquifer include irrigation, domestic, and municipal use.

General water quality of the Outside of Corcoran Clay Principal Aquifer is described several paragraphs above under the section for Above Corcoran Clay where the literature refers to both the Principal Aquifers together as the "unconfined aquifers". In general, groundwater salinity is lowest in the easterly portion of the Subbasin. Salinity increases westward toward the San Joaquin River and southward toward the Chowchilla River. A small area of predominantly sodium-chloride type water has been identified near the confluence of the Merced and San Joaquin Rivers.

Data gaps and uncertainties related to the principal aquifers are primarily related to water quality and to the extent to which the Corcoran Clay reduces the vertical flow of water. Both the depth below ground and thickness of the clay varies throughout the basin (Figure 2-37 and Figure 2-38), and there are areas where the clay may be thin or not present. Additionally, the presence of numerous wells that penetrate the Corcoran Clay provides conduits for flow. Some of these wells are screened above and below the Corcoran Clay, although this practice is not currently allowed by Merced County Code, greatly increasing opportunities for vertical flow when pumps are not operating. With regards to water quality, there is limited depth-specific water quality data for the basin. The most recent, comprehensive study on general water quality types in the Subbasin dates from the 1970s and should be updated in the future with more recent, depth-specific water quality measurements.

Figure 2-37: Corcoran Clay Depth Below Ground Surface

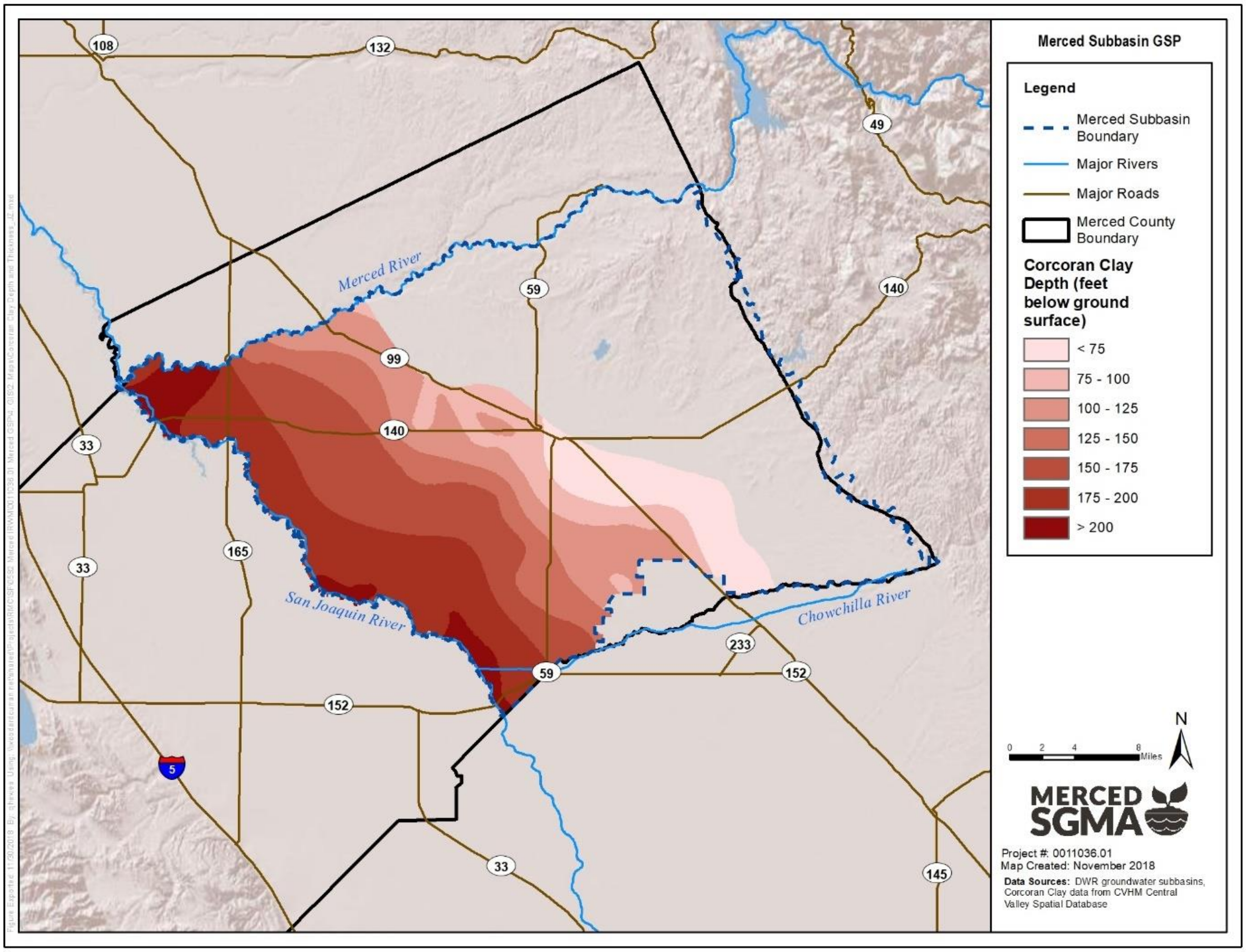


Figure 2-38: Corcoran Clay Thickness

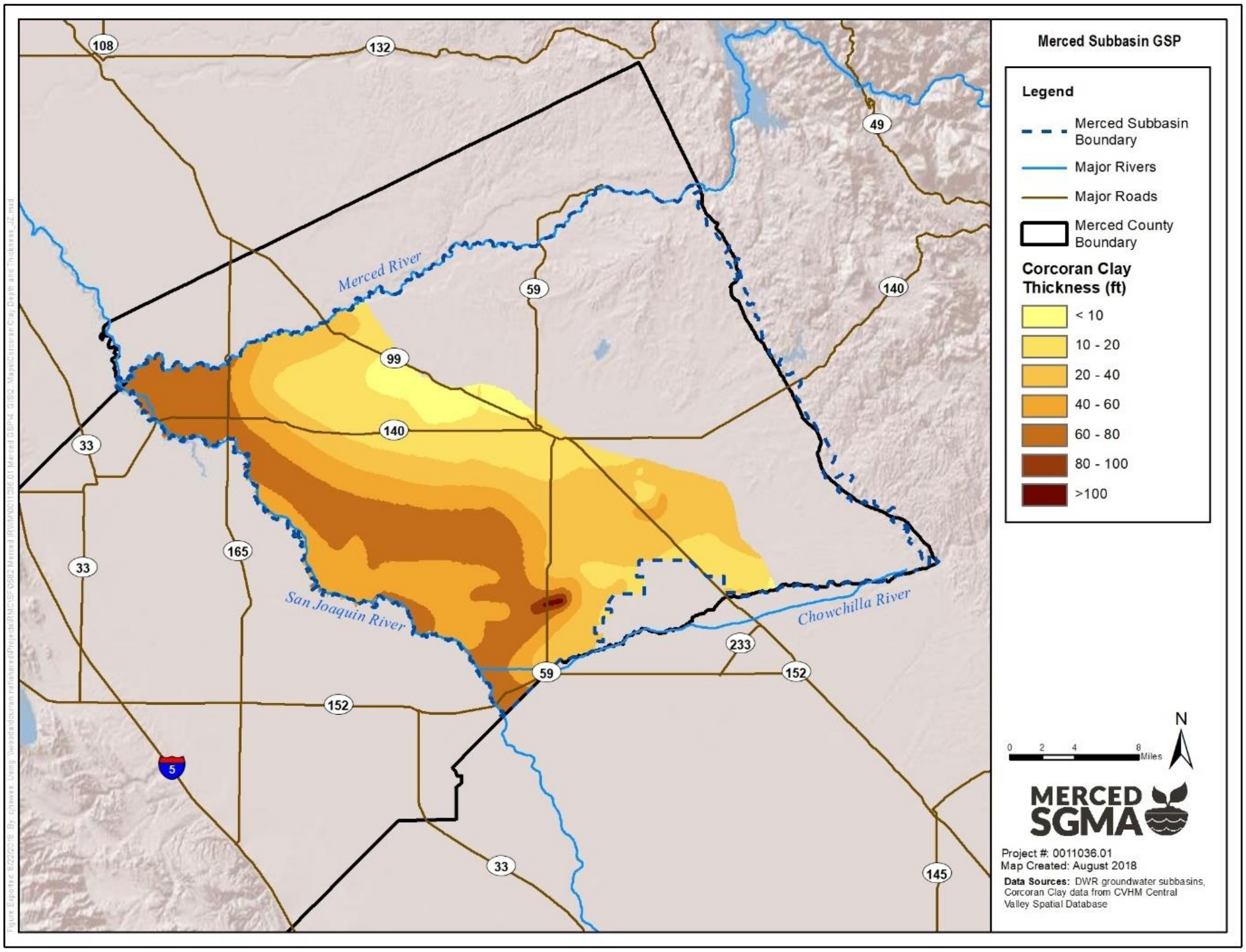
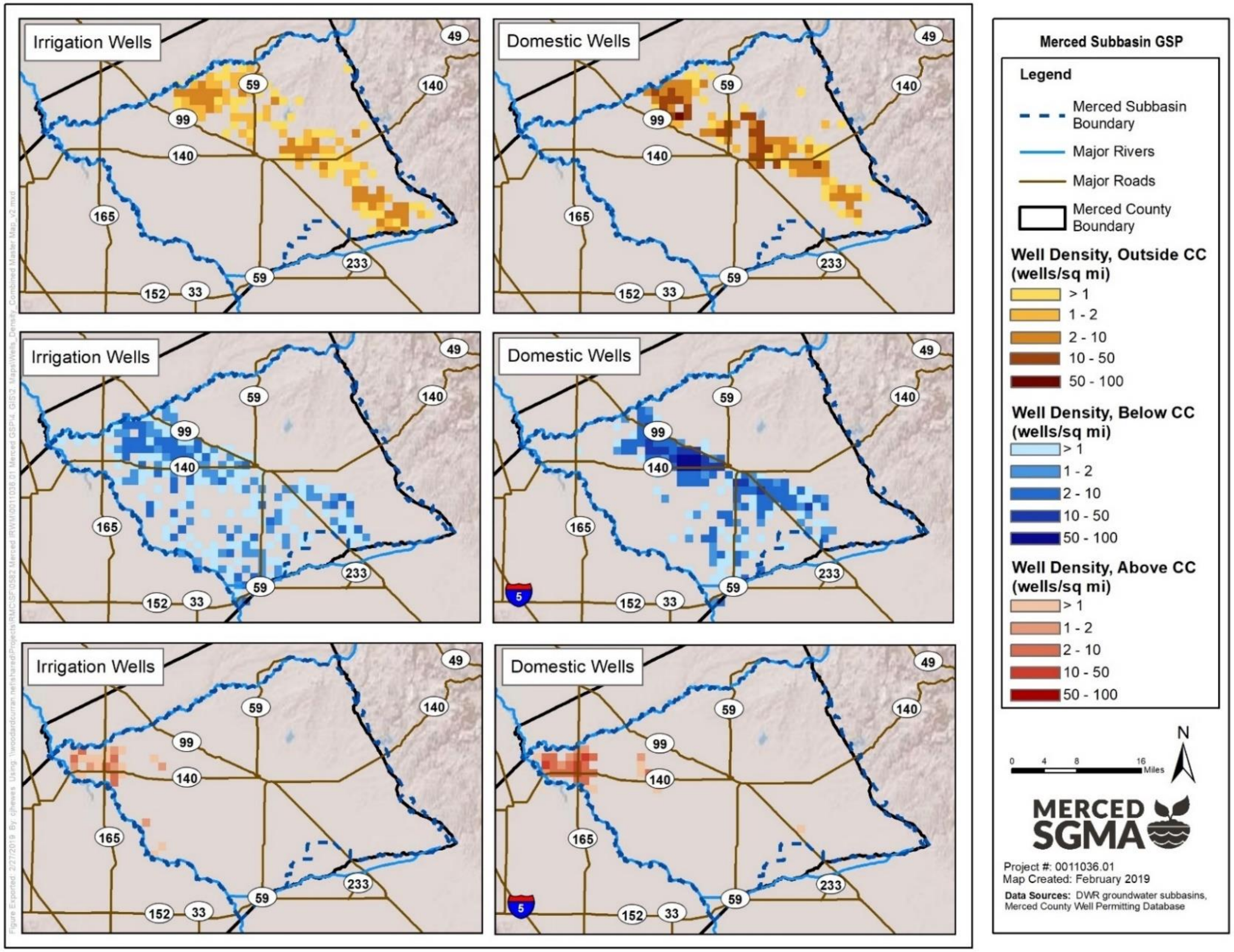


Figure 2-39 contains a series of maps showing the density per square mile of irrigation and domestic wells per principal aquifer. These wells were mapped based on the Merced County Well Permitting Database which contains a record of domestic and irrigation wells permitted from the early to mid-1990s through present. Only wells that were flagged with an “active” status (e.g., not flagged as “inactive” or “destroyed”) were included. It is possible that some of wells with an “active” flag may have been abandoned but the information is not yet reflected in the database. About 9 percent of active wells in the database either did not have a latitude/longitude recorded or could not be matched to a location by parcel number and are thus not included in the density map. About 7 percent of the remaining wells with locations did not have a depth value and were also not included in the density map. As Figure 2-39 shows, within the Corcoran Clay area, there is a greater density and spatial distribution of both domestic and irrigation wells within the Below Corcoran Clay Principal Aquifer than the Above Corcoran Clay Principal Aquifer.

Figure 2-39: Domestic and Non-Domestic/Non-Observation Well Densities by Principal Aquifer



2.1.8 HCM Data Gaps

All hydrogeologic conceptual models contain a certain amount of uncertainty and can be improved with additional data and analysis. The Merced Subbasin HCM data gaps are present in the understanding of the HCM presented in this GSP. These data gaps will be revised after further research and data gathering for future GSP updates:

- Water quality of principal aquifers
  - Lack of depth-specific water quality data makes it difficult to spatially characterize the water quality in the aquifer.
  - Additional monitoring at various depths that cover all three Principal Aquifers for different constituents will help inform the understanding of water quality. This can be achieved through installation of new monitoring wells or through determination of screened intervals of existing monitoring wells.
- Aquifer Characteristics
  - Aquifer characteristics (such as hydraulic conductivity) have a significant impact on how projects and management action in one part of the basin may influence sustainability in other parts of the basin. Aquifer characteristics should be confirmed through additional aquifer testing or additional monitoring wells.

2.1.9 HCM Data Recommendations

While not necessarily data gaps, the item below is a recommendation for improving or updating existing information:

- Supplement the Page & Balding (1973) and Page (1977) cross-sections with more recent data. While the MercedWRM uses these cross sections as well as more recent supplemental information from the USGS texture model, incorporation of more recent work (e.g., work by K. Schmidt) could be used to provide additional information for updating cross sections in the future.

2.2 CURRENT AND HISTORICAL GROUNDWATER CONDITIONS

This section describes the current and historical groundwater conditions in the Merced Subbasin. As defined by the GSP regulations by DWR, the Groundwater Conditions section is intended to:

- Define current groundwater conditions in the Subbasin
- Describe historical groundwater conditions in the Subbasin
- Describe the distribution, availability, and quality of groundwater
- Identify interactions between groundwater, surface water, groundwater dependent ecosystems, and subsidence
- Establish a baseline of quality and quantity conditions that will be used to monitor changes in the groundwater conditions relative to measurable objectives and minimum thresholds
- Inform development of measurable objectives to maintain or improve specified groundwater conditions

- Support monitoring to demonstrate that the GSP is achieving sustainability goals of the Subbasin

The groundwater conditions described in this section are intended to convey the present and historical availability, quality, and distribution of groundwater. These conditions are used elsewhere in the GSP to identify sustainability indicators, establish undesirable results, and define measurable objectives.

2.2.1 Groundwater Elevation

2.2.1.1 Historical Groundwater Elevations

To visually show long-term trends in groundwater elevations in the Merced Subbasin, 13 wells with long periods of record and that are relatively evenly distributed across the Subbasin were selected from the larger available dataset (see Figure 2-40). Across all three Principal Aquifers, this includes four wells screened above the Corcoran Clay, five wells screened from below the Corcoran Clay, and four wells located outside the extent of the Corcoran Clay. Long-term hydrographs prepared for these wells show that, throughout most of the Merced Subbasin, groundwater elevations are declining with time (see Figure 2-40).

Average groundwater level decline per Principal Aquifer was quantified for 1996-2015. In Section 2.3 –Water Budget Information, the Historical Water Budget uses 1996-2015 as a representative hydrologic period which includes an average annual precipitation of 11.6 inches, nearly the same as the long-term average of 12.2 inches. The 1996-2015 period also includes the recent 2012-2015 drought, the wet years of 1996-1998, and periods of normal precipitation. This was calculated using all California Statewide Groundwater Elevation Monitoring Program (CASGEM) and Voluntary wells with groundwater level data available for 1996-2015 (totaling 51 wells).

Based on data from 11 wells in the Above Corcoran Clay Principal Aquifer, average groundwater level decline was 1.3 ft/yr from 1996-2015. Based on data from 15 wells in the Below Corcoran Clay Principal Aquifer, average groundwater level decline was 2.4 ft/yr from 1996-2015. Based on data from 25 wells in the Outside Corcoran Clay Principal Aquifer, average groundwater level decline was 1.2 ft/yr from 1996-2015. Note that most of the CASGEM wells for the Outside Corcoran Clay Principal Aquifer were Voluntary wells that did not report beyond 2012. It is possible that some portion of additional groundwater level decline during the 2012-2015 drought is missing from the overall 1996-2015 average for the Outside Corcoran Clay Principal Aquifer. Voluntary wells provide important long-term historical information about groundwater levels, but since they do not meet the full CASGEM program standards, they are not included in the future monitoring program for this GSP.

Figure 2-40: Hydrographs for Selected Wells in the Merced Subbasin

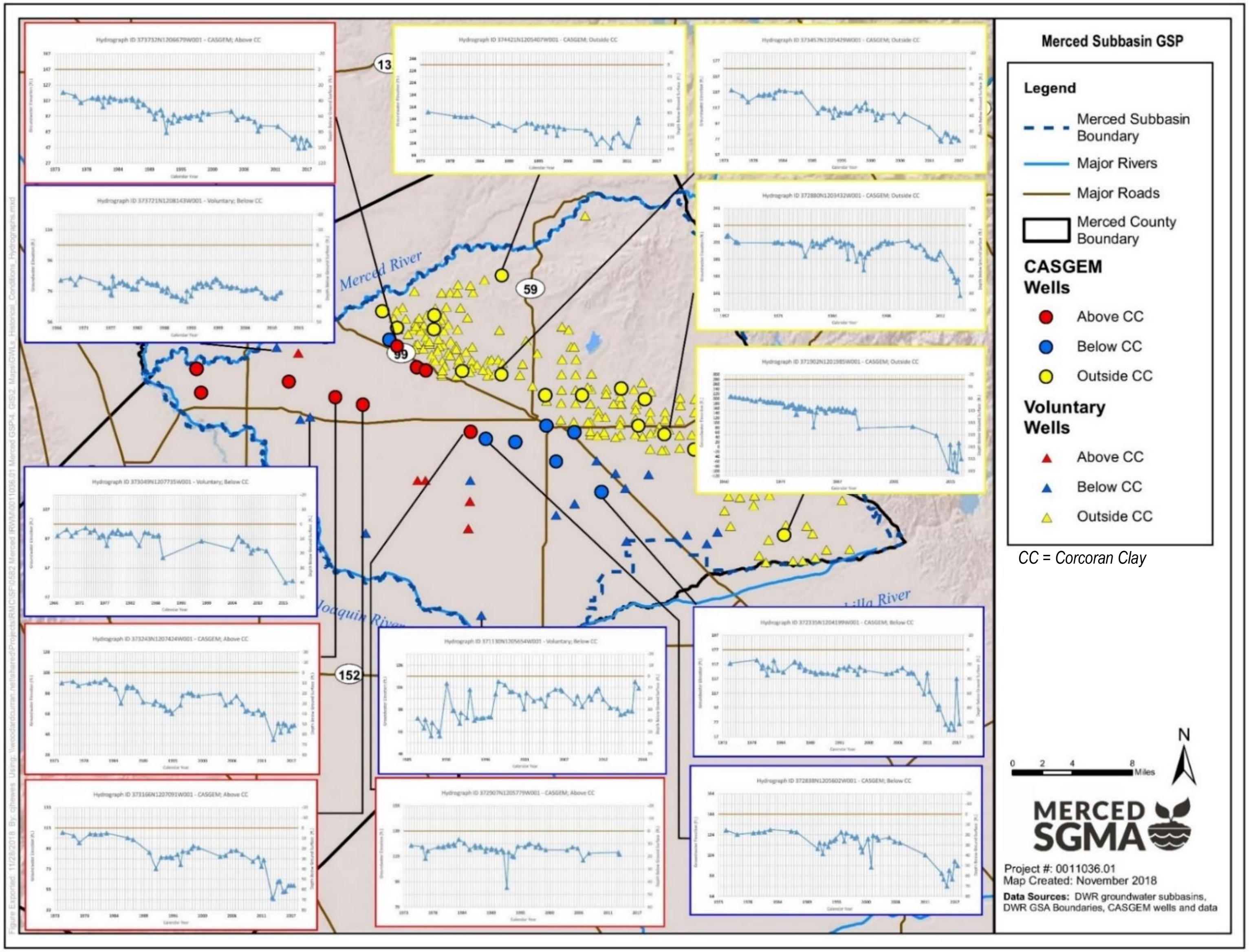


Figure 2-41 through Figure 2-43 show groundwater elevations (in feet above sea level, datum NAVD88) in fall 2014 based on measurements recorded at CASGEM wells, including voluntary wells where data was available. Fall 2014 is the closest season of available CASGEM data to display conditions as of January 1, 2015, representing conditions when SGMA became law. Groundwater elevations are mapped separately for the three principle aquifers: Above, Below, and Outside of the Corcoran Clay.

Figure 2-41: Fall 2014 Groundwater Elevation, Principal Aquifer: Above Corcoran Clay

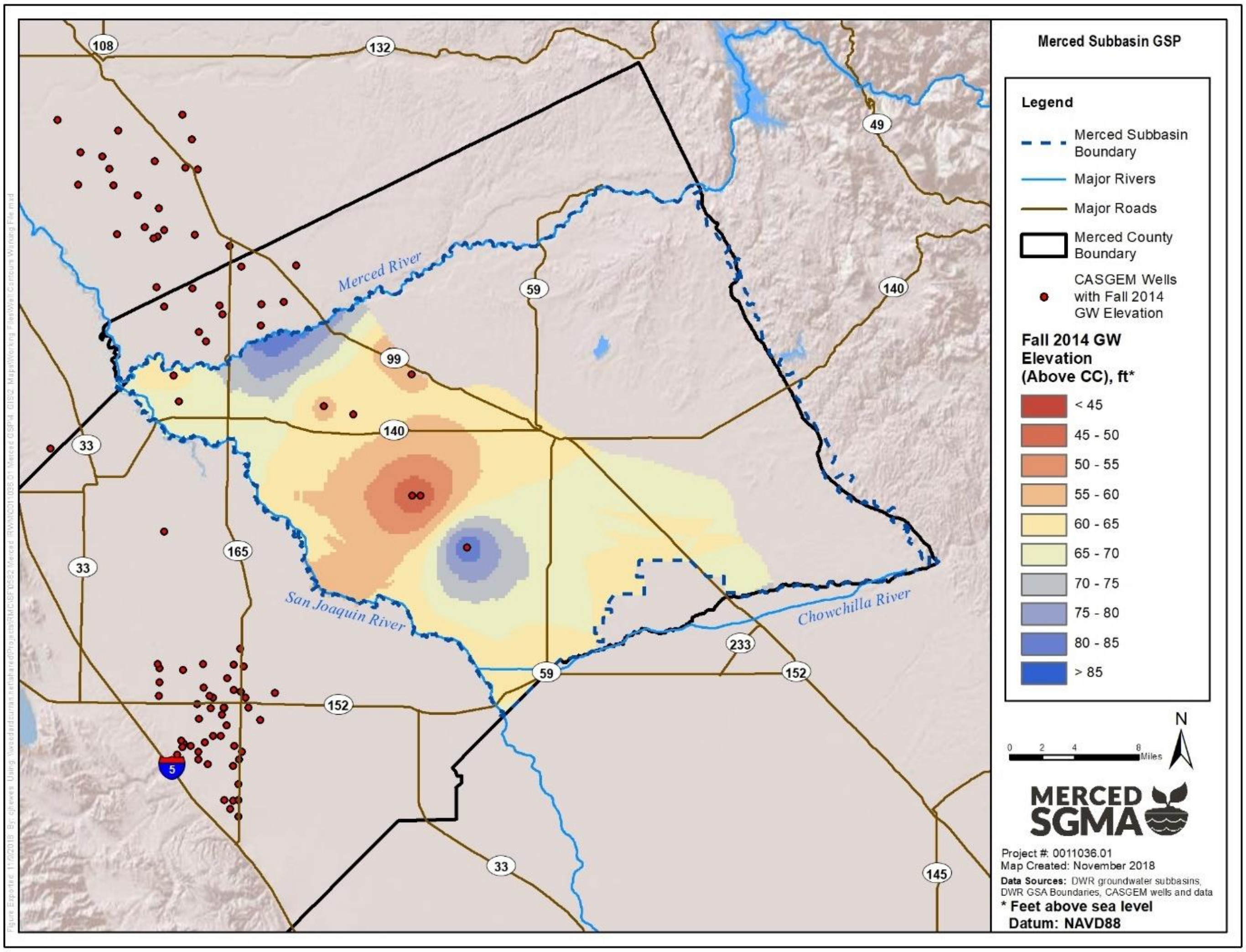


Figure 2-42: Fall 2014 Groundwater Elevation, Principal Aquifer: Below Corcoran Clay

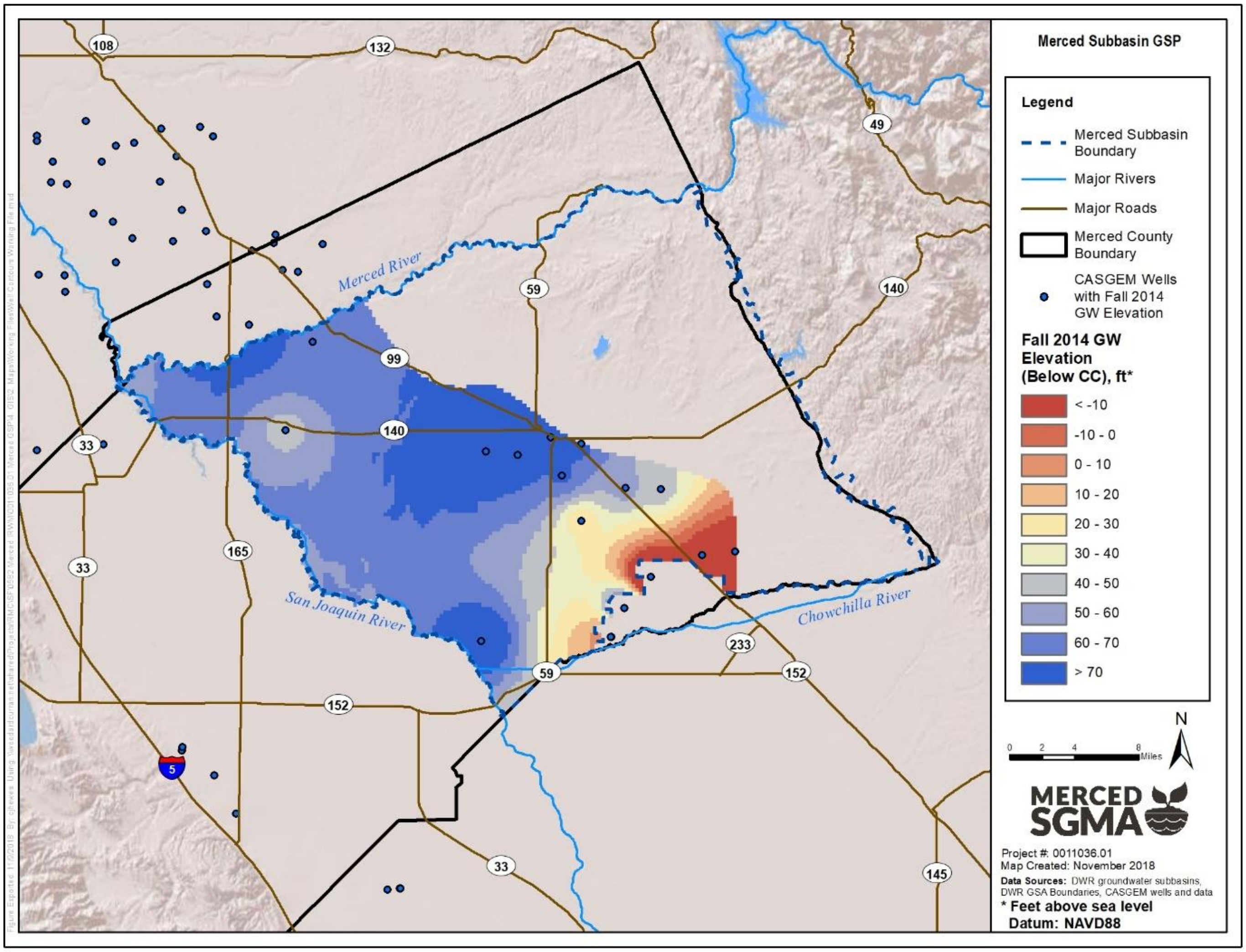
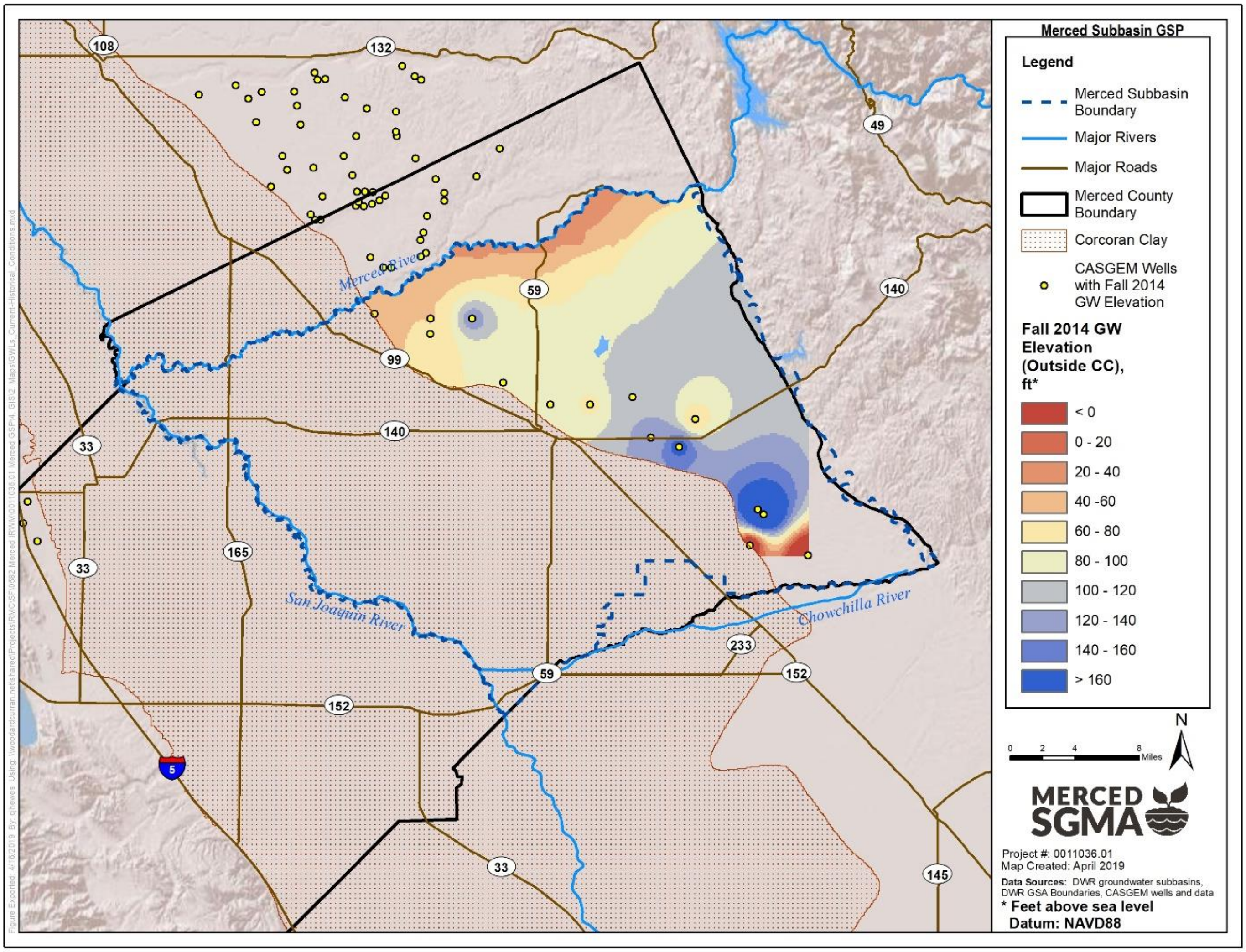


Figure 2-43: Fall 2014 Groundwater Elevation, Principal Aquifer: Outside Corcoran Clay[1]



[1] Groundwater elevations are missing for the southeast corner of the Outside Corcoran Clay Principal Aquifer due to a lack of data in this corner of the Subbasin from Fall 2014.

2.2.1.2 Current Groundwater Conditions

Figure 2-44 through Figure 2-46 show groundwater elevations in spring 2017 (most recent seasonal high), while Figure 2-47 through Figure 2-49 show groundwater elevations in fall 2017 (most recent seasonal low). Groundwater elevations are mapped for California Statewide Groundwater Elevation Monitoring Program (CASGEM) wells (including voluntary wells) separately for the three principle aquifers: Above, Below, and Outside of the Corcoran Clay.

Above the Corcoran Clay, groundwater generally flows northerly from the southern portion of the aquifer boundary and southerly from the northern portion of the aquifer boundary, meeting at a low point in the middle. The lateral gradient is fairly shallow at approximately 4 ft/mi.

Below the Corcoran Clay, groundwater generally flows in an easterly or southeasterly direction towards the Chowchilla Subbasin. The lateral gradient is approximately 7 ft/mi.

Outside of the Corcoran Clay, groundwater generally flows from the center of the aquifer region to the north. There also appears to be localized highs and depressions without a dominant lateral gradient to the southern end of the aquifer region, possibly due to pumping or stream influences. The lateral gradient is approximately 5.2 ft/mi.

Figure 2-44: Spring 2017 Groundwater Elevation, Principal Aquifer: Above Corcoran Clay

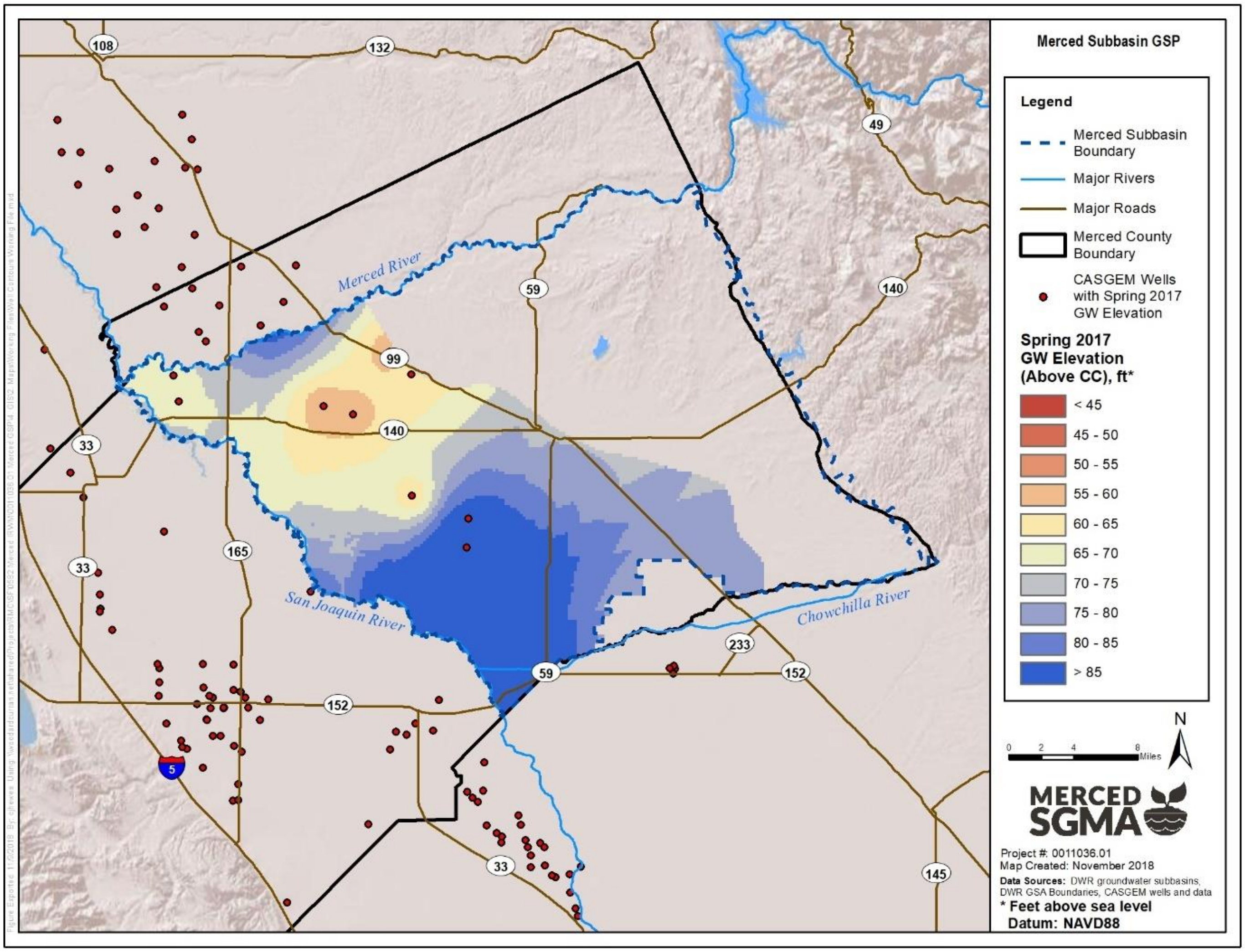


Figure 2-45: Spring 2017 Groundwater Elevation, Principal Aquifer: Below Corcoran Clay

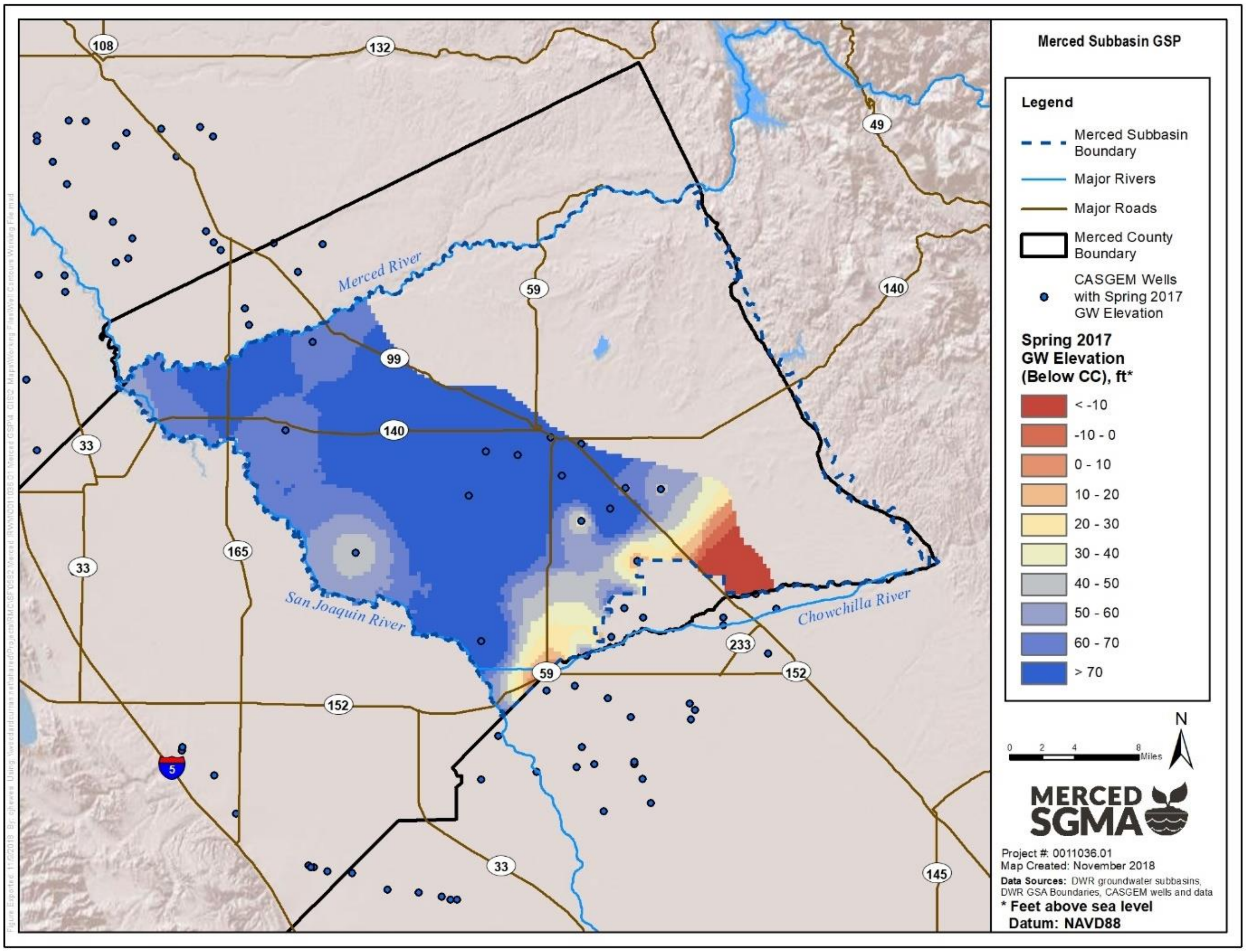


Figure 2-46: Spring 2017 Groundwater Elevation, Principal Aquifer: Outside Corcoran Clay

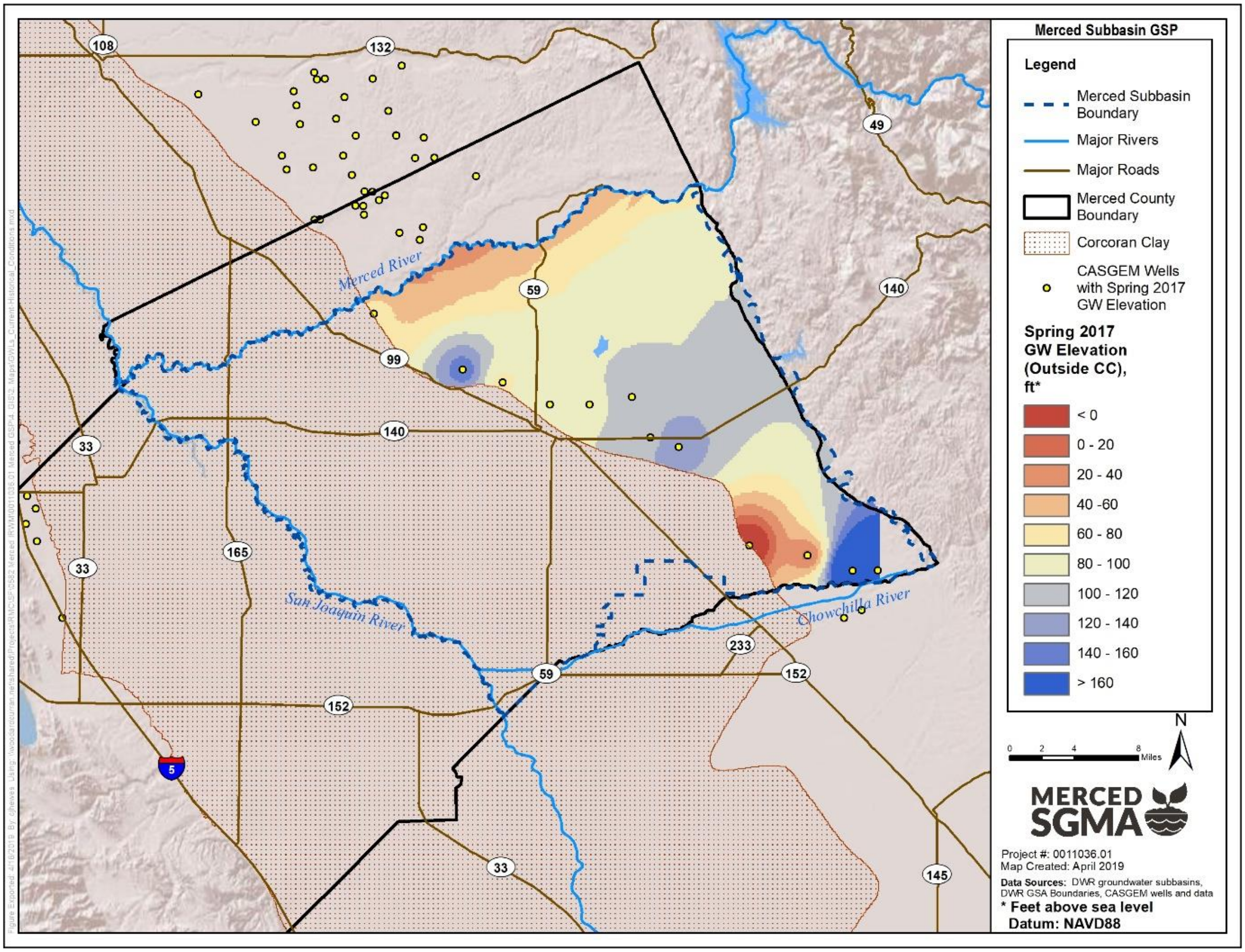


Figure 2-47: Fall 2017 Groundwater Elevation, Principal Aquifer: Above Corcoran Clay

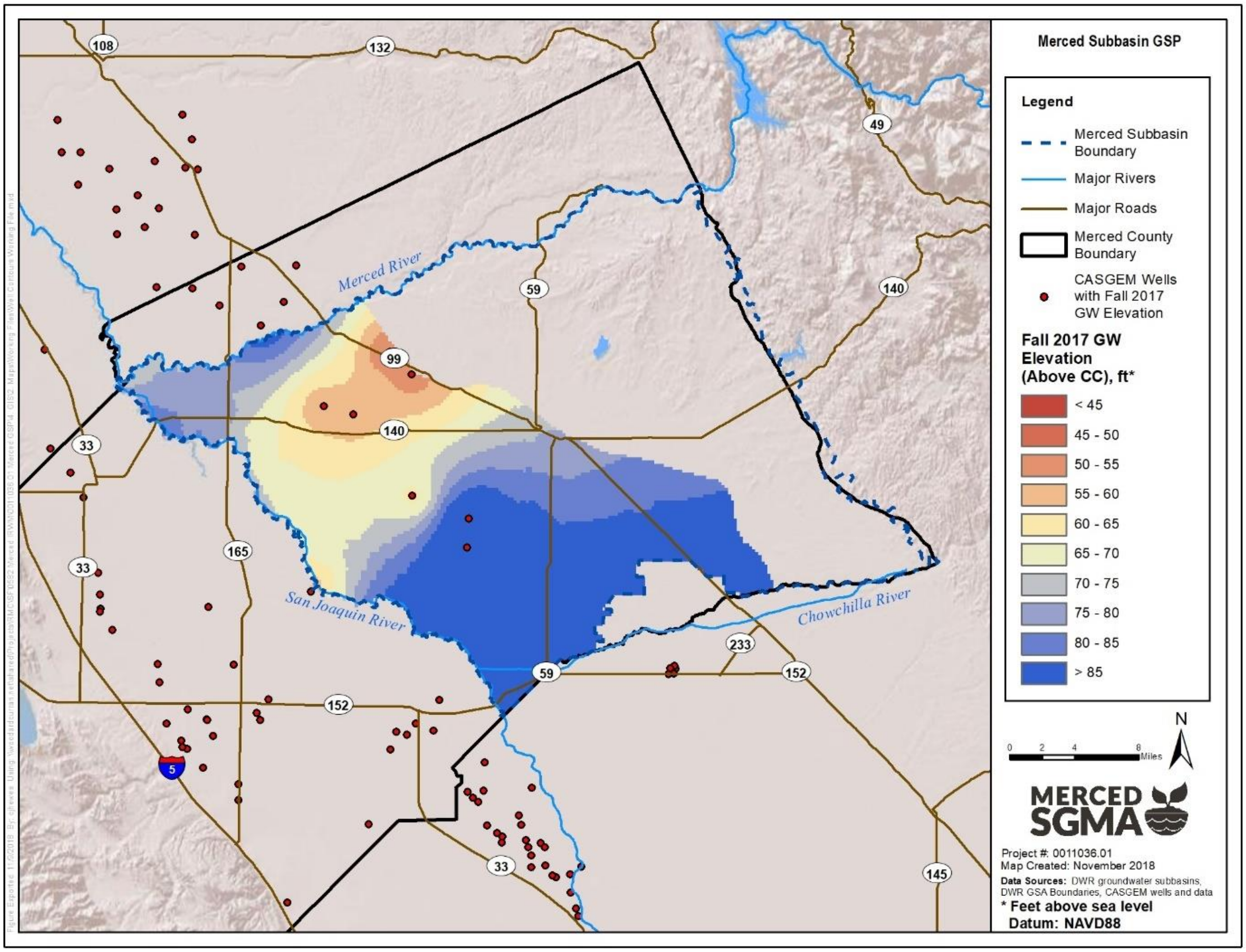


Figure 2-48: Fall 2017 Groundwater Elevation, Principal Aquifer: Below Corcoran Clay

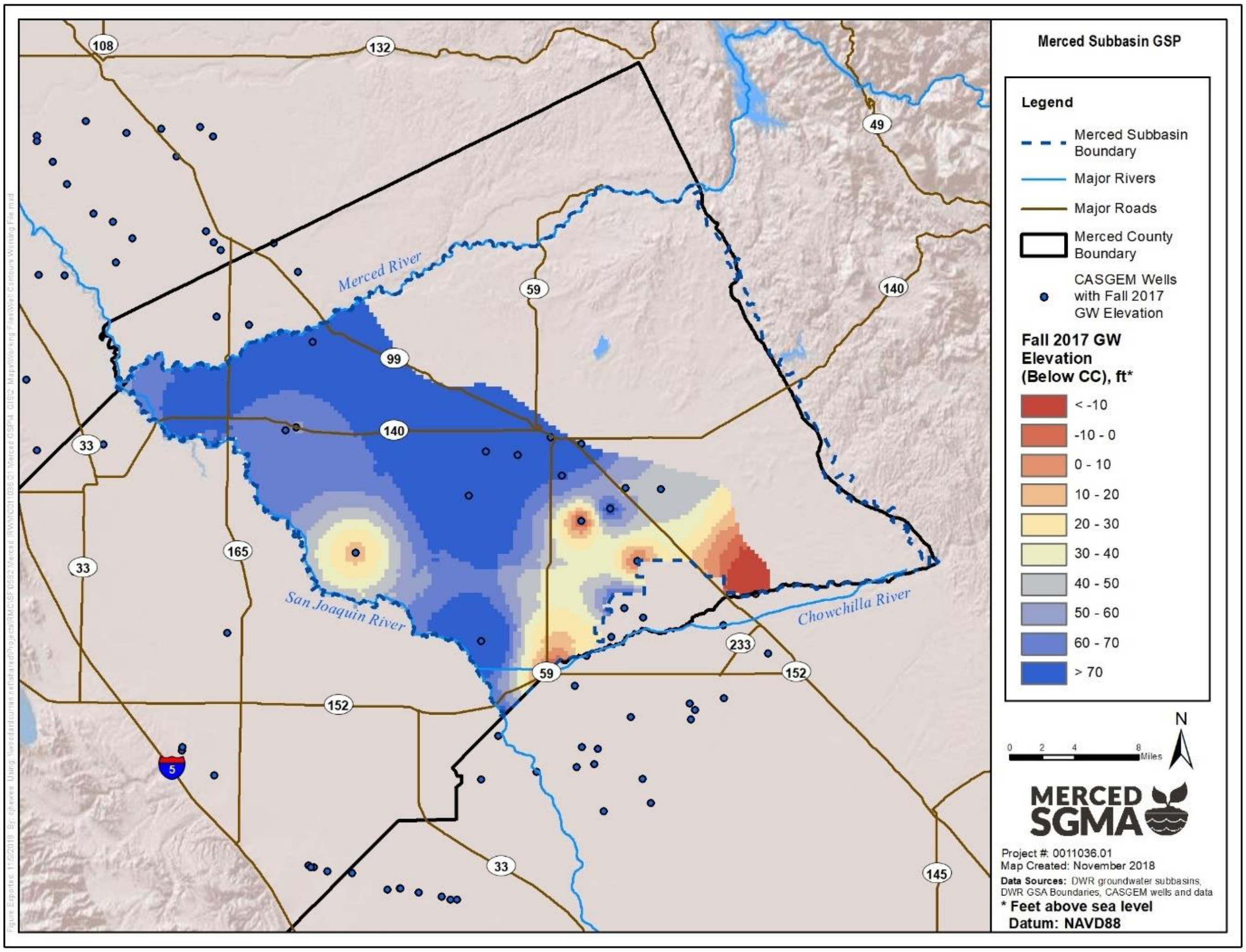
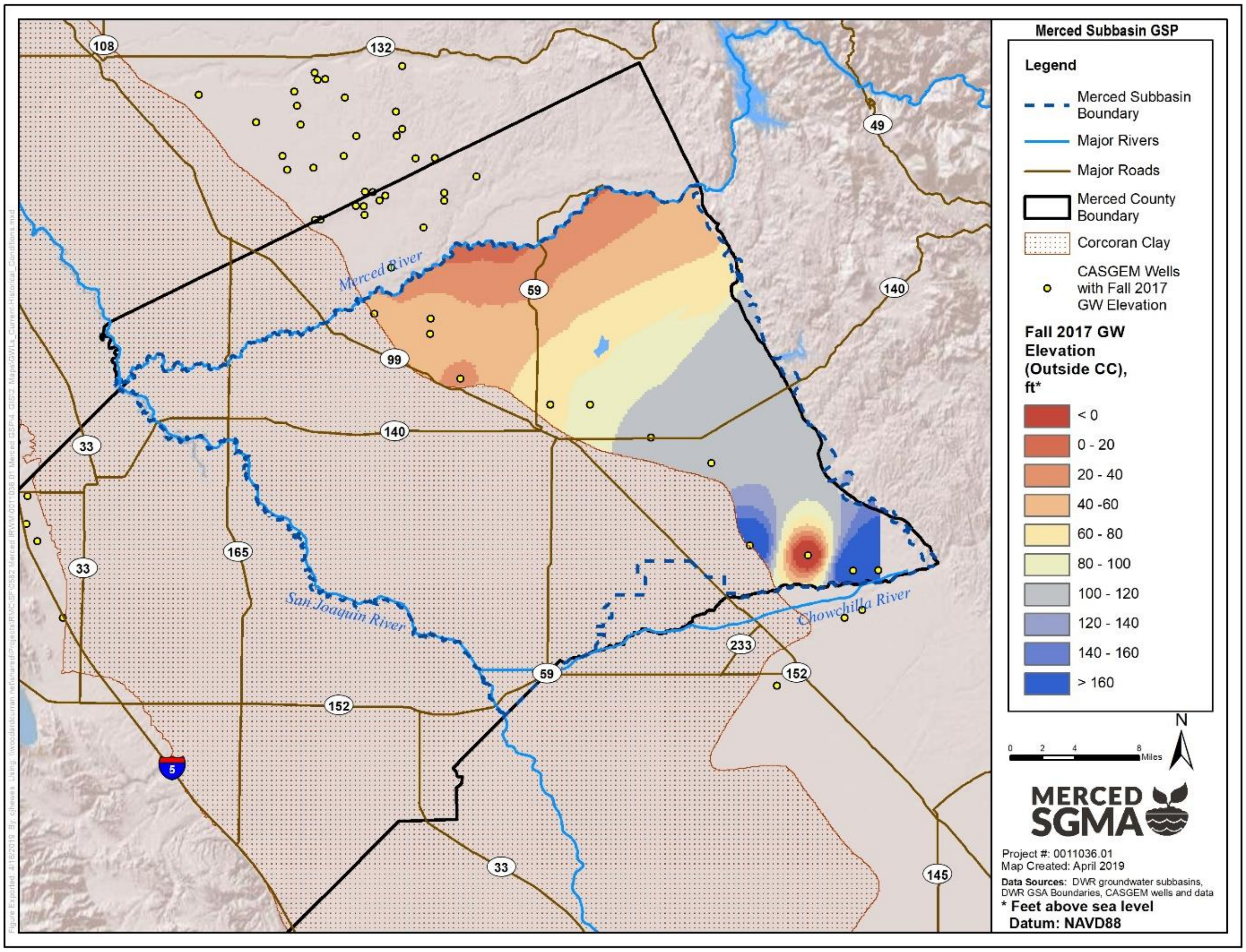


Figure 2-49: Fall 2017 Groundwater Elevation, Principal Aquifer: Outside Corcoran Clay



2.2.1.3 Vertical Gradients

A vertical gradient describes the movement of groundwater perpendicular to the ground surface and is typically measured by comparing the elevations of groundwater in a well with multiple completions that are of different depths. If groundwater piezometric elevations in the shallower completions are higher than in the deeper completions, the gradient is identified as a downward gradient. A downward gradient is one where groundwater is moving downward through the subsurface. If groundwater piezometric elevations in the shallower completions are lower than in the deeper completions, the gradient is identified as an upward gradient. An upward gradient is one where groundwater is moving upward through the subsurface. If groundwater elevations are the same throughout the completions, there is no vertical gradient. Knowledge about vertical gradients is required by regulation and is useful for understanding how groundwater moves in the Subbasin.

There are six multiple completion wells located in the Merced Subbasin, all of which are monitored through the CASGEM program. The locations of the multiple completion wells are shown in Figure 2-50. Hydrographs with groundwater elevations for each respective set of completion wells are shown in Figure 2-51 through Figure 2-54. The four sets of multiple completion wells in the Below and Outside Corcoran Clay Principal Aquifers are owned and operated by the City of Merced primarily for municipal water quality monitoring. There are no known recent studies dedicated to vertical gradients using groundwater elevations recorded at these wells.

One of the two sets of multiple completion wells in the Below Corcoran Clay Principal Aquifer shows an upward gradient (see Figure 2-52). The other shows a slight indication of an upward gradient but is not significant across all screened intervals (see Figure 2-51). These wells are located right at the edge of the extent of the Corcoran Clay where it is most shallow and thin and the level of confinement is not as well understood. The top of the Corcoran Clay is approximately 55 feet below ground surface (bgs) and 15 feet thick (extending to a depth of approximately 70 feet bgs), while the shallowest wells have screened intervals 60-110 feet or 89-170 feet bgs.

One of the two sets of multiple completion wells in the Outside Corcoran Clay Principal Aquifer shows evidence of a downward gradient (see Figure 2-54) which is consistent with previous studies (Elliott, 1984), as referenced by (AMEC, 2008). The other set of wells shows a slight indication of a downward gradient (see Figure 2-53) but is not significant across all screened intervals. Consequently, in the Outside Corcoran Clay, degradation of shallow groundwater can potentially affect deeper water supply wells if downward flow is significant and if dilution and chemical/biological processes are insufficient to adequately reduce the concentrations of constituents of concern (AMEC, 2008).

Both sets of multiple completion wells in the Above Corcoran Clay Principal Aquifer show no strong gradient (see Figure 2-55 and Figure 2-56).

Figure 2-50: CASGEM Multiple Completion Wells

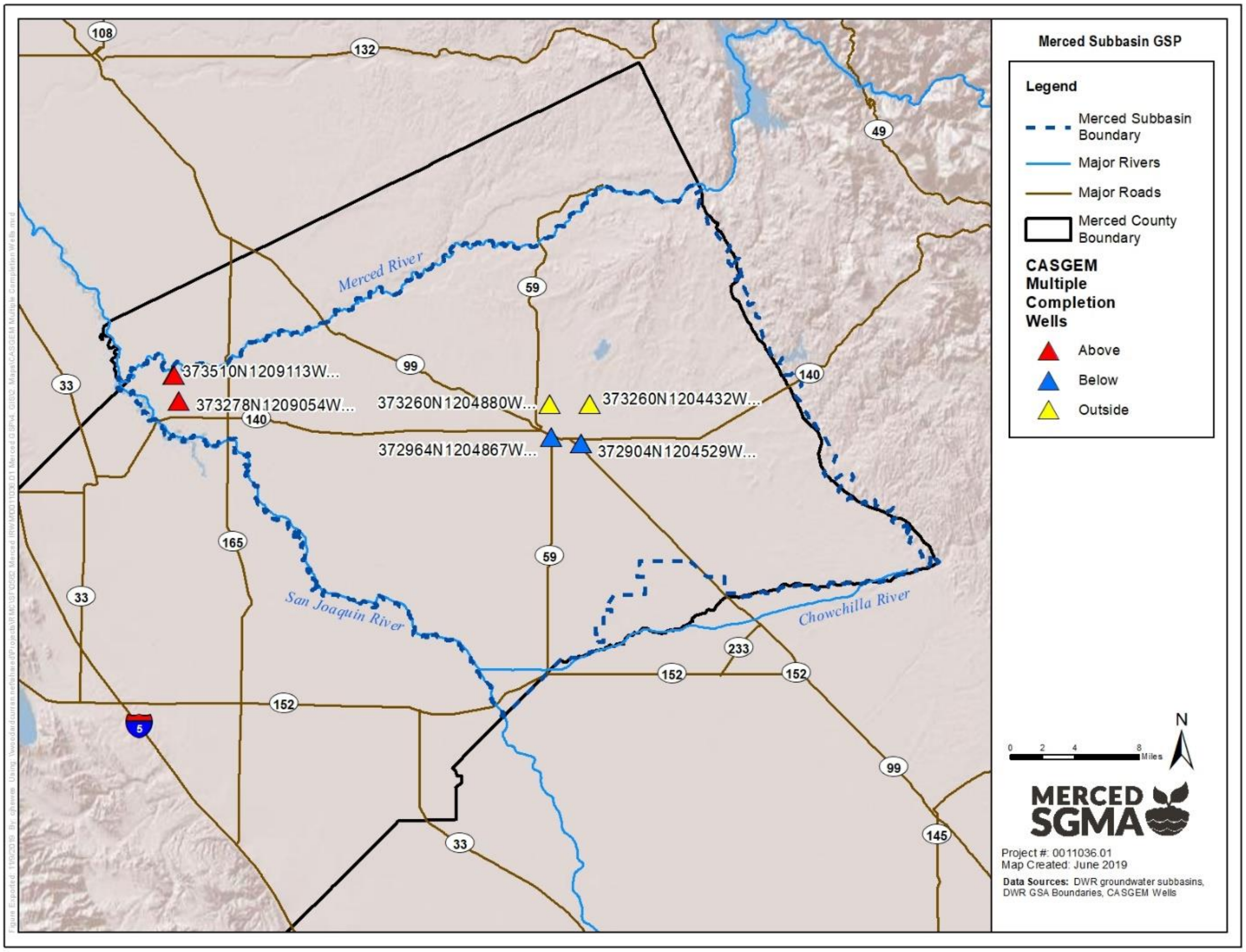


Figure 2-51: Vertical Gradient at Wells with Site Code Beginning 372964N1204867 (Below Corcoran Clay)

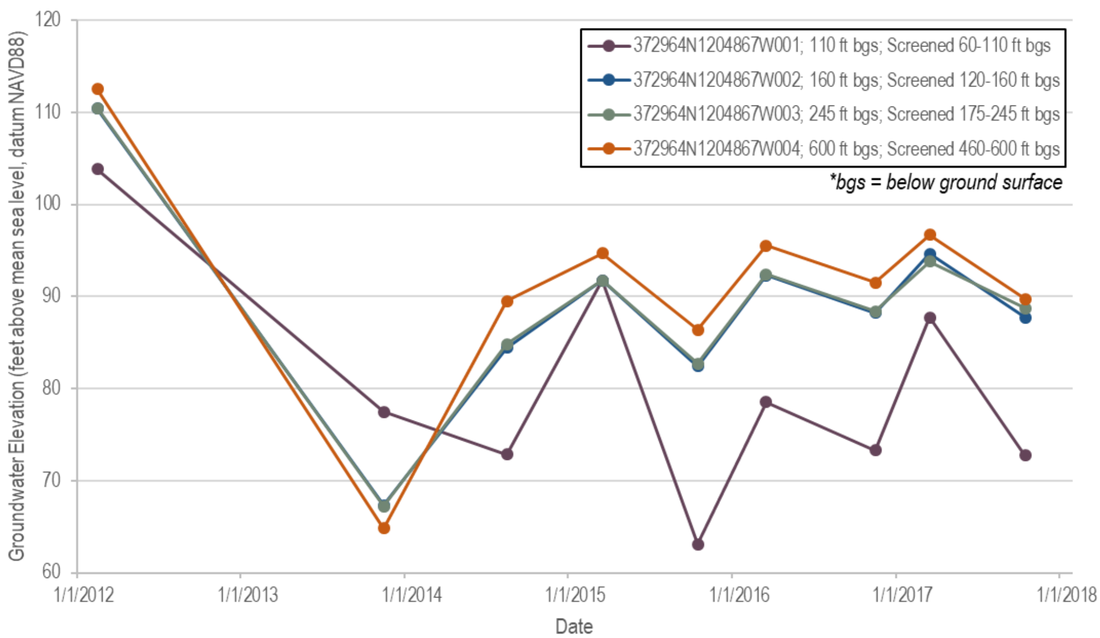


Figure 2-52: Vertical Gradient at Wells with Site Code Beginning 372904N1204207 or 372904N1204529 (Below Corcoran Clay)

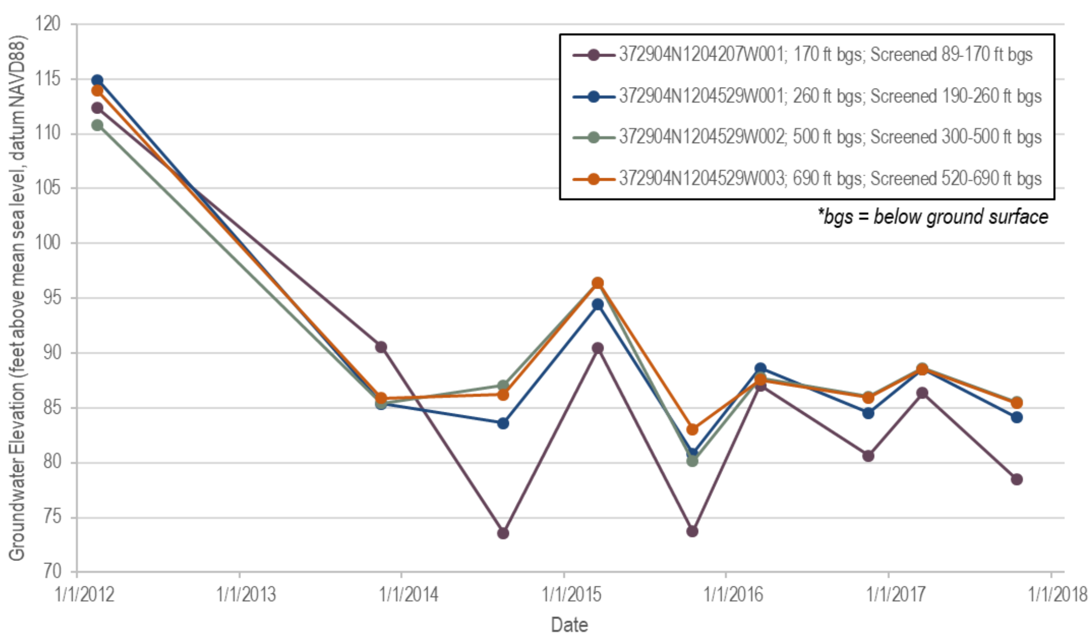


Figure 2-53: Vertical Gradient at Wells with Site Code Beginning 373260N1204432 (Outside Corcoran Clay)

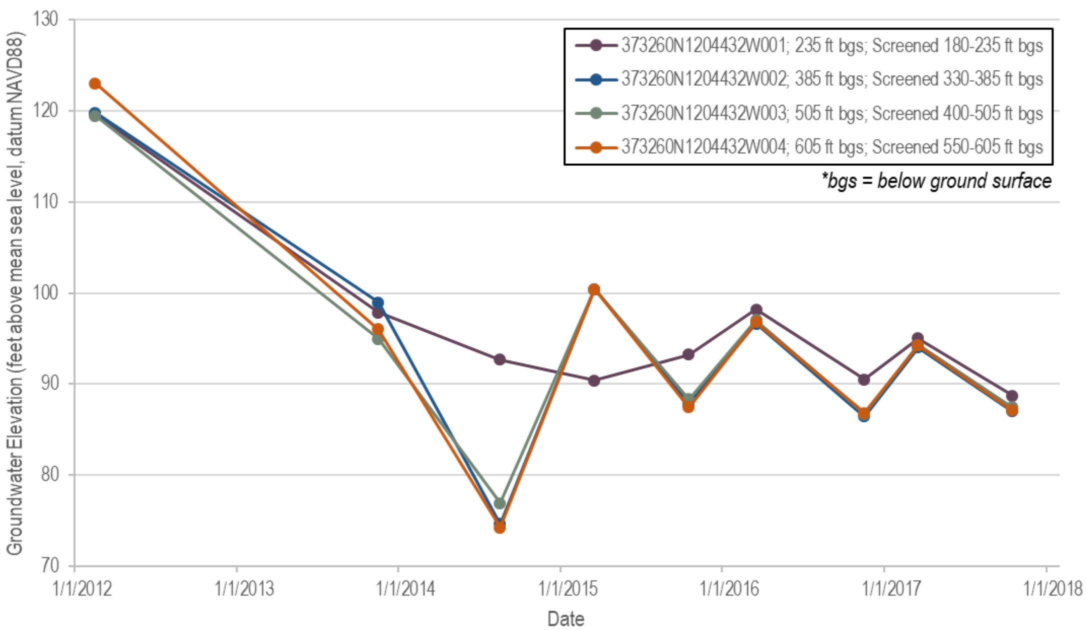


Figure 2-54 Vertical Gradient at Wells with Site Code Beginning 373260N1204880 (Outside Corcoran Clay)

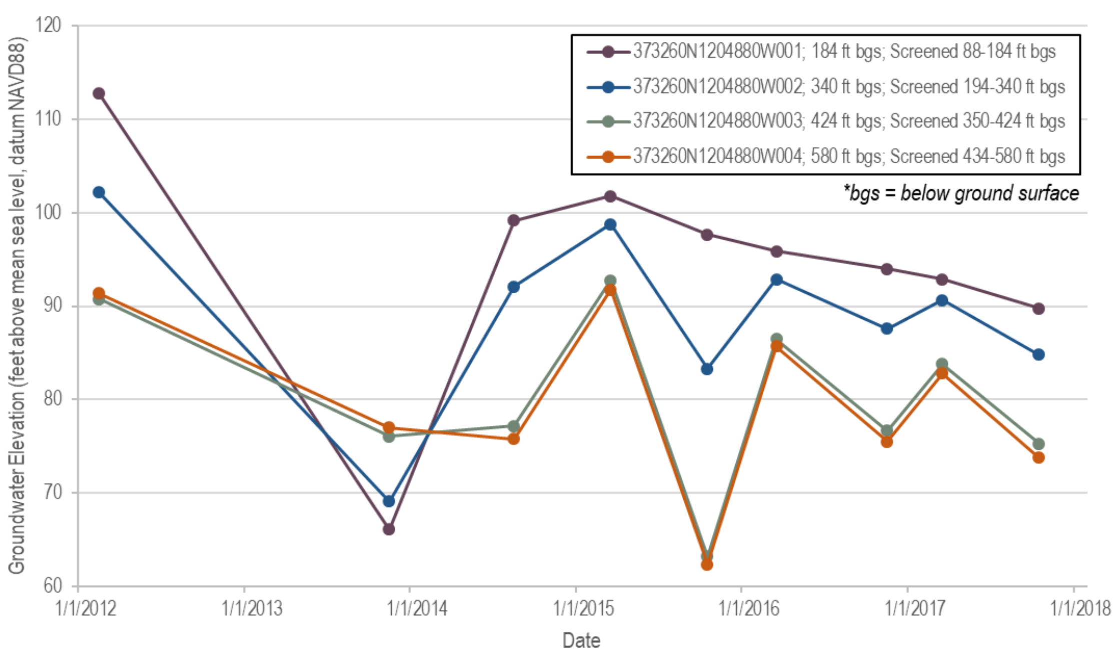
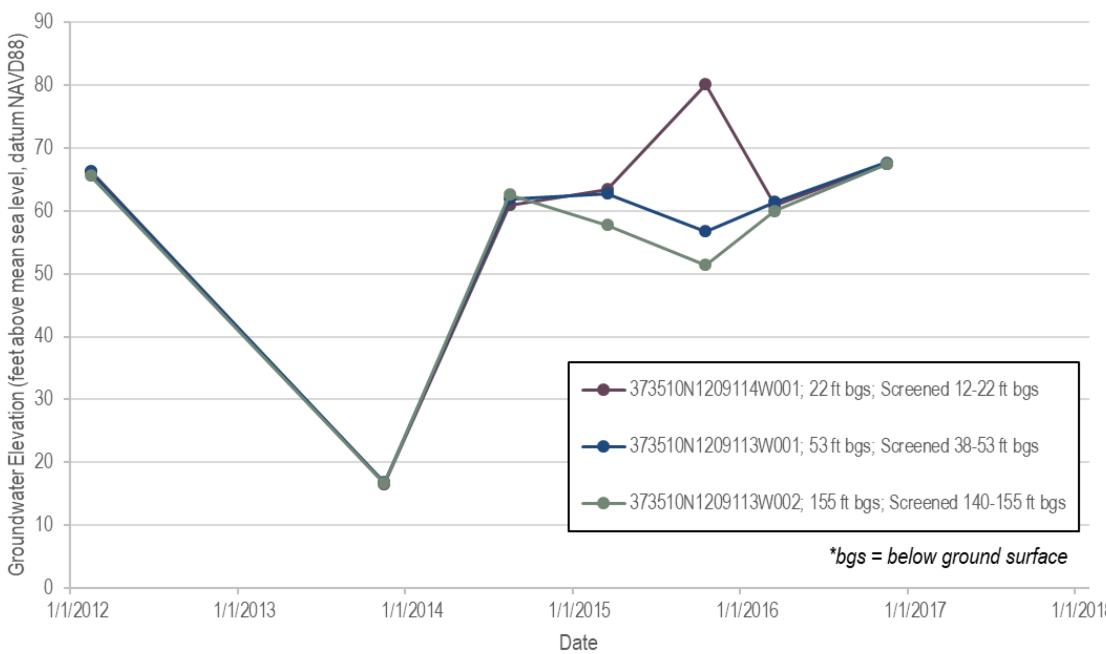


Figure 2-55: Vertical Gradient at Wells with Site Code Beginning 373278N1209054 or 373277N1209054 (Above Corcoran Clay)

Figure 2-56: Vertical Gradient at Wells with Site Code Beginning 373510N1209114 or 373510N1209113 (Above Corcoran Clay)



2.2.2 Groundwater Storage

The MercedWRM was used to estimate historical change in storage of the Merced Subbasin from 1995-2015. Figure 2-57 shows annual total storage for each MercedWRM layer (not including the deep layer of relative higher salinity) as well as the cumulative change in storage. In 2015, the total fresh groundwater storage was estimated as 45.3 million acre-feet (MAF) and the cumulative change in storage from 2006-2015 was estimated as -1.92 MAF, or 192 TAF per year. An additional 72 MAF in Layer 6 of the model (not pictured) is a water body of relatively higher salinity. More information about the layers of the MercedWRM and calculation of storage changes can be found in Appendix D. Figure 2-58 shows the same cumulative change in storage against budgeted groundwater uses and water year type.

Figure 2-57: Historical Modeled Change in Storage by MercedWRM Layer

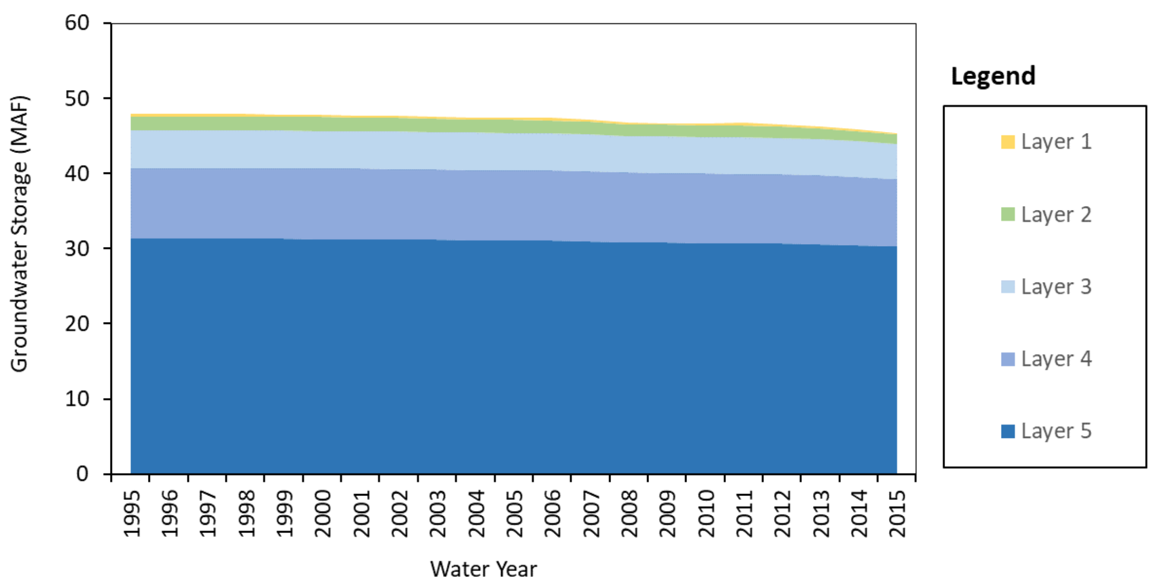
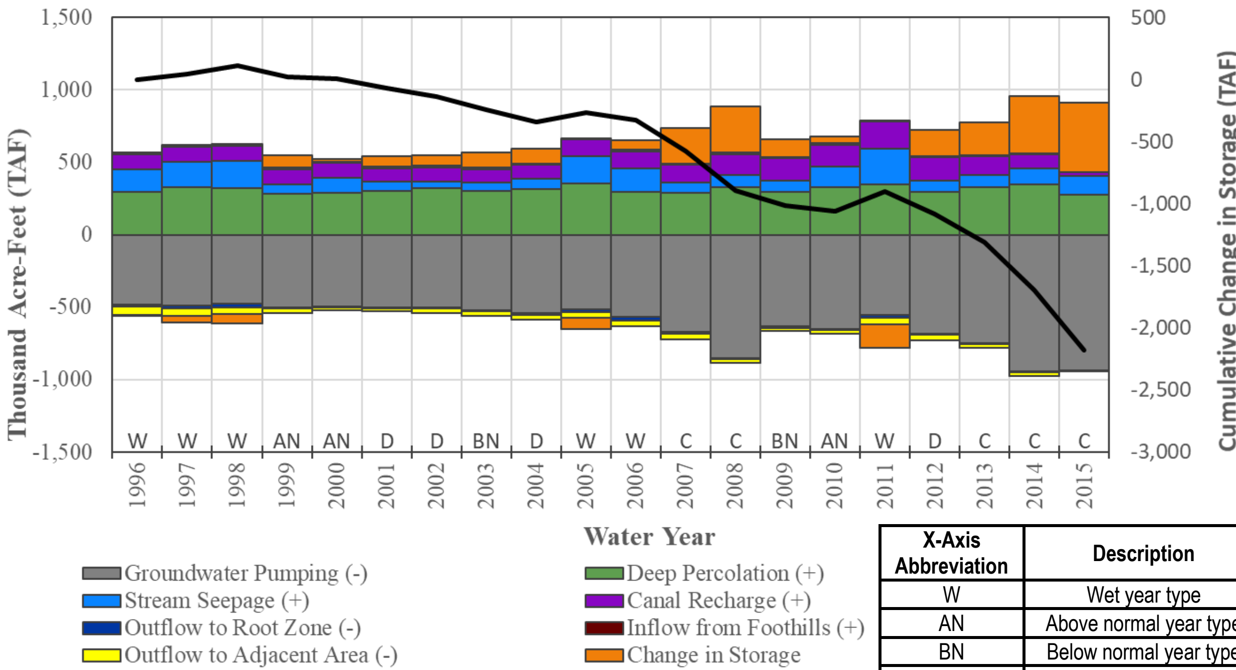


Figure 2-58: Historical Modeled Change in Storage with Groundwater Use and Water Year Type



X-Axis Abbreviation	Description
W	Wet year type
AN	Above normal year type
BN	Below normal year type
D	Dry year type
C	Critical year type

[1] "Change in Storage" is placed on the chart to balance the water budget. For instance, if annual outflows (-) are greater than inflows (+), there is a decrease in storage, and this is shown on the positive side of the bar chart to balance out the increased outflows on the negative side of the bar chart.

Source: Water year types based on San Joaquin Valley Water Year Index (DWR, 2017c)

2.2.3 Seawater Intrusion

Seawater intrusion is not a potential risk in the Merced Subbasin, as the Subbasin is not near any seawater source. However, groundwater quality conditions related to salinity are described in the following section.

2.2.4 Groundwater Quality

Groundwater in the Merced Subbasin contains both anthropogenic and naturally occurring constituents. While groundwater quality is often sufficient to meet beneficial uses, some of these constituents either currently impact groundwater use within the Subbasin or have the potential to impact it in the future. Depending on the water quality constituent, the issue may be widespread or more of a localized concern.

The primary naturally-occurring water quality constituents of concern are arsenic and uranium. There are also aesthetic issues related to iron and manganese.

The primary water quality constituents of concern related to human activity include salinity, nitrate, hexavalent chromium, petroleum hydrocarbons (such as benzene and MTBE), pesticides (such as DBCP, EDB, 1,2,3 TCP), solvents (such as PCE, TCE), and emerging contaminants (such as PFOA, PFOS). Of these issues, nitrate is the most widespread issue with a direct impact on public health. Salinity is also an issue due to the widespread nature of the problem and difficulty of management given increases in salinity as a result of both urban and agricultural use.

The Merced County Department of Public Health, Division of Environmental Health maintains a list of areas of known adverse water quality in the County, shown below in Table 2-9.

Table 2-9: Adverse Groundwater Quality by Area

Region	Parameters
Atwater	Nitrates, DBCP[2], EDB[2], TCE[3] and 1,2,3 TCP[2&3]
Cressey	Nitrates & DBCP
El Nido	Nitrates, Arsenic, Sodium, & TDS[4]
Le Grand	Hard Water[1]
Livingston	Nitrates, Arsenic, DBCP, EDB, TCE and 1,2,3 TCP
McSwain Area	Nitrates, DBCP, EDB, TCE and 1,2,3 TCP
Merced	Nitrates & Hard Water
Planada	DBCP & Hard Water
Stevinson	Arsenic, Sodium, TDS[4], Manganese, Chlorides, Hard Water, & Tannins
Winton	Nitrates, DBCP, EDB, TCE and 1,2,3 TCP

Source: (Merced County Department of Public Health, Division of Environmental Health, 2018)

1 Hard Water = Total hardness > 150 mg/L (mg/L = milligrams per liter = parts per million)
2 Dibromochlopropane (DBCP), Ethylene Dibromide (EDB) and 1,2,3 Trichloropropane (1,2,3 TCP) are soil fumigants, use of DBCP and EDB was banned in 1977.
3 TCE and 1,2,3 TCP are solvent/degreases.
4 TDS refers to the total dissolved solids in water.

General Notes from the Merced County Department of Public Health, Division of Environmental Health:

a. Chlorides, manganese, hard water, iron, tannins, TDS, and sodium in drinking water are, of themselves, not known causes of health problems.
b. The water quality information above refers to private wells in unincorporated areas and does not necessarily apply to the municipal water supply of the towns and cities.

The sections below provide information on the historical and current groundwater quality conditions for constituents grouped by (1) salinity and nutrient constituents (Section 2.2.4.1), (2) metals (Section 2.2.4.2), (3) pesticides (Section 2.2.4.3), and (4) point-source contamination (Section 2.2.4.4), which includes petroleum hydrocarbons, solvents, and emerging contaminants. Salinity and nitrate data from 2008-2018 are described in the section below for each of the Principal Aquifers. Water quality data for the remaining constituents are based on a more limited range of data collected 2007-2012, largely without depth, that were analyzed for the 2013 Salt and Nutrient Study as part of the Merced Integrated Regional Water Management Plan (IRWMP). These data limitations have been identified as a data gap, and it is expected that additional water quality monitoring will be developed as part of this GSP which will further inform the understanding of current water quality conditions in the Subbasin, particularly as they pertain to depth and the characterization of the three Principal Aquifers.

The Merced IRWMP Salt and Nutrient Study collected 61,543 periodic water quality measurements from Merced County Department of Public Health, Division of Environmental Health as well as the State Water Board's GeoTracker and USGS GAMA Program. The 5-year average distribution map views were prepared using kriging or natural neighbor methods as implemented in SURFER© software by Golden Software and displayed in ArcGIS© software by Esri. These map views have been included directly in the GSP sections below (2.2.4.1.3 through 2.2.4.4.10) along with a discussion of each constituent. Time concentration plots of each constituent are included in Appendix E.

2.2.4.1 Salinity and Nutrient Constituents

As part of the comprehensive Salt and Nutrient Management Plan (SNMP) for the Central Valley, developed by the Central Valley Salinity Alternatives for Long Term Sustainability (CV-SALTS) program, detailed water quality analysis was conducted for salinity (represented by total dissolved solids [TDS]) and nitrates measured in wells across multiple agencies from 2000-2016. Supporting documents contain summary information about these constituents by subbasin, including Merced (Luhdorff and Scalmanini Consulting Engineers, 2016). Within the Central Valley, several aquifer zones were established in which to categorize well depths and segregate summary statistics. These zones are summarized below:

- Upper Zone
  - Includes the depth from the bottom of the vadose zone to the top of the Lower Zone
  - Where the Corcoran Clay is present, the Upper Zone does not extend below the Corcoran Clay
- Lower Zone
  - Includes the depth from the bottom of the Upper Zone to the depth of the bottom of the Lower Zone
  - Within the Corcoran Clay area, the Lower Zone is bounded at the bottom by the top of the Corcoran Clay layer
- Production Zone
  - Combination of Upper Zone and Lower Zone
- Lower Part of the Aquifer System (Below the Corcoran Clay)
  - This refers to the groundwater beneath the Corcoran Clay, where present, and groundwater at greater depths than most municipal well depths where the Corcoran Clay is not present

The two subsections below provide more detail and analysis specific to nitrates and salinity.

2.2.4.1.1 Nitrates

Nitrate (NO_3) occurs from both natural and anthropogenic sources and is widespread in groundwater in many parts of the San Joaquin Valley. High nitrate concentrations in groundwater are often associated with the use of fertilizers (commercial/animal waste) and onsite wastewater treatment systems (OWTS or septic systems).

Table 2-10 shows a summary of the number of wells with nitrate results, broken down by CV-SALTS aquifer category and agency type. Nitrate statistical summary information by aquifer category is shown in Table 2-11. These values are presented "as Nitrogen" which has an MCL of 10 mg/L. Generally, nitrate concentrations were found to be higher, on average, in the Upper Zone than in the Below Corcoran Clay Zone.

Table 2-10: Wells with Nitrate Results (Merced Subbasin)

Aquifer Well Source	Number of Wells	Wells with Construction Information[1]	Wells Without Construction Information[1]
Upper	355	52	303
California Department of Public Health (CDPH)	6	6	0
Domestic	226	0	226
Environmental monitoring (wells)	111	36	75
United States Geological Survey (USGS) (Unknown well type)	12	10	2
Upper and Lower	15	15	0
CDPH	13	13	0
USGS (Unknown well type)	2	2	0
Lower	108	37	71
Agricultural	38	0	38

Aquifer Well Source	Number of Wells	Wells with Construction Information[1]	Wells Without Construction Information[1]
CDPH	59	34	25
USGS (Unknown well type)	3	3	0
Water supply (wells)	8	0	8
Below Corcoran Clay	191	55	136
Agricultural	109	0	109
CDPH	64	44	20
Environmental monitoring (wells)	4	4	0
USGS (Unknown well type)	7	7	0
Water supply (wells)	7	0	7
Too Deep[2]	1	1	0
CDPH	1	1	0
Total	**670**	**160**	**510**

[1] Construction information means information is available about the depth(s) of well screens which indicates which aquifer the well is drawing from. With absent well construction information, water quality data is more difficult to interpret.

[2] Indicates a small number of wells uncharacteristically deep for the region in which they are located.

Source: CV-SALTS (Luhdorff and Scalmanini Consulting Engineers, 2016)

Table 2-11: Average Well Nitrate Concentration (mg/L as N) Statistics (Merced Subbasin)

Aquifer Zone	Number of Wells	Minimum	Average	Median	Maximum
Upper Zone	355	0.10	11.30	5.20	179.61
Upper and Lower Zone	15	0.98	5.26	5.26	12.66
Lower Zone	108	0.23	4.58	3.40	24.60
Below Corcoran Clay Zone	191	0.10	7.52	3.00	71.00

Source: CV-SALTS (Luhdorff and Scalmanini Consulting Engineers, 2016)

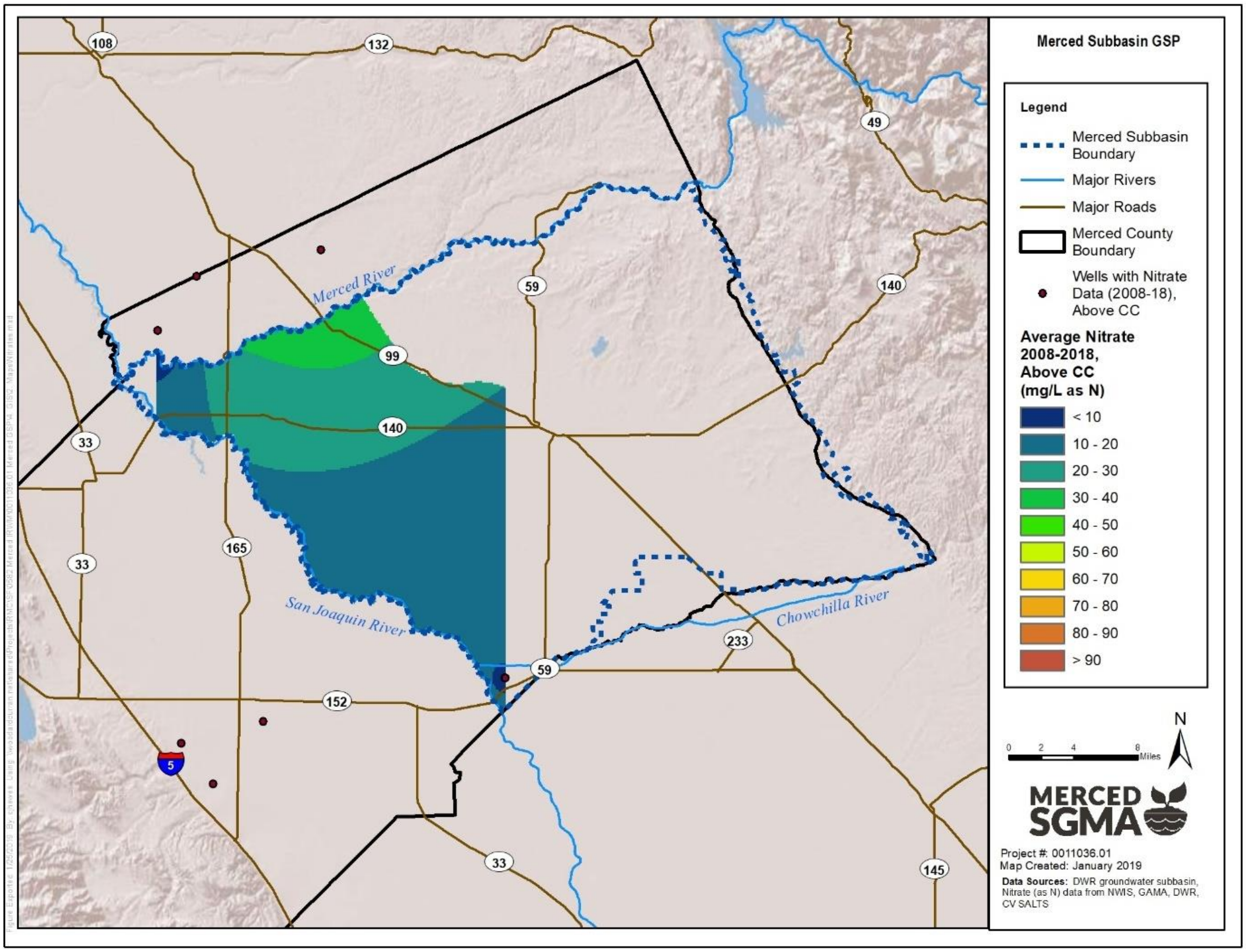
For the purpose of mapping nitrate concentration separately for each principal aquifer, nitrate data was collected from several data sources including National Water Information System (NWIS), Groundwater Ambient Monitoring Assessment (GAMA), DWR, and CV-SALTS. Nitrate data is presented "as nitrogen", with an MCL of 10 mg/L. Wells located within the boundary of the extent of the Corcoran Clay were sorted into their respective Above (see Figure 2-59) or Below (see Figure 2-60) Corcoran Clay Principal Aquifer if depth information was available. Wells with nitrate data but without depth information were mapped as "Unknown Aquifer" (see Figure 2-61). Wells located outside of the Corcoran Clay (regardless of availability of depth information) were mapped as Outside Corcoran Clay (see Figure 2-62). Nitrate concentrations at each well were averaged over a period of 2008-2018.

Nitrate data availability for wells with depth information is very limited. For both the Above and Below Corcoran Clay Principal Aquifers, the limited number of data points for 2008-2018 mean that spatial interpolation across the aquifer areas produces results with expected low accuracy.

In the northwest quadrant (Figure 2-61 for Unknown Aquifer), there are several small areas where nitrate concentrations exceed 40 mg/L and several larger areas where nitrate concentrations range from 20 to 40 mg/L. The elevated nitrate concentration in these areas may be associated with animal confinement facilities and other agricultural non-point sources (AMEC, 2013). Elevated nitrate in groundwater exists in small areas northeast of Merced and southwest of Atwater among areas where high density OWTS occur (Figure 2-62 for Outside Corcoran Clay). The primary Maximum Contaminant Level (MCL) for nitrate is 45 mg/L (SWRCB, 2018). Identifying the exact sources of nitrates in these areas would require additional study.

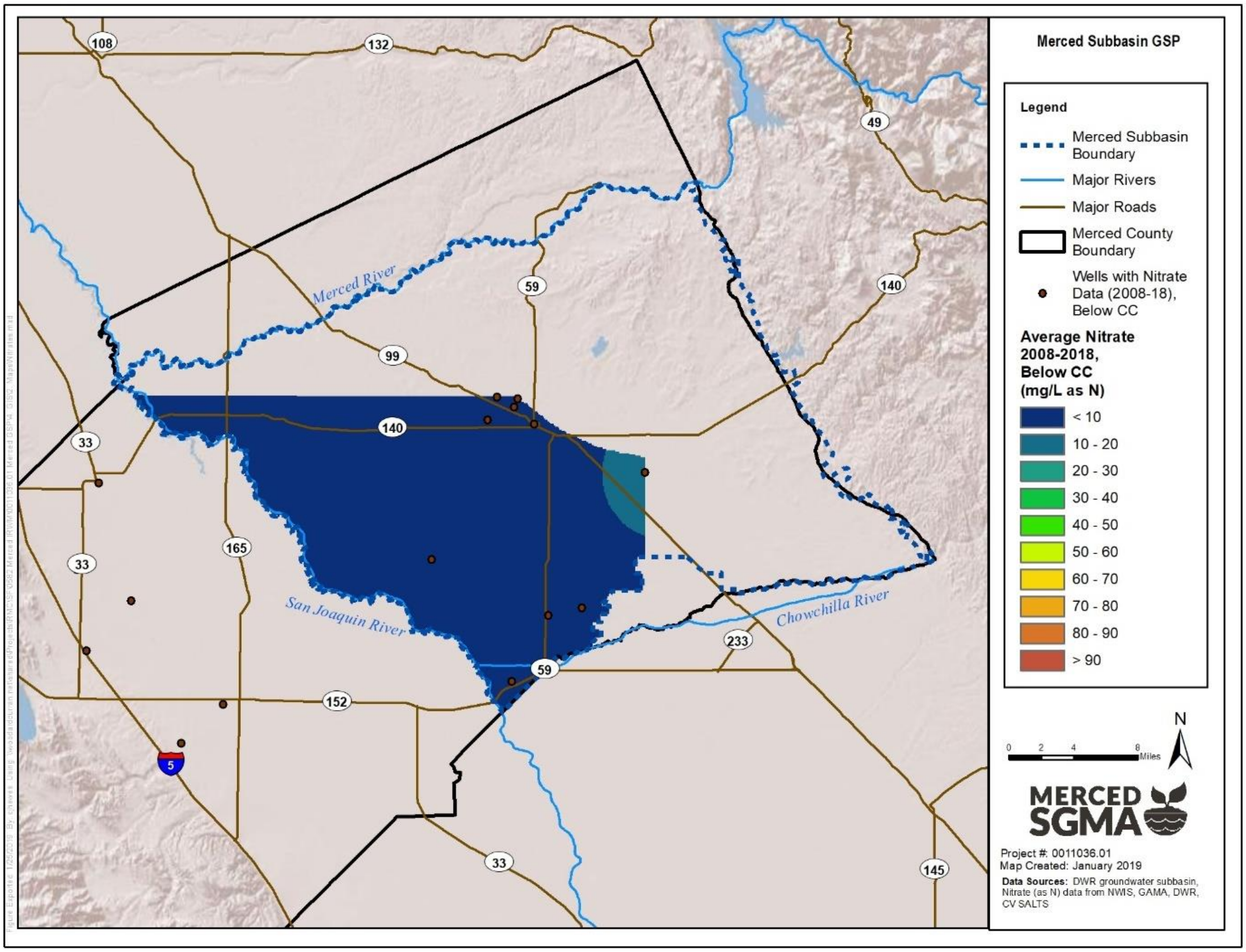
Time concentration plots of nitrate from 2007-2012 are shown in Appendix E.

Figure 2-59: Average Nitrate (as N) Concentration 2008-2018, Above Corcoran Clay[1]



[1] Nitrate data availability for wells with depth information is very limited. The Above Corcoran Clay Principal Aquifer contains only one confirmed data point for average nitrate 2008-2018 within the Subbasin, meaning that spatial interpolation across the aquifer area produces results with expected low accuracy.

Figure 2-60: Average Nitrate (as N) Concentration 2008-2018, Below Corcoran Clay[1]



[1] Nitrate data availability for wells with depth information is very limited. The Below Corcoran Clay Principal Aquifer contains only ten confirmed data points for average nitrate 2008-2018 within the Subbasin, meaning that spatial interpolation across the aquifer area produces results with expected low accuracy.

Figure 2-61: Average Nitrate (as N) Concentration 2008-2018, Unknown Aquifer

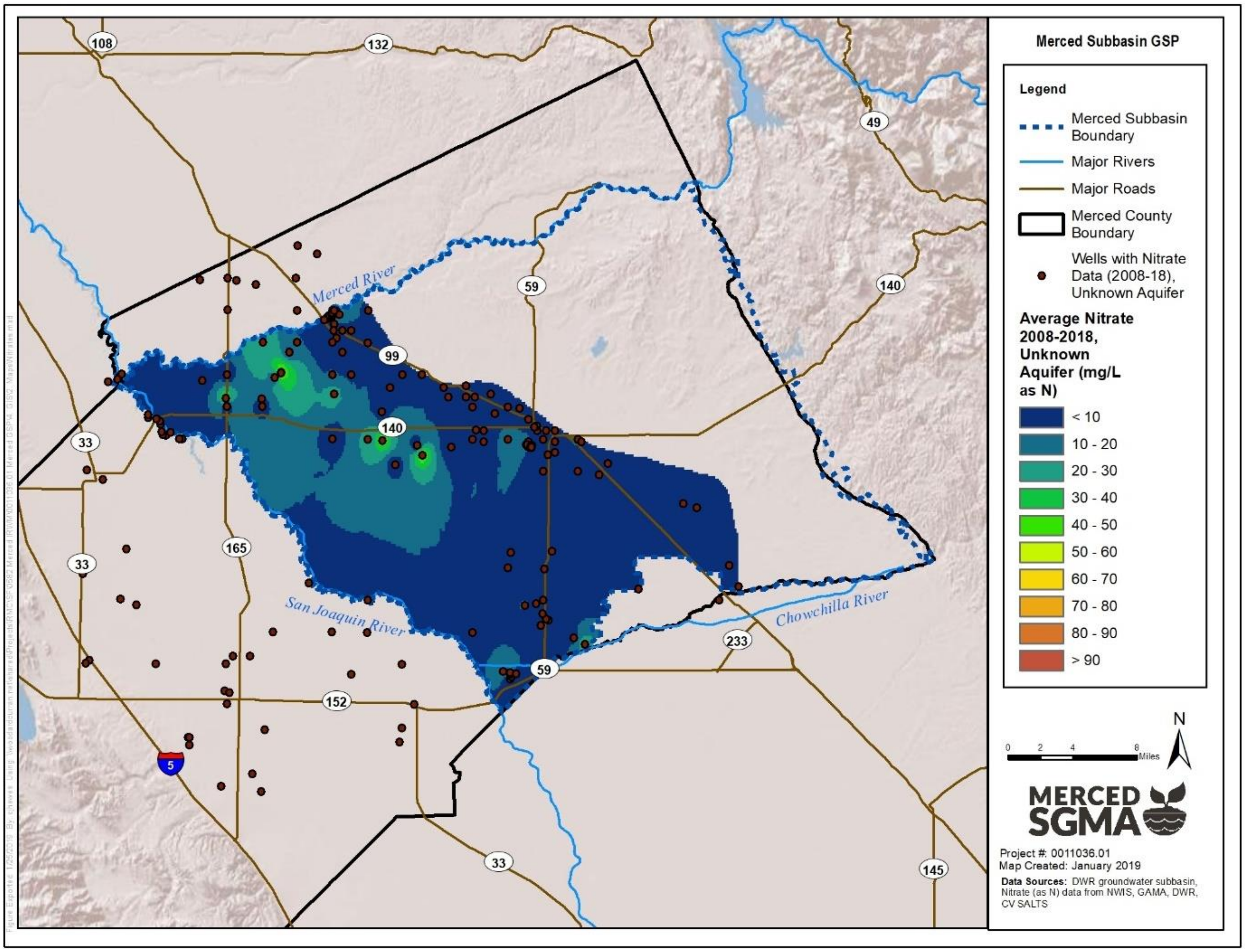
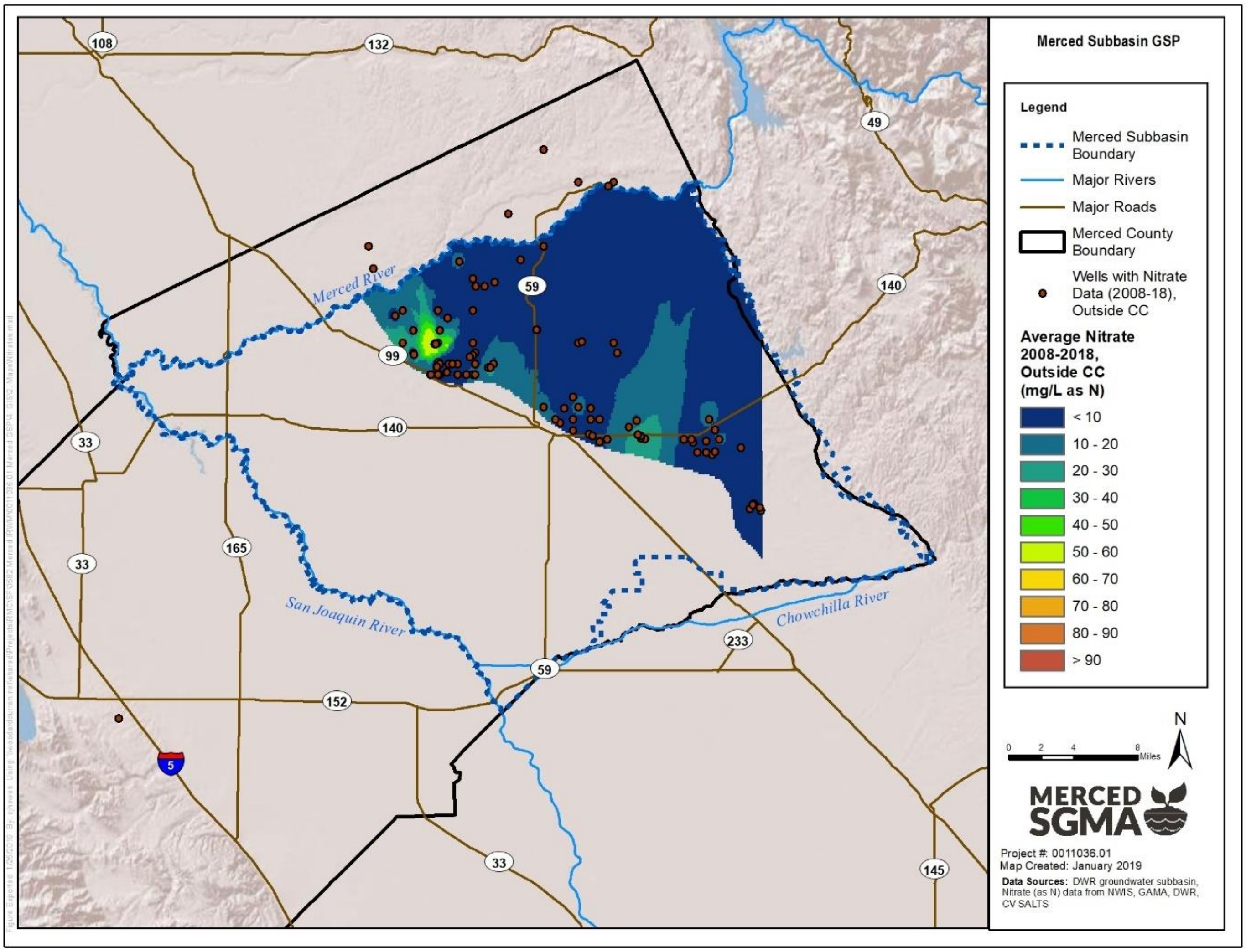


Figure 2-62: Average Nitrate (as N) Concentration 2008-2018, Outside Corcoran Clay



2.2.4.1.2 Salinity

Salinity levels within the Merced Subbasin range from less than 90 to greater than 3,000 mg/L as measured by TDS. The recommended drinking water secondary MCL for TDS is 500 mg/L, with an upper secondary MCL of 1,000 mg/L and a short-term second MCL[5] of 1,500 mg/l (SWRCB, 2006). The secondary MCL is established by the USEPA and then adopted by the SWRCB. The secondary MCL is a Secondary Drinking Water Standard that is established for aesthetic reasons such as taste, odor, and color and is not based on public health concerns. For agricultural uses, salt tolerance varies by crop, with common crops within the Merced Subbasin tolerant of irrigated water with TDS below 640 mg/L (Ayers & Westcot, 1985). TDS in the northern portion of the Subbasin is slightly elevated beneath the Atwater and Winton areas. Otherwise, TDS in the eastern two-thirds of the Subbasin is generally less than 400 mg/L. TDS in

[5] Short-term secondary MCLs are acceptable only for existing community water systems on a temporary basis pending construction of treatment facilities or development of acceptable new water sources (California Code of Regulations Title 22 § 64449).

groundwater increases westward and southwestward towards the San Joaquin River and southward towards the Chowchilla River. In these areas, high TDS water is found in wells deeper than 350 feet (AMEC, 2008).

Better quality groundwater (less than 1,000 mg/L) in these western and southwestern areas is generally found at shallower depths. Groundwater with high TDS concentrations in the Merced Subbasin is principally the result of the migration of a deep water body with relative higher salinity which originates in regionally deposited marine sedimentary rocks that underlie the San Joaquin Valley. The depth of this water body with relative higher salinity within the Merced Subbasin boundaries is shallow compared to other parts of the San Joaquin Valley (AMEC, 2008).

Groundwater with high concentrations of TDS is present beneath the entire Merced Subbasin at depths from about 400 feet in the west to over 800 feet in the east. The shallowest high TDS groundwater occurs in zones 5 to 6 miles wide adjacent and parallel to the San Joaquin River and the lower part of the Merced River west of Hilmar, where high TDS groundwater is upwelling (AMEC, 2008).

Under natural pressure, the groundwater body of relative higher salinity is migrating upward. Brines move up through permeable sedimentary rocks and also through wells, faults, and fractures. The chemistry of groundwater in the Merced Subbasin indicates that mixing is occurring between the shallow fresh groundwater and the brines, which produces the high TDS groundwater observed. Pumping of deep wells in the western and southern parts of the Merced Subbasin may be causing these saline brines to upwell and mix with freshwater aquifers more rapidly than under natural conditions (AMEC, 2008).

The Corcoran Clay has provided a natural impediment to the migration of high TDS groundwater from the confined aquifer into the unconfined aquifer. High permeability pathways through the clay from the confined to the unconfined aquifer may be created by wells perforated in both the unconfined and confined aquifers (AMEC, 2008), even though this practice is prohibited by Merced County's well standards.

Table 2-12 shows a summary of the number of wells with TDS results, broken down by CV-SALTS aquifer category and agency type. TDS statistical summary information by aquifer category is shown in Table 2-13. Generally, TDS concentrations were found to average higher in the Upper Zone than the Below Corcoran Clay Zone.

For the purpose of mapping TDS concentration separately for each principal aquifer, TDS data was collected from several data sources including NWIS, GAMA, DWR, and CV-SALTS within all of Merced County. Wells located within the boundary of the extent of the Corcoran Clay were sorted into their respective Principal Aquifer. There was only one well with TDS measurements within the Above Corcoran Clay Principal Aquifer (located in the very southern tip of the Subbasin), and so a contour map could not be developed due to lack of data. Wells completed within the Below Corcoran Principal Aquifer are shown in Figure 2-63. Wells with TDS data but without depth information were mapped as "Unknown Aquifer" (see Figure 2-64). Wells located outside of the Corcoran Clay (regardless of availability of depth information) were mapped as Outside Corcoran Clay (see Figure 2-65). TDS concentrations at each well were averaged over a period of 2008-2018.

TDS data availability for wells with depth information is very limited. For both the Above and Below Corcoran Clay Principal Aquifers, the limited number of data points for 2008-2018 means that spatial interpolation across the aquifer areas produces results with expected low accuracy.

Time concentration plots of TDS from 2007-2012 are shown in Appendix E.

Table 2-12: Wells with TDS Results (Merced Subbasin)

Aquifer Well Source	Number of Wells	Wells with Construction Information[1]	Wells Without Construction Information[1]
Upper	80	39	41
CDPH	4	4	0
Environmental monitoring (wells)	55	20	35
USGS (Unknown well type)	21	15	6
Upper and Lower	13	13	0
CDPH	9	9	0
USGS (Unknown well type)	4	4	0
Lower	62	32	30
CDPH	40	29	11
USGS (Unknown well type)	3	3	0
Water supply (wells)	19	0	19
Below Corcoran Clay	74	49	25
CDPH	48	37	11
USGS (Unknown well type)	12	12	0
Water supply (wells)	14	0	14
Too Deep[2]	2	2	0
CDPH	1	1	0
USGS (Unknown well type)	1	1	0
Total	**231**	**135**	**96**

[1] Construction information means information is available about the depth(s) of well screens which indicates which aquifer the well is drawing from. With absent well construction information, water quality data is more difficult to interpret.
[2] Indicates a small number of wells uncharacteristically deep for the region in which they are located.

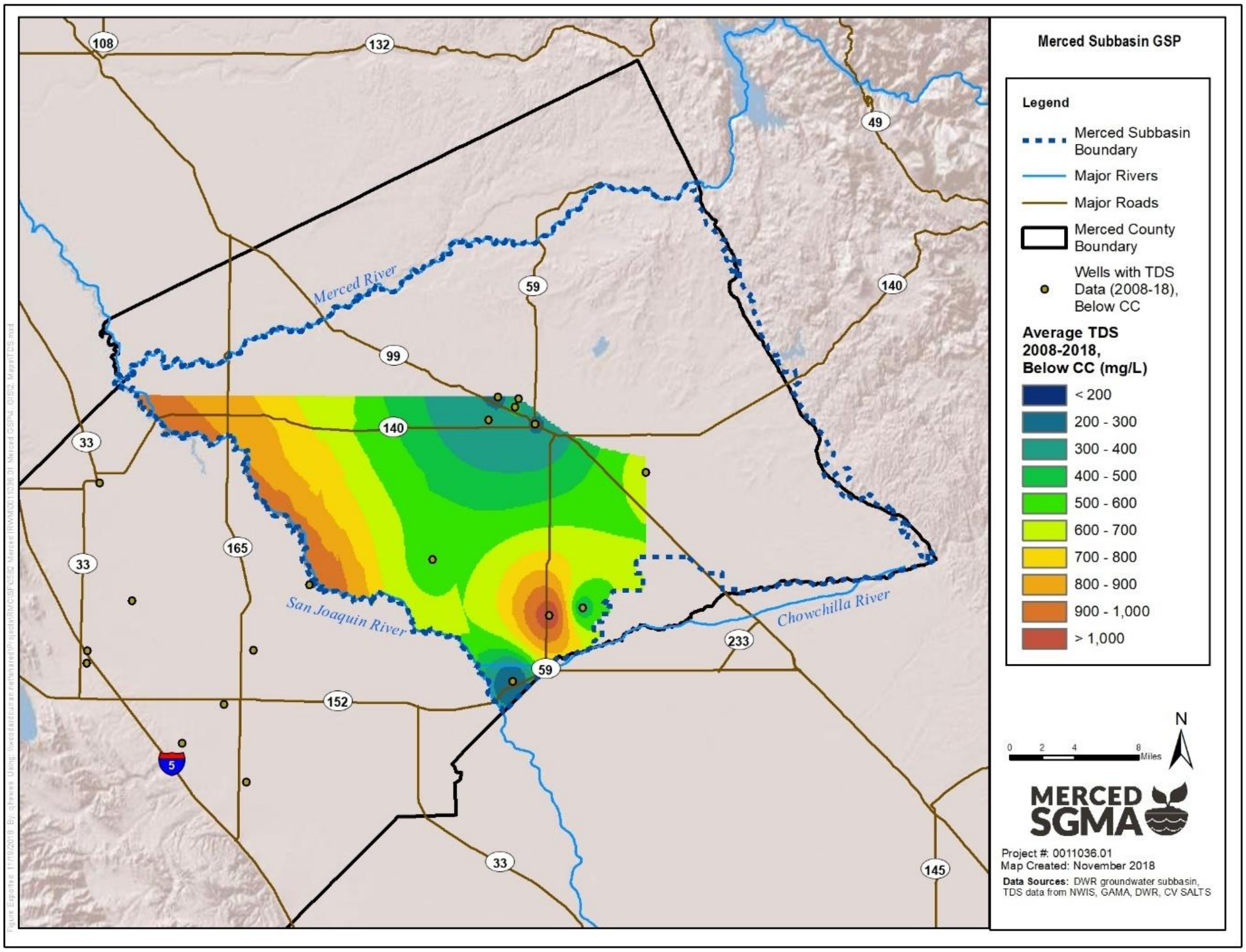
Source: CV-SALTS (Luhdorff and Scalmanini Consulting Engineers, 2016)

Table 2-13: Average Well TDS Concentration (mg/L) Statistics (Merced Subbasin)

Aquifer Zone	Number of Wells	Minimum	Average	Median	Maximum
Upper Zone	80	111	498	392	1,951
Upper and Lower Zone	13	125	249	236	354
Lower Zone	62	111	289	211	2,005
Below CC Zone	74	90	268	224	1,035
Below Production Zone	2	246	280	280	314

Source: CV-SALTS (Luhdorff and Scalmanini Consulting Engineers, 2016)

Figure 2-63: Average TDS Concentration 2008-2018, Below Corcoran Clay[1]



[1] TDS data availability for wells with depth information is very limited. The Below Corcoran Clay Principal Aquifer contains only ten confirmed data points for average TDS 2008-2018 within the Subbasin, meaning spatial interpolation across the aquifer area produces results with expected low accuracy.

Figure 2-64: Average TDS Concentration 2008-2018, Unknown Aquifer

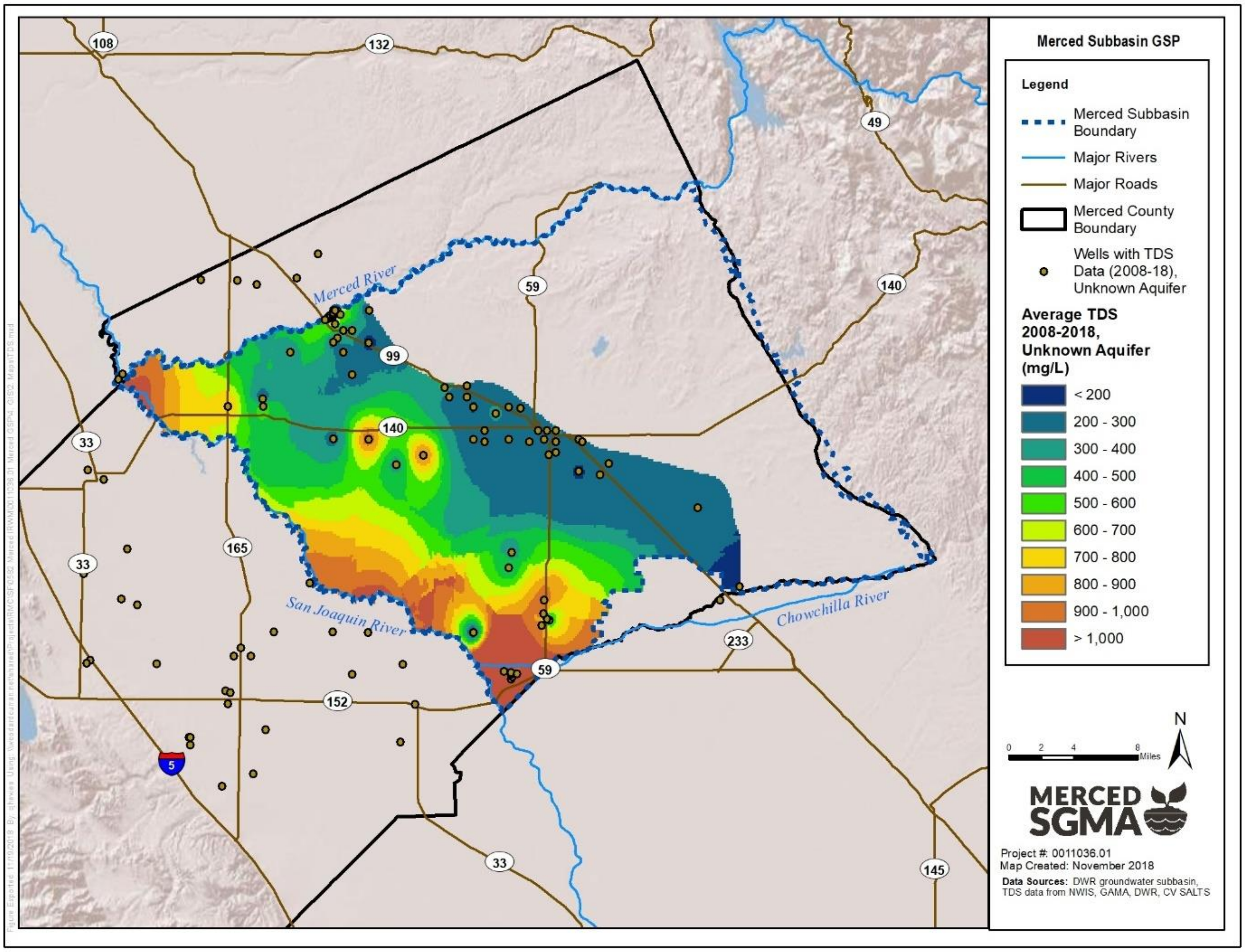
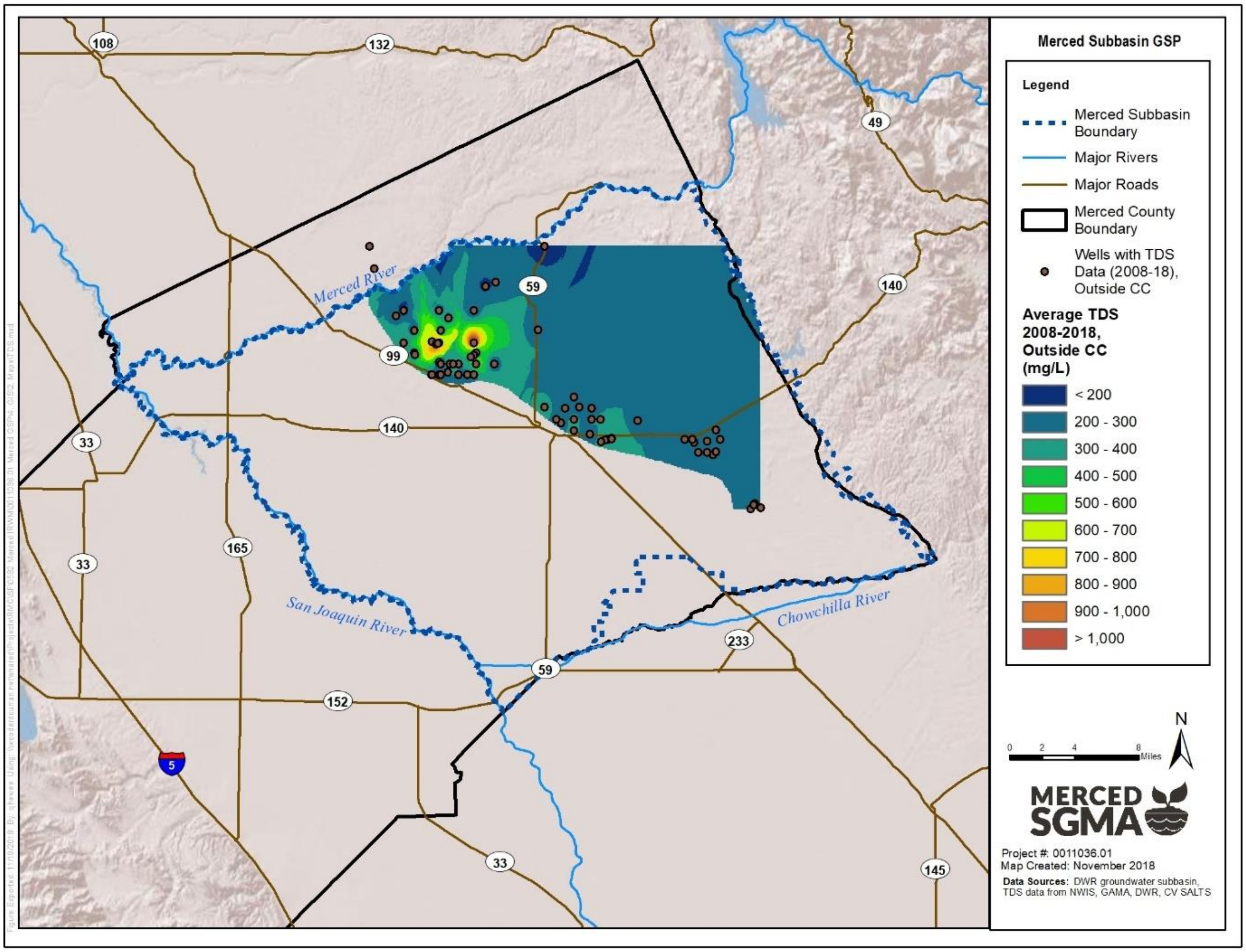


Figure 2-65: Average TDS Concentration 2008-2018, Outside Corcoran Clay

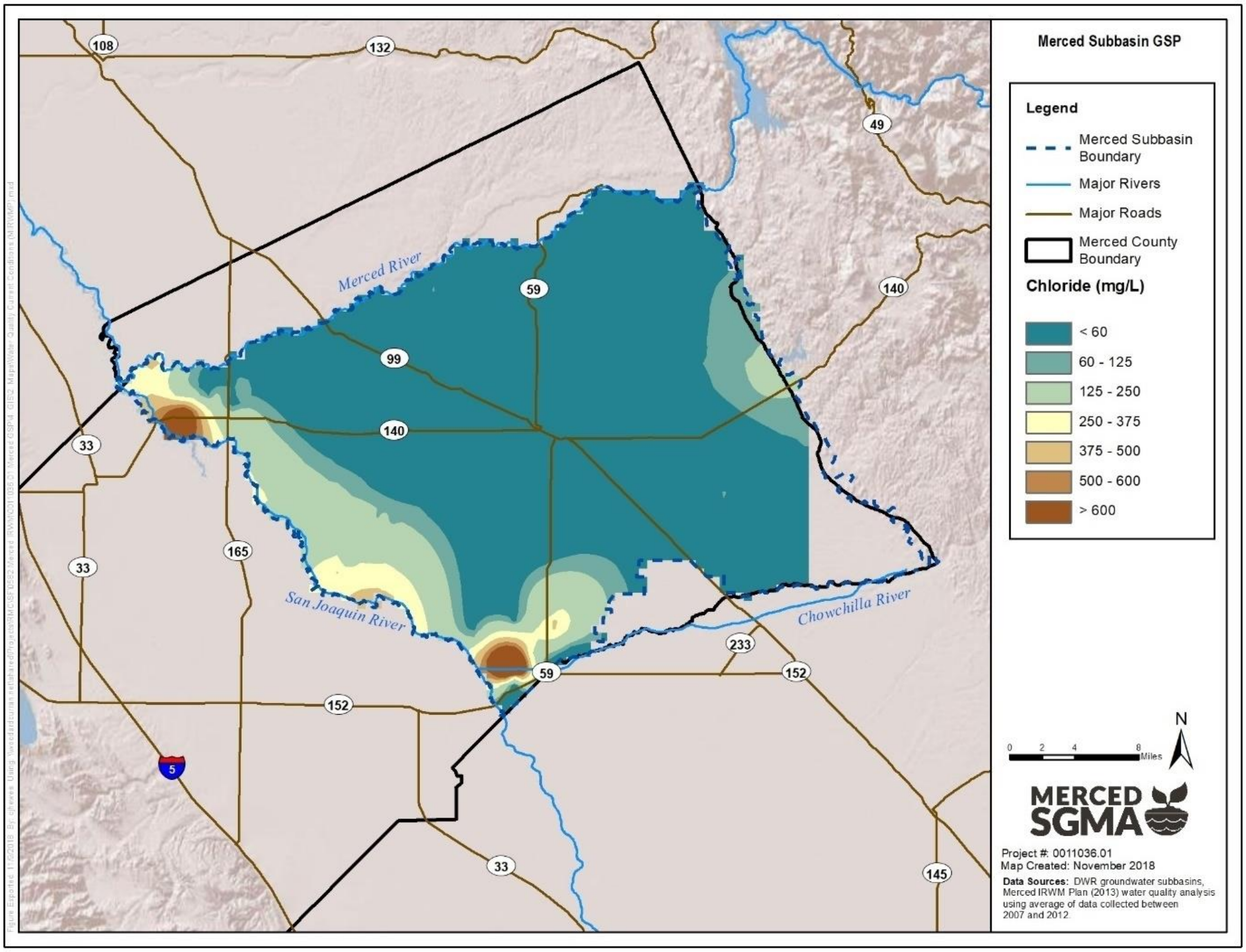


2.2.4.1.4 Chloride

Chloride (Cl) is a dissolved salt commonly associated with saline groundwater. Within the Merced Subbasin area, chloride concentrations range from non-detect (typically less than 2 mg/L) to as much as 1,850 mg/L. The recommended secondary MCL for Cl is 250 mg/L and the upper secondary MCL is 500 mg/L (SWRCB, 2006). The secondary MCL is established by the USEPA and then adopted by the SWRCB. The secondary MCL is a Secondary Drinking Water Standard that is established for aesthetic reasons such as taste, odor, and color and is not based on public health concerns. The 5-year average (2007-2012) Cl concentration in groundwater in the northern two quadrants of the Merced Subbasin area is generally less than 50 mg/L (Figure 2-66). Like TDS, Cl in groundwater increases in the southern quadrants towards the San Joaquin River to as much as 500 mg/L.

Time concentration plots of Cl are shown in Appendix E.

Figure 2-66: 5-Year Average Distribution of Chloride in Groundwater (2007-2012)



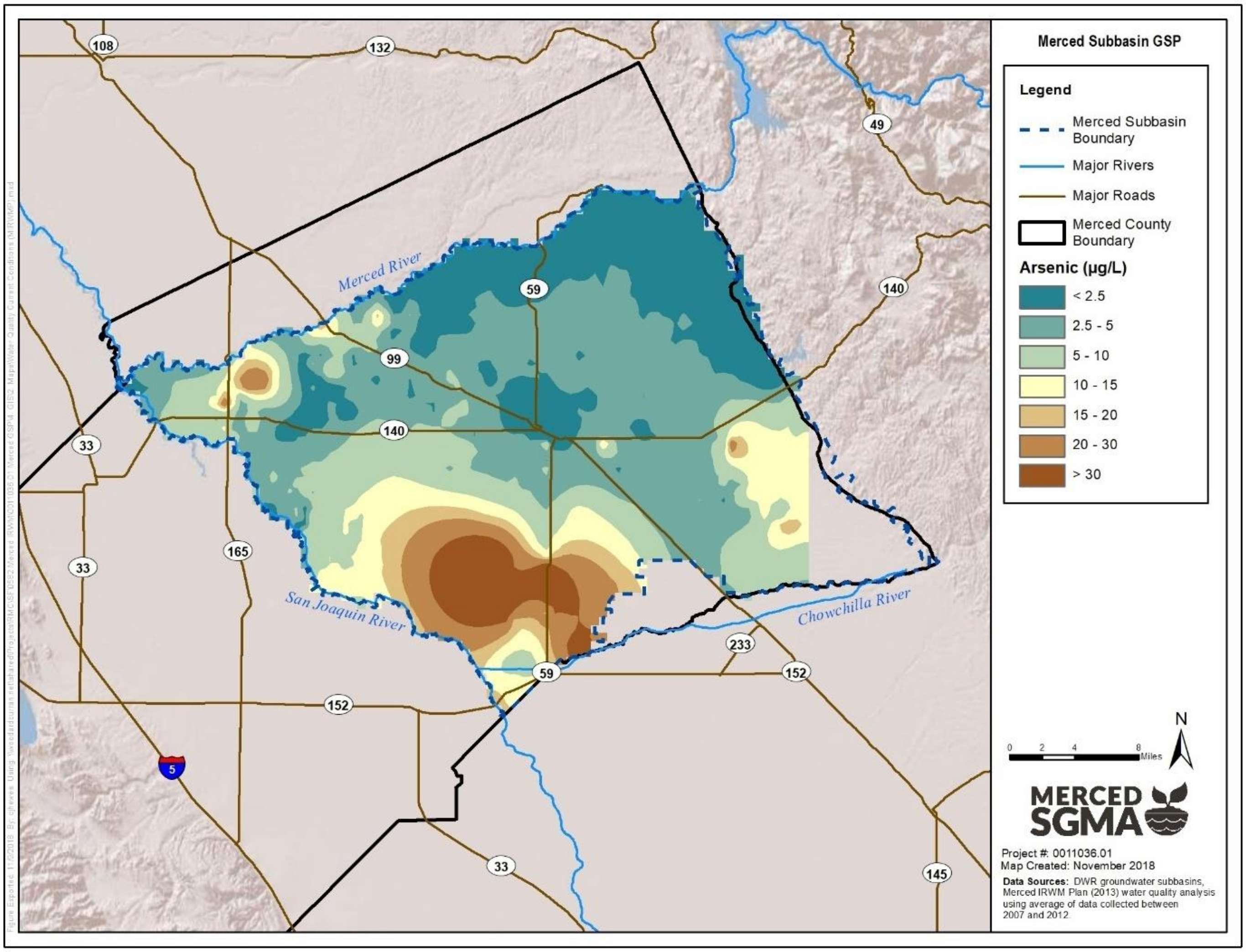
2.2.4.2 Metals

2.2.4.2.1 Arsenic

Arsenic (As) is a dissolved metal found in many bedrock formations which can have human health impacts. Within the Merced Subbasin area, As concentrations range from non-detect (less than 1 microgram per liter [µg/L]) to as much as 800 µg/L. The primary MCL for As is 10 µg/L (SWRCB, 2018). The 5-year average (2007-2012) As concentration in groundwater in the northern two quadrants of the Merced Subbasin area is generally less than 10 µg/l (Figure 2-67). There are localized areas where the average As concentrations in shallow groundwater range between 20 and 50 µg/L northeast of Atwater, near Stevinson, and in the southwest Merced Subbasin area near the intersection of Sandy Mush Road and Highway 59. The City of Livingston also has wells with As levels at or above the MCL. The City has constructed groundwater treatment systems at multiple wells to reduce As concentrations below the MCL (City of Livingston, 2016).

Time concentration plots of As are shown in Appendix E.

Figure 2-67: 5-Year Average Distribution of Arsenic in Groundwater (2007-2012)

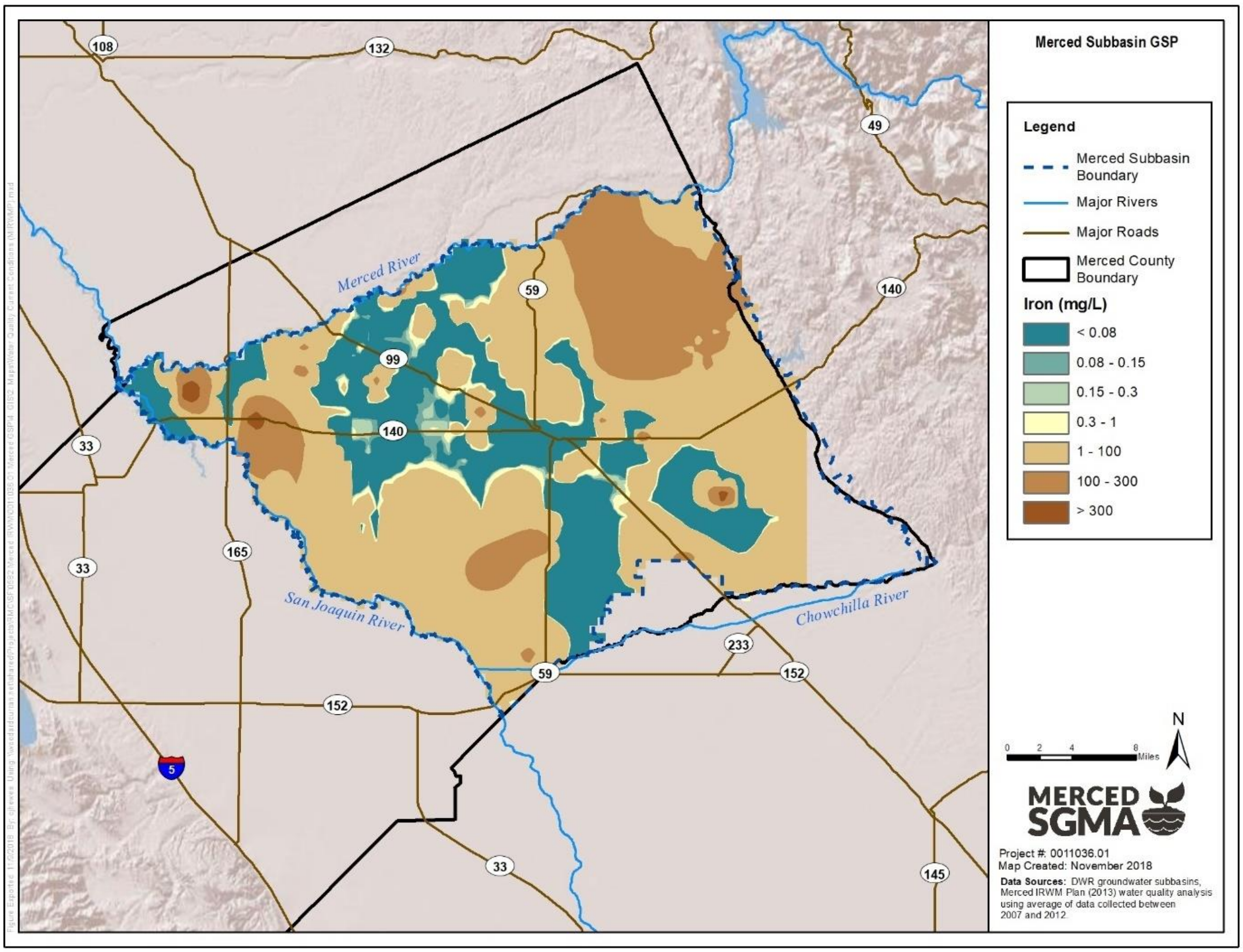


2.2.4.2.3 Iron

Iron (Fe) is a dissolved metal commonly associated with mineralized groundwater. Within the Merced Subbasin area, Fe concentrations range from non-detect (less than 1 mg/L) to as much as 600 mg/L. The secondary MCL for Fe is 0.3 mg/L (SWRCB, 2006). The secondary MCL is established by the USEPA and then adopted by the SWRCB. The secondary MCL is a Secondary Drinking Water Standard that is established for aesthetic reasons such as taste, odor, and color and is not based on public health concerns. The 5-year average (2007-2012) Fe concentration in groundwater in the eastern two quadrants of the Merced Subbasin area ranges from non-detect to over 300 mg/L (Figure 2-68), while the Fe concentration in groundwater in the western two quadrants is generally between 1 and 100 mg/L in most areas. The elevated Fe concentration in the eastern portion of the Merced Subbasin area is a result of leaching of Fe from the subsurface materials in the source area. The Fe in groundwater oxidizes and precipitates as the groundwater moves west towards the San Joaquin River (AMEC, 2013).

Time concentration plots of Fe are shown in Appendix E.

Figure 2-68: 5-Year Average Distribution of Iron in Groundwater (2007-2012)

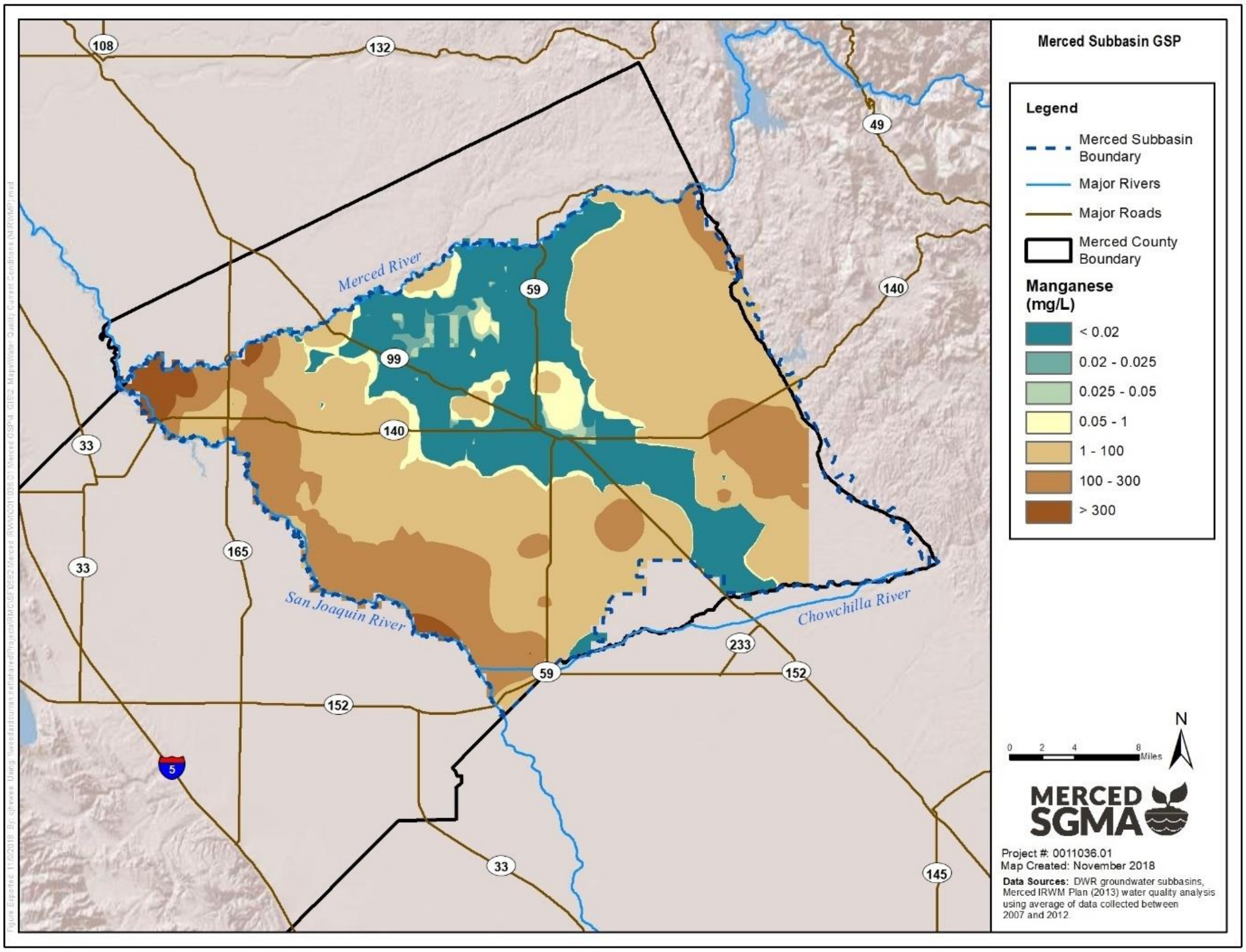


2.2.4.2.4 Manganese

Manganese (Mn) is a dissolved metal commonly associated with mineralized groundwater. Within the Merced Subbasin area, Mn concentrations range from non-detect (less than 1 µg/L) to as much as 1,300 mg/L. The secondary MCL for Mn is 0.05 mg/L (SWRCB, 2006). The 5-year average (2007-2012) Mn concentration in groundwater beneath most of the center of the Subbasin is below 0.05 mg/L, with elevated levels from 0.05 mg/L to over 300 mg/L along the eastern and western portions of the Subbasin (Figure 2-69). Like TDS, the Mn concentration in groundwater increases towards the San Joaquin River to as much as 500 mg/L.

Time concentration plots of Mn are shown in Appendix E.

Figure 2-69: 5-Year Average Distribution of Manganese in Groundwater (2007-2012)

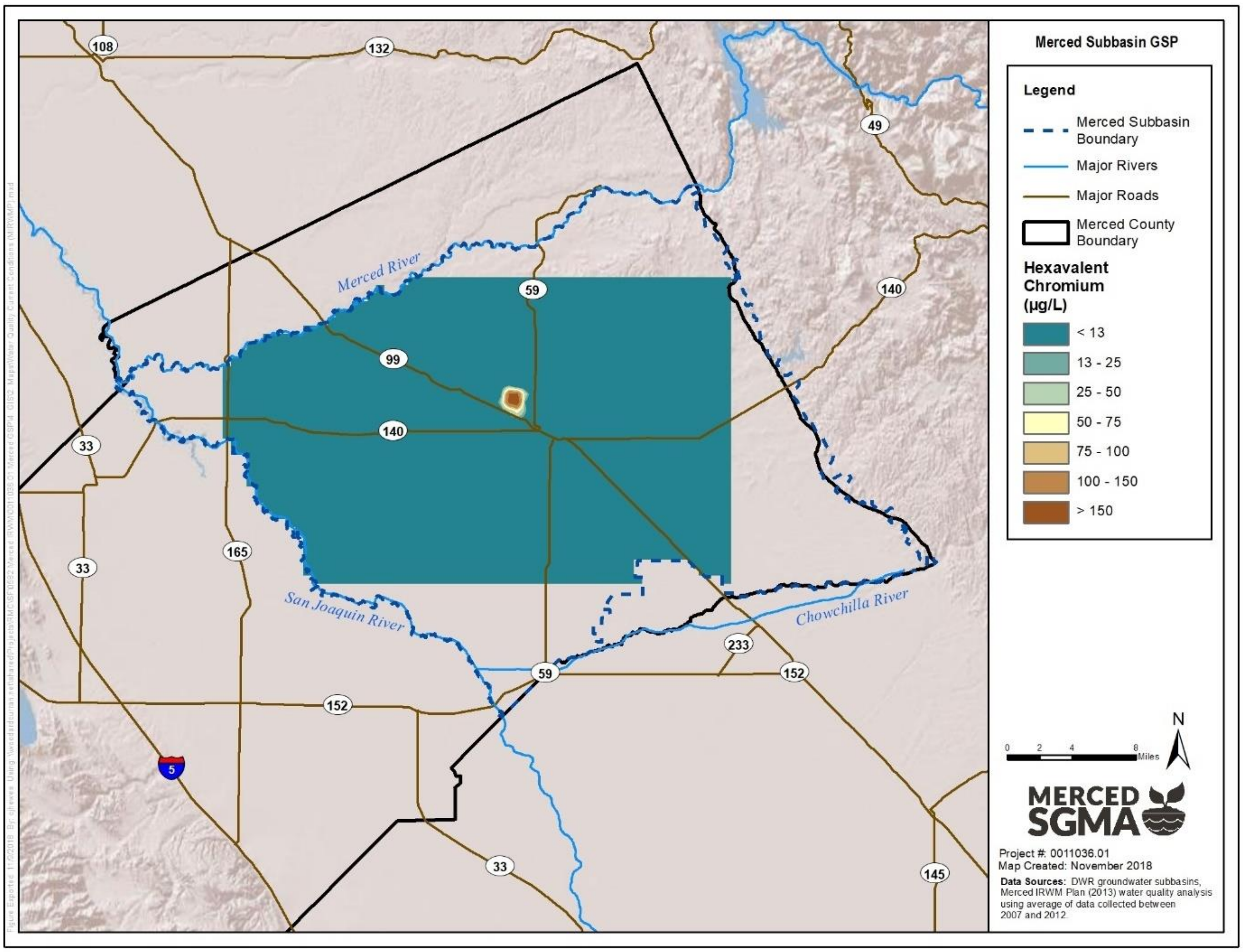


2.2.4.2.5 Hexavalent Chromium

Hexavalent Chromium (Cr^6) is a dissolved metal that rarely occurs naturally and is usually associated with industrial contamination in groundwater. Within the Merced Subbasin area, Cr^6 concentrations range from non-detect (less than 0.01 µg/L) to as much as 370 µg/L. The SWRCB established an MCL for Cr^6 of 10 µg/L in 2014, but it was withdrawn in August 2017 due to a state court ruling. The 5-year average (2007-2012) Cr^6 concentration in groundwater in the Merced Subbasin area is generally less than 1 µg/L, except for a small area of over 100 µg/L in the northwest quadrant (Figure 2-70) due to a point source in the Beachwood subdivision (Central Valley RWQCB, 2011).

Time concentration plots of Cr^6 are shown in Appendix E.

Figure 2-70: 5-Year Average Distribution of Hexavalent Chromium in Groundwater (2007-2012)



2.2.4.3 Pesticides

The following information on pesticides includes subsections for Dibromochloropropane (DBCP) and 1,2,3-Trichloropropane (123-TCP).

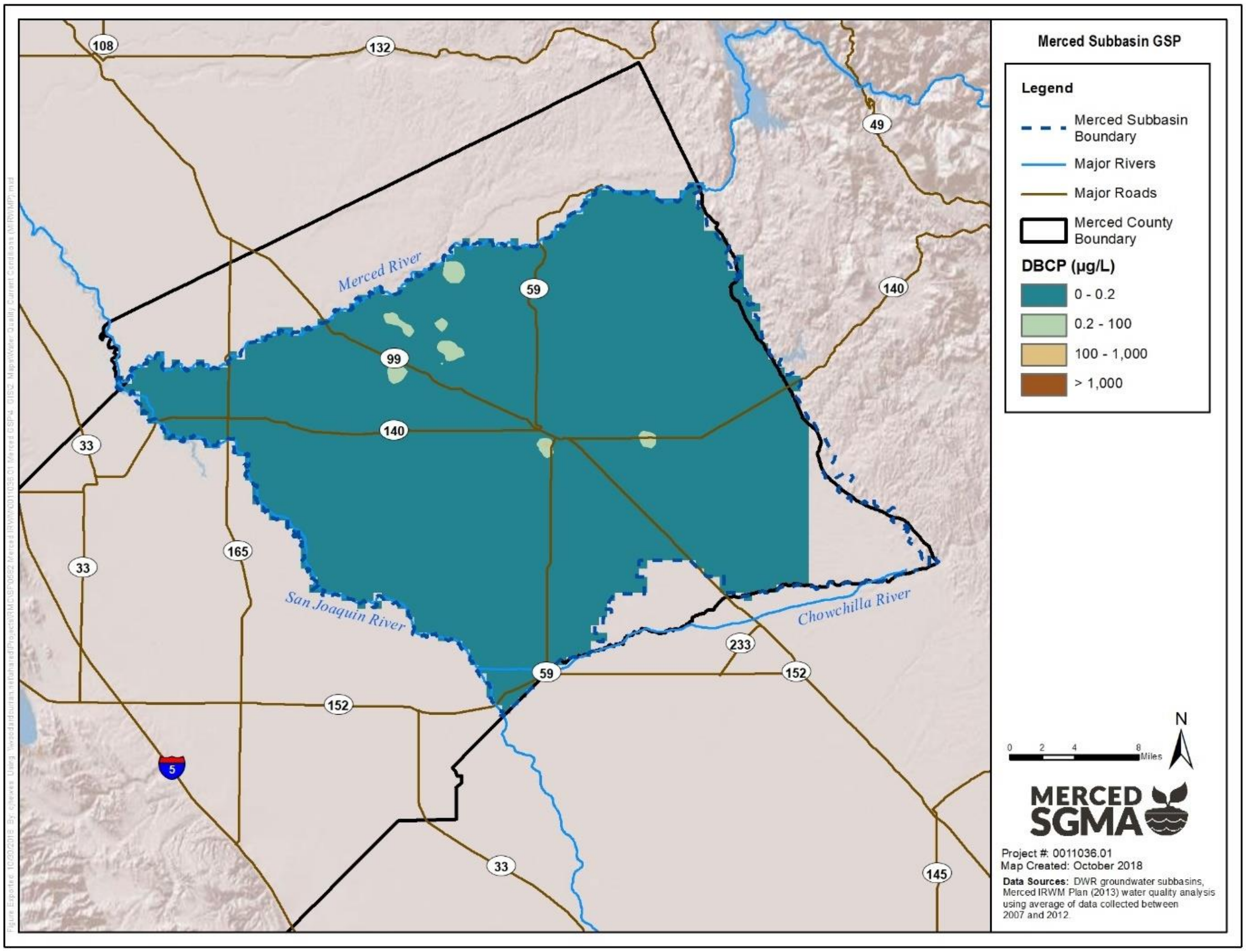
2.2.4.3.1 Dibromochloropropane (DBCP)

The pesticide DBCP was a common pesticide used to control nematodes in vineyards prior to 1977. DBCP concentrations in groundwater in the Merced Subbasin range from non-detect (variable, but typically 0.2 µg/L) to 335 µg/L. The primary MCL for DBCP is 0.2 µg/L (SWRCB, 2018). The 5-year average (2007-2012) DBCP concentration in groundwater in the Merced Subbasin is generally less than 0.2 µg/L (

Figure 2-71), with elevated concentrations found in localized areas near the Cities of Atwater, Delhi, Le Grand, Livingston, Merced, Planada, and Winton.

Time concentration plots of DBCP are shown in Appendix E.

Figure 2-71: 5-Year Average Distribution of DBCP in Groundwater (2007-2012)

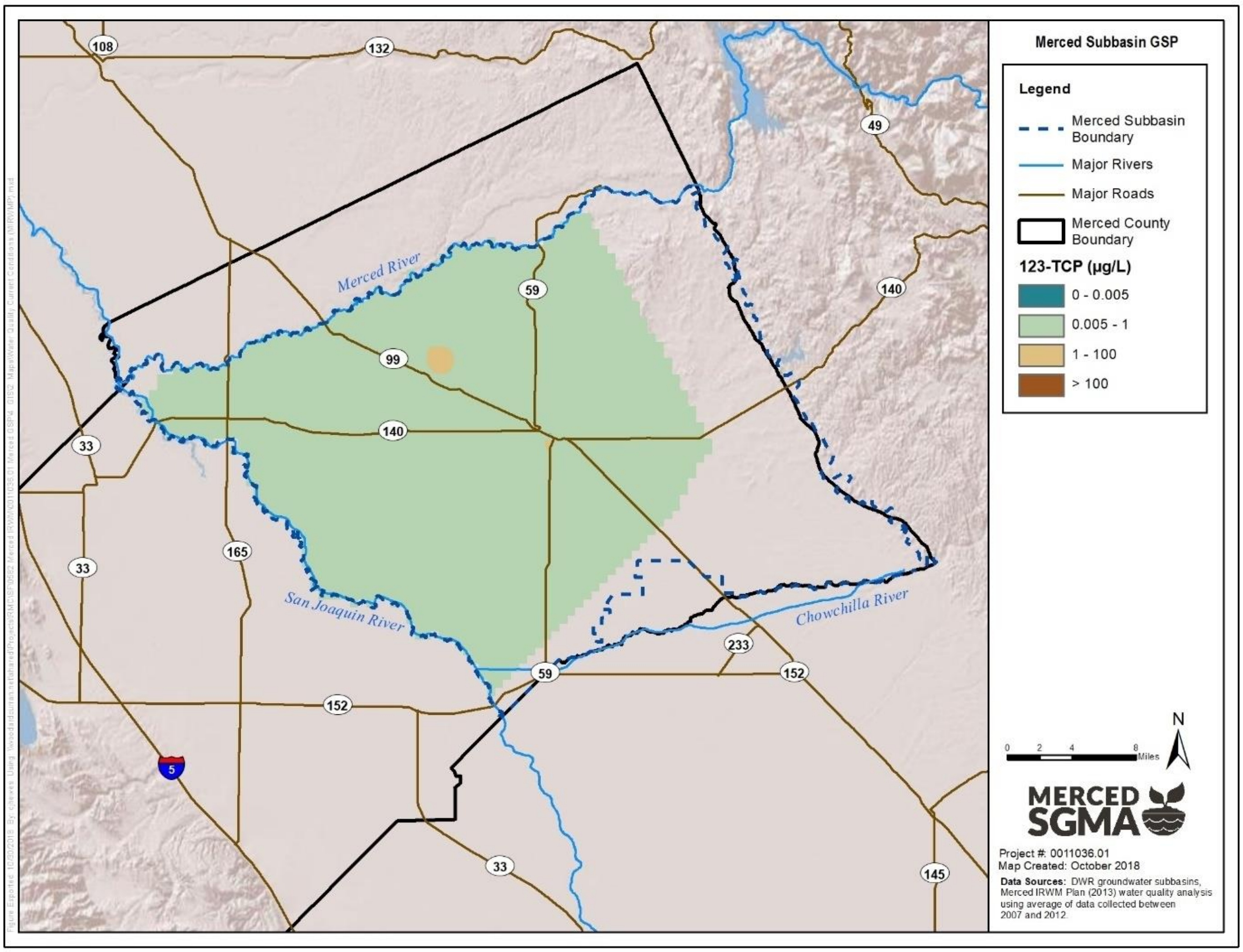


2.2.4.3.3 1,2,3-Trichloropropane (123-TCP)

The volatile organic compound (VOC) 123-TCP is a commonly used solvent in manufacturing facilities and as a carrier solvent for DBCP and other pesticides. 123-TCP concentrations in groundwater in the Merced Subbasin range from non-detect (variable, but typically 0.5 µg/L) to over 300 µg/L. The primary MCL for 123-TCP is 0.005 µg/L (SWRCB, 2018). The 5-year average (2007-2012) 123-TCP concentration in groundwater in the Merced Subbasin is generally between 0.005 µg/L and 1 µg/L (Figure 2-72), with elevated concentrations found in localized areas in the northwest quadrant and beneath the City of Merced. Note, however, that the typical detection limit of 0.5 µg/L is greater than the 0.005 µg/L MCL, meaning that non-detects could still indicate MCL exceedances. This indicates better lab analysis is needed for detection of 123-TCP at lower concentrations.

Time concentration plots of 123-TCP are shown in Appendix E.

Figure 2-72: 5-Year Average Distribution of 123-TCP in Groundwater (2007-2012)

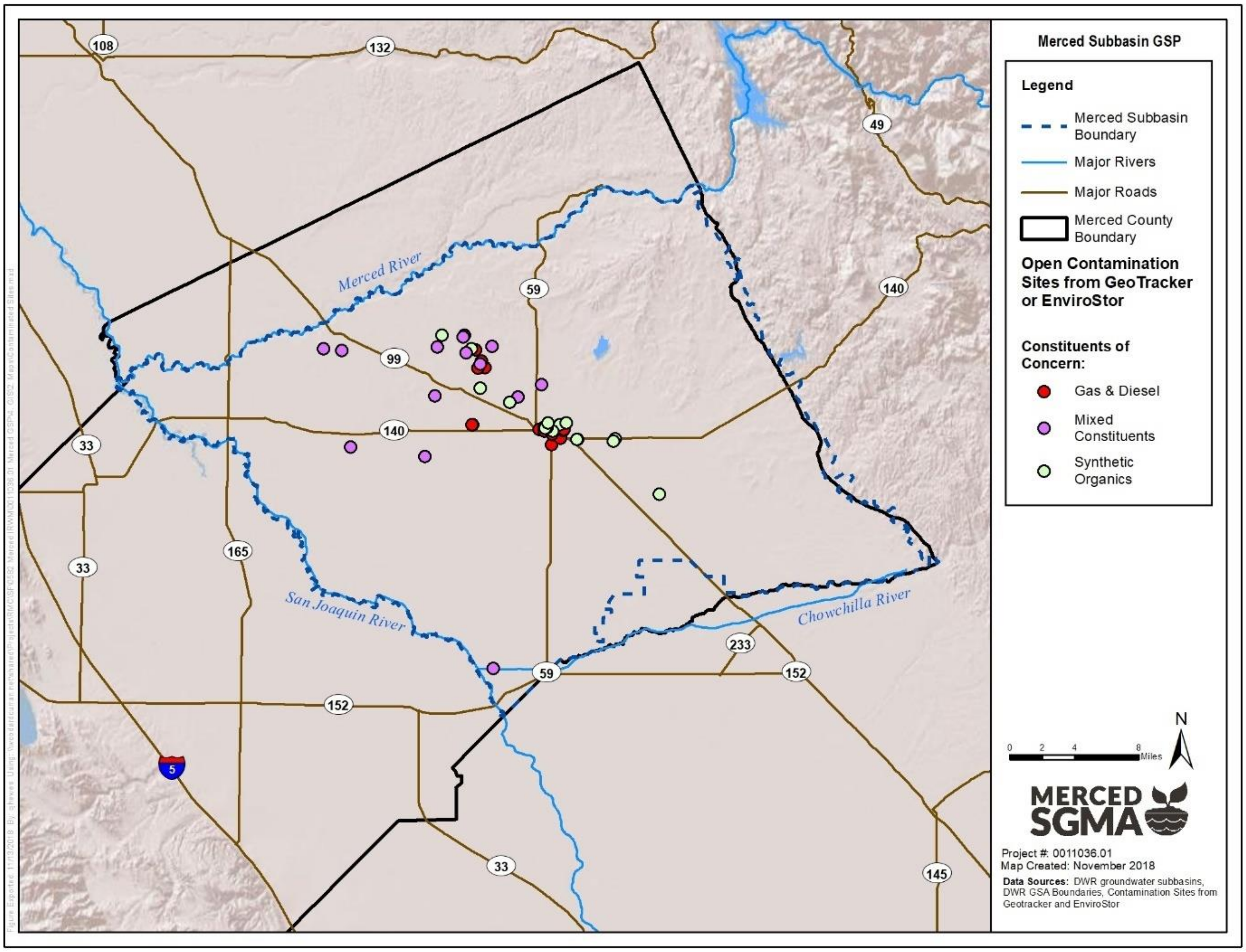


2.2.4.4 Point-Source Contamination

Data collection activities also take place in the Merced Subbasin in response to known or potential sources of groundwater contamination. These sources include areas in and around Castle Air Force Base, leaking underground storage tanks, landfills, and others. Groundwater has been monitored and evaluated at Castle Air Force Base since the 1980s and has resulted in the removal of contaminant sources and the implementation of remedial activities such as the installation of groundwater treatment facilities (SWRCB - GeoTracker).

The Regional Water Quality Control Board's (RWQCB) GeoTracker GAMA database shows 31 open Leaking Underground Storage Tank (LUST) or other cleanup sites with potential or known groundwater contamination located within the Merced Subbasin. The California Department of Toxic Substances Control (DTSC) EnviroStor database shows 21 additional open cleanup sites with potential or known groundwater contamination located within the Merced Subbasin. Figure 2-73 shows the location of the combined sites from GAMA and EnviroStor, color-coding the sites based on groupings of constituents of concern: gas and diesel, synthetic organics (pesticides, herbicides, etc.), or mixed constituents (multiple categories, such as heavy metals and pesticides).

Figure 2-73: Contaminated Sites (GeoTracker and EnviroStor)



2.2.4.4.1 Petroleum Hydrocarbons

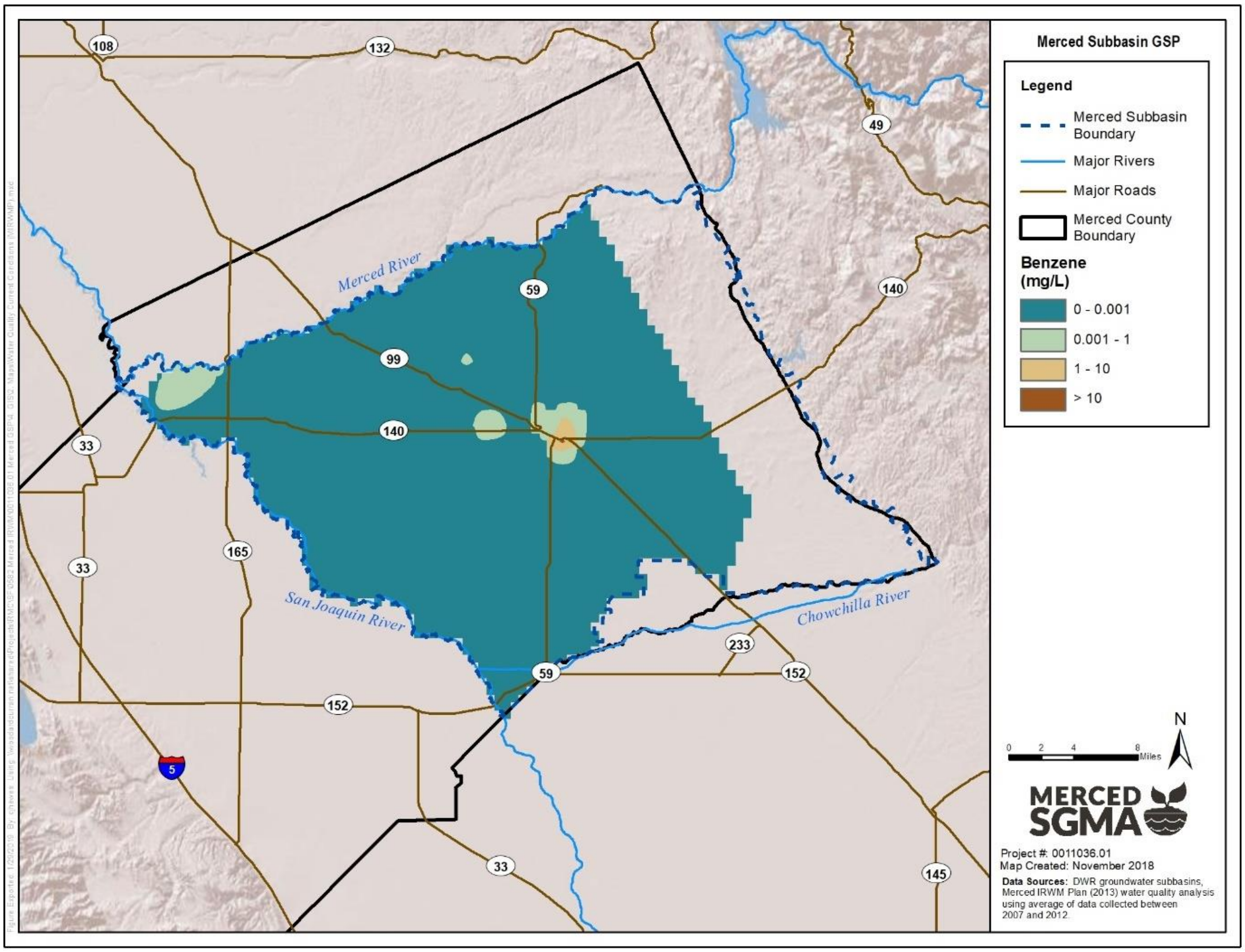
More than 150 unauthorized releases of petroleum hydrocarbons from underground storage tanks have occurred in the Merced Subbasin, according to the SWRCB GeoTracker database. The primary hydrocarbons of concern are benzene and MTBE, both of which are suspected carcinogens.

2.2.4.4.3 Benzene

Benzene concentrations in groundwater in the Merced Subbasin range from non-detect (variable, but typically less than 0.5 mg/L) to greater than 15,000 mg/L (Figure 2-74). The primary MCL for benzene is 0.001 mg/L (SWRCB, 2018). The 5-year average (2007-2012) benzene concentration in groundwater in the Merced Subbasin is generally less than 0.001 mg/L, with elevated concentrations found in localized urban areas along transportation corridors, including Highway 99 and Highway 140.

Time concentration plots of benzene are shown in Appendix E.

Figure 2-74: 5-Year Average Distribution of Benzene in Groundwater (2007-2012)

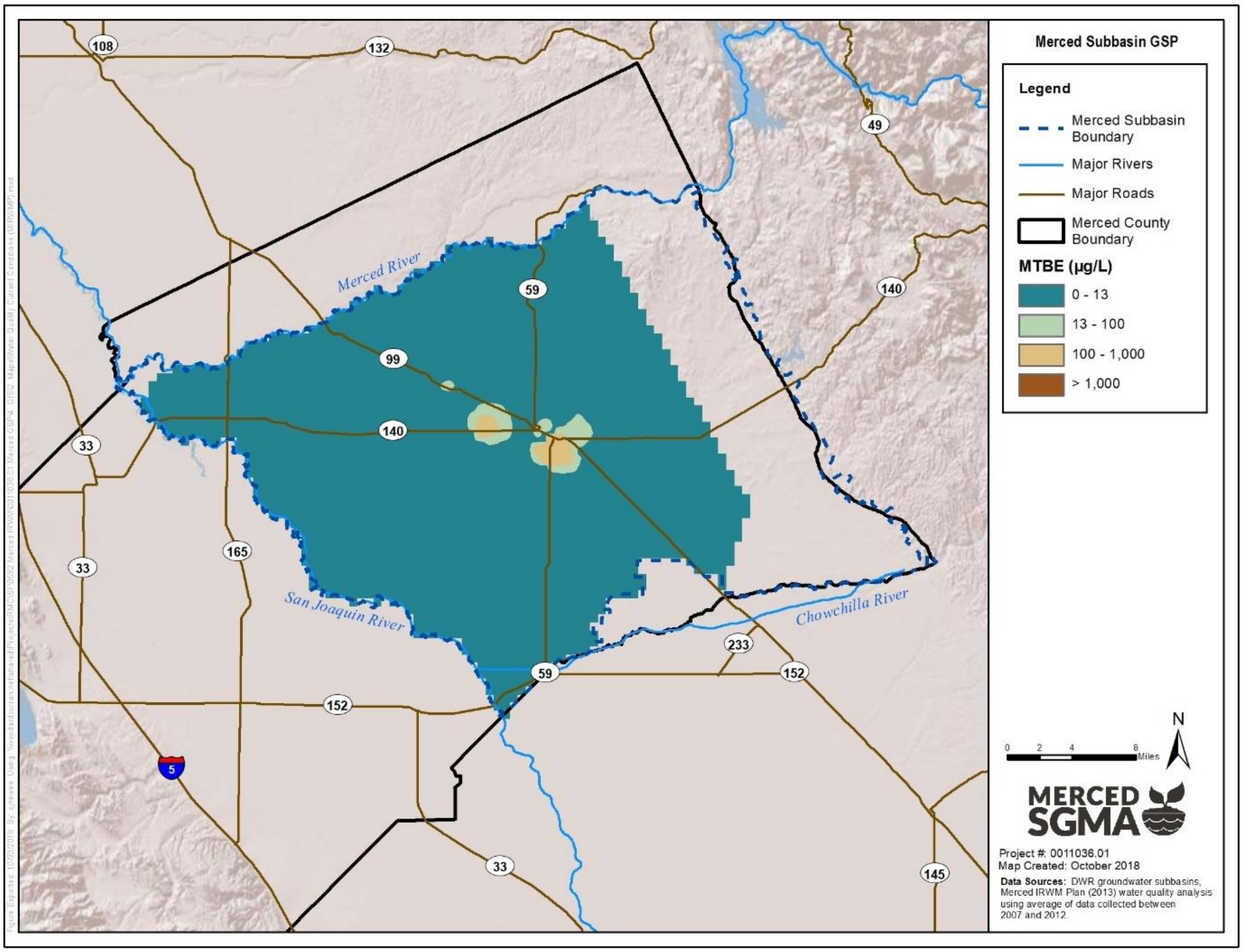


2.2.4.4.5 Methyl Tertiary Butyl Ether (MTBE)

MTBE concentrations in groundwater in the Merced Subbasin range from non-detect (variable, but typically less than 0.2 µg/L) to greater than 440,000 µg/L. The primary MCL for MTBE is 13 µg/L (SWRCB, 2018). The 5-year average (2007-2012) MTBE concentration in groundwater in the Merced Subbasin is generally less than 5 µg/L (Figure 2-75), with elevated concentrations generally found in localized urban areas along Highway 99.

Time concentration plots of MTBE are shown in Appendix E.

Figure 2-75: 5-Year Average Distribution of MTBE in Groundwater (2007-2012)



2.2.4.4.6 Solvents

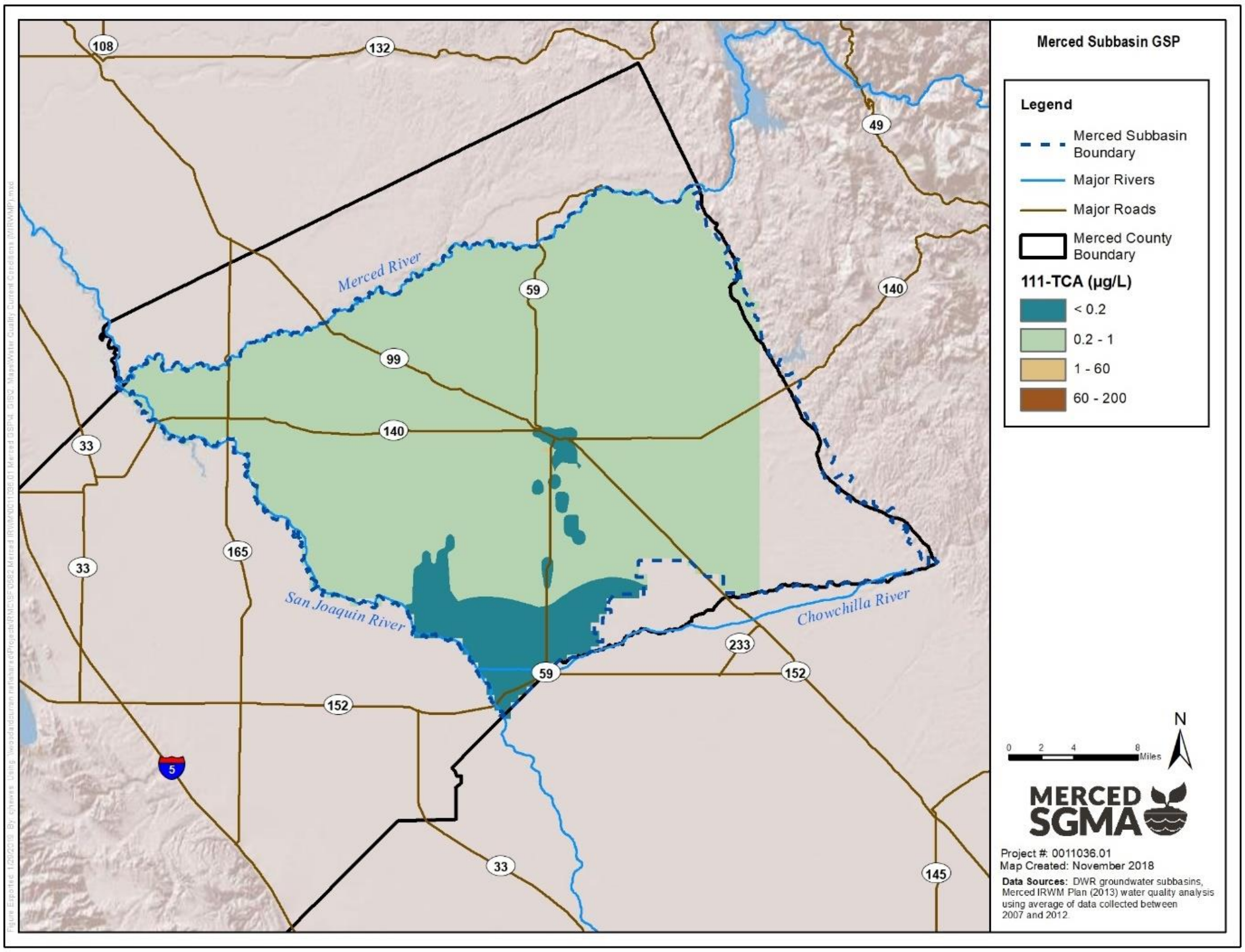
Solvents includes subsections for 1,1,1-Trichloroethane (111-TCA), Tetrachloroethylene (PCE), and Trichloroethylene (TCE).

2.2.4.4.7 1,1,1-Trichloroethane (111-TCA)

The VOC 111-TCA is a commonly used solvent utilized in manufacturing facilities, auto repair shops, and various other uses within the Merced Subbasin. 111-TCA concentrations in groundwater in the Merced Subbasin range from non-detect (variable, but typically 0.2 µg/L) to 60 µg/L. The primary MCL for 111-TCA is 200 µg/L (SWRCB, 2018). The 5-year average (2007-2012) 111-TCA concentration in groundwater in the Merced Subbasin is generally less than 1 µg/L (Figure 2-76).

Time concentration plots of 111-TCA are shown in Appendix E.

Figure 2-76: 5-Year Average Distribution of 111-TCA in Groundwater (2007-2012)

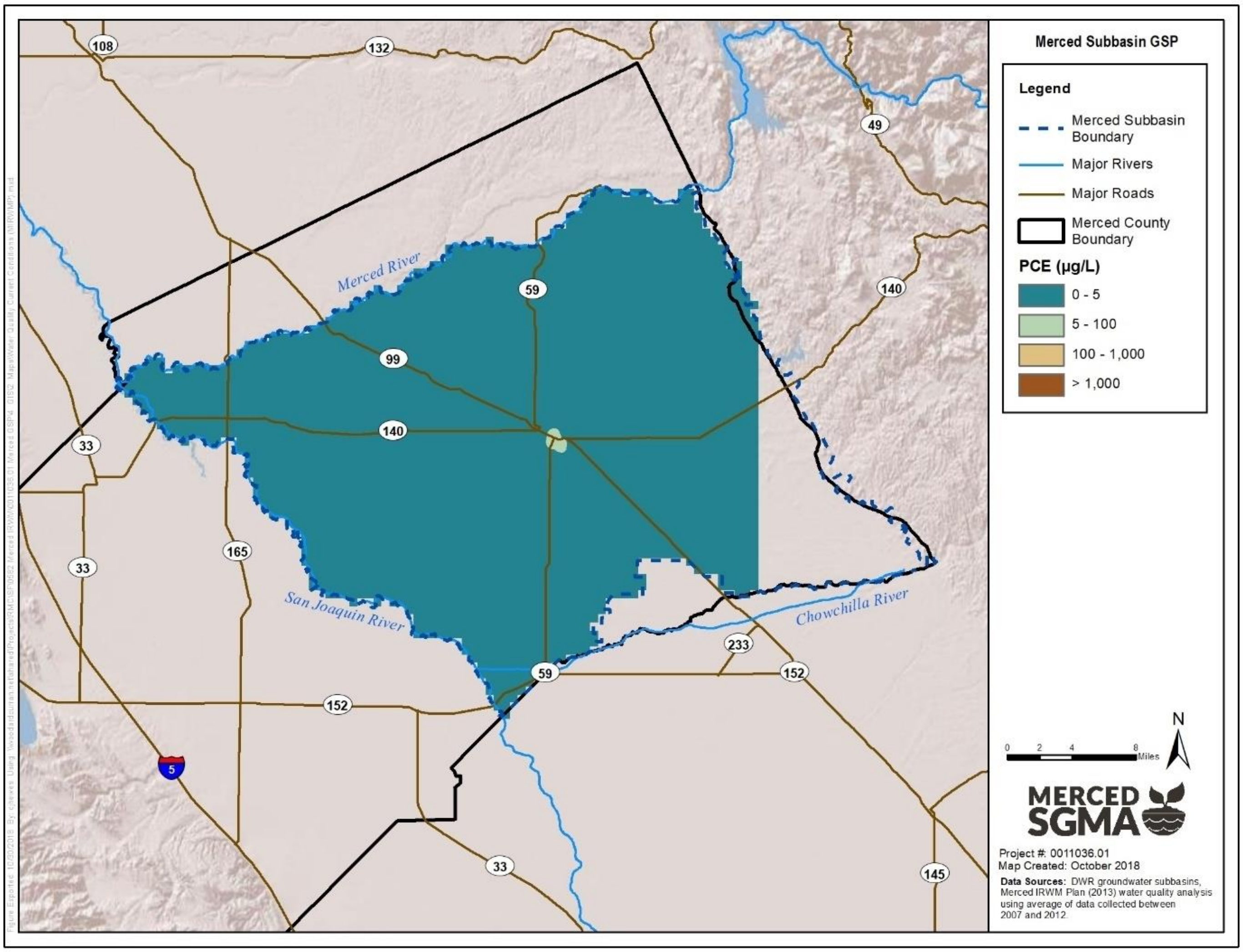


2.2.4.4.8 Tetrachloroethylene (PCE)

The VOC PCE is a commonly used solvent in manufacturing facilities and dry cleaners. PCE concentrations in groundwater in the Merced Subbasin range from non-detect (0.5 µg/L) to over 500 µg/L. The primary MCL for PCE is 5 µg/L (SWRCB, 2018). The 5-year average (2007-2012) PCE concentration in groundwater in the Merced Subbasin is generally less than 5 µg/L (Figure 2-77), with elevated concentrations found in localized areas in the northwest quadrant, beneath the City of Merced.

Time concentration plots of PCE are shown in Appendix E.

Figure 2-77: 5-Year Average Distribution of PCE in Groundwater (2007-2012)

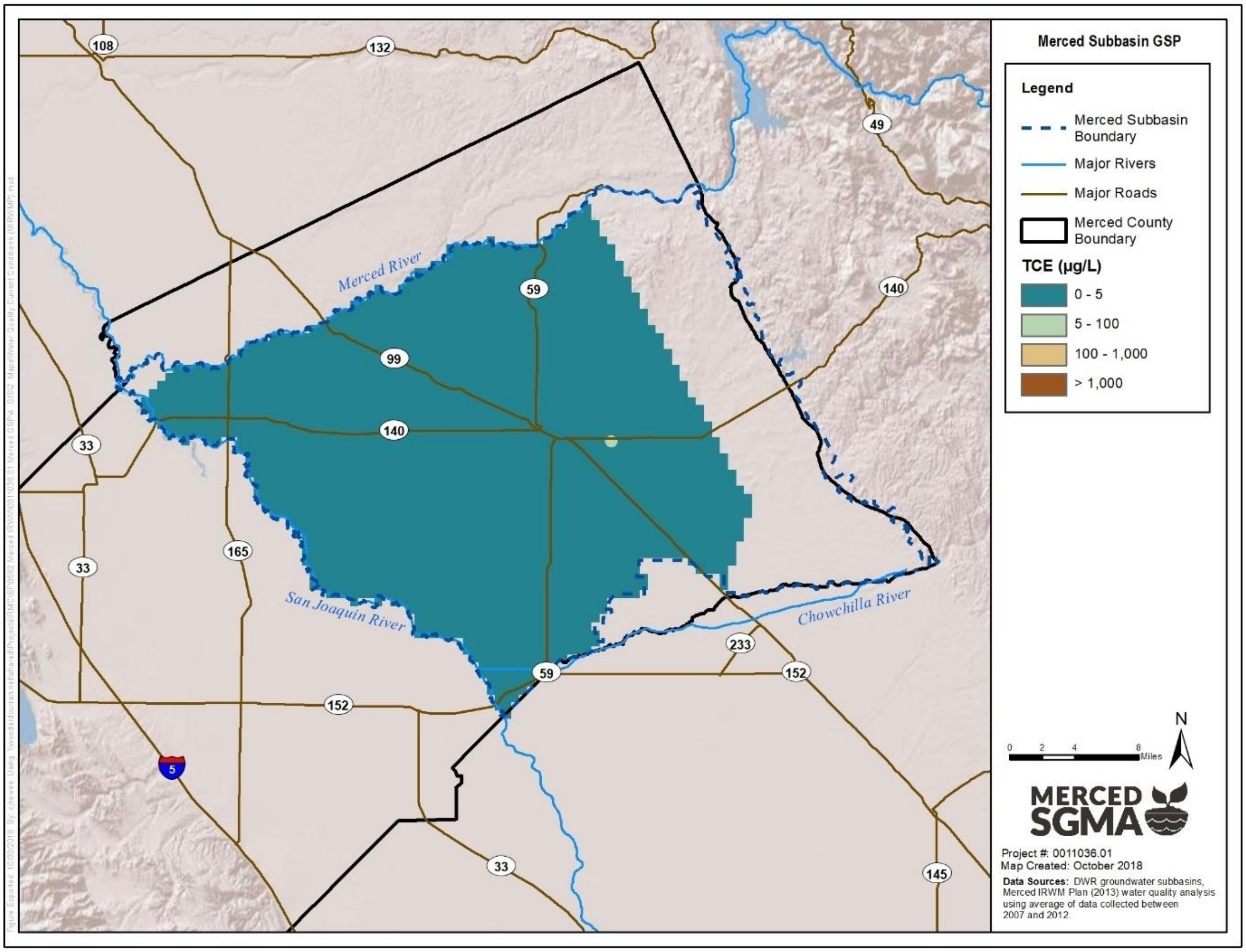


2.2.4.4.9 Trichloroethylene (TCE)

The VOC TCE is a commonly used solvent in manufacturing facilities. TCE concentrations in groundwater in the Merced Subbasin range from non-detect (0.5 µg/L) to over 800 µg/L. The primary MCL for TCE is 5 µg/L (SWRCB, 2018). The 5-year average (2007-2012) TCE concentration in groundwater in the Merced Subbasin is generally less than 5 µg/L (Figure 2-78). While not shown directly in the figure, the Merced IRWMP indicates that elevated concentrations can be found in localized areas in the northwest quadrant and along Highway 140 beneath a point source (RMC Water and Environment, 2013a).

Time concentration plots of TCE are shown in Appendix E.

Figure 2-78: 5-Year Average Distribution of TCE in Groundwater (2007-2012)



2.2.4.4.10 Emerging Contaminants

Many chemical and microbial constituents that have not historically been considered as contaminants are occasionally, and in some cases with increasing frequency, detected in groundwater. These newly recognized (or emerging) contaminants are commonly derived from municipal, agricultural, industrial wastewater, and domestic wastewater sources and pathways. These newly recognized contaminants are dispersed to the environment from domestic, commercial, and industrial uses of common household products and include caffeine, artificial sweeteners, pharmaceuticals, cleaning products, and other personal care products. Residual waste products of genetically modified organisms are also of potential concern. A recently completed survey for pharmaceuticals at dairies in the Merced Subbasin area by UC Davis and the USGS detected pharmaceuticals in shallow groundwater (Watanabe, Harter, and Bergamaschi, 2008 as cited by (AMEC, 2013)).

Perfluorooctanesulfonic acid (PFOS) and perfluorooctantoic acid (PFOA) are organic chemicals synthesized for water and lipid resistance, used in a wide variety of consumer products as well as fire-retarding foam and various industrial processes. These chemicals tend to accumulate in groundwater, though typically in a localized area in association with a specific facility, such as a factory or airfield (California Water Boards, 2018). There are currently no MCLs for PFOS or PFOA.

Currently, data on PFOS and PFOA is limited in the Merced Subbasin since these are emerging contaminants. However, according to the Geotracker database, both PFOA and PFOS have been detected at the Castle Air Force Base military cleanup sites. In 2004, USEPA and the State of California concurred that the Air Force was suitably implementing plume capture and cleanup which is still underway (SWRCB - GeoTracker).

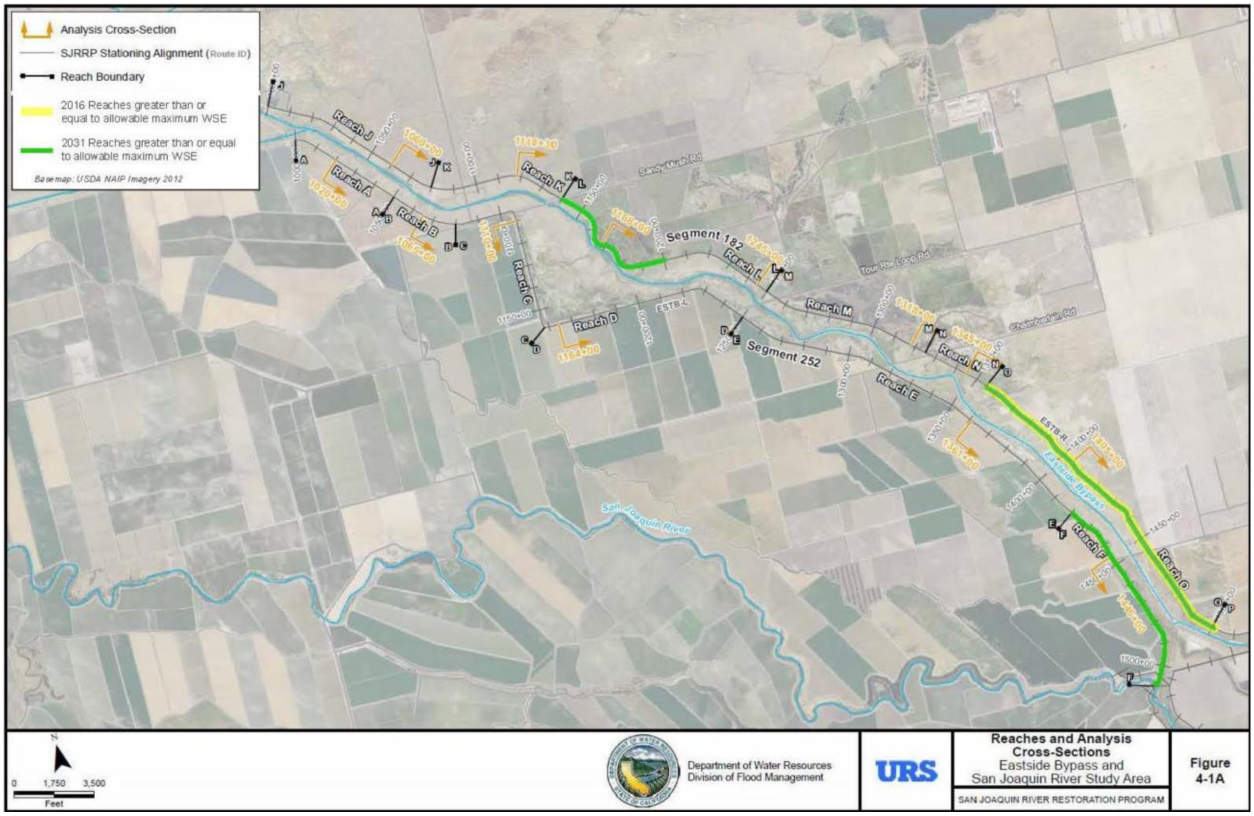
2.2.5 Land Subsidence

Land subsidence is a significant issue in the southwestern portion of the Subbasin and in the neighboring Delta-Mendota and Chowchilla Subbasins. While there are no extensometers in the area to provide data on the depths at which compaction is occurring, the subsidence is thought to be caused by groundwater extraction below the Corcoran Clay and compaction of clays below the Corcoran Clay (DWR, 2017b).

The transition from pasture or fallowed land to row and permanent crops adjacent to the San Joaquin River is thought to have created an increased groundwater pumping demand in an area that is not, at this time, serviced by an irrigation district or alternate surface water supply (Reclamation, 2016). This demand is thought to have resulted in recent increases in land subsidence along the river. The subsidence poses difficulties for local, state, and federal agencies with existing or planned infrastructure in the area (Reclamation, 2016).

The San Joaquin River Restoration Program's *2020 Channel Capacity Report* analyzed the impacts of future subsidence on the flow capacity of the Middle Eastside Bypass, which is located in the southwest corner of the Merced Subbasin. The analysis projected total subsidence from 2016 through 2031 by extrapolating average subsidence measured 2011-2018. It estimated that by 2031, three reaches will encroach upon or exceed the maximum allowable water surface elevation under 2,500 cfs conditions (see Figure 2-79), with indirect impacts on a fourth reach upstream (DWR, 2020). The flowrate is based on a SJRRP goal of having 2,500 cfs channel capacity by the end of 2024. In 2020, levee improvements were implemented in one of the three reaches to resolve flow capacity concerns which also eliminated the projected 2031 subsidence impacts in this particular reach (DWR & Reclamation, 2022). The *2022 Channel Capacity Report* stated that "…capacities through the Middle Eastside Bypass are equal to or greater than 2,600 cfs. However, because subsidence continues, the capacity will continue to be reduced over time" (DWR & Reclamation, 2022).

Figure 2-79: 2020 Channel Capacity Report Subsidence and Flow Capacity Analysis Findings



Source: (DWR, 2020)

Subsidence rates are variable, and highest during the drought period. Annual subsidence averaged up to 0.45 feet per year from December 2011 to December 2017, as shown in Figure 2-80 based on data from USBR's SJRRP (see description of program in Section 1.2.2.3 - Land Subsidence Monitoring). This relatively long period averages years of drought and years of normal or wet precipitation. Noting that these measurements incorporate both elastic and inelastic subsidence, the highest maximum annual rate of subsidence reported in Reclamation's regular mapping program was -0.67 feet per year, seen from December 2012 to December 2013 (see Figure 2-81), closely followed by -0.65 feet per year from December 2014 to December 2015. The lowest maximum annual rate of subsidence reported in Reclamation's regular mapping program was -0.18 feet per year, seen from December 2016 to December 2017 (see Figure 2-82).

Figure 2-80: Average Land Subsidence December 2011 – December 2017

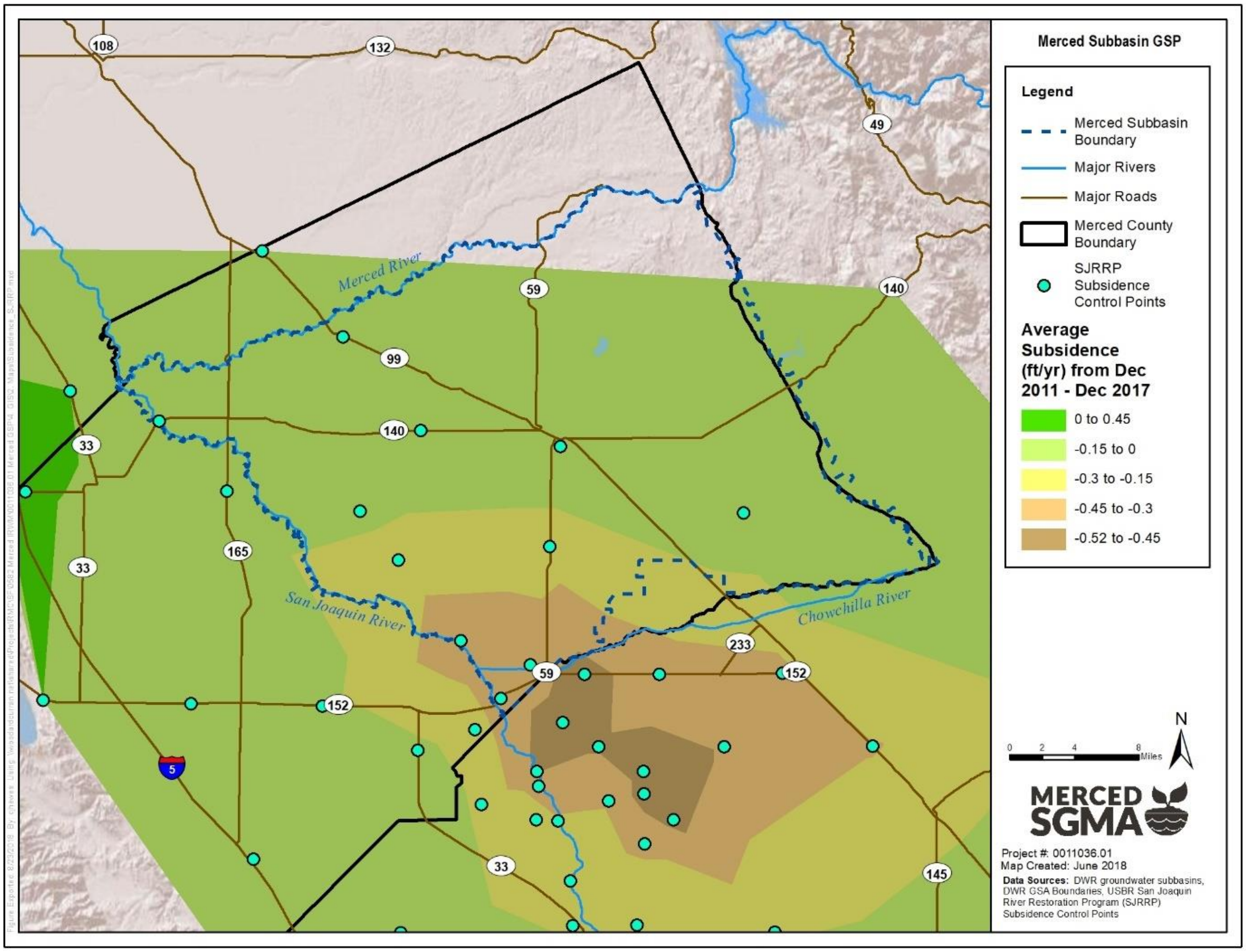


Figure 2-81: Land Subsidence December 2012 – December 2013

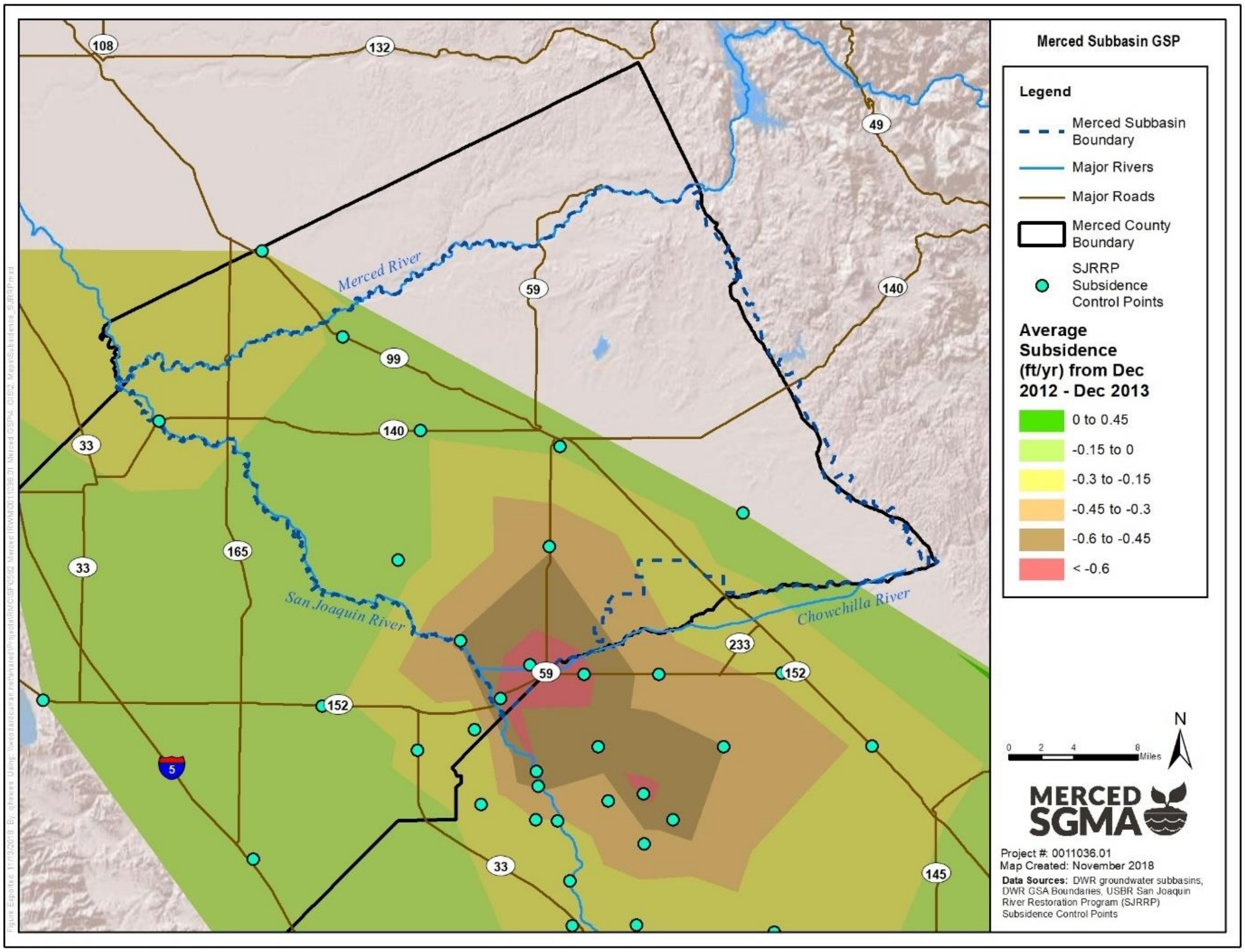
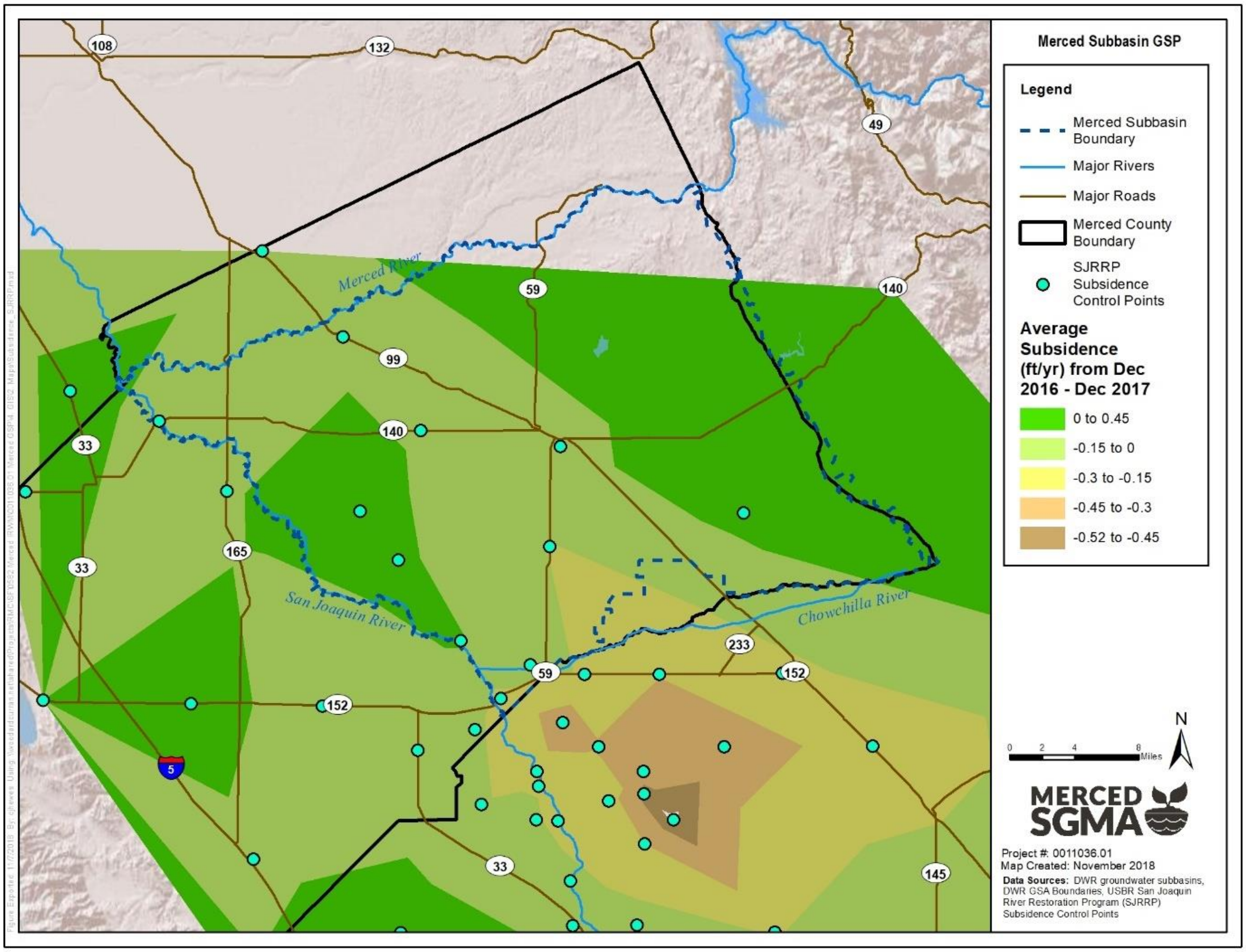


Figure 2-82: Land Subsidence December 2016 – December 2017



Subsidence in the southern corner of the Subbasin was compared against groundwater levels measured in the Below Corcoran Clay principal aquifer. Subsidence locations and historical land surface elevations measurements were obtained from two control points in the San Joaquin River Restoration Program. Historical groundwater elevations were obtained from two wells in the CASGEM program. Figure 2-83 shows a map of the four locations.

Figure 2-84 shows that at SJRRP point 156, subsidence has continued at a relatively steady pace from December 2011 until December 2016 where the decline in land surface elevation paused between December 2016 and December and 2017. At CASGEM well 371130N1205654W001, groundwater elevation increased during the same time period where subsidence halted. In this case, rising groundwater levels appear to have stabilized land subsidence.

Figure 2-85 shows that at SJRRP point 2065, subsidence has continued at a relatively steady pace from December 2011 through the most recent data point in December 2017. At CASGEM well 371852N1203899W001, groundwater elevation decreased from December 2011 through December 2015, showing a small net increase between December 2016 and December 2017. In this case, rising groundwater levels do not appear to have an impact on land subsidence, though groundwater levels fluctuated (i.e., was not a steady increase) during this time.

There are no additional available wells located in the Below Corcoran Clay Principal Aquifer with historical groundwater elevation data for further comparisons against SJRRP land subsidence data.

Figure 2-83: Map of Subsidence and Groundwater Well Comparison Points

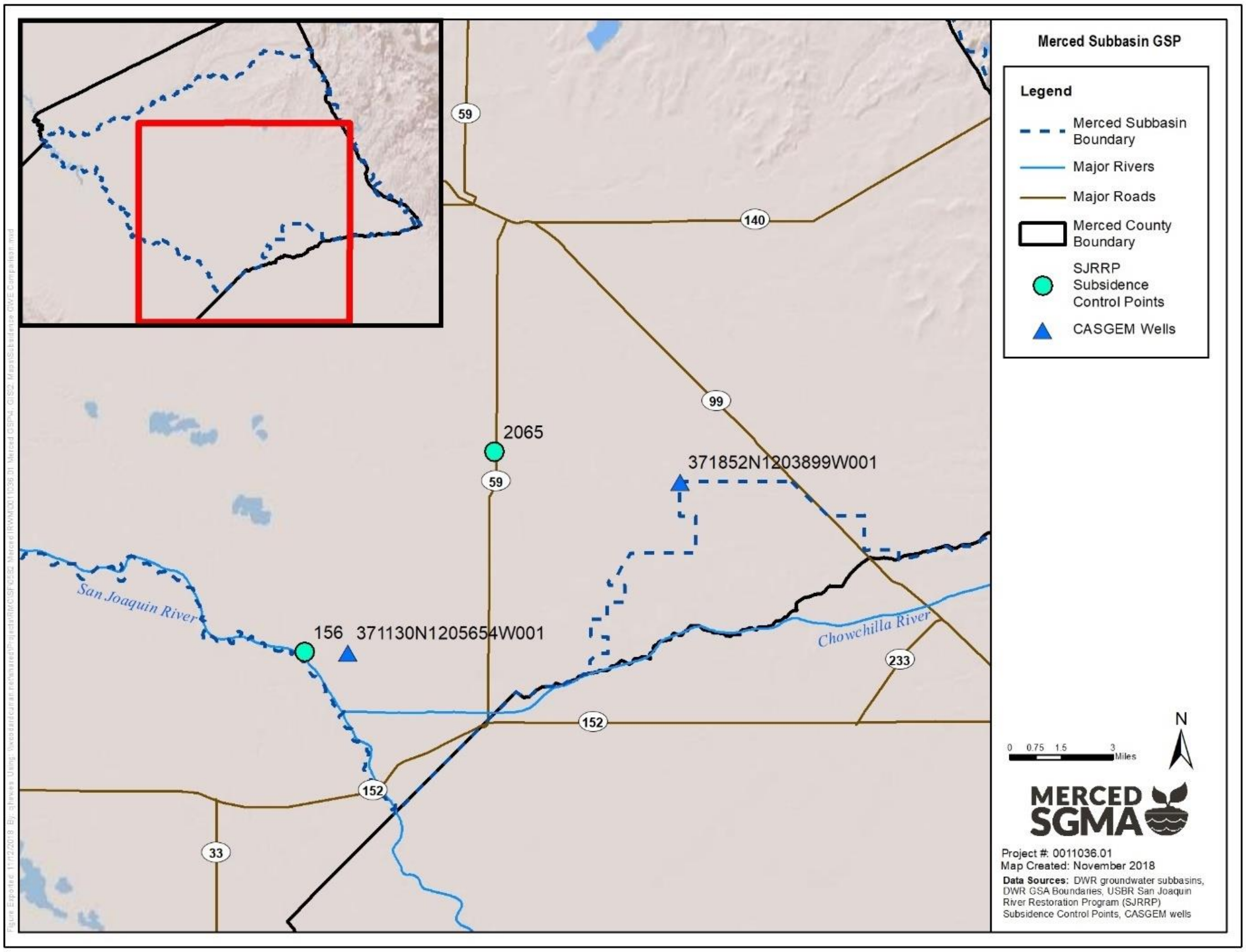


Figure 2-84: Subsidence vs Groundwater Elevation Comparison #1

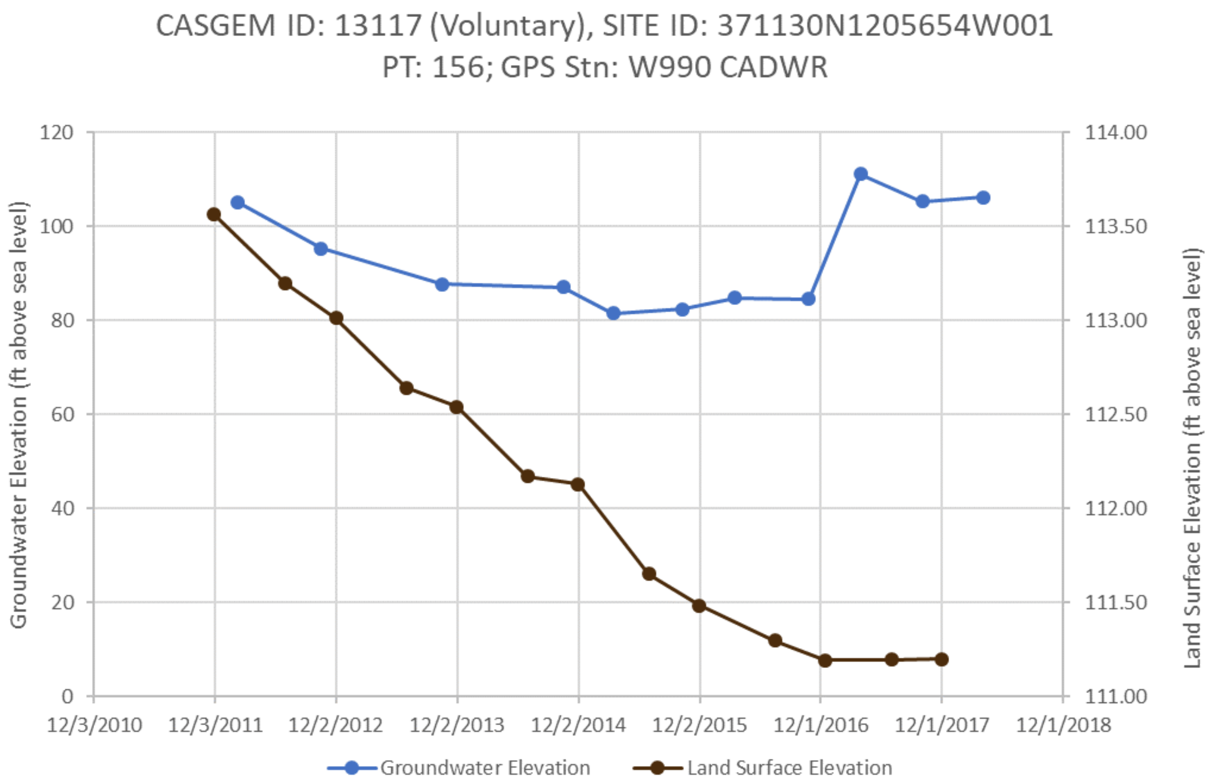
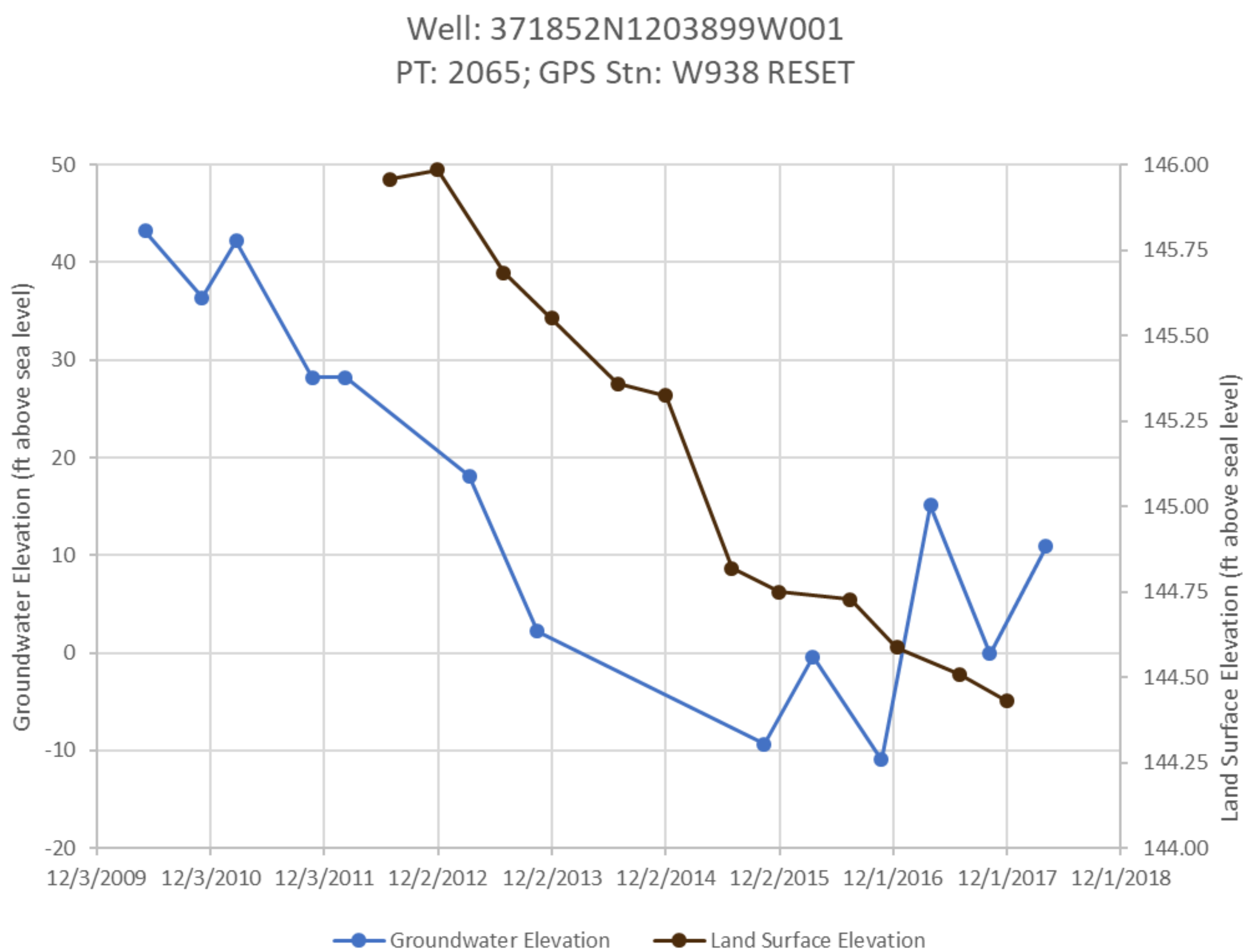


Figure 2-85: Subsidence vs Groundwater Elevation Comparison #2



2.2.6 Interconnected Surface Water Systems

Interconnected surface waters are surface water features that are hydraulically connected by a saturated zone to the groundwater system. In other words, where water table elevations and surface water features intersect at the same elevations and locations. Interconnected surface waters may be either gaining or losing, wherein the surface water feature is either gaining water from the aquifer system or losing water to outflowing into the aquifer system.

See Section 2.1.3.5 - Groundwater Recharge and Discharge Areas for identification of Interconnected/Disconnected streams (Figure 2-10) and Gaining/Losing streams (Figure 2-9). Increased losses or decreased gains (to either groundwater or stream systems) can be expected due to groundwater pumping adjacent to streams, but this is difficult to quantify. While the MercedWRM has been used to identify connections and disconnections (Figure 2-10) between the groundwater system and streams, depletions have not yet been calculated. There are no known field studies of interconnected surface water systems within the Subbasin.

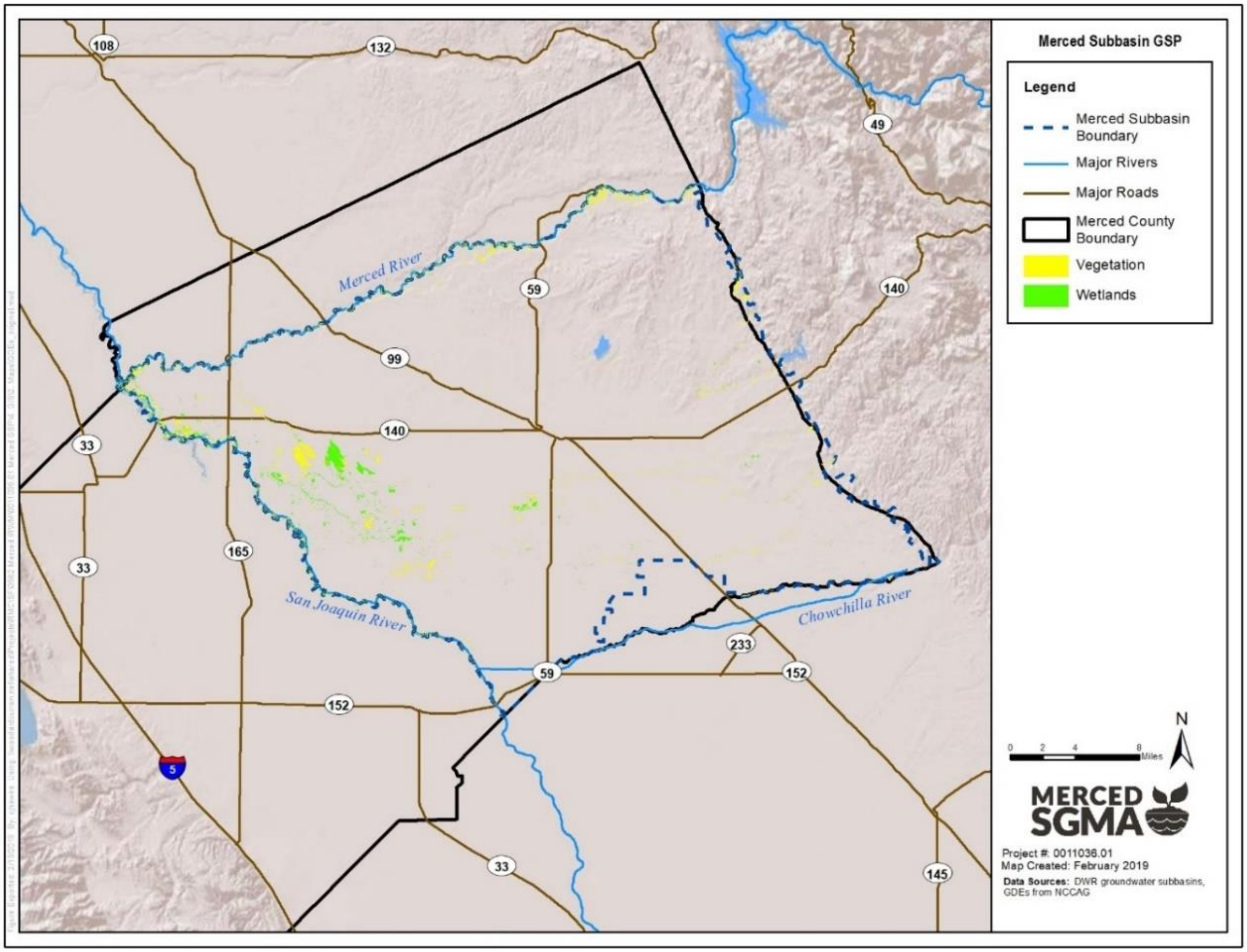
2.2.7 Groundwater-Dependent Ecosystems

Groundwater Dependent Ecosystems (GDEs) are defined in the SGMA regulations as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface". GDEs exist within the Merced Subbasin largely where vegetation accesses shallow groundwater for survival; without the access to shallow groundwater, these plants would die. GDEs were identified within the Merced Subbasin as areas dependent on groundwater.

Certain species of plants are commonly associated with groundwater use. However, the presence of these plants does not necessarily indicate that these are also GDEs. The identification of GDEs was performed by first identifying the types of plants that are often associated with accessing groundwater, then by identifying if those plants are dependent on groundwater, or if they can access alternate water supplies.

The Natural Communities Commonly Associated with Groundwater (NCCAG) database was used to identify plants commonly associated with groundwater use. The NCCAG database was developed by a working group comprised of DWR, California Department of Fish and Wildlife (CDFW), and The Nature Conservancy (TNC) by reviewing publicly available state and federal agency datasets that mapped California vegetation, wetlands, springs, and seeps and by conducting a screening process to retain types and locations commonly associated with groundwater. The results were compiled into the NCCAG database with two habitat classes defined. The first class includes wetland features commonly associated with the surface expression of groundwater under natural, unmodified conditions. The second class includes vegetation types commonly associated with the sub-surface presence of groundwater (phreatophytes). Figure 2-86 shows the locations identified by the NCCAG database within the Merced Subbasin.

Figure 2-86: Natural Communities Commonly Associated with Groundwater (NCCAG)



The next step in identifying GDEs was to analyze each GDE for groundwater dependence. This was performed by identifying NCCAG locations that are likely to have access to alternate water supplies. In the Merced Subbasin, areas with alternate water supplies are substantial, partly due to the fact that groundwater levels are already deep in most portions of the Subbasin, but also due to the availability of other water supplies that ecosystems are often able to access. Figure 2-87 shows the locations of NCCAG identified as not likely to be GDEs due to the presence of alternate water supplies and thus a lack of dependence on groundwater.

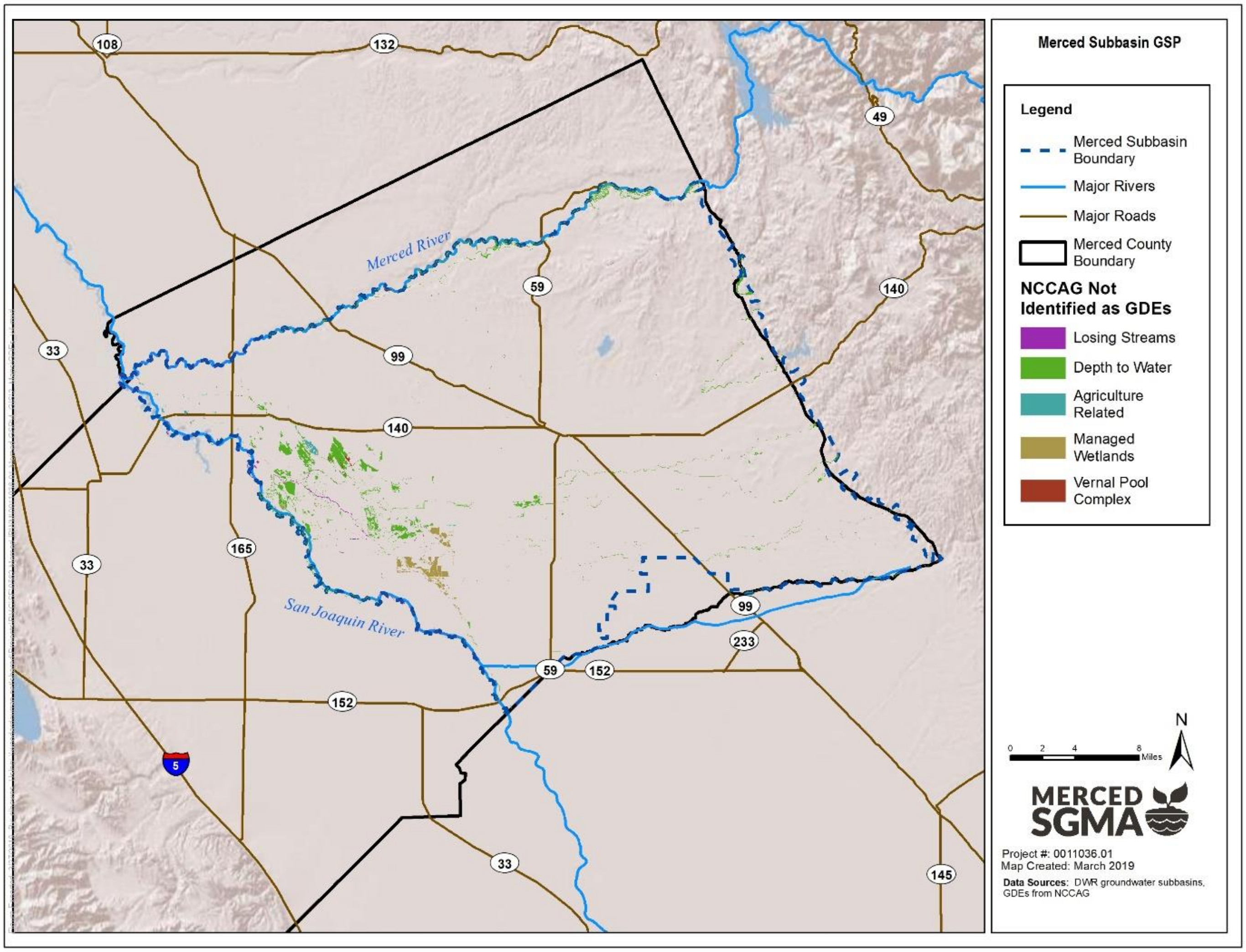
Noting that no land use protections are conveyed on GDEs or NCCAG through this document or other documents, the distinction between GDEs and NCCAG that are not GDEs is important from a management perspective. While NCCAG may have ecological value, management of groundwater may not be the most appropriate way to allow those communities to thrive. Instead, management of NCCAG may require more focus on changing land use or irrigation efficiencies more so than groundwater management. The rigorous analysis to identify GDEs was developed to focus groundwater management activities on the most appropriate areas.

The analysis was conducted by thorough review of aerial photographs from several sources across multiple years for all GDE areas as well as comparison against external databases, such as vernal pool complexes published by the California Department of Fish and Game. While many NCCAG areas were identified as not being GDEs, several GDEs not captured in the NCCAG database were digitized where a likely GDE was observed through this additional analysis.

NCCAG areas not identified as GDEs can be categorized as follows. The locations are shown in Figure 2-87 to support improved understanding of ecosystems in the Merced Subbasin.

1. **Areas with a depth to groundwater greater than 30 feet in Spring 2015** – Oak trees are considered the deepest-rooted plant in the region with a root zone of roughly 25 feet, and zones where the depth to water was deeper than 30 feet were excluded because they are unlikely to support vegetative growth. The 25-foot value is considered conservative, as this depth is unlikely to support recruitment of new oak seedlings. These areas are assumed to be accessing other water sources rather than groundwater that is inaccessibly deep. Thus, they are not identified as GDEs; these areas are represented as "Depth to Water" in Figure 2-87.
2. **Habitat areas with supplemental water** – Managed wetlands were identified and reviewed with local water managers to verify supplemental water deliveries. These areas are assumed to be accessing supplemental water deliveries and not reliant on groundwater. Thus, they are not identified as GDEs; these areas are represented as "Managed Wetlands" in Figure 2-87. A substantial portion of this area overlaps with the Merced National Wildlife Refuge which receives an average 11,000 AFY of surface water (2009-2013), with reduced deliveries during drought (100 to 4,000 AFY during 2014-2016).
3. **Areas adjacent to irrigated fields** – Agricultural lands are dependent on reliable water supplies to ensure a successful harvest and substantial surface water or deeper groundwater is used to irrigate crops in the Merced Subbasin. Such irrigation benefits not only the crops, but also surrounding vegetation. These areas are assumed to be accessing irrigation water. Thus, they are not identified as GDEs. Aerial photography was used to examine and determine if vegetated areas were adjacent to irrigated fields or drainage canals. These areas are identified as "Agriculture Related" in Figure 2-87**.**
4. **Areas depending on adjacent losing surface water bodies** – Losing streams are streams that recharge the groundwater system. This requires groundwater levels that are lower than stage in the stream and that are progressively lower away from the stream. These areas are assumed to be accessing water flowing out of the stream. Areas with losing streams were identified using the MercedWRM (see Section 2.1.3.5 - Groundwater Recharge and Discharge Areas); NCCAG within 300 feet of losing stream areas were assumed to not be GDEs. Areas depending on adjacent losing surface water are represented as "Losing Streams" in Figure 2-87.
5. **Areas of vernal pool complexes** – Vernal pools are shallow, intermittently flooded wetlands. They typically appear in winter due to rainfall and evaporate completely by summer and fall. Vernal Pool Complexes were identified based on the "Vernal Pool Complexes – Central Valley, 1989-1998" dataset published by the California Department of Fish and Game. Vernal pools are dependent on rainfall-fed, extremely shallow groundwater conditions not directly connected with the deeper aquifer system, thus these areas are not dependent on groundwater and are not identified as GDEs. These areas are represented as "Vernal Pool Complexes" in Figure 2-87.

Figure 2-87: NCCAG Not Identified as GDEs



Based on the analysis, areas were identified as likely GDEs. These areas are shown "Likely GDEs – NCCAG Vegetation" and "Likely GDEs - NCCAG Wetland" in two regions within the Subbasin. Figure 2-88 shows likely GDEs at the confluence of the Merced and San Joaquin Rivers while Figure 2-89 shows likely GDEs in the region of the southern portion of the San Joaquin River within the Merced Subbasin.

Figure 2-88: Likely GDEs – Confluence of Merced and San Joaquin Rivers

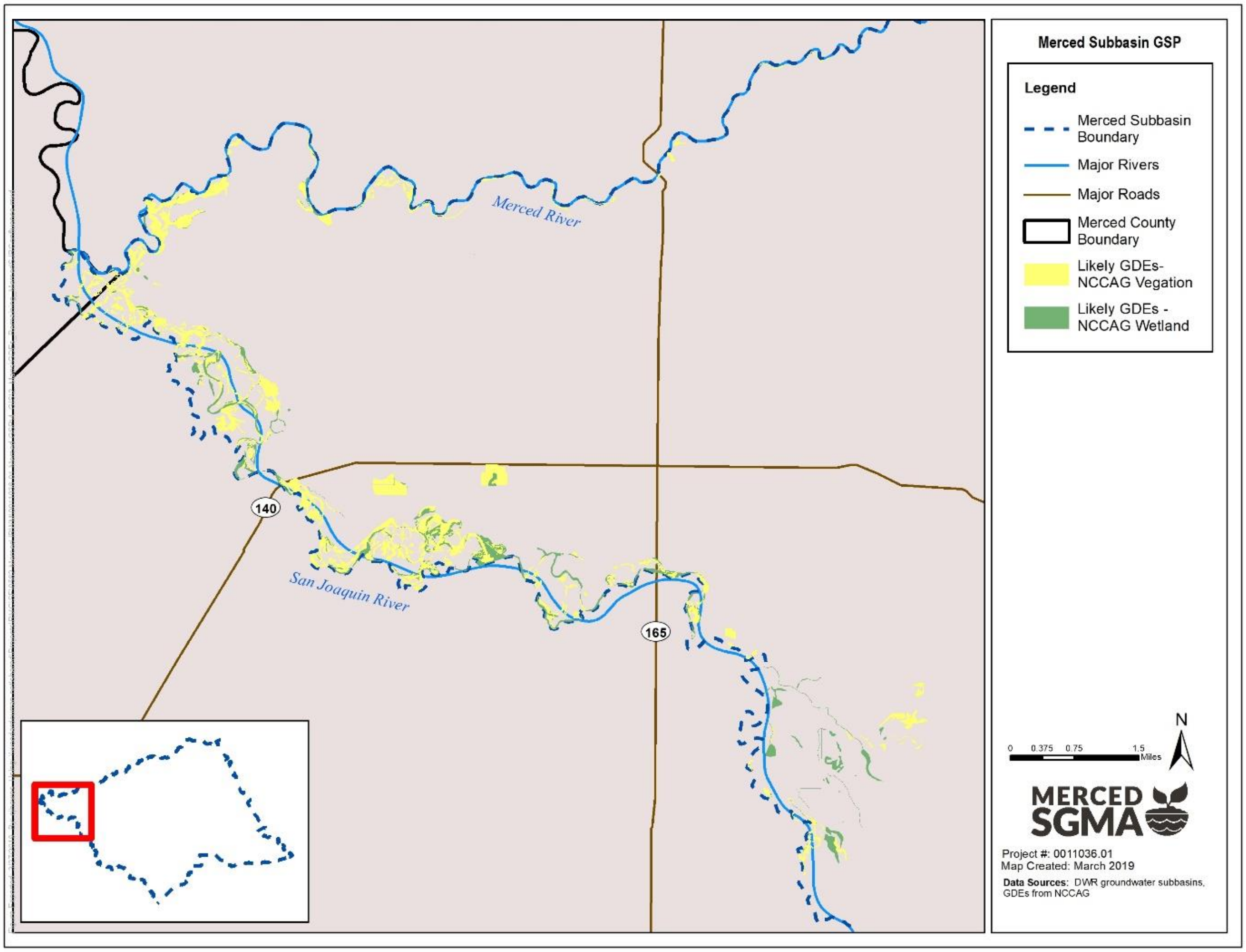
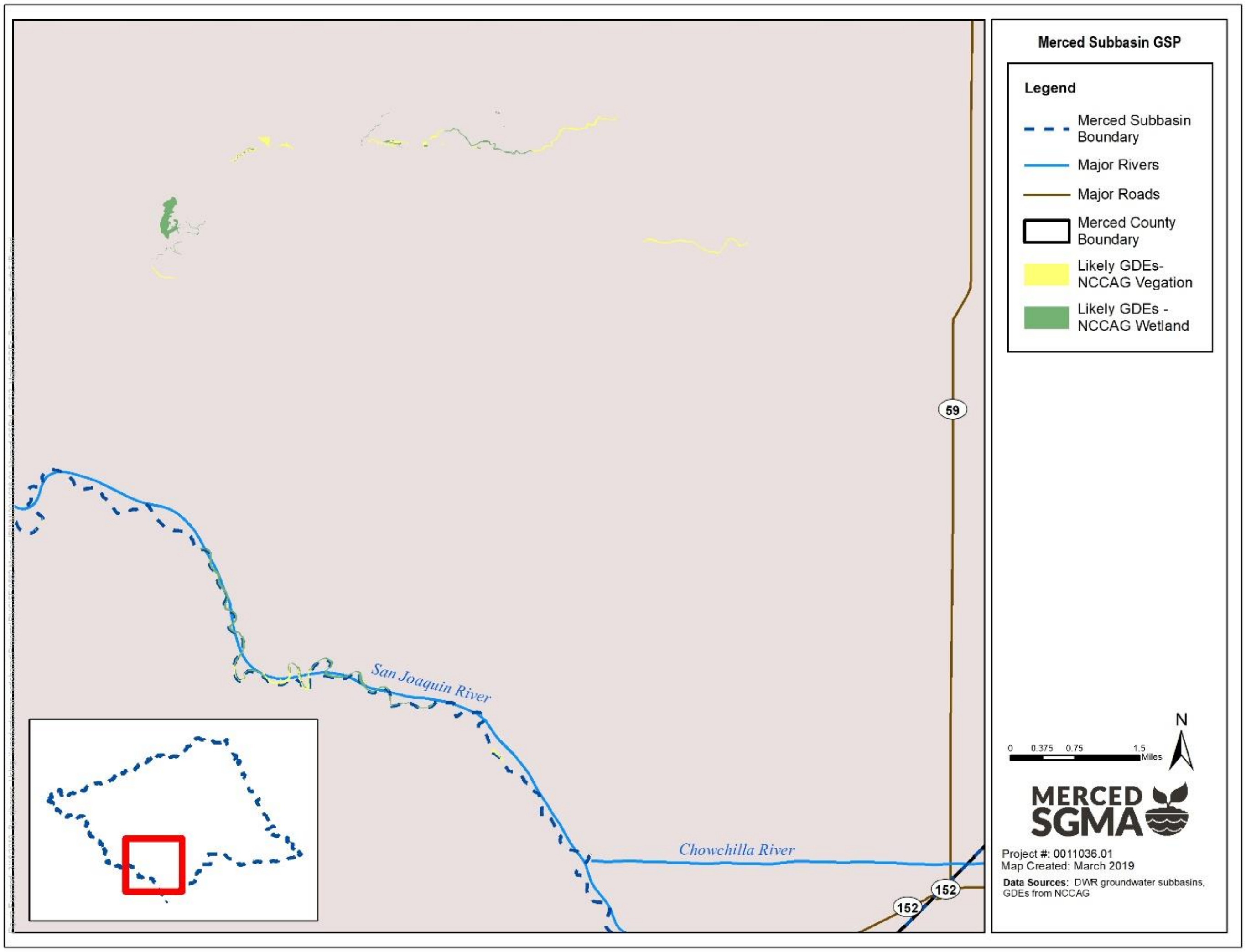


Figure 2-89: Likely GDEs – South Region of San Joaquin River

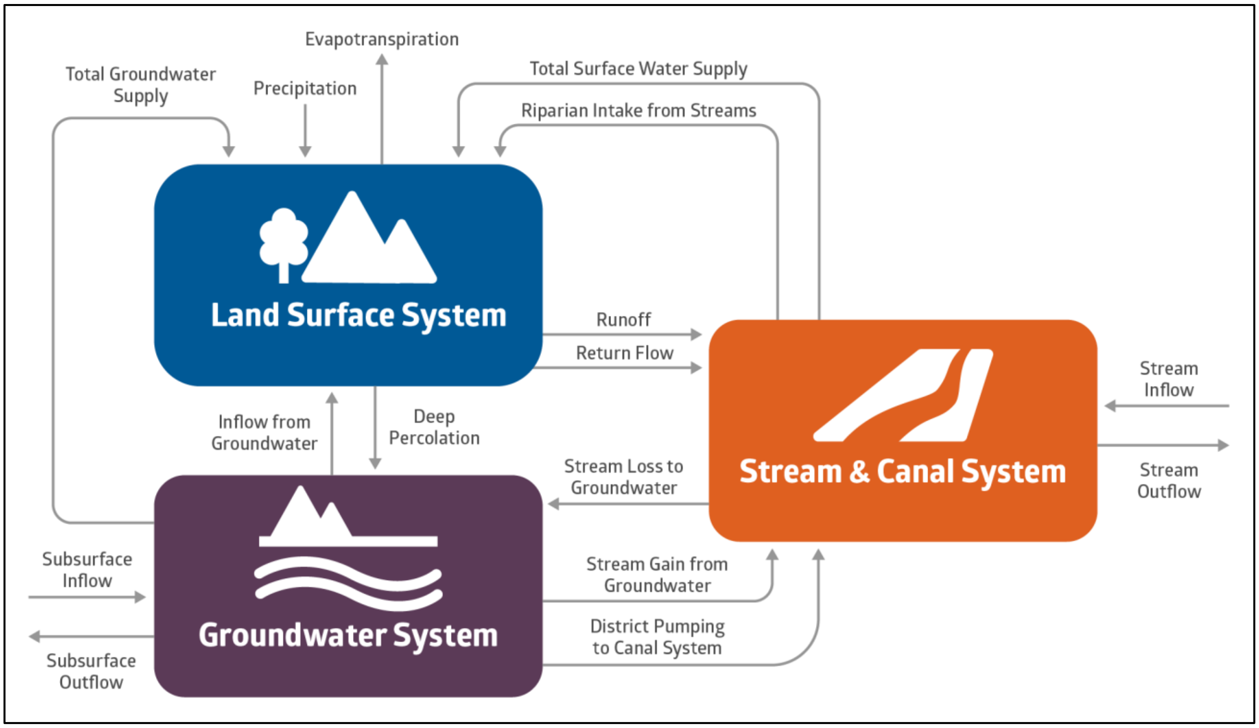


2.3 WATER BUDGET INFORMATION

Water budgets were developed to provide a quantitative account of water entering and leaving the Merced Subbasin. Water entering the Subbasin includes water entering at the surface and through the subsurface. Similarly, water leaving the Subbasin leaves at the surface and through the subsurface. Water enters and leaves naturally, such as precipitation and streamflow, and through human activities, such as pumping and recharge from irrigation. Figure 2-90 highlights the interconnectivity of stream, surface, and groundwater components of the natural and human related hydrologic system used in this analysis.

The values presented in the water budget provide information on historical, current, and projected conditions as they relate to hydrology, water demand, water supply, land use, population, climate change, sea level rise (not applicable in the Merced Subbasin), groundwater and surface water interaction, and subsurface groundwater flow. This information can assist in management of the Subbasin by identifying the scale of different uses, highlighting potential risks, and identifying potential opportunities to improve water supply conditions, among others.

Figure 2-90: Generalized Water Budget Diagram



Water budgets can be developed on different scales. In agricultural use, water budgets may be limited to the root zone, improving irrigation techniques by estimating the inflows and outflows of water from the upper portion of the soil accessible to plants through their roots. In a pure groundwater study, water budgets may be limited to water flow within the subsurface, aiding in understanding how water flows beneath the surface. Global climate models simulate water budgets that incorporate atmospheric water, allowing for simulation of climate change conditions. In this document, consistent with the Regulations (California Code of Regulations), the water budgets investigate the combined land surface, stream, and groundwater systems, specifically for the Merced Subbasin.

Water budgets can also be developed at different temporal scales. Daily water budgets may be used to demonstrate how evaporation and transpiration increase during the day and decrease at night. Monthly water budgets may be used to demonstrate how groundwater pumping increases in the dry, hot summer months and decreases in the cool, wet winter months. In this document, consistent with the Regulations, water budgets are represented based on water year (WY), with some consideration to monthly variability.

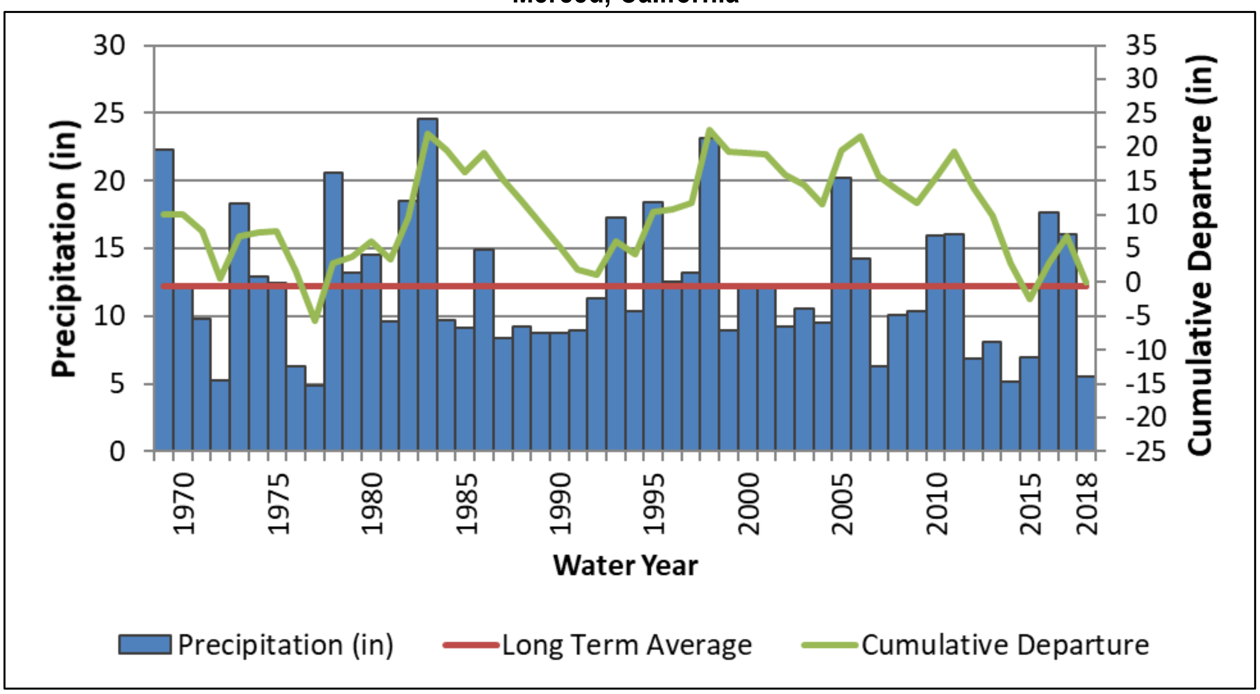
The Regulations require the annual water budgets be based on three different levels of development: historical, current, and projected conditions. Budgets are developed to capture typical conditions during these time periods. Typical conditions are developed through averaging hydrologic conditions that incorporate droughts, wet periods, and normal periods. By incorporating these varied conditions within the budgets, analysis of the system under certain hydrologic conditions, such as drought, can be performed along with analysis of long-term averages. Information is provided in the following subsections on the hydrology dataset used to identify time periods for budget analysis, the usage of the MercedWRM and associated data in water budget development, and on the budget estimates.

2.3.1 Identification of Hydrologic Periods

Hydrologic periods were selected to meet the needs of developing historical, current, and projected water budgets. The Regulations require that the projected water budget incorporate a 50-year hydrologic period, in order to reflect long-term average hydrologic conditions. Precipitation for the Merced Subbasin was used to identify hydrologic periods that would provide a representation of wet and dry periods and long-term average conditions needed for water budget analyses.

Rainfall data for the Subbasin is derived from the PRISM (Precipitation-Elevation Regressions on Independent Slopes Model) dataset of the DWR's California Simulation of Evapotranspiration of Applied Water (CALSIMETAW) model. Identification of periods with a balance of wet and dry periods was performed by evaluating the cumulative departure from mean precipitation. Under this method, the long-term average precipitation is subtracted from annual precipitation within each water year to develop the departure from mean precipitation for each water year. Wet years have a positive departure and dry years have a negative departure; a year with exactly average precipitation would have zero departure. Starting at the first year analyzed, the departures are added cumulatively for each year. So, if the departure for Year 1 is 5 inches and the departure for Year 2 is -2 inches, the cumulative departure would be 5 inches for Year 1 and 3 inches (5 plus -2) for Year 2. A chart is used to graphically illustrate the cumulative departure from mean precipitation within the Merced Subbasin (Figure 2-91). The chart includes bars displaying annual precipitation for each water year from 1969 through 2018 and a horizontal line representing the mean precipitation of 12.3 inches which varies only slightly from the full period of record (1922-2018) average of 12.0 inches. The cumulative departure from mean precipitation is displayed as a line that starts at zero and highlights wet periods with upward slopes and dry periods with downward slopes. More severe events are shown by steeper slopes and greater changes. Thus, the period from 1976 to 1977 illustrates a short period with dramatically dry conditions (13-inch decline in cumulative departure over 2 years).

Figure 2-91: 50-Year Historical Precipitation and Cumulative Departure from Mean Precipitation, Merced, California



2.3.2 Usage of the MercedWRM and Associated Data in Water Budget Development

Water budgets were developed utilizing the MercedWRM, a fully integrated surface and groundwater flow model covering approximately 1,500 square miles of the Merced Groundwater Region (Region), which fully encompasses the Merced Subbasin plus the Dry Creek watershed North of the Merced River and the section of Chowchilla Water District north of the Chowchilla River. The MercedWRM, a quasi-three-dimensional finite element model, was developed using the Integrated Water Flow Model (IWFM) 2015 software package to simulate the relevant hydrologic processes prevailing in the Region. The MercedWRM integrates the groundwater aquifer with the surface hydrologic system and land surface processes and operations. Using data from federal, state, and local resources, the MercedWRM was calibrated for the hydrologic period of October 1995 to September 2015 by comparing simulated evapotranspiration, groundwater levels, and streamflow records with historical observed records. Development of the model involved the study and analyses of hydrogeologic conditions, agricultural and urban water demands, agricultural and urban water supplies, and an evaluation of regional water quality conditions (Woodard & Curran, 2019). Additional information on the data used to develop the MercedWRM are included as Appendix D.

All groundwater models contain assumptions and some level of uncertainty. They are decision support tools used to better understand complex interactive systems. Sources of model uncertainty include heterogeneity in hydrogeologic properties and stratigraphy, quality of historical data, projections of future land use, hydrology, and climate. The MercedWRM model has been calibrated and validated. Inputs for GSP-related modeling runs used the best available data and science. Projections of future land use and water demands were based on the most recent planning documents prepared by agencies in the Subbasin. The model in its current form represents the best available representation of the basin. As additional information is collected during GSP implementation, the model will be updated to reflect the newly available data. Efforts to address basin data gaps will improve information available for the model.

With the MercedWRM as the underlying framework, model simulations were developed to allow for the estimation of water budgets. Three model simulations were used to develop the water budgets for historical, current, and projected conditions, which are discussed in detail below:

- The **historical water budget** is based on a simulation of historical conditions in the Merced Subbasin.
- The **current water budget** is based on a simulation of current (2015) land and water use over historical hydrologic conditions, assuming no other changes in population, water demands, land use, or other conditions.
- The **projected water budget** is based on a simulation of future land and water use over the historical hydrologic conditions.

2.3.3 Water Budget Definitions and Assumptions

Definitions and assumptions for the historical, current, and projected water budgets are provided below.

2.3.3.1 Historical Water Budget

The historical water budget is intended to evaluate availability and reliability of past surface water supply deliveries, aquifer response to water supply, and demand trends relative to water year type. The historical calibration of the MercedWRM was last updated to reflect the historical conditions in the Merced Subbasin through WY 2015. The hydrologic period of WY 2006 through 2015 is selected for the GSP historical water budget based on input from the stakeholder and coordinating committees, because it provides a period of representative hydrology, while capturing recent Subbasin operations, particularly the 2005 consolidation of El Nido Irrigation District into the MID service area. The period WY 2006 through 2015 has an average annual precipitation of approximately 10.0 inches, compared to the long-term average of 12.2 inches and includes the recent 2012-2015 drought, the wetter years of 2010-2011, and periods of normal precipitation.

As WYs 1996-2015 were used to develop and calibrate the MercedWRM, along with being a longer period of hydrology, a 20-year period is also included in the detailed tables below for comparative purposes. Additional details of the data used in the development of the historical calibration model are included in Appendix D.

2.3.3.2 Current Water Budget

While a budget indicative of current conditions could be developed using the most recent historical conditions, like the historical water budget (1996-2015), such an analysis would be difficult to interpret due to the drought conditions of the 2012-15 and its effect on local agricultural operations. Instead, in order to analyze the long-term effects of current land and water use on groundwater conditions and to accurately estimate current inflows and outflows for the basin, a Current Conditions Baseline scenario is developed using the MercedWRM. This baseline applies current land and water use conditions to historical hydrology over a 50-year period of 1969-2018.

The Current Conditions Baseline includes the following conditions:

- Hydrologic period:
    - WY 1969-2018 (50-year hydrology)
- River flow is based on:
    - Merced River: MercedSIM releases from New Exchequer under the 2018 Federal Energy Regulatory Commission (FERC) Requirements
    - San Joaquin River and Local Tributaries: historical records from USGS, CDEC, MID stream gauges, and the simulation of small-stream watersheds
- Land use is based on:
    - 2013 USDA CropScape Cropland Data Layer (CDL), which reflects the pre-drought conditions
    - Local ground truthing and refinement
- Urban water demand is based on:
    - 2015 demands as reported in the 2015 Urban Water Management Plans (UWMPs)
        - For regions outside of the UWMP boundaries, population (by US Census tract) was multiplied by the average 2015 per-capita demands across all UWMP regions. For example, the average gallons per capita per day (GPCD) for Merced (276 GPCD), Atwater (300 GPCD), and Livingston (467 GPCD) were averaged to 348 GPCD for non-city regions.
    - Municipal pumping records
- Agricultural water demand is based on:
    - The IWFM Demand Calculator (IDC) in conjunction with historical remote sensing technology, Mapping Evapotranspiration at High Resolution and Internalized Calibration (METRIC)
- Surface water deliveries are based on data from:
    - Merced Irrigation District (MID)
    - Stevinson Water District (SWD)

- Merquin County Water District (MCWD)
- Turner Island Water District (TIWD)
- Lone Tree Mutual Water Company (LTMWC)

2.3.3.3 Projected Water Budget

The projected water budget is intended to assess the conditions of the Subbasin under estimates of projected water supply, agricultural demand and urban demand, including quantification of uncertainties in the projected water budget components. The Projected Conditions Baseline applies future land and water use conditions to the 50-year hydrologic period of WY 1969-2018. The first twenty-five years of the Projected Conditions Baseline is assumed to be the early implementation period of the GSP, and is represented using current conditions; years 2040 and beyond are represented using projected population (General Plans), land use (General Plans), and water demand and supply projections (AWMP/UWMPs).

The Projected Conditions Baseline includes the following conditions:

- Hydrologic period:
  - WY 1969-2018 (50-year hydrology)
- River flow is based on:
  - Merced River: MercedSIM releases from New Exchequer under FERC Final Environmental Impact Statement (FEIS) Requirements
  - San Joaquin River and Local Tributaries: historical records from USGS, CDEC, MID stream gauges, and the simulation of small-stream watersheds
- Land use is based on:
  - 2013 USDA CDL
  - 2015 Agricultural Water Management Plan projections
  - Direct communication on future projections with local agencies and farmers
  - MID Water Resources Management Plan – Summary Report (Draft)
- Urban water demand is based on:
  - Decadal population projections from 2015 Urban Water Management Plans (UWMPs)
    - For regions outside of the UWMP boundaries, population (by US Census tract) was increased at an average of the rate of growth projected for the UWMP regions, and then multiplied by the average projected per-capita demands across all UWMP regions.
  - Projected gallons per capita per day (GPCD) calculated from historical pumping records with conservation reductions according to the state's 20% mandated conservation reduction by 2020 (Senate Bill SB X7-7).
    - For regions outside of the UWMP boundaries, population was multiplied by the average projected per-capita demands across all UWMP regions.
- Agricultural water demand is based on:
  - The IDC in conjunction with historical remote sensing technology, METRIC

- Surface water deliveries are based on data from:
    - 2040 estimates provided by Merced Irrigation District (MID)
    - 2040 estimates provided by Stevinson Water District (SWD)
    - 2040 estimates provided by Merquin County Water District (MCWD)
    - 2040 estimates provided by Turner Island Water District (TIWD)
    - 2040 estimates provided by Lone Tree Mutual Water Company (LTMWC)

Table 2-14: Summary of Groundwater Budget Assumptions

Water Budget Type	Historical	Current	Projected
Tool	MercedWRM	MercedWRM	MercedWRM
Scenario	Historical Simulation	Current Conditions Baseline	Projected Conditions Baseline
Hydrologic Years	WY 2006-2015	WY 1969-2018	WY 1969-2018
Level of Development	Historical	Current	General Plan buildout
Agricultural Demand	Historical Records	Current Conditions	Projected based on local AWMP data
Urban Demand	Historical Records	Current Conditions	Projected based on local UWMP data
Water Supplies	Historical Records	Current Conditions	Projected based on local reservoir operations model

2.3.4 Water Budget Estimates

The primary components of the stream and canal system are:

- Inflows:
    - Stream inflows
    - Stream gain from the groundwater system
    - Surface runoff to the stream system
    - Return flow to stream system
    - Groundwater pumping to canal systems
- Outflows:
    - San Joaquin River outflows
    - Stream losses to groundwater
    - Surface water deliveries
    - Groundwater delivery via canal system
    - Riparian uptake from streams

The primary components of the land surface system are:

- Inflows:
    - Precipitation
    - Surface water supplies
    - Groundwater supplies
    - Riparian uptake from streams
    - Inflow from the groundwater system
- Outflows:
    - Evaporation
    - Surface runoff to the stream system
    - Return flow to the stream system
    - Deep percolation

The primary components of the groundwater system are:

- Inflows:
    - Deep percolation
    - Stream losses to the groundwater system
    - Subsurface inflow
- Outflows:
    - Stream gain from the groundwater system
    - Groundwater production (pumping)
    - Subsurface outflow
- Change in groundwater storage

The estimated water budgets are provided below in Table 2-15 through Table 2-17 for the historical, current, projected, sustainable yield, and climate change water budgets. Background on the sustainable yield water budget analysis and assumptions is provided in Section 2.3.5 and for climate change water budget in Section 2.4.

Table 2-15: Average Annual Water Budget – Stream and Canal Systems, Merced Subbasin (AFY)

Component	Historical Condition Water Budget	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget	Sustainable Condition Water Budget
Hydrologic Period	WY 1996- 2015	WY 2006- 2015	WY 1969 - 2018	WY 1969 - 2018	WY 1969 - 2018
Inflows					
Stream Inflows	2,050,000	1,731,000	2,480,000	2,480,000	2,480,000
Merced River	980,000	892,000	981,000	981,000	981,000
Eastside Bypass	644,000	442,000	773,000	773,000	773,000
San Joaquin River	300,000	295,000	581,000	581,000	581,000
Chowchilla River	59,000	54,000	72,000	72,000	72,000
Local Tributaries[1]	67,000	48,000	74,000	74,000	74,000
Stream Gain from Groundwater	49,000	42,000	51,000	49,000	50,000
Merced Subbasin	30,000	26,000	31,000	29,000	29,000
Merced River	7,000	6,000	10,000	9,000	9,000
Eastside Bypass	1,000	1,000	1,000	1,000	1,000
San Joaquin River	9,000	8,000	7,000	7,000	7,000
Chowchilla River	1,000	2,000	2,000	2,000	2,000
Local Tributaries[1]	11,000	10,000	11,000	11,000	11,000
Other Subbasins[2]	20,000	17,000	21,000	20,000	20,000
Merced River	9,000	7,000	11,000	10,000	11,000
San Joaquin River	8,000	7,000	6,000	6,000	6,000
Chowchilla River	3,000	3,000	3,000	3,000	3,000
Runoff to the Stream System	322,000	244,000	355,000	357,000	353,000
Merced Subbasin	188,000	147,000	204,000	206,000	207,000
Other Subbasins[2]	133,000	97,000	151,000	151,000	147,000
Return Flow to Stream System	102,000	106,000	126,000	143,000	139,000
Merced Subbasin	75,000	74,000	63,000	79,000	77,000
Other Subbasins[2]	27,000	32,000	62,000	64,000	62,000
Groundwater Pumping to Canals	49,000	61,000	45,000	45,000	44,000
Other[3]	62,000	85,000	33,000	32,000	33,000
Total Inflow	**2,634,000**	**2,270,000**	**3,090,000**	**3,105,000**	**3,099,000**

Component	Historical Condition Water Budget	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget	Sustainable Condition Water Budget
Hydrologic Period	**WY 1996- 2015**	**WY 2006- 2015**	**WY 1969 - 2018**	**WY 1969 - 2018**	**WY 1969 - 2018**
Outflows					
San Joaquin River Outflows	1,946,000	1,603,000	2,341,000	2,360,000	2,350,000
Stream Losses to Groundwater	332,000	349,000	389,000	401,000	406,000
Merced Subbasin	260,000	272,000	312,000	318,000	321,000
Merced River	45,000	48,000	37,000	42,000	43,000
Eastside Bypass	28,000	29,000	39,000	44,000	47,000
San Joaquin River	23,000	25,000	34,000	36,000	36,000
Chowchilla River	2,000	2,000	2,000	2,000	2,000
Local Tributaries[1]	45,000	40,000	50,000	52,000	52,000
Canal Recharge	116,000	129,000	149,000	141,000	141,000
Other Subbasins[2]	72,000	77,000	77,000	83,000	84,000
Merced River	45,000	48,000	37,000	42,000	43,000
San Joaquin River	26,000	27,000	38,000	39,000	39,000
Chowchilla River	1,000	1,000	2,000	2,000	2,000
Surface Water Deliveries	282,000	232,000	290,000	274,000	275,000
Groundwater Delivery via Canals	49,000	61,000	45,000	45,000	44,000
Riparian Uptake from Streams	25,000	25,000	25,000	25,000	25,000
Merced Subbasin	18,000	16,000	15,000	14,000	13,000
Other Subbasins	6,000	9,000	10,000	11,000	11,000
Total Outflow	**2,634,000**	**2,270,000**	**3,090,000**	**3,105,000**	**3,099,000**

[1] Local Tributaries include Bear Creek, Black Rascal Creek, Deadman Creek, Duck Slough, Dutchman Creek, Mariposa Creek, Miles Creek, and Owens Creek. Additional smaller creeks exist but were not modeled due to minimal natural flows.

[2] Other Subbasins include the Turlock, Chowchilla, and Delta-Mendota Subbasins. As supporting data was not available, modeling inputs such as curve number and return flow fractions were assumed to be similar to those used in the Merced Subbasin.

[3] Other flows is a closure term that captures the stream and canal system including gains and losses not directly measured or simulated within IWFM. Some of these features include but may not be limited to direct precipitation, evaporation, unmeasured riparian diversions and return flow, temporary storage in local lakes and regulating reservoirs, and inflow discrepancies resulting from simulating impaired flows.

Table 2-16: Average Annual Water Budget – Land Surface System, Merced Subbasin (AFY)

Component	Historical Condition Water Budget	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget	Sustainable Condition Water Budget
Hydrologic Period	WY 1996- 2015	WY 2006- 2015	WY 1969 - 2018	WY 1969 - 2018	WY 1969 - 2018
Inflows[1]					
Precipitation	475,000	404,000	506,000	506,000	506,000
Total Surface Water Supply	282,000	232,000	290,000	274,000	275,000
Surface Water - Local	235,000	187,000	244,000	229,000	229,000
Surface Water - Riparian	47,000	45,000	46,000	46,000	46,000
Total Groundwater Supply	612,000	723,000	598,000	660,000	570,000
Agricultural - Agency	49,000	61,000	45,000	45,000	44,000
Agricultural - Private	484,000	580,000	490,000	526,000	442,000
Urban - Municipal	44,000	44,000	36,000	50,000	47,000
Urban - Domestic	34,000	37,000	28,000	39,000	37,000
Riparian Uptake from Streams	18,000	16,000	15,000	14,000	13,000
Inflow from Groundwater System	12,000	11,000	12,000	12,000	10,000
Total Inflow	**1,399,000**	**1,386,000**	**1,420,000**	**1,466,000**	**1,374,000**
Outflows[1]					
Evapotranspiration	821,000	847,000	834,000	853,000	798,000
Agricultural	641,000	683,000	661,000	682,000	613,000
Municipal and Domestic	41,000	42,000	31,000	37,000	43,000
Refuge, Native, and Riparian	139,000	122,000	142,000	134,000	142,000
Runoff to the Stream System	188,000	147,000	204,000	206,000	207,000
Return Flow to the Stream System	75,000	74,000	63,000	79,000	77,000
Agricultural	28,000	25,000	25,000	26,000	27,000
Municipal and Domestic	47,000	49,000	38,000	54,000	50,000
Deep Percolation	314,000	316,000	318,000	327,000	293,000
Precipitation	76,000	67,000	81,000	79,000	76,000
Surface Water	75,000	60,000	78,000	73,000	70,000
Surface Water - Local	62,000	49,000	65,000	61,000	59,000
Surface Water - Riparian	12,000	12,000	12,000	12,000	12,000
Groundwater	163,000	188,000	160,000	175,000	146,000
Agricultural - Agency	13,000	16,000	12,000	12,000	11,000
Agricultural - Private	129,000	151,000	131,000	139,000	113,000

Component	Historical Condition Water Budget	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget	Sustainable Condition Water Budget
Hydrologic Period	WY 1996- 2015	WY 2006- 2015	WY 1969 - 2018	WY 1969 - 2018	WY 1969 - 2018
Urban - Municipal	12,000	12,000	10,000	13,000	12,000
Urban - Private	9,000	10,000	7,000	10,000	9,000
Other[2]	1,000	1,000	1,000	1,000	0
Total Outflow	**1,399,000**	**1,386,000**	**1,420,000**	**1,466,000**	**1,374,000**

[1] Managed wetlands and habitat areas are recognized as additional areas that have unique water use characteristics, often using both delivered surface water and pumped groundwater. The values for applied surface water and applied groundwater, as well as deep percolation, for private wetland/habitat areas are aggregated into larger categories (e.g., "Local" or "Riparian" or "Agricultural") due to a lack of information for demands from these private wetlands/habitat areas. Demands were estimated based on DWR land use categorizations of native vegetation or agricultural land. Furthermore, the MercedWRM was calibrated to remote sensing of evapotranspiration data (METRIC) which is expected to result in a net accurate model result for consumptive use for these aggregated categories, even if the individual wetland components couldn't be tabulated separately. Surface water and groundwater supplied to the Merced Wildlife Refuge are known values and are included in the aggregated categories.

[2] Other flows is a closure term that captures the gains and losses due to land expansion and seasonal storage in the root-zone.

Table 2-17: Average Annual Water Budget – Groundwater System, Merced Subbasin (AFY)

Component	Historical Condition Water Budget	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget	Sustainable Condition Water Budget
Hydrologic Period	**WY 1996- 2015**	**WY 2006- 2015**	**WY 1969 - 2018**	**WY 1969 - 2018**	**WY 1969 - 2018**
Inflows					
Deep Percolation	314,000	316,000	318,000	327,000	293,000
Precipitation	76,000	67,000	81,000	79,000	76,000
Surface Water	75,000	60,000	78,000	73,000	70,000
Surface Water - Local	62,000	49,000	65,000	61,000	59,000
Surface Water - Riparian	12,000	12,000	12,000	12,000	12,000
Groundwater	163,000	188,000	160,000	175,000	146,000
Agricultural - Agency	13,000	16,000	12,000	12,000	11,000
Agricultural - Private	129,000	151,000	131,000	139,000	113,000
Urban - Municipal	12,000	12,000	10,000	13,000	12,000
Urban - Private	9,000	10,000	7,000	10,000	9,000
Stream Losses to Groundwater	260,000	272,000	312,000	318,000	321,000
Merced River	45,000	48,000	37,000	42,000	43,000
Eastside Bypass	28,000	29,000	39,000	44,000	47,000
San Joaquin River	23,000	25,000	34,000	36,000	36,000
Chowchilla River	2,000	2,000	2,000	2,000	2,000
Local Tributaries[1]	45,000	40,000	50,000	52,000	52,000
Canal Recharge	116,000	129,000	149,000	141,000	141,000
Subsurface Inflow	70,000	75,000	69,000	79,000	87,000
Total Inflow	**643,000**	**663,000**	**700,000**	**723,000**	**702,000**
Outflows					
Stream Gain from Groundwater	30,000	26,000	31,000	29,000	29,000
Merced River	7,000	6,000	10,000	9,000	9,000
Eastside Bypass	1,000	1,000	1,000	1,000	1,000
San Joaquin River	9,000	8,000	7,000	7,000	7,000
Chowchilla River	1,000	2,000	2,000	2,000	2,000
Local Tributaries	11,000	10,000	11,000	11,000	11,000
Groundwater Production	612,000	723,000	598,000	660,000	570,000
Agricultural - Agency	49,000	61,000	45,000	45,000	44,000
Agricultural - Private	484,000	580,000	490,000	526,000	442,000

Component	Historical Condition Water Budget	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget	Sustainable Condition Water Budget
Hydrologic Period	WY 1996- 2015	WY 2006- 2015	WY 1969 - 2018	WY 1969 - 2018	WY 1969 - 2018
Urban - Municipal	44,000	44,000	36,000	50,000	47,000
Urban - Private	34,000	37,000	28,000	39,000	37,000
Subsurface Outflow	96,000	92,000	110,000	103,000	93,000
Outflow to Land Surface System	12,000	11,000	12,000	12,000	10,000
Other[2]	2,000	3,000	1,000	1,000	-1,000
Total Outflow	**752,000**	**855,000**	**752,000**	**805,000**	**702,000**
Change in Storage	**-109,000**	**-192,000**	**-52,000**	**-82,000**	**0**

[1] Local Tributaries include Bear Creek, Black Rascal Creek, Deadman Creek, Duck Slough, Dutchman Creek, Mariposa Creek, Miles Creek, and Owens Creek. Additional smaller creeks exist but were not modeled due to minimal natural flows.

[3] Other flows within the groundwater system including temporary storage in the vadose zone, and root water uptake from the aquifer system.

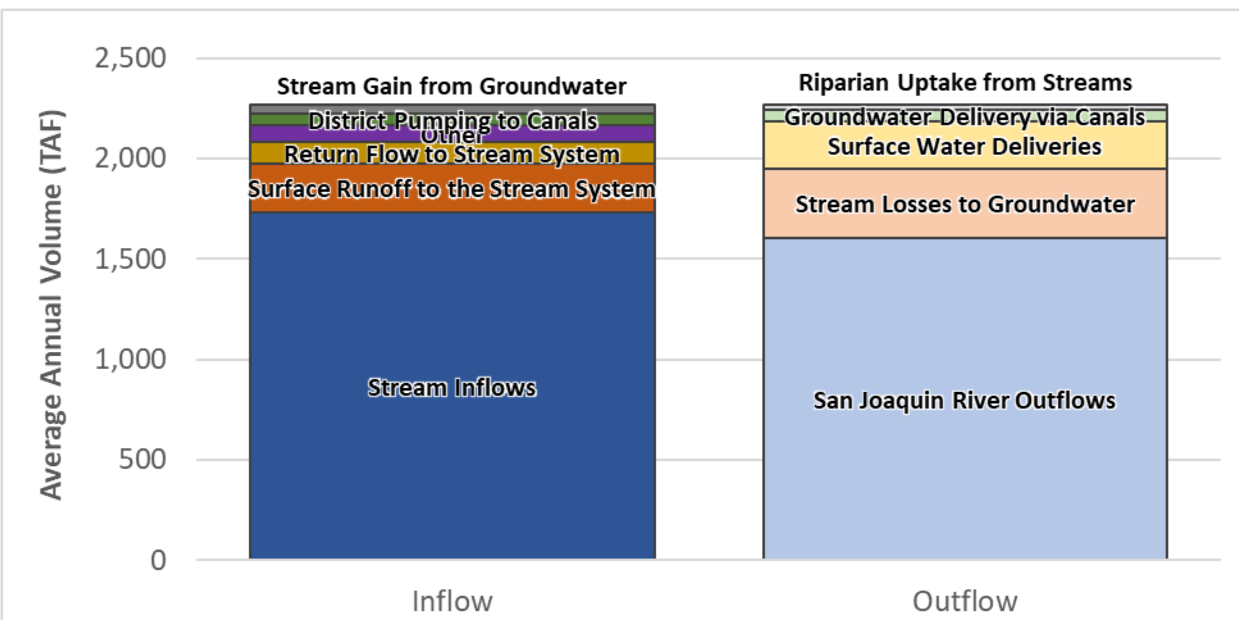
2.3.4.1 Historical Water Budget

The historical water budget is a quantitative evaluation of the historical surface and groundwater supply covering the 10-year period from WY 2006 to 2015. This period was selected as the representative hydrologic period as it reflects the most recent basin operations, particularly the annexation of the El Nido area into MID. The goal of the water budget analysis is to characterize the supply and demand, while summarizing the hydrologic flow within the Subbasin, including the movement of primary sources of water such as rainfall, irrigation, streamflow, and subsurface flows.

The existing stream and canal network supplies multiple water users and agencies in the Merced Groundwater Subbasin, including MID, SWD, MCWD, TIWD, and LTMWC. When analyzing the stream and canal system, it is important to note potentially significant effects resulting from the natural interactions and managed operations of adjacent groundwater subbasins. Because of this, the water budget in Table 2-14 and Figure 2-92 below attempt to not only quantify surface and canal system flows within the Merced Subbasin, but also estimate contributions from adjoining areas.

Average annual surface water inflows of 2,270,000 AF travel through or along the Subbasin boundary. The majority of these flows enter the Subbasin through inflows from natural streams and the Eastside Bypass (1,731,000 AF) and are supplemented by surface runoff (244,000 AF), return flow (106,000 AF), natural groundwater contributions (42,000 AF), and groundwater pumping from local water agencies (61,000 AF). Outflows of the Merced Subbasin stream and canal system total 2,270,000 AF and include downstream flow from the San Joaquin River (1,603,000 AF), stream losses to the aquifer system (349,000 AF), surface water deliveries (232,000 AF), groundwater delivered via local canal systems (61,000 AF), and riparian uptake (25,000 AF).

Figure 2-92: Historical Average Annual Water Budget – Stream and Canal Systems, Merced Subbasin



The land surface system of the Merced Subbasin, shown below in Figure 2-93, experiences 1,386,000 acre-feet of inflows each year, a combination of precipitation (404,000 AF), surface water deliveries (232,000 AF), groundwater pumping (723,000 AF), riparian uptake from the stream system (16,000 AF), and natural inflow from the aquifer system (11,000 AF). Equivalent to the inflows in magnitude, outflows from the land surface system are comprised of evapotranspiration (847,000 AF), surface runoff (147,000 AF) and return flow (74,000 AF) to the stream and canal system, and deep percolation (316,000 AF). Figure 2-94 shows the annual change in the land surface water budget through the simulation period. Note the surface water supply in this water budget is reflective of the volume available to the grower, and thus does not include operational spills, canal seepage, or canal evaporative losses.

Figure 2-93: Historical Average Annual Water Budget – Land Surface System, Merced Subbasin

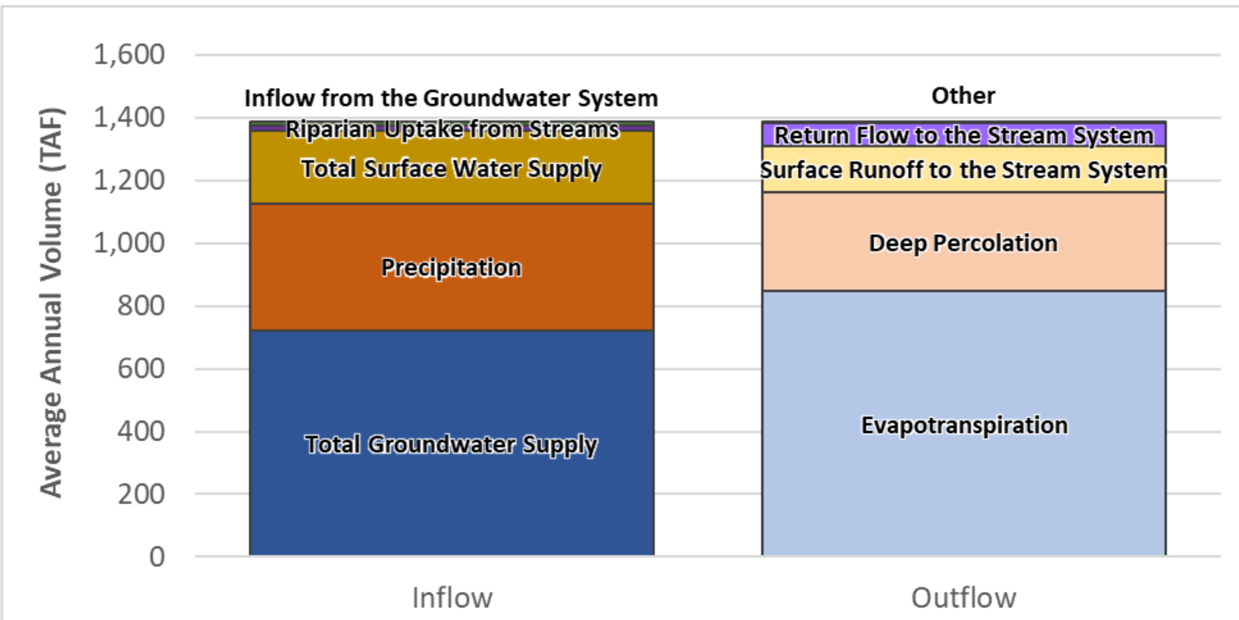
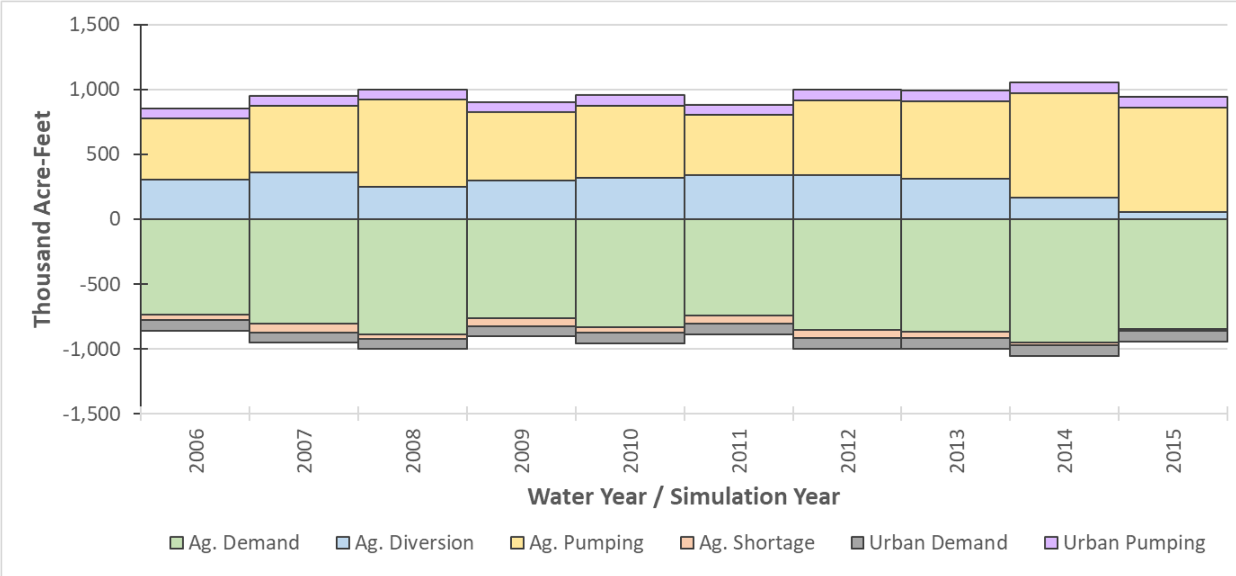


Figure 2-94: Historical Annual Water Budget – Land Surface System, Merced Subbasin



The groundwater system of the Merced Subbasin experiences over 663,000 acre-feet of inflows each year, of which 316,000 AF is surface infiltration. There is also recharge from rivers, streams, and canals (272,000 AF), and subsurface inflows (75,000 AF) from the Sierra Nevada foothills and the neighboring subbasins of Turlock, Delta-Mendota, and Chowchilla.

On average, the inflows exceed outflows. The largest outflow of the groundwater system is pumping (723,000 AF), followed by subsurface flow into neighboring subbasins (92,000 AF) and losses due to local stream-groundwater interaction (26,000 AF).

The greater outflows than inflows leads to an average annual decrease in groundwater storage of 192,000 acre-feet. Figure 2-95 summarizes the average historical groundwater inflows and outflows in the Merced Subbasin. Figure 2-96 shows the annual change in the groundwater budget components, as well as cumulative storage, through the 1996 to 2015 period.

Figure 2-95: Historical Average Annual Water Budget – Groundwater System, Merced Subbasin

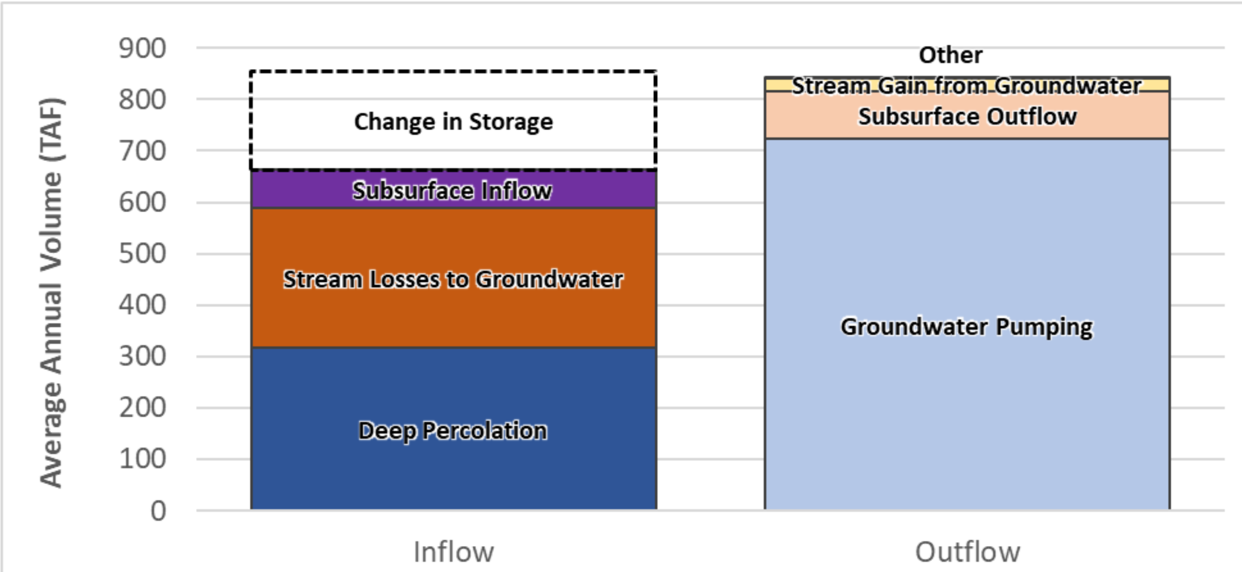
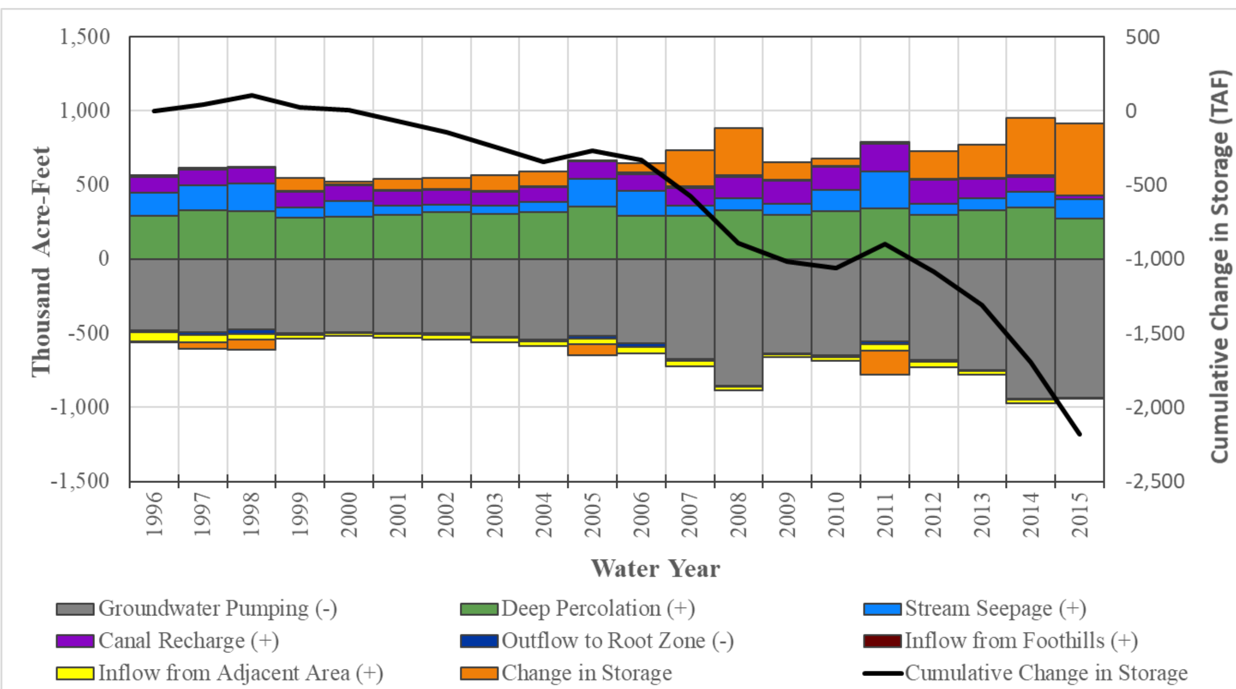


Figure 2-96: Historical Annual Water Budget – Groundwater System, Merced Subbasin



The historical inflows and outflows change by water year type. In wet years, precipitation meets more of the water demand, and greater availability of surface water reduces the need for groundwater. However, in dry years, more groundwater is pumped to meet the agricultural demand not met by surface water or precipitation. This leads to an increase in groundwater storage in wet years and a decrease in dry years. While demand of applied water increases in dry years due to lack of precipitation, surface water supply remains consistent in most non-critical years. Table 2-18 breaks down the average historical water supply and demand by water year type.

Table 2-18: Average Annual Values for Key Components of the Historical Water Budget by Year Type (AFY)

Component	Water Year Type (San Joaquin River Index)					
	Wet	Above Normal	Below Normal	Dry	Critical	10-Year Average WY 2005-15
Water Demand						
Agricultural Demand	790,000	873,000	824,000	917,000	907,000	873,000
Urban Demand	81,000	82,000	80,000	83,000	82,000	82,000
Total Demand	**871,000**	**955,000**	**904,000**	**1,000,000**	**990,000**	**955,000**
Water Supply						
Total Surface Water Supply	309,000	306,000	269,000	319,000	161,000	232,000
Local	263,000	262,000	217,000	266,000	118,000	186,000
Riparian	46,000	44,000	52,000	53,000	42,000	45,000
Total Groundwater Supply	562,000	649,000	634,000	681,000	829,000	723,000
Agricultural - Agency	29,000	32,000	46,000	41,000	87,000	61,000
Agricultural - Private	452,000	535,000	509,000	557,000	659,000	580,000
Urban - Municipal	44,000	45,000	44,000	45,000	45,000	44,000
Urban - Domestic	37,000	37,000	36,000	38,000	37,000	37,000
Total Supply	**871,000**	**955,000**	**904,000**	**1,000,000**	**990,000**	**955,000**
Change in GW Storage	**49,000**	**-46,000**	**-121,000**	**-185,000**	**-333,000**	**-192,000**

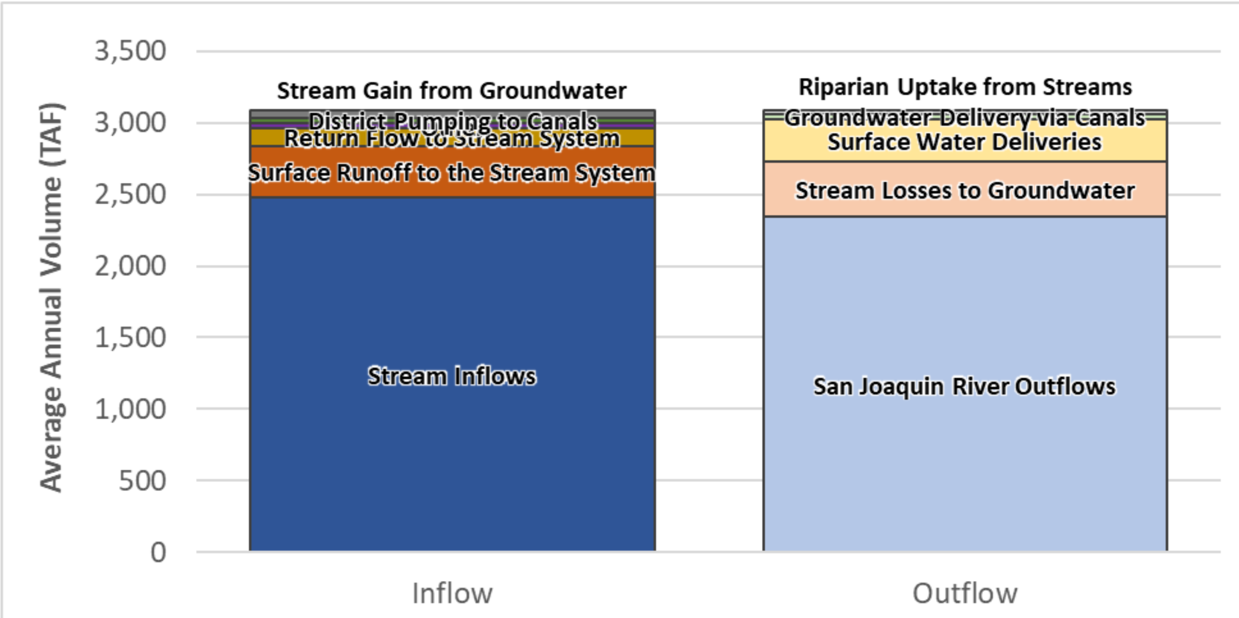
2.3.4.2 Current Water Budget

The current water budget quantifies inflows to and outflows from the basin using 50-years of hydrology in conjunction with 2015 water supply, demand, and land use information. These conditions are incorporated in the Current Conditions Baseline simulation of the MercedWRM.

The stream and canal system in the Current Conditions Baseline supplies agricultural users with an average of 290,000 AF in surface water diversions from local streams with an additional 45,000 AF of pumping by local surface water purveyors supplementing their conveyance system. In addition to these volumes, on average, 2,341,000 AFY leaves the Subbasin's surface water features as downstream flow in the San Joaquin River, 389,000 AFY is lost to the groundwater system, and 25,000 AFY is used by riparian vegetation as direct-uptake.

Inflows to the stream and canal system include 2,480,000 AFY of local stream inflow, 355,000 AFY of surface runoff, 126,000 of return flow, 51,000 AFY of groundwater contributions, 45,000 AFY of district pumping, and 33,000 AFY of uncategorized flows. Figure 2-97 summarizes the average annual inflows and outflow of the Current Conditions Baseline in the Merced Subbasin surface water network.

Figure 2-97: Current Conditions Average Annual Water Budget – Stream and Canal Systems, Merced Subbasin



Based on pre-drought cropping patterns and 2015 urban buildout, over the simulation period, the Current Conditions land surface water budget simulates annual inflows of 1,420,000 AF, including 506,000 AF of precipitation, 880,000 AF of applied water (290,000 AF of surface water and 598,000 AF of groundwater), 15,000 AF of riparian uptake from the stream system, and 12,000 AF of inflow from the groundwater system. The 1,420,000 of outflows include evapotranspiration (834,000 AF), surface runoff to the stream system (204,000 AF), return flow to the stream system (63,000 AF), deep percolation (318,000 AF), and other flows (1,000 AF). Figure 2-98 summarizes the average annual current condition inflows and outflows in the land surface budget for the Merced Subbasin. Figure 2-99 shows the annual change in the land surface water budget components through the simulation period.

Figure 2-98: Current Conditions Average Annual Water Budget – Land Surface System, Merced Subbasin

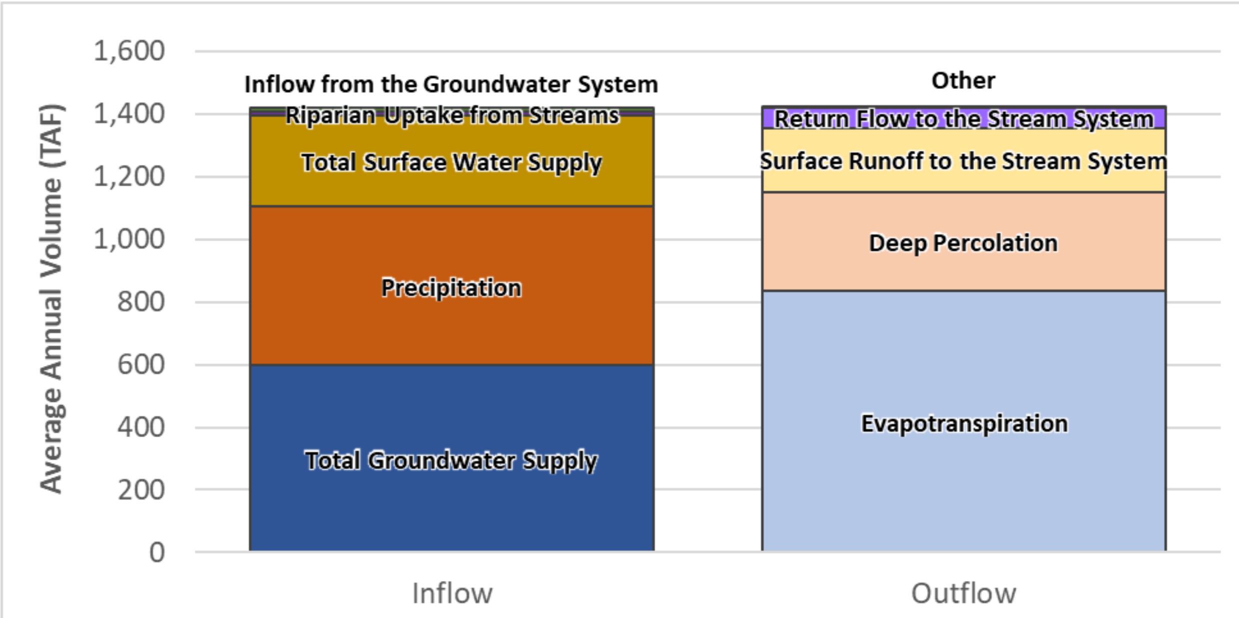
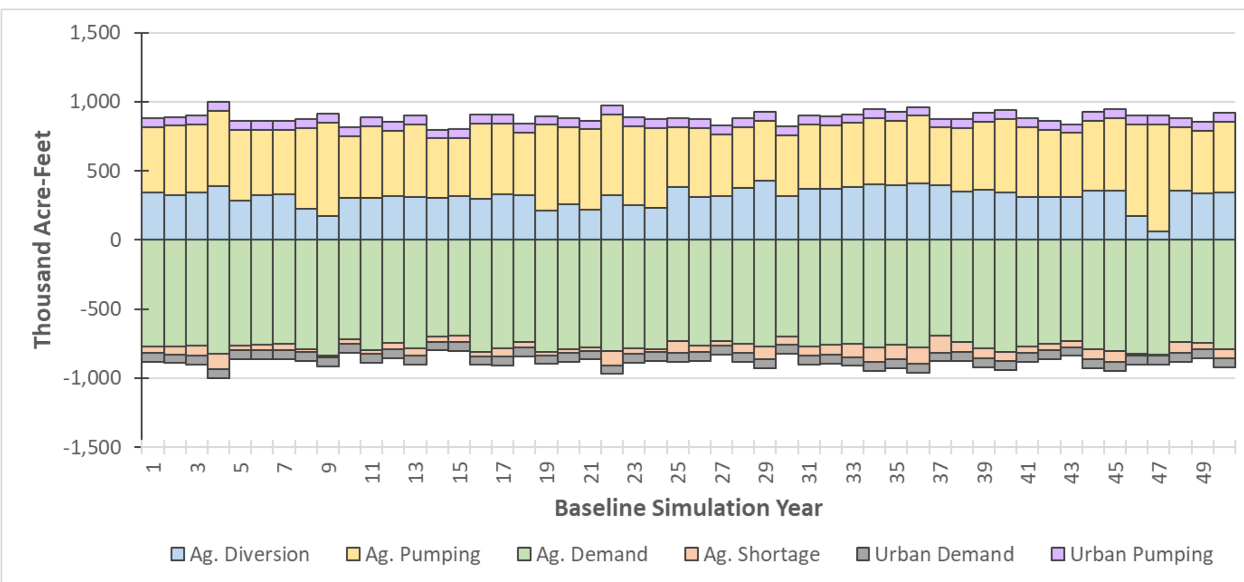


Figure 2-99: Current Conditions Annual Water Budget – Land Surface System, Merced Subbasin



The Current Conditions Baseline simulates 50 years of hydrology whose initial conditions are reflective of the start of WY 2016. Over the simulation period, the Current Conditions groundwater water budget simulates annual inflows of 700,000 AF, including 318,000 AF of deep percolation, 312,000 AF of stream and canal seepage, and subsurface inflows totaling 69,000 AF.

Similar to the historical water budget, average aquifer outflows exceed the inflows under current conditions. Groundwater production (598,000 AF) remains the largest point of aquifer discharge, with subsurface outflow

(110,000 AF), losses to the local stream system (31,000 AF), and other flows (13,000 AF) bringing the total system outflows to 752,000 acre-feet annually.

The Merced Subbasin current conditions groundwater budget has greater outflows than inflows, resulting in an average annual deficit in groundwater storage of 52,000 acre-feet. Figure 2-100 summarizes the average current conditions groundwater inflows and outflows in the Merced Subbasin. Figure 2-101 shows the annual change in the groundwater budget components, as well as cumulative storage, through the 50-year simulation period.

Figure 2-100: Current Conditions Average Annual Water Budget – Groundwater System, Merced Subbasin

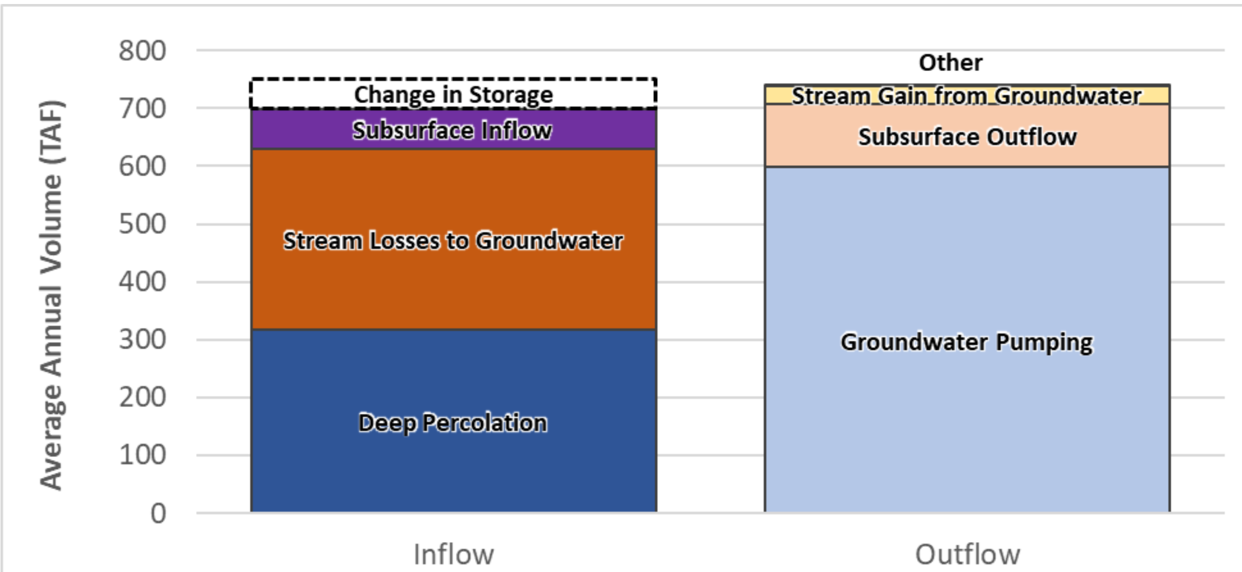
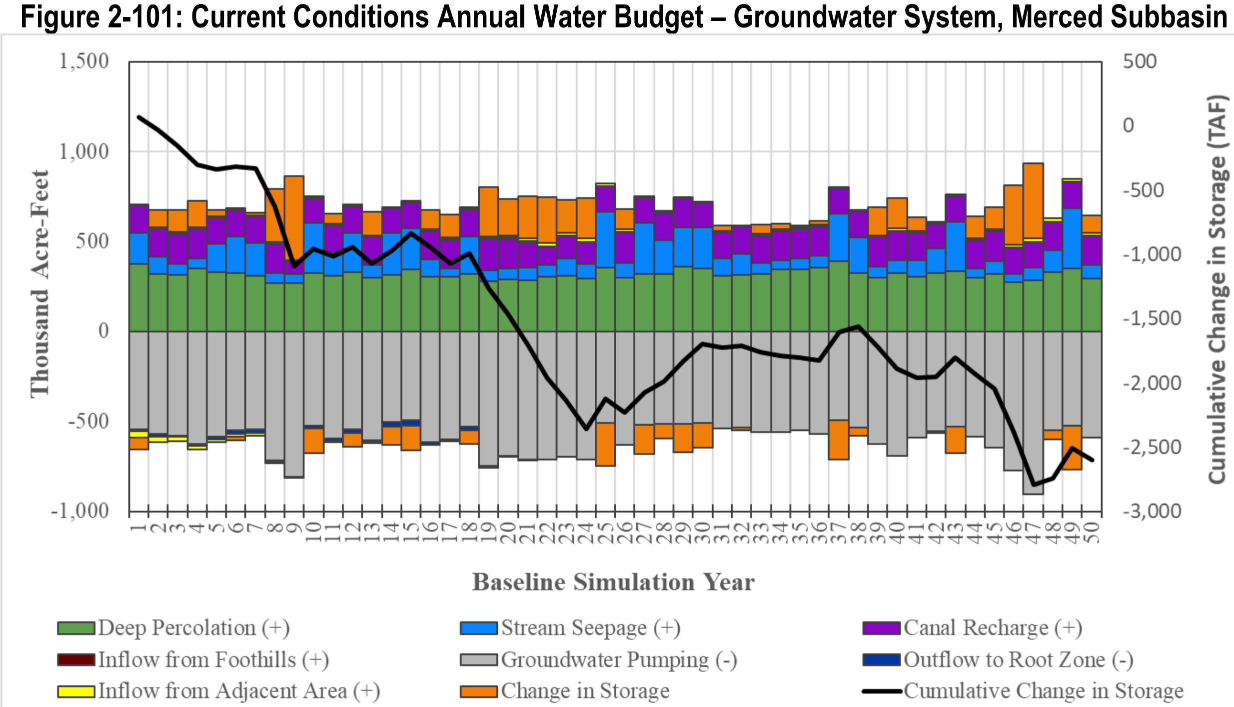


Figure 2-101: Current Conditions Annual Water Budget – Groundwater System, Merced Subbasin



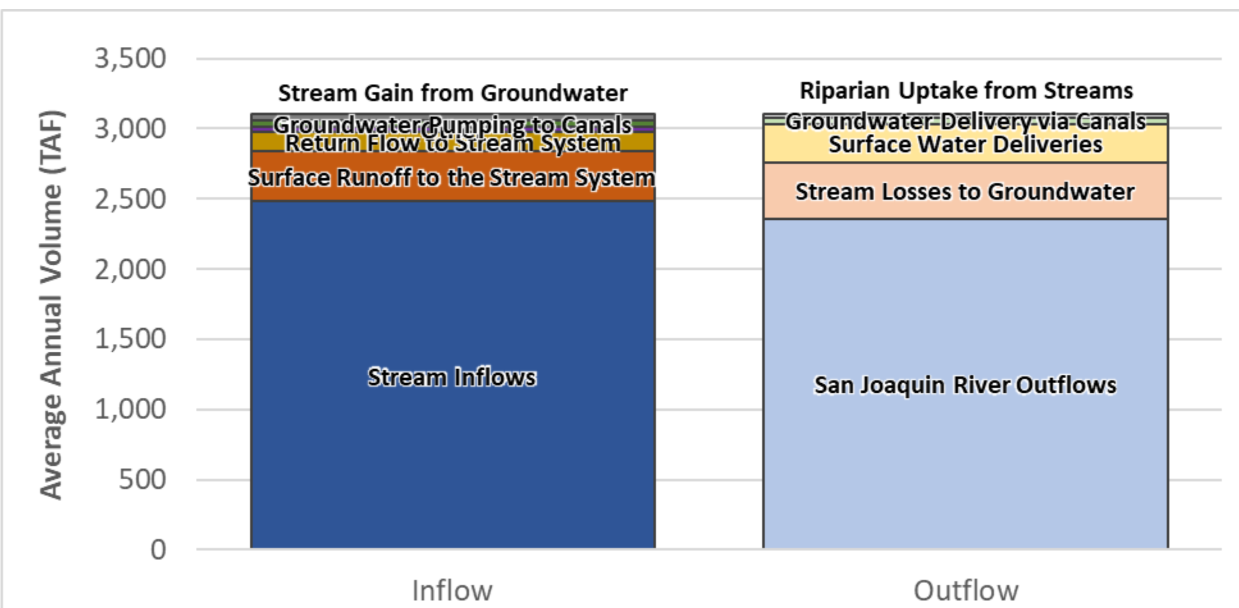
2.3.4.3 Projected Water Budget

The projected water budget is used to estimate future baseline conditions of supply, demand, and aquifer response to plan implementation. The Projected Conditions Baseline simulation of the MercedWRM is used to evaluate the projected conditions of the water budget using hydrology from 1969 to 2018. As previously discussed, this represents a hydrologic period of at least 50 years and has average precipitation similar to the long-term average.

Development of the projected water demand is based on the population growth trends reported in the 2015 UWMPs, and land use, evapotranspiration, and crop coefficient information from the 2015 AWMP. This data has been adjusted based on projected growth identified in general, agricultural, and urban water management plans to evaluate future scenarios of water demand uncertainty associated with projected changes in local land use planning, population growth, and climate. Similarly, projected surface water supplies were determined through analysis of MercedSIM, Merced Irrigation District's reservoir and surface water operations model, and accounts for the FERC's operations schedule under their FEIS for the 2018 licensing of the Lake McClure Reservoir.

Average annual surface water inflows to the Merced Subbasin's stream and canal system total an average of 3,105,000 AF. Under projected conditions, local water district pumping will supplement surface water supplies with 45,000 AF of groundwater production. Of these volumes, it is anticipated that 319,000 AF will be distributed to local growers to meet agricultural demand (274,000 AF of surface water deliveries and 45,000 AF of groundwater deliveries) and the remaining amount will leave the system in the form of San Joaquin River outflow (2,360,000 AF), aquifer recharge (401,000 AF), or riparian uptake (25,000 AF). Figure 2-102 summarizes the average projected inflows and outflows in the Merced Subbasin surface water network.

Figure 2-102: Projected Conditions Average Annual Water Budget – Stream and Canal Systems, Merced Subbasin



The land surface water budget for the Projected Conditions Baseline has annual average inflows and outflows of 1,466,000 AF. Inflows comprise precipitation (506,000 AF), applied surface water (274,000 AF), applied groundwater (660,000 AF), riparian uptake from streams (14,000 AF), and inflow from the aquifer system (12,000 AF). The balance of this is the summation of average annual evapotranspiration (853,000 AF), surface runoff (206,000 AF) and return flow (79,000 AF) to the stream system, deep percolation (327,000 AF), and other flows (1,000 AF). A summary of these flows can be seen below in Figure 2-103. Figure 2-104 shows the annual change in the land surface water budget components through the simulation period.

Figure 2-103: Projected Conditions Average Annual Water Budget – Land Surface System, Merced Subbasin

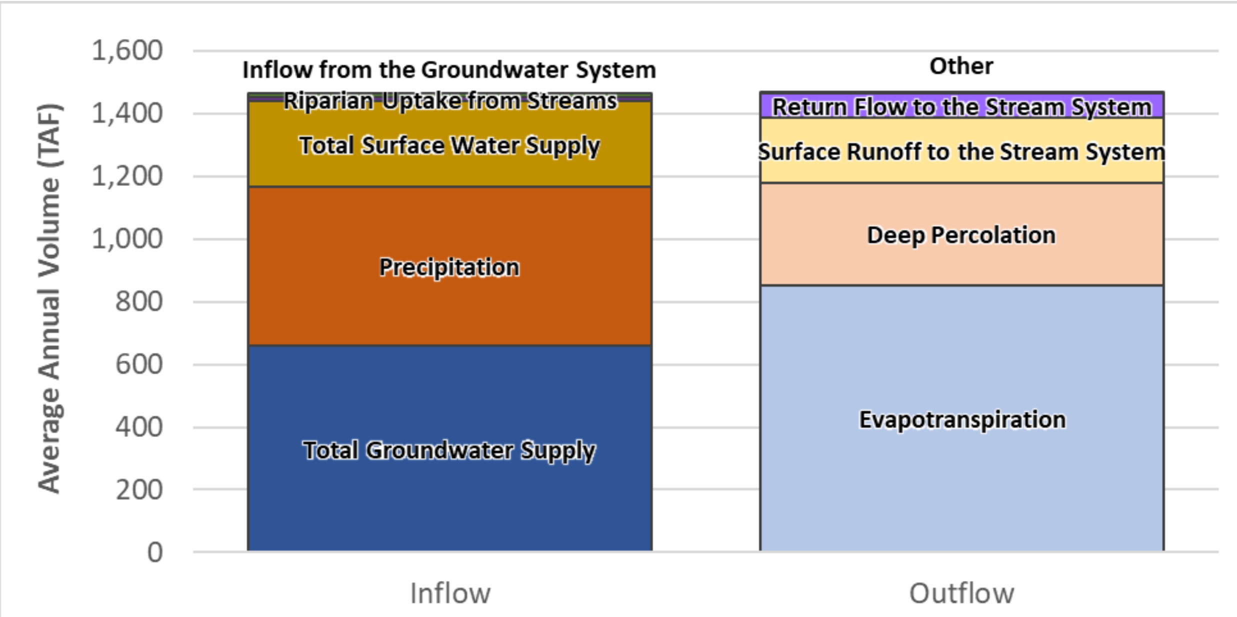


Figure 2-104: Projected Conditions Annual Water Budget – Land Surface System, Merced Subbasin

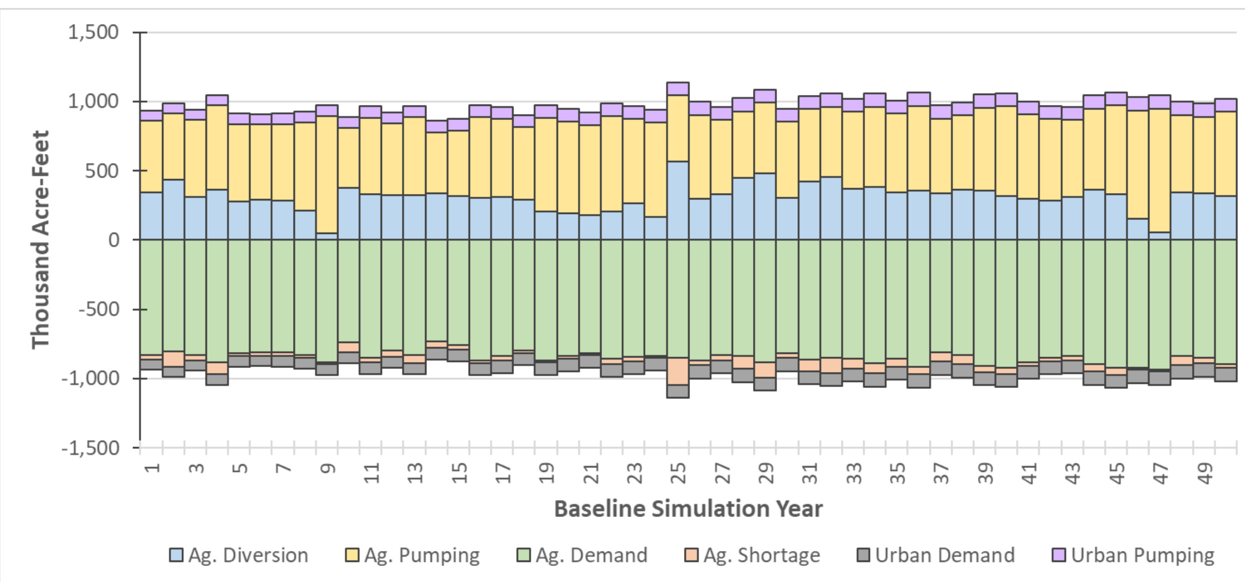


Figure 2-105 below shows how anticipated growth in the Projected Conditions Baseline is reflected in increases to groundwater production (660,000 AF) across the Subbasin. Subsurface outflow to neighboring subbasins (103,000 AF), stream gain from groundwater (29,000 AF), and other flows (13,000 AF) bring the total Subbasin discharges to 805,000 AFY.

Under projected conditions, the groundwater system of the Merced Subbasin experiences an average of 723,000 AF of inflows each year, of which 327,000 AF is deep percolation. There is also recharge from rivers, streams, and canals (318,000 AF), and subsurface inflows (79,000 AF) from the Sierra Nevada foothills and the neighboring subbasins of Turlock, Delta-Mendota, and Chowchilla.

The Projected Conditions Baseline has greater outflows than inflows, resulting in an average annual deficit in groundwater storage of 82,000 AF. Figure 2-105 summarizes the average projected groundwater inflows and outflows in the Merced Subbasin. Figure 2-106 shows the annual change in the groundwater budget, as well as cumulative storage, through the simulation period.

Figure 2-105: Projected Conditions Average Annual Water Budget – Groundwater System, Merced Subbasin

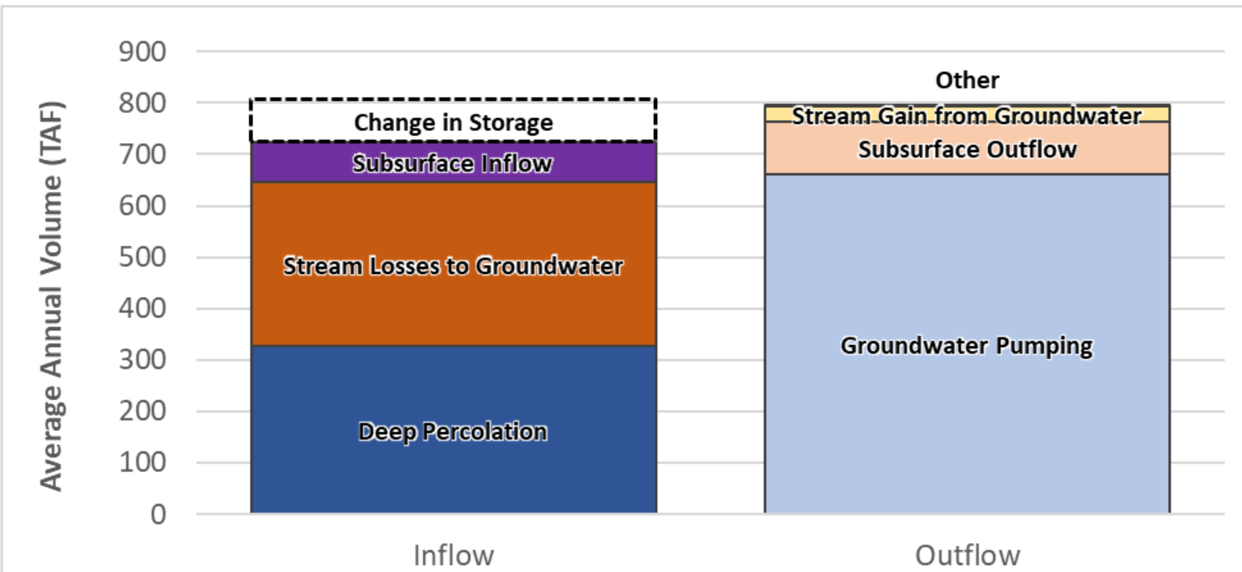
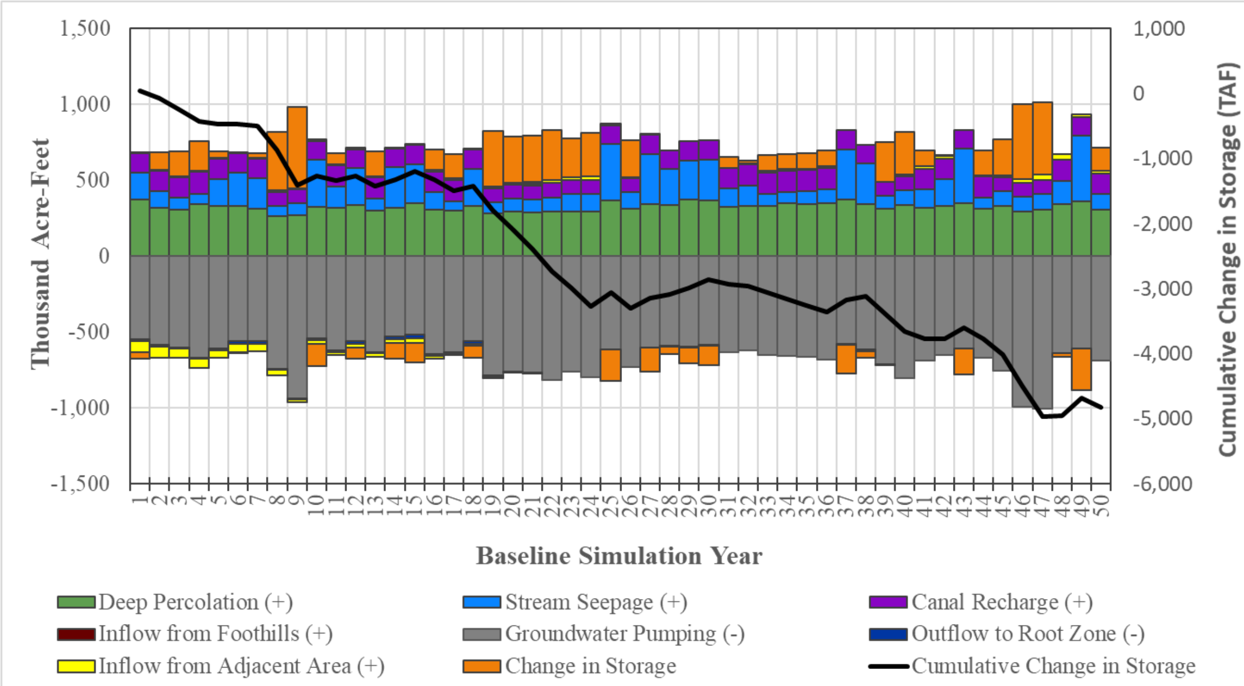


Figure 2-106: Projected Conditions Annual Water Budget – Groundwater System, Merced Subbasin



2.3.5 Sustainable Yield Estimate

Sustainable yield is defined for SGMA purposes as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result." (CWC §10721(w)). Sustainable yield for the Merced Subbasin was calculated through development of a MercedWRM scenario in which the long-term (50-year) change in Subbasin storage is zero. In order to account for the challenges of implementation, it was assumed the projected operations will remain consistent for a 25-year period and groundwater levels may continue to decline until 2040, at which point the basin will operate sustainably. The sustainable yield water budget is based on the Projected Conditions Baseline and is modified by lowering groundwater production through reduced agricultural and urban demand across the model domain.

The Sustainable Yield Scenario varies from the Projected Conditions Baseline in the following ways:

- **Planning Period**: WYs 2041-2090 (1969-2018 hydrologic period)
- **Agricultural Water Demand**: Reductions in agricultural water demand are implemented through a reduction in agricultural land use by globally reducing the projected 2040 cropped acreage at the element level.
- **Urban Water Demand**: Reductions in urban water use are implemented through a percent reduction in the per-capita water use equal to the percent reduction in agricultural use.
- The sustainable yield water budget is intended to estimate future conditions of supply, demand, and aquifer response to implementation of sustainable conditions in the Subbasin. The sustainable yield water budget is estimated using the sustainable conditions scenario for MercedWRM. In order to achieve a net-zero change in groundwater storage over a 50-year planning period, agricultural and urban groundwater demand in the Merced Subbasin would need to be reduced by approximately ten percent, absent implementation of any new supply-side projects. The methodology for reducing basinwide pumping to estimate sustainable yield is