CHOWCHILLA SUBBASIN

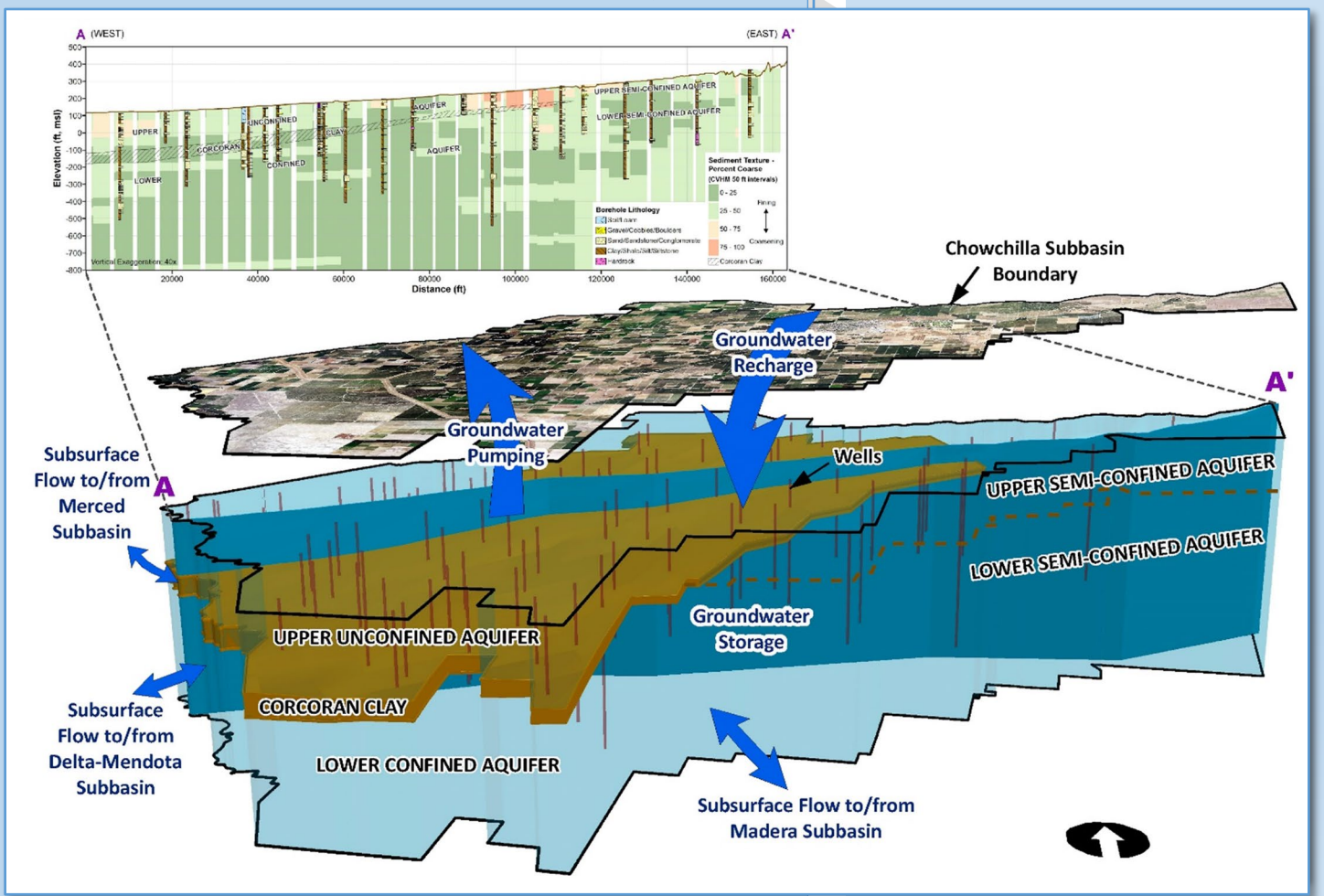
Sustainable Groundwater Management Act (SGMA)

Groundwater Sustainability Plan

Prepared by

Davids Engineering, Inc
Luhdorff & Scalmanini
ERA Economics
Stillwater Sciences and
California State University, Sacramento

January 2020



PUBLIC REVIEW DRAFT

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Prepared For

Chowchilla Subbasin GSP Advisory Committee

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TABLE OF CONTENTS

2 PLAN AREA AND BASIN SETTING 2-1

2.1 Description of the Plan Area (23 CCR § 354.8) 2-1

2.1.1 Summary of Jurisdictional Areas and Other Features (23 CCR § 354.8(b)) 2-1

2.1.2 Water Resources Monitoring and Management Programs (23 CCR § 354.8(c), (d), (e)) 2-2

2.1.2.1 Water Planning Documents 2-7

2.1.2.2 Surface Water Monitoring and Management Programs 2-8

2.1.2.3 Groundwater Monitoring and Management Programs 2-10

2.1.2.4 Conjunctive Use Programs 2-11

2.1.3 Land Use Elements or Topic Categories of Applicable General Plans (23 CCR § 354.8 (f)) 2-12

2.1.3.1 Madera County General Plan 2-12

2.1.3.2 Merced County General Plan 2-13

2.1.3.3 City of Chowchilla General Plan 2-14

2.1.3.4 Permitting Process for Wells in Chowchilla Subbasin 2-15

2.1.3.5 Effects of Land Use Plans Outside Subbasin 2-16

2.1.4 Additional GSP Elements (23 CCR § 354.8 (g)) 2-16

2.1.5 Notice and Communication (23 CCR § 354.10) 2-19

2.1.5.1 Overview 2-19

2.1.5.2 Description of Beneficial Uses and Users in the Basin 2-20

2.1.5.3 Communications 2-20

2.1.5.4 Informing the Public about GSP Development Progress 2-22

2.2 Basin Settings 2-25

2.2.1 Hydrogeologic Conceptual Model (23 CCR § 354.14) 2-25

2.2.1.1 Regional Geologic and Structural Setting 2-25

2.2.1.2 Lateral and Vertical Subbasin Boundaries 2-26

2.2.1.3 Major Aquifers/Aquitards 2-27

2.2.1.4 Aquifer Parameters 2-29

2.2.1.5 Recharge and Discharge Areas 2-30

2.2.1.6 Surface Water Bodies and Source/Delivery Points for Local and Imported Water Supplies 2-31

2.2.2 Current and Historical Groundwater Conditions (23 CCR § 354.16) 2-31

2.2.2.1 Groundwater Levels 2-31

DRAFT

2.2.2.2 Groundwater Storage 2-35
2.2.2.3 Groundwater Quality 2-37
2.2.2.4 Land Subsidence 2-39
2.2.2.5 Groundwater - Surface Water Interaction 2-39
2.2.2.6 Groundwater Dependent Ecosystems 2-40
2.2.3 Water Budget Information (23 CCR § 354.18) 2-43
2.2.3.1 Water Budget Conceptual Model 2-45
2.2.3.2 Water Budget Analysis Period 2-52
2.2.3.3 Water Budget Components and Uncertainties 2-57
2.2.3.4 Historical Water Budget Analysis 2-72

LIST OF TABLES

Table 2-1. Chowchilla Subbasin GSAs.

Table 2-2. Land Use Categories.

Table 2-1. Chowchilla Subbasin Land Use Areas (Acres).

Table 2-2. Chowchilla Subbasin Agricultural Land Use Areas (Acres).

Table 2-3. Surface Water Monitoring Stations.

Table 2-4. Stakeholder Engagement Chart for GSP Development.

Table 2-5. Estimates of Total Groundwater Storage Above Base of Freshwater (as of 2014)

Table 2-6. Calculated Change in Groundwater Storage

Table 2-7. Chowchilla Subbasin GSAs and Water Budget Subregions.

Table 2-8. Water Budget Components by Accounting Center and Associated GSP Regulations.

Table 2-9. Land Surface System Water Budget Components.

Table 2-10. Rivers and Streams System Water Budget Components.

Table 2-11. Canal System Water Budget Components.

Table 2-12. Land Surface System Water Budget General Detailed Components and Estimation Techniques.

Table 2-13. Chowchilla Subbasin Weather Data Time Series Summary.

Table 2-14. Subbasin Rivers and Streams System Water Budget Detailed Components and Estimation Techniques.

Table 2-15. Chowchilla Water District Canal System Water Budget General Detailed Components and Estimation Techniques.

Table 2-16. Estimated Uncertainty of Subbasin Water Budget Components.

Table 2-17. Chowchilla Subbasin Surface Water Inflows by Water Source Type (Acre-Feet) (23 CCR §354.18(b)(1)).

DRAFT

Table 2-18. Chowchilla Subbasin Surface Outflows by Water Source Type (Acre-Feet) (23 CCR §354.18(b)(1)).

Table 2-19. Chowchilla Subbasin Groundwater System Inflows (Acre-Feet) (23 CCR §354.18(b)(2)).

Table 2-20. Chowchilla Subbasin Groundwater Extraction by Water Use Sector (Acre-Feet) (23 CCR §354.18(b)(3)).

Table 2-21. Chowchilla Subbasin Total Evapotranspiration by Water Use Sector (Acre-Feet) (23 CCR §354.18(b)(3)).

Table 2-22. Chowchilla Subbasin Evaporation from the Surface Water System (Acre-Feet) (23 CCR §354.18(b)(3)).

Table 2-23. Development of Projected Future Precipitation and Evapotranspiration Timeseries.

Table 2-24. Development of Projected Future Surface Water Supply Timeseries.

Table 2-25. Comparative Summary of all Water Budget Scenarios, Annual Average Volumes by Flow Path (Acre-Feet).

Table 2-26. Historical Water Budget: Average Overdraft by Water Year Type, 1989-2014 (Acre-Feet) (23 CCR §354.18(b)(5)).

Table 2-27. Current Land Use Water Budget: Average Overdraft by Water Year Type, 1989-2014 (Acre-Feet) (23 CCR §354.18(b)(5)).

Table 2-28. Historical Water Budget: Average Net Recharge from SWS by Water Year Type, 1989-2014 (Acre-Feet).

Table 2-29. Current Land Use Water Budget: Average Net Recharge from SWS by Water Year Type, 1989-2014 (Acre-Feet).

Table 2-30. Comparative Summary of Annual Supply, Demand, and Change in Storage by Water Year Type (Acre-Feet per Year) (23 CCR §354.18(b)(6)).

Table 2-31. Summary of Sustainable Yield Estimates from Projected with Projects Water Budget (23 CCR §354.18(b)(7)).

LIST OF FIGURES

(Figure titles that are bolded can be found at the end of the document)

Figure 2-1. Chowchilla Subbasin Land Use Map

Figure 2-2. Chowchilla Subbasin Land Use Areas

Figure 2-3. Chowchilla Subbasin Agricultural Land Use Areas

Figure 2-4. Map of Well Information by Section: Number of Domestic Wells (from WCR data)

Figure 2-5. Map of Well Information by Section: Number of Agricultural Wells (from WCR data)

Figure 2-6. Map of Well Information by Section: Number of Public Supply Wells (from WCR data)

Figure 2-7. Plan Development Sequence (public meetings in yellow)

Figure 2-8. GSA Public Event

Figure 2-9. Topographic Map

Figure 2-10. Soil Unit Map

Figure 2-11. Soil Hydraulic Conductivity Map

Figure 2-12. General Geologic Map

Figure 2-13. Surficial Geology Map

Figure 2-14. Extent and Depth of The Corcoran Clay: After Page (1986)

Figure 2-15. Thickness of The Corcoran Clay: After Page (1986)

Figure 2-16. Geologic Fault Map

Figure 2-17. Elevation of Base of Freshwater: Modified from Page (1973)

Figure 2-18. Depth to Base of Continental Deposits or Basement Complex

Figure 2-19. Elevation of Top of Basement Complex (from Mitten, 1970) and Bottom of Continental Deposits (from C2VSim-FG, 2018)

Figure 2-20. Geologic Cross-Section Location Map

Figure 2-21. Geologic Cross-Section: Mitten et al. (1970) Section A-A'

Figure 2-22. Geologic Cross-Section: Page (1986) Section B-B'

Figure 2-23. Madera County Geologic Cross-Section A

Figure 2-24. Madera County Geologic Cross-Section B

Figure 2-25. Madera County Geologic Cross-Section C

Figure 2-26. Madera County Geologic Cross-Section D

Figure 2-27. Madera County Geologic Cross-Section E

Figure 2-28. Madera County Geologic Cross-Section F

Figure 2-29. Madera County Geologic Cross-Section G

Figure 2-30. Madera County Geologic Cross-Section H

Figure 2-31. Madera County Geologic Cross-Section I

Figure 2-32. Madera County Geologic Cross-Section J

Figure 2-33. Madera County Geologic Cross-Section K

Figure 2-34. Chowchilla Subbasin Conceptual Hydrogeologic System

Figure 2-35. CVHM Sediment Texture Model: 0 To 700 Feet

Figure 2-36. CVHM Sediment Texture Model: 700 To 1,400 Feet

Figure 2-37. Map of Well Test Aquifer Property Data: Upper Aquifer

DRAFT

Figure 2-38. Map of Well Test Aquifer Property Data: Lower Aquifer

Figure 2-39. Map of Well Test Aquifer Property Data: Composite Wells or Unknown Dept

Figure 2-40. SAGBI Deep Percolation Potential: Unmodified by Tilling

Figure 2-41. SAGBI Deep Percolation Potential: Modified by Tilling of All Restrictive Layers

Figure 2-42. Areas of Higher Recharge Potential

Figure 2-43. Map of Well Information by Section: Average Domestic Well Depth (from WCR Data)

Figure 2-44. Map of Well Information by Section: Average Agricultural Well Depth (from WCR Data)

Figure 2-45. Map of Well Information by Section: Average Public Supply Well Depth (from WCR Data)

Figure 2-46. Groundwater Surface Elevation Map: Winter/Spring 1988 - Unconfined Groundwater

Figure 2-47. Groundwater Surface Elevation Map: Winter/Spring 2014 - Unconfined Groundwater

Figure 2-48. Groundwater Surface Elevation Map: Winter/Spring 2016 - Unconfined Groundwater

Figure 2-49. Groundwater Surface Elevation Map: Winter/Spring 1988 And 1989 - Lower Aquifer Within Corcoran Clay

Figure 2-50. Groundwater Surface Elevation Map: Winter/Spring 2014 - Lower Aquifer Within Corcoran Clay

Figure 2-51. Groundwater Surface Elevation Map: Winter/Spring 2016 - Lower Aquifer Within Corcoran Clay

Figure 2-52. Select Groundwater Level Hydrographs: Outside the Corcoran Clay Or Upper Aquifer Within the Corcoran Clay

Figure 2-53. Select Groundwater Level Hydrographs: Lower Aquifer Within the Corcoran Clay

Figure 2-54. Select Groundwater Level Hydrographs: Wells of Unknown Construction

Figure 2-55. Groundwater Level Change Map: Winter/Spring 1988 To 2014 - Unconfined Groundwater

Figure 2-56. Groundwater Level Change Map: Winter/Spring 1988 To 2016 - Unconfined Groundwater

Figure 2-57. Groundwater Quality Map: Total Dissolved Solids Concentrations in All Wells

Figure 2-58. Groundwater Quality Map: Total Dissolved Solids Concentrations in Upper Aquifer Wells

Figure 2-59. Groundwater Quality Map: Total Dissolved Solids Concentrations in Lower Aquifer Wells

Figure 2-60. Groundwater Quality Map: Nitrate Concentrations in All Wells

Figure 2-61. Groundwater Quality Map: Nitrate Concentrations in Upper Aquifer Wells

Figure 2-62. Groundwater Quality Map: Nitrate Concentrations in Lower Aquifer Wells

Figure 2-63. Groundwater Quality Map: Arsenic Concentrations in All Wells

DRAFT

Figure 2-64. Groundwater Quality Map: Arsenic Concentrations in Upper Aquifer Wells

Figure 2-65. Groundwater Quality Map: Arsenic Concentrations in Lower Aquifer Wells

Figure 2-66. Map of Historical Land Subsidence Contours: 1926-1970

Figure 2-67. Map of Historical Land Subsidence: 2007-2011

Figure 2-68. Map of Land Subsidence: 2015 To 2017

Figure 2-69. Map of Subsidence Monitoring Locations

Figure 2-70. Map of Depth to Groundwater: Winter/Spring 2014 - Unconfined Groundwater

Figure 2-71. Map of Depth to Groundwater: Winter/Spring 2016 - Unconfined Groundwater

Figure 2-72. GDE units and depth to groundwater in the Chowchilla Subbasin

Figure 2-73. Stratified canopy along the banks of the San Joaquin River in the San Joaquin River Riparian GDE.

Figure 2-74. Chowchilla Subbasin Water Budget Subregions.

Figure 2-75. Water Budget Accounting Structure (Source: DWR, 2016).

Figure 2-76. Chowchilla Subbasin Boundary Water Budget Diagram.

Figure 2-77. San Joaquin Valley Water Year Index, 1965-2015.

Figure 2-78. Annual Precipitation and Cumulative Departure from Mean Precipitation in Madera, CA

Figure 2-78. Annual CVP Supplies and Cumulative Departure from Mean CVP Supplies along Madera Canal.

Figure 2-80. Annual Natural Flow and Cumulative Departure from Mean Natural Flow along Chowchilla River at Buchanan Dam.

Figure 2-81. Chowchilla Subbasin Inflows and Outflows.

Figure 2-82. Chowchilla Subbasin Surface Water Inflows by Water Source Type.

Figure 2-83. Chowchilla Subbasin Surface Outflows by Water Source Type.

Figure 2-84. Chowchilla Subbasin Groundwater System Inflows.

Figure 2-85. Chowchilla Subbasin Groundwater Extraction by Water Use Sector.

Figure 2-86. Chowchilla Subbasin Total Evapotranspiration by Water Use Sector.

Figure 2-87. Chowchilla Subbasin Evaporation from the Surface Water System.

Figure 2-88. Chowchilla Subbasin Groundwater System Change in Storage.

Figure 2-89. Chowchilla Subbasin Surface Water System Historical Water Budget.

Figure 2-90. Chowchilla Subbasin Surface Water System Current Water Budget.

Figure 2-91. Chowchilla Subbasin Surface Water System Projected without Projects Water Budget, GSP Implementation Period (2019-2040).

Figure 2-92. Chowchilla Subbasin Surface Water System Projected without Projects Water Budget, GSP Implementation Period (2041-2090).

LIST OF APPENDICES (Bound Separately)

APPENDIX 2. PLAN AREA AND BASIN SETTING

2.A. Chowchilla Subbasin Annual Spatial Land Use
2.B. Assessment of Groundwater Dependent Ecosystems for the Chowchilla Subbasin GSP
2.C. Notice and Communication
- 2.C.a. Chowchilla Subbasin Stakeholders Communication and Engagement Plan
- 2.C.b. Chowchilla Subbasin Interested Parties List
- 2.C.c. Chowchilla Subbasin Engagement Matrix
- 2.C.d. Chowchilla Subbasin Stakeholder Input Matrix

2.D. Hydrogeologic Conceptual Model
2.E. Current and Historical Groundwater Conditions
2.F. Water Budget Information
- 2.F.a. Surface Water System Water Budget: Chowchilla Water District GSA
- 2.F.b. Surface Water System Water Budget: Madera County East GSA
- 2.F.c. Surface Water System Water Budget: Madera County West GSA
- 2.F.d. Surface Water System Water Budget: Sierra Vista Mutual Water Company
- 2.F.e. Surface Water System Water Budget: Triangle T Water District GSA
- 2.F.f. Daily Reference Evapotranspiration and Precipitation Quality Control
- 2.F.g. Development of Daily Time Step IDC Root Zone Water Budget Model

APPENDIX 6. REFERENCES AND TECHNICAL STUDIES

6.A. Interbasin and Coordination Agreements (as applicable) (Reg. § 357)
6.B. Contact Information for Plan Manager and GSA Mailing Address (Reg. § 354.6)
6.C. List of Public Meetings (Reg. § 354.10)
6.D. Technical Appendices
6.E. Groundwater Model Documentation
6.F. Comments and Responses (Reg. § 354.10)

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LIST OF ABBREVIATIONS

AFY	acre-feet/year
AG	Agricultural Land
AN	above normal
AWMPs	agricultural water management plans
AWS	Automatic Weather Stations
bgs	below ground surface
BMP	Best Management Practice
BN	below normal
C	critical
C2VSim	California Central Valley Groundwater-Surface Water Simulation Model
C2VSim-CG	published coarse-grid version of C2VSim, Version R374
CCC	Columbia Canal Company
CCID	Central California Irrigation District
CCR	California Code of Regulations
CDEC	California Data Exchange Center
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
CSUS	California State University, Sacramento
CVHM	Central Valley Hydrologic Model
CVP	Central Valley Project
CWC	California Water Code
CWD	Chowchilla Water District
D	dry
DDW	Division of Drinking Water
DE	Davids Engineering
DMS	Data Management System
DQO	data quality objectives
DTW	depth to water
DWR	California Department of Water Resources
EFH	Essential Fish Habitat
ERA	ERA Economics, LLC
ET	evapotranspiration
ET_a	actual ET
ET_{aw}	ET of applied water
ET_c	crop ET
ET_o	grass reference ET
ET_{pr}	ET of precipitation
ET_r	alfalfa reference ET
ET_{ref}	reference crop evapotranspiration
eWRIMS	Electronic Water Rights Information Management System
Flood-MAR	Flood Managed Aquifer Recharge
FTE	full-time-equivalent
GAMA	Groundwater Ambient Monitoring and Assessment
GDEs	groundwater dependent ecosystems
GFWD	Gravelly Ford Water District
GIS	geographic information system
GMP	Groundwater Management Plan
GRF	Gravelly Ford
GSA	Groundwater Sustainability Agencies
GSP	Groundwater Sustainability Plan
GWE	Groundwater Elevation
GWS	groundwater system

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HCM	hydrogeologic conceptual model
HGL	hydraulic grade line
IDC	Integrated Water Flow Model Demand Calculator
iGDE	indicators of GDEs
ILRP	Irrigated Lands Regulatory Program
IWFM	Integrated Water Flow Model
K	hydraulic conductivity
Kh	horizontal hydraulic conductivity
Kv	vertical hydraulic conductivity
LDC	Little Dry Creek
LSCE	Luhdorff & Scalmanini Consulting Engineers
MA	Management actions
Madera Co	Madera County
maf	millions of acre-feet
MAR	Managed aquifer recharge
MC	Madera County
MCDEH	Merced County Department of Public Health, Division of Environmental Health
MCL	maximum contaminant level
MCWPA	Madera-Chowchilla Water and Power Authority
Merced	Merced Irrigation District
Merced Co	Merced County
Merced ID	Merced Irrigation District
mg/L	milligrams/liter
MID	Madera Irrigation District's
MIGR	Warm and cold migration habitat
MO	measurable objectives
MSL	mean sea level
MT	minimum thresholds
MUN	Municipal and domestic supply
MWELO	Model Water Efficient Landscape Ordinance
NCCAG	Natural Communities Commonly Associated with Groundwater
NOAA NCEI	National Oceanic and Atmospheric Administration National Centers for Environmental Information
NV	Native Vegetation Land
NWIS	National Water Information System
O&M	operation and maintenance
ORP	oxidation-reduction potential
pCi/L	picocuries per liter
pTb	Pre-Tertiary basement complex
PV	Present Value
Qb	Quaternary flood-plain deposits
Qoa	Older Quaternary alluvium
QTc	Tertiary and Quaternary continental deposits
QTcd	Quaternary continental rocks and deposits
Qya	younger Quaternary alluvium
Reclamation	United States Bureau of Reclamation
redox	reduction-oxidation
RFP	Request for Proposals
RH	relative humidity
RMS	Representative monitoring sites
RPE	Reference Point Elevation
Rs	solar radiation
SAGBI	Soil Agricultural Groundwater Banking Index
SB	Senate Bill

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SCS-CN	SCS curve number
SEBAL	Surface Energy Balance Algorithm for Land
SGMA	Sustainable Groundwater Management Act of 2014
SJRRP	San Joaquin River Restoration Program
SJV	San Joaquin Valley
SLDMWA	San Luis Delta-Mendota Water Authority
SMC	Sustainable Management Criteria
SPWN	Warmwater spawning habitat
SS	Stillwater Sciences
SVMWC	Sierra Vista Mutual Water Company
SWRCB	State Water Resources Control Board
SWS	surface water system
Sy	specific yield
T	transmissivity
Ta	air temperature
TAF	thousand acre-feet
TDS	total dissolved solids
TM	Technical Memorandum
TMWA	Truckee Meadows Water Authority
TpTu	Pre-Tertiary and Tertiary marine and continental sedimentary rocks
TTWD	Triangle T Water District
UR	Urban Land
USACE	United States Army Corps of Engineers
USBR	U.S. Bureau of Reclamation, or Reclamation
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
UWMPs	urban water management plans
W	wet
WARM	Warm freshwater habitat
WCRs	well completion reports
WDL	Water Data Library
WILD	Wildlife habitat
Ws	wind speed
WYI	Water Year Index
YCWA	Yuba County Water Agency
yield	groundwater benefit
µg/L	micrograms per liter

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2 PLAN AREA AND BASIN SETTING

2.1 Description of the Plan Area (23 CCR § 354.8)

The Plan Area is defined as the Chowchilla Subbasin (5-022.05), part of the San Joaquin Valley Groundwater Basin, as described in DWR Bulletin 118 (DWR, 2016) with boundary updates approved in early 2019.

The lateral extent of the subbasin is defined by the subbasin boundaries provided in Bulletin 118 (DWR, 2016), with boundary updates approved in late 2018. The subbasin is bounded in the south and east by the Madera Subbasin, in the west by the San Joaquin River and the Delta-Mendota Subbasin, and in the north by the Merced Subbasin (Figure 1-1).

The vertical boundaries of the subbasin are the land surface (upper boundary) and the definable bottom of the basin (lower boundary). The definable bottom was established as part of development of the preliminary hydrogeologic conceptual model (HCM) during previous data collection and analysis efforts conducted by DE and LSCE (2017). The vertical extent of the subbasin is subdivided into a surface water system (SWS) and groundwater system (GWS). The SWS represents the land surface down to the bottom of plant root zone,[1] within the lateral boundaries of the subbasin. The GWS extends from the bottom of the root zone to the definable bottom of the subbasin, within the lateral boundaries of the subbasin.

2.1.1 Summary of Jurisdictional Areas and Other Features (23 CCR § 354.8(b))

As identified in Section 1.3, four GSAs cover the Chowchilla Subbasin: CWD GSA, Madera Co GSA, Merced Co GSA, and TTWD GSA. These four GSAs have agreed to cooperate and develop a single GSP for the Chowchilla Subbasin.

Table 1-2 and **Figure 1-1** delineate the areas managed exclusively by each GSA in this GSP and portions of the subbasins adjacent to the Plan Area. No area in the subbasin is covered by an alternative. The subbasin is within the jurisdictional boundaries of Madera County and Merced County and is covered by the respective general plans of the counties. The area covered by the City of Chowchilla General Plan is contained within the CWD GSA boundaries. The Chowchilla Subbasin is not adjudicated and contains no considerable state land or federal land.[2]

Land in the Chowchilla Subbasin is broadly classified across three land use sectors: agricultural, urban, and native vegetation. Agricultural land use includes all agricultural crops reported in the Chowchilla Subbasin, including idle agricultural land. Urban land use includes urban, industrial, and semi-agricultural land. Native vegetation land use includes all land covered by native vegetation and water surfaces.

[1] The depth to the bottom of the root zone varies by crop, but typically ranges from 2-7 feet (ASCE, 2016).

[2] Federal land includes primarily rights of way along canals conveying USBR Central Valley Project water.

Figure 2-1 depicts land use in the Chowchilla Subbasin as reported in the 2011 DWR Madera County Land Use Survey and 2012 DWR Merced County Land Use Survey spatial coverages[3]. Annual land use areas within Chowchilla Subbasin were derived from the aforementioned DWR spatial land use surveys of Madera and Merced Counties, Land IQ remotely sensed land use data obtained through DWR, and Madera County and Merced County Agricultural Commissioner annual crop production area reports. Additional detail for the process used to develop an annual land use database for Madera County is provided in **Appendix 2.A**.

Annual land use within each of the three sectors are summarized in **Figure 2-2** and **Table 2-1** for the entire Chowchilla Subbasin between 1989-2015. Agricultural land use categories are further detailed in **Figure 2-3** and **Table 2-2**. Average land use across each sector and category is provided for the 1989-2014 historical water budget period described below in Section 2.2.3. Land use summaries are provided for each GSA in **Appendix 2.F**.

The densities of domestic wells and irrigation wells per section within the Chowchilla Subbasin are shown in **Figures 2-4 and 2-5**, respectively. Notably, the number of wells reported by section were determined from Well Completion Report (WCR) data provided by DWR. These numbers include only reported wells and may not reflect the total number of existing or active wells in the subbasin. The highest concentrations of domestic wells are centered primarily along the southern side of the City of Chowchilla. Irrigation wells are generally less concentrated and more evenly distributed across the subbasin, though slightly higher concentrations are found in sectors within the western portions of Madera Co GSA and CWD GSA. Maps of general locations of domestic, agricultural, and public supply wells are provided in **Figures 2-4, 2-5, and 2-6**.

2.1.2 Water Resources Monitoring and Management Programs (23 CCR § 354.8(c), (d), (e))

Existing surface water and groundwater monitoring and management programs within the Chowchilla Subbasin are identified below following a summary of water planning documents applicable to the subbasin GSAs.

Continued monitoring is required to track the progress of the GSP implementation plan by providing data on groundwater and surface water availability in the subbasin. One overarching project in the implementation plan adds additional monitoring to fill data gaps (see Section 4 for more details).

[3] The 2011 DWR Madera County Land Use Survey and 2012 DWR Merced County Land Use Survey are the most recent parcel-based land use data available at the time of GSP development. Field-based data is also available in 2014 from Land IQ, LLC. The DWR Land Use interpolation tool was used to estimate spatial land use data in years without parcel-based or field-based data, including 2015.

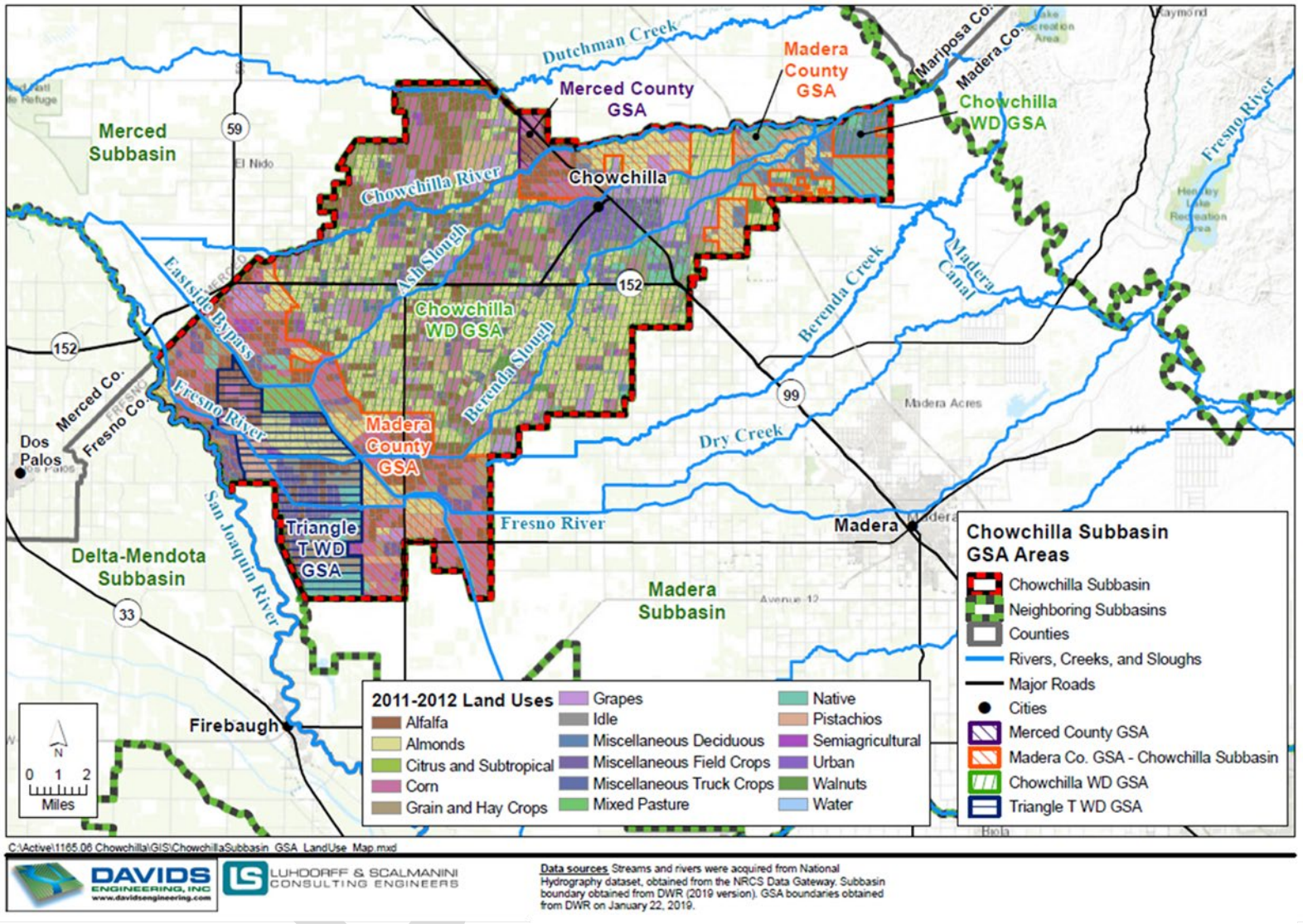

Figure 2-1. Chowchilla Subbasin Land Use Map.[4]

[4] Land uses extracted from the 2011 DWR Madera County and 2012 DWR Merced County spatial land use survey results.

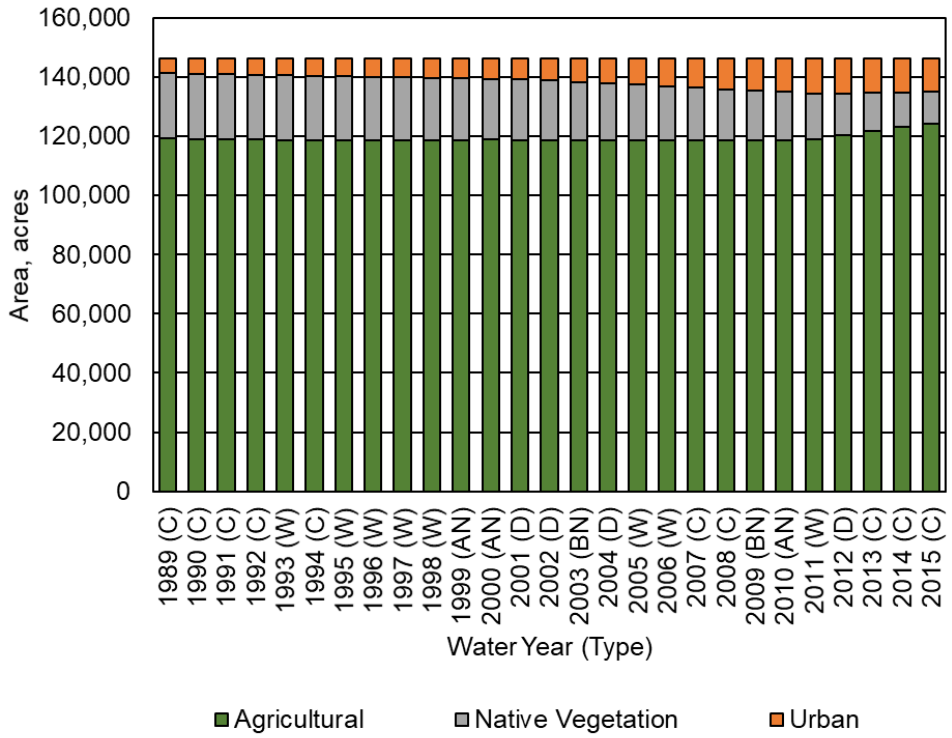

Figure 2-2. Chowchilla Subbasin Land Use Areas.

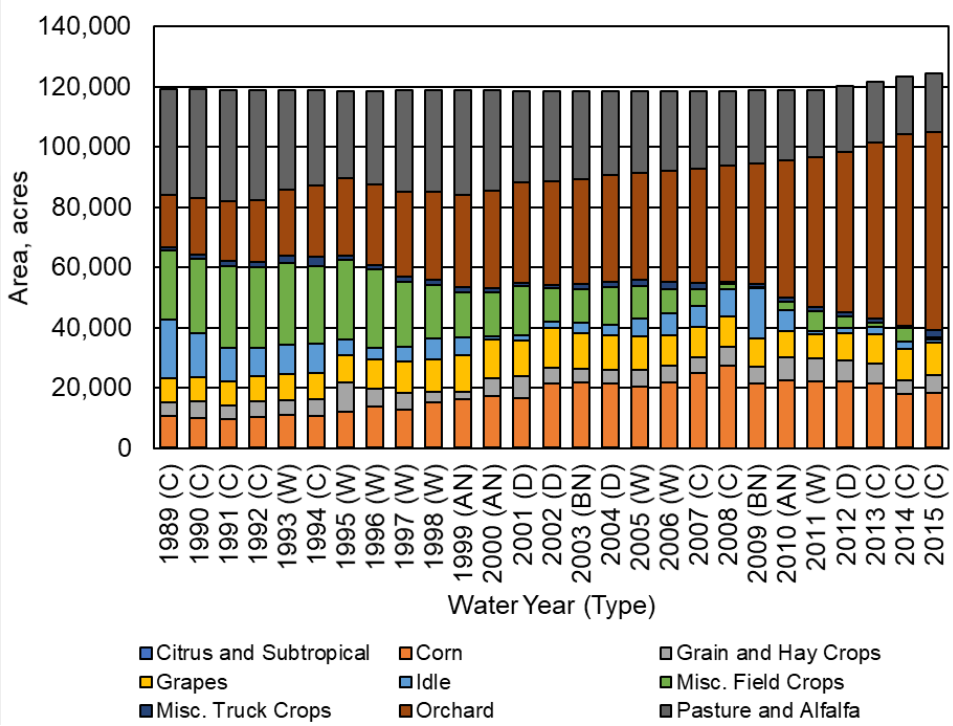

Figure 2-3. Chowchilla Subbasin Agricultural Land Use Areas.

Table 2-1. Chowchilla Subbasin Land Use Areas (Acres).

Water Year (Type)	Agricultural	Native Vegetation[1]	Urban[2]	Total
1989 (C)	119,134	22,046	5,145	146,325
1990 (C)	119,000	22,040	5,285	146,325
1991 (C)	118,929	21,960	5,436	146,325
1992 (C)	118,784	21,942	5,599	146,325
1993 (W)	118,737	21,824	5,764	146,325
1994 (C)	118,658	21,730	5,936	146,325
1995 (W)	118,601	21,612	6,112	146,325
1996 (W)	118,634	21,411	6,280	146,325
1997 (W)	118,667	21,210	6,448	146,325
1998 (W)	118,700	21,010	6,615	146,325
1999 (AN)	118,733	20,809	6,783	146,325
2000 (AN)	118,766	20,608	6,950	146,325
2001 (D)	118,577	20,613	7,135	146,325
2002 (D)	118,605	20,156	7,564	146,325
2003 (BN)	118,611	19,666	8,048	146,325
2004 (D)	118,616	19,177	8,531	146,325
2005 (W)	118,623	18,686	9,015	146,325
2006 (W)	118,629	18,197	9,499	146,325
2007 (C)	118,635	17,707	9,982	146,325
2008 (C)	118,641	17,219	10,465	146,325
2009 (BN)	118,648	16,727	10,949	146,325
2010 (AN)	118,653	16,238	11,433	146,325
2011 (W)	118,861	15,570	11,894	146,325
2012 (D)	120,293	14,184	11,848	146,325
2013 (C)	121,760	12,822	11,743	146,325
2014 (C)	123,247	11,425	11,653	146,325
2015 (C)	124,350	10,645	11,330	146,325
Average (1989-2014)	119,067			

[1] Area includes land classified as native vegetation and water surfaces.
[2] Area includes land classified as urban, industrial, and semi-agricultural.

Table 2-2. Chowchilla Subbasin Agricultural Land Use Areas (Acres).

Water Year (Type)	Citrus and Subtropical	Corn	Grain and Hay Crops	Grapes	Idle	Misc. Field Crops	Misc. Truck Crops	Orchard[1]	Pasture and Alfalfa	Total
1989 (C)	59	10,439	4,590	8,023	19,511	22,850	1,201	17,449	35,012	119,134
1990 (C)	64	9,875	5,545	8,033	14,688	24,528	1,521	18,680	36,065	119,000
1991 (C)	67	9,519	4,369	8,119	11,065	27,411	1,566	19,889	36,925	118,929
1992 (C)	67	10,302	5,097	8,387	9,450	26,605	1,815	20,739	36,322	118,784
1993 (W)	67	10,845	4,993	8,529	9,912	27,249	2,162	22,078	32,902	118,737
1994 (C)	64	10,691	5,287	8,823	9,761	25,913	2,834	23,832	31,454	118,658
1995 (W)	112	11,782	9,891	8,981	5,264	26,486	1,178	25,975	28,932	118,601
1996 (W)	146	13,597	5,919	9,759	3,729	26,040	1,543	26,709	31,193	118,634
1997 (W)	135	12,628	5,686	10,325	4,768	21,525	1,785	28,138	33,677	118,667
1998 (W)	34	15,211	3,462	10,753	6,930	17,799	1,530	29,306	33,674	118,700
1999 (AN)	78	16,084	2,457	12,262	5,926	14,983	1,591	30,817	34,535	118,733
2000 (AN)	83	17,212	5,730	12,941	966	14,844	1,199	32,292	33,500	118,766
2001 (D)	72	16,574	7,383	11,604	1,683	16,445	1,197	33,159	30,462	118,577
2002 (D)	85	21,273	5,408	13,044	1,983	11,156	1,240	34,368	30,049	118,605
2003 (BN)	39	21,785	4,537	11,820	3,432	11,190	1,533	35,020	29,255	118,611
2004 (D)	37	21,217	4,860	11,199	3,520	12,484	1,876	35,279	28,144	118,616
2005 (W)	33	20,227	5,845	10,846	5,927	10,907	1,980	35,569	27,288	118,623
2006 (W)	30	21,811	5,595	10,139	7,070	8,117	2,269	36,905	26,693	118,629
2007 (C)	26	25,012	5,039	10,115	6,829	5,710	2,174	37,866	25,865	118,635
2008 (C)	21	27,377	6,092	10,023	9,086	1,724	677	38,640	25,002	118,641
2009 (BN)	18	21,245	5,664	9,386	16,696	398	1,153	39,895	24,193	118,648
2010 (AN)	22	22,514	7,498	8,822	6,866	2,918	1,201	45,530	23,281	118,653
2011 (W)	17	21,979	7,679	8,133	890	6,889	1,228	49,602	22,445	118,861
2012 (D)	46	22,131	6,950	8,940	1,723	3,875	1,301	53,289	22,037	120,293
2013 (C)	87	21,465	6,605	9,755	2,307	1,254	1,426	58,411	20,449	121,760
2014 (C)	190	17,660	4,510	10,624	2,236	4,497	785	63,752	18,992	123,247
2015 (C)	130	18,117	5,805	10,934	1,085	666	2,479	65,699	19,435	124,350
Average (1989-2014)	65	17,325	5,642	9,976	6,624	14,377	1,537	34,353	29,167	119,067

[1] Orchard crops include primarily almonds and pistachios, as well as walnuts and miscellaneous deciduous crops.

2.1.2.1 Water Planning Documents

As stewards of the water resources within their jurisdictions, the local agencies that have formed each of Chowchilla Subbasin's GSAs have prepared and adopted several water planning documents. These include:

- Regional Water Plans
    - Madera Integrated Regional Water Management Plan (approved in 2008, updated in 2015)
        - This plan is a collaborative effort to improve regional coordination in management of water resources among the 17 groups and agencies forming the Madera Regional Water Management Group as well as other interested parties. These agencies include two currently organized as GSAs in the Chowchilla Subbasin (CWD and Madera Co). The plan establishes regional water management goals and serves as a basis for pursuing funding to accomplish these goals.
    - Madera Regional Groundwater Management Plan (adopted in 2014)
        - This plan provides a framework for regional groundwater management among six participating groups and agencies, including two currently organized as GSAs in the Chowchilla Subbasin (CWD and Madera Co). The objectives of the plan are to establish collaborative governance, stabilize and recover groundwater levels, mitigate subsidence, improve public awareness, and maintain and improve the economic viability of the Madera region.
- Water Management Plans
    - Chowchilla Water District Water Management Plan (2017)
- Groundwater Management Plans
    - Chowchilla-Red Top Resource Conservation District Joint Powers Authority Groundwater Management Plan (1997)
    - Madera County Groundwater Management Plan (2002)
- Other Plans
    - City of Chowchilla General Plan (updated 2017)
    - City of Chowchilla Urban Water Management Plan (2008)
    - City of Chowchilla Sphere of Influence Expansion and Municipal Service Review (2011)
    - Clayton Water District Municipal Service Review (2017)
    - Madera County General Plan (updated 2015)
    - Madera County Storm Water Resource Plan (2017)
    - Merced County General Plan (updated 2016)
    - Triangle T Water District Municipal Service Review (2017)

Information developed for these plans regarding GSA surface water and groundwater supplies, distribution infrastructure, and monitoring programs have contributed to the development of this GSP.

2.1.2.2 Surface Water Monitoring and Management Programs

Surface water flows into and within the Chowchilla Subbasin are extensively monitored through existing federal, state, regional, and local programs. Data and spatial information from these monitoring programs have been incorporated directly into this GSP to support water budget development, per 23 CCR Section 354.18.

These sources and the data they provide are summarized below.

Federal, State, and Regional Programs

In support of GSP development, surface water data were collected from the following agencies and programs:

- California Data Exchange Center (CDEC)
- California State Water Resources Control Board (SWRCB)
    - SWRCB GeoTracker
- Department of Water Resources Water Data Library (WDL)
- Madera-Chowchilla Water and Power Authority (MCWPA)
- San Joaquin River Restoration Program (SJRRP)
- San Luis Delta-Mendota Water Authority (SLDMWA)
- United States Army Corps of Engineers (USACE)
- United States Bureau of Reclamation (Reclamation)
- United States Geological Survey (USGS)
    - National Water Information System (NWIS)

Key federal and state surface water monitoring stations and the agency collecting the data are identified in Table 2-3. In the Chowchilla Subbasin, Chowchilla Bypass and San Joaquin River inflows are compiled from CDEC and WDL data, Chowchilla River inflows are measured and reported by USACE, Fresno River inflows are measured by the MID recorder network (this is also the Fresno River outflow from the Madera Subbasin), and Madera Canal inflows are recorded and reported by Reclamation.

Deliveries of Central Valley Project (CVP) water along Madera Canal to lands within Chowchilla Subbasin are managed by MCWPA. Reclamation monitors and reports these deliveries as part of the CVP Friant Division.

Local Programs

Water data were also collected from the following local monitoring programs:

- The City of Chowchilla's SCADA system and records of monthly volumes pumped from groundwater supply wells (available since 2003).
- CWD's SCADA system and records of canal flows and conveyance system spillage (available since 1995).
- CWD's records of monthly water supply from Madera Canal (Class 1, Class 2, 215, URF, RWA, Free Water, Flood Releases), Buchanan Dam (Irrigation Releases, Flood Releases), Legrand, and transfers.

- CWD's records of grower deliveries in their STORM[5] database (available since 2000).
- CWD's records of riparian deliveries to white areas (available since 1996)
- CWD's records of riparian deliveries to Roduner Ranch (available since 1994)
- CWD's records of prescriptive water rights deliveries to growers along Chowchilla River (available since 1981)
- Madera County's requirement to include a flow measurement device on new wells and the resulting groundwater pumping records.
- Madera Irrigation District's (MID) recorders network with records of Fresno inflows to the Chowchilla Subbasin (available since the 1950s).
- Triangle T Ranch well reports (available since 2011) and water level reports (available since 2016).

Streamflow monitoring stations and MID recorders along waterways were used to prepare timeseries datasets for subbasin surface water inflows and outflows, as applicable. CWD SCADA records at spillage sites were used to prepare timeseries datasets for CWD conveyance system outflows. Records of groundwater pumping, and deliveries were used to prepare timeseries datasets for agricultural land inflows. These data and methodologies are described in Section 2.2.3.

Table 2-3. Surface Water Monitoring Stations.

Waterway	Source	Site ID	Site Name	Available Data Period	Details
Chowchilla Bypass	CDEC	CBP	Chowchilla Bypass	1997-2018	Station operated by SLDMWA
Chowchilla Bypass	WDL	B07802	Chowchilla Bypass at Head Below Control Structure	1978-1991	
Chowchilla River	USACE	Buchanan Reservoir	Buchanan Reservoir, Chowchilla River, California	1981-2017	
Fresno River	MID	Recorder 24	Rd. 9 at Fresno River	2005-2013	
Madera Canal	Reclamation	Indicated by Mile	Miles 33.6, 35.6	1978-2018	CVP water deliveries to CWD reported by Mile
San Joaquin River	WDL	B07610	San Joaquin River near Dos Palos	1980-2018	

Program Limitations on Operation Flexibility in Basin

Continued operation of these water monitoring programs will support tracking the progress of the GSP implementation plan by providing data on water availability as well as inflows and outflows from the subbasin.

[5] The water ordering and delivery management software used by Chowchilla Water District and Madera Irrigation District.

Limitations on surface water deliveries will limit operational flexibility by reducing surface water supplies available for conjunctive use programs.

2.1.2.3 Groundwater Monitoring and Management Programs

There are a variety of local, state, and federal monitoring programs currently and historically conducted in Chowchilla Subbasin related to groundwater levels, groundwater quality, and land subsidence. Each monitoring category is described in more detail in the sections below.

Groundwater Level Monitoring

Groundwater level monitoring has been conducted historically by variety of entities in the Subbasin including Chowchilla Water District, Madera County, Triangle T Water District, DWR, USBR, and Geospacer GAMA. The California State Groundwater Elevation Monitoring Program (CASGEM) was initiated in 2011, with the Madera-Chowchilla Groundwater Monitoring Group as the local monitoring entity. This Group includes Chowchilla Water District and the County, along with other entities in Madera Subbasin. Groundwater levels are collected and submitted each Fall and Spring as part of the CASGEM program. **Appendix 2.G** includes a map presenting the well locations and most recent monitoring date for historical groundwater level monitoring conducted in the Subbasin.

Groundwater Quality Monitoring

Groundwater quality monitoring has historically been conducted by a variety of entities in the Subbasin including the City of Chowchilla and other public drinking water suppliers, regulated facility operators and other contaminant site monitoring for the RWQCB, the East San Joaquin Water Quality Coalition (the third-party entity representing growers in the area) as part of the Irrigated Lands Regulatory Program (ILRP), USGS for the Groundwater Ambient Monitoring and Assessment Program (GAMA), and other programs under the direction of agencies such as the RWQCB, DPR, EPA, DTSC, USGS. Some historical groundwater quality monitoring has also been conducted by well owners in the Subbasin for other purposes.

All public drinking water supply systems must conduct groundwater quality monitoring as part of requirements for the Division of Drinking Water (DDW). The required frequency and constituents for DDW monitoring vary by water system and monitoring point. Groundwater quality monitoring is also conducted at regulated facilities and contaminant sites for the RWQCB in association with tracking and reporting on the status of groundwater contamination near these sites. More recently, groundwater quality monitoring required by the Irrigated Lands Regulatory Program has been initiated. Groundwater quality assessment and monitoring for the ILRP included preparation of a Groundwater Quality Assessment Report with five-year updates, including delineation of High Vulnerability Areas relative to groundwater quality impacts from irrigated agricultural practices and also includes development and maintenance of a network of wells for groundwater quality sampling as part of a Groundwater Quality Trend Monitoring (GQTM) program. The GQTM program includes annual monitoring results reporting and five-year evaluations of groundwater quality trends and conditions relative to irrigated agriculture. Additionally, as part of the ILRP, all domestic wells on parcels enrolled in the agricultural coalition must also be tested for nitrate. The ILRP domestic well monitoring efforts are newly underway and results nor well locations related to this monitoring are not available at the time of preparation of this report. **Appendix 2.G** includes a map presenting the well locations, monitoring programs, and most recent monitoring date for historical groundwater quality monitoring conducted in the Subbasin.

The Chowchilla Subbasin is identified as a Priority 1 Area for nitrate control efforts to be required under the Nitrate Control Program included in the Basin Plan Amendment approved by the RWQCB in May 2018

and in the process of undergoing approval by the SWRCB (anticipated Summer or Fall 2019). After adoption of the Basin Plan Amendment, the RWQCB is expected to issue notices to comply within a short time period, which will start the clock on requirements of the Nitrate Control Program. As a Priority 1 Subbasin identified by CV-SALTS, dischargers in the Chowchilla Subbasin will be among the first required to comply with the program and develop an approach to ensure shallow groundwater is protected. The Nitrate Control Program requires development of Early Action Plans in areas where nitrate discharges to groundwater may be impacting public drinking water supplies. Once in effect, it is expected that the Nitrate Control Program will include considerable analysis and/or monitoring of groundwater quality conditions and development of actions to address groundwater quality impacts from nitrate discharges.

Land Subsidence Monitoring

Land subsidence monitoring has been conducted by various agencies including USGS, DWR, USBR, USACE, San Luis & Delta-Mendota Water Authority (SLDMWA), Central California Irrigation District (CCID), California Department of Transportation (Caltrans), National Geodetic Survey (NGS), UNAVCO, and others (MRGMP, 2014). A key ongoing subsidence program is conducted by USBR in conjunction with DWR, USGS, and USACE, which collects and publishes subsidence data twice per year as part of the SJRRP. **Appendix 2.G** includes a map presenting the monitoring sites and most recent monitoring date for historical land subsidence monitoring conducted in the Subbasin and vicinity. Additionally, through remote sensing and similar data acquisition methods such as InSAR, maps of periodic snapshots of spatial distribution of land subsidence have been historically generated including by DWR, USGS, and The Jet Propulsion Laboratory (JPL). The frequency of such land subsidence mapping efforts has been variable but has increased in frequency and regularity since 2010 and are anticipated to continue in the future.

2.1.2.4 Conjunctive Use Programs

To support overall water management objectives, water distributors in the Chowchilla Subbasin strategically manage their conjunctive use of surface and groundwater supplies.

CWD receives surface water supplies from Millerton Reservoir (along Madera Canal) and Eastman Lake (along Chowchilla River) that is delivered to customers in CWD, Madera Co, and Sierra Vista Mutual Water Company (SVMWC). The districts practice conjunctive use of these surface water supplies through policies to encourage grower use of surface water when available. These practices reduce groundwater pumping and increase groundwater recharge in wet years, providing increased groundwater supplies available for use by private groundwater wells in dry years. For growers, the historical advantages of groundwater are many and include greater flexibility in providing water for frost protection, chemigation, and fertigation and to better align irrigations with crop water demands, field activities, and harvest. Irrigation by surface water supplies also provides the advantage of in-lieu recharge of groundwater. Because of these many perceived advantages, policies encouraging surface water use when the water is available are important.

Domestic water users in the City of Chowchilla rely solely on groundwater, while some agricultural water users within the City limits use groundwater to supplement surface water supplies from CWD. The domestic water system infrastructure includes seven active groundwater wells and with two additional off-line wells, that together supply up to 6,000 gpm of water to 37 miles of main distribution pipelines and over 3,700 connections.[6] The Central California Women's Facility and the Valley State Prison for Women in Chowchilla each operate their own separate water systems.

[6] Madera Regional Groundwater Management Plan, December 2014. Pg. 130-131.

Conjunctive use programs in the subbasin include indirect reuse and recharge of surface water supplies, treated wastewater, and/or stormwater in CWD, City of Chowchilla, and Madera County.

In addition to encouraging growers to use surface water when available, CWD provides or facilitates groundwater recharge through infiltration of surface water along 150 miles of unlined canals, local sloughs, and nearby stream channels (Chowchilla River, Dutchman Creek, Ash Slough and Berenda Slough). [7] Recharge is also provided through two surface water retention reservoirs, eight recharge basins, and the City of Chowchilla stormwater basins.[8] CWD also utilizes various water management techniques to enhance water delivery efficiency, including measurement weirs, water meters, rated canal gates, regulating reservoirs and ponds, long-crested weirs, flap gates, and a SCADA system.[9]

The City of Chowchilla provides groundwater recharge through incidental infiltration of secondary treated wastewater released from the city's wastewater treatment plant.[10] The wastewater treatment plant collects approximately 1.8 MGD of wastewater from Chowchilla's population of over 19,000 people along 26 miles of sanitary sewers, and discharges approximately 1.0 MGD to percolation ponds.[11]

2.1.3 Land Use Elements or Topic Categories of Applicable General Plans (23 CCR § 354.8 (f))

The Chowchilla Subbasin lies primarily within Madera County, though a small portion lies within Merced County. Thus, both the Madera County General Plan and Merced County General Plan are applicable to the subbasin. Additionally, the City of Chowchilla General Plan is applicable to land in CWD GSA defined by the boundaries of City of Chowchilla.

2.1.3.1 Madera County General Plan

In the Madera County General Plan updated in 2015[12], Madera County affirms its general land use policies to designate sufficient land for projected population growth in the county (Policy 1.A.2), but plans for this growth through higher-density, or infill, development in existing communities and "designated new growth areas" to minimize urban encroachment into agricultural lands and other open spaces and to consolidate infrastructure expansion (Policies 1.A.3-4, 1.B.2, 1.C.2). Furthermore, Madera County restricts development in "areas with sensitive environmental resources" (Policy 1.A.5).

With regard to agricultural land, Madera County maintains policies to encourage soil conservation practices, land improvement programs, and enrollment of agricultural land in the Williamson Act program (Policies 5.A.6-8,12).

With regard to water resources, Madera County's policies are to "protect and preserve areas with groundwater recharge capabilities" (Policy 5.C.1), minimize groundwater overdraft by utilizing surface water for urban and agricultural use where available, and support the policies of the San Joaquin River Parkway Plan (Policy 5.E.11).

With regard to open spaces, Madera County supports the preservation of natural vegetation, land forms, and resources as open space, with permanent protection where feasible (Policy 5.H.1).

[7] Madera Regional Groundwater Management Plan, December 2014. Pg. 119, 132.
[8] Madera Regional Groundwater Management Plan, December 2014. Pg. 119, 133.
[9] Madera Regional Groundwater Management Plan, December 2014. Pg. 132.
[10] Madera Regional Groundwater Management Plan, December 2014. Pg. 119.
[11] Madera Regional Groundwater Management Plan, December 2014. Pg. 131.
[12] Madera County General, Plan Policy Document Adopted October 1995, housing element updated November 2015.

Implementation Effects on Water Demands and Sustainability

Implementation of proposed land use developments under this general plan is not expected to shift water demands, in part due to the County's ordinance for large developments to not exceed available sustainable yield (e.g. equivalent to a 'net zero' impact policy). Furthermore, the 2009 remote sensing ET results developed as part of this GSP indicate that medium and high-density housing consume less water on a per-acre basis than the agricultural uses replaced. Thus, even though domestic water demand is met entirely by groundwater, urban growth is estimated to slightly reduce overall water consumption.

GSP Implementation Effects on Water Supply Assumptions

Implementation of the GSP will require the Chowchilla Subbasin to be operated within its sustainable yield by 2040, which may include restrictions on groundwater pumping and implementation of projects to increase groundwater recharge (see Chapter 4). However, urban water use has historically represented a small fraction of all water consumption in the subbasin and is unlikely to be as significantly affected as agricultural water use. Furthermore, some of this urban development is expected on currently irrigated agricultural land and, because new urban developments consume less water per acre, will lower water use compared to the agricultural consumption. New development and retrofitted landscape water efficiency standards are governed by numerous state statutory requirements, such as the Model Water Efficient Landscape Ordinance (MWELO) and the Urban Water Management Planning Act. The MWELO increases water efficiency standards for new and retrofitted landscapes by encouraging more efficient irrigation systems, graywater usage, and onsite storm water capture, and by limiting the portion of landscapes that can be covered in turf. Studies and reviews by Olmos and Loge (2013), Engelhardt et al. (2016), and Loux et al. (2012) support the feasibility of achieving these standards through adoption of such water conservation measures in California and elsewhere, particularly when considered in early planning stages of developments.

Generally, implementation of policies related to agricultural land, water resources, and open spaces are in alignment with GSP planning efforts and are expected to support achievement of subbasin sustainability.

2.1.3.2 Merced County General Plan

In the Merced County General Plan adopted in December 2013 and amended in July 2016[13], Merced County affirms its countywide growth and development goal to shape land use patterns that "enhance the integrity of both urban and rural areas" by limiting urban sprawl and protecting agricultural and wetland habitat areas (Goal LU-1). To achieve this, Merced County has established policies to promote compact development of existing or well-planned new urban communities established apart from productive agricultural land, to limit growth in rural centers, and to forbid development adjacent to wetland habitat (Policies LU-1.1-5,7,9-10,13).

With regard to agricultural land, Merced County maintains policies that would "preserve, promote, and expand the agricultural industry" (Goal LU-2) by limiting land use activities in designated agricultural and foothill pasture land use areas to agricultural crop production, grazing, and related ancillary uses that directly support farm operations or produce renewable energy without interfering with agriculture or natural resources (Policies LU-2.1-7). These policies stipulate that ancillary agricultural land uses "shall not have a detrimental effect on surface or groundwater resources" (Policy LU-2.5(h)).

[13] 2030 Merced County General Plan, Adopted December 10, 2013 and Amended July 12, 2016.

With regard to water resources, Merced County's goals are to ensure the reliability and quality of surface and groundwater resources to meet the existing and future needs of users (Goals W-1-2). Toward these goals, policies have been established to support water management planning (Policies W-1.1,3), to require demonstration of sufficient water supply for new development (Policies W-1.2,7), to support surface water storage and groundwater recharge projects (Policies W-1.4,6), to develop guidelines for new well construction (Policy W-1.5), to encourage conjunctive use of groundwater and surface water supplies (Policy W-1.10), and to develop regulations and/or promote practices that reduce point source and non-point source water pollution (Policies W-2.2-8)

Merced County also promotes maximizing water use efficiency through policies that support conservation, reuse and recycling, and public education programs (Policies W-3.1-15)

Implementation Effects on Water Demands and Sustainability

Implementation of proposed land use developments under this general plan is not expected to increase water demands in the subbasin because the County's policies require that new developments demonstrate sufficient water supply and because, as described above, medium and high density housing consumes less water than the agricultural uses replaced. Implementation of policies to promote surface water storage, groundwater recharge, conjunctive use, water conservation, and recycling will all benefit subbasin sustainability by enhancing surface water supplies and groundwater recharge.

GSP Implementation Effects on Water Supply Assumptions

Implementation of the GSP will require the Chowchilla Subbasin to be operated within its sustainable yield by 2040, which may include restrictions on groundwater pumping and implementation of projects to increase groundwater recharge. However, urban water use has historically represented a small fraction of all water consumption in the subbasin and is unlikely to be as significantly affected as agricultural water use. Furthermore, some of this urban development is expected on agricultural land and will lower water use requirements. As described above, new development is governed by the MWELO, which increases water efficiency standards and encourages more efficient irrigation systems, graywater usage, and onsite storm water capture, while limiting the portion of landscapes that can be covered in turf. Such measures will result in lower water use.

Generally, implementation of policies related to agricultural land, water resources, and open spaces are in alignment with GSP planning efforts and are expected to support achievement of subbasin sustainability.

2.1.3.3 City of Chowchilla General Plan

In the City of Chowchilla General Plan[14], City of Chowchilla establishes a vision for future development that would, among other goals, support contiguous urban development, even into agricultural land when necessary, within and around the existing city bounds.

In the plan, City of Chowchilla identifies critical growth challenges, including managing urban expansion efficiently, resisting premature conversion of agricultural land, and discouraging urban encroachment on prime agricultural land. For future growth into 2040, City of Chowchilla's projected planning area would absorb approximately 8,000 acres for residential, commercial, and industrial uses between 2020 and

[14] City of Chowchilla 2040 General Plan.

2040, including land within and outside the existing city limits.[15] Much of this would go into expanding high and medium density housing and mixed use land[16], reflecting City policies to develop a mixture of residential types and densities (Policies LU 2.1-4, 3.1-2, 4.1).

While the plan allows conversion of agricultural lands to urban uses, it establishes growth management policies to resist premature conversion, to require contiguous urban expansion within the City, and to seek an agreement with Madera County to regulate eastward growth and maintain agricultural buffer zones (Policies LU 17.1-2, 4-6).

Finally, the City of Chowchilla General Plan maintains a policy to support Madera County's General Plan goals, objectives, and policies for land outside the City limits (Policies LU 19.1).

Implementation Effects on Water Demands and Sustainability

Similar to the Madera County and Merced County General Plans, implementation of proposed land use developments under the City of Chowchilla General Plan is expected to reduce water demands because new developments are required to follow the MWELO and because, as described above, medium and high density housing consumes less water than the agricultural uses replaced.

GSP Implementation Effects on Water Supply Assumptions

Implementation of the GSP will require the Chowchilla Subbasin to be operated within its sustainable yield by 2040, which may include restrictions on groundwater pumping and implementation of projects to increase groundwater recharge. Because the City of Chowchilla does not have surface water rights and does not currently import surface water from other sources, larger urban communities will require additional groundwater extraction. However, urban development would extend partly into agricultural lands, which also consume significant groundwater resources. Thus, water use requirements are projected to decrease slightly due to urban expansion, benefitting subbasin sustainability.

Implementation of the GSP will also provide for recharge projects to achieve subbasin sustainability. Within the bounds of CWD GSA, City of Chowchilla has opportunities to recharge stormwater and flood flows, which will benefit sustainability and help to offset potential increases in water use associated with urban development.

2.1.3.4 Permitting Process for Wells in Chowchilla Subbasin

Permitting Process for Wells in Madera County

Within Madera County, including much of the Chowchilla Subbasin, the Madera County Environmental Health Division is entrusted with all permitting and enforcement for the construction, reconstruction, and destruction of wells. Wells under their oversight include, but are not limited to, agricultural wells, observation/monitoring wells, community water supply wells, and individual domestic water supply wells.

The application process for Water Well Permits is handled online through the Madera County Permits Online website: https://www.maderacounty.com/services/county-permits-online. This site allows parties to apply for a permit, submit plans, remit payment, and monitor the status of their permit. Annular seal appointments are scheduled by contacting the Madera County Water Wells Permitting Program by phone.

[15] City of Chowchilla 2040 General Plan, Land Use Element Table LU-1, pg. LU-5.

[16] City of Chowchilla 2040 General Plan, Land Use Element Figures LU-2 and LU-3, pg. LU-7.

Madera County Environmental Health Division restricts work on all water wells to be performed only by those possessing an active C-57 Water Well Contractors License. Destruction of wells within City of Madera are handled by the City of Madera Building Department.

Permitting Process for Wells in Merced County

Within Merced County, including a portion of CWD GSA and the entirety of Merced Co GSA, the permitting process for all well construction and destruction is managed by the Merced County Department of Public Health, Division of Environmental Health (MCDEH). Wells under their oversight include, but are not limited to, agricultural/irrigation wells, domestic private wells, industrial wells, municipal wells, test wells, and monitoring wells.

The application process for well permits is detailed on the MCDEH Well Systems website: https://www.co.merced.ca.us/2247/Well-Systems. MCDEH restricts work on all water wells to be performed only by those possessing an active C-57 Water Well Contractors License.

2.1.3.5 Effects of Land Use Plans Outside Subbasin

Outside the Chowchilla Subbasin, other land use plans have been developed as part of the general plans for the City of Merced to the north and the City of Madera and Fresno County to the south. These general plans are similar in scope to the Madera County, Merced County, and City of Chowchilla General Plans described above.

The subbasins underlying City of Merced, City of Madera, and Fresno County have also been identified by DWR as critically overdrafted and are also required to prepare and be managed under a GSP by January 31, 2020 (CWC Section 10720.7(a)(1)). As such, future land use changes in these jurisdictions will also need to be managed to achieve sustainability in the subbasins adjacent to Chowchilla Subbasin. Provided that these subbasins are managed to achieve sustainability, these land use plans are not expected to affect the ability of the Chowchilla Subbasin GSAs to achieve sustainable groundwater management.

2.1.4 Additional GSP Elements (23 CCR § 354.8 (g))

There are various GSP elements to be addressed in this subsection of the GSP as described below. In some cases, the related information is provided elsewhere in the GSP and the section where the information is provided is noted. In other cases, additional information is provided below.

2.1.4.1 Control of saline water intrusion

Seawater intrusion is not applicable to Chowchilla Subbasin as explained in Section 3.2.6. It should also be noted that the Lower Aquifer in the subbasin is underlain by brackish water below the base of fresh water as described in Section 2.2.1.2. Upward movement of brackish water from greater depths has not been a reported problem historically or currently, but excessive pumping from the lowermost coarse-grained layers (should it occur in the future) may have the potential to cause such upward migration of brackish water in the future. The Madera Regional Groundwater Management Plan (MRGMP) (Provost & Pritchard, Wood Rodgers, KDSA, 2014), which includes most of the Chowchilla Subbasin, lists no existing activities, but did include the following planning activities: 1) amend County well standards for new well designs to ensure proper sealing of test holes that penetrate below the known base of fresh water; 2) amend County well standards to require exploratory test holes to be sealed with approved materials from total depth to ground surface; and 3) use well permitting process to require use of borehole geophysical surveys in all new boreholes that have potential to penetrate the base of fresh water, which would enhance groundwater protection by aiding in the current and future design of well seals to help prevent upward migration of brackish water.

2.1.4.2 Wellhead Protection

Wellhead protection refers to both the immediate location of the well in terms of well and pump station design features (e.g., well pad, annual seal) and the broader area surrounding the well. As noted in the MRGMP, a wellhead protection area is the area surrounding a public water supply well through which contaminants are reasonably able to move towards the well (i.e., the recharge area that provides water to the well).

The Madera County and City of Chowchilla well ordinances do not specifically address wellhead protection but do include requirements related to placement of annual seals. The MRGMP lists existing activities as: design new wells with appropriate wellhead protection features. The MRGMP lists planned actions as: 1) manage potential sources of contamination to minimize threat to drinking water sources; 2) develop contingency plan to prepare for emergency well closing and to plan for future water supply needs; 3) encourage establishment of wellhead project areas for non-municipal wells; and 4) develop more detailed wellhead protection standards for Madera County and City of Chowchilla.

2.1.4.3 Migration of Contaminated Groundwater

Migration of contaminated groundwater can occur through improperly constructed wells, which can become conduits for vertical flow of poor-quality water between aquifers. Inadequate surface sanitary seals can allow downward migration of contaminants from ground surface into the well structure and ultimately the aquifers screened by the well. Abandoned and improperly destroyed wells are also potential conduits for migration of contaminants in the subsurface. There are also numerous types of facilities and land uses that can be potential sources of chemical constituents that migrate down through the vadose zone and into aquifers with subsequent migration to pumping wells.

The MRGMP describes the main sources of information related to groundwater contamination including: the California Water Resources Control Board (SWRCB), the Department of Toxic Substance Control (DTSC), and the Groundwater Ambient Monitoring and Assessment Program (GAMA). The MRGMP describes related existing activities as including: 1) current County regulation for new well construction permitting that requires sanitary/annual seal depths sufficient to avoid creating conduit for contamination of shallow groundwater or co-mingling of aquifers with different water quality; and 2) current County regulation to properly abandon existing wells when connecting to a municipal water system. Planned actions listed in the MRGMP included: 1) review online databases for existing plumes and ensure that existing and new well operations do not induce downward migration of contaminants; 2) during new well construction permitting - require sanitary/annual seal depths sufficient to avoid creating conduit for downward migration of shallow groundwater contamination or co-mingling of aquifers with different water quality; 3) design a well abandonment program to identify abandoned wells and develop plans to properly destroy wells.

2.1.4.4 Well Abandonment and Well Destruction Program

An existing Madera County ordinance and state law require proper abandonment of wells. Madera County is responsible for administration and enforcement of the well ordinance, and oversees well abandonment in the subbasin, including within cities, irrigation districts, water districts, and private wells. Wells are required to be abandoned in accordance with State standards as delineated in Water Well Standards (DWR, 1981). The County requires that a property owner properly destroy any abandoned or unused wells prior to permitting construction of a new well (unless it is determined the well is appropriate for use as a monitoring well). In addition, the City of Madera requires that existing wells be destroyed per requirements of County Environmental Health Department standards prior to connecting to the City municipal water system (MRGMP, 2014). The MRGMP lists existing related activities as encouraging

property owners to abandon wells in accordance with County and State standards. Planned actions listed in the MRGMP included: 1) outreach and education for property owners about well abandonment standards and proper conversion of abandoned wells to monitoring wells; 2) conduct inventory of unused/abandoned wells to identify wells for abandonment or conversion to monitoring wells; and 3) emphasize and promote to the extent possible the conversion of production wells to monitoring wells when appropriate.

2.1.4.5 Replenishment of Groundwater Extractions

The replenishment of groundwater extractions occurs through various forms of recharge. The types and amounts of historical and current recharge are described in detail in Section 2.2.3 (Water Budget Information), and future estimates of recharge are detailed in **Appendix 6.E** (Groundwater Model Documentation). Future replenishment for groundwater extractions that will occur with implementation of projects and management actions for this GSP are described in detail in Chapter 4.

2.1.4.6 Conjunctive Use and Underground Storage

Historic and current conjunctive use operations in the subbasin have primarily been conducted by Chowchilla Water District. CWD and other subbasin conjunctive use activities are described in more detail in Section 2.1.2.4 (Conjunctive Use Programs). There have also been recent efforts by Triangle T Water District and Chowchilla Water District, along with some private landowners, to conduct recharge for underground storage during wet years in 2016-17 and 2018-19. Planned future conjunctive use and underground storage operations are described in detail in Chapter 4 and simulated by the groundwater model as described in **Appendix 6.E**.

2.1.4.7 Well Construction Policies

Well construction policies are described in Section 2.1.3.4 (Well Permitting Process for Wells in Chowchilla Subbasin).

2.1.4.8 Groundwater Contamination Cleanup, Recharge, Diversions to Storage, Conservation, Water Recycling, and Extraction Projects

Monitoring and remediation of pre-existing and historical groundwater contamination areas are primarily being addressed by various regulatory programs under the RWQCB and DTSC. Various types of projects (e.g., recharge, extraction, diversions) are described in Section 2.2.3 Water Budget Information) and in the Chapter 4 discussion of projects and management actions. There are no significant water recycling projects in the Plan area, because such projects are generally not feasible in sparsely populated areas that dominate in Chowchilla Subbasin. Water conservation projects are covered under Section 2.1.4.9 (Efficient Water Management Practices) below.

2.1.4.9 Efficient Water Management Practices

Water conservation and efficient water management practices are described in Section 2.1.3 (Land Use Elements or Topic Categories in Applicable General Plans). In addition, agricultural irrigation practices have been evolving towards use of more efficient irrigation methods such as drip irrigation and decreased use of less efficient methods such as spray and flood irrigation.

2.1.4.10 Relationships with State and Federal Agencies

The GSAs in Chowchilla Subbasin have relationships with a number of State and Federal agencies related to surface water supply, water quality, and water management. Chowchilla Water District obtains a portion of its surface water supply from Millerton Lake/Friant Dam via Madera Canal; Friant Dam is owned

and operated by the United States Bureau of Reclamation (USBR). The USBR is also the lead agency for the San Joaquin River Restoration Project (SJRRP), which requires current and future reductions in surface water diversions for irrigation. The GSAs also apply for and occasionally receive grants from various State/Federal agencies for water-related projects; a current grant being implemented is drilling of several new monitoring wells in the subbasin to provide better definition of subbasin geology, water levels, and water quality; and for ultimate incorporation in the GSP monitoring network. The State Regional Water Quality Control Board (RWQCB) provides oversight of contaminant sites within the subbasin, the Irrigated Lands Regulatory Program, and is considering potential adoption of a Basin Plan amendment related to salt and nutrient management issues. There are many other important GSA relationships with Federal/State agencies, some of which are described throughout this GSP, including in Chapter 5 (Plan Implementation).

Land Use Plans and Efforts to Address Potential Risks to Groundwater Quality and Quantify

Land use plans are described in Section 2.1.3 (Land Use Elements or Topic Categories in Applicable General Plans).

Impacts on Groundwater Dependent Ecosystems

Potential impacts to groundwater dependent ecosystems (GDEs) are described in detail in various sections in Chapters 2 and 3, and in **Appendix 2.B**.

2.1.5 Notice and Communication (23 CCR § 354.10)

2.1.5.1 Overview

California's Sustainable Groundwater Management Act (SGMA) of 2014 requires broad and diverse stakeholder involvement in GSA activities and the development and implementation of Groundwater Sustainability Plans (GSPs) for groundwater basins around the state, including the Chowchilla Subbasin. The intent of SGMA is to ensure successful, sustainable management of groundwater resources at the local level. Success will require cooperation by all beneficial users (defined below), and cooperation is far more likely if beneficial users have consistent messaging of valid information and are provided with opportunities to help shape the path forward.

To facilitate stakeholder involvement in the GSA process, a Communication and Engagement Plan (**Appendix 2**) was created for the GSAs in the Chowchilla Subbasin to:

- Provide GSAs, community leaders, and other beneficial users a roadmap to follow to ensure consistent messaging of SGMA requirements and related Chowchilla Subbasin information and data.
- Provide a roadmap to GSAs, community leaders, and other beneficial users to ensure everyone has meaningful input into GSA decision-making, including GSP development.
- Ensure the roadmap demonstrates a process that is widely seen by beneficial users as fair and respectful to the range of interested parties.
- Make transparent to beneficial users, their opportunities to contribute to the development of a GSP that can effectively address groundwater management within the Chowchilla Subbasin.
- Ensure that information reaches all beneficial users who have an interest in the Basin.

2.1.5.2 Description of Beneficial Uses and Users in the Basin

Under the requirements of SGMA, all beneficial uses and users of groundwater must be considered in the development of GSPs, and GSAs must encourage the active involvement of diverse social, cultural, and economic elements of the population. Beneficial users, therefore, are any stakeholders who have an interest in groundwater use and management in the Chowchilla Subbasin community. Their interest may be related to GSA activities, GSP development and implementation, and/or water access and management in general.

To assist in identifying categories of beneficial uses and users in the Chowchilla Subbasin, the Communications and Engagement Plan included a Stakeholder Engagement chart (Table 2-4).

2.1.5.3 Communications

Decision-making Processes

As noted above, the Chowchilla Subbasin is divided among four GSAs for GSP development. The four GSAs have jointly developed this coordinated GSP.

GSA Boards are the final decision-makers for the Chowchilla Subbasin. To assist in GSP development, the GSAs convened a Chowchilla Subbasin GSP Advisory Committee (Advisory Committee) in 2018 to bring together local agencies and related parties vested with the authority and/or ability to support implementation of SGMA in the Chowchilla Subbasin. Representatives from Merced County, Merced Irrigation District, Madera County, CWD, Madera Farm Bureau, Triangle T Water District, Sierra Vista Mutual Water Company, Clayton Water District and City of Chowchilla regularly attend the Advisory Committee meetings. The Advisory Committee has been meeting approximately monthly since its formation.

Generally, the representatives attending the Advisory Committee are technical experts associated with the various Subbasin GSAs and water districts. In addition to coordinating between the GSAs, the Advisory Committee developed recommendations for GSP development which were presented to the GSA boards in public meetings as well as at subbasin-wide public meetings.

Public Engagement Opportunities

There were a number of different meetings at which the public had the opportunity to engage during the GSP development process:

Table 2-4. Stakeholder Engagement Chart for GSP Development.

Category of Interest	Examples of Stakeholder Groups [17]	Engagement purpose
General Public	• Citizens groups • Community leaders	Inform to improve public awareness of sustainable groundwater management
Land Use	• Municipalities (City, County planning departments): City of Chowchilla • Regional land use agencies	Consult and involve to ensure land use policies are supporting GSPs

[17] The groups and communities referenced are examples identified during initial assessment. GSA Interested Parties lists shall maintain current and more exhaustive lists of stakeholders fitting into these groups.

Category of Interest	Examples of Stakeholder Groups [17]	Engagement purpose
Private users	• Private pumpers • Domestic users • School systems: Chowchilla Elementary School District • Hospitals: Chowchilla Memorial Health Care District	Inform and involve to minimize negative impact to these users
Urban/ Agriculture users	• Water agencies • Irrigation districts • Mutual water companies • Resource conservation districts: Madera/Chowchilla RCD (formerly the Chowchilla Red Top RCD) • Farm Bureau: Merced Farm Bureau, Madera County Farm Bureau	Collaborate to ensure sustainable management of groundwater
Industrial users	• Commercial and industrial self-supplier • Local trade association or group	Inform and involve to avoid negative impact to these users
Environmental and Ecosystem	• Federal and State agencies - CDFW • Environmental groups	Inform and involve to sustain a vital ecosystem
Economic Development	• Chambers of commerce: Chowchilla District Chamber of Commerce • Business groups/associations • Elected officials (Board of Supervisors, City Council) • State Assembly members • State Senators	Inform and involve to support a stable economy
Human right to water	• Disadvantaged Communities • Small community systems • Environmental Justice Groups: Leadership Council for Justice and Accountability, Self-Help Enterprises, Community Water Center	Inform and involve to provide a safe and secure groundwater supplies to all communities reliant on groundwater
Tribes	• Federally Recognized Tribes and non-federally recognized Tribes with Lands or potential interests in Chowchilla Subbasin	Inform, involve and consult with tribal government
Federal lands	• Bureau of Reclamation (USBR) • Bureau of Land Management	Inform, involve and collaborate to ensure basin sustainability
Integrated Water Management	• Regional water management groups (IRWM regions) • Flood agencies	Inform, involve and collaborate to improve regional sustainability

- **GSA meetings**: Each of the GSAs in the Chowchilla Subbasin held regular public meetings, generally on a monthly schedule and in many cases in conjunction with standing board meetings.
- **Joint Subbasin meetings:** The intent of the Joint Subbasin meetings was to provide a forum for representatives from the Chowchilla Subbasin and the adjacent Madera Subbasin to share perspectives and information about GSP development and SGMA implementation.

- **Subbasin-wide Technical meetings:** Subbasin-wide technical meetings were held throughout the GSP development process to provide opportunities for the public to learn about the SGMA process and GSP components, receive updates about GSP planning activities, and provide input on GSP development. These meetings often included presentations by the GSP preparation consultants about technical aspects of GSP preparation, on topics such as basin setting, water budgets, and undesirable results.
- **County Advisory Committee**: The Madera County GSA was supported by an advisory committee which consisted of members from different demographic groups and communities. The County Advisory Committee provided feedback on GSP development to the board of the Madera County GSA as well as relaying information back to the communities to which the committee members belong. The County Advisory Committee met quarterly in 2018 and bi-monthly in 2019.
- **Madera County Farm Bureau Water Forum**: The Chowchilla and Madera Subbasins made a joint presentation on SGMA efforts by the subbasin GSAs.
- **City of Chowchilla**: The Chowchilla GSA gave a SGMA presentation in the City of Chowchilla City Council Chambers.
- **Madera County Regional Water Management Group:** Updates on Chowchilla Subbasin GSP activities were given at the monthly meetings of the Madera County Regional Water Management Group.

Figure 2-7 (TBD) describes the GSP process steps, including topic development, technical review, and public meetings both at the Subbasin and individual level.

Encouraging Active Involvement

There were also activities related to encouraging involvement and building capacity for engagement, including the following activities organized in coordination with Self-Help Enterprises and the Leadership Counsel for Justice and Accountability:

- **Capacity-building workshops**: Workshops encouraged and prepared community members to participate in GSP development by providing technical information as well as information about opportunities for engagement.
- **Educational tours**: Tours provided members of the public with additional opportunities to hear about the concerns of people with differing perspectives. Tours included stops in the community of Fairmead, La Vina, a farm, and at a groundwater recharge basin.
- **Presentations in communities**: Self-Help Enterprises and the Leadership Counsel for Justice and Accountability both encouraged participation in GSP preparation through presentations held in communities around the Subbasin.

2.1.5.4 Informing the Public about GSP Development Progress

Interested Parties List

An email distribution list of Subbasin-wide stakeholders and beneficial users was developed for outreach throughout the GSP planning process. The list was maintained and updated by the CWD and is included in **Appendix 2**. In many cases, information was distributed in both English and Spanish.

Figure 2-7. Plan Development Sequence (public meetings in yellow).

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Distribution of Flyers

Typically, before a public meeting in the Chowchilla Subbasin, a flyer was created with key information provided. The flyer was emailed out to the Interested Party list as well as to the GSAs and the Madera County Farm Bureau for electronic distribution. The flyer was also handed out at GSA meetings and other public meetings. (Figure 2-8).

Press Outreach

Press releases were issued at key junctures and decision-making points for the Chowchilla Subbasin.

A Centralized Chowchilla Subbasin Website

Throughout the planning process (and beyond) the County has maintained a Subbasin website (http://www.maderacountywater.com) with information about Chowchilla Subbasin-wide planning efforts related to SGMA.

The Chowchilla Subbasin website contains:

- Calendar of public meetings and other events
- Information about past public meetings, including relevant meeting materials
- Links to external sites (e.g., Department of Water Resources SGMA portal) and other resources such as white papers
- A link to the website of the Triangle T Water District GSA
- Information about the County GSAs , adjacent Madera GSAs, Chowchilla Subbasin technical meetings and the Advisory Committee
- GSP background documents
- Fact sheets and Subbasin maps

Engagement Matrix

The Engagement Matrix, in **Appendix 2**, (TBD) provides details about the implementation of each of the communication methods outlined above. The matrix presents each communication strategy, as required by statute or laid out in the Chowchilla Subbasin Communication and Engagement Plan, along with details about specific instances of that strategy. For example, each public GSP-related meeting is listed with information about the date, topic, and location of the meeting as well as how it was publicized, to whom it was targeted, what opportunities for feedback were provided, and who participated.

Stakeholder Input and Responses

The engagement opportunities described above provided various avenues for stakeholders to provide input on GSP development. The matrix in **Appendix 2 (TBD)** summarizes the public comments received, organized by type of water user, and outlines how this input influenced decision-making in GSP development.

Figure 2-8. GSA Public Event.

2.2 Basin Setting

2.2.1 Hydrogeologic Conceptual Model (23 CCR § 354.14)

A preliminary hydrogeologic conceptual model (HCM) was developed for the Chowchilla Subbasin (DWR Subbasin No. 5-22.05) based on existing reports/data and published in a previous report (DE/LSCE, July 2017). Various aspects of the preliminary HCM were subsequently updated for GSP efforts and are documented in this GSP report. Overall, this chapter of the GSP provides the updated HCM based on a combination of previous reports/data and recent updated analyses performed as part of GSP preparation efforts.

2.2.1.1 Regional Geologic and Structural Setting

The Chowchilla Subbasin is generally comprised of relatively flat topography that slopes gently downward to the west. Topographic elevations vary from about 340 feet above mean sea level (MSL) in the east to about 120 feet above MSL in the west over a distance of about 25 miles (**Figure 2-9**). The major geomorphic features of the subbasin are the alluvial fan and floodplain associated with sediment deposition from the Chowchilla River (Mitten et al., 1970). A map of hydrologic soil groups in Chowchilla Subbasin is provided in **Figure 2-10**, and a map of soil saturated hydraulic conductivity (K_{sat}) is provided in **Figure 2-11.** These maps indicate that soils with higher permeability and infiltration rates are present along and between the Chowchilla River, Ash Slough, and Berenda Slough channels in the central portion

of the subbasin. It should be noted that these soil maps are relatively general in nature, and localized areas of higher permeability/infiltration capacity may exist in areas otherwise indicated to be low permeability/infiltration capacity in these figures and vice versa. In addition, it is recognized that hard pan, which tends to greatly limit infiltration capacity, exists in many areas at depths typically in the range of 5 to 10 feet below ground surface. However, many areas with irrigated agricultural (particularly orchards) have constructed holes through the hard pan to facilitate proper drainage.

Surface geology maps are provided in **Figures 2-12 and 2-13**. The surficial geology of the Chowchilla Subbasin is dominated by Younger and Older Alluvium (generally equivalent to Modesto, Riverbank, and Turlock Lake Formations), which are described in more detail below. Younger Alluvium is most prevalent between the Chowchilla River and Berenda Slough in the middle portion of the subbasin.

The Preliminary HCM Report provided some existing geologic cross-sections distributed throughout the subbasin, which varied considerably in quality and level of detail. In addition, new cross-sections were developed as part of GSP tasks performed subsequent to publication of the Preliminary HCM Report. The existing and new geologic cross-sections are further described in the section below (and in **Appendix 2.D**) on Major Aquifers/Aquitards.

The stratigraphy of the Chowchilla Subbasin from the surface down is comprised primarily of Continental Deposits of Quaternary Age (Younger and Older Alluvium), Continental Deposits of Tertiary and Quaternary age, Marine and Continental sedimentary rocks, and crystalline basement rock. The Continental Deposits are unconsolidated, and underlying sedimentary and basement rocks are consolidated. It is uncertain if Mehrten and Ione Formation are present in the Madera Subbasin. Younger Alluvium is generally limited to 50 feet thickness and typically unsaturated. The Older Alluvium consists of up to 1,000 feet of interbedded clay, silt, sand, and gravel. Older Alluvium becomes finer-grained with depth and is underlain by the generally finer-grained Continental deposits of Tertiary and Quaternary age (Mitten et.al., 1970). The primary water bearing unit is Older Alluvium, although recent deeper drilling of agricultural wells is tapping into the underlying Continental Deposits of Tertiary/Quaternary age (Provost & Pritchard, 2014).

The Corcoran Clay occurs in the middle and western portions of Chowchilla Subbasin (**Figure 2-14**) within the upper portion of Older Alluvium (Mitten et al., 1970). The Corcoran Clay is also considered to be a member of the Turlock Lake Formation (Page, 1986). The depth to top of the Corcoran Clay generally ranges from about 50 to 275 feet where present within Chowchilla Subbasin (Provost & Pritchard, 2014). The Corcoran Clay is comprised of clay and silt ranging in thickness from 10 feet at its eastern extent to 80 feet on the western edge of Chowchilla Subbasin (**Figure 2-15**). As explained further in the section on major aquifers/aquitards, the depth to Corcoran Clay in the central to eastern portions of the subbasin becomes shallow enough such that the regional aquifer occurs entirely below the Corcoran Clay.

2.2.1.2 Lateral and Vertical Subbasin Boundaries

The Chowchilla Subbasin is bordered by the Madera Subbasin to the east and south, Merced Subbasin to the north, and Delta-Mendota Subbasin to the west (**Figure 2-16**). All subbasin boundaries are political/agency boundaries across which groundwater flow can and does occur. A basin boundary modification request was approved by DWR in 2016, and the revised boundary is incorporated in this study.

The base of fresh water was evaluated by Page (1973), and was defined in this study as including water with conductivity up to 3,000 umhos/cm. Overall, the base of freshwater was mapped as ranging approximately from elevation -600 to -1,200 feet msl within Chowchilla Subbasin. In general, the shallowest depths to base of fresh water were along the southern boundary of the subbasin, and the greatest depths were areas located just south of the City of Chowchilla and beneath the Chowchilla River

in the central portion of the subbasin (**Figure 2-17).** This base of fresh water mapped by Page should be considered approximate and might be expected to be slightly shallower, because fresh water is generally considered to have total dissolved solids of less than 1,000 milligrams/liter (mg/L) and conductivity of less than 1,600 umhos/cm.

Maps of the depth to basement rock (**Figure 2-18**) and elevation of basement rock (**Figure 2-19**) show increasing depths (and decreasing elevations) to basement rock from northeast to southwest across the subbasin. The depths to bedrock range from about 500 feet to greater than 3,500 feet at the southwestern boundary of the subbasin. In general, the aquifer base is controlled mostly by the base of fresh water provided in **Figure 2-17** except in the far eastern portions of the subbasin.

2.2.1.3 Major Aquifers/Aquitards

Geologic cross-sections are a key element of the HCM required in a GSP under SGMA. Related work completed for this GSP included review of existing literature to extract the available geologic cross-sections and construction of additional new geologic cross-sections based on data compiled for GSP efforts. This section of the GSP (and **Appendix 2.D**) provides a general description of the existing and new cross-sections, and documents the source of available existing geologic cross-sections along with details of how the new cross-sections were developed.

Existing Geologic Cross-Sections

The geologic cross-sections derived from previous reports are presented in **Appendix 2.D**, and were described in a previous report (DE/LSCE, 2017). Two of these existing cross-sections are described below to provide overall regional context for the stratigraphy of the subbasin (Mitten, et al.,1970; Page, 1986). The locations of these two existing geologic cross-sections are provided in **Figure 2-20**, and the individual cross-sections are provided in **Figures 2-21 and 2-22**. A summary of the two regional geologic cross-sections is provided below.

Mitten's (1970) cross-section A-A' (**Figure 2-21**) runs west to east across the northern portion of the Chowchilla Subbasin, and extends down to an elevation of -1,400 feet msl. The top of the E-Clay (Corcoran Clay) is present at a depth of approximately 200 feet below ground surface (bgs) on the western edge of the section (with a thickness of about 50 feet) and thins and tapers out near Ash Slough at a depth of about 80 feet bgs. A small deposit of Quaternary floodplain deposits (Qb) is present at the surface on the western edge of the section, and thin layers of younger Quaternary alluvium (Qya) are present at the surface across the rest of the section. Older Quaternary alluvium (Qoa) underlies the surface deposits, and overlies Tertiary and Quaternary continental deposits (QTc). Undifferentiated Pre-Tertiary and Tertiary marine and continental sedimentary rocks (TpTu) underlie QTc in the eastern portion of the section. Pre-Tertiary basement complex (pTb) is present at the surface along the eastern edge of the section.

Page (1986) cross-section B-B' (**Figure 2-22**) runs north to south through the western portion of the Chowchilla Subbasin, and extends to a depth of about 9,000 feet bgs. Within the Chowchilla Subbasin, the Corcoran Clay is present throughout, at an approximate elevation of -100 feet msl. Thin deposits of Quaternary floodplain deposits (Qb) are present at the surface, underlain by Quaternary continental rocks and deposits (QTcd). A layer of Tertiary marine rocks and deposits interfinger the QTcd layer. A layer of Pre-Tertiary and Tertiary continental and marine rocks and deposits (i.e., bedrock) underlies these units at elevations ranging from about -2,500 to -3,500 feet msl.

New Geologic Cross-Sections

New geologic cross-sections were developed during GSP preparation efforts utilizing data collected for the GSP. A location map for new geologic cross-sections is provided in **Figure 2-20**. The new geologic cross-sections include some that do not cross Chowchilla Subbasin, but are included here because they occur within the Model Domain for the Madera-Chowchilla Groundwater-Surface Water Simulation (MCSim) Model developed for Chowchilla Subbasin. The CVHM well log dataset and DWR well log database developed for this project were reviewed to select logs for relatively deep wells that had fairly detailed descriptions of geologic units encountered. Locations for screened well logs were plotted to selected representative well logs at a reasonable spacing along each geologic cross-section line.

New geologic cross-sections D-D', E-E', and F-F' (**Figures 2-26, 2-27, and 2-28**) are included here but not described further as they do not cross Chowchilla Subbasin. New geologic cross-sections A-A', B-B', and C-C' (**Figures 2-23, 2-24, and 2-25**) extend from southwest to northeast across Chowchilla Subbasin towards (perpendicular to) the Sierra Nevada Mountains, with A-A' being furthest north and C-C' being furthest south. Each cross-section generally shows the ground surface, the lithology associated with each well log, the Spring 2014 unconfined groundwater level, the Corcoran Clay (from C2VSim), and the base of fresh water (from Page 1986). The well logs generally range from very close to section lines to one mile of offset from the section line. The cross-sections illustrate the interbedded and variable nature of fine- and coarse-grained sediments both laterally and vertically. There are significant coarse-grained layers to depths of at least 800 feet. However, fine-grained sediments comprise a larger percentage of the subsurface than do coarse-grained sediments overall. Thus, it can be expected that vertical hydraulic conductivity (Kv) values will likely be orders of magnitude lower than horizontal hydraulic conductivity (Kh) values for a given aquifer. Geologic cross-sections A-A', B-B', and C-C' also illustrate the Corcoran Clay extends beneath the western and central portions of the subbasin, and other clay layers are prominent throughout the subbasin.

New geologic cross-sections G-G' through K-K' (**Figures 2-29, 2-30, 2-31, 2-32, 2-33**) were constructed parallel to the Sierra Nevada Mountain front starting from the southwestern end of Chowchilla Subbasin and progressing towards the northeast (i.e., cross-section G-G' is furthest from and parallel to the Sierra Nevada Mountain front and K-K' is closest to the mountain front). These geologic cross-sections further demonstrate and confirm the features/characteristics described above for the cross-sections perpendicular the Sierra Nevada Mountains. While it is challenging to reliably correlate coarse-grained units in these cross-sections, they do illustrate well the general distribution of coarse- and fine-grained sediments both laterally and vertically. The textural analysis described in the Groundwater Model Documentation (**Appendix 6.E**) used to develop inputs to the groundwater model attempts to capture the somewhat disconnected distribution of coarse-grained sediments reflected in the cross-sections.

Geologic Cross-Section Summary

The existing geologic cross-sections provided in Mitten et al. (1970) and Page (1986) illustrate the vertical distribution of major geologic formations, but do not provide any detail on distribution of fine and coarse-grained sediments of the major aquifer units. The new geologic cross-sections illustrate in a fairly detailed manner the lateral and vertical distribution of fine- and coarse-grained sediments throughout the subbasin. It is apparent from these cross sections that significant coarse-grained intervals are present to the full depths of most borings shown on the cross sections, although overall the percentage of fine-grained sediments exceeds that of coarse-grained sediments. These cross sections further demonstrate that Kv values are likely to be orders of magnitude less than Kh values.

Groundwater System Conceptualization

The Chowchilla Subbasin is underlain by the Corcoran Clay over approximately the western and central two-thirds of the subbasin area. The depth to top of Corcoran Clay varies from 50 to 100 feet at its northeastern extent to in excess of 250 feet in the southwestern portion of the subbasin (**Figure 2-14**). In the western portion of the subbasin, the aquifer system is subdivided into an upper unconfined aquifer above the Corcoran Clay and a lower confined aquifer below the Corcoran Clay (**Figure 2-34**). In the central and eastern portions of the subbasin where the Corcoran Clay is shallow or does not exist, the aquifer system is generally considered to be semi-confined with discontinuous clay layers interspersed with more permeable coarse-grained units (**Figure 2-34**).

As illustrated in the geologic cross-sections described above and provided in **Appendix 2.D,** the upper 800 feet of sediments are comprised of multiple layers of coarse-grained sediments. Thus, it can be anticipated that most wells will obtain close to their maximum yield within approximately the upper 800 feet of sediments. The vast majority of water wells are constructed within the upper 1,000 feet because sediments generally become finer with depth and towards the center of the valley (Provost and Pritchard, 2014).

The general distribution of percentages of coarse-grained sediments at various depths is further illustrated by the sediment texture model developed by the United States Geological Survey (USGS) for the Central Valley Hydrologic Model (CVHM). **Figures 2-35 and 2-36** illustrate the spatial distribution of coarse-grained sediments at 50-foot depth intervals from the ground surface to a total depth of 1,400 feet. These maps indicate overall percentages of coarse-grained sediments are less than 50 percent of total sediment thicknesses.

2.2.1.4 Aquifer Parameters

A detailed summary of aquifer parameter data derived from existing reports was presented in the Preliminary HCM and is included in **Appendix 2.D**. For Madera County as a whole, the Madera Regional Groundwater Management Plan indicates the Older Alluvium generally has transmissivity values ranging from about 20,000 to 250,000 gpd/ft. Well test data indicate that wells tapping a significant thickness of coarse-grained materials in the upper 500 feet tend to have the highest specific capacities. The underlying Continental Deposits are reported to have transmissivities ranging from 10,000 to 30,000 gpd/ft (Provost and Pritchard, 2014).

Specific yield (Sy) values for Madera County were evaluated in previous studies for use in groundwater storage change calculations (Provost and Pritchard, 2014; Todd, 2002). These county-wide studies used Sy values ranging from 0.10 to 0.13. A study specific to Chowchilla Subbasin (DWR, 2004) cited a specific yield value of 0.086 for use in calculating total groundwater in storage. Given that sediments generally become finer grained with depth, it is possible that the lower Sy value from DWR (2004) is due to evaluation of specific yield to a deeper depth than in the other studies.

As part of recent GSP efforts related to the HCM, DWR well completion reports (WCRs) were reviewed to obtain additional specific capacity data from various wells throughout Chowchilla Subbasin and the greater model domain. The details of the specific wells, well construction data, and specific capacity data are summarized in **Appendix 2.D**. The specific capacity data were converted to transmissivity values based on methodology developed by Driscoll (1986). Maps of transmissivity (T) values were prepared for the Upper Aquifer (**Figure 2-37**), Lower Aquifer (**Figure 2-38**), and for composite wells screened in both aquifers (**Figure 2-39**).

There are six transmissivity values displayed on the map for the Upper Aquifer, all of which are located in the western portion of the subbasin (**Figure 2-37**). Transmissivity values were quite variable ranging from

less than 25,000 to 100,000 gpd/ft. The transmissivity map for the Lower Aquifer (**Figure 2-38**) includes data for 15 wells with 5 wells in the eastern portion of the basin, 6 wells in the central subbasin and 4 wells in the western subbasin area. Wells in the eastern subbasin area show significant variability in estimated transmissivity values from less than 25,000 to 100,000 gpd/ft. The central subbasin wells have transmissivity values from less than 25,000 to 75,000 gpd/ft, and the western region has wells with estimated transmissivity values ranging from less than 25,000 to 50,000 gpd/ft. Although data for the Upper Aquifer is limited, there were no wells with estimated transmissivity values greater than 100,000 gpd/ft in the Lower Aquifer while 3 of 6 available wells with estimated transmissivity values exceeded 100,000 gpd/ft in the Upper Aquifer. The map of transmissivity values for composite/unknown wells shows three wells in the western portion of the subbasin (**Figure 2-39**). The transmissivity values range from 50,000 to 100,000 gpd/ft.

2.2.1.5 Recharge and Discharge Areas

Groundwater recharge can occur throughout Chowchilla Subbasin from infiltration of precipitation and excess irrigation water, streamflow percolation, and other sources. However, some areas may provide greater potential for existing recharge and future managed recharge that may occur during GSP implementation. Areas with increased recharge potential were evaluated using soil mapping data and the SAGBI index. Soils data are evaluated for infiltration potential and categorized into one of four hydrologic groups with hydrologic group A having highest infiltration potential and hydrologic group D having lowest infiltration potential (**Figure 2-10**). The map of hydrologic soil groups shows the main areas with hydrologic group A soils located along Chowchilla River, Ash Slough, and Berenda Slough. A relatively large area of hydrologic group A and B soils is located in the central portion of the subbasin from north of Chowchilla River to south of Berenda Slough, and from the City of Chowchilla on the east to Eastside Bypass on the west. Mapping of saturated soil vertical hydraulic conductivity (K) shows a similar distribution of areas with higher infiltration potential as the soil hydrologic group map (**Figure 2-11**). The large area of hydrologic group A and B soils described above has soil saturated vertical K from 1.1 to greater than 5 feet/day, whereas most other areas have soil saturated vertical K of less than 1 foot/day.

The Soil Agricultural Groundwater Banking Index (SAGBI) provides a characterization of potential for groundwater recharge on agricultural land. The SAGBI index is based on five main factors: deep percolation, root zone residence time, topography, chemical limitations, and soil surface conditions. The unmodified (by tilling) SAGBI index map (**Figure 2-40**) shows the main areas of high deep percolation potential mirror the relatively large area of higher infiltration potential on the soil hydrologic group map between Highway 99 and Eastside Bypass from north of Chowchilla River to south of Berenda Slough. The modified SAGBI map (**Figure 2-41**) shows similar results as the unmodified SAGBI map with an additional area in the western portion of Chowchilla Subbasin west of Eastside Bypass with moderate to high deep percolation potential.

Another mechanism of groundwater recharge is subsurface inflow from adjacent subbasins, including Merced, Madera, Delta Mendota Subbasins. Subsurface groundwater inflows (and outflows) are currently being evaluated with the subbasin groundwater model and will be summarized in **Appendix 6.E.**, Groundwater Model Documentation.

Overall, the primary areas with the highest recharge potential occur along and between rivers/sloughs in the central portion of the subbasin, and secondary areas with greater recharge potential occur in the western portions of the subbasin to the west of Eastside Bypass. **Figure 2-42** shows areas of higher recharge potential if defined by mapped soils with relatively high vertical hydraulic conductivities (greater than 2 feet/day). It is worth noting that areas of high infiltration/deep percolation potential shown in **Figures 2-40 to 2-42** occur in the region underlain by the Corcoran Clay, which may constrain the ability

to recharge the maximum volumes of water that may be available for recharge basins and on-farm recharge during wet years.

Under current and recent historical groundwater conditions, the primary source of groundwater discharge from the subbasin is via groundwater pumping for agricultural, municipal, domestic, and industrial uses. Maps of general locations of domestic, agricultural, and public supply wells are provided in **Figures 2-5, 2-6, and 2-7**. Maps of the average depths of domestic, agricultural, and public supply wells by section are provided in **Figures 2-43, 2-44, and 2-45**. These maps generally indicated the majority of domestic wells are located in the central to eastern portions of the subbasin, agricultural wells are relatively spread out throughout the entire subbasin, and public supply wells are concentrated in the central to eastern portions of the subbasin. Domestic well depths are variable across the subbasin, with the most common well depth in the 300 to 400-foot range. Similarly, agricultural well depths are variable across the subbasin, with the most common well depths in the 500 to 750-foot range. Public supply wells are most commonly in the 500 to 750-foot depth range.

A secondary mechanism of groundwater discharge may be subsurface outflow to portions of some adjacent subbasins. Subsurface groundwater outflows (and inflows) are currently being evaluated with the subbasin groundwater model and will be summarized in **Appendix 6.E.**, Groundwater Model Documentation.

2.2.1.6 Surface Water Bodies and Source/Delivery Points for Local and Imported Water Supplies

The primary surface water bodies within the boundaries of Chowchilla Subbasin include Chowchilla River, Ash Slough, Berenda Slough, Eastside Bypass, and San Joaquin River (along a portion of the western subbasin boundary). The major reservoirs within the watersheds upstream of Chowchilla Subbasin include Eastman Lake along the Chowchilla River and Millerton Lake along the San Joaquin River (via the Madera Canal). These surface water features are shown on several maps included in the HCM (e.g., **Figures 2-9, 2-12, and 2-20**), and are described in more detail in the subsequent water budget section of Chapter 2. In addition, the sources and delivery points for local and imported water are described in detail in the water budget section.

2.2.2 Current and Historical Groundwater Conditions (23 CCR § 354.16)

2.2.2.1 Groundwater Levels

Considerable historical groundwater level data are available in the Chowchilla Subbasin. These data include water level observations in wells and groundwater elevation contour maps prepared by others. Additional groundwater elevation maps and hydrographs were generated to evaluate historical and current groundwater level conditions in the Subbasin. The existing data and maps are described below, along with updated groundwater elevation contour maps and hydrographs prepared as part of this GSP. The discussion of groundwater elevation contour maps focuses on Spring season water levels (as opposed to Fall) to limit influences actively pumping wells may have on interpretations of groundwater conditions. However, available historical Fall groundwater elevation contour maps were compiled and are included in **Appendix 2.E**.

Groundwater Elevation Contours

Maps of groundwater elevation from the early 1900s indicate groundwater flow from northeast to southwest prior to significant development of groundwater in the Chowchilla Subbasin. The western portion of the subbasin was considered part of an “artesian zone” running through the center of the San Joaquin Valley (Mendenhall, 2016). More recently, groundwater elevation contour maps developed by

DWR are available for selected years between 1958 and 1989, and annual maps were published from 1989 to 2011 (**Appendix 2.E**). Groundwater elevation data and GIS data files of groundwater contours are also available from DWR for 2012 to 2016 (**Appendix 2.E**). Although the DWR maps are developed with water level measurements that include wells with unknown construction details, DWR has categorized these groundwater contour maps as being representative of unconfined and semi-confined aquifer groundwater levels across the Chowchilla Subbasin. To evaluate recent groundwater level conditions in the Subbasin, separate groundwater elevation contour maps were prepared for Winter/Spring 1988, Winter/Spring 2014, and Winter/Spring 2016 for unconfined groundwater and for the Lower Aquifer within the extent of the Corcoran Clay. For the purpose of mapping groundwater elevations, the aquifer system in areas outside the Corcoran Clay was treated as a single unconfined groundwater system. In areas within the Corcoran Clay, the aquifer system was separated into an unconfined system above the Corcoran Clay and a Lower Aquifer below the Corcoran Clay. Contour maps of the different depth zones are presented and discussed below. Historical groundwater contour maps of unconfined groundwater prepared by others are referenced in the discussion below and are provided in **Appendix 2.E**.

Unconfined Groundwater

Groundwater elevation contour maps of the unconfined/semi-confined aquifer zone developed by DWR are available for selected years between 1958 and 1989, and annual maps were published from 1989 to 2011 (**Appendix 2.E**). Groundwater elevation data and GIS files of groundwater contours are also available from DWR for 2012 to 2016 (**Appendix 2.E**). Although the DWR maps are developed with water level measurements that include wells with unknown construction details, DWR has categorized these groundwater contour maps as being representative of unconfined and semi-confined aquifer groundwater levels across the Chowchilla Subbasin. The groundwater contour maps referenced in the discussion below for 1958 through 1984 are provided in **Appendix 2.E**.

The Spring 1958 DWR groundwater contours generally run northwest to southeast with elevations decreasing from northeast to southwest. A significant groundwater depression was developing in the northwest portion of the groundwater basin, initially centered just north of the Chowchilla River in Merced County in the 1950's. Groundwater elevations range from highs exceeding 220 feet msl northeast of the City of Chowchilla to lows of 70 feet msl in the groundwater depression in the northwest portion of Chowchilla Subbasin (as originally defined). Within the city of Chowchilla, groundwater elevations ranged from 200 to 210 feet msl.

The Spring 1962 DWR groundwater elevations showed declines of approximately 20 to 30 feet in the late 1950s/early 1960s, with highs exceeding 190 feet msl northeast of the City of Chowchilla to lows of 50 feet msl in the groundwater depression in the northwest portion of the subbasin. Within the City of Chowchilla, groundwater elevations were approximately 180 feet msl. The Spring 1969 groundwater elevations showed continued declines in the northeastern portion of the subbasin, with an overall range from 150 feet msl within the City of Chowchilla to lows of 50 feet msl in the northwestern portion of the subbasin.

Spring 1976 DWR groundwater elevations indicated declines of approximately 10 feet in the western portion and approximately 10 to 30 feet in the eastern portion of the basin during the 1970s. The depression in the northwest expanded in size throughout the decade, while a separate depression formed in the northeast near the City of Chowchilla along the Chowchilla River. Within the City of Chowchilla, groundwater elevations ranged from 110 to 130 feet msl.

The Spring 1984 DWR groundwater elevations generally showed increases of approximately 10 to 20 feet in the early to mid-1980s. Two groundwater depressions were still present in the northwest and

northeast, but a mound had formed in the center of the basin between the two pumping depressions. Within the City of Chowchilla, groundwater elevations ranged from 130 to 140 feet msl.

Contours of groundwater elevations in Winter and Spring 1988 (**Figure 2-46**) show similar patterns as historical groundwater elevations with groundwater flow generally from northeast to southwest. Areas of locally lower groundwater levels are apparent in **Figure 2-46** north of the City of Chowchilla and Chowchilla River (in the adjacent Merced Subbasin), southeast of City of Chowchilla (along the boundary with Madera Subbasin), and in the northwestern portion of the subbasin. Locally slightly higher groundwater elevations are apparent in 1988 along Chowchilla River, Ash Slough, and Berenda Slough in the central to eastern portions of the subbasin. In Winter/Spring 1988 groundwater elevations near the City of Chowchilla are between about 150 and 160 feet msl.

In Winter/Spring 2014, unconfined groundwater elevations in the Subbasin are generally lower than in 1988 with several groundwater depressions apparent in **Figure 2-47**. Although the general prevailing groundwater flow direction remains northeast to southwest, a few notable areas of locally low water levels exist in the Subbasin. These local depressions cause more local variability in the groundwater flow directions including most prominently to the south of the City of Chowchilla along the boundary with Madera Subbasin, and in the northwestern and southwestern portions of the Subbasin. A small area of slightly higher groundwater elevations occurs within the City of Chowchilla (180 ft msl). Although more limited water level data are available in Winter/Spring 2016, a contour map of groundwater elevation in 2016 is presented in **Figure 2-48** for comparison and illustrates similar patterns in groundwater flow and relative elevations. Groundwater elevation contours in the western part of the Subbasin indicate groundwater flowing into the Subbasin from the west near the San Joaquin River in 2014 and 2016.

Considerably more groundwater level data are available along the San Joaquin River in 2014 and 2016, in part because of recent monitoring being conducted in association with the San Joaquin River Restoration Program. However, it is worth noting that many of the San Joaquin River Restoration Program monitoring wells are very shallow (less than 50 feet) and exhibit water levels that may be shallower than the regional groundwater system. In evaluating and comparing groundwater level contour maps, it can be difficult to distinguish between influences of the unique water level datapoints used for each contour snapshot from what may be actual differences in water level conditions. Some of the differences in the contour maps for 2014 and 2016 are a result of differences in the spatial distribution of water level datapoints.

Perched Groundwater Conditions

The definition of perched groundwater is shallow groundwater present above a low-permeability (e.g., clay) layer with an unsaturated zone present between the perching layer and the regional water table. Perched groundwater has been documented in Chowchilla Subbasin at several sites from review and comparison of local groundwater level data from regulated facility sites obtained from Geotracker and regional groundwater level data from CASGEM and other sources. These regulated facilities have shallow monitoring wells that reflect shallow groundwater conditions that can differ from regional groundwater levels in the deeper zones in which groundwater extraction wells are typically screened. It is likely that other occurrences of perched groundwater exist in the subbasin, although their existence may not be apparent due to lack of available information on water levels at different depths. A primary area of perched groundwater is expected to be present in the central to eastern portion of Chowchilla Subbasin above the Corcoran Clay, and it has been specifically documented in the City of Chowchilla area. There are three documented sites with groundwater level data in the City of Chowchilla area. These sites show perched groundwater levels ranging from 36 to 58 feet below ground surface (corresponding to groundwater elevations of 179 to 203 feet msl) over the time period from May 1995 to February 2018. Review of regional groundwater level data from CASGEM and other wells for this same time frame showed groundwater elevations ranging from less than -30 to about 70 feet msl. The perching layer in this area is

likely the Corcoran Clay, which is estimated to be present at depths of approximately 70 to 80 feet beneath the City of Chowchilla.

Lower Aquifer

Contouring groundwater elevations in the Lower Aquifer is challenging because of combined limitations in availability of groundwater level data with well construction information and wells screened exclusively in the Lower Aquifer. In contouring groundwater levels in the Lower Aquifer, water levels from wells known to be constructed in the Lower Aquifer and any water levels below the Corcoran Clay (even if well construction is not known) were used for mapping groundwater elevations.

A combined dataset of Winter/Spring 1988 and Winter/Spring 1989 water level measurements was used to map Winter/Spring 1988 and 1989 groundwater elevation contours. The limited spatial representation of Lower Aquifer water level data is apparent in **Figure 2-49** with only one water level datapoint available in the central to western portion of Chowchilla Subbasin during the 1988 and 1989 time period. With this datapoint, groundwater elevation in the Lower Aquifer was estimated to be around 130 feet msl in Winter/Spring of 1988/1989. The pattern in Lower Aquifer groundwater elevations, including direction of groundwater flow, is difficult to interpret from the few datapoints and limited spatial representation.

More recent groundwater elevation contours for Winter/Spring 2014 and 2016 have greater spatial coverage than the 1988/1989 map, but still have relatively limited point control in the Lower Aquifer within the Chowchilla Subbasin. The Winter/Spring 2014 groundwater elevation contour map for the Lower Aquifer is presented as **Figure 2-50** and indicates Lower Aquifer groundwater elevations of between -30 and -40 feet msl in the area of the Chowchilla Subbasin within the extent of the Corcoran Clay. The contour map for Lower Aquifer in Winter/Spring 2016 (**Figure 2-51**) shows relatively lower groundwater elevations with some areas from -40 and -60 feet msl in the Lower Aquifer in the city of Chowchilla and in the southwestern portion of the subbasin east of the Eastside Bypass. However, there is also an area of higher groundwater elevations than in 2014 in the middle portion of the subbasin along Highway 152. Due to the limited spatial coverage of wells with Lower Aquifer water levels, evaluating groundwater flow gradients and directions within the Lower Aquifer in Chowchilla Subbasin is challenging.

Groundwater Hydrographs

Hydrographs of time-series groundwater level data were reviewed to evaluate long-term trends in groundwater levels. Selected groundwater level hydrographs for unconfined groundwater, Lower Aquifer, and composite wells or wells with unknown construction are presented in **Figures 2-52 to 2-54** to illustrate temporal trends in groundwater levels across the subbasin. Overall, long-term declines were prevalent throughout the subbasin.

Select hydrographs of water levels in the unconfined groundwater (outside the Corcoran Clay or above the Corcoran Clay) are displayed in **Figure 2-52**. All of the hydrographs displayed on **Figure 2-52** with extended water level histories exhibit long-term water level declines. Two wells (TTR-1 and TTR-35) in the western portion of the subbasin with short-term water level histories show steep declines between 2013 and 2016 but subsequent recovery of groundwater levels in 2017. The wells in Figure 2-52 with longer-term records in the eastern to central part of the subbasin (9S/16E-15Q1, 9S/17E-19L1, 10S/16E-17C1, 10S/15E-35A2) show groundwater level declines of between 4 and 6 feet per year over the period from the mid-1980s through about 2015.

Select hydrographs of water levels in the Lower Aquifer (within the extent of the Corcoran Clay) are displayed in **Figure 2-53**. As discussed above, the availability of groundwater level data known to be specific to the Lower Aquifer is limited. Only two of the wells (9S/15E-23J2 and 9S/16E-16N1) shown in **Figure 2-53** have a period of record sufficiently long to interpret trends in water levels. Over the period of

time from the mid-1980s through 2015 there was an annual groundwater level decline of about 5 to 6 feet per year.

Because of limitations related to available well construction information, there are many wells with long periods of record for water levels but lacking well construction information. Select hydrographs of water levels in wells of unknown construction are presented in **Figure 2-54**. The hydrographs on **Figure 2-54** show groundwater level trends generally consistent with those seen in the Upper and Lower Aquifers with declines of 4 to 6 feet/year over the time period between the mid-1980s and 2015. However, two wells (10S/13E-22R1 and 10S/14E-26C2) located in the western portion of the subbasin show lower rates of decline between 1 and 3 feet/year. Trends of more stable water levels, although slightly declining, prior to the mid-1980s are apparent in most wells with greatly increased rates of groundwater level declines over the period from the mid-1980s to 2015.

Additional groundwater level hydrographs are presented in **Appendix 2.E**.

2.2.2.2 Groundwater Storage

Total Groundwater Storage

The total groundwater storage volume within the Chowchilla Subbasin above the basement and base of freshwater is estimated to be between about 6.5 million AF and 13 million AF based on an analysis using contouring of 2014 groundwater levels and an assumed specific yield range of 5 to 10 percent. **Table 2-5** summarizes the calculations of total groundwater storage in the subbasin using a range of specific yield values, although recent groundwater modeling conducted to support development of the GSP suggest average specific yield values for the full saturated thickness in the subbasin (i.e., from the regional water table to the base of fresh water) may be lower than previously estimated and closer to the lower end of the values listed in **Table 2-5**. In Bulletin 118, DWR previously estimated the total groundwater storage in the Chowchilla Subbasin above the base of freshwater to be about 13.9 million AF using 1995 groundwater levels and a specific yield value of 8.6 percent. However, DWR's Bulletin 118 estimate was for a larger area of about 159,000 acres compared to the current Chowchilla Subbasin area of a little under 146,000 acres.

Table 2-5. Estimates of Total Groundwater Storage Above Base of Freshwater (as of 2014)

Chowchilla Subbasin Area (acres)	Specific Yield (percent)	Total Groundwater Storage (AF)	Notes on Specific Yield Basis
145,574	5%	6,453,000	
	7%	9,034,000	
	8.6%	11,099,000	DWR Bulletin 118
	10%	12,906,000	2002 AB3030 Madera County GMP value (Todd Engineers)
	12%	15,487,000	
	13%	16,777,000	2014 Regional GMP value (P&P, Wood Rodgers, KDSA)

Change in Groundwater Storage

Based on a comparison of the contour maps of unconfined groundwater elevation for Winter/Spring 1988 and the two more recent contour maps for Winter/Spring 2014 and 2016, changes in groundwater

elevation were calculated between 1988 and both 2014 and 2016. **Figure 2-55** shows the calculated change in unconfined groundwater levels for 1988 to 2014 and **Figure 2-56** presents the calculated change over the period 1988 to 2016. Unconfined groundwater levels declined substantially across much of the Chowchilla Subbasin between 1988 and both 2014 and 2016. Groundwater level declines of 50 to 150 feet occurred throughout most of the subbasin in 2014, except for an area around the City of Chowchilla and to the west/northwest of the City of Chowchilla and in the far western portion of the subbasin along the San Joaquin River. The greatest areas of groundwater level decline occurred in the far eastern portion of the subbasin and in the south-central portion of the subbasin adjacent to the Madera Subbasin boundary. The patterns of groundwater level declines between 1988 and 2016 were similar to 1998 to 2014, with slightly greater overall declines in the 1988 to 2016 period. The areas indicated in **Figures 2-55 and 2-56** to have increasing groundwater levels are primarily a result of differences in water level data availability between the different time periods and are unlikely to be an indication of actual rising groundwater levels.

The calculated changes in groundwater levels translate to changes in groundwater storage estimated to range between -700,000 to -1.3 million AF between 1988 and 2014 and between -800,000 and -1.5million AF between 1988 and 2016, assuming a range of specific yield values from 7 to 13 percent. This calculation, which represents the upper portion of the total saturated sediment thickness in the subbasin, utilizes a more representative higher range of specific yield values compared to the total basin groundwater storage calculation presented above. These storage decreases translate to annual decreases of about -27,000 to -50,000 AFY for 1988 to 2014 and -31,000 to -57,500 AFY for 1988 to 2016. Table 2-6 summarizes the calculations of changes in groundwater storage from 1988 to 2014 and 1988 to 2016 under different specific yield values.

Table 2-6. Calculated Change in Groundwater Storage

Analysis Time Period	Specific Yield (percent)	Total Groundwater Storage Change (AF)	Average Annual Groundwater Storage Change (AFY)	Notes on Specific Yield Basis
Change 1988 to 2014	7%	-701,000	-27,000	
	8.6%	-861,000	-33,000	DWR Bulletin 118
	10%	-1,002,000	-38,500	2002 AB3030 Madera County GMP value (Todd Engineers)
	12%	-1,202,000	-46,000	
	13%	-1,302,000	-50,000	2014 Regional GMP value (P&P, Wood Rodgers, KDSA)
Change 1988 to 2016	7%	-805,000	-31,000	
	8.6%	-989,000	-38,000	DWR Bulletin 118
	10%	-1,150,000	-44,000	2002 AB3030 Madera County GMP value (Todd Engineers)
	12%	-1,380,000	-53,000	
	13%	-1,495,000	-57,500	2014 Regional GMP value (P&P, Wood Rodgers, KDSA)

Previous estimates of groundwater storage change for Madera County include DWR (1992), Todd (2002), and Provost & Pritchard (2014). DWR (1992) estimated groundwater storage decline from 1970 to 1990 to be 74,115 AFY. Todd (2002) calculated a groundwater storage decline of 68,338 AFY for the period from 1990 to 1998. The most recent of these evaluations of groundwater level and storage change is included in the 2014 Groundwater Management Plan (Provost & Pritchard, 2014), and covers the time period from 1980 to 2011. In general, groundwater levels declined between 30 and 150 feet throughout Madera County, or an average of 1 to 5 feet per year. Groundwater storage change was not quantified by subbasin. For the Madera County area included in the plan (not including areas of Root Creek Water District, Madera Water District, Aliso Water District, or Columbia Canal Company) studied in 2014 (plus the area of Merced County included in Chowchilla Water District), groundwater storage between 1980 and 2011 was estimated to have declined at an average rate of 143,000 AFY, which equates to a total decline of 4.4 million AF over the 31-year period.

2.2.2.3 Groundwater Quality

Maps of available groundwater quality data for a variety of constituents were prepared to characterize groundwater quality in the Subbasin. Key groundwater quality constituents discussed below include nitrate, total dissolved solids (TDS), and arsenic. These constituents have greater potential for presenting broader regional groundwater quality concerns extending beyond localized or site-specific contamination cases and are likely to reflect a range of potential contamination sources. A variety of maps of other groundwater quality constituents are included in **Appendix 2.E** and highlight local areas of groundwater quality contamination that are important for consideration when evaluating GSP-related projects and management actions and their potential to have adverse groundwater quality impacts.

Nitrate is one of the most common groundwater contaminants and is generally the water quality constituent of greatest concern in agricultural areas where application of fertilizers containing nitrogen can lead to elevated nitrate levels in groundwater. Additionally, nitrate is a constituent of concern in groundwater near dairy or other large-scale livestock operations. Natural concentrations of nitrate in groundwater are generally low, and elevated levels usually indicate impacts from land use activities. Nitrate presents health concerns at high concentrations and is regulated in public drinking water systems. The U.S. Environmental Protection Agency (USEPA) has established a maximum contaminant level (MCL) for nitrate (as nitrogen) of 10 mg/L under its National Primary Drinking Water Regulations; this MCL standard is established for public health reasons and is a requirement of all public drinking water systems. Total Dissolved Solids (TDS) is a general measure of salinity and overall water quality. Elevated salinity in groundwater can be a result of land use activities, but can also be naturally-occurring, especially in western parts of the San Joaquin Valley where subsurface geologic materials are derived from marine sediments. Arsenic is a naturally occurring chemical found in groundwater and has a primary MCL of 10 mg/L.

Additional maps of other groundwater quality constituents are presented in **Appendix 2.E** including maps of select chemicals typically found associated with point-source contamination including hydrocarbon products and pesticides. Several studies and maps of regional groundwater quality have also been prepared in recent years, and some of these maps are included in **Appendix 2.E**. Work for CV-SALTS (LSCE and LWA, 2016) evaluated ambient TDS and nitrate concentrations for the period 2000 to 2016 in the upper and lower zones within the Upper Aquifer. LSCE (2014) conducted groundwater quality mapping for the San Joaquin Valley for various constituents including TDS, nitrate, arsenic, vanadium, uranium, DBCP/fumigants, herbicides, solvents, and perchlorate. Maps of TDS and nitrate from the Groundwater Quality Assessment Report prepared for the East San Joaquin Water Quality Coalition (LSCE, 2014) presents groundwater quality data delineated by shallow and deep wells. Although the maps were not necessarily aquifer specific (shallow wells were distinguished from deeper wells for this study primarily

based upon well use type), they do illustrate general concentrations in wells across the subbasin. Other mapping of regional groundwater quality was included in the Regional Groundwater Management Plan (Provost & Pritchard, 2014). Typically, the major considerations for municipal/domestic and agricultural use with respect to groundwater quality include salinity (specific conductance, TDS), nutrients (nitrate), and metals (arsenic, manganese). For the purposes of their groundwater quality evaluation, Provost & Prichard (2014) defined shallow wells (0 to 400 feet), intermediate wells (400 to 600 feet), and deep wells (greater than 600 feet deep). This depth classification differs slightly from how groundwater conditions are represented in the HCM as defined in this GSP, and is utilized only for the discussion of groundwater quality in this section. Groundwater quality maps from previous reports are provided in **Appendix 2.E**.

Groundwater quality data for other constituents as presented in published reports, particularly data from the USGS Groundwater Ambient Monitoring and Assessment (GAMA) Program investigations conducted for the area, are also presented in **Appendix 2.E**.

Total Dissolved Solids

Maps of maximum historical TDS concentrations in groundwater in the Chowchilla Subbasin (**Figures 2-57 to 2-59**) indicate variable salinity across the subbasin with more elevated TDS concentrations in the western portion of the subbasin. However, wells having high (greater than 1,000 mg/L) TDS concentrations are also intermingled with wells with relatively low (less than 500 mg/L) TDS concentrations. Higher TDS concentrations in the western part of the subbasin may be caused by natural salinity present in groundwater occurring within Coast Range derived sediments of marine source material. Given the number of wells with groundwater quality data but without well construction details, it is difficult to make interpretations of relationships between water quality and screen depths across the Subbasin from these data.

Regional groundwater quality mapping of TDS concentrations was conducted for the CV-SALTS project (LSCE and LWA, 2016). These analyses for the upper zone (of the upper aquifer) showed generally increasing TDS from east to west across Chowchilla Subbasin. TDS concentrations ranged from less than 250 mg/L in the east to greater than 1,000 mg/L in the northwestern portion of the subbasin. Analyses of the lower zone (of the upper aquifer) showed a similar pattern of increasing TDS from east to west, but with a considerably larger area of high TDS groundwater (**Appendix 2.E**).

Nitrate

Maps of maximum historical nitrate concentrations in groundwater are presented for all wells and also individually for Upper Aquifer wells and Lower Aquifer wells in **Figures 2-60 to 2-62**. Due to the limited number of datapoints with known well construction information, many results cannot be attributed to a specific aquifer zone. These maps highlight patterns in historical nitrate concentrations across the subbasin. A large percentage of the wells with nitrate data have maximum historical concentrations below 7.5 mg/L and many have concentrations below 5 mg/L. However, a number of areas of locally high nitrate concentrations above 7.5 mg/L or above 10 mg/L are apparent across the subbasin. The higher concentrations appear to be more common in the central parts of the subbasin. Several notable areas with a high density of wells with nitrate concentrations above the MCL of 10 mg/L (as N) are located in the more central parts of the subbasin to the west and southwest of the City of Chowchilla and between Ash Slough and Highway 152. Most of the higher concentrations are from wells with unknown construction information.

Regional mapping of nitrate concentrations in groundwater were also performed as part of the CV-SALTS project (LSCE and LWA, 2016). Maps of nitrate concentrations in the upper zone (of the upper aquifer) showed a relatively large area exceeding the MCL of 10 mg/L (as N) in the central part of the subbasin,

while nitrate in the lower zone (of the upper aquifer) was indicated to exceed 10 mg/L in a smaller area in southwest portion of the subbasin (**Appendix 2.E**).

Arsenic

Maps of maximum historical arsenic concentrations in groundwater are presented in **Figures 2-63 to 2-65**. Although there are a few wells with higher arsenic concentrations above 7.5 µg/L, most of the wells with data have concentrations below 5 µg/L with a considerable number having concentrations of less than 2.5 µg/L. The available groundwater quality data do not indicate any wells with arsenic concentrations above the MCL of 10 µg/L. The map of arsenic concentrations in the Lower Aquifer (**Figure 2-65**) suggest that concentrations of arsenic may be somewhat higher in the Lower Aquifer, although still generally below the MCL.

Other Groundwater Quality Constituents

Maps of a variety of other groundwater quality constituents are presented in **Appendix 2.E**. Many of these maps highlight distinct areas of local groundwater contamination of groundwater characteristics that should be considered when evaluating potential groundwater quality impacts from implementation of projects and management actions to achieve sustainability.

2.2.2.4 Land Subsidence

Recent land subsidence has been a major concern in the western portion of the Chowchilla Subbasin. A map of subsidence that occurred between 1926 and 1970 shows 1 to 2 feet of subsidence in the western portion of Chowchilla Subbasin (**Figure 2-66**). Subsidence mapping using InSAR data for the 2007 to 2011 time period is shown in **Figure 2-67**. A maximum subsidence of 2+ feet for this time period occurred in the northwest part of the Chowchilla Subbasin between Eastside Bypass and the western basin boundary. The most recent map of subsidence that occurred between 2015 and 2017 (**Figure 2-68**) shows 1 to 2 feet of subsidence in a large portion of the western subbasin. Overall, the available subsidence maps for the three time periods show up to approximately five feet of subsidence in some areas of western Chowchilla Subbasin since 1920. Specific subsidence monitoring locations are shown in **Figure 2-69**, which shows a relatively continuous monitoring record of subsidence at eight locations in the subbasin between 2011 and 2017. Review of the subsidence monitoring location records about 3.5 feet of subsidence in the western portion of the subbasin and about two feet of subsidence near the intersection of Highway 152 and Highway 99 in the eastern portion of Chowchilla Subbasin.

Other mapping of recent subsidence is included in **Appendix 2.D**. In northwest Chowchilla Subbasin, subsidence from 2008 to 2010 was 1.5 to 2 feet. Mapping by USBR between July 2012 and December 2016 showed total subsidence ranging up to three feet in western portion of Chowchilla Subbasin. Various ongoing subsidence monitoring programs are being funded and/or conducted by DWR, USGS, USBR, and NASA-JPL.

2.2.2.5 Groundwater - Surface Water Interaction

The primary surface water features in Chowchilla Subbasin are the Chowchilla River, Ash Slough, Berenda Slough, and San Joaquin River (**Figure 2-10**). Each of these streams is considered to be a natural source of recharge to the subbasin. A review of historical regional aquifer groundwater levels compared to stream thalweg (deepest portion of stream channel) elevations conducted for this study indicate that surface water – groundwater interactions are not a significant issue (i.e., regional groundwater levels are relatively far below creek thalweg elevations) along Chowchilla River, Ash Slough, and Berenda Slough in Chowchilla Subbasin. However, comparison of historical groundwater levels to the stream thalweg (i.e., deepest portion of stream channel) indicate that the San Joaquin River along the western subbasin boundary was

connected with groundwater from 1958 (and likely before) through 2008. Groundwater levels were generally below (and apparently disconnected from) the San Joaquin River from 2009 through 2016.

The depths to shallow groundwater for 2014 and 2016 are displayed on **Figures 2-70** and **2-71**. Some of the areas in western Chowchilla Subbasin along/adjacent to the San Joaquin River are underlain by the "C" clay and other shallow clay layers that are above the more regional Corcoran Clay. Shallow groundwater in these areas can be considered perched/mounded aquifers in that shallow clay layers help to maintain shallow groundwater levels but there is no unsaturated zone beneath them as in a truly perched aquifer condition described below in the section on groundwater dependent ecosystems. It is likely that seepage from the San Joaquin River is the source of water that combined with the presence of shallow clay layers that serves to maintain shallow groundwater levels at these locations. Review of Figures 2-70 and 2-71 indicates that the San Joaquin River is disconnected from the shallow perched/mounded aquifer. However, given the apparent fully saturated water column at these locations, there is at least potential for regional groundwater pumping to impact groundwater dependent ecosystems (GDEs) with roots extending down 20 to 30 feet along the San Joaquin River. Thus, shallow groundwater areas adjacent to the San Joaquin River were further evaluated in regard to GDEs in the following section and in Chapter 3.

2.2.2.6 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) are defined in California's Sustainable Groundwater Management Act (SGMA) as "ecological communities of species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (23 CCR § 351(m)). As described in The Nature Conservancy's guidance for GDE analysis (Rohde et al. 2018), a GDE's dependence on groundwater refers to reliance of GDE species and/or communities on groundwater for all or a portion of their water needs. Review of available groundwater level data indicates that shallow groundwater levels (i.e., within 30 feet of ground surface) exist in some portions of the subbasin. The depth to water (DTW) evaluation described in the above section for Groundwater – Surface Water Interaction also provides input for evaluation of GDEs. A DTW cutoff of 30 feet was used in the initial screening of potential GDEs. The use of a 30-foot DTW criterion to identify potential GDEs is based on reported maximum rooting depths of California phreatophytes[18] and is consistent with guidance provided by The Nature Conservancy (Rohde et al. 2018) for identifying potential GDEs. It was therefore determined that areas within the subbasin where DTW is equal to or shallower than 30 feet have the potential to support GDEs.

One GDE unit, the San Joaquin River Riparian GDE Unit, was identified in the Chowchilla Subbasin (**Appendix** 2.B). The GDE unit was identified using the California Department of Water Resources' (DWR) indicators of GDEs (iGDE) dataset, published online and referred to as the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset (Klausmeyer et al. 2018), augmented with other relevant vegetation mapping data, aerial imagery, and hydrologic data. Field reconnaissance was conducted in portions of the unit in May 2019 to help characterize the vegetation composition and structure, document dominant plant species, and assess habitat characteristics to determine the potential for presence of special-status species.

Groundwater beneath the San Joaquin River Riparian GDE Unit was approximately 20–30 feet deep in winter/spring 2014 and 2016 (i.e., the upper 20–30 feet of the subsurface was unsaturated during this time). This is too deep for the river's surface flow to be connected to groundwater, but within the 30-foot maximum rooting depth of the dominant riparian plants in the unit. Below the San Joaquin River, the

[18] A phreatophyte is a deep-rooted plant that obtains its water from the phreatic zone (zone of saturation) or the capillary fringe above the phreatic zone (Rohde et al. 2018).

groundwater is perched or mounded atop the shallow clay layer, but there is no unsaturated zone below the perched/mounded aquifer (Section 2.2.2.5). It is therefore at least possible that changes to the regional aquifer could affect the shallower perched/mounded aquifer that maintains the GDE, although any such connection would be limited by presence of multiple clay layers between the shallow perched/mounded aquifer and the deeper regional aquifer where pumping occurs. The riverine aquatic habitat of the San Joaquin River is not contained within the GDE unit because available hydrologic data indicates no groundwater contribution to the surface flow in this reach of the river (i.e., this reach of the San Joaquin River does not gain but rather is generally disconnected and loses water to the groundwater system). The net-losing condition of the San Joaquin River in this area likely began in 2009 or earlier (Section 2.2.2.5; TNC 2014).

San Joaquin River Riparian GDE Unit

The San Joaquin River Riparian GDE Unit is located along the San Joaquin River on the western margin of the Chowchilla Subbasin (**Figure 2-72**) and is composed of a mix of riparian forest, shrub, and herbaceous habitat types totaling approximately 70 acres. The May 2019 reconnaissance assessment of representative portions of the San Joaquin River Riparian GDE Unit identified areas of mature riparian forest with a stratified canopy and moderately open understory, overhanging vegetation along the riverbank, and downed wood (**Figure 2-**). Vegetation at the representative sites provided over 90% native cover in the shrub and tree layer and 15–25% native cover in the herbaceous ground cover, with the balance occupied by non-native species.

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Figure 2-73. Stratified canopy along the banks of the San Joaquin River in the San Joaquin River Riparian GDE.

The GDE unit is located in the current and former floodplain of the San Joaquin River, which has been subject to major land use and water use modifications over the last century, primarily resulting from agricultural development and the near-complete curtailment of flow in the San Joaquin River subsequent to completion of Friant Dam in 1944 (McBain & Trush 2002). Despite these changes, the San Joaquin River Riparian GDE Unit provides habitat or ecosystem support for several special-status species and natural communities, including aquatic species that use the adjacent San Joaquin River for all or part of their life cycle including:

- bald eagle (*Haliaeetus leucocephalus),*
- Swainson's hawk (*Antrozous pallidas),*
- pallid bat (*Antrozous pallidas),*
- western red bat *(Lasiurus blossevillii),*
- western pond turtle (*Emys marmorata),*
- Sanford's arrowhead (*Sagittaria sanfordii),*
- California satintail (*Imperata brevifolia),*
- brittlescale (*Atriplex depressa),*
- heartscale (*Atriplex cordulata* var. *cordulata),*
- palmate-bracted bird's-beak (*Chloropyron palmatum),*
- spiny-sepaled button-celery (*Eryngium spinosepalum),*

- California alkali grass (*Puccinellia simplex),*
- Valley Sacaton Grassland, and
- Sycamore Alluvial Woodland.

These species include special-status species that satisfy one or more of the following criteria: (1) known to occur in the region and suitable habitat present in the GDE unit, (2) documented occurrence within the GDE Unit, or (3) directly observed during the May 2019 reconnaissance survey conducted by Stillwater Sciences (see **Appendix 2.B** for the status of each species listed above). This unit does not contain or overlap any known protected lands or critical habitat for federally listed species (USFWS 2019, NMFS 2019) but the adjacent San Joaquin River contains Essential Fish Habitat (EFH) for Chinook salmon which is partially dependent on riparian inputs to provide important salmon habitat elements including shade, overhead cover, nutrients, and woody material for instream cover and habitat complexity (PFMC 2014).

Designated fish and wildlife beneficial uses of other surface water bodies in the Chowchilla Subbasin, including the Fresno River and Chowchilla River, are limited to warm freshwater habitat (WARM) and wildlife habitat (WILD). The Basin Plan also lists coldwater spawning habitat (SPWN) for salmon and trout as a potential beneficial use for this portion of the San Joaquin River.

The San Joaquin River Riparian GDE Unit was determined to have **high ecological value** because of: (1) the known occurrence and presence of suitable habitat for several special-status species in the unit; (2) the vulnerability of these species and their habitat to changes in groundwater levels; and (3) contributions of the unit to the ecological function of adjacent riverine habitat that supports special-status salmonids and other species.

2.2.3 Water Budget Information (23 CCR § 354.18)

The Chowchilla Subbasin is managed by four GSAs (CWD GSA, Madera Co GSA, Merced Co GSA, TTWD GSA) whose jurisdictional areas have been organized into five subbasin subregions for GSP planning efforts (**Figure 2-74**). These subregions include: CWD GSA, Madera Co GSA – East, Madera Co GSA – West, Sierra Vista Mutual Water Company (SVMWC), and TTWD GSA.

This section presents the historical and current water budgets for the entire Chowchilla Subbasin refined with information and knowledge gained during the assembly of individual water budgets for each of the five subregions within the subbasin.

DWR has published guidance and Best Management Practice (BMP) documents related to the development of GSPs (DWR, 2016), including Water Budget BMPs. Consistent with these BMPs, this section presents the water budget development methodology and results to describe the hydrologic systems within the Study Area, and includes estimates of uncertainty for various water budget components. An estimate of the sustainable yield of the Chowchilla Subbasin is provided at the end of this section for (1) the reference historical period (1989-2014 hydrologic conditions and land use), (2) the current period (2015 land use with 1989-2014 average hydrologic conditions), and (3) the projected future period (2041-2090) following the GSP implementation period (2020-2039) using projected future land use and historical 1965-2015 hydrologic data.

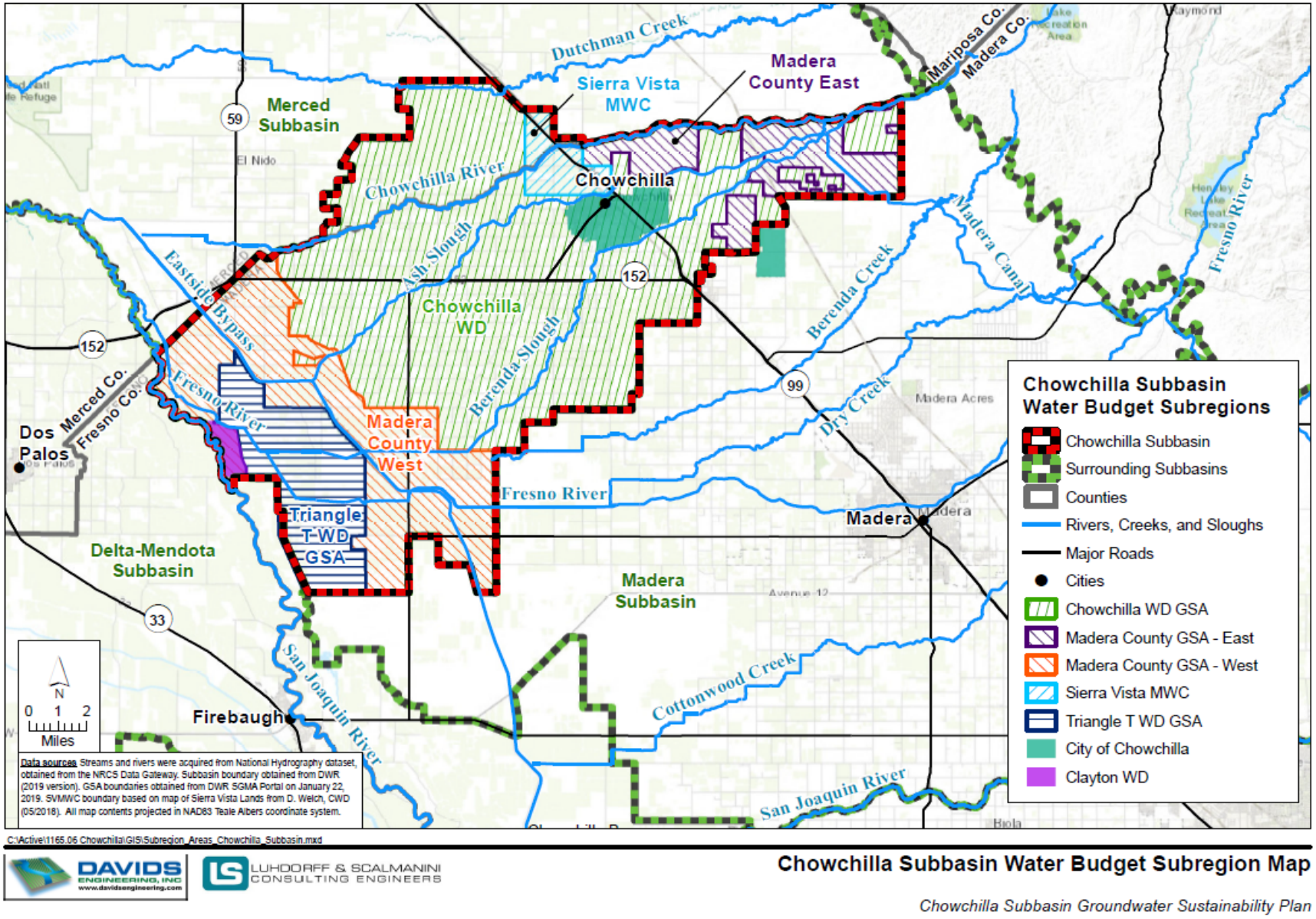

Figure 2-74. Chowchilla Subbasin Water Budget Subregions.

2.2.3.1 Water Budget Conceptual Model

A water budget is defined as a complete accounting of all water flowing into and out of a defined volume[19] over a specified period of time. When the water budget volume is an entire subbasin, the water budget facilitates assessment of the total volume of groundwater and surface water entering and leaving the subbasin over time, along with the change in the volume of water stored within the subbasin. When applied to a GSA or subregion, this method also facilitates assessment of the total volume of surface water entering and leaving a defined GSA or subregion boundary.

The conceptual model for the Chowchilla Subbasin and subregion water budgets was developed during previous data collection and analysis efforts conducted by DE and LSCE (2017). This conceptual model is consistent with the GSP Regulations, adhering to sound water budget principles and practices described in the Water Budget BMPs, including the use of defined water budget accounting centers covering the three-dimensional subbasin area and defined water budget components quantified according to best available information and science (DWR, 2016).

Water budgets were developed for the defined study area during defined historical, current, and projected study periods. These water budgets were developed for the subbasin and individual subregions utilizing the data sources and procedures outlined in Section 2.2.3.3 below.

Study Area

The water budget study area is defined as the Chowchilla Subbasin Plan Area, described above in Section 2.1 (23 CCR § 354.8). The lateral and vertical extents of the study area are the same as those defined for the Plan Area.

Similar to the Plan Area, the vertical extent of the water budget study area is subdivided into a surface water system (SWS) and groundwater system (GWS). The SWS represents the land surface down to the bottom of plant root zone, within the lateral boundaries of the subbasin. The GWS extends from the bottom of the root zone to the definable bottom of the subbasin, within the lateral boundaries of the subbasin.

During water budget development, the study area was also subdivided into five subregions: CWD GSA, Madera Co GSA – East, Madera Co GSA – West, SVMWC, and TTWD GSA. The relationships between the Chowchilla Subbasin GSAs and subregions is outlined in Table 2-7. Each subregion represents either one entire GSA (CWD GSA, TTWD GSA), a portion of one GSA (Madera Co GSA – East, Madera Co GSA – West), or combined areas across more than one GSA (SVMWC).

For each subregion, the SWS water budget was developed based on subregion-specific information describing land use, available surface water supplies, and other flow paths to facilitate estimation of groundwater extraction.

[19] Where 'volume' refers to a space with length, width and depth properties, which for purposes of the GSP means the defined aquifer and associated surface water system.

Table 2-7. Chowchilla Subbasin GSAs and Water Budget Subregions.

GSA	Subregion	Subregion Abbreviation	Subregion Area, Acres
Chowchilla Water District GSA	Chowchilla Water District GSA	CWD GSA	85,200
Madera County GSA	Madera County GSA – East	Madera Co GSA – East	11,400
	Madera County GSA – West	Madera Co GSA – West	31,200
Merced County GSA	Sierra Vista Mutual Water Company	SVMWC	3,800
Triangle T WD GSA	Triangle T Water District GSA	TTWD GSA	14,700
		Total	**146,300**

General Water Budget Accounting Structure and Components

For accounting purposes, the water budget is divided into the Surface Water System (SWS) and Groundwater System (GWS), described above. These systems are referred to as *accounting centers*. Flows between accounting centers and storage within each accounting center represent water budget *components*. Separate but related water budgets were prepared for each accounting center that together represent the overall subbasin water budget. A schematic of the general water budget accounting structure is provided in **Figure 2-75.**

For accounting for water in the SWS, interrelated water budgets were prepared individually for each subregion and for the entire subbasin. For accounting for water in the GWS, a subbasin water budget was prepared integrating components in a numerical model of both the SWS and GWS, referred to as the MCSim model.

A conceptual representation of the MCSim model water budget accounting centers and components is provided in **Figure 2-76**. Required components for each accounting center are listed in Table 2-8, along with the corresponding section of the GSP Regulations. Note that precipitation is not explicitly listed as a required water budget component, though it is needed to provide complete accounting of subbasin inflows and outflows.

Subbasin boundary inflows and outflows must be quantified according to GSP regulations, as stated in 23 CCR Section 354.18(b). Inflows and outflows may cross the subbasin boundary or may represent exchanges of water between the SWS and the underlying GWS within the subbasin.

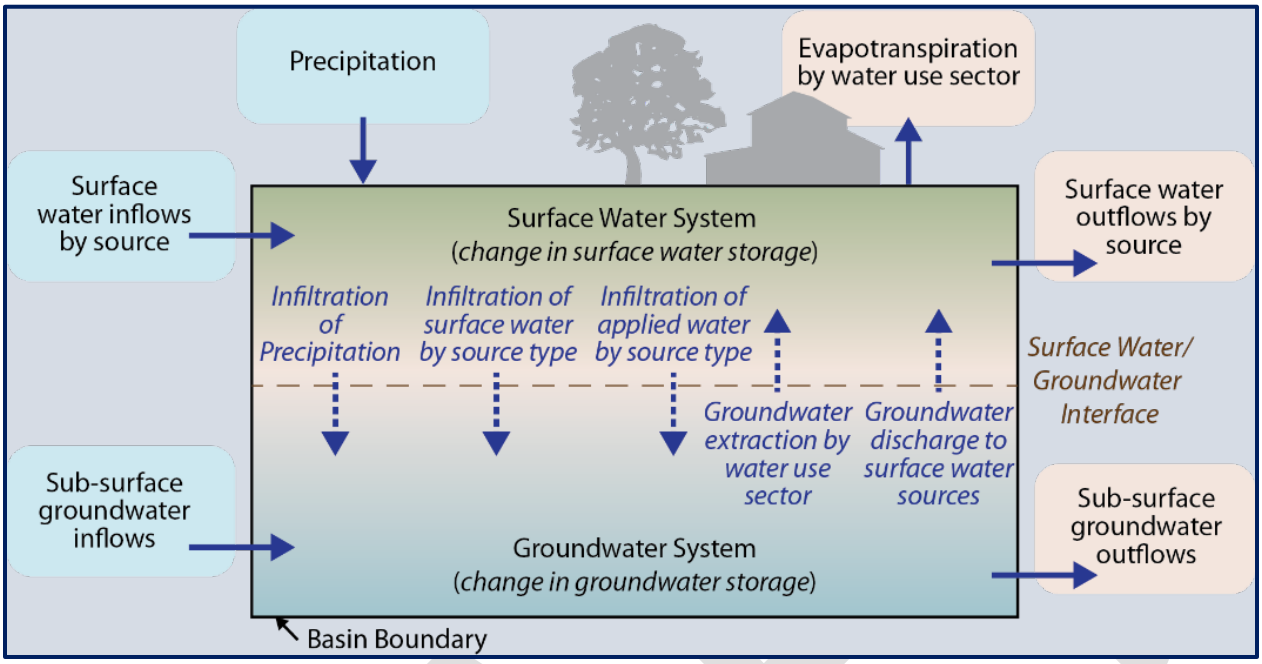

Figure 2-75. Water Budget Accounting Structure (Source: DWR, 2016).

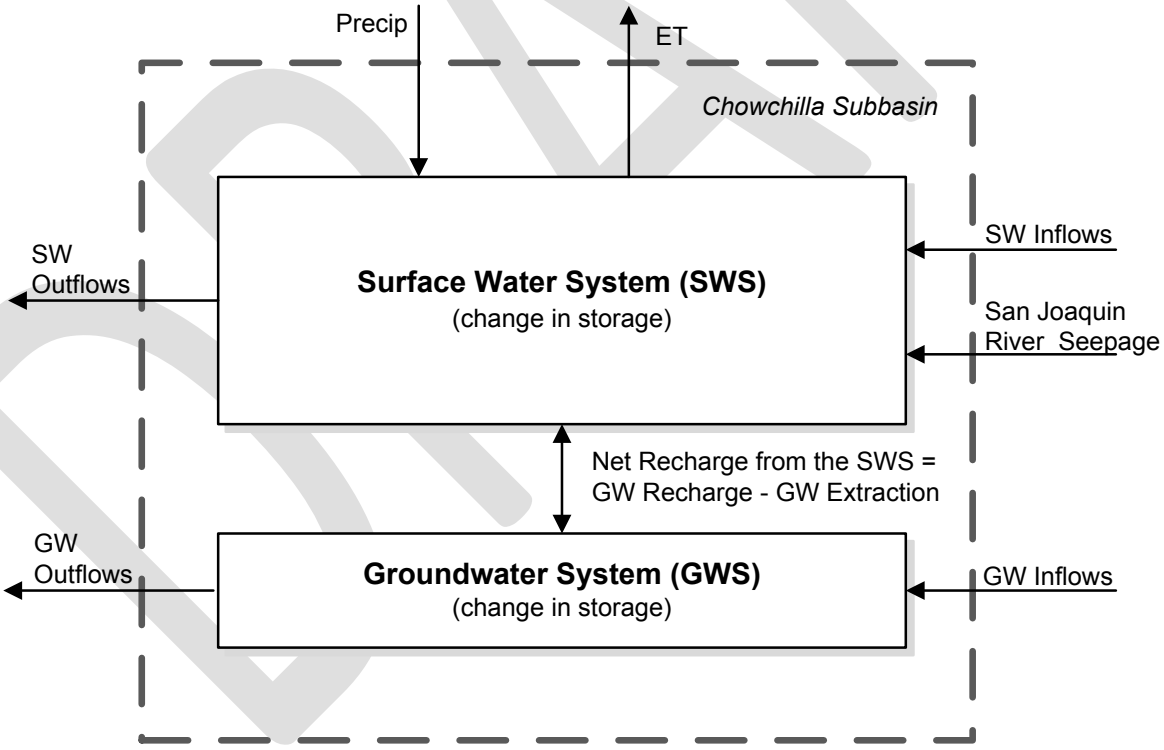

Figure 2-76. Chowchilla Subbasin Boundary Water Budget Diagram.

Table 2-8. Water Budget Components by Accounting Center and Associated GSP Regulations.

Accounting Center	Water Budget Component (flow direction)	GSP Regulation Section[20]
Basin	Surface Water Inflow[1] (+)	§354.18(b)(1)
	Precipitation (+)	Implied
	Subsurface Groundwater Inflow (+)	§354.18(b)(2)
	Evapotranspiration[2] (-)	§354.18(b)(3)
	Surface Water Outflow[1] (-)	§354.18(b)(1)
	Subsurface Groundwater Outflow (-)	§354.18(b)(3)
	Change in Storage	§354.18(b)(4)
Surface Water System	Surface Water Inflow[1] (+)	§354.18(b)(1)
	Precipitation (+)	Implied
	Groundwater Extraction (+)	§354.18(b)(3)
	Groundwater Discharge (+)	§354.18(b)(3)
	Evapotranspiration[2] (-)	§354.18(b)(3)
	Surface Water Outflow[1] (-)	§354.18(b)(1)
	Infiltration of Applied Water[3,4] (-)	§354.18(b)(2)
	Infiltration of Surface Water[5] (-)	§354.18(b)(2)
	Infiltration of Precipitation[4] (-)	§354.18(b)(2)
	Change in SWS Storage[6]	§354.18(a)
Groundwater System	Subsurface Groundwater Inflow (+)	§354.18(b)(2)
	Infiltration of Applied Water[3,4] (-)	§354.18(b)(2)
	Infiltration of Surface Water[5] (-)	§354.18(b)(2)
	Infiltration of Precipitation[4] (-)	§354.18(b)(2)
	Subsurface Groundwater Outflow (-)	§354.18(b)(3)
	Groundwater Extraction (-)	§354.18(b)(3)
	Groundwater Discharge (-)	§354.18(b)(3)
	Change in Storage	§354.18(b)(4)

1. By water source type.
2. By water use sector.
3. Includes applied surface water, groundwater, recycled water, and reused water.
4. Synonymous with deep percolation.
5. Includes lakes, streams, canals, drains, and springs. Synonymous with seepage.
6. Includes surface water streams and root zone (not groundwater system).

Boundary inflows include precipitation, surface water inflows (in various canals and streams), boundary watercourse seepage and groundwater inflows from adjoining subbasins. Outflows include evapotranspiration (ET), surface water outflows (in various canals and streams), and groundwater outflows. Also represented in **Figure 2-76** are groundwater recharge and extraction, which are "internal"

[20] California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2 Groundwater Sustainability Plans, Article 5 Plan Contents

flows between the SWS and GWS. Net recharge from the SWS is defined as groundwater recharge minus groundwater extraction, and is useful for understanding and analyzing the combined effects of land surface processes on the underlying GWS. Subbasin boundary inflows and outflows are quantified on a monthly basis, including accounting for any changes in storage, such as changes is water stored in the root zone (Equation 2-1).

Inflows – Outflows = Change in Storage (monthly time step) [2-1]

Selection of the water budget analysis period is discussed in Section 2.2.3.2 below. The specific components of SWS inflows and outflows and the available data and calculation methodology for each component are summarized briefly in Section 2.2.3.3 below. Additional detail regarding inflows to and outflows from each subregion is provided in **Appendix 2.F.** Inflows and outflows were calculated independently using measurements and other data or were calculated as the water budget closure term.

The subbasin water budget was completed on a monthly time step and water year annual results are reported in Section 2.2.3.4 according to GSP regulations. Detailed SWS water budgets are reported for each individual subregion in **Appendix 2.F.a.** through **Appendix 2.F.e.**

Quantification of GWS inflows and outflows is described below and in **Appendix 6.F.**, Groundwater Model Documentation. The GWS water budget was completed for the entire subbasin on a monthly time step. Some subregions are small or are composed of noncontiguous small areas, making it difficult to accurately calculate the change in volume of groundwater stored. As a result, GWS water budgets were not calculated for individual subregions.

Detailed Water Budget Accounting Centers and Components

To estimate the water budget components required by the GSP Regulations, the SWS water budget accounting center is further subdivided into detailed accounting centers representing the Land Surface System (irrigated and non-irrigated lands), the Rivers and Streams System (natural waterways), and the Canal System.

Finally, the Land Surface System is subdivided into accounting centers representing water use sectors identified in the GSP regulations as "categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed recharge, and native vegetation" (23 CCR Section 351(al)). Across the Chowchilla Subbasin and within each subregion, the water use sector accounting centers include Agricultural Land (AG), Urban Land (UR) (urban, industrial, and semi-agricultural), and Native Vegetation Land (NV). Industrial land covers only a small area of the subbasin, so industrial water uses have been combined with urban and semi-agricultural uses in the Urban land use.

Detailed water budget components are defined for each detailed accounting center. Within the Land Use Sector accounting center, detailed water budget components are also defined for each water use sector accounting center. The addition of these detailed water budget accounting centers and components facilitates the development of water budgets based on the best available data and science by facilitating the incorporation of information from agricultural water management plans (AWMPs), urban water management plans (UWMPs) and other sources.

Water budget components for each detailed accounting center within the Chowchilla Subbasin SWS are described in Tables 2-9 through 2-11. These water budget components were independently considered for each subregion to account for unique inflows and outflows to each subregion water budget presented in **Appendix 2.F.**

Table 2-9. Land Surface System Water Budget Components.

Detailed Accounting Center	Detailed Component	Category	Description
Land Surface System *Water Use Sectors: Agricultural Land, Native Vegetation Land, Urban Land*	Deliveries	Inflow	Deliveries from canal system to customers.
	Riparian Deliveries	Inflow	Deliveries from rivers and streams system to water rights users on lands adjacent to a river or stream.
	Groundwater Extraction	Inflow	Groundwater pumping to meet water demands.
	Precipitation	Inflow	Direct precipitation on the land surface.
	Reuse	Inflow	Reuse of percolated water from the unsaturated zone[21] (considered negligible in the Chowchilla Subbasin).
	ET of Applied Water	Outflow	Consumptive use of applied irrigation water. In wetlands and riparian areas, may represent shallow groundwater uptake.
	ET of Precipitation	Outflow	Consumptive use of infiltrated precipitation.
	Runoff of Applied Water	Outflow	Direct runoff of applied irrigation water, includes tailwater and pond drainage for ponded crops (no ponded crops are grown in the Chowchilla Subbasin).
	Runoff of Precipitation	Outflow	Direct runoff of precipitation.
	Infiltration of Applied Water	Outflow	Percolation of applied water below the root zone.
	Infiltration of Precipitation	Outflow	Percolation of precipitation below the root zone.
	Change in SWS Storage	Storage	Change in SWS storage of applied water within the root zone.

[21] "The unsaturated zone is below the land surface system and represents the portion of the basin that receives percolated water from the root zone and either transmits it as deep percolation to the groundwater system or to reuse within the land surface system, or both." In *Water Budget BMP* (DWR, 2016).

Table 2-10. Rivers and Streams System Water Budget Components.

Detailed Accounting Center	Detailed Component	Category	Description
Rivers and Streams System	Surface Inflows	Inflow	Surface inflows at upper boundary of water budget area.
	Evaporation	Outflow	Direct evaporation from river and stream water surfaces.[22]
	Infiltration of Surface Water (Seepage)	Outflow	Seepage from rivers and streams to the groundwater system during times of natural flow (during the times that rivers and streams serve as conveyance for irrigation releases, seepage is considered as part of the Canal System accounting center).
	Riparian Deliveries	Outflow	Deliveries from the rivers and streams system to water rights users on lands adjacent to a river or stream.
	Surface Outflows	Outflow	Surface outflows at lower boundary of water budget area.

Table 2-11. Canal System Water Budget Components.

Detailed Accounting Center	Detailed Component	Category	Description
Canal System	Diversions	Inflow	Diversions from Rivers and Streams System, including lakes and reservoirs in some cases.
	Evaporation	Outflow	Direct evaporation from canal water surfaces (unlined canals are generally maintained to be weed-free, so ET from bankside vegetation is not included).
	Infiltration of Surface Water (Seepage)	Outflow	Seepage from canals to the groundwater system and seepage from rivers and streams during the times that they serve as conveyance for irrigation releases.
	Spillage	Outflow	Spillage resulting from canal operations to the Rivers and Streams System.
	Deliveries	Outflow	Deliveries from the canal system to customers.

Characterization of Water Budget Components by Hydrologic Year Type

Surface water hydrology of the San Joaquin Valley is characterized by large variability in inter-annual precipitation and runoff resulting in both drought and flooding, sometimes in the same year. In contrast, relative differences in seasonal runoff are more predictable, with rainfall runoff occurring during the winter or snowfall forming snowpack in higher elevations that runs off as it melts in the spring and early summer.

[22] Does not include evapotranspiration of riparian vegetation (accounted in Land Surface System evapotranspiration).

A key indicator of seasonal variability in inter-annual hydrology is the San Joaquin Valley Water Year Index[23] (WYI), which is used to classify individual water years as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), or Critical (C) with respect to surface water runoff in the San Joaquin River Basin. These classifications are termed "water year types." A water year is defined as the period from October 1 of the preceding calendar year to September 30 of the current calendar year. For example, the 2000 water year represents the period from October 1, 1999 to September 30, 2000.

Rivers contributing to runoff from the San Joaquin Basin include, amongst others, the San Joaquin River itself, the Tuolumne River, the Stanislaus River, and the Merced River. The WYI for each year is weighted 80 percent based on unimpaired runoff from the San Joaquin Basin for the current year and 20 percent based on unimpaired runoff from the prior year (expressed in millions of acre-feet (maf)).[24] Unimpaired runoff represents the amount of runoff that would occur in the basin absent any diversions, storage, or inter-basin imports and exports.

The San Joaquin Valley WYI for the 51-year period from 1965 to 2015 is shown in **Figure 2-77**, along with corresponding water year type classifications. During this period, the WYI ranged from 0.81 maf in 2015 to 7.22 maf in 1983, representing a nine-fold difference. The average WYI over this period is 3.2 maf. Historical and recent drought periods are evident in the figure. Notably, only two above normal or wet years occurred between 2007 and 2015, and only four above normal or wet years have occurred between 2001 and 2015.

The distribution of water year types was considered in selecting water budget analysis periods that appropriately represent average historical hydrologic conditions. To support evaluation of differences in water budget components related to variable hydrology, the water year type associated with each year is also shown along with the SWS water budget results reported in section 2.2.3.4 of this report.

2.2.3.2 Water Budget Analysis Period

Criteria for Base Period Selection

In accordance with GSP regulations, a base period must be selected so that the analysis of sustainable yield is performed for a representative period with minimal bias that might result from the selection of an overly wet or dry period, while recognizing changes in other conditions including land use and water demands.

Per GSP regulations, the historical base period must include a minimum of 10 years of surface water supply information, with 30 years recommended; the current base period must include a representative recent one-year period; and the projected base period must include a minimum of 50 years of historical precipitation, evapotranspiration, and stream flow data.

[23] California Department of Water Resources, California Cooperative Snow Surveys, *Chronological Reconstructed Sacramento and San Joaquin Valley Water Year Hydrologic Classification Indices* (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST). Last accessed on 2/22/2019.

[24] California Environmental Protection Agency State Water Resources Control Board (SWRCB). 1995. *Water Quality Control Plan for the San Francisco Bay/ Sacramento-San Joaquin Delta Estuary*, pg. 24.

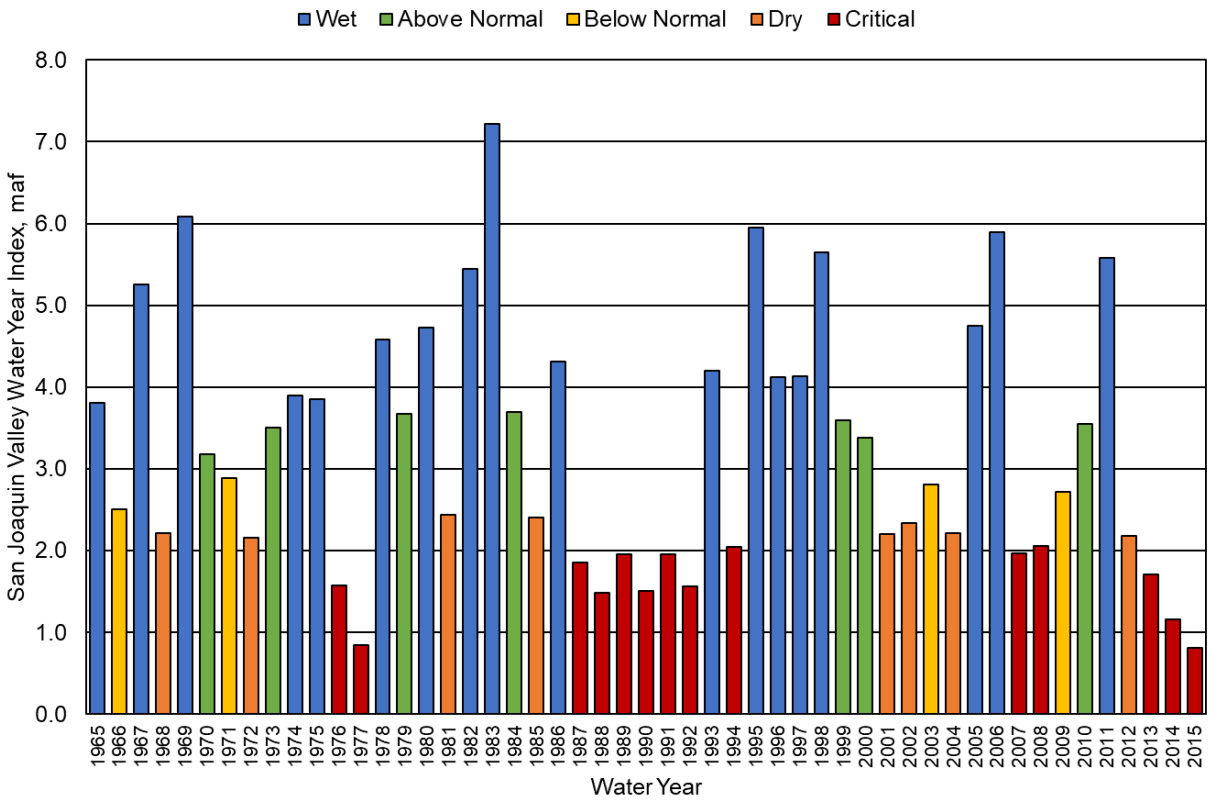

Figure 2-77. San Joaquin Valley Water Year Index, 1965-2015.

The historical, current, and projected water budget base periods were selected on a water year basis considering the following criteria: San Joaquin Valley water year type; long-term mean annual water supply; inclusion of both wet and dry periods, antecedent dry conditions, adequate data availability; and inclusion of current hydrologic, cultural, and water management conditions in the subbasin. Historical records of precipitation, unimpaired flows along the Chowchilla River, and USBR Central Valley Project (CVP) supplies served as an indicator of long-term mean water supply and potential for natural groundwater recharge during evaluation of proposed periods.

Historical Period

For the Chowchilla Subbasin GSP, a 26-year historical water budget base period of water years 1989 through 2014 was selected.

As described in the Data Collection and Analysis Technical Memorandum for Madera County (DE and LSCE, 2017), available data was sufficient to develop a historical water budget for water years 1989 through 2015. However, the 1989 through 2014 period was found to be more representative of the long-term average as compared to the 1989 through 2015 following analysis of precipitation, unimpaired flows, and CVP supplies. Due to the comparative dryness of 2015 and corresponding low water supplies that year, including 2015 in the historical period would result in drier average hydrologic conditions than the long-term average.

Precipitation records from a nearby weather station in Madera, including annual precipitation, mean annual precipitation, and cumulative departure[25] from mean annual precipitation, are provided in **Figure 2-78**. As shown, alternating wet and dry periods between the late 1920s and late 1950s were followed by a 20-year average period between the late 1950s and the late 1970s. This was followed by alternating wet and dry periods, an average period between the late 1990s and 2011, and a dry period between 2012 and 2015.

In this context, 1989 to 2014 is a relatively balanced climatic period compared to the 1929 through 2015 period with a similar number of wet and dry years and some prolonged periods of wet, dry, and average conditions, representing a reasonable base period for conducting sustainability analyses.

Historical patterns of CVP supplies along Madera Canal and unimpaired flows[26] along the Chowchilla River are shown in **Figures 2-79 and 2-80**. Given the extremely low CVP supplies and unimpaired flows in 2015, a historical base period of water years 1989 through 2014 was selected.

This period begins in 1989, a critical year preceded by two critical years, and ends in 2014, a critical year with several prior critical or dry years, so that any water unaccounted for in the unsaturated zone is minimized[27]. Lastly, the proposed historical base period ends near the present time so that this period can also be used to assess groundwater conditions as they currently exist.

Thus, the historical base period of 1989 to 2014 provides an appropriate base period for assessing historical groundwater conditions with minimal bias from long-term land use changes or imbalances due to wet or dry conditions.

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[25] Cumulative departure curves are useful to illustrate long-term hydrologic characteristics and trends during drier or wetter periods relative to the mean annual precipitation or streamflow. Downward slopes of the cumulative departure curve represent drier periods relative to the mean, while upward slopes represent wetter periods relative to the mean. A steep slope indicates a drastic change in dryness or wetness during that period, whereas a flat slope indicates average conditions during that period, regardless of whether the total cumulative departure falls above or below zero.

[26] Unimpaired flow is defined as flow "that would have occurred had water flow remained unaltered in rivers and streams instead of stored in reservoirs, imported, exported, or diverted." (DWR, 2007).

[27] Antecedent (i.e., prior or left-over year) dry conditions minimize differences in groundwater in the unsaturated zone at the beginning and at the end of a study period. Given that the volume of water in the unsaturated zone is difficult to determine, particularly at the scale of a groundwater subbasin, selection of a base period with relatively dry conditions antecedent to the beginning and end of the period of record is preferable.

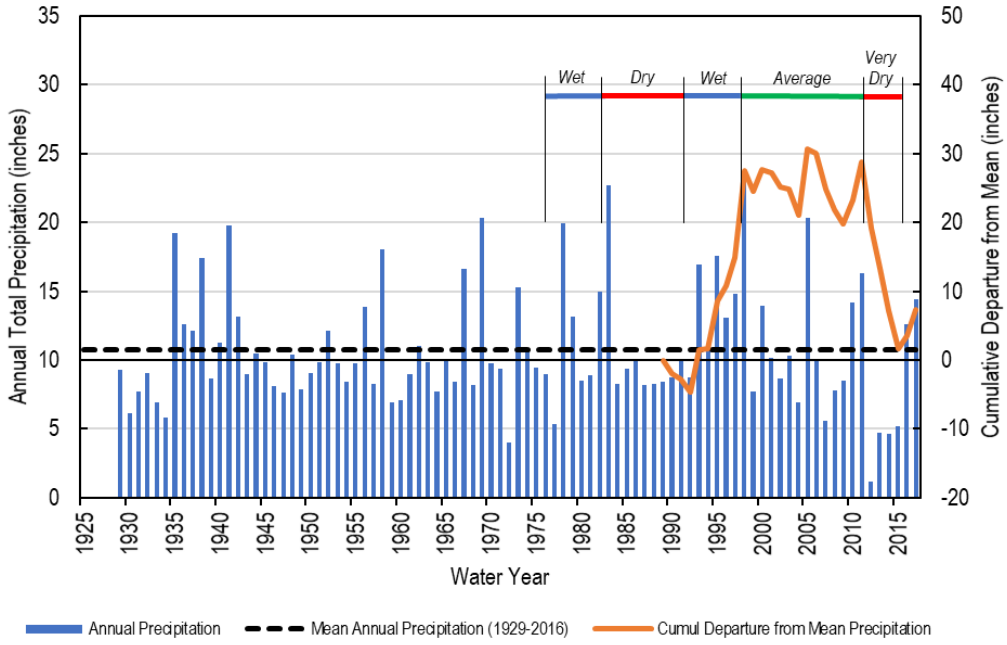

Figure 2-78. Annual Precipitation and Cumulative Departure from Mean Precipitation in Madera, CA.[28]

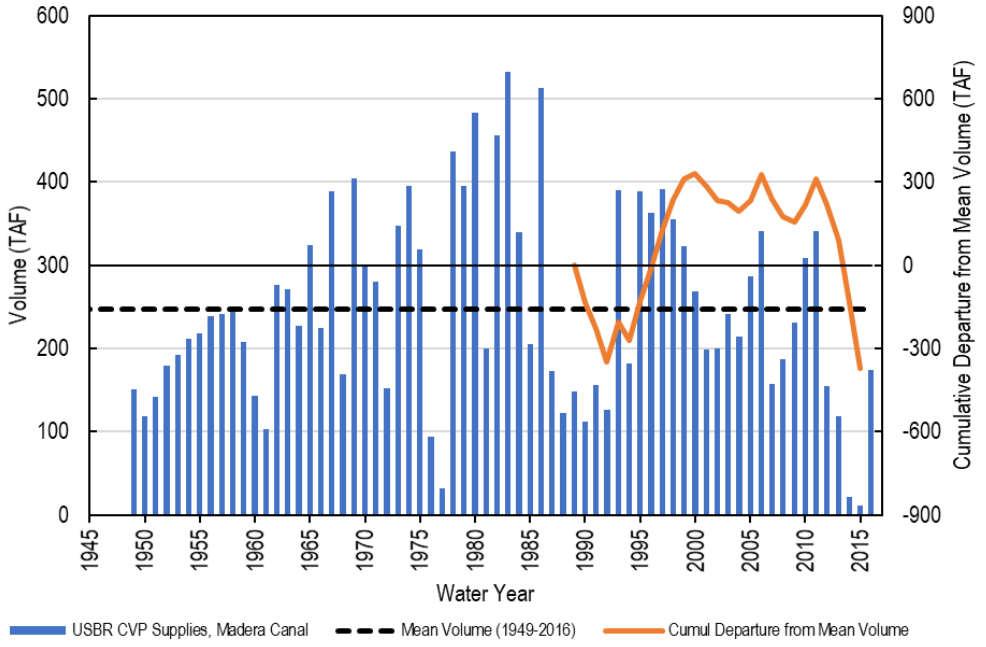

Figure 2-79. Annual CVP Supplies and Cumulative Departure from Mean CVP Supplies along Madera Canal.[29]

[28] Precipitation data from National Oceanic and Atmospheric Administration National Centers for Environmental Information (NOAA NCEI) Station 045233.

[29] Madera Canal inflows from U.S. Geologic Survey (USGS) Site 11249500 (MADERA CN A FRIANT CA).

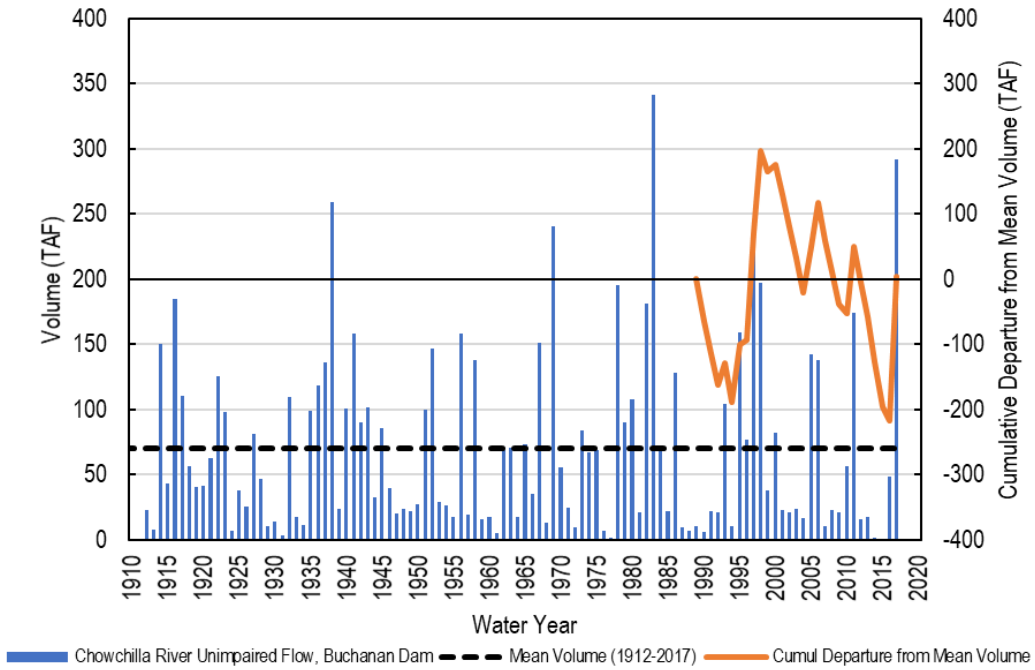

Figure 2-80. Annual Natural Flow and Cumulative Departure from Mean Natural Flow along Chowchilla River at Buchanan Dam.[30]

Current Period

For the current water budget, land use data from 2015 was used to calculate consumptive use and other root zone components in the Land Surface System water budget. This year was selected as most representative of current land use among years with available data at the initiation of SGMA data collection and analysis work in early 2017. The objective of completing a current water budget is to understand the impact of current land use on the water budget. This requires applying average historical climatic demands and water supplies to the current water budget. This was accomplished by assuming the 2015 land use occurred in each year during the 1989 through 2014 historical base period. .

Projected Period

For the projected water budgets used to evaluate projects, a 72-year projected period was chosen to provide a 22-year project implementation period from 2019-2040 and a 50-year period to evaluate sustainability from 2041-2090. Timeseries data for water years 2019-2090 were developed using:

1. Historical hydrologic data from water years 1965-2015
2. Historical water supply data from 1989-2015, with adjustment of CVP supply based on projected alteration of available Friant Releases by the San Joaquin River Restoration Program[31]

[30] Chowchilla River natural flows compiled from: U.S. Army Corps of Engineers (USACE) computed natural flows at Buchanan Lake (1912-1970); U.S. Geological Survey (USGS) Station 11259000 (CHOWCHILLA R BL BUCHANAN DAM NR RAYMOND CA) (1971-1975); USACE computed inflows to Eastman Lake (1976-2017).

[31] Adjustment is based on the San Joaquin River Restoration Settlement hydrographs (called the Kondolf Hydrographs, as provided by Daniel B. Steiner in *Effects to Water Supply and Friant Operations Resulting From Plaintiffs' Friant Release Requirements*, September 16, 2005.

3. 2017 land use adjusted for urban area projected growth from 2017-2070 (areas were held constant from 2071-2090)

The first eleven years of the projected period were simulated with hydrologic and water supply data from 2005-2015. Other years were simulated with hydrologic and water supply data matched to each year based on expected similarities in water year indices.

To evaluate sensitivity to climate change, projected water budgets were also developed using:

1. Historical hydrologic data from water years 1965-2015 adjusted by DWR-provided 2030 mean climate change factors[32]
2. Historical water supply data from 1989-2015 adjusted similarly by climate change factors, with additional adjustment of CVP supply based on projected alteration of available Friant Releases by the San Joaquin River Restoration Program
3. 2017 land use adjusted for urban area projected growth from 2017 through 2070 (areas were held constant from 2071 through 2090)

Water Budget Time Step

GSP regulations specify that sustainability analyses be conducted on at least an annual time step. However, a monthly time step is recommended to support evaluation of sustainability indicators and potential projects and management actions. These sustainability evaluations, which may include analyses involving hydrologic modeling, require data and analyses at a time step sufficient to assess seasonal conditions and trends within an annual interval in addition to long-term trends spanning years.

Water budget calculations were performed on a monthly time step, although certain water budget components identified in Section 2.2.3.3 (e.g. runoff of precipitation) were calculated on a daily basis before being summed to monthly values. For reporting purposes, water budget results are summarized by water year.

Water Budget Reporting by Analysis Period

The historical and current water budgets were completed for the SWS outside of the MCSim model. The historical budget was used to develop model inputs and to confirm and calibrate model outputs. The current budget was used to estimate the net recharge from the SWS to the GWS (referred to as the "shortage" in public presentations). This "shortage" was used to inform stakeholders regarding the subbasin status and to determine the extent of projects and/or demand management required for the subbasin to reach sustainability.

The projected water budget was completed only in the MCSim model. The projected water budget in the MCSim model was first developed without projects. Then, the projects and/or demand reduction actions developed to bring the subbasin to sustainability were added to the projected water budget to confirm that these projects and/or demand reduction actions were sufficient to reach sustainability by 2040.

2.2.3.3 Water Budget Components and Uncertainties

This section provides a summary of the data sources and calculations used to develop time series datasets for each component in the subbasin SWS water budget. The datasets include surface water inflows and outflows, meteorological data used to compute reference crop evapotranspiration (ET_{ref}), land use and

[32] Climate change factors are from the DWR CalSim II simulated volume projections from State Water Project (SWP) and CVP operations under the 2030 mean climate change scenario.

cropping patterns, crop water use (evapotranspiration, or ET), surface water diversions, applied surface water volumes, and groundwater pumping volumes. Each of these datasets is summarized below by accounting center.

Land Surface System

In the Chowchilla Subbasin, the Land Surface System encompasses all land surface area apart from rivers, streams, and canal systems. As required by the GSP regulations, the total Land Surface System is subdivided into four water budget accounting centers representing Agricultural Land (AG), Urban Land (UR) (urban, industrial, and semi-agricultural land), Native Vegetation Land (NV), and Managed Recharge Land (MR) water use sectors. In the Chowchilla Subbasin, land is not exclusively demarcated for managed recharge, so the MR water use sector represents a small portion of agricultural land receiving flood deliveries for managed recharge during non-irrigation season months.

Water budgets for each water use sector accounting center are developed with distinct, but similar, inflow and outflow components. Water budgets for each water use sector accounting center were developed uniquely for each Chowchilla Subbasin subregion, as described in **Appendix 2.F.**

Detailed Land Surface System water budget components are summarized in Table 2-12, including general components included in every water use sector water budget and specific components unique to individual water use sectors. This table also includes a brief description of the estimation methods and information sources for each component.

Meteorological Data

In the Land Surface System water budgets, meteorological data is used directly in calculating precipitation inflows and indirectly in estimating crop consumptive use, or evapotranspiration, and in simulating root zone characteristics over time.

The California Irrigation Management Information System (CIMIS) and National Oceanic and Atmospheric Administration National Centers for Environmental Information (NOAA NCEI) weather stations provide all weather data required for developing timeseries of many of the Land Surface System water budget components. CIMIS and NOAA NCEI data were obtained and quality controlled following the procedure described in **Appendix 2.F.f.** to develop daily reference crop evapotranspiration (ET_{ref}) and precipitation records for the Chowchilla Subbasin during the water budget analysis periods described in the previous section. Table 2-13 lists the stations and periods of record used for each station.

Precipitation

Precipitation inflows to each Land Surface System water use sector were calculated as the daily precipitation depth derived from weather station data applied over the total area of that water use sector within the subbasin. Daily precipitation volumes were summarized to monthly and annual volumes for water budget development. Daily precipitation depths were also provided as inputs to the root zone model to simulate precipitation availability for consumptive use, infiltration, and runoff.

Table 2-12. Land Surface System Water Budget General Detailed Components and Estimation Techniques.

Detailed Component	Category	Water Use Sector	Subregion	Data Type	Calculation/Estimation Technique	Information Sources
Precipitation	Inflow	AG, UR, NV	All	Meteorological Data	Calculated as the precipitation depth over the total land area by Water Use Sector	Madera NCEI, Fresno/Madera/Madera II CIMIS, land use data
Groundwater Extraction/Upflux	Inflow	AG, UR, NV	All	Closure Term	Calculated as the difference of total inflows and total outflows from the Water Use Sector water balance	Closure Term
Surface Water Deliveries	Inflow	AG	CWD GSA	Surface Water Data	Measured by CWD	CWD STORM delivery database, CWD monthly water supply reports
Water Rights Deliveries[1]	Inflow	AG	CWD GSA, Madera Co GSA – East, Madera Co GSA – West, SVMWC, TTWD GSA	Surface Water Data	Reported riparian/appropriative/prescriptive water rights deliveries during flood releases and/or natural flood flows; estimated from streamflow and crop ET when records not available	CWD delivery records, eWRIMS, Fresno State/Madera/Madera II CIMIS Stations, land use data
Flood Deliveries	Inflow	MR	CWD GSA	Surface Water Data	Measured by water supplier during flood releases outside the irrigation season	CWD STORM delivery database
Evapotranspiration (ET) of Applied Water	Outflow	AG, UR	All	Meteorological Data, Crop Water Use (Root Zone Model)	Estimated by IDC root zone water budget using CIMIS reference ET, precipitation, estimated crop coefficients from energy balance (SEBAL) analysis, cropped area by crop type	Fresno/Madera/Madera II CIMIS, land use data
Evapotranspiration (ET) of Precipitation	Outflow	AG, UR, NV	All	Meteorological Data, Crop Water Use (Root Zone Model)	Estimated by IDC root zone water budget using CIMIS reference ET, CIMIS precipitation, estimated crop coefficients from energy balance (SEBAL) analysis, cropped area by crop type	Fresno/Madera/Madera II CIMIS, land use data
Infiltration of Applied Water	Outflow	AG, UR	All	Root Zone Model	Estimated by IDC root zone water budget using CIMIS precipitation, NRCS soils characteristics, cropped area by crop type	Fresno/Madera/Madera II CIMIS, land use data, NRCS soil survey
Infiltration of Precipitation	Outflow	AG, UR, NV	All	Root Zone Model	Estimated by IDC root zone water budget using CIMIS precipitation, NRCS soils characteristics, cropped area by crop type	Fresno/Madera/Madera II CIMIS, land use data, NRCS soil survey
Runoff of Applied Water	Outflow	AG, UR	All	Root Zone Model	Estimated as negligible in the Chowchilla Subbasin	Fresno/Madera/Madera II CIMIS, land use data, NRCS soil survey
Runoff of Precipitation	Outflow	AG, UR, NV	All	Root Zone Model	Estimated by IDC root zone water budget using CIMIS precipitation, NRCS soils characteristics, cropped area by crop type	Fresno/Madera/Madera II CIMIS, land use data, NRCS soil survey
Change in SWS Storage	Outflow	AG, UR, NV	All	Root Zone Model	Estimated by IDC root zone water budget as net change in root zone water due to consumption or infiltration.	Fresno/Madera/Madera II CIMIS, land use data, NRCS soil survey

[1] Includes riparian, appropriative, and prescriptive water rights deliveries during flood releases and/or natural flood flows along subbasin waterways.

Table 2-13. Chowchilla Subbasin Weather Data Time Series Summary.

Weather Station	Station Type	Start Date	End Date	Comment
Fresno State	CIMIS	Oct. 2, 1988	May 12, 1998	Used before Madera CIMIS station was installed.
Madera	CIMIS	May 13, 1998	Apr. 2, 2013	Moved eastward 2 miles in 2013 and renamed "Madera II."
Madera II	CIMIS	Apr. 3, 2013	Dec. 31, 2015	
Madera	NOAA NCEI	Jan. 1, 1928	Dec. 31, 2017	Used for developing ET_{ref} timeseries for projected water budget period before CIMIS station data was available.

Reference Evapotranspiration

Daily reference crop evapotranspiration (ET_{ref}) was determined by following the scientifically sound and widely accepted standardized Penman-Monteith (PM) method, as described by the ASCE Task Committee Report on the Standardized Reference Evapotranspiration Equation (ASCE-EWRI, 2005). The Task Committee Report standardizes the ASCE PM method for application to a full-cover alfalfa reference (ET_r) and to a clipped cool season grass reference (ET_o). The clipped cool season grass reference is widely used throughout California and was selected for this application. Daily ET_o values were provided as inputs to the root zone model for simulating crop consumptive use requirements.

Root Zone Model

To support water budget development for each Land Surface System water use sector, the IDC daily root zone water budget model was used to develop an accurate and consistent calculation of historical crop ET (ET_c) and other water budget components in the root zone. A daily root zone water budget is a generally accepted and widely used method to estimate effective rainfall (ASCE, 2016 and ASABE, 2007).

Flows through the root zone and plant surfaces of irrigated lands were modeled using a stand-alone tool, that can also be linked to the Integrated Water Flow Model (IWFM), known as the IWFM Demand Calculator (IDC). The physically-based IDC version 2015.0.0036 (DWR, 2015) is developed and maintained by the California Department of Water Resources (DWR). For developing SWS water budgets, a daily IDC was used as a stand-alone root zone model independent of IWFM. For developing the integrated SWS and GWS water budgets in the MCSim model, this daily IDC application was converted to a monthly application, recalibrated to equal monthly flows by component in the SWS water budgets, and then integrated with the Chowchilla Subbasin C2VSIM application. The IDC application thus served as the foundation for coupling the SWS water budget to the groundwater model used in GSP development.

IDC was used to develop time series estimates for the following water budget components:

- ET of applied water
- ET of precipitation
- Infiltration of applied water
- Infiltration of precipitation
- Uncollected surface runoff of applied water (estimated as negligible in the Chowchilla Subbasin)
- Uncollected surface runoff of precipitation
- Change in root zone storage

Details regarding the improved crop coefficients used by IDC for estimating ET are described in the Crop Water Use section below. Additional details regarding development of the full IDC root zone water budget, including major inputs, are provided in **Appendix 2.F.g.**

Land Use Data

Accurate land use areas are required for determining crop consumptive use (ET) and for developing an accurate root zone model. Thus, the objective of the land use analysis was to develop Madera and Merced County-wide annual spatial crop acreage datasets from which annual crop areas in the Chowchilla Subbasin and each subregion were derived. The procedure used for land use data development is described in **Appendix 2.A.**

Land use estimates for 1989 through 2015 corresponding to water use sectors (as defined by the GSP Regulations) are summarized above in Section 2.1 Description of the Plan Area (**Figure 2-2** and **Table 2-1**). The Urban land use category includes urban, industrial, and semi-agricultural lands. Industrial land use in the Subbasin covers only a small area, so these lands were included in the Urban water use sector. Between 1989 and 2015, the expansion of agricultural and urban lands has coincided with a reduction in native vegetation across the subbasin.

Agricultural land uses are also detailed in Section 2.1 above (**Figure 2-3** and **Table 2-2**). Across the subbasin, agriculture has historically been dominated by orchard crops, mixed pasture, alfalfa, and corn. In particular, orchard acreage, which includes primarily almonds and pistachios, has more than tripled since 1989. As these crops have higher consumptive water use requirements than many other commodities grown in the subbasin, agricultural water demand has increased in recent years.

Detailed land use summaries are provided for each subregion in **Appendix 2.F.**

Crop Water Use

The daily IDC root zone water budget application described above was used to develop an accurate and consistent calculation of historical crop ET (ET_c) using the widely accepted reference ET-crop coefficient method (ASCE, 2016). Crop coefficients for major crops, native vegetation, and urban areas were derived from actual ET (ET_a) estimated by the Surface Energy Balance Algorithm for Land (SEBAL) for 2009. Remotely sensed energy balance ET results account for soil salinity, deficit irrigation, disease, poor plant stands, and other stress factors that affect crop ET. Studies by Bastiaanssen, et al. (2005), Allen, et al. (2007 and 2011), Thoreson, et al. (2009) and others have found that when performed by an expert analyst, seasonal ET_a estimates produced by SEBAL are within plus or minus five percent of actual crop ET. For crops grown in the Chowchilla Subbasin, annual historic ET_c was computed by the IDC application using the quality controlled CIMIS ET_o and these local, remote sensing derived crop coefficients. The aforementioned IDC root zone model parsed these ET_c estimates into the ET of applied water and ET of precipitation estimates used in the Chowchilla Subbasin water budgets.

Surface Water Data

In the Land Surface System, surface water inflows primarily include surface water deliveries and riparian, appropriative, or prescriptive water rights deliveries to agricultural lands.

Surface water deliveries are reported by CWD in its monthly water summary records for 1981-2018 and in its STORM deliveries database for 2000-2018. The STORM delivery database is the water ordering and delivery management software used by Chowchilla Water District which is used to track all delivery events to turnouts within the district conveyance system.

Water rights deliveries – including riparian, appropriative, and prescriptive water rights deliveries – are comprised of water that is diverted directly to riparian parcels from adjacent waterways. Deliveries along the Chowchilla River system are reported by monthly or annual district or user records and by the State Water Resources Control Board's Electronic Water Rights Information Management System (eWRIMS). Deliveries along Fresno River are also reported by eWRIMS.

When monthly records are unavailable, annual records are distributed to monthly values in proportion to the monthly pattern of ET of applied water provided by the root zone model during the irrigation season. Missing records were estimated based on the quality control procedures described following the component data source descriptions.

Groundwater Extraction

Groundwater extraction was calculated as the Land Surface System water budget "closure" term – the difference between all other estimated or measured inflows and outflows from each water use sector. Groundwater extraction was selected as the closure because groundwater pumping data is generally unavailable across the subbasin. Also, groundwater extraction serves as a relatively large inflow to the Land Surface System, resulting in lower relative uncertainty when calculated as a closure term compared to smaller flow paths following the procedure outlined by Clemmens and Burt (1997).

Rivers and Streams System

At the subbasin level, the Rivers and Streams System includes all inflows and outflows from natural waterways that cross a portion of the subbasin, including intermittent and ephemeral streams. The San Joaquin River, a perennial waterway flowing along the subbasin boundary, was not explicitly included in the water budgets[33], although estimates of boundary seepage were included in the subbasin and subregion estimates of net recharge from the SWS.

Detailed Rivers and Streams System water budget components are summarized for the entire Chowchilla Subbasin in Table 2-14 along with a brief description of the estimation technique and information sources for each. Additional detailed components unique to individual subregion water balances are summarized in **Appendix 2.F.**

Surface Water Data

Surface water data includes primarily surface water inflows and surface water outflows for each of the major waterways within the Chowchilla Subbasin. A surface hydrology map summarizing the Chowchilla Subbasin inflows, outflows, and available data sources is provided in **Figure 2-81**. Surface water diverted under surface water rights is included in the associated agencies' GSA water budgets found in **Appendix 2.F.**

Inflow and outflow data sources and estimation procedures are described for each waterway below.

[33] The San Joaquin River does not cross the lateral boundaries of the Chowchilla Subbasin, as defined above, and San Joaquin River flows are thus not considered surface water inflows to the subbasin within this water budget. A portion of infiltration of surface water from the San Joaquin River is considered to cross the subbasin boundaries into the groundwater system and is included in the calculation of the subbasin estimates of overdraft and net recharge from SWS.

Table 2-14. Subbasin Rivers and Streams System Water Budget Detailed Components and Estimation Techniques.

Detailed Component	Category	Data Type	Waterway	Calculation/Estimation Technique	Information Sources
Surface Inflows	Inflow	Surface Water Data	Chowchilla Bypass	Calculated from SLDMWA CBP station measurements adjusted downstream to the subbasin boundary for estimated seepage and evaporation	SLDMWA CBP station, NRCS soil survey, Fresno State/Madera/Madera II CIMIS Stations
			Chowchilla River	Reported Buchanan Dam flood releases	USACE records
			Dutchman Creek	Estimated as equal to Received Legrand water reported by CWD	CWD monthly water supply reports
			Fresno River	Calculated from MID recorder measurements (downstream of convergence with Dry Creek) adjusted downstream to the subbasin boundary for estimated seepage and evaporation	MID Recorder 4, NRCS soil survey, Fresno State/Madera/Madera II CIMIS Stations
			Madera Canal	Reported Madera Canal flood releases	USBR records for Madera Canal Miles 33.6 and 35.6
Spillage	Inflow	Surface Water Data	Berenda Slough, Ash Slough, Chowchilla River	Reported by CWD monthly records; estimated as average monthly values of available records.	CWD SCADA records
Runoff of Precipitation	Inflow	Meteorological Data	All	Calculated in IDC root zone water budget as daily rainfall runoff using SCS curve number analysis.	Root zone simulation model, NRCS soils characteristics, CIMIS precipitation data
Evaporation	Outflow	Meteorological Data	All	Estimated from reference ET, evaporation coefficient, and estimated water surface area.	Fresno State/Madera/Madera II CIMIS Stations
Infiltration of Surface Water	Outflow	Soils Data	All	Estimated from wetted area and estimated seepage coefficient by soil type	NRCS soil survey, GIS waterway attributes analysis
Flood Diversions	Outflow	Surface Water Data	Chowchilla River, Ash Slough, Berenda Slough	Calculated from CWD delivery records during Buchanan Dam and Madera Canal flood releases	CWD STORM delivery database, CWD monthly water supply reports, USACE records, USBR records
Water Rights Deliveries[1]	Outflow	Surface Water Data	All	Reported riparian/appropriative/prescriptive water rights deliveries during flood releases and/or natural flood flows; estimated from streamflow and crop ET when records not available	CWD delivery records, eWRIMS, Fresno State/Madera/Madera II CIMIS Stations, land use data
Surface Outflows	Outflow	Closure Term	All	Calculated as the difference of total inflows and total outflows from the Water Use Sector water balance	Closure Term

[1] Includes riparian, appropriative, and prescriptive water rights deliveries during flood releases and/or natural flood flows along subbasin waterways.

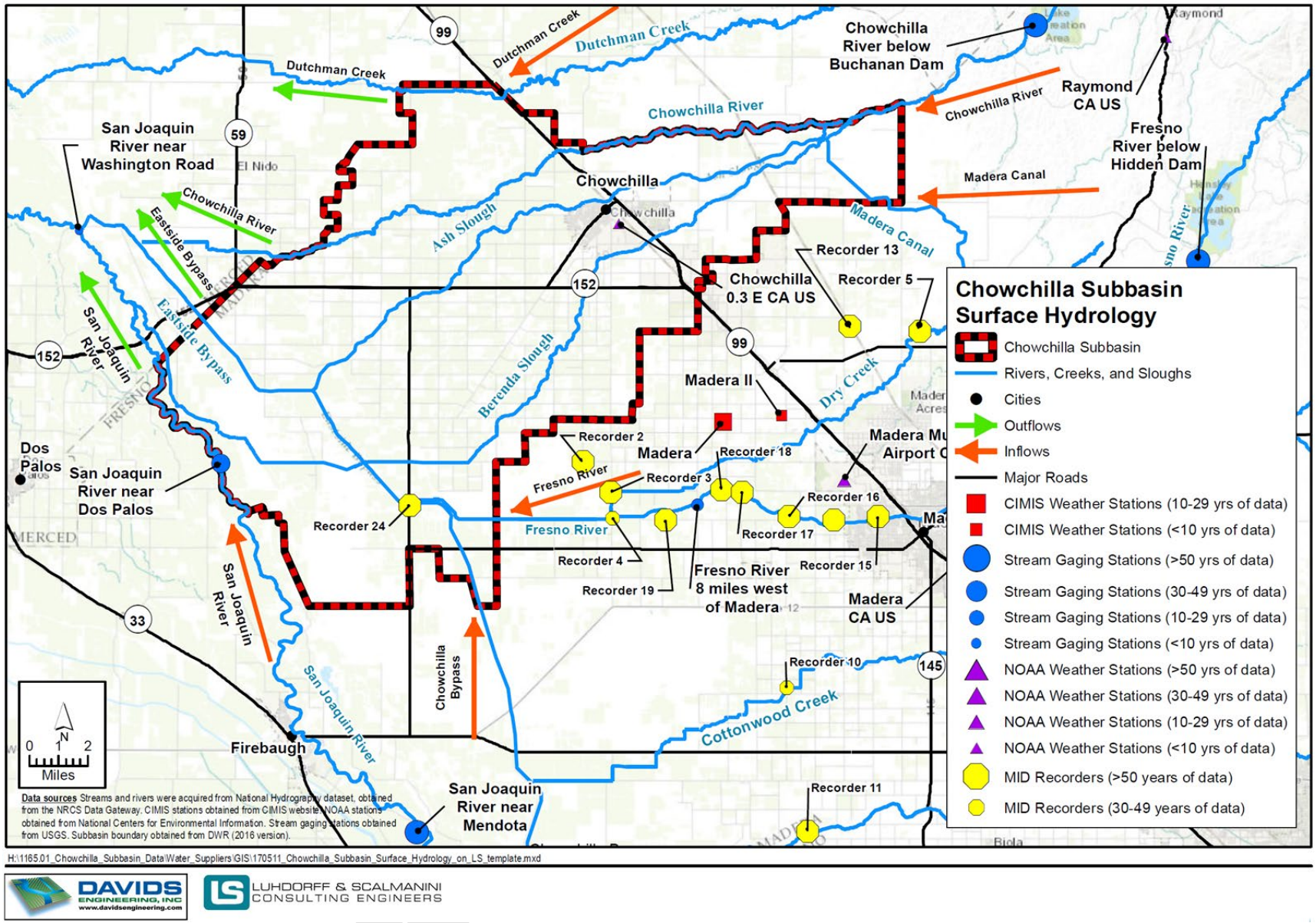

Figure 2-81. Chowchilla Subbasin Inflows and Outflows.

Chowchilla Bypass

The Chowchilla Bypass is located in the western part of the Chowchilla Subbasin, serving as a flood control channel operated via gates along the San Joaquin River during times when San Joaquin River flows would exceed the river's downstream capacity. Inflow data for Chowchilla Bypass at its head below the control structure were assembled using a combination of DWR's Water Data Library (WDL) records (1982-1991) and California Data Exchange Center (CDEC) records (1997-2017). Daily average flow values were summarized as monthly and annual volumes. Missing records were estimated based on the quality control procedures described following the component data source descriptions.

Subbasin inflows were estimated by adjusting the CDEC and WDL records for estimated seepage and evaporation from the measurement point to the Chowchilla Subbasin boundary inflow point. Downstream of where the Fresno River enters the Chowchilla Bypass, the waterway is known as the Eastside Bypass.

Chowchilla River

Inflow data for Chowchilla River were assembled from daily USACE records of irrigation and flood releases from Eastman Lake at Buchanan Dam upstream of the northeastern subbasin boundary. Daily records of irrigation releases and flood releases in cubic feet per second (cfs) were available for 1981-2017.

During irrigation releases, the Chowchilla River is considered part of the CWD conveyance system, while at other times the Chowchilla River is considered a natural waterway. Thus, irrigation releases are accounted as inflows to the CWD GSA Canal System accounting center, and flood releases are accounted as inflows to the subbasin Rivers and Streams System.

Subbasin inflows along Chowchilla River to the Rivers and Streams System were estimated by adjusting the associated daily data for estimated seepage and evaporation along the portion of the river downstream of Buchanan Dam and upstream of the subbasin boundary.

Fresno River

Inflow data for the Fresno River were assembled from records provided by MID from its extensive network of recorders, which measure key inflows and outflows from the MID conveyance system and waterways within the Madera Subbasin. Fresno River inflows to Chowchilla Subbasin were derived from "Recorder 4: Fresno River Rd. 16" records available for years 1951-2018. This recorder measures flow in the Fresno River where it exits the MID service area, downstream of the location where Dry Creek joins the Fresno River and approximately 4 miles upstream of the subbasin boundary. Thus, Dry Creek flows are accounted as part of the Fresno River inflow.

Surface inflows were estimated from these records with adjustment for estimated seepage and evaporation from the portion of the river downstream of the Recorder 4 measurement site and upstream of the Chowchilla Subbasin boundary.

Madera Canal

The Madera Canal enters the Chowchilla Subbasin along its eastern boundary and runs northwesterly through Madera Co GSA, terminating near the inflows to Ash Slough, Berenda Slough, and the lower Chowchilla River. Located along the canal are two delivery points to CWD at miles 33.6 and 35.6.

Surface inflows to Chowchilla Subbasin were assembled from USBR CVP recorded irrigation deliveries and flood deliveries at Madera Canal Miles 33.6 and 35.6. Daily records of irrigation deliveries and flood deliveries in cubic feet per second (cfs) were provided by CWD for 1978-2018.

During irrigation releases, Madera Canal inflows are considered part of the CWD conveyance system. During flood releases, water discharged from Madera Canal Miles 33.6 and 35.6 are considered to enter natural waterways in the subbasin. Thus, irrigation releases are accounted as inflows to the CWD GSA Canal System accounting center, and flood releases are accounted as inflows to the subbasin Rivers and Streams System.

Madera Canal inflows to the subbasin Rivers and Streams system were estimated from flood release records by adding an adjustment for estimated seepage and evaporation that occurred in the portion of the Madera Canal between the Mile 33.6 and Mile 35.6 measurement points and the Chowchilla Subbasin boundary.

Water Rights Deliveries

Water rights deliveries from the Rivers and Streams System include riparian, appropriative, and prescriptive water rights deliveries to riparian parcels during flood releases and/or natural flood flows along subbasin waterways. Water rights deliveries data sources are described above in the Land Surface System components descriptions.

Flood Diversions

While irrigation releases from Buchanan Dam and Madera Canal serve as the major source of water delivered by CWD for irrigation, a portion of flood releases is also diverted from waterways within CWD for irrigation. These flood diversions were calculated as the volume of water required to supply reported CWD deliveries during available flood releases from Buchanan Dam and Madera Canal.

Surface water deliveries are reported by CWD in its monthly water summary records for 1981-2018 and in its STORM deliveries database for 2000-2018, as described in the Land Surface System components descriptions above. Daily records of flood releases are available for Buchanan Dam during 1981-2017 and for Madera Canal during 1978-2018.

Spillage from CWD

Excess flows in the CWD conveyance system are released at spill sites into Berenda Slough, Ash Slough, and Chowchilla River. Monthly spillage volumes were assembled from CWD SCADA data available between 1995-2017. Missing records were estimated based on the quality control procedures described following the component data source descriptions.

San Joaquin River

The San Joaquin River flows along the western subbasin boundary but does not cross the lateral boundaries of the Chowchilla Subbasin. Thus, flow along the San Joaquin River was not explicitly included in surface water inflows to the subbasin water budget. Only a portion of infiltration of surface water from the San Joaquin River is considered to cross the subbasin boundaries into the groundwater system and is included in the subbasin estimates of overdraft and net recharge from SWS.

To develop these seepage estimates, measured inflow data were assembled for 1980-2013 from WDL records of USGS site 11256000 (“San Joaquin River near Dos Palos”), located near the town of Dos Palos in Merced County. Seepage was calculated based on these available inflows and the waterway attributes of San Joaquin River reaches along the subbasin boundary, following the process described below. These

seepage estimates were found to be consistent with San Joaquin River Restoration Study values.[34] For the section of the San Joaquin River bordering the Chowchilla Subbasin, half of the total estimated seepage was assigned to the subbasin.

Meteorological Data

As in the Land Surface System water budgets, meteorological data from CIMIS and NOAA NCEI weather stations was used in calculating weather-related inflows and outflows to the Rivers and Streams system. These components are summarized below.

Evaporation

Evaporation was calculated from quality controlled daily ET_o records obtained from the weather stations identified previously in Table 2-13 multiplied by the waterway surface area and a free water surface evaporation coefficient of 1.05 from UCCE (1989) and ASCE (2016). When, based on streamflow records and related water balances, water was estimated to be in the waterway reach, evaporation was estimated. Evaporation was calculated on a reach-by-reach basis along each waterway and summed for all waterway reaches within the subbasin and for each subregion.

Runoff of Precipitation

Runoff of precipitation was calculated by the IDC root zone water budget as the component of total uncollected runoff attributed to precipitation. The IDC application uses a modified version of the SCS curve number (SCS-CN) method to estimate runoff of precipitation. Curve numbers are used as described in the National Engineering Handbook Part 630[35] (USDA, 2004, 2007) based on land use or cover type, surface treatments (e.g. straight rows, bare soil), hydrologic condition, and hydrologic soil group. Additional details regarding IDC root zone water budget development are provided in **Appendix 2.F.g.**

Soils Data

As in the Land Surface System water budget, soils data from SSURGO was used in calculating infiltration from the Rivers and Streams System.

Infiltration of Surface Water

Infiltration of surface water (seepage) was calculated based on the wetted area and seepage characteristics of each waterway reach, as determined from a detailed waterway analysis to identify reach dimensions, soil types, soil distribution, and associated seepage characteristics based on NRCS soils data. Seepage was first calculated on a reach-by-reach basis along each waterway and summed for all reaches in each subregion. Total subbasin seepage was calculated as the sum of seepage in all subregions.

Canal System

In the Chowchilla Subbasin, the Canal System includes all canals in the CWD conveyance system as well as natural waterways used to convey irrigation releases to CWD from Buchanan Dam and Chowchilla River. Other than the TTWD GSA, which uses pipelines to convey water to different areas, all other subregions do not contain subregion-wide irrigation water distribution systems.

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[34] Friant Water Users Authority Natural Resources Defense Council. 2002. *San Joaquin River Restoration Study Background Report,* Chapter 2: Surface Water Hydrology.

[35] Table 1. Runoff curve numbers for agricultural lands.

Detailed Canal System water budget components are summarized in Table 2-15 for CWD GSA. This table also includes brief descriptions of the estimation techniques and information sources for each component. Details for each component are briefly summarized below.

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Table 2-15. Chowchilla Water District Canal System Water Budget General Detailed Components and Estimation Techniques.

Detailed Component	Category	Data Type	Calculation/Estimation Technique	Information Sources
Irrigation Releases from Buchanan Dam	Inflow	Surface Water Data	Reported Buchanan Dam irrigation releases	USACE records
Irrigation Releases from Madera Canal	Inflow	Surface Water Data	Reported Madera Canal irrigation releases	USBR records for Madera Canal Miles 33.6 and 35.6
Flood Diversions to CWD	Inflow	Surface Water Data	Calculated from CWD delivery records during combined Buchanan Dam and Madera Canal flood releases	CWD STORM delivery database, CWD monthly water supply reports, USACE records, USBR records
Infiltration of Surface Water (Seepage)	Outflow	Closure Term	Calculated as the difference of total inflows and total outflows from the Canal System water budget	Closure Term
Evaporation	Outflow	Meteorological Data	Estimated from reference ET, evaporation coefficient, and estimated canal surface area.	Fresno State/Madera/Madera II CIMIS Stations
Spillage	Outflow	Surface Water Data	Reported by CWD monthly records; estimated as average monthly values of available records.	CWD SCADA records
Surface Water Deliveries	Outflow	Surface Water Data	Measured by CWD	CWD STORM delivery database, CWD monthly water supply reports
Water Rights Deliveries during Irrigation Releases	Outflow	Surface Water Data	Reported riparian/appropriative/prescriptive water rights deliveries to growers in TTWD, SVMWC and Madera Co GSA – East and Madera Co GSA – West during irrigation releases	CWD delivery records

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Surface Water Data

Surface water data includes diversions of irrigation releases and flood releases from various sources and surface water outflows from canals, including spillage and deliveries. Inflow and outflow data sources and estimation procedures are briefly described below.

Irrigation Releases to CWD

Diversions to the CWD distribution system include irrigation releases from Buchanan Dam along the Chowchilla River and irrigation releases from Madera Canal at Mile 33.6 and Mile 35.6. Irrigation releases from both sources converge and are distributed downstream along Chowchilla River, Berenda Slough, and part of Ash Slough. These waterways serve as an integral part of the CWD conveyance system as they are used to distribute water to CWD canals. For water budget accounting, diversions to CWD include all irrigation releases from Buchanan Dam and Madera Canal at the measurement points described for each waterway in the Rivers and Streams System component descriptions above. Daily records of irrigation releases were available for Buchanan Dam during 1981-2017 and for Madera Canal Mile 33.6 and 35.6 during 1978-2018.

Flood Diversions to CWD

Flood diversions to CWD are described in the Rivers and Streams System component descriptions above

Spillage

Spillage from the CWD conveyance system is described in the Rivers and Streams System component descriptions above.

Surface Water Deliveries

Surface water deliveries from the CWD conveyance system are described in the Land Surface System component descriptions above.

Water Rights Deliveries during Irrigation Releases

Water rights deliveries include all riparian, appropriative, and prescriptive water rights deliveries to riparian parcels. These deliveries occur during both the irrigation releases and flood releases and/or natural flood flows along subbasin waterways. When appropriative and prescriptive water rights deliveries coincide with irrigation releases, they are accounted for within the CWD Canal System water budget. Data sources for all Water rights deliveries are described above in the Land Surface System components descriptions.

Meteorological Data

As in the Land Surface System and Rivers and Stream System water budgets, meteorological data from CIMIS and NOAA NCEI weather stations was used in calculating evaporation from the CWD Canal System.

Evaporation

Evaporation was calculated from quality controlled daily ET_o records obtained from the weather stations identified in Table 2-13 multiplied by the free water surface evaporation coefficient of 1.05 from UCCE (1989) and ASCE (2016) and the total surface area of CWD canals and waterways used in conveying irrigation releases.

Soils Data

As in the Land Surface System and Rivers and Streams System water budgets, soils data from SSURGO was used in calculating infiltration from the Canal System.

Infiltration of Surface Water

Similar to the Rivers and Streams System water budgets, infiltration of surface water (seepage) can be calculated based on the wetted area and seepage characteristics of each subregion's conveyance system. However, due to the relative uncertainty of canal wetted area characteristics and soil conditions combined with higher certainty of diversions to the canal system and deliveries from the canal system, seepage was instead calculated as the Canal System closure term. During water rights deliveries to SVMWC, some seepage along Chowchilla River is allocated to SVMWC upstream of their service area.[36]

Inflow and Outflow Data Quality Control

Quality control procedures were applied to identify data gaps and data values outside of plausible ranges. Data gaps were filled with monthly estimates based on available daily, monthly, or annual data and historical average monthly patterns of streamflow and crop water demand by hydrologic water year type according to the San Joaquin Valley WYI described in Section 2.2.3.1 above.

Surface Water Data

For months with missing surface water data, the monthly volume was estimated as the average volume of that same month calculated across all years of the same water year type. When the number of years with available data for developing water year type monthly averages was less than five, the five water year types were grouped into simply "Wet" and "Dry" years. "Wet" years were defined as wet or above normal, and the "Dry" years were defined as below normal, dry, or critical.

For years with annual stream inflow/outflow data, monthly volumes were estimated as a portion of the measured annual volume distributed by the average monthly pattern of flow observed during water years of the same type.

For years with annual deliveries or diversions data, monthly volumes were estimated as a portion of the measured annual volume distributed by the average monthly pattern of crop water demand as calculated by the IDC root zone water budget for lands receiving those deliveries.

Meteorological Data, Soils Data, and Root Zone Water Budget Inputs

Quality control procedures applied to meteorological data, soils data, and other data prepared for IDC root zone water budget development are described in **Appendix 2.F.f.**

Uncertainties in Water Budget Components

Uncertainties associated with each water budget component have been estimated as described by Clemmens and Burt (1997) as follows:

1. The uncertainty in each independently estimated water budget component is estimated as a percentage representing approximately a 95% confidence interval. These uncertainties are estimated based on professional judgement.

[36] SVMWC and CWD are still negotiating the allocation of infiltration of surface water in reach C-2 of the Chowchilla River as of July 2019. Although infiltration of surface water may change in the CWD and SVMWC water budgets as these negotiations proceed, the net effect of infiltration at the subbasin level will remain the same.

2. Assuming random, normally-distributed error, the standard deviation is estimated as the confidence interval divided by 2 for each independently estimated component.
3. The variance is estimated for each component as the square of the standard deviation for each independently estimated component.
4. The variance in the closure term is estimated as the sum of variances for each independently estimated component.
5. The standard deviation in the closure term is estimated as the square root of the sum of variances.
6. The 95% confidence interval in the closure term is estimated as twice the estimated standard deviation.

Estimated uncertainties were calculated following the above procedure for the subbasin water budgets as well as all subregion water budgets. Table 2-16 provides a summary of typical uncertainty values associated with major SWS inflows and outflows. These uncertainties provide a basis for evaluating confidence in water budget results and help to identify data needs that may be addressed during GSP implementation.

2.2.3.4 Historical Water Budget Analysis

The conceptual water budget model for the Chowchilla Subbasin and the subregions identified in Table 2-8 was previously presented and discussed in Section 2.2.3.1. It is structured to include separate but related water budgets for the SWS and for the underlying GWS.

This section presents SWS water budget components within the Chowchilla Subbasin as per GSP regulations for the historical base period (1989 through 2014) and 2015. These are followed by a summary of the water budget results by accounting center. The historical water budgets for each subregion are presented and discussed in **Appendices 2.F.a.** through **2.F.e.** along with summaries of subregion land use data relevant to water budget development.

Surface Water Inflows

Surface water inflows include surface water flowing into the basin across the basin boundary. Per the Regulations, surface inflows must be reported by water source type. According to the Regulations:

> *"Water source type" represents the source from which water is derived to meet the applied beneficial uses, including groundwater, recycled water, reused water, and surface water sources identified as Central Valley Project, the State Water Project, the Colorado River Project, local supplies, and local imported supplies.*

Additionally, runoff of precipitation from upgradient areas adjacent to the subregion represents a potential source of surface water inflow.

Local Supplies

Local supply inflows to the Chowchilla Subbasin include surface water inflows along Chowchilla Bypass; pre-1914, riparian, and prescriptive water rights on the Chowchilla River; and water received from Legrand Dam.

Local Imported Supplies

Chowchilla Subbasin does not receive local imported supplies.

CVP Supplies

Agencies with CVP contracts can receive CVP supplies in the Chowchilla Subbasin. These CVP supplies include Buchanan Dam irrigation and flood releases received via Chowchilla River and Millerton Reservoir

irrigation and flood releases received via Madera Canal. Millerton Reservoir releases are diverted to Chowchilla Water District from Madera Canal Mile 33.6 and Mile 35.6. Irrigation releases from both sources are accounted as inflows to the CWD GSA water budget Canal System, while flood releases are accounted as inflows to the subbasin Rivers and Stream System.

Table 2-16. Estimated Uncertainty of Subbasin Water Budget Components.

Flowpath Direction (relative to SWS)	Water Budget Component	Data Source	Estimated Uncertainty (%)	Source
Inflows	Surface Water Inflows	Measurement	5%	Estimated streamflow measurement accuracy
	Deliveries	Measurement	6%	Estimated delivery measurement accuracy (accuracy required for Reclamation contractors)
	Water Rights Deliveries	Measurement	10%	Estimated measurement accuracy.
	Precipitation	Calculation	30%	Clemmens, A.J. and C.M. Burt, 1997.
	Groundwater Extraction	Calculation	20%	Typical uncertainty when calculated for Land Surface System water balance closure;
Outflows	Surface Water Outflows	Measurement	15%	Estimated streamflow measurement accuracy with adjustment for infiltration and evaporation.
	Evaporation	Calculation	20%	Estimated accuracy of calculation based on CIMIS reference ET and free water surface evaporation coefficient.
	ET of Applied Water	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, estimated crop coefficients from SEBAL energy balance, and annual land use.
	ET of Precipitation	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, precipitation, estimated crop coefficients from SEBAL energy balance, and annual land use.
	Infiltration of Applied Water	Calculation	20%	Estimated accuracy of daily IDC root zone water budget based on annual land use and NRCS soils characteristics.
	Infiltration of Precipitation	Calculation	20%	Estimated accuracy of daily IDC root zone water budget based on annual land use, NRCS soils characteristics, and CIMIS precipitation.
	Infiltration of Surface Water	Calculation	15%	Estimated accuracy of daily seepage calculation using NRCS soils characteristics and measured streamflow data compared to field measurements.
	Change in SWS Storage	Calculation	50%	Professional Judgment.
Net Recharge from SWS		Calculation	20%	Estimated water budget accuracy; typical value calculated for subbasin-level net recharge from SWS.

Recycling and Reuse

Recycling and reuse are not a significant source of supply within Chowchilla Subbasin.

Other Surface Inflows

For the water budgets presented herein, precipitation runoff from outside the subbasin is considered relatively minimal and is expected to enter the subbasin along the waterways above as natural flows following relatively large storm events and are accounted as part of local supplies. Precipitation runoff from lands inside the subbasin is internal to the surface water system and is thus not considered as surface inflows to the subbasin boundary.

Summary of Surface Inflows

Surface water inflows by water year type are summarized in **Figure 2-82** and **Table 2-17**. During the study period, surface water supplies vary greatly with water year type, with substantial local supply inflows during wet years that are reduced in above normal years and remain relatively constant during all other year types. CVP supplies remain more consistent between years. Total surface water inflows range from under 70 taf during average critical years to over 900 taf during average wet years.

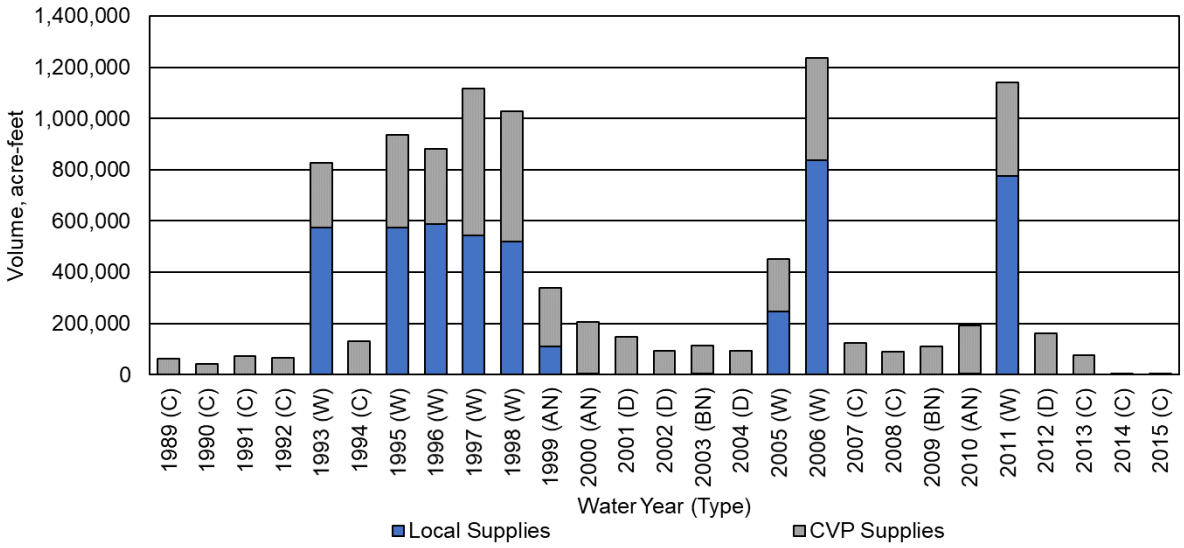

Figure 2-82. Chowchilla Subbasin Surface Water Inflows by Water Source Type.

Table 2-17. Chowchilla Subbasin Surface Water Inflows by Water Source Type (Acre-Feet) (23 CCR §354.18(b)(1)).

Water year (Type)	Local Supplies			CVP Supplies						Surface Water Inflows Total
	Chowchilla Bypass	Received LeGrand	Water Rights Deliveries*	Irrigation Releases from Buchanan Dam	Flood Releases from Buchanan Dam	Irrigation Releases from Madera Canal	Flood Releases from Madera Canal	Fresno River	Deliveries to CWD Growers from MID	
1989 (C)	0	0	0	7,890	0	54,730	0	0	0	62,620
1990 (C)	0	0	0	3,480	0	38,790	0	0	0	42,270
1991 (C)	0	0	1,240	17,040	0	55,060	0	0	0	73,350
1992 (C)	0	0	790	16,970	0	46,470	0	0	0	64,220
1993 (W)	571,210	0	2,830	18,210	0	166,480	0	66,920	0	825,650
1994 (C)	0	0	1,660	62,630	0	65,320	0	170	0	129,780
1995 (W)	572,200	0	3,460	47,580	24,860	84,660	81,530	120,760	0	935,040
1996 (W)	587,640	0	1,560	53,420	29,450	135,210	3,410	71,330	0	882,010
1997 (W)	541,010	0	930	37,660	186,330	136,550	26,850	188,130	0	1,117,450
1998 (W)	517,240	0	1,840	83,240	108,760	42,800	82,930	192,100	0	1,028,910
1999 (AN)	108,790	910	1,490	48,320	0	131,550	17,620	30,300	0	338,980
2000 (AN)	4,240	1,020	310	57,980	6,840	113,230	0	22,010	0	205,630
2001 (D)	0	880	890	81,760	0	64,750	0	330	0	148,610
2002 (D)	0	1,120	760	22,160	0	69,850	0	0	0	93,880
2003 (BN)	0	320	2,140	10,730	0	99,040	0	0	0	112,230
2004 (D)	0	690	860	19,620	0	70,290	0	0	0	91,460
2005 (W)	244,630	70	1,930	46,330	0	112,740	16,870	27,130	0	449,700
2006 (W)	831,930	540	3,480	54,850	76,550	98,770	44,750	126,760	0	1,237,640
2007 (C)	0	190	760	80,450	0	39,110	0	4,640	0	125,160
2008 (C)	0	0	570	24,090	0	64,860	0	0	0	89,530
2009 (BN)	0	0	840	15,070	0	94,850	0	0	0	110,760
2010 (AN)	0	530	1,990	17,620	0	159,480	0	13,940	0	193,560
2011 (W)	771,100	390	3,190	26,050	64,340	156,740	10,860	106,810	150	1,139,640
2012 (D)	0	0	810	97,830	0	55,340	0	8,140	140	162,260
2013 (C)	0	0	80	36,620	0	36,290	0	1,700	80	74,770
2014 (C)	0	0	0	0	0	440	0	0	0	440
2015 (C)	0	0	0	0	0	530	0	0	0	530
Average (1989-2014)	182,690	260	1,320	37,980	19,120	84,360	10,950	37,740	10	374,440
Average (1989-2014) W	579,620	130	2,400	45,920	61,290	116,740	33,400	112,490	20	952,000
Average (1989-2014) AN	37,680	820	1,260	41,310	2,280	134,750	5,870	22,080	0	246,050
Average (1989-2014) BN	0	160	1,490	12,900	0	96,940	0	0	0	111,490
Average (1989-2014) D	0	670	830	55,340	0	65,060	0	2,120	30	124,050
Average (1989-2014) C	0	20	510	24,920	0	40,160	0	650	10	66,270

*Includes water diverted under pre-1914, riparian, and prescriptive water rights along Chowchilla River.

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Surface Water Outflows

Surface water outflows are summarized in **Figure 2-83** and **Table 2-18**. These include natural flows along waterways, runoff of precipitation, and flood releases or spillage of CVP deliveries. As surface outflows serve as the water budget closure term, the monthly proportion of outflows of each water source type is estimated as equal to the proportion of inflows of each water source type by waterway. Overall, total surface outflows are significantly higher in wet years, averaging over 700 taf during wet years.

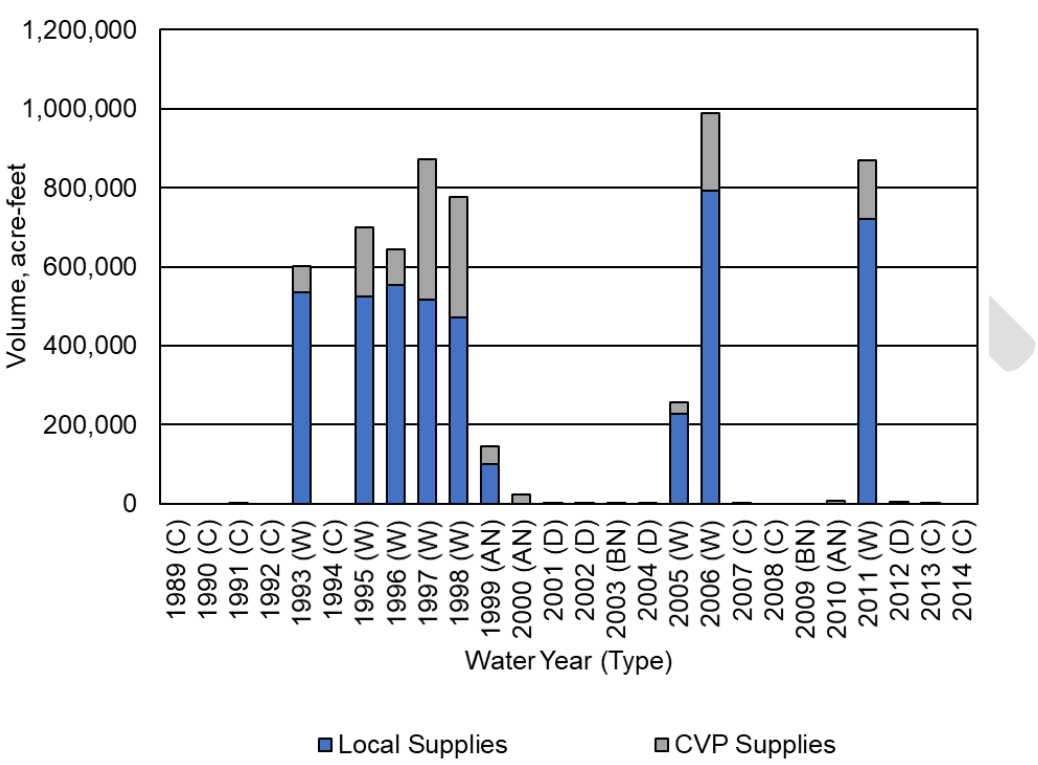

Figure 2-83. Chowchilla Subbasin Surface Outflows by Water Source Type.

Table 2-18. Chowchilla Subbasin Surface Outflows by Water Source Type (Acre-Feet) (23 CCR §354.18(b)(1)).

Water Year	Local Supplies	CVP Supplies	Total
1989 (C)	0	0	0
1990 (C)	0	0	0
1991 (C)	240	0	240
1992 (C)	0	0	0
1993 (W)	535,240	66,690	601,930
1994 (C)	0	0	0
1995 (W)	524,170	176,640	700,810
1996 (W)	554,090	89,210	643,300
1997 (W)	516,760	356,340	873,100
1998 (W)	471,770	306,340	778,110
1999 (AN)	99,710	45,300	145,010

Water Year	Local Supplies	CVP Supplies	Total
2000 (AN)	440	24,460	24,900
2001 (D)	300	560	860
2002 (D)	860	140	1,000
2003 (BN)	50	170	220
2004 (D)	0	320	320
2005 (W)	228,820	27,640	256,460
2006 (W)	792,690	195,090	987,780
2007 (C)	90	1,930	2,020
2008 (C)	0	0	0
2009 (BN)	0	0	0
2010 (AN)	430	7,470	7,900
2011 (W)	721,820	148,630	870,450
2012 (D)	170	4,330	4,500
2013 (C)	130	220	350
2014 (C)	0	0	0
2015 (C)	0	0	0
Average (1989-2014)	171,070	55,830	226,890
Average (1989-2014) W	543,170	170,820	713,990
Average (1989-2014) AN	33,530	25,740	59,270
Average (1989-2014) BN	30	90	110
Average (1989-2014) D	330	1,340	1,670
Average (1989-2014) C	50	240	290

Groundwater System Inflows

Estimates of groundwater system inflows are provided in **Figure 2-84** and **Table 2-19**. These inflows include calculated inflows from the SWS and subsurface groundwater inflows from adjacent subbasins[37]. Infiltration of precipitation to the groundwater system is highly variable from year to year due to variation in the timing and amount of precipitation, while infiltration of applied water has remained comparatively steady over time. Infiltration of surface water (seepage) also exhibits substantial variability, particularly from the Rivers and Streams system, matching the annual variability of surface water inflows. Although the San Joaquin River passes along the subbasin boundary, it provides significant infiltration to the groundwater system.

[37] Subsurface groundwater inflows to Chowchilla Subbasin include simulated inflows from the Delta-Mendota, Madera, and Merced subbasins.

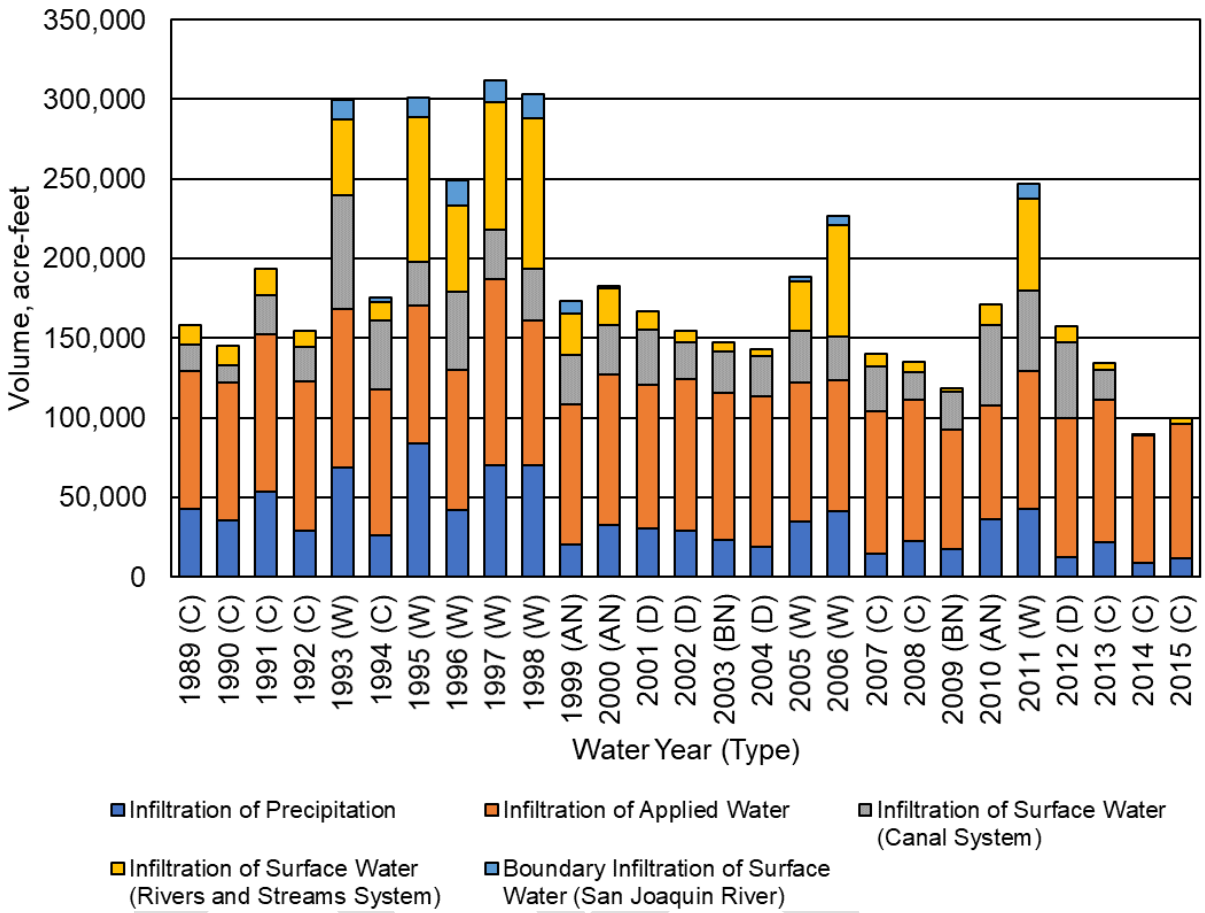

Figure 2-84. Chowchilla Subbasin Groundwater System Inflows.

Table 2-19. Chowchilla Subbasin Groundwater System Inflows (Acre-Feet) (23 CCR §354.18(b)(2)).

Water Year (Type)	Net Subsurface Groundwater Inflow*	Infiltration of Precip	Infiltration of Applied Water	Infiltration of Surface Water (Canal System)	Infiltration of Surface Water (Rivers and Streams System)[1]
1989 (C)	*	42,470	87,050	16,410	11,930
1990 (C)	*	35,580	86,210	11,330	12,030
1991 (C)	*	53,200	99,140	25,590	16,740
1992 (C)	*	29,150	93,670	22,290	10,390
1993 (W)	*	68,910	99,510	74,020	59,820
1994 (C)	*	26,450	91,210	44,720	14,610
1995 (W)	*	83,880	86,780	30,630	103,330
1996 (W)	*	42,280	87,980	49,960	70,030
1997 (W)	*	70,440	116,280	32,210	94,033
1998 (W)	*	70,160	91,040	33,990	109,978
1999 (AN)	*	20,630	87,680	32,670	33,613

Water Year (Type)	Net Subsurface Groundwater Inflow*	Infiltration of Precip	Infiltration of Applied Water	Infiltration of Surface Water (Canal System)	Infiltration of Surface Water (Rivers and Streams System)[1]
2000 (AN)	*	32,960	94,410	31,180	24,203
2001 (D)	*	30,220	90,370	35,540	11,210
2002 (D)	*	28,890	95,360	24,450	6,950
2003 (BN)	*	23,120	92,400	28,280	5,820
2004 (D)	*	18,640	94,860	26,480	3,950
2005 (W)	*	34,490	87,680	34,660	33,930
2006 (W)	*	41,170	82,150	31,420	75,850
2007 (C)	*	14,710	89,190	28,890	7,900
2008 (C)	*	22,610	88,330	18,680	6,150
2009 (BN)	*	17,160	75,160	24,790	2,620
2010 (AN)	*	36,210	71,730	52,700	13,000
2011 (W)	*	42,450	86,770	54,170	66,610
2012 (D)	*	12,590	87,410	47,810	10,060
2013 (C)	*	22,000	89,080	18,840	4,330
2014 (C)	*	9,070	79,630	30	390
2015 (C)	*	11,500	84,610	10	3,770
Average (1989-2014)	47,280	35,750	89,660	31,990	31,130
Average (1989-2014) W	*	56,720	92,270	42,630	76,700
Average (1989-2014) AN	*	29,930	84,610	38,850	23,610
Average (1989-2014) BN	*	20,140	83,780	26,540	4,220
Average (1989-2014) D	*	22,590	92,000	33,570	8,040
Average (1989-2014) C	*	28,360	89,280	20,750	9,390

*Year type values and averages are not reported because of the variable quality and timing of available groundwater level data and the resulting potential for biasing subsurface lateral flow calculations based on discrete snapshots of groundwater level conditions.
[1] Includes combined infiltration of surface water from the subbasin Rivers and Streams System and boundary infiltration of surface water from the San Joaquin River.
[2] Average infiltration of precipitation higher in critical years due to relatively higher amounts of precipitation in 1989-1992.

Groundwater Extraction by Water Use Sector

Estimates of groundwater extraction by water use sector are provided in **Figure 2-85** and **Table 2-20**. For agricultural and urban (urban, semi-agricultural and industrial) lands, groundwater extraction represents pumping, while for native vegetation lands, groundwater extraction by riparian vegetation was considered to be negligible because of the depth to groundwater in the subbasin. Groundwater extraction is dominated by irrigated agriculture, varying substantially from year to year based on variability in surface water supplies and crop water demands.

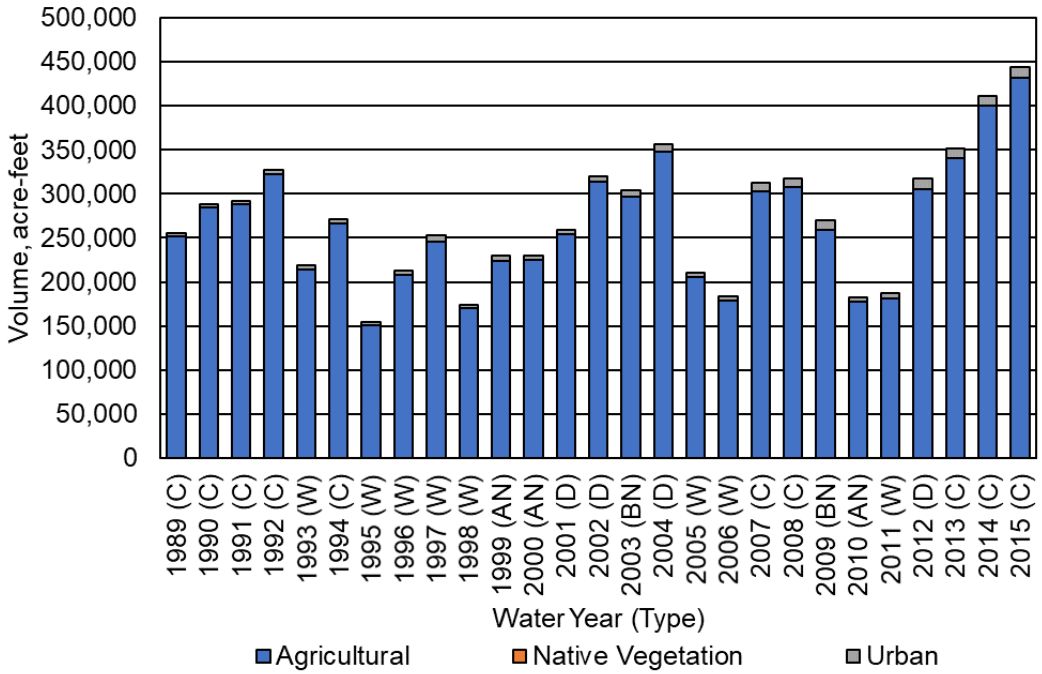

Figure 2-85. Chowchilla Subbasin Groundwater Extraction by Water Use Sector.

Table 2-20. Chowchilla Subbasin Groundwater Extraction by Water Use Sector (Acre-Feet) (23 CCR §354.18(b)(3)).

Water Year	Agricultural	Native Vegetation	Urban	Total
1989 (C)	251,340	0	3,440	254,780
1990 (C)	283,970	0	3,760	287,730
1991 (C)	288,060	0	3,810	291,870
1992 (C)	321,910	0	4,930	326,840
1993 (W)	214,460	0	3,930	218,390
1994 (C)	266,480	0	4,880	271,360
1995 (W)	151,330	0	2,640	153,970
1996 (W)	208,230	0	4,030	212,260
1997 (W)	245,760	0	6,650	252,410
1998 (W)	170,840	0	3,470	174,310
1999 (AN)	224,000	0	5,620	229,620
2000 (AN)	224,830	0	4,950	229,780
2001 (D)	254,620	0	4,820	259,440
2002 (D)	313,640	0	6,580	320,220
2003 (BN)	296,800	0	6,670	303,470
2004 (D)	347,970	0	8,830	356,800
2005 (W)	205,020	0	5,790	210,810
2006 (W)	178,220	0	5,820	184,040
2007 (C)	303,090	-10	9,640	312,720
2008 (C)	307,660	0	9,920	317,580
2009 (BN)	259,520	0	10,010	269,530
2010 (AN)	177,000	0	5,920	182,920

Water Year	Agricultural	Native Vegetation	Urban	Total
2011 (W)	181,040	0	6,570	187,610
2012 (D)	305,780	0	11,110	316,890
2013 (C)	340,050	0	11,150	351,200
2014 (C)	399,610	0	10,960	410,570
2015 (C)	432,110	0	12,080	444,190
Average (1989-2014)	258,510	0	6,380	264,890
Average (1989-2014) W	194,360	0	4,860	199,230
Average (1989-2014) AN	208,610	0	5,500	214,100
Average (1989-2014) BN	278,160	0	8,340	286,490
Average (1989-2014) D	305,500	0	7,840	313,340
Average (1989-2014) C	306,910	0	6,940	313,850

Groundwater Discharge to Surface Water Sources

The depth to groundwater is greater than 100-200 ft across much of the Chowchilla Subbasin. Given the substantial depth to the water table, groundwater discharge to surface water sources is negligible.

Evapotranspiration by Water Use Sector

Total evapotranspiration (ET) by water use sector is reported in **Figure 2-86** and **Table 2-21**. Total ET varies between years but has gradually increased over time due to changes in crops, with the lowest observed in 1989, at approximately 300 taf, and the greatest in 2015, at over 400 taf. Agricultural ET tends to increase in drier years, while native vegetation ET decreases.

In addition to total ET from land surfaces, estimates of evaporation from rivers and streams are reported in **Figure 2-87** and **Table 2-22**. Evaporation is highest in wet years when surface water inflows are typically higher, averaging approximately 2.5 taf overall.

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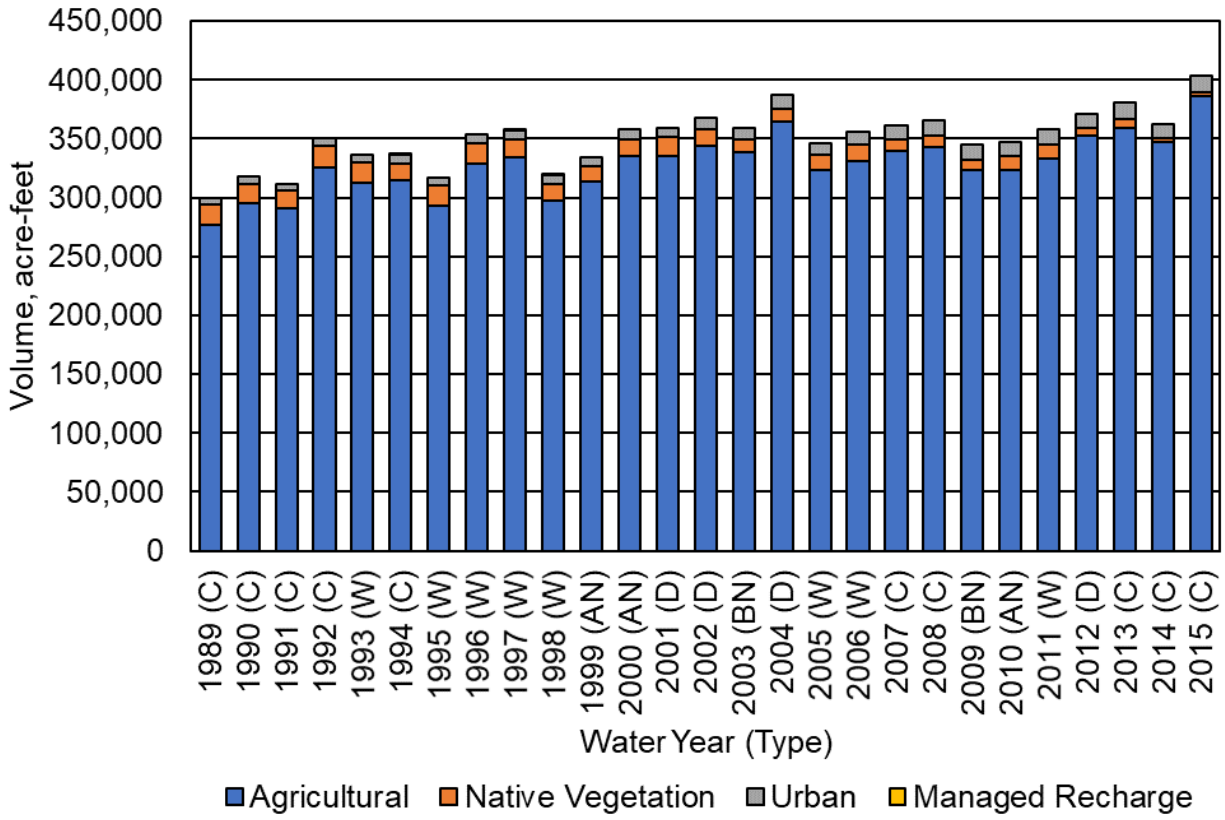

Figure 2-86. Chowchilla Subbasin Total Evapotranspiration by Water Use Sector.

Table 2-21. Chowchilla Subbasin Total Evapotranspiration by Water Use Sector (Acre-Feet) (23 CCR §354.18(b)(3)).

Water Year	Agricultural	Native Vegetation	Urban	Managed Recharge	Total
1989 (C)	277,050	16,730	5,960	0	299,740
1990 (C)	295,140	16,670	6,360	0	318,170
1991 (C)	290,960	14,820	5,780	0	311,560
1992 (C)	325,520	18,030	7,230	0	350,780
1993 (W)	312,470	17,220	7,080	0	336,770
1994 (C)	314,570	14,280	7,190	10	336,050
1995 (W)	293,420	16,550	6,750	0	316,720
1996 (W)	328,400	17,490	7,450	0	353,340
1997 (W)	333,910	15,470	8,070	20	357,470
1998 (W)	297,250	14,180	7,230	30	318,690
1999 (AN)	313,390	12,940	7,480	0	333,810
2000 (AN)	335,290	14,130	8,160	0	357,580
2001 (D)	335,770	15,330	8,260	0	359,360
2002 (D)	343,980	14,250	9,370	0	367,600
2003 (BN)	338,240	11,140	9,630	0	359,010
2004 (D)	364,120	11,820	11,320	0	387,260
2005 (W)	323,270	12,920	10,430	0	346,620
2006 (W)	331,270	13,790	11,180	0	356,240

Water Year	Agricultural	Native Vegetation	Urban	Managed Recharge	Total
2007 (C)	339,570	10,030	11,680	0	361,280
2008 (C)	342,680	10,050	13,240	0	365,970
2009 (BN)	323,520	8,170	13,500	0	345,190
2010 (AN)	323,730	11,330	12,590	0	347,650
2011 (W)	333,570	11,790	13,220	0	358,580
2012 (D)	353,050	6,230	12,310	0	371,590
2013 (C)	359,330	7,040	14,320	0	380,690
2014 (C)	347,440	3,400	11,990	0	362,830
2015 (C)	386,190	3,610	13,350	0	403,150
Average (1989-2014)	326,040	12,920	9,530	0	348,480
Average (1989-2014) W	319,200	14,930	8,930	10	343,050
Average (1989-2014) AN	324,140	12,800	9,410	0	346,350
Average (1989-2014) BN	330,880	9,660	11,570	0	352,100
Average (1989-2014) D	349,230	11,910	10,320	0	371,450
Average (1989-2014) C	321,360	12,340	9,310	0	343,010

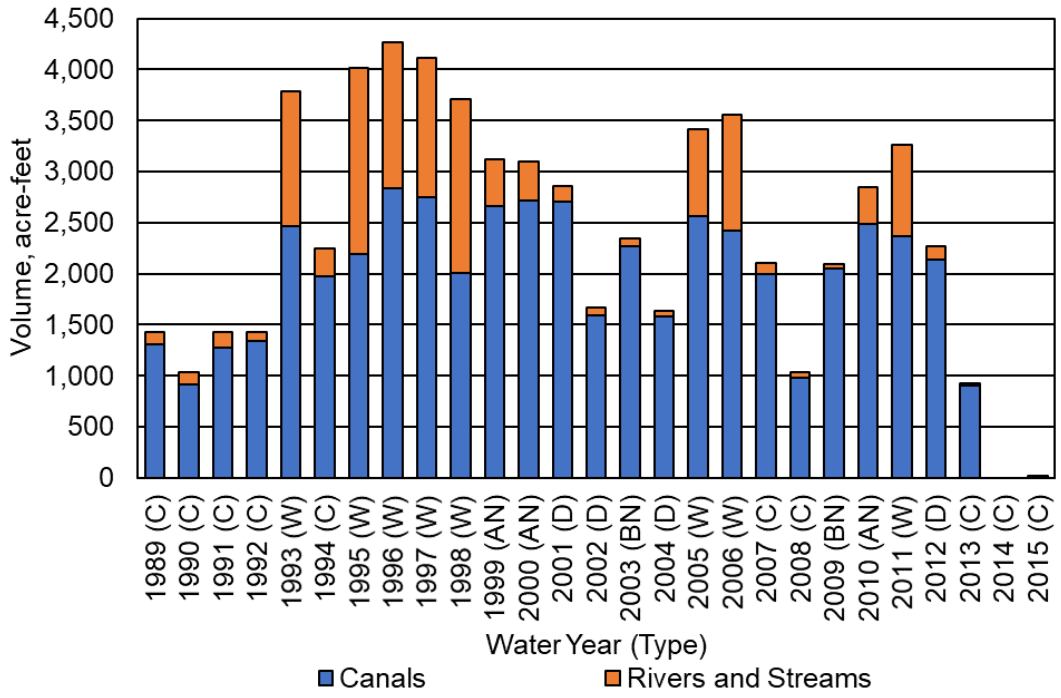

Figure 2-87. Chowchilla Subbasin Evaporation from the Surface Water System.

Table 2-22. Chowchilla Subbasin Evaporation from the Surface Water System (Acre-Feet) (23 CCR §354.18(b)(3)).

Water Year	Canals	Rivers and Streams	Total
1989 (C)	1,310	120	1,430
1990 (C)	910	130	1,040
1991 (C)	1,270	160	1,430
1992 (C)	1,340	90	1,430
1993 (W)	2,460	1,330	3,790
1994 (C)	1,970	270	2,240
1995 (W)	2,190	1,820	4,010
1996 (W)	2,840	1,430	4,270
1997 (W)	2,750	1,360	4,110
1998 (W)	2,010	1,700	3,710
1999 (AN)	2,660	460	3,120
2000 (AN)	2,720	380	3,100
2001 (D)	2,710	150	2,860
2002 (D)	1,590	80	1,670
2003 (BN)	2,270	80	2,350
2004 (D)	1,580	50	1,630
2005 (W)	2,560	860	3,420
2006 (W)	2,420	1,140	3,560
2007 (C)	2,000	100	2,100
2008 (C)	980	50	1,030
2009 (BN)	2,050	40	2,090
2010 (AN)	2,490	360	2,850
2011 (W)	2,370	890	3,260
2012 (D)	2,140	130	2,270
2013 (C)	900	30	930
2014 (C)	0	0	0
2015 (C)	0	20	20
Average (1989-2014)	1,940	510	2,450
Average (1989-2014) W	2,450	1,320	3,770
Average (1989-2014) AN	2,620	400	3,020
Average (1989-2014) BN	2,160	60	2,220
Average (1989-2014) D	2,010	100	2,110
Average (1989-2014) C	1,190	110	1,290

Change in Storage

Estimates of average annual change in storage within the GWS are summarized for each water budget scenario in **Table 2-25**.

Historical Water Budget Summary

Annual inflows, outflows, and change in SWS storage under historical conditions in the Chowchilla Subbasin SWS are summarized in **Figure 2-89**. Inflows are shown as positive values, while outflows and change in SWS storage are shown as negative values. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the surface water system water budget and opportunities for projects to increase groundwater recharge and the sustainable yield.

Detailed historical water budget components in each subregion are summarized in detail in **Appendices 2.F.a.** through **2.F.e.**

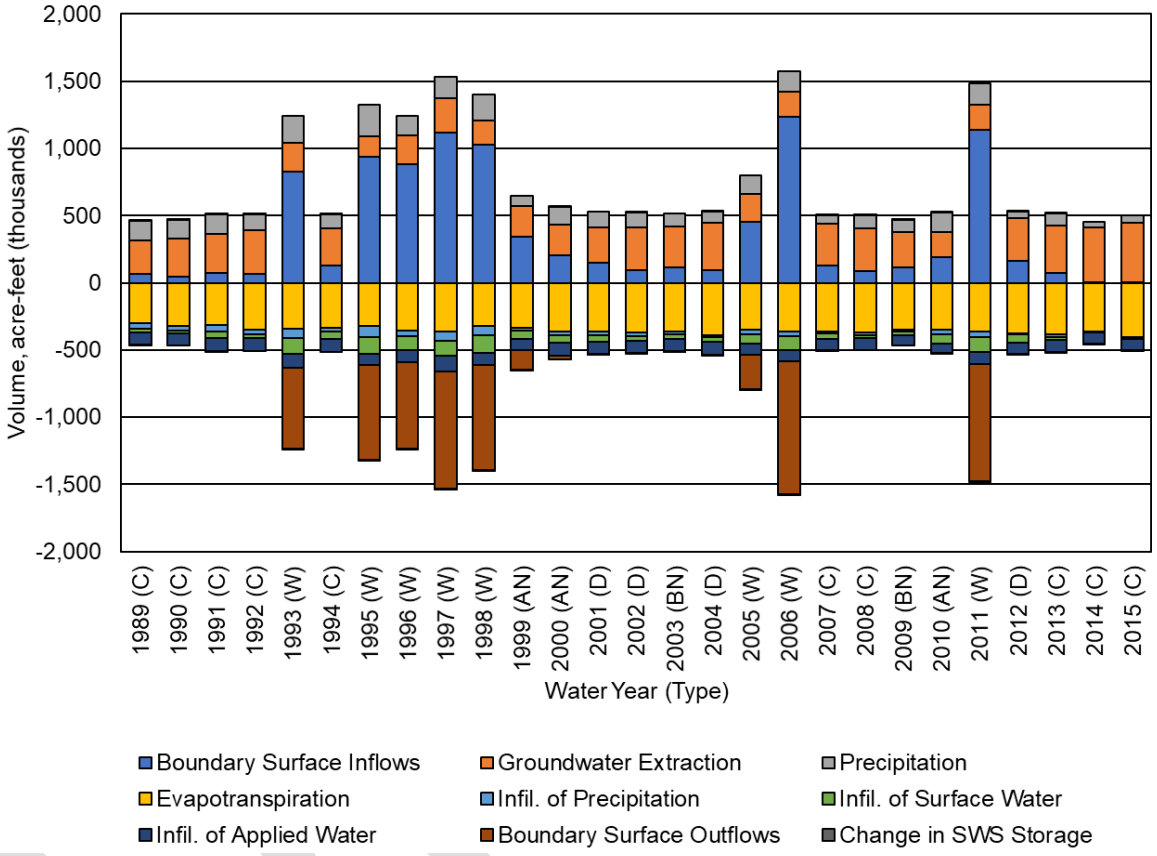

Figure 2-89. Chowchilla Subbasin Surface Water System Historical Water Budget.

Current Water Budget Summary

Annual inflows, outflows, and change in SWS storage under current land use conditions in the Chowchilla Subbasin SWS are summarized in **Figure 2-90**. Inflows are shown as positive values, while outflows and change in SWS storage are shown as negative values. Review of the variability in component volumes across years provides insight into the impacts of current land use on SWS inflows and outflows over time.

Detailed current water budget components in each subregion are summarized in detail in **Appendices 2.F.a.** through **2.F.e.**

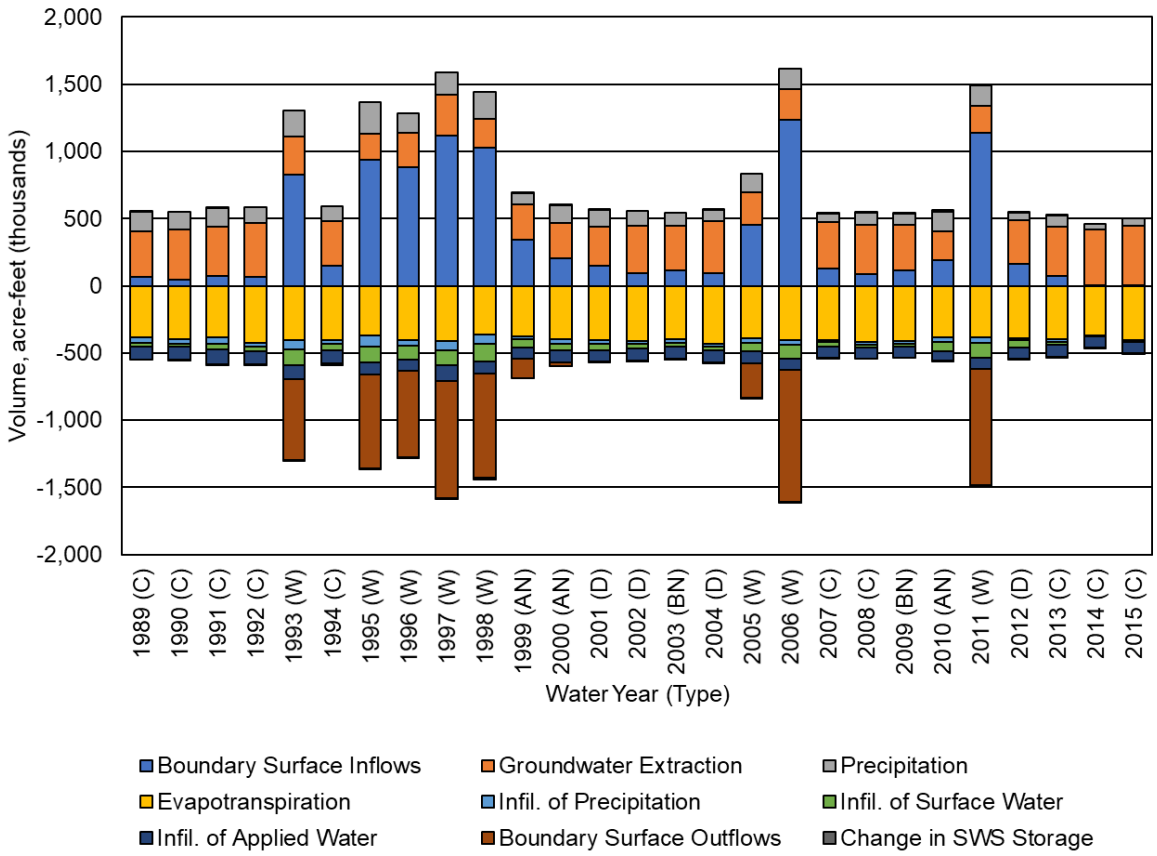

Figure 2-90. Chowchilla Subbasin Surface Water System Current Water Budget.

Projected Water Budget Development

Water budgets were projected into the future to estimate future water demands under different future scenarios and to evaluate the potential effects of different management actions and implementation of different projects.

Two primary projected water budget scenarios were considered: a projected without projects (no action) scenario, and a projected with projects scenario. Both these projected scenarios were also considered in the context of potential climate change effects on surface water supply and weather parameters.

Two major time periods exist in the future projected model: the implementation period (2020-2039), during which projects and management actions are implemented to bring the basin into sustainability, and the sustainability period (2040-2090), after which projects and management actions have been fully implemented.

The development of the projected future scenarios is described in detail in **Appendix 6.E.**, Groundwater Model Documentation. The development of projected timeseries for precipitation, evapotranspiration, and surface water flows are briefly summarized in **Tables 2-23** and **2-24** below.

Table 2-23. Development of Projected Future Precipitation and Evapotranspiration Timeseries.

Water Budget Component	Without Climate Change Adjustments		With Climate Change Adjustments	
	Implementation Period	Sustainability Period	Implementation Period	Sustainability Period
	(2020-2039)	(2040-2090)	(2020-2039)	(2040-2090)
Precipitation	2001-2010 historical data (2020-2029 and 2030-2039)	1965-2015 historical data (2040-2090)	2001-2010 historical data (2020-2029 and 2030-2039) adjusted by CalSim II 2030 monthly change factors by water year type	1965-2015 historical data (2040-2090) adjusted by CalSim II 2030 monthly change factors by water year type
Evapotranspiration	2001-2010 historical data (2020-2029 and 2030-2039), assuming 2017 land use adjusted for projected urban area growth from 2017-2039	1965-2015 historical data, assuming 2017 land use adjusted for projected urban area growth from 2017-2070 (urban area constant from 2071-2090)	2001-2010 historical data (2020-2029 and 2030-2039) adjusted by CalSim II 2030 monthly change factors by water year type, assuming 2017 land use adjusted for projected urban area growth from 2017-2039	1965-2015 historical data (2040-2090) adjusted by CalSim II 2030 monthly change factors by water year type, assuming 2017 land use adjusted for projected urban area growth from 2017-2070 (urban area constant from 2071-2090)

Table 2-24. Development of Projected Future Surface Water Supply Timeseries.

Water Budget Component	Without Climate Change Adjustments		With Climate Change Adjustments	
	Implementation Period	Sustainability Period	Implementation Period	Sustainability Period
	(2020-2039)	(2040-2090)	(2020-2039)	(2040-2090)
Surface Water Inflow - Unimpaired Streams	2001-2010 historical data (2020-2029 and 2030-2039)	1965-2015 historical data (2040-2090)	2001-2010 historical data (2020-2029 and 2030-2039) adjusted by CalSim II 2030 monthly streamflow change factors by water year type	1965-2015 historical data (2040-2090) adjusted by CalSim II 2030 monthly streamflow change factors by water year type
Surface Water Inflow - Chowchilla River (Buchanan Dam Releases)	2001-2010 historical data (2020-2029 and 2030-2039)	1965-2015 historical data (2040-2090)	2001-2010 data (2020-2029 and 2030-2039): 2001-2003 historical data adjusted by CalSim II 2030 climate change projections for Eastman Lake; 2004-2010 data estimated as the historical volume adjusted by the average monthly climate-adjusted volume by water year type	1965-2003 historical data (2040-2078) adjusted by CalSim II 2030 climate change projections for Eastman Lake; 2004-2015 data (2079-2090) estimated as the historical volume adjusted by the average monthly climate-adjusted volume by water year type

Water Budget Component	Without Climate Change Adjustments		With Climate Change Adjustments	
	Implementation Period	Sustainability Period	Implementation Period	Sustainability Period
	(2020-2039)	(2040-2090)	(2020-2039)	(2040-2090)
Surface Water Inflow - Fresno River (Hidden Dam Releases)	2001-2010 historical data (2020-2029 and 2030-2039)	1965-2015 historical data (2040-2090)	2001-2010 data (2020-2029 and 2030-2039): 2001-2003 historical data adjusted by CalSim II 2030 climate change projections for Hensley Lake; 2004-2010 data estimated as the historical volume adjusted by the average monthly climate-adjusted volume by water year type	1965-2003 historical data (2040-2078) adjusted by CalSim II 2030 climate change projections for Hensley Lake; 2004-2015 data (2079-2090) estimated as the historical volume adjusted by the average monthly climate-adjusted volume by water year type
Surface Water Inflow - San Joaquin River (Friant Dam Releases)	Estimated based on the Friant Water Authority Report* (same as the implementation period with climate change adjustments**, see right)	Estimated based on the Friant Water Authority Report* (same as the implementation period with climate change adjustments**, see right)	2001-2010 data (2020-2029 and 2030-2039): 2001-2003 data provided by Friant Water Authority Report*, considering the CalSim II 2030 climate change projections and implementation of the SJRRP; 2004-2010 data estimated as the historical volume adjusted by the average Friant Report volume by month and water year type	1965-2003 data (2040-2078) provided by Friant Water Authority Report*, considering the CalSim II 2030 climate change projections and implementation of the SJRRP; 2004-2015 data (2079-2090) estimated as the historical volume adjusted by the average Friant Report volume by month and water year type
Surface Water Inflow - Chowchilla Bypass	Estimated based on the historical monthly ratio of Chowchilla Bypass (CBP) and San Joaquin River (SJR) flows, with projected SJR inflow data provided by the Friant Water Authority Report* (same as the implementation period with climate change adjustments**, see right)	Estimated based on the historical monthly ratio of CBP and SJR flows, with projected SJR inflow data provided by the Friant Water Authority Report* (same as the implementation period with climate change adjustments**, see right)	2001-2010 data (2020-2029 and 2030-2039): 2001-2003: estimated based on the historical monthly ratio of CBP and SJR flows by water year type, with projected SJR inflow data provided by the Friant Water Authority Report*, considering the CalSim II 2030 climate change projections and implementation of the SJRRP; 2004-2010: estimated based on the historical monthly ratio of CBP to SJR flows by water year type, with average projected SJR inflows calculated from 1921-2003 by month and water year type	1965-2003 (2040-2078): estimated based on the historical monthly ratio of CBP to SJR flows by water year type, with projected SJR inflow data provided by the Friant Water Authority Report*, considering the CalSim II 2030 climate change projections and implementation of the SJRRP; 2004-2015 (2079-2090): estimated based on the historical monthly ratio of CBP to SJR flows by water year type, with average projected SJR inflows calculated by month and water year type

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Water Budget Component	Without Climate Change Adjustments		With Climate Change Adjustments	
	Implementation Period	Sustainability Period	Implementation Period	Sustainability Period
	(2020-2039)	(2040-2090)	(2020-2039)	(2040-2090)
Diversions from Madera Canal	Estimated based on the Friant Water Authority Report* (same as the implementation period with climate change adjustments**, see right)	Estimated based on the Friant Water Authority Report* (same as the implementation period with climate change adjustments**, see right)	2001-2010 data (2020-2029 and 2030-2039): 2001-2003 data provided by Friant Water Authority Report*, considering the CalSim II 2030 climate change projections and implementation of the SJRRP; 2004-2010 data estimated as the historical volume adjusted by the average Friant Report climate change volume by month and water year type	1965-2003 data (2040-2078) provided by Friant Water Authority Report*, considering the CalSim II 2030 climate change projections and implementation of the SJRRP; 2004-2015 data (2079-2090) estimated as the historical volume adjusted by the average Friant Report climate change volume by month and water year type
Other Diversions/ Bypasses	2001-2010 historical data (2020-2029 and 2030-2039)	1965-2015 historical data (2040-2090)	2001-2010 historical data (2020-2029 and 2030-2039)***	1965-2015 historical data (2040-2090)***

* "Estimate of Future Friant Division Supplies for use in Groundwater Sustainability Plans, California," Friant Water Authority, 2018.

** Although the Friant Water Authority Report (or Friant Report) accounts for climate change, it is considered the best available estimate of projected Madera Canal deliveries under SJRRP. For comparison, projected Madera Canal deliveries under SJRRP were also estimated without account for climate change from the Steiner Report Kondolf Hydrograph (Steiner, 2005). These estimates were approximately equal to the Friant Report 2030 climate change adjusted deliveries. Thus, the Friant Report projections were used instead to maintain consistent assumptions in estimating Madera Canal deliveries across all projected simulations.

*** Historical volumes specified in the model to ensure that GSAs can use as much surface water as is available in a given time step up to the maximum historical surface water used.

Comparison of Water Budget Scenarios

Table 2-25 provides a summary of the average annual inflows, outflows, change in GWS storage, and overdraft estimated at the subbasin-level in the historical, current, projected without projects, and projected with projects water budgets. This table also provides an estimate of subbasin sustainable yield from the projected with projects water budget.

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Table 2-25. Comparative Summary of all Water Budget Scenarios, Annual Average Volumes by Flow Path (Acre-Feet).

23 CCR Section	Flow Path Direction (Relative to GWS)	Flow Path	Water Budget Period				Reason for Difference from Historical
			Historical	Current	Projected, No Action	Projected, With Projects	
			1989-2014	2017 land use, 1989-2014 average hydrology/supply	2040-2090	2040-2090	
354.18(b)(1)	N/A (SWS flow path)	Surface Water Inflows	374,400	374,400	329,200	309,600	Decrease due to SJRRP (Projected), upstream (Madera Subbasin) GSP project diversions (With Projects)
		Local Supplies	*182,900*	*182,900*	*143,600*	*123,100*	Decrease in Chowchilla Bypass flows with SJRRP (Projected), upstream (Madera Subbasin) GSP project diversions (With Projects)
		CVP Supplies	*191,500*	*191,500*	*185,600*	*186,500*	Decrease in CVP deliveries with SJRRP (Projected)
354.18(b)(1)	N/A (SWS flow path)	Surface Water Outflows	226,900	226,900	206,100	129,200	Decrease due to decreased surface water inflows described above (Projected), upstream (Madera Subbasin) GSP project diversions (With Projects)
		Local Supplies	*171,100*	*171,100*	*187,000*	*117,200*	
		CVP Supplies	*55,800*	*55,800*	*19,100*	*12,000*	
Implied	N/A (SWS flow path)	Precipitation	124,200	124,300	144,100	144,100	Increase due to higher proportion of W water years anticipated in projected period (35% of years, versus 31% in historical period)
354.18(b)(2)	Inflow	Infiltration of Surface Water	63,100	62,100	67,200	120,500	Increase due to infiltration of GSP projects (With Projects)
354.18(b)(2)	Inflow	Infiltration of Applied Water	89,700	89,300	83,000	82,300	Decrease due to urban growth (Projected), demand management (with Projects)

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23 CCR Section	Flow Path Direction (Relative to GWS)	Flow Path	Water Budget Period				Reason for Difference from Historical
			Historical	Current	Projected, No Action	Projected, With Projects	
			1989-2014	2017 land use, 1989-2014 average hydrology/supply	2040-2090	2040-2090	
354.18(b)(2)	Inflow	Infiltration of Precipitation	35,700	33,700	34,500	38,400	N/A
354.18(b)(3)	N/A (SWS flow path)	Evapotranspiration	350,900	398,000	394,300	369,500	Increase due to cropping (Current; Projected, No Action); Decrease due to demand management (Projected, With Projects)
354.18(b)(3)	Outflow	GW Pumping	264,900	307,600	297,800	248,500	Increase due to cropping (Current; Projected, No Action); Decrease due to demand management (Projected, With Projects)
354.18(b)(3)	Outflow	GW Discharge to Surface Water Sources	0	0	0	0	Low groundwater levels
354.18(b)(2),(3)	Inflow (Net)	Net Subsurface Inflow	47,300	N/A[1]	71,400	9,700	Increase due to low groundwater levels (Projected, No Action); Decrease due to GSP projects and management actions used to achieve sustainability (Projected, With Projects)
354.18(b)(4)	Inflows - Outflows	Average Annual Change in Groundwater Storage	-29,100	N/A[1]	-41,700	2,400	Decrease due to cropping and related groundwater extraction (Current; Projected, No Action); Increase due to GSP projects and management actions used to achieve sustainability (Projected, With Projects)

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23 CCR Section	Flow Path Direction (Relative to GWS)	Flow Path	Water Budget Period				Reason for Difference from Historical
			Historical	Current	Projected, No Action	Projected, With Projects	
			1989-2014	2017 land use, 1989-2014 average hydrology/supply	2040-2090	2040-2090	
354.18(b)(5)	Inflows - Outflows	Average Overdraft	-29,100	N/A[1]	-41,700	2,400	Changes due to reasons above.
354.18(b)(7)	Inflows - Outflows	Sustainable Yield, Method 1[2]	N/A	N/A	N/A	248,500	N/A
354.18(b)(7)	Inflows - Outflows	Sustainable Yield, Method 2[3]	N/A	N/A	N/A	250,900	N/A

[1]Net subsurface inflow not estimated for current water budget due to uncertainties in adjacent basin groundwater conditions.
[2]Method 1: Sustainable Yield estimated as groundwater extraction and GWS change in storage, assuming zero change in groundwater storage on average under sustainable operation of the subbasin.
[3]Method 2: Sustainable Yield estimated as total inflows to GWS

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Overdraft Conditions

Overdraft is defined in DWR Bulletin 118 as "the condition of a groundwater basin or subbasin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions" (DWR, 2003). The Chowchilla Subbasin water budget indicates that overdraft conditions occurred during the 1989-2014 historical base period. Per 23 CCR Section 354.18(b)(5), the subbasin overdraft has been quantified for this period. Overdraft is calculated as the sum of all outflows from the groundwater system, including groundwater extraction and subsurface outflow, minus the sum of all inflows to the groundwater system, including infiltration from all sources and subsurface inflow.

The average subbasin overdraft is presented below for 1989-2014 based on the historical water budget (**Table 2-26**) and current land use water budget (**Table 2-27**).

Net Recharge from SWS

For estimates of the SWS contribution to overdraft, the term net recharge from the SWS is defined as groundwater recharge minus groundwater extraction. Net recharge from the SWS is useful for understanding and analyzing the combined effects of land surface processes on the underlying GWS.

When calculated from the historical water budget, average net recharge from the SWS represents the average recharge (when positive) or shortage (when negative) of recharge from the SWS based on historical cropping, land use practices, and average hydrologic conditions. When calculated from the current land use water budget, average net recharge represents the average recharge or shortage based on current cropping, land use practices, and average hydrologic conditions.

Table 2-26. Historical Water Budget: Average Overdraft by Water Year Type, 1989-2014 (Acre-Feet) (23 CCR §354.18(b)(5)).

Year Type	Number of Years	Net Subsurface Groundwater Inflow (a)	Infiltration of Applied Water (b)	Infiltration of Precipitation (c)	Infiltration of Surface Water[1] (d)	Groundwater Extraction (e)	Overdraft (a+b+c+d-e)
W	8	*	92,270	56,720	119,330	199,230	*
AN	3	*	84,610	29,930	62,460	214,100	*
BN	2	*	83,780	20,140	30,760	286,490	*
D	4	*	92,000	22,580	41,610	313,340	*
C	9	*	89,280	28,360	30,140	313,850	*
Annual Average (1989-2014)	26	47,280[2]	89,660	35,750	63,120	264,890	-29,080

* Year type values and averages are not reported because of the variable quality and timing of available groundwater level data and the resulting potential for biasing subsurface lateral flow calculations based on discrete snapshots of groundwater level conditions.

[1] Includes infiltration of surface water from the Canal System and Rivers and Streams System, and boundary infiltration of surface water from San Joaquin River.

[2] Significant uncertainty in net groundwater inflow arises from the use of different methods/tools and boundary assumptions in groundwater system analysis. As a result, net subsurface inflow has been revised since initial presentation based on additional groundwater modeling resulting in a lower overdraft than was originally presented.

Table 2-27. Current Land Use Water Budget: Average Overdraft by Water Year Type, 1989-2014 (Acre-Feet) (23 CCR §354.18(b)(5)).

Year Type	Number of Years	Subsurface Groundwater Inflow (a)	Infiltration of Applied Water (b)	Infiltration of Precipitation (c)	Infiltration of Surface Water[1] (d)	Groundwater Extraction (e)	Overdraft (a+b+c+d-e)
W	8	*	92,140	53,830	118,190	239,510	*
AN	3	*	82,150	28,240	62,000	245,370	*
BN	2	*	84,180	18,710	30,140	336,830	*
D	4	*	86,190	20,940	41,120	340,770	*
C	9	*	91,730	26,550	28,700	367,580	*
Annual Average (1989-2014)	26	N/A[2]	89,320	33,670	62,100	307,580	N/A[2]

* Year type values and averages are not reported because of the variable quality and timing of available groundwater level data and the resulting potential for biasing subsurface lateral flow calculations based on discrete snapshots of groundwater level conditions.
[1] Includes infiltration of surface water from the Canal System and Rivers and Streams System, and boundary infiltration of surface water from San Joaquin River.
[2] Net subsurface inflow not estimated for current water budget due to uncertainties in adjacent basin groundwater conditions.

Average net recharge from the SWS is presented below for 1989-2014 based on the historical water budget (**Table 2-28**) and current land use water budget (**Table 2-29**). Historically, average annual net recharge from the SWS in the Chowchilla Subbasin was approximately -76 taf between 1989 and 2014. Under current land use conditions, average net recharge from the SWS in the Chowchilla Subbasin has decreased to approximately -122 taf.

Table 2-28. Historical Water Budget: Average Net Recharge from SWS by Water Year Type, 1989-2014 (Acre-Feet).

Year Type	Number of Years	Infiltration of Applied Water (a)	Infiltration of Precipitation (b)	Infiltration of Surface Water[1] (c)	Groundwater Extraction (d)	Net Recharge from SWS (a+b+c-d)
W	8	92,270	56,720	119,330	199,230	69,090
AN	3	84,610	29,930	62,460	214,100	-37,100
BN	2	83,780	20,140	30,760	286,490	-151,810
D	4	92,000	22,580	41,610	313,340	-157,150
C	9	89,280	28,360	30,140	313,850	-166,070
Annual Average (1989-2014)	26	89,660	35,750	63,120	264,890	-76,360

[1] Includes infiltration of surface water from the Canal System and Rivers and Streams System, and boundary infiltration of surface water from San Joaquin River.

Table 2-29. Current Land Use Water Budget: Average Net Recharge from SWS by Water Year Type, 1989-2014 (Acre-Feet).

Year Type	Number of Years	Infiltration of Applied Water (a)	Infiltration of Precipitation (b)	Infiltration of Surface Water[1] (c)	Groundwater Extraction (d)	Net Recharge from SWS (a+b+c-d)
W	8	92,140	53,830	118,190	239,510	24,650
AN	3	82,150	28,240	62,000	245,370	-72,980
BN	2	84,180	18,710	30,140	336,830	-203,800
D	4	86,190	20,940	41,120	340,770	-192,520
C	9	91,730	26,550	28,700	367,580	-220,600
Annual Average (1989-2014)	26	89,320	33,670	62,100	307,580	-122,490

[1] Includes infiltration of surface water from the Canal System and Rivers and Streams System, and boundary infiltration of surface water from San Joaquin River.

Annual Supply, Demand, and Change in Groundwater Stored by Water Year Type

Annual supply, demand, and change in groundwater stored is summarized by water year type in **Table 2-30** for historical, current, projected without projects (no action), and projected with projects conditions.

Table 2-30. Comparative Summary of Annual Supply, Demand, and Change in Storage by Water Year Type (Acre-Feet per Year) (23 CCR §354.18(b)(6)).

Water Year Type	Water Budget Element	Water Budget Flow Paths	Water Budget Period			
			Historical	Current	Projected, No Action	Projected, With Projects
			1989-2014	2017 land use, 1989-2014 average hydrology/supply	2040-2090	2040-2090
W	Supply	Surface Water Inflows	952,000	952,000	702,000	638,900
	Supply	Precipitation	173,400	173,400	201,900	201,900
	Demand	Evapotranspiration	346,800	393,200	392,300	366,300
	Change in Storage	Change in Groundwater Storage	106,900	N/A[1]	92,300	289,900
AN	Supply	Surface Water Inflows	246,100	246,100	243,900	260,800
	Supply	Precipitation	119,600	119,600	145,500	145,500
	Demand	Evapotranspiration	349,400	387,900	398,700	372,300
	Change in Storage	Change in Groundwater Storage	-4,200	N/A[1]	-8,900	-54,200
BN	Supply	Surface Water Inflows	111,500	111,500	119,800	118,600

Water Year Type	Water Budget Element	Water Budget Flow Paths	Water Budget Period			
			Historical	Current	Projected, No Action	Projected, With Projects
			1989-2014	2017 land use, 1989-2014 average hydrology/supply	2040-2090	2040-2090
	Supply	Precipitation	91,600	91,600	115,500	115,500
	Demand	Evapotranspiration	354,300	407,100	400,100	375,200
	Change in Storage	Change in Groundwater Storage	-93,800	N/A[1]	-106,900	-138,900
D	Supply	Surface Water Inflows	124,100	124,100	124,900	127,800
	Supply	Precipitation	91,800	91,800	105,700	105,700
	Demand	Evapotranspiration	373,600	408,900	407,200	380,100
	Change in Storage	Change in Groundwater Storage	-109,500	N/A[1]	-121,900	-182,400
C	Supply	Surface Water Inflows	66,300	66,300	69,000	69,200
	Supply	Precipitation	99,200	99,200	99,200	99,200
	Demand	Evapotranspiration	350,200	399,300	385,600	364,500
	Change in Storage	Change in Groundwater Storage	-121,100	N/A[1]	-165,800	-192,900

[1]Net subsurface inflow not estimated for current water budget due to uncertainties in adjacent basin groundwater conditions.

Subbasin Sustainable Yield Estimate.

GSP Regulations require the water budget to quantify the sustainable yield for the subbasin. Sustainable yield is defined 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 Section 10721(w)).

Sustainable yield is dependent upon conditions in existence at the time, and therefore changes during implementation of projects that increase recharge or lead to reductions in demand. As such, sustainable yield was not calculated for the historical (1989-2014) and 2020-2039 GSP implementation period because each time a recharge or "in lieu" project is completed, the sustainable yield will increase.

For the 2040-2090 period, model results show that the schedule for project implementation together with the mitigation program for domestic wells results in MOs and related values for the sustainability indicators that avoid MTs and associated undesirable results. Thus, the sustainable yield for this 2040-2090 projected period ensures this is a quantity of water "…that can be withdrawn annually from a groundwater supply without causing an undesirable result" (CWC Section 10721(w)). In alignment with GSP Regulations and DWR's Sustainable Management Criteria BMP (DWR, 2017), sustainable yield has been calculated for the 2040-2090 projected period using two methods (**Table 2-31**) with a single value of sustainable yield for the subbasin as a whole (DWR, 2017).

The first method estimates sustainable yield as the average annual groundwater extraction minus the average annual change in groundwater storage during the projected 2040-2090 period. Since average

groundwater inflows approximately equal outflows during the 2040-2090 period, the average annual change in the groundwater storage was assumed to be zero over this 50-year period. The second method calculates sustainable yield as the sum of the average projected annual inflows to the groundwater system (infiltration of applied water, infiltration of precipitation, infiltration of surface water, and subsurface inflows). After the Chowchilla and neighboring basins reach sustainability, subsurface groundwater inflows are expected to decrease as the groundwater system reaches new equilibrium levels.

Table 2-31. Summary of Sustainable Yield Estimates from Projected with Projects Water Budget (23 CCR §354.18(b)(7)).

Quantification Method	Average Volume, 2040-2090 (AF)	Estimated Confidence Interval (percent)	Confidence Interval Source	Average minus CI (AF)	Average plus CI (AF)
Groundwater Extraction and GWS Change in Storage	248,500	25%	Professional judgment based on historical calculations.	186,400	310,600
Total Inflows to GWS	250,900	25%	Professional judgment based on historical calculations.	188,200	313,600

Surface Water Available for Groundwater Recharge

Implementation of the GSP will require the Chowchilla Subbasin to be operated within its sustainable yield by 2040. To achieve this, GSAs may implement projects to restrict groundwater pumping or to increase groundwater recharge.

There are five potential sources of water available for groundwater recharge projects: Buchanan flood releases, Madera Canal flood releases, Eastside Bypass flows, additional CVP diversions, and water purchased from outside the subbasin.

Buchanan flood releases include designated flood releases from Buchanan Dam along the Chowchilla River and exclude irrigation releases to CWD. During the historical base period (1989-2014), Buchanan flood releases occurred during six of eight years classified as wet and one year classified as above normal by DWR's San Joaquin River Water Year Index. The average annual inflow volume during the historical base period was 61 taf during wet years and 2 taf during above normal years. Across the 1965-2015 projected dataset used to develop the 2019-2090 projected water budgets (historical hydrologic and water supply data, as described in Section 2.2.3.2), Buchanan flood releases are expected during 11 out of 18 wet years (averaging 46 taf per wet year) and during 2 out of 7 above normal years (averaging 2 taf per above normal year).

Madera Canal flood releases are comprised of flood releases to the Chowchilla Subbasin along Madera Canal (including Section 215 water[38], 16(b) water[39], or other sources of CVP yield determined by Reclamation to be available to its contractors). During the historical base period, Madera Canal flood releases occurred in 8 of 26 years. Seven of these years were classified as wet years (33 taf per year on average), while the remaining year was classified as above normal (6 taf per year). Madera Canal flood releases are projected to occur in an estimated 21 years out of 51 years of the 1965-2015 projected dataset used to develop the 2019-2090 projected water budgets.

Eastside Bypass flows include all water entering the subbasin along Fresno River and Chowchilla Bypass downstream of Madera Subbasin. During the historical base period, combined flood inflows from the Chowchilla Bypass and Fresno River[40] are available in eight wet years and three above normal years, averaging approximately 680 taf and 54 taf across all wet and above normal years, respectively. Eastside Bypass flows are projected to occur during wet and above normal years, which include 25 out of 51 total years of the 1965-2015 projected dataset used to develop the 2019-2090 projected water budgets. It is important to note that when water historically flows in the Chowchilla Bypass, the major contributor to Eastside Bypass flow, the duration of flow averages approximately 40 days.

The remaining potential sources of water available for groundwater recharge – additional CVP diversions and purchased water – are new sources of water that would be brought into the subbasin to supply GSP projects.

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[38] Reclamation Reform Act of 1982, Section 215 allows delivery of large, temporary, and non-storable water supplies to land that is otherwise ineligible to receive federal water.

[39] San Joaquin River Restoration Settlement, Paragraph 16(b): Recovered Water Account.

[40] The total historical available Fresno River flood inflows exclude appropriative water rights diversions and riparian diversions along Fresno River in Chowchilla Subbasin, which are considered unavailable to groundwater recharge projects.