





Colusa Groundwater Authority &
Glenn Groundwater Authority

Colusa Subbasin Groundwater Sustainability Plan

ANNUAL REPORT - DRAFT

APRIL 2022

COLUSA SUBBASIN

Colusa Subbasin
Groundwater Sustainability Plan

DRAFT
2022 Annual Report

For Water Year 2021
(October 2020 – September 2021)

April 2022

Prepared For

Colusa Groundwater Authority
Glenn Groundwater Authority

Prepared By

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List of Abbreviations

af	acre-feet
AG	Agricultural Land
AMSL	above mean sea level
ASCE	American Society of Civil Engineers
C2VSim-FG	fine-grid version of C2VSim
CASGEM	California Statewide Groundwater Elevation Monitoring
CCWD	Colusa County Water District
CDMWC	Colusa Drain MWC
cfs	cubic feet per second
CGA	Colusa Groundwater Authority
CIMIS	California Irrigation Management Information System
CVP	Central Valley Project
DE	Davids Engineering
DMS	Data Management System
DWD	Dunnigan Water District
DWR	California Department of Water Resources
E	evaporation
ET	evapotranspiration
ETaw	ET of applied water
ETpr	ET of precipitation
Fall 2021	During fall of calendar year 2021
GCID	Glenn-Colusa Irrigation District
GGA	Glenn Groundwater Authority
GIS	geographic information system
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
IM	Interim milestone
InSAR	Interferometric Synthetic Aperture Radar
LAFCO	Local Agency Formation Commission
MO	measurable objectives
MT	minimum thresholds
MW	Managed Wetlands
NAVD88	North American Vertical Datum of 1988
NV	Native Vegetation Land
OAWD	Orland-Artois Water District
OUWUA	Orland Unit Water Users' Association
P&G	Proctor and Gamble
PMAs	projects and management actions
RD108	Reclamation District 108
RMS	Representative monitoring sites
SCS-USDA	Soil Conservation Service (renamed Natural Resources Conservation Service)
SMC	Sustainable Management Criteria
Spring 2021	During spring of calendar year 2021
SWS	surface water system
T	crop transpiration
taf	thousands of acre-feet
TCCA	Tehama-Colusa Canal Authority
TCC	Tehama Colusa Canal
TNC	The Nature Conservancy
UR	Urban Land
USDA	U.S. Department of Agriculture
WMPP	Well Monitoring Pilot Program

Introduction

The California Code of Regulations Title 23 (23 CCR) §356.2 requires that Annual Reports be submitted to the California Department of Water Resources (DWR) by April 1 of each year following the adoption of the Groundwater Sustainability Plan (GSP). The Groundwater Sustainability Agencies (GSAs) in the Colusa Subbasin (Subbasin) adopted the Colusa Subbasin GSP in December 2021 and submitted the GSP to DWR in January 2022. This 2022 Annual Report is the first Annual Report for the Colusa Subbasin GSP, which is required to be submitted to DWR by April 1, 2022.

The 2022 Annual Report for the Colusa Subbasin GSP has been developed in compliance with all of the requirements of 23 CCR §356.2. This Annual Report describes conditions across the entire Colusa Subbasin and the efforts made toward GSP implementation by the GSAs and other proponents in the Colusa Subbasin during the current reporting period. The Colusa Subbasin is managed by two GSAs: the Colusa Groundwater Authority (CGA) GSA, which manages the Colusa and Yolo County portions of the Colusa Subbasin, and the Glenn Groundwater Authority (GGA) GSA, which manages the Glenn County portions of the Colusa Subbasin.

Information contained in this Annual Report includes:

- Groundwater elevation data from monitoring wells
- Contour maps and hydrographs of groundwater elevations
- Total groundwater extractions
- Surface water supply used, including for groundwater recharge or other in-lieu uses
- Total water use
- Change in groundwater storage
- Progress towards implementing the Colusa Subbasin GSP

The structure of the Annual Report generally follows the structure of the requirements outlined in 23 CCR §356.2.

This Annual Report provides basic information about the Colusa Subbasin plan area and presents technical information from water year 2016 (after the end of the historical water budget period reported in the Colusa Subbasin GSP) through the current reporting year (water year 2021). A water year is defined as the period between October 1 of the preceding year and September 30 of the current year, so water year 2021 includes the period from October 1, 2020 through September 30, 2021. Some information provided in this Annual Report is also reported after the end of water year 2021, including groundwater level measurements collected in Fall 2021 (after September 30, 2021) and implementation of projects, management actions, and other activities that occurred before April 1, 2022. It is noted that spring and fall groundwater level measurements are reported according to calendar year (i.e., Fall 2021 groundwater level measurements occurred in the fall of calendar year 2021, typically in September-November).

Also included with this Annual Report are appendices that contain the required groundwater maps and hydrographs that must be submitted with each Annual Report, as well as other general information describing conditions in the Colusa Subbasin and GSP implementation. The following appendices are located at the end of this Annual Report:

- **Appendix A.** Groundwater Elevation Contour Maps – Spring/Fall 2020.
- **Appendix B.** Groundwater Elevation Hydrographs for Groundwater Level RMS Wells.
- **Appendix C.** Maps of Annual Change in Groundwater Storage – 2015 through 2021.

The first months of GSP implementation in the Colusa Subbasin, like many others throughout California, has coincided with extreme drought conditions.[1] Ongoing management of the Colusa Subbasin under the GSP will follow an "adaptive management" strategy that involves active monitoring of groundwater conditions and addressing any challenges related to maintaining groundwater sustainability by scaling and implementing projects and management actions in a targeted and proportional manner in accordance with the needs of the Colusa Subbasin. Due to the short time period between the GSP submittal deadline (January 31, 2022) and the Annual Report submittal deadline (April 1, 2022), appreciable progress has only been made on those projects or management actions that were already being planned, developed, or implemented prior to the adoption and submission of the Colusa Subbasin GSP. The initial benefits and costs from the first full year of implementation of projects and management actions will be reported in the second Annual Report to be submitted in April 2023.

[1] The U.S. Drought Monitor (https://droughtmonitor.unl.edu/) is produced through a partnership between the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Center. Information for the State of California is available online at:
https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?CA.

Executive Summary (§356.2.a)

The Colusa Subbasin GSP was adopted by the CGA GSA and the GGA GSA in December 2021, and was submitted to DWR in January 2022 in fulfillment of the requirements established under SGMA. The full extent of the Colusa Subbasin is managed under the Colusa Subbasin GSP (**Figure ES-1**). Coordinated implementation of the Colusa Subbasin GSP is now underway, with the goal:

> *"…to maintain, through a cooperative and partnered approach, locally managed sustainable groundwater resources to preserve and enhance the economic viability, social well-being and culture of all Beneficial Uses and Users, without experiencing undesirable results."* (Colusa Subbasin GSP, Section 5.2)

Following adoption of the Colusa Subbasin GSP, 23 CCR §356.2 requires that GSAs submit Annual Reports to DWR by April 1 of each year to document the progress made in GSP implementation. This Annual Report is the first Annual Report for the Colusa Subbasin GSP. In accordance with 23 CCR §356.2, this Annual Report summarizes groundwater conditions and water use in the entire Colusa Subbasin, as well as the progress that has been made to implement projects and management actions and achieve interim milestones established in the GSP. Key data sources and findings from each section of the Annual Report are summarized below, and are described in fuller detail in the associated Annual Report section.

Groundwater Elevations (§356.2.b.1)

Groundwater level monitoring and groundwater elevations are described in **Section 1.1** of this Annual Report. Groundwater level monitoring data were assembled from online State of California databases for the entire available period of record. Data were collected from various sources, including the DWR Water Data Library and the California Statewide Groundwater Elevation Monitoring (CASGEM) Program.

During spring of calendar year 2021 (Spring 2021), groundwater elevations at available representative monitoring site (RMS) wells in the Subbasin ranged from -9.0 ft above mean sea level (AMSL) to 179.4 ft AMSL (mean groundwater elevation was 81.8 ft AMSL). During fall of calendar year 2021 (Fall 2021), groundwater elevations at available RMS wells in the Colusa Subbasin ranged from -49.1 ft AMSL to 173.9 AMSL (mean groundwater elevation of 69.6 ft AMSL).

Groundwater Elevation Contour Maps (§356.2.b.1.A)

Groundwater elevation contour maps are described in **Section 1.2** of this Annual Report. The Colusa Subbasin GSP documented existing and historical groundwater elevation conditions through the end of calendar year 2020. This Annual Report contains spring and fall groundwater elevation contour maps for calendar year 2020 (**Appendix A**) and calendar year 2021 (**Figures 1-2 and 1-3**). Spring contours are intended to represent seasonal high groundwater levels, while fall contours are intended to represent seasonal low groundwater levels. Data were assembled from all known and available groundwater level information in the Colusa Subbasin area.

Seasonal groundwater flow directions through the Colusa Subbasin in calendar year 2021 were consistent with those seen in calendar year 2020 and earlier; however, the groundwater gradients are lower and the overall depth to groundwater increased.

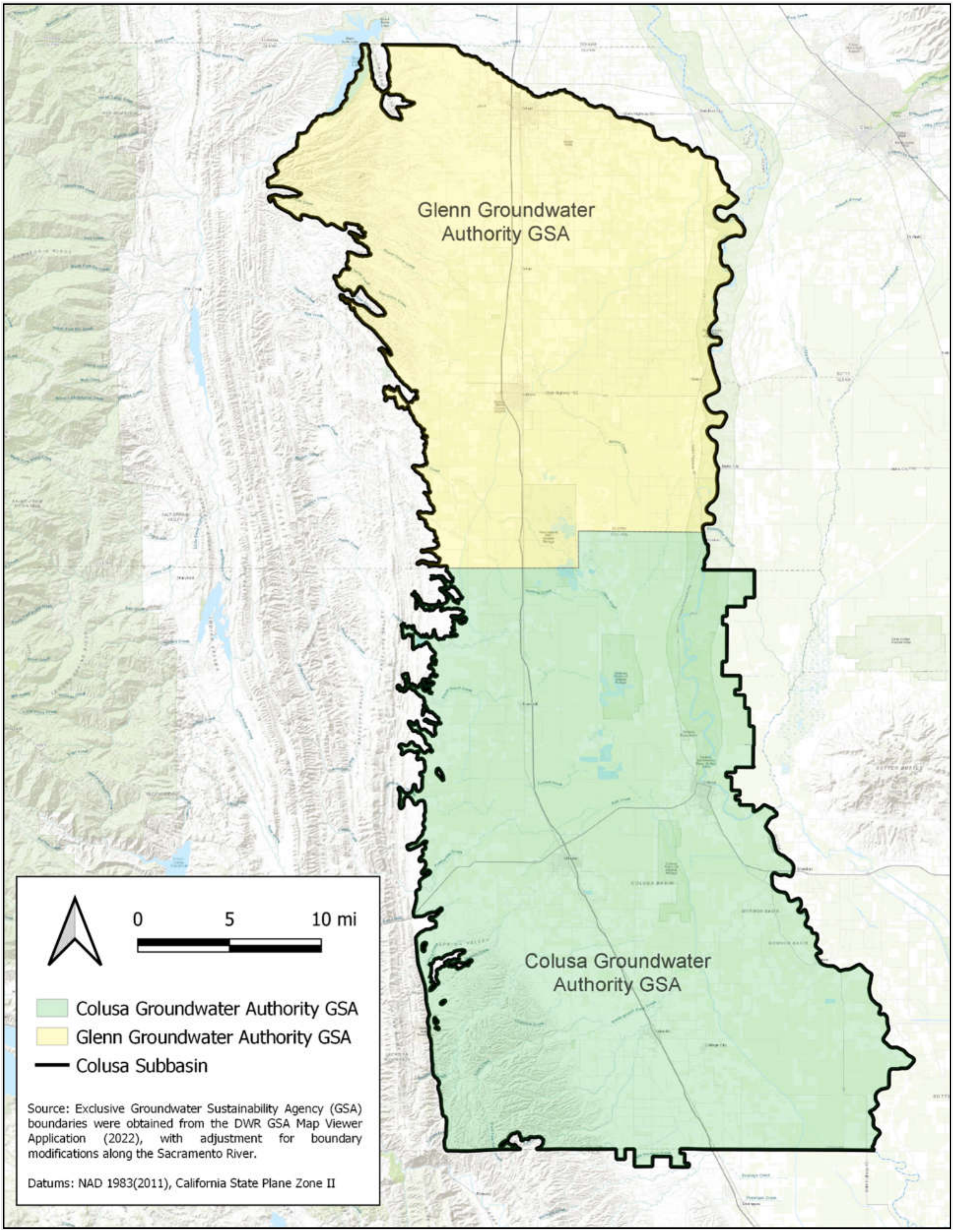

Figure ES-1. Map of Colusa Subbasin GSP Area and GSAs.[2]

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[2] Basin boundary modifications have been requested, but have not been approved as of March 2022. These updates, if approved, will be shown in future Annual Reports.

Groundwater Hydrographs (§356.2.b.1.B)

Groundwater hydrographs are described in **Section 1.3** and shown in **Appendix B** of this Annual Report. All available groundwater level monitoring data from RMS wells were used to prepare groundwater hydrographs for the entire period of record. Groundwater elevations have been decreasing in response to dry conditions beginning in 2007. In water year 2021, groundwater elevations throughout most of the Colusa Subbasin dropped to levels similar to, or lower than, water year 2015. Both of these water years were critically dry.

RMS wells within the northern portion of the Subbasin, near Orland and Artois, and RMS wells along the western margin of the Colusa Subbasin were impacted the most during water year 2021. RMS wells closer to the Sacramento River were more likely to exhibit stable or recovering groundwater levels (e.g., RMS 16N02W25B002M).

Groundwater Extractions (§356.2.b.2)

Groundwater extractions are summarized in **Section 3** of this Annual Report. Groundwater extraction in the Colusa Subbasin was either measured directly from flowmeters or was estimated as the volume of water needed to meet applied water demand after accounting for available surface water supplies. Flowmeter records were used when available; otherwise, groundwater extraction was estimated using the best available information (specific sources and methods are summarized in **Section 3**).

In total, an estimated 977,000 acre-feet (af) of groundwater was extracted for use within the Colusa Subbasin area during water year 2021. Of this total, the majority was extracted for agricultural use (933,000 af), while the remainder was extracted by managed wetlands (34,000 af) or for urban and domestic use (10,000 af).

Surface Water Supplies (§356.2.b.3)

Surface water supplies used or available for use are summarized in **Section 4** of this Annual Report. Surface water supplies available to certain entities within the Colusa Subbasin include surface water deliveries (Central Vally Project (CVP) supplies from the Tehama-Colusa Canal and the Sacramento River), water rights diversions, and riparian or other diversions of natural flows crossing the Colusa Subbasin. In this Annual Report, surface water supplies used or available for use are assumed to be the volume of surface water diverted and delivered by agencies and water rights users in the Colusa Subbasin. Total diversions are also reported. During water year 2021, approximately 1,014,000 af of surface water supplies were diverted by water users in the Colusa Subbasin, including approximately 986,000 af of CVP supplies and approximately 28,000 af of local supplies. Of that total, an estimated 918,000 af of surface water supplies were delivered (used or available for use) in the Colusa Subbasin in water year 2021, including approximately 895,000 af of CVP supplies and approximately 23,000 af of local supplies.

Total Water Use (§356.2.b.4)

Total water use is summarized in **Section 5** of this Annual Report. In this Annual Report, total water use is assumed to equal the total combined groundwater extractions (described in **Section 3**) and surface water supplies used or available for use (described in **Section 4**) in the Colusa Subbasin. During water year 2021, total water use in the Colusa Subbasin area was estimated to be 1,895,000 af. Of this total, slightly more than half came from groundwater while the remaining use came from surface water.

Change in Groundwater Storage (§356.2.b.5)

Change in groundwater storage is described in **Section 6** and shown in **Appendix C** of this Annual Report. Consistent with §354.18.b, annual changes in groundwater elevation were calculated for the principal aquifer between Spring 1980 and Spring 2021 based on the difference in annual spring groundwater elevations (representing seasonal high groundwater conditions).

Change in groundwater storage reported within the Colusa Subbasin GSP was estimated using the C2VSimFG-Colusa groundwater model, an integrated hydrologic flow model application created and used during GSP development. Due to uncertainty in the model and limitations in the ability to update the complete groundwater model for this Annual Report, an alternative method for determining change in groundwater storage was utilized for this Annual Report. Change in groundwater storage was estimated using a Thiessan polygon method. Annual change in groundwater storage was calculated based on change in measured spring-to-spring groundwater elevations multiplied by the area of the Thiessen polygon associated with each groundwater level RMS well and a storage coefficient of 0.1. Pre-2015 results using this method are comparable to the simulated change in storage outputs from the C2VSimFG-Colusa groundwater model.

Table ES-1 lists the spring-to-spring changes in groundwater storage for water years 2015 through 2021, as well as the cumulative change in groundwater storage over the 2015-2021 and 1980-2021 periods. A positive change in groundwater storage means that the volume of groundwater in storage increased, whereas a negative change in groundwater storage means that the volume of groundwater in storage decreased. Cumulative Spring 2015 to Spring 2021 change in groundwater storage was -589 thousand acre-feet (taf). Cumulative change in groundwater storage from Spring 1980 to Spring 2021 was -1,120 taf.

Table ES-1. Estimated Change in Groundwater Storage in the Primary Aquifer – Spring 2015 through Spring 2021

Analysis Time Period	Annual Change in Groundwater Storage (taf)	Cumulative Change in Groundwater Storage since Spring 2015-2016 (taf)
Spring 2015-2016	-161	-161
Spring 2016-2017	+376	+215
Spring 2017-2018	-238	-23
Spring 2018-2019	+221	+198
Spring 2019-2020	-369	-171
Spring 2020-2021	-418	-589

Interim Milestone Status (§356.2.c)

In the Colusa Subbasin GSP, interim milestones (IMs) were established to provide numerical metrics for the GSAs to track progress toward meeting the Subbasin's sustainability goal and to ensure that the Colusa Subbasin remains sustainable. To track groundwater conditions in relation to the Sustainable Management Criteria in the Colusa Subbasin GSP, the status of monitoring network sites are presented in relation to the IMs, Measurable Objectives (MOs), and Minimum Thresholds (MTs) defined in the GSP.

Review of the available groundwater elevation RMS well measurements for calendar year 2021 shows that half of the Spring 2021 groundwater elevation measurements and thirty-five of the Fall 2021 measurements (73 percent) were lower than their MO. This is attributed to drought conditions and associated reductions to surface water supplies and resulting groundwater demands in the Colusa Subbasin.

None of the Spring or Fall 2021 groundwater level measurements exceeded their MT values; however, groundwater levels at two RMS wells (14N03W14Q003M and 22N03W24E002M) exceeded their MT values during Summer 2021 before recovering above the MT values in Fall 2021. Primary areas of concern are the southern and northern portions of the Colusa Subbasin, in the greater Arbuckle and Orland areas, respectively. Domestic well users within these regions have also reported failed or failing wells due to lowering groundwater elevations.

As described in the Colusa Subbasin GSP, the MT for land subsidence is 0.5 feet per five years (i.e., averaged 0.1 foot per year), while the MO and IM for land subsidence is 0.25 feet per five years. As GSP implementation and monitoring has just begun, conclusive comparisons of land subsidence rates with these MTs, MOs, and IMs cannot be made until at least five years of data are collected. However, vertical displacement measured between June 2015 and October 2021, a six-year period, near Arbuckle amounted to about -2 feet, which is approximately three times the MT rate. An undesirable result for land subsidence is defined as “20% or more (13 of 63) monitoring sites (benchmarks) experience subsidence rates above the MT.” The benchmarks need to be resurveyed to confirm if an undesirable result has occurred. Primary areas of concern for land subsidence coincide with areas of concern for lowering of groundwater levels. The GSAs will continue monitoring land subsidence, particularly in the Arbuckle area, and will implement or facilitate measures to address land subsidence to avoid undesirable results.

Implementation of Projects and Management Actions (§356.2.c)

Projects and management actions are described in **Section 7** of this Annual Report. Due to the short time period between the GSP submittal deadline (January 31, 2022) and the Annual Report submittal deadline (April 1, 2022), appreciable progress has only been made on those projects or management actions that were already being planned, developed, or implemented prior to the adoption and submission of the Colusa Subbasin GSP. As of April 2022, noted progress has been made for five projects and management actions, including four direct or in-lieu recharge projects and one ongoing management action for urban water conservation. In total, an estimated 8,300 af of benefits to the Colusa Subbasin were achieved in water year 2021 from planned and ongoing projects and management actions.

Development of some projects that began prior to adoption and submittal of the Colusa Subbasin GSP are still underway, but may have not yet reached the point where benefits have been realized. Additional projects and management actions planned to start in 2022 are still in the early stages of implementation and have not progressed to the point where average annual benefits, average annual operating costs, or actual capital costs can be accurately quantified. The initial benefits and costs from the first year of implementation of these projects will be reported in the second Annual Report to be submitted in April 2023.

1 Groundwater Elevations (§356.2.b.1)

1.1 GROUNDWATER LEVEL MONITORING

This Annual Report provides an update on groundwater elevation conditions and presents the change in groundwater elevation conditions in the Colusa Subbasin since calendar year 2020. The Colusa Subbasin GSP documented existing and historical groundwater elevation conditions through the end of calendar year 2020.

The representative monitoring sites (RMS) currently include 48 well completions within the Colusa Subbasin. RMS wells are shown in **Figure 1-1**. The RMS wells are a mix of active supply and dedicated observation wells. For nested multiple completion observation wells, the completion that best represents the pumping depth of nearby water supply wells was selected as the RMS well. Of the 48 RMS wells, five were not monitored in spring of calendar year 2021 (Spring 2021) and six were not monitored in fall of calendar year 2021 (Fall 2021). Three of the RMS wells have not been monitored since 2017 or earlier for unknown reasons. Notes and issues regarding the RMS wells are documented in **Section 7.2, Interim Milestone Status.**

Groundwater elevations measured in Spring and Fall 2021 are listed in **Table 1-1**. Groundwater elevation conditions prior to Spring 2020 were discussed in the Colusa Subbasin GSP. During Spring 2021, groundwater elevations at available RMS wells in the Subbasin ranged from -9.0 feet above mean sea level (AMSL) to 179.4 feet AMSL (mean groundwater elevation of 81.8 feet AMSL). During Fall 2021, groundwater elevations at available RMS wells in the Colusa Subbasin ranged from -49.1 feet AMSL to 173.9 feet AMSL (mean groundwater elevation of 69.6 feet AMSL).

Groundwater elevations were obtained from various State of California online databases, including the DWR Water Data Library and the CASGEM Program.

1.2 GROUNDWATER ELEVATION CONTOUR MAPS (§356.2.B.1.A)

Spring and Fall 2021 groundwater elevation contour maps are provided for the Primary Aquifer in **Figures 1-2 and 1-3**, respectively. Spring and Fall 2020 groundwater elevation contour maps from the Colusa Subbasin GSP are included in **Appendix A** for reference. Spring contours are intended to represent seasonal high groundwater levels, while fall contours are intended to represent seasonal low groundwater levels. Groundwater elevation contours were created by applying an iterative finite difference interpolation technique to available groundwater elevation data from RMS wells using the ArcGIS Topo to Raster tool. Questionable measurements were excluded, and minor refinements were made to the contours based on professional judgement.

Seasonal groundwater flow directions through the Colusa Subbasin in calendar year 2021 were consistent with those seen in calendar year 2020 and earlier; however, the groundwater gradients are lower and the overall depth to groundwater increased.

Regionally, groundwater flowed from the north and west towards the south and east. Cones of depression caused by groundwater pumping and/or a reduction in recharge resulted in locally varying flow regimes, which can be seen in the areas around Orland and Arbuckle in both the Spring and Fall 2021 groundwater elevation contour maps (**Figures 1-2 and 1-3**, respectively). These depressions in groundwater elevations are also evident in the Spring and Fall 2020 contours, but to a much lesser degree (**Appendix A**).

Groundwater gradients in calendar year 2021 were generally less steep than in calendar year 2020. This is most evident in the northern portion of the Subbasin. In Spring 2020, groundwater elevations near Orland ranged from approximately 80 feet relative to the North American Vertical Datum of 1988 (NAVD88) to 240 feet NAVD88. In Spring 2021, groundwater elevations ranged between approximately 80 to 170 feet NAVD88 over the same area.

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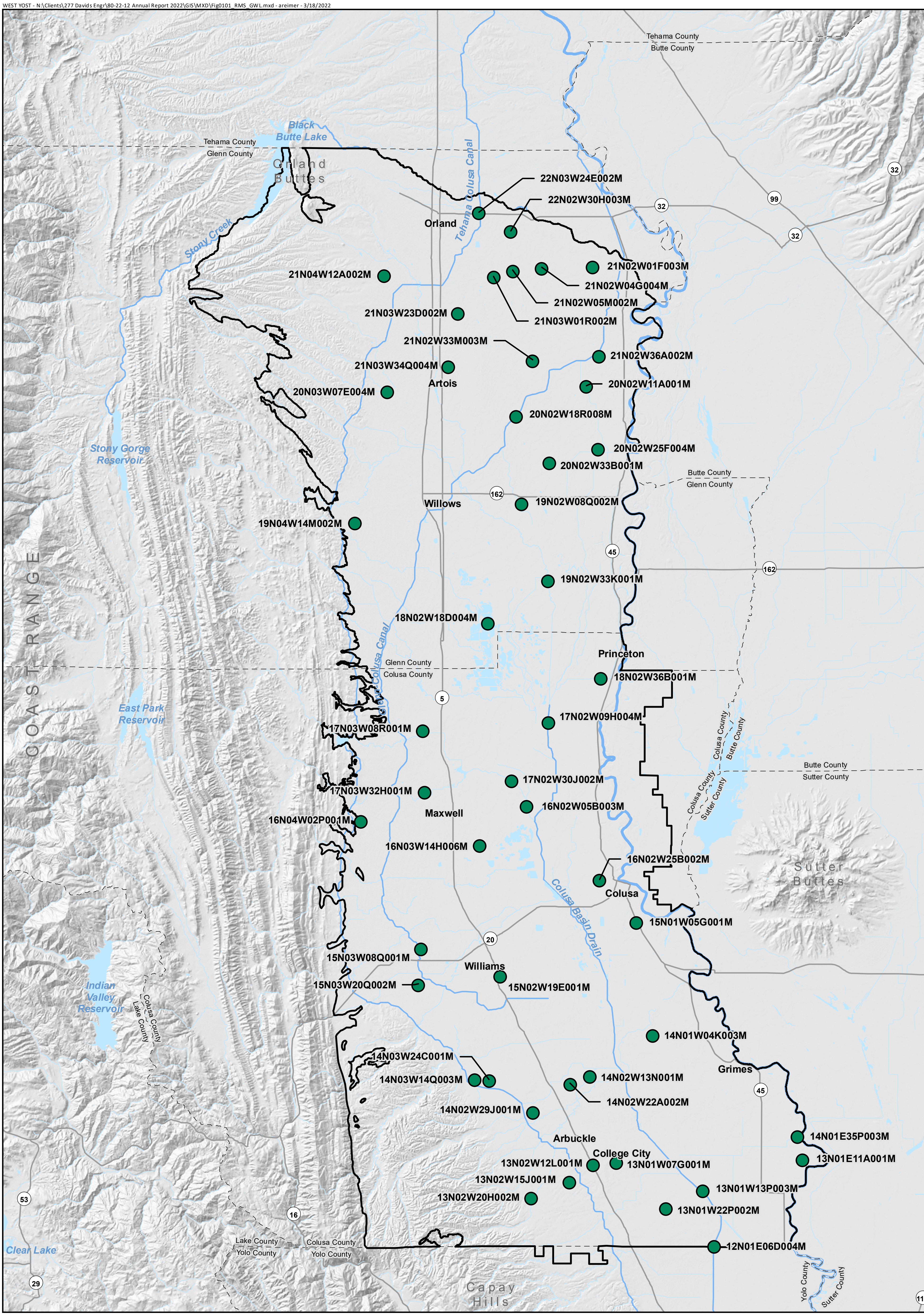


Groundwater Elevation Representative Monitoring Well

Colusa Subbasin

N

0 2.5 5

Scale in Miles
1 inch = 5 miles

Datum: NAD 83 California State Plane Zone II, feet.

Figure 1-1

Representative Groundwater Level Monitoring Network

Colusa Groundwater Authority
Glenn Groundwater Authority
Colusa Subbasin Annual Report 2022

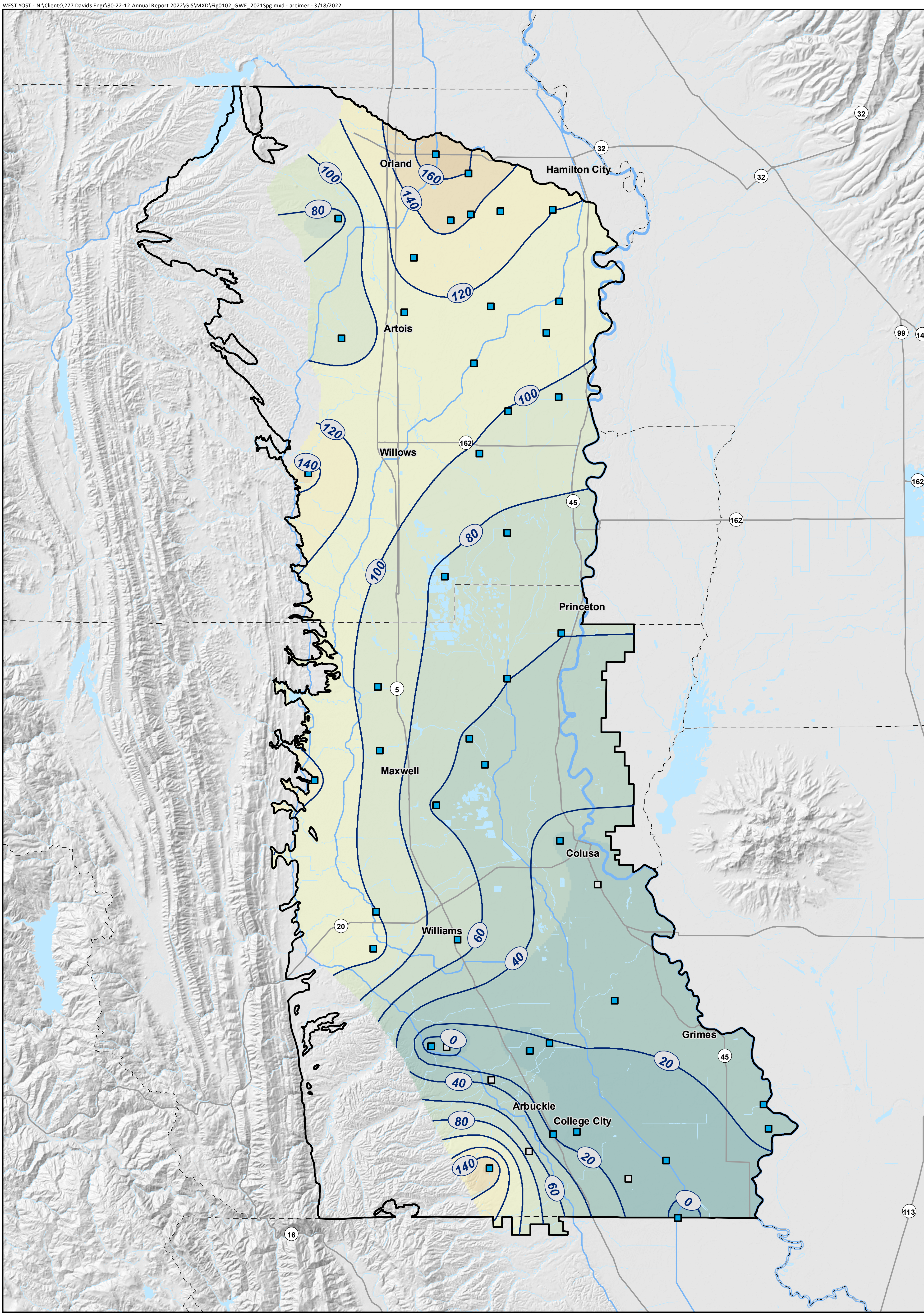
Table 1-1. Summary of Groundwater Level RMS Well Information and Measurements During Annual Report Year (2021).

State Well Number	Ground Surface Elevation (feet msl)[1]	Completed Well Depth (feet bgs)[2]	Screen Interval(s) (Top-Bottom) (feet bgs)	Spring 2021 GWE (feet msl)	Date of Spring 2021 GWE (feet msl)	Fall 2021 GWE (feet msl)	Date of Fall 2021 GWE (feet msl)	GSA
12N01E06D004	27.94	298	275-285	-5.62	3/17/2021	-19.56	10/12/2021	CGA
13N01E11A001	31.8	145	136-158	26.69	3/18/2021	23.70	10/12/2021	CGA
13N01W07G001	90.47	180	108-180	4.37	3/16/2021	-22.33	10/12/2021	CGA
13N01W13P003	32.23	355	271-278	0.39	3/17/2021	-5.81	10/12/2021	CGA
13N01W22P002	60.46	236	196-236	Not Monitored	Not Monitored	Not Monitored	Not Monitored	CGA
13N02W12L001	135.49	Not Available	Not Available	6.69	3/24/2021	-40.31	10/13/2021	CGA
13N02W15J001	212.52	362	270-362	Not Monitored	Not Monitored	Not Monitored	Not Monitored	CGA
13N02W20H002	342.58	320	200-260, 300-320	177.68	3/16/2021	173.88	10/14/2021	CGA
14N01E35P003	46.88	275	135-145, 215-225	27.99	3/18/2021	23.72	10/12/2021	CGA
14N01W04K003	37.43	73	46-70	27.03	3/18/2021	23.03	10/12/2021	CGA
14N02W13N001	62.45	392	104-392	20.35	3/23/2021	6.85	10/13/2021	CGA
14N02W22A002	84	1050	1020-1030	8.01	3/16/2021	-28.10	10/12/2021	CGA
14N02W29J001	162.5	412	119-143, 152-158, 176-182, 198-208, 215-239, 264-276, 307.5-319.5, 334.5-349.5	Not Monitored	Not Monitored	Not Monitored	Not Monitored	CGA
14N03W14Q003	172.52	685	390-480, 500-590, 614-685	-8.98	3/16/2021	-49.08	10/14/2021	CGA
14N03W24C001	172.51	312	292-312	Not Monitored	Not Monitored	Not Monitored	Not Monitored	CGA
15N01W05G001	47.42	140	75-140	Not Monitored	Not Monitored	Not Monitored	Not Monitored	CGA

State Well Number	Ground Surface Elevation (feet msl)[1]	Completed Well Depth (feet bgs)[2]	Screen Interval(s) (Top-Bottom) (feet bgs)	Spring 2021 GWE (feet msl)	Date of Spring 2021 GWE (feet msl)	Fall 2021 GWE (feet msl)	Date of Fall 2021 GWE (feet msl)	GSA
15N02W19E001	87.46	334	162-182, 198-206, 262-274, 290-294, 310-334	72.91	3/18/2021	65.11	10/14/2021	CGA
15N03W08Q001	116.26	350	30-130, 250-350	100.58	3/30/2021	109.58	10/14/2021	CGA
15N03W20Q002	128.56	170	130-160	114.06	3/16/2021	110.74	10/14/2021	CGA
16N02W05B003	65	301	174-184, 246-256	53.01	3/17/2021	37.42	10/13/2021	CGA
16N02W25B002	55.42	274	254-274	37.92	3/18/2021	Not Monitored	Not Monitored	CGA
16N03W14H006	65.7	378	295-305	54.40	3/18/2021	39.62	10/13/2021	CGA
16N04W02P001	162.53	203	112-203	126.32	3/16/2021	135.73	10/14/2021	CGA
17N02W09H004	67	302	250-260	60.11	3/17/2021	42.21	10/31/2021	CGA
17N02W30J002	63.43	159	157-159	56.23	3/18/2021	41.63	10/14/2021	CGA
17N03W08R001	107.46	130	125-130	91.36	8/5/2021	89.96	10/14/2021	CGA
17N03W32H001	100.47	112	68-72, 104-112	93.77	8/4/2021	93.57	10/14/2021	CGA
18N02W18D004	85.43	266	246-256	73.19	3/18/2021	35.05	10/14/2021	GGA
18N02W36B001	75.4	410	88-128, 195-225, 240-340	60.20	3/18/2021	55.80	10/13/2021	CGA
19N02W08Q002	108.36	228	208-218	98.52	3/16/2021	82.48	10/19/2021	GGA
19N02W33K001	87.41	260	160-260	71.11	8/6/2021	57.01	10/14/2021	GGA
19N04W14M002	185.83	65	45-55	145.78	3/19/2021	142.82	10/14/2021	GGA
20N02W11A001	125.4	90	70-90	112.27	3/18/2021	113.40	10/13/2021	GGA
20N02W18R008	131.38	201	140-150, 70-180	115.10	3/18/2021	114.59	10/13/2021	GGA
20N02W25F004	102.2	85	55-65	96.75	3/18/2021	95.16	10/13/2021	GGA

State Well Number	Ground Surface Elevation (feet msl)[1]	Completed Well Depth (feet bgs)[2]	Screen Interval(s) (Top-Bottom) (feet bgs)	Spring 2021 GWE (feet msl)	Date of Spring 2021 GWE (feet msl)	Fall 2021 GWE (feet msl)	Date of Fall 2021 GWE (feet msl)	GSA
20N02W33B001	105.41	320	100-120, 200-320	98.91	3/18/2021	98.09	10/13/2021	GGA
20N03W07E004	179.17	138	118-128	88.3	3/19/2021	68.85	10/12/2021	GGA
21N02W01F003	161.84	124	109-119	120.09	3/16/2021	107.74	10/13/2021	GGA
21N02W04G004	178.41	289	165-175, 269-279	127.57	3/16/2021	101.43	10/13/2021	GGA
21N02W05M002	188.93	153	122-132	141.35	3/16/2021	115.02	10/13/2021	GGA
21N02W33M003	149	171.1	140-150	114.49	3/16/2021	106.79	10/12/2021	GGA
21N02W36A002	135.39	145	120-140	106.69	3/18/2021	102.19	10/13/2021	GGA
21N03W01R002	203.32	255	235-245	146.35	3/16/2021	118.57	10/13/2021	GGA
21N03W23D002	204.76	191.5	142-152, 160-170	139.15	3/17/2021	122.62	10/12/2021	GGA
21N03W34Q004	166.65	80	60-70	106.57	3/17/2021	97.42	10/12/2021	GGA
21N04W12A002	247.88	278	247-257	68.66	3/17/2021	42.21	10/12/2021	GGA
22N02W30H003	204.43	275	130-140, 150-160, 250-260	160.42	3/16/2021	121.36	10/11/2021	GGA
22N03W24E002	230.51	195	130-150, 170-180	179.38	3/15/2021	144.93	10/12/2021	GGA

[1] Elevations are in reference to mean sea level (msl).
[2] Depths are below ground surface (bgs).



Groundwater Elevation Representative Monitoring Well Used for Contouring

Groundwater Elevation Representative Monitoring Well Not Used for Contouring

Groundwater Elevation Contour (20-Foot Interval)

Colusa Subbasin

Groundwater Elevation (feet)

160 - 180
140 - 160
120 - 140
100 - 120
80 - 100
60 - 80
40 - 60
20 - 40
0 - 20
-20 - 0

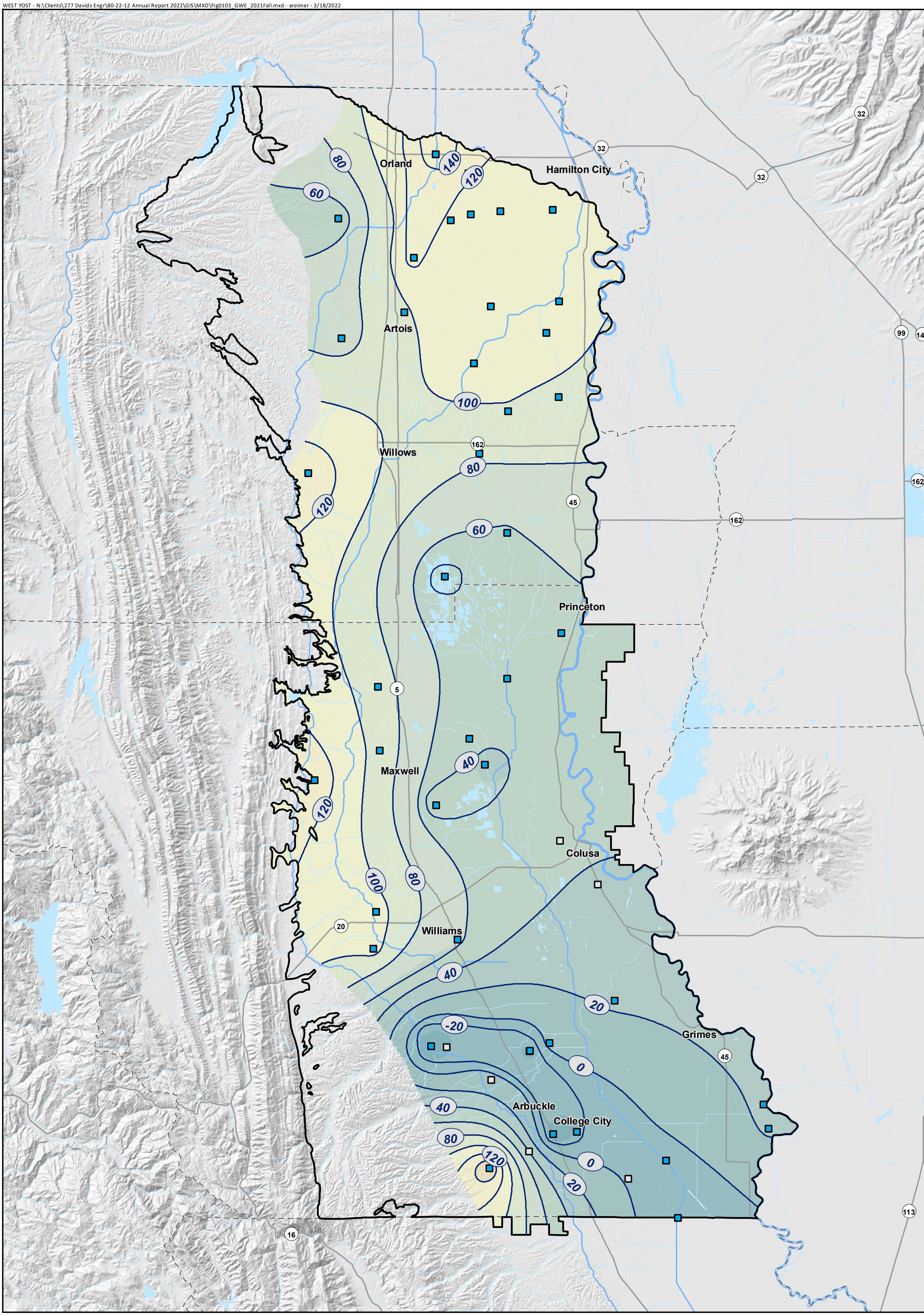
Scale in Miles: 0, 2.5, 5
1 inch = 5 miles

Datum: NAD1983 California State Plane Zone II, feet. North American Vertical Datum 1988, feet.

Figure 1-2

Groundwater Elevation Contours Spring 2021

Colusa Groundwater Authority
Glenn Groundwater Authority
Colusa Subbasin Annual Report 2022



Groundwater Elevation Representative Monitoring Well Used for Contouring

Groundwater Elevation Representative Monitoring Well Not Used for Contouring

Groundwater Elevation Contour (20-Foot Interval)

Colusa Subbasin

Groundwater Elevation (feet)

160 - 180	80 - 100	0 - 20
140 - 160	60 - 80	-20 - 0
120 - 140	40 - 60	-40 - -20
100 - 120	20 - 40	

N

0 2.5 5
Scale in Miles
1 inch = 5 miles

Datum: NAD1983 California State Plane Zone II, feet. North American Vertical Datum 1988, feet.

Figure 1-3

Groundwater Elevation Contours Fall 2021

Colusa Groundwater Authority
Glenn Groundwater Authority
Colusa Subbasin Annual Report 2022

1.3 GROUNDWATER HYDROGRAPHS (§356.2.B.1.B)

Groundwater levels typically fluctuate seasonally between and within water years. Groundwater fluctuations are particularly noticeable in groundwater dependent areas or where/when groundwater is relied upon during drought years to compensate for reductions in surface water supplies. RMS wells are monitored two to three times per year, typically in spring, fall, and/or summer.

Seasonal fluctuations of groundwater levels occur primarily in response to groundwater pumping and recovery but can also be affected by land and water use activities (such as rice flood-up), recharge, and natural discharge. Precipitation, applied irrigation water, managed aquifer recharge projects, local streams, rivers, and canals are all likely sources of groundwater recharge in the Colusa Subbasin. Groundwater pumping, which typically occurs from April to September, is the predominant contributor to groundwater discharge. Interconnected surface waters throughout the Subbasin may be gaining or losing, depending on groundwater and surface water flow conditions. Consequently, groundwater levels are usually highest in the spring and lowest during the irrigation season in the summer months; however, the timing and spatial distribution of the above-mentioned events and activities may result in localized impacts to the typical seasonal trend. Fall groundwater measurements (usually measured in October) provide an indication of groundwater conditions after the primary irrigation season and usually before winter flood-up for rice decomposition and wetlands habitat. In rice growing areas, summer groundwater levels can be relatively high compared to spring and fall levels due to field flooding using surface water supplies.

Groundwater elevation hydrographs for each RMS well identified in the Colusa Subbasin GSP are presented in **Appendix B**. The hydrographs include the sustainability management criteria (SMC), SMC rationale, and water year index and type. The Spring and Fall 2021 water levels measured at each RMS well are presented in **Table 1-1**.

Groundwater elevations have been decreasing in response to dry conditions beginning in 2007. In water year 2021, groundwater elevations throughout most of the Colusa Subbasin dropped to levels similar to, or lower than, water year 2015. Both of these water years were critically dry.

RMS wells within the northern portion of the Subbasin, near Orland and Artois, and RMS wells along the western margin of the Colusa Subbasin were impacted the most during water year 2021. This trend can also be seen in the groundwater elevation contour maps (**Figures 1-2 and 1-3**). RMS wells closer to the Sacramento River or near the wildlife refuges were more likely to exhibit stable or recovering groundwater levels (e.g., RMS 16N02W25B002M).

2 Boundary Water Budget Approach for Quantifying Groundwater Extraction, Surface Water Supplies, and Total Water Use

In fulfillment of the Annual Report requirements, a boundary water budget approach was used to facilitate quantification of groundwater extraction, surface water supply use and availability, and total water use in the Colusa Subbasin. This section describes the structure, general data sources, and uncertainties of the boundary water budget.

2.1 BOUNDARY WATER BUDGET APPROACH

Water supply and water use in the Colusa Subbasin were quantified for this Annual Report using the best available data sources and information. Where available, groundwater extraction and surface water supplies were quantified directly from measured and reported groundwater pumping, surface water diversions, and deliveries data. However, much of the water use in the Colusa Subbasin is not measured or available, including groundwater extraction from many privately owned pumps subbasin-wide. To quantify these unmeasured water uses, a boundary water budget approach was applied.

A water budget is defined as an accounting of water flowing into and out of a defined volume[3] over a specified period of time. During development of the Colusa Subbasin GSP, the C2VSimFG-Colusa groundwater model was used to prepare water budgets for the Colusa Subbasin that characterized historical, current, and projected water supply and water use conditions. For this Annual Report, a boundary water budget was prepared for water use sectors in the Colusa Subbasin during the period between water year 2016 (after the end of the historical water budget period described in the GSP) and the current reporting year (water year 2021), as required in 23 CCR §356.2. Key inflows and outflows from the boundary water budget were quantified and compared with results of the C2VSimFG-Colusa during the historical water budget period (1990-2015), allowing verification of the consistency between the approach used for the Annual Report and the approach used in the Colusa Subbasin GSP.

The boundary water budget was prepared for water use sectors in the Colusa Subbasin Surface Water System (SWS). The SWS represents the land surface down to the bottom of the plant root zone, within the lateral boundaries of the Colusa Subbasin. The SWS was further 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 §351(al)). Across the Colusa Subbasin, the water use sector accounting centers include Agricultural Land (AG), Urban Land (UR) (including urban, industrial, rural residential, and semi-agricultural areas), Native Vegetation (NV), and Managed Wetlands (MW) areas. To meet the Annual Report requirements, groundwater extraction and total water use were tracked by water use sector, and surface water supplies and total water use were tracked by water source type (e.g., Central Valley Project supplies, local supplies, etc.). The boundary water budget approach resulted in all water budget components required to quantify groundwater extraction, surface water supplies, and total water use.

[3] Where 'volume' refers to a space with length, width and depth properties, which for purposes of this Annual Report refers to the Colusa Subbasin land surface area and root zone in each water use sector.

2.2 GENERAL DATA SOURCES

The data sources, calculation procedures, and results pertaining specifically to quantification of groundwater extraction, surface water supplies, and total water use are described in the respective sections later in this Annual Report. General data sources and methods used to support the boundary water budget approach are summarized below.

2.2.1 Evapotranspiration

Evapotranspiration (ET), or consumptive water use, is the major driver of water use in the Colusa Subbasin, particularly in the agricultural water use sector. In this context, consumptive water use is defined as "*the part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment*" (ASCE, 2016). In many cases, total consumptive water use is generally equivalent to the combined evaporation (E) and crop transpiration (T), together referred to as ET. Unlike deep percolation, runoff, or infiltration of water into the groundwater system, ET is water that cannot be recovered or directly reused in the Colusa Subbasin.

For this Annual Report, ET was quantified from remote sensing analyses available through OpenET, a multi-agency web-based geospatial information system (GIS) utility that quantifies ET using satellite imagery. While OpenET is a new utility, the underlying methodologies to quantify ET apply a variety of well-established modeling approaches that are widely used in government and research. The OpenET modeling approaches are also similar to the approaches used to quantify ET in the C2VSimFG-Colusa groundwater model used in GSP development. OpenET results are available in the Colusa Subbasin with a spatial resolution of 30 x 30 square meters (approximately 0.22 acres), allowing easily scalable ET quantification (**Figure 2-1**). Additional information about the OpenET team, data sources, and methodologies are available at: https://openetdata.org/.

Agricultural ET in the Colusa Subbasin was quantified on a monthly timestep over the 2016-2021 period using the OpenET ensemble model, representing the average ET of all models after excluding outlying data points. This approach results in ET values that represent the average "actual ET" in the Colusa Subbasin, accounting for actual changes in water use over time due to irrigation practices, cropping changes, and other characteristics observed on the land surface. For agricultural areas in the Colusa Subbasin, monthly ET rates were compared to ET rates from the C2VSimFG-Colusa model over a period with similar hydrology and cropping, and were found to be within 1-2 percent agreement, on average (**Figure 2-2**).

For urban areas, ET was also calculated using OpenET data. However, urban water uses were ultimately quantified based on population and per capita water use data (described in **Section 3**). Thus, these ET values were not directly used in this Annual Report.

For native vegetation and managed wetlands areas, OpenET data were found to diverge more significantly from ET inputs to the C2VSimFG-Colusa model. In those areas, ET was estimated for this Annual Report similar to the GSP analyses through the "crop-coefficient – reference Crop ET" method. In this approach, ET is calculated for a reference crop under local weather conditions and is then extrapolated and adjusted to other land uses using local crop-specific "crop coefficients" (ASCE, 2016). A monthly aggregate crop coefficient was calculated for each land use type from the C2VSimFG-Colusa model inputs, and was then applied to the reference ET values reported from nearby weather stations reported by the California Irrigation Management Information System (CIMIS). This approach was used to provide better consistency between water use quantified in the GSP analyses and water use quantified in this Annual Report. The best methodology for quantifying ET in native vegetation and managed wetland areas will be assessed in subsequent analyses moving forward and documented to the extent applicable in subsequent annual reports and/or the five-year update.

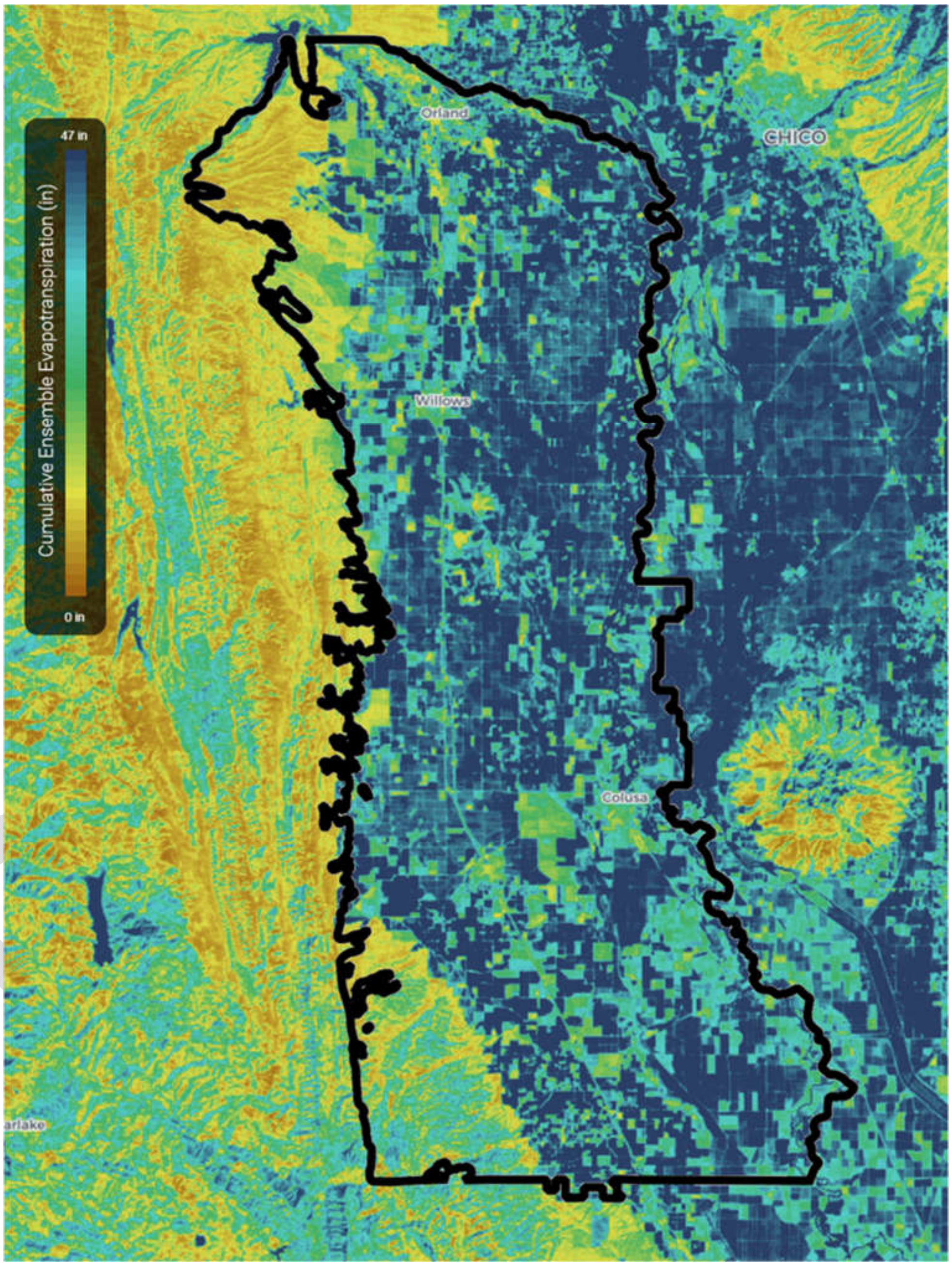


Figure 2-1. Sample OpenET Data in Areas Within and Surrounding the Colusa Subbasin, 2020 (Source: https://openetdata.org/, with Overlay of Colusa Subbasin Boundaries).

In all cases, total ET was then parsed into the portion derived from applied water and irrigation (referred to as ET of applied water, or ET_{aw}) and the portion derived from precipitation (referred to as ET of precipitation, or ET_{pr}) using available spatial precipitation data, soil data, and typical crop root characteristics in the Colusa Subbasin. ET_{pr} was quantified first on a monthly timestep following a method developed by the United States Department of Agriculture - Soil Conservation Service (USDA-SCS), as described in Part 623 of the National Engineering Handbook (USDA-SCS, 1993). ET_{aw} was quantified as the remaining portion of total ET, after accounting for ET_{pr}.

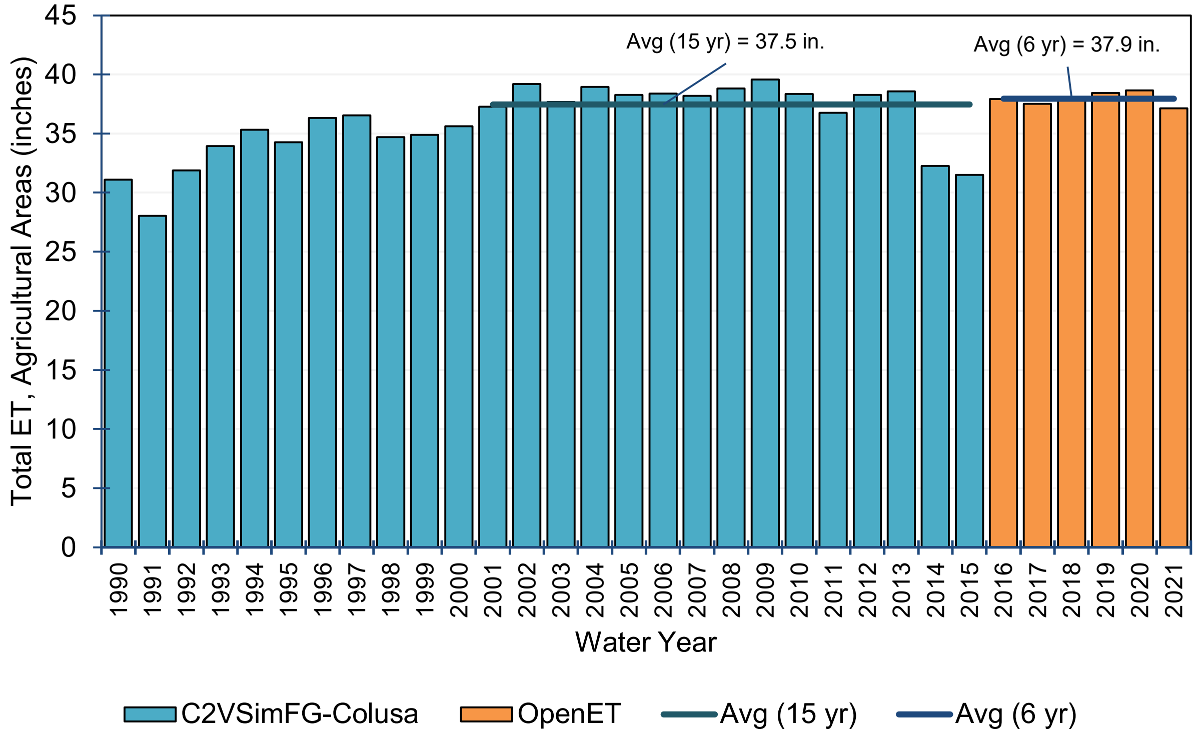


Figure 2-2. Comparison of Total ET in Agricultural Areas, from C2VSimFG-Colusa (GSP Analyses) and OpenET (Annual Report Analyses).

2.2.2 Land Use

Areas in each water use sector were identified from the most recent and reliable spatial land use data available for that sector. These areas were used to determine the total area where water demand in that sector may have occurred, and where measured or estimated water supplies may have been applied. These land use data sources and applications were similar to those used in development of the Colusa Subbasin GSP.

In the agricultural and urban water use sectors, land use was summarized from the Land IQ spatial land use database for water year 2018, available through DWR. In the boundary balance approach, agricultural and urban land uses represent the aggregation of all land use types in that sector in 2018. Notably, some shifts in land use across water use sectors likely occurred between 2018 and 2021 (e.g., native vegetation converted to agricultural land, or agricultural land converted to urban). Newer spatial land use data will be incorporated as it is available.

Land use in the managed wetlands water use sector was identified within the boundaries of the three National Wildlife Refuges in the Colusa Subbasin: the Sacramento National Wildlife Refuge, the Delevan National Wildlife Refuge, and the Colusa National Wildlife Refuge. Managed wetlands areas are predominantly found within these National Wildlife Refuges. Some additional managed wetlands areas were also considered to match the total managed wetlands area identified from GSP analyses in 2015, as 2015 and 2021 were determined to have similar hydrology, water supply, and water use conditions.

Land use in the native vegetation water use sector is represented as the difference of all other water use sectors in the Colusa Subbasin.

3 Groundwater Extraction (§356.2.b.2)

This section summarizes the measurement methods, accuracy, and volumes of groundwater extraction in the Colusa Subbasin for the current reporting year (2021).

3.1 QUANTIFICATION AND ACCURACY

Groundwater extraction in the Colusa Subbasin was either measured directly from flowmeters or was estimated as the volume of water needed to satisfy applied water demand (i.e., ET_{aw} or per capita water use requirements) after accounting for available surface water supplies. Flowmeter records were used when available. Otherwise, groundwater extraction was estimated using the best available information to characterize water use requirements in the Colusa Subbasin. Specific data sources and methods are described in **Section 3.2**, below. **Table 3-1** summarizes groundwater extraction in 2021 and the associated measurement methods, by water use sector. **Table 3-2** summarizes the total groundwater extraction by water use sector in the Colusa Subbasin between water year 2016 (following the historical water budget period in the Colusa Subbasin GSP) and water year 2021 (the current reporting year).

Figure 3-1 provides a map of the 2021 total groundwater extraction volumes and depths in each water use sector in the Colusa Subbasin. Notably, this figure illustrates the average depth of groundwater extraction over the entire gross area of each water use sector from available spatial land use data. In the agricultural and urban water use sectors, these aggregations include all land use types (e.g., all crops) in that sector in 2018, as identified from Land IQ mapping. Some shifts in land uses may have occurred between 2018 and 2021 that are not captured in these maps (e.g., native vegetation converted to agricultural land, or agricultural land converted to urban). However, the OpenET data used to estimate ET in agricultural areas (described in **Section 2.2**) account for actual water use conditions in 2021, including changes due to cropping, irrigation practices, and other factors that may not be captured in the Land IQ 2018 data. Therefore, estimates of total water use and groundwater extraction are not expected to be significantly impacted by changes in land use within each water use sector (e.g., cropping changes). Newer and more refined spatial land use data will be incorporated as it is available.

Figure 3-1 also provides a map of areas in the Colusa Subbasin with known access to surface water supplies. Groundwater extraction is quantified and reported in this Annual Report in aggregate by water use sector, so the precise location of groundwater extraction is neither verified nor indicated in **Figure 3-1**. However, it is expected that groundwater pumping would generally be higher in areas of the Colusa Subbasin without access to surface water, and generally lower in areas of the Colusa Subbasin with access to surface water.

Table 3-1. Groundwater Extraction Volumes and Measurement Methods by Water Use Sector, and Uncertainty (2021).

Water Use Sector	Groundwater Extraction, 2021 (acre-feet, rounded)	Measurement Method	Description
Agricultural	933,000	Estimate	Estimated from boundary water budget (based on land use, ET, and surface water supplies)
Urban	6,200	Estimate	Estimated from boundary water budget (based on population and per capita water use requirements)
	4,030	Direct	Flowmeter records
Managed Wetlands	34,000	Estimate	Estimated from boundary water budget (based on land use, ET, surface water supplies, and ponding water use requirements from GSP analyses)
Native Vegetation	-	Estimate	No noted groundwater extraction for native vegetation, per GSP analyses
Colusa Subbasin	**Groundwater Extraction, 2021 (acre-feet, rounded)**	**Estimated Uncertainty**	**Uncertainty Source**
Total	977,200	20%	Volume-weighted combined uncertainty of water budget estimates (approximately 20%) and flowmeter records (approximately 5%)

Table 3-2. Groundwater Extractions, by Water Use Sector (acre-feet, rounded).

Water Year (Type)	Agricultural	Urban[1]	Managed Wetlands	Native Vegetation	Total
2016 (D)	598,000	9,500	24,000	-	631,500
2017 (W)	542,000	9,700	21,000	-	572,700
2018 (BN)	566,000	9,800	26,000	-	601,800
2019 (W)	611,000	9,600	22,000	-	642,600
2020 (D)	723,000	10,200	27,000	-	760,200
2021 (C)	933,000	10,200	34,000	-	977,200
Average (2016-2021)	662,000	9,800	26,000	-	697,800

[1] Includes urban, industrial, rural residential, and semi-agricultural areas.

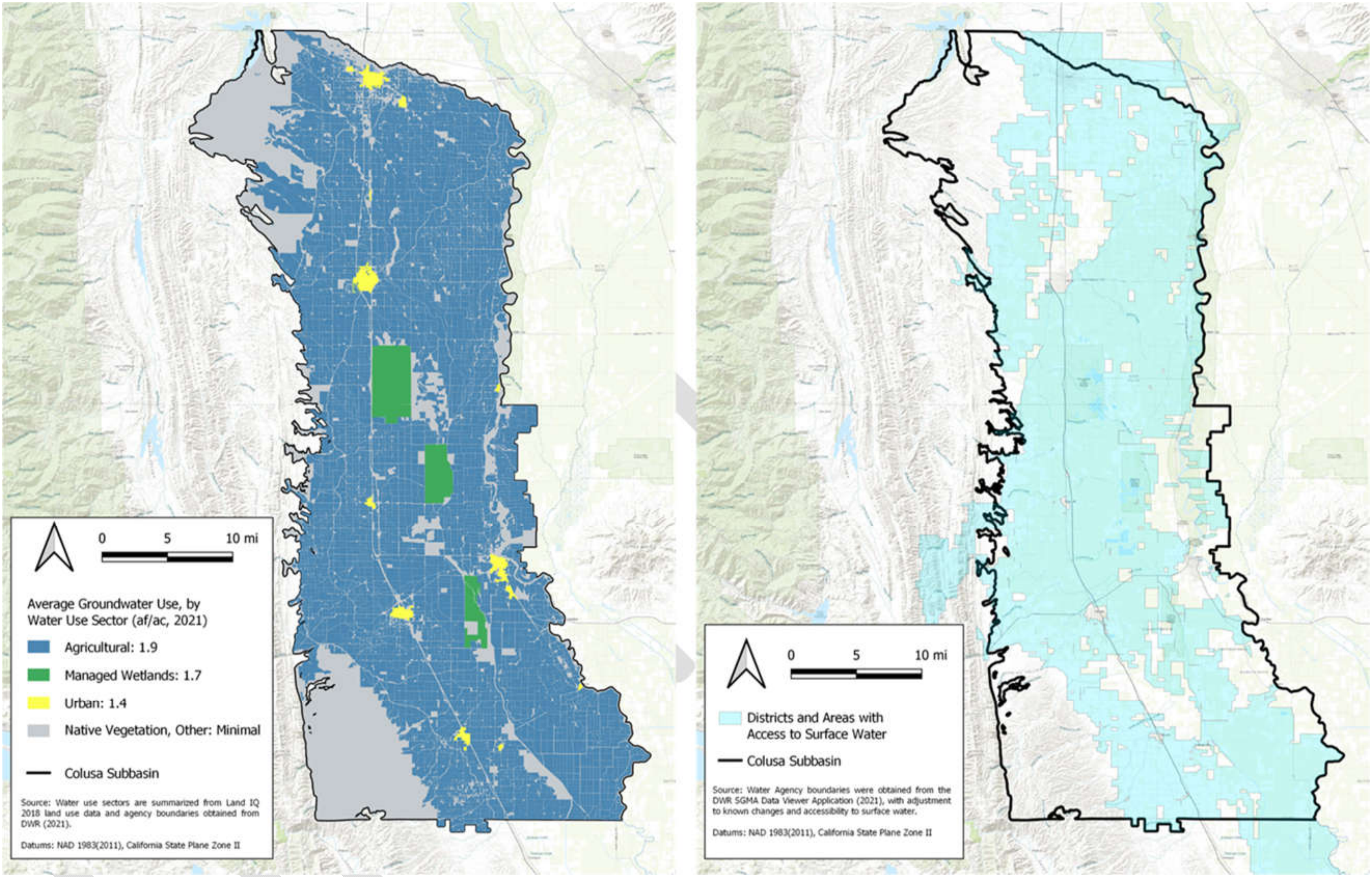


Figure 3-1. Total Groundwater Extraction Volumes and Depths over Each Water Use Sector, and Areas of the Colusa Subbasin with Access to Surface Water.*

**Agricultural and urban areas shown are based on the 2018 Land IQ spatial cropping data available from DWR. The groundwater extraction volumes per acre represent measured or estimated groundwater extraction in 2021.*

3.2 DATA SOURCES

Direct measurements of groundwater extraction were summarized from groundwater flowmeter records available from the Cities of Orland, Williams, and Willows in 2016-2021. Data for the Cities of Orland and Williams were provided directly by the cities. Data for the City of Willows were extracted from Urban Water Supplier Reports available from the State Water Resources Control Board (System ID CA1110003). These data are assumed to represent urban groundwater extraction for delivery and use within the boundaries of each respective city.

Estimates of groundwater extraction in agricultural and managed wetland areas of the Colusa Subbasin were quantified in each respective water use sector boundary balance based on the remaining ET_{aw} demand after accounting for available surface water supplies. The total ET_{aw} demand was adjusted upward to account for other applied water uses (e.g., infiltration, runoff, ponded operations of managed wetlands) according to the weighted average fraction of ET_{aw} versus applied water simulated in the GSP groundwater model. Available surface water supplies were quantified as described in **Section 4**, below.

Estimates of groundwater extraction in urban areas where flowmeter records were unavailable were estimated based on annual population data and monthly per capita water use requirements. Annual population data were obtained from the California Department of Finance for all cities and unincorporated areas in Colusa and Glenn Counties. Where available, population data were considered directly for cities in the Colusa Subbasin. In Arbuckle and unincorporated areas, population estimates identified during GSP development were adjusted annually according to the year-over-year population changes calculated elsewhere in the Colusa Subbasin. Average monthly per capita water use rates in 2016-2021 were quantified from population data and available pumping data in the Cities of Orland, Williams, and Willows. Monthly per capita water use in the City of Colusa was estimated to be the average of those monthly values in Orland, Williams, and Willows. Monthly per capita water use in Arbuckle and other unincorporated areas with the Colusa Subbasin was estimated through adjustment of the City of Colusa rates, according to their relationship identified during GSP development (six percent greater use than City of Colusa, on average).

In the Colusa Subbasin, precipitation is understood to be the primary originating source of water available to native vegetation. Groundwater uptake through the root zone of native vegetation was evaluated during GSP analyses, but was ultimately not included in the final water budgets due to confounding factors regarding the origins of water that is used. During GSP implementation, the GSAs will seek to work with resource agencies, stakeholders, beneficial users and the public to fill data gaps and refine the understanding of groundwater use by native vegetation, including GDEs that may be identified in the Colusa Subbasin. The best methodology for quantifying water use by native vegetation will be assessed in subsequent analyses moving forward and documented to the extent applicable in subsequent annual reports and/or the five-year update.

4 Surface Water Supplies (§356.2.b.3)

This section summarizes the annual volumes and data sources for surface water supplies used, or available for use, within the Colusa Subbasin through the current reporting year (2021).

4.1 QUANTIFICATION BY WATER SOURCE TYPE

Surface water supplies available to certain entities within the Colusa Subbasin include surface water contract deliveries, water rights diversions, and riparian or other diversions of natural flows crossing the Colusa Subbasin.

In this Annual Report, surface water supplies used or available for use are assumed to be the volume of surface water diverted and delivered by agencies and water rights users in the Colusa Subbasin. Total diversions are also reported.

Per the GSP Regulations, surface water supplies 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.*

Table 4-1 summarizes the total surface water supplies diverted and **Table 4-2** summarizes the total surface water supplies delivered (used or available for use) in the Colusa Subbasin, by water source type. The supplies included in these totals are described below.

CVP Supplies

Agencies that have contracts with the United States Bureau of Reclamation for Central Valley Project (CVP) supplies can receive CVP supplies in the Colusa Subbasin. CVP supplies used for agriculture are received via the Tehama-Colusa Canal and via the Sacramento River. CVP supplies are also delivered to the Sacramento, Delevan, and Colusa National Wildlife Refuges through the Refuge Water Supply Program according to their respective contract quantities established through the Central Valley Project Improvement Act.

Diversions and deliveries of CVP supplies reported in this Annual Report include only those supplies delivered to contractors whose service areas are located within the Colusa Subbasin. This water is used or available for various beneficial uses within and downstream of the service area of the entities that receive this water.

Local Supplies

Local supplies available to certain entities within the Colusa Subbasin include Orland Project supplies delivered along the South Canal to areas within the Colusa Subbasin, and relatively smaller diversions of natural flows, when available, from along the Sacramento River and the Colusa Basin Drain. Diversions of natural flows, especially along the Colusa Basin Drain, are generally limited in dry years. Most of the water in the Colusa Basin Drain is generally passed through from upstream diverters from the Sacramento River, and are therefore not accounted as local supplies to avoid double-counting surface water supplies.

Reuse

Some reuse does occur within the Colusa Subbasin, primarily along the Colusa Basin Drain. The Colusa Basin Drain captures rainfall runoff, agricultural runoff, return flows, and spillage away from the agricultural lands in the Colusa Subbasin to the Sacramento River and the Tule Canal near Knights Landing, Yolo County. Some of the water within the Colusa Basin Drain is captured and reused prior to being discharged into the Sacramento River. Some local reuse also occurs, particularly for irrigation of rice crops. However, these supplies originate as part of the CVP supplies and local supplies accounted in **Table 4-1**, and are generally not distinguished from those supplies. Reuse is not quantified in this Annual Report to avoid double-counting water supplies, though reuse may be quantified in future Annual Reports.

Table 4-1. Surface Water Diversions, by Water Source Type (acre-feet, rounded).

Water Year (Type)	CVP Supplies	Local Supplies	Total
2016 (D)	1,258,000	42,000	1,300,000
2017 (W)	1,232,000	44,000	1,276,000
2018 (BN)	1,298,000	50,000	1,348,000
2019 (W)	1,191,000	45,000	1,236,000
2020 (D)	1,200,000	54,000	1,254,000
2021 (C)	986,000	28,000	1,014,000
Average (2016-2021)	1,194,000	44,000	1,238,000

Table 4-2. Surface Water Deliveries (Supplies Used or Available for Use), by Water Source Type (acre-feet, rounded).

Water Year (Type)	CVP Supplies	Local Supplies	Total
2016 (D)	1,146,000	35,000	1,181,000
2017 (W)	1,120,000	37,000	1,157,000
2018 (BN)	1,185,000	42,000	1,227,000
2019 (W)	1,082,000	37,000	1,119,000
2020 (D)	1,093,000	45,000	1,138,000
2021 (C)	895,000	23,000	918,000
Average (2016-2021)	1,087,000	37,000	1,123,000

4.2 DATA SOURCES

Table 4-3 summarizes the data sources and estimation procedures for quantifying diversions and deliveries in the Colusa Subbasin, by water source type. Missing deliveries data were estimated based on available diversions data, adjusted for seepage, evaporation, and downstream spillage outflows following methods similar to those used in GSP development.

Table 4-3. Data Sources for Surface Water Supplies

Associated Agency	Water Source Type	Water Source Detail	Diversions Data Sources	Deliveries Data Sources
4-M Water District	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	Estimated from diversions
Andreotti, Arnold and Arthur, et al	CVP Supplies	Sacramento River Deliveries (Long-term contracts)	USBR CVO delivery reports (2016-2021)	Estimated from diversions
Carter Mutual Water Company	CVP Supplies	Sacramento River Deliveries (Long-term contracts)	USBR CVO delivery reports (2016-2021)	Estimated from diversions

Associated Agency	Water Source Type	Water Source Detail	Diversions Data Sources	Deliveries Data Sources
Colusa County Water District	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	DWR WUEdata Aggregated Farm Gate Deliveries reports (2018, 2020)
Colusa National Wildlife Refuge	CVP Supplies	Refuge Water Supply Program Contract Deliveries	Contract Quantities and USBR Annual CVP Allocation Quantities	Estimated from diversions
Cortina Water District	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	Estimated from diversions
Davis Water District	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	Estimated from diversions
Delevan National Wildlife Refuge	CVP Supplies	Refuge Water Supply Program Contract Deliveries	Contract Quantities and USBR Annual CVP Allocation Quantities	Estimated from diversions
Glenn Valley Water District	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	Estimated from diversions
Glenn-Colusa Irrigation District	CVP Supplies	Tehama-Colusa Canal Deliveries, Main Canal Diversions from Sacramento River	USBR CVO delivery reports (2016-2021)	DWR WUEdata Aggregated Farm Gate Deliveries reports (2016-2020), estimated
Glide Water District	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	DWR WUEdata Aggregated Farm Gate Deliveries reports (2018-2020)
Holthouse Water District	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	Estimated from diversions
Kanawha Water District	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	DWR WUEdata Aggregated Farm Gate Deliveries reports (2018-2020)
La Grande Water District	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	Estimated from diversions
Maxwell Irrigation District	CVP Supplies	Sacramento River Deliveries (Long-term contracts)	USBR CVO delivery reports (2016-2021)	Estimated from diversions
Misc Sac River Riparian Diversions	CVP Supplies	Sacramento River Deliveries (Long-term contracts)	USBR CVO delivery reports (2016-2021), aggregated for various small water users in the Colusa Subbasin	Estimated from diversions
Myers-Marsh Mutual Water Company	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	Estimated from diversions
Orland-Artois Water District	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	DWR WUEdata Aggregated Farm Gate Deliveries reports (2016-2019)
Princeton-Codora-Glenn Irrigation District	CVP Supplies	Sacramento River Deliveries (Long-term contracts)	USBR CVO delivery reports (2016-2021)	DWR WUEdata Aggregated Farm Gate Deliveries reports (2016-2020)
Provident Irrigation District	CVP Supplies	Sacramento River Deliveries (Long-term contracts)	USBR CVO delivery reports (2016-2021)	DWR WUEdata Aggregated Farm Gate Deliveries reports (2016-2020)
Reclamation District #108	CVP Supplies	Sacramento River Deliveries (Long-term contracts)	USBR CVO delivery reports (2016-2021)	DWR WUEdata Aggregated Farm Gate Deliveries reports (2016-2020)
Sacramento National Wildlife Refuge	CVP Supplies	Refuge Water Supply Program Contract Deliveries	Contract Quantities and USBR Annual CVP Allocation Quantities	Estimated from diversions
Sycamore Mutual Water Company	CVP Supplies	Sacramento River Deliveries (Long-term contracts)	USBR CVO delivery reports (2016-2021)	DWR WUEdata Aggregated Farm Gate Deliveries reports (2016-2020)

Associated Agency	Water Source Type	Water Source Detail	Diversions Data Sources	Deliveries Data Sources
Westside Water District	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	DWR WUEdata Aggregated Farm Gate Deliveries reports (2018)
Orland Unit Water Users' Association	Local Supplies	Orland Project (South Canal only)	USBR Central Valley Operations (CVO) delivery reports (2016-2021)	DWR WUEdata Aggregated Farm Gate Deliveries reports (2016-2021)
4-M Water District	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	Estimated from diversions
Andreotti, Arnold and Arthur, et al	CVP Supplies	Sacramento River Deliveries (Long-term contracts)	USBR CVO delivery reports (2016-2021)	Estimated from diversions
Carter Mutual Water Company	CVP Supplies	Sacramento River Deliveries (Long-term contracts)	USBR CVO delivery reports (2016-2021)	Estimated from diversions
Colusa County Water District	CVP Supplies	Tehama-Colusa Canal Deliveries	USBR CVO delivery reports (2016-2021)	DWR WUEdata Aggregated Farm Gate Deliveries reports (2018, 2020)

5 Total Water Use (§356.2.b.4)

Total water use in the 2021 water year is reported in **Table 5-1** by water use sector and water source type, where water source type distinguishes only between surface water and groundwater. The volume of total water use is summarized from the results presented in **Section 3** and **Section 4** of this Annual Report.

Table 5-1. Total Water Use in Water Year 2021, by Water Use Sector and Water Source Type (acre-feet, rounded).

Water Use Sector	Groundwater	Surface Water	Total
Agricultural	933,000	849,000	1,782,000
Urban	10,200	0	10,200
Managed Wetlands	34,000	69,000	103,000
Native Vegetation	-	-	-
Total	977,000	918,000	1,895,000

6 Change in Groundwater Storage (§356.2.b.5)

6.1 CHANGE IN GROUNDWATER STORAGE MAPS

Consistent with §354.18.b, changes in groundwater elevation were calculated for individual years between Spring 2015 and Spring 2021, based on a comparison of the annual spring groundwater elevations representing seasonal high groundwater conditions.

Change in groundwater storage reported in the Colusa Subbasin GSP was estimated using the C2VSimFG-Colusa groundwater model, an integrated hydrologic flow model application created and used during GSP development. Due to uncertainty in the model and limitations in the ability to update the complete groundwater model for this Annual Report, an alternate method for determining change in groundwater storage was utilized for this Annual Report. Pre-2015 results using this method are comparable to the simulated change in storage outputs from the C2VSimFG-Colusa groundwater model.

Change in groundwater storage was estimated using a Thiessan polygon method. Thiessan polygons, also known as Voronoi polygons, were constructed for each groundwater level RMS well with consecutive year-to-year spring groundwater elevation measurements. Annual change in groundwater storage was then calculated based on change in measured spring-to-spring groundwater elevations multiplied by the area of the Thiessen polygon associated with the groundwater level RMS well and a storage coefficient of 0.1. A storage coefficient of 0.1 is within the expected range given the depositional history, sediment types and aquifer characteristics of the principal aquifer within the Colusa Subbasin. A constant storage coefficient was applied to the entire Colusa Subbasin. **Figures 6-1 and 6-2** show the annual spring-to-spring change in groundwater storage for 2019 to 2020 and 2020 to 2021, respectively. Values are reported in acre-feet (af). **Appendix C** contains the annual spring-to-spring change in groundwater storage maps for 2015 to 2021. A positive change in groundwater storage means that the volume of groundwater in storage increased, and is shown in blue, whereas a negative change in groundwater storage means that the volume of groundwater in storage decreased, and is shown in red.

Fluctuations in groundwater storage in the Colusa Subbasin follow a pattern typically seen in the majority of the Sacramento Valley. Groundwater extraction typically peaks in the summer when demand is high. During this time the primary pathways for groundwater recharge are deep percolation from irrigation applications and canal seepage. During wetter years, net reductions in groundwater storage during the summer are replenished over the winter from precipitation and surface water inputs, allowing storage to potentially rebound by the following spring. This pattern is often disrupted during drier years and drought periods when demands for groundwater may equal or exceed those of normal and wet years, and reduced precipitation, lower stream levels and the possibility of curtailed surface water deliveries reduces opportunities to replenish depleted storage. The seasonal and annual change in groundwater storage trends can be seen in groundwater level RMS hydrographs and the Thiessan polygon change in storage estimates. **Figure 6-3** depicts estimates of the annual and cumulative change in the volume of groundwater in storage between seasonal high groundwater conditions (spring) from calendar year 1980 to 2021. Values are reported in thousands of acre-feet (taf). **Table 6-1** lists the average change in groundwater elevation, annual change in storage, and cumulative change in storage since Spring 2015. **Table 6-1** also summarizes the overall cumulative change in groundwater storage between 1980-2021.

Between Spring 2019 to Spring 2020 the Subbasin experienced an estimated annual reduction in storage of about 369,000 af (**Figure 6-1**). Increased groundwater extractions in calendar year 2020 relative to long-term average groundwater demand and reduced natural recharge in 2021 resulted in lower groundwater levels in Spring 2021 compared to Spring 2020. This amounts to an estimated reduction in groundwater in storage of about 418,000 af for this time period, cumulative reduction in storage of about 589,000 af since 2015, and cumulative reduction in storage of about 1,160,000 af since 1980 (**Table 6-1, Figure 6-2 and Figure 6-3**).

Based on the change in storage estimates, the Colusa Subbasin is currently experiencing a long-term cumulative reduction in groundwater storage. Although the Colusa Subbasin has experienced both annual reductions and annual increases in groundwater storage since 1980, the cumulative 1980 to current change in storage did not drop below baseline until 2014, and the Colusa Subbasin has yet to recover (**Figure 6-3**). Single wet years, as seen in 2017 and 2019, have not been sufficient to replenish the groundwater aquifer system.

6.2 GROUNDWATER USE AND CHANGE IN GROUNDWATER STORAGE

Annual groundwater extractions and change in groundwater storage in the Colusa Subbasin are shown in **Figure 6-4** for water years 2015 through 2021. Groundwater extractions in water years 2016 through 2021 were estimated or directly measured following the procedures described in **Section 3**. Change in groundwater storage was estimated based on an annual comparison of spring groundwater elevations, described in **Section 6.1**. Historical groundwater extraction in water years 1990 through 2015 – including the period from January 1, 2015, to September 30, 2015 (the end of water year 2015) – are provided in the Colusa Subbasin GSP historical water budgets (see Section 3.3.4 and Appendix 3E of the Colusa Subbasin GSP). Historical groundwater extractions shown in water year 2015 were calculated based on a water balance of the Colusa Subbasin using the C2VSimFG-Colusa groundwater flow model (described in the Colusa Subbasin GSP).

Total annual groundwater extraction has generally increased over the past six years, while the annual change in groundwater storage has fluctuated between approximately -418,000 af and +376,000 af since water year 2016 (**Figure 6-4**).

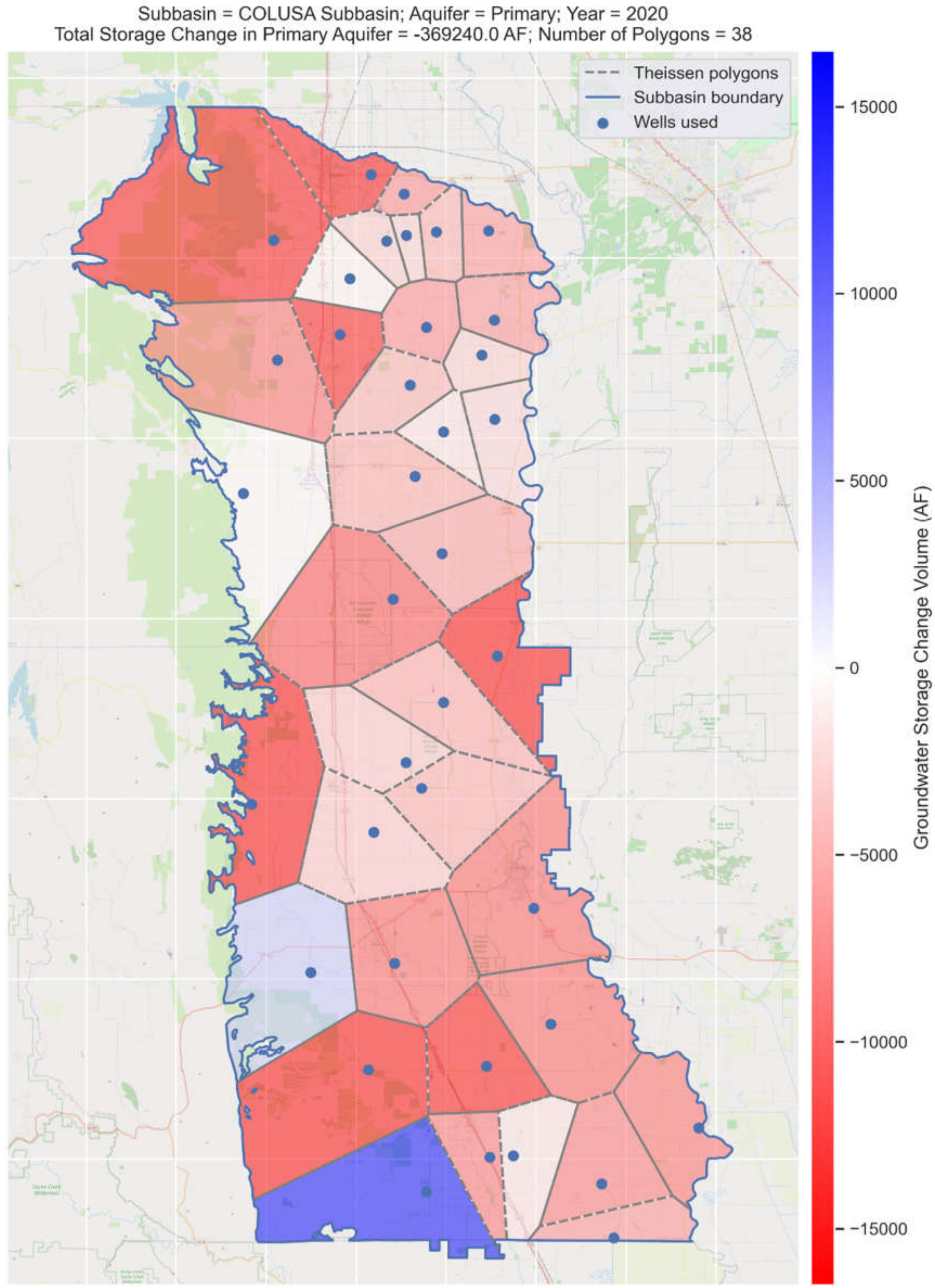


Figure 6-1. Change in Groundwater Storage in the Primary Aquifer – Spring 2019 through Spring 2020.

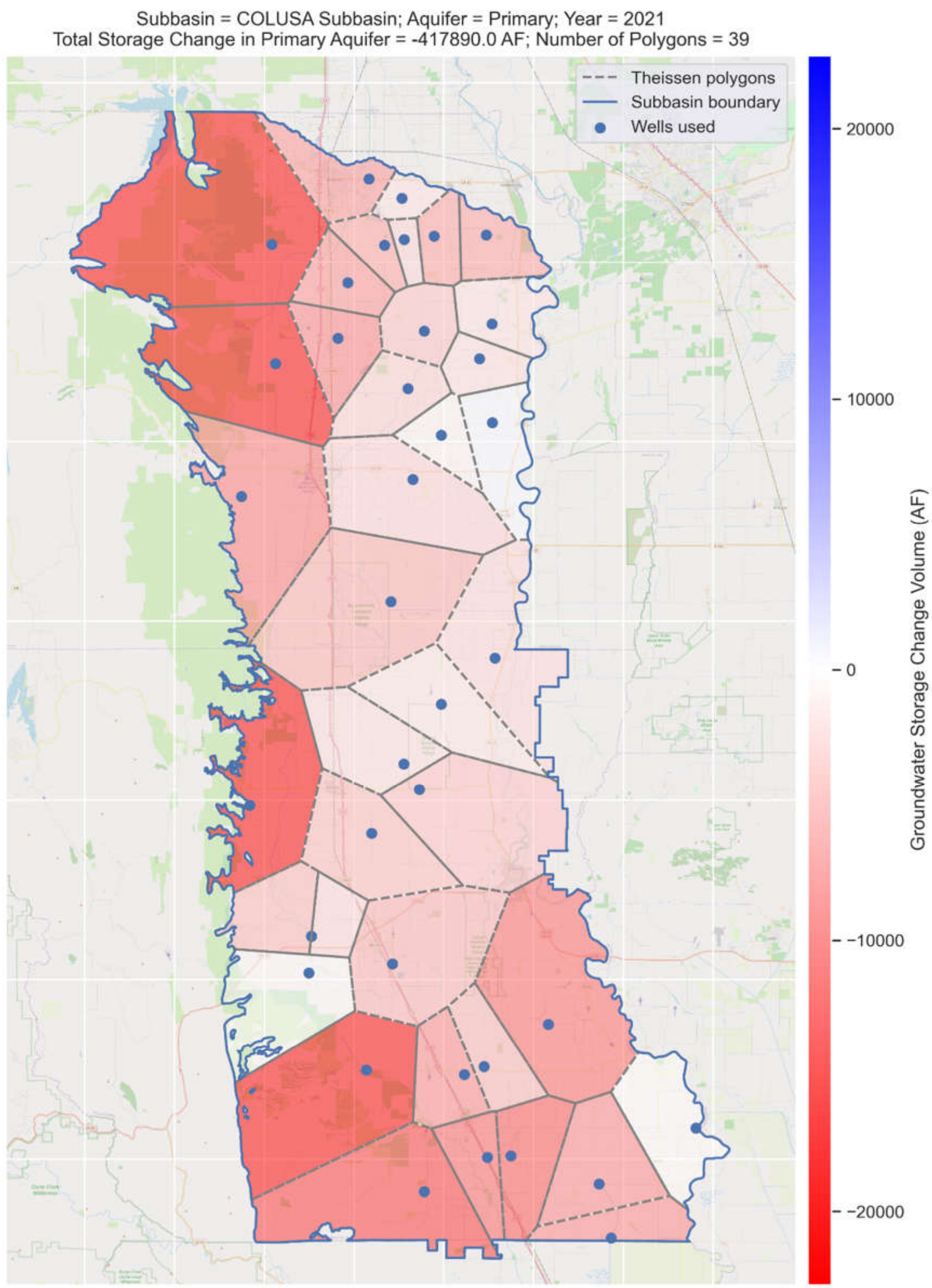


Figure 6-2. Change in Groundwater Storage in the Primary Aquifer – Spring 2020 through Spring 2021.

Figure 6-3. Annual and Cumulative Change in Groundwater Storage in the Primary Aquifer – Spring 1980 through Spring 2021.

Table 6-1. Estimated Change in Groundwater Storage in the Primary Aquifer – Spring 2015 through Spring 2021

Analysis Time Period	Annual Change in Groundwater Storage (taf)	Cumulative Change in Groundwater Storage since Spring 2015-2016 (taf)
Spring 2015-2016	-161	-161
Spring 2016-2017	+376	+215
Spring 2017-2018	-238	-23
Spring 2018-2019	+221	+198
Spring 2019-2020	-369	-171
Spring 2020-2021	-418	-589

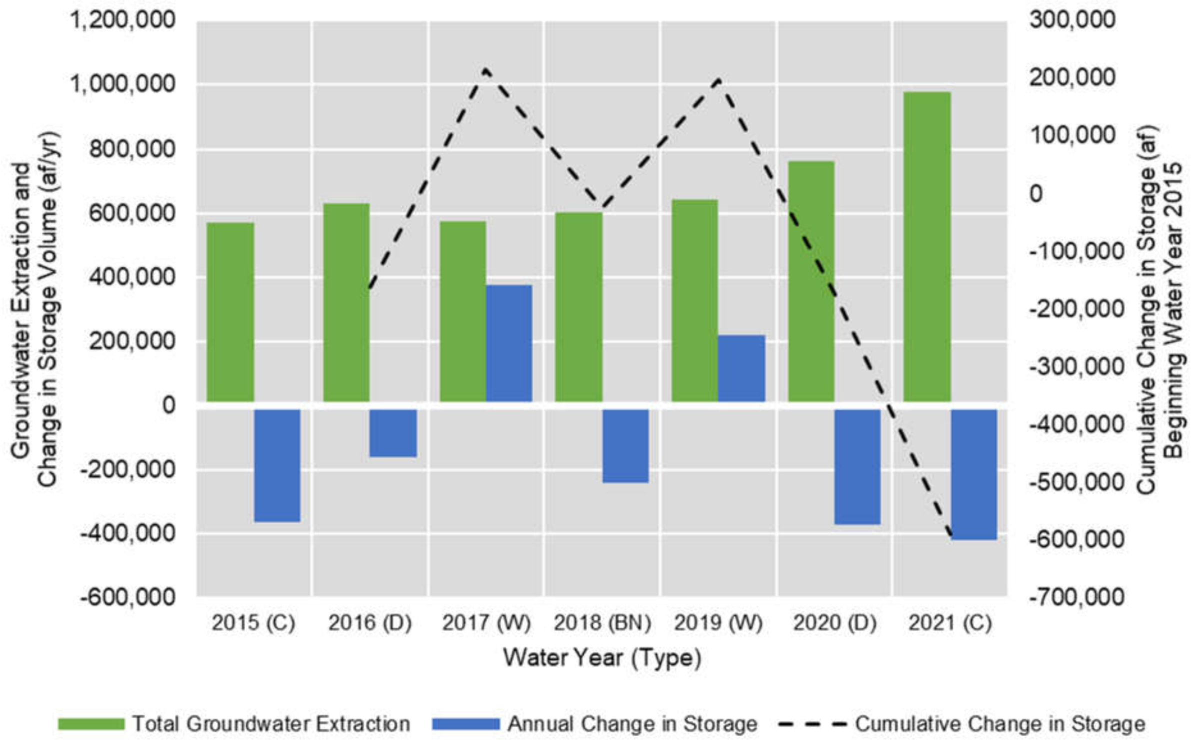


Figure 6-4. Annual Groundwater Extraction and Change in Groundwater Storage.

7 Groundwater Sustainability Plan Implementation Progress (§356.2.c)

This section describes the various efforts that have been initiated toward GSP implementation in the Colusa Subbasin. The sections below describe progress toward monitoring and addressing data gaps in the Colusa Subbasin, progress of groundwater conditions relative to the interim milestones established in the Colusa Subbasin GSP, and implementation of projects and management actions and other efforts by project proponents and the Colusa Subbasin GSAs.

There was a short time period between the GSP submittal deadline of January 31, 2022, and the Annual Report submittal deadline of April 1, 2022. Due to this short time period, appreciable progress has only been made on those actions and PMAs that were already being implemented or were actively being developed prior to the adoption and submission of the Colusa Subbasin GSP. Additional information will be reported in the 2023 Annual Report, following the first full year of GSP implementation.

7.1 IMPLEMENTATION OF MONITORING AND ADDRESSING DATA GAPS

During the period of GSP development, and since GSP adoption and submittal concluding in January 2022, the GSAs have been conducting monitoring of RMS wells in coordination with DWR and other monitoring entities. As described in **Section 7.2**, below, approximately 5-6 RMS wells were not sampled in 2021. Field-verification is needed to ensure the accessibility of those wells, and further verification will be needed with DWR to ensure that those are monitored in the future.

Other activities that have been initiated to improve monitoring and address data gaps are described below.

7.1.1 Hydrogeologic Investigation

During the Colusa Subbasin GSP development process, various data gaps were identified, in addition to areas where additional studies will be needed to support refinements of the GSP. In Chapter 7 of the Colusa Subbasin GSP, the GSAs identified 15 technical studies and planning efforts that could be conducted during GSP implementation, pending available funding. These studies and planning efforts are focused to address data gaps and help the GSAs meet the annual and five-year reporting requirements under 23 CCR §356.2 and §356.4.

In 2021-2022, GSA staff have worked with a consultant team to create a strategic planning document to guide implementation of many of these technical studies and planning efforts. This strategic planning document, referred to as the Hydrogeologic Investigation, will provide background information on the data gaps identified in the GSP, and then identify specific measurable actions that can be completed to improve monitoring and address those data gaps. Information in the Hydrogeologic Investigation will include siting considerations, equipment installation guidelines, and other information to support monitoring improvements to address data gaps in the Colusa Subbasin. The Hydrogeologic Investigation will be organized to facilitate future grant applications to fund those efforts. The Hydrogeologic Investigation is anticipated to be completed in spring 2022, after submittal of this Annual Report.

7.1.2 Well Monitoring Pilot Program

In 2021, GSA staff worked with a consultant team to implement the first phase of the Well Monitoring Pilot Program (WMPP). The WMPP is a voluntary, non-regulatory program that was created to investigate opportunities for monitoring groundwater levels and groundwater use to support irrigation management and groundwater sustainability efforts in the Colusa Subbasin. Six initial participants were selected for the program through an application process in early 2021.

Well monitoring equipment was installed at participating sites in summer 2021, providing well users with near-real time access to information on production and groundwater levels.

In 2022, GSA staff again worked with a consultant team to implement the second phase of the WMPP. Additional applicants were solicited in February-March 2022. In March-April 2022, the GSAs plan to review applications, refine eligibility criteria established in the first phase, form agreements with suitable participants, and then procure and install equipment at the new monitoring sites. The GSAs are targeting 16 additional sites, pending funding and availability of a sufficient number of suitable applicants. The GSAs also plan to set up weekly and monthly reports on aggregate groundwater levels and groundwater pumping data that will be used to inform GSP implementation. The program is expected to operate through December 2024.

7.1.3 Additional Subsidence Benchmarks

In an effort to address subsidence-related data gaps in the Colusa Subbasin, the GSAs have proposed installing 10 additional land subsidence benchmarks in areas of the Colusa Subbasin where recent subsidence rates have increased most significantly, including the Arbuckle-College City area in Colusa County and the Orland-Artois area in Glenn County.

New sites would be prioritized based on: 1) the proximity of suspected ongoing subsidence to critical infrastructure that is subject to adverse effects due to subsidence, 2) the known or suspected historical rate of subsidence, 3) lateral extent of the subject area without representative monitoring, and 4) input from the CGA and GGA technical advisory committees, DWR, Colusa Subbasin stakeholders, and members of the public. In March 2022, a grant amendment was approved that allocates funding for the installation of additional subsidence benchmarks. Planning and installation is anticipated to occur in spring 2022, coinciding with completion of the Hydrogeologic Investigation described above.

7.1.4 Other Available Data and Monitoring Tools

In 2021-2022, DWR released information about additional monitoring data and monitoring tools that will be available to the GSAs to support sustainable groundwater management. Those data and tools include:

- CalGW Live (https://sgma.water.ca.gov/CalGWLive/): DWR has released an application that provides statewide data on current groundwater conditions, groundwater levels, well infrastructure, and land subsidence.
- More frequent land subsidence data: DWR contracts with TRE ALTAMIRA to process and report measurements of land subsidence from satellite data. InSAR subsidence measurements have historically been reported on an annual basis in the Colusa Subbasin. Moving forward, InSAR land subsidence data will be available more frequently, on a quarterly basis, to support GSP monitoring and implementation.

7.2 INTERIM MILESTONE STATUS (§356.2.C)

To track groundwater conditions in relation to the Sustainable Management Criteria (SMC) established in the Colusa Subbasin GSP, this section presents the status of RMS measurements in relation to the Interim Milestones (IMs), Measurable Objectives (MOs), and Minimum Thresholds (MTs) defined in the GSP. In the Colusa Subbasin GSP, IMs were established to maintain groundwater conditions in the Colusa Subbasin's margin of operational flexibility, as established by the MTs and MOs. The interim milestones for chronic lowering of groundwater levels are consistent with the MOs shown in **Table 7-1**.

Undesirable results occur when significant and unreasonable effects to any of the five applicable sustainability indicators defined by SGMA are caused by groundwater conditions occurring in the Colusa Subbasin. The overarching sustainability goal and the absence of undesirable results are expected to continue through 2042 through proactive monitoring and management by the GSAs, including implementation of PMAs.

Table 7-1. Summary of Minimum Thresholds, Measurable Objectives, and Undesirable Results (from Table 5-1 of the Colusa Subbasin GSP)

Sustainability Indicator	Monitoring Network	Undesirable Result	Minimum Threshold (MT)	Measurable Objective (MO)
Chronic Lowering of Groundwater Levels	48 RMS wells monitored at least 2 times annually by DWR	25% (12 of 48) RMS wells fall continuously below their MT for 24 consecutive months	The lower of 50% of measured historical groundwater elevation range below the historical measured low elevation and the elevation corresponding to the 20th percentile of domestic well depths in the RMS well's Thiessen polygon, subject to interbasin coordination and consistency to ensure operational compatibility	Mean of last the most recent five years of available groundwater elevation measurements up to 2020, subject to interbasin coordination and consistency to ensure operational compatibility; A fixed value, not a rolling average
Reduction in Groundwater Storage	Same as Groundwater Level monitoring network	Use groundwater levels as proxy	Use groundwater levels as proxy	Use groundwater levels as proxy
Degraded Groundwater Quality	25 RMS wells monitored by others at variable intervals under existing State of California regulatory programs	Electrical conductivity (EC) in 25% (6 of 23) of the RMS wells exceeds the MT for two consecutive years	The higher of the recommended California Secondary Maximum Contaminant Level for EC (900 microSiemens per centimeter [µS/cm]) OR the pre-2015 historical maximum measured EC	EC of 700 µS/cm (corresponding to an agricultural water quality objective providing for no yield reduction for crops commonly grown in the Subbasin)
Land Subsidence	Existing Sacramento Valley Height Modernization Project (SVHMP) benchmarks (63 sites)	20% or more (13 of 63) monitoring sites (benchmarks) experience subsidence rates above the MT	0.5 feet per five years	0.25 feet per five years
Depletions of Interconnected Surface Waters	12 RMS wells less than 200 feet deep and between 2,000 feet and five miles of interconnected streams (Sacramento River, Colusa Basin Drain, Stony Creek)	25% (3 of 12) RMS wells fall below their MT for 24 consecutive months	Ten feet below the observed fall 2015 groundwater level (Fall 2015 level is the measured elevation recorded on the date closest to Oct 15)	Mean of last 5 years available groundwater elevation measurements subject to interbasin coordination and consistency to ensure operational compatibility; A fixed value, not a rolling average

7.2.1 Groundwater Elevations

Table 7-2 provides a comparison of Spring and Fall 2021 water levels to the established MT and MO groundwater elevations. The status of known monitoring site issues to date are also provided in **Table 7-2**. Note that there are some RMS wells that were not monitored during calendar year

2021, and so have no measurements to compare with IMs, MOs, and MTs. Hydrographs comparing the measured groundwater elevations with the IMs, MOs, and MTs are in **Appendix B**.

Since groundwater levels were at or near the MO in the Colusa Subbasin at the time of GSP development, the Colusa Subbasin GSP established IMs equal to the MOs to provide numerical metrics for GSAs to track maintenance of the Colusa Subbasin's sustainability goal, ensuring that the Colusa Subbasin remains sustainable.

Half of the Spring 2021 groundwater elevation measurements were lower than their MO, and thirty-five (73 percent) of Fall 2021 measurements were lower than their MO, of which four RMS well measurements exceeded 50 percent of the margin of operational flexibility. This is attributed to the ongoing drought conditions, associated reductions in surface water supplies, and resulting increases in groundwater demands in the Colusa Subbasin in 2021. The central portion of the Colusa Subbasin, near the county lines, experienced groundwater levels near the MO values, and well above the MT values, in calendar year 2021.

None of the Spring or Fall 2021 groundwater level measurements exceeded their MT values; however, groundwater levels at two RMS wells (14N03W14Q003M and 22N03W24E002M) exceeded their MT values during Summer 2021 before recovering above the MT values in Fall 2021. Primary areas of concern include the southern and northern portions of the Colusa Subbasin, in the greater Arbuckle and Orland areas, respectively. Domestic well users near these regions have reported failed or failing wells due to lowering groundwater levels. As described in the preface to the Colusa Subbasin GSP, Glenn and Colusa Counties have been supporting the public through several local and regional drought relief and response programs that assist with, among other activities, well assessments, well repair and replacement, installation or updates to household water systems, and potable water hauling. While GSP implementation has only just begun, these responsibilities may shift to or be coordinated with the GSAs, as described in Chapter 7 of the Colusa Subbasin GSP. In the meantime, the GSAs will continue monitoring groundwater conditions, particularly in the Orland and Arbuckle areas, and will implement or facilitate measures to address groundwater level decline to avoid undesirable results, as described in the Colusa Subbasin GSP.

7.2.2 Land Subsidence

The Colusa Subbasin GSP reports on land subsidence up to May 2017. **Figure 7-1** presents the annual vertical ground displacement measured by satellite Interferometric Synthetic Aperture Radar (InSAR) surveys for October 2018 through October 2021. **Figure 7-2** presents the net vertical ground displacement measured from June 2015 to October 2021. Negative vertical displacement values depict a decrease in land surface elevation, and positive values depict an uplift in land surface. Subsidence is opposite, where positive subsidence depicts a decrease in land surface elevation and negative subsidence depicts an increase in land elevation.

As shown on **Figure 7-1**, the annual detected land subsidence has increased since October 2018. Between October 2019 and October 2020, InSAR surveys detected vertical displacement of as much as -0.4 feet (approximately 5 inches) near Arbuckle and as much as -0.2 feet (approximately 3 inches) near Orland. Between October 2020 and October 2021, vertical displacement increased and was detected to as much as -0.8 feet (approximately 10 inches) near Arbuckle and to as much as -0.4 feet (approximately 5 inches) near Orland.

As described in the Colusa Subbasin GSP, the MT for land subsidence is 0.5 feet per five years (i.e., averaged 0.1 foot per year), while the MO and IM for land subsidence is 0.25 feet per five years. As GSP implementation and monitoring has just begun, conclusive comparisons of land subsidence rates with these MTs, MOs, and IMs cannot be made until at least five years of data are collected. However, vertical displacement measured between June 2015 and October 2021, a six-year period, near Arbuckle amounted to about -2 feet (**Figure 7-2**), which is approximately three times the MT rate. Data from continuous GPS stations supports the InSAR satellite measurements.

An undesirable result for land subsidence is defined as “20% or more (13 of 63) monitoring sites (benchmarks) experience subsidence rates above the MT”. Approximately ten to 15 benchmarks are located near the subsidence areas of concern identified on **Figures 7-1 and 7-2**. Resurvey data has not been published for the Sacramento Valley benchmarks since 2017, which is discussed in the Colusa Subbasin GSP. The benchmarks need to be resurveyed to confirm if an undesirable result has occurred. The GSAs will continue monitoring land subsidence, particularly in the Orland and Arbuckle areas, and will implement or facilitate measures to address land subsidence to avoid undesirable results.

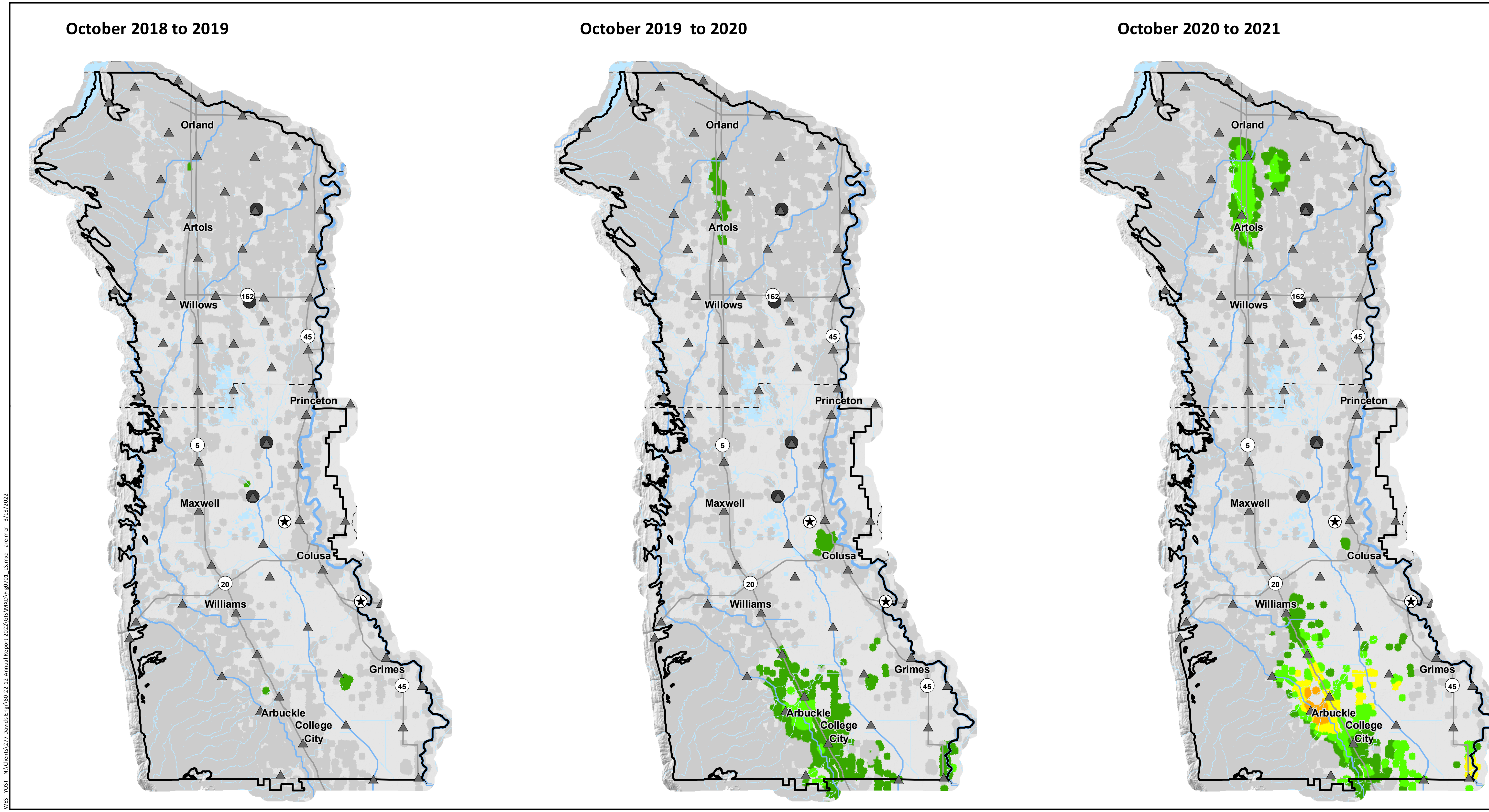
Table 7-2. Summary of RMS Well Groundwater Levels Relative to Interim Milestones, Minimum Thresholds, and Measurable Objectives

State Well Number	Minimum Threshold (feet MSL)[1]	Interim Milestone and Measurable Objective (IM, MO) (feet MSL)	Spring 2021 Conditions			Fall 2021 Conditions			GSA	Status
			Groundwater Elevation (feet MSL)	Difference relative to MT (feet)[2]	Difference relative to IM, MO (feet)	Groundwater Elevation (feet MSL)	Difference relative to MT (feet)	Difference relative to IM, MO (feet)		
12N01E06D004	-108	-1	-5.62	102.38	-4.62	-19.56	88.44	-18.56	CGA	
13N01E11A001	-75	22	26.69	101.69	4.69	23.70	98.70	1.70	CGA	
13N01W07G001	-106*	-9	4.37	110.37	13.37	-22.33	83.67	-13.33	CGA	
13N01W13P003	-88	8	0.39	88.39	-7.61	-5.81	82.19	-13.81	CGA	
13N01W22P002	-124	26	Not Monitored	Not Monitored	Not Monitored	Not Monitored	Not Monitored	Not Monitored	CGA	Last Meas. 2016
13N02W12L001	-72*	9	6.69	78.69	-2.31	-40.31	31.69	**-49.31**[3]	CGA	
13N02W15J001	-62*	61	Not Monitored	Not Monitored	Not Monitored	Not Monitored	Not Monitored	Not Monitored	CGA	Last Meas. 2015
13N02W20H002	95	174	177.68	82.68	3.69	173.88	78.88	-0.12	CGA	
14N01E35P003	-118	28	27.99	145.99	-0.01	23.72	141.72	-4.28	CGA	
14N01W04K003	-86	12	27.03	113.03	15.03	23.03	109.03	11.03	CGA	
14N02W13N001	-80	24	20.35	100.35	-3.65	6.85	86.85	-17.15	CGA	
14N02W22A002	-126	84	8.01	134.01	-75.99	-28.10	97.91	**-112.10**	CGA	
14N02W29J001	-86*	22	Not Monitored	Not Monitored	Not Monitored	Not Monitored	Not Monitored	Not Monitored	CGA	Last Meas. 2017
14N03W14Q003	-89*	-13	-8.98	80.02	4.02	-49.08	39.92	-36.08	CGA	
14N03W24C001	-5*	38	Not Monitored	Not Monitored	Not Monitored	Not Monitored	Not Monitored	Not Monitored	CGA	Last Meas. 2020
15N01W05G001	-54	28	Not Monitored	Not Monitored	Not Monitored	Not Monitored	Not Monitored	Not Monitored	CGA	Last Meas. 2020
15N02W19E001	-13	73	72.91	85.91	-0.09	65.11	78.11	-7.89	CGA	
15N03W08Q001	43	107	100.58	57.58	-6.42	109.58	66.58	2.58	CGA	
15N03W20Q002	60	113	114.06	54.06	1.06	110.74	50.74	-2.26	CGA	
16N02W05B003	-71	47	53.01	124.01	6.01	37.42	108.42	-9.58	CGA	

State Well Number	Minimum Threshold (feet MSL)[1]	Interim Milestone and Measurable Objective (IM, MO) (feet MSL)	Spring 2021 Conditions			Fall 2021 Conditions			GSA	Status
			Groundwater Elevation (feet MSL)	Difference relative to MT (feet)[2]	Difference relative to IM, MO (feet)	Groundwater Elevation (feet MSL)	Difference relative to MT (feet)	Difference relative to IM, MO (feet)		
16N02W25B002	-25	30	37.92	62.92	7.92	Not Monitored	Not Monitored	Not Monitored	CGA	No Fall 2021
16N03W14H006	-94	51	54.40	148.40	3.40	39.62	133.62	-11.38	CGA	
16N04W02P001	63	139	126.32	63.32	-12.68	135.73	72.73	-3.27	CGA	
17N02W09H004	-52	56	60.11	112.11	4.11	42.21	94.21	-13.79	CGA	
17N02W30J002	-119	44	56.23	175.23	12.23	41.63	160.63	-2.37	CGA	
17N03W08R001	-13	88	91.36	104.36	3.36	89.96	102.96	1.96	CGA	
17N03W32H001	-38	92	93.77	131.77	1.77	93.57	131.57	1.57	CGA	
18N02W18D004	-80	62	73.19	153.19	11.19	35.05	115.05	-26.95	GGA	
18N02W36B001	-3	53	60.20	63.20	7.20	55.80	58.8	2.80	CGA	
19N02W08Q002	12	98	98.52	86.52	0.52	82.48	70.48	-15.52	GGA	
19N02W33K001	21	71	71.11	50.11	0.11	57.01	36.01	-13.99	GGA	
19N04W14M002	46	151	145.78	99.78	-5.22	142.82	96.82	-8.18	GGA	
20N02W11A001	49	119	112.27	63.27	-6.73	113.40	64.4	-5.60	GGA	
20N02W18R008	47	120	115.1	68.10	-4.90	114.59	67.59	-5.41	GGA	
20N02W25F004	37	97	96.75	59.75	-0.25	95.16	58.16	-1.84	GGA	
20N02W33B001	31	100	98.91	67.91	-1.09	98.09	67.09	-1.91	GGA	
20N03W07E004	31	100	88.30	57.30	-11.70	68.85	37.85	-31.15	GGA	
21N02W01F003	71	124	120.09	49.09	-3.91	107.74	36.74	-16.26	GGA	
21N02W04G004	51*	121	127.57	76.57	6.57	101.43	50.43	-19.57	GGA	
21N02W05M002	55	140	141.35	86.35	1.35	115.02	60.02	-24.98	GGA	
21N02W33M003	67	119	114.49	47.49	-4.51	106.79	39.79	-12.21	GGA	
21N02W36A002	24*	91	106.69	82.69	15.69	102.19	78.19	11.19	GGA	
21N03W01R002	48*	151	146.35	98.35	-4.65	118.57	70.57	-32.43	GGA	
21N03W23D002	84*	140	139.15	55.15	-0.84	122.62	38.62	-17.38	GGA	

State Well Number	Minimum Threshold (feet MSL)[1]	Interim Milestone and Measurable Objective (IM, MO) (feet MSL)	Spring 2021 Conditions			Fall 2021 Conditions			GSA	Status
			Groundwater Elevation (feet MSL)	Difference relative to MT (feet)[2]	Difference relative to IM, MO (feet)	Groundwater Elevation (feet MSL)	Difference relative to MT (feet)	Difference relative to IM, MO (feet)		
21N03W34Q004	42	112	106.57	64.57	-5.43	97.42	55.42	-14.58	GGA	
21N04W12A002	18*	73	68.66	50.66	-4.34	42.21	24.21	**-30.79**	GGA	
22N02W30H003	82*	150	160.42	78.42	10.42	121.36	39.36	-28.64	GGA	
22N03W24E002	122*	176	179.38	57.38	3.38	144.93	22.93	**-31.07**	GGA	

[1] Minimum thresholds with an asterisk (*) were calculated as 50 percent of the measured water level range below the historical low within the monitoring well. All other MTs were calculated as the 20th percentile of domestic well depth near the RMS well.
[2] Negative differences relative to the MT or MO indicate that the measured groundwater elevation is deeper than the MT or MO.
[3] Bolded difference relative to MO values indicate an RMS well with measured groundwater elevation closer to the MT then the MO.



Notes:
1. Gaps in the InSAR satallite data are places where the InSAR survey was unable to collect data due to field conditions.

Datum: NAD1983 California State Plane Zone II, feet.

Source: TRE ALTAMIRA. 2021. InSAR Land Survey and Mapping Services to DWR supporting SGMA, October 2021 Update. Technical Report and GIS Image Services. Website: https://data.cnra.ca.gov/dataset/tre-altamira-insar-subsidence

- Sacramento Valley Benchmark
- Extensometer
- Continuous GPS Station
- Colusa Subbasin

Vertical Displacement (feet)

- -0.8 to -0.6
- -0.6 to -0.4
- -0.4 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1

N

0 4 8

Scale in Miles

1 in = 8 miles

Figure 7-1

Annual Vertical Displacement 2018 through 2021

Colusa Groundwater Authority

Glenn Groundwater Authority

Colusa Subbasin Annual Report 2022

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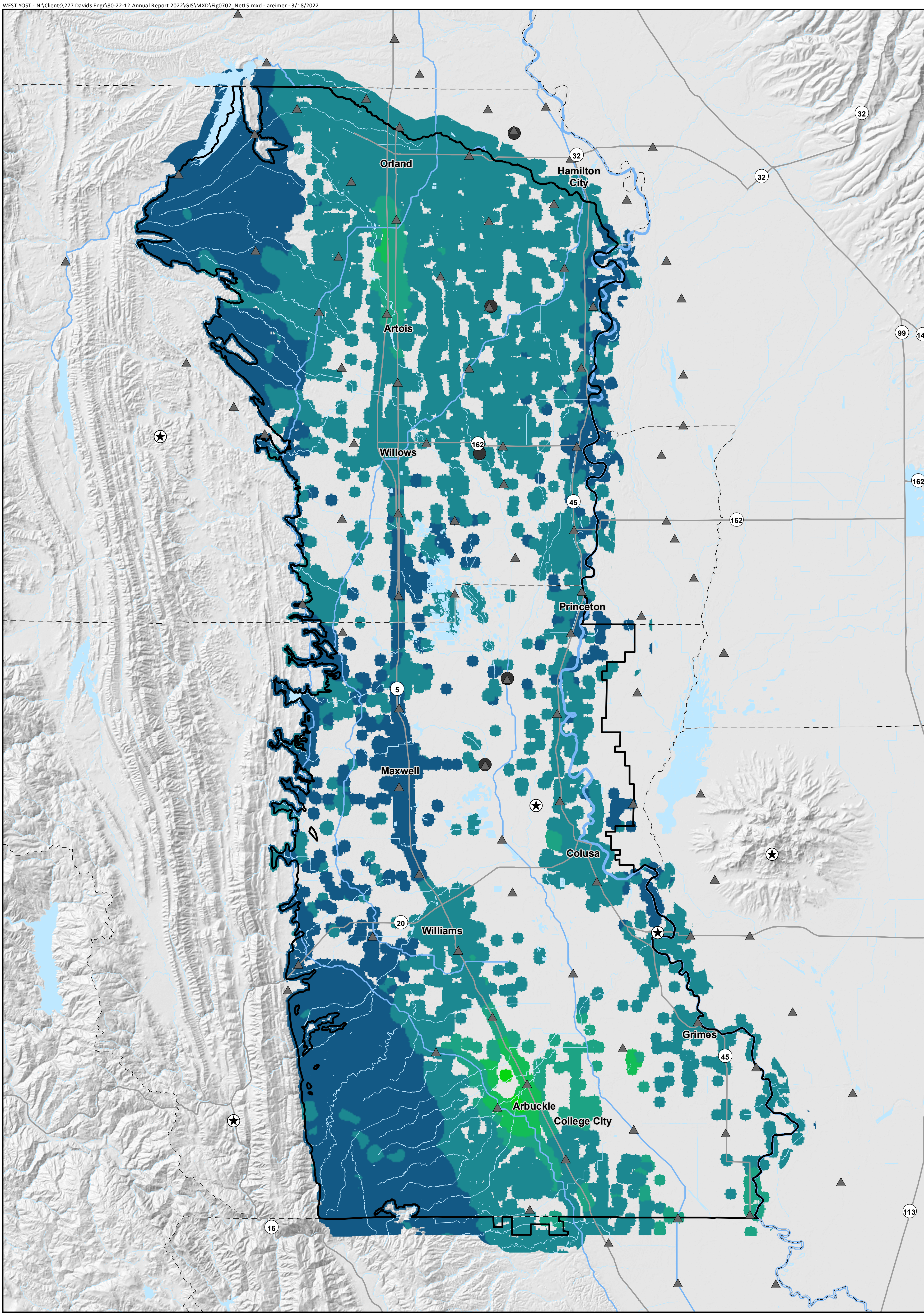

Notes:
1. Gaps in the InSAR satallite data are places where the InSAR survey was unable to collect data due to field conditions.

Datum: NAD1983 California State Plane Zone II, feet.

Source: TRE ALTAMIRA. 2021. InSAR Land Survey and Mapping Services to DWR supporting SGMA, October 2021 Update. Technical Report and GIS Image Services. Website: https://data.cnra.ca.gov/dataset/tre-altamira-insar-subsidence

Sacramento Valley Benchmark
Extensometer
Continuous GPS Station
Colusa Subbasin

Net Vertical Displacement (feet)

-2 to -1.5
-1.5 to -1
-1 to -0.5
-0.5 to 0
0 to 0.5

N

0 2.5 5
Scale in Miles
1 inch = 5 miles

Figure 7-2

Net Vertical Displacement 2015 through 2021

Colusa Groundwater Authority
Glenn Groundwater Authority
Colusa Subbasin Annual Report 2022

7.3 IMPLEMENTATION OF PROJECTS AND MANAGEMENT ACTIONS (§356.2.C)

The implementation of projects and management actions (PMAs) is critical for maintaining groundwater sustainability and avoiding undesirable results. As described in the Colusa Subbasin GSP, PMAs have been conceptualized and categorized in three groups: planned PMAs, ongoing PMAs, and potential PMAs. The estimated costs, timing, and benefits (i.e., increased groundwater recharge or reduced groundwater use) of the PMAs are described in the GSP.

There was only a short amount of time between the GSP submittal deadline of January 31, 2022, and the Annual Report submittal deadline of April 1, 2022. Due to this short time period, appreciable progress has only been made on those PMAs that were already being implemented or were actively being developed prior to the adoption and submission of the Colusa Subbasin GSP. Some PMAs started prior to adoption and submittal of the GSP are underway but may have not yet progressed to where benefits are being realized, as described below. Additional PMAs planned to start in 2022 are still in the early stages of implementation and have not progressed to the point where average annual benefits, average annual operating costs, or actual capital costs can be accurately quantified. The initial benefits and costs from the first year of implementation of these PMAs will be reported in the 2023 Annual Report.

This Annual Report reports progress only on planned PMAs, ongoing PMAs, and potential PMAs that have noted changes in implementation since GSP development. As described in Section 6.1 of the Colusa Subbasin GSP, PMA development and implementation applies an adaptive management approach informed by continued monitoring of groundwater conditions in the Colusa Subbasin using the GSP monitoring network. The CGA and GGA GSAs are committed to adaptive management of groundwater resources in the Colusa Subbasin through the suite of PMAs identified in the Colusa Subbasin GSP. As PMAs are implemented and monitored, the project timelines and consequential effects on the Colusa Subbasin will be reviewed. If adjustments are needed to meet the sustainability objectives identified in the Colusa Subbasin GSP, project timelines will be evaluated and adjusted. In addition to continuous monitoring and review of PMA implementation, each Annual Report represents an opportunity to review the status of GSP implementation efforts.

Table 7-3 describes updates to planned PMAs, ongoing PMAs, and potential PMAs that have had noted changes in implementation since GSP development. **Table 7-4** provides further updates on actual benefits and updates to anticipated benefits of PMAs since GSP development, in comparison with the anticipated benefits presented in the Colusa Subbasin GSP. The remainder of this section describes in greater detail the progress made for PMAs proposed in the Colusa Subbasin GSP.

Table 7-3. Updates to Projects and Management Actions Since GSP Development

Category (from GSP)	Project/Management Action Name	Proponent	Year Planned (from GSP)	Brief Description from GSP	Updates Since GSP
Planned	Colusa County Water District (CCWD) In-Lieu Groundwater Recharge	CCWD	2021	CCWD will utilize 30,000 af of additional surface water for irrigation in all years but Shasta Critical years for in-lieu recharge. The additional surface water will be made available through full use of the district's existing CVP contract and annual and multi-year water purchase and transfer agreements. Additional surface water deliveries are estimated to be 27,000 af/yr, enabling reduction of groundwater pumping by a like amount.	*No change in implementation noted since GSP development. Project planning is still underway.*
Planned	Colusa Drain MWC (CDMWC) In-Lieu Groundwater Recharge	CDMWC	2021	CDMWC diverters use both ground and surface water because Colusa Drain supplies are insufficient to satisfy all irrigation requirements. This project would provide additional surface supplies averaging approximately 28,000 af/yr in the Drain allowing CDMWC diverters to increase their diversions of surface water to provide in lieu groundwater recharge of a like amount.	*No change in implementation noted since GSP development. Project planning is still underway.*
Planned	Colusa Subbasin Multi-Benefit Groundwater Recharge	CGA, GGA and TNC	2021	The Nature Conservancy (TNC) is partnering with entities for an on farm, multi benefit groundwater recharge incentive program. The pilot program was initiated in Colusa County in 2018 and concluded in the spring of 2021, with plans to expand and continue into the future. DWR is a partner in the Colusa Subbasin Multi-Benefit Groundwater Recharge project as it moves into the expanded program..	Recharge was conducted in 2021. Only one field participated (66 acres) due to surface water restrictions. The total applied surface water was 290 af, and the estimated recharge benefit was 220 af.
Planned	Orland-Artois Water District (OAWD) Land Annexation and Groundwater Recharge	OAWD	2020	OAWD is planning to annex approximately 12,000 acres of groundwater dependent agricultural lands. Additional direct recharge may be considered on suitable annexed lands. The project is an area where groundwater levels have been in decline in recent years. It is estimated that a long term average of approximately 23,000 af/yr of surface water would be available, reducing groundwater pumping by approximately 23,000 af/yr.	Since GSP development, planning efforts and discussions have continued with OAWD, the Tehama-Colusa Canal Authority (TCCA), the Glenn Local Agency Formation Commission (LAFCO), and USBR. Processes have been initiated processes with OAWD and USBR to review annexation (anticipated 2023). The project benefits and costs have also been refined (targeting 15,000 af/yr of deliveries in Shasta Non-Critical years, estimated

Category (from GSP)	Project/Management Action Name	Proponent	Year Planned (from GSP)	Brief Description from GSP	Updates Since GSP
					pumping reduction of 14,000 af/yr, and estimated $12 million capital costs)
Planned	Sycamore Slough Groundwater Recharge Pilot Project	Landowner	2021	Proctor and Gamble (P&G) and Davis Ranches have entered into an agreement to implement a 10 year groundwater recharge pilot project. A 66 acre field on Davis Ranches will receive surface water for groundwater recharge and provide habitat for migrating shorebirds. Water would be diverted from the Sacramento River during fall/winter months using existing riparian rights or would be available from settlement contract supplies (should the project begin before November 1). An expansion of the project is planned for recharge and revegetation in the neighboring Sycamore and Dry Sloughs.	In 2021, Davis Ranches purchased additional monitoring equipment and prepared for recharge. The first season of groundwater recharge was completed through field flooding in early 2022. Field data has been collected, and analyses of the recharge benefit are in progress.
Ongoing	Reclamation District 108 (RD108) and CCWD Agreement for Five-Year In-Lieu Groundwater Recharge Project	RD108 and CCWD	N/A (Ongoing)	CCWD (and Dunnigan Water District [DWD]) purchases surface water from RD108 for distribution within its service area. The agreement expires in 2022. This project supplies additional surface water to CCWD (and DWD) that provides in lieu recharge.	*No change in implementation noted since GSP development. Project is still ongoing, pending extension.*
Ongoing	Glenn-Colusa Irrigation District (GCID) Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits	GCID	N/A (Ongoing)	GCID holds a water right for winter water. This project will increase the groundwater recharge and habitat enhancement benefits of winter water use by increasing use for rice straw decomposition, irrigation, and frost control provided that certain constraints can be alleviated.	*No change in implementation noted since GSP development. Project is still ongoing.*
Ongoing	Sycamore Marsh Farm Direct Recharge Project	Landowner	N/A (Ongoing)	Sycamore Marsh Farm is developing a groundwater recharge plan to store groundwater. The plan provides for 205 acres of year round recharge basins and 163 additional acres of winter recharge areas.	*No change in implementation noted since GSP development. Project is still ongoing.*
Ongoing	GCID Expansion of In-Basin Program for In-lieu Groundwater Recharge	GCID	N/A (Ongoing)	GCID has developed arrangements to supply district surface water to neighboring non district agricultural lands that primarily use groundwater. These temporary arrangements expired in 2020. There is interest in continuing and expanding this in basin surface water use for in lieu groundwater recharge. Supplies would potentially be available only in Shasta Non Critical years.	*No change in implementation noted since GSP development. Project is still ongoing.*
Ongoing	Orland Unit Water Users' Association	OUWUA	N/A (Ongoing)	Modernization of OUWUA southside system for more reliable and flexible farm deliveries that will provide	*No change in implementation noted since GSP development.*

Category (from GSP)	Project/Management Action Name	Proponent	Year Planned (from GSP)	Brief Description from GSP	Updates Since GSP
	(OUWUA) Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping			incentive for growers to use more surface water and less groundwater.	*Project is still ongoing. OUWUA is very interested in developing this project further, pending funding.*
Ongoing	Urban Water Conservation in Willows	California Water Service – Willows District	N/A (Ongoing)	This project includes urban water conservation measures through water waste prevention ordinances, metering, conservation pricing, public education, and outreach programs to assess and manage distribution system real loss, water conservation program coordination and staffing support, and other demand management measures.	From 2020-2021, the California Water Service – Willows District had a 5.8 percent total reduction in groundwater production for urban use (approximately 80 af).
Potential	Tehama-Colusa Canal Trickle Flow to Ephemeral Streams	RD108	N/A (Potential)	Operate Tehama Colusa Canal (TCC) existing gates for discharge into ephemeral streams at a rate where they do not flow out of the Colusa Subbasin but recharge the groundwater system.	Further concept development has occurred, with identification of potential streams, water sources, and operating strategies. Potential discharge locations have been identified with CCWD and TCCA. Coordination has also occurred with landowners to identify potential project monitoring and funding opportunities. In 2021, a proof-of-concept test of the trickle flow project and benefits was conducted when a portion of the Tehama-Colusa Canal was dewatered.
Potential	*All Others Listed in GSP*	-	-	-	*No change in implementation noted since GSP development*

Table 7-4. Anticipated Benefits and Actual Benefits of Projects and Management Actions

Category (from GSP)	Project/Management Action Name	Proponent	Anticipated or Reported Benefits from GSP		Actual Benefits		Note
			Average Annual Benefits from GSP (af/yr)	Refined Average Annual Benefits Since GSP (af/yr)	Actual Benefits in 2021 (af/yr)	Actual Average Annual Benefits Since GSP (af/yr)	
Planned	Colusa County Water District (CCWD) In-Lieu Groundwater Recharge	CCWD	27,000	-	-	-	*No update since GSP development.*
Planned	Colusa Drain MWC (CDMWC) In-Lieu Groundwater Recharge	CDMWC	28,000	-	-	-	*No update since GSP development.*
Planned	Colusa Subbasin Multi-Benefit Groundwater Recharge	CGA, GGA and TNC	5,200		220	220	Recharge occurred in in one field (66 acres) due to surface water restrictions in 2021.
Planned	Orland-Artois Water District (OAWD) Land Annexation and Groundwater Recharge	OAWD	23,000	14,000	-	-	Project benefits have been refined since GSP development. The project is targeting 15,000 af of deliveries in Shasta Non-Critical years, with an updated gross average annual benefit of approximately 14,000 af/yr.
Planned	Sycamore Slough Groundwater Recharge Pilot Project	Landowner	500	-	*Not quantified as of Annual Report development*	-	Recharge occurred in early 2022. Actual benefits have not yet been quantified at the time of Annual Report development.
Ongoing	Reclamation District 18 (RD108) and CCWD Agreement for Five-Year In-Lieu Groundwater Recharge Project	RD108 and CCWD	8,000	-	8,000	8,000	*No update since GSP development. Actual benefits assumed to equal average annual benefits from GSP.*
Ongoing	Glenn-Colusa Irrigation District (GCID) Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits	GCID	*TBD*	-	-	-	*No update since GSP development.*
Ongoing	Sycamore Marsh Farm Direct Recharge Project	Landowner	*TBD*	-	-	-	*No update since GSP development.*

Category (from GSP)	Project/Management Action Name	Proponent	Anticipated or Reported Benefits from GSP		Actual Benefits		Note
			Average Annual Benefits from GSP (af/yr)	Refined Average Annual Benefits Since GSP (af/yr)	Actual Benefits in 2021 (af/yr)	Actual Average Annual Benefits Since GSP (af/yr)	
Ongoing	GCID Expansion of In-Basin Program for In-lieu Groundwater Recharge	GCID	*TBD*	-	-	-	*No update since GSP development.*
Ongoing	Orland Unit Water Users' Association (OUWUA) Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping	OUWUA	*TBD*	-	-	-	*No update since GSP development.*
Ongoing	Urban Water Conservation in Willows	California Water Service – Willows District	2	-	80	80	From 2020-2021, the City of Willows had a 5.8 percent total reduction in water production (approximately 80 af).
Potential	Tehama-Colusa Canal Trickle Flow to Ephemeral Streams	RD108	-	-	-	-	*No update since GSP development.*
Potential	*All Others Listed in GSP*	-	-	-	-	-	*No update since GSP development.*

7.3.1 Planned Projects and Management Actions

This section describes updates to planned PMAs as of April 2022. Descriptions are provided only for those PMAs with noted updates since GSP submission.

7.3.1.1 Colusa Subbasin Multi-Benefit Groundwater Recharge

The Nature Conservancy (TNC) is partnering with private landowners and the CGA and GGA for an on farm, multi-benefit groundwater recharge incentive program that provides benefits to: groundwater conditions (via groundwater recharge), migratory shorebirds through the creation of critical winter habitat on farms, disadvantaged communities and other communities by replenishing critical domestic and agricultural water supplies, and private landowners through incentive payments. A pilot program was conducted between 2018 and 2021 to evaluate different durations and locations of flooding that would provide multiple benefits for migratory shorebird habitat and groundwater recharge. The program is planned to expand into the future. This project is described in greater detail in Section 6.3.3 of the Colusa Subbasin GSP.

Since GSP development, recharge was conducted on one participating field in 2021. The total applied surface water was 290 af, and the estimated recharge benefit was 220 af. Participation was reduced from earlier years due to surface water restrictions, though the expanded program plans to enroll additional fields.

7.3.1.2 Orland-Artois Water District Land Annexation and Groundwater Recharge

Orland-Artois Water District (OAWD), a Central Valley Project (CVP) water contractor, is working with a group of neighboring non-district landowners to annex approximately 12,000 acres into the district service area. These lands are already developed agricultural properties that currently rely solely on groundwater for irrigation water supplies. Supplemental surface water for the annexed lands would be secured through annual and multi-year purchase or transfer agreements with willing sellers, conveyed through the existing Tehama Colusa Canal (TCC), and distributed to the annexed lands through existing OAWD facilities and new distribution facilities. New facilities include turnouts off the TCC, pipelines, pumping plants, and metered farm turnouts. At the time of GSP development, it was estimated that approximately 25,000 af of surface water would be delivered to annexed lands in all years but Shasta Critical years, resulting in a reduction of groundwater pumping of 23,000 af/yr on average across all years. This project is described in greater detail in Section 6.3.4 of the Colusa Subbasin GSP.

This project is of key interest, as it would directly address groundwater conditions in a hotspot area within the Colusa Subbasin where groundwater levels have declined and land subsidence has occurred in recent years. Planning efforts and discussions have continued with OAWD, the Tehama-Colusa Canal Authority (TCCA), the Glenn Local Agency Formation Commission (LAFCO), and USBR. This project is planned for implementation as soon as possible, with planning for annexation and new facilities design already underway. Accounts have been opened and deposits submitted to OAWD and USBR for their costs to review the annexation and associated infrastructure. The initial feedback from all agencies has been positive to date.

Since GSP development, refinements have been made to several aspects of the project, including planned infrastructure, benefits, and costs:

- Six new turnouts (versus four described in the GSP) are planned to be constructed on the TCC to regulate releases from the canal into newly constructed distribution facilities, and distribution pipelines are expected to range in size from approximately 8 to 36 inches in diameter.
- It is estimated that approximately 15,000 af of surface water would be delivered to annexed lands in all years but Shasta Critical years (versus 25,000 af described in the

GSP), resulting in a reduction of groundwater pumping of 14,000 af/yr on average across all years.

- The estimated total capital costs of the project have been revised to $12 million

Project development is expected to continue in 2022.

7.3.1.3 Sycamore Slough Groundwater Recharge Pilot Project

Proctor and Gamble (P&G) and Davis Ranches entered into a cooperative agreement to implement a 10-year groundwater recharge pilot project from fall 2021 through 2030. The project plans to apply surface water diverted from the Sacramento River to a 66-acre field on Davis Ranches for 30 to 45 days each fall or winter, providing multiple benefits to the Colusa Subbasin through groundwater recharge and by providing habitat for migrating birds. This project is described in greater detail in Section 6.3.5 of the Colusa Subbasin GSP.

Since GSP development, Davis Ranches has continued with project development and planning through fall 2021, and has begun project implementation with field flooding and monitoring in winter 2021/2022. Surface water was applied to the field between mid-January 2022 and late February 2022 to provide recharge and habitat benefits. Applied water and groundwater recharge benefits are being monitored through a combination of existing and newly installed data collectors in the field. Davis Ranches is considering installing spill boxes to enhance outflow measurements in the future. Davis Ranches is also in the process of adapting a water budget application for computing the field-scale water balance and quantifying recharge benefits. The volume of these recharge benefits will be reported when known.

7.3.2 Ongoing Projects and Management Actions

This section describes updates to ongoing PMAs as of April 2022. Descriptions are provided only for those ongoing PMAs with noted updates since GSP implementation.

7.3.2.1 Urban Water Conservation in Willows

The California Water Service – Willows District is implementing urban water conservation measures through water waste prevention ordinances, metering, conservation pricing, public education and outreach, programs to assess and manage distribution system real loss, water conservation program coordination and staffing support, and other demand management measures. These are described in greater detail in Chapter 9 of the 2020 Urban Water Management Plant (UWMP) for the California Water Service, and are described in Section 6.4.2.1 of the Colusa Subbasin GSP.

Since GSP development, the California Water Service – Willows District has continued implementation of these many measures. From 2020-2021, the California Water Service – Willows District had a 5.8 percent total reduction in groundwater production for urban use (approximately 80 af).

7.3.3 Potential Projects and Management Actions

This section describes updates to potential PMAs as of April 2022. Descriptions are provided only for those potential PMAs with noted updates since GSP implementation.

7.3.3.1 Tehama-Colusa Canal Trickle Flow to Ephemeral Streams

The Tehama-Colusa Canal (TCC) has existing gates that are used to dewater sections of the canal into ephemeral streams that intersect the canal. In the GSP, a potential recharge project concept was proposed in which water could be discharged from the TCC into these streams at a rate where they do not flow out of the Colusa Subbasin but recharge the groundwater system. Flow measurement devices would need to be added to the gates for project implementation. Surface water for recharge would be sourced from the Sacramento River under existing USBR water supply contracts held by Tehama-Colusa Canal contractors, existing water rights settlement contracts, and annual Section 215 contracts. A summary of the project is provided in Section 6.5.1.8 of the Colusa Subbasin GSP.

Further conceptual development of this project has occurred since the GSP, with identification of potential streams, water sources, and operating strategies to most effectively conduct recharge. Potential discharge locations have recently been identified by RD108 in partnership with CCWD and the TCCA. Coordination has also occurred with landowners to identify potential funding measures and to identify potential project monitoring opportunities near those ephemeral streams. In 2021, a proof-of-concept test of the trickle flow project was conducted when a portion of the Tehama-Colusa Canal was dewatered. Project development is anticipated to continue in 2022.

7.3.4 GSP Implementation Efforts by the GSAs

In addition to the PMAs described above, the CGA and the GGA have also continued efforts toward GSP implementation. Specific efforts are described below.

7.3.4.1 Funding and Financing Plan Discussion

In early 2021, CGA and GGA staff worked with a consultant team to develop a presentation for the CGA and GGA Boards to prompt discussion of funding and financing planning for GSP implementation. The presentation was developed to provide an overview of GSP costs, the finance plan development process, and various options and examples that the GSAs may consider for equitably assigning GSP implementation costs. The presentation was given at a Joint Board meeting in March 2022, spurring discussions and serving as a foundation for development of a finance plan in the future.

7.3.4.2 Hydrogeologic Investigation

In 2021-2022, GSA staff have worked with a consultant team to create a strategic planning document, referred to as the Hydrogeologic Investigation, to guide implementation of various technical studies and planning efforts to fill data gaps identified in the Colusa Subbasin GSP. Development of the Hydrogeologic Investigation is described in **Section 7.1**.

7.3.4.3 Well Monitoring Pilot Program

In 2021-2022, GSA staff have worked with a consultant team to implement the first and second phases of the Well Monitoring Pilot Program (WMPP), described in **Section 7.1**.

7.3.4.4 Additional Subsidence Benchmarks

In an effort to address subsidence-related data gaps in the Colusa Subbasin, the GSAs have proposed installing 10 additional land subsidence benchmarks in areas of the Colusa Subbasin where recent subsidence rates have increased most significantly, including the Arbuckle-College City area in Colusa County and the Orland-Artois area in Glenn County. Planning and installation is anticipated to occur in spring 2022, coinciding with development of the Hydrogeologic Investigation. Additional information is described in **Section 7.1**.

7.3.4.5 Data Management System

In 2018, the CGA and GGA worked with a consulting team to develop a preliminary data management system (DMS) to support GSP development. The preliminary DMS was used to process and store data related to groundwater levels, surface water inflows, diversions, weather, and other information pertaining to the Colusa Subbasin. In 2022, the GSAs are continuing efforts to identify potential permanent DMS platforms and desired DMS features that would benefit ongoing GSP reporting and implementation

8 References

American Society of Civil Engineers (ASCE). (2016) ASCE Manuals and Reports on Engineering Practice No. 70, Evaporation, Evapotranspiration, and Irrigation Water Requirements (Second Edition).

United States Department of Agriculture - Soil Conservation Service (USDA-SCS). 1993. Chapter 2. Irrigation Water Requirements. In Part 623 National Engineering Handbook. September 1993.