Table 3-1. Summary of Undesirable Results Applicable to the Plan Area

Sustainable Indicator	Historical Period (Prior to 2015)	Existing Conditions	Future Conditions without GSP Implementation	Future Conditions with GSP Implementation
Chronic Lowering of Groundwater Levels	Yes	Yes	Yes	No
Reduction of Groundwater Storage	Yes	Yes	Yes	No
Land Subsidence (Western Management Area)	Yes	Yes	Yes	No
Land Subsidence (Eastern Management Area)	No	No	Possibly	No
Seawater Intrusion	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Degraded Water Quality	Yes	Yes	Yes	No[1]
Depletion of Interconnected Surface Water	Yes	Possibly[2]	Possibly	No

[1] There may be future continued degradation of groundwater quality that is not related to GSP Projects and Management Actions.
[2] Surface water and groundwater are disconnected under existing conditions for most of Subbasin; insufficient data exists to fully evaluate interconnected surface water along the San Joaquin River.

3.1.2 Description of Measures

Recharge projects, which include projects that replace groundwater use with surface water use (in lieu recharge), and management actions that reduce total demand are planned to be implemented over the 20-year Implementation Period from 2020 through 2040. Together the projects and the management actions will increase groundwater inflows and decrease groundwater outflows to bring the groundwater system into balance by 2040 and will allow its operation to remain sustainable over a 50-year period representing average hydrologic conditions.

3.1.3 Explanation of How the Goal Will Be Achieved in 20 Years

Implementation of recharge projects will increase inflow to the groundwater system, thus increasing groundwater levels in wet years when water is available for recharge. Implementation of projects that replace groundwater use with surface water use will reduce groundwater pumping to maximize the use of surface water, also contributing to increases or stabilization in groundwater levels. Demand reduction will decrease the consumptive use of groundwater, also contributing to increases or stabilization of groundwater levels. The combination of the increased inflows through recharge, decreased outflows through the projects that replace groundwater use with surface water use, and through the reduced demand resulting from the management actions result in groundwater inflows equaling outflows over the Sustainability Period (2040 to 2090), as described in Section 2.

3.2 Measurable Objectives (23 CCR § 354.30)

As detailed below, the MOs represent the expected operating conditions for the Subbasin. If the GSAs successfully operate to the MOs described, the Subbasin will be operating sustainably. MOs and interim milestones are detailed below. A description of the MOs and how they were established are provided, along with recognition of the anticipated fluctuations in basin conditions around the established MOs. In addition, this section describes how the GSP helps to meet each measurable objective, how each measurable objective is intended to achieve the sustainability goal for the Subbasin for long-term beneficial uses, how MOs are integrated for the two different Management Areas, and how the interim milestones are intended to reflect the anticipated progress toward the MOs during the 2020 to 2040 implementation period.

The GSP regulations define MOs as specific, quantifiable goals for the maintenance or improvement of specific groundwater conditions that have been included in an adopted Plan to achieve the sustainability goal for the basin.

Per the GSP regulations:

1. MOs shall be established, including interim milestones in increments of five years, to achieve the sustainability goal for the basin within 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon.
2. MOs shall be established for each sustainability indicator, based on quantitative values using the same metric and monitoring sites as are used to define the MTs.
3. MOs shall provide a reasonable margin of operational flexibility under adverse conditions, which shall take into consideration components such as historical water budgets, seasonal and long-term trends, and periods of drought, and be commensurate with levels of uncertainty.
4. A representative measurable objective for groundwater elevation to serve as the value for multiple sustainability indicators may be established where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual MOs as supported by adequate evidence. Each Plan shall describe a reasonable path to achieve the sustainability goal for the basin within 20 years of Plan implementation, including a description of interim milestones for each relevant sustainability indicator, using the same metric as the measurable objective, in increments of five years.

The MOs developed for each applicable sustainability indicator in this GSP are based on the current understanding of the Plan Area and basin setting as discussed in detail in Chapter 2. Representative Monitoring Sites (RMS) are identified for monitoring of interim milestones, MOs, and MTs for each sustainability indicator, and are also known as sustainability indicator wells.

3.2.1 Chronic Lowering of Groundwater Levels

MOs and interim milestones for chronic lowering of groundwater levels are described below.

3.2.1.1 Measurable Objectives

MOs for groundwater levels were established in accordance with the sustainability goal through review and evaluation of measured groundwater level data and future projected fluctuations in groundwater levels utilizing the numerical groundwater flow model (**Appendix 6.D**), which simulated implementation of PMAs. This analysis provides estimates of the expected groundwater level variability due to climatic and operational variability. Both annual (year to year) and seasonal (winter/spring to summer/fall) variability were considered. MOs for groundwater levels were calculated as the model-derived average groundwater levels over the Sustainability Period from 2040 to 2090, modified if necessary to account for occasional offset between historically observed and modeled groundwater levels. MOs for groundwater levels for each sustainability indicator well or RMS are summarized in **Table 3-2**, and locations of groundwater level RMS are shown in **Figure**[61] **3-1**. These MOs are set specific to aquifer zones (where possible) designated as Upper Aquifer (above the Corcoran Clay where present, and equivalent depth to the east where Corcoran Clay is not present) and Lower Aquifer. Groundwater level hydrographs showing MOs for each groundwater level RMS are provided in **Appendix 3.A.**

Groundwater level is the sustainability indicator most likely to affect GDEs in the Subbasin. The Subbasin's single GDE unit, the San Joaquin River Riparian GDE Unit, is located along the San Joaquin River in the Western Management Area (see Section 2.2.2.6 and **Appendix 2.B**). Groundwater in the GDE unit is tightly coupled with surface flow and runoff and is generally maintained at depths within the maximum rooting depth range of the dominant phreatophytic species present in the unit (see Section 2.2.2). The groundwater that is potentially accessible to the vegetation composing the GDE unit likely occurs as a shallow perched/mounded aquifer fed largely by percolation of surface flow from the San Joaquin River. As described in Section 2.2.5, it has been determined that a connection between regional groundwater and streams does not currently exist in most of the Subbasin. However, there remains some potential for shallow groundwater and the associated GDE Unit to be affected by pumping from the regional aquifer (although the risk of this potential impact is considered low). Therefore, MOs for the shallow Upper Aquifer wells in closest proximity to the San Joaquin River Riparian GDE Unit (MCW RMS-10, MCW RMS-11, and MCW RMS-12) are included in the list of RMS and are considered representative of groundwater conditions that could affect the GDE unit.

[61] Figure titles that are bolded can be found at the end of each chapter

Table 3-2. Summary of Groundwater Level Measurable Objectives for Representative Monitoring Sites

Well I.D.	Surface Elevation	Well Depth	Screen Top-Bottom	Model Layer(s)	Aquifer Designation	MO Depth[1]	MO Elev[1]	GSA	CASGEM Well?
CWD RMS-1	171	275	160-275	4	Lower	196	-25	CWD	CASGEM
CWD RMS-2	193	780	230-775	4	Lower	243	-50	CWD	No
CWD RMS-3	206	Unknown	Unknown	4	Lower	238	-32	CWD	No
CWD RMS-4	225	800	320-800	4	Lower	210	15	CWD	CASGEM
CWD RMS-5	207	Unknown	Unknown	4	Lower	219	-12	CWD	Voluntary
CWD RMS-6	275	820	257-726	4	Lower	304	-29	CWD	CASGEM
CWD RMS-7	169	330	135-288	3,4	Lower	134	35	CWD	CASGEM
CWD RMS-8	219	Unknown	Unknown	4	Lower	228	-9	CWD	Voluntary
CWD RMS-9	164	97	82-97	3	Upper	84	80	CWD	CASGEM
CWD RMS-10	182	Unknown	Unknown	4	Lower	188	-6	CWD	Voluntary
CWD RMS-11	199	529	187-529	4	Lower	190	9	CWD	CASGEM
CWD RMS-12	176	Unknown	Unknown	3	Upper	106	70	CWD	Voluntary
CWD RMS-13	167	Unknown	Unknown	4	Lower	133	34	CWD	Voluntary
CWD RMS-14	152	455	185-365	4	Lower	121	31	CWD	CASGEM
CWD RMS-15	213	955	290-935	4	Lower	230	-17	CWD	CASGEM
CWD RMS-16	212	Unknown	Unknown	4	Lower	211	1	CWD	Voluntary
CWD RMS-17	203	624	278-588	4	Lower	171	32	CWD	CASGEM
MCE RMS-1	276	Unknown	Unknown	4	Lower	296	-20	Madera County East	Voluntary
MCE RMS-2	272	466	218-464	4	Lower	284	-12	Madera County East	CASGEM
MCW RMS-1	120	186	Unknown	3	Upper	46	74	Madera County West	Voluntary
MCW RMS-2	123	Unknown	Unknown	2	Upper	31	92	Madera County West	No

Well I.D.	Surface Elevation	Well Depth	Screen Top-Bottom	Model Layer(s)	Aquifer Designation	MO Depth[1]	MO Elev[1]	GSA	CASGEM Well?
MCW RMS-3	122	Unknown	Unknown	2,3	Upper	32	90	Madera County West	Voluntary
MCW RMS-4	138	Unknown	Unknown	4	Lower	127	11	Madera County West	Voluntary
MCW RMS-5	146	Unknown	Unknown	4	Lower	118	28	Madera County West	Voluntary
MCW RMS-6	139	Unknown	Unknown	4	Lower	107	32	Madera County West	Voluntary
MCW RMS-7	138	800	290-400	4	Lower	93	45	Madera County West	CASGEM
MCW RMS-8	142	480	160-475	3,4	Composite	87	55	Madera County West	CASGEM
MCW RMS-9	155	700	265-696	5	Lower	110	45	Madera County West	CASGEM
MCW RMS-10	123	26	25-Oct	1	Upper	14	109	Madera County West	No
MCW RMS-11	127	30	Unknown	1	Upper	13	114	Madera County West	No
MCW RMS-12	127	29	Unknown	1	Upper	17	110	Madera County West	No
MER RMS-1	225	Unknown	Unknown	4	Lower	254	-29	SVMWC	No
TRT RMS-1	134	196	158-192	3	Upper	67	67	TTWD	No
TRT RMS-2	135	500	300-500	4	Lower	76	59	TTWD	CASGEM
TRT RMS-3	137	799	168-790	5	Lower	88	49	TTWD	No
TRT RMS-4	141	840	190-260	3,4	Composite	91	50	TTWD	CASGEM

[1] The actual MO is based on the groundwater elevation, but the depth to water corresponding to the surface elevation in the project database is also provided.
* Each GSA is responsible for collecting groundwater levels for the representative monitoring sites within their GSA area. However, SJRRP well data is collected by USBR.

3.2.1.2 Interim Milestones

Interim milestones for chronic lowering of groundwater levels were established at five-year intervals over the Implementation Period from 2020 to 2040 at 2025, 2030, 2035 and 2040. Interim milestones for groundwater levels were established through review and evaluation of measured groundwater level data and future projected fluctuations in groundwater levels utilizing the numerical groundwater flow model, which simulated implementation of PMAs. Each interim milestone was developed based on the modeled groundwater level for the month of October in the year preceding the interim milestone date (e.g., October 2024 for the 2025 interim milestone). Where necessary, adjustments were made to account for occasional offsets between historically observed and modeled data. Interim milestones for groundwater levels for each RMS are summarized in **Table 3-3**, and locations of groundwater level RMS are shown in **Figure 3-1**.

Table 3-3. Summary of Groundwater Level Interim Milestones for Representative Monitoring Sites

Well I.D.	Model Layer(s)	2025 DTW	2030 DTW	2035 DTW	2040 DTW	2025 Elev	2030 Elev	2035 Elev	2040 Elev	GSA
CWD RMS-1	4	230	234	256	250	-59	-62	-85	-78	CWD
CWD RMS-2	4	256	268	288	289	-63	-75	-95	-96	CWD
CWD RMS-3	4	277	284	307	303	-71	-78	-100	-97	CWD
CWD RMS-4	4	308	318	335	336	-83	-92	-109	-110	CWD
CWD RMS-5	4	281	280	306	297	-74	-73	-99	-90	CWD
CWD RMS-6	4	352	353	362	357	-77	-78	-87	-82	CWD
CWD RMS-7	3,4	219	210	237	227	-50	-41	-68	-58	CWD
CWD RMS-8	4	304	301	327	316	-85	-82	-108	-97	CWD
CWD RMS-9	3	85	86	85	86	79	78	79	78	CWD
CWD RMS-10	4	246	242	270	257	-64	-60	-87	-75	CWD
CWD RMS-11	4	268	259	288	270	-69	-60	-89	-71	CWD
CWD RMS-12	3	123	124	124	124	53	53	52	52	CWD
CWD RMS-13	4	212	194	224	205	-45	-27	-57	-38	CWD
CWD RMS-14	4	284	272	298	277	-132	-120	-146	-125	CWD
CWD RMS-15	4	312	309	335	322	-99	-96	-122	-109	CWD
CWD RMS-16	4	295	288	315	300	-83	-76	-102	-87	CWD
CWD RMS-17	4	319	308	334	316	-116	-105	-131	-113	CWD
MCE RMS-1	4	346	349	356	355	-69	-73	-80	-79	Madera County East
MCE RMS-2	4	369	377	384	387	-97	-105	-112	-115	Madera County East
MCW RMS-1	3	58	60	60	63	62	60	60	57	Madera County West
MCW RMS-2	2	33	35	36	38	90	89	87	85	Madera County West
MCW RMS-3	2,3	47	50	50	54	75	72	72	68	Madera County West
MCW RMS-4	4	158	159	173	171	-20	-20	-35	-33	Madera County West
MCW RMS-5	4	164	163	180	178	-18	-17	-33	-32	Madera County West

Well I.D.	Model Layer(s)	2025 DTW	2030 DTW	2035 DTW	2040 DTW	2025 Elev	2030 Elev	2035 Elev	2040 Elev	GSA
MCW RMS-6	4	142	147	155	159	-2	-8	-16	-20	Madera County West
MCW RMS-7	4	132	136	145	148	6	2	-7	-10	Madera County West
MCW RMS-8	3,4	166	155	177	165	-24	-13	-35	-23	Madera County West
MCW RMS-9	5	202	198	209	203	-47	-43	-54	-48	Madera County West
MCW RMS-10	1	8	14	9	16	115	109	114	107	Madera County West
MCW RMS-11	1	11	22	13	23	116	105	114	104	Madera County West
MCW RMS-12	1	15	32	19	32	112	95	109	95	Madera County West
MER RMS-1	4	285	316	313	335	-60	-90	-88	-110	SVMWC
TRT RMS-1	3	96	113	108	124	38	21	27	10	TTWD
TRT RMS-2	4	110	114	121	125	25	21	14	10	TTWD
TRT RMS-3	5	132	133	143	142	5	5	-6	-4	TTWD
TRT RMS-4	3,4	149	153	157	160	-8	-12	-16	-19	TTWD

3.2.1.3 Achieving and Maintaining Sustainability

The combination of interim milestones and MOs reflect how the basin anticipates achieving and maintaining sustainability. It should be noted that future projections require assumptions about future hydrologic conditions, including the sequence of wet, average, and dry climatic years. The future climatic assumptions for the Implementation Period used in this GSP incorporate sequences of wet, average, and dry years that represent overall long-term average historical climatic conditions over the Implementation Period without any prolonged periods of extremely dry or extremely wet years. Under these climatic assumptions, the Implementation Period would involve some gradual and continued decline in groundwater levels after 2020 while PMAs are being implemented. Groundwater at most well locations are anticipated to reach future lows between 2030 and 2040, before rebounding to higher levels after 2040 (when all PMAs are implemented). Groundwater levels at Upper Aquifer wells representative of the shallow zone along the San Joaquin River are considered representative of the single GDE unit in the Subbasin, located along the San Joaquin River in the Western Management Unit, and are generally anticipated to be maintained at levels suitable for continued support of GDEs during the Implementation Period and Sustainability Period. At many RMS locations, average groundwater levels are considerably higher during the Sustainability Period than is anticipated to occur during portions of the Implementation Period (and in some cases even higher than the recent historical period). This overall pattern of anticipated fluctuations in groundwater levels reflects the time to design, permit, and construct projects and implement demand reduction that is planned to incrementally increase linearly between 2020 and 2040.

It is also important to note that review of RMS groundwater level hydrographs in **Appendix 3.A** demonstrate that average domestic well depths are generally below (with one exception), and in many cases far below, the lowest predicted groundwater levels during the Implementation Period. It should further be recognized that review of data for existing wells and ongoing installation of new nested monitoring wells generally indicate that water levels in deeper wells (i.e., depths typical for agricultural and municipal wells) are generally lower than groundwater levels in zones screened by shallower domestic wells. This means that comparison of observed and modeled groundwater levels for RMS wells screened in deeper zones to average domestic well depths likely shows a worst-case scenario (i.e., groundwater levels for most nearby domestic wells will be higher than indicated on the hydrograph for a deep zone RMS well). That being said, a detailed domestic well inventory and analysis that was recently conducted (**see Appendix 2.G**) reinforces the need for a Domestic Well Mitigation Program during the GSP Implementation Period prior to achieving basin sustainability. As described in Section 3.3.1, the GSAs have expressed and formalized their clear **commitment to fund and implement the Domestic Well Mitigation Program beginning no later than January 1, 2023**. Additional information about the Domestic Well Mitigation Program is provided in **Appendix 3.D**.

3.2.1.4 Impact of Selected Measurable Objectives on Adjacent Basins

The MOs established for Chowchilla Subbasin provide a good basis for evaluation of anticipated impacts on adjacent subbasins from implementation of the GSP. This is because MOs are set to reflect the average groundwater levels to be maintained during the Sustainability Period. Ultimately, the potential for impacts on adjacent subbasins will be primarily a function of average water levels in Chowchilla Subbasin during the Sustainability Period, average water levels in adjacent subbasins during the Sustainability Period, and natural groundwater flow conditions that would be expected to occur at subbasin boundaries (e.g., pre-development groundwater flow conditions). The average groundwater levels expected for Chowchilla Subbasin are reflected in the MOs. As indicated in the individual RMS hydrographs in **Appendix 3.A**, the MOs are generally higher than historical lows (where recent water level are available for comparison) and in many cases much higher than historical low groundwater elevations. Groundwater model results indicate that the average groundwater levels reflected in the MOs will result in greatly reduced net subsurface inflow to Chowchilla Subbasin from surrounding basins compared to historical net subsurface inflow. Therefore, the PMAs implemented for this GSP are expected to benefit adjacent basins (compared to historical conditions) and not hinder the ability of adjacent basins to be sustainable. Discussions between Chowchilla Subbasin representatives and adjacent subbasin representatives have occurred in meetings described in **Appendices 2.C and 6.C**.

3.2.2 Reduction in Groundwater Storage

MOs and interim milestones for reduction in groundwater storage are described below.

3.2.2.1 Measurable Objective

There is a direct relationship between groundwater levels and groundwater storage (see Section 3.3 for additional discussion) allowing groundwater levels to be used as a proxy for the groundwater storage sustainability indicator in this GSP. Therefore, the measurable objective for reduction in groundwater storage is based on the MOs for chronic lowering of groundwater levels. The measurable objective for reduction in groundwater storage is no long-term reduction in groundwater storage within the Subbasin during the sustainability period after 2040, which will be represented by the MOs for groundwater levels.

3.2.2.2 Interim Milestones

Groundwater levels are being used as a proxy for groundwater storage; therefore, the interim milestones for reduction in groundwater storage are based on the interim milestones for chronic lowering of groundwater levels.

3.2.2.3 Achieving and Maintaining Sustainability

The combination of interim milestones and MOs reflect how the basin will achieve and maintain sustainability. Since groundwater levels serve as a practical proxy for evaluating reduction in groundwater storage, achieving and maintaining sustainability relative to this indicator is similar to that described above in the groundwater level section.

3.2.2.4 Impact of Selected Measurable Objectives on Adjacent Basins

Groundwater model results indicate that the average groundwater levels reflected in the MOs will result in greatly reduced net subsurface inflow to Chowchilla Subbasin from surrounding basins compared to historical net subsurface inflow. This will serve to allow more groundwater to remain in storage in adjacent basins. Therefore, the projects and management actions implemented for this GSP will not hinder the ability of adjacent basins to be sustainable with regards to groundwater storage.

3.2.3 Land Subsidence

Information on historical subsidence in the Subbasin is presented in the HCM (Chapter 2). The Western Management Area has experienced significant subsidence and damage to infrastructure since 2005. MOs and interim milestones for land subsidence in the Western Management Area are described below.

Land subsidence has not resulted in significant and unreasonable impacts to infrastructure in the Eastern Management Area. However, land subsidence sustainability criteria have been developed to avoid significant and unreasonable impacts from occurring in the future.

3.2.3.1 Measurable Objective

Groundwater levels are being used as a proxy for land subsidence in the Western Management Area (subject to contemporaneous review of ongoing subsidence surveys during the Implementation Period and adaptive management as necessary); therefore, the MOs for land subsidence are based on the MOs for chronic lowering of groundwater levels. In the Eastern Management Area, an amount of cumulative subsidence coupled with groundwater levels as a proxy are being used as the metrics for the subsidence sustainability indicator. The MOs for subsidence in the Eastern Management Area are based on groundwater levels and are the same as the MOs established for chronic lowering of groundwater levels.

3.2.3.2 Interim Milestones

As with the Measurable Objective, groundwater levels are being used as a proxy for land subsidence interim milestones (subject to contemporaneous review of ongoing subsidence surveys during the Implementation Period and adaptive management as necessary); therefore, the interim milestones for land subsidence are based on the interim milestones for chronic lowering of groundwater levels.

3.2.3.3 Achieving and Maintaining Sustainability

The combination of interim milestones and MOs reflect how the basin will achieve and maintain sustainability. In the Western Management Area where undesirable results have recently occurred with regard to land subsidence, interim milestones were selected to minimize the occurrence of near-term water levels below recent historical low groundwater levels, while the long-term (MOs) water levels were selected to result in groundwater levels above recent historical lows (except possibly during severe or extended droughts). Achieving these interim milestones and MOs is intended to slow the rate of recent/current subsidence and minimize future subsidence.

3.2.3.4 Impact of Selected Measurable Objectives on Adjacent Basins

Groundwater levels are being used as a proxy for land subsidence in the Western Management Area (subject to contemporaneous review of ongoing subsidence surveys during the Implementation Period and adaptive management as necessary); therefore, the impact on adjacent basins for land subsidence MOs is the same as for chronic lowering of groundwater levels. Similarly, because land subsidence MOs in the Eastern Management Area are also based on the MOs for chronic lowering of groundwater levels, the impact on adjacent subbasins is the same as for chronic lowering of groundwater levels.

3.2.4 Degraded Water Quality

Varied levels of particular constituents within the groundwater exist and affect water quality considerations throughout the Subbasin (see Section 2). In some cases, the level of certain constituents have raised water quality concerns for the use of groundwater for drinking or for irrigated agriculture. Effects on GDEs due to degraded water quality can include visually detectable declines in the health of terrestrial vegetation. However, available data do not provide evidence of any such effects in the Subbasin and no such effects are expected in the future (**Appendix 2.B**). Elevated concentrations of naturally occurring and existing constituent concentrations resulting from historical land use practices are present in certain areas of the basin. As noted in Section 2 (HCM), elevated concentrations of nitrate are present in some wells in the Subbasin, and trends in these wells may be increasing with time. Continued increases in these concentrations may occur due to historical nitrogen loading in the unsaturated zone independent of any GSP activities. The planned PMAs are not intended to remediate or halt these trends of increasing concentrations; however, they also are not anticipated to exacerbate these trends and conditions. Rather, over the long term, the GSP anticipates that achieving sustainability will actually help the Subbasin's interested parties meet water quality objectives. Municipal and domestic supply (MUN) is a designated beneficial use for groundwater in the Subbasin; therefore, groundwater quality degradation is considered significant and unreasonable based on adverse impacts to this beneficial use. This GSP intends to implement planned PMAs in manners that do not further exacerbate groundwater quality impacts to beneficial uses.

3.2.4.1 Measurable Objectives

MOs for groundwater quality are established to not exacerbate adverse impacts on all beneficial uses of groundwater resulting from implementation of GSP projects or management actions. MOs for the groundwater quality sustainability indicator are intended to assure that GSP PMAs do not cause groundwater quality conditions to become unsuitable for any beneficial use, especially municipal and domestic supply uses since these are the most restrictive from a water quality standpoint. The groundwater quality MOs are defined for individual representative groundwater quality indicator wells (RMS) for the key water quality constituents arsenic, nitrate, and TDS based on consideration of existing or historical groundwater quality conditions and the drinking water MCLs for each of the key constituents. These key constituents were selected for assigning of MOs for groundwater quality because they currently exist at elevated concentrations in the Subbasin or reflect a range of potential groundwater quality impacts related to implementation of GSP PMAs. As discussed in Section 2 of this GSP, nitrate is the most widespread water quality constituent of concern in the area, occurring at elevated concentrations in groundwater in some areas, mainly as a result of historical agricultural practices and associated legacy groundwater quality impacts. Because of the widespread association of elevated nitrate concentrations with agricultural fertilization application, MOs for nitrate are also likely to address other groundwater quality impacts associated with agricultural activities, including for much less common groundwater contaminants such as pesticides. The MOs for arsenic and TDS are intended to address additional potential groundwater quality impacts associated with GSP PMAs that may result from lowered groundwater levels in some areas or altered groundwater flow dynamics.

The RMS consist of wells to be monitored by the GSAs along with wells being monitored by the other entities through existing groundwater quality monitoring programs for the Division of Drinking Water (DDW) or Irrigated Lands Regulatory Program (ILRP) and were selected to represent groundwater quality conditions across the Subbasin including in areas of greater domestic and public water supply well density (see **Section 2**). For all groundwater quality RMS, the measurable objective concentrations for arsenic, nitrate, and TDS are set at levels representative of recent concentrations observed in the well with the intent to ensure that activities related to GSP projects or management actions do not significantly adversely impact groundwater quality conditions. Recent concentrations observed from 2015 to early 2019, as well as anticipated continued trends that this period may reflect, were used as the basis for setting the measurable objective concentrations. The measurable objective concentrations for wells with existing or historical water quality results are the average of the recent concentrations for each of the key constituents rounded up to the nearest full integer of concentration for arsenic (in units of µg/L) and nitrate (in units of mg/L as nitrogen) and rounded up to the nearest interval of 50 mg/L for TDS. Measurable objective concentrations for groundwater quality for each sustainability indicator well are summarized in **Table 3-4**, and locations of groundwater quality sustainability indicator wells are shown in **Figure 3-2**. Tables and graphs of historical results for key water quality constituents in the representative groundwater quality indicator wells are presented in **Appendix 3.B**.

Table 3-4. Summary of Groundwater Quality Measurable Objectives for Representative Monitoring Sites

Well ID	Well Type	Well Depth	Screen Top-Bottom	Aquifer Designation	MO Arsenic Concentration (µg/L)	MO Nitrate Concentration (mg/L)	MO TDS Concentration (mg/L)	GSA Location	Entities to Conduct Monitoring	Measurement Frequency
Wells Monitored by GSAs: Existing										
CWD RMS-1	Domestic	275	160-275	Lower	8†	8†	400†	CWD	CWD	Annual
CWD RMS-2	Irrigation	780	230-775	Lower	8†	8†	400†	CWD	CWD	Annual
CWD RMS-4	Irrigation	800	320-800	Lower	8†	8†	400†	CWD	CWD	Annual
CWD RMS-5	Unknown	Unknown	Unknown	Lower	8†	8†	400†	CWD	CWD	Annual
CWD RMS-6	Irrigation	820	257-726	Lower	8†	8†	400†	CWD	CWD	Annual
CWD RMS-7	Irrigation	330	135-288	Lower	8†	8†	400†	CWD	CWD	Annual
CWD RMS-9	Monitoring	97	82-97	Upper	8†	8†	400†	CWD	CWD	Annual
CWD RMS-10	Unknown	Unknown	Unknown	Lower	8†	8†	400†	CWD	CWD	Annual
CWD RMS-11	Irrigation	529	187-529	Lower	8†	8†	400†	CWD	CWD	Annual
CWD RMS-12	Unknown	Unknown	Unknown	Upper	8†	8†	400†	CWD	CWD	Annual
CWD RMS-13	Unknown	Unknown	Unknown	Lower	8†	8†	400†	CWD	CWD	Annual
CWD RMS-15	Irrigation	955	290-935	Lower	8†	8†	400†	CWD	CWD	Annual
MCE RMS-1	Unknown	Unknown	Unknown	Lower	8†	8†	400†	Madera County East	Madera County	Annual
MCW RMS-1	Irrigation	186	Unknown	Upper	8†	8†	400†	Madera County West	Madera County	Annual
MCW RMS-4	Unknown	Unknown	Unknown	Lower	8†	8†	400†	Madera County West	Madera County	Annual
MCW RMS-7	Irrigation	800	290-400	Lower	8†	8†	400†	Madera County West	Madera County	Annual
MCW RMS-9	Irrigation	700	265-696	Lower	8†	8†	400†	Madera County West	Madera County	Annual
TRT RMS-1	Unknown	196	158-192	Upper	8†	8†	400†	TTWD	TTWD	Annual
TRT RMS-3	Unknown	799	168-790	Lower	8†	8†	400†	TTWD	TTWD	Annual
TRT RMS-4	Irrigation	840	190-260	Composite	8†	8†	400†	TTWD	TTWD	Annual
Clayton Ag Well #2	Irrigation	135	Unknown	Upper	8†	8†	400†	Madera County West	Madera County	Annual
Wells Monitored by GSAs: Future Monitoring Wells										
Site 1 MW – Shallow	Monitoring	150*	50-150*	Upper	8†	8†	400†	MID*	ILRP/Madera County	Annual
Site 1 MW – Middle	Monitoring	400*	200-400*	Lower	8†	8†	400†	MID*	Madera County	Annual
Site 1 MW – Deep	Monitoring	700*	500-700*	Lower	8†	8†	400†	MID*	Madera County	Annual
Site 2 MW – Shallow	Monitoring	100*	50-100*	Upper	8†	8†	400†	Madera County West*	ILRP/Madera County	Annual
Site 2 MW – Middle	Monitoring	350*	150-350*	Lower	8†	8†	400†	Madera County West*	Madera County	Annual
Site 2 MW – Deep	Monitoring	700*	500-700*	Lower	8†	8†	400†	Madera County West*	Madera County	Annual
Site 3 MW – Shallow	Monitoring	100*	50-100*	Upper	8†	8†	400†	Madera County East*	ILRP/Madera County	Annual
Site 3 MW – Middle	Monitoring	350*	150-350*	Lower	8†	8†	400†	Madera County East*	Madera County	Annual
Site 3 MW – Deep	Monitoring	700*	500-700*	Lower	8†	8†	400†	Madera County East*	Madera County	Annual

Well ID	Well Type	Well Depth	Screen Top-Bottom	Aquifer Designation	MO Arsenic Concentration (µg/L)	MO Nitrate Concentration (mg/L)	MO TDS Concentration (mg/L)	GSA Location	Entities to Conduct Monitoring	Measurement Frequency
Site 5 MW – Shallow	Monitoring	150*	50-150*	Upper	8†	8†	400†	MID/Madera County West*	ILRP/Madera County	Annual
Site 5 MW – Middle	Monitoring	400*	200-400*	Lower	8†	8†	400†	MID/Madera County West*	Madera County	Annual
Site 5 MW – Deep	Monitoring	700*	500-700*	Lower	8†	8†	400†	MID/Madera County West*	Madera County	Annual
Site 6 MW – Shallow	Monitoring	200*	100-200*	Upper	8†	8†	400†	Madera County West*	ILRP/Madera County	Annual
Site 6 MW – Middle	Monitoring	400*	200-400*	Lower	8†	8†	400†	Madera County West*	Madera County	Annual
Site 6 MW – Deep	Monitoring	700*	500-700*	Lower	8†	8†	400†	Madera County West*	Madera County	Annual
Site 7 MW – Shallow	Monitoring	250*	100-250*	Upper	8†	8†	400†	Madera County East*	ILRP/Madera County	Annual
Site 7 MW – Middle	Monitoring	400*	200-400*	Lower	8†	8†	400†	Madera County East*	Madera County	Annual
Site 7 MW – Deep	Monitoring	700*	500-700*	Lower	8†	8†	400†	Madera County East*	Madera County	Annual
Site 9 MW – Shallow	Monitoring	150*	50-150*	Upper	8†	8†	400†	MID*	ILRP/Madera County	Annual
Site 9 MW – Middle	Monitoring	400*	200-400*	Lower	8†	8†	400†	MID*	Madera County	Annual
Site 9 MW – Deep	Monitoring	700*	500-700*	Lower	8†	8†	400†	MID*	Madera County	Annual
Wells Monitored By Non-GSA Entities										
2000511-001	Public Supply	Unknown	Unknown	Unknown	2	6	350	CWD	DDW	Variable, according to DDW reqs.
2000597-001	Public Supply	Unknown	300-?	Lower	1	5	200	CWD	DDW	
2000681-002	Public Supply	Unknown	Unknown	Unknown	1	2	200	CWD	DDW	
2010001-008	Public Supply	Unknown	242-297	Lower	2	2	200	CWD	DDW	
2010001-010	Public Supply	Unknown	358-474	Lower	2	6	450	CWD	DDW	
2010001-011	Public Supply	Unknown	310-393	Lower	1	1	200	CWD	DDW	
2400216-001	Public Supply	Unknown	400-460	Lower	5	2	200	Madera County East	DDW	
ESJ11	Domestic	340	Unknown	Unknown	N/A‡	8	550	CWD	ILRP	Annual‡

* Construction details and locations for future monitoring wells are estimated; information will be updated upon completion of final site selection and well construction.
† Values will be confirmed and/or adjusted as needed based on results from initial sampling for constituents.
‡ Monitoring for the Irrigated Lands Regulatory Program does not include testing for arsenic; annual monitoring includes nitrate and specific conductance (SC), TDS is tested every five years; SC will be used as proxy for TDS in years in which TDS is not tested.

3.2.4.2 *Interim Milestones*

The interim milestones for the groundwater quality sustainability indicator are the same as the MOs and include ensuring that during the Implementation Period, GSP PMAs do not lead to degradation of existing groundwater quality conditions that would make groundwater unsuitable for the most restrictive beneficial use of municipal and domestic supply. The groundwater quality interim milestones are maintaining existing groundwater quality concentrations for arsenic, nitrate, and TDS at each sustainability indicator well over the Implementation Period as summarized in **Table 3-5**. Consistent with the MOs, groundwater quality interim milestones also include maintaining existing or historical groundwater quality conditions over the Implementation Period for wells in which the existing or historical conditions already exceed the MCL. The GSP does not include any plan or milestones specifically intended to improve groundwater quality conditions in wells with existing or historical MCL exceedances.

3.2.4.3 *Achieving and Maintaining Sustainability*

The combination of interim milestones and MOs reflect how the basin will achieve and maintain sustainability by ensuring that GSP PMAs do not significantly and unreasonably degrade groundwater quality conditions or exacerbate already degraded conditions, impacting beneficial uses in the Subbasin. The network of groundwater quality sustainability indicator wells will enable tracking of groundwater quality conditions as they relate to GSP-related activities and activities unrelated to GSP actions. If evaluation of groundwater quality monitoring suggests that GSP PMAs are having adverse impacts on groundwater quality affecting beneficial uses, modifications to the GSP PMAs may be required.

3.2.4.4 *Impact of Selected Measurable Objectives on Adjacent Basins*

Groundwater quality MOs are set to protect and maintain groundwater quality conditions suitable for all beneficial uses in the Subbasin, including municipal and drinking water supply, and as a result not anticipated to impact beneficial uses for groundwater in adjacent subbasins.

3.2.5 Depletion of Surface Water

As described in the HCM in Chapter 2, regional unconfined groundwater levels have generally been below the stream channel bottoms in the Chowchilla Subbasin for at least the last several years, and for many decades in most of the Subbasin. Thus, the connection between regional groundwater and streams was broken prior to 2015 along most streams, and the surface water depletion sustainability criterion is not applicable for most of the Subbasin. However, at times when sufficient water is released from Millerton Lake into the San Joaquin River, shallow groundwater levels are observed along the portion of the San Joaquin River adjacent to western Chowchilla Subbasin boundary. These shallow groundwater levels indicate the San Joaquin River may be technically connected to groundwater during some portion of a given time period. The underlying stratigraphy and hydrogeologic relationships between groundwater in shallow zones along the San Joaquin River and deeper zones where regional pumping occurs are not well understood, and a workplan is being developed to refine and improve the hydrogeologic understanding related to interconnected surface water (ISW). In the meantime, interim SMC have been developed for ISW along the San Joaquin River.

Table 3-5. Summary of Groundwater Quality Interim Milestones for Representative Monitoring Sites

Well ID	Aquifer Designation	2025 Arsenic Concentration (µg/L)	2030 Arsenic Concentration (µg/L)	2035 Arsenic Concentration (µg/L)	2040 Arsenic Concentration (µg/L)	2025 Nitrate Concentration (mg/L)	2030 Nitrate Concentration (mg/L)	2035 Nitrate Concentration (mg/L)	2040 Nitrate Concentration (mg/L)	2025 TDS Concentration (mg/L)	2030 TDS Concentration (mg/L)	2035 TDS Concentration (mg/L)	2040 TDS Concentration (mg/L)	GSA Location	Entities to Conduct Monitoring	Measurement Frequency
Wells Monitored by GSAs: Existing																
CWD RMS-1	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	CWD	CWD	Annual
CWD RMS-2	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	CWD	CWD	Annual
CWD RMS-4	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	CWD	CWD	Annual
CWD RMS-5	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	CWD	CWD	Annual
CWD RMS-6	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	CWD	CWD	Annual
CWD RMS-7	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	CWD	CWD	Annual
CWD RMS-9	Upper	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	CWD	CWD	Annual
CWD RMS-10	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	CWD	CWD	Annual
CWD RMS-11	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	CWD	CWD	Annual
CWD RMS-12	Upper	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	CWD	CWD	Annual
CWD RMS-13	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	CWD	CWD	Annual
CWD RMS-15	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	CWD	CWD	Annual
MCE RMS-1	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County East	Madera County	Annual
MCW RMS-1	Upper	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County West	Madera County	Annual
MCW RMS-4	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County West	Madera County	Annual
MCW RMS-7	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County West	Madera County	Annual
MCW RMS-9	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County West	Madera County	Annual
TRT RMS-1	Upper	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	TTWD	TTWD	Annual
TRT RMS-3	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	TTWD	TTWD	Annual
TRT RMS-4	Composite	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	TTWD	TTWD	Annual
Clayton Ag Well #2	Upper	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County West	Madera County	Annual
Wells Monitored by GSAs: Future Monitoring Wells																
Site 1 MW – Shallow	Upper	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	MID*	ILRP/Madera County	Annual
Site 1 MW – Middle	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	MID*	Madera County	Annual
Site 1 MW – Deep	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	MID*	Madera County	Annual

Well ID	Aquifer Designation	2025 Arsenic Concentration (µg/L)	2030 Arsenic Concentration (µg/L)	2035 Arsenic Concentration (µg/L)	2040 Arsenic Concentration (µg/L)	2025 Nitrate Concentration (mg/L)	2030 Nitrate Concentration (mg/L)	2035 Nitrate Concentration (mg/L)	2040 Nitrate Concentration (mg/L)	2025 TDS Concentration (mg/L)	2030 TDS Concentration (mg/L)	2035 TDS Concentration (mg/L)	2040 TDS Concentration (mg/L)	GSA Location	Entities to Conduct Monitoring	Measurement Frequency
Site 2 MW – Shallow	Upper	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County West*	ILRP/Madera County	Annual
Site 2 MW – Middle	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County West*	Madera County	Annual
Site 2 MW – Deep	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County West*	Madera County	Annual
Site 3 MW – Shallow	Upper	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County East*	ILRP/Madera County	Annual
Site 3 MW – Middle	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County East*	Madera County	Annual
Site 3 MW – Deep	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County East*	Madera County	Annual
Site 5 MW – Shallow	Upper	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	MID/Madera County West*	ILRP/Madera County	Annual
Site 5 MW – Middle	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	MID/Madera County West*	Madera County	Annual
Site 5 MW – Deep	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	MID/Madera County West*	Madera County	Annual
Site 6 MW – Shallow	Upper	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County West*	ILRP/Madera County	Annual
Site 6 MW – Middle	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County West*	Madera County	Annual
Site 6 MW – Deep	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County West*	Madera County	Annual
Site 7 MW – Shallow	Upper	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County East*	ILRP/Madera County	Annual
Site 7 MW – Middle	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County East*	Madera County	Annual
Site 7 MW – Deep	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	Madera County East*	Madera County	Annual
Site 9 MW – Shallow	Upper	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	MID*	ILRP/Madera County	Annual
Site 9 MW – Middle	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	MID*	Madera County	Annual
Site 9 MW – Deep	Lower	8†	8†	8†	8†	8†	8†	8†	8†	400†	400†	400†	400†	MID*	Madera County	Annual

Well ID	Aquifer Designation	2025 Arsenic Concentration (μg/L)	2030 Arsenic Concentration (μg/L)	2035 Arsenic Concentration (μg/L)	2040 Arsenic Concentration (μg/L)	2025 Nitrate Concentration (mg/L)	2030 Nitrate Concentration (mg/L)	2035 Nitrate Concentration (mg/L)	2040 Nitrate Concentration (mg/L)	2025 TDS Concentration (mg/L)	2030 TDS Concentration (mg/L)	2035 TDS Concentration (mg/L)	2040 TDS Concentration (mg/L)	GSA Location	Entities to Conduct Monitoring	Measurement Frequency
Wells Monitored By Non-GSA Entities																
2000511-001	Unknown	2	2	2	2	6	6	6	6	350	350	350	350	CWD	DDW	Variable, according to DDW reqs.
2000597-001	Lower	1	1	1	1	5	5	5	5	200	200	200	200	CWD	DDW	
2000681-002	Unknown	1	1	1	1	2	2	2	2	200	200	200	200	CWD	DDW	
2010001-008	Lower	2	2	2	2	2	2	2	2	200	200	200	200	CWD	DDW	
2010001-010	Lower	2	2	2	2	6	6	6	6	450	450	450	450	CWD	DDW	
2010001-011	Lower	1	1	1	1	1	1	1	1	200	200	200	200	CWD	DDW	
2400216-001	Lower	5	5	5	5	2	2	2	2	200	200	200	200	Madera County East	DDW	
ESJ11	Unknown	N/A‡	N/A‡	N/A‡	N/A‡	8	8	8	8	550	550	550	550	CWD	ILRP	Annual‡

* Construction details and locations for future monitoring wells are estimated; information will be updated upon completion of final site selection and well construction.
† Values will be confirmed and/or adjusted as needed based on results from initial sampling for constituents.
‡ Monitoring for the Irrigated Lands Regulatory Program does not include testing for arsenic; annual monitoring includes nitrate and specific conductance (SC), TDS is tested every five years; SC will be used as proxy for TDS in years in which TDS is not tested.

Available data and analyses (see Section 2.2.2.5) indicate the source of shallow groundwater that occurs along the San Joaquin River is infiltrating streamflow (i.e., shallow groundwater is surface water dependent) and that regional groundwater likely does not support streamflow along this reach of the San Joaquin River adjacent to the western boundary of Chowchilla Subbasin. Nonetheless, it is assumed that these conditions constitute interconnected surface water as defined under the GSP regulations for the purposes of establishing interim SMC prior to more fully characterizing shallow hydrogeologic conditions along the San Joaquin River and making a final determination regarding the presence/absence of interconnected surface water.

For the purposes of establishing interim SMC for ISW along the San Joaquin River, six RMS wells screened in the Upper Aquifer in close proximity to the San Joaquin River were evaluated by comparing modeled groundwater elevations to adjacent stream thalweg elevations (**Figure 3-3** and **Table 3-6)**. It is assumed that when groundwater elevations are at or above the stream thalweg elevation interconnected surface water is present at this location, and when groundwater elevations are below the adjacent stream thalweg elevation that interconnected surface water is not present. The amount of time over a given time period for which the groundwater elevations at an RMS well are at/above the stream thalweg elevation are defined as the percent of time ISW exists at that given location. As indicated in **Table 3-6**, the percent of time connected among the six RMS wells was 3% at MCW RMS-1 and MCW RMS-3, 11 to 26% at MCW RMS-2, MCW RMS-11 and MCW-12, and 78% at MCW RMS-10 over the historical time period from 1989 to 2015.

San Joaquin River restoration flows were initiated in October 2009 and continued through November 2011, prior to being interrupted by drought conditions from December 2011 through January 2016. In the Chowchilla Subbasin, the San Joaquin River flows adjacent to the San Joaquin River Riparian GDE Unit and is in a net-losing condition, with infiltrating surface water flows likely contributing directly to the shallow groundwater system that supports the vegetation in the unit. While it appears the source of shallow groundwater is infiltrating surface water and therefore shallow groundwater can only occur when surface flows are present (i.e., groundwater does not support surface water flows, but rather surface water flows support shallow groundwater), there is at least some potential for surface water flows and the shallow groundwater system supporting GDEs to be affected by regional pumping during certain periods of time when shallow groundwater is present. If regional pumping depletes shallow groundwater, beneficial uses and users of surface water and groundwater could be negatively affected. These include riparian vegetation along the San Joaquin River and the wildlife habitat and ecosystem functions it provides, as well as riverine habitat in the San Joaquin River that supports migration and potentially spawning of special-status fishes including salmon and steelhead. Special-status species and their habitat in the San Joaquin River are included in the analyses of potential effects on the San Joaquin River Riparian GDE Unit presented in **Appendix 2.B**. However, it should be noted relative to historical conditions prior to October 2009 that the additional flows required to remain in the San Joaquin River (and not be diverted for irrigation purposes) for the San Joaquin River Restoration Program will also serve to provide support for the shallow groundwater system and GDEs that did not exist before.

There are three primary options for the metric that can be used as the basis for SMC for interconnected surface water: 1) an amount of surface water depletion; 2) shallow groundwater levels as a proxy; and 3) percent of time that a surface water – groundwater condition exists over a given time period. The metric used needs to be capable of distinguishing that an impact has occurred related to groundwater pumping in the Subbasin. Analyses described in Section 2.2.2.5 indicate that the amount of surface water seepage (i.e., depletion) is most closely related to the amount of streamflow entering the San Joaquin River reach of concern from upstream, which is related to releases from Friant Dam. Therefore, the amount of surface water depletion would not be a good choice as the metric for ISW SMC. Similarly, review of available data indicates that shallow groundwater elevations are also closely tied to the amount of streamflow; therefore, using groundwater levels as a proxy for ISW SMC would also not be a good choice. The best option for the metric is percent of time connected as discussed further in Section 3.2.5.1.

Table 3-6. Comparison of Interconnected Surface Water Representative Monitoring Sites Groundwater Elevations to Stream Thalweg Elevations – Percent of Time Connected

	Count of Groundwater Elevation Measurements	Count of Groundwater Elevation Measurements that are greater than the Stream Thalweg Elevation	Percent of Time that Groundwater and Surface Water are Connected
MCW RMS-1 (streambed elevation = 100.93 feet; Model Layer 3)			
1989-2015	325	11	3%
2016-2019	48	0	0%
2020-2039	240	0	0%
2040-2090	612	34	6%
MCW RMS-2 (streambed elevation = 103.63 feet; Model Layer 2)			
1989-2015	325	67	21%
2016-2019	48	0	0%
2020-2039	240	11	5%
2040-2090	612	117	19%
MCW RMS-3 (streambed elevation = 109.08 feet; Model Layers 2 & 3)			
1989-2015	650	18	3%
2016-2019	96	0	0%
2020-2039	480	0	0%
2040-2090	1224	124	10%
MCW RMS-10 (streambed elevation = 106.72 feet; Model Layer 1)			
1989-2015	325	254	78%
2016-2019	48	45	94%
2020-2039	240	183	76%
2040-2090	612	455	74%
MCW RMS-11 (streambed elevation = 115.01 feet; Model Layers 1 & 2)			
1989-2015	650	172	26%
2016-2019	96	19	20%
2020-2039	480	51	11%
2040-2090	1224	349	29%

	Count of Groundwater Elevation Measurements	Count of Groundwater Elevation Measurements that are greater than the Stream Thalweg Elevation	Percent of Time that Groundwater and Surface Water are Connected
MCW RMS-12 (streambed elevation = 116.05 feet; Model Layers 1 & 2)			
1989-2015	650	72	11%
2016-2019	96	0	0%
2020-2039	480	21	4%
2040-2090	1224	284	23%

3.2.5.1 Measurable Objective

The measurable objective for ISW along the San Joaquin River is to maintain the percent of time the San Joaquin River is connected to shallow groundwater levels equal to or greater than existing and historical conditions at RMS wells screened in the Upper Aquifer in close proximity to the San Joaquin River. The interim MOs are established as the percent of time connected over the historical base period (1989 to 2015), as indicated in **Table 3-7** for the six RMS wells screened in the Upper Aquifer near the San Joaquin River (**Figure 3-3**). However, in terms of the percent of time connected percentages that serve as a baseline for annual comparisons in the future, these MOs may need to be adjusted to reflect an equivalent hydrologic period from the baseline to make a proper comparison to the future five-year rolling average as described below.

In order to create SMC that can be evaluated using this metric on an annual basis, a rolling average for the past five years will be used as the current conditions for percent of time connected. The five-year current rolling average will be compared to the historical base period percent of time connected (i.e., the MOs listed in **Table 3-7**) to determine if MOs are being achieved. It should be noted that while the 1989-2015 period is considered to represent long-term average climatic/hydrologic conditions, a given five-year rolling average may or may not represent a period with average climatic/hydrologic conditions. Therefore, an adjustment of the baseline period used for comparison to the current five-year rolling average may be needed. For example, if the last five years included in the rolling average represent drought years, the percent of time connected during the most similar period in the historical base period will be used for comparison.

Table 3-7. Summary of Interconnected Surface Water Measurable Objectives for Representative Monitoring Sites

Well I.D.	Surface Elevation	Well Depth	Screen Top-Bottom	Model Layer(s)	Aquifer Designation	MO[1]	GSA
MCW RMS-1	120	186	Unknown	3	Upper	3%	Madera County West
MCW RMS-2	123	Unknown	Unknown	2	Upper	21%	Madera County West
MCW RMS-3	122	Unknown	Unknown	2,3	Upper	3%	Madera County West
MCW RMS-10	123	26	Unknown	1	Upper	78%	Madera County West
MCW RMS-11	127	30	Unknown	1	Upper	26%	Madera County West
MCW RMS-12	127	29	Unknown	1	Upper	11%	Madera County West

[1] The MOs are established as the percent of time connected over the historical base period (1989 to 2015). For comparison to future five-year rolling average, baseline MOs may need to be updated to reflect climatic/hydrologic conditions represented in five-year rolling average.

3.2.5.2 Interim Milestones

Interim Milestones for ISW along the San Joaquin River are the same as the MOs described in Section 3.2.5.1.

3.2.5.3 Achieving and Maintaining Sustainability

Sustainability will be achieved and maintained through implementation of projects (e.g., dedicated recharge basins, Flood-MAR) and management actions (e.g., pumping reductions). In addition, implementation of the SJRRP since 2009 has been, and is expected to continue, changing the hydrology along the San Joaquin River. If the SJRRP is implemented as planned, it is expected that more streamflow (than would have been present without the SJRRP) will be present in the San Joaquin River along the western boundary of Chowchilla Subbasin under certain climatic/hydrologic conditions. To the extent that the SJRRP adds more streamflow to the system, it is expected there will be more stream depletion, higher groundwater levels in the shallow zone beneath/adjacent to the San Joaquin River, and an equal or greater percentage of time during which shallow groundwater levels and the San Joaquin River are connected. Thus, the combination of Chowchilla Subbasin PMAs and the SJRRP are expected to achieve and maintain sustainability relative to ISW during the sustainability period.

3.2.5.4 Impact of Selected Measurable Objectives on Adjacent Basins

Maintaining a similar percent of time connected under sustainable groundwater conditions for Chowchilla Subbasin is not expected to have any significant impacts on adjacent subbasins. However, if the percent of time connected increases significantly, whether it be through PMAs conducted by Chowchilla Subbasins GSAs and/or due to other factors such as the SJRRP, it is possible that the adjacent Delta-Mendota Subbasin may be affected by higher groundwater levels in the shallow zone.

3.2.6 Seawater Intrusion

The seawater intrusion sustainability criteria is not applicable to this Subbasin, because it is located more than 70 miles inland from and hydraulically disconnected from the ocean.

3.2.7 Management Area Measurable Objectives

Chowchilla Subbasin was divided into two Management Areas – the Western Management Area and the Eastern Management Area. The primary differences between these two Management Areas in terms of SMC are related to land subsidence and GDEs.

Undesirable results for subsidence during the time period from 2005 to 2015 have occurred in the Western Management Area related to infrastructure but not in the Eastern Management Area. The MTs for subsidence for the two Management Areas are different, as described in the next section. However, the subsidence MOs are based on the same methodology in both the Western Management Area and the Eastern Management Area. There will be ongoing review of subsidence surveys and adaptive management in both Management Areas to adjust subsidence MOs, if necessary.

A single GDE unit occurs in the Western Management Area along the San Joaquin River, and there are no GDE units in the Eastern Management Area. Because GDEs are present in only one of the two Management Areas, there are no concerns about the basin operating under different MOs for GDEs in the two Management Areas.

Thus, there will be no inconsistencies caused by setting of MOs for the two different Management Areas. Differences in management area measurable thresholds for land subsidence and GDEs are discussed below in the section on MTs.

3.3 Minimum Thresholds (23 CCR § 354.28)

The regulations define undesirable results as occurring when significant and unreasonable effects are caused by groundwater conditions occurring throughout the Subbasin for a given sustainability indicator. Significant and unreasonable effects occur when MTs are exceeded for one or more sustainability indicators. This section describes the following for each sustainability indicator relevant to Chowchilla Subbasin: the methodology used to set the minimum threshold and how selected MTs avoid causing undesirable results, relationships to other sustainability indicators, impact on adjacent subbasins, impacts on beneficial use/users, comparison to relevant federal, state, local standards, the measurement method, and integration of MTs for the two different Management Areas.

3.3.1 Chronic Lowering of Groundwater Levels

The GSP regulations provide that the "MTs for chronic lowering of groundwater levels shall be the groundwater level indicating a depletion of supply at a given location that may lead to undesirable results." Chronic lowering of groundwater levels in the Subbasin cause significant and unreasonable declines if they are sufficient in magnitude to lower the rate of production of pre-existing groundwater wells below that necessary to meet the minimum required to support overlying beneficial use(s) where alternative means of obtaining sufficient groundwater resources are not technically or financially feasible. In addition, groundwater levels will be managed with consideration of the MTs to ensure the major aquifers in the Subbasin are not depleted in a manner to cause significant and unreasonable impacts to other sustainability indicators. At the same time, the GSAs recognize that groundwater levels are anticipated to fall below 2015 levels during the GSP implementation period while the Subbasin works to become sustainable. Furthermore, DWR recognizes in the SGMA SMC Best Management Practices (BMP) guidance documents that groundwater levels exceeding MTs during the GSP implementation period may be acceptable if the GSAs are managing groundwater and implementing PMAs as outlined in the GSP.

The decisions to set MTs for chronic lowering of groundwater levels were made with consideration of the time it will take to implement PMAs that increase groundwater recharge and decrease net groundwater extraction, and with consideration for the need to balance and protect the water supply needs of all beneficial uses and users of groundwater through an approach that is both sustainable and economically reasoned and maintaining some level of operational flexibility in the Subbasin under projected future conditions.

Discussions and stakeholder input during public GSP development meetings (**Appendix 2.C.c**) indicated a clear desire to balance the water supply needs of all beneficial uses and users of groundwater to the greatest extent practicable. Stakeholders expressed clear intent to protect domestic well users that rely on groundwater, but also expressed a desire to protect the local agricultural economy – the economic lifeblood of the region – while GSP implementation ramps up. The GSAs considered many groundwater management approaches to achieve these goals of balancing diverse beneficial user interests. The MTs established for groundwater levels in the Subbasin reflect the outcome of this balanced approach allowing groundwater use for agricultural production to continue, albeit at a gradually reducing rate, while GSP implementation ramps up, and recognizing that this would likely result in lowered groundwater levels impacting some domestic, agricultural, and public water supply well users in the Chowchilla Subbasin. This approach was considered preferable to alternatives that would require immediate and substantial cutbacks in agricultural groundwater pumping in order to avoid significant and unreasonable adverse impacts on well users, especially domestic wells. Such an alternative would result in major economic impacts to the local communities and all stakeholders in the Subbasin, including domestic well users and disadvantaged communities. The GSAs evaluated the economic tradeoffs of these alternatives (**Appendix 3.C**), and determined that the avoided costs (fewer domestic wells requiring replacement) resulting from immediate demand reduction would be small ($4.6 million) relative to the additional lost agricultural net return ($122.9 million) in the Chowchilla Subbasin, even after accounting for pumping cost savings ($82.5 million). These analyses considered the impacts of immediate demand reduction only on agricultural net return, but in reality the economic impacts would spread to other county businesses and industries, significantly increasing the net effect on all beneficial uses and users of groundwater in the Chowchilla Subbasin, including domestic well owners.

With these findings, the GSAs determined that implementing a Domestic Well Mitigation Program would provide the best and most economically reasonable outcome for beneficial uses and users of groundwater in the Subbasin by preserving the local economy and protecting domestic well users' access to groundwater. For this reason, the GSAs have elected to mitigate for potential impacts to domestic well users caused by temporary further declines in groundwater levels during the implementation period or until groundwater sustainability is achieved. Implementation of the Domestic Well Mitigation Program will allow the GSAs to establish lower MTs that avoid undesirable results to other groundwater users, while still preserving access to critical water supplies for domestic well users.

Impacts of lowered groundwater levels on agricultural and public water system well users were also considered in defining undesirable results. Based on discussions with the GSAs and stakeholders, including informal surveys of agricultural beneficial users, the agricultural stakeholders in the Subbasin have a relatively high tolerance for potential impacts on wells from lowered groundwater levels when considering the economic tradeoffs of alternatives involving immediate and substantial pumping cutbacks. Based on these considerations, the GSAs believe that 25 percent of agricultural wells requiring replacement because of lowered water levels represents the threshold for an undesirable result for this beneficial user group. This definition considers the GSP Implementation Period since it is the most likely time frame for continuing declines in groundwater levels, and the well replacement rate (due to declining groundwater levels) is expected to be greatly reduced and likely insignificant once the Subbasin is sustainable. An undesirable result related to impacts on public water system wells from lowered groundwater levels is defined at a lower threshold recognizing the importance of protecting this beneficial use. Accordingly, the threshold for defining an undesirable result for public water system wells was determined to be 10 percent of public water supply wells requiring replacement. Although there are potentially additional pumping costs resulting from lowered groundwater levels, these costs are significantly less than the larger economic tradeoffs for the local communities. Using general assumptions on overall pumping plant efficiency (70%) and cost of electricity ($0.25/kWh), increased pumping costs for well users would be in the range of $3 to $4 per AF per year for every 10 feet of groundwater level decline. For domestic wells that pump less than two AF per year, the increased pumping costs from lowered groundwater levels are not believed to be significant and unreasonable. Although the increased pumping costs for larger-capacity agricultural and municipal pumping wells is expected to be greater, recognizing the economic tradeoffs associated with transitioning to sustainability while maintaining a reasonable level of agricultural economic productivity to support the local communities, increased pumping costs also do not represent significant and unreasonable impacts to the agricultural and municipal water beneficial user groups and are not a primary consideration in setting of minimum thresholds for groundwater levels.

The SMC for chronic lowering of groundwater levels have been designated with these considerations in mind, and with the clear commitment of the GSAs to fund and implement a Domestic Well Mitigation Program beginning in 2023 and continuing until groundwater sustainability is achieved. Considerations for setting the MTs for chronic lowering of groundwater levels are described further in the sections below.

3.3.1.1 *Domestic Well Mitigation Program*

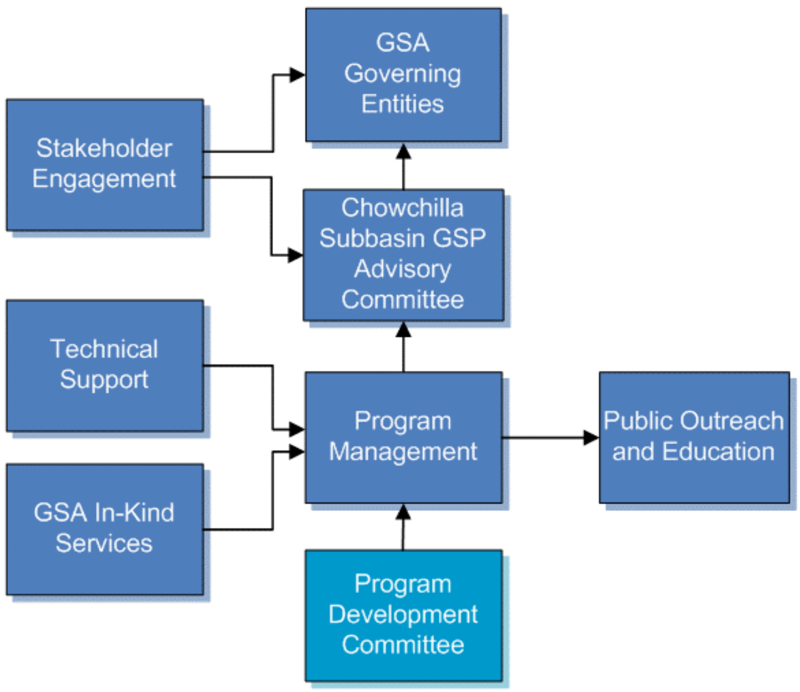
Recognizing that groundwater levels are anticipated to decline further during the Implementation Period while projects are implemented and demand reduction programs expand, the GSAs are implementing a Domestic Well Mitigation Program (Program) until groundwater sustainability is achieved (**Appendix 3.C**). As proposed, the Program will sustain long-term access to drinking water in the Chowchilla Subbasin and avoid undesirable results for domestic well users during GSP implementation or until sustainable groundwater conditions are achieved. Implementation of the Program will allow the GSAs to establish lower MTs that avoid undesirable results to other groundwater users, while still preserving access to critical water supplies for domestic well users. The alternative of specifying higher MTs that avoid any additional groundwater level declines (to avoid the need for a Domestic Well Mitigation Program) would require immediate and substantial cutbacks in groundwater pumping that result in major impacts to the local economy and all basin stakeholders, including domestic well owners. As described in **Appendix 3.C**, the GSAs completed an economic analysis to evaluate the costs of setting MTs at higher levels to protect domestic well users, and determined that the avoided costs (fewer domestic wells requiring replacement) resulting from immediate demand reduction would be small ($4.6 million) relative to the additional lost agricultural net return ($122.9 million) in the Chowchilla Subbasin, even after accounting for pumping cost savings ($82.5 million). These analyses considered the impacts of immediate demand reduction only on agricultural net return, but in reality the economic impacts would spread to other county businesses and industries, significantly increasing the net effect on all beneficial uses and users of groundwater in the Chowchilla Subbasin, including domestic well owners. With these considerations in mind, the GSAs have elected to mitigate for potential impacts to domestic well users caused by temporary further declines in groundwater levels during the implementation period or until groundwater sustainability is achieved.

The GSAs in the Chowchilla Subbasin have expressed and formalized their clear **commitment to fund and implement the Program beginning no later than January 1, 2023**. GSA staff and representatives have made substantial and material progress toward Program development and implementation by executing a Memorandum of Understanding (MOU). The MOU is provided in **Appendix 3.D**, and was developed with review and consideration of the content and recommendations set forth by Self-Help Enterprises, the Leadership Counsel for Justice and Accountability, and the Community Water Center in their publication titled, "Framework for a Drinking Water Well Impact Mitigation Program" (SHE et al., 2020). The MOU defines, among other aspects, the:

- <u>Proportionate responsibilities for implementing the Program –</u> Assigned by the proportionate share of the average water budget shortage, not including subsurface flows (i.e., negative net recharge from the surface water system) attributed to each GSA.
- <u>Program term –</u> Effective no later than January 1, 2023, and covering all wells eligible for mitigation between January 31, 2020, and through the duration of the GSP Implementation Period or until groundwater sustainability is achieved.
- <u>Program eligibility, terms and conditions –</u> Agreement among the GSAs to develop eligibility, terms, and conditions that include, but are not limited to: eligibility of properties and property owners, program application process, preliminary inspection process, prioritization of sites, preferred contractors, eligible/non-eligible mitigation.
- <u>Repercussions of failure to pay –</u> Resulting in legal action, ineligibility to vote on any subject or issue (unless formally excused), and explicit annotation of that failure to pay in the Annual Report.

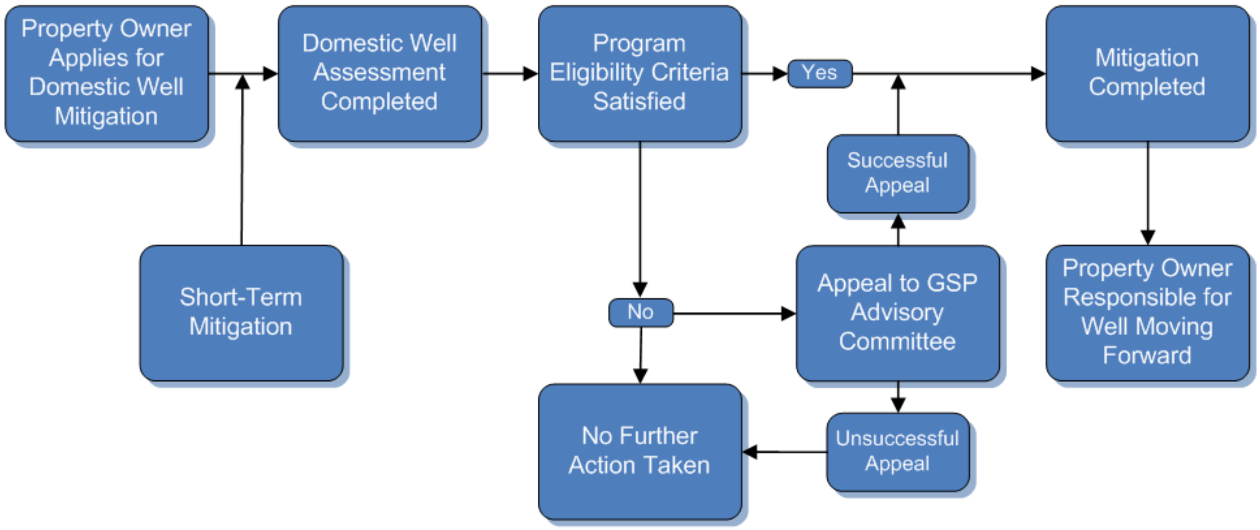
GSA representatives have met at least monthly during 2022 to jointly discuss and advance plans for creating and administering the Program within the Chowchilla Subbasin by 2023. As part of these efforts, the GSAs have created an organizational structure and a workflow to guide operation of the Program **(Figures 3-4** and **3-5**). Efforts to refine program eligibility, terms and conditions, program management, and other principles for implementing the Program are ongoing. Program development is on track for implementation beginning in 2023.

By 2040 and during the sustainability period, groundwater levels are expected to stabilize and potentially rebound, thus the Domestic Well Mitigation Program is not anticipated to be needed beyond the Implementation Period. Nevertheless, as stated in the MOU, the Program is intended to remain in place until groundwater sustainability is achieved, whether that occurs prior to or after 2040.



Notes:
1. That shown herein is subject to revision by the Parties.
2. Public Outreach and Engagement is a necessary component as outlined by Self-Help Enterprises, Leadership Counsel for Justice and Accountability, and the Community Water Center in their publication titled, "Framework for a Drinking Water Well Impact Mitigation Program."
3. The Chowchilla Subbasin GSP Advisory Committee is as defined and established under Section 3 of the Memorandum of Understanding with Respect to the Coordination, Cooperation and Cost Sharing in the Implementation of Chowchilla Subbasin Groundwater Sustainability Plan entered into by the Parties on December 17, 2019.

Figure 3-4. Chowchilla Subbasin Domestic Well Mitigation Program Organizational Structure.



Notes:
1. Steps shown herein are intended to demonstrate critical decision points and is not intended to be indicative of all steps that may be required.
2. That shown herein is subject to revision by the Parties.
3. The GSAs have reviewed and considered the content and recommendation set-for by Self-Help Enterprises, Leadership Counsel for Justice and Accountability, and the Community Water Center in their publication titled, "Framework for a Drinking Water Well Impact Mitigation Program."

Figure 3-5. Chowchilla Subbasin Domestic Well Mitigation Program Implementation Flowchart.

3.3.1.2 Other Considerations for Setting Minimum Thresholds

The MTs for groundwater levels and overall SMC program for this GSP are based on generally setting SMC for each sustainability independent of one another in order to allow the cause of undesirable results (if any) to be readily identified. However, GDEs were also considered in setting of MTs for chronic lowering of groundwater levels. The single GDE unit identified in the Subbasin is dominated by terrestrial vegetation, which is susceptible to adverse impacts (i.e., undesirable results) if shallow groundwater levels in the underlying perched/mounded aquifer experience chronic lowering exceeding historical lows (see **Appendix 2.B**). The development of MTs for chronic lowering of groundwater levels included review of the hydrogeologic conceptual model, climate, current and historical groundwater conditions including groundwater level trends and groundwater quality, and the water budget discussed in previous chapters.

The MTs for chronic lowering of groundwater levels are based on selection of RMS from among existing production and monitoring wells located throughout the Subbasin and screened in both in the Upper and Lower Aquifers. The selected sustainability indicator wells are listed in **Table 3-8** and shown on **Figure 3-1**. Groundwater level hydrographs showing MTs for each groundwater level RMS are provided in **Appendix 3.A.**

The RMS described in **Table 3-8** and **Figure 3-1** are in locations that reflect a wide cross section of Subbasin groundwater conditions. These locations are representative of the overall Subbasin conditions because they are spatially distributed throughout the Subbasin both vertically (within the Upper and Lower Aquifers in the Corcoran Clay area) and laterally throughout the Subbasin. The distribution of designated Upper Aquifer wells is limited because the definition of Upper Aquifer used in this study (above the Corcoran Clay where present, and equivalent depth to the east where Corcoran Clay is not present), results in relatively large areas of unsaturated conditions in the Upper Aquifer (including some areas where Corcoran Clay is present) in the central to eastern portions of the Subbasin. The GSAs have determined that use of the minimum groundwater elevation thresholds at each of the listed RMS (along with a Domestic Well Mitigation Program) will help avoid the undesirable results of chronic lowering of groundwater levels by reducing the likelihood that access to adequate water resources for beneficial uses and users within the Subbasin will be compromised.

Table 3-8. Summary of Groundwater Level Minimum Thresholds for Representative Monitoring Sites

Well I.D.	Surface Elevation	Well Depth	Screen Top-Bottom	Model Layer(s)	Aquifer Designation	Reduced Deposits	MT Depth[1]	MT Elev[1]	GSA	CASGEM Well?
CWD RMS-1	171	275	160-275	4	Lower	NA	274	-103	CWD	CASGEM
CWD RMS-2	193	780	230-775	4	Lower	575	307	-114	CWD	No
CWD RMS-3	206	Unknown	Unknown	4	Lower	450	323	-117	CWD	No
CWD RMS-4	225	800	320-800	4	Lower	450	338	-112	CWD	CASGEM
CWD RMS-5	207	Unknown	Unknown	4	Lower	NA	314	-107	CWD	Voluntary
CWD RMS-6	275	820	257-726	4	Lower	450	365	-90	CWD	CASGEM
CWD RMS-7	169	330	135-288	3,4	Lower	NA	262	-93	CWD	CASGEM
CWD RMS-8	219	Unknown	Unknown	4	Lower	NA	321	-102	CWD	Voluntary
CWD RMS-9	164	97	82-97	3	Upper	NA	103	61	CWD	CASGEM
CWD RMS-10	182	Unknown	Unknown	4	Lower	NA	280	-98	CWD	Voluntary
CWD RMS-11	199	529	187-529	4	Lower	NA	283	-84	CWD	CASGEM
CWD RMS-12	176	Unknown	Unknown	3	Upper	NA	140	36	CWD	Voluntary
CWD RMS-13	167	Unknown	Unknown	4	Lower	NA	236	-69	CWD	Voluntary
CWD RMS-14	152	455	185-365	4	Lower	NA	293	-141	CWD	CASGEM
CWD RMS-15	213	955	290-935	4	Lower	600	335	-122	CWD	CASGEM
CWD RMS-16	212	Unknown	Unknown	4	Lower	600	315	-103	CWD	Voluntary
CWD RMS-17	203	624	278-588	4	Lower	600	336	-133	CWD	CASGEM
MCE RMS-1	276	Unknown	Unknown	4	Lower	450	367	-91	Madera County East	Voluntary
MCE RMS-2	272	466	218-464	4	Lower	450	394	-122	Madera County East	CASGEM
MCW RMS-1	120	186	Unknown	3	Upper	NA	104	16	Madera County West	Voluntary

Well I.D.	Surface Elevation	Well Depth	Screen Top-Bottom	Model Layer(s)	Aquifer Designation	Reduced Deposits	MT Depth[1]	MT Elev[1]	GSA	CASGEM Well?
MCW RMS-2	123	Unknown	Unknown	2	Upper	NA	82	42	Madera County West	No
MCW RMS-3	122	Unknown	Unknown	2,3	Upper	NA	100	22	Madera County West	Voluntary
MCW RMS-4	138	Unknown	Unknown	4	Lower	NA	217	-79	Madera County West	Voluntary
MCW RMS-5	146	Unknown	Unknown	4	Lower	NA	216	-69	Madera County West	Voluntary
MCW RMS-6	139	Unknown	Unknown	4	Lower	NA	197	-58	Madera County West	Voluntary
MCW RMS-7	138	800	290-400	4	Lower	NA	179	-41	Madera County West	CASGEM
MCW RMS-8	142	480	160-475	3,4	Composite	NA	194	-52	Madera County West	CASGEM
MCW RMS-9	155	700	265-696	5	Lower	NA	222	-67	Madera County West	CASGEM
MCW RMS-10	123	26	Unknown	1	Upper	NA	48	75	Madera County West	No
MCW RMS-11	127	30	Unknown	1	Upper	NA	47	80	Madera County West	No
MCW RMS-12	127	29	Unknown	1	Upper	NA	51	76	Madera County West	No
MER RMS-1	225	Unknown	Unknown	4	Lower	400	344	-118	SVMWC	No
TRT RMS-1	134	196	158-192	3	Upper	NA	152	-18	TTWD	No
TRT RMS-2	135	500	300-500	4	Lower	NA	154	-19	TTWD	CASGEM
TRT RMS-3	137	799	168-790	5	Lower	NA	166	-29	TTWD	No
TRT RMS-4	141	840	190-260	3,4	Composite	NA	180	-39	TTWD	CASGEM

[1] The actual MT is based on the groundwater elevation, but the depth to water corresponding to the surface elevation in the project database is also provided.

* Each GSA is responsible for collecting groundwater levels for representative monitoring sites within their GSA area.

3.3.1.3 Methodology

The methodology to develop MTs for groundwater levels was based on discussion with GSA staff and technical representatives, input received from interested stakeholders and the public through public meetings, individual public/stakeholder input to various GSA representatives, review of the DWR January 2022 consultation letter, and meetings with DWR in 2022. There were several steps involved with determination of groundwater level MTs as follows:

1) Review available wells with regard to several variables/criteria (e.g., is well in CASGEM program, known well construction details, preference for wells with relatively long history of observed water levels, availability of recent water level data, good spatial distribution) and select appropriate representative monitoring sites;
2) For each selected representative monitoring site, review/evaluate the fluctuation of observed vs. modeled historical groundwater levels and projected future with projects/MAs model results;
3) Evaluate anticipated future groundwater elevations after January 1, 2040 when the Subbasin is being operated under sustainable groundwater conditions, and identify the lowest groundwater elevation that would occur;
4) Subtract a 10-foot operational buffer from the lowest groundwater elevation that occurs after January 1, 2040;
5) Adjust MT to account for offset between historical observed and modeled data, if necessary;
6) Conduct evaluation of selected MT values at each RMS well to ensure that undesirable results would not occur the selected MT groundwater elevations.

Example hydrographs showing the various steps in determining MTs for the Eastern Management Area are provided in **Figure 3-6**. The hydrograph for Representative Monitoring Sites CWD RMS-8 (**Figure 3-6a**) and CWD RMS-13 (**Figure 3-6b**) demonstrate the minimum threshold determination steps 1 through 5 listed above. In this case, no adjustments were needed for offset of observed vs. modeled data (Step 5). Example hydrographs illustrating additional minimum threshold determination steps related to potential offsets are provided in **Figure 3-7**. The hydrographs for Representative Monitoring Site TRT RMS-2 (**Figure 3-7a**) and MCW RMS-9 (**Figure 3-7b**) demonstrates steps 1 through 5. The consideration of offset of observed vs. modeled data (Step 5) is intended to reflect cases where observed data are either consistently above or below modeled water levels, or situations where observed water levels occasionally spike below seasonal low modeled water levels. Overall, the purpose of Step 5 is to ensure MTs account for the anticipated range in potential future water levels as best possible. Step 5 reflects GSA and stakeholder input and discussions with DWR. The GSP regulations, DWR BMPs, and GSA discussions with DWR in 2022 indicate there is allowance for measured water levels to temporarily dip below MTs during the Implementation Period provided GSAs are implementing projects and management actions as outlined in the GSP and managing the Subbasin consistent with interim milestones leading to sustainability by January 2040.

The GSAs are in the process of instituting a Domestic Well Mitigation Program to address potential declines in groundwater levels during the Implementation Period while PMAs are being implemented to achieve sustainability by 2040. The GSAs have expressed and formalized their clear commitment to fund and implement the Program beginning no later than January 1, 2023. GSA staff and representatives have already made substantial and material progress toward Program development and implementation by creating and executing an MOU (**Appendix 3.D**). Economic analyses conducted for this GSP (**Appendix 3.C**) demonstrate that the impacts to the County and its residents would be much greater if projects and management actions were implemented immediately to try to avoid further declines in groundwater levels during the Implementation Period. Therefore, it was determined that the phased implementation schedule of PMAs adopted in this GSP (Chapter 4 and Chapter 5) combined with a Domestic Well Mitigation Program reduces economic impacts to the County and its residents.

It should be noted that groundwater level MTs (and MOs) were set based on Fall groundwater levels, which are more protective of domestic wells than using Spring groundwater levels. Comparison of existing recent groundwater levels to MTs (as well as MOs) should use historical low groundwater elevations (in most cases, most likely to be recent Fall measurements) for existing levels as the basis of comparison.

3.3.1.4 Relationship to Other Sustainability Indicators

Groundwater elevation MTs were set independently of other sustainability indicators in order to clearly identify the cause of undesirable results should they occur. The groundwater elevation MTs relationships to other sustainability indicators are described below.

1. Reduction in groundwater storage. A significant and unreasonable condition for change in groundwater storage is pumping groundwater in excess of the sustainable yield for an extended period of years during the Sustainability Period. Pumping at or less than the sustainable yield will maintain or raise average groundwater elevations in the Subbasin. The groundwater elevation MTs are set to encompass a historical drought sequence that may occur again in the future and span multiple years during the Sustainability Period. However, the MTs represent only temporary groundwater levels at the low end of groundwater level fluctuations under sustainable conditions (that avoid undesirable results), whereas MOs represent anticipated long-term average groundwater levels. Therefore, the groundwater elevation MTs established for this GSP will not result in long term significant or unreasonable change in groundwater storage.
2. Subsidence. A significant and unreasonable condition for land subsidence is measurable permanent (inelastic) subsidence that significantly damages existing infrastructure. Inelastic subsidence is caused by reduction in pore pressure and compaction of clay-rich sediments in response to declining groundwater levels. Subsidence -based groundwater level proxy MTs are set at historical low groundwater elevations. Chronic lowering of groundwater level MTs are set based on an analysis of the percentage of different well types going dry. It is possible that the subsidence-based groundwater level MTs may be exceeded (to the point of causing undesirable results) while chronic lowering of groundwater level MTs are not exceeded. In this example, the cause of undesirable results would be related to subsidence but not chronic groundwater level declines. Again, the MTs for these two sustainability indicators have been set independently based on occurrence of undesirable results for each indicator, of which sustainability indicator(s) is/are associated with potential future occurrences of undesirable results (if any).
3. The additional metric of the amount of subsidence occurring at a subsidence RMS well in the Eastern Management Area (relative to the nearest surface water conveyance control point) also is set independent of the MTs for chronic lowering of groundwater levels.
4. Degraded water quality. Protecting groundwater quality is critically important to all who depend upon the groundwater resource, particularly drinking water and agricultural uses. A significant and unreasonable condition of degraded water quality is exceeding regulatory limits for constituents of concern in wells due to actions proposed in the GSP. Water quality could be affected through three processes.
   a. Low groundwater elevations in an area could cause deeper, poor-quality groundwater to flow upward into existing wells. Groundwater elevation MTs are generally set well above depths to reduced sediments from which poorer quality water (with respect to naturally occurring

constituents) may be derived, thereby reducing opportunities for poor quality groundwater to flow into wells.

b. Changes in groundwater elevation as a result of PMAs implemented to achieve sustainability could change groundwater gradients, which could cause poor quality groundwater (i.e., contaminant plumes) from documented contaminant sites to flow towards wells that would not have otherwise been impacted. These groundwater gradients, however, are dependent on differences between groundwater elevations, not in the groundwater elevations themselves. Therefore, the MTs for groundwater elevations do not directly lead to significant and unreasonable degradation of groundwater quality in wells. Although there are no current documented large-scale contaminant plumes of concern in the regional groundwater aquifers, RWQCB files for existing and potential new documented contaminant site plumes will be reviewed every five years for potential changes in contaminant movement that may be related to GSP PMAs, and adaptive management implemented as necessary.

c. GSP PMAs include a number of recharge basins and Flood MAR programs that will recharge surface water available in wet years through the vadose zone to the water table. Such projects have the potential to flush existing constituents of concern (i.e., TDS, nitrates) from the vadose zone to the water table. While such flushing has been occurring and will continue to occur naturally (e.g., via rainfall recharge, excess irrigation recharge) without such GSP projects, it may be the case that GSP projects temporarily increase the rate of vadose zone flushing and result in temporarily higher constituent concentrations in groundwater prior to eventual dilution (due to recharge of higher quality water) and a reduction in these constituent concentrations. Overall, it is anticipated that there will likely be an overall net benefit to groundwater quality from GSP projects; however, the overall groundwater monitoring program developed for this GSP plus any additional site-specific monitoring (e.g., soil and/or groundwater sampling) determined to be needed will be utilized to evaluate need for adaptive management related to GSP recharge projects.

5. Depletion of interconnected surface waters. The assessment of surface water flows and groundwater levels indicate that there are not interconnected surface waters in most of the Subbasin. Interim sustainable management criteria for interconnected surface water have been established for the San Joaquin River based on the percent of time groundwater elevations at key Upper Aquifer RMS wells near the San Joaquin River are considered connected to the San Joaquin River. However, SMC for each sustainability indicator are being set independent of other sustainability indicators so that if an undesirable result occurs it will be clear which sustainability indicator is the cause of the undesirable results. Therefore, MTs and undesirable results for interconnected surface water will not be affected by the groundwater elevation MTs. Additionally, it should be noted that changes in groundwater elevations could at least potentially impact GDE areas, as described previously in this section and in Section 3.2.5.

3.3.1.5 Impact of Selected Minimum Thresholds to Adjacent Basins

The groundwater level MTs established for Chowchilla Subbasin do not provide a good indication of anticipated impacts on adjacent subbasins from implementation of the GSP. This is because groundwater level MTs are set to prevent undesirable effects, and groundwater levels are not expected to drop to the MTs. If reached, the MTs are the lowest of temporary low points that potentially could occur during the Sustainability Period. Ultimately, the potential for impacts on adjacent subbasins will primarily be a function of average water levels in Chowchilla Subbasin during the Sustainability Period, average water level in adjacent subbasins during the Sustainability Period, and natural groundwater flow conditions that would be expected to occur along Subbasin boundaries (e.g., pre-development groundwater flow conditions). The average groundwater levels expected for Chowchilla Subbasin are reflected in the MOs. Therefore, the impact to adjacent subbasins is described in more detail under the section on MOs.

3.3.1.6 Minimum Thresholds Impact on Beneficial Uses and Users

Groundwater level MTs are likely to have several effects on beneficial uses, users, land use, and property owners. Those expected to be impacted include agricultural land use and users, urban land use and users, domestic land use and users, and ecological land use and users. Overall agricultural land use and users will be significantly impacted in terms of increased costs to design and construct recharge projects and in terms of reduced crop yields from required reductions in consumptive use for irrigation. While conversion of current agricultural lands to urban areas that may occur in the future will tend to reduce per acre water demands, it is likely that urban water users will need to continue water conservation efforts due to limited water supplies. Domestic well owners can generally expect to see declining groundwater levels during the initial 10 to 15 years of the Implementation Period, followed by stabilization of water levels during the latter portion of the Implementation Period and some potential recovery in groundwater levels after 2040. However, significant adverse impacts to domestic wells from declining groundwater levels will be addressed through a Domestic Well Mitigation Program being implemented by the GSAs. The GSAs have executed an MOU (**Appendix 3.D**), and have expressed and formalized their clear commitment to fund and implement the Program beginning no later than January 1, 2023. The economic analyses conducted to compare costs of implementing a Domestic Well Mitigation Program versus immediately requiring full implementation of demand reduction in 2020 is provided in **Appendix 3.C**.

Potential ecological impacts are possible in the San Joaquin River Riparian GDE Unit along the western margin of the Subbasin, but the severity of the effects is likely to be minor, if any. The GDE unit is composed of vegetation which may access shallow groundwater within approximately 30 feet of the surface. Modeled historical lows and modeled future lows show depths to water exceeding 30 feet. This is an indication that GDE units are able to survive short-term declines in water levels, possibly due in part to the presence of a capillary fringe above the water table. In general, modeled future lows during severe droughts are on the order of five to seven feet below historical modeled low water levels. However, it should be noted that the historical model period does not capture all the climate variability and droughts covered in the future model period (e.g., 1970's short-term but extreme drought). Although the minimum threshold depths of 47–51 feet below ground surface for representative wells MCW RMS-10, MCW RMS-11, and MCW RMS-12 (**Table 3-8**) are greater than the known maximum rooting depth of the dominant woody riparian plant species composing the GDE, modeled historical lows reach depths of up to about 40 feet. As noted previously both modeled historical and future levels do exceed 30 feet for short durations. Historical model results for these wells reflect shallow groundwater conditions under which the GDE vegetation currently composing the unit has persisted since 1989 with no apparent adverse effects, suggesting that similar conditions in the future (and possibly deeper water levels) would continue to support the GDEs. If a future drought and projected reductions to MT levels were to occur, potential effects on GDEs could include short term adverse impacts such as water stress and possibly longer-term impacts such as reduced growth and recruitment, and potential branch dieback or tree mortality resulting in some loss of vegetation structure, ecological function, and habitat for special status species. Given the relatively low projected frequency and short duration of the shallow groundwater level declines to depths greater than 40 feet, uncertainty in the relationship between shallow zone groundwater and groundwater pumping from deeper zones, and apparent resiliency of the GDE to historical drought periods, adverse impacts due to groundwater pumping are unlikely. Overall, sustainable groundwater management in the Chowchilla Subbasin is expected to maintain the health and resiliency of the vegetation communities composing the San Joaquin River Riparian GDE despite some potential future impacts that may occur if the minimum groundwater level thresholds are reached.

3.3.1.7 Comparison between Minimum Thresholds and Relevant State, Federal or Local Standards

There are no Federal, State, or local standards that exist for chronic lowering of groundwater levels.

3.3.1.8 Minimum Thresholds Measurement Method

Groundwater level MTs will be directly measured for existing and new monitoring wells. The groundwater level monitoring will be conducted in accordance with the monitoring plan and protocols outlined in Section 3.5. Furthermore, the groundwater level monitoring will meet the requirements of the technical and reporting standards included in the SGMA regulations. As noted in Section 3.5, the current groundwater monitoring network includes 9 wells in the Upper Aquifer and 25 wells in the Lower Aquifer (plus 2 additional composite wells). Madera County has already installed 8 new nested monitoring wells (with two or three separate wells at each site) in the Subbasin since 2019 (with additional nested monitoring wells planned for installation in 2022-2023), which will subsequently be incorporated in the monitoring program.

3.3.2 Reduction in Groundwater Storage

The cause of basin groundwater conditions that would result in significant and unreasonable reduction in groundwater storage is excessive overall annual average groundwater pumping and other outflows from the Subbasin that exceed average annual inflows. Locally defined significant and unreasonable conditions were determined based on discussion with GSA staff and technical representatives, input received from interested stakeholders and the public through public meetings, and through individual stakeholder input to various GSA representatives. Significant and unreasonable reduction in groundwater storage occurs when there is: 1) Long term reduction in groundwater storage during the sustainability period (i.e., after 2040), or 2) Interference with other sustainability indicators.

3.3.2.1 Methodology

The methodology to develop MTs for reduction in groundwater storage was based on discussion with GSA staff and technical representatives, input received from interested stakeholders and the public through public meetings, and through individual stakeholder input to various GSA representatives, and a meeting with DWR.

The selected methodology of using groundwater levels as a proxy involves field measurement of groundwater levels in the RMS monitoring well network and comparison to established groundwater level MTs. To the extent that groundwater levels are collectively (on average) maintained above MTs, groundwater storage would be considered not to exceed its minimum threshold. A key benefit of this approach is that it is the simplest and most direct approach to ensuring that groundwater storage MTs align with groundwater level MTs. In addition, groundwater levels are the fundamental underlying field data required to implement any method of quantifying groundwater storage.

Given that the minimum threshold is no long-term reduction in groundwater storage during the Sustainability Period, periodic evaluations of changes in groundwater storage will be conducted after 2040. These analyses will involve evaluation and comparison of groundwater levels over a period of average climatic conditions that occurs within the Sustainability Period after 2040. Groundwater level contour maps will be developed for the beginning and ending year of the analysis period (of average climatic conditions) and the beginning year contour map is then “subtracted” from the ending year contour map. If the net result of this process is essentially no change in levels/storage or a net positive gain in levels/storage, then there is no long-term reduction in groundwater storage. If there is a significant net negative change in groundwater levels/storage, then there may be a reduction in groundwater storage. This method evaluates changes in groundwater storage and most specifically addresses the concept of a reduction in groundwater storage. It should be noted that this calculation relies on contouring groundwater levels using RMS that may not provide coverage of the entire basin such as would be important for a total basin-wide groundwater storage calculation. However, this calculation is not as reliant upon accurate assumptions for key variables (e.g., specific yield, depth of fresh water, area of calculation) as a total basin groundwater storage calculation. Rather, the main purpose is to determine the representative relative change in storage for the basin and the spatial distribution of RMS should be adequate for that purpose.

The groundwater storage reduction metric will be evaluated using groundwater levels as a proxy in conjunction with periodic evaluations of long-term groundwater level changes over average climatic periods during the Sustainability Period. Based on considerations applied in developing the groundwater level MTs, reduction in groundwater storage MTs do not exceed any identified significant and unreasonable level of depleted groundwater storage volume.

3.3.2.2 Relationship to Other Sustainability Indicators

The representative monitoring sites described in **Table 3-8** and **Figure 3-1** are in locations that reflect a wide cross section of Subbasin groundwater conditions. These locations are representative of the overall Subbasin conditions because they are spatially distributed throughout the Subbasin both vertically (across the Upper and Lower Aquifer) and spatially. The distribution of Upper Aquifer wells is limited because the definition of Upper Aquifer used in this study (above the Corcoran Clay where present, and equivalent depth to east of where Corcoran Clay is present), results in relatively large areas of unsaturated Upper Aquifer in the central to eastern portions of the Subbasin. The GSAs have determined that use of the groundwater level MTs at each of the listed wells will help avoid the undesirable result of reduction in groundwater storage because it will minimize the chance that access to adequate water resources for beneficial users within the Subbasin will be compromised.

The reduction in groundwater storage minimum threshold is closely related to the chronic lowering of groundwater level MT and set independently of other sustainability indicators.

1. Chronic Lowering of Groundwater Levels. Because groundwater elevation will essentially be used as a proxy for estimating changes in groundwater storage, the reduction in groundwater storage would not cause undesirable results for this sustainability indicator.
2. Subsidence. Because future average groundwater levels will be stable under the reduction in groundwater storage minimum threshold, they will not induce any additional active subsidence.
3. Degraded water quality. The minimum threshold proxy of stable groundwater levels for reduction in groundwater storage will not directly lead to a degradation of groundwater quality.
4. Depletion of interconnected surface waters. The assessment of surface water flows and groundwater levels indicate that there are not interconnected surface water bodies in most of the Subbasin. Since MTs are being set independently for each sustainability indicator, interconnected surface water MTs and undesirable results will not be affected by the reduction in groundwater storage minimum threshold. The potential for reduction in

groundwater storage to impact GDE areas is covered under chronic lowering of groundwater levels.

3.3.2.3 *Impact of Selected Minimum Thresholds to Adjacent Basins*

A minimum threshold that does not allow for reduction in groundwater storage during the sustainability period will not have negative impacts on adjacent basins. A minimum threshold for reduction in groundwater storage tied to evaluation of changes in groundwater storage over long-term periods with average climatic conditions during the Sustainability Period will be protective of adjacent subbasins.

3.3.2.4 *Minimum Thresholds Impact on Beneficial Uses and Users*

The reduction in groundwater storage minimum threshold of maintaining stable average groundwater elevations during the Sustainability Period will require some amount of reduction in groundwater pumping in the Subbasin. Reduced pumping may impact beneficial uses and users of groundwater in the Subbasin. Those expected to be most impacted by pumping reductions are agricultural land use and users. In general, agricultural land use/users will be negatively impacted by pumping reductions since it is their pumping that will be reduced, while other users may benefit from agricultural pumping reductions. Most domestic well pumping is considered de minimis and will not be subject to pumping reductions. These impacts will be similar to those described above for chronic lowering of groundwater levels. Beneficial uses and users will also be impacted during the Implementation Period by gradual increases in required groundwater pumping reductions over the time period from 2020 to 2040.

3.3.2.5 *Comparison between Minimum Thresholds and Relevant State, Federal or Local Standards*

There are no Federal, State, or local standards that exist for reduction in groundwater storage.

3.3.2.6 *Minimum Thresholds Measurement Method*

The MTs for groundwater storage reduction are based on groundwater levels being measured for the groundwater level MT methodology. The representative wells use the groundwater level MTs for avoidance of reduction in groundwater storage.

3.3.3 Land Subsidence

The cause of basin groundwater conditions that would result in significant and unreasonable land subsidence is excessive overall average annual groundwater pumping and other outflows from the Subbasin, primarily from the Lower Aquifer, that exceed average annual inflows. Locally defined significant and unreasonable conditions were determined based on discussion with GSA staff and technical representatives, input received from interested stakeholders and the public through public meetings, and through individual stakeholder input to various GSA representatives.

Undesirable results for land subsidence are significant and unreasonable adverse impacts from land subsidence on critical surface infrastructure that impair the operation and function of the infrastructure. Critical infrastructure identified in the Subbasin include water conveyance infrastructure, well infrastructure, transportation-related infrastructure, and other water and wastewater-related infrastructure in the Chowchilla Subbasin. An analysis of infrastructure sensitivity to land subsidence in the Chowchilla Subbasin is provided in **Appendix 3.E** and summarized in Section 3.3.3.7, below. Minimum thresholds for land subsidence in both the Western and Eastern Management Areas of the Subbasin were established with consideration for infrastructure sensitivity.

MTs for land subsidence in the Western Management Area were also established with consideration for ongoing actions by landowners to mitigate subsidence in and adjacent to Triangle T Water District, in areas of the Chowchilla Subbasin where subsidence rates have historically been greatest. Landowners managing more than 14,000 acres in the Western Management Area of the Chowchilla Subbasin have entered into an agreement with agencies in the Delta-Mendota Subbasin to reduce pumping from the Lower Aquifer with the goal of mitigating subsidence in the Western Management Area and preventing adverse impacts to surrounding critical infrastructure. Details and provisions of the Subsidence Control Measures Agreement are summarized in see Section 3.3.3.7, below, and are included in **Appendix 3.F**. Subsidence-based MTs established for RMS in the Western and Eastern Management Areas are intended to mitigate future adverse impacts from subsidence on critical surface infrastructure. As described in chapter 2, historical subsidence that has occurred in the Subbasin, and also more regionally in the San Joaquin Valley, has been related to declining groundwater levels in the Lower Aquifer. Therefore, groundwater levels in the Lower Aquifer are being used as a proxy for subsidence, in conjunction with the use of subsidence MTs (from contemporaneous and ongoing review of subsidence surveys in the region) established at RMS in the Eastern Management Area. RMS identified for subsidence in the Western Management Area are presented on **Figure 3-8a** and **Table 3-9a**; RMS identified for subsidence in the Eastern Management Area and presented on **Figure 3-8b** and **Table 3-9b**.

Western Management Area

Subsidence MTs in the Western Management Area were established recognizing a strong interest in limiting subsidence by avoiding activating any new subsidence in this part of the Subbasin. Accordingly, subsidence MTs in the Western Management Area use groundwater levels in the Lower Aquifer as a proxy, recognizing there is likelihood that considerable residual subsidence will continue to occur for some time as a result of historical groundwater conditions. It is not possible to accurately quantify how much residual subsidence is likely to occur and this residual subsidence is believed to be unavoidable based on historical conditions; however, limiting additional groundwater level declines in the Western Management Area will stop the activation of any new subsidence. Therefore, using groundwater levels in the Lower Aquifer as a proxy, subsidence MTs in the Western Management Area were set in a manner to avoid groundwater levels declining below historical lows. Keeping groundwater levels above the historical low levels is expected to limit any additional subsidence to only residual subsidence resulting from historical conditions.

Eastern Management Area

Critical infrastructure in the Eastern Management Area includes key surface water features used for surface water conveyance consisting of the Chowchilla River, Ash Slough, and Berenda Slough. All of these conveyance features are natural surface water channels and do not have structural components that are sensitive to subsidence. However, an important consideration for these conveyance features is their capacity to transport water from east to west within the Subbasin based on the gradient of the channels. Historical subsidence in the Western Management Area has increased the conveyance capacity of these features by increasing the east to west gradient in Eastern Management Area. Although historical subsidence in the Eastern Management Area has been much less than in the Western Management Area, excessive future subsidence of a magnitude greater than that occurring in the Western Management Area could decrease the gradient of these water conveyance features and reduce their capacity to convey water. Subsidence in the Eastern Management Area causing a reduction of the conveyance capacity from decreasing of the gradient in these features below the condition that existed prior to the occurrence of recent subsidence, is considered to represent an adverse impact on this infrastructure. To assess how much additional subsidence in the Eastern Management Area may be acceptable for avoiding adverse impacts on surface water conveyance, considering limitations in available subsidence data prior to 2007, an adverse impact was determined to be the reduction of the gradient in the conveyance features from the condition that existed prior to 2007. The total observed subsidence from 2007 through 2021 (**Figure 2-67**) was used to estimate conditions prior to 2007, a time prior to the largest amounts of subsidence in the Subbasin. Total subsidence from 2007 through 2021 in the Eastern Management Area ranged from about 0.2 feet in the east to almost -6 feet in the west, with higher values ranging from -3 to almost -7 feet within the Western Management Area.

Although there is no systematic documentation of adverse impacts on well infrastructure from subsidence in the Subbasin, there are anecdotal reports of a greater number of agricultural well structure failures in areas of greater historical subsidence. The actual cause of well structure failures is generally unknown and can be difficult to identify because of the many potential causes (e.g., age, design, operational history, water quality conditions), but anecdotal reports suggest that wells having structural problems tend to occur in higher subsidence areas and are mostly limited to agricultural wells. Agricultural wells tend to be deeper than domestic wells and many of the public water system wells. As with groundwater level impacts, there is overall willingness of agricultural beneficial users in the Subbasin to accept a higher number of well structure failures from subsidence when faced with the alternative of greater reductions in groundwater pumping and the associated economic impacts. Consistent with the tolerance of agriculture beneficial users of well impacts from lowered groundwater levels (see Section 3.3.1), subsidence impacts resulting in well structure failures of greater than 25 percent of agricultural wells are considered to be significant and unreasonable.

Although the tolerance of stakeholders for public water system well structure failures caused by subsidence is lower, it is believed that an acceptable failure rate for well structures as a result of subsidence is 10 percent. The operation and maintenance schedules and budgets for public water systems commonly account for the need for periodic well repairs and replacement which likely could address such a low failure rate. Because of the shallow construction of domestic wells, the vulnerability of domestic well structures to impacts from subsidence is expected to be very limited because of the shallow construction of these wells. The definitions for acceptable well impacts consider the GSP Implementation Period since it is the most likely time frame for continuing declines in groundwater levels and associated subsidence, and the well failure rate is expected to be greatly reduced and likely insignificant once the Subbasin is sustainable.

Because little information is known about the rates of well structure failures resulting from subsidence and the amount of subsidence wells can accommodate without failure, recognizing the unique characteristic of individual wells that may affect failure including design, age, construction materials, and geologic setting, it is not possible to determine MTs for the amount of additional subsidence to avoid excessive numbers of well failures. It is notable that some newer wells in the Subbasin are being designed to accommodate greater amounts of subsidence, including though use of compression sleeves. The understanding of well characteristics and their relationship to well structure failures as a result of subsidence will continue to be considered during GSP implementation. Although the minimum thresholds for subsidence relative to impacts on critical surface water conveyance infrastructure are anticipated to mitigate impacts on well structures caused by subsidence, subsidence MTs for avoiding well impacts will be established if determined appropriate and necessary in the future.

3.3.3.1 Methodology

(The methodology to develop subsidence MTs for the Subbasin are described below. In the Western Management Area subsidence MTs used only groundwater levels in the Lower Aquifer as a proxy, but in the Eastern Management area subsidence MTs are establishing using a combination of subsidence amount (the difference in subsidence between RMS well location and surface water conveyance control point) and groundwater levels in the Lower Aquifer.

Western Management Area

In the Western Management Area the subsidence minimum threshold is established as follows:

1) Determine if the RMS represents the Lower Aquifer or Upper Aquifer; the subsidence minimum threshold only applies to Lower Aquifer wells (and composite Aquifer wells).
2) Review the modeled groundwater level data to determine the historical low groundwater elevation prior to January 2015, which typically occurred in Fall 2014 ;
3) If necessary, adjust the subsidence-based groundwater level minimum threshold to account for observed groundwater levels in the well that are below the modeled Fall 2014 low elevation.

Example hydrographs showing the various steps in determining MTs for the Lower Aquifer in the Western Management Area are provided in **Figure 3-7a and 3-7b**. The hydrographs for TRT RMS-2 and MCW RMS-9 demonstrate steps 1 through 3 listed above. In this case, adjustments were needed to move the original subsidence-based groundwater level minimum threshold down to accommodate observed historical lows. Most RMS wells did not require the Step 3 adjustment.

The methodology also includes periodic review of various subsidence surveys being conducted by others (e.g., benchmark surveys, InSAR surveys, extensometer data, etc.) to review the progress towards mitigation of subsidence. It is anticipated that while some residual subsidence will likely occur due to lag times associated with recent and previous cycles of historical low groundwater levels, meeting MTs described in this GSP should result in reduced rates of subsidence in the future until compaction of clay layers (and subsidence) initiated by pre-SGMA low groundwater levels becomes minimal.

Eastern Management Area

In the Eastern Management Area the groundwater level proxy portion of the subsidence minimum threshold is established as follows:

1) Determine if the RMS represents the Lower Aquifer or Upper Aquifer; the subsidence minimum threshold only applies to Lower Aquifer wells.
2) Review the modeled groundwater level data to determine the historical low groundwater elevation;
3) If necessary, adjust the subsidence-based groundwater level minimum threshold to account for observed groundwater levels in the well that are below the historical low model elevation.

Example hydrographs showing the various steps in determining MTs for the Lower Aquifer in the Eastern Management Area are provided in **Figures 3-7c and 3-7d**. The hydrographs for CWD RMS-3 and MCE RMS-2 demonstrate steps 1 through 3 listed above. In case of MCE RMS-2, adjustments were needed to move the original subsidence-based groundwater level minimum threshold down to accommodate observed historical lows. Most RMS wells did not require the Step 3 adjustment.

The methodology also includes periodic review of various subsidence surveys being conducted by others (e.g., benchmark surveys, InSAR surveys, extensometer data, etc.) to review the progress towards mitigation of subsidence. It is anticipated that while some residual subsidence will likely occur due to lag times associated with recent and previous cycles of historical low groundwater levels, meeting MTs described in this GSP should result in reduced rates of subsidence in the future until compaction of clay layers (and subsidence) initiated by pre-SGMA low groundwater levels becomes minimal.

Minimum thresholds for the amount of subsidence (relative to the amount of subsidence at downgradient surface water conveyance control points) in the Eastern Management Area were established at all Lower Aquifer RMS within the Eastern Management Area and were coupled with minimum thresholds for groundwater levels as a proxy as the basis for defining an exceedance of the subsidence minimum threshold that is a result of future groundwater pumping withdrawals and not related to delayed or residual subsidence caused by historical conditions. The minimum thresholds for subsidence at each RMS represent the amount of acceptable future subsidence that is in excess of future subsidence that occurs at a downgradient control point along each of the three critical surface water conveyance features in the Eastern Management Area. Because there is potential for additional residual subsidence to occur in the Western Management Area (and at the point where surface water infrastructure enters the Western Management Area), any potential future subsidence in the Western Management Area must be considered when evaluating potential for adverse impacts on surface water conveyance in the Eastern Management Area caused by reduction of the channel gradient along these features. **Figure 3-9** and **Table 3-10** present the historical subsidence since 2007 at each of the Lower Aquifer RMS wells located in the Eastern Management Area, the critical surface water conveyance feature in the Subbasin associated with the RMS, the historical subsidence (since 2007) at the downgradient point where the nearest critical water conveyance feature enters the Western Management Area (downgradient control point), and the difference between the amount of subsidence since 2007 at the RMS and at the downgradient control point. The subsidence minimum threshold at each Lower Aquifer RMS in the Eastern Management Area was defined as the difference between the subsidence since 2007 at the RMS and at the downgradient control point plus any additional future subsidence occurring at the downgradient control point, which is intended to ensure the gradient and conveyance capacity of these critical infrastructure components are maintained at no less than 2007 gradients and conveyance capacities.

Groundwater levels were used as a proxy for subsidence as a second metric in the Eastern Management Area. The use of groundwater levels is to ensure that future subsidence that may occur is limited to residual subsidence and that no new active subsidence would occur. This was accomplished by setting groundwater level proxy MTs at modeled or observed low groundwater elevations. Both modeled and observed data are used for two reasons: 1) Observed data are not necessarily available for the times when historical lows occurred; 2) In some cases, observed data do not sufficiently match modeled data. In general, groundwater level proxy MTs were based on modeled historical lows, adjusted as necessary for offsets with observed data. If these groundwater level proxy MTs are met, future additional subsidence would be limited to residual subsidence related only to previous cycles of historical low groundwater elevations.

Table 3-9b presents the MTs for subsidence in the Eastern Management Area at each of the identified RMS. An exceedance of a MT at a given RMS is defined as exceeding both the subsidence amount MT and the subsidence groundwater level MT. Evaluation of Subbasin conditions relative to the subsidence amount MT will be based on annual review of subsidence mapping data published by DWR and conditions relative to the subsidence groundwater level MT will be based on annual fall groundwater level measurements, with fall water level measurements below the MT in two consecutive years required to trigger an MT exceedance.

Table 3-9a. Summary of Western Management Area Land Subsidence Minimum Thresholds for Representative Monitoring Sites

Well I.D.	Surface Elevation	Well Depth	Screen Top-Bottom	Model Layer(s)	Aquifer Designation[1]	MT Depth	MT Elev	GSA	Management Area
MCW RMS-4	138	Unknown	Unknown	4	Lower	174	-36	Madera County West	Western
MCW RMS-5	146	Unknown	Unknown	4	Lower	186	-40	Madera County West	Western
MCW RMS-6	139	Unknown	Unknown	4	Lower	168	-29	Madera County West	Western
MCW RMS-7	138	800	290-400	4	Lower	156	-18	Madera County West	Western
MCW RMS-9	155	700	265-696	5	Lower	185	-30	Madera County West	Western
TRT RMS-2	135	500	300-500	4	Lower	140	-5	TTWD	Western
TRT RMS-3	137	799	168-790	5	Lower	168	-31	TTWD	Western

Table 3-9b. Summary of Eastern Management Area Subsidence Minimum Thresholds

Well I.D.	Surface Elevation (ft msl)	Well Depth (ft bgs)	Screens Top-Bottom (ft bgs)	Aquifer Designation	Associated Critical Conveyance	Downgradient Critical Conveyance Control Point	Subsidence MT: Subsidence Amount (ft)	Subsidence MT: Groundwater Elevation (ft msl)	Subsidence MT: Depth to Groundwater (ft bgs)
CWD RMS-1	171	275	160-275	Lower	Chowchilla River	Chowchilla R. @ WMA	-0.19 + subsidence Chowchilla R. @ WMA	-90	261
CWD RMS-2	193	780	230-775	Lower	Chowchilla River	Chowchilla R. @ WMA	-1.46 + subsidence Chowchilla R. @ WMA	-71	264
CWD RMS-3	206	Unknown	Unknown	Lower	Chowchilla River	Chowchilla R. @ WMA	-1.22 + subsidence Chowchilla R. @ WMA	-77	283
MCE RMS-1	276	Unknown	Unknown	Lower	Chowchilla River	Chowchilla R. @ WMA	-3.03 + subsidence Chowchilla R. @ WMA	-63	339
MER RMS-1	225	Unknown	Unknown	Lower	Chowchilla River	Chowchilla R. @ WMA	-2.08 + subsidence Chowchilla R. @ WMA	-77	302
CWD RMS-4	225	800	320-800	Lower	Ash Slough	Ash Sl. @ WMA	-1.88 + subsidence Ash Sl. @ WMA	-87	313
CWD RMS-5	207	Unknown	Unknown	Lower	Ash Slough	Ash Sl. @ WMA	-1.25 + subsidence Ash Sl. @ WMA	NA[1]	NA[1]

Well I.D.	Surface Elevation (ft msl)	Well Depth (ft bgs)	Screens Top-Bottom (ft bgs)	Aquifer Designation	Associated Critical Conveyance	Downgradient Critical Conveyance Control Point	Subsidence MT: Subsidence Amount (ft)	Subsidence MT: Groundwater Elevation (ft msl)	Subsidence MT: Depth to Groundwater (ft bgs)
CWD RMS-7	169	330	135-288	Lower	Ash Slough	Ash Sl. @ WMA	-0.33 + subsidence Ash Sl. @ WMA	-87	256
CWD RMS-10	182	Unknown	Unknown	Lower	Ash Slough	Ash Sl. @ WMA	-0.74 + subsidence Ash Sl. @ WMA	-79	261
MCE RMS-2	272	466	218-464	Lower	Ash Slough	Ash Sl. @ WMA	-2.97 + subsidence Ash Sl. @ WMA	-82	354
CWD RMS-6	275	820	257-726	Lower	Berenda Slough	Berenda Sl. @ WMA	-4.79 + subsidence Berenda Sl. @ WMA	-73	348
CWD RMS-8	219	Unknown	Unknown	Lower	Berenda Slough	Berenda Sl. @ WMA	-2.37 + subsidence Berenda Sl. @ WMA	-89	308
CWD RMS-11	199	529	187-529	Lower	Berenda Slough	Berenda Sl. @ WMA	-1.54 + subsidence Berenda Sl. @ WMA	NA[1]	NA[1]
CWD RMS-13	167	Unknown	Unknown	Lower	Berenda Slough	Berenda Sl. @ WMA	-0.16 + subsidence Berenda Sl. @ WMA	-88	255
CWD RMS-14	152	455	185-365	Lower	Berenda Slough	Berenda Sl. @ WMA	-0.75 + subsidence Berenda Sl. @ WMA	-98	250
CWD RMS-15	213	955	290-935	Lower	Berenda Slough	Berenda Sl. @ WMA	-2.36 + subsidence Berenda Sl. @ WMA	-90	303
CWD RMS-16	212	Unknown	Unknown	Lower	Berenda Slough	Berenda Sl. @ WMA	-1.77 + subsidence Berenda Sl. @ WMA	-80	292
CWD RMS-17	203	624	278-588	Lower	Berenda Slough	Berenda Sl. @ WMA	-1.51 + subsidence Berenda Sl. @ WMA	-99	302

1. Groundwater elevations recorded at this well were likely representative of a zone below the Corcoran Clay when it was actively pumped, but in recent years are more representative of a shallow zone above the Corcoran Clay since it is no longer actively pumped. It is recommended this RMS well be removed from the monitoring program and replaced (if necessary) with a new RMS well for the GSP five-year update.

Table 3-10. Summary of Eastern Management Area Subsidence Minimum Threshold Development

Well I.D.	Surface Elevation (ft msl)	Well Depth (ft bgs)	Screens Top-Bottom (ft bgs)	Aquifer Designation	2007-2021 Subsidence at RMS (ft)	Associated Critical Surface Water Conveyance	Downgradient Critical Conveyance Control Point	2007-2021 Subsidence at Downgradient Control Point (ft)	Difference 2007-2021 Subsidence at RMS and Downgradient Control Point (ft)
CWD RMS-1	171	275	160-275	Lower	-3.77	Chowchilla River	Chowchilla R. @ WMA	-3.96	-0.19
CWD RMS-2	193	780	230-775	Lower	-2.50	Chowchilla River	Chowchilla R. @ WMA	-3.96	-1.46
CWD RMS-3	206	Unknown	Unknown	Lower	-2.74	Chowchilla River	Chowchilla R. @ WMA	-3.96	-1.22
MCE RMS-1	276	Unknown	Unknown	Lower	-0.93	Chowchilla River	Chowchilla R. @ WMA	-3.96	-3.03
MER RMS-1	225	Unknown	Unknown	Lower	-1.88	Chowchilla River	Chowchilla R. @ WMA	-3.96	-2.08
CWD RMS-4	225	800	320-800	Lower	-2.79	Ash Slough	Ash Sl. @ WMA	-4.67	-1.88
CWD RMS-5	207	Unknown	Unknown	Lower	-3.42	Ash Slough	Ash Sl. @ WMA	-4.67	-1.25
CWD RMS-7	169	330	135-288	Lower	-4.34	Ash Slough	Ash Sl. @ WMA	-4.67	-0.33
CWD RMS-10	182	Unknown	Unknown	Lower	-3.92	Ash Slough	Ash Sl. @ WMA	-4.67	-0.74
MCE RMS-2	272	466	218-464	Lower	-1.70	Ash Slough	Ash Sl. @ WMA	-4.67	-2.97
CWD RMS-6	275	820	257-726	Lower	-1.13	Berenda Slough	Berenda Sl. @ WMA	-5.92	-4.79
CWD RMS-8	219	Unknown	Unknown	Lower	-3.55	Berenda Slough	Berenda Sl. @ WMA	-5.92	-2.37
CWD RMS-11	199	529	187-529	Lower	-4.38	Berenda Slough	Berenda Sl. @ WMA	-5.92	-1.54
CWD RMS-13	167	Unknown	Unknown	Lower	-5.76	Berenda Slough	Berenda Sl. @ WMA	-5.92	-0.16
CWD RMS-14	152	455	185-365	Lower	-5.17	Berenda Slough	Berenda Sl. @ WMA	-5.92	-0.75
CWD RMS-15	213	955	290-935	Lower	-3.56	Berenda Slough	Berenda Sl. @ WMA	-5.92	-2.36
CWD RMS-16	212	Unknown	Unknown	Lower	-4.15	Berenda Slough	Berenda Sl. @ WMA	-5.92	-1.77
CWD RMS-17	203	624	278-588	Lower	-4.41	Berenda Slough	Berenda Sl. @ WMA	-5.92	-1.51

3.3.3.2 Relationship to Other Sustainability Indicators

The wells described in **Table 3-8** and **Figure 3-1** are in locations that reflect a wide cross section of Subbasin groundwater conditions. These locations are representative of the overall Subbasin conditions because they are spatially distributed throughout the Subbasin both vertically (across the Upper and Lower Aquifer) and spatially throughout the Western and Eastern Management Areas. The distribution of Upper Aquifer wells is limited because the definition of Upper Aquifer used in this study (above the Corcoran Clay where present, and equivalent depth to east of where Corcoran Clay is present), results in relatively large areas of unsaturated Upper Aquifer in the central to eastern portions of the Subbasin. The GSAs have determined that use of land subsidence-based minimum groundwater level thresholds at Lower Aquifer wells will help avoid the undesirable results for land subsidence because it will minimize future subsidence that has not already been initiated.

Subsidence-based groundwater level MTs can influence other sustainability indicators. The subsidence-based groundwater level MTs were set to avoid undesirable results for other sustainability indicators.

1. Chronic Lowering of Groundwater Levels. The methodology to establish MTs for groundwater levels generally results in MTs lower than those being established for subsidence. Thus, the MTs established for subsidence will not cause undesirable results for this sustainability indicator.
2. Reduction in groundwater storage. Given the dependence of the reduction in groundwater storage on groundwater levels and the relationship to subsidence described above, MTs established for subsidence will not cause undesirable results for this sustainability indicator.
3. Degraded water quality. The subsidence minimum threshold will not change the groundwater flow direction or rates, and therefore will not result in a significant or unreasonable change in groundwater quality.
4. Depletion of interconnected surface waters. The assessment of surface water flows and groundwater levels indicate that there are not interconnected surface waters in most of the Subbasin. Although interim interconnected surface water MTs have been established for the San Joaquin River along the western Subbasin boundary, they are based on Upper Aquifer RMS wells whereas subsidence MTs are based on Lower Aquifer RMS wells. In addition, it should be noted that MTs for each sustainability indicator are being set independently of each other in order to clearly identify the cause of undesirable results should they occur. Therefore, interconnected surface water MTs and undesirable results will not be directly affected by the subsidence MTs. While GSP projects will significantly increase recharge to the Upper Aquifer in western Chowchilla Subbasin and result in higher overall average groundwater levels, it remains possible that the transfer of groundwater pumping from the Lower Aquifer to the Upper Aquifer to help mitigate subsidence concerns may result in temporarily lower groundwater levels in the Upper Aquifer during long-term droughts after 2040. However, once the San Joaquin River becomes disconnected the continued lowering of groundwater levels does not affect stream depletion. This issue was evaluated by review of groundwater model results for historical versus projected future with projects conditions in the GDE sections of this GSP, which incorporate groundwater level and biologic monitoring of the GDE unit along the San Joaquin River in western Chowchilla Subbasin.

3.3.3.3 Impact of Selected Minimum Thresholds to Adjacent Basins

The Based on recent discussions with the adjacent GSAs along the western and northern borders of Chowchilla Subbasin (San Joaquin River Exchange Contractors or SJREC, Merced Subbasin GSAs), land subsidence MTs in the Western Management Area (based on historical groundwater elevation lows) are generally consistent with those being set in adjacent areas of Delta-Mendota and Merced Subbasins.

Furthermore, the MTs for land subsidence in the Western Management Area were established to be consistent with the Subsidence Control Measures agreement between landowners in and around the Triangle T Water District and agencies in the Delta-Mendota Subbasin. The provisions of this agreement are specifically designed to mitigate subsidence and avoid undesirable results to critical infrastructure in the Delta-Mendota and Chowchilla Subbasins (see Section 3.3.3.7, below). Chowchilla Subbasin representatives plan to continue working closely with SJREC to monitor groundwater levels and subsidence during the Implementation Period, and will work together to consider adjustments to SMC if needed.

However, it should be noted that it is difficult to estimate how much residual subsidence may occur for a given situation. In the case of Chowchilla Subbasin, historical low groundwater levels generally occurred in the 2014-2015 time period, although some wells lack observed (i.e., measured) data for 2014-2015 and more recent groundwater level measurements for some RMS wells during 2020 and 2021 are the lowest measured groundwater levels due to recent extreme drought conditions. Groundwater elevations that occur in 2022 and beyond will be highly dependent on the potential continued occurrence of drought conditions extending over the next few years. As discussed in Section 2, even if historical lows are never again exceeded some amount of residual subsidence is expected to occur.

In addition, while the Chowchilla Subbasin GSAs have been and will continue to implement PMAs as quickly as possible, our analysis indicates that some continued decline in groundwater levels is likely unavoidable during the initial 10 to 15 years of the GSP Implementation Period as the GSAs work to become sustainable within the SGMA 20-year allowable time frame between 2020 and 2040. PMAs that focus on creating more imported surface water to use in lieu of groundwater, increased recharge to groundwater, and reductions in existing groundwater pumping require time to set up and adopt the policies and frameworks, construction, and availability of excess water for recharge during wet years. Therefore, it can be anticipated that some additional active subsidence may occur beyond the ongoing residual subsidence if regional groundwater levels go below historical lows during the GSP implementation period.

Additional studies related to subsidence may include field data collection and subsidence modeling to evaluate the anticipated magnitude of future residual (and possibly additional active) subsidence that can be expected to occur. Again, it is important to note that even if groundwater elevations were to never exceed historical lows that have occurred through the Fall of 2021, a certain amount of residual subsidence will still occur and cannot be avoided.

3.3.3.4 Minimum Thresholds Impact on Beneficial Uses and Users

The land subsidence minimum threshold of maintaining groundwater levels at or above historical low groundwater levels to minimize future subsidence and slow the rate of current subsidence (which may still be occurring due to lag times) will necessarily require shifting of some current Lower Aquifer groundwater pumping to the Upper Aquifer combined with some net overall reduction in groundwater pumping. Shifting of pumping from the Lower Aquifer to Upper Aquifer and reduced overall groundwater pumping may impact beneficial uses and users of groundwater in the Subbasin. Those expected to be impacted include agricultural land use and users, urban land use and users, domestic land use and users, and ecological land use and users. Those expected to be most impacted by pumping reductions are agricultural land uses and users, as those users are the primary users of groundwater from the Lower Aquifer in the Chowchilla Subbasin. In general, agricultural land use/users will be negatively impacted by pumping reductions since it is their pumping that will be reduced, while other users may benefit from agricultural pumping reductions. Most domestic well pumping is considered de minimis and will not be subject to pumping reductions. These impacts will be similar to those described above for chronic lowering of groundwater levels, but with increased impacts to agricultural land use and users where subsidence MTs are set higher than groundwater level based MTs. In addition, requirements to pump less from the Lower Aquifer and more from the Upper Aquifer may impact groundwater levels for GDEs (ecological land use and users) during droughts (depending on the balance between GSP recharge projects in the Upper Aquifer vs. additional pumping from the Upper Aquifer).

It should be noted that landowners within and adjacent to Triangle T Water District have already entered into an agreement to mitigate subsidence in a portion of the Western Management Area of Chowchilla Subbasin. The agreement, in effect since 2017, contains provisions that limit pumping from the Lower Aquifer to reduce subsidence in areas of the Chowchilla Subbasin where subsidence rates have historically been greatest, and also provide irrigators in the Chowchilla Subbasin access to surface water for irrigation in-lieu of groundwater. These actions are designed and have already begun to mitigate impacts of land subsidence on beneficial uses and users in the Chowchilla Subbasin. Additional information is provided in Section 3.3.3.7, below.

3.3.3.5 Comparison between Minimum Thresholds and Relevant State, Federal or Local Standards

There are no Federal, State, or local standards that exist for land subsidence.

3.3.3.6 Minimum Thresholds Measurement Method

The MTs for land subsidence are based on groundwater levels being measured for the groundwater level minimum threshold. In the Eastern Management Area the amount of subsidence occurring at RMS wells and the nearest surface water conveyance control points well be based on InSAR data and SJRRP benchmark surveys.

3.3.3.7 Other Considerations for Setting Minimum Thresholds

3.3.3.7.1 Infrastructure Sensitivity Assessment

The GSAs completed an infrastructure assessment to evaluate the characteristics of critical infrastructure in the Chowchilla Subbasin, including its proximity, orientation, and relative vulnerability to adverse effects of land subsidence. The assessment is documented in **Appendix 3.E.** and has been used to develop SMC in the Chowchilla Subbasin with the goal of protecting this critical infrastructure from URs of groundwater conditions during implementation of the GSP.

3.3.3.7.2 Subsidence Control Measures Agreement

The MTs for land subsidence in the Western Management Area were established to be consistent with the Subsidence Control Measures Agreement (initial Agreement) between certain landowners in the Western Management Area of the Chowchilla Subbasin, the Central California Irrigation District (CCID), and San Luis Canal Company. Landowners that have entered into the initial Agreement collectively manage more than 14,000 acres in the Western Management Area. A copy of the initial Agreement is provided in **Appendix 3.F.** The initial Agreement was executed in 2017, and was in effect from 2017-2021. The parties are currently working under a one-year extension through 2022 with the goal of signing a new five-year extension starting in 2023. Negotiations are ongoing as of summer 2022.

The provisions of the initial Agreement were designed to mitigate subsidence and avoid undesirable results to beneficial uses and users and critical infrastructure in the Chowchilla Subbasin and the adjacent Delta-Mendota Subbasin. The expressed purpose of the initial Agreement is to:

1. Reduce the use of groundwater from the Lower Aquifer. Loss of groundwater storage and associated reduction in pore pressures in clay layers in the Lower Aquifer (indicated by lowering groundwater levels) is understood by all parties to lead to conditions that cause and/or exacerbate land subsidence. The relationship between loss of groundwater storage and associated reduction in pore pressures in clay layers, lowering groundwater levels, and land subsidence is a central and common point of understanding between all parties who signed the initial Agreement, including the Expert Panel established under the Agreement.
2. Facilitate the distribution and use of surface water in areas of the Chowchilla Subbasin that are managed by participating landowners in order to reduce groundwater extraction (particularly from the Lower Aquifer), reduce subsidence, recharge the Upper Aquifer, and mitigate effects to critical infrastructure, including Sack Dam and the Poso Canal. Both systems are gravity-flow systems that are vulnerable to capacity reductions due to land subsidence and may require significant operational changes if subsidence continues unabated (e.g., pumping, relocation or reconstruction of diversion infrastructure).

Under the initial Agreement, parties in the Chowchilla Subbasin are required, among other provisions, to restrict the amount of groundwater they pump from the Lower Aquifer and to report, under penalty of perjury, the amounts of groundwater pumped, the source of that groundwater (Upper Aquifer or Lower Aquifer), the amounts recharged, the amounts of surface water used for irrigation, and other information about their irrigated acreage and crops. Parties in the Chowchilla Subbasin are also required to implement projects that increase use of surface water for irrigation (providing in-lieu recharge benefits to the Lower Aquifer) and increase use of surface water for direct recharge (increasing storage in the Upper Aquifer to support sustainable use of groundwater from the Upper Aquifer instead of the Lower Aquifer).

The initial Agreement also requires evaluation of the Lower Aquifer safe Yield by an Expert Panel to determine the allowable amount of pumping from the Lower Aquifer that can occur without causing continuation of subsidence. While this Safe Yield evaluation was being conducted, the initial Agreement set specific limits for Lower Aquifer pumping as follows: 0.9 acre-feet per acre (AF/ac) in 2017, 0.75 AF/ac in 2018, 0.65 AF/ac in 2019, 0.6 AF/ac in 2020, and 0.5 AF/ac in 2021. Following completion of the Lower Aquifer Safe Yield Study by the Expert Panel, the annual limits and future allowable groundwater pumping amounts from the Lower Aquifer were modified in accordance with Expert Panel findings. The most recent Draft 2021 Expert Panel Report prepared in April 2022 is provided in **Appendix 3.F**.

Since the initial Agreement was signed in 2017, parties to the Agreement have successfully constructed facilities to supply and distribute surface water to users in the Chowchilla Subbasin. Despite the dry start to the GSP implementation period and through the actions and infrastructure improvements performed in accordance with the initial Agreement, more than 25,000 AF of surface water has been delivered to participating landowners in the Chowchilla Subbasin since 2018. This surface water has provided direct benefits to participating landowners for irrigation and groundwater recharge in an area that has historically relied solely on groundwater pumping, resulting in reduced pumping and helping to mitigate subsidence.

Landowners in the Chowchilla Subbasin that are party to the Agreement have also consistently fulfilled their obligation to report, under penalty of perjury, the amounts of groundwater pumped, the source of that groundwater (Upper Aquifer or Lower Aquifer), the amount recharged, the amounts of surface water used for irrigation, and other information about their irrigated acreage and crops. **Table 3-11** provides a summary of groundwater pumping, surface water use, and irrigated acreage from the Draft 2021 Expert Panel Report (**Appendix 3.F**). Beginning in 2017, participating landowners in the Chowchilla Subbasin have reduced pumping from the Lower Aquifer, including shifting considerable pumping from the Lower Aquifer to the Upper Aquifer. Each year since signing the initial Agreement, the participating landowners have collectively reported pumping between 0.13 and 0.50 AF/ac from the Lower Aquifer, less than the specified limits for Lower Aquifer pumping in the initial Agreement. Use of surface water during years it has been available has also provided between 0.66 and 1.76 AF/ac of benefit to those irrigated lands, providing direct recharge to the Upper Aquifer and offsetting demand for groundwater.

Efforts under the initial Agreement have already been successful for mitigating subsidence in the TTWD area of the Western Management Area. Annual vertical displacement rates in the Subbasin, as reported from InSAR data, indicate a relative decrease in the rate of subsidence within Triangle T Water District since approximately 2017, as compared with rates of subsidence in surrounding areas (see Section 2.2.2.4).

Table 3-11. Reported Groundwater Use, Surface Water Use, and Total Water Use by Chowchilla Subbasin Landowners that are Signatories to the Subsidence Control Measures Agreement.[1]

Description	2017	2018	2019	2020	2021
Total Groundwater Use (AF)	**17,089**	**27,764**	**23,988**	**30,478**	**34,744**
Lower Aquifer Pumping (AF)	***1,777***	***6,978***	***1,770***	***5,355***	***5,262***
Upper Aquifer Pumping (AF)	***15,312***	***20,786***	***22,218***	***25,123***	***29,482***
Total Surface Water Use (AF)	22,653	10,244	24,798	9,329	0
Surface Water Purchases (AF)	*0*	*8,279*	*10,746*	*9,329*	*0*
Surface Water Diversions, Fresno River (AF)	*15,666*	*620*	*11,007*	*0*	*0*
Surface Water Diversions, Eastside Bypass (AF)	*6,987*	*1,345*	*3,045*	*0*	*0*
Total Water Use (AF)	39,742	38,008	48,786	39,807	34,744
Total Irrigated Area (ac)	13,911	13,911	14,111	14,111	14,111
Total Groundwater Use (AF/ac)	**1.23**	**2.00**	**1.70**	**2.16**	**2.46**
Lower Aquifer Pumping (AF/ac)	***0.13***	***0.50***	***0.13***	***0.38***	***0.37***
Upper Aquifer Pumping (AF/ac)	***1.10***	***1.49***	***1.57***	***1.78***	***2.09***
Total Surface Water Use (AF/ac)	1.63	0.74	1.76	0.66	0.00
Surface Water Purchases (AF/ac)	*0.00*	*0.60*	*0.76*	*0.66*	*0.00*
Surface Water Diversions, Fresno River (AF/ac)	*1.13*	*0.04*	*0.78*	*0.00*	*0.00*
Surface Water Diversions, Eastside Bypass (AF/ac)	*0.50*	*0.10*	*0.22*	*0.00*	*0.00*
Total Water Use (AF/ac)	2.86	2.73	3.46	2.82	2.46

[1] Source: Appendix 3.F. Draft 2021 Expert Panel Report ("2021 Monitoring Data for the Sack Dam-Red Top Area"), Table S3-Subsidence Abatement Agreement Summary.

Landowners in the Chowchilla Subbasin that are party to the initial Agreement are committed to fulfilling the obligations under the Agreement. Fulfillment of these obligations is expected to also support sustainable groundwater management in the Chowchilla Subbasin in accordance with the SMC established in this GSP. Actions under the Agreement are expected to help maintain groundwater levels in the Lower Aquifer at or above recent historical levels, thereby avoiding undesirable results related to land subsidence. Compliance with the Agreement will help avoid undesirable results to infrastructure – including Sack Dam, Poso Canal, and other waterways in the Western Management Area – as well as other beneficial uses of land and groundwater in the surrounding region. The initial Agreement has already provided significant and measurable benefits to the Chowchilla Subbasin. The outcomes and effectiveness of the Agreement will continue to be evaluated, and will be reported in subsequent periodic GSP updates and Annual Reports as more is known.

3.3.3.7.3 Other Subsidence Control Measures in the Western Management Area

Outside of areas managed under the Agreement, the GSAs in the Chowchilla Subbasin plan to couple their GSP projects and implementation efforts with provisions that complement and are consistent with the Agreement.

For example, Madera County GSA and TTWD GSA are developing large, coordinated groundwater recharge projects in the Western Management Area that will enhance groundwater storage in the Upper Aquifer. The GSAs will be executing agreements with participating landowners as part of these projects. In these agreements the GSAs plan to include provisions that only permit the recovery of project groundwater recharge benefits from wells in the Upper Aquifer, where the recharge from the projects will be occurring. These provisions will effectively reduce groundwater extraction from the Lower Aquifer and shift extraction to the Upper Aquifer, similar to the Agreement, and are anticipated to reduce subsidence rates in parts of the Western Management Area outside of the TTWD GSA. Together, the combined benefit area of these projects and the lands managed under the Subsidence Control Measures Agreement represent the majority of land within the Western Management Area (**Figure 3-10**).

While development of these groundwater recharge projects is ongoing, the GSAs will continue to monitor the progress and subsidence mitigation benefits of the initial Agreement. These findings will be used to inform development of Lower Aquifer groundwater pumping restrictions or other efforts to mitigate subsidence in the Madera County GSA area. Limitations on groundwater pumping from the Lower Aquifer may also be achieved through well permitting provisions in response to Executive Order N-7-22 or by other means determined by the GSAs. Based on the results of the “Projected, With Projects” water budget scenario modeled in the Madera-Chowchilla Groundwater-Surface Water Simulation (MCSim)[62], it is expected that shifts in pumping practices, paired with implementation of the planned PMAs, will help to achieve sustainable groundwater conditions in the Chowchilla Subbasin. Updates and outcomes of other subsidence mitigation measures will be reported in future GSP updates and Annual Reports. Together, landowners and GSAs are making consistent efforts to achieve and maintain groundwater sustainability in the Western Management Area.

[62] See Appendix 6.D, Section 3.5.3.2. In the MCSim projected model, approximately 90 percent of groundwater pumping was simulated from the Upper Aquifer and approximately 10 was simulated from the Lower Aquifer.

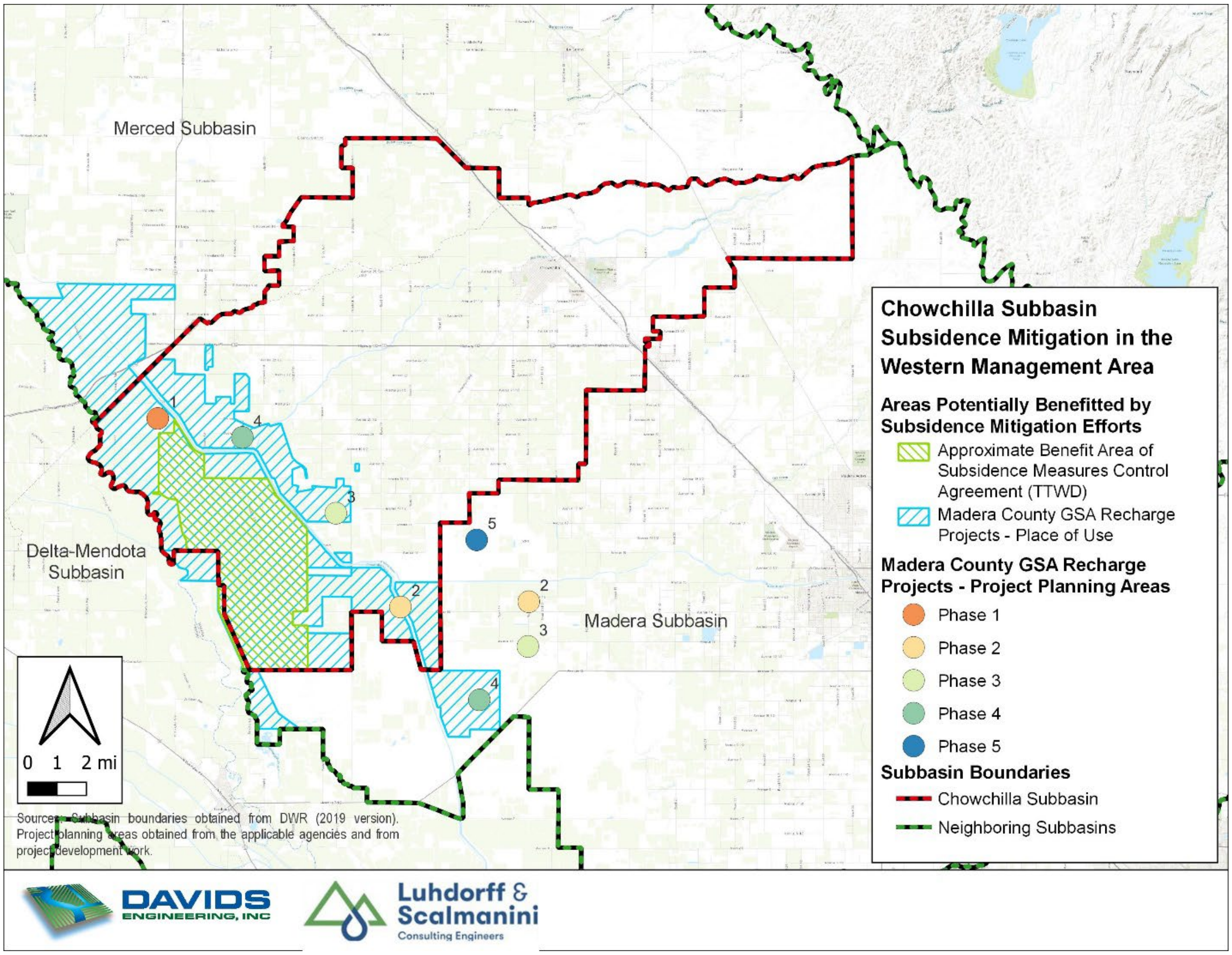


Figure 3-10. Subsidence Mitigation Efforts in the Western Management Area.

3.3.4 Degraded Water Quality

The cause of basin groundwater conditions that would result in significant and unreasonable degraded water quality is implementation of a GSP project or management action that causes concentrations of key groundwater quality constituents to increase to concentrations exceeding the MCLs for drinking water for identified key constituents (10 mg/L for nitrate as nitrogen; 500 mg/L for TDS; 10 ug/L for arsenic). There are no known significant large-scale groundwater quality contamination plumes in regional groundwater aquifers within the Subbasin. Municipal and domestic supply (MUN) is a designated beneficial use for groundwater in the Subbasin; therefore, groundwater quality degradation is considered significant and unreasonable based on adverse impacts to this beneficial use. Locally defined significant and unreasonable conditions were determined based on discussion with GSA staff and technical representatives, input received from interested stakeholders and the public through public meetings, and through individual stakeholder input to various GSA representatives. Significant and unreasonable degradation of water quality occurs when beneficial uses for groundwater are adversely impacted by constituent concentrations increasing to levels above the drinking water MCLs for one of the key constituents (nitrate, arsenic, TDS) previously identified in Section 2 of the GSP at indicator wells in the representative groundwater quality monitoring network due to implementation of a GSP project or management action. When existing or historical concentrations for the key constituents already exceed the MCL, the minimum threshold is set at the recent concentration plus 20 percent.

The MTs for degraded water quality apply to RMS selected from among existing and proposed future wells located throughout the Subbasin and screened in both the Upper and Lower Aquifers. The RMS for groundwater quality include a combination of irrigation, public supply, domestic, and monitoring wells to be sampled and analyzed by the Subbasin GSAs together with wells that are sampled by others as part of other groundwater quality monitoring programs. The selected RMS for groundwater quality are listed in **Table 3-12** and shown on **Figure 3-2**.

3.3.4.1 Methodology

The methodology to develop MTs for groundwater quality is based on the objective of protecting all designated beneficial uses from significant and unreasonable adverse impacts from implementation of GSP PMAs. In accordance with the Basin Plan, groundwater in the Subbasin is considered suitable or potentially suitable for municipal and domestic water supply (MUN), agricultural supply (AGR), industrial service supply (IND), and industrial process supply (PRO) beneficial uses. From a groundwater quality standpoint, the municipal and domestic supply beneficial use is the most restrictive with Basin Plan water quality objectives linked to drinking water MCLs. As a result, the MTs for groundwater quality set for each of the three identified key water quality constituents (nitrate, arsenic, TDS) are the respective MCL values, except for cases where existing or historical concentrations for these constituents already exceed the MCL. When existing or historical concentrations for the key constituents already exceed the MCL, the minimum threshold is set at the current concentration plus 20 percent. When current or historical water quality for the key constituents has not been measured, the minimum threshold will be set as the MCL and will be adjusted if needed after water quality monitoring commences. The applicable MTs for groundwater quality in the GSP apply to degraded groundwater quality as a direct result of impacts from projects/MAs under the GSP that cause an exceedance to occur. Future exceedances of the MT may occur due to activities or conditions unrelated to implementation of the GSP, in which case they would not constitute an MT exceedance that contributes to an undesirable result.

3.3.4.2 Relationship to Other Sustainability Indicators

Although there are potential relationships between groundwater quality and other sustainability indicators, setting of MTs for groundwater quality does not conflict with other sustainability indicators and associated MTs. Management of groundwater for other sustainability indicators and associated MTs may not ensure that impacts on groundwater quality are avoided.

3.3.4.3 Impact of Selected Minimum Thresholds to Adjacent Basins

The MTs for groundwater quality established for the Subbasin are intended to protect all beneficial uses within the Subbasin, including municipal and domestic water supply uses, from groundwater quality degradation caused by projects or management actions included in the GSP, and are therefore not likely to impact adjacent subbasins or their ability to achieve sustainability.

3.3.4.4 Minimum Thresholds Impact on Beneficial Uses and Users

Municipal and domestic supply is the most restrictive beneficial use standard for groundwater quality with water quality objectives equal to drinking water MCLs. Setting the groundwater quality MTs for key constituent concentrations at respective drinking water MCLs, or within a tolerance for no more than a 20 percent increase above historical concentrations when existing or historical concentrations already exceed the MCL, is intended to limit degradation of groundwater quality caused by GSP PMAs in order to protect municipal and domestic supply beneficial uses. Protection of municipal and domestic beneficial uses is also protective of all other groundwater beneficial uses.

3.3.4.5 Comparison between Minimum Thresholds and Relevant State, Federal or Local Standards

The Federal and State drinking water quality standards are represented through MCLs that are applicable to public drinking water supplies and provide reasonable guidance on water quality for safe drinking water in non-public supplies. As described above, the State of California drinking water MCLs for arsenic, nitrate, and TDS are being used to define MTs for groundwater quality degradation caused by GSP PMAs, except in cases where existing or historical groundwater quality conditions already exceed these levels.

3.3.4.6 Minimum Thresholds Measurement Method

Groundwater quality will be monitored on an annual basis at identified representative groundwater quality monitoring indicator wells presented in **Table 3-12** and **Figure 3-2**. Monitoring will be conducted through sampling of groundwater quality conducted for the GSP monitoring along with evaluation of groundwater quality data reported for other monitoring programs. All groundwater quality sampling and analysis will be conducted in accordance with the monitoring protocols and procedures described in the GSP. The monitoring network and monitoring protocols for groundwater quality are described in Section 3.5 (Monitoring Network and Monitoring Protocols for Data Collection).

Table 3-12. Summary of Groundwater Quality Minimum Thresholds for Representative Monitoring Sites

Well ID	Well Type	Well Depth	Screen Top-Bottom	Aquifer Designation	MT Arsenic Concentration (µg/L)	MT Nitrate Concentration (mg/L)	MT TDS Concentration (mg/L)	GSA Location	Entities to Conduct Monitoring	Measurement Frequency
Wells Monitored by GSAs: Existing										
CWD RMS-1	Domestic	275	160-275	Lower	10†	10†	500†	CWD	CWD	Annual
CWD RMS-2	Irrigation	780	230-775	Lower	10†	10†	500†	CWD	CWD	Annual
CWD RMS-4	Irrigation	800	320-800	Lower	10†	10†	500†	CWD	CWD	Annual
CWD RMS-5	Unknown	Unknown	Unknown	Lower	10†	10†	500†	CWD	CWD	Annual
CWD RMS-6	Irrigation	820	257-726	Lower	10†	10†	500†	CWD	CWD	Annual
CWD RMS-7	Irrigation	330	135-288	Lower	10†	10†	500†	CWD	CWD	Annual
CWD RMS-9	Monitoring	97	82-97	Upper	10†	10†	500†	CWD	CWD	Annual
CWD RMS-10	Unknown	Unknown	Unknown	Lower	10†	10†	500†	CWD	CWD	Annual
CWD RMS-11	Irrigation	529	187-529	Lower	10†	10†	500†	CWD	CWD	Annual
CWD RMS-12	Unknown	Unknown	Unknown	Upper	10†	10†	500†	CWD	CWD	Annual
CWD RMS-13	Unknown	Unknown	Unknown	Lower	10†	10†	500†	CWD	CWD	Annual
CWD RMS-15	Irrigation	955	290-935	Lower	10†	10†	500†	CWD	CWD	Annual
MCE RMS-1	Unknown	Unknown	Unknown	Lower	10†	10†	500†	Madera County East	Madera County	Annual
MCW RMS-1	Irrigation	186	Unknown	Upper	10†	10†	500†	Madera County West	Madera County	Annual
MCW RMS-4	Unknown	Unknown	Unknown	Lower	10†	10†	500†	Madera County West	Madera County	Annual
MCW RMS-7	Irrigation	800	290-400	Lower	10†	10†	500†	Madera County West	Madera County	Annual
MCW RMS-9	Irrigation	700	265-696	Lower	10†	10†	500†	Madera County West	Madera County	Annual
TRT RMS-1	Unknown	196	158-192	Upper	10†	10†	500†	TTWD	TTWD	Annual
TRT RMS-3	Unknown	799	168-790	Lower	10†	10†	500†	TTWD	TTWD	Annual
TRT RMS-4	Irrigation	840	190-260	Composite	10†	10†	500†	TTWD	TTWD	Annual
Clayton Ag Well #2	Irrigation	135	Unknown	Upper	10†	10†	500†	Madera County West	Madera County	Annual
Wells Monitored by GSAs: Future Monitoring Wells										
Site 1 MW – Shallow	Monitoring	150*	50-150*	Upper	10†	10†	500†	MID*	ILRP/Madera County	Annual
Site 1 MW – Middle	Monitoring	400*	200-400*	Lower	10†	10†	500†	MID*	Madera County	Annual
Site 1 MW – Deep	Monitoring	700*	500-700*	Lower	10†	10†	500†	MID*	Madera County	Annual
Site 2 MW – Shallow	Monitoring	100*	50-100*	Upper	10†	10†	500†	Madera County West*	ILRP/Madera County	Annual
Site 2 MW – Middle	Monitoring	350*	150-350*	Lower	10†	10†	500†	Madera County West*	Madera County	Annual
Site 2 MW – Deep	Monitoring	700*	500-700*	Lower	10†	10†	500†	Madera County West*	Madera County	Annual
Site 3 MW – Shallow	Monitoring	100*	50-100*	Upper	10†	10†	500†	Madera County East*	ILRP/Madera County	Annual
Site 3 MW – Middle	Monitoring	350*	150-350*	Lower	10†	10†	500†	Madera County East*	Madera County	Annual

Well ID	Well Type	Well Depth	Screen Top-Bottom	Aquifer Designation	MT Arsenic Concentration (µg/L)	MT Nitrate Concentration (mg/L)	MT TDS Concentration (mg/L)	GSA Location	Entities to Conduct Monitoring	Measurement Frequency
Site 3 MW – Deep	Monitoring	700*	500-700*	Lower	10†	10†	500†	Madera County East*	Madera County	Annual
Site 5 MW – Shallow	Monitoring	150*	50-150*	Upper	10†	10†	500†	MID/Madera County West*	ILRP/Madera County	Annual
Site 5 MW – Middle	Monitoring	400*	200-400*	Lower	10†	10†	500†	MID/Madera County West*	Madera County	Annual
Site 5 MW – Deep	Monitoring	700*	500-700*	Lower	10†	10†	500†	MID/Madera County West*	Madera County	Annual
Site 6 MW – Shallow	Monitoring	200*	100-200*	Upper	10†	10†	500†	Madera County West*	ILRP/Madera County	Annual
Site 6 MW – Middle	Monitoring	400*	200-400*	Lower	10†	10†	500†	Madera County West*	Madera County	Annual
Site 6 MW – Deep	Monitoring	700*	500-700*	Lower	10†	10†	500†	Madera County West*	Madera County	Annual
Site 7 MW – Shallow	Monitoring	250*	100-250*	Upper	10†	10†	500†	Madera County East*	ILRP/Madera County	Annual
Site 7 MW – Middle	Monitoring	400*	200-400*	Lower	10†	10†	500†	Madera County East*	Madera County	Annual
Site 7 MW – Deep	Monitoring	700*	500-700*	Lower	10†	10†	500†	Madera County East*	Madera County	Annual
Site 9 MW – Shallow	Monitoring	150*	50-150*	Upper	10†	10†	500†	MID*	ILRP/Madera County	Annual
Site 9 MW – Middle	Monitoring	400*	200-400*	Lower	10†	10†	500†	MID*	Madera County	Annual
Site 9 MW – Deep	Monitoring	700*	500-700*	Lower	10†	10†	500†	MID*	Madera County	Annual
Wells Monitored By Non-GSA Entities										
2000511-001	Public Supply	Unknown	Unknown	Unknown	10	10	500	CWD	DDW	Variable, according to DDW reqs.
2000597-001	Public Supply	Unknown	300-?	Lower	10	10	500	CWD	DDW	
2000681-002	Public Supply	Unknown	Unknown	Unknown	10	10	500	CWD	DDW	
2010001-008	Public Supply	Unknown	242-297	Lower	10	10	500	CWD	DDW	
2010001-010	Public Supply	Unknown	358-474	Lower	10	10	500	CWD	DDW	
2010001-011	Public Supply	Unknown	310-393	Lower	10	10	500	CWD	DDW	
2400216-001	Public Supply	Unknown	400-460	Lower	10	10	500	Madera County East	DDW	
ESJ11	Domestic	340	Unknown	Unknown	N/A‡	10	650	CWD	ILRP	Annual‡

* Construction details and locations for future monitoring wells are estimated; information will be updated upon completion of final site selection and well construction.
† Values will be confirmed and/or adjusted as needed based on results from initial sampling for constituents.
‡ Monitoring for the Irrigated Lands Regulatory Program does not include testing for arsenic; annual monitoring includes nitrate and specific conductance (SC), TDS is tested every five years; SC will be used as proxy for TDS in years in which TDS is not tested.

3.3.5 Depletion of Surface Water

As described in the HCM in Section 2, regional groundwater levels have been below the stream channel bottoms in Chowchilla Subbasin for at least the last several years, and for many decades in most of the Subbasin. It has been determined that a direct hydraulic connection between regional groundwater and streams does not exist for streams in most of the Subbasin; therefore, surface water depletion sustainability criteria are not applicable over most of the Subbasin. However, water levels in the shallowest groundwater zone below and along parts of the San Joaquin River at the western boundary of Chowchilla Subbasin periodically rise to elevations equal to or above the stream thalweg. Although it appears this shallow groundwater is associated with infiltration of streamflow from the nearby river resulting from upstream reservoir releases and other tributary inflows upstream of Chowchilla Subbasin, interim SMC are being established for ISW along the San Joaquin River until additional field investigations, studies, evaluations, and monitoring can be completed to update and refine the hydrogeologic understanding of subsurface conditions and interactions between groundwater and surface water in this area. The interim minimum thresholds are the same as the interim measurable objectives: to maintain the percent of time of surface water – groundwater connectivity consistent with conditions during the baseline historical time period, as measured over a rolling five-year period.

3.3.5.1 Methodology

As described in the HCM in Section 2 and in the discussion the measurable objectives in Section 3.2.5, interim SMC are being established for interconnected surface water along the San Joaquin River. It is intended to put the interim SMC in place with submittal of this GSP, with final SMC pending further data collection and analysis to make a more informed assessment of whether or not interconnected surface water is present at this location and, if so, to refine SMC if necessary based on the improved understanding of hydrogeologic conditions. The interim minimum thresholds are the same as the interim measurable objectives: to maintain the percent of time with surface water – groundwater connection over a given time period as equal to or greater than the percent of time connected over the baseline time period. Therefore, the minimum thresholds for each RMS well shown in **Figure 3-3** and **Table 3-13** are the same as those shown for measurable objectives and shown in **Table 3-7**.

3.3.5.2 Relationship to Other Sustainability Indicators

The interim MTs established for ISW along the San Joaquin River will be evaluated independent of other sustainability indicators. The other sustainability indicator most closely related to ISW is chronic decline of groundwater levels as described in Section 3.3.1. However, the MTs for chronic groundwater level decline are based on potential impacts relative to wells going dry, whereas MTs for interconnected surface water are established in relation to maintaining a certain percentage of time with connection to the San Joaquin River. While it may be the case that the six RMS wells being assigned MTs for both chronic decline in groundwater levels and ISW may produce different conclusions regarding undesirable results when groundwater levels in these wells are at a certain elevation (e.g., UR for ISW but no UR for chronic groundwater level decline), the assignment of independent MTs for two different sustainability indicators at the same well will inform basin stakeholders if a given conclusion that an undesirable result has occurred is related to chronic groundwater level declines (and therefore caused too many wells to go dry and impacting well users) vs. being related to interconnected surface water (and having potential impacts on surface water flows or GDEs).

The subsidence sustainability indicator also has what might be considered an indirect relationship to ISW. As discussed in Section 2 (HCM) and in Sections 3.2.3 and 3.3.3, subsidence MTs are related only to Lower Aquifer wells, whereas ISW SMC described in Sections 3.2.5 and 3.3.5 are related only to Upper Aquifer wells near the San Joaquin River. Therefore, while these two sustainability indicators use different sets of non-overlapping RMS wells to assign MOs and MTs, they are indirectly related by the fact that an important aspect of addressing subsidence sustainability is to move a certain amount of groundwater pumping from the Lower Aquifer to the Upper Aquifer. Furthermore, while new recharge projects are intended to provide additional water to the Upper Aquifer to support increased pumping from the Upper Aquifer, groundwater modeling conducted for this GSP indicates there will be a wider range of Upper Aquifer groundwater level fluctuations in the future. It is possible that the PMAs proposed for subsidence will alter the percent of time surface water is connected to shallow groundwater. Although groundwater modeling conducted for this GSP indicates that subsidence PMA effects on Upper Aquifer groundwater elevations will not necessarily decrease (and may actually increase) the percent of time connected, it will be necessary to conduct future data reviews and updated modeling assessments related to these subsidence PMAs.

3.3.5.3 Impact of Selected Minimum Thresholds to Adjacent Basins

Maintaining a similar percent of time connected for interconnected surface water along the San Joaquin River under sustainable groundwater conditions for Chowchilla Subbasin is not expected to have any significant impacts on adjacent subbasins. However, if the percent of time connected increases significantly, whether it be through PMAs conducted by Chowchilla Subbasins GSAs and/or due to other factors such as the SJRRP, it is possible that the adjacent Delta-Mendota Subbasin may be affected by higher groundwater levels in the shallow zone.

3.3.5.4 Minimum Thresholds Impact on Beneficial Uses and Users

Interconnected surface water MTs may have effects on certain beneficial uses, users, land use, and property owners. Those with potential to be impacted include agricultural land use and users, and ecological land use and users. Overall, agricultural land use and users will be impacted in terms of increased costs to design and construct recharge projects (to provide additional water to the Upper Aquifer) and in terms of reduced crop yields from required reductions in consumptive use for irrigation. Additional water is needed for the Upper Aquifer to support migration of Lower Aquifer pumping to the Upper Aquifer as part of the actions needed to address subsidence in the Western Management Area. While it does not appear likely based on analyses conducted to date, it is possible that meeting minimum thresholds for interconnected surface water may constrain how the Upper Aquifer is operated to help address the subsidence minimum thresholds. Ecological beneficial users are expected to benefit from implementation of minimum thresholds for interconnected surface water.

3.3.5.5 Comparison between Minimum Thresholds and Relevant State, Federal or Local Standards

There are no relevant state, federal, or local standards for comparison related to this sustainability criterion.

3.3.5.6 Minimum Thresholds Measurement Method

Interconnected surface water will be monitored on an annual basis by measuring groundwater levels at identified representative ISW RMS wells presented in **Table 3-13** and **Figure 3-3**. The groundwater level monitoring will be conducted in accordance with the monitoring plan and protocols outlined in Section 3.5. Furthermore, the groundwater level monitoring will meet the requirements of the technical and reporting standards included in the SGMA regulations.

Table 3-13. Summary of Interconnected Surface Water Minimum Thresholds for Representative Monitoring Sites

Well I.D.	Surface Elevation	Well Depth	Screen Top-Bottom	Model Layer(s)	Aquifer Designation	MT[1]	GSA
MCW RMS-1	120	186	Unknown	3	Upper	3%	Madera County West
MCW RMS-2	123	Unknown	Unknown	2	Upper	21%	Madera County West
MCW RMS-3	122	Unknown	Unknown	2,3	Upper	3%	Madera County West
MCW RMS-10	123	26	Unknown	1	Upper	78%	Madera County West
MCW RMS-11	127	30	Unknown	1	Upper	26%	Madera County West
MCW RMS-12	127	29	Unknown	1	Upper	11%	Madera County West

[1] The MTs are established as the percent of time connected over the historical base period (1989 to 2015). For comparison to future five-year rolling average, baseline MTs may need to be updated to reflect climatic/hydrologic conditions represented in five-year rolling average.

3.3.6 Seawater Intrusion

The seawater intrusion sustainability criteria is not applicable to this Subbasin.

3.3.7 Management Area Minimum Thresholds

As described above, Chowchilla Subbasin was divided into two Management Areas – the Western Management Area and the Eastern Management Area. The primary differences between these two Management Areas in terms of SMC are related to land subsidence and GDEs.

Significant impacts to infrastructure related to subsidence occurred during the time period from 2005 to 2015 in the Western Management Area, but similar infrastructure impacts have not occurred in the Eastern Management Area. The measurable objective methodology for subsidence for the two Management Areas is the same, as described in a previous section. The subsidence MTs are based on the different methodologies for the two Management Areas due to differences in historical impacts related to subsidence in the two areas. Subsidence MTs and how undesirable results are defined for subsidence in the Western Management Area are generally more strict than those established for the Eastern Management Area due to differences in historical impacts to infrastructure from subsidence in the two areas. There will be ongoing review of subsidence surveys and adaptive management in both Management Areas to adjust subsidence MTs, if necessary.

A single GDE unit occurs in the Western Management Area along the San Joaquin River, and there are no GDE units in the Eastern Management Area. Because GDEs are present in only one of the two Management Areas, there are no concerns about the basin operating under different MTs for GDEs in the two Management Areas.

Thus, there will be no undesirable results caused by setting of different MTs for certain sustainability criteria in the two different Management Areas.

3.4 Undesirable Results (23 CCR § 354.26)

The regulations define undesirable results as occurring when significant and unreasonable effects are caused by groundwater conditions occurring throughout the Subbasin for a given sustainability indicator during the sustainability period. This section provides a description of undesirable results for the relevant sustainability indicators, including:

- Cause of groundwater conditions that would lead to undesirable results
- Criteria used to define undesirable results based on MTs
- Potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results

A summary of criteria used to define undesirable results is provided below in **Table 3-14**, and detailed discussion of each sustainability indicator is provided in subsequent sections of this Chapter.

Table 3-14. Summary of MTs, MOs and undesirable results.

Sustainability Indicator	Minimum Threshold	Measurable Objective	Undesirable Result
Chronic Lowering of Groundwater Levels (Eastern Management Area)	The projected lowest future groundwater level after January 2040 plus a 10-foot operational buffer with an adjustment for offset between observed and modeled groundwater elevations (if necessary)	Projected average future groundwater level from projected with projects model simulation (2040-2090)	Greater than 30 percent of wells below minimum threshold for two consecutive fall measurements
Chronic Lowering of Groundwater Levels (Western Management Area)	The projected lowest future groundwater level after January 2040 plus a 10-foot operational buffer with an adjustment for offset between observed and modeled groundwater elevations (if necessary)	Projected average future groundwater level from projected with projects model simulation (2040-2090)	Greater than 30 percent of wells below minimum threshold for two consecutive fall measurements
Reduction of Groundwater Storage	No long-term reduction in groundwater storage based on measured groundwater levels, consistent with chronic lowering of groundwater level MTs	Projected average future groundwater level from projected with projects model simulation (2040-2090)	Greater than 30 percent of wells below minimum threshold for two consecutive fall measurements
Land Subsidence (Western Management Area)	The historical low groundwater elevation based on model results for Fall 2014 or lowest observed measurement (whichever is lower)	Projected average future groundwater level from projected with projects model simulation (2040-2090)	Greater than 25 percent of wells near key infrastructure below MT, or greater than 33 percent of wells not considered to be near key infrastructure below MT for two consecutive fall measurements
Land Subsidence (Eastern Management Area)	The additional subsidence tolerance amount based on difference between subsidence at RMS well and at boundary with WMA,in combination with groundwater level subsidence value based on historical low groundwater elevation based on model results or lowest observed measurement (whichever is lower)	Projected average future groundwater level from projected with projects model simulation (2040-2090)	Exceedance of subsidence tolerance amount MT and subsidence water level MT at greater than 25 percent of RMS associated with any individual critical conveyance feature for two consecutive years
Seawater Intrusion	Not Applicable	Not Applicable	Not Applicable

Sustainability Indicator	Minimum Threshold	Measurable Objective	Undesirable Result
Degraded Water Quality	Nitrate = 10 mg/L or existing level plus 20% (whichever is greater) Arsenic = 10 µg/L or existing level plus 20% (whichever is greater) TDS = 500 mg/L or existing level plus 20% (whichever is greater)	Current constituent concentrations	10 percent of wells above the minimum threshold for the same constituent due to GSP projects and/or management actions, based on average of most recent three year period
Depletion of Interconnected Surface Water	A percent of time surface water is connected to shallow groundwater equal to historical conditions for a similar climatic/hydrologic period.	A percent of time surface water is connected to shallow groundwater equal to historical conditions for a similar climatic/hydrologic period.	Greater than 30 percent of RMS wells below MT for two consecutive annual five-year rolling average annual evaluations

3.4.1 Chronic Lowering of Groundwater Levels

The cause of basin groundwater conditions that would result in significant and unreasonable lowering of groundwater levels is excessive overall average annual groundwater pumping and other outflows from the Subbasin that continue to exceed average annual inflows, thus continuing the long-term trend of lowering groundwater levels. Locally defined significant and unreasonable conditions were determined based on discussion with GSA staff and technical representatives, input received from interested stakeholders and the public through public meetings, and through individual stakeholder input to various GSA representatives. Significant and unreasonable lowering of groundwater levels are those conditions that: 1) Cause significant financial burden to local agricultural interests or other beneficial uses and users relying on Subbasin groundwater resources, 2) Cause groundwater level conditions at private domestic wells that cannot be mitigated, and 3) Interfere with other sustainability indicators. As described in Section 3.3.1, the GSAs elected to implement a Domestic Well Mitigation Program to allow the GSAs to establish lower MTs that avoid undesirable results to other groundwater users, while still preserving access to critical water supplies for domestic users. Following an economic analysis of the relative impacts of alternate MTs, the GSAs determined that implementing a Domestic Well Mitigation Program would provide the best and most economically reasonable outcome for all beneficial uses and users of groundwater in the Subbasin by preserving the local economy and protecting domestic water users' access to groundwater.

For the Chowchilla Subbasin, the chronic lowering of groundwater levels undesirable result is defined as a relationship between frequency of groundwater elevation minimum threshold exceedances at a given RMS, and the number of RMS locations experience the exceedances at the same time. Using the Fall measurements (assumed to be collected in late October), a groundwater elevation undesirable result is defined to occur when greater than 30% of the same RMS each exceed the groundwater level MTs for two consecutive Fall readings. Given a total of 36 RMS sites, a total of 11 or more the RMS would need to exceed MTs as defined above to constitute an undesirable result for chronic lowering of groundwater levels. As the number of RMS evolves over time (e.g., adding nested monitoring well sites), the total number of RMS that have to exceed their MTs will change accordingly.

The definition of undesirable results under SGMA provides flexibility in defining sustainability. Increasing the percentage of allowed minimum threshold exceedances provides more flexibility but may lead to significant and unreasonable conditions for a number of beneficial uses and users. Reducing the percentage of allowed MTs exceedances ensures strict adherence to MTs but reduces flexibility due to uncertainty related to hydrogeologic conditions. The 30 percent criterion was selected to balance the interest of beneficial use with the practical aspect of groundwater management uncertainty.

Conditions other than excessive regional basin wide pumping (plus other outflows) greater than average annual inflows that may lead to an undesirable result include extensive and unanticipated drought. MTs were established based on historical groundwater levels and reasonable estimates of future groundwater levels (including a future drought of equal duration to the longest historical drought since 1965). Extensive unanticipated droughts (beyond that accounted for already, or earlier in the Implementation Period or Sustainability Period than assumed herein) may lead to excessively low groundwater levels and undesirable results.

3.4.2 Reduction in Groundwater Storage

The cause of basin groundwater conditions that would result in significant and unreasonable reduction in groundwater storage is excessive overall groundwater pumping and other outflows from the Subbasin that exceed average annual inflows. Locally defined significant and unreasonable conditions were determined based on discussion with GSA staff and technical representatives, input received from interested stakeholders and the public through public meetings, and through individual stakeholder input to various GSA representatives. Significant and unreasonable reduction in groundwater storage occurs when there is: 1) Long term reduction in groundwater storage during the sustainability period (i.e., after 2040), or 2) Interference with other sustainability indicators.

Reduction of groundwater storage in the Subbasin has the potential to impact the beneficial uses and users of groundwater by limiting the volume of groundwater available for agriculture, municipal, industrial and domestic use. The undesirable results of reduction in groundwater storage are the same as those previously described for chronic lowering of groundwater levels. Continuing the current rate of loss of groundwater in storage could also impact other sustainability indicators such as groundwater quality. Reduction in groundwater storage is significant and unreasonable if its sufficient in magnitude to lower the rate of production in pre-existing groundwater wells below that needed to meet the minimum required to support overlying beneficial uses and users and where means of obtaining sufficient groundwater or imported resources are not technically or financially feasible for the well owner to absorb, either independently or with assistance from the GSA or other available assistance (grants). As described in Section 3.3.1, the GSAs elected to implement a Domestic Well Mitigation Program to mitigate the effects on domestic well owners of declining groundwater levels that would result from actions of this Plan, and to allow the GSAs to establish lower MTs that avoid undesirable results to other groundwater users, while still preserving access to critical water supplies for domestic users. Following an economic analysis of the relative impacts of alternate MTs, the GSAs determined that implementing a Domestic Well Mitigation Program would provide the best and most economically reasonable outcome for all beneficial uses and users of groundwater in the Subbasin by preserving the local economy and protecting domestic water users' access to groundwater.

Conditions that may lead to an undesirable result for the reduction in groundwater storage sustainability indicator include an extensive and unanticipated drought. Similar to groundwater levels, which act as a proxy for the groundwater storage sustainability indicator, MTs were established based on historical groundwater levels and reasonable estimates of future groundwater elevations that would occur with the GSP PMAs, and accounting for a future drought equivalent to historical droughts (since the mid-1960s). Extensive, unanticipated droughts (beyond that accounted for already, or earlier in the Implementation Period or Sustainability Period than assumed herein) may lead to excessively low groundwater elevations and undesirable results.

The practical effect of the reduction in groundwater storage undesirable result is that it encourages no net change in groundwater elevation and storage during average hydrologic conditions and over the long-term during the Sustainability Period. Therefore, during average hydrologic conditions and over the long-term, beneficial uses and users will have access to the same amount of groundwater in storage that exists in a basin with average inflows equal to average outflows, and the undesirable result will not have a negative effect on the beneficial uses and users of groundwater. Pumping at the long-term sustainable yield during dry years will temporarily lower groundwater elevations and reduce the amount of groundwater in storage. Groundwater storage would then be replenished during wet years. Therefore, basin groundwater users can expect significant fluctuations in groundwater levels above the minimum threshold.

3.4.3 Land Subsidence

The cause of basin groundwater conditions that would result in significant and unreasonable land subsidence is excessive overall average annual groundwater pumping and other outflows from the Subbasin that exceed average annual inflows and results in groundwater levels below historical lows in areas that have already experienced significant impacts to infrastructure (i.e., the Western Management Area) and areas were significant impacts to infrastructure are possible (i.e., the Eastern Management Area). Locally defined significant and unreasonable conditions were determined based on discussion with GSA staff and technical representatives, input received from interested stakeholders and the public through public meetings, and through individual stakeholder input to various GSA representatives. Significant and unreasonable land subsidence results in significant impacts to infrastructure.

The SGMA regulations state that the subsidence undesirable result is a quantitative combination of subsidence minimum threshold exceedances. For the Western Management Area of the Subbasin, significant continued subsidence that impacts infrastructure is unacceptable. To address the inherent data uncertainty, undesirable results for subsidence in the Western Management Area are defined by either having more than 25 percent of RMS near key infrastructure exceeding their respective MTs for the same RMS for two consecutive Fall readings (i.e., 1 of the current 3 RMS for the Lower Aquifer considered to be in close proximity to the Bypass in the Western Management Area), or by having greater than 33% of RMS considered not in close proximity to key infrastructure exceeding their respective MTs for the same RMS for two consecutive Fall readings (e.g., 2 of the current 4 RMS for the Lower Aquifer considered not in close proximity to key infrastructure in the Western Management Area). Historical water level data and modeling results indicate that a significant shift in pumping from the Lower Aquifer to the Upper Aquifer will be necessary to achieve land subsidence MT thresholds. In addition, several successful recharge projects and overall demand reduction (as described elsewhere in this GSP) will also be needed to meet subsidence MTs.

For the Eastern Management Area of the Subbasin, significant continued subsidence that impacts infrastructure is unacceptable. To address the inherent data uncertainty, undesirable results for subsidence in the Eastern Management Area are defined by having a combination of both cumulative subsidence amount exceedances and groundwater level proxy exceedances beyond those defined below. The rationale behind requiring both exceedance of the cumulative subsidence amount thresholds and groundwater level proxy thresholds is to avoid an undesirable result finding that is caused only by residual subsidence (i.e., the cumulative subsidence threshold is exceeded but the groundwater level proxy threshold is not exceeded), and to avoid an undesirable result finding that involves some amount of additional active subsidence (combination of groundwater level proxy MTs are exceeded) but does not exceed the subsidence tolerance threshold.

An undesirable result for the groundwater level proxy metric for the Eastern Management Area is defined as having more than 25 percent of RMS associated with one of the three major surface water conveyances exceed their MTs for the same RMS for two consecutive Fall readings (e.g., 2 of the current 5 RMS associated with the Chowchilla River in the Eastern Management Area). An undesirable result for the subsidence tolerance metric is defined as having greater than 25% of RMS wells exceeding the amount of allowable differential subsidence at the RMS well compared to the surface water conveyance control point at the boundary with the Western Management Area. Historical water level data and modeling results indicate that several successful recharge projects and overall demand reduction (as described elsewhere in this GSP) will be necessary to achieve land subsidence MT thresholds.

Conditions that lead to an undesirable result of a significant and unreasonable amount for land subsidence have historically occurred during periods with groundwater pumping in excess of sustainable yield in areas where critical infrastructure exists. This is of particular concern in the Lower Aquifer where the Corcoran Clay exists. Conditions that may lead to an undesirable result include extensive, unanticipated drought. MTs were established based on not going below historical groundwater elevations. However, extensive, unanticipated droughts may lead to excessively low groundwater elevations and subsidence. The subsidence MTs are set to initially slow down and eventually minimize ongoing subsidence that could continue to harm infrastructure.

3.4.4 Degraded Water Quality

The cause of basin groundwater conditions that would result in significant and unreasonable degraded water quality is implementation of a GSP project or management action that causes levels of key groundwater quality constituents to increase to concentrations exceeding the MCLs for drinking water. Municipal and domestic supply (MUN) is a designated beneficial use for groundwater in the Subbasin; therefore, groundwater quality degradation is considered significant and unreasonable based on adverse impacts to this beneficial use. Locally defined significant and unreasonable conditions were determined based on discussion with GSA staff and technical representatives, input received from interested stakeholders and the public through public meetings, and through individual stakeholder input to various GSA representatives. Significant and unreasonable degradation of water quality occurs when beneficial uses for groundwater are adversely impacted by constituent concentrations increasing to levels above the drinking water MCLs for one of the key constituents of interest previously identified in Section 2 of the GSP (nitrate, arsenic, TDS) at indicator wells in the representative groundwater quality monitoring network due to implementation of a GSP project or management action. There are no known significant and large-scale groundwater quality contamination plumes in the regional aquifers within the Subbasin; therefore, exacerbating plume migration or impacting the ability to contain localized contamination plumes is not a significant concern for GSP PMAs.

Degraded water quality is significant and unreasonable if the magnitude of degradation precludes the use of groundwater for existing beneficial use(s). Therefore, an undesirable result for degraded groundwater quality occurs when groundwater quality exceeds an established MCL and minimum threshold for arsenic, nitrate, or TDS for a significant duration of time and at a significant number of representative monitoring sites and is the direct result of projects or management actions undertaken as part of the GSP implementation. An exceedance of a minimum threshold at a given representative monitoring site is defined based on the average concentration over a three-year monitoring period. An undesirable result for degraded groundwater quality is greater than 10 percent of representative groundwater quality monitoring wells exceeding the minimum threshold for a given key constituent related to a GSP project or management action.

A notable condition that may lead to an undesirable result for degraded groundwater quality sustainability indicator is the following:

- Enhanced Groundwater Recharge – Active recharging of groundwater through use of recharge basins or Flood-MAR activities could cause localized mounding of groundwater near recharge sites resulting in altered flow directions and potentially movement of chemical constituents towards wells in concentrations that exceed relevant water quality standards. Enhanced groundwater recharge activities may also impact groundwater quality by leaching of constituents from the unsaturated zone and into groundwater. This mechanism may be of particular importance when considering enhanced groundwater recharge on actively or formerly cultivated lands where high residual concentrations of nutrients, especially nitrogen, may exist in the unsaturated zone and may be susceptible to leaching into the groundwater resulting in degraded groundwater quality conditions. Water of poor quality characteristics should not be used for enhanced recharge activities. Altered chemical conditions from enhanced recharge projects could also lead to changes in groundwater chemistry.

3.4.5 Depletion of Surface Water

The surface water depletion sustainability criterion is not applicable to most of this Subbasin. However, the occurrence of shallow groundwater levels during certain time periods along the San Joaquin River at the western boundary of the Chowchilla Subbasin, combined with extensive data gaps related to hydrogeologic conditions affecting characterization of interconnected surface water in this area, require that interim SMC be established pending further data collection and studies. The SMC for interconnected surface water along the San Joaquin River are based on a metric for the percent of time shallow groundwater levels are connected to the San Joaquin River (i.e., groundwater elevations at RMS wells are at/above stream thalweg elevations). An undesirable is defined as greater than 30 percent of RMS wells exceeding their minimum thresholds for two consecutive five-year rolling averages (e.g., 2 of the current 6 RMS wells).

As discussed in Section 3.2.5, the San Joaquin River is adjacent to, but not a part of, the San Joaquin River Riparian GDE Unit and is in a net-losing condition, with surface flow likely contributing directly to the shallow groundwater system that supports the vegetation in the unit. The shallow groundwater system adjacent to the San Joaquin River (regardless of whether or not it is considered connected to surface water), which supports the GDE unit, does have at least the potential (albeit quite muted) to be affected by regional groundwater pumping. Therefore, hydrologic and biologic GDE monitoring are incorporated as discussed elsewhere in this GSP.

3.4.6 Seawater Intrusion

The seawater intrusion sustainability criterion is not applicable to this Subbasin.

3.5 Monitoring Network

This section describes the monitoring network and includes the following subsections:

- Description of Monitoring Network
- Monitoring Protocols for Data Collection and Monitoring

- Representative Monitoring
- Assessment and Improvement of Monitoring Network

3.5.1 Description of Monitoring Network (23 CCR § 354.34)

This subsection on the monitoring network is intended to:

- Describe how the monitoring network is capable of collecting sufficient data about groundwater conditions to evaluate Plan implementation
- Describe monitoring network objectives
- Describe how monitoring network demonstrates progress towards achieving MOs, monitors impacts to beneficial uses/users, monitors changes in groundwater conditions, and quantifies annual changes in water budget components
- Describe how monitoring network allows documentation of groundwater occurrence, flow, and hydraulic gradients, calculation of annual groundwater storage change, rate and extent of subsidence, and groundwater quality trends
- Describe how monitoring network provides adequate coverage of sustainability indicators
- Describe monitoring network density and measurement frequency
- Describe monitoring network site selection rationale
- Describe data and reporting standards
- Provide map(s) with location and types of monitoring sites
- Describe level of monitoring and analysis for each management area (if necessary)

The GSP groundwater level monitoring network was initially developed using existing wells in the Subbasin and will be supplemented (and/or some initial wells replaced) by new nested monitoring wells installed since 2019. The database for existing wells was reviewed with the following criteria in mind:

- CASGEM wells preferred;
- Known construction (screen intervals, depth) preferred;
- Long histories of water level data (including recent data) preferred;
- Relatively good match between observed and modeled water levels preferred;
- Good spatial distribution preferred;
- Representation of both Upper (where present in western portion of Subbasin) and Lower Aquifers preferred.

To the extent possible, the network was composed of wells known to represent either the Upper or Lower Aquifer, but not screened in both. However, this was not always possible due to need to consider all the criteria above and because many wells have unknown well construction. Matching of modeled to observed data was used to some extent to initially assign wells with unknown construction details to a given aquifer. The network will enable the collection of data to assess sustainability indicators, the effectiveness of management actions and projects to achieve sustainability, and evaluate the MOs and MTs of each applicable sustainability indicator (i.e., chronic lowering of groundwater levels, reduction in groundwater storage, land subsidence, degraded water quality, and interconnected surface water). The Subbasin is isolated from the Pacific Ocean and is not threatened by seawater intrusion; therefore, this GSP does not provide monitoring for the seawater intrusion sustainability indicator.

As described above, for the purposes of the GSP monitoring program, a subset of existing wells was identified that best meet certain criteria. Not all the criteria were satisfied for each well, but this effort resulted in 36 wells to represent the Subbasin, with 9 wells in the Upper Aquifer and 25 wells in the Lower Aquifer, and 2 composite wells – referred to as the representative monitoring sites. Due to incomplete well construction information for some these wells, the portion of the aquifer being monitored could not be determined with certainty for all wells, but was initially classified based on match to model results where construction data is unknown.

These wells are distributed throughout the Subbasin to provide coverage of the entire area to the extent possible. This initial coverage generally allows for the collection of data to evaluate groundwater gradients and flow directions over time and the annual change in storage over most of the Subbasin for the Lower Aquifer. The spatial coverage for the Upper Aquifer is currently limited to the southwestern portion of the Subbasin due to availability of existing wells and the general lack of Upper Aquifer saturation in the eastern portion of the Subbasin (installation of nested monitoring wells since 2019 helps to expand the area of coverage for the Upper Aquifer). Furthermore, the monitoring frequency of the representative monitoring sites will allow for the monitoring of seasonal highs and lows. For wells that have relatively long historical data records, future groundwater data will be able to be compared to historical data. The monitoring network is expected to evolve over time as new wells are drilled and water level data histories are developed (included DWR grant funded nested monitoring wells installed since 2019). The monitoring network will be periodically reviewed and improvements made where possible.

3.5.1.1 Groundwater Level Monitoring Program

The MTs and MOs for the chronic lowering of groundwater levels sustainability indicator are evaluated by monitoring groundwater levels. The SGMA regulations require a network of monitoring wells sufficient to demonstrate groundwater occurrence, flow direction and hydraulic gradients between principal aquifers and surface water features. The overall monitoring network for groundwater levels, comprised of wells monitored for CASGEM, by GSAs, and by USBR, is provided in **Appendix 3.A**.

The objectives of the groundwater level monitoring program include the following:

- Improve the understanding of the occurrence and movement of groundwater; monitor local and regional groundwater levels including seasonal and long-term trends; and identify vertical hydraulic head differences in the aquifer system and aquifer-specific groundwater conditions, especially in areas where short- and long-term development of groundwater resources are planned;
- Detect the occurrence of, and factors attributable to, natural (e.g., direct infiltration of precipitation), irrigation, and surface water seepage to groundwater or recharge PMAs (recharge basins, Flood MAR) that affect groundwater levels and trends;
- Establish a monitoring network to aid in the assessment of changes in groundwater storage; and
- Generate data to better estimate groundwater basin conditions and assess local current and future water supply availability and reliability; update analyses as additional data become available.

A map of the Subbasin showing the overall groundwater level monitoring network is provided in **Appendix 3.A**, along with a table listing each well. **Figures 3-11** and **3-12** illustrate the locations of the wells selected as representative monitoring sites for monitoring of groundwater levels in the Upper and Lower Aquifers, respectively (composite wells are shown in **Figure 3-13**). **Tables 3-15** and **3-16** list the well identification, location, monitoring frequency, well construction data, and measurement years, and number of measurements for the Upper and Lower Aquifer, respectively. Similar information for composite wells is provided in **Table 3-17**.

Table 3-15. Summary of Upper Aquifer Groundwater Level Monitoring Network Wells

Well I.D.	Latitude	Longitude	Frequency	First Year Data	Last Year Data	Years Measured	Number Measurements	Selection Rationale
CWD RMS-9	37.0882	-120.3471	Spring/Fall	2015	2022	7	14	CASGEM well; known well construction; spatial/vertical distribution
CWD RMS-12	37.0613	-120.3746	Spring/Fall	1961	2022	61	91	CASGEM voluntary well; long history of WL data; spatial/vertical distribution
MCW RMS-1	37.043	-120.5288	Spring/Fall	1963	2022	59	84	CASGEM voluntary well; known well construction; long history of WL data; spatial/vertical distribution
MCW RMS-2	37.0202	-120.5349	Spring/Fall	1964	2022	58	79	Long history of WL data; spatial/vertical distribution
MCW RMS-3	37.018	-120.5179	Spring/Fall	1960	2022	62	69	CASGEM voluntary well; long history of WL data; spatial/vertical distribution
MCW RMS-10	37.028	-120.5444	Daily	2010	2021	11	3,341	SJRRP well; known well construction; spatial/vertical distribution
MCW RMS-11	36.9816	-120.4918	Monthly	2012	2021	9	278	SJRRP well; known well depth; spatial/vertical distribution
MCW RMS-12	36.9817	-120.4859	Monthly	2012	2021	9	269	SJRRP well; known well depth; spatial/vertical distribution
TRT RMS-1	37.011	-120.4603	Summer	2011	2021	10	15	Known well construction; spatial/vertical distribution

Table 3-16. Summary of Lower Aquifer Groundwater Level Monitoring Network Wells

Well I.D.	Latitude	Longitude	Frequency	First Year Data	Last Year Data	Years Measured	Number Measurements	Selection Rationale
CWD RMS-1	37.1166	-120.4193	Spring/Fall	1949	2022	73	108	CASGEM well; known well construction; spatial/vertical distribution
CWD RMS-2	37.171	-120.3746	Spring/Fall	1980	2022	42	45	Known well construction; spatial/vertical distribution
CWD RMS-3	37.1446	-120.3474	Spring[1]	1980	2022	42	45	Long history of WL data; spatial/vertical distribution
CWD RMS-4	37.1271	-120.2927	Spring/Fall	2015	2022	7	10	CASGEM well; known well construction; spatial/vertical distribution
CWD RMS-5	37.1049	-120.3296	Spring[2]	1968	2022	54	76	CASGEM voluntary well; long history of WL data; spatial/vertical distribution
CWD RMS-6	37.1265	-120.1498	Spring/Fall	2015	2022	7	14	CASGEM well; known well construction; spatial/vertical distribution
CWD RMS-7	37.0618	-120.4232	Spring/Fall	2015	2022	7	11	CASGEM well; known well construction; spatial/vertical distribution
CWD RMS-8	37.0913	-120.2924	Spring[1]	1957	2022	65	96	CASGEM voluntary well; long history of WL data; spatial/vertical distribution
CWD RMS-10	37.0902	-120.3741	Spring[1]	1961	2022	61	92	CASGEM voluntary well; long history of WL data; spatial/vertical distribution
CWD RMS-11	37.0568	-120.3307	Spring/Fall	1946	2022	76	129	CASGEM well; known well construction; long history of WL data; spatial/vertical distribution
CWD RMS-13	37.0168	-120.3593	Spring[1]	1934	2022	88	127	CASGEM voluntary well; long history of WL data; spatial/vertical distribution
CWD RMS-14	37.0238	-120.3107	Spring/Fall	2015	2022	7	12	CASGEM well; known well construction; spatial/vertical distribution
CWD RMS-15	37.0732	-120.2342	Spring/Fall	2015	2022	7	13	CASGEM well; known well construction; spatial/vertical distribution
CWD RMS-16	37.0516	-120.2571	Spring	1961	2022	61	99	CASGEM voluntary well; spatial/vertical distribution
CWD RMS-17	37.0182	-120.2433	Spring/Fall	2015	2022	7	14	CASGEM well; known well construction; spatial/vertical distribution
MCE RMS-1	37.156	-120.2063	Spring[3]	1987	2022	35	37	CASGEM voluntary well; long history of WL data; spatial/vertical distribution

Well I.D.	Latitude	Longitude	Frequency	First Year Data	Last Year Data	Years Measured	Number Measurements	Selection Rationale
MCE RMS-2	37.1418	-120.2338	Spring/Fall	1980	2022	42	61	CASGEM well; known well construction; long history of WL data; spatial/vertical distribution
MCW RMS-4	37.0663	-120.4779	Spring1	1980	2022	42	55	CASGEM voluntary well; long history of WL data; spatial/vertical distribution
MCW RMS-5	37.0391	-120.4443	Spring1	1980	2022	42	52	CASGEM voluntary well; long history of WL data; spatial/vertical distribution
MCW RMS-6	37.0393	-120.4649	Spring1	1980	2022	42	37	CASGEM voluntary well; long history of WL data; spatial/vertical distribution
MCW RMS-7	37.018	-120.4515	Spring/Fall	2015	2022	7	11	CASGEM well; known well construction; spatial/vertical distribution
MCW RMS-9	36.9675	-120.3748	Spring/Fall	2015	2022	7	9	CASGEM well; known well construction; spatial/vertical distribution
MER RMS-1	37.1638	-120.3021	Spring1	1964	2020	56	75	Long history of WL data; spatial/vertical distribution
TRT RMS-2	36.9998	-120.4577	Spring/Fall	2010	2021	11	22	CASGEM well; known well construction; spatial/vertical distribution
TRT RMS-3	36.9899	-120.4326	Summer	2010	2021	11	13	Known well construction; spatial/vertical distribution

[1] Fall measurements stopped in 2009
[2] Fall measurements stopped in 1999
[3] Fall measurements stopped in 2007

Table 3-17. Summary of Composite Aquifer Groundwater Level Monitoring Network Wells

Well I.D.	Latitude	Longitude	Frequency	First Year Data	Last Year Data	Years Measured	Number Measurements	Selection Rationale
MCW RMS-8	37.0047	-120.3929	Spring/Fall	2015	2022	7	13	CASGEM well; known well construction; spatial/vertical distribution
TRT RMS-4	36.96	-120.4283	Spring/Fall	2013	2021	8	31	CASGEM well; known well construction; spatial/vertical distribution

In order to assist GSAs with the preparation of their GSP's, DWR released a series of best management practices. The best management practices document for monitoring networks provides guidance on determining an appropriate number of monitoring wells for a given district. The method developed by Hopkins (1984) was applied to the Subbasin. This methodology states that, for districts pumping more than 10,000 AFY over 100 square miles, they should have four monitoring wells for every 100 square miles. The Subbasin occupies an area of approximately 228 square miles, yielding 9 monitoring wells for this minimum density requirement. This number was taken to be the minimum number of monitoring wells for the Subbasin and several additional wells were added based on informational needs resulting from management actions and historical trends in groundwater levels. This GSP includes 36 existing RMS with a potential for future addition (and/or substitution for some existing RMS wells) of up to 25 monitoring wells from the nested well installation program. The selection rationale for all water level monitoring wells is summarized in **Tables 3-15** through **3-17.**

3.5.1.2 Reduction in Groundwater Storage Monitoring Program

The objectives of the monitoring program to calculate changes in groundwater storage include the following:

- Improve the understanding of the occurrence of groundwater; monitor Upper Aquifer and Lower Aquifer groundwater levels including seasonal and long-term trends in the aquifer system to calculate changes in groundwater storage on an annual basis and in areas where management actions and projects are planned;

Because changes in groundwater storage are directly dependent on changes in groundwater levels, this GSP adopts groundwater levels as a proxy for assessing change in storage, as described previously in this section. The wells selected for monitoring changes in groundwater storage will be the same wells used for groundwater level monitoring. **Figures 3-11** and **3-12** illustrate the locations of the wells selected for monitoring of groundwater levels for the Upper and Lower Aquifers, respectively. **Tables 3-15** and **3-16** list the well identification, location, monitoring frequency, well construction data, and measurement years, and number of measurements for the Upper Aquifer and Lower Aquifer wells, respectively. Because the same wells for water level monitoring are being used for groundwater storage monitoring, the selection process and rationale for selection is also the same (**Tables 3-15** and **3-16**).

3.5.1.3 Land Subsidence Monitoring Program

The objectives of the monitoring program to calculate changes in land subsidence include the following:

- Monitor groundwater levels and review ongoing subsidence surveys to improve the understanding of the relationship between groundwater levels in the Lower Aquifer and the potential occurrence of subsidence;
- Monitor local groundwater levels in the Subbasin combined with periodic review of ongoing subsidence surveys compute the differential in subsidence between EMA RMS wells and surface water conveyance control points at the boundary between the EMA and WMA and to inform the need for adaptive management actions relative to subsidence.

Because of the dependence of land subsidence on groundwater levels (as well as soil properties), this GSP adopts groundwater levels as a proxy for assessing land subsidence (in combination with periodic review of ongoing subsidence surveys) for both the Eastern and Western Management Areas, as described previously in this section. In addition, a tolerance for some amount of additional subsidence was computed for the Eastern Management Area related to surface water conveyance infrastructure. The wells selected for monitoring land subsidence will be the Lower Aquifer wells used for groundwater level monitoring. **Figure 3-12** illustrates the locations of the wells selected for monitoring of groundwater levels for the Lower Aquifer. **Table 3-16** lists the well identification, location, monitoring frequency, well construction data, and measurement years, and number of measurements for the Lower Aquifer wells. Because the same wells for water level monitoring are being used for land subsidence monitoring, the selection process and rationale for selection is also the same (**Table 3-16**).

The land subsidence sustainability indicator will also be evaluated by annual review of ongoing subsidence surveys, including SJRRP benchmark surveys, InSAR data, USGS studies, and subsidence surveys/studies conducted by others. Results of these subsidence surveys/studies will be compared to groundwater level data collected in the Subbasin to determine if adaptive management actions are needed in both Management Areas.

3.5.1.4 Groundwater Quality Monitoring Program

The sustainability indicator for degraded water quality is evaluated by monitoring groundwater quality at a network of wells.

The objectives of the groundwater quality monitoring program for the Subbasin include the following as they relate to the implementation of GSP PMAs:

- Evaluate groundwater quality conditions in the various areas of the basin, and identify differences in water quality spatially between areas and vertically in the aquifer system;
- Detect the occurrence of and factors attributable to key constituents of interest as represented by nitrate, arsenic, and TDS;
- Assess the changes and trends in groundwater quality; and
- Identify the natural and human factors that affect changes in water quality.

For the purpose of monitoring groundwater quality conditions and potential impacts from GSP PMAs, a network of representative monitoring sites selected from among existing and proposed future wells located throughout the Subbasin and screened in both in the Upper and Lower Aquifers. The representative monitoring sites for groundwater quality include a combination of irrigation, public supply, domestic, and monitoring wells to be sampled and analyzed by the Subbasin GSAs together with wells that are sampled by others as part of other groundwater quality monitoring programs. The selected RMS for groundwater quality are listed in **Table 3-12** and shown on **Figure 3-2**. Information on well construction and historical groundwater quality monitoring for each of the indicator wells is included in **Appendix 3.B**.

The network of groundwater quality representative monitoring sites includes 21 existing wells that are also part of the water level monitoring indicator well network and will also be sampled for groundwater quality by the Subbasin GSAs. Additionally, eight nested monitoring well sites have been constructed in the Subbasin and each of the three individual monitoring wells at each site will be sampled for groundwater quality by the Subbasin GSAs. Ongoing groundwater quality monitoring being conducted by other entities for the State Water Resources Control Board (SWRCB) Division of Drinking Water (DDW) program of seven selected public supply wells will also be incorporated into the representative groundwater quality monitoring in the Subbasin. Available results from groundwater quality sampling conducted by the monitoring entities for these public supply wells will be acquired and incorporated into the ongoing evaluation of groundwater quality monitoring as part of implementing the GSP. Monitoring and assessment of groundwater quality is also being conducted for the Irrigated Lands Regulatory Program (ILRP), currently including sampling of one domestic well and future incorporation of the new monitoring wells described above as part of the Groundwater Quality Trend Monitoring program for the East San Joaquin Water Quality Coalition. The one current domestic well will also be included in the representative groundwater quality monitoring network. As details of GSP PMAs are refined, the groundwater quality monitoring network will be reviewed and modified if needed to ensure that the network is sufficient to achieve the objective of monitoring for groundwater quality impacts caused by GSP PMAs.

In addition to the regular monitoring of groundwater quality using the selected sustainability indicator wells, ongoing assessment of groundwater quality conditions for the ILRP is also occurring and involves annual sampling of a regional network of relatively shallow wells, evaluation of trends in groundwater quality related to irrigated agricultural practices, and also includes additional compilation and analysis of groundwater quality trends and conditions at five-year intervals based on readily available public data. Under the ILRP Waste Discharge Requirements for the East San Joaquin Water Quality Coalition, growers in the Subbasin also must sample and report groundwater quality for domestic wells on parcels enrolled in the Coalition. Data and reports on groundwater quality conditions developed through the ILRP will be considered and evaluated as part of assessing the groundwater quality sustainability indicator and in terms of relationships with GSP PMAs. Additionally, many more public water supply wells exist with recent groundwater quality monitoring for the three key constituents of interest. Some of these wells are incorporated as part of the representative groundwater quality monitoring network; however, data for other wells will also be considered in evaluating any potential groundwater quality impacts from GSP PMAs.

Groundwater quality impacts from activities unrelated to specific GSP PMAs are under the purview of separate regulatory programs including the ILRP or other regulatory programs overseeing waste discharges to groundwater and groundwater contamination sites.

3.5.1.5 Interconnected Surface Water Monitoring Program

The sustainability indicator for interconnected surface water is evaluated by monitoring groundwater levels at a network of wells screened in the Upper Aquifer near the San Joaquin River. Streamflow data from gaging stations is also collected and will be used in future studies and evaluations of interconnected surface water.

The objectives of the groundwater level and streamflow monitoring programs related to interconnected surface water include the following:

- Improve the understanding of the occurrence and movement of shallow groundwater; monitor groundwater levels relative to the nearby stream thalweg to evaluate the percent of time groundwater levels are above vs. below the thalweg;
- Track and improve understanding of streamflows, including seasonal and year to year variability, and potential changes to the hydrologic regime related to the San Joaquin River Restoration Program;
- Detect the occurrence of, and factors attributable to surface water seepage to groundwater in the San Joaquin River where it forms the western boundary of Chowchilla Subbasin; and
- Generate data to better estimate groundwater basin conditions related to interconnected surface water; update analyses as additional data become available.

For the purpose of monitoring interconnected surface water conditions and potential impacts from GSP PMAs and groundwater pumping, a network of representative monitoring sites was selected from among existing RMS wells screened in the Upper Aquifer and located near the San Joaquin River. The representative monitoring sites for interconnected surface water include a combination of irrigation and monitoring wells to be monitored by the Subbasin GSAs. The selected RMS for interconnected surface water are listed in **Table 3-13** and shown on **Figure 3-3**. Information on well construction and historical groundwater levels for each of the indicator wells is included in **Appendix 3.B**.

3.5.2 Monitoring Protocols for Data Collection and Monitoring (23 CCR § 352.2)

This section is intended to provide a description of technical standards, methods, and procedures/protocols to ensure comparable data and methodologies for data collection and monitoring. All field monitoring activities will follow established Standard Operating Procedures (SOPs) for the Subbasin, which will be developed to reflect the standards, methods, and procedures described below.

3.5.2.1 Groundwater Level Monitoring Program

The protocols for measuring groundwater levels include the following:

- Measure depth to water in the well using procedures appropriate for the measuring device. Equipment must be operated and maintained in accordance with manufacturer's instructions. Groundwater levels should be measured to the nearest 0.01 foot (or at least to the nearest 0.1 foot at a minimum) relative to the Reference Point (RP). Measurements and RPs should not be recorded in feet and inches.
- For measuring wells that are under pressure, allow a period of time for the groundwater levels to stabilize. In these cases, multiple measurements should be collected to ensure the well has reached equilibrium such that no significant changes in water level are observed. Every effort should be made to ensure that a representative stable depth to groundwater is recorded. If a well does not stabilize, the quality of the value should be appropriately qualified as a questionable measurement. In the event that a well is artesian, site specific procedures should be developed to collect accurate information and be protective of safety conditions associated with a pressurized well. In many cases, an extension pipe may be adequate to stabilize head in the well. Record the dimension of the extension and document measurements and configuration.
- The groundwater elevation should be calculated using the following equation.

  GWE= RPE−DTW
  Where:
  GWE = Groundwater Elevation in NAVD88 datum
  RPE = Reference Point Elevation in NAVD88 datum
  DTW = Depth to Water

- The well caps or plugs should be secured following depth to water measurement.
- Groundwater level measurements are to be made on a semi-annual basis at a minimum during periods which will generally capture seasonal highs and lows (target months for groundwater level measurements are March and late October).
- The sampler should record the well identifier, date, time (24-hour format), RPE, height of RP above or below ground surface, DTW, GWE, and comments regarding any factors that may influence the depth to water readings such as weather, oil in the well, nearby irrigation, flooding, or well condition. Of particular concern may be pumping of nearby irrigation wells or time since pumping stopped in the well being monitored; such conditions should be specifically identified and noted to the extent possible. If there is a questionable measurement or the measurement cannot be obtained, it should be noted. Standardized field forms will be used for all data collection.

- The sampler should have a record of previous measurements in the field for each well to compare with the current measurements being recorded. If a current measurement appears anomalous compared to previous measurements it should be checked again and verified.
- All data should be entered into the GSP data management system (DMS) as soon as possible. Care should be taken to avoid data entry mistakes and the entries should be checked by a second person.

3.5.2.1.1 Installing Pressure Transducers and Downloading Data

The following procedures will be followed in the installation of a pressure transducer and periodic data downloads:

- The sampler must use an electronic sounder or chalked steel tape and follow the protocols listed above to measure the groundwater level and calculate the groundwater elevation in the monitoring well to properly program and reference the installation. It is recommended that transducers record measured groundwater level to conserve data capacity; groundwater elevations can be calculated at a later time after downloading.
- The sampler must note the well identifier, the associated transducer serial number, transducer range, transducer accuracy, and cable serial number.
- Transducers must be able to record groundwater levels with an accuracy of at least 0.1 foot. Professional judgment will be exercised to ensure that the data being collected is meeting the data quality objectives (DQO) and that the instrument is capable of meeting DQO. Consideration of the battery life, data storage capacity, range of groundwater level fluctuations, and natural pressure drift of the transducers should be included in the evaluation.
- The sampler must note whether the pressure transducer uses a vented or non-vented cable for barometric compensation. Non-vented units are preferred (generally less expensive, require less maintenance than vented units, and are less prone to failure) and provide accurate data if properly corrected for natural barometric pressure changes. This requires the consistent logging of barometric pressures to coincide with measurement intervals.
- Follow manufacturer specifications for installation, calibration, data logging intervals, battery life, correction procedure (if non-vented cables used), and anticipated life expectancy to assure that DQOs are being met for the GSP.
- Secure the cable to the well head with a well dock or another reliable method. Mark the cable at the elevation of the reference point with tape or an indelible marker. This will allow estimates of future cable slippage.
- The transducer data should be periodically checked against hand measured groundwater levels to monitor electronic drift or cable movement. This should happen during routine site visits, at least annually to maintain data integrity. The data should be downloaded as necessary to ensure no data is lost and entered into the basin's DMS following the QA/QC program established for the GSP. Data collected with non-vented data logger cables should be corrected for atmospheric barometric pressure changes, as appropriate. After the sampler is confident that the transducer data have been safely downloaded and stored, the data should be deleted from the data logger to ensure that adequate data logger memory remains.

3.5.2.2 Groundwater Storage Reduction Monitoring Program

The monitoring protocols for evaluating change in groundwater storage are the same as the protocols described above for groundwater levels.

3.5.2.3 Land Subsidence Monitoring Program

Subsidence monitoring will include the following protocols:

- Download and review subsidence data collected by the USGS, DWR, the SJRRP, and other entities. This data will be input into the DMS following QA/QC.
- Groundwater level data collected as part of the subsidence monitoring program will follow the same protocols as described above for groundwater level monitoring.

3.5.2.4 Groundwater Quality Monitoring Program

Annual monitoring of groundwater quality will include sampling and laboratory analysis of key parameters of interest as indicated on **Table 3-18** to be conducted by GSAs as presented in **Tables 3-4, 3-5,** and **3-12**. Additional groundwater quality results reported by monitoring entities to DDW (in accordance with DDW testing requirements) for indicator public supply wells will be obtained for evaluation as part of the groundwater quality monitoring program, although the sampling of these wells will not necessarily be performed by the GSAs. Water quality parameters may be added to the groundwater quality monitoring program in the future, if appropriate. During sampling events, measurement of select water quality parameters will take place in the field. These field parameters should be measured at an annual frequency and include electrical conductivity at 25 °C (EC) in µS/cm, pH, temperature (in °C), redox, and dissolved oxygen (DO) in mg/L. The annual testing is summarized in **Table 3-18**.

Table 3-18. Summary of Groundwater Quality Monitoring Constituents and Measurement Frequency for Representative Monitoring Sites

Well ID	Well Type	Monitoring Entity	Field Measurements					Laboratory Measurements											
			Specific Conductance	pH	Dissolved Oxygen	ORP	Temperature	Nitrate (as nitrogen)	Arsenic	Total dissolved solids (TDS)	Carbonate	Bicarbonate	Chloride	Sulfate	Calcium	Sodium	Magnesium	Potassium
Wells Monitored by GSAs: Existing																			
CWD RMS-1	Domestic	CWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
CWD RMS-2	Irrigation	CWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
CWD RMS-4	Irrigation	CWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
CWD RMS-5	Unknown	CWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
CWD RMS-6	Irrigation	CWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
CWD RMS-7	Irrigation	CWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
CWD RMS-9	Monitoring	CWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
CWD RMS-10	Unknown	CWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
CWD RMS-11	Irrigation	CWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
CWD RMS-12	Unknown	CWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
CWD RMS-13	Unknown	CWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
CWD RMS-15	Irrigation	CWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
MCE RMS-1	Unknown	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
MCW RMS-1	Irrigation	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
MCW RMS-4	Unknown	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
MCW RMS-7	Irrigation	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
MCW RMS-9	Irrigation	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
TRT RMS-1	Unknown	TTWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
TRT RMS-3	Unknown	TTWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
TRT RMS-4	Irrigation	TTWD	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Clayton Ag Well #2	Irrigation	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Wells Monitored by GSAs: Future Monitoring Wells																			
Site 1 MW – Shallow	Monitoring	ILRP/Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year

Well ID	Well Type	Monitoring Entity	Field Measurements					Laboratory Measurements											
			Specific Conductance	pH	Dissolved Oxygen	ORP	Temperature	Nitrate (as nitrogen)	Arsenic	Total dissolved solids (TDS)	Carbonate	Bicarbonate	Chloride	Sulfate	Calcium	Sodium	Magnesium	Potassium
Site 1 MW – Middle	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 1 MW – Deep	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 2 MW – Shallow	Monitoring	ILRP/Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 2 MW – Middle	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 2 MW – Deep	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 3 MW – Shallow	Monitoring	ILRP/Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 3 MW – Middle	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 3 MW – Deep	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 5 MW – Shallow	Monitoring	ILRP/Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 5 MW – Middle	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 5 MW – Deep	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 6 MW – Shallow	Monitoring	ILRP/Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 6 MW – Middle	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 6 MW – Deep	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 7 MW – Shallow	Monitoring	ILRP/Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 7 MW – Middle	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 7 MW – Deep	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 9 MW – Shallow	Monitoring	ILRP/Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 9 MW – Middle	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Site 9 MW – Deep	Monitoring	Madera County	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year
Wells Monitored By Non-GSA Entities																		
2000511-001	Public Supply	DDW	Frequency and schedule for constituent testing in public supply wells being monitored by non-GSA entities will be in accordance with monitoring entity and DDW schedule and requirements.															
2000597-001	Public Supply	DDW																
2000681-002	Public Supply	DDW																
2010001-008	Public Supply	DDW																
2010001-010	Public Supply	DDW																
2010001-011	Public Supply	DDW																
2400216-001	Public Supply	DDW																

Well ID	Well Type	Monitoring Entity	Field Measurements					Laboratory Measurements											
			Specific Conductance	pH	Dissolved Oxygen	ORP	Temperature	Nitrate (as nitrogen)	Arsenic	Total dissolved solids (TDS)	Carbonate	Bicarbonate	Chloride	Sulfate	Calcium	Sodium	Magnesium	Potassium
ESJ11	Domestic	ILRP	Annual	Annual	Annual	Annual	Annual	Annual	Not tested*	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year	Five-Year

* Arsenic is not among the constituents required for the ILRP

The GSP monitoring program will utilize the following protocols for collecting groundwater quality samples.

- Prior to sampling, the analytical laboratory will be contacted to schedule laboratory time, obtain appropriate sample containers, and clarify any sample holding times or sample preservation requirements.
- Each well used for groundwater quality monitoring will have a unique identifier. This identifier will appear on the well housing or the well casing to verify well identification.
- In the case of wells with dedicated pumps, samples should be collected at or near the wellhead following purging.
- Prior to sampling, the sampling port and sampling equipment will be cleaned of any contaminants. The equipment will be decontaminated after purging and collection of water samples at each site to avoid any cross-contamination between wells.
- The groundwater elevation in the well should be measured following appropriate protocols described above in the groundwater level measuring protocols.
- For any well not equipped with low-flow or passive sampling equipment, an adequate volume of water should be purged from the well to ensure that the groundwater sample is representative of ambient groundwater and not stagnant water in the well casing. Purging three well casing volumes is generally considered adequate. Professional judgment should be used to determine the proper configuration of the sampling equipment with respect to well construction such that a representative ambient groundwater sample is collected. If pumping causes a well to be evacuated (go dry), document the condition and allow well to recover to within 90% of original level prior to sampling.
- Field parameters of pH, electrical conductivity, pH, temperature, and turbidity should be collected periodically during purging and prior to the collection of each sample. Field parameters should be evaluated during the purging of the well and should stabilize prior to collection of the water sampling. Measurements of pH values should occur in the field since the short hold times for laboratory pH analysis are typically unachievable. Other parameters, such as oxidation-reduction potential (ORP), dissolved oxygen (DO) (in situ measurements preferable), or turbidity, may also be useful for assessing purge conditions. All field instruments should be calibrated daily and evaluated for drift throughout the day.
- Sample containers should be labeled prior to sample collection. The sample label must include: sample ID (often well ID), sample date and time, sample personnel, sample location, preservative used, and analytes and analytical method.
- Samples should be collected under laminar flow conditions. This may require reducing pumping rates prior to sample collection. Alternatively, the flow rate from the sampling tap should correspond to laminar flow conditions when possible.
- All samples requiring preservation must be preserved as soon as practically possible, ideally at the time of sample collection. Ensure that samples are appropriately filtered as recommended for the specific analyte. Entrained solids can be dissolved by preservative leading to inconsistent results of dissolved analytes. Specifically, samples to be analyzed for metals should be field-filtered prior to preservation; do not collect an unfiltered sample in a preserved container.
- Samples should be chilled and maintained at 4 °C to prevent degradation of the sample. The laboratory's Quality Assurance Management Plan should detail appropriate chilling and shipping requirements.

- Samples must be shipped under chain of custody documentation to the appropriate laboratory promptly to avoid violating holding time restrictions.
- Ensure the laboratory uses appropriate reporting limits that are at or below levels needed for the objectives of the monitoring.
- Groundwater quality samples are to be collected annually for key constituents and every five years for all other constituents.
- For wells monitored by other entities, obtain results and associated information on sampling activities through coordination and communication directly with the monitoring entity or through public databases such as SWRCB Geotracker where these data are available.

All groundwater quality data and other information from sampling activities should be entered into the DMS as soon as possible and in accordance with established QA/QC procedures. Care should be taken during any data entry to avoid mistakes and data entered into the database should be checked for accuracy and completeness.

3.5.2.5 Interconnected Surface Water Monitoring Program

The protocols for measuring groundwater levels are described above in Section 3.5.2.1. Streamflow monitoring protocols would be addressed by the various agencies monitoring streamflow in the Subbasin.

3.5.2.6 GDE Monitoring Program

The GDE monitoring program will include monitoring of groundwater levels and biologic monitoring. Groundwater level monitoring being conducted for the overall GSP includes three shallow SJRRP monitoring wells adjacent to the GDE unit along the San Joaquin River in western Chowchilla Subbasin. Biological monitoring was conducted in May 2019 and will be conducted every five years to document ecological condition of the San Joaquin River Riparian GDE Unit. Biological data will be analyzed in conjunction with hydrological data to assess potential ecological effects related to changes in groundwater levels and the relative degree of influence on GDE conditions exerted by streamflows and groundwater levels associated with the GDE.

3.5.3 Representative Monitoring (23 CCR § 354.36)

This section of Chapter 3 is intended to provide the following:

- Description of representative sites
- Demonstration of adequacy of using groundwater elevations as proxy for other sustainability indicators
- Adequate evidence demonstrating representative monitoring sites reflect general conditions in the area

Groundwater level data are collected from a large network of CASGEM and USBR wells (**Appendix 3.G**). Representative monitoring sites (RMS) are defined in the SGMA regulations as a subset of monitoring sites that are representative of conditions in the Subbasin. All the monitoring sites in this section are considered RMS utilizing methods of selection consistent with best management practices described above under the groundwater level protocols. Groundwater level monitoring will be used to determine changes in groundwater storage and to assist in monitoring subsidence. As previously stated, reduction in groundwater storage is directly dependent on measuring changes in groundwater levels. In the case of subsidence, there are various entities monitoring for subsidence in and around the Subbasin. Significant impacts to infrastructure (e.g., bypass, canals, wells) have occurred and been documented within the Western Management Area of Chowchilla Subbasin since 2005. The occurrence of subsidence in this area has been linked to groundwater pumping and declining groundwater levels in the Lower Aquifer from 2005 through 2015-16. The drought from 2012 to 2015 resulted in historical low groundwater elevations in many Lower Aquifer wells in the 2014 to 2016 time frame, which correlate to elevated rates of subsidence during this time period. As described in Section 2, residual subsidence occurs after groundwater levels stabilize and recover due to compaction lag times in Lower Aquifer clay layers. The analysis provided in Section 2 indicated that while the occurrence of residual subsidence complicates the relationship between groundwater levels and subsidence, it is clear that occurrence of active (new) subsidence is a function of groundwater levels declining below historical low groundwater levels. Thus, representative Lower Aquifer monitoring wells are included in the RMS sites with MTs tied to recent groundwater levels to minimize future subsidence.

Ongoing monitoring of changes in water levels will be used in combination with subsidence surveys to develop the relationship/correlation between groundwater levels, the amount/rate of subsidence, and the occurrence of residual subsidence.

3.5.4 Assessment and Improvement of Monitoring Network (23 CCR § 354.38)

Per Section 354.38 of the GSP regulations, this section of the GSP is intended to provide the following:

- Review and evaluation of the monitoring network
- Identification and description of data gaps
- Description of steps to fill data gaps
- Description of monitoring frequency and density of sites

3.5.4.1 Review and Evaluation of the Monitoring Network

The monitoring networks described above for each of the applicable sustainability indicators will be evaluated on a yearly basis. This evaluation will involve a review of the described MTs and MOs and their comparison to observed trends in the networks. Furthermore, a more comprehensive review of the monitoring networks will be conducted every five years. During this review, management actions and projects will be evaluated and the monitoring networks will be assessed for their efficacy in tracking progress based on the actions and projects. These evaluations and assessments will also highlight any additional data gaps and recommended changes to the monitoring networks.

3.5.4.2 Identification and Description of Data Gaps

Identification and description of data gaps for the monitoring networks described above for each of the applicable sustainability indicators are described below.

3.5.4.2.1 Groundwater Elevation

Groundwater elevation data has been extensively collected within the Subbasin over the past several decades. However, despite this data collection effort, spatial data gaps still exist. Specifically, in the Upper Aquifer in the northern portion of the Subbasin, and the Lower Aquifer in the south central and extreme eastern and western portions of the Subbasin are lacking in monitoring wells. These gaps are evident in the designed monitoring network as no existing wells represent the areas described. In addition to these spatial gaps, temporal data collection gaps also exist at some of the monitoring network sites. Many times the lack of measurements is due to the inaccessibility of the monitoring wells or active pumping, or relatively recent inclusion in a monitoring program. Some of the spatial data gaps will be filled with installation of the new nested monitoring wells – particularly for the Upper Aquifer and extreme western portion of the Lower Aquifer. Temporal data gaps will begin to be filled by more regular collection of data as part of the GSP, and installation of transducers in new nested monitoring wells.

Data gaps relative to GDEs can be characterized as incomplete information on the extent to which the vegetation composing the San Joaquin River GDE Unit may be impacted by occurrence of temporary short-term declines in shallow groundwater levels below historical lows. Biological monitoring, recommended every five years, will be used to evaluate potential beneficial or adverse effects on GDEs that may be related to changes in future groundwater conditions during the Implementation and Sustainability Periods.

3.5.4.3 Groundwater Storage

Groundwater storage data gaps are described in the groundwater elevation section as water levels are being used as a proxy for groundwater storage.

3.5.4.3.1 Subsidence

Significant subsidence that has impacted infrastructure has occurred since 2005, particularly in the Western Management Area of Chowchilla Subbasin. Subsidence benchmark surveys for the SJRRP related to subsidence occurring in the Western Management Area have indicated the occurrence of some subsidence in the Eastern Management Area of Chowchilla Subbasin as well. In terms of correlation of subsidence surveys with groundwater level data, the existing and future (with incorporation of nested monitoring wells installed since 2019) monitoring network for groundwater levels in the Lower Aquifer (which is most important for subsidence monitoring) is generally adequate for both the Western and Eastern Management Areas. The subsidence monitoring network is currently being evaluated with regard to adequacy considering recent and upcoming installation of new nested monitoring wells.

3.5.4.3.2 Groundwater Quality

Considerable historical groundwater quality data exist for the Subbasin although the spatial distribution and association of well construction information with groundwater quality observations present limitations. Some of the wells in the groundwater quality sustainability indicator monitoring network have not historically been monitored for groundwater quality. The addition of these wells and the monitoring wells recently and currently being constructed together with other groundwater quality monitoring being conducted for public supply wells and the ILRP help provide a sufficient network for monitoring of groundwater quality and impacts from GSP projects and managements actions. As GSP PMAs are implemented and the planned locations for these activities are better known, the groundwater quality monitoring network will be reviewed and modified if needed to provide sufficient groundwater quality monitoring to meet the stated objectives.

3.5.4.3.3 Interconnected Surface Water

Significant data gaps exist for adequately characterizing interconnected surface water along the San Joaquin River along the western boundary of Chowchilla Subbasin. The relationships between occurrence of shallow groundwater levels, streamflow, and pumping need an improved understanding. Whether or not (and to what degree) shallow groundwater levels that occur along the San Joaquin River may be impacted by regional groundwater pumping is yet to be determined, and requires an improved understanding of shallow subsurface stratigraphy, groundwater elevations in various depth zones, and potential variations in streamflow along this reach of the San Joaquin River.

3.5.4.4 Description of Steps to Fill Data Gaps

Data gaps have been presented in the groundwater level, groundwater storage, land subsidence, groundwater quality, and interconnected surface water monitoring networks. The following steps will be taken to address these data gaps:

- Madera County recently added eight new nested monitoring well sites with three well completions at each site (total of 24 new monitoring wells) within the Subbasin, along with one new shallow single-completion monitoring well. These new wells will address many of the data gaps described in the Upper and Lower Aquifers for groundwater level and quality data (**Figures 3-1** and **3-2**). Groundwater level and quality data are being collected from these monitoring wells to evaluate baseline conditions, and the will be considered for addition to the RMS monitoring network for the 2025 GSP Update. Additional nested monitoring wells are planned for construction in 2022-2023.
- The GSAs will install sampling taps (as needed) on groundwater level wells designated for groundwater quality monitoring. These wells will then be sampled for both groundwater elevation data and groundwater quality data.
- Sampling events will be coordinated with well owners to prevent pumping and access issues.
- Review of potential additional steps to address data gaps related to subsidence and interconnected surface water is currently in progress.

In addition to these steps, the monitoring networks will be evaluated on a yearly and five-year basis. If additional data gaps arise, the GSA will consider the implications of these gaps, associated costs, and importance to the continued implementation of the GSP and take appropriate actions to address the gaps.

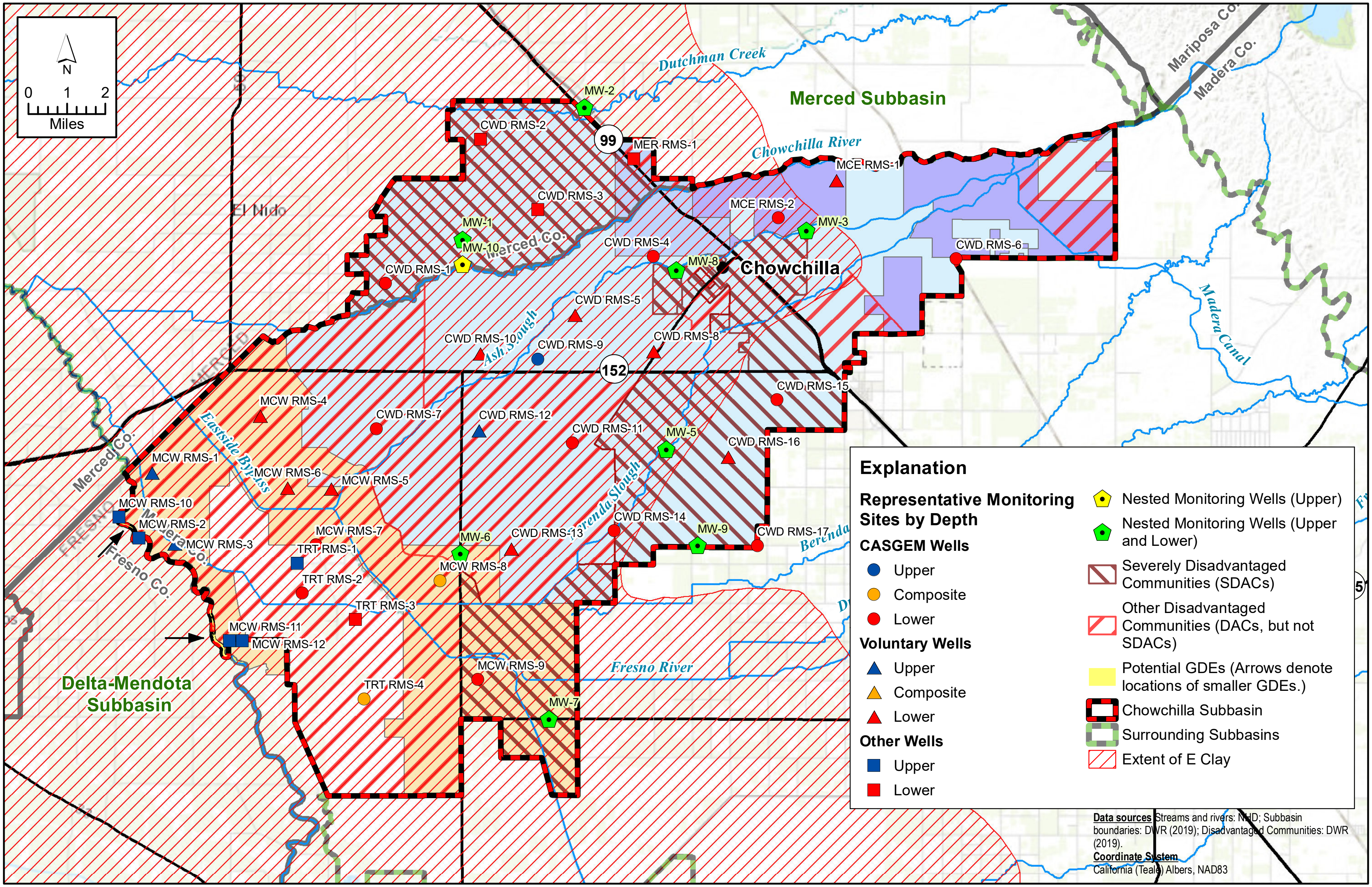
3.5.4.5 Description of Monitoring Frequency and Density of Sites

Monitoring frequency and density of sites for all sustainability indicators are described in previous sections of this report.

CHAPTER 3 SUSTAINABLE MANAGEMENT CRITERIA

3.6 Selected Figures

The following figures can be found after this page: Figures 3-1 to 3-3, 3-6 to 3-9, and 3-11 to 3-13.



\\SERVER-01\Clerical\2018\18-017 Chowchilla GSP Development\GIS\Map files\Report Figures\Figure 3-1 Chowchilla Subbasin Proposed Sustainability Indicator Wells.mxd

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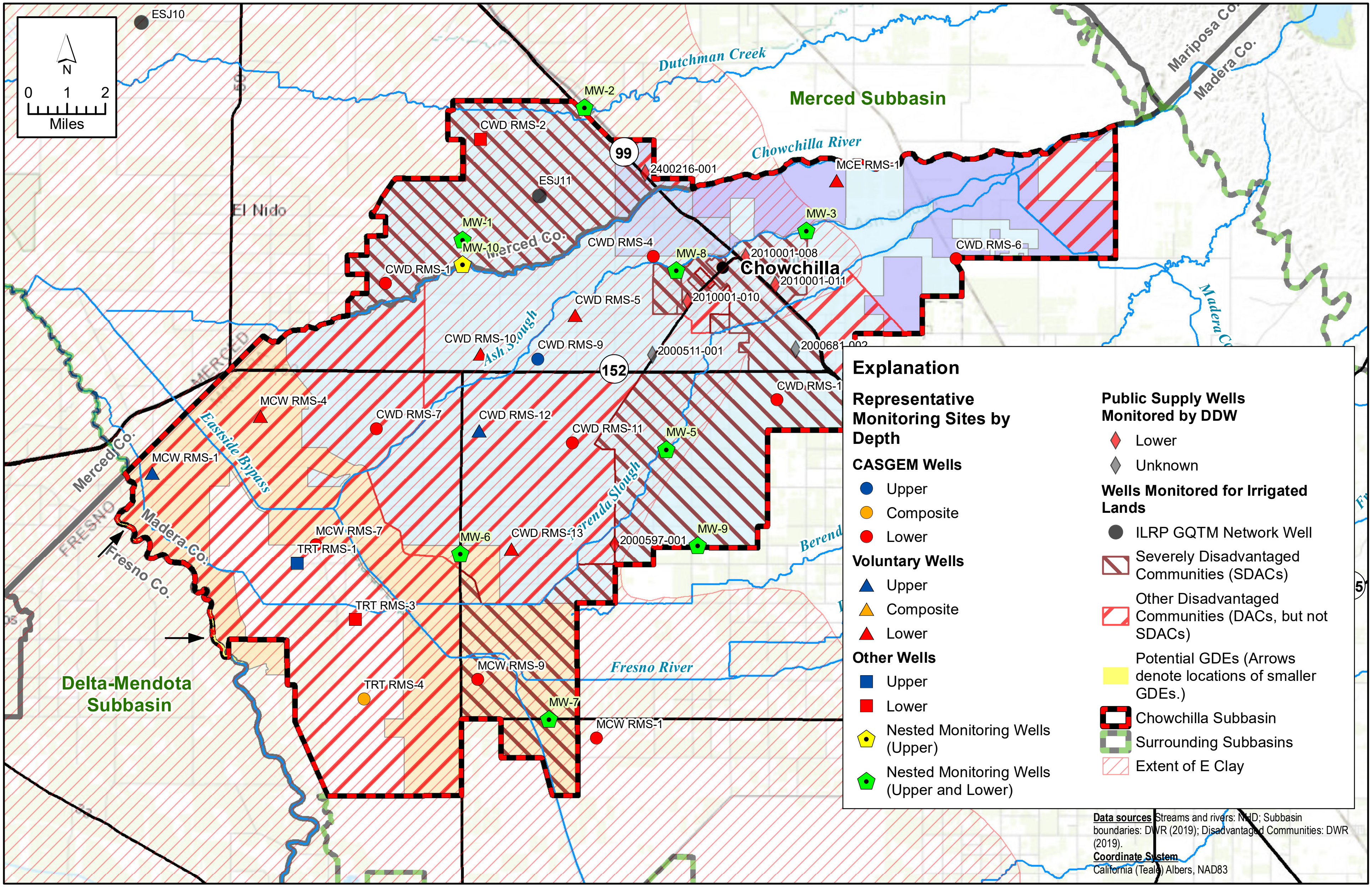
FIGURE 3-1
Proposed Groundwater Level Sustainability Indicator Representative Monitoring Sites

Chowchilla Subbasin Groundwater Sustainability Plan



\\SERVER-01\Clerical\2018\18-017 Chowchilla GSP Development\GIS\Map files\Report Figures\Figure 3-2 Chowchilla Subbasin Proposed Groundwater Quality Indicator Wells.mxd

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FIGURE 3-2
Proposed Groundwater Quality Sustainability Indicator Representative Monitoring Sites

Chowchilla Subbasin
Groundwater Sustainability Plan

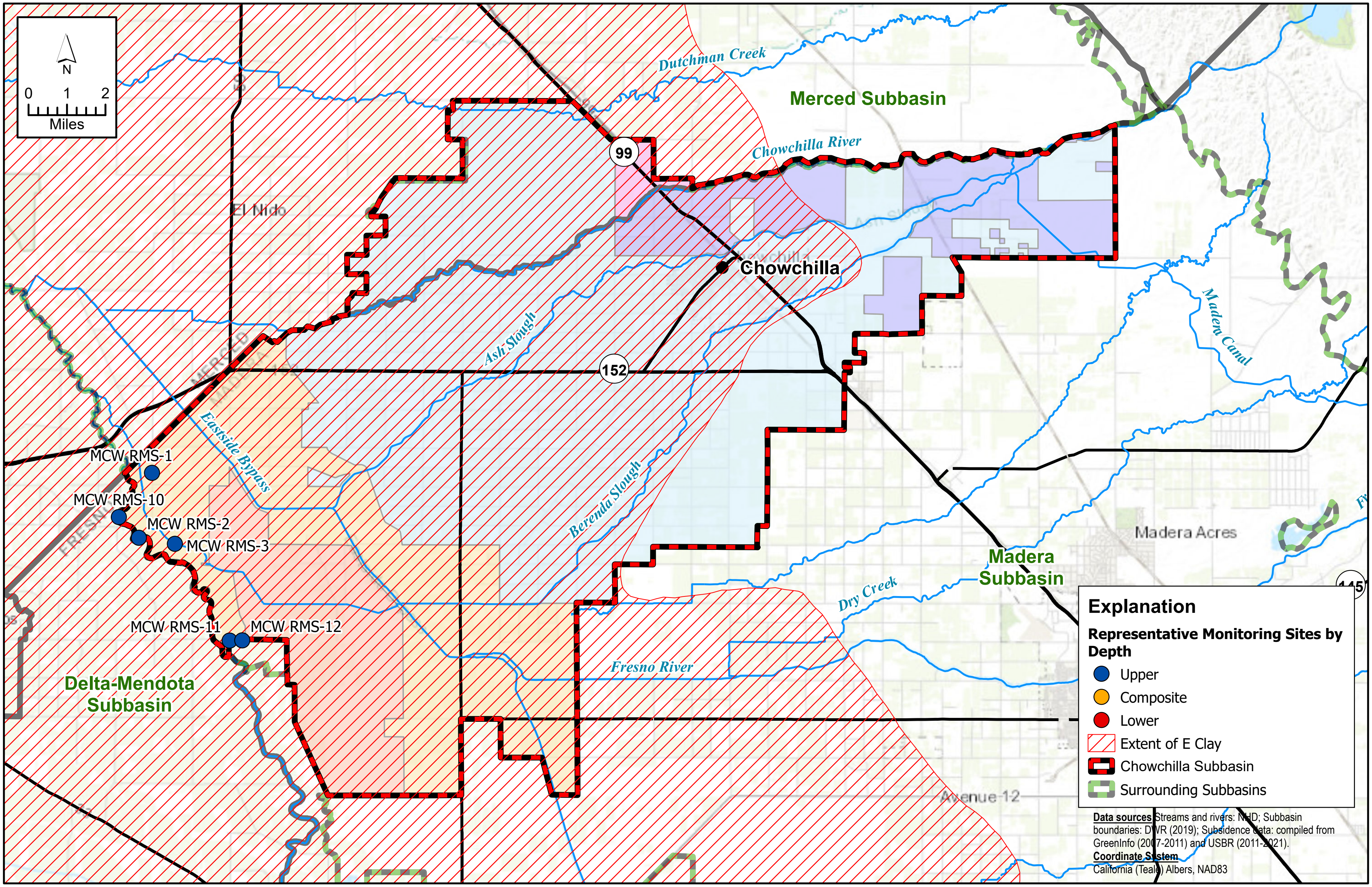

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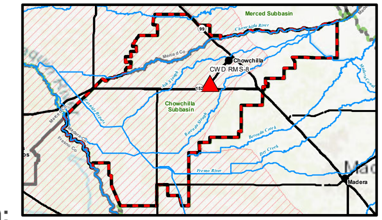
FIGURE 3-3

Proposed Interconnected Surface Water Sustainability Indicator Representative Monitoring Sites

Chowchilla Subbasin
Groundwater Sustainability Plan

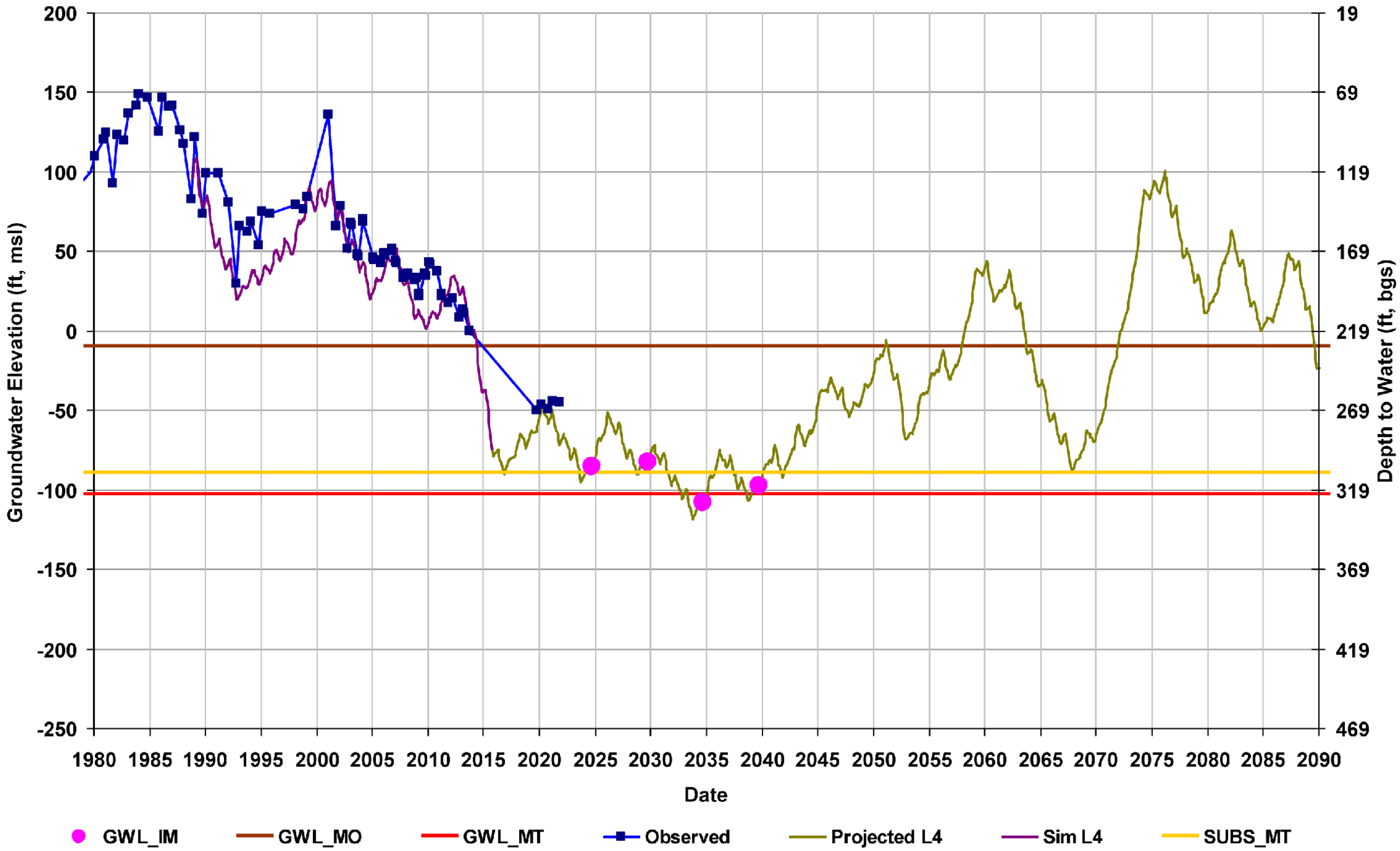


Well Name: CWD RMS-8
Depth Zone: Lower
Subbasin: Chowchilla
GSE (ft, msl): 219

<u>**Domestic Well Data:**</u> *Total Sections Included: 9*

Total Depth Count: 110	Top Perf. Count: 77
Total Depth Average: 373	Top Perf. Average: 241
Total Depth Minimum: 130	Top Perf. Minimum: 112
Total Depth Maximum: 700	Top Perf. Maximum: 365

Total Depth (ft):
Perf Top (ft):
Perf Bottom (ft):
Top Model Layer: 4
Bottom Model Layer: 4



\\SERVER-01\Clerical\2018\18-017 Chowchilla GSP Development\GIS\Map files\Report Figures\Figure 3-3a Chowchilla Subbasin Hydrograph 10S15E1E1_10S15E32L1.mxd

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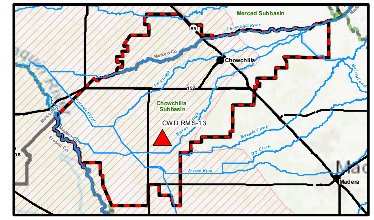
FIGURE 3-6A
Selected Hydrographs for Proposed Indicator Wells
Lower Aquifer

Chowchilla Subbasin
Groundwater Sustainability Plan



Well Name: CWD RMS-13
Depth Zone: Lower
Subbasin: Chowchilla
GSE (ft, msl): 167

Domestic Well Data: *Total Sections Included: 9*

Total Depth Count: 24	Top Perf. Count: 15
Total Depth Average: 313	Top Perf. Average: 224
Total Depth Minimum: 126	Top Perf. Minimum: 145
Total Depth Maximum: 600	Top Perf. Maximum: 389

Total Depth (ft):
Perf Top (ft):
Perf Bottom (ft):
Top Model Layer: 4
Bottom Model Layer: 4

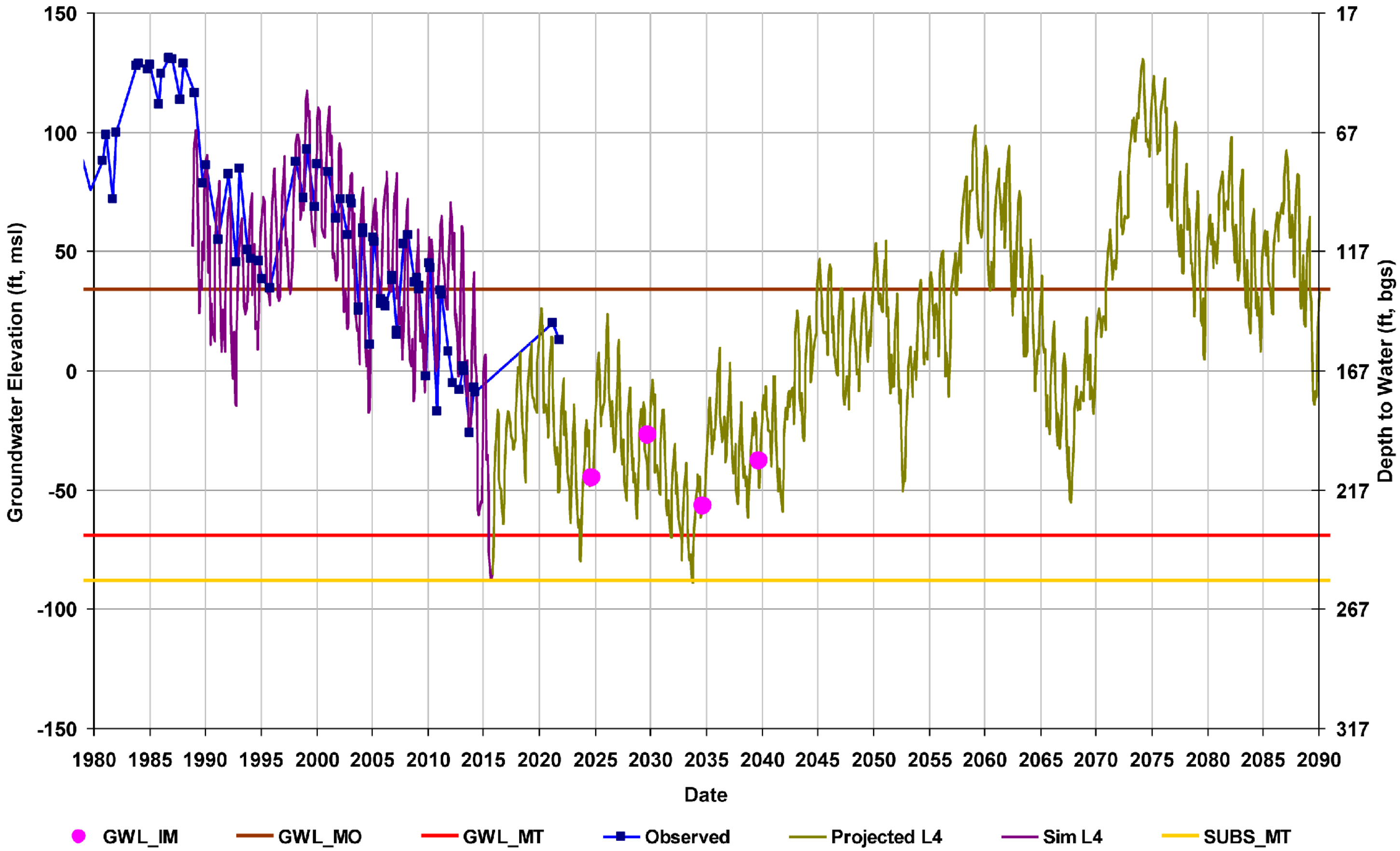


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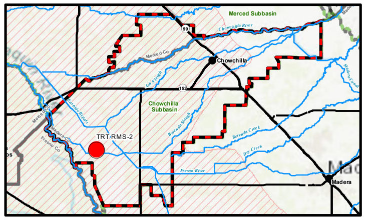
FIGURE 3-6B

Selected Hydrographs for Proposed Indicator Wells Lower Aquifer

Chowchilla Subbasin
Groundwater Sustainability Plan



Well Name: TRT RMS-2
Depth Zone: Lower
Subbasin: Chowchilla
GSE (ft, msl): 135

Domestic Well Data: *Total Sections Included: 9*

Total Depth Count: 7
Total Depth Average: 314
Total Depth Minimum: 150
Total Depth Maximum: 500

Top Perf. Count: 4
Top Perf. Average: 202
Top Perf. Minimum: 100
Top Perf. Maximum: 300

Total Depth (ft): 500
Perf Top (ft): 300
Perf Bottom (ft): 500
Top Model Layer: 4
Bottom Model Layer: 4

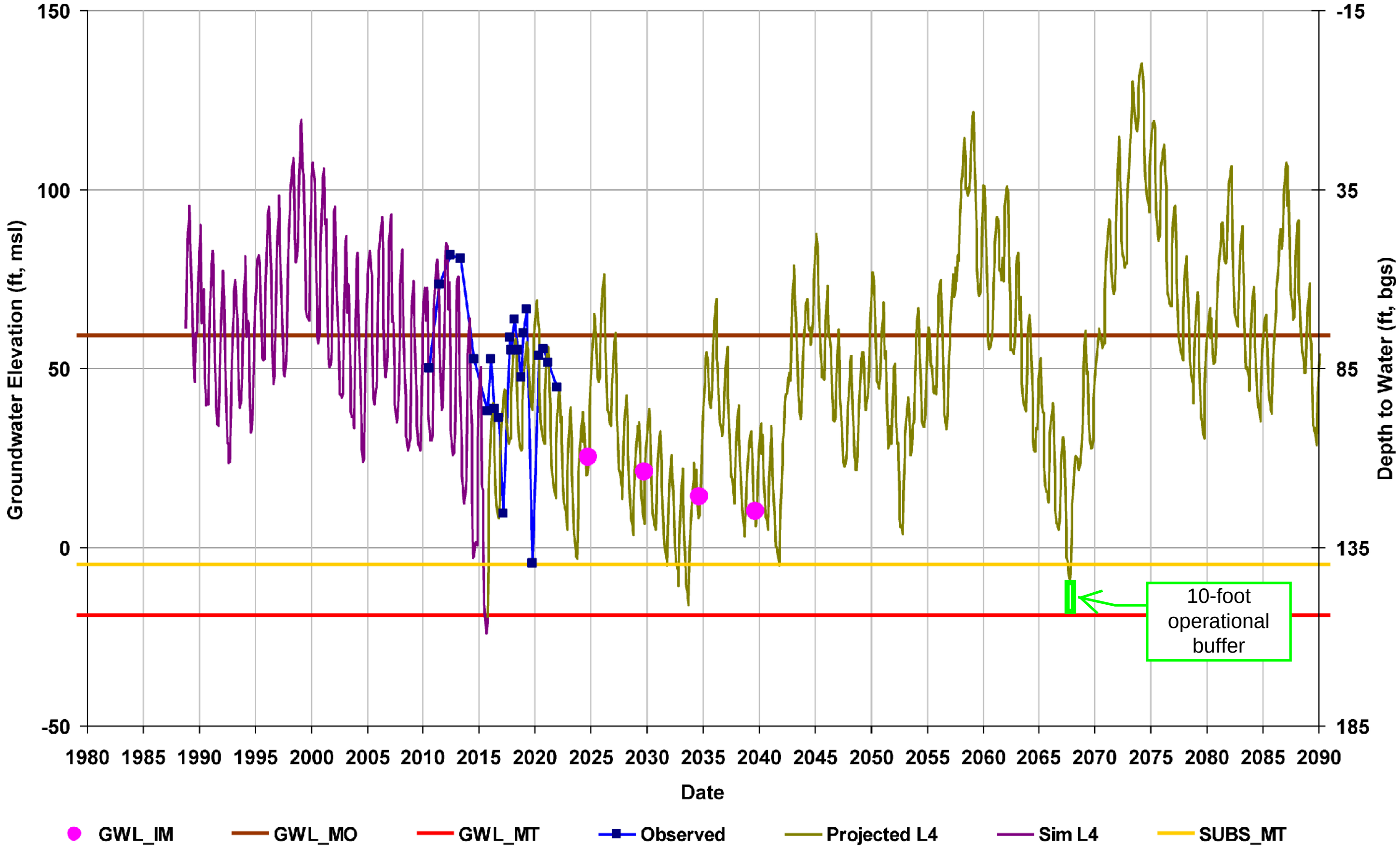


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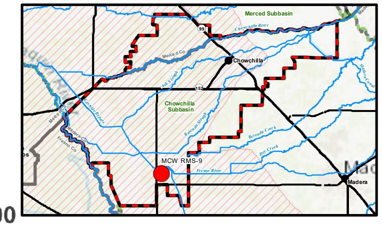
FIGURE 3-7A
Selected Hydrographs for Proposed Indicator Wells Lower Aquifer

Chowchilla Subbasin
Groundwater Sustainability Plan



Well Name: MCW RMS-9
Depth Zone: Lower
Subbasin: Chowchilla
GSE (ft, msl): 155

Domestic Well Data: *Total Sections Included: 10*

Total Depth Count: 9	Top Perf. Count: 3
Total Depth Average: 246	Top Perf. Average: 256
Total Depth Minimum: 110	Top Perf. Minimum: 160
Total Depth Maximum: 400	Top Perf. Maximum: 308

Total Depth (ft): 700
Perf Top (ft): 265
Perf Bottom (ft): 696
Top Model Layer: 5
Bottom Model Layer: 5

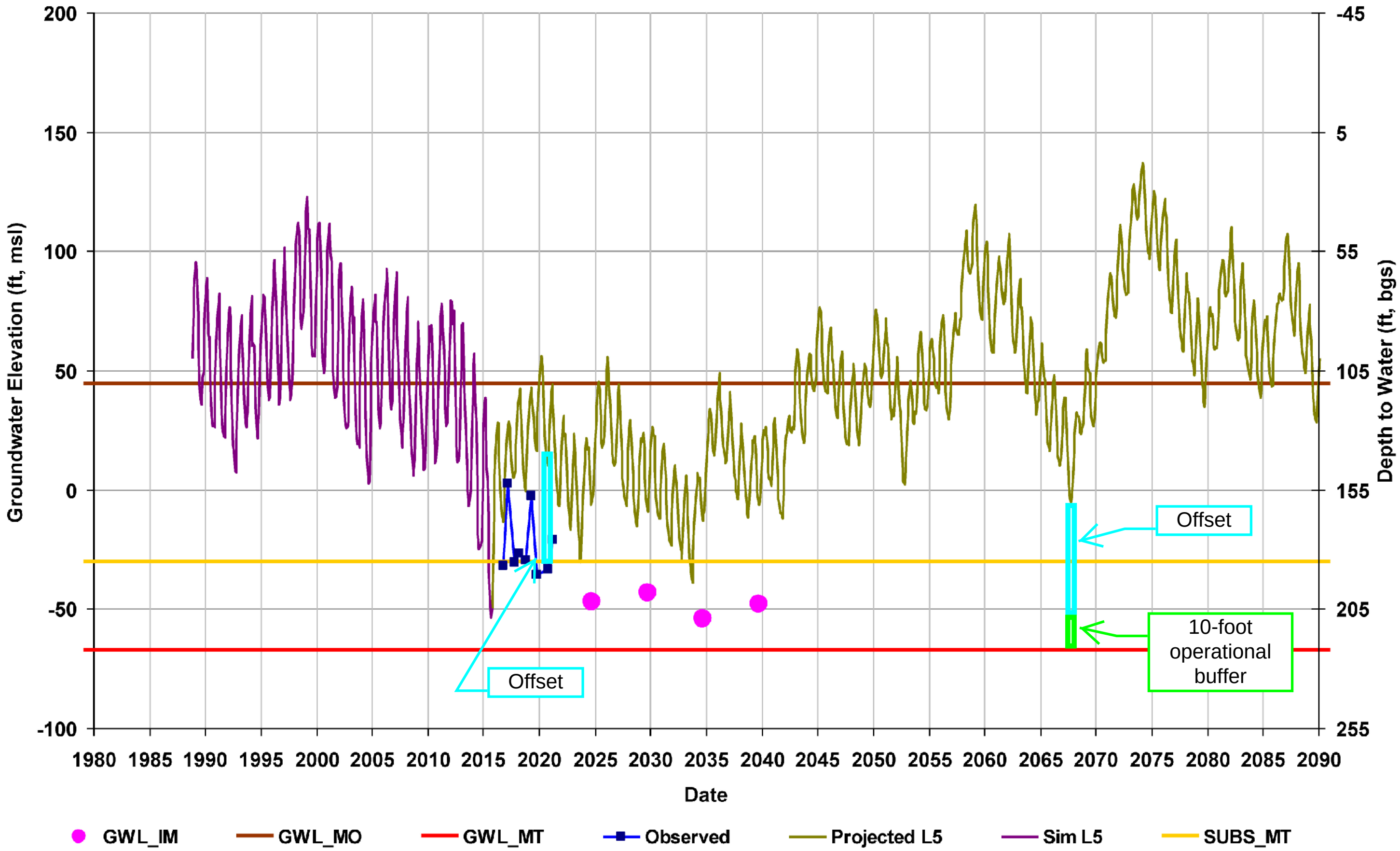


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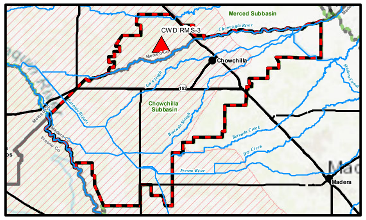
FIGURE 3-7B
Selected Hydrographs for Proposed Indicator Wells Lower Aquifer

Chowchilla Subbasin
Groundwater Sustainability Plan



Well Name: CWD RMS-3
Depth Zone: Lower
Subbasin: Chowchilla
GSE (ft, msl): 206

Domestic Well Data: *Total Sections Included: 9*

Total Depth Count:	3	Top Perf. Count:	1
Total Depth Average:	352	Top Perf. Average:	279
Total Depth Minimum:	280	Top Perf. Minimum:	279
Total Depth Maximum:	467	Top Perf. Maximum:	279

Total Depth (ft):
Perf Top (ft):
Perf Bottom (ft):
Top Model Layer: 4
Bottom Model Layer: 4

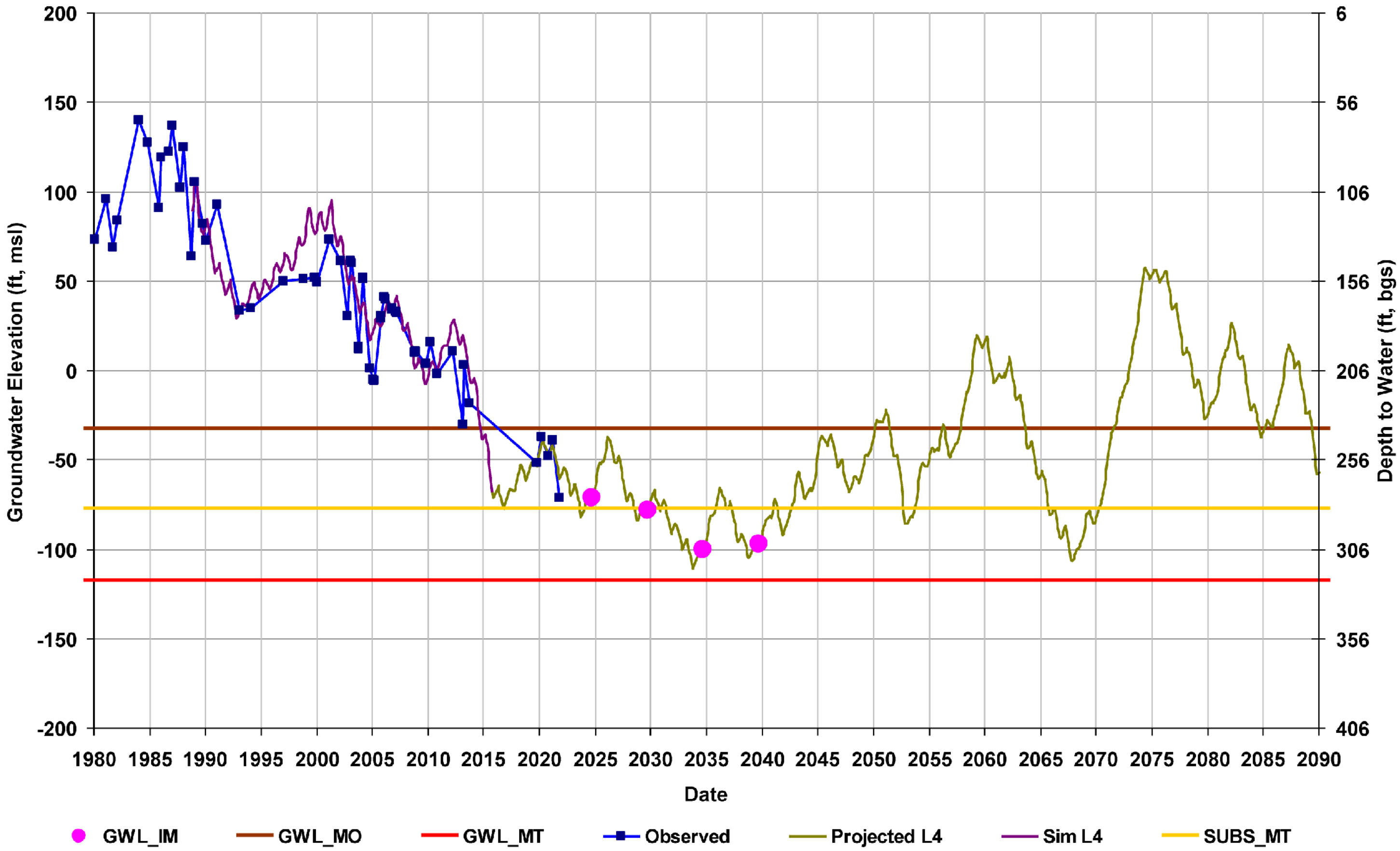


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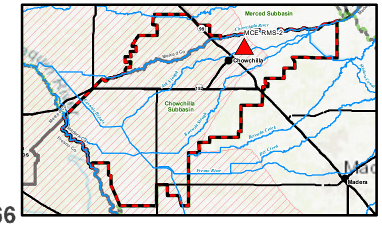
FIGURE 3-7C
Selected Hydrographs for Proposed Indicator Wells Lower Aquifer

Chowchilla Subbasin
Groundwater Sustainability Plan



Well Name: MCE RMS-2
Depth Zone: Lower
Subbasin: Chowchilla
GSE (ft, msl): 272

<u>Domestic Well Data:</u> *Total Sections Included: 9*

Total Depth Count:	14	Top Perf. Count:	11
Total Depth Average:	378	Top Perf. Average:	245
Total Depth Minimum:	204	Top Perf. Minimum:	155
Total Depth Maximum:	600	Top Perf. Maximum:	338

Total Depth (ft): 466
Perf Top (ft): 218
Perf Bottom (ft): 464
Top Model Layer: 4
Bottom Model Layer: 4

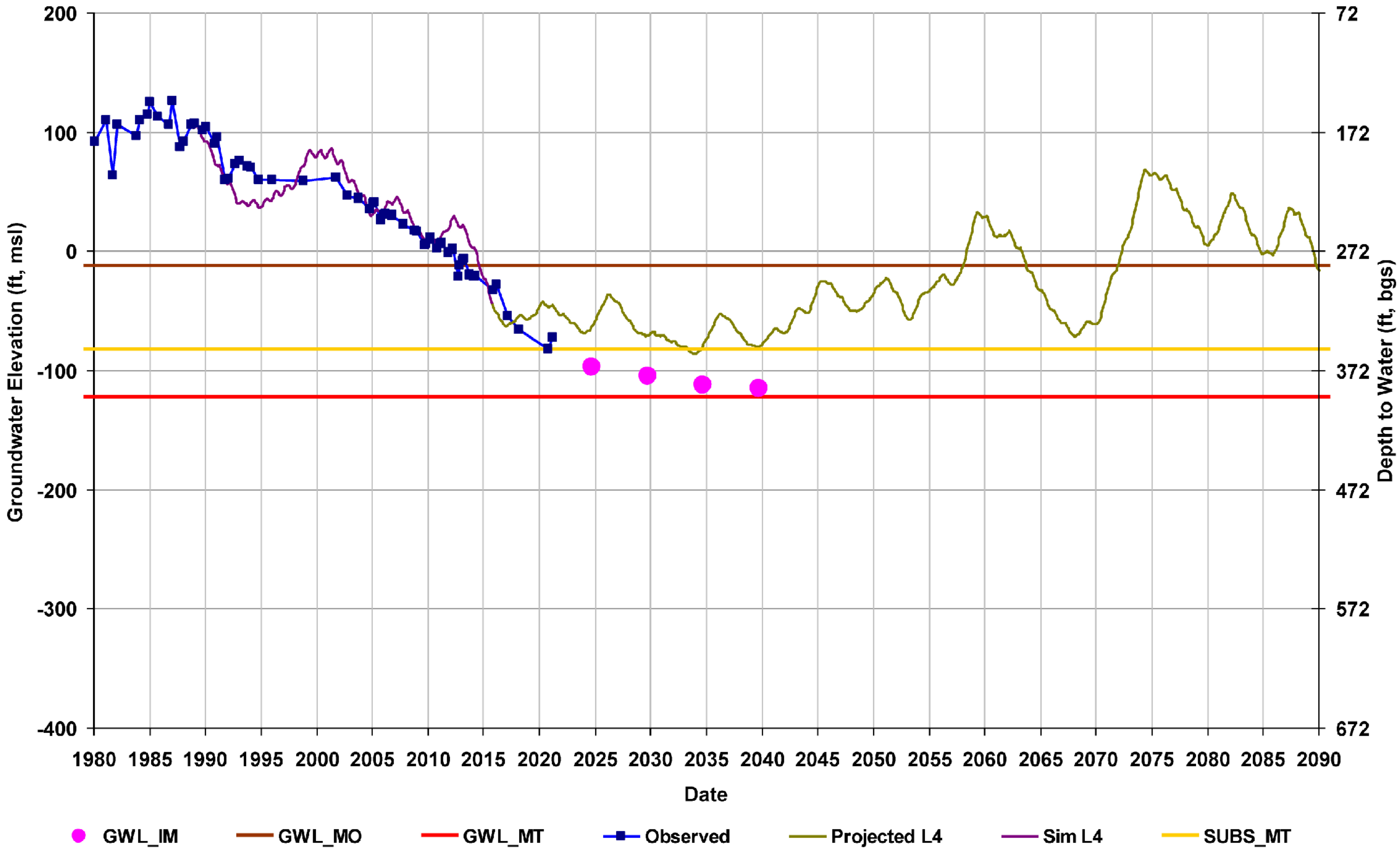


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FIGURE 3-7D
Selected Hydrographs for Proposed Indicator Wells Lower Aquifer

Chowchilla Subbasin Groundwater Sustainability Plan

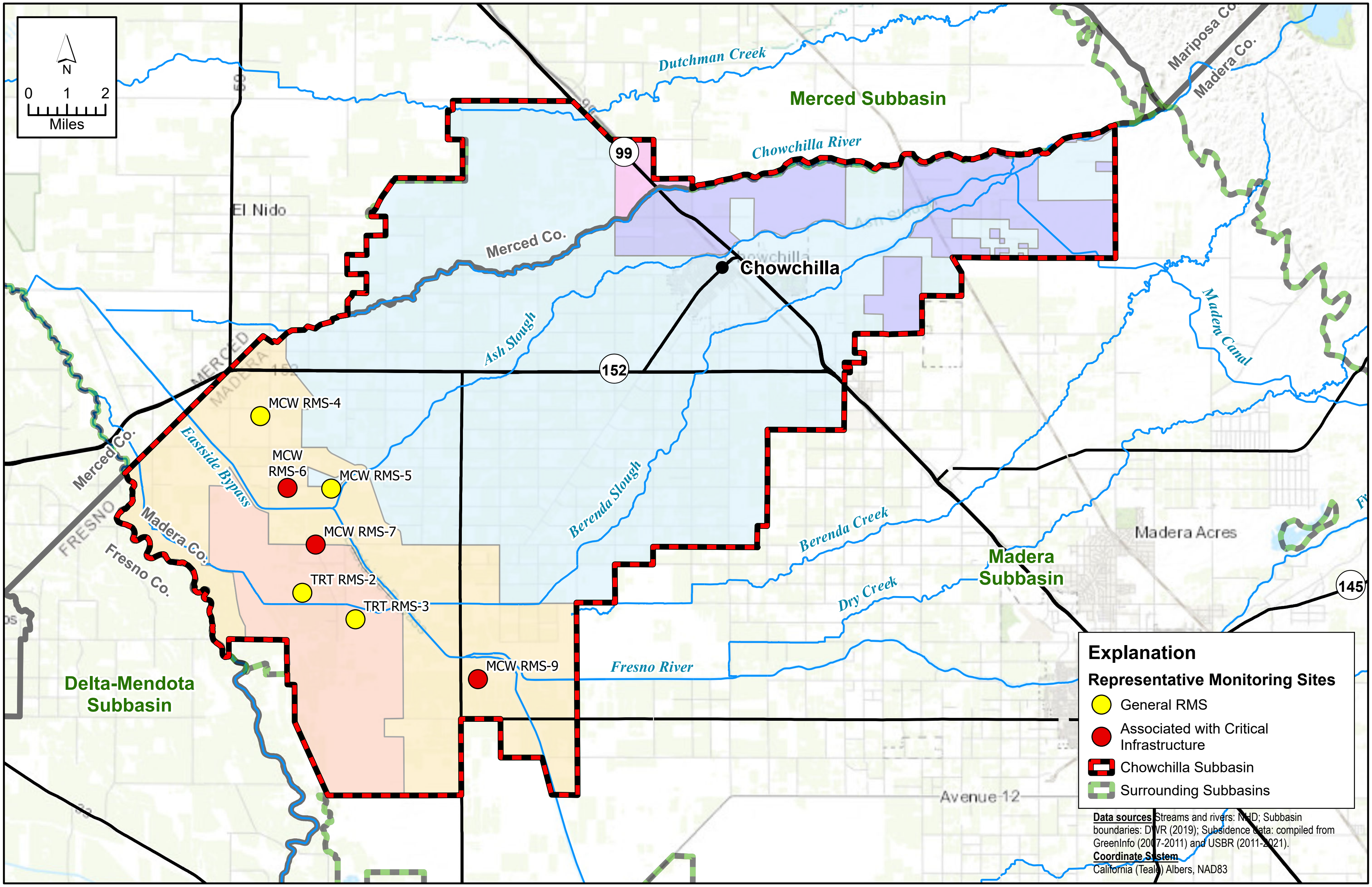

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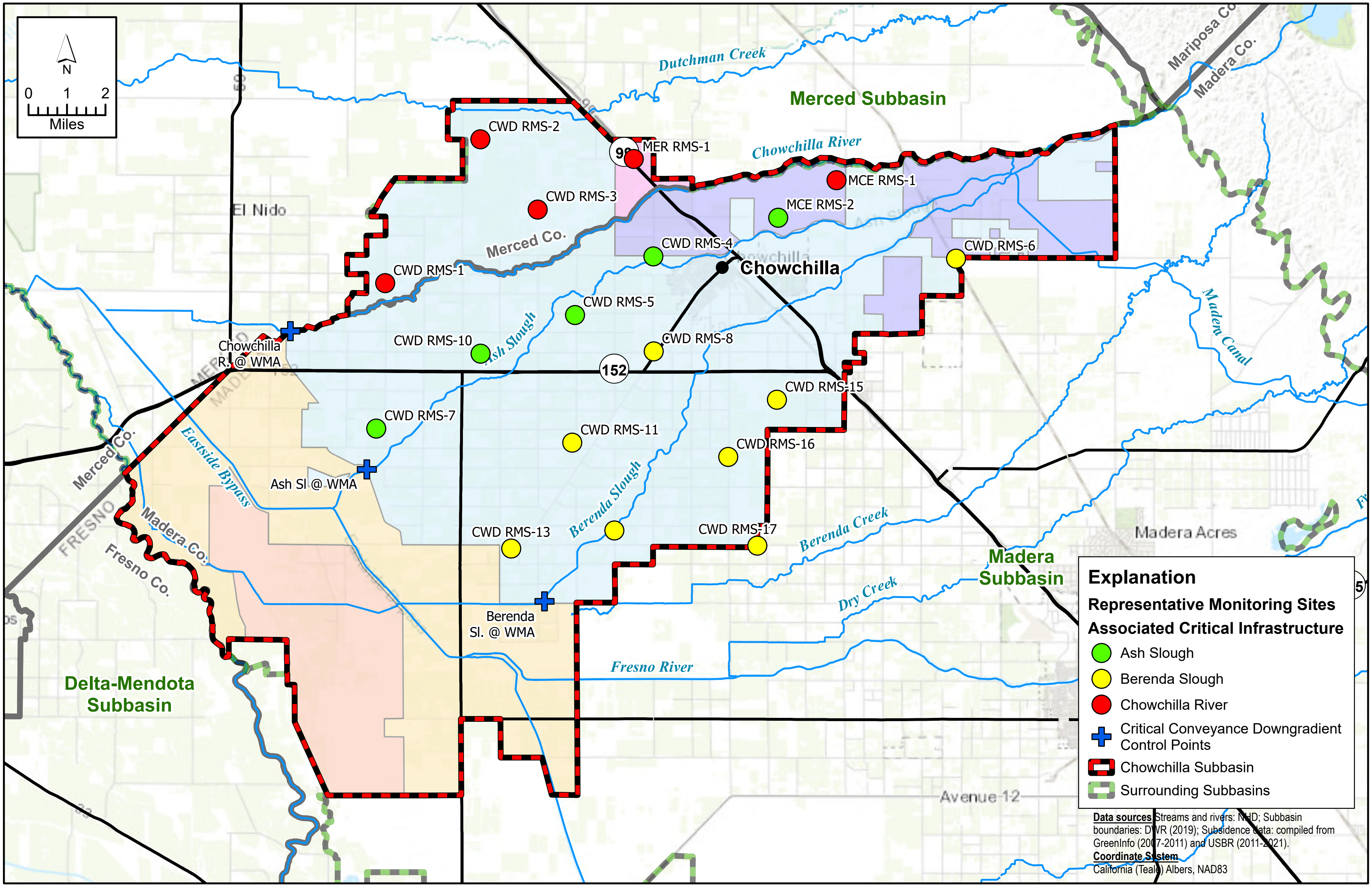
FIGURE 3-8A
Proposed Land Subsidence Sustainability Indicator
Representative Monitoring Sites – Western Management Area

Chowchilla Subbasin
Groundwater Sustainability Plan



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DAVIDS ENGINEERING, INC

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FIGURE 3-8B

Proposed Land Subsidence Sustainability Indicator
Representative Monitoring Sites – Eastern Management Area

Chowchilla Subbasin
Groundwater Sustainability Plan

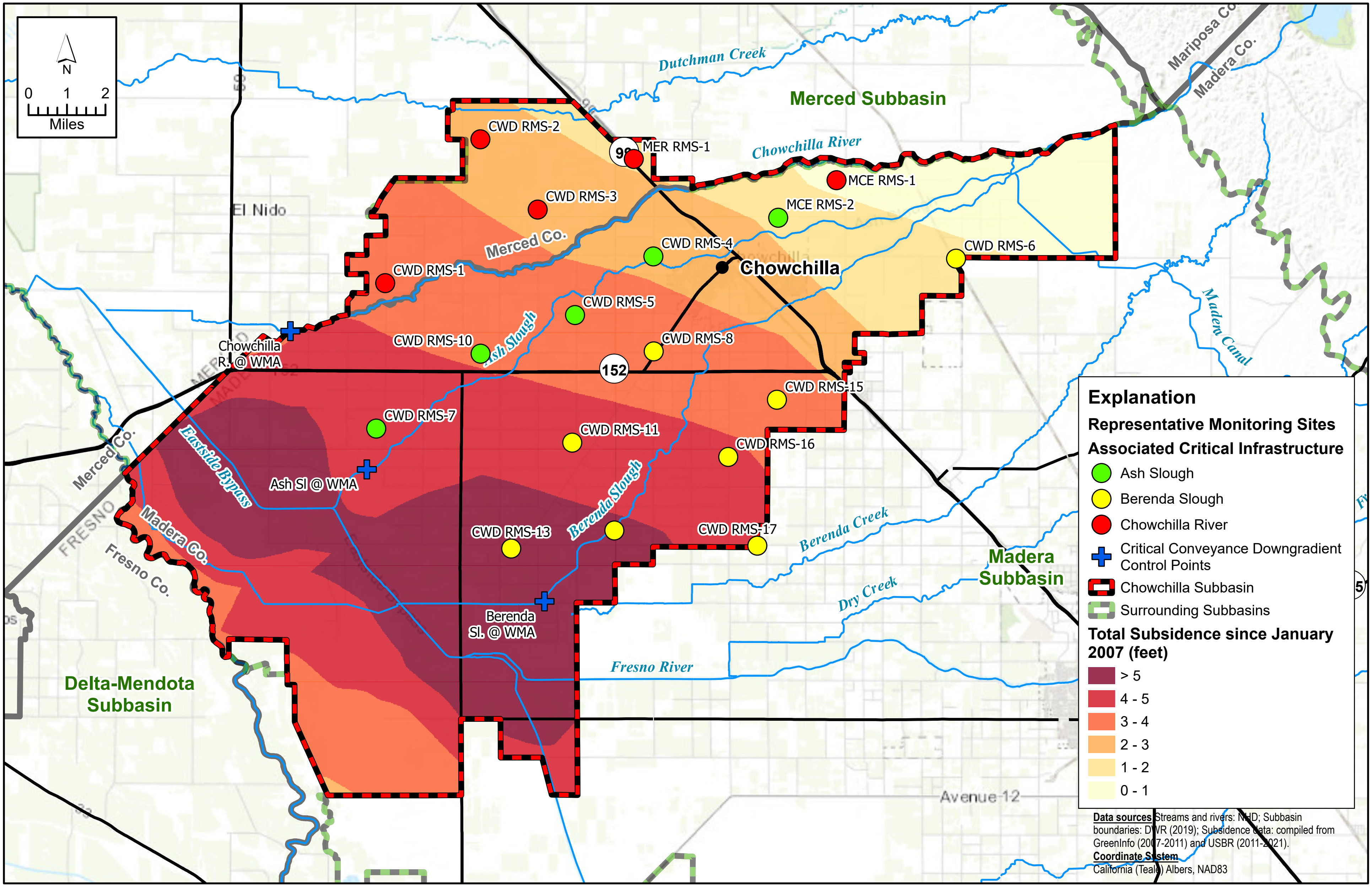

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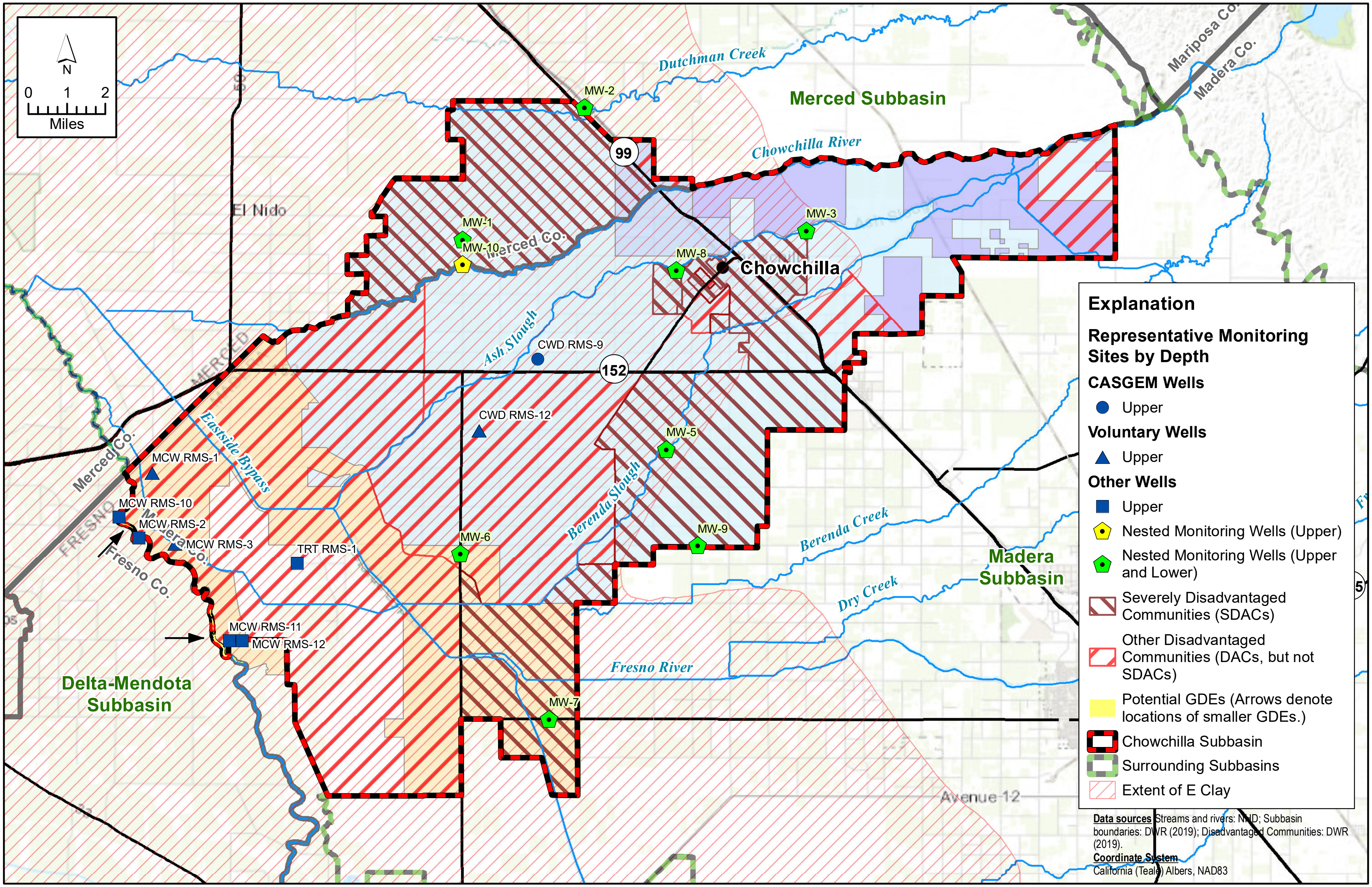
FIGURE 3-9

Historical Subsidence since 2007 at the Lower Aquifer Representative Monitoring Sites in the Eastern Management Area

Chowchilla Subbasin
Groundwater Sustainability Plan



\\SERVER-01\Clerical\2018\18-017 Chowchilla GSP Development\GIS\Map files\Report Figures\Figure 3-6 Chowchilla Subbasin Proposed Sustainability Indicator Wells Upper.mxd

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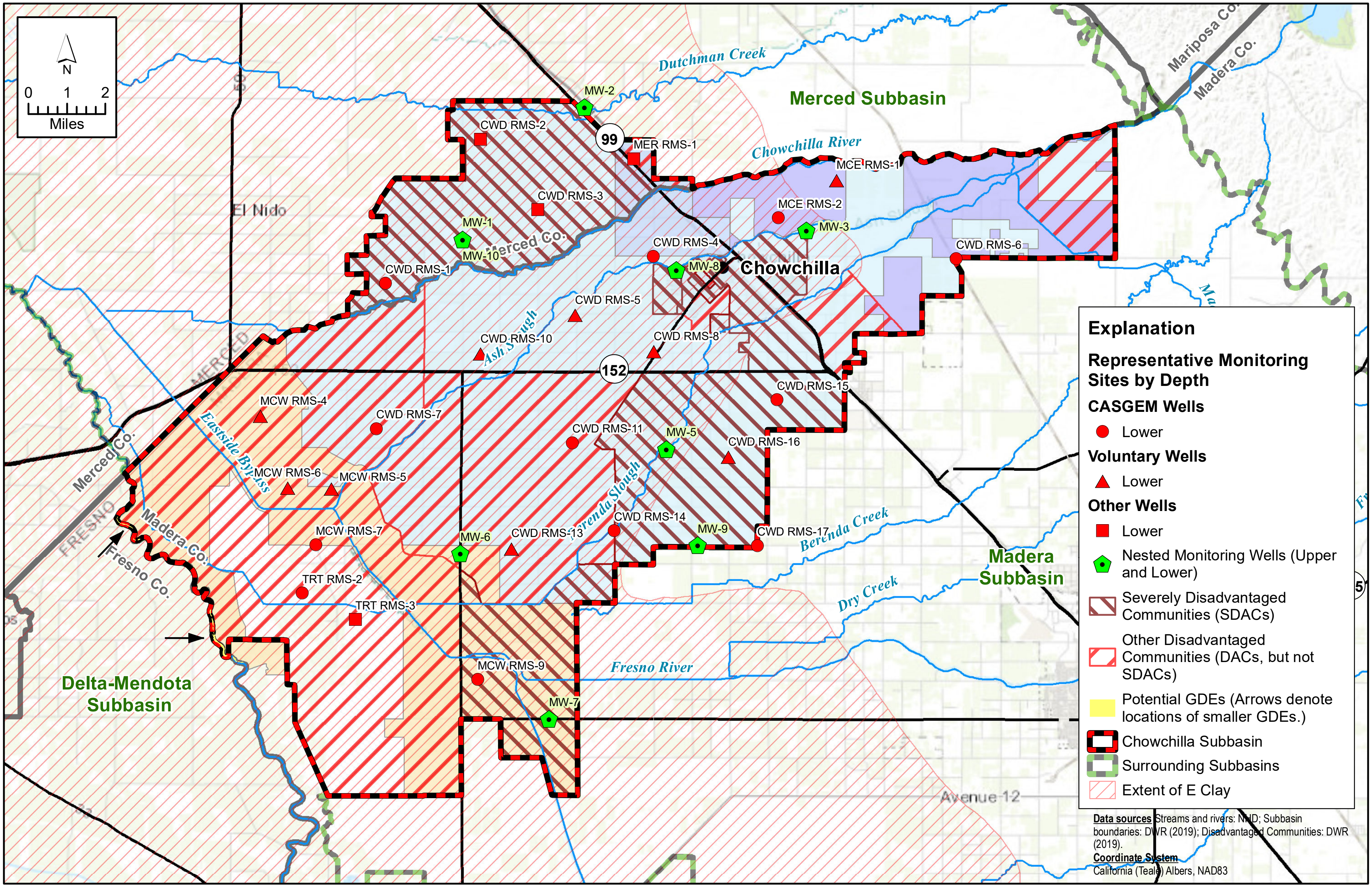
FIGURE 3-11
Proposed Groundwater Level Sustainability Indicator Representative Monitoring Sites - Upper Aquifer

Chowchilla Subbasin Groundwater Sustainability Plan



\\SERVER-01\Clerical\2018\18-017 Chowchilla GSP Development\GIS\Map files\Report Figures\Figure 3-7 Chowchilla Subbasin Proposed Sustainability Indicator Wells Lower.mxd

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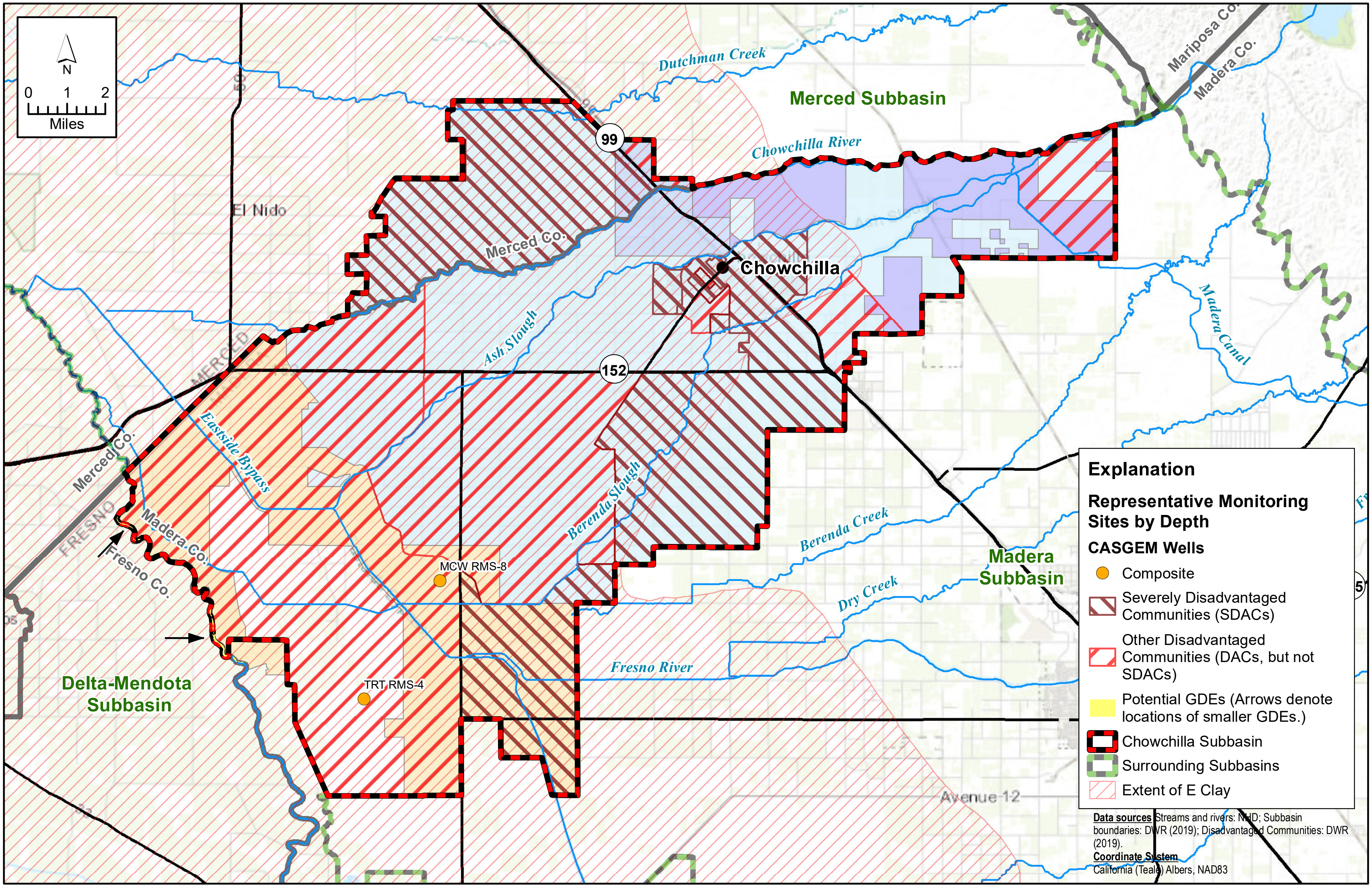
FIGURE 3-12
Proposed Groundwater Level Sustainability Indicator Representative Monitoring Sites - Lower Aquifer

Chowchilla Subbasin
Groundwater Sustainability Plan



\\SERVER-01\Clerical\2018\18-017 Chowchilla GSP Development\GIS\Map files\Report Figures\Figure 3-8 Chowchilla Subbasin Proposed Sustainability Indicator Wells Composite.mxd

DAVIDS ENGINEERING, INC

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FIGURE 3-13
Proposed Groundwater Level Sustainability Indicator Representative Monitoring Sites - Composite Wells

Chowchilla Subbasin
Groundwater Sustainability Plan

4 SUBBASIN PROJECTS AND MANAGEMENT ACTIONS

To achieve the Subbasin sustainability goal by 2040 and avoid undesirable results through 2090 as required by SMGA regulations, various projects and management actions (PMAs) have been developed and will be implemented by the GSAs between 2020 and 2040. This chapter describes the types of PMAs that are expected to be implemented by each GSA in the Subbasin to meet sustainability objectives. Projects generally refer to structural features whereas management actions are typically non-structural programs or policies designed to incentivize reductions in groundwater pumping.

Subbasin PMAs are described in accordance with §354.42 and §354.44 of the SGMA regulations. The estimated groundwater recharge benefit and capital, operating, and maintenance costs of developing and operating each PMA is shown. PMA cost information is limited for many PMAs because a detailed feasibility assessment has not been completed. Other PMAs have cost estimates that were developed several years ago and may not reflect current conditions. To the extent possible, PMA costs are adjusted and reported on a consistent basis. For example, a consistent water purchase price is applied across all PMAs that would purchase and import water from other Subbasins (unless a specific cost is already provided in an existing agreement). All costs are indexed using an appropriate index (either the Implicit Price Deflator or the Engineering News Report Construction Cost Index) and reported in current (2019) dollars. GSAs will further develop PMAs during the GSP implementation period and refine estimated costs.

GSAs will identify sources of funding to cover PMA development, capital, and operating costs, including but not limited to, groundwater extraction fees, increasing water rates, grants, low interest loans, and other assessments. The exact funding mechanism will vary by PMA and the legal authority of each GSA. A general description of how each GSA expects to cover the cost of all PMAs it will implement is presented after the description of PMAs for each GSA.

The GSAs have prioritized implementing PMAs that provide additional surface water supply, thereby reducing groundwater pumping. The GSAs also are committed to adaptive management of PMAs. As PMAs are implemented and monitored, the PMA timelines and volume of demand management necessary will be reviewed. If adjustments are needed to meet the sustainability objective, first PMA timelines will be evaluated and adjusted.

Three types of projects are included in the Chowchilla Subbasin GSP for implementation: recharge, conveyance, and storage (**Table 4-1**). Recharge projects are designed to support sustainability by increasing recharge. Conveyance projects facilitate the delivery of additional water supplies for increased recharge or for direct use for irrigation, thereby reducing groundwater pumping (in-lieu recharge). Storage projects store additional water supplies for increased recharge or for direct use for irrigation, thereby reducing groundwater pumping. Some projects have a specific water source, but many of the recharge projects can draw from the same general sources. A section at the end of this chapter describes and quantifies available water from the potential sources. A demand management action is described for the Madera County GSA, though the other GSAs within the Subbasin can also use it as needed to attain sustainability. The demand management action provides groundwater users a flexible way to meet any future pumping restrictions.

The cost, timing, and gross groundwater benefit (yield) of the PMAs included in the GSP vary by GSA. **Table 4-2** lists all of the PMAs, by GSA or subregion, and the estimated implementation timeline, capital cost, operating cost, and gross benefit of the PMAs. Recharge basins, a common project, may also provide environmental benefits that are not quantified in the table. **Table 4-3** further summarizes the total gross benefits and costs of all PMAs developed for each GSA or subregion.

The gross yield across all PMAs at full implementation (2040) equals approximately 134,400 acre-feet per year (AFY). 2vai includes the Madera County demand management program implemented by the Madera County GSA that will reduce net groundwater pumping by about 28,000 AFY.

The remaining subsections of this chapter provide additional details about:

- Plans for implementation of PMAs by each GSA or agency, including anticipated costs and benefits,
- The amount of water available for recharge by projects, and
- Actual PMA implementation efforts that have been completed as of the latest GSP Annual Report (water year 2021).

Table 4-1. Projects and Management Actions and Water Sources considered in the Chowchilla Subbasin

GSA	PMA type	PMA Mechanism	Water Source			
			Chowchilla River Flood Release	Millerton Flood Release and Section 215 water	Eastside Bypass flows	Purchase
Recharge						
All	Recharge Basins	Increase Recharge	X	X	X	X
All	Flood-MAR	Increase Recharge	X	X	X	X
Conveyance						
TTWD	Poso Canal Pipeline	Increase Recharge or Reduce GW Pumping				X
TTWD	Columbia Canal Company Pipeline	Increase Recharge or Reduce GW Pumping				X
CWD	Merced Intertie	Increase Recharge or Reduce GW Pumping				X
CWD	Madera Canal Capacity Increase	Increase Recharge or Reduce GW Pumping		X		X
Storage						
CWD	Eastman Lake Increase	Increase Recharge or Reduce GW Pumping	X			
Management Actions						
MC	Demand Management	Reduce demand at lower cost by trading groundwater credits				

Table 4-2. Chowchilla Subbasin Projects and Management Actions

GSA[1]	PMA	First Year of Implementation	Gross Average Annual Benefit at Full Implementation (AF)	Estimated Capital Cost ($, millions)	Estimated Average Annual Operating Cost ($/year, millions)
CWD	Recharge Basin	2018	1,359	3.1	0.01
CWD	Flood-MAR	2020	5,836	N/A	0.2
CWD	Additional Recharge Basins (1,000 acres)	2021	10,803	38.6	0.5
CWD	Madera Canal Capacity Increase	2035	5,147	61.2	0.3
CWD	Merced-Chowchilla Intertie	2035	7,350	6.7	1.5
CWD	Eastman Lake (Buchannan Dam) Enlargement	2040	8,753	49.2	0.2
Madera County (East)	Water Purchase/Import for Direct or In-Lieu Recharge	2020	3,015	1.0	1.1
Madera County (West)	Water Purchase/Import for Direct or In-Lieu Recharge	2020	27,953	118.0	0.7
Madera County (All)	Demand Management	2020	27,550	N/A	19.6[3]
SVMWC[2]	SVMWC Recharge Basin	2020	4,344	7.5	0.2
TTWD	Poso Canal Pipeline / Settlement Agreement	2020	7,647	5.2	4.6
TTWD	Eastside Bypass Flood Water / Redtop Joint Banking	2021	24,657	24.5	0.7
Total			**134,414**	**315.0**	**29.6**

[1] PMAs summarized by each GSA, GSA subregion, or local agency responsible for implementation.
[2] SVMWC includes portions of both Madera County GSA and Merced County GSA.
[3] Costs of demand management include reduced economic activities in Madera County, this includes approximately $19.1 million per year in direct economic impacts alone (excluding multiplier effects).

Table 4-3. Summary of Chowchilla Subbasin Projects and Management Actions by GSA

GSA[1]	Gross Average Annual Benefit at Full Implementation (AF)	Estimated Capital Cost ($, millions)	Estimated Average Annual Operating Cost ($/year, millions)
CWD	39,248	158.8	2.7
Madera County	58,518	119.0[3]	21.4[3]
SVMWC[2]	4,344	7.5	0.2
TTWD	32,304	29.7	5.3
Total	**134,414**	**315.0**	**29.6**

[1]PMAs summarized by each GSA or local agency responsible for implementation.
[2] SVMWC includes portions of both Madera County GSA and Merced County GSA.
[3] Costs of demand management include reduced economic activities in Madera County, this includes approximately $19.1 million per year in direct economic impacts alone (excluding multiplier effects).

4.1 Chowchilla Water District GSA Projects

The Chowchilla Water District GSA (CWD) has identified several projects to include in its implementation of the GSP. These include new or expanded recharge capacity, storage, and additional capacity to move water available from other areas. CWD has also specified other management actions that may be implemented to meet sustainability objectives as warranted by hydrologic conditions and the performance of other projects. The project descriptions are based on information developed during the initial GSP development process and, where applicable, previous studies.

At the time of initial GSP development, planning for the projects was at varying stages of development, so complete information on construction requirements, operations, costs, permitting requirements, and other details were not available. Section 4.6 summarizes PMA implementation efforts and updates from the time of initial GSP development through the latest GSP Annual Report (water year 2021). A description of how all the PMAs operate as part of the overall GSP is provided in Chapter 5: Plan Implementation.

4.1.1 Groundwater Recharge Basins

Recharge basins are artificial ponds of varying size that are filled with water supply that would have otherwise left the Subbasin, which instead percolates into the groundwater system. The size, location, and performance of a recharge basin depends on site-specific characteristics that will be assessed by CWD. For example, some of the water that percolates from the recharge basin may move laterally to nearby streams and flow out of the basin before it can reach the deeper aquifer. CWD will develop recharge basins to maximize recharge efficiency to ensure maximum net recharge benefits stay within the Subbasin.

4.1.1.1 Project Overview

CWD will construct groundwater recharge basins totaling about 1,000 acres, distributed throughout its service area. Locations and sizes of basins will be selected based on land uses, access to delivery facilities, and soils having appropriate percolation rates. Sites will be selected to maximize recharge efficiency and benefits to the Subbasin groundwater system.

4.1.1.2 Implementation

Implementation will start immediately with additional development staged over a ten-year period, beginning in 2020. CWD will conduct a study in 2020 to identify sites that are good locations for construction of groundwater recharge ponds. Permitting and environmental documentation will be initiated, and financing for construction will be identified and secured. CWD completed a 40-acre recharge basin in 2018 and began using it in early 2019. Construction of additional basins will start in 2021 and continue potentially through 2040, with the target of about 1,000 acres of basins to be completed in total. CWD will monitor recharge pond performance and select sites that provide the greatest recharge benefit (**Table 4-4**).

Table 4-4. CWD Recharge Basins Implementation Timeline

Phase	Start	End
Permitting and environmental documentation	2020	2030
Financing	2020	2040
Construction	2021	2030
Operation	2021	Indefinite

4.1.1.2.1 Construction activities and requirements

Construction activities vary by recharge basin site. General activities include survey, initial feasibility assessment, permitting, environmental review, land purchase, earthwork, site development, water supply development, and operating infrastructure. Details on construction activities, schedule, and project costs will be developed as part of final project design for each recharge basin developed by CWD.

4.1.1.2.2 Water source

Water for recharge is expected to be available from one or more of the following sources:

- CWD has a contract for CVP Class 1 and Class 2 water, and it can receive CVP surplus flows when they are available.
- Flood releases from Buchanan Dam, and potentially additional yield from an increase in storage capacity.
- Other water supplies that may be available in future, potentially via exchange through the larger Friant system and delivered by Madera Canal.

The analysis of benefits provided by the CWD recharge basins assumes that the source of water will be flood flows available from Buchanan Dam. It does not account for other potential sources nor for any changes in operations elsewhere in the CVP system that might affect availability of surplus water.

4.1.1.2.3 Conditions or constraints on implementation

This is a planned project of the GSP and its implementation does not depend on the performance of other projects or activities. CWD will monitor conditions in the GSA to determine the location and scale of additional recharge ponds that are developed over the implementation period.

4.1.1.2.4 Permitting process and agencies with potential permitting and regulatory control

The following agencies have potential permitting roles for the project: Madera County, Merced County, Regional Water Quality Control Board, Reclamation (if using CVP contract supply or Section 215 water). CWD will obtain grading permits from Madera County and Merced County for construction of the groundwater basins. The District will apply for permits required from the State Water Board for diversion of water into the recharge basins to the extent that diversion is not already permitted under existing water rights and contracts. Recharge basin projects may require an environmental review process under CEQA. This would require either an Environmental Impact Report, and Negative Declaration, or a Mitigated Negative Declaration.

4.1.1.3 Project Operations and Monitoring

CWD will be responsible for project operations and monitoring. It will begin implementing the project in 2020 and continue to develop additional recharge basins up to the estimated buildout capacity of 1,000 acres by 2040. CWD will assess the performance of recharge basins in its feasibility assessments prior to development and continue to monitor and maintain basins after implementation.

The project will be operated based on the availability of flood flows or other sources of water supply. CWD expects that water will be available for recharge in approximately one out of three years. It will be delivered using existing CWD canals and laterals. During years in which water is available, at the maximum buildout of the project, CWD expects to deliver enough water to fill all 1,000 acres for 90 days. Delivery would typically occur during the winter and spring but could occur any time that surplus water is available.

CWD will monitor deliveries and performance of recharge basins. Extraction of recharged groundwater will be done by water users in CWD. If CWD determines that allocation of groundwater recharge is necessary, groundwater extraction will be monitored and enforced by CWD with meters installed on individual deep wells.

4.1.1.4 Project Benefits

Recharge basins provide groundwater benefits by diverting flows that would have otherwise left the Subbasin into ponds that allow water to percolate into the aquifer. CWD expects that the efficiency of recharge basins it develops will vary depending on the location of the basin and timing of deliveries. Recharge might be lower during wet periods if the soil is already saturated or if groundwater moves laterally into nearby streams, ultimately leaving the Subbasin. The estimated project benefits developed for the GSP are based on average conditions and assume that CWD will be able to develop basins in areas with the greatest potential recharge efficiency.

Based on a hydrologic and operations analysis covering the historical period, 1989-2014, and the resulting frequency and amount of recharge, the average annual net recharge benefit for an 80-acre basin would be 924 AF. For the full 1,000 acres at buildout, the net yield would average 10,800 AFY. The reliability of source water is based on historical hydrology being a good projection of future hydrology. **Table 4-5** summarizes the estimated annual net recharge benefit (new water that stays within the basin), expected probability of water year type, and the weighted-average annual recharge for the 80-acre recharge basin. **Appendix 4.A.** summarizes the estimated monthly benefit and corresponding weighted-average annual benefit of the project.

The reliability of the source water is based on historical hydrology being a good projection of future hydrology. In addition, the reliability depends on future water supply management, including changes to the CVP system and the San Joaquin River Restoration Program, as well as diversions of other flood flows or sources of water by other GSAs or other entities with rights to that water.

Table 4-5. CWD 80-acre Recharge Basin Estimated Average Recharge Volume by Year Type, in AF

Year Type	Total Annual Volume	% of Years	Weighted Avg.
W	2,772	35%	978
AN	2,772	14%	380
BN	0	8%	0
D	0	16%	0
C	0	27%	0
Avg. Annual			**1,359**

The gross benefit of additional recharge basins, up to the project buildout of 1,000 acres, is estimated to scale in proportion to the 80-acre basin. **Table 4-6** summarizes the estimated annual net recharge benefit (new water that stays within the basin), expected probability of water year type, and the weighted-average annual recharge for project buildout of 1000 acres of recharge basin in CWD. **Appendix 4.A.** summarizes the estimated monthly benefit and weighted-average annual benefit of the total CWD basin recharge project.

Table 4-6. CWD 1000-acres of Recharge Basins Estimated Average Recharge Volume by Year Type, in AF

Year Type	Total Annual Volume	% of Years	Weighted Avg.
W	28,325	35%	9,997
AN	5,869	14%	806
BN	0	8%	0
D	0	16%	0
C	0	27%	0
Avg. Annual			**10,803**

Recharge basins may also provide environmental benefits by creating seasonal or perennial habitat for wildlife including waterfowl, amphibians, and reptiles and serve as drinking water sources and foraging habitat for mammals.

4.1.1.5 Project Costs

CWD developed project costs for a typical 80-acre recharge basin. Costs for each basin will vary based on site characteristics and market conditions affecting land, construction, and material costs at that time. For example, CWD developed a recharge basin in 2018 for significantly less than the costs shown in **Table 4-7** because it was able to acquire land below current market prices. Capital costs include site survey, soil sampling, land purchase costs, earthwork, pumps, fencing, and power connection. Additional development costs including project administration, legal, permitting, and environmental review. Actual project costs may be lower than estimated costs if some of these activities are not required. Estimated project costs do not include groundwater extraction costs (which would be borne by private pumpers in CWD). All costs are reported in current 2019 dollars.

Table 4-7. Estimated Project Costs for an 80-Acre Recharge Basin

Item	Total Cost	Year Incurred	Notes
Capital Costs			
Land purchase and construction, 80-acre basin	$3,060,000	Start of construction	
O&M Costs			
Annual Power and other O&M	$10,000	All	$30,000 in 1 out of 3 years when water is available

Total capital and operating costs of 1,000 acres of recharge basins at project buildout will depend on site-specific characteristics of additional recharge basins that will be developed by CWD. If costs are approximately proportional to the 80-acre basin, the total capital cost of 1,000 acres of new recharge basins would be approximately $38.6 million in current dollars. Capital costs would be spread over the implementation period as additional recharge basins are developed. Operating costs for the project at buildout would be proportional to the 80-acre basin, depending on the efficiency of each individual recharge basin and water supply costs. Total capital costs, including land purchase, planning, permitting, and construction, are summarized in **Table 4-7**, in 2019 dollars.

4.1.2 Flood-MAR (Winter Recharge)

Flood Managed Aquifer Recharge (Flood-MAR) diverts surplus flows that would have otherwise left the basin onto farms and fields of willing participants (growers) to percolate into the aquifer and provide recharge benefits for the Subbasin. Flood-MAR requires that the GSA has capacity to capture and divert water to growers and requires willing growers to participate in the program. The Flood-MAR project assumes that growers would operate existing irrigation systems on their fields when CWD is able to provide water.

Preliminary feedback from stakeholders indicates that Flood-MAR may increase risks of crop damage. It imposes additional management costs on the GSA and additional operating costs on the grower to divert water, manage fields, and operate irrigation systems. CWD will evaluate incentive structures to encourage growers to participate in the program.

4.1.2.1 Project Overview

Flood-MAR is a groundwater recharge approach in which flood water available during winter and spring months is spread on agricultural or other suitable land for percolation to groundwater. The project is distinct from recharge basins that will be developed by CWD because existing land uses would be maintained, no basins would be constructed, and existing delivery facilities would be used. However, both projects rely on the same sources of supply: flood flows that are typically available in the winter and early spring that would have otherwise left the Subbasin.

A preliminary assessment using the Soil Agricultural Groundwater Banking Index (SAGBI) and current district cropping patterns was developed to evaluate the potential scale of the Flood-MAR project at full buildout. Assuming that Flood-MAR will be targeted to fields that provide the greatest recharge benefit (based on the SAGBI) and have crops that are suitable for Flood-MAR activities (including grapes and tree crops), CWD anticipates that about 13,000 acres will participate in its Flood-MAR program. CWD will develop economic analysis to identify incentive structures and further develop the Flood-MAR program starting in 2020.

4.1.2.2 Implementation

Because no new facilities are needed, the project can be implemented relatively quickly after CWD completes planning and permitting and prepares agreements with participating landowners. The rate of implementation will depend on the rate of adoption by CWD growers. CWD will develop economic studies to identify incentive structures to encourage participation in the Flood-MAR program. It is assumed that the project will be implemented starting in 2020 and will scale up as additional growers participate in the program (**Table 4-8**).

Table 4-8. Implementation Timeline

Phase	Start	End
Permitting and environmental documentation	2020	2020
Financing	2020	Indefinite
Construction	NA	NA
Operation	2020	Indefinite

4.1.2.2.1 Construction activities and requirements

Flood-MAR requires CWD to secure water supply and manage deliveries. Growers are required to manage fields and operate irrigation systems. However, no large-scale construction projects or significant capital outlays are required.

4.1.2.2.2 Water source

Water for recharge is expected to be available from one or more of the following sources:

- Flood releases from Buchanan Dam
- CVP surplus flows, when they are available, delivered by Madera Canal

The analysis of benefits below assumes that the source of water will be flood flows available from Buchanan Dam and Madera Canal. It does not account for other potential sources nor for any changes in operations elsewhere in the CVP system that might affect availability of surplus water.

The CWD Flood-MAR project will compete for water with recharge basins developed by CWD, and potentially, other GSAs. However, a preliminary assessment indicates that in very high runoff years the combined projects could capture and recharge more water in total than is included in the GSP implementation plan. The CWD project to expand Buchanan Dam (see Section 4.1.5) would also reduce available flood flows by the additional amount it would capture and store. The GSP analysis of potential yield (benefit) to the entire Subbasin includes a preliminary assessment of the joint effect of all proposed GSA PMAs.

4.1.2.2.3 Conditions or constraints on implementation

Winter and spring flooding can impose costs and inconvenience on participating landowners and therefore they must receive an incentive to participate. The incentive could be financial, or if CWD decides to monitor individual groundwater pumping it could come in the form of additional groundwater pumping credits that would accrue to participating landowners in proportion to the net recharge (percolation) benefits generated by their activity. The general incentive structure would need to provide a greater benefit to the landowner (in financial compensation or the value of recharge credits) than the total cost (including risk) to the grower. CWD will evaluate options as it further develops the Flood-MAR program.

Deliveries of flood flows will need to be coordinated with maintenance activities on canals and other delivery facilities, both within CWD and, if applicable, Madera Canal operators. The diversions are expected to occur during periods when flow exceeds beneficial or environmental uses. Nevertheless, CWD will need to evaluate whether the diversion of winter flood water affects existing uses of the water.

4.1.2.2.4 Permitting process and agencies with potential permitting and regulatory control

CWD has legal authority to deliver water to its customers. It would negotiate agreements with participating landowners for spreading the water and potentially develop additional incentive structures and agreements. If CWD determines that allocation of groundwater recharge is necessary, potentially to allocate groundwater recharge credits for participating in the Flood-MAR program, groundwater extraction will be monitored and enforced by CWD with meters installed on individual wells.

Additional percolation of water on agricultural lands can affect movement of nitrates or other constituents into groundwater. Coordination with the Central Valley RWQCB's Irrigated Lands Regulatory Program (ILRP) may be needed. Reclamation will be consulted if using CVP contract supply or Section 215 water.

4.1.2.3 Project Operations and Monitoring

During flood releases from Buchanan Dam and Madera Canal, CWD will make water available for flooding cropland under the Flood-MAR program. It is anticipated that the water will be delivered to about 21,400 acres of participating lands that have high percolation rates.

Extraction of a portion (for example, 80% to 90%, which will be determined by CWD) of the recharged groundwater will be done by water users in CWD using their private wells. If allocation of the project's groundwater recharge is determined to be necessary, groundwater extraction will be monitored and enforced by CWD with meters installed on individual wells.

4.1.2.4 Project Benefits

Groundwater recharge benefits are estimated using available flood flow over the historical hydrologic period 1989-2014. Based on the analysis, flood releases are expected to occur in approximately 1 out of 3 years. Flood-MAR sites will be identified such that nearly all will percolate to the groundwater. The expected average annual quantity of groundwater recharge is 5,836 AF (**Table 4-9**).

The reliability of the CWD Flood-MAR project is similar to the groundwater recharge basin project. Namely, the reliability of the source water is based on historical hydrology being a good projection of future hydrology. In addition, the reliability depends on future water supply management, including changes to the CVP system and the San Joaquin River Restoration Program.

Table 4-9. CWD Flood-MAR Estimated Average Annual Recharge Volume by Year Type, in AF

Year Type	Total Annual Volume	% of Years	Weighted Avg.
W	15,777	35%	5,522
AN	2,287	14%	314
BN	0	8%	0
D	0	16%	0
C	0	27%	0
Avg. Annual			**5,836**

4.1.2.5 Project Costs

Capital costs of the CWD Flood-MAR project are expected to be minimal because the project uses existing CWD facilities and grower irrigation systems. No construction or land acquisition costs are currently anticipated. It is also assumed that no additional permitting costs would be incurred.

The Flood-MAR project will create additional operating costs to CWD and growers that participate in the program. Operating costs are uncertain at this time and will be evaluated by CWD as part of its initial project development and evaluation of potential incentive structures. In general, operating costs for the Flood-MAR project include the cost of the water, CWD operating and maintenance costs, grower irrigation system cost, labor to irrigate, and labor to manage fields for recharge during times of the year when soils are typically saturated. O&M costs are not well known at this time. A cost of $50 per acre-foot (including district and grower O&M costs) is used to illustrate the potential costs of the Flood-MAR project (**Table 4-10**). Flood-MAR costs vary significantly depending on site specific characteristics. $50 per acre-foot is used as a conservative estimate of O&M (labor, energy, operations, maintenance, field work) based on a review of recent studies[63]. This assumes no (or minimal) field work or other management besides running irrigation systems.

Table 4-10. CWD Flood-MAR Estimated Project Costs

Item	Total Cost	Year Incurred	Notes
Capital Costs			
All	N/A	N/A	None anticipated
O&M Costs			
Estimated average annual district and grower O&M cost	$177,000	All	$177,000 reflects average annual cost. O&M costs are higher in years when water is available

4.1.3 Merced-Chowchilla Intertie

The CWD Merced-Chowchilla Intertie project would provide benefits to the Subbasin by allowing CWD to purchase excess water supply from Merced during years in which excess supplies are available. The project would consist of building a pipeline connection and negotiating short- and long-term transfer arrangements between CWD and water management entities in Merced. A preliminary reconnaissance-level feasibility assessment of the project was developed under earlier San Joaquin River Restoration Program planning efforts (**Appendix 4.B**). CWD will perform additional studies of the project to refine costs and explore partnership opportunities during the GSP implementation period.

4.1.3.1 Project Overview

Water conveyance facilities consisting of a canal, pipeline and appurtenant facilities would be constructed to convey water from Merced Irrigation District (Merced ID) to CWD. CWD would then use that water

[63] McMullin Groundwater Recharge Area Farmer Survey Report. Sustainable Conservation. 2015.

Groundwater Recharge through Winter Flooding of Agricultural Land in the San Joaquin Valley. RMC. October 2015.

Analyzing Cost-Effectiveness for Kings Basin Flood Flow Recovery. Report for Sustainable Conservation. March 2016.

Kocis and Dahlke. 2017. Availability of high-magnitude streamflow for groundwater banking in the Central Valley, California. Environ. Res. Lett. 12 084009.