Merced Subbasin Groundwater Sustainability Plan Sustainable Management Criteria

June 2019

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ACRONYMS

AF	Acre-Feet
AFY	Acre-Feet/Year
CASGEM	California Statewide Groundwater Elevation Monitoring
CCR	California Code of Regulations
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
CWC	California Water Code
DDW	Division of Drinking Water
DPR	Department of Pesticide Regulation
DWR	Department of Water Resources
EC	electrical conductivity
EPA	Environmental Protection Agency
ESJWQC	East San Joaquin Water Quality Coalition
GAMA	Groundwater Ambient Monitoring and Assessment
GQTM	Groundwater Quality Trend Monitoring
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
ILRP	Irrigated Lands Regulatory Program
MAF	million acre-feet
MCL	maximum contaminant level
mg/L	milligrams per liter
MOI	memorandum of intent
MOU	Memorandum of Understanding
RWQCB	Regional Water Quality Control Board
SED	Substitute Environmental Document
SGMA	Sustainable Groundwater Management Act
SMCL	secondary maximum contaminant level
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
USBR	United States Bureau of Reclamation

3. SUSTAINABLE MANAGEMENT CRITERIA

This section presents the sustainable management criteria developed for the Merced Subbasin GSP. GSP regulations collect several requirements of GSPs under the heading of "Sustainable Management Criteria." These criteria include:

- Sustainability Goal
- Undesirable Results
- Minimum Thresholds
- Measurable Objectives

The development of these criteria for the Merced GSP relied upon information about the Subbasin developed in the hydrogeologic conceptual model (chapter reference to be added), the descriptions of current and historical groundwater conditions (chapter reference to be added), the water budget (chapter reference to be added), and input from stakeholders during the GSP development process. The sustainable management criteria were discussed at multiple coordinating committee and stakeholder committee meetings over the months of March 2018 through August 2018 and revisited in Spring 2019 as additional progress was made on the water allocation framework and sustainable yield analysis.

This GSP considers the six sustainability indicators defined by SGMA in the development of sustainable management criteria. SGMA allows several pathways to meet the distinct local needs of each basin, including development of sustainable management criteria, usage of other sustainability indicators as a proxy, and identification as not being applicable to the basin.

3.1 SUSTAINABILITY GOAL

SGMA defines sustainable groundwater management as the "*management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results*" [CWC §10721(v)]. It further defines the sustainability goal to mean "*the existence and implementation of one or more groundwater sustainability plans that achieve sustainable groundwater management by identifying and causing the implementation of measures targeted to ensure that the applicable basin is operated within its sustainable yield*," [CWC §10721(u)] and requires the GSP(s) to define a succinct sustainability goal statement.

The sustainability goal succinctly states the GSAs' objectives and desired conditions of the Merced Subbasin. The Merced Subbasin is heavily reliant on groundwater, and users recognize the basin has been in overdraft for a long period of time. Undesirable results that have been experienced in the Subbasin are discussed in greater detail below, and include lowering of water levels, land subsidence, and wells going dry.

The sustainability goal for the Merced Subbasin is *to achieve sustainable groundwater management on a long-term average basis by increasing recharge and / or reducing groundwater pumping, while avoiding undesirable results.*

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

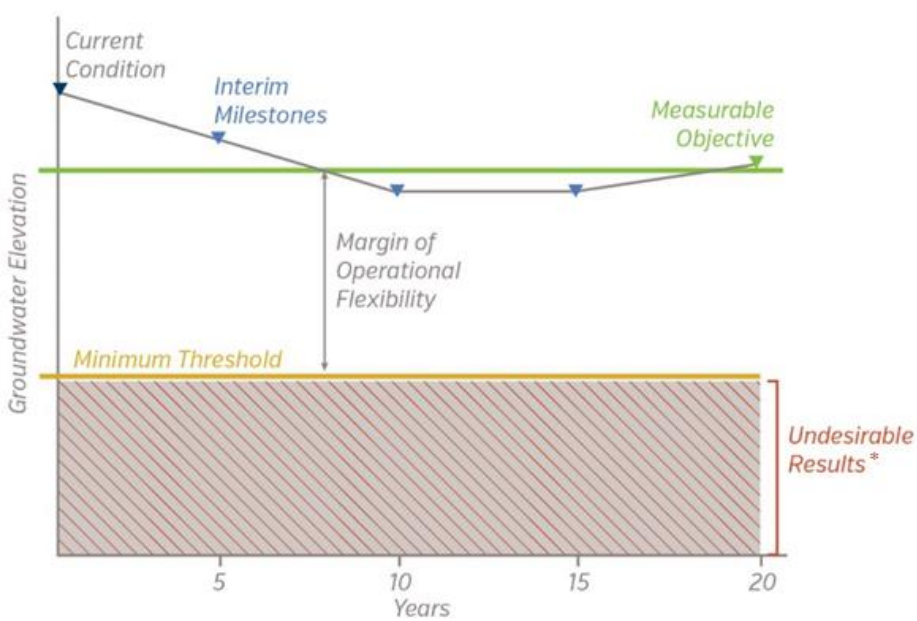
This sustainability goal is supported by the locally-defined minimum thresholds that sufficiently prevent undesirable results, presented later in this section. Demonstration by 2040 of stable groundwater elevations on a long-term average basis, combined with the absence of undesirable results, will support a determination that the basin is operating within its sustainable yield, and thus that the sustainability goal has been achieved.

Sustainable Management Criteria Definitions

- **Undesirable Results** – Significant and unreasonable negative impacts for each sustainability indicator that are used to guide development of GSP components
- **Minimum Thresholds** – "*A numeric value for each sustainability indicator used to define undesirable results" [*CCR Title 23, Division 2, §351(t)]
- **Measurable Objectives** – Quantitative targets that establish points above the minimum thresholds that allow for a range of active management in order to achieve the sustainability goal for the basin. Defined in the CCR as "*Specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted Plan to achieve the sustainability goal for the basin"* [CCR Title 23, Division 2, §351(r)]
- **Interim Milestones** – "*Target values representing measurable groundwater conditions, in increments of five years, set by an Agency as part of a Plan"* [CCR Title 23, Division 2, §351(q)]
- **Margin of Operational Flexibility**: The space between the measurable objective and the minimum threshold

See Figure 3-1 for a graphic that illustrates the conceptual relationship between the Sustainable Management Criteria terms.

Figure 3-1: Sustainable Management Criteria Conceptual Graphic (Groundwater Levels Example*)



** Note that exceeding the minimum threshold at one representative well does not necessarily trigger an undesirable result. Undesirable results are defined for each sustainability indicator in the sections below.*

3.2 MANAGEMENT AREAS

SGMA provides the option for GSAs to define management areas for portions of basins to facilitate groundwater management and monitoring. A management area is defined in SGMA as an "*area within a basin for which the [GSP] may identify different minimum thresholds, measurable objectives, monitoring, or projects and management actions based on differences in water use sector, water source type, geology, aquifer characteristics, or other factors*" [CCR Title 23, Division 2, §351(r)].

For example, GSAs may establish management areas where they desire a higher level of monitoring or wish to set more stringent minimum thresholds relative to the rest of the basin. Per DWR Guidance:

> *Management areas may be defined by natural or jurisdictional boundaries, and may be based on differences in water use sector, water source type, geology, or aquifer characteristics. Management areas may have different minimum thresholds and measurable objectives than the basin at large and may be monitored to a different level. However, GSAs in the basin must provide descriptions of why those differences are appropriate for the management area, relative to the rest of the basin.* (DWR, 2017, p. 6)

Management Areas have been discussed in the Merced GSP Stakeholder and Coordinating Committee Meetings, as well as GSA Board Meetings. At this time, there are no management areas established for the purposes of defining sustainability criteria for the Subbasin. However, the GSAs recognize that a consistent application of methods used to establish minimum thresholds and management objectives for each sustainability indicator can have a similar result of managing areas of the Subbasin without formally creating Management Areas. The GSAs may informally establish zones within their jurisdiction, in which to manage differently.

3.3 GROUNDWATER LEVELS

3.3.1 Undesirable Results

Description of Undesirable Results

The undesirable result related to groundwater levels is defined in SGMA as:

> *Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods. [CWC §10721(x)(1)]*

The undesirable result for chronic lowering of groundwater levels in the Merced Subbasin is sustained groundwater elevations that are too low to satisfy beneficial uses within the basin over the planning and implementation horizon of this GSP. During development of the GSP, undesirable results identified by stakeholders included:

- Significant and unreasonable unusable and stranded groundwater extraction infrastructure
- Significant and unreasonable reduced groundwater production
- Significant and unreasonable increased pumping costs due to greater lift and deeper installation or construction of new wells
- Significant and unreasonable number of shallow domestic wells going dry

Identification of Undesirable Results

For the Merced Subbasin, an undesirable result for declining groundwater levels is considered to occur during GSP implementation when November groundwater levels at greater than 25% of representative monitoring wells (7 of 25) fall below their minimum thresholds for two consecutive years where both years are categorized hydrologically as below normal, above normal, or wet[1]. Groundwater levels that fall below the minimum threshold during hydrologically dry or critical years are not considered to be an undesirable result, unless the groundwater levels fail to return to levels above the minimum thresholds following two consecutive non-dry/critical years.

Note that dewatering of a single domestic well is not considered significant and unreasonable and is not considered an undesirable result. The GSAs are evaluating mitigation for domestic wells that may be dewatered due to future declining groundwater levels.

Potential Causes of Undesirable Results

The Subbasin is currently considered in a state of critical overdraft per the DWR Bulletin 118 Interim 2016 Update. Potential causes of future undesirable results for the chronic lowering of groundwater levels could result from insufficient pumping reductions in the basin that result in localized or basin-wide groundwater level lowering, or delays in implementation of GSP programs or projects due to regulatory, permitting, or funding obstacles. Other potential causes could be external factors such as increased groundwater outflow from the Merced Subbasin to adjacent groundwater subbasins as a result of imbalances in groundwater pumping between the subbasins. Additionally, state- or federally-driven regulatory programs could dedicate surface water resources to environmental uses in the San Joaquin River or in downstream waterbodies such as the Sacramento-San Joaquin Delta, thus reducing water available to the Merced Subbasin. For example, increased flow requirements described by the Substitute Environmental Document (SED) for the Lower San Joaquin River and Southern Delta Bay-Delta Plan Update would likely cause impacts to groundwater levels.

Potential Effects of Undesirable Results

If groundwater were to reach levels that cause undesirable results, effects could include: de-watering of a subset of the existing groundwater infrastructure, starting with the shallowest wells, which are generally domestic wells; and adverse effects on groundwater dependent ecosystems, to the extent connected with the production aquifer. Lowering levels to this degree could necessitate changes in irrigation practices and crops grown, and could cause adverse effects to property values and the regional economy. Additionally, undesirable results for groundwater levels could adversely affect current and projected municipal uses, which rely on groundwater in the Subbasin, increasing costs for potable water supplies.

3.3.2 Minimum Thresholds

Minimum Threshold Background

The minimum thresholds for the chronic lowering of groundwater levels are selected to represent water levels that are just above conditions that could generate significant and unreasonable undesirable results in the Merced Subbasin, to the extent possible given available information. Future data may allow for refinement of these thresholds.

Within the Merced Subbasin, groundwater levels have been declining for several years (see Section # - Current & Historical Conditions). Groundwater levels during the recent drought declined at a faster rate, especially in the region designated as the Outside Corcoran Clay Principal Aquifer which is just east of the City of Merced, causing many domestic wells to go dry. As an emergency measure during the drought, Merced County facilitated a State of California tanked water program to make potable water available to approximately 130 domestic users whose wells had gone dry. This program ended in 2018. Figure 3-2 shows a map with the location of the tanked water program deliveries.

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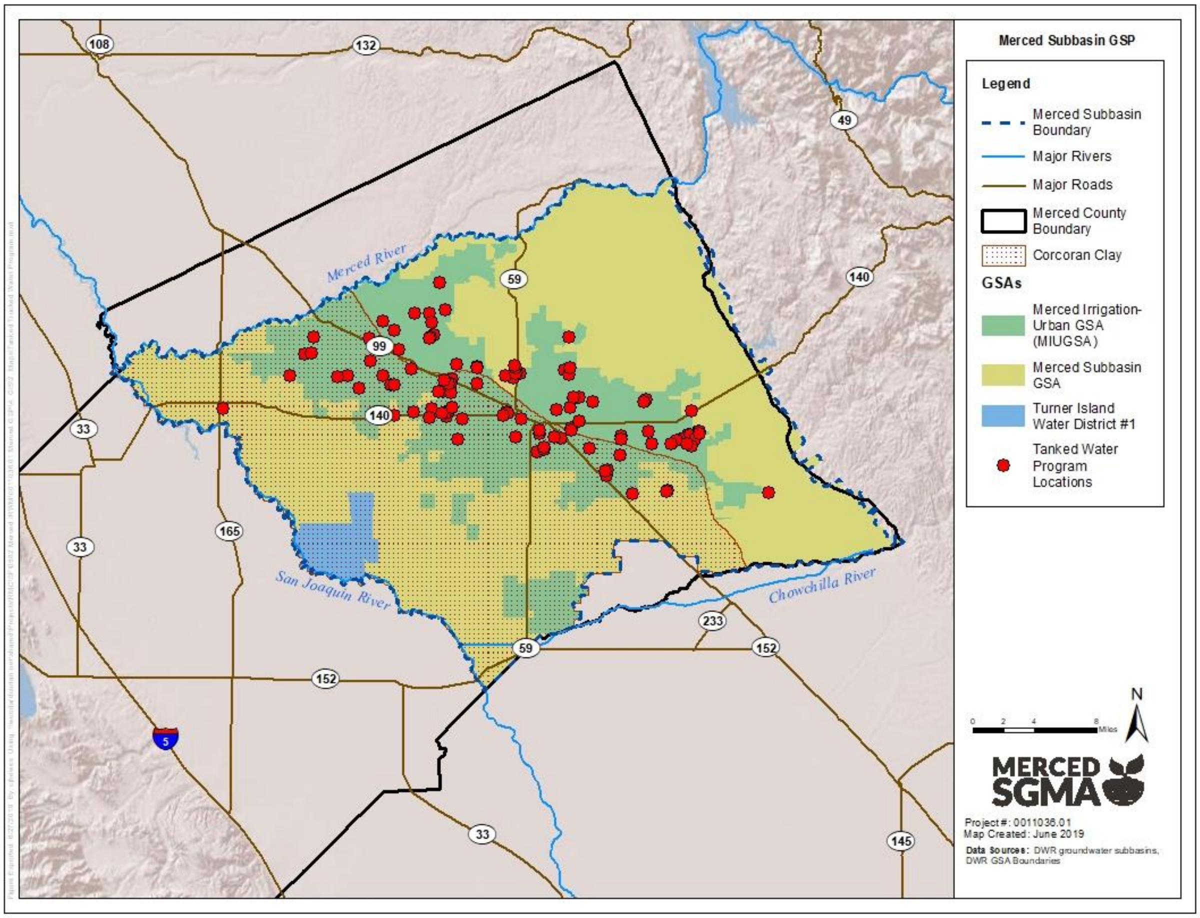
[1] Water Year Types based on San Joaquin Valley Water Year Index (DWR, 2018)

Figure 3-2: Merced Subbasin Tanked Water Program Locations



The Subbasin, as described in the Section # - Hydrogeologic Conceptual Model, is composed of three principal aquifers: Above, Below, and Outside of the Corcoran Clay. Minimum thresholds were defined for these three areas by selecting monitoring wells considered representative within each principal aquifer and establishing a threshold groundwater elevation for each well.

Domestic wells were used during the analysis of developing the thresholds at monitoring wells, as they are generally shallower than agricultural and municipal wells and thus more protective for setting thresholds. Additionally, a domestic well going dry usually results in impacts to those relying on that water source including a loss of water for consumption, cooking, and sanitary purposes, and financial burdens associated with finding alternative water sources or deepening wells.

Minimum Threshold Selection

The minimum threshold for groundwater levels was defined as the construction depth of the shallowest domestic well within a 2-mile radius. Based on the undesirable results described in Section 3.3.1, dewatering of domestic wells is considered the most protective indicator since domestic wells are expected to be the most shallow groundwater-accessing infrastructure.

Merced County's electronic well permitting database was used to determine the shallowest domestic well depth within two miles of each representative monitoring well (defined as a circle around the monitoring well with radius of 2 miles).

The Merced County well permitting database includes domestic wells permitted by the County well since the early- to mid-1990s. The database was filtered to omit known inactive wells, wells that do not meet County annular seal requirements (depth of 50 feet or less), and a small number of other outliers[1]. However, it is still possible that the resulting dataset includes wells that have become inactive but are not flagged in the County's database.

In the case of one representative monitoring well (CASGEM ID 28392), recent elevation data indicate the shallowest domestic well may already have been dewatered. In this case, the minimum threshold was moved to match the minimum groundwater elevation recorded at that location prior to January 1, 2015.

Representative Monitoring Wells for Minimum Threshold

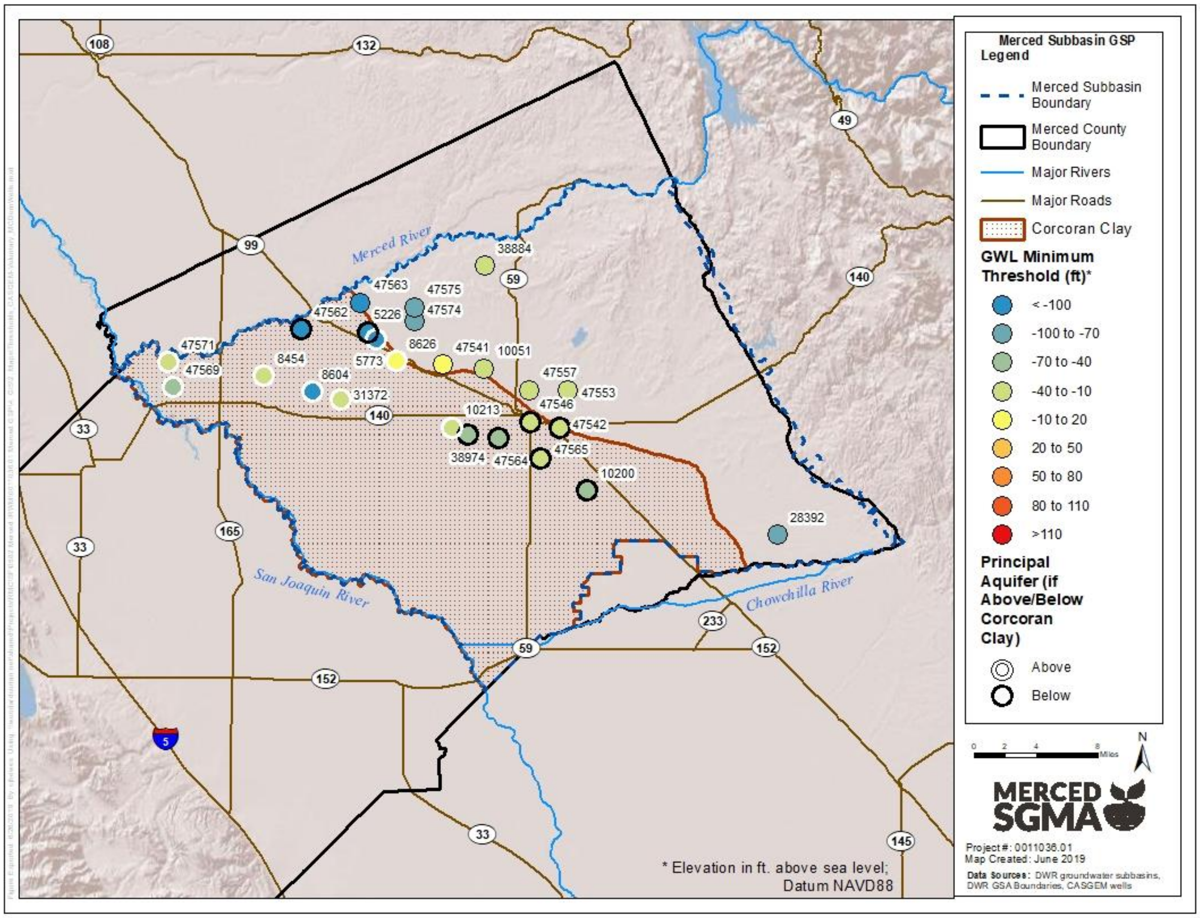
A subset of CASGEM wells serve as the representative monitoring wells. Minimum thresholds were developed for 25 out of 50 CASGEM wells in the Subbasin and are considered the best representation of the Subbasin using best available information. CASGEM wells were selected as they are actively managed and have previously been identified as appropriate for regional monitoring activities. Not all CASGEM wells were selected to be representative. For instance, only one well per unique set of multiple completion wells was considered for representative monitoring.

A data gap has been identified for the western portion of the Subbasin and this is described in more detail in Section #.#.

As additional wells are added to the monitoring network, they will be reviewed against the minimum threshold methodology for inclusion as representative monitoring wells. For regions of the Subbasin where there are no domestic wells within a 2-mile radius and/or there are no data available for pre-2015 groundwater levels, the GSAs will develop a new method for setting minimum thresholds during the next five-year update. One option may be to use projected groundwater levels from the MercedWRM to determine a suitable minimum threshold. Figure 3-3 shows the elevation of the minimum threshold for all the representative monitoring wells. Additional information about minimum thresholds can be found in Table 3-1 following the discussion of measurable objectives.

[1] Outlier Analysis: at each representative monitoring well, the interquartile range of domestic wells was calculated (75th percentile depth minus 25th percentile depth). Domestic wells were flagged as outliers and excluded from the threshold analysis if they had a depth that was shallower than: (25th percentile domestic well depth) – 1.5 * (Interquartile Range)

Figure 3-3: Minimum Thresholds at Representative Monitoring Well Sites



Groundwater levels are also used as a proxy indicator for depletion of interconnected surface water in Section 3.8.

3.3.3 Measurable Objectives and Interim Milestones

Measurable objectives are quantitative targets that establish a point above the minimum threshold that allow for a range of active management of the basin in order to achieve the sustainability goal for the basin. The condition between the measurable objective and the minimum threshold is known as the margin of operational flexibility (MoOF). The MoOF is intended to accommodate droughts, climate change, conjunctive use operations, or other groundwater management activities.

The measurable objective is set at the projected average future groundwater level, which was developed under the MercedWRM sustainable yield simulation described in Section #.# - Water Budgets. In cases in which the average sustainable yield groundwater level was projected to be within 25 feet of the minimum threshold or below the minimum threshold, the measurable objective was set at a level 25 feet above the minimum threshold. The value of 25 feet was based on a 10-year decline of -2.4 ft/yr in the Below Corcoran Clay Principal Aquifer in historical groundwater elevations discussed in Section #.#.#.#, and was intended to provide a reasonable margin of operational flexibility. Table 3-1 shows the measurable objective for each representative monitoring well. Appendix # contains a hydrograph for each representative monitoring well in Table 3-1, showing the relationship between historical groundwater elevations, simulated groundwater levels, the shallowest domestic well within a 2-mile radius, the minimum threshold, and the measurable objective.

To facilitate the Subbasin reaching its measurable objective for groundwater levels, interim milestones have been established to keep implementation on track. Where historical groundwater levels are consistently higher than the measurable objective, interim milestones were set equal to the measurable objective. When at least one historical groundwater level is below the measurable objective, the interim milestones were developed as follows:

- Year 5 (2025) and Year 10 (2030): set at the lowest groundwater level in the past 5 years (2014-2018). For three sites without groundwater level data 2014-2018, the most recent groundwater level from 2012 or 2013 was used instead.
- Year 15 (2035): set at the midpoint between the recent historical low and the measurable objective.

Interim milestones are shown on Table 3-1.

Table 3-1: Groundwater Level Minimum Thresholds, Measurable Objectives, 2015 Elevations, and Interim Milestones for Representative Wells

State Well ID	CASGEM ID	Principal Aquifer	Minimum Threshold Elevation[1]	Measurable Objective Elevation[1]	2015 Elevation[1,2]	2015 Elevation Measurement Date[2]	Interim Milestone Elevation[1]		
							2025	2030	2035
06S12E33D001M	5773	Above	-102.5	50.4	57.5	10/9/2014	46.5	46.5	48.4
07S11E07H001M	8454	Above	-17.4	72.6	29.4	12/1/2013	50.5	50.5	61.6
07S11E15H001M	8604	Above	-112.0	63.6	58.9	10/20/2014	31.2	31.2	47.4
07S12E03F001M	8626	Above	4.9	41.5	59.4	10/15/2014	41.5	41.5	41.5
07S13E30R002M	10213	Above	-28.9	41.1	18.6	12/1/2013	41.1	41.1	41.1
07S11E24A001M	31372	Above	-27.2	54.9	60.6	10/20/2014	50.8	50.8	52.9
07S10E17D003M	47569	Above	-43.0	66.3	67.6	10/14/2014	70.2	70.2	68.2
07S10E06K002M	47571	Above	-39.8	63.6	62.0	10/14/2014	49.9	49.9	56.7
06S12E29L002M	5226	Below	-156.0	54.4	68.4	3/1/2012	36.1	36.1	45.3
08S14E15R002M	10200	Below	-52.8	5.5	100.5	12/1/2013	5.5	5.5	5.5
07S13E32H001M	38974	Below	-55.6	34.3	86.4	10/16/2014	34.3	34.3	34.3
07S14E35E001M	47542	Below	-31.1	10.4	73.6	8/19/2014	10.4	10.4	10.4
07S14E30R001M	47546	Below	-10.9	14.1	72.9	8/20/2014	14.1	14.1	14.1
06S11E27F001M	47562	Below	-107.2	69.0	65.8	10/16/2014	58.8	58.8	63.9
07S13E34G001M	47564	Below	-50.3	21.8	78.2	10/16/2014	-101.5	-101.5	-39.8
08S14E06G001M	47565	Below	-15.1	12.5	71.9	10/31/2014	12.5	12.5	12.5
07S13E09A001M	10051	Outside	-27.5	34.0	85.7	10/8/2014	34.0	34.0	34.0
08S16E34J001M	28392	Outside	-88.5	-51.9	-88.5	10/30/2014	-51.9	-51.9	-51.9
06S13E04H001M	38884	Outside	-35.7	70.8	138.0	12/1/2013	69.3	69.3	70.0
07S12E07C001M	47541	Outside	14.7	39.7	61.1[3]	3/4/2015[3]	39.7	39.7	39.7
07S14E16F004M	47553	Outside	-21.1	14.9	74.3	8/21/2014	61.2	61.2	38.1
07S13E13H004M	47557	Outside	-23.2	9.2	75.8	9/23/2014	9.2	9.2	9.2
06S12E17M001M	47563	Outside	-126.5	68.5	53.5	10/9/2014	29.4	29.4	49.0
06S12E23P001M	47574	Outside	-75.0	46.9	66.0	9/29/2014	46.9	46.9	46.9
06S12E23C001M	47575	Outside	-89.0	58.7	59.0	9/29/2014	58.7	58.7	58.7

1. *Minimum Thresholds, Measurable Objectives, 2015 Elevations, and Interim Milestones are reported as groundwater elevations in feet above sea level, datum: NAVD88.*
2. *"2015 Elevations" are shown for the most recent elevation recorded before 1/1/2015. For most wells, this is fall 2014. A handful of wells show a most recent elevation prior to 1/1/2015 that is in 2012 or 2013.*
3. *CASGEM ID 47541 does not have groundwater elevations recorded prior to 1/1/2015, so the earliest elevation in 2015 is reported.*

3.4 REDUCTION OF GROUNDWATER STORAGE

3.4.1 Undesirable Results

Undesirable results related to significant and unreasonable depletions of groundwater storage are not present and not expected to occur in the Subbasin, as described below.

The Merced Subbasin has approximately 50 million acre-feet (MAF) of fresh (non-saline) groundwater storage as of 2015 (see Section #). Additionally, analysis of groundwater storage has shown a cumulative change in storage of less than -3 MAF over the 20-year period of 1995-2015. This cumulative change in storage, which includes both representative dry and wet years, is approximately 5%-6% of the total estimated available fresh groundwater in storage, or 0.3% per year. It is not reasonable to expect that the available groundwater in storage would be exhausted to a significant and unreasonable extent within any foreseeable time period.

3.4.2 Minimum Thresholds and Measurable Objectives

Minimum thresholds and measurable objectives for reduction of groundwater storage were not developed because, as discussed previously, undesirable results related to groundwater storage are not present and are not likely to occur in the Subbasin.

3.5 SEAWATER INTRUSION

Seawater intrusion is not an applicable sustainability indicator, because seawater intrusion is not present and is not expected to occur due to the distance between the Subbasin and the Pacific Ocean (and Sacramento-San Joaquin Delta).

3.6 DEGRADED WATER QUALITY

3.6.1 Undesirable Results

Description of Undesirable Results

The undesirable result related to degraded water quality is defined in SGMA as:

> *Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies. [CWC §10721(x)(4)]*

Where it exists, the undesirable result for degraded water quality is a result stemming from a causal nexus between groundwater extractions and potential other SGMA-related groundwater quantity management activities, and groundwater quality that causes significant and unreasonable reduction in the long-term viability of domestic, agricultural, municipal, or environmental uses over the planning and implementation horizon of this GSP.

In identifying undesirable results for the Subbasin, the GSAs sought input from beneficial users through multiple venues including the stakeholder advisory committee and public workshops held in locations specifically selected to provide access to disadvantaged communities. The protection of water quality for drinking and for agricultural use was identified as a priority for users in the basin. Degraded water quality is unique among the six sustainability indicators because it is already the subject of extensive federal, state, and local regulations carried out by numerous entities and SGMA does not directly address the role of GSAs relative to these other entities (Moran & Belin, 2019). The GSAs also sought input from the Merced County Division of Environmental Health. There are several constituents of concern in the Subbasin (see Section #.# - Current and Historical Conditions - Water Quality). This GSP focuses on salinity as the constituent with the strongest causal nexus between water quality and SGMA groundwater management activities while including coordination with other water quality programs and agencies in the Subbasin.

Identification of Undesirable Results

This result is considered to occur during GSP implementation when at least 25% of representative monitoring wells (5 of 19 sites) exceed the minimum threshold for degraded water quality for two consecutive years.

Note that while a concentration exceeding a minimum threshold at a single representative well is not considered an undesirable result as defined by this GSP, it will trigger review and investigation by the GSAs as described below.

Potential Causes of Undesirable Results

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

Salinity was selected by the GSAs based on stakeholder input and the recommendation of the Merced County Division of Environmental Health as a constituent to monitor because of the causal nexus between water quality and SGMA groundwater management activities (see Section 3.6.2 - Minimum Thresholds). Relatively high salinity groundwater in the basin has the potential for migration which could be induced by groundwater extraction. These areas of relatively high salinity groundwater are primarily located along the west side of the Subbasin, adjacent to the San Joaquin River and urban use areas such as the cities of Livingston and Atwater. High salinity groundwater is principally the result of the migration of a deep saline water body which originates in regionally-deposited marine sedimentary rocks that underlie the San Joaquin Valley. High TDS water in the Subbasin is naturally occurring from these naturally occurring marine sedimentary rocks and well pumping can result in upwelling of saline brines. Though Corcoran Clay naturally impedes high TDS groundwater, high permeability pathways through the clay from the Below Corcoran Principal Aquifer to the Above Corcoran Principal Aquifer may be created by perforated wells. In addition, this poorer-quality water can migrate across the Subbasin from the west to the east (AMEC, 2008). Better quality groundwater (less than 1,000 mg/L) in these western and southwestern areas is generally found at shallower depths (AMEC, 2008), generally in the Below Corcoran Principal Aquifer .

Note that accumulation of salts due to agricultural activities, urban wastewater, or other land use activities do not have a causal nexus with SGMA groundwater management activities and are not part of the undesirable results.

Potential Effects of Undesirable Results

If groundwater quality were degraded to reach levels causing undesirable results, the effect could potentially cause a reduction in usable supply to groundwater users, with domestic wells being most vulnerable as treatment or access to alternate supplies may be unavailable or at a high cost for small users. Water quality degradation could cause potential changes in irrigation practices, crops grown, adverse effects to property values, and other economic effects. Additionally, reaching undesirable results levels for groundwater quality could adversely affect current and projected municipal uses, and users could have to install wellhead treatment systems or seek alternate supplies.

3.6.2 Minimum Thresholds

Minimum Threshold Applicability

Degraded water quality is unique among the six sustainability indicators because it is already the subject of extensive federal, state, and local regulations carried out by numerous entities and SGMA does not directly address the role of GSAs relative to these other entities (Moran & Belin, 2019). SGMA does not specify water quality constituents that must have minimum thresholds. Establishing minimum thresholds for constituents that cannot be managed by increasing or decreasing pumping was deemed inappropriate by the GSAs. Groundwater management is the mechanism available to GSAs to implement SGMA. Other water quality concerns are being addressed through various water quality programs (e.g., CV-SALTS and ILRP) and agencies (e.g., RWQCB, EPA) that have the authority and responsibility to address them. The GSAs will abide by any future local restrictions that may be implemented by the agencies or coalitions managing these programs. These water quality issues without a causal nexus in the Merced Subbasin include:

- **Naturally occurring constituents such as arsenic, uranium, iron, and manganese:** the GSAs do not have control over the presence of these constituents in aquifer materials. Thresholds are not set for these constituents as there is no demonstrated local correlation between fluctuations in groundwater elevations and/or flow direction and concentrations of these constituents at wells.

- **Constituents from human activities that are not managed under SGMA:** pesticides, herbicides, and fertilizers may be present from agricultural and, to a lesser degree, urban uses. Existing programs, including CV-SALTS, ILRP, and regulation by the California Department of Pesticide Regulation, are designed to address these concerns. Thresholds are not set for these constituents as the GSAs have no authority to limit the loading of nutrients or agrochemicals. However, as mentioned above, the GSAs will abide by any future local restrictions that may be implemented by agencies managing such programs.

- **Constituents from human activities at contaminated sites managed under other regulatory authority:** constituents at the former Castle Air Force Base and other smaller contaminated sites are under cleanup orders set by state or federal agencies. The potentially responsible parties are required to contain contaminants and remediate the groundwater. Data collected as part of GSP monitoring will be provided to regulators upon request. Thresholds are not set for these constituents as the GSAs are not responsible and do not have authority for containment or cleanup of these sites.

The major water quality issue being addressed by sustainable groundwater management is the migration of relatively higher salinity water into the freshwater principal aquifers. The nexus between water quality and water supply management exists for the pumping-induced movement of low-quality water from the west and northwest to the east.

The GSAs sought input from the Merced County Division of Environmental Health (Division) during the development of water quality minimum thresholds. The Division agrees that salinity is a good indicator for water quality issues and trends that are related to Subbasin groundwater management activities. In addition, the Division recommended that the GSAs make use of resources like GeoTracker and Envirostor and to closely coordinate with agencies that already monitor contamination plumes.

While the GSP does not set thresholds for the types of constituents described above, conditions in the basin are summarized in Section # and will be summarized in future GSP updates. The GSAs will conduct the following ongoing water quality coordination activities:

- Monthly review of data submitted to the Department of Pesticide Regulation (DPR), Division of Drinking Water (DDW), Department of Toxic Substances Control (EnviroStor), and GeoTracker as part of the Groundwater Ambient Monitoring and Assessment (GAMA) database.

- Quarterly check-ins with existing monitoring programs, such as CV-SALTS and ESJWQC GQTM.

- Annual review of annual monitoring reports prepared by other programs (such as CV-SALTS and ILRP)

- GSAs will invite representative(s) from the Regional Water Quality Control Board, Merced County Division of Environmental Health, and ESJWQC to attend an annual meeting of the GSAs to discuss constituent trends and concerns in the Subbasin in relation to groundwater pumping.

The purpose of these reviews will be to monitor and summarize the status of constituent concentrations throughout the Subbasin with respect to typical indicators such as applicable MCLs or SMCLs. The Merced Subbasin GSP Annual Report and 5-Year Update will include a summary of the coordination and associated analyses of conditions. The GSP 5-year updates may include evaluation of whether additional minimum thresholds are needed.

Minimum Threshold Selection

Salinity is a measure of the amount of dissolved particles and ions in water. Salinity can include several different ions, but the most common are chloride, sodium, nitrate, calcium, magnesium, bicarbonate, and sulfate. While there are several different ways to measure salinity, the two most frequently used are Total Dissolved Solids (TDS) and Electrical Conductivity (EC). TDS is a measure of all dissolved substances that can pass through a very small filter (typically with 2-micrometer pores) and is typically reported in milligrams per liter (mg/L). EC measures the ability of an electric current to pass through water because conductivity is proportional to the amount of dissolved salts in the water. It is generally reported in microSiemens/cm. Salinity throughout this GSP is reported in terms of TDS.

Minimum thresholds for salinity are defined based on its potential impact on drinking water and agricultural uses, as aligned with state and federal regulations. The recommended drinking water secondary MCL for TDS is 500 mg/L with an upper limit of 1,000 mg/L and a short-term limit[1] of 1,500 mg/L (SWRCB, 2006). The secondary MCL was established by the USEPA and then adopted by the SWRCB. The secondary MCL is a secondary drinking water standard that is established for aesthetic reasons such as taste, odor, and color and is not based on public health concerns. For agricultural uses, salt tolerance varies by crop, with common crops within the Merced Subbasin (almonds, sweet potatoes, tomatoes, alfalfa, corn, and grapes (Merced County Department of Agriculture, 2017)) tolerant of irrigated water with TDS below about 1,200 mg/L at a 90% crop yield potential (Ayers & Westcot, 1985). [2]

Salinity levels within the Merced Subbasin have historically ranged widely from less than 90 mg/L to greater than 3,000 mg/L as measured by TDS. Generally, similar to other basins in the eastern San Joaquin Valley, TDS tends to increase from the foothills to the trough of the Valley. TDS in the eastern two-thirds of the Subbasin is generally less than 400 mg/L. TDS increases westward and southwestward towards the San Joaquin River and southward towards the Chowchilla River. In these areas, high TDS water is found in wells deeper than 350 feet (AMEC, 2008). TDS is slightly elevated in certain urban portions of the northern Subbasin, such as beneath the Atwater and Winton areas (AMEC, 2008).

Most recent 2000-2016 TDS concentrations in the Merced Subbasin, as analyzed by the CV-SALTS program, ranged widely from 90 mg/L to 2,005 mg/L. In the northwest area of the Above Corcoran Clay, average TDS is greater than 751 mg/L. Average TDS concentration in the Below Corcoran Clay is lowest in the North (less than 501 mg/L) and increases in the Southwest to over 1,000 mg/L (Luhdorff and Scalmanini Consulting Engineers, 2016).

Given these conditions, a minimum threshold of 1,000 mg/L was selected for each representative monitoring well to be protective against undesirable results related to elevated salinity.

Representative Monitoring Wells for Minimum Threshold

The East San Joaquin Water Quality Coalition (ESJWQC) is a group of agricultural interests and growers formed to represent all dischargers who own or operate irrigated lands east of the San Joaquin River within Madera, Merced, Stanislaus, Tuolumne and Mariposa Counties and portions of Calaveras County. The ESJWQC has developed a Groundwater Quality Trend Monitoring workplan (GQTM) as part of the Irrigated Lands Regulatory Program (ILRP), which includes a targeted set of domestic wells (denoted as principal wells) supplemented by public water system wells (denoted as complementary wells) (ESJWQC, 2018). All ESJWQC GQTM program principal monitoring wells in the Merced Subbasin are used as representative monitoring wells for this GSP. More information about these representative monitoring wells and plans to fill data gaps are included in Section #.# - Monitoring Networks. Additional information about minimum thresholds can be found in Table 3-2 following the discussion of measurable objectives.

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

[2] An average value of 1.8 dS/m was converted using University of California Agriculture and Natural Resources salinity unit conversion formula of TDS (mg/L) = Electrical Conductivity (dS/m) * 640 (applicable for electrical conductivity ranging 0.1 to 5 dS/m).

3.6.3 Measurable Objectives and Interim Milestones

The measurable objective is a TDS concentration of 500 mg/L, which aligns with the Secondary MCL for TDS. The margin of operational flexibility (MoOF) is 500 mg/L TDS, the difference between the measurable objective of 500 mg/L and the minimum threshold of 1,000 mg/L.

In the case of degraded water quality, specifically for salts, there is a natural tendency for salt concentrations to increase over time due to agricultural and urban uses of water, which add salts either directly or through evapotranspiration. As previously noted, such increases are not due to a causal nexus with SGMA activities and would not constitute an undesirable result under this GSP. Continued monitoring data will be analyzed for trends, and future increasing trends will be analyzed for evidence of the sources of the trends, such as upward migration of the body of relatively higher salinity water due to overpumping or due to continued agricultural and urban uses. If caused by upward migration, GSAs will respond accordingly due to the causal nexus with groundwater pumping. If caused by continued urban and agricultural use, the trends will be noted and communicated with other programs, such as CV-SALTS.

Table 3-2 shows the measurable objective for each representative monitoring well. Interim milestones are set at the same concentrations as the measurable objectives.

Table 3-2: Groundwater Quality Minimum Thresholds & Measurable Objectives

ESJGWQC GQTM Well ID	Complementary or Principal?[1]	Principal Aquifer	Minimum Threshold (mg/L TDS)	Measurable Objective (mg/L TDS)
P06	Principal	Outside	1,000	500
P07	Principal	Below	1,000	500
P08	Principal	Outside	1,000	500
P09	Principal	Below	1,000	500
P10	Principal	Below	1,000	500
C35	Complementary	Above	1,000	500
C41	Complementary	Above	1,000	500
C45	Complementary	Above	1,000	500
C38	Complementary	Below	1,000	500
C44	Complementary	Below	1,000	500
C40	Complementary	Outside	1,000	500
C42	Complementary	Outside	1,000	500
C43	Complementary	Outside	1,000	500
C46	Complementary	Outside	1,000	500
C47	Complementary	Outside	1,000	500
C39	Complementary	Outside	1,000	500
C48	Complementary	Outside	1,000	500
C49	Complementary	Unknown	1,000	500
C50	Complementary	Unknown	1,000	500

1. *Complementary and Principal wells are defined in Section #.#.#.*

3.7 LAND SUBSIDENCE

3.7.1 Undesirable Results

Description of Undesirable Results

The Undesirable Result for land subsidence is a result that causes significant and unreasonable reduction in the viability of the use of infrastructure over the planning and implementation horizon of this GSP. Land subsidence that substantially interferes with surface land uses causes damage to public and private infrastructure (e.g., roads and highways, flood control, canals, pipelines, utilities, public buildings, residential and commercial structures).

The undesirable result related to land subsidence is defined in SGMA as:

> *Significant and unreasonable land subsidence that substantially interferes with surface land uses. [CWC §10721(x)(5)]*

The main conveyance facility that has the potential to be damaged or have reduced flood conveyance capacity due to subsidence is the Eastside Bypass, located in the southwest corner of the Merced Subbasin.

Identification of Undesirable Results

Exceedances of land subsidence minimum thresholds at three or more monitoring sites out of four for two consecutive years, where both years are categorized hydrologically as below normal, above normal, or wet[1], will quantitatively indicate that the Subbasin has reached undesirable results for land subsidence.

Potential Causes of Undesirable Results

Land subsidence is a direct result of over extraction of groundwater in the Subbasin overall. Subsidence has been observed in the southwestern portion of the Subbasin and encompasses areas included in all three GSAs. Subsidence is thought to be caused by groundwater extraction below the Corcoran Clay and compaction of clays below the Corcoran Clay (DWR, 2017). The transition from pasture or fallowed land to row and permanent crops adjacent to the San Joaquin River is thought to have created an increased groundwater pumping demand in an area that is not, at this time, provided with significant alternate surface water supplies (Reclamation, 2016).

Potential Effects of Undesirable Results

Land subsidence leads to compaction of the subsurface, changing the ground surface and potentially impacting existing infrastructure and land use. Effects include potential increases in the conveyance costs of irrigation water and in the ability to convey floodwater. The integrity of conveyance structures, which are typically gravity-driven, may be compromised with changes in land surface gradient. Subsidence could result in the need for higher dams or pumps to move surface water. Similarly, the capacity of flood conveyance systems can be reduced due to subsidence, resulting in a need for higher levees or other flood control infrastructure.

3.7.2 Minimum Thresholds

Minimum thresholds were selected to represent conditions that are just above conditions that could collectively generate undesirable results. While the sensitivity of local infrastructure to land subsidence is not well understood, the ability to convey water supplies and flood water, including the ability to maintain levees, are currently observed to be the most sensitive to land subsidence. Should additional information be developed on vulnerability to subsidence, these minimum thresholds may be refined.

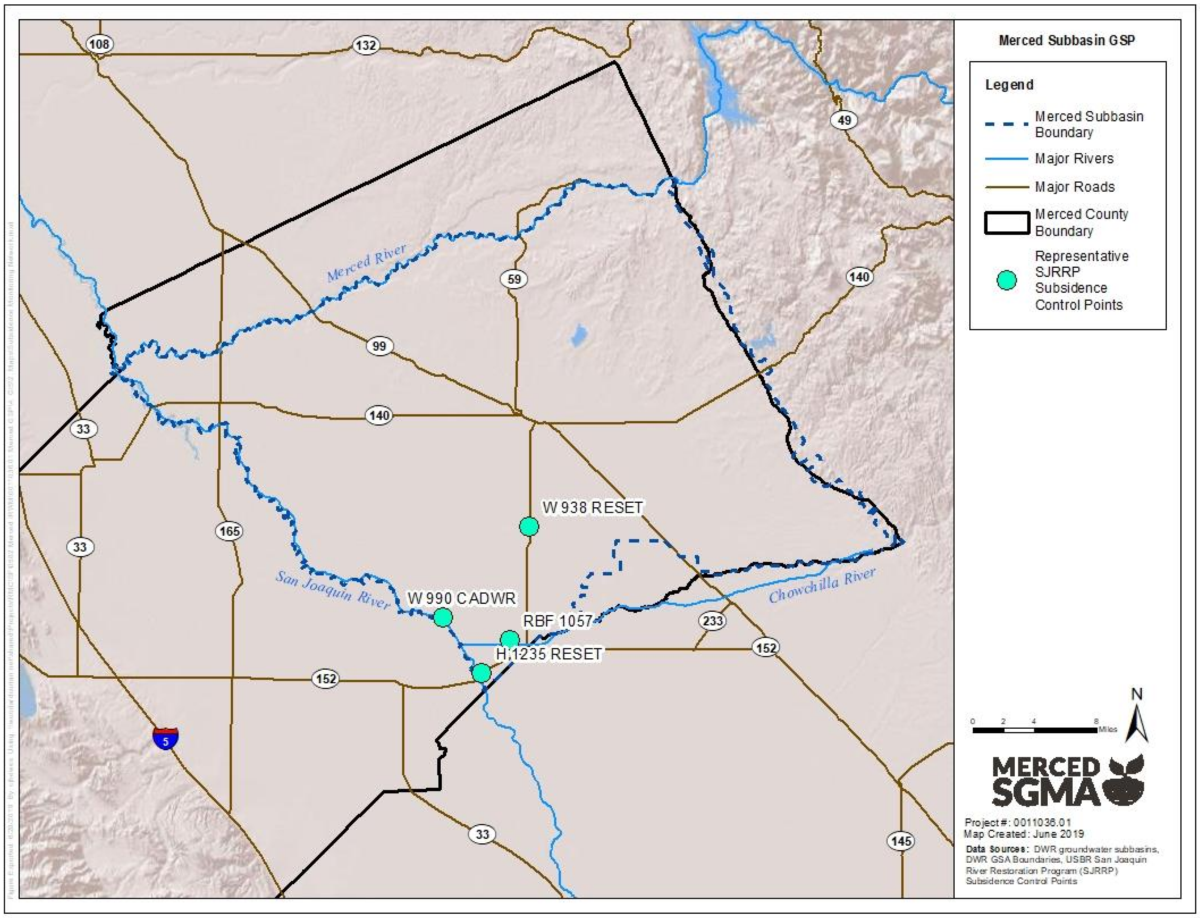
Minimum thresholds are set at four locations within the area of subsidence risk which are monitored for land subsidence by the US Bureau of Reclamation (USBR)on a semiannual basis as part of their San Joaquin River

[1] Water Year Types based on San Joaquin Valley Water Year Index (DWR, 2018)

Restoration Program. These locations, with their maximum single year (December-to-December) subsidence rates during USBR's monitoring period of 2011 to 2018, are listed below. A map of the locations is shown in Figure 3-4.

- W 990 CADWR: maximum recent subsidence of -0.65 ft/year (December 2014 – December 2015)
- RBF 1057: maximum recent subsidence of -0.67 ft/year (December 2012 – December 2013)
- H 1235 Reset: maximum recent subsidence of -0.61 ft/year (December 2012 – December 2013)
- W 938 Reset: maximum recent subsidence of -0.58 ft/year (December 2014 – December 2015)

Figure 3-4: Minimum Threshold Subsidence Locations



Within the Merced Subbasin, while subsidence has been recognized by the GSAs as an area of concern, it is not considered to have caused a significant and unreasonable reduction in the viability of the use of infrastructure. However, it is noted that subsidence has caused a reduction in freeboard of the Middle Eastside Bypass over the last 50 years and has caused problems in neighboring subbasins, highlighting the need for ongoing monitoring and management in the Merced Subbasin.

Recent subsidence in the Merced Subbasin, December 2017 – December 2018, is between -0.17 ft/yr and -0.32 ft/year, depending on the location, despite wetter conditions. Continued subsidence at this rate, despite groundwater levels that are likely higher due to wetter conditions, is common with compaction of clays dewatered over time from historical lowering of groundwater levels. Thus, some level of future subsidence may already be locked in, with long-term subsidence due to pre-2015 groundwater elevations. Subsidence is a gradual process that takes time to develop and time to halt. Some portion of the experienced subsidence is inelastic compaction, meaning that the soil subsidence due to groundwater pumping is permanent.

Given the lack of historical undesirable results and given the degree to which subsidence may already be locked-in due to historical groundwater production, land subsidence minimum thresholds are set at each of the four locations at a rate of -0.75 ft/year. This is a rate that is slightly higher than maximum annual subsidence rates experienced between 2011 and 2018 that did not result in significant and unreasonable effects within the Merced Subbasin.

Subsidence rates for minimum thresholds may be reconsidered if additional information becomes available on the sensitivity of existing infrastructure on subsidence and for consistency with neighboring subbasins.

3.7.3 Measurable Objectives and Interim Milestones

The measurable objective for subsidence is set at recent subsidence rates, which are believed to be reflective of subsidence due to historical dewatering: -0.25 ft/year. Interim milestones are also set at -0.25 ft/year.

The GSAs have also defined a locally-derived, non-regulatory level of -0.50 ft/yr of subsidence that will act as an adaptive management threshold. If subsidence rates are observed at or beyond this level at representative monitoring sites, then the GSAs may consider additional actions in an effort to avoid continued increase in subsidence rates to the minimum threshold.

3.8 DEPLETIONS OF INTERCONNECTED SURFACE WATER

Depletion of interconnected surface water is a reduction in flow or levels of surface water caused by groundwater use. This reduction in flow or levels, at certain magnitudes or timing, may have adverse impacts on beneficial uses of the surface water and may lead to undesirable results. Quantification of depletions is relatively challenging and requires significant data on both groundwater levels near streams and stage information supported by groundwater modeling.

3.8.1 Undesirable Results

Description of Undesirable Results

Undesirable results related to depletions of interconnected surface water are defined in SGMA as:

> *Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water. [CWC §10721(x)(6)]*

The undesirable results for depletions of interconnected surface water in the Merced Subbasin are depletions that result in reductions in flow or levels of major rivers and streams that are hydrologically connected to the basin such that the reduced surface water flow or levels have a significant and unreasonable adverse impact on beneficial uses of the surface water within the Subbasin over the planning and implementation horizon of this GSP.

Major rivers and streams that potentially have a hydraulic connection to groundwater system in certain reaches are the Merced and San Joaquin Rivers. Many of the smaller creeks and streams are used for conveyance of irrigation water and generally surface water depletions (of irrigation water) would not impact natural flows in these systems; thus, these systems have not been considered in the analysis of depletions. However, future GSP updates may include considerations of these systems in the analysis of depletions. Hydraulic connection may occasionally be associated with perched water tables which are discussed further in Section #.# - Groundwater Recharge and Discharge Areas in the Hydrogeologic Conceptual Model.

Identification of Undesirable Results

As chronic lowering of groundwater levels is used as a proxy for depletions of interconnected surface water, the identification of undesirable results for the depletion of interconnected surface water sustainability indicator is performed through the identification of undesirable results for the chronic lowering of groundwater levels sustainability indicator.

Potential Causes of Undesirable Results

As chronic lowering of groundwater levels is used as a proxy for depletions of interconnected surface water, the potential causes of undesirable results are the same as those for groundwater levels.

Potential Effects of Undesirable Results

If depletions of interconnected surface water were to reach levels causing undesirable results, effects could include reduced flow and stage within rivers and streams in the Subbasin to the extent that insufficient surface water would be available to support diversions for agricultural uses or to support regulatory environmental requirements. This could result in increased groundwater production, changes in irrigation practices and crops grown, and could cause adverse effects to property values and the regional economy. Reduced flows and stage, along with potential associated changes in water temperature, could also negatively impact aquatic species in the rivers and streams. Such impacts are tied to the inability to meet minimum flow requirements, which are defined for both the Merced River, and San Joaquin River, which, in turn, are managed through operations at New Exchequer Dam and other reservoirs.

Justification of Groundwater Levels as a Proxy

Because of the challenges associated with directly measuring streamflow depletions and because of the significant correlation between groundwater levels and depletions, this GSP uses groundwater levels as a proxy for the depletion of interconnected surface water sustainability indicator. Additionally, since the Merced Subbasin shares riverine borders with multiple other subbasins, additional complex inter-basin coordination will be involved in understanding and monitoring stream depletions directly. As such, the minimum thresholds for the interconnected surface water sustainability indicator are consistent with the minimum thresholds for the chronic lowering of groundwater levels sustainability indicator.

As indicated in Section #.#, GSP regulations allow GSAs to use groundwater levels as a proxy metric for any sustainability indicator, provided the GSP demonstrates that there is a significant correlation between groundwater levels and the other metrics. The following approach from DWR is used to justify the proxy metric:

> *Demonstrate that the minimum thresholds and measurable objectives for chronic declines of groundwater levels are sufficiently protective to ensure significant and unreasonable occurrences of other sustainability indicators will be prevented. In other words, demonstrate that setting a groundwater level minimum threshold satisfies the minimum threshold requirements for not only chronic lowering of groundwater levels but other sustainability indicators at a given site.* (DWR, 2017)

To use the minimum thresholds for chronic lowering of groundwater levels as a proxy for depletions of interconnected surface water, the depletions that would occur when undesirable results for groundwater levels are reached must not be significant and unreasonable. In this way, the groundwater level minimum thresholds are sufficiently protective to ensure significant and unreasonable occurrences of depletions will be prevented. The analysis was performed by first considering historical depletions and then considering potential increases in depletions under conditions that are estimated to cause undesirable results for groundwater levels.

Historical depletions of interconnected surface water in the Subbasin have not been considered significant and unreasonable. Therefore, the depletions in MercedWRM's historical simulation are assumed to have no associated undesirable results. If groundwater levels were to decline to the groundwater level minimum thresholds, there is a corresponding level of additional surface water depletions that would occur, above those seen historically.

Groundwater modeling results were analyzed to estimate the volume of depletions associated with groundwater levels that would be classified as undesirable results for groundwater levels (non-dry/critical year pairings where 25% or more representative wells fall below their groundwater level minimum thresholds). A hypothetical scenario was simulated to select groundwater levels that would be classified as undesirable results based on the minimum thresholds for groundwater levels (described above in Section 3.3.2). The additional stream losses that occurred under this scenario compared to the historical simulation are estimates of depletions, as they can be linked largely to simulated increases in groundwater pumping, although changes in streamflow are also present in this example scenario. The additional depletions under the example scenario are 65,000 AFY, which is approximately 3% of average annual total surface water outflows from the Subbasin. An additional 65,000 AFY of stream depletions is not considered a significant and unreasonable amount of stream depletions. Depletions greater than an additional 65,000 AFY are estimated to require reductions in groundwater levels that would be classified as undesirable results based on the groundwater level sustainability indicator. Therefore, groundwater level thresholds are protective of the depletions of interconnected surface water.

3.8.2 Minimum Thresholds and Measurable Objectives

As chronic lowering of groundwater levels is used as a proxy for depletions of interconnected surface water, the measurable objectives and interim milestones for the depletion of interconnected surface water sustainability indicator are the measurable objectives and interim milestones for the chronic lowering of groundwater levels sustainability indicator.

3.9 COORDINATION WITH ADJACENT BASINS

Adjacent subbasins include Turlock, Chowchilla, and Delta-Mendota. A formal Memorandum of Understanding (MOU) has been finalized between the Merced and Chowchilla Subbasin GSAs. Inter-subbasin modeling coordination with Chowchilla was intended to provide the basis for consistency in the way minimum thresholds are determined; however future coordination must continue to confirm consistency. In addition, the technical approach for the sustainability analysis and its relationship to inter-basin coordination is intended to result in minimum thresholds that do not negatively impact adjacent basins.

A memorandum of intent to coordinate (MOI) has been finalized between each of the GSAs in the Turlock and Merced Subbasins. The MOI outlines the intention to share data and coordinate GSPs in the Merced and Turlock Subbasins without adversely impacting the adjacent basin. The MOI also recognizes that the Turlock Subbasin is on a different timeline and will not have a GSP complete until 2022, thus the GSAs intend to work together to develop and refine common knowledge and understanding over time. An MOU with Delta-Mendota was also under development at the time of preparation of this document.

Formal coordination with other subbasin GSAs has not been finalized due to differences in GSP development timelines.

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