5 SUSTAINABLE MANAGEMENT CRITERIA

GSP regulations provide a framework of sustainable management criteria, which allow the GSAs to define, quantitatively measure, and track ongoing sustainable management. These criteria include the following terms, along with a summary[26] of how each is used in this GSP:

- Undesirable Result – significant and unreasonable conditions for any of the six sustainability indicators
- Minimum Threshold (MT[27]) – numeric value used to define undesirable results for each sustainability indicator
- Measurable Objective (MO[24]) – specific, quantifiable goals to track the performance of sustainable management
- Interim Milestone – target value representing measurable groundwater conditions, in increments of five years, as set by the GSAs as part of the GSP.

Collectively, these terms provide the framework on which to:

- define sustainable management for the KRGSA Plan Area
- provide guidelines for favorable groundwater conditions
- identify unfavorable groundwater conditions and associated warning signs
- select and evaluate appropriate management projects and actions
- monitor progress on achieving the sustainability goal.

Development of the sustainable management criteria is based on the analysis of SGMA-defined sustainability indicators, such as declining water levels or degraded water quality. Although the concept of a sustainability indicator is simple, and achievement of sustainability is highly beneficial, evaluating these indicators over the 1.8 million acres of the Kern County Subbasin is complex. Moreover, the groundwater system is highly dynamic, given extensive groundwater banking, managed recharge and diversions, water exchanges and purchases, and a complex system of water rights. Further, the inflows and outflows to and from the KRGSA groundwater system are relatively large, occur at irregular intervals, and are not all attributable to KRGSA actions.

In such an environment, actual measured water levels along with trends and fluctuations are responding to a variety of inputs and actions, some of which are beyond the control of the KRGSA Plan Managers. A simple assessment of water levels without consideration of ongoing conjunctive management can produce misleading results. Yet, groundwater levels are foundational and provide the best available data

[26] Sustainable management criteria are more fully defined in §351 of the GSP regulations.

[27] Because of the frequency of use, and to facilitate review of the text, the terms "minimum threshold" and "measurable objective" are abbreviated as "MT" and "MO", respectively, throughout remaining sections of the GSP. However, the terms are provided in full, un-abbreviated form where helpful for context and clarity or when contained in a direct quotation.

with which to monitor groundwater conditions and to document the performance of management actions. However, KRGSA water levels require analysis within the context of the ongoing dynamic groundwater system and the management actions that control them. Annual reporting and five-year updates to the GSP will be used to track both water levels selected as MTs and MOs and analyze them in the context of the overall water budget and management activities.

5.1 SUSTAINABILITY GOAL

The Sustainability Goal of the KRGSA GSP is to manage groundwater sustainably in the KRGSA Plan Area to:

- Support current and future beneficial uses of groundwater including municipal, agricultural, industrial, public supply, domestic, and environmental
- Optimize conjunctive use of surface water, imported water, and groundwater
- Avoid or eliminate undesirable results throughout the planning and implementation horizon
- Evaluate GSP performance through ongoing monitoring and reporting of groundwater conditions.

This sustainability goal is based on the information in the Plan Area (**Section 2**), Basin Setting (**Section 3**), and Water Budget (**Section 4**) sections of this GSP that:

- Identify the types and quantities of groundwater reliance and use across the KRGSA Plan Area including an estimate of more than 1,200 active water supply wells
- Document the thick and permeable aquifer system, especially in the northern, central, and western KRGSA Plan Area where more than 1,000 feet of primarily sand and gravel are highly conducive to large quantities of recharge
- Identify and quantify surface water supplies including local Kern River water, imported SWP water, recycled water, and stormwater
- Describe the ongoing water management actions and banking operations, which have optimized conjunctive management of local and imported surface water supplies, thereby increasing the reliability of water supply in the KRGSA Plan Area
- Recognize the potential for additional enhanced recharge, expanded groundwater banking opportunities, and improved water treatment facilities to better manage a projected deficit in imported supplies and to balance that deficit against the projected increase in KRGSA water demands.

The KRGSA will achieve this goal through coordinated implementation of projects and programs to increase recharge, reduce reliance on the groundwater basin, and better manage high river flows and excess imported water opportunities for a more sustainable future. As described in subsequent sections, two large management projects are being proposed in this GSP that are ready for implementation in Year One of the 20-year timeline for achieving sustainability. This will allow early monitoring of GSP project performance and time for project adjustments, as needed. Further, these projects involve continuation and expansion of similar ongoing management actions that already have a proven track record for successful conjunctive management.

The GSP includes improvements to monitoring networks for ongoing tracking of management performance. Direct monitoring of groundwater will be supplemented by ongoing tracking of checkbook water budget components to better understand measured data within the context of conjunctive management. To ensure that the entire Subbasin will be operated within its sustainable yield by 2040, the KRGSA will do its part through active monitoring and adaptive management to better match the groundwater response to specific management actions.

5.2 SUSTAINABLE MANAGEMENT AREAS

GSP regulations allow GSAs to define management areas for the purposes of assigning "different MTs, MOs, monitoring, or projects and management actions based on difference in water use sector, water source type, geology, aquifer characteristics or other factors" (351(r)). Three Management Areas (MAs) have been delineated within the KRGSA to accommodate the need for different sustainable management criteria, to facilitate management actions, and to align management responsibilities with agency jurisdictional boundaries. These three MAs are shown on **Figure 5-1** and designated as follows:

- Urban Management Area (Urban MA)
- Agricultural Management Area (Agricultural MA)
- Banking Management Area (Banking MA).

As indicated by the designations, the KRGSA MAs are generally delineated by the primary land use for each area, which governs how most of the water used in the MA is delivered and managed. It is acknowledged that there is overlapping land use throughout each of the three KRGSA MAs and MA boundaries are not perfectly aligned with either land use or agency jurisdictional boundaries. Nonetheless, MAs provide a useful delineation for primary differences in sustainable management criteria.

The approximate size of each of the KRGSA MAs along with primary responsible agencies are summarized in **Table 5-1**. Due to substantial overlap in jurisdictional boundaries of KRGSA agencies, and also the overlap of MAs within each agency's service area, each MA will require coordinated management among several agencies/entities in the KRGSA. Jurisdictional boundaries of the three largest agencies in the KRGSA, the City, ID4, and KDWD, are shown with the MA boundaries on **Figure 5-2**.

Because KRGSA MAs are being defined prior to GSP implementation, boundaries are considered preliminary and may require future adjustment to support sustainable management. There may also be a need to adjust MA boundaries to better align with certain jurisdictional boundaries or to better reflect future land use as it evolves across the KRGSA Plan Area (**Figure 5-2**).

Table 5-1: KRGSA Management Areas

KRGSA Management Area	Size (acres)	Responsible Agencies	Coordinating Agency/Entity
KRGSA Urban MA	93,473	City of Bakersfield, ID4	KDWD, ENCSD, Vaughn WC, NORMWD, Cal Water
KRGSA Agricultural MA	132,282	KDWD, Greenfield CWD GSA	Lamont PUD, City of Bakersfield
KRGSA Banking MA	5,045	KCWA/ID4, City of Bakersfield	
TOTAL KRGSA Plan Area Acres	230,800		

5.2.1 KRGSA Urban Management Area

The KRGSA Urban MA was created to allow groundwater management to focus on urban supplies; it contains most of the municipal wells in the KRGSA Plan Area. As shown by the agency boundaries that are added to the MAs on **Figure 5-2**, the Urban MA includes almost all of the ID4 service area and most of the City of Bakersfield. A portion of the southern KRGSA Urban MA also extends into the KDWD service area, where KDWD coordinates with the City to ensure that newly-developed urban lands have a water supply. Importantly, the Urban MA includes more than 162 municipal wells owned by the City and Cal Water. It also includes additional public water supply wells owned and operated by ENCSD, NORMWD/OMWC, Vaughn Water Company (portions in KRGSA only), and other smaller water systems.

Municipal wells in the KRGSA Urban MA are shown on **Figure 5-3** for reference. **Figure 5-3** highlights a variety of data and analyses that are considered in the KRGSA sustainability criteria analysis, as described in subsequent sections below.

Although most of the KRGSA Urban MA is characterized by urban development or undeveloped lands, there are pockets of irrigated agriculture in the Urban MA. The largest of these is located in the northwest corner of the Urban MA and covers a portion of Rosedale Ranch ID (as indicated by crops in the northwestern KRGSA Plan Area – see **Figure 2-9**). Because its location is not adjacent to other KRGSA agricultural lands and because Rosedale Ranch ID has coordinated with both North Kern WSD and the City on past water supplies, its inclusion in the Urban MA seems reasonable. However, there may need to be special consideration for sustainable management criteria in this area.

5.2.2 KRGSA Agricultural Management Area

The KRGSA Agricultural MA was created to allow KDWD to continue to manage the complex Kern River water rights, SWP rights, and extensive infrastructure associated with almost all of the irrigated acres in the KRGSA Plan Area. The Agricultural MA is defined by the primary areas of mostly contiguous irrigated acres and includes almost all of the KDWD service area (**Figure 5-2**). The MA extends northward to include agricultural lands outside of KDWD in the east-central and west-central KRGSA Plan Area (**Figure 5-2**). These agricultural lands in the KRGSA Agricultural MA are encompassed by the City limits; lands in the east-central KRGSA (outside of KDWD) are also encompassed by the ID4 service area (**Figure 5-2**). As discussed above, the agricultural areas of Rosedale Ranch ID in the northwestern KRGSA Plan Area are included in the Urban MA.

The mostly urbanized area of the community of Greenfield is included in the Agricultural MA because of the close relationship between Greenfield CWD GSA and KDWD (**Figure 5-2**). Specifically, KDWD recharges water locally to maintain water levels at the Greenfield CWD municipal wells. Because the GSA is adjacent to the Urban MA, sustainable management criteria will consider conditions in both the Urban and Agricultural MAs.

The KRGSA Agricultural MA is also created to better manage areas more susceptible to land subsidence and perched water conditions (see **Section 3.3.5** and **Figures 3-37** and **3-38)**. The southern and eastern rim of the KRGSA Agricultural MA (see **Figure 5-3**) are the only KRGSA areas where significant rates of subsidence have been documented; this area warrants delineation because subsidence can be a primary driver of sustainable management criteria.

5.2.3 KRGSA Banking Management Area

The KRGSA Banking MA was created to acknowledge the specialized groundwater banking activities that occur in the western KRGSA Plan Area and along the Kern River channel (**Figure 5-1**). Although the KRGSA Banking MA is relatively small in size, its location adjacent to other major groundwater banking projects provides for consistent management across these west-central KRGSA Plan Area boundaries. As discussed in other sections of this GSP, these lands are managed primarily for recharge and recovery operations and have water levels fluctuations that are more similar to adjacent groundwater banking projects outside of the KRGSA (i.e., Pioneer Project and Kern Water Bank) than other KRGSA areas. The groundwater banking projects outside the KRGSA but adjacent to the Banking MA are indicated by the blue recharge basins on **Figure 5-3**.

The KRGSA Banking MA covers the two largest groundwater banking projects in the western KRGSA – COB 2800 Recharge Facility and Berrenda Mesa Project – along with downstream portions of the Kern River that are primarily used for recharge and recovery (**Figure 5-1**). City facilities used for recharge including ponds at Aera Park, Park at Riverwalk, and Truxtun Lakes are covered by the Banking MA. Most of the banking recovery wells, shown on **Figure 5-3** as yellow triangles, are included in the Banking MA. ID4 recovery wells located along banking areas of the river channel are also included.

The groundwater banking project in KDWD is not included in the KRGSA Banking MA. As indicated on **Figure 5-3**, recharge basins and recovery wells in KDWD occur throughout the Agricultural MA and are dispersed among agricultural lands. In addition, these recharge and recovery facilities are managed separately by KDWD and are not shared among multiple agencies as are many of the banking facilities in the Banking MA. Accordingly, assignment of different sustainable management criteria may be appropriate for the KDWD banking areas.

Although additional upstream portions of the Kern River channel are also managed for groundwater replenishment and banking, the channel is also flanked by numerous municipal wells owned by the City and Cal Water. These wells have different considerations with respect to sustainable management criteria. Accordingly, the Banking MA does not extend upstream along the entire Kern River recharge area. MA designations do not preclude consideration of the recharge/banking operations occurring upstream including those in the unlined portion of the Cross Valley Canal, Calloway Pool, and other important areas of managed recharge.

The KRGSA Banking MA also includes areas of undeveloped land surrounding other banking projects, including land north of the Pioneer Project. This land may be targeted for development in the near future and could be reassigned to the Urban MA, if needed. Similarly, land use changes south of the Pioneer Project may require reassignment from the Urban MA to the Banking MA. Recently, water banking has been expanded into this area.

5.2.4 Management Areas and Sustainable Management Criteria

The Hydrogeologic Conceptual Model, groundwater conditions, and water budget analyses as presented in **Sections 3** and **4** cover all of these MAs and are not repeated here. Those analyses form the foundation for establishing sustainable management criteria in each MA. The analyses also summarize conditions within each MA that require special considerations for sustainable management criteria. Monitoring networks for each MA are discussed in **Section 6**.

Sustainable management criteria will be considered on an MA-basis, KRGSA-basis, and in coordination with adjacent GSAs to ensure that sustainable management criteria will not create undesirable results in adjacent MAs or GSAs. Agencies within the KRGSA have been coordinating groundwater management activities for decades (examples in **Section 2.5** and throughout the GSP). KRGSA Plan Managers are well-equipped for close cooperation to achieve the KRGSA sustainability goal in each MA and across the entire Plan Area.

5.3 APPROACH TO UNDESIRABLE RESULTS

The approach to definition of undesirable results in the KRGSA relies on analysis of the six sustainability indicators as defined by SGMA:

- Chronic lowering of water levels
- Reduction of groundwater in storage
- Seawater intrusion
- Degradation of water quality
- Land subsidence that substantially interferes with surface land uses
- Depletions of interconnected surface water that adversely impact beneficial use of surface water.

GSP regulations state that if any of these indicators are causing significant and unreasonable effects in the Subbasin, then that indicator is defined as an undesirable result. As noted in the Sustainability Goal for the KRGSA GSP, sustainable management is meant to eliminate and avoid any undesirable results in the Plan Area over the planning and implementation horizon.

The GSAs in the Kern County Subbasin have coordinated on sustainable management criteria and have defined consistent undesirable results for the entire Subbasin. These definitions provide a flexible construct that allow each GSA to further define local undesirable results within the framework defined for the larger Subbasin. This GSP re-states the Subbasin definition of each undesirable result and refines each definition to local conditions within the KRGSA Plan Area.

Each of these indicators is examined with respect to conditions within the KRGSA Plan Area based primarily on the data and analysis described in **Section 2** (Plan Area) **Section 3** (Basin Setting), and **Section 4** (Water Budgets). The approach for the analysis of each of the sustainability indicators is summarized as follows:

- Describe each indicator and summarize the potential causes of undesirable results
- State the coordinated definition of undesirable results for the Kern County Subbasin
- Refine the Subbasin definition to define local undesirable results for the KRGSA GSP
- Determine if an undesirable result is occurring as of the SGMA baseline of January 2015
- Predict whether the undesirable result has occurred historically or has the potential to occur in the future
- Propose an appropriate minimum threshold (MT) and measurable objective (MO) as targets for elimination and future avoidance of undesirable results.

5.3.1 Approach for Minimum Thresholds (MT)

MTs are evaluated and selected based on either the occurrence of undesirable results (historically or currently) or the potential for undesirable results to occur in the future. In some cases, previous undesirable results – for some municipal wells, for example – have been partially mitigated through well modification, wellhead treatment, well replacement, and other actions. For these areas, MTs are established to avoid future undesirable results in recognition of these previous actions in place. These previous actions allow for either a lower MT or the ability to tolerate the threshold longer than would have been acceptable prior to the actions.

Water level monitoring is the foundation of determining undesirable results for the KRGSA. As explained in the remainder of this section, water levels are a good proxy for identifying undesirable results for all sustainability indicators relevant to the KRGSA.

5.3.2 Approach for Measurable Objectives (MO)

Water levels are less reliable for establishment of MOs. BMPs and guidance documents provide a simplistic condition where water levels would be expected to rise substantially in response to sustainable management actions. For these conditions, a MO associated with a water level higher than current conditions would be appropriate. However, for the KRGSA, it is more important to manage water levels locally and offset future deficits rather than to have water levels rise overall. As explained in the following sections, undesirable results in the KRGSA are more related to the water budget and localized undesirable results.

Specifically, the change in groundwater in storage based on water level contour maps, modeling, and the physical checkbook water budget suggested that the KRGSA was operating within a sustainable yield (see **Section 4.5.4** and **Table 4-10**). However, resulting water levels were influenced by groundwater banking activities inside the KRGSA for and by others. KRGSA Plan Managers decided to adjust the checkbook water budget to only include banking related to KRGSA agencies for use inside the KRGSA. Accordingly, a water budget deficit of about 29,153 AFY was estimated.

To eliminate this deficit, a GSP project is proposed for implementation in Year One of the implementation period that will provide additional supply to the large Agricultural MA (WAP, see **Section 7.1.1**). Recognizing that this added water supply will be delivered for the benefit of landowners over about 90,000 acres, the associated rise in water levels as a result of the project is less than a foot per year. Groundwater modeling associated with the SEIR for this project indicated an overall water level rise of only about three to six feet over a 50-year period (KDWD, SEIR, 2018). Given the wide fluctuations in water levels over much of the KRGSA Plan Area, this small change will not be sufficiently detectable for use as a reliable MO.

While the projected water budget modeling in **Section 4.7.3** indicates that water levels will rise substantially, that simulation represented the physical groundwater system and, again, did not account for in-KRGSA banking attributable to others. When projected changes in supply and demand are evaluated on a checkbook method, projected future deficits associated with climate change and urban growth are larger than indicated in the modeling. Therefore, management projects are providing the ability for water levels to remain within the historical range.

Given these complexities, a simplistic approach to a Measurable Objective is incorporated into this GSP. Recognizing the need to maintain water levels within a reasonable operational range similar to an historical range, the midpoint of an operational range is selected as a guide for a MO as explained in the following sections.

5.3.3 Summary of Sustainable Management Criteria

To facilitate review of the analysis of each sustainability indicator and how the criteria are proposed in various subareas of each MA, the MT for each sustainability indicator is summarized in **Table 5-2**. The analysis leading to the selection of the MTs shown on **Table 5-2** is providing in the following sections, organized by each of the sustainability indicators.

Table 5-2a: Minimum Thresholds for Sustainability Indicators in the KRGSA Management Areas

KRGSA Management Area (MA)	MA Subarea and Considerations for Management		Sustainability Indicator and Minimum Threshold (MT)			
			Chronic Lowering of Water Levels	Reduction of Groundwater in Storage	Degraded Water Quality	Land Subsidence
KRGSA Urban MA	Central/South/Northeast	Municipal wellfields	Historic Low WL	Historic Low WL	Historic Low WL	Historic Low WL
	Northwest corner	Transition to agricultural lands	20' below Historic Low WL	20' below Historic Low WL	20' below Historic Low WL	20' below Historic Low WL
KRGSA Agricultural MA	Along southern Urban MA	Transition with municipal wells	Historic Low WL	50' below Historic Low WL	Historic Low WL	50' below Historic Low WL
	North-Central	Greenfield CWD wells	Historic Low WL	50' below Historic Low WL	Historic Low WL	10' below Historic Low WL
	Northwest	Agricultural and recovery wells	50' below Historic Low WL	50' below Historic Low WL	50' below Historic Low WL	50' below Historic Low WL
	South and East	Subsidence potential	50' below Historic Low WL	50' below Historic Low WL	50' below Historic Low WL	20' below Historic Low WL
KRGSA Banking MA	Kern River Channel	ID4/KCWA recovery activities	20' below Historic Low WL	Not applicable	20' below Historic Low WL	50' below Historic Low WL
	Berrenda Mesa	KCWA operational area	Historic Low WL	Not applicable	Historic Low WL	50' below Historic Low WL
	COB 2800 Facility	City of Bakersfield municipal wells	Historic Low WL	Not applicable	Historic Low WL	50' below Historic Low WL

Historic low water level (WL) is the lowest level observed in an area during the recent drought of 2013-2016.
Measurable Objective (MO) for each sustainability indicator is the average of the MT and the historical high groundwater elevation during the historical Study Period.
Highlighted green cell indicates the controlling sustainability indicator(s) for that area in each MA.

Table 5-2b:

KRGSA Management Area (MA)	MA Subarea and Considerations for Management		Undesirable Results for Controlling Sustainability Indicators			
			Controlling Indicator	Minimum Threshold (MT)	Percent of Wells <MT	Duration of MT Exceedance
KRGSA Urban MA	Central/South/Northeast	Municipal wellfields	Water Levels/Quality	Historic Low WL	Any well	>3 Consecutive Months
	Northwest corner	Transition to agricultural lands	Water Levels	20' below Historic Low WL	Any well	>3 Consecutive Months
KRGSA Agricultural MA	Along southern Urban MA	Transition with municipal wells	Water Levels/Quality	Historic Low WL	Greenfield CWD MW	>2 Consecutive Years
	North-Central	Greenfield CWD wells	Water Levels/Quality	Historic Low WL	40% in Urban MA	>2 Consecutie Years
	Northwest	Agricultural and recovery wells	Water Levels	50' below Historic Low WL	40% in Agricultural MA	>2 Consecutive Years
	South and East	Subsidence potential	Subsidence	20' below Historic Low WL	40% in Agricultural MA	>2 Consecutive Years
KRGSA Banking MA	Kern River Channel	ID4/KCWA recovery activities	20' below Historic Low WL	20' below Historic Low WL	Any well	>3 Consecutive Months
	Berrenda Mesa	KCWA operational area	Historic Low WL	Historic Low WL	Any well	>3 Consecutive Months
	COB 2800 Facility	City of Bakersfield municipal wells	Historic Low WL	Historic Low WL	Any well	>3 Consecutive Months

Historic low water level (WL) is the lowest level observed in an area during the recent drought of 2013-2016.

5.4 CHRONIC LOWERING OF WATER LEVELS

SGMA defines an undesirable result from chronic lowering of water levels as "indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon" (§10721(x)(1)). The definition considers the duration of water level declines, as well as the result (i.e., depletion of supply). The definition also allows water levels to decline under certain conditions: "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 reduction in groundwater levels or storage during a period of drought are offset by increasing groundwater levels or storage during other periods" (§10721(x)(1)).

As described in **Section 3.3.2.2**, water level declines within the KRGSA have occurred primarily during drought cycles, which are also associated with low flows on the Kern River, less precipitation, and decreases in imported water supplies. This decrease in surface water supply is typically coupled with an increase in groundwater pumping. Collectively, these changes also result in decreases in recharge from banking activities, surface water conveyance, and surface water infiltration associated with irrigation and other outdoor water use. In addition, these drought periods are typically associated with increased recovery pumping at groundwater banking projects, which can result in significant local declines. Hydrographs on **Figure 3-24** also demonstrate the ability for water levels in the KRGSA to recover following drought conditions (e.g., the water level rise in the late 1990s following drought in the early 1990s). Although the hydrographs in **Figure 3-24** end in the drought of record (2015-2016), water levels have since risen in response to recent wet conditions in 2017 and 2019.

The impacts of groundwater level declines are fundamental to most of the remaining sustainability indicators. As indicated in the quote above, SGMA links chronic lowering of water levels to a reduction of groundwater in storage – a separate sustainability indicator. Chronic lowering of water levels are also closely related to inelastic land subsidence, interconnected surface water, seawater intrusion, and degraded water quality (e.g., where constituents of concern occur in depth-specific portions of the aquifer). Undesirable results related to these other sustainability indicators are discussed separately in each associated section below. This section examines the potential for water levels to impact the ability of wells to access groundwater for beneficial uses.

5.4.1 Potential Causes of Undesirable Results from Water Levels

Chronic lowering of water levels can adversely impact pumping wells and, in some cases, prevent practical or economical access to groundwater supply. With more than 1,200 active wells estimated in the KRGSA Plan Area, these impacts can be widespread and represent a significant economic impact on KRGSA groundwater users.

As water levels decline, well owners face an increase in energy costs due to the extra distance that the well pump must lift the water from the aquifer to the ground surface. Well capacity can also decline and may not produce sufficient water to meet the beneficial use. If water levels decline below the pump intake, the well will no longer produce. In this case, the pump must be lowered to depths sufficient to accommodate pumping water levels, sometimes at considerable cost. For some wells, this modification may not be feasible, and the well may need to be replaced.

If water levels fall below the tops of screens, water will cascade downward to the pumping water level, entraining air during the fall. This can cause cavitation at the pump as the mixture of air and water passes the pump impellor, resulting in vibration, potential pump damage, and a reduction in well efficiency. The introduction of oxygen can also create an environment for naturally-occurring iron bacteria to proliferate, potentially leading to biofouling and clogging. Well rehabilitation may be able to address some of the damage, but long-term well operation with water levels below the top of screens can ultimately result in inefficient wells, higher operating costs, increases in corrosion, and shorter well life.

If water levels continue to decline, the well may become dry and lose its ability to produce groundwater. Dry wells will occur first in the shallowest wells, such as is more common for a domestic well. If the dry well is the sole source of water for the well owner, drilling a deeper replacement well may be the only option for water supply – an option that may not be economically viable for the water user.

5.4.2 Subbasin Definition of Undesirable Results from Water Levels

In coordination with other GSAs in the Subbasin, the KGA developed a Subbasin-wide definition of an undesirable result for each sustainability indicator (December 14, 2018). KRGSA Plan Managers participated in development of the definitions, which were reviewed and approved by the KRGSA Board for Subbasin-wide coordination on January 10, 2019. This undesirable result for chronic lowering of water levels in the Subbasin is defined as:

> The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.
>
> This is determined when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas which represent at least 15% of the sub-basin or greater than 30% of the Sub-Basin (as measured by each Management Area). Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans.

5.4.3 KRGSA GSP Definition of Undesirable Results from Water Levels

The KRGSA GSP adopts the Subbasin definition of undesirable results for the water level sustainability indicator as provided above and provides further clarification for the KRGSA definition as follows:

> "The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users."

These impacts are focused on groundwater wells and balance the need for higher water levels in some wells with the need to lower water levels in other wells, primarily to support recovery of banked surface water during multi-year droughts.

Specifically, this sustainability indicator allows the transitioning of MTs across the KRGSA Plan Area to balance water level objectives for multiple types of groundwater wells. This balance provides operational flexibility to support the KRGSA Sustainability Goal, which includes optimization of conjunctive use (**Section 5.1**). The KRGSA GSP also recognizes that undesirable results may be mitigated if a shallow impacted well can be reasonably modified to accommodate anticipated water level declines, if pumping can be readily re-distributed, or if alternative water supplies are available. If impacts to water supply wells cannot be mitigated, pumping of groundwater recovery wells may require re-distribution, reduced rates, and/or temporary cessation.

5.4.4 Sustainable Management Criteria for Water Levels in the Plan Area

The definition for an undesirable result due to water levels is tested against conditions in each KRGSA MA to determine whether undesirable results are occurring as of the SGMA baseline January 2015 or if the sustainability indicator has the potential for future undesirable results. This analysis is used, in turn, to select appropriate MTs and MOs for the water level sustainability indicator in each MA.

5.4.4.1 KRGSA Urban Management Area

The recent drought of record produced historic lows in groundwater levels across the KRGSA Urban MA in 2015-2016 (**Section 3.3.2.5** and **Figure 3-27**), providing a test period for potential undesirable results at existing groundwater supply wells. In particular, the City and Cal Water, who collectively own more than 160 municipal supply wells identified significant issues during this time, as discussed in **Section 3.3.2.5**. Wells were affected across Metropolitan Bakersfield with declining capacity, well inefficiency, water levels falling below pump intakes, degraded water quality[28], and both pumping and static water levels falling below the top of well screens (i.e., cascading water).

To estimate the extent of Urban MA wells affected from declining water levels, average depth to water during Fall 2015 (see **Figure 3-27**) was plotted on a one-square-mile grid across the KRGSA Plan Area and compared to well screens in the large municipal wellfields. The average depth to water is shown by the color-ramp on **Figure 5-4**; the large municipal well fields are also shown on the map. On a system-wide basis, tops of well screens average about 290 feet deep.

As shown on **Figure 5-4**, the shallowest groundwater in the Urban MA (northern Plan Area) generally occurs beneath the river with deeper groundwater transitioning away from the river. An area of relatively deep groundwater (greater than 200 feet deep) and relatively shallow well screens occurs in the municipal wellfields south of the river (**Figure 5-4**). Wells where aquifer water levels fell below the top of screens (i.e., cascading water) are indicated by the triangles on **Figure 5-4**, generally consistent

[28] Water quality impacts are addressed separately in **Section 5.7.4.1**.

with the lower water levels. This analysis indicated that about 42 municipal wells, representing about one-quarter of the larger-capacity municipal wells in the KRGSA Plan Area, were affected by water levels falling below the top of well screens, creating well issues primarily in the central KRGSA Urban MA. Additional wells encountered this problem on a more intermittent basis, depending on the then-current pumping rates.

These conditions required operational changes and significant capital expenditures by the City and Cal Water to re-distribute pumping, lower pumps, remove impacted wells from service, secure supplemental supplies, and otherwise manage wellfield operations to meet water demands through the drought. Inefficient wells were no longer operating within the range of well pump performance, incurring un-due wear on pumps and potential damage to well equipment. Pumping rates were decreased in City wells equipped with variable drive motors for partial mitigation of pumping water levels below the top of screen; however, this resulted in a system-wide decrease in capacity. SWP water (including banked water) provided a buffer during this period, but these supplies are subject to future curtailment (see **Section 4.7.2**).

Although the City and Cal Water were able to actively manage wells and secure supplemental supplies to meet demands during 2015 and 2016, numerous challenges remain with the municipal well system. Only when water levels began to rise did the ongoing well problems subside. Lowered pumps in some wells reduce the risk of future adverse impacts in some wells, but the potential for cascading water remains. Because most of the municipal wells are similarly constructed, any future declines below the historic low water level will place more wells at risk. Widespread deepening of municipal wells is not an option due to water quality issues (discussed in **Section 3.3.4.6** summarized in the subsequent **Section 5.7.4.1**).

Minimum Thresholds and Measurable Objectives for Municipal Wellfields

Given the economic impact, large number of municipal wells, and future risk to additional wells, the City has determined that the historic low water levels during Fall 2015 represent an undesirable result for the chronic lowering of water levels in the KRGSA Urban MA **(Table 5-2a)**. Accordingly, the minimum threshold (MT) selected for these wells is the historical low water level as measured in representative GSP monitoring wells (see **Section 6**). As discussed in more detail in **Section 6**, monitoring wells located within and adjacent to the large municipal wellfields are targeted for GSP monitoring.

Recognizing that these conditions could be managed in a relatively small number of wells for a relatively short period of time, the definition of the undesirable result is further modified. For the KRGSA Urban MA, the undesirable result is defined as occurring when the representative monitoring wells in the municipal wellfields of the Urban MA fall below the MT for more than three consecutive months (**Table 5-2b**).

Short-term operational measures, such as turning on resting wells, operating some wells outside of the normal capacity range for short periods, and other measures, allow water levels to be temporarily lowered below historic lows. With the modifications made to wells during the previous drought, such as lowering of pumps, these measures will provide some operational flexibility to well owners. It is recognized that municipal wells made it through the recent drought with aquifer levels at the historic low for much longer time periods. Although the pumping and static water level records are not continuous, some wells appear to have operated in a range of lowered pumping water levels for numerous consecutive months over a two-year period. During this period of operational challenges, all urban demands were met. With GSP implementation beginning in Year One, water levels can be more locally managed to provide this operational flexibility.

To better track the performance of representative monitoring wells with respect to the MT, a measurable objective (MO) is selected for representative monitoring locations within the KRGSA Urban MA. Because the KRGSA Urban MA managers wish to operate within a reasonable range of water levels above the MT, the MO is defined as the average of the high water level of the historical Study Period (typically 1998) and the MT in each GSP monitoring well. It should be noted that the MO is defined here as the midpoint of an operable range. It is not in itself the objective (i.e., desirable or optimal) water level, but along with the high-water mark and the MT, provides a useful guideline for fluctuating groundwater levels. In addition, given that the range of KRGSA water levels represent an average water level associated with a sustainable water budget (see **Section 4.5.4** and **Table 4-10**), the MO also provides an average target water level that indicates ongoing sustainable management.

While maintaining water levels above the MT in representative monitoring wells is anticipated to result in improved wellfield operation in the KRGSA Urban MA, the exact water level that will prevent undesirable results cannot currently be quantified with certainty. Rather the MT, MO, and representative monitoring points will require ongoing testing and potential future adjustment.

Minimum Thresholds and Measurable Objectives in Northwest Agricultural Wells

It is recognized that areas outside of the large municipal wellfields (including agricultural areas in the northwest Urban MA, the Banking MA to the west and the Agricultural MA to the south) may not have similar adverse impacts to groundwater wells due to differing well designs, the absence of municipal wells, and other factors. Accordingly, water levels in these areas could decline below the historic lows without the same undesirable results as in the municipal wellfields. To accommodate differing beneficial uses and well operational requirements, MTs are transitioned slightly downward moving away from the municipal wellfields toward the northwestern agricultural area in the Urban MA as described below.

In the northwestern corner of the KRGSA Urban MA, the MT is lowered 20 feet below the historic water level lows in those areas to allow some operational flexibility for groundwater users in the RRID agricultural area **(Table 5-2)**. As indicated on **Figure 5-4**, the northwestern corner of the KRGSA Plan Area contains some of the deepest water levels in the Plan Area and management actions may not benefit these areas immediately. Further, this area is subject to subsurface flows toward significantly lower water levels in the north. The MO is defined as the average of the selected MT and the highest groundwater level observed during the historical Study Period, consistent with the methodology for the MO in the remaining Urban MA.

Representative monitoring wells are selected for various areas of the KRGSA Urban MA to track water levels during the GSP implementation and planning horizon. The GSP monitoring well network used to define the numerical values of MTs and MOs as discussed herein are provided in **Section 6**.

5.4.4.2 KRGSA Agricultural Management Area

Similar to the KRGSA Urban MA, the KRGSA Agricultural MA has competing objectives with respect to the selection of MTs and MOs to avoid undesirable results. In particular, municipal wells owned by Greenfield CWD occur inside the KRGSA Agricultural MA in the central Plan Area (**Figure 5-3**). As described below, different MTs and MOs are selected for certain areas across the KRGSA Agricultural MA to meet varying objectives.

Urban Wells along the southern Urban MA Boundary

Well problems similar to those identified for the KRGSA Urban MA have been documented in a Greenfield CWD well located in the north-central KRGSA Agricultural MA (see Greenfield CWD service area on **Figure 5-2**). When water levels declined during the drought, the pumping water level in the Panama Well fell below the relatively shallow well screen (top of screen 180 feet deep) resulting in a need to cut the pumping rate (QK, 2016). This well was recently replaced to maintain the existing capacity of the Greenfield CWD well systems (QK, 2016). Two replacement wells have been drilled, both with deeper screens (top of screens at about 420 feet deep) to accommodate lower water levels and also to decrease concentrations of TCP, which are generally higher in shallow groundwater (see **Section 3.3.4.6** on TCP and **Figure 3-32**).

Although installation of treatment and the two replacement wells provide improved resiliency to the Greenfield CWD wellfield, maintenance of higher water levels would be protective of the older system wells. Because the historic low water level is the MT selected for municipal wells in the adjacent KRGSA Urban MA, this MT is maintained for the Greenfield CWD representative monitoring well **(Table 5-2)**. This MT is also selected for areas where municipal wells are located adjacent to the southern Urban MA boundary or just across the boundary in the Agricultural MA **(Table 5-2)**. Consistent with the methodology for the Urban MA, the MO is defined as the average of the MT and the historic high water level during the historical Study Period (typically 1998).

Remaining Areas of the KRGSA Agricultural MA

In general, well problems have not been documented in remaining areas of the KRGSA Agricultural MA. DWR completion reports identify some shallow water supply wells throughout the MA, but it is unknown whether shallow wells are active. Although matching well construction to specific private wells in the Agricultural MA has been difficult, most wells in the southern Plan Area appear to be sufficiently deep to accommodate the historic lows of 2015; in addition, DWR completion reports indicate that well depths have been increasing over time.[29] In addition, recent questionnaires and surveys of well owners

[29] A management action to better document domestic well owners and well construction in the southern Plan Area is included in **Section 7** to address the uncertainty in well analyses (see discussion on data gaps in **Section 3.4**).

did not identify any dry well issues in the KRGSA Agricultural MA in addition to water system wells along the southern MA boundary as described above.

An absence of documented well issues associated with declining water levels may be due to a shallower water table in the southern Plan Area than in the northern Plan Area (**Figure 5-4**[30]). Conditions contributing to shallower groundwater include lower surface elevations, more widespread recharge along unlined canals, and deliveries of surface water for irrigation. An absence of well problems may also be attributable to deeper agricultural and banking recovery wells, deeper well pumps, or other factors. Based on available information, undesirable results associated with water levels are not occurring in the KRGSA Agricultural MA. However, because water level declines have the potential to cause undesirable results in the future, MTs and MOs are selected for the Agricultural MA.

KDWD operates large-capacity banking recovery wells in the north-central and northwestern Agricultural MA (and also in the southern Urban MA); banking recovery wells owned by KDWD and others are shown by the yellow triangles on **Figure 5-3**. In order to continue to maintain a mutually-beneficial groundwater banking program in KDWD, MTs need to be lower than in municipal wellfields to accommodate large-scale recovery of banked water during a multi-year drought. KDWD banking wells within the Urban MA are already being constrained by the MT set at historic low water levels. Setting a MT too high in the Agricultural MA could prevent beneficial use of the recovery wells, especially during the GSP implementation period; preventing the beneficial uses of recovery wells is an undesirable result, especially when considering the importance of conjunctive use to the KRGSA GSP in achieving the sustainability goal.

In addition, more than 640 active agricultural wells have been identified in the KRGSA. These wells provide landowners critical supplemental supply for irrigation and other agricultural needs. Landowners require flexibility to lower water levels during multi-year droughts in order to meet demands. As a large contributor to the economic vitality of Metropolitan Bakersfield, access to groundwater supply is an important beneficial use for the entire KRGSA and Kern County Subbasin.

Finally, both small water systems and domestic wells occur throughout the KRGSA Agricultural Area. Although well problems with historic low water levels have not been documented, such problems could be occurring with stakeholders that have not yet engaged with the GSP process. To account for this uncertainty, management actions have been included in this Plan to provide for improved identification and documentation of wells throughout the KRGSA Agricultural MA to adapt future sustainable management criteria to consider all wells and landowners.

To balance the competing objectives of the recovery, agricultural, and drinking water supply wells in the Agricultural MA, KRGSA Plan Managers will need to cooperate on wellfield operation. Because some KDWD recovery wells are several miles south of the Urban MA, those wells could be used for recovery

[30] Although perched water has been identified in the KRGSA Agricultural MA, groundwater depths on **Figure 5-4** are associated with the Principal Aquifer.

(including potential water exchanges) when adjacent Urban MA water levels are close to the MTs. Recovery wells within the Urban MA could be used for recovery when water levels are sufficiently high. It is noted that the management projects included in this GSP are anticipated to result in higher water levels than recorded during the recent drought, providing some assurance that multiple objectives can be accomplished (see projected water budget results in **Section 4.7.3** and descriptions of management projects in **Section 7.1**).

In the absence of any identified well problems – and recognizing the need for recovery and agricultural wells to meet beneficial uses – there is no indication that lower local water levels would trigger undesirable results for this sustainability indicator[31] in the KRGSA Agricultural MA (except in areas of drinking water wells as described above). Given that water levels declined about 40 to 50 feet during the previous drought of record (see **Section 3.3.2.2**), a MT of 50 feet below the historic low is selected as the MT for representative monitoring points away from the urban wells on the KRGSA Urban MA/Agricultural MA boundary **(Table 5-2)**. This would allow for the southern recovery wells and agricultural wells in the KRGSA Agricultural MA to accommodate a multi-year drought cycle slightly longer than encountered in 2013 - 2016. This MT is selected to preserve the beneficial use of the KDWD banking recovery wells and agricultural wells yet recognizes the close proximity of municipal wells that require a higher MT. Because the MT suggests an operational range between high groundwater levels of the historical Study Period and the new MT, the selected MO is defined as the average of the high water level and the MT, the same method used for the MO in the Urban MA.

Because local water levels may fall lower than this MT during short periods of agricultural and recovery pumping without impact to long-term water levels, the definition of undesirable results for water levels is further modified to incorporate the potential of a multi-year drought during the GSP implementation period. To allow operational flexibility for implementing the GSP in drought conditions, the undesirable result will be triggered when levels in 40 percent or more of the representative monitoring wells in the Agricultural MA remain below the MT over a period of two years. These criteria for numbers of wells and duration below the MT were coordinated with adjacent water districts and are consistent with the definitions of undesirable results in adjacent GSPs for the AEWSD and Wheeler Ridge-Maricopa Water Storage District (WRMWSD).

Coordination within the KRGSA Agricultural MA and with the KRGSA Urban MA

As the primary GSP manager of the KRGSA Agricultural MA, KDWD will coordinate water level management with the primary GSP managers (City of Bakersfield and ID4) and municipal well owners in the KRGSA Urban MA, as described above. In addition, KDWD and Greenfield CWD will continue their ongoing coordination activities including maintenance of water levels through local recharge in canals. Finally, KDWD will begin coordination with other small water systems in the KRGSA Agricultural MA to better understand local system needs. As a primary KRGSA Plan Manager for the Urban MA with respect

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[31] These MTs are adjusted for the subsidence sustainability indicator as explained in **Section 5.8**.

to municipal wells, the City will want to coordinate with the recovery operations, as well as agricultural well operators in the KRGSA Agricultural MA.

5.4.4.3 KRGSA Banking Management Area

The KRGSA Banking MA contains both dedicated recovery wells and municipal wells (which also recover banked water). The locations of recovery wells are represented by the yellow triangles on **Figure 5-3**; the two municipal wells are shown by the three purple dots in the western banking MA. The selection of MTs and MOs in the KRGSA Banking MA considers the beneficial use of both well types and balances the needs of both.

Recovery Well Considerations

ID4 banks imported water in the Kern River channel for subsequent recovery in its recovery wells to provide a critical water source for the Henry C. Garnett WPP during times of limited imported water. These wells are the eastern-most recovery wells shown on **Figure 5-3** (yellow triangles in east Banking MA). Further to the west, banking in the Berrenda Mesa project provides a critical water source to project participants within the Subbasin who require water in areas of limited to no groundwater supply (due to water quality).

Recovery wells operated by KCWA and others both inside and outside the Banking MA affect water levels throughout the western KRGSA Plan Area due to the close proximity of recovery wells and relatively large pumping volumes. The adjacent Pioneer Project has set a MT equivalent to about 50 feet below historic low water levels to accommodate the need for extensive recovery pumping during multi-year droughts. For the Banking MA, an undesirable result could result if pumping wells were prohibited from lowering water levels sufficiently to recover critical banked water supplies during a multi-year drought. This could occur if the water level MT is set too high in the Banking MA.

Municipal Well Considerations

While a high MT may negatively impact recovery wells, a low MT would present a challenge for sustainable management at the three municipal wells located within the Banking MA (and perhaps other nearby municipal wells in the Urban MA). Specifically, City municipal wells – Olcese No. 1, No. 2, and No.3 – are located at the COB 2800 banking facility and pump banked water directly into the City water distribution system. These wells have relatively shallow screens (about 200 feet deep), and Olcese No. 1 experienced cascading water during the recent drought (as well as water quality problems mentioned in **Section 5.6.4.1**). These conditions are part of the definition of undesirable results in the Urban MA.

With the implementation of the City's management project to optimize conjunctive use of Kern River water, described in **Section 7.1.2**, water levels should be able to be maintained at higher levels locally than in the past. Increased recharge of surface water will provide flexibility to raise water levels at different locations to meet differing objectives. The project also provides more surface water for direct use, allowing wellfields to pump at lower capacities and prevent excessive drawdown in sensitive areas. This would provide a buffer for the recovery wells during future droughts. Additional recharge in the COB 2800 facility near the Olcese municipal wells could mitigate any potential undesirable results.

MT and MO Selection for the Banking MA
With a successful City optimization project summarized above, water levels could be managed to accomplish multiple objectives in the Banking MA including focused mitigation for problems at the Olcese wells and perhaps allowing more drawdown to occur for relatively short periods at recovery wells.

Accordingly, a MT up to 20 feet below the historic water level low is selected for the ID4 recovery wells in the Kern River Channel of the eastern Banking MA **(Table 5-2)**. To protect the Olcese municipal wells, a higher MT equal to the historical low is selected for the remainder of the Banking MA including Berrenda Mesa and the COB 2800 facility **(Table 5-2)**. Although these areas are in close proximity, a difference of 20 feet between monitoring wells may be feasible, especially if recovery pumping and municipal pumping is managed and coordinated for water level maintenance. Consistent with the methodology for this sustainability indicator in other MAs, the MO for the Banking MA is defined as the average of the high-water level during the historical Study Period and the MT.

It is recognized that the City may be able to mitigate levels in municipal wells through focused recharge in the COB 2800 facility or make other short-term operational changes to manage municipal wells in the Banking MA. Further, it is recognized that recovery wells need as much operational flexibility as possible to allow critical water supplies to be recovered. To incorporate these factors, the undesirable result for the KRGSA Banking MA is further refined as follows:

> An undesirable result for the water level sustainability indicator in the Banking MA occurs when levels in representative monitoring wells are below the MT for a period of three or more consecutive months.

As described in Section 5.4.4.1 above, municipal well operators should be able to implement short-term operational measures to manage wellfields for several months without incurring undesirable results. Measures will be more effective with the implementation of the GSP project, which will provide Cal Water and the City with an increased ability to manage water levels locally. Short-term lower water levels in the Banking MA are not expected to affect municipal wells outside of the City service area due to the distance between recovery wells and other municipal wells. This three-month duration allows for recovery wells to operate during critical periods but also requires cessation of pumping or mitigation to allow water levels to rebound. Balancing water levels to achieve multiple objectives will require close coordination among KRGSA Plan Managers and the willingness to re-distribute recovery pumping and/or municipal pumping as needed to avoid undesirable results as provided in the KRGSA Sustainability Goal. These management actions are captured in the GSP as described in **Section 7.2.1**.

5.5 Reduction of Groundwater in Storage

GSP regulations require that the groundwater storage sustainability indicator consider a total volume of groundwater that can be withdrawn from the Subbasin without causing undesirable results (§354.28(c)(2)), a concept consistent with the SGMA definition of sustainable yield (see **Section 4.5.4**). The indicator involves a potential depletion of groundwater supply, or overdraft. Overdraft refers to conditions when the average annual amount of groundwater outflow (e.g., groundwater extraction) exceeds the long-term average groundwater inflow. Because avoidance of overdraft is fundamental to sustainable management, this sustainability indicator focuses on water budget results and the potential for overdraft.

SGMA links overdraft conditions to both the water level sustainability indicator and the groundwater storage sustainability indicator as evidenced by portions of the California Water Code (§10721) as reproduced below. This Water Code section specifically addresses the reduction of groundwater that occurs during drought and relates overdraft to storage.

> 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 reduction in groundwater levels *or storage* during a period of drought are offset by increasing groundwater levels *or storage* during other periods" (§10721(x)(1)) (*emphasis added*).

As indicated by the text above, overdraft and sustainable yield are related to the amount of recharge/replenishment that can be accomplished during non-drought conditions to balance any declines in water levels and storage during drought. As applied in this GSP, undesirable results related to chronic lowering of water levels focuses on potential impacts to wells and the ability to support beneficial uses. This sustainability indicator for groundwater in storage focuses on the depletion of supply and overdraft conditions.

5.5.1 Potential Causes of Undesirable Results for Reduction of Groundwater in Storage

In general, overdraft conditions occur when average annual inflows into the groundwater system are significantly less than average annual outflows, causing a continual depletion of groundwater supplies over time. Overdraft conditions result from a wide variety of groundwater mismanagement (or an absence of management) involving either a net increase in outflows or a net decrease in inflows, or both. Such activities may include over-pumping, changes in land use (e.g., paving recharge areas or other reduction in reduce surface infiltration), reduction in surface water (reducing recharge), or an absence of other water supplies to meet demands.

GSP regulations (§354.44(b)(2)) require that if the water budget analyses identify conditions of overdraft, the imbalance must be mitigated through projects, management actions, and/or demand reduction. For relatively thin aquifer systems or systems with deep confined groundwater that cannot be readily replenished at the surface, a depletion in supply may be more difficult to mitigate.

Conditions of critical overdraft also have the potential to cause a chronic lowering of water levels, inelastic land subsidence, and/or reduction of surface water supply (as a reduction in baseflow to streams or an increase in induced surface water recharge). This close linkage to other sustainability indicators highlights the potential for a reduction in groundwater in storage to cause undesirable results.

5.5.2 Subbasin Definition of Undesirable Results for Reduction of Groundwater in Storage

In coordination with other GSAs in the Subbasin, the KGA developed a Subbasin-wide definition of an undesirable result for each sustainability indicator (December 14, 2018). KRGSA Plan Managers participated in the development of the definitions, which were reviewed and approved by the KRGSA Board for Subbasin-wide coordination on January 10, 2019. This Subbasin-wide definition of Undesirable Results for the Groundwater Storage sustainability indicator is as follows:

> The point at which significant and unreasonable impacts, as determined by the amount of groundwater in the basin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users over an extended drought period. (10-years)
>
> This is determined when the volume of storage (above the groundwater level minimum thresholds) is depleted to an elevation lower than the groundwater level minimum threshold in at least three (3) adjacent management areas that represent at least 15% of the subbasin or greater than 30% of the subbasin (as measured by the acreage of each Management Area).
>
> Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans.

5.5.3 KRGSA GSP Definition of Undesirable Results for Reduction of Groundwater in Storage

In the KRGSA, the Principal Aquifer contains a thick column of fresh water extending several thousand feet deep. The total amount of groundwater in storage beneath the KRGSA likely exceeds 20,000,000 AF above the base of fresh water (see **Section 3.2.5.4**, last paragraph), not including deeper groundwater available for emergency supply. Although access to the entire water column is not readily available with existing wells, the risk of depleting a significant quantity of groundwater supply is small. The sustainable average annual groundwater withdrawals are about 290,000 to 320,000 AFY (see **Section 4.5.4**), equivalent to less than two percent of the total supply. Even when withdrawals increased to about 400,000 AFY during the drought of record (**Table 4-4**) when water levels reached historic lows, the total associated change in groundwater in storage was estimated at 238,072 AF, about two percent of the total amount of groundwater in storage.

However, a more important assessment of undesirable results for the KRGSA is the potential for overdraft conditions, which would also result in a chronic lowering of water levels. As shown in **Table 4-10** and discussed in **Section 4.5.4**, three independent methods of analysis indicate collectively that there has not been a significant and unreasonable reduction in groundwater in storage over the average conditions of the historical Study Period. This conclusion suggests that there were no undesirable results occurring in the physical groundwater system as of the SGMA baseline of January 2015 for this sustainability indicator.

However, when adjusted for banking obligations outside of the KRGSA and recharge inside of the KRGSA attributable to others, the change in storage increases to about -29,153 AFY (**Table 4-10**), suggesting that overdraft conditions should be considered for planning purposes. In addition, future increases in demand and projected decreases in supply have the potential to exacerbate overdraft conditions in the future. Importantly, water levels may not reflect overdraft conditions when they occur due to the extensive recharge and groundwater banking operations inside and adjacent to the KRGSA by non-KRGSA entities.

Based on this analysis, the KRGSA GSP adopts the Subbasin definition for this sustainability indicator by reference and adds the following definition for KRGSA undesirable results:

> The point at which significant and unreasonable amounts of overdraft is indicated by the ongoing KRGSA adjusted checkbook water budget analysis, based on average hydrologic conditions.

As indicated in **Section 5.5.2** above, the Subbasin has defined the MT for this sustainability indicator to be the same MT as defined for the chronic lowering of water levels sustainability indicator. Given the close linkage of water levels and storage, using the same MTs for both indicators provides a practical limit for operating levels and storage beneath the KRGSA. In addition, the high groundwater level from 1998, used in the development of the MO for water levels (see **Section 5.4.4**) provides a reasonable upper limit for this range. The amount of storage represented by this operational range is estimated at about 1,500,000 AFY[32]. An additional MT is added for the entire KRGSA Plan Area to address the KRGSA-specific definition of undesirable results relating to overdraft.

5.5.4 Sustainable Management Criteria for Groundwater in Storage in the KRGSA Plan Area

As indicated in the analysis above, the definition of undesirable results for this sustainability indicator has an MT based on the ongoing water budget analysis being established for the entire Plan Area. The MT for the Plan Area water budget is defined as negative change in groundwater in storage that is greater than 7 percent of the total groundwater inflows on an average annual basis. This percentage is selected to account for uncertainty in measurements and will be evaluated for applicability in ongoing water budget analyses. The goal of the water budget is to maintain a zero or positive change in groundwater in storage on an average annual basis; accordingly, this is selected as the MO for this sustainability indicator. This analysis will be included in each Annual Report for the KRGSA.

The MTs and MOs selected for the water level sustainability indicator provide additional numerical values for this groundwater storage indicator. The combination of these two closely-linked sustainability indicators create an operational range of water levels and storage for each MA. However, the Banking MA is not subject to a reduction of groundwater in storage because of the operation of groundwater banks on the Kern River Fan. For each banking project, recharge occurs before recovery and recovery does not exceed recharge. Accordingly, the MT and MO for water levels are not applicable to the

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[32] Based on an average water level change of about 70 feet across most of the KRGSA Plan Area from 1998 to 2015 and using a 10 percent specific yield.

Banking MA, as stated below. The MTs and MOs for chronic lowering of water levels for the Urban and Agricultural MAs are re-stated below for completeness.

5.5.4.1 KRGSA Urban Management Area

The MT for the reduction of groundwater in storage sustainability indicator in the KRGSA Urban MA is selected as the historic low water level except in the northwestern corner where the MT is lowered 20 feet below the historic water level lows to allow operational flexibility for groundwater users in the RRID area **(Table 5-2)**. The MO is defined as the average of the high groundwater level from 1998 and the MT.

5.5.4.2 KRGSA Agricultural Management Area

The MT for the KRGSA Agricultural MA is defined as 50 feet below the historic low water level for this sustainability indicator to accommodate a multi-year drought cycle slightly longer than encountered in 2013 – 2016 **(Table 5-2).** The assumption here is that the water budgets would be adjusted to account for average conditions, even if an extended drought occurs, as is planned for the 2030 and 2070 climate change scenarios presented in **Section 4.7.3**. The MO is defined as the average of the high groundwater level (typically 1998) and the MT.

5.5.4.3 KRGSA Banking Management Area

The KRGSA Banking MA is not subject to a reduction of groundwater in storage. Banking projects are operated such that recharge occurs before recovery, and recovery pumping does not exceed the quantity of banked water. It is recognized that recovery pumping can lower water levels to depths below what would have occurred in the absence of banking because banked water can migrate away from the capture zone of the recovery wells. However, this occurrence would already be incorporated into the analysis for the sustainability indicator associated with chronic lowering of water levels. Therefore, no additional MT or MO is selected for this sustainability indicator in this MA.

5.6 SEAWATER INTRUSION

The KRGSA is more than 50 miles from the closest shoreline and separated from the Pacific Ocean by the bedrock units of the Coast Ranges. Accordingly, seawater intrusion is not occurring, not expected to occur in the future, and is not an applicable sustainability indicator for the KRGSA Plan Area or the Subbasin. As allowed in the GSP regulations (§354.28(e)), no sustainable management criteria are defined for this indicator and seawater intrusion is not considered further in this GSP.

5.7 DEGRADED WATER QUALITY

Unlike the other sustainability indicators, water quality is already regulated through numerous programs by a variety of federal, state, and local agencies. GSAs do not have the mandate or authority to duplicate these programs. Further, the GSAs are not required to correct for historical issues, naturally-occurring degradation, or degradation caused by others. Nonetheless, to support sustainable groundwater supplies for all beneficial uses, this GSP recognizes and states the intention to cooperate with the regulatory programs in the KRGSA for the management and prevention of degraded groundwater quality. The GSP proposes coordination with these programs through data sharing and analyses. In addition, local management actions are proposed that support compliance with water quality programs (described in **Sections 7.1** and **7.2**). GSP Projects and management actions also support the improvement of groundwater quality and assist with the prevention of future contamination (**Sections 7.1** and **7.2**).

GSAs have a mandate to avoid management actions that would contribute to water quality degradation or spread groundwater contamination through pumping or other means. Therefore, the definition of undesirable results and selection of MTs focuses on groundwater quality that could be impacted by management actions.

5.7.1 Potential Causes of Undesirable Results for Water Quality

Degraded water quality can impair water supply, impact human health and the environment, and create the need for alternative water sources. Degraded water quality has the potential to affect beneficial uses of groundwater including drinking water, agricultural or industrial supply, and environmental uses. Impacts to drinking water supply wells can cause expensive response actions including contaminant investigations, well modifications, increased sampling and monitoring, increased treatment costs, loss of wells, and/or a loss of water supply. Impacts to agricultural supply can cause poor yields, loss of crops, changes in irrigation methods/sources, impacts to property values, and other economic effects. Impacts to industrial supply can cause product damage, inadequate process water, increased treatment costs, degraded wastewater, and other problems. Discharge of degraded groundwater can cause harm to surface water, wetlands, and other habitats/ecosystems.

Both naturally-occurring and human-related (anthropogenic) constituents of concern have been identified in the KRGSA. Naturally-occurring constituents can be difficult to predict and control. Anthropogenic impacts can create plumes that migrate and spread contaminants downgradient (horizontally and vertically). Non-point sources can create widespread impacts that can be difficult to contain and manage. Impacts associated with releases of constituents at the surface may remain undetected for years or decades before migration through the vadose zone allows detection in underlying groundwater. Degraded water quality can be spread or exacerbated by pumping wells.

5.7.2 Subbasin Definition of Undesirable Results for Water Quality

In coordination with other GSAs in the Subbasin, the KGA developed a Subbasin-wide definition of an undesirable result for each sustainability indicator (December 14, 2018). KRGSA Plan Managers participated in the development of the definitions, which were reviewed and approved by the KRGSA Board for Subbasin-wide coordination on January 10, 2019. The definition of Undesirable Results for the Degraded Water Quality Trends sustainability indicator is as follows:

> The point at which significant and unreasonable impacts over the planning and implementation horizon, as caused by water management actions, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

This is determined when the minimum threshold for a groundwater quality constituent of concern is exceeded in at least three (3) adjacent management areas that represent at least 15% of the subbasin or greater than 30% of the designated monitoring points within the basin. Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans.

5.7.3 KRGSA GSP Definition of Undesirable Results for Water Quality

The Subbasin definition of an undesirable result focuses on impacts *caused by management actions*. Consistent with this definition, the primary concern of this GSP is to ensure that management actions proposed by the KRGSA Plan Area agencies do not cause an undesirable result for water quality. Such actions could potentially involve:

- operation of groundwater levels that increase concentrations of contaminants in wells such that the beneficial use of groundwater is impacted,
- recharge of surface water supplies that could impact water quality, or
- pumping wells that are likely to spread or exacerbate contaminant plumes.

The potential for the second and third bullets to cause undesirable results is unlikely under current conditions in the KRGSA. Surface water quality of the Kern River is acceptable for all beneficial uses and supplies high quality drinking water to the KRGSA. Therefore, the extensive managed recharge operations using Kern River water is likely to improve groundwater quality rather than degrade it. Imported water that is banked for subsequent recovery is also considered high quality water and would not contribute to water quality degradation.

With regards to the potential to spread contaminant plumes, no distinct plumes have been identified in the KRGSA Plan Area. Pumping centers have been established for decades and wells are routinely monitored for groundwater quality. It is recognized that there are some areas of unknown impacts from anthropogenic sources (see **Section 3.3.4.6** and **Table 3-4**). Accordingly, the KRGSA will continue to monitor groundwater and work with the Central Valley Water Board to identify key contaminant sites (see **Section 7.2**).

As described in **Section 3.3.4.6**, the primary constituents of concern for the KRGSA Plan Area drinking water are arsenic and TCP. Because TCP is primarily related to legacy application of fumigants in agricultural areas, it would have been applied at the surface and likely occurs at highest concentrations in shallow portions of the Principal Aquifer. However, this relationship was difficult to evaluate with current data and requires additional analysis. Further, elevated concentrations of TCP are currently being managed through wellhead treatment facilities installed on more than 55 wells with additional lawsuits pending to fund treatment on other impacted wells.

A correlation between water levels and arsenic has been interpreted for some KRGSA wells and could be affected by management actions. As shown by the graph on **Figure 3-34**, arsenic concentrations increase in some wells when water levels decline. If arsenic is associated with the deeper aquifer zones, then contributions from those zones could be higher when water levels are low. If water levels are allowed to decline significantly below historic lows, arsenic concentrations could exceed the MCL in wells with current low concentrations. Although wellhead treatment has been installed on eleven of the more vulnerable wells identified to date (**Figure 3-33**), tens of additional municipal wells have detected arsenic near or above the MCL and are at risk of increasing arsenic concentrations over time. An undesirable result could be triggered if arsenic concentrations rose in untreated wells such that wells could not be used to meet the beneficial use of drinking water supply.

5.7.4 Sustainable Management Criteria for Water Quality in the KRGSA Plan Area

This definition for an undesirable result due to degraded water quality is tested against conditions in each KRGSA MA to determine whether undesirable results are occurring as of the SGMA baseline January 2015 or if the sustainability indicator has the potential for future undesirable results. This analysis is used, in turn, to select appropriate MTs for the water quality sustainability indicator in each MA.

GSP regulations state that the minimum threshold for degraded water quality be based on "the number of supply wells, a volume of water, or a location of an isocontour that exceeds concentrations of constituents determined by the agency to be of concern for the basin" (§354.28(4)). The number of supply wells are considered in the minimum threshold, but volumes of water or the position of an isocontour is not applicable to naturally-occurring arsenic that creates impacts across the Plan Area. Such impacts vary based on well construction, well capacity, and depth and thickness of the arsenic-bearing strata.

Regulations also state that "…the Agency shall consider local, state, and federal water quality standards applicable to the basin." (§354.28(4)). The water quality standard for arsenic is considered in the minimum threshold but is not a reliable target. First, arsenic concentrations in some wells peak to levels above the MCL without a steady increase in concentration over time. Further, some wells have detected arsenic at levels close to the MCL for long periods without further increases. Impacts may be more closely related to water levels than to trends in water quality. Controlling water levels is considered the most manageable method for avoiding undesirable results as explained in more detail below.

5.7.4.1 KRGSA Urban Management Area

In the KRGSA Urban MA, elevated arsenic concentrations above the MCL have been detected in at least 20 municipal wells that do not have wellhead treatment; many other nearby wells are vulnerable to arsenic concentrations. During the drought of 2015-2016, concentrations rose in certain wells, but concentrations were managed with blending and with re-distribution of pumping.

Although these are not ideal management conditions, the costs of lost wells and additional treatment facilities were minimized. Wells were modified and are now better-positioned to manage drought conditions. Nonetheless, the historic lows caused multiple well and management problems that could be avoided by maintaining water levels above the critical levels reached in the recent drought. This goal is consistent with the City's intention to provide high quality water to urban residents at the lowest possible price.

It is recognized that the actual water level needed to avoid undesirable results may require adjustment over time. However, because the historic low created management problems for KRGSA municipal wells, that level is selected as the MT for this sustainability indicator as monitored in representative monitoring wells. To monitor ongoing performance for operating above the MT, an MO is defined as the average of the MT and the high water level in the representative monitoring well during the historical Study Period (average hydrologic conditions). This is the same MT and MO as selected for the sustainability indicator conveniently facilitating GSP monitoring and management.

KRGSA Plan Managers considered the potential for setting water levels higher than the historic low to create more certainty for avoiding undesirable results. However, managers recognized that water levels adjacent to the KRGSA may take more time to recover as GSP projects are brought online during the GSP Implementation period; therefore, higher water levels will not likely be achievable until GSP implementation is underway. Also, as discussed previously (**Section 5.4.4**), banking recovery wells may need the operational flexibility to lower water levels locally during critical periods of drought.

Accordingly, the MT is maintained at the historic low for this water quality indicator and will be tested during the GSP Implementation period for control of arsenic levels **(Table 5-2)**. As described in **Section 4.7.3**, a proposed KRGSA GSP management project is expected to maintain higher water levels in the KRGSA Urban MA. Luckily, the KRGSA Urban MA can implement its GSP project (Kern River Conjunctive Use Optimization project) early in the implementation phase and begin maintenance of water levels directly for the benefit of drinking water supply (see **Section 7.1.2**). Consistent with other MOs, an MO is defined for the water quality indicator as the average of the high groundwater level during the historical Study Period (typically 1998) and the MT.

The MT for the northwest corner of the Urban MA is lowered to allow for the transition to agricultural wells both inside and north of the Urban MA. Consistent with the water level sustainability indicator, the MT is defined as 20 feet below the historic low water level and the MO is the average of the high groundwater level and the MT **(Table 5-2)**.

5.7.4.2 KRGSA Agricultural Management Area

Arsenic has been identified as a constituent of concern in the north-central KRGSA Agricultural MA where Greenfield CWD (**Figure 5-2**) has installed wellhead treatment facilities for elevated arsenic levels in two of its wells (see **Section 3.3.4.6** and **Figure 3-33**). Greenfield CWD has recently completed two deep replacement wells and can now accommodate slightly deeper water levels on a system-wide basis. Also, the replacement wells were constructed to minimize arsenic concentrations after water testing identified the highest arsenic-bearing zones (QK, 2016). Accordingly, the water quality is currently being managed and undesirable results have been mitigated. However, to protect Greenfield CWD and other water supply wells along the urban fringe and avoid undesirable results in the future, KRGSA Plan

Managers have selected the historic low as the MT in Greenfield CWD and along the southern boundary of the Urban MA, consistent with the adjacent municipal wellfields to the north **(Table 5-2)**. The MO is defined as the average of the MT and the high groundwater level during average historical conditions.

However, conditions throughout the remaining KRGSA Agricultural MA have not experienced arsenic issues similar to those in the north. In addition, arsenic is not a constituent of concern for agricultural operations (**Section 3.3.4**). Lowering water levels in areas away from the Urban MA would not be expected to exacerbate arsenic concentrations in municipal wells to the north. Accordingly, a lower MT of 50 feet below the historic low water level is selected for the remaining Agricultural MA with an MO defined as the average of the high groundwater level during the historical Study Period (typically 1998) and the MT **(Table 5-2)**.

5.7.4.3 KRGSA Banking Management Area

Arsenic has been detected at concentrations above the MCL in the three municipal wells located in the KRGSA Banking MA (City wells in the COB 2800 Recharge facility); as seen in other municipal wells, arsenic concentrations increased in proportion to water level declines during the recent drought. In addition, wells in the adjacent Pioneer banking project have also detected arsenic concentrations at depth. Those offsite wells are managing arsenic levels through blending and other actions and have set MTs at about 50 feet below the historic low water level at a monitoring well adjacent to the KRGSA Banking MA. Although it may be difficult to maintain water levels in the KRGSA Banking MA significantly higher than in those adjacent areas, a planned GSP project involves less pumping and more recharge in the KRGSA Urban and Banking MAs (**Section 7.1.2**).

Therefore, to protect the municipal wells in the banking MA, the MT is defined as the historic low water level in the COB 2800 facility and adjacent Berrenda Mesa banking project **(Table 5-2)**. The MT is lowered 20 feet for ID4 recovery wells in the eastern Banking MA **(Table 5-2)**. In that area, wellhead treatment has been installed on local municipal wells, allowing better management of arsenic concentrations (**Figure 5-3**). For all subareas of the Banking MA, the MO is defined as the average of the high groundwater level over the historical Study Period (typically 1998 levels) and the MT.

5.8 LAND SUBSIDENCE AFFECTING BENEFICIAL USE

Historical land subsidence has been documented in the KRGSA Plan Area and is likely being exacerbated by water levels lowered during the recent drought. As water levels decline in the subsurface, dewatering and compaction of aquifer materials, predominantly fine-grained materials such as clay, can cause the overlying ground surface to subside (see analysis in **Section 3.3.5**). Historical and current land subsidence in the KRGSA Plan Area is illustrated on **Figures 3-37** and **3-8**, respectively. **Figure 5-3** outlines the general area of the largest historical subsidence, which occurs primarily in the southern and southeastern portions of the Agricultural MA.

5.8.1 Potential Causes of Undesirable Results for Land Subsidence

Inelastic compaction is initiated when the magnitude of the greatest pressure that has acted on the clay layer since its deposition, or pre-consolidation stress, is exceeded. With respect to the effects of groundwater pumping, the pre-consolidation stress is exceeded when groundwater levels in the aquifer reach a new historically low water level. The volumetric compaction of the clay layers in the subsurface is transmitted to the land surface where it is manifested as land subsidence.

Land subsidence can impact land use and damage critical infrastructure. Adverse impacts would be more pronounced if subsidence occurred unevenly through the area (referred to as differential subsidence). The following potential impacts have been associated with land subsidence due to groundwater withdrawals (modified from LSCE, et al., 2014):

- Damage to infrastructure including foundations, roads, bridges, or pipelines
- Loss of conveyance in canals, streams, or channels
- Diminished effectiveness of levees
- Collapsed or damaged well casings
- Land fissures.

Undesirable results for land subsidence would clearly include loss of capacity in major water conveyance infrastructure such as the Friant-Kern Canal or California Aqueduct. Subsidence damage along the Friant-Kern Canal has resulted in loss of capacity and the need for expensive repairs. The Friant-Kern Canal terminates at the Kern River in the northern KRGSA, where little to no land subsidence has been documented. The California Aqueduct is more than four miles from the closest portion of the KRGSA and current levels of subsidence in the KRGSA are unlikely to affect it. However, KRGSA Plan Managers rely on the conveyance capacity of the Aqueduct and are interested in the mitigation of any undesirable results with respect to land subsidence along the aqueduct caused by others.

For the KRGSA, undesirable results would also be triggered if damage occurred to critical infrastructure identified in **Section 3.3.5.3**. In brief, KRGSA Plan Managers rely on numerous canals and pipelines for water conveyance and management (**Figure 3-39**). Major roadways such as I-5 and Highway 99 traverse across the KRGSA Plan Area. The City of Bakersfield contains a myriad of critical infrastructure including municipal wells, water and other utility pipelines, roads, buildings, associated appurtenances and numerous other facilities that may be at risk if inelastic subsidence occurred in the city. Nearby oil fields contain oil and gas pipelines, wells, pumping facilities and other infrastructure to be considered. The three water treatment facilities in the Bakersfield area are also specifically recognized as critical infrastructure. Other critical infrastructure exists outside of the City limits and/or away from urban centers including the Bakersfield Meadows Field Airport, industrial pipelines/conduits, and other features.

Damage to any of the critical infrastructure could result in expensive repairs, loss of capacity, interruption of utility service, loss of damage to transportation corridors, impacts to the economy, and, in the event of catastrophic damage, possible risks to human health and the environment.

5.8.2 Subbasin Definition of Undesirable Results for Land Subsidence

In coordination with other GSAs in the Subbasin, the KGA developed a Subbasin-wide definition of an undesirable result for each sustainability indicator (December 14, 2018). KRGSA Plan Managers participated in the development of the definitions, which were reviewed and approved by the KRGSA Board for Subbasin-wide coordination on January 10, 2019. The definition of Undesirable Results for the Land Subsidence Trends sustainability indicator is as follows:

> The point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the basin, that affects the surface land uses or critical infrastructure.
>
> This is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin wide coordinated GSP subsidence monitoring plan.

5.8.3 KRGSA GSP Definition of Undesirable Results for Land Subsidence

The KRGSA GSP definition of an undesirable result for this indicator adopts the Subbasin definition by reference and refines the definition for the KRGSA Plan Area as follows:

The impacts from land subsidence are determined to be significant and unreasonable if surface land use or critical infrastructure is materially impacted. For the KRGSA, critical infrastructure is defined in **Section 3.3.5.3**.

5.8.4 Sustainable Management Criteria for Subsidence in the KRGSA Plan Area

The definition for an undesirable result due to inelastic land subsidence is tested against conditions in each KRGSA MA to determine whether undesirable results are occurring as of the SGMA baseline January 2015 or if the sustainability indicator has the potential for future undesirable results. This analysis is used, in turn, to select appropriate MTs for the water level sustainability indicator in each MA.

5.8.4.1 KRGSA Urban Management Area

The aquifer system in the KRGSA Urban MA is likely less susceptible to land subsidence from groundwater withdrawal than other areas in the KRGSA. First, the aquifer system is composed of predominantly coarse-grain sediments with no evidence of confining layers in the zones of municipal pumping (i.e., about 700 feet deep, see **Figure 3-20**). Although clay content increases somewhat to the west, the large quantities of recharge in the western banking projects demonstrate the highly permeable shallow subsurface. Historical subsidence data do not indicate significant subsidence rates in this area and recent data from the NPL suggest that subsidence over most of the Urban MA is minimal.

Given the absence of significant land subsidence and no reports of damage to critical infrastructure, undesirable results do not appear to be occurring in the Urban MA as of January 2015.

Nonetheless, the Urban MA contains the most critical infrastructure subject to damage if significant amounts of inelastic differential subsidence occurred in the future. Therefore, MTs and MOs consider subsidence potential and also recognize that the MTs for the other sustainability indicators are set at the historic low water level for most of the MA (see **Sections 5.4.4** and **5.7.4**). If water levels are maintained at or near the historic low water level, the potential for future subsidence would be mitigated and additional analysis would be unnecessary. Accordingly, the MT of the historic low water level is adopted for the land subsidence indicator **(Table 5-2).** The MO is selected as the average of the high groundwater level during the historical Study Period and the MT. If KRGSA Plan Managers decide to modify the MT for the water level and water quality sustainability indicators in the future, then selection of sustainable management criteria for land subsidence should be re-visited.

The agricultural lands in the northwest corner of the Plan Area have not experienced significant rates of subsidence based on historical investigations and current JPL analysis (see **Figure 3-38**). There is no indication that undesirable results are occurring or have the potential to occur in this area. However, given that previous MT and MO definitions for other indicators are set at or near the historic low water levels, potential future impacts would already be mitigated without further analysis. Accordingly, previous MT and MO designations are adopted for this sustainability indicator, setting the MT at the historic low water level and the MO at the average of the high groundwater level and the MT **(Table 5-2)**.

Because subsidence monitoring has not occurred in the Urban MA, the KRGSA will conduct a preliminary monitoring program that incorporates the DWR SGMA portal where updated InSAR data will be posted. As instructed by DWR, several key one-mile sections will be selected in the Urban MA for evaluating the new data on an annual basis. Data will be provided in the Annual Report; if significant subsidence rates of more than 1 inch per year are indicated by the tool over a two-year period, additional monitoring of subsidence may be added to the GSP monitoring network such as GPS benchmarks.

5.8.4.2 KRGSA Agricultural Management Area

Northwest and North-Central KRGSA Agricultural MA

Significant amounts of historical land subsidence have not been associated with the northwestern KRGSA Agricultural MA (see discussion in **Section 3.3.5** and **Figure 3-37**). Current analyses from JPL indicate some subsidence associated with the recent drought ranging from about one to three inches (see **Figure 3-38**). Yet there has been no evidence of damage to any infrastructure to date. KDWD has not observed land subsidence along its unlined canals or around other infrastructure even though they have field staff continually monitoring and managing the canals. KDWD landowners have not reported any damage to well casings or other local infrastructure. Therefore, undesirable results do not appear to be occurring in this area of the KRGSA Agricultural MA as of January 2015. Although there is a potential for future subsidence in this area based on the JPL analysis, rates and extents are not known.

The water level MT, set at 50 feet below the historic low water level, would allow for additional subsidence to occur, but the rate is expected to be less than in southern, more clay-rich areas of the Agricultural MA. In order to maintain the operational flexibility needed for agricultural and banking recover wells in this area, especially until the GSP projects have been fully implemented, the water level MT and MO are also selected for the land subsidence indicator in the northwest Agricultural MA. Specifically, the MT is selected to be the historic low water level that occurred during the 2012-2016 drought and the MO is defined as the average of the high groundwater levels during the historical Study Period and the MT **(Table 5-2)**. This selection is further bolstered by a management action (**Section 7**) and monitoring network commitment (**Section 6**) to further investigate subsidence potential in this area.

Southern and Eastern Agricultural MA

In the southern and eastern KRGSA Agricultural MA, historical subsidence between one and nine feet has been documented in the south, occurring over a period of about 1926 to 1970 with most of the subsidence occurring in the 1950s and 1960s (see **Section 3.3.5.1** and **Figure 3-37**). More recent JPL mapping between May 2015 and December 2016 indicates ground surface displacement of 4 to 8 inches, which are associated with the recent water level declines. As in other areas of the KRGSA, no damage to critical infrastructure has been identified and undesirable results do not appear to be occurring as of January 2015. This may be the result of large-scale agricultural development, undeveloped land, and the absence of widespread critical infrastructure such that no impact from subsidence is observed.

It is not surprising to see additional subsidence triggered during this recent drought, although much of this ongoing subsidence is likely due to the slow compaction of the thick clay sequences in the area, which may have been triggered by historical water levels as well. Nonetheless, historical and current rates of subsidence, along with the presence of thick clay deposits indicate that future potential subsidence is a risk. The water level MT assigned for this area of 50 feet below historic low water levels seems excessive, given the historical and current indications of subsidence. Because these rates of subsidence are not currently evident, local subsidence requires future ground-truthing and maintenance of water levels near historic lows to mitigate the subsidence potential.

However, to provide a transition from the MT in the northwest Agricultural MA and the MT assignments in adjacent WRMWSD and AEWSD, an allowance of 20 feet below the historic low water level is selected as the MT in the southern and eastern Agricultural MA **(Table 5-2)**. This also provides a means of transitioning from the MT of historic low water levels along the boundary between the Agricultural MA and the Urban MA in the eastern Plan Area. Although a MT set below the historic low water level will allow some additional subsidence to occur during the early portions of the GSP implementation period, management projects are expected to allow future maintenance of water levels above historic low levels (see **Section 4.7.3** and **Section 7.1**).

To provide additional protection to this area during GSP implementation, the KRGSA will supplement water level monitoring with additional evaluations of subsidence. As indicated in the subsidence monitoring discussion in **Section 6**, KDWD will use the InSAR data portal being developed by DWR to monitor subsidence rates across this area. KDWD field staff will continue to examine canals and roadways in the area to identify field evidence. In addition, data from three existing GPS monitoring stations will be obtained, reviewed and documented in Annual Reports (**Section 6.2.3**). Finally, the KRGSA is cooperating with KGA and the other GSAs in a Subbasin-wide subsidence monitoring program for shared interests in critical infrastructure in the Subbasin (documented in **Section 5.8.4.4** below).

In consideration of the above discussion, an MT of 20 feet below the historic low water level is selected for the southern and eastern KRGSA Agricultural MA **(Table 5-2)**. The MO is defined as the average of the high groundwater elevation during the historical Study Period (typically from Spring 1998) and the MT. Consistent with the criteria defined in WRMWSD and AEWSD, an undesirable result is triggered if levels in 40 percent of the representative monitoring wells remain below the MT for two consecutive years or if material damage to critical infrastructure from land subsidence is observed (**Table 5-2b**). This provides management flexibility during a future multi-year drought before GSP projects are fully implemented.

5.8.4.3 KRGSA Banking Management Area

Similar to the Urban MA, the KRGSA Banking MA is less likely to be susceptible to significant land subsidence under current operations. No historical subsidence has been documented in the Banking MA. Subsidence monitoring by others at the banking projects, including the Kern Water Bank, have not documented any inelastic land subsidence. No infrastructure damage relating to land subsidence has been documented in the Banking MA and undesirable results as of January 2015 do not appear to be occurring. The potential for future damage to critical infrastructure in this area also seems unlikely. Wells at the adjacent Pioneer banking project observed water levels close to -50 feet msl with no subsidence indicated, about 35 feet below the historic water level low in the KRGSA. Pioneer has selected an MT of 50 feet below that level for sustainable management criteria in the Pioneer Project.

The MT selected for other sustainability indicators maintain water levels at or near the historic low level and would be the controlling indicator for GSP compliance. Nonetheless, with no historical subsidence indicated at adjacent banking programs when water levels declined below those observed in the KRGSA, an MT of 50 feet below the historic low water level in the KRGSA is not likely to trigger significant levels of subsidence and is selected for the Banking MA including Berrenda Mesa, the COB 2800 facility, and the ID4 recovery wells along the Kern River channel **(Table 5-2)**. As in the Urban MA, water level monitoring will occur in the Banking MA and document the maintenance of water levels.

5.8.4.4 Coordinated Subbasin Monitoring for Land Subsidence

Because of the mutual interest in protecting critical infrastructure from land subsidence, the KRGSA plans to cooperate with the other GSAs in the Subbasin for a coordinated land subsidence monitoring program. This program would supplement monitoring of land subsidence and MTs and MOs in the KRGSA Agricultural and Urban MAs as described above and provide additional protection for the shared critical infrastructure across the Subbasin (see also **Section 6.2.3**).

5.9 DEPLETION OF INTERCONNECTED SURFACE WATER

An analysis of interconnected surface water and GDEs, as described in **Section 3.3.6**, did not identify applicable areas of interconnected surface water/GDEs in the KRGSA Plan Area. Given the depth to water beneath the NCCAG areas, and ongoing management activities along the Kern River channel and local unlined canals, interconnected surface water is not likely to be present or to occur in the near future. An analysis by KGA confirmed the assessment that interconnected surface water was not likely present in the Subbasin; accordingly, a Subbasin-wide definition of undesirable results was not developed for this sustainability indicator. Given the results of the analysis in the KRGSA GSP, no sustainability criteria are defined including undesirable results, or a MT or MO.

This GSP involves projects that raise or maintain water levels near the historic low level observed during the 2015-2016 drought, which would protect any un-identified GDEs. The GSP monitoring network will document the ongoing water level conditions beneath the Plan Area. Additional monitoring has been added along the Kern River to track any future changes in interconnected surface water, including wells 30S/27E-05D01 and ID4#13 as shown on **Figures 3-47a** and **3-47b**, respectively.

In coordination with other GSAs in the Subbasin, the KGA developed Subbasin-wide definitions of undesirable results for each sustainability indicator applicable to the Kern County Subbasin. Because the Basin Setting analyses conducted by the KGA and the KRGSA have not identified interconnected surface water in the Subbasin, no Subbasin-wide definition of undesirable results was developed for this sustainability indicator.

5.10 SUSTAINABLE MANAGEMENT CRITERIA AND ADAPTIVE MANAGEMENT

The MTs for the applicable sustainability indicators described above are summarized in **Table 5-2a**. **Table 5-2b** provides addition criteria for defining undesirable results including consideration of the number of wells and duration that the MT is exceeded. Generalized subareas described within each of the MAs are included on the table along with considerations for the MT selection. As shown in **Table 5-2**, historic low water levels encountered during the drought of 2013-2016 are used as the basis for each MT associated with every applicable sustainability indicator. For each indicator, the historic low water level is either used directly as the MT or adjusted based on the analysis discussed above.

Although each MT is slightly different for the subareas within each MA, the shallowest MT will be the controlling MT for GSP compliance. The controlling sustainability indicator for each subarea in the MA is highlighted in green in **Table 5-2**. For subareas that include or are adjacent to municipal wells that are already experiencing undesirable results related to both chronic lowering of water levels and degraded water quality, both indicators are highlighted.

The subareas will be monitored with representative monitoring wells as described in **Section 6**. Monitoring wells will be selected based on location and water level record. Wells with long records and frequent measurements are prioritized to allow historical context for local water levels. An example hydrograph on **Figure 5-5** illustrates how the sustainability criteria are being applied. As shown on the hydrograph and summarized in **Table 5-2**, the historic low water level is the basis for the MTs and is adjusted, as needed, based on the analysis of the sustainability indicator discussed above. The MO is the average between the high-water level mark and the MT (**Figure 5-5**). The high and low water level provide a reasonable operational range of water levels in the KRGSA Plan Area. Importantly, as mentioned in **Section 5.2.4**, this MO also reflects a water level range associated with a sustainable yield in the KRGSA (see also **Section 4.5.4**). This method of monitoring sustainability illustrates the reliance on groundwater levels and the importance of selecting representative monitoring wells, discussed in **Section 6**.

The use of water levels as a proxy for all of the applicable sustainability indicators is allowed by the regulations, provided the justification and basis for doing so is technically defensible. As explained for each indicator above, water levels are directly linked to how the indicator is being applied in this GSP. The actual water level for each MT may require future adjustment, however, once the aquifer response to management actions is more accurately measured.

As mentioned previously, this selection of water level MTs and MOs represents the first attempt to quantify sustainable management criteria for the KRGSA Plan Area. Management of water levels and water budgets have not previously been linked to groundwater usage on a real-time basis, and operation of the groundwater resource at this level of detail contains inherent uncertainty. Groundwater management within these constraints may not prevent all undesirable results or allow sufficient operational flexibility to optimize groundwater resources.

Accordingly, the selected MTs and MOs in **Table 5-2** and management actions will require adaptation. Modification of management criteria as well as improvements in management are expected to be identified as KRGSA Plan Managers cooperate and coordinate in meeting the GSP sustainability goal. This concept of adaptive management will be continually evaluated during the implementation horizon to achieve sustainability by 2040 while also providing for beneficial uses of groundwater.

5.11 INTERIM MILESTONES

As the GSP in being implemented between 2020 and 2040, results of the management actions and GSP performance are tracked, in part, by interim milestones established by the GSAs. GSP regulations define interim milestone as follows:

> “Interim milestone” refers to a target value representing measurable groundwater conditions, in increments of five years, set by an Agency as part of a Plan. (§351(q)).

The selection of interim milestones considers the time period required to implement the primary management projects and the potential for observed changes in the groundwater system as a result of these actions. Numerous future factors will affect performance with respect to the interim milestones and achievement of sustainability criteria most notably the timing and duration of the next multi-year drought. Nonetheless, the GSP Annual and Five-Year Assessment Reports can refer to interim milestones in evaluating GSP progress.

Water levels fell to historic lows during the recent drought and are now recovering from those low levels. As water levels rise closer to the average during the implementation period, the MO will be achieved. The MO, as defined in this GSP, represents the average water level within the operational range of the groundwater beneath the KRGSA. To reach the MO target, interim milestones are defined between the historic low water level and the MO. Regulations require that the milestones be developed in five-year increments over the 20-year GSP implementation period (2020 to 2040), resulting in four increments. Accordingly, three increments are developed evenly between the MT and the MO, with the MO established at the end of the fourth period. This method is summarized in **Table 5-3**:

Table 5-3: Methodology for Interim Milestones

GSP Implementation Period	Interim Milestone Groundwater Elevation (ft msl)	Method Example: IF MT = 100 ft msl AND MO = 200 ft msl
Begin Implementation	Minimum Threshold (MT)	100 ft msl
Year 5	((MO-MT) x 0.25) + MT	125 ft msl
Year 10	((MO-MT) x 0.5) + MT	150 ft msl
Year 15	((MO-MT) x 0.75) + MT	175 ft msl
Year 20 Achieve Sustainability	Measurable Objective (MO)	200 ft msl

In addition to water levels, the ongoing analysis of water budgets in the KRGSA Plan Area will also serve as interim milestones. Increments of additional inflows to groundwater will be used to measure progress toward meeting the KRGSA sustainability goal. Monitoring of water budget components are documented in **Section 6**.

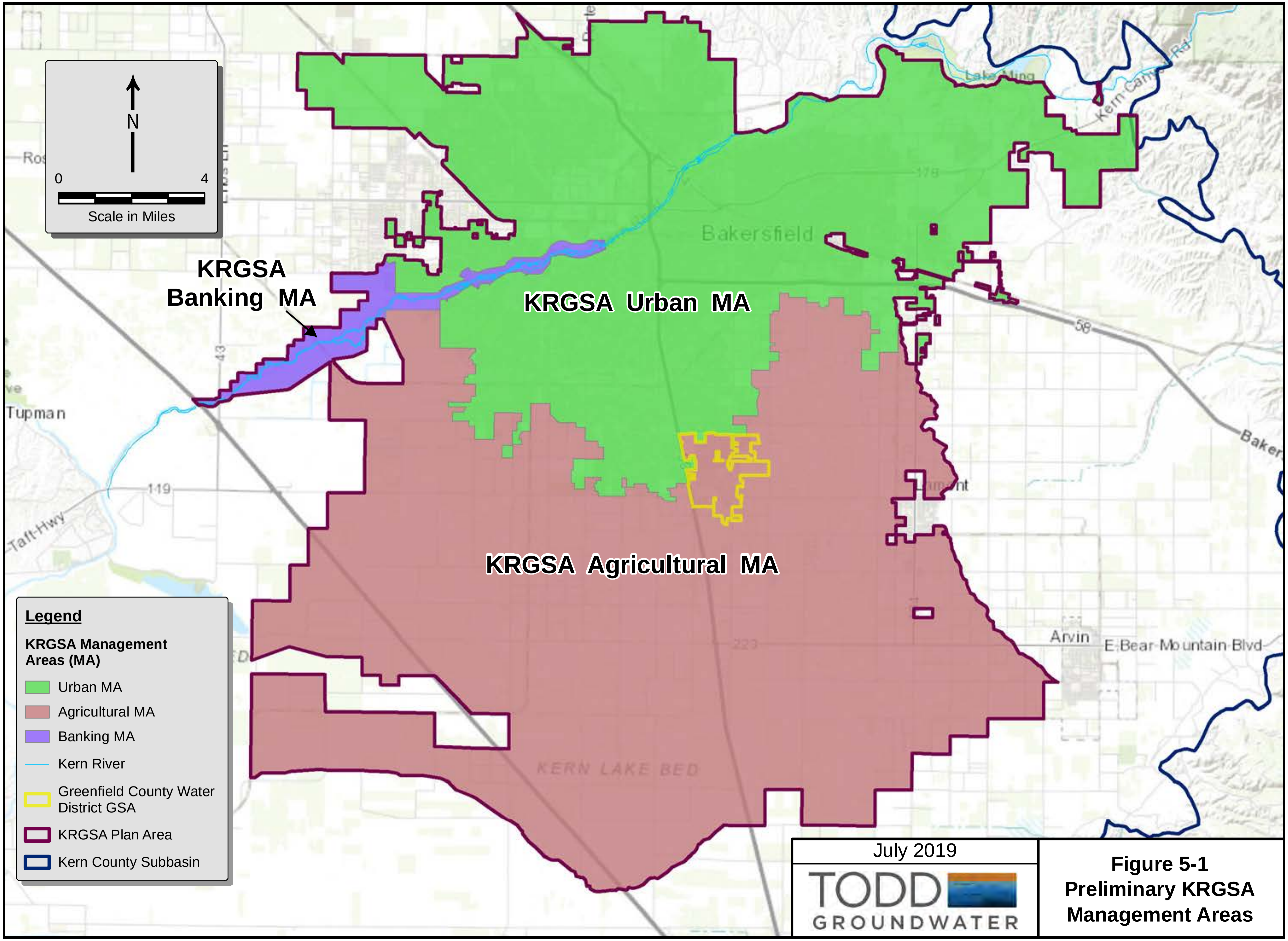


Figure 5-1
Preliminary KRGSA Management Areas

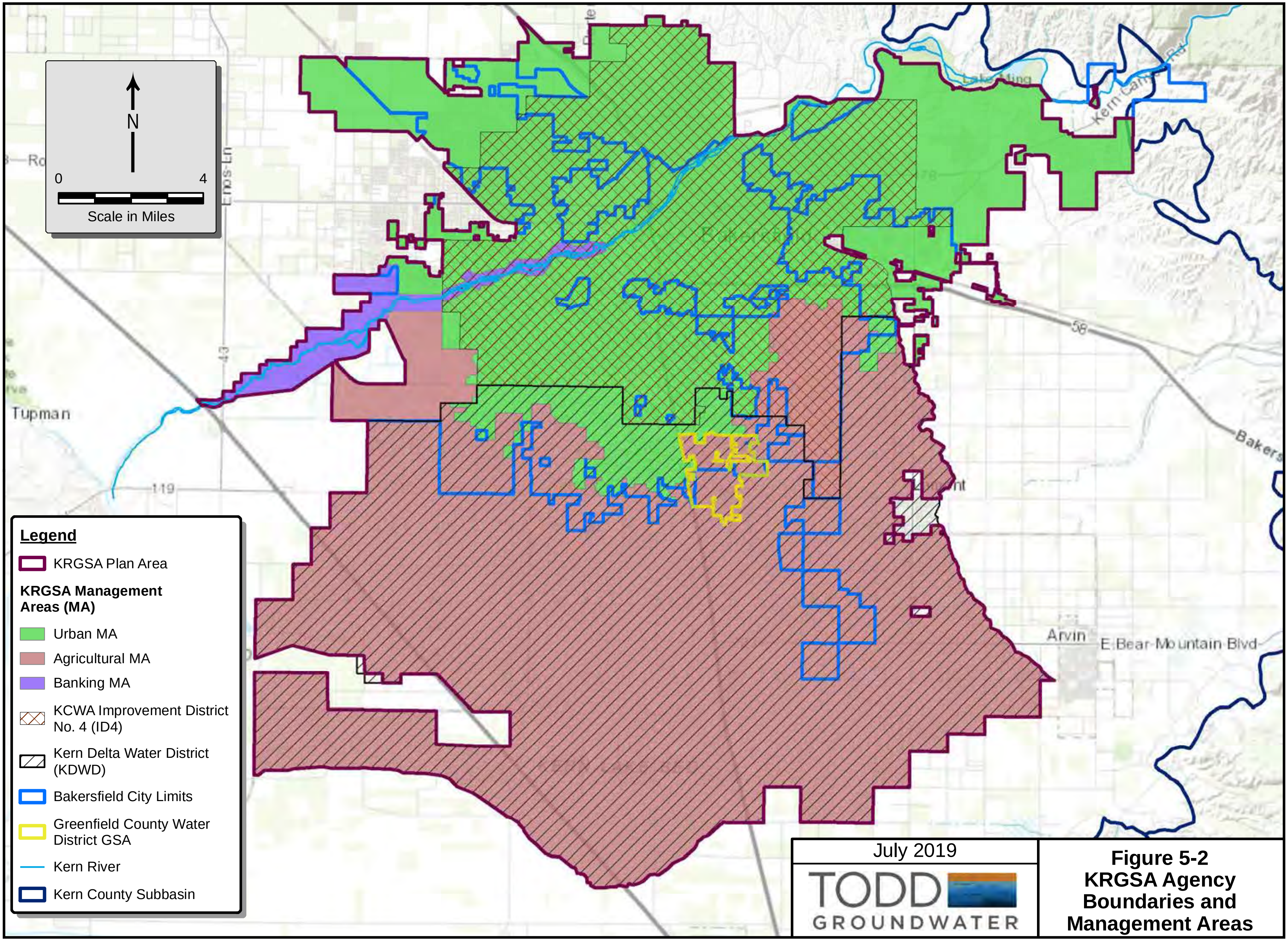
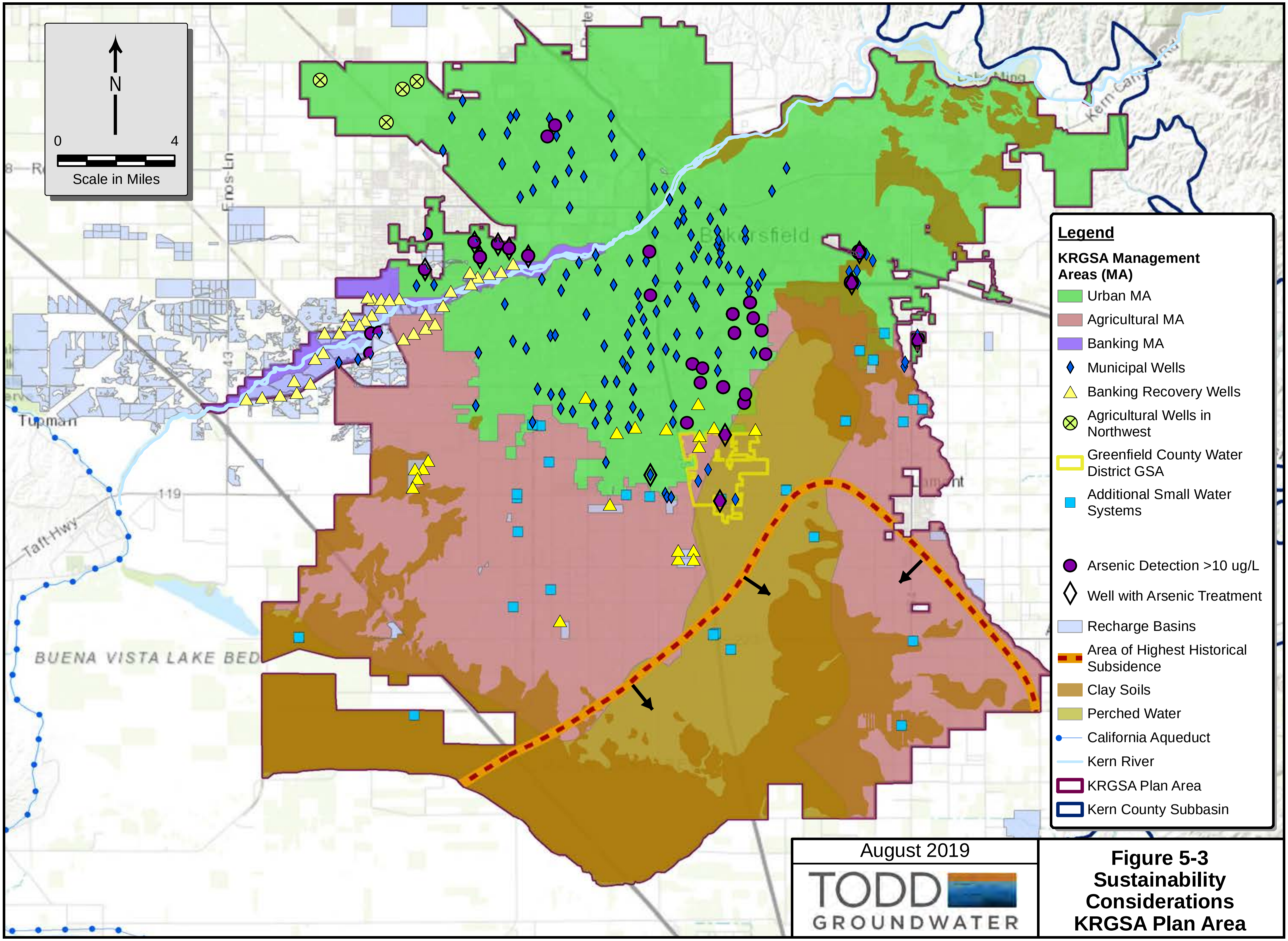


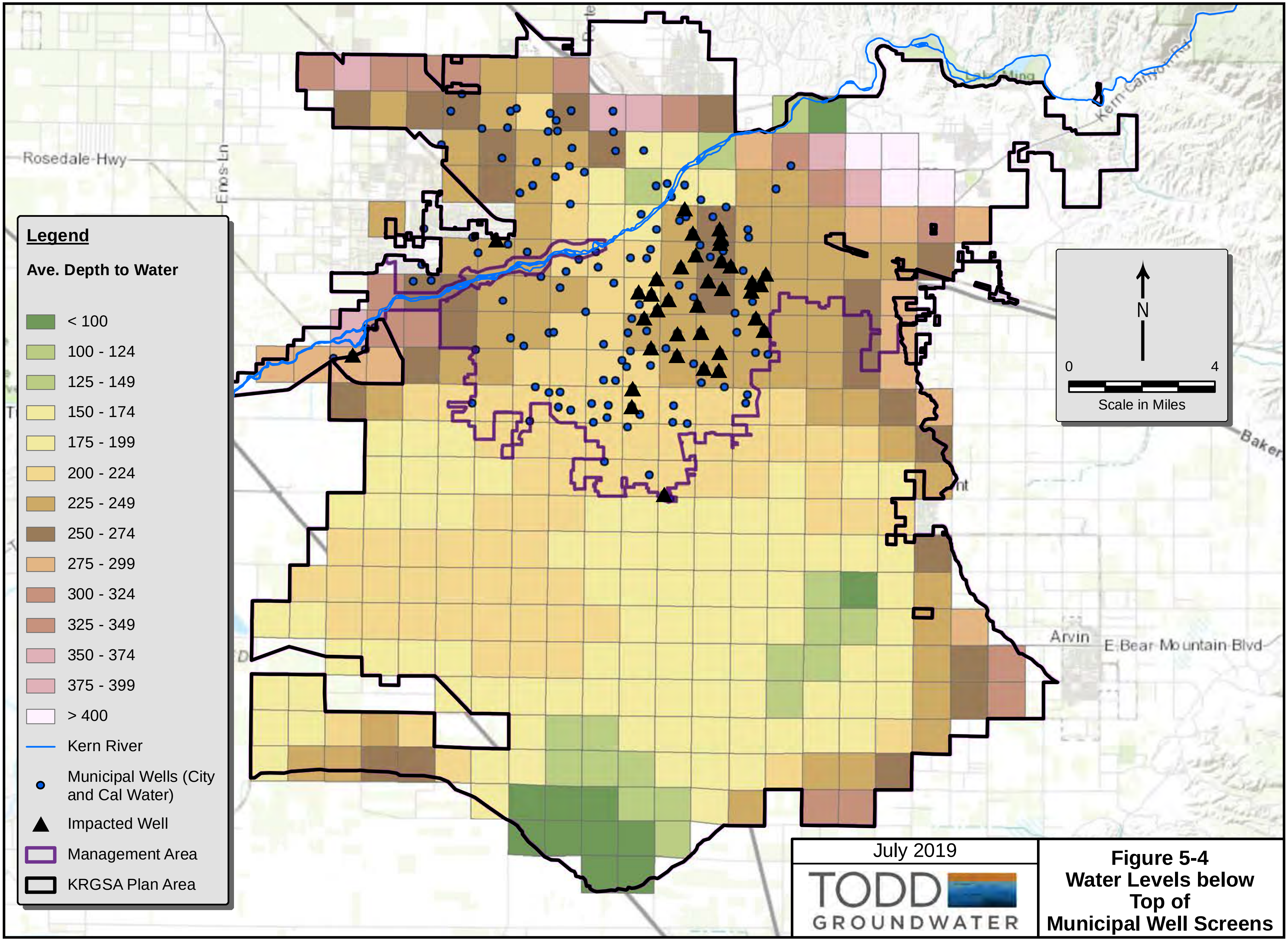
Figure 5-2
KRGSA Agency Boundaries and Management Areas



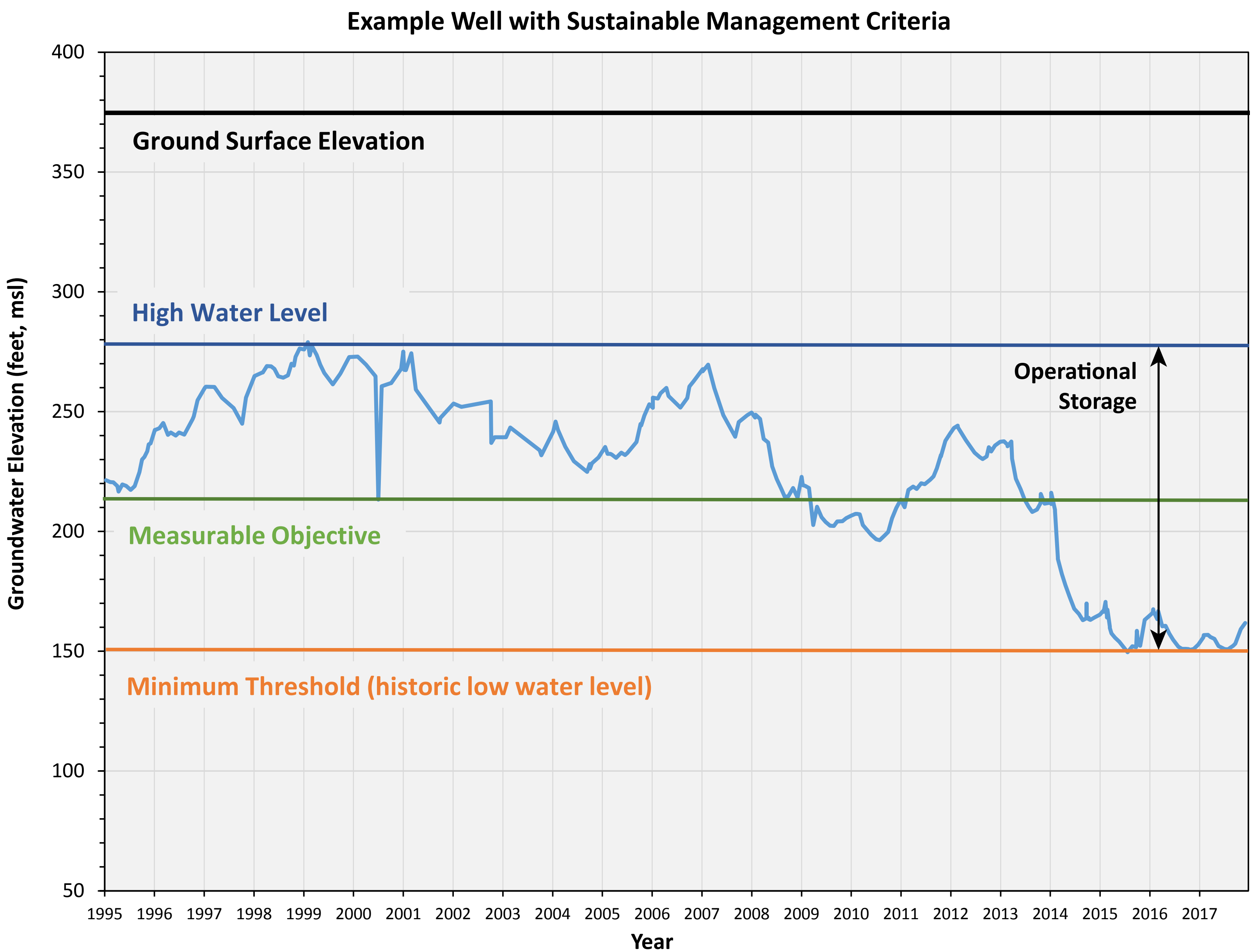
August 2019

TODD GROUNDWATER

Figure 5-3
Sustainability Considerations
KRGSA Plan Area



July 2019
TODD GROUNDWATER
Figure 5-4
Water Levels below Top of Municipal Well Screens



July 2019

TODD GROUNDWATER

Figure 5-5
Example Sustainable Management Criteria