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# AMENDED CHAPTER GROUNDWATER SUSTAINABILITY PLAN

## WESTSIDE DISTRICT WATER AUTHORITY

### Kern County, California

Prepared for:
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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ~ | Approximately |
| > | Greater than |
| < | Less than |
| % | Percent |
| 1,2-DCP | 1,2-dichloropropane |
| 40 CFR | Title 40 of the Code of Federal Regulations |
| AB | Assembly Bill |
| AF | acre-feet |
| AF/acre | acre-feet per acre |
| AFY | acre-feet per year |
| AGR | Agriculture |
| Amec | Amec Foster Wheeler |
| AWMP | Agricultural Water Management Plan |
| bgs | below ground surface |
| BMWD | Berrenda Mesa Water District |
| BPAW | Basin Plan Amendment Workplan |
| BWSD | Belridge Water Storage District |
| BVWSD | Buena Vista Water Storage District |
| °C | degrees Celsius |
| Ca | calcium |
| CASGEM | California Statewide Groundwater Elevation Monitoring |
| CCR | California Code of Regulation |
| CEQA | California Environmental Quality Act |
| CFR | Code of Federal Regulations |
| CGS | California Geological Survey |
| CIMIS | California Irrigation Management Information System |
| Cl | chloride |
| cm | centimeters |
| CRC | California Resource Corporation |
| COC | constituents of concern |
| CV-SALTS | Central Valley Salinity Alternatives for Long-Term Sustainability |
| CVP | Central Valley Project |
| CWC | California Water Code |
| DAC | disadvantaged community |
| DAU | Detailed Analysis Unit |
| DBCP | 1,2-dibromo-3-chloropane |
| DDWD | Devil's Den Water District |
| DO | dissolved oxygen |
| DOGGR | California Division of Oil, Gas, and Geothermal Resources |
| DPH | California Department of Public Health |
| DQO | data quality objectives |
| DRWD | Dudley Ridge Water District |
| DTSC | Department of Toxic Substances Control |
| DWR | California Department of Water Resources |

| | |
|---|---|
| EOR | enhanced oil recovery |
| ETAW | evapotranspiration of applied water |
| ETo | evapotranspiration |
| °F | degrees Fahrenheit |
| FAO | Food and Agriculture Organization of the United Nations |
| feet/year | feet per year |
| FS | Feasibility Study |
| GAMA | Groundwater Ambient Monitoring and Assessment |
| GEI | GEI Consultants |
| General Plan | Kern County General Plan |
| GMA | groundwater management area |
| GSA | Groundwater Sustainability Agency |
| GSP | Groundwater Sustainability Plan |
| HCM | Hydrogeologic Conceptual Model |
| I-5 | Interstate-5 |
| ILRP | Irrigated Lands Regulatory Program |
| inches/year | inches per year |
| IND | Industrial |
| KCWMD | Kern County Waste Management District |
| KCPNRD | Kern County Planning and Natural Resources Department |
| KCS | Kern County Subbasin |
| KCWA | Kern County Water Agency |
| KGA | Kern Groundwater Authority |
| LER | Lokern Ecological Reserve |
| LHSL | Lost Hills Sanitary Landfill |
| LHWD | Lost Hills Water District |
| LUST | leaking underground storage tank |
| MCL | maximum contaminant level |
| mg/L | milligrams per liter |
| mg/L-N | milligrams per liter as nitrogen |
| mmohs/cm | millimohs per centimeter |
| MNP | Monitoring Network Plan |
| MO | measurable objective |
| MSL | mean sea level |
| MT | minimum threshold |
| MUN | Municipal |
| Na | sodium |
| NA | not available |
| $NO_3$ | Nitrate |
| NOAA | National Oceanic and Atmospheric Administration |
| NOI | Notice of Intent |
| NPDES | National Pollutant Discharge Elimination System |
| NWIS | National Water Information System |
| pH | potential of hydrogen |
| POE | point of entry |
| POU | point of use |

| | |
|---|---|
| ppb | parts per billion |
| ppt | parts per trillion |
| QA/QC | quality assurance/quality control |
| RO | reverse osmosis |
| RWQCB | Regional Water Quality Control Board |
| SB | Senate Bill |
| SGMA | Sustainable Groundwater Management Act |
| SMCL | secondary maximum contaminant level |
| SO4 | sulfate |
| SpC | specific conductance |
| State | State of California |
| s.u. | standard unit |
| SWP | State Water Project |
| SWRCB | State Water Resources Control Board |
| SWSD | Semitropic Water Storage District |
| TCP | 1,2,3-trichloropropane |
| TDS | total dissolved solids |
| ug/L | micrograms per liter |
| UIC | Underground Injection Control |
| umhos/cm | micromhos per centimeter |
| uS/cm | micro siemens per centimeter |
| USDA | United States Department of Agriculture |
| USDW | Underground Source of Drinking Water |
| US EPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |
| Valley | Central Valley |
| WDR | waste discharge requirement |
| WDWA | Westside District Water Authority |
| WKWD | West Kern Water District |
| WWQC | Westside Water Quality Coalition |
| WY | Water Year |

# EXECUTIVE SUMMARY

The Westside District Water Authority (WDWA), member agency of the Kern Groundwater Authority (KGA) originally submitted this Chapter Groundwater Sustainability Plan (GSP) as a component of the comprehensive KGA "Umbrella GSP" in January 2020. This same process will be followed for submittal of this amended report.

In a letter dated January 28, 2022, to the KGA, the California Department of Water Resources (DWR) identified three general deficiencies applicable to the KGA Umbrella and some or all the component Chapter GSPs. In addition, the DWR letter also provided one WDWA specific deficiency that required further explanation. Revisions to the WDWA Chapter GSP to address DWR comments are provided herein as REDLINE text. While there are REDLINE edits interspersed throughout the body of this report, the most relevant, in response to the stated DWR deficiencies, are found in **Sections 2.11, 2.12, 3.0, 4.0 and 5.0.** The three stated KGA-specific deficiencies are:

A. **Deficiency-1, The GSPs do not establish undesirable results that are consistent for the entire Subbasin**.

1. *While the Coordination Agreement presents Subbasin-wide undesirable results, the Subbasin's fragmented approach towards establishing management criteria that define undesirable conditions in various parts of the Subbasin does not satisfy SGMA's requirement to use same data and methodologies.*

Please see **Section 2.11** which provides the amended sustainability goals and coordinated management criteria for the Subbasin and WDWA. **Section 2.12** discusses WDWA Undesirable Results.

**B. Deficiency-2, The Subbasin's chronic lowering of groundwater levels sustainable management criteria do not satisfy the requirements of SGMA and the GSP Regulations.**

1. *The GSPs relied on disparate methods to develop groundwater level minimum thresholds across the numerous GSPs and management areas*.

2. *The GSPs do not consistently and sufficiently document the effects of their selected minimum thresholds on beneficial use and users in the Subbasin, nor explain how the minimum thresholds and measurable objectives that are set below historical lows will impact other applicable sustainability indicators, specifically water quality, land subsidence, and reduction of groundwater storage*.

The WDWA has revised this amended Chapter GSP to rely on the coordinated KGA methods that define and develop groundwater minimum thresholds. Because of naturally poor water quality, the WDWA relies on surface water as its primary water source. Groundwater pumping in the WDWA is typically limited for use as blending. Therefore, the groundwater Measurable Objectives and Minimum Thresholds in the WDWA have been consistently above historic groundwater lows and no specific WDWA sustainability indicators are impacted. Please see **Sections 2.12.3 and 4.0** for additional details. . **Appendix I** provides KCS Coordination Summary Matrix spreadsheets.

**C. Deficiency-3, The Subbasin's land subsidence sustainable management criteria do not satisfy the requirements of SGMA and the GSP Regulations.**

1. *The Plan lacks a Subbasin-wide, coordinated approach to establishing land subsidence sustainable management criteria.*

2. *The GSPs and management areas that use their minimum thresholds for the chronic lowering of groundwater levels as a proxy criteria for subsidence do not sufficiently demonstrate that groundwater levels (specifically groundwater levels below historical lows) are a reasonable proxy to avoid land subsidence that would substantially interfere with surface land uses.*

With regard to Deficiency 3, the Subbasin has established a coordinated approach for establishing land subsidence sustainable management criteria that is consistent with the respective unique conditions that exist across the breadth and width of the Subbasin. The subject criteria have been incorporated herein. The WDWA is not relying on chronic lowering of groundwater levels as a proxy for subsidence, nor have groundwater MT/MOs been set below historical lows. In addition, per discussions with DWR, interim sustainable management criteria for subsidence (i.e., MOs/MTs) for Regional Critical Infrastructure (i.e., Aqueduct and Friant-Kern Canal) have been established. The interim subsidence MOs/MTs which are detailed in the white paper, will be updated in 2025 pending collection and analysis of additional information in coordination with DWR California Aqueduct Subsidence Project (CASP) staff to address previously identified subsidence data gaps. Please see **Sections 2.12.6 and 4.1.2** for additional details. **Appendix I** provides the white paper titled: Basin-Wide GSP Subsidence Plan Definitions and Sustainable Management Criteria (CA. Aqueduct) and the WDWA subsidence review for Aqueduct pools 23-25.

**DWR Specific Deficiency Pertaining To The WDWA**:

1. *The KGA GSP Westside management area states that total groundwater demand is about 3,000 acre-feet per year due to water quality; therefore, the potential for significant lowering of groundwater levels due to pumping is believed to be minimal. In*

*establishing the minimum thresholds, the management area first divided the area into two sentry coordination zones along the north and east boundaries of the management area (shown in **Figure 30a** and **Figure 30b**). There is one minimum threshold established for Sentry Zone #1 and three for Sentry Zone #2. These minimum thresholds values are not explained or justified. The established minimum thresholds do not apply for the majority of the management area and the rest of the management area is not being monitored for water levels. The management area plan states that minimal pumping takes place within the management area due to water quality; however, based on Figure 28a and Figure 28b subsidence appears to be occurring within the middle of the management area. For this reason, sustainable management criteria must be applied to the entirety of the management area, including the establishment of thresholds and monitoring.*

Please see **Sections 3.0, 2.12.6 and 4.0** for detailed explanations and justifications for the proposed sentry monitor approach. As noted by DWR, pumping is minimal in the WDWA due to naturally poor water quality. Oil field activities are widespread throughout the WDWA. Based on data acquired after submittal of the KGA Umbrella GSP in 2020, a focused study of the Lost Hills oil field (Aqueduct pools 23-25) concluded the subsidence referred to in the DWR comment is related to oil field activities and not SGMA related beneficial use (i.e., potential chronic lowering of groundwater levels). The WDWA does not have control over the oil field mode of subsidence or subsidence related to other non-SGMA modes such as, natural settlement or conditions related to the construction or age of the 60 year old Aqueduct. The WDWA oil field study, along with other KGA subsidence data, was presented to both DWR SGMA and DWR CASP staff in advance of the submittal of this amended GSP.

Regarding the potential change in groundwater levels, the WDWA has unique physiographic and hydrogeologic characteristics. Because of the limited pumping of naturally degraded groundwater, the principal factor related to CV2Sim modeled change in groundwater levels in the WDWA is the natural migration of groundwater underflow from the WDWA located on the western edge of the Subbasin towards the axis of the Valley. To monitor for this phenomenon the WDWA established representative sentry monitor wells along its eastern boundary with down gradient GSAs and GSPs. Because groundwater pumping in the WDWA is minimal, interior areas of the WDWA that have no significant current or planned SGMA related groundwater use (e.g., non-cultivated land, range land, oilfields etc.) are designated as “Watch Areas”. As such, these areas will not have MO/MTs. Watch Areas will be monitored for land use changes and groundwater conditions that could change its designation to a "management area" with specified sustainable management criteria. Additional monitor wells for the interior management areas are in the KGA review process for approval in Fall 2022. Further details on groundwater Watch Areas is provided in **Sections 2.10 and 3.0.** As noted above, **Appendix I**

provides the white paper titled: Basin-Wide GSP Subsidence Plan Definitions and Sustainable Management Criteria (CA. Aqueduct). The white paper contains the interim MO/MTs for land subsidence. The interim MO/MTs will be reassessed in 2025 based on data gathered between 2022 and 2025.

On September 16, 2014, the State of California enacted into law three legislative bills (Senate Bill [SB] 1168 [Pavely], SB 1319 [Pavely], and Assembly Bill [AB] 1739 [Dickinson]). These bills are collectively known as the Sustainable Groundwater Management Act (SGMA). In simple terms the goal of SGMA is the sustainable management and use of the State of California's (State's) groundwater resources in a way that does not cause undesirable results.

To achieve the sustainable management of groundwater, SGMA requires that all groundwater basins identified by the State as high or medium priority, and subject to conditions of critical overdraft, be managed under a Groundwater Sustainability Plan (GSP) by January 31, 2020. The Kern County Subbasin (KCS, subbasin, or Subbasin) has been identified as a critically over drafted High Priority Basin subject to SGMA. As such, a special entity called the Kern Groundwater Authority (KGA) was formed on April 26, 2017. An amended and restated Joint Powers Agreement between Kern County and the general members of the KGA provided the necessary legal authority for the KGA to prepare, submit, and implement the required GSP.

Because of the many independent Water Districts within the KCS, which serve a variety of differing water users, it was decided to prepare a general GSP for the KGA, referred to in this Chapter GSP as the "KGA Umbrella GSP" or "Plan". Within this framework individual Water Districts or groups of Water Districts in the KGA are to prepare more detailed individual "Chapter GSPs", which discuss local groundwater conditions that, although are often related to adjoining Water Districts, have hydrogeology or other factors which may be distinct to their respective management area(s). Additionally, the Chapter GSPs provide the ability for the KGA to identify which of the undesirable results identified in SGMA may apply to a specific area of the KCS, and how these results would best be monitored and mitigated over both the short- and long-term, in order to meet KGA and SGMA sustainability goals.

This Chapter GSP focuses on a select subset of Water Districts within the KGA. Those participating Districts, referred to as the Westside District Water Authority (WDWA), are:

1. Lost Hills Water District (LHWD);
2. Belridge Water Storage District (BWSD); and
3. Berrenda Mesa Water District (BMWD).

Commensurate with SGMA, and based on the current level of understanding of the WDWA within the KCS basin setting, the purpose of this Chapter GSP is to describe in plain language the groundwater conditions that currently exist within the WDWA. This Chapter GSP also identifies hydrologic data gaps and focused remedies, and presents a proposed groundwater management plan that, if determined to be technically and economically feasible, has the potential to achieve and maintain the sustainability goals of the WDWA and, by extension, those of the KGA over the required SGMA implementation horizon. Due the complex and interrelated nature of the hydrology and consumptive use of the water resources within the KGA, details and data from the KGA GSP, and some data from individual adjacent GSPs and/or Groundwater Sustainability Agencies (GSAs), may be included in this Chapter GSP. Issues related to preliminary coordination with adjacent Districts, if any, will be addressed during the first five-year reassessment period after acceptance of the KGA Plan.

The WDWA currently covers approximately 227,193 acres, or roughly 355 square miles of western Kern County, California. Of this total, approximately 88,989 acres (~140 square miles) is irrigated. A large percentage of the acreage within the WDWA is comprised of Undistricted Lands most of which is non-irrigated or native rangeland juxtaposed with former or active oil field activities. Most of the Undistracted Lands are administered by the KGA. Actual groundwater well density within the WDWA is sparse and groundwater extraction for agriculture or other SGMA related uses is low due to naturally poor water quality. A recent survey identified only two “domestic wells” in the WDWA, which may actually be used for livestock watering. An update to well status in the WDWA is planned to begin in fall 2022. Preliminary numerical modeling by the KGA indicates that the WDWA has a historic annual water demand of approximately 285,000 acre-feet per year (AFY), which is projected to escalate to approximately 316,000 AFY by 2040 due primarily to climate change. Historically, significantly more than 95% of the water used for irrigation in the WDWA has been surface water, with most of the supply coming from the State Water Project (SWP) and other supplemental sources delivered via the California Aqueduct (Aqueduct). This volume of water consists of a combination of SWP “Table A” and “Article 21” water along with purchased supplemental import water, although not all supplemental water is SWP water. When available, a combined 100 percent (%) WDWA allocation from the SWP is around 332,218 AFY. Current surface water deliveries (all WDWA sources) are approximately 266,290 AFY. The WDWA preliminary minimum estimated volume of groundwater available that would not cause an undesirable result (i.e. “Native Yield”), is approximately 34,079 AFY. This volume is based on basic water supply inputs. When additional water budget inputs, such as those proposed in Project Management Action #3, are considered this volume may be higher (~68,158 AFY). Groundwater is primarily utilized for blending when California Aqueduct (Aqueduct) water supply is low. Current SGMA related groundwater pumping in the WDWA is on the order of 3,000 to 5,000 AFY. It is emphasized that groundwater in the WDWA is of naturally poor quality

due to the type of geologic sediments found in the WDWA and is unsuitable for practical use without blending or treatment. As such, brackish groundwater is considered to be "outside" the water budget unless blended or treated.

Unique hydrogeologic characteristics of the WDWA that set it apart from the other Water Districts in the KCS are:

1. The WDWA is isolated from other groundwater basins and adjoining water districts along its entire western boundary by the Temblor Mountain Range, its primary source of subsurface groundwater inflow. On the north and east, groundwater underflow from the WDWA towards the axis of the basin is impeded or slowed by a series of roughly north-south oriented geologic anticlines and synclines (up folds and down folds). To the south groundwater flow is impeded by geologic structural ridges that include spurs of the Temblor Range and the Elk Hills Anticline. This geologic setting has contributed to the poor groundwater quality in the WDWA, and limits necessary groundwater coordination to just a few downgradient management areas to the north and east.

2. Groundwater is naturally degraded and of poor quality throughout most of the WDWA due to the presence of geologic sediments derived from marine environments, some of which contain saline connate water. These conditions make groundwater in the WDWA unsuitable for practical beneficial use, without treatment or blending with better quality water.

3. Irrigation demand is met almost entirely by water delivered via the Aqueduct. Groundwater is estimated to make up less than 2% of the water used for irrigation by private well owners due to its poor quality. Current pumping for the purpose of blending with the Aqueduct-delivered water supply is estimated to be approximately 3,000 to 5,000 AFY.

4. The most significant amount of brackish groundwater discharge from the WDWA modeled by the KGA is in the form of natural subsurface groundwater underflow to the north, towards the former Tulare Lakebed, a beneficial use exemption area, and eastward towards the axis of the Valley. The total combined volume of modeled underflow discharge to these areas is estimated to be approximately 111,000 AFY. Given the limited amount of pumping in the WDWA, underflow out of the WDWA is the most significant contributor to estimated groundwater deficits (change in groundwater storage) in the WDWA. This natural phenomenon is beyond the control of the WDWA.

5. Pumping for consumptive use in downgradient adjacent water districts has resulted in noticeable differences in groundwater elevations between the WDWA and these areas. The adjacent pumping has likely increased the velocity and volume of underflow out of the WDWA along shared administrative boundaries to the east and southeast. While the WDWA

plans to coordinate with adjacent water districts during the implementation of the GSP, activities in adjacent districts which may affect WDWA groundwater elevations are beyond the direct control of the WDWA.

6. In 2016, due to the near ubiquitous poor quality of groundwater in the KCS west side, the Westside Water Quality Coalition (WWQC) prepared a Basin Plan Amendment Workplan (BPAW), which is inclusive of a significant percentage of the irrigated lands within the WDWA. The BPAW recommends delisting municipal and unlimited agriculture as a designated beneficial use for perched groundwater and deeper unconfined/semi-confined groundwater above the sub-regional Corcoran Clay (or its equivalent) due to naturally poor groundwater quality. The draft BPAW has been provided to the CV-SALTS Technical Committee and the Regional Water Quality Control Board (RWQCB) for preliminary review and input. The final determination by the RWQCB on the BPAW application will be reported in the relevant GSP annual update report.

A brief description of the member districts of the WDWA follows.

## Lost Hills Water District

The LHWD was formed in 1963 to provide irrigation water from the SWP to the District. The LHWD boundaries begin just south of the town of Lost Hills and extend north and west to the Kings-Kern County line. Key landmarks include the California Aqueduct and Interstate 5 (I-5), the latter of which bisects the District diagonally from northwest to southeast. Adjacent Water Districts include Dudley Ridge Water District (DRWD) to the north (Kings County, Tulare Lake Subbasin), the BWSD to the south, the Semitropic Water Storage District (SWSD) and a portion of the Buena Vista Water Storage District (BVWSD) to the east, and the BWSD to the west.

The LHWD is comprised of approximately 74,357 acres, of which 70,453 acres are considered farmable. Not all of this acreage is currently being utilized for agricultural purposes. As of 2015, the net area under irrigated cultivation is approximately 27,900 acres. Agricultural activities rely primarily on surface water from the Aqueduct. In addition to agriculture, oil and gas production is an important non-irrigated land use within the LHWD. Oil field activities has been identified as a source of subsidence along the Aqueduct. Additional information pertaining to oil field activities and subsidence in the WDWA is provided in Section 2.12.6 . Groundwater use in the LHWD is mostly limited to periods of contracted surface water shortfalls and is generally relied upon for the purpose of blending. During periods of drought the LHWD also relies on groundwater coordination with adjacent Water Districts or growers as well as for surface water transfers, supplemental water purchases and nearby water banking programs (i.e., Berrenda Mesa and Pioneer Projects). These two banking projects are located outside of the District, just southwest of the City of Bakersfield. Individual landowners within the WDWA may also

participate in surface-water banking projects, which can provide a significant amount of banked water for, and on, their own behalf. Groundwater quality is documented to be naturally degraded due to elevated concentrations of total dissolved solids (TDS). Groundwater is considered unsuitable for most uses and is non-beneficial for a majority of crops, and in some cases livestock. The LHWD supplies no municipal water from surface water or groundwater.

## Berrenda Mesa Water District

Like the LHWD, the BMWD was formed in 1963 by landowners for the purpose of providing a reliable supply of irrigation water to the BMWD from the SWP. To the north of the BMWD lies the adjacent Devil's Den Water District (DDWD) (Kern County, outside of the KCS), to the south is the BWSD, to east are Undistricted Lands and the LHWD, and to the west is the Temblor Mountain Range.

Of the approximate 55,440 acres within the BMWD, all but 6,400 acres are considered farmable. The estimated net acreage currently being farmed is around 35,240 acres, of which 24,204 acres is irrigated by surface water from the SWP. Remaining lands are used for dry land farming or livestock grazing. At 100% delivery, the volume of contract water available to the BMWD is approximately 92,600 acre-feet (AF). Current water demand is approximately 88,000 AFY.

During times of drought, when contract water deliveries are reduced, in addition to groundwater blending, the BMWD can recover previously stored (i.e. banked) surface water from the Pioneer and Berrenda Mesa Projects. These two banking projects are located outside of the District, just southwest of the City of Bakersfield. Individual landowners within the WDWA may also participate in surface-water banking projects, which can provide a significant amount of banked water for, and on, their own behalf.

Groundwater use is limited in the BMWD due to elevated concentrations of TDS. The BMWD supplies no municipal water either from groundwater or surface water supply.

## Belridge Water Storage District

The BWSD was formed by landowners in 1962 to provide surface water from the SWP for irrigation. The BWSD is bounded on the north by the LHWD and BMWD along with some currently Undistricted Lands, to the south by additional currently Undistricted Lands and the West Kern Water District (WKWD), to the east by the BVWSD, and to the west by the Temblor Mountain Range.

The principal source of water supply for the BSWD is surface and other imported water delivered by the Aqueduct, with agriculture as the main consumer. Of the 91,397 acres within

the BWSD, approximately 88,223 acres are considered farmable, although not all of this land is currently being used for agriculture. As of 2015, there were approximately 36,885 acres being irrigated in the BWSD. In addition to agriculture, a percentage of the BWSD annual import allocation, when available, is delivered for industrial use in oil recovery operations in the North and South Belridge oil fields.

During periods of drought the BWSD relies chiefly on groundwater blending and coordination with adjacent Water Districts or growers for water transfers, supplemental water purchases and transfers from nearby water banking programs (i.e., Berrenda Mesa and Pioneer Projects). These two banking projects are located outside of the District, just southwest of the City of Bakersfield. Individual landowners within the WDWA may also participate in surface-water banking projects, which can provide a significant amount of banked water for, and on, their own behalf. The BWSD supplies no municipal water either from groundwater or surface water supply.

## Public Meetings and Stakeholder Engagement

The KGA maintains a website (www.kerngwa.com) where it routinely posts information related to the GSP preparation process and proactively solicits stakeholder engagement and input. KGA Coordination Meetings with stakeholders are typically held on the first Monday of every month. A partial list of items that are made available on the KGA website includes:

- Agendas and dates for upcoming and past public meetings;
- Stakeholder surveys;
- Relevant documents and reports for public review and input;
- Presentations, research, and white papers; and
- KGA contact information.

Additionally, the WDWA members have their own individual websites that provide information that is focused on the status of WDWA operations and GSP development within their respective district areas. The WDWA-member websites are:

- LHWD: www.lhwd.org
- BWSD: www.belridgewsd.com
- BMWD: www.bmwd.org

WDWA public outreach activities to date include:

- The WDWA participated in a KGA sponsored public workshop at the Kern County Agricultural Center in Bakersfield, California on May 14, 2019. The evening workshop was open to all community members and stakeholders. The workshop afforded interested

parties the opportunity to interact one-on-one with WDWA staff and consultants who were there to answer and discuss questions or concerns related to the WDWA Chapter GSP, potential undesirable results and groundwater sustainability. The forum afforded the public an opportunity to also learn more about other KGA Chapter GSPs and the SGMA process.

- A second public KGA workshop was held on the evening of September 26, 2019 at the Kern County Agricultural Center in Bakersfield, California. This workshop took place during the KGA Umbrella GSP 90-day public review period and provided another opportunity for interested parties to communicate with WDWA staff and consultants regarding SGMA, the WDWA Chapter GSP, potential undesirable results and groundwater sustainability in the WDWA.

- A public meeting (WDWA regularly scheduled Board meeting) was held on June 5, 2019 at the BWSD offices. The purpose of this meeting was to discuss WDWA-specific issues related to this Draft Chapter GSP, such as current and projected water budgets, potential undesirable results, groundwater quality and Measurable Thresholds (MTs) and Measurable Objectives (MOs). The meeting updated Board members, the public and stakeholders on the status of the WDWA GSP Chapter findings, costs and the SGMA process. Initial comments received from the public or other stakeholders were incorporated into the Chapter GSP prior to the next scheduled update on August 21, 2019.

- A second update meeting with the WDWA Board and members of the public to discuss the Draft Chapter GSP was held on August 21, 2019 at the BWSD offices. In addition to presenting the latest information on the draft WDWA Chapter GSP, the WDWA Board approved submittal of the draft Chapter GSP for inclusion in the KGA Umbrella GSP prior to a 90-day public review period for the KGA Umbrella GSP. Initial comments received from stakeholders were incorporated in the update Chapter GSP presented at this meeting.

- The Draft Chapter GSP components and status were presented at three other regularly scheduled WDWA Board meetings open to the public, and at two public KGA Board Meetings held in Bakersfield on August 28, 2019 and December 18, 2019.

- The WDWA Manager received one direct comment letter during the 90-day public comment period for the KGA Draft Umbrella GSP. Relevant and applicable comments pertaining to the WDWA were incorporated in this version of the Chapter GSP. A copy of the letter is provided in the appendices of this report. Five other, more global, comment letters related to the Draft KGA Umbrella GSP and addressed to the KGA GSP Manager were also reviewed for relevant or applicable comments for incorporation that might pertain to the WDWA. It should be noted that the WDWA does not supply groundwater for municipal supply. Copies

of those letters are on file with the KGA. Based on Fish & Wildlife comments the Lokern Ecological Reserve was identified and discussed in the Chapter GSP.

- The WDWA Board at its public meeting on July 13, 2022 approved submittal of the Amended GSP Report.

## Basin Setting

The Central Valley of California (Valley) covers about 20,000 square miles and is bounded by the Cascade Mountain Range to the north, the Sierra Nevada Mountain Range (Sierra Nevada) to the east, the Tehachapi Mountains to the south, and the Coast Ranges (e.g., Temblor Range) and San Francisco Bay area to the west. The Valley is divided into three groundwater hydrologic regions according to the California Department of Water Resources (DWR's) Bulletin 118: (1) the northern one-third of the Valley is within the Sacramento River Basin; (2) the central one-third is within the San Joaquin River Basin; and (3) the southern one-third is within the Tulare Lake Basin, which in turn contains the KCS and the WDWA (DWR, 2016; GEI Consultants [GEI] 2019).

The WDWA, which is the focus of this Chapter GSP, covers approximately 227,193 acres (i.e. 355 square miles) along the extreme western side of the KCS. Of this total, approximately 89,989 acres, or about 140 square miles, is currently irrigated. The WDWA is bounded on the north by the Kings-Kern County line and the DRWD, on the south by the WKWD, on the east by various Undistricted Lands, the SWSD, and BVWSD, and on the west by the Temblor Mountain Range.

## Topography

Topography in the WDWA is mostly gentle and flat, with steeper foothills of the Temblor Range lying at the western edge. Elevations range from approximately 250 feet above mean sea level (MSL) in the east-southeast to 1,200 feet above MSL in the southwest. Typical slopes within the WDWA range from 25 to 50 feet per mile. The California Aqueduct, which runs along the eastern edge and through other parts of the WDWA, is at an approximate elevation of 310 feet above MSL. The western portion of the WDWA, known as the Antelope Plain, is enclosed by the Coastal (Temblor) Range on the west and north and by various geologic structural arches (anticlinal folds) on the east and south.

## Climate

The climate in the WDWA is generally hot and dry and is characterized as inland Mediterranean. The main growing season for the KCS runs from May through October, although various crops are grown year-round. Historic wet season precipitation averages around 5.2 inches per year (inches/year). The length of the frost-free season is currently about nine months, or

approximately 270 days per year. Surface water delivered by the SWP is the chief source of supply for irrigation in the WDWA (GEI, 2019; Amec Foster Wheeler [Amec], 2015).

## Basin Setting and Geology

The KCS is located in the southern most extent of the Tulare Lake Basin Hydrologic Region. The KCS encompasses a surface area of around 1,792,000 acres (2,800 square miles) and is underlain by approximately 32,000 feet (6 miles) of marine and continental sediments (Page, 1986; DWR, 2006; Amec, 2015; GEI, 2019). Near the end of the Late Cretaceous, tectonic movements elevated the Coast Ranges to the west of the Valley and created a marine embayment. During the Tertiary, seas episodically advanced and retreated within the embayment, resulting in deposits comprised of both continental and marine sediments. Structural deformation along the early and present-day San Andreas fault zone resulted in the formation of a series of anticlinal folds that form many of the prolific oil fields along the west side of the KCS (Farrar and Bertoldi, 1988; GEI, 2019).

During Pleistocene and Holocene times, the seas retreated, and continental deposits from alluvial and fluvial systems were deposited over Tertiary-age marine deposits. Some of these marine deposits contained naturally occurring connate (saline) water which have subsequently migrated into adjacent and overlying continental deposits (Page, 1986). Within the WDWA in general, eroded marine deposits are common and contribute to the overall poor, and mostly unusable, groundwater quality in the western KCS (GEI, 2019).

## Surface Water

Ephemeral streams that originate on the east-facing slopes of the Temblor Range drain eastward toward the Antelope Plain and from there towards the Valley floor. The stormwater runoff in these channels is not controlled and typically percolates within the Antelope Plain and does not reach the bed of the former Tulare Lake to the northeast or the axis of the Valley as surface flow. The 10-year, 24-hour, storm event for the area ranges from 3.0 to 3.5 inches of precipitation (National Oceanic and Atmospheric Administration [NOAA], 2013; Amec, 2015; GEI, 2019).

Lined irrigation canals and drainage facilities are the principal surface and imported water conveyance features in the WDWA. Chief among these are the California Aqueduct, and its Coastal Aqueduct inter-tie.

Partially overlapping with a small area in the LHWD, and adjacent to the WDWA on the east, is the Kern National Wildlife Refuge (KNWR). The KNWR is another important natural surface water feature in the KCS that variably depends primarily on precipitation and seasonal irrigation to maintain several different wildlife habitats at the KNWR. The portion of the KNWR that overlaps with the WDWA is designated as dry "Uplands Habitat", which relies on precipitation for its sole water source.

To the south, in the Belridge WSD, are portions of the 3,100 acre Lokern Ecological Reserve (LER). Within the WDWA the LER consists of small, scattered and generally non-contiguous parcels. A review of Google Earth imagery shows those portions of the LER in the WDWA are likely Valley sink scrub, and/or Valley saltbrush scrub habitat (aka Alkali Scrub). The scattered parcels are more or less centered on either side of the Aqueduct and along the dry Kern River Flood Channel between the 7$^{th}$ Standard Road to the north and Lokern Road (Highway 58) to the south. Typical native plant species in Valley sink scrub, as described by the California Department of Fish and Wildlife, are iodine bush and seepweed, with the understory dominated by non-native species. Those portions of the LER in the WDWA appear to consist entirely of dry, non-irrigated scrub lands that, with no operational wells, rely on annual precipitation as its source of water.

Larger, more contiguous blocks of the LER are present further south of the WDWA roughly between the towns of Lokern and Tubman. The California Department of Fish and Wildlife website describes the LER at large as consisting of marsh, valley sink scrub, and valley saltbush scrub habitat. Although not likely present in the WDWA, vegetation in the marsh habitat includes tule, cattail and other common marsh species.

Current uses for surface and imported water in the WDWA include:

- Agriculture,
- Industrial and Process Water, and
- Groundwater Recharge (banking).

Agriculture on the west side of Kern County has become a mainstay of the State and local economy. In response to a myriad of factors including climate change, imported surface water availability, emerging farm technologies, and product market forces; the land use and crop selection on the west side of the KCS has evolved. A majority of the irrigated acreage in the WDWA is currently supplied by Aqueduct water and is utilized for growing permanent crops such as almonds, pistachios, citrus, and pomegranates.

## Principal Aquifers and Aquitards

The thickness of the aquifer systems beneath the WDWA vary greatly from a few hundreds of feet to around 2,500 feet in thickness (DWR, 2003). From oldest to youngest, the principal water bearing zones in western Kern County include the Etchegoin Formation, the Tulare Formation, older alluvium and terrace deposits, and younger alluvium and floodplain deposits. Groundwater occurs in three loosely constrained aquifer packages within the WDWA. These are:

- Shallow perched groundwater,
- Unconfined/semi-confined groundwater, and
- Confined groundwater.

The occurrence of perched groundwater in the WDWA is sporadic, limited in quantity, and is recognized as having poor quality due to elevated TDS. It therefore has no beneficial use, nor does it contribute to or support groundwater dependent ecosystems.

Unconfined/semi-confined aquifers represent the principal aquifer packages for groundwater in the WDWA. These zones exist below occasional shallow perched groundwater in the upper and lower Tulare. The Tulare Formation was deposited as a series of coalescing alluvial fans and debris flows shed from the Temblor Mountain Range. As such it contains interbedded and interlensing sequences of fine-grained silt and clay mixed with gravels and sands. The unconfined/semi-confined aquifer zone extends from approximately 50 feet below ground surface (bgs), downward to the top of the so called modified “E-Clay” that is considered to be equivalent to the Corcoran Clay. This sub-regional aquitard, where present, is typically found at approximately 500 feet bgs or deeper.

Confined groundwater conditions exist below the Corcoran Clay and its generally accepted equivalent on the Westside, the modified E-Clay. Studies by the United States Geological Survey (USGS) (2009) indicate that the Corcoran Clay extends from the Valley floor westward to approximately the east-facing flank of the Lost Hills Anticline. The modified E-Clay is poorly constrained and is not known to extend significantly into the Antelope Plain, which constitutes a majority of the interior surface area of the WDWA. Depths to confined groundwater are variable but are usually deeper than 500 feet bgs. Concentrations of TDS in the confined groundwater zones (typically Etchegoin Formation and deeper) can initially range between 250 to 434 milligrams per liter (mg/L), but often degrade over time, suggesting the volume of better-quality water is limited. Sediments in this stratigraphic package consist of unconsolidated to consolidated, interbedded medium to coarse sand, silt, and clay (Amec, 2015; GEI, 2019). The presence or lack thereof of a well-defined and contiguous confining layer beneath the Antelope Plain separating shallow and deeper groundwater zones, and Westside complex structural geology could explain the general poor quality of groundwater throughout the WDWA, as well as the occurrence of better-quality groundwater in certain areas. Together with the

documented low volumes of groundwater pumping in the WDWA it may also explain why, with the possible exception of oilfield areas, there does not appear to be any significant inelastic land subsidence in the WDWA.

## Groundwater Quality

In the WDWA management area, marine-derived geologic sediments have contributed to the documented naturally poor and unsuitable quality of groundwater. Along the western side of the KCS, including the WDWA, unconfined/semi-confined groundwater is characterized geochemically as sodium/calcium-sulfate (Na/Ca-$SO_4$) water with TDS concentrations often exceeding 2,000 mg/L. Other deeper groundwater aquifers beneath the WDWA, and elsewhere in the KCS, are referred to as sodium-chloride (Na-Cl) water, which exhibits high to very high levels of TDS and is likely saline connate water (Amec, 2015; GEI, 2019).

In 2016, the WWQC prepared a Basin Plan Amendment Workplan (BPAW) which is inclusive of a significant portion of the irrigated lands within the WDWA. The BPAW recommends delisting municipal and unlimited agriculture as a designated beneficial use for perched and deeper unconfined/semiconfined groundwater due to natural poor groundwater quality. Confined groundwater sources immediately east of the Lost Hill Anticline would remain unchanged with regards to current designated use, pending further monitoring. The draft BPAW has been provided to the CV-SALTS Technical Committee and the Regional Water Quality Control Board (RWQCB) for review and input. Final determination by the RWQCB on the request for a change in designated beneficial uses will be included in the relevant annual update to the KGA Umbrella GSP.

The occurrence of high TDS groundwater in the west side of the KCS has recently been further documented in a preliminary groundwater salinity mapping study conducted by the USGS (Metzger and Landon, 2018). In the study, the distribution of groundwater salinity for 31 oil fields and adjacent aquifers across major oil-producing areas of central and southern California were mapped. The objective of the study was to describe the distribution of groundwater near oil fields having TDS less than 10,000 mg/L by using existing TDS data from petroleum and groundwater wells to map concentrations and document data gaps. Within the KCS, the study reported much higher TDS in groundwater from Westside oil field wells and groundwater wells, when compared with east side groundwater wells and oil wells. Metzger and Landon (2018), among others, suggest that higher TDS in the Westside could be related to a combination of natural conditions (Westside sediments derived from marine deposits containing saline connate water) and anthropogenic factors such as infiltration from former oil field produced water evaporation ponds and/or agricultural drainage ponds. This higher TDS water is consistent with historical reports completed prior to widespread agricultural development and is documented

for more than 60 miles from north to south in the west side of the KCS (KCDEH, 1980; KCDEH and KCWA, 1982; GEI, 2019).

## Lateral Boundaries and Bottom of the Basin

To the west of the WDWA the consolidated rocks that form the Temblor Range mountain front is both a boundary of the KCS, and a barrier to westward groundwater flow. Structural impediments to downgradient eastward groundwater flow from the Antelope Plain are poorly constrained but may include post-depositional folding of then-soft sediments and faulting. These fold belt structures include, among others, the Belridge, Lost Hills, and Kettleman Anticlines, and the Buttonwillow and Semitropic ridges and associated north-south oriented synclines. Page (1986) and the DWR (2006) also identified the anticlinal folds, and specifically Lost Hills Anticline, as restrictions that slow or impede groundwater flow towards the Valley axis. To the south, groundwater flow is impeded by geologic structures that include spurs of the Temblor Range and the Elk Hills Anticline. This condition likely applies to other geologic structures within the WDWA.

In simplest form, the geologic bottom of the sedimentary Subbasin can be identified as the depth at which crystalline basement rock is encountered. Alternatively, and more applicable with regards to the conditions within the WDWA and the objectives of SGMA, the bottom of the groundwater Subbasin is more aptly defined by applying criteria of Title 40 of the Code of Federal Regulations (40 CFR) §146.4. The bottom of the Subbasin varies vertically and laterally with:

- Depth to commercially producible minerals or hydrocarbons;
- Depth to exempted aquifers;
- The depth that makes recovery of water for drinking water purposes no longer economically or technologically feasible; and
- The depth at which groundwater cannot now, or in the future, serve as a source of drinking water (GEI, 2019).

Recognizing that the hydrogeology of the Subbasin is highly variable, and that it is not possible at this time to predict the future maximum depth at which groundwater might be economically recoverable, or at which groundwater TDS concentrations below 10,000 mg/L may be economically treatable for drinking water, the KGA umbrella GSP has proposed the following combination of criteria for determining the hydrologic bottom of the Subbasin. The criteria take into account existing relevant and applicable rules and regulations. Utilizing this approach, the bottom of the Subbasin may be described as the combination of the itemized list below (i.e., item A, and either item B or C) (GEI, 2019).

A. Depth to commercially producible minerals or hydrocarbons (40 CFR §146.4) (where it applies to discrete areas of the Subbasin), or the depth to an exempted aquifer which has been approved by the United States Environmental Protection Agency (US EPA) and California Division of Oil, Gas, and Geothermal Resources (DOGGR) according to the criteria of 40 CFR §146.4; and either:

B. Depth to water at a TDS that is no longer economically or technologically feasible for groundwater beneficial use; or

C. Depth to waters of TDS greater than 10,000 mg/L (40 CFR §144.3), these being referred to here as not suitable as an Underground Source of Drinking Water (USDW).

In the WDWA, oil is produced from geologic structures that are comprised of some of the same formations that produce brackish groundwater elsewhere in the WDWA. The Tulare and Etchegoin Formations are two examples of this condition. In addition to containing hydrocarbons, many of these oil-bearing zones also contain naturally degraded formation water (i.e. produced water). Based on the presence of hydrocarbons in these structures, many of the associated formations are also designated as exempt aquifers by the DOGGR and the US EPA, within the administrative limits of the individual oil field. Examples of oil fields with aquifer exemptions include, among many others, the Lost Hills Oil Field and the Belridge Oil Field complex. Both oil field produced water and WDWA groundwater are naturally degraded by elevated concentrations of TDS and other constituents. With few exceptions, these conditions are found throughout the WDWA.

There have been numerous groundwater studies conducted in the west side of the KCS over the past 90 years. Several of these were conducted in the 1930s and 1950s prior to wide-spread development of agriculture. With rare exception all such studies have documented the poor quality of groundwater due to the presence of marine derived geologic sediments. Because groundwater in the WDWA is degraded to a level where it is unsuitable for most practical beneficial use without blending or treatment, it is proposed the base of groundwater suitable for general beneficial use in the WDWA is where TDS concentrations exceed 2,000 mg/L. Groundwater quality is discussed further in **Section 2.6.5** of this Chapter GSP.

## Groundwater Trends

Groundwater elevation data in the WDWA is scarce due to the minimal amount of annual groundwater pumping. Groundwater elevation data has been identified as a data gap that will be addressed during the first five-year reassessment period. However, based on the limited data available, groundwater trends in the WDWA appear to be generally downward, albeit likely not at rates currently simulated in the KGA C2VSim-Kern groundwater model. Groundwater trends in the WDWA are governed principally by drought and downgradient subsurface outflows

that may be accelerated by irrigation withdrawals in adjacent water districts. Groundwater flow direction in the WDWA is believed to be primarily eastward from the Temblor Range toward the floor of the Valley, and northeastward along the northern boundary of the WDWA towards the former bed of Lake Tulare. Subsurface flow is thought to be both impeded, and sometimes sourced by, runoff from the aforementioned structural ridges and anticlines that separate the Antelope Plain from the axis of the Valley floor. In the north, geologic gaps between the Lost Hills Anticline and the South Dome of the Kettleman Hills Anticline may provide pathways for restricted groundwater migration. In the south, geologic gaps around the Belridge Anticline complex and the more easterly Buttonwillow and Semitropic ridges may be pathways for groundwater to move towards the Valley. Further study of WDWA geology and groundwater trends will be conducted during the first five-year reassessment period (i.e. 2020-2025).

## Climate Change

Current climate modeling indicates that by 2050 there may be a significant reduction in the amount of winter snowpack in the Sierra Nevada. The gradual late-spring to mid-summer snowpack melt has historically allowed for organized management of this important resource, which currently provides around 65% of California's water supply. If current predictions are realized, it is possible that runoff from the Sierra Nevada Range will occur earlier in the year, and a majority of precipitation may come in the form of rain instead of snow. The ability to harvest and store the runoff for use later in the growing season may become a critical issue for Valley agriculture and by extension, the State's economy, in the next decade. Assuming no change to cropping patterns, and no new water storage or reuse projects, predicted climate change will likely result in increased competition for all water resources. In the KCS at large, it is expected that reliance on groundwater will increase in order to augment potential further reductions to deliveries from the SWP and the CVP. Adaptive planning and management actions that may mitigate these conditions include demand reduction measures, continued conservation, improvements in groundwater and surface water storage, and the innovative treatment and conjunctive reuse of all water resources. This Chapter GSP has included many of these concepts in its sustainability planning (**Section 6.0**).

## Beneficial Use and Users

As noted previously, a BPAW which proposes delisting unlimited agricultural and municipal use of perched and unconfined/semiconfined groundwater over a significant portion of the WDWA is under regulatory review. Current beneficial uses of groundwater for the WDWA are established in the Tulare Lake Basin Plan. The WDWA is within Detailed Analysis Unit (DAU) 259. Existing designated beneficial uses of groundwater in the WDWA include:

- Municipal (MUN);

- Agriculture (AGR); and
- Industrial (IND).

There currently is no MUN pumping of groundwater in the WDWA. Because of the ubiquitous presence of elevated concentrations of TDS, the use for AGR is primarily limited to blending with higher-quality Aqueduct water when those deliveries are reduced. Industrial use is mainly limited to oil field operations, such as water for well drilling or enhanced oil recovery (EOR) via steam generation and reinjection, etc.

## Water Budget

All GSAs in the Kern County subbasin (Subbasin) coordinated and collaborated on the development of a groundwater model (Model) to evaluate historical, baseline and projected groundwater conditions. The GSAs entered into a Cost Share Agreement with the Kern River GSA who took the lead and contracted with Todd Groundwater to develop the Model on behalf of the Subbasin. The contract required that Todd Groundwater use the C2VSim model provided by DWR. Considerable effort and resources were expended to update the C2VSim model with local data to better represent Subbasin conditions. The process Todd Groundwater used to update C2VSim is more fully described in the Historical and Projected Future Water Budget Development (see Attachment H in Umbrella GSP). Basin-wide water budget results from the Model are provided in Attachment H and show the Subbasin, as a whole, has a total storage deficit of approximately 324,326 AFY over the baseline period.

The Subbasin's dynamic conjunctive use programs, water banking operations, and water transfers/exchanges made it necessary to coordinate a GSA-level water accounting system (Checkbook) using Subbasin specific values for supply, demand and net results. The Model results reflect Subbasin-wide conditions and do not allocate water shortages/surpluses, nor do the results allocate the "ownership" of water. As a result, the GSAs, through a coordinated effort, developed the Checkbook that estimates current conditions for each GSA that are generally consistent with the Model results under baseline condition. The Checkbook and Model budgets are based upon best available information, recognizing however, each estimate includes data gaps and has varying degrees of accuracy and/or reliability in the interest of developing a Subbasin coordinated approach.

To ensure the individual water budgets reflected actual conditions, the KGA members developed the Checkbook budget and coordinated water accounting methodology. The result of that effort indicates a current baseline shortage/deficit for KGA members of approximately-256,281 AFY. This reflects the difference between a total demand for KGA members of 1,939,409 AFY, and a total supply of 1,683,128 AFY. Of the shortage/deficit of the KGA, the

WDWA's portion of the KGA shortage/deficit is a surplus of +33,167 AFY. Or a difference in demand of 285,000 AFY and a water supply of 318,167 AFY.

As is mentioned above, each estimate includes data gaps and has varying degrees of accuracy and/or reliability. The Checkbook is complimentary to the Model and reflects the allocation of water supply benefits and obligations independent of geographic constraints within the Subbasin. This was important to recognize and ensure the coordination of the various groundwater banking projects and water management programs amongst the various GSAs within the groundwater basin.

It should be noted that the six unique WDWA hydrogeologic conditions (e.g. naturally degraded groundwater quality etc.), relative to the rest of the Subbasin, rend WDWA groundwater unusable unless it is blended or treated.

With regard to the WDWA, agricultural activities are the largest source of water demand. These activities rely almost exclusively on imported water delivered by the Aqueduct; groundwater pumping is minimal. Sources of surface water include SWP Table A and Article 21 water and purchased supplemental imported water, although not all supplemental water is SWP water. Because of a lack of representative groundwater data, the water budget for the WDWA is currently based on two independent and contrasting surrogate approaches that bookend the range of potential water supply: (1) the Checkbook Approach and (2) C2VSim-Kern. The Checkbook Approach is a typical approach based on a simple accounting of preliminary supply and demand and as noted previously, is also used by other GMAs in the KGA. The KGA Checkbook approach combines SWP water, imported water, a preliminary value of groundwater Native Yield, and a current value of precipitation to estimate the available water supply. Groundwater pumping is not explicitly accounted for in the Checkbook but is rather considered a portion of the Native Yield. The Checkbook value of Native Yield is intended to encompass all groundwater recharges and discharges that apply to the WDWA but does not explicitly include groundwater underflow, which is a critical component of the WDWA water budget. It is also important to understand that the term, "Native Yield", implies *suitable groundwater quality*, a condition that does not generally apply to the WDWA.

The WDWA Native Yield for the purpose of the preliminary Brackish Water Checkbook is conservatively estimated to be 0.15 acre-feet per acre (af/ac) multiplied by all WDWA acreage (i.e. 227,193 acres). This results in a volume of approximately 34,079 AFY. The currently estimated Checkbook precipitation factor is based on KGA and CIMIS data for the WDWA. It utilizes a factor of 0.2 af/ac. multiplied by the number of irrigated acres (88,989 acres) in the WDWA. This results in a volume of approximately 17,798 AFY that can potentially meet a portion of crop demand. Unique to the WDWA is the fact that all sources of groundwater (i.e. underflow, natural recharge etc.) are eventually degraded due to the geology and are rendered

unsuitable for most direct use. Therefore, brackish groundwater in the WDWA is considered as "outside" the water balance unless blended or treated. If the poor water quality, minimal levels of pumping in the WDWA, the volume of KGA-modeled underflow (~111,000 AFY) leaving the WDWA, and potential reuse of oil field produced water (considered outside the water budget) are accounted for, a Native Yield range of 0.15 af/ac. to 0.30 af/ac. is supportable. If applied, it would result in a potential Native Yield of 34,079 AFY to 68,158 AFY, depending on the volume of oil field produced water, which together with brackish groundwater could be utilized for blending or treatment for conjunctive reuse. This volume represents approximately 30%-60% of the current total KGA-modeled brackish groundwater underflow leaving the WDWA. Project Management Action (PMA) #3, discussed in **Section 5.3.1,** proposes to treat brackish groundwater and potentially, oil field produced water for irrigation and other beneficial reuses.

The WDWA Brackish Water Checkbook is at best an illustration of potential groundwater resources and is only capable of providing an estimate of the current operational water budget, as well as preliminary 2030 and 2040 water supply operational budgets. The projected future estimates encompass phased pumping of naturally degraded groundwater for the twin purposes of landowner blending, including anticipated increased pumping for this purpose in response to climate change, and for pumping and treatment as part of a proposed conjunctive reuse management action discussed in **Section 5.0** of this Chapter GSP (i.e. PMA #3). It is stressed that the Checkbook approach groundwater volumes (i.e. Native Yield) should not be construed as a current or future groundwater allocation.

The second approach to estimating the WDWA water budget is based on groundwater numerical modeling conducted by the KGA with C2VSim-Kern. The C2VSim-Kern is considered a preliminary, albeit more detailed water budget than the Checkbook approach. It is emphasized that the subject KGA model is intended to be a KCS-wide assessment of groundwater conditions and is not specifically calibrated to the WDWA service area. Additional reconciliation of basin water budgeting efforts is a high priority for all of the GSAs within the KCS as part of GSP implementation.

C2VSim-Kern is based on a Beta version of the DWR California Central Valley Groundwater-Surface Water Simulation Model, C2VSimFG-BETA (2018). KGA updated the managed supply and demand components of the model for the purpose of calculating preliminary volumetric flow rates for water budget components for the individual GMAs within the KCS. Like the Checkbook approach, the KGA model does not take into account that groundwater in the WDWA is naturally degraded and is unsuitable for most uses without blending or treatment. Currently, C2VSim-Kern modeling results for the WDWA are available only for historical conditions (1995-2014), which were used to develop the current-conditions water budget. It should be noted that the C2VSim-Kern model simulations of historical conditions overstate the amount of groundwater pumping that has and is occurring in the WDWA. It is expected that the C2VSim-

Kern modeling results for WDWA "future scenarios", which will include groundwater pumping volumes more aligned WDWA projections, will be available as part of future data assessment efforts. Details of the preliminary WDWA groundwater budget are provided in **Section 2.7** of this report.

Neither of these two approaches (Brackish Water Checkbook or KGA Model) currently provides a definitive illustration of the WDWA water budget and neither considers that the WDWA groundwater is naturally degraded and therefore outside the water budget However, in the absence of any alternative methodology they do provide a framework for revising the KGA water budget components based on additional data collected in the coming years. Given this, the Brackish Water Checkbook approach presented in this Chapter GSP is currently the more representative estimate of a "water balance" for the WDWA. Additional reconciliation of basin water budgeting efforts is a high priority for all of the GSAs within the basin as part of KGA Umbrella GSP implementation.

## Sustainable Yield

Sustainable yield, as defined by SGMA, means the maximum quantity of water, calculated over a base period representative of long-term conditions in a basin, and including any temporary surplus; which can be withdrawn annually from a groundwater supply without causing an undesirable result. This definition implies that the groundwater supply is of *suitable quality* for beneficial use without significant treatment (i.e., the groundwater supply is not brackish or otherwise naturally degraded). Data to support an assessment of detailed Sustainable Yield is not currently available for the WDWA. This data gap will be addressed by implementing a Network Monitoring Plan (MNP) during the first 5-year reassessment period. Based on the basin-wide estimates promulgated by the KGA, the normalized (native) sustainable yield for the KCS at large is estimated to be 0.15 af/ac. This factor was applied to all acreage (developed and undeveloped) in the WDWA (KGA, 2019; Todd Groundwater Consultants [Todd], 2019), resulting in a WDWA Native Yield of approximately 34,079 AFY that could be potentially harvested in a phased fashion through 2040 for blending and potential treatment and conjunctive reuse by the WDWA. The KGA Native Yield is considered to be a preliminary minimum estimate pending (1) continued refinement and calibration of theC2VSim-Kern model, (2) WDWA-specific sampling, and (3) modeling updates conducted by the KGA during the first five-year reassessment period. Data collected during the first five-year reassessment period will be utilized to model and refine the estimated sustainable yield for the WDWA. This information will be reported in relevant future update reports.

## Water Budget Baseline and Projected Conditions

Due to the previously mentioned lack of reliable groundwater data, the water budget presented herein is considered preliminary. The water budget will be refined by incorporation of updated KGA C2VSim-Kern modeling results and new data acquired by the implementation of the MNP discussed in **Section 3.0** of this Chapter GSP. For the purpose of this submittal, the WDWA is assessing the two approaches noted above, namely, the Checkbook approach and the draft KGA C2VSim-Kern hydrologic model, to represent the key water budget components described below, with adjustments to account for known inaccuracies of the current model.

## WDWA Estimated Groundwater Inflows

Based on current KGA modeling with C2VSim-Kern for the period WY 1995-2014, total groundwater recharge is ~92,300 AFY:

- Underflow from the Coastal Ranges: ~55,300 AFY
- Underflow from adjacent Districts: ~800 AFY
- Water loss from imported water canals: ~8,800 AFY
- Areal recharge (deep percolation): ~24,200 AFY
- Water loss from ephemeral stream flow: ~3,200 AFY

## WDWA Estimated Groundwater Discharges

Because the primary source of water for agriculture in the WDWA is the SWP and various supplemental purchases of imported water, the volume of discharge due to extraction by pumping wells has historically averaged less than 2% of annual demand (pumping is currently estimated to be 3,000 AFY). However, the current C2VSim-Kern historical simulation overstates groundwater pumping by nearly a factor of ten. The total estimated discharge for the current C2VSim-Kern historical model simulation, which includes the overstated pumping, is 138,540 AFY. The KGA-modeled discharge volumes for the Westside are approximately:

- ~111,000 AFY for underflow out of the WDWA and
- ~28,000 AFY by pumping extraction.

Overdraft, under the current C2VSim-Kern model simulation, is estimated to be ~46,200 AFY (rounded up to 47,000 AFY to account for model uncertainty). However, because groundwater pumping is overstated in the model, the estimated overdraft is likely significantly less (~22,000 AFY). KGA-calculated climate change estimates adjust the recharge (deep percolation) downwards from 24,200 AFY to 18,900 AFY, while the WDWA simultaneously estimates an increase in pumping extractions for the purpose of blending from the current 3,000 AFY to 5,400 AFY by 2030. The deficit under this scenario would be approximately 29,400 AFY (conservatively

rounded to 30,000 AFY). This conservative estimate is still lower than the current modeled overdraft of ~46,200 AFY. It should be reiterated and noted that:

1. WDWA groundwater is naturally degraded, is generally unsuitable for most use, and is therefore considered outside of the water budget unless used for blending or treated.

2. The WDWA meets almost all of its demand through the use of surface water delivered by the Aqueduct.

3. Even if the WDWA were to theoretically cease all pumping extractions, a deficit would still be realized under the C2VSim-Kern model simulations due entirely to the projected downgradient groundwater underflow of approximately 111,000 AFY leaving the WDWA, a phenomenon outside the control of the WDWA.

## Sustainability Goals

Sustainable management in the KCS will result from continuation of current water management practices and the implementation of projects and management actions at the member-agency level to maintain their respective use of groundwater within the sustainable yield of the Subbasin, operate at or above established measurable objectives, and operate above established minimum thresholds. The sustainable yield, measurable objectives, and minimum thresholds have been developed based on available technical information and will be reviewed, updated, and reported as additional data are collected, as required by SGMA. The overarching goal of the KGA is to bring the subbasin into sustainability and maintain sustainability over the implementation and planning horizon.

Sustainability goals for the WDWA are designed to support those proposed in the KGA Umbrella GSP while simultaneously acknowledging and addressing: 1.) the previously listed unique hydrogeologic characteristics of the WDWA. 2.) identified data gaps and, 3.) the potential for undesirable results within the WDWA. The goals will be achieved through the implementation of coordinated measurable objectives (MOs), such as specific administrative policies, projects and plans designed to enhance the sustainability of groundwater resources within the WDWA and the KCS at large. The sustainability goals for the WDWA are:

- Collect representative hydrologic information to more fully characterize and model the occurrence, condition, and elevation of groundwater beneath the WDWA through the implementation of a comprehensive Monitoring Network Plan (MNP);

- Leverage, to the extent feasible, the harvesting and treatment of naturally degraded groundwater underflow leaving the WDWA for the twin benefits of conjunctive reuse and

mitigation of potential adverse effects to better quality water in adjacent downgradient districts; and

- Mitigate the potential for the chronic lowering of groundwater levels and significant reduction of groundwater in storage through the coordinated implementation of minimum thresholds (MTs) and MOs within WDWA areas that are adjacent to other downgradient GMAs.

## Monitoring Network Objectives

Data related to representative aquifer characteristics and groundwater monitoring within the WDWA has, until most recently, been limited and non-contemporaneous. This is likely due to the limited amount of annual groundwater pumping in the WDWA. The lack of groundwater elevation data has been identified as an important data gap that must be filled for effective implementation of this Chapter GSP over the short-term, and for the assessment and planning of future adaptive management strategies over the long-term and SGMA implementation horizon. Associated groundwater components that rely on representative groundwater level monitoring include, among others, groundwater in storage and changes in storage, water budgets, and SGMA related land subsidence. Objectives and elements of the MNP will address the need for representative data and will help reduce uncertainty for the purpose of sustainability planning. The MNP, once fully implemented, will help achieve the following objectives:

- Acquisition of representative groundwater data sufficient to assess and document short-term, seasonal, and long-term groundwater trends related to WDWA water budgets, groundwater pumping volumes, groundwater in storage, groundwater elevation, and potential future land subsidence;

- Ability to assess changes in groundwater conditions relative to identified MOs and MTs; and

- Coordination with adjacent GMAs by way of scheduled sampling events, updating MTs and MOs that mutually lead to groundwater sustainability, and regularly scheduled status meetings to ensure sustainability outcomes.

The MNP will assess a minimum of 21 primary wells for inclusion of the management area MNP. Representative monitor well selection will be based, to the extent feasible, on existing locations currently being monitored by the Westside Water Quality Coalition (WWQC). The preliminary monitoring locations were selected to cover all three aquifer zones (perched, unconfined/semi-confined, and confined). To the extent feasible selected wells will be used for both groundwater elevation and water quality monitoring. The initial distribution of wells across the WDWA is as follows:

- LHWD: 8 wells
- BMWD: 4 wells
- BWSD: 6 wells

The area of the WDWA is approximately 355 square miles. The well density of the proposed MNP is around one well per every 19.72 miles. While there is currently no established number for monitoring well density in a basin or management area, for comparison the monitoring well density for a basin recommended by the California Statewide Groundwater Elevation Monitoring (CASGEM) Groundwater Elevation Monitoring Guidelines ranges between one to 10 wells per 100 square miles. The current proposed groundwater monitoring network is capable of providing representative data to define short-term, seasonal, and long-term data trends in groundwater and associated surface conditions. Based on the density of the monitoring well network there will be sufficient data to utilize groundwater elevation changes as a surrogate for evaluating potential changes in groundwater in storage. To ensure reliable groundwater-level data, monitoring events will be scheduled in the late fall and early spring when many irrigation wells are typically idled. Monitoring activities will follow KGA guidance protocols.

## Minimum Thresholds and Measurable Objectives

Pursuant to SGMA, MTs/ MOs shall be established for each sustainability indicator, based on quantitative analysis using the same metrics and monitoring sites as those utilized to define MTs. In accordance with the KGA Plan, the following general definitions apply to this Chapter GSP (California Code of Regulation [CCR] Title 23):

- MTs: Numeric values for each sustainability indicator used to define an undesirable result.
- MOs: Interim milestones in increments of five years, to achieve the sustainability goals for the WDWA, and by extension, the KGA, within 20 years of the Plan implementation.

## Minimum Thresholds and Measurable Objectives for the WDWA Groundwater Management Area

Based on an assessment of the six potential undesirable results identified in SGMA, there are three co-related elements (lowering of groundwater elevation, change in groundwater storage, and inelastic land subsidence) that require monitoring and/or focused MTs and MOs in order to sustainably manage the groundwater resources of the WDWA. The WDWA will conduct sentry monitoring to track groundwater elevations and quality along its northern and eastern boundary where groundwater leaves the WDWA as underflow. This underflow has been identified as the most significant contributor to the modeled groundwater deficit in the WDWA. Preliminary MTs and MOs have been proposed for these areas and are discussed further in **Section 4.0.**

## Land Subsidence

Irrigation pumping, an activity sometimes correlated to land subsidence, has been limited in the WDWA due to its naturally degraded water quality. The potential for land subsidence will be monitored by the WDWA in coordination with a KCS-wide subsidence monitoring plan administered by the KGA and as described in the white paper section detailing subsidence monitoring along the Aqueduct (see **Section 4.2 and Appendix I** ). Special emphasis will be placed on monitoring between Aqueduct Mileposts 195 and 215. In 2011, an Aqueduct embankment failure of unknown cause at the time was documented at Milepost 208. Changes in topographic surface elevations will be reported at a minimum every five years or as available from the DWR in the relevant GSP update report. The MT for inelastic land subsidence in the KGA will be established and reviewed in consultation with adjacent GMA's and will be based on future KGA InSAR and other geodetic land survey data that may be collected by the WDWA in coordination with adjacent districts to the east. Data will be utilized to assess for potential inelastic subsidence and the potential for undesirable results to critical infrastructure. Subsidence associated with local oil field activities is under the oversight of CalGEM (formerly DOGGR). Subsidence in the WDWA caused by oil field activities and by pumping in adjacent GMAs is outside the control of the WDWA. To the extent feasible the WDWA will coordinate the sharing of land-subsidence data with DOGGR and local oil producers that are party to the KGA Umbrella GSP.

## Reduction of Groundwater Elevation/Groundwater Storage

Because changes in groundwater storage cannot be measured directly, the WDWA will utilize changes in groundwater elevations as a proxy to assess potential changes in groundwater storage. According to the draft C2VSim-Kern model, a principal cause of the groundwater deficit in the WDWA is the discharge of poor-quality groundwater (~111,000 AFY) from the WDWA as underflow toward the axis of the basin. By comparison, current groundwater pumping extractions in the WDWA are approximately 3,000 AFY. Said another way, even if all pumping extractions were to cease in the WDWA, it would still be in deficit and would experience reductions in groundwater elevation and changes in groundwater storage due to the preliminary modeled volume of underflow leaving the WDWA. The rate of underflow leaving the WDWA may be further influenced by groundwater extraction being conducted in some of the adjacent down-gradient GMAs. These conditions are beyond the control of the WDWA. Therefore, the WDWA has proposed two coordination sentry zones along shared boundaries with adjacent GMAs to monitor groundwater level elevations at the north and east boundaries of the WDWA. Based on hydrologic conditions and preliminary simulated hydrographs, these zones each have separate preliminary MOs and MTs.

The preliminary MTs are:

- Sentry Zone #1 (well 25S21E-01-aka well# 7108-66): ~-115 feet below MSL
- Sentry Zone #2 (well 27S22E-30H- aka well #7106-63): ~ 0 feet MSL*
-
- Sentry Zone #2(well S-#14): ~150 feet above MSL*

The preliminary MOs are:

- Sentry Zone #1 (well 25S21E-01- aka well# 7108-66): ~-62 feet below MSL
- Sentry Zone #2 (well 27S22E-30H- aka well # 7106-63): ~40 above MSL*
-
- Sentry Zone #2 (well S-#14):~200 feet above MSL*

The new wells and respective MOs and MTs are listed above, and replacement wells or changes are connoted with an asterisk. Revision to the MT/MO for well 7106-63 included herein is pending review by the KGA Board. The original MO/MT range was set based on flawed CV2Sim model data. Subsequent to the 2020 GSP submittal more representative field data has been acquired. The pending MT/MO is above historic lows for this part of the WDWA based on available data. In addition, The WDWA has submitted two new wells for potential approval. These wells are the RTS North Lerdo Well 7 and the Starrh Well 8-3 in Sentry Zone 2. If approved, this will bring the total of representative sentry monitor wells to five. Additional wells for areas interior to the Sentry Zones are currently being screened for inclusion in the monitoring network as discussed in **Section 3.0**.

Changes to the suite of former representative monitoring wells were necessary due to various issues including reliable well access and representativeness related to beneficial use and users. All proposed changes to the monitoring network are submitted to the KGA Board for technical review and determination. If approved, the new information is posted to the KGA data management system.

These MTs and MOs are preliminary and subject to review and change at a minimum every five years based on newly acquired data, and subsequent coordination discussions with adjacent GMAs. Proposed changes will be reported in the relevant GSP update report. There are currently no MTs, or MOs proposed at this time for interior WDWA Watch Areas (i.e., non-irrigated lands, rangelands ,oil fields etc.) outside of the specified sentry coordination zones. The rationale for this approach is the aforementioned minimal historic pumping, and natural groundwater underflow over which the WDWA has no control. Data collected as part of the MNP for this Chapter GSP will be utilized to coordinate with adjacent downgradient GMAs and to assess whether the proposed MTs need updating. Planned coordination with adjacent management areas and data collected as part of the MNP for this Chapter GSP will be utilized to assess whether and how this approach may need to be revised.

## Projects, Management Actions, and Adaptive Management

To meet WDWA sustainability goals, and ensure the ability to reduce current uncertainty related to the characterization of MTs, MOs, groundwater elevation monitoring, and other sustainability indicators, the WDWA will address the data gaps identified in this Chapter GSP through:

- The preparation and implementation of a comprehensive MNP during the first five-year reassessment period to collect data and document short-term, seasonal, and long-term groundwater trends related to the WDWA. The MNP will be designed to collect the necessary data to establish or update MTs and MOs, as needed in order to refine WDWA water budgets, and sustainably manage and assess the potential for the chronic lowering of groundwater levels and significant reduction of groundwater in storage over the implementation horizon of the GSP;
- Coordination of water resources and data with adjacent GMAs; and
- The identification and assessment of potential projects and WDWA-specific management actions designed to support the sustainability goals of the WDWA, and by extension, the KGA.

To further enhance its sustainable and adaptive management strategies the WDWA is evaluating the feasibility of an innovative project that will integrate the treatment and conjunctive reuse of naturally degraded brackish groundwater and oil field produced water. Based on preliminary planning the project will ultimately harvest and treat approximately 40% oil field produced water and 60% brackish groundwater underflow for multiple beneficial uses including, among other things:

- A potential new water supply for adjacent and nearby disadvantaged communities (DACs) in order to improve water reliability and drought resiliency;
- A reliable supplemental source of better-quality water that, together with imported water, can be used for irrigation;
- Provide potential environmental flows to the adjacent Kern National Wildlife Refuge; and
- Protect groundwater quality adjacent to the WDWA by reducing the volume of naturally degraded groundwater underflow migrating to the northeast and east from the WDWA toward potentially better-quality groundwater in the axis of the Valley and adjacent management areas. This objective will be accomplished via strategic and sustainable monitoring and focused pumping for treatment and conjunctive reuse.

## GSP Reporting and Periodic Evaluations

SGMA reporting standards, as enumerated in Section 352.4 of CCR 23, Subchapter 2, Groundwater Sustainability Plans, shall apply to all WDWA Chapter GSP reporting. Additional reporting details are provided below. Data from the various monitoring and well installation activities, if any, will be provided to the appropriate State and County databases (e.g., well installation information and groundwater level and water quality monitoring). Data will also be coordinated with adjacent GMAs and the KGA, which will coordinate with the KCS database. All data collected by the WDWA will be provided and summarized in the various reports detailed in this section.

Pursuant to SGMA, the WDWA will prepare Annual Reports for inclusion in the KGA GSP. The Annual Reports will comport with KGA guidance and will be submitted by the KGA by April 1st of each year following adoption of the Plan. The Annual Reports shall include the following topics:

- Groundwater elevation data and contour maps,
- Key well hydrographs,
- Groundwater extractions,
- Surface water supplies,
- Total water use,
- Change in groundwater storage, and
- Implementation progress.

Periodic reevaluation reports will be prepared a minimum of every five years for inclusion in the Plan. The five-year reassessments will be submitted electronically by the KGA to the DWR via the online reporting system and format provided by the Agency per Section 10733.2, Water Code and Section 353.2 and 356.4, of CCR 23, Subchapter 2, Groundwater Sustainability Plans. The submittal of updates or amendments to this Chapter GSP will be accompanied by a transmittal letter signed by the Plan Manager, or duly authorized representative. A coordinated data management system for the KCS is necessary to improve the accuracy, usefulness and confidence in groundwater data reported by the individual GMA's and GSA's within the KGA. Data system perimeters, inputs and a coordinated data system methodology will be established and reported in the relevant KGA update report. In the meantime, the WDWA will continue to rely on established State data bases for updating and reporting new data.

# 1.0 INTRODUCTION AND PURPOSE OF THE CHAPTER GSP

## 1.1 General Information

On September 16, 2014, the State of California (State) enacted into law three legislative bills (Senate Bill [SB] 1168 [Pavely], SB 1319 [Pavely], and Assembly Bill [AB] 1739 [Dickinson]). These bills are collectively known as the Sustainable Groundwater Management Act (SGMA). In simple terms, the goal of SGMA is the sustainable management and use of the State's groundwater resources in a way that does not cause undesirable results. SGMA defines undesirable results as:

- Chronic lowering of groundwater levels,
- Significant and unreasonable reduction of groundwater stored in aquifers,
- Seawater intrusion,
- Significant and unreasonable degraded water quality,
- Significant and unreasonable land subsidence, and
- Depletions of interconnected surface water that have significant and unreasonable impacts on the beneficial use of surface water.

## 1.2 Legal Authority

To achieve the sustainable management of groundwater, SGMA requires that all groundwater basins identified by the State as high or medium priority, and subject to conditions of critical overdraft, be managed under a Groundwater Sustainability Plan (GSP) by January 31, 2020. The Kern County Subbasin (KCS, subbasin, or Subbasin) has been identified as a critically over drafted High Priority Basin subject to SGMA. As such, a special entity called the Kern Groundwater Authority (KGA) was formed on April 26, 2017. An amended and restated Joint Powers Agreement between Kern County and the general members of the KGA provided the necessary legal authority for the KGA to prepare, submit, and implement the required GSP. Recently, due to potential liability concerns regarding groundwater rights, Kern County supervisors decided to cede their leadership role in SGMA-related issues to the Kern County Water Agency (KCWA). Reportedly, the State Water Board, in a letter to Kern County, has stated that the withdrawal of Kern County from direct involvement in the SGMA process for the subbasin will not trigger the State's intervention nor jeopardize local control of sustainable groundwater use.

Because of the many independent Water Districts within the KCS, which serve a variety of differing water users, it was decided to prepare a general GSP for the KGA, referred to in this Chapter GSP as the "KGA Umbrella GSP" or "Plan". Within this framework individual Water Districts or groups of Water Districts (groundwater management areas [GMAs]) in the KGA are

to prepare more detailed individual "Chapter GSPs", which discuss local groundwater conditions that, although are often related to adjoining Water Districts, have hydrogeology or other factors that may be distinct to their respective management area(s). Additionally, the Chapter GSPs provide the ability for the KGA to identify which of the undesirable results identified in SGMA may apply to a specific area of the KCS, and how these results would best be monitored and mitigated over both the short- and long-term, in order to meet KGA and SGMA sustainability goals. The individual GMAs have also entered into a Coordination Agreement, the components of which are:

1. Groundwater Elevation Data
2. Groundwater Extraction Data
3. Surface Water Supply
4. Total Water use
5. Change in Groundwater Storage
6. Water Budget
7. Sustainable Yield

This Chapter GSP focuses on a select subset of Water Districts within the KGA. Those participating Districts, referred to as the Westside District Water Authority (WDWA), are:

1. Lost Hills Water District (LHWD)
2. Belridge Water Storage District (BWSD)
3. Berrenda Mesa Water District (BMWD)

**Figure 1a** presents the current extent of the KGA administrative area, member agencies, and adjacent groundwater sustainability agencies (GSAs) in the KCS. **Figure 1b** presents the KGA member agencies. **Figure 2a** shows details of the WDWA. A list of the other agencies and groups in alphabetical order that are participating in the KCS are:

- Arvin-Edison Water Storage District;
- Buena Vista Water Storage District (BVWSD);
- Cawelo Water District;
- City of Bakersfield;
- Delano Cutout;
- Henry Miller Water District;
- Kern-Tulare Water District;
- Kern Water Bank Authority;
- North Kern Water Storage District;
- Olcese Water District;
- Pioneer Project;

- Rosedale-Rio Bravo Water Storage District;
- Semitropic Water Storage District (SWSD);
- Shafter-Wasco Irrigation District;
- Southern San Joaquin Municipal Utility District;
- Undistricted Lands of Kern County (or "unmanaged" on certain figures);
- West Kern Water District (WKWD); and
- Wheeler Ridge-Maricopa Water Storage District.

Commensurate with SGMA, and based on the current level of understanding of the WDWA within the KCS basin setting, the purpose of this Chapter GSP is to describe in plain language the groundwater conditions that currently exist within the WDWA. This Chapter GSP also identifies hydrologic data gaps and focused remedies, and presents a proposed groundwater management plan that, if determined to be technically and economically feasible, has the potential to achieve and maintain the sustainability goals of the WDWA and, by extension, those of the KGA, over the SGMA implementation horizon. Due the complex and interrelated nature of the hydrology and consumptive use of the water resources within the KGA, details and data from the KGA GSP, and some data from individual adjacent GSPs and/or GSAs, may be included in this Chapter GSP. Issues related to coordination with adjacent Districts, if any, will be addressed during the first five-year reassessment period after acceptance of the KGA Plan.

## 1.3 WDWA Agency Information and Contacts

The WDWA currently covers approximately 227,193 acres, or roughly 355 square miles of western Kern County, California. Of this total, approximately 89,989 acres (140 square miles) is irrigated. Preliminary numerical modeling by the KGA indicates that the WDWA has a historic annual water demand of approximately 297,000 acre-feet per year (AFY). However, the KGA modeled water demand appears to be overestimated. WDWA data shows that current demand is approximately 285,000 AFY, which is projected to escalate to approximately 316,000 AFY by 2040 due to climate change. Significantly more than 95% of the water used for irrigation in the WDWA has historically been delivered via the Aqueduct from SWP Table A and Article 21 water and supplemental import water purchases, although not all supplemental water is from the SWP. When available, a combined 100 percent (%) contract allocation from the SWP is around 332,218 AFY. Current surface water deliveries (all WDWA sources) are estimated by the WDWA to be approximately 266,290 AFY. This volume does not include supplemental water purchases and transfers by individual growers. Current estimated recharge by precipitation is 17,798 AFY, and minimum "Native Yield is approximately 34,079 AFY. This results in an estimated total water supply of 318,167 AFY. The WDWA water budget is described in more detail in **Section 2.7**. Groundwater is estimated to have made up less than 2% of the water used for irrigation by private well owners due to the general poor quality of groundwater in the WDWA. Groundwater pumping in the WDWA is approximately 3,000 AFY. The main use of groundwater in the WDWA

has been for blending to augment supply when Aqueduct deliveries have been reduced by drought or other factors.

A brief description of the WDWA participating members follows. More detailed information regarding each member is provided on their respective District websites, and in their specific 2015 Agricultural Water Management Plan (AWMP) reports. The AWMP reports are prepared to comply with the requirements of California SB X7-7 (Water Conservation Act of 2007), and are available online at the relevant District's website.

### 1.3.1 Lost Hills Water District

The LHWD was formed in 1963 to provide irrigation water from the SWP to the District. The LHWD boundaries begin just south of the town of Lost Hills and extend north and west to the Kings-Kern County line. Key landmarks include the California Aqueduct and Interstate 5 (I-5), which bisect the District diagonally from northwest to southeast. Adjacent Water Districts include Dudley Ridge Water District (DRWD) to the north (Kings County, Tulare Lake Subbasin), the BWSD to the south, the SWSD to the east, and the BMWD to the west.

The LHWD is governed by a five-member Board of Directors, all of which must be landowners or be designated as a representative of a landowner. Day-to-day administration of the District is the responsibility of the General Manager, who reports directly to the Board of Directors. The LHWD has two offices. The main administration office is located at 1405 Commercial Way, Bakersfield, California. The operations office is located in the town of Lost Hills. The website address is: www.lhwd.org.

The LHWD is comprised of approximately 74,357 acres, of which 70,453 acres are considered farmable. Not all of this acreage is currently being utilized for agricultural purposes. As of 2015, the net area under irrigated cultivation is approximately 27,900 acres. Agricultural activities rely primarily on surface water from the SWP. In addition to agriculture, oil and gas production is an important non-irrigated land use within the LHWD. A small portion of the LHWD surface water supply is sometimes delivered as industrial water to agricultural processors and oil field production customers. Other non-farmable service areas within the LHWD include Service Area 6E, which has been excluded from the water service area, and Service Area 8 which includes lands that were annexed by the District, for which a water delivery system is not yet available. During times of reduced allocations, the District relies on coordination with adjacent water districts and landowners for water transfers, supplemental water purchases and water banking (e.g., Berrenda and Pioneer Projects). The District owns and operates over 23 miles of concrete- or geomembrane-lined canals, 42 miles of pipelines, and an additional 27 miles of unlined canals, most of which are out of use.

Groundwater use in the LHWD is mostly limited to periods of SWP and other supplemental source delivery shortfalls, and is principally relied upon for the purpose of blending. During periods of drought or other shortages the LHWD relies on coordination with adjacent Water Districts or growers for water transfers, supplemental import water purchases, and nearby water banking programs (i.e., Berrenda Mesa and Pioneer Projects). These two banking projects are located outside of the WDWA, just southwest of the City of Bakersfield. Individual landowners within the WDWA may also participate in surface water banking projects, which can provide a significant amount of banked water for, and on, their own behalf. Groundwater quality is naturally degraded in many areas due to elevated concentrations of total dissolved solids (TDS) and other minerals. Groundwater is considered unsuitable for most uses and is non-beneficial for a majority of crops, and in some cases livestock. There are three groundwater monitoring wells in the LHWD with extended historic groundwater-level monitoring data. These wells are monitored for groundwater elevation and a focused suite of water quality analytes on a now-regular schedule (last few years) by the KGA and are also part of the California Statewide Groundwater Elevation Monitoring (CASGEM) Program. The subject wells are discussed further in **Section 2.6**.

The LHWD supplies no municipal water from surface water or groundwater. The town of Lost Hills is served by two groundwater supply wells owned and operated by the Lost Hills Utility District (LHUD). These wells are located 12 miles east of the town and are outside of the WDWA (Provost & Prichard, 2015).

### 1.3.2 Berrenda Mesa Water District

Like the LHWD, the BMWD was formed in 1963 by landowners for the purpose of providing a reliable supply of irrigation water to the BMWD from the SWP. To the north of the BMWD lies the adjacent Devil's Den Water District (DDWD) (Kern County, outside of the KCS), to the south is the BWSD, to east are Undistricted Lands and the LHWD, and to the west is the Temblor Range (**Figure 2**).

The BMWD is also governed by a five-member Board of Directors, all of which must be landowners or be designated as a representative of a landowner. Day-to-day administration of the District is the responsibility of the General Manager, who reports directly to the Board of Directors. The administration office for the BMWD is located at 14823 Highway 33, Lost Hills, California. A field office for the District is located in nearby unincorporated Blackwell's Corner, California, located at the intersection of Highways 33 and 46. The website address for the BMWD is: www.bmwd.org.

Of the approximate 55,440 acres within the BMWD, all but 6,400 acres are considered farmable. The estimated net acreage currently being farmed is around 35,240 acres, of which 24,204 acres is irrigated by surface water from the SWP. Remaining lands are used for dry-land farming or

livestock grazing. At 100% delivery, the volume of contract water available to the BMWD from the SWP is approximately 92,600 acre-feet (AF). Current water demand is approximately 88,000 AFY. During periods of drought or other shortages the BMWD relies on coordination with adjacent Water Districts or growers for water transfers, supplemental import water purchases, and nearby water banking programs (i.e., Berrenda Mesa and Pioneer Projects). These two banking projects are located outside of the WDWA, just southwest of the City of Bakersfield. Individual landowners within the WDWA may also participate in surface-water banking projects, which can provide a significant amount of banked water for, and on, their own behalf. Other alternative management techniques include discretionary deficit irrigation implemented by individual growers.

Groundwater use is limited in the BMWD due to elevated levels of TDS. The BMWD supplies no municipal water either from groundwater or surface water supply (Provost & Prichard, 2015b).

### 1.3.3 Belridge Water Storage District

The BWSD was formed by landowners in 1962 to provide surface water from the SWP for irrigation. The BWSD is bounded on the north by the LHWD and BMWD along with some currently Undistricted Lands, to the south by additional currently Undistricted Lands and the WKWD, to the east by the Buena Vista Water Storage District (BVWSD), and to the west by the Temblor Range (**Figure 2**).

Similar to the LHWD and BMWD, the BWSD is also governed by a five-member Board of Directors, all of which must be landowners or be designated as a representative of a landowner. Day-to-day administration of the District is the responsibility of the General Manager, who reports directly to the Board of Directors. The administration office for the BWSD is located at 21908 Seventh Standard Road, McKittrick, California. The website address for the BWSD is: http://www.belridgewsd.com.

The principal source of water supply for the BWSD is surface water from the SWP, with agriculture as the main consumer. Of the 91,396 acres within the BWSD, approximately 88,223 acres are considered farmable, although not all of this land is currently being used for agriculture. As of 2015, approximately 36,885 net acres are irrigated. In addition to agriculture, a percentage of the BWSD annual allocation from the SWP is delivered for industrial use in oil recovery operations in the North and South Belridge oil fields.

Groundwater use in the BWSD has historically been limited, primarily due to the readily available source of good quality water provided by the SWP and various supplemental import sources, versus the naturally degraded groundwater found in the WDWA. The main use of groundwater by private well owners in the BWSD is for blending with SWP water. During periods of drought or other shortages the BWSD relies on coordination with adjacent Water Districts or

growers for water transfers, supplemental import water purchases, and nearby water banking programs (i.e., Berrenda Mesa and Pioneer Projects). These two banking projects are located outside of the WDWA, just southwest of the City of Bakersfield. Individual landowners within the WDWA may also participate in surface-water banking projects, which can provide a significant amount of banked water for, and on, their own behalf. Other alternative management techniques include discretionary deficit irrigation implemented by individual growers. Representative historic groundwater data are limited within the BWSD because of the aforementioned availability of other better quality water sources, and because until recently, records from privately owned wells in the WDWA at large were generally sporadic or not available. The BWSD supplies no municipal water either from groundwater or surface water supply (BWSD AWMP, 2015).

### 1.3.4 WDWA Undistricted Lands

There are approximately 341,048 acres of Undistricted Lands within the KCS (**Figure 2b**). Of these, approximately one third (113,682 acres) are located within the WDWA. These lands consist of a mixture of uses, including, among other things, mountain-front slopes, non-irrigated lands, grazing land, oil field production, quarry operations, and limited agriculture. Groundwater use among these different categories varies widely. Mountain-front slopes, grazing and non-irrigated lands, which comprise a large portion of the Undistricted Lands within the WDWA, use no groundwater and instead rely on precipitation. The limited agriculture and quarry uses in the WDWA are believed to use little or no groundwater based on typical operational practices. Oil field activities may utilize some groundwater from water wells for field activities (e.g. well drilling, enhanced oil recovery "make-up water" etc.). Oil fields also generate produced water as part of oil extraction activities. Produced water contains residual oil, elevated TDS derived from geologic formations, and other constituents common to crude oil production. A majority of produced water from oil field operations is either reinjected into the same zone it was extracted from for enhanced oil recovery (EOR), or is sequestered in deeper exempt aquifers pursuant to the United States Environmental Protection Agency (US EPA) Underground Injection Control (UIC) Program which, along with other oilfield activities in California, is administered by the Division of Oil, Gas, and Geothermal Resources (DOGGR).

The potential for impacts to the occurrence or quality of groundwater posed by oil field operations, and those Undistricted lands that are not part of the WDWA Chapter GSP, are beyond the control of the WDWA. Recently, in response to potential water rights liability and County staff resource considerations, Kern County decided it would no longer oversee these lands with regard to SGMA compliance. Going forward, the KGA will oversee these lands within the KCS for the purpose of SGMA compliance, provided they are covered by a KCS GSP. The KGA has initiated an effort to enroll these landowners into an appropriate existing GSP group. Those Undistricted Lands that do not join the KGA or other GSP will be responsible for individually

complying with all relevant SGMA requirements (KGA, 2019). The Kern County Public Health Services Department (KCPHSD) has retained its jurisdictional authority over, among other things, groundwater well permitting and destruction in the County. The Kern County Environmental Health Services Department develops guidelines for the protection of groundwater quality and well construction standards.

### 1.3.5 Non-Managed Monitoring Areas

Non-Managed Monitoring Areas are lands defined within the KCS and included in an adopted GSP, in which underlying groundwater has not been significantly developed or used historically and is not actively pumped, excepting *de minimis* extractors[1], and whose consumptive use of groundwater (e.g., evapotranspiration [ETo]) is less than or equal to the consumptive use of native vegetation. As such, lands within a Non-Managed Monitoring Area are typically native/range land. All lands designated as Non-Managed Monitoring Areas will be monitored by satellite imaging or equivalent technology that provides a comparative estimate of the amount of consumptive water use relative to native vegetation (KGA, 2019).

If non *de minimis* groundwater extraction, or if water consumed increases above the baseline of native vegetation ETo, is either proposed or is documented within a Non-Managed Monitoring Area, the lands overlying these areas will be reclassified as "Actively Managed Lands" and will become subject to the groundwater monitoring, sustainability criteria, water budget requirements of the governing GSP, and any applicable water management actions (e.g., water use restrictions) under the governing GSP. Upon reclassification as Actively Managed Lands, failure to comply with the requirements for Actively Managed Lands under the governing GSP may result in the subject lands being removed from coverage under the GSP (KGA, 2019). Any such lands would be subject to State Water Resources Control Board (SWRCB) regulations.

### 1.3.6 Chapter GSP Development Costs

Development and implementation costs for the KGA Umbrella GSP incurred to date are currently being shared by the individual member water districts. Costs are being allocated under a Special Activity Agreement. The agreement is basically a two-tiered system that allows for cost-sharing either by a direct pro rata approach (i.e., split 16 ways by the member water districts) for such items as KGA administration costs, or by allocating costs based on a water district's (or Management Area's) percentage of total acreage overlying the area of fresh groundwater in the KCS. This method is applied to various required scientific studies, such as the KCS numerical groundwater flow model. Costs for the development of the WDWA Chapter

[1] *De minimis* extractors are defined under SGMA; California Water Code (CWC) §1072 (e).

GSP are being allocated on a direct pro rata basis between the three member agencies of the WDWA (LHWD, BWSD, and BMWD) (WDWA, 2019).

### 1.3.7 Chapter GSP Implementation Funding

Estimates for the implementation and administration of the Chapter GSP are currently being assessed as part of the GSP development activities. The sources of implementation funding, while not specially identified at this time, may likely include a combination of State and Federal low-interest financing and grants for specific projects, as well as base and incremental water tolls paid by member landowners of the various respective Water Districts that comprise the WDWA (WDWA, 2019).

## 1.4 Description of Plan Area

### 1.4.1 Geographic Areas Covered

As noted previously, the WDWA encompasses approximately 227,193 acres, or roughly 355 square miles along northwestern edge of Kern County, California. The WDWA is bounded on the north by the Kings-Kern County line (an administrative boundary); on the south by areas of Undistricted Lands and the WKWD; on the east by some scattered Undistricted Lands, the SWSD, and BVWSD; and on the west by some Undistricted Lands and the Temblor Range.

As discussed in **Section 1.3.4**, Undistricted Lands are those lands within the WDWA that are not currently a part of a recognized GSA, but may be assimilated through separate agreements by the KGA. These areas are primarily associated with grazing lands and oil and gas operations such as the Belridge and Lost Hills Oil Fields. The KGA is currently working with these interested stakeholders to execute the necessary agreements to include them in the KGA GSP framework. Oil and gas operators within the WDWA include among others, California Resource Corporation (CRC), Chevron U.S.A, Inc., and Aera Energy, LLC.

### 1.4.2 Plan Area Setting

Geography and geology of the western KCS are discussed in further detail in **Section 2.0**. Within the WDWA; there are currently no adjudicated areas. A small dryland portion of the LHWD overlaps on the Kern National Wildlife Refuge (KNWR). The KNWR parcels within the LHWD are designated “Upland Habitat” areas, which rely on annual precipitation as its sole source of water (i.e. no operational wells). To the south, in the Belridge WSD, are portions of the 3,100 acre Lokern Ecological Reserve (LER). Within the WDWA the LER consists of small, scattered and generally non-contiguous parcels. A review of Google Earth imagery shows those portions of the LER in the WDWA are likely Valley sink scrub, and/or Valley saltbrush scrub habitat (aka Alkali Scrub). The scattered parcels are more or less centered on either side of the Aqueduct and along the dry Kern River Flood Channel between the 7$^{th}$ Standard Road to the north and Lokern Road

(Highway 58) to the south. Typical native plant species in Valley sink scrub, as described by the California Department of Fish and Wildlife, are iodine bush and seepweed, with the understory dominated by non-native species. Those portions of the LER in the WDWA appear to consist entirely of dry, non-irrigated scrub lands that, with no operational wells, rely on annual precipitation as its source of water. Other discrete State, Federal and County parcels in the WDWA are primarily associated with rangeland and mineral extraction activities (e.g. oil, gas, and gypsum).

As stated previously, the majority of water within the WDWA that is utilized for agricultural purposes is delivered as surface water via the Aqueduct. The WDWA distributes this water through a network of infrastructure facilities including, but not limited to, lined main canals, pipelines, pump stations, and control structures. Some of this surface water, when available, is provided to oil field operators and others for industrial use. As noted previously, the use of groundwater by landowners in the WDWA is generally limited and is mostly used for blending. The town of Lost Hills obtains its municipal water supply from two wells located approximately 12 miles to the east of the LHWD, an area outside of the WDWA. Existing land use is predominately agricultural, followed by currently Undistricted oil field operations, some natural range and grazing uses, and fallow lands.

### 1.4.3 Existing General Plans

The Kern County Planning and Natural Resources Department (KCPNRD) provides consolidated land use planning and development guidance and programs for the County's industry, businesses, and residents through the Kern County General Plan (General Plan). The General Plan is a policy document designed to provide long-range guidance to County officials and stakeholders regarding the priorities, growth, and resources of the unincorporated jurisdictional portions of the County, of which the WDWA is a part. Metropolitan areas, such as the City of Bakersfield, are part of separate planning areas. The stated objectives of the subject General Plan are:

- Encourage economic development;
- Adopt policies and goals that reflect the County's commitment to consult and cooperate with State, Federal, and local agencies to plan for the long-term future of Kern County;
- Ensure protection of environmental resources, the development of adequate infrastructure with specific emphasis on conserving agricultural areas, adequate water supplies, and addressing air quality issues;
- Periodically revise the General Plan to reflect ongoing activities, changes to rules and regulations, and demographic changes in the County in order to ensure that the interests of

the County in the health, safety, and welfare of residents and visitors are reflected in current policies and goals; and

- Maintain compliance with the provisions of State Planning and Zoning Laws as they pertain to General Plan requirements (KCPNRD, 2009).

Implementation of the WDWA Chapter GSP will provide additional drought resiliency and flexibility for agriculture and sustainability to water planning in Kern County. As such, it will not adversely affect water supply assumptions in the current General Plan and, by coordinating with adjacent GMAs and the KGA at large; will satisfy the requirements of SGMA.

### 1.4.4 Existing Groundwater Ordinances

Well drillers have been required by State law (CWC 13751) to submit well logs to the State since 1949. Public entity and other groundwater well owners within the WDWA are subject to all relevant and applicable rules and regulations regarding groundwater well drilling, development, monitoring, well abandonment, water use, and recycling, unless otherwise exempted by the State. An existing Kern County Ordinance, enacted in 1998, which requires a conditional use permit for groundwater exports both external and internal to the County, applies only to the southeastern drainage of the Sierra Nevada and the Tehachapi Mountains; and, thus, is not applicable to groundwater management in the WDWA. It should be noted that, based on a review of State records, it appears not all private well owners in Kern County have fully complied with well data reporting requirements.

### 1.4.5 Well Drilling, Replacement, and Abandonment

Kern County and the State Division of Water Resources (DWR) have respective water well permitting, wellhead protection and well construction and abandonment requirements that are germane to protection of groundwater quality and this Chapter GSP. Well drilling and monitoring requirements specific to the WDWA will be documented in the WDWA Monitoring Network Plan (MNP), which will be developed and implemented in coordination with adjacent management areas during the first 5-yeat reassessment period. Both sets of requirements (Kern County and State) for well permitting, construction and abandonment will apply in relation to applicable site-specific conditions and permitted drilling activities conducted in support of this Chapter GSP. Kern County well requirements can be found at: https://kernpublichealth.com/water-wells. State of California well drilling requirements can be found in DWR Bulletin 74, located, along with other details, at: https://water.ca.gov/Programs/Groundwater-Management/Wells.

A general summary of the process for permitting new or replacement wells in the WDWA is:

- Compliance with the most current version of the WDWA MNP and KGA protocols with regards to sediment logging, well and water quality testing and reporting;
- Compliance with Kern County Public Health requirements for well permitting, wellhead protection and well inspection; and
- Compliance with all applicable requirements as detailed in California Well Standards (Bulletin 74) for water wells, monitoring wells and cathodic protection wells.

Oil and gas wells in the WDWA are drilled under the purview of the DOGGR and US EPA rules and regulations.

## 1.5 Notice of Intent and Stakeholder Outreach and Communication

Stakeholder outreach and communication is central to the successful outcome of the KGA GSP. As such, the KGA has implemented a wide-ranging outreach program designed to maximize stakeholder involvement in order to ensure a transparent and inclusive GSP process. The subsections below provide further information on this important topic.

### 1.5.1 GSP Participating Agencies

A list of KGA-participating Water Districts is provided in **Section 1.2**. In addition to regulatory oversight by the California Department of Water Resources (DWR) for GSP development and implementation, participating agencies include, among others, the State Water Resources Control Board (SWRCB), Regional Water Quality Control Board (RWQCB), United States Geological Survey (USGS), and the KCWA. The KGA and the WDWA recognize that maintaining a close collegial relationship with the various State and Federal regulatory agencies with oversight on water management and SGMA in the KCS are essential to achieving proposed sustainability objectives. Private landowners are also supporting the GSP effort by providing, among other things, historic and current groundwater well and hydrogeologic data, as well as relevant planning and land-use information.

### 1.5.2 Public Meetings and Stakeholder Engagement

The KGA maintains a website (www.kerngwa.com) where it routinely posts information related to the GSP preparation and development process and actively solicits stakeholder engagement and input. KGA Coordination Meetings with stakeholders are typically held on the first Monday of every month. A partial list of items that are made available on the KGA website includes:

- Agendas and dates for upcoming and past public meetings;
- Stakeholder surveys;
- Relevant documents and reports for public review and input;
- Presentations, research, and white papers; and

- KGA contact information.

Additionally, the WDWA maintains a website for growers and the community at: www.westsidedwa.org. Member Water Districts within the WDWA have their own individual websites that provide information that is focused on Water District operations and GSP development within their respective management areas. As previously noted, the WDWA-member websites are:

- LHWD: www.lhwd.org
- BWSD: www.belridgewsd.com
- BMWD: www.bmwd.org

WDWA public outreach activities to date include:

- The WDWA participated in a KGA sponsored public workshop in Bakersfield, California at the Kern County Agricultural Center on May 14, 2019. The evening workshop was open to all community members and stakeholders. The workshop afforded interested parties the opportunity to interact one-on-one with WDWA staff and consultants who were there to answer and discuss questions or concerns related to the WDWA Chapter GSP, and afford the public an opportunity to learn more about other KGA Chapter GSPs, WDWA undesirable results, and the SGMA process.

- A second public KGA workshop was held the evening of September 26, 2019 at the Kern County Agricultural Center in Bakersfield, California. This workshop took place during the KGA Umbrella GSP 90-day public review period and provided another opportunity for interested parties to communicate with WDWA staff and consultants regarding SGMA, the WDWA Chapter GSP, undesirable results and groundwater sustainability in the WDWA.

- A public meeting (WDWA regularly scheduled Board meeting) to discuss WDWA-specific issues related to this Draft Chapter GSP, such as current and projected water budgets, groundwater quality and Measurable Thresholds (MTs) and Measurable Objectives (MOs) was held on June 5, 2019 at the BWSD offices. The meeting updated the Board members, the public and stakeholders on the status of the WDWA GSP Chapter findings, undesirable results, GSP costs and the SGMA process.

- The Draft Chapter GSP components and key findings and conclusions were presented a second time to the public at a regularly scheduled WDWA Board meeting on August 21, 2019 at the offices of the BWSD. At the meeting the WDWA Board approved submittal of the WDWA Chapter GSP to the KGA for inclusion in the formal 90-day KGA Umbrella GSP public review process. Prior comments were addressed in the draft Chapter GSP prior to this update presentation.

- The Draft Chapter GSP components and status were presented at three other regularly scheduled WDWA Board meetings open to the public, and at two public KGA Board meetings held in Bakersfield on August 21, 2019 and December 18, 2019.

- The WDWA Manager received one direct comment letter (Wonderful Orchards) during the 90-day public comment period for the KGA Draft Umbrella GSP. Relevant and applicable comments pertaining to the WDWA were incorporated in this version of the Chapter GSP. A copy of the letter is provided in Appendix A. Five other more global comment letters related to the Draft KGA Umbrella GSP (The Nature Conservancy, California Fish & Wildlife, Hancock Farmland Services, Westchester Group, and Leadership Council for Justice and Accountability) addressed to the KGA GSP Manager were also reviewed for relevant or applicable comments for incorporation that might pertain to the WDWA. It should be noted that the WDWA does not provide groundwater for municipal supply. Copies of those letters are on file with the KGA. Based on Fish & Wildlife comments the Lokern Ecological Reserve was identified and discussed in the Chapter GSP.

- The WDWA Board, at its public meeting on July 13, 2022, discussed and approved the Amended GSP Report.

The WDWA will continue stakeholder outreach during the implementation and planning horizon with periodic updates at its Board meetings, which are open to the general public, and by making SGMA annual reports and other relevant information available on its website.

### 1.5.3 SGMA Checklist and Notice of Intent to Develop a GSP

The SGMA check list for preparation of this Chapter GSP is provide in the front portion of this report. A copy of the KGA Notice of Intent (NOI) to prepare a GSP is provided in **Appendix B**. The NOI outlines the organization of the KGA and the general approach for developing the Plan. The NOI was submitted to the DWR on December 20, 2017. A complete list of Undistricted lands to date that have opted into the WDWA Chapter GSP is included as **Appendix C.**

### 1.5.4 Kern Groundwater Authority GSP Managers

The KGA GSP Managers are:

Mr. Terry Erlewine, Basin Coordinator
Kern Groundwater Authority
1800 30th Street, Suite 280
Bakersfield, California 93301
Email: terlewine@ppeng.com
Telephone: 530.220.0752

Ms. Patricia Poire, Planning Manager
Kern Groundwater Authority
1800 30th Street, Suite 280
Bakersfield, California 93301
Email: ppoire@kerngwa.com
Telephone: 661.479.7171

### 1.5.5 WDWA Chapter GSP Manager

The WDWA Chapter GSP Manager is:

Mr. Mark Gilkey, General Manager, WDWA
1405 Commercial Way, Suite 125
Bakersfield, California 93309
Email: mgilkey@lhwd.org
Telephone: 661.633.9022

The KGA is responsible for making decisions on issues related to the GSP and KCS at large. Individual Water Districts and GMAs are responsible for taking the day to day decisions necessary to simultaneously meet the needs of their individual members and those actions related to meeting the sustainability objectives detailed in their respective Chapter GSPs. Decisions related to the funding and implementation of items specific to the WDWA Chapter GSP are considered for adoption by the Boards of the respective WDWA member districts and the WDWA at large.

## 1.6 Chapter GSP Organization

This Chapter GSP for the WDWA is organized into the following sections.

- *Section 1.0 Introduction and Purpose of the Chapter GSP*
  This section discusses the regulatory requirements of the SGMA, participating Water Districts that comprise the KGA, and the subset of those agencies that make up the WDWA, which is the subject of this Chapter GSP.

- *Section 2.0 Basin Setting*
  This section includes a description, based on the current understanding of the subbasin, of the physical characteristics of the subbasin and the dynamic groundwater and local water budget conditions. A Hydrogeologic Conceptual Model (HCM) for the area covered by this Chapter GSP discusses hydrogeologic conditions, current and projected water budgets, identified data gaps, how these gaps will be addressed, the qualitative and quantitative understanding of the subbasin, and how the local aquifers might react to stress over time. The HCM takes into account how conditions in the WDWA may affect, or be affected by, adjacent Water Districts.

- *Section 3.0 Sustainability Goals and Undesirable Results*
  This section discusses and describes the suite of sustainability goals that, once fully implemented, will result in the absence of undesirable results identified in the WDWA within the statutory deadlines described in the SGMA.

- *Section 4.0 WDWA Monitoring Network*
  This section describes existing monitoring wells in the WDWA and the improved monitoring network that will be developed during the implementation of the Monitoring Network Plan (MNP) and reassessment periods after GSP approval. Development of the improved monitoring network will result in representative data sufficient to document attainment of identified WDWA sustainability goals, the monitoring for undesirable results, and the ability to provide for adaptive management of groundwater, both within the WDWA and as coordinated with adjacent GMAs.

- *Section 5.0 Minimum Thresholds and Measurable Objectives*
  This section describes relevant sustainability indicators and the numerical value(s) for each sustainability indicator used to define undesirable results, and the specific, quantifiable objectives for the maintenance or improvement of specified groundwater conditions.

- *Section 6.0 Projects, Management Actions, and Adaptive Management*
  This section describes the necessary sustainability projects and management actions that are currently being planned for implementation beginning in the first five-year reassessment period to address identified data gaps within the WDWA. The objective is to coordinate with other adjacent GMAs in order help achieve the stated sustainability goals for the WDWA and KCS.

- *Section 7.0 GSP Reporting and Periodic Evaluations*
  This section discusses the coordinated data management system that will be used to store GSP data and required reports pursuant to the SGMA, as wells as report submittal schedules.

- *Section 8.0 References*
  This section contains relevant technical references relied upon to prepare this Chapter GSP.

- *Tables, Figures, and Appendices*
  These appendices s contain figures, tables, guidance protocols and other documents relevant to this Chapter GSP.

# 2.0 BASIN SETTING

## 2.1 WDWA Plan Setting within the Kern Groundwater Authority

The Central Valley of California (Valley) covers about 20,000 square miles and is bounded by the Cascade Mountain Range to the north, the Sierra Nevada Mountain Range (Sierra Nevada) to the east, the Tehachapi Mountains to the south, and the Coast Ranges (e.g., Temblor Range) and San Francisco Bay area to the west. The Valley is an expansive agricultural region drained by the Sacramento and San Joaquin rivers. The Valley averages about 50 miles in width and extends around 400 miles from the Tehachapi Mountains in the south, to near the town of Redding, California in the north. The Valley is divided into three groundwater hydrologic regions according to DWR's Bulletin 118: (1) the northern one-third of the Valley is within the Sacramento River Basin; (2) the central one-third is within the San Joaquin River Basin; and (3) the southern one-third is within the Tulare Lake Basin, which in turn contains the KCS and the WDWA (DWR, 2016; GEI Consultants [GEI], 2019) (**Figure 3a and 3b**). Conceptual inflow of groundwater into the WDWA is presented on **Figure 3c**. The groundwater conditions in the KCS at large are described in the KGA umbrella GSP.

Unique hydrogeologic characteristics of the WDWA that set it apart from the other water districts in the KCS are:

1. The WDWA is isolated from other groundwater basins and adjoining water districts along its entire western boundary by the Temblor Mountain Range, its primary source of subsurface groundwater inflow. On the north and east, groundwater underflow towards the axis of the basin is impeded or slowed by a series of roughly north-south oriented geologic anticlines and synclines (up folds and down folds). To the south groundwater flow is impeded by geologic structural ridges that include spurs of the Temblor Range and the Elk Hills Anticline. This geologic setting has contributed to the poor groundwater quality in the WDWA and limits necessary groundwater coordination to just a few downgradient management areas to the north and east.

2. Groundwater is naturally degraded and of poor quality throughout most of the WDWA due to the presence of geologic sediments derived from marine environments, some of which contain saline connate water. These conditions make groundwater in the WDWA unsuitable for practical beneficial use, except for blending with better quality water.

3. Irrigation demand is met almost entirely by surface and imported water delivered via the California Aqueduct (Aqueduct). Groundwater is estimated to make up less than 2% of the water used for irrigation by private well owners due to its poor quality. Current pumping for the purpose of blending with Aqueduct water is estimated to be approximately 3,000 AFY.

4. The most significant amount of discharge from the WDWA simulated by the KGA model is in the form of subsurface groundwater flow to the north towards the former Tulare Lakebed, a beneficial use exemption area, and eastward towards the axis of the Valley. The total combined volume of underflow discharge to these areas is estimated to be approximately 111,000 AFY. Given the limited amount of pumping in the WDWA, underflow out of the WDWA is the most significant contributor to estimated groundwater deficits (change in groundwater storage) in the WDWA. This phenomenon is beyond the control of the WDWA.

5. Pumping for consumptive use in adjacent water districts has resulted in noticeable differences in groundwater elevations between the WDWA and these areas, and has likely increased the velocity and volume of underflow out of the WDWA along shared administrative boundaries to the east and southeast. Pumping activities in adjacent downgradient water districts are beyond the control of the WDWA.

6. In 2016, due to the near ubiquitous poor quality of groundwater in the KCS West Side, the Westside Water Quality Coalition (WWQC) prepared a Basin Plan Amendment Workplan (BPAW), which is inclusive of a significant percentage of the irrigated lands within the WDWA. The BPAW recommends delisting municipal and unlimited agriculture as a designated beneficial use for perched groundwater and deeper unconfined/semi-confined groundwater above the sub-regional Corcoran Clay (or its equivalent) due to natural poor groundwater quality. The draft BPAW has been provided to the CV-SALTS Technical Committee and the Regional Water Quality Control Board (RWQCB) for preliminary review and input. The final determination by the RWQCB on the BPAW application will be reported in the relevant GSP annual update report.

The WDWA, which is the focus of this Chapter GSP, covers approximately 227,193 acres (355 square miles) along the western side of the KCS. Of this total, approximately 89,989 acres, or about 140 square miles, is currently irrigated. The WDWA is bounded on the north by the Kings-Kern County line (administrative boundary) and the DRWD, on the south by the WKWD, on the east by various Undistricted Lands, the SWSD, and BVWSD, and on the west by the Temblor Mountain Range.

Topography in the WDWA is mostly gentle and flat, with steeper foothills of the Temblor Range lying at the western edge (**Figure 4**). Elevations range from approximately 250 feet above mean sea level (MSL) in the east-southeast to 1,200 feet above MSL in the southwest. Typical slopes within the WDWA range from 25 to 50 feet per mile. The California Aqueduct, which runs along the eastern edge and through other parts of the WDWA, is at an approximate elevation of 310 feet above MSL. The elevation of I-5, which transects portions of the WDWA, varies from approximately 225 to 240 feet above MSL. East of I-5, the ground surface is nearly flat. The western portion of the WDWA is known as the Antelope Plain and is enclosed by the Temblor

Range on west and north, and by various geologic structural arches (folds) on the east and south.

## 2.2 Climate

The climate in the WDWA is generally hot and dry and is characterized as inland Mediterranean. The main growing season for the KCS runs from May through October, although various crops are grown year-round. The length of the frost-free season is currently about nine months, or approximately 270 days per year. Surface water delivered by the SWP and supplemental purchases of supplemental import water, not all of which are SWP water, are the chief sources of supply for irrigation (Amec, 2015; GEI, 2019).

The WDWA is characteristic of the southern Valley climate with temperatures in the summer often exceeding 100 degrees Fahrenheit (°F), and winter low temperatures occasionally falling below freezing. Summers are generally hot and dry, and winters are semi-arid with ground fog a common occurrence. The rainy season usually occurs from November through April, when nine-tenths of the annual precipitation falls (Provost & Prichard, 2015a). The average annual KCS precipitation for the period extending from 1998 through 2012 was approximately 5.2 inches per year (inches/year). KCS reference ETo rates range from 52.4 to 65.8 inches/year, with an average of 58.3 inches/year. Rainfall is considered sufficient for grazing purposes, but not for large-scale agricultural purposes. The SWP was specifically designed to offset the lack of regional precipitation (Amec, 2015; GEI, 2019).

Monthly reference ETo and precipitation data for the WDWA for the most recent 10-year period, water year (WY) 2009-2018, were obtained from the California Irrigation Management Information System (CIMIS) website for the Blackwells Corner (Station 54) and Belridge (Station 146) stations (**Figure 5**). These stations were chosen for the continuity of their respective data sets and because their locations, near the northern and southern extent of the WDWA, provided representative data for extrapolation across the WDWA.

For the Blackwells Corner station during the 10-year period, the average annual ETo rate ranged from 59.4 inches/year in 2011 to 70.2 inches/year in 2014 (**Figure 6**). The average monthly ETo ranged from 1.6 inches in December to 10.0 inches in July. The average annual precipitation rate ranged from 2.5 inches/year in 2013 to 8.4 inches/year in 2011. The average monthly precipitation ranged from 0.01 inches in June to 0.98 inches in January (**Figure 7**). During the 10-year period, the maximum monthly precipitation of 3.4 inches occurred in May 2014.

For the Belridge station during the same 10-year period, the average annual ETo rate ranged from 51.4 inches/year in 2011 to 61.9 inches/year in 2014 (**Figure 8**). The average monthly ETo ranged from 1.5 inches in December to 8.2 inches in July. The average annual precipitation rate ranged from 1.1 inches/year in 2014 to 9.3 inches/year in 2011. The average monthly

precipitation ranged from 0.02 inches in August/September to 1.0 inches in December (**Figure 9**). During the 10-year period, the maximum monthly precipitation of 5.3 inches occurred in December 2010.

## 2.3 Surface Water

The major surface water feature in the WDWA, is the California Aqueduct (**Figure 10a**). Ephemeral streams that originate on the east-facing slopes of the Temblor Range drain eastward toward the Valley floor. The stormwater runoff in these channels is not controlled and typically percolates within the Antelope Plain and does not reach the bed of the former Tulare Lake or the axis of the Valley as surface flow. The 10-year, 24-hour storm event for the area ranges from 3.0 to 3.5 inches of precipitation (National Oceanic and Atmospheric Administration [NOAA], 2013; Amec, 2015).

A small northeastern portion of the LHWD overlaps with a dry Upland Habitat Area of the KNWR (**Figure 10b**). The KNWR at large covers approximately 11,250 acres, most of which lie within the adjacent SWSD. Established in 1960, habitats within the KNWR consist of:

- Seasonal Wetlands of which a significant portion are irrigated via deliveries from the Central Valley Project (CVP);
- Moist Soil Units are wetland habitats that are divided into irrigated and seasonal units;
- Seasonal Marsh are areas within the KNWR that maintain water depths of between 4 feet and a few inches and do not typically receive summer irrigation;
- Riparian Areas are located along former or seasonal stream courses within the KNWR; and
- Upland Areas are drier and are not irrigated during the summer and rely solely on precipitation as their source of water. Upland areas within the KNWR are generally closed to the public and are located in the northeast and northwest portions (LHWD portion) of the refuge.

To the south, in the Belridge WSD, are portions of the 3,100 acre Lokern Ecological Reserve (LER). Within the WDWA the LER consists of small, scattered and generally non-contiguous parcels (**Figure 10c**). A review of Google Earth imagery shows those portions of the LER in the WDWA are likely Valley sink scrub, and/or Valley saltbrush scrub habitat (aka Alkali Scrub). Those portions of the LER in the WDWA appear to consist entirely of dry, non-irrigated scrub lands that, with no operational wells, rely on annual precipitation as its source of water.

Larger, more contiguous blocks of the LER are present further south of the WDWA roughly between the towns of Lokern and Tubman. The California Department of Fish and Wildlife website describes the LER at large as consisting of marsh, valley sink scrub, and valley saltbush

scrub habitat. Although not likely present in the WDWA, vegetation in the marsh habitat includes tule, cattail and other common marsh species.

Irrigation canals and drainage facilities are the principal surface water conveyance features in the WDWA. Chief among these are the California Aqueduct, and its Coastal Aqueduct inter-tie.

Current designated uses for surface water provided by the SWP in the WDWA include:

- Agriculture;
- Industrial and process water; and
- Groundwater recharge (i.e. banking).

Other uses of California Aqueduct and CVP water adjacent to the WDWA include irrigation, non-contact recreation, wildlife habitat, and warm freshwater habitat.

The topographic highlands that source naturally occurring surface water runoff in the WDWA consist of several small watersheds that range from less than 10 square miles to around 100 square miles in area. Surface water runoff flow in the WDWA is considered unreliable and of poor (brackish) quality. As a result, it is unsuitable for beneficial use, does not support most agricultural uses, and requires blending with better quality water for irrigation**. Insert 1** summarizes a USGS 1959 survey of water quality in highland streams and springs, which predates much of the later agricultural development of the Westside (Amec, 2105).

**INSERT 1: 1959 USGS Water Quality**

| Surface Water | EC (umhos/cm) | TDS (mg/L) |
|---|---|---|
| USGS Streams | 590 – 3,100 | 540 – 3,200 |
| USGS Springs | 542 – 16,100 | 362 – 10,900 |

Notes:
EC: electrical conductivity
umhos/cm: micromhos per centimeter
mg/L: milligrams per liter

By contrast, the average concentration of TDS in surface water imported via the Aqueduct indicates that this water is of markedly better quality. Sample data from Kettleman Check 21 between 2008 and spring 2013 found EC averaging around 449 umhos/cm, and an average TDS concentration of 252 mg/L (Amec, 2015). A general definition of freshwater is TDS concentrations of less than 500 mg/L.

## 2.4 Land Use

Prior to the development of the Kern County Westside for agriculture, much of the land in the area was dry, native rangeland. A USGS (1959) report on groundwater conditions in the vicinity of Avenal and McKittrick described the area as: "*…uninhabited desert*" (GEI, 2019). Since that time, along with oil and gas, Westside agriculture has become a mainstay of the State and local economy. In response to a myriad of factors including climate change, imported water availability, emerging farm technologies, and product market forces, Westside land use, crop selection and agricultural practices have evolved. A majority of the 89,989 acres presently under cultivation in the WDWA are utilized for growing permanent crops such as almonds, pistachios, citrus, and pomegranates. Scattered State, Federal, and County parcels are adjacent or present in the WDWA. A preponderance of such parcels, aside from the aforementioned portions of the KNWR and the LER, are related to rangeland or mineral extraction activities like those in the Shale Hills, Pyramid Hills, and Lost Hills Anticline areas. **Figures 11a through 11d** provide WDWA land use for the years 1992 and 2014.

## 2.5 Hydrogeologic Conceptual Model

The HCM is the framework for the iterative development of water budgets, numerical and analytical models, and assessment of groundwater monitoring networks. Details from a subset of previous reports and investigations relating to the regional geologic and structural setting of the KCS, as well as the occurrence, quantity, and quality of groundwater in the WDWA are described below. This information, along with data provided in the KGA Umbrella GSP and KGA groundwater modeling, is the foundation for the HCM. An HCM differs from a numerical or analytical model in that it does not quantify or compute actual specific quantities of water flowing through or moving into or out of the basin via the surface or subsurface. Its purpose is to provide a general understanding of the physical setting and processes related to groundwater sources, occurrence and movement in the WDWA (**Figure 12a**). Therefore, it does not provide specific data on the water balance for the WDWA. In general, recharge to the WDWA occurs via mountain-front underflow, water loss as a result of leakage from imported water canals, area deep percolation, and water loss from ephemeral streams. Based on the preliminary KGA C2V Sim-Kern groundwater model, by far the largest component of discharge in the WDWA is groundwater underflow (~111,000 AFY) migrating toward down-gradient GMAs. Pumping for the purpose of blending in the WDWA is presently estimated at around 3,000 to 5,000 AFY. A more detailed discussion of KCS geology is provided in the KGA umbrella GSP. A summary of the physical setting follows.

### 2.5.1 Kern County Subbasin Geology

The KCS is located in the southern most extent of the Tulare Lake Basin Hydrologic Region. The KCS encompasses a surface area of around 1,792,000 acres (2,800 square miles) and is underlain by approximately 32,000 feet (6 miles) of marine and continental sediments (Page, 1986; DWR, 2006; Amec, 2015; GEI, 2019). **Figure 12b** provides a geologic map of the KCS. **Figures 12c – 12e** provides conceptual KGA geologic cross sections for the vicinity of the WDWA.

Near the end of the Late Cretaceous, tectonic movements elevated the Coast Ranges to the west of the Valley and created a marine embayment. During the Tertiary, seas episodically advanced and retreated within the embayment, resulting in deposits comprised of both continental and marine sediments. Structural deformation along the early and present-day San Andreas fault zone resulted in the formation of a series of geologic faults and anticlinal folds that form many of the prolific oil fields along the west side of the KCS (Farrar and Bertoldi, 1988; GEI, 2019). During and since marine deposition, sediments derived from erosion of igneous and metamorphic rocks and consolidated marine sediments in the surrounding mountains to the east and west were transported into the Valley by streams. The continental sediments at the southern end of the Valley have an average thickness of about 2,400 feet (Planert and Williams, 1995). The continental sediments consist mostly of basin-fill or lake and marsh deposits of interlensing sand and gravel interbedded with clay and silt. Within the WDWA, sediments deposited by coalescing alluvial fans and debris flows are common. Depending on location, deposits of fine-grained materials (mostly clay and silt) comprise as much as 50% of the thickness of the basin-fill sediments (Planert and Williams, 1995; GEI, 2019).

During Pleistocene and Holocene times, the seas retreated, and continental deposits from alluvial and fluvial systems were deposited over Tertiary-age marine deposits (Page, 1986). Some of these marine deposits contained naturally occurring connate (saline) water which have subsequently migrated into adjacent and overlying continental deposits (Page, 1986). Overall, the continental deposits make up a significant portion of the regional aquifer system within the eastern and central parts of the Valley. Within the WDWA, and Westside in general, eroded marine deposits are common and contribute to the overall poor groundwater quality that has been documented throughout the western KCS (GEI, 2019). According to several reports, the Pleistocene Epoch saw the development of brackish and freshwater lakes within the basin, resulting in thick deposits of silts and clay and associated minerals, as found throughout the upper Tulare Formation. In particular, the Corcoran Clay has been mapped over much of the central and eastern San Joaquin Valley. The Corcoran Clay has been correlated to equivalent clays beneath the Kern and Buena Vista dry lake beds in the southern part of the KCS; as well as the Tulare Lake sediments on the northern boundary of Kern County (Wood and Dale, 1964; Croft, 1972; GEI, 2019). This clay, when present, acts as an aquitard that isolates accessible shallow poor-quality water from slightly higher quality water of the deeper regional aquifer

system. On the Westside, including beneath the WDWA, and those other areas west of the Lost Hills Anticline, this clay appears to be either poorly constrained or absent (**Figure 13**).

Since the Pleistocene, stream channels, lakes, and rivers have dominated the deposition of sediments in the Valley. Alluvial fans have continued to form on both sides of the Valley, especially on the eastern side. Over time, shifting stream channels have created overlapping and coalescing sediment fans, forming broad sheets of inter-fingering, wedge-shaped lenses of gravel, sand, and finer sediments which make up the shallow continental water-bearing deposits of the regional aquifer system (Page, 1986). During this time, fine-grained floodplain, lake, and marsh conditions were predominate on the western side of the Valley resulting in aquifers with less reliable hydraulic properties (Amec, 2015; GEI, 2019).

### 2.5.2 Surficial Geology

The surficial geology of the KCS has been documented in a variety of previous investigations (Bartow, 1991; Page, 1986; California Geological Survey [CGS], 2010; GEI, 2019). Based on published studies, the center of the basin consists mainly of Pleistocene to recent unconsolidated and semi-consolidated alluvial lake, playa (alkali/salt flat), and terrace deposits. Older Pleistocene alluvium is present in the eastern portion of the basin on top of Pliocene-Pleistocene deposits of sandstone, shale, and gravel deposits, including the Kern River Formation. The Pliocene-Pleistocene sediments also include the Tulare Formation. The Tulare and Etchegoin Formations are known to be variably a source of both brackish groundwater (unconfined/semi-confined) and oil within the WDWA. Small remnants of older continental sediments along the southeastern flank of the KCS, consist of undivided Tertiary-age sandstone, shale, conglomerate, breccia (clastic rock with a matrix of sand and/or mud), and lake deposits. Miocene-age sandstone, shale, conglomerate, and fanglomerate, plus smaller remnants of older marine sediments are also present. These remnant units include the Santa Margarita Formation, Round Mountain Silt, and Olcese Sand (Amec, 2015; GEI, 2019).

The geologic structure of the western KCS is distinguished by numerous northwest-trending folds that are subparallel to the nearby right-lateral San Andreas Fault. Most of the mapped folds are anticlines that occur in the older sediments and appear as anticlinal ridges that crop out approximately 30 to 50 feet or more above the surrounding topography. Some of these features include the Buttonwillow Ridge, Semitropic Ridge, and the Lost Hills and Elk Hills Anticlines (Bartow, 1991; GEI, 2019). Many anticlines and associated synclines in the Westside are known to be concealed beneath younger Quaternary age sediments. Similarly, several northwest-trending faults are concealed by the younger sediments, and some have also been mapped within outcrop islands of older sediments (GEI, 2019).

### 2.5.3 Surface Soils

Surface soils for western Kern County have been described in various studies and reports (United States Department of Agriculture [USDA], 1986; USDA, 1988; USDA, 2018; Amec 2015). In the WDWA, surface soils are somewhat poorly drained basin clays and silty loams derived predominately from the erosion of sediments deposited in former continental environments. These soil types are considered to be a contributing factor to the overall natural poor quality of groundwater in the WDWA. **Insert 2** lists near surface soils in western Kern County generally include the following soil type series (USDA, 1988, Amec, 2015).

**INSERT 2: Western Kern County Soils**

| Series | pH (s.u.) | Salinity (mmhos/cm) |
|---|---|---|
| Buttonwillow | 7.9 – 8.4 | < 4 |
| Kimberlina | 6.6 – 8.4 | <2 – 8 |
| Lethent | >7.8 – 9.0 | 4 – 16 |
| Lokern | 6.6 – 9.0 | <2 – 16 |
| Milham | 7.4 – 8.4 | <2 – <8 |
| Nahrub | >7.4 – >7.8 | 4 – 16 |
| Panoche | 7.4 – 8.4 | <2 – 16 |
| Twisselman | 7.9 – 9.0 | <2 – >16 |
| Yribarren | 7.9 – 8.4 | <2 – <8 |

Notes:
mmhos/cm: millimhos per centimeter
s.u.: standard unit
pH: potential of hydrogen

Soil maps for the three individual Water Districts that comprise the WDWA, are presented in **Figures 14a through 14c**. The USDA's list of landscape soil types is provided in **Appendix D**.

### 2.5.4 WDWA Management Area Hydrogeology

WDWA hydrogeology is unique from other areas of the KGA. A key distinction is, with the exception of small, localized areas of higher-quality groundwater, the groundwater beneath the WDWA is almost exclusively naturally brackish, with TDS levels generally exceeding the drinking water maximum contaminant level (MCL) of 500 mg/L (**Figure 15a**). Overall, TDS concentrations routinely exceed 2,000 mg/L in many areas. The sediments that comprise the subsurface in the WDWA have accumulated since the Cretaceous. A large portion of the sediments were either eroded into, or deposited by, an inland sea bounded by an ancient fore-arc ridge to the west and the Sierra Nevada Range to the east. Naturally occurring saline connate water still exists in some of these sediments today. These saline waters, along with naturally occurring salts and

other minerals in surface soil and shallow sediments, are the primary sources of the elevated TDS concentrations detected in WDWA groundwater (Amec, 2015; GEI, 2019). **Figure 15b** provides a general stratigraphic column, which depicts the transitional nature of the environments of sediment deposition in the KCS. Elevated concentrations of other constituents, such as arsenic, boron, and nitrates (most naturally occurring), have also been detected in parts of the WDWA. Data indicate that these minerals are likely the result of depositional concentration as the former marine embayments and lakes that previously covered much of the WDWA retreated and evaporated. Isolated pockets of fresh groundwater exist within relatively thin layers of continental sediments deposited on top of the marine sediment layers. Due the predominance of surrounding brackish groundwater conditions, these pockets of higher-quality water have been known to degrade after only a few months or years of pumping. Available data appear to indicate that poor-quality water is migrating from the WDWA down-gradient to the north and east, towards areas of higher-quality water found in adjacent GMAs, such as SWSD and BVWSD. Impediments to this underflow are likely presented by various geologic structures including folding and faulting. One such example is the Buttonwillow Syncline.

The Pliocene-Pleistocene Tulare Formation represents a west-to-east change in depositional environments across the Subbasin. The Tulare Formation in the western part of the Subbasin contains up to 2,200 feet of interbedded, oxidized to reduced sands, gypsiferous clays, and gravels derived predominantly from erosion of Coast Range sources. Up to 250 feet of Pleistocene-age older alluvium/stream and terrace deposits occur as lenticular deposits of clay, silt, sand, and gravel that are loosely consolidated to cemented, and are exposed mainly at the margins of the Subbasin and along the crests of some Valley anticlines. Collectively, these sediments are typically moderately to highly permeable and can initially yield large quantities of water to wells (DWR, 2003; Amec, 2015; GEI, 2019). These deposits are reportedly often indistinguishable from the underlying Tulare Formation, and together, form the principal (unconfined/semi-confined) aquifer system in the WDWA.

The younger Holocene-age lacustrine, alluvium and flood plain deposits vary in character and thickness across the WDWA and consist of silt, silty clay, sandy clay, and clay interbedded with poorly permeable sand layers. The flood plain deposits are reported to be difficult to distinguish from underlying fine-grained alluvium and the total thickness of both units may be as much as 1,000 feet (DWR, 2003; GEI, 2019).

### 2.5.5 Principal Aquifers, Physical Properties and Aquitards

The thickness of the aquifer systems beneath the WDWA and Westside are thought to vary greatly from a few hundreds of feet to around 2,500 feet in thickness (DWR, 2003; GEI, 2019). From oldest to youngest, the principal water-bearing zones in western Kern County include the Etchegoin, and Tulare Formations, Older Alluvium and Terrace Deposits, and Younger Alluvium

and Floodplain Deposits. Groundwater occurs in three loosely constrained aquifer packages within the WDWA. These are:

- Shallow perched groundwater;
- Unconfined/semi-confined groundwater; and
- Confined groundwater.

Perched groundwater was reported historically in the WDWA, especially along the eastern side of the WDWA management area. Its presence is attributed to a shallow clay layer known as the "A-Clay". Depth to perched water was historically measured at 3 feet to 24 feet below ground surface (bgs). Perched water samples analyzed from six tile drains between 1986 and 2012 found average TDS concentrations of 13,250 mg/L, in addition to elevated concentrations of boron and other elements (Amec, 2015).

In late 2018, the Westside Water Quality Coalition (WWQC) reportedly attempted to record water-level data from several previously monitored perched zone piezometers; a majority of which were found to be dry (WDWA, 2019). The change in perched groundwater levels from 1989 to present indicates its occurrence is greatly reduced and sporadic. This condition is believed to be due to a change in crop types, recent drought conditions, and the increased efficacy of irrigation methods. For example, approximately 97% of crop irrigation in the WDWA now utilizes drip or micro-irrigation technology. The evolution in crop types away from the cotton and row crops being grown in the mid-1990s to predominately nut and other permanent crops today, coupled with more modern irrigation methods, may have reduced the volume of direct recharge via irrigation return flows. These return flows are believed to have been a likely contributor to perched groundwater in those areas where geologic conditions favored the accumulation of perched groundwater. Given the unreliability of the occurrence, the de minimis available volume of perched water, and its documented high salinity and mineral content, it is considered to be non-beneficial for Municipal (MUN), Agriculture (AGR), and most, if not all, Industrial (IND) use in the WDWA. Consequently, perched water wells will not be used to establish sustainability minimum thresholds (MTs) or measurable objectives (MOs) in the WDWA. It will however continue to be monitored along the eastern boundary of the WDWA. If future planned monitoring identifies a change in status of perched groundwater, these findings will be presented in future reassessment reports.

Unconfined/semi-confined aquifers represent the principal aquifer packages for groundwater in the WDWA. These zones generally exist well below the afore-described potential shallow perched groundwater zones in the upper and lower Tulare Formation or deeper. Groundwater quality in these sediments is regarded as poor to very poor due to significant concentrations of naturally occurring TDS, which often exceed 2,000 mg/L. The unconfined/semi-confined aquifer zone extends variably from approximately 50 feet bgs, downward to the top of the so called

modified "E-Clay" that may be equivalent to the Corcoran Clay. This aquitard, where present, is typically found at approximately 500 feet bgs or deeper. Most groundwater in the unconfined/semi-confined zone in the WDWA is found at depths greater than 75 ft. bgs.

Where the modified E-Clay is present, confined groundwater conditions can exist below this horizon. Studies by the USGS in 2009 indicate that this confining layer extends from the Valley floor westward to approximately the east-facing flank of the Lost Hills Anticline. The modified E-Clay is poorly constrained and not known to extend with any significance into the Antelope Plain. This area constitutes a majority of the surface area of the WDWA, and occupies the structural trough between the Temblor Range and the west facing flank of the Lost Hills Anticline. Depths to confined groundwater, where present, are variable, but are usually deeper than 500 feet bgs. Concentrations of TDS from confined groundwater reportedly range between 250 to 434 mg/L, but are known to sometimes degrade over time. Sediments in this stratigraphic package consist of unconsolidated, interbedded medium to coarse sand, silt, and clay (Amec, 2015; GEI, 2019). The presence, or lack thereof of a well-defined and contiguous confining layer beneath the Antelope Plain separating shallow and deeper groundwater zones, and complex structural geology, could explain the general poor quality of groundwater throughout the WDWA, as well as the occurrence of better quality groundwater in certain areas. Together with the documented low volumes of groundwater pumping in the WDWA it may also explain why, with the possible exception of oilfield areas, there does not appear to be any significant inelastic land subsidence in the WDWA.

Physical properties of aquifers within the KCS are derived from both well pumping tests and calibrated groundwater flow models. These data are summarized in the KGA Umbrella GSP. Physical properties include hydraulic conductivity (i.e. transmissivity), which is a function of the ability of an aquifer to transmit water through a given saturated thickness of aquifer, and specific yield (unconfined aquifers) and storage coefficient (confined aquifers). Specific yield and the storage coefficient are functions of the ability of an aquifer to store and release water. **Figure 15c** provides the range of horizontal conductivity for the principal aquifer types in the KCS (i.e. Unconfined/Semi-confined, and Confined). These ranges are typical of the silty sands and clean medium to coarse sands found in KCS aquifers, and are collaborated by various calibrated groundwater flow models predicated on field test data.

The Corcoran Clay varies from fine grained silts and clays to coarse sands in parts. The USGS estimated horizontal conductivities for the silts to medium sands within the range of 0.0024 to 33 feet per day. The vertical conductivity for these sediments was estimated at between 6.6 x $10^{-6}$ and 1.5 x $10^{-3}$ feet per day.

### 2.5.6 Lateral Boundaries and Structural Impediments to Groundwater Flow

The following federal regulations are foundational to the subsections pertaining to the lateral and basal extents of the effective groundwater Subbasin:

- Title 40 of the Code of Federal Regulations (40 CFR) §144.3
- 40 CFR §146.4

Title 40 of the Code of Federal Regulations defines an underground source of drinking water (USDW) in §144.3, as an aquifer or its portion which (GEI, 2019):

*a. 1. supplies any public water system; or*
*2. contains a sufficient quantity of ground water to supply a public water system; and*
*i. currently supplies drinking water for human consumption; or*
*ii. contains fewer than 10,000 mg/L total dissolved solids; and*
*b. is not an exempted aquifer.*

It should also be noted that the area of the effective groundwater Subbasin can be separated from the jurisdictional boundaries of the Subbasin by the criteria for exempted aquifers per 40 CFR §146.4; which includes, but is not limited to, areas in which the presence of commercially producible minerals or hydrocarbons are present in the aquifer, such as those found within the WDWA at the Belridge, South Belridge, Monument Junction, Lost Hills, and many other oil and gas fields in the WDWA (GEI, 2019).

To the west of the WDWA, the consolidated rocks that form the Coastal (Temblor) Range mountain front is both a boundary of the KCS and a barrier to westward groundwater flow. Structural impediments to downgradient eastward groundwater flow from the Antelope Plain are poorly constrained, but may include post-depositional folding of then-soft sediments. These fold belt structures include among others, the Belridge, Lost Hills, and Kettleman Anticlines, and the Buttonwillow and Semitropic Ridges (Bartow, 1991) and associated synclines. To the south, groundwater flow is impeded by geologic ridges that include spurs of the Temblor Range and the Elk Hills Anticline. Page (1986) and the DWR (2006) also identified the anticlinal folds and specifically Lost Hills, as restrictions that slow or impede groundwater flow downgradient and eastward towards the Valley axis. This condition likely applies to other folds and anticlines in the Subbasin beneath the WDWA. It is believed that several of these anticlines are associated with faults that trend subparallel to the San Andreas Fault and, if confirmed by future studies, they may also affect groundwater flow. Based on current draft C2VSim-Kern hydrologic modeling by the KGA, there appears to be some underflow towards the immediate north and the former bed of Lake Tulare. In that direction, Subbasin boundaries include the separate Kettleman Plain, the former Tulare Lakebed, which is a beneficial use exemption area, and the Tule subbasin (GEI, 2019).

### 2.5.7 Bottom of the Basin

In simplest form, the geologic bottom of the sedimentary Subbasin can be identified as the depth at which crystalline basement rock is encountered. Alternatively, and more applicable with regards to the objectives of SGMA, the bottom of the groundwater Subbasin is more aptly defined by applying criteria of 40 CFR §146.4. The bottom of the Subbasin varies vertically and laterally with the following criteria:

- Depth to commercially producible minerals or hydrocarbons, or primacy productive limits;
- Depth to exempted aquifers;
- The depth that makes recovery of water for drinking water purposes no longer economically or technologically feasible; or
- The depth at which groundwater cannot now, or in the future, serve as a source of drinking water.

Recognizing that the hydrogeology of the WDWA is highly variable, and that it is not possible at this time to predict the future maximum depth at which groundwater might be economically recoverable, or at which groundwater TDS concentrations below 10,000 mg/L may be economically treatable for drinking water. The following combinations of criteria are proposed for determining the hydrologic bottom of the Subbasin. The criteria take into account existing relevant and applicable rules and regulations. Utilizing this approach, the bottom of the Subbasin (i.e., base of "fresh water") may be described as the combination of the itemized list below (i.e., item A, and either item B or C) (GEI, 2019):

A. Depth to commercially producible minerals or hydrocarbons (40 CFR §146.4) (where it applies to discrete areas of the Subbasin), or the depth to an exempted aquifer which has been approved by the US EPA and DOGGR according to the criteria of 40 CFR §146.4; and either:

B. Depth to water with a TDS concentration that is no longer economically or technologically feasible for groundwater beneficial use; or

C. Depth to waters of TDS greater than 10,000 mg/L (40 CFR §144.3), these being referred to here as not suitable as an USDW.

In the WDWA, concentrations of TDS routinely exceed 2,000 mg/L, making the groundwater unsuitable for practical beneficial use in the WDWA. The base of fresh groundwater in the KCS (**Figure 16**) has historically been defined by Page (1973), as the depth at which specific conductance (SpC) is 3,000 umhos/cm or micro siemens per centimeter (uS/cm). This value is considered to be generally equivalent to a TDS concentration of 2,000 mg/L. These values are reported in this Chapter GSP because they are considered a limiting factor for irrigation and

other practical beneficial uses in the WDWA. The conversion factor from SpC to TDS used for this determination was 0.67, which is midway between the typical range of 0.55 to 0.75 (Hem, 1985), and is dependent on the composition of groundwater. Available groundwater data indicates that, with few exceptions, most of the accessible groundwater of sufficient quantity to be economically viable within the WDWA meets or exceeds this threshold (Amec, 2015; GEI, 2019). Further, in support of this concept, the WWQC is in the process of submitting a BPAW for regulatory review that proposes delisting agriculture and municipal beneficial uses for perched and unconfined/semiconfined aquifers over a significant portion of the WDWA.

In reference to item "A" above, in the WDWA oil and gas is produced from geologic structures that are comprised of some of the same formations that produce brackish groundwater elsewhere in the WDWA. The Tulare and Etchegoin Formations are two examples of this condition. The uppermost hydrocarbon producing zones are variable, but can be a shallow as 400 feet below ground surface. In addition to containing hydrocarbons, many of these oil-bearing zones also contain naturally degraded formation water (i.e. produced water). Based on the presence of hydrocarbons in these structures many of the associated formations are also designated as exempt aquifers by the DOGGR and the US EPA, within the administrative limits of the individual oil field. Examples of oil fields with aquifer exemptions include, among many others, the Lost Hills Oil Field and the Belridge Oil Field complex. Both oil field produced water and WDWA groundwater are naturally degraded by elevated concentrations of TDS and other minerals and compounds. Brackish groundwater conditions are found throughout a majority of the WDWA.

The depth to groundwater with a TDS of 10,000 mg/L, also known as the base of the USDW, is predicated on recent research in the KCS (Gillespie et. al., 2017; Kong, 2016). As described by Gillespie et al. (2017), the base of USDW is identified by geochemical analysis of discrete water samples and geophysical log (E-log) analysis. Gillespie found that salinity in the western KCS are much higher, and the depth to the base of USDW is more variable, than elsewhere in the KCS. These findings may be due to the geological complexity of the western KCS. Gillespie and others cite numerous wells with TDS between 3,000 mg/L and 10,000 mg/L in the non-marine Tulare Formation and overlying alluvium in the western KCS. Although lacking an extensive data set, Page (1973) reported very little data with specific conductance of less than 3,000 umhos/cm (i.e., ~2,000 mg/L) in the western KCS. TDS concentrations in the WDWA are often found to be much higher than 2,000 mg/L, supporting the conclusion there is very little "fresh water" on the western side of the KCS as corroborated further by other sources (Metzger and Landon, 2018; Amec, 2015 etc.). Therefore, the base and lateral extent of groundwater suitable for general beneficial use in the WDWA is proposed as where TDS concentrations exceed 2,000 mg/L.

### 2.5.8 Geologic Cross-Sections

The two geologic cross-sections provided in this Chapter GSP are based on driller descriptive logs and well completion forms filed with Kern County. The datum for both cross-sections is ground surface. Cross-sections presenting the structure and hydrogeology of the KCS at large are provided in the KGA umbrella GSP. The WDWA cross-section location map is provided on **Figure 17a**.

WDWA cross-section A-A' (**Figure 17b**) extends from near the northeastern edge of the LHWD, southwards to near the southern boundary of the BWSD. Stratigraphy depicted on this cross-section matches that described in **Section 2.0** and is generally comprised of interbedded and interlensing series of silts, sands, and clays. Of note are the apparent fine-grained (silt and clay) layers that are evident in several of the wells (e.g., Well No.7108-69). Based on the similar geochemistry of groundwater found across the WDWA it is not clear if any of these fine-grained or clayey sediments are fully competent confining layers. This condition will be assessed further as part of the Chapter MNP data collection.

Cross-section B-B' (**Figure 17c**) extends from west to east, from well 026S020E07E001M to a location near the boundary between LHWD and the adjacent SWSD (well 026S021E14EH002M). This cross-section exhibits the same sediment types as those in the Section A-A', and transects the Lost Hills anticline.

### 2.5.9 Data Gaps

The limited use of groundwater in the WDWA has resulted in data gaps related to the availability of DWR data, well construction information, and continuous and representative groundwater level and pumping data over historic and contemporaneous intervals. Historic studies by the USGS and others have provided sufficient hydrogeologic data and background to construct a preliminary HCM. The current HCM and WDWA water budget presented in this report are based on the preliminary KGA CV2Sim-Kern hydrologic model and the "Brackish Water Checkbook" approach from which an estimate of available water supply was derived. Once additional representative hydrogeologic data has been collected, the existing preliminary groundwater modeling will be further refined by the KGA to include the incorporation of local groundwater elevation, groundwater in storage, cropping, and groundwater pumping and water quality data. The WDWA will also refine and report its HCM and water budget information as new data become available. Until then, the WDWA will rely upon the Brackish Water Checkbook approach for estimating available water and Native Yield. Data gaps will be addressed through the implementation of the focused network monitoring plan described further in **Section 3.0** of this Chapter GSP.

## 2.6 Groundwater Conditions

Groundwater within the WDWA has been documented by numerous studies to be of poor quality and unsuitable for most practical beneficial use without blending or treatment. Because of the dynamic nature of the occurrence and movement of groundwater in the subsurface, it is recognized that groundwater conditions are transient through time and are subject to change. Factors that can affect groundwater conditions and quality include, but are not limited to, volume of precipitation, quality and quantity of direct recharge, topography, climate (ETo), soil geochemistry, aquifer thickness and physical properties, and subsurface geologic impediments or restrictions to groundwater flow. Land use, and anthropogenic activities (e.g., evaporation ponds) are other factors that might further degrade existing brackish groundwater quality. Data to more fully quantify groundwater elevation and occurrence within the WDWA will be addressed as a priority during the first five-year reassessment period. However, current KGA C2VSim-Kern modeling indicates that the principal source of discharge, and thus the most significant change in storage in the WDWA, is not pumping extractions. Instead it is natural subsurface groundwater underflow towards the axis of the Valley. This condition may be accelerated by pumping in adjacent downgradient water districts. Both conditions are beyond WDWA control.

### 2.6.1 Description of Historic and Current Groundwater Conditions

Historic and current groundwater data that is representative of local conditions is a recognized data gap in the WDWA. Although there are many well installations recorded in various agency databases, for the most part a majority of these are lacking the continuous information necessary to fully characterize groundwater conditions. **Figure 18** presents the universe of known well installations as derived from various regulatory agency databases, and a 2015 groundwater assessment conducted by Amec on behalf of the WWQC. In total there are approximately 409 known well sites in the WDWA. This number represents a well density of approximately 1.2 wells per square mile.

Available water quality data in the WDWA confirms that a significant portion of groundwater is brackish and of poor, unsuitable quality. The trend for groundwater elevation levels are downward although, based on the limited data available, appear generally to be at a rate that is less pronounced than as modeled by the KGA and documented elsewhere in the KCS. This is likely due to the limited pumping in the WDWA which is currently estimated at 3,000 AFY, and the fact that natural downgradient groundwater underflow is believed to be the most significant discharge factor in the current C2VSim-Kern model simulation.

Information regarding historic and recent groundwater elevations in the WDWA is limited because many wells are often completed in more than one aquifer, and it is rare that pumping volume or water-level data is collected in a systematic and coordinated way using a common set

of sampling protocols and data recording standards that are implemented on a set schedule. In addition, public availability of gauged pumping volumes has been, and still is, difficult to obtain, as most wells are privately owned. Another contributing factor to this data gap is the fact that, historically in the WDWA, groundwater was generally considered a secondary source when compared to the ready availability of good-quality surface water from the SWP for the purpose of irrigation. This factor may have further militated against consistent detailed record keeping. Currently, based on the best available information, the aforementioned data gaps related to the need for additional representative data persist. Steps to decisively remedy this data gap pursuant to SGMA will be addressed in the WDWA MNP, described in **Section 3.0**.

### 2.6.2 Groundwater Trends

Groundwater elevation data in the WDWA are scarce due to the minimal amount of annual groundwater pumping. Groundwater elevation data has been identified as a data gap that will be addressed during the first five-year reassessment period. However, based on the data available, including historic maps generated prior to widespread development of the WDWA, groundwater trends in the WDWA appear to be generally downward, albeit not at the rates currently simulated in the KGA groundwater model. Groundwater trends in the WDWA are governed principally by drought and downgradient subsurface outflows that may be accelerated by irrigation withdrawals in adjacent water districts. Groundwater flow direction in the WDWA is believed to be primarily eastward toward the floor of the Valley, with some northeastward flow along the northern boundary of the WDWA towards the former bed of Lake Tulare. Subsurface flow is reportedly impeded by geologic synclinal troughs, and sometimes sourced by runoff from the aforementioned anticlinal ridges that separate the Antelope Plain from the axis of the Valley floor. Seismic profiles and other geologic data made publicly available in applications for oil field aquifer exemptions in the WDWA show that gaps do exist in and around anticlinal ridges and synclinal down-folds that could present pathways for groundwater underflow. For example, in the north, geologic gaps between the Lost Hills Anticline and the South Dome of the Kettleman Hills Anticline could provide pathways for subsurface groundwater migration. In the southeast, geologic gaps around the Belridge Anticline complex, and the more easterly Buttonwillow and Semitropic Ridges, may also be pathways for restricted groundwater movement towards the Valley (**Figures 19a and 19b**). A possible obstruction to groundwater flow further eastward may be the Buttonwillow Syncline. Further study of groundwater trends and flow will be conducted during the first five-year reassessment period (i.e. 2020-2025).

An alternative interpretation for the occurrence and condition of groundwater in the WDWA is based on the presence of buried complex geologic structures that are known to exist beneath the Antelope Plain. Many of these features are visible only by viewing geophysical seismic data. It is possible that these structures may have some added influence over the distribution and

quality of groundwater in the WDWA beyond what is currently known. The WDWA plans to assess these conditions by reviewing new data, including publicly available seismic data, during the first five-year reassessment period. Findings of this evaluation will be included in the HCM as appropriate and reported in the relevant SGMA update report

Preliminary C2VSim-Kern modeling conducted by the KGA indicates that the WDWA management area is variably recharged by underflow from the east-facing slopes of Coastal Mountain Ranges, seepage losses from the mostly ephemeral streams after significant storm events, deep percolation of precipitation above calculated ETo, by direct recharge returns of imported water from crop (surface water) application, and incidental losses from irrigation canals and ditches.

Pumping extractions under current conditions in the WDWA are minimal (estimated at ~3,000 AFY), primarily due to the poor groundwater quality and the availability of better quality Aqueduct import water. The simulated estimate of WDWA groundwater recharge is sufficient to cover pumping extraction volumes. However, as noted previously, based on the preliminary KGA C2VSim-Kern model, the largest component of discharge in the WDWA is natural underflow (111,000 AFY) downgradient towards the axis of the Valley. Recharge via agricultural applications of surface water (i.e., deep percolation of agricultural return flow), although still an important source of recharge in the WDWA, is believed to be somewhat less than in the past because of the now-widespread use of modern drip and micro-irrigation technology by growers.

The general lack topographic of definition of stream drainage channels in the WDWA management area indicates that these are likely seasonal losing streams, and that most stream flow never leaves the Antelope Plain as surface water flow; with the possible exception of during extreme precipitation events (GEI 2019). Deep percolation of rainfall may be a source of recharge, but only during periods that significantly exceed the current 5.2 inches of average annual rainfall. The average ETo of approximately 58.3 inches/year, and long-term precipitation data for the KCS, suggest that direct percolation of precipitation in the Antelope Plain is not a significant source of recharge in the WDWA (Amec, 2015; GEI, 2019). There is no evidence for widespread, continuous saturated conditions extending from the surface to first regional groundwater aquifer in the WDWA.

As noted previously, representative groundwater elevation data within the WDWA is limited. The KCWA now (last few years) monitors three groundwater monitoring wells within the LHWD area as part of the CASGEM Program. In addition to these three wells, the WDWA has proposed to monitor another 18 (total of 21) well locations throughout the WDWA. In coordination with the WWQC, the WDWA MNP will implement monitoring on a biannual (Spring and Fall) basis going forward.

A hydrograph for one of the three aforementioned KCWA CASGEM wells (25S/21E-01R001M), located in the extreme northeast of the LHWD, was selected to assess for current and projected groundwater trends due to its continuous record of groundwater elevations for the period 1976 through 2017. **Figure 20a** shows the hydrograph for the period 1975-2018 for well 25S/21E-01R001M. This well is located basin-ward on the boundary between the WDWA and the SWSD. The general groundwater elevation trend in this well has been downward since approximately 1992. Monitoring data are more or less continuous, with some minor gaps starting in 1976 and extending periodically to other short intervals where data was not collected. Groundwater elevations range from a low of 6.2 feet above MSL in 2017, to a high of 84 feet above MSL in 1987. For the period 2007 through 2017, the average downward trend was approximately 5.3 feet per year (feet/year). The reported top of the well screen intervals is approximately 409 feet below MSL (624 feet bgs), which suggest that groundwater in 2017 was standing at approximately 400 feet above the top of the first well screen. Projecting a linear decline rate of 5.3 feet/year outwards to 2040 indicates that groundwater levels would be approximately -62 feet below MSL in 2030 and at 2040 approximately -115 feet below MSL.

Three other well hydrographs and linear decline graphs were generated for the period 1995 through 2004 by CV2SimFG-BETA to help assess groundwater elevation trends along the shared boundary of the WDWA with the BVWSD. One hydrograph is located in the center of Section 16, Township 28S, Range 21E (**Section 4.1.1)**. Based on the simulation data, the projected rate of decline for a well at this location for the specified period would be approximately 5.6 feet/year. The projected water level in 2030 would be approximately 112 feet above MSL, and in 2040 it would be approximately 56 feet above MSL. A second hydrograph is a relatively new well located at Township 27S, Range 22E, Section 30 (**Section 4.1.1**). The projected decline rate for this well based on reported groundwater elevations was determined to be approximately 4.2 feet/year. The projected water level in 2030 is estimated to be approximately 101 feet above MSL. The 2040 level is approximately 59 feet above MSL. The third hydrograph is for a well located 28S21E30H. The projected decline rate is approximately 6.8 ft. year. Estimated water level in 2030 is 127 feet above MSL. The projected 2040 water level is approximately 59 feet above MSL. These projected water levels inform the selection of the preliminary MOs and MTs, which are discussed further in **Section 4.0**.

### 2.6.3 Projected 2016-2065 Climate Change

Current climate modeling indicates that by 2050 there may be a significant reduction in the amount of winter snowpack in the Sierra Nevada Mountain Range. The gradual late-spring to mid-summer snowpack melt has historically allowed for an organized management of this important resource, which currently provides around 65% of California's water supply. If the current predictions are realized, it is possible that runoff from the Sierra Nevada will occur earlier in the year, and a majority of precipitation may come in the form of rain instead of snow.

The ability to harvest and store the runoff for use later in the growing season may become a critical issue for Valley agriculture, and by extension, the State's economy in the coming decades. Assuming no change to cropping patterns, and no new water storage or reuse projects, predicted climate change will likely result in increased competition for all water resources.

In the KCS at large, it is expected that demand reduction measures and reliance on groundwater will increase in order to augment any potential further reductions to deliveries from imported surface water. In the Sacramento River Delta, which is a source of SWP water, less summer Sierra Nevada runoff equates to calculated reductions in Valley surface water deliveries. A corresponding rise in sea level caused by glacier and ice sheet melt off and a rise in ocean temperatures, could also affect water quality for irrigation by increasing the salinity in the Sacramento Delta. In the WDWA, where SWP water is the primary contractual supply of irrigation water and groundwater is used primarily for blending, it is anticipated that SWP deliveries may be further reduced and could become less reliable, while ETo will increase with rising temperatures.

Total (100%) designated SWP allocations to the WDWA, when available, are on the order of 332,218 AFY. However, current KGA preliminary modeling with C2VSim-Kern for the baseline period 1995 to 2014 indicates SWP deliveries averaged around (~272,000 AFY). A preliminary KGA-modeled climate-change scenario for the WDWA covering the period 2016 to 2065 assumes SWP deliveries would be reduced to approximately 61% of the current total Table A allocation (i.e., ~204,698 AFY). Preliminary KGA C2VSim-Kern modeled projections of climate change influences may result in the following groundwater budget components:

Inflows

- Underflow from Coastal Ranges: 55,600 AFY
- Water loss from imported water canals: 8,800 AFY
- Areal recharge (deep percolation): 18,900 AFY
- Water loss from ephemeral stream flow: 3,200 AFY
- Total inflow: 86,500 AFY

Outflows

- Underflow out of the WDWA: 111,000 AFY
- Pumping Extraction: 5,400 AFY
- Total outflow: ~116,400 AFY

Modeled groundwater underflow out of the WDWA and not pumping is by far the most significant factor contributing to change in groundwater storage. This natural phenomenon is outside the control of the WDWA. Due to the poor quality of groundwater, irrigation demand in

the WDWA is and will continue to be met almost entirely by Aqueduct water. To help ameliorate the modeled groundwater outflows over the GSP implementation horizon, the WDWA will continue to utilize conservation and demand reduction measures, intra-area water trading, advanced irrigation technology, deficit irrigation methods, and the potential innovative conjunctive reuse of degraded groundwater and oilfield produced water. Data derived from the MNP will be used to update the KGA water budget model for the WDWA in order to coordinate forward looking and sustainable water management strategies and projects with adjacent GMAs.

As a first step towards future sustainability and climate change resiliency, the WDWA is considering an innovative approach to treat and reuse oil field produced water and naturally degraded groundwater to increase flexibility and diversity in its water portfolio. This project is discussed further in **Section 6.0**.

### 2.6.4 Beneficial Uses and Users

Current designated beneficial uses of groundwater for the WDWA are established in the Tulare Lake Basin Plan. The WDWA is within Detailed Analysis Unit (DAU) 259. Existing designated beneficial uses of groundwater in DAU 259 include:

- MUN,
- AGR, and
- IND.

It should be clarified that although MUN is a designated beneficial use for groundwater within the WDWA, there is no MUN use in the WDWA at this time. For these designated beneficial uses, the Tulare Lake Basin Plan specifies numeric water quality criteria for certain water quality parameters and provided narrative water quality for other parameters. In the Tulare Lake Basin Plan, the designated water quality criteria for MUN are described as (Amec, 2015):

> *"At a minimum, waters designated MUN shall not contain concentrations of chemical constituents in excess of maximum contaminant levels (MCLs)…or secondary Maximum Contaminant Levels (SMCLs)…"*

The Tulare Lake Basin Plan also identified the following narrative water quality criteria for groundwater (Amec, 2015):

> *"Ground waters shall not contain chemical constituents in concentrations that adversely affect beneficial uses."*

> *"Ground waters shall not contain taste or odor-producing substances in concentrations that cause nuisance or adversely affect beneficial uses."*

The US EPA drinking water SMCL for TDS is 500 mg/L. The SWRCB Division of Drinking Water (formerly California Department of Public Health) has established a range of TDS and EC in drinking water (Section 64449, Title 22, CFR). The California SMCLs are presented in **Insert 3**.

**INSERT 3: California SMCLs**

| Constituent | Recommended | Upper Level | Short-Term |
|---|---|---|---|
| TDS | 500 mg/L | 1,000 mg/L | 1,500 mg/L |
| EC | 900 umhos/cm | 1,600 umhos/cm | 2,200 umhos/cm |

Aside from potential hazards to irrigated crops, adverse effects from the consumption of water with elevated TDS include nuisance aesthetic concerns such as bad taste or unpleasant odor, and cosmetic effects, such as skin or tooth discoloration. Physical effects to infrastructure, such as staining, corrosion, pitting, and scaling of pipes, valves, and other water equipment is also common. Consumption of highly brackish to saline waters can result in severe health effects. Based on available data, a majority of the groundwater in the WDWA contains elevated levels of TDS that make it unsuitable for MUN use without additional treatment (Amec, 2015).

The SWP, along with other supplemental sources of surface water, delivers the vast majority of the water used for AGR activities, such as crop irrigation in the WDWA. Groundwater in the WDWA is of sufficiently poor mineral quality to severely impair AGR beneficial uses, and often exceeds published water quality criteria for MUN and AGR-Irrigation (severe restrictions; Food and Agriculture Organization of the United Nations [FAO], 1994). The Tulare Lake Basin Plan has designated beneficial uses of AGR that, for the most part, do not currently exist and cannot be sustained in the WDWA due to poor groundwater quality. Groundwater in the WDWA requires significant blending to be usable for AGR-Irrigation. As noted in **Section 2.1** and elsewhere in this Chapter GSP, the WWQC has transmitted a Draft Basin Plan Amendment Workplan (BPAW) to the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) Technical Committee and the Regional Water Quality Control Board (RWQCB) for their preliminary review and input, prior to final submittal to the RWQCB (**Figure 20b**) for a regulatory determination. The BPAW currently recommends the following:

- Delist the beneficial use of MUN and domestic supply in perched and unconfined/semi-confined groundwater in a portion of the WWQC, which also includes a significant portion of the WDWA; and
- Delist the beneficial use of AGR water supply in perched and unconfined/semiconfined groundwater in those same areas.

Principal land use within the WDWA, aside from open undeveloped rangeland, consists of two general categories:

- AGR: farming, livestock, etc.
- IND: primarily oil and gas production

Users that could be potentially affected by use of groundwater in the WDWA include:

- AGR users;
- IND users (i.e., principally oil and gas); and
- MUN and individual domestic users.

There is no public water supply use of groundwater in the WDWA, nor is there likely to be over the duration of Plan implementation because of the ubiquitous extent of naturally degraded groundwater, and the remoteness of the WDWA where the predominate land uses are agriculture, oil and gas production and grazing. The ready supply of other water sources of better quality, such as Aqueduct water, and groundwater from adjacent management areas also make it unlikely that WDWA groundwater would be used for local public water system supply. According to the DWR well completion reporting and the CASGEM Program, historically there have been a few well completions recorded as "domestic" within the WDWA. However, it is unknown if this well designation is accurate or, if so, whether any of these wells are still in use. The majority of active groundwater wells in the WDWA were completed for the following purposes:

- Irrigation/stock, etc.;
- Industrial; and
- Monitoring/observation.

### 2.6.5 Groundwater Quality

A literature review was conducted to ascertain and document water quality. Among the various technical reports reviewed were USGS studies as well as data culled from the State GeoTracker and EnviroStor databases, which identify contaminant releases to soil and groundwater. The SWRCB's Human Right to Water Quality Portal was accessed to identify common contaminants that are typically found to be in concentrations that are out of compliance with drinking water standards. The evaluation also included data from local Water Districts and the State Drinking Water Information System (SDWIS).

This characterization of groundwater quality was conducted to comply with California Code of regulations (CCR) Title 23-Waters: Sub-article 2§ 354.16(d)-Groundwater Conditions. Of the regulated *drinking water* constituents considered, the most common water quality constituents encountered in the WDWA are; Arsenic, Nitrate, Boron, Hexavalent Chrome, Pesticides (Synthetic Organics), and TDS. To the extent applicable, the constituents evaluated, and the methodology utilized are consistent with guidance provided in:

- Assembly Bill 1249 (AB 1249), which states *"…if the Integrated Regional Water Management (IRWM) region has areas of nitrate, arsenic, or hexavalent chromium contamination, the (IRWM) Plan must include a description of location, extent, and impacts of the contamination; actions undertaken to address the contamination, and a description of any additional actions needed to address the contamination*" (Water Code §10541.(e)(14).

- Division of Drinking Water (DDW) Human Right to Water (HR2W) portal, which identifies the contaminants for which public water systems have received MCL violations.

- Water Quality Control Plan for the Tulare Lake Basin (Basin Plan) dated May 2018, which is the SWRCB's implementation plan for Water Code §106.3. The amended basin Plan requires permitees to *"…address the immediate needs of those drinking groundwater that exceeds the drinking water standard for nitrate*."

Much of this information, including maps of public water systems within the KCS, is contained in the KGA Umbrella GSP. Because of the naturally degraded quality of groundwater in the WDWA, district groundwater is not utilized as a source for public supply.

The quality of groundwater varies greatly across the KCS. Most of this difference is due to natural conditions related to the mineral content of the sediments and lithology and geologic structure of the Subbasin. In the WDWA management area, marine-derived formations have contributed to the documented poor and unsuitable quality of groundwater. Along the western side of the KCS, including the WDWA, unconfined/semi-confined groundwater is characterized geochemically as Na/Ca-$SO_4$ water with TDS concentrations most often above 2,000 mg/L. Other deeper groundwater aquifers beneath the WDWA, and elsewhere in the KCS, are referred to as sodium-chloride (Na-Cl) water, which exhibits high to very high levels of TDS and is likely saline connate water (Amec, 2015; GEI, 2019).

Groundwater beneath the WDWA exhibiting TDS concentrations above 2,000 mg/L are naturally degraded and are considered unsuitable for all practical beneficial use. This includes waters found in, or produced from, oil field hydrocarbon-bearing zones, and US EPA designated exempt aquifers regardless of depth. In addition to TDS, other minerals and compounds that can affect groundwater quality present in WDWA groundwater are described in the subsections below.

It should be noted that generally accepted concentrations of TDS for defining water quality are:

- Fresh Water: up to 500 mg/L
- Brackish Water: 500 mg/L to 30,000 mg/L
- Saline: 30,000 mg/L to 40,000 mg/L
- Hypersaline: greater than 40,000 mg/L

In its 2003 update to California Water Bulletin 118, the DWR provided the following information with regard to the range of TDS values and related suitability for agricultural use (DWR, 2003):

- TDS: <500 mg/L, no restrictions
- TDS: 500 mg/L to 1,250 mg/L, slight restrictions on use
- TDS: 1,250 mg/L 2,500 mg/L, moderate restrictions on use
- TDS: >2,500 mg/L, severe restrictions on use

#### 2.6.5.1 Arsenic

Arsenic has a primary drinking water MCL of 10 micrograms per liter (ug/L) (parts per billion [ppb]), and an agricultural goal of 100 ppb. Reports published by the Department of Pesticide Regulation and USGS studies indicate that the major source of arsenic in the KCS is naturally occurring. A significant source of arsenic in KCS groundwater is derived from erosion and mobilization of arsenic found in geologic sediments. Throughout the southern San Joaquin Valley arsenic rich minerals, such as arsenopyrite, a common constituent of shales, the mineral apatite, and phosphorites are the most frequent sources of arsenic leaching to groundwater. **Figure 21** presents the KCS regional distribution of arsenic in wells for the years 2001 to 2007 (GEI, 2019). The distribution of elevated arsenic concentrations in the KCS is localized and appear to be associated with natural clay deposition in and around the former Tulare Lake, Kern Lake, and Buena Vista Lake areas, where the process of evaporative concentration likely acted to further increase naturally occurring concentrations in associated clays and silts (DWR, 2003; Amec, 2015). A study by the USGS reported that arsenic is the trace element most often present at elevated concentrations in the KCS, with concentrations ranging from 10ppb to 30 ppb.

#### 2.6.5.2 Nitrate

Nitrate ($NO_3$) has an acute drinking water MCL of 10 mg/L (ppm) nitrate-nitrogen. There is no agricultural goal. Nitrate is a form of nitrogen that can be produced naturally by the atmosphere or by decomposing organic matter. Naturally occurring nitrate concentrations are generally less than 10 milligrams per liter as nitrogen (mg/L-N), and generally do not exceed 20 mg/L-N in groundwater (Hounslow, 1995; Todd, D.K. [Todd], 2008; Amec, 2015). Elevated nitrate concentrations are also attributable to the application of nitrogen fertilizers, runoff from feedlots or dairies, percolation of wastewater and food processing waste, and leachate from septic systems (Harter et al., 2012). Groundwater recharge from septic systems is not thoroughly measured or estimated in the KCS, but this potential source is believed to be a minor contributor in the WDWA due to the sparse population and remoteness of towns and individual dwellings. Recharge from wastewater generated by food processing, confined animal facilities, and other industries can also be significant but, like some other wastes, are generally regulated under individual waste discharge requirements (WDRs) (Amec, 2015). Treated wastewater is

regulated by the various RWQCBs under site/facility-specific WDRs. Point source discharges from facilities, including stormwater discharges to surface water are regulated by the National Pollutant Discharge Elimination System (NPDES) under the Federal Clean Water Act (Amec, 2015).

Wells in the San Joaquin Valley, including those on the western side of the KCS, have higher nitrate concentrations in shallower zones, likely the result of return-flow percolation due to past agricultural activities and irrigation practices. Recent improvements to irrigation technology and the evolution to permanent crops like nut trees in the WDWA have significantly reduced the amount of agricultural return flows and fertilizer application. Public water supplies are required to treat raw water to meet all established drinking water MCLs. Within the WDWA, there are no public water systems sourced by district groundwater. The water supply for the town of Lost Hills is from outside the WDWA and is managed by LHUD (Amec, 2015). **Figure 22** presents nitrate as nitrogen detected in KGA wells and proximity of septic tanks for the years 2009 to 20019 (GEI, 2019).

#### 2.6.5.3 Boron

Currently, there is no Federal or State drinking water MCL for boron. However, the State does have a notification level of 1,000 ug/L, and there is an agricultural goal of 700 ug/L. Since the WDWA is largely dedicated to agriculture, the agricultural goal is used as a reference point in this Chapter GSP. The agricultural goal is intended to protect various agricultural uses of water including various crop types and stock watering. The agricultural level is a baseline to compare against and should not be used to represent an acceptable maximum level for the KCS. According to USGS Scientific Investigations Report 2011-5218, boron is commonly found in the southern part of the KCS. It generally occurs in association with basin-fill sediments of marine origin like those in the southern and western sides of the Subbasin. Brackish and saline connate waters, common to the WDWA, are also known to contain elevated concentrations of naturally occurring boron. Other sources of boron include leaching from wastewater, and fertilizer/pesticides (Amec, 2015; GEI 2019).

#### 2.6.5.4 Hexavalent Chromium

Currently, there is no Federal drinking water MCL for hexavalent chromium. A court-challenged State drinking water MCL of 10ug/L is in the legislative process to be re-adopted. In the meantime, the Federal MCL of 50 ppb for total chromium applies. Anthropogenic sources of hexavalent chromium include commercial and industrial activities such as discharges of chrome-plating liquid wastes, various pigments, wood preservatives, and leaching from landfills and hazardous waste sites. Chromium is also prevalent in soils and plants. The process of leaching chromium into groundwater is believed to be similar to that for arsenic described in a previous section above. The occurrence and concentrations of hexavalent chromium detected to date in

the KCS (i.e., in the range of ~5 ug/L to 13 ug/L [or ppb]) indicate that many of the existing detections are likely result of natural conditions (Amec, 2015). There is no Agricultural Water Quality Goal for hexavalent chromium. A review of the GeoTracker and EnviroStor databases found no open contamination hexavalent chromium cleanup sites or point source releases in the WDWA.

#### 2.6.5.5 Pesticides (Synthetic Organic Chemicals)

In a Groundwater Assessment Report prepared for the WDWA and the Western Supplemental Area in 2015 (Undistricted Lands), it was reported that a review of available relevant databases for pesticide detections in the study area determined pesticides were infrequently detected in groundwater samples, and these were generally below established corresponding MCLs. **Insert 4** summarizes the review of the GeoTracker and Groundwater Ambient Monitoring and Assessment (GAMA) databases for the pesticides atrazine, simazine, 1,2-dichloropropane (1,2-DCP), Diuron, 1,2,3-trichloropropane (TCP), and 1,2-dibromo-3-chloropane (DBCP) (Amec,2015).

**INSERT 4: Summary of Pesticide Detections**

| Pesticide | Wells with Data | Wells with Detections | MCL (mg/L) |
|---|---|---|---|
| Atrazine | 24 | 1(E) | 0.001 |
| Simazine | 30 | 1(E) | 0.004 |
| TCP | 21 | 0 | 0.000005 |
| Diuron | 15 | 0 | NA |
| DBCP | 31 | 0 | 0.0002 |
| 1,2-DCP | 25 | 1 | 0.005 |

Note:
(E): estimated value at or below established reporting limit

The US EPA cancelled registrations for DBCP use, with the exception of Hawaii, in 1977. Its use was subsequently banned in the continental United States in 1979. In 1985, the registration for use in Hawaii was also cancelled. The State MCL for DBCP is 0.2 ug/L (ppb). There is no Agricultural Water Quality Goal for this chemical.

To date, there have been no reported detections of TCP in the WDWA. The drinking water MCL for TCP is 5 parts per trillion (ppt.), which became effective in January 2018. In Kern County, 18 water systems have a combined total of 124 wells impacted with TCP. This number represents approximately 52% of all wells for these specific water systems. Typically released to the environment through industrial processes and leaching of soil fumigants, residual concentrations of these chemicals are still reportedly being detected in soil and groundwater in the KCS. These detections are expected to attenuate over time (Amec, 2015; SWRCB, 2019). As stated previously, there is no municipal supply use of groundwater in the WDWA.

#### 2.6.5.6 Total Dissolved Solids, Sodium and Chloride

Based on current drinking water standards, the recommended SMCL for TDS is 500 ppm, with an upper limit of 1,000 ppm. The SMCL for chloride is 250 ppm, with an upper limit of 500 ppm. There are no drinking water standards for sodium. Agricultural Water Quality Goals set by the United Nations Food and Agriculture Organization (FAO) for TDS, sodium and chloride are 450 ppm, 69 ppm and 106 ppm, respectively. Chloride concentrations in the WDWA often exceed FAO limits. This is likely due to leaching from geologic sediments, the presence of saline connate water in the WDWA and anthropogenic impacts from oil industry evaporation ponds. The naturally occurring concentration of TDS in groundwater in the WDWA typically exceeds 2,000 Mg/L (ppm), the level at which it is considered unsuitable for practical beneficial use in the WDWA.

#### 2.6.5.7 United States Geological Survey

A USGS study designed to assess the groundwater quality of the western KCS, prior to widespread agricultural development, sampled 45 supply wells between 1930 and 1955**.** **Insert 5** provides water uses of the 45 study wells.

**INSERT 5: WDWA Well Uses 1930 – 1955**

| Number of Wells | Well Use |
|---|---|
| 2 | Industrial |
| 3 | Domestic |
| 6 | Idle/Unused |
| 13 | Stock |
| 21 | Irrigation |

In a subsequent report that discussed the study data, USGS (1959) provided the following results for EC, TDS, boron and sulfate. Based on these data, most of the groundwater tested beneath the USGS study area exceeded current water quality criteria for MUN, AGR-Irrigation, AGR-Livestock, and AGR-Poultry (Amec, 2015).

**INSERT 6: USGS 1959 General Minerals**

| EC (umhos/cm) | TDS (mg/L) | Boron (mg/L) | Sulfate (mg/L) |
|---|---|---|---|
| 890 – 8,370 | 537 – 7,040 | 0.4 – 18 | 48 – 3,930 |

In 1963, a multi-depth monitoring well cluster was installed near the Kern County National Wildlife Refuge (25S/21E-01N). The well cluster was part of a wider USGS study to characterize

vertical groundwater quality in the KCS. The various individual well screens that made up the subject well cluster were as follows (Amec, 2015):

- Well 1N15: 10 feet to 20 feet bgs,
- Well 1N57: 56 feet to 62 feet bgs,
- Well 1N95: 90 feet to 100 feet bgs, and
- Well 1N194: 189 feet to 199 feet bgs.

Each well in the cluster was sampled in August 1990. The data are summarized in the **Insert 7** below.

**INSERT 7: 1990 WDWA Water Quality Data**

| Well | EC (umhos/cm) | TDS (mg/L) | Boron (mg/L) | Sulfate (mg/L) | Arsenic (ug/L) |
|---|---|---|---|---|---|
| 1N15 | 1,750 | 1,270 | 0.87 | 220 | 6 |
| 1N57 | 12,000 | 9,280 | 9.4 | 4,600 | 16 |
| 1N95 | 6,250 | 4,260 | 2.1 | 1,500 | 10 |
| 1N194 | 4,540 | 2,620 | 1.3 | 420 | 8 |

These data, together with data from other studies identified in this Chapter GSP, reinforce the finding that the groundwater in the WDWA is, with few exceptions, brackish and of poor quality and is unsuitable for current designated uses including MUN and AGR-related uses. The relatively better water quality found in the shallow zone well (1N15) may be attributable to imported fresh surface water used to artificially maintain surface water levels and quality at the Kern County National Wildlife Refuge (Amec, 2015). Deeper groundwater zones appear to be representative of sub-regional conditions, as evidenced by comparison other study data.

A USGS (1995) report provided data on 15 perched groundwater wells in eastern LHWD and BWSD. Concentration of TDS ranged from 1,130 mg/L to 37,300 mg/L. Boron detections ranged from 0.8 mg/L to 70 mg/L. Sulfate and arsenic concentrations ranged from 160 mg/L to 34,000 mg/L and 1.0 ug/L to 20 ug/L, respectively (Amec, 2015). The data show that perched water, where present, in eastern LHWD and BWSD, generally exceed current water quality criteria for MUN, AGR-Irrigation, ARG-Livestock, and ARG Poultry (Amec, 2015).

As part of a separate USGS KCS study, groundwater data below the Westside (hydrographic unit 18030012) were obtained from the National Water Information System (NWIS) (USGS/NWIS) (Amec, 2015). This data set was comprised of 59 wells for which some general mineral data had been collected between 1930 and 1992. The data is summarized as follows (Amec, 2015) in **Insert 8** below.

**INSERT 8: WDWA General Mineral Data**

| EC (umhos/cm) | TDS (mg/L) | Boron (mg/L) | Sulfate (mg/L) | Chloride (mg/L) |
|---|---|---|---|---|
| 1,080 – 102,000 | 544 – 91,900 | 58 – 70 | 100 – 27,000 | 59 – 44,000 |

These data reiterate the conclusion that, with few exceptions, a majority of the groundwater, including oil field produced water beneath the WDWA on a sub-regional basis is brackish, and of little, if any, beneficial use without blending or treatment.

#### 2.6.5.8 California Department of Water Resources

As a technical basis for the adoption of WDRs for oil field operations, the SWRCB contracted with the DWR for a hydrologic assessment of selected oil fields within the Westside, including several located in the WDWA. The following subsections provide a summary of those and other assessments with in the WDWA (Amec, 2015).

Vicinity of Lost Hills Water District

In the 1956 Geologic and Waste Disposal Investigation, Lost Hills Oil Field, the DWR identified 12 supply wells: 10 stock wells and 2 domestic wells. The ranges of general mineral concentrations were reported as shown below (Amec, 2015) in **Insert 9**.

**INSERT 9: 1956 DWR General Mineral Data**

| Wells | EC (umhos/cm) | TDS (mg/L) | Boron (mg/L) | Sulfate (mg/L) | Chloride (mg/L) |
|---|---|---|---|---|---|
| Stock | 2,750 – 8,410 | 1,860 – 6,780 | 2.9 – 10 | 470 – 3,630 | 230 – 1,460 |
| Domestic | 3,600 – 6,100 | 2,700 | 5.2 | 920 – 2,700 | 500 – 542 |

These data indicate that groundwater in the vicinity of the Lost Hills Oil Field is of poor quality and generally not suitable for use without expensive treatment. Chloride and boron concentrations from all but one well (26S/21E-12F), are sufficient to be classified as injurious for irrigation use (Amec, 2015).

A RWQCB (1990) report of groundwater quality samples collected from Tulare Lake Basin tile drains, including four in the LHWD, found TDS concentrations in these drains ranging from 11,000 mg/L to 14,000 mg/L. Concentrations of boron ranged from 29 mg/L to 63 mg/L (Amec, 2015). Based on the reported data, the LHWD tile drain water samples do not meet the criteria for beneficial use for MUN or AGR.

In 2012, as part of DWR's Agricultural Drainage Monitoring Program, the DWR collected samples from two tile drains in the LHWD. The concentration of TDS from the subject drains (DWR 5467 and DWR 6467) ranged between 12,520 mg/L and 23,300 mg/L. Boron was detected at concentrations between 26.6 mg/L to 43.5 mg/L (DWR, 2013; Amec, 2015). The results are comparable to those from the 1990 study described immediately above. Neither data set meets the beneficial use criteria for MUN or ARG use.

Vicinity of Berrenda Mesa Water District

In the 1957 Geologic and Waste Disposal Investigation, Blackwells Corner Oil Field, and Geologic and Waste Disposal Investigation, Welcome Valley Oil Field, the DWR identified nine irrigation wells and one stock well for study. The ranges of general mineral concentrations were reported as shown below (Amec, 2015) in **Insert 10**. ;

**INSERT 10: Berrenda Mesa Water District General Mineral Data**

| Wells | EC (umhos/cm) | TDS (mg/L) | Boron (mg/L) | Sulfate (mg/L) | Chloride (mg/L) |
|---|---|---|---|---|---|
| Stock | 8,370 – 15,700 | 5,450 – 10,400 | 11 – 18 | 1,180 – 4,870 | 2,200 – 4,870 |
| Irrigation | 2,030 – 3,450 | 1,370 – 2,660 | 1.0 – 2.7 | 600 – 1,450 | 166 – 288 |

In their report the DWR concluded that, *"These concentrations are excessive for drinking water"* (Amec, 2015). In addition, these concentrations would also be excessive for most if not all AGR use without treatment or blending with better quality water.

Vicinity of Belridge Water Storage District

In the 1957, Geologic and Waste Disposal Investigation, North and South Belridge Oil Fields the DWR was able to sample two water wells in the vicinity of the Belridge Oil Fields; an industrial supply well in the oil field and a nearby stock well. The ranges of general mineral concentrations were reported (Amec, 2015) as shown below in **Insert 11**.

**INSERT 11: Belridge Water Storage District General Mineral Data**

| Wells | EC (umhos/cm) | TDS (mg/L) | Boron (mg/L) | Sulfate (mg/L) | Chloride (mg/L) |
|---|---|---|---|---|---|
| Stock | 5,450 | 3,863 | 3.3 | 1,775 | 766 |
| Industrial | 4,730 | 2,848 – 2,950 | 0.4 – 7.6 | 462 – 464 | 830 – 870 |

#### 2.6.5.9 Regional Water Quality Control Board

The RWQCB has oversight on several facilities and sites within the WDWA and Westside at large. A selection of these facilities and sites are described below.

Vicinity of Lost Hills Water District

As of 2015, the RWQCB regulated two facilities in the vicinity of the LHWD. These are the former Chevron USA oil field ponds, and the irrigation drainage evaporation ponds operated by the LHWD. The former Chevron ponds are located along the eastern flank of the Lost Hills Oil Field, north of the town of Lost Hills and Highway 46. **Insert 12** presents the results of down-gradient general mineral monitoring in 2012 (Amec, 2015).

**INSERT 12: Former Chevron Pond General Mineral Data**

| Wells | EC (umhos/cm) | TDS (mg/L) | Sulfate (mg/L) | Chloride (mg/L) |
|---|---|---|---|---|
| Chevron | 4,600 – 30,000 | 4,100 – 30,000 | 1,500 – 23,000 | 880 – 7,900 |

These data exceed the criteria for MUN and AGR use, and the poor water quality is consistent with other studies and locations discussed in this Chapter GSP.

The LHWD evaporation ponds consist of six cells covering about 534 acres. In the LHWD 2018 Biannual Wildlife Monitoring Report, it was stated that the ponds were dry for that year due to a lack of discharge by the LHWD. Shallow and deep groundwater monitoring samples collected in 2009/2010 reported the following concentrations (Amec, 2015), as shown in **Insert 13**.

**INSERT 13: LHWD Evaporation Pond General Mineral Data**

| Wells | EC (umhos/cm) | Sulfate (mg/L) | Chloride (mg/L) |
|---|---|---|---|
| LHWD Shallow | 13,000 – 171,000 | NA | NA |
| LHWD Deep | 2,500 – 50,600 | 500 – 20,000 | 980 – 23,000 |

Note:
NA: not available

These data show that groundwater at this location is very brackish and has been impacted, likely both by the nearby ponds and the naturally poor quality of groundwater found throughout the WDWA. As such, this groundwater would be unsuitable for any beneficial use without expensive advanced water treatment technology capable of desalination such as reverse osmosis (RO) or other membrane technology. Because of the location of the ponds on the eastern boundary of the LHWD there is also the likelihood that brackish, poor quality

groundwater, has migrated down-gradient towards the adjacent SWSD. If confirmed, coordinated monitoring and management of the brackish water will be required during the implementation of the KGA GSP to mitigate the potential for further undesirable results to better quality water to the east of the WDWA.

Vicinity of Berrenda Mesa Water District

The RWQCB oversees the Lost Hills Sanitary Landfill (LHSL), operated by Kern County, and the cleanup of the Antelope Pump Station, managed by Chevron. The LHSL is located along the southwestern flank of the Lost Hills Anticline, while the Antelope Pump Station is located in the west-central part of the BMWD. Monitoring of shallow groundwater at the LHSL was reported by Kern County Waste Management District (KCWMD) in 2012. This report found TDS in the range of 3,400 mg/L to 4,300 mg/L, chloride concentrations in the range of 620 mg/L to 1,200 mg/L, and sulfate concentrations in the range of 1,400 mg/L to 1,500mg/L.

Monitoring of shallow groundwater at the Antelope Pump Station and reported by Chevron in 2012, found EC values in the range of 1,175 umhos/cm to 2,416 umhos/cm. For comparison, a value of 3,000 umhos/cm equates to approximately 2,000 mg/L of TDS.

Vicinity of Belridge Water Storage District

In the vicinity of the BWSD, the RWQCB regulates several sites. Among these are:

- Aera Energy's former South Belridge Oil Field Ponds;
- Clean Harbors Disposal Facility;
- Exxon/Mobil Hill Lease; and
- Valley Water Management Ponds.

Aera's former oil field ponds are located on the southern edge of the BWSD on State Highway 33. Adjacent areas to the north include the other member Districts of the WDWA, while to the east are the BVWSD and Undistricted Lands. To the west lies the Temblor Range, and to the south is the WKWD. Monitoring wells in shallow groundwater are maintained to assess groundwater quality both beneath, and down-gradient of the former ponds.

**Insert 14** presents data from a 2012 sampling event (Amec, 2015).

**INSERT 14: Former Aera Pond General Mineral Data**

| Wells | EC (umhos/cm) | TDS (mg/L) | Boron (mg/L) | Sulfate (mg/L) |
|---|---|---|---|---|
| Aera | 3,000 – 70,000 | 2,400 – 45,000 | 2.4 - 110 | 520 – 3,000 |

At the Clean Harbors Buttonwillow facility groundwater is monitored in three zones identified by the company. The zones are described as the Upper Perched Zone (80 to 140 feet bgs), Intermediate Perched Zone (185 to 201 feet bgs), and Lower Water Table (260 to 290 feet bgs). Adjacent down-gradient areas to this facility include the town of McKittrick, California, and the WKWD. **Insert 15** presents a summary of a 2012 groundwater monitoring event (Cameron-Cole, 2013; Amec, 2015).

**INSERT 15: Buttonwillow Facility General Mineral Data**

| Wells | TDS (mg/L) | Boron (mg/L) | Sulfate (mg/L) | Chloride (mg/L) |
|---|---|---|---|---|
| Upper | 1,390 – 3,980 | 4.7 – 11.8 | 559 – 2,100 | 185 – 2,400 |
| Intermediate | 2,230 – 2,670 | 4.8 – 6.9 | 980 – 1,560 | 162 – 555 |
| Lower | 2,100 -3,200 | 6.2 – 9.4 | 806 – 1,280 | 385 – 527 |

The Exxon/Mobil Hill Lease is located in the western part of the BWSD along State Highway 33. Shallow groundwater is monitored both beneath and down-gradient of the Hill Lease. **Insert 16** presents data from a 2012 monitoring event (Cardno ERI, 2013; Amec, 2015).

**Insert 16: Exxon/Mobil Hill Lease General Mineral Data**

| Wells | EC (umhos/cm) | TDS (mg/L) | Boron (mg/L) | Sulfate (mg/L) |
|---|---|---|---|---|
| Hill Lease | 4,000 – 25,000 | 4,160 – 19,300 | 2.5 – 48.7 | 830 – 2,000 |

The Valley Water Management (VWM) Ponds located near the Belridge oil field complex were recently found to be in non-compliance with several regulations by the RWQCB. Members of the VWM cooperative are reportedly working with the RWQB to come into compliance in order to avoid further enforcement, including the recent imposition of a Cease and Desist Order from the RWQCB.

As with the totality of other data sets discussed elsewhere in this subsection, these data support the conclusion that the groundwater quality beneath the BWSD is largely naturally degraded and is sometimes impacted by localized anthropogenic activity (e.g., evaporation ponds). That said; the groundwater beneath the WDWA is almost exclusively unsuitable for MUN and most, if not all, AGR or other beneficial use without blending and/or desalination. There is also the potential for these primarily naturally degraded groundwaters to migrate outside the WDWA where it would produce or perpetuate an undesirable result in adjacent GMAs. To mitigate any undesirable result related to poor water quality originating from the WDWA, the WDWA will work in close cooperation with oil producers and down-gradient, adjacent GMAs during the

implementation of the KGA GSP to conduct sentry monitoring as part of the WDWA MNP in order to assess for changes in groundwater quality on its boundaries.

#### 2.6.5.10 Kern County Water Agency

As part of a recent study, Amec (2015) requested the KCWA groundwater data from across the Westside. A review of data for 66 wells found that EC values ranged from 370 umhos/cm to 55,600 umhos/cm. Boron ranged from 0.48 mg/L to 14 mg/L, and sulfate ranged from 130 mg/L to 1,300 mg/L (Amec, 2015). The breadth and scope of this review again documents and confirms that, with few exceptions, the water quality beneath the WDWA is predominately brackish to saline and of poor quality.

#### 2.6.5.11 Adjacent Areas and Other Studies

The Dudley Ridge Water District (DRWD), located outside and generally down-gradient to parts of the WDWA, is immediately north of the LHWD in Kings County. Like the WDWA, the groundwater beneath the DRWD is similarly degraded by naturally occurring TDS and salts. A DWR (1964) Feasibility Study (FS) to evaluate the viability of providing SWP surface water to the DRWD found that, *"There are some producing water wells in the extreme northern portion of the District which provide a small portion of the present water supply. Most wells that have been drilled, however, have been abandoned due to poor yield and poor quality of groundwater..."* (Amec, 2015). A subsequent siting study and monitoring program conducted by Amec on behalf of the Los Angeles County Sanitation District for its bio-solids composting facility on the eastern side of the DRWD, found TDS and sulfate concentrations in groundwater ranging from of 5,920 mg/L to 26,800 mg/L and 2,930 mg/L to 11,600 mg/L, respectively.

Starrh & Starrh Growers provided Amec with 2010 data from a then newly installed well in the southern part of the WDWA. The summarized results are provided below (Sanden, 2012; Amec, 2015) in **Insert 17**.

**Insert 17: Southern WDWA General Mineral Data**

| Wells | EC (umhos/cm) | TDS (mg/L) | Boron (mg/L) | Sulfate (mg/L) | Arsenic (mg/L) |
|---|---|---|---|---|---|
| Starrh & Starrh | 3,000 | 2,300 | 7.1 | 1,000 | 16 |

The Starrh & Starrh well data is consistent with a majority of the other groundwater data in the WDWA and indicates this water is unsuitable for MUN without membrane desalination, and is also unsuitable for many sustained AG uses without blending.

Adjacent, and generally down-gradient to the east of the WDWA; the SWSD is susceptible to undesirable results from naturally degraded brackish groundwater migrating out of the WDWA

and towards the SWSD. In a recent SWSD AWMP, the SWSD stated that, *"In general, groundwater in the west has higher TDS content relative to the eastern part of the District. Groundwater of poor quality, typically a sodium chloride or sodium chloride-sulfate type with high concentrations of dissolved solids and chlorides, can be found extensively along the western side of the San Joaquin Valley"* (Provost & Prichard, GEI 2013; Amec, 2015).

As described elsewhere in this section, the BVWSD, located to the east and southeast of the WDWA, and portions of the WKWD located to the south of the WDWA, are also potentially susceptible to groundwater quality undesirable results by migration of brackish groundwater originating from the WDWA.

In 2013, Amec, on behalf of the WWQC, sampled a total of 21 wells. Twenty samples were collected from the WDWA, and one sample from the adjacent down-gradient DRWD. The wells were of various depths and screen intervals and were distributed across the WDWA as follows (Amec, 2015):

- LHWD (4 wells)
- BMWD (6 wells)
- BWSD (10 wells)
- DRWD (1 well)

The results for this sampling event are summarized below (Amec, 2015) in **Insert 18**.

**Insert 18: WWQC General Mineral Data**

| Wells | EC (umhos/cm) | TDS (mg/L) | Boron (mg/L) | Sulfate (mg/L) | Arsenic (mg/L) |
|---|---|---|---|---|---|
| LHWD | 2,700 – 5,800 | 2,000 – 4,000 | 0.8 – 3.3 | 470 – 1,300 | <2 – 10 |
| BMWD | 1,800 – 3,200 | 1,300 -2,600 | 1.6 – 6.7 | 450 – 1,200 | <2 – 22 |
| BWSD | 2,900 – 21,000 | 1,800 – 18,000 | 3.3 – 47 | 510 – 2,200 | 2 – 33 |
| DRWD | 4,500 | 3,000 | 1.2 | 1,200 | 14 |

In addition, water hardness was also evaluated. The results for the hardness analysis are provided below (Amec, 2015) in **Insert 19**.

**Insert 19: WDWA Water Hardness Data**

| Wells | Hardness (mg/L) |
|---|---|
| LHWD | 790 – 1,200 |
| BMWD | 470 – 890 |
| BWSD | 510 – 5,600 |
| DRWD | 960 |

It was concluded that all 21 samples exceeded the State MCLs for drinking water for EC and TDS. The results for hardness in this study would classify all of the samples as being very hard water. Hardness values above 120 mg/L typically require softening in order to prevent scaling deposits in pipes and water heaters (Amec, 2015).

The occurrence of high TDS groundwater in the Westside has recently been further documented in a preliminary groundwater salinity mapping study conducted by the USGS (Metzger and Landon, 2018). In the study, the distribution of groundwater salinity for 31 oil fields and adjacent aquifers across major oil-producing areas of central and southern California were mapped. The objective of the study was to describe the distribution of groundwater near oil fields having TDS less than 10,000 mg/L by using existing TDS data from petroleum and groundwater wells to map concentrations and document data gaps. Within the KCS, the study reported much higher TDS in groundwater from Westside oil field wells and groundwater wells, when compared with east side groundwater wells and oil wells. Metzger and Landon (2018), among others, suggest that higher TDS in the Westside of the KCS could be related to a combination of natural conditions (Westside sediments derived from marine deposits with some saline connate water) and anthropogenic factors such as, among other things, infiltration of TDS from former oil field disposal ponds and/or agricultural drainage ponds. Naturally occurring higher TDS water is consistent with historical reports (several reports from before wide-spread agricultural development) and is documented for more than 60 miles from north to south in the KCS (KCDEH, 1980; KCDEH and KCWA, 1982; GEI, 2019).

#### 2.6.5.12 Contamination Plumes

An evaluation of contamination plumes was conducted via the GAMA Groundwater Information System. The GAMA contains information from other State data bases such as the Department of Toxic Substances Control (DTSC) EnviroStor, and the SWRCB GeoTracker. This section presents the potentially impacted sites as were listed in the regulatory databases it should be noted that it is not the intent of this Chapter GSP to evaluate or confirm whether any of these sites are impacting beneficial use. It is important to recall that information provided in this Chapter GSP has documented that groundwater in the WDWA is primarily naturally degraded

and is not suitable for most uses, including drinking water, nor is there any public water system use. The following programs from GAMA were reviewed:

- WDR;
- Underground Storage Tank (UST);
- Leaking Underground Storage Tank (LUST);
- Cleanup Program Sites;
- DTSC Hazardous Waste Sites;
- Department of Pesticide Regulation;
- Oil and Gas Sites; and
- Integrated Lands Regulatory Program.

Although the GeoTracker database did not show any sites with WDRs, in the WDWA, there are many sites in the KCS and WDWA that operate on WDRs issued by the Central Valley Regional Water Quality Control Board (CVRWQCB or RWQCB). Facilities with WDR's typically include water treatment facilities, wastewater treatment facilities, oil and gas produced water treatment facilities, confined animal facilities and sites that are under active groundwater remediation. The GeoTracker also does not identify any confined animal facilities in the KCS, even though CIWQS shows there are approximately 264 such sites in Kern County. A non-profit Central Valley Dairy Monitoring program was formed in 2010 to develop a monitoring and research program to study the ecological effects of dairies in the Valley. This group recently submitted a report summarizing the findings of their monitoring. One of the recommendations was to develop and administer a web-based portal and data management system. Sites that were or are currently being studied under the oversight of the RWQCB were discussed in **Section 2.6.5.9**

Oil field wells permitted under the DOGGR, and the US EPA UIC Program were not included on the figures, or the related site table described below because the UIC requires that oil operators confine injected produced water to the approved zone to ensure that injected fluid does not impact off site underground sources of drinking water. Produced oil field water is discussed further in **Section 2.7.4.**

**Figure 23a** shows the location of sites extracted from the EnviroStor and GeoTracker data bases. **Figure 23b** presents Permitted Discharge Locations, of which there are approximately 44 in the WDWA, a majority of which appear to be related to oil field produced water treatment facilities. **Appendix E** lists the data acquired from the aforementioned regulatory sources in this section. Data was included on the subject table only if they applied to the following criteria (GEI, 2019):

1. Potential media was described as "groundwater," "other groundwater", or "unknown"
2. Contaminate of concern was described or classified as "unknown"

3. Site was classified as “not closed”, and had one of the following modifiers:
    - Active cleanup
    - Active land use restrictions
    - Open remediation
    - Open site assessment
    - Open-eligible for closure
    - Inactive-action required
    - Under review
    - Open-inactive
    - Inactive permitted
    - Inactive unpermitted

## 2.7 Water Budget

### 2.7.1 KCS and KGA Water Budget Development

All GSAs in the Kern County subbasin (Subbasin) coordinated and collaborated on the development of a groundwater model (Model) to evaluate historical, baseline and projected groundwater conditions. The GSAs entered into a Cost Share Agreement with the Kern River GSA who took the lead and contracted with Todd Groundwater to develop the Model on behalf of the Subbasin. The contract required that Todd Groundwater use the C2VSim model provided by DWR. Considerable effort and resources were expended to update the C2VSim model with local data to better represent Subbasin conditions. The process Todd Groundwater used to update C2VSim is more fully described in the Historical and Projected Future Water Budget Development (see Attachment H in Umbrella GSP). Basin-wide water budget results from the Model are provided in Attachment H and show the Subbasin, as a whole, has a total storage deficit of approximately 324,326 AFY over the baseline period.

The Subbasin’s dynamic conjunctive use programs, water banking operations, and water transfers/exchanges made it necessary to coordinate a GSA-level water accounting system (Checkbook) using Subbasin specific values for supply, demand and net results. The Model results reflect Subbasin-wide conditions and do not allocate water shortages/surpluses, nor do the results allocate the “ownership” of water. As a result, the GSAs, through a coordinated effort, developed the Checkbook that estimates current conditions for each GSA that are generally consistent with the Model results under baseline condition. The Checkbook and Model budgets are based upon best available information, recognizing however, each estimate includes data gaps and has varying degrees of accuracy and/or reliability in the interest of developing a Subbasin coordinated approach.

To ensure the individual water budgets reflected actual conditions, the KGA members developed the Checkbook budget and coordinated water accounting methodology. The result

of that effort indicates a current baseline shortage/deficit for KGA members of approximately-256,281 AFY. This reflects the difference between a total demand for KGA members of 1,939,409 AFY, and a total supply of 1,683,128 AFY. Of the shortage/deficit of the KGA, the WDWA's portion of the KGA shortage/deficit is a surplus of +33,167 AFY. Or a difference in demand of 285,000 AFY and a water supply of 318,167 AFY.

As is mentioned above, each estimate includes data gaps and has varying degrees of accuracy and/or reliability. The Checkbook is complimentary to the Model and reflects the allocation of water supply benefits and obligations independent of geographic constraints within the Subbasin. This was important to recognize and ensure the coordination of the various groundwater banking projects and water management programs amongst the various GSAs within the groundwater basin.

As with other GSA-level budgets, the preliminary WDWA estimates also include data gaps and have varying degrees of accuracy and/or reliability that will be addressed by the collection, analysis, and reporting of additional representative data. However, it should be noted that the six unique WDWA hydrogeologic conditions (e.g. naturally degraded groundwater quality etc.), relative to the rest of the KCS, rend WDWA groundwater unusable unless it is blended or treated.

### 2.7.2 WDWA-Specific Water Budget Development and Issues

With regard to the WDWA, agricultural activities are the largest source of water demand, and such activities rely almost exclusively on surface and other imported water from the Aqueduct. There is currently a lack of representative groundwater elevation data in the WDWA. This data gap is due to the limited amount of annual groundwater pumping, which is directly attributable to naturally poor water quality. As discussed in **Section 2.7.1**, the water budget for the WDWA is currently based on the two independent and contrasting surrogate approaches described below that bookend the range of potential water supply: (1) The Checkbook Approach and (2) The Modeling Approach.

The Checkbook Approach is a typical approach based on an accounting of preliminary supply and demand and, as previously noted, is used by other GMAs in the KGA. The KGA Checkbook approach combines SWP water, alternative imported water (i.e. total Aqueduct water), a preliminary value of groundwater "Native Yield", and a currently estimated value of precipitation in areas of irrigated acreage, to estimate the available water supply. The Checkbook value of "Native Yield" is intended to encompass all groundwater recharges and discharges that apply to the WDWA but does not explicitly include groundwater underflow, which as discussed below is a critical element of the WDWA water budget. Furthermore, it is important to understand that the term, "Native Yield*",* implies *suitable groundwater quality,* a condition that does not generally apply to the WDWA. Due to the six aforementioned unique

hydrogeologic characteristics of the WDWA discussed in the **Executive Summary** and **Section 2.1**, with geologic sediments of marine origin contributing directly to naturally degraded groundwater, and degraded brackish groundwater underflow chief among them, groundwater quality in the WDWA is poor and unsuitable for most uses. For example, virtually all groundwater pumping is and has been minimal and is used for the sole purpose of blending with better quality imported surface water when the supply of Aqueduct water is low.

All of the groundwater in the Native Yield in the modified WDWA Checkbook is comprised of naturally degraded brackish groundwater that is considered unsuitable for most use without blending or treatment and is therefore *"outside"* of the water budget. The Checkbook approach is a simplified illustration of potential groundwater resources and is only capable of providing an estimate of the current operational water budget, as well as preliminary 2030 and 2040 water supply operational budgets. The projected estimates are sufficient to encompass phased groundwater pumping for the twin purposes of landowner blending, including anticipated increased pumping in response to climate change, as well as pumping and treatment for a proposed conjunctive reuse management action discussed in **Section 5.0** of this Chapter GSP.

The second Water Budget approach used in this Chapter GSP is based on available modeling conducted by the KGA. As noted above, it should be emphasized that the subject numerical groundwater model, C2VSim-Kern, is intended as a Subbasin-wide assessment of groundwater conditions and is not specifically calibrated to the WDWA service area. The C2VSim-Kern model is based on an uncalibrated Beta version of the DWR California Central Valley Groundwater-Surface Water Simulation Model, known as the C2VSimFG-BETA. The C2VSim-Kern modeling results are available for historical conditions for the WDWA, which were used to develop the current conditions water budget. C2VSim-Kern modeling results are also available for future baseline conditions and future conditions that include water projects proposed by all KCS GSAs, but these results are only available for the KCS at large; WDWA-specific results are not currently available (see **Section 2.7.2.2**). These scenarios will continue to be updated and adjusted for the KCS as a whole during the first GSP reassessment period. Additional pumping to support the planned treatment conjunctive reuse of brackish groundwater is described in **Section 2.7.2.1 and Section 5.3**.

Neither of these two approaches (Brackish Water Checkbook or C2VSim-Kern) explicitly considers the poor water quality in the WDWA or provides a definitive illustration of the WDWA-specific water budget but, in the current absence of sufficient groundwater elevation data in the WDWA, they do provide a framework for revising the water budget components based on data collected in the coming years. **Figure 24a** presents the C2VSim-Kern model zone map for the water budget area. **Figures 24b, 24c, and 24d** show graphic presentations of both approaches to estimating a preliminary WDWA groundwater budget, and current and projected groundwater pumping.

It should be noted that the C2VSim-Kern historical model overstates the amount of groundwater pumping that has and is occurring in the WDWA. For the purpose of comparison, the relatively low actual groundwater pumping (i.e. currently 3,000 AFY) is used in the following and ongoing discussions, and the overstated pumping volume from the C2VSim-Kern historical model is retained for the time being in those respective current-condition water budget estimates, as described below in **Sections 2.7.2.1 and 2.7.2.2**. Given this, the Brackish Water Checkbook approach is presently the more representative estimate of a water balance for the WDWA. Additional reconciliation of basin water budgeting efforts is a high priority for all of the GSAs as part of GSP implementation.

#### 2.7.2.1 Brackish Water Checkbook Approach

The WDWA Checkbook approach combines SWP surface water, various supplemental surface water supplies (i.e. other Aqueduct water), a preliminary value of operational Native Yield, and a current value of precipitation to estimate the available water supply. Groundwater pumping is not explicitly accounted for in the Checkbook but is rather considered a portion of the Native Yield. As noted above, the Checkbook value of Native Yield is intended to encompass all groundwater recharges and discharges that apply to the WDWA but does not include groundwater underflow. The WDWA Native Yield for the purpose of the preliminary Checkbook is conservatively estimated to be 0.15 af/ac., multiplied by all WDWA acreage (i.e. 227,193 acres). This results in a volume of approximately 34,079 AFY. Unique to the WDWA is the fact that all sources of groundwater (e.g. underflow, recharge etc.) are eventually degraded due to the geology and are unsuitable for most use. Therefore, the brackish groundwater is necessarily considered as "*outside*" the water balance unless blended or treated. If the poor water quality, minimal levels of pumping in the WDWA, and volume of modeled degraded underflow (~111,000 AFY; see **Section 2.7.2.2**) leaving the WDWA are accounted for, a Native Yield of up to 0.30 af/ac may be supportable. If applied, it would result in a potential Native Yield range of 34,079 AFY to 68,158 AFY that could be utilized for blending or treatment for conjunctive reuse. This volume represents approximately 30%-60% of the current total C2VSim-Kern estimate of brackish groundwater underflow leaving the WDWA (**Figures 24b, 24c and 24d**).

The currently estimated Brackish Water Checkbook precipitation factor was based on KGA and CIMIS data for the WDWA. It utilizes a factor of 0.2 af/ac. multiplied by the number of irrigated acres (88,989 acres) in the WDWA. This results in a volume of approximately 17,798 AFY that can potentially meet a portion of crop demand.

The volume of available surface water includes SWP Table "A" water (204,698 AFY), Article 21 water (23,878 AFY), as well as purchased alternative imported water (37,714 AFY), which includes just WDWA purchases from outside the basin, but excludes WDWA intra-basin purchases/transfers and intra-basin purchases/transfers by individual landowners. All of this

water is delivered to WDWA via the California Aqueduct. Together, this results in a currently available surface water supply of approximately 266,290 AFY. The surface water supply for current conditions was not adjusted for the preliminary 2030 and 2040 water budgets. Rather, if delivered volumes of surface water decrease over this time horizon it was assumed that management actions would be taken by the WDWA and is growers to reduce demand or increase supply.

As noted above, groundwater pumping is not explicitly accounted for in the Checkbook, but illustrations of current and projected pumping are shown on **Figures 24b, 24c, and 24d**. Pumping in the WDWA is not expected to approach the preliminary range of brackish Native Yield until 2040. Current conditions (**Figure 24b)** indicate only 3,000 AFY of brackish groundwater is utilized to meet demand, and this water is used primarily for blending with Aqueduct water. In 2030 (**Figure 24c),** a projected pumping increase to 5,400 AFY is anticipated for the purpose of blending in order to account for climate change, in addition to another 20,000 AFY of brackish groundwater underflow being pumped for treatment and conjunctive reuse as described in Proposed Management Action (PMA) No. 3. In 2040 (**Figure 24d),** the full potential range of brackish Native Yield of 34, 079 to 68,158 AFY is utilized: 5,400 AFY for blending, and the remainder for proposed PMA No. 3 feedstock water for treatment and conjunctive reuse. This amount of feedstock pumping is considered a maximum value, because it is anticipated that some percentage of oilfield-produced water will be available for treatment and reuse in conjunction with brackish groundwater underflow. In the WDWA, total water demand is essentially equivalent to crop demand. For current conditions, demand is estimated to be 285,000 AFY (**Figure 24b**). To account for climate change, estimated demand is conservatively increased to 300,000 AFY in 2030 (**Figure 24c**) and 316,000 AFY in 2040 (**Figure 24d**).

The Brackish Water Checkbook method provides a preliminary estimate of available water supply. It should be emphasized that the values stated above provide a framework for data-based updates in the coming years and are not intended to be used for allocation purposes. Future allocations, if any, will be addressed through a stakeholder process.

#### 2.7.2.2 Modeling Approach

Groundwater modeling conducted for the KGA utilizing the C2VSim-Kern model provided estimated volumetric flow rates for key water budget components. It should be noted again that the subject model is intended to be a Subbasin-wide assessment of groundwater conditions and is not specifically calibrated to the WDWA service area at this time. Additional reconciliation of water budgeting efforts for the Subbasin and the WDWA is a priority as part of GSP implementation. The managed supply and demand components of the model were updated with data provided by KGA-member water management agencies and other KCS GSAs to

develop C2VSim-Kern. The details of the model updates, as well as the KCS-level modeling results, are described in a Technical Memorandum prepared by Todd Groundwater, *Historical and Projected Future Water Budget Development* (Attachment H in the KGA Umbrella GSP).

Water demand in the WDWA is dominated by irrigated agriculture. The C2VSim-Kern model calculates crop demand based on crop type and distribution, climate, and soil type. In the WDWA, water supply is predominately (approximately 95-98%) delivered via the California Aqueduct, which includes SWP water and other supplemental import (i.e. Aqueduct) water. Based on available data, less than 2% of the WDWA water demand is met by groundwater pumping, which is utilized primarily for the purpose of blending.

According to the C2VSim-Kern model, there is currently an imbalance in the WDWA between agricultural water supply and demand, resulting in an average agricultural shortage (deficit) of 80,000 AFY for the WY 1995-2014 period. This equates to an estimated shortage of 8.4 inches/year per irrigated acre. By way of contrast, available data indicate that actual demand more or less tracks with average Aqueduct deliveries for this same period. Locally, this imbalance indicates that either: (1) a substantial amount of deficit irrigation or other water management techniques are being implemented by the growers in the WDWA and/or (2) the crop demand is overestimated by the C2VSim-Kern model. A preliminary review of the model data indicates that an overestimation of crop types and associated demand (i.e. pumping) likely account for a majority of this disparity in the model. This phenomenon, and other refinements to the numerical model, will be assessed further during the first five-year reassessment period and reported in a future reassessment report. As noted previously, current WDWA Aqueduct surface water deliveries, less intra-basin WDWA purchases and individual land-owner intra-basin purchase and transfers are approximately 266,290 AFY. Total current demand WDWA is estimated at 285,000 AFY.

Current Conditions

Based on KCS-level C2VSim-Kern modeling for the period WY 1995-2014 (i.e. current conditions), total groundwater recharge is approximately 92,341 AFY:

- Underflow from the Coastal Ranges: ~ 55,264 AFY
- Underflow into the WDWA from adjacent Districts: ~837 AFY
- Water loss from imported water canals: ~8,844 AFY
- Areal recharge (deep percolation): ~24,227 AFY
- Water loss from ephemeral stream flow: ~3,169 AFY

Area wide recharge (i.e., deep percolation in C2VSim-Kern) is the distributed recharge to groundwater from the unsaturated zone. It is equal to percolation out of the root zone plus or

minus flow out of or into unsaturated zone storage. Percolation out of the root zone is a combination of applied water and precipitation in excess of ET.

As noted previously in this report, C2VSim-Kern is overestimating the volume of WDWA pumping extractions under current conditions. Because the primary source of water for agriculture in the WDWA is via the Aqueduct, the volume of discharge due to extraction by pumping wells has historically averaged less than 2% of annual demand. Pumping is currently estimated at approximately 3,000 AFY. The overestimated pumping volumes in the model will be addressed in future model simulations. The total estimated groundwater discharge for the current-conditions model simulation is approximately 138,540 AFY. The individual C2VSim-Kern discharge volumes, which will be refined as new data become available, are:

- 98,581 AFY for underflow out of the WDWA towards the down-gradient axis of the Valley;
- 12,403 AFY for underflow to non-districted areas to the north, south, and west; and
- 27,556 AFY by pumping extraction (significantly overstated in the current model).

The current C2VSim-Kern overdraft for the WDWA, which uses the overstated higher value of pumping, is estimated to be -46,200 AFY (rounded up here to 47,000 AFY to account for uncertainty in the model). This deficit in the water budget is met in the C2VSim-Kern model by approximately 46,000 AFY that enters the groundwater flow system from groundwater storage. Because groundwater pumping is overstated in C2VSim-Kern, the current simulated change in groundwater storage is also overstated and is likely significantly lower (i.e.~22,000 AFY). Taking into account future conditions due to climate change (i.e. reduced precipitation and recharge) and an associated increase in pumping extraction from the current 3,000 AFY to 5,000 AFY, the change in storage could conservatively increase to approximately 30,000 AFY. This adjusted estimate of change in groundwater storage is still significantly less than that derived from the current C2VSim-Kern model. Because actual discharge by pumping extraction is approximately 3,000 AFY, the majority of the modeled change in groundwater storage for the WDWA is due to downgradient groundwater underflow out of the WDWA towards adjacent management areas generally to the north and east. Said another way; even if all pumping were to cease in the WDWA, a deficit (and resultant decrease in groundwater storage) would still exist due solely to groundwater underflow leaving the WDWA toward the axis of the basin. This natural phenomenon, which is possibly being accelerated by pumping in adjacent downgradient GMAs, is beyond the control of the WDWA.

C2VSim-Kern Future Conditions

A total of six C2VSim-Kern future-conditions model scenarios were developed by Todd Groundwater for the KGA for the KCS as a whole (KGA Umbrella GSP Attachment H). Future-conditions scenarios are not available for the WDWA at this time. Three of these KCS scenarios are for “baseline” conditions, i.e. scenarios that do not consider water management actions:

- Future Baseline Conditions: Repeat historical hydrology with expected future water supply;
- 2030 Climate Conditions: Adjust historical hydrology for 2030 climatic conditions and expected water supply; and
- 2070 Climate Conditions: Adjust historical hydrology for 2070 climatic conditions and expected water supply.

The other three future-conditions scenarios are the same as above but include proposed water management actions (i.e. SGMA and other projects). Future-conditions results for the KCS as a whole are:

- Future Baseline Conditions:
  - No Projects: shortage/deficit of -324,326 AFY
  - With Projects: surplus of +85,578 AFY
- 2030 Climate Conditions
  - No Projects: shortage/deficit of -372,120 AFY
  - With Projects: surplus of +46,829
- 2070 Climate Conditions:
  - No Projects: shortage/deficit of -472,336 AFY
  - With Projects: shortage/deficit of -45,969 AFY

It should be noted that C2VSim-Kern is uncalibrated, particularly with regard to the groundwater flow system (i.e. geologic complexity, aquifer storage parameters, and hydraulic conductivity). The lack of calibration may significantly affect the modeled change in groundwater storage and groundwater underflow. For purposes of this Chapter GSP, it is assumed that this issue will be addressed in the coming years and any changes will be reported in the relevant update report.

### 2.7.3 Surface Water

All significant surface and imported water delivered by the Aqueduct to the WDWA is utilized for agricultural irrigation, except for minor amounts diverted for industrial use, when available. The supplies sourced from the Aqueduct are primarily SWP water, along with some supplemental import water purchases, although not all supplemental water is from the SWP. Current annual surface water deliveries (i.e. all Aqueduct sources) are estimated at approximately 266,290 AFY. The C2VSim-Kern average annual Aqueduct deliveries to the WDWA for the WY 1995-2014 period are approximately 272,000 AFY. The C2VSim-Kern evapotranspiration of applied water (ETAW) for this period is 241,000 AFY, for a balance of 31,000 AFY potentially available for groundwater recharge. For comparison purposes, the C2VSim-Kern ETAW in 1989 was 287,000

AFY and in 2015 it was 257,000 AFY. **Figure 25** presents annual surface water deliveries to the combined WDWA.

### 2.7.4 Source and Point of Delivery of Imported Water Supply

The sources of imported surface water used for irrigation in the WDWA are the SWP and other supplemental surface water delivered via the Aqueduct to the member water districts of the WDWA. Member water-district infrastructure for delivery of Aqueduct water is detailed in their individual AWMPs, which are available on their respective websites.

#### 2.7.4.1 State Water Project (SWP)

Two types of contract water are available from the SWP, including a contract supply of "Table A Water", and surplus "Article 21 Water". Table A Water takes its name from an exhibit to the contract between the DWR and the SWP contracting agencies that serves as the basis for allocating surface water among the agencies. Due to a variety of factors, including hydrologic conditions, reservoir storage capacity, and projected runoff, the SWP cannot deliver full Table A Water allocations in most years. Accordingly, a percent allocation is set each year and is applied to each contractor's Table A Water amount. Deliveries to the WDWA from the SWP are via the California Aqueduct (GEI, 2019).

While the reliability of SWP water is less than was anticipated when the contracts were executed, a contract amendment, introduced in the Monterey Agreement of 1994, put agricultural and urban contractors on equal footing with respect to the allocation of water supply during shortages. Prior to the amendment, agricultural contractors were burdened with a larger share of any shortages (Amec, 2015; GEI, 2019).

Article 21 Water cannot be scheduled and must be taken when declared to be available. The following conditions govern the availability of Article 21 Water:

- Available only when deliveries do not interfere with Table A allocations and SWP operations;
- Available only when excess water is determined to be available by DWR;
- Available only when conveyance capacity is not being used for SWP purposes or scheduled SWP deliveries; and
- Cannot be stored within the SWP system. In other words, contractors must be able to use the Article 21 water directly or store it in their own system.

Article 21 Water is typically only available during the December through March wet months of the year (GEI, 2019). **Figures 27a** through **27c** present the infrastructure utilized for the delivery of import water to the three members of the WDWA. Average Article 21 deliveries to the combined WDWA member water districts over the period between 1995 and 2017 were approximately 23,878 AFY (KGA, 2019).

#### 2.7.4.2 Central Valley Project (CVP)

In 1973, DWR completed the initial facilities of the SWP, including the main line of the California Aqueduct. Portions of the SWP were constructed for use in conjunction with the facilities of the CVP. As the State and Federal projects developed, a group of water users planned the Cross Valley Canal as a means of taking delivery of CVP water conveyed through the California Aqueduct. The KCWA was formed in the 1960s to contract with the DWR for the importation of SWP water to Kern County. The California Aqueduct, the SWP's principal conveyance feature, transports water from the Delta along the western side of the San Joaquin Valley to the KCS. Individual water districts holding contracts with KCWA have turnouts directly from the Aqueduct into their service areas or receive water via the Cross Valley Canal. The Cross Valley Canal was completed in 1975 and, in 1976, the water users entered into three-party contracts with DWR and the Department of Reclamation. Under these contracts, CVP water available to Reclamation in the Sacramento River Delta can be pumped by the SWP's Harvey O. Banks Pumping Plant into the California Aqueduct for delivery to the Tupman turnout, where this water is diverted into the Cross Valley Canal. This Federal water conveyance, which is subordinate to conveyance of SWP water, can then be delivered to water users in the KCS (GEI, 2019).

### 2.7.5 Oil field Produced Water

There are currently 16 oil and gas fields or portions thereof in the WDWA (**Figure 26**). Productive oil and gas reservoirs (pools) include:

- Tulare Formation (Pleistocene);
- Etchegoin Formation (Pliocene);
- Monterey Formation (Miocene);
- Temblor Formation (Oligocene); and
- Kreyenhagen Formation (Eocene).

Oil field produced water in western Kern County typically contains entrained oil, elevated TDS, and other constituents. Because of this, oil field produced water is unsuitable for any beneficial use without extensive treatment. Produced water is managed by either recycling it for enhanced oil recovery (EOR) operations, such as steam/cyclic steam flooding or water flooding, or by exempted disposal in deeper zones. Both of these activities are under the regulatory oversight of the DOGGR and the US EPA. Produced water used for steam or water flood EOR is typically reinjected under permit into the same geologic zone from which it was produced (e.g., Tulare or Etchegoin Formations) to help maintain oil reservoir pressures and sweep residual oil towards planned oil extraction wells. During this process, a portion of the water that is recycled is inevitably lost to the geologic formations within the field or to the process of steam generation, etc. In addition, so called "*make up water*", from freshwater sources like the Aqueduct, may be added to the process depending on field conditions. Reinjection of produced water back into

the zone from which it was extracted potentially helps to mitigate the rate of local land subsidence. It is important to clarify that the type of EOR discussed here is not hydraulic fracturing.

Disposal of brackish and saline oil field produced water in Western Kern County has typically employed two methods: (1) evaporation ponds; or (2) reinjection into exempt aquifers identified for this purpose pursuant to regulations of the Federal UIC Program. The UIC is administered in California under the oversight of the DOGGR and the US EPA. Due to water quality concerns, many of the produced water disposal ponds in Kern County have been closed. Consequently, reinjection into exempt aquifers has become the primary method of produced water disposal. Aquifers identified for permitted disposal reinjection are by design isolated from nonexempt underground sources of drinking water. As with the EOR methods described above, disposal-well reinjection does not involve, nor is it in this case related to, hydraulic fracturing. As part of the aquifer exemption (AE) process, oil producers are required to complete a detailed geologic study of the zones selected for reinjection. When reviewing applications for AE permits, DOGGR consults with the SWRCB and/or the relevant RWQCB. A key requirement of this multi-agency review for AE approval is to ensure that oil field reinjection activities do not impact designated underground sources of drinking water.

In summary, a significant percentage of the oil field produced water in the WDWA is either recycled into the same geologic zones it was produced from for the purpose of EOR or is sequestered in deeper zones that are isolated from underground sources of drinking water. Like groundwater in the WDWA in general, produced oil field water is naturally degraded and exhibits elevated levels of TDS. The concentrations of TDS and crude oil residual in untreated produced water make it unsuitable for any beneficial use without treatment.

Oil field activities, including land subsidence associated with the extraction of oil and gas, are under the oversight of DOGGR, and are therefore outside the control of the WDWA. This element will be assessed further as part of the WDWA MNP and the KGA land subsidence monitoring plan. Data and findings will be reported during the first five-year reassessment period. **Table 1** provides a summary of produced water statistics for the selected oil and gas fields found within the WDWA.

### 2.7.6 Sustainable Yield

Unique to the WDWA is the fact that all sources of groundwater (e.g. underflow, recharge etc.) are eventually degraded due to the geology and are unsuitable for most uses. Therefore, the brackish groundwater is considered as "*outside*" the water balance unless blended or treated. As defined by SGMA, Sustainable Yield means the maximum quantity of water, calculated over a base period representative of long-term conditions in a basin, and including any temporary surplus; which can be withdrawn annually from a groundwater supply without causing an

undesirable result, such as a significant change in groundwater storage or impacts to water quality. The WDWA relies almost entirely on imported surface water to meet current and projected demand. Groundwater use in the WDWA is chiefly limited to blending because of the documented poor quality of WDWA groundwater. Current pumping is on the order of 3,000 AFY. A vast majority of the C2VSim-Kern-modeled change in groundwater storage for the WDWA is therefore not related to groundwater pumping. Instead it is due to brackish groundwater underflow moving downgradient out of the WDWA towards adjacent management areas generally to the north and east. This natural condition, which could potentially impact water quality in adjacent downgradient GMAs, is possibly being accelerated by pumping in adjacent downgradient GMAs and is beyond the control of the WDWA.

The WDWA normalized sustainable yield (i.e. Native Yield) for the purpose of the preliminary Brackish Water Checkbook approach discussed in **Section 2.7** is conservatively estimated to be 0.15 af/ac., multiplied by all WDWA acreage (i.e. 227,193 acres). This results in a volume of approximately 34,079 AFY. If the poor water quality, minimal levels of pumping in the WDWA, the volume of C2VSim-Kern-modeled underflow (~111,000 AFY) leaving the WDWA, and the potential treatment and potential reuse of oil field produced water are accounted for, a Native Yield range of 0.15 af/ac. to 0.30 af/ac. may be supportable. If applied, it would result in a potential Native Yield of 34,079 AFY to 68,158 AFY that could be utilized for blending or treatment for conjunctive reuse. This volume, depending on the amount of oilfield-produced water utilized, represents approximately 30%-60% of the current total C2VSim-Kern-modeled brackish groundwater underflow leaving the WDWA.

### 2.7.7 Groundwater Storage

The assessment of the quantity and extent of groundwater in the subsurface, and the amount of water that can be sustainably extracted for use, is dependent on the understanding and monitoring of a myriad of factors of a complex natural system; none of which can be determined with absolute certainty. This is because all of these systems are interrelated in some fashion, and most are transitory through time. As a result, the WDWA will use directly observable groundwater elevation data as a proxy for determining change in groundwater storage.

Key hydraulic properties used to define changes in storage of groundwater within the saturated parts of an unconfined aquifer system are specific yield and specific retention (irreducible storage). Specific yield and specific retention are functions of sediment porosity and moisture retention characteristics (Faunt et al., 2015; Todd, 2008). Specific yield plus specific retention is equal to sediment porosity. These two properties represent and govern the reversible uptake and release of water to and from storage in unconfined aquifers. In its simplest form, specific yield is a volumetric fraction of the bulk aquifer volume, representing the amount of water that

an aquifer yields when it drains under the force of gravity, the results of which are observable by changes in water table elevations. Storativity is defined as the amount of water an aquifer releases from, or takes into, storage per unit surface area of the aquifer per unit of change in head. In unconfined aquifers, storativity is equal to specific yield.

The availability of storage capacity changes with the amount of groundwater withdrawn or recharged. For unconfined aquifers, which comprise a majority of the well completions in the WDWA, a change in storage is expressed as the product of the volume of the aquifer lying between the water table (i.e., groundwater elevation) at the beginning and end of a period of time and the average specific yield of the formation (Todd, 2008). Based on the current preliminary KGA model, the average WDWA groundwater-in-storage during the WY 1995-2014 period is estimated to be 42,400,000 AF. One acre-foot is equivalent to approximately 325,851 US gallons of water.

### 2.7.8 Water Budget Baseline and Projected Conditions

As previously noted, there is a general lack of representative water budget data available for the WDWA, including changes in groundwater storage. This condition will be remedied by implementation of the MNP discussed in **Section 4.0**. The MNP will collect representative groundwater elevation data for the purpose of, among other things, assessing for lowering of groundwater levels, calculation of changes in groundwater storage and monitoring for land subsidence. The WDWA water budget will be assessed and revised during the first five-year reassessment period as additional representative data become available. For the purpose of this initial submittal, the WDWA is relying on the Brackish Water Checkbook approach to estimate total water supply and demand **(Section 2.7.2.1).** Additionally, the Brackish Water Checkbook and C2VSim-Kern model are being used as a framework for revising the water budget components based on data collected in the coming years. Because of the reliance on Aqueduct water as the primary source of irrigation, the historic use of groundwater has been primarily for blending due to high levels of TDS. Assuming projected climate change estimates are realized, it is likely that projected water budget components over the GSP implementation period of 2040 and beyond will change and evolve as will groundwater and land use management practices. It is expected that pumping volumes for the purpose of blending would increase to approximately 5,400 AFY by 2030 and beyond, up from the current 3,000 AFY.

## 2.8 Existing/Ongoing Water Resources Programs/Policies

Knowledge of existing and ongoing water resource programs and a close working relationship with the respective lead agencies are key to successful groundwater sustainability planning and management. The sections below discuss some of the key programs utilized to help coordinate data between the various KGA Chapter GSPs.

### 2.8.1 Existing Monitoring Programs

Various public agencies currently collect and coordinate groundwater monitoring data for wells within the KCS. Based on current conditions, these programs and proposed MNP monitoring activities will not limit the operational flexibility in the WDWA. Where applicable, several databases were utilized to prepare the Basin Setting and other sections of this Chapter GSP for the WDWA. Chief among these are the following:

#### 2.8.1.1 Local Agency Monitoring Programs

Within the WDWA, there are two local groundwater monitoring programs. As reported elsewhere in this Chapter GSP, those agencies are the KCWA, which manages and maintains the CASGEM Program, and the WWQC, which includes the WDWA. The WWQC began an annual groundwater monitoring program in 2018. These programs will be used as the primary basis of the WDWA MNP described in more detail in **Section 4.0** of this Chapter GSP.

#### 2.8.1.2 Groundwater Ambient Monitoring and Assessment Program (GAMA)

GAMA was implemented in 2000 by the SWRCB to integrate existing groundwater monitoring programs in order to better assess and monitor groundwater quality. The GAMA Basin Priority Project assessed public water system wells to identify and understand risks to drinking water supply. Historically, the program has sampled over 2,900 public and domestic drinking water supply wells. Relevant data from this program will be utilized to compare with the future MNP data for this Chapter GSP in order to quantify and interpret historic and contemporary groundwater level and quality trends.

#### 2.8.1.3 GeoTracker and EnviroStor Databases

GeoTracker is a SWRCB database which allows the agency to manage and share data related to sites that currently impact groundwater or have the ability to adversely impact groundwater resources. Data available on GeoTracker include records of Leaking Underground Storage Tank (LUST) sites, Department of Defense sites, and various permitted activities such as land disposal sites, and oil and gas production sites. GeoTracker is unique in that it collects data from multiple agencies, making it very useful.

The EnviroStor database is managed by the DTSC. EnviroStor provides records of site cleanup activities beginning in 2009 or later. EnviroStor only maintains records of sites where the DTSC is the lead agency and is typically focused on soil cleanups, many of which could have impacted groundwater as a secondary condition. Both GeoTracker and EnviroStor were utilized to assess for potential anthropogenic impacts to groundwater in the WDWA.

#### 2.8.1.4 California Statewide Groundwater Elevation Monitoring Program (CASGEM)

The CASGEM program was created by the State legislature as part of the 2009 California Comprehensive Water Package, which established a coordinated statewide program to collect groundwater elevations and facilitate cooperation between local monitoring agencies and the DWR. The CASGEM database was utilized to search for representative groundwater level and well completion data within the WDWA.

#### 2.8.1.5 Irrigated Lands Regulatory Program (ILRP)

The goal of the ILRP is to protect receiving waters (natural surface waters) from impairment associated with agricultural runoff, tile drain flows, and stormwater flows from irrigated crops and fields. To augment existing surface water data collected by the program, the ILRP was to have started collecting groundwater data beginning in late 2018. The focus of the groundwater sampling will be to assess water quality related to individual domestic wells. The WWQC, of which the WDWA is a member, has been cooperating with ILRP surface water sampling efforts since its inception in 2003. While the number of individual domestic wells within the WDWA is believed to be limited, the requirements and goals of the ILRP will be considered in **Section 4.0**.

#### 2.8.1.6 Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS)

CV-SALTS is a stakeholder-managed program whose main objective is to facilitate salt and nitrate management and reduction strategies in the Valley. The objectives and goals of the CV-SALTS program are foundational to those of SGMA and the KCS GSP. Key CV-SALTS goals are:

- Ensure safe drinking water supply;
- Achieve balanced salt and nitrate loading of surface water and groundwater; and
- Implement the long-term restoration and management of impaired water bodies.

Sampling, when required, is conducted in association with explicit WDRs specified by the State and relevant RWQCBs. These typically include, among other things, sampling for chloride, sodium, nitrate/nitrite, and EC. As mentioned, because of the naturally occurring elevated levels of TDS found throughout the WDWA, the WWQC has engaged the CV-SALTS Technical Committee to review its recent draft BPAW prior to submittal to the State. The subject plan recommends the de-listing of MUN and AGR as beneficial uses for perched and unconfined/semi-confined groundwater found beneath a portion of the WDWA. The WDWA plans to coordinate the Chapter GSP MNP with the ongoing sampling activities being conducted by the WWQC to support the BPAW.

### 2.8.2 Monitoring Data Gaps and Uncertainty

A coordinated (and standardized) database and calibrated groundwater numerical flow model is necessary to ensure that all relevant data is input in a timely manner for the purpose of ongoing

sustainability planning. Planning discussions within the KGA at large regarding this topic are ongoing. To achieve coordinated monitoring, data must be collected and reported by local well owners in a systematic way on contemporaneous schedules. To the extent feasible and practical, until a KCS-wide data system is identified, components of the above referenced existing programs and databases will be utilized to help address identified data gaps. It is not anticipated that these plans will significantly limit the flexibility of operations in the WDWA as they will be implemented in cooperation with well owners, adjacent groundwater management areas, existing programs such as the WWQC, and established water banking operations being utilized by the WDWA and its member landowners. Minimum sampling parameters include:

- Groundwater elevation;
- Annual extraction (pumping) volumes; and
- Groundwater quality.

These data, along with surface water supply volumes provided by the WDWA members, will be utilized to assess identified data gaps, and the potential for undesirable results in order to update WDWA water budget components, including precipitation, ETo, sustainable yield and groundwater storage. It is important to note that per SGMA requirements, water budgets must include current, historic, and future conditions. Projected water budgets will be used to estimate and refine future conditions of supply, demand in response to Umbrella GSP implementation, and to identify any new or evolving data gaps or uncertainties pertaining to these water budget components.

Within the WDWA, existing monitoring for representative groundwater occurrence and elevation levels is recognized as a key data gap. A WDWA-specific MNP will be designed to address, to the extent feasible, uncertainties that would affect the efficacy of the implementation of the KGA Plan and, therefore, the WDWA's ability to assess whether the WDWA is being managed sustainably. Identified data gaps within the WDWA management area are:

- Representative groundwater occurrence, groundwater elevations, groundwater trends, groundwater quality and flow directions, and annual extraction volumes; and
- WDWA-specific water budget components and modeling.

## 2.9 Plans to Address Identified Data Gaps

Preparation and implementation of a comprehensive MNP will directly address the identified data gaps by coordinating a systematic and contemporaneous collection of representative groundwater monitoring and pumping data in consultation with adjacent GMAs. The data will be utilized to update water budget and model components.

## 2.10 Groundwater Management Area

For the purpose of this Chapter GSP, the WDWA is considered a single combined GMA. Within the WDWA there is one management area and two defined groundwater Watch Areas. Watch Areas have no significant current or planned groundwater use (e.g., non-cultivated land, range land, oil fields etc.) Watch Areas will be monitored for land use changes and groundwater conditions that could change its designation to a "management area" with specified SMCs.

The rationale for this approach is threefold:

1. The similar hydrogeologic conditions found across the WDWA and the occurrence of poor-quality brackish groundwater identified throughout the WDWA;

2. The ability to cost effectively leverage and better coordinate future monitoring and adaptive management actions due to the similarities of organizational structure among the WDWA member Districts, as well as similar groundwater use (primarily blending) by stakeholders that are served by the WDWA; and

3. The ability to streamline communications, coordination, and planning of sustainability objectives and management actions between the WDWA and adjacent KGA GMAs that are implementing their individual Chapter GSPs.

As designated, the WDWA sentry areas will operate under a set of MTs and MOs which, while focused on the WDWA, are also designed to coordinate, to the extent feasible, with adjacent GMAs. As part of the SGMA-required annual update and five-year reassessment process, the status of the WDWA GMA will be re-evaluated and adjusted, as needed. In the unlikely event of internal conflicts between individual member districts of the WDWA, the WDWA Board will consider and resolve the item pursuant to its established rules.

## 2.11 WDWA Sustainability Goals

The Sustainability goals of the Subbasin, which are fundamental to the specific goals of the WDWA, are:

- Collectively bring the Subbasin into sustainability and to maintain sustainability over the implementation and planning horizon and beyond
- Achieve sustainable groundwater management in the Kern County Subbasin through the implementation of projects and management actions at the member agency level of each GSA
- Maintain its groundwater use within the sustainable yield of the basin as demonstrated by monitoring and reporting groundwater conditions

- Operate within the established sustainable management area criteria, which are based on the collective technical information presented in the GSPs in the Subbasin
- Protect beneficial uses for municipal and domestic drinking water supply wells

Sustainable management in the KCS will result from the implementation of projects and management actions at the member-agency level to maintain its respective use of groundwater within the sustainable yield of the Subbasin, operate at or above established measurable objectives, and operate above established minimum thresholds. The sustainable yield, measurable objectives, and minimum thresholds have been developed based on available technical information and will be reviewed and updated as additional data are collected, as required by SGMA.

Sustainability goals for the WDWA are designed to support and coordinate with the goals proposed in the KGA umbrella GSP, address identified and projected issues and hydrogeologic data gaps, and mitigate the potential for undesirable results within the WDWA. The goals will be achieved through the implementation of coordinated MTs and MOs, and specific administrative policies, projects, and plans designed to enhance the sustainability of groundwater resources within the WDWA, and by association the KGA at large. It is not anticipated that County land use plans, as currently formulated, will affect the ability of WDWA to achieve its planned sustainability goals, nor will WDWA activities, as part of the GSP, adversely affect County land use planning. The coordination process established in development of the KGA Umbrella GSP and memorialized in the KCS Coordination Agreement will ensure that the KCS is managed as a cohesive unit, and that the individual GMAs within the KCS work collaboratively towards sustainability.

The sustainability goals for the WDWA are:

- Collect additional representative hydrogeologic information to more fully characterize and model the occurrence, condition, and elevation of groundwater beneath the WDWA through the implementation of a comprehensive MNP;
- Leverage, to the extent feasible, the harvesting and treatment of naturally degraded groundwater underflow leaving the WDWA for the twin benefits of conjunctive reuse and mitigation of potential adverse effects to better quality water in adjacent downgradient districts; and
- Mitigate and avoid the potential for the chronic lowering of groundwater levels and significant reduction of groundwater in storage through the coordinated implementation of minimum thresholds (MTs) and MOs within WDWA areas that are adjacent to other downgradient GMAs.

## 2.12 WDWA Undesirable Results

Based on the current understanding of available WDWA data, an assessment of the six undesirable results identified in SGMA found that two of these do not directly apply to the WDWA. These being:

- Seawater intrusion; and
- Depletion of interconnected surface water.

Of the remaining four, further assessment is provided in the following subsections. The four potential undesirable results are:

- Chronic lowering of groundwater levels;
- Significant reduction of groundwater in storage;
- Degraded water quality; and
- Land subsidence.

### 2.12.1 Seawater Intrusion

The WDWA is located more than 40 miles inland from the Pacific Ocean. Seawater intrusion to aquifers is not feasible, and will not affect groundwater quality within the WDWA, which is naturally brackish. Therefore, seawater intrusion is not considered further in this Chapter GSP.

### 2.12.2 Depletion of Interconnected Surface Water

Interconnected surface water systems are defined by the State as surface waters that are known to be hydraulically connected by a "*…continuous saturated zone*" to an underlying aquifer (DWR, 2016). As such, there are no interconnected natural surface water systems in monitored areas associated within the WDWA. Various small creeks and drainages within the WDWA are ephemeral and only carry water for brief times during the wet season, usually only immediately after intense precipitation events. The dryland portion of the KNWR that overlaps with the WDWA is not irrigated and relies on seasonal precipitation for habitat maintenance. The scant volume of annual precipitation, and high level of ETo in the WDWA, militates against the likelihood of interconnected surface water systems. Further, recent WWQC monitoring activities have found that the presence of perched groundwater in the WDWA is greatly reduced and sporadic. As such, depletion of interconnected natural surface water and associated groundwater dependent ecosystems are not considered a recognized or feasible undesirable result. Therefore, no MTs or MOs will be established at this time. Further assessment will be conducted as part of the proposed monitoring Network Plan. Any changes in this finding will be reported in the relevant GSP update report.

### 2.12.3 Chronic Lowering of Groundwater Levels

The following terms and concepts, which are consistent and coordinated with those of the KCS at large, are applicable to the WDWA. If specific conditions change over time the WDWA will remain coordinated with Subbasin goals and objectives, as well as those of adjacent districts. Please see the KGA Umbrella Report for additional details.

***Management Area:*** Management Areas are areas that will be considered against the determination of an undesirable result at the basin level.

***Watch Areas:*** Areas with no significant groundwater use and no planned groundwater use as documented in the management area plan. Watch Areas will be monitored for land use changes and groundwater conditions that could change its designation to a "management area" with specified SMCs.

***Monitoring Areas:*** Areas that have significance within a Management Area for monitoring groundwater conditions or impacts to certain beneficial users but are not considered towards the determination of an Undesirable Result.

***MT Exceedance:*** *Where a single representative monitoring well exceeds its minimum threshold.*

***MT Trigger:*** *A management area exceedance is triggered when groundwater levels decline below established MTs in 40% or more of any representative monitoring wells within the management area over four consecutive bi-annual SGMA required monitoring events .*

***Management Area Exceedance****: Occurs when a management area exceeds minimum thresholds at 40% or more of representative monitor wells within a given management area over four consecutive bi-annual SGMA monitoring events, referred to as the MT Trigger. Once a management area triggers the Management Area Exceedance, the management area will be counted towards calculation of an undesirable result for the entire Subbasin.*

**Undesirable Result:** The basin-wide definition of unreasonable impacts to beneficial uses and users of groundwater. A Subbasin undesirable result is defined as the geographic extent of minimum threshold exceedances across the entire Subbasin, measured by the accumulation of management area exceedances. The equivalent designation at the management area is a “Management Area Exceedance.”

The KGA has developed sustainable management criteria that meets SGMA requirements and enhances the process by including additional steps to better manage operational and demographic conditions found across the Kern Subbasin. The WDWA has adopted the KGA process.

The KGA process is proactive in identifying and managing the occurrence of undesirable results to the beneficial users identified in each management area of the Subbasin. The complexity of the Subbasin required that the KGA and other Subbasin GSAs coordinate this process in order to recognize and account for the SGMA related beneficial use and hydrogeologic diversity found across the Subbasin. The core of this process is the identification of key beneficial users within each management area and the conditions that create significant and unreasonable impacts to those beneficial users from groundwater operations in a particular management area. This enhanced process incorporates the following steps:

- Sustainability Goal (SGMA Requirement) – Developed as a Subbasin wide goal for achieving conditions of sustainability that recognizes the diversity of the Subbasin. Due to this diversity in addition to the Subbasin goals each management area could elect to develop a supportive Sustainability Goal that specifies the objectives and desired conditions for sustainability within a management area and the protection of beneficial users and uses within that management area.

- Minimum Threshold Exceedances (KGA Enhancement) – Establishes a process for identifying and addressing a single minimum threshold exceedance to proactively manage potential degradation of groundwater conditions and impacts to beneficial users. This is facilitated through the KGA Exceedance Policy. The Exceedance Policy focuses on an area surrounding the exceedance to proactively identify and address the causes of the exceedance, thus attempting to limit to the potential of an entire management area exceedance (next step in the process). Although this is a KGA-specific policy, the KGA members have committed to also work with other surrounding GSAs to explore the cause and to find solutions that limit further impacts to beneficial users and uses.

- Management Area Exceedance (KGA Enhancement) – Establishes the first trigger towards an undesirable result, defining the condition by which the management area could likely contribute to an undesirable result. It also establishes a process for the Subbasin entities to collaborate on corrective measures to address further degradation of groundwater conditions and potential impacts to beneficial users. This proactive approach allows the KGA to collaboratively work amongst KGA members and other GSAs in the Subbasin to identify and address causes of degrading groundwater conditions to prevent the reaching an Subbasin-wide undesirable result.

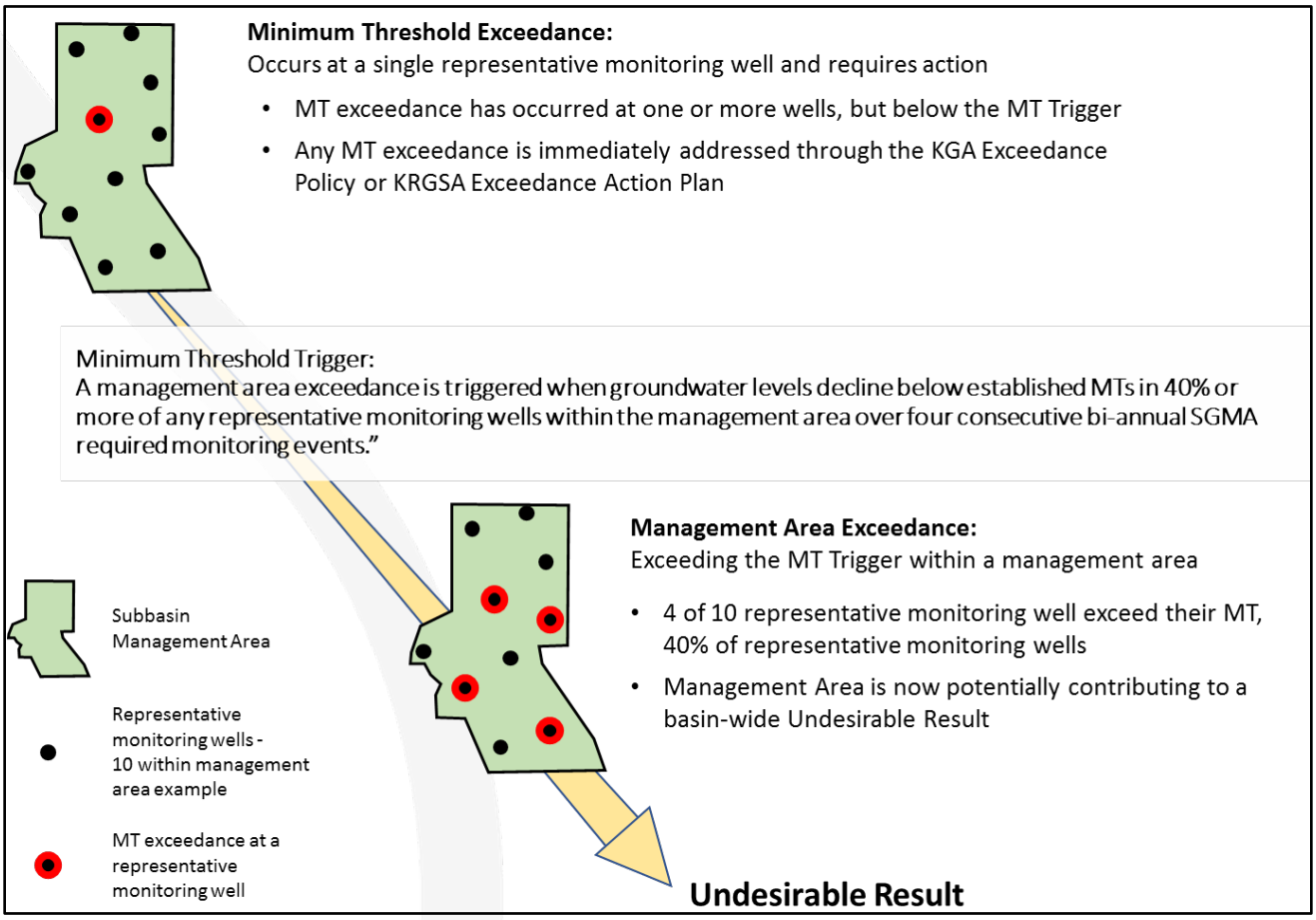
- Undesirable Results (SGMA Requirement) – In the Kern Subbasin an undesirable result is defined as the geographic extent of minimum threshold exceedances across the entire Subbasin, measured by the accumulation of management area exceedances.

- Minimum Thresholds (SGMA Requirement) – Minimum thresholds have been set at each representative monitoring well as the point at which impacts to beneficial uses and users become significant and unreasonable and that cannot be mitigated. Minimum thresholds are collaboratively set with all Subbasin GSAs and are set within each management area with the overlying managing entity to ensure that the diversity of geographic conditions and distribution of beneficial users are considered and represented.

- Measurable Objectives (SGMA Requirement) – Similar to the minimum thresholds, the measurable objectives have been set at each representative monitoring well to represent a condition of sustainability. All KGA members, including the WDWA, have agreed and have management actions to operate their respective management areas at or above their measurable objectives.

An undesirable result is a condition that occurs throughout the Subbasin, demonstrating that the Subbasin is not sustainably managing groundwater conditions in the aggregate and that impacts to beneficial users are occurring on a scale (spatially and temporally) that is significant and unreasonable to beneficial users and groundwater managers alike. However, the KGA and other GSAs of the Subbasin, recognize that as groundwater approaches an undesirable result conditions, exceedances of minimum thresholds will likely progressively occur in the absence of intervention, beginning with isolated exceedances which could impact beneficial users. A proactive approach to identifying and working with management areas to address these conditions will help address and mitigate degrading groundwater conditions. This approach, referred to as the 40/4 Method, is illustrated in **Insert 20** and is described more fully below.

**Insert 20: KCS 40/4 Method**




Within the Subbasin a Management Area Exceedance occurs when a management area exceeds minimum thresholds at 40% or more of representative monitoring wells (RMWs) within a management area over four consecutive bi-annual SGMA monitoring events, referred to as the Minimum Threshold Trigger. Once a management area triggers the Management Area Exceedance, the management area will be counted towards the calculation of an undesirable result for the entire Subbasin.

Defining the point of a Subbasin level undesirable result begins with a defined level of significant and unreasonable impacts over the GSP implementation horizon, as determined by the depth/elevation of water, which affects the reasonable and beneficial use of, and access to, groundwater by overlying users. In the KGA, the accumulation of impacts to beneficial users throughout the Subbasin, and across multiple management areas, representing a persistent and prevalent occurrence of impacts to beneficial users is considered an undesirable result. An undesirable result on the Subbasin level is when the MT for groundwater levels are exceeded by at least three adjacent management areas that collectively represent at least 15% of the

Subbasin or, if non-contiguous management areas, comprising 30% or more of the Subbasin, as measured by the acreage of each management area that exceed their respective MTs (GEI/KGA, 2019).

A key objective of monitoring for chronic lowering of groundwater levels is to prevent dewatering of beneficial user wells. Based on KGA well inventory information there are two designated domestic wells in the WDWA and a total of 35 industry/agricultural wells. There are no municipal wells. The "domestic wells" are believed to be used for periodic livestock watering. The status of these two wells will be updated as part of a planned Project Management Action No. 1 (see **Section 5.1**). There are no dewatered beneficial user wells within the WDWA, and none are anticipated based on current MTs/MOs. The use of mitigation plans to ameliorate and avoid dewatering has been coordinated in the KGA. Any management area with 5% of Municipal/Domestic wells dewatered is required to prepare a mitigation plan. In the unlikely event of future dewatering of a domestic or municipal well, WDWA will prepare a mitigation plan to address this condition in the management area. **Insert 21** provides a KGA summary of Municipal (M), Agricultural (A) and Domestic (D) wells. The WDWA has identified potential discrepancies in some databases regarding the number and status (use) of wells in its member districts. The WDWA plans to conduct an updated well inventory in Fall 2022.

**INSERT 21: KGA Well Summary**

| | Number of Wells | | | | Number of Dewatered Wells | | | |
|---|---|---|---|---|---|---|---|---|
| | M | D | A | % M/D Wells | M | D | A | % M/D Wells |
| CWD | 0 | 80 | 186 | 30% | 0 | 3 | 2 | 4% |
| NK | 0 | 21 | 158 | 12% | 0 | 3 | 3 | 14% |
| KTWD | 0 | 18 | 94 | 16% | 0 | 0 | 0 | 0% |
| RRB | 24 | 149 | 156 | 53% | 0 | 21 | 0 | 12% |
| SWID | 16 | 68 | 118 | 42% | 0 | 22 | 14 | 26% |
| SSJMUD | 19 | 67 | 243 | 26% | 0 | 29 | 25 | 34% |
| SWSD | 4 | 138 | 763 | 16% | 0 | 41 | 52 | 29% |
| WDWA | 0 | 2 | 35 | 5% | 0 | 0 | 0 | 0% |
| 7th Standard | 2 | 9 | 19 | 37% | 0 | 5 | 2 | 45% |
| **Total** | **65** | **552** | **1772** | **26%** | **0** | **124** | **98** | **20%** |

These coordinated criteria were developed to recognize early on any condition of widespread degradation of groundwater conditions (including dewatering) across the whole of the Subbasin, which encompasses a diverse range of operational, hydrogeologic and land use activities. The WDWA will use coordinated and consistent data and methodologies (e.g., the 40%/4 method

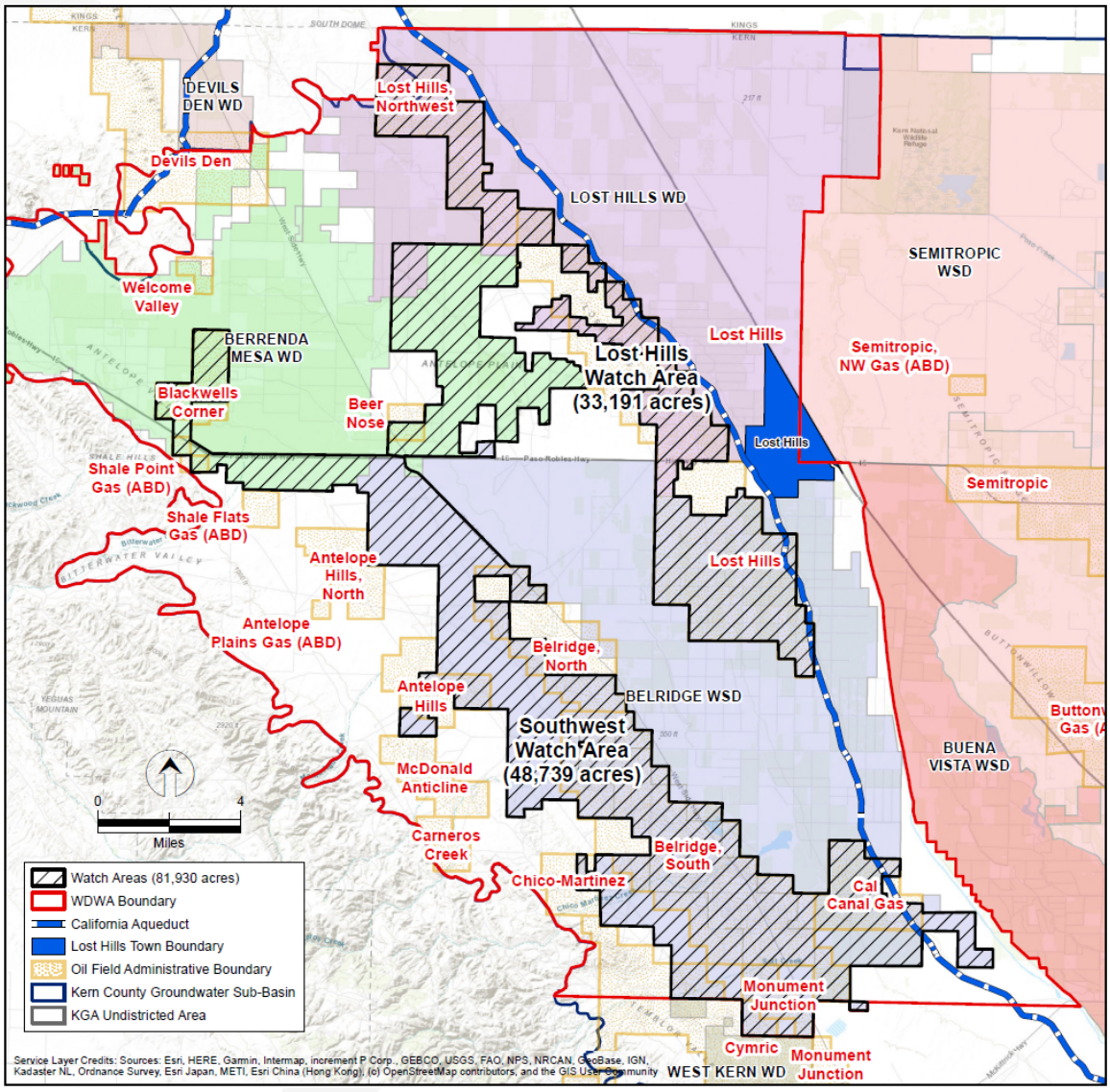
and sentry RMWs) for assessing groundwater level sustainable management criteria in designated management areas.

Because groundwater pumping has historically been limited, groundwater levels in the WDWA are being reduced primarily by the modeled volume of underflow migrating downgradient towards the axis of the basin. SGMA related extractions by pumping (and thus the number of wells) has been limited due to the demonstrated naturally degraded quality of groundwater. Due to the limited number of representative wells there is presently a lack of reliable data in the WDWA sufficient to assess for potential chronic lowering of groundwater elevations with a high level of certainty, especially along the downgradient eastern border of the WDWA. A review of currently available data, including, but not limited to, various recorded WDWA well pumping volumes and the individual AWMP reports for the WDWA, indicate there has been little historic reliance on groundwater for the purpose of irrigation in the WDWA due to the availability of Aqueduct and other imported surface water.

The current estimated annual volume of SGMA related pumping for irrigation is less than 2% of total demand (i.e., ~3,000 AFY). Of further relevance, the C2VSim-Kern modeled water budget for the WDWA has identified approximately 111,000 AFY of brackish groundwater underflow migrating from the WDWA towards adjacent downgradient GMAs. The WDWA is studying the feasibility of a project management action to harvest a portion of the lost underflow by focused pumping for advanced treatment and conjunctive reuse. If determined to be viable, this project could substantially increase the quality and quantity of groundwater retained in the WDWA water budget. In the interim, while MNP data are being collected and the C2VSim-Kern model is refined and calibrated, the WDWA proposes to utilize representative groundwater well hydrographs to determine historic and projected groundwater trends along its eastern boundary. These data will also be used to establish provisional informational MOs and MTs for the area of the WDWA directly adjacent to the aforementioned down-gradient GMAs (i.e., Sentry Zones) The MTs are set above historic groundwater level lows. Additional existing wells to assess groundwater levels in the WDWA interior management area are being assessed for approval by the KGA. Based on the limited pumping in the WDWA, there are no MTs or MOs proposed for groundwater elevation for the remaining Watch Areas interior to the WDWA at this time. These interior Watch Areas are defined to as having no significant current or planned groundwater use (e.g., non-irrigated land, lands under regulatory review for basin plan amendment, range land, oil fields etc.) Watch Areas will be monitored for land use changes and groundwater conditions that could change its designation to a "management area" with specified SMCs. This approach allows for sentry monitoring along the WDWA's downgradient northern and eastern borders with the objective of sustainable management via the harvesting and treatment of a portion of the groundwater underflow as it leaves the WDWA. If reuse is determined to be feasible, it will significantly reduce the potential for an undesirable result

related to the accelerated chronic lowering of groundwater levels WDWA and significant reduction of groundwater in storage. **Insert 22** provides a figure showing the WDWA groundwater Watch Areas.

**INSERT 22: WDWA Groundwater Watch Areas**




### 2.12.3.1 Groundwater Dependent Ecosystems

The following factors weigh against the presence of groundwater dependent ecosystems in the WDWA:

- The sporadic occurrence and further diminution of the already limited amount of perched water in the WDWA due to drought, physiographic and hydrogeologic conditions and less agricultural surface runoff as a result of improved irrigation and water conservation methods;
- The overall general depth to the unconfined/semiconfined groundwater zone (~200 feet bgs);
- The lack of interconnected surface water systems in the WDWA; and
- The predominately brackish quality of groundwater.

As stated elsewhere in this Chapter GSP a small portion of the WDWA in the LHWD overlaps with the Kern National Wildlife Refuge. These lands are designated as "Uplands Habitat". As such, the area is dry rangeland and, with no operating wells, relies solely on precipitation for its only source of water. To the south, in the Belridge WSD, are portions of the 3,100 acre Lokern Ecological Reserve (LER). Within the WDWA the LER consists of small, scattered and generally non-contiguous parcels (**Figure 10c**). A review of Google Earth imagery shows those portions of the LER in the WDWA are likely Valley sink scrub, and/or Valley saltbrush scrub habitat (aka Alkali Scrub). Those portions of the LER in the WDWA appear to consist entirely of dry, non-irrigated scrub lands that, with no operational wells, rely on annual precipitation as its source of water.

Larger, more contiguous blocks of the LER are present further south of the WDWA roughly between the towns of Lokern and Tubman. The California Department of Fish and Wildlife website describes the LER at large as consisting of marsh, valley sink scrub, and valley saltbush scrub habitat. Although not likely present in the WDWA, vegetation in the marsh habitat includes tule, cattail and other common marsh species.

Further assessment of these areas will be conducted as part of the proposed monitoring Network Plan. Any change to current conditions regarding groundwater dependent ecosystems in the WDWA will be discussed in the relevant annual updates and five-year reassessment reports as required by SGMA. In the meantime, impacts to groundwater dependent ecosystems will not be evaluated further, and no MTs or MOs are warranted at this time. **Figures 27d through 27f** provide the additional supporting information pertaining to groundwater dependent ecosystems in the KCS.

### 2.12.4 Significant Reduction of Groundwater in Storage

Change in groundwater in storage cannot be measured directly. In its simplest form, a change in groundwater in storage is reflected by a change in groundwater elevations. A significant reduction in groundwater storage is the point at which significant and unreasonable impacts, as determined by the estimated amount of groundwater in the subbasin, affect the reasonable and

beneficial use of, and access to, groundwater by overlying users over an extended drought period, which is proposed to be 10 years for the purpose of the KGA GSP. Within the KGA, an undesirable result is determined when groundwater elevations, which act as the proxy for groundwater storage, are depleted to elevations lower than the respective groundwater-level MTs in at least three adjacent management areas that collectively represent at least 15% of the Subbasin or, if non-contiguous GMAs, comprising 30% or more of the Subbasin, as measured by the acreage of each management area that exceed their respective MTs (GEI/KGA, 2019).

The current KGA C2VSim-Kern simulated water budget for the WDWA indicates that changes in groundwater storage in the WDWA management area are largely attributable to non-pumping activities, such as the downgradient underflow of brackish groundwater from the WDWA towards adjacent GMAs and the axis of the KCS. As such, this natural condition, which may be accelerated by pumping in adjacent downgradient GMAs, is beyond the control of the WDWA. As described in **Section 2.11**, additional groundwater elevation data and numerical modeling is required, especially along the WDWA's downgradient eastern and northern borders, in order to fully assess this important hydrologic parameter with a high level of certainty. Data gaps related to groundwater elevation (a proxy for change in storage) will be addressed by the collection of representative groundwater elevation data during the first five-year reassessment period. In the interim, the MTs and MOs for this component will be assessed as presented in **Section 4.0**.

### 2.12.5 Degraded Water Quality

Degraded groundwater quality is defined in SGMA as the point at which significant and unreasonable impacts occur over the GSP 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. In the KGA, this is determined when the MT for a groundwater quality constituent of concern is exceeded in at least three adjacent management areas that collectively represent at least 15% of the subbasin or, if non-contiguous GMAs, comprising 30% or more of the subbasin, as measured by the acreage of each management area exceed their respective MTs (KGA, 2019).

Due to the overall naturally degraded quality of WDWA groundwater, as documented by the various groundwater studies presented in this Chapter GSP, no water quality MTs or MOs are proposed for the selected interior areas (i.e., non-management areas) west of the California Aqueduct in the WDWA at this time. These areas are designated Watch Areas with no current or planned significant SGMA related pumping (e.g., non-irrigated land, lands under regulatory review for basin plan amendment, range land, oil fields etc.) . Watch Areas will be monitored for land use changes and groundwater conditions that could change its designation to a "management area" with specified SMCs.

Groundwater within the WDWA has been documented to be predominately degraded by elevated concentrations of TDS due primarily to the presence of naturally occurring basin-fill sediments derived from marine dispositional environments and associated saline connate waters. These conditions have been documented to exist before widespread development of the west side of the KCS and are outside the control of the WDWA. Because of the poor quality water, agriculture within the WDWA relies primarily on surface water and other imported water provided by the Aqueduct for irrigation. Historically, the primary use of brackish groundwater has been for blending when deliveries of surface water from the Aqueduct are low. Groundwater with TDS concentrations in excess of 2,000 mg/L, which is common in the WDWA, is considered unsuitable for designated beneficial uses without blending or treatment. Because of the presence of naturally occurring brackish groundwater beneath a majority of the WDWA, the WWQC has prepared a BPAW for regulatory review that recommends delisting the designated agriculture and municipal beneficial use for perched and unconfined/semiconfined groundwater under a significant portion of the WDWA.

The current KGA C2VSim-Kern model water budget for the WDWA estimates there is a significant volume of combined natural downgradient groundwater underflow (~111,000 AFY) migrating from the WDWA towards adjacent down-gradient GMAs and the axis of the KCS. This underflow is predominantly brackish. This condition, which may be accelerated by groundwater pumping in adjacent downgradient GMAs, is beyond the control of the WDWA. The downgradient migration of brackish groundwater has the potential to cause an undesirable result by impacting better quality groundwater found in adjacent downgradient GMAs. Therefore, assessment of groundwater quality within the WDWA will focus on sentry monitoring of the boundary between the WDWA and potentially affected down-gradient GMAs to the northeast, east and southeast in the KCS. The purpose of the sentry monitoring will be to provide timely notification to adjacent GMAs in the event that existing water quality related to TDS concentrations changes significantly. Sentry monitoring will be implemented for groundwater quality along the boundary area that lies generally east of the California Aqueduct in the WDWA. The sentry monitoring activities will be detailed in the MNP and will be coordinated with the relevant adjacent GMAs.

As part of GSP implementation groundwater quality will be assessed in any new wells drilled in the interior management area of WDWA to help inform planning and implementation of future sustainable management practices and projects.

### 2.12.6 Land Subsidence

The Sustainable Groundwater Management Act (SGMA) identified land subsidence as an undesirable result and the DWR review of the KGA GSP placed subsidence as one of the deficiencies (i.e., Deficiency 3) to be further described and addressed. Additionally, the DWR

Incomplete Determination letter of January 28, 2022, specifically referenced subsidence in the WDWA and suggested it was linked to chronic lowering of groundwater levels. Data obtained subsequent to the 2020 KGA GSP submittal shows that the subject subsidence in the WDWA is more likely related to oil field activities, and not SGM related beneficial uses of groundwater or chronic lowering of groundwater levels by the WDWA. Groundwater use in the WDWA is limited. Oil field activities are extensive throughout the entire west side of the KCS. The KGA and WDWA do not have control over oil field activities.

In response to DWR Deficiency 3, the KCS has developed coordinated definitions for Subsidence Undesirable Results and Critical Infrastructure. The WDWA has incorporated these definitions into its planning. The Kern Subbasin coordinated definitions are:

**Undesirable Results – Land Subsidence**

An undesirable result for land subsidence is defined as the point at which the amount of inelastic subsidence, if caused by Subbasin SGMA related groundwater extractions, creates a significant and unreasonable impact to surface land uses or Subbasin critical infrastructure. The definitions are designed to be a foundation for Subbasin-wide monitoring and coordination while simultaneously providing the for flexibility and autonomy in assessing localized subsidence.

**Critical Infrastructure – Land Subsidence**

Because the causes of subsidence in the Subbasin are complex the Subbasin has adopted two classifications for critical infrastructure: *Regional Critical Infrastructure* and *Management Area Critical Infrastructure*.

- *Regional Critical Infrastructure* is defined as infrastructure located within the Subbasin that serves multiple areas of the Subbasin and whose loss of significant functionality due to inelastic subsidence, if caused by Subbasin (i.e.,SGMA related) groundwater extractions, would have significant impacts to beneficial users. The Subbasin has collectively determined that the only infrastructure that meets the definition for Regional Critical Infrastructure are the California Aqueduct and the Friant-Kern Canal.

- *Management Area Critical Infrastructure* is defined as infrastructure located within a particular Subbasin Management Area whose loss of significant functionality due to inelastic subsidence, if caused by Subbasin (i.e., SGMA related) groundwater extractions, would have significant impacts to beneficial users within that Subbasin Management Area. Each Subbasin Management Area has identified their respective Management Area Critical Infrastructure in their Management Area Plan or individual GSP.

In the WDWA, critical infrastructure includes portions of the Aqueduct and two north south trending oil and gas pipelines. Both the Aqueduct and the two management area pipelines are subject to oil field-related activities over which the KGA or WDWA have no control. Further, the pipelines also pass beneath areas where there is little or no SGMA-related groundwater extraction by the WDWA (i.e., they are in defined groundwater Watch Areas, see **Section 4.0**). The WDWA will monitor the subject Watch Areas and associated infrastructure for changes to land use or SGMA-related groundwater extractions. The pipelines are currently monitored for safety and operational functions by private pipeline operating companies and the office of State Fire Marshall. The recent LBL subsidence study concluded that, given the current rates of subsidence occurring in the west side, buried infrastructure, like pipelines would not experience adverse effects provided "hinge-related" affects (e.g. stream crossings, faults etc.) are minimal.

The WDWA subsidence noted by the DWR on page 29 of their 2022 Incomplete Determination letter is not related to SGMA related groundwater pumping (i.e., chronic lowering of groundwater levels by the WDWA). This conclusion is supported by the scarcity of extraction wells for beneficial use in the WDWA, the low annual volumes of groundwater pumped primarily for the purpose of blending (3,000- 5,000 AFY) with surface water deliveries, and two recent subsidence reviews conducted by the WDWA and the KGA.

Historically, it was commonly believed that the principal, if not sole cause of subsidence in the KCS was groundwater extraction for agriculture and municipal use. However, three recent separate subsidence reviews conducted by the WDWA, and the KGA have found that the underlying causes of subsidence in the Subbasin at large are more complex and likely include several interrelated contributing factors. Chief among these are groundwater extraction for beneficial use, oilfield activities and geotechnical conditions related to the disparate types of soil native to the KCS, natural geologic settlement, and the construction and age of critical infrastructure. None of the subsidence modes besides groundwater extraction for agricultural and other Management Area beneficial uses (i.e., SGMA related use) are within the control of Subbasin GSAs.

A condensed discussion of the aforementioned subsidence reviews and their respective key findings are summarized herein. As noted previously, these reviews were conducted subsequent to the 2020 GSP submittal and thus this data was not included in those reports. Both reviews have been incorporated in the KGA Umbrella GSP Report.

***WDWA Subsidence Review Area of Interest (AOI) 2 Aqueduct Milepost 195-215, January 2020***
As one of five subsidence AOIs identified for further study in the 2020 KGA Umbrella GSP (i.e., AOI 2), the study area covers some or all of Aqueduct pools, 23, 24 and 25. The subject

subsidence review was presented to the DWR-California Aqueduct Subsidence Project (CASP) three times. The first time in late January 2020, again in March 2020, and most recently in May 2022. The findings of the review were also presented to DWR-SGMA staff in June 2022. The documentation basis for this review were the KGA GSP, Google Earth imagery of the WDWA and, most importantly, technical materials submitted by oil field operators of the Lost Hills Oil Field (LHOF) to the Central Valley Regional Water Quality Control Board (CVRWQCB) in support of an underground injection control (UIC) permit process for activities at the LHOF, and the March 2019, *California Aqueduct Subsidence Study: Supplemental Report* prepared by the DWR California Aqueduct Subsidence Project (DWR-CASP).

The objectives of the WDWA subsidence review were:

1. Determine the cause of subsidence in AOI 2
2. Assess the cause of the 2011 Aqueduct embankment failure at MP 208
3. Assess the type of subsidence (i.e., elastic or inelastic) in the study area

Due to naturally poor water quality in the WDWA SGMA related extractions are between 3,000 and 5,000 AFY. The primary water source in the WDWA is surface water delivered by the SWP via the Aqueduct. Pumped groundwater is typically used by the WDWA for blending to extend the usefulness of surface water deliveries. By contrast, California Geologic Energy Management (CalGEM, formerly DOGGR) data show that in 2018 alone the LHOF generated approximately 104.8 million barrels (i.e., approx. 13,500 AF) of produced water. Produced water is a byproduct of oil production in almost all oil fields in the Subbasin. The LHOF 2018 volume of produced water is around three to four times the volume of groundwater extracted by the WDWA for beneficial use.

The LHOF is an elongated anticline (upward fold in the subsurface geology) that is oriented roughly northwest to southeast and extends north of Aqueduct MP 195 to around MP 215. The sloping sides of the anticline (i.e., limbs) extend away from the structural crest to the west and the east. Significantly, the eastern limb of the anticline extends up to and likely beneath the Aqueduct in places. The western limb extends out into the nearby interior of the WDWA. One such place where the eastern limb likely extends beneath the Aqueduct is at MP 208, the site of the 2011 embankment failure. The proximity of the LHOF is important because a geologic cross section submitted by the LHOF operators to the CVWQCB shows that pumping along the crest of the anticline creates a pressure differential in the underlying geologic formations. The difference in pressure cause surrounding groundwater to flow up gradient toward the oil pumping. In other words, oil field activities are dewatering zones adjacent and beneath the Aqueduct in the study area. The geologic formation illustrated in the subject cross section is the Tulare Formation, one of two groundwater formations relied upon in the WDWA and KGA for

SGMA related beneficial use. The other formation is the Etchegoin. Oil operator documents identify the Etchegoin Formation as another oil-bearing zone that is pumped in the LHOF (Aquilogic, 2020).

The March 2019, *California Aqueduct Subsidence Study: Supplemental Report* prepared by DWR-CASP provided much substantive data on the Aqueduct that was incorporated in the WDWA review. In particular, DWR subsidence profile Plates 12 through 14 were assessed. Collectively these plates cover Aqueduct MP 185 to 218 (i.e., Pools 23-25). In reviewing the referenced DWR profile data there are three important observations that can be made:

1. There is a clear nexus between oil field activity and subsidence illustrated on the DWR profiles in the study area (i.e., subsidence starts where the oil field and Aqueduct are in proximity and subsides where there is no oil field activity).

2. There is no correlation between agriculture pumping (i.e., SGMA related) pumping and subsidence (i.e., or chronic lowering of groundwater levels by WDWA) in the subject study area.

3. The DWR profile data indicates that subsidence in the study area may have an elastic component (i.e., subsidence is recoverable) as indicated by elevation data on the historical subsidence profiles.

In summary, some observations of the 2020 WDWA subsidence review are:

- Poor groundwater quality has historically limited SGMA-related extractions by the WDWA to around 3,000 to 5,000 AFY and well density is sparse.

- In 2018 alone LHOF produced water volumes were between 3 and 4.5 times the volume extracted by the WDWA (i.e. approx. 13,500 AF).

- Limbs of the LHOF anticline extend up to and likely beneath the Aqueduct including at MP 208, the site of a 2011 embankment failure.

- Oil field documents submitted to the CVRWQCB illustrate how groundwater flows up gradient on either side of the LHOF in response to pressure differentials toward the areas of oil pumping, resulting in dewatering adjacent and beneath the Aqueduct.

- DWR subsidence profiles show that AOI 2 subsidence (MP 195 -215) is related to oil field activities and not SGMA related beneficial use of groundwater (i.e., not chronic lowering of groundwater levels by the WDWA).

***Kern County Subbasin InSAR Study, March 2021***

The scope of the subject Subbasin wide study were threefold:

1. Assess magnitude and potential drivers of subsidence in the KCS
2. Compare the study results to the NASA/JPL InSAR results for 2015-2017
3. Provide recommendations to KCS stakeholders

NASA/JPL InSAR data for the period of 2015 through 2017 were utilized to assess KCS subsidence occurrence and rates in the KGA 2020 GSP submittals. These data identified five subsidence AOIs that require further study. These are:

1. AOI 1: Friant-Kern canal MP 120-130 (eastern KCS)
2. AOI 2: LHOF Aqueduct MP 195-215 (western KCS/WDWA)
3. AOI 3: Friant Kern Canal MP130-137 (eastern KCS)
4. AOI 4: Aqueduct MP 267-271 (southern KCS)
5. AOI 5: Northern and Central portions of the KCS

In the NASA/JPL InSAR study cumulative subsidence in the KCS ranged from near 0 inches to 10 inches in places for the period 2015 to 2017. The estimated annual rate of subsidence ranged from approximately 8 inches to 9 inches.

The subject 2021 KGA InSAR study utilized 172 Sentinel-1 satellite radar images to produce 86 synthetic aperture radar (SAR) images. The 86 paired SAR images were then combined to make 526 interferogram images (i.e., Interferometric Synthetic Aperture Radar, or InSAR). The data was then processed multiple times to minimize atmospheric interference that could result in decorrelation or other unwanted effects that could impair data quality. The resultant data was then correlated to KCS Continuous Global Positioning System (CGPS) station data. The data used in the KGA study has surface (horizontal pixel resolution of 82 ft., with no spaces between pixels, and a vertical resolution of approximately 2.4 mm/year (ECI and Aquilogic, 2021).

Key conclusions of the KGA /KCS study are:

- Discerning the difference between subsidence caused by seasonal (cyclical) groundwater extraction and non-seasonal (i.e., long term) oil field activities is possible utilizing InSAR.
- Previous NASA/JPL studies (2015-2017) may be overestimating subsidence rates by 45 to 50 % in areas associated with seasonal groundwater extraction. This phenomenon may be associated with the short time intervals assessed in the NASA/JPL studies.
- The northern boundary of the KCS is administrative and not hydraulically-based. Groundwater extraction activities to the north of the KCS should be considered in SGMA planning.

- In addition to vertical displacement, subsidence also has a horizontal stress component that can have effect on infrastructure.

With regard to the individual AOIs the KCS/KGA study found:

AOI 1: The annual subsidence rate averaged between 2 and 3 inches/year versus about 5 inches/year in the NASA/JPL study.

AOI 2: Identified the LHOF as the contributing factor of subsidence and rates were around 3 inches/year.

AOI 3: The annual subsidence rate averaged between 1 and 2 inches/year versus 2 to 3 inches/year in the NASA/JPL study.

AOI 4: The annual subsidence rate averaged between 1 and 2 inches/year versus 2 to 4 inches/year in the NASA/JPL study.

AOI 5: The annual subsidence rate averaged between 2 and 4 inches/year within the KCS versus 5 to 8 inches/year in the NASA/JPL study.

***Lawrence Berkeley Laboratory Kenn Subbasin InSAR, July 2022***

This study was undertaken in order to determine the baseline rate of subsidence in the Kern County Subbasin for the study period 92015-2021). Study data was also compared to The March 2021 Differential Interferometric Synthetic Aperture Radar (DInSAR) Study conducted by Earth Consultants International (ECI) on behalf of the Kern Groundwater Authority (KGA) and other Groundwater Sustainability Agencies (GSAs) in the Kern County Subbasin (KCS). This study determined that the data from the ECI study was in reasonable scientific agreement with the LBL Data.

The KGA has identified additional data gaps pertaining to Subbasin subsidence that require further study. Based on current data, and as noted above, these gaps include oilfield activities adjacent to identified critical infrastructure in the Subbasin, geotechnical contributors such as the construction and age of the critical infrastructure, potentially deleterious soils and natural settlement. The KGA had committed to acquire additional necessary data to assess the nexus between subsidence and Regional Critical Infrastructure over the next three years (i.e., by 2025).

It is important to emphasize that agricultural groundwater pumping in the WDWA has historically been limited due to naturally poor groundwater quality. Another area of subsidence in the WDWA is located approximately midway between town of McKittrick and State Highway 46 and is likely associated with the Belridge Anticline oil field complex. InSAR subsidence there has reportedly ranged from 4 inches and higher. (**Figure 28a**). This area will be studied further,

and findings will be reported in the five year update (in 2025). As noted above, the NASA/JPL study data were likely overestimating the rate of subsidence.

A subsequent update to the earlier NASA/JPL InSAR data for the period 2015 to 2016 found improved conditions, with the areas adjacent to the town of Lost Hills (e.g. Mileposts 195-215) mostly displaying only minimal subsidence (approximately 2 inches to 6 inches). The areas around the Belridge Anticline oil field also improved somewhat, with the exception of areas immediately proximal to the oil fields, which appear to have remained more or less unchanged from the findings of the earlier InSAR survey (**Figure 28b**). The rebound of topographic surface elevation indicated by the latter InSAR survey in several areas suggests that some of the WDWA subsidence may have a reversible (elastic) component that benefited from the increased winter precipitation during 2015 to 2016. These earlier data were likely overestimating the rate of subsidence. Figure 28c provides subsidence rate data for the period October 2020 to October 2021. This data appears to be in reasonable agreement with both the 2021 ECI and 2022 LBL studies.

Inelastic land subsidence related to the potential dewatering of the Corcoran Clay or other clay layers by water-well pumping is recognized as a potential undesirable result in that portion of the WDWA east of the California Aqueduct, between the WDWA boundary with the SWSD and the BVWSD. To monitor for this type of land subsidence going forward, the WDWA will rely on future InSAR studies and other iterative subsidence monitoring techniques (e.g. CGPS, DWR-CASP survey data, extensometer, etc.) to be implemented over time in coordination with adjacent management areas and DWR-CASP as part of the KCS-wide land subsidence monitoring program administered by the KGA.

The WDWA has established a preliminary (i.e., interim) MO and MT for land subsidence for those areas closest to the Aqueduct (i.e., five mile wide monitor corridor extending 2.5 miles on either side) in coordination with adjacent GMAs. The interim MOs/MTs, will be re-evaluated in 2025 against new data for adjustment during the first five-year reassessment report (i.e., in 2025). The subject MO/MT corridor follows the entire length of Aqueduct within the Subbasin and is more or less along the downgradient eastern boundary between the WDWA, the Semitropic Water Storage District and the Buena Vista Water Storage District, and immediately adjacent to the west of the Aqueduct along the interior of the WDWA. . It should be noted that subsidence associated with oil and gas activities is under the oversight of DOGGR (i.e., CalGEM) pursuant to the California Public Resources Code, and not the WDWA. The WDWA will coordinate and share subsidence data with those operators that are a party to the KGA Umbrella GSP, but oil field related subsidence is outside the control of the WDWA. A white paper (Basin-wide Coordinated GSP Subsidence Plan) that coordinates land subsidence monitoring and establishment of related interim MOs/MTs for regional critical infrastructure within the KCS is discussed in **Sections 4.1.2 and 4.2.2.**

## 2.13 Effects Beyond the WDWA Chapter Area

Assessment of identified undesirable results that could potentially extend beyond the boundaries of the WDWA will be coordinated with adjacent GMAs, as needed, to ensure the integrated and sustainable management of the WDWA and, by extension, adjacent GMAs and the KGA. For example, although these natural systems and conditions are outside the control of the WDWA, underflow of brackish groundwater found to be migrating downgradient from the WDWA, towards areas of better-quality groundwater in response to regional groundwater flow patterns and adjacent GMA pumping, will be assessed in cooperation with the Dudley Ridge (Kings County) and the Semitropic, and Buena Vista GMAs. To help ameliorate the potential for impacts to adjacent water quality, the WDWA will share groundwater level and water quality data with these adjacent management areas, and will work to coordinate relevant groundwater monitoring activities so that sentry monitoring occurs at the WDWA boundaries contemporaneously with sampling activities being conducted at the SWSD and BVWSD. These data will then become the foundation for other WDWA initiated, or joint management actions with adjacent GMAs, such as detailed groundwater numerical flow modeling to better track and predict brackish water occurrence and migration.

# 3.0 WDWA MONITORING NETWORK

To reduce the current level of uncertainty pertaining to groundwater conditions and occurrence within the WDWA, a Monitoring Network Plan (MNP) will be prepared and implemented during the first five-year reassessment period after adoption of KGA GSP. The MNP, which will be reassessed and updated as needed based on data results, will be specifically designed to address data gaps and sustainability indicators identified in this Chapter GSP. The MNP will simultaneously promote coordination with adjacent GMAs and GSAs through the collection of representative data necessary to evaluate changing groundwater conditions that may occur during the planning and implementation horizon of the WDWA Chapter GSP. **Figure 29a** presents the existing and proposed representative MNP wells. After submittal of the 2020 GSPs it was determined that data from the original set of RMW sentry wells was not completely representative of the SGMA-related beneficial users. Therefore, two new wells were added, and existing two wells were deleted from the proposed 2020 sentry network. The two new RMWs are S#14 (RMW 279), and 7108-66 (RMW 203) . The two deleted wells are a CV2Sim model simulation centroid location (i.e., a modeled location with no actual well) and well 28S21E13H.

**Table 2** presents well construction details for the proposed future MNP monitoring wells. To the extent possible, wells included in the MNP will serve as monitor points for both groundwater quality and groundwater elevation and include wells currently being monitored by the Westside Water Quality Coalition (WWQC) as part of the basin plan amendment process. . Any new wells constructed expressly by the WDWA for the MNP will be permitted, constructed or abandoned pursuant to relevant Kern County and State requirements. To the extent feasible, costs for new wells and monitoring may be shared with the WWQC and/or other adjacent GMAs/GSAs.

## 3.1 Monitoring Network Objectives and Rationale

As reported in this Chapter GSP, data related to representative aquifer characteristics and groundwater elevation monitoring within the WDWA is limited and have been identified as an important data gap that must be filled for effective implementation of this Chapter GSP over the short-term, and for the assessment and planning of future adaptive management strategies over the long-term and SGMA implementation horizon. Associated groundwater components that rely on representative SGMA related groundwater level monitoring include, among others, water budget components, and the identified undesirable results of chronic lowering of groundwater levels, and reduction of groundwater in storage. Although not identified as requiring a specific MT/MO, due to previously discussed physiographic and hydrogeologic conditions (**Section 2.12.2**), monitoring of perched groundwater, if any, will also be conducted in coordination with the WWQC (and WDWA Watch Areas) in order to assess for potential changes in the status of depletion of interconnected natural surface water or undesirable results to

groundwater dependent ecosystems. Objectives and elements of the MNP will address the need for representative data and help reduce uncertainty for the purpose of sustainability planning. The MNP, once fully implemented, will help achieve the following objectives:

- Acquisition of representative groundwater level and water quality data sufficient to assess and document short-term, seasonal, and long-term groundwater trends related to WDWA water budgets, SGMA related groundwater pumping volumes, changes to groundwater in storage, groundwater elevation, and potential future land subsidence;
- Ability to assess for changes in groundwater conditions relative to identified MOs and MTs; and
- Coordination with adjacent management areas by way of contemporaneous scheduled sampling events, mutually sustainable SGMA related MTs and MOs, and regularly scheduled status meetings to ensure sustainable outcomes.

The rationale for selecting monitoring wells for inclusion in the MNP are:

- Ability to economically meet the overall MNP objectives; and
- Ability to provide representative data based on SGMA related beneficial users, physical location, age of well construction and aquifer screened intervals.

The MNP shall incorporate the data quality objective (DQO) process as outlined in the US EPA Guidance on Systematic Planning Using the DQO Process. The MNP shall also include a data quality assurance/quality control (QA/QC) plan to guide the collection and assessment of data. Monitoring will include the use of a standardized database and well data collection form. A summary of MNP protocols and a sample well data collection form is provided in **Appendix F**. MNP field activities will be based on the methodologies described in the USGS National Field Manual for the Collection of Water Quality Data as well as Kern County and State well permitting, construction and abandonment regulations. At a minimum, the following sampling analytical methods and monitoring frequency summarized in Insert 23 will be implemented as part of the MNP:

**INSERT 23: Analytical Methods and Monitoring Frequency**

| Groundwater Sampling Analysis – Initial and 5-Year | | | | |
|---|---|---|---|---|
| **Indicator Parameter** | **Reporting Units** | **Field Measurement** | **Laboratory Analysis** | **Analysis Method** |
| **SEMI-ANNUAL** | | | | |
| EC | umhos/cm | • | | Field Instrument |
| pH | s.u. | • | | Field Instrument |
| Dissolved Oxygen (DO) | mg/L | • | | Field Instrument |
| Temperature | °C | • | | Field Instrument |
| **ANNUAL** | | | | |
| Nitrate as Nitrogen | mg/L | | • | Method 300.0 |
| TDS | mg/L | | • | Method 2540C |
| General Minerals – Anions (carbonate, bicarbonate, chloride, sulfate) | mg/L | | • | Method 2320B |
| General Minerals – Cations (boron, calcium, sodium, magnesium, potassium) | mg/L | | • | Method 200.7 |

Note: C°: degrees Celsius

### 3.1.1 Monitoring Protocols

Monitoring protocols are designed to detect changes in groundwater elevation levels, groundwater quality, and act as a proxy to assess for changes in groundwater storage. In addition, MNP data will be utilized to assess for potential inelastic subsidence and groundwater flow that may directly affect groundwater levels, quality, or changes caused by groundwater extraction in adjacent GMAs. The WDWA will comport with all KGA-established monitoring protocols and will coordinate its monitoring activities and well access/agreements with adjacent GMAs, GSAs and other established monitoring programs, such as the WWQC **(Appendix G and Appendix H)**. Note: some well access agreements are pending.

### 3.1.2 Description of Monitoring Network

The modeled overdraft in the WDWA is largely attributed to natural groundwater underflow leaving the WDWA to the northeast and east. The most critical sustainability criteria to be monitored by the MNP are chronic lowering of groundwater levels, if any, associated with groundwater underflow leaving the WDWA, associated naturally degraded groundwater quality that might affect downgradient GMAs, reduction (changes) in groundwater in storage and the potential for significant SGMA related inelastic land subsidence. The direct measurement of groundwater levels along the northeast and east boundary of the WDWA that is shared with adjacent down-gradient management areas is best suited to provide representative data for this

purpose. The geochemical composition of naturally degraded water that may impact better water quality in adjacent down-gradient management area will also be assessed as part of the sentry monitoring implemented as part of the MNP. The location of proposed monitoring wells (including MT/MO regional monitoring wells) in this Chapter GSP are intended to be preliminary and are subject to change in number and/or location as data becomes available. For example, additional monitoring well location(s) in the interior and northeast of the LHWD management area may be necessary to better characterize groundwater conditions in the area where groundwater underflow is believed to be migrating from the WDWA toward the former bed of Lake Tulare. Data collected as part of the GSP implementation will be utilized to assess the need for MNP modifications and to optimally site new monitoring locations for best technical and economic benefit.

#### 3.1.2.1 Chronic Lowering of Groundwater Levels

Monitoring of representative groundwater levels are an important and obvious metric for determining changes to groundwater storage and thus WDWA and KCS sustainability. The recording of groundwater levels along the northern and eastern boundary between the WDWA and interior and downgradient management areas will also provide insight into changes in groundwater in storage and potential land subsidence. The rationale for focusing the sentry monitoring wells in the MNP along the north and eastern boundaries of the WDWA are:

- The western and southern sides of the WDWA are isolated from other groundwater basins and districts by the Temblor Mountain Range and geologic structures such as the Elk Hills Anticline;
- There is minimal pumping in the WDWA (~3,000 AFY);
- A majority of WDWA groundwater underflow is towards the northeast and east (modeled to be ~111,000 AFY); and
- Groundwater quality in the WDWA is naturally degraded with TDS concentrations often exceeding 2,000 mg/L, making it unsuitable for practical beneficial uses in the WDWA.

The initial MNP will assess i a minimum of 21 primary wells for inclusion into the MNP. Representative monitoring well selection, to the extent feasible, will include the three locations currently monitored by the WWQC. The monitoring locations will be selected to be representative of SGMA related beneficial users, and cover the aquifer zones associated with economic (agricultural) pumping activities (unconfined/semi-confined, and confined). As stated previously, Watch Areas will not include active monitoring unless groundwater use conditions change. Interior parts on the management area will be monitored as representative wells are identified and approved by the KGA. The proposed RMWs are distributed across the WDWA as follows:

- LHWD: 8 wells
- BMWD: 4 wells
- BWSD: 6 wells

The extent of the WDWA is approximately 355 square miles. The well density of the proposed MNP is around one well per every 19.72 square miles. While there is currently no established number for monitoring well density in a basin or management area, for comparison the monitoring well density for a basin recommended by the CASGEM Groundwater Elevation Monitoring Guidelines ranges between one to ten wells per 100 square miles. The current proposed groundwater monitoring network is therefore capable of collecting representative data of sufficient quantity to define short-term, seasonal and long-term data trends in groundwater and associated surface conditions. To ensure reliable groundwater level data, monitoring events will be scheduled in the late fall and early spring when many irrigation wells are typically idled.

#### 3.1.2.2 Reduction in Groundwater in Storage

Changes in groundwater in storage cannot be measured directly. For the proposed MNP, groundwater elevations and CV2sim model data will be used as a proxy indicator for calculating estimated changes in groundwater in storage. The MNP monitoring well network will be used to gather groundwater elevations and generate groundwater elevation contour maps and discern groundwater flow direction. Based on the density of the proposed monitoring well network and the low volumes of annual SGMA-related groundwater extractions, there will be sufficient data to utilize groundwater elevation changes as a surrogate for evaluating potential changes in groundwater in storage.

#### 3.1.2.3 Land Subsidence

Land subsidence in the WDWA will be monitored utilizing various iterative geodetic techniques over time including InSAR, DWR-CASP surveying of permanent benchmarks, CGPS monitoring, and installation of well extensometers etc. Special emphasis will be placed on the previously identified area of interest In the WDWA between Aqueduct Mileposts 195-215 and those identified in the Aqueduct white paper (Basin-wide Coordinated GSP Subsidence Plan) discussed in **Section 4.1.2**.

CGPS continuously collects geodetic data related to land surface monitoring at established stations within the KCS. CGPS is a reliable method for assessing changes related to geologic processes such a folding or faulting.

Extensometers measure a depth- discrete interval in the subsurface. Extensometer data is useful for identifying changes in land elevation that may be caused by groundwater extractions

in a specific ground water bearing zone, and together with CGPS and InSAR help provide a more complete understanding of factors contributing to subsidence (GEI 2019).

InSAR is a proven technology and is capable of reliably detecting variations of land surface elevations over time on the order of millimeters, particularly when the surveyed elevations of CGPS and so called "persistent scatterers" of InSAR signals are utilized to ground-truth the results. Persistent scatterers include hard fixed surfaces such as buildings, roadways and intersections, InSAR reflective corners, tanks and other permanent infrastructure that provide a stable reflective surface of known elevation for InSAR signal calibration.

Subsidence monitoring and reporting activities in the WDWA will be coordinated with adjacent GMAs and the KGA Land Subsidence Monitoring Plan for the KCS (see **Section 4.1.2**). In the KGA, an undesirable result for land subsidence is defined by significant and unreasonable impacts to regional critical infrastructure as indicated by monitoring points established by a basin-wide coordinated GSP subsidence monitoring plan (KGA, 2019). Oil field related activities, including subsidence, is under the oversight of DOGGR and are therefore outside the control of the WDWA. However, the WDWA will coordinate and share data with DOGGR and oil field operators that are a party to the KGA Umbrella GSP. With few exceptions InSAR data for non-oil field areas in the WDWA indicate there is little or no significant inelastic subsidence at this time. InSAR data and other geodetic data for the WDWA will be evaluated a minimum of every five years.

## 3.2 Assessment and Improvement of the Monitoring Network and Timelines

As envisioned, the WDWA MNP will be dual-phased. Phase I would be implemented during the initial five-year reassessment period of 2020 to 2025 and would consist of preparing the detailed MNP for review and approval, coordination with adjacent GMAs and the WWQC, and implementation of the subject monitoring activities. A key component of the Phase I MNP will be the assimilation of some of the initial proposed 21 monitoring wells into the MNP. These locations are spatially located throughout the WDWA boundary areas and interior management area. If it is determined after further review that some of these wells are either not needed or are unacceptable, adjustments will be made to the MNP to better characterize targeted groundwater conditions and beneficial users. All substantive changes to the MNP will be reported in the relevant update report. The goal of Phase I is to identify and sample a sufficient number of wells to establish representative data within and along the northeast and east boundary of the WDWA where groundwater underflow is migrating from the WDWA. To ensure reliable groundwater level data, monitoring events will be scheduled in cooperation with the WWQC and adjacent GMAs in the late fall and early spring. Phase I will also include completion of the technical and economic feasibility studies for the proposed Project Management Action

No.3, (PMA No.3) described in **Section 5.3** of this Chapter GSP. PMA No.3 proposes to harvest a combination of brackish groundwater and oil field produced water for treatment and conjunctive reuse.

Phase II will utilize the Phase I data during the second five-year reassessment period (2030 to 2035) to adjust the monitoring network as needed and coordinate as necessary with adjacent GMAs in order to better maximize the cost effective collection of representative data. A central objective of Phase II is to provide the data necessary to plan and implement adaptive management strategies and projects, such as PMA No.3, which are designed to achieve long term sustainable management of the groundwater resources in the WDWA. Undistricted lands within the WDWA that are subsequently incorporated into the KGA GSP framework will be assessed for potential as additional monitoring locations.

# 4.0 MINIMUM THRESHOLDS AND MEASURABLE OBJECTIVES

Pursuant to SGMA, MOs and MTs shall be established for each sustainability indicator, based on quantitative analysis using the same metrics and monitoring sites as those utilized to define MTs. In accordance with the KGA Plan, the following general definitions apply to this Chapter GSP (CCR Title 23). **Figures 29b and 29c** depict the KGA regional MO and MT groundwater elevations for the KGA. The lack of representative data is a recognized data gap in the WDWA. Hydrographs related to MTs/MOs are preliminary and will be updated based on data collected during the first reassessment period.

- MTs: Numeric values for each sustainability indicator used to define an undesirable result.
- MOs: Interim milestones in increments of five years, to achieve the sustainability goals for the WDWA, and by extension, the KGA, within 20 years of the Plan implementation.

## 4.1 Minimum Thresholds for the WDWA Groundwater Management Area

Based on an assessment of the six potential undesirable results identified in SGMA, there are three co-related elements that require monitoring or MTs to sustainably manage the groundwater resources of the WDWA. Two potential undesirable results (Seawater Intrusion and Depletion of Interconnected Surface Water) were determined to be not applicable to the WDWA. A sixth element, Degraded Water Quality, is predominately the result of naturally occurring sub-regional geologic conditions. Therefore, it is not feasible to set direct MOs or MTs for this condition as the WDWA has no control over this natural phenomenon. However, the quality of groundwater underflow leaving the WDWA as it migrates toward the axis Valley will be monitored as a surrogate to assess for potential undesirable results to neighboring (down-gradient) management areas.

The SGMA three indicators that require monitoring and/or MOs and MTs are:

- Chronic lowering of groundwater levels;
- Reduction in groundwater storage; and
- Potential for localized land subsidence.

### 4.1.1 Chronic Lowering of Groundwater Levels/Significant Reduction of Groundwater in Storage

Fluctuations in groundwater levels and changes to groundwater in storage are linked to the extent that if sustainable groundwater level elevations are achieved, significant reductions in groundwater storage are avoided. There has been little historic reliance on groundwater for the purpose of irrigation or other uses in the WDWA due to poor groundwater quality. Therefore,

the potential for a significant lowering of groundwater levels or reduction in storage due to WDWA SGMA related pumping extractions is believed to be minimal. It is unlikely this condition will change through at least 2025. Current estimates of WDWA groundwater well extraction is less than 2% of total demand (i.e. ~3,000 AFY). According to the current and projected KGA C2VSim-Kern model results, a principal cause of the lowering of groundwater levels in the WDWA, and by extension changes to groundwater in storage and projected groundwater deficits, is groundwater underflow (~111,000 AFY) migrating downgradient northeast and east toward the axis of the Valley. This condition, if confirmed by future modeling and data, indicates that a significant portion of changes to groundwater storage in the WDWA are not caused by pumping. It is believed that rate of underflow migrating from the WDWA could also be influenced by groundwater extractions being conducted in some of the adjacent downgradient GMAs. Therefore, the subject conditions of sub-regional downgradient underflow and most specifically adjacent pumping are outside the control of the WDWA. The WDWA has proposed two sentry coordination zones with adjacent GMAs to monitor groundwater elevations along the north and east boundaries of the WDWA where underflow exits the WDWA. Based on known hydrologic conditions, and preliminary hydrographs these zones each have separate preliminary MTs and MOs. These are depicted in **Figures 30a through 30e**.

The preliminary MTs are:

- Sentry Zone #1 (well 25S21E-01-aka well# 7108-66): ~-115 feet below MSL
- Sentry Zone #2 (well 27S22E-30H- aka well #7106-63): ~ 0 feet MSL
- Sentry Zone #2(well S-#14): ~150 feet above MSL

As noted, some of the proposed RWMs were determined to be not representative of SGMA related beneficial use. Therefore, three wells have been deleted and two wells have been added and approved by the KGA Board. Two other proposed RMWs (RTS North Lerdo Well 7 (Sentry Zone #2) and Starrh Well 8-3 (Sentry Zone #2) ) are in the process of KGA Board review for possible approval. If accepted, that would bring the total of approved RMWs to date to five sentry wells. Further, the original MTs and MOs for well 7106-63 were based on flawed CV2Sim model results. The WDWA now has accurate groundwater for that well and will, if accepted by the KGA Board, reset the MT for that well at 0 feet above MSL. Other wells designed to monitor the interior parts of the management area are being assessed for inclusion in the monitoring network.

Because groundwater underflow is beyond the control of the WDWA, these MTs are preliminary and will be revised as necessary as additional groundwater elevation data is acquired. The proposed MTs are subject to review and revision at a minimum of every five years based on new data and subsequent coordination discussions with adjacent GMAs. Proposed changes will be reported in the relevant GSP update report. There are currently no MTs proposed for the

WDWA Watch Areas outside of the specified management area zones at this time. Watch Areas are defined as areas with no significant groundwater use and no planned groundwater use as documented in the management area plan. Watch Areas will be monitored for land use changes and groundwater conditions that could change its designation to a "management area" with specified SMCs.

The rationale for this approach is the aforementioned minimal historic pumping, and natural groundwater underflow over which the WDWA has no control. Data collected as part of the MNP for this Chapter GSP will be utilized to coordinate with adjacent downgradient GMAs and to assess whether the proposed MTs need updating or supplementing with additional MT/MO monitoring locations.

### 4.1.2 Land Subsidence

Recognizing there are still significant data gaps related to the cause and rate of subsidence the Subbasin has developed two coordinated white papers (one each for the Aqueduct and Friant Kern Canal) as part of its Basin-wide Coordinated GSP Subsidence Plan. The purpose of the plan is to document the process and methods for establishing interim Sustainable Management Criteria (SMCs) for Land Subsidence on regional critical infrastructure. The Aqueduct and the Friant-Kern Canal have been identified as Regional Critical Infrastructure within the Subbasin, each have a coordinated approach to address the unique characteristics of these infrastructure. The WDWA has incorporated the white paper pertaining to the Aqueduct into is planning for both regional and management area infrastructure. The respective white papers describes the methods and data used to determine a coordinated approach for establishing interim, and later long term, subsidence SMCs that are consistent with the unique conditions that exist across the breadth and width of the Subbasin. Therefore, while the overall methodology to arrive at interim SMCs at the Aqueduct and Friant-Kern Canal are fundamentally similar there are variations to account for local conditions along each infrastructure, such as local beneficial users, geologic and hydrogeologic conditions, and operational consideration of the facilities.

The Subbasin's coordinated definition for a basin-wide undesirable result for land subsidence is:

> *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.*

An WDWA undesirable result for land subsidence is further identified as the occurrence of a single minimum threshold exceedance along the Aqueduct. The interim minimum thresholds for the Aqueduct are detailed in the Subbasin white paper (**Appendix I**).

The interim Minimum Threshold for land subsidence for the Aqueduct is defined as the avoidance of a permanent loss (associated with inelastic subsidence) of conveyance capacity as attributable to subsidence as limited by remaining concrete liner freeboard for a specific Aqueduct Pool that exceeds twice the average observed rate from 2016-2022. Using the 2022 CASP survey data and comparing InSAR data, twice the average observed rate was calculated to be -0.10 ft/yr for Pools 23-32 of the Aqueduct within the Kern Subbasin. These pools encompass the entirety of the WDWA. The interim MT rate of subsidence is calculated and assessed as an average annual rate over a rolling 6-year monitoring period. For Pools 33-35 the interim MT is slightly higher based on available free board. Those pools are outside of the WDWA.

The interim Measurable Objectives and Minimum Thresholds will be updated in the 2025 GSP Update, and only apply when the permanent loss of freeboard is a result of subsidence due to SGMA related groundwater extractions from the following beneficial uses/users: agricultural, domestic, municipal, or urban. Permanent loss of freeboard from land subsidence due to other causes including but not limited to oil or gas production, natural compaction of shallow underlying soils beneath or near the Aqueduct, or any other cause that is not within the jurisdiction of a GSA, shall not be considered as a loss of freeboard that contributes to the amount specified for any MO or MT. When considering Measurable Objective and Minimum Threshold rates beyond 2025 it will be critical to fully understand design considerations of the identified critical infrastructure. It is typical that major infrastructure designs incorporate assumptions for natural settling, subsidence of any type, service life, repair and replacement cycles, etc. It is expected that when selecting Minimum Threshold rates of subsidence beyond the interim 2025 period that MO and MT rates may require reduction based on these and other critical elements as the basin approaches its 2040 sustainability goal. The complete subsidence white papers for both the Aqueduct and the Friant-Kern Canal and a copy of the WDWA subsidence review for the Lost Hills area (i.e., Aqueduct pools 23-25) are provided in **Appendix I.**

### 4.1.3 Degraded Groundwater Quality

Given the ubiquitous occurrence of naturally degraded groundwater quality throughout the WDWA, groundwater is considered to be unsuitable for general use without treatment or blending with better quality water. The WDWA has no control over this phenomenon, therefore, no MTs or MOs are proposed at this time for this condition. To assist adjacent downgradient GMAs in their sustainability planning, the WDWA will conduct sentry monitoring within the WDWA lands (i.e., Sentry Zones #1 and 2) east of the California Aqueduct adjacent to the shared boundaries with the GMAs northeast and east of the WDWA. The sentry monitoring data will be utilized to assess for any significant changes in groundwater quality (e.g., TDS) that might be

migrating to the north or east from the WDWA as underflow. This condition, in conjunction with the aforementioned sentry data, will be re-assessed a minimum of every five years. Any proposed changes will be reported in the relevant GSP update report.

## 4.2 Measurable Objectives for the WDWA Groundwater Management Area

### 4.2.1 Chronic Lowering of Groundwater Levels/Significant Reduction of Groundwater in Storage

As discussed in **Section 2.12.3** and elsewhere in this report, the existing KGA C2VSim-Kern model has identified natural downgradient underflow (~111,000 AFY) as a principal cause of discharge and groundwater deficits (change in storage) in the WDWA. The rate of groundwater underflow migrating out of the WDWA may be accelerated by pumping activities in adjacent downgradient GMAs. Collectively these conditions are outside the control of the WDWA. Therefore, the WDWA has proposed two sentry coordination zones near the WDWA boundary with adjacent GMAs to monitor water level elevations to the north and east. Representative data will be collected for use in modeling changes to groundwater storage, and to act as a sentry for naturally degraded water quality migrating from the WDWA. The objective is to assess the potential for undesirable results to groundwater levels, and by proxy changes in groundwater storage, within the WDWA. In addition, the data will be used to assess groundwater quality in interior parts of the management area and groundwater migrating into adjacent down-gradient management areas. The coordination zones each have separate preliminary MTs and MOs that will be re-evaluated, as needed, in coordination with the subject downgradient GMAs/GSAs and the KGA.

The preliminary MOs are:

- Sentry Zone #1 (well 25S21E-01- aka well# 7108-66): ~-62 feet below MSL
- Sentry Zone #2 (well 27S22E-30H- aka well # 7106-63): ~40 above MSL
- Sentry Zone #2 (well S-#14): ~200 feet above MSL

As noted in **Section 4.1.1** , the previous suite of proposed RWMs were not representative of SGMA related beneficial use. Therefore, three wells have been deleted and two wells have been added and approved by the KGA Board. Two other proposed RMWs (RTS North Lerdo Well 7 (Sentry Zone #2) and Starrh Well 8-3 (Sentry Zone #2) are in the process of KGA Board review for possible approval. If accepted, that would bring the total of approved RMWs to date to five sentry wells. Further, the original MTs and MOs for well 7106-63 were based on flawed CV2Sim

model results. The WDWA now has accurate groundwater data for that well and, if accepted by the KGA Board, will reset the MO for that well at 40 feet above MSL.As discussed, these MOs are preliminary and subject to review and change at a minimum every five years based on new data and subsequent coordination discussions with adjacent GMAs. Proposed changes will be reported in the relevant GSP update report. There are currently no MOs proposed for the areas not within the specified sentry coordination zones (i.e., Watch Areas internal to the WDWA) at this time. The rationale for this approach is the aforementioned naturally poor quality groundwater and the low volume of historic pumping, which is expected to continue for the foreseeable future. As stated, additional MT/MO monitoring locations may be proposed and reported in relevant GSP update reports based on MNP monitoring data collected during the first reassessment period.

### 4.2.2 Land Subsidence

The Kern Subbasin has developed two coordinated white papers (Basin-wide Coordinated GSP Subsidence Plan) to document the process and methods for establishing interim Sustainable Management Criteria (SMCs) for Land Subsidence for regional critical infrastructure. The Aqueduct and the Friant-Kern Canal have been identified as Regional Critical Infrastructure within the Subbasin, each have a separate, but coordinated white paper to address the unique characteristics of these infrastructure. The WDWA has incorporated the white paper pertaining to the Aqueduct into its planning for both regional and management area infrastructure. The respective white papers describes the methods and data used to determine a coordinated approach for establishing interim subsidence SMCs that are consistent with the unique conditions that exist across the breadth and width of the Subbasin. Therefore, while the overall methodology to arrive at interim SMCs at the Aqueduct and Friant-Kern Canal are fundamentally similar there are variations to account for local conditions along each infrastructure, such as local beneficial users, geologic and hydrogeologic conditions, and operational consideration of the facilities. The interim MO/MTs for the Aqueduct and Friant-Kern Canal are found in the respective white papers in **Appendix I**.

The Subbasin's coordinated definition for a basin-wide undesirable result for land subsidence is:

> *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.*

An undesirable result for land subsidence is further identified as the occurrence of a single minimum threshold exceedance along either the Aqueduct or the Friant-Kern Canal. The

minimum thresholds for the Aqueduct are detailed in this white paper. See the Friant-Kern white paper for a detailed discussion the MTs/MOs for that facility.

The Interim Measurable Objective for land subsidence for the California Aqueduct is defined as the avoidance of a permanent loss (associated with inelastic subsidence) of conveyance capacity as attributable to subsidence as limited by remaining concrete liner freeboard for a specific Aqueduct Pool that exceeds the average observed rate from 2016-2022. Using the 2022 CASP survey data, and recent InSAR data. The average observed rate was calculated to be -0.05 ft/yr for Pools 23-32 of the Aqueduct within the Kern Subbasin. For pools 33 to 35 the MOs are slightly higher because of additional available freeboard. Those pools are outside of the WDWA. The MO rate of subsidence is calculated and assessed as an average annual rate over a rolling 6-year monitoring period.

### 4.2.3 Degraded Groundwater Quality

As explained elsewhere in this Chapter GSP, because of the widespread occurrence of naturally degraded groundwater quality in the WDWA, there are no proposed MOs for this indicator. Instead, the WDWA will conduct sentry monitoring along its down-gradient (northeastern and eastern) boundaries in order to assess for significant changes to existing concentrations of TDS in groundwater underflow leaving the WDWA. A pending Basin Plan Amendment Workplan being submitted by the WWQC requests delisting of beneficial use designations for MUN and AGR for perched and unconfined/semi-confined groundwater over a portion of the WDWA.

# 5.0 PROJECTS, MANAGEMENT ACTIONS, AND ADAPTIVE MANAGEMENT

Groundwater quality in the WDWA is largely naturally degraded by elevated concentrations of TDS and other minerals that make it generally unsuitable for beneficial use. Further, due to the degraded quality of this groundwater, pumping extractions in the WDWA are estimated to be minimal (~3,000 - 5,000 AFY). The most significant source of discharge from the WDWA is groundwater underflow (~111,000 AFY) towards the north and east. This condition is a natural phenomenon that is outside the control of the WDA, and which may also be influenced by groundwater extractions in some adjacent GMAs. To the extent feasible and practical, Projects and Management Actions (PMAs) have been developed to address sustainability goals, undesirable results and MTs/ MOs for the WDWA. Recognizing that the hydrogeologic characteristics of the WDWA are transitory through time and that adaptive management is an iterative process, the PMAs have been selected and developed with consideration to climate change and drought resiliency, as well as coordination with adjacent GMAs. The initial proposed PMAs are:

1. Collect Representative Hydrogeologic Data
2. Water Resource Coordination
3. Conjunctive Reuse of Naturally Degraded Brackish Groundwater

A table summarizing the WDWA PMAs is provided in **Appendix J.**

## 5.1 PMA No.1 – Collect Representative Hydrogeologic Data

Historically, because of the brackish and naturally degraded quality of groundwater in the WDWA, growers have relied almost exclusively on surface water from the SWP for their irrigation needs. Groundwater is used primarily for blending when annual SWP deliveries are less than expected. As a result, there is currently little representative hydrogeologic data in the WDWA. This lack of data represents a significant data gap that must be addressed in order to refine the current understanding of the WDWA HCM, including key elements such as native yield/sustainable yield, groundwater elevations, pumping, and changes to groundwater in storage as well as the overall water budget.

### 5.1.1 Description of PMA No. 1

As reported in this Chapter GSP, representative data related to aquifer characteristics and groundwater elevation monitoring within the WDWA is limited. This important data gap will be filled by implementation of the MNP. The MNP, once fully implemented, will help achieve the following objectives:

- Acquisition of additional representative groundwater elevation data sufficient to assess and document short-term, seasonal, and long-term groundwater trends related to WDWA, native yield/sustainable yield, proposed sentry MTs/MOs, water budgets, groundwater pumping volumes, groundwater in storage, groundwater elevation, and potential future land subsidence;

- Ability to assess for changes in groundwater storage and conditions relative to identified MOs and MTs; and

- Coordination with adjacent management areas by way of scheduled sampling events, mutually sustainable MTs and MOs, and regularly scheduled status meetings to ensure sustainable outcomes.

As a first step, by 2025 the WDWA will complete an review of groundwater well data, to update previous well assessment information, by recording their physical number, status (active, non-active etc.), number, type and location in relation to WDWA groundwater Watch Areas, Management Area, and critical infrastructure.

### 5.1.2 Expected Benefits of PMA No. 1

The expected benefits to be realized from the coordinated collection of groundwater data within the WDWA are:

- The ability to generate representative data for use in updating native yield/sustainable yield, sentry MTs/MOs and various water budget elements;
- Improved numerical groundwater modeling results; and
- Better forecasting and planning of adaptive management projects and management actions.

The PMA No. 1 will also directly support WDWA MTs/MOs by providing foundational data to monitor and manage adaptive management projects that are designed and implemented to ameliorate the potential for significant reduction of groundwater elevations and groundwater in storage.

### 5.1.3 Timetable and Metrics for PMA No. 1

Public noticing of proposed sampling activities or other field implemented as part of the MNP will be made on the WDWA member websites in advance of any field work. Permitting, if necessary, will comply with State and local requirements.

The PMA No. 1 will be implemented beginning with implementation of the GSP and subsequent acceptance of the MNP. It will directly support WDWA MT/MOs by providing foundational data to monitor and manage adaptive management projects that are designed and implemented to

ameliorate the potential for significant reduction of groundwater elevations and groundwater in storage. Metrics include sufficient representative water level data, pumping data, and additional water quality data.

### 5.1.4 Costs of PMA No. 1

The cost of implementing PMA No 1. will be apportioned between the member water districts of the WDWA. It is possible that some costs might also be shared by adjacent management areas, and/or the WWQC as part of coordination agreements that are currently being negotiated. Detailed costs and the MNP document will be developed and implemented during the first five-year reassessment period. If cost sharing with adjacent areas is implemented, it will increase efficiency and flexibility in data collection and will reduce costs to the WDWA. Preliminary annual monitoring and reporting costs are estimated at $150,000 to $175,000. A more refined estimate of monitoring costs will be available and reported once the MNP is finalized for implementation.

## 5.2 PMA No. 2 – Water Resource Coordination

### 5.2.1 Description of PMA No. 2

The landowners in the WDWA have historically made significant investment in efficient irrigation technologies and methods that promote water conservation and sustainable management. They have also coordinated amongst themselves as individuals or via the various water districts to implement focused reduction demand measures, and trade or purchase surplus water when deliveries from the SWP have been reduced. It is assumed that these effective approaches and arrangements will continue after GSP implementation. In addition, the WDWA will work cooperatively and in close consultation with its landowners, the KGA and adjacent GMAs/GSAs to coordinate groundwater resource monitoring, testing and reporting as part of its overall strategy for the sustainable management of all its available water resources.

### 5.2.2 Expected Benefits of PMA No. 2

Expected benefits from PM No. 2 include:

- More reliability and flexibility in water availability;
- Drought resiliency; and
- Sustainable water strategies for both short- and long-term planning horizons.

### 5.2.3 Timetable and Metrics for PMA No. 2

The implementation of the different Water Resource Coordination Programs varies; some as described above are already in place and ongoing. Others, like a KCS-wide groundwater coordination program would likely begin with planning by the KGA during the first five-year

reassessment period after KCS Plan implementation. Groundwater coordination between the WDWA and its immediately adjacent GMAs, although already in place, would likely be structured to begin with meetings shortly after the Umbrella GSP approval. Metrics for PMA No.2 include regularly scheduled coordination meetings, a common data base system, frequent sharing of relevant water resource data (surface and groundwater) and discussion and planning of coordinated groundwater management actions and projects where feasible. Public noticing for SGMA related activities will be via WDWA district websites.

### 5.2.4 Costs of PMA No. 2

Costs related to spot purchase or trading of supplemental water between individual growers is typically transactional between the relevant parties and thus not directly part of the WDWA operations. Purchase of supplemental water by the WDWA or individual member water districts is generally conducted on an as-needed (and available basis). Therefore, these transactions are not standard and subject to future market forces and an estimate of cost cannot be made at this time. The cost of this type of purchase would be within the WDWA or individual water district budget. The costs of each such unit of water would ultimately be borne by the respective recipient (i.e. pass-through cost). All such data would be reported in the member district AWMP report. Costs related to groundwater testing and monitoring will be determined once the MNP is finalized.

## 5.3 PMA No. 3 – Conjunctive Reuse of Naturally Degraded Brackish Groundwater

To further enhance the sustainable and adaptive management strategies for the WDWA, the WDWA is evaluating the feasibility of an innovative, phased project that will integrate the treatment and conjunctive use of brackish groundwater and oil field produced water for potential multiple beneficial uses including, among other things:

- A new water supply for adjacent and nearby disadvantaged communities (DACs) in order to improve water reliability and drought resiliency;
- A reliable supplemental source of better-quality water that, together with the Aqueduct supplies, can be used for irrigation and other uses;
- Provide for potential environmental flows to the adjacent Kern National Wildlife Refuge; and
- Protect groundwater quality adjacent to the WDWA and reduce potential changes to groundwater storage by reducing the volume of naturally degraded groundwater migrating north and east from the WDWA toward better-quality groundwater in the axis of the Valley via the focused pumping, treatment and conjunctive reuse of modeled groundwater

underflow leaving the WDWA (provided adjacent GMAs address their existing pumping-related groundwater gradient issues through their individual GSP management actions).

### 5.3.1 Description of PMA No. 3

The supporting rationale for PMA No. 3 is multifaceted and relies on the unique hydrogeologic characteristics of the WDWA previously enumerated in this Chapter GSP, proven and available water treatment technologies that allow for innovative solutions to seemingly complex water quality challenges, and the potential for a variety of beneficial reuse opportunities derived from a degraded resources of little to no current practical use. Unlike other existing and proposed State water supply projects, PMA No. 3 would also have the added benefit of being planned, constructed and operated under local control.

Sub-regionally, most of the groundwater in the WDWA is of poor to very poor quality, with TDS concentrations routinely greater than 2,000 mg/L, making it unsuitable for practical beneficial use within the WDWA without blending or treatment. The poor water quality is caused by geologic sediments of marine origin, some of which contain saline connate water. The principal source of modeled deficit in the WDWA is due to natural downgradient underflow out of the WDWA towards the northeast (former Tulare Lakebed, a designated beneficial use exemption area), and eastward towards the axis of the basin. Historically, WDWA growers have, among other water management techniques, used Aqueduct water (significantly more than 95%) to meet their water supply demand. Groundwater withdrawals have been minimal (~3,000 AFY), and have been used largely for the purpose of blending. However, climate variability has placed stress on the reliability of imported water. During the recent extended drought period (2007 to 2016), actual deliveries from the SWP to the WDWA averaged less than 50% of the stipulated allocation. The proposed drought resiliency infrastructure project (Project), when fully implemented, would provide for treatment and conjunctive reuse of a mixture of oil field produced water, and naturally degraded groundwater that is currently escaping the WDWA as underflow.

Membrane technologies and associated system control software to treat brackish and saline water are well established and the cost of treatment is declining. Many of these proven technologies are now “off the shelf” and modular, allowing for cost-effective facility upscaling as part of planned project phasing, or as operational conditions change. The Project proposes to utilize a modular treatment system in order to right-size the project and maximize and maintain the balance between project economics and desired benefits. As envisioned, the PMA No. 3 would include at least two similar construction phases over the next 10-20 years, each with an array of brackish groundwater underflow-capture wells located along the eastern or northern boundaries of the WDWA. These wells along with some oilfield produced water would eventually provide the source water for two or more distributed modular treatment systems.

When fully operational, the Project, as currently planned, could produce up to 50,000 AFY of new, high-quality water for multi-beneficial reuse options.

Potential sources of feed water for the project include degraded brackish groundwater underflow from the WDWA and surplus oil field produced water. Current groundwater underflow that migrates from the WDWA, downgradient towards the axis of the basin, has been preliminarily estimated by the KGA C2VSim-Kern model at approximately 111,000 AFY. Because of the brackish quality of this water, it is considered to be non-beneficial without treatment or blending.

The oil fields of West Kern County generate approximately 10 to 12 barrels of brackish or saline produced water for every barrel of oil. A large portion of the produced water is recycled and used at the oil fields for steam flooding for EOR, and other oil field operations. However, any remaining surplus volume of produced water requires disposal. Due to water quality concerns, many of the produced water disposal ponds in Kern County have been closed. This leaves permitted reinjection into typically deeper zones under the oversight of the DOGGR and the Federal UIC program as the primary method for disposal of produced waters. The Project would, if determined to be feasible, divert a portion of this surplus produced water for additional treatment and conjunctive reuse.

### 5.3.2 Expected Benefits of PMA No.3

When operational, the Project will result in multiple potential beneficial uses, including many of the "One Water" concepts enumerated in the State's California Water Action Plan:

1. Increase drought resiliency, regional and local water self-reliance, and flexible integrated water management;
2. Potentially help protect, maintain and restore important ecosystems (e.g., Kern National Wildlife Refuge);
3. Provide a potential alternative water source for use by local DACs;
4. Increase WDWA operational flexibility and regulatory efficiency; and
5. Help mitigate the rate of subsidence through the treatment, potential banking and conjunctive reuse of surplus oilfield produced water.

The Project will also directly support WDWA MTs/MOs by providing a new reliable local source of better quality water for conjunctive reuse that is derived from groundwater that is currently considered unsuitable for beneficial use and is typically lost to underflow from the WDWA, or is

injected deep underground as part of oilfield produced water disposal where it beyond practical reach for reuse.

### 5.3.3 Timetable and Metrics for PMA No. 3

Preliminary planning for a Project Engineering feasibility study (FS) for the first phase of the project has begun and will be presented to the WDWA Board in 2022. It is expected there will be at a minimum two phases of distributed treatment facility construction. The FS will examine the viability of the project for regulatory acceptance, potential for undesirable results (e.g. significant subsidence), and for the economics of treating both brackish groundwater and oil field produced waters in a distributed modular facility via the use of readily available membrane technologies, such as reverse osmosis (RO).

Treatment technologies to be assessed would include pre-treatment, pH adjustment and filtration followed by either a single-pass RO configuration, a double-pass RO, or a RO modification called a closed-circuit RO. Treated water quality would, at a minimum, meet Basin Plan requirements.

Project FS components include:

- Evaluating existing hydrogeologic data pertaining to brackish groundwater and oil field produced water quality, water use, and volumes;
- Development of preliminary engineering options and costs for siting the treatment facility, source wells, water treatment, energy demand, concentrate disposal, and treated water transmission;
- Examination of the potential for undesirable results (e.g. subsidence); and
- Assessment of permitting and public notification requirements (California Environmental Quality Act [CEQA], etc.).

Sustainable objectives and metrics will be developed to comport with those identified in the KGA Umbrella GSP and the WDWA Chapter GSP. Data gaps will be filled, as needed, through water sample analysis, geophysics (e.g. airborne, surface, borehole), aquifer pumping tests, and groundwater flow and solute transport modeling.

The FS will include information on the study area, as well as water supply, source water, and RO concentrate characteristics and treatment facilities. A project alternative analysis will be performed leading to a recommended plan for implementation including a preliminary construction schedule and financing plan, a revenue program, and a net present worth analysis. Findings and status of the FS implementation would be reported in the first five-year GSP reassessment. It is a goal to have the first modular treatment system online before the end of

the second five-year reassessment period (by 2030). Public noticing for this project would be implemented pursuant to relevant and applicable rules and regulations and would be distributed via the websites of the stakeholder water districts and other methods, as required. Permitting (CEQA, construction, etc.) will also comply with relevant and applicable rules and regulations.

### 5.3.4 PMA No. 3 Issues, Outcomes and Costs

Key issues to be addressed during the FS include those related to technical feasibility, project phasing, regulatory and public acceptance, potential project-related undesirable results, the development of an engineering cost/benefit analysis, State or other funding alternatives and permitting (e.g. CEQA, etc.). The FS will seek to identify the preferred project alternative by examining the CEQA required "no project alternative", in addition to several different construction and RO configurations, combined with varying approaches for concentrate (brine) disposal. End-users of the new water supply will be identified, including local DACs, agricultural, oil field, and environmental users.

Ultimately, this project directly supports WDWA water resources and provides the benefit of a new water supply to the State. Specific benefits include:

- Ability to wheel water of acceptable quality to neighboring management areas that may be facing shortage;
- Increased regional and local water self-reliance, flexibility and integrated management;
- Drought resiliency;
- Ability to decrease agricultural reliance on diversions from the Delta via the Aqueduct; and
- Increase operational and regulatory efficiency for improved drought resiliency.

Only broad order-of-magnitude cost ranges are available at this time. More refined cost estimates will be generated by the proposed FS. Rough order-of-magnitude costs for the initial phase of the project range from $50 million to $60 million +/- 20% depending on site location and number of capture wells to be installed. Refined costs will be generated by the aforementioned FS. Project costs and funding are among key feasibility factors. Funding sources could include a combination of State, WDWA and other stakeholder or private funding.

# 6.0 GSP REPORTING AND PERIODIC EVALUATIONS

SGMA reporting standards, as enumerated in Section 352.4 of CCR 23, Subchapter 2, Groundwater Sustainability Plans, shall apply to all WDWA Chapter GSP reporting and WDWA Chapter GSP amendments. Additional reporting details are provided below. Data from the various monitoring and well installation activities will be provided to the appropriate State and County databases (e.g., well installation information and groundwater level and water quality monitoring). Data will also be coordinated with adjacent GMAs, and will be maintained in the appropriate State data bases (e.g. GeoTracker), and a WDWA data base that is coordinated with the KGA. All data collected by the WDWA will be provided and summarized in the various reports detailed in this section (**Appendix G and Appendix H**).

## 6.1 GSP Reporting and Data Management

Pursuant to SGMA, the WDWA will prepare Annual Reports for inclusion in the KGA GSP. The Annual Reports will be prepared consistent with KGA guidance and formats. The compiled reports from the individual Chapter GSPs/ GSAs will submitted by the KGA by April 1st of each year following adoption of the Umbrella GSP. The Annual Reports shall, at a minimum, include the following topics:

- Groundwater elevation data and contour maps;
- Key well hydrographs;
- Groundwater extractions;
- Surface water supplies;
- Total water use;
- Change in groundwater storage; and
- Implementation progress.

Periodic reevaluation reports will be prepared a minimum of every five years for inclusion in the Umbrella GSP. The five-year reassessments will be submitted electronically by the KGA to the DWR via the online reporting system and format provided by the Agency per Section 10733.2, Water Code and Section 353.2 and 356.4, of CCR 23, Subchapter 2, Groundwater Sustainability Plans. The submittal of updates or amendments to this Chapter GSP will be accompanied by a transmittal letter signed by the Plan Manager, or duly authorized representative. A coordinated data management system for the KCS is necessary to improve the accuracy, usefulness and confidence in groundwater data reported by the individual GMA's and GSA's within the KGA. Data system perimeters, inputs and a coordinated data system methodology will be established and reported in the relevant KGA update report. In the meantime, the WDWA will continue to rely on established State data bases for updating and reporting new data.

# 7.0 REFERENCES

A spreadsheet of the report references is provided in **Appendix K**.

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