Appendix 7-1

Kern Water Bank Study Area Physical Data Collection Technical Report

Prepared for:

State of California
California Natural Resources Agency
Department of Water Resources

Prepared by:

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Sacramento, CA 95814

With Technical Assistance from:

RMC Water and Environment
Fugro Consultants
The Sandberg Group

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ACRONYMS AND OTHER ABBREVIATIONS

AF	acre-feet
AFY	acre-feet per year
Amec	Amec Foster Wheeler
As	arsenic
B	boron
bgs	below ground surface
Br	bromide
C2VSim	California Central Valley Groundwater–Surface Water Simulation
CASGEM	California Statewide Groundwater Elevation Monitoring
CCR	California Code of Regulations
CDPH	California Department of Public Health
CDPR	California Department of Pesticide Regulation
CDWA et al. v. DWR et al.	*Central Delta Water Agency et al. v. California Department of Water Resources et al.*
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
COC	constituent of concern
Cr+6	chromium-6
CVC	Cross Valley Canal
CVP	Central Valley Project
DBCP	dibromochloropropane
DEIR	draft environmental impact report
DOC	dissolved organic carbon
DWR or Department	California Department of Water Resources
EC	electrical conductivity
EDB	ethylene dibromide
EIR	environmental impact report
ET	evapotranspiration
F	fluoride
Fe	iron
GAMA	Groundwater Ambient Monitoring and Assessment Program
ID4	Improvement District No. 4
JPA	joint powers authority
K	hydraulic conductivity
KCWA	Kern County Water Agency
KFE	Kern Fan Element
KFMC	Kern Fan Monitoring Committee
KWB	Kern Water Bank
KWBA	Kern Water Bank Authority
LLNL	Lawrence Livermore National Laboratory
MAF	million acre-feet
Mn	manganese
MCL	maximum contaminant level

Monterey Plus	Monterey Amendment to the State Water Project Contracts (Including Kern Water Bank Transfer) and Associated Actions as Part of a Settlement Agreement
Monterey Plus EIR	Environmental Impact Report for the Monterey Amendment to the State Water Project Contracts (Including Kern Water Bank Transfer) and Associated Actions as Part of a Settlement Agreement
Monterey Plus Revised EIR	REIR
MOU	memorandum of understanding
MRL	minimum reporting level
NO_3	nitrate
NRMS	normalized root mean squared
PBP	Priority Basin Project
PCL v. DWR	*Planning and Conservation League v. Department of Water Resources*
ppb	parts per billion
ppm	parts per million
R25E	Range 25 East
Rosedale	Rosedale–Rio Bravo Water Storage District
SO_4	sulfate
SWP	State Water Project
SWRCB	State Water Resources Control Board
Semitropic WSD	Semitropic Water Storage District
T30S	Township 30 South
TCP	1,2,3-Trichloropropane
TDS	total dissolved solids
U	uranium
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
VOC	volatile organic compound
WD	water district
WSD	water storage district

1. INTRODUCTION

1.1 PURPOSE AND SCOPE OF TECHNICAL REPORT

The purpose of this technical report is to:

- Identify readily available water resources data that can be used to characterize the Kern Water Bank (KWB) environmental setting,

- Identify readily available water resources data that can be used to identify and evaluate groundwater and water quality impacts from KWB operations and maintenance, and

- Present this supporting technical information in an appendix to the Revised Environmental Impact Report (REIR).

The scope of this technical report consisted of summarizing readily available geology, hydrogeology, hydrology, and hydraulic data sets to determine the historical and current environmental conditions of the KWB and surrounding region, as well as to provide an information database necessary to prepare the environmental impact analyses for groundwater and water quality.

This technical report is organized into four chapters as follows:

- Chapter 1 presents the background, purpose and scope of this technical report, and data collection, analysis, and types;

- Chapter 2 presents the geology, hydrogeology, and hydrology data;

- Chapter 3 presents the water quality data; and

- Chapter 4 presents references cited in this technical report.

1.2 DATA COLLECTION AND ANALYSIS METHODOLOGY

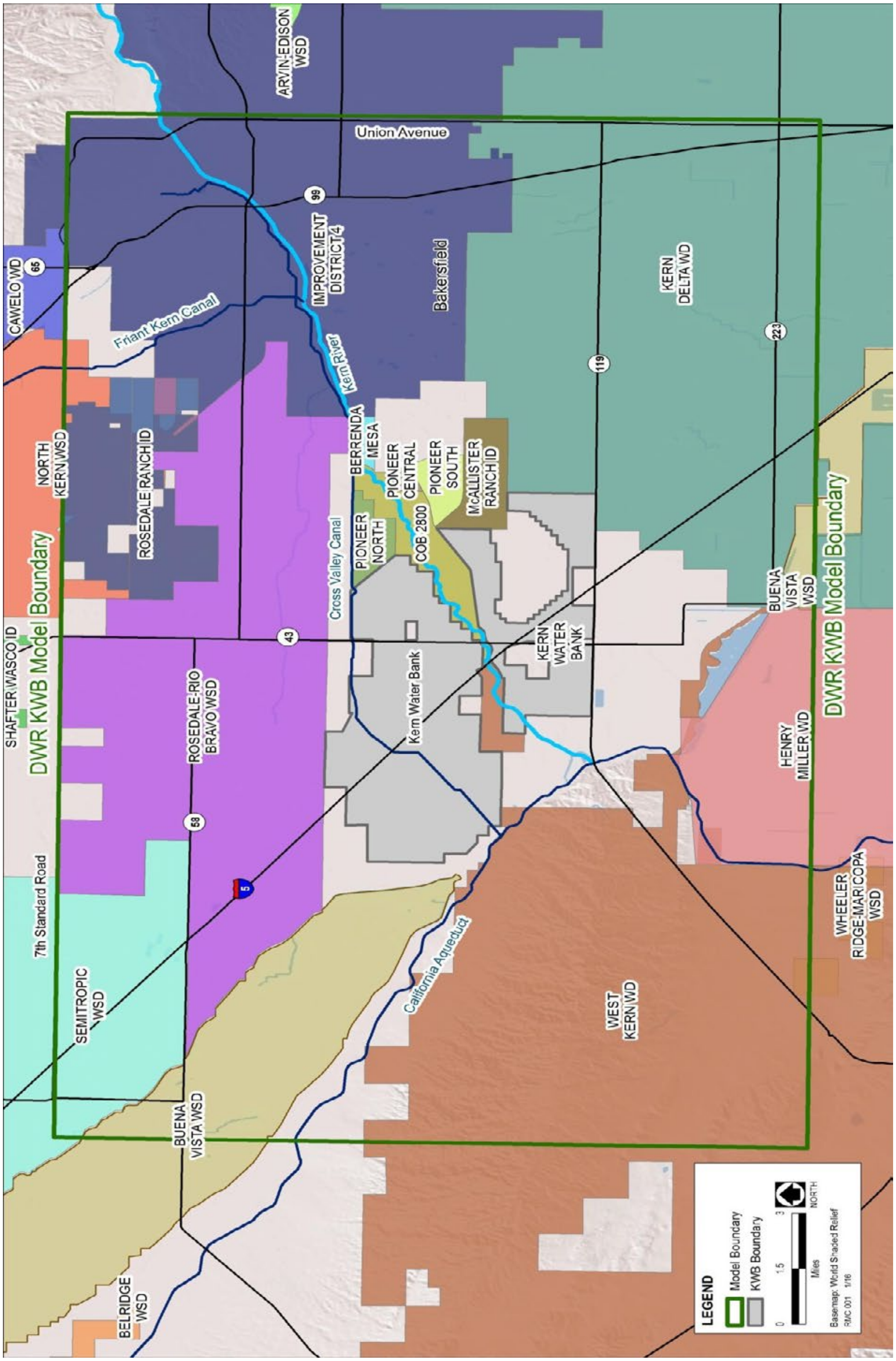
Data collection activities occurred between January 1 and November 1, 2015. The identification, collection, review, and analysis of multiple types of data were necessary to evaluate groundwater-flow model components. Collection activities focused on data available between 1984 and 2015, which was the time frame covered in the groundwater models being evaluated.

Data were collected in an area that included KWB Lands and the surrounding area ("study area") outward to a point where potential impacts from KWB activities would be minimal and/or speculative. The Elk Hills are located to the west and the City of Bakersfield is located to the east. The Kern River divides the northern and southern portions of the data collection area. The California Aqueduct, the KWB Canal, and the Cross Valley are three major canals that can serve KWB Lands (Figure 1.2-1).

1.3 OVERVIEW OF DATA TYPES AND SOURCES

The types of data collected and evaluated as part of this technical report encompass geology, soils/ lithology, hydrogeology, surface water hydrology, water supplies, climate, crop types/land use, topography, remote sensing, and groundwater recharge and recovery. Groundwater levels, groundwater quality data, and well construction information were extracted from database files provided by Kern County Water Agency (KCWA). Other types of data necessary for model evaluation and analysis were compiled into spreadsheets and summary tables. Information sources included:

- modeling data provided by the California Department of Water Resources (Department or DWR), Kern Water Bank Authority (KWBA), Rosedale-Rio Bravo Water Storage District (Rosedale), and the U.S. Geological Survey (USGS);
- information provided by KCWA, KWBA, and Rosedale through information requests by the Department and its consulting team;
- Kern Fan Monitoring Committee (KFMC) area operations and monitoring reports, 1995–2006 (all available reports);
- hydrologic and water quality data from large-scale databases maintained by DWR and KCWA;
- previous environmental documentation provided by the Department; and
- other data available from online sources.



Source: Data compiled by RMC in 2015

FIGURE 1.2-1. Study Area and Nearby Municipal and Agricultural Entities

2. GEOLOGY, HYDROGEOLOGY, AND HYDROLOGY DATA

The study area has been evaluated by geologists and hydrogeologists for more than 50 years, and extensive volumes of data are available. Additionally, new investigations that focus on both regional and site-specific issues are being initiated and performed on an ongoing basis, so that the knowledge of the local and regional setting is continually expanding. The primary investigations used to develop an understanding of the geologic, hydrologic, and hydrologic conditions of the study area include the following:

- Croft, M.G. 1972. *Subsurface Geology of the Late Tertiary and Quaternary Water-Bearing Deposits of the Southern Part of the San Joaquin Valley, California*. U.S. Geological Survey Water-Supply Paper 1999H (Croft 1972)
- DWR. 1990. *Kern Water Bank First Stage Kern Fan Element Feasibility Report, California* (DWR 1990)
- Faunt, C.C. (ed.). 2009. *Groundwater Availability of the Central Valley Aquifer, California.* U.S. Geological Survey Professional Paper 1766 (Faunt 2009)
- Page, R.W. 1986, *Geology of the Fresh Ground-water Basin of the Central Valley, California, with texture maps and sections*. U.S. Geological Survey Professional Paper 1401C (Page 1986)
- Williamson, A.K., D.E. Pudic, and L.A. Swain. 1989. *Ground-water Flow in the Central Valley, California Regional Aquifer-System Analysis—Central Valley, California.* U.S. Geological Survey Professional Paper 1401-D (Williamson et al. 1989)
- Available groundwater flow models and supporting documentation for the study area

2.1 GEOLOGY DATA

In addition to key reference documentation, a combination of well completion reports, geophysical logs, and pumping test data was reviewed for information on subsurface geologic conditions; well construction details, including well depth and screen interval; and hydrologic conditions, including aquifer characteristics, depth to groundwater, and estimated groundwater yield in the study area. A summary of these data sets is provided below.

<u>Well Completion Reports</u>

Reference: DWR 2015a

Data Source: DWR

Years of Data Available: 1936–2014

Study Relevance: Subsurface geology, groundwater levels, aquifer characteristics

Type of Data Collected: Geologic log and well construction details, including date of construction, well screen type and interval, total well depth and groundwater levels, and estimated yield.

Data Collection Equipment: Well completion report records completed by third parties and submitted to DWR.

Comments/Limitations to Data Use: Well completion reports are stored in a database maintained by DWR using the Public Land Survey System (Township, Range, and Section), with a cross reference to property ownership at time of drilling. A search for well completion reports was performed using Township, Range, and Section. Many older well completion reports can be located only by providing the property address and name of the owner at the time the well was drilled. A substantially more time-consuming evaluation of available well completion reports by property address or time of drilling was not performed. Any confidential well information obtained was reviewed and handled in accordance with California Water Code Section 13752.

Geophysical Well Logs

Reference: KCWA 2015a

Data Source: KCWA

Years of Data Available: 1990 to 2010

Study Relevance: Subsurface geology

Type of Data Collected: Geophysical well logs for 257 production wells in the study area. Geophysical well logs vary between gamma ray, electrical resistivity, and spontaneous potential logs. Some logs also contain plots of electrical conductivity (EC).

Data Collection Equipment: Wire-line geophysical probe and/or gamma ray tool.

Comments/Limitations to Data Use: Electrical resistivity logs measure the electrical properties of the geologic formations along with the formation fluids. Spontaneous-potential logs measure the differences in electrical potentials (voltages) that result from chemical and physical changes in the geologic materials. The spontaneous potential is measured between an electrode in the borehole and a grounded electrode at the land surface, which when coupled with the electrical resistivity log provides clues to permeability or porosity of the aquifer materials, the character and thickness of the various strata, and an indication of the water quality.

Aquifer Pump Test Data

Reference: KCWA 2015b

Data Source: KCWA

Years of Data Available: 1998–2009

Study Relevance: Aquifer characteristics

Type of Data Collected: Spreadsheets containing single-well pump test data and computations for 31 wells located within Improvement District No. 4 (ID4), Berrenda Mesa, and City of Bakersfield 2,800 Acre Groundwater Recharge project (2800 Acre Recharge Project) areas. Computations are based on the drawdown response to a pumping well and provide estimates of the hydraulic properties of the aquifer area around the well, including estimates of aquifer thickness, transmissivity, hydraulic conductivity, and well efficiency.

Data Collection Equipment: Electronic pressure transducers were used to collect water level data; no specific data were provided on production flow measurement equipment or data loggers.

Comments/Limitations to Data Use: Aquifer pumping test data were used to determine the transmissivity of the aquifer (and therefore hydraulic conductivity). Test results represent the average hydraulic properties of all the different material layers combined. Most pump test data were analyzed using the Cooper-Jacob method, a time-drawdown straight-line method used for confined aquifers**.** The pumping test data are important indications of the in situ parameter values of the aquifer materials. Potential limitations to the data with respect to use in modeling efforts are that the results are nonunique; that is, the data can often be interpreted to be from leaky, unconfined, and/or bounded systems.

2.1.1 GEOLOGIC SETTING

The San Joaquin Valley is a geographically significant structural depression that extends from the city of Stockton on the north to the Tehachapi Mountains on the south (Faunt 2009). The San Joaquin Valley basin is bordered to the south and east by the Tehachapi Mountains and Sierra Nevada, respectively, which are composed of crystalline igneous and metamorphic rock. Consolidated marine sedimentary rock from the Coast Ranges overlies the bedrock underlying the San Joaquin basin. The marine sedimentary rock is overlain by a thick series of continental rocks and semi-consolidated to unconsolidated sediments. The Kern Fan Element (KFE) overlies a large, deep, and asymmetrical sedimentary basin located in the southern portion of the San Joaquin Valley (DWR 2007). These sediments are several thousand feet thick under the KFE (DWR 2007).

The sediments in the eastern part of the San Joaquin Valley are predominantly coarse-grained, particularly along and associated with the major rivers and tributaries emerging from the Sierra Nevada. In the southern part of the valley; the alluvial fans derived from the glaciated parts of the Sierra Nevada are much coarser grained than the alluvial fans to the north. In contrast, the western San Joaquin Valley sediments are generally finer grained than the sediments along the eastern side of the valley and include the Corcoran Clay Member of the Tulare Formation, a fine-grained, laterally extensive horizon that retards vertical groundwater movement throughout the western part of the valley. These fine-grained textures reflect the nature of source material, which is predominantly shales and marine deposits of the Coast Ranges to the west of the basin. Furthermore, this finer grained texture may be related to the fact that the western side of the valley has lower elevation drainage basins and is drained internally, with no outlet for exporting the finer grained materials (Faunt 2009).

The southern San Joaquin Valley, including the study area, is dominated by the alluvial fan deposited by the Kern River, and consists of thick sand and gravel deposits with extensive but discontinuous silt and clay beds. These deposits are remnants of old streambed channels that generally occur in interconnecting stringers and sheets that are prevalent throughout KWB Lands, but are less evident along its borders. The silt and clay deposits are more extensive along the edges of the alluvial fan and in some areas may intersect with clay beds deposited in lakes (DWR 2007).

Hydrologically, the San Joaquin Valley is generally split into the San Joaquin Basin and the Tulare Basin (Faunt 2009). Geographically, the San Joaquin Basin is bounded on the east by the Sierra Nevada and on the west by the Coast Ranges. The Sacramento–San Joaquin Delta borders its northern extent and the internally drained Tulare Basin borders its southern extent. The dominant geographic feature is the San Joaquin River (Faunt 2009).

The Tulare Basin, which composes the geographic southern part of the San Joaquin Valley, is bounded by crystalline rocks of the Sierra Nevada to the east, crystalline rocks of the Tehachapi Mountains to the south and southeast, and Tertiary marine rocks of the Coast Ranges to the southwest (Page 1986; Faunt 2009; Harder 2011). The northern extent is less well-defined, but generally corresponds to the Kings River. Significant geographic features include the Tulare Lake Basin and the Kettleman Hills. The Tulare Basin was separated from the southern end of the San Joaquin Basin by the merging of alluvial fans from the Kings River to the east and Los Gatos Creek to the west (Faunt 2009).

The study area is located in the Tulare Basin. The structural depression in the Tulare Basin is filled with marine and nonmarine sediments that extend to depths of more than 20,000 feet below the Buena Vista Lake bed (Croft 1972). The deepest sediments were deposited within a marine environment associated with an inland sea that inundated the valley between 200 million years ago (Jurassic Period) and 2 million years ago (end of the Tertiary Period) (Croft 1972). The deeper marine sediments are overlain by approximately 2,400 feet of nonmarine continental deposits associated with Quaternary (2 million years ago to present) lacustrine and alluvial deposition (Planert and Williams 1995). The current depositional environment consists of multiple coalescing alluvial fans along the basin margins, with localized lacustrine deposits at the terminus of the fans in the central portion of the basin (Harder 2011). Until recently, multiple lakes have existed in the lowest portions of the Tulare Basin, including Tulare Lake, Goose Lake, Kern Lake, and Buena Vista Lake (Harder 2011).

The study area is located on the flat distal portions of the alluvial fan deposited by the Kern River as it flows out of the Sierra Nevada on the east side of the Tulare Basin. Land surface elevation ranges from approximately 400 feet above mean sea level on the east to approximately 300 feet above mean sea level on the west (with the exception of the Elk Hills). In general, the proportion of fine-grained sediments increases toward the terminus of the Kern River and in the southwest portion of the study area, where the depositional environment is dominated by lacustrine, marsh, and flood-basin deposits (Harder 2011).

Previously named geologic units of the Tulare Basin in the study area include, in order of youngest to oldest, Younger Alluvium and Basin Deposits, Older Alluvium, Tulare Formation, and the Kern River Formation. These units are discussed in detail in Section 2.1.3.

2.1.2 GEOLOGIC STRUCTURE

The primary structural feature of the Tulare Basin is the cross-valley White Wolf Fault, which is located at the base of the Tehachapi Mountains near the southern boundary of the basin. This is an active fault; the last major seismic event along the fault, a magnitude 7.2 earthquake, occurred in 1952 (Stein and Thatcher 1981). Before the 1952 earthquake, evidence of the White Wolf Fault was based solely on topography. However, surface ruptures in 1952 formed along nearly the entire 16.5-mile-long known course of the White Wolf Fault, mostly on or near its previously mapped trace. Most geologic evidence indicates that the latest movement on the White Wolf Fault has been left lateral and reverse along a somewhat steeply dipping reverse fault. Evidence of earlier offset (before 1952) is sparse, but left-lateral offset is suggested by subsurface Tertiary units.

Numerous other named and unnamed faults trend throughout the Tulare Basin and at least partially affect the structural controls of the basin. The Buena Vista Fault, located in the Elk Hills northeast of Taft, is likely the surface expression of prehistoric movement along a bedding-plane fault at depth, and may have been the source of the anticlinal growth that resulted in the Pleito Hills south of the KWB. Fault slip has likely occurred along a preexisting fault along which the underlying Plio-Pleistocene units have been offset. This fault continues to exhibit movement during historic time in the form of both slip and creep.

Across the Tulare Basin, on the eastern edge, are the Premier, Kern Front, and New Hope Faults. All three faults are westerly dipping, north-south striking, normal faults at the southern end of the western flank of the Sierra Nevada foothills. Historic fault creep has occurred along all three faults and displacement is actively continuing. The Premier Fault may be a locally discontinuous zone of historically active faults. The Kern Front is a prehistoric fault that dips toward an area of subsidence over the Kern Front oil field. Most of the New Hope Fault lies with the northwest portion of the Poso Creek oil field.

Other structural features in the Tulare Basin include the Bakersfield Arch and Elk Hills Anticlines. The Bakersfield Arch trends northeast-southwest and is approximately coincident with the current active channel of the Kern River. Some studies have suggested that the uplift that formed this anticline resulted in erosion of the Corcoran Clay in the study area. The Elk Hills Anticline is parallel to the long axis of the Elk Hills and is related to the uplift that formed the hills (Harder 2011).

2.1.3 NATURE OF SEDIMENTS

The unconsolidated alluvial and Plio-Pleistocene to Holocene sediments of the Tulare Basin region extend to depths of several thousand feet; however, the focus of this study and the dominantly affected sediments of the aquifer system underlying the KWB are generally considered to be within the uppermost approximately 1,000 feet of these sediments. The units composing this geologic section include the Younger and Older Alluvium, the Tulare Formation, and the Kern River Formation (Croft 1972; Page 1986; Negrini et al. 2008).

The southern San Joaquin Valley, including the study area, is dominated by the alluvial fan deposited by the Kern River, and consists of thick deposits of sand and gravel with extensive but discontinuous silt and clay beds. The sand and gravel deposits are remnants of old streambed channels that generally occur in long, winding, and interconnecting sheets that are prevalent throughout KWB Lands, but less evident along their borders. These sand and gravel deposits are highly permeable, but are imbedded with less permeable areas comprised of fine-grained silt and clay deposits. The silt and clay deposits are more extensive along the edges of the alluvial fan and in some areas may intersect with clay beds deposited in former lakes.

In general, in the western portion of the Bakersfield Arch, the upper 1,000 feet of alluvial sediments in the study area consist of a highly stratified sequence of more permeable sand and gravel interbedded with silt and clay. No significant laterally extensive fine-grained units (i.e., silt and clay) were observed (Harder 2011).

2.1.3.1 Younger Alluvium and Basin Deposits

This Holocene-age unit varies in character and thickness around the subbasin. At the subbasin's eastern and southern margins, the unit is composed of up to 150 feet of interlayered and discontinuous beds of clay, silt, sand, and gravel. In the southwestern part of the basin, the material is finer grained as it grades into fine-grained basin deposits underlying the historic beds of Buena Vista and Kern Lakes (Hilton et al. 1963; Wood and Dale 1964). The basin deposits consist of silt, silty clay, sandy clay, and clay interbedded with poorly permeable sand layers. These basin deposits are difficult to distinguish from underlying fine-grained older alluvium and the total thickness of both units may be as much as 1,000 feet (Wood and Dale 1964).

2.1.3.2 Older Alluvium/Stream and Terrace Deposits

This unit is composed of up to 250 feet of Pleistocene-age lenticular deposits of clay, silt, sand, and gravel that are loosely consolidated to cemented and are exposed mainly at the basin's margins (Hilton et al. 1963; Wood and Davis 1959; Wood and Dale 1964). This sedimentary unit is often indistinguishable from the Tulare and Kern River Formations below it (DWR 2006; Harder 2011).

2.1.3.3 Tulare Formation

In the extreme southwestern part of the San Joaquin Valley and along most of its western flank, the unconsolidated continental rocks and deposits make up the Tulare Formation, which in many places is overlain by younger deposits. There, the continental rocks and deposits dip gently northeastward beneath the valley. Woodring et al. (1940) defined the Tulare Formation as the youngest folded strata exposed in the Kettleman Hills.

The Tulare Formation conformably overlies the San Joaquin Formation in the Kettleman Hills and in the subsurface to the east, but where it is exposed elsewhere in the Coast Ranges, it generally lies unconformably on Pliocene and older formations. In the southwestern part of the San Joaquin Valley, the exposed Tulare Formation ranges in thickness from a few tens of feet to more than 4,000 feet (Wood and Dale 1964:39). Northward from the Elk Hills to the Kettleman Hills, the exposed Tulare Formation ranges in thickness from a few tens of feet along the western flank of the valley to about 3,500 feet in the Kettleman Hills (Wood and Davis 1959:23; Woodring et al. 1940:14).

The formation is of Plio-Pleistocene age and represents a west/east facies change across the basin. In the western part of the basin, the Tulare Formation contains up to 2,200 feet of interbedded, oxidized to reduced sands; these are gypsiferous clays and gravels derived predominantly from sources in the Coast Ranges. The formation includes the Corcoran Clay Member, which is present in the subsurface from the Kern River Outlet channel on the west through the central and much of the eastern subbasin at depths of 300–650 feet (Croft 1972).

The Tulare Formation dips eastward under the alluvium in the study area and interfingers with the upper portion of the Kern River Formation in the subsurface. The Tulare Formation is exposed in the Elk Hills, where it consists of interbedded mudstones and pebbly sandstones (DWR 1972).

The Corcoran Clay is a significant deposition that forms an extensive, confining stratum throughout much of the western portion of the basin (Croft 1972; DWR 2007). It is generally very fine-grained (Page 1986; Burow et al. 2004); however, isolated, coarser zones are apparent from drillers' logs, particularly where the clay is less than 20 feet thick (Page 1986). Laboratory tests indicate that the clay is highly susceptible to compaction (Williamson et al. 1989; Bertoldi et al. 1991; Gronberg and Belitz 1992).

The deposits below the Corcoran Clay are generally finer grained than those above. Although the area below the Tulare Lake bed usually is thought of as a clay plug, borings that have extended below the base of the Corcoran Clay near the Tulare Lake bed record alternating series of sands and clays (coarse- and fine-grained sequences). As a result, the lower deposition shows a relatively coarse-grained area in the southern part of the Central Valley (Faunt 2009).

Lacustrine and marsh deposits crop out in the San Joaquin Valley beneath the Buena Vista, Kern, and Tulare Lake beds, and along the western flank of the valley just west of Los Banos. The Tulare Lake bed is a distal part of an alluvial-fan deposit derived from the Coast Ranges (Page 1983). Some fine-grained beds probably include flood-basin deposits.

2.1.3.4 Kern River Formation

The Miocene to Pleistocene Kern River Formation, as described by Bartow and Pittman (1983), outcrops from Caliente Creek northward to the vicinity of Terra Bella on the east side of the San Joaquin Valley. It consists of a westward dipping and thickening sequence of sandstones and conglomerates with interbedded siltstone and mudstone. The Kern River Formation is generally thought to reflect alluvial fan deposition (based on its similarity to the modern Kern River alluvial fan), although the upper portion may be predominantly of glaciofluvial origin (Graham et al. 1988).

The Kern River Formation includes 500–2,000 feet of poorly sorted, lenticular deposits of clay, silt, sand, and gravel derived from the Sierra Nevada (Hilton et al. 1963). Where it crops out, the Kern River Formation consists mostly of pale-yellow to light-brown sandstone and conglomerate with interbeds of greenish-gray or greenish-brown siltstone and mudstone. The deposits are generally poorly sorted and crudely bedded, although medium- and large-scale trough crossbedding is common. The sediments were deposited in a fluvial environment, probably braided river channels for the most part. Some of the thicker siltstone or mudstone interbeds may represent the deposits in small ephemeral lakes or ponds (Page 1983).

2.1.4 SUBSIDENCE

In California, subsidence is caused primarily by the dewatering and subsequent compaction of unconsolidated clay and silt deposits within the groundwater aquifer, oil extraction or dewatering, and subsequent decomposition of organic soils (Sneed et al. 2013). In the San Joaquin Valley, subsidence results mainly from groundwater consumption. Between 1926 and 1970, some areas of Kern County experienced subsidence of only up to 11.8 feet, whereas subsidence of more than 50 feet was common in other areas of the San Joaquin Valley (Sneed et al. 2013).

Subsidence can have significant impacts on infrastructure and has resulted in expensive damage to structures, including aqueducts, roads, bridges, buildings, and well casings. Subsidence-related damages and repairs include the loss of capacity for canals to convey and deliver water or remove floodwaters; realignment of canals as their constant gradient becomes variable; raising of infrastructure such as canal check stations; and releveling of furrowed fields, many of which are laser-leveled for maximum irrigation efficiency. The California Aqueduct, Delta-Mendota Canal, Outside Canal, Friant-Kern Canal, San Luis Canal, State Route 198, and other infrastructure in the San Joaquin Valley have all undergone repairs and modifications (Sneed et al. 2013; LSCE et al. 2014a).

Sneed et al. (2013) gathered current information about subsidence, groundwater levels, and measurement methods, particularly regarding issues associated with impacts on the Delta-Mendota Canal, and presented a discussion of relationships between subsidence occurrence and groundwater levels. Luhdorff & Scalmanini Consulting Engineers, Borchers, and Carpenter (LSCE et al. 2014a, 2014b) analyzed land subsidence from groundwater use in California (2014b) and specifically in the San Joaquin Valley (2014a), reporting on groundwater extraction, subsidence measurements, major areas affected by subsidence, and the effects of subsidence on infrastructure. Earlier (pre-1980) reports on subsidence attributable to groundwater and oil extraction related to the California Aqueduct system were presented by Ireland, Poland, and Riley in 1984.

As early as 1950, the Department started installing and monitoring borehole extensometers (i.e., compaction recorders) in wells throughout the San Joaquin Valley to monitor subsidence (Sneed et al. 2013). By the end of the 1960s, the subsidence monitoring network consisted of 31 extensometers operating at 21 sites, but the network was reduced to 26 extensometers at only 18 sites by the 1980s. A new regional monitoring network is currently being developed. By 2010, there were only six extensometers operating at five sites, 21 had been discontinued, and one had been constructed. By 2012, four were refurbished and measurement frequency was increasing.

As of 2014, subsidence was occurring in seven basins within the Tulare Lake Hydrologic Region. Historical and recent subsidence nearest the study area in the Kern County Subbasin has been most severe in areas just northwest of Mettler, California, near Maricopa Road (i.e., the Arvin-Maricopa area) because of oil field and groundwater extraction, and in areas north of Bakersfield (i.e., the Tulare-Wasco area) because of groundwater extraction (Ireland et al. 1984; DWR 2014b). The majority of the Taft and Maricopa economy is directly influenced by the petroleum industry. The Midway-Sunset Oil Field is the third largest in the United States and has produced approximately 2.8 billion gallons of crude oil (KCWA 2011). Although severe drought conditions in the San Joaquin Valley have spurred increased groundwater pumping, which has renewed subsidence of several feet in some parts of the valley (Sneed et al. 2013), the KWB has been one of the exceptions (KWBA 2015). It is likely that the lack of subsidence has been prevented through significant aquifer recharge by the KWB, more than has been recovered, and because the KWB aquifer does not contain a significant volume of sediments susceptible to compaction (clays and fine silts) (KWBA 2015).

KWBA has granted permission to the Department to access KWB Lands to continue the monitoring and maintenance of four extensometers that make up the Subsidence Monitoring Network of the Kern Fan. Extensometers correspond to Sections 16L1, 16L2, 16L3, and 16L4 of T30S, R25E. The Department monitors the network to determine whether operations are causing subsidence damage to the adjacent reach of the California Aqueduct, and provides KWBA with copies of all information DWR collects. Since June 1994, DWR has independently maintained and monitored one extensometer and three transducers in well T30S, R25E-16L-1 on KWB Lands, adjacent to a triple completion monitoring well. Monitoring began before any recovery operations, such that it would allow for tracking of land-surface elevation recovery and subsidence. A description of the data set and the subsidence data available in the study area is provided below.

Extensometer Subsidence Data

Reference: DWR (2015b)

Data Source: DWR

Years of Data Available: 1994-2015

Study Relevance: Subsidence

Type of Data Collected: Borehole bottom / ground surface elevations.

Data Collection Equipment: Cable extensometer connected to data recorder. Instrumentation can detect changes in land surface elevations to 1/1000 of a foot on a daily basis.

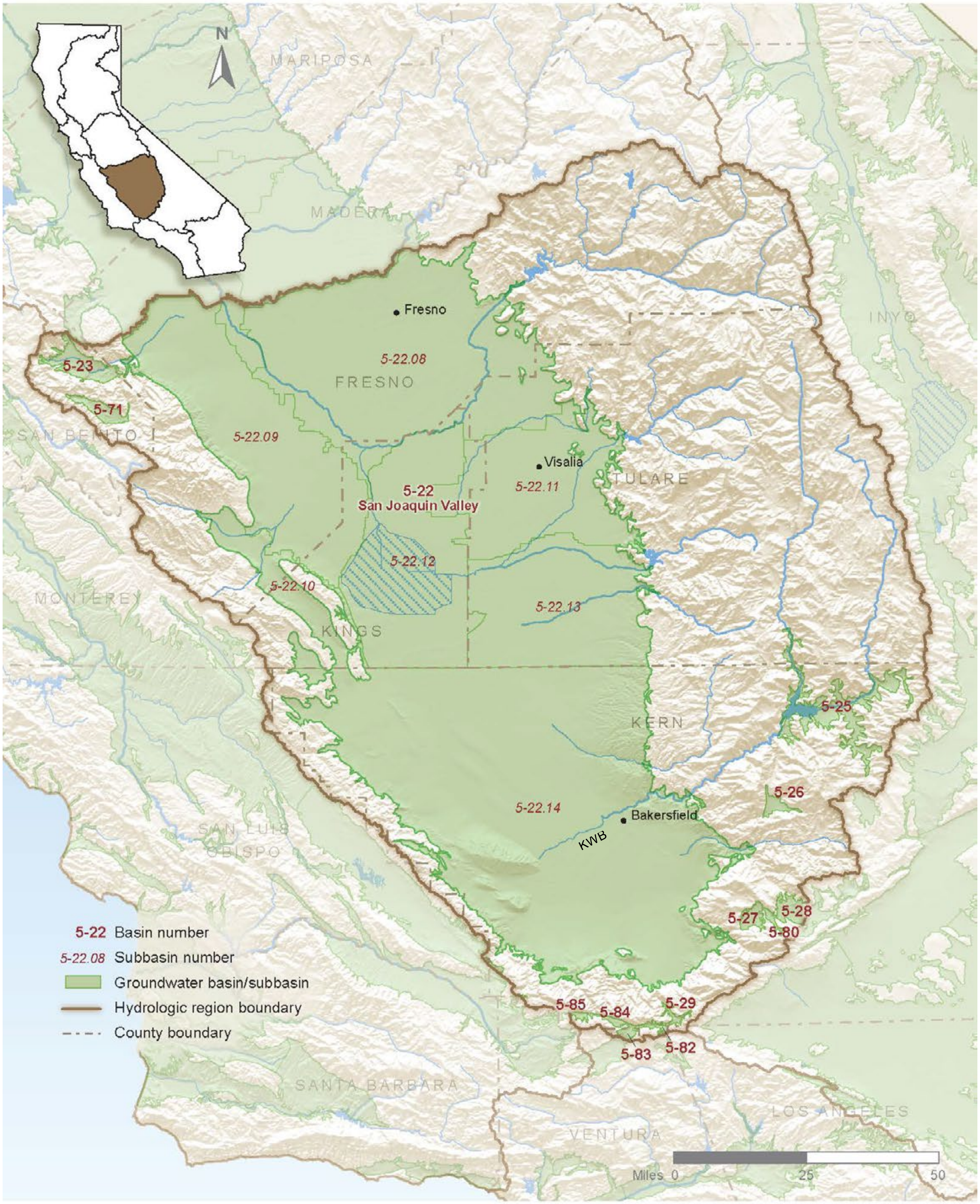
Comments/Limitations to Data Use: The KWB extensometer is part of a multi-completion monitoring well complex (T30S, R25E-16L-1,-2, -3, and -4) that allows for evaluation of subsidence, groundwater level fluctuation, and the physical properties of the various aquifer systems located within the study area.

Periodic measurements of 28 benchmarks distributed throughout the Kern Fan area have been used to monitor elevations of the land surface (KCWA 1996). The benchmark network in the San Joaquin Valley has grown irregularly since the early 1900s and is surveyed by the National Geodetic Survey only periodically. Control benchmarks are concentrated in three subsidence areas (Los Banos–Kettleman, Tulare-Wasco, and Arvin-Maricopa), with roughly 12 stable bedrock reference benchmarks around the perimeter of the valley (Ireland et al. 1984).

2.2 HYDROGEOLOGY DATA

The study area is located within the Kern County Subbasin of the San Joaquin Valley Groundwater Basin of the Tulare Lake Hydrologic Region (Figure 2.2.1). It is designated Groundwater Basin Number 5-22.14, with a surface area of 3,040 square miles (1,945,000 acres) (DWR 2006). The Kern County Subbasin lies at the south end of the San Joaquin Groundwater Basin (DWR 2007).

The aquifers are generally quite thick in the subbasins of the San Joaquin Valley Groundwater Basin, with groundwater wells commonly exceeding 1,000 feet in depth. The maximum thickness of freshwater-bearing deposits (4,400 feet) occurs at the southern end of the San Joaquin Valley (DWR 2003).



Source: Department of Water Resources, CWP 2013

FIGURE 2.2.1. Tulare Lake Hydrologic Region

2.2.1 GENERAL AQUIFER CHARACTERISTICS

The aquifer system in the study area is characterized by lenticular sand and gravel deposits of varying thickness and lateral extent that are separated by less permeable deposits of silt and clay (Harder 2011). Page (1973) mapped the base of freshwater in the Kern River Fan area using available electric logs, and defined freshwater as having a conductivity of less than 3,000 micro-mhos per centimeter. He showed that the base of freshwater varies from an elevation of about -2,800 feet below mean sea level near the eastern edge of the study area to about elevation -800 feet below mean sea level adjacent to Elk Hills (DWR 1990).

The hydrogeology of KWB Lands above the base of freshwater is dominated by the alluvial fan that has been deposited by the Kern River. The Kern River Fan is a large composite alluvial fan extending across the southern San Joaquin Valley from near Bakersfield to the Elk Hills. The alluvium of the fan has been informally divided into older and younger units. The older alluvium dips westward under the younger alluvium of the present fan and probably corresponds to the “gravel lentil” identified by Wood and Dale (1964). The alluvial fan’s depositional system consists of thick deposits of sand and minor gravel with extensive but discontinuous silt and clay beds (DWR 1990).

The Elk Hills, located in the southwest portion of the study area, have been mapped as Quaternary semi-consolidated rocks and are likely part of the Tulare Formation. Given the lack of production wells in the area, they are assumed to consist of low-permeability sediments (Harder 2011).

In the western portion of the study area, fan deposits of the Kern River interfinger with those of ephemeral western streams that have deposited larger material, with some beds containing coarse gravel. The sand and gravel occur in sinuous and interconnected stringers and sheets that can be found throughout the fan and were deposited by active stream channels. These highly permeable deposits are interbedded with less permeable silt and clay units representing overbank, deltaic, and possibly lacustrine deposits.

Deep (about 700 feet) monitoring wells were constructed on KWB Lands and in the adjacent 2,800 Acre Recharge Project area. The fluvial nature of the depositional system lends tentative correlations in two areas. The first is a distinctive cemented zone identified in geologists’ logs in the area north of the Kern River. The second is a zone of low-permeability material at a depth of about 200 feet that seems to be relatively continuous beneath the western half of the 2,800 Acre Recharge Project area (DWR 1990).

In the area along the Kern River and to the south, the upper 200–300 feet of the aquifer system is dominated by thick, rather massive sand units. Most production wells are screened in a zone 250–700 feet deep and directly tap the deeper portions of this high-transmissivity zone. Interbedded with these upper sands are less extensive and generally less massive deposits of silty and clayey material (DWR 1990).

Hydrographs and water quality data suggest that hydraulic communication between the shallow and deep zones declines to the west (DWR 1990).

A larger anomalous area is located in the area near the intersection of the Kern River and Interstate *5.* The monitoring wells in this area suggest very low transmissivity and highly confined conditions. Specific capacity values from nearby production wells also indicate low transmissivity in the area (DWR 1990).

2.2.1.1 Aquifer Type

Sediments that comprise the shallow to intermediate-depth water-bearing deposits in the Kern County groundwater subbasin are primarily continental deposits of Tertiary and Quaternary age. From oldest to youngest, the deposits include the Tulare Formation (western subbasin) and its eastern subbasin equivalent, the Kern River Formation; older alluvium/stream deposits; and younger alluvium and coeval flood-basin deposits. Specific-yield values for the unconfined aquifer (Tulare and Kern River Formations and overlying alluvium) were compiled from two sources. Estimates by DWR's San Joaquin District office (DWR 2006) range from 5.3 to 19.6 percent and average 11.8 percent for the interval from surface to 300 feet below ground. The DWR (1977) groundwater model of Kern County listed the range as 8.0 to 19.5 percent, with an average value of 12.4 percent, representing an interval thickness of 175–2,900 feet and averaging approximately 600 feet. The greatest thickness of unconfined aquifer occurs along the eastern subbasin margin. The highest specific-yield values are associated with sediments of the Kern River Fan west of Bakersfield (DWR 2006).

The Younger Alluvium/Flood Basin Deposits, Holocene-age unit varies in character and thickness around the subbasin. At the eastern and southern subbasin margins, the unit is composed of up to 150 feet of interstratified and discontinuous beds of clay, silt, sand, and gravel. In the southwestern subbasin, it is finer grained and less permeable as it grades into fine-grained flood basin deposits underlying the historic beds of Buena Vista and Kern Lakes in the southern subbasin (Hilton et al. 1963; Wood and Dale 1964). The flood-basin deposits consist of silt, silty clay, sandy clay, and clay interbedded with poorly permeable sand layers.

The Older Alluvium/Stream and Terrace Deposits unit is composed of up to 250 feet of Pleistocene-age lenticular deposits of clay, silt, sand, and gravel that are loosely consolidated to cemented, and are exposed mainly at the subbasin's margins. The unit is moderately to highly permeable and yields large quantities of water to wells (Hilton et al. 1963; Wood and Davis 1959; Wood and Dale 1964). This sedimentary unit is often indistinguishable from the Tulare and Kern Formations below and, together with these underlying formations, forms the principal aquifer body in the Kern County groundwater subbasin (DWR 2006).

Unconfined/Semi-Confined

In general, the upper layers of the alluvial fan deposits form an unconfined to semi-confined aquifer system that provides a large amount of groundwater recharge area (DWR 2007). The upper saturated sediments are likely unconfined (Harder 2011).

Confined

A significant hydrogeological feature in parts of the Kern County subbasin is the Corcoran Clay, or the so-called E clay of the Tulare Formation (Croft 1972). This clay layer divides the aquifer system into two distinct aquifers, an unconfined to semi-confined upper aquifer above the clay layer and a confined aquifer below it. However, the clay layer is not laterally continuous across the subbasin, being absent in the eastern part of the basin as it interfingers with the Kern River Formation (Croft 1972).

2.2.1.2 Aquifer Properties

The sediments of the Central Valley compose an aquifer system comprising confining units and unconfined, semi-confined, and confined aquifers. This aquifer system generally consists of alluvial deposits shed from the surrounding Sierra Nevada and Coast Ranges. The chief source of groundwater in the Central Valley is located within the upper 1,000 feet of deposits (Page 1986). The aquifers are generally characterized by highly permeable, discontinuous lenses of sand and gravel deposits of variable thickness, interbedded with less permeable lenses of fine-grained silts and clays. As described previously, the uppermost portion of the aquifer (above approximately 150 feet) is generally unconfined; below 150 feet, to the Corcoran Clay where present, the aquifer is generally semi-confined. With depth, and below the Corcoran Clay, the aquifer is generally confined.

Transmissivity

Transmissivity is a measure of the ability of groundwater to flow within an aquifer and is defined as the rate at which groundwater flows through a unit width of aquifer under a unit hydraulic gradient (Fetter 1994). Multiple sources of data for estimating transmissivity were obtained, reviewed, and analyzed, including previous modeling efforts (DWR 1995), studies (KWBA 1997; Harder 2011), and KCWA pumping test records.

Generally, aquifer transmissivity in the vicinity of the Kern River east of KWB Lands is in the range of 200,000–600,000 gallons per day per foot (Harder 2011). Transmissivity values in the western part of KWB Lands tend to be somewhat lower, in the range of 50,000–200,000 gallons per day per foot (KWBA 1997; Harder 2011).

Specific Yield and Specific Storage

When water is drained from a saturated material under gravity, the material releases only part of the total volume stored in its pores. The quantity of water that a unit volume of unconfined aquifer gives up by gravity is called the unconfined aquifer’s specific yield. Throughout KWB Lands, the specific yield values of the unconfined portion of the aquifer (generally above 150 feet) are in the range of 0.14 to 0.20 percent (DWR 2006).

Specific storage is the volume of water that a confined aquifer can release from, or take into, storage per unit surface area of aquifer per unit change in hydraulic head. The storativity of an aquifer is the specific storage times aquifer thickness, and is generally derived in long-term pumping tests where pumping interference is measured in a monitoring well located a known distance from the pumping well. Storativity values for KWB Lands range from 6e-07 to 2e-03 (Harder 2011; Amec 2015).

Hydraulic Conductivity

Thousands of large-diameter irrigation wells perforated in the aquifers above and below the Corcoran Clay have increased the hydraulic connection between these aquifers and have substantially increased the equivalent vertical hydraulic conductivity of the aquifer system (Williamson et al. 1989; Bertoldi et al. 1991; Gronberg and Belitz 1992).

In general, the valley deposits compose an aquifer system characterized by large variations in properties. The water-transmitting properties of the aquifer sediments, as represented by hydraulic conductivity and vertical anisotropy, are functions of lithology and differ according to grain size and the degree of sorting of the sediments.

The hydraulic conductivity (K) of an aquifer is a function of the aquifer transmissivity and aquifer thickness. Based on pumping test data from wells with known or estimated aquifer thickness, the estimated K values of the confined production zones throughout KWB Lands are typically in the range of 10–300 feet per day, with an average of approximately 50 feet per day (DWR 2006).

Well Yield

Typical well yields in KWB Lands are in the range of 2,400–5,000 gallons per minute (DWR 1990).

2.2.1.3 Groundwater Flow and Movement

Groundwater flow direction and hydraulic gradient vary in the study area according to artificial recharge and recovery. Generally, groundwater in KWB Lands flows from northeast to southwest, following regional topography. Before the start of KWB operations and the Pioneer Project and during periods when artificial recharge exceeds pumping, groundwater generally flows away from the Kern River; that is, recharge (both natural and artificial) to the river creates a sustained groundwater divide along the river stretch. The exception to this is in the southwestern portion of the study area, where groundwater flows north toward the river.

2.3 HYDROLOGY DATA

This section generally describes the components of the hydrologic cycle and the water balance data across the study area, including natural and imported surface water; groundwater recovery and exports; precipitation; and losses from evaporation, evapotranspiration (ET), and migration.

Comprehensive data collection, monitoring, and reporting of hydrologic conditions, water supply, and groundwater banking activities throughout the study area are performed by the Kern Fan Monitoring Committee and KCWA. These two data sets are described below. Figure 2.3.1 shows the KWB facilities and nearby groundwater banking projects.

<u>Kern Fan Operations and Monitoring Reporting</u>

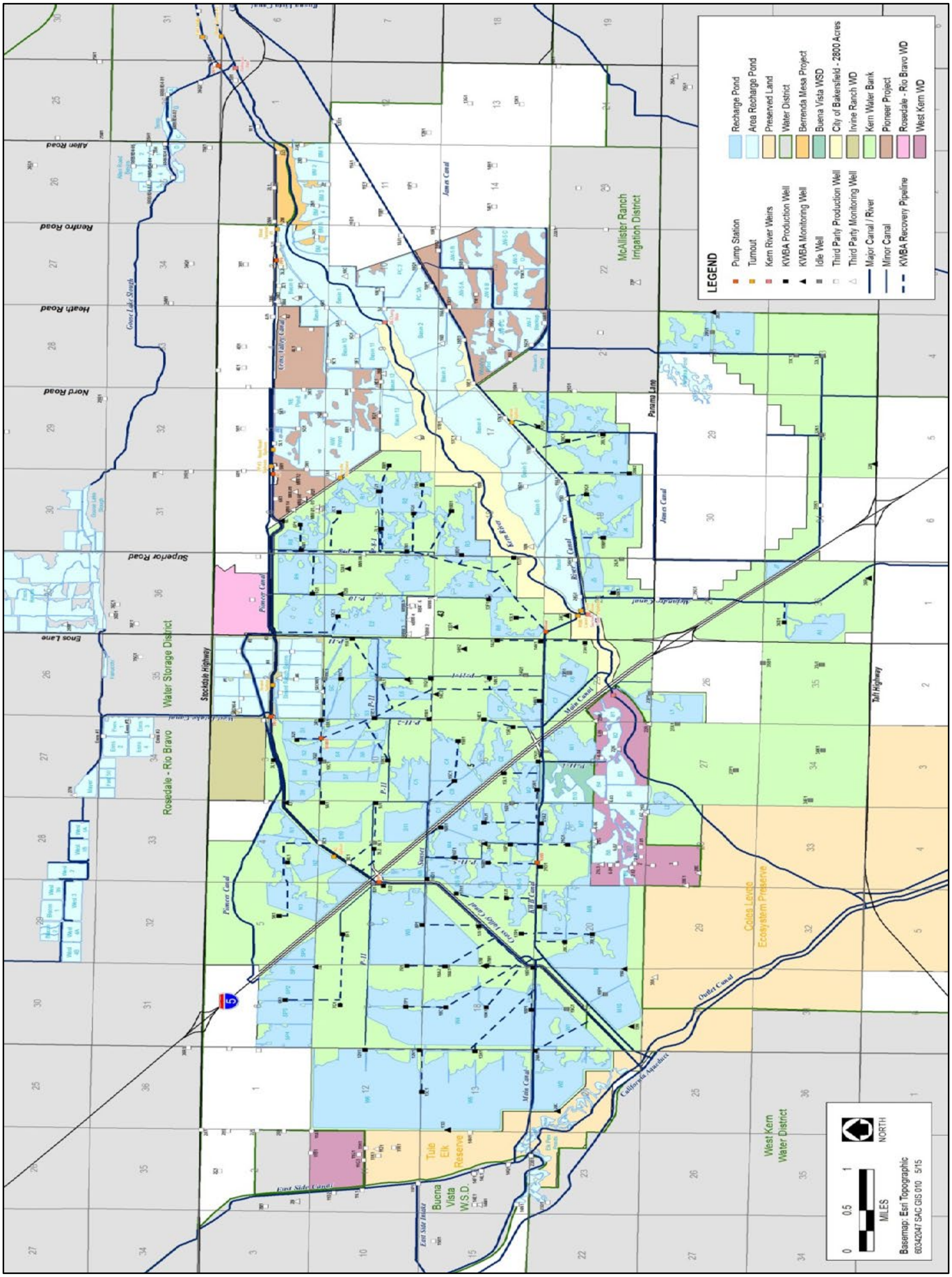
Reference: KCWA 1995a, 2005, 2007, 2009, 2013

Data Source: Kern Fan Monitoring Committee, KCWA (data from KFMC)

Study Relevance: Local banking program operations and deliveries, groundwater quality, subsurface flow, local water balances.

Years of Data Available: 1995, 1996–2000, 2001, 2002–2004, 2005–2006; unpublished interpretive studies data for the 2006–2010 report (in press); unpublished spreading program delivery data for 1995–2012 (The term “spreading” has been used in some recharge project descriptions and is retained here but means “recharge.")

Type of Data Collected: 1) Kern Fan water banking operations and monitoring programs, including annual and cumulative summaries of recharge and recovery banking and overdraft correction operations by project facility and participant and surrounding areas. Recharge spreading program deliveries are summarized by physical source, location, and participant. Kern Fan waterbank facilities and locations included in the reports are Berrenda Mesa, Pioneer, the 2,800 acres, KWB, Poso Creek (Poso Creek is an ephemeral stream downstream of the Friant-Kern Canal crossing), and the Kern River channel. In 2005, the spreading program data for the Pioneer Project was further divided into the Pioneer North, Pioneer Central, and Pioneer South facilities. In 2011, the Second Point of Measurement (a measurement point on the Kern River near Enos Lane) was added to the spreading program summaries; 2) Hydrograph data and interpretive studies with maps displaying areas of facilities utilization, groundwater quality, surface elevation, direction of flow, and changes in water levels. An annual water balance estimate and analysis is also provided; 3) Water quality data are included, along with evaluations of water quality constituents and areas of concern, salt balance ratios for spreading programs and recovered water supplies, and water quality blending operations for Pump-in water to the California Aqueduct. In some instances, water quality statistical trends through 2009 are provided for select monitoring wells.



Source: Data compiled by KWBA in 2015

FIGURE 2.3.1. KWB Facilities and Nearby Groundwater Banking Projects

Data Collection and Equipment: Flow measurements for the Kern Fan monitoring reporting are performed by the following entities:

- *DWR*—deliveries from the California Aqueduct to the KWB Canal and Cross Valley Canal (CVC)
- *Friant Water Users Authority*—deliveries from the Friant-Kern Canal turnouts into the Kern River channel, Arvin Edison Canal, and Poso Creek
- *City of Bakersfield*—Kern River flows to River Canal and KWB Canal turnouts/inlets, and other deliveries above (east of) the Second Point
- *KCWA*—deliveries from the California Aqueduct, Arvin Edison Canal, and Calloway Canal, and diversions out of the Cross Valley Canals to other local canals
- *Buena Vista Water Storage District (WSD)*—Kern River flows from the Second Point to the Kern River Intertie Basin, including deliveries via the Cross River Pipeline
- *Arvin Edison WSD*—inflows from the Friant-Kern Canal and outflows to the CVC

The entities conveying and receiving the water reconcile monthly spreading volumes as inflow and outflow. KCWA is responsible for collecting recharge inflow measurements to the KWB facilities.

Flow measurements are taken at weirs, turnouts, siphons, pumps, bridge trestles, laterals/canals, and recharge basins. Measuring devices include propeller meters, sharp-crested weirs, Parshall flumes, rated gate openings on pipes, and simple board constrictions/devices.

Water quality sampling of KWB monitoring wells occurs using a purge pump unit (which purges the well of standing water). California Aqueduct and KWB Canal water quality samples are collected in accordance with DWR Pump-in Policies and/or DWR sampling protocols.

Comments/Limitations to Data Use: Data collected and reported by the KFMC for the years 2007–2014 are unpublished. The data consists of maps and hydrographs depicting changes in water levels. Because of transfers, exchanges, and in-lieu recharge activities, spreading programs data may not depict the “legal source/location” of monthly recharge supplies for a particular banking project or participant. Tables in available reports also do not account for all banking projects described in every district’s memorandum of understanding (MOU). Data adjustments for physical source and location to legal source and location, and associated losses are only available for 1995–2006.

Kern County Water Agency Water Supply Reports

Reference: KCWA (1984–2011)

Data Source: KCWA (data from local water districts)

Study Relevance: Water accounting, watershed information, rainfall, and evaporation

Years of Data Available: 1984–2011 annual reports.

Type of Data Collected: 1) Inventory of water resources for the San Joaquin Valley portion of Kern County, comprising data on supplies, applied use, depletions including groundwater exports out of the county, and groundwater basin storage. Data include State Water Project (SWP) deliveries/exchanges and Central Valley Project (CVP) deliveries for Kern County entities, and regulated and natural flow volumes for the Kern River at specific sites; 2) Annual salt load from imported water supplies for the Kern Subbasin; 3) Recycled and oil field-produced water supplies.

Also provided are flows in the Kern River through the California Aqueduct Intertie, water contributions by watershed group, and runoff from all minor streams. Surface water and groundwater usage, and changes in groundwater storage are summarized.

Monthly rainfall and evaporation at selected stations throughout the county and effective annual precipitation are compiled. The reports includes a series of hydrographs and maps displaying groundwater quality, surface elevation, and changes in water levels. A summary of data on Kern County groundwater banking activities, including recharge/purchases, recovery/sales, and storage balances, is also provided. In addition, the reports present total countywide recharge volumes recorded as part of groundwater overdraft correction and replenishment programs.

Comments/Limitations to Data Use: 1) The water supply reports rely on outside data from other districts and cannot be published until all information is received. Data for 2012, 2013, and 2014 are unavailable. The most recent report, 2011, described a very wet year and is not representative of current drought conditions; 2) Volumes associated with water banking activities for the KWB, 2,800 Acre Recharge Project facility, and Pioneer Project are all reported as a combined volume rather than individually for 1971–1985, but annual volumes for the KWB from 1986–2011; 3) Municipal and industrial water, operational spill water, and nonproject water delivered via the CVP is combined in most years; 4) Volumes of Kern River water are not reported below Second Point; 5) Salt loading from imported water into the basin is reported as an annual tonnage and are not broken out by water source type for most years; 6) Exports of groundwater out of the county are combined, rather than by individual banking program.

2.3.1 SURFACE WATER HYDROLOGY AND CONVEYANCE

A variety of surface water sources are available in the study area for consumptive use and water banking purposes. Water recharged in Kern Fan banking facilities comes from three main sources: the SWP, the CVP, and the Kern River. An extensive surface-water conveyance network comprising lined and unlined canals, piping, and agricultural ditches transports surface water from the major water sources to recharge facilities (Figure 2.3.2). The following sections further describe surface water hydrology, supply conditions, and associated data availability in the study area.

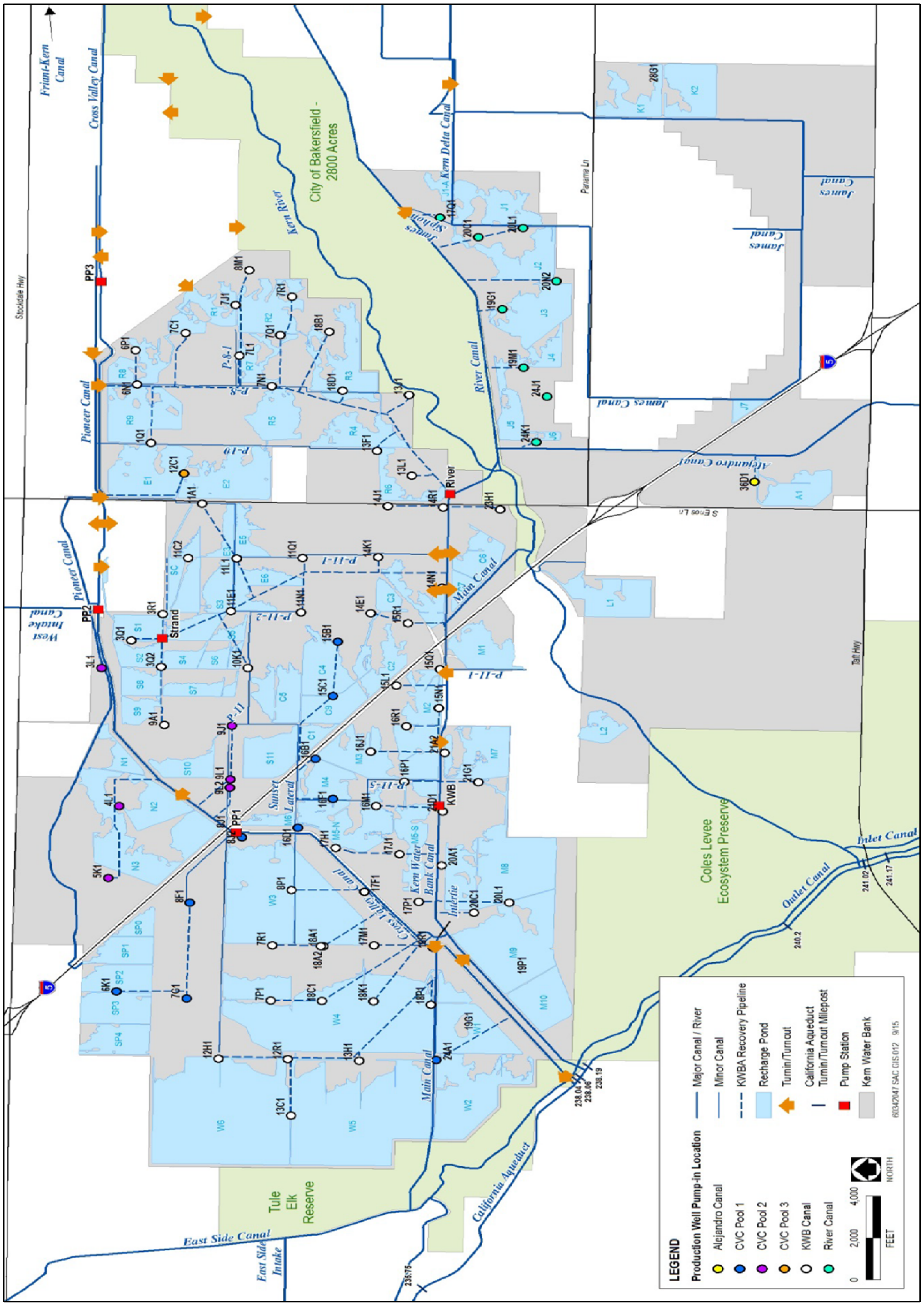
2.3.1.1 State Water Project (California Aqueduct)

The SWP is a complex system of reservoirs, dams, power plants, pumping plants, pipelines, and aqueducts. The 444-mile-long main aqueduct (California Aqueduct) conveys water to the mainly agricultural lands of the San Joaquin Valley and the urban regions of Southern California. The KWB Canal (operated by KWBA) and the CVC (operated by KCWA) transport water from the California Aqueduct (Aqueduct) to most of the water banking projects in the study area and convey recovered water back into the Aqueduct. Water recovered from the KWB can be delivered to KWB participants located south of the KWB via the California Aqueduct, or to participants located north of the KWB via upstream exchange with SWP water in the Aqueduct. Permanent “turnouts” provide water from the Aqueduct to subsequent water district canals/pipelines. DWR meters and measures the volumes of water delivered from or into the Aqueduct, with meter requirements within 2 percent accuracy.

<u>Water Deliveries to and from the California Aqueduct</u>

Reference: DWR (2015c)

Data Source: DWR State Water Project Analysis Office



Sources: Data compiled by KCWA in 2014 and by AECOM in 2015

FIGURE 2.3.2. KWB Facilities

Study Relevance: Deliveries for KWB water accounting and water quality analysis

Years of Data Available: 1984–2015

Type of Data Collected: Monthly volumes delivered from/into the Aqueduct.

Data Collection Equipment: DWR has established procedures and specific criteria relating to flow control equipment standards, measurements, and recording of data. DWR is responsible for calibrating the metering systems at California Aqueduct turnouts/turn-ins, and for determining and reporting delivery volumes.

Limitations to Data Use: For the KWB canal, DWR accounts for water delivered into/from the Aqueduct, but does not identify water to individual KWB participants. KWB water accounting details are handled by the Dudley Ridge Water District, or KCWA on behalf of its member agencies.

2.3.1.2 Central Valley Project (Friant-Kern Canal)

The Friant-Kern Canal, operated by the Friant Water Users Authority, is one of several CVP facilities that convey CVP water supplies to several districts with long-term CVP water contracts, including Arvin-Edison WSD. The Friant-Kern Canal carries San Joaquin River water south from Millerton Lake, located northeast of Fresno, to its terminus at the Kern River. Millerton Lake has a maximum capacity of approximately 520,500 acre-feet (AF).

The Friant-Kern Canal terminates at the Kern River channel outlet near Bakersfield. Here the CVC siphons run under the Friant-Kern Canal outlet channel. The CVC and the Kern River channel can be used to transport CVP water from the Friant-Kern Canal to water banking projects in the study area. CVP water can at times be acquired by local banking participants through exchanges, temporary contracts, direct purchases, and "Section 215" flood water. CVP water from the Friant-Kern Canal can also be delivered to the Arvin-Edison Canal. The Friant Water Authority meters the flows into the Kern River with rated gates and at the Arvin Edison Canal with a Parshall flume. The City of Bakersfield is responsible for managing all CVP water in the Kern River channel until it reaches Second Point.

In addition to delivering CVP water, the Friant-Kern Canal is sometimes used to convey floodwaters from the Kings, Kaweah, and Tule Rivers. Historically, if not pumped into the Friant-Kern Canal, these waters would flood the Tule Lake bed.

Friant-Kern Canal Report of Operations

Reference: U.S. Bureau of Reclamation (USBR) 2015

Data Source: USBR, Central Valley Operations Office (CVO)

Study Relevance: Friant-Kern water is a KWB water source

Years of Data Available: 1985–2015

Type of Data Collected: Annual and monthly deliveries for each Friant-Kern Canal water user.

Data Collection Equipment: Lateral turnouts on the Friant-Kern Canal.

Comments/Limitations to Data Use: Reported volumes are not categorized into Class 1 or 2, or Section 215 floodwater supply classifications.

<u>Friant Weekly Water Reports</u>

Reference: Friant Water Authority 2015

Data Source: Friant Water Authority

Study Relevance: Frian-Kern water is a KWB water source

Years of Data Available: January–April 2015

Type of Data Collected: 1) Millerton weekly reservoir storage, inflow, and releases; 2) Madera and Friant-Kern Canal deliveries; 3) San Joaquin River flows with comparisons to the previous year; 4) snow survey data within the San Joaquin, Kings, Kaweah, Tule, and Kern River watersheds; 5) Daily and weekly total California Irrigation Management Information System (CIMIS) ET data for 12 reporting stations spread throughout the San Joaquin Valley. Precipitation data are included for the Huntington, Crane Valley, and Friant Stations.

Data Collection Equipment: Stream gauges; snow sensor data.

Comments/Limitations to Data Use: Data availability is limited to 2015; however, USBR has similar data categories.

2.3.1.3 Kern River and Kern River Channel

The Kern River is approximately 164 miles long and is fed by annual snowmelt from the southern Sierra Nevada approximately 60 miles north of Mount Whitney, and terminates at the Kern River Intertie Basin at the California Aqueduct. The river is used for generation of hydroelectric power as it flows through and out of the Sierra Nevada and provides flood control, recreation, and water storage at Lake Isabella reservoir. Reservoir operations are regulated and monitored by the U.S. Army Corps of Engineers and the Kern River Watermaster. Lake Isabella was designed to store approximately 570,000 AF of water; however, since 2006, because of seepage and earthquake concerns, water storage in the reservoir was limited to approximately 60 percent of capacity, or 340,860 AF. The U.S. Army Corps of Engineers will implement dam safety modifications with the intent of restoring reservoir capacity. Construction is scheduled to begin in 2017, with modifications to be completed by 2022 (U.S. Army Corps of Engineers 2015).

After exiting Lake Isabella and Kern Canyon, Kern River flows are measured by the City of Bakersfield at First Point of Measurement facility (for upper river water rights), and at Second Point of (for lower river water rights) downstream of the southern end of the 2,800 Acre Recharge Project facility. There are seven main diversion and conveyance facilities downstream of First Point that can convey Kern River and Poso Creek water:

- *Beardsley Canal*—flows northwest to North Kern WSD.
- *Carrier Canal*—flows into the River Canal at Coffee Road.
- *Kern Island Canal*—flows south to Kern Delta Water District (WD).
- *Calloway Canal*—flows north to North Kern WSD and into the ID4 Water Purification Plant.
- *Cross Valley Canal*—flows via the various CVC river turnouts and Friant-Kern Canal water via the terminus of the canal at the river and connects to the California Aqueduct.
- *Belleview Weir*—diverts water to the Rosedale intake canal for both flood control and the district's use for groundwater recharge. Belleview Pipe diverts water to the Wilson Ditch, which delivers water to the Berrenda Mesa Joint-Use Facility).

- *KWB Canal*—flows east-west and provides connection to the California Aqueduct; delivers water to KWB and West Kern WD recharge ponds.

The aquifer in the KWB area is recharged by deliberate spreading (i.e. recharge operations) or or by natural percolation in the Kern River channel and from water percolating through unlined canals. Since 1977, the area along the Kern River west of the City of Bakersfield has been used for groundwater recharge and recovery. The river flows through the 2,800 Acre Recharge Project facility. At the ID4 Water Purification Plant, the river can be used as a water conveyance or recharge facility by accepting CVC water via River Turnout 4. Between First Point and the Kern River's terminus, the river is used as a groundwater recharge facility by ID4, the Pioneer Project, the Berrenda Mesa Joint-Use Facility, and the City of Bakersfield.

The City of Bakersfield operates and measures all deliveries upstream of Second Point, including the KWB Canal headworks. Buena Vista WSD operates and measures all deliveries below Second Point, including deliveries via the Cross River Pipeline. Flows that extend past Second Point either are used by lower river water rights holders or, in times of high flows, continue to either the Kern River Intertie at the California Aqueduct or even reach the Tulare Lake basin to the north through a series of sloughs and flood channels.

Table 2.3.1.3 lists facilities along the Kern River that are used for KWB operations, the agencies responsible for measuring and reporting flows, and sources of flow data.

TABLE 2.3.1.3.

KWB Points of Diversion / Rediversion from the Kern River

Facility Name	Max Flow Rate (cfs)	Maximum Annual Amount (acre-feet)	Monitoring Entity
Kern River Canal East	900	657,000	City of Bakersfield
Pioneer Canal Headworks	350	255,500	City of Bakersfield
City of Bakersfield Basin 2	500	365,000	City of Bakersfield/KCWA
City of Bakersfield Basin 9	600	438,000	City of Bakersfield/KCWA
City of Bakersfield Basin 10	150	109,500	City of Bakersfield/KCWA
Kern Water Bank Canal	800	584,000	City of Bakersfield
Kern River Canal West	300	219,000	City of Bakersfield
Main Canal	250	182,500	Buena Vista WSD
KWB Basin L1 (Sand Plug)	40	29,200	Buena Vista WSD
West Kern Basin 1	200	146,000	Buena Vista WSD
Kern River–California Aqueduct Intertie	3,500	2,555,000	DWR

Notes:

cfs = cubic feet per second; WSD = Water Storage District; KCWA = Kern County Water Agency, KWB = Kern Water Bank

Sources: KWBA 2007, 2015b

Data for the Kern River watershed are reported in the annual Kern River Watermaster's Report, which is also included in the City of Bakersfield's annual Kern River reports. The data sources for Lake Isabella reservoir and Kern River channel operations are described below.

Kern River Reports

Reference: City of Bakersfield 1987–2014

Data Source: City of Bakersfield and Kern Watermaster

Study Relevance: Kern River and River Canal operations

Years of Data Available: 1987–2014

Type of Data Collected: 1) Lake Isabella monthly operations including storage and releases; 2) Kern River operations including regulated deliveries and unimpaired flow; 3) Kern River watershed precipitation, runoff, snowpack, and temperature. Historical monthly full natural Kern River flow and runoff data from 1893–2014 and regulated flow from 1957–2013, both at First Point, are available; 4) Kern River entitlements and diversions below First Point, including entitlements and diversions specific to Kern Delta WD, the City of Bakersfield, and North Kern WD; 5) Kern River monthly flow at the First and Second Points and 18 diversions between these points; 6) Kern River losses and gains over river reaches: Rocky Point to Calloway Weir; Calloway Weir to River Canal Weir; River Canal Weir to Bellevue Weir; Bellevue Weir to the ID4 Boundary; the ID4 Boundary to 2,800 Acres Recharge Project; and the 2,800 Acres Recharge Project to Second Point; 7) Carrier and River Canals operations data; 8) Monthly KWB, ID4, Berrenda Mesa, and City-Olcese banking recovery water to the River Canal; 9) Deliveries into the CVC.

Data Collection Equipment: Stream gauge or metering system.

Comments/Limitations to Data Use: These Kern River reports do not include flow data within the river channel between the First and Second Points or any diversion data for the Kern River channel below Second Point. River losses between Second Point and the Intertie are also not reported. Although flow data and some diversion data are provided for the River Canal, diversion volumes into the Alejandro Canal from the River Canal are not reported because they are under the jurisdiction of Buena Vista WSD.

2.3.1.4 Kern Water Bank Canal

The KWB Canal, which is jointly operated by KWBA and Buena Vista WSD, can convey Kern River water at an intake at the west end of the 2,800 Acre Recharge Project facility, SWP water from the California Aqueduct, and recovered KWB water back to the California Aqueduct. Completed in 2001, the KWB Canal is approximately 6 miles long and 90 feet wide. The canal is unlined and functions as both a water conveyance facility and a groundwater recharge facility. The bi-directional canal has one pumping plant (KWB Pumping Plant) with the capability to divert up to 750 cfs from the California Aqueduct and 800 cfs from the Kern River via Buena Vista WSD's Main Canal and River Canal Pumping Plant. The KWB Canal also includes a recovery canal with a capacity of 500 cfs that runs north-south and connects the KWB Canal to the CVC. Most of the SWP water entering the KWB Canal from the California Aqueduct is delivered to KWB recharge ponds; however, a small portion of the water has been delivered to West Kern WD ponds. Table 2.3.1.4 below lists turnout facilities along the KWB Canal.

Deliveries to the KWB Canal from the California Aqueduct are measured with an ultrasonic acoustic meter that is calibrated and maintained by the Department. Water delivered to West Kern WD from the KWB Canal is measured by KCWA and Buena Vista WSD through a rated gate structure or a rated weir structure.

2.3.1.5 Cross Valley Canal

The CVC was constructed in 1975 to transport CVP water from the California Aqueduct to CVP water districts on the east side of the San Joaquin Valley. The first 17 miles are concrete lined to minimize water losses, while the remaining sections are unlined to facilitate groundwater recharge. The CVC was originally designed to convey up to 800 cfs via eight horizontal pools and seven pump stations.

TABLE 2.3.1.4. Kern Water Bank Canal Conveyance Facilities.			
Facility Name	**Max Flow Rate (cfs)**	**Metering System Type or Status**	**Flow Direction**
P11-1 Turnout	80	Staff Gauge	North
C-6 Turnout	80	Staff Gauge	South
C-3 Turnout	240	Headgate	North
C-7 Turnout	80	Staff Gauge	South
M-2 Turnout	240	Staff Gauge (48-inch round pipe)	North
M-7 Turnout	204	Gauge (48-inch box)	South
Main Canal Turnout	300	Staff Gauge	West
M-9 Turnout	80	Gauge (42-inch round)	East
Outlet Canal Turnout	125	Staff Gauge	West

Notes:
cfs = cubic feet per second
Source: KWBA 2015b

Expansion of the canal was completed in 2012, increasing the capacity to 1,410 cfs. The CVC can operate three independent reaches that can flow west to east or east to west, thereby integrating recharge and recovery operations of local groundwater banks.

Water can be conveyed through the CVC to all of the banking projects in the Kern Fan region including the KWB, the Pioneer Project, the Berrenda Mesa Project, and others farther eastward. Deliveries from the CVC to the KWB are through several structures identified in Table 2.3.1.5. Deliveries from CVC Pools 1 and 2 are exclusively to the KWB. Pools 3, 4, and 6 can deliver water to the Berrenda Mesa Project, Pioneer Project, and/or 2,800 Acre Recharge Project facility.

TABLE 2.3.1.5. Cross Valley Canal Conveyance Facilities.						
CVC Pool/ Reach	**Facility Name**	**Max Flow Rate (cfs)**	**Flowmeter Type or Turnout Status**	**Metering System Type or Status**	**Monitoring Entity(s)**	**Flow Direction**
1	Turntable Pump*	30	NA	Meter	KCWA	NA
1	Pool 1 Pump*	100	NA	Pump Curves	KCWA	NA
1	Pool 1B Pump*	100	NA	Pump Curves	KCWA	NA
2	N2 Siphons	40	Siphon	McCrometer Propeller	KCWA	North
2	Strand Siphons	220	Siphon	Propeller Meter	KCWA	South
2	KWB Turnout (P11)	200	Unknown	Head Differential Calculation	KCWA	North
2	KWB River Pipeline Turnout	80	Unknown	Accusonic Meter	KCWA	South
3	Nord Siphons	70	Siphon	McCrometer Propeller	KCWA	South
4	Section 4	90	Unknown	Ultrasonic Flowmeter	KCWA	Unknown
4	River Turnout No. 1	400	Gravity	Accusonic Meter/Head Differential Calculations	KCWA	South
6	River Turnout No. 2	180	Gravity	Head Differential Calculation	KCWA	South

Notes:
cfs = cubic feet per second; NA = not applicable;
Source: KWBA 2015b

Deliveries from the California Aqueduct to the CVC are metered by an acoustic (ultrasonic) meter that is maintained and calibrated by DWR. KCWA is responsible for metering the deliveries out of the CVC. The metering system comprises a variety of sonic meters and rated gate/culvert (gravity) structures, or siphon structures. The flows from these facilities are further measured at diversion/weir structures between the projects (e.g., the Trestle and James Siphon). KCWA monitors flows at these facilities daily during recharge periods.

2.3.1.6 Other Canals and Conveyance Facilities

Several additional canals and facilities in the study area are used to deliver both imported and local surface water and recovered groundwater. These facilities include the River, James, Outlet, Main, and Alejandro Canals, and the 2,800 Acre Recharge Project and Pioneer Water Banking Project. All of these facilities were constructed and operational before development of the KWB (see Figures 2.3-1,2). Table 2.3.1.6 below shows which canals can service recharge basins throught the KWB.

River Canal

The River Canal is a concrete-lined canal owned and operated by the City of Bakersfield. This canal runs from its connection with the City of Bakersfield Carrier Canal to its terminus at the southern end of the 2,800 Acre Recharge Project. Flow measurement devices on the canal are weirs. The City of Bakersfield is responsible for data collection and weir maintenance, and data are archived at the City of Bakersfield Water Department, and published in the annual Kern River Report.

Pioneer – James Canal System

The James-Pioneer Improvement District operated in the Kern Fan area before the formation of the KWB. The Pioneer Canal diverts water to the south from the Kern River and is used to transport recharge water to the South Pioneer Canal and the KWB. The James Canal is no longer connected to agricultural irrigation, but remnants of it can convey surface water for recharge in various groundwater banking facilities within the study area.

Alejandro Canal

The Alejandro Canal is an unlined canal that is owned and operated by Buena Vista WSD. The canal begins at its turnout on the River Canal, and runs southerly at the Buena Vista Aquatic Lakes Recreational Facilities. It delivers water primarily to the Buena Vista WSD Maples District and the Buena Vista Aquatic Lakes Recreational Facilities. Water deliveries from the canal can also be made directly to or through its connection to the Alejandro Canal to the Buena Vista Canal, Kern Delta WD, Henry Miller WD, Buena Vista WSD, and KWBA recharge facilities. Buena Vista WSD is responsible for flow measurements and data archival reporting. The canal serves several ponds (J5, J6, A1) in the southern portion of the KWB.

Main Canal

The unlined Main Canal diverts water to the northwest form the Kern River near the Second Point of Measurement and transports it through the KWB and Eastside Canals. The Main Canal's turnout capacity from the KWB Canal is 500 cfs. Its capacity between the KWB Canal and the Eastside Canal is 400 cfs. The Main Canal is also used to transport recharge water to the recharge ponds on the KWB lands and is used as a recharge facility by Buena Vista WSD. Buena Vista WSD is responsible for flow measurements and data archival reporting. In addition, KCWA measures deliveries of water to recharge facilities and recovered water that is pumped into the canal from the KWB.

TABLE 2.3.1.6.

KWB Recharge Basins.

Number	KWB Basin ID	Approximate Acreage[1]	Year of Construction/ Development	SWP	CVP	KR	Conveyance Facilities Used for Deliveries of Recharge Water
1	A1	77.8	1998		X	X	Alejandro Canal via River Canal
2	C1	26.7	1995	X	X	X	KWB Canal
3	C2	50.6	1995	X	X	X	KWB Canal
4	C3	78.4	2001	X	X	X	KWB Canal
5	C4	114.3	2001	X	X	X	KWB Canal
6	C5	84.9	2001	X	X	X	KWB Canal
7	C6	65.3	2001	X	X	X	KWB Canal
8	C7	27.0	2001	X	X	X	KWB Canal
9	C9	70	2009	X	X	X	KWB Canal
10	E1	140.6	2001		X	X	Pioneer Canal
11	E2	141.5	1995		X	X	Pioneer Canal
12	E3	40.4	1995		X	X	Pioneer Canal
13	E5	36.6	1995		X	X	Pioneer Canal
14	E6	64.6	1995		X	X	Pioneer Canal
15	J1	90.3	1995		X	X	James Canal via River Canal
16	J1-A	22.1	1995		X	X	River Canal
17	J2	101.1	1995		X	X	James Canal via River Canal
18	J3	123.5	1995		X	X	James Canal via River Canal
19	J4	35.5	1998		X	X	James Canal via River Canal
20	J5	54.6	1998		X	X	James Canal via River Canal
21	J6	8.2	1998		X	X	James Canal via River Canal
22	J7	19.9	1975		X	X	James Canal via River Canal
23	K1	68.9	1998		X	X	James Canal via River Canal
24	K2	98.6	1998		X	X	James Canal via River Canal
25	L1	111.4	1998		X	X	Kern River Turnout
26	L2	38.5	1998		X	X	West Kern Basin[1]
27	M1	84.5	1995	X	X	X	KWB Canal
28	M10	99.4	2001	X	X	X	KWB Canal
29	M2	154.1	1995	X	X	X	KWB Canal
30	M3	93.0	1995	X	X	X	KWB Canal
31	M4	66.1	1995	X	X	X	KWB Canal
32	M5-N	131.6	1995	X	X	X	KWB Canal
33	M5-S	90.7	1995	X	X	X	KWB Canal
34	M6	21.6	1995	X	X	X	KWB Canal
35	M7	109.2	1998	X	X	X	KWB Canal
36	M8	285.7	1998	X	X	X	KWB Canal
37	M9	249.7	1998	X	X	X	KWB Canal
38	N1	31.5	1995	X	X	X	CVC Canal
39	N2	75.2	1995	X	X	X	CVC Canal
40	N3	213.9	1995	X	X	X	CVC Canal
41	R1	71.7	1995	X	X	X	North Pioneer Pond /Pioneer Canal
42	R2	108.4	1995	X	X	X	North Pioneer Pond /Pioneer Canal
43	R3	114.9	1995	X	X	X	Pioneer Canal
44	R4	81.9	1995	X	X	X	Pioneer Canal
45	R4-A	17.7	1995	X	X	X	Pioneer Canal
46	R5	82.6	1995	X	X	X	Pioneer Canal
47	R6	42.1	1998	X	X	X	Pioneer Canal
48	R7	45.9	1998	X	X	X	Pioneer Canal
49	R8	56.5	1998	X	X	X	Pioneer Canal
50	R9	127.9	1998	X	X	X	Pioneer Canal
51	S1	50.4	1995	X	X	X	CVC Canal
52	S10	49.0	1995	X	X	X	CVC Canal
53	S11	88.4	1995	X	X	X	CVC Canal

TABLE 2.3.1.6. KWB Recharge Basins.							
Number	**KWB Basin ID**	**Approximate Acreage[1]**	**Year of Construction/ Development**	**SWP**	**CVP**	**KR**	**Conveyance Facilities Used for Deliveries of Recharge Water**
54	S2	43.3	1995	X	X	X	CVC Canal
55	S3	141.3	1995	X	X	X	CVC Canal
56	S4	28.0	1995	X	X	X	CVC Canal
57	S5	17.5	1995	X	X	X	CVC Canal
58	S6	32.8	1995	X	X	X	CVC Canal
59	S7	39.1	1995	X	X	X	CVC Canal
60	S8	42.4	1995	X	X	X	CVC Canal
61	S9	33.6	1995	X	X	X	CVC Canal
62	SC	29.8	1998	X	X	X	CVC Canal
63	SP	6.4	1995	X	X	X	Pioneer Canal
64	SP0	28.2	1975	X	X	X	Pioneer Canal
65	SP1	60.6	1975	X	X	X	Pioneer Canal
66	SP2	72.5	1975	X	X	X	Pioneer Canal
67	SP3	87.7	1975	X	X	X	Pioneer Canal
68	SP4	73.9	1975	X	X	X	Pioneer Canal
69	W1	143.7	1995	X	X	X	Main Canal
70	W2	188.4	1998	X	X	X	Main Canal
71	W3	442.1	1997	X	X	X	Main Canal
72	W4	508.5	1997	X	X	X	Main Canal
73	W4	62.5	1997	X	X	X	Main Canal
74	W5	481.0	1998	X	X	X	Main Canal
75	W6	555.8	1998	X	X	X	Main Canal
Total Recharge Area:		**7,554.0**					

Notes:
KWB = Kern Water Bank; KR = Kern River; SWP = State Water Project; CVP = Central Valley Project; T.O. = Turnout; CVC = Cross Valley Canal
1. Acreage information obtained from KWBA 2007
Sources: KWBA 2007, KWBA 2015c

Pioneer Project

The Pioneer Project, besides being a recharge and recovery banking facility, can also operate as a water conveyance facility through its Pioneer North ponds to the KWB. It also can receive water from the CVC via several CVC diversion facilities and/or siphon structures. Surface water moved through this facility is delivered to KWB Lands via the Trestle Turnout located on the western edge of the North Pioneer West Pond. This turnout is a rated gate structure. Data from this facility are collected and reported as noted in the previous reports.

2,800 Acre Recharge Project

The 2,800 Acre Recharge Project functions as a water conveyance facility to transfer surface water to KCWA's Pioneer North facility via Basin 9, 10, and 13 Turnouts. It also can transfer water to the KWB via the 2,800 Acre KWB Turnout on the Kern River. Data from this facility are collected and reported as noted in the previous reports.

2.3.1.7 Local Streams

Local minor streams collectively are the second largest source of surface water in the study area after the Kern River. Streams with measurable runoff are typically grouped into four separate watershed areas: Poso Creek (an ephemeral stream), Caliente Group (including Caliente and Tehachapi Creeks), El Paso Creek, and San Emigdio Creek. The streams with the largest historical flows, including Poso and Tehachapi Creeks, are equipped with flow meters, while the flow rates of smaller streams are estimated by statistical methods based on historical watershed, precipitation, and runoff data. In dry years, flows on Poso and Tehachapi Creeks are typically too small to be measured. A very small percentage of runoff from these local minor streams flows into and is used to irrigate agriculture located in the North Kern WSD and the Semitropic WSD. As described previously, several reports include data related to local streams.

2.3.1.8 Precipitation

Precipitation, as either rainfall or snowpack, is an important factor to consider in determining the availability of both local and imported water supplies, the amount of runoff and related surface water flows within streamgroups, and irrigation demands in any given year. All of these factors influence the amount of water available to replenish groundwater through natural processes and groundwater banking activities. The study area's effective precipitation (the portion of precipitation that is added and stored in the soil and can be beneficially used by crops), averages 3.4 inches in a normal year (KCWA 2005).

For local precipitation in the Kings, Kaweah, Tule, and Kern River watersheds and immediate study area, the following sources provide relevant rainfall and runoff data: KCWA Water Supply Reports, Kern River Reports, and Friant Weekly Water Reports.

TABLE 2.3.1.8.

Average Monthly Evaporation in Irrigated Pasture Environments near Bakersfield, California from 1958 through 2010.

Month	Average (inches)	Standard Deviation (inches)	Standard Error
January	1.44	0.34	0.05
February	2.25	0.45	0.06
March	4.13	0.71	0.10
April	5.95	0.86	0.12
May	8.35	0.82	0.12
June	9.58	0.79	0.11
July	9.94	0.82	0.11
August	8.85	0.71	0.10
September	6.62	0.64	0.09
October	4.47	0.43	0.06
November	2.24	0.36	0.05
December	1.35	0.36	0.05
Mar-Oct Total	57.83	0.72	0.10
Jan-Dec Total	65.11	0.61	0.08

Source: DWR 2014a

2.3.1.9 Evapotranspiration/Evaporation

The planting and harvesting of crops and other vegetation for dust control or habitat enhancement in the study area has altered the natural patterns of ET (KCWA 2011). Potential ET, the amount of water evaporated and transpired from irrigated pasture in the study area, averages around 65 inches annually (DWR 2014a). The KCWA Water Supply Reports, Kern River Reports, and Friant Weekly Water Reports provide data regarding ET.

2.3.2 GROUNDWATER HYDROLOGY

2.3.2.1 Groundwater Recharge

Groundwater recharge is a hydrogeologic process by which water percolates into a groundwater aquifer, and is a function of available water and soil properties. In the study area, groundwater recharge is naturally occurring or artificial, and enhanced by water management activities involving imported water supplies for consumptive use and water banking, and agricultural and municipal return flows.

Natural Recharge

Natural recharge is a function of local precipitation, ET, and soil moisture-holding capacity. Natural recharge occurs through flows in rivers and streams and, to a lesser extent, through rainfall percolation. Natural recharge is generally estimated across a particular watershed, hydrologic basin, or river system. Watershed data available for the Kern River and local streams and available precipitation data are discussed previously.

Artificial and In-Lieu Recharge

Artificial recharge is a function of the availability of imported and local water supplies, ET, and the estimated infiltration rate of the soils below recharge facilities. A number of groundwater recharge projects in the study area use unlined canals/ponds to convey water with the understanding that a portion of that water will contribute to recharge below the canals. During wet periods, every effort is made to deliver water through unlined canals to maximize groundwater recharge (KCWA 2011).

Table 2.3.1.6 lists the recharge basins located on KWB Lands. In-lieu recharge activities also occur as part of significant recharge management practices in the study area. In-lieu recharge occurs when groundwater use is reduced by using surface water sources, in lieu of pumping groundwater. As a result, groundwater can remain in the aquifer. This groundwater savings is accounted for in the same manner as if the water were artificially recharged. The Kern Fan Operations and Monitoring Reports and the KCWA Water Supply reports have data for local recharge facilities operations.

Return Flows

Return flow can be defined as the part of both groundwater and surface-water diversions that “return” to a groundwater basin. Return flows can result from over-application of irrigation water and from wastewater discharges from septic system facilities, oil and gas extraction, and other industrial processes such as food production and confined-animal facilities. Recharge from septic systems is typically not measured or estimated. Recharge from wastewater generated by food processing, confined-animal facilities, and other industries are generally regulated under waste discharge requirements. In the study area, irrigation return flows are measured as select locations. In some instances, this water is blended with other surface water sources in conveyance facilities.

Return flows are commonly calculated as groundwater withdrawals minus groundwater depletions, plus surface water diversions minus surface water depletions, or as the difference between the gross and net water requirements for a hydrologic basin. The KCWA Water Supply Reports provide annual estimates of applied agricultural water returned to usable groundwater storage in Kern County. The data set also estimates the volume of treated wastewater that was reused for municipal and industrial purposes.

Subsurface Flow

Once surface water has joined an aquifer, it still has movement. The groundwater slowly moves through the spaces and cracks between the soil particles on its way to lower elevations. Groundwater can also move horizontally, and when it discharges to a lake or stream it then becomes surface water. In the study area, comparing groundwater levels from monitoring wells can indicate the movement of water during recovery and recharge operations.

Prescribed "Loss Factors" for Banking Projects

The term "loss factor" in the context of groundwater banking projects means that the amount of water to be recovered in the future is less than the amount put into recharge. Therefore, it is a loss to the applied surface water to be banked, but it is a "gain" to the groundwater system overall. It is a small portion of recharge that by groundwater banking rules may not be recovered. The 1995 KWB MOU (see Appendix 7-5a) prescribes loss factors for banking operations, such as an ET of 6 percent of the gross amount of all water recharged. This 6 percent loss factor is conservative and provides assurance that banking operations will not recover more water than actually recharged. The 1995 KWB MOU provides that an additional 5 percent loss factor will apply to any sales of KWB water to entities outside of Kern County. This additional water provides an overall benefit to the groundwater basin, and cannot be recovered for other uses. In addition to these losses, 4 percent of the water recharged and stored in the KWB can be purchased by adjoining groundwater districts for overdraft correction purposes to help with their overdraft issues. Other local groundwater banking programs also assign loss factors.

2.3.2.2 Groundwater Extractions/Depletions

Pumping and Banking Recovery

Groundwater pumping is extensively monitored throughout the study area. Recovered volumes of water are measured by the Department at the California Aqueduct turn-ins, including the KWB Canal and the CVC. At times, a portion of recovered water may flow east in the CVC. When this is the case, KCWA determines those volumes. Within the KWB, Pioneer, and 2,800 Acre Recharge Project, water volumes are measured and recorded by KCWA on a daily basis and summarized in various reports. Table 2.3.2.2 below summarizes the recovery facilities located on KWB Lands. Data on groundwater pumping are obtained by the Kern Fan Operations and Monitoring Reporting sets, and the KCWA Water Supply Reports.

TABLE 2.3.2.2.

Summary of KWB Recovery Facilities.

Well ID	Primary Pump-In Conveyance Facility	Secondary Conveyance
30S/25E-36D01	Alejandro Canal	Buena Vista Aquatic Lakes/Lake Webb
30S/24E-24A01	CVC Pool 1	CA Aqueduct or pumped east in CVC
30S/25E-06K01	CVC Pool 1	CA Aqueduct or pumped east in CVC
30S/25E-07G01	CVC Pool 1	CA Aqueduct or pumped east in CVC
30S/25E-08F01	CVC Pool 1	CA Aqueduct or pumped east in CVC
30S/25E-08J02	CVC Pool 1	CA Aqueduct or pumped east in CVC
30S/25E-15B01	CVC Pool 1	CA Aqueduct or pumped east in CVC
30S/25E-15C01	CVC Pool 1	CA Aqueduct or pumped east in CVC
30S/25E-16B01	CVC Pool 1	CA Aqueduct or pumped east in CVC
30S/25E-16D01	CVC Pool 1	CA Aqueduct or pumped east in CVC
30S/25E-16F01	CVC Pool 1	CA Aqueduct or pumped east in CVC
30S/25E-04L01	CVC Pool 2	CA Aqueduct or pumped east in CVC

TABLE 2.3.2.2.

Summary of KWB Recovery Facilities.

Well ID	Primary Pump-In Conveyance Facility	Secondary Conveyance
30S/25E-05K01	CVC Pool 2	CA Aqueduct or pumped east in CVC
30S/25E-03L01	CVC Pool 2	CA Aqueduct or pumped east in CVC
30S/25E-09J01	CVC Pool 2	CA Aqueduct or pumped east in CVC
30S/25E-09L01	CVC Pool 2	CA Aqueduct or pumped east in CVC
30S/25E-09L02	CVC Pool 2	CA Aqueduct or pumped east in CVC
30S/25E-12C01	CVC Pool 3	CA Aqueduct or pumped east in CVC
30S/24E-12H01	KWB Canal	CA Aqueduct
30S/24E-12R01	KWB Canal	CA Aqueduct
30S/24E-13C01	KWB Canal	CA Aqueduct
30S/24E-13H01	KWB Canal	CA Aqueduct
30S/25E-01Q01	KWB Canal	CA Aqueduct
30S/25E-03Q01	KWB Canal	CA Aqueduct
30S/25E-03Q02	KWB Canal	CA Aqueduct
30S/25E-03R01	KWB Canal	CA Aqueduct
30S/25E-07P01	KWB Canal	CA Aqueduct
30S/25E-07R01	KWB Canal	CA Aqueduct
30S/25E-08P01	KWB Canal	CA Aqueduct
30S/25E-09A01	KWB Canal	CA Aqueduct
30S/25E-10K01	KWB Canal	CA Aqueduct
30S/25E-11A01	KWB Canal	CA Aqueduct
30S/25E-11C02	KWB Canal	CA Aqueduct
30S/25E-11E01	KWB Canal	CA Aqueduct
30S/25E-11L01	KWB Canal	CA Aqueduct
30S/25E-11N01	KWB Canal	CA Aqueduct
30S/25E-11Q01	KWB Canal	CA Aqueduct
30S/25E-13F01	KWB Canal	CA Aqueduct
30S/25E-13J01	KWB Canal	CA Aqueduct
30S/25E-13L01	KWB Canal	CA Aqueduct
30S/25E-14E01	KWB Canal	CA Aqueduct
30S/25E-14J01	KWB Canal	CA Aqueduct
30S/25E-14K01	KWB Canal	CA Aqueduct
30S/25E-14N01	KWB Canal	CA Aqueduct
30S/25E-14R01	KWB Canal	CA Aqueduct
30S/25E-15L01	KWB Canal	CA Aqueduct
30S/25E-15N01	KWB Canal	CA Aqueduct
30S/25E-15Q01	KWB Canal	CA Aqueduct
30S/25E-15R01	KWB Canal	CA Aqueduct
30S/25E-16J01	KWB Canal	CA Aqueduct
30S/25E-16M01	KWB Canal	CA Aqueduct
30S/25E-16P01	KWB Canal	CA Aqueduct
30S/25E-16R01	KWB Canal	CA Aqueduct
30S/25E-17F01	KWB Canal	CA Aqueduct
30S/25E-17H01	KWB Canal	CA Aqueduct
30S/25E-17J01	KWB Canal	CA Aqueduct
30S/25E-17M01	KWB Canal	CA Aqueduct
30S/25E-17P01	KWB Canal	CA Aqueduct
30S/25E-18A01	KWB Canal	CA Aqueduct
30S/25E-18A02	KWB Canal	CA Aqueduct
30S/25E-18C01	KWB Canal	CA Aqueduct
30S/25E-18K01	KWB Canal	CA Aqueduct
30S/25E-18P01	KWB Canal	CA Aqueduct
30S/25E-18R01	KWB Canal	CA Aqueduct
30S/25E-20A01	KWB Canal	CA Aqueduct
30S/25E-20C01	KWB Canal	CA Aqueduct

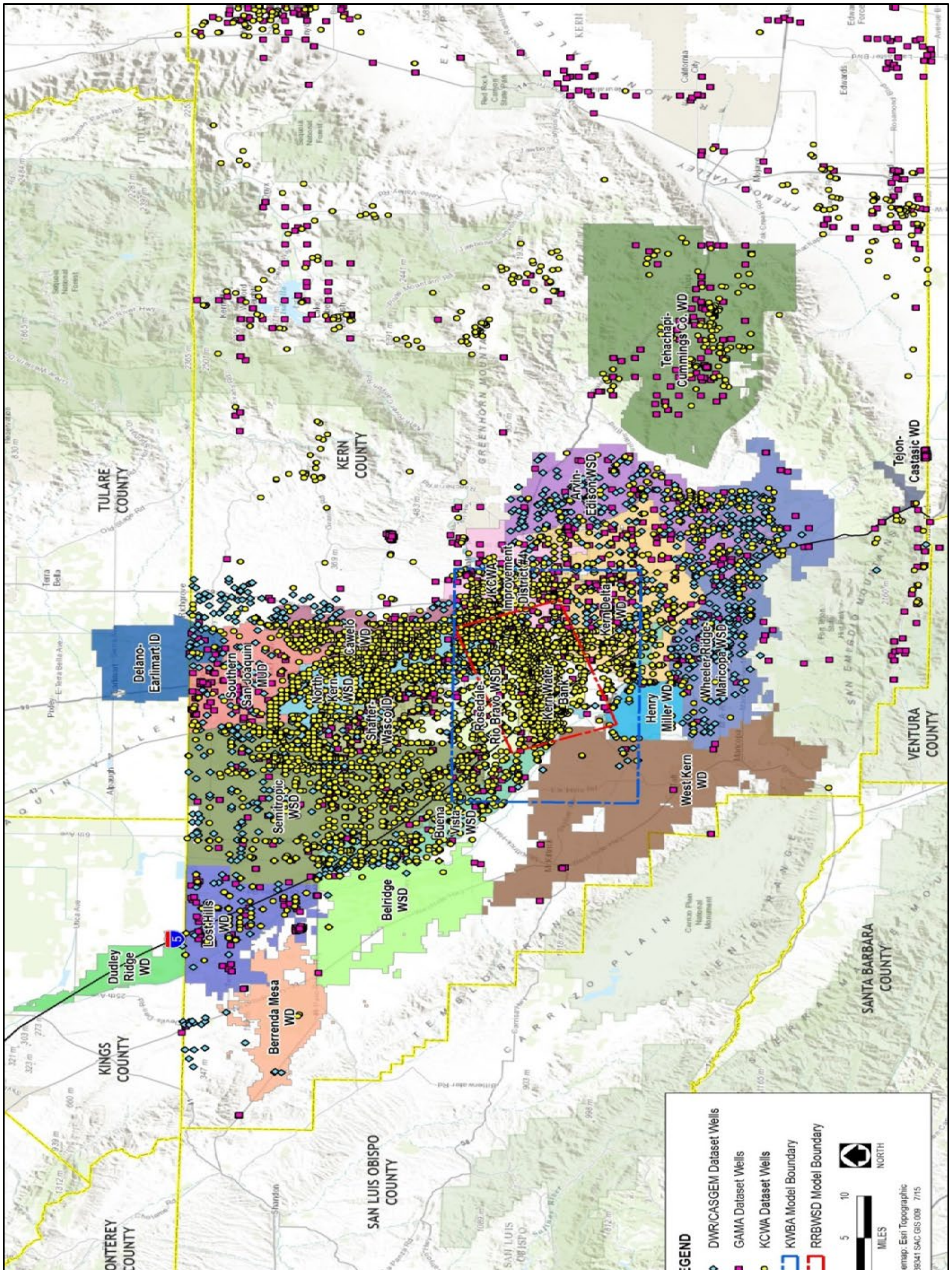
TABLE 2.3.2.2. Summary of KWB Recovery Facilities.		
Well ID	**Primary Pump-In Conveyance Facility**	**Secondary Conveyance**
30S/25E-20L01	KWB Canal	CA Aqueduct
30S/25E-21A02	KWB Canal	CA Aqueduct
30S/25E-21D01	KWB Canal	CA Aqueduct
30S/25E-21G01	KWB Canal	CA Aqueduct
30S/25E-23H01	KWB Canal	CA Aqueduct
30S/26E-06N01	KWB Canal	CA Aqueduct
30S/26E-06P01	KWB Canal	CA Aqueduct
30S/26E-07C01	KWB Canal	CA Aqueduct
30S/26E-07J01	KWB Canal	CA Aqueduct
30S/26E-07L01	KWB Canal	CA Aqueduct
30S/26E-07N01	KWB Canal	CA Aqueduct
30S/26E-07Q01	KWB Canal	CA Aqueduct
30S/26E-07R01	KWB Canal	CA Aqueduct
30S/26E-08M01	KWB Canal	CA Aqueduct
30S/26E-18B01	KWB Canal	CA Aqueduct
30S/26E-18D01	KWB Canal	CA Aqueduct
30S/25E-24J01	River Canal	KWB Canal or diversion to Alejandro Canal
30S/25E-24K01	River Canal	KWB Canal or diversion to Alejandro Canal
30S/26E-17Q01	River Canal	KWB Canal or diversion to Alejandro Canal
30S/26E-19G01	River Canal	KWB Canal or diversion to Alejandro Canal
30S/26E-19M01	River Canal	KWB Canal or diversion to Alejandro Canal
30S/26E-20C01	River Canal	KWB Canal or diversion to Alejandro Canal
30S/26E-20L01	River Canal	KWB Canal or diversion to Alejandro Canal
30S/26E-20N02	River Canal	KWB Canal or diversion to Alejandro Canal
Notes: CVC = Cross Valley Canal; KWB = Kern Water Bank Source: KWBA 2015b, KWBA 2015c, KCWA 2015c		

2.3.2.3 Groundwater Level Monitoring Programs

Through various state, regional, and local monitoring programs, groundwater levels throughout the study area are typically measured twice a year in spring and fall, as well as at regular intervals during periods of groundwater recovery. The groundwater level monitoring programs in the study area are described further. Figure 2.3.2.3 shows well data available from three agency datasets – DWR, the State Water Resources Control Board (SWRCB), and KCWA.

Regional Groundwater Level Monitoring

State and Federal agencies with groundwater-level monitoring programs in the region include DWR and USGS. Regional and statewide groundwater monitoring information is managed by DWR through their Water Data Library. DWR recently established the California Statewide Groundwater Elevation Monitoring (CASGEM) program to collect groundwater elevation data in collaboration between local monitoring entities. The statewide groundwater elevation monitoring program tracks seasonal and long-term trends in groundwater elevations in California's groundwater basins. The intent of the CASGEM program is to establish a permanent, locally managed program of regular and systematic monitoring in all of California's alluvial groundwater basins, including that underlying the the study area.



Source: Basemap: ESRI topographic 07/15

FIGURE 2.3.2.3. Well Data Sets for the Study Area

Groundwater-level monitoring is also performed by CASGEM-designated monitoring entities, and by local cooperators that measure, or contract others to measure, groundwater levels. Most water districts in the study area and the KWBA are CASGEM-designated monitoring entities. CASGEM data available for the study area are included in the DWR Groundwater Level Database and summarized in Table 2.3.2.3.

TABLE 2.3.2.3.

DWR Groundwater Levels Database.

Water District	Total Number of District Wells in the Dataset	Overall Sampling Period	
		From	To
ARVIN-EDISON WSD	192	2/9/1984	10/7/2014
BELRIDGE WSD	215	8/1/2003	7/22/2010
BERRENDA MESA WD	6	1/23/1984	11/8/2004
BUENA VISTA WSD	4	1/26/1984	1/14/2015
BUENA VISTA WSD/HENRY MILLER WD	26	1/24/1984	10/20/2014
Cawelo WD	90	1/4/1984	10/9/2014
Delano-Earlimart ID	15	2/8/1984	11/20/2014
Dudley Ridge WD	1	1/25/2007	10/6/2011
Henry Miller WD	1	8/1/2003	8/18/2008
Henry Miller WD/West Kern WD	7	8/1/2003	7/31/2009
Kern Co WA ID #4	50	1/31/1984	10/13/2014
Kern Co WA ID #4/North Kern WSD	4	2/2/1984	10/17/2014
Kern Delta WD	194	1/18/1984	10/7/2014
Kern Water Bank	82	1/16/1984	10/8/2014
Lost Hills WD	60	1/10/1984	10/6/2011
North Kern WSD	238	1/30/1984	10/8/2014
North Kern WSD/Kern Water Bank	1	10/10/1984	10/8/2014
North Kern WSD/Shafter-Wasco ID	2	1/31/1984	10/7/2014
Rosedale-Rio Bravo WSD	64	1/19/1984	12/2/2014
Semitropic WSD	328	1/23/1984	11/18/2014
Shafter-Wasco ID	97	1/30/1984	11/13/2014
Southern San Joaquin MUD	51	1/26/1984	10/9/2014
West Kern WD	9	1/20/1984	9/30/2014
West Kern WD/Kern Water Bank	3	2/10/1986	10/8/2014
Wheeler Ridge-Maricopa WSD	159	2/1/1984	10/6/2014
Wheeler Ridge-Maricopa WSD/Arvin-Edison WSD	51	2/23/1984	10/7/2014
Other	192	1/10/1984	10/26/2011

Notes:

ID = Improvement District; MUD = Municipal Utility District; WD = Water District; WA = Water Agency; WSD = Water Storage District

Source: DWR 2015d

DWR Groundwater Level Database

Reference: DWR Groundwater Level Database

Data Source: DWR 2015d

Years of Data Available: 1984–2011. This data set includes data entered into the Water Data Library database, which has been merged with the data set from CASGEM that covers the period January 2012–December 2014.

Type of Data Collected: Data on groundwater levels from various well types. There are a total of 45,342 water level observations in the combined database (Table 2.3.2.3).

Data Collection Equipment: Several types of equipment were used to gather measurements of groundwater levels, including acoustic water level recorders, electric tapes, airline, pressure gauges or nanometers, steel tape, and electronic pressure transducers. For some data entries, the data collection equipment is specified.

Comments/Limitations to Data Use: Acoustic water-level measuring devices may not be as accurate as that achieved with chalk tape, electrical tape, or pressure transducers. The frequency of measurements varies between each well. Most wells have spring and fall measurements, some wells have only a single measurement in spring or fall, and some wells have only a single measurement. Generally the most complete measurement set is the fall water elevation data. Also, in some cases there are duplicate listings for a given well, so the data need to be screened before use.

KCWA also coordinates with DWR to collect semiannual groundwater levels measured in Kern County and to ensure that areal coverage of water levels is complete in portions of the county not located in specific local district monitoring areas. KCWA's current monitoring network includes more than 200 wells that cover most of the study area. The KCWA network overlaps some of the local networks. KCWA maintains measured groundwater level data and data reported by local districts in a database described below (Table 2.3.2.3a).

TABLE 2.3.2.3a.

KCWA Groundwater Levels Database.

Water District and Well Type	Total Number of Wells in the District	Measurement Period	
		From	To
ARVIN-EDISON WSD		**1/1/1985**	**10/1/2014**
Unclassified	197	1/1/1985	10/1/2014
Monitor (Single)	3	12/15/1986	7/11/2014
Production Well	3	2/21/1985	10/29/2012
Unknown	1	2/20/2009	10/25/2010
BELRIDGE WSD		**8/6/1985**	**7/25/2014**
Monitor (Single)	3	8/6/1985	7/25/2014
Unknown	2	8/15/2003	7/16/2014
BELRIDGE WSD/LOST HILLS WD		**7/11/1995**	**7/25/2014**
Monitor (Single)	1	7/11/1995	7/25/2014
BERRENDA MESA WD		**1/23/1984**	**1/23/2015**
Unclassified	4	1/23/1984	1/23/2015
BUENA VISTA WSD		**2/7/1984**	**3/3/2015**
Unclassified	66	2/7/1984	1/20/2015
Monitor (Cluster)	6	8/11/1993	2/25/2015
Monitor (Single)	51	7/18/1985	7/25/2014
Production Well	9	2/7/1984	2/2/2015
Unknown	2	12/10/1992	3/3/2015
BUENA VISTA WSD/HENRY MILLER WD		**2/1/1984**	**1/15/2015**
Unclassified	6	1/15/2015	1/15/2015
Monitor (Single)	14	12/10/1985	7/15/2014
Production Well	1	2/1/1984	1/8/2010
CAWELO WD		**2/3/1984**	**2/4/2015**
Unclassified	51	2/3/1984	2/1/2015
Production Well	34	1/27/1993	2/4/2015
Unknown	10	10/4/1993	2/1/2015
DELANO-EARLIMART ID		**1/24/1995**	**3/1/2014**
Unclassified	12	1/27/1995	3/1/2014
Production Well	2	1/24/1995	1/16/2009
HENRY MILLER WD		**6/30/1987**	**7/14/2014**
Unclassified	1	7/3/1990	1/14/1997
Monitor (Single)	1	6/30/1987	7/14/2014

TABLE 2.3.2.3a.

KCWA Groundwater Levels Database.

Water District and Well Type	Total Number of Wells in the District	Measurement Period	
		From	To
HENRY MILLER WD/WEST KERN WD		**6/22/1988**	**7/15/2014**
Monitor (Single)	8	6/22/1988	7/15/2014
KERN COUNTY WATER AGENCY IMPROVEMENT DISTRICT #4		**2/3/1984**	**3/18/2015**
Unclassified	95	2/3/1984	3/13/2015
Monitor (Single)	28	2/23/1984	2/27/2015
Production Well	176	2/23/1984	3/18/2015
Unknown	4	2/1/1999	2/1/2015
KERN CO WATER AGENCY IMPROVEMENT DISTRICT #4/NORTH KERN WSD		**2/3/1984**	**3/20/2015**
Unclassified	11	2/3/1984	2/13/2015
Monitor (Single)	14	10/10/1984	3/20/2015
Production Well	10	3/7/1989	3/18/2015
KERN DELTA WD		**1/18/1984**	**3/4/2015**
Unclassified	206	1/20/1984	3/4/2015
Monitor (Cluster)	4	9/17/1992	2/25/2015
Monitor (Single)	49	12/4/1985	7/15/2014
Production Well	86	1/18/1984	3/4/2015
Unknown	4	2/1/1999	2/1/2015
Kern Water Bank		1/16/1984	3/5/2015
Unclassified	1	1/4/1990	1/13/2009
Monitor (Cluster)	7	11/18/1992	3/2/2015
Monitor (Nested)	30	6/15/1989	3/4/2015
Monitor (Single)	42	1/16/1984	2/25/2015
Production Well	109	1/16/1984	3/5/2015
Unknown	1	12/17/1997	7/2/2007
LOST HILLS WD		**1/23/1984**	**1/23/2015**
Unclassified	21	1/23/1984	1/23/2015
Monitor (Single)	27	7/17/1985	8/19/2014
Unknown	1	11/28/2006	8/18/2014
NORTH KERN WSD		**2/1/1984**	**3/13/2015**
Unclassified	8	2/1/1984	2/4/2015
Monitor (Cluster)	25	3/5/1984	3/5/2015
Monitor (Nested)	10	7/1/1988	3/5/2015
Monitor (Single)	2	7/1/1988	3/2/2015
Production Well	264	2/1/1984	3/13/2015
Unknown	106	11/12/1990	10/1/2014
NORTH KERN WSD/CAWELO WD		**3/1/2010**	**10/1/2014**
Unknown	1	3/1/2010	10/1/2014
NORTH KERN WSD/KERN WATER BANK		**9/26/1989**	**3/5/2015**
Production Well	2	9/26/1989	3/5/2015
NORTH KERN WSD/SHAFTER-WASCO ID		**1/27/1993**	**2/15/1995**
Production Well	1	1/27/1993	2/15/1995
NORTH KERN WSD/WEST KERN WD		**6/16/1989**	**3/4/2015**
Monitor (Cluster)	2	5/5/2006	3/4/2015
Monitor (Nested)	3	6/16/1989	2/25/2015
Production Well	1	10/4/2012	3/4/2015
ROSEDALE–RIO BRAVO WSD		**1/1/1984**	**3/13/2015**
Unclassified	39	1/1/1984	3/3/2015
Monitor (Cluster)	11	3/5/1984	3/3/2015
Monitor (Single)	18	1/1/1984	3/3/2015
Production Well	57	1/1/1984	3/13/2015

TABLE 2.3.2.3a.

KCWA Groundwater Levels Database.

Water District and Well Type	Total Number of Wells in the District	Measurement Period	
		From	To
Unknown	4	10/8/2009	3/3/2015
SEMITROPIC WSD		**1/1/1984**	**2/25/2015**
Unclassified	306	1/23/1984	1/27/2015
Monitor (Cluster)	4	8/11/1993	2/25/2015
Monitor (Single)	80	1/1/1984	8/18/2014
Production Well	94	1/24/1984	1/27/2015
Unknown	16	1/8/1992	1/15/2013
SEMITROPIC WSD/BUENA VISTA WSD		**12/10/1992**	**4/5/2011**
Unclassified	1	12/10/1992	4/5/2011
SHAFTER-WASCO ID		**2/1/1984**	**10/16/2014**
Unclassified	31	2/1/1984	10/16/2014
Monitor (Cluster)	2	1/17/1996	2/5/2014
Production Well	47	2/1/1984	10/14/2014
Unknown	2	2/9/1998	3/11/2014
SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT		**1/26/1984**	**2/1/2015**
Unclassified	31	1/26/1984	2/1/2015
Production Well	7	1/25/1993	10/1/2014
Unknown	4	10/4/1993	2/1/2015
WEST KERN WD		**1/1/1984**	**3/5/2015**
Unclassified	6	3/1/1987	1/16/2015
Monitor (Cluster)	1	9/2/1992	2/25/2015
Monitor (Single)	5	9/2/1992	3/5/2015
Production Well	10	1/1/1984	3/4/2015
Unknown	1	3/1/1987	3/5/2014
WEST KERN WD/KERN WATER BANK		**1/24/1986**	**3/5/2015**
Monitor (Cluster)	2	11/18/1992	3/5/2015
Monitor (Nested)	3	7/17/1989	3/5/2015
Monitor (Single)	1	6/24/1987	7/9/2014
Production Well	2	1/24/1986	3/5/2015
WHEELER RIDGE–MARICOPA WSD		**2/1/1984**	**1/16/2015**
Unclassified	107	2/1/1984	1/16/2015
Monitor (Single)	14	12/10/1985	7/14/2014
Production Well	10	1/26/1993	2/19/2014
Unknown	1	11/20/2002	7/11/2014
WHEELER RIDGE–MARICOPA WSD/ARVIN-EDISON WSD		**1/1/1985**	**7/11/2014**
Unclassified	54	1/1/1985	3/27/2014
Monitor (Single)	1	12/15/1986	7/11/2014
Production Well	3	1/1/1986	3/27/2014
Total Number of Wells	***2,812***		

Notes:

KCWA = Kern County Water District; ID = Improvement District; WD = Water District; WSD = Water Storage District

Source: KCWA 2015d

Kern County Water Agency Groundwater Level Database

Reference: KCWA 2015d

Data Holder/Source: KCWA

Years of Data Available: 1984–2011. This data set includes data entered into the Water Data Library database, which has been merged with the data set from CASGEM that covers the period January 2012–December 2014.

Type of Data Collected: Data on groundwater levels. There are 45,342 water level observations in the combined database.

Comments/Limitations to Data Use: Acoustic water-level measuring devices may not be as accurate as that achieved with chalk tape, electrical tape, or pressure transducers. The database does not always distinguish well type or construction details.

In addition, interpretive information regarding groundwater levels and regional water level maps in the study area are included in the KCWA Water Supply Reports.

KWBA Participants and Adjoining Entities Groundwater Level Monitoring

As required as part of an MOU regarding operation and monitoring of the KWB groundwater banking program, KWBA participants and adjoining entities established a Kern Fan Monitoring Committee and an associated groundwater monitoring program to oversee banking operations and monitoring in the Kern Fan region. As part of the monitoring program, existing regional and local district monitoring networks were incorporated into the KFMC monitoring program. Local networks include:

- **Buena Vista WSD**—monitoring network of 47 wells
- **Cawelo WD**—monitoring network of 50 wells
- **Henry Miller WD**—monitoring network of 24 wells
- **ID4**—monitoring network of approximately 100 wells
- **Kern Delta WD**—monitoring network of approximately 180 wells
- **North Kern WSD**—monitoring network of 62 wells
- **Rosedale**—monitoring network of 22 wells
- **Semitropic WSD**—monitoring network of approximately 180 wells
- **West Kern WD**—monitoring network of approximately 7 wells

Water level measurements are collected at least twice a year during spring and fall. Measurements are taken more frequently during periods of groundwater recovery.

Groundwater-level monitoring well data for the KFMC monitoring project is captured in both the DWR and KCWA groundwater-level databases. In addition, the Kern Fan Operations and Monitoring Reports (1995-2006) and the KCWA Water Supply Reports (1984-2011) include interpretive information regarding groundwater levels in the study area:

Kern Fan Monitoring Committee Groundwater Level Monitoring

As part of the KFMC monitoring program, the groundwater monitoring program on KWB Lands consists of 57 monitoring wells (Figure 2.3.1). These wells are measured semiannually in spring and fall.

In addition to the KFMC program monitoring, KWBA and KCWA have implemented a shallow-groundwater monitoring program on KWB Lands to evaluate the shallow-groundwater condition and assist in operation of the CVC. The monitoring network consists of approximately 32 piezometers in the vicinity of the CVC. Monitoring frequency is variable depending on changes in groundwater levels.

KWBA and Rosedale have also developed an interim joint operations plan to monitor groundwater conditions on KWB Lands. Projected changes in water levels that may result from KWB operations are predicted with groundwater models, and mitigation measures may be considered under certain conditions.

Groundwater-level monitoring data for the KWB are included in both the DWR and KCWA groundwater level databases. In addition, the Kern Fan Operations and Monitoring Reports (1995-2006) include interpretive information regarding groundwater levels in the study area.

2.3.3 DATA SUMMARY - LIMITATIONS

Groundwater Banking Recharge and Recovery Data

While DWR measures and records the amount of SWP water going into and out of the CVC and KWB Canal, but it does not break down SWP water stored at the KWB by the KCWA member units who are KWB participants. It does account for water delivered to the KWB by the Dudley Ridge Water District. REIR Appendix E (Revised) provides an overview of KWB water deliveries by source and water accounting from 1995 through 2014 on an annual basis.

Data collected and reported by the KFMC for the years 2007–2014 are unpublished. The data consisted of maps and hydrographs depicting changes in water levels).

Measuring Devices

Metering systems used for measuring deliveries to recharge, and primary and secondary conveyance systems, include propeller meters, sharp-crested weirs, Parshall flumes, rated gate openings over certain diameter pipes, and rated boards over other types of structures. The type of delivery system, its condition, and flow rates can affect the accuracy of the measurement. Turbine and propeller meter accuracy generally ranges from 2 to 5 percent and tends to be less accurate during low flow conditions. Over time, parts can get “sticky,” which may further affect accuracy if the systems are not properly maintained. Parshall flume systems generally provide approximately 2 percent accuracy; however, the greater the flow, the less precise the measurement. In addition, ongoing calibration and routine maintenance is critical because vegetation in the channel, trash and silt accumulations near the flume, and flume deterioration from corrosion and algae on the surface can reduce the accuracy of measurements. The accuracy of measurements at rated gate or boards are influenced by the system design or shape, and flow rate and maintenance requirements similar to Parshall flumes. For SWP deliveries, DWR adheres to 2 percent metering accuracy (i.e., at the KWB turnout or CVC turnout).

In addition, data collection efforts revealed that field measurement data performed by KCWA during recharge events at individual recharge ponds, turnouts, and other points of diversion are also unavailable, except for 12 days of continuous monitoring in January 2011, as described in Section 3.3.14. Because of the significant lack of available field measurement data from recharge facilities, the actual infiltration/recharge rates and influence of metering and measurement system accuracy within the banking facilities could not be evaluated.

3. WATER QUALITY DATA

The following sections describe the groundwater quality, surface water quality, and blended water quality data available for the study area.

3.1 GROUNDWATER QUALITY DATA

Groundwater quality data have been collected throughout Kern County as part of various monitoring programs since before 1984. Data collected since January 1, 1984, have been summarized for this report.

Groundwater constituents of concern (COCs) at the KWB site include total dissolved solids (TDS), EC, nitrates (NO_3), arsenic (As), fluoride (F), chlorine (Cl), iron (Fe), manganese (Mn), dibromochloropropane (DBCP) fumigant, ethylene dibromide (EDB) insecticide, uranium (U), and alpha activity. Boron (B), bromide (Br), dissolved organic carbon (DOC), salts, sulfate (SO_4), and 1,2,3-Trichloropropane (TCP) are also COCs that can be present in groundwater, but they generally have resulted in localized impairments and present more of an issue in surface water resources (KCWA 2011; KFMC 2012). Other COCs in groundwater include various petroleum and hydrocarbon constituents.

Sources of water quality data in Kern County include California Department of Public Health (CDPH), DWR, USBR, USGS, Lawrence Livermore National Laboratory (LLNL), California Department of Pesticide Regulation (CDPR), KCWA, and other environmental monitoring programs related to specific monitoring of known contamination areas. These data sets are described further below.

<u>**KCWA Groundwater Quality Monitoring Database**</u>

Reference: KCWA 2015e

Data Source: KCWA (Various water agencies submit data to KCWA).

Years of Data Available: Data coverage varies throughout the data set, depending on the well and constituents sampled for, from before 1984 to August 2014. Coverage specific to the KWB ranges from April 1985 to July 2014.

Study Relevance: KWB groundwater quality (1985-2014)

Type of Data Collected: The well networks in Kern County consist primarily of production and monitoring wells, with some multiple completion monitoring wells (Kern Water Bank Working Group 1992). In most cases, production wells are sampled in accordance with protocols developed by CDPH to test public drinking water supplies. This typically includes semiannual to annual sampling for COCs and constituents required by Title 22 of the California Code of Regulations (CCR), among others, but sampling schedules can be highly variable. Table 3.1.1 provides the production-well sampling schedule for the KWB. Monitoring wells typically are sampled more frequently for general water quality parameters, such as minerals, metals, organics, and physical parameters such as TDS. Some monitoring wells are sampled monthly or semiannually for more general constituents, and annually for more comprehensive CCR Title 22 constituents and COCs.

TABLE 3.1.1.

KWB Production Well Water Quality Sampling Schedule.

Chemical	MCL (mg/L)	Frequency
Primary Inorganics • Section 64432		
Aluminum	1	Every 3 years
Antimony	0.006	Every 3 years
Arsenic	0.05	Every 3 years
Barium	1	Every 3 years
Beryllium	0.004	Every 3 years
Cadmium	0.005	Every 3 years
Chromium (Total Cr)	0.05	Every 3 years
Chromium (hexavalent)	0.010	Initial monitoring before 1/1/15
Cyanide	0.2	Waived[2]
Mercury	0.002	Every 3 years
Nickel	0.1	Every 3 years
Selenium	0.05	Every 3 years
Thallium	0.002	Every 3 years
Lead	Lead Rule	Every 3 years
Fluoride	1.4 to 2.4	Every 3 years
Asbestos—Section 64432.2		
Asbestos—Source Water	7 MFL	Waived
Asbestos—Distribution System sampling if Asbestos-Cement pipe used	7 MFL	Every 9 years if Aggressive Index <11.5
Nitrate/Nitrite—Section 64432.1		
Nitrate (as $N0_3$)*	45	Annually if <23 ma/l*
Nitrite (as nitrogen)**	1	Every 3 years if <0.5 mg/L**
Nitrate + Nitrite (sum as nitrogen)	10	N/A
Secondary Standards—Table 64449-A		
Aluminum	0.2	Every 3 years
Color	15	Every 3 years
Copper	1	Every 3 years
Corrosivity	non-corrosive	Every 3 years
Foamina Aaents	0.5	Every 3 years
Iron	0.3	Every 3 years
Manganese	0.05	Every 3 years
Methyl-tert-butyl ether (MTBE)	0.005	**Every 3 years**
Odor	3	Every 3 years
Silver	0.1	Every 3 years
Thiobencarb	0.001	Waived
Turbidity	5	Every 3 years
Zinc	5	Every 3 years
General Minerals—Section 64449		
Bicarbonate	N/A	Every 3 years
Carbonate	N/A	Every 3 years
Hydroxide Alkalinity	N/A	Every 3 years
Calcium	N/A	Every 3 years
Magnesium	N/A	Every 3 years
Sodium	N/A	Every 3 years
Hardness	N/A	Every 3 years
pH	N/A	Every 3 years
Secondary Standards • Table 64449-8		
Total Dissolved Solids	500-1000;1500	Every 3 years
Specific Conductance	900- 1600; 2200	Every 3 years
Chloride	250-500'600	Every 3 years
Sulfate	250-500;600	Every 3 years
VOCs—Table 64444-A (a)		
Benzene	0.001	Every 9 years
Carbon Tetrachloride	0.0005	Every 9 years

TABLE 3.1.1.

KWB Production Well Water Quality Sampling Schedule.

Chemical	MCL (mg/L)	Frequency
1,2-Dichlorobenzene	0.6	Every 9 years
1 4-Dichlorobenzene	0.005	Every 9 years
1 1-Dichloroethane	0.005	Every 9 years
1,2-Dichloroethane	0.0005	Every 9 years
1,1-Dichloroethvlene	0.006	Every 9 years
cis- 1 2-Dichloroethylene	0.006	Every 9 years
trans-1,2-Dichloroethylene	0.01	Every 9 years
Dichloromethane	0.005	Every 9 years
1 2-Dichloroorooane	0.005	Every 9 years
1 3-Dichloropropene	0.0005	Every 9 years
Ethylbenzene	0.7	Every 9 years
Methyl-tert-butyl ether (MTBE)	0.013[1]	Every 9 years
Monochlorobenzene	0.07	Every 9 years
Styrene	0.1	Every 9 years
1,1 2 2-Tetrachloroethane	0.001	Every 9 years
Tetrachloroethylene (PCE)	0.005	Every 9 years
Toluene	0.15	Every 9 years
1,2 4-Trichlorobenzene	0.07	Every 9 years
1 1,1-Trichloroethane	0.2	Every 9 years
1,1,2-Trichloroethane	0.005	Every 9 years
Trichloroethylene (TCE)	0.005	Every 9 years
Trichlorofluoromethane	0.15	Every 9 years
1,1,2-Trichloro-1,2,2-Trifluoroethane	1.2	Every 9 years
Vinyl Chloride	0.0005	Every 9 years
Xylenes (total)	1.75	Every 9 years
SOCs- Table 64444-A(b)		
Alachlor	0.002	Every 9 years
Atrazine	0.003	Every 9 years
Bentazon	0.018	Waived
Benzo(a)nvrene	0.0002	Waived
Carbofuran	0.018	Waived
Chlordane	0.0001	Waived
2,4-D	0.07	Waived
Dalaoon	0.2	Waived
Dibromochloropropane (DBCP)	0.0002	Every 9 years
Di(2-ethylhexyl)adipate	0.4	Waived
Di(2-ethylhexyl)phthalate	0.004	Waived
Dinoseb	0.007	Waived
Diquat	0.02	Waived
Endothall	0.1	Waived
Endrin	0.002	Waived
Ethylene Dibromide (EDB)	0.00005	Every 9 years
Glyphosate	0.7	Waived
Heptachlor	0.00001	Waived
Heptachlor Epoxide	0.00001	Waived
Hexachlorobenzene	0.001	Waived
Hexachlorocyclopentadiene	0.05	Waived
Lindane	0.0002	Waived
Methoxychlor	0.04	Waived
Molinate	0.02	Waived
Oxamvl	0.2	Waived
Pentachlorophenol	0.001	Waived
Picloram	0.5	Waived
Polychlorinated Biphenyls	0.0005	Waived
Simazine	0.004	Every 9 years

TABLE 3.1.1. **KWB Production Well Water Quality Sampling Schedule.**		
Chemical	**MCL (mg/L)**	**Frequency**
Thiobencarb	0.07	Waived
Toxaphene	0.003	Waived
2 3,7 8-TCDD (Dioxin)	0.00000003	Waived
2,4,5-TP (Silvex)	0.05	Waived
Unregulated VOCs—Table 64450-A		
Bromobenzene, Bromodichloromethane	N/A	Waived
Bromoform, Bromomethane	N/A	Waived
Chlorodibromomethane	N/A	Waived
Chloroethane	N/A	Waived
Chloroform	N/A	Waived
Chloromethane	N/A	Waived
2-Chlorotoluene	N/A	Waived
4-Chlorotoluene	N/A	Waived
Dibromomethane	N/A	Waived
1,3-Dichlorobenzene	N/A	Waived
Dichlorodifluoromethane	N/A	Waived
1,3-Dichloropropane	N/A	Waived
2,2-Dichloroorooane	N/A	Waived
1,1-Dichloropropene	N/A	Waived
1,1,1 2-Tetrachloroethane	N/A	Waived
1,2,3-Trichloropropane	N/A	Waived
Unregulated VOCs & SOCs—Table 64450-B		
Bromacil	N/A	Every 9 years
Bromochloromethane	N/A	Waived
n-Butylbenzene	N/A	Waived
sec-Butylbenzene	N/A	Waived
tert-Butylbenzene	N/A	Waived
Chlorothalonil	N/A	Waived
Dimethoate	N/A	Waived
Diuron	**N/A**	**Every 9 years**
Ethyl-tertiary-butyl ether (ETBE)	N/A	Sample only if MTBE is detected
Hexachlorobutadiene	N/A	Waived
Isopropylbenzene	N/A	Waived
p-Isopropyltoluene	N/A	Waived
Naohthalene	N/A	Waived
1-Phenvlpropane	N/A	Waived
Prometrvn	N/A	Waived
Tertiary-amyl-methyl ether (TAME)	N/A	Sample only if MTBE is detected
1,2,3-Trichlorobenzene	N/A	Waived
1,2,4-Trimethylbenzene	N/A	Waived
1,3,5-Trimethylbenzene	N/A	Waived
Unregulated SOCs—Table 64450-C		
Aldicarb	N/A	Waived
Aldicarb sulfone	N/A	Waived
Aldicarb sulfoxide	N/A	Waived
Aldrin	N/A	Waived
Butachlor	N/A	Waived
Carbaryl	N/A	Waived
Dicamba	N/A	Waived
Dieldrin	N/A	Waived
3-Hvdroxycarbofuran	N/A	Waived
Methomyl	N/A	Waived
Metolachlor	N/A	Waived

TABLE 3.1.1. KWB Production Well Water Quality Sampling Schedule.		
Chemical	**MCL (mg/L)**	**Frequency**
Metribuzin	N/A	Waived
Prooachlor	N/A	Waived
Unregulated inorganics—Table 64450-D		
Perchlorate	N/A	Waived
Radioactivity—Section 64441		
Gross Aloha	15 pCi/L	4 quarters every 4 years
Radium 226 + 228***	3 pCi/L	Onlv when GA > 5 pCi/L
Uranium***	20 pCi/L	Onlv when GA > 5 pCi/L
Man Made Radioactivity—Section 64443		
Tritium	20000 pCi/L	Not Required
Strontium	8 pCi/L	Not Required
Gross Beta	50 pCi/L	Not Required

Notes:

MCL = Maximum Contaminant Level; mg/L = milligrams per liter; pCi/L = picocuries per liter; VOC = volatile organic compund

1. Also has a secondary MCL of 0.005 mg/L
2. “Waive” means constituent has been waived from sampling requirement in accordance with DWR’s 2001 W.Q. Pump-in Policy and/or according to the CDPH.

*Nitrate sampling shall be increased to quarterly following any result greater than or equal to 23 mg/L; this may be reduced to annual upon request, if all four quarterly results are < 45 mg/L.

**Nitrite sampling shall be increased to quarterly following any result greater than or equal to 0.5 mg/L; this may be reduced to annual, upon request, if all four quarterly results are < 1.0 mg/L.

***Sampling for Radium 226, 228 and Uranium is required only when the Gross Alpha exceeds 5 pC1/L.

Source: DWR 2004

The KCWA database includes data collected from 1,953 wells (monitoring and production), many of which are sampled as part of the KWB Groundwater Monitoring Program (Kern Water Bank Working Group 1992) and the Kern Fan Water Banking Program Monitoring (KFMC 1997). This data set includes groundwater quality data from various agencies and districts associated with the Kern Fan and the KWB. Because some districts have overlapping boundaries, some wells are sampled by multiple districts and multiple entities. The database includes 286,755 records from 1,953 locations, which include 1,154 production wells, 63 cluster monitoring wells, 46 nested monitoring wells, 307 single monitoring wells, 141 unknown wells, and 242 unclassified wells. Unclassified wells are wells that do not have a well type associated with them in the database. Cluster monitoring wells (35–714 feet deep) and nested monitoring wells (120–735 feet deep) tend to be shallow to moderately deep. Single monitoring wells tend to be very shallow, ranging from 7 to 20 feet deep, with some 30–480 feet deep. Production wells are the deepest and range from 106 to 2,120 feet.

Coverage of the data set ranges from January 1984 to August 2014 for 385 constituents, including various CCR Title 22 constituents, hydrocarbons, pesticides, and the following COCs: As, B, Br, Cl, Cr, chromium-6 (Cr+6), F, Fe, Mn, NO_3, SO_4, TCP, TDS, DBCP, EDB, U, and alpha activity. Specifically, this data set includes 80,117 sample records from the KWB for 318 constituents that were sampled for between April 1985 and December 2011. KWB data include samples from 43 monitoring wells and 104 production wells. Table 3.1.2 summarizes the wells sampled by district with available sample data in the KCWA database. The single monitoring wells were sampled for COCs the least, but COC data exist for most of the other types of monitoring wells. Many production wells also were not sampled for COC concentrations. Table 3.1.3 summarizes the availability of COC sample data per district, well type, and the sampling period for which the data are available. It is noteworthy that not all wells in Table 3.1.3 have available COC data.

TABLE 3.1.2. KCWA Groundwater Water Quality Database.			
Water District and Well Type	**Total Number of Wells in the District**	**Sampling Period**	
		From	**To**
ARVIN-EDISON WSD		7/25/1984	4/10/2013
Production Well	13	6/9/1987	4/10/2013
Unclassified	33	7/25/1984	7/26/1993
BELRIDGE WSD		7/18/1986	11/12/1998
Monitor (Single)	3	7/18/1986	11/12/1998
BERRENDA MESA WD		6/10/2009	7/13/2009
Production Well	2	6/10/2009	7/13/2009
BUENA VISTA WSD		3/30/1984	7/31/2014
Monitor (Cluster)	6	6/13/1996	7/29/2014
Monitor (Single)	44	7/1/1986	7/25/2014
Production Well	14	10/10/1988	4/1/2010
Unknown	1	8/15/2007	1/29/2008
Unclassified	27	3/30/1984	7/31/2014
BUENA VISTA WSD/HENRY MILLER WD		7/1/1986	7/15/2014
Monitor (Single)	12	7/1/1986	7/15/2014
Production Well	2	6/2/2008	1/19/2009
CAWELO WD		10/31/1984	3/11/2014
Production Well	8	7/6/1987	3/10/2010
Unknown	2	4/25/1985	6/30/1988
Unclassified	3	10/31/1984	3/11/2014
DELANO-EARLIMART ID		10/16/2007	4/26/2010
Production Well	4	10/16/2007	4/26/2010
HENRY MILLER WD		6/30/1987	7/14/2014
Monitor (Single)	1	6/30/1987	7/14/2014
HENRY MILLER WD/WEST KERN WD		7/1/1986	7/15/2014
Monitor (Single)	8	7/1/1986	7/15/2014
KERN COUNTY WATER AGENCY IMPROVEMENT DISTRICT NO. 4		**1/9/1984**	**7/24/2014**
Monitor (Single)	8	12/6/1988	7/16/2013
Production Well	139	1/9/1984	7/24/2014
Unclassified	12	3/1/1984	7/10/2013
KERN CO WA ID #4/NORTH KERN WSD		**4/25/1984**	**4/16/2008**
Production Well	8	4/25/1984	4/16/2008
Unclassified	3	8/28/1986	2/17/1999
KERN DELTA WD		**3/27/1984**	**7/17/2014**
Monitor (Cluster)	2	12/5/1997	7/17/2014
Monitor (Single)	36	7/1/1986	7/14/2014
Production Well	88	3/27/1984	1/20/2011
Unknown	2	1/19/2005	10/1/2008
Unclassified	16	4/5/1985	8/14/2008
KERN WATER BANK		**4/15/1985**	**12/1/2111**
Monitor (Cluster)	6	10/8/1997	7/22/2014
Monitor (Nested)	30	5/2/1989	7/25/2014
Monitor (Single)	7	9/18/1990	9/15/2011
Production Well	104	4/15/1985	12/1/2111
LOST HILLS WD		**4/5/1984**	**8/19/2014**
Monitor (Single)	24	5/15/1985	8/19/2014
Production Well	2	8/10/2009	10/13/2009
Unknown	1	11/28/2006	8/18/2014
Unclassified	3	4/5/1984	12/15/2010

TABLE 3.1.2. KCWA Groundwater Water Quality Database.			
Water District and Well Type	Total Number of Wells in the District	Sampling Period	
		From	To
NORTH KERN WSD		**4/3/1984**	**7/9/2102**
Monitor (Cluster)	9	7/15/1987	7/17/2013
Monitor (Nested)	10	12/18/1989	7/9/2102
Production Well	99	4/25/1985	7/31/2014
Unknown	6	4/3/1984	2/24/1988
NORTH KERN WSD/KERN WATER BANK		**4/5/1991**	**3/22/2013**
Production Well	2	4/5/1991	3/22/2013
NORTH KERN WSD/SHAFTER-WASCO ID		**7/31/2008**	**7/31/2008**
Production Well	1	7/31/2008	7/31/2008
NORTH KERN WSD/WEST KERN WD		**9/29/1997**	**7/22/2014**
Monitor (Nested)	3	9/29/1997	7/22/2014
Production Well	1	11/11/2003	6/5/2007
OTHER DISTRICTS		**3/19/1984**	**6/1/2796**
Monitor (Cluster)	25	7/16/1987	7/16/2014
Monitor (Single)	84	7/1/1986	7/25/2014
Production Well	500	3/27/1984	6/1/2796
Unknown	113	2/6/1986	3/10/2014
Unclassified	44	3/19/1984	3/10/2014
ROSEDALE–RIO BRAVO WSD		**10/5/1984**	**8/5/2014**
Monitor (Cluster)	8	11/5/1997	8/5/2014
Monitor (Single)	5	7/2/1986	7/15/2014
Production Well	41	10/5/1984	7/24/2014
Unknown	2	8/27/1986	10/26/2009
Unclassified	4	4/10/1985	8/5/2008
SEMITROPIC WSD		**4/2/1984**	**7/31/2014**
Monitor (Cluster)	3	8/18/1998	7/29/2009
Monitor (Single)	62	7/3/1986	7/25/2014
Production Well	69	4/2/1984	3/9/2010
Unknown	14	4/29/1985	8/15/2007
Unclassified	71	4/17/1984	7/31/2014
SHAFTER-WASCO ID		**6/24/1987**	**10/20/2010**
Monitor (Cluster)	1	12/6/2004	12/6/2004
Production Well	11	6/24/1987	10/20/2010
SOUTHERN SAN JOAQUIN MUNICIPAL UTILITY DISTRICT		**4/3/1984**	**3/22/2010**
Production Well	21	4/3/1984	3/22/2010
Unclassified	4	4/3/1984	6/24/1987
WEST KERN WD		**1/12/1984**	**7/24/2014**
Monitor (Cluster)	1	6/8/1994	7/24/2014
Monitor (Single)	3	6/8/1994	7/24/2014
Production Well	10	1/12/1984	12/18/2007
Unclassified	4	1/13/1987	7/10/2008
WEST KERN WD/KERN WATER BANK		**6/1/1989**	**7/31/2014**
Monitor (Cluster)	2	9/30/1997	7/24/2014
Monitor (Nested)	3	4/9/1991	7/24/2014
Monitor (Single)	1	7/14/1999	8/2/2005
Production Well	2	6/1/1989	7/31/2014

TABLE 3.1.2. KCWA Groundwater Water Quality Database.			
Water District and Well Type	Total Number of Wells in the District	Sampling Period	
		From	To
WHEELER RIDGE-MARICOPA WSD		**3/28/1984**	**7/14/2014**
Monitor (Single)	9	7/1/1986	7/14/2014
Production Well	10	12/2/2004	2/18/2014
Unclassified	5	3/28/1984	4/5/2013
WHEELER RIDGE-MARICOPA WSD/ARVIN-EDISON WSD		**8/8/1984**	**8/18/2014**
Production Well	3	8/14/1992	11/26/2008
Unclassified	13	8/8/1984	8/18/2014
Total Number of Wells	**1953**		

Notes:
WD = Water District; WSD = Water Storage District
Source: KCWA 2015e

TABLE 3.1.3. KCWA Groundwater Quality Database for Contaminants of Concern.					
District	Well Type	COC Sampled For	Total Number of Wells with COC Data	Sampling Period with COC Data	
				From	To
Arvin-Edison WSD	Production Well	Alpha Activity, U, DBCP, EDB, TCP, As, B, Cl, Cr, F (total), Fe, Mn, NO3, SO4, TDS	13	6/9/1987	4/10/2013
	Unclassified	B, Cl, Fe, Mn, NO3, SO4, TDS	33	7/25/1984	7/26/1993
Belridge WSD	Monitor (Single)	No COC measured	0		
Berrenda Mesa WD	Production Well	Alpha Activity, DBCP, EDB, As, B, Cl, F (total), NO3, SO4, TDS	2	6/10/2009	7/13/2009
Buena Vista WSD	Monitor (Cluster)	Alpha Activity, As, As (dissolved), B, Cl, F (total), Fe, Mn, NO3, SO4, TDS	6	6/13/1996	7/29/2014
	Monitor (Single)	TDS	9	3/30/2000	4/12/2000
	Production Well	Alpha Activity, DBCP, EDB, As, B, Cl, F (total), Fe, Mn, NO3, SO4, TDS	14	10/10/1988	4/1/2010
	Unknown	Alpha Activity, As, B, Cl, Cr, F (total), Fe, Mn, NO3, SO4, TDS	1	8/15/2007	1/29/2008
	Unclassified	Alpha Activity, U, As, As (dissolved), B, Cl, Cr, F (dissolved), F (total), Fe, Mn, NO3, SO4, TDS	26	3/30/1984	7/31/2014
Buena Vista WSD/Henry Miller WD	Monitor (Single)	No COC measured	0		
	Production Well	Alpha Activity, As, B, Cl, F (total), NO3, SO4, TDS	2	6/2/2008	1/19/2009
Cawelo WD	Production Well	Alpha Activity, U, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS	8	7/6/1987	3/10/2010
	Unknown	B, Cl, NO3, SO4, TDS	2	4/25/1985	6/30/1988
	Unclassified	As, B, Cl, F (total), NO3, SO4, TDS	3	10/31/1984	3/11/2014
Delano-Earlimart ID	Production Well	Alpha Activity, U, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS	4	10/16/2007	4/26/2010
Henry Miller WD	Monitor (Single)	No COC measured	0		

TABLE 3.1.3.

KCWA Groundwater Quality Database for Contaminants of Concern.

District	Well Type	COC Sampled For	Total Number of Wells with COC Data	Sampling Period with COC Data	
				From	To
Henry Miller WD/West Kern WD	Monitor (Single)	EDB	1	9/8/1997	9/8/1997
KCWA Improvement District No. 4	Monitor (Single)	No COC measured	0		
	Production Well	Alpha Activity, U, As, B, Br, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP, TOC, DOC	129	1/9/1984	7/24/2014
	Unclassified	Alpha Activity, U, As, B, Br, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP, TOC, DOC	12	3/1/1984	7/10/2013
KCWA Improvement District No. 4/North Kern WSD	Production Well	Alpha Activity, U, As, B, Br, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP, TOC, DOC	8	4/25/1984	4/16/2008
	Unclassified	Alpha Activity, B, Cl, F (total), Fe, Mn, NO3, SO4, TDS	3	8/31/1989	2/17/1999
Kern Delta WD	Monitor (Cluster)	Alpha Activity, U, As, B, Cl, F (total), Fe, Mn, NO3, SO4, TDS	2	12/5/1997	7/17/2014
	Monitor (Single)	No COC measured	0		
	Production Well	Alpha Activity, U, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP	86	3/27/1984	1/20/2011
	Unknown	Alpha Activity, U, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS	2	1/19/2005	10/1/2008
	Unclassified	Alpha Activity, U, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS	16	4/5/1985	8/14/2008
Kern Water Bank	Monitor (Cluster)	Alpha Activity, U, As, As (dissolved), B, Br, Cl, Cr, Cr6 (dissolved), DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP, DOC	6	10/8/1997	7/22/2014
	Monitor (Nested)	Alpha Activity, U, As, As (dissolved), B, Br, Cl, Cr, Cr6 (dissolved), DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP, TOC, DOC	30	5/2/1989	7/25/2014
	Monitor (Single)	Alpha Activity, Br	1	3/4/1992	9/1/1992
	Production Well	Alpha Activity, U, As, As (dissolved), B, Br, Cl, Cr, Cr6 (dissolved), DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP, TOC, DOC	104	4/15/1985	12/1/2111
Lost Hills WD	Monitor (Single)	As, NO3	1	5/15/1985	6/10/1985
	Production Well	Alpha Activity, As, B, Cl, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS	2	8/10/2009	10/13/2009
	Unknown	No COC measured	0		
	Unclassified	B, Cl, NO3, SO4, TDS	2	4/5/1984	4/5/1984

TABLE 3.1.3.

KCWA Groundwater Quality Database for Contaminants of Concern.

District	Well Type	COC Sampled For	Total Number of Wells with COC Data	Sampling Period with COC Data	
				From	To
North Kern WSD	Monitor (Cluster)	Alpha Activity, As, As (dissolved), B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP	9	7/15/1987	7/17/2013
	Monitor (Nested)	Alpha Activity, U, As, As (dissolved), B, Br, Cl, Cr, DBCP, EDB, F (total), F (dissolved), Fe, Mn, NO3, SO4, TDS, TCP	10	12/19/1989	7/9/2102
	Production Well	Alpha Activity, U, As, As (dissolved), B, Br, Cl, Cr, Cr6 (dissolved), DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP, DOC, TOC	98	4/25/1985	7/31/2014
	Unknown	B, Cl, NO3, SO4, TDS	6	4/3/1984	2/24/1988
North Kern WSD/Kern Water Bank	Production Well	Alpha Activity, As, B, Br, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP, DOC, TOC	2	4/5/1991	3/22/2013
North Kern WSD/ Shafter-Wasco ID	Production Well	U, As, Cr, Fe, Mn	1	7/31/2008	7/31/2008
North Kern WSD/West Kern WD	Monitor (Nested)	As, As (dissolved), B, Cl, F (total), Fe, Mn, NO3, SO4, TDS	3	9/29/1997	7/22/2014
	Production Well	Alpha Activity, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP	1	11/11/2003	6/5/2007
Other Districts	Monitor (Cluster)	As, As (dissolved), B, Cl, Cr, F (total), Fe, Mn, NO3, SO4, TDS, TOC	25	7/16/1987	7/16/2014
	Monitor (Single)	Alpha Activity, U, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP, TOC	46	4/16/1996	8/4/2009
	Production Well	Alpha Activity, U, As, As (dissolved), B, Br, Cl, Cr, Cr6 (dissolved), DBCP, EDB, F (dissolved), F (total), Fe, Mn, NO3, SO4, TDS, TCP, TOC, DOC	493	3/27/1984	7/31/2014
	Unknown	Alpha Activity, U, As, B, Br, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP, TOC	90	2/6/1986	3/10/2014
	Unclassified	Alpha Activity, U, As, B, Br, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP, TOC	42	3/19/1984	3/10/2014
Rosedale–Rio Bravo WSD	Monitor (Cluster)	Alpha Activity, As, As (dissolved), B, Cl, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP	8	11/5/1997	8/5/2014
	Monitor (Single)	EDB, TDS	2	11/28/1994	3/4/2012
	Production Well	Alpha Activity, U, As, As (dissolved), B, Br, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TOC, TCP, DOC	41	4/10/1985	7/24/2014
	Unknown	U, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS	2	8/27/1986	10/26/2009
	Unclassified	Alpha Activity, U, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS	4	4/10/1985	8/5/2008

TABLE 3.1.3.

KCWA Groundwater Quality Database for Contaminants of Concern.

District	Well Type	COC Sampled For	Total Number of Wells with COC Data	Sampling Period with COC Data	
				From	To
Semitropic WSD	Monitor (Cluster)	U, As, B, Br, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TOC	3	8/18/1998	7/9/2007
	Monitor (Single)	U, As, B, Br, Cl, Cr, DBCP, EDB, F (total), Mn, NO3, SO4, TDS, TOC	4	8/19/1998	7/10/2007
	Production Well	Alpha Activity, U, As, As (dissolved), B, Br, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TOC, TCP	18	4/2/1984	3/9/2010
	Unknown	U, As, B, Br, Cl, Cr, DBCP, EDB, F (total), Mn, NO3, SO4, TDS, TOC	14	4/29/1985	8/15/2007
	Unclassified	Alpha Activity, U, As, As (dissolved), B, Br, Cl, Cr, Cr6 (dissolved), DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TOC, TCP	70	4/17/1984	7/31/2014
Shafter-Wasco ID	Monitor (Cluster)	As, B, Cl, Cr, DBCP, EDB, F (total), Mn, NO3, SO4, TDS	1	12/6/2004	12/6/2004
	Production Well	Alpha Activity, U, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS	10	6/24/1987	10/20/2010
Southern San Joaquin Municipal Utility District	Production Well	Alpha Activity, U, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS	21	4/3/1984	3/22/2010
	Unclassified	As, B, Cl, NO3, SO4, TDS	3	4/3/1984	4/21/1987
West Kern WD	Monitor (Cluster)	As, As (dissolved), B, Cl, F (total), Fe, Mn, NO3, SO4, TDS	1	9/30/1997	7/24/2014
	Monitor (Single)	As, As (dissolved), B, Cl, F (total), Fe, Mn, NO3, SO4, TDS	3	9/30/1997	7/24/2014
	Production Well	Alpha Activity, U, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP	10	1/12/1984	12/18/2007
	Unclassified	Alpha Activity, U, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP	4	1/13/1987	7/10/2008
West Kern WD/Kern Water Bank	Monitor (Cluster)	Alpha Activity, As, As (dissolved), B, Cl, F (total), Fe, Mn, NO3, SO4, TDS	2	9/30/1997	7/24/2014
	Monitor (Nested)	As, As (dissolved), B, Br, Cl, F (total), Fe, Mn, NO3, SO4, TDS, TOC	3	4/9/1991	7/24/2014
	Monitor (Single)	No COC measured	0		
	Production Well	Alpha Activity, U, As, As (dissolved), B, Br, Cl, Cr, Cr6 (dissolved), DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS, TCP, DOC	2	6/20/1994	7/31/2014
Wheeler Ridge–Maricopa WSD	Monitor (Single)	No COC measured	0		
	Production Well	Alpha Activity, U, As, B, Cl, Cr, DBCP, EDB, F (total), Fe, Mn, NO3, SO4, TDS	9	4/25/2007	2/18/2014
	Unclassified	B, Cl, NO3, SO4, TDS	5	3/28/1984	4/5/2013
Wheeler Ridge-Maricopa WSD/Arvin-Edison WSD	Production Well	Alpha Activity, As, B, Cl, DBCP, EDB, F (total), NO3, SO4, TDS	3	8/14/1992	11/26/2008
	Unclassified	B, Cl, NO3, SO4, TDS	13	8/8/1984	8/18/2014
Total Number of Wells with COC Data			***1,610***		

Notes:

As = arsenic; B = boron; Cl = chlorine; COC = constituent of concern; DBCP = dibromochloropropane; EDB = ethylene dibromide; F = fluoride; Fe = iron; Mn = manganese; NO3 = nitrate; SO4 = sulfate; TCP = 1,2,3-Trichloropropane; TDS = total dissolved solids; TOC = total organic carbon; U = uranium; WD = Water District; WSD = Water Storage District

Source: KCWA 2015e

Data Collection Equipment: Grab samples from purged wells. Sampling and analytical methods depend on constituents sampled.

Limitations to Data Use: The following limitations associated with the database were identified:

- The availability of well depth and geometry information is variable. Multiple completion wells are indistinguishable in the data set because the data set identifies only the total depth of the wells.
- Some typographical errors exist in the sampling dates of the data set.
- The database is inconsistent in specifying whether some values for constituents are dissolved concentrations (a portion of the total) or total concentrations.

TDS was determined with two different methods. It was either calculated or determined through analysis, or both.

__Groundwater Ambient Monitoring Assessment Program Database__

The Groundwater Ambient Monitoring and Assessment Program (GAMA) was developed in response to the Groundwater Quality Monitoring Act of 2001 (Assembly Bill 599), and is being implemented by the State Water Resources Control Board (SWRCB). There are four GAMA programs: the Priority Basin Project (PBP), Domestic Wells Project, GeoTracker GAMA, and Special Studies Project. GAMA has been implemented throughout California and provides a comprehensive assessment of groundwater quality designed to characterize chemical constituents and identify trends (SWRCB 2013a).

Documents and reports for the GAMA PBP, Special Studies, and Domestic Well Projects are available through the SWRCB website. GAMA water quality data are available through the SWRCB GeoTracker GAMA database (SWRCB website [a]), which integrates water quality data from various sources and displays the information on an online interactive, searchable map. The entire GAMA data set for Kern County (2,670 wells) includes sample data from the following sources:

- SWRCB Division of Drinking Water, formerly CDPH (includes public water supply wells)
- CDPR (includes private domestic wells, agricultural irrigation wells, and public supply wells)
- DWR (includes either irrigation, stock, or domestic supply wells)
- Environmental Monitoring Program Clean-up Sites (includes wells at regulated facilities with known or suspected potential contamination)
- LLNL (includes data collected for the Special Studies Project)
- USGS (categorized in the database as “USGS” for the Priority Basin Project and “USGSNEW” for monitoring) (public and domestic water supply wells)

Table 3.1.4 summarizes the source data available through the SWRCB’s GeoTracker GAMA for each Kern County district (water districts, water storage districts, improvement districts, and irrigation districts), including the time frame of sampling after January 1, 1984, through November 2010. Joint powers authority (JPA) and adjoining entity districts are noted where applicable. Some districts overlap and collect data from the same wells; therefore, the overlaps are shown as groupings in addition to the individual district information provided.

Each data source compiled into the GAMA GeoTracker database is further discussed individually below.

TABLE 3.1.4.

GeoTracker GAMA Database Groundwater Quality Water Data Availability.

District	Data Source	Number of Wells	Sampling Period	
			From	To
Arvin-Edison WSD	CDPH	47	8/7/1985	9/8/2010
	DPR Water Supply Wells	14	9/10/1987	9/26/1995
	DWR Water Supply Wells	19	7/25/1984	6/29/1988
	Environmental Monitoring Wells (EDF)	11	3/16/2002	8/30/2010
	USGS Water Supply Wells	5	1/10/2006	2/28/2006
	USGS (New) Water Supply Wells	7	7/16/1986	8/5/1986
Belridge WSD	USGS (New) Water Supply Wells	1	6/23/1989	6/23/1989
Berrenda Mesa WSD	CDPH	1	4/23/2002	4/23/2002
	USGS (New) Water Supply Wells	1	3/29/1988	3/29/1988
Buena Vista WSD	CDPH	11	9/15/1986	11/18/2010
	CDPR Water Supply Wells	1	4/16/1996	4/16/1996
	Environmental Monitoring Wells (EDF)	3	3/26/2003	1/4/2008
	USGS Water Supply Wells	3	1/11/2006	2/6/2006
	USGS (New) Water Supply Wells	11	7/17/1986	7/12/1989
Buena Vista WSD/Henry Miller WD	USGS (New) Water Supply Wells	1	6/29/1989	6/29/1989
Cawelo WD	CDPH	15	1/9/1986	8/2/2010
	CDPR Water Supply Wells	3	4/26/1995	10/16/2001
	DWR Water Supply Wells	6	7/10/1984	7/18/1990
	USGS Water Supply Wells	3	1/23/2006	2/27/2006
	USGS (New) Water Supply Wells	3	7/22/1986	9/11/2002
Delano-Earlimart ID	CDPH	3	9/1/1987	6/11/2010
	CDPR Water Supply Wells	4	10/16/2001	5/20/2010
	DWR Water Supply Wells	1	4/21/1987	4/21/1987
	USGS (New) Water Supply Wells	1	6/6/1995	8/7/2002
KCWA Improvement District No. 4	CDPH	268	1/4/1984	10/4/2010
	DWR Water Supply Wells	135	1/9/1984	4/2/1991
	Environmental Monitoring Wells (EDF)	311	10/17/2001	9/20/2010
	LLNL Wells	26	8/12/2003	5/24/2004
	USGS Water Supply Wells	8	1/10/2006	3/1/2006
	USGS (New) Water Supply Wells	11	7/16/1986	5/21/2003
KCWA Improvement District No. 4/North Kern WSD	DWR Water Supply Wells	3	8/27/1985	3/13/1991
	Environmental Monitoring Wells (EDF)	40	3/25/2003	11/14/2007
	LLNL Wells	2	10/21/2003	4/2/2004
	USGS Water Supply Wells	2	1/24/2006	1/26/2006
	USGS (New) Water Supply Wells	1	7/23/1986	8/13/2002
Kern Delta WD	CDPH	72	5/15/1984	9/2/2010
	CDPR Water Supply Wells	38	9/9/1985	5/18/2010
	DWR Water Supply Wells	1	5/16/1988	3/28/1991
	Environmental Monitoring Wells (EDF)	25	1/9/2003	9/7/2006
	LLNL Wells	5	8/15/2003	12/1/2004
	USGS Water Supply Wells	6	1/10/2006	3/1/2006
	USGS (New) Water Supply Wells	21	7/18/1986	8/26/2010
Kern Water Bank	CDPH	2	5/20/1994	3/3/2010
	CDPR Water Supply Wells	5	4/27/1993	8/10/1994
	USGS (New) Water Supply Wells	1	7/30/1986	7/30/1986
Lost Hills WD	CDPH	1	9/3/1987	10/19/1987
	Environmental Monitoring Wells (EDF)	3	2/7/2006	5/6/2010
	USGS (New) Water Supply Wells	35	7/31/1986	10/20/1992
North Kern WSD	CDPH	15	7/28/1986	7/26/2010
	CDPR Water Supply Wells	8	9/28/1989	5/19/2010
	DWR Water Supply Wells	2	7/23/1985	4/21/1987
	LLNL Wells	1	8/15/2003	3/10/2004
	USGS Water Supply Wells	3	1/25/2006	3/2/2006
	USGS (New) Water Supply Wells	2	7/20/1986	7/31/1986

TABLE 3.1.4.

GeoTracker GAMA Database Groundwater Quality Water Data Availability.

District	Data Source	Number of Wells	Sampling Period	
			From	To
Rosedale-Rio Bravo WSD	CDPH	58	10/5/1984	11/18/2010
	CDPR Water Supply Wells	3	11/14/2000	5/19/2010
	DWR Water Supply Wells	2	5/16/1988	4/1/1991
	LLNL Wells	1	9/4/2003	3/19/2004
	USGS (New) Water Supply Wells	4	7/18/1986	7/21/1986
Semitropic WSD	CDPH	25	1/30/1985	11/18/2010
	CDPR Water Supply Wells	14	9/28/1989	6/6/2006
	DWR Water Supply Wells	2	7/23/1985	7/23/1985
	Environmental Monitoring Wells (EDF)	3	9/18/2001	4/28/2003
	USGS Water Supply Wells	4	1/11/2006	2/16/2006
	USGS (New) Water Supply Wells	19	7/17/1986	9/10/2002
Shafter-Wasco ID	CDPH	48	1/17/1984	8/17/2010
	CDPR Water Supply Wells	24	10/3/1990	5/19/2010
	DWR Water Supply Wells	1	5/8/1985	5/8/1985
	Environmental Monitoring Wells (EDF)	1	1/23/2003	3/4/2009
	USGS Water Supply Wells	4	1/12/2006	2/27/2006
	USGS (New) Water Supply Wells	5	7/17/1986	8/7/1986
Southern San Joaquin MUD	CDPH	38	9/20/1984	8/4/2010
	CDPR Water Supply Wells	22	8/22/1990	6/5/2008
	DWR Water Supply Wells	26	1/7/1984	5/5/1987
	Environmental Monitoring Wells (EDF)	42	12/13/2001	8/13/2010
	USGS Water Supply Wells	4	1/11/2006	2/28/2006
	USGS (New) Water Supply Wells	6	7/28/1986	8/13/1986
Tehachapi-Cummings Co WD	CDPH	109	7/24/1986	9/8/2010
	CDPR Water Supply Wells	1	10/3/2007	10/3/2007
	Environmental Monitoring Wells (EDF)	44	8/14/2001	7/28/2010
	USGS Water Supply Wells	28	6/5/2006	6/24/2008
	USGS (New) Water Supply Wells	1	6/28/1984	8/20/1987
Tejon-Castaic WD (JPA)	CDPH	5	9/2/1986	7/14/2010
West Kern WD	CDPH	12	9/24/1985	9/1/2010
	Environmental Monitoring Wells (EDF)	6	5/25/2007	4/22/2010
	USGS Water Supply Wells	3	1/10/2006	2/13/2006
	USGS (New) Water Supply Wells	1	7/29/1986	7/29/1986
Wheeler Ridge-Maricopa WSD	CDPH	12	5/15/1986	10/5/2010
	CDPR Water Supply Wells	5	8/21/1990	4/16/1996
	USGS Water Supply Wells	1	1/30/2006	1/30/2006
	USGS (New) Water Supply Wells	13	7/18/1986	2/26/1991
Wheeler Ridge-Maricopa WSD (JPA)/Arvin-Edison WSD	CDPH	1	6/14/1989	3/15/2010
	CDPR Water Supply Wells	1	3/31/1994	3/31/1994
	USGS Water Supply Wells	1	3/1/2006	3/1/2006
	USGS (New) Water Supply Wells	2	7/28/1986	6/30/1989
Wheeler Ridge-Maricopa WSD/West Kern WD	USGS (New) Water Supply Wells	2	7/15/1986	7/15/1986
Other Districts	CDPH	511	1/3/1984	10/20/2010
	CDPR Water Supply Wells	6	9/29/1992	5/19/2010
	DWR Water Supply Wells	18	6/26/1984	7/18/1990
	Environmental Monitoring Wells (EDF)	74	11/5/2001	9/21/2010
	LLNL Wells	14	5/7/2003	4/1/2004
	USGS Water Supply Wells	74	1/9/2006	12/11/2008
	USGS (New) Water Supply Wells	141	6/26/1984	8/25/2010
Total Number of Wells in Kern County		**2,670**		

Notes:

CDPH = California Department of Public Health; DWR = California Department of Water Resources; ID = Improvement District; JPA = joint powers authority; LLNL = Lawrence Livermore National Laboratory; USGS = U.S. Geological Survey; WSD = Water Storage District; WD = Water District

Source: SWRCB Website [b]

California Department of Public Health Data

Reference: SWRCB Website [b]

Data Source: SWRCB Division of Drinking Water (formerly CDPH)

Years of Data Available: January 1984 through November 2010

Study Relevance: 60 samples from the KWB (1994-2010)

Type of Data Collected: The CDPH data set includes records for active and inactive public drinking water sources (systems serving 15 or more connections or more than 25 people per day). The majority of CDPH water quality data are for untreated water supplies, including groundwater sources (wells) and surface water sources. Many of the sources, including wells, receive treatment before delivery to consumers; therefore, the water quality results in the CDPH data set may not be representative of the water delivered to customers. The database includes 713,726 records from 1,254 locations for 187 constituents, including various CCR Title 22 constituents, hydrocarbons, pesticides, and the following COCs: As, B, Br, Cl, Cr, Cr+6, F, Fe, Mn, NO_3, SO_4, TCP, TDS, DBCP, EDB, U, and alpha activity. Specifically, this data set includes 60 sample records from the KWB that were collected between May 1994 and March 2010.

Data Collection Equipment: Grab samples from purged wells. Analytical methods and reporting limits vary for analyte and are included in the data set.

Limitations to Data Use: 1) Sampling depth and well screen information is not included in the data set. 2) The database does not specify whether constituents are reported as dissolved or total concentrations.

California Department of Pesticide Regulation Data

Reference: SWRCB Website [b]

Data Source: SWRCB/CDPR

Years of Data Available: September 1985 through May 2010

Study Relevance: 32 samples from the KWB (limited data)

Type of Data Collected: CDPR's Well Inventory data set is collected as part of the Groundwater Protection Program. It is used to monitor for a wide variety of pesticides and compile sample data to improve understanding of the environmental impact and behavior of pesticides, and to develop pesticide-use practices that reduce threats to groundwater. The majority of CDPR data are for untreated water supplies. The database includes 1,213 records from 149 locations for 27 constituents, including hydrocarbons and pesticides. Specifically, this data set includes 32 sample records from the KWB that were collected between April 1993 and August 1994.

Data Collection Equipment: Grab samples from purged wells. Analytical methods and reporting limits vary for analyte and are included in the data set. Public supply wells typically are drilled to depths between 600 and 800 feet below land surface, consist of solid casing from the land surface to a depth of about 275–450 feet, and are perforated or screened below the solid casing (Burton and Belitz 2012).

Limitations to Data Use: 1) Sampling depth and well screen information is not included in the data set. 2) This data set does not provide data for any of the listed COC. 3) The database does not specify whether constituents are reported as dissolved or total concentrations.

California Department of Water Resources Data

References: DWR 2015e, SWRCB Website [b]

Data Holder/Source: SWRCB/DWR. 1) Water quality for DWR statewide wells has been brought into the GAMA GeoTracker database by the SWRCB. 2) DWR's Water Data Library primarily has groundwater level and surface water quality data related to pump-ins and California Aqueduct water quality.

Years of Data Available: January 1984 through April 1991

Study Relevance: Water quality of the KWB Canal and other canals introducing water into the California Aqueduct

Type of Data Collected: DWR monitors groundwater basins throughout California to determine water quality and related factors affecting beneficial uses. Comprehensive assessments are conducted to determine general chemical characteristics, including concentrations of minerals, nutrients, and heavy metals; and occasionally, organic and bacterial constituents. Most of the wells sampled by DWR are either irrigation (e.g., agricultural-use), stock, or domestic wells, and are sampled on 3- to 4-year rotations. The database includes 3,635 records from 216 locations for 21 constituents, including the following COCs: As, B, Cl, F, Fe, Mn, NO_3, SO_4, and TDS.

Data Collection Equipment: Grab samples from purged wells. Analytical methods and reporting limits vary for analyte and are included in the data set.

Limitations to Data Use: There are no data specific to the KWB.

U.S. Geological Survey Water Supply Well Data

Reference: SWRCB Website [b]

Data Source: SWRCB/USGS.

Years of Data Available: June 1984 through August 2010

Study Relevance: 69 samples from the KWB on only July 30, 1986

Type of Data Collected: USGS samples public and domestic water supply wells. Before January 2006, data were in hard-copy reports. Those data were translated into an electronic spreadsheet by GAMA staff in 2009 for use in the GeoTracker database. Currently, data are being uploaded directly to the GAMA database and classified as "USGSNEW." The database includes 17,606 records from 290 locations for 152 constituents, including the following COCs: As, B, Br, Cl, Cr, Cr+6, F, Fe, Mn, NO_3, SO_4, TCP, TDS, DBCP, EDB, U, and alpha activity. Additional groundwater quality data may be found at http://waterdata.usgs.gov/nwis. Reports produced by USGS that are associated with these data are available online at http://pubs.er.usgs.gov/.Sampling schedules tend to be variable across data sets and PBP study units (discussed below). Some of the chemical constituents that are routinely sampled by GAMA include: low-level volatile organic compounds (VOCs) and pesticides; stable isotopes (deuterium and oxygen-18); tritium-helium/noble gases; emerging contaminants; potential wastewater indicators, pharmaceuticals, perchlorate, 1,4-dioxane, and chromium (total and Cr+6); carbon isotopes (C-13, C14); radon, radium, uranium, and gross alpha/beta radioactivity; field parameters (temperature, electric conductivity, dissolved oxygen, turbidity, pH, and alkalinity); major ions and trace elements; arsenic and iron speciation; nutrients (nitrates and phosphates); dissolved organic carbon; and total fecal coliform bacteria.

Data Collection Equipment: Grab samples from purged wells. Analytical methods and reporting limits vary for analyte and are included in the data set. Public supply wells typically are drilled to depths between 600 and 800 feet below land surface, consist of solid casing from the land surface to a depth of about 275–450 feet, and are perforated or screened below the solid casing (Burton and Belitz 2012). Domestic supply wells are commonly drilled to shallow aquifers (USGS 2013).

Limitations to Data Use: 1) Sampling depth and well screen information are not included in the data set. 2) The database does not specify whether constituents are reported as dissolved or total concentrations. 3) Data specific to the KWB for one day only.

3.1.1 GROUNDWATER QUALITY MONITORING PROGRAMS

The following subsections describe the groundwater monitoring programs in the study area.

3.1.1.1 KWBA Participants and Adjoining Entities

In the regional and local monitoring networks of KWBA and adjoining entities, all monitoring wells were sampled initially for constituents listed under CCR Title 22 and various agricultural constituents. Following the initial sampling effort, wells in regional networks are sampled for EC quarterly; general minerals, physical characters, and inorganic constituents annually; radiological constituents every 4 years; and organic constituents sampled initially, with continuance of sampling contingent upon special circumstances. Wells in the local monitoring networks are sampled for EC annually, and general minerals, physical characters, and inorganic constituents every 3 years; radiological and organic constituents are sampled initially with continuance of sampling contingent on special circumstances, but would be otherwise discontinued (Kern Water Bank Working Group 1992).

Groundwater quality monitoring data for KWB participants and adjoining entities is included in both the KCWA groundwater quality and GAMA databases. In addition, the Kern Fan Operations and Monitoring Reports include interpretive information (1995-2006) regarding groundwater quality in the study area:

3.1.1.2 Kern Water Bank

The KWB has a network of 57 monitoring wells that are tested regularly by the Monitoring Committee. In addition, the 85 recovery wells are tested pursuant to parameters set by CDPH for drinking water wells (CCR Title 22).

The *Kern Water Bank Groundwater Monitoring Program Draft Report* ("1992 Monitoring Report") was developed by the Kern Water Bank Working Group in 1992 to assess potential impacts of KWB operations on groundwater levels and quality by collecting data to meet planning and operational requirements of the KWB. The program incorporated existing local networks (i.e., programs) into a new regional network and designed an overall network of monitoring and production wells for groundwater level and water quality sampling (Kern Water Bank Working Group 1992). The local networks generally relied on active and converted production wells, while the regional network relies on specially constructed monitoring wells throughout the Kern County Subbasin. Monitoring network development included construction of numerous monitoring wells to complement the wells that agencies are currently monitoring in Kern County. Participating agencies and districts include DWR, KCWA, Kern Fan Monitoring Committee, City of Bakersfield, Cawelo WD, and North Kern WSD; the adjoining entities Buena Vista WSD, Henry Miller WD, Kern Delta WD, Rosedale, and West Kern WD; KCWA on behalf of ID4 and the Semitropic WSD; and other local elements that tend to overlap considerably with DWR, KCWA, and USBR networks. Data collected in nonparticipating local districts are reported by individual districts to DWR, KCWA, and USBR. Because of potential conflicts of interest, KCWA became the interim monitoring manager, and later the KFMC was developed to take over long-term management. Monitoring network development, well construction characteristics, and groundwater level monitoring are discussed further in the 1992 Monitoring Report.

The KWB's groundwater monitoring program called for different levels of water quality analysis for different elements of the networks. The program is outlined in Appendix 1 of the 1992 Monitoring Report. Monitoring requirements are limited in areas where primary groundwater usage is for irrigation. In contrast, higher levels of analysis are necessary in areas where groundwater is extracted and delivered to the California Aqueduct or CVC. In addition, the KWB monitoring program attempts to obtain copies of water quality analyses performed by urban water districts and other agencies operating in Kern County.

The 1992 Monitoring Report called for several levels of monitoring in the Kern Fan, such as (1) ongoing detection monitoring to evaluate suitability of groundwater and (2) development of a monitoring plan to define groundwater monitoring methods and analyses at time of extraction (Kern Water Bank Working Group 1992). As a result, the *Kern Fan Water Banking Program Groundwater Monitoring Sampling Plan* was developed for monitoring wells on the Kern Fan. It details the specific sampling protocols for various wells and types of analyses, including equipment, sample size, quality control measures, sample preparation, and sample storage (KFMC 1997). The two main components of the monitoring plan are to collect water-level measurements and groundwater samples for analyses from the various monitoring, production (i.e., water supply), and recovery wells located on the Kern Fan.

KWBA's 1997 recovery plan, *Hydrogeologic Conditions for Development of the Maximum Recovery Plan for the Kern Water Bank Authority*, identified COCs, delineated Kern Fan areas of poor water quality, and made recommendations for mitigation. Figure 3.1.1.2 shows water quality areas of concern in 1995. Groundwater COCs in Kern County, and particularly on the Kern Fan, include TDS, EC, NO_3, As, F, Cl, Fe, Mn, DBCP, EDB, U, and alpha activity. Other potential COCs include various petroleum and hydrocarbon constituents (KWBA 1997). The most significant potential groundwater quality problems north of the Kern River are DBCP, NO_3, and possibly EDB and U in some areas. The most significant potential groundwater quality problems south of the Kern River are As, F, and U (KWBA 1997).

The recovery plan recommended monitoring the area north of the Kern River for DBCP, EDB, NO_3, TDS, Cl, As, Mn, Fe, and alpha activity; monitoring for As, F, alpha activity, TDS, Cl, Fe, and Mn in the areas south of the river; and noting hydrogen sulfide odors (KWBA 1997). Salt in imported water supplies, such as SWP and CVP water, and in irrigation water is the major source of salt entering Kern County groundwater (KCWA 2011). High salinity (measured as EC or TDS) in groundwater has been mapped in some areas where the proposed recovery wells in Sections 18 and 19 of T30S, R25E and Sections 13 and 24 of T30S, Range 24E are located. Therefore, concern exists over possible easterly migration of this high-salinity groundwater to the east. The 1997 recovery plan advised relocating about one-half dozen of the proposed recovery wells in the area to sites farther east or northeast to mitigate potential problems with the easterly migration of the high-salinity groundwater (KWBA 1997).

Groundwater quality monitoring data for the KWB is included in both the KCWA groundwater quality and GAMA databases. In addition, the Kern Fan Operations and Monitoring Report include interpretive information regarding groundwater quality in the KWB (1995-2006).

3.2 SURFACE WATER QUALITY DATA

There is an extensive network of canals, piping, and pumping plants in the study area that convey imported and local water sources to recharge facilities and to various districts for use (see Figure 2.3.1). Many of the surface conveyance facilities can flow in either direction or, as in the case of the

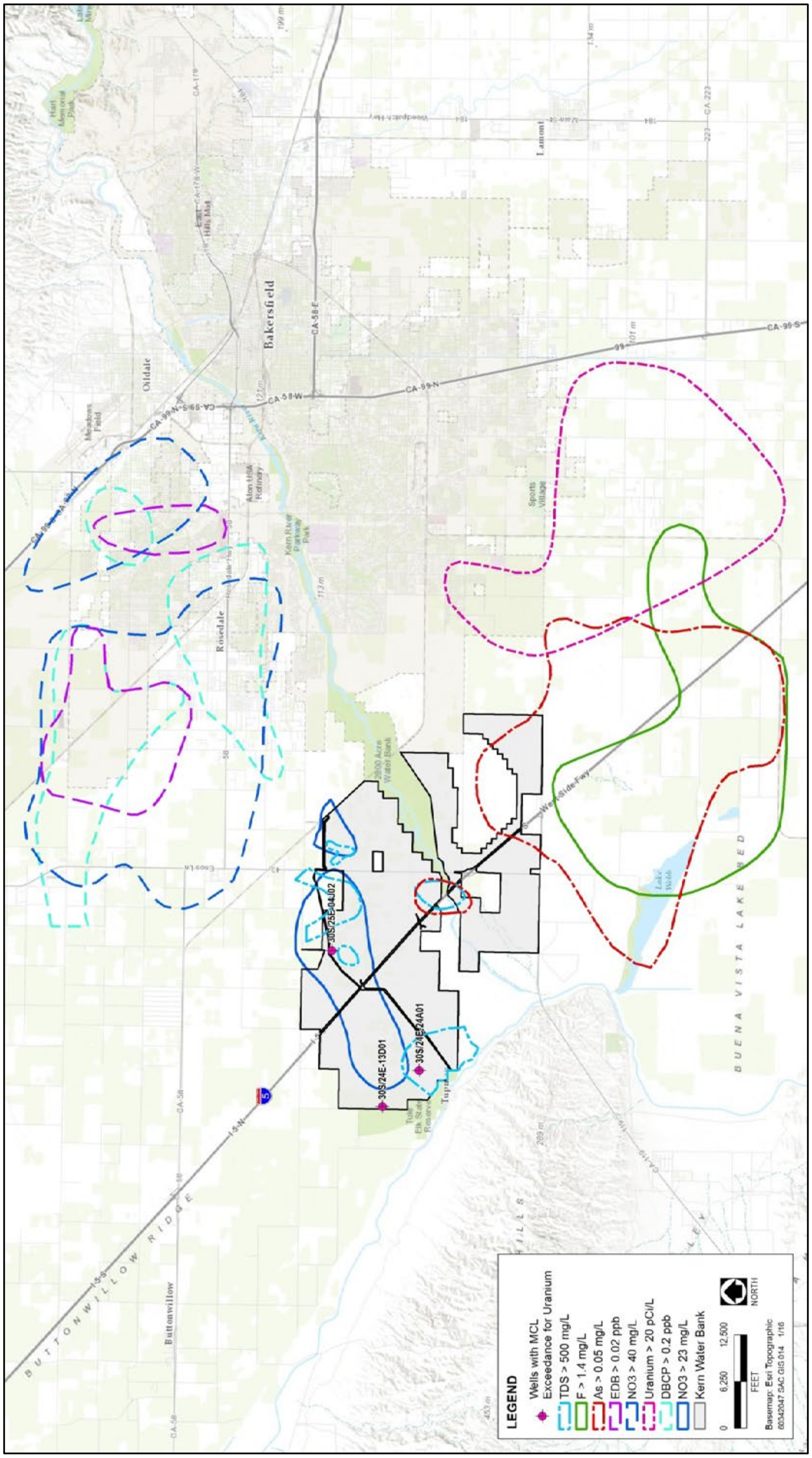


FIGURE 3.1.1.2. Water Quality Areas of Concern

CVC and Kern River channel, can isolate two or more independent reaches. These same surface water conveyance systems also convey groundwater that has been recovered from water banking facilities. Because of the multiple conveyance facilities, the water quality of water supplies is influenced by imported water and local surface water quality, as well as groundwater quality.

Surface water COCs are similar to groundwater constituents. However, surface water quality in conveyance facilities is critical to banking programs because, in some cases, blending of surface water and groundwater quality is necessary to meet background concentrations in other conveyance facilities, like the California Aqueduct. Surface water COCs include As, Br, total Cr, Cr+6, Cl, NO_3, SO_4, organic carbon (dissolved and total), U, and TDS.

3.2.1 KERN RIVER

The Kern River is the primary surface supply in the study area and is generally considered a high-quality water supply; however, portions of the river have water quality issues that are not listed on the Clean Water Act Section 303(D) list. Lake Isabella, which serves as the source for the lower Kern River, has two constituents listed on the 303(D) list with a completed total maximum daily load in 2021.

The Henry C. Garnet Water Purification Plant, operated by ID4, takes water quality samples for the Kern River, the Friant-Kern Canal, and the SWP annually to fulfill CCR Title 22 sampling requirements. During recent sampling, COC concentrations in the Kern River ranged as follows (KCWA 2015f):

- *Arsenic*—3.0 to 4.6 parts per billion (ppb)
- *Bromide*—64–100 ppb
- *Total chromium*—less than 1 ppb
- *Chromium-6*—less than 0.1 ppb
- *Nitrate*—less than 0.4 parts per million (ppm)
- *Total dissolved solids*—69–100 ppm
- *Dissolved organic carbon*—2.4 to 4.1 ppm
- *Sulfate*—7.03 to 11 ppm
- *Uranium*—1.4 to 3.4 picocuries per liter

Kern River Water Quality Monitoring Data Set

Reference: KCWA 2015f.

Data Source: KCWA (ID4 provides data)

Years of Data Available: 2006 to 2014; Quarterly sampling in March, May, July, and October

Study Relevance: Kern River water quality

Type of Data Collected: Kern River quarterly water quality sampling summary tables and raw laboratory data for the Kern River. Reports contain sampling results for primary inorganic chemical; general minerals; radioactivity; regulated and unregulated volatile and semi-volatile organic chemicals; secondary standards including TDS, specific conductance, sulfate and chloride; and additional analysis including total organic carbon, hexavalent chromium, and phosphate.

Data Collection Equipment: Grab method for raw water intake at Henry C. Garnet Water Purification Plant.

Comments/Limitations to Data Use: Data prior to 2006 were not provided. Data from summary reports must be cross referenced with raw laboratory reports to determine U.S. Environmental Protection Agency methods for laboratory analysis and laboratory detection limits. In addition to the data set above, additional Kern River water quality data are included in the Kern Fan Operations and Monitoring Report.

3.2.2 CALIFORNIA AQUEDUCT

DWR, the water banking entities in Kern County, and several SWP municipal and industrial (M&I) contractors have developed pump-in guidelines to protect the quality of the water downstream of banking programs. To ensure that existing background water quality in the California Aqueduct is not changed in a way that would potentially result in impacts to drinking water due to human health threats from water quality contaminants, consumer acceptance issues, and additional treatment costs to downstream SWP M&I contractors, the Pump-in Guidelines provide for a two-tiered approach for accepting non-SWP water into the California Aqueduct. Tier 1 programs have a "no adverse impact" criterion and are tied to historical water quality levels in the California Aqueduct. Programs meeting the Tier 1 criterion are simply approved by DWR. Tier 2 programs have water quality levels that exceed the historical water quality levels of one or more constituents in the California Aqueduct and have the potential to cause adverse impacts on SWP contractors. Tier 2 programs are referred to a SWP water contractor facilitation group for review. The facilitation group reviews the program and, if needed, makes recommendations to DWR.

In practice, the water banking proponent develops a "pump-in proposal" that documents how much water will be introduced, where the water will be introduced, the quality of the water to be introduced, and the expected changes in water quality in the Aqueduct in response to the program. The facilitation group reviews the proposal and provides comments as appropriate. Most programs increase the background concentration of one or more constituents in the Aqueduct, and are therefore Tier 2 programs. For Kern County programs, a model that predicts the expected water quality changes in the California Aqueduct is forwarded to this facilitation group on a weekly basis for the duration of any specific pump-in program.

DWR regulates the water quality of the SWP through the DWR Water Quality Criteria for Acceptance of Non-Project Water into the SWP and the Implementation Procedures for the Review of Water Quality from Non-Project Water Introduced into the SWP. DWR has provided draft criteria that are still undergoing revision. In the interim, between the time when the criteria were established and the current proposed criteria, new or modified regulations for some additional COCs have been developed.

The current water quality criteria for the SWP are compared to current water quality conditions in the California Aqueduct and to the current Federal primary and secondary drinking water standards, and provided in Table 2-18. Table 2-18 reports water quality in the California Aqueduct from a point just upstream of Kern County (data taken from Station KA017226, Check 21 near Kettleman City). It is important to note that not all constituents currently in the Water Supply Contract between DWR and KCWA (October 2003) are sampled for by DWR. It is also important to note that while some constituents do not have SWP pump-back criteria and/or an MCL standard (Br, total organic carbon, TDS, and Cl), high levels of these constituents can be of concern, especially with regard to potential treatment costs to downstream users.

Water quality data collected as part of this study for the California Aqueduct are described further below.

California Aqueduct Surface Water Quality Data Set

Reference: DWR 2015e, 2015f

Data Holder/Source: DWR – SWP Analysis Office

Years of Data Available: Data availability varies widely at the various locations and spans from 1970 to December 2015. See Table 3.2.2 below for years of data available for specific locations.

TABLE 3.2.2.

Water Quality Sampling at California Aqueduct Locations Upstream/Downstream from the KWB Canal

Milepost	Pool	Facility Name	Sampling Location	Years (Months) Sampled	COC Sampled
172.40	22	Check 21	In Aqueduct	1984–2014 (Jan–Dec)	Title 22 constituents
				2015 (Jan–Mar)	EC
					COC (TCP, EDB, and DBCP)
					Dissolved COC
					(As, Br, B, Cl, Cr, Cr6, F, Fe, Mn, NO3, DOC, SO4, TDS)
					Total COC (As, Cr, Fe, Mn, NO3, TOC)
197.05	24	Check 23	In Aqueduct	2007 (Sep–Dec)	EC
				2008 (Jan–Mar, Sep–Oct)	Dissolved COC
				2009 (Jan–Jun)	(As, Br, Cl, Cr, NO3, DOC, SO4, TDS)
				2013 (Sep–Dec)	Total As
206.99	24	KCWA (Semitropic #3)	In Aqueduct	2007 (Sep)	EC
					Dissolved COC
					(As, Br, B, Cl, Cr, Fe, Mn, NO3, DOC, SO4, TDS)
					Total COC (TOC)
206.99	24	KCWA (Semitropic #3)	In Facility	2007 (Oct–Dec)	EC
				2008 (Jan–Mar, Sep–Nov)	Dissolved COC
				2009 (Jan–Jun)	(As, Br, B, Cl, Cr, Fe, Mn, NO3, DOC, SO4, TDS)
				2013 (Sep–Oct)	Total COC (As, Cr, Fe, Mn, TOC)
207.94	25	Check 24	In Aqueduct	1997 (Jan)	EC
				2013 (Sep)	Dissolved COC
					(As, B, Br, Cl, Cr, F, NO3, DOC, SO4, TDS)
209.8	25	KCWA (Semitropic #2) *Semitropic Penstock in GIS	In Facility	2007 (Oct–Dec)	EC
				2008 (Jan, Oct–Dec)	Dissolved COC
				2009 (Jan–Jun)	(As, Br, B, Cl, Cr, F, Fe, Mn, NO3, DOC, SO4, TDS)
				2013 (Oct)	Total COC (As, TOC)
209.8	25	KCWA (Semitropic #2) *Semitropic Penstock in GIS	In Aqueduct	2004 (Sep–Nov)	EC
					Dissolved COC

TABLE 3.2.2. Water Quality Sampling at California Aqueduct Locations Upstream/Downstream from the KWB Canal					
Milepost	**Pool**	**Facility Name**	**Sampling Location**	**Years (Months) Sampled**	**COC Sampled**
					(As, Br, B, Cl, Cr, F, Fe, Mn, NO3, DOC, SO4, TDS)
					Total COC (TOC)
217.79	26	Check 25	In Aqueduct	2007 (Sep–Oct)	EC
				2008 (Jan)	Dissolved COC
				2013 (Oct–Dec)	(As, Br, Cl, Cr, NO3, DOC, SO4, TDS)
					Total As
231.73	28	Check 27	In Aqueduct	2012 (Mar–Jun, Dec)	EC
				2013 (Jan–Aug)	Dissolved COC
					(As, B, Br, Cl, Cr, Mn, NO3, DOC, SO4, TDS)
					Total As
238.04	28	KCWA (Cross Valley Canal No 1)	In Cross Valley Canal	2008 (Nov–Dec)	EC
				2009 (Jan, Mar–May)	Dissolved COC
				2011 (Apr)	(As, Br, B, Cl, Cr, Fe, Mn, NO3, DOC, SO4, TDS)
				2012 (Mar)	Total COC (As, Cr, Fe, Mn, TOC)
				2013 (Feb, Apr, Aug)	
238.04	28	KCWA (Cross Valley Canal No 1)	In Aqueduct	1994 (Nov)	EC
				1995 (Jan)	Dissolved COC
					(As, B, Cl, Cr, F, Fe, Mn, SO4, TDS)
238.11	29	Check 28	In Aqueduct	2001 (Mar)	EC
				2007 (May–Jun)	Dissolved COC
					(As, Br, B, Cl, Cr, Cr6, F, Fe, Mn, NO3, DOC, SO4, TDS)
					Total COC (TOC)
238.19	29	KCWA (KWB Canal)	In Kern Water Bank Canal	2009 (May)	EC
				2010 (Jun)	Dissolved COC
				2011 (May)	(As, Br, B, Cl, Cr, Fe, Mn, NO3, DOC, SO4, TDS)
				2012 (Mar, Jun, Dec)	Total COC (As, Fe, Mn, TOC)
				2013 (Apr, Oct)	
241.02	29	Kern River Intertie (Flood Inflow)	In Aqueduct	1998 (May–Jun)	Title 22 constituents
				2006 (May–Jun)	EC
					COC (TCP, EDB, and DBCP)
					Dissolved COC
					(As, Br, B, Cl, Cr, F, Fe, Mn, NO3, DOC, SO4, TDS)
					Total COC (TOC)

TABLE 3.2.2. Water Quality Sampling at California Aqueduct Locations Upstream/Downstream from the KWB Canal					
Milepost	**Pool**	**Facility Name**	**Sampling Location**	**Years (Months) Sampled**	**COC Sampled**
240.2	29	KCWA (West Kern Turnin)	In Facility	2013 (Dec)	EC
					Dissolved COC
					(As, Br, B, Cl, Cr, Fe, Mn, NO3, DOC, SO4, TDS)
					Total COC (As, Cr, Fe, Mn, TOC)
244.54	30	Check 29	In Aqueduct	1984–2014 (Jan–Dec)	Title 22 constituents
				2015 (Jan–Feb)	EC
					COC (TCP, EDB, and DBCP)
					Dissolved COC
					(As, Br, B, Cl, Cr, Cr+6, F, Fe, Mn, NO3, DOC, SO4, TDS)
					Total COC (As, Cr, Fe, Mn, NO3, TOC)
NA	NA	Check 41	In Aqueduct	1988 (Jun–Dec)	Title 22 constituents
				1989–2014 (Jan–Dec)	EC
				2015 (Jan–Feb)	COC (TCP, EDB, and DBCP)
					Dissolved COC
					(As, Br, B, Cl, Cr, Cr6, F, Fe, Mn, NO3, DOC, SO4, TDS)
					Total COC (As, Cr, Fe, Mn, NO3, TOC)

Study Relevance: California Aqueduct water quality

Type of Data Collected: Surface water quality samples taken from the California Aqueduct and the turn-in conveyance facilities before the water entered and mixed with aqueduct water; some site-specific historical California Aqueduct baseline water quality data. Water quality sampled at turn-in facilities before entering the California Aqueduct are indicative of the source water quality at the conveyance facility, such as the CVC, the KWB Canal, and other servicing districts. Pump-in water is typically monitored for both CCR Title 22 and a short list of COCs based on the baseline water quality tests for either individual or representative wells. Current COCs listed in the DWR pump-in policy include As, Br, Cl, NO_3, SO_4, organic carbon (dissolved and total), and TDS (DWR 2013). However, COCs may be changed as needed and chromium (total and Cr+6) is now commonly sampled for in conjunction with others on the COC list (DWR 2014c). Monitoring is conducted at initial well start-up, with periodic well retesting and ongoing testing during operation. Well data are sampled at least every 3 years (DWR 2013). The table below summarizes the surface water quality grab sample data available through DWR for COCs at each check location along the California Aqueduct between Check 21 and Check 41 since January 1, 1984.

Data Collection Equipment: Grab samples reported at depths of 1 foot, 3 feet, and 1 meter. Analytical methods and reporting limits vary for each analyte and are included in the data set.

Comments/Limitations to Data Use: 1) The data set does not include data collected from other agencies and water districts, and is limited to data collected between Check 23 and Check 29, just above the Buena Vista Pumping Plant (i.e., Check 30). 2) Several KCWA turn-ins for the Elk Hills, Arvin-Edison WSD, Teerink-Maricopa, Tejon-Castac WD, Wheeler Ridge–Maricopa WSD, and part of the Henry Miller WD, Buena Vista WSD, and West Kern WD turn-ins cannot be evaluated with this data set. 3) The DWR database does not include samples taken at Check 21, Tupman Road (KWBA), Cole's Levee (KWBA), and Highway 119 (West Kern WD) because those locations are monitored by other agencies. DWR monitors Check 21, but those data are not included in this data set. However, the data for 2013 are included in an appendix to the 2013 pump-in report (DWR 2014c) described below. 4) Water quality sampling data coverage in the database varies greatly from year to year.

California Department of Water Resources Pump-in Reports

References: DWR-2013; DWR-2014c.

Data Source: DWR San Joaquin Field Division

Years of Data Available: 2012 and 2013. Water quality conditions at the O'Neill Forebay Outlet averaged from 1988–2011 are used as the historical/baseline conditions for Aqueduct water quality.

Study Relevance: California Aqueduct water quality

Type of Data Collected: The 2012 and 2013 pump-in reports provide a comprehensive assessment of current water quality conditions. In 2012 DWR conducted an analysis of changes in California Aqueduct water quality resulting from turn-ins from the CVC and KWBC, and Arvin-Edison WSD and Wheeler Ridge–Maricopa WSD. Water quality from the CVC and KWBC were jointly evaluated by sampling Checks 27 and 29, which bracketed the turn-ins within 12.8 miles. Farther downstream, turn-ins from Arvin-Edison WSD and Wheeler Ridge–Maricopa WSD were jointly assessed by sampling Checks 29 and 39, which bracketed the turn-ins within 45.7 miles. 2012 data provided by DWR, KCWA, and Wheeler Ridge–Maricopa WSD are provided separately in the appendices of the 2013 document *Water Quality Assessment of Non-Project Turn-ins to the California Aqueduct, 2012* (DWR 2013). In 2012, the KWB Canal contributed 79.6 percent of the groundwater turn-ins in the San Joaquin Field Division and contributed 55 percent in 2013. A comprehensive assessment of the water quality status and monthly trends was conducted during 2013. This included COCs and conductivity (As, Br, Cl, chromium, conductivity, NO_3, organic carbon, SO_4, and TDS) provided by San Joaquin turn-ins and supplemented by DWR sampling, and is provided in Appendix B of DWR's *Water Quality Assessment of Non-Project Turn-ins to the California Aqueduct, 2013* (2014c). Table 3.2.3 summarizes the sampling site and period of each turn-in operation associated with the data presented in that report and in the report's Appendix B.

TABLE 3.2.2a.

Sampling Sites for the 2013 Pump-in Program to the California Aqueduct

Facility Name	Upstream Sampling Site	Timeframe
Semitropic Water Storage District 3	Check 21 and Check 23	September to December
Semitropic Water Storage District 2	Check 21, Check 23 and Check 24	August to December
Central Valley Canal	Check 25, Check 27 and Tupman Road	February to May, August to December
Kern Water Bank Canal	Check 25, Check 27 and Tupman Road	January to August, October to December
West Kern Water District	Cole's Levee	November to December
Wheeler Ridge–Maricopa Water Storage District	Check 29 and Hwy 119	April to August, November to December
Arvin-Edison Water Storage District	Check 29 and Hwy 119	February to December
Source: DWR 2014c		

Data Collection Equipment: Grab samples reported from DWR, KCWA, and Wheeler Ridge–Maricopa WSD. Analytical methods vary for analytes, and disparities exist because of differences in reporting limits (see limitation below).

Comments/Limitations to Data Use: 1) Significant pump-ins have occurred since 2001 as a result of the construction of conveyance facilities. Pump-in reports that include data sets provided by various agencies, water districts, and DWR are currently available only for years 2012 and 2013. 2) The baseline conditions in Table A1, Historical Water Quality Conditions 1988 to 2011 at O'Neill Forebay Outlet, of Appendix A (DWR 2013, 2014b) provides the mean, maximum, minimum, and standard deviation of water quality measurements taken at the forebay outlet from 1988 to 2011. O'Neill Forebay is located directly east of San Luis Reservoir, roughly 170 miles from the KWB, and does not necessarily represent the historical conditions of water quality at the KWB. 3) Disparity in the data exists, as the 2013 analysis focused on whichever data set reported, either total (unfiltered) or dissolved (filtered) constituents, was the largest. 4) Some COC results were reported with different minimum reporting levels (MRLs) because of different laboratory methods, so some data were reported as below the MRLs of other data. Therefore, data reported below the MRL were included in the analysis as the value of the MRL, and only general comparisons can be made because of the differences in data sets reported and used to calculate average values. Calculated averages used data from the closest California Aqueduct sampling site upstream of each turn-in and only for the time period the turn-in was actively transferring flows (DWR 2014c).

In addition to the data sets above, water quality data within the California Aqueduct are included in the Kern Fan Operations and Monitoring Report.

3.2.3 FRIANT-KERN CANAL (CENTRAL VALLEY PROJECT)

Water quality in the Friant-Kern Canal is considered to be of high quality because the water originates as snowmelt from the Sierra Nevada; however, similar to the California Aqueduct, non-CVP water is pumped into the Friant-Kern Canal before it reaches the CVC and its terminus at the Kern River channel. The Henry C. Garnet Water Purification Plant, operated by ID4, takes water quality samples from the Kern River, the Friant-Kern Canal, and the SWP annually to fulfill CCR Title 22 sampling requirements. During recent sampling, COCs in water from the Friant-Kern Canal entering the CVC were recently reported to be at the following levels (KCWA 2014):

- *Arsenic*—less than 2.0 ppb
- *Bromide*—less than 50 ppb
- *Total chromium*—less than 2 ppb
- *Chromium-6*—less than 0.1 ppb
- *Nitrate*—less than 0.4 ppm
- *Total dissolved solids*—20 ppm
- *Dissolved organic carbon*—3.2 ppm
- *Sulfate*—2 ppm
- *Uranium*—0.4 picocurie per liter

USBR regulates water quality of the Friant Division CVP through the Baseline Water Quality Report for CVP, and the Policy for Accepting Non-project Water into the Friant-Kern and Madera Canals, which is currently being updated to incorporate agricultural water quality standards. The quality of water pumped into the canal will vary; however, it must meet CCR Title 22 water quality standards, and water quality standards established for the CVC and Friant-Kern Canal. Under USBR's Regional Baseline Monitoring Program, samples are collected from the Friant-Kern Canal on a biannual basis.

<u>Friant-Kern Canal Water Quality Monitoring Data</u>

Reference: USBR 2015

Data Source: USBR

Years of Data Available: 2003 to 2014

Study Relevance: Kern River water quality

Type of Data Collected: Friant-Kern Canal water quality sampling for total dissolved solids at Millerton Dam (2003-2008), Woollomes Avenue (2003-2008) or Calloway Avenue (2011-2014). Summary tables and raw laboratory data for the Kern River are included.

Reports contain sampling results for primary inorganic chemicals; general minerals; radioactivity; regulated and unregulated volatile and semi-volatile organic chemicals; secondary standards including TDS, specific conductance, sulfate, and chloride; and additional analysis including total organic carbon, hexavalent chromium, and phosphate.

Data Collection Equipment: Grab method at reported sampling location. Type of filtration used for sample collection was not reported. Collection was in accordance with Standard Methods Committee 2540C procedures.

Comments/Limitations to Data Use: Data provided is limited for each sampling location along the Friant-Kern Canal. The sample location at Calloway Avenue is closest to the KWB. Analytical data provided prior to April 10, 2014 were reported as rounded up to two significant figures. Another data source for water quality in the Friant-Kern Canal is the Kern Fan Operations and Monitoring Reports.

During periods of groundwater recovery, conveyance facilities in the study area could be carrying either water transported from its originally designated source or a blend of surface water and extracted local groundwater. For these blending operations, water quality is an important consideration.

As described previously, the California Aqueduct is used as the major conveyance facility to deliver Kern County water bank water (which can include by exchange surface water) to downstream KCWA water districts or other SWP water contractors participating in groundwater banking programs. Pump-in volumes and water quality are monitored regularly when the following entities are introducing local groundwater into the SWP: Semitropic WSD, KCWA via CVC, KWBA via the KWB Canal, Buena Vista WSD, Arvin-Edison WSD, Wheeler Ridge–Maricopa WSD.

For Kern County pump-in programs, KCWA has developed a model that calculates and tracks the water quality changes in water to be pumped into the California Aqueduct as a result of various surface water and groundwater blending operations. The modeling results are used to forecast annual water quality changes for pump-in proposals and provided to the facilitation group on a weekly basis for the duration of any specific pump-in program. It is a joint responsibility of the operators of local surface water canals to continually sample and report the water quality of the sources of water and the blending occurring within the canal facility. The following constituents are COCs for the Kern County pump-in programs: arsenic, bromide, total chromium, chromium-6, chloride, nitrate, TDS, dissolved organic carbon, and uranium.

Kern County Water Agency Pump-in Blending Operations Data Set

Reference: KCWA 2015c

Data Source: KCWA Groundwater Division

Years of Data Available: Table 4.3-1 summarizes the availability of blending model data. Modeling data are presented in a series of spreadsheets for each month of pump-in activity.

Study Relevance: CVC and California Aqueduct water quality

Type of Data Collected: The blending model calculations include background and operational water quality data for COCs, and flow for surface water conveyance facilities associated with pump-in activities in Kern County. The models track or calculate daily delivery (as flow) and water quality for the Arvin Edison, CVC, KWB, and Semitropic Canals and California Aqueduct changes in flow and water quality. Flow and water quality data reporting for the CVC is broken out into six separate blending pools. Pumping volumes and water quality data are reported for individual groundwater wells and then summarized for each major manifold or turn-in facility blending pool. The model also includes charts summarizing water quality changes in the California Aqueduct for each COC in relation to the average blended pump-in concentration and the MCL; changes in water quality in the California Aqueduct by pump-in location; well manifold concentrations for each COC; and changes associated with the pump-in program for the CVC.

Data Collection and Equipment: Flow and pumping information is received from the entities that manage the conveyance facility or groundwater wells. KCWA is responsible for collecting data for KWB facilities. California Aqueduct and canal water quality samples are collected in accordance with DWR pump-in policies and/or DWR sampling protocols. Water quality sampling of KWB monitoring wells occurs using a purge pump unit. Five casing volumes of water were purged before sample collection.

Comments/Limitations to Data Use: KWB recovery operations began in 2001. Blending model data were not available for all pump-in activities that occurred between 2001 and 2014.

Blending model calculations and associated data are archived with KCWA along with operation and reporting of the model results. Table 4.3-2 presents the contribution of KWB wells to blending operations in 2014. Table 4.3-3 summarizes the total number of groundwater wells included in each blending pool for Kern County pump-in facilities in 2014. Figure 3.3-2 shows the KWB wells associated with each blending pool in relation to recharge ponds and surface water conveyance facilities on KWB Lands.

3.3 DATA SUMMARY

3.3.1 GROUNDWATER QUALITY DATA

Extensive groundwater quality data are available for evaluation in the study area; however, because of the complex shallow, middle, and deep aquifer characteristics, the usefulness of the data is limited if related well construction details are not also available.

KFMC has performed interpretive studies of available groundwater quality data collected in the study area through 2006. In some instances, statistical analysis of water quality data through 2009 has also been performed. Data collected and reported by the KFMC for the years 2007–2014 are unpublished. The data consists of maps and hydrographs depicting changes in water levels.

Time trends in constituent concentrations have been evaluated by the KFMC particularly in terms of influences of recharge and recovery operations for the Kern Fan water banking projects. Concentrations of NO_3, TDS, and U are generally higher in the shallow groundwater. Arsenic concentrations, in contrast, are generally higher in the deep groundwater. Interpretive studies have identified areas of elevated concentrations of COCs and poor water quality, as shown in Figure 3.3-2. It should be noted that the interruptive studies for arsenic were previously performed using the former MCL of 50 micrograms per liter. Arsenic concentrations exceeding 10 micrograms per liter (the current MCL) are present in both shallow and deep groundwater farther northwest of the currently delineated area. A smaller area of high arsenic concentrations is also present in groundwater near Elk Hills, generally in the area where relatively high TDS levels are also present in groundwater.

3.3.2 SURFACE WATER QUALITY DATA

Data on surface water quality in the study area are readily available for the major conveyance facilities through various data sources and blending operations data. Source water is considered to be of high quality; however, the concentrations of salts (TDS) in the source waters are of particular concern in the study area because it the closed hydrologic basin which accumulates salts that must be continually managed.

Through 2006, the KFMC has performed salt balance evaluations of TDS sources on a monthly basis (from milligrams per liter to tons per AF) and summed calculations annually for each water source and Kern Fan water banking projects.

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