# KAWEAH SUBBASIN COORDINATION AGREEMENT

GREATER KAWEAH GROUNDWATER SUSTAINABILITY AGENCY
MID-KAWEAH GROUNDWATER SUSTAINBILITY AGENCY
EAST KAWEAH GROUNDWATER SUSTAINABILITY AGENCY

Plan Manager: Eric Osterling
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**Appendices:**

## DEFINITIONS

1. "Agency" or "GSA": refers to a groundwater sustainability agency as defined in SGMA.

2. "Agreement": refers to this Coordination Agreement, unless indicated otherwise.

3. "Annual Report": refers to the report required by California Water Code Section 10728.

4. "Basin": means the Kaweah Subbasin within the Tulare Lake HydrolBogic Region, San Joaquin Valley Groundwater Basin, defined in DWR's 2016 Bulletin 118 Interim Update as Basin 5-22.11, as same may be amended from time to time.

5. "Basin setting": refers to the information about the physical setting, characteristics, and current conditions of the Basin as described by the Agency in the hydrogeologic conceptual model, the groundwater conditions, and water budget, and Management Areas (if applicable) pursuant to California Code of Regulations, title 23, sections 354.12-354.20.

6. "Confidential Information": as discussed in Section 3.3 of this Agreement, refers to data, information, modeling, projections, estimates, plans, and other information that are not public and in which the Party has a reasonable expectation of confidentiality, regardless of whether such information is designated as "Confidential Information" at the time of its disclosure. Confidential Information also includes information which is, at the time provided, (a) disclosed as such in writing and marked as confidential (or with other similar designation) at the time of disclosure and/or (b) disclosed in any other manner and identified as confidential at the time of disclosure and is also summarized and designated as confidential in a written memorandum delivered within thirty (30) days of disclosure.

7. "DWR": refers to the California Department of Water Resources.

8. "Groundwater": means water beneath the surface of the earth within the zone below the water table in which the soil is completely saturated with water, but does not include water that flows in known and definite channels.

9. "Groundwater flow": refers to the volume and direction of groundwater movement into, out of, or throughout a basin.

10. "Management Team Committee": refers to the governing body originally established in the Parties' MOU that is charged with making recommendations regarding this Agreement and other Kaweah Subbasin related compliance issues to each GSA.

11. "Measurable objectives": refers to specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted GSP to achieve the sustainability goal for the Basin.

12. "Memorandum of Understanding" or "MOU": refers to the November 1, 2017 Memorandum of Understanding signed by the Parties concerning GSP-related cooperation and coordination in the Kaweah Subbasin.

13. "Minimum Thresholds": refers to a numeric value for each sustainability indicator used to define undesirable results.

14. "Plan" or "GSP": refers to a groundwater sustainability plan as defined by SGMA.

15. "Plan Manager": refers to an employee or authorized representative of the Parties appointed by the Coordination Committee to perform the role of the Plan Manager set forth in Section 1.3 of this Agreement.

16. "Principal aquifers": refers to aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems.

17. "Representative monitoring": refers to a monitoring site within a broader network of sites that typifies one or more conditions within the Basin or an area of the Basin.

18. "Sustainability indicator": refers to any of the effects caused by groundwater conditions occurring throughout the Basin that, when significant and unreasonable, cause undesirable results, as described in Water Code Section 10721(x). Sustainability indicators include 1) chronic lowering of groundwater levels, 2) reduction of groundwater storage, 3) seawater intrusion [not applicable], 4) degraded groundwater quality, 5) land subsidence, and 6) depletions of interconnected surface water.

19. "Water source type": represents the source from which water is derived to meet the applied beneficial uses, including groundwater, recycled water, reused water, and surface water sources identified as Central Valley Project, local supplies, and local imported supplies.

20. "Water use sector": refers to categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed recharge, and native vegetation.

21. "Water year": refers to the period from October 1 through the following September 30, inclusive, and is labeled by the ending year (e.g. the last day of Water Year 2019 is September 30, 2019).

22. "Water year type": refers to the classification provided by DWR for the San Joaquin Valley, based on unimpaired runoff. The water year type is based on a numerical index and includes five (5) classifications: Wet, Above Normal, Below Normal, Dry, and Critical.

# 1. INTRODUCTION

## 1.1. PURPOSE.

The purpose of this Agreement is to comply with SGMA's coordination agreement requirements and ensure that the multiple GSPs within the Basin are developed and implemented utilizing the same methodologies and assumptions as required under SGMA and Title 23 of the California Code of Regulations, and that the elements of the GSPs are appropriately coordinated to support sustainable management.

The Parties intend that this Agreement describe how the multiple GSPs, developed by the individual GSAs, are implemented together to satisfy the requirements of SGMA. The Parties intend this Agreement will be incorporated as part of each individual GSP developed by the Parties.

## 1.2. ADJUDICATION OR ALTERNATIVE PLANS IN THE BASIN. (§357.4(f).)

As of the date of this Agreement, there are no portions of the Basin that have been adjudicated or have submitted for DWR approval an alternative to a GSP pursuant to Water Code Section 10733.6.

## 1.3. PLAN MANAGER. (§357.4(b)(1).)

In accordance with the Title 23, California Code of Regulations Section 357.4(b)(1), the Parties hereby agree on a point of contact with DWR. The Plan Manager shall be the General Manager for the Greater Kaweah GSA. The Parties may agree to amend the appointed Plan Manager upon unanimous consent of the GSAs and written notification to DWR. The Plan Manager shall serve as the point of contact for DWR as specified in California Code of Regulations, section 357.4, subd. (b)(1). The Plan Manager's role as the point of contact between the Management Team Committee and DWR. In this role, the Plan Manager shall, at the direction of the Management Team Committee, submit all GSPs, plan amendments, supporting information, monitoring data and other pertinent information, Annual Reports, and periodic evaluations to DWR when required. The Plan Manager may communicate other information to DWR at the request of the Management Team only. The Plan Manager has no authority to take any action or represent the Management Team Committee or a particular GSA without the specific direction and authority of the Management Team Committee or the particular GSA. The Plan Manager is obligated to disclose all communications he/she receives in his/her capacity as Plan Manager to the Management Team Committee, either in open or closed session meetings, or as otherwise appropriate.

# 2. BASIN SETTING

## 2.1. INTRODUCTION (§354.12)

The detailed basin setting for the Kaweah Subbasin, as required for GSPs prepared in accordance with Title 23, California Code of Regulations Section 354.12, is provided in Appendix 1 of this Agreement. The attached Basin Setting includes the physical setting, the Hydrogeologic Conceptual Model, groundwater conditions and water budget pursuant to Title 12, CCR Sections 354.12-354.18.

# 3. EXCHANGE OF DATA AND INFORMATION (§357.4(b)(2))

## 3.1. EXCHANGE OF INFORMATION.

In accordance with Title 23, California Code of Regulations Section 357.4(b)(2) of the GSP Regulations, the GSA Parties acknowledge and recognize that for this Coordination Agreement to be effective in the enhancement of the goals of basin-wide groundwater sustainability and compliance with the SGMA and the basin level coordinating and reporting regulations, the GSA Parties will have an affirmative obligation to exchange certain minimally necessary information among and between the other GSA Parties. Likewise, the GSA Parties acknowledge and recognize that individual GSA Parties, in providing certain information, and in particular certain raw data, may contend that limitations apply in the sharing and other dissemination of certain types of said information which may subject the individual GSA Party to certain duties regarding non-disclosure and privacy restrictions and protections.

## 3.2. PROCEDURE GOVERNING THE EXCHANGE OF INFORMATION.

The Parties may exchange information through collaboration and/or informal requests made at the Management Team Committee level. To the extent it is necessary to make a written request for information to another Party, each Party shall designate a representative to respond to information requests and provide the name and contact information of the designee to the Management Team Committee. Requests may be communicated in writing and transmitted in person or by mail, facsimile machine or other electronic means to the appropriate representative as named in this Agreement.

Nothing in this Agreement shall be construed to prohibit any Party from voluntarily exchanging information with any other Party by any other mechanism separate from the Management Team Committee.

## 3.3. NON-DISCLOSURE OF CONFIDENTIAL INFORMATION.

It is understood and agreed to that, pursuant to Section 3.1 of this Agreement, a Party to this Agreement may provide one or more of the other Parties with confidential information. To ensure the protection of such confidential information and in consideration of the agreement to exchange said information, the Parties agree as follows:

3.3.1. The confidential information to be disclosed under this Agreement ("Confidential Information") includes data, information, modeling, projections, estimates, plans, and other information that are not public and in which the Party has a reasonable expectation of confidentiality, regardless of whether such information is designated as "Confidential Information" at the time of its disclosure.

3.3.2. In addition to the above, Confidential Information shall also include, and the Parties shall have a reasonable duty to protect, other confidential and/or sensitive information which is, at the time provided (a) disclosed as such in writing and marked as confidential (or with other similar designation) at the time of disclosure; and/or (b) disclosed in any other manner and identified as confidential at the time of disclosure and is also summarized and designated as confidential in a written memorandum delivered within thirty (30) days of the disclosure.

3.3.3. The Parties shall use the Confidential Information only for the purposes set forth in this Agreement.

3.3.4. The Parties shall limit disclosure of Confidential Information within its own organization to its directors, officers, partners, attorneys, consultants, members and/or employees having a need to know and shall not disclose Confidential Information to any third party (whether an individual, corporation, or other entity) without prior written consent. A Party shall satisfy its obligations under this paragraph if it takes affirmative measures to ensure compliance with these confidentiality obligations by its employees, agents, consultants and others who are permitted access to or use of the Confidential Information.

3.3.5. This Agreement imposes no obligation upon the Parties with respect to any Confidential Information that (a) was possessed before receipt; (b) is or becomes a matter of public knowledge through no fault of the receiving Party; (c) is rightfully received from a third party not owing a duty of confidentiality; (d) is disclosed without a duty of confidentiality to a third party by, or with the authorization of, the disclosing Party; or (e) is independently developed.

3.3.6. If there is a breach or threatened breach of any provision of this section, it is agreed and understood that the non-breaching Party shall have no adequate remedy in money or other damages and accordingly shall be entitled to injunctive relief; provided however, no specification in this Agreement of any particular remedy shall be construed as a waiver or prohibition of any other remedies in the event of a breach or threatened breach of any provision of this Agreement.

3.3.7. If and to the extent the information covered by this provision is requested pursuant to the California Public Records Act (PRA), the Party subject to the PRA shall coordinate with the other Parties regarding its disclosure and obtain approval from a Party prior to disclosing information that the Party has disclosed pursuant to this provision in response to the PRA. To the extent the Party responding to the PRA is sued or otherwise challenged for withholding confidential information at the request of another Party, the Party requesting the non-disclosure shall indemnify the Party subject to the PRA for any costs and fees related to litigation or other such challenge.

# 4. METHODOLOGIES & ASSUMPTIONS (§357.4(b)(3))

In accordance with the Title 23, California Code of Regulations Section 357.4(b)(3) and California Water Code section 10727.6 the Parties have entered into this Agreement to ensure that the individual GSPs in the Basin utilize the same data and methodologies for the following assumptions: 1) groundwater elevation data, 2) groundwater extraction data; 3) surface water supply; 4) total water use; 5) change in groundwater storage; 6) water budget; and 7) sustainable yield, and that such methodologies and assumptions will continue to be used in the future development and implementation of such GSPs.

The methodologies and assumptions were developed based on existing data/information, best management practices, and/or best modeled or projected data available.

Information regarding the agreed upon methodologies and assumptions, is attached as Appendix 1 to this Agreement.

# 5. MONITORING NETWORK (§§354.32-354.40)

5.1. The Parties developed a monitoring network and monitoring network objectives for the Basin in accordance with California Code of Regulations, Title 23, sections 354.32 – 354.40. Each network facilitates the collection of data in order to characterize groundwater and related surface water conditions in the Basin and evaluate changing conditions that occur from implementation of the individual GSPs. The individual GSPs include monitoring objectives, protocols, and data reporting requirements as necessary under SGMA and SGMA Regulations.

5.2. The monitoring network(s) demonstrate short-term, seasonal, and long-term trends in groundwater and related surface water conditions. Each Party's GSP will include the monitoring network objectives for the Basin, including an explanation of how the network develops and implements to monitor groundwater and related surface water conditions, and the interconnection of surface water and groundwater, with sufficient temporal frequency and spatial density to evaluate the effectiveness of GSP implementation. The monitoring network(s) accomplish the following: a) demonstrate progress toward achieving measurable objectives described in the GSPs; b) monitor impacts to the beneficial uses or users of groundwater; c) monitor changes in groundwater conditions relative to applicable measurable objectives and minimum thresholds; and d) assist with quantifying annual changes in water budget components.

5.3. The Parties hereby agree, consistent with Section 3 of this Agreement, to share information necessary to create a Basin map displaying the location and type of each monitoring site within the Basin, and a report in tabular format, including information regarding the monitoring site type, frequency of measurement, and purpose for which the monitoring site is being used.

5.4. Information regarding the agreed upon monitoring networks, which is subject to future review and modification, is attached as Appendix 2 to this Agreement.

# 6. COORDINATED WATER BUDGET (§357.4(b)(3)(B))

6.1 In accordance with the California Code of Regulations, Title 23, section 357.4 (b)(3)(B), the Parties have prepared a coordinated water budget for the Basin as described herein and required by California Code of Regulations, Title 23, section 354.18. The water budget provides an accounting and assessment of the total volume of groundwater and surface water entering and leaving the Basin, including historical, current, and projected water budget conditions, and the change in the volume of water stored. Said water budget is included as part of Appendix 1 to this Agreement.

6.2 All aspects of the coordinated water budget as described herein are addressed in the Basin Setting. In addition, the current water budget for the period 1997-2017 has been apportioned under a water accounting framework among each of the Parties as set forth in Appendix 3 to this Agreement. This water budget is preliminary and based on best available data. Further discussions among the Parties must occur after adoption of GSPs concerning mutual responsibilities in achieving the Subbasin's Sustainable Yield by 2040, or as may be otherwise extended by DWR per Water Code §10727.2 (b) (3) once further data is obtained. The Parties acknowledge that significant data gaps exist within the existing Basin Setting as further described in Section 8 below. The Parties explicitly acknowledge to use good faith efforts to obtain data necessary and to reevaluate the water budget as needed. The Parties agree to use scientifically approved methods of data collection of such data relative to the development or understanding of groundwater extractions, groundwater inflow, and groundwater storage/levels.

6.3 With improved data collection and basin understanding, the water budget will be modified to reflect the updated understanding. The Subbasin GSAs will meet at least annually to review Subbasin data relative to the water budget. Revisions to the water budget will occur no less than every two years. Attached hereto and incorporated by reference is Appendix 3, the Water Accounting Framework.

# 7. SUSTAINABLE YIELD AND UNDESRIABLE RESULTS (§357.4(b)(3)(C)

In accordance with Title 23, California Code of Regulations Section 357.4(b)(3)(C), the Parties hereby agree to a sustainable yield for the basin, which is supported by a description of the undesirable results for the basin, and an explanation of how the minimum thresholds and measurable objectives defined by each Plan relate to those undesirable results, based on information described in the basin setting as described in Appendix 1 attached hereto and incorporated by reference. The sustainable yield is further defined in Appendix 3.

# 8. COORDINATED DATA MANAGEMENT SYSTEM (§357.4(e))

In accordance with the Title 23, California Code of Regulations Section 357.4(e), the Parties hereby describe a coordinated data management system for the Basin. As required by SGMA and accompanying Regulations, the Parties will coordinate to maintain a data management system that is capable of storing and reporting information relevant to the development and/or implementation of the GSPs and monitoring network of the Basin.

Information regarding the agreed upon coordinated data management system, which is subject to future review and modification, shall be attached as Appendix 4 to this Agreement.

# 9. IDENTIFICATION OF DATA GAPS (§354.38)

The Parties will periodically evaluate the monitoring network in Appendix 2 to determine if there are data gaps that could affect the ability of the Subbasin to meet the sustainability goal of the subbasin. Current data gaps are identified in Appendix 5. At minimum, every five years, the Parties will provide an evaluation of data gaps in the five-year assessment, including steps to be taken to address data gaps before the next five-year assessment. The Parties agree to use good faith efforts to obtain data needed to fill all data gaps and to reevaluate both this Coordination Agreement and the GSPs as necessary once data gaps have been filled.

# 10. ADOPTION AND USE OF THE COORDINATION AGREEMENT

## 10.1. COOPERATIVE IMPLEMENTATION OF GSPS. (§357.4(C))

In accordance with the Title 23, California Code of Regulations Section 357.4(c), the Parties hereby explain how the Plans implemented together, satisfy the requirements of the Act and are in substantial compliance with SGMA and SGMA regulations. Each Party will ensure their GSP complies with the statutory requirements of SGMA. The Parties to this Agreement intend that their individual GSPs will be implemented together in order to satisfy the requirements of SGMA. In a coordinated manner, the collective GSPs have satisfied the requirements of sections 10727.2 and 10727.4 of the California Water Code by providing a description of the physical setting and characteristics of the separate aquifer systems within the Basin, the methodologies and assumptions specified in Water Code section 10727.6, both as referenced in Section 2.1 herein. They have further developed a common sustainability goal and description of the Subbasin's undesirable results, both as set forth in Appendix 6. The Parties' minimum thresholds, measurable objectives, and monitoring protocols together provide a description of how the Subbasin will be sustainably managed during the GSP implementation phase. Furthermore, the Parties have developed a coordinated water budget and monitoring network, in addition to their individual GSPs, which, when implemented together, suffice to provide the mandated data and fulfill the requirements set out in SGMA and its accompanying regulations.

The Parties have developed and calibrated a Subbasin numerical groundwater and surface water model that has been applied to simulate the operation of their combined projects and management actions and thereby demonstrate how their GSPs conform to measurable objectives and achieve sustainable yield by 2040. A description of the relevant model simulations and results are as described in Appendix 7 to this Agreement. Through the five-year GSP assessment process and continued dialogue with neighboring subbasins as to their role in influencing the changes in storage within the Kaweah Subbasin, residual storage reductions remaining from the modeling scenarios analyzed thus far will be addressed with implementation of additional projects and/or accelerated implementation of management actions designed to reduce groundwater extractions.

### 10.2. GSP AND COORDINATION AGREEMENT SUBMISSION (§357.4(D).)

In accordance with the Title 23, California Code of Regulations Section 357.4(d), the Parties hereby agree to the following process for submitting all Plans, Plan amendments, supporting information, all monitoring data and other pertinent information, along with annual reports and periodic evaluations. The Parties agree to submit their respective GSPs to DWR through the Management Team Committee and Plan Manager in accordance with SGMA and its accompanying regulations. The Plan Manager will be responsible for submittal of GSPs to DWR in accordance with California Water Code section 10733.4, subdivision (b)(1)-(c). However, prior to this submittal, the Management Team Committee shall vote to approve submittal. The approval shall consist of the review of the multiple GSPs in the Subbasin by the Management Team Committee for coordination and consistency. If the Management Team Committee identifies incomplete coordination or inconsistencies that amount to a concern regarding compliance with sections of SGMA, the Management Team Committee will work with the Parties to resolve these issues prior to submittal. Parties intend that this Agreement suffice to fulfill the requirements of providing an explanation of how the GSPs implemented together satisfy Water Code sections 10727.2, 10727.4 and 10727.6 for the entire Basin.

## 11. KAWEAH SUBBASIN ORGANIZATIONAL STRUCTURE AND OTHER MISCELLANEOUS PROVISIONS

### 11.1. GOVERNANCE. (§357.4(b)(2))

In accordance with the Title 23, California Code of Regulations Section 357.4(b)(2), the Parties hereby agree on the following responsibilities for meeting the terms of the agreement and the procedures for resolving conflicts.

11.1.1. <u>Management Team Committee.</u>

The Parties intend for the Management Team Committee as previously established in the Parties' MOU agreed upon until the effective date of this Coordination Agreement. The Management Team Committee will consist of three (3) representatives appointed by each Party to this Agreement.

- Compensation. Each Management Team Committee member's compensation for service on the Management Team Committee, if any, is the responsibility of the appointing Party.

- Term. Each Management Team Committee member shall serve at the pleasure of the appointing Party and may be removed from the Management Team Committee by the appointing Party at any time.

- Meetings. The Management Team Committee will meet at least monthly, or more frequently as needed, to carry out the activities described in this Agreement. The Management Team Committee will prepare and maintain minutes of its meetings.

11.1.2. Quorum for Management Team Committee Meetings.

In order to take action at a meeting of the Management Team Committee, a majority of the Management Team Committee members must be present at the meeting, with at least one representative from each Party.

11.1.3. Compliance with Open Meetings Laws.

The Management Team Committee shall meet on a regular basis for the purposes described in this Agreement. The Management Team Committee shall comply with the Ralph M. Brown Act (Government Code section 54950 et seq.) as applicable and shall post agendas as required.

11.1.4. Management Team Committee Officers.

The Management Team Committee may, from time to time, select from amongst its members a Chairman, who shall act as presiding officer, a Vice Chairman, to serve in the absence of the Chairman, and any other officers as determined by the Management Team Committee. There also shall be selected a Secretary, who may, but not need be, a member of the Management Team Committee. All officers shall remain in office for two years, unless removed pursuant to a majority vote of the Management Team Committee.

11.1.5. Management Team Committee Meeting Voting Provisions.

Each GSA will be entitled to one (1) vote on the Management Team Committee. The process for declaring such vote must be determined by each respective GSA. Recommendations from the Management Team Committee shall be made to the Parties' respective GSAs only upon the unanimous vote of the Management Team Committee. Should unanimity not be reached, the votes shall be reported to each GSA's Board of Directors for further direction.

11.1.6. Adoption of Management Team Committee Recommendations.

Recommendations approved by unanimous consent of the Management Team Committee shall be reported to each GSA Board, with the process and manner for GSA approval left to the discretion of each GSA. If a GSA fails to approve a recommendation of the Management Team Committee, the Management Team Committee shall reconvene and endeavor to develop an alternative recommendation that may resolve any issues which resulted in the failure to approve. If the Management Team Committee is unable to develop an alternative recommendation, or if a GSA fails to approve the Management Committee's alternative recommendation, the Parties shall evaluate whether to enter into the dispute resolution process outlined in Section 9.3 of this Agreement.

11.1.7. Failure of Management Team Committee to Reach Consensus.

The Parties acknowledge that at all times consensus may not be reached amongst the Management Team Committee. All matters in which consensus of the Management Team Committee cannot be reached shall be reported to the GSA Boards of Directors. The Management Team Committee shall reconvene after the unresolved issue has been reported to the GSA Boards of Directors. If the Management Team Committee is still unable to reach consensus, the Parties shall evaluate whether to enter into the dispute resolution process outlined in Section 9.3 of this Agreement.

11.2. RESPONSIBILITIES OF THE PARTIES.

The Parties to this Agreement agree to work collaboratively to comply with SGMA and this Agreement. Each Party to this Agreement is a GSA and acknowledges it is bound by the terms of the Agreement. This Agreement does not otherwise affect each Party's responsibility to implement the terms of their respective GSP. Rather, this Agreement is the mechanism through which the Parties will coordinate portions of the multiple GSPs to ensure such GSP coordination complies with SGMA.

11.3. DISPUTE RESOLUTION.

Any GSA may choose to initiate the following dispute resolution process by serving written notice to the remaining GSAs of the following: (1) identification of the conflict; (2) description of how the conflict may negatively impact the sustainability of the Kaweah Subbasin; and (3) a proposal for one or more resolutions. The Parties agree to designate representatives to meet and confer with each other within thirty (30) days of the date such notice is given and said representatives shall then meet within a reasonable time to address all issues identified in the notice. Should the representatives be unable to reach a resolution within ninety (90) days of the written notice, the Parties shall enter informal mediation in front of a mutually agreeable mediator.

11.4. MODIFICATION.

The Parties hereby agree that this Agreement shall be reviewed as part of each five-year assessment and may be supplemented, amended, or modified only by the mutual agreement of all the Parties. No supplement, amendment, or modification of this Agreement shall be binding unless it is in writing and signed by all Parties.

11.5. WITHDRAWAL, TERMINATION, ADDING PARTIES.

11.5.1. A Party may withdraw from this Agreement without causing or requiring termination of this Agreement effective upon six months' notice to the Management Team Committee. Any Party who withdraws shall remain obligated to pay its share of all debts, liabilities, and obligations the Party incurred, accrued, or approved pursuant to this Agreement prior to the effective date of such withdrawal.

11.5.2. A new Party may be added to this Agreement if such entity is an exclusive GSA that has developed and will implement its own separate and complete GSP.

11.5.3. This Agreement may be rescinded by unanimous written consent of all the Parties. Nothing in this Agreement shall prevent the Parties from entering into another coordination agreement.

11.6. MISCELLANEOUS.

11.6.1. <u>Severability.</u>

If any provision of this Agreement is for any reason held to be invalid, unenforceable, or contrary to any public policy, law, statute and/or ordinance, then the remainder of this Agreement shall not be affected thereby and shall remain valid and fully enforceable.

11.6.2. <u>Third Party Beneficiaries.</u>

This Agreement shall not create any right of interest in any non-Party or in any member of the public as a third-party beneficiary.

11.6.3. <u>Construction and Interpretation.</u>

This Agreement was finalized through negotiations of the Parties. Each Party has had a full and fair opportunity to review and revise the terms herein. As a result, the normal rules of construction that any ambiguities are to be interpreted against the drafting Party shall not apply in the construction or interpretation of this Agreement.

11.6.4. <u>Good Faith.</u>

Each Party shall use its best efforts and work in good faith for the expeditious completion of the purposes and goals of this Agreement and the satisfactory performance of its terms.

11.6.5. Execution.

This Agreement may be executed in counterparts and the signed counterparts shall constitute a single instrument. The signatories to this Agreement represent that they have the authority to sign this Agreement and to bind the Party for whom they are signing.

11.6.6. Notices.

All notices, requests, demands or other communications required or permitted under this Agreement shall be in writing unless provided otherwise in this Agreement, and shall be deemed to have been duly given and received on: (i) the date of service if personally served or served by electronic mail or facsimile transmission on the Party to whom notice is to be given at the address(es) below; (ii) on the first day after mailing, if mailed by Federal Express, U.S. Express Mail, or other similar overnight courier service; or (iii) on the third day after mailing if mailed to the Party to whom notice is to be given by first class mail, registered certified to the official addresses for each Party according to DWR.

11.6.7. No Admission or Waiver

Nothing in this Coordination Agreement is intended to modify the water rights of any Party or of any Person (as that term is defined under Section 19 of the Water Code). Nothing in this Coordination Agreement shall be construed as an admission by any Party regarding any subject matter of this Coordination Agreement, including without limitation any water right or priority of any water right that is claimed by a Party or any Person. Nor shall this Coordination Agreement in any way be construed to represent an admission by a Party with respect to the subject or sufficiency of another Party's claim to any water or water right or priority or defenses thereto, or to establish a standard for the purposes of the determining the respective liability of any Party or Person, except to the extent otherwise specified by law. Nothing in this Coordination Agreement shall be construed as a waiver by any Party of its election to at any time assert a legal claim or argument as to water, water right or any subject matter of this Coordination Agreement or defenses thereto. The Parties hereby agree that this Coordination Agreement, to the fullest extent permitted by law, preserves the water rights of each of the Parties as they may exist as of the effective date of this Coordination Agreement or at any time thereafter. Any dispute or claim arising out of or in any way related to a water right alleged by a Party may be separately resolved before the appropriate judicial, administrative or enforcement body with proper jurisdiction and is specifically excluded from the dispute resolution procedures set forth under this Coordination Agreement.

IN WITNESS WHEREOF, the Parties have entered into this Agreement as of the date executed below:

GREATER KAWEAH GROUNDWATER
SUSTANABILITY AGENCY

By: Don Mills

Date: 1-22-2020

MID KAWEAH GROUNDWATER
SUSTAINABILITY AGENCY

By: Dennis A. Mederos

Date: 1/22/2020

EAST KAWEAH GROUNDWATER
SUSTAINABILITY AGENCY

By: Ed Milanesio

Date: 1/17/2020

# Appendices

## Coordination Agreement

## Kaweah Subbasin

# Appendix 1
# Basin Setting Report

# Kaweah Subbasin
# Basin Setting Components

**January 10, 2020**

**Submitted to:**

East Kaweah Groundwater Sustainability Agency

Greater Kaweah Groundwater Sustainability Agency

Mid-Kaweah Groundwater Sustainability Agency

**Submitted by:**

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PROFESSIONAL GEOLOGIST TIMOTHY A. NICELY NO. 898 CERTIFIED HYDROGEOLOGIST STATE OF CALIFORNIA

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*Professional Hydrogeologist License Number 898*


**Reviewed by:** Tim Thompson and Maria Pascoal

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AUTHOR INITIALS:TN, NP, BC, CP

# List of Abbreviations and Acronyms

| | |
|---|---|
| AB | Assembly Bill |
| AF | Acre-feet |
| AF/WY | Acre-feet per Water Year |
| AFY | Acre-feet per Year |
| B-E | Bookman-Edmonston |
| bgs | Below Ground Surface |
| CalTrans | California Department of Transportation |
| Cal Water | California Water Service |
| CCTAG | Climate Change Technical Advisory Group |
| CIMIS | California Irrigation Management Information System |
| CVP | Central Valley Project |
| CRTN | California Real Time Network |
| CSRC | California Spatial Reference Center |
| CV-SALTS | Central Valley Salinity Alternatives for Long-term Sustainability |
| CWSC | U.S. Geological Survey California Water Science Center |
| DBCP | Dibromochloropropane |
| DDW | State Water Resources Control Board – Division of Drinking Water |
| DEM | Digital Elevation Model |
| DPR | Department of Pesticide Regulations |
| DTSC | Department of Toxic Substances Control |
| CDWR | California Department of Water Resources |
| EC | electrical conductivity |
| EKGSA | East Kaweah Groundwater Sustainability Agency |
| ESA | European Space Agency |
| ET | Evapotranspiration |
| FWA | Friant Water Authority |
| GAMA | Groundwater Ambient Monitoring and Assessment Program |
| GDE | Groundwater Dependent Ecosystem |
| GIS | Geographic Information System |
| GKGSA | Greater Kaweah Groundwater Sustainability Agency |
| GMP | Groundwater Management Plan |
| gpd | Gallons per Day |
| $gpd/ft^2$ | Gallons per Day per Foot squared |
| GPS | Global Positioning System |
| GSA | Groundwater Sustainability Agency |

| | |
|---|---|
| GSP | Groundwater Sustainability Plan |
| HCM | Hydrogeologic Conceptual Model |
| HUC | Hydrologic Unit Code |
| ILRP | Irrigated Lands Regulatory Program |
| InSAR | Interferometric Synthetic Aperture Radar |
| IRWM | Integrated Regional Water Management |
| JPL | Jet Propulsion Laboratory |
| KDWCD | Kaweah Delta Water Conservation District |
| KSJRA | Kaweah & St. Johns River Association |
| LAS | Lower Aquifer System |
| LLNL | Lawrence Livermore National Laboratory |
| LUST | Leaking Underground Storage Tank |
| M&I | Municipal and Industrial |
| MCL | Maximum Contaminant Level |
| MKGSA | Mid-Kaweah Groundwater Sustainability Agency |
| NASA | National Aeronautics and Space Administration |
| NDVI | Normalized Difference Vegetation Index |
| NGS | National Geodetic Survey |
| NRCS | National Resource Conservation Service |
| NWIS | U.S. Geological Survey National Weather Information System |
| PBO | Plate Boundary Observation |
| PCE | Tetrachloroethylene |
| POTW | Publicly Owned Treatment Works |
| ppb | Parts per Billion |
| ppm | Parts per Million |
| RWQCB | Regional Water Quality Control Boards |
| SAGBI | Soil Agricultural Groundwater Banking Index |
| SAS | Single Aquifer System |
| SB | Senate Bill |
| SCE | Southern California Edison |
| SDWIS | State Drinking Water Information System |
| SGMA | Sustainable Groundwater Management Act |
| Sierra Nevada | Sierra Nevada Mountains |
| SJRRP | San Joaquin River Restoration Program |
| SMCL | Secondary Maximum Contaminant Level |
| SNMP | Salt and Nitrate Management Plan |

| | |
|---|---|
| SOPAC | Scripps Orbit and Permanent Array Center |
| SR | California State Route |
| Subbasin | Kaweah Subbasin |
| SWRCB | State Water Resources Control Board |
| TAF | thousand acre-feet |
| TCE | Trichloroethylene |
| TCP | 1,2,3-Trichloropropane |
| TID | Tulare Irrigation District |
| UAS | Upper Aquifer System |
| UAVSAR | Uninhabited Aerial Vehicle Synthetic Aperture Radar |
| UC Davis | University of California at Davis |
| USBR | U.S. Bureau of Reclamation |
| USGS | U.S. Geological Survey |
| UST | Underground Storage Tank |
| VIC | Variable Infiltration Capacity |
| VOC | Volatile Organic Compound |
| WDR | Waste Discharge Requirement |
| WRI | Water Resources Investigation |
| WSIP | Water Storage Investment Program |
| WWTP | Wastewater Treatment Plant |

# Chapter 2. Basin Setting (§354.12)

This chapter provides a summary of the physical setting and geologic characteristics of the Kaweah Subbasin (Subbasin) that pertain to its groundwater conditions. Key aspects of this chapter include specific details related to the hydrogeologic conceptual model (HCM); current groundwater conditions and groundwater storage; the water budget including inflow and outflow details; the tools used to quantify the water budget, and, an overview of existing groundwater monitoring programs in the Subbasin.

# 2.1 Overview of Plan Area

The Kaweah Subbasin, as defined in California's Department of Water Resources (CDWR) Bulletin 118 (2016), lies in the Tulare Lake Hydrologic Region of the San Joaquin Valley Groundwater Basin. The Subbasin is bounded by the Kings River Subbasin to the north, the Tulare Lake Subbasin to the west, the Tule Subbasin to the south, and the Sierra Nevada Mountains (Sierra Nevada) to the east. There are three groundwater sustainability agencies (GSAs) located in the Kaweah Subbasin: East Kaweah GSA (EKGSA), Greater Kaweah GSA (GKGSA), and Mid-Kaweah GSA (MKGSA). The GKGSA and MKGSA are roughly bisected by California State Route 99 (SR 99). The Kaweah and St. Johns Rivers, Cottonwood and Mill Creeks flow from the Sierra Nevada through the northern portion of the EKGSA and GKGSA jurisdictional areas, turning southwest and toward the Tulare Lake Basin. The Yokohl and Lewis Creeks also flow from the Sierra Nevada and appear along the eastern portion of the EKGSA.

The Kaweah Subbasin is mostly located in Tulare County, with western portions of the Subbasin in Kings County. The cities of Visalia and Tulare are located in the MKGSA jurisdictional area. The cities of Exeter, Farmersville, and Woodlake are in the GKGSA jurisdictional area, as well as a portion of the City of Hanford. The City of Lindsay is in the EKGSA jurisdictional area. The land use within the cities located in the Subbasin is classified as urban, while the majority of the Subbasin's acreage is classified as agricultural. This land use is further divided into field crops, grain and hay crops, pasture, or deciduous fruits and nuts.

## 2.1.1 Topographic Information

The topography of the Kaweah Subbasin area is characterized by a surface of low topographic relief, with variations rarely exceeding 10 feet except in stream channels. Elevations of the Kaweah Subbasin vary from about 800 feet above sea level near the easterly boundary to about 200 feet at the westerly boundary (***Figure 1***). The land generally slopes in a southwesterly direction at about 10 feet per mile, with this slope lessening near the westerly boundary.

## 2.2 Hydrogeologic Conceptual Model §354.14

The purpose of a Hydrogeologic Conceptual Model (HCM) is to provide an easy to understand qualitative description of the physical characteristics of the regional hydrology; land use; geology; water quality; and principal aquifers and aquitards in the Subbasin. Once developed, an HCM is useful in providing the context to develop water budgets, monitoring networks, and identifying data gaps.

An HCM is neither a numerical groundwater model nor a water budget model. Rather, it is a written and graphical description of the hydrologic and hydrogeologic conditions that establish a foundation for development of a water budget. Refer to ***Section 2.5*** for information on the Subbasin water budget.

The narrative HCM description provided in this section is accompanied by graphical representations of physical characteristics of the Kaweah Subbasin to aid in the understanding of the geographic setting, regional geology, and basin geometry. This section describes the Subbasin HCM and includes an introduction and geologic context of the Subbasin within the overall Central Valley (CV) and San Joaquin Valley Groundwater Basin areas.

The HCM is primarily based on data compiled from two recent Water Resources Investigations (WRIs) within the Subbasin (Fugro West, 2007; Fugro Consultants, 2016), as well as additional data and analyses. Data include over 5,000 well completion reports for geologic data and water well design, geophysical electric logs and pumping test data from approximately 100 wells throughout the Kaweah Subbasin, as well as monitoring well data collected from DWR, Kaweah Delta Water Conservation District (KDWCD), and other GSA member agencies within the Subbasin.

The three reports cited below represent the key technical references used for this HCM. In addition to these reports, information to support the HCM was also collected from unpublished consultant reports and datasets related to work performed throughout the area, and personal communication with stakeholders and regulators.

> **Report on Investigation of the Water Resources of Kaweah Delta Water Conservation District (B-E, 1972).** An early, comprehensive study was conducted by Bookman-Edmonston (B-E) in the early 1970s, which integrated the conjunctive supply of both the surface and groundwater of the KDWCD. During the 32-year period between water years 1935 and 1966, land use and total consumptive use narrowly varied. The report presents historical elements of several water budget components including streamflow from as early as 1903 and precipitation dating back to 1877.
>
> **Water Resources Investigation of the Kaweah Delta Water Conservation District (Fugro West, 2003 [revised 2007]).** This WRI was prepared for the KDWCD in 2003 and presented a detailed geologic and hydrogeologic investigation and analysis that evaluated the quantity of groundwater in the KDWCD boundaries. The report included sources and volumes of natural recharge, water budgets, trends in water levels, and estimation of safe yield for the period of water years between 1981 and 1999. The 2003 report was revised in 2007 to account for adjustments to surface water delivery and crop water usage estimates used in the inventory method to determine changes of groundwater in storage. The overall conclusions of the 2007 report were consistent with the original 2003 investigation.

**Water Resources Investigation Update, Kaweah Delta Water Conservation District (Fugro Consultants, 2016).** The 2016 WRI is an updated investigation that provides technical information regarding groundwater gradients, sources and volumes of natural recharge, the annual changes of the quantity of groundwater produced (based on estimated crop water uses), changes in groundwater storage, and the trends of groundwater levels throughout the study area. This report provided updates to the 2007 WRI including the conversion of calendar years to water years and extension of the analysis to the end of calendar year 2012. Additionally, the improved crop water use results (presented in the 2013 Davids Engineering report) were also incorporated into the study.

This HCM has been written by adhering to the requirements set forth in the California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2, Article 5, Subarticle 2 (§354.14).

### 2.2.1 Regional Setting

The Subbasin lies within the Tulare Lake Hydrologic Region of the Central Valley of California. The Central Valley covers approximately 20,000 square miles and extends from the Cascade Range to the north, the Sierra Nevada to the east, the Tehachapi Mountains to the south, and the Coast Ranges and San Francisco Bay to the west. The Central Valley is a vast agricultural region, drained by the Sacramento and San Joaquin rivers, averaging about 50 miles in width and extending about 400 miles northwest from the Tehachapi Mountains to Redding, CA. Generally, the land surface has low relief and is the result of millions of years of alluvial and fluvial deposition of sediments derived from the tectonic uplift of the surrounding mountain ranges. Most of the valley is near sea level but is higher along the valley margins. The Central Valley is divided into three groundwater basins according to CDWR's Bulletin 118 (2016). The northern one-third of the valley is within the Sacramento River Basin, the central one-third is within the San Joaquin River Basin, and the southern one-third is within the Tulare Lake Basin. The two southernmost basins, San Joaquin River and Tulare Lake, are generally referred to as the San Joaquin Valley region. The Kaweah Subbasin is located within the Tulare Lake Basin. In the vicinity of the Kaweah Subbasin, the Central Valley is approximately 65 miles wide and is bordered on the east by the Sierra Nevada and on the west by the Coast Range (***Figure 2***).

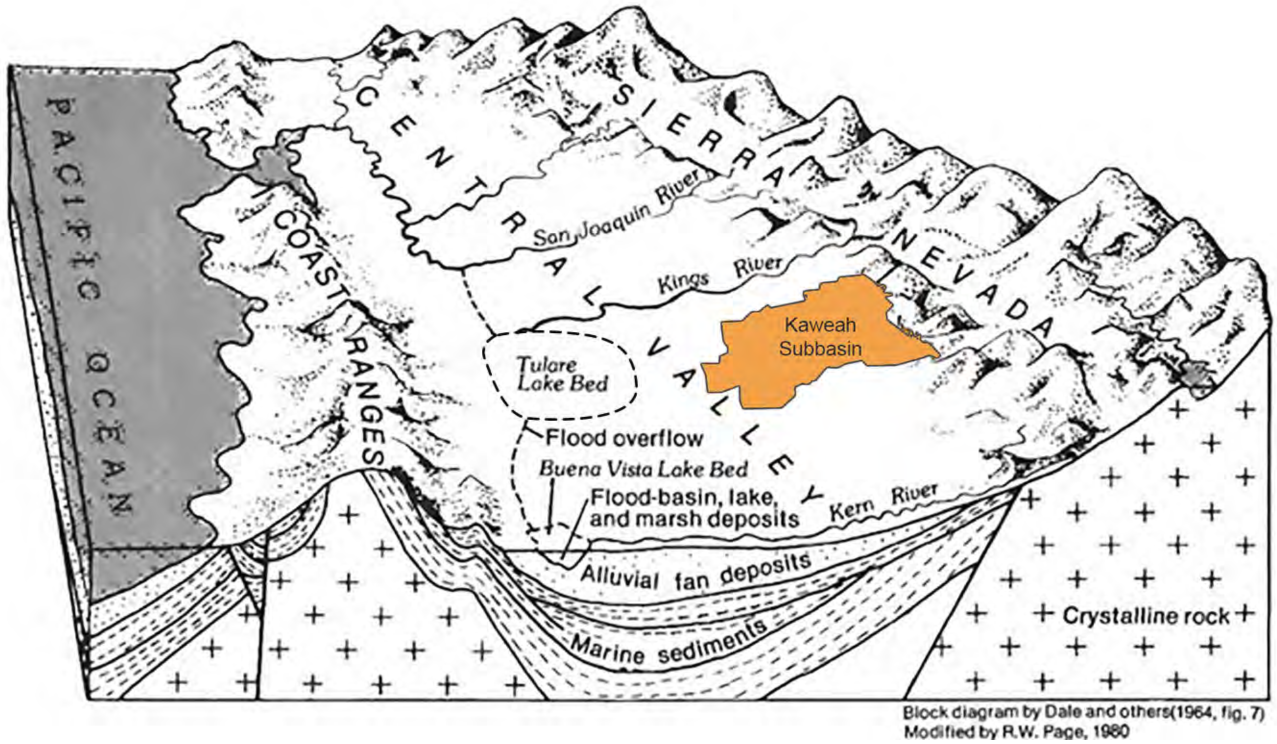



**Figure 2: Isometric Block Diagram of Central San Joaquin Valley**

The southern end of the Central Valley is a closed feature without external surface drainage. Tributary streams drain to depressions, the largest of which is the Tulare Lake bed located to the west of the Kaweah Subbasin boundary. The Kings, Kaweah, and Tule rivers and, on occasion, the Kern River, naturally discharge into Tulare Lake, but diversions by foothill reservoirs and irrigation activities commonly limit or prevent flows from reaching the lake (Fugro West, 2007).

#### *2.2.1.1 Subbasin Features*

The eastern portion of the Subbasin is a large alluvial deposit known as the Kaweah River fan. It is classified as a broad plain formed by a series of large coalescing alluvial deposits created by streams and rivers that drain the western slope of the Sierra Nevada.

The Kaweah River fan is characterized by a surface of low topographic relief, with variations rarely exceeding 10 feet except in stream channels. Elevations of the Kaweah Subbasin vary from about 800 feet above sea level near the easterly boundary to about 200 feet at the westerly boundary. The land generally slopes in a southwesterly direction at about 10 feet per mile, with this slope lessening near the westerly boundary.

The Kaweah River fan is separated from the larger Kings River fan to the north by Cross Creek. To the south, Elk Bayou separates the Kaweah River fan from the Tule River fan. Cottonwood Creek, an intermediate stream between Kings and Kaweah rivers, discharges onto the inter-fan area of these two systems (Davis et al, 1959; Fugro West, 2007).

In the easterly part of the Kaweah Subbasin, within and surrounding the principal rivers, surface soils are sandy and permeable, generally grading to finer materials to the west. In the inter-fan areas adjacent to Elk Bayou and Cross Creek, soils are alkaline and less fertile than in the remainder of the Kaweah Subbasin (Fugro West, 2007).

#### 2.2.1.2 Regional Geology

This section provides a summary of the regional geologic history and rock types of the Subbasin.

***Table 1***, adapted from Page, 1986 and Bertoldi et. al., 1991, provides an overview of geologic deposits in the region within the context of regional hydrologic units. The following discussion provides a summary of the major geologic units present in the area, in sequence from oldest to youngest.

**Table 1: Generalized Regional Geologic & Hydrologic Units of the San Joaquin Valley**

| | Generalized Regional Geology (adapted from Page, 1986, table 2 and Bertoldi et. al. 1991). | Generalized Regional Hydrologic Units |
|---|---|---|
| Quaternary | Flood basin deposits (0 to 100 ft thick) – Primarily clay, silt, and some sand; including muck, peat, and other organic soils in Delta area. These restrict yield to wells and impede vertical movement of water.<br>River deposits (0 to 100 ft thick) – Primarily gravel, sand, and silt; include minor amounts of clay. Among the more permeable deposits in valley. | Undifferentiated upper water-bearing zone; unconfined to semiconfined.<br>Principal confining unit (modified E Clay) |
| Tertiary and Quaternary | Lacustrine and marsh deposits (up to 3,600± ft thick) – Primarily clay and silt; include some sand. Thickest beneath Tulare Lake bed. Include three widespread clay units – A, C, and modified E clay. Modified E clay includes the Corcoran Clay Member of the Tulare Formation. These impede vertical movement of water.<br>Continental rocks and deposits (15,000± ft thick) – Heterogeneous mix of poorly sorted clay, silt, sand, and gravel; includes some beds of mudstone, claystone, shale, siltstone, and conglomerate. They form the major aquifer system in the valley. | Undifferentiated lower water-bearing zone; semiconfined to confined. Extends to base of freshwater which is variable. |
| Tertiary | Marine rocks and deposits – Primarily sand, clay, silt, sandstone, shale, mudstone, and siltstone. Locally they yield fresh water to wells, mainly on the southeast side of the valley but also on the west side near Kettleman Hills. | Below the base of freshwater and depth of water wells. In many areas, post-Eocene deposits contain saline water. |
| Pre-Tertiary | Crystalline basement rocks – Non-water-bearing granitic and metamorphic rocks, except where fractured. | |

The oldest rocks in the area are Pre-Tertiary granitic and metamorphic rocks of the surrounding Sierra Nevada. These rocks crop out along the eastern flank of the Valley and form an almost impermeable boundary for groundwater in the Valley. In some areas, fractures and joints permit small yields of water to wells from these rocks (Page, 1986). For instance, in the eastern portion of the Kaweah Subbasin, water wells produce groundwater from fractures within the granitic bedrock.

Near the end of the Late Cretaceous period (approximately 65 million years ago), tectonic movements elevated the Coast Ranges to the west of the Central Valley and created a marine embayment. During the subsequent Tertiary period, sea levels rose and fell, periodically inundating this southern embayment. This resulted in deposition of both continental and marine sediments.

During the Pleistocene period (a period of time defined as from approximately 2.5 million to 12,000 years ago), the sea level fell, and continental sediments from alluvial and fluvial systems were deposited over the Tertiary-age deposits. These marine sediments are, in part, the source for some of the saline water that has migrated into adjacent and overlying continental deposits (Page, 1986). It is the overlying continental deposits and alluvium, however, that make up most of the regional aquifer system. During a portion of this period, brackish and freshwater lakes formed within the Central Valley and resulted in thick deposits of clay, as found throughout the upper Tulare Formation. The Corcoran Clay, specifically, has been mapped over much of the western and southwestern San Joaquin Valley. This clay layer constitutes a considerable impermeable to semipermeable zone that divides shallower upper zone water from lower zone groundwater of the regional aquifer system.

Since the Pleistocene period, the Central Valley has been dominated by sedimentary processes associated with stream channels, lakes, and rivers. Alluvial fans formed on both sides of the valley, especially on the eastern side. Deposition of fine-grained sediment carried by streams has progressively shifted toward the valley axis leaving the coarse-grained materials closer to the valley margins. The coarse-grained sediments in the fans typically are associated with stream channels. On the eastern side of the valley, these stream channels are large, laterally migrating distributary channels. Over time, shifting stream channels have created coalescing fans, forming broad sheets of interfingering, wedge-shaped lenses of gravel, sand, and fine-grained sediments, which make up the shallow continental water-bearing deposits of the regional aquifer system. Page (1986) identified various depositional environments for the continental sediments, including alluvial fan and deltaic conditions, primarily on the eastern side of the valley, and flood-plain, lake, and marsh conditions on the western side. Consequently, coarse-grained deposits are predominant on the eastern side while finer-grained deposits are predominant within the central and western areas of the Subbasin.

#### 2.2.1.3 Kaweah Subbasin Geology

The geology underlying the Kaweah Subbasin is generally consistent with the regional geology as summarized in the preceding section. Details of the local geology, as it affects the occurrence and movement of groundwater, are provided below based on previous investigations in the area (Fugro West, 2007; Fugro Consultants, 2016). The following units are presented in sequence from the youngest (i.e., shallowest) to oldest:

**Alluvium (Q), unconsolidated deposits:** Non-marine (i.e., continental), water-bearing material comprised of the Tulare Formation and equivalent units. Alluvium is generally mapped in the Subbasin except where the following specific units are provided.

- <u>Flood-basin deposits (Qb):</u> Clay, silt, and some sand on the lateral edges of alluvial fan sediment distal from the Kaweah River.
- <u>Younger alluvium (Qya), oxidized older alluvium (Qoa[o]) and reduced older alluvium (Qoa[r]):</u> Coarse-grained, water-bearing alluvial fan and stream deposits.
- <u>Lacustrine and Marsh Deposits (QTl):</u> Fine-grained sediments representing a lake and marsh phase of equivalent continental and alluvial fan deposition. Includes the Tulare Formation and Corcoran Clay Member.

**Continental Deposits – (QTc):** Heterogeneous mix of water-bearing poorly sorted clay, silt, sand, and gravel.

**Marine Rocks – (Tmc):** Non-water-bearing marine sediments including the San Joaquin Formation. Historically, the top contact of Tmc marked the effective base of the Kaweah aquifer system because of the low permeability of Tmc and the general occurrence of brackish to saline water in Tmc (B-E, 1972).

**Basement Rocks – (pT):** Insignificant water-bearing granitic and metamorphic rocks, except where highly fractured in the eastern portion of the Subbasin.

A correlation table of these geologic units within the context of the hydrogeology of the Subbasin is provided as ***Table 1***. ***Figure 3*** illustrates a location map of the geologic cross sections. These cross sections are included as ***Figure 4*** through ***Figure 13*** and demonstrate the distribution of units both laterally and with depth. A description of each geologic unit is presented below.

### *Unconsolidated Deposits – (Q)*

The unconsolidated deposits include Alluvium (Q), younger alluvium (Qya), older alluvium (Qoa), lacustrine and marsh deposits (QTl) which include the Tulare Formation and Corcoran Clay Member, and unconsolidated continental deposits (QTc). The base of the unconsolidated deposits within the Kaweah Subbasin is projected by electric log correlation from the "upper Mya zone" (Tmc) beneath Tulare Lake Bed, eastward to the top of marine rocks (Woodring et al., 1940). The unconsolidated deposits are equivalent to the "continental deposits" from the Sierra Nevada shown on the cross sections by Klausing and Lohman (1964) and to the "unconsolidated deposits" as used by Hilton et al. (1963).

The unconsolidated deposits gradually thicken from along the western front of the Sierra Nevada to a maximum of about 10,000 feet at the western boundary of the Kaweah Subbasin. The unconsolidated deposits are divided into three stratigraphic units:  younger alluvium, older alluvium, and lacustrine and continental deposits (Fugro West, 2007).

The younger alluvium interfingers and/or grades laterally into the flood basin deposits and into undifferentiated alluvium. The older alluvium and continental deposits interfinger and/or grade laterally into the lacustrine and marsh deposits or into alluvium. Furthermore, the older alluvium and continental deposits are further subdivided into "oxidized older alluvium" and "reduced older alluvium" based on depositional environment (Fugro West, 2007).

Unconsolidated deposits, which locally crop out east of the Kaweah Subbasin and extend beneath the Valley floor, were eroded from the adjacent mountains, then transported by streams and mudflows, and deposited in lakes, bogs, swamps, or on alluvial fans (Fugro West, 2007).

Oxidized deposits generally represent subaerial deposition, and reduced deposits generally represent subaqueous deposition (Davis et al., 1959). Oxidized deposits are red, yellow, and brown, consist of gravel, sand, silt and clay, and generally have well-developed soil profiles.

### *Flood-Basin Deposits – Qb*

At the lateral edges of fanned sediment distal of the Kaweah River, there are flood-basin deposits that represent the final deposition of fine-grained sediments from periodic flooding. Clay, silt, and some sand were mapped by Page (1986).

### *Younger Alluvium – Qya*

In the eastern portion of the Kaweah Subbasin, Qya is generally above the water table and does not constitute a major water-bearing unit. Younger alluvium consists of gravelly sand, silty sand, silt, and clay deposited along stream channels and laterally away from the channels in the westerly portion of the Kaweah Subbasin. Younger alluvium is relatively thin, reaching a maximum depth below ground surface of approximately 100 feet (Fugro West, 2007).

### *Oxidized Older Alluvium – Qoa(o)*

The oxidized older alluvium may be unconfined in the eastern and central parts of the Subbasin. The Corcoran Clay and other lacustrine and marsh deposits (QTl) in the western part of the Subbasin divide water bearing zones of the Qoa(o) into both unconfined and confined conditions. The oxidized deposits that underlie the younger and older alluvium throughout most of the Subbasin are 200 to 500 feet thick (Croft, 1968). These consist mainly of deeply weathered, reddish brown, calcareous sandy silt and clay which can be readily identified when present. Beds of coarse sand and gravel are rare, but where present, they commonly contain significant silt and clay. The highly oxidized character of the deposits is the result of deep and prolonged weathering. Many of the easily weathered minerals presumably have altered to clay. Therefore, these deposits have low permeability (Fugro West, 2007).

The oxidized older alluvium unconformably overlies the continental deposits. The beds consist of fine to very coarse sand, gravel, silt and clay derived mainly from granitic rocks of the Sierra Nevada. Beneath the channels of the Kaweah, Tule and Kings rivers, electric logs indicate that the beds are very coarse. In the inter-fan areas in the eastern portions of the Kaweah Subbasin, metamorphic rocks and older sedimentary units contributed to the deposits. In those areas, the beds are not as coarse as the beds beneath the Kaweah, Tule, and Kings rivers. Fine grain deposits occur in the channel of Cross Creek (Fugro West, 2007).

East of SR 99, the contact of the older alluvium with the underlying oxidized continental deposits is well defined in electric logs. Structural contours, based on electric-log data, show the altitude above or below sea level of the base of the unit. The older alluvium thickens irregularly from east to west, most likely due to filling gorges cut by the ancient Tule River in the underlying oxidized continental deposits near Porterville. The base of the deposits occurs approximately 195 feet below land surface near Exeter and declines to 430 feet below land surface near Visalia and the unincorporated community of Goshen.

### *Reduced Older Alluvium – Qoa(r)*

These deposits are saturated with unconfined conditions in the eastern part of the Subbasin and confined in the western part of the Subbasin. Reduced deposits are blue, green, or gray, calcareous, and generally are finer grained than oxidized deposits. Commonly, these deposits have a higher organic content than the oxidized deposits. In some cases, the separation between the oxidized and reduced deposits are identified on well logs based on lithologic color, although such delineation is subjective. The coarsest grained reduced deposits were laid down in a flood plain or deltaic environment bordering lakes and swamps. Due to a high water table in parts of the eastern portion of the Kaweah Subbasin, the sediments have not been exposed to subaerial weathering conditions. The finest grained reduced sediments were mapped as flood basin, lacustrine, and marsh deposits.

The reduced older alluvium consists mainly of fine to coarse sand, silty sand, and clay that were deposited in a flood plain or deltaic environment. It overlies the continental deposits, interfingers with lacustrine and marsh deposits beneath the Tulare Lake Bed, and interfingers with alluvium, undifferentiated, north of the Tulare Lake Bed. Gravel that occurs in the oxidized older alluvium is generally absent. The deposits are sporadically cemented with calcium carbonate. Those descriptions imply, however, that the calcium carbonate is probably less abundant than in the underlying reduced continental deposits (Fugro West, 2007).

### *Lacustrine and Marsh Deposits – QTl*

These fine-grained deposits generally do not provide reliable groundwater storage, but act as confining to semi-confining zones. The lacustrine and marsh deposits of Pliocene and Pleistocene age consist of blue-green or gray gypsiferous silt, clay, and fine sand that underlie the flood basin deposits and conformably overlie the marine rocks of late Pliocene age. In the subsurface beneath parts of Tulare Lake Bed, these beds extend to about 3,000 feet below land surface. Where the equivalent beds crop out in the Kettleman Hills on the west side of the Valley, they are named the Tulare Formation. Woodring et al. (1940) considered the top of the Tulare Formation to be the uppermost deformed bed. Therefore, by this definition, all the deformed unconsolidated deposits would form the Tulare Formation (Fugro West, 2007).

In the subsurface around the margins of the Tulare Lake Bed, lacustrine and marsh deposits form several clay zones that interfinger with more permeable beds of the continental deposits, alluvium, and older alluvium. Diagnostic fossils and stratigraphic relationships to adjacent deposits indicate these clays are principally of lacustrine origin. Clay zones are generally indicated by characteristic curves on electric logs and thereby facilitate some areal correlations between adjacent logs as shown on the hydrogeologic cross sections (***Figure 4*** through ***Figure 13).***

As many as six laterally continuous clay zones have locally been defined in the southern Valley. The most prominent of these clay zones is referred to as the Corcoran Clay. It is a member of the Tulare Formation within the Kaweah Subbasin. Clay deposits are nearly impermeable and do not yield significant water to wells (which is generally of poor water quality; Fugro West, 2007). The Corcoran Clay is the largest confining body in the area and underlies about 1,000 square miles west of SR 99. The beds were deposited in a pre-historic lake that occupied the Valley trough which varied from 10 to 40 miles in width and was more than 200 miles in length (Davis et al., 1959). The first wide-scale correlation of the Corcoran Clay was made by Frink and Kues (1954). The Corcoran Clay extends from Tulare Lake Bed to SR 99 and is vertically bifurcated near Goshen. It is about 75 feet thick on average but is approximately 140 feet thick near Corcoran (a city immediately southwest of the Kaweah Subbasin).

### *Continental Deposits – QTc*

Represent the poorly sorted clay, silt, sand, gravel, claystone, shale, siltstone, and conglomerate that grade into the older alluvium and/or underlie older alluvium. These continental deposits are underlain by the Tertiary marine rocks (Tmc).

#### *Marine Rocks (Non-water bearing) – Tmc*

Along the eastern border of the Valley, Tertiary rocks, mainly of marine origin, underlie the unconsolidated deposits and overlap the basement complex. This unit may locally include beds of continental origin in the upper part (Croft, 1968). Outcrops of these marine rocks have not been identified in the Subbasin. The Tertiary marine rocks range in age from Eocene to late Pliocene and consist of consolidated to semi-consolidated sandstone, siltstone, and shale. They have traditionally been locally divided into several formations (Park and Weddle, 1959). Since they generally contain poor quality water (brackish and saline connate or dilute connate water) they are treated as one unit (Fugro West, 2007). Historically, the top of the Tmc is considered the effective base of the Subbasin because of the low permeability of Tmc and the general occurrence of brackish to saline water Tmc (B-E, 1972).

#### *Basement Complex (non-water bearing) – pT*

The basement complex of pre-Tertiary age consists of metamorphic and igneous rocks. These rocks occur as resistant inliers in the alluvium and as linear ridges in the foothills in the eastern-most portion of the Kaweah Subbasin. In the subsurface, they slope steeply westward from the Sierra Nevada beneath the deposits of Cretaceous age and younger rocks that compose the Central Valley fill. Escarpments interpreted as buried fault scarps are found along the eastern portion of Subbasin associated with the Rocky Hill fault. West of the escarpments, the slope of the basement complex steepens (Fugro West, 2007).

While the basement complex is considered to be non-water bearing in most areas, it is fractured and present at shallow depths in the eastern portion of the Kaweah Subbasin. Areas of Lindsay, Strathmore, and Ivanhoe and in the intermontane valleys are penetrated by many water wells. Near Farmersville and Exeter, the basement complex forms a broad, gently westward-sloping shelf overlain by 100 to 1,000 feet of unconsolidated deposits (Fugro West, 2007).

### 2.2.2 Geologic Features that Affect Groundwater Flow in the Kaweah Subbasin

According to CDWR's Bulletin 118 (2003), there are no reported groundwater barriers restricting horizontal flow in and out of the Kaweah Subbasin. However, the Rocky Hill fault zone as shown on ***Figure 3*** and ***Figure 5*** is not believed to affect groundwater flow within of the Subbasin. While, in the eastern portion of the Subbasin, the Rocky Hill fault offsets pre-Eocene deposits and may locally offset older alluvial deposits. These offsets are not known to disrupt groundwater flow. The linear alignment of ridges in this area generally define the fault line. Lithology data from boreholes along Cross Section B (***Figure 5***) suggest that older alluvium may be offset or vary in thickness across the Rocky Hill fault. While previous studies (Fugro West, 2007) suggested that the hydrologic connection of the oxidized alluvial aquifer may be restricted near the Rocky Hill fault, evidence of such restriction has not been noted by groundwater managers.

### 2.2.3 Lateral Boundaries of the Subbasin

The Kaweah Subbasin (Basin Number 5-022.11[1]) is situated within the Tulare Lake Hydrologic Region of the overall San Joaquin River Basin (Basin Number 5-022). The Kaweah Subbasin has a

[1] As defined in CDWR Bulletin 118 2016

surface area of approximately 441,000 acres (696 square miles) (CDWR, 2003). The lateral boundaries of the Subbasin are defined by various jurisdictional and geographical segments as shown on ***Figure 14***. Crystalline bedrock of the Sierra Nevada foothills defines the eastern boundary of the Subbasin while the other three sides of the Subbasin are politically, but not geologically, bounded by the following Subbasins:

Kings Groundwater Subbasin on the North

Tule Groundwater Subbasin on the South

Tulare Lake Groundwater Subbasin on the West

The political boundaries do not coincide with natural features that affect groundwater flow. Groundwater generally flows from natural recharge at higher elevations from the Sierra Nevada, west through the Subbasin to the Tulare Lake Groundwater Subbasin along the West boundary. Although groundwater flow is generally from northeast to southwest, there are some northern and southern areas where the flow direction is from east to west. These conditions indicate that there is a limited amount of underflow between Kaweah, Kings, and Tule Groundwater Subbasins.

### 2.2.4 Bottom of the Subbasin

The effective base of the Subbasin corresponds with the base of freshwater. This is generally defined as the elevation below which total dissolved solids are greater than 2,000 milligrams per liter (mg/l) (Bertoldi et al, 1991). The top of the Tmc has historically been used as the effective base of the Kaweah aquifer system because of its low permeability and general occurrence of brackish to saline water (B-E, 1972). However, based on abundant water quality data from wells throughout the area, the current designation of the base of freshwater is established as the base of the Tulare Formation, which is several hundred feet above the top of the Tmc in most places. This designation is based on two factors: (a) recent review of well completion reports for wells drilled within the last decade and (b) the opinions of groundwater managers and hydrogeologists working in this and adjacent basins.

The range of elevations of the effective base of the alluvial aquifer systems varies within the Subbasin from as deep as 1,100 feet below sea level in the western portion of the Subbasin near Corcoran, as indicated in B-E (1972) and Fugro West (2007), to as shallow as 50 feet below sea level east of the Rocky Hill fault (coinciding with the depth to crystalline bedrock) in the eastern portion of the Subbasin. The effective base of the aquifer system as shown on ***Figure 15*** and throughout the geologic cross sections. The depth to crystalline bedrock to the east of Rocky Hill fault marks the eastern effective bottom of the basin (***Figure 4*** through ***Figure 13***).

### 2.2.5 Principal Aquifers and Aquitards of the Subbasin

Groundwater in the Kaweah Subbasin occurs primarily in an alluvial aquifer system that is present throughout the area. In the central and western parts of the Subbasin, the alluvial aquifer system consists of an upper unconfined zone (Upper Aquifer System [UAS]) above the Corcoran Clay and a lower confined zone (Lower Aquifer System [LAS]) below the Corcoran Clay. In the eastern portions of the Subbasin, the Corcoran Clay is not present, and the aquifer system consists of a single merged aquifer zone (Single Aquifer System [SAS]) that is unconfined or semi-confined. ***Table 2*** provides a summary of the Hydrostratigraphy of the Subbasin.

**Table 2: Hydrostratigraphy of Kaweah Subbasin**

| Relative Depth | Kaweah Subbasin Hydrostratigraphy<br>West | <br>East | Equivalent Geology<br>West East | General Characteristics |
|---|---|---|---|---|
| Shallow | Upper Aquifer System<br>(unconfined to semi-confined)<br>(thickness 200 to 400 ft) | Principal Aquifer A/B (Merged Zone)<br>(semiconfined with depth) (thickness 300 to 1000 ft) | Younger Alluvium – Qya<br>Oxidized Older Alluvium – Qoa(o) | Qoa is the major aquifer of the Subbasin |
| | Principal confining unit<br>(modified Corcoran "E" Clay)<br>(thickness 60 to 200 ft) | | Lacustrine and marsh deposits – QTl:<br>Corcoran Clay Member | |
| Deep | Lower Aquifer System<br>(confined)<br>(thickness 500 to 1000 ft) | | Oxidized Older Alluvium – Qoa(o)<br>Reduced Older Alluvium – Qoa(r)<br>Continental Deposits - QTc | |

### *2.2.5.1 Formation Names*

The primary aquifer system in the Subbasin is made up of unconsolidated deposits of Holocene, Pleistocene, and Pliocene age, younger and older alluvium, and continental deposits. The aquifer system is split in the western and central Subbasin by confining fine-grained beds of the Tulare lake bed or the Corcoran Clay member of the Tulare Formation. These confining beds may also include flood-basin and lacustrine deposits. The Corcoran Clay confining bed grades eastward until it effectively thins and becomes either absent or discontinuous. The split aquifer is merged as a single aquifer zone of alluvium and continental deposits made up of coarser material derived from the Sierra Nevada.

#### *Upper Aquifer System (UAS)*

The UAS is present above the Corcoran Clay in the western and central portions of the Subbasin. It is made up of the following:

> Flood-basin deposits (Qb) consisting of poorly permeable silt, clay, and fine sand with groundwater of poor quality, and
>
> Younger alluvium (Qya) consisting of beds of moderately to highly permeable sand and silty sand, and
>
> Older alluvium (Qoa[o]) which is moderately to highly permeable and is the major productive aquifer horizon in the Subbasin.

#### *Aquitard*

The upper aquifer system is underlain by an aquitard (Corcoran Clay or lacustrine and marsh deposits [QTl]) consisting of blue, green, or gray silty clay and fine sand. The Corcoran Clay separates the upper aquifer from the lower confined aquifer and underlies the western half of the Subbasin at depths ranging from about 200 to 500 feet (Jennings, 2010). In the eastern portion of the Subbasin, where the Corcoran Clay becomes thin, discontinuous or absent, groundwater occurs in a merged Aquifer A/B under unconfined and semiconfined conditions.

The areas between the easterly edge of the Corcoran Clay and the Rocky Hill fault contain groundwater in the merged SAS in both unconfined and semi-confined continental deposits underlying the alluvium. East of the Rocky Hill Fault, the aquifer is considered merged and is semi-confined.

#### *Lower Aquifer System (LAS)*

The LAS, present in the western and central part of the Subbasin below the Corcoran Clay, is made up of the older alluvium (Qoa[o] and Qoa[r]) which is moderately to highly permeable. The LAS also includes the underlying continental deposits (QTc) where fresh water occurs; however, the majority of aquifer pumping occurs in the older alluvium. The bottom of the lower aquifer is the base of the Tulare Formation.

#### *Single Aquifer System*

In the eastern part of the Subbasin, where the Corcoran Clay thins, is discontinuous, or is absent, the upper and lower aquifers are merged into a single aquifer unit that is semiconfined. The merged zone is made up of younger alluvium (Qya), older alluvium (Qoa[o] and Qoa[r]), and continental deposits (QTc) (see ***Figure 4*** and ***Figure 5***).

### 2.2.5.2 Physical Characteristics

Hydrogeologic parameters of the aquifers and aquitards in the Kaweah Subbasin include average specific yield values for the upper 200 feet of sediments and numerical values of hydraulic conductivity, which are defined below. For the most part, reliable coefficients of storativity (aquifer storage) were documented in technical studies from controlled pumping tests with observation wells. The majority of these studies were carried out in the KDWCD portion, located in the GKGSA and MKGSA areas, of the Subbasin (Fugro West, 2007).

Specific Yield is defined as the volume of water that will drain by gravity from sediments within an aquifer if the regional water table were lowered. Within the Kaweah Subbasin, specific yield has been used to calculate changes of groundwater in storage for comparison to earlier time periods by the "specific yield method" (Fugro West, 2007; Fugro Consultants, 2016). Specific yield values ranged from about 6.5 percent to as high as 13.7 percent. The average specific yield of the deposits within the 10- to 200-foot-depth range is 9.9 percent, slightly below the Valley-wide average of 10.3 percent, but considerably above the average specific yield of any of the inter-stream storage units (Fugro Consultants, 2016). DWR estimated that the average specific yield for the Subbasin is 10.8 percent (DWR internal data; Davis, 1959). Sand and gravel together make up 25.6 percent of the total thickness, which is slightly below the Valley-wide average of 28 percent. Eighty percent of these coarse-grained deposits are reported as sand, twenty percent as gravel (Fugro West, 2007).

Hydraulic Conductivity is "a measure of the capacity for a rock or soil to transmit water" (Aqtesolv, 2016). Hydraulic conductivity values and storage coefficients for the entire Central Valley were compiled by Bertoldi et al. (1991). Efficiency tests for several hundred wells within the Tule and

Kaweah Subbasins were converted to well-specific capacity data, from which a single horizontal hydraulic conductivity value was assigned to each section (KDWCD, 2012; Fugro West, 2007). A range of hydraulic conductivity values are present, reflecting the broad geographic area of the entire Valley. The broad range of values, which span several orders of magnitude within the Kaweah Subbasin, reflect a heterogeneous mixture of aquifers, aquitards, and aquicludes. The horizontal hydraulic conductivity values range from approximately 1 gallon per day per foot squared (gpd/$ft^2$) for the confined aquifer west of SR 99 to s high as 1,000 gpd/$ft^2$ in the semi-confined aquifer in the eastern half part of the Kaweah Subbasin (Fugro West, 2007).

Based upon SCE (Southern California Edison) pump test reports, which provide the "specific capacity" (i.e., the gallons per minute pumped per foot of drawdown) for tested wells, representative values of regional and local hydraulic conductivity were calculated. While these data are dependent on the manner of well drilling and development, age of the well, well design, and a variety of other factors, the results are considered representative for the purposes of this study. The hydraulic properties of the principal aquifers within the Kaweah Subbasin are presented on ***Table 3*** (based on Fugro West, 2007).

**Table 3: Aquifer Properties**

| Kaweah Subbasin Hydrostratigraphy | Associated Deposits | Average Thickness of Saturated Aquifer (feet) | Average Hydraulic Conductivity (gpd/ft$^2$) |
|---|---|---|---|
| **Western Side** Upper Aquifer | Older alluvial deposits | 150 | 250 |
| Lower Aquifer | Younger continental deposits | 150 | 150 |
| | Older continental deposits | 800 | 70 |
| Corcoran Clay | Corcoran Clay and Lacustrine and Marsh Deposits | 80 to 100 | <1 |
| **Eastern Side** Single Aquifer | Older alluvium (oxidized) | 250 | 500 |
| | Older alluvium (reduced) | 250 | 250 |
| | Younger continental deposits | 150 | 150 |
| | Older continental deposits | 800 | 70 |

Source: Modified from Fugro West, 2007

### *2.2.5.3 Structural Properties that Restrict Groundwater Flow*

The Corcoran Clay is the most significant subsurface feature in the Kaweah Subbasin affecting the occurrence and movement of groundwater. The Corcoran Clay is a relatively impervious stratum, the eastern edge of which follows generally a north-south line about two to three miles east of SR 99. The Corcoran Clay dips to the west and usable groundwater is found both above and below this stratum.

While there is significant uncertainty about the completion of most wells in the Subbasin, it is generally suspected that wells located within the Corcoran Clay area are, for the most part, perforated in and pump from the confined aquifer system (Fugro West, 2007). The heterogeneity of aquifer properties in the Subbasin and known presence of several interfingering aquitards in the west part of the Subbasin complicate the separation of water level data representative of the confined or unconfined aquifer systems. Through 1988, annual "pressure" system water level maps (prepared by DWR) suggested that the water levels in the unconfined system and the pressure system differed by no more than 20 feet and were both substantially above the Corcoran Clay. The water level data demonstrates similar water levels between the two aquifer systems, with considerable inter-aquifer groundwater flow occurring between the two systems (via wells with perforations in both systems).

The Rocky Hill Fault disrupts pre-Eocene deposits and may locally penetrate older alluvial deposits. The fault does not offset younger alluvium (based on water level data) and does not appear to constitute a horizontal barrier to groundwater flow (CDWR, 2003; Fugro Consultants, 2007).

### *2.2.5.4 General Water Quality of Principal Aquifers*

The Subbasin aquifer system consists of unconsolidated marine and continental deposits of Pliocene, Pleistocene, and Holocene age. The eastern half of the Subbasin consists of three stratigraphic layers: continental deposits, older alluvium, and younger alluvium (Belitz and Burton, 2012). Continental deposits from the Pliocene and Pleistocene age are poorly permeable. The major aquifer of the Subbasin is the older alluvium. The older and younger alluvium are moderately to highly permeable. The western half of the Subbasin is less permeable, and the groundwater aquifer is confined by the Corcoran Clay layer. The remainder of this section provides a summary of several key constituents including: arsenic; nitrate; sodium; chloride; uranium1,2,3 – Trichloropropane (TCP); and Tetrachloroethylene (PCE). These constituents are known water quality concerns in the Subbasin.

In the Southeast San Joaquin Valley, arsenic is the constituent which most frequently occurs at concentrations above the drinking water standard (maximum contaminant level [MCL] = 10 ppb) in the primary aquifers (Burton and Belitz, 2012). Arsenic concentrations greater than 5 parts per billion (ppb) are primarily located within the the western part of the Subbasin (***Figure 68***). Wells evaluated in the eastern portion of the Subbasin rarely have arsenic detections. However, wells that do have detections are at concentrations less than 5 ppb. United States Geological Survey (USGS) reports indicate that wells constructed deeper than 250 feet tend to have higher arsenic levels; and these wells tend to be in the western portion of the Subbasin where wells are commonly deeper (***Figure 69***).

Nitrate is commonly detected throughout the Kaweah Subbasin with concentrations commonly higher than 8 parts per million (ppm). Wells in the eastern portion of the Subbasin have shown increasing trends over the past several years (***Figure 70***). Shallow wells have higher nitrate levels than wells deeper than 250 feet, because nitrate is a surface contaminant that primarily impacts shallower groundwater. Generalized water level contour maps were used to determine if changing water levels corresponds with increasing nitrate concentrations (***Figure72***). Sufficient data were not available to determine if nitrate is migrating into the deeper aquifer. Overall, nitrate detections are prevalent throughout the Subbasin, with highest concentrations in the eastern portion.

A total of 21 contaminated sites have been identified in the Subbasin. There is a large PCE plume located in the city of Visalia shown on ***Figure 76.*** A city-wide investigation, lead by California Department of Toxic Substances Control (DTSC), began in 2007 to determine the responsible party and the extent of the PCE plume. Nine sites are involved in this ongoing investigation (***Figure 77***). Management actions are currently in place through the DTSC agreement with California Water Service (Cal Water) to limit these surface contaminants from spreading further in the aquifer.

Sodium and chloride levels were detected in a small portion of the wells within the Subbasin (***Figure 81***). Sodium concentrations above the Agricultural Water Quality Goal of 69 ppm were detected in 13 wells. Chloride concentrations above the Agricultural Water Quality Goal of 106 ppm were detected in five wells. Without sufficient well construction reports or depth to water level data, it is difficult to determine if there is a correlation between the two. Overall, the common water quality issues for this Subbasin are arsenic, nitrate, TCP, PCE, sodium, uranium, and chloride. More data gathering such as through a monitoring program would be beneficial to gain a better understanding between these correlations.

#### *2.2.5.5 Primary Use of Aquifers*

The Kaweah Subbasin covers an area of 441,000 acres and has been highly developed with about 322,000 acres devoted to a variety of irrigated crops and approximately 53,000 acres of urbanized area (USDA, 2018).

At present, about 1,076,400 AF of water (surface and groundwater) per year are delivered for irrigation, municipal, and industrial uses. Water used for irrigated agriculture comprises more than 94 percent of the total water use, or 1,007,400 Acre-feet per year (AFY). Irrigation requirements are met from both surface and groundwater sources, while municipal and industrial supplies are obtained mostly from groundwater. Likewise, groundwater is the main source of water for small to large animal farms and residential dwellings in unincorporated parts of the Subbasin that are not served by municipal or small community water systems. This includes dairies and the non-agricultural ranchette properties throughout the Subbasin. The public water agencies and districts located within the Subbasin include the following:

- City of Woodlake
- City of Exeter
- City of Tulare
- Consolidated Peoples Ditch Company
- Ivanhoe Public Utilities District
- City of Lindsay
- Exeter Irrigation District
- Evans Ditch Company
- Ivanhoe Irrigation District
- Kaweah-Delta Water Conservation District
- Kings River Conservation District
- Kings County Water District
- Lakeside Irrigation Water District
- Lindmore Irrigation District
- Lindsay-Strathmore Irrigation District
- Strathmore Public Utilities District
- St. Johns Water District
- Tulare Irrigation District
- Stone Corral Water District
- Lewis Creek Water District

Private water agencies within the Subbasin include the following:

- California Water Service within Visalia, Goshen
- Goshen Ditch Company
- Evans Ditch Company
- Modoc Ditch Company

- Melga Canal Company
- Settlers Ditch Company
- Corcoran Irrigation Company
- Wutchumna Water Company
- West Goshen Mutual Water Company
- Longs Canal Company
- Hamilton Ditch Company
- Sweeney Ditch Company
- Mathews Ditch Company
- Uphill Ditch Company
- Sentinel Butte Water Utilities Company
- Farmers Ditch Company
- Fleming Ditch Company
- Lemon Cove Ditch Company
- Oakes Ditch Company
- Persian Ditch Company
- Tulare Irrigation Company
- Elk Bayou Ditch Company
- Pratt Mutual Water Company

### 2.2.6 Geologic Cross Sections

Geologic cross sections depicting the structural geology and hydrologic units of the Subbasin were created based on historical reports and lithologic data from over 5,000 driller's logs and various existing geologic maps (Davis et al., 1957; Croft, 1968; B-E, 1972; Bertoldi et al, 1991; Page, 1986). Cross Sections A through J (***Figure 4*** through ***Figure 13***), provide the following information:

- Relative depths and screened intervals of production wells
- Lithology
- Geophysical log profiles
- Topography from the USGS digital elevation model (DEM)
- Interpreted elevation of the top of the Corcoran clay surface

- Effective base of the alluvial aquifer system

The geologic cross sections were constructed by a professional geologist. The cross sections are presented with uniform vertical exaggeration to more clearly present the subsurface data. The locations of the cross sections are shown on the map in ***Figure 3***.

These cross sections are based on interpretations of Fugro West (2007; ***Figure 4*** through ***Figure 9***) with minor modifications to the elevation of the "Effective Base of Fresh Water System." The original Fugro West cross sections were extended to include the entire Subbasin based on newly acquired well log data. ***Figure 10*** through ***Figure 13*** in the EKGSA portion of the Subbasin are based on published cross sections (USBR, 1949; Davis et. al., 1959, and Croft and Gordon, 1968).

Cross sections demonstrate in the eastern portion of the Subbasin, the Rocky Hill fault disrupts pre-Eocene deposits and may locally penetrate older alluvial deposits. The linearity of the ridges in this area defines the fault line. The Rocky Hill fault does not offset younger alluvium based on water level data (Croft, 1968; Fugro West, 2007). The primary east-west geologic cross sections (***Figure 4*** through ***Figure 6***) indicate a thickening section of unconsolidated deposits to the west across the Subbasin. For the most part, regional folding has little effect on the patterns of groundwater flow within the Subbasin or at the political Subbasin boundary. The relative relationship between the "Effective Base of Fresh Water System" within the Continental Deposits (Qtc) and the marine rocks is evident in many of these cross sections. The several hundred feet between the marine rocks and the "Effective Base of Fresh Water System" is comprised of sedimentary deposits containing saline water.

The cross sections within the EKGSA's area (***Figure 10*** through ***Figure 13***) show the relative depth of the aquifer materials in the area, which are underlain by marine rocks and/or basement complex. These cross sections are relatively short to be presented at similar scales for easy comparison to ***Figure 4*** through ***Figure 9***.

## 2.2.7 Physical Characteristics

### 2.2.7.1 Surficial geology

As presented on ***Figure 2***, the rocks that outcrop in the Subbasin include a basement complex of pre-Tertiary age consisting of consolidated metamorphic and igneous rocks to the east and unconsolidated deposits of Holocene, Pliocene, and Pleistocene age throughout the remainder of the Subbasin. Consolidated marine rocks of Pliocene age and older do not crop out in this area but are penetrated by wells in the subsurface (Jennings, 2010; Croft, 1968; Fugro West, 2007).

### 2.2.7.2 Soil recharge characteristics

Obtaining information on soil recharge characteristics in the Subbasin is important in understanding natural recharge to the groundwater system and for siting locations for artificial recharge projects. The University of California at Davis (UC Davis), in conjunction with the University of California Division of Agriculture and Natural Resources, developed the Soil Agricultural Groundwater Banking Index (SAGBI). The SAGBI is a composite evaluation of groundwater recharge feasibility on agricultural land (also called Irrigation Field Flooding). The following five parameters are incorporated into the Index:

1. Deep percolation is dependent upon the saturated hydraulic conductivity of the limiting layer.

2. Root zone residence time estimates drainage within the root zone shortly after water application.

3. Topography is scored according to slope classes based on ranges of slope percent.

4. Chemical limitations are quantified using the electrical conductivity (EC) of the soil.

5. Soil surface condition is identified by the soil erosion factor and the sodium adsorption ratio.

Proximity to a water conveyance system is not a factor considered in the SAGBI composite evaluation. Each factor was scored on a range, rather than discretely, and weighted according to significance. Adjustments were then made to reflect soil modification by deep tillage (i.e., shallow hard pan is assumed to have been removed by historic farming activities) to create a modified SAGBI. Ultimately, SAGBI seeks to categorize recharge potential according to risk of crop damage at the recharge site. Usefulness of the index is diminished when evaluating locations for dedicated recharge basins. In these cases, a soil profile illustrating deep percolation potential may prove to be more useful. As is the case with any model, the SAGBI is best applied in conjunction with other available data and on-site evaluation.

***Figure 16*** illustrates the modified SAGBI for the Subbasin which indicates that a majority of the land within the Subbasin is favorable for recharge. This model assumes that hardpans have been largely removed by previous farming practices. Hardpans are still extensive within the EKGSA, so this model should be considered in conjunction with the unmodified SAGBI. It is locally well known that surface recharge is ineffective in the EKGSA area, but water introduced deep enough into the strata infiltrates easily in those areas identified in the modified SAGBI as "good." Soils in the Subbasin were categorized by the National Resource Conservation Service (NRCS), which indicate that the soils are mostly of fine- to course-loamy in texture. As shown on the soils map in ***Figure 18***, the soils along the Lower Kaweah and St. Johns rivers, as well as those along Cottonwood, Yokohl, and Lewis creeks are the coarsest, whereas most of the remainder of the Subbasin is comprised mostly of fine to fine-loamy soil.

The presented data are based on a UC Davis study to identify potential areas favorable for enhanced groundwater recharge projects. Those projects are discussed below.

#### 2.2.7.3 Delineation of recharge areas, potential recharge areas, and discharge areas, including springs, seeps, and wetlands

<u>*Natural Recharge Areas*</u>

Natural recharge in the Subbasin is primarily derived from seepage from the Kaweah and St. Johns rivers, and intermittent streams. Seepage of water from rivers, streams, irrigation canals, and irrigation water applied in excess of plant and soil-moisture requirements constitute the principal sources of groundwater recharge to the aquifers. Direct precipitation contributes minor quantities of water to these aquifers (Croft and Gordon, 1968).

Potential recharge areas are presented in ***Figure 16*** as part of the soil map in support of potential future groundwater recharge projects. The data presented are the result of a study focused on the possibilities of using fallow agricultural land as (temporary) percolation basins during periods when excess surface water is available. The UC Davis study developed a methodology to determine and assign an index value to agricultural lands (i.e., SAGBI). The SAGBI analysis incorporates the following five important agricultural factors into the analysis: deep percolation, root zone residence time, topography, chemical limitations (salinity), and soil surface conditions. Notably, the data presented show the unmodified SAGBI data, which do not include areas that would benefit from the deep ripping of soils to a depth of 6 feet.

### *Potential Areas for Artificial Recharge*

Potential artificial recharge areas can be identified using the soil data shown on ***Figure 16*** and ***Figure 18***. These maps provide a regional assessment of recharge potential and can be useful for initial screening. Local permeability, geologic structure, and an overall lack of suitable land limit the recharge potential in many areas of the Subbasin, particularly in the eastern portion (USBR, 1948). The map in ***Figure 16*** shows areas that are categorized as somewhat conducive to successful groundwater recharge projects including areas categorized as: Excellent, Good, Moderately Good and Moderately Poor. The map includes the existing recharge ponds for reference, many of which have been recharging groundwater for several decades. The results of the analysis in the Subbasin show that areas surrounding portions of the Lower Kaweah and St. Johns rivers, as well as portions of the Cottonwood Creek on the east side of the Subbasin are "Excellent" areas for agricultural recharge projects. "Good" and "Moderately Good" are present throughout all three GSAs in the Subbasin.

Existing groundwater recharge basins are locally present throughout the Subbasin for purposes of augmenting natural groundwater recharge. The supply to each recharge basin is variable from year to year. The northeast portion of the Subbasin is most suitable for artificial recharge, and the southwest portion is likewise fairly suitable. However, the northwest and southeast portion of the Subbasin are generally unfavorable, although there are some areas of moderate permeability in each (Provost and Pritchard, 2010).

### *Discharge Areas*

East of McKay Point, the Kaweah River is a gaining stream, meaning that it derives some of its flow from groundwater that seeps upward into the riverbed. There are currently no other known groundwater discharges at ground surface (springs, seeps, etc.) originating in the area. Groundwater level maps will be presented in the Current and Historic Groundwater Conditions chapter of the EKGSA Groundwater Sustainability Plan (GSP). Other groundwater discharges include groundwater pumping and subsurface fluxes across basin boundaries. These topics are addressed in ***Section 2.4***.

### *Seeps, Springs, and Wetlands*

Areas indicated as being wetlands in the National Wetland Inventory are illustrated in ***Figure 17***. Some areas of freshwater emergent wetlands are present in the eastern margins of the EKGSA, where small waterways come down from the foothills. Many small freshwater ponds are located within the EKGSA, the largest of which is located northwest of the junction of SR 137 and SR 65.

Areas identified as being potential Groundwater Dependent Ecosystems (GDEs) are presented in ***Figure 19***. The information presented originates from data compiled by the Nature Conservancy, which used vegetative cover and historic maps to develop a statewide map showing the locations of potential GDEs. The locations of these potential GDEs and hydrographs for the Subbasin indicate that the vegetation of these areas are dependent surface water flows, rather than shallow groundwater.

#### 2.2.7.4 Surface water bodies

***Figure 21*** depicts the major surface water features within the Subbasin, such as natural channels, man-made channels (ditches), and lakes.

*Natural Channels*

The Kaweah River rises in the Sierra Nevada at an elevation of over 12,000 feet and drains a watershed area of about 630 square miles above the foothill line. Terminus Reservoir, located about 3-1/2 miles east of the easterly Subbasin boundary, has a tributary drainage area of about 560 square miles, which produces about 95 percent of the total runoff of the watershed. Seepage from the river contributes to recharge within the Subbasin.

Dry Creek and Yokohl Creek are tributaries entering the Kaweah River below Terminus Reservoir and produce significant quantities of water only during flood periods. Runoff in Kaweah River is largely retained within the Subbasin and only in infrequent years of exceptionally large runoff is there escape to Tulare Lake bed. Since completion of Terminus Dam and Reservoir in 1961, seasonal storage of Kaweah River flows has been provided, which assists in regulation to irrigation demand schedules. Other than maintenance of a minimum pool for recreation, no carryover storage is provided in the reservoir.

At McKay Point, the Kaweah River divides into the St. Johns River and Lower Kaweah River branches. Water is diverted from the St. Johns and Lower Kaweah rivers and distributed through a complex system of natural channels and canals owned or operated by numerous agencies and entitlement holders within the subbasin, all of which have established rights to the use of water from the Kaweah River.

The St. Johns River, from McKay Point, flows northwesterly through the northern part of the Subbasin to a point approximately 2 miles east of SR 99 where it changes course and flows in a southwesterly direction and is joined by Cottonwood Creek. Prior to reaching SR 99 at the confluence of Cottonwood Creek, the St. Johns River becomes Cross Creek. River flows at this point are diverted into Lakeside Ditch for irrigation use by Lakeside Irrigation Water District and Lakeside Ditch Company. Corcoran Irrigation District and other Tulare Lake water users divert flows from Cross Creek into Lakelands Canal No. 2. During periods of flooding, river flows continue in the Cross Creek channel into Tulare Lake bed.

A total of about 180,000 acres can receive irrigation water from the St. Johns River through the facilities of 15 entities. It is estimated that on the average about 142,000 AF/WY was diverted from the St. Johns River between 1981 and 1999.

The principal diversion works from the St. Johns River in downstream order are as follows:

- Longs Canal
- Ketchum Ditch

- Tulare Irrigation District Main Intake Canal
- Mathews Ditch
- Uphill Ditch
- Modoc Ditch
- St. Johns Ditch
- Goshen Ditch
- Lakeside Ditch
- Lakelands Canal No. 2

Water is diverted from the Friant-Kern Canal to Tulare Irrigation District (TID) at a large Parshall flume (a flow measurement device) and into the St. Johns River. In addition, there are several riparian users, with the principals being the Fisher & Harrell Ranch in the lower reach of the St. Johns River east of SR 99 and Basile Ranch, west of the highway.

The Lower Kaweah River, below McKay Point, conveys water to a series of distributary channels and canals throughout the central and southerly portions of the Subbasin. Outflow from the Subbasin occurs through Mill Creek to Cross Creek and from Elk Bayou to the Tule River in the southeasterly portion of the Subbasin.

About 126,000 acres can receive irrigation water from the Lower Kaweah River system through the facilities of 10 entities. The principal diversions from the Lower Kaweah River below McKay Point in downstream order are listed below.

- Hamilton Ditch
- Hanna Ranch
- Consolidated Peoples Ditch
- Deep Creek
- Crocker Cut
- TIC Main Intake Canal
- Fleming Ditch
- Packwood Creek
- Oakes Ditch
- Evans Ditch

- Persian and Watson

A turnout on the Friant-Kern Canal provides for releases directly into the Lower Kaweah River. The Ketchum Ditch, which diverts water from the St. Johns River, discharges into the Lower Kaweah channel.

### *Man-made canals and ditches*

Surface water is delivered from the natural rivers and imported sources through a combination of pipes as well as man-made canals and ditches. Within the East Kaweah GSA, all surface water deliveries are conveyed through piped systems with the single exception of the Wutchumna Ditch, which is the principal water course supplying supplies water to the Ivanhoe Irrigation District. The ditch, which flows parallel to and slightly north of the St. Johns River, diverts water from the Kaweah River about 1.5 miles above McKay Point and is operated by the Wutchumna Water Company. The Friant-Kern Canal, managed by the U.S. Bureau of Reclamation (USBR), runs the length of the EKGSA, generally following the eastern border. East of the City of Lindsay it turns south and runs through the interior of the EKGSA, skirting Strathmore and continuing to the south.

Within the remainder of the Kaweah Subbasin, principal man-made conveyance system is the Main Intake Canal of the TID, which delivers comingled Kaweah River and Central Valley Project (CVP) waters for use in the TID. TID also delivers water through the Cameron Creek and Packwood Creeks below the Tagus Evans Ditch. Within the Tulare Irrigation District, the largest entitlement holder within the Kaweah Subbasin, there are a total of approximately 300 miles of unlined canals and ditches, 30 miles of piped conveyances and ¼ mile of lined canals (TID, 2012).

The headgates (diversions) from the Kaweah and St. Johns Rivers discussed in the previous section are conveyed from the headgate to the crops within the entitlement holder service areas by hundreds of miles of ditches (***Figure 21***).

Several ditch companies divert water from the Lower Kaweah River, the principal ones are listed below:

- Consolidated Peoples, Farmers, and Elk Bayou Ditch Companies
- Mathews
- Jennings
- Uphill
- Modoc
- Goshen
- Lakeside Ditch Companies

TID, Fleming, Oakes, Evans, Watson, and Persian Ditch Companies receive water from both the Lower Kaweah and St. Johns Rivers. A schematic diagram of the Kaweah system is presented as **Figure 42**.

#### *2.2.7.5 Source and point of delivery for imported water supplies*

Imported water within the Kaweah Subbasin is delivered from both the CVP and Kings River systems, which have provided approximately 170,900 AFY on average over the historical period. These supplemental sources of water supply have been imported to the Subbasin to lands within the boundaries of the Subbasin from as early the late 1800s from the Kings River, which is currently delivered to the west portion of the Kaweah Subbasin into Lakeside Irrigation Water District. An additional source of supplemental supply to lands located within the Subbasin in the early 1950s was made available from the CVP, which is delivered through the Friant-Kern Canal (Fugro Consultants, 2016).

CVP water is diverted to the TID from three turnouts, which are located where Friant-Kern Canal crosses the Tulare Irrigation Main Canal, the St. Johns River channel, and the Lower Kaweah River channel, respectively. In addition, from time to time CVP water has been released into the Kings River channel and from there into canal systems traversing the western portion of the District towards the Lakeside Irrigation Water District. Imported water is delivered to the East Kaweah GSA through approximately 27 turnouts along the Friant-Kern Canal. The locations of the delivery points from the Friant-Kern Canal turnouts and headgates from the Kaweah, St. Johns and Lower Kaweah Rivers are presented on ***Figure 21***.

# 2.3 Overview of Existing Monitoring Programs §354.8(c)

Groundwater monitoring and management has been underway for many decades in the Kaweah Subbasin. Currently, numerous local agencies are actively involved in the collection, review and evaluation of groundwater data for the purpose of groundwater management and protection. This section describes these monitoring programs. A groundwater management program (GMP) for TID was drafted in 1992 and 2010. The GMP focused on basin management; specifically, groundwater monitoring and sustainability, water quality, land subsidence, and surface water flow. These monitoring programs track the parameters listed below.

- Groundwater Levels
- Groundwater Quality
- Land Subsidence
- Surface Water Flow

## 2.3.1 Existing Groundwater Level Monitoring

The agencies located within the Kaweah Subbasin are involved in several long-term water level measurement program of wells throughout the Subbasin. Twenty-three-member agencies have collaborated and contributed data, which has been compiled and used for this Basin Setting effort. ***Table 4*** provides a summary of the groundwater level monitoring programs being conducted in each jurisdiction throughout the Subbasin. Groundwater level monitoring locations are shown on ***Figure 20***.

Within the Kaweah Subbasin, water level data were compiled using data from DWR's CASGEM program, the three GSAs within the Subbasin and the cooperating agencies are listed below.

- Several cities and communities within the Subbasin
- Kaweah Delta Water Conservation District
- Tulare Irrigation District
- Kings County Water District
- Cal Water (City of Visalia)
- City of Tulare
- Lindmore Irrigation District
- Exeter Irrigation District
- Ivanhoe Irrigation District
- Lindsay-Strathmore Irrigation District
- Stone Corral Irrigation District

In total, more than 1,300 wells have been identified that have water level data. However, only a small percentage of these wells (on the order of 6 percent) have available well construction information (e.g., total depth, casing diameter, screened intervals, lithologic logs, e logs, etc.). Knowledge about the depth ranges of the screened intervals in the wells is important since there are significant water level differences in the various aquifers. The limited amount of information determining whether the wells are screened exclusively in the aquifers above or below the Corcoran Clay confining unit (i.e., the UAS or LAS, respectively) reduces the number of wells that can be used to create reliable water level contour maps. It is known that some wells are screened in the aquifers both above and below the Corcoran Clay.

Two agencies are known to have installed nested piezometers (i.e., monitoring wells with two or more separate, hydraulically-distinct casings that can measure water levels in different aquifers) in the Subbasin. KDWCD installed four such sets of wells on the west side of the Subbasin within Greater Kaweah GSA, each with separate casings that have screened intervals either above or below the Corcoran Clay. These wells show that water level difference above and below the clay can diverge by as much as 150 feet in this location. This illustrates the point that well construction information is needed to use water level monitoring data. Additionally, TID has installed four paired monitoring wells in the central part of the Subbasin within the Mid-Kaweah GSA.

#### 2.3.1.1 Key Wells

A series of "key wells" have been identified to establish a consistent, long-term source of data to monitor the water levels in the various aquifers over the long-term. Approximately 118 wells have been preliminarily selected as key wells for the Subbasin (location shown on ***Figure 20***). The wells were selected based on the following criteria:

1. A long period of record of water level data, generally extending to the present;
2. Adequate information on well construction and aquifer of completion; and
3. Geographically distributed to be representative of all areas throughout the Subbasin to provide data that adequately tracks variations in groundwater levels throughout the area.

The key wells were chosen as a subset of the entire water level monitoring database to adequately represent the Subbasin both laterally and vertically. These key wells were used along with the other monitored wells for the creation of water level contour maps and water level hydrographs. Most of the known wells in the Subbasin are either missing or have limited well construction information. Therefore, the data gap will be addressed with the following the steps below.

1. Further review of acquired well logs;
2. Conducting down-hole video surveys of wells; and
3. Installing additional monitoring wells as funds become available.

While there are limitations associated with using water level data from wells without construction information, we have performed an initial assessment of many of the available wells with a long period of record. This process allowed for the selection of wells that were used for developing an initial understanding of groundwater level variations throughout the Subbasin. It is understood that this snapshot of groundwater conditions is limited based on the unknown completion information about the wells and may change as construction data is obtained in the future. ***Table 4*** provides a summary of groundwater level monitoring by agency.

**Table 4: Existing Groundwater Level Monitoring Programs in the Kaweah Subbasin**

| Agency | GSA Monitored | Frequency of Monitoring | Period of Record of Monitoring | Types of Wells Monitored | Number of Wells (approximate) | Known Completion of Wells Monitored | Number of Dual Completion Wells | Auotomated Monitoring |
|---|---|---|---|---|---|---|---|---|
| Alta Irrigation District | EK, GK | Monthly to bi-annually | 1921 - 2011 | Ag / Domestic | 5 | None | None | Unknown |
| Bureau of Reclamation | All | Monthly to bi-annually | 1924 - 2008 | Unknown | 118 | 15 | Unknown | Unknown |
| Cal Water (City of Visalia) | MK, GK | monthly | 1971 - 2018 | Municipal | 104 | None | Unknown | Unknown |
| City of Lindsay | EK | bi-annually | 2016 - 2017 | Municipal | 3 | None | None | Unknown |
| City of Tulare | MK | Monthly to bi-annually | 1992 - 2018 | Municipal | 30 | 11 | None | Unknown |
| Deer Creek & Tule River Authority | None? | Bi-annually | 2011 - 2018 | Ag / Domestic | 1 | None | None | Unknown |
| Department of Water Resources | All | Bi-annually | 1930 - 2016 | Various | 182 | 7 | Unknown | Unknown |
| Exeter Irrigation District | EK, GK | Bi-annually | 1963 - 2016 | Agricultural | 40 | None | Unknown | Unknown |
| Ivanhoe Irrigation District | EK | Bi-annually | 1961 - 2014 | Agricultural | 36 | Few to none | Unknown | Unknown |
| Kaweah Delta Water Conservation District | GK, MK, (EK?) | Monthly to bi-annually | 1919 - 2018 | Agricultural | 425 | 30 | 4 | Unknown |
| Kings County Water District | GK, MK | Monthly to bi-annually | 1963 - 2017 | Agricultural | 100 | 3 | Unknown | Unknown |
| Kings River Conservation District | GK | Bi-annually | 2011 - 2018 | Agricultural | 6 | 3 | Unknown | Unknown |
| Lakeside Irrigation Water District | GK, MK | Bi-annually | 2012 - 2017 | Agricultural | 33 | 2 | Unknown | Unknown |
| Lewis Creek Water District | EK | Bi-annually | 1971 - 2016 | Agricultural | 3 | 1 | Unknown | Unknown |
| Lindmore Irrigation District | EK | Bi-annually | 1945 - 2016 | Agricultural | 104 | 1 | Unknown | Unknown |
| Lindsay-Strathmore Irrigation District | EK | Bi-annually | 1955 - 2016 | Agricultural | 7 | None | Unknown | Unknown |
| Porterville Irrigation District | EK | Rarely | 1960 - 1978 | Agricultural | 1 | None | Unknown | Unknown |
| Stone Corral Irrigation District | EK | Bi-annually | 2006 - 2016 | Agricultural | 6 | 1 | Unknown | Unknown |
| Tulare Irrigation District | MK | Bi-annually | 1945 - 2018 | Agricultural | 128 | 5 | 4 | Unknown |
| Tule River Lower Irrigation District | EK | Bi-annually | 1953 - 2010 | Agricultural | 10 | 1 | Unknown | Unknown |

Since the early 1900's, TID has been observing declining groundwater levels in wells they monitor. TID began managing, supplying, and delivering water to growers within their district in 1889. Recorded monitoring of groundwater levels began in the 1940's and demonstrate seasonal fluctuations as well as periods of drought. During a seven-year drought from 1987 to 1995, groundwater levels dropped as much as 50 to 120 feet. Water level recovery was accomplished in 2000, five years after the drought ended. As of 2010, TID measures groundwater levels from approximately 100 wells each spring and fall and plans on installing dedicated monitoring wells to track groundwater levels in unconfined and confined aquifers. Likewise, KDWCD also measures the depths to groundwater in wells in the central KDWCD portion of the Subbasin.

## 2.3.2 Existing Groundwater Quality Monitoring

Groundwater quality monitoring and reporting is currently conducted through numerous public agencies. The following sections provide a summary of databases, programs, and agencies that actively collect groundwater data and information on where the data is stored and how it was used in this Basin Setting. A summary of these programs is provided in ***Section 2.2.2.3*** as ***Table 5***.

### 2.3.2.1 Local Agency Groundwater Monitoring

Many existing, local water level monitoring programs were expanded by local water districts partly in response to Assembly Bill (AB)-3030 groundwater management planning in the mid-1990's, and subsequent Senate Bill (SB) 1938 compliant GMPs in the mid-2000s. Some district GMPs, such as those prepared by KDWCD and TID, are very detailed in providing subsurface hydrogeology, land use, and historical groundwater extents and fluctuations. Most plans provide a list of monitoring wells, associated well construction, a monitoring program, sampling plan, and an accompanying CASGEM monitoring plan.

In general, water levels and water quality in the Subbasin have been monitored annually, or twice a year where possible, and data reported biennially. Where viable, these monitoring networks will be incorporated into the defined monitoring networks for this Basin Setting and leveraged with monitoring network requirement for the Sustainable Groundwater Management Act (SGMA).

Water quality is monitored in many wells throughout the Subbasin. TID has a water quality sampling program which collects groundwater samples on a yearly basis from five private agricultural wells. However, this data is confidential to the owners and TID. Other agencies such as the Regional Water Quality Control Board, state and federal Environmental Protection Agency, USGS, SWRCB, City of Tulare, and various neighboring irrigation and water districts monitor groundwater quality in the region. TID collects and reviews data released from these agencies. The goal of the 2010 GMP was to maintain good water quality, specifically for agricultural irrigation, and to consolidate groundwater quality data into a single database (Provost & Pritchard, 2010).

TID water quality is generally excellent for both surface and groundwater supplies. Runoff from the Kaweah River and San Joaquin River is of very good to excellent quality and provides surface water supply and natural recharge for groundwater supply. The City of Tulare 2008 Consumer Confidence Report validates excellent water quality with parameters including: Total dissolved solids ranging from 86-220 ppm; specific conductance ranging from 130-340 uS/cm; and arsenic ranging from 2.1 -10 ppb.

#### 2.3.2.2 California Drinking Water Information System Database (SDWIS)

All public drinking water systems (a system that has 15 or more service connections or regularly serves 25 individuals daily at least 60 days out of the year) are regulated by the State Water Resources Control Board (SWRCB) – Division of Drinking Water (DDW) and must demonstrate compliance with State and Federal drinking water standards through a rigorous monitoring and reporting program. Required monitoring for each well within each water system is uploaded to the DDW's database and subsequently available for the public through the State Drinking Water Information System (SDWIS). In addition to providing compliance monitoring data for each regulated water system, other information is available including monitoring frequency, basic facility descriptions, lead and copper sampling, violations and enforcement actions, and consumer confidence reports.

All drinking water systems are required to collect samples, that must include a comprehensive suite of constituents known as the "Title 22" list on a given frequency depending on the constituent and regional groundwater vulnerability. The following is a summary of the minimum sampling frequency for a public water supply well:

> General minerals, metals and organics (Synthetic Organic Chemicals and Volatile Organic Compounds) sampling is required every 3 years. If any organics are detected, sampling frequency must be increased to quarterly.
>
> Nitrate is required annually. If nitrate is ≥5 ppm, then sampling is required quarterly.

If arsenic is ≥5 ppb, sampling should be increased to quarterly.

Radiological constituents (i.e., gross alpha and uranium) are sampled periodically, depending on historical results: once every 3 years (when initial monitoring is ≥ ½ the MCL); once every 6 years (when initial monitoring is ≤ ½ the MCL), or once every 9 years (when initial monitoring is non-detect).

Public water systems provide the most abundant source of data since the testing requirements are at frequent intervals and data collection began in 1974. All sample results are easily available from the SDWIS database. When using these data to characterize groundwater quality for the Basin Setting, only raw water quality data are considered. It is important to understand that this characterization is not intended to represent water supplied by purveyors because they may provide wellhead treatment to remove or reduce contamination.

#### *2.3.2.1 Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS)*

CV-SALTS is a collaborative stakeholder driven and managed program to develop sustainable salinity and nitrate management planning for the Central Valley. The program objective is intended to facilitate the salt-reduction and nitrate-reduction implementation strategies recommended in the Salt and Nitrate Management Plan (SNMP) developed in 2017. The strategies are designed to address both legacy and ongoing salt and nitrate accumulation issues in surface and groundwater. The overarching management goals and priorities of the control efforts are: ensure safe drinking water supply; achieve balanced salt and nitrate loading; and implement long-term, managed restoration of impaired water bodies. The program is phased with the primary focus of early actions on nitrate impacts to groundwater drinking water supplies and established specific implementation activities. The Kaweah Subbasin is a Priority 1 basin for nitrate management. Consequently, the nitrate control program schedule is set to begin in 2019.

CV-SALTS will enact a nitrate control program as part of the SNMP which requires forming a management zone as a regulatory option to comply with the requirements of the nitrate program. The management zones will consist of a defined management area to manage nitrates, ensure safe drinking water, and meet applicable water quality objectives. Local management plans will be created to implement the long-term goals of the nitrate control program. As programs are implemented, there will be criteria established within each of the management areas to meet the objectives of their individual programs. While Irrigated Lands Regulatory Program (ILRP) allows for compliance of their regulatory program through coalitions that cover a broad, non-contiguous area based on similar land use, SGMA and CV-SALTS will both require management areas/zones to be contiguous areas regardless of land use.

Both the ILRP and CV-SALTS programs involve permittees and local stakeholders working towards water management objectives set forth by the State. In this regard, collaborative efforts should be made to maximize the resources of each program and provide a more integrated approach to developing local solutions for groundwater management.

#### *2.3.2.1 Department of Pesticide Regulation*

The Department of Pesticide Regulations (DPR) Ground Water Protection Program collects and evaluates samples for pesticides to (a) determine if there is a risk of groundwater contamination; (b) identify areas sensitive to pesticide contamination; and (c) develop mitigation measures to prevent that movement. DPR obtains groundwater sampling data from other public agencies, such as SDWIS, USGS, and Groundwater Ambient Monitoring and Assessment Program (GAMA), and through its own sampling program. Sampling locations and constituents are determined by pesticides used in a region, and from review of pesticide detections reported by other agencies.

Because of their sample selection methodology, DPR typically only collects one sample per well. Repeat sampling is not performed if there are positive detections. Rather, their focus is on validating contamination through their research and sampling program. These data are reported annually along with the actions taken by DPR and the SWRCB to protect groundwater from contamination by agricultural pesticides. Annual reports are reviewed, and contaminant detections are identified in the groundwater quality characterization. In the Kaweah Subbasin, only legacy pesticides (dibromochloropropane (DBCP) and 1,2,3-TCP) are detected in the public water system wells. No pesticides currently in use were identified.

#### 2.3.2.1 GeoTracker and EnviroStor Databases

The SWRCB oversees the GeoTracker database. This database systems allows the SWRCB to house data related to sites that impact or have the potential to impact groundwater quality. Records available on GeoTracker include cleanup sites for Leaking Underground Storage Tank (LUST) sites, Department of Defense sites, and Cleanup Program sites. Other records for various unregulated projects and permitted facilities includes Irrigated Lands, Oil and Gas production, operating Permitted Underground Storage Tanks (USTs), and Land Disposal sites.

GeoTracker is a public and secure portal that can retrieve records and view data sets from multiple SWRCB programs and other agencies through a Google maps GIS interface. This database is useful for the public and can help other regulatory agencies monitor the progress of cases. It also provides a web application tool for secure reporting of lab data, field measurement data, documents, and reports.

The DTSC oversees the EnviroStor database. This data management system tracks cleanup, permitting, enforcement, and investigation efforts at hazardous waste facilities and sites with known contamination or sites where further investigation is warranted by the DTSC. This database only provides reports, inspection activities and enforcement actions completed on or after 2009. Like the GeoTracker database, this is useful for the public and other regulatory agencies to monitor progress of ongoing cases. The primary difference between the two databases is that EnviroStor only houses records for cases that DTSC is the lead regulatory agency, whereas the GeoTracker database houses records to cases from different regulatory agencies, such as at State and local levels. For the Basin Setting, both databases were searched to identify and report on any contamination sites that may have impacts to groundwater quality.

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

The GAMA Program was created by the SWRCB in 2000. It was later expanded by the Groundwater Quality Monitoring Act of 2001 (AB 599). AB 599 required the State Water Board to integrate existing monitoring programs and design new program elements as necessary to monitor and assess groundwater quality. The GAMA Program is based on collaboration among agencies including the State and Regional Water Boards, CDWR, DPR, USGS, and USGS National Water

Information System (NWIS), and Lawrence Livermore National Laboratory (LLNL). In addition to these state and federal agencies, local water agencies and well owners also participate in this program. The main goals of GAMA are to: improve statewide comprehensive groundwater monitoring; and increase the availability of groundwater quality and contamination information to the public. Monitoring projects in this program are described below.

**GAMA Priority Basin Project**: This project provides a comprehensive groundwater quality assessment to help identify and understand the risks to groundwater. The project started assessing public system wells (deep groundwater resources) in 2002 and shifted focus to shallow aquifer assessments in 2012. Since 2002, the USGS, the project's technical lead, has performed baseline and trend assessments and sampled over 2,900 public and domestic water supply wells that represent 95% of the groundwater resources in California.

**GAMA Domestic Well Project**: This project was conducted between 2002 and 2011 as part of the GAMA Program and sampled over 1,100 private wells in six California counties (Yuba, El Dorado, Tehama, Tulare, San Diego, and Monterey) for commonly detected chemicals. The voluntary participants received analytical test results and fact sheets, and the water quality data was included in the GeoTracker GAMA online database. The Domestic Well Project is currently on hiatus. Data from this project included nitrate concentrations and stable isotopic analysis for 29 domestic wells within the Kaweah Subbasin; these data have been incorporated into the Basin Setting.

**GAMA Technical Hydrogeologic and Data Support**: These efforts have expanded to include several Divisions and Programs at both the SWRCB and the Regional Water Quality Control Boards, other state agencies, and non-governmental organizations. GAMA staff are providing support for the following activities:

- Hydrogeologic analyses to evaluate drinking water sources
- Development of geothermal well and water well standards
- Technical support for state actions involving groundwater
- Hydrogeologic analysis for desalination projects
- Technical assistance for developing standard operating procedures for grant projects
- High-level Geographic Information System (GIS) projects
- Source water protection planning
- Antidegradation in groundwater planning

Although these GAMA activities were provided at a statewide level, Kaweah-specific groundwater information was used for this Basin Setting.

#### *2.3.2.1 Irrigated Lands Regulatory Program (ILRP)*

The ILRP was initiated in 2003 with a focus of protecting surface waters. Groundwater regulations were added in 2012. ILRP was implemented to protect receiving water bodies from impairment associated with agricultural runoff, tile drain flows, and storm water runoff from irrigated fields. Elements of this program that overlap with SGMA requirements are the monitoring programs focused on identifying groundwater impairment associated with irrigated agriculture.

Currently, the program has focused on sampling surface waters. Although groundwater regulations were implemented in 2012, data collection is not scheduled to begin until Fall 2018. Throughout the Central Valley, ILRP Coalitions and other participating water agencies are coordinating their efforts as the Central Valley Groundwater Monitoring Collaborative. The Kaweah Basin Water Quality Association (an ILRP Coalition) represents a large area of irrigated agriculture within the Kaweah Subbasin.

The Coalition's Comprehensive Groundwater Quality Management Plan identified areas where groundwater is vulnerable to degradation that is caused by agricultural irrigation practices. The Groundwater Trend Monitoring Work Plan, Phase II outlines the Coalition's compliance strategies which include continuing to educate their members on management practices that are protective of water quality; reporting on management practices that are actively used; and an annual sampling program to track nitrate level trends in groundwater.

The focus of ILRP's groundwater regulation is to track nitrate level trends and determine if current management practices are protecting groundwater from further degradation. The SWRCB's objective is to eventually restore nitrate concentrations to levels below the drinking water standard of 10 parts per million (mg/L, as nitrogen). Data collected and reported as a part of ILRP are provided to the SWRCB and are available in the GAMA database for download and use. Groundwater sampling will collect samples annually from shallow domestic wells (<600-ft deep). As the program progresses, the number of wells sampled may increase. Initially, the Regional Board recommended 0-3 wells per township, but the Coalitions were not able to gain landowner authorization for this number of wells. In compromise, the Regional Board approved sampling wells with landowner agreements and have suggested the Coalitions work along with as part of the SGMA process to develop a more comprehensive monitoring network.

Once established, the annual monitoring under this program will include static water level; temperature; pH; electrical conductivity; dissolved oxygen; and nitrate. Once every five years, a limited group of general minerals will also be collected.

#### *2.3.2.2 United States Geological Survey*

The USGS California Water Science Center (CWSC), provides California water data services by conducting data collection, processing, analysis, reporting, and archiving. Data types include surface water, groundwater, spring sites, and atmospheric sites, with data often available in real-time via satellite telemetry. The NWIS groundwater database consists of wide range of data on wells, springs, test holes, tunnels, drains, and excavations. Available groundwater-specific information includes groundwater level data, well depth, aquifer parameters, and more. USGS studies and reports that were specifically used for the Basin Setting and groundwater characterization include:

> Groundwater Quality in the Shallow Aquifers of the Tulare, Kaweah, and Tule Groundwater Basins and Adjacent Highlands areas, Southern San Joaquin Valley, California. USGS and SWRCB. Fact Sheet, January 2017.

Groundwater Quality in the Southeast San Joaquin Valley, California. USGS and SWRCB. June 2012.

Status and Understanding of Groundwater Quality in the Two Southern San Joaquin Valley Study Units, 2005-2006: California GAMA Priority. Scientific Investigations Report 2011-5218. 2012.

Groundwater Quality Data in the Southeast San Joaquin Valley, 2005-2006: Results from the California GAMA Program. Data Series 351. USGS and SWRCB. 2008.

Environmental Setting of the San Joaquin-Tulare Basins, California. Water Resources Investigations Report 97-4205. 1998.

#### *2.3.2.3 Groundwater Quality Monitoring Programs Summary*

***Table 5*** provides summary information relating to the programs described above. Each program summary includes monitoring parameters and frequency, program objectives, and items of note relating to the Kaweah Subbasin Basin Setting.

**Table 5: Existing Groundwater Quality Monitoring Programs**

| Programs or Data Portals | Parameters | Frequency | Program Objectives | Notes |
|---|---|---|---|---|
| AB-3030 and SB-1938 | • Water levels are typically monitored annually.<br>• Ag Suitability analysis (limited suite of general minerals) monitoring frequency between annual to once every 3 years. | Semiannual to Annual | | Monitoring is recommended as a part of groundwater management planning. Data availability is inconsistent between Districts. |
| California SDWIS | Database for all public water system wells and historical sample results. Data available includes all Title 22 regulated constituents. | • Title 22 General Minerals and Metals every 3 years.<br>• Nitrate as N annually, if ≥ 5 ppm, sampled quarterly<br>• VOCs and SOCs sampled every 3 years.<br>Uranium sampling depends on historical results but varies between 1 sample every 3 (when ≥ 10 pCi/L), 6 (when < 10 pCi/L) or 9 (when no historical detection) years. | Demonstrate compliance with Drinking Water Standards through monitoring and reporting water quality data. | An abundant source of data because of the required testing frequency and list of parameters. |
| CV-SALTS | Sampling parameters required through Waste Discharge Requirements (WDR): typically include monthly sodium, chloride, electrical conductivity, nitrogen species (N, $NO_2$, $NO_3$, $NH_3$), pH and other constituents of concern identified in the Report of Waste Discharge. A limited suite of general minerals is required quarterly from the source and annually from the wastewater. | Most constituents sampled monthly, quarterly general minerals from source water and annual general minerals from waste discharge. Kaweah is a Priority 1 Basin, meaning that management strategies will be initiated in 2019. | To monitor degradation potential from wastewaters discharged to land application areas. | Water quality monitoring required by CV-SALTS is consistent with the Regional Water Boards existing requirements through their WDR process. It is unlikely that additional monitoring will be required. The initial phases of the program are strongly focused on identifying sources of salinity and reducing salinity and nitrogen species in wastewaters discharged to land. By 2030, the program is expected to implement projects to aid with salt and nitrate management in the Central Valley. |

| Programs or Data Portals | Parameters | Frequency | Program Objectives | Notes |
|---|---|---|---|---|
| Department of Pesticide Regulation | Pesticides | • Annual | DPR samples groundwater to determine (1) whether pesticides with the potential to pollute groundwater are present, (2) the extent and source of pesticide contamination, and (3) the effectiveness of regulatory mitigation measures. | Data available at: https://www.cdpr.ca.gov/docs/emon/grndwtr/index.htm |
| GAMA (Collaboration with SWQCB, RWQCB, DWR, DPR, NWIS, LLNL) | • Constituents sampled vary by the Program Objectives.<br>• Typically, USGS is the technical lead in conducting the studies and reporting data. | • The Priority Basin Project performed baseline and trend assessments and sampled over 2,900 public and domestic wells that represent 95% of the groundwater resources in CA.<br>• The Domestic Well Project sampled over 180 domestic wells in Tulare County: 29 Wells were within the Kaweah Subbasin. | • Improve statewide comprehensive groundwater monitoring.<br>• Increase the availability of groundwater quality and contamination information to the public. | USGS reports prepared for the Priority Basin Project were used to identify constituents of concern in the basin and confirm water quality trends prepared for groundwater characterization. |

| Programs or Data Portals | Parameters | Frequency | Program Objectives | Notes |
|---|---|---|---|---|
| Geotracker and Envirostor Databases | Many contaminants of concern, organic and inorganic. | Depends on program. Monthly, Semiannually, Annually, etc. | Records database for cleanup program sites, permitted waste dischargers | Records available on GeoTracker include:<br>• Cleanup for Leaking Underground Storage Tank (LUST) sites<br>• Department of Defense Sites<br>• Cleanup Program Sites<br>Other records for various unregulated projects and permitted facilities includes:<br>• Irrigated Lands<br>• Oil and Gas production<br>• Operating Permitted Underground Storage Tanks (USTs)<br>• Land Disposal Sites |
| ILRP | • Annually: static water level, temperature, pH, electrical conductivity, nitrate as nitrogen, and dissolved oxygen.<br>• Once every five years: general minerals collection | Annual and Every 5 years | Monitor impacts of agricultural and fertilizer applications on first encountered groundwater | Sampling will begin in Fall 2018 with a limited number of wells sampled. The program will be expanded and may incorporate a shared sampling program with SGMA. |
| USGS California Water Science Center | Conducted multiple groundwater quality studies of the Kaweah Subbasin | Reports and fact sheet publications range from 1998 through 2017. | Special studies related to groundwater quality that provide comprehensive studies to characterize the basin. | Studies used for Basin Setting:<br>• Groundwater Quality in the Shallow Aquifer (2017)<br>• Status and Understanding (2012)<br>• Groundwater Quality in SESJ (2012)<br>• Groundwater Quality Data in the SESJ (2008)<br>• Environmental Setting (1998) |

### 2.3.3 Existing Land Subsidence Monitoring

Past, recent, and potential future monitoring of land subsidence in the Kaweah Subbasin are briefly summarized below in ***Table 6***. Details and results of recent and historical subsidence monitoring are discussed in ***Section 2.8***. of this document.

**Table 6: Summary of Land Subsidence Monitoring in the Kaweah Subbasin**

| Category | Monitoring Entity(s) | Period of Record |
|---|---|---|
| Historical Monitoring | • National Geodetic Survey of benchmarks (repeat level surveys) | • 1926-1970 |
| Recent Monitoring | • National Geodetic Survey of benchmarks (repeat level surveys and installation and measurement of Deer Creek extensometer [8.5 miles south of subbasin])<br>• Local benchmark monitoring network (Kaweah Subbasin collaborators)<br>• CGPS data from UNAVCO and CVSRN stations: P056, P566, CRCN, LEMA, and RAPT.<br>• NASA including both InSAR and UAVSAR programs | • NGS – 1970 to Present<br>• Tie into NGS and CGPS benchmarks<br>• CGPS – ~2006 to Present (depending on station)<br>• NASA – 2006 to 2017 (except from 2011-2014) |
| Future Data Availability | • National Geodetic Survey of benchmarks (repeat level surveys)<br>• Deer Creek Extensometer to the South<br>• CGPS data from UNAVCO and CVSRN stations: P056, P566, CRCN, LEMA, and RAPT<br>• NASA including both InSAR and UAVSAR programs, potentially new extensometers in the Kaweah Subbasin | • 2018 through 2020<br>• 2018 to present<br>• CGPS – continuous daily readings<br>• Ongoing |

Subsidence monitoring includes both land elevation surveying as well as groundwater level monitoring to consider the effects that the change in groundwater levels have on the rate and change of land subsidence over time. Land elevation survey monitoring includes National Geodetic Survey (NGS) benchmark repeat level surveys, remote sensing by Interferometric Synthetic Aperture Radar (InSAR), and in-situ compaction monitoring by an extensometer south of the Subbasin. Groundwater level monitoring, as briefly discussed in ***Section 2.3.1***, includes collecting data from representative monitoring wells throughout the Subbasin in all three aquifer systems: UAS, LAS, and SAS. In areas where the Corcoran Clay is present, preliminary monitoring results suggest that groundwater level decline in the lower aquifer system is contributing to increased land subsidence. The relationship between groundwater levels and land subsidence are discussed in ***Section 2.8.***

#### 2.3.3.1 Future Data Availability

The effectiveness of future subsidence monitoring will require continued support by National Aeronautics and Space Administration/Jet Propulsion Laboratory (NASA/JPL), USGS, and Scripps Orbit and Permanent Array Center (SOPAC)/UNAVCO/California Department of Transportation (CalTrans) for InSAR and Global Positioning System (GPS) data processing and reporting. According to USGS, the European Space Agency's (ESA's) Sentinel satellites collect InSAR data at approximately weekly intervals, and data are available for download and use as necessary. These data require processing which has been performed by JPL at the request of DWR. Similarly, GPS data has been made available by UNAVCO, SOPAC/California Real Time Network (CRTN), and CalTrans. Although there are currently no extensometers within the Kaweah Subbasin, USGS has replaced extensometer 22S-27E-30D2 (Deer Creek south of Porterville and in the Tule Subbasin), and will provide data to interested parties (personal communication, USGS).

## 2.3.4 Existing Stream Flow Monitoring

At the upper reaches of the Kaweah River watershed, the U.S. Army Corps of Engineers measures and records inflow to Lake Kaweah. The Kaweah and St. Johns Rivers Association (KSJRA) measure data on a daily basis for the Kaweah River, Dry Creek, and Yokohl Creek. These data are summarized in annual reports and published by KSJRA.

The records of the stream groups impacting the facilities and stockholders of the ditch companies that they manage were acquired. Although data gaps exist, these may represent relatively small quantities of contributory flows. The records of the USGS are, for the most part, supplemental to the records of the Association and local agencies. The information that is published by the USGS, however, does fill some of the data gaps that exist in the information related to the local stream groups. ***Figure 20*** shows the locations of stream flow gauges monitored within the Subbasin.

Supplies made available from the Kings River impact the north, northwestern, and westerly areas of the Subbasin. Information as to the gross deliveries made available to these areas is available from the Kings River Water Association, as published in annual reports that contains the information necessary to document the gross delivery information. Specific information related to deliveries into areas in and adjacent to the Subbasin on the north, northwest, and westerly boundaries are available from records of the Corcoran Irrigation Company, the Corcoran Irrigation District, the Kings County Water District, the Lakeside Irrigation Water District, and the Melga Water District.

TID's main sources of surface water come from the San Joaquin and the Kaweah rivers. Surface water is provided from the San Joaquin River through a USBR contract which delivers water to TID from the Friant Dam via the Friant-Kern Canal. Kaweah River water is delivered to TID from KSJRA. TID can also obtain surface water from several small surface streams which pass through TID's service area.

Surface water quality is recorded by Friant Water Authority (FWA), USBR, and KSJRA to monitor long-term hydrology, water availability, and water quality changes. TID monitors published data from these agencies to ensure surface water quality does not affect groundwater quality.

# 2.4 Groundwater Elevation and Flow Conditions §354.16

This section describes available information to document current and historical groundwater elevation data, flow directions, lateral and vertical gradients, and regional pumping patterns in the Subbasin.

## 2.4.1 Current and Historical Groundwater Trends

Current and historical groundwater level trends are provided below. This section provides an overview of groundwater flow conditions by describing groundwater elevation maps and key well hydrographs.

### 2.4.1.1 Elevation and flow directions

Water level measurements and groundwater elevation data from over 1,300 wells within and adjacent to the Subbasin were used to generate water level contour maps and water level hydrographs for individual water wells throughout the Subbasin. Water level contour maps for spring seasons of years 2015 through 2017 and earlier key years - 1981, 1999, and 2011 - during the representative base period are provided as ***Figure 23*** through ***Figure 28***. Water level contour maps for the fall season of the four most recent years - 2014 through 2017 - are provided as ***Figure 29*** through ***Figure 32***.

Groundwater flow direction was calculated for the spring of every year from 1981 to 2017 for the entire Kaweah subbasin. Groundwater flow directions were generally similar for the majority of the Subbasin during the subsequent years of 2013 through 2017. Flow directions are further quantified through numerical groundwater model development. The approach and methods used for numerical groundwater model development and described in the technical memorandum included as ***Appendix A***.

Groundwater within the Kaweah Subbasin flows from the Sierra Nevada towards the southwest. The presence of Corcoran Clay in the western portion of the Subbasin and lack of well construction information available for the measured water wells has resulted in meager determination of water level conditions in the confined aquifers of the region.

Inflow of groundwater into the Kaweah Subbasin occurs both from the north (Kings Subbasin), from mountain front recharge along the eastern edge of the basin, and in some years, from the south in response to pumping. Outflow of groundwater from the Kaweah Subbasin occurs to the west generally into the Tulare Lake Subbasin, but also occurs to the south into the Tule Lake Subbasin. Large areas of lowered groundwater levels were present in most years of the current drought in the west and southwestern portion of the Kaweah Subbasin, near the cities of Hanford and Corcoran. Groundwater levels are directly affected by the distribution of groundwater pumping in the basin which is further addressed in **Section 2.4.1.3**.

### 2.4.1.2 Lateral and vertical gradients

Due to the inherent variability in aquifer properties and the complexity of the gradients, estimates of subsurface flow within the Kaweah Subbasin are considered approximations.

### *Lateral Gradients*

The rates of groundwater flow are a function of the slope of the groundwater surface and the permeability of the water-bearing materials. In the Subbasin, groundwater flow rates are on the order of a several feet per day. However, in materials of low permeability, such rates may be reduced to as little as a few feet per year. The gradients of the groundwater in this Subbasin vary but are typically between 10 vertical feet per mile (0.002 feet per foot) to 16 feet per mile (0.003 feet per foot) outside of significant groundwater pumping depressions.

Groundwater flow in underlying confined aquifers Lower Aquifer System (LAS), is analogous to the flow of water in a pressure conduit and moves in response to pressure differentials created by pumping extractions from the confined aquifer or by a buildup in the water table in the unconfined groundwater body supplying the aquifer (Fugro West, 2007). Along the western portion of the Subbasin, where dynamic pumping depressions are present, gradients steepen, and groundwater flow rates increase by an order of magnitude. In these areas, groundwater levels can show vertical differences of 100 feet within less than a mile due to localized pumping stresses.

### *Vertical Gradients*

Many wells in the Kaweah Subbasin west of SR 99 penetrate aquifers above and below the Corcoran Clay and provide significant vertical leakage and hydraulic communication, which affects the pattern of groundwater movement and rates of regional recharge and discharge (Malcolm Pirnie, 2001).

The water level analysis included an attempt to correlate 1,300 wells included in the monitoring network to well construction details. It was determined that very few well construction details were available for the monitored wells, making it difficult to determine whether measured water levels were representative of upper or lower aquifer systems. As early as 1972, "…it was found that many of the wells measured drew from more than one aquifer system and water level measurements therein reflected a composite of the water levels" (B-E, 1972).

Even without certainty about the specific completion of most wells, it is believed that wells located east of the Corcoran Clay extent reflect water level conditions representative of the SAS, while wells located within the area of the Corcoran Clay are, for the most part, perforated in the confined aquifer system below the Corcoran Clay (Fugro West, 2007). Furthermore, the heterogeneity of aquifer properties in the Subbasin and known presence of many interbedded aquitards in the west part of the Subbasin complicate the separation of water level data representative of the confined versus unconfined aquifer systems. According to Bertoldi (1991), the many fine-grained lenses of overlapping, discontinuous clay beds within the Valley have a combined effect that controls vertical flow to a greater degree than the Corcoran Clay.

There are currently eight paired (shallow and deep) monitoring wells within or in close proximity to the Kaweah Subbasin. Four are monitored by KDWCD and four are monitored by TID. The locations of these wells are shown on ***Figure 33*** and ***Figure 34***. Each monitoring location has two paired (shallow and deep) monitoring wells; one screened above the Corcoran Clay and the other screened below the Corcoran Clay. This enables water level monitoring agencies to measure vertical gradients distinctly without inaccuracies caused by hydraulic communication in wells screened in multiple aquifer zones. Several of these wells were installed recently; thus, only a limited amount of data is available. The KDWCD wells were installed between 2005 and 2006 and have consistent water level data to present, but the TID wells were installed in 2016 and only have one distinct water level measurement each.

As discussed previously, not all wells screened below the Corcoran Clay exhibit truly confined groundwater conditions. However, it is widely accepted that "the degree of confinement in the continental deposits generally increases in a westerly direction and becomes greater as depth to the aquifer increases" (B-E, 1972). This generality is corroborated by the paired hydrographs presented on ***Figure 33*** and ***Figure 34***. The TID wells, which are relatively close to the eastern extent of the Corcoran Clay, show relatively small vertical gradients. Water level differences in the shallow and deep wells vary between approximately 35 feet and 7 feet. The KDWCD wells, which are further west (three of the four wells are outside the basin), show much greater vertical gradients than the TID wells. Water elevations differences in the KDWCD nested wells average from about 50 feet to 200 feet. The two wells furthest to the southwest exhibit higher vertical gradients on average than the two northernmost wells, which are closer to the eastern extent of the Corcoran Clay.

#### 2.4.1.3 Regional patterns

***Figure 23*** through ***Figure 32*** illustrate the groundwater elevation contour maps of the following periods: Spring 1981, Spring 1999, Spring 2011, Spring 2015 through 2017, and Fall 2014 through 2017. Review of the contour maps indicate that the principal direction of groundwater flow is to the southwest in the unconfined groundwater of the Kaweah River alluvial fan and continental deposits. Subsurface inflow occurs in the unconfined aquifer system above the Corcoran Clay, and from the Tule River system to the south. Outflow of confined groundwater occurs to the west in the confined aquifer system below the Corcoran Clay (Fugro West, 2007).

The influence of water extraction from the Kings River occurs to lands generally west of the Kaweah Subbasin and can be seen by contours that reflect replenishment from various tributaries in that area. The contours also show pumping depressions, which have been created in southwest corner of the Kaweah Subbasin north of Corcoran and west of Visalia.

The groundwater contours presented in this report were mapped as a single homogenous unit. Ideally, the contours would have been mapped by the principal aquifer units (SAS, LAS, and UAS); however, this wasn't feasible given the lack of well completion information for most wells in the Subbasin.

Wells located east of the Corcoran Clay boundary are all considered to be representative of the SAS. The SAS is generally unconfined to semi-confined aquifer system in the eastern half of the basin. All wells within the extent of the Corocan Clay could be representative of either the LAS or the UAS, depending on their depth and screened intervals. To contour the LAS and UAS separately, water level data would be needed in numerous wells of known completion that are dispersed throughout the basin. There are a small number of wells with known completion in the Corcoran Clay extent, but not enough to create reliable contour maps. Additionally, water level data from any wells with multiple screen zones that span both aquifer systems are not eligible for contour mapping. Until more well completion information for wells in the Corcoran Clay extent is acquired, it will remain infeasible to create contours for the separate principal aquifer units in the Kaweah Subbasin.

Water level hydrographs were selected from several of the wells with a long-term period of record. These are the key wells referenced throughout the Basin Setting. The selected hydrographs, presented as ***Figure 35***, provide a baseline of groundwater conditions throughout the Subbasin. The hydrographs selected demonstrate appropriate geographic distribution within the Subbasin and generally provide excellent records of both Spring and Fall water level conditions and long-term trends in water levels, some of which extend back to the 1940s.

#### 2.4.1.4 Water Year Type

Discussion of water level trends must include context with regard to hydrologic variations in historical wet-dry cycles, referred to by DWR as "water year type". Water levels vary in response to the cyclical nature of precipitation, surface water flows, and diversions from the Kaweah River system. ***Figure 36*** illustrates the changing hydrologic conditions within the Subbasin for rainfall recorded in Visalia from water year 1878 through 2017. Average rainfall in the basin is 10.1 inches per year. The bottom half of the chart shows the annual precipitation. The upper portion of the chart shows the climactic variability by stacking subsequent years, such that upward trending portions (blue areas) represent wet periods and downward trending portions (yellow areas) represent drought periods.

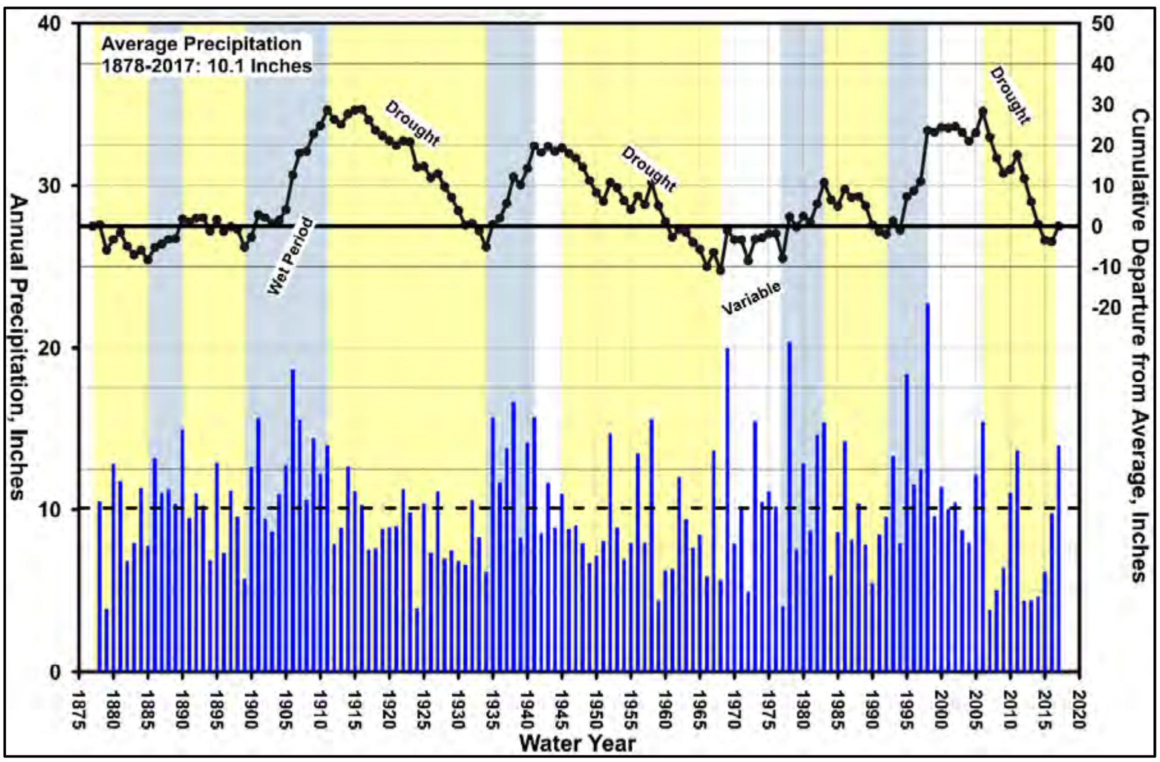



**Figure 36: Cumulative Departure from Mean Precipitation – Visalia, California**

**Table 7: Historic Hydrologic Conditions (Water Year Types)**

| Period (Water Years) | Hydrologic Condition | Duration (No. of Years) | Precipitation Deviation (Inches) | Deviation Rate (Inches/year) |
|---|---|---|---|---|
| 1878 to 1885 | Drought | 8 | - 6 | - 0.7 |
| 1886 to 1890 | Wet | 5 | 10 | 2.0 |
| 1891 to 1899 | Drought | 9 | 7 | - 0.8 |
| 1900 to 1911 | Wet | 12 | 34 | 2.8 |
| 1912 to 1934 | Drought | 23 | - 34 | - 1.5 |
| 1935 to 1941 | Wet | 7 | 25 | 3.6 |
| 1942 to 1945 | Variable | 4 | 4 | - 0.1 |
| 1946 to 1968 | Drought | 23 | - 30 | - 1.3 |
| 1969 to 1977 | Variable | 9 | 3 | 0.3 |
| 1978 to 1983 | Wet | 5 | 19 | 3.1 |
| 1984 to 1993 | Drought | 8 | -10 | -1.0 |
| 1994 to 1998 | Wet | 5 | 22 | 4.5 |
| 1999 to 2006 | Variable | 8 | 5 | 0.6 |
| 2007 to 2016 | Drought | 10 | 32 | - 3.2 |

Precipitation data from Visalia California NOAA gauge.
Precipitation Deviation is the cumulative departure from average precipitation for the period
Deviation Rate provides a relative sense of the severity of the wet or dry periods.

***Figure 36*** and ***Table 7*** emphasize the highly variable climactic cycles common to the southern San Joaquin Valley consisting of prolonged periods of modest drought punctuated by short, intense wet periods. Notable aspects of this graph include:

- A 23-year drought including water years 1946 through 1968 received below-average precipitation, when an average of 1.5 inches below normal fell each year.
- A wet period from 1978 through 1983 received an annual average precipitation of 3.1 inches above normal each year.
- An eight-year drought period between 1984 and 1993 received an average of 1 inch below normal precipitation each year.
- A wet period from 1994 through 1998 which was recorded as wetter than the previous wet period. Annual rainfall averaged a full 4.5 inches above normal each year.

The most recent drought changed the long-term pattern of prolonged, but somewhat modest, droughts. During the period of ten years - water years 2007 to 2016 - the area received a total of 30 inches less rainfall than the long-term average, which is equal to an annual rainfall of 3 inches less than normal each year. During this decade, the Subbasin received 30 percent less rainfall than the long-term average; the most severe drought on record.

The water level hydrographs presented on ***Figure 35*** are color coded to show the varying climactic cycles (water year type) as above, where wet periods are shaded blue and dry periods (drought) are shaded yellow. White areas on the hydrographs represent variable conditions (alternating wet and dry years).

Throughout the Subbasin, water levels generally follow characteristic patterns following climactic cycles and availability of surface water to offset groundwater pumping. During wet periods water levels either remained relatively unchanged or rose moderately. During the wet periods between 1978 and 1983, and again during 1994 to 1998, water levels rose between 20 and 50 feet in most parts of the Subbasin.

During the eight-year drought of the late 1980s through mid-1990s, typical water levels declined by as much as 80 feet in the central and eastern portions of the basin. During this period, water levels in the southwestern portion of the basin declined more than 100 feet, within TID and near the Corcoran Irrigation District well field.

The most recent severe drought, which started in water year 2007, included an unprecedented multi-year period during between 2013 and 2015 when CVP deliveries were unavailable in the Subbasin. The combination of lack of precipitation and unavailability of CVP water reduced recharge and required local water demands to be met from groundwater pumping, collectively leading to lowered water levels throughout the basin. While in some areas, including north of Visalia, water level declines were limited to approximately 40 to 50 feet, other areas experienced water level declines of as much as 100 to 150 feet.

In many parts of the Subbasin, but particularly in the southern portion of EKGSA, west of the Cities of Lindsay and Strathmore and within MKGSA south of the city of Tulare, water levels in 2015 and 2016 declined to the lowest levels on record. Cumulatively, water levels declined since the record high levels of the (early 1940s or) early 1980s, by 50 to 150 feet. Notably, in one well south of the City of Tulare, the water level declined by more than 200 feet between the early 1980s through 2015. See ***Appendix B***.

Although the Subbasin experienced widespread water level declines, water levels in a few wells in the eastern portion of the basin along the Kaweah River experienced only limited declines. These wells are presumed to be both relatively shallow and to benefit from almost continual recharge from the flow of the Kaweah and St. Johns rivers. Since the 1960s, one well has experienced only 10 feet of decline with very limited seasonal fluctuations.

# 2.5 Kaweah Subbasin Water Budget §354.18

This section is provided for compliance with GSP Regulations § 354.18 which states that "Each Plan shall include a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored. Water budget information shall be reported in tabular and graphical form."

The GSP Regulations § 354.18(b) detail the required components for a water budget which are illustrated below in ***Figure 37.*** The Kaweah Subbasin water budget includes each of these required components and more.

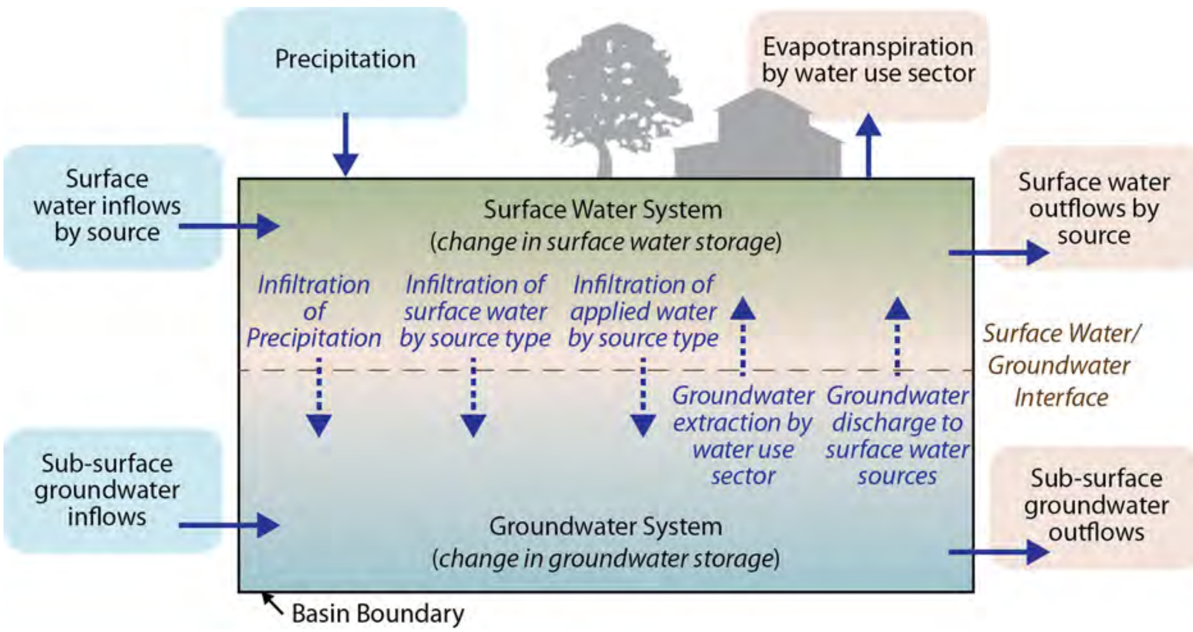



**Figure 37: Water Budget Components (source, DWR)**

The Kaweah Subbasin water budgets were created to quantify the inflows and outflows through the Subbasin based on a long period of hydrology, water supply availability, water demand, and land use information. The selected periods also include sufficient variability in these components to quantify and evaluate the aquifers' responses to these changes.

The historical and current water budgets for the Kaweah Subbasin are presented in ***Section 2.5.1*** below. The projected water budget is provided in ***Section 2.5.2***.

## 2.5.1 Historical and Current Water Budget

Water budget information was compiled for the three GSAs within the Subbasin to evaluate the historic availability and reliability of past surface water supply deliveries and the aquifer response to water supply and demand trends relative to water year type (or hydrologic condition). All readily available data were collected, and water budget compiled in accordance with a coordination agreement between the three GSAs, "to ensure that the three plans are developed and implemented utilizing the same data and methodologies, and that the elements of the Plans necessary to achieve the sustainability goal for the basin are based upon consistent interpretations of the basin setting." (§354.4 (a))

Within the Kaweah Subbasin, the historical water budget period (base period) was selected to be between water years 1981 and 2017. The current water budget period was between water years 1997 and 2017. The projected water budget extends to 2070 (***Figure 38***).

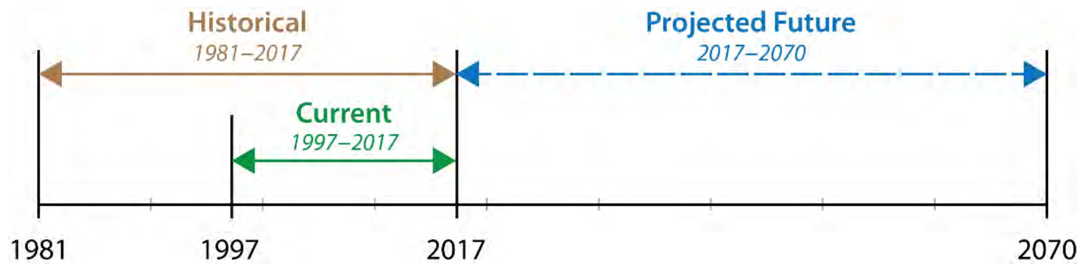



**Figure 38: Historical, Current, and Projected Future Water Budget Periods for Kaweah Subbasin**

### *2.5.1.1 Historical Water Budget Period Selection*

The GSP Regulations describe the historical water budget as "A quantitative assessment of the historical water budget, starting with the most recently available information and extending back a minimum of 10 years, or as is sufficient to calibrate and reduce the uncertainty of the tools and methods used to estimate and project future water budget information and future aquifer response to proposed sustainable groundwater management practices over the planning and implementation horizon." The historical period selected also includes, "the most recently available information."

The selected representative period of the historical water budget for the Kaweah Subbasin, begins in water year 1981 and extends to the most-recent water year of 2017. The 37-year period selected for the historical water budget, includes two wet-dry hydrologic cycles; recent changes in water supply availability including an unprecedented lack of availability of imported water for several recent years; changes to water demand associated with new cropping patterns and associated land use.

The historical water budget (also referred to as the hydrologic base period) was used to define a specific time period over which elements of recharge and discharge to groundwater basin may be compared to the long-term average. This period allows the identification of long-term trends in groundwater basin supply and demand as well as water level trends, changes of groundwater in storage (both seasonal and long term), estimates of the annual components of inflow and outflow to the zone of saturation, safe yield estimates, and groundwater modeling.

The following summarizes the main considerations for base period selection:

> "The base period should be representative of long-term hydrologic conditions, encompassing dry, wet, and average years of precipitation. It must be contained within the historical record and should include recent cultural conditions to assist in determining projected basin operations. To minimize the amount of water in transit in the zone of aeration, the beginning and end of the base period should be preceded by comparatively similar rainfall quantities" (CDWR, 1962).

Determination of an appropriate period included consideration of data availability, surface water reservoir management, and the historical development of water supplies imported from outside the Subbasin.

Furthermore, the GSP Regulations require that the historical water budget provide a "quantitative evaluation of the availability or reliability of historical surface water supply deliveries" and are to start "with the most recently available information … extending back a minimum of 10 years (§ 354.18 (c)(2)."

This base periods selection also helps inform the projected water budget which is to "utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology (§ 354.18 (c)(3)." Notably, the selection of both the historical water budget, described in this section, and current water budget, which is described in the subsequent section, are based on this requirement and both closely approximate long-term hydrologic conditions based up both precipitation and streamflow patterns, which are significant components of the overall supply. A strong correlation exists between Kaweah River flow and precipitation for the historical and current periods.

Precipitation records for 15 stations in and adjacent to the Subbasin were reviewed, six of which are shown on ***Table 8***. These six stations were selected as best representing the historical record of precipitation within and surrounding the Subbasin, based both on geographic distribution and period of record.

**Table 8: Precipitation Stations Used for Base Period Analysis and Selection**

| Station Name | Elevation (feet, MSL) | Township/ Range/ Section | Start of Period* | Average for Period of Record (inches) | Average Precipitation 1945 to 2017 (inches) | Average Precipitation 1981 to 2017 (inches) | Average Precipitation 1999 to 2017 (inches) |
|---|---|---|---|---|---|---|---|
| Hanford 1 S | 242 | T18S/R21E-S31 | 1932 | 7.98 | 7.94 | 8.25 | 7.60 |
| Corcoran Irrigation District | 200 | T21S/R22E-S15 | 1946 | 6.91 | 6.85 | 6.98 | 6.31 |
| Visalia | 325 | T18S/R25E-S30 | 1878 | 10.14 | 10.21 | 10.08 | 8.90 |
| Lindsay | 420 | T20S/R27E-S9 | 1932 | 11.65 | 11.53 | 11.67 | 10.68 |
| Lemon Cove | 513 | T18S/R27E-S3 | 1932 | 13.77 | 13.68 | 14.07 | 13.00 |
| Three Rivers Edison PH 1 | 1,140 | T17S/R29E-S8 | 1949 | 21.69 | 21.69 | 22.47 | 18.46 |
| **Average** | | | | **12.02** | **11.98** | **12.25** | **10.83** |

*Note: Period of Record extends through water year 2017

Generally, total precipitation is lower along the western portion of the Subbasin (Hanford and Corcoran Irrigation District stations), where at this lower elevation an average of less than 8 inches of precipitation per year are recorded. Along the eastern portion of Subbasin, at a relatively higher elevation (as represented by Lindsay and Lemon Cove), an average of 12 to 14 inches of precipitation is recorded. Outside of the Subbasin to the east, at a much higher elevation, greater precipitation occurs (as represented by the Three Rivers Edison gauge located in the foothills of the Sierra Nevada).

The key precipitation station for the Kaweah Subbasin is the Visalia station, because

it has a long period of record between 1878 and current,

is centrally located within the Subbasin, and

approximates the average rainfall in the Subbasin.

A graph presenting the variability of rainfall recorded at the Visalia station is presented as ***Figure 39***. Average rainfall at this station is 10.1 inches per year. The bottom half of the chart shows the annual precipitation. The upper portion of the chart shows the climactic variability by stacking subsequent years, such that upward trending portions (blue areas) represent wet periods and downward trending portions (yellow areas) represent drought periods.

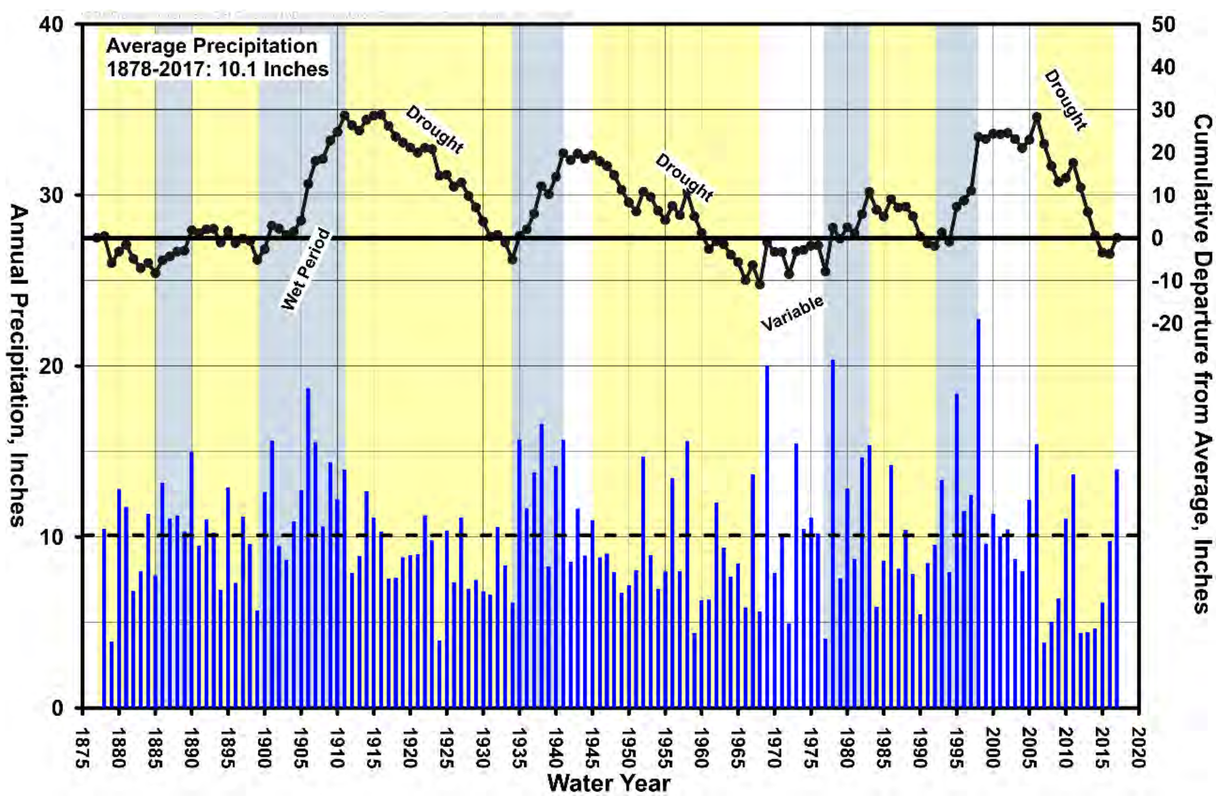



**Figure 39: Cumulative Departure from Average Annual Precipitation, Visalia**

Kaweah River flow records for the period of 1904 through 1989 were obtained from KDWCD staff and calculated as the summation of flow data from gauges at Kaweah River at Three Rivers and South Fork of Three Rivers. Flow records for the period of 1990 through 2017 were obtained from the U.S. Army Corps of Engineers' records of inflow to Lake Kaweah. Flow records at the Dry Creek gauging station and at the Kaweah River below McKay Point were similarly reviewed and are shown on ***Table 9***. As presented, Kaweah River flow as measured at Three Rivers (plus the South Fork of Three Rivers) during the 37 year (inclusive) historical period of 1981 to 2017 closely approximates the long-term average during the period of record (within 3 percent).

**Table 9: Surface Water Flow Stations Used for Base Period Analysis and Selection**

| Station Name | Elev. (feet, MSL) | Period of Record (Water Year) | Average for Period of Record (AFY) | Average for Historical Period 1981-2017 (AFY) | Range for Period of Record (AFY) |
|---|---|---|---|---|---|
| Kaweah River at Three Rivers + South Fork of Three Rivers (Full Natural Flow) | 833 | 1904-Present | 426,600 | 438,700 | 90,100 - 1,359,000 |
| Dry Creek Near Lemon Cove | 589 | 1962-Present | 17,200 | 17,100 | 173 - 93,800 |
| Kaweah River plus St. Johns River Below McKay Point | 455 | 1962-Present | 396,300 | 382,100 | 43,800 - 1,331,300 |

As presented on ***Figure 40***, variations in Kaweah River flow exhibit somewhat similar trends to climactic variations exhibited in the precipitation data.

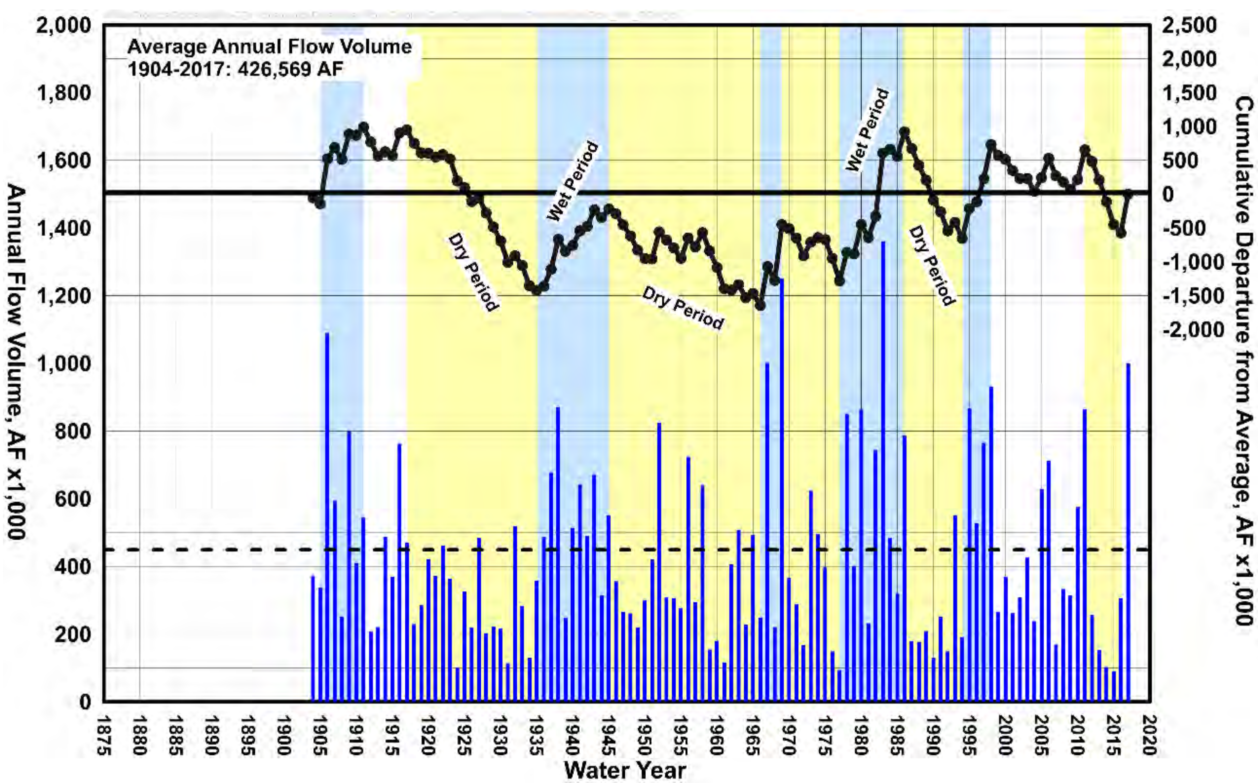



**Figure 40: Cumulative Departure from Average Annual Flow, Kaweah River**

An analysis of the statistical relationship between the composite precipitation and river flow data is presented as ***Figure 41***. The average composite precipitation and Kaweah River flow for the base period approximated the long-term average (within several percent).

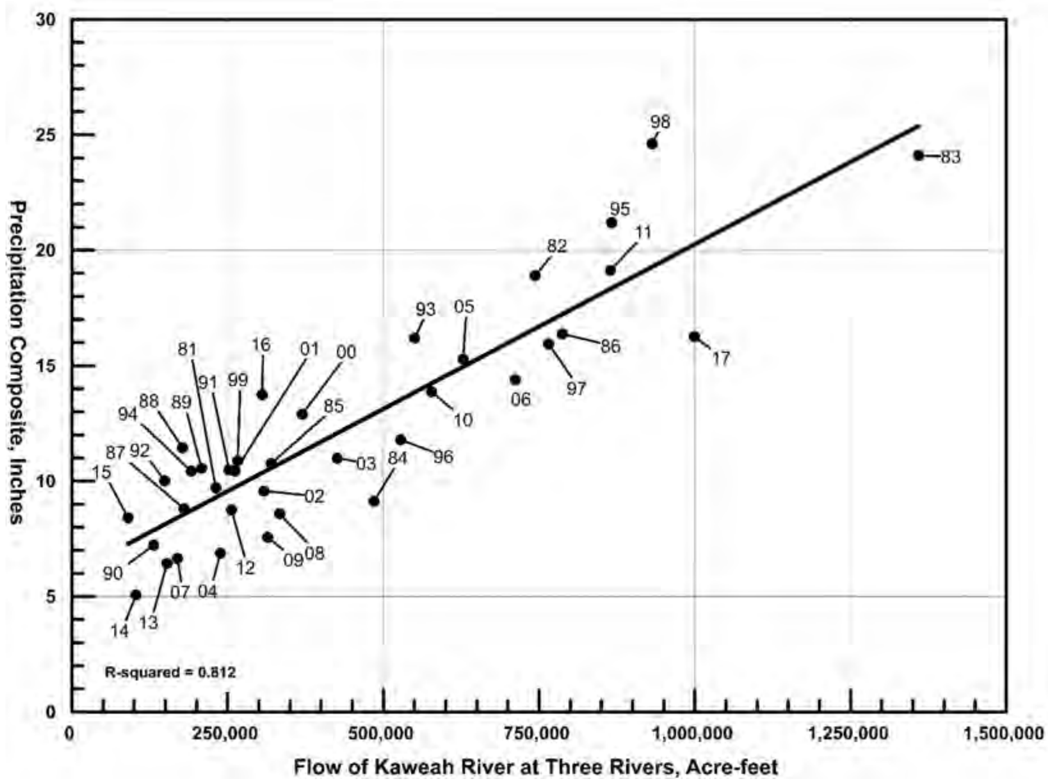



**Figure 41: Kaweah River Runoff Versus Mean Precipitation**

A review of the cumulative departure graphs for the precipitation station and Kaweah River flow identify candidate years for beginning the base period to include 1981, 1986, 1993 and 1999. The most recent water year (2017) was identified as a suitable year for ending the hydrologic base period. Importantly, 2017 is representative of current cultural conditions in the Subbasin relative to changes in land and water use. Precipitation totals in each year between 2012 and 2016 were below average, which would minimize significant amounts of water in transit through the unsaturated zone. A review of the differences in cumulative departure for these years is summarized in the following ***Table 10***.

**Table 10: Historical Base Period Analysis (Relative to 1945 - 2017)**

| Station Number | Station Name | Difference in Cumulative Departure Between Base Period Years (inches) | | | |
|---|---|---|---|---|---|
| | | 1981-2017 | 1986-2017 | 1993-2017 | 1999-2017 |
| 43747 | Hanford | 0.38 | 0.38 | 0.57 | -0.34 |
| 42012 | Corcoran | 0.06 | 0.06 | 0.38 | -0.53 |
| 49367 | Visalia | -0.22 | -0.22 | 0.01 | -1.31 |
| 44957 | Lindsay | -0.14 | -0.14 | 0.31 | -0.85 |
| 44890 | Lemon Cove | 0.10 | 0.10 | 0.75 | -0.68 |
| 48917 | Three Rivers Edison | -0.70 | -0.70 | -0.52 | -3.23 |
| Average Cumulative Departure: | | 0.27 | -0.09 | 0.25 | -1.16 |

Based on comparison of precipitation averages, the most suitable candidates for a representative hydrologic base period are water years 1981 to 2017 and 1993 to 2017. Considering the availability of data, especially land use and California Irrigation Management Information System (CIMIS) data, the longer period of 1981 to 2017 is preferred. The relationship of surface water flow to precipitation was also considered in the selection of the base period by plotting flow at Three Rivers versus precipitation for various periods. For the most part, a strong correlation was obtained, showing a strong linear relationship, regardless of the period selected.

Based on the above, one appropriate base period was selected for use as the historical water budget: water years 1981 through 2017 (37 years inclusive). The average precipitation during both periods is within approximately 1 percent of each other and the long-term period. The position of the base period relative to historical wet-dry cycles is appropriate. If a smooth curve is fitted to the precipitation patterns, the base period includes two full cycles of wet and dry conditions. The base period ends in 2017, which incorporates recent cultural conditions, including an unprecedented lack of imported surface water availability between 2013 and 2015. The precipitation is similar for years leading into the beginning of the base period.

Compared to the long period of record from the Visalia station (130 years) average precipitation for the base period varies by less than 2 percent. Similarly, average flow for the base period varies by less than 3 percent compared to the long period of record of flow data from the Kaweah River at Three Rivers gauge (104 years), and by about 2 percent from the period of 1945 to 2017.

#### *2.5.1.2 Current Water Budget*

The GSP regulations state "current water budget information shall quantify current inflows and outflows for the basin using the most recent hydrology, water supply, water demand, and land use information."

The period 1997 to 2017 was selected for the current water budget in the Kaweah Subbasin. This period was selected because it represents current water supply conditions in the subbasin including surface water supply availability under average, extremely dry and extremely wet conditions. This period also represents the current crop and municipal water demands which have remained consistent throughout this period. The average annual overdraft during this period is 77,600 AFY. This overdraft value will be used as the starting point for the development of projects and management actions to bring the subbasin into balance and achieve Sustainable Yield by 2040. Groundwater modeling accounting for projected future supplies and demands, i.e., the projected water budget, will be used to evaluate the benefits of our planned projects and management actions at arresting the overdraft in the subbasin.

#### *2.5.1.3 Summary of Water Budget Components*

This section provides a description of each of the water budget components quantified as part of the historic budget evaluation.

*Surface Water*

Water from both locally derived and imported surface water sources are distributed in the natural and constructed channels in the Subbasin. The natural channels are the streams, rivers and creeks that flow from the catchments in the Sierra Nevada Mountains and foothill regions along the eastern side of the Subbasin. The constructed channels (ditches) are a system of hydraulically inter-connected canals and channels that deliver surface water from the natural channels to the entitlement holders, and ultimately to individual land units. Some natural channels receive diversions of imported surface water, comingled with native (local) sources, and divert it via ditches to entitlement holders.

The Kaweah River flows westward into the subbasin from the Sierra Nevada Mountains, beginning at an elevation of over 12,000 feet and drains a watershed area of about 630 square miles above the foothill line. Terminus Reservoir, located in the foothills of the Sierra Nevada, has a tributary drainage area of about 560 square miles, which produces about 95 percent of the total runoff of the watershed (Fugro Consultants, 2016).

During the period of record from water years 1901 through 2017, the average annual flow within the Kaweah River at Three Rivers (plus the South Fork of Three Rivers) was 426,600 AF/WY, ranging from a minimum of 90,100 AF/WY in 2015 to a maximum of 1,360,000 AF/WY in 1983. The average annual flow for the historical (1981 to 2017) period of 435,500 AF/WY was 104 percent of the long-term average since 1901.

The principal local source of water, the Kaweah River, is divided equally at McKay Point between the Lower Kaweah and St. Johns rivers, which occurs each year until the flow has diminished in the late summer months (Fugro West, 2007). Thereafter, the entire entitlement flow, regardless of the amount, is diverted into the Lower Kaweah River. A schematic diagram of the Kaweah River system is presented as ***Figure 42***. As presented on ***Table 11*** an average of 336,710 AF/WY of AF/WY Kaweah River water (through the entire Kaweah River system) was diverted through headgates for agricultural purposes.

**Table 11: Surface Water in Kaweah Subbasin (AF/WY)**

| Water Year | CVP Water | Kings Water | Total Imported | Kaweah Water Diversions (Local Sources) | Total of Surface Water (Headgate Diversions) |
|---|---|---|---|---|---|
| 1981 | 153,960 | 11,117 | 165,077 | 192,814 | 357,891 |
| 1982 | 324,038 | 3,217 | 327,255 | 594,413 | 921,668 |
| 1983 | 141,947 | 0 | 141,947 | 964,811 | 1,106,758 |
| 1984 | 224,960 | 42,685 | 267,645 | 446,364 | 714,009 |
| 1985 | 170,262 | 3,205 | 173,467 | 255,935 | 429,402 |
| 1986 | 273,525 | 18,068 | 291,593 | 568,236 | 859,829 |
| 1987 | 114,407 | 2,430 | 116,837 | 133,945 | 250,782 |
| 1988 | 141,865 | 1,996 | 143,861 | 140,009 | 283,870 |
| 1989 | 133,034 | 1,000 | 134,034 | 157,589 | 291,623 |
| 1990 | 69,224 | 0 | 69,224 | 96,294 | 165,518 |
| 1991 | 108,907 | 0 | 108,907 | 201,631 | 310,538 |
| 1992 | 108,785 | 1,226 | 110,011 | 105,851 | 215,862 |
| 1993 | 250,502 | 7,093 | 257,595 | 454,179 | 711,774 |
| 1994 | 106,309 | 1,392 | 107,701 | 136,046 | 243,747 |
| 1995 | 212,823 | 13,383 | 226,206 | 632,021 | 858,227 |
| 1996 | 255,721 | 33,753 | 289,474 | 401,832 | 691,306 |
| 1997 | 199,376 | 20,733 | 220,109 | 562,767 | 782,876 |
| 1998 | 169,292 | 13,919 | 183,211 | 698,203 | 881,414 |
| 1999 | 233,760 | 20,106 | 253,866 | 239,440 | 493,306 |
| 2000 | 224,684 | 2,575 | 227,259 | 297,865 | 525,124 |
| 2001 | 109,268 | 6,926 | 116,195 | 208,051 | 324,246 |
| 2002 | 133,824 | 2,341 | 136,165 | 230,074 | 366,238 |
| 2003 | 183,657 | 11,732 | 195,389 | 320,161 | 515,550 |
| 2004 | 123,718 | 5,562 | 129,279 | 175,451 | 304,730 |
| 2005 | 328,005 | 8,948 | 336,952 | 454,252 | 791,204 |
| 2006 | 239,266 | 15,723 | 254,990 | 531,308 | 786,298 |
| 2007 | 80,972 | 9,037 | 90,009 | 120,844 | 210,853 |
| 2008 | 107,908 | 0 | 107,908 | 264,142 | 372,050 |
| 2009 | 143,689 | 2,624 | 146,313 | 241,048 | 387,361 |
| 2010 | 240,826 | 3,223 | 244,050 | 440,838 | 684,887 |
| 2011 | 235,335 | 2,041 | 237,376 | 666,658 | 904,034 |
| 2012 | 98,102 | 2,688 | 100,789 | 198,608 | 299,397 |
| 2013 | 52,515 | 0 | 52,515 | 105,476 | 157,991 |
| 2014 | 24,169 | 0 | 24,169 | 72,652 | 96,821 |
| 2015 | 13,304 | 0 | 13,304 | 59,694 | 72,998 |
| 2016 | 97,606 | 0 | 97,606 | 231,650 | 329,256 |
| 2017 | 211,386 | 11,645 | 223,031 | 857,122 | 1,080,153 |
| **Maximum** | **328,005** | **42,685** | **336,952** | **964,811** | **1,106,758** |
| **Minimum** | **13,304** | **0** | **13,304** | **59,694** | **72,998** |
| **Average** | **163,268** | **7,578** | **170,846** | **336,710** | **507,556** |

During the historical period, an average of 170,846 AF/WY of water is imported annually, of which a majority (some 163,300 AF/WY) is imported from the CVP system. The remainder of the imported water, is directed into the Subbasin through the Kings River.

On average, for the historical base period, a total of 507,556 AF/WY of Kaweah River and imported water from both the CVP Friant Division system and Kings River system was diverted for irrigation within the Kaweah Subbasin. These local and imported water supplies are comingled during conveyance (**Table 11)**. The trend of deliveries of imported water is generally downward in recent years, with the exception of the wet years (e.g. 2005, 2011 and 2017). The gross irrigation demand is supplied by both surface and groundwater sources; of this an average of 685,400 AF/WY was extracted from the groundwater reservoir to satisfy crop demands (discussed later in this report). Conveyance losses related to the delivery of surface water is significant, and the estimated annual quantity of such a "loss" is discussed later in this section.

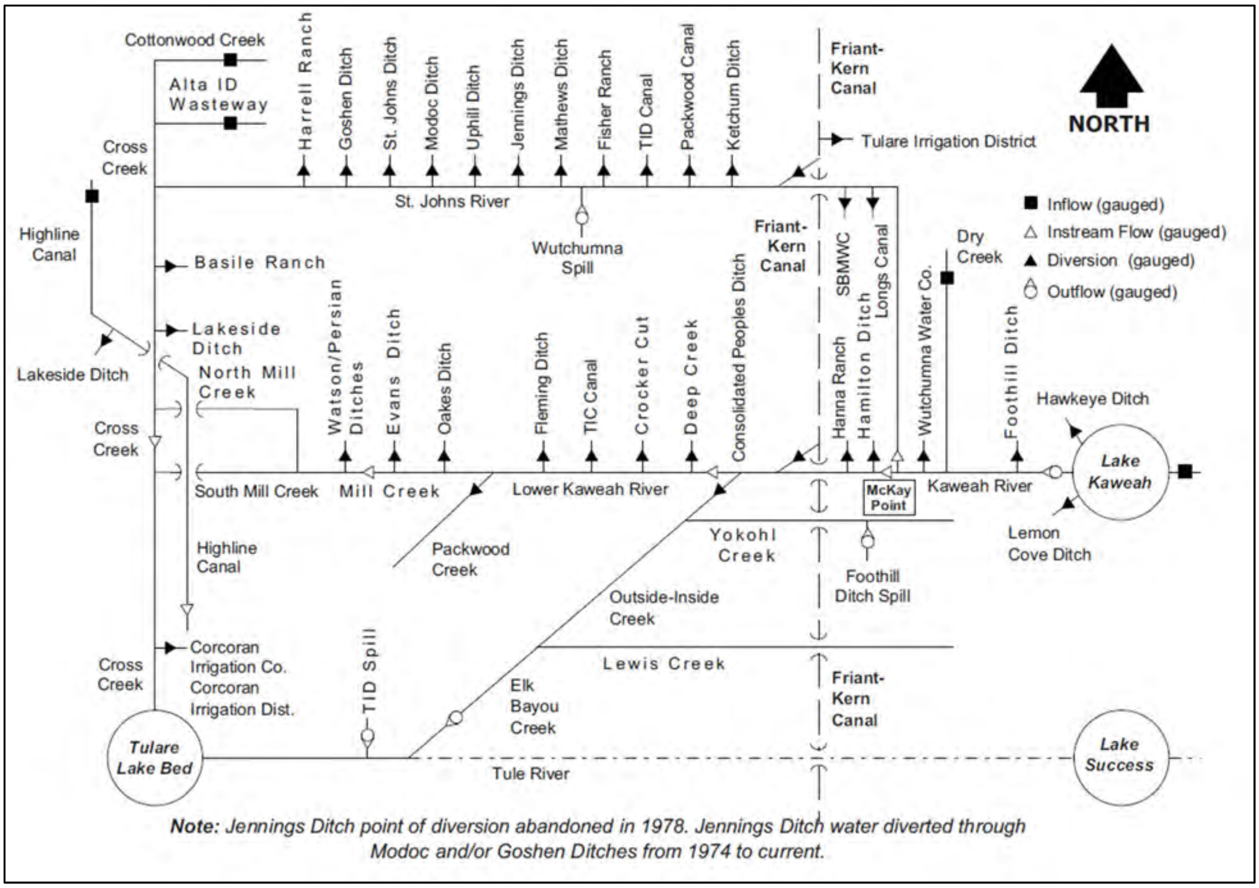



**Figure 42: Schematic Diagram of Kaweah River System**

Supplemental sources of water supply have been imported to the Subbasin for decades. Deliveries to lands within the boundaries of the Subbasin started in the late 1800s and were made available from the Kings River. An additional source of supplemental supply to lands located within the Subbasin in the early 1950s was made available from the CVP, with both long-term and short-term contract supplies. With the termination of short-term contracting procedures, supplemental supplies, in addition to the long-term CVP supplies, have been made available through temporary contracts.

The delivery of ample surface water by local and imported sources for agricultural irrigation is a key to avoiding several of the undesirable results in the Kaweah Subbasin. Within the historical base period, in the late 1980s, surplus water was available in the system beyond the needs of contractors.

During the 1987 to 1992 drought, when imported water was available and no significant contract limitations were in place, no significant water level declines were noted.

Beginning in the 2010s, surplus water began to be partially allocated to the San Joaquin River Restoration Program. In the recent 2012 to 2015 drought, CVP contract deliveries were severely limited, such that in 2012 only 50% Class 1 water was delivered. In 2013 only 62% was delivered. In both 2014 and 2015, none of the contracted water was delivered. During these dry years, TID did not receive Class 2 contract water. Meanwhile, groundwater levels reached record lows.

**Surface Water Crop Delivery**

Crop water demands constitute the largest portion of groundwater and surface water demand in the Subbasin. Therefore, the complete understanding of how much of these two sources of water are applied to crops is central to the groundwater budget calculations. This section summarizes the methodology used to determine the volumes of surface water delivered to crops, which will in turn be used to estimate the additional crop water demand, which is provided through un-metered groundwater pumpage.

Surface water in the Kaweah Subbasin is used primarily to satisfy the irrigated agricultural demands, which constitutes the majority of water use. The irrigation of the agricultural lands is satisfied by a combination of diverted surface water and pumped groundwater. The calculation of the volume of surface water delivered to fields to meet agricultural crop demands is described using the following equation adapted from previous methods (Fugro West, 2007; Fugro Consultants, 2016):

$$SW_C = HG_{DIV} + R_{DIV} + RW - TotDS_P - RB_{DIV} - S$$

Where:

$SW_C$ = Surface water delivered to crops
$HG_{DIV}$ = Headgate diversions
$R_{DIV}$ = Riparian diversions
$RW$ = Recycled water
$TotDS_P$ = Total ditch system percolation
$RB_{DIV}$ = Recharge basin diversions
$S$ = Spills

The annual quantities of water associated with each of the components in the equation above are presented in subsequent sections with focus on "loss" of the water from the surface water system and subsequent inflow into the aquifer. The average volumes of water for each of the components of the above equation during the historical (base) period are:

$$SW_C = HG_{DIV} + R_{DIV} + RW - TotDS_P - RB_{DIV} - S$$

$$SW_C \cong 507{,}600 + 4{,}900 + 8{,}800 - 117{,}000 - 51{,}200 - 16{,}800$$

$$SW_C \cong 335{,}100$$

Based on the above calculation, the total volume of surface water delivered to crops averaged 335,100 AF/WY. This volume of surface water was used to offset groundwater pumpage for irrigated agriculture, the remainder of which was satisfied by groundwater pumpage. While this calculation was used for most areas of the Subbasin, in two limited cases the quantity of water delivered crops were reported directly and not calculated using this method.

These summaries of surface water flow components described in this section are provided to calculate the total amount of surface water delivered to crops. Several of these components will also be described further in a later section with regard to estimates of inflows to the groundwater system.

In general terms, the components of riparian diversions, recycled water applied to crops, total ditch system percolation, recharge basin diversions, and spills are presented in the following paragraphs.

*Headgate Diversions ($HG_{DIV}$)*

Headgate diversions for each appropriator are an integral component into the water budget for the calculation of groundwater pumpage. Headgate diversions occur as surface water diverted from the natural channels into constructed canals and channels for delivery to entitlement holders for farm delivery. Data for these diversions were compiled from Kaweah and St. Johns Rivers Association records. Annual volumes of headgate diversions throughout the Subbasin are presented in ***Table 11***. Basin-wide, an average of 507,600 AF/WY was diverted through headgates from the surface water flow (from comingled local and imported sources). Such headgate diversions, in turn, experience seepage (ditch) losses, can be redistributed to artificial recharge basins, or in years of very high surface water flow, leave the District as "spill" or outflow.

*Riparian Diversions ($R_{DIV}$)*

Annual quantities of surface water diverted by riparian users for agricultural use from the Lower Kaweah and St. Johns river systems were quantified in prior reports (Fugro West, 2007; Fugro Consultants, 2016). These riparian diversions were quantified in concert with the calculation of reach losses (natural channel percolation). The riparian diversions (located within GKGSA) are presented in ***Table 12***. On average, 4,922 AF/WY of surface water were diverted for riparian use.

**Table 12: Riparian Diversions (AF/WY)**

| Water Year | Riparian Diversions |
|---|---|
| 1981 | **3,046** |
| 1982 | **9,971** |
| 1983 | **12,054** |
| 1984 | **8,729** |
| 1985 | **4,899** |
| 1986 | **9,789** |
| 1987 | **2,677** |
| 1988 | **1,388** |
| 1989 | **2,032** |
| 1990 | **696** |
| 1991 | **1,843** |
| 1992 | **815** |
| 1993 | **5,640** |
| 1994 | **2,271** |
| 1995 | **9,031** |
| 1996 | **7,466** |
| 1997 | **7,553** |
| 1998 | **11,040** |
| 1999 | **5,806** |
| 2000 | **5,522** |
| 2001 | **2,162** |
| 2002 | **2,332** |
| 2003 | **3,260** |
| 2004 | **2,038** |
| 2005 | **8,418** |
| 2006 | **9,796** |
| 2007 | **2,381** |
| 2008 | **3,423** |
| 2009 | **2,080** |
| 2010 | **5,854** |
| 2011 | **10,346** |
| 2012 | **3,543** |
| 2013 | **1,521** |
| 2014 | **618** |
| 2015 | **242** |
| 2016 | **1,994** |
| 2017 | **9,825** |
| **Maximum** | **12,054** |
| **Minimum** | **242** |
| **Average** | **4,922** |

*Recycled Water (RW)*

The cities of Visalia and Tulare both produce recycled water for crop irrigation as a portion of the effluent from their wastewater treatment plants (WWTPs). The managers of each WWTP provided Annual Use Monitoring Reports for this analysis. Based on these records, the WWTP effluent applied to nearby crops is estimated to be on average 20 percent of the effluent flow for Visalia and an average of 70 percent of the Tulare's effluent flow[2] over the period of record. The results of the recycled water applied to crops are presented in ***Table 13***. As presented, an average of 8,792 AF/WY of recycled water from the municipal wastewater treatment plants was delivered to crops on adjacent fields. There are no other applications of recycled water to crops within the Subbasin.

[2] Based on Annual Use Reports

**Table 13: Recycled Water Delivered to Crops (AF/WY)**

| Water Year | Recycled Water |
|---|---|
| 1981 | **5,019** |
| 1982 | **5,199** |
| 1983 | **5,379** |
| 1984 | **5,558** |
| 1985 | **5,739** |
| 1986 | **5,919** |
| 1987 | **6,099** |
| 1988 | **6,279** |
| 1989 | **6,459** |
| 1990 | **6,595** |
| 1991 | **6,786** |
| 1992 | **6,414** |
| 1993 | **6,942** |
| 1994 | **7,516** |
| 1995 | **7,749** |
| 1996 | **7,733** |
| 1997 | **7,879** |
| 1998 | **7,996** |
| 1999 | **8,590** |
| 2000 | **8,928** |
| 2001 | **9,077** |
| 2002 | **9,791** |
| 2003 | **10,671** |
| 2004 | **10,915** |
| 2005 | **11,359** |
| 2006 | **11,599** |
| 2007 | **11,781** |
| 2008 | **11,441** |
| 2009 | **11,350** |
| 2010 | **11,566** |
| 2011 | **11,548** |
| 2012 | **12,079** |
| 2013 | **11,825** |
| 2014 | **11,651** |
| 2015 | **11,092** |
| 2016 | **11,144** |
| 2017 | **11,374** |
| **Maximum** | **12,079** |
| **Minimum** | **5,019** |
| **Average** | **8,792** |

*Total Ditch System Percolation ($TotDS_P$)*

The volumes of total ditch system percolation are the portion of water that percolated through the bottom and sides of the ditch system between a headgate diversion point and a grower turnout for agricultural irrigation. These volumes are used to estimate how much of the water diverted at a headgate is ultimately delivered for agricultural irrigation. The results of the total ditch system percolation analysis are presented in ***Table 14***. Basin wide, the average annual volume of surface water that percolates through the ditch systems is 117,001 AF/WY.

**Table 14: Ditch Percolation (AF/WY)**

| Water Year | Ditch Percolation |
|---|---|
| 1981 | **70,745** |
| 1982 | **243,470** |
| 1983 | **257,593** |
| 1984 | **149,426** |
| 1985 | **85,151** |
| 1986 | **226,874** |
| 1987 | **35,502** |
| 1988 | **50,098** |
| 1989 | **50,355** |
| 1990 | **19,649** |
| 1991 | **61,780** |
| 1992 | **32,401** |
| 1993 | **177,784** |
| 1994 | **46,311** |
| 1995 | **215,126** |
| 1996 | **161,633** |
| 1997 | **189,363** |
| 1998 | **216,275** |
| 1999 | **104,433** |
| 2000 | **114,612** |
| 2001 | **65,837** |
| 2002 | **76,638** |
| 2003 | **120,560** |
| 2004 | **58,082** |
| 2005 | **206,240** |
| 2006 | **207,682** |
| 2007 | **38,028** |
| 2008 | **80,803** |
| 2009 | **90,254** |
| 2010 | **151,862** |
| 2011 | **196,378** |
| 2012 | **65,852** |
| 2013 | **29,293** |
| 2014 | **26,177** |
| 2015 | **17,698** |
| 2016 | **78,869** |
| 2017 | **310,206** |
| **Maximum** | **310,206** |
| **Minimum** | **17,698** |
| **Average** | **117,001** |

*Recharge Basin Diversions ($RB_{DIV}$)*

The recharge basin diversions are the portions of water that percolate to groundwater via recharge basins subsequent to being diverted through a headgate. A summary of the recharge basin diversions is presented in ***Table 15***. Basin wide, an average of 51,191 AF/WY of the surface water is diverted to recharge basins. Total recharge basin inflow will be discussed below. There are no recharge basin diversions in EKGSA.

**Table 15: Recharge Basin Percolation (AF/WY)**

| Water Year | Basin Recharge |
|---|---|
| 1981 | **16,706** |
| 1982 | **103,579** |
| 1983 | **74,439** |
| 1984 | **43,474** |
| 1985 | **35,435** |
| 1986 | **99,137** |
| 1987 | **8,318** |
| 1988 | **20,892** |
| 1989 | **14,332** |
| 1990 | **4,687** |
| 1991 | **12,270** |
| 1992 | **9,032** |
| 1993 | **95,849** |
| 1994 | **9,582** |
| 1995 | **123,637** |
| 1996 | **71,069** |
| 1997 | **114,110** |
| 1998 | **115,638** |
| 1999 | **42,075** |
| 2000 | **37,608** |
| 2001 | **14,373** |
| 2002 | **14,790** |
| 2003 | **53,149** |
| 2004 | **16,701** |
| 2005 | **111,102** |
| 2006 | **83,625** |
| 2007 | **15,835** |
| 2008 | **16,943** |
| 2009 | **22,761** |
| 2010 | **94,110** |
| 2011 | **155,756** |
| 2012 | **26,090** |
| 2013 | **7,695** |
| 2014 | **349** |
| 2015 | **382** |
| 2016 | **22,073** |
| 2017 | **186,458** |
| **Maximum** | **186,458** |
| **Minimum** | **349** |
| **Average** | **51,191** |

*Spills (S)*

In years of significant surface water availability, the quantity of surface water can exceed the crop demands and recharge capacity of the conveyance systems and basins (Fugro Consultants, 2016). This occurred in 1983, 1995, 1997, 2006, 2011 and 2017. In such years, surface water flows out of the Subbasin in the form of surface water "spills"(***Figure 22***). Quantification of these spills is straightforward because these spill points are gauged and records are maintained by both KDWCD and TID. A summary of the surface water spills from the Subbasin is presented as ***Table 16***. Basin wide, an average of 16,767 AF/WY has been spilled from the Subbasin. Of these spills, only the Cross Creek spill occurs from the natural channels. There are no spills from the Subbasin from EKGSA.

**Table 16: Spills from the Subbasin (AF/WY)**

| Water Year | Spills |
|---|---|
| 1981 | **3,277** |
| 1982 | **56,246** |
| 1983 | **204,315** |
| 1984 | **37,993** |
| 1985 | **2,879** |
| 1986 | **51,784** |
| 1987 | **804** |
| 1988 | **757** |
| 1989 | **556** |
| 1990 | **0** |
| 1991 | **633** |
| 1992 | **74** |
| 1993 | **5,674** |
| 1994 | **152** |
| 1995 | **23,124** |
| 1996 | **6,730** |
| 1997 | **50,994** |
| 1998 | **38,904** |
| 1999 | **4,318** |
| 2000 | **10,567** |
| 2001 | **3,468** |
| 2002 | **3,321** |
| 2003 | **14,380** |
| 2004 | **2,382** |
| 2005 | **6,593** |
| 2006 | **24,675** |
| 2007 | **773** |
| 2008 | **1,651** |
| 2009 | **1,274** |
| 2010 | **7,263** |
| 2011 | **34,805** |
| 2012 | **1,541** |
| 2013 | **0** |
| 2014 | **0** |
| 2015 | **0** |
| 2016 | **177** |
| 2017 | **18,313** |
| **Maximum** | **204,315** |
| **Minimum** | **0** |
| **Average** | **16,767** |

*Surface Water Delivered to Crops*

The results of the calculations for the volume of surface water delivered to crops are summarized in ***Table 17***. As indicated, the average annual amount of surface water delivered to meet crop demand within the Subbasin is about 335,081 AF/WY over the base period (historical period). The deliveries show a clear correlation to the availability of surface water and ranged from about 65,799 AF/WY (2015) to 583,928 AF/WY (2017) just two years later. These values indicate that approximately two-thirds of the total water diverted through the headgates is ultimately delivered to the crops within the Subbasin.

**Table 17: Surface Water Delivered to Crops (AF/WY)**

| Water Year | SW Delivered to Crops |
| --- | --- |
| 1981 | **278,671** |
| 1982 | **530,403** |
| 1983 | **587,280** |
| 1984 | **497,124** |
| 1985 | **316,088** |
| 1986 | **495,387** |
| 1987 | **214,159** |
| 1988 | **219,328** |
| 1989 | **234,313** |
| 1990 | **147,874** |
| 1991 | **243,654** |
| 1992 | **180,900** |
| 1993 | **443,681** |
| 1994 | **196,360** |
| 1995 | **511,710** |
| 1996 | **465,774** |
| 1997 | **442,074** |
| 1998 | **527,890** |
| 1999 | **356,181** |
| 2000 | **375,275** |
| 2001 | **250,475** |
| 2002 | **282,037** |
| 2003 | **339,763** |
| 2004 | **239,493** |
| 2005 | **485,483** |
| 2006 | **488,422** |
| 2007 | **169,232** |
| 2008 | **286,352** |
| 2009 | **285,166** |
| 2010 | **446,511** |
| 2011 | **536,716** |
| 2012 | **220,069** |
| 2013 | **133,663** |
| 2014 | **80,923** |
| 2015 | **65,799** |
| 2016 | **239,854** |
| 2017 | **583,928** |
| **Maximum** | **587,280** |
| **Minimum** | **65,799** |
| **Average** | **335,081** |

## *Inflows to The Groundwater System*

The inflow components to the groundwater system include the following:

- Subsurface inflow
- Percolation of precipitation
- Streambed percolation in the natural and man-made channels
- Artificial recharge
- Percolation of irrigation water
- Percolation of waste water

Each of these components and the method by which each was calculated is presented in this section.

**Subsurface Inflow**

Subsurface inflow is the flow of groundwater into and out of a groundwater basin. During the base period, subsurface inflow into the Kaweah Subbasin exceeded subsurface outflow from the Subbasin by 64,501 AF/WY (***Table 18***).

Annual estimates were prepared to determine the subsurface flow between the three GSAs within the Subbasin and both into and out of the Subbasin as a whole. These calculations were performed by two methods.

During the earlier period between 1981 and 1998, these calculations were performed using the Darcy flow equation, which requires input values of groundwater gradient and hydraulic conductivity. The gradient was calculated for every year of the base period using the groundwater contour maps prepared for this Basin Setting. Horizontal hydraulic conductivity values were used from the numerical groundwater model.

In this method, the rate of groundwater flow is expressed by the Darcy equation Q = PiA, where 'P' is the coefficient of aquifer permeability (horizontal hydraulic conductivity), 'i' is the average hydraulic gradient, and 'A' is the cross-sectional area of the saturated aquifer. Permeability data for the aquifers in the Kaweah Subbasin were discussed in **Section 2.2.5.2**, which were used in the numerical groundwater model. Hydraulic gradient data, derived from annual water level contour maps developed for this Basin Setting were analyzed on an annual basis over the base period. The cross-sectional areas of the aquifer at each groundwater flux line representing the boundaries of the Subbasin were estimated using GIS analysis. The general directions of which are presented in ***Figure 43***. From these, annual magnitudes of subsurface flow were tallied.

The second method used to compute groundwater flux along the Subbasin boundary was based on the numerical groundwater flow model. Groundwater flow into and out of the Subbasin were calculated as an output from the model. These estimates of groundwater flow are considered to be superior to the Darcian flux method.

These subsurface flow calculations include an estimate of mountain-front recharge, which is the contribution of water from the mountains to recharge the aquifers in the adjacent basins. For the Kaweah Subbasin, this flow enters the Subbasin from the Sierra Nevada on the east. Mountain front recharge is limited and most of the flow into the basin occurs principally as surface runoff, which subsequently percolates rapidly into alluvial valleys. Based on several sources, mountain-front recharge is estimated to contribute an average of 52,000 AF/WY to the Kaweah Subbasin. This volume of mountain-front recharge includes estimated percolation from minor streams along the eastern periphery of the Subbasin. For the purposes of this water budget, this estimation was varied based on water year type based on relative precipitation in any year.

A summary of the total estimated annual subsurface inflow and outflow is presented in ***Table 18***. The average total subsurface inflow into the Subbasin during the historical period was estimated to be 155,640 AF/WY. During this same period, average subsurface outflow was only 91,139 AF/WY, resulting in a net subsurface inflow into the basin of 64,501 AF/WY. A map of the typical subsurface flow within the Subbasin is presented as ***Figure 43***.

**Table 18: Subsurface Flow (AF/WY)**

| Water Year | Subsurface Inflows | Subsurface Outflows | Net Subsurface Flows |
|---|---|---|---|
| 1981 | 7,416 | 113,057 | **-105,641** |
| 1982 | 102,364 | 108,566 | **-6,202** |
| 1983 | 193,509 | 113,190 | **80,319** |
| 1984 | 71,758 | 112,636 | **-40,878** |
| 1985 | 35,970 | 50,210 | **-14,240** |
| 1986 | 110,886 | 53,331 | **57,555** |
| 1987 | 43,989 | 95,673 | **-51,685** |
| 1988 | 81,490 | 125,284 | **-43,795** |
| 1989 | (15,488) | 74,850 | **-90,338** |
| 1990 | (4,763) | 32,566 | **-37,329** |
| 1991 | 36,014 | 54,523 | **-18,509** |
| 1992 | 87,139 | 123,629 | **-36,490** |
| 1993 | 171,393 | 112,885 | **58,508** |
| 1994 | 76,131 | 116,379 | **-40,248** |
| 1995 | 135,459 | 109,653 | **25,806** |
| 1996 | 229,839 | 83,117 | **146,722** |
| 1997 | 238,893 | 96,499 | **142,395** |
| 1998 | 208,409 | 93,089 | **115,320** |
| 1999 | 194,083 | 35,425 | **158,659** |
| 2000 | 197,904 | 57,725 | **140,178** |
| 2001 | 192,026 | 79,952 | **112,073** |
| 2002 | 192,215 | 89,440 | **102,775** |
| 2003 | 187,739 | 96,878 | **90,861** |
| 2004 | 164,507 | 93,392 | **71,116** |
| 2005 | 246,894 | 74,913 | **171,981** |
| 2006 | 247,302 | 61,294 | **186,008** |
| 2007 | 154,061 | 101,444 | **52,617** |
| 2008 | 180,795 | 166,204 | **14,590** |
| 2009 | 186,598 | 153,981 | **32,617** |
| 2010 | 246,030 | 117,451 | **128,579** |
| 2011 | 288,083 | 62,978 | **225,106** |
| 2012 | 199,932 | 68,294 | **131,638** |
| 2013 | 187,277 | 107,638 | **79,639** |
| 2014 | 193,692 | 93,867 | **99,825** |
| 2015 | 191,677 | 82,095 | **109,582** |
| 2016 | 200,844 | 93,551 | **107,293** |
| 2017 | 296,623 | 66,478 | **230,145** |
| **Maximum** | **296,623** | **166,204** | **230,145** |
| **Minimum** | **-15,488** | **32,566** | **-105,641** |
| **Average** | **155,640** | **91,139** | **64,501** |

### Percolation of Precipitation

The amount of rainfall that percolates deeply into the groundwater depends on many factors including the type and structure of the soil; density of the vegetation; the quantity, intensity and duration of rainfall; the vertical permeability of the soil; the relative saturation of the soil during rainfall episodes; and local topography. Deep percolation of rainfall does not occur until the initial soil moisture deficiency is exceeded. In most years, rainfall events do not produce sufficient quantities and timing of rainfall to penetrate beyond the root zone of native vegetation. However, in irrigated soils, because of the artificial application of water, the initial fall and winter moisture content is greater, and less annual rainfall is required to meet and exceed the soil moisture deficiency. Once the soil moisture deficiency within the root zone has been satisfied, continued precipitation (occurring prior to evapotranspiration) will percolate downward and eventually reach the groundwater reservoir.

Estimation of the deep percolation of precipitation was performed for the earlier period (prior to 2000) using an established method that incorporates the distribution of known crop types, rainfall distribution, reference evapotransporation (ET) data from the CIMIS, and soil data. From these data, the percolation of precipitation was calculated with the development of a monthly moisture model spreadsheet that accounted for immediate evaporation, effective rainfall, percolation of infiltrated rainfall, and percolation of rainfall runoff (Fugro West, 2007).

Since 2000, estimates of the percolation of precipitation were made by a different method, based on a combination of remote sensing (satellite) images and computer simulations, which relied on a daily root zone water balance model and crop ET. The method utilizes Davids Engineering's "Normalized Difference Vegetation Index" (NDVI) analysis methods, which were applied to the area of the KDWCD (Davids Engineering, 2013) and the entire Subbasin (Davids Engineering, 2018[***Appendix C***]).

The Davids Engineering analysis estimated percolation of precipitation applied to agricultural land. For the period of 2000 to 2017, the clipped irrigated fields GIS data was exported from GIS and imported into the Davids Engineering database model to develop an "irrigated fields" table. From this, the annual estimated percolation of precipitation on irrigated fields located within the Subbasin was calculated. The results were checked against previously calculated values (Fugro Consultants, 2016). Both the earlier DWR land use survey-based method and the Davids Engineering database-model method account for the agricultural land that has been converted to urban land use over time.

Percolation of precipitation on non-irrigated lands was estimated with published methods based on the distribution of annual precipitation with comparison parcel areas provided by Davids Engineering (Williamson et. al., 1989). Based on this method, an average of approximately 8 percent of the annual precipitation percolated into the groundwater during the base period. Within Visalia and Tulare, the principal urban areas, net percolation of precipitation directly on the urban areas is assumed to be negligible as these cities generally divert storm water into nearby channels that distribute it away from the city. However, the runoff amount from these areas is generally believed to be included in both the estimate of percolation into non-agricultural areas in the Kaweah Subbasin and streambed percolation.

Estimated percolation of precipitation is presented in ***Table 19***. These results indicate that the percolation of precipitation onto the irrigated lands within the Subbasin averaged 89,197 AF/WY.

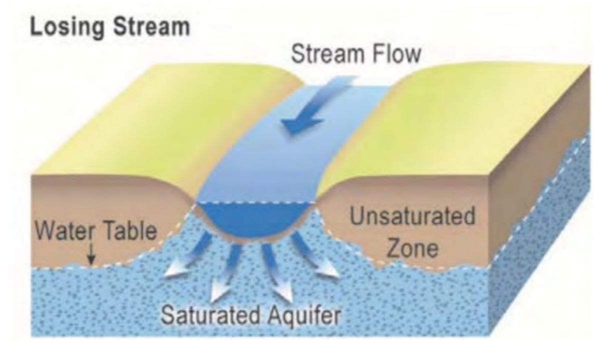
On non-agricultural areas, an average of 18,428 AF/WY percolated to the groundwater reservoir. In total, an annual average of 107,625 AF/WY of precipitation percolated during the base period.

**Table 19: Percolation of Precipitation (AF/WY)**

| Water Year | Precip on Ag Land | Precip on Non-Ag Land | Total Precip Percolation |
|---|---|---|---|
| 1981 | 97,708 | 16,530 | **114,238** |
| 1982 | 107,397 | 25,860 | **133,256** |
| 1983 | 170,393 | 27,693 | **198,086** |
| 1984 | 26,301 | 12,071 | **38,373** |
| 1985 | 46,527 | 16,136 | **62,664** |
| 1986 | 133,058 | 25,011 | **158,068** |
| 1987 | 93,024 | 14,987 | **108,011** |
| 1988 | 78,888 | 18,779 | **97,667** |
| 1989 | 42,700 | 15,065 | **57,765** |
| 1990 | 65,033 | 11,440 | **76,473** |
| 1991 | 123,099 | 16,042 | **139,140** |
| 1992 | 67,582 | 17,417 | **85,000** |
| 1993 | 130,116 | 23,932 | **154,049** |
| 1994 | 73,708 | 15,729 | **89,437** |
| 1995 | 213,159 | 31,577 | **244,736** |
| 1996 | 100,127 | 20,371 | **120,498** |
| 1997 | 109,374 | 22,132 | **131,507** |
| 1998 | 258,852 | 29,960 | **288,812** |
| 1999 | 69,233 | 16,800 | **86,034** |
| 2000 | 82,482 | 19,653 | **102,135** |
| 2001 | 63,426 | 16,661 | **80,087** |
| 2002 | 67,840 | 16,451 | **84,292** |
| 2003 | 59,007 | 16,212 | **75,220** |
| 2004 | 48,927 | 12,831 | **61,758** |
| 2005 | 97,108 | 24,112 | **121,220** |
| 2006 | 129,634 | 25,387 | **155,022** |
| 2007 | 32,225 | 9,179 | **41,404** |
| 2008 | 52,943 | 13,801 | **66,745** |
| 2009 | 36,310 | 12,164 | **48,474** |
| 2010 | 72,084 | 19,666 | **91,750** |
| 2011 | 172,399 | 28,407 | **200,807** |
| 2012 | 50,752 | 13,618 | **64,370** |
| 2013 | 33,043 | 9,540 | **42,583** |
| 2014 | 25,505 | 8,047 | **33,552** |
| 2015 | 49,875 | 12,477 | **62,352** |
| 2016 | 88,100 | 20,329 | **108,429** |
| 2017 | 132,352 | 25,758 | **158,111** |
| **Maximum** | **258,852** | **31,577** | **288,812** |
| **Minimum** | **25,505** | **8,047** | **33,552** |
| **Average** | **89,197** | **18,428** | **107,625** |

### Streambed Percolation and Delivered Water Conveyance Losses

*Natural Channels*




Source: DWR

**Figure 44: Losing Stream Diagram**

Percolation of water from flows in natural channels has been estimated for the entire Subbasin. Within the GKGSA and MKGSA area, streambed percolation was based on comparison of flow between the Terminus Reservoir and the appropriators' headgates. This percolation is often referred to as "conveyance loss" (or seepage loss) (***Figure 44)***. Percolation through the riverbeds of the St. Johns and Lower Kaweah rivers has been calculated for specific lengths of each river and is referred to as individual "reach losses." Percolation in these natural channels was estimated based on the number of days that water flowed in each reach and the difference between an adjusted reach loss and any known riparian diversion within the reach (Fugro West, 2007; Fugro Consultants, 2016).

Within the EKGSA, reliable, long-term streamflow gauges do not exist for the four major tributaries flowing into the area from the Sierra Nevada foothills. A single streamflow gauge exists on Yokohl Creek. The other three creeks, Cottonwood Creek, Lewis Creek, Fraiser Creeks, are ungauged. Therefore, in the absence of empirical data, the streambed percolation for all four creeks were assumed to be included within the mountain-front recharge estimate for the Subbasin. The natural channel reaches (portions) within the Subbasin are presented on ***Table 20***. In total, natural channel percolation within the Subbasin averaged 79,080 AF/WY as presented on ***Table 21***.

**Table 20: Stream Reaches within the Kaweah Subbasin**

| Reach | Total Length (feet) |
|---|---|
| Lower Kaweah Reach #2 | 15,767 |
| Lower Kaweah Reach #3 | 5,666 |
| Lower Kaweah Reach #4 | 8,129 |
| Lower Kaweah Reach #5 | 9,325 |
| Lower Kaweah Reach #6 | 39,731 |
| | |
| St. Johns Reach #1 | 18,168 |
| St. Johns Reach #2 | 31,545 |
| St. Johns Reach #3 | 8,318 |
| St. Johns Reach #4 | 6,601 |
| St. Johns Reach #5 | 10,331 |
| St. Johns Reach #6 | 31,878 |
| St. Johns Reach #7 | 61,066 |
| St. Johns Reach #8 | 64,580 |

**Table 21: Streambed Percolation (AF/WY)**

| Water Year | Streambed Percolation |
|---|---|
| 1981 | **54,231** |
| 1982 | **126,001** |
| 1983 | **188,773** |
| 1984 | **138,378** |
| 1985 | **69,467** |
| 1986 | **125,734** |
| 1987 | **45,507** |
| 1988 | **34,888** |
| 1989 | **38,409** |
| 1990 | **32,199** |
| 1991 | **47,071** |
| 1992 | **38,473** |
| 1993 | **98,293** |
| 1994 | **46,885** |
| 1995 | **135,990** |
| 1996 | **84,356** |
| 1997 | **102,699** |
| 1998 | **122,161** |
| 1999 | **64,052** |
| 2000 | **68,501** |
| 2001 | **40,490** |
| 2002 | **61,508** |
| 2003 | **73,346** |
| 2004 | **46,977** |
| 2005 | **126,312** |
| 2006 | **109,920** |
| 2007 | **35,725** |
| 2008 | **60,114** |
| 2009 | **60,710** |
| 2010 | **112,106** |
| 2011 | **144,354** |
| 2012 | **50,429** |
| 2013 | **46,119** |
| 2014 | **23,790** |
| 2015 | **19,552** |
| 2016 | **73,309** |
| 2017 | **179,122** |
| **Maximum** | **188,773** |
| **Minimum** | **19,552** |
| **Average** | **79,080** |

*Ditches*

Percolation of water from ditches within the Subbasin was estimated based on the best available data. Ditch system percolation was estimated by assigning a specified percentage of the water delivered to the appropriators' headgates as ditch percolation for each system for each year of the base period (Fugro West, 2007), which is described below.

The ditch system percolation analysis was calculated using a GIS analysis of the irrigated fields parcel data within each of the appropriators' service areas (Davids Engineering, 2018). The extents of the service areas were provided by agencies within the Subbasin including KDWCD and Lindsay-Strathmore Irrigation District, the areas of which are partially, or wholly, contained within Subbasin. A list of the names and irrigated field acreage within each of the service areas is presented in ***Table 22***, which cover a total of 259,059 acres within the approximately 443,000 acre Subbasin, or approximately 58 percent of the land area. Within the Subbasin the percolation within the ditches averaged 117,001 AF/WY, as presented on ***Table 23***.

**Table 22: Appropriator Service Areas**

| Service Area | Acres |
|---|---|
| Consolidated Peoples D.C. | **15,770** |
| Evans D.C. | **4,369** |
| Exeter I.D. | **14,939** |
| Farmers D.C. | **13,202** |
| Fleming D.C. | **1,641** |
| Goshen D.C. | **5,586** |
| Hamilton D.C. | **350** |
| Ivanhoe I.D. | **10,466** |
| Lakeside Irrigation W.D. | **24,126** |
| Lemon Cove D.C. | **787** |
| Lewis Creek W.D. | **1,307** |
| Lindmore I.D. | **27,292** |
| Lindsay-Strathmore I.D. | **16,417** |
| Longs Canal Area | **952** |
| Mathews D.C. | **1,831** |
| Modoc D.C. | **6,486** |
| Oakes D.C. | **1,104** |
| Persian D.C. | **6,321** |
| Sentinel Butte | **815** |
| St. Johns W.D. | **13,355** |
| Stone Corral I.D. | **6,671** |
| Tulare I.D. | **70,446** |
| Tulare Irrigation Company | **7,887** |
| Uphill D.C. | **1,819** |
| Wutchumna W.C. | **5,218** |
| **Total** | **259,159** |

**Table 23: Total Ditch Percolation (AF/WY)**

| Water Year | All Conveyance Percolation |
|---|---|
| 1981 | 70,745 |
| 1982 | 243,470 |
| 1983 | 257,593 |
| 1984 | 149,426 |
| 1985 | 85,151 |
| 1986 | 226,874 |
| 1987 | 35,502 |
| 1988 | 50,098 |
| 1989 | 50,355 |
| 1990 | 19,649 |
| 1991 | 61,780 |
| 1992 | 32,401 |
| 1993 | 177,784 |
| 1994 | 46,311 |
| 1995 | 215,126 |
| 1996 | 161,633 |
| 1997 | 189,363 |
| 1998 | 216,275 |
| 1999 | 104,433 |
| 2000 | 114,612 |
| 2001 | 65,837 |
| 2002 | 76,638 |
| 2003 | 120,560 |
| 2004 | 58,082 |
| 2005 | 206,240 |
| 2006 | 207,682 |
| 2007 | 38,028 |
| 2008 | 80,803 |
| 2009 | 90,254 |
| 2010 | 151,862 |
| 2011 | 196,378 |
| 2012 | 65,852 |
| 2013 | 29,293 |
| 2014 | 26,177 |
| 2015 | 17,698 |
| 2016 | 78,869 |
| 2017 | 310,206 |
| **Maximum** | 310,206 |
| **Minimum** | 17,698 |
| **Average** | 117,001 |
| **Total** | **4,329,038** |

**Artificial Recharge**

Artificial recharge basins receive surface water, which percolates directly to groundwater, the volumes of which were estimated for the entire Subbasin. The method of estimating these volumes was developed as part of the WRIs for KDWCD, which involved multiplying the number of days each recharge basin received water by the basin's known percolation rate (recharge factor) (Fugro West, 2007). Artificial recharge occurs throughout the GKGSA and EKGSA. The basin recharge factors were refined for the entire period of the WRI (Fugro Consultants, 2016), and were utilized for this analysis for the entire base period.

There are 42 recharge basins completely within the Kaweah Subbasin (refer to ***Table 24***), over a total of 1,916 acres. Within these, the recharge inflows were determined for each recharge basin, using the methodology described in the previous reports (Fugro West, 2007; Fugro Consultants, 2016). The results of the recharge basin inflow analysis are presented as ***Table 15***. As indicated, an average of 51,191 AF/WY of surface water was recharged to the groundwater by recharge basins. The volume of water recharged by this method varies widely and episodic recharge occurs principally during times of excess flow associated with wet years.

**Table 24: Recharge Basins in the Kaweah Subbasin**

| Source | Basin ID | Source | Acres |
|---|---|---|---|
| Evans | Nelson Pit - 13 | Evans | **25** |
| Farmers | Anderson - 24 | Farmers | **130** |
| Farmers | Art Shannon - 1 | Farmers | **27** |
| Farmers | Ellis - 27 | Farmers | **9** |
| Farmers | Gary Shannon - 7 | Farmers | **3** |
| Farmers | Gordon Shannon - 21 | Farmers | **39** |
| Farmers | Nunes - 29 | Farmers | **9** |
| Goshen Ditch | Doe-Goshen - 28 | Goshen Ditch | **28** |
| Harrell No. 1 | Harrell - 30 | Harrell No. 1 | **25** |
| Lakeside Ditch | Alcorn | Lakeside Ditch | **10** |
| Lakeside Ditch | Batti | Lakeside Ditch | **33** |
| Lakeside Ditch | Burr | Lakeside Ditch | **6** |
| Lakeside Ditch | Caeton | Lakeside Ditch | **4** |
| Lakeside Ditch | Green - 23 | Lakeside Ditch | **4** |
| Lakeside Ditch | Guernsey | Lakeside Ditch | **4** |
| Lakeside Ditch | Howe - 15 | Lakeside Ditch | **49** |
| Lakeside Ditch | Lakeside #2 | Lakeside Ditch | **58** |
| Lakeside Ditch | Sousa | Lakeside Ditch | **6** |
| Lakeside Ditch | Youd | Lakeside Ditch | **6** |
| Modoc | Doe-Ritchie - 26 | Modoc | **0** |
| Modoc | Goshen: Doe - 9 | Modoc | **30** |
| Modoc | Shannon-Modoc - 22 | Modoc | **8** |
| Modoc | Willow School - 5 | Modoc | **14** |
| Peoples | Bill Clark - 32 | Peoples | **1** |
| Peoples | Hammer - 31 | Peoples | **1** |
| Peoples | Sunset - 95 | Peoples | **95** |
| Persian | Packwood - 4 | Persian | **147** |
| TID | Abercrombie - 14 | TID | **17** |
| TID | Colpien - 3 | TID | **144** |
| TID | Corcoran Hwy - 8 | TID | **106** |
| TID | Creamline - 16 | TID | **133** |
| TID | Doris - 25 | TID | **26** |
| TID | Enterprise - 2 | TID | **18** |
| TID | Franks - 17 | TID | **33** |
| TID | Franks - 19 | TID | **108** |
| TID | Guinn - 18 | TID | **142** |
| TID | Liberty | TID | **29** |
| TID | Machado - 6 | TID | **128** |
| TID | Martin | TID | **16** |
| TID | Swall | TID | **153** |
| TID | Tagus - 11 | TID | **78** |
| TID | Watte - 20 | TID | **14** |
| | | **Total** | **1,916** |

### Percolation of Irrigation Return Water

Estimates for percolation of irrigation return water are presented in ***Table 25.***

**Table 25: Percolation of Irrigation Water and Additional Recharge (AF/WY)**

| Water Year | Irrigation Return Flow | Additional Recharge |
|---|---|---|
| 1981 | **285,574** | **18,416** |
| 1982 | **276,604** | **36,740** |
| 1983 | **253,708** | **39,055** |
| 1984 | **344,152** | **51,797** |
| 1985 | **313,508** | **14,930** |
| 1986 | **251,295** | **8,565** |
| 1987 | **271,198** | **6,311** |
| 1988 | **274,740** | **10,130** |
| 1989 | **290,799** | **0** |
| 1990 | **285,874** | **219** |
| 1991 | **246,574** | **0** |
| 1992 | **246,249** | **0** |
| 1993 | **245,247** | **8,190** |
| 1994 | **247,267** | **0** |
| 1995 | **218,632** | **12,491** |
| 1996 | **226,064** | **8,161** |
| 1997 | **226,793** | **4,342** |
| 1998 | **173,211** | **23,281** |
| 1999 | **234,804** | **24,943** |
| 2000 | **237,762** | **19,190** |
| 2001 | **213,593** | **0** |
| 2002 | **226,064** | **5,482** |
| 2003 | **228,157** | **0** |
| 2004 | **219,653** | **2,342** |
| 2005 | **208,530** | **34,807** |
| 2006 | **230,550** | **18,983** |
| 2007 | **236,599** | **6,039** |
| 2008 | **229,848** | **1,812** |
| 2009 | **220,352** | **1,501** |
| 2010 | **216,833** | **15,107** |
| 2011 | **243,286** | **33,094** |
| 2012 | **236,186** | **0** |
| 2013 | **236,137** | **412** |
| 2014 | **242,824** | **0** |
| 2015 | **225,281** | **0** |
| 2016 | **208,859** | **3,142** |
| 2017 | **231,809** | **74,633** |
| **Maximum** | **344,152** | **74,633** |
| **Minimum** | **173,211** | **0** |
| **Average** | **243,368** | **13,084** |

Percolation of irrigation return water was estimated using two approaches, 1) the earlier (1981 to 1999) period, and 2) the later (2000 to 2017) period. Both approaches were based on the same analysis of "irrigated fields" used in the ditch system percolation analysis. A somewhat simplified version of this method was also utilized for the portion of the basin that are located outside of the KDWCD area.

Since 2000, GIS files of updated irrigated fields were acquired for the entire Subbasin. These were imported into the Davids Engineering database model for the calculation of the annual estimated percolation of irrigation return water for the irrigated fields as described by Davids Engineering (2013 and 2018).The Davids Engineering database model accounts for the agricultural land that has been converted to urban land use over time. The results of the analyses are presented in ***Table 25***. This principal form of groundwater recharge occurs within a relatively narrow range due to the continually-irrigated nature of the agricultural areas and near-constant recharge throughout the Subbasin. The average percolation of irrigation return water was 243,368 AF/WY during the historical (base) period ***Figures 45*** through ***49***, present the estimated distribution of groundwater pumping throughout the Subbasin.

In addition to the percolation calculated by the above method, some additional recharge occurs between the surface water headgate diversion and the fields calculated apart from ditch percolation. In some years, recharge occurs when excess water is delivered to the fields, which is beyond the requirements of the crop, either as additional ditch percolation or direct over-irrigation of the crops via on-farm recharge. On average, the volume of this recharge water is approximately 13,084 AF/WY, which occurs within the irrigated areas that receive surface water throughout the Subbasin.

**Percolation of Wastewater**

Several municipal WWTPs are operated within the Kaweah Subbasin, the principal ones of which are the cities of Visalia and Tulare, located entirely within MKGSA. Treated wastewater is discharged to holding ponds for percolation, evaporation, or agricultural reuse. Both WWTPs are regulated by Waste Discharge Requirements (WDRs) and Monitoring and Reporting Programs by the RWQCB (Fugro West, 2007). The managers of the two treatment plants were contacted by GSI and Annual Use Monitoring Reports for the City of Tulare were consulted during this analysis. Based on this research, on average, approximately 80 percent of the Visalia WWTP effluent percolates to groundwater while the other 20 percent is applied to adjacent crops. At the city of Tulare's WWTP, on average, 30 percent of the WWTP effluent percolates to groundwater while the other 70 percent is applied to nearby crops. The annual sums of wastewater that percolate to groundwater within MKGSA are presented in ***Table 26***. The table indicates that a total of 16,289 AF/WY of wastewater is recharged to the groundwater reservoir.

**Table 26: Wastewater Percolation (AF/WY)**

| Water Year | Wastewater Percolation |
|---|---|
| 1981 | **11,082** |
| 1982 | **11,203** |
| 1983 | **11,588** |
| 1984 | **11,970** |
| 1985 | **12,375** |
| 1986 | **12,591** |
| 1987 | **13,159** |
| 1988 | **13,436** |
| 1989 | **13,874** |
| 1990 | **13,939** |
| 1991 | **14,231** |
| 1992 | **14,147** |
| 1993 | **14,519** |
| 1994 | **15,183** |
| 1995 | **15,655** |
| 1996 | **15,725** |
| 1997 | **16,133** |
| 1998 | **16,374** |
| 1999 | **16,982** |
| 2000 | **17,728** |
| 2001 | **18,063** |
| 2002 | **17,917** |
| 2003 | **18,645** |
| 2004 | **19,016** |
| 2005 | **19,172** |
| 2006 | **19,593** |
| 2007 | **19,440** |
| 2008 | **19,661** |
| 2009 | **19,434** |
| 2010 | **19,512** |
| 2011 | **19,409** |
| 2012 | **19,188** |
| 2013 | **18,975** |
| 2014 | **18,834** |
| 2015 | **18,025** |
| 2016 | **17,610** |
| 2017 | **18,299** |
| **Maximum** | **19,661** |
| **Minimum** | **11,082** |
| **Average** | **16,289** |

### *Outflows from the groundwater system*

Outflow from the groundwater system occurs through the following components:

Subsurface outflow,

Agricultural and municipal groundwater pumpage,

Phreatophyte evapotranspiration, and

Evaporation.

Each of these components and the method used for each calculation is presented in this section.

**Subsurface Outflow**

Subsurface outflow is the flow of groundwater at depth that passes beyond the downgradient boundary of a groundwater basin. As presented on **Table 18**, during the historical base period, a total of 91,139 AF/WY of groundwater flowed out of the Subbasin, while subsurface inflow exceeded subsurface outflow by an average of 64,501 AF/WY.

**Agricultural Water Demand and Consumptive Use**

Agricultural water demand is the principal component of water use within the Kaweah Subbasin. Similar to and associated with the analysis for percolation of precipitation and percolation of irrigation water, the calculation of the agricultural water demand was calculated using two different methods, each of which are described below.

> For the earlier portion of the historical period prior to 2000, the agricultural water demand was based principally on periodic land surveys, which were separated by as many as 10 years (Fugro West, 2007). These methods were updated for the later (2000 to 2017) period, when remote sensing methods were adopted and which incorporated data from satellite images for the period from September 1998 to January 2011 (Davids Engineering, 2013) and again through the end of water year 2017 (Davids Engineering, 2018).
>
> For the later period since 2000, the irrigated fields were input into the Davids Engineering database model (2018) and then queried from the full Subbasin irrigated fields table to return annual estimated gross applied irrigation water for the irrigated fields. Because of the magnitude and importance of this component of water use in the area, considerable database model error checking was performed to verify the accuracy and reasonableness of the data. The Davids Engineering database model accounts for the agricultural land that has been converted to urban land use over time. The results of the gross applied irrigation water analyses indicated that an average of 1,007,363 AF/WY of water, from a combination of surface and groundwater sources, were delivered to the agricultural lands within the Subbasin (***Table 27*).**

**Table 27: Gross Applied Water to Crops (Acre-Feet/WY)**

| Water Year | Crop Water Demand |
|---|---|
| 1981 | 981,809 |
| 1982 | 933,059 |
| 1983 | 855,764 |
| 1984 | 1,160,572 |
| 1985 | 1,057,233 |
| 1986 | 909,899 |
| 1987 | 983,920 |
| 1988 | 997,082 |
| 1989 | 1,055,096 |
| 1990 | 1,037,574 |
| 1991 | 967,375 |
| 1992 | 968,204 |
| 1993 | 964,278 |
| 1994 | 971,984 |
| 1995 | 860,068 |
| 1996 | 965,166 |
| 1997 | 970,414 |
| 1998 | 741,888 |
| 1999 | 953,826 |
| 2000 | 1,013,101 |
| 2001 | 1,016,803 |
| 2002 | 1,072,721 |
| 2003 | 1,061,020 |
| 2004 | 1,087,721 |
| 2005 | 953,219 |
| 2006 | 981,903 |
| 2007 | 1,110,079 |
| 2008 | 1,101,383 |
| 2009 | 1,154,190 |
| 2010 | 1,022,157 |
| 2011 | 1,014,507 |
| 2012 | 1,103,581 |
| 2013 | 1,125,567 |
| 2014 | 1,146,453 |
| 2015 | 1,055,737 |
| 2016 | 964,415 |
| 2017 | 952,655 |
| **Maximum** | **1,160,572** |
| **Minimum** | **741,888** |
| **Average** | **1,007,363** |

**Municipal and Industrial Demand**

Municipal and industrial (M&I) pumping from the Subbasin was estimated using a variety of methods. The categories of water users included in this summarized component include:

- Urban
- Small public water system
- Golf course
- Dairy
- Nursery
- Rural domestic

The total M&I groundwater pumping estimate within the Subbasin is the sum of the individual groundwater demands estimated for the components discussed in the following sections. Data used in the M&I groundwater pumping estimate were collected from a variety of sources. Sources of these data include: metered municipal groundwater pumping records, demand estimates based on service connections and categories of facilities, population and dwelling unit density estimates, interviews with various industrial facility managers (nursery, food processing, and packing plants, etc.), and information provided by the County Agricultural Commissioner's Office and the Dairy Advisor. As presented on **Table 28,** M&I demand within the Subbasin averaged approximately 69,040 AF/WY, or 9 percent of the total groundwater pumpage.

**Table 28: Municipal and Industrial Demand (AF/WY)**

| Water Year | Urban Demand | Small Water System Demand | Rural Demand | Golf Course Demand | Dairy Demand | Nursery Demand | Total M&I Demand |
|---|---|---|---|---|---|---|---|
| 1981 | 26,875 | 2,824 | 1,591 | 1,350 | 4,545 | 0 | **37,185** |
| 1982 | 26,425 | 2,898 | 1,591 | 1,350 | 5,300 | 0 | **37,564** |
| 1983 | 27,643 | 2,973 | 1,591 | 1,350 | 6,054 | 0 | **39,611** |
| 1984 | 31,285 | 3,046 | 1,591 | 1,350 | 6,808 | 0 | **44,081** |
| 1985 | 31,951 | 3,120 | 1,591 | 1,350 | 7,562 | 0 | **45,574** |
| 1986 | 34,399 | 3,194 | 1,591 | 1,350 | 8,316 | 0 | **48,850** |
| 1987 | 35,629 | 3,268 | 1,591 | 1,350 | 9,071 | 0 | **50,910** |
| 1988 | 36,110 | 3,342 | 1,591 | 1,350 | 8,983 | 0 | **51,376** |
| 1989 | 35,599 | 3,416 | 1,591 | 1,350 | 10,761 | 0 | **52,717** |
| 1990 | 37,506 | 3,490 | 1,591 | 1,350 | 11,222 | 0 | **55,160** |
| 1991 | 35,415 | 3,554 | 1,591 | 1,350 | 11,721 | 500 | **54,130** |
| 1992 | 38,153 | 3,615 | 1,591 | 1,350 | 12,433 | 500 | **57,641** |
| 1993 | 38,392 | 3,680 | 1,591 | 1,350 | 12,354 | 500 | **57,868** |
| 1994 | 41,359 | 3,742 | 1,591 | 1,350 | 13,590 | 500 | **62,132** |
| 1995 | 42,355 | 3,805 | 1,591 | 1,350 | 15,360 | 500 | **64,961** |
| 1996 | 44,876 | 3,863 | 1,591 | 1,485 | 14,581 | 500 | **66,896** |
| 1997 | 46,368 | 3,925 | 1,591 | 1,485 | 16,613 | 500 | **70,483** |
| 1998 | 39,285 | 3,989 | 1,591 | 1,620 | 16,623 | 500 | **63,607** |
| 1999 | 46,556 | 4,051 | 1,591 | 1,620 | 16,632 | 500 | **70,950** |
| 2000 | 47,129 | 4,113 | 1,591 | 1,620 | 16,641 | 500 | **71,593** |
| 2001 | 51,137 | 4,185 | 1,591 | 1,620 | 16,650 | 500 | **75,683** |
| 2002 | 54,474 | 4,266 | 1,591 | 1,755 | 17,550 | 500 | **80,136** |
| 2003 | 55,696 | 4,349 | 1,591 | 1,755 | 18,449 | 500 | **82,341** |
| 2004 | 59,623 | 4,431 | 1,591 | 1,755 | 19,349 | 500 | **87,250** |
| 2005 | 57,390 | 4,515 | 1,591 | 1,755 | 20,249 | 500 | **85,999** |
| 2006 | 57,932 | 4,597 | 1,591 | 1,485 | 21,148 | 500 | **87,253** |
| 2007 | 61,707 | 4,680 | 1,591 | 1,485 | 22,048 | 500 | **92,010** |
| 2008 | 62,340 | 4,763 | 1,591 | 1,485 | 22,947 | 500 | **93,626** |
| 2009 | 61,376 | 4,845 | 1,591 | 1,485 | 23,840 | 500 | **93,637** |
| 2010 | 57,918 | 4,927 | 1,591 | 1,485 | 24,740 | 500 | **91,161** |
| 2011 | 56,461 | 4,953 | 1,591 | 1,485 | 23,463 | 500 | **88,451** |
| 2012 | 57,977 | 4,979 | 1,591 | 1,485 | 19,338 | 500 | **85,870** |
| 2013 | 60,484 | 5,005 | 1,591 | 1,485 | 20,138 | 500 | **89,203** |
| 2014 | 54,963 | 5,031 | 1,591 | 1,485 | 20,138 | 500 | **83,707** |
| 2015 | 47,889 | 5,067 | 1,591 | 1,215 | 20,138 | 500 | **76,400** |
| 2016 | 49,143 | 5,104 | 1,591 | 1,215 | 20,888 | 500 | **78,440** |
| 2017 | 51,447 | 5,177 | 1,591 | 1,215 | 20,088 | 500 | **80,018** |
| **Maximum** | **62,340** | **5,177** | **1,591** | **1,755** | **24,740** | **500** | **93,637** |
| **Minimum** | **26,425** | **2,824** | **1,591** | **1,215** | **4,545** | **0** | **37,185** |
| **Average** | **45,980** | **4,075** | **1,591** | **1,452** | **15,576** | **365** | **69,040** |

**Urban Demand**

Urban groundwater demand in the Subbasin is the demand occurs in the major cities:

- Visalia and Tulare (in the MKGSA),
- Exeter, Farmersville, Ivanhoe and Woodlake (within the GKGSA), and
- Lindsay in the EKGSA, which relies only partially on groundwater to meet demands.

All other water demand in the unincorporated areas are met by small public water systems regulated by the local environmental health departments or by private domestic wells. A summary of annual urban groundwater pumping is presented in **Table 28*.*** As indicated, urban demand increased from about 26,875 (1981) to 60,484 (2013) AF/WY over the period. Since 2013, when statewide conservation measures were implemented, total urban water demand declined significantly through 2015 to 2017, by which time urban demands had declined to levels not seen since the late 1990s. Urban demand averaged about 45,980 AF/WY over the base period.

**Small Water Systems Demand**

Analysis of annual water demand for small, regulated public water systems in the Subbasin was accomplished based on data provided previous reports (Fugro West, 2007; Fugro Consultants, 2016) and an analysis of the types of water systems in the area available from the County of Tulare Health and Human Services Agency. The listings of water systems provided information such as the facility identification/name, general location within the respective counties, a code related to the approximate number of service connections for the facility, and a contact name and phone number for each facility. Typical groupings of facility types common to the lists included mutual water companies, schools, mobile home parks, county facilities (e.g. civic centers, road yards), motels, livestock sales yards, and miscellaneous industries such as nurseries, food processing facilities, packing houses, etc.

Approximately one-third of the groundwater pumped by small public water systems occurs in a rural setting. Of this groundwater pumping, approximately 70 percent of the pumped water is believed to return to groundwater via septic system percolation and landscape irrigation return flow, with the remainder being consumptively used (Dziegielewski and Kiefer, 2010). A summary of the net small water system groundwater pumping values is provided in ***Table 28.*** Although small in the context of the overall water use, the increase in small water system groundwater demand over the base period was noted and commensurate with population changes within the Subbasin.

**Rural Domestic Demand**

Rural domestic water demand in the Subbasin consists of the demand of residences not served by a municipal connection, mutual water company, or other small public water system. Rural residential units can be described as "ranchette" type homes of several acres in size with an average of population per dwelling unit of about three people. Net water demand for such dwelling units is on the order of 2 AF/WY.

Unlike the small, public water system demand estimates that were indexed to population changes in Tulare County, the density of rural domestic dwellings has not changed significantly in the Subbasin over the base period, other than being replaced to a small degree by urban expansion. Similar to the rural small water system analysis above, a 70 percent portion of the pumped rural domestic water is assumed to return to groundwater via septic system percolation and irrigation return flows (Dziegielewski and Kiefer, 2010). Throughout the Subbasin, an annual total pumpage for rural users was 2,272 AF/WY on average, 30 percent of which returned to groundwater. Therefore, the net pumpage for rural users was 1,591 AF/WY. The rural domestic groundwater pumping calculations are included on ***Table 28***, and demonstrates demand from rural domestic users is very minor.

**Golf Course Demand**

Golf courses have operated within the Subbasin for the entire base period and the supply is believed to be groundwater pumping and recycled water from WWTPs. Based on this assumption, golf course demand was calculated using an estimated 300 AFY of demand per 18-holes water duty factor (Fugro West, 2007). It is estimated that 10 percent of the irrigation water applied on the golf courses returns to groundwater via deep percolation (Grismer, 1990; Cahn and Bali, 2015; Ayers and Westcot, 1985). A summary of the golf course groundwater pumping estimates is included in ***Table 28.*** During the base period, between 1,215 and 1,755 AF/WY were pumped, of which between 140 and 200 AF/WY returned to the groundwater reservoir. An average of 1,452 AF/WY of net pumping occurred to satisfy golf course demand.

**Dairy Pumping**

The dairy industry and related processing and distribution facilities requires a significant amount of water. Estimates of net water consumed by the dairy industry (farms) were based on cow census records maintained by the County and a per-cow based water use factor. Conversations with County personnel indicate the gross daily water use per cow is on the order of 125 gallons per day (gpd). Net water use (after consideration for the recycling of the water for irrigation on adjacent agricultural lands) is on the order of 75 gpd (Fugro West, 2007). Groundwater pumping by dairies in the Subbasin is an average of 15,576 AF/WY (**Table 28**). This volume of net pumping has increased significantly since the beginning of the period when 4,545 AF/WY was pumped (net). Notably, the groundwater demand is influenced directly to dairy cow populations, which are in turn directly affected by the market price for milk. The highest groundwater demand for dairy use was during 2010 when a total of 24,740 AF/WY of (net) groundwater was pumped for dairy uses.

**Nursery Demand**

The Kaweah Subbasin has a single relatively minor nursery-based agricultural operation that has extracted an estimated average of 500 AF/WY since 1991, which is included in ***Table 28***.

**Total M&I Groundwater Pumping**

The total M&I groundwater pumping was estimated as the sum of the total pumping for each of the individual components described in the preceding paragraphs. For several of the M&I components, such as small water systems, rural domestic users, and golf courses, a portion of the pumped groundwater deep percolates and returns to the groundwater reservoir. A summary of the total M&I groundwater pumping calculations is included in ***Table 28*** which indicates that total M&I demand, satisfied mainly by groundwater sources, averaged 69,040 AF/WY.

**Agricultural Pumping**

The principal groundwater outflow from the Subbasin is pumping to satisfy irrigated agriculture. Over 90 percent of the total groundwater pumpage is used to fulfill this demand.

The distribution of groundwater pumping in the Subbasin for the irrigation of agriculture has been determined based on the spatial distribution of crop water demand and annual surface water delivery to individual surface water appropriator service areas (***Figures 50 through 54***). Crop water demand was calculated using two different methods for the 37-year period of record, as discussed earlier. Briefly, the analysis for water years prior to 2000 using estimated crop water use based on DWR land use surveys and irrigation efficiency factors (Fugro West, 2007). The analysis for water years from 2000 onward was completed by Davids Engineering (2018) using satellite data to calculate the NDVI. A detailed spatial distribution of crop water demand is available from the NDVI analysis method.

Surface water deliveries to crops from a combination of local Kaweah River and imported (CVP and Kings River) water sources for the 37-year period of record have been calculated by appropriator service area. Because the spatial distributions of surface water deliveries within each service area are unknown, it is assumed that surface water deliveries are distributed evenly across the irrigated fields within each service area. The current extent of irrigated agricultural land and the establishment of surface water appropriators in the Kaweah Subbasin was fully developed well before the beginning of the historical base period (B-E, 1972 and Fugro West, 2007). The appropriator service areas have remained essentially unchanged since that time. The only minor changes that have taken place are isolated conversions of agricultural lands to urban development (Davids Engineering, 2018) and conversion of land use within each service area. These minor changes to appropriator service areas have been accounted for in the surface water delivery analysis.

To determine distributions of groundwater pumping in the Subbasin for irrigated agriculture, the surface water volumes distributed among the known-irrigated fields within each service area were subtracted from the spatially precise NDVI crop water demand dataset, using the following equation:

$$AP = CD - SWc$$

where: AP = Agricultural Pumping

CD = Agricultural Crop Demand

SWc = Surface Water Crop Delivery

On average, a total of 685,375 AF/WY was pumped from the groundwater reservoir as shown on **Table 29**. This ranged from a low of 237,278 AF/WY in 1998, which was the wettest year of the period, and a high of over 1,065,530 AF/WY in 2014 during the recent drought and associated lack of imported surface water.

**Table 29: Groundwater Pumping for Irrigated Agriculture (AF/WY)**

| Water Year | Ag Irrigation Pumping |
|---|---|
| 1981 | **721,553** |
| 1982 | **439,395** |
| 1983 | **307,540** |
| 1984 | **715,245** |
| 1985 | **756,074** |
| 1986 | **423,077** |
| 1987 | **776,072** |
| 1988 | **787,884** |
| 1989 | **820,783** |
| 1990 | **889,919** |
| 1991 | **723,721** |
| 1992 | **787,119** |
| 1993 | **528,788** |
| 1994 | **775,625** |
| 1995 | **360,849** |
| 1996 | **507,553** |
| 1997 | **532,683** |
| 1998 | **237,278** |
| 1999 | **622,587** |
| 2000 | **657,015** |
| 2001 | **766,328** |
| 2002 | **796,166** |
| 2003 | **721,257** |
| 2004 | **850,570** |
| 2005 | **502,543** |
| 2006 | **512,464** |
| 2007 | **946,886** |
| 2008 | **816,843** |
| 2009 | **870,526** |
| 2010 | **590,752** |
| 2011 | **511,468** |
| 2012 | **883,485** |
| 2013 | **992,285** |
| 2014 | **1,065,530** |
| 2015 | **989,938** |
| 2016 | **727,703** |
| 2017 | **443,360** |
| **Maximum** | **1,065,530** |
| **Minimum** | **237,278** |
| **Average** | **685,375** |

The results of the analysis for water years 1999, 2001, 2006, 2015 and 2016 are presented on Figure 42 through Figure 51. As expected, the results of this analysis show a pattern of increased agricultural pumping during drought periods to compensate for a reduction in surface water deliveries to irrigated lands from both local and imported sources and a commensurate increase in crop water demand. Pronounced increases in agricultural pumping occurred during extended periods of drought, such as the 2011 to 2015 period when imported water supplies were limited or non-existent.

During the following three periods, notable groundwater pumping increases occurred to satisfy agricultural demand:

- Between 1987 and 1992 when annual pumpage averaged 800,000 AF/WY;
- Between 2007 and 2009, when average pumpage for agriculture averaged 878,000 AF/WY; and
- Between 2012 and 2016 when average pumpage for agriculture exceeded 931,200 AF/WY.

Based upon this analysis and as shown on Figure 42 through Figure 51*,* the following key observations regarding changes in water usage over the entire base period are noted:

- Groundwater pumping for agricultural uses has varied with surface water availability, but has increased at an average of 0.8% per year (5,500 AF/WY on average);
- Crop water demand has increased modestly (at a rate of 0.3% or 2,800 AF/WY);
- Surface water deliveries have declined at a rate of 1% or (-3,000 AF/WY on average); and
- Since 1999, groundwater pumping has increased at a rate of 1.2% or 6,500 AF/WY.

**Phreatophyte Extractions**

Phreatophyte extraction refers to groundwater use by vegetation with roots extending into groundwater in riparian areas. Phreatophyte extractions within the Subbasin constitute a minor outflow component and were estimated in a manner constant with previous estimates (Fugro West, 2007). The results of phreatophyte extraction analysis are presented in **Table 30**, which indicate that this component constitutes a minor extraction from the groundwater reservoir (480 AF/WY).

**Table 30: Phreatophyte Extractions (Acre-Feet/WY)**

| Water Year | Phreatophyte Extractions |
|---|---|
| 1981 | **411** |
| 1982 | **692** |
| 1983 | **727** |
| 1984 | **280** |
| 1985 | **406** |
| 1986 | **672** |
| 1987 | **385** |
| 1988 | **491** |
| 1989 | **370** |
| 1990 | **258** |
| 1991 | **400** |
| 1992 | **451** |
| 1993 | **630** |
| 1994 | **376** |
| 1995 | **870** |
| 1996 | **545** |
| 1997 | **589** |
| 1998 | **1,075** |
| 1999 | **455** |
| 2000 | **537** |
| 2001 | **478** |
| 2002 | **493** |
| 2003 | **412** |
| 2004 | **377** |
| 2005 | **575** |
| 2006 | **730** |
| 2007 | **178** |
| 2008 | **237** |
| 2009 | **303** |
| 2010 | **523** |
| 2011 | **645** |
| 2012 | **207** |
| 2013 | **209** |
| 2014 | **219** |
| 2015 | **291** |
| 2016 | **462** |
| 2017 | **660** |
| **Maximum** | **1,075** |
| **Minimum** | **178** |
| **Average** | **476** |

#### *2.5.1.4 Change in Storage §354.16 (b)*

Annual variations in the volumes of groundwater in storage in the Subbasin were calculated for each year of the historical (base) period. The changes in storage for the 37-year period were used to evaluate conditions of water supply surplus and deficiency, and in identifying conditions of long-term overdraft.

As shown on **Table 31** and **Figure 55** below, there was an accumulated water supply deficiency of 2,428,487 AF over the 37-year study period, or an average deficit of 65,635 AF/WY.

Prior to 2000, a net surplus occurred throughout the Subbasin as calculated by this method, when inflows exceeded outflows by 323,000 AF, or an average of 17,900 AF/WY.

Between 1999 and 2017, when surface water supplies were occasionally unavailable and precipitation was low, the groundwater reservoir lost 2,176,000 AF, or an average of 143,000 AF/WY.

**Table 31: Change of Groundwater in Storage (Acre-Feet/WY)**

| Water Year | Total Inflow | Total Outflow | Inflow - Outflow | Cumulative Change in Storage |
|---|---|---|---|---|
| 1981 | 578,407 | 875,019 | (296,613) | **(296,613)** |
| 1982 | 1,033,218 | 590,880 | 442,338 | **145,725** |
| 1983 | 1,216,750 | 464,621 | 752,129 | **897,854** |
| 1984 | 849,328 | 873,998 | (24,670) | **873,184** |
| 1985 | 629,499 | 854,223 | (224,724) | **648,461** |
| 1986 | 993,150 | 529,801 | 463,349 | **1,111,809** |
| 1987 | 531,995 | 925,272 | (393,277) | **718,533** |
| 1988 | 583,340 | 966,953 | (383,613) | **334,919** |
| 1989 | 450,046 | 950,735 | (500,689) | **(165,770)** |
| 1990 | 428,276 | 979,969 | (551,692) | **(717,462)** |
| 1991 | 557,081 | 835,059 | (277,978) | **(995,440)** |
| 1992 | 512,440 | 971,114 | (458,674) | **(1,454,115)** |
| 1993 | 965,324 | 702,939 | 262,385 | **(1,191,730)** |
| 1994 | 530,796 | 956,997 | (426,201) | **(1,617,930)** |
| 1995 | 1,101,727 | 539,252 | 562,475 | **(1,055,455)** |
| 1996 | 917,345 | 660,958 | 256,386 | **(799,069)** |
| 1997 | 1,023,840 | 703,536 | 320,304 | **(478,765)** |
| 1998 | 1,164,159 | 398,369 | 765,791 | **287,026** |
| 1999 | 767,406 | 731,503 | 35,903 | **322,929** |
| 2000 | 795,440 | 789,818 | 5,622 | **328,550** |
| 2001 | 624,469 | 925,262 | (300,793) | **27,758** |
| 2002 | 678,906 | 969,061 | (290,155) | **(262,397)** |
| 2003 | 756,815 | 903,916 | (147,101) | **(409,498)** |
| 2004 | 589,036 | 1,034,025 | (444,990) | **(854,487)** |
| 2005 | 1,074,278 | 667,099 | 407,179 | **(447,309)** |
| 2006 | 1,072,676 | 666,545 | 406,131 | **(41,178)** |
| 2007 | 547,132 | 1,143,054 | (595,922) | **(637,100)** |
| 2008 | 656,721 | 1,079,896 | (423,174) | **(1,060,274)** |
| 2009 | 650,083 | 1,121,433 | (471,350) | **(1,531,624)** |
| 2010 | 947,309 | 803,915 | 143,394 | **(1,388,230)** |
| 2011 | 1,281,167 | 667,375 | 613,792 | **(774,438)** |
| 2012 | 662,047 | 1,040,730 | (378,682) | **(1,153,120)** |
| 2013 | 568,489 | 1,191,559 | (623,070) | **(1,776,190)** |
| 2014 | 539,217 | 1,246,520 | (707,303) | **(2,483,494)** |
| 2015 | 534,967 | 1,150,819 | (615,852) | **(3,099,346)** |
| 2016 | 713,134 | 903,004 | (189,870) | **(3,289,216)** |
| 2017 | 1,455,261 | 594,532 | 860,729 | **(2,428,487)** |
| **Maximum** | **1,455,261** | **1,246,520** | **860,729** | |
| **Minimum** | **428,276** | **398,369** | **-707,303** | |
| **Average** | **783,278** | **848,912** | **-65,635** | |

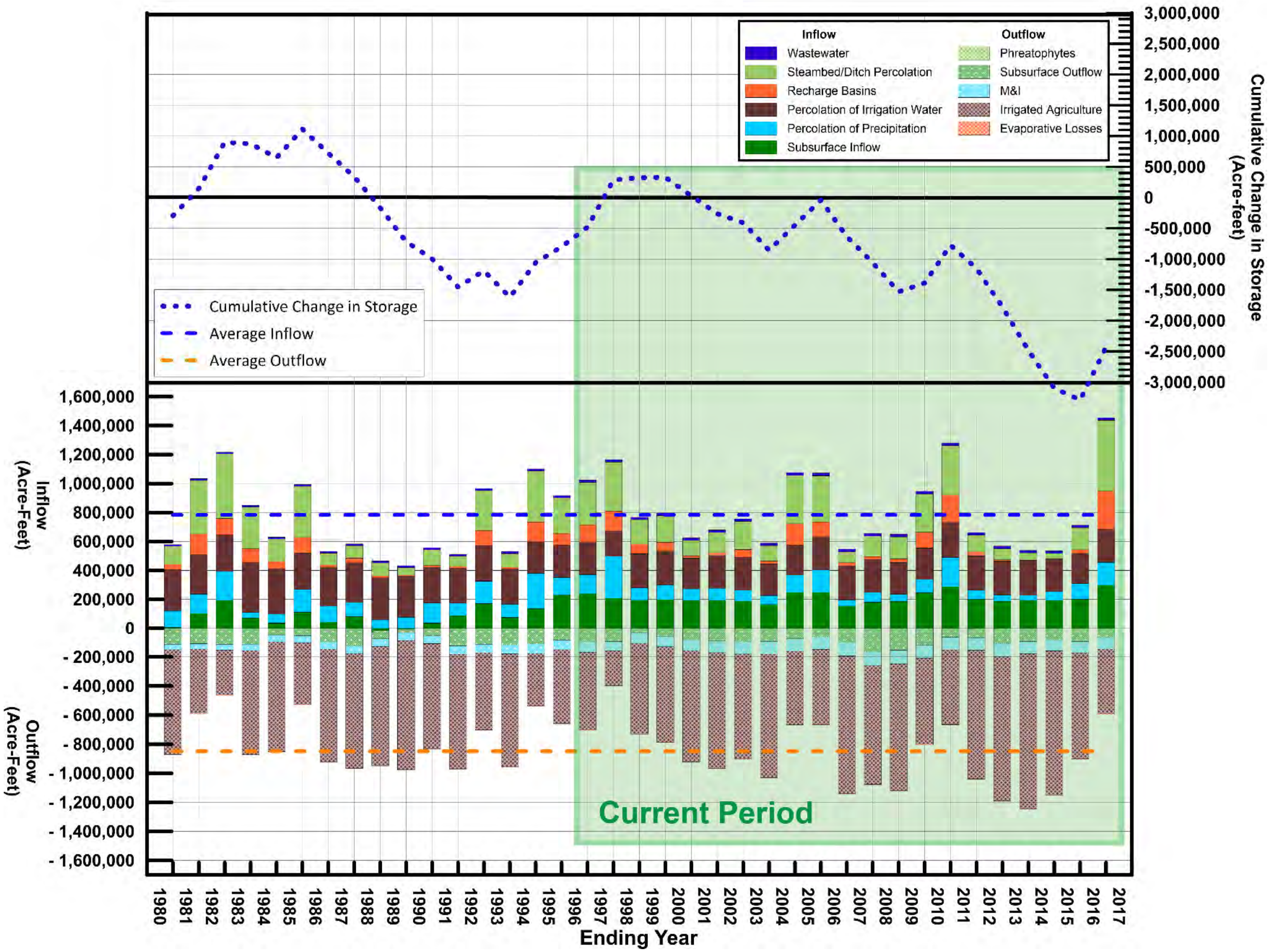



**Figure 55: Kaweah Subbasin Hydrologic Budget Summary, Historical and Current Periods**

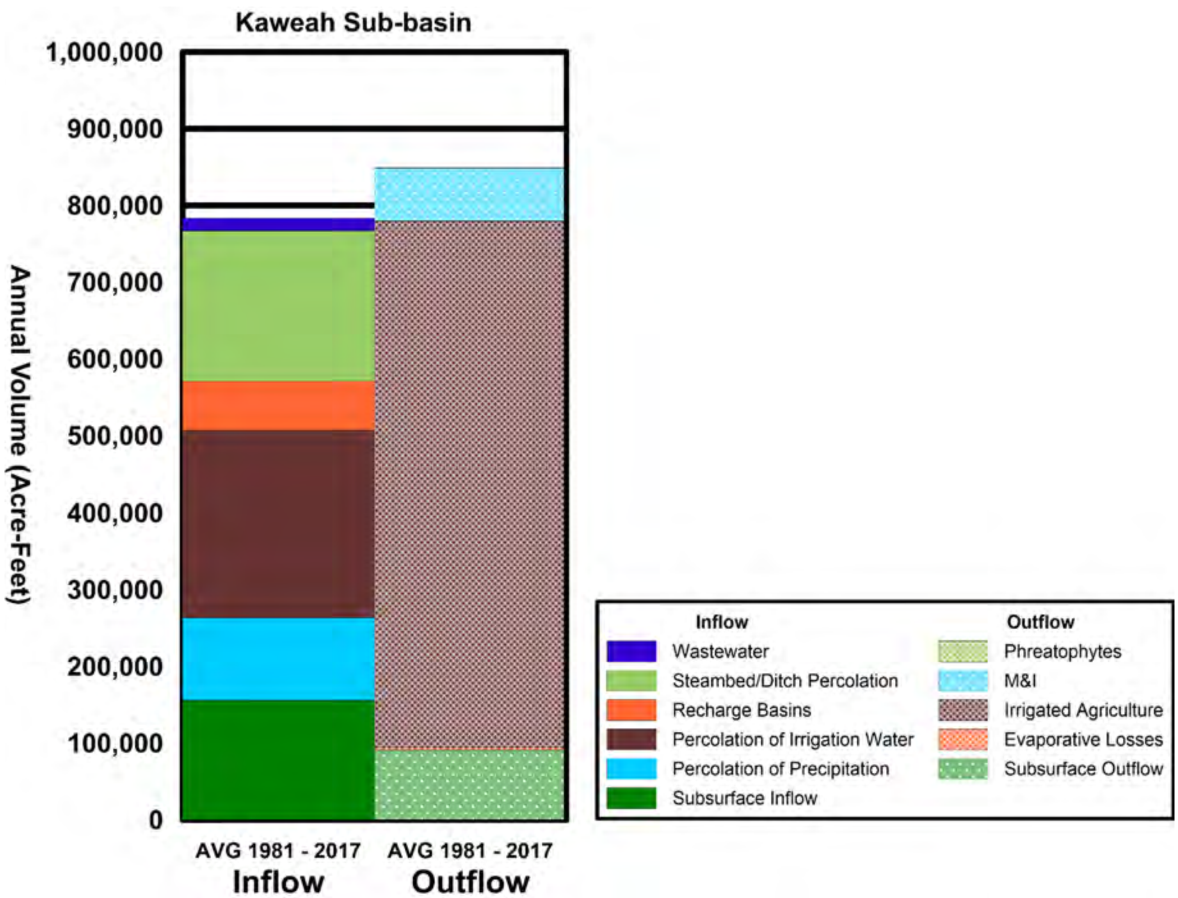



**Figure 56: Kaweah Subbasin Hydrologic Budget Average, Historical Period**

**Figure 56** presents the annual amounts of each component of deep percolation and extractions within the Subbasin as computed using the hydrologic equilibrium equation (the "inventory method"). The results of the water budget show that the Kaweah Subbasin is in a severe overdraft during the historical period of water years 1981 to 2017. The magnitude of the overdraft for the Kaweah Subbasin during the overall base period was 65,600 AF/WY on average, which increased to 142,900 AF/WY since 1999.

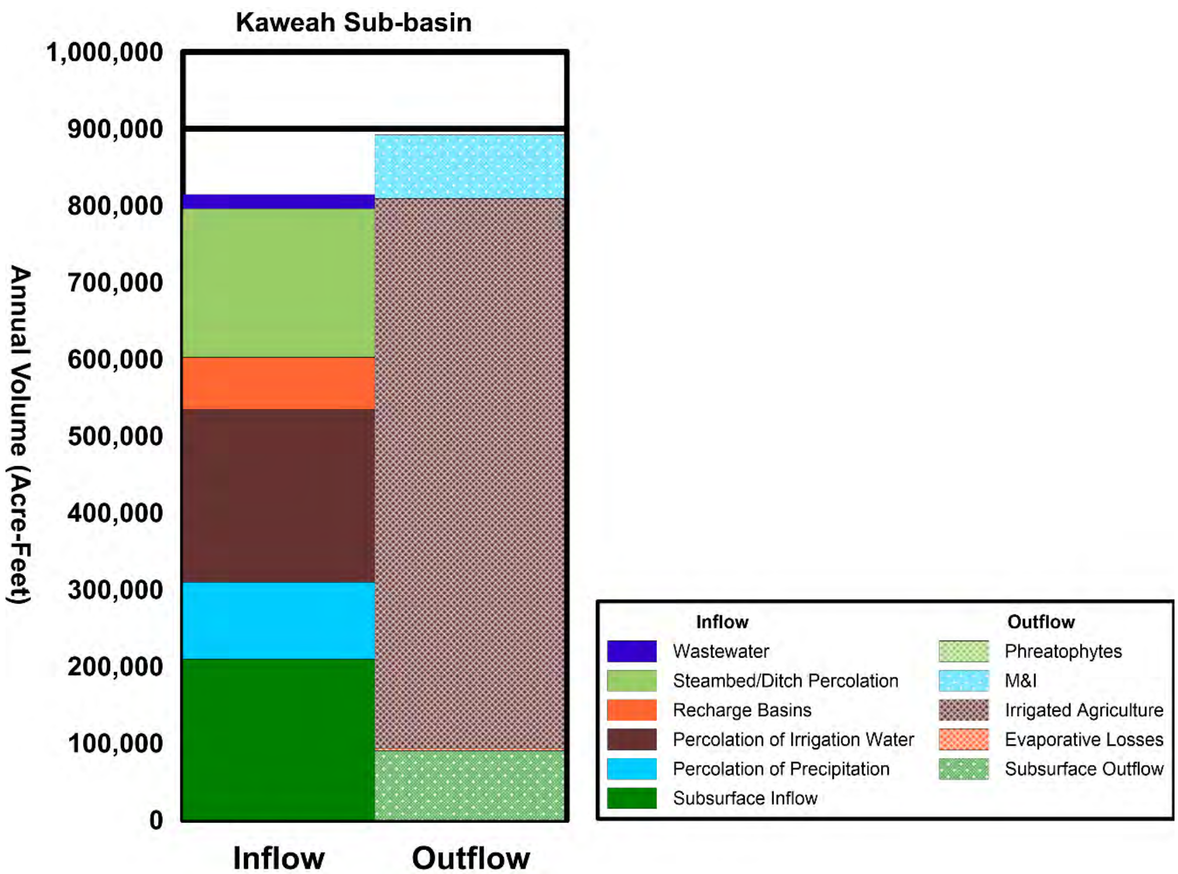



**Figure 54: Kaweah Subbasin Hydrologic Budget Average, Current Period**

**Figure 57** summarizes the current water budget components. The results of the water budget for the current water budget show the magnitude of the overdraft for the Kaweah Subbasin during the overall base period was is 77,600 AF/WY on average for the period 1997 to 2017. **Table 32** summarizes each component of the current water budget by year and shows a total decrease in storage during the period of 1.630 MAF.

**Table 32: Current Period - Estimated Deep Percolation, Extractions and Change in Storage - Kaweah Subbasin (values in 1,000s AF)**

| Water Year | Rainfall | | Components of Inflow | | | | | | Components of Outflow | | | | | | | | Total Inflow | Total Outflow | Change in Storage | Cumulative Change in Storage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Groundwater Pumpage | | | | | | | | | | | |
| | Inches | % of Average | Subsurface Inflow | Wastewater Inflow | Steambed Percolation and Conveyance Losses | Percolation of Recharge Basins | Percolation of Irrigation Water | Percolation of Precipitation (Crop and Non-Ag Land) | M & I | Gross Applied Irrigation Water (Crop Water Demand) | Delivered Surface Water | *GW Pumping for Irrigated Agriculture* | *Total Net Extraction* | Extraction by Phreatophytes | Evaporative Losses | Subsurface Outflow | *Total Inflow* | *Total Outflow* | *Inventory Method* | *Inventory Method* |
| 1997 | 12.5 | 128% | 238.9 | 16.1 | 292.1 | 118.5 | 226.8 | 131.5 | 70.5 | 970.4 | 442.1 | *532.7* | *603.2* | 0.6 | 3.3 | 96.5 | *1,023.8* | *703.5* | *320.3* | *320.3* |
| 1998 | 22.8 | 234% | 208.4 | 16.4 | 338.4 | 138.9 | 173.2 | 288.8 | 63.6 | 741.9 | 527.9 | *237.3* | *300.9* | 1.1 | 3.3 | 93.1 | *1,164.2* | *398.4* | *765.8* | *1,086.1* |
| 1999 | 9.6 | 99% | 194.1 | 17.0 | 168.5 | 67.0 | 234.8 | 86.0 | 70.9 | 953.8 | 356.2 | *622.6* | *693.5* | 0.5 | 2.1 | 35.4 | *767.4* | *731.5* | *35.9* | *1,122.0* |
| 2000 | 11.4 | 117% | 197.9 | 17.7 | 183.1 | 56.8 | 237.8 | 102.1 | 71.6 | 1,013.1 | 375.3 | *657.0* | *728.6* | 0.5 | 2.9 | 57.7 | *795.4* | *789.8* | *5.6* | *1,127.6* |
| 2001 | 10.1 | 103% | 192.0 | 18.1 | 106.3 | 14.4 | 213.6 | 80.1 | 75.7 | 1,016.8 | 250.5 | *766.3* | *842.0* | 0.5 | 2.8 | 80.0 | *624.5* | *925.3* | *-300.8* | *826.8* |
| 2002 | 10.4 | 107% | 192.2 | 17.9 | 138.1 | 20.3 | 226.1 | 84.3 | 80.1 | 1,072.7 | 282.0 | *796.2* | *876.3* | 0.5 | 2.8 | 89.4 | *678.9* | *969.1* | *-290.2* | *536.7* |
| 2003 | 8.7 | 90% | 187.7 | 18.6 | 193.9 | 53.1 | 228.2 | 75.2 | 82.3 | 1,061.0 | 339.8 | *721.3* | *803.6* | 0.4 | 3.0 | 96.9 | *756.8* | *903.9* | *-147.1* | *389.6* |
| 2004 | 8.0 | 82% | 164.5 | 19.0 | 105.1 | 19.0 | 219.7 | 61.8 | 87.3 | 1,087.7 | 239.5 | *850.6* | *937.8* | 0.4 | 2.4 | 93.4 | *589.0* | *1,034.0* | *-445.0* | *-55.4* |
| 2005 | 12.2 | 125% | 246.9 | 19.2 | 332.6 | 145.9 | 208.5 | 121.2 | 86.0 | 953.2 | 485.5 | *502.5* | *588.5* | 0.6 | 3.1 | 74.9 | *1,074.3* | *667.1* | *407.2* | *351.8* |
| 2006 | 15.4 | 159% | 247.3 | 19.6 | 317.6 | 102.6 | 230.5 | 155.0 | 87.3 | 981.9 | 488.4 | *512.5* | *599.7* | 0.7 | 4.8 | 61.3 | *1,072.7* | *666.5* | *406.1* | *757.9* |
| 2007 | 3.8 | 39% | 154.1 | 19.4 | 73.8 | 21.9 | 236.6 | 41.4 | 92.0 | 1,110.1 | 169.2 | *946.9* | *1,038.9* | 0.2 | 2.5 | 101.4 | *547.1* | *1,143.1* | *-595.9* | *162.0* |
| 2008 | 5.0 | 52% | 180.8 | 19.7 | 140.9 | 18.8 | 229.8 | 66.7 | 93.6 | 1,101.4 | 286.4 | *816.8* | *910.5* | 0.2 | 3.0 | 166.2 | *656.7* | *1,079.9* | *-423.2* | *-261.2* |
| 2009 | 6.4 | 66% | 186.6 | 19.4 | 151.0 | 24.3 | 220.4 | 48.5 | 93.6 | 1,154.2 | 285.2 | *870.5* | *964.2* | 0.3 | 3.0 | 154.0 | *650.1* | *1,121.4* | *-471.4* | *-732.6* |
| 2010 | 11.1 | 114% | 246.0 | 19.5 | 264.0 | 109.2 | 216.8 | 91.7 | 91.2 | 1,022.2 | 446.5 | *590.8* | *681.9* | 0.5 | 4.0 | 117.5 | *947.3* | *803.9* | *143.4* | *-589.2* |
| 2011 | 13.7 | 140% | 288.1 | 19.4 | 340.7 | 188.9 | 243.3 | 200.8 | 88.5 | 1,014.5 | 536.7 | *511.5* | *599.9* | 0.6 | 3.8 | 63.0 | *1,281.2* | *667.4* | *613.8* | *24.6* |
| 2012 | 4.4 | 45% | 199.9 | 19.2 | 116.3 | 26.1 | 236.2 | 64.4 | 85.9 | 1,103.6 | 220.1 | *883.5* | *969.4* | 0.2 | 2.9 | 68.3 | *662.0* | *1,040.7* | *-378.7* | *-354.1* |
| 2013 | 4.4 | 45% | 187.3 | 19.0 | 75.4 | 8.1 | 236.1 | 42.6 | 89.2 | 1,125.6 | 133.7 | *992.3* | *1,081.5* | 0.2 | 2.2 | 107.6 | *568.5* | *1,191.6* | *-623.1* | *-977.1* |
| 2014 | 4.7 | 48% | 193.7 | 18.8 | 50.0 | 0.3 | 242.8 | 33.6 | 83.7 | 1,146.5 | 80.9 | *1,065.5* | *1,149.2* | 0.2 | 3.2 | 93.9 | *539.2* | *1,246.5* | *-707.3* | *-1,684.4* |
| 2015 | 6.2 | 63% | 191.7 | 18.0 | 37.2 | 0.4 | 225.3 | 62.4 | 76.4 | 1,055.7 | 65.8 | *989.9* | *1,066.3* | 0.3 | 2.1 | 82.1 | *535.0* | *1,150.8* | *-615.9* | *-2,300.3* |
| 2016 | 9.8 | 100% | 200.8 | 17.6 | 152.2 | 25.2 | 208.9 | 108.4 | 78.4 | 964.4 | 239.9 | *727.7* | *806.1* | 0.5 | 2.8 | 93.6 | *713.1* | *903.0* | *-189.9* | *-2,490.1* |
| 2017 | 14.0 | 143% | 296.6 | 18.3 | 489.3 | 261.1 | 231.8 | 158.1 | 80.0 | 952.7 | 583.9 | *443.4* | *523.4* | 0.7 | 4.0 | 66.5 | *1,455.3* | *594.5* | *860.7* | *-1,629.4* |
| Maximum | 22.8 | 234% | 296.6 | 19.7 | 489.3 | 261.1 | 243.3 | 288.8 | 93.6 | 1,154.2 | 583.9 | 1,065.5 | 1,149.2 | 1.1 | 4.8 | 166.2 | 1,455.3 | 1,246.5 | 860.7 | -81470.9 |
| Minimum | 3.8 | 39% | 154.1 | 16.1 | 37.2 | 0.3 | 173.2 | 33.6 | 63.6 | 741.9 | 65.8 | 237.3 | 300.9 | 0.2 | 2.1 | 35.4 | 535.0 | 398.4 | -707.3 | |
| **Average** | **9.7** | **100%** | **209.3** | **18.5** | **193.6** | **67.7** | **225.1** | **100.2** | **82.3** | **1,028.7** | **325.5** | **716.1** | **798.4** | **0.5** | **3.1** | **90.1** | **814.4** | **892.0** | **-77.6** | |
| % of Total | | | 26% | 2% | 24% | 8% | 28% | 12% | 9% | | | 80% | | 0.05% | 0.34% | 10% | | | | |
| | | | 100% | | | | | | 100% | | | | | | | | | | | |

*Italic* = Calculation
= Component of Inflow
= Component of Outflow

### *Specific Yield*

One additional method of determining the annual change of groundwater in storage involves use of the specific yield method, which is based on water level contour maps created for key years throughout the Subbasin. To that end, groundwater contour maps were prepared for every year of the historical period by plotting water level data and accurately contouring the water surfaces. The contours of the water level surfaces represent spring conditions, based on as many as 655 wells evenly distributed throughout the Subbasin.

The storage calculations involved creating automated routines in GIS to develop a gridded surface, which were used to calculate the changes in water levels between the spring period of three key years of 1981, 1999 and 2017. The water surface changes were then integrated with the specific yield data available for the basin and described in Section 2.1.6.2 Physical Characteristics to calculate total change in basin storage.

Results of the analysis indicated that water levels declined by a total of 74 feet during the 37-year historic period on average throughout the Subbasin. During this period, a water supply deficiency of 3,127,300 AF has occurred, which is equal to an average rate of decline of 84,500 AF/WY. During the more recent (modeling) period since 2000, the water supply deficiency was approximately 2,948,600 AF, which is equal to a higher average rate of decline of 163,800 AF/WY. During this modeling period, water levels declined by a total of 70 feet on average throughout the subbasin. The results indicate that the water budget and specific yield methods are in general agreement, indicating that water supply deficiency in the Subbasin during the historical period was between 2,430,000 AF (water budget method) and 3,127,000 AF (specific yield method). During the more-recent modeling period since 2000, when water budget (inventory method) data quality is higher and thought to be more reliable, the agreement between the two methods is much better. During this modeling period the total water supply deficit was between 2,660,000 and 2,950,000 AF, or roughly 148,000 to 155,000 AF/WY.

### *Safe Yield*

The safe or perennial yield of a groundwater basin, when discussed in SGMA, is defined as the volume of groundwater that can be pumped on a long-term average basis without producing an undesirable result. Long-term withdrawals in excess of safe yield is considered overdraft. While the definition of "undesirable results" mentioned in the definition have changed in recent years and have now been codified in SGMA regulations, they are recognized to include not only the depletion of groundwater reserves, but also deterioration in water quality, unreasonable and uneconomic pumping lifts, creation of conflicts in water rights, land subsidence, and depletion of streamflow by induced infiltration (Freeze and Cherry, 1979). It should be recognized that the concepts of safe yield and overdraft imply conditions of water supply and use over a long-term period. Given the importance of the conjunctive use of both surface water and groundwater in the Subbasin, short-term water supply differences are satisfied by groundwater pumpage, which in any given year, often exceed the safe yield of the Subbasin. The Subbasin, however, has a very large amount of groundwater in storage that can be used as carryover storage during years when there is little natural recharge, and replaced in future years by reduced pumping (when surface water is available instead or from various types of projects, including, for instance, artificial recharge), or by groundwater recharge projects.

While safe yield of the Subbasin is difficult to estimate due to the inherent uncertainties in the estimates of recharge and discharge, there are several methods available to estimate the safe yield under the conditions of water supply and use that prevailed during the 37-year historical base period. Use of these methods requires acknowledgement of the inherent uncertainties in the estimates of recharge and discharge as well as the challenges associated with calculating the changes of groundwater in storage in the confined "pressure" area of the Subbasin.

The first methods assumes that the safe yield is equal to the long-term recharge inflow, calculated as the total inflow minus the annual overdraft. Although there are considerable assumptions used to estimate each component of inflow in the hydrologic equation, the results of this method suggest that the safe yield of the Subbasin would be approximately 717,800 AF/WY (summation of the components of inflow, that is 783,300 AF/WY, less the average annual overdraft, which is about 65,600 AF/WY). This average is approximate and does not encompass the non-uniformity in safe yield application across the entire basin. Based on the water budget for the historical period, discharge from the Subbasin exceeded recharge by some 65,600 AF/WY, resulting in a decline in water levels. Imbalances of pumping demand related to patterns of land use over the base period are apparent, which created a progressive lowering of water levels.

A second method to estimate the safe yield is to compare the annual extractions over the base period to the net changes of groundwater in storage. The resulting graphs provide the rate of extraction in which there is a zero-net change of groundwater in storage. This method, the so-called "practical rate of withdrawal," is a useful method so long as the coefficient of correlation between annual pumpage and storage changes is sufficiently robust and the calculated annual values of inflow and outflow are relatively accurate. Estimates compiled for this GSP are believed to be reasonably accurate in the estimates of annual groundwater extractions. Likewise, annual storage change estimates are also believed to be reasonably accurate, based on the distribution of wells and frequency of water level measurements. As presented on **Figure 58**, the intercept of zero storage change occurs at an annual pumpage of about 723,000 AFY, implying that net annual groundwater extractions at this approximate amount would produce no change of groundwater in storage.

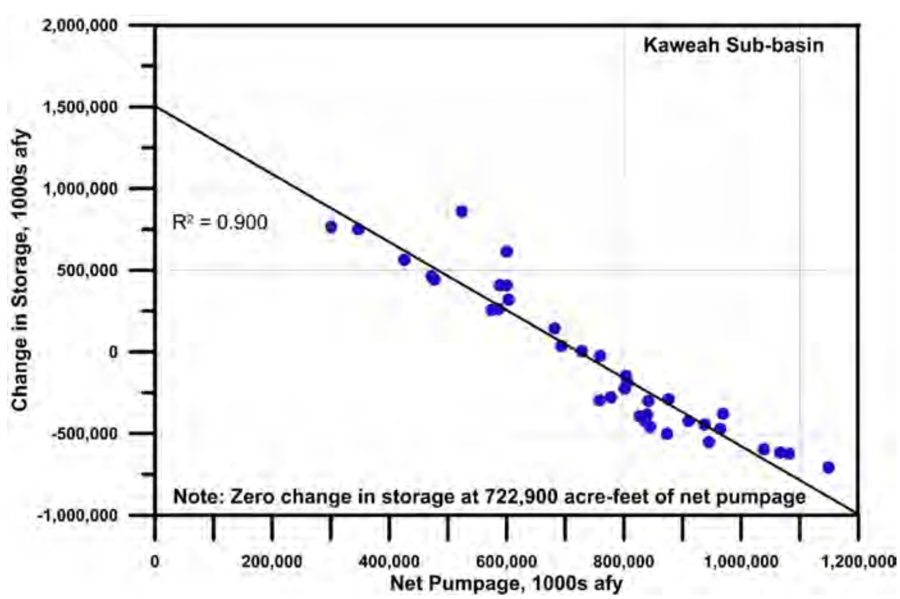



**Figure 58. Practical Rate of Withdrawal**

A summary of the safe yield estimates is provided in **Table 33**, which indicates that the safe yield of the Kaweah Subbasin is approximately 720,000 AFY. Based on the above, under the current conditions of development and water supply, it is apparent that the Subbasin is in a condition of overdraft.

**Table 33: Estimated Safe Yield, Historical Period (AFY)**

| Method | Safe Yield |
|---|---|
| Long-term Recharge | 717,800 |
| Practical Rate of Withdrawal | 722,900 |

The estimates of safe yield will be refined with the forthcoming predictive numerical model runs with the Kaweah Subbasin groundwater model and will then will also be re-visited through the planning and implementation phase of the SGMA process. Furthermore, the safe yield estimate will likely be superseded by forthcoming sustainable yield values for the basins to avoid undesirable results and achieve measurable objectives.

## 2.5.2 Projected/Future Water Budget

The GSP regulations require the following regarding Projected water budgets:

> "Projected water budgets shall be used to estimate future baseline conditions of supply, demand, and aquifer response to Plan implementation, and to identify the uncertainties of these projected water budget components."
>
> "Projected hydrology shall utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology…"
>
> "Projected water demand shall utilize the most recent land use, evapotranspiration, and crop coefficient information as the baseline condition for estimating future water demand…"
>
> "Projected surface water supply shall utilize the most recent water supply information as the baseline condition for estimating future surface water supply. The projected surface water supply shall also be applied as the baseline condition used to evaluate future scenarios of surface water supply availability and reliability as a function of the historical surface water supply identified in Section 354.18(c)(2)(A), and the projected changes in local land use planning, population growth, and climate."

The subsurface inflow and outflow components of the future water budget in the Kaweah Subbasin will be estimated through application of the numerical groundwater model. Alternative future water supply and demand scenarios will be developed in coordination with the GSA managers as input to the numerical groundwater model. This section briefly describes the estimated components of the future water budget impacted by climate change and legal/environmental water reallocations on supply availability and projected water demands.

#### 2.5.2.1 Climate Change Analysis and Results

SGMA requires local agencies developing and implementing GSPs to include water budgets which assess the current, historical, and projected water budgets for the basin, including the effects of climate change. Additional clarification can be found in DWR's Water Budget and Modeling BMPs which describe the use of climate change data to compute projected water budgets and simulate related actions in groundwater/surface water models. DWR has also provided SGMA Climate Change Data and published a Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development (Guidance Document) as the primary source of technical guidance.

The DWR-provided climate change data are based on the California Water Commission's Water Storage Investment Program (WSIP) climate change analysis results which used global climate models and radiative forcing scenarios recommended for hydrologic studies in California by the Climate Change Technical Advisory Group (CCTAG). Climate data from the recommended GCM models and scenarios have also been downscaled and aggregated to generate an ensemble time series of change factors which describe the projected change in precipitation and evapotranspiration values for climate conditions that are expected to prevail at mid-century and late-century, centered around 2030 and 2070, respectively. The DWR dataset also includes two additional simulation results for extreme climate scenarios under 2070 conditions. Use of the extreme scenarios which represent Drier/Extreme Warming (2070DEW) and Wetter/Moderate Warming (2070WMW) conditions in GSPs is optional.

This section describes the retrieval, processing, and analysis of DWR-provided climate change data to project the impact of climate change on precipitation, evapotranspiration, upstream inflow, and imported flows in the Kaweah Subbasin under 2030 and 2070 conditions. The precipitation and evapotranspiration change projections are computed relative to a baseline period of 1981 to 2010 and are summarized for the EKGSA, GKGSA and MKGSA areas. For upstream inflow into Kaweah Lake and imported water from the Friant-Kern Canal, change projections are computed using a baseline period of 1981 to 2003. The choice of baseline periods was selected based on the baseline analysis period for the Basin Settings report (which includes water years from 1981 to 2017), and the available of concurrent climate projections (calendar years 1915 to 2011) and derived hydrologic simulations (water years 1922 to 2011) from the SGMA Data Viewer.

##### *Data Processing*

The 2030 and 2070 precipitation and ET data are available on 6 km resolution grids. The climate datasets have also been run through a soil moisture accounting model known as the Variable Infiltration Capacity (VIC) hydrology model and routed to the outlet of subbasins defined by 8-digit Hydrologic Unit Codes (HUCs). The resulting downscaled hydrologic time series are available also on the SGMA Data Viewer hosted by DWR. Precipitation and ET data used in this analysis were downloaded from the SGMA Data Viewer for 69 climate grid cells covering the Kaweah Subbasin. Separate monthly time series of change factors were developed for each of the three Kaweah Subbasin GSAs by averaging grid cell values covering each GSA area. Monthly time series of change factors for inflow into Kaweah Lake and flow diversions from the Friant-Kern Canal were similarly retrieved from the SGMA Data Viewer. Mean monthly and annual values were computed from the subbasin time series to show projected patterns of change under 2030 and 2070 conditions.

## *Projected Future Changes in Evapotranspiration*

Crops require more water to sustain growth in a warmer climate, and this increased water requirement is characterized in climate models using the rate of evapotranspiration. Under 2030 conditions, all three GSAs in the Kaweah Subbasin are projected to experience annual increases of 3.2% relative to the baseline period. ***Table 34; Figures 59 and 60*** signify the largest monthly changes would occur in Winter and early Summer with projected increases of 4.3% to 4.8% in January and 3.8% to 4% in June. Under 2070 conditions, annual evapotranspiration is projected to increase by 8.2% relative to the baseline period in all three GSA areas. The largest monthly changes would occur in December with projected increases of between 12.8% to 13.5%. Summer increases peak approximately 8% in May and June.

**Table 34: Summary of Projected Changes in Evapotranspiration**

| | East Kaweah | Greater Kaweah | Mid-Kaweah | Largest Monthly Change | Month of Largest Change |
|---|---|---|---|---|---|
| Projected ET Change 2030 | 103.2% | 103.2% | 103.2% | 4.6% | Jan |
| Projected ET Change 2070 | 108.2% | 108.2% | 108.2% | 13.5% | Dec |

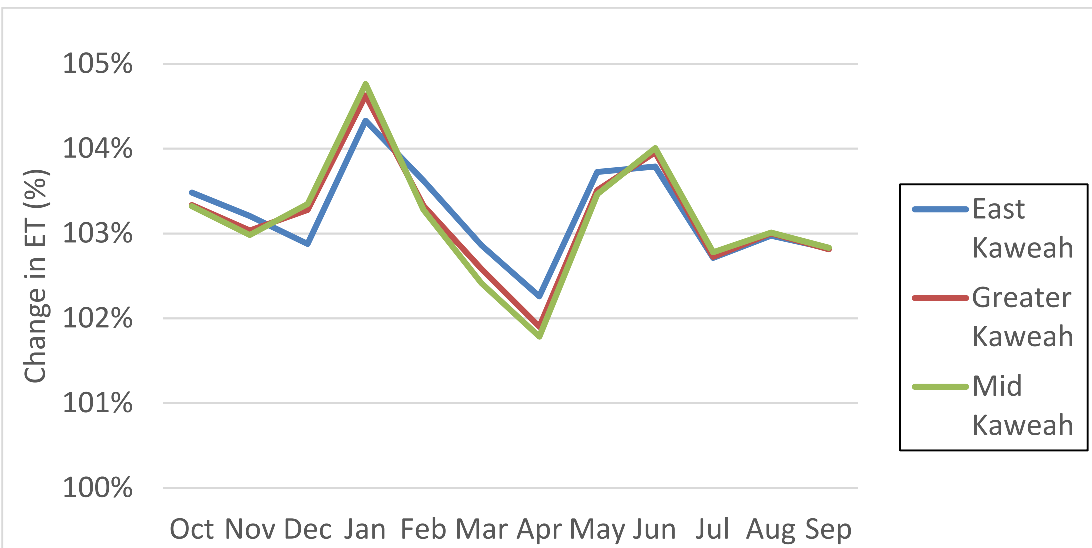



**Figure 59: Evapotranspiration Projections under 2030 Conditions**

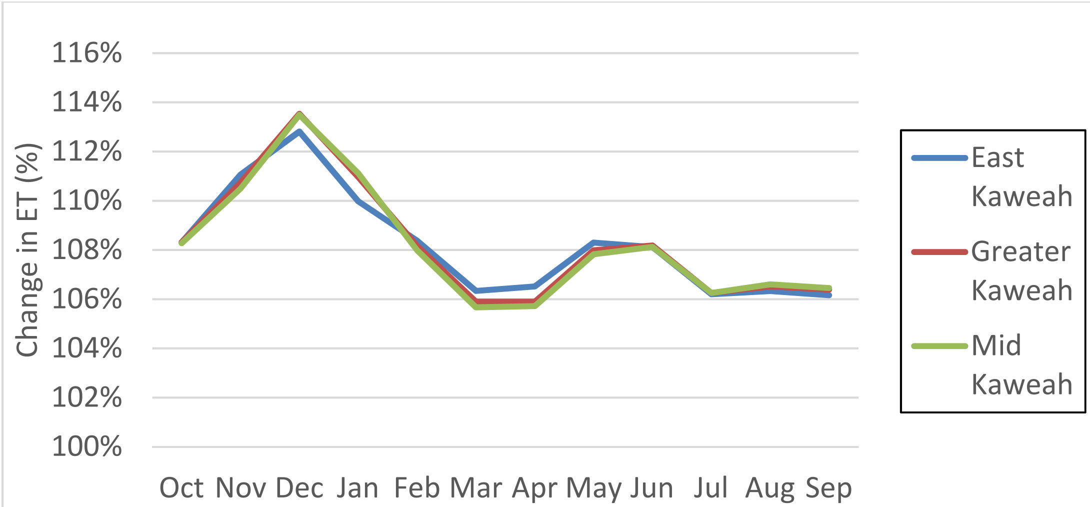



**Figure 60: Evapotranspiration Projections under 2070 Conditions**

## *Projected Future Changes in Precipitation*

The seasonal timing of precipitation in the Kaweah Subbasin is projected to change. Sharp decreases are projected early Fall and late Spring precipitation accompanied by increases in Winter and Summer precipitation. ***Table 35; Figures 61 and 62*** display that under 2030 conditions, the largest monthly changes would occur in May with projected decreases of 14% while increases of approximately 9% and 10% are projected in March and August, respectively. Under 2070 conditions, decreases of up to 31% are projected in May while the largest increases are projected to occur in September (25%) and January (17%). All three GSA areas are projected to experience minimal changes in total annual precipitation. Annual increases in annual precipitation of 0.8% or less under 2030 conditions relative to the baseline period. Under 2070 conditions, small decreases in annual precipitation are projected with changes ranging from 0.6% in East Kaweah to 1.7% in Greater Kaweah and 1.9% in Mid-Kaweah.

**Table 35: Summary of Projected Changes in Precipitation**

| | East Kaweah | Greater Kaweah | Mid-Kaweah | Largest Monthly Change | Month of Largest Change |
|---|---|---|---|---|---|
| Projected Precipitation Change 2030 | 100.4% | 100.8% | 100.8% | -14% | May |
| Projected Precipitation Change 2070 | 99.4% | 98.3% | 98.1% | 25% | Sep |

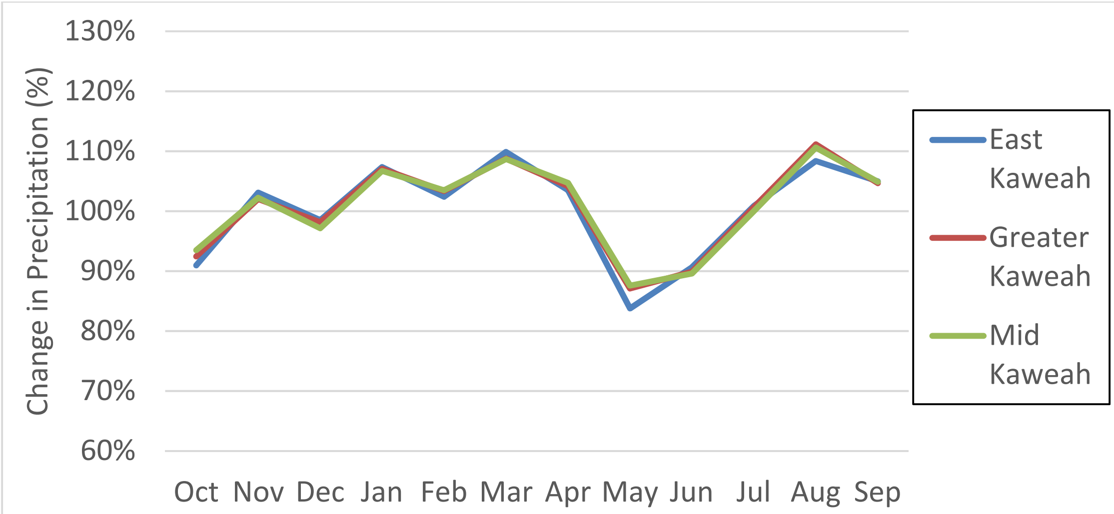



**Figure 61: Precipitation Projections under 2030 Conditions**

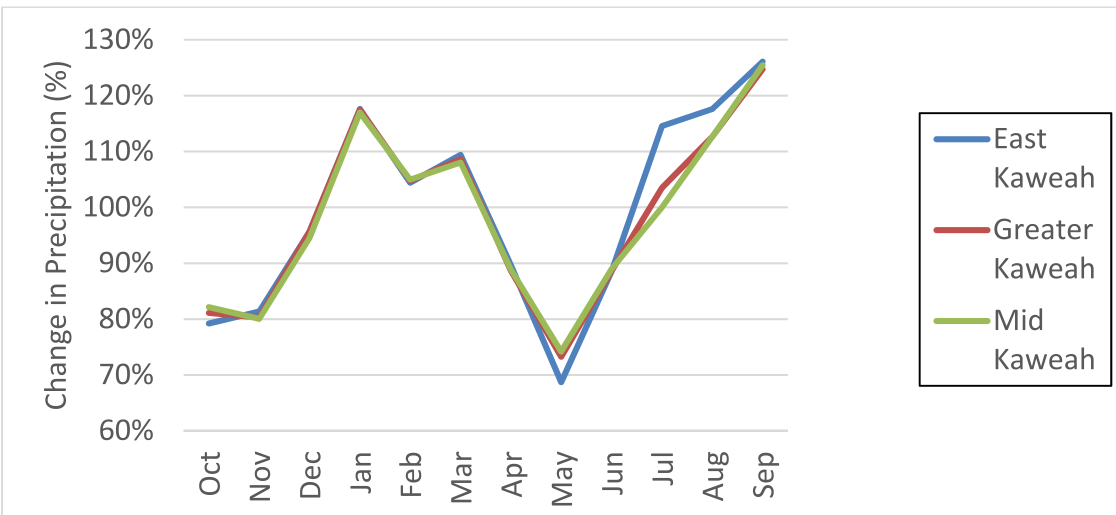



**Figure 62: Precipitation Projections under 2070 Conditions**

## *Projected Future Changes in Full Natural Flow*

The quantity of inflows into Kaweah Lake, which is the main source of local water, are projected to decrease from 465 thousand acre-feet (TAF) per year under current climate conditions to 442 TAF under both 2030 and 2070 conditions. ***Figure 63*** shows peak flows are similarly projected to decrease from monthly peaks of 102 TAF under current climate conditions to 82 TAF by 2030 followed by a minimal decline to 81 TAF under 2070 conditions. However, significant changes in the seasonal timing of flows are expected. Under current and 2030 conditions, the monthly inflows into the reservoir are projected to peak in May. By 2070, inflows are projected to occur much earlier in the water year, with peak monthly inflows occurring in March.

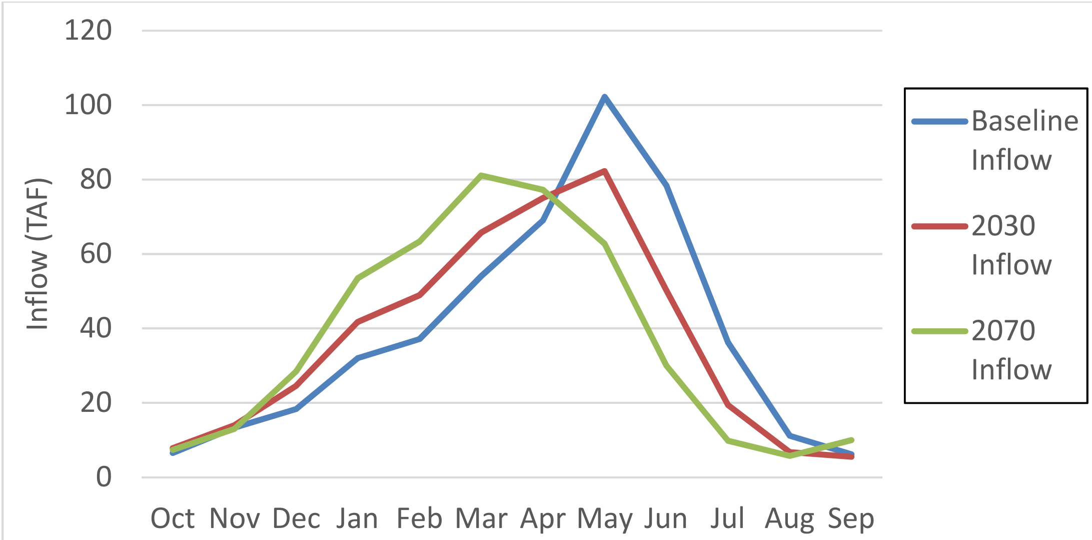



**Figure 63: Projected Average Inflow into Kaweah Lake**

## *Projected Future Changes in Imported Flow Diversions*

Climate change could also impact the quantity and timing of imported water delivered to the Kaweah Subbasin from the CVP and the Kings River Basin. The Friant Water Authority has developed an analysis documented in a spreadsheet and a technical memorandum (***Appendix D***) showing the impact of climate change and the San Joaquin River Restoration Program (SJRRP) on water deliveries to the Friant-Kern Canal. The memorandum which is intended for use by water contractors preparing estimates of future Friant Division supplies in their groundwater sustainability plans summarizes results for five climate change conditions including:

2015 Conditions which represents a historical hydrology modified to match climate and sea level conditions for a thirty-year period centered at 1995 with a reference climate period of 1981 – 2010,

Near-Future 2030 Central Tendency which represents a 2030 future hydrology with projected climate and sea level conditions for a thirty-year period centered at 2030 with a reference climate period of 2016 – 2045,

Late-Future 2070 Central Tendency which represents a 2070 future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 with a reference climate period of 2056 – 2085,

Late-Future 2070 Drier/Extreme Warming Conditions (DEW) which represents a 2070 DEW future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 with a reference climate period of 2056 – 2085, and

Late-Future 2070 Wetter/Moderate Warming Conditions (WMW) which represents a 2070 WMW future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 with a reference climate period of 2056 – 2085.

The five scenarios analyzed also reflect progressive changes in implementation of the SJRRS Restoration and Water Management Goals which also have a direct effect on Friant Division water supplies. Under the 2015 scenario, implementation of the SJRRS Restoration Goal is limited because of capacity restrictions in the San Joaquin River below Friant Dam, and the need for further buildout of groundwater infiltration facilities to take full advantage wet year supplies limits implementation of the SJRRS Water Management Goals. Restrictions on implementation are expected to remain in place until 2025. The 2030 and 2070 scenarios assume full implementation of the Reclamation's Funding Constrained Framework of the SJRRS.

***Table 36*** shows future projections of water deliveries to the Kaweah Subbasin from Friant with climate change and SJRRP implementation. The results indicate that relative to baseline conditions, the central tendency of water deliveries from the Friant-Kern system to the Kaweah Subbasin would decrease by 8.5% to 154.4 TAF under 2030 conditions and by 16.8% to 140.4 TAF under 2070 conditions. The two extreme climate conditions for 2070 would results in a 37.9% decrease to 104.7 TAF for the Drier/Extreme Warming Conditions and a 10.4% increase to 186.3 TAF for the Wetter/Moderate Warming Conditions, respectively. These projections suggest that the Kaweah subbasin needs to prepare for decreasing water deliveries from Friant in the Near-Future and under most scenarios in the Far-Future.

**Table 36: Future Projections of Water Deliveries to the Kaweah Subbasin from Friant with Climate Change and SJRRP Implementation**

| Future Projections of Kaweah Imports from Friant with SJRRP | | | | | |
|---|---|---|---|---|---|
| **Model Run** | **Scenario Description** | **Class 1 (TAF/yr)** | **Class 2 / Other (TAF/yr)** | **16B and Recapture (TAF/yr)** | **Total Delivery (TAF/yr)** |
| **2015.c** | Applies 2015 Climate Conditions and assumes implementation of SJRRS is limited by downstream capacity limitations. | **105.5** | **37.5** | **25.6** | **168.7** |
| **2030.c** | Applies the Near-Future 2030 Central Tendency climate conditions and assumes Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018). | **101.6** | **22.6** | **30.1** | **154.4** |
| **2070.c** | Applies the Late-Future 2070 Central Tendency climate conditions and assumes Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018). | **95.9** | **13.7** | **30.8** | **140.4** |
| **2070 DEW.c** | Applies the Late-Future 2070 Drier/Extreme Warming climate conditions and assumes Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018). | **76.7** | **3.1** | **24.8** | **104.7** |
| **2070 WMW.c** | Applies the Late-Future 2070 Wetter/Moderate Warming climate conditions and assumes Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018). | **109.9** | **30.0** | **46.4** | **186.3** |

Full natural flow of the Kings River at Pine Flat Dam is projected to decrease from 1,751 TAF under baseline conditions to 1,733 TAF under 2030 conditions and 1,731 TAF by 2070. The relative change in water supply is so small that Kings River water deliveries to Kaweah Subbasin would be assumed to remain unchanged at 13 TAF under both 2030 and 2070 conditions (***Table 37***).

**Table 37. Summary of Projected Water Balance under 2030 and 2070 Conditions**

| | Annual Water Supply and Demand (TAF/yr) | | |
|---|---|---|---|
| Changes in Primary Water Sources | Baseline | 2030 | 2070 |
| Upstream Inflow into Kaweah Lake | 465 | 442 | 442 |
| Total CVP Friant-Kern Canal Diversions | 1200 | 1093 | 991 |
| Total Kings River Full Natural Flow | 1751 | 1733 | 1731 |
| | | | |
| Surface Water Supply in Kaweah | | | |
| Rain Percolation (Cropland + Non-Ag) | 118 | 119 | 116 |
| Upstream Inflow Available for Kaweah | 365 | 347 | 347 |
| Imported Water CVP Friant-Kern Canal | 169 | 154 | 140 |
| Imported Water Kings River | 13 | 13 | 13 |
| Total Surface Water Supply in Kaweah | 672 | 625 | 603 |
| | | | |
| Water Demand in Kaweah | | | |
| Crop Water Demand | 1004 | 1036 | 1086 |
| Municipal & Industrial Demand | 69 | 69 | 69 |
| Total Water Demand in Kaweah | 1073 | 1105 | 1155 |
| Total Water Deficit in Kaweah | 408 | 472 | 539 |

#### *2.5.2.2 Projected Future Demand Estimates*

Based upon the historical and current water budget, the total water demands within the Subbasin were estimated for the future demand period extending 50 years into the future through 2070. To estimate total demand for this period,  two components of demand were considered. These components include extraction from the groundwater reservoir and agriculture and M&I pumping.

#### *Projected Future Agricultural Demand*

For the base period, irrigated agriculture demand averaged 1,055,700 AF/WY, which was satisfied by a combination of surface water and groundwater. Recent crop survey data indicate that this demand is from a variety of crops including almonds, alfalfa, citrus, cotton, grapes, olives, truck crops, walnuts, wheat and several others (Davids Engineering, 2018). Crop ET was derived for each of these crops for each year during the recent period of 1999 to 2017, based upon trends in water use for each crop. During the period, total water demand related to the growing of almonds has increased by 14 percent, while total water demand to satisfy miscellaneous field crops has declined by 18 percent. By considering all of the trends for a total of 16 crop categories on a net basis, the average change in crop water ET demand has been relatively unchanged, increasing modestly each year between 1999 and 2018.

Future projection of crop demand to 2040 and 2070 indicates that agricultural demand will increase to 1,138,200 AF/WY in 2030 and 1,239,500 AF/WY in 2070, which includes projected climate change affects.

#### *Projected Future M&I and Other Demands*

This section briefly summarizes future M&I demands as well as other demands not included in M&I. These other demands include dairies, small water systems, rural domestic, golf courses and nursery users. To estimate future M&I demands, GEI reviewed the 2015 Urban Water Management Plans for the Cities of Visalia, Tulare, along with California Department of Finance population projections.

***Table 38 demonstrates*** future M&I and other demands in the Kaweah Subbasin. As shown, 76,400 AF/WY in 2015 was met with groundwater pumping.  M&I and other demand is projected to increase to 126,421 AF/WY in 2030 and 186,445 AF/WY in 2070.

**Table 38: Projected Water Demand (AF/WY)**

| | 2015 Demand | Estimated 2040 Demand | Estimated 2070 Demand |
|---|---|---|---|
| Irrigation Demand | 1,055,737 | 1,138,249 | 1,239,447 |
| Tulare | 9,055 | 20,372 | 33,952 |
| Visalia | 27,453 | 54,987 | 88,028 |
| Exeter | 1,825 | 2,336 | 2,949 |
| Farmersville | 822 | 1,052 | 1,328 |
| Ivanhoe | 694 | 888 | 1,122 |
| Woodlake | 1,688 | 2,161 | 2,728 |
| Lindsay | 518 | 663 | 837 |
| Other Demand 2 | 34,345 | 43,961 | 55,501 |
| Total M&I and Other | 76,400 | 126,421 | 186,445 |
| **Total** | **1,132,137** | **1,264,670** | **1,425,892** |
| **Change** | **--** | **132,533** | **293,755** |

Notes: 1. This period selected for consistency with climate change datasets provided by DWR (DWR, 2018)
2. Other demand includes dairies, small water systems, rural domestic, golf courses, and nursery users

***Figure 64*** shows the increase in total Agricultural and M&I demand from 1,132,137 AF/WY in 2015, to 1,425,892 AF/WY in 2070, a 26% increase over the 50-year period. This increased demand results from increases in all three categories of users: agricultural, M&I and other demands.

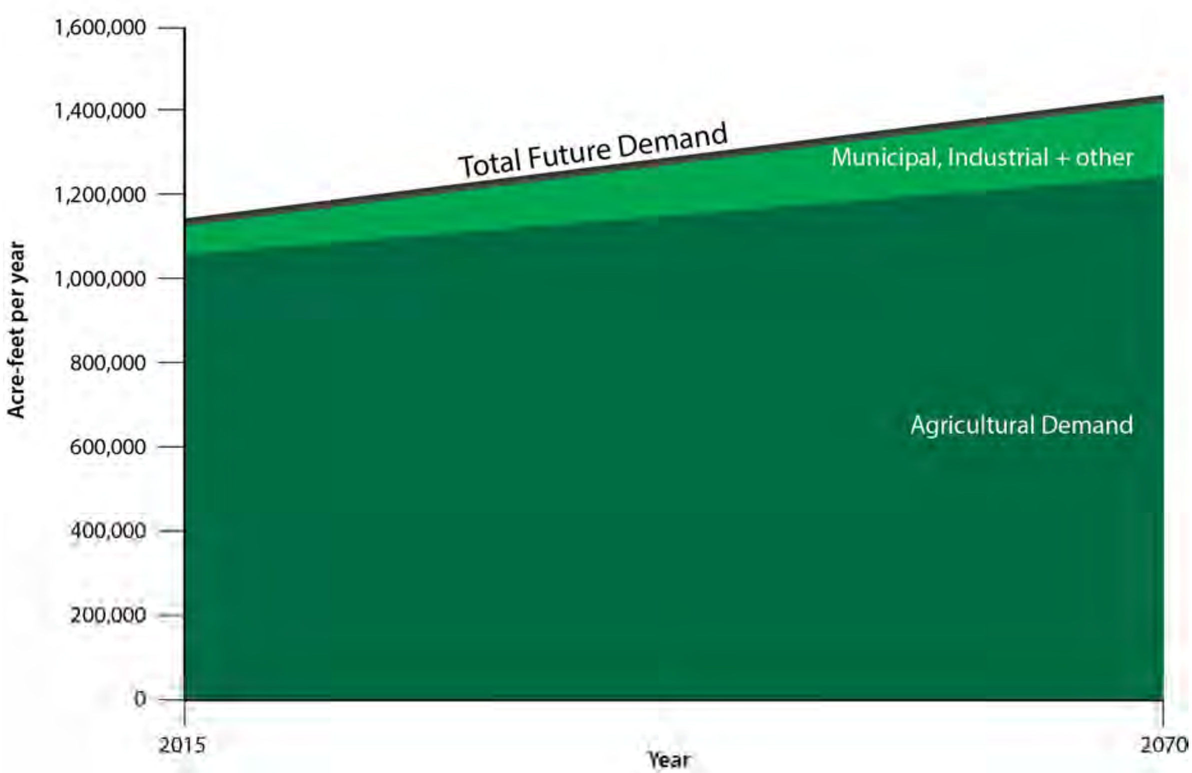



**Figure 64: Kaweah Subbasin Projected Future Water Demand**

During the projected future period, water supply availability is projected to slightly decrease in response to climate change and because of restoration of flows on the San Joaquin River. ***Figures***

***65 and 66*** illustrate the gap between forecast water supply and forecast demand. This gap between future supply and demand will be met by groundwater supply produced at a sustainable yield that does not cause undesirable results. This sustainable yield will be established once measurable objectives are agreed upon throughout the basin. Groundwater modeling will be used to estimate the sustainable yield once initial thresholds and objectives are established.

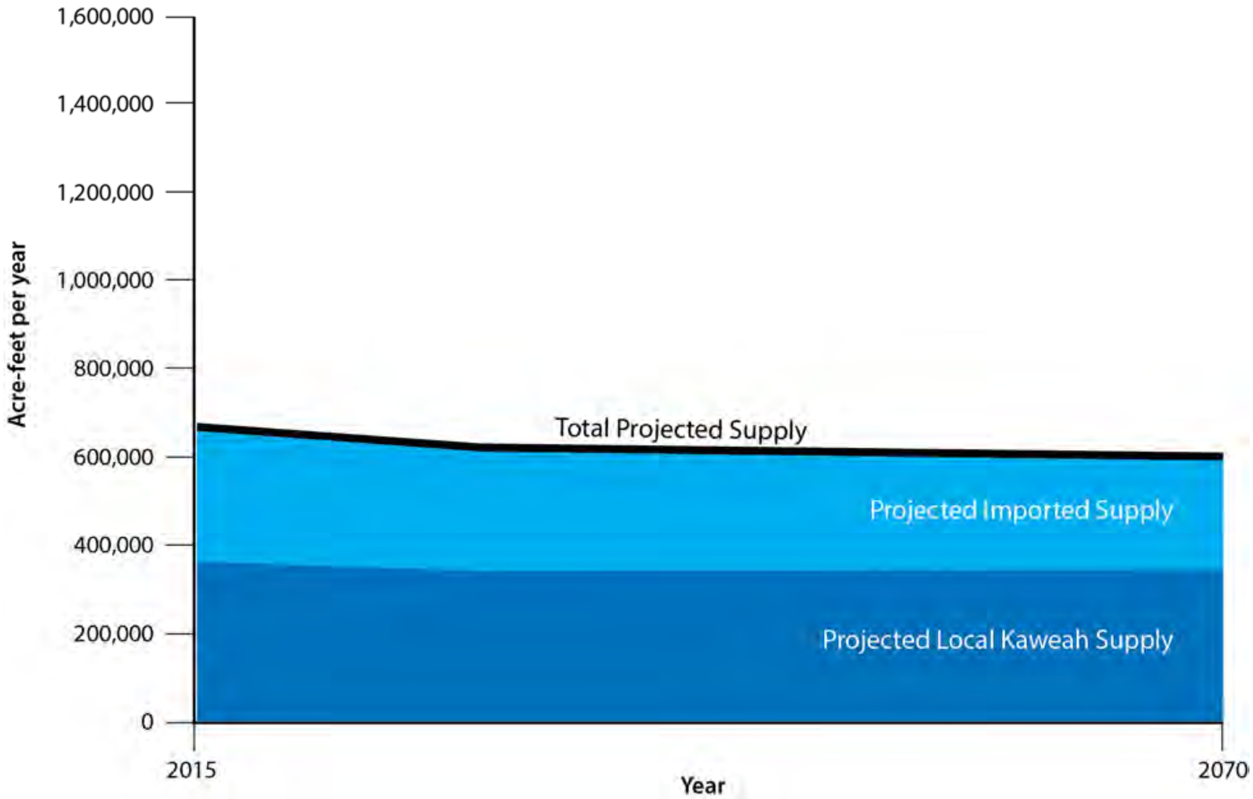



**Figure 65: Kaweah Subbasin Projected Future Water Supply**

## *Impacts of Climate Change Projections on Future Water Balance*

The impacts of climate change on the water balance of the Kaweah Subbasin is presented in ***Table 37***. The first section of the table shows baseline conditions and project changes under 2030 and 2070 conditions for the Subbasin's primary water sources including Kaweah Lake, CVP Friant-Kern Canal Diversions, and full natural flow of the Kings River. The second section of the table shows estimated impacts of changes at primary water sources on surface water supplies delivered to the Kaweah Subbasin. Rain percolation is assumed to change in direct proportion to projected changes in local precipitation. To estimate future changes in water deliveries from upstream inflows and imported sources, Kaweah Subbasin's share (expressed as a percentage) of source water available is assumed to remain unchanged. Imported water deliveries consequently change in direction proportion to projected changes at the respective sources. Annual crop water demands are projected to similarly change in direct proportion to changes in evapotranspiration.

Overall, total surface water supply in Kaweah Subbasin is projected to decrease from 665 TAF under baseline conditions to 633 TAF under 2030 conditions and 616 TAF by 2070, as shown on **Figure 66**. Conversely, total water demand is projected to increase from 1,073 TAF under baseline conditions to 1,105 TAF under 2030 conditions and 1,155 TAF under 2070 conditions. The combined effect of these changes is that total water deficit in the Subbasin will increase from 408 TAF under baseline conditions to 472 TAF under 2030 conditions and 539 TAF by 2070 unless measures are implemented to increase supply or reduce demand.

***Figure 66*** demonstrates that a widening future shortfall in supply is anticipated. Future projects and management actions will be developed and presented in subsequent chapters of this GSP. These projects and management actions will address the shortfall through either demand reduction (i.e. water use efficiency, reduction in crop acreage) or supply augmentation (i.e. increases in artificial recharge during wet periods, increased surface water delivery).

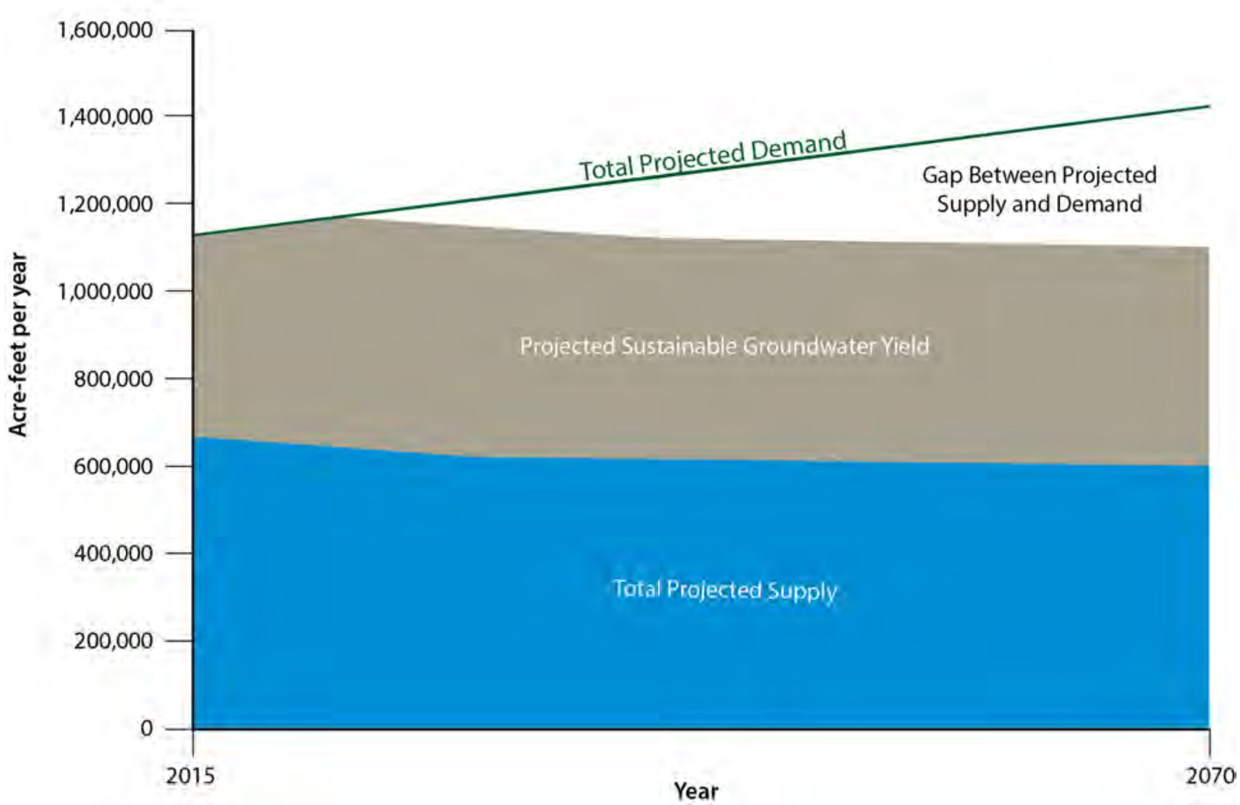



**Figure 66: Kaweah Subbasin Projected Water Supply and Demand**

## 2.6 Seawater Intrusion §354.16 (c)

Seawater intrusion is not an issue in the Kaweah Subbasin because the subbasin does not have a coastal boundary.  Seawater intrusion is an issue in coastal basins that may be induced by creating a landward gradient through lowering of the groundwater table. Once seawater reaches the area of groundwater production, the production wells will not be suitable for drinking or irrigation use and it will likely take decades and significant changes in water supply and use patterns to restore an aquifer's productivity. Maintaining a "wedge" of freshwater in coastal areas, between the ocean and the freshwater aquifers, may prevent undesirable results. Knowledge of the aquifer system, groundwater levels, and water gradients are needed to manage seawater intrusion.

# 2.7 Groundwater Quality Conditions §354.16 (d)

This groundwater quality discussion is largely generalized, although constituents of concern are identified geographically. In 2007, Fugro conducted a Water Resources Investigation for the Kaweah Delta Water Conservation District. This report is referenced along with USGS studies and data collected from a wide variety of sources including state agencies, federal agencies, and county and city water departments. The Fugro study was limited by the volume of groundwater quality data that was available (Fugro West, 2007). At the time of this report, available groundwater quality data was confirmed to be insufficient to represent a large portion of the Subbasin. The primary source of data referenced for this characterization was obtained from the SDWIS which collects sample results from all State regulated public water systems.

## 2.7.1 Data Sources

There are 47 public water systems with data available in SDWIS. These systems are generally representative of the basin as they're located throughout the Subbasin. ***Figure 67*** shows the Kaweah Subbasin boundary, as well as the locations and density of wells with available water quality data. Between all 47 active public water systems, 174 wells were evaluated. In addition to SDWIS, GeoTracker and EnviroStor were searched to identify contaminant plumes, and the SWRCB's Human Right to Water Portal was searched to identify contaminants that commonly violate drinking water standards.

A limited amount of data are available for private domestic wells within the Subbasin; the State Water Board's GAMA Domestic Well Project provided insight to some private wells. Through their Groundwater Protection Section, the State Water Board offered voluntary groundwater monitoring to provide private well owners with information about their water quality. Groundwater samples were analyzed for bacteria, inorganic parameters, volatile organic compounds, and non-routine analytes. Select groundwater samples were also analyzed for stable isotopes of oxygen and hydrogen in water and stable isotopes of nitrogen and oxygen in nitrate. The State Board's GAMA report of the Domestic Well Project conducted for private well owners in Tulare County analyzed 29 of the 181 domestic well samples collected by the SWRCB for stable isotopes of nitrogen and oxygen in nitrate. The study found that nitrate isotopic composition varies with land use (dairies, agricultural/residential, and natural settings). Dairy site nitrate-N isotopic data are isotopically consistent with a manure source. While nitrate-O isotopic data are isotopically consistent with local nitrification of ammonium (from manure, septic effluent, or synthetic ammonium fertilizer).

The 29 samples that were analyzed for stable isotopes of nitrogen and oxygen were wells with higher nitrate concentration (median of 5 ppm and mean of 11 ppm nitrate as nitrogen). For a majority of the heavily impacted wells, the nitrate isotopic compositions indicate a dairy manure or septic effluent source, except for one well with a high nitrate concentration and an isotopic composition indicative of a synthetic fertilizer. Their study acknowledged that the data is under-represented by domestic wells with no potential anthropogenic sources within 500 meters of the well and that land uses were assigned on a high level.

## 2.7.2 Approach to Characterizing Groundwater Quality

Characterizing groundwater quality was conducted to comply with California Code of Regulations – Title 23 – Waters; Subarticle 2 §354.16(d) – Groundwater Conditions: groundwater quality issues that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes. Constituents evaluated and the methodology used were consistent with guidance provided in Assembly Bill 1249 (AB 1249) which states that "if the Integrated Regional Water Management (IRWM) region has areas of nitrate, arsenic, perchlorate, or hexavalent chromium contamination, the (IRWM) Plan must include a description of location, extent, and impacts of the contamination; actions undertaken to address the contamination, and a description of any additional actions needed to address the contamination" (Water Code §10541.(e)(14)). This approach of incorporating guidance from both programs was used to consider all major constituents of concern and characterize groundwater in a manner that is consistent with current water quality focused programs.

## 2.7.3 Results

While all regulated drinking water constituents were considered, findings from this evaluation show that the most common water quality issues within the Subbasin are: nitrate, arsenic, tetrachloroethylene (PCE), dibromochloropropane (DBCP), 1,2,3-trichloropropane (TCP), sodium, and chloride. This water quality discussion is divided by constituent to explain the drinking water standard, agricultural standard (sodium and chloride), and how these constituents impact beneficial uses in the different regions of the Subbasin. ***Table 39*** provides a summary of the range of these constituents within the Kaweah Subbasin referenced to the MCL.

**Table 39: Summary of Water Quality Constituents in Kaweah Subbasin**

| Constituent | Units | Drinking Water Limits (MCL/SMCL) | Agricultural Water Quality Goal | Range in Kaweah Subbasin |
|---|---|---|---|---|
| Arsenic | ppb | 10 | 100 | ND - 20 |
| Nitrate as N | ppm | 10 | n/a | ND - 27 |
| Hexavalent Chromium | ppb | previously 10 ppb, currently under evaluation | n/a | ND - 14 |
| Dibromochloropropane (DBCP) | ppb | 0.2 | n/a | ND - 0.31 |
| 1,2,3-Trichloropropane | ppt | 5 | n/a | ND - 230 |
| Tetrachloroethylene (PCE) | ppb | 5 | n/a | ND - 270 |
| Chloride | ppm | 250 | 106 | 2 - 940 |
| Sodium | ppm | n/a | 69 | 1 - 270 |

### *2.7.3.1 Arsenic*

Arsenic has a primary drinking water MCL of 10 ppb and an Agricultural Water Quality Goal of 100 ppb. Based on review of the Department of Pesticide Regulation studies and the hydrogeology of the Kaweah Subbasin, the major source of arsenic in this groundwater appears to be naturally occurring from erosion of natural deposits. Throughout the southern San Joaquin Valley, arsenic-rich minerals are present, including arsenopyrite, a common constituent of shales and apatite, a common constituent of phosphorites and the most common source of arsenic leaching materials in the aquifer (Burton, et. al., 2012). Data from public water systems shows that arsenic detections around 5-10 ppb are more prevalent in the western portion of the Subbasin, generally within the Corcoran clay. ***Figure 68*** shows the areas where arsenic is between 5- 10 ppb and/or shows an increasing trend to 10 ppb. The eastern boundary of the Corcoran clay generally follows the boundary of St. Johns River on the north till it crosses Highway 63 and extends south of Highway 63, where it continues south through the Subbasin and extends to the westerns portion of the Kaweah Subbasin.

USGS found that when arsenic is naturally occurring in the Kaweah Subbasin aquifer, concentrations tend to increase as pH increases due to desorption from aquifer sediments. Burton, et.al. (2012) report that almost all wells with moderate (5-10 ppb) or high (>10 ppb) arsenic concentrations were in samples with pH values greater than 7.6 units. This correlation between arsenic and pH is consistent in the public water wells evaluated. Wells with arsenic detections are located generally west of Highway 63 and Road 124.

When comparing the data from the municipal wells within the western portion of the Subbasin that have the Corcoran Clay present to the area east of Highway 63 where the aquifer is predominately alluvium, the pH levels were slightly lower than the western portion. This is further evidenced by the two wells located in the western portion of the Subbasin, west of Highway 63 and Road 124 that consistently have arsenic levels above 10 ppb, and pH levels that range from 9.1 – 9.6 units. Wells with arsenic levels less than 5 ppb typically have pH ranges from 7.0 – 8.6 units.

USGS also identified that arsenic concentrations were significantly higher in older and deeper groundwater. USGS assessed depth dependent arsenic concentrations by evaluating both the lateral and vertical extents of arsenic concentrations. Their conclusion is that higher arsenic concentrations directly correlate to well construction (completed depth and top of the perforations). Almost all detections with arsenic concentrations greater than 5 ppb were in wells deeper than 250-ft. These findings were compared with data obtained for this report. While the data is limited, there are two wells consistent with findings from the USGS Report. ***Figure 69*** shows that Well A with a total depth of 284 feet has historically had no arsenic detections. However, in Well B with a total depth of 760 feet also located in the same area has higher arsenic levels and at times exceeds 10 ppb.

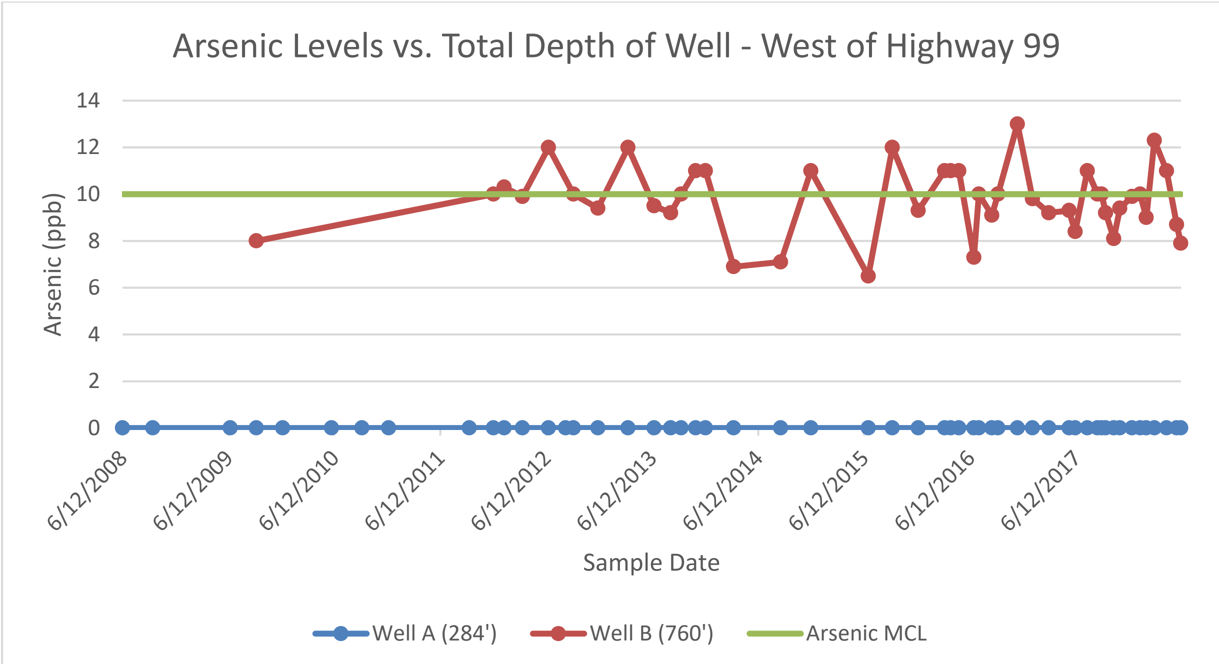



**Figure 69: Hydrogeologic Zone 2 – Arsenic Levels vs. Total Depth of Well**

### *2.7.3.2 Nitrate*

Nitrate has an acute drinking water MCL of 10 ppm (as N). There is no Agricultural Water Quality Goal for nitrate. Nitrate predominately comes from runoff leaching from fertilizer use, leaching from septic systems and sewage, and small concentrations from erosion of natural deposits. Characterizing nitrate contamination in the Kaweah Subbasin includes identifying known and estimated sources of nitrate contamination, identifying public water system wells with nitrate concentrations above the MCL, and correlating the concentrations with land uses and water level trends.

Public water systems with high nitrate levels or increasing nitrate trends are common throughout the Subbasin. ***Figure 70*** provides a spatial observation of where the public water system wells with nitrate issues are generally located. Most nitrate concentrations greater than 5 ppm were detected in the eastern part of the studied area. In areas east of Highway 63 and Road 152 to the eastern extent of the Subbasin, nitrate tends to be higher than 5 ppm with increasing trends. All other areas of the Subbasin have nitrate levels ranging from non-detect to 5 ppm.

While Burton et. al. (2012) report that nitrate contaminations correlates to orchard and vineyard land uses, USGS finds that these regions also have medium to high density septic systems. ***Table 40*** shows the percentages of orchard and vineyard land uses and septic system density for each hydrogeologic zone (Tulare County 2007 land use data and Kings County 2003 land use data were used to create this table). Greater than 50 percent of the land use in this region are orchards or vineyards.

Septic-system density greater than the median value of 5 septic systems in a 500-meter radius around each selected GAMA well occurred throughout the Subbasin, with very high density of 9.4 septic systems within 500 meters of the selected well(s) between Highway 63 and Highways 245 and 65.

***Figure 71*** shows the location of wells selected by USGS to evaluate septic system density. Well locations are overlaid with land uses and public water system wells with high nitrate levels.

USGS data was used for this evaluation to develop a clearer understanding of potential sources of nitrate contamination. While previous reports point towards orchard and vineyard land uses, septic system density is an unquantified source of contamination. Data gathered by USGS was determined from housing characteristics data from the 1990 U.S. Census. The density of septic systems in each housing census block was calculated from the number of tanks and block area. The density of systems around each well was calculated from the area-weighted mean of the block densities for blocks within a 500-m buffer around the well location. To more precisely identify the nitrate sources, current data should be compiled and evaluated with proximity to domestic water wells. This effort is being made through the Disadvantaged Community Involvement Program to identify septic system density and condition in the Tulare-Kern Funding Area.

**Table 40: Percentages of Nitrate Contributing Land Uses**

| Geographic Description | Orchard Percent | Vineyard Percent | Septic System Density (per 500 meters) |
|---|---|---|---|
| West of Hwy 63 | 8.91% | 1.33% | 5.5 |
| Between Hwy 63 and Hwy 245 and Hwy 65 | 50.88% | 3.19% | 9.4 |
| East of Friant-Kern Canal | 45.64% | 0.19% | 5.5 |

It is well understood that nitrate is a surface contaminant and predominately impacts shallower wells, particularly wells with minimum sanitary features (i.e. the required 50-ft sanitary seal). Nitrate impacts based on well construction is demonstrated by the 3 wells with varied construction that are all located within the City of Tulare, Wells B and C are relatively close in proximity of each other but shows significantly different trends. While each of these wells are influenced by similar land uses and aquifer conditions, they each have varying levels of nitrate contamination. ***Table 41*** summarizes nitrate concentration and well construction for each of these wells. ***Figure 72*** graphically displays the nitrate trends.

**Table 41: Comparison of Nitrate Concentrations and Well Construction**

| | Well A | Well B | Well C |
|---|---|---|---|
| Completed Depth | 710 | 800 | 800 |
| Sanitary Seal | 280 | 260 | 370 |
| Highest Perforations | 320 | 280 | 400 |
| Nitrate as N (ppm) current median value | 8.2 | 14 | 3 |

While each of these wells show nitrate contamination related to land uses, vulnerability is substantially lower in Well C, which has a 370-ft sanitary seal. Both wells A and B have increasing trends, with the highest concentrations and steepest increasing trend found in Well B which has a sanitary seal of only 260-ft. Well B also shows significant variation in nitrate concentration that is likely associated with pumping duration at the time of sampling. Typically, shallow wells that are vulnerable to surface contamination will show the highest contaminant concentration with low pumping hours. Increased pumping hours will show lower contaminant concentrations. Regardless of contaminant/pumping correlations, this well has an increasing nitrate trend over time. Well A shows similar trends and pumping correlation, but the variation is less severe. Whereas Well C doesn't appear to be impacted by pumping or showing a significant increasing trend.

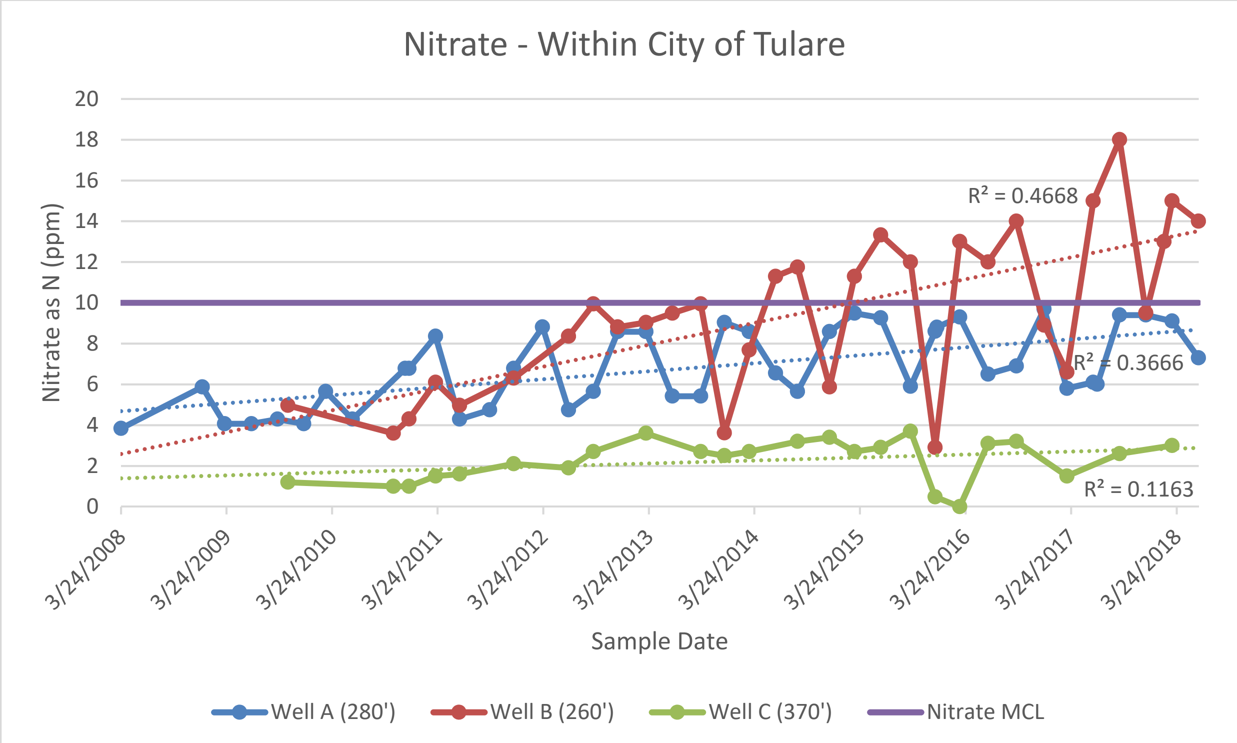



**Figure 72: Nitrate Levels in Relation to Well Construction**

In an effort to evaluate the extent of nitrate contamination basin-wide, a comparison was made between the general depth to water and nitrate concentrations. Since there was no well specific depth to water level data available, the use of the generalized depth to water levels of the Subbasin from DWR modeling database was used to determine if there is correlation between nitrate levels and changing water levels. In some of the wells located in the central portion of the Subbasin, there is no apparent correlation; however, in some wells located within the same area, it appears that nitrate levels are influenced by changing water levels. An evaluation of the wells between Highway 65 and Yokohl Creek shows that it does not appear that the declining water levels were causing nitrate to migrate deeper into the aquifer. See ***Figure 73*** as an example.

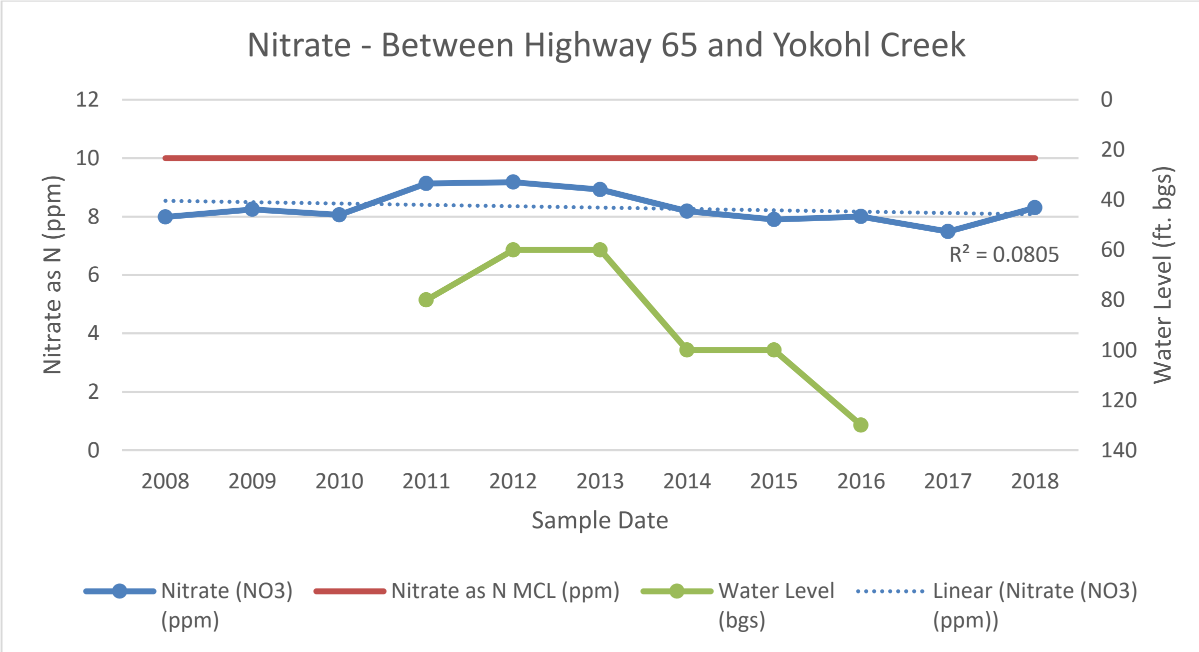



**Figure 73: Nitrate Levels Remain Consistent Between Hwy 65 and Yokohl Creek**

In contrast, the area south of Highway 137 between Roads 124 and 152, as shown in ***Figure 74***, there appears to be a correlation between declining water levels and increasing nitrate concentrations. This trend indicates that nitrate is migrating deeper into the aquifer and is within the pumping zone of the domestic wells evaluated in this region. This preliminary assessment is based on the limited amount of data available. To confirm accuracy of this trend, further studies are needed.

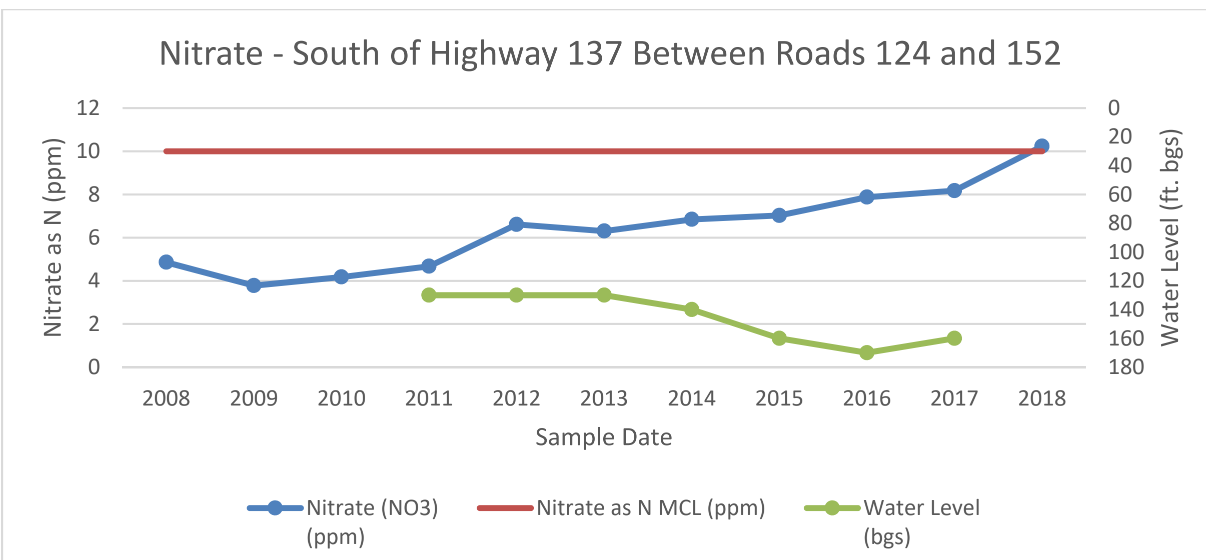



**Figure 74: Nitrate levels increase south of Hwy 137**

***Figure 75*** shows the nitrate trend that is representative of wells north of Highway 137 between Highway 99 and 63. The nitrate and water level trends that follow a parallel pattern indicate that nitrate is not migrating deeper into the aquifer. Nitrate in this well has decreased from its maximum concentration of 6 ppm to non-detect levels. This type of trend indicates that there are confining layers in the aquifer preventing nitrate from migrating with the water levels.

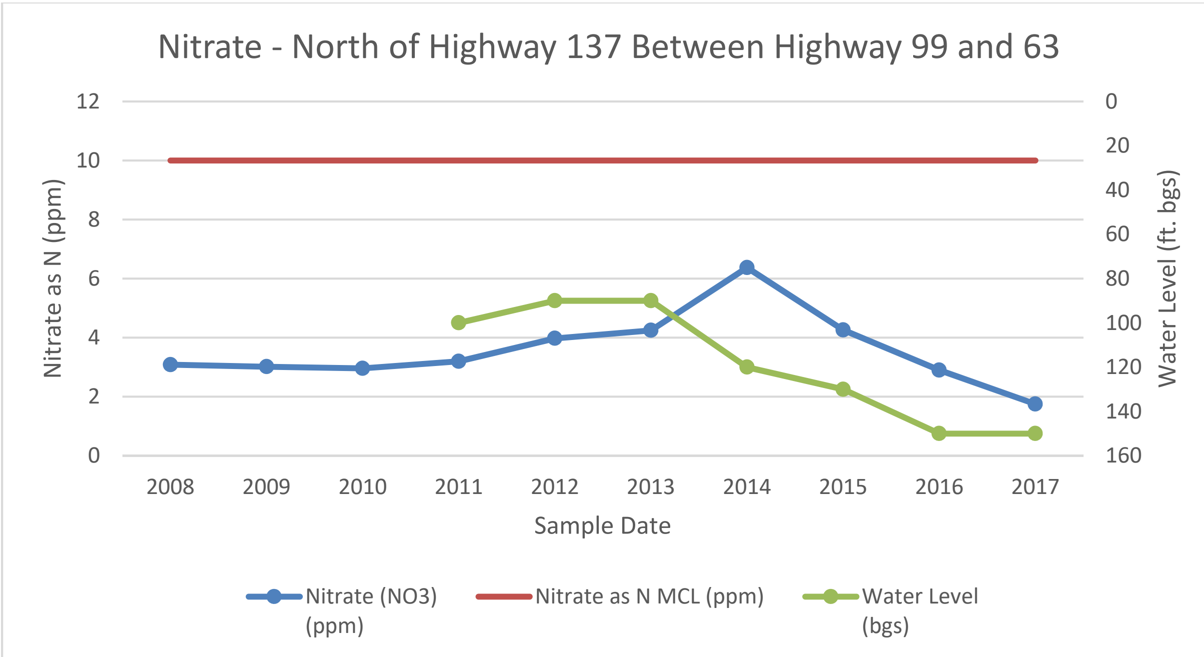



**Figure 75: Nitrate levels decrease north of Hwy 137**

#### *2.7.3.3 Hexavalent Chromium*

Hexavalent chromium is not commonly found in concentrations greater than 10 ppb in the Kaweah Subbasin. An evaluation of hexavalent chromium results indicates that only one well has historic levels with a maximum result of 14 ppb and an increasing trend. This well is located on the eastern border of the Subbasin, near the Friant-Kern Canal in hydrogeologic zone eight.

The federal MCL for total chromium (which includes chromium-3 and chromium -6) is 100 ppb, a specific federal MCL for chromium-6 has not been established. In California, the MCL for chromium-6 is currently 50 ppb. This MCL is a reversion from the July 2014 establishment of a primary MCL of 10 ppb. While DDW repeats the regulatory process for adopting the new MCL, the federal MCL of 50 ppb for total chromium applies. There is no Agricultural Water Quality Goal for hexavalent chromium.

#### *2.7.3.4 Dibromochloropropane (DBCP)*

Dibromochloropropane (DBCP) is a synthetic organic contaminant with a drinking water MCL of 0.2 ppb. There is no Agricultural Water Quality Goal. DBCP is a banned nematicide that is still present in soils and groundwater due to runoff or leaching from former use on soybeans, cotton, vineyards, tomatoes, and tree fruit.

Since the use of this pesticide was banned in 1977, concentrations of DBCP detected in the public water system wells have been either steady or decreasing trends. Presently, detections are found in 7 of the 47 public water systems, at concentrations below the MCL of 0.2 ppb.

Studies on the half-life of DBCP in groundwater estimate it will last from 3 to 400 years depending on ambient conditions. In 2008 the Department of Public Health (transferred to State Water Board as DDW in July 2014) estimated the median half-life of DBCP in the Central Valley is 20 years. This is consistent with the data that's been evaluated for this Subbasin since the levels are steady or decreasing.

#### 2.7.3.5 1,2,3-Trichloropropane (TCP)

TCP is a semi-volatile organic compound with a primary drinking water MCL of 5 ppt. There is currently no federal MCL and no Agricultural Water Quality Goal. The majority of TCP in California's Central Valley is believed to be from an impurity in certain 1,3-D soil fumigants used to kill nematodes. When applied to land, TCP passes through soil and bonds to water, then sinks into the aquifer. It is a highly stable compound, meaning that it is resistant to degradation and has a half-life of hundreds of years[3].

Large public water systems began sampling their wells for TCP using a low-level analytical method around 2003, as a requirement of the Unregulated Chemical Monitoring Rule. From this data, DDW determined that the most impacted counties are Kern, Fresno, Tulare, Merced and Los Angeles. All water systems are required to test their wells quarterly beginning January 2018. Since only a few of the 47-public water system had data available in SDWIS at the time data was extracted for this report, the majority of detections were located in the central portion of the Subbasin. ***Figure 78*** shows wells with historical TCP detections in the Kaweah Subbasin.

#### 2.7.3.6 Tetrachloroethylene (PCE) / Contamination Plumes

PCE is a volatile organic compound with a primary drinking water MCL of 5 ppb. There is no Agricultural Water Quality Goal for PCE. Sources of PCE include discharges related to dry cleaning operations and metal degreasing processes. An evaluation of contamination plumes in the Subbasin was identified through the SWRCB – GeoTracker and Department of Toxic Substances (DTSC) – EnviroStor databases. There is a total of 21 sites identified within the Kaweah Subbasin.

The largest PCE contamination plume involves nine sites in the city of Visalia, which are all dry cleaners. DTSC is leading this case and it's considered a city-wide investigation. According to the DTSC Fact Sheet dated January 2009, this investigation began after DTSC identified 25 public drinking water wells having detection of PCE. It is believed that the PCE plume is related to solvent releases from dry cleaning facilities in the city of Visalia. Soil and groundwater samples were first collected in 2007. Currently, the database indicates that from the nine sites identified there are three municipal drinking water wells that are within 1,500 feet of the plume vicinity. The three wells are located within the Cal Water area. One of the wells was shut down in 2000 due to PCE detection over the MCL. The well is now back online with PCE treatment.

Cal Water and DTSC entered into their first agreement in May 2007. One of the agreements identified between the two parties was for Cal Water to assist in preventing groundwater wells from spreading the PCE plume by early identification of problem areas or determination of appropriate remedial actions such as continued monitoring, pumping, not pumping, treatment, or well

[3] Transformation and biodegradation of 1,2,3-trichloropropane (TCP) 2012. https://link.springer.com/content/pdf/10.1007%2Fs11356-012-0859-3.pdf

destruction. The agreement was amended in June 2009 and again in March 2013. The most recent agreement stated for Cal Water to evaluate the effects of pumping groundwater at two specific well locations. Subsequently the evaluation was focused to one well and based on a report completed in November 2015 of that well, it showed that the well resides in a dynamic geohydrologic environment. When the well is not pumping or under ambient condition, fresh water displaces PCE contaminated water from the shallow part of the aquifer near the well. When the well is pumping, it draws in the water from deep and shallow sources, including upper aquifer contaminated water. ***Figure 76*** shows the increasing PCE levels of the Cal Water well, with it peaking at 270 ppb in July 2014. Levels have significantly decreased but intermittently show increasing trends.

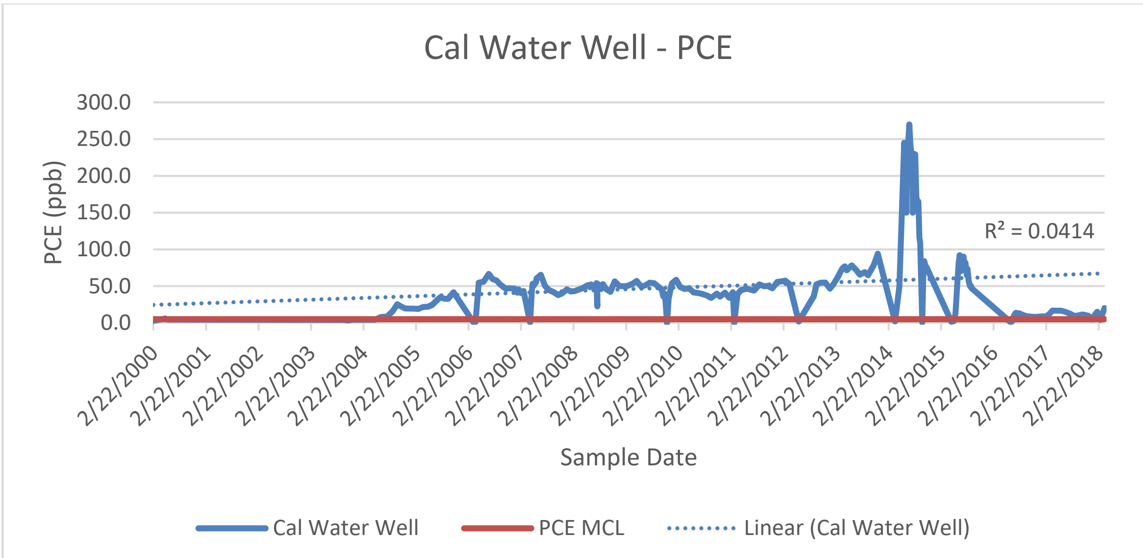



**Figure 76: Historical PCE Levels of Cal Water Well Impacted by PCE Plume**

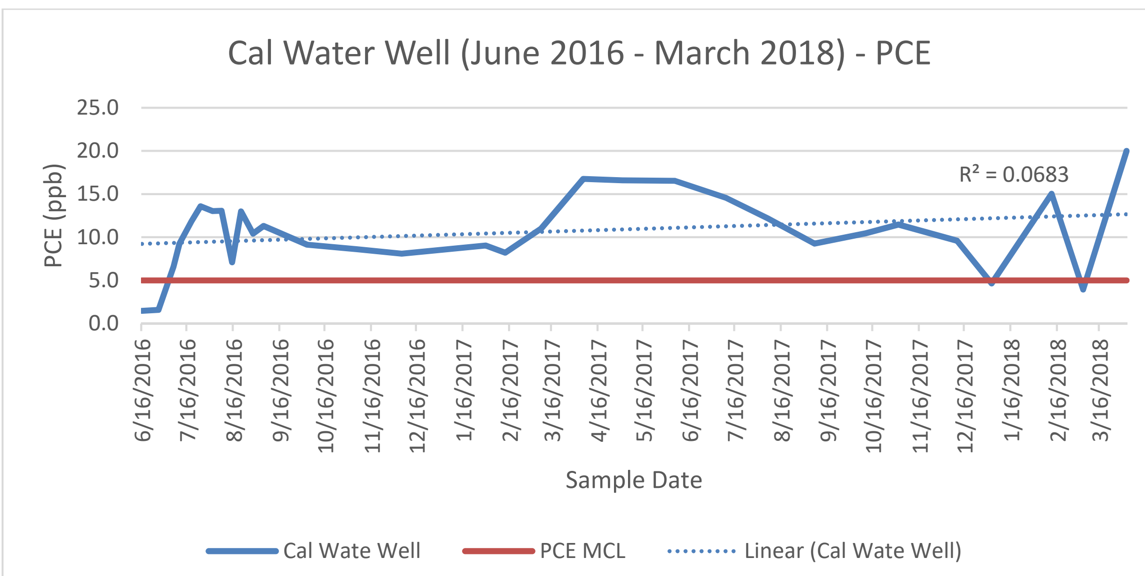



**Figure 77: PCE Levels of Cal Water Well Impacted by PCE Plume from June 2016 – March 2018**

This city-wide PCE investigation is still underway and each of the nine sites are in varying stages of investigation with work plans approved by DTSC. Monitoring wells that have been installed with screens about 100 feet below ground surface (bgs) have detected PCE levels above 5 ppb. The size of the plume has not been determined and is still under investigation. ***Figure 79*** shows the nine sites in relation to the municipal drinking water wells.

Other contamination sites were identified within the Subbasin. These other sites are summarized in ***Table 42*** An extensive summary for each of the contamination sites is not presented since most did not have more recent information or reports on the ongoing investigation of these sites. From reviewing the available reports, none of the sites listed have been determined to have an impact on the aquifer.

**Table 42: Summary of Active Contamination Sites Not Part of PCE City-Wide Investigation**

| Global ID# / EnviroStor ID# | Lead Agency | Potential Contaminants of Concern | DDW Wells within 1500 Feet of Site | Status |
|---|---|---|---|---|
| SLT5FR184373 / 54270005 | DTSC | VOC | No | Open – Remediation as of 5/12/10 |
| SLT5FT344509 | Regional Board | TCA, DCE, other inorganic/salt | Yes, but well inactivated in 2014 | Open – Site Assessment as of 4/18/16 |
| SL0610711757 | Regional Board | Gasoline, MTBE, TBA, other fuel oxygenates, Diesel | Yes, but well was destroyed in 1995 | Open – Inactive as of 4/28/16 |
| T0610700032 | Regional Board | Gasoline | No | Open – Eligible for closure as of 8/30/17 |
| T0610700138 | Regional Board | Gasoline | Yes | Open – Assessment & interim remedial action as of 1/29/17 |
| T0610700075 | Regional Board | Gasoline | Yes | Open – Site assessment as of 8/1/17 |
| T10000011363 | Regional Board | Polychlorinated biphenyls (PCBs), insecticides, pesticides, herbicides, arsenic, lead, mercury, total petroleum hydrocarbons (TPH)<br>After testing, focus is arsenic | Yes – 4 total, but 3 have been inactivated in 1984 due to water system inactivation | Open – Site assessment as of 3/5/18 |
| SL205194270 | Regional Board | PCE, TCE, other chlorinated hydrocarbons | None identified, but reports indicate impacts to wells | Open – Verification monitoring as of 4/18/16 |

| Global ID# / EnviroStor ID# | Lead Agency | Potential Contaminants of Concern | DDW Wells within 1500 Feet of Site | Status |
|---|---|---|---|---|
| SLT5FT424517 | DTSC | Pesticides/ Herbicides | No | Open – Site assessment as of 1/22/87 |
| SLT5S3483663 | Regional Board | Pesticides, herbicides | No | Open – Inactive as of 5/21/09 |
| 80001396 | DTSC | Soil - Lead, Sulfuric acid, TPH | No | Open – Active as of 1/1/08 |
| 80001510 | DTSC | Cadmium, copper, lead, and zinc | Unknown | Open – Active as of 3/1/17 |

Out of all the contamination sites identified, there are 16 contamination sites that will need to be monitored to determine the extent of impact to the groundwater (***Figure 80***). Sites that have no information at all or eligible for closure is not counted towards the 16 contamination sites that needs further monitoring. The 9 PCE sites that are not listed in the table are also included in the count of 16 sites. In some of the sites, shallow monitoring wells went dry due to the water table levels dropping and deeper monitoring wells had to be drilled to continue the investigations. Currently, there is not enough information to determine if the contaminants are sinking with the groundwater levels. The main constituents of concern due to contamination plumes in this Subbasin are volatile organic compounds (VOCs), more specifically PCE and TCE, and gasoline related constituents. The two pesticide/herbicide plumes that were identified in the GeoTracker database have no information or data available.

#### 2.7.3.7 Sodium and Chloride

Based on drinking water standards, the recommended secondary maximum contaminant level (SMCL) of chloride is 250 parts per million (ppm) with an upper limit of 500 ppm. There is no primary drinking water standard for sodium, however Water Quality Goals for Agriculture, published by the Food and Agriculture Organization of the United Nations in 1985, has set Agricultural Water Quality Goals for sodium and chloride at 69 ppm and 106 ppm, respectively. The criteria identified are protective of various agricultural uses of water, including irrigation of various types of crops and stock watering. These levels are used as a baseline to compare against and are not intended to represent an acceptable maximum value for the Subbasin. Since a majority of the land use in the Subbasin is irrigated lands, the Agricultural Water Quality Goals for sodium and chloride are used for this portion of the water quality evaluation.

There are four primary sources of sodium: agriculture, municipal, industrial, and natural. Agriculture practices result in evaporation of irrigation water which removes water and leaves the salts behind. Plants may also naturally increase soil salinity as they uptake water and exclude the salts. Application of synthetic fertilizers and manure from confined animal facilities are also other means by agriculture. A municipal source of sodium occurs through the use of detergents, water softeners, and industrial processes. Wastewater discharged to Publicly Owned Treatment Works (POTWs) and septic systems can increase salinity levels. An industrial source is by industrial processes such as cooling towers, power plants, food processors, and canning facilities. The last source is naturally from the groundwater, which contains naturally-occurring salts from dissolving rocks and organic material.

Only a few wells within the Kaweah Subbasin that have increasing or elevated sodium and chloride levels. However, there are small pockets within the Subbasin that have increasing or elevated sodium and chloride levels. ***Figure 81*** identifies where those wells are located. Sodium and chloride levels are increasing and, in some cases, already over the Agricultural Water Quality goals.

***Figure 82*** shows trends from two wells in a public water system located between Highway 65 and the Friant-Kern Canal with increasing chloride trends that have exceeded the Agricultural Water Quality goals and in one well, also exceeding the secondary drinking water standard. ***Figure 83*** also shows trends from wells within the City of Lindsay, where the chloride levels show a similar trend.

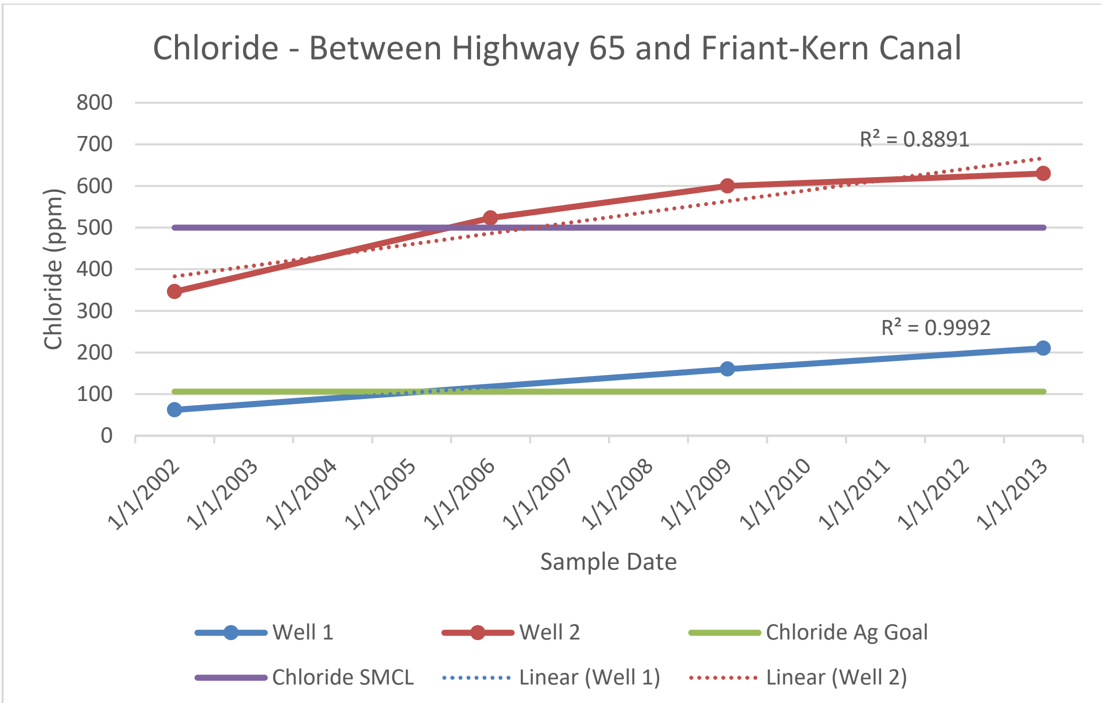



**Figure 82: Chloride Trend of Two Wells Located Between Highway 65 and Friant-Kern Canal**

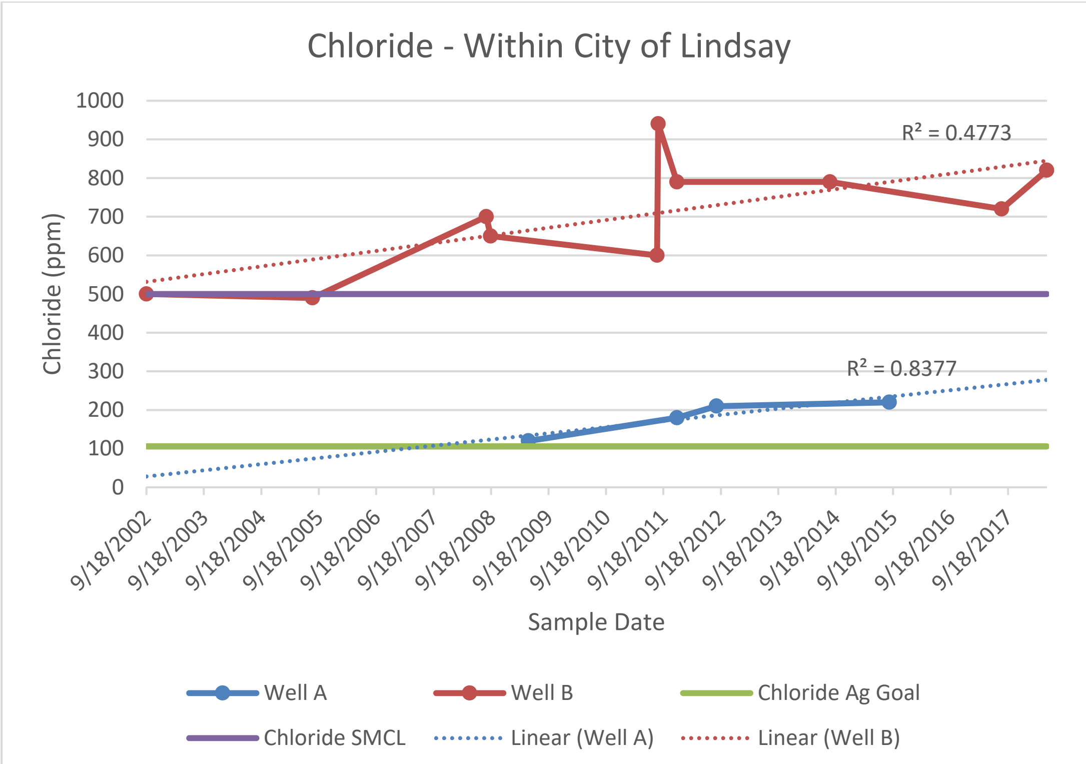



**Figure 83: Chloride Trends of a Public Water System with Wells Within City of Lindsay**

Findings from this evaluation show that the most common water quality issues within the Subbasin are: nitrate, arsenic, and PCE. Wells with high arsenic correlates with deeper, older water that is associated with the Corcoran Clay. The pH levels were also higher with wells having arsenic levels over 10 ppb. Nitrate is prevalent throughout the Subbasin with higher concentrations from east of Highway 63 to Highway 245 in the north and from Road 152 to the eastern extent of the Subbasin. These zones had greater than 50% of the land use as orchard and vineyards. Also, septic system density is greater in these areas compared to the rest of the Subbasin. Well construction also plays a factor in both elevated arsenic and nitrate levels. Deeper wells, greater than 250 ft., tend to have higher arsenic levels. On the other hand, shallow wells or wells with sanitary seals less than 250 ft. tend to have higher nitrate levels. The city-wide PCE plume in Visalia is something that needs to be monitored since it is an ongoing investigation. All other constituents that were evaluated are not a Subbasin-wide issue.

# 2.8 Land Surface Subsidence §354.16 (e)

Inelastic (irrecoverable) land subsidence (subsidence) is a major concern in areas of active groundwater extraction due to increased flood risk in low lying areas; well casing, canal and infrastructure damage or collapse; and permanent reduction in the storage capacity of the aquifer.

## 2.8.1 Cause of Land Subsidence

Several processes contribute to land subsidence in the Subbasin and include, in order of decreasing magnitude: aquifer compaction by overdraft, hydrocompaction (shallow or near-surface subsidence) of moisture deficient deposits above the water table that are wetted for the first time since deposition, petroleum reservoir compaction due to oil and gas withdrawal, and subsidence caused by tectonic forces.

Inelastic compaction (subsidence) typically occurs in the fine-grained beds of the aquifers and in the aquitards due to the one-time release of water from the inelastic specific storage of clay layers caused by groundwater pumping. When long-term groundwater pumping and overdraft occurs, the aquifer system can become depressurized, and water originally deposited within the fine-grained units can be released from the clay layers. This depressurization allows for the permanent collapse and rearrangement of the structure, or matrix, of particles in fine-grained layers. Groundwater cannot re-enter the clay structure after it has inelastically collapsed. This condition represents a permanent loss of the water storage volume in fine-grained layers due to a reduction of porosity and specific storage in the clay layers. Although space within the overall aquifer is reduced by subsidence of the land surface and reduced thickness of the clay layers, this storage reduction does not substantially decrease usable storage for groundwater because the clay layers do not typically store significant amounts of recoverable, usable groundwater (LSCE, 2014). However, this one-time release of water from compaction has been substantial in some areas of the San Joaquin Valley. Although the largest regional clay unit in and adjacent to the Kaweah Subbasin is the Corcoran Clay, a relatively insignificant volume of water has been released from storage from it (Faunt et al., 2009). This is likely because of its large thickness and low permeability. However, the groundwater quality of the aquifers, however, could be impacted by the lower quality of groundwater emanating from the depressurized clay layers.

## 2.8.2 Regional Cause and Effect of Subsidence

***Figure 84*** through ***Figure 88*** of this section present land subsidence at a subbasin scale; however, the data also show that subsidence occurs regionally where the Corcoran Clay and other associated fine-grained units are present in the subsurface. Areas where greater groundwater pumping has occurred coupled with newly installed deeper well screen intervals below the Corcoran Clay may contribute to land subsidence from dewatered clays in previously unpumped depth intervals of the aquifer system. This topic is further discussed in the sustainable management criteria section of this report. These pumping intervals occur in the Kaweah Subbasin as well as in neighboring subbasins to the Northwest, West, Southwest, and South of the Subbasin. Additional data and coordination between subbasins are recommended to better understand the effects of groundwater management on the mitigation of land subsidence.

### 2.8.3 Past Land Subsidence

Historical documentation of subsidence within the Central Valley has relied on various types of data, including topographic mapping and ground surveys (including the remote sensing NASA JPL InSAR data), declining groundwater levels, borehole extensometers, and continuous GPS station information. Within the Subbasin, subsidence has been documented by the National Geodetic Survey at up to 8 feet from 1926 to 1970, as shown on ***Figure 84***. Groundwater overdraft (when there is a lack of surface water supply for irrigation) is considered to be the primary driver for historical land subsidence in the Central Valley (Faunt et. al., 2009). USGS estimates that about 75 percent of historical subsidence in the Central Valley occurred in the 1950s and 1960s, corresponding to extensive groundwater development. Time-series charts of historical water levels were compared with the DWR water year indices corresponding to above normal, below normal, and normal climatic conditions. In general, water levels declined during below normal water year indices (critical, dry, or below normal), while water levels were more stable or recovering during high water year indices (wet, above normal).

### 2.8.4 Recent Land Subsidence

Recent subsidence studies of the Central Valley, including the Subbasin, have utilized satellite-based, remote sensing data from the InSAR and aircraft-based L-band SAR or Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR) programs, led by NASA/JPL, as well as other international researchers. These datasets, shown on ***Figure 85*** and ***Figure 86***, provide a continuous estimate of subsidence over a large portion of the Subbasin. The annual rate of subsidence for these datasets are shown on ***Figure 87*** through ***Figure 88***.

Recent subsidence in the Subbasin and in the Tule Subbasin (immediately to the south) can also be observed at two continuous GPS (CGPS) stations, shown on ***Figure 85*** through ***Figure 88***. These monitoring points are located to the northwest of Farmersville (station P566), and southwest of Porterville (P056) and provide recent, localized subsidence data from November 2005 to present. These CGPS stations are monitored as a part of UNAVCO's Plate Boundary Observation (PBO), the California Real Time Network (CRTN) and California Spatial Reference Center (CSRC) of the Scripps Orbit and Permanent Array Center (SOPAC). Daily CGPS position time-series data with 6 month moving averages are plotted and displayed with InSAR data for comparative purposes on ***Figure 85*** through ***Figure 88***. The quality of these datasets is deemed "reproducible" by UNAVCO, and cumulative rates of subsidence were calculated by taking annual water year averages of the dataset. Annual averages of CGPS or future extensometer data may permit a more meaningful comparison with InSAR data in future calculations and analyses. Another dataset to be used in the future for comparing InSAR and CGPS data, are level surveying data from local subsidence monitoring benchmarks. These benchmarks represent a piece of the subsidence monitoring network as described in the monitoring section of this report.

Time-series charts of subsidence data are included on ***Figure 85*** and ***Figure 86***, and are compared with the DWR water year indices. Greater rates of compaction/subsidence generally correlate with below normal water year indices (critical, dry, or below normal), while lower rates of subsidence are observed during high water year indices (wet, above normal). The inserted hydrographs show that, in recent times, nearby water levels do not consistently correspond with DWR water year indices, likely due to changes in groundwater management practices and improved surface water supplies since the 1960's. Upon further examination of time-series data for the Corcoran Station, water levels in the lower aquifer (deep) better correlate with the water year indices and changes in subsidence rates, in contrast to the water levels in the upper aquifer (shallow), which do not correlate as readily with changes in subsidence rates.

Recent and historical subsidence data are summarized in ***Table 43.*** It includes a summary of InSAR data published in a subsidence study commissioned by the California Water Foundation (LSCE, 2014), and by JPL. The InSAR data were collected from a group of satellites (Japanese PALSAR, Canadian Radarsat-2, and ESA's satellite-borne Sentinel-1A and -1B), from 2006 to 2017, with a data gap from 2011 to 2014 because there was a gap in satellite data collection until the ESA Sentinel satellites were launched in 2014.

According to the California Water Foundation study (LSCE, 2014), subsidence is on-going and leading to significant impairment of water deliveries from the Friant-Kern Canal south of the Kaweah Subbasin. According to DWR (2014), the Kaweah Subbasin was rated at a high risk for future subsidence due to 1) a significant number of wells with water levels at or below historical lows; 2) documented historical subsidence; and 3) documented current subsidence. Moreover, greater amounts of subsidence are occurring to the west, southwest, and south of Kaweah in adjacent subbasins. The amount of future subsidence will depend on whether future water level elevations decline below previous lows and remain at these levels for years. Maintaining water at a suitable water level elevation (threshold) may limit future subsidence caused by groundwater pumping within the Kaweah Subbasin.

## 2.8.5 Subsidence Locations

Historical subsidence within the Subbasin, as determined by the data sources discussed above, are presented on ***Figure 84*** through ***Figure 88***. Hydrographs for selected wells are plotted with subsidence data for comparison purposes. Although undesirable results due to subsidence are dependent up on declines in groundwater elevations and potentiometric surfaces for deeper aquifers, the presence of regional fine-grained stratigraphic units, such as the Corcoran Clay, and localized areas of substantial thicknesses of fine-grained layers is also a major factor. Likewise, key infrastructure that may be impacted by land subsidence should also be considered to determine areas that are sensitive to impacts from subsidence.

In general, groundwater levels lowered by pumping correspond with observed land subsidence, as seen on ***Figure 84***. The groundwater elevation declines shown on this figure can also be compared to the subsidence trends shown on other subsidence maps. The magnitude and annual rate of subsidence increases toward the west and southwest within the Kaweah Subbasin, and progressively increase to the south and west of the Subbasin boundaries, according to InSAR data as well as CGPS data and historical data from the Deer Creek Extensometer and surveying information along the Friant-Kern Canal.

Cumulative and annual rates of recent subsidence (Spring 2015 through 2017) are presented in ***Figure 86*** and ***Figure 88***, respectively. When compared to the cumulative and annual rates of subsidence shown for January 2007 through May 2011, shown on ***Figure 85*** and ***Figure 87***, it is apparent that land subsidence has increased in recent years, in response to drought conditions and increased groundwater demand. This trend is also reinforced by regional extensometer and CGPS data. Overall the limited CGPS data presented in the figures reasonably corresponds with the estimated magnitude of subsidence estimated by the InSAR data.

## 2.8.6 Measured Subsidence

The following tabulated data includes cumulative inches of subsidence within Kaweah, and approximate annual rates for various data collection periods.

**Table 43: Land Subsidence Data**

| Subbasin Area | Date Range | Cumulative Subsidence (inches) | Calculated Annual Rate of Subsidence (inches/year) | Source |
|---|---|---|---|---|
| Kaweah Subbasin | 1926 - 1970 | ~0 - 96 | 0 – 2.2 | Ireland, 1984. Topographic Maps and Leveling Data. |
| North of Farmersville | 2007 - 2017 | 4.9 | 0.5 | CGPS PBO (P566). Data are averaged by water year 2007 to 2017 |
| South of Porterville (just outside of Subbasin) | 2007 - 2017 | 21.3 | 2.1 | CGPS PBO (P056 just south of Subbasin). Data are averaged by water year 2007 to 2017 |
| Deer Creek. South of Porterville | 1970 – 1982 | 15.8 | 1.3 | Extensometer Data from USGS CA Water Science Center |
| Corcoran[4] | Sep. 2010 – May. 2017 | 76.35 | 11.4 | Corcoran CGPS Station (CRCN). Central Valley Spatial Reference Network (CVSRN) Caltrans via California Real Time Network (CRTN) at SOPAC. |
| West and central Kaweah Subbasin *(Highest values in SW near Corcoran)* | Jan. 2007 – Mar. 2011 | 0 – 33.9 | 0 - 8 | LSCE, 2014. Compiled from InSAR. |
| Kaweah Subbasin *(Highest values in SW near Corcoran)* | 2015 - 2017 | 0 – 26.7 | 0 – 13.4 | InSAR. Downloaded from DWR SGMA Viewer. |
| Mile Post 88. Friant-Kern Canal (FKC). Between Lindsay and Strathmore | 1945/1951 to 2017 | ~4.6 | ~0.07 | USBR FKC Subsidence Monitoring Surveys. NGVD29 to NAVD88 |
| Mile Post 92 FKC. South of Subbasin | 1945/1951 to 2017 | ~6.7 | ~0.1 | |
| Mile Post 95 FKC. Tule River Siphon | 1945/1951 to 2017 | ~21.6 | ~0.3 | |

4 Cumulative Subsidence calculated from Annual Rate Value of 11.4 inches per year.

| Subbasin Area | Date Range | Cumulative Subsidence (inches) | Calculated Annual Rate of Subsidence (inches/year) | Source |
|---|---|---|---|---|
| | 1959 to 2017 | ~20.3 | ~0.4 | |
| Mile Post 96 FKC. South of Tule River. | 1945/1951 to 2017 | ~27.4 | ~0.4 | |
| | 1959 to 2017 | ~25.2 | ~0.4 | |
| Mile Post 99 FKC. West of CGPS P056 | 1945/1951 to 2017 | ~78.9 | ~1.1 | |

Although the highest rates of subsidence occur outside of the Kaweah Subbasin; to the west and south in the Tulare Lake and Tule subbasins, respectively; there has been significant subsidence within the Subbasin, largely focused in the western and southwest portions. It is apparent that this subsidence is coincident with both a decline in water levels from pumping near Corcoran, as well as pumping within the Kaweah and the Tule subbasins. Higher levels of subsidence have also been estimated southeast of Tulare and appear to correlate with neighboring subsidence in the Tule Subbasin. Overall, annual subsidence rates vary spatially but have increased in magnitude during the recent drought conditions, as groundwater supplied a higher percentage of agricultural demand.

### 2.8.7 Release of Water from Compression of Fine-Grained Units

Long-term overdraft conditions from groundwater pumping can lead to depressurization of the aquifer system and corresponding dewatering of fine-grained units (or dewatering of clays). The one-time release of water from dewatered clays may represent a one-time principle source of groundwater released from storage to the aquifer system, because fine-grained deposits constitute more than half of the unconsolidated sediments in the Central Valley (Faunt et. al., 2009). The 1989 USGS model (CV-RASA) and other studies attributed most of this one-time release of water to the aquifer system to dewatering of fine grained interbeds of clays and not from regional confining beds such as the Corcoran Clay (Ireland and others, 1984; Williamson and others, 1989; and Faunt et. al., 2009). It is further postulated that “a relatively significant volume of water has not yet been released from storage in the Corcoran Clay” (Faunt et. al., 2009).

#### *2.8.7.1 Water Volume Calculation*

The dewatering of clays may lead to measurable land subsidence, in which case, a rudimentary estimate of the volume of water contributing to the aquifer system by the dewatering of clays can be calculated. The land subsidence is a proxy for estimating one-time release of water from clays to aquifer system. A rough estimate of the volume water is calculated herein, by taking the land surface area multiplied by the measured change in vertical elevation of land surface, mostly attributed to land subsidence. Ideally, extensometers would provide depth-specific measurements of compaction of specific zones, instead of using changes in land surface; however, CGPS measuring points were used in the absence of extensometer data for this calculation. In addition, reliable InSAR data are not available for this time period, or for the entire Subbasin, to use as a control for this calculation. For a preliminary volume calculation of one-time water release from the clay layers to the aquifer system, the Subbasin was divided into relative zones of decreasing subsidence starting from the Southwest of the basin to the East-Northeast. These zones were approximated by using the 2015 to 2017 InSAR data as a qualitative tool to identify regimes or different zones of cumulative subsidence.

***Figure 77*** illustrates the zones which were chosen to correspond with nearby areas of subsidence that have a CGPS station. The Southwest zone corresponds with the 1. CRCN Corcoran station, the adjacent area to the Northeast corresponds with the 2. P056 Porterville station, the next adjacent area corresponds with the 3. P566 Visalia station which is situated in this zone, and the 4. Eastern-most area where negligible to zero subsidence has historically been recorded is not assigned to a CGPS station but is estimated as zero for this calculation. These areas or regimes of subsidence are base only on InSAR data and would require further refinement by additional data for better accuracy. It is likely that the Southwestern-most zone is overestimating the amount of water contributed to the system due to clay dewatering because the Corcoran station reports very high values of subsidence, which decreases rapidly toward the Northeast. The date range of analysis was chosen from September 30, 2011 to September 30, 2017, for the CGPS Stations as presented in ***Table 44***.

**Table 44: Preliminary Estimate of Volume of Water (AF) by Land Subsidence (2011 to 2017)**

| | **1. CRCN** | **2. P056** | **3. P566** | **4. East** |
|---|---|---|---|---|
| **Year** | **(Mean Vertical Change (inches))** | | | |
| 2011 | -0.8 | -5.2 | -2.4 | -- |
| 2012 | -3.7 | -6.1 | -2.7 | -- |
| 2013 | -15.5 | -7.4 | -3.1 | -- |
| 2014 | -27.2 | -9.5 | -3.5 | -- |
| 2015 | -38.9 | -12.5 | -4.0 | -- |
| 2016 | -52.4 | -16.9 | -4.6 | -- |
| 2017 | -62.1 | -22.1 | -5.3 | -- |
| **Cumulative Total (inches) (9/30/11 to 9/30/17)** | -61.3 (-5.1 ft) | -16.9 (-1.4 ft) | -2.9 (-0.2 ft) | -- (0 ft) |
| **Rate (inches/year) (9/30/11 to 9/30/17)** | -10 | -2.8 | -0.2 | -- |
| **Acreage for each Subsidence Area** | 98,100 | 156,000 | 127,700 | 64,300 |
| **Preliminary Estimate of Volume of Water (AF) by Land Subsidence (2011 to 2017)** | 500,600 | 219,300 | 31,700 | 0 |

# 2.9 Interconnected Surface Water

Both the loss of streamflow to groundwater (losing streams) and the loss of groundwater to surface streams (gaining streams) are part of the natural hydrologic system. The direction of flow depends on the relative elevation of these inter-connected waters, and the rate of flow depends on the properties of the aquifer matrix and the gradients of the water sources. Many surface water-groundwater systems reverse the flow direction seasonally in response to either groundwater extraction or significant groundwater recharge related to spring and early summer runoff.

The flow rate between interconnected surface water-groundwater systems will generally increase as groundwater levels are pumped below the bottom of the surface channel and the flow gradient steepens. While not altogether common in the southern San Joaquin Valley, in many areas, the depth-to-groundwater results in a nearly vertical gradient from the surface stream, and depletion of streamflow becomes nearly constant, varying only with the wetted area of the stream channel.

Declining groundwater levels may decrease the discharge to surface streams and result in reduced instream flow and supply to wetland, estuary areas, and other groundwater dependent ecosystems. Loss of streamflow may reduce the supply available for downstream diverters or require additional releases to be made from surface water reservoirs to meet required instream and downstream needs.

An analysis of baseline conditions has been performed, which considered both local knowledge of natural streamflow within the Kaweah River system including timing and flow regimes (gaining and losing stretches) and gaged streamflow compared to groundwater-level information. Based on this, an estimate of streamflow contribution to the groundwater supply is included in the water budget for the period between water years 1981 and 2017.

Because the streamflow data has been compiled from continuous monitors (Parshall flumes) located throughout a majority of the Subbasin and compiled for every month of the base period, the cumulative effects of both wet year and drought year impacts are well-understood. Furthermore, semiannual groundwater-level measurements collected within Subbasin wells support the understanding of the variability of the relative proximity and/or separation of the surface water from the groundwater in both wet and drought conditions.

In general, the vast majority of the natural streams and manmade ditches (channels) throughout the Subbasin are considered losing channels throughout the year with considerable vertical separation between the channels and groundwater. This vertical separation and disconnection between surface and groundwater throughout much of the San Joaquin Valley floor is recognized by DWR and USGS in the conceptualizations for their regional numerical groundwater models CVHM and C2VSim. Streams located in the eastern portion of the Subbasin, generally between the Friant Kern Canal eastward to McKay Point (See ***Figure 20***), are more likely to be relatively neutral to gaining stream reaches during limited times of year.

# 2.10 Groundwater Dependent Ecosystems

Where groundwater and surface water are separated by significant distances, as is the case with most of the Kaweah Subbasin, the groundwater does not interact with the natural streams or manmade ditches. In these areas, therefore, no possibility exists for the presence of Groundwater Dependent Ecosystems to exist. However, where the base of the aquifer is relatively shallow, as is the case along the eastern boundary of the Subbasin adjacent the Sierra Nevada, groundwater levels are closer to the surface.

As presented on ***Figure 19***, areas where groundwater is within 50 feet of the ground surface are located along the Kaweah River (Greater Kaweah GSA) and in two areas within the East Kaweah GSA. Notably, these represent areas where groundwater elevations as of the Spring of 2015 has risen to within 50 feet of the ground surface. The indicated areas are preliminary and subject to review of the local GSAs, who know better which areas can be considered Potential GDEs. This can be addressed as part of a further study.

# 2.11 Conditions as of January 1, 2015

Groundwater levels measured in the spring and fall of each year by the DWR and member agencies provide the data required to document groundwater conditions January 1, 2015, as required. To document the groundwater conditions as of January 1, 2015 when SGMA was enacted, we are using the first round of groundwater level measurements that occurred after that date as the “baseline” condition against which future conditions will be compared. Groundwater levels at that time are presented as ***Figure 30***, along with the water level hydrographs presented as ***Figure 35***.

Review of the map and hydrograph indicate that water levels were near the lowest levels on record. In the spring of 2015 groundwater elevations varied from as low below sea level in the western portion of the basin near the cities of Hanford and Corcoran, to a high of over 400 feet above in the East Kaweah GSA area. As discussed, the exceptionally high pumpage was due in part to the severe drought coupled with a complete lack of delivery of imported CVP water for two years leading up to this period.

# 2.12 References

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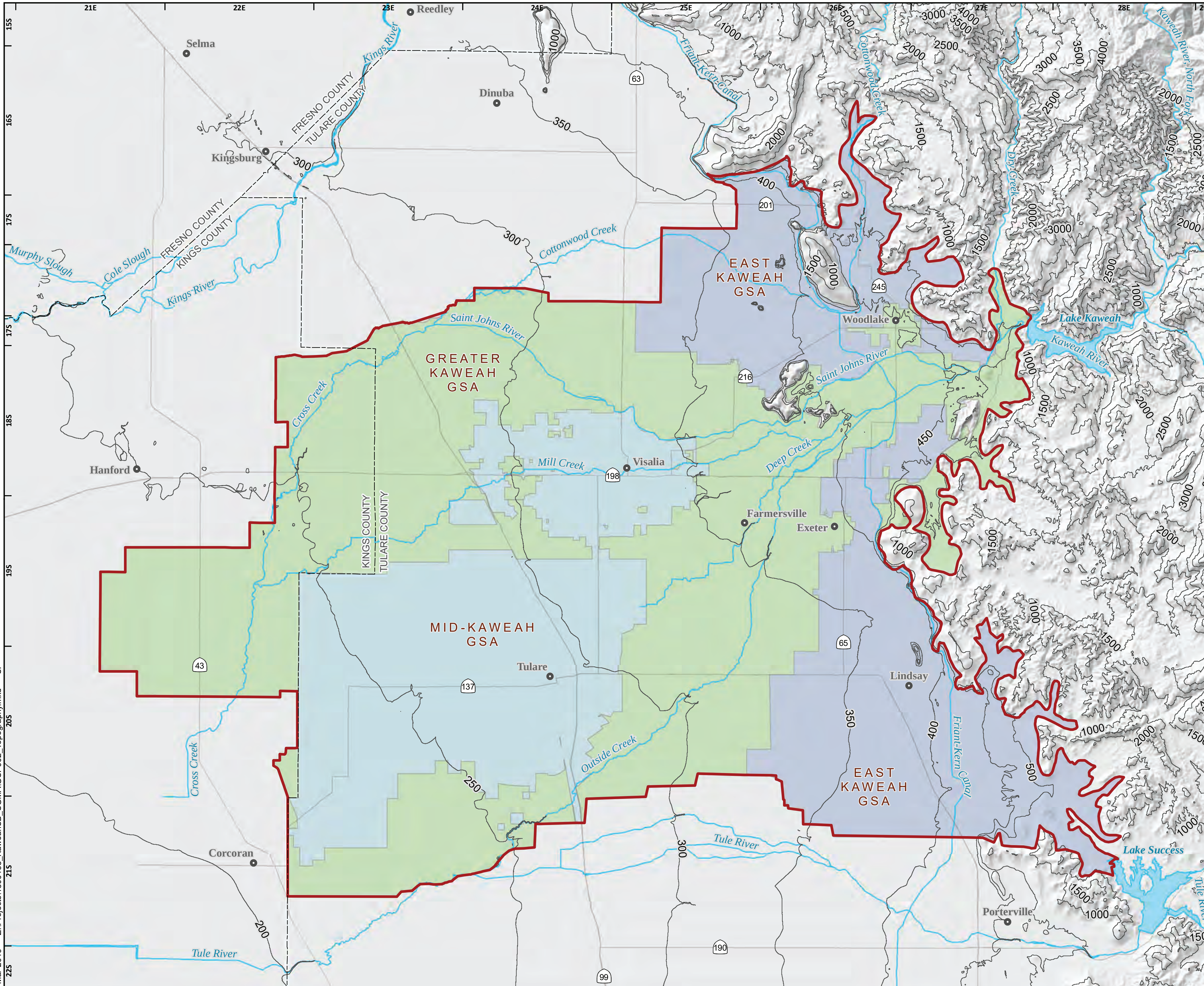
# Large Format Figures

# TOPOGRAPHIC MAP




## Topographic Elevation Contours

Ground Surface Elevation Contours (500-ft interval at greater than 500 ft msl; 50-ft interval at less than 500 ft msl)

## GSA Boundaries

East Kaweah GSA

Greater Kaweah GSA

Mid-Kaweah GSA

Kaweah Subbasin Boundary

## All Other Features

Highway

Waterway

Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

GEI Consultants

GSI Water Solutions, Inc.

MARCH 2019

FIGURE 1

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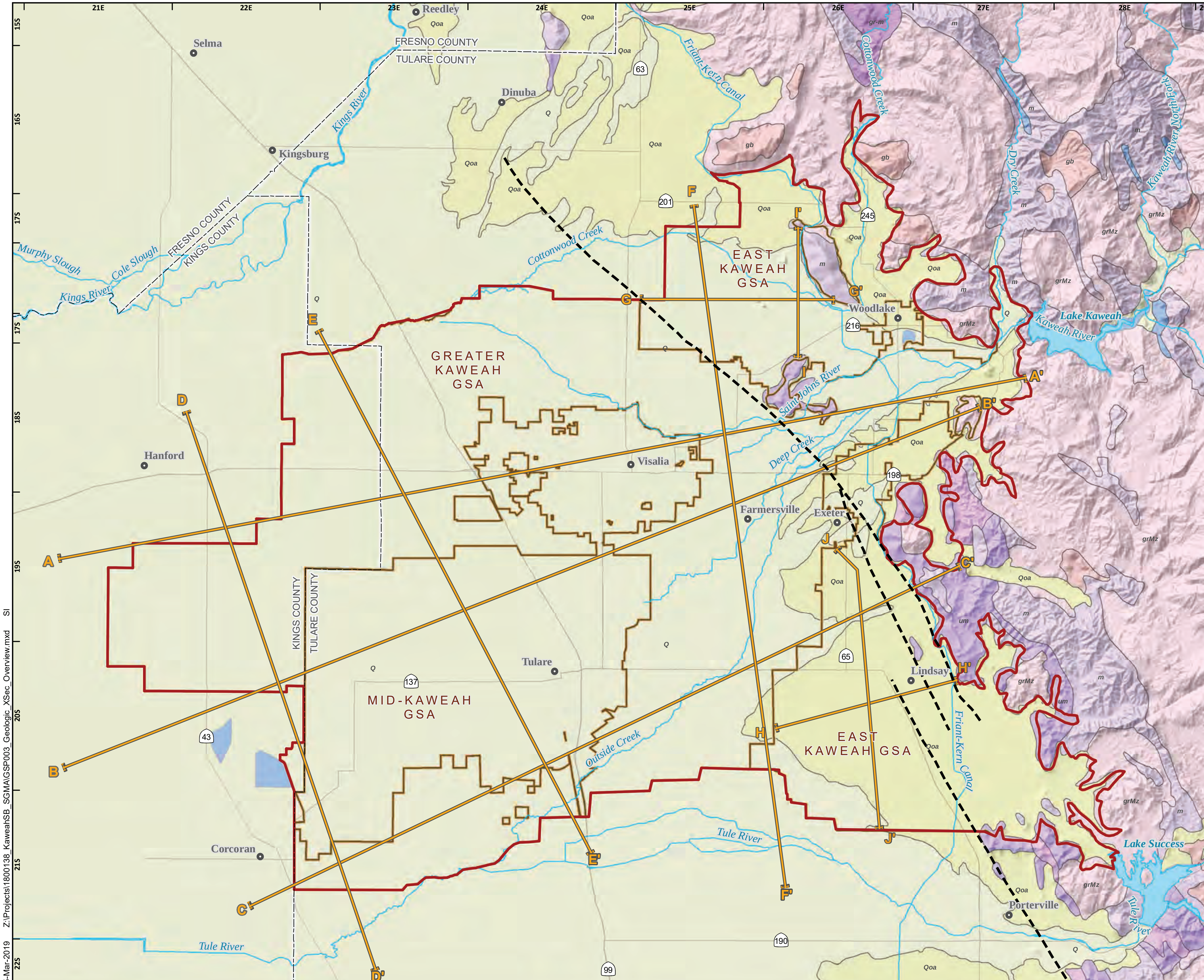



# GEOLOGIC AND CROSS SECTION LOCATION MAP

- Rocky Hill Fault Zone
- Cross Section Line

**Surficial Geology**

- Alluvium (Q)
- Older Alluvium (Qoa)
- Marine Sedimentary Rocks (ls)
- Mixed Granitic and Metamorphic Rocks (gr-m)
- Metavolcanic Rocks (mv)
- Granite (grMz)
- Ultramafic Plutonic Rocks (um)
- Gabbro (gb)
- Undated Granitic Rocks (gr)
- Mixed Rocks (m)
- Water
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lakes

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

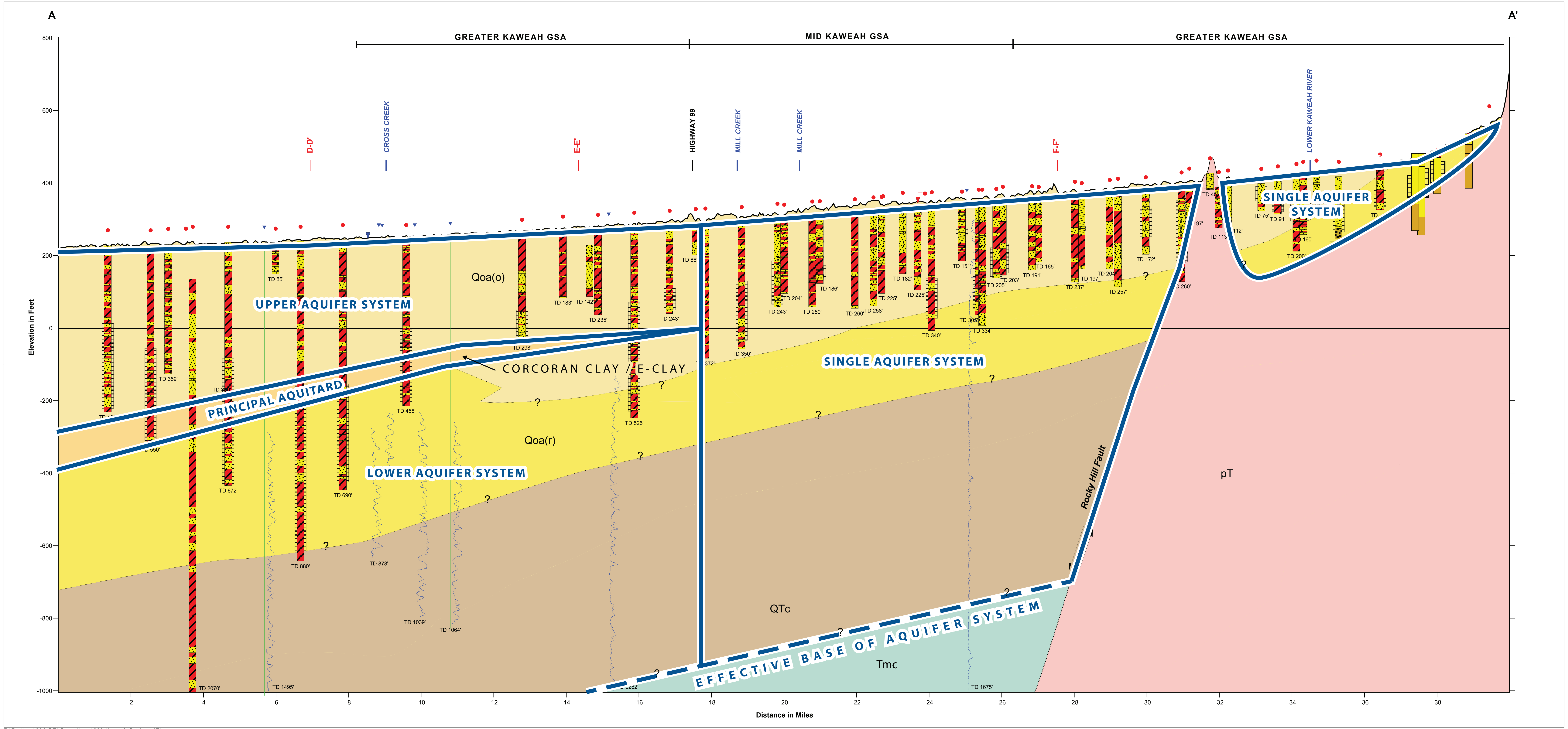
Kaweah Subbasin

GEI Consultants

GSI Water Solutions, Inc.

MARCH 2019

FIGURE 3




# FIGURE 4

## Cross Section A

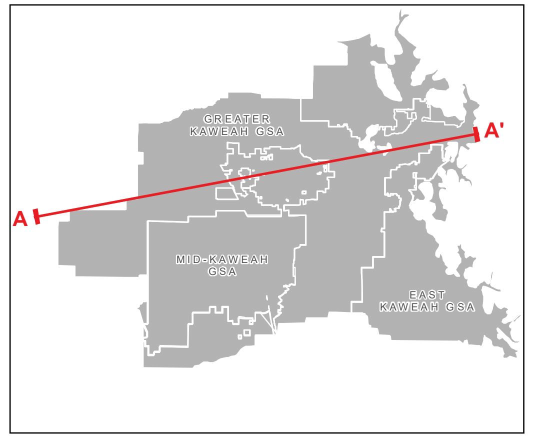
Kaweah Subbasin
Groundwater Sustainability Plan

**LEGEND**

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

**Boring**

- Clay
- Sand
- Sandstone/Rock




**NOTES:**

Cross section modified from Fugro, 2007, Plate 14, Geologic Cross Section A

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

**SCALE**

200 ft

0 2 mi

**VERTICAL EXAGGERATION:** 52.8X

GEI Consultants

GSI Water Solutions, Inc.

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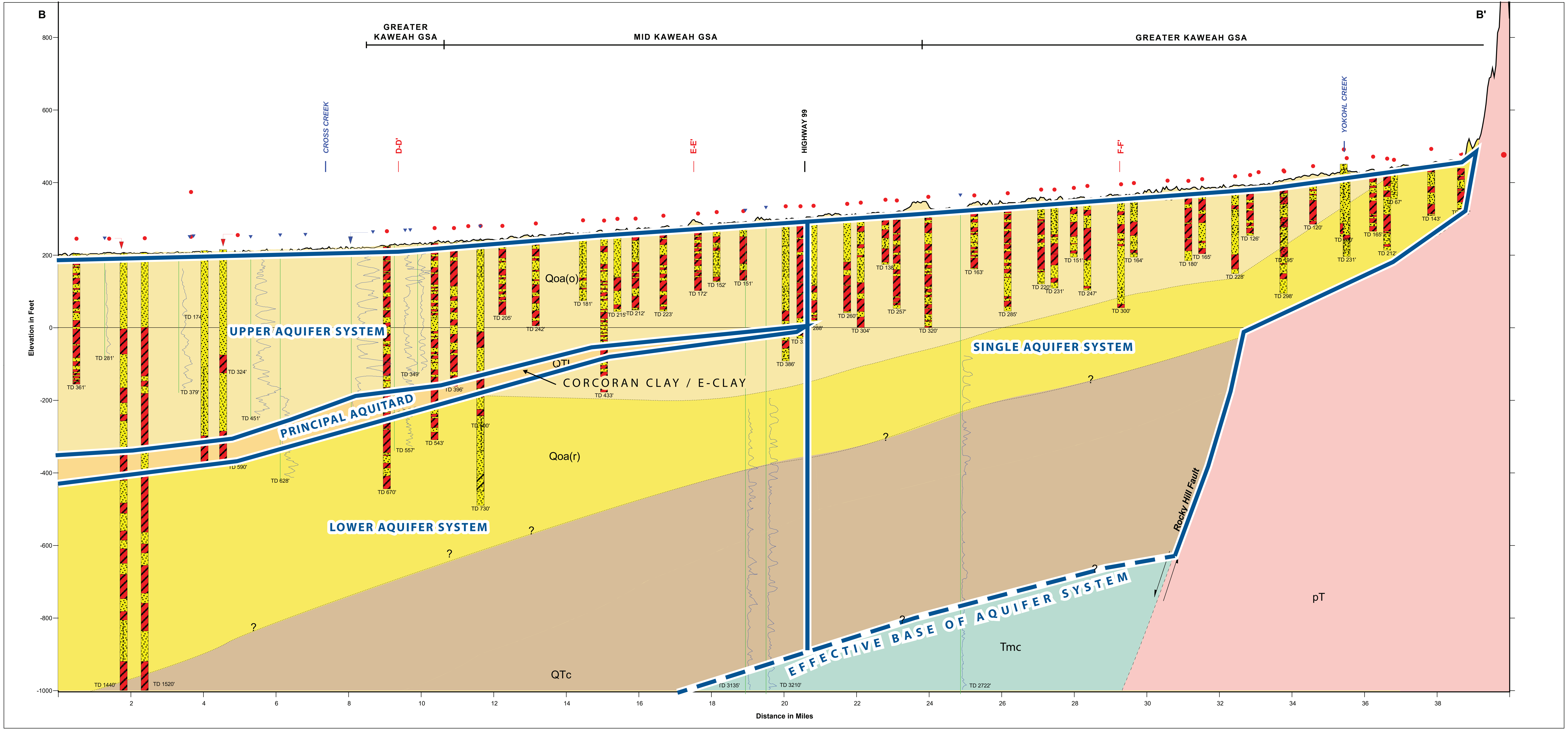



# FIGURE 5

## Cross Section B

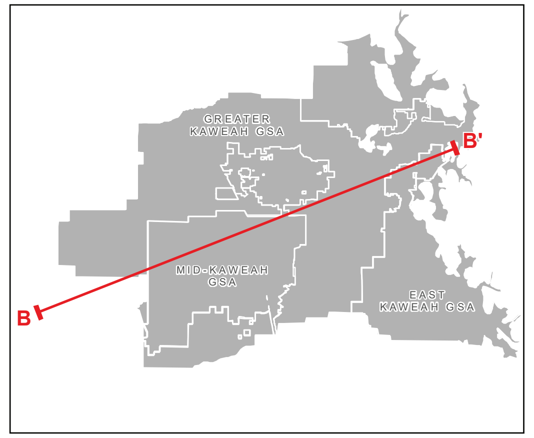
Kaweah Subbasin
Groundwater Sustainability Plan

### LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

**Boring**

- Clay
- Sand
- Sandstone/Rock




### NOTES:

Cross section modified from Fugro, 2007, Plate 15, Geologic Cross Section B

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

### SCALE

200 ft — 0 — 2 mi

**VERTICAL EXAGGERATION:** 52.8X

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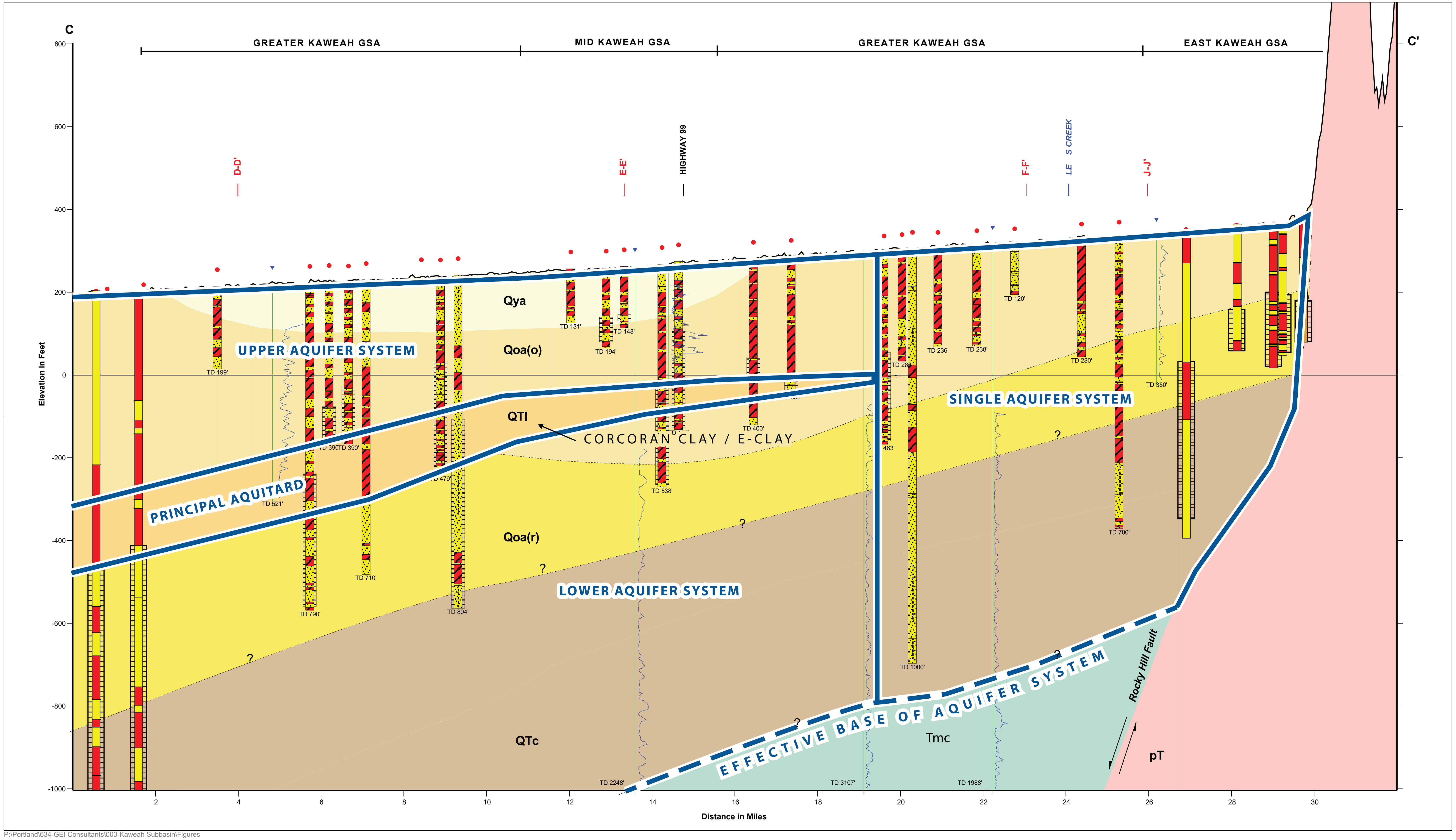



# FIGURE 6

## Cross Section C

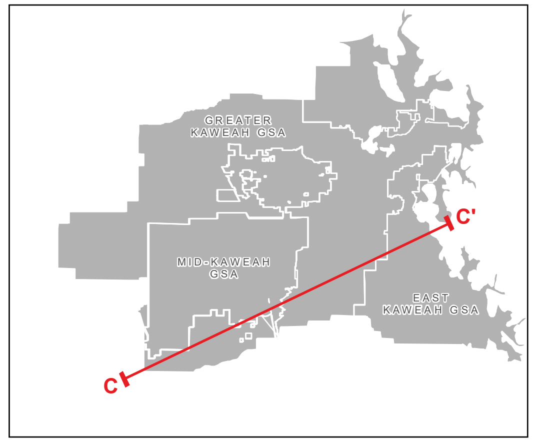
Kaweah Subbasin
Groundwater Sustainability Plan

**LEGEND**

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

**Boring**

- Clay
- Sand
- Sandstone/Rock




**NOTES:**

Cross section modified from Fugro, 2007, Plate 16, Geologic Cross Section C

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

**SCALE**

200 ft

0 — 2 mi

**VERTICAL EXAGGERATION:** 52.8X

GEI Consultants

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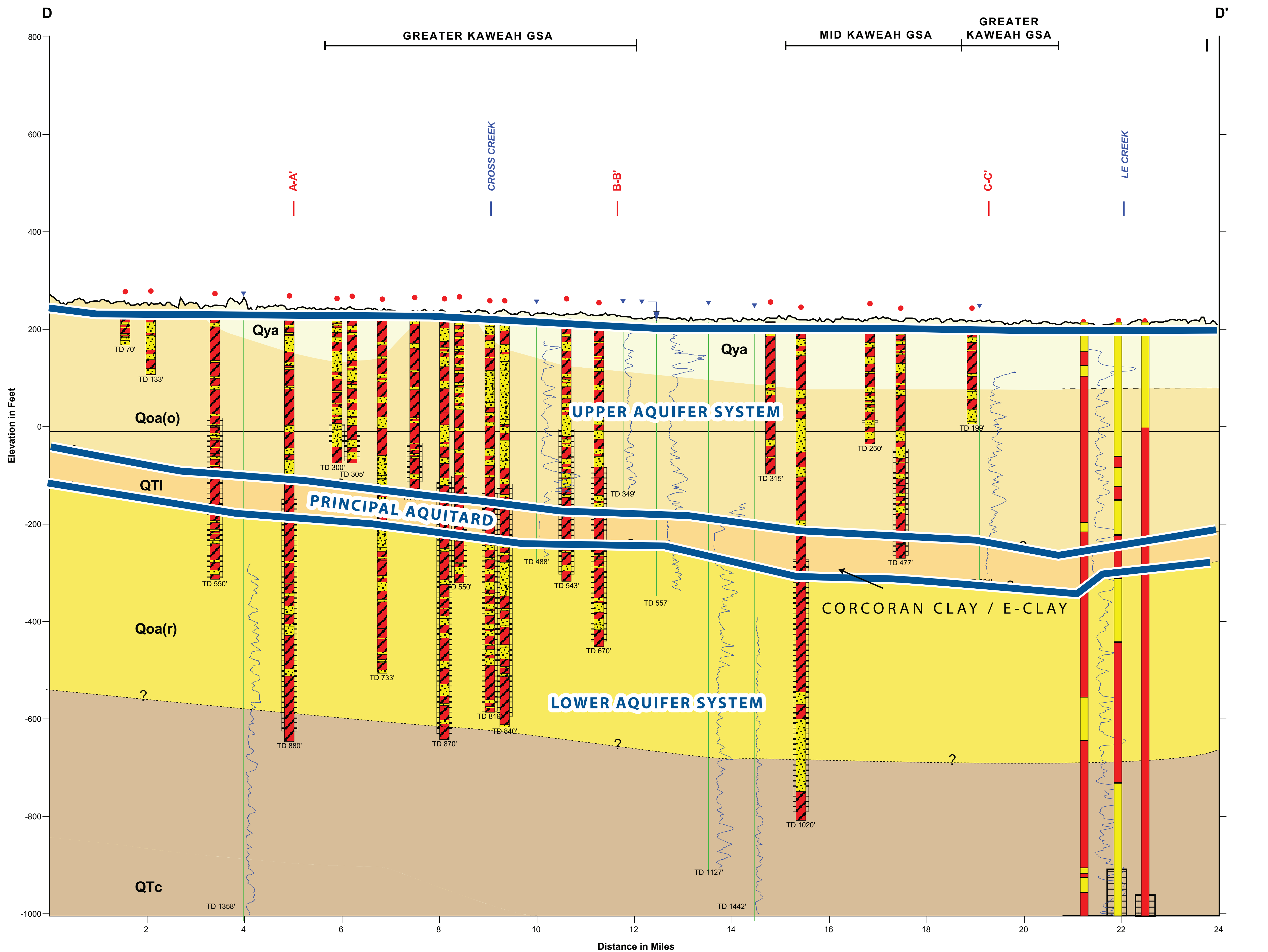



# FIGURE 7

## Cross Section D

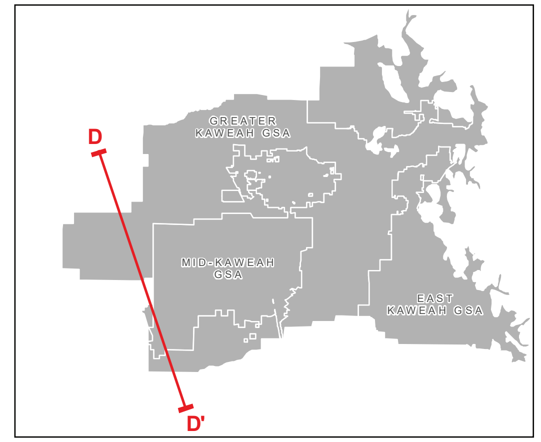
Kaweah Subbasin
Groundwater Sustainability Plan

**LEGEND**

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

**Boring**

- Clay
- Sand
- Sandstone/Rock




**NOTES:**

Cross section modified from Fugro, 2007, Plate 14, Geologic Cross Section D

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.
4. Effective Base of Aquifer System is base of continental deposits (Tulare Formation)

**SCALE**

200 ft

0 — 2 mi

VERTICAL EXAGGERATION: 52.8X

GEI Consultants

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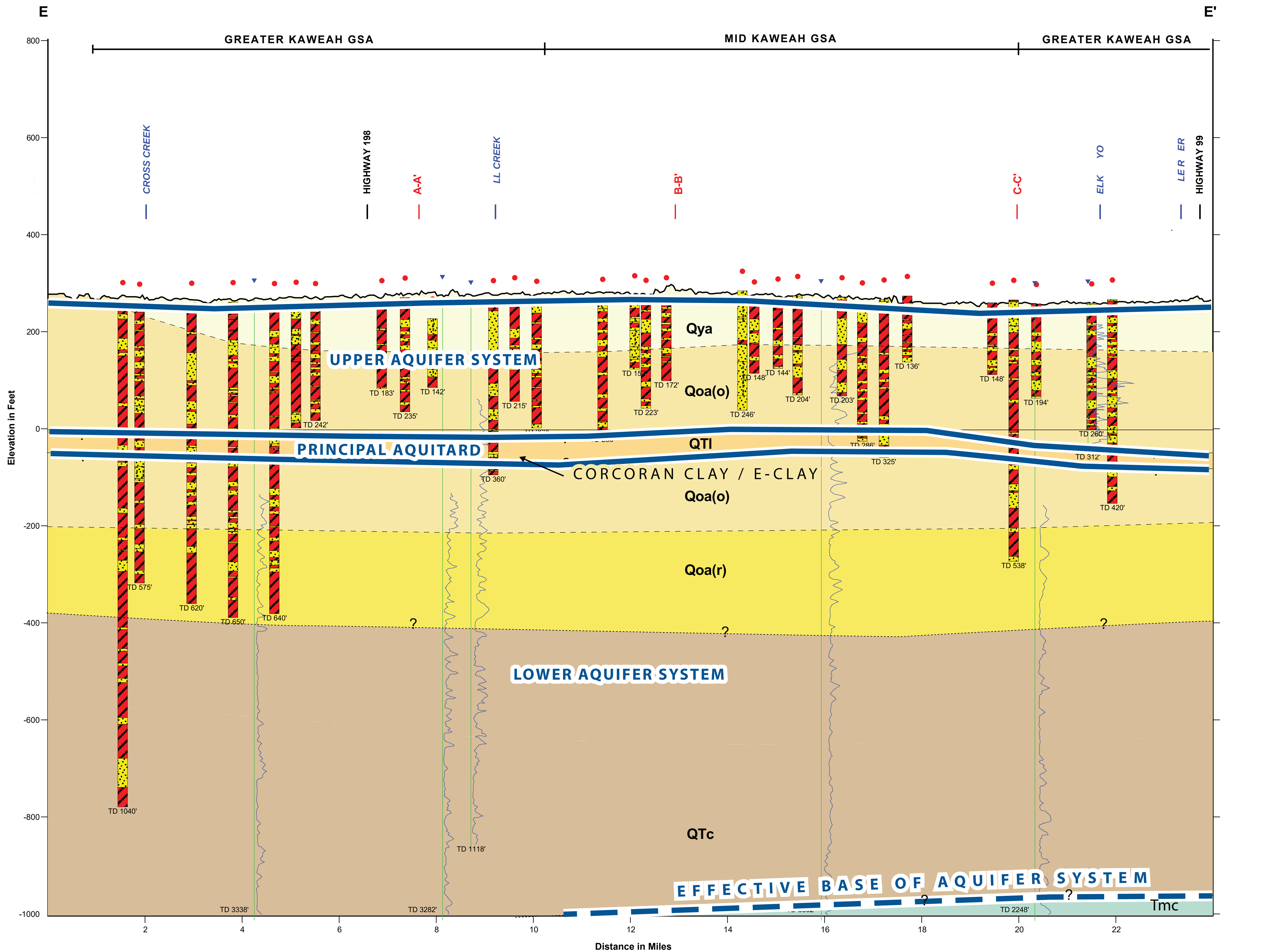


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# FIGURE 8

## Cross Section E

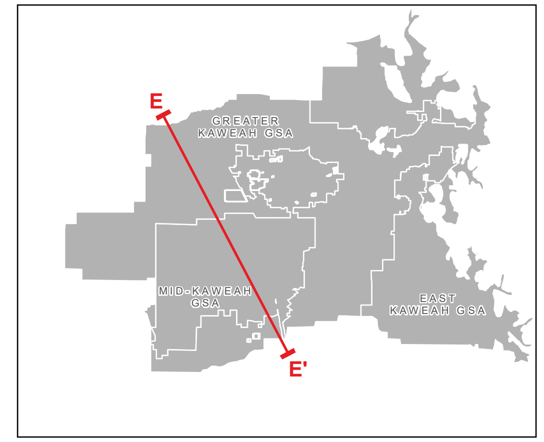
Kaweah Subbasin
Groundwater Sustainability Plan

### LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

**Boring**

- Clay
- Sand
- Sandstone/Rock




**NOTES:**

Cross section modified from Fugro, 2007, Plate 18, Geologic Cross Section E

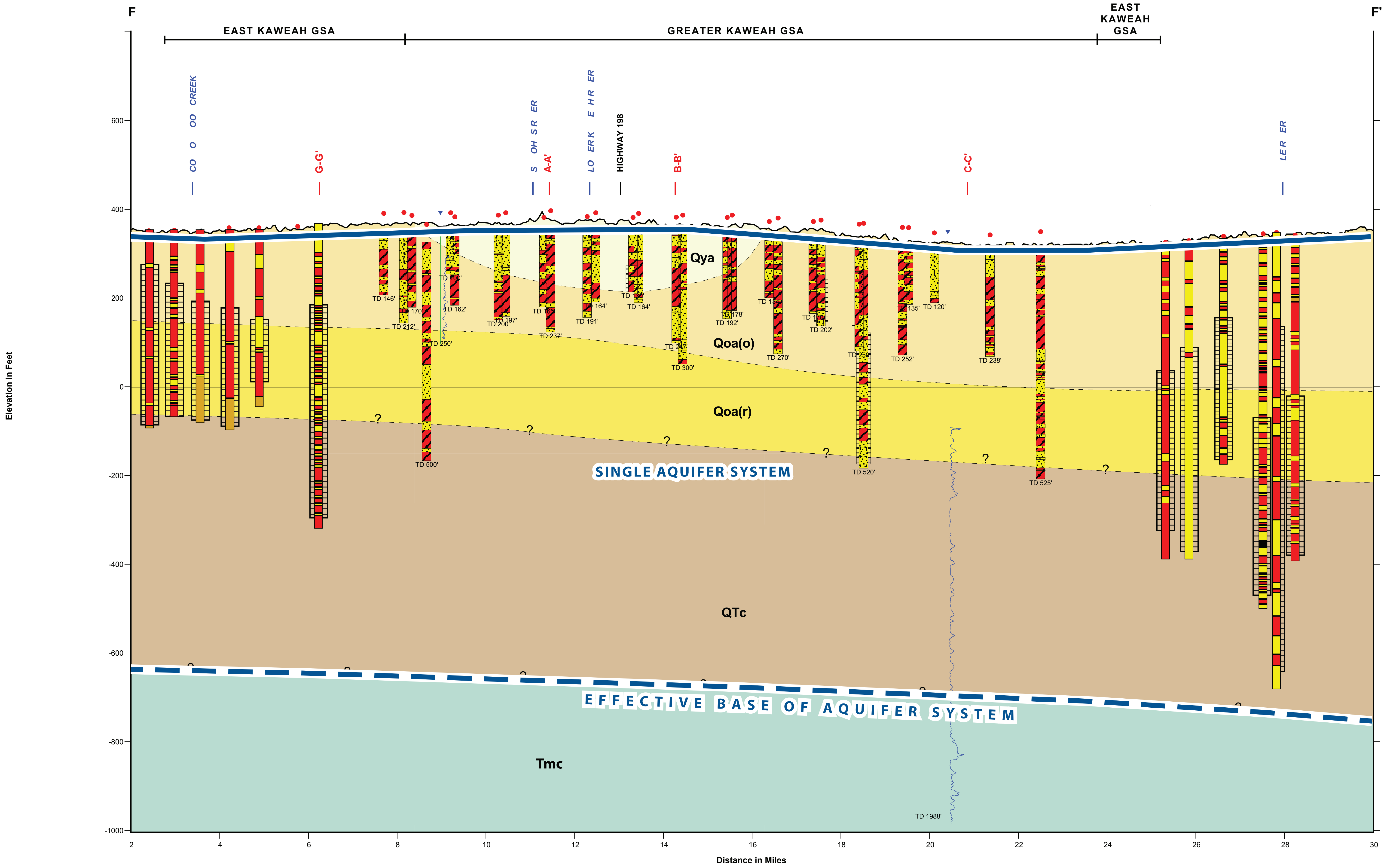
1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

**SCALE**

200 ft — 0 — 2 mi

**VERTICAL EXAGGERATION:** 52.8X

GEI Consultants
GSI Water Solutions, Inc.




# FIGURE 9

## Cross Section F

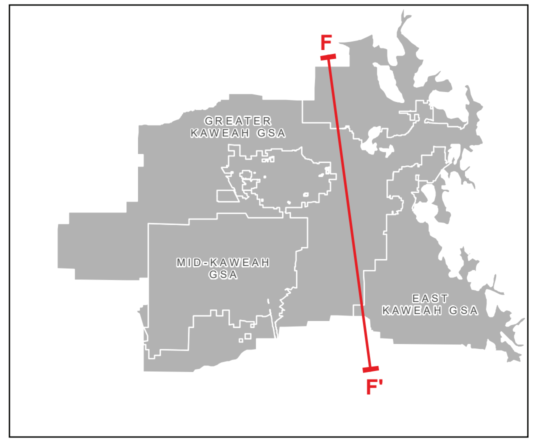
Kaweah Subbasin
Groundwater Sustainability Plan

**LEGEND**

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

**Boring**

- Clay
- Sand
- Sandstone/Rock




**NOTES:**

Cross section modified from Fugro, 2007, Plate 19, Geologic Cross Section F

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

**SCALE**

200 ft

0 — 2 mi

**VERTICAL EXAGGERATION:** 52.8X

GEI Consultants
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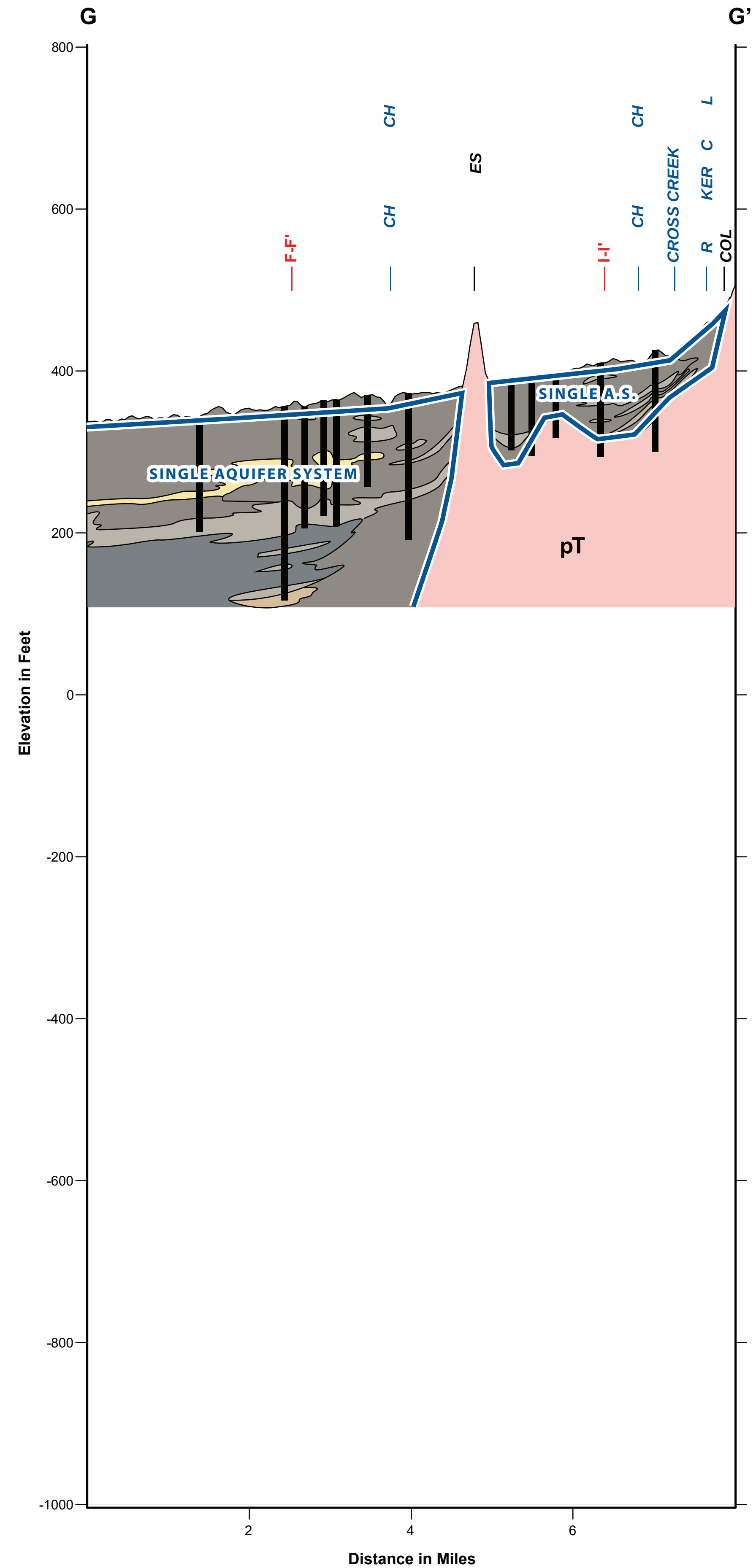


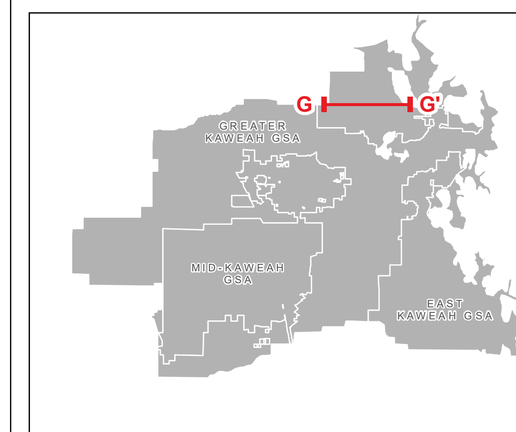

# FIGURE 10

## Cross Section G

Kaweah Subbasin
Groundwater Sustainability Plan

### LEGEND

- Gravel
- Sand
- Silt
- Sandy Clay
- Clay
- pT - Basement Complex
- Generalized Boundaries of Aquifer System




### NOTES:

Cross section modified from U.S. Bureau of Rec. (1949), Geologic Cross Section A

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.
4. Effective Base of Aquifer System is base of continental deposits (Tulare Formation)

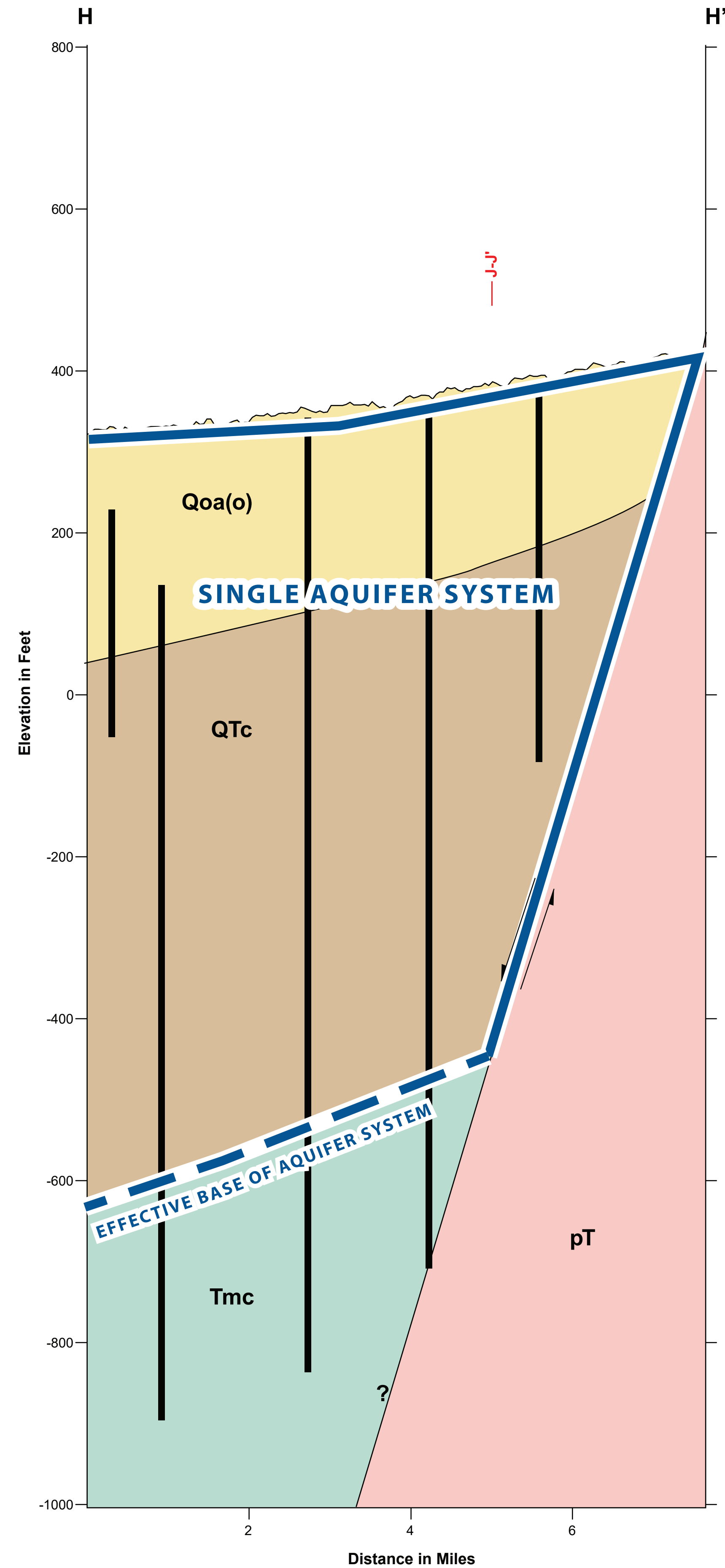
### SCALE

200 ft

**VERTICAL EXAGGERATION:** 52.8X

0 — 2 mi

GEI Consultants
GSI Water Solutions, Inc.



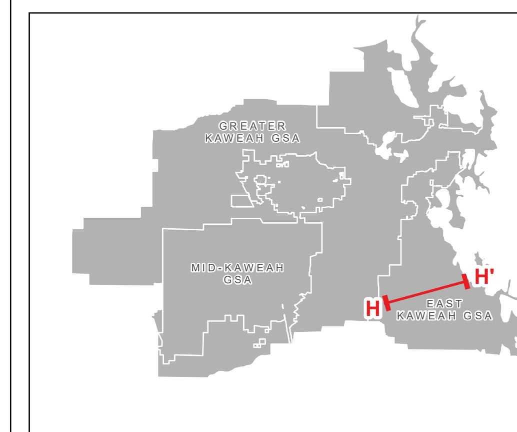

# FIGURE 11

## Cross Section H

Kaweah Subbasin
Groundwater Sustainability Plan

### LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System




**NOTES:**

Cross section modified from Davis et al. (1959), Geologic Cross Section G

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

**SCALE**

200 ft
0
2 mi

**VERTICAL EXAGGERATION:** 52.8X

GEI Consultants
GSI Water Solutions, Inc.

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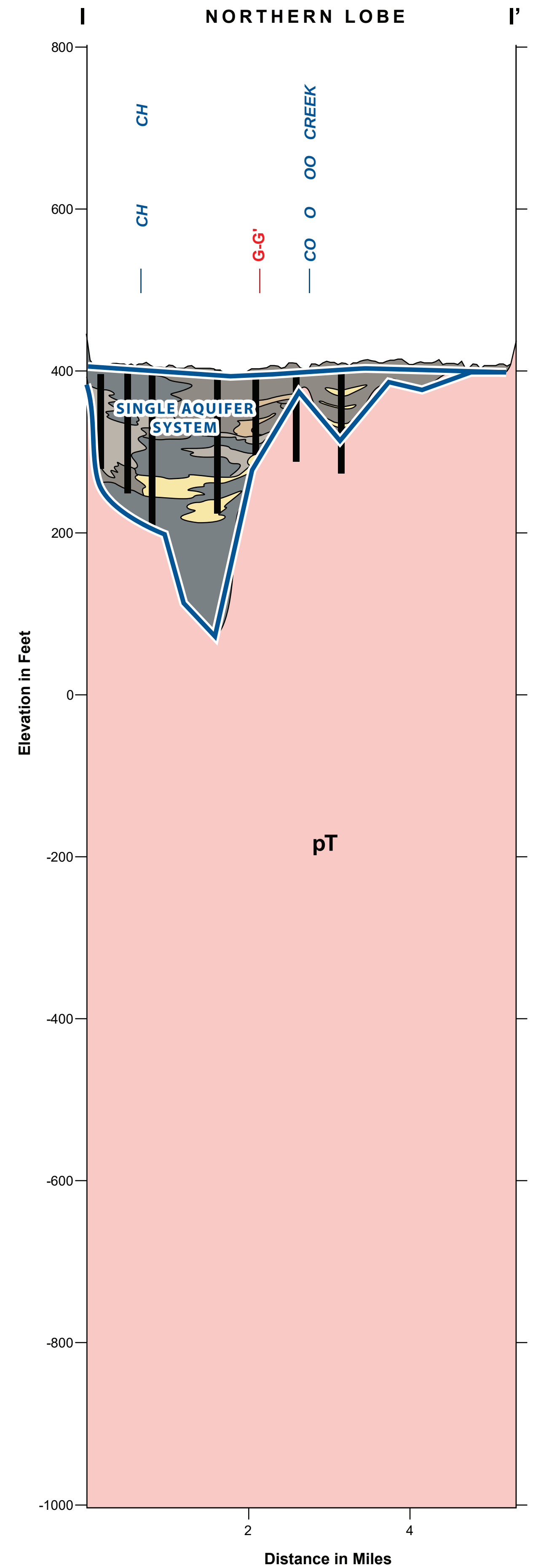


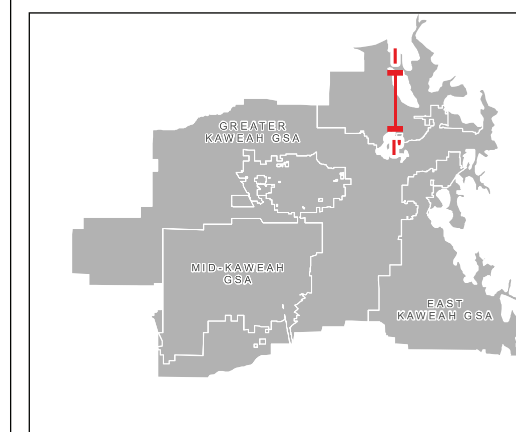

# FIGURE 12

## Cross Section I

Kaweah Subbasin
Groundwater Sustainability Plan

### LEGEND

- Gravel
- Sand
- Silt
- Sandy Clay
- Clay
- pT - Basement Complex
- Generalized Boundaries of Aquifer System




### NOTES:

Cross section modified from U.S. Bureau of Rec. (1949), Geologic Cross Section D

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.
4. Effective Base of Aquifer System is base of continental deposits (Tulare Formation)

### SCALE

200 ft

**VERTICAL EXAGGERATION:** 52.8X

0 2 mi

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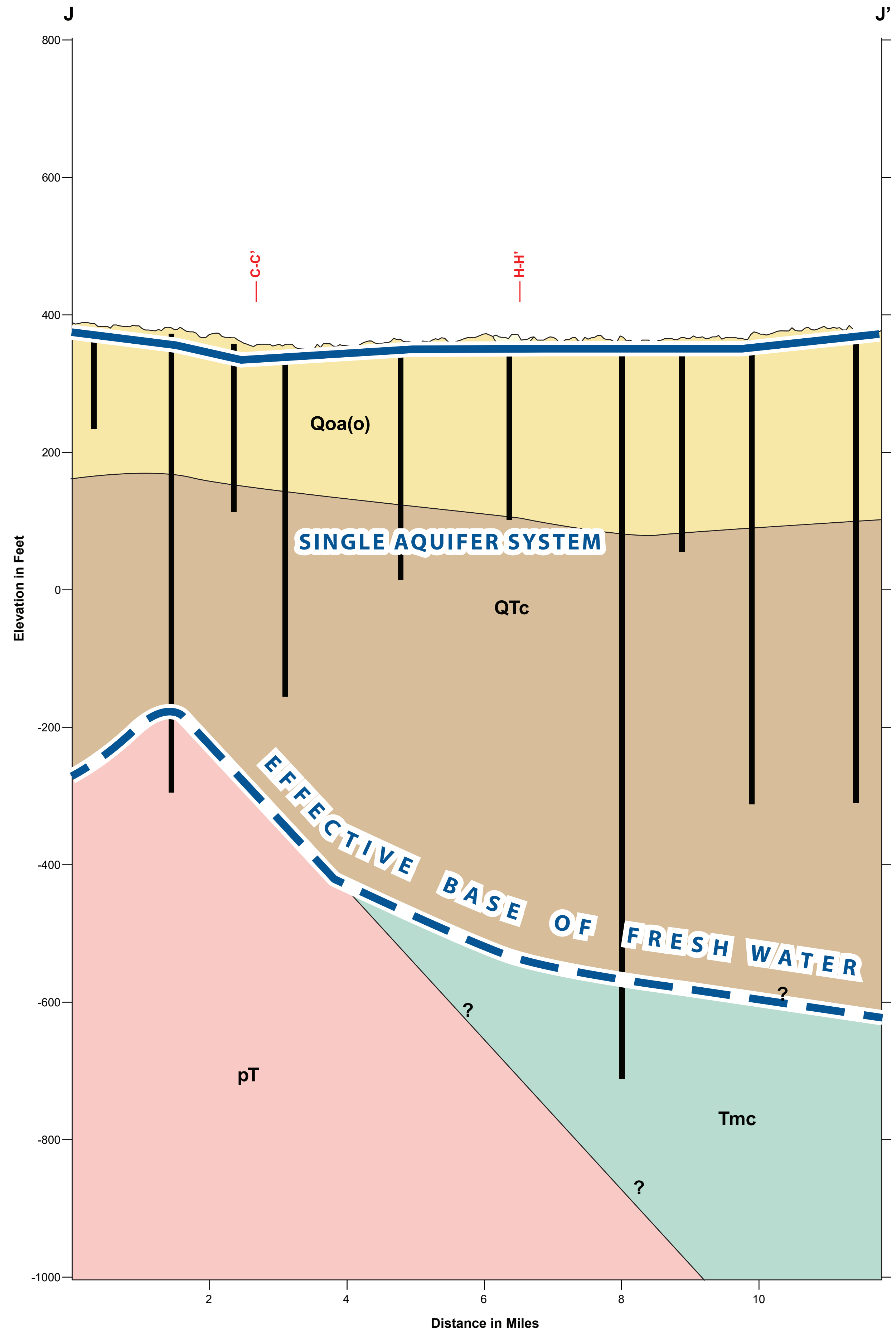


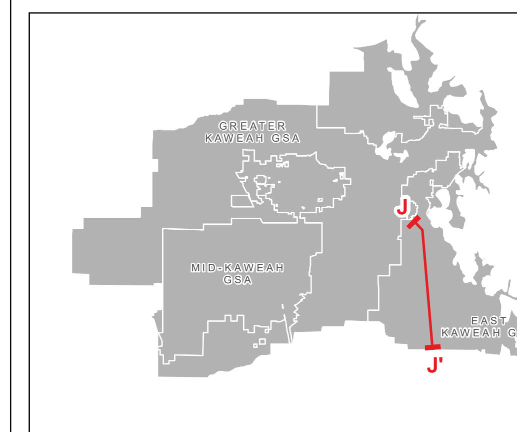

# FIGURE 13

## Cross Section J

Kaweah Subbasin
Groundwater Sustainability Plan

### LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System




**NOTES:**

Cross section modified from Croft and Gordon (1968), Geologic Cross Section E

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

**SCALE**

200 ft
VERTICAL EXAGGERATION: 52.8X
0
2 mi

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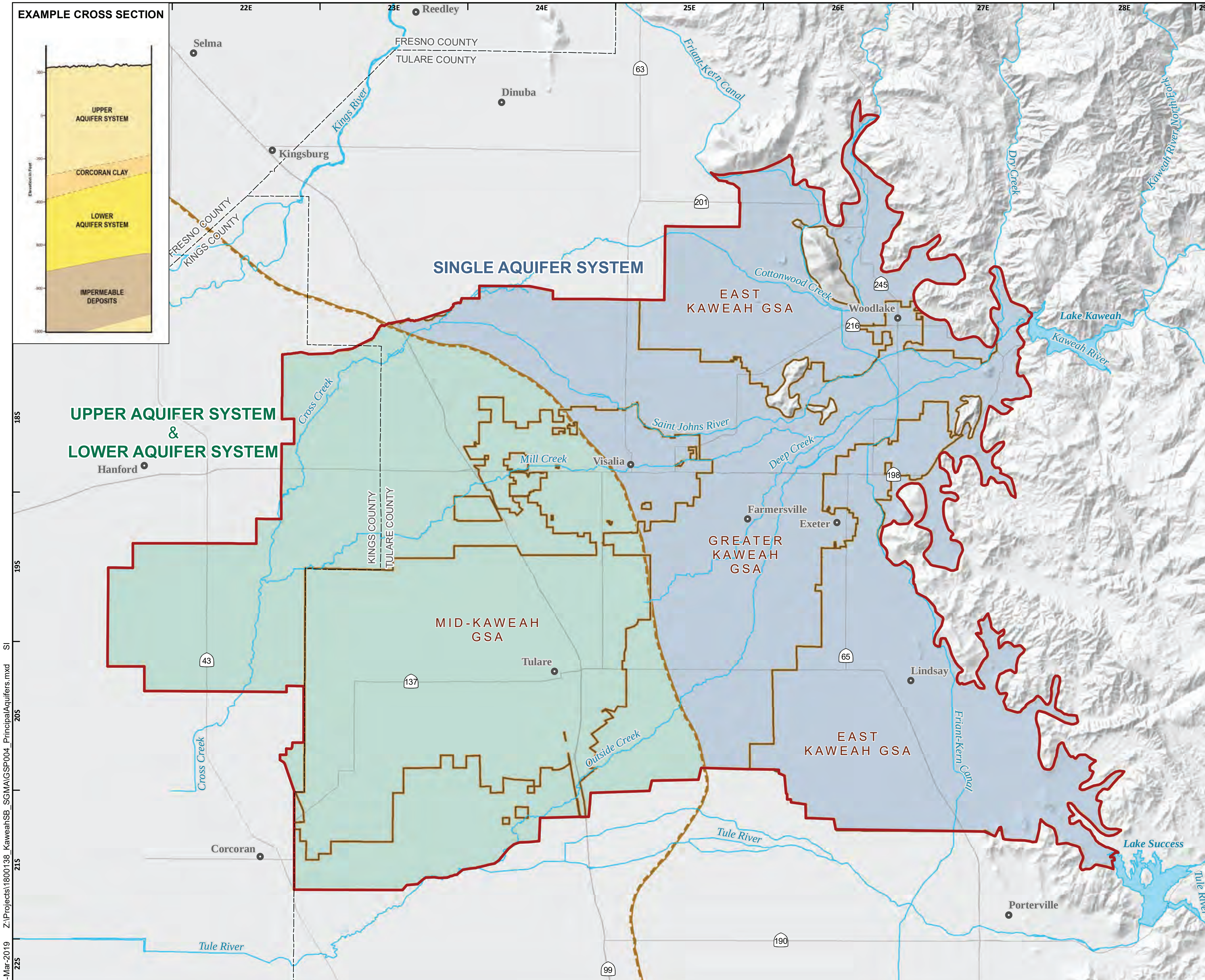


# IDENTIFICATION OF PRINCIPAL AQUIFERS

Approximate Extent of Corcoran Clay
Upper/Lower Aquifer System
Single Aquifer System
Kaweah Subbasin Boundary
Kaweah Subbasin GSA

**All Other Features**

Highway
Waterway
Lake

0 2 4 8
Miles

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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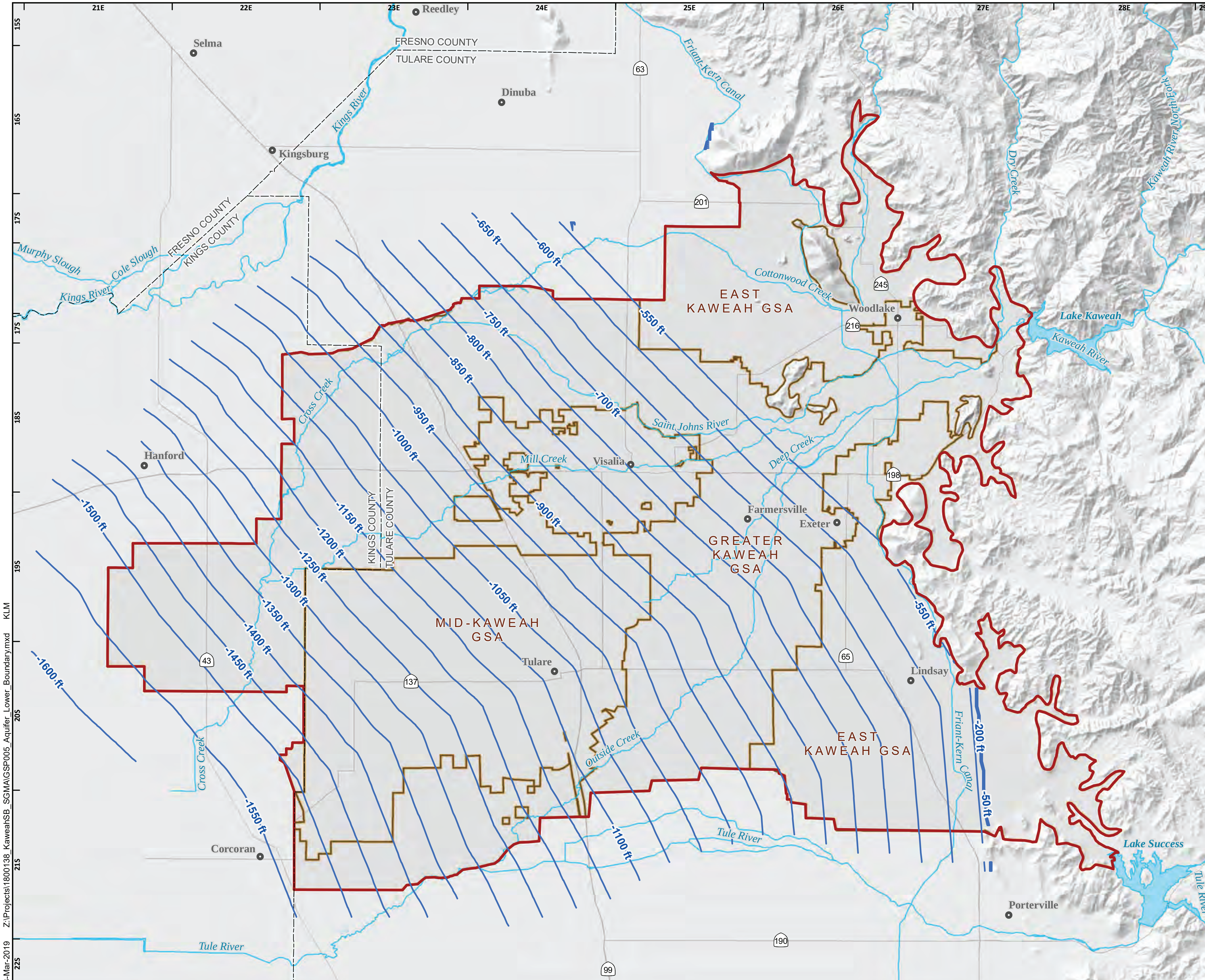
FIGURE 14

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP004_PrincipalAquifers.mxd SI

# APPROXIMATE ELEVATION OF EFFECTIVE BASE OF FRESHWATER SYSTEM




Approx. Elevation of Effective Base of Freshwater System (ft MSL)

Kaweah Subbasin Boundary

Kaweah Subbasin GSA

**All Other Features**

Highway

Waterway

Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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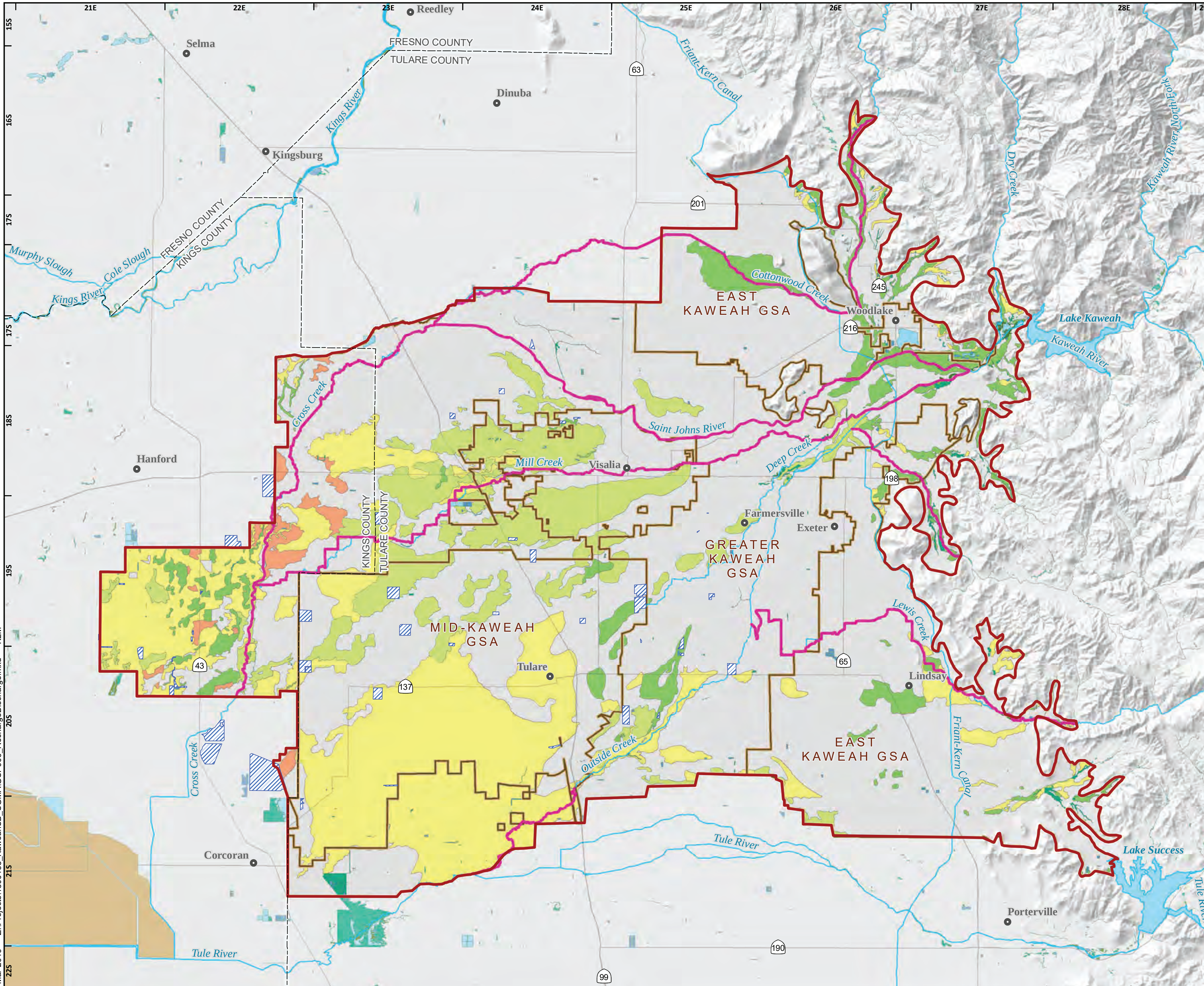
FIGURE 15

# GROUNDWATER RECHARGE AND DISCHARGE AREAS AND WETLANDS




**Wetland Type (National Wetland Inventory, 2018)**

- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater/Recharge/Irrigation Pond
- Lake
- Farmed Wetland

**Soil Agricultural Groundwater Banking Index (2015)**

**Rating Class**

- Excellent
- Good
- Moderately Good
- Moderately Poor
- Recharge Basin
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Losing Stream Reach
- Lake

Note: Data is preliminary and subject to field verification for accuracy.

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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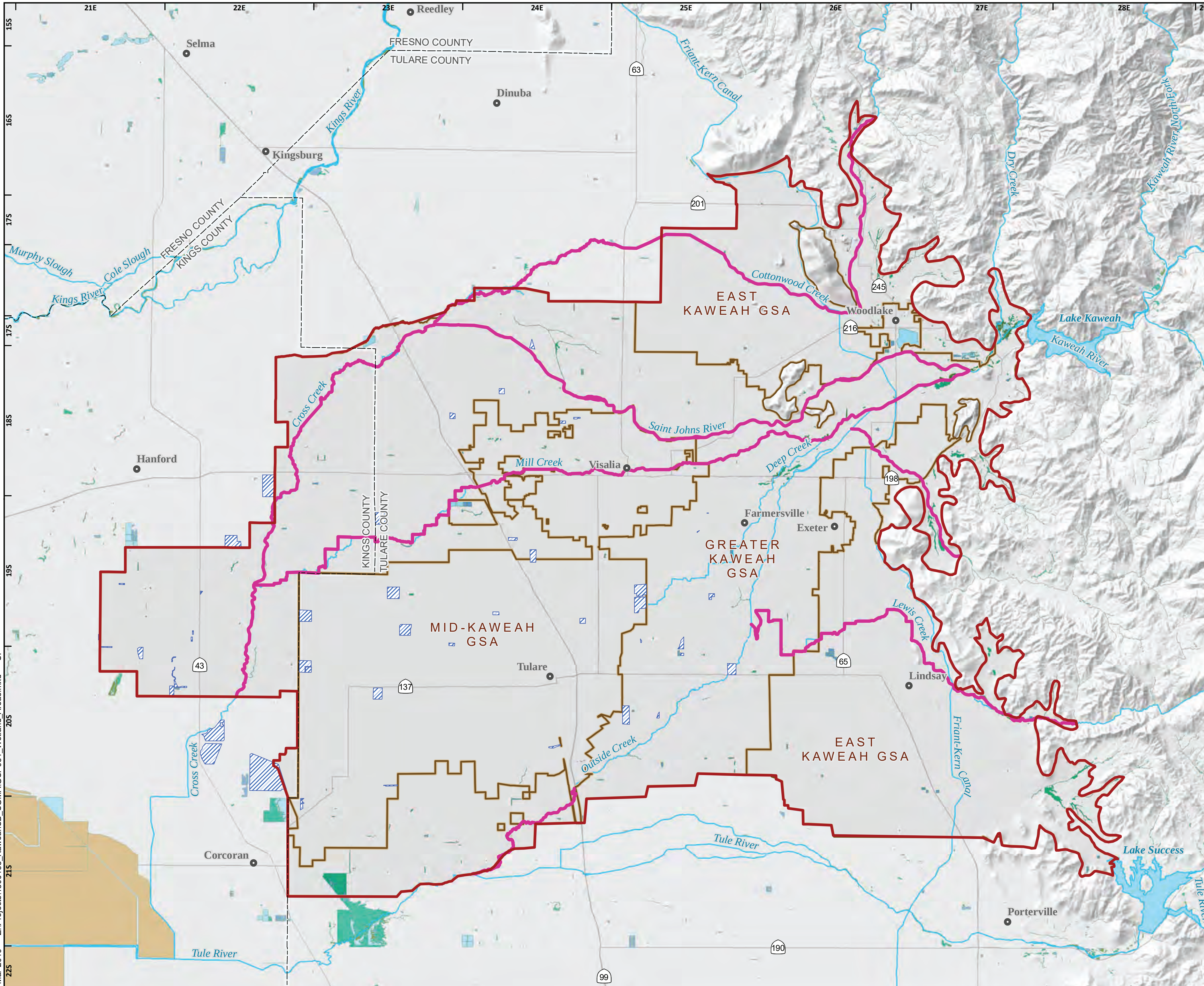
FIGURE 16

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP006_RechargeDischarge.mxd KLM




# WETLAND AREAS

**Wetland Type (National Wetland Inventory, 2018)**

- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater/Recharge/Irrigation Pond
- Lake
- Farmed Wetland
- Recharge Basin
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Losing Stream Reach
- Lake

Note: Data is preliminary and subject to field verification for accuracy.

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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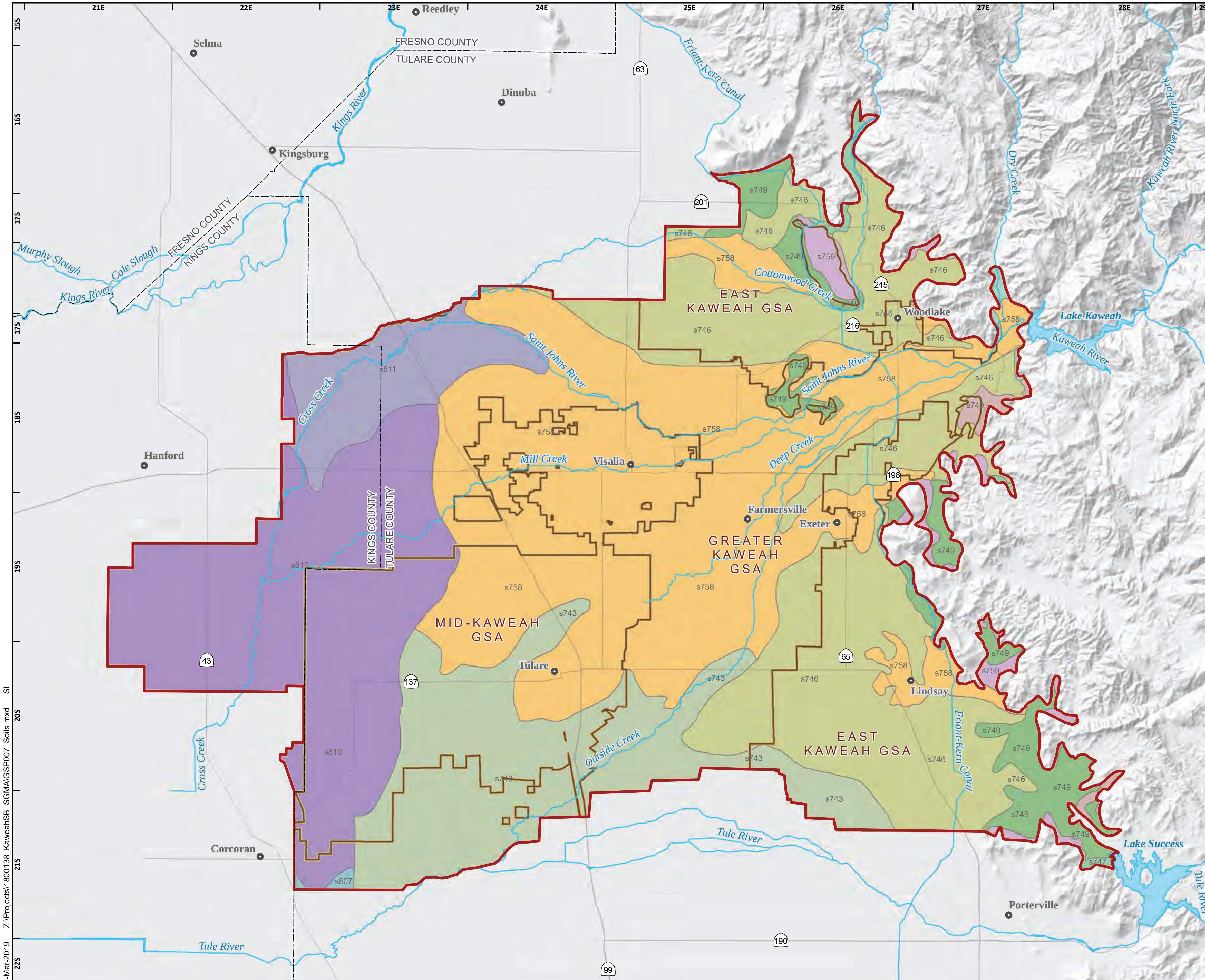
FIGURE 17

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP051_Wetland_Areas.mxd SI




# SOILS MAP

**National Resource Conservation Service Soils Categories (STATSGO)**

- Hanford-Delhi (s745)
- Lakeside-Kimberlina-Garces (s810)
- Lewis-Fresno-Dinuba (s742)
- Nord-Grangeville-Chino (s744)
- Porterville-Centerville (s749)
- Rock outcrop-Friant-Coarsegold (s751)
- Rock outcrop-Las Posas-Cibo (s759)
- San Joaquin-Madera-Cometa (s746)
- Sheephead-Rock outcrop-Holland-Crouch (s752)
- Tulare (s808)
- Vista-Rock outcrop-Auberry-Ahwahnee (s740)
- Vista-Rock outcrop-Cieneba (s747)
- Water (s8369)
- Waukena-Temple-Pond (s743)
- Westcamp-Houser-Gepford-Armona (s807)
- Woolstalf-Rock outcrop-Jocal-Hotaw-Chaix (s1072)
- Yettem-San Emigdio-Honcut (s758)
- Youd-Remnoy-Melga-Kimberlina (s811)
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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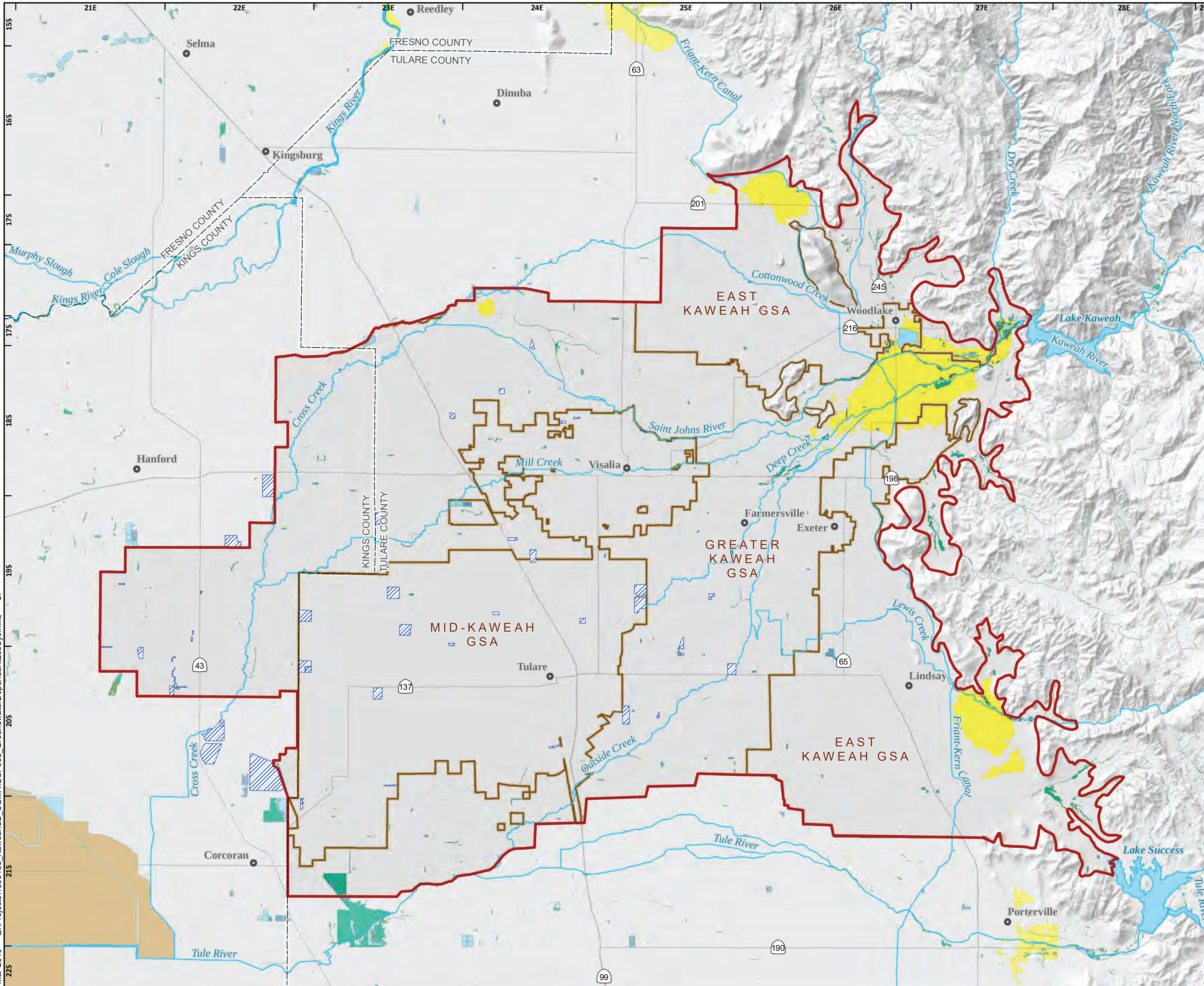
# POTENTIAL GROUNDWATER DEPENDENT ECOSYSTEMS




**Potential Groundwater Dependant Ecosystem**

- Spring 2015 Groundwater Surface within 50 feet of Ground Surface

**Wetland Type (National Wetland Inventory, 2018)**

- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater/Recharge/Irrigation Pond
- Lake
- Farmed Wetland
- Recharge Basin
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

Note: Data is preliminary and subject to field verification for accuracy.

0 2 4 8
Miles

N

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Groundwater Sustainability Plan
Tulare County, California

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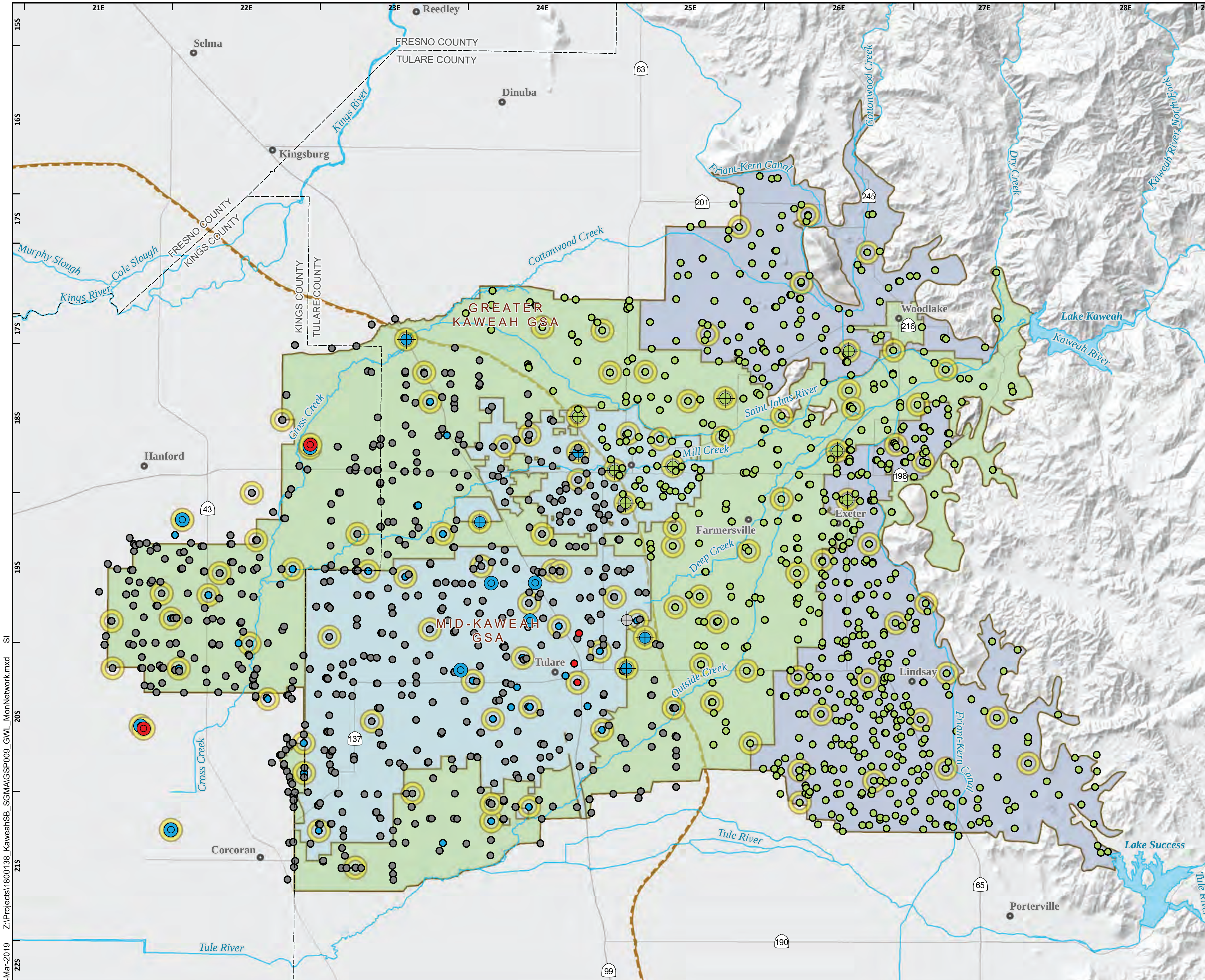
11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP008_GroundwaterDependantEcoSys.mxd SI

# GROUNDWATER LEVEL MONITORING NETWORK




**Well Types**

- Lower Aquifer
- Upper Aquifer
- Single Aquifer
- Unknown
- Dedicated Monitoring Well
- Dual Completion Well
- Monitoring Well
- Key Well

Approximate Extent of Corcoran Clay

**GSA Boundaries**

- East Kaweah GSA
- Greater Kaweah GSA
- Mid-Kaweah GSA
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles
N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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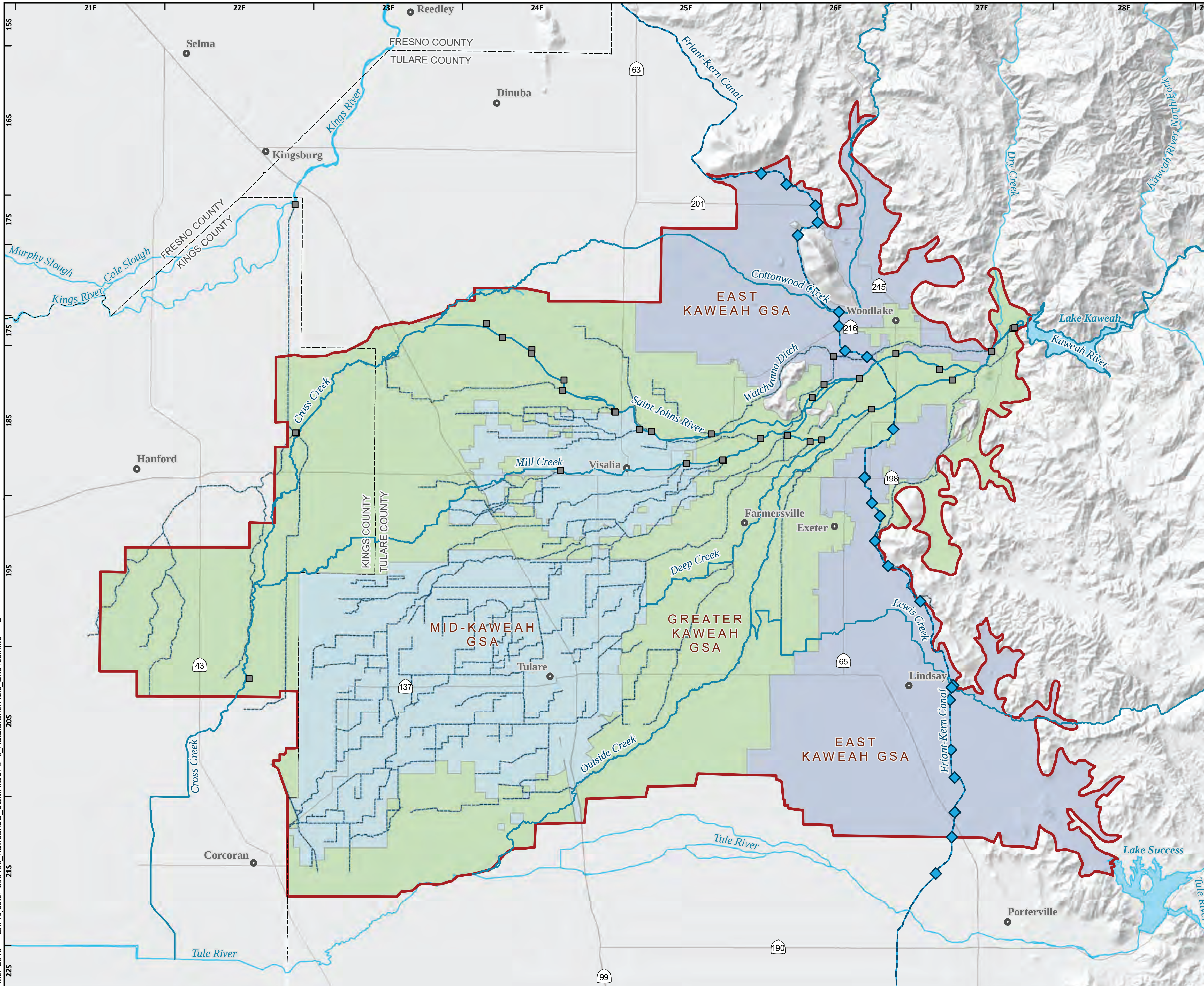
11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP009_GWL_MonNetwork.mxd SI

# NATURAL AND MAN-MADE CHANNELS




Friant-Kern Turnout
Headgate
Principal KSB Natural Channel
Friant-Kern Canal
Other Natural Channel
Man-Made Channel

**GSA Boundaries**

East Kaweah GSA
Greater Kaweah GSA
Mid-Kaweah GSA
Kaweah Subbasin Boundary

**All Other Features**

Highway
Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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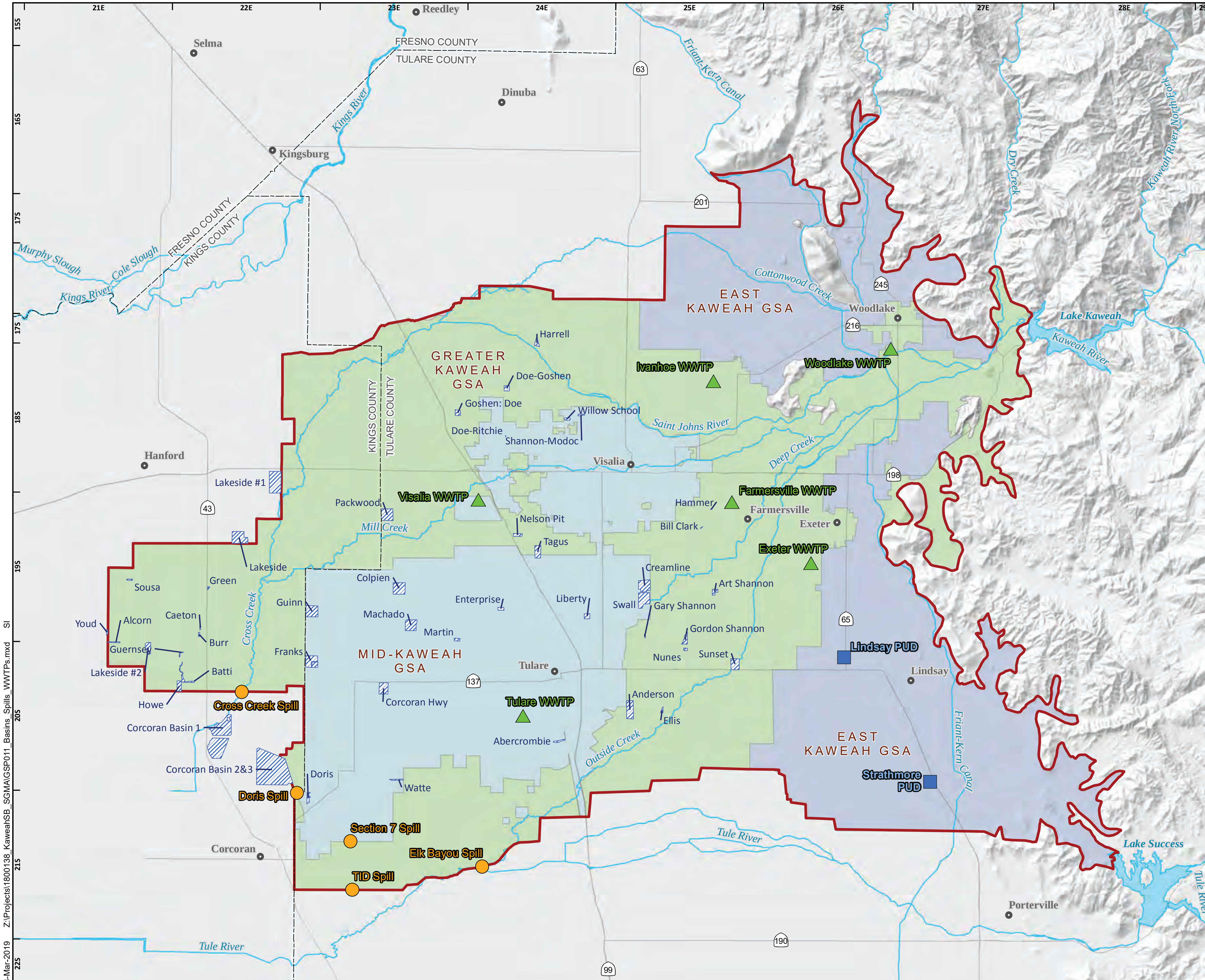
FIGURE 21




# RECHARGE BASINS, SPILLS AND WASTEWATER TREATMENT PLANTS

- Surface Water Spill Point
- Waste Water Treatment Plant (WWTP)
- PUD Treatment Plant
- Recharge Basin

**GSA Boundaries**

- East Kaweah GSA
- Greater Kaweah GSA
- Mid-Kaweah GSA
- Kaweah Subbasin Boundary

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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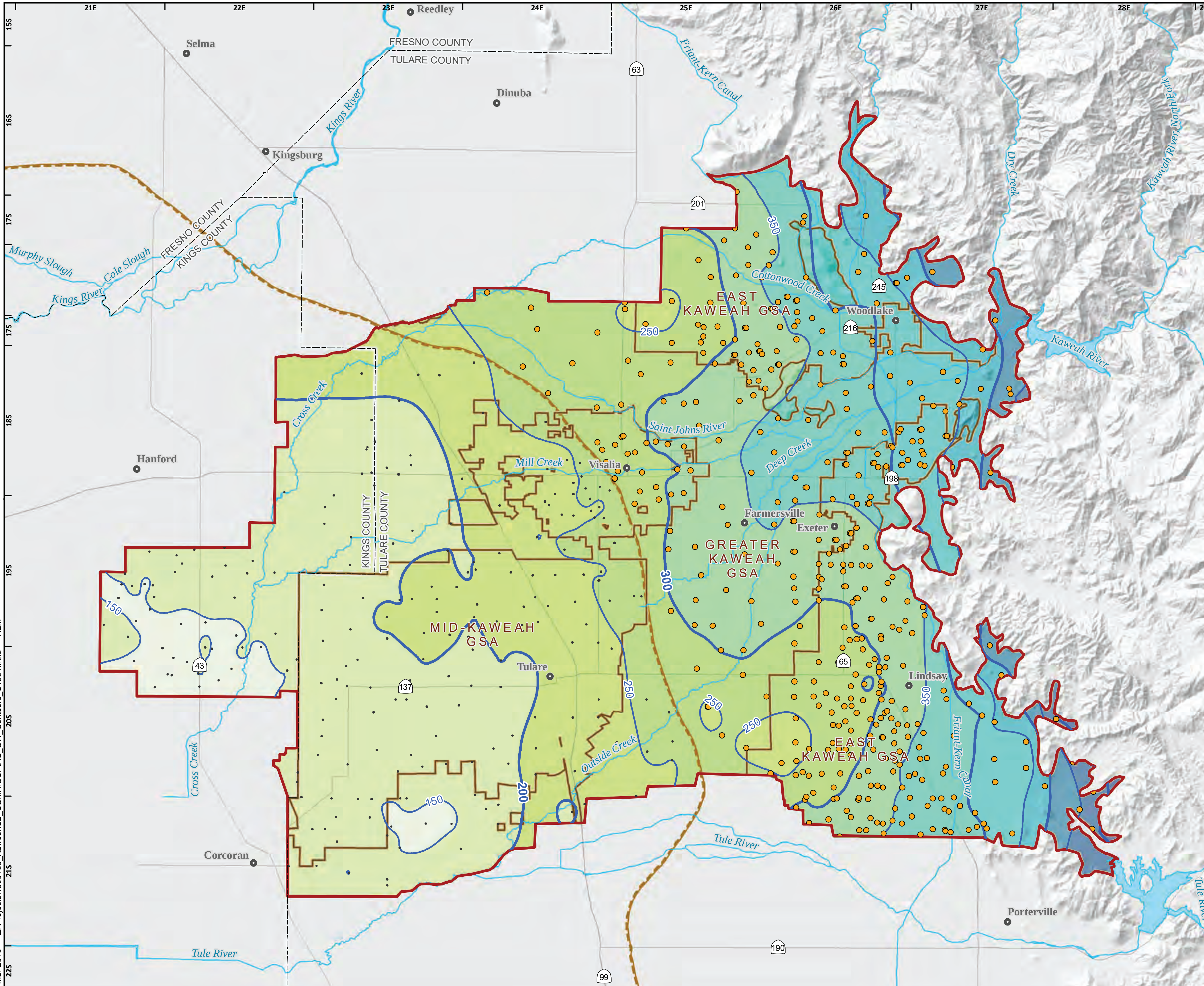
FIGURE 22

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11-Mar-2019

# SPRING 1981 GROUNDWATER ELEVATION CONTOURS

- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

**Groundwater Elevation Contours, Spring 1981 (GWE ft msl)**

- Major (100-foot interval)
- Minor (50-foot interval)
- 123 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- 501 - 550
- 551 - 600
- 601 - 650
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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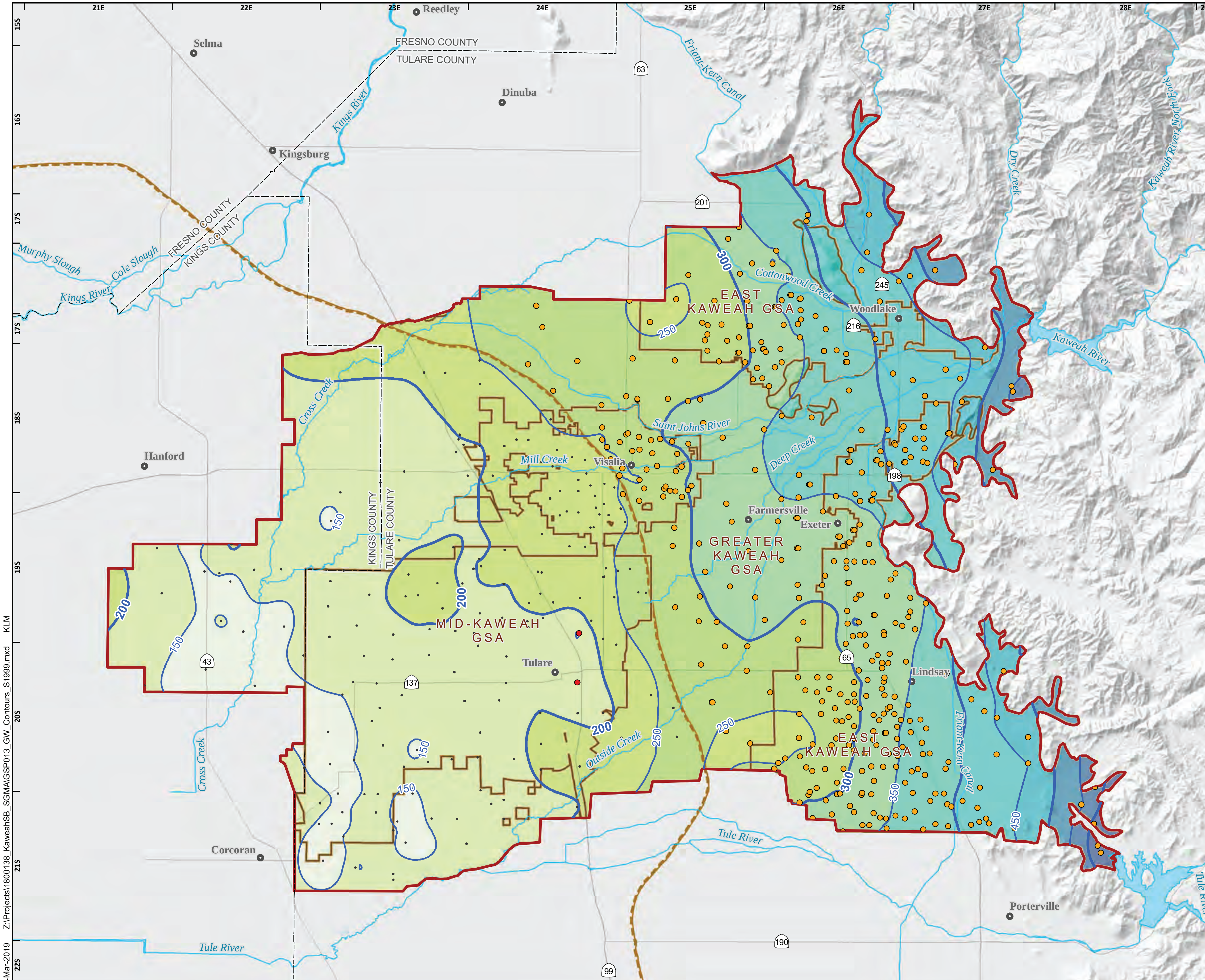
FIGURE 23

# SPRING 1999 GROUNDWATER ELEVATION CONTOURS




- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

**Groundwater Elevation Contours, Spring 1999 (GWE ft msl)**

- Major (100-foot interval)
- Minor (50-foot interval)
- 120 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- 501 - 550
- 551 - 600
- 601 - 650
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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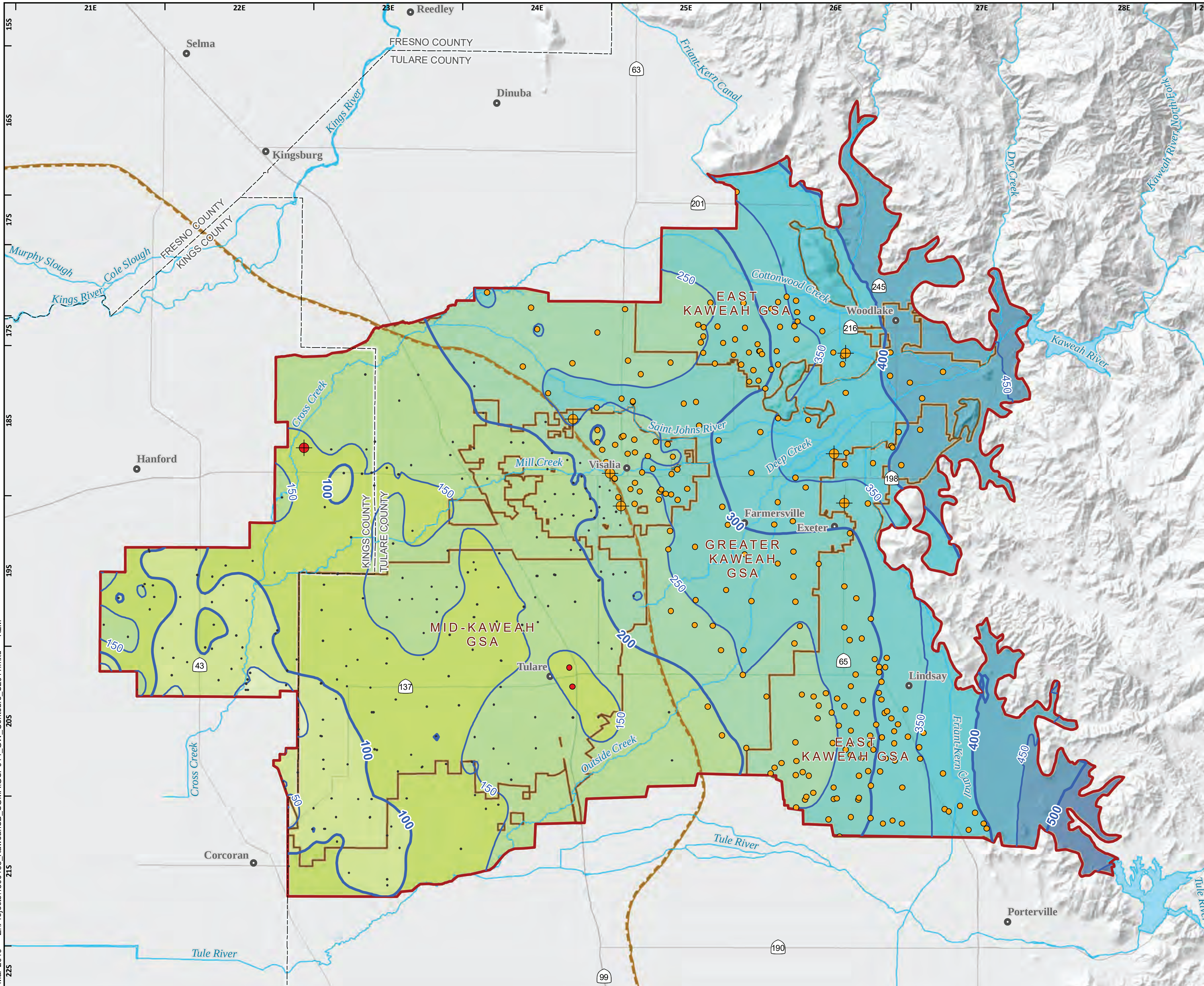
Z:\Projects\1800138_KaweahSB_SGMA\GSP013_GW_Contours_S1999.mxd KLM
11-Mar-2019

# SPRING 2011 GROUNDWATER ELEVATION CONTOURS




Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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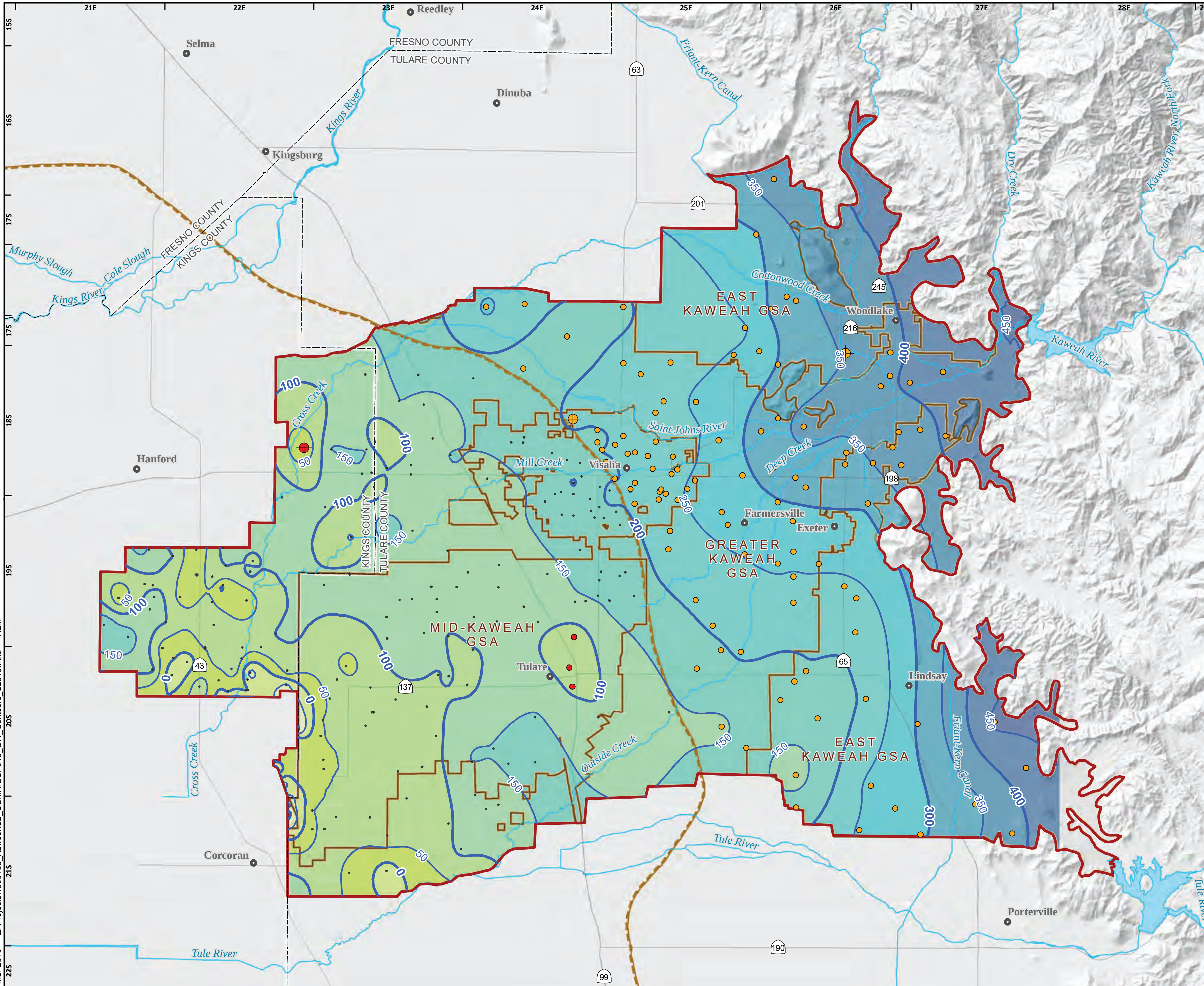
FIGURE 25

# SPRING 2015 GROUNDWATER ELEVATION CONTOURS




Lower Aquifer System, Dedicated Monitoring Well
Single Aquifer System, Dedicated Monitoring Well
Lower Aquifer System Well
Single Aquifer System Well
Well Construction Details Unknown

**Groundwater Elevation Contours, Spring 2015 (GWE ft msl)**

Major (100-foot interval)
Minor (50-foot interval)
-112 - -100
-99 - -50
-49 - 0
1 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
Approximate Extent of Corcoran Clay
Kaweah Subbasin Boundary
Kaweah Subbasin GSA

**All Other Features**

Highway
Waterway
Lake

0 2 4 8
Miles

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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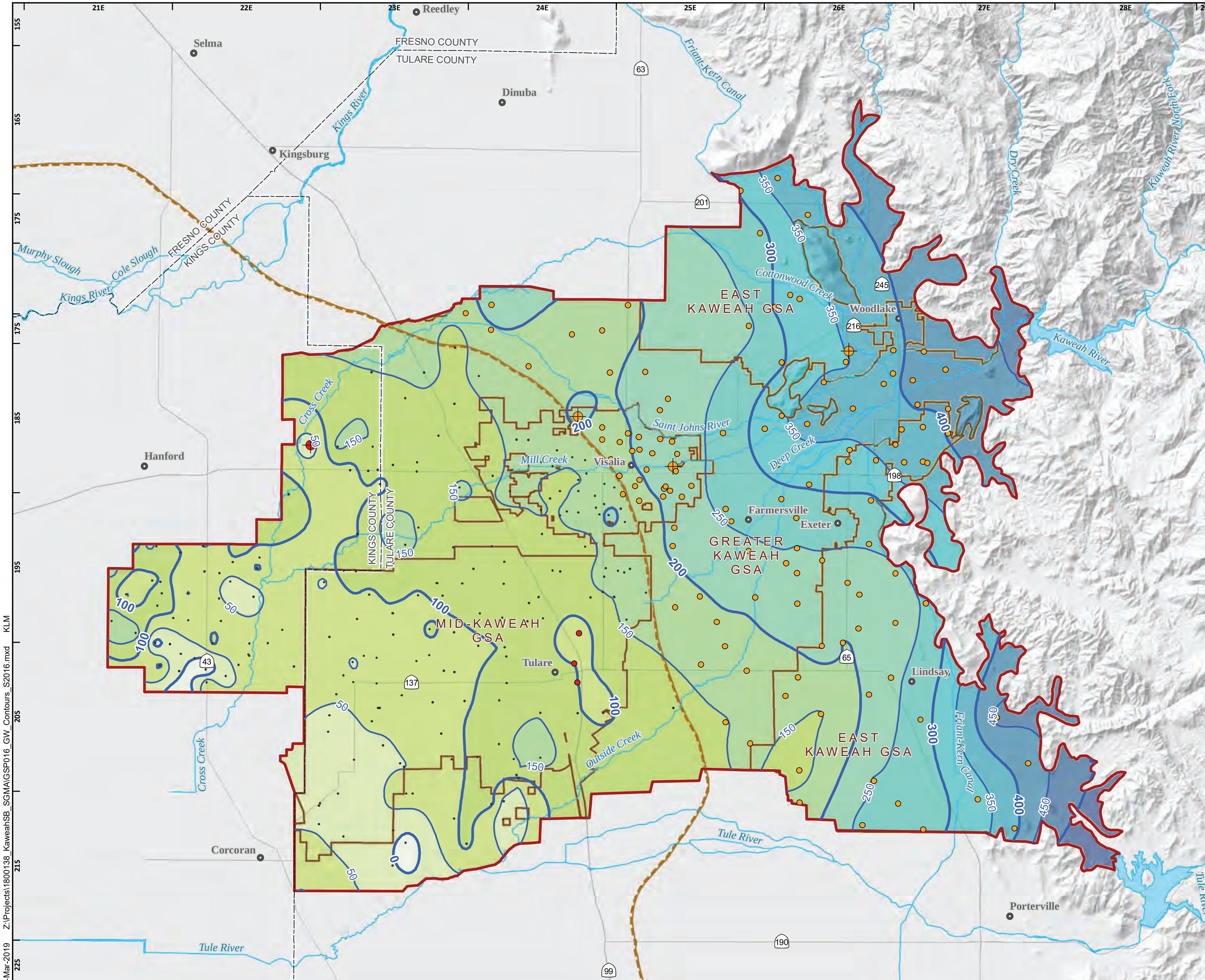
FIGURE 26

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP015_GW_Contours_S2015.mxd KLM

# SPRING 2016 GROUNDWATER ELEVATION CONTOURS




Lower Aquifer System, Dedicated Monitoring Well

Single Aquifer System, Dedicated Monitoring Well

Lower Aquifer System Well

Single Aquifer System Well

Well Construction Details Unknown

**Groundwater Elevation Contours, Spring 2016 (GWE ft msl)**

Major (100-foot interval)

Minor (50-foot interval)

-46 - 0

1 - 50

51 - 100

101 - 150

151 - 200

201 - 250

251 - 300

301 - 350

351 - 400

401 - 450

451 - 500

501 - 550

Approximate Extent of Corcoran Clay

Kaweah Subbasin Boundary

Kaweah Subbasin GSA

**All Other Features**

Highway

Waterway

Lake

0 2 4 8

Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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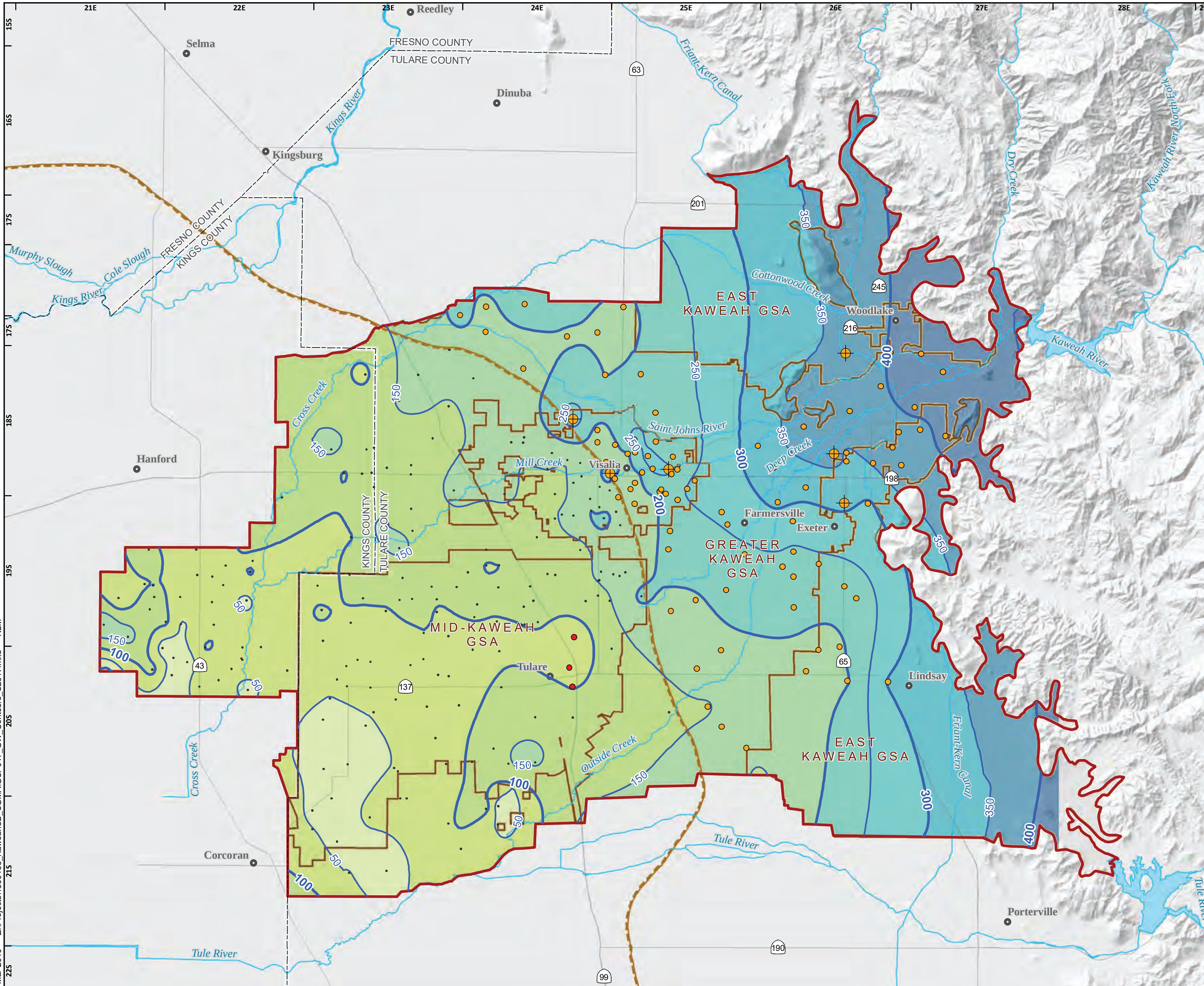
FIGURE 27

# SPRING 2017 GROUNDWATER ELEVATION CONTOURS




- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

**Groundwater Elevation Contours, Spring 2017 (GWE ft msl)**

- Major (100-foot interval)
- Minor (50-foot interval)
- -6 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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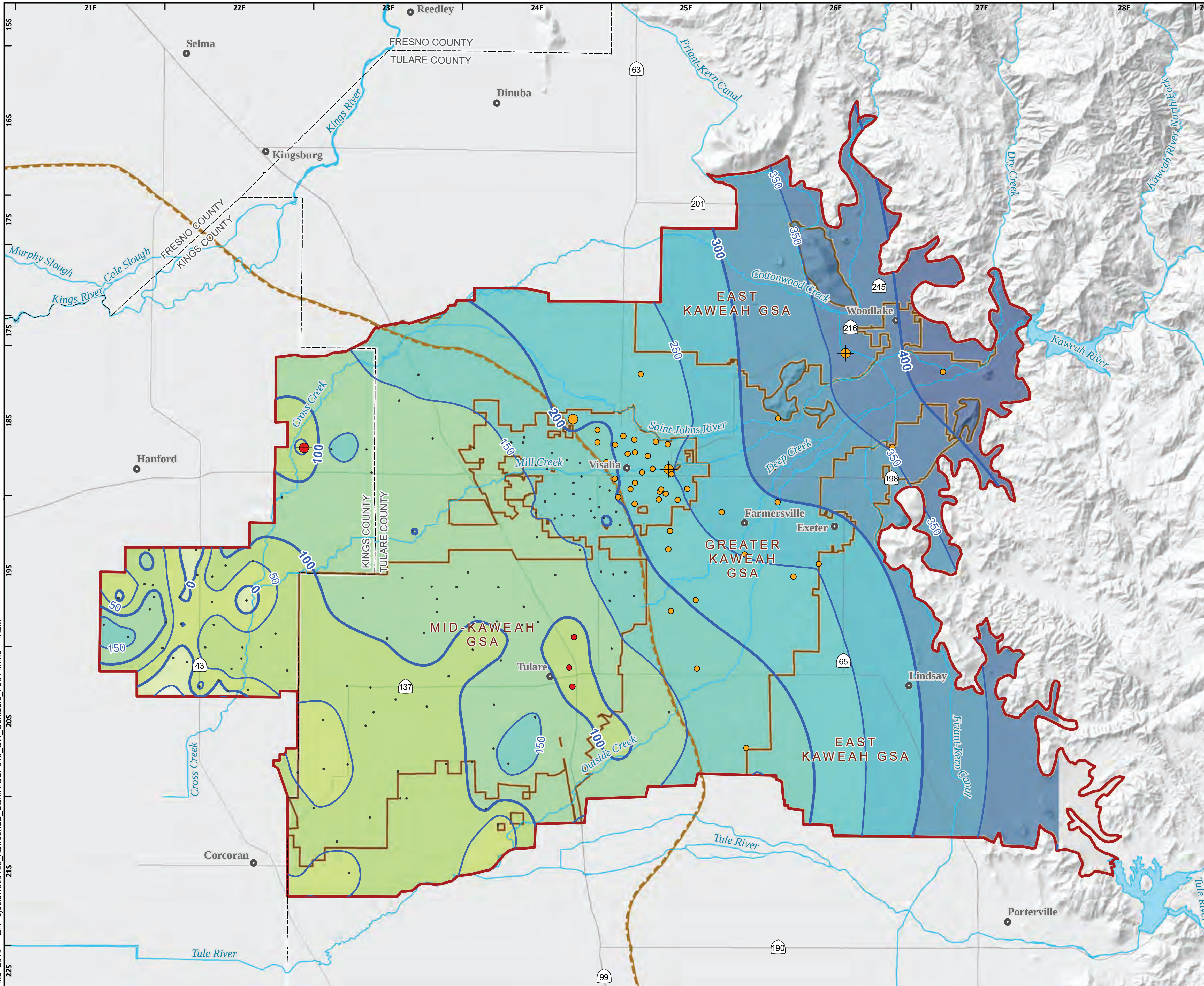
FIGURE 28

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP017_GW_Contours_S2017.mxd KLM

# FALL 2014 GROUNDWATER ELEVATION CONTOURS




- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

**Groundwater Elevation Contours, Fall 2014 (GWE ft msl)**

- Major (100-foot interval)
- Minor (50-foot interval)
- -75 - -50
- -49 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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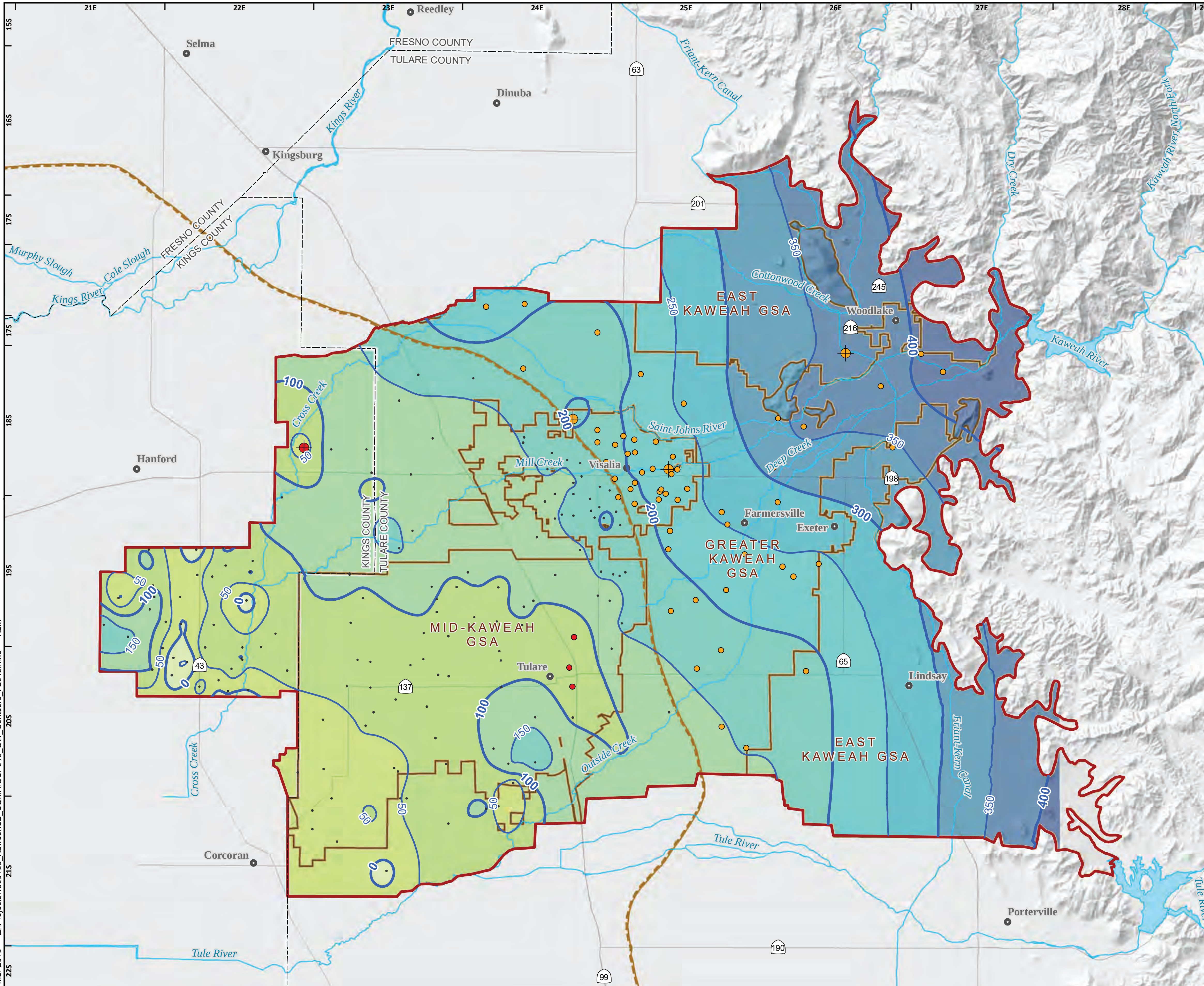
FIGURE 29

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP018_GW_Contours_F2014.mxd KLM




# FALL 2015 GROUNDWATER ELEVATION CONTOURS

- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

**Groundwater Elevation Contours, Fall 2015 (GWE ft msl)**

- Major (100-foot interval)
- Minor (50-foot interval)
- -52 - -50
- -49 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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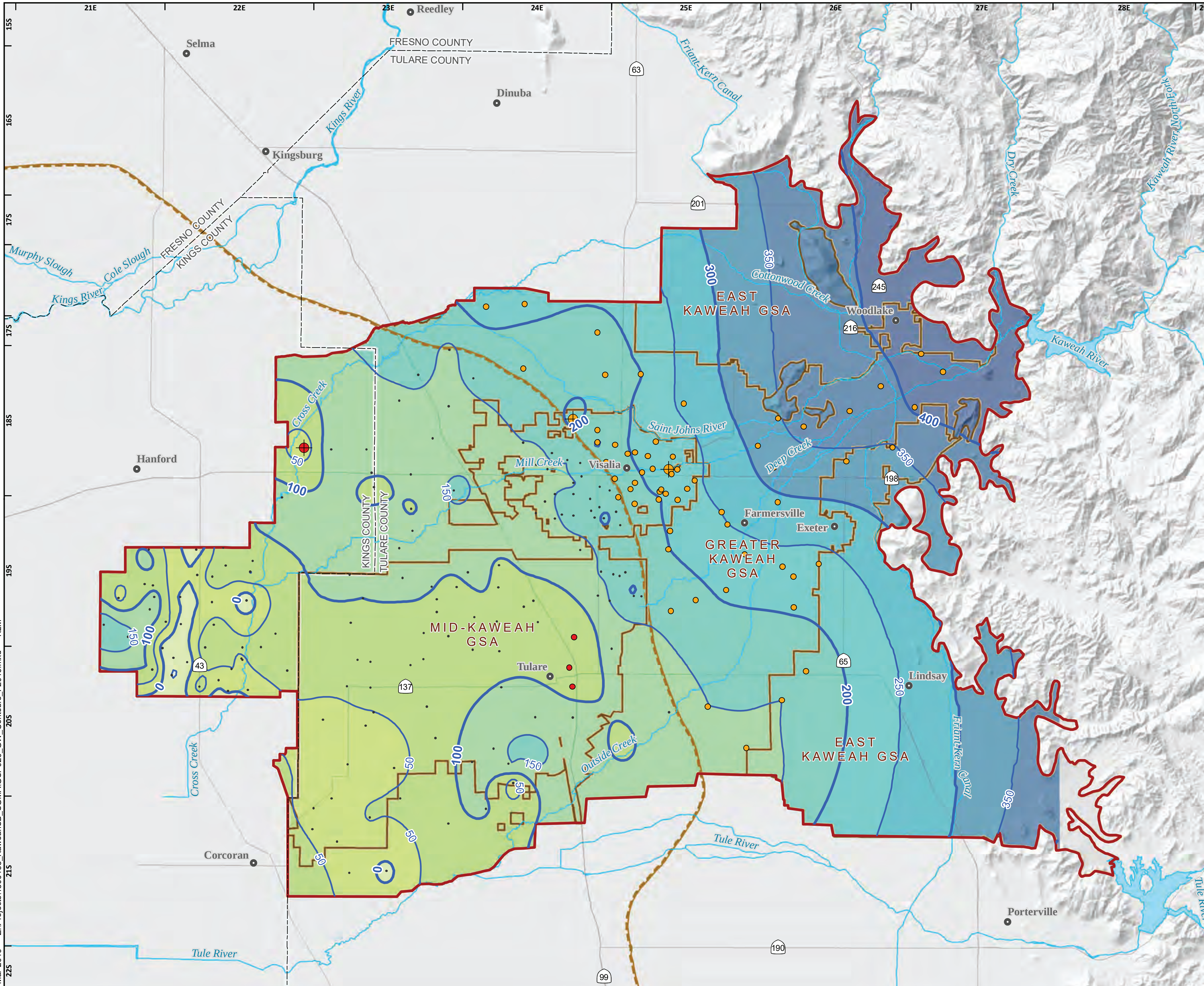
Z:\Projects\1800138_KaweahSB_SGMA\GSP019_GW_Contours_F2015.mxd KLM
11-Mar-2019





# FALL 2016 GROUNDWATER ELEVATION CONTOURS

- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

**Groundwater Elevation Contours, Fall 2016 (GWE ft msl)**

- Major (100-foot interval)
- Minor (50-foot interval)
- -56 - -50
- -49 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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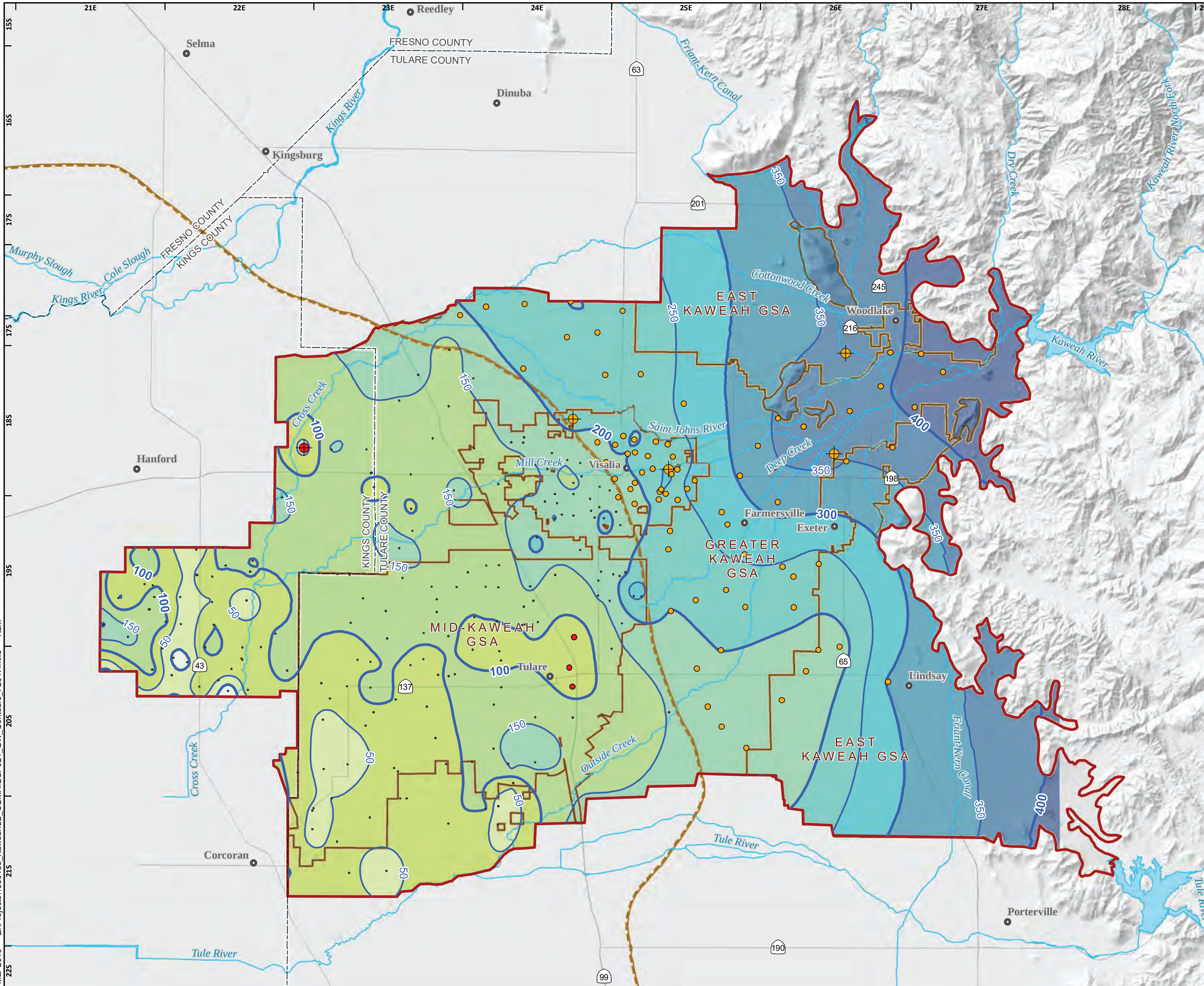
MARCH 2019 FIGURE 31

# FALL 2017 GROUNDWATER ELEVATION CONTOURS




- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

**Groundwater Elevation Contours, Fall 2017 (GWE ft msl)**

- Major (100-foot interval)
- Minor (50-foot interval)
- -44 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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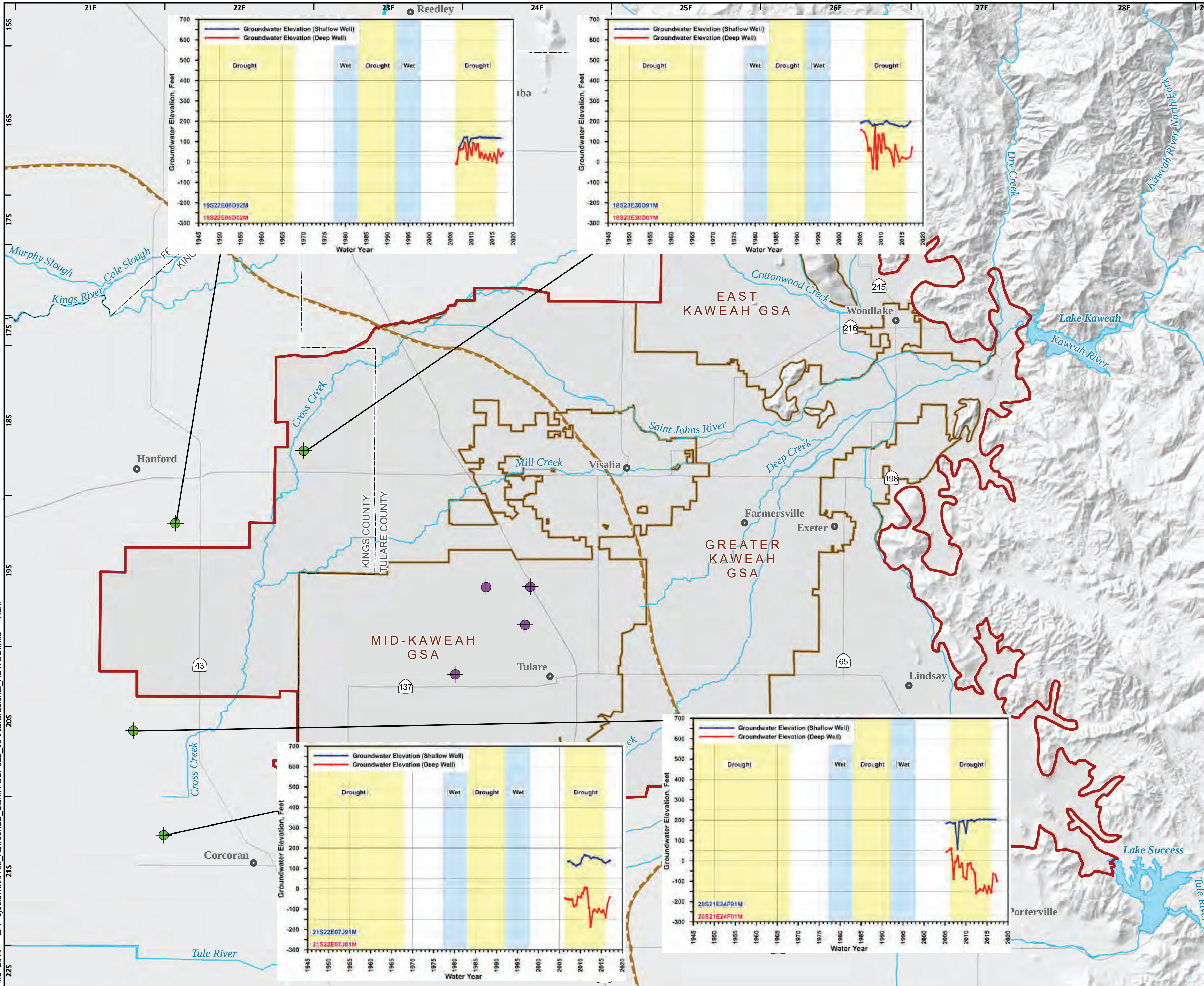
FIGURE 32

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP021_GW_Contours_F2017.mxd KLM

# VERTICAL GRADIENTS KAWEAH DELTA WATER CONSERVATION DISTRICT WELLS




**Dual Completion Monitoring Wells**

- KDWCD Dual Completion Wells
- TID Dual Completion Wells
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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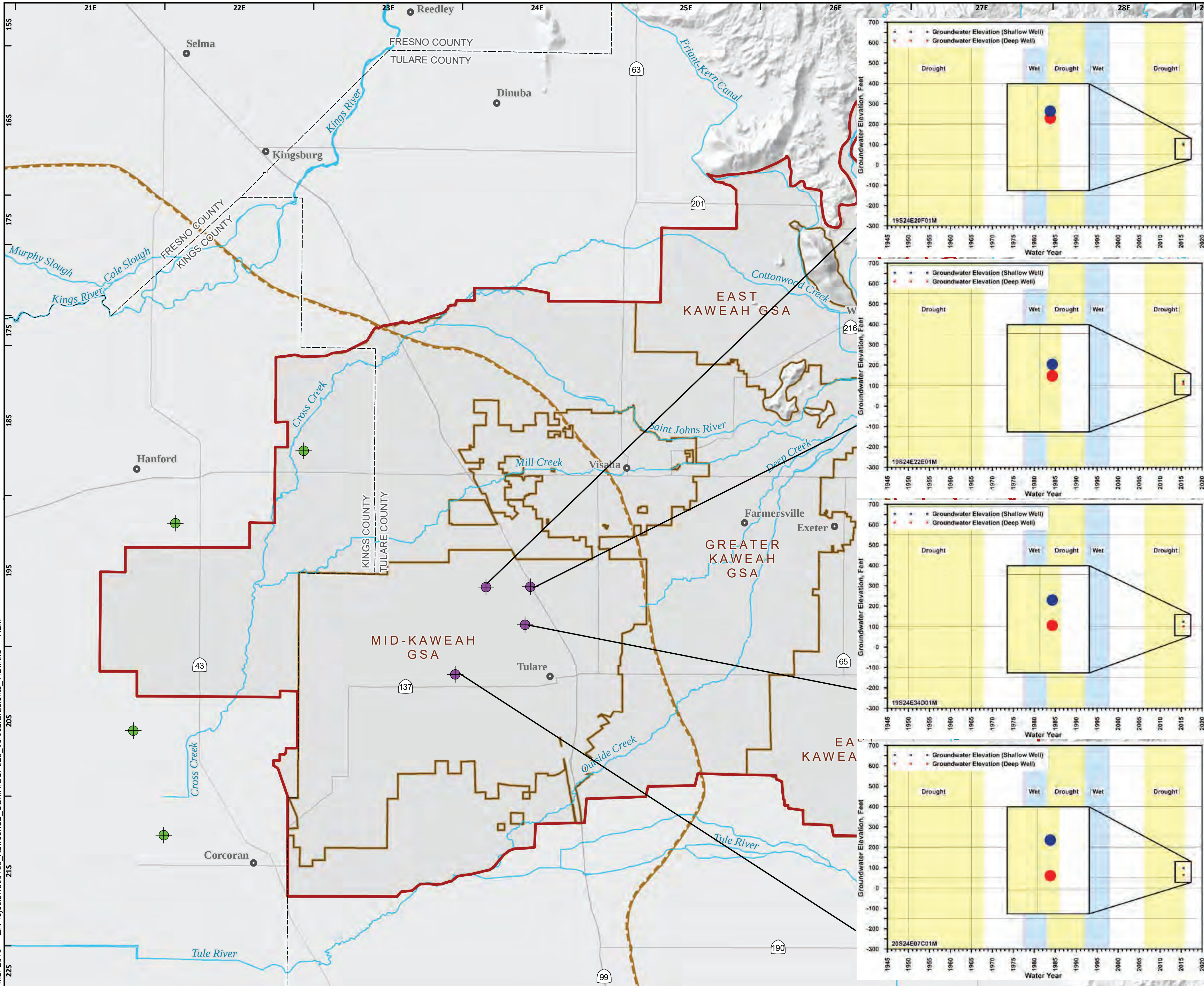
FIGURE 33

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP022_VerticalGradients_KDWCD.mxd KLM

# VERTICAL GRADIENTS TULARE IRRIGATION DISTRICTWELLS




**Dual Completion Monitoring Wells**

- KDWCD Dual Completion Wells
- TID Dual Completion Wells
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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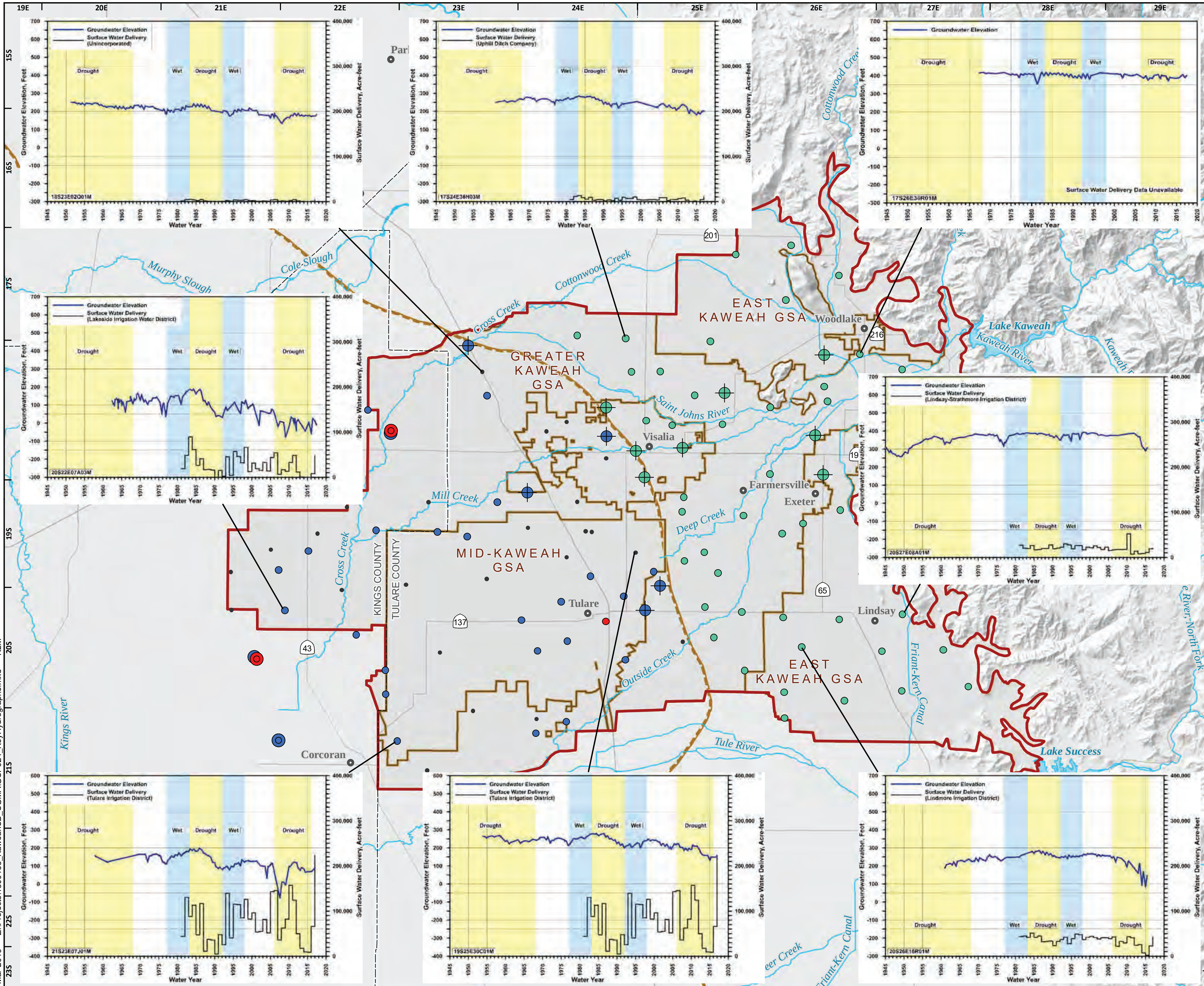
FIGURE 34

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP023_VerticalGradients_TID.mxd KLM

# SELECT KEY WELL HYDROGRAPHS




Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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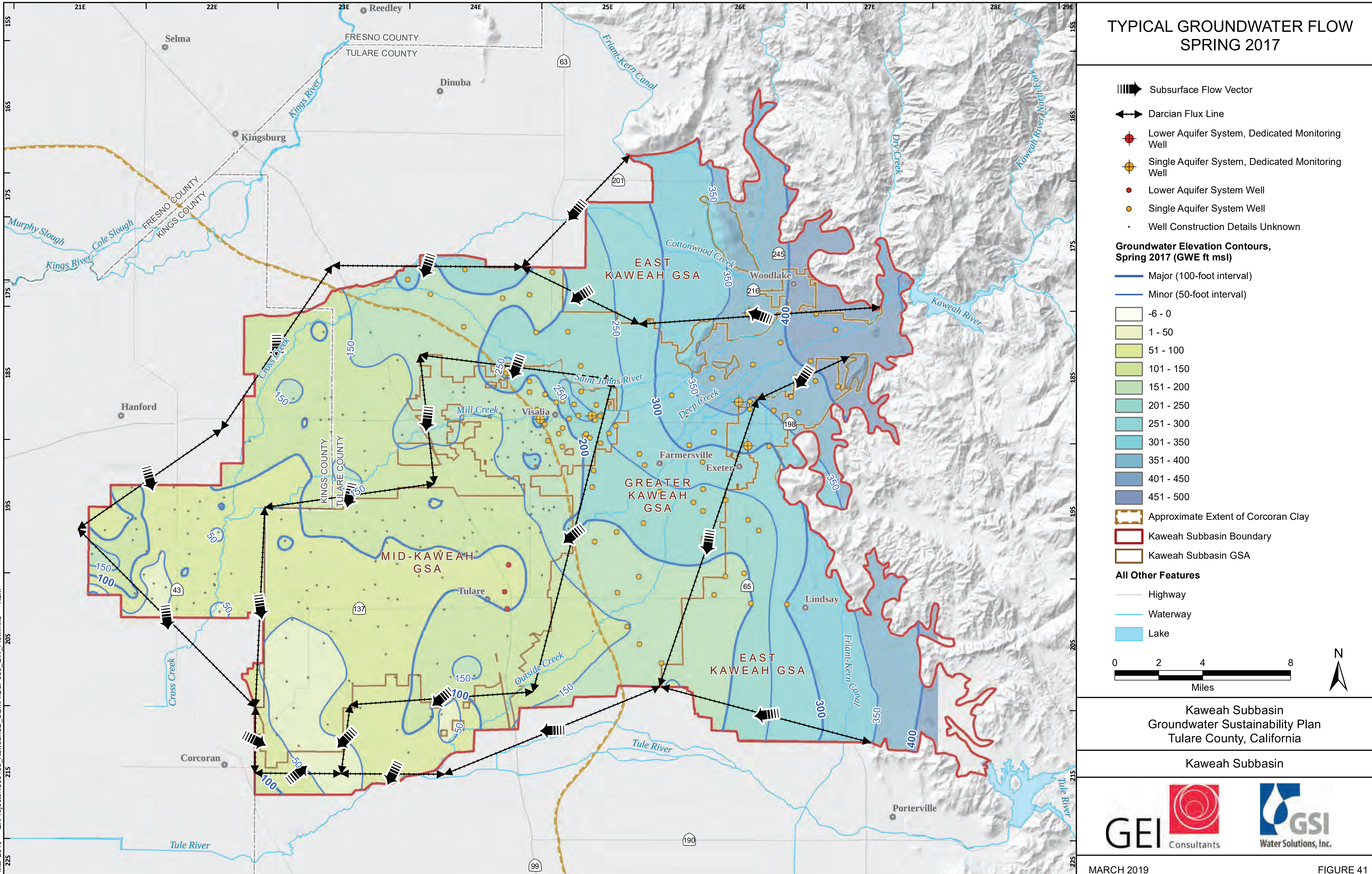
FIGURE 35

Z:\Projects\1800138_KaweahSB_SGMA\GSP024_KeyHydrographs.mxd KLM

11-Mar-2019

# TYPICAL GROUNDWATER FLOW SPRING 2017




Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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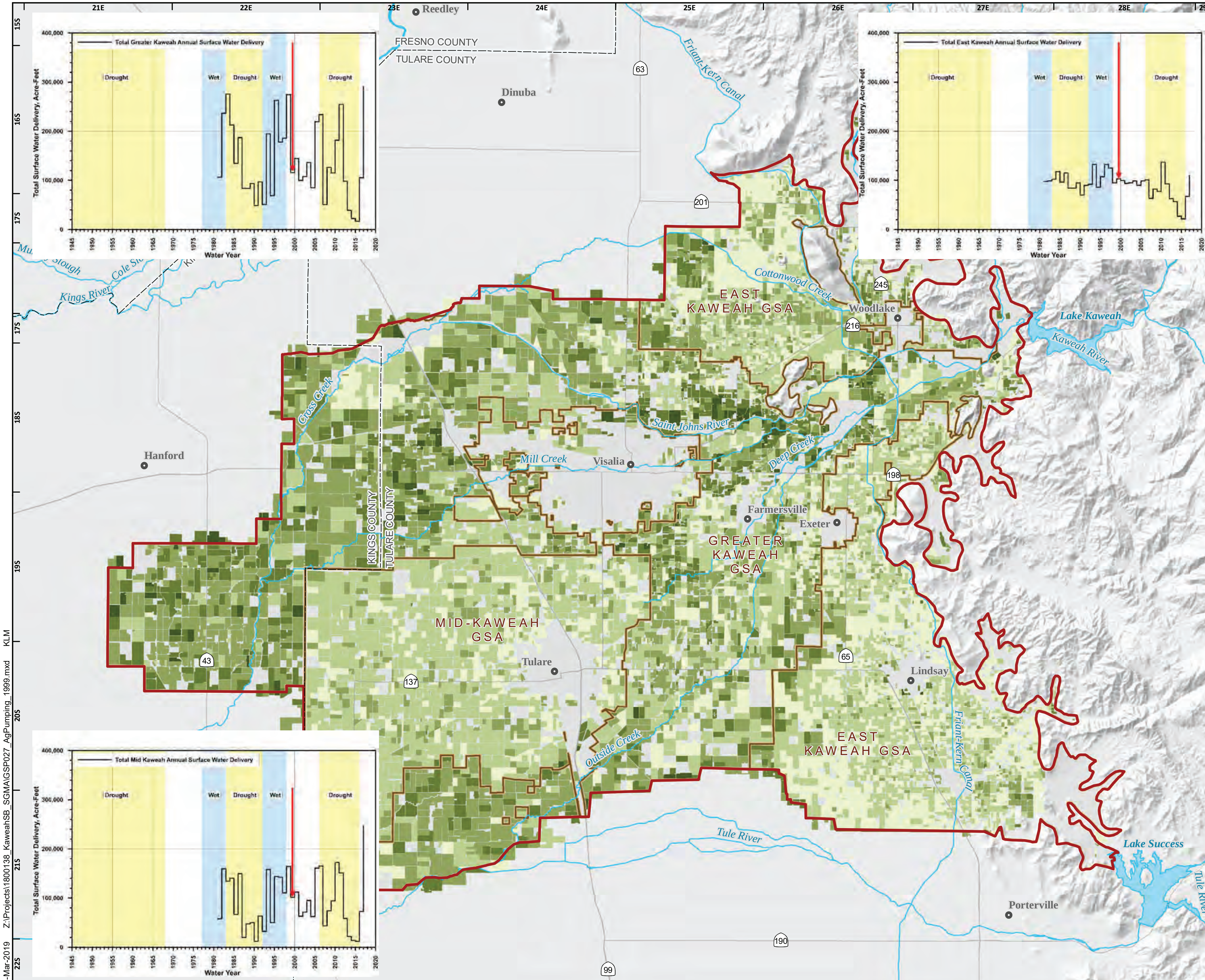
FIGURE 41

# ANNUAL AGRICULTURAL PUMPING WATER YEAR 1999




**Agricultural Pumping, acre-feet/acre**

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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FIGURE 42

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP027_AgPumping_1999.mxd KLM

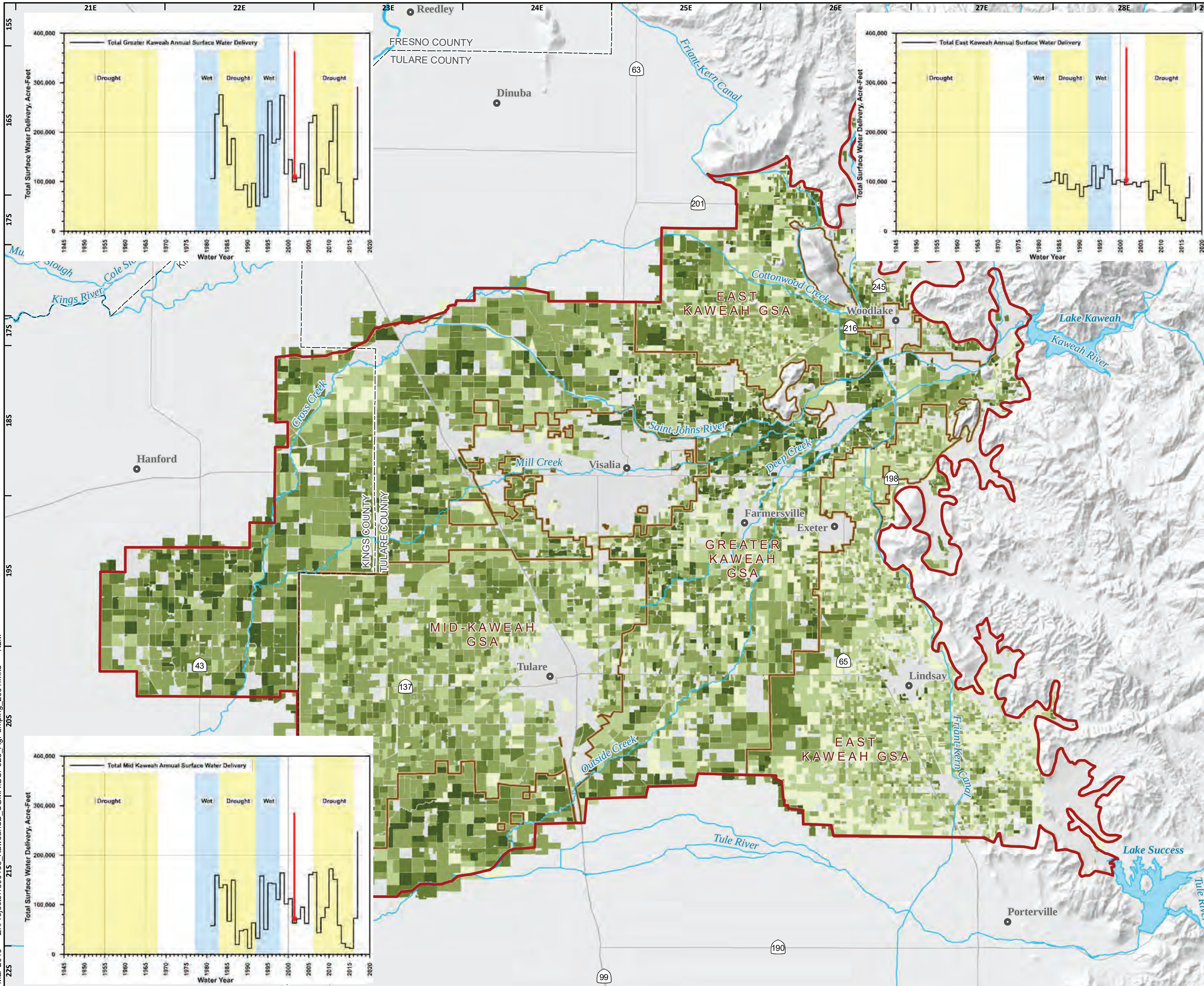
# ANNUAL AGRICULTURAL PUMPING WATER YEAR 2001

**Agricultural Pumping, acre-feet/acre**

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake




Z:\Projects\1800138_KaweahSB_SGMA\GSP028_AgPumping_2001.mxd KLM

11-Mar-2019

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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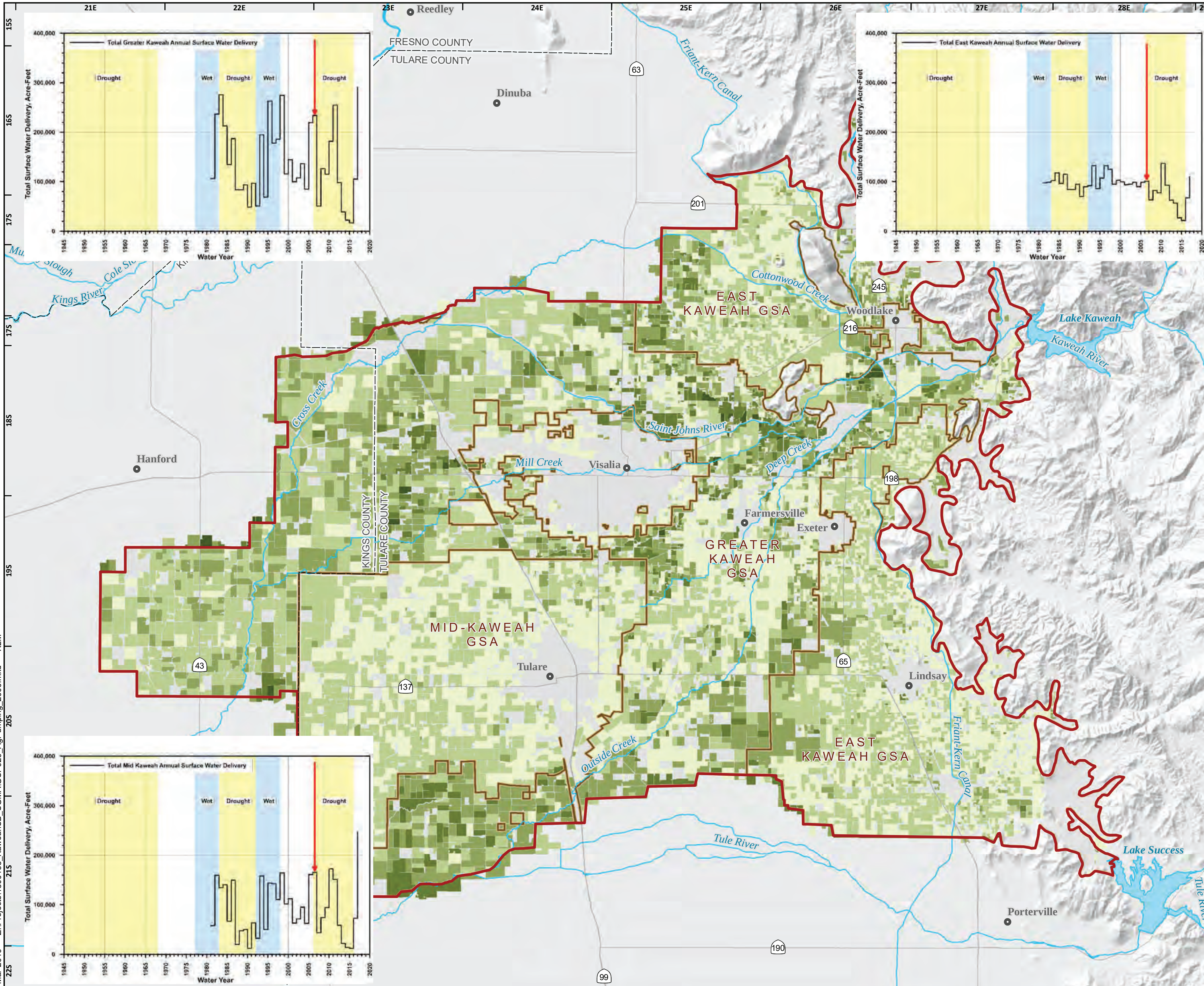
FIGURE 43

# ANNUAL AGRICULTURAL PUMPING WATER YEAR 2006




**Agricultural Pumping, acre-feet/acre**

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8 Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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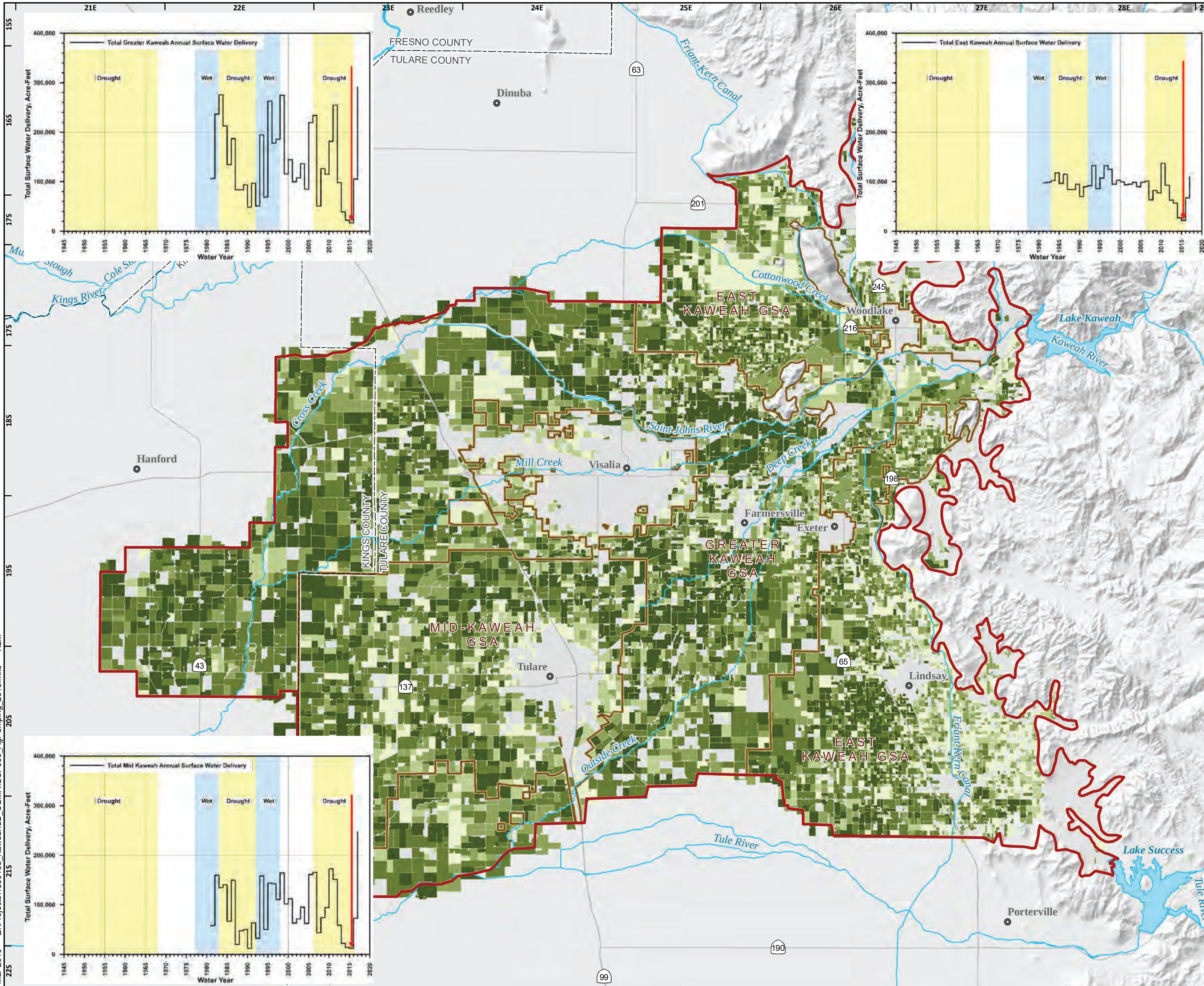
11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP029_AgPumping_2006.mxd KLM




# ANNUAL AGRICULTURAL PUMPING WATER YEAR 2015

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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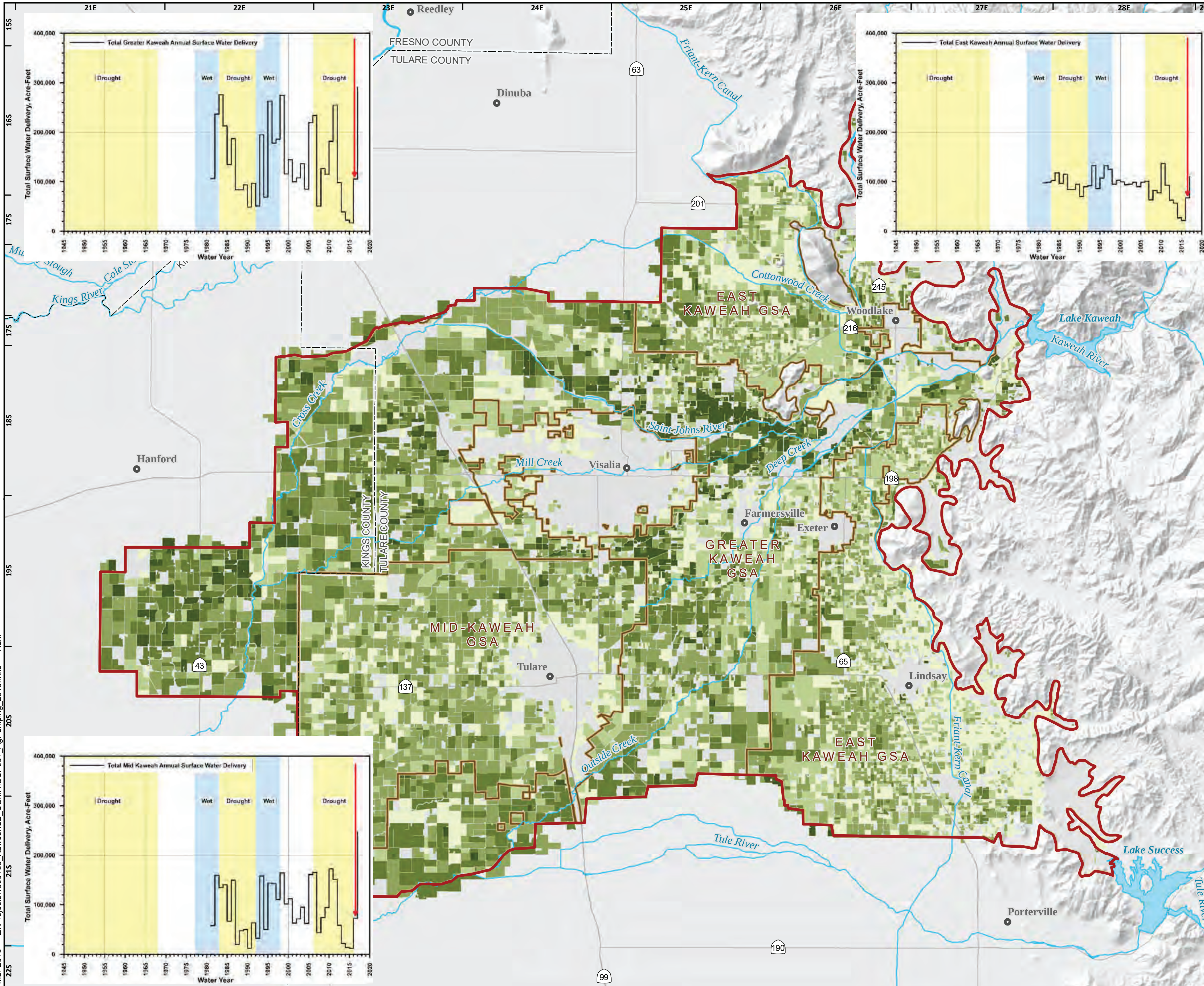
FIGURE 45

Z:\Projects\1800138_KaweahSB_SGMA\GSP030_AgPumping_2015.mxd KLM

11-Mar-2019




# ANNUAL AGRICULTURAL PUMPING WATER YEAR 2016

**Agricultural Pumping, acre-feet/acre**

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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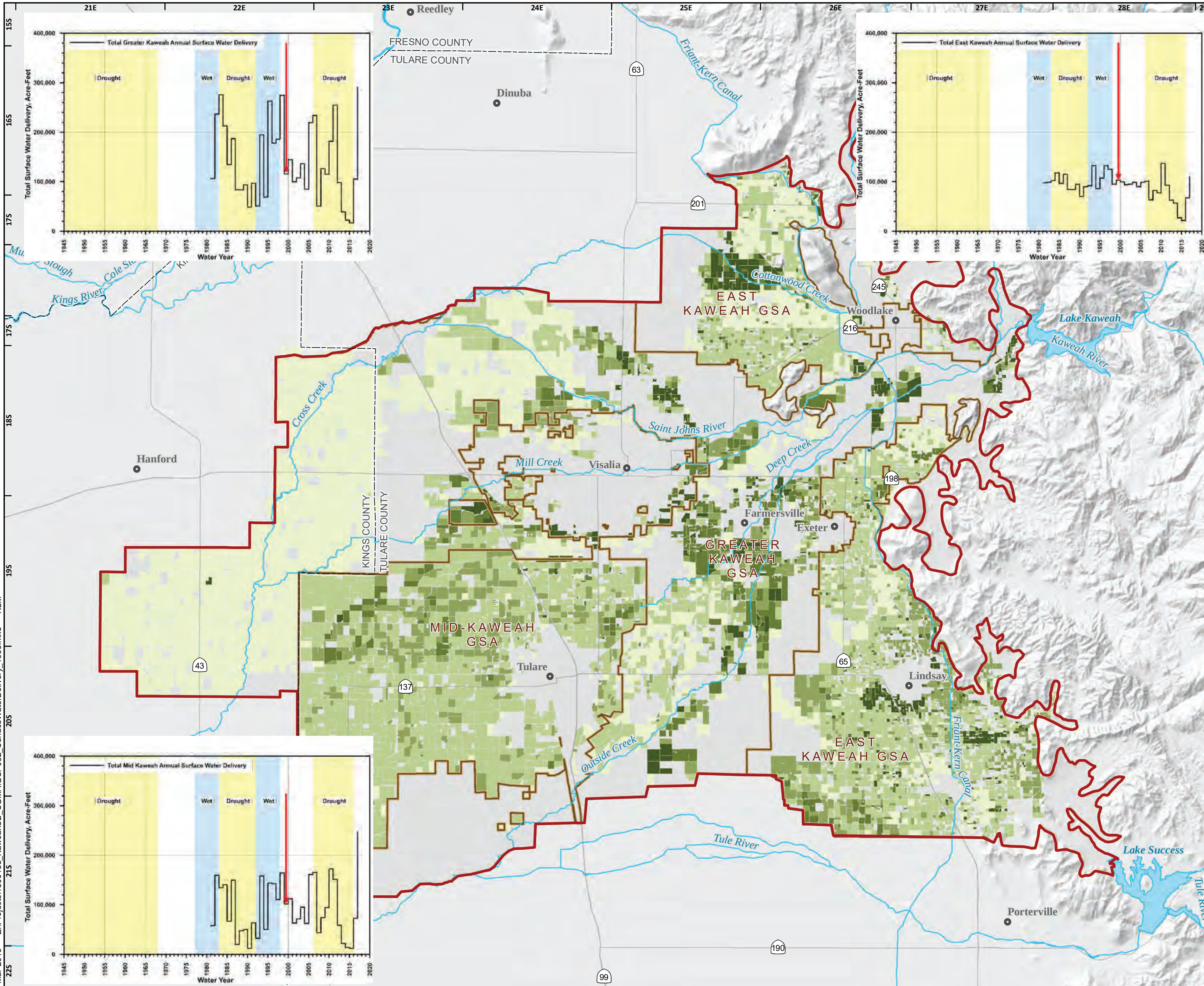
FIGURE 46

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP031_AgPumping_2016.mxd KLM

# ANNUAL SURFACE WATER DELIVERY WATER YEAR 1999




**Surface Water Delivery, acre-feet/acre**

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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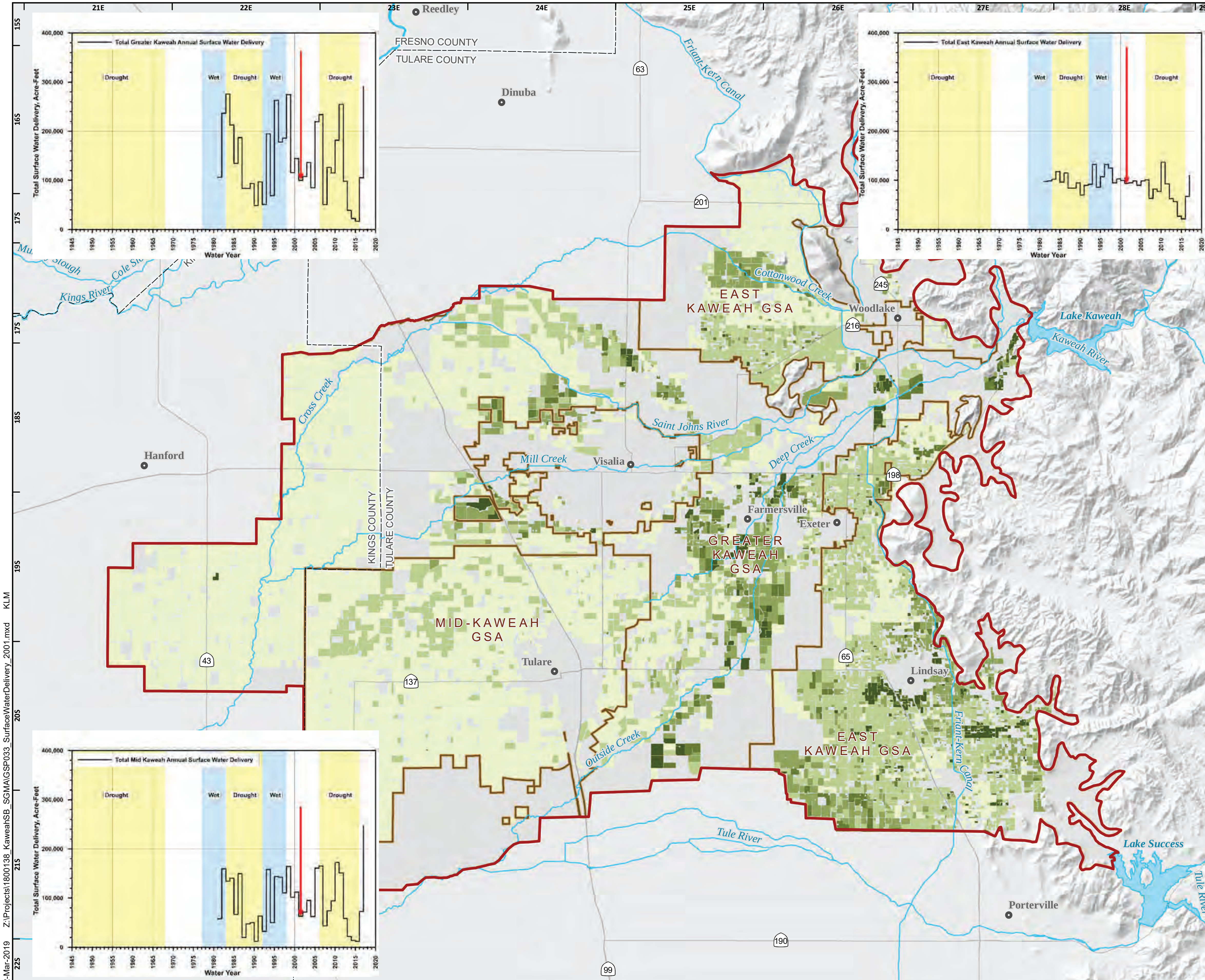
FIGURE 47

Z:\Projects\1800138_KaweahSB_SGMA\GSP032_SurfaceWaterDelivery_1999.mxd KLM

12-Mar-2019




Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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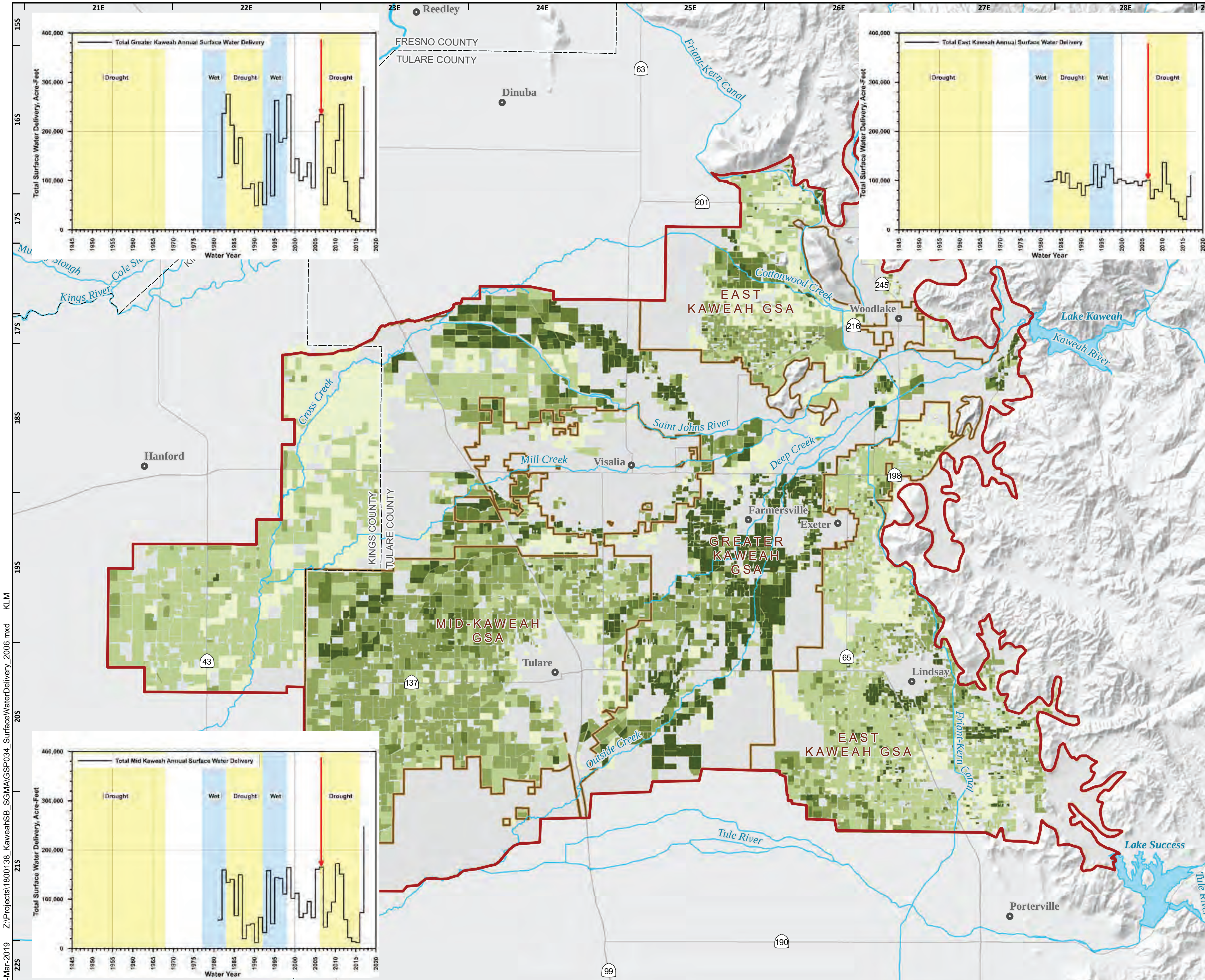
MARCH 2019

FIGURE 48




# ANNUAL SURFACE WATER DELIVERY WATER YEAR 2006

**Surface Water Delivery, acre-feet/acre**

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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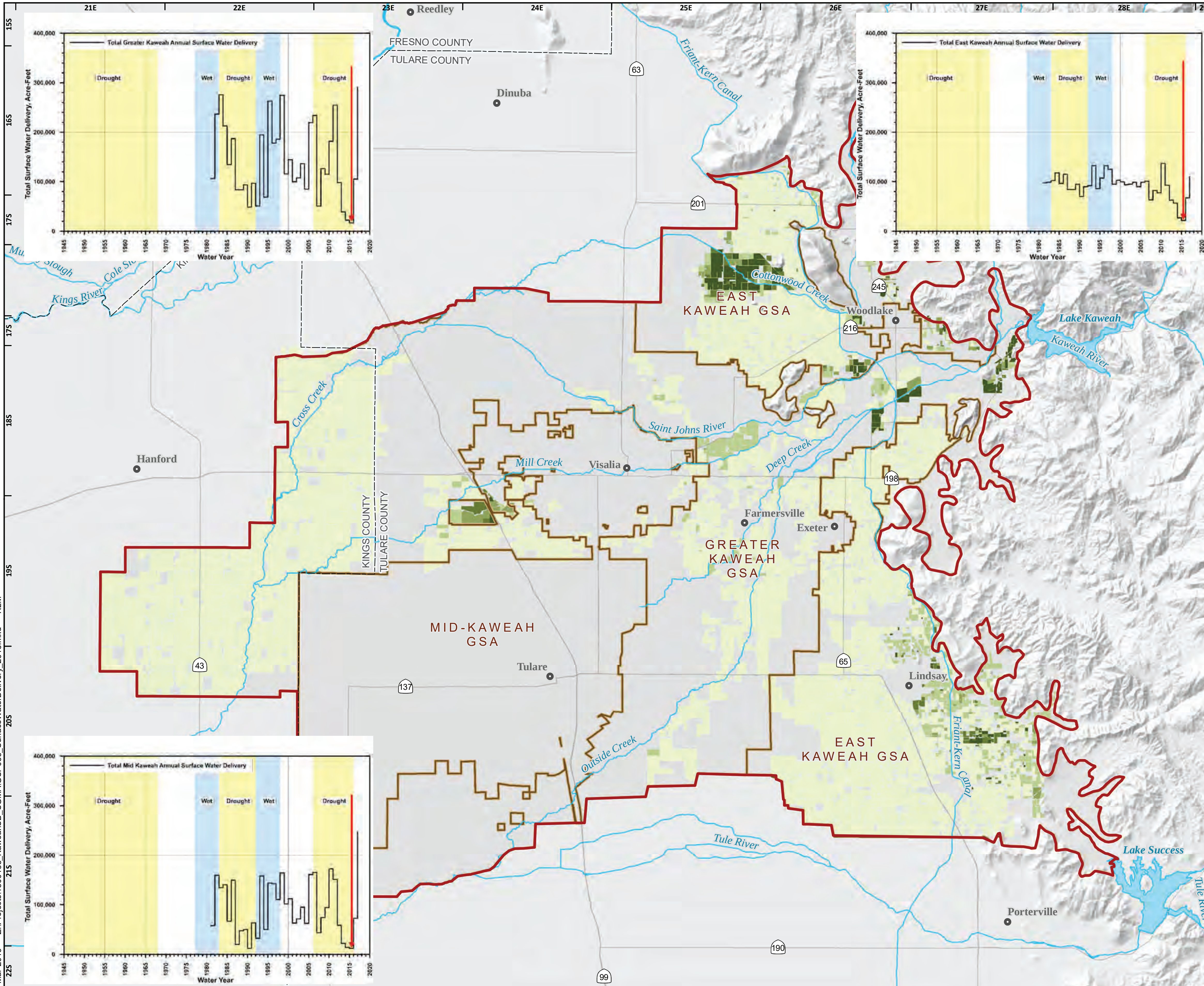
FIGURE 49

12-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP034_SurfaceWaterDelivery_2006.mxd KLM




# ANNUAL SURFACE WATER DELIVERY WATER YEAR 2015

**Surface Water Delivery, acre-feet/acre**

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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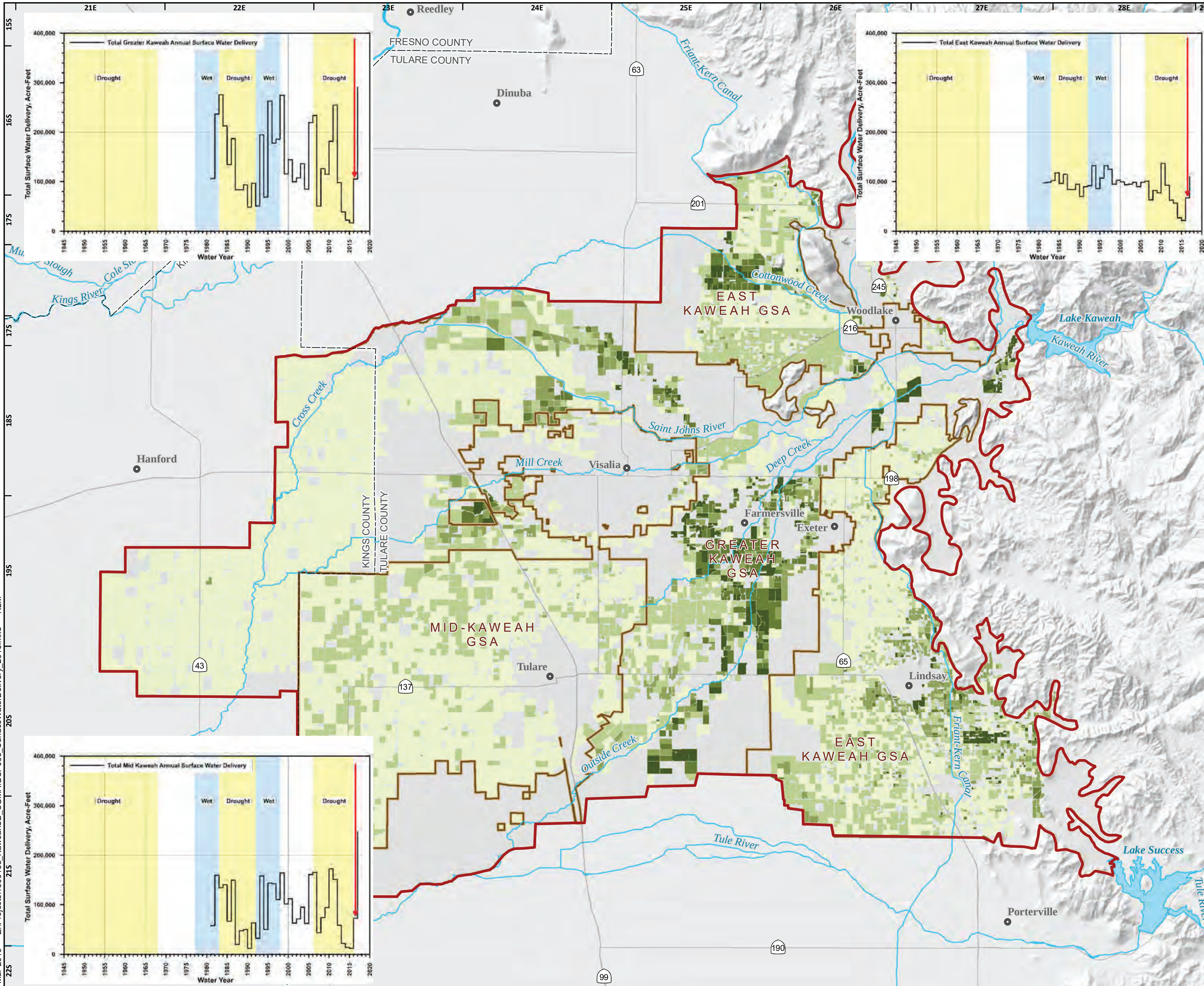
MARCH 2019 FIGURE 50

Z:\Projects\1800138_KaweahSB_SGMA\GSP035_SurfaceWaterDelivery_2015.mxd KLM
12-Mar-2019

# ANNUAL SURFACE WATER DELIVERY WATER YEAR 2016




**Surface Water Delivery, acre-feet/acre**

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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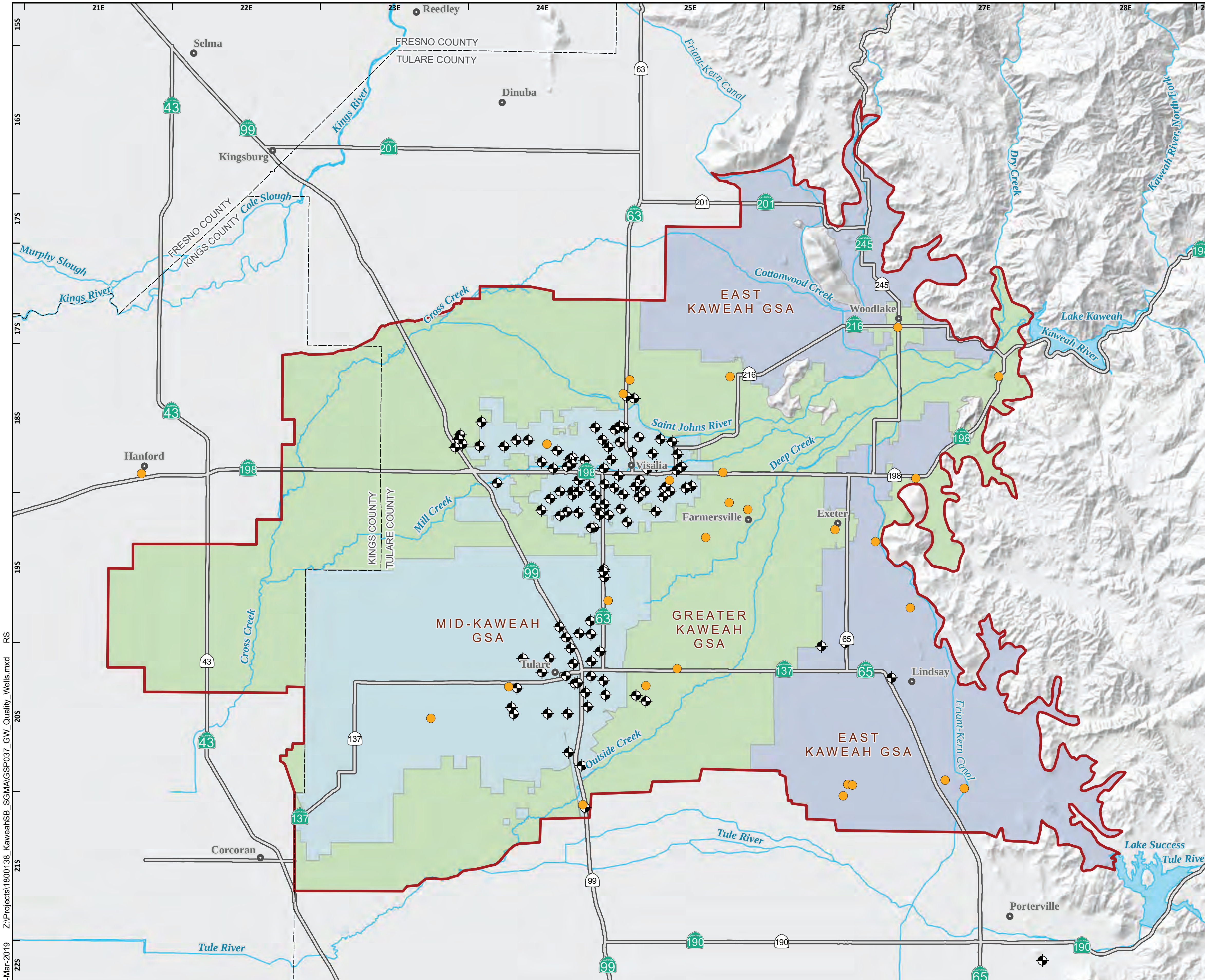
FIGURE 51

Z:\Projects\1800138_KaweahSB_SGMA\GSP036_SurfaceWaterDelivery_2016.mxd KLM

12-Mar-2019

# KAWEAH SUBBASIN GROUNDWATER QUALITY WELL LOCATIONS




Representation of PWS with unknown Well Locations

Approximate Well Location

**GSA Boundaries**

East Kaweah GSA

Greater Kaweah GSA

Mid-Kaweah GSA

Kaweah Subbasin Boundary

**All Other Features**

Highway

Waterway

Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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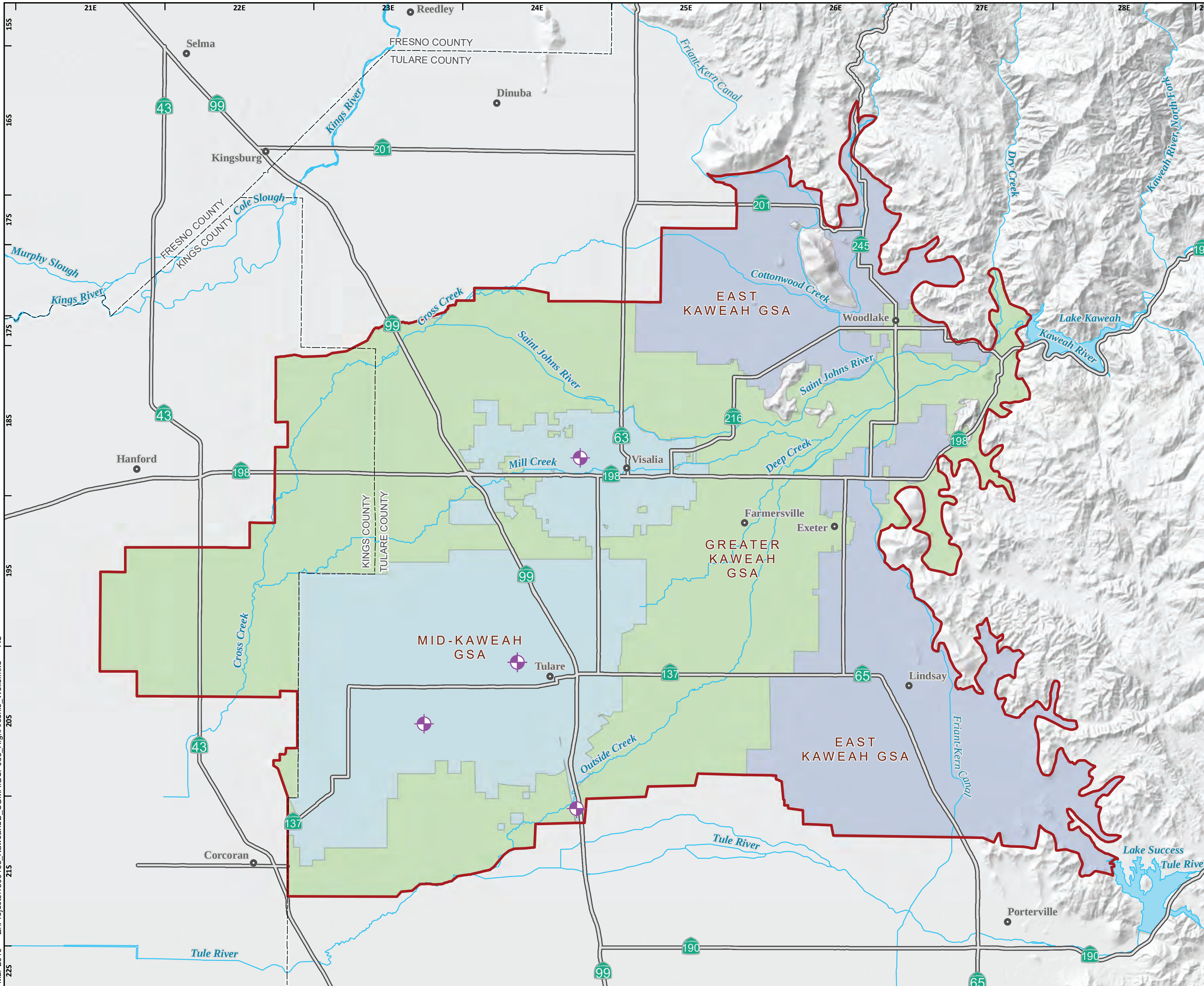
FIGURE 58

12-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP037_GW_Quality_Wells.mxd RS

# KAWEAH SUBBASIN
# HIGH ARSENIC WELLS




Arsenic Concentrations 5-10 ppb, or Increasing Trends

**GSA Boundaries**

- East Kaweah GSA
- Greater Kaweah GSA
- Mid-Kaweah GSA
- Kaweah Subbasin Boundary

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

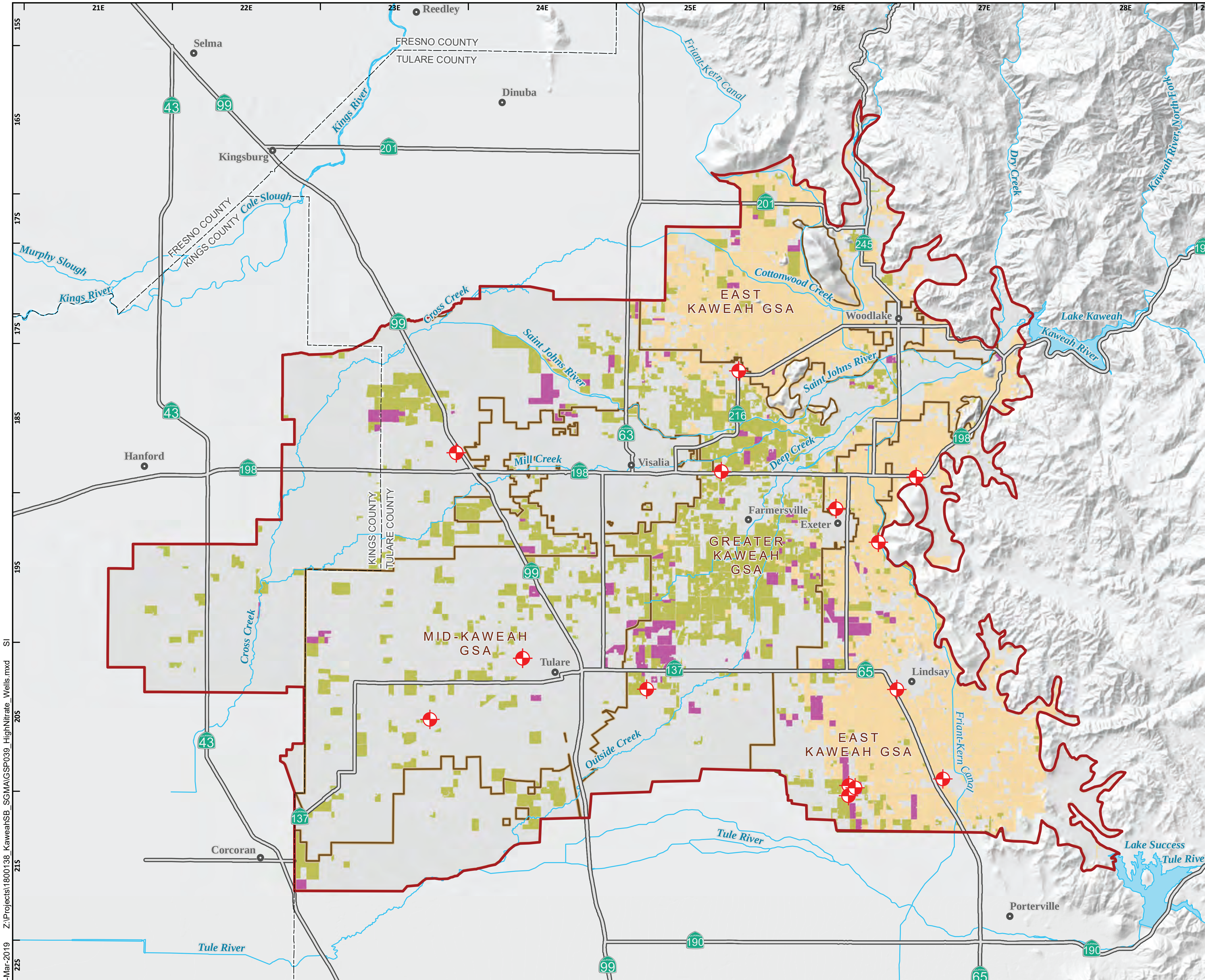
Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

MARCH 2019

FIGURE 59

# KAWEAH SUBBASIN HIGH NITRATE WELLS




Nitrate Concentrations 5-10 ppm, or Increasing Trends
Kaweah Subbasin GSA
Kaweah Subbasin Boundary

**Land Use**

Citrus and Subtropical
Deciduous Fruits and Nuts
Vineyard

**All Other Features**

Highway
Waterway
Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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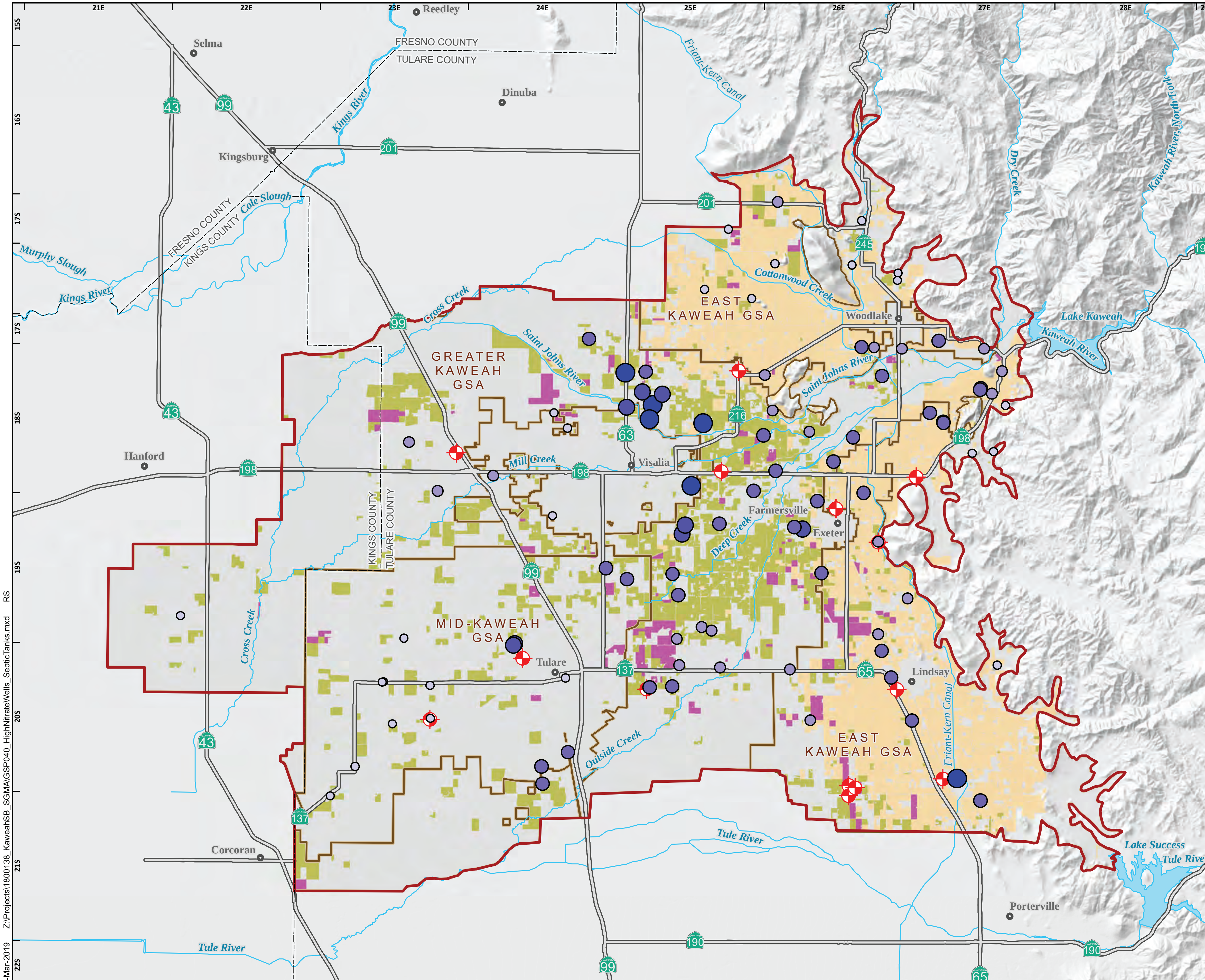
FIGURE 61

12-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP039_HighNitrate_Wells.mxd SI

# KAWEAH SUBBASIN HIGH NITRATE WELLS AND SEPTIC TANKS




Nitrate Concentrations 5-10 ppm, or Increasing Trends
Kaweah Subbasin GSA
Kaweah Subbasin Boundary

**USGS Study Septic Tank Density per 500 meters**

- 0.9 to 3.7
- >3.7 to 6.4
- > 6.4 to 10.6
- >10.6 to 15.4
- >15.4 to 35.9

**Land Use**

- Citrus and Subtropical
- Deciduous Fruits and Nuts
- Vineyard

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles
N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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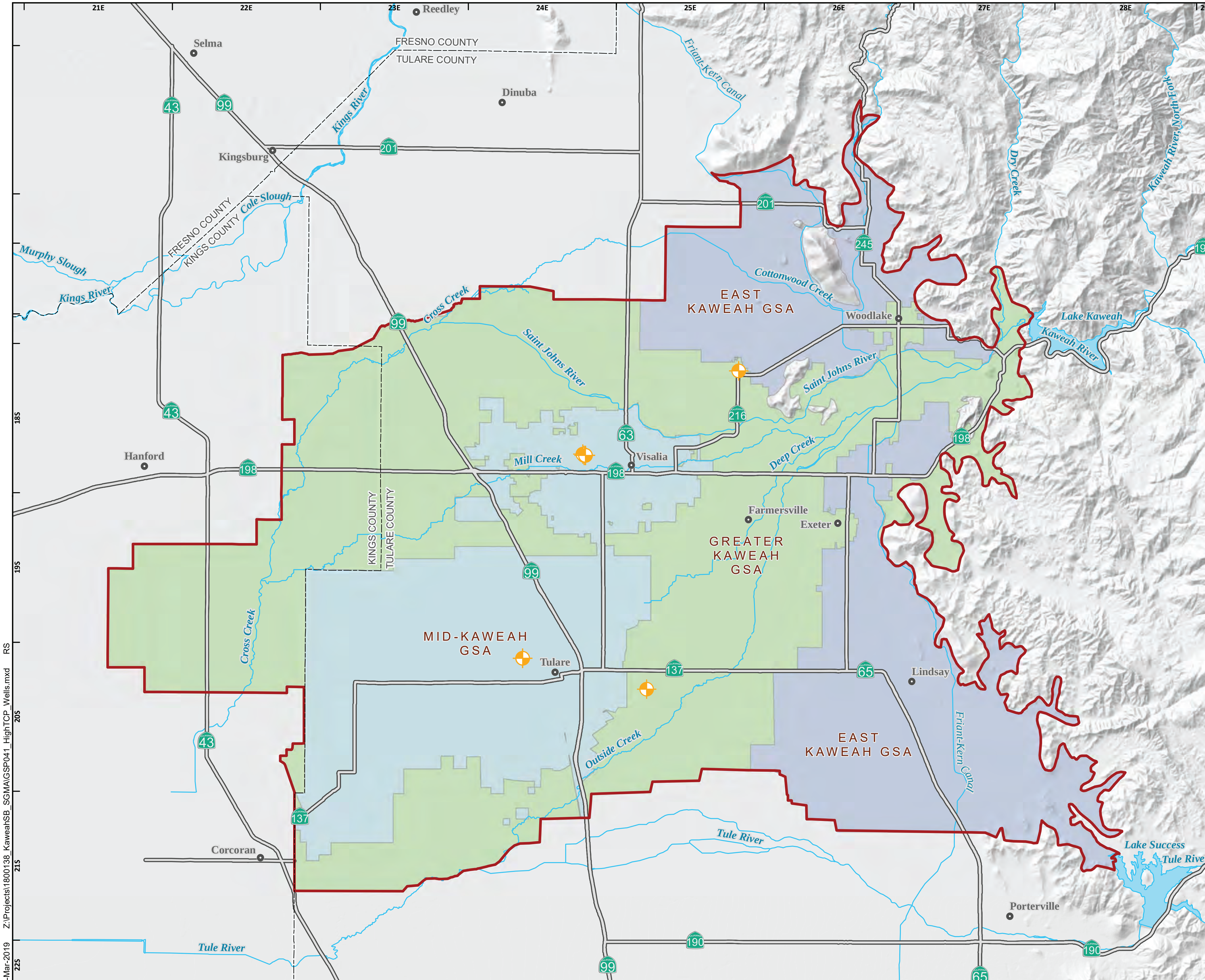
FIGURE 62

12-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP040_HighNitrateWells_SepticTanks.mxd RS

# KAWEAH SUBBASIN HIGH TCP WELLS




Areas of TCP Levels Greater Than 5 ppt

**GSA Boundaries**

- East Kaweah GSA
- Greater Kaweah GSA
- Mid-Kaweah GSA
- Kaweah Subbasin Boundary

**All Other Features**

- Highway
- Waterway
- Lake

0 2 4 8
Miles

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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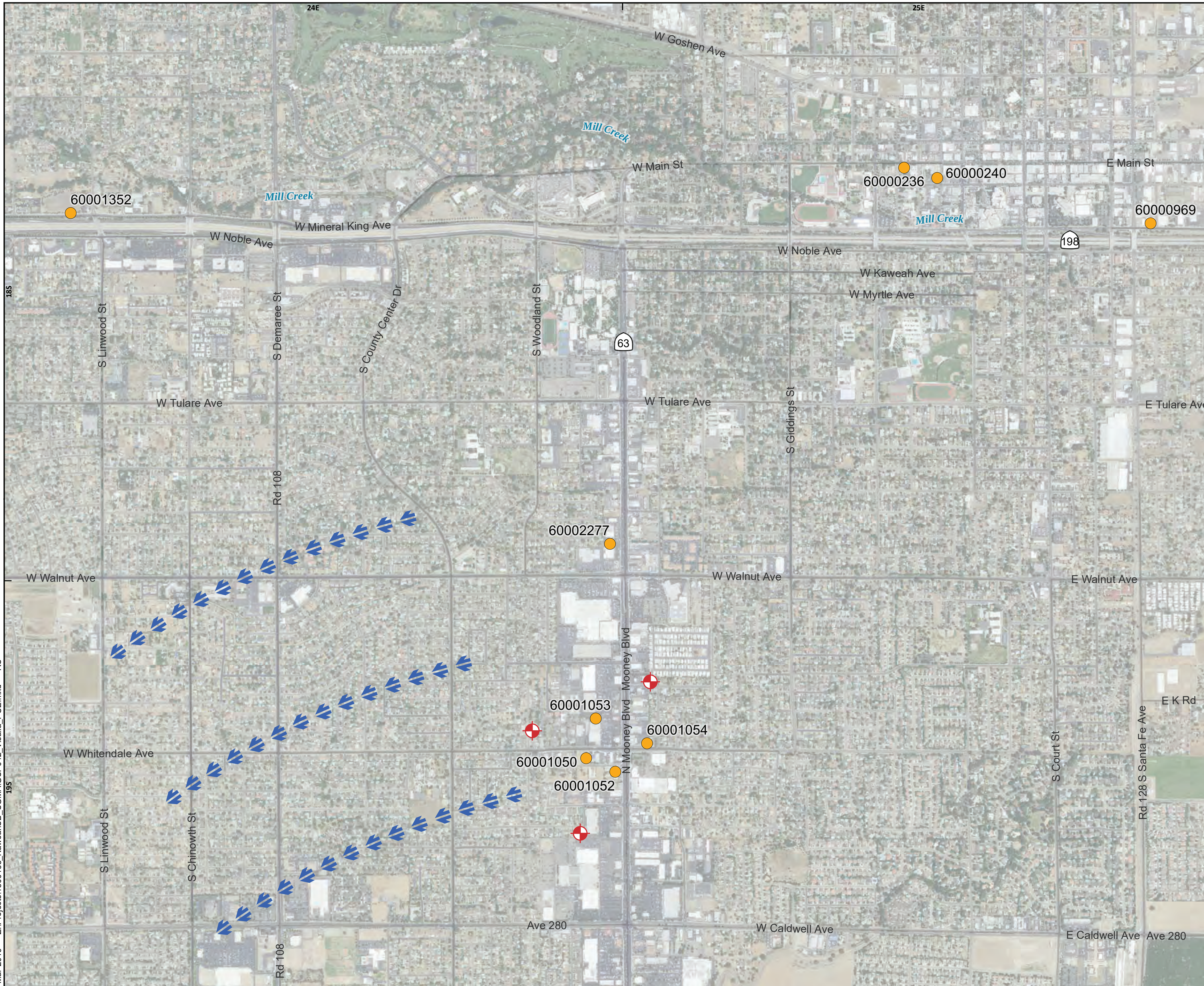
FIGURE 78

Z:\Projects\1800138_KaweahSB_SGMA\GSP041_HighTCP_Wells.mxd RS
12-Mar-2019

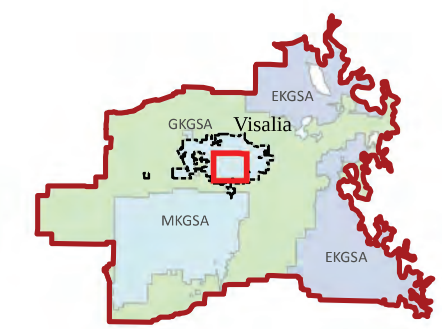
# KAWEAH SUBBASIN
# VISALIA CITYWIDE PCE PLUME




PCE Contamination Site

Municipal Well

General GW Flow Direction




0 1,500 3,000

Feet

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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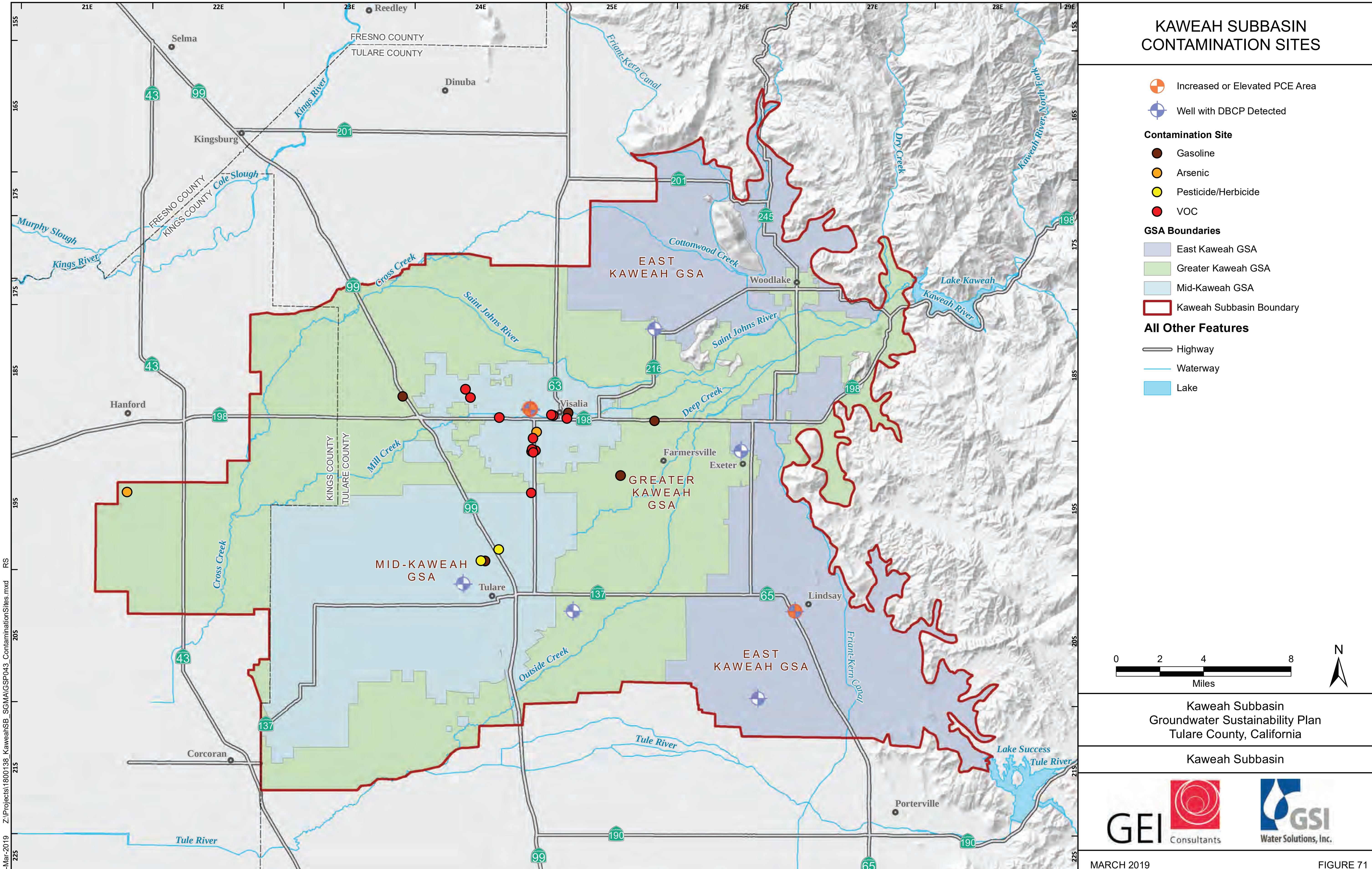
FIGURE 70

12-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP042_Visalia_PCE.mxd RS


KAWEAH SUBBASIN
CONTAMINATION SITES
Increased or Elevated PCE Area
Well with DBCP Detected
Contamination Site
Gasoline
Arsenic
Pesticide/Herbicide
VOC
GSA Boundaries
East Kaweah GSA
Greater Kaweah GSA
Mid-Kaweah GSA
Kaweah Subbasin Boundary
All Other Features
Highway
Waterway
Lake
0 2 4 8
Miles
N
EAST KAWEAH GSA
GREATER KAWEAH GSA
MID-KAWEAH GSA
Reedley
Selma
Dinuba
Kingsburg
Hanford
Visalia
Farmersville
Exeter
Woodlake
Tulare
Lindsay
Corcoran
Porterville
FRESNO COUNTY
TULARE COUNTY
KINGS COUNTY
Kings River
Cole Slough
Murphy Slough
Cross Creek
Gross Creek
Saint Johns River
Mill Creek
Cottonwood Creek
Deep Creek
Outside Creek
Tule River
Friant-Kern Canal
Dry Creek
Kaweah River, North Fork
Kaweah River
Lake Kaweah
Lake Success
99
43
201
245
216
63
198
137
65
190
Z:\Projects\1800138_KaweahSB_SGMA\GSP043_ContaminationSites.mxd RS
12-Mar-2019
Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California
Kaweah Subbasin
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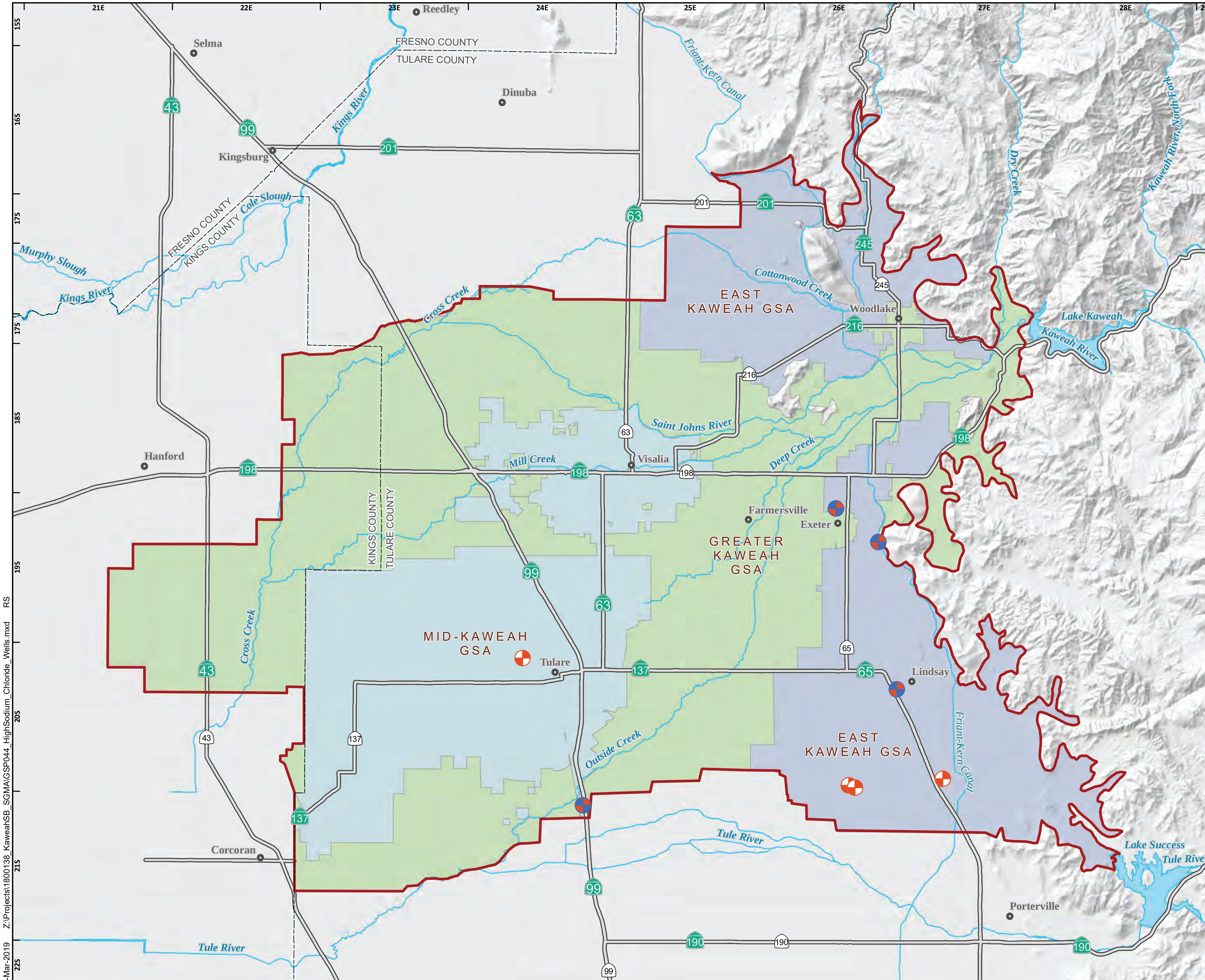
MARCH 2019
FIGURE 71

# KAWEAH SUBBASIN
# HIGH SODIUM AND CHLORIDE WELLS




Increasing or Elevated Chloride Area

Increasing or Elevated Sodium Area

**GSA Boundaries**

East Kaweah GSA

Greater Kaweah GSA

Mid-Kaweah GSA

Kaweah Subbasin Boundary

**All Other Features**

Highway

Waterway

Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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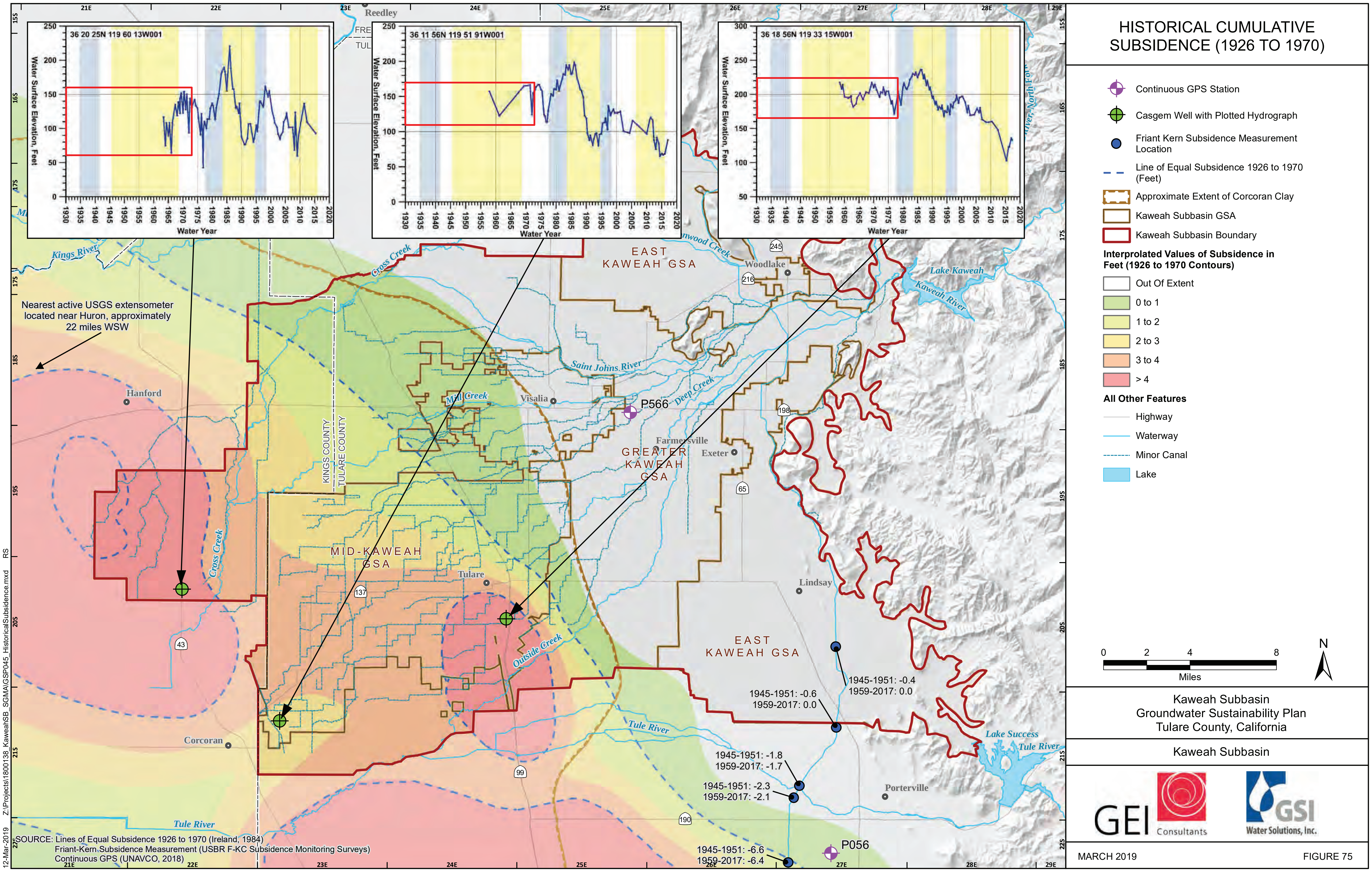
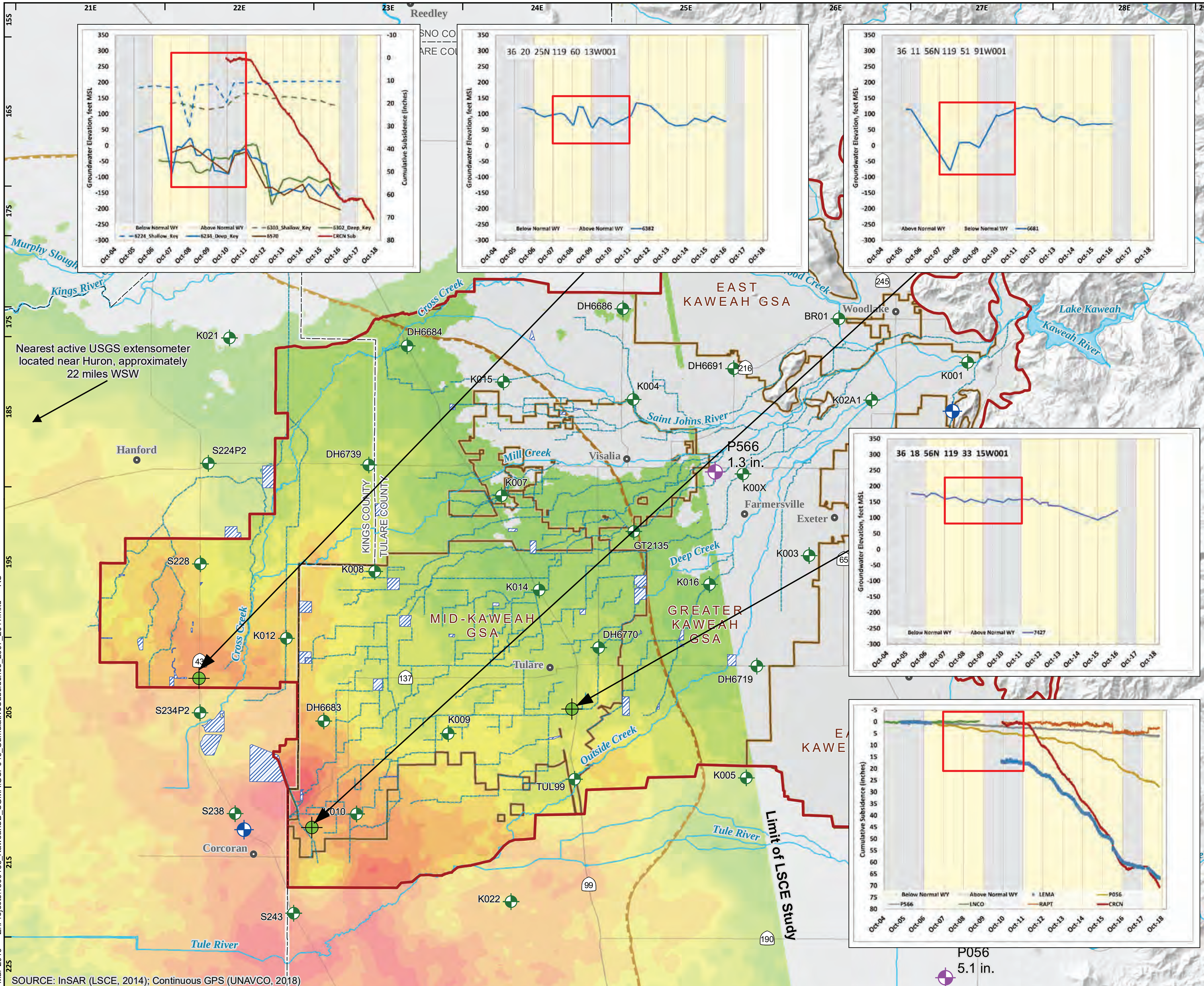
FIGURE 72

12-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP044_HighSodium_Chloride_Wells.mxd RS


HISTORICAL CUMULATIVE SUBSIDENCE (1926 TO 1970)
Continuous GPS Station
Casgem Well with Plotted Hydrograph
Friant Kern Subsidence Measurement Location
Line of Equal Subsidence 1926 to 1970 (Feet)
Approximate Extent of Corcoran Clay
Kaweah Subbasin GSA
Kaweah Subbasin Boundary
Interpolated Values of Subsidence in Feet (1926 to 1970 Contours)
Out Of Extent
0 to 1
1 to 2
2 to 3
3 to 4
> 4
All Other Features
Highway
Waterway
Minor Canal
Lake
0 2 4 8
Miles
N
Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California
Kaweah Subbasin
GEI Consultants
GSI Water Solutions, Inc.
MARCH 2019
FIGURE 75
36 20 25N 119 60 13W001
36 11 56N 119 51 91W001
36 18 56N 119 33 15W001
Water Surface Elevation, Feet
Water Year
Nearest active USGS extensometer located near Huron, approximately 22 miles WSW
EAST KAWEAH GSA
GREATER KAWEAH GSA
MID-KAWEAH GSA
KINGS COUNTY
TULARE COUNTY
P566
P056
Hanford
Visalia
Farmersville
Exeter
Woodlake
Tulare
Lindsay
Corcoran
Porterville
Reedley
Kings River
Cross Creek
Mill Creek
Saint Johns River
Deep Creek
Outside Creek
Tule River
Lake Kaweah
Kaweah River
Lake Success
1945-1951: -0.4
1959-2017: 0.0
1945-1951: -0.6
1959-2017: 0.0
1945-1951: -1.8
1959-2017: -1.7
1945-1951: -2.3
1959-2017: -2.1
1945-1951: -6.6
1959-2017: -6.4
SOURCE: Lines of Equal Subsidence 1926 to 1970 (Ireland, 1984)
Friant-Kern Subsidence Measurement (USBR F-KC Subsidence Monitoring Surveys)
Continuous GPS (UNAVCO, 2018)
Z:\Projects\1800138_KaweahSB_SGMA\GSP045_HistoricalSubsidence.mxd RS
12-Mar-2019




# CUMULATIVE SUBSIDENCE JANUARY 2007 TO MARCH 2011

- Casgem Well with Plotted Hydrograph
- Continuous GPS Station
- SOPAC Location
- Land Surface Elevation Monitoring Station
- Recharge Basin
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin GSA
- Kaweah Subbasin Boundary

**Interferometric Synthetic Aperture in Inches (InSAR)**

- Limit of LSCE Study
- 0 to 3
- 3 to 6
- 6 to 9
- 9 to 12
- 12 to 15
- 15 to 18
- 18 to 21
- 21 to 24
- 24 to 27
- 27 to 30

**All Other Features**

- Highway
- Waterway
- Minor Canal
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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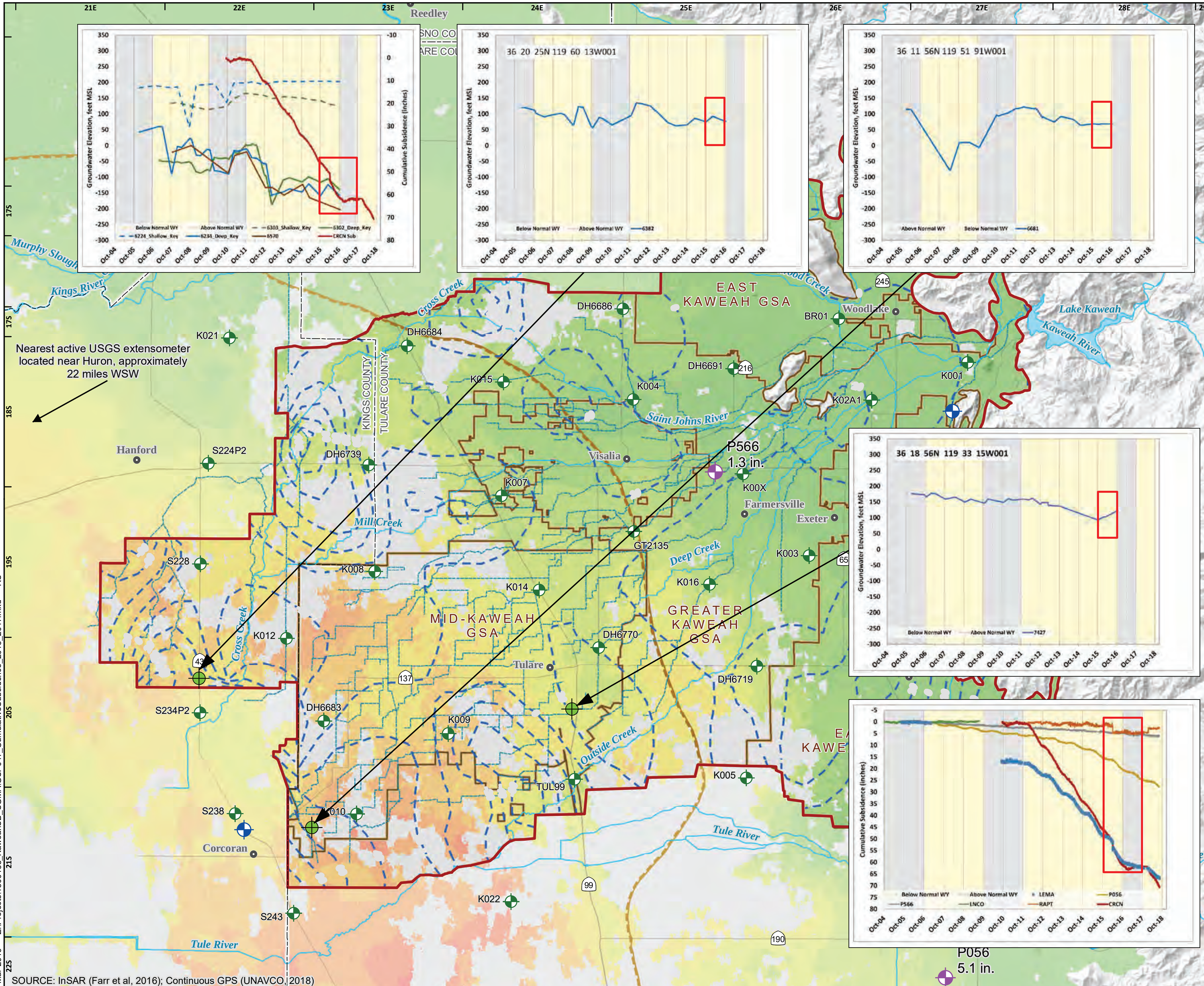
FIGURE 76

# CUMULATIVE SUBSIDENCE GROUNDWATER LEVEL DECLINE SPRING 2015 TO SPRING 2017




Casgem Well with Plotted Hydrograph

Continuous GPS Station

Land Surface Elevation Monitoring Station

SOPAC Location

Groundwater Elevation Decline Contour (20-foot Interval)

Approximate Extent of Corcoran Clay

Kaweah Subbasin GSA

Kaweah Subbasin Boundary

**Subsidence in Inches (NASA JPL InSAR Dataset)**

0 to 3

3 to 6

6 to 9

9 to 12

12 to 15

15 to 18

18 to 21

21 to 24

24 to 27

27 to 30

**All Other Features**

Highway

Waterway

Minor Canal

Lake

0 2 4 8

Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

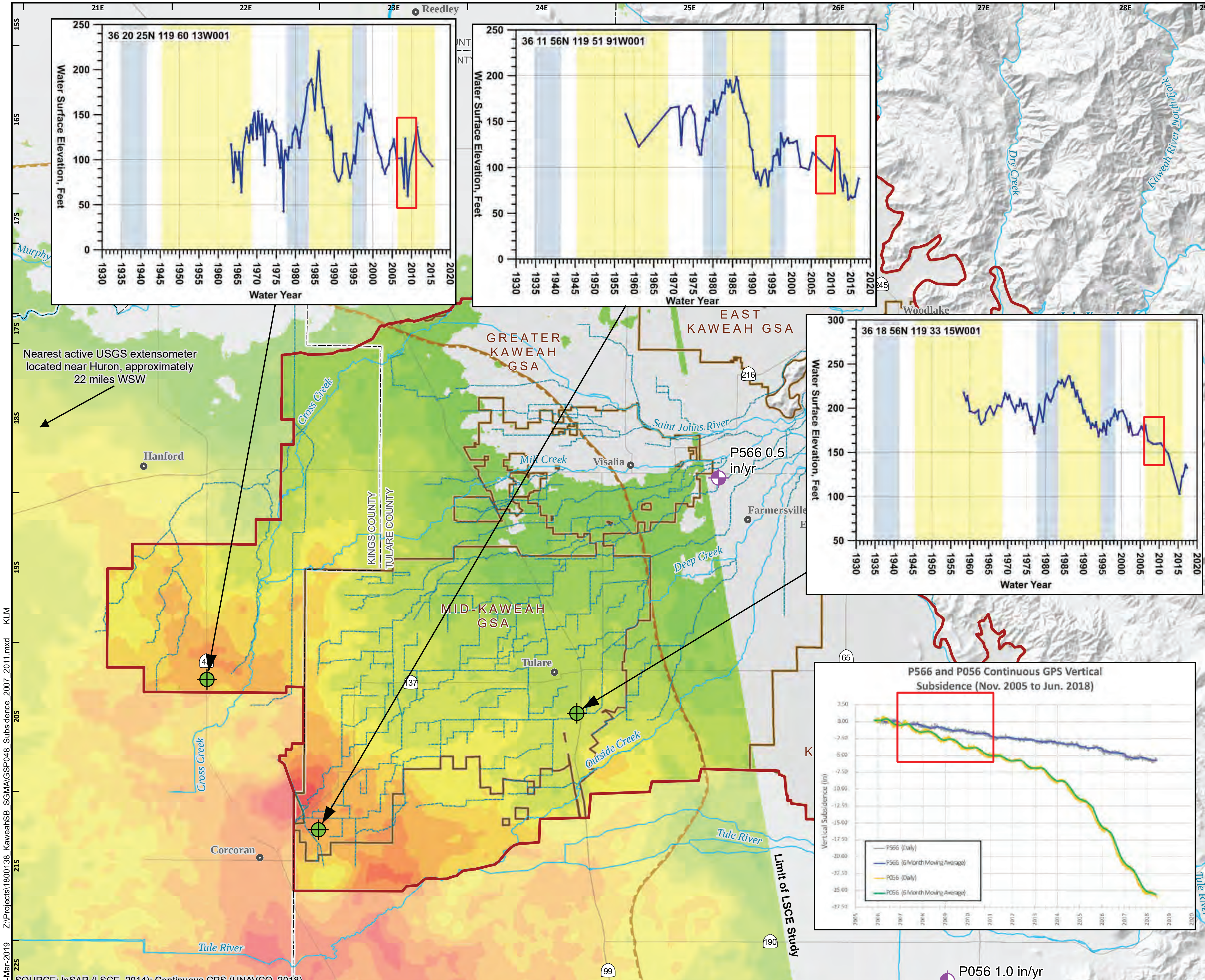
Kaweah Subbasin

GEI Consultants

GSI Water Solutions, Inc.

MARCH 2019

FIGURE 77




# ANNUAL RATE OF SUBSIDENCE (JANUARY 2007 TO MARCH 2011)

- Continuous GPS Station
- Casgem Wells with Plotted Hydrograph
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

**Interferometric Synthetic Aperture in Inches per Year (InSAR)**

- Limit of LSCE Study
- 0 to 0.75
- .75 to 1.5
- 1.5 to 2.25
- 2.25 to 3
- 3 to 3.75
- 3.75 to 4.5
- 4.5 to 5.25
- 5.25 to 6
- 6 to 6.75
- 6.75 to 7.5

**All Other Features**

- Highway
- Waterway
- Minor Canals
- Lake

0 2 4 8 Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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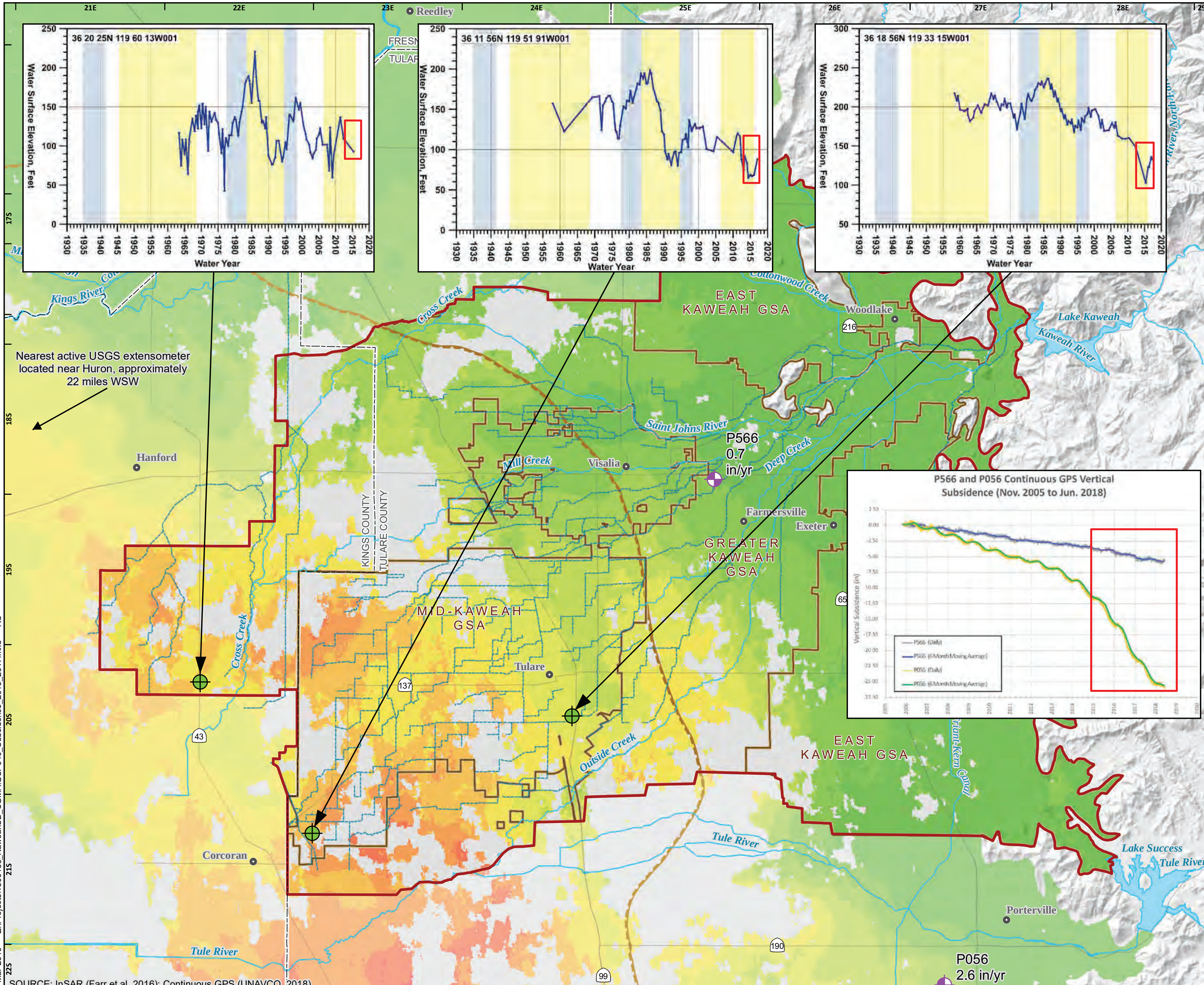
FIGURE 78

# ANNUAL RATE OF SUBSIDENCE (SPRING 2015 TO SPRING 2017)




Continuous GPS Station
Casgem Well with Plotted Hydrograph
Approximate Extent of Corcoran Clay
Kaweah Subbasin GSA
Kaweah Subbasin Boundary

**Subsidence in Inches per Year (NASA JPL InSAR Dataset)**

- 0 to 1.5
- 1.5 to 3
- 3 to 4.5
- 4.5 to 6
- 6 to 7.5
- 7.5 to 9
- 9 to 10.5
- 10.5 to 12
- 12 to 13.5
- 13.5 to 15

**All Other Features**

- Highway
- Waterway
- Minor Canal
- Lake

0 2 4 8
Miles
N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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MARCH 2019

FIGURE 79

# Appendix A

## Groundwater Modeling Technical Memorandum

Consulting Engineers and Scientists

GEI Consultants

# D R A F T

# T E C H N I C A L   M E M O R A N D U M

TO: Kaweah Sub-Basin Management Team

FROM: GEI Consultants, Inc.; GSI Water Solutions, Inc.

DATE: August 24, 2018

RE: TASK 1 – REVIEW OF EXISTING KAWEAH SUB-BASIN GROUNDWATER MODELS AND APPROACH FOR MODEL DEVELOPMENT TO SUPPORT GSPs

## Introduction

Early in 2017, the GEI Consultants, Inc. (GEI) and GSI Water Solutions, Inc. (GSI) teams prepared a Technical Memorandum (TM) to evaluate the groundwater models available for use in development of the Groundwater Sustainability Plans (GSP) for the three Groundwater Sustainability Agencies (GSA) in the Kaweah Sub-Basin (Sub-Basin). That TM, dated March 8, 2017, presented the significant comparative details of three numerical groundwater flow models that cover the Sub-Basin, including:

- Kaweah Delta Water Conservation District (KDWCD) Groundwater Model,
- Central Valley Hydrologic Model (CVHM), and
- California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) coarse grid and fine grid variants.

The March 2107 TM identified the water budget from the most recent update of the KDWCD Water Resources Investigation (WRI) as an accounting "model", but it is essentially a water accounting analysis that uses water consumption and soil moisture models. It is not a three-dimensional, numerical groundwater flow model, but is a valuable analysis that will be used as primary inputs to the groundwater model. The March 2017 TM recommended use of the KDWCD Groundwater Model as the preferred tool for Sustainable Groundwater Management Act (SGMA) applications based upon its relative ability to address the potential model needs cited in SGMA regulations. Model selection criteria used in the TM included: model availability; cost of development and implementation; regulatory acceptance; suitability for GSP-specific analyses; and relative abilities to assess Sub-Basin water budget components, future undesirable results, and impacts of future management actions and projects.



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More recently, the Kaweah Management Team, consisting of the East Kaweah, Greater Kaweah, and Mid-Kaweah Groundwater Sustainability Agencies (EKGSA, GKGSA, and MKGSA) approved a scope of work to develop a Sub-Basin wide numerical groundwater model to support GSP development and implementation. Efforts related to groundwater model development and use of the calibrated tool were generally defined within three tasks, as follows:

1. Task 1 – Perform a technical assessment of existing groundwater models that cover the Kaweah Sub-Basin, with emphasis on the KDWCD Model, and develop an approach to update and revise the selected source model as required to support the objectives of the GSP.
2. Task 2 – Perform model revisions and updates for the selected groundwater model as documented in Task 1, with a focus on supporting GSP objectives.
3. Task 3 – Apply the updated model predictively for each GSA and cumulatively for the entire Sub-Basin to simulate future conditions, with and without potential management actions and projects proposed to support GSP implementation.

This TM documents the results of Task 1. GEI and GSI (the Modeling Team), as part of supporting Sub-Basin SGMA compliance, have evaluated the existing KDWCD Groundwater Model for update to simulate the entire Sub-Basin and relevant adjacent areas. The following presents technical details and performance aspects of the KDWCD Model and proposes a general approach for utilizing the model to support development of the GSP. Specifics of this approach may change over the course of model development as dictated by data constraints and improved conceptualization provided by the updated Sub-Basin Basin Setting developed through the Management Team. This TM and associated analyses satisfies Task 1 requirements, including:

- Perform a detailed evaluation of the existing KDWCD groundwater model inputs and outputs, including test runs and simulations, comparisons with water budget data, and a general comparison with regional C2VSim and CVHM models.
- Develop a plan to move forward with the model update, including assessment of status of required hydrogeologic data, updates to model area, parameters, fluxes, spatial framework, stress periods, validation periods, and calibration periods and general approach for the model domain.
- Prepare a TM summarizing the path forward for modeling support of the GSP, including technical coordination with adjacent basin GSA representatives regarding groundwater modeling methods and assumptions.

Additionally, the Modeling Team will present the key findings of this TM in a workshop for representatives of the Sub-Basin GSAs. This working session will allow GSA representatives to better understand the model design and capabilities as well as provide a forum for discussion of current, future, and outstanding data as well as planning needs for model development and predictive simulations.

After submittal of this proposed modeling approach and path forward, the Modeling Team will execute the recommended actions described in this document. Once updated, the Modeling Team is recommending adoption of the name Kaweah Sub-Basin Hydrologic Model (KSHM) for this new SGMA tool to differentiate it from the previous modeling efforts and to reflect the fact that it includes complex hydrologic analyses in addition to groundwater flow.

## Comparison with Regional Modeling Tools

The Modeling Team previously performed a cursory review of pertinent aspects affecting the efficient use of the three major groundwater modeling tools that cover the Sub-Basin. This TM is built upon that analysis and includes a more in-depth assessment of the newly released beta version of the C2VSim model provided by the California Department of Water Resources (DWR). Although the results of the March 2017 analysis were reinforced with findings from this review, the Modeling Team also looked at the datasets contained within these valuable, regional modeling tools to see if they may be of use in the development of the KSHM.

### *Central Valley Hydrologic Model*

CVHM is an 11-layer model that covers the entire Central Valley. It has a spatial resolution of one square mile and includes both a coupled lithologic model and Farm Process module (model) that are used to estimate hydraulic parameters and agricultural groundwater demand and recharge, respectively. The CVHM was previously deemed not to be a viable modeling alternative for the Sub-Basin analyses by the Modeling Team due to several factors. Most significant of these is the fact that the model data is only current to 2009, well before the SGMA-specified accountability date of 2015. The model resolution is also not suitable to reflect all water budget components at the precision required to assess past and current groundwater responses to water management within each GSA. The CVHM is also not suitably calibrated nor reflective of the hydrostratigraphy in the Sub-Basin and does not match the higher resolution and more accurate crop and related groundwater pumping estimates produced by Davids Engineering, Inc. (Davids Engineering) time-series analysis of evaporation and applied water estimates for the KDWCD; soon to be provided for the entire Sub-Basin through water year 2017. Lastly, the use of the Farm Process is cost prohibitive, given the fact that it would have to be rigorously calibrated to the evapotranspiration and deep percolation estimates already provided by the Davids Engineering analysis.

### *California Central Valley Groundwater-Surface Water Simulation Model (C2VSim)*

The DWR-supported C2VSim Fine Mesh Beta Version was assessed in greater detail as part of the development of this modeling approach. Like CVHM, the C2VSim fine mesh does not include the high resolution of crop demands and surface water deliveries that are in the existing KDWCD model and can be easily updated with the KSHM. It also does not have the element resolution, flexibility to change fluxes, cost savings, and GSA-level accuracy of a sub-regional model designed to incorporate the highest resolution and locally accurate consumptive use and recharge information available. The Modeling Team assessed model layering, significant water budget components, storage change, and groundwater level elevation changes used in C2VSim relative to KDWCD monitoring well locations. The previous KDWCD model produced a better match for the data and estimates from the WRI, and at a significantly higher resolution. Simulated storage change within the Sub-Basin was greater than that estimated by C2VSim by over 20,000 acre-feet per year (AFY); without documentation of how the quantification of water budget components was performed. Calibration of regional flow directions and gradients were reasonable but not as accurate nor locally refined as that observed with the KDWCD modeling efforts.

The beta version of the C2VSim model is not currently considered to be calibrated in a quantitative sense, and no documentation is publicly available to assess the resolution or accuracy of the model inputs for the Sub-Basin. Because of our analysis and comparison of the C2VSim Fine Mesh Beta Model with the water budget and groundwater conditions from the WRI and the draft Basin Setting; the C2VSim was deemed to be a viable source of regional information to supplement development of the KSHM. However, relative to a modeling approach using the KSHM, the C2VSIM model would not provide a more accurate or cost-efficient option for satisfying SGMA regulations.

## KDWCD Model Assessment and Review with Respect to an Updated Model

The KDWCD Groundwater Model was originally developed by Fugro Consultants, Inc. (Fugro) under the direction and sponsorship by KDWCD. Model development was documented in the report "*Numerical Groundwater Flow Model for the Kaweah Delta Water Conservation District, Final Report*" (April 2005). The objective of the model was to simulate the water budget estimates as refined under the WRI in 2003 and evaluate calibrated groundwater elevations, and modeled fluxes to and from adjacent sub-basins.

In May 2012, the KDWCD model was expanded to the east and southeast by Fugro to include the service areas of the Cities of Lindsay and Exeter, and adjacent irrigation districts, including: the Lewis Creek Water District; some unincorporated land and significant portions of Exeter Irrigation District, Lindmore Irrigation District, and Lindsay-Strathmore Irrigation District. The purpose of this effort was to update only the geographic extent, and it did not include updates to the simulation period or the calibration. The model was intended to be updated, refined, and improved in the coming years to provide a rigorously calibrated model over this larger extent, but this proposed work was not performed prior to initiation of SGMA and GSP development efforts.

### *Modeling Code and Packages*

The KDWCD model was developed using MODFLOW 2000. MODFLOW, developed and maintained by the United States Geological Survey (USGS), is one of the most commonly used groundwater modeling codes in the world and is considered an industry standard. The pre- and post-processing of groundwater model data was performed using Groundwater Vistas, a third-party graphical user interface (GUI) that is among the most commonly used software in the groundwater industry to facilitate the use of MODFLOW.

The previous two KDWCD model variants used the following MODFLOW modules, or "packages":

- Well Package (WELL)
- Recharge Package (RCH)
- General Head Boundary (GHB) Package

MODFLOW utilizes large text files of numerical values as input files that provide the model with the values of various physical parameters and fluxes; all incorporated into the three-dimensional (3D) model structure. Much of the pre-processing and spatial organization of the data used to develop the MODFLOW input files was accomplished by Fugro using customized FORTRAN routines, as well as a geographic information system (GIS). Because of more recently available evapotranspiration and applied water estimates from Davids Engineering, the use of these FORTRAN routines is no longer necessary; providing a significant cost and time savings.

A summary of the construction and implementation of various water budget components into these model packages is discussed in following sections.

### Model Extent and Discretization

The spatial extent of the current KDWCD model is presented in Figure 1. The figure displays the original model extent as well as the expanded extent to the east from the 2012 update. The model extends approximately twelve miles from east to west and 7.5 miles from north to south. It is composed of uniform 1,000 foot by 1,000-foot model cells for each layer.

There are some areas of the Sub-Basin that are not currently within the model domain (Figure 1), including much of what is now the EKGSA area. To evaluate the entire Sub-Basin area, in support of SGMA, it will be necessary to expand the model area to include all of the areas within the Sub-Basin. The updated model must also have shared boundaries and shared buffer zones with all adjacent groundwater sub-basins, as well as an evaluation of subsurface inflow and outflow (underflow) between the sub-basins. Figure 2 shows the proposed, expanded model grid for the new KSHM extent.

### Model Layers

The KDWCD model is vertically discretized into three layers as shown on hydrogeologic cross sections shown on Figures 3, 4, and 5. These hydrogeologic cross sections show the principal aquifers, aquitard, and associated geologic units located throughout the Sub-Basin. Layer 1 represents the unconfined, basin sediments from the ground surface down to the Corcoran Clay in the western portion of the model domain or deeper; also including some older Quaternary alluvial deposits in the eastern portion of the domain. Layer 2 represents the Corcoran Clay, which is the primary aquitard in the Sub-Basin, where it is present in the western portion of the domain. In the eastern portion of the model area, where the Corcoran Clay pinches out, Layer 2 is simply represented with a minimal thickness and hydraulic parameters comparable to those of Layer 1. Layer 3 represents the largely confined basin sediments below the Corcoran Clay, where it is present, and deeper unconsolidated sediments to the east of the occurrence of this regional confining unit.

Although some of the regional models covering large areas of the Central Valley (i.e., CVHM and C2VSim) have a more highly discretized vertical layering, the Modeling Team believes that the three-layer conceptual model represented in the KDWCD model is likely suitable for the primary modeling objectives that support GSP development.

### Model Simulation Time Periods

The KDWCD model was originally set up with 38 6-month stress periods to simulate the 19-year (calendar) calibration period of 1981 through 1999. Water budget components as documented in the 2003 WRI were used as input into the model and spatially distributed to the degree feasible given the spatial resolution and precision of the data sources and model grid.

It is likely that, after any recommended changes to the KDWCD model are implemented into the KSHM, the Modeling Team will calibrate the model through water year 2017 and perform validation simulations to confirm that the previous calibration developed with the historic WRI information is a suitable starting point the new simulation period. After validation, additional model refinements and updates can proceed to further improve the predictive capabilities of the KSHM using the aforementioned recent, high-resolution datasets as well as updated Basin Setting information.

### *Model Parameters*

- **Hydraulic Conductivity/Transmissivity.** Hydraulic conductivity values are documented in the 2005 Model Report as well as in previous iterations of the WRI and conform with industry-standard literature values for the types of aquifer materials encountered at these depth intervals. Calibrated, horizontal hydraulic conductivities for Layer 1 (upper, unconfined aquifer) range from 50 feet/day (ft/d) to 235 ft/d, with the highest values in the southwest portion of the model area. Horizontal hydraulic conductivities for the portion of Layer 2 representing the Corcoran Clay were set at 0.024 ft/d. In the eastern area of Layer 2, where the Corcoran Clay pinches out, hydraulic conductivity values range from 50 to 150 ft/d and are essentially equal to the values assigned to the same area in Layer 1. Horizontal hydraulic conductivities for Layer 3 range from 25 ft/d to 125 ft/d. This distribution of hydraulic conductivity is consistent with previously published estimates from both the WRI and industry-standard literature estimates for the lithologies encountered.
- **Vertical hydraulic conductivity.** Vertical hydraulic conductivity in the model is set to a ratio of the estimated horizontal hydraulic conductivity, or an anisotropy ratio of 1:1. This essentially means that the vertical hydraulic conductivity of the Corcoran Clay was assumed to be equal to its horizontal conductivity and was apparently based upon the extensive perforation of the Corcoran Clay and other aquifer units by fully penetrating wells. This perforation of the regional aquitard allows for greater hydraulic connection between the upper and lower aquifer units. The Modeling Team will assess the validity of this anisotropy ratio during the validation simulation and adjust where merited.
- **Storage Parameters.** Specific yields in the unconfined aquifer (Layer 1) range from approximately 8% to 14%. Storage coefficients for the confined areas were set at an order of magnitude of approximately $1 \times 10^{-4}$. The storage coefficients used for the unconfined and the confined portions of the model are typical of those found in the basin and documented in the WRI as well as other commonly referenced literature for large basin fill valleys.

### *Current Model Boundary Packages and WRI Water Budget Components*

As mentioned previously, the current KDWCD model uses three MODFLOW packages: WELL, RCH, and GHBs. A discussion of how those packages are used follows below.

- **Well Package (WELL).** As currently constructed, the KCWCD model represents the following WRI water budget components; which were calculated outside of the model Groundwater Vistas graphical user interface (GUI) using GIS and a FORTRAN routine that are unavailable to the Modeling Team. The flux values specified in the WELL package input files are essentially "lumped" fluxes representing the sum of the following water budget components:
  - Well pumpage (outflow)
  - Rainfall-based recharge (inflow)
  - Irrigation return flows (inflow)
  - Ditch loss (inflow)
  - Recharge basins (inflow)

The compilation of multiple water budget components into a single MODFLOW package makes tracking and assessment of the individual water budget components from model simulations difficult. Additionally, this model flux accounting approach and design makes evaluation of possible changes in the water budget because of management actions, changes in water demand or availability, and groundwater projects problematic. Because of this lumping of separate water budget components, every cell in Layer 1 is represented in the WELL Package. This makes the exact validation of the test runs and verification of the calibration with the WRI challenging. Without access to the spatial and temporal distributions of all water budget components utilized by Fugro, it is not possible to re-create the exact WELL package input file. However, the gross water budget inflow, outflow and storage values from the earlier WRI's match those simulated by the model and were reproduced by the Modeling Team.

- **Recharge Package (RCH).** The natural stream channels of the St. John's and the Lower Kaweah Rivers are represented in the model using the MODFLOW RCH Package. The RCH package applies a flux (ft/yr) in the surficial (shallowest) cells at the location where applied. The natural seepage flux values (or groundwater recharge) applied to the model correspond to the values of stream infiltration spatially estimated for these rivers and documented in the WRI.
- **General Head Boundaries (GHB).** The KDWCD model has GHBs assigned to all cells on the exterior perimeter of the model, as seen on Figure 1. GHBs are commonly used to represent the edges of a model domain within a larger aquifer extent. Reference heads (groundwater elevations) and "conductance" terms for adjacent aquifers just outside the model domain are used by this package to calculate fluxes in and out across the boundary. The Modeling Team generally agrees with the use of GHBs in the north, south, and west portions of the Sub-Basin. However, we propose the removal of the GHBs along the eastern portion of the sub-basin at the Sierra Nevada mountain front. Conceptually, the eastern model boundary, especially with the expansion and inclusion of the EKGSA area, is not a head-dependent boundary, but a flux-dependent one based on mountain front recharge and seepage from natural drainages and streams adjacent to relatively impermeable material. Thus, this boundary will be better represented using a no-flow condition coupled with a recharge or prescribed underflow component.

Previous WRIs have included estimates of inflow and outflow across the study boundaries, and comparisons between modeled and calculated values vary significantly both spatially and by magnitude. However, there are several variables that directly impact estimated underflow values that have not been sufficiently constrained, due to the focus of previous work being on the interior of the KDWCD area. Recently updated basin conditions, improved understanding of appropriate regional groundwater conditions adjacent to the Sub-Basin and use of an expanded model area will significantly improve the certainty of these underflow estimates.

**Model Calibration.** Calibration of the KDWCD model for the historic simulation period of 1981-1999 is discussed in the April 2005 model report. These include charts of observed versus modeled water levels for three different time periods and transient hydrographs for 30 target well locations. The density of calibration targets was deemed adequate by the Modeling Team for a model of this area and with the resolution of the model input datasets. Detailed calibration statistics are not documented in the report, but qualitative inspection of the hydrographs indicates that the calibration is adequate for future use in predictive simulations. Additionally, an open-source and industry-standard parameter estimation and optimization algorithm and code (PEST) was used to enhance model calibration. This is a common and robust industry practice that typically improves model calibration statistics.

## Adequacy of the KDWCD Groundwater Model for GSP Development

**Layering scheme.** The 3-layer model layering scheme incorporated into the KDWCD model was deemed adequate by the Modeling Team for use in GSP analyses, and likely does not need significant revision prior to use. This decision was based upon the agreement of the model layers with the hydrogeologic conceptual model for the Sub-Basin as well as the ability of the previous model to simulate historic fluctuations in groundwater elevations over an extensive spatial extent and temporal period. However, should the refinement of the lithologic and stratigraphic understanding of the basin and identification of specific pumping intervals require additional vertical resolution, both Layer 1 and Layer 2 can be split into two layers to improve the model's ability to match and describe key vertical gradients and changes in groundwater level elevations and pressures near prominent pumping centers. At present, this vertical refinement is not required nor supported by data.

**Model area.** The model area will need to be expanded so that the entire Sub-Basin is included in the model. In addition, at the request of and in coordination with the technical groups for both Kaweah and adjacent sub-basins, a buffer zone will be included outside the defined Sub-Basin boundaries so that adjacent models will overlap and share model input and monitoring data. This overlap will assist in reconciling differences between the direction and magnitude of groundwater gradients along sub-basin boundaries. The preliminary extent of this buffer zone is proposed to be approximately 3 miles; however, this value will be revised in areas based on of the estimated locations of pervasive groundwater divides or apparent hydrologic boundaries.

**Cell size.** The 1,000 feet square cell size appears to be adequate for the data density for most model inputs. However, due to improvements in computing speed and power, the Modeling Team recommends initially using a smaller cell size of 500 feet square to 1) accommodate improvements in assigning real world boundaries to the model grid, and 2) leverage the improved resolution of crop demand and evapotranspiration data available for this effort.

**Parameters.** Hydraulic conductivity and storage parameters will remain unchanged at the start of model revisions and calibration scenarios. These will be adjusted if the Modeling Team determines it is necessary during the model validation run or if model calibration standards require parameter refinements.

**Stress Periods.** The previous temporal discretization of the model incorporated 6-month stress periods. To appropriately characterize seasonal rainfall, surface water delivery and pumping patterns; one-month stress periods should be adopted for predictive simulations. This decision will be finalized after review and conditioning of the input groundwater demand and recharge datasets.

With these revisions to the model framework and geometry of the KDWCD model to support the development of the KSHM will be adequate for use to support GSP analyses. The following section summarizes additional, recommended revisions to the organization of the model inputs, parameters, boundary conditions, and MODLFOW packages.

## Proposed Revisions to KDWCD Groundwater Model and Model Approach

The Modeling Team concludes that the KDWCD model is suitable to support GSP development if the following revisions and refinements to the model are performed to develop the KSHM. As mentioned above, once updated, the Modeling Team is recommending adoption of the name Kaweah Sub-Basin Hydrologic Model for this new SGMA tool. This nomenclature is based upon that fact that this model incorporates more than simply a groundwater model in the final analysis. It also incorporates crop demand/evapotranspiration (with precipitation modeling) and applied water models.

The Modeling Team recommends that the relationships between the water budget components, as defined in the WRI (December 2003, revised July 2007), and the MODFLOW modeling packages currently available, be re-organized such that lumping of different water budget components within single MODFLOW packages is minimized. Some degree of aggregation may be unavoidable, but efforts will be made to apply unique water budget components from the updated WRIs and associated water budget components to more appropriate and recent MODFLOW packages. Additionally, we will utilize features of MODFLOW and Groundwater Vistas that allow for tracking of unique components within a single model package when possible. The current and proposed revised conceptual assignments of water budget components to MODFLOW packages are summarized below.

A major change and advantage of this effort relative to previous modeling work involves the availability and use of time-series evapotranspiration and applied water estimates from 1999 through water year 2017, provided by Davids Engineering. This data set uses remote sensing imagery from Landsat satellites to estimate agricultural water demand throughout the Sub-Basin at a very high resolution (approximately 30 meters). This information was not available for previous model builds, and its use will not only improve the understanding and accuracy of agricultural water requirements relative to the previous land use and soil moisture balance calculations that have been used, but also enhance the spatial calibration and predictive capability of the updated and expanded KSHM. The Davids Engineering dataset also includes estimates of deep percolation of applied water and precipitation. During the review of the KDWCD model and development of this modeling approach, the Modeling Team performed testing of the use of this dataset and was able to readily develop crop requirements and associated pumping estimates at a resolution even finer than the proposed model resolution.

**Well Pumping.** Groundwater pumpage will be the dominant water budget component represented in the WELL package. Other, more limited fluxes may also be used to represent mountain front fluxes or other unforeseen fluxes that are specified but do not have a specific package that is appropriate. All pumpage will be coded within the WELL package input files to identify the pumping by source, use, or entity. Municipal wells will be specifically located and simulated when well permits and required data reports are accessible and provide data specific to each well. Agricultural well pumpage will likely be spatially averaged, or "spread across", irrigated areas because of the uncertainty associated with irrigation well location, construction, and monthly or seasonal pumping rates.

**Precipitation-based recharge.** The Modeling Team proposes to represent this water budget component using the Recharge package.

**Natural channel infiltration.** Infiltration of surface water in the natural stream channels of the St. John's and the Lower Kaweah Rivers is currently assigned to the Recharge Package. The Modeling Team proposes to maintain this data in the recharge package along the spatial location of the courses of the rivers. If deemed appropriate and more beneficial the latest version of the Stream Package (SFR2) may be used for localized reaches of continuously flowing water, where gages do not adequately monitor seepage that can be applied directly as recharge. The Stream package calculates infiltration (inflow) to the aquifer based on defined parameters regarding bed geometry and vertical conductivity, and this will likely involve some iterative re-definition of STREAM package components to accurately portray the calculated water budget component flux. Native evapotranspiration (ET), where relevant, will be subtracted from either the precipitation or natural channel infiltration modules. The inclusion of natural, riparian ET will be addressed specifically upon finalization of the water budget for the Sub-Basin.

**Man-made channel recharge.** (i.e., ditch and canal loss). This is currently incorporated with four other water budget components as a single summed value in the Well Package. The Modeling Team proposes to represent this water budget component using either the Recharge package or another Type 3 boundary condition type, such as a prescribed stage above land surface. Should another more advanced MODFLOW module prove to more effective in simulating this flux, it will be utilized, and the reasoning documented in the model development log.

**Irrigation Return Flows.** Irrigation return flows are the component of the water budget that infiltrates into the subsurface due to over-watering of crops. This is currently incorporated with four other water budget components as a single summed value in the WELL Package. The Modeling Team proposes to represent this water budget component using the Recharge package, but to differentiate it from precipitation-based recharge within Groundwater Vistas by assigning zone identifiers that are different from the rainfall-based recharge.

**Artificial Recharge Basins.** This is currently incorporated with four other water budget components as a single summed value in the WELL Package. Recharge basins are likely to be a common management strategy to help achieve sustainability in the Sub-Basin. As such, the model should be able to individually represent each recharge basin. These could be represented in the Recharge Package or other more sophisticated module if specifically merited.

**Lateral Model Boundaries.** These are currently simulated using the GHB Package. We will maintain this concept, but the locations of the GHBs will be moved to locations beyond the edge of the Sub-Basin up to the extent of the expanded model area. Assigned reference heads for the GHB cells will be based on observed groundwater elevations from historic groundwater elevation maps. GHB head assignments for predictive runs may be lowered over time if current trends indicate declining water levels over the next 20-40 years. These head assignments will be finalized in consultation and coordination with adjacent sub-basin technical groups as well as any regional modeling or State-derived predictive information.

**Mountain Front Recharge.** Currently, a GHB is assigned to the eastern edge of the Sub-Basin, along the front of the Sierra Nevada foothills. The modeling team will remove this GHB and represent mountain front recharge using the Recharge Package. Conceptually, mountain front recharge is not a head-dependent boundary, but a specified flux-dependent boundary.

**Calibration Period and Validation Period.** As discussed previously, the original model was calibrated to a 19-year calibration period using 6-month stress periods. The Modeling Team suggests that upon completion of the KSHM model, a validation run simulating the time period of 1999-2017 be made to assess that the model is still adequately calibrated. Upon assessment of the validation simulation, the KSHM will undergo the calibration process using both qualitative and quantitative measures, such as parameter estimation software (PEST), to produce the final calibrated simulation modeling tool to be used to refine the Sub-Basin water budget and be used for predictive simulations. Moving forward, the updated groundwater model for the Kaweah Sub-Basin will begin in 1999 and continue to be updated as new GSP updates are required and deemed necessary by the GSAs. This new start date is due to the substantially increased accuracy and spatial resolution of water budget features, primarily crop demand and surface water deliveries that result in agricultural pumping estimates, beginning with the first year that high quality satellite imagery and associated evapotranspiration/soil moisture balance models were provided by Davids Engineering. This modeling effort can be updated in the future with newer and more accurate local and regional data from neighboring GSAs to benefit required SGMA reporting, refinements, and optimization of the GSPs within the Sub-Basin.

**Predictive Simulations.** Predictive simulations through the SGMA timeframe of 2040 and beyond will be performed using the same monthly stress period interval and will be developed using the projected climate dataset provided by DWR. Correlations between this climatic projection and previously quantified groundwater demands and surface water deliveries will be developed to produce a suitable baseline predictive simulation that will serve as a starting point for assessing the impacts of various adaptive management actions and groundwater projects. Simulations will be performed for individual GSAs, but also the cumulative effects of future groundwater management in the Sub-Basin will be assessed relative to the baseline predictive simulation.

## Collaboration with Neighboring Sub-Basins

The Modeling Team will be collaborating with neighboring sub-basin technical representatives during the update and application of the KSHM, with permission from the Kaweah Sub-Basin GSAs. The purpose for this coordination is to accomplish the following objectives:

- Receive input from GSAs' representatives on modeling tools and approaches in adjacent basins.
- Exchange data and information for consistency between tools.
- Agree on boundary conditions including both gradients and heads located at and outside of the boundaries of the Sub-Basin.
- Ensure that the KSHM integrates well, to the extent possible, with adjacent tools that our approaches for Kaweah Sub-Basin will not result in conflicting boundary conditions or water budgets.

The Modeling Team recommends that inter-basin model coordination meetings begin in August of 2018 and continue until the simulations required for use in developing the draft GSP is are completed. We anticipate the need for four (4) focused meetings on this approximate schedule:

1. KSHM Approach Meeting – Mid September 2018
2. KSHM Update Meeting – Late October 2018
3. KSHM Model Baseline Run and Boundary Flux Meeting – Late November 2018
4. KSHM Model Simulation Results Meeting – January 2019

The Modeling Team attended one meeting with the Tulare Lake Sub-Basin modeling group on June 15th, 2018 to facilitate data transfer between the two modeling efforts and improve agreement and conceptual consistency between the Sub-Basins. Upon request from the Kaweah Sub-Basin managers and committees, the Modeling Team will continue to collaborate and improve consensus with adjacent modeling groups to improve model agreement and sub-regional consistency between calibrated and predictive simulations. The Modeling Team is also prepared to develop and share baseline predictive simulation results with neighboring basins and accept in-kind data sharing to further improve predictive accuracy and understanding on adaptive management and project options and collaboration. These activities will be approved by GSA representatives prior to the Modeling Team sharing any information or data.

## Conclusions and Recommendations Regarding Model Updates

In general, the Modeling Team believes that the KDWCD model provides an adequate precursor model that will be suitable for use in GSP development if the following revisions and updates are incorporated.

Groundwater Vistas Version 7 will be the processing software package utilized. We will maintain MODFLOW as the basic code and will update to MODFLOW-USG or MODFLOW-NWT to take advantage of advances in numerical solution techniques that are available in these updated MODFLOW revisions.

1. **Extent**. The model will need to be expanded to fill the area between the general head boundary of the current model and the Sub-Basin boundary shown in Figure 1 to include the entire area of the Kaweah Sub-Basin.
2. **Layers.** The model layering scheme depicting two water-bearing layers above and below the Corcoran Clay is suitable for the objective of supporting the GSP development.
3. **Historical Simulations.** The KDWCD model has been calibrated to the 1981-1999 hydrologic period. Based on inspection of the hydrographs presented in the 2005 modeling report and the 2012 Model update report, observed water levels are adequately simulated to consider this model effectively calibrated. The objective is to have a model suitable to simulate projected management actions through the entire Sub-Basin. No changes will be made to the inputs to the 1981-1999 run. Therefore, it is already calibrated to that period. We are just re-organizing the assignment of water budget components to different MODFLOW packages from 1999-2017, and beyond. Monthly stress periods will be used.
4. **Assignment of water budget components to MODFLOW Packages.** The Modeling Team proposes to revise the conventions used in the current KDWCD model. This will be the most involved part of the model revision. The updated water budget values that have been generated by the GSA will continue to be the primary input as far as flux values go. However, we propose to organize them into more readily identifiable currently available MODFLOW packages to help with the analyses of potential water budget changes that may correspond to management actions in the future.
5. **Recharge Components.** Spatial distribution of such water budget components as percolation of precipitation, irrigation return flow, recharge basins, etc., will be updated based on the most currently available data.
6. **Model Parameters**. Hydraulic conductivity (horizontal and vertical) and storage coefficient will initially stay unchanged during the validation period simulation. If the calibration target hydrographs for the validation period indicate that a suitable match is retained between observed and modeled water levels, the existing parameters will be retained.
7. **Flow Boundaries.** In areas where the current GHB boundaries are within the Kaweah Sub-Basin, they will be expanded approximately 1-2 miles, or at locations of any likely groundwater divides from the Sub-Basin boundary on the north, south, and west sides of the Sub-Basin. The assigned heads for these GHBs for the 1999-2017 verification run will be based on published groundwater elevations in the vicinity as depicted in contour maps published by DWR. Seasonal variability in assigned GHB heads can be incorporated.
8. **No-Flow Boundaries.** The eastern GHB along the base of the Sierra foothills will be removed. Instead, the flux in the Recharge Package will be increased along this boundary to represent mountain front recharge. The flux volume from the GHB will be evaluated, and this flux volume will be approximated using the Recharge Package.

## Estimated Schedule of Model Update Activities

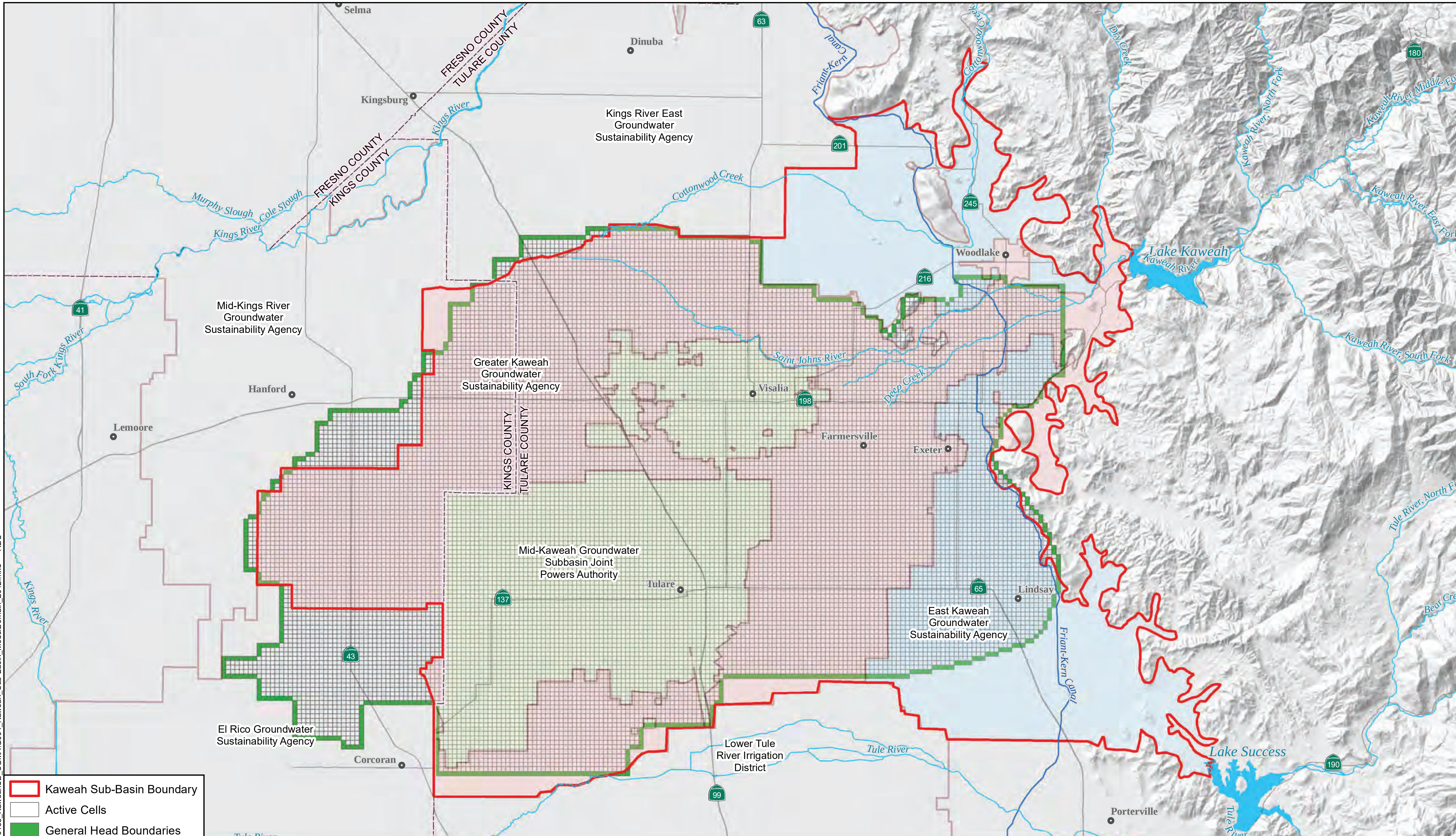
The Modeling Team proposes the following schedule for the major groundwater model update activities. Estimated timeframes for key inter-basin model coordination meetings and updates are also included in the following table to provide a more comprehensive schedule and to facilitate meeting planning. Specific model development and simulation tasks may shift to earlier or later timeframes, but it is the intention of the Modeling Team to comply with the overall schedule and satisfy deadlines for the final deliverable of the calibrated modeling tool and associated predictive scenarios. Should information not be available to the Modeling Team in time to use them in development of the calibrated model simulation or predictive simulations, the data will either not be included, or the schedule may be adjusted to accommodate their inclusion, per guidance from Sub-Basin GSA leadership.

Updates and presentations on the status of the groundwater modeling efforts will occur at regular intervals during Coordinated Sub-Basin and individual GSA meetings, per the scope of work for the groundwater modeling task order.

**Table 1: Anticipated Schedule of Groundwater Model Update Activities**

| Modeling Activity | Estimated Completion Timeframe |
|---|---|
| Refinement and expansion of model domain and boundary conditions | Early September 2018 |
| Update water budget with Davids Engineering and EKGSA data | Early September 2018 |
| Development of calibration targets | Mid-September 2018 |
| Parameterization of model layers | Mid-September 2018 |
| Refinement of groundwater fluxes | Mid-September 2018 |
| Inter-basin KSHM Approach Meeting (inter-basin) | Mid-September 2018 |
| Adjust boundary conditions, fluxes, and parameters using any new adjacent basin data | Late September 2018 |
| Initiate Formal Calibration Process | Early October 2018 |
| Inter-basin KSHM Update Meeting | Late October 2018 |
| Complete initial calibration process | Early November 2018 |
| Calibration and model refinements and preparation for predictive simulations | Late November 2018 |
| Inter-basin KSHM Calibrated Model and Boundary Flux Meeting | Late November 2018 |
| Develop predictive baseline scenario – Sub-Basin level – | Early December 2018 |
| Develop GSA specific predictive simulations | Mid December 2018 |
| Cumulative Sub-Basin simulations | Early January 2019 |

## LIST OF FIGURES




6 3 0 6

Miles

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Kaweah Sub-Basin
Groundwater Modeling Task 1
Tulare County, California

Kaweah Sub-Basin

GSI Water Solutions, Inc.

GEI Consultants

# 2012 KDWCD EXPANDED MODEL DOMAIN WITH GENERAL HEAD BOUNDARIES

AUGUST 2018 DRAFT FIGURE 1

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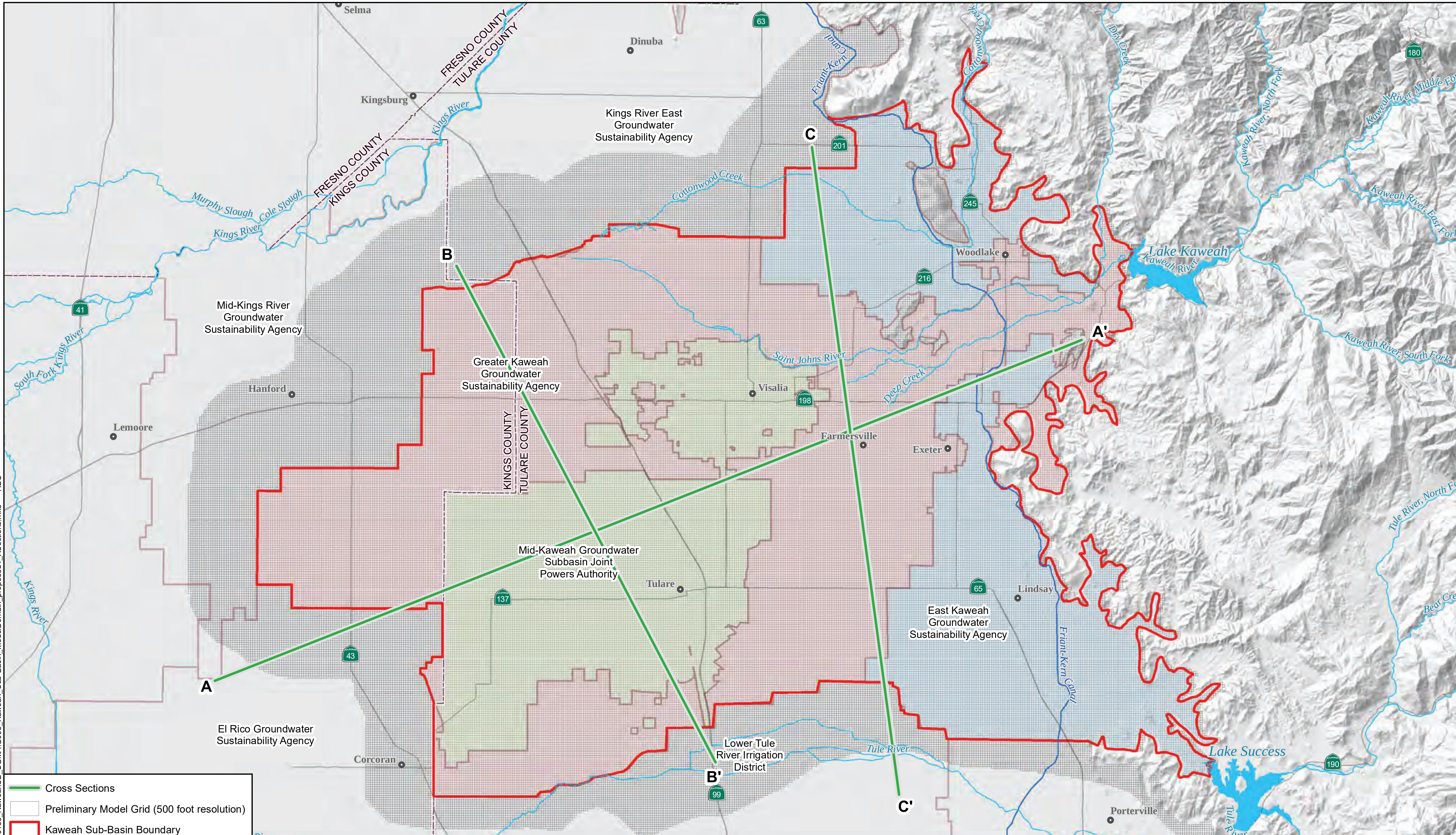


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Kaweah Sub-Basin
Groundwater Modeling Task 1
Tulare County, California

Kaweah Sub-Basin

GSI Water Solutions, Inc.

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PRELIMINARY KSHM GRID EXTENT AND RESOLUTION INCLUDING BUFFER ZONES AND CROSS SECTION LOCATIONS

AUGUST 2018 DRAFT FIGURE 2

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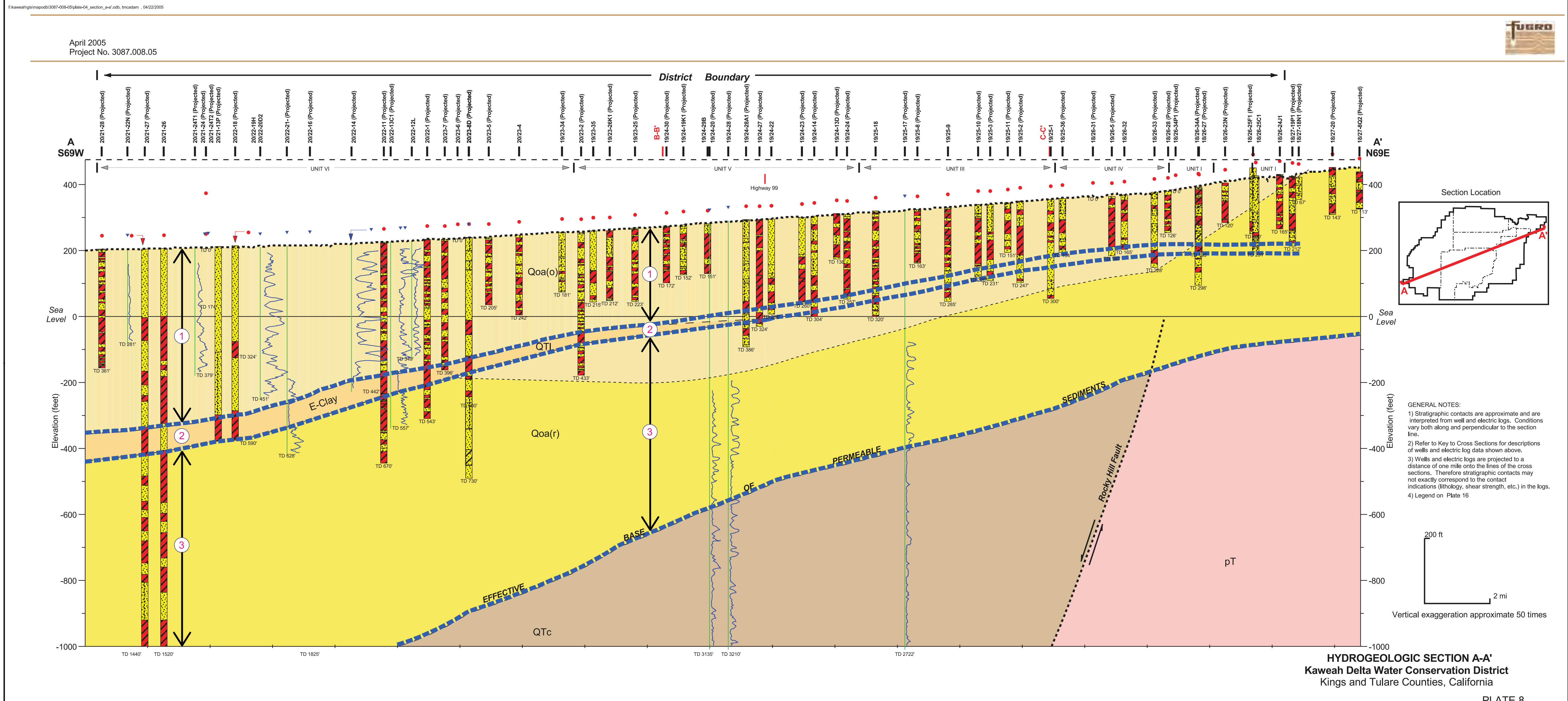


| | |
|---|---|
| Qoa(o) | Principal Aquifer A (Model Layer 1) |
| E-Clay/QTl | Principal Aquitard (E/Corcoran Clay) (Model Layer 2) |
| Qoa(o) / Qoa(r) | Principal Aquifer B (Model Layer 3) |
| ▬ ▬ ▬ | Model Layer Boundary |

SOURCE: Numerical Groundwater Flow Model for the Kaweah Delta Water Conservation District (April 2005) Prepared for: Kaweah Delta Water Conservation District by Fugro West, Inc.

2 1 0 2
Miles

Kaweah Sub-Basin
Groundwater Modeling Task 1
Tulare County, California

Kaweah Sub-Basin

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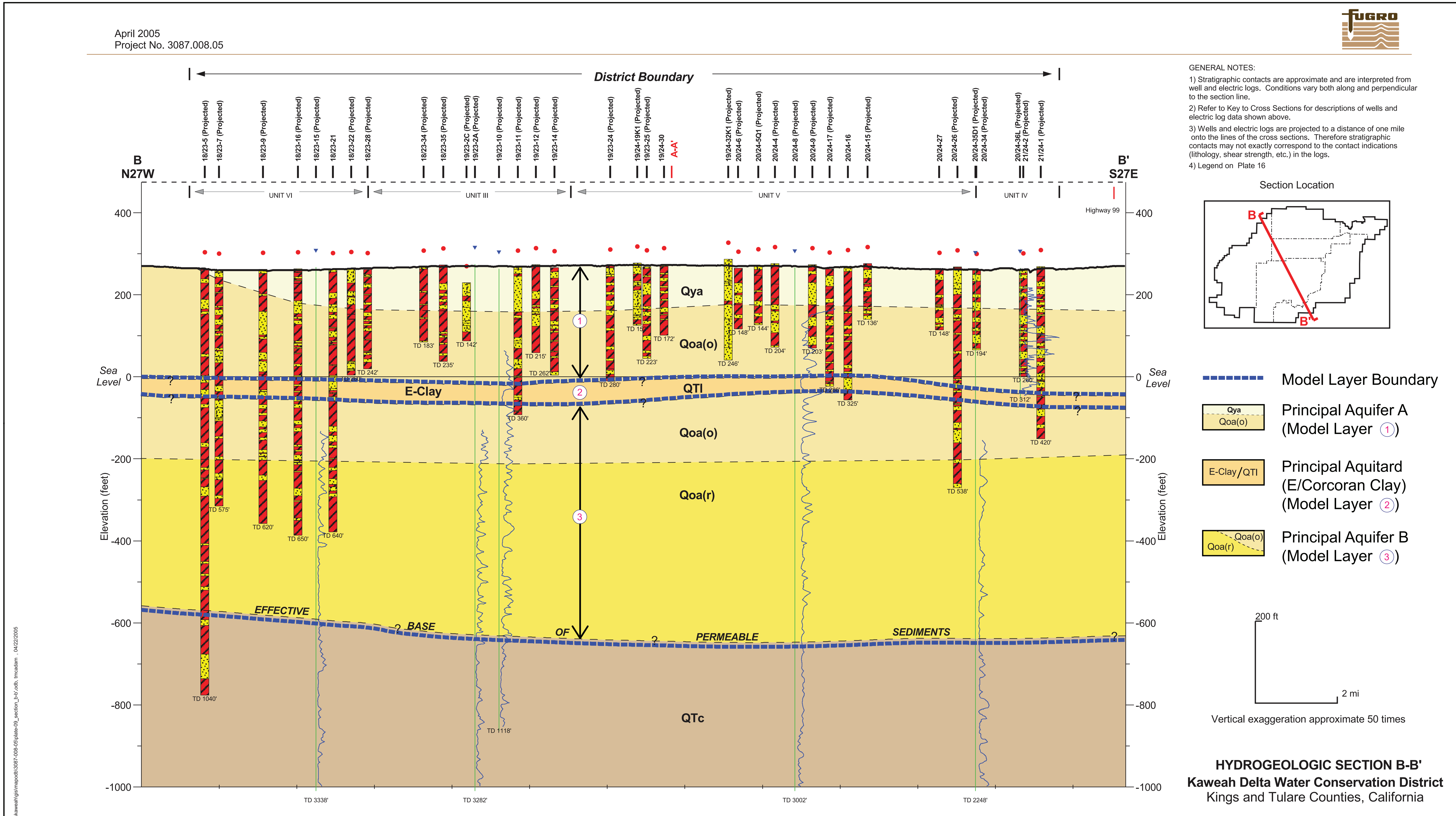
**Model Layering Scheme along Hydrogeologic Cross Section A-A'**

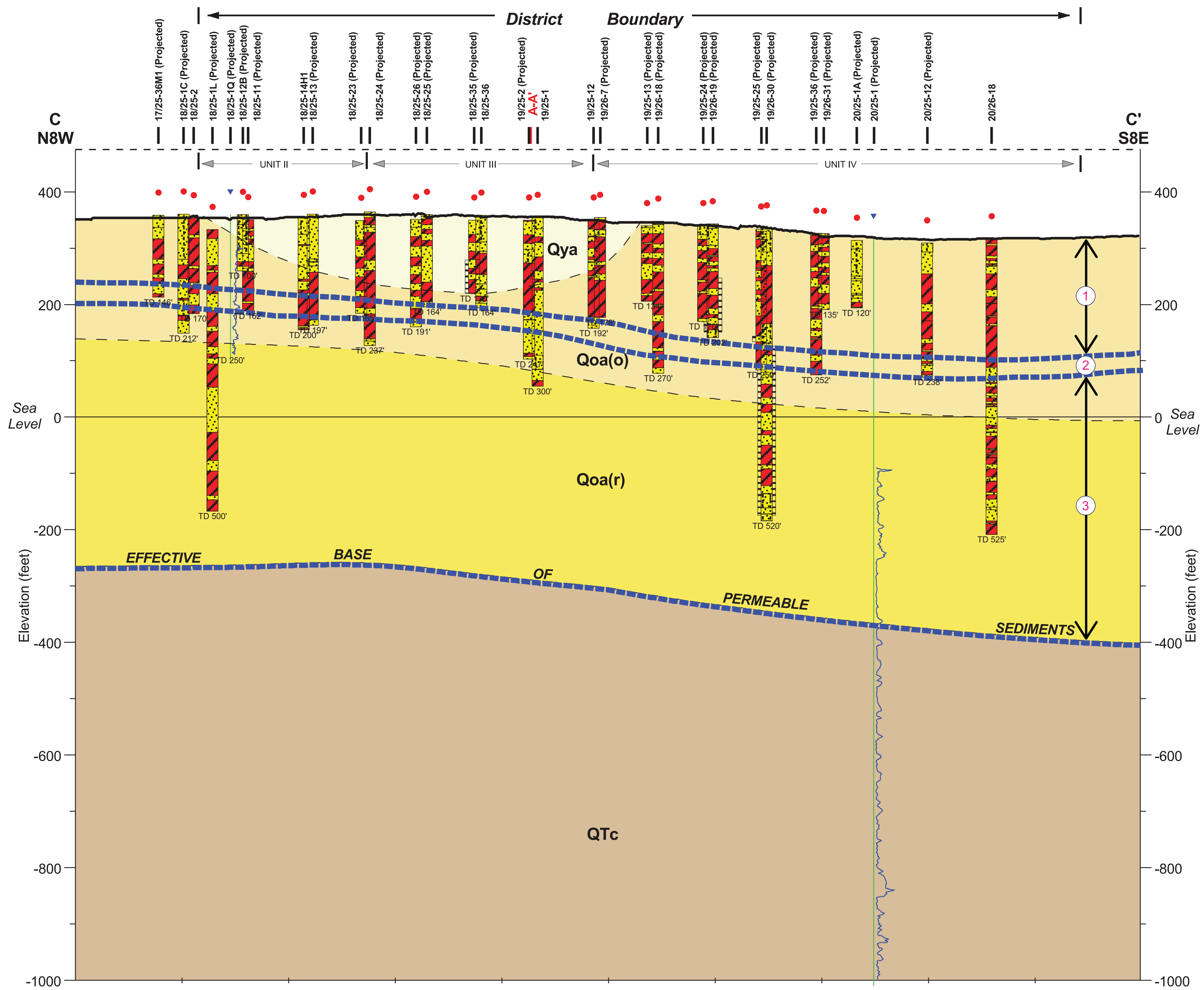
AUGUST 2018 | DRAFT | FIGURE 3



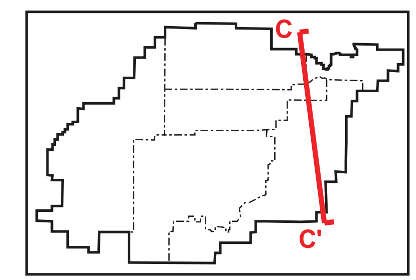

SOURCE: Numerical Groundwater Flow Model for the Kaweah Delta Water Conservation District (April 2005) Prepared for: Kaweah Delta Water Conservation District by Fugro West, Inc.

| | | | |
|---|---|---|---|
| 2 1 0 2 Miles | Kaweah Sub-Basin<br>Groundwater Modeling Task 1<br>Tulare County, California | GSI Water Solutions, Inc. / GEI Consultants | Model Layering Scheme along Hydrogeologic Cross Section B-B' |
| | Kaweah Sub-Basin | | AUGUST 2018 DRAFT FIGURE 4 |

April 2005
Project No. 3087.008.05




Section Location




GENERAL NOTES:
1) Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2) Refer to Key to Cross Sections for descriptions of wells and electric log data shown above.
3) Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
4) Legend on Plate 16

Model Layer Boundary

Qya / Qoa(o) — Principal Aquifer A (Model Layer 1)

Qoa(o) — Principal Aquifer A (Model Layer 2)

Qoa(o) / Qoa(r) — Principal Aquifer B (Model Layer 3)

200 ft
2 mi
Vertical exaggeration approximate 50 times

**HYDROGEOLOGIC SECTION C-C'**
**Kaweah Delta Water Conservation District**
Kings and Tulare Counties, California

PLATE 10

SOURCE: Numerical Groundwater Flow Model for the Kaweah Delta Water Conservation District (April 2005) Prepared for: Kaweah Delta Water Conservation District by Fugro West, Inc.

2 1 0 2
Miles

Kaweah Sub-Basin
Groundwater Modeling Task 1
Tulare County, California

Kaweah Sub-Basin

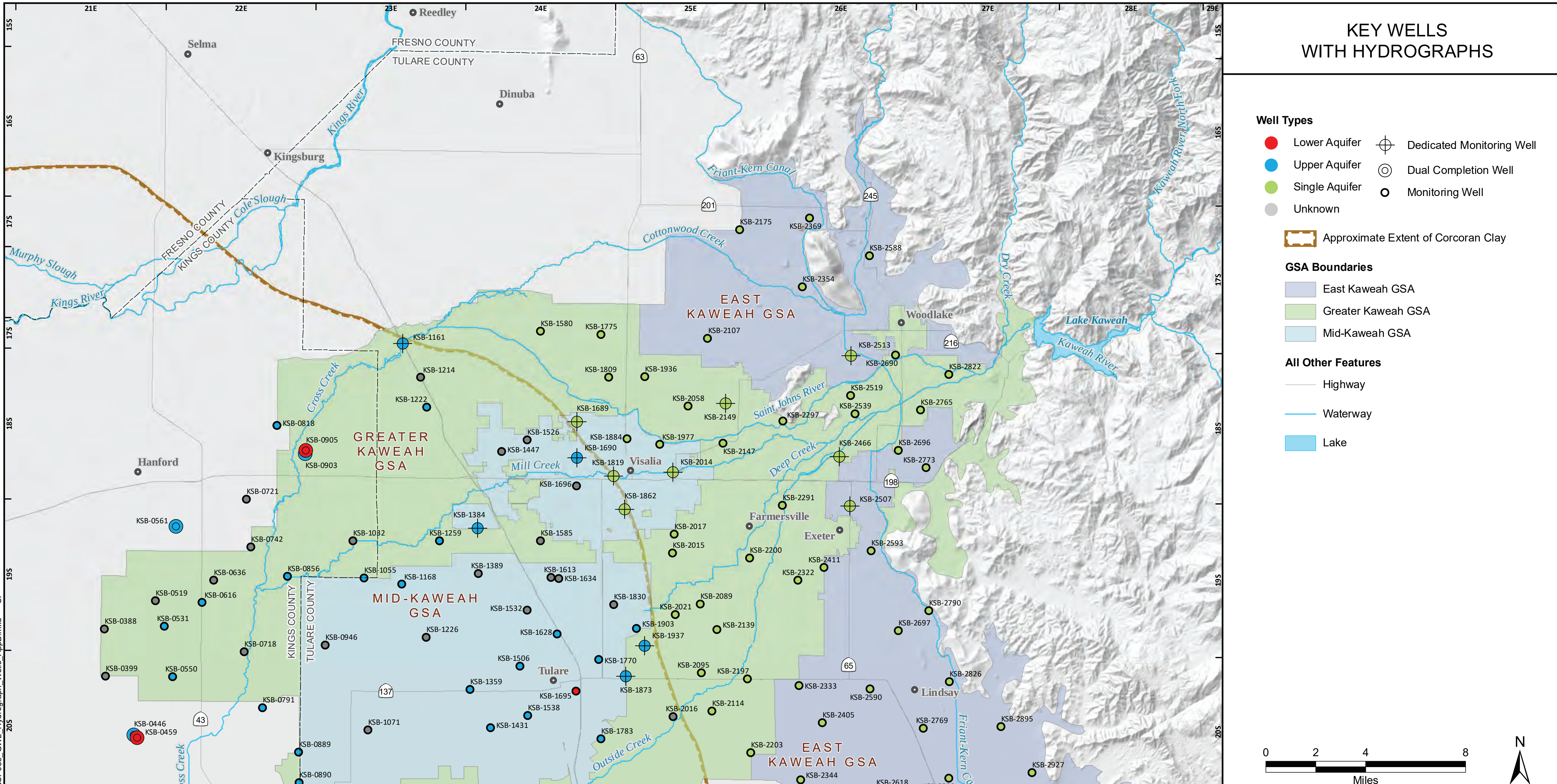
Model Layering Scheme along Hydrogeologic Cross Section C-C'

AUGUST 2018 DRAFT FIGURE 5

# Appendix B

## Key Well Information

# KEY WELLS WITH HYDROGRAPHS




Kaweah Subbasin Managers
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

GEI Consultants

GSI Water Solutions, Inc.

DECEMBER 2018 **DRAFT** FIGURE B-1

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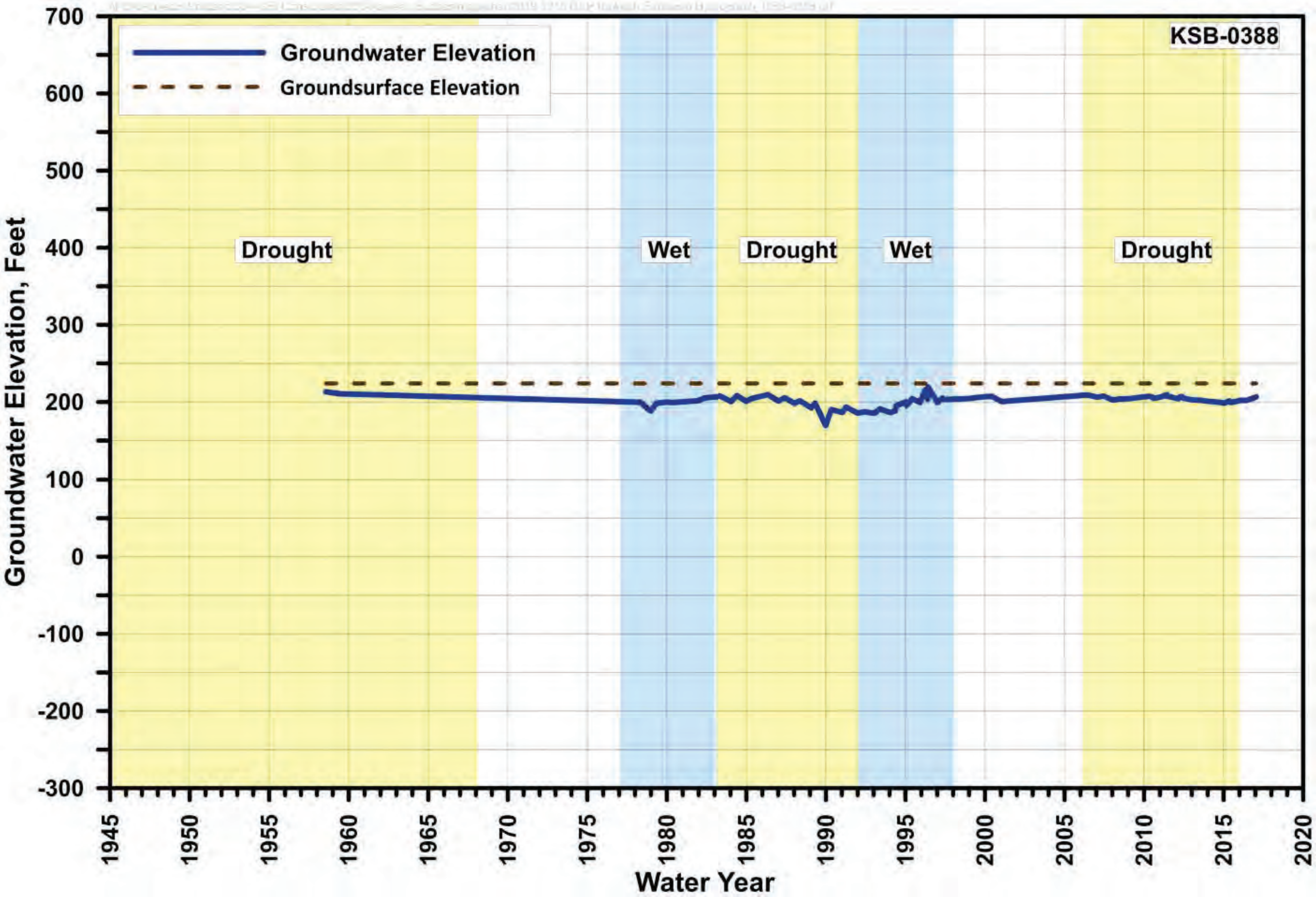
11-Dec-2019

**Table _ - Kaweah Sub-basin Key Well Information**

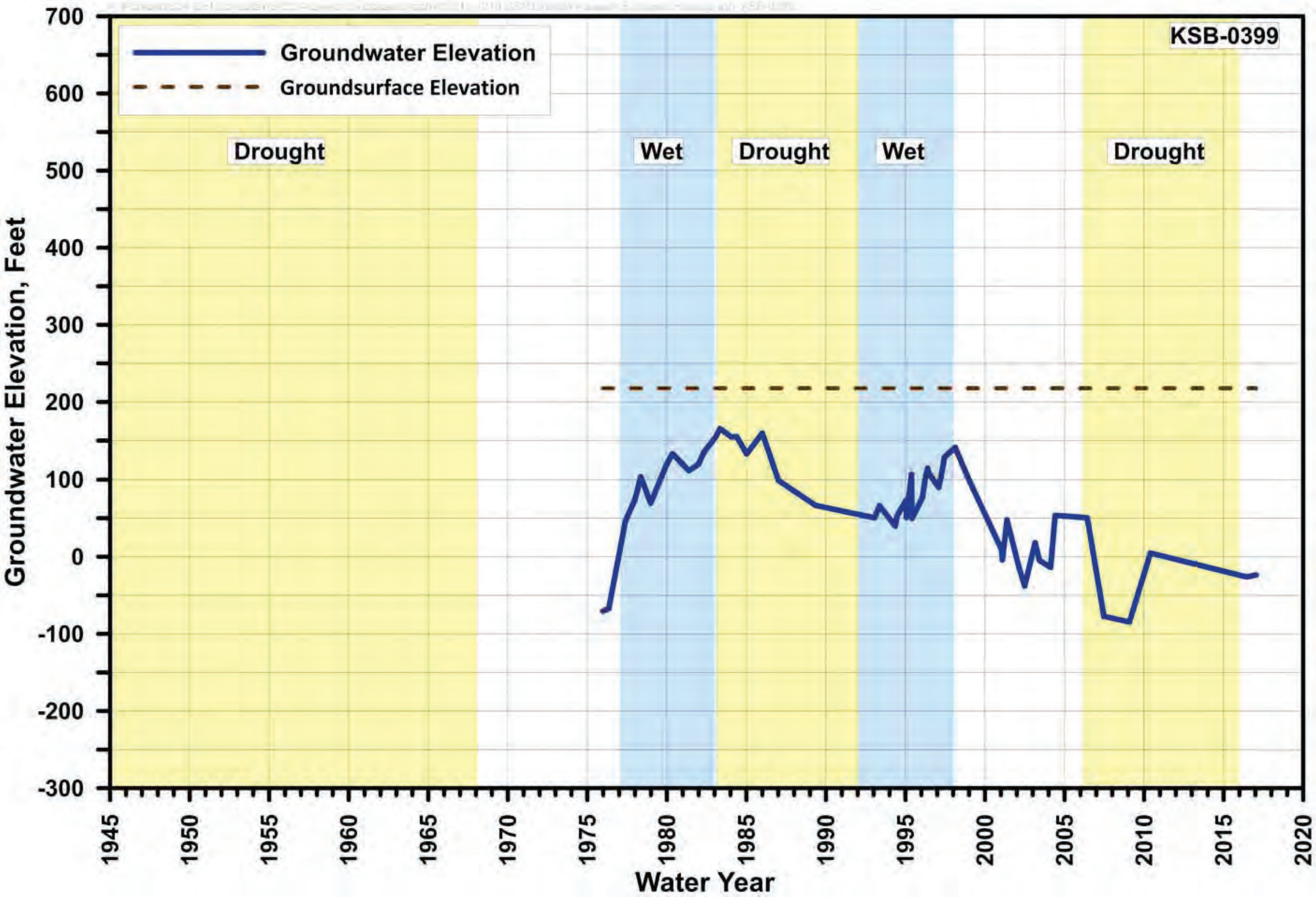
| KSB ID | State Well # | CASGEM SITE_CODE | Common Name Well | Water Level Measurement Organization | Water Supply Service Area | GSA | Count of Water Level Measurements | Earliest Measurement Date on Record | Latest Measurement Date on Record | Known Construction? (Y/N) | Dedicated Monitoring Well (Y/N) | Dual Completion Well (Y/N) | Total Depth (Feet) | Top of Screen (Feet) | Bottom of Screen (Feet) | Within the Corcoran Clay? (Y/N) | Reported Ground Surface Elevation (Feet) | Aquifer Screened | LATITUDE | LONGITUDE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KSB-0388 | 19S21E35D001M | 362383N1196704W001 | | Department of Water Resources | Lakeside Irrigation W.D. | Greater Kaweah GSA | 80 | Apr-59 | Oct-17 | N | N | N | | | | y | 227 | UNK | 36.2383 | -119.67 |
| KSB-0399 | 20S21E11D001M | 362106N1196685W001 | | Bureau of Reclamation | | | 52 | Sep-76 | Oct-17 | N | N | N | | | | y | 217 | UNK | 36.2106 | -119.669 |
| KSB-0446 | 20S21E24F901M | | | Kaweah Delta Water Conservation District | Melga W.D. | | 23 | Feb-06 | Oct-17 | Y | Y | Y | 186 | 170 | 186 | y | 213 | UAS | 36.176661 | -119.648219 |
| KSB-0459 | 20S21E24F001M | 361753N1196460W001 | | Kaweah Delta Water Conservation District | Melga W.D. | | 42 | Feb-06 | Mar-18 | Y | Y | Y | 700 | 650 | 690 | y | 213 | LAS | 36.1753 | -119.646 |
| KSB-0519 | 19S22E30D001M | 362547N1196341W001 | | Kaweah Delta Water Conservation District | Lakeside Irrigation W.D. | Greater Kaweah GSA | 119 | Feb-63 | Oct-17 | N | N | N | | | | y | 230 | UNK | 36.2547 | -119.634 |
| KSB-0531 | 19S22E31B002M | 362400N1196274W001 | | Bureau of Reclamation | Lakeside Irrigation W.D. | Greater Kaweah GSA | 200 | Feb-63 | Oct-13 | Y | N | N | | 247 | 271 | y | 226 | UAS | 36.24 | -119.627 |
| KSB-0532 | 21S22E07J001M | 361158N1196258W001 | | Kaweah Delta Water Conservation District | Corcoran I.D. | | 40 | Feb-07 | Oct-17 | Y | Y | Y | 775 | 735 | 775 | y | 204 | LAS | 36.1158 | -119.626 |
| KSB-0533 | 21S22E07J901M | | | Kaweah Delta Water Conservation District | Corcoran I.D. | | 20 | Oct-07 | Oct-17 | Y | Y | Y | 314 | 274 | 314 | y | 204 | UAS | 36.115798 | -119.625828 |
| KSB-0550 | 20S22E07A003M | 362106N1196216W001 | | Kings River Conservation District | Lakeside Irrigation W.D. | Greater Kaweah GSA | 120 | Feb-63 | Mar-18 | Y | N | N | 421 | 181 | 421 | y | 220 | UAS | 36.2106 | -119.622 |
| KSB-0560 | 19S22E08D002M | 362981N1196189W001 | | Kaweah Delta Water Conservation District | Lakeside Irrigation W.D. | | 40 | Feb-07 | Mar-18 | Y | Y | Y | 700 | 625 | 665 | y | 243 | LAS | 36.2981 | -119.619 |
| KSB-0561 | 19S22E08D902M | | | Kaweah Delta Water Conservation District | Lakeside Irrigation W.D. | | 21 | Oct-07 | Oct-17 | Y | Y | Y | 355 | 315 | 355 | y | 244 | UAS | 36.298133 | -119.618932 |
| KSB-0616 | 19S22E28D001M | 362539N1196004W001 | | Bureau of Reclamation | Lakeside Irrigation W.D. | Greater Kaweah GSA | 198 | Feb-63 | Mar-18 | Y | N | N | 362 | 190 | 360 | y | 232 | UAS | 36.2539 | -119.6 |
| KSB-0636 | 19S22E21C001M | 362669N1195924W001 | | Kings County Water District | Lakeside Irrigation W.D. | Greater Kaweah GSA | 117 | Feb-63 | Oct-17 | N | N | N | | | | y | 237 | UNK | 36.2669 | -119.592 |
| KSB-0718 | 20S22E03B001M | 362256N1195702W001 | | Department of Water Resources | Lakeside Irrigation W.D. | Greater Kaweah GSA | 104 | Feb-66 | Oct-17 | N | N | N | | | | y | 232 | UNK | 36.2256 | -119.57 |
| KSB-0721 | 18S22E34R001M | 363142N1195685W001 | | Bureau of Reclamation | Lakeside Irrigation W.D. | | 81 | Jan-72 | Mar-18 | N | N | N | | | | y | 245 | UNK | 36.3142 | -119.569 |
| KSB-0742 | 19S22E10R002M | 362864N1195654W002 | | Bureau of Reclamation | Lakeside Irrigation W.D. | | 85 | Oct-61 | Oct-17 | N | N | N | | | | y | 244 | UNK | 36.2864 | -119.565 |
| KSB-0791 | 20S22E14C001M | 361928N1195563W001 | | Kaweah Delta Water Conservation District | Corcoran I.D. | | 23 | Oct-88 | Oct-13 | Y | N | N | | 323 | 1600 | y | 225 | UAS | 36.1928 | -119.556 |
| KSB-0818 | 18S22E24D001M | 363572N1195468W001 | | Department of Water Resources | Kings County W.D. | | 138 | Oct-49 | Oct-17 | Y | N | N | | 240 | 340 | y | 258 | UAS | 36.3572 | -119.547 |
| KSB-0856 | 19S22E24B001M | 362694N1195393W001 | | Kaweah Delta Water Conservation District | Kings County W.D. | Greater Kaweah GSA | 77 | Sep-69 | Mar-18 | N | N | N | 160 | | | y | 244 | UAS | 36.2694 | -119.539 |
| KSB-0889 | 20S22E24R001M | 361672N1195299W001 | | Bureau of Reclamation | Corcoran I.D. | Greater Kaweah GSA | 37 | Sep-87 | Mar-18 | Y | N | N | 332 | 196 | 204 | y | 227 | UAS | 36.1672 | -119.53 |
| KSB-0890 | 20S22E36A001M | 361497N1195296W001 | | Bureau of Reclamation | Unincorporated | Greater Kaweah GSA | 143 | Oct-75 | Oct-17 | Y | N | N | 210 | 155 | 206 | y | 222 | UAS | 36.1497 | -119.53 |
| KSB-0903 | 18S23E30D901M | | | Kaweah Delta Water Conservation District | Kings County W.D. | Greater Kaweah GSA | 22 | Feb-06 | Oct-17 | Y | Y | Y | 154 | 114 | 154 | y | 255 | UAS | 36.340824 | -119.526639 |
| KSB-0905 | 18S23E30D001M | 363426N1195264W001 | | Kaweah Delta Water Conservation District | Kings County W.D. | Greater Kaweah GSA | 39 | Feb-06 | Mar-18 | Y | Y | Y | 440 | 400 | 440 | y | 255 | LAS | 36.3426 | -119.526 |
| KSB-0922 | 21S23E07J001M | 361156N1195191W001 | | Bureau of Reclamation | Tulare I.D. | Mid-Kaweah GSA | 171 | Aug-58 | Oct-17 | Y | N | N | 428 | 322 | 420 | y | 221 | UAS | 36.1156 | -119.519 |
| KSB-0946 | 19S23E31R001M | 362297N1195121W001 | | Department of Water Resources | Tulare I.D. | Mid-Kaweah GSA | 148 | Oct-45 | Mar-17 | N | N | N | | | | y | 245 | UNK | 36.2297 | -119.512 |
| KSB-1031 | 21S23E21C003M | 360942N1194921W001 | | Department of Water Resources | Unincorporated | Greater Kaweah GSA | 82 | Feb-63 | Oct-17 | N | N | N | | | | y | 219 | UNK | 36.0942 | -119.492 |
| KSB-1032 | 19S23E08J001M | 362903N1194927W001 | | Department of Water Resources | Kings County W.D. | Greater Kaweah GSA | 146 | Oct-49 | Mar-17 | N | N | N | | | | y | 256 | UNK | 36.2903 | -119.493 |
| KSB-1055 | 19S23E21C001M | 362686N1194846W001 | | Kaweah Delta Water Conservation District | Tulare I.D. | Mid-Kaweah GSA | 83 | Feb-64 | Oct-13 | Y | N | N | | 168 | 195 | y | 255 | UAS | 36.2686 | -119.485 |
| KSB-1071 | 20S23E21B001M | 361803N1194813W001 | | Department of Water Resources | Tulare I.D. | Mid-Kaweah GSA | 100 | Oct-60 | Oct-17 | N | N | N | | | | y | 241 | UNK | 36.1803 | -119.481 |
| KSB-1161 | 17S23E34J001M | 364049N1194573W001 | | Kaweah Delta Water Conservation District | Unincorporated | Greater Kaweah GSA | 38 | Apr-07 | Mar-18 | Y | Y | N | 126 | 96 | 126 | y | 275 | UAS | 36.4049 | -119.457 |
| KSB-1168 | 19S23E22H001M | 362653N1194571W001 | | Bureau of Reclamation | Tulare I.D. | Mid-Kaweah GSA | 129 | Oct-52 | Mar-16 | Y | N | N | 331 | 178 | 190 | y | 265 | UAS | 36.2653 | -119.457 |
| KSB-1183 | 21S23E02A001M | 361378N1194513W001 | | Kaweah Delta Water Conservation District | Elk Bayou D.C. | Greater Kaweah GSA | 100 | Sep-63 | Oct-17 | N | N | N | | | | y | 238 | UNK | 36.1378 | -119.451 |
| KSB-1214 | 18S23E02Q001M | 363856N1194443W001 | | Kings County Water District | Unincorporated | Greater Kaweah GSA | 144 | Feb-52 | Mar-18 | N | N | N | | | | y | 278 | UNK | 36.3856 | -119.444 |
| KSB-1222 | 18S23E14A001M | 363683N1194399W001 | | Bureau of Reclamation | Goshen D.C. | Greater Kaweah GSA | 160 | Oct-69 | Oct-14 | Y | N | N | | 115 | 330 | y | 280 | UAS | 36.3683 | -119.44 |
| KSB-1226 | 19S23E35H001M | 362344N1194396W001 | | Tulare Irrigation District | Tulare I.D. | Mid-Kaweah GSA | 142 | Oct-53 | Jan-18 | N | N | N | | | | y | 264 | UNK | 36.2344 | -119.44 |
| KSB-1259 | 19S23E12L001M | 362906N1194304W001 | | Department of Water Resources | Persian D.C. | Greater Kaweah GSA | 144 | Sep-69 | Oct-13 | Y | N | N | | 192 | 600 | y | 275 | UAS | 36.2906 | -119.43 |
| KSB-1359 | 20S24E07G001M | 362042N1194082W001 | | Tulare Irrigation District | Tulare I.D. | Mid-Kaweah GSA | 75 | Feb-55 | Mar-15 | Y | N | N | 456 | 216 | 456 | y | 264 | UAS | 36.2042 | -119.408 |
| KSB-1384 | 19S24E08D002M | 362979N1194028W001 | | Kaweah Delta Water Conservation District | Persian D.C. | Greater Kaweah GSA | 29 | Apr-07 | Mar-18 | Y | Y | N | 121 | 91 | 121 | y | 287 | UAS | 36.2979 | -119.403 |
| KSB-1389 | 19S24E17N001M | | | Tulare Irrigation District | Tulare I.D. | Mid-Kaweah GSA | 115 | Feb-54 | Oct-14 | N | N | N | | | | y | 287 | UNK | 36.27166667 | -119.4016667 |
| KSB-1425 | 21S24E08A001M | 361219N1193946W001 | | Kaweah Delta Water Conservation District | Elk Bayou D.C. | Greater Kaweah GSA | 109 | Oct-51 | Mar-18 | Y | N | N | 520 | 144 | 356 | y | 247 | UAS | 36.1219 | -119.395 |
| KSB-1428 | 21S24E05H002M | 361319N1193938W001 | | Kaweah Delta Water Conservation District | Elk Bayou D.C. | Greater Kaweah GSA | 108 | Jan-70 | Mar-18 | N | N | N | | | | y | 250 | UNK | 36.1319 | -119.394 |
| KSB-1431 | 20S24E17P001M | 361819N1193935W001 | | Department of Water Resources | Tulare I.D. | Mid-Kaweah GSA | 128 | Feb-56 | Oct-17 | Y | N | N | 229 | 170 | 210 | y | 257 | UAS | 36.1819 | -119.394 |
| KSB-1447 | | | 075-01 | | Unincorporated | Mid-Kaweah GSA | 120 | Sep-93 | Dec-10 | N | N | N | | | | y | | UNK | 36.34244882 | -119.3853457 |
| KSB-1506 | 20S24E04K01M | | Well 26 | | Unincorporated | Mid-Kaweah GSA | 114 | Mar-92 | Feb-18 | Y | N | N | 720 | 300 | 720 | y | 280 | UAS | 36.21798677 | -119.371617 |
| KSB-1526 | 18S24E22E001M | | | Kaweah Delta Water Conservation District | St. Johns W.D. | Mid-Kaweah GSA | 9 | Mar-12 | Oct-17 | N | N | N | | | | y | 307 | UNK | 36.34930676 | -119.3671998 |
| KSB-1532 | 19S24E28H001M | 362503N1193677W001 | | Department of Water Resources | Tulare I.D. | Mid-Kaweah GSA | 127 | Oct-54 | Oct-17 | N | N | N | | | | y | 292 | UNK | 36.2503 | -119.368 |
| KSB-1535 | 21S24E03L001M | 361303N1193665W001 | | Bureau of Reclamation | Elk Bayou D.C. | Greater Kaweah GSA | 126 | Feb-53 | Oct-17 | Y | N | N | 325 | 200 | 317 | y | 257 | UAS | 36.1303 | -119.367 |
| KSB-1538 | 20S24E16H001M | 361892N1193667W001 | | Department of Water Resources | Tulare I.D. | Mid-Kaweah GSA | 182 | Oct-53 | Jan-18 | Y | N | N | | 157 | 357 | y | 265 | UAS | 36.1892 | -119.367 |
| KSB-1580 | 17S24E34B001M | 364125N1193588W001 | | Kaweah Delta Water Conservation District | Unincorporated | Greater Kaweah GSA | 208 | Sep-30 | Mar-14 | N | N | N | | | | n | 298 | SAS | 36.4125 | -119.359 |
| KSB-1585 | 19S24E10G001M | 362911N1193579W001 | | Department of Water Resources | Tulare Irrigation Company | Greater Kaweah GSA | 115 | Oct-56 | Oct-17 | N | N | N | | | | y | 304 | UNK | 36.2911 | -119.358 |
| KSB-1613 | 19S24E15R001M | | | Kaweah Delta Water Conservation District | Tulare I.D. | Mid-Kaweah GSA | 7 | Mar-14 | Mar-17 | N | N | N | | | | y | 306 | UNK | 36.26949556 | -119.3497664 |
| KSB-1628 | 19S24E35E01M | | Well 27 | | Tulare I.D. | Mid-Kaweah GSA | 104 | Jul-93 | Feb-18 | Y | N | N | 720 | 320 | 720 | y | 293 | UAS | 36.23653948 | -119.345132 |
| KSB-1634 | 19S24E23D001M | 362689N1193445W001 | | Department of Water Resources | Tulare I.D. | Mid-Kaweah GSA | 139 | Oct-36 | Jan-18 | N | N | N | | | | y | 307 | UNK | 36.2689 | -119.345 |
| KSB-1689 | 18S24E13N001M | 363601N1193320W001 | | Kaweah Delta Water Conservation District | Modoc D.C. | Mid-Kaweah GSA | 34 | May-08 | Mar-18 | Y | Y | N | 110 | 70 | 110 | n | 321 | SAS | 36.3601 | -119.332 |
| KSB-1690 | 18S24E25D001M | 363391N1193316W001 | | Kaweah Delta Water Conservation District | Modoc D.C. | Mid-Kaweah GSA | 32 | May-08 | Mar-18 | Y | Y | N | 123 | 83 | 123 | y | 317 | UAS | 36.3391 | -119.332 |
| KSB-1695 | 20S24E11J02M | | Well 11 | | Unincorporated | Mid-Kaweah GSA | 121 | Mar-92 | Feb-18 | Y | N | N | 774 | 348 | 756 | y | 288 | LAS | 36.20362572 | -119.3315452 |
| KSB-1696 | | | 025-01 | | Unincorporated | Mid-Kaweah GSA | 393 | Jan-71 | Apr-18 | N | N | N | | | | y | | UNK | 36.32262819 | -119.3314731 |
| KSB-1770 | 20S24E01H02M | | Well 15 | | Unincorporated | Mid-Kaweah GSA | 115 | Mar-92 | Feb-18 | Y | N | N | 715 | 300 | 700 | y | 112 | UAS | 36.22191281 | -119.3154621 |
| KSB-1775 | 17S24E36H003M | 364106N1193145W001 | | Kaweah Delta Water Conservation District | Uphill D.C. | Greater Kaweah GSA | 128 | Oct-61 | Oct-17 | N | N | N | | | | n | 314 | SAS | 36.4106 | -119.315 |
| KSB-1783 | 20S24E24H001M | 361756N1193140W001 | | Bureau of Reclamation | Farmers D.C. | Greater Kaweah GSA | 160 | Feb-69 | Oct-16 | Y | N | N | 355 | 178 | 182 | y | 281 | UAS | 36.1756 | -119.314 |
| KSB-1809 | 18S25E06P001M | | | Kaweah Delta Water Conservation District | Unincorporated | Greater Kaweah GSA | 4 | Mar-16 | Oct-17 | N | N | N | | | | n | 323 | SAS | 36.386016 | -119.308785 |
| KSB-1819 | 18S25E30Q001M | 363286N1193054W001 | | Kaweah Delta Water Conservation District | Unincorporated | Mid-Kaweah GSA | 23 | May-08 | Mar-17 | Y | Y | N | 123 | 83 | 123 | n | 326 | SAS | 36.3286 | -119.305 |
| KSB-1830 | 19S25E30C001M | 362539N1193051W001 | | Department of Water Resources | Tulare I.D. | Mid-Kaweah GSA | 167 | Oct-54 | Oct-17 | N | N | N | | | | y | 313 | UNK | 36.2539 | -119.305 |
| KSB-1862 | 19S25E06A001M | 363094N1192974W001 | | Kaweah Delta Water Conservation District | Evans D.C. | Mid-Kaweah GSA | 21 | May-08 | Mar-14 | Y | Y | N | 124 | 84 | 124 | n | 327 | SAS | 36.3094 | -119.297 |
| KSB-1873 | 20S25E06R002M | 362122N1192962W001 | | Kaweah Delta Water Conservation District | Farmers D.C. | Greater Kaweah GSA | 18 | Apr-07 | Oct-13 | Y | Y | N | 125 | 95 | 125 | y | 299 | UAS | 36.2122 | -119.296 |
| KSB-1884 | | | 036-01 | | Unincorporated | Mid-Kaweah GSA | 368 | Jul-71 | Apr-18 | N | N | N | | | | n | | SAS | 36.35027811 | -119.2954358 |
| KSB-1903 | 19S24E36C002M | | Well 36 | | Farmers D.C. | Mid-Kaweah GSA | 27 | Oct-04 | Feb-18 | Y | N | N | 620 | 320 | 620 | y | 302 | UAS | 36.24008 | -119.2882 |

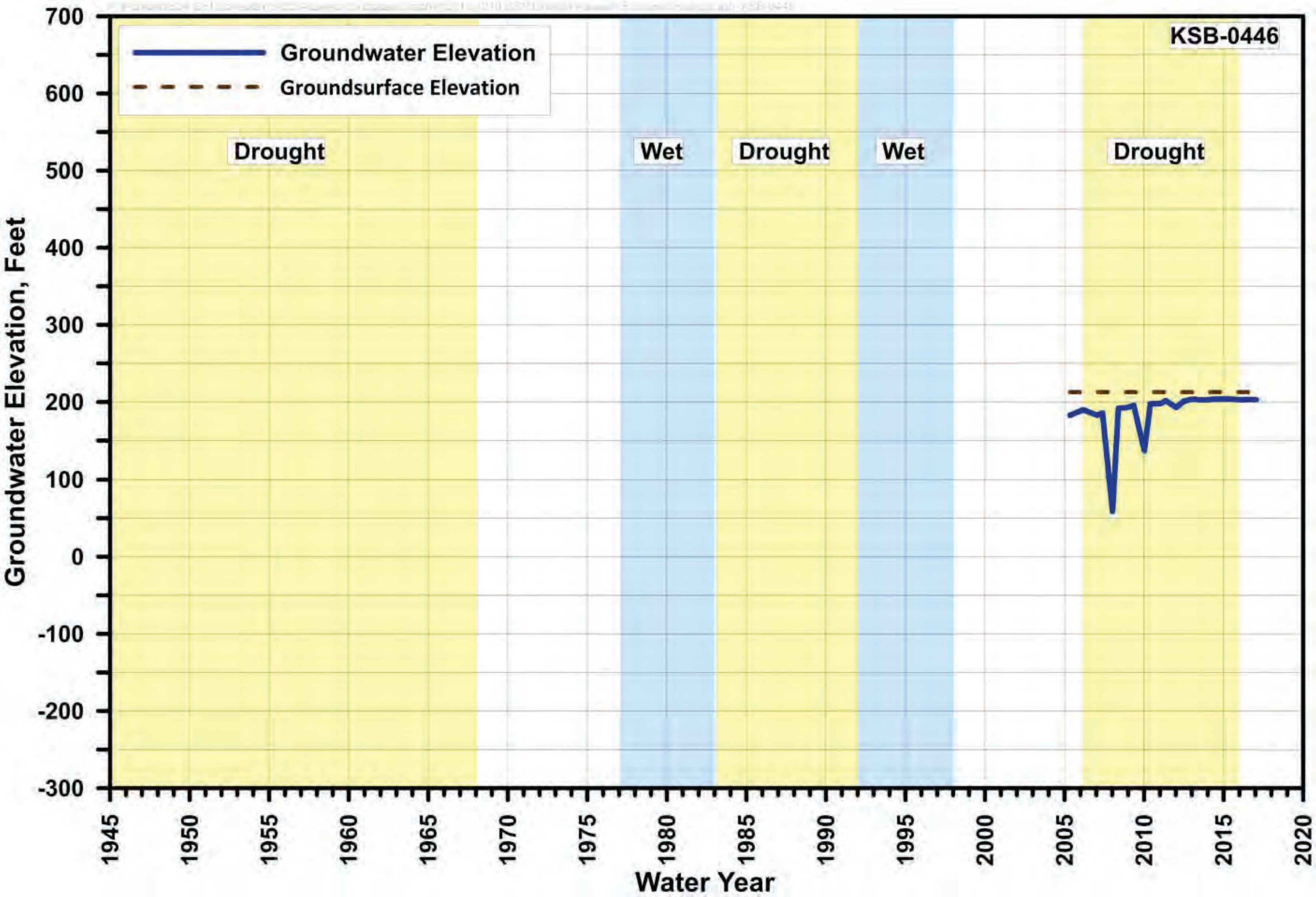
**Table _ - Kaweah Sub-basin Key Well Information**

| KSB ID | State Well # | CASGEM SITE_CODE | Common Name Well | Water Level Measurement Organization | Water Supply Service Area | GSA | Count of Water Level Measurements | Earliest Measurement Date on Record | Latest Measurement Date on Record | Known Construction? (Y/N) | Dedicated Monitoring Well (Y/N) | Dual Completion Well (Y/N) | Total Depth (Feet) | Top of Screen (Feet) | Bottom of Screen (Feet) | Within the Corcoran Clay? (Y/N) | Reported Ground Surface Elevation (Feet) | Aquifer Screened | LATITUDE | LONGITUDE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KSB-1936 | 18S25E05Q001M | 363864N1192834W001 | | Kaweah Delta Water Conservation District | Mathews D.C. | Greater Kaweah GSA | 140 | Feb-64 | Mar-18 | N | N | N | 278 | | | n | 333 | SAS | 36.3864 | -119.283 |
| KSB-1937 | 19S25E32J001M | 362301N1192828W001 | | Kaweah Delta Water Conservation District | Farmers D.C. | Greater Kaweah GSA | 20 | Apr-07 | Oct-13 | Y | Y | N | 115 | 85 | 115 | y | 312 | UAS | 36.2301 | -119.283 |
| KSB-1977 | | | 053-01 | | Unincorporated | Mid-Kaweah GSA | 276 | Mar-80 | Apr-18 | N | N | N | | | | n | | SAS | 36.34705864 | -119.2719874 |
| KSB-2014 | 18S25E28R001M | 363309N1192627W001 | | Kaweah Delta Water Conservation District | Unincorporated | Mid-Kaweah GSA | 21 | Oct-11 | Oct-17 | Y | Y | N | 100 | 60 | 100 | n | 342 | SAS | 36.3309 | -119.263 |
| KSB-2015 | 19S25E16A002M | 362839N1192634W001 | | Kaweah Delta Water Conservation District | Unincorporated | Greater Kaweah GSA | 140 | Oct-50 | Mar-18 | N | N | N | | | | n | 335 | SAS | 36.2839 | -119.263 |
| KSB-2016 | 20S25E16J002M | 361889N1192620W001 | | Kaweah Delta Water Conservation District | Farmers D.C. | Greater Kaweah GSA | 138 | Feb-67 | Oct-17 | N | N | N | | | | y | 299 | UNK | 36.1889 | -119.262 |
| KSB-2017 | 19S25E09H001M | 362947N1192617W001 | | Kaweah Delta Water Conservation District | Unincorporated | Greater Kaweah GSA | 133 | Oct-61 | Oct-17 | N | N | N | | | | n | 338 | SAS | 36.2947 | -119.262 |
| KSB-2021 | 19S25E28H001M | 362481N1192609W001 | | Kaweah Delta Water Conservation District | Farmers D.C. | Greater Kaweah GSA | 135 | Feb-68 | Oct-17 | N | N | N | | | | n | 322 | SAS | 36.2481 | -119.261 |
| KSB-2058 | 18S25E15C001M | 363692N1192520W001 | | Kaweah Delta Water Conservation District | Unincorporated | Greater Kaweah GSA | 175 | Oct-41 | Oct-17 | N | N | N | 90 | | | n | 348 | SAS | 36.3692 | -119.252 |
| KSB-2089 | 19S25E27A001M | 362544N1192431W001 | | Kaweah Delta Water Conservation District | Farmers D.C. | Greater Kaweah GSA | 137 | Feb-68 | Oct-17 | N | N | N | | | | n | 332 | SAS | 36.2544 | -119.243 |
| KSB-2095 | 20S25E03R001M | | | Kaweah Delta Water Conservation District | Unincorporated | Greater Kaweah GSA | 97 | Feb-63 | Oct-17 | N | N | N | | | | n | 308 | SAS | 36.214539 | -119.24285 |
| KSB-2107 | 17S25E35E001M | 364086N1192381W001 | | Ivanhoe Irrigation District | Ivanhoe I.D. | East Kaweah GSA | 169 | Mar-53 | Mar-14 | N | N | N | | | | n | 354 | SAS | 36.4086 | -119.238 |
| KSB-2114 | 20S25E14F004M | 361922N1192337W003 | | Kaweah Delta Water Conservation District | Consolidated Peoples D.C. | Greater Kaweah GSA | 118 | Feb-68 | Oct-17 | N | N | N | | | | n | 306 | SAS | 36.1922 | -119.234 |
| KSB-2139 | 19S25E35B002M | 362394N1192309W001 | | Kaweah Delta Water Conservation District | Unincorporated | Greater Kaweah GSA | 133 | Sep-63 | Oct-16 | N | N | N | | | | n | 327 | SAS | 36.2394 | -119.231 |
| KSB-2147 | 18S25E23J001M | 363478N1192267W001 | | Kaweah Delta Water Conservation District | Fleming D.C. | Greater Kaweah GSA | 136 | Sep-63 | Mar-15 | N | N | N | | | | n | 360 | SAS | 36.3478 | -119.227 |
| KSB-2149 | 18S25E12N001M | 363711N1192250W001 | | Kaweah Delta Water Conservation District | Wutchumna W.C. | Greater Kaweah GSA | 21 | Apr-07 | Mar-13 | Y | Y | N | 82 | 52 | 82 | n | 397 | SAS | 36.3711 | -119.225 |
| KSB-2175 | 17S25E01P001M | 364718N1192151W001 | | Bureau of Reclamation | Unincorporated | East Kaweah GSA | 355 | Dec-31 | Oct-10 | N | N | N | | | | n | 356 | SAS | 36.4718 | -119.215 |
| KSB-2197 | 20S25E12A001M | 362108N1192092W001 | | Kaweah Delta Water Conservation District | Consolidated Peoples D.C. | Greater Kaweah GSA | 130 | Feb-66 | Oct-16 | N | N | N | | | | n | 316 | SAS | 36.2108 | -119.209 |
| KSB-2200 | 19S25E13A002M | 362811N1192076W001 | | Kaweah Delta Water Conservation District | Consolidated Peoples D.C. | Greater Kaweah GSA | 156 | Oct-61 | Mar-18 | N | N | N | | | | n | 350 | SAS | 36.2811 | -119.208 |
| KSB-2203 | 20S25E24R001M | 361681N1192067W001 | | Kaweah Delta Water Conservation District | Unincorporated | Greater Kaweah GSA | 151 | Oct-45 | Oct-17 | N | N | N | 170 | | | n | 315 | SAS | 36.1681 | -119.207 |
| KSB-2291 | 19S26E05C001M | 363117N1191842W001 | | Kaweah Delta Water Conservation District | Unincorporated | Greater Kaweah GSA | 143 | Sep-63 | Oct-17 | N | N | N | | | | n | 367 | SAS | 36.3117 | -119.184 |
| KSB-2297 | 18S26E17L001M | 363606N1191837W001 | | Kaweah Delta Water Conservation District | Unincorporated | Greater Kaweah GSA | 166 | Oct-50 | Mar-18 | N | N | N | | | | n | 385 | SAS | 36.3606 | -119.184 |
| KSB-2322 | 19S26E20A001M | 362683N1191728W001 | | Bureau of Reclamation | Unincorporated | Greater Kaweah GSA | 195 | Nov-48 | Oct-17 | N | N | N | | | | n | 353 | SAS | 36.2683 | -119.173 |
| KSB-2333 | 20S26E08H001M | 362069N1191723W001 | | Lindmore Irrigation District | Lindmore ID | East Kaweah GSA | 102 | Feb-54 | Mar-16 | N | N | N | | | | n | 329 | SAS | 36.2069 | -119.172 |
| KSB-2344 | 20S26E32A001M | 361522N1191706W001 | | Bureau of Reclamation | Lindmore ID | East Kaweah GSA | 270 | Oct-45 | Mar-16 | N | N | N | 340 | | | n | 335 | SAS | 36.1522 | -119.171 |
| KSB-2345 | 21S26E04F001M | 361333N1191703W001 | | Bureau of Reclamation | Lower Tule ID | East Kaweah GSA | 132 | Oct-61 | Mar-16 | N | N | N | | | | n | 343 | SAS | 36.1333 | -119.17 |
| KSB-2354 | 17S26E21E001M | 364388N1191703W001 | | Bureau of Reclamation | Ivanhoe I.D. | East Kaweah GSA | 179 | Jan-61 | Mar-14 | N | N | N | | | | n | 397 | SAS | 36.4388 | -119.17 |
| KSB-2369 | 17S26E04F002M | 364788N1191653W001 | | Stone Corral Irrigation District | Stone Corral I.D. | East Kaweah GSA | 98 | Feb-62 | Mar-16 | N | N | N | | | | n | 406 | SAS | 36.4788 | -119.165 |
| KSB-2405 | 20S26E16R001M | 361853N1191551W001 | | Bureau of Reclamation | Lindmore ID | East Kaweah GSA | 182 | Sep-61 | Mar-16 | Y | N | N | 492 | 210 | 485 | n | 338 | SAS | 36.1853 | -119.155 |
| KSB-2411 | 19S26E16J002M | 362756N1191545W001 | | Bureau of Reclamation | Unincorporated | East Kaweah GSA | 186 | Oct-61 | Mar-18 | N | N | N | 131 | | | n | 366 | SAS | 36.2756 | -119.154 |
| KSB-2466 | 18S26E27B001M | 363403N1191434W001 | | Kaweah Delta Water Conservation District | Unincorporated | Greater Kaweah GSA | 30 | Apr-07 | Mar-18 | Y | Y | N | 29 | 9 | 29 | n | 394 | SAS | 36.3403 | -119.143 |
| KSB-2507 | 19S26E03A001M | 363115N1191358W001 | | Kaweah Delta Water Conservation District | Exeter I.D. | East Kaweah GSA | 28 | Apr-07 | Mar-18 | Y | Y | N | 90 | 60 | 90 | n | 402 | SAS | 36.3115 | -119.136 |
| KSB-2513 | 18S26E02D002M | 363990N1191352W001 | | Kaweah Delta Water Conservation District | Ivanhoe I.D. | East Kaweah GSA | 38 | Apr-07 | Oct-17 | Y | Y | N | 69 | 39 | 69 | n | 422 | SAS | 36.399 | -119.135 |
| KSB-2519 | 18S26E10J001M | 363755N1191353W001 | | Department of Water Resources | Unincorporated | Greater Kaweah GSA | 233 | Oct-51 | Mar-13 | Y | N | N | 140 | 57 | 87 | n | 408 | SAS | 36.3755 | -119.135 |
| KSB-2539 | 18S26E14E001M | 363649N1191318W001 | | Kaweah Delta Water Conservation District | Lindsay-Strathmore I.D. | Greater Kaweah GSA | 9 | Mar-16 | Mar-18 | N | N | N | | | | n | 404 | SAS | 36.3649 | -119.132 |
| KSB-2588 | 17S26E14B001M | 364568N1191217W001 | | Bureau of Reclamation | Unincorporated | East Kaweah GSA | 115 | Nov-48 | Mar-07 | N | N | N | | | | n | 489 | SAS | 36.4568 | -119.122 |
| KSB-2590 | 20S26E11H001M | 362053N1191217W001 | | Kaweah Delta Water Conservation District | Lindmore ID | East Kaweah GSA | 99 | Feb-54 | Mar-13 | N | N | N | | | | n | 359 | SAS | 36.2053 | -119.122 |
| KSB-2593 | 19S26E11R001M | 362853N1191209W001 | | Exeter Irrigation District | Exeter I.D. | East Kaweah GSA | 107 | Oct-50 | Mar-16 | N | N | N | | | | n | 394 | SAS | 36.2853 | -119.121 |
| KSB-2618 | 20S26E35H001M | 361461N1191165W001 | | Lindmore Irrigation District | Lindmore ID | East Kaweah GSA | 148 | Feb-54 | Mar-16 | N | N | N | | | | n | 364 | SAS | 36.1461 | -119.117 |
| KSB-2690 | 17S26E36R001M | 363993N1191028W001 | | Kaweah Delta Water Conservation District | Sweeney Ditch Area | Greater Kaweah GSA | 121 | Feb-68 | Mar-18 | N | N | N | | | | n | 427 | SAS | 36.3993 | -119.103 |
| KSB-2696 | 18S26E24J003M | 363438N1191012W001 | | Bureau of Reclamation | Exeter I.D. | East Kaweah GSA | 141 | Oct-61 | Mar-18 | N | N | N | | | | n | 432 | SAS | 36.3438 | -119.101 |
| KSB-2697 | 19S26E25R001M | 362389N1191009W001 | | Bureau of Reclamation | Lewis Creek WD | East Kaweah GSA | 178 | Jan-70 | Mar-16 | Y | N | N | 290 | 96 | 226 | n | 358 | SAS | 36.2389 | -119.101 |
| KSB-2765 | 18S27E18A001M | | | Kaweah Delta Water Conservation District | Unincorporated | Greater Kaweah GSA | 4 | Mar-16 | Oct-17 | N | N | N | | | | n | 429 | SAS | 36.367412 | -119.084864 |
| KSB-2769 | 20S27E18R001M | 361822N1190831W001 | | Lindmore Irrigation District | Lindmore ID | East Kaweah GSA | 113 | Nov-52 | Mar-16 | N | N | N | | | | n | 412 | SAS | 36.1822 | -119.083 |
| KSB-2773 | 18S27E30H001M | 363338N1190817W001 | | Exeter Irrigation District | Exeter I.D. | East Kaweah GSA | 82 | Feb-62 | Mar-16 | N | N | N | 213 | | | n | 456 | SAS | 36.3338 | -119.082 |
| KSB-2790 | 19S27E29D001M | 362506N1190795W001 | | Lindsay-Strathmore Irrigation District | Lindsay-Strathmore ID | East Kaweah GSA | 99 | Oct-49 | Mar-16 | N | N | N | 200 | | | n | 388 | SAS | 36.2506 | -119.08 |
| KSB-2822 | 18S27E05J001M | 363880N1190651W001 | | Bureau of Reclamation | Unincorporated | Greater Kaweah GSA | 237 | Oct-61 | Mar-18 | Y | N | N | 98 | 24 | 79 | n | 447 | SAS | 36.388 | -119.065 |
| KSB-2823 | 20S27E29R001M | 361533N1190645W001 | | Lindmore Irrigation District | Lindmore ID | East Kaweah GSA | 125 | Oct-61 | Oct-11 | N | N | N | | | | n | 403 | SAS | 36.1533 | -119.065 |
| KSB-2826 | 20S27E08A001M | 362094N1190645W001 | | Lindsay-Strathmore Irrigation District | Lindsay-Strathmore ID | East Kaweah GSA | 130 | Oct-36 | Mar-16 | N | N | N | | | | n | 403 | SAS | 36.2094 | -119.065 |
| KSB-2895 | 20S27E15R001M | 361833N1190278W001 | | Lindsay-Strathmore Irrigation District | Lindsay-Strathmore ID | East Kaweah GSA | 108 | Feb-52 | Mar-16 | N | N | N | 200 | | | n | 468 | SAS | 36.1833 | -119.028 |
| KSB-2927 | 20S27E25N001M | 361564N1190048W001 | | Lindsay-Strathmore Irrigation District | Lindsay-Strathmore ID | East Kaweah GSA | 139 | Feb-52 | Mar-16 | N | N | N | | | | n | 478 | SAS | 36.1564 | -119.005 |

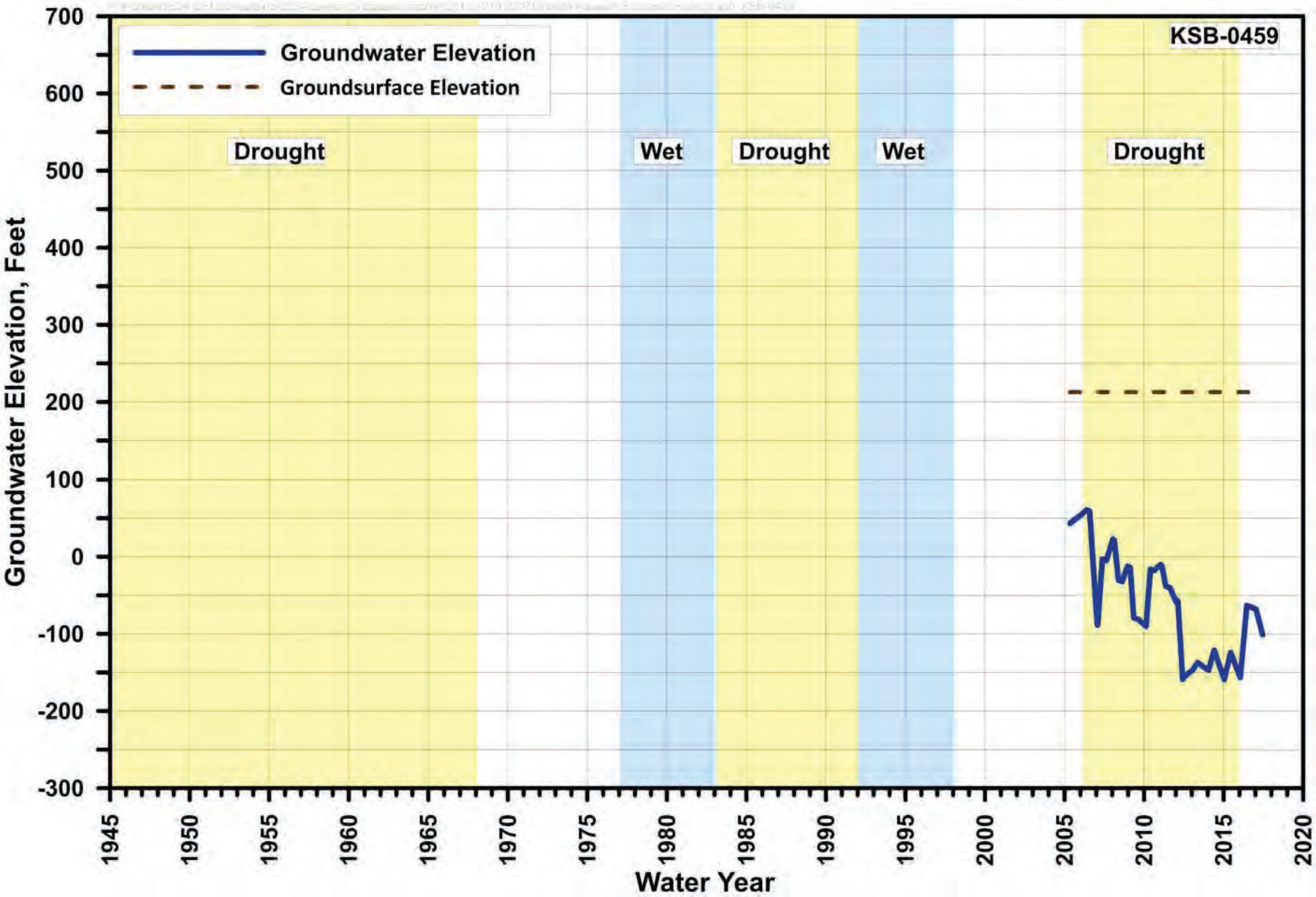


KSB-0388
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


KSB-0399
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020



KSB-0446
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020



KSB-0459
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
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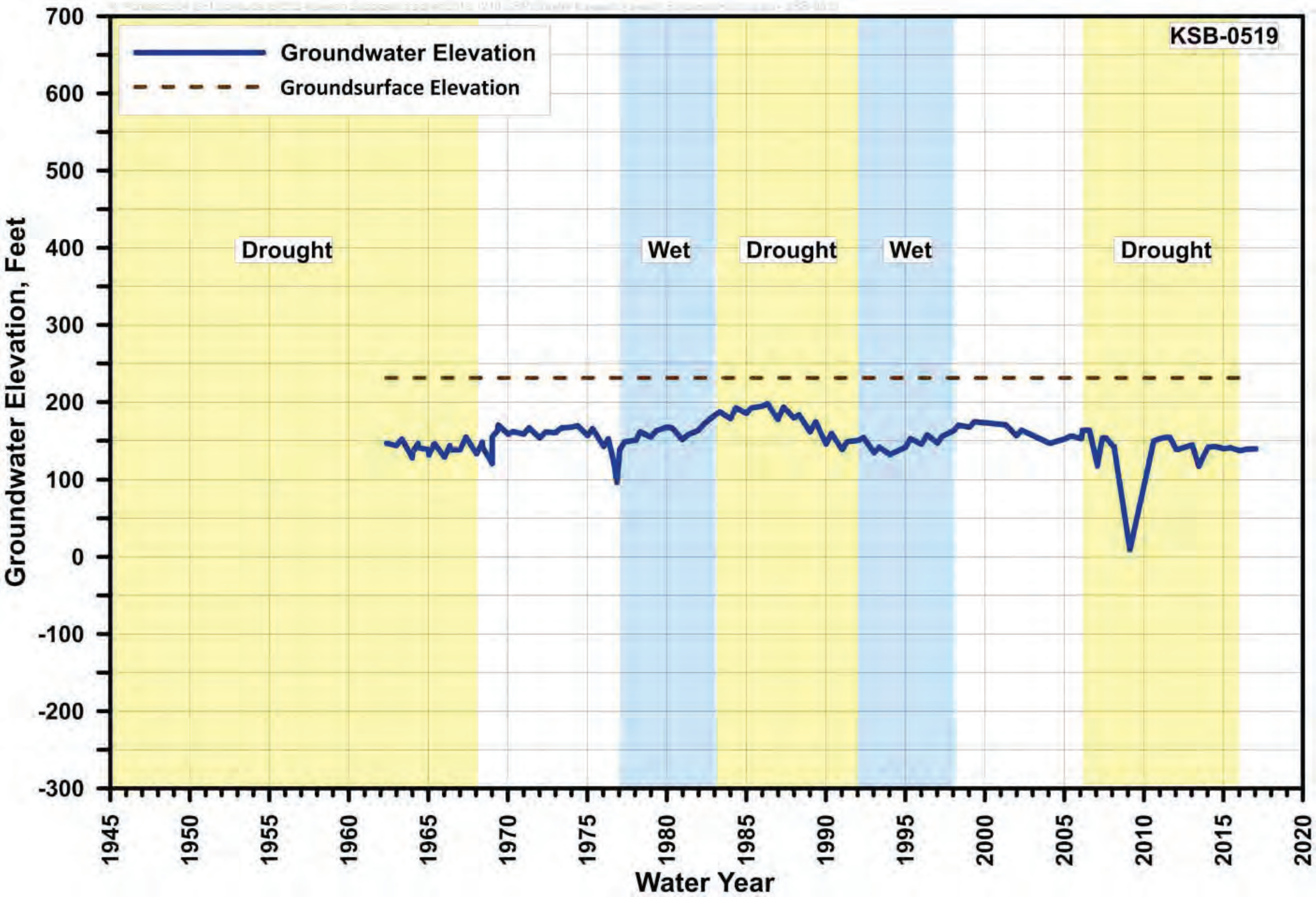
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-0519
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
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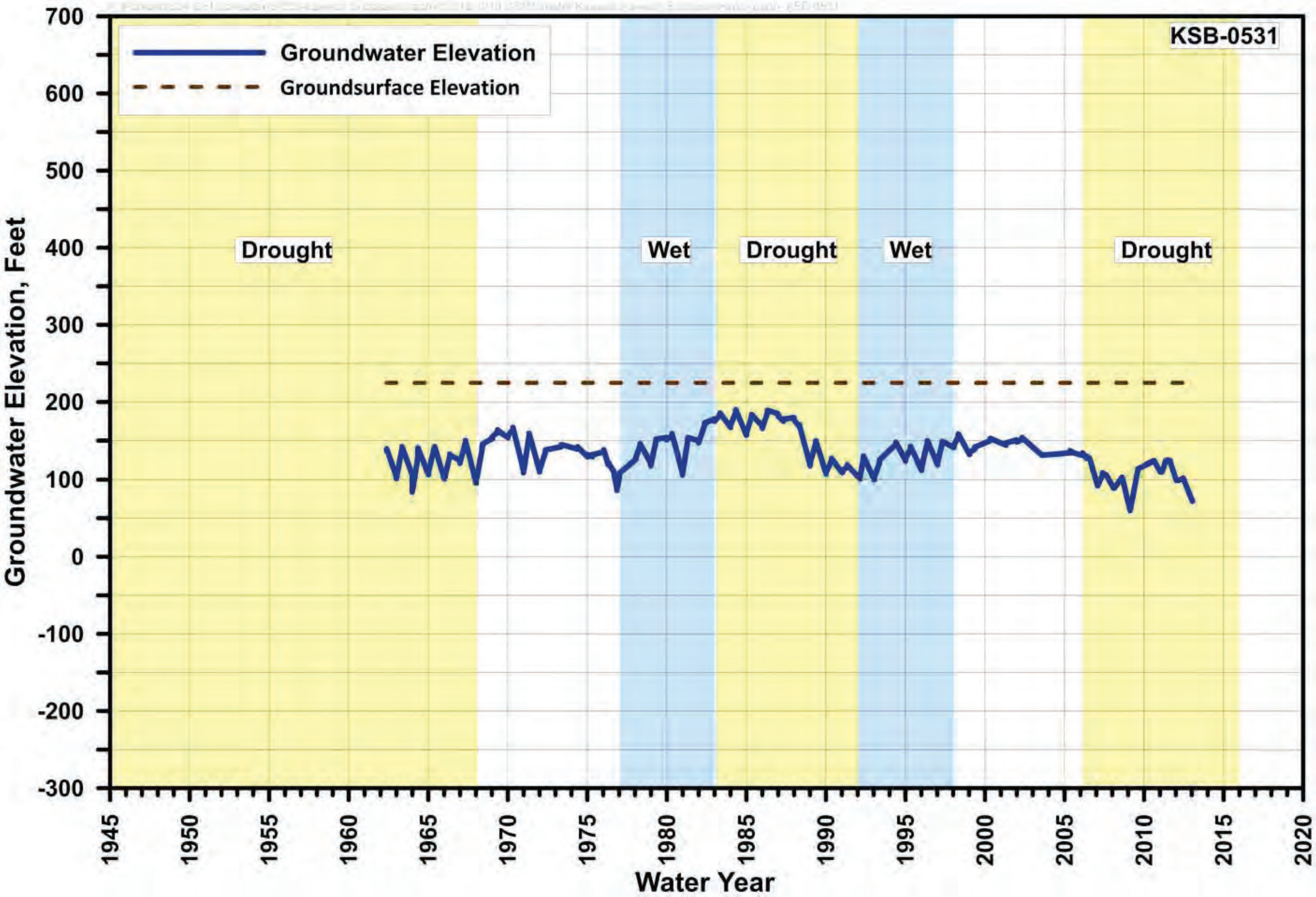
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year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Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
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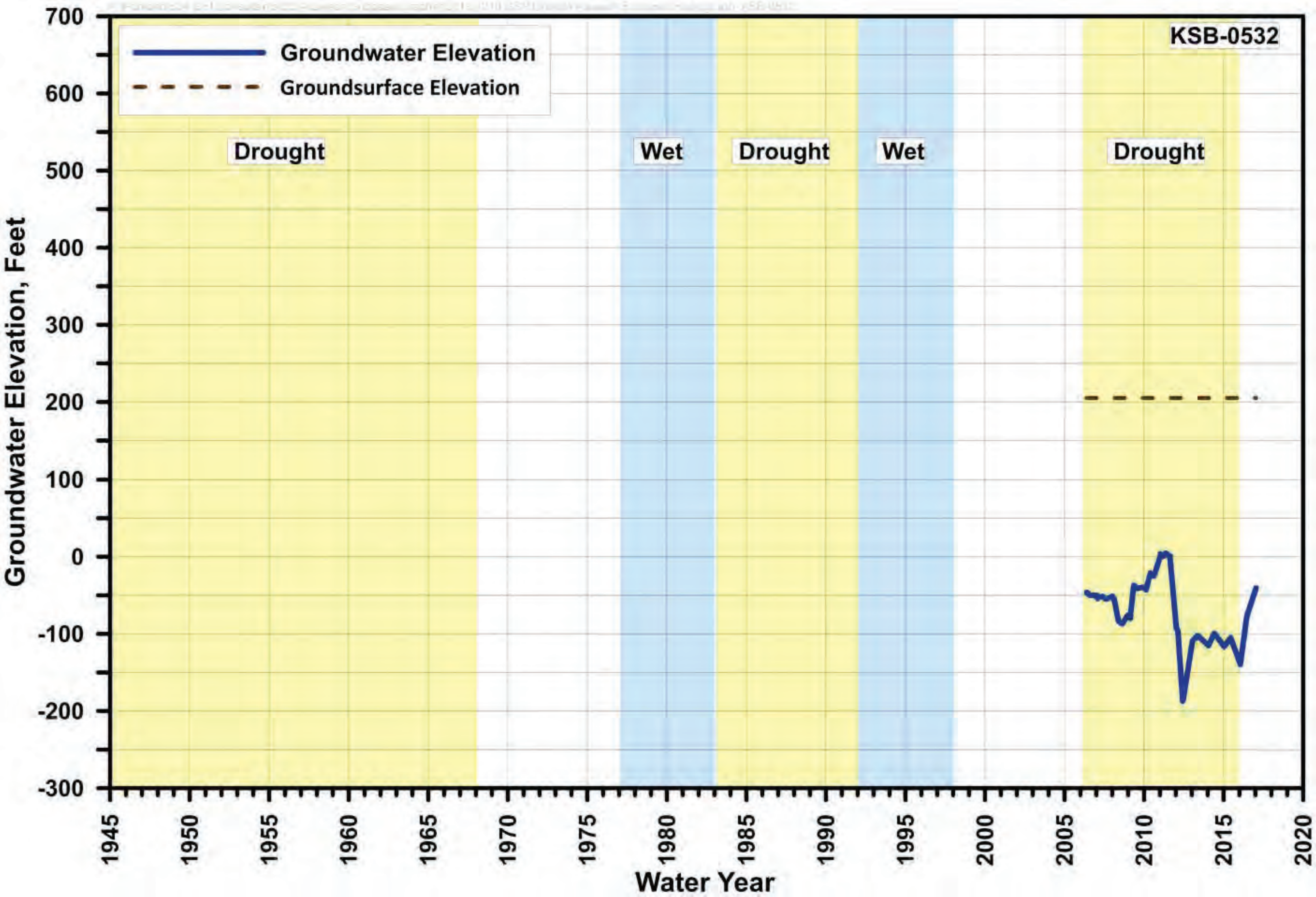
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-0532
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
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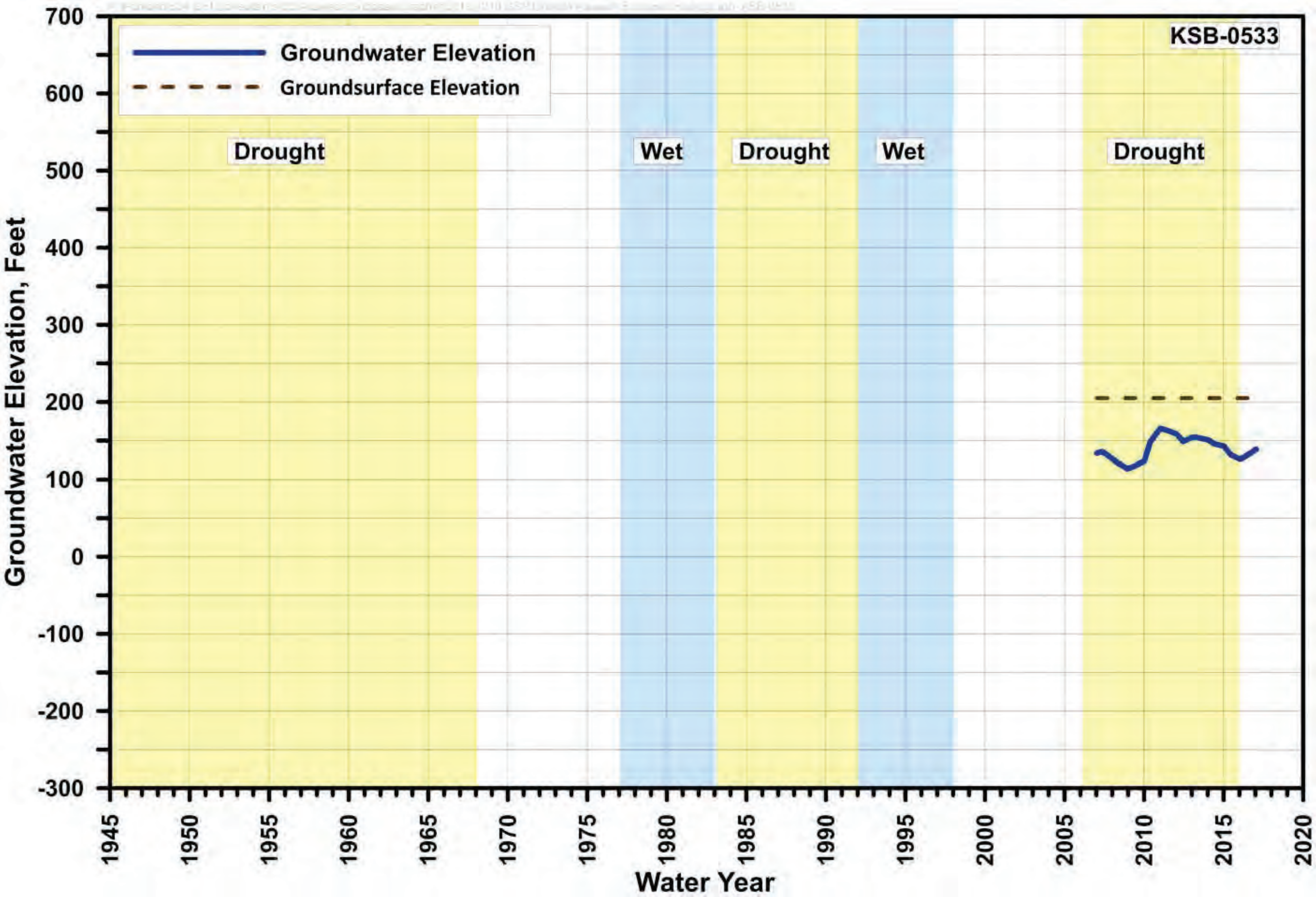
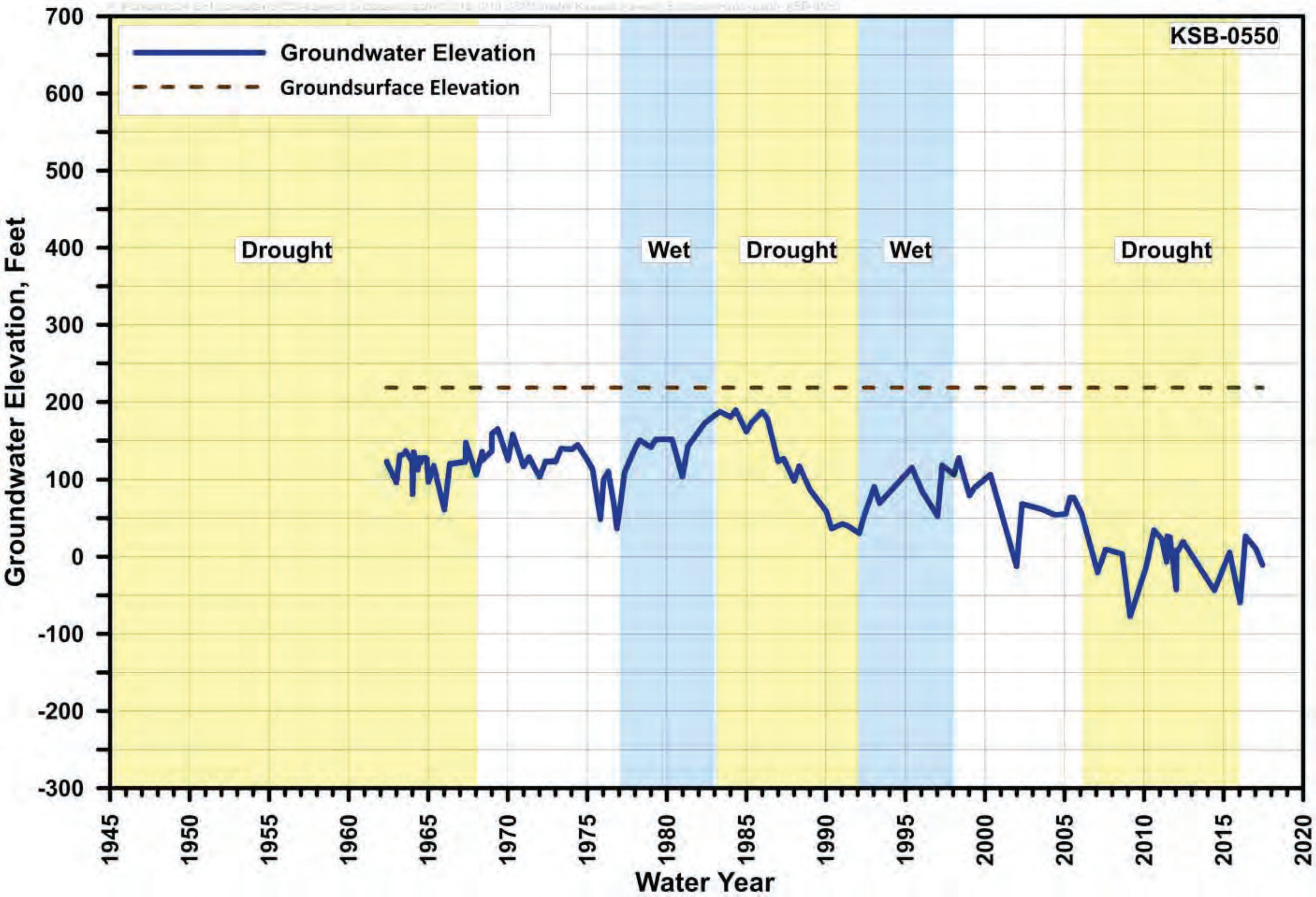
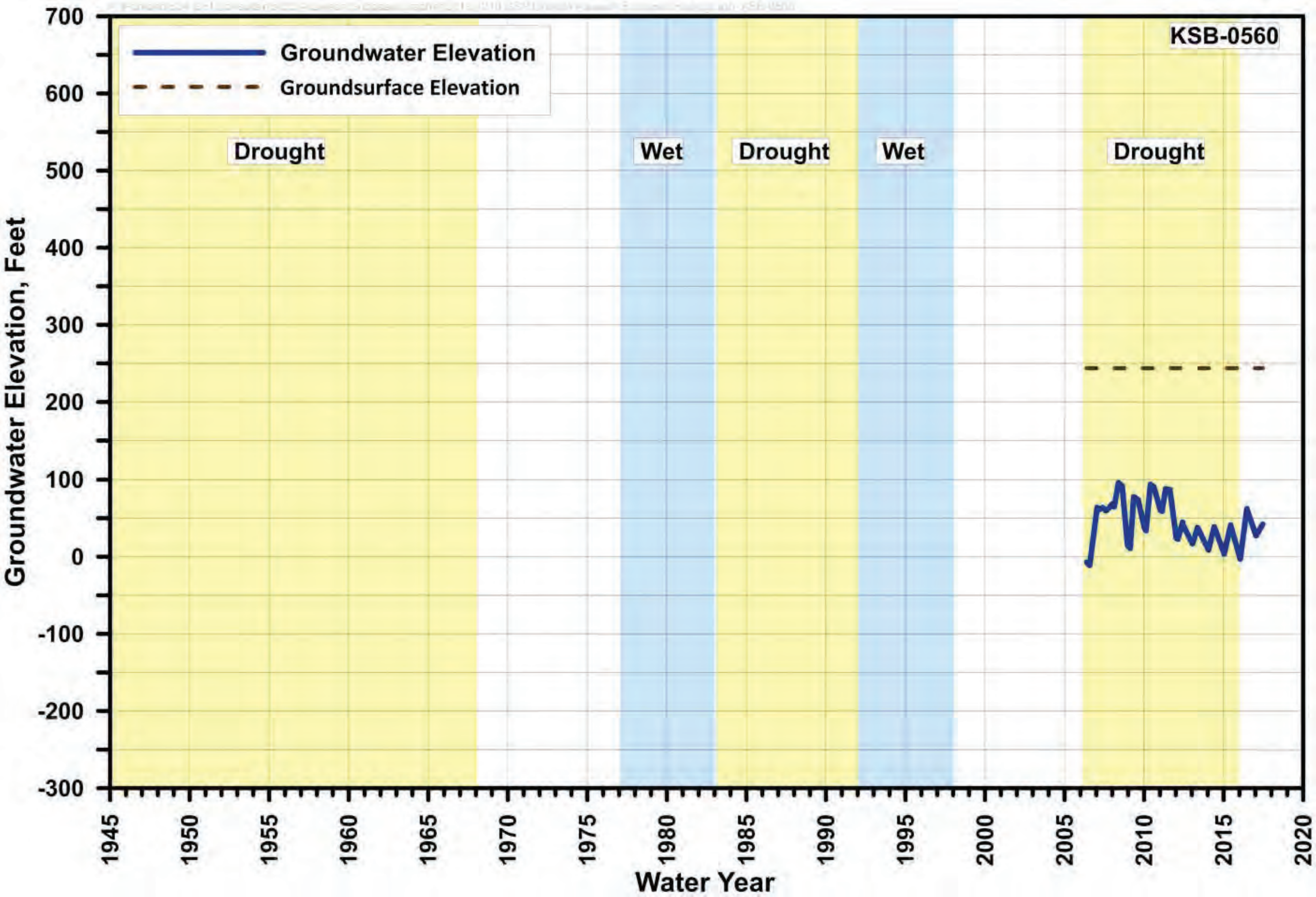
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



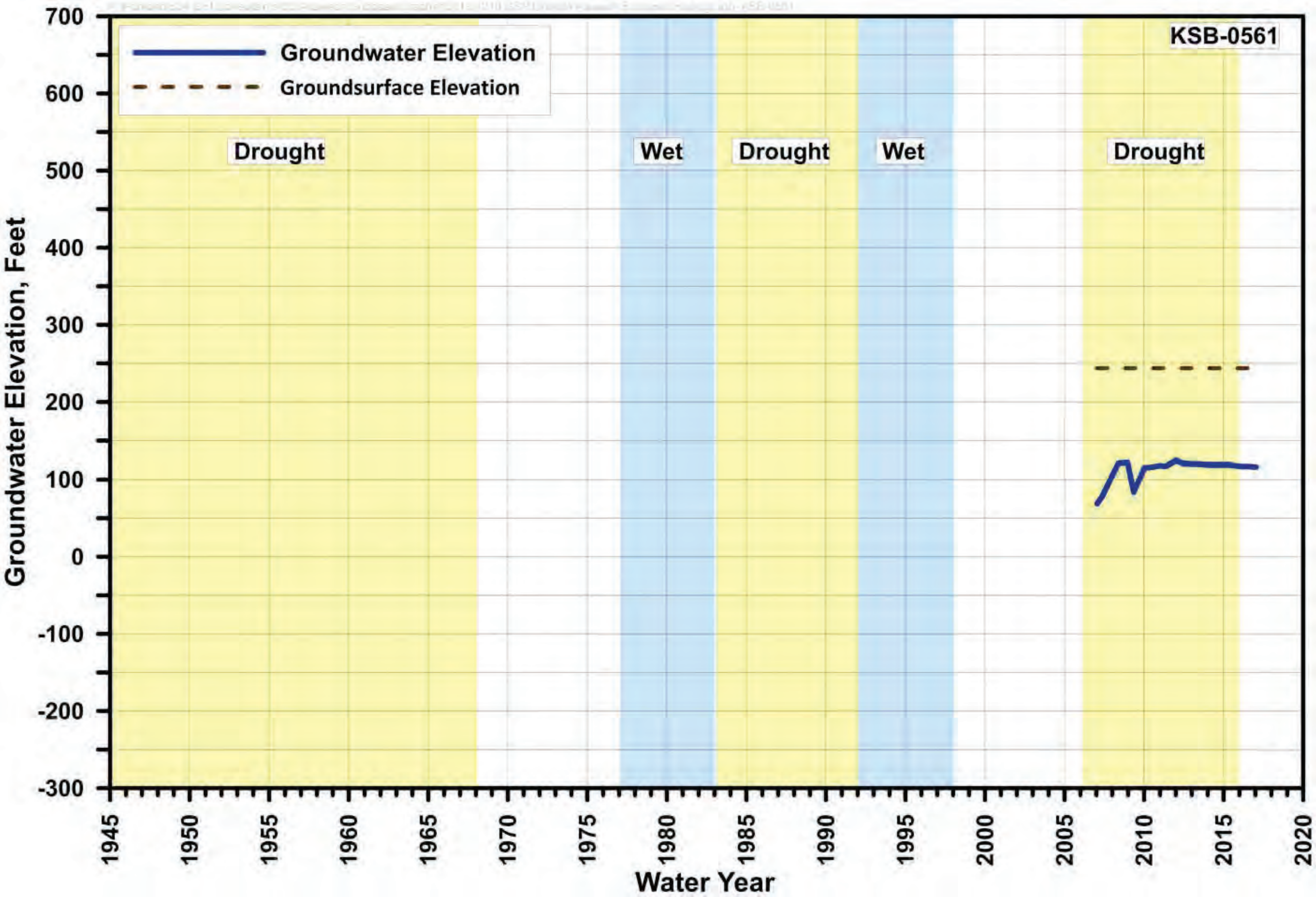
KSB-0533
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year

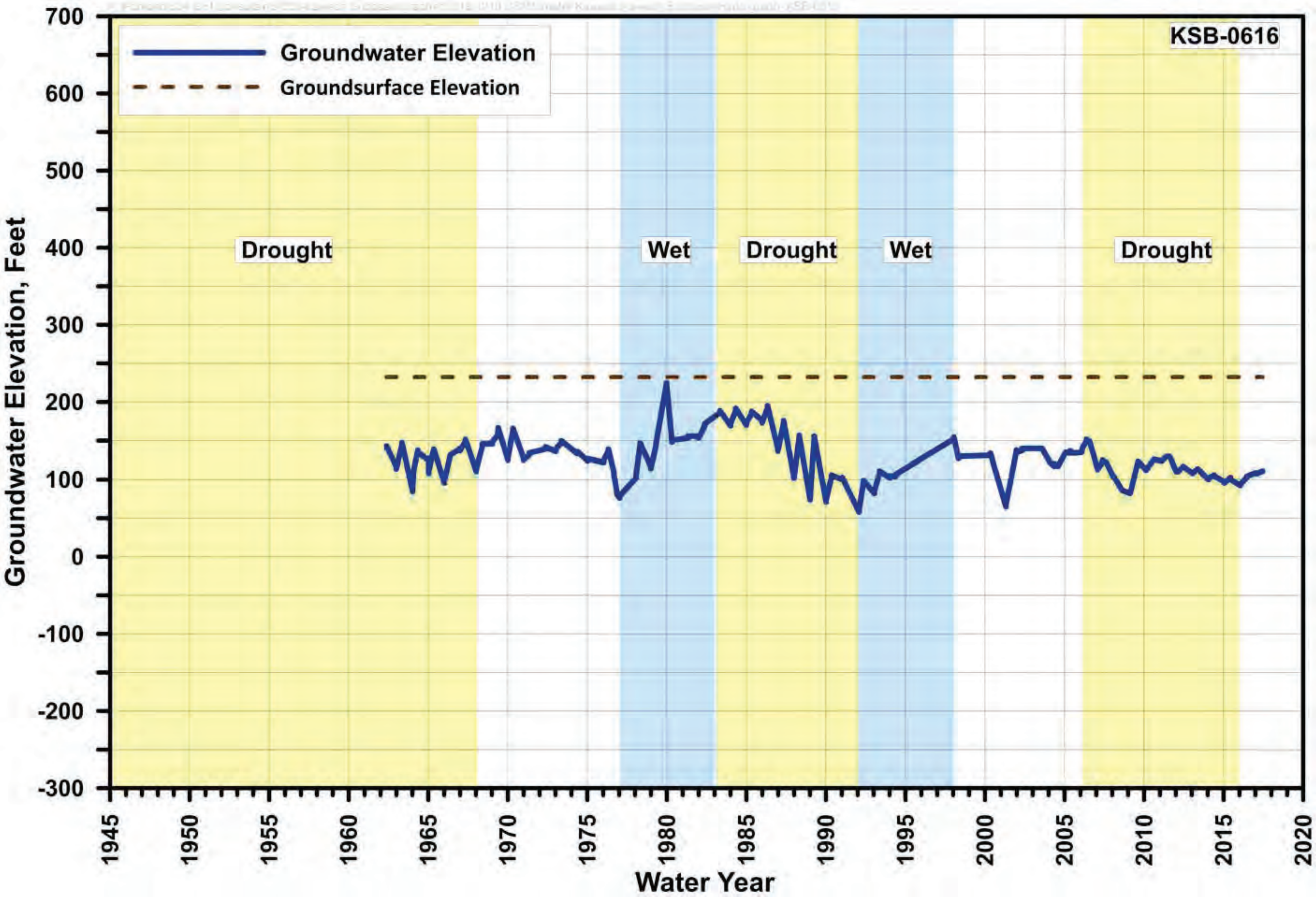


KSB-0550
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year

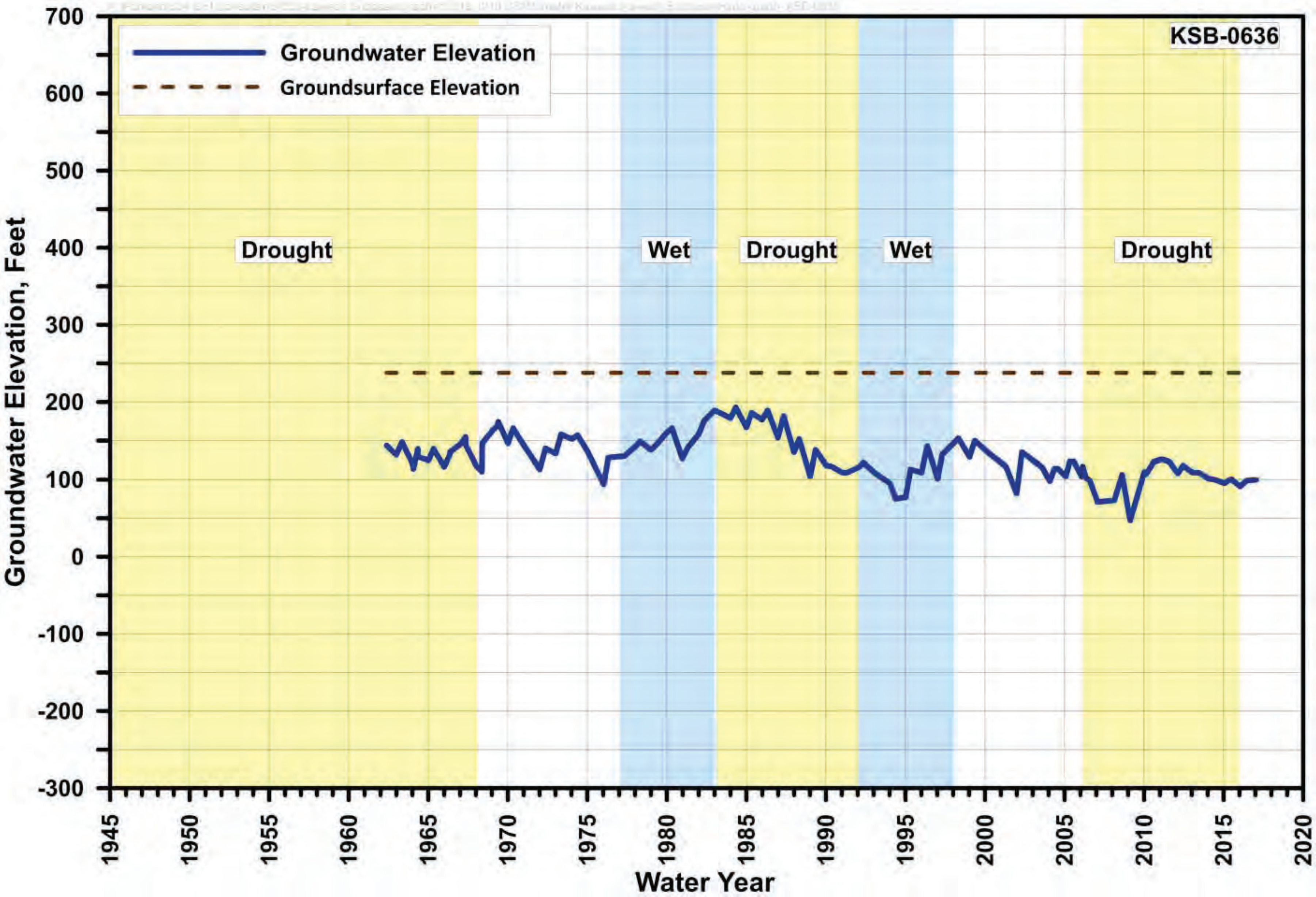


KSB-0560
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year


KSB-0561
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-0616
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


KSB-0636
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
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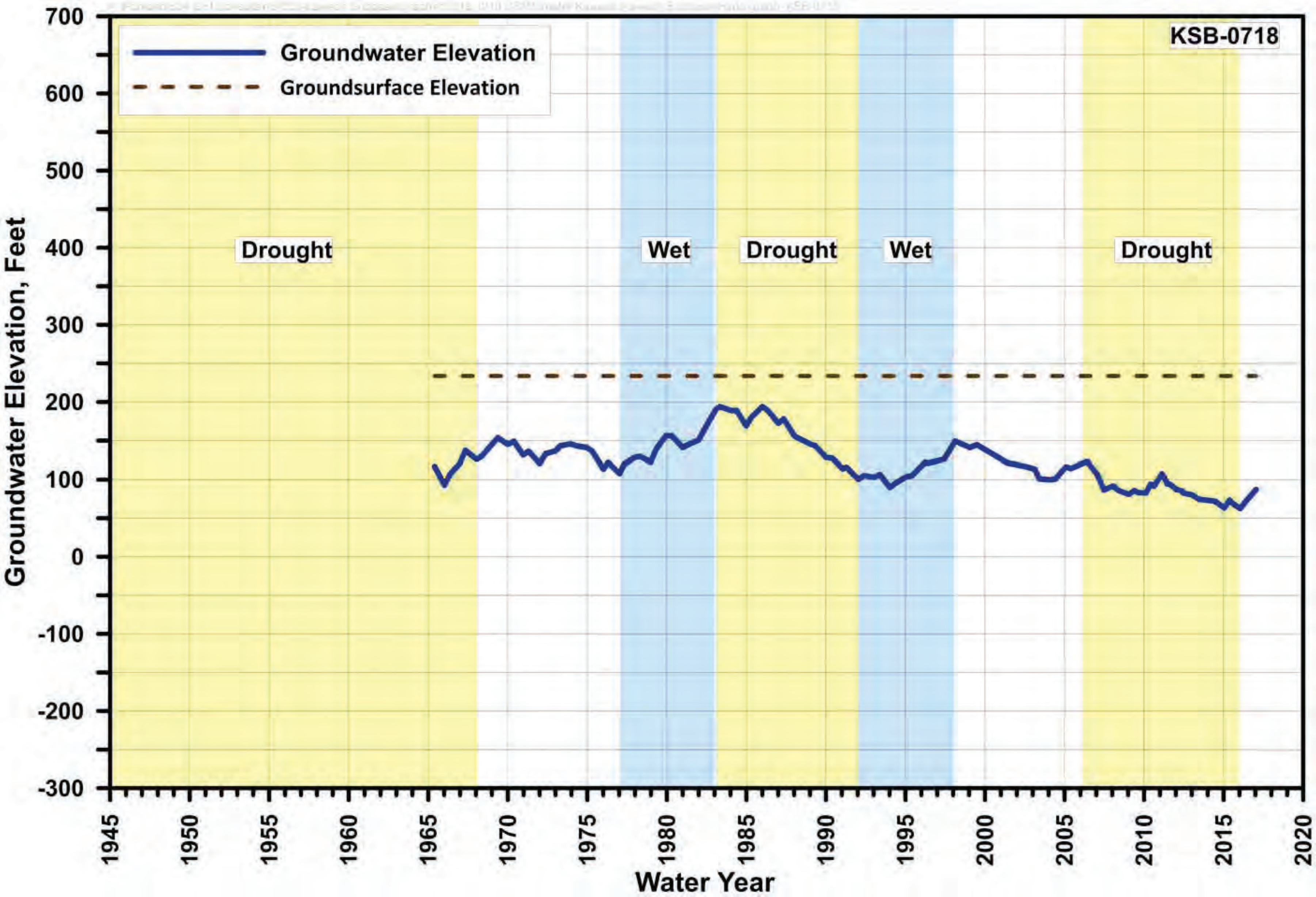
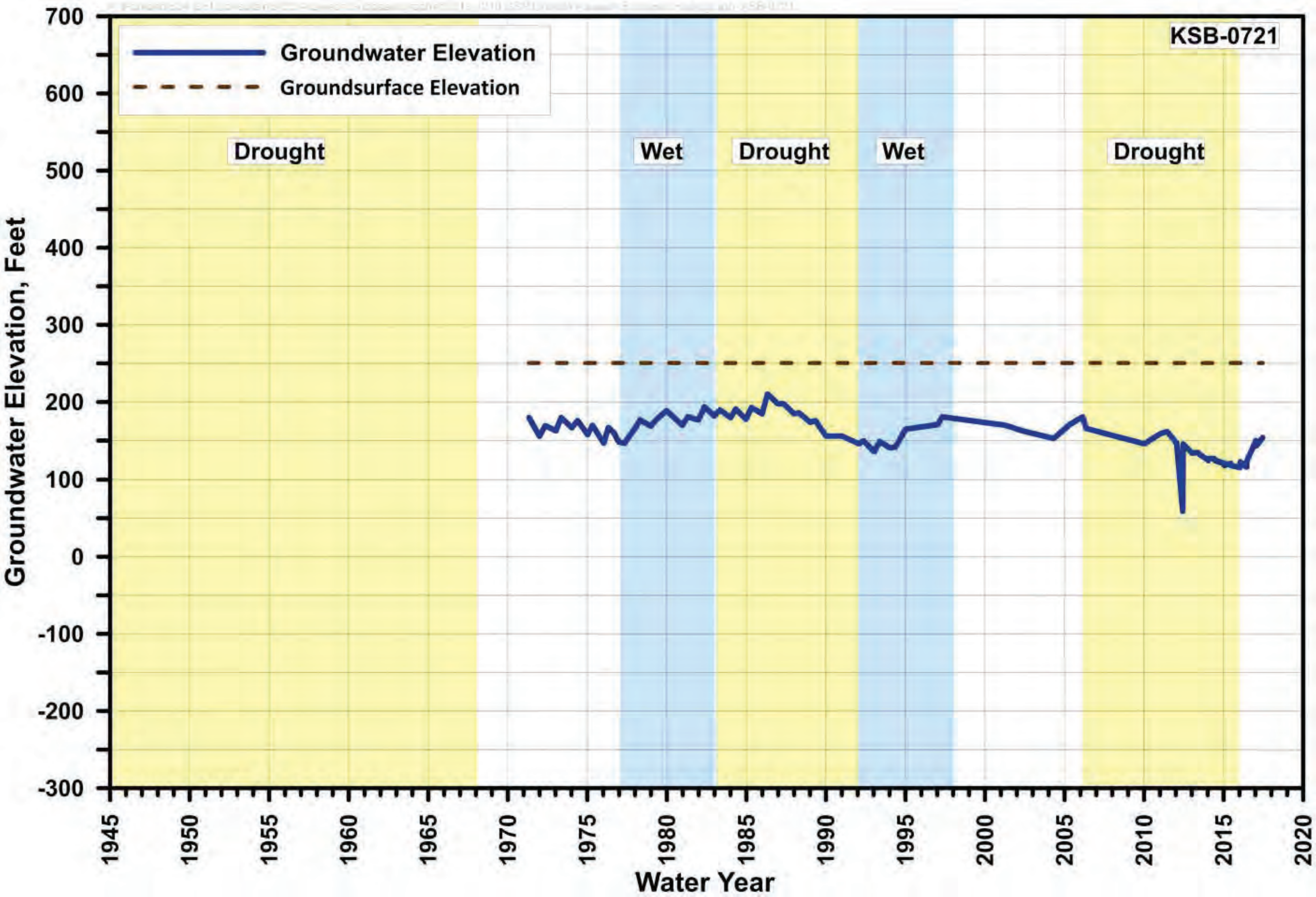
1995
2000
2005
2010
2015
2020
Water Year


KSB-0718
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-0721
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
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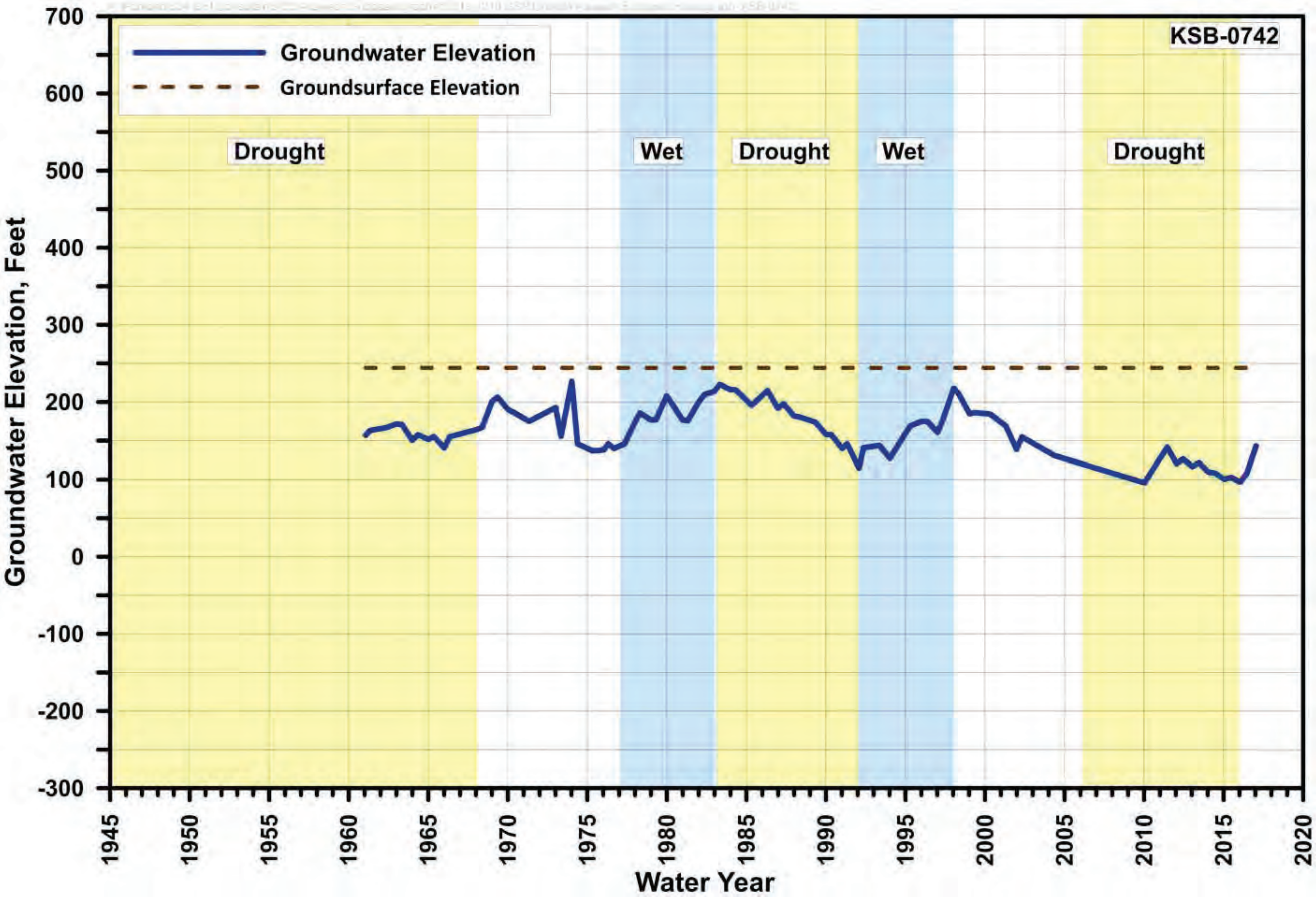
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year


KSB-0742
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
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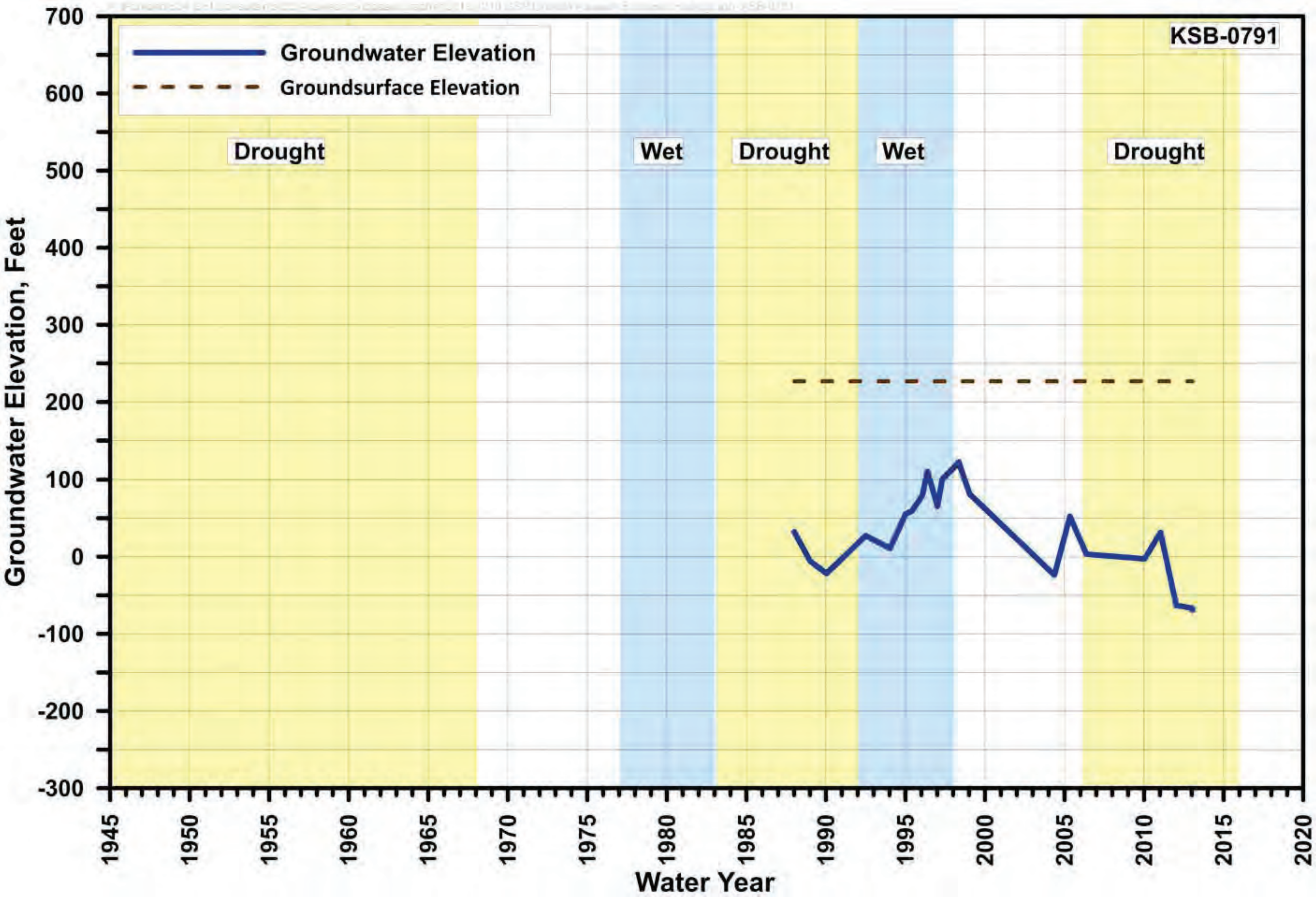
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-0791
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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1960
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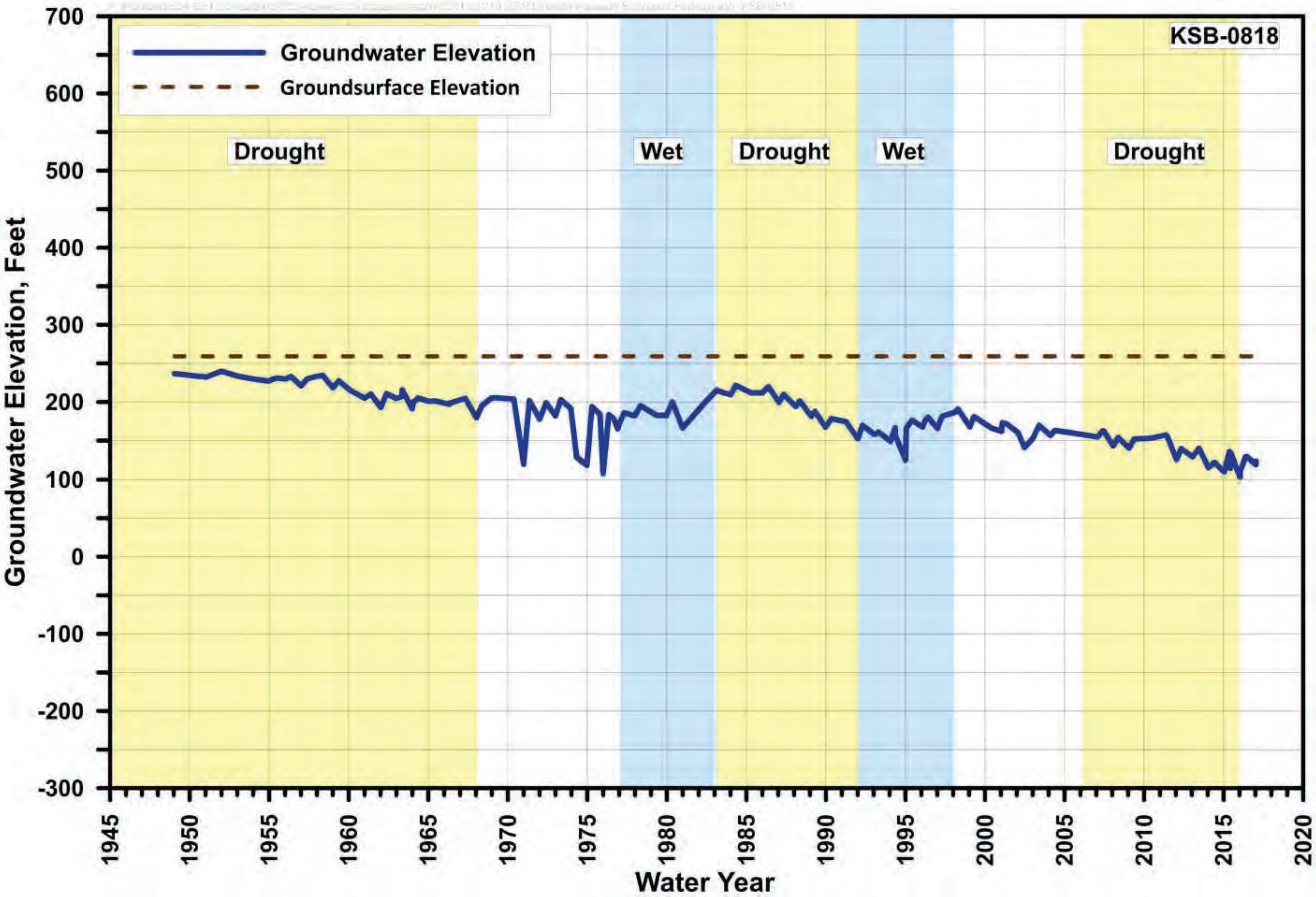
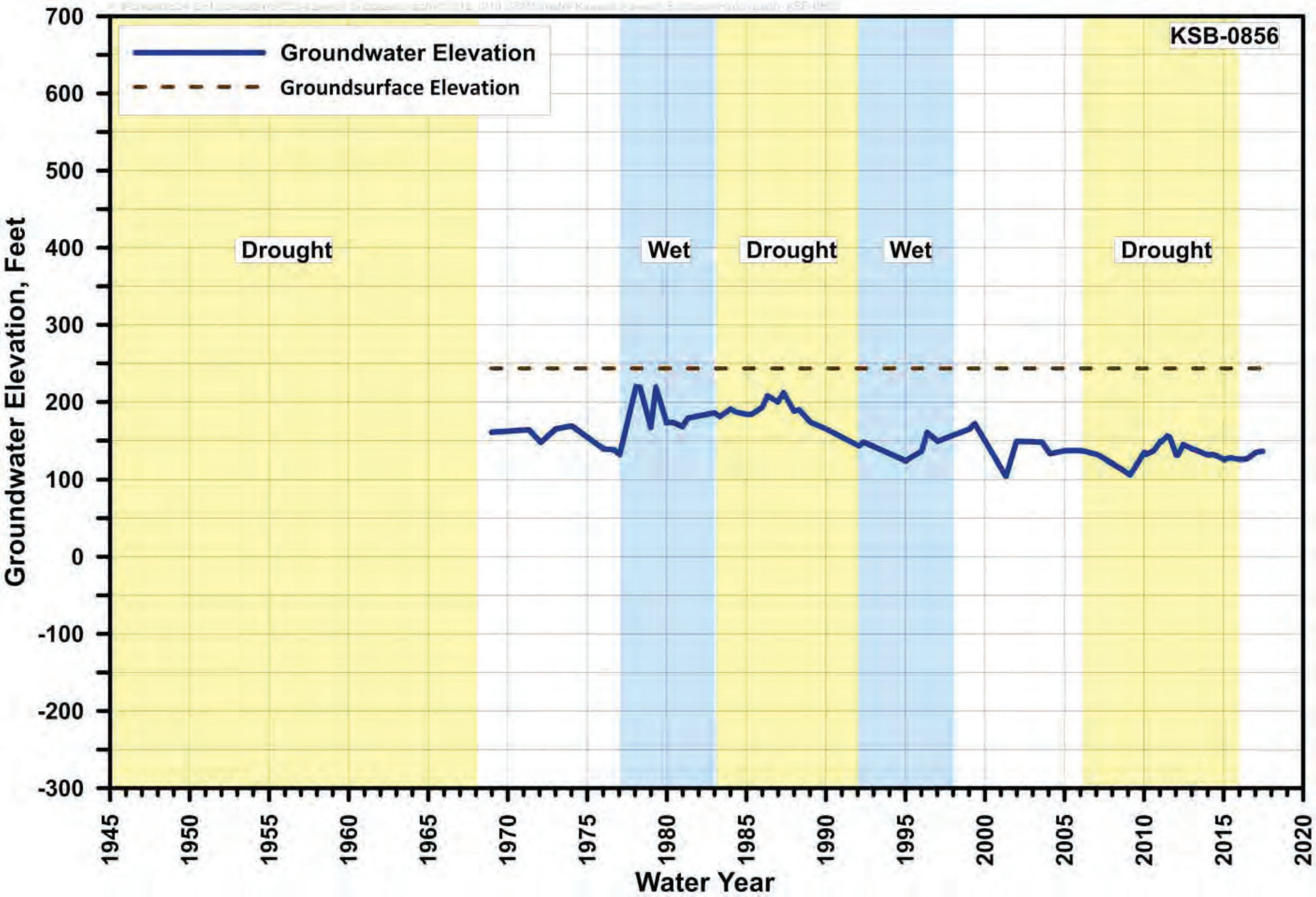
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020



KSB-0818
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-0856
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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1960
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1970
1975
1980
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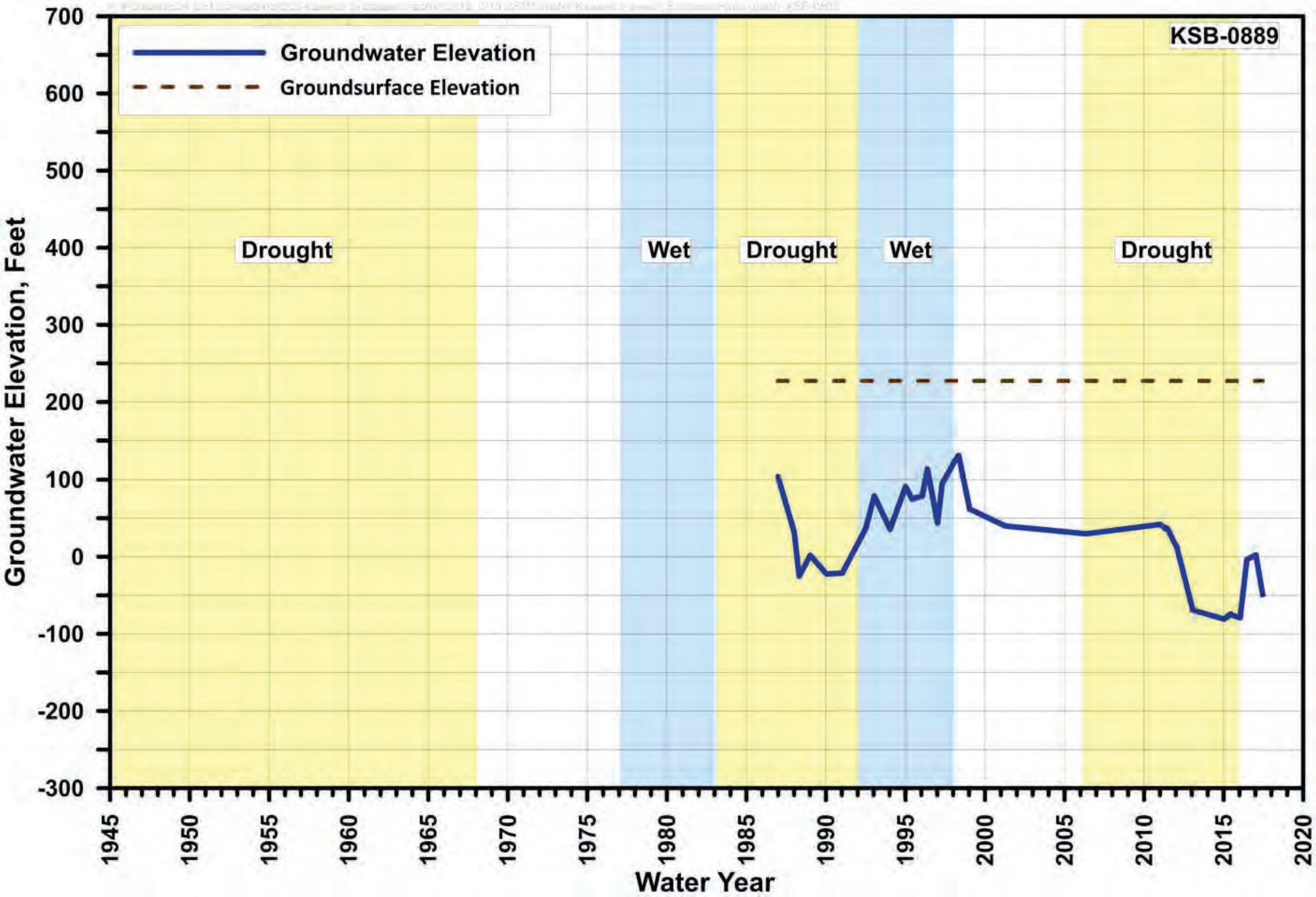
1990
1995
2000
2005
2010
2015
2020



KSB-0889
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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1980
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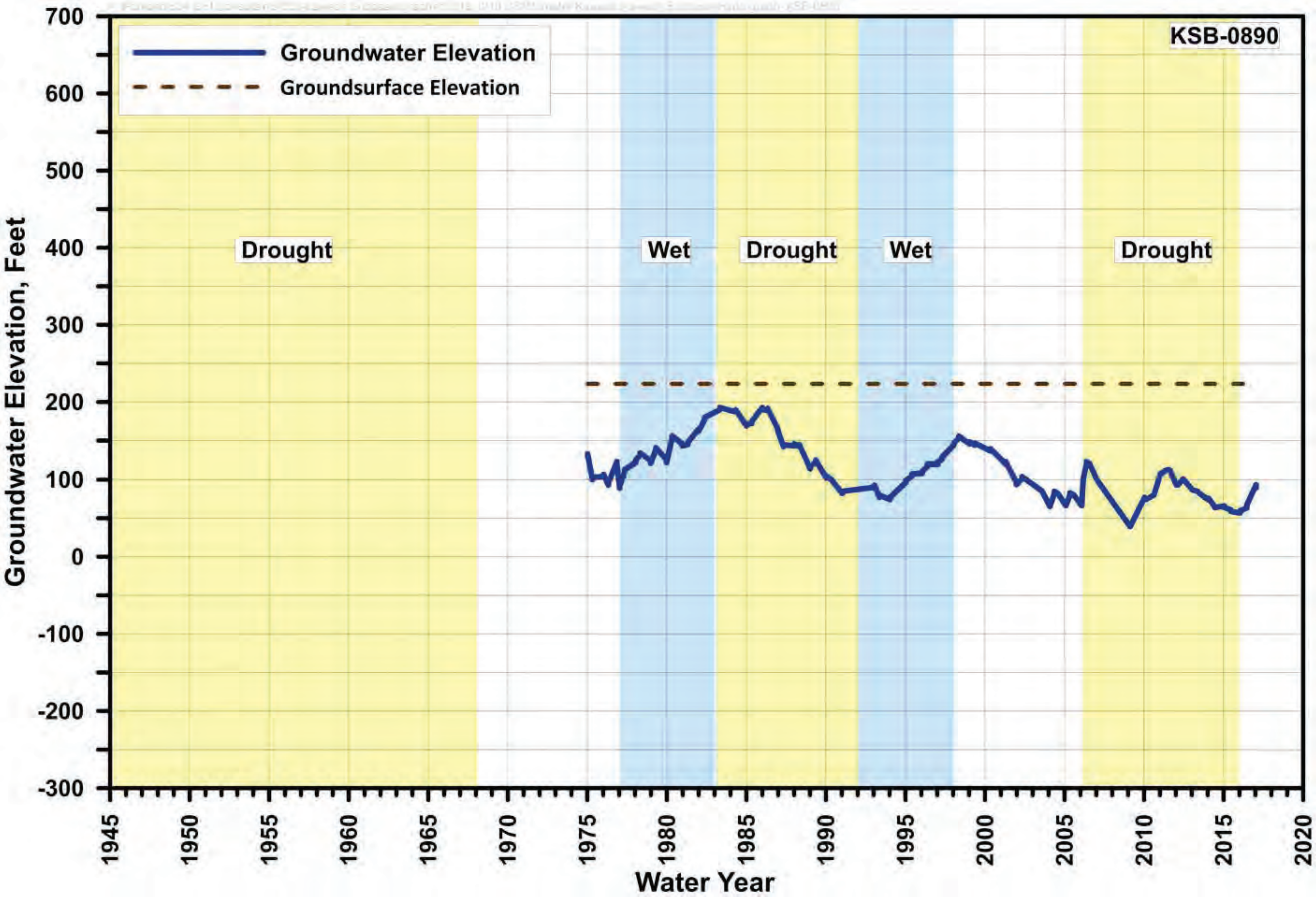
1990
1995
2000
2005
2010
2015
2020


KSB-0890
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
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1980
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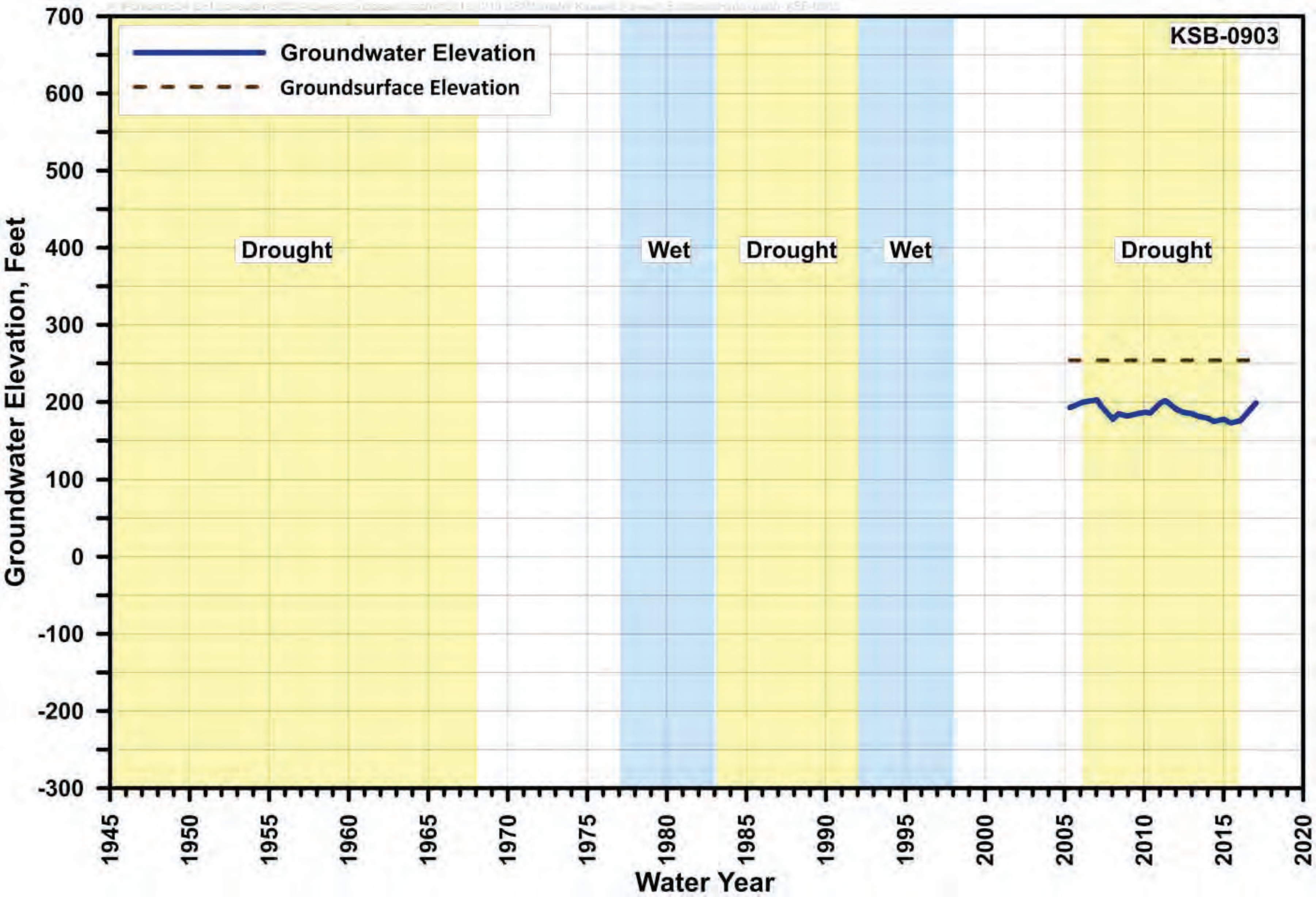
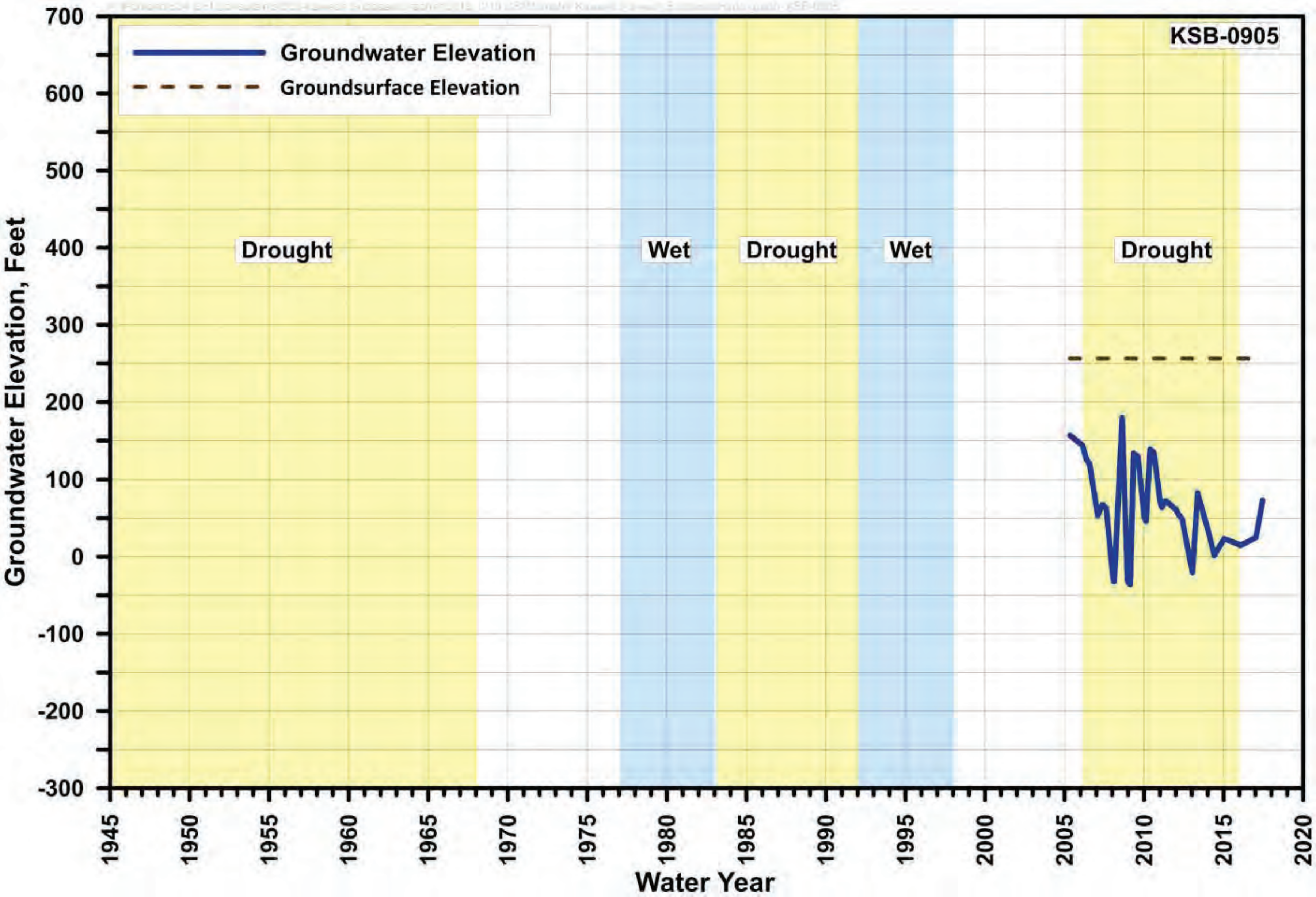
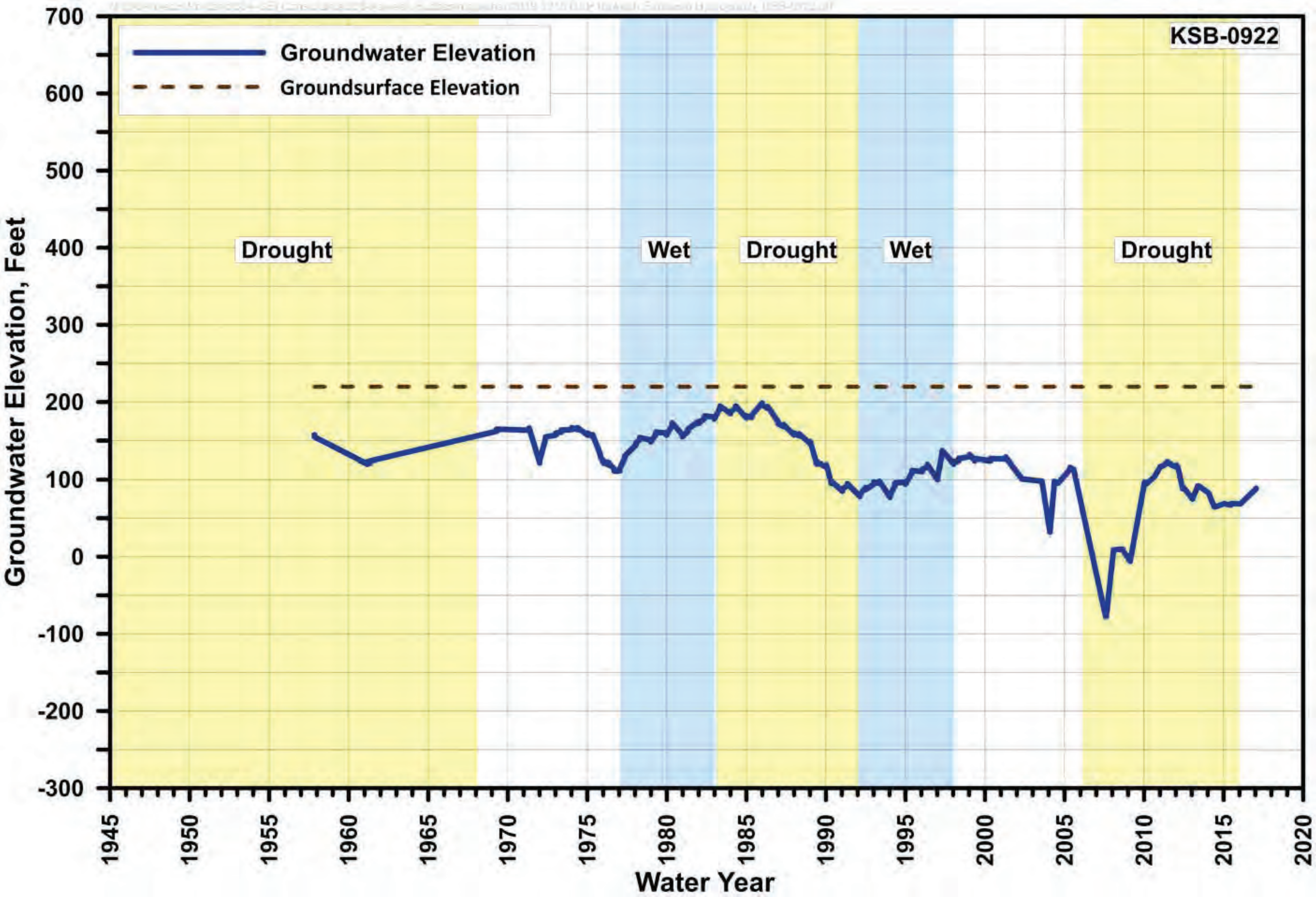
1990
1995
2000
2005
2010
2015
2020
Water Year



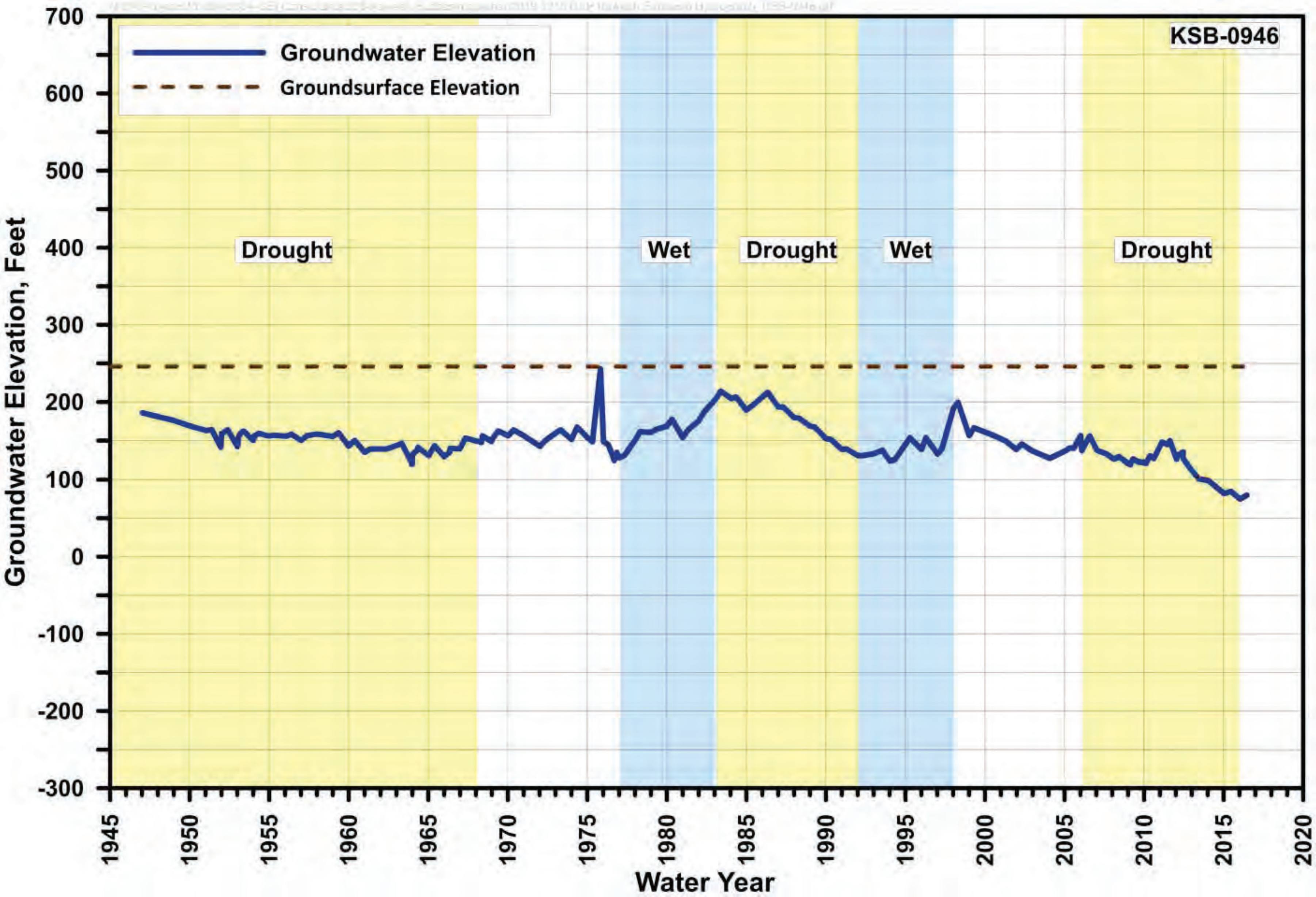
Groundwater Elevation
Groundsurface Elevation
KSB-0903
Drought
Wet
Drought
Wet
Drought
700
600
500
400
300
200
100
0
-100
-200
-300
Groundwater Elevation, Feet
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



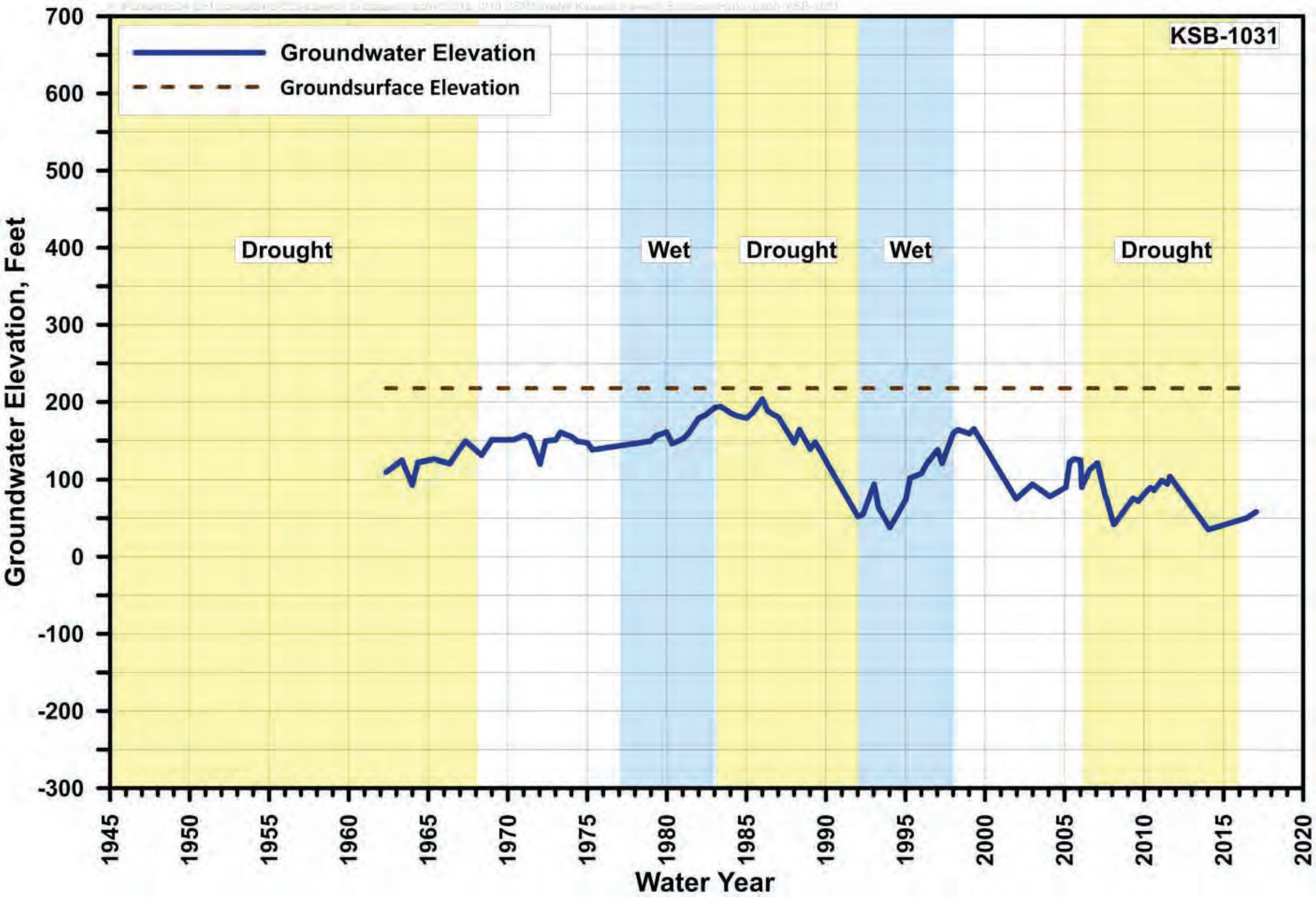
KSB-0905
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

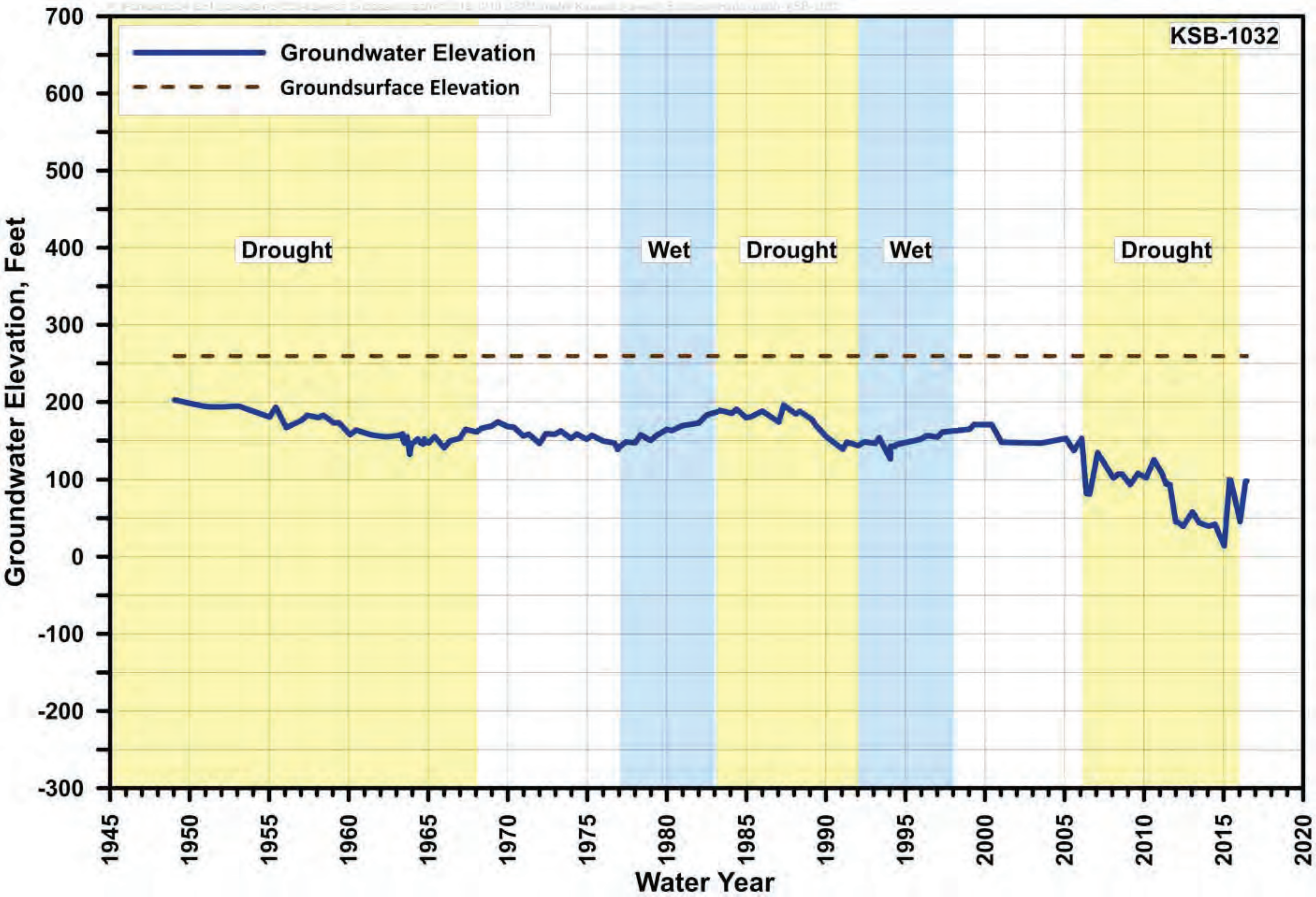


Groundwater Elevation
Groundsurface Elevation
KSB-0922
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year

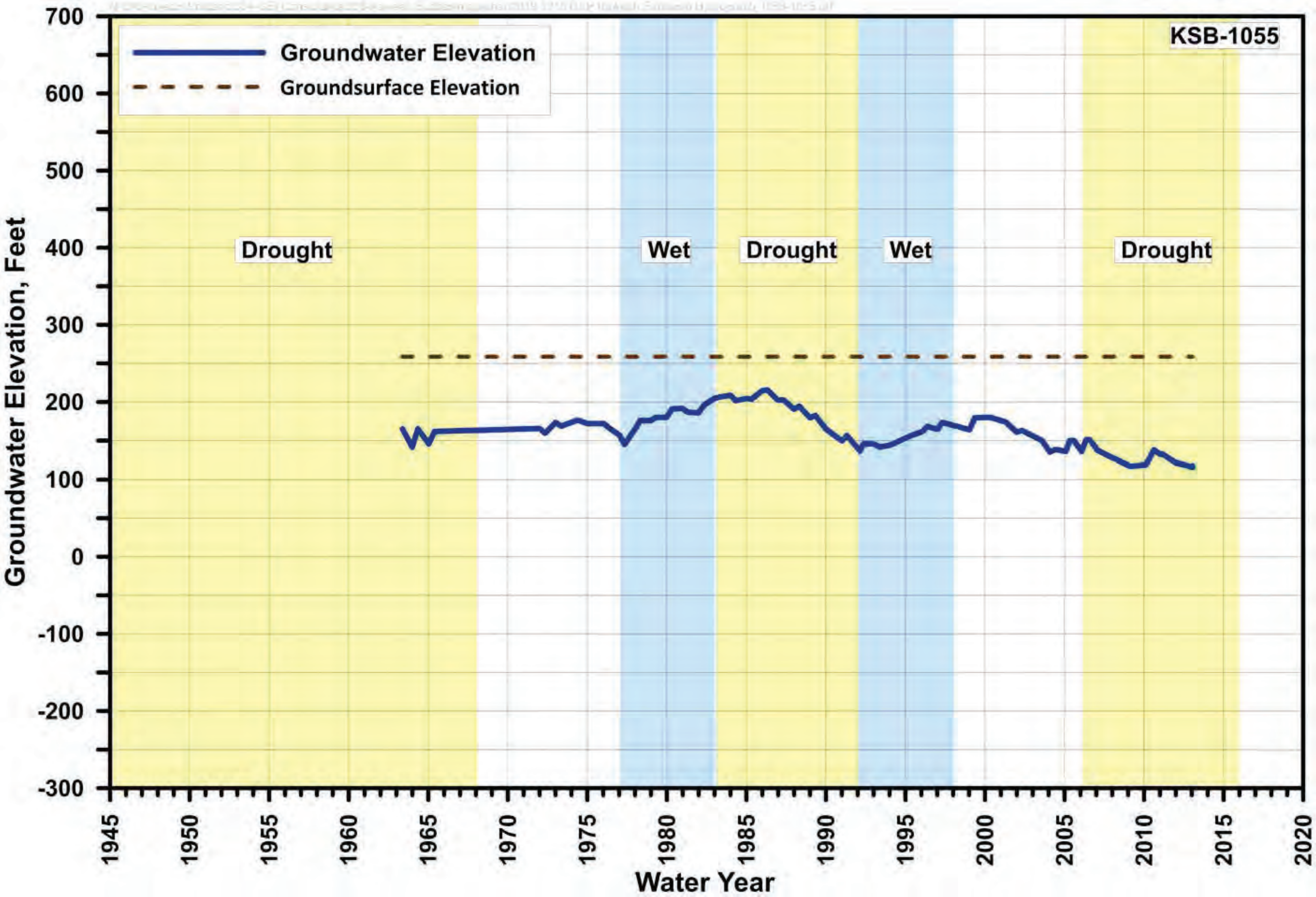


KSB-0946
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


KSB-1031
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-1032
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year


KSB-1055
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
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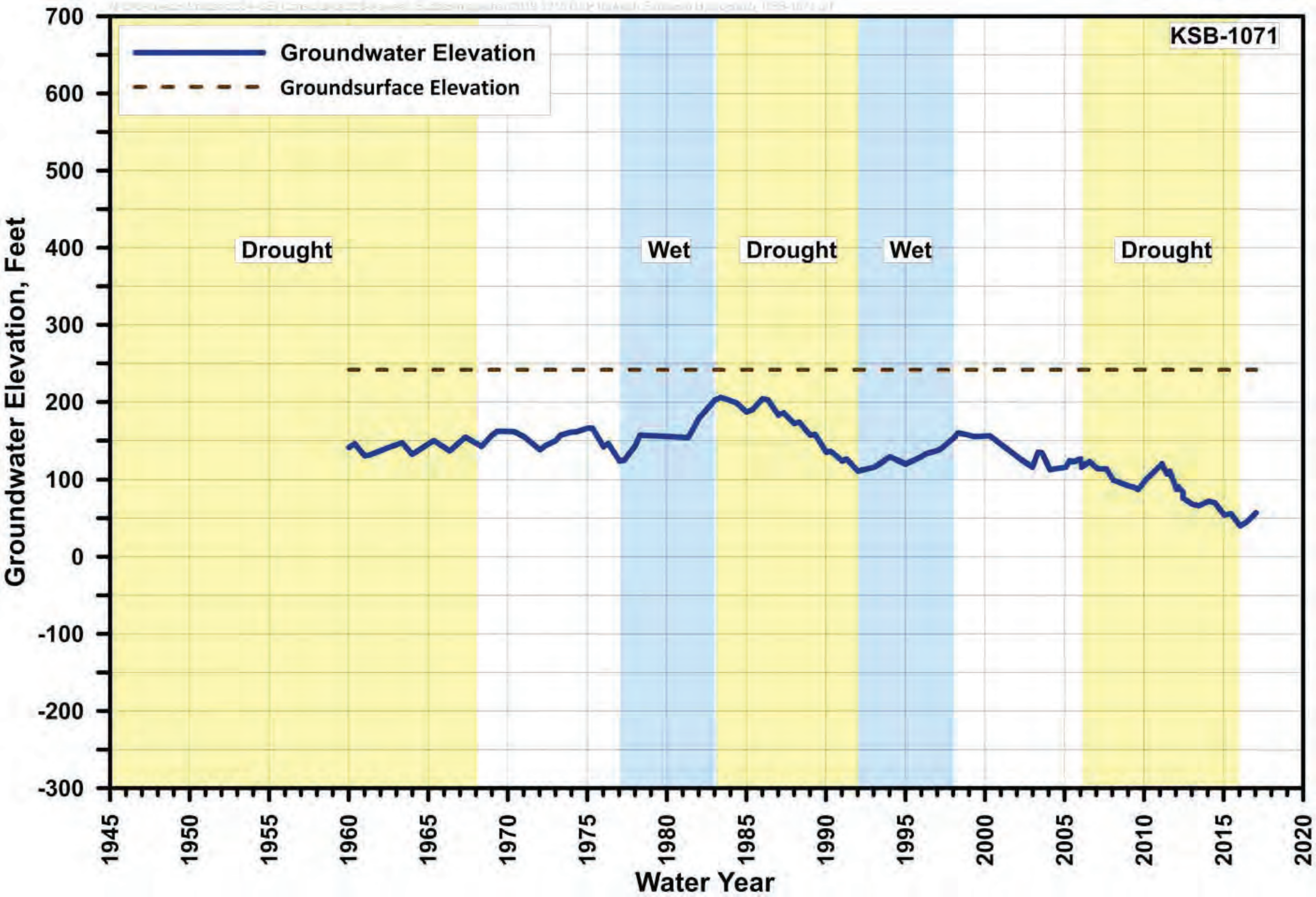
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-1071
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
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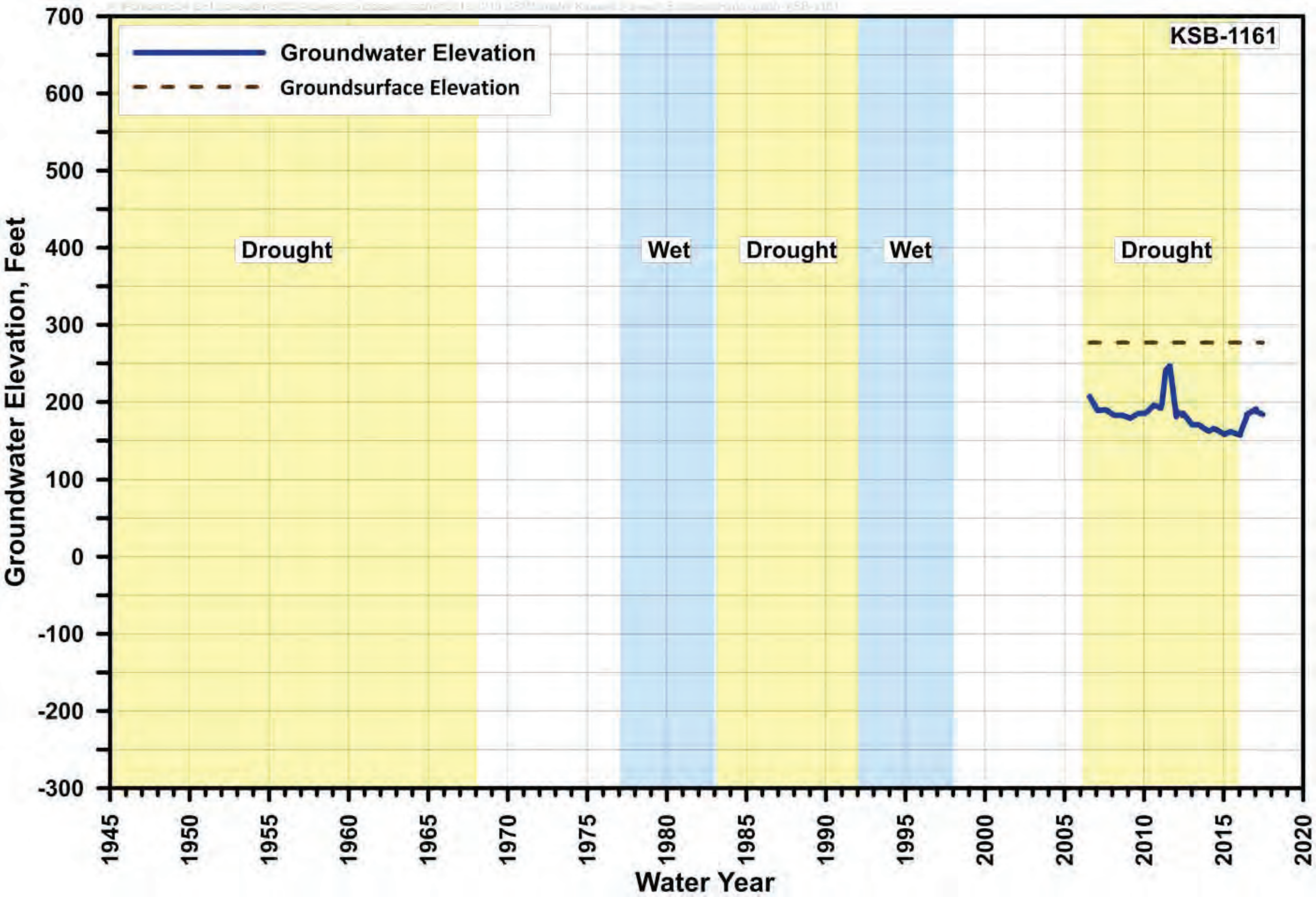
2005
2010
2015
2020
Water Year



KSB-1161
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
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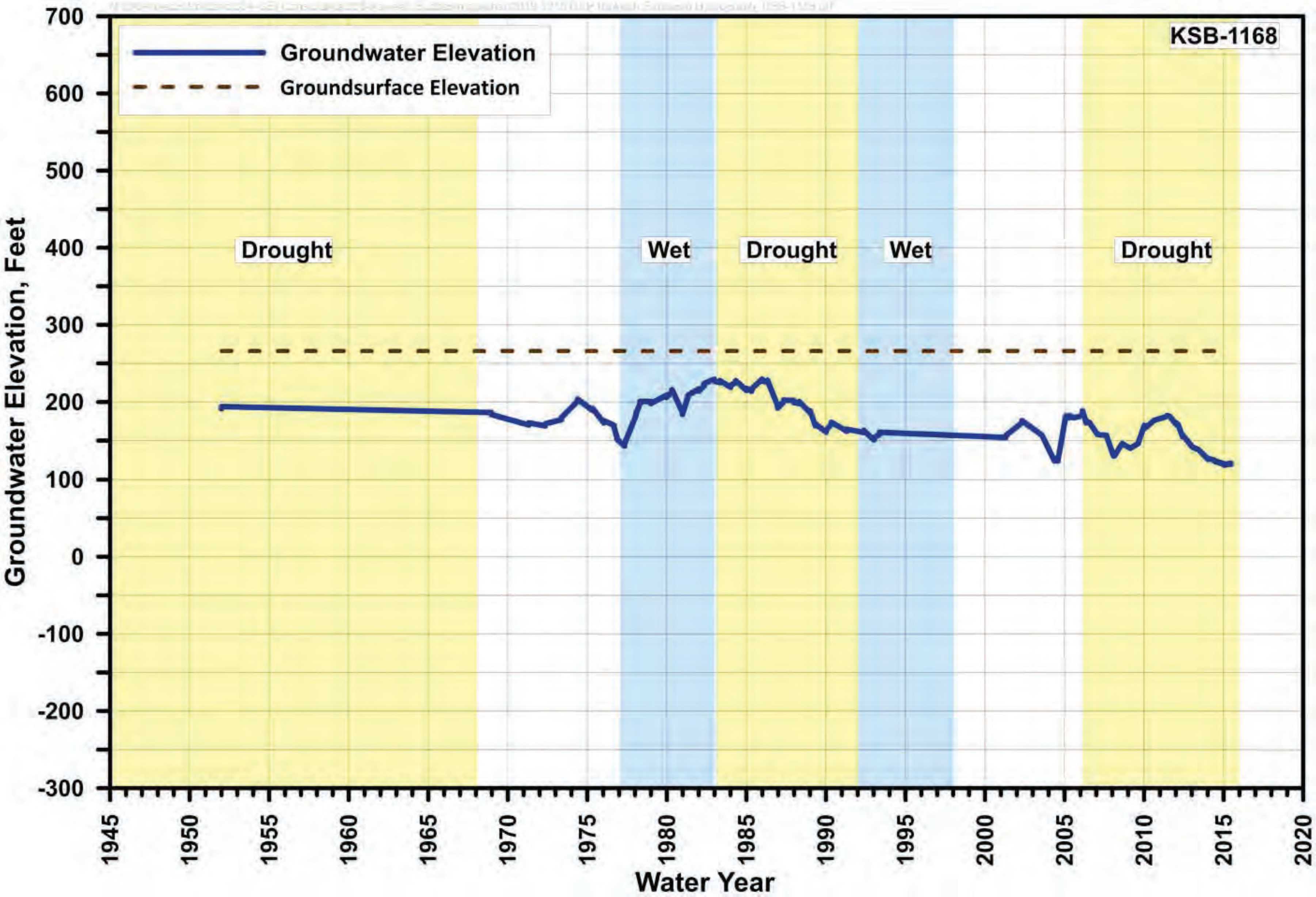
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-1168
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
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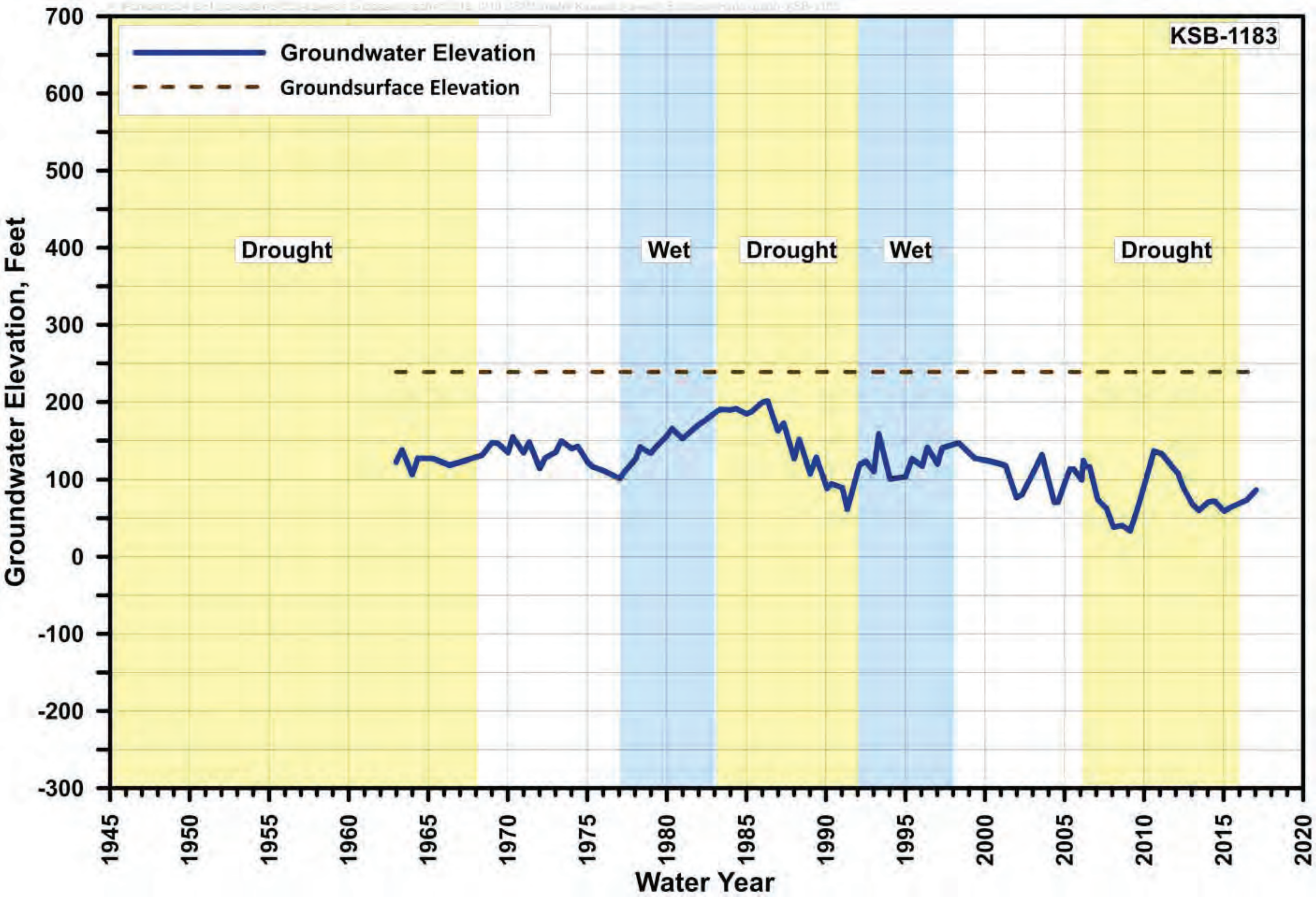
2005
2010
2015
2020
Water Year



Groundwater Elevation
Groundsurface Elevation
KSB-1183
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
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1990
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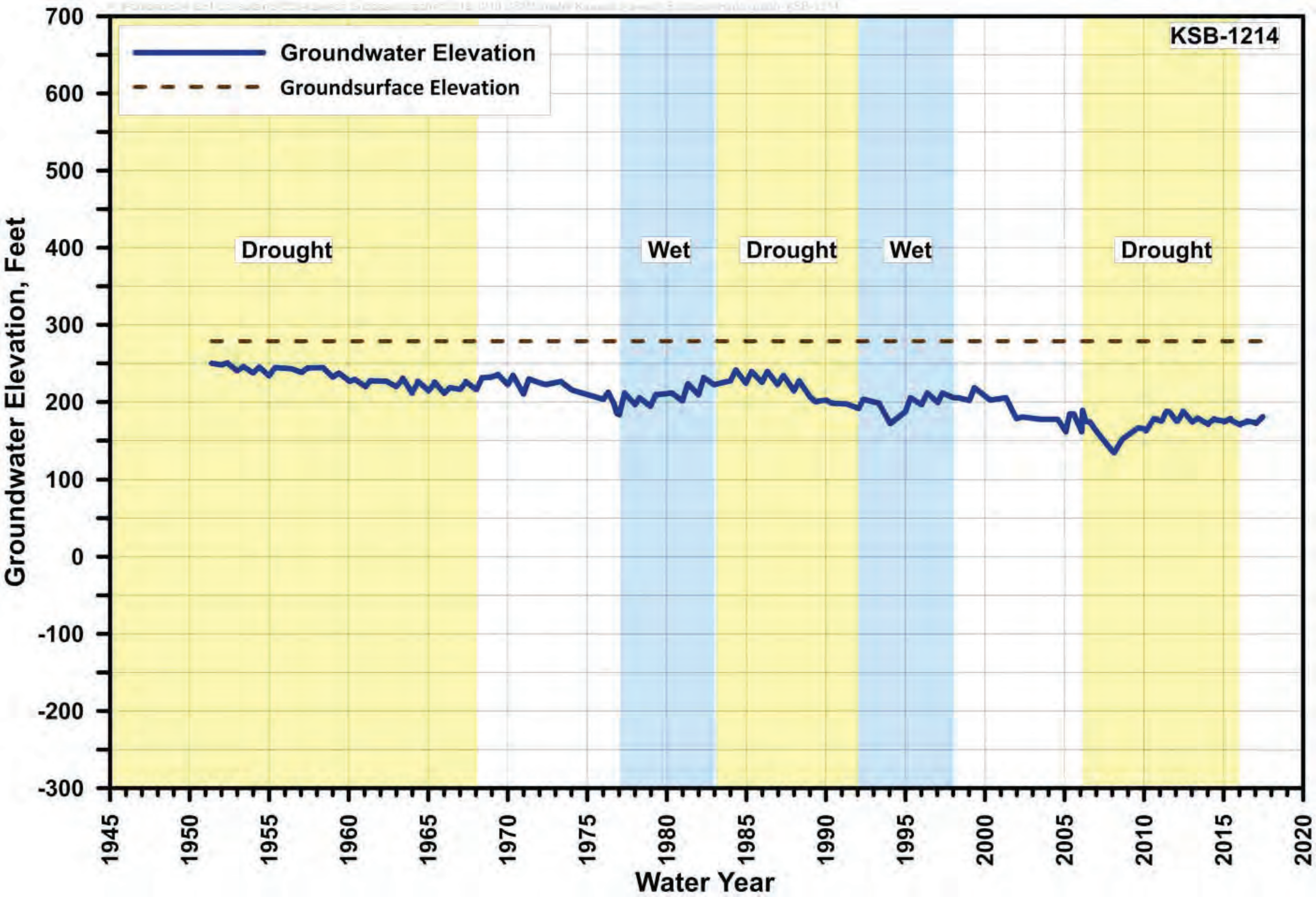
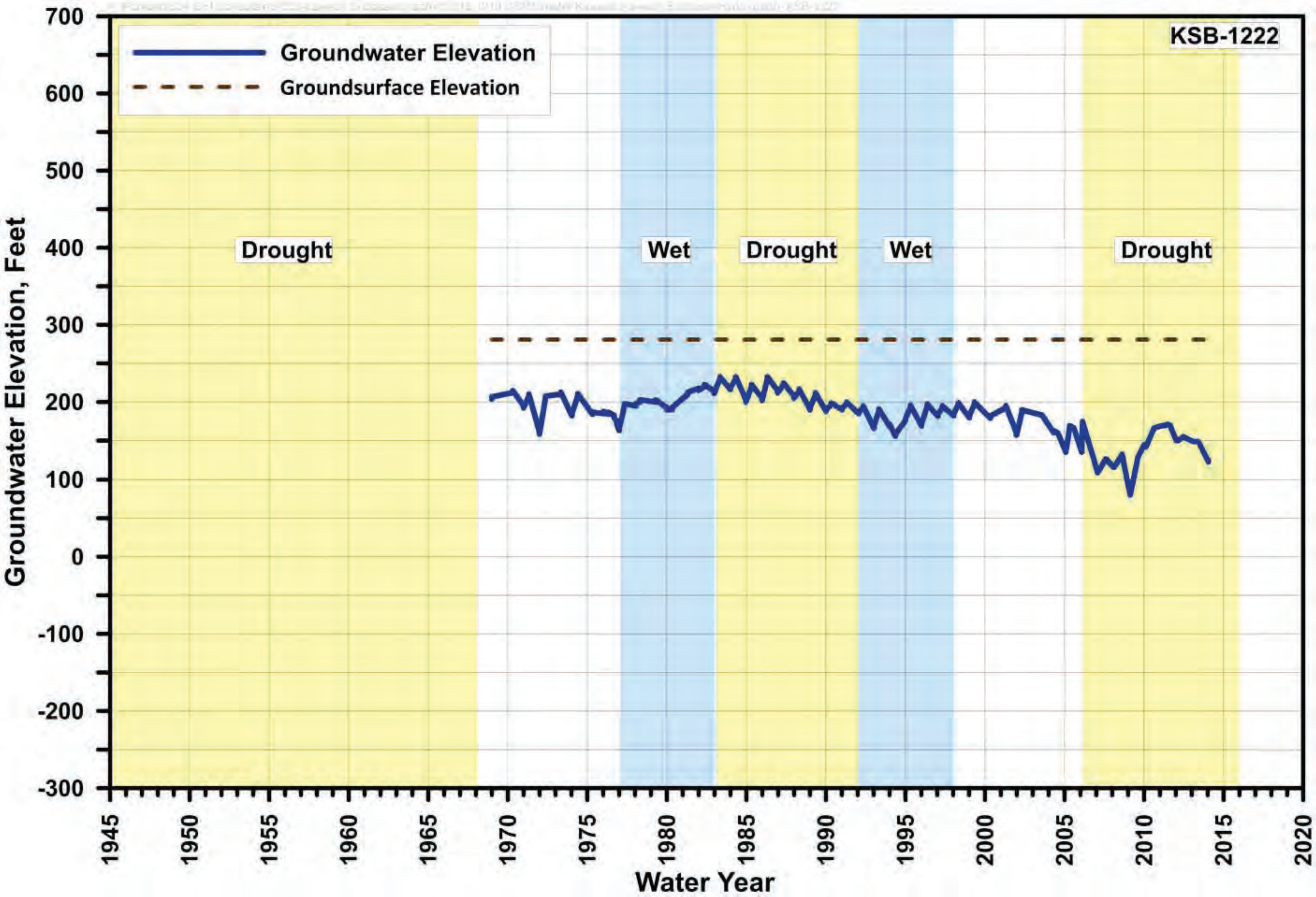
2000
2005
2010
2015
2020
Water Year



KSB-1214
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-1222
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
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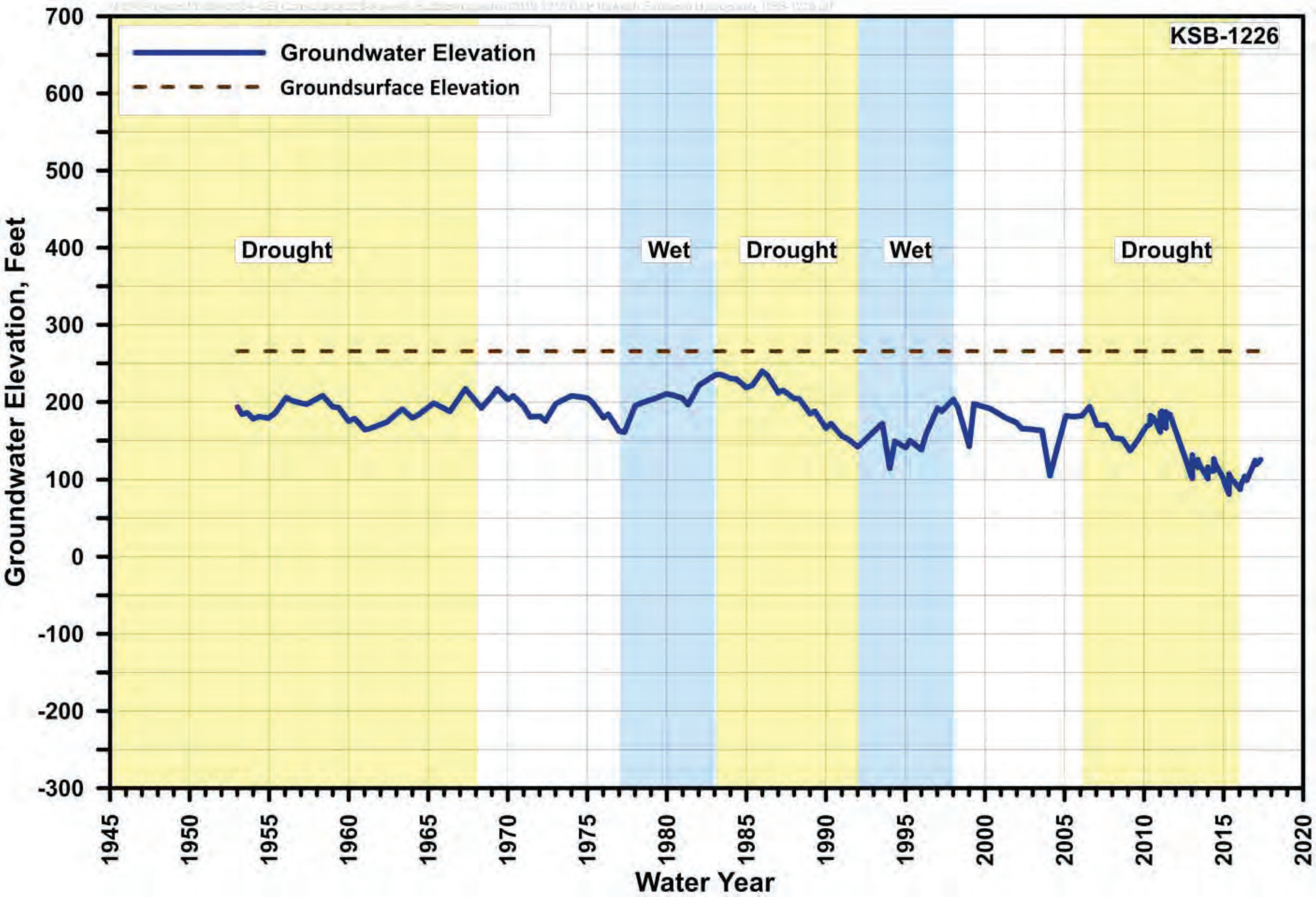
2005
2010
2015
2020
Water Year


KSB-1226
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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1965
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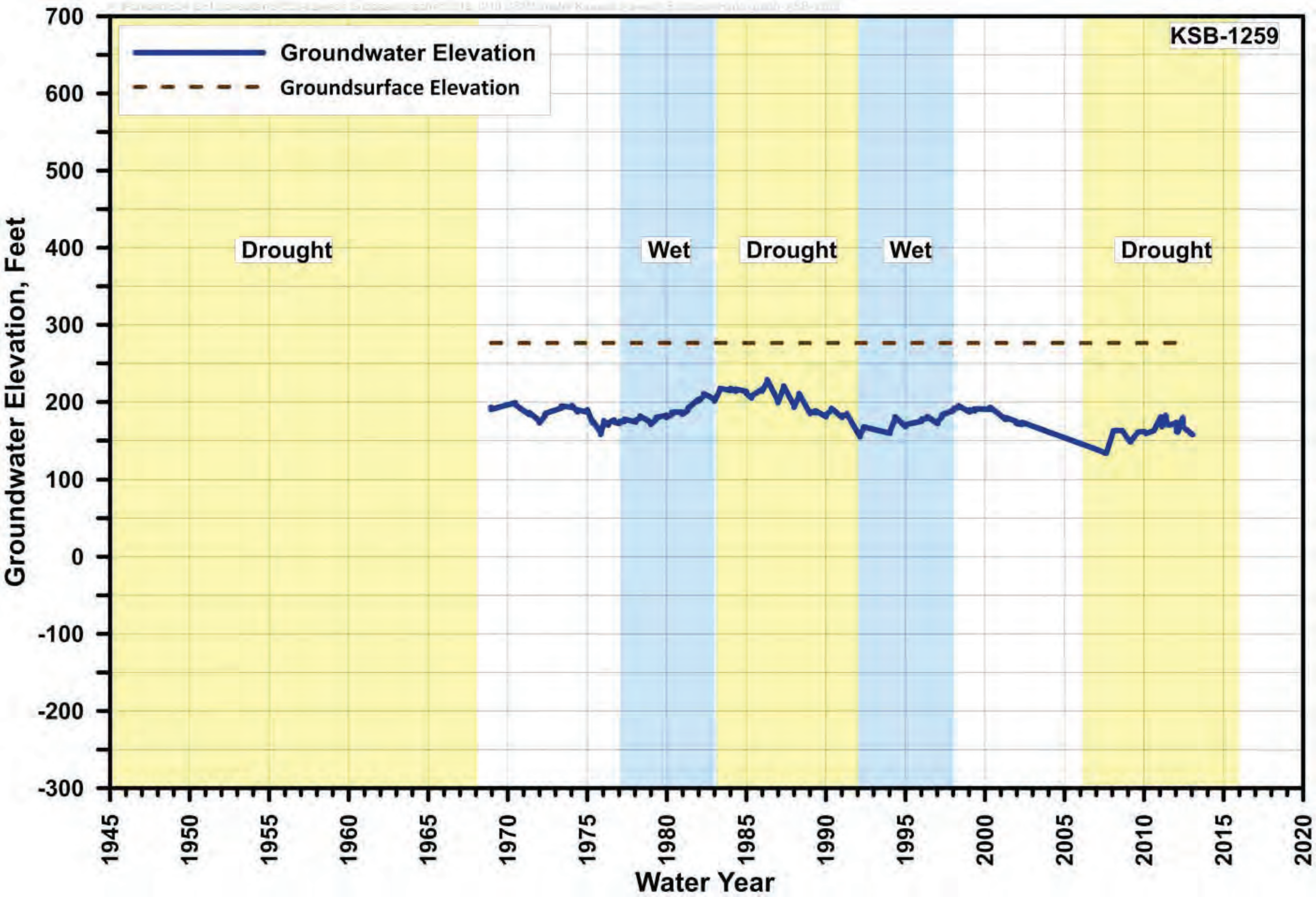
2015
2020



KSB-1259
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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1965
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2015
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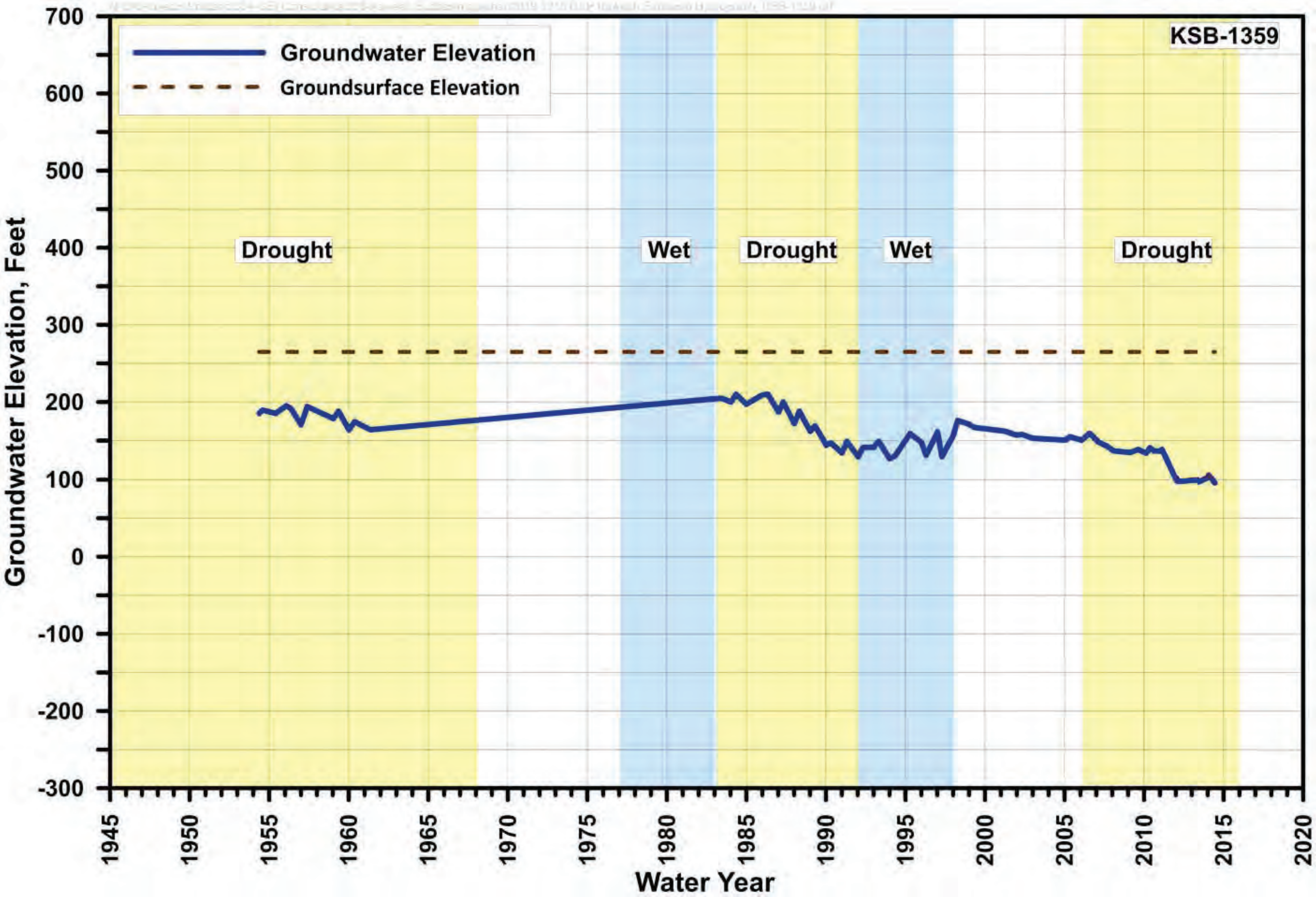
KSB-1359
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
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2005
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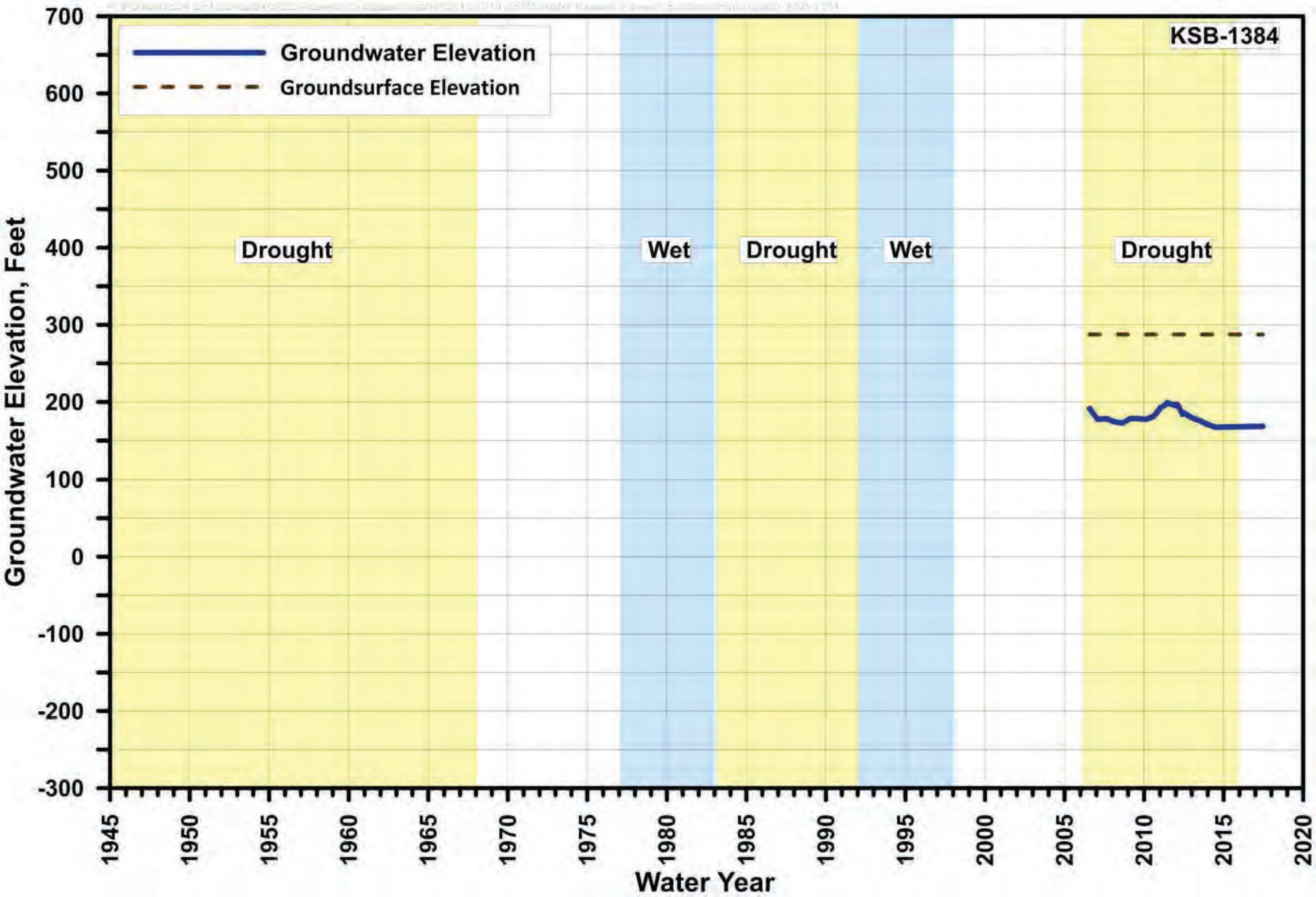
2015
2020
Water Year



KSB-1384
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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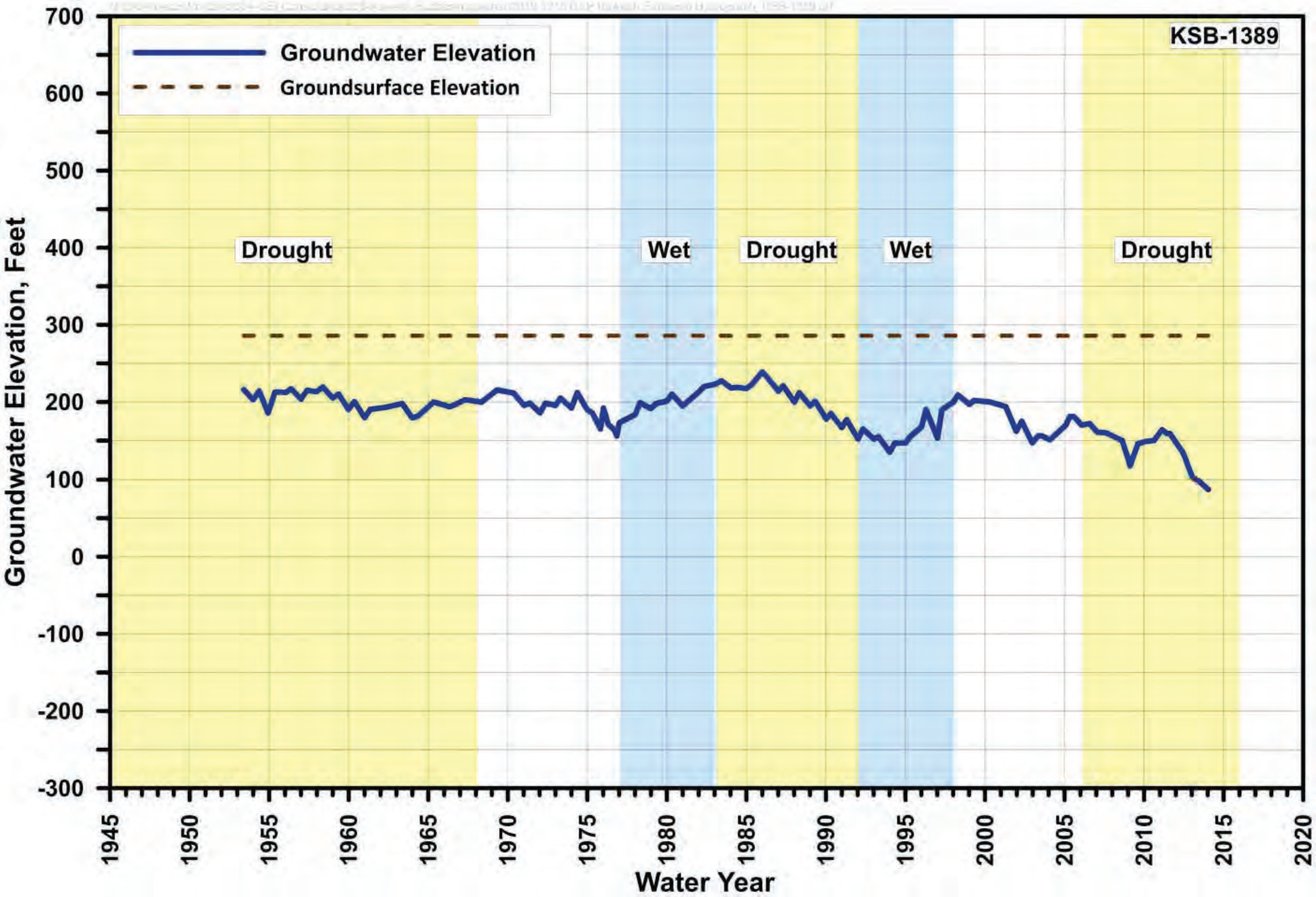
2010
2015
2020


KSB-1389
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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1995
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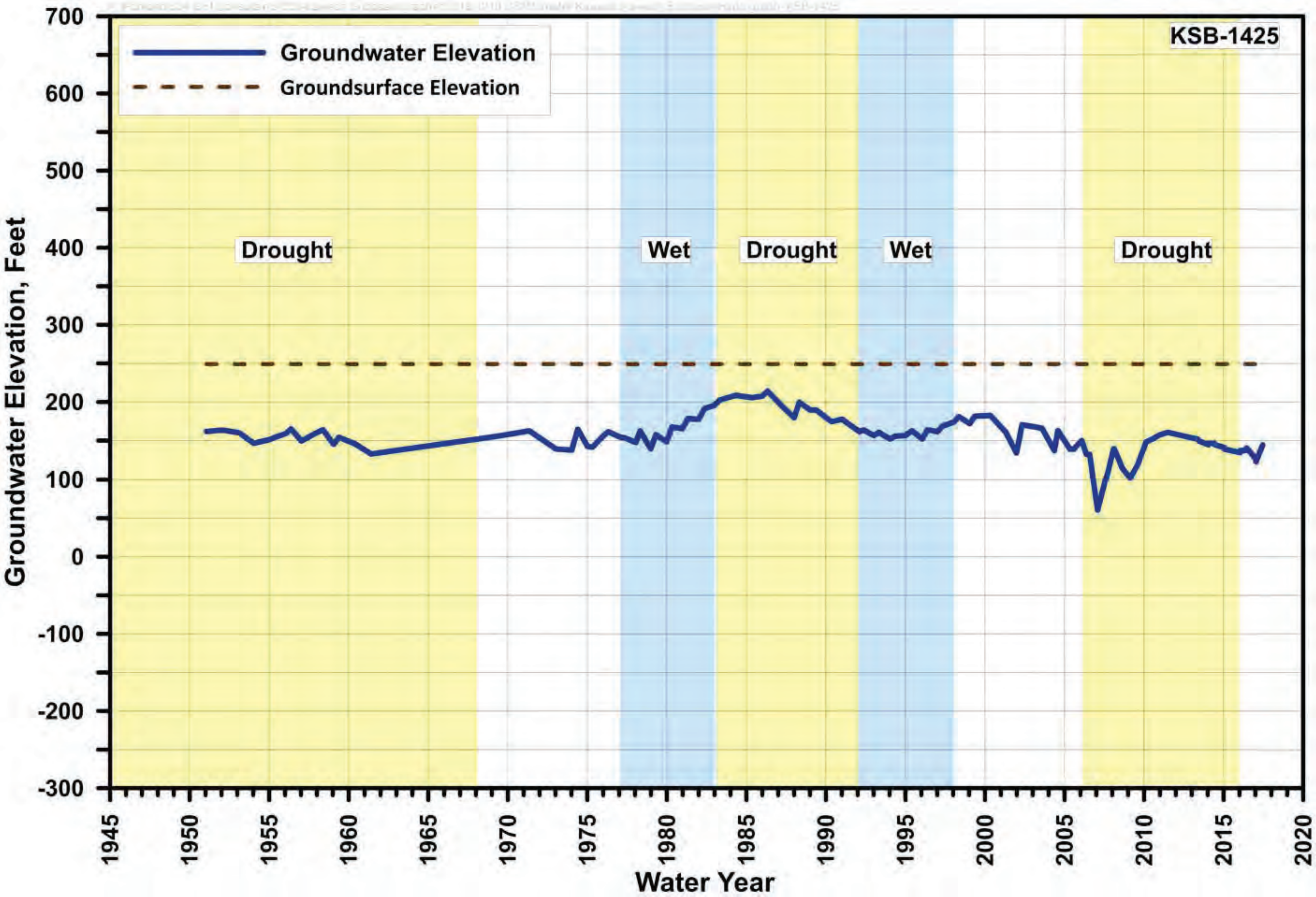
2005
2010
2015
2020
Water Year



KSB-1425
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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1960
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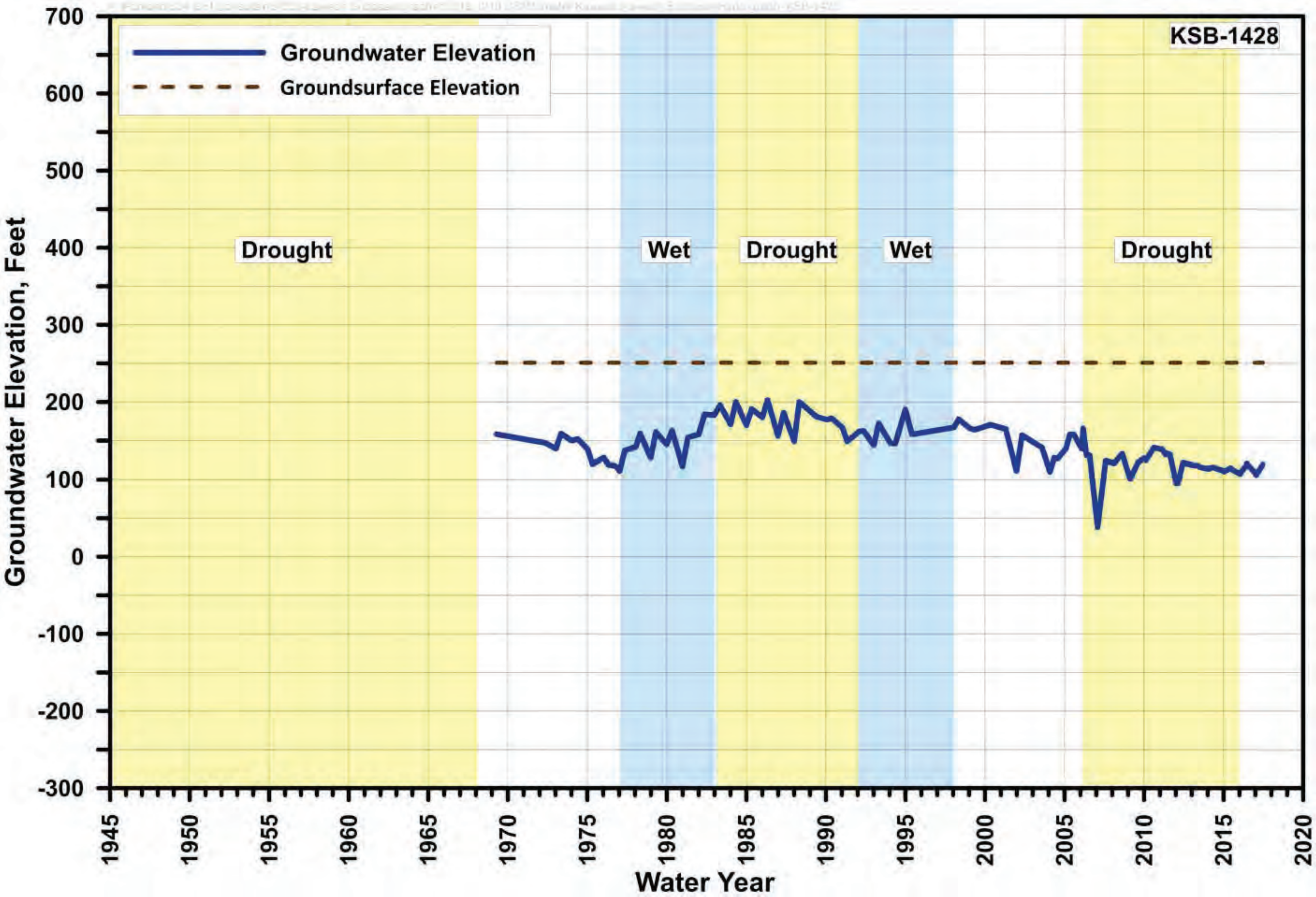
2015
2020


KSB-1428
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
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-100
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-300
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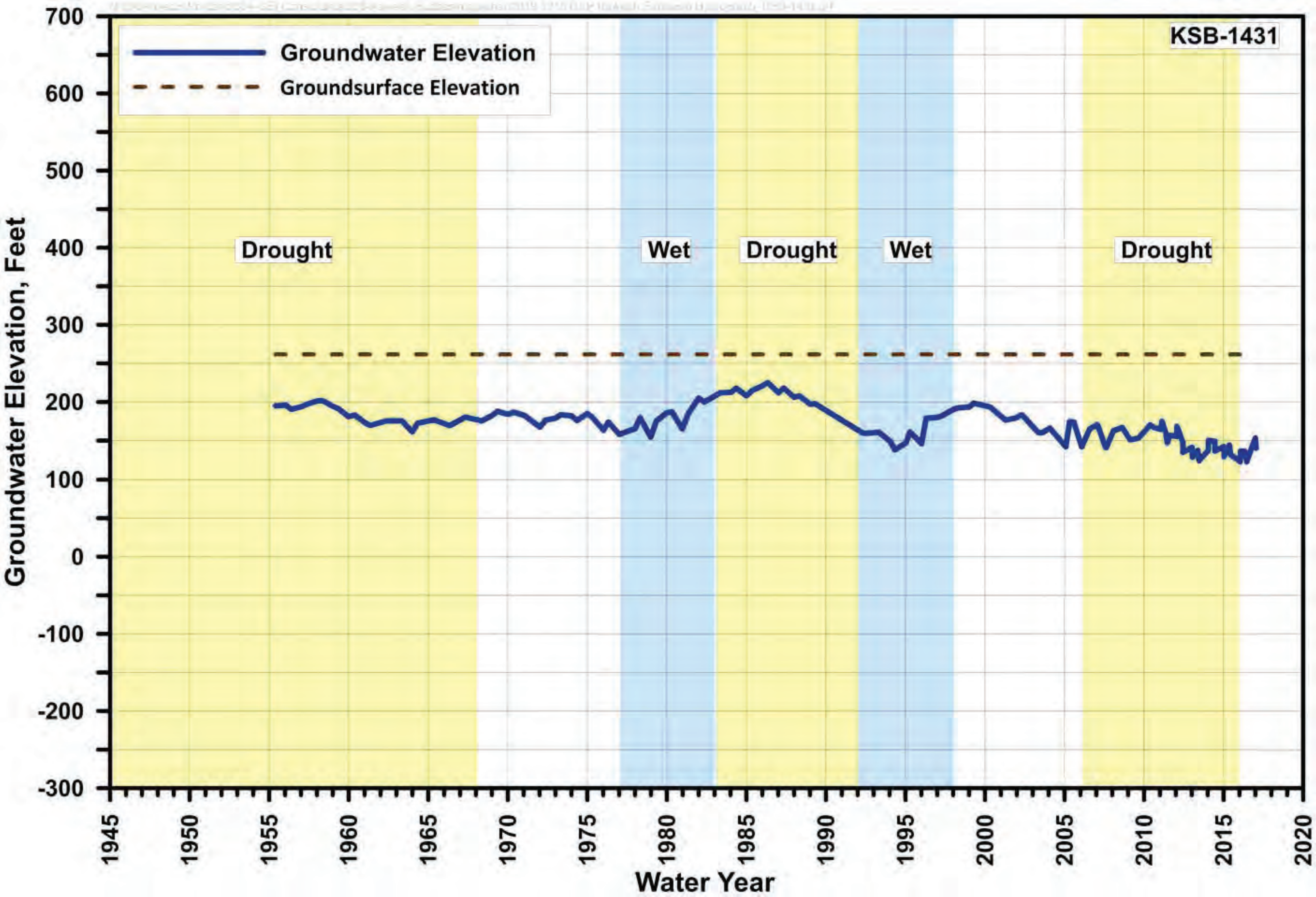
2000
2005
2010
2015
2020
Water Year


KSB-1431
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
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2015
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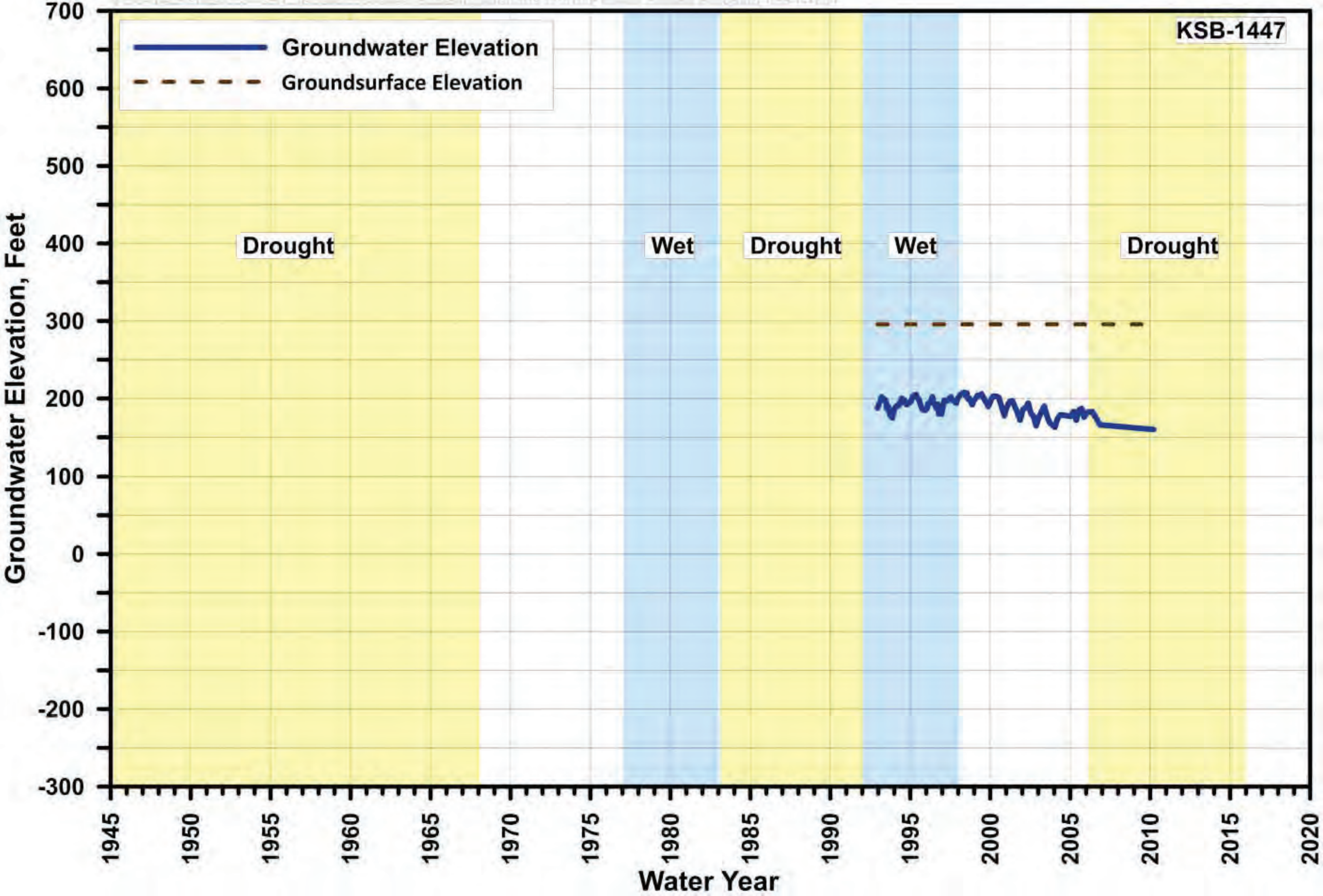

KSB-1447
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
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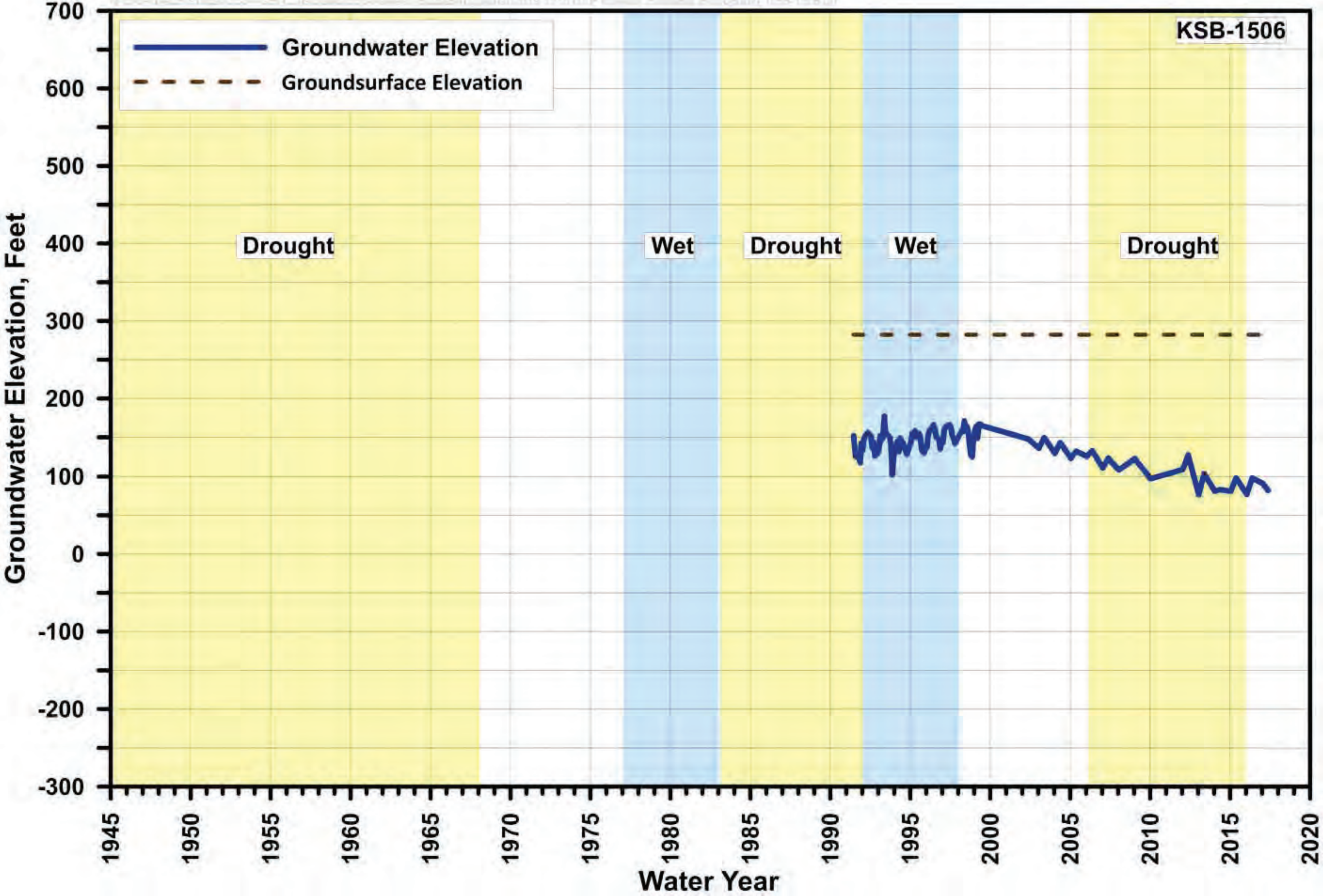
2010
2015
2020



KSB-1506
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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1995
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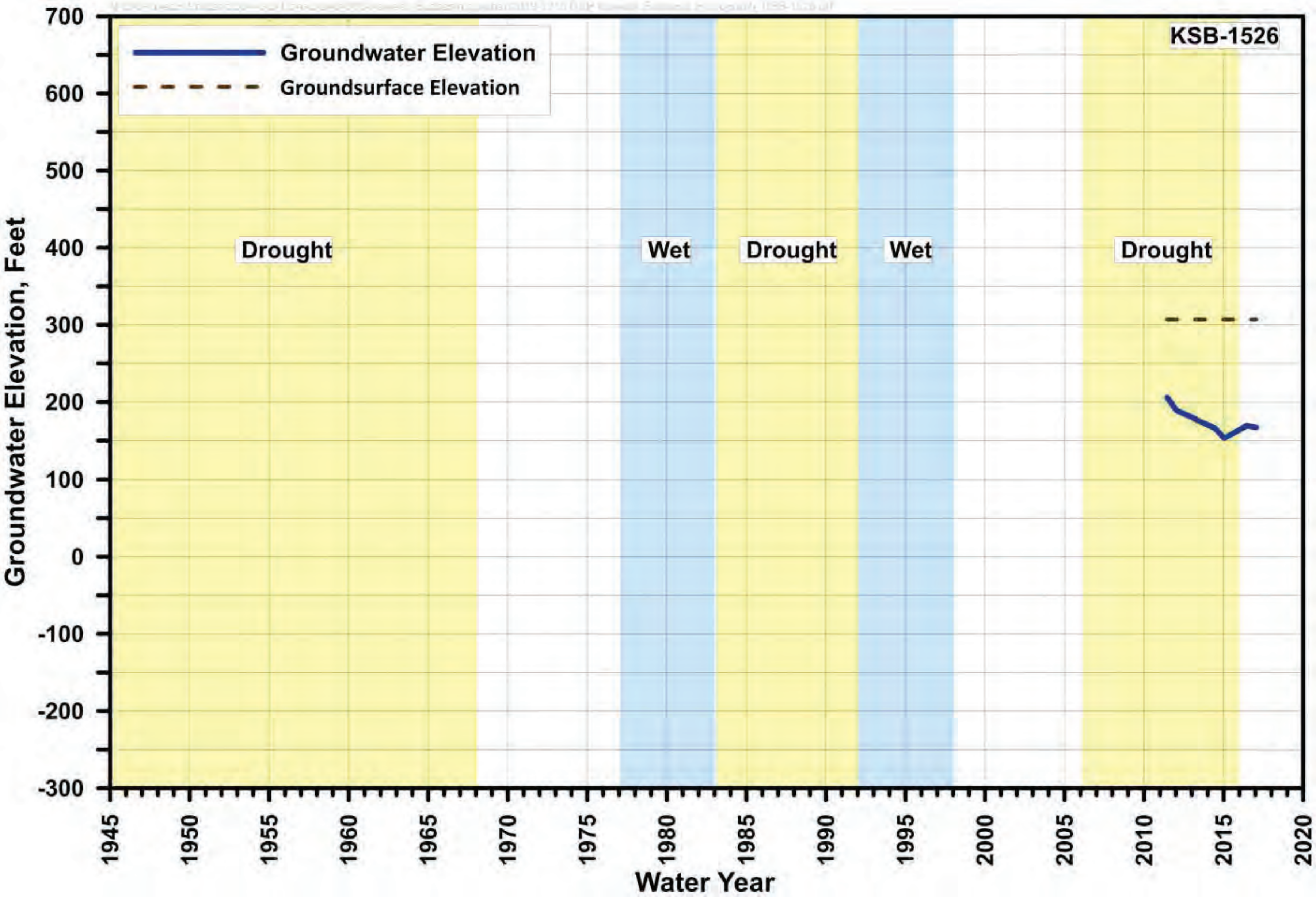
2005
2010
2015
2020
Water Year



KSB-1526
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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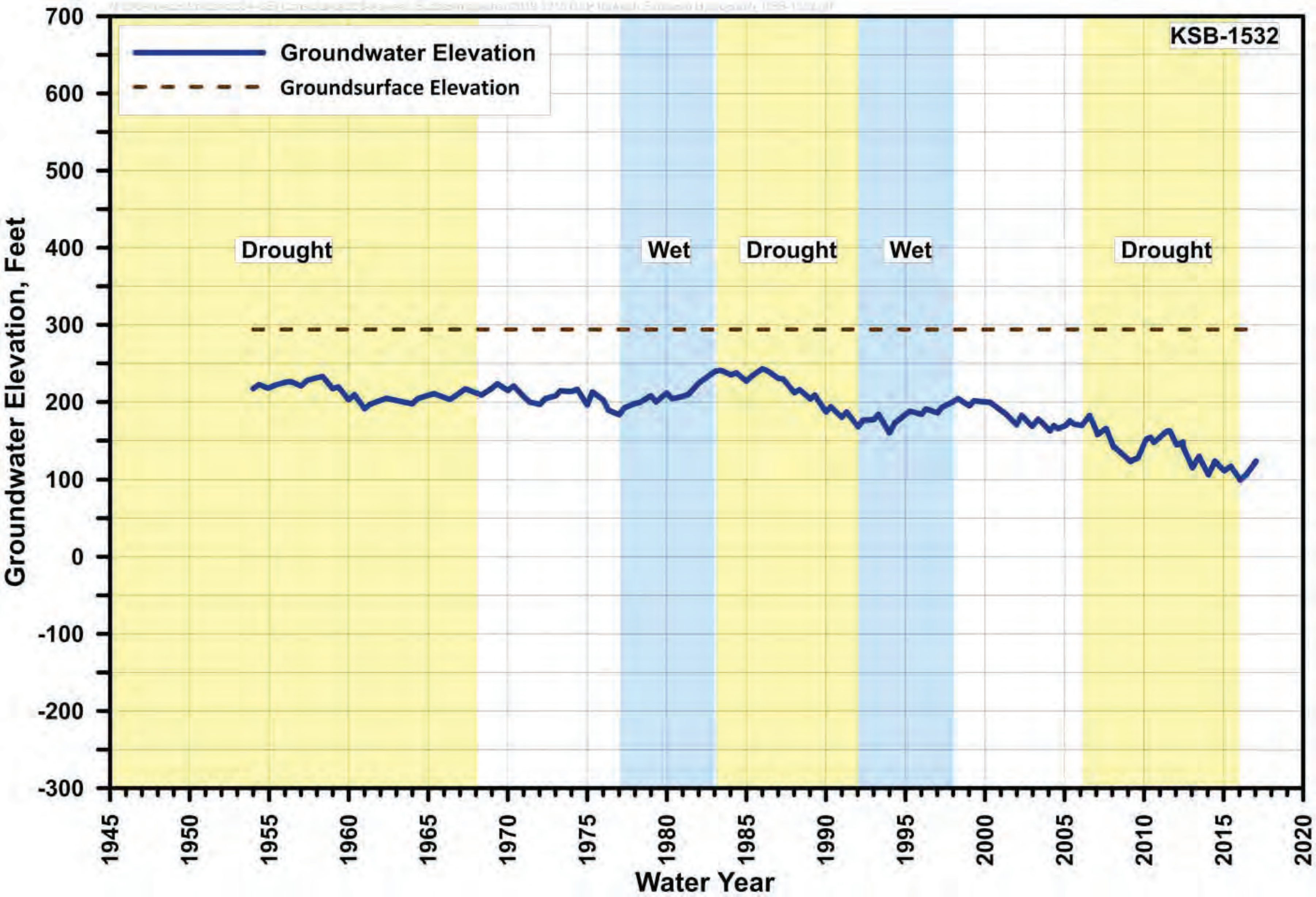
1995
2000
2005
2010
2015
2020
Water Year



KSB-1532
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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1995
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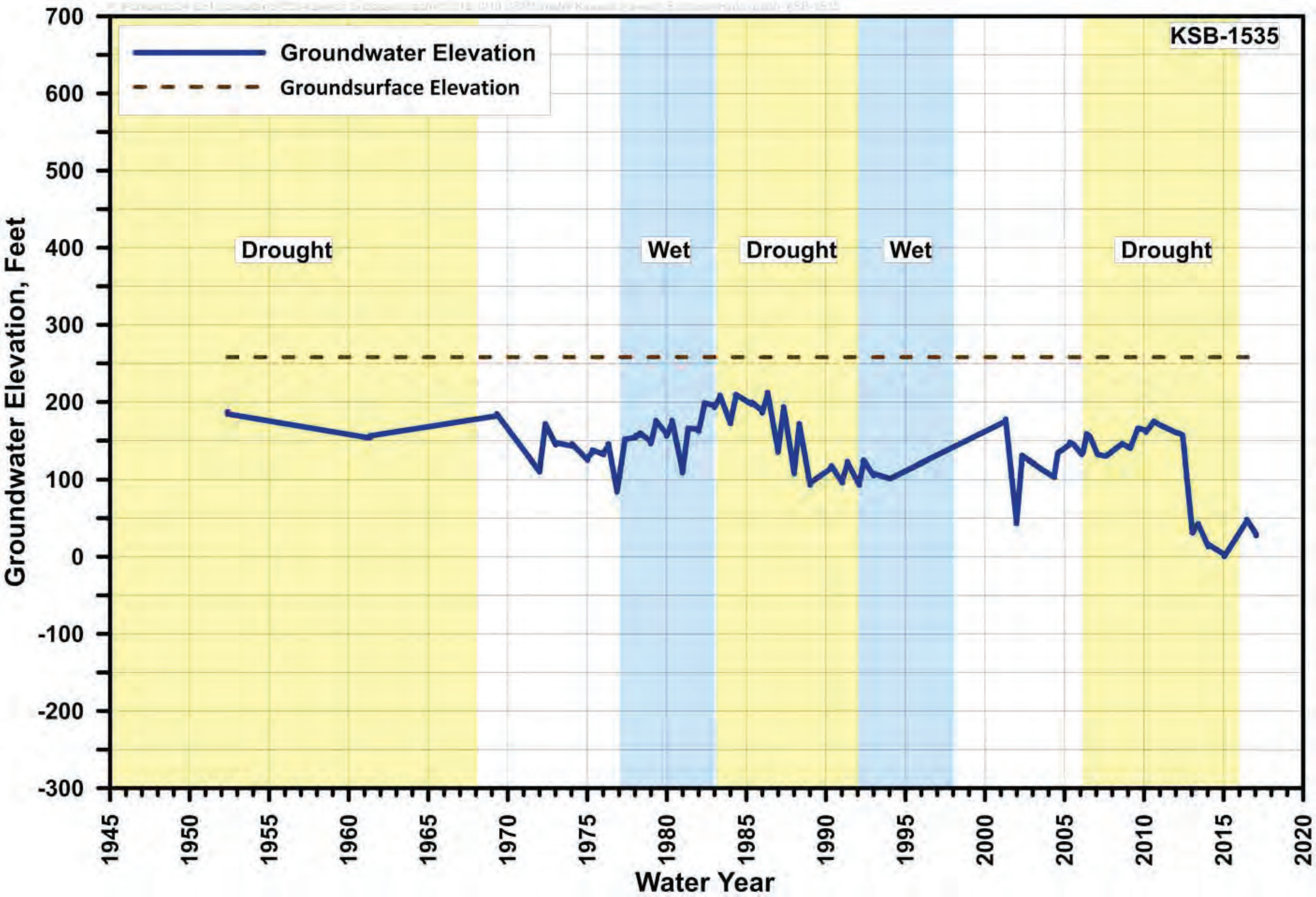
2005
2010
2015
2020
Water Year



KSB-1535
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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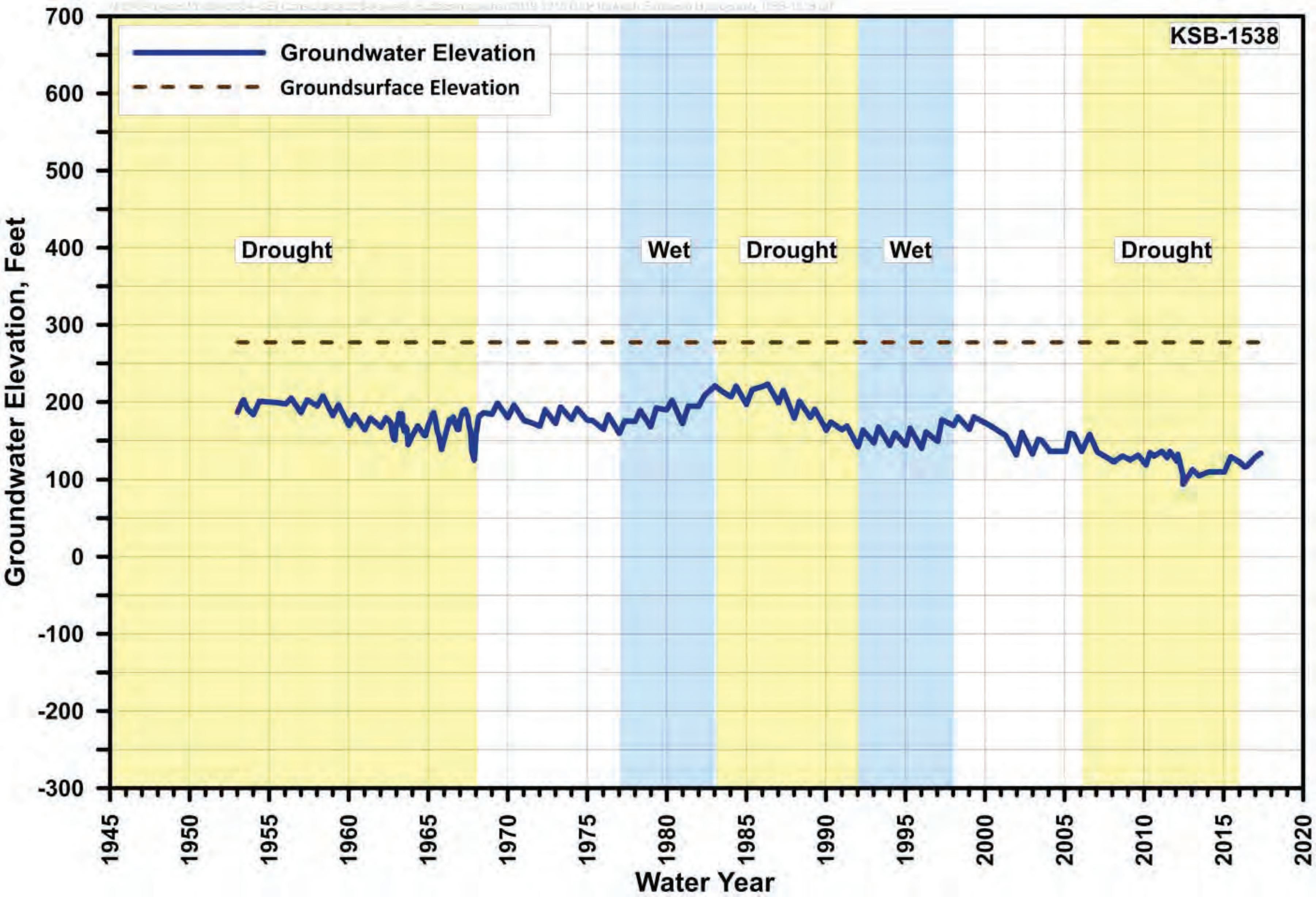
2005
2010
2015
2020
Water Year



KSB-1538
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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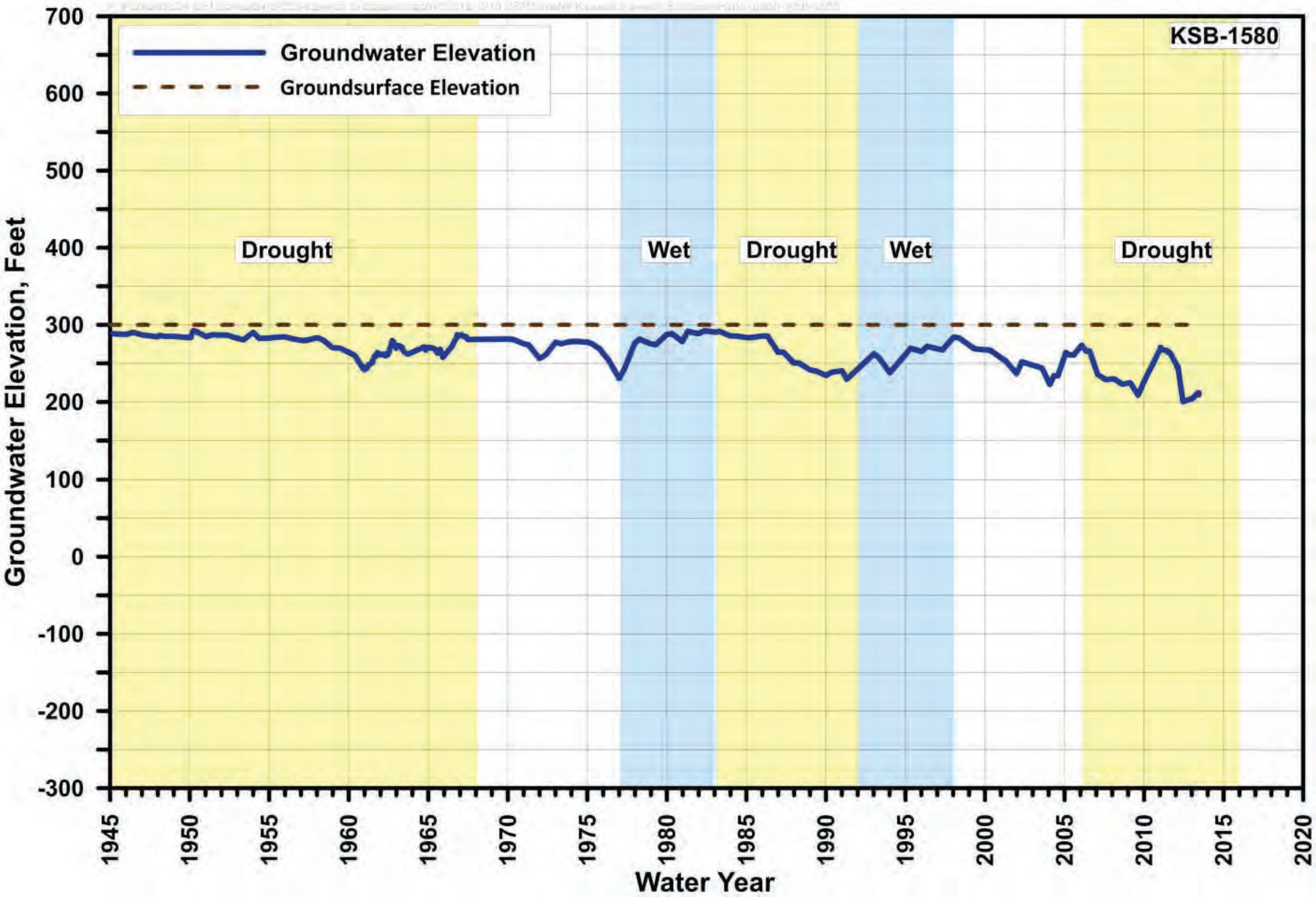
2010
2015
2020
Water Year


KSB-1580
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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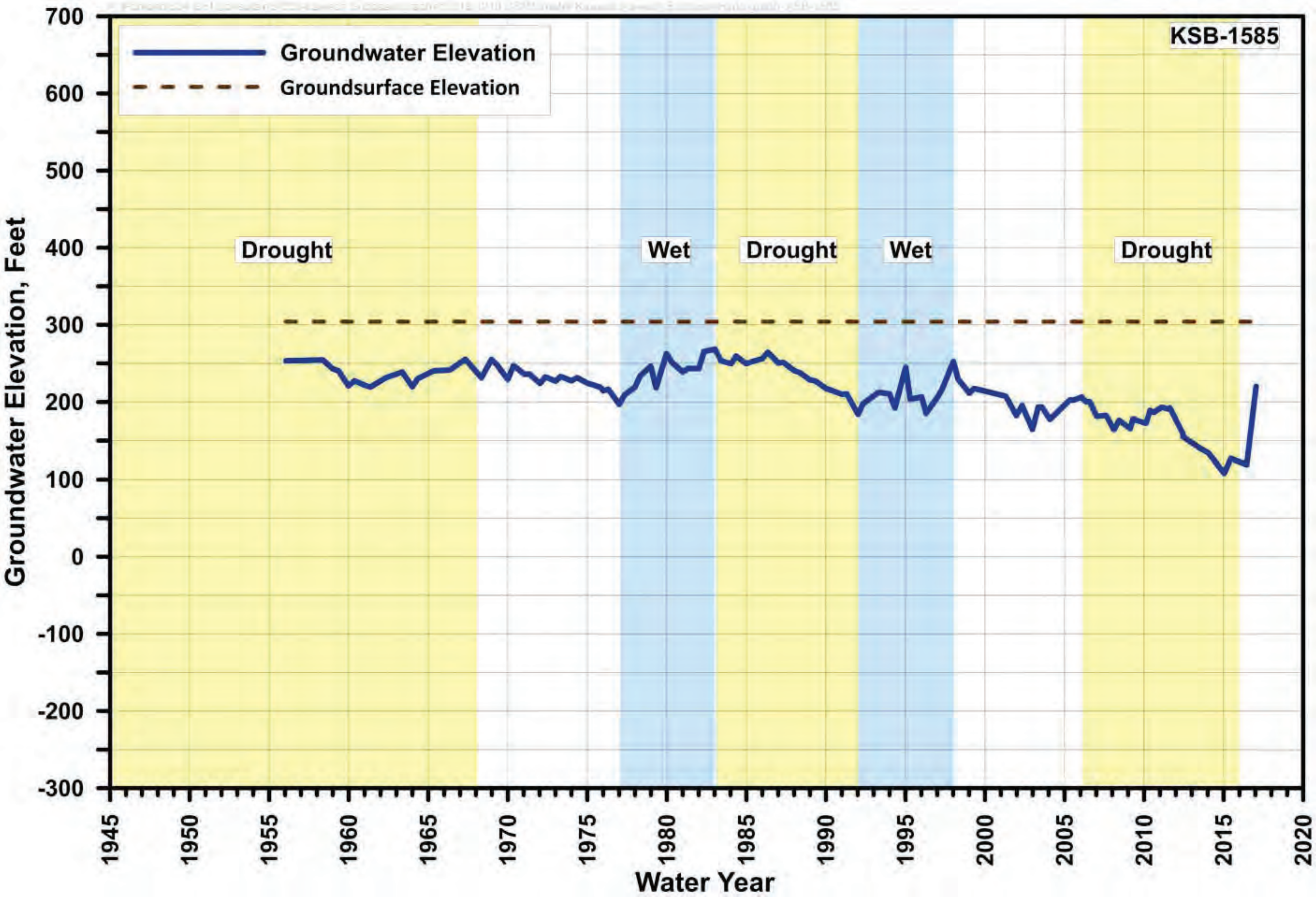
2010
2015
2020
Water Year



KSB-1585
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
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-100
-200
-300
1945
1950
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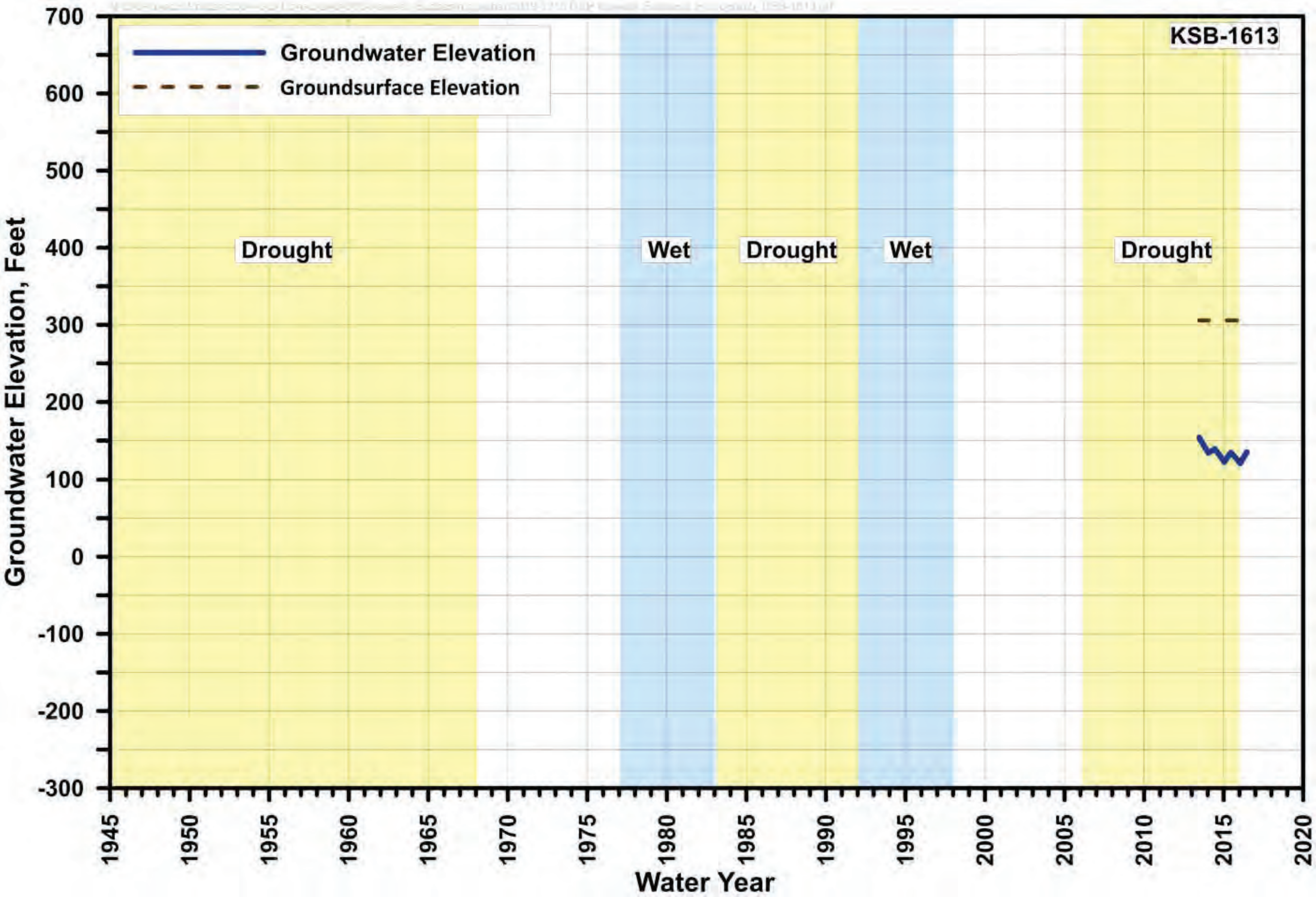
KSB-1613
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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2010
2015
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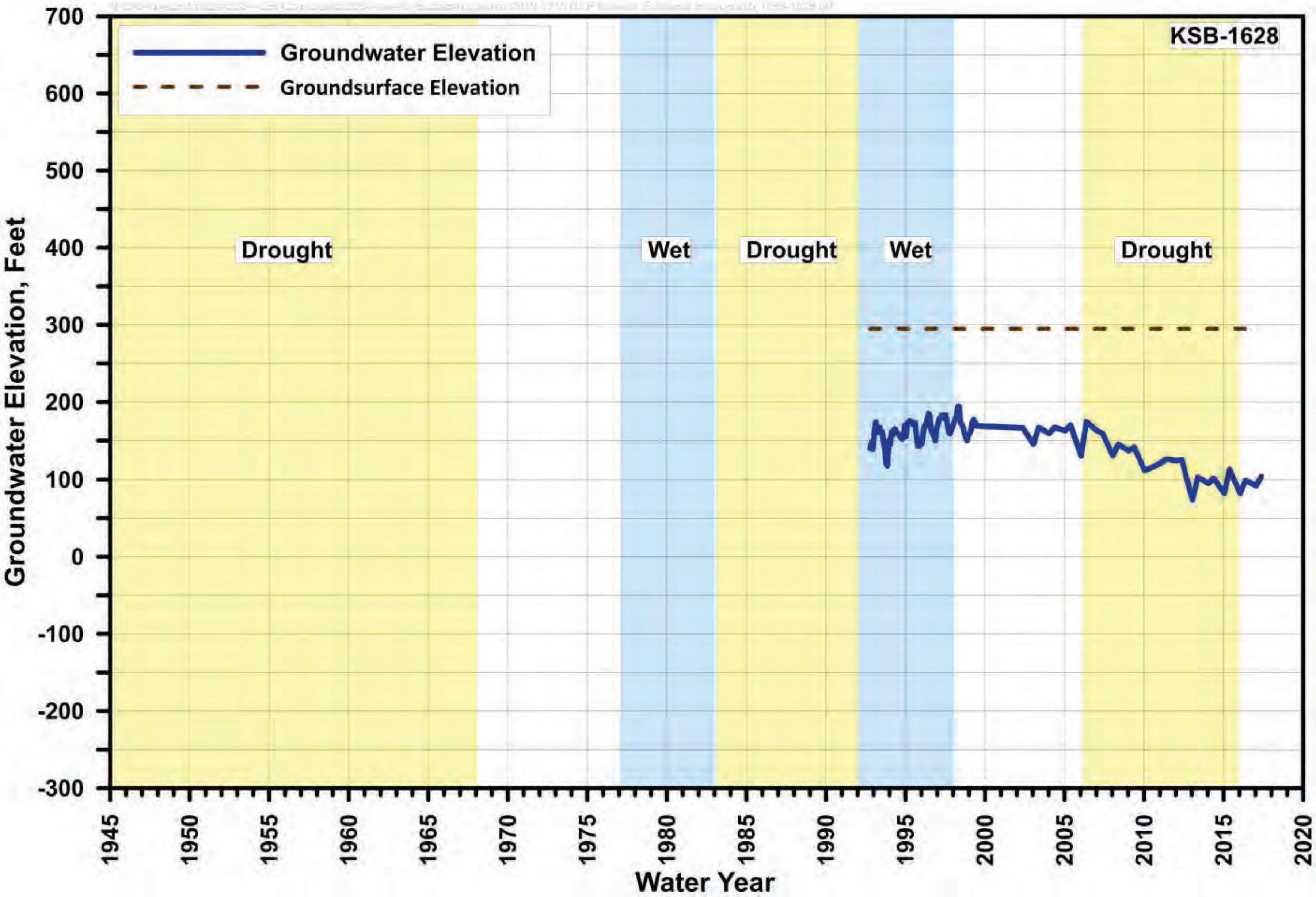

KSB-1628
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
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100
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-300
1945
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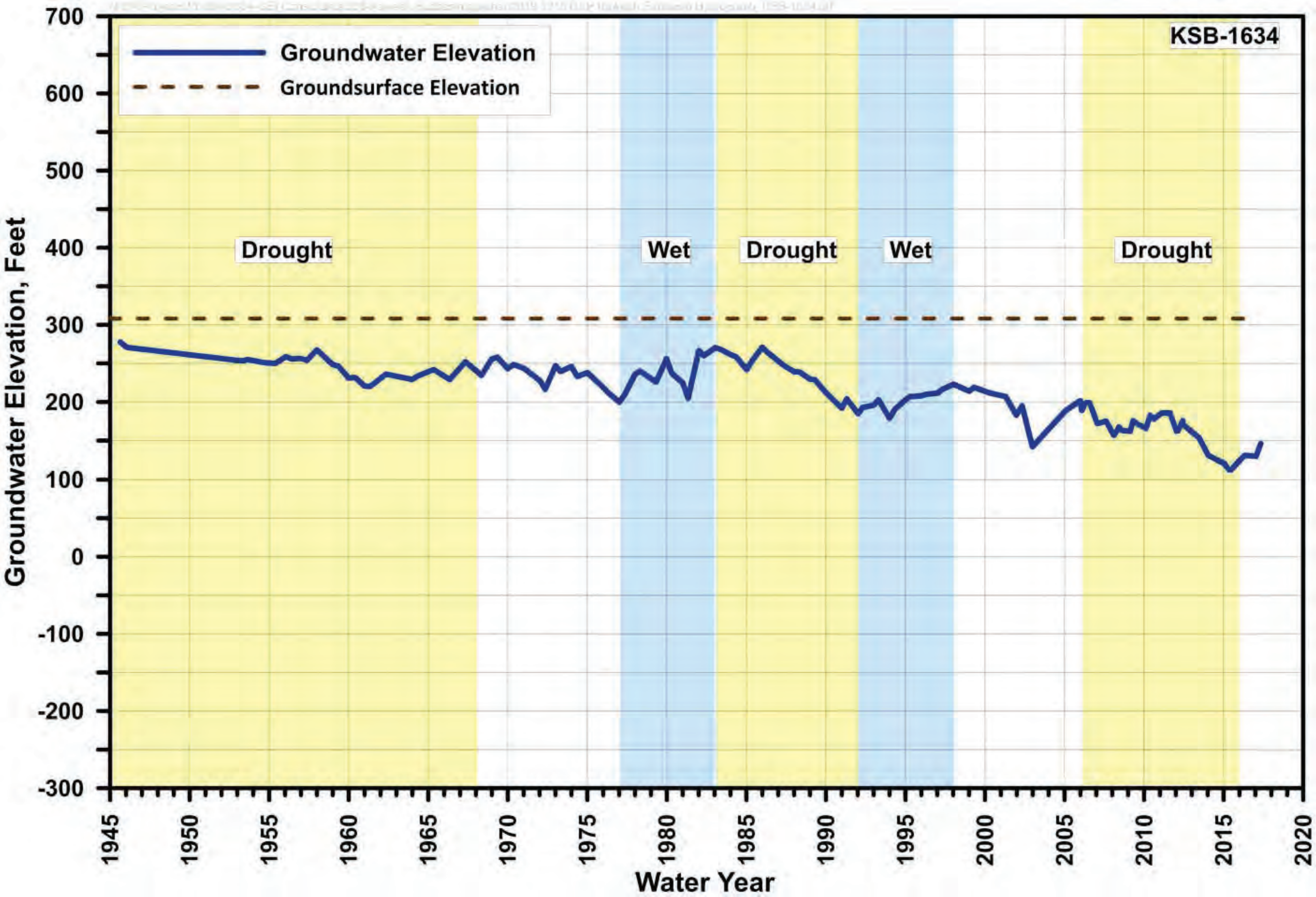
2015
2020
Water Year



KSB-1634
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
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-200
-300
1945
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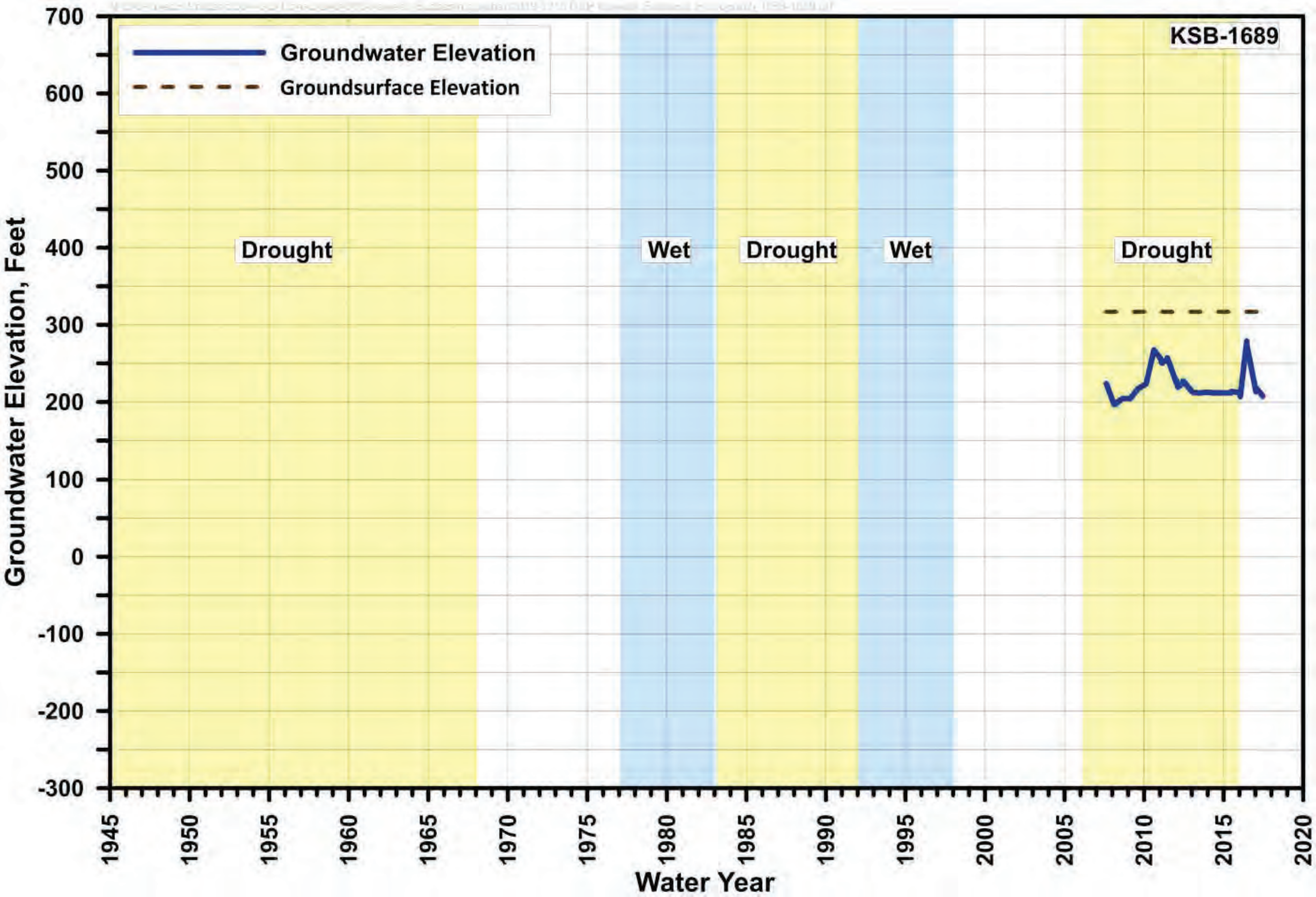
2020



KSB-1689
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
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-100
-200
-300
1945
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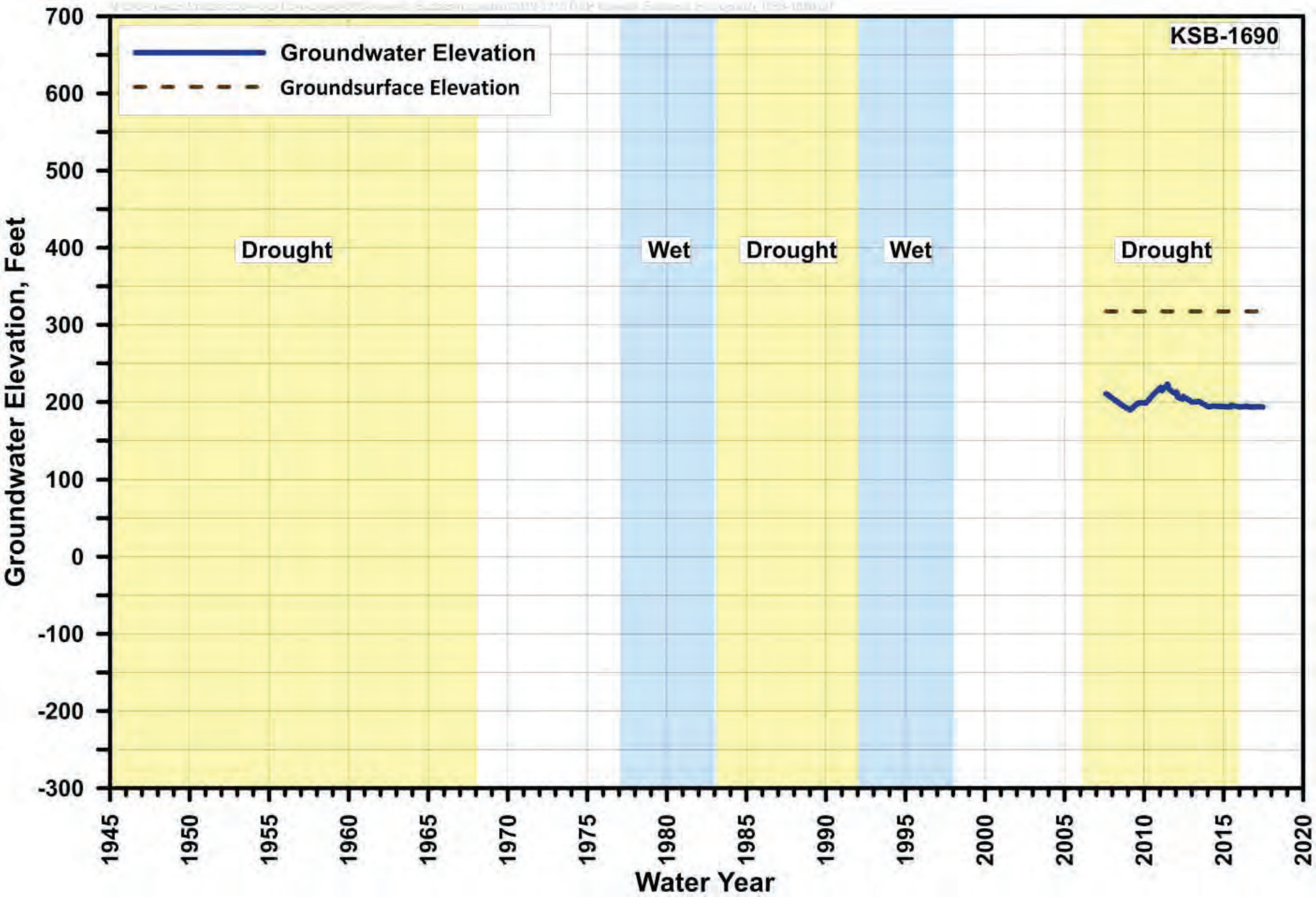
2015
2020
Water Year


KSB-1690
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
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300
200
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-100
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-300
1945
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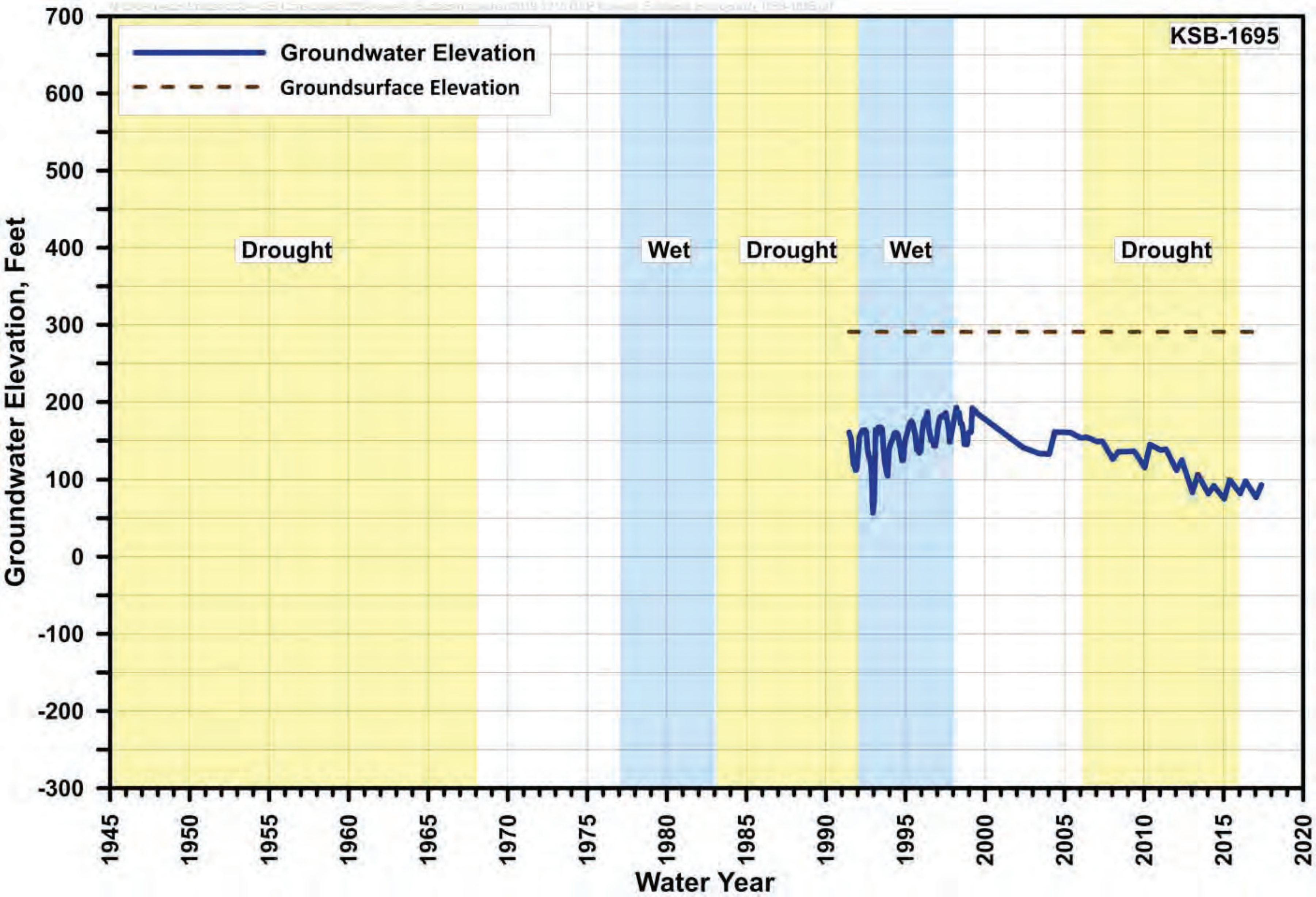
2015
2020
Water Year



KSB-1695
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
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400
300
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100
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-100
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1945
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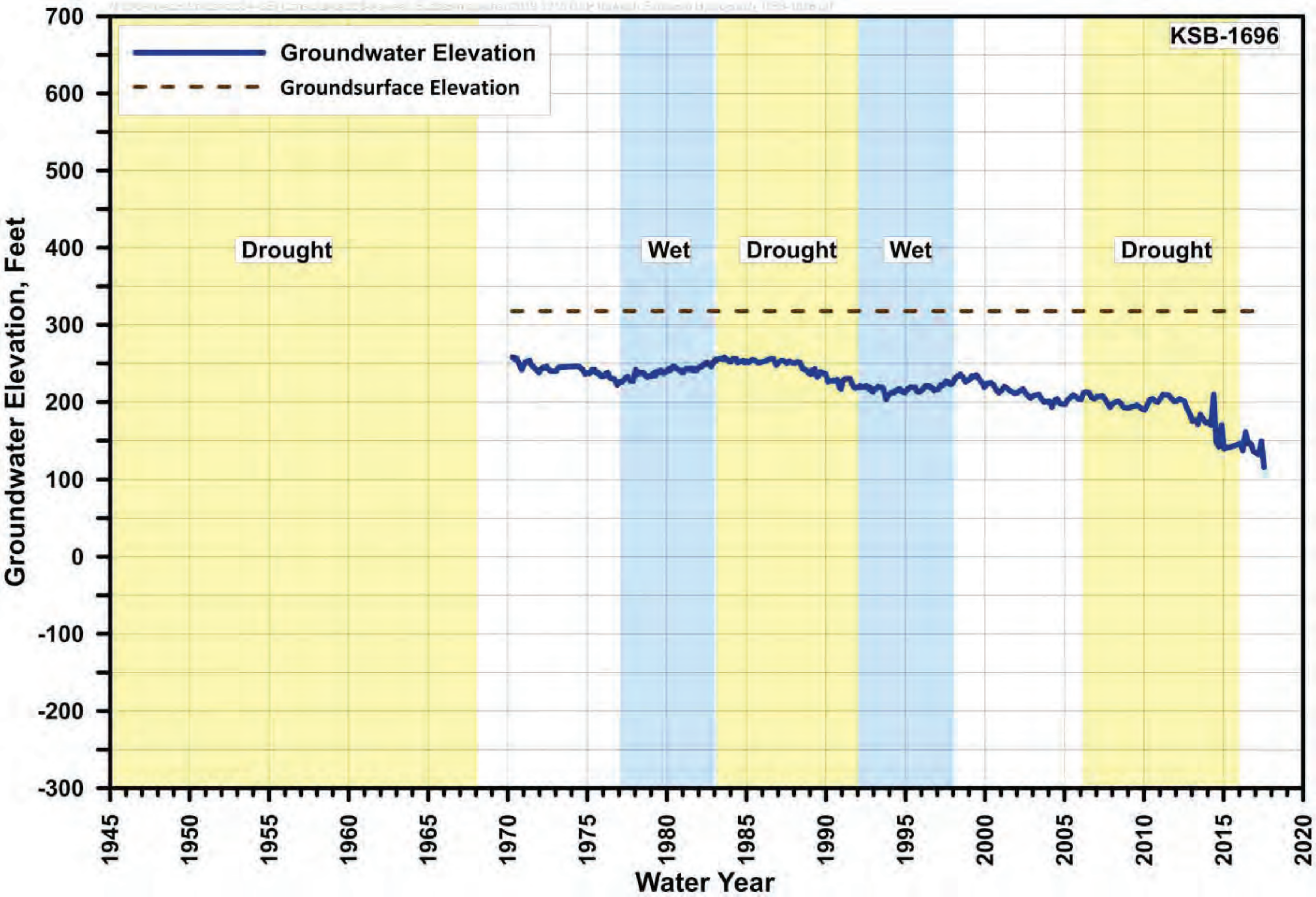
2015
2020
Water Year



KSB-1696
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
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-100
-200
-300
1945
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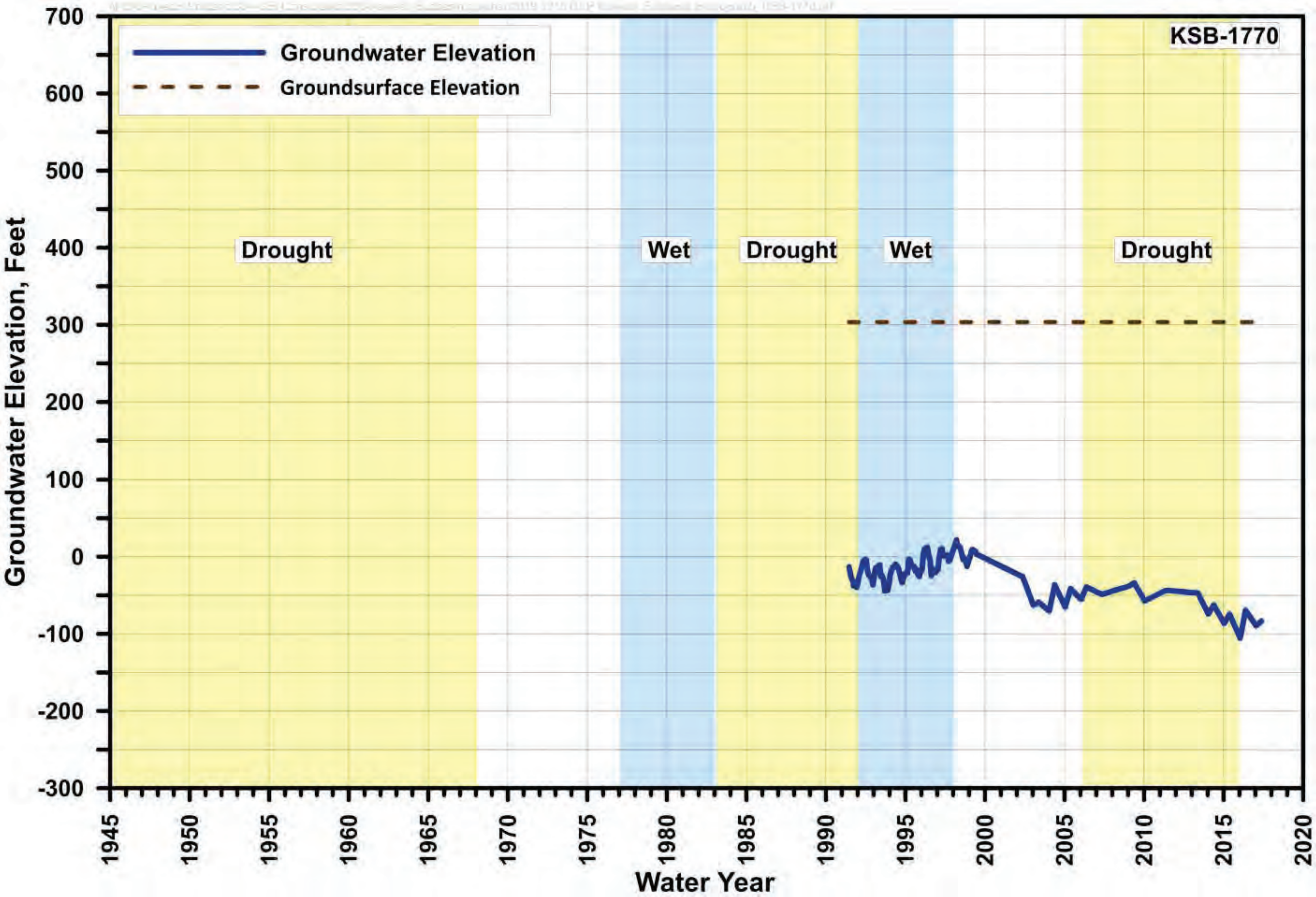
2010
2015
2020
Water Year



Groundwater Elevation
Groundsurface Elevation
KSB-1770
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
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1945
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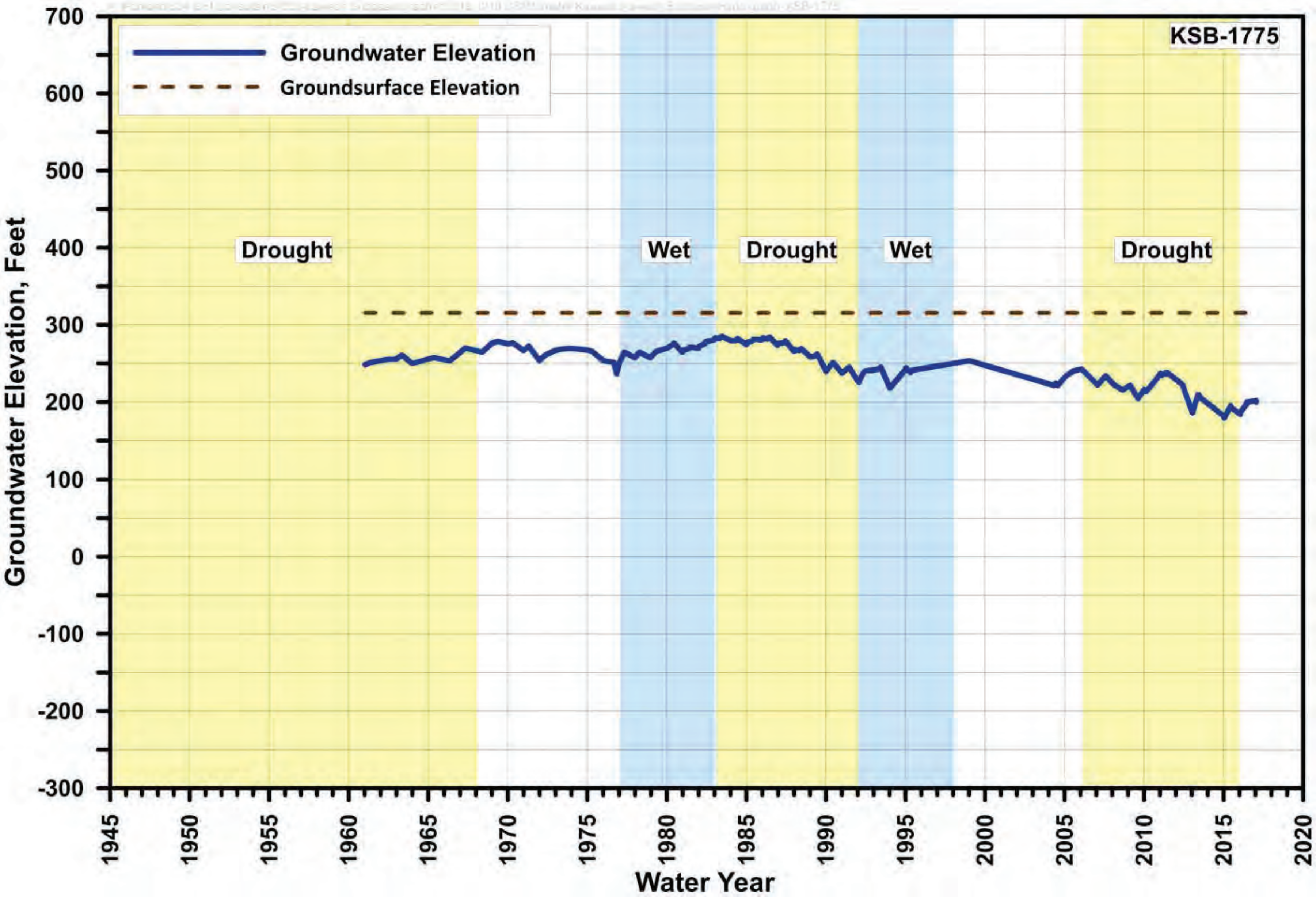
2010
2015
2020
Water Year



KSB-1775
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
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-200
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1945
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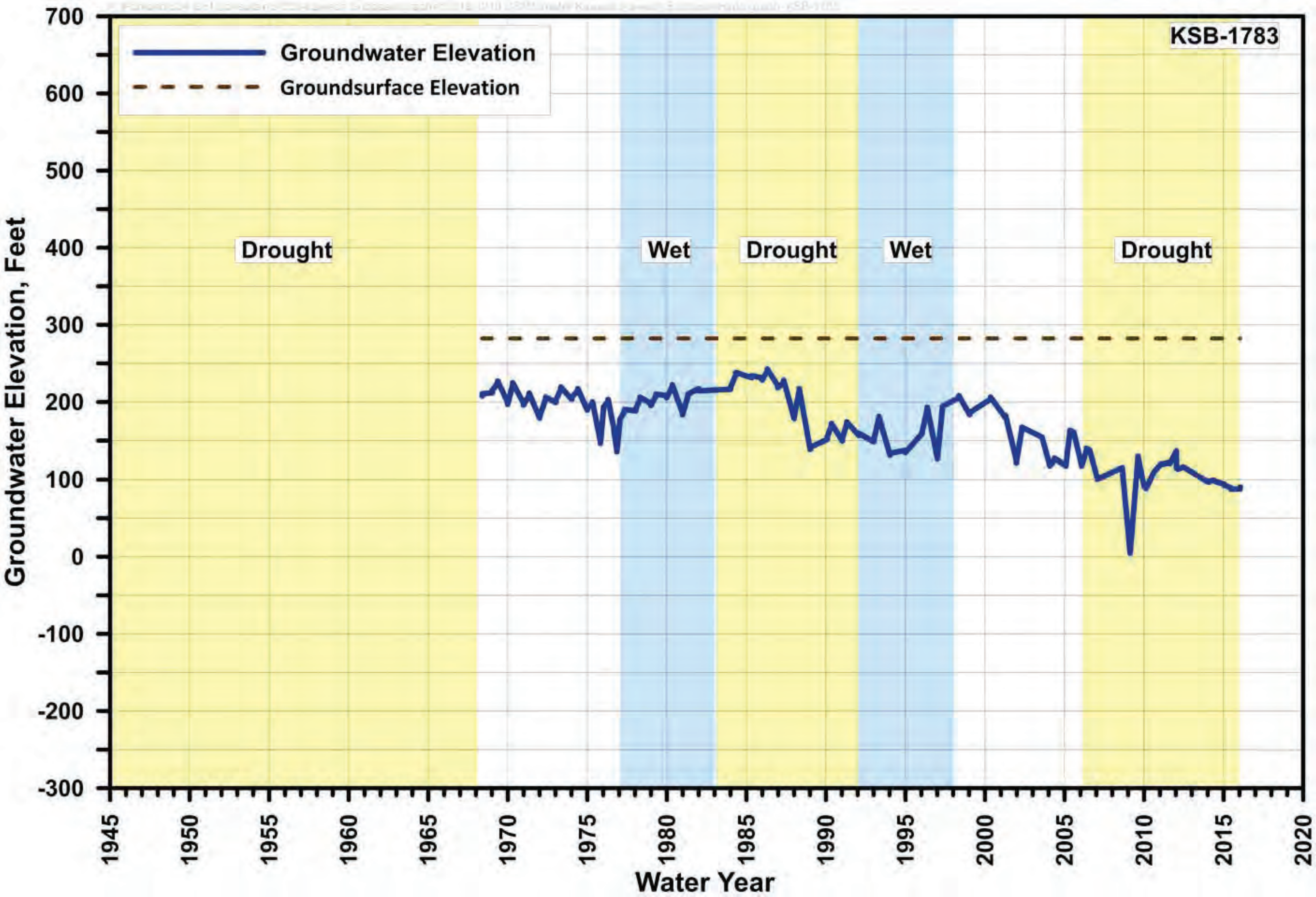
2015
2020



KSB-1783
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
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-200
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1945
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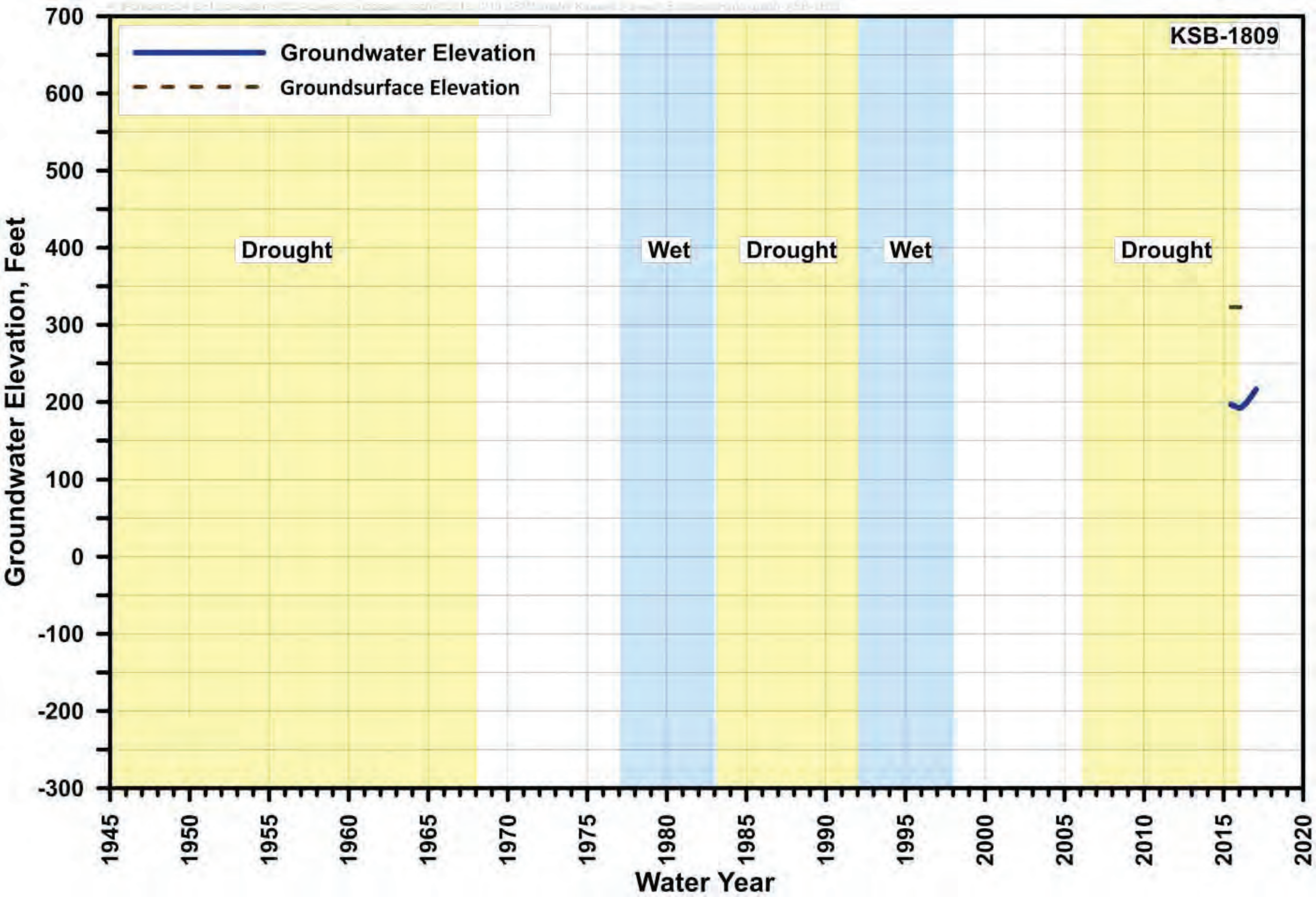
KSB-1809
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
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500
400
300
200
100
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-200
-300
1945
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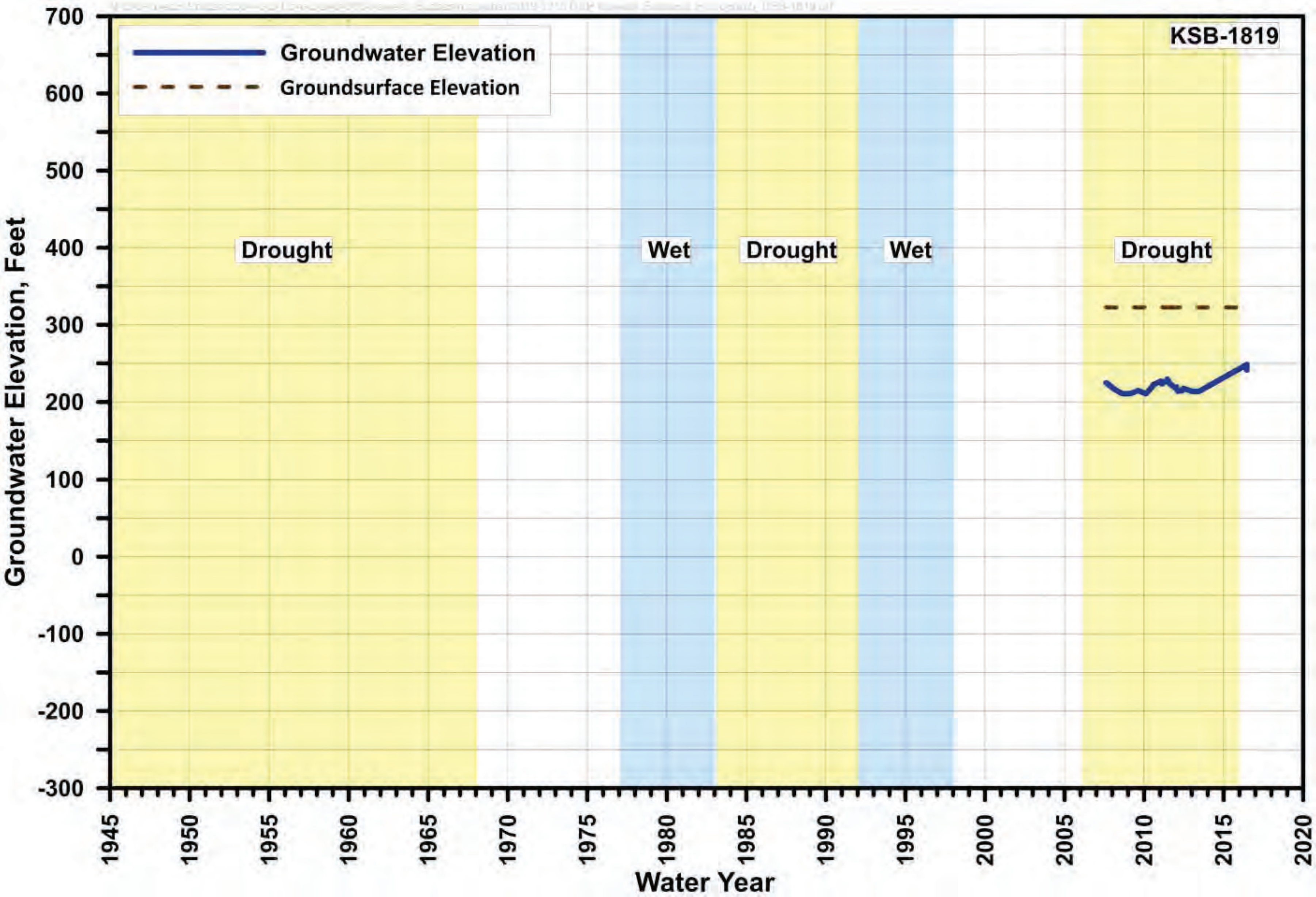

KSB-1819
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
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500
400
300
200
100
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1945
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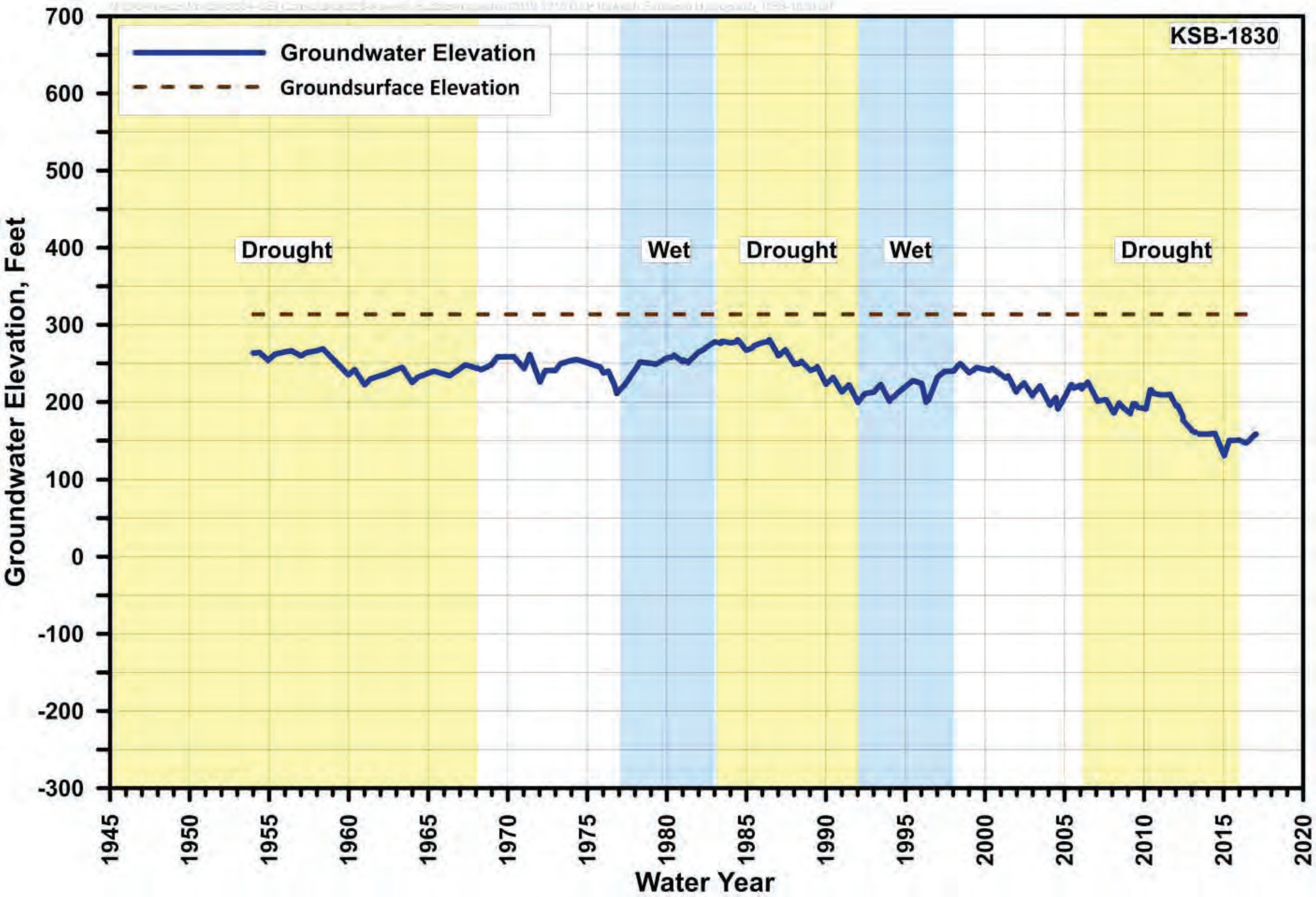

KSB-1830
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
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1945
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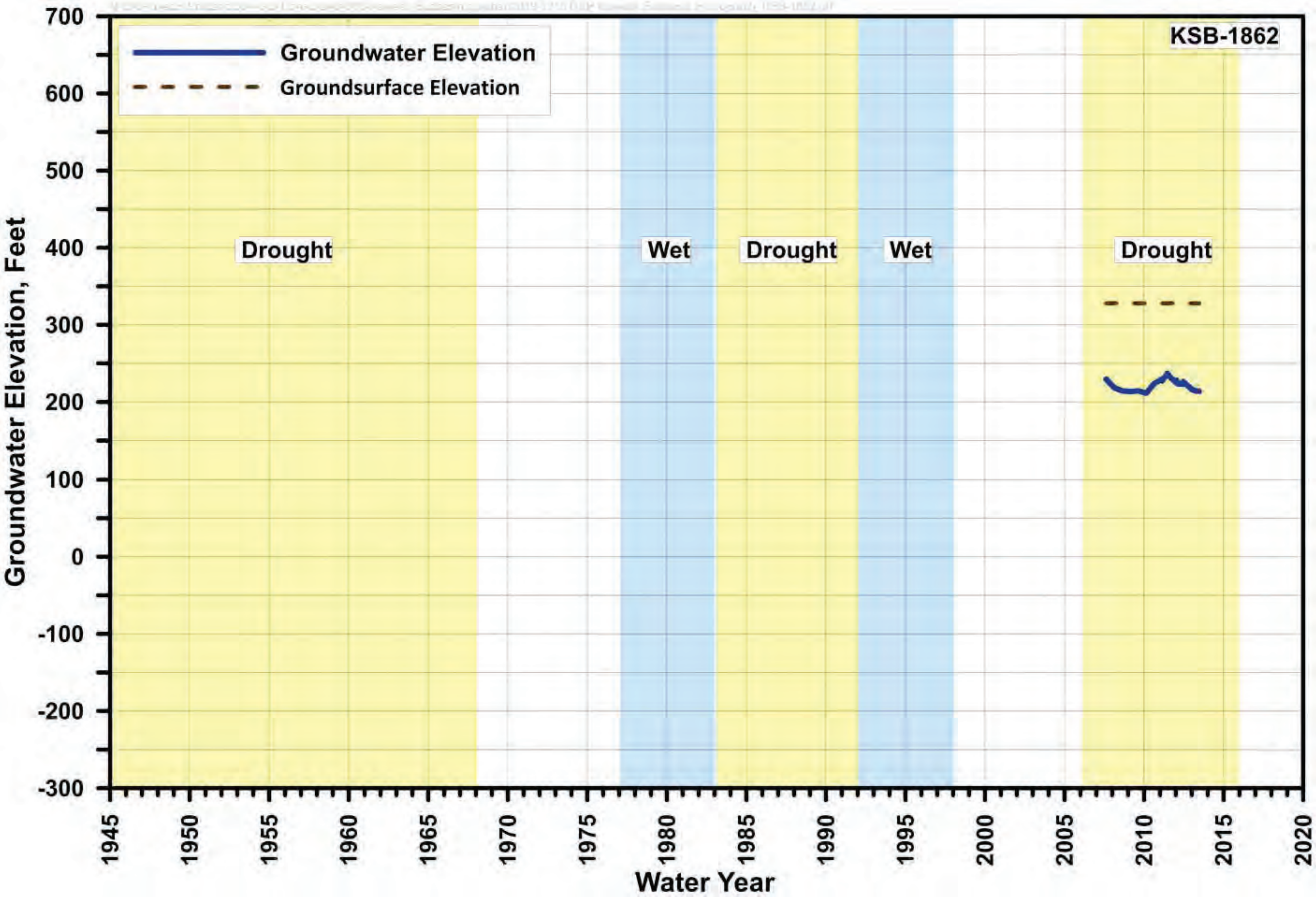

KSB-1862
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
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1945
1950
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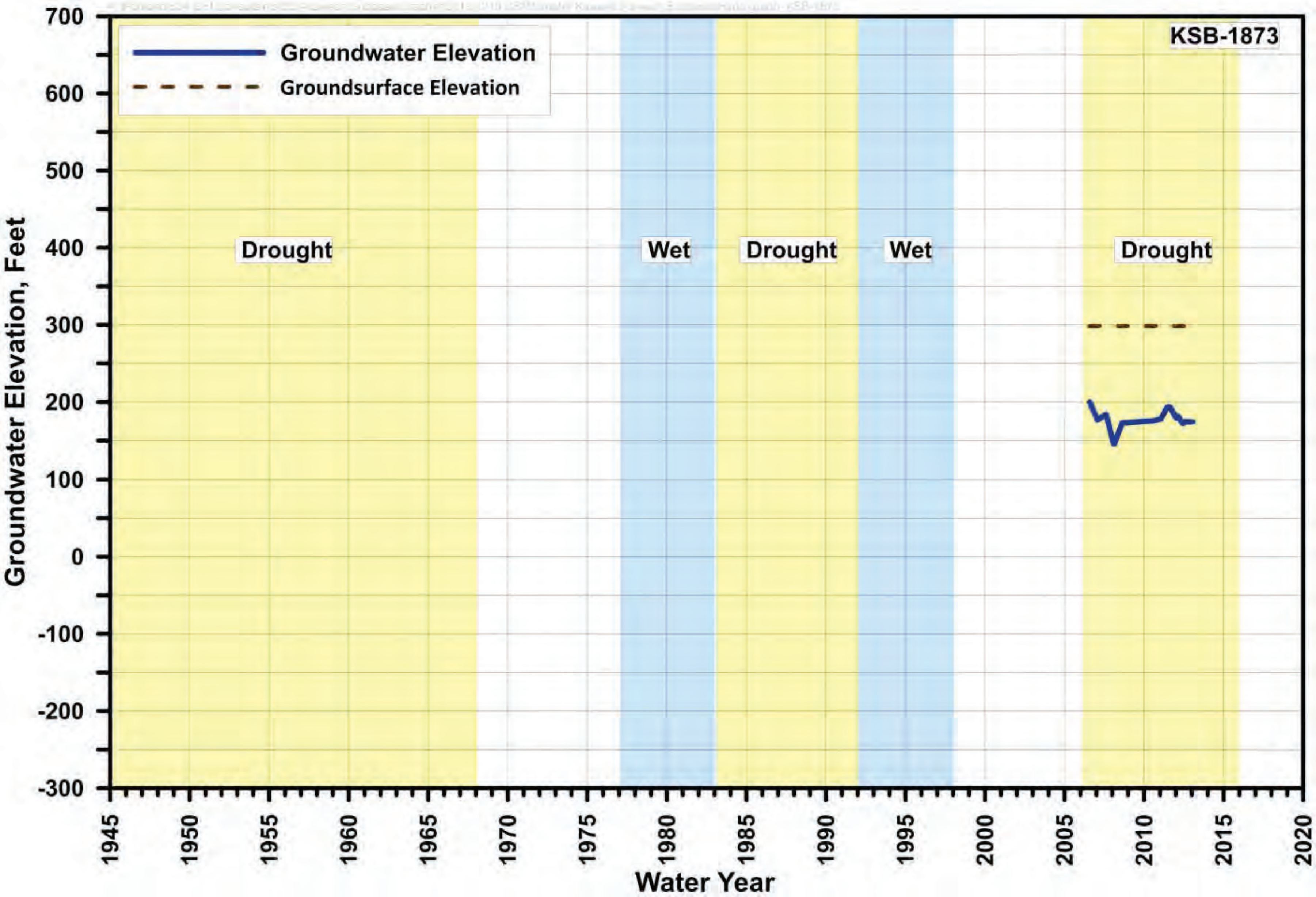
2015
2020
Water Year



KSB-1873
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
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1945
1950
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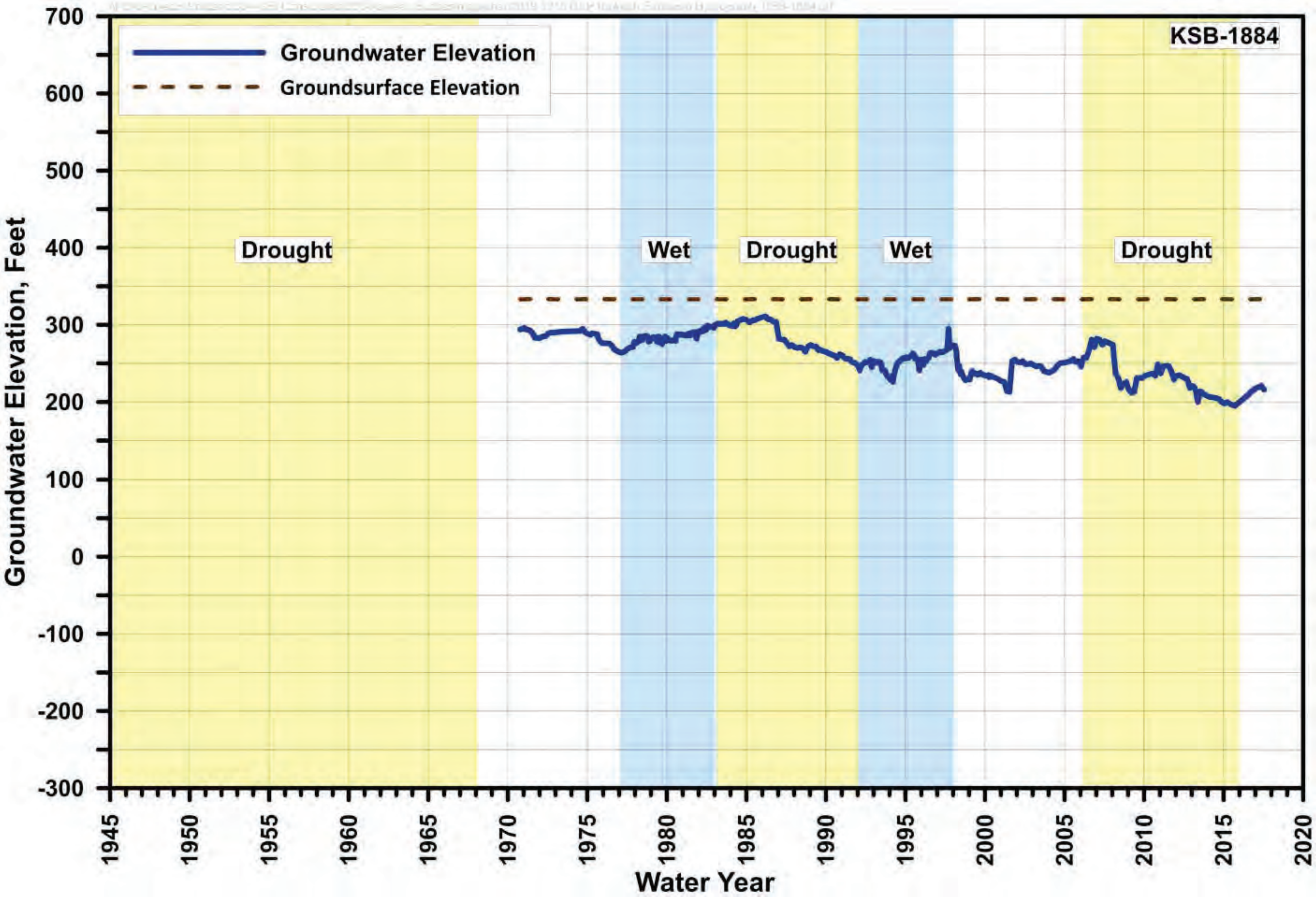
KSB-1884
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
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200
100
0
-100
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1945
1950
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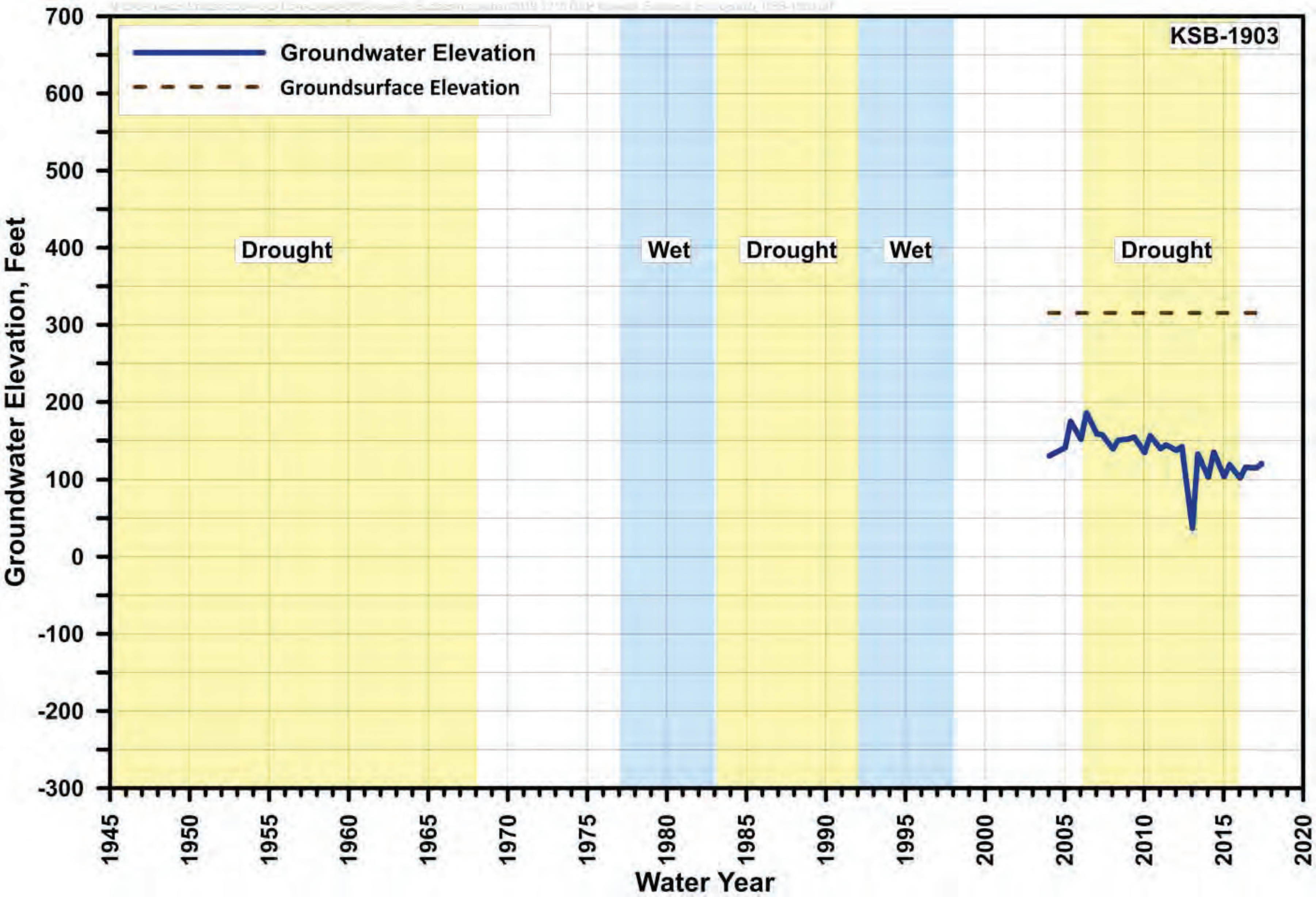
2015
2020
Water Year



Groundwater Elevation
Groundsurface Elevation
KSB-1903
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
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300
200
100
0
-100
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1945
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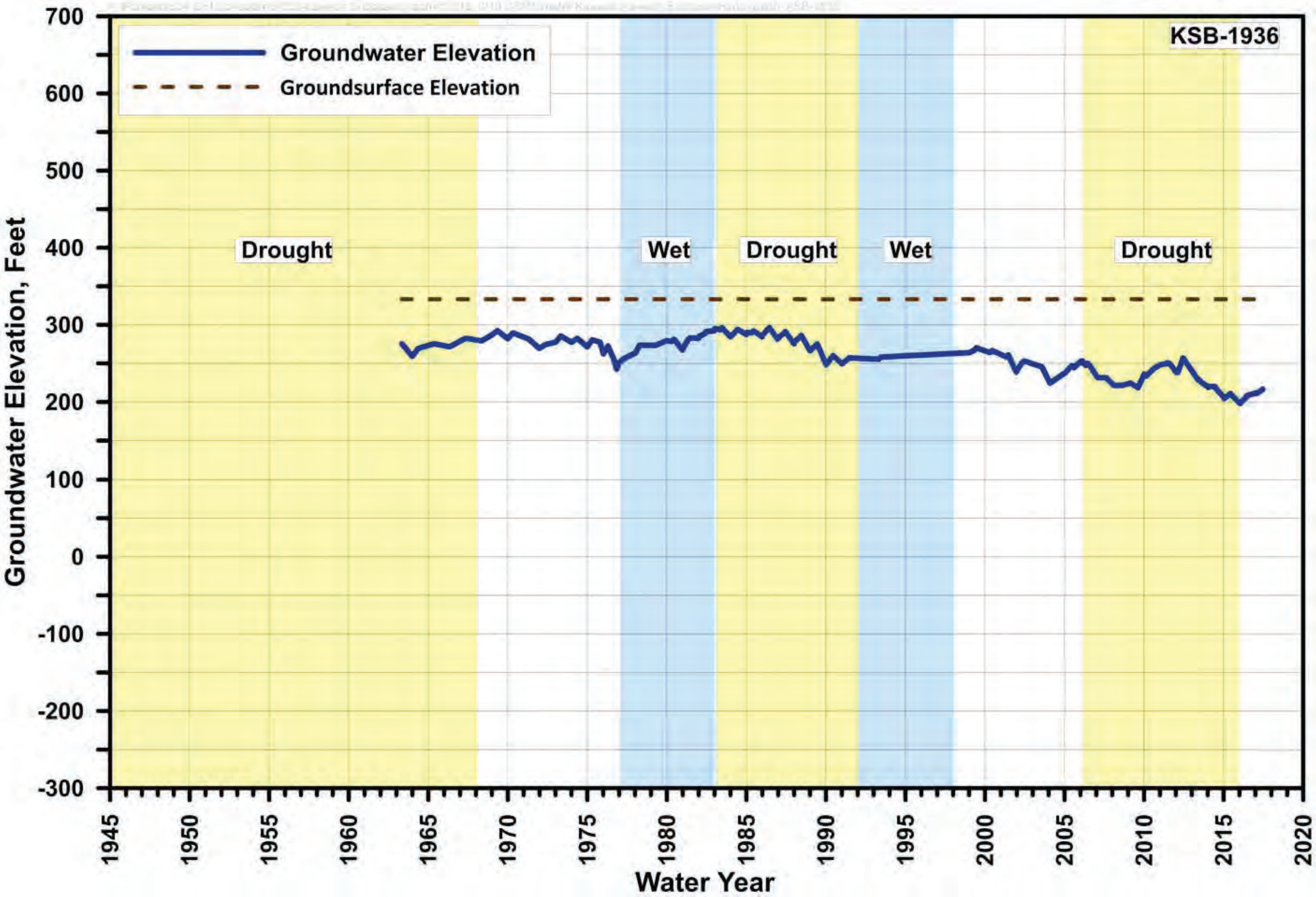
2015
2020
Water Year



KSB-1936
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
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200
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-100
-200
-300
1945
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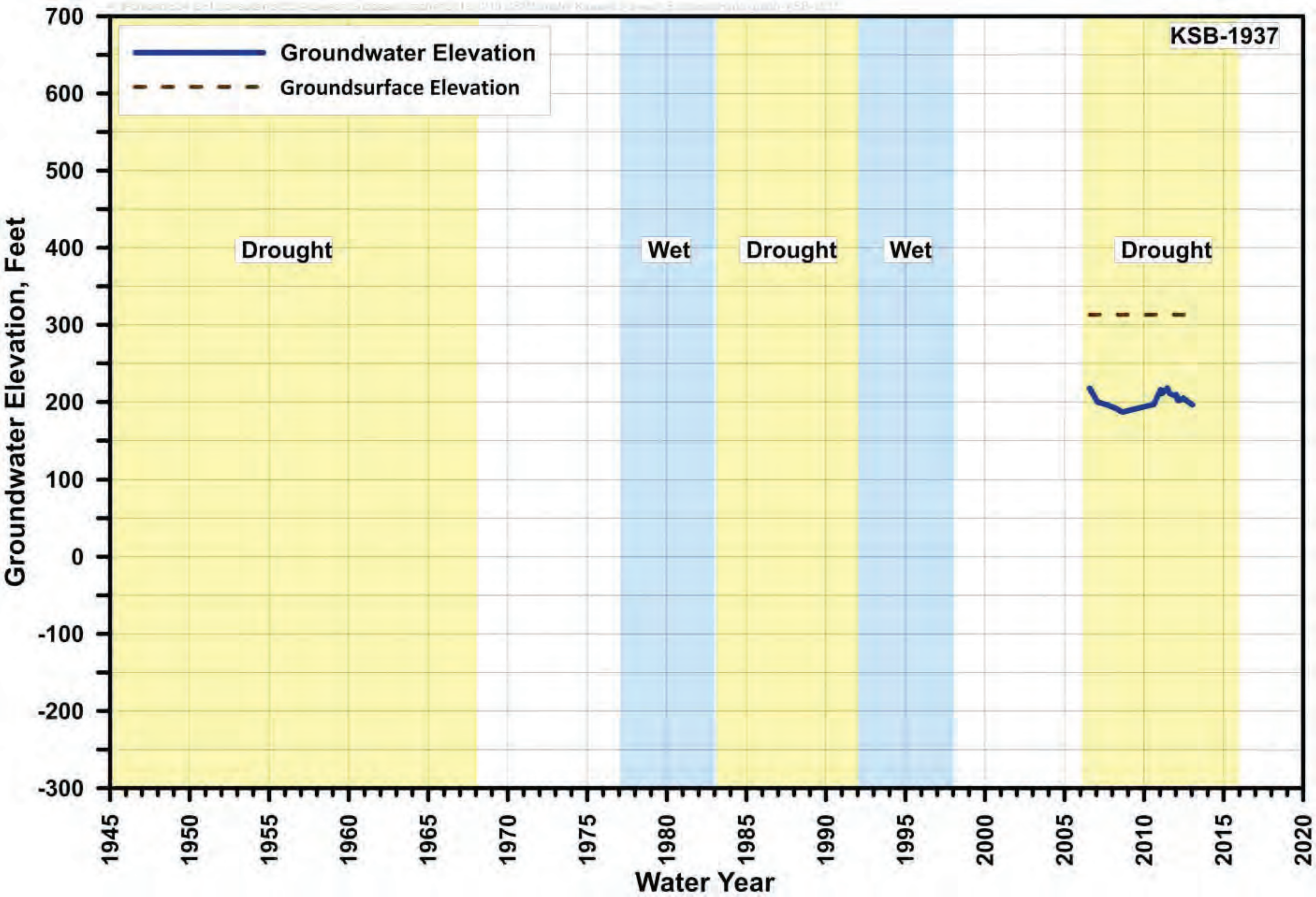
2015
2020
Water Year


KSB-1937
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
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-100
-200
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1945
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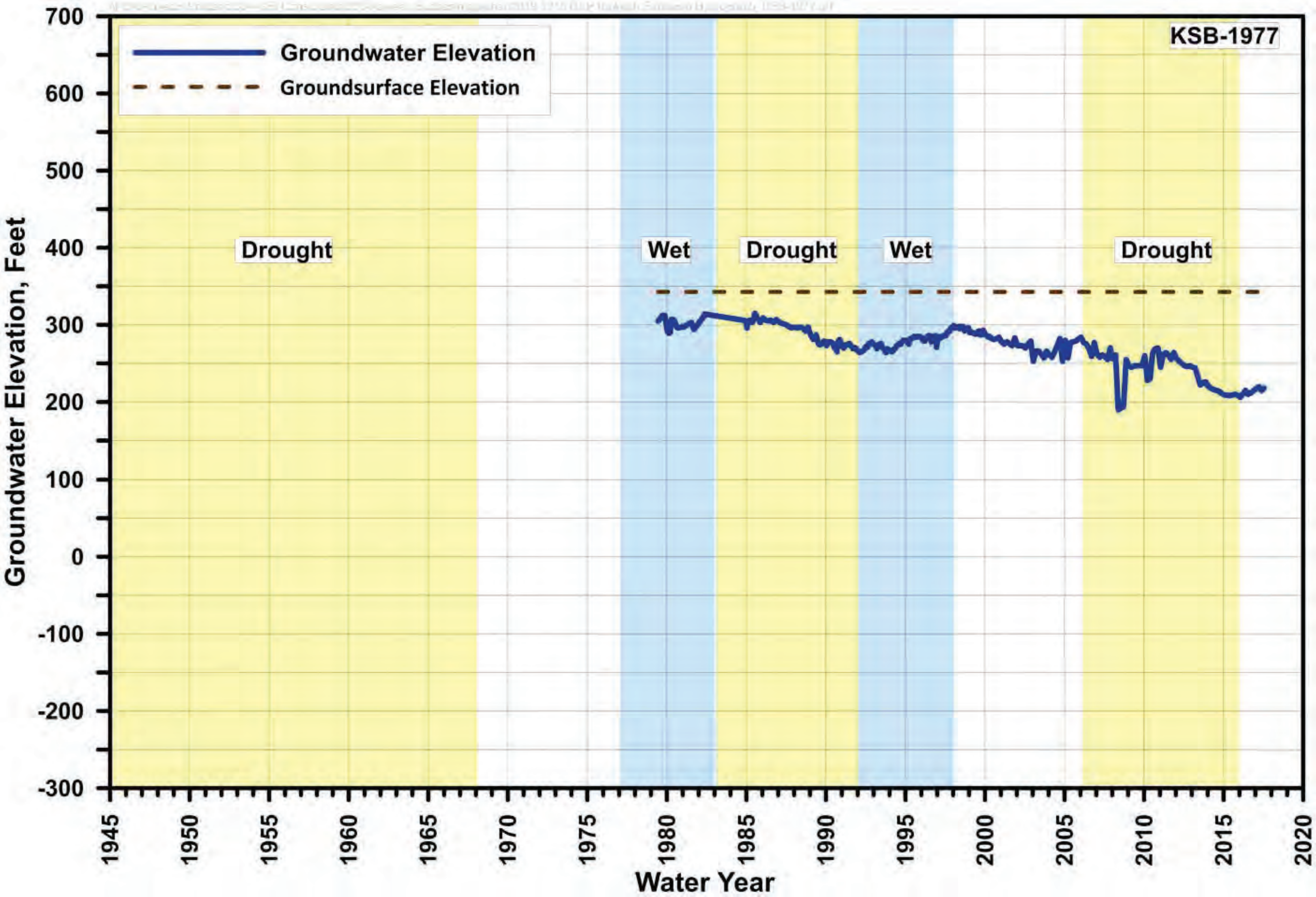

KSB-1977
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
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-100
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1945
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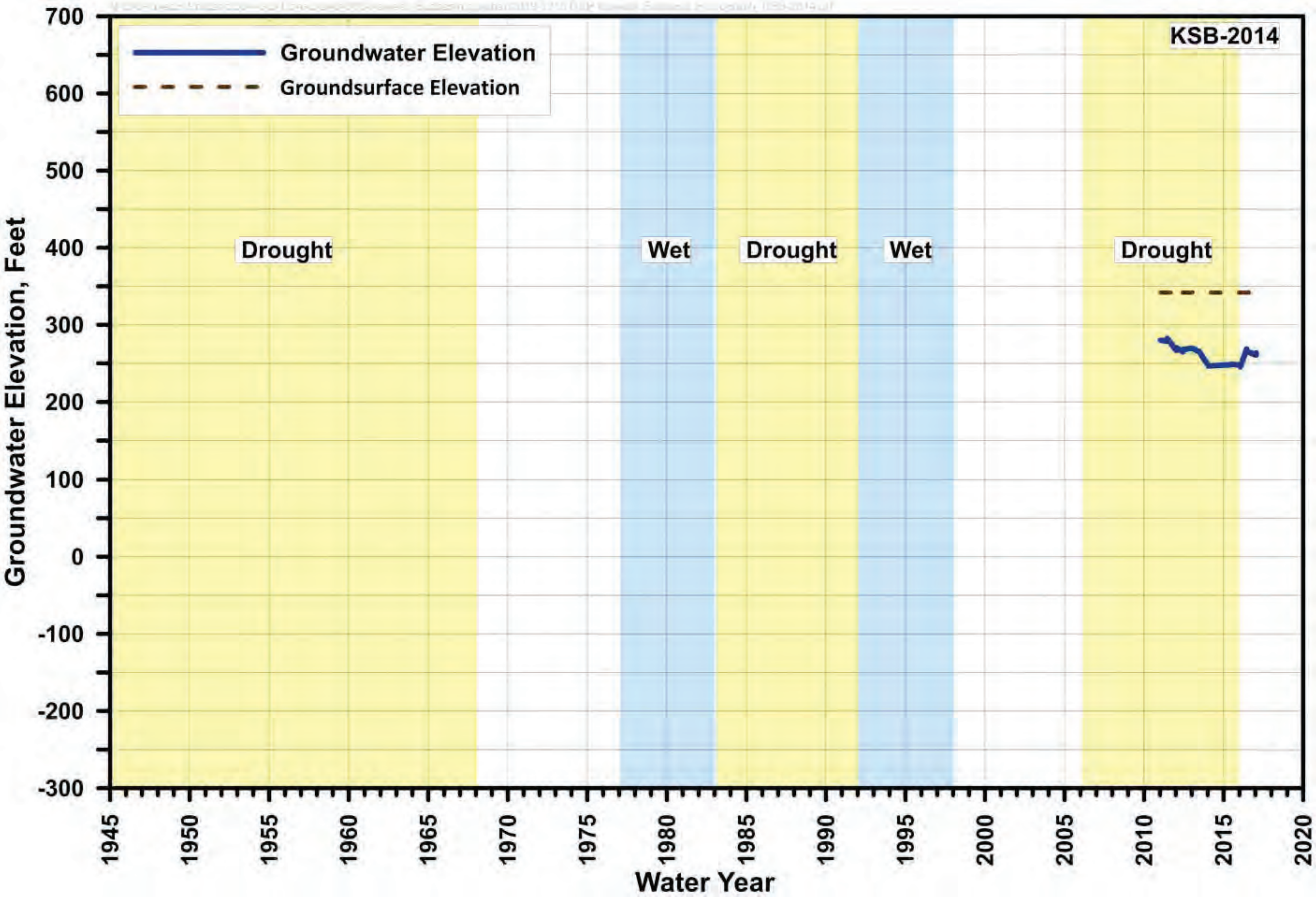

KSB-2014
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
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-100
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1945
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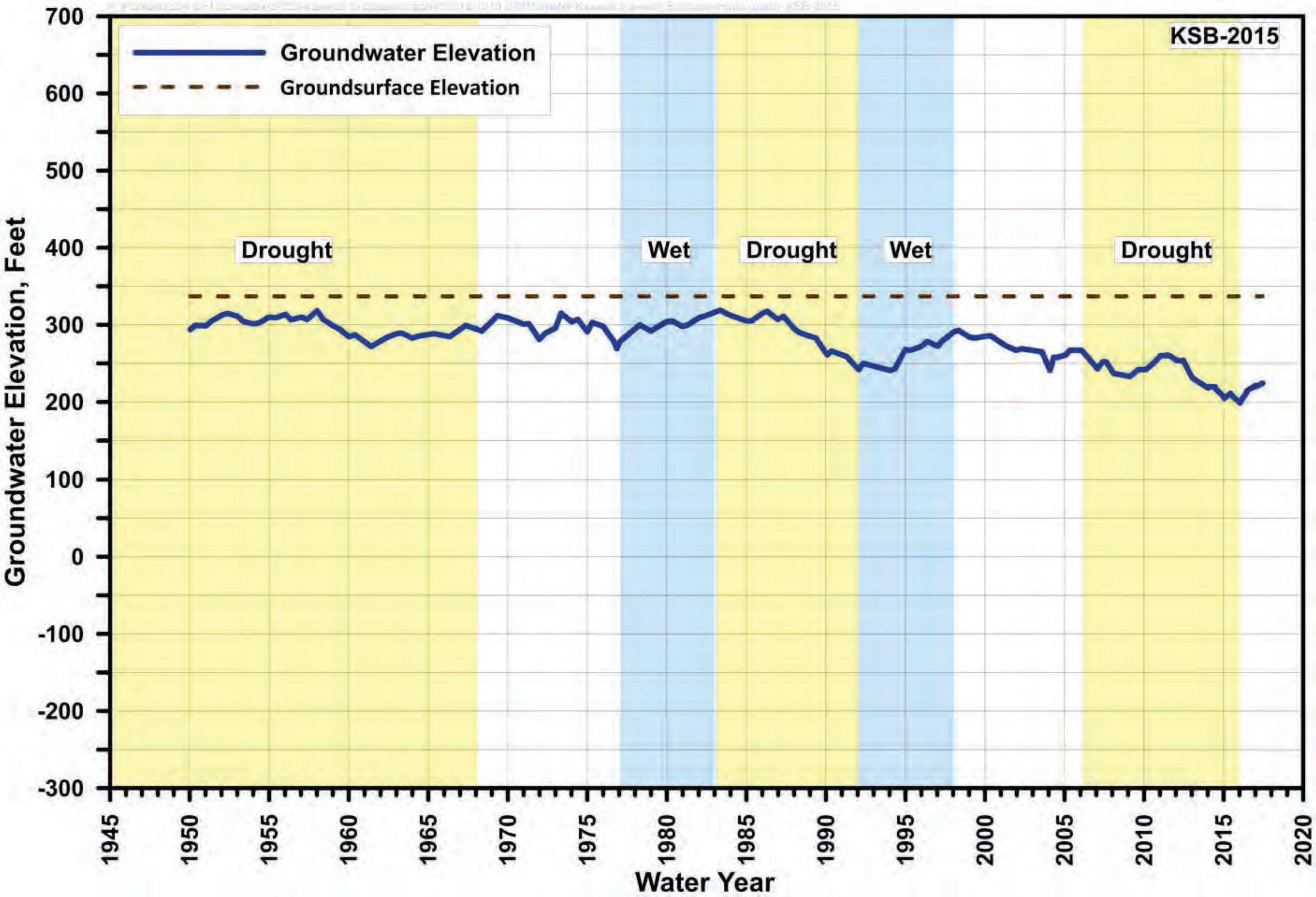

KSB-2015
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
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-100
-200
-300
1945
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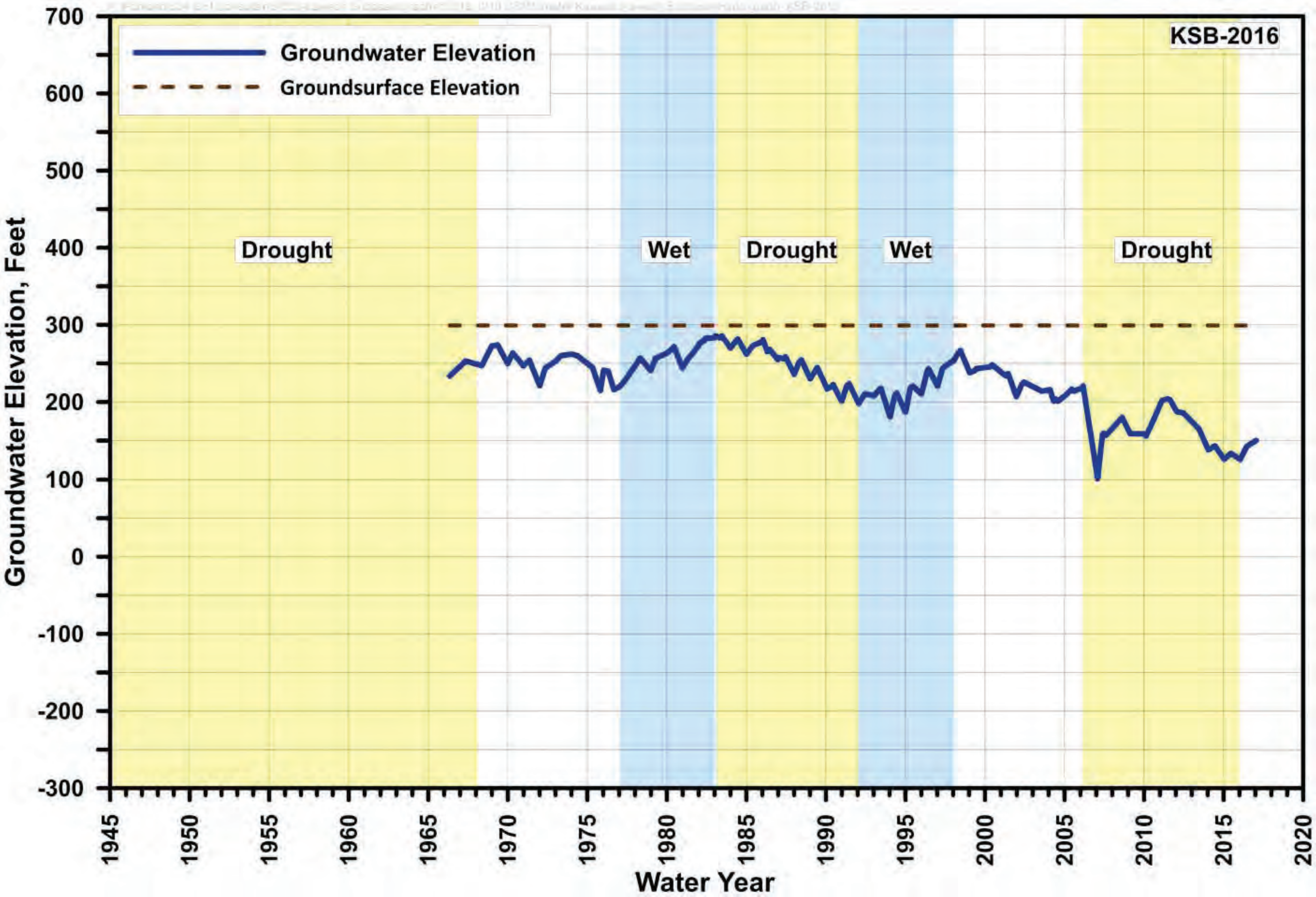
2015
2020
Water Year



Groundwater Elevation
Groundsurface Elevation
KSB-2016
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
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-100
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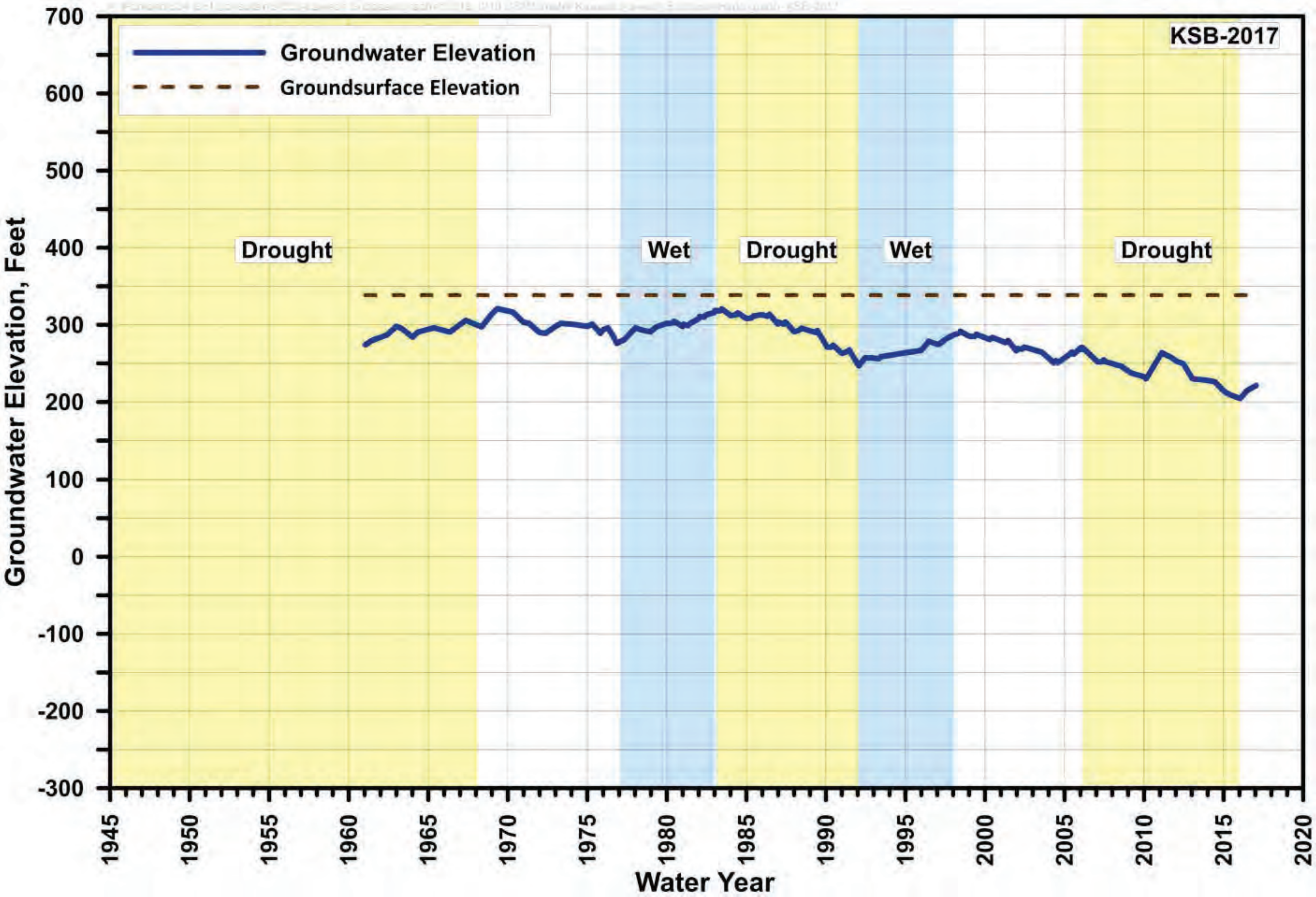
2020
Water Year



KSB-2017
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
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-100
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-300
1945
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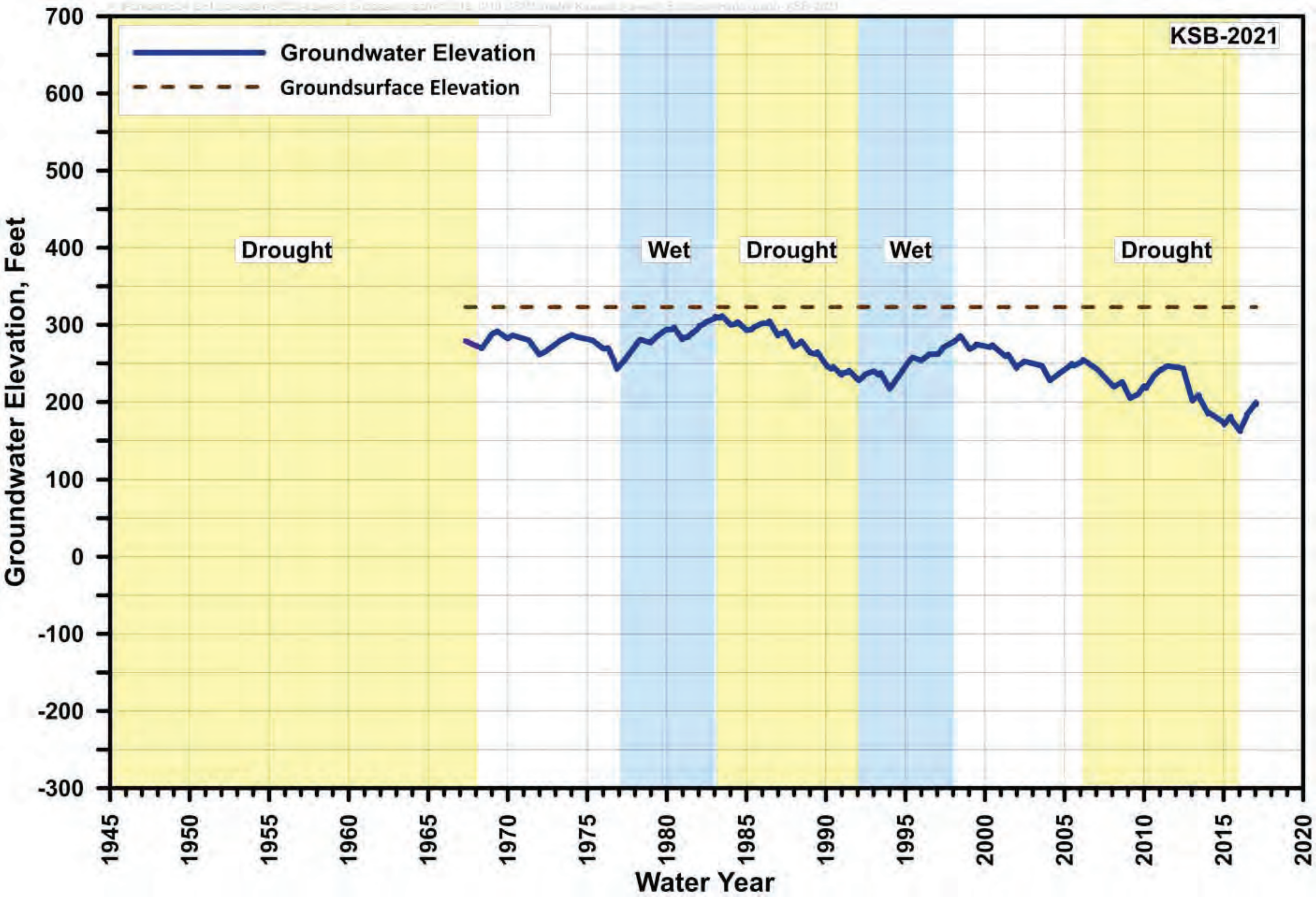
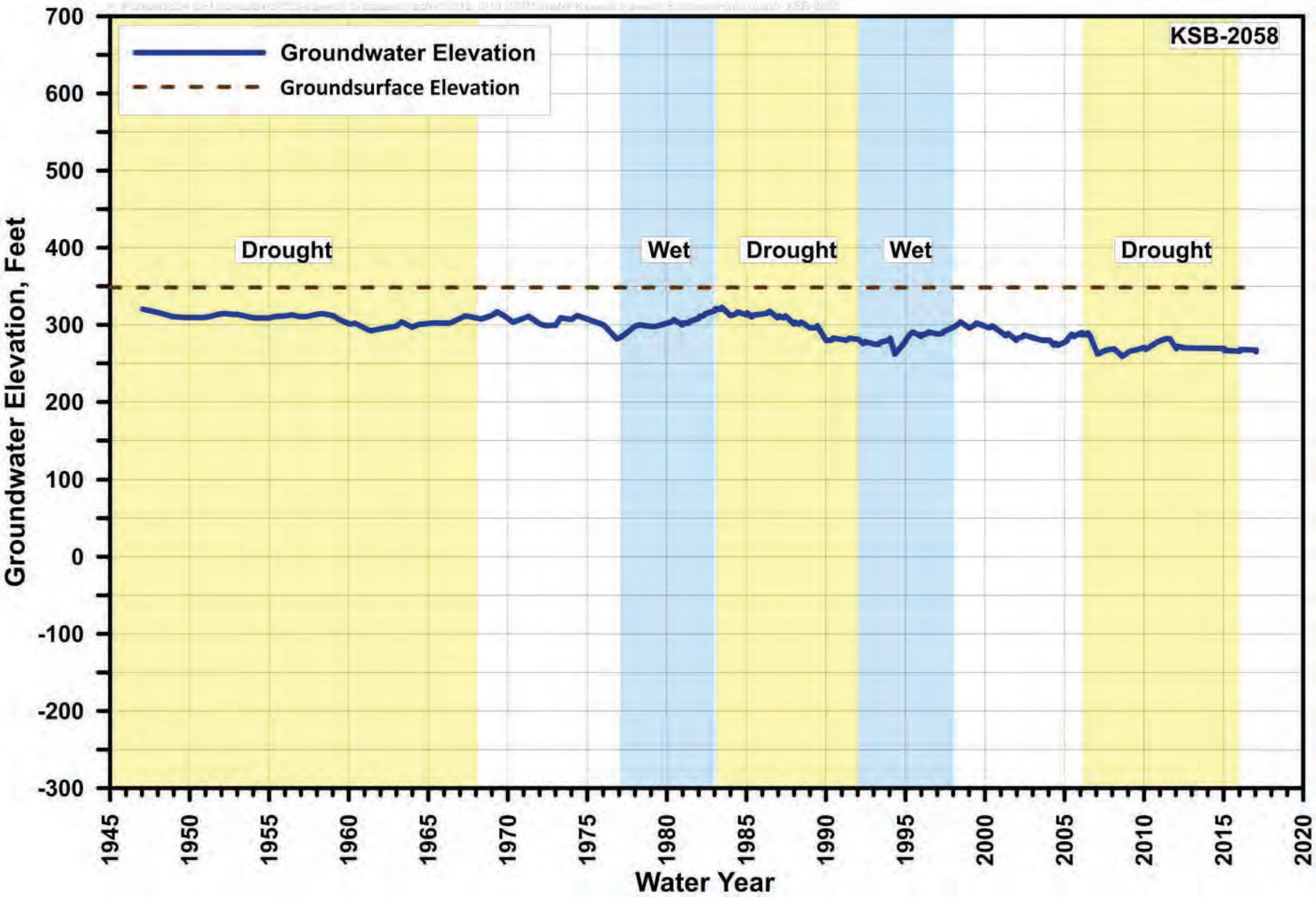
2015
2020



KSB-2021
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-2058
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
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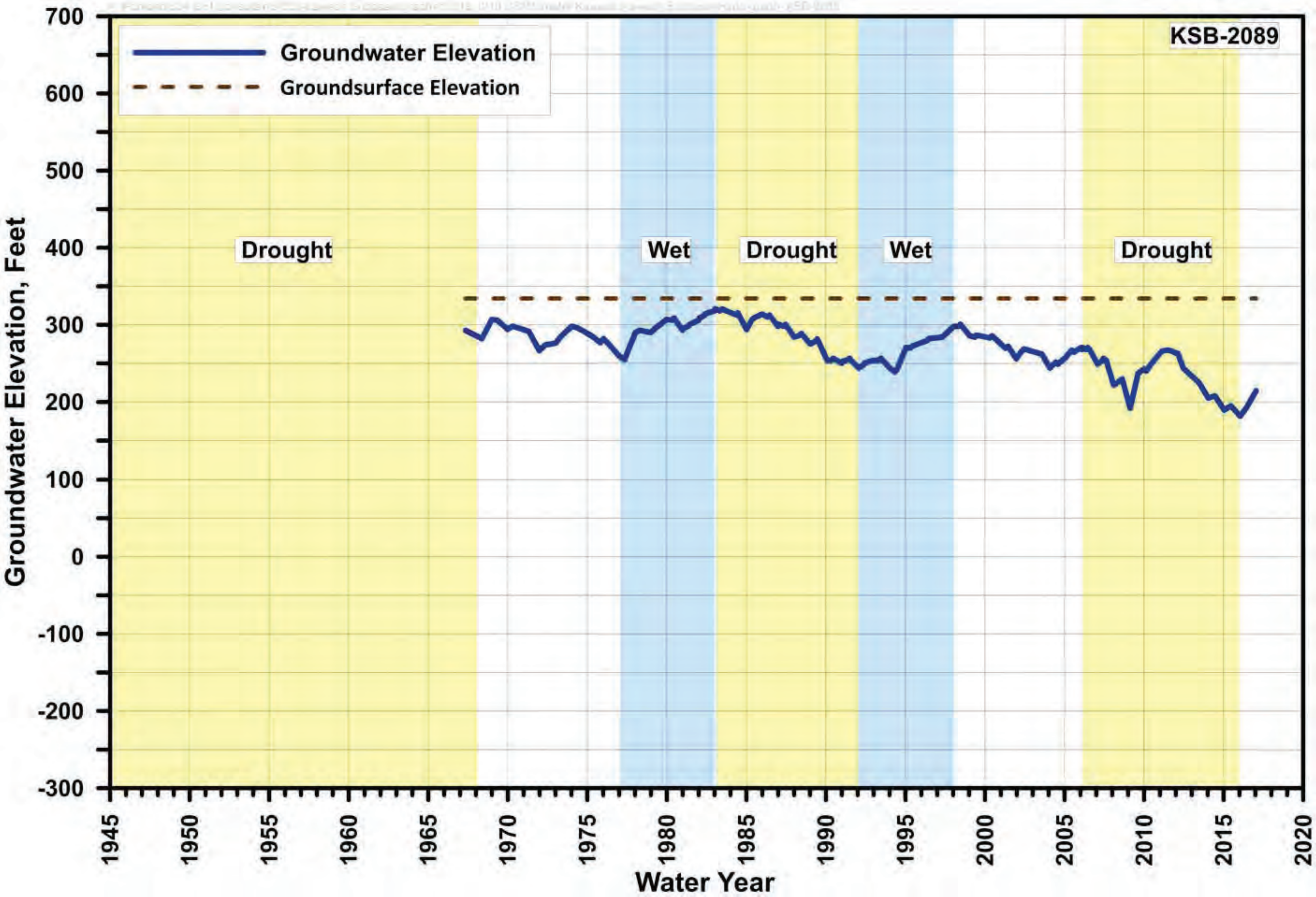
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020



KSB-2089
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
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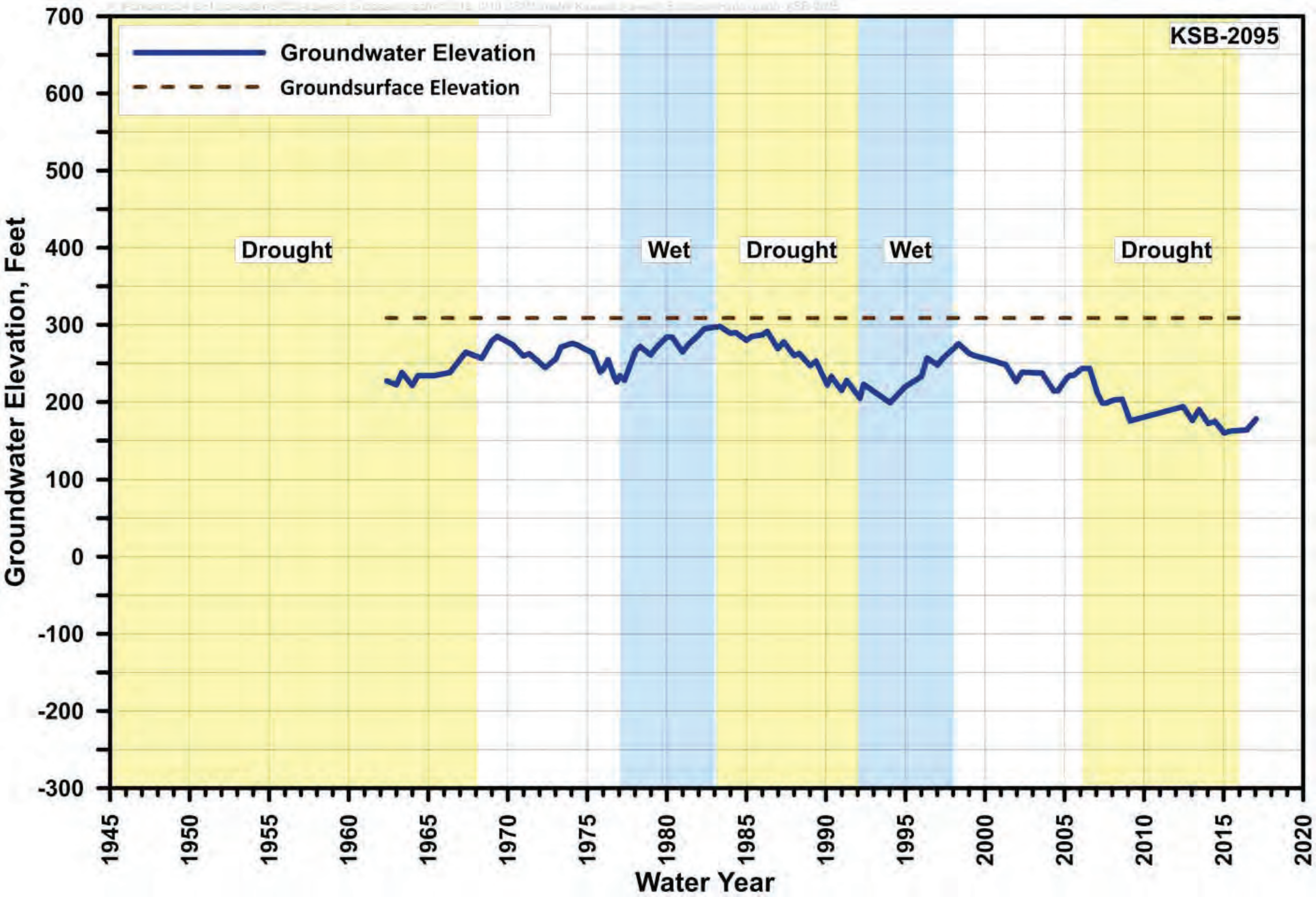
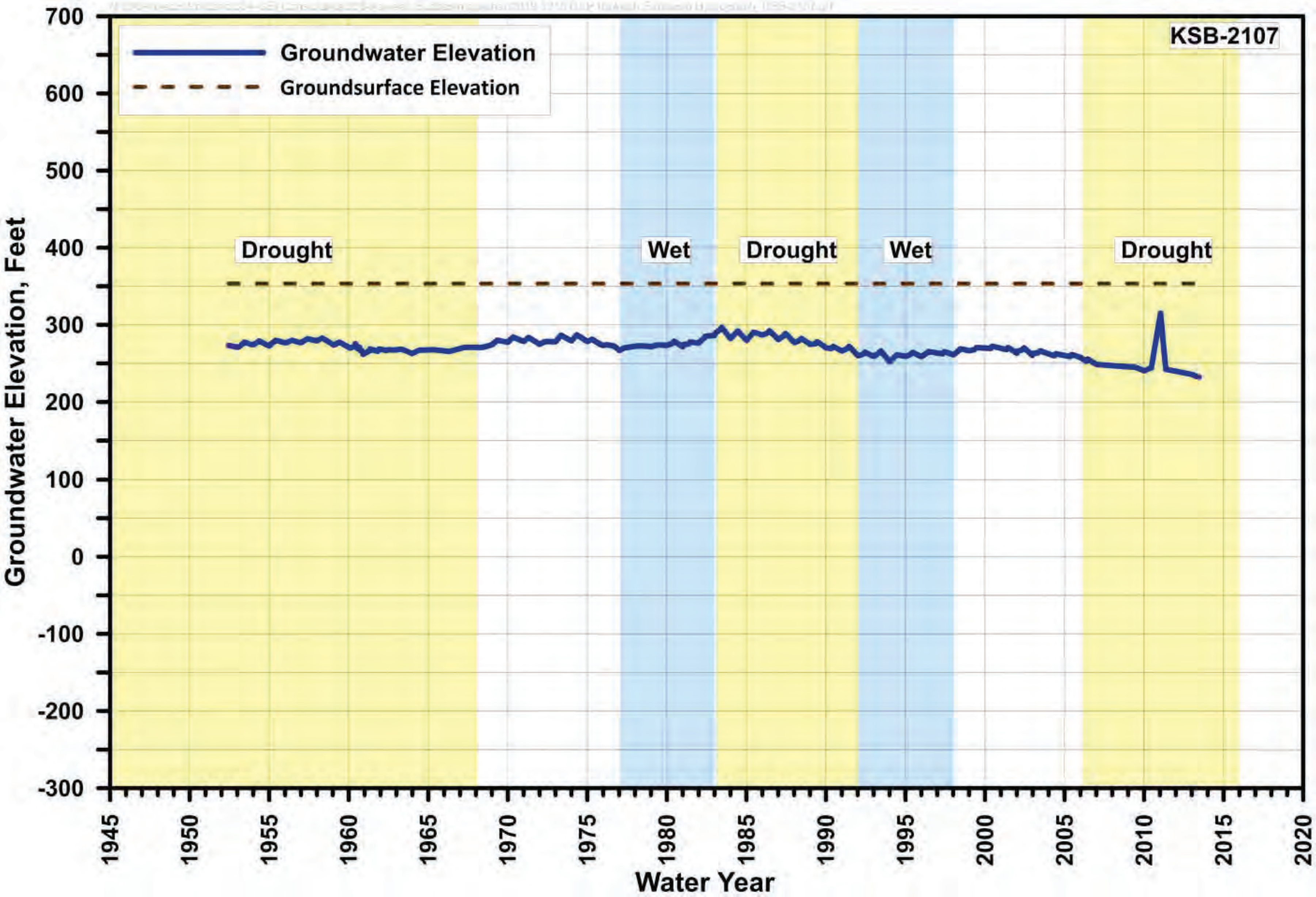
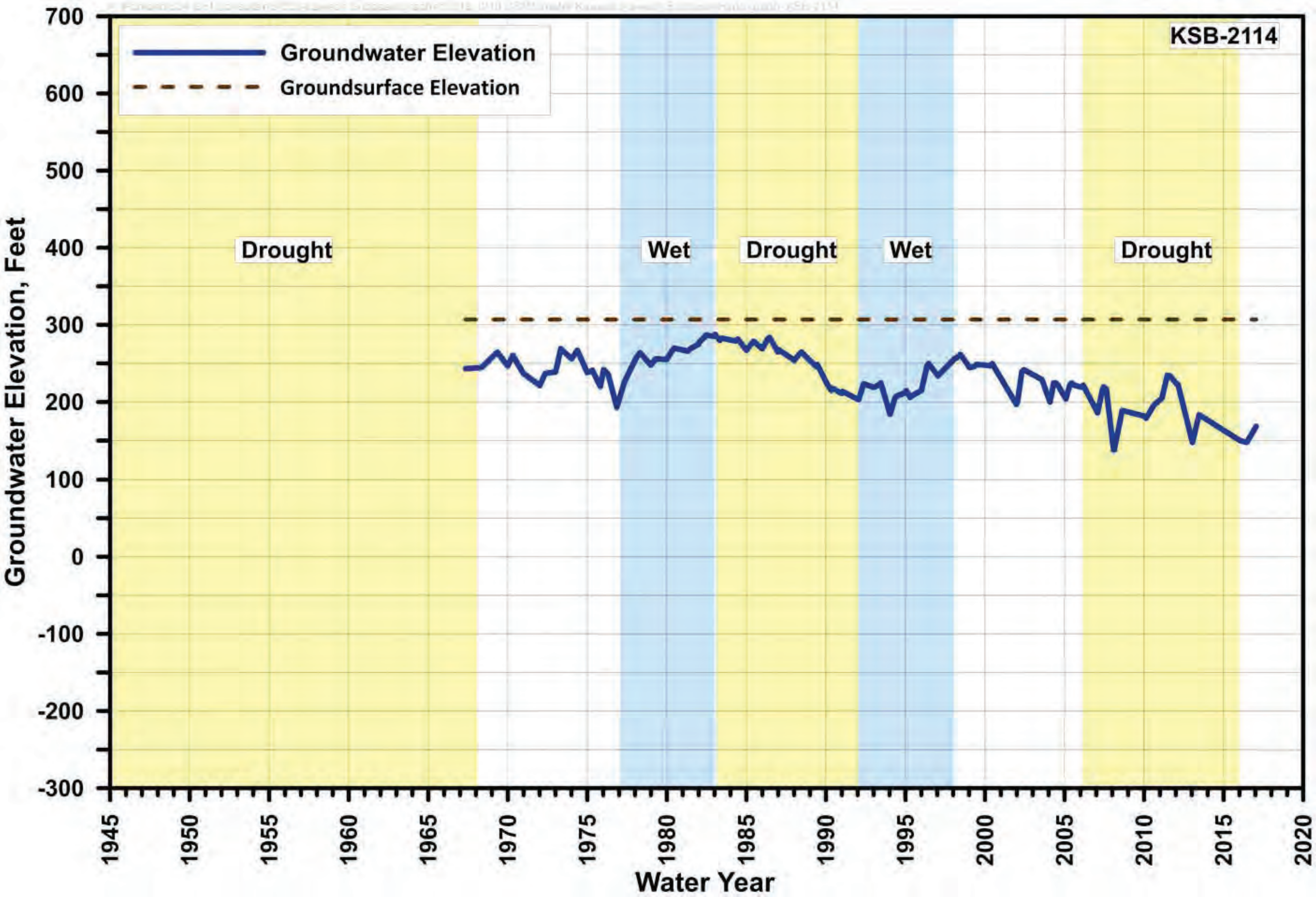
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-2095
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-2107
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


KSB-2114
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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1980
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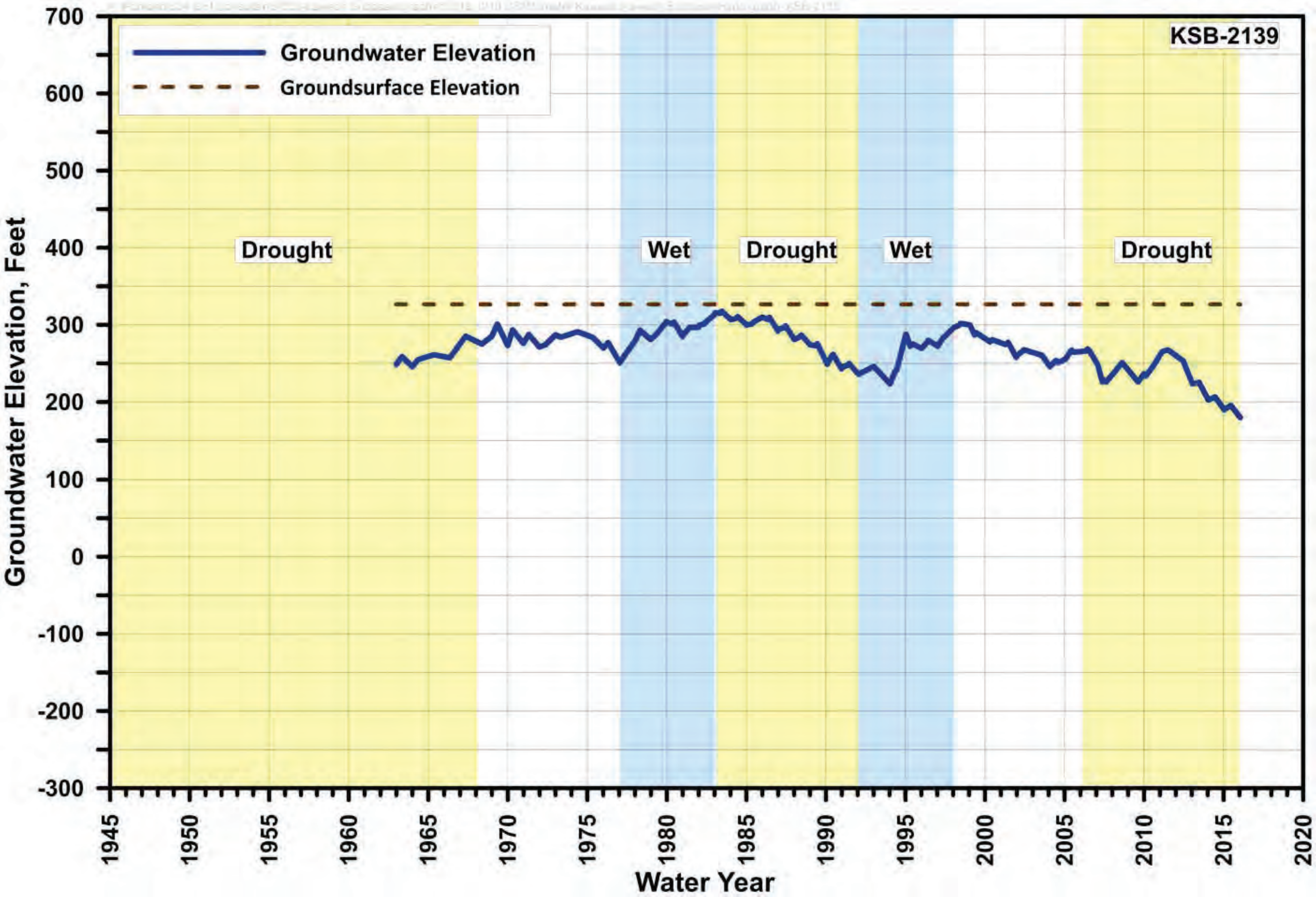
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-2139
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
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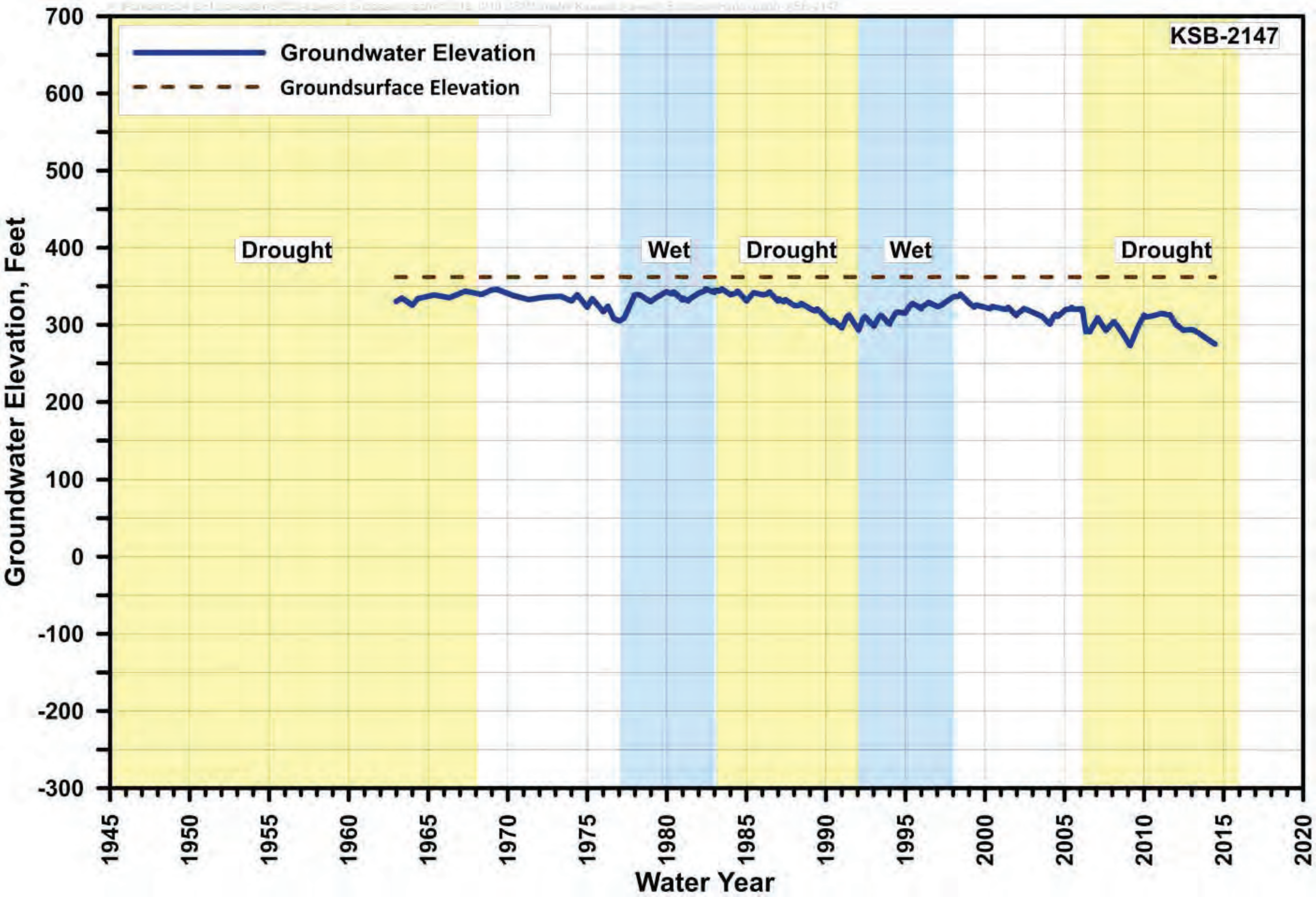
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-2147
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
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1965
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1980
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1995
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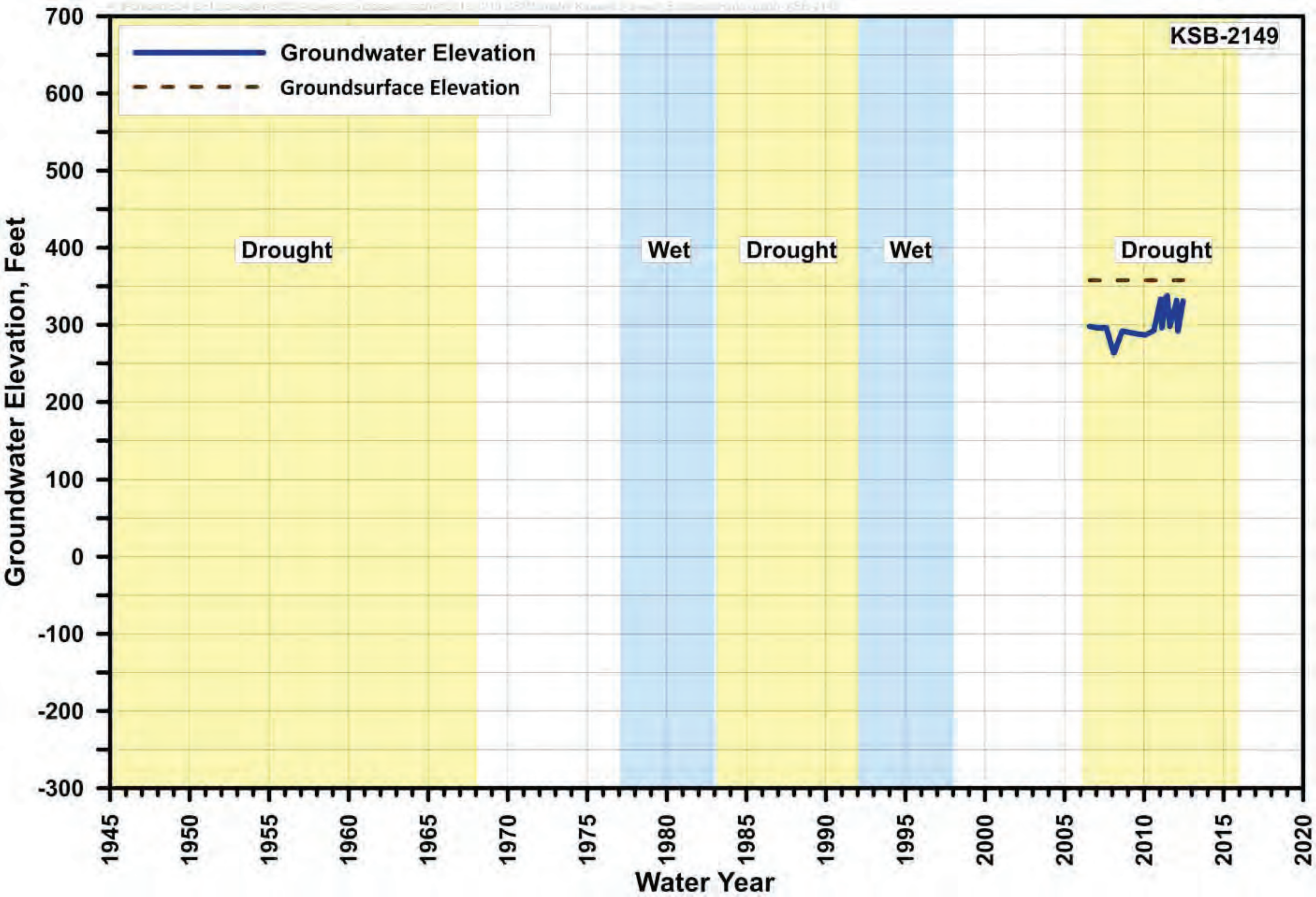
2005
2010
2015
2020
Water Year



KSB-2149
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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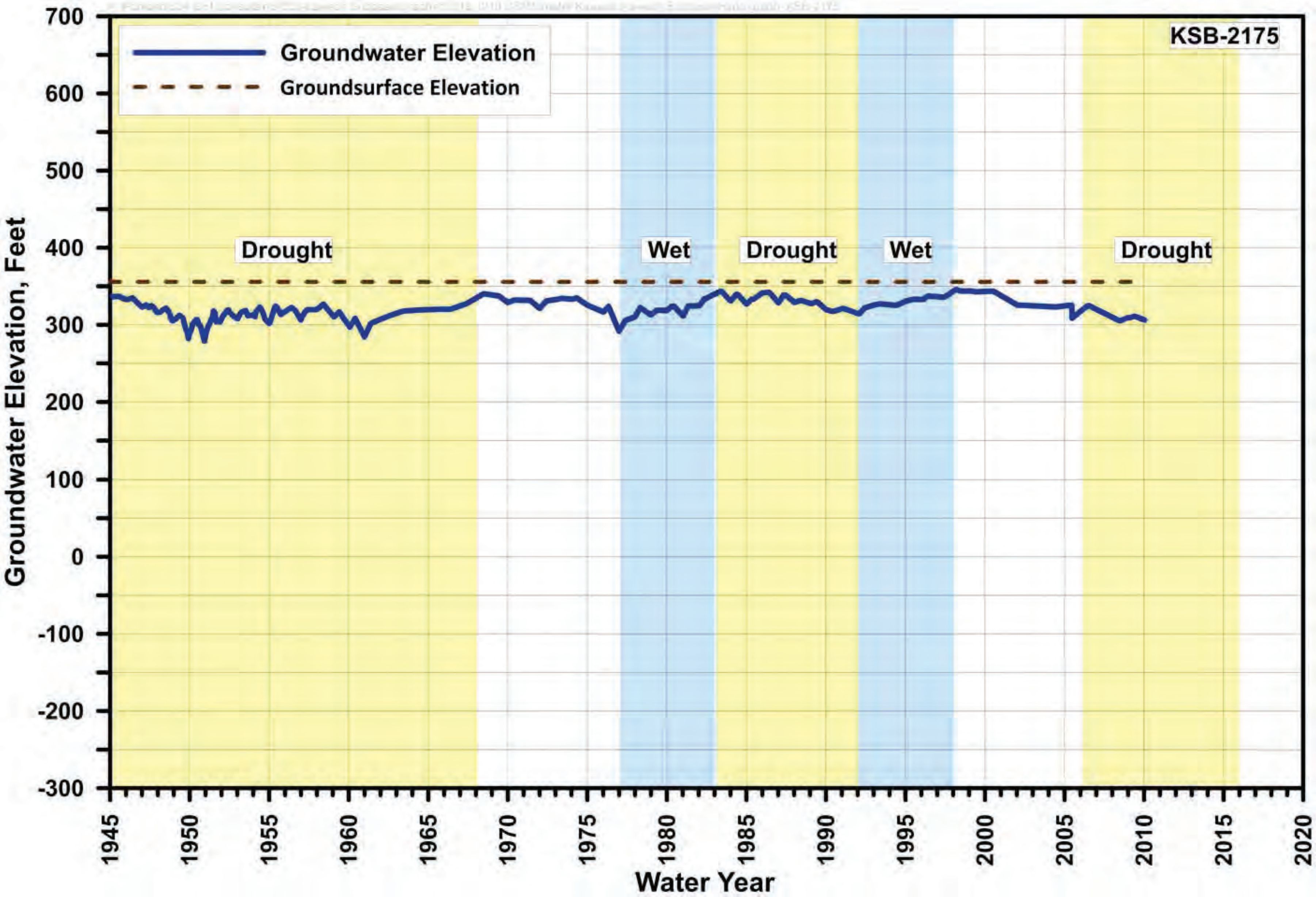
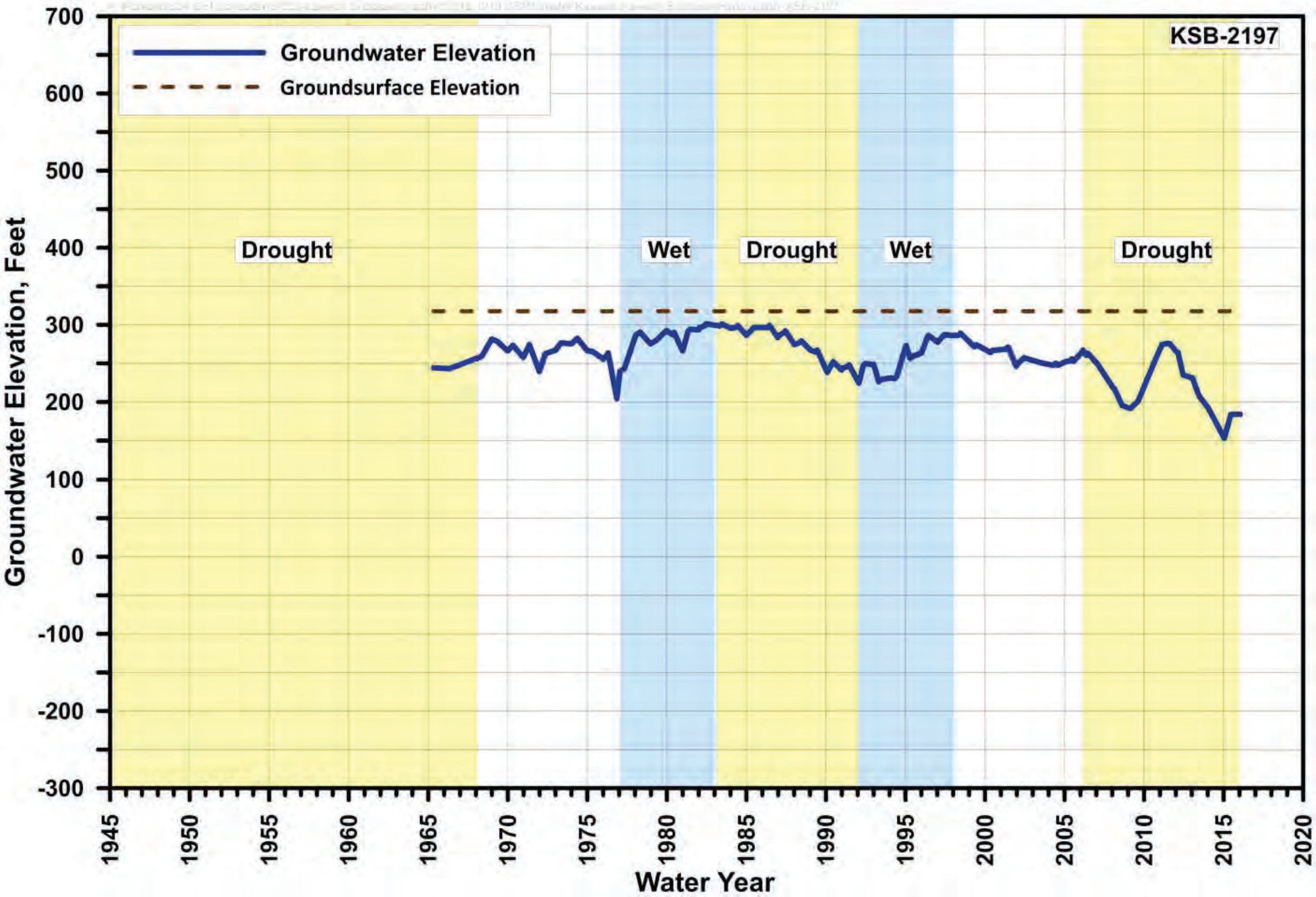
2010
2015
2020
Water Year



KSB-2175
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
700
600
500
400
300
200
100
0
-100
-200
-300
Groundwater Elevation, Feet
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-2197
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
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1995
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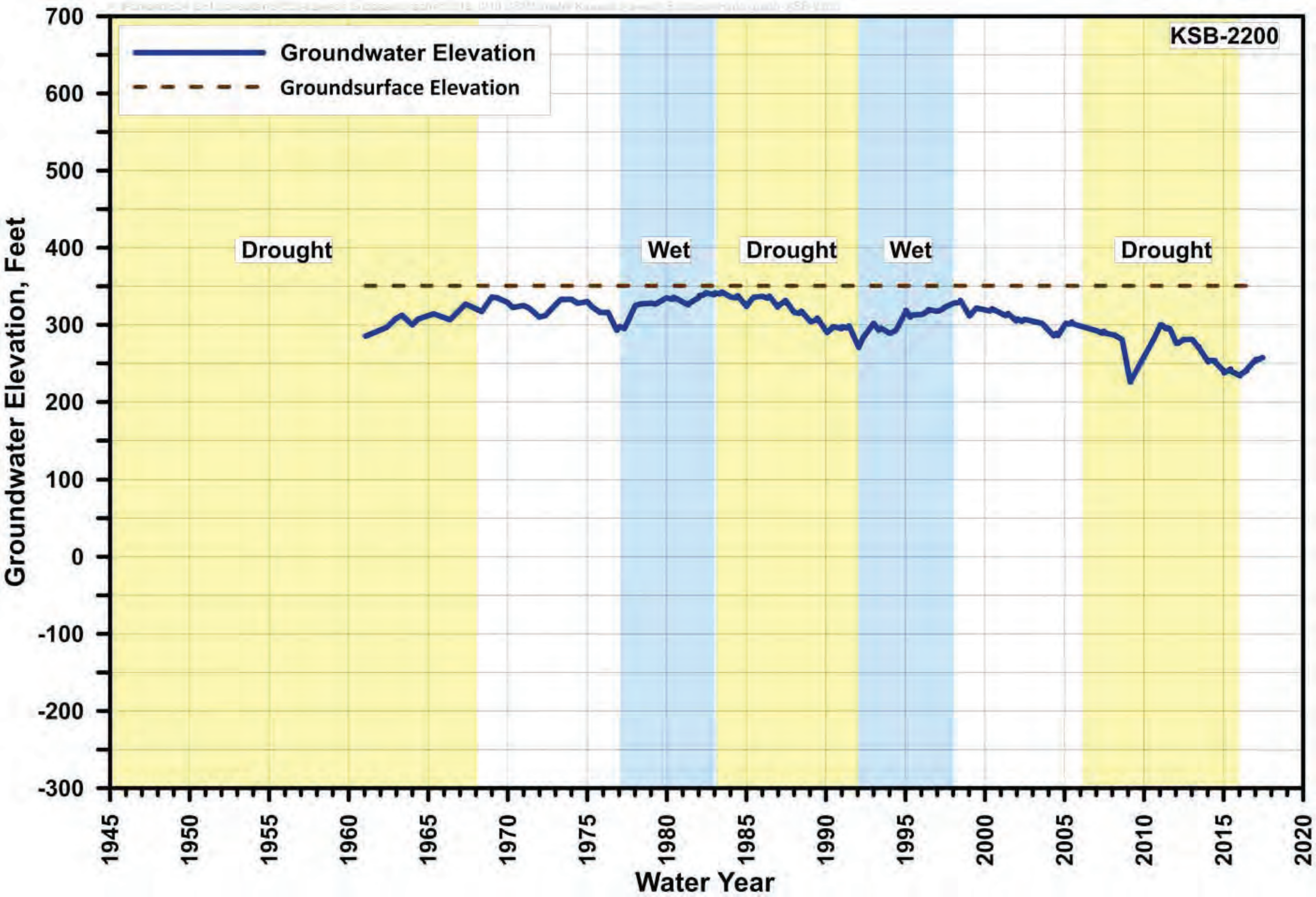
2005
2010
2015
2020
Water Year



KSB-2200
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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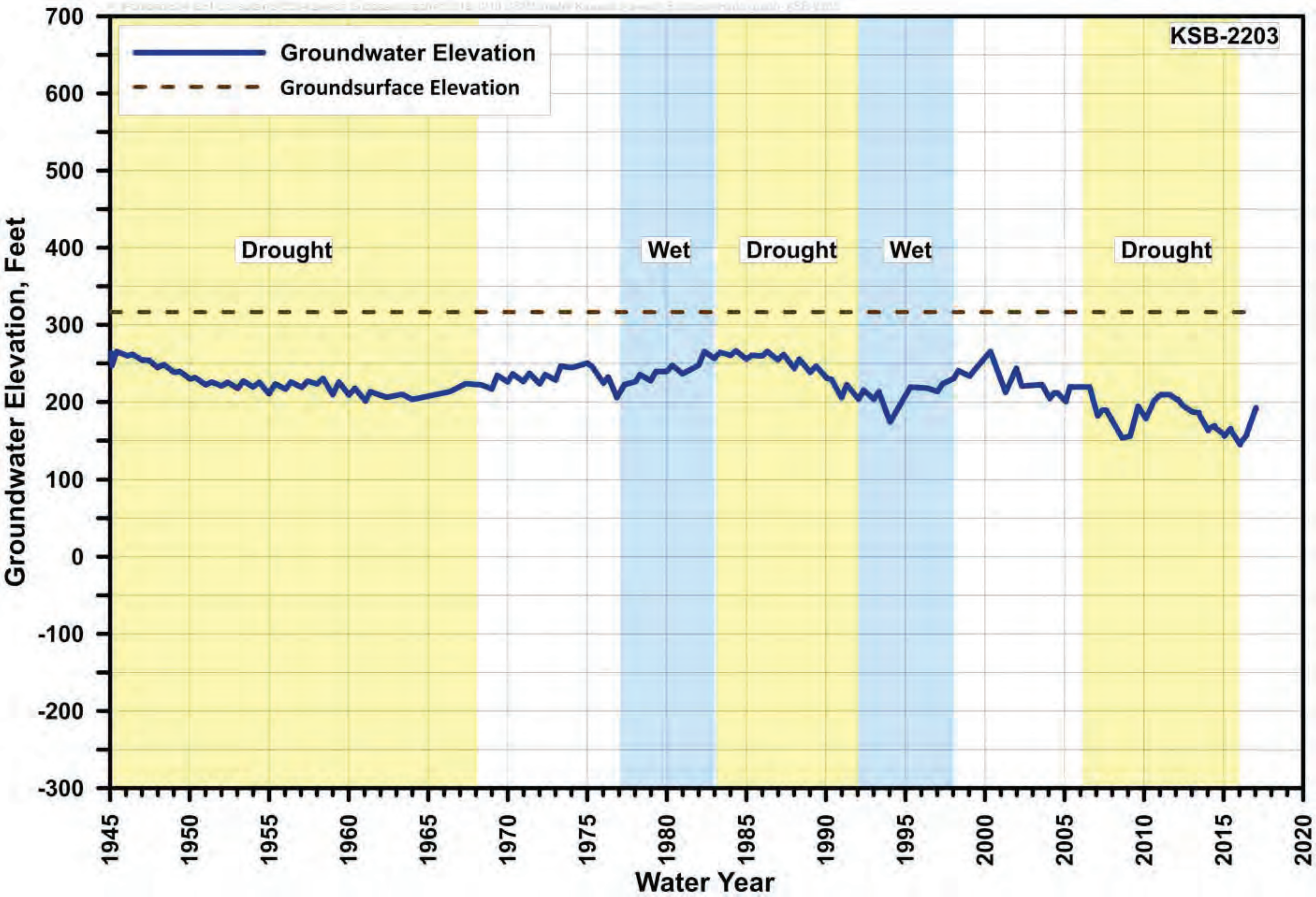
2005
2010
2015
2020



Groundwater Elevation
Groundsurface Elevation
KSB-2203
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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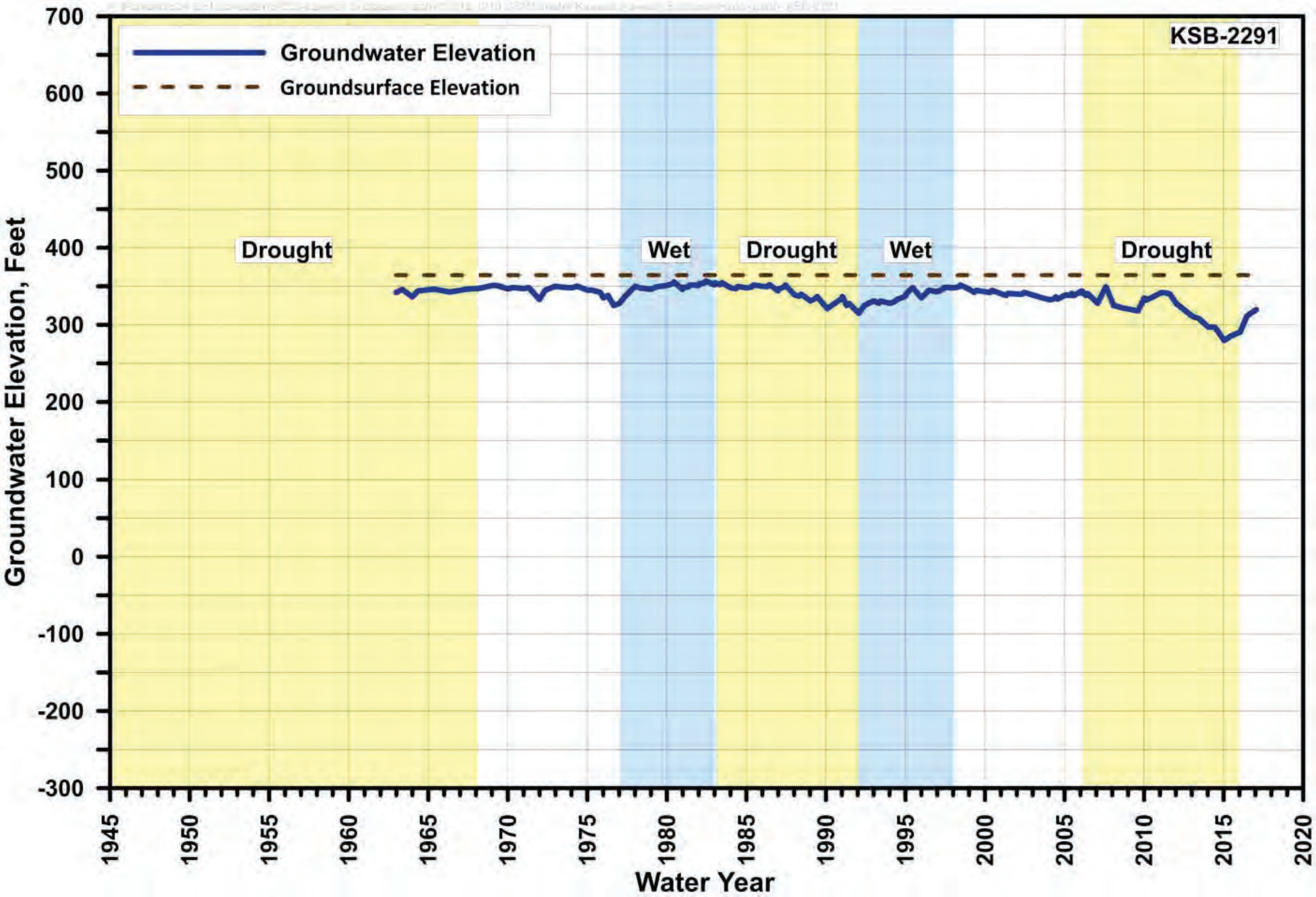
2005
2010
2015
2020



KSB-2291
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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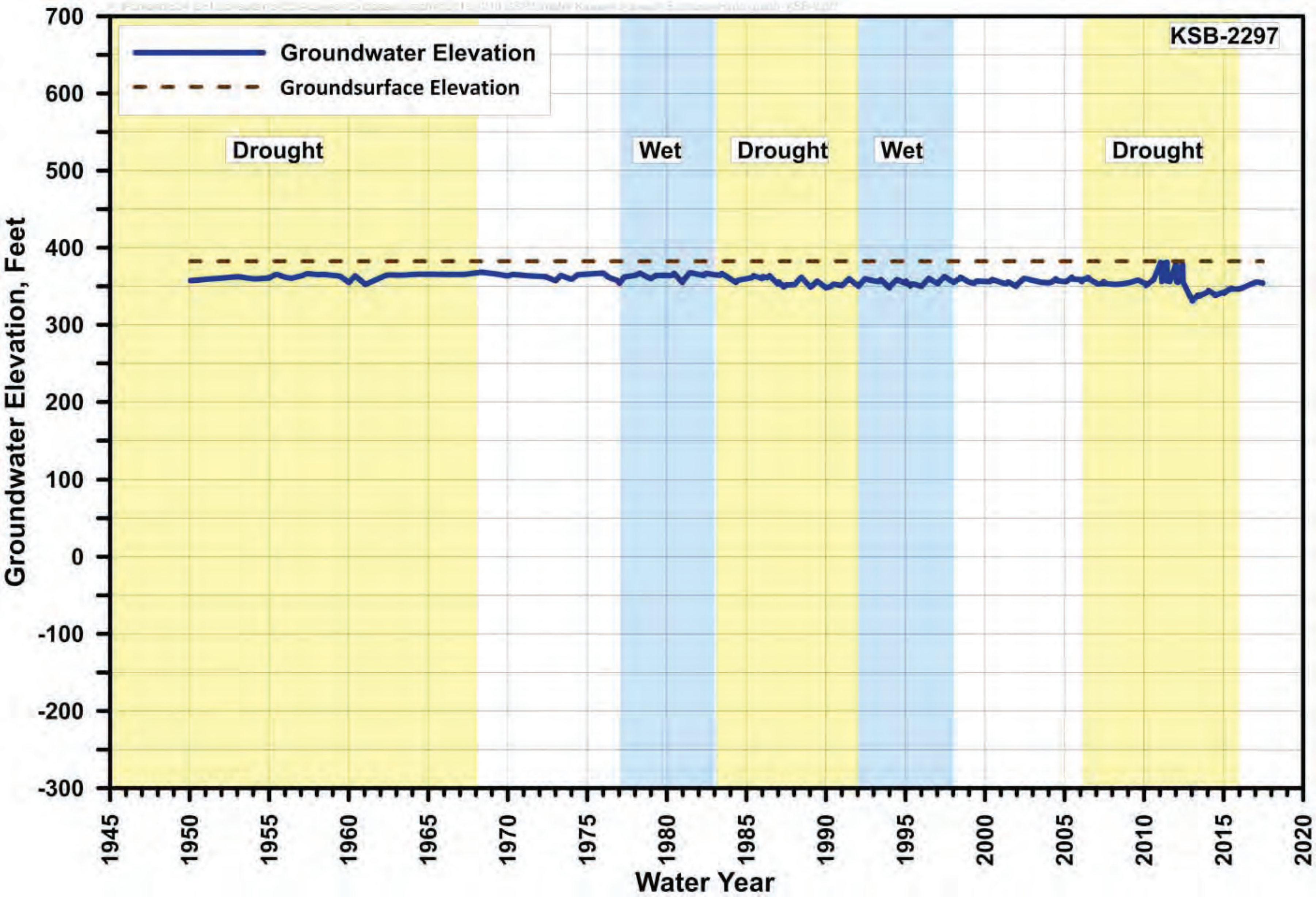
2005
2010
2015
2020
Water Year



Groundwater Elevation
Groundsurface Elevation
KSB-2297
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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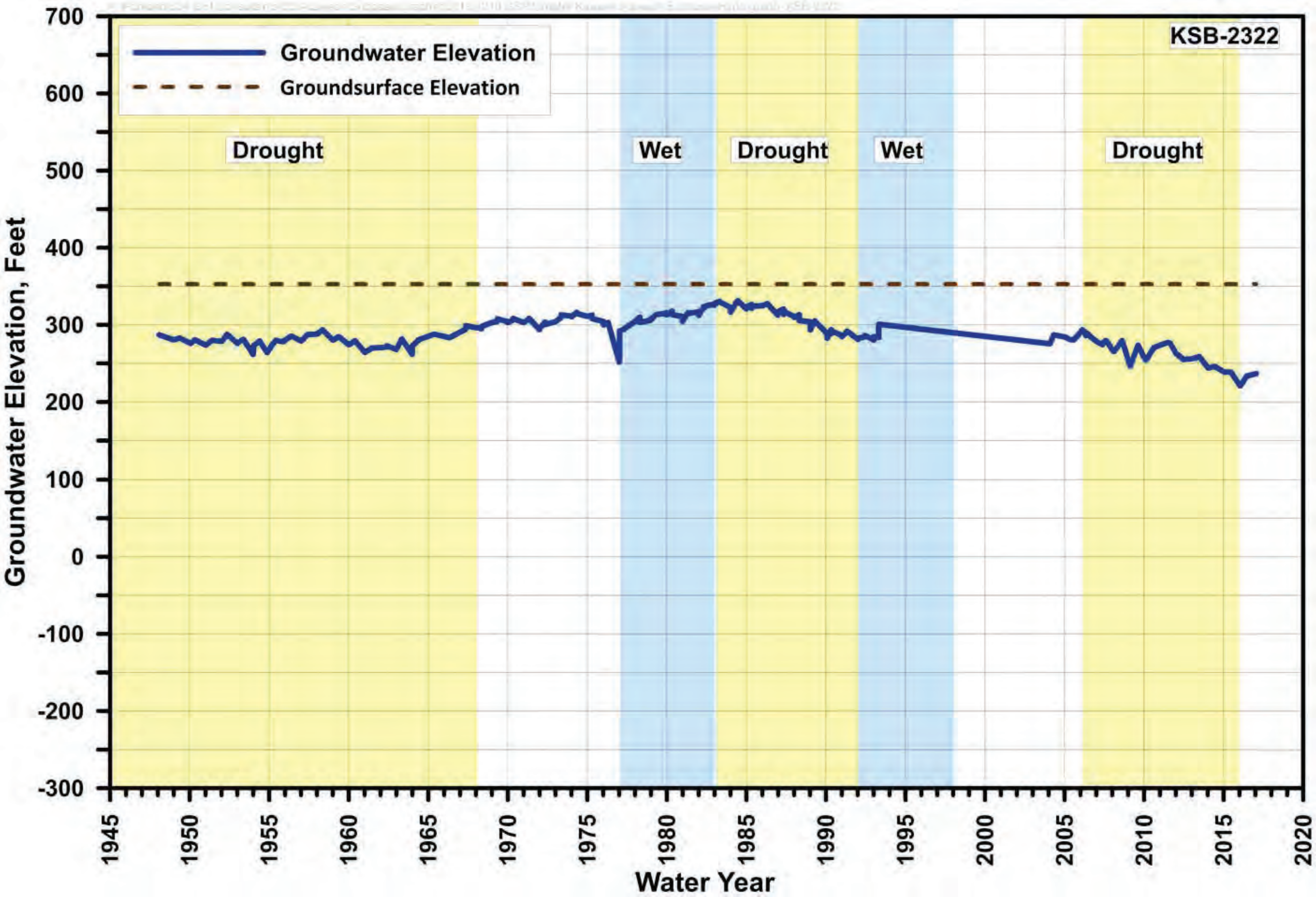
2005
2010
2015
2020
Water Year



KSB-2322
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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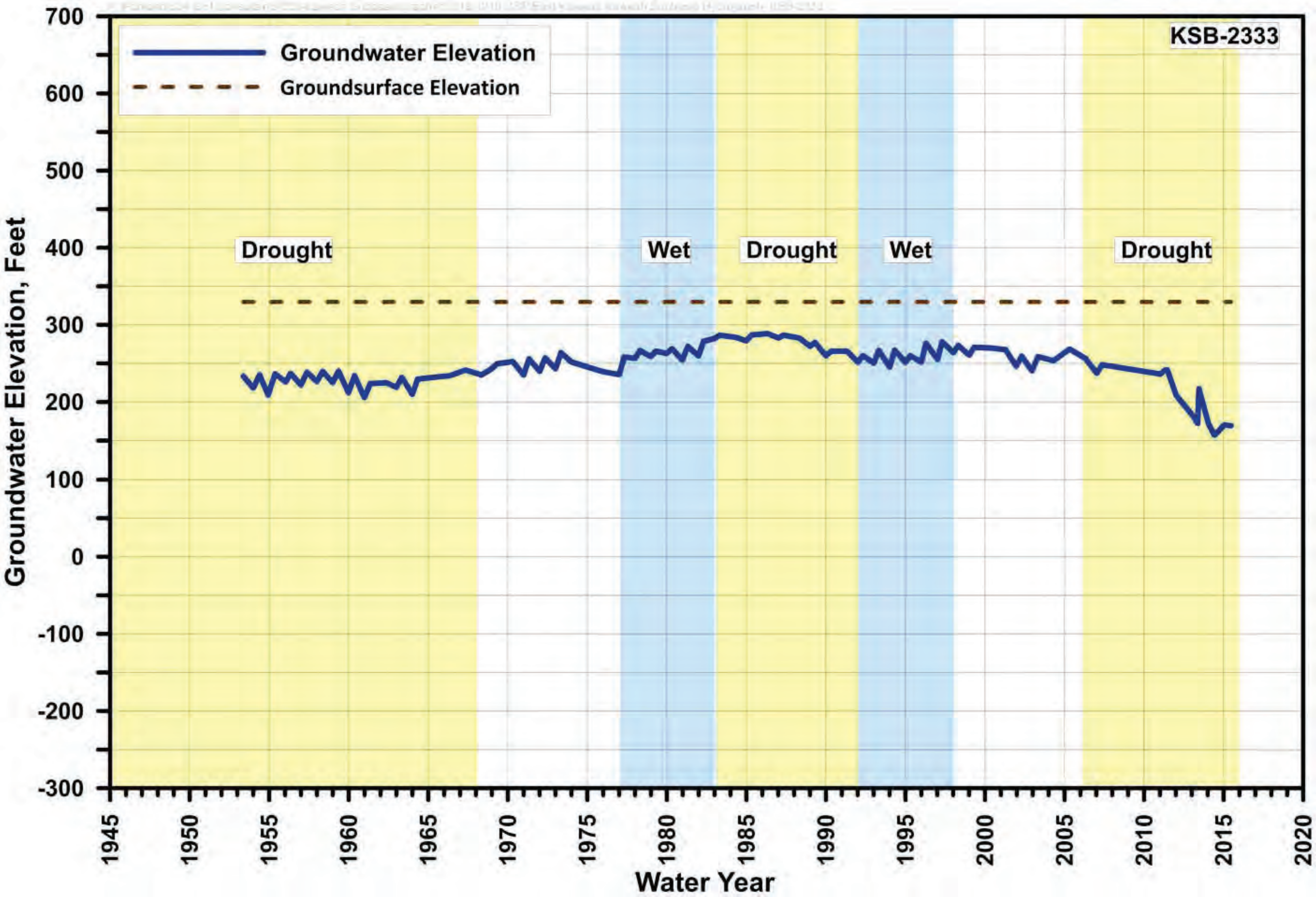
2000
2005
2010
2015
2020
Water Year


KSB-2333
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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1960
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1970
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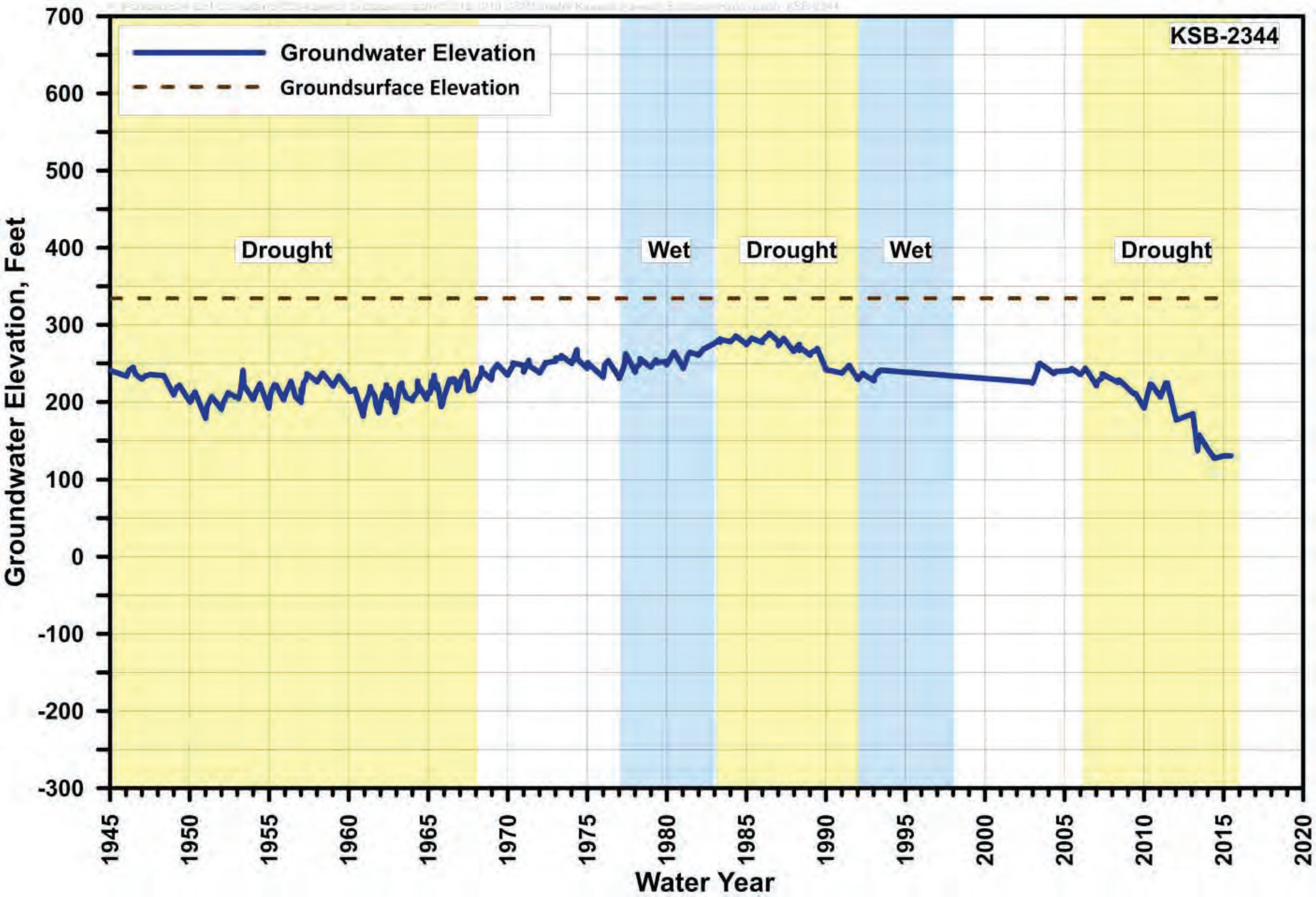
2005
2010
2015
2020



KSB-2344
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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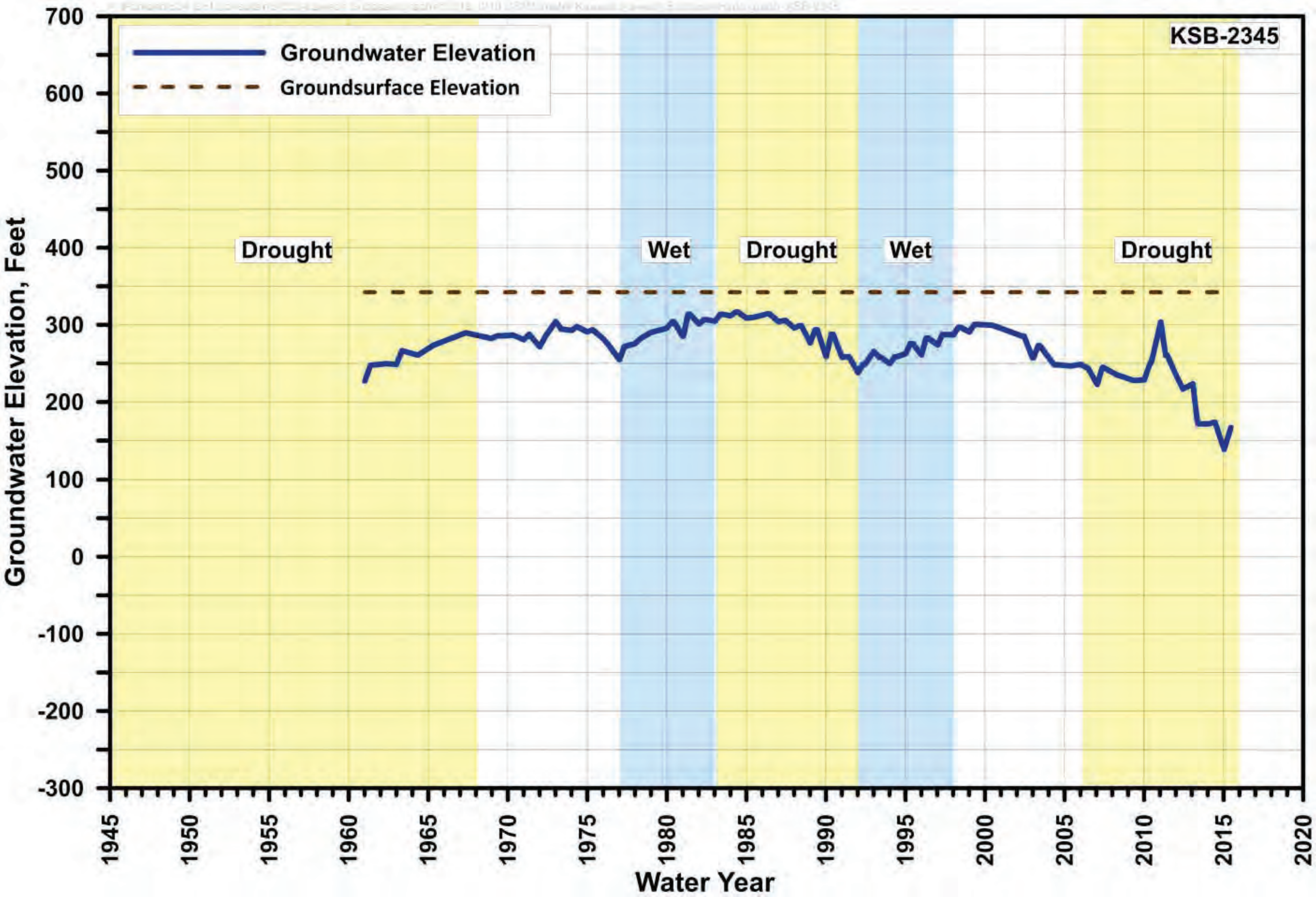
2005
2010
2015
2020



KSB-2345
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
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1970
1975
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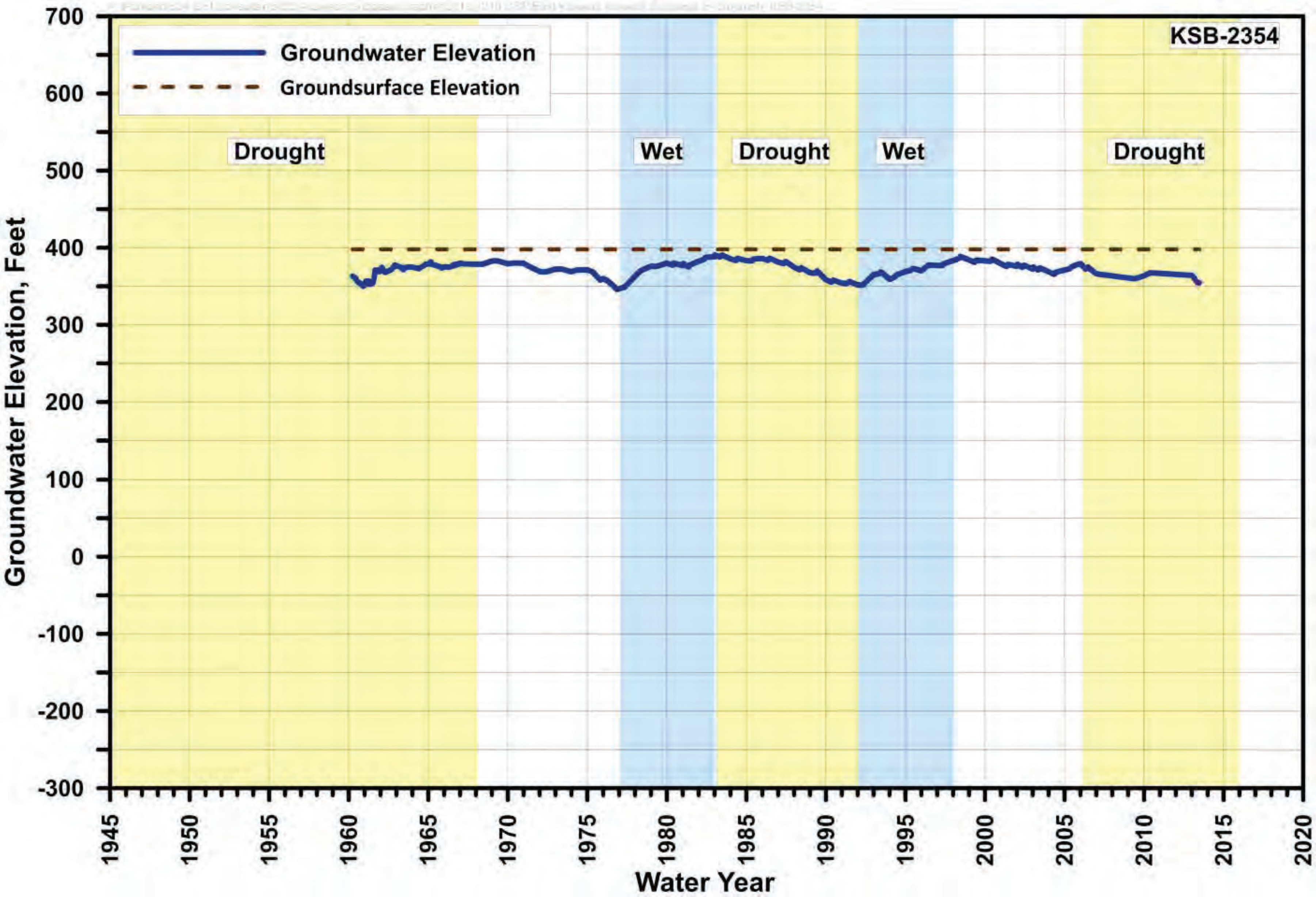
1985
1990
1995
2000
2005
2010
2015
2020



KSB-2354
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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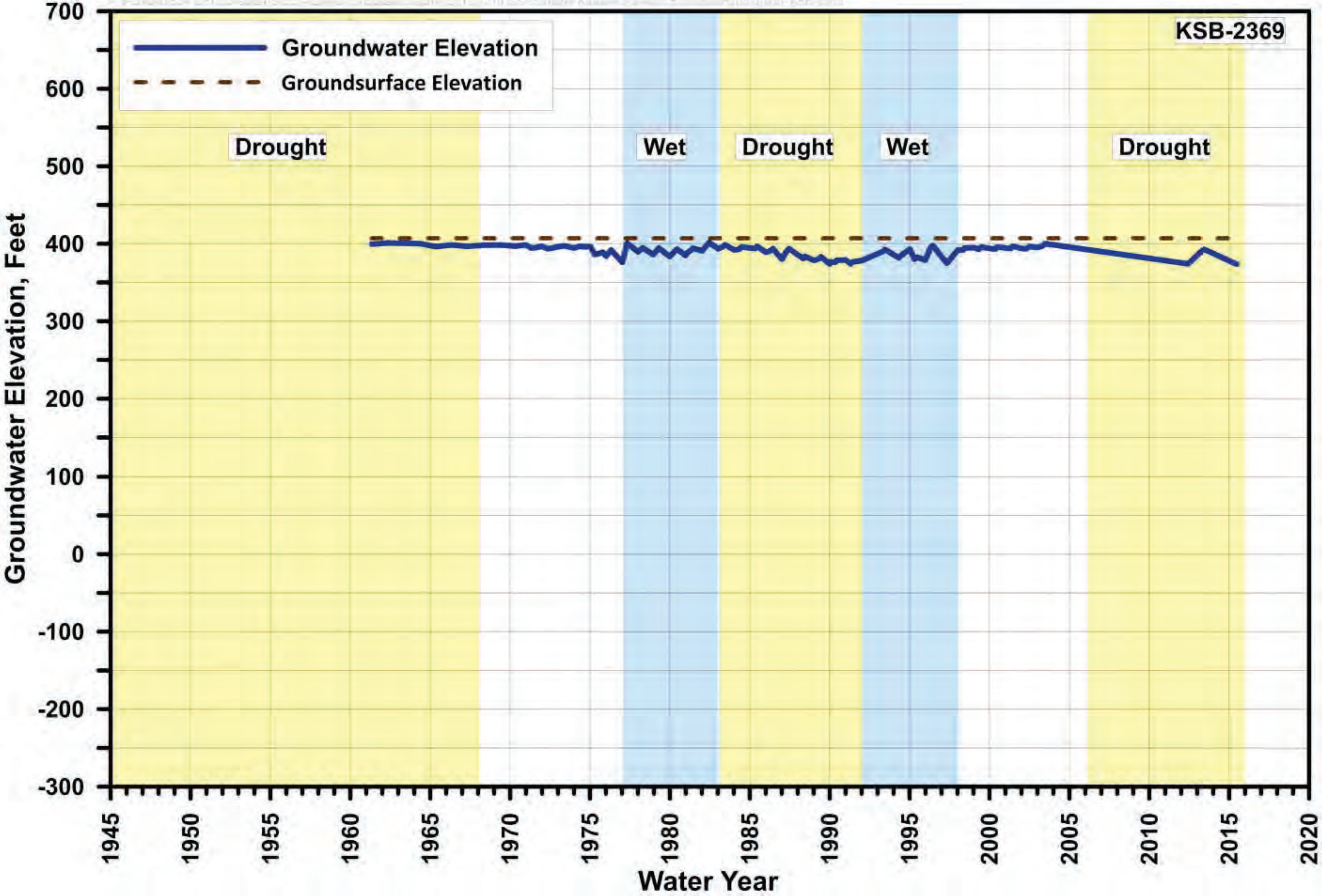
2000
2005
2010
2015
2020
Water Year



KSB-2369
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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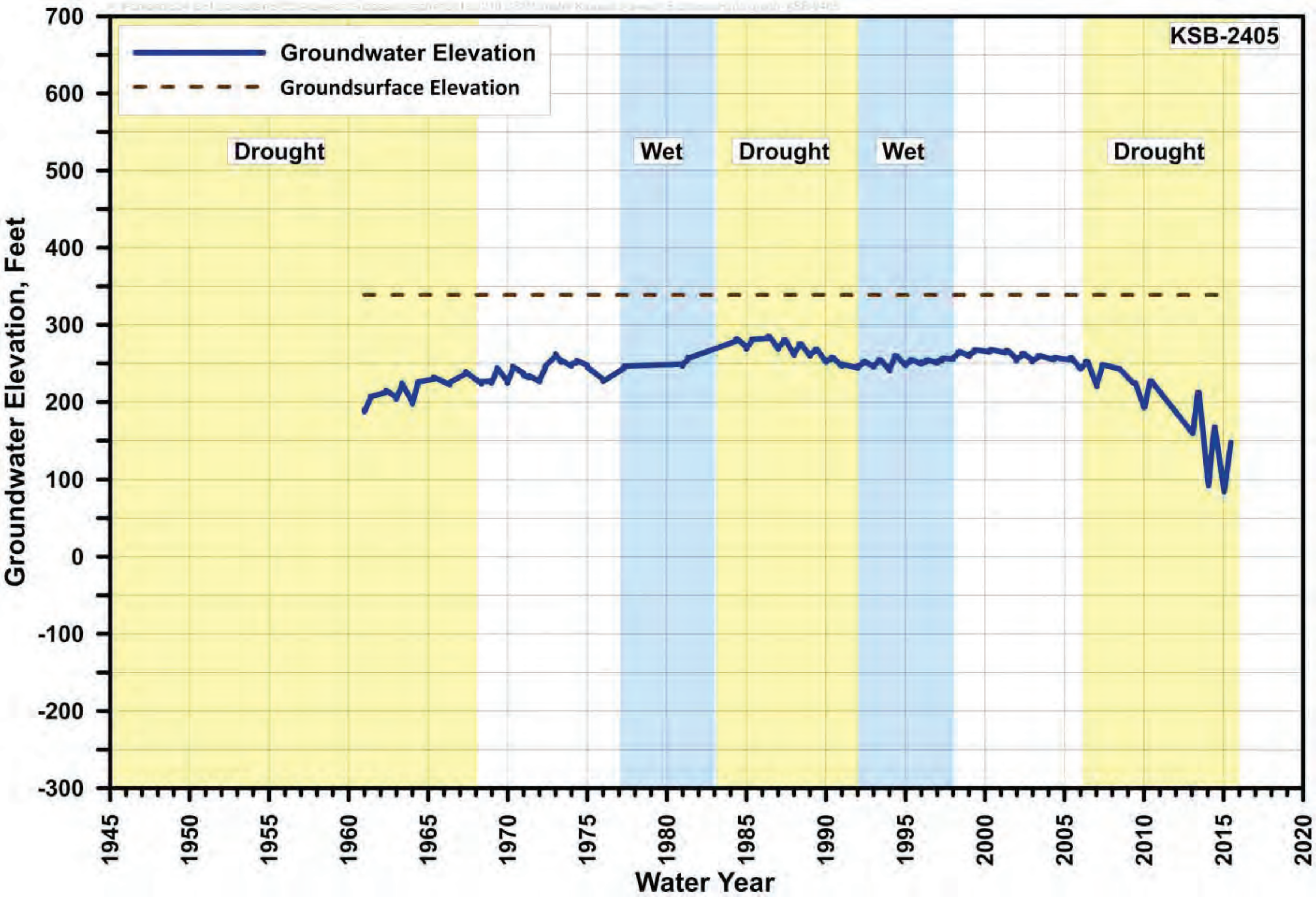
2005
2010
2015
2020
Water Year



KSB-2405
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
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1990
1995
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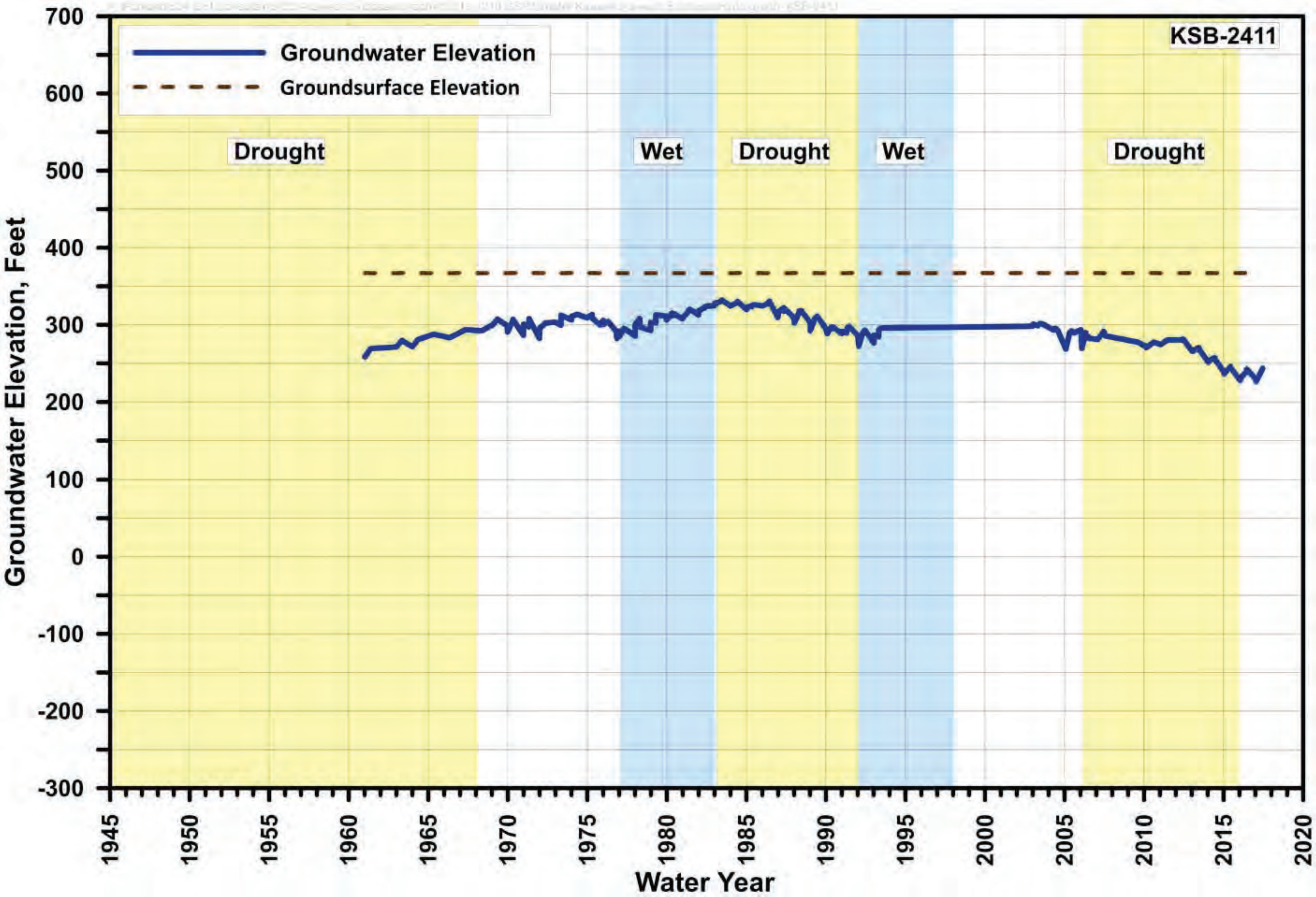
2010
2015
2020
Water Year



KSB-2411
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
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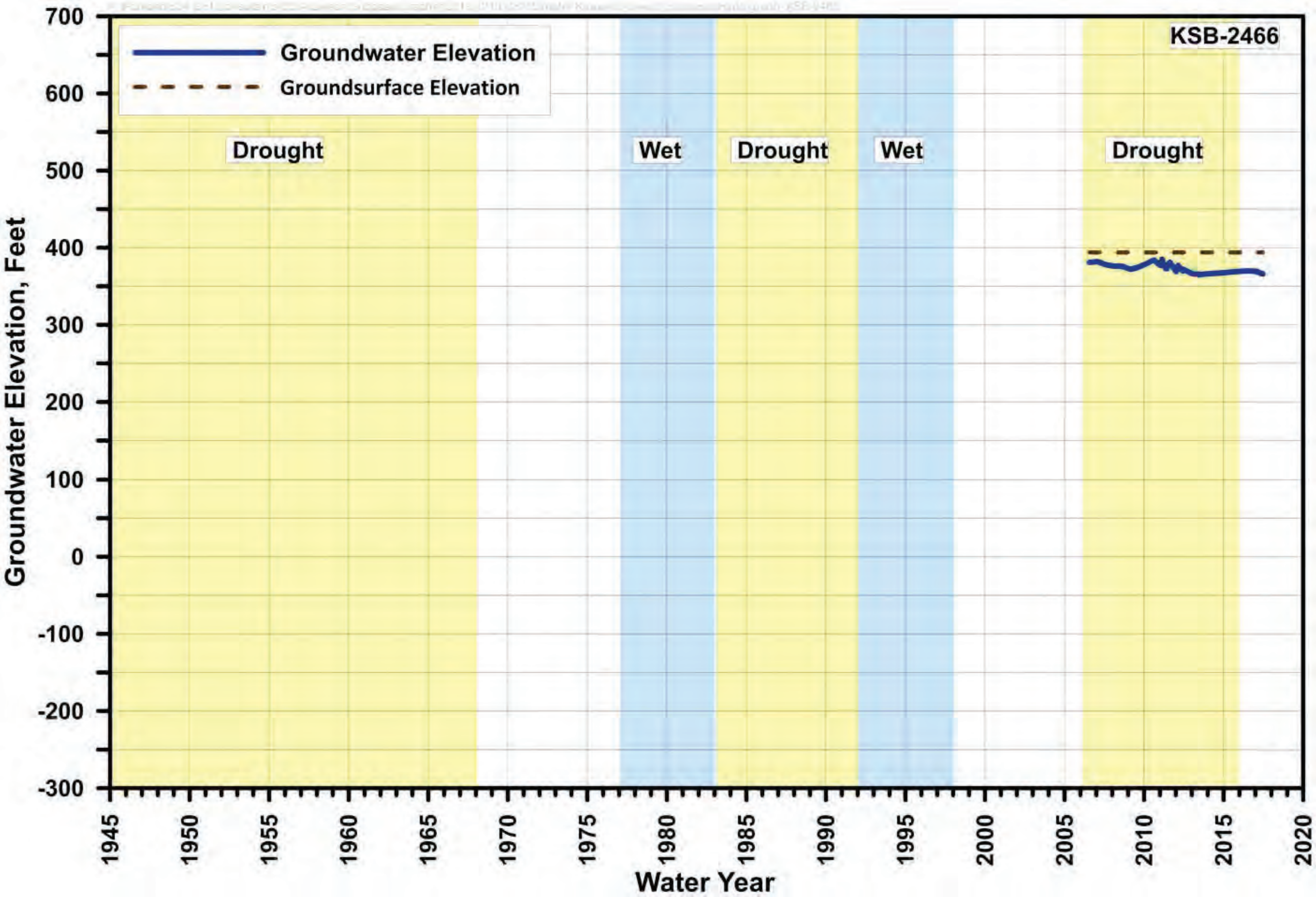
2015
2020
Water Year



KSB-2466
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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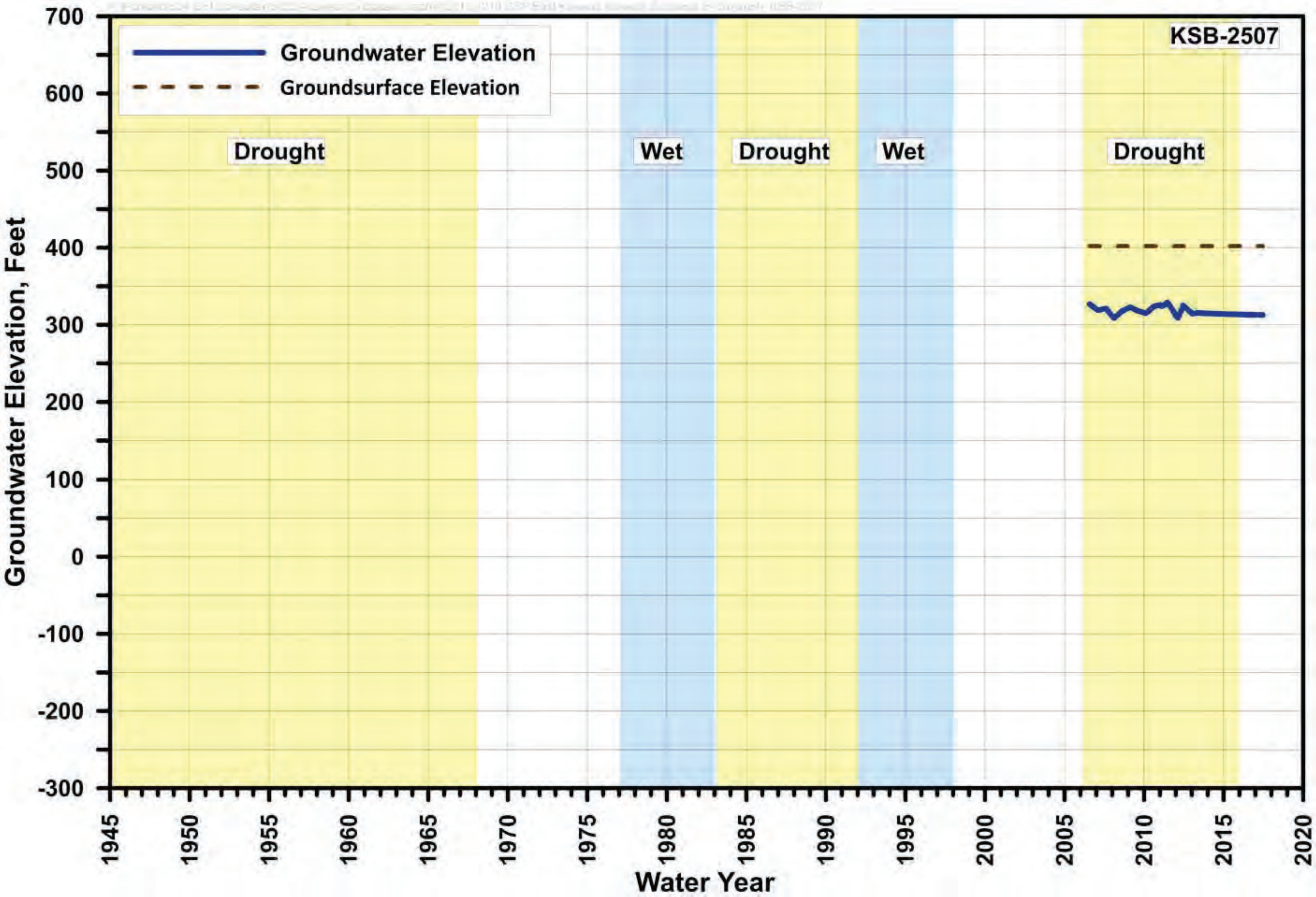
2010
2015
2020
Water Year


KSB-2507
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
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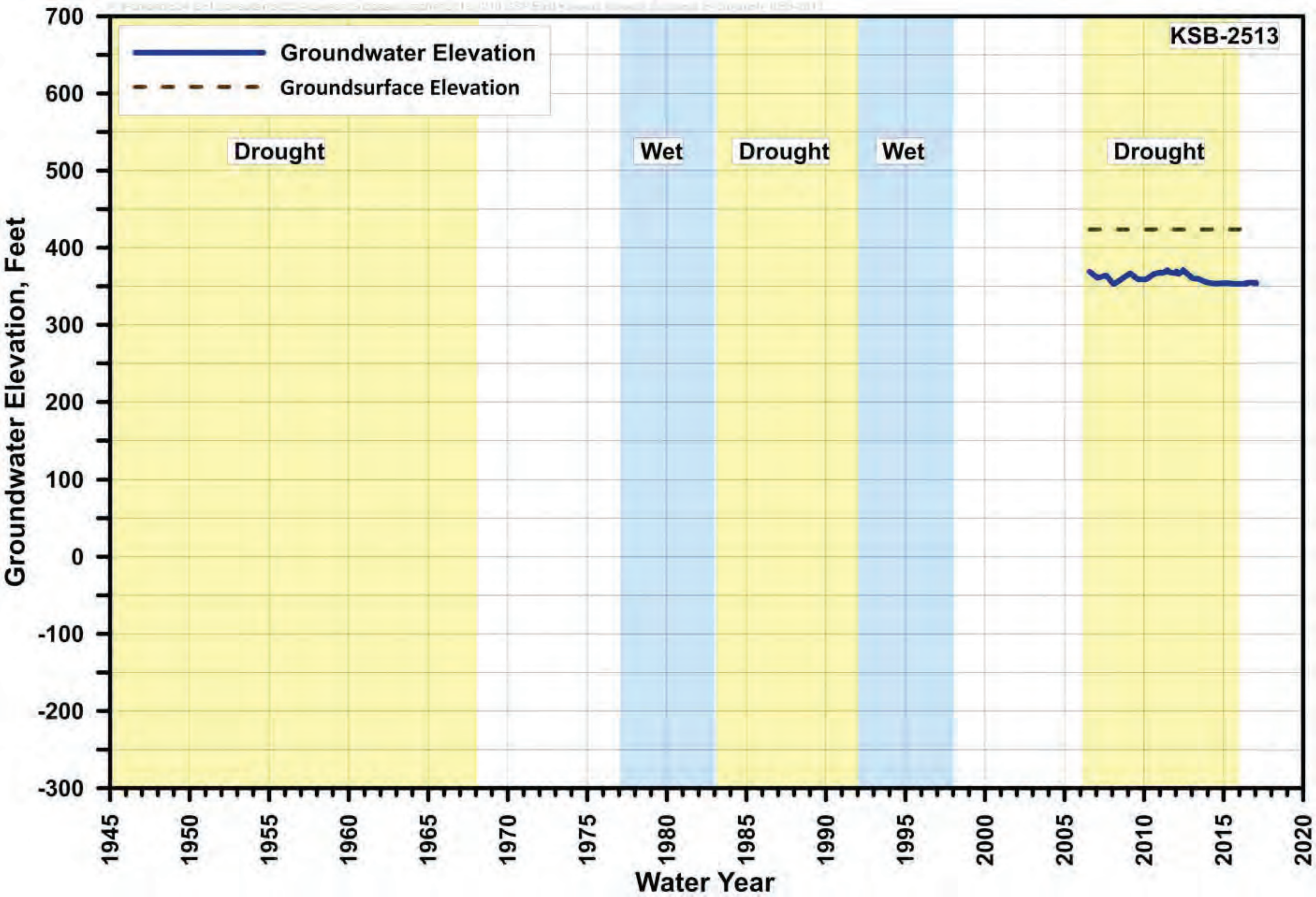
2010
2015
2020
Water Year



KSB-2513
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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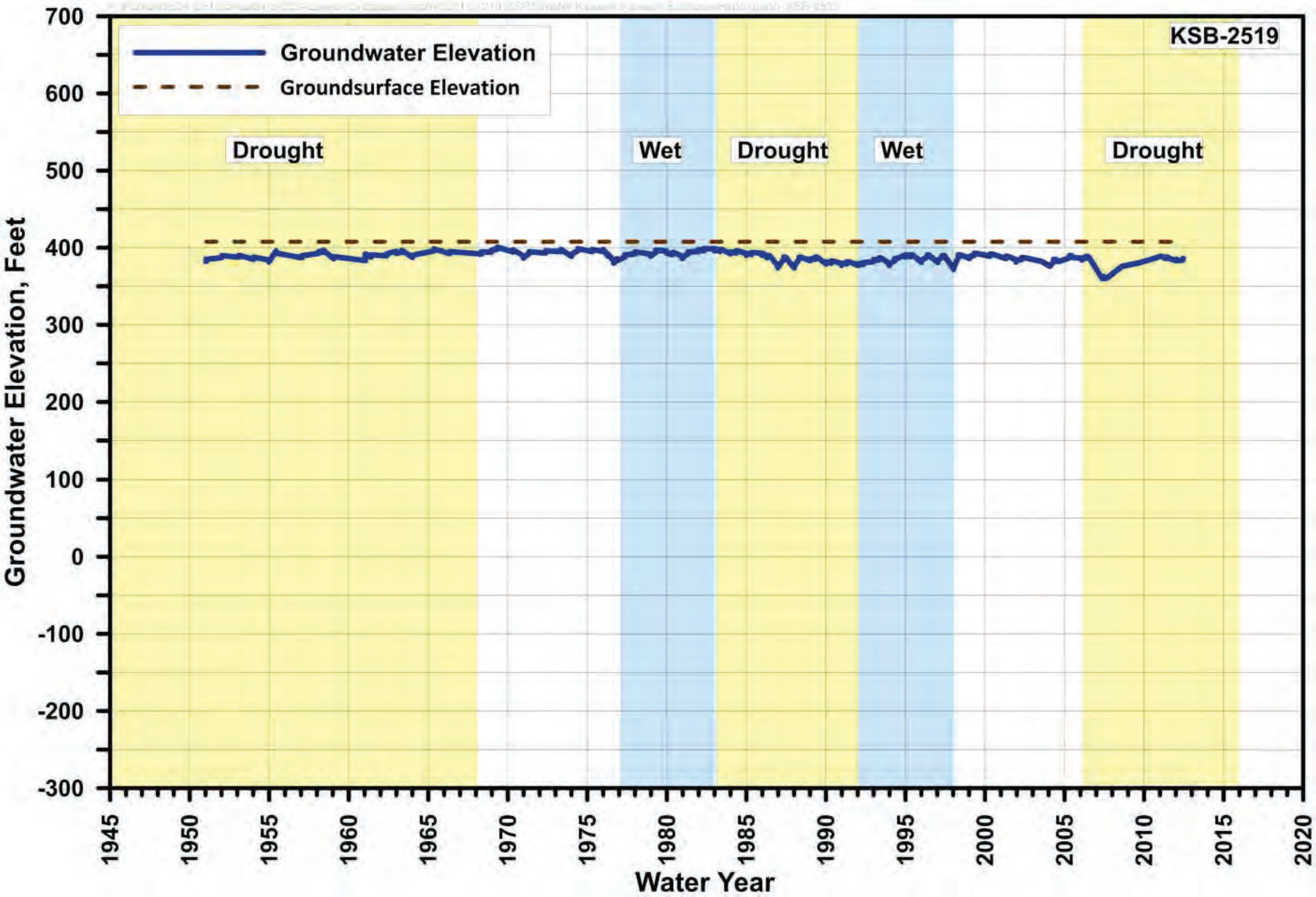
2010
2015
2020
Water Year



KSB-2519
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
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1970
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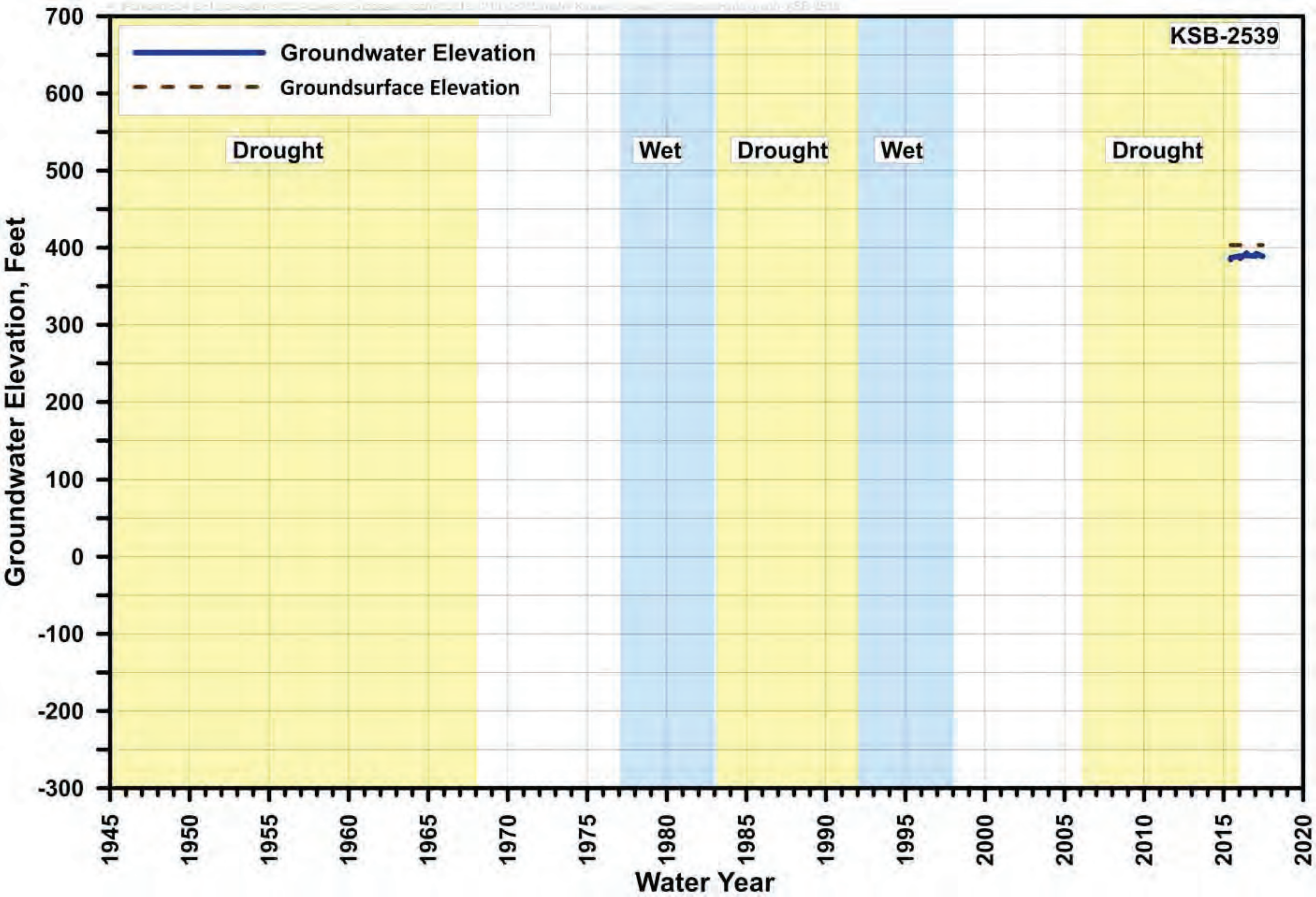
2005
2010
2015
2020
Water Year



KSB-2539
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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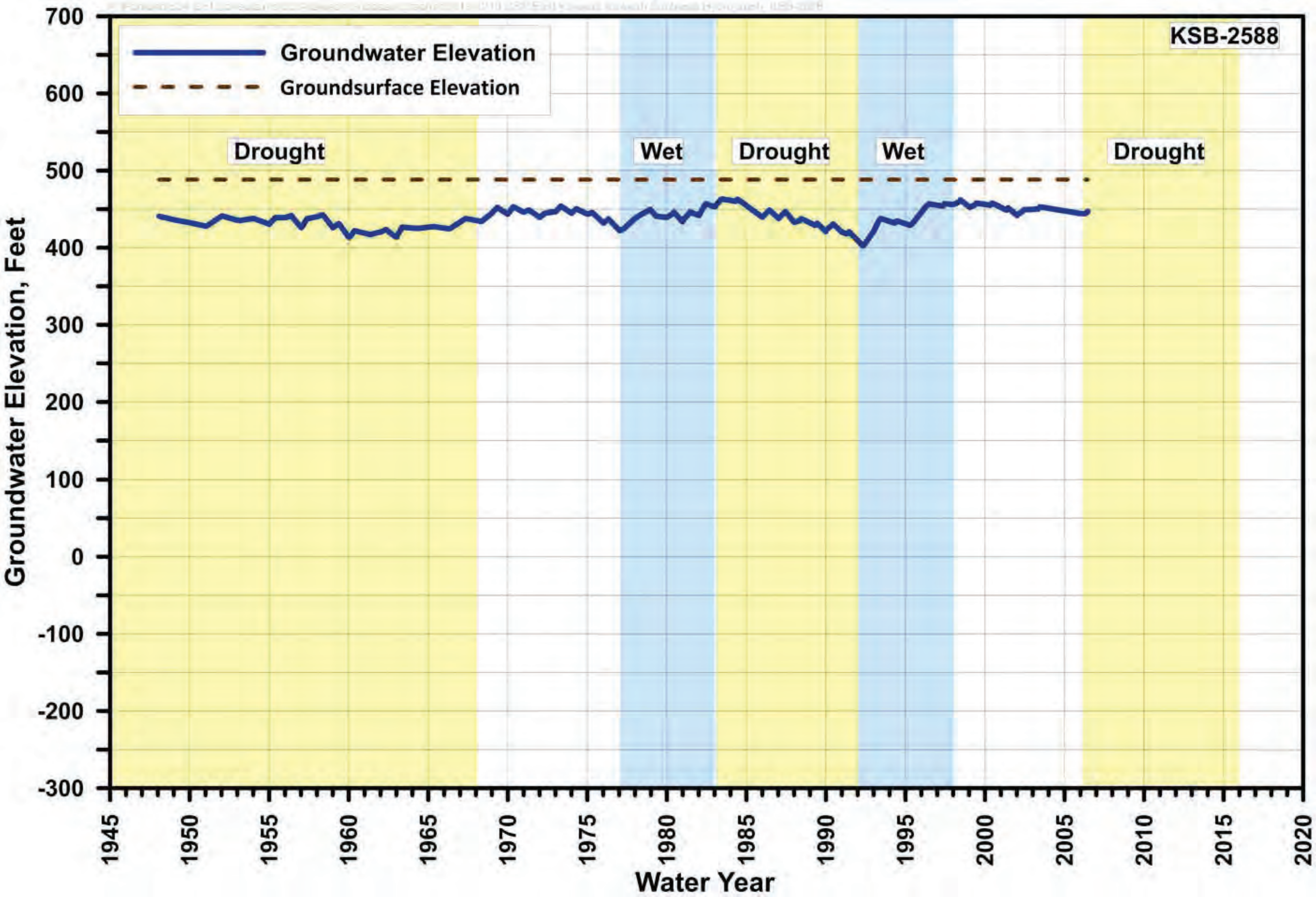
2015
2020
Water Year



KSB-2588
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
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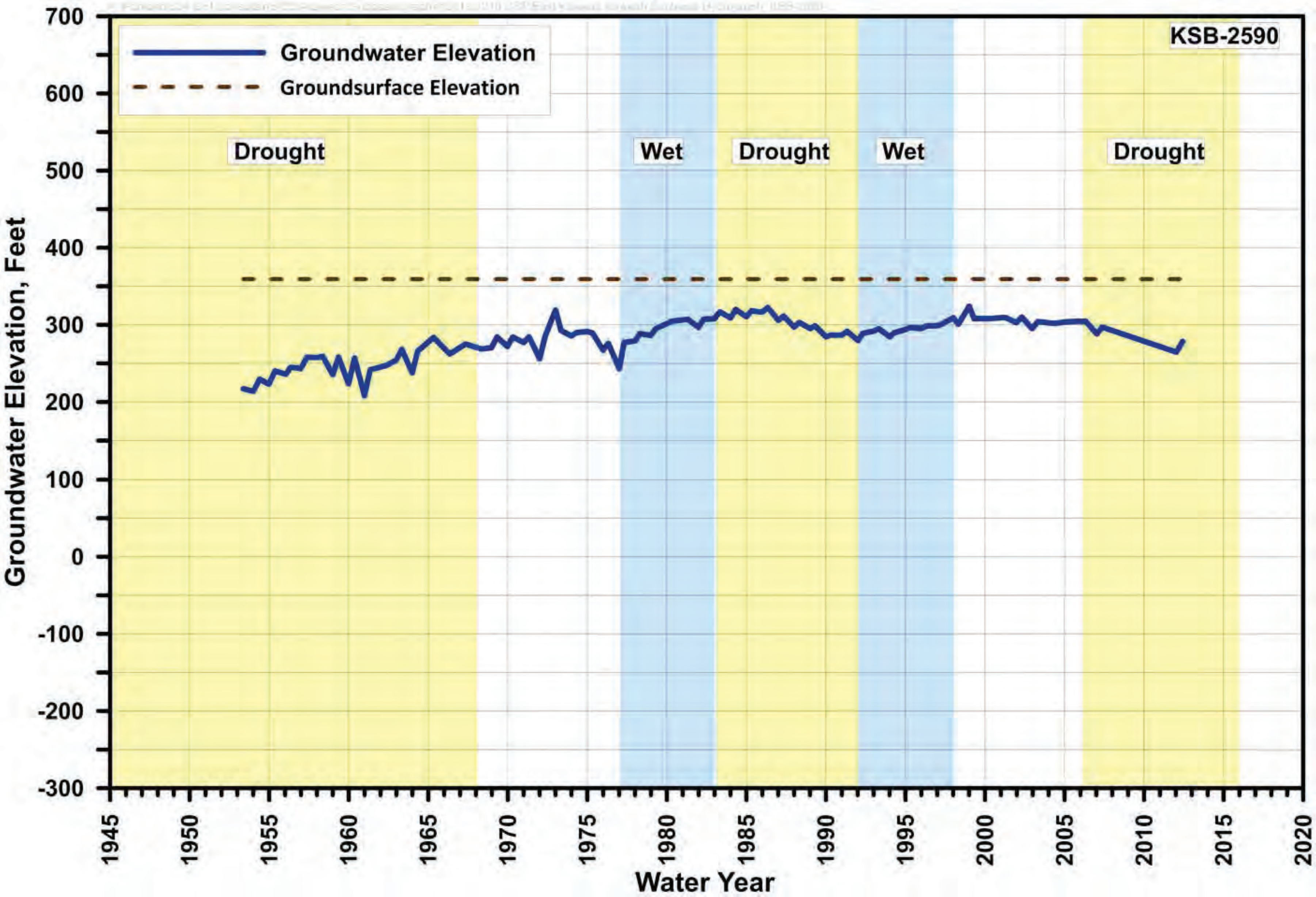
2015
2020
Water Year



KSB-2590
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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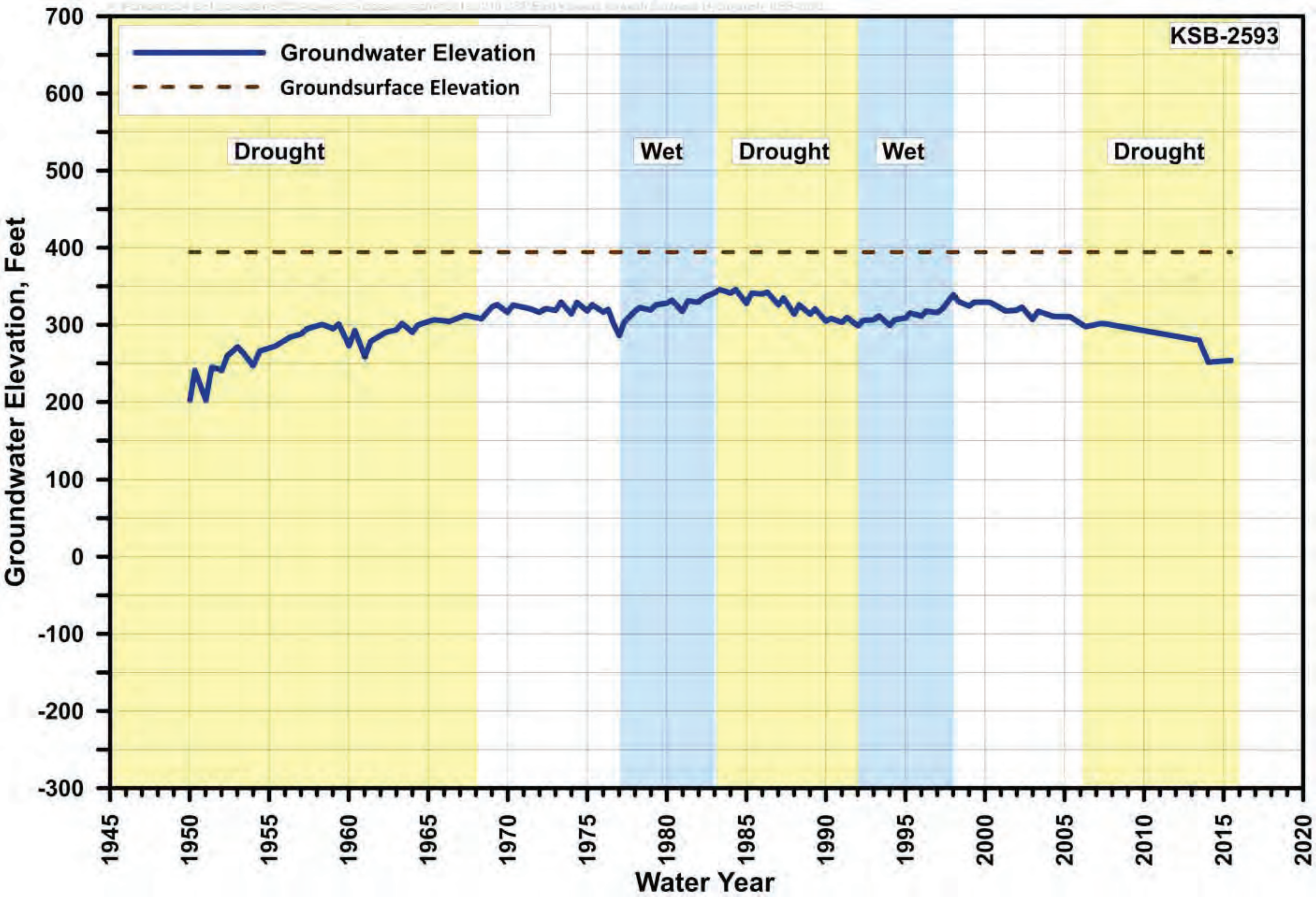
2015
2020
Water Year



KSB-2593
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
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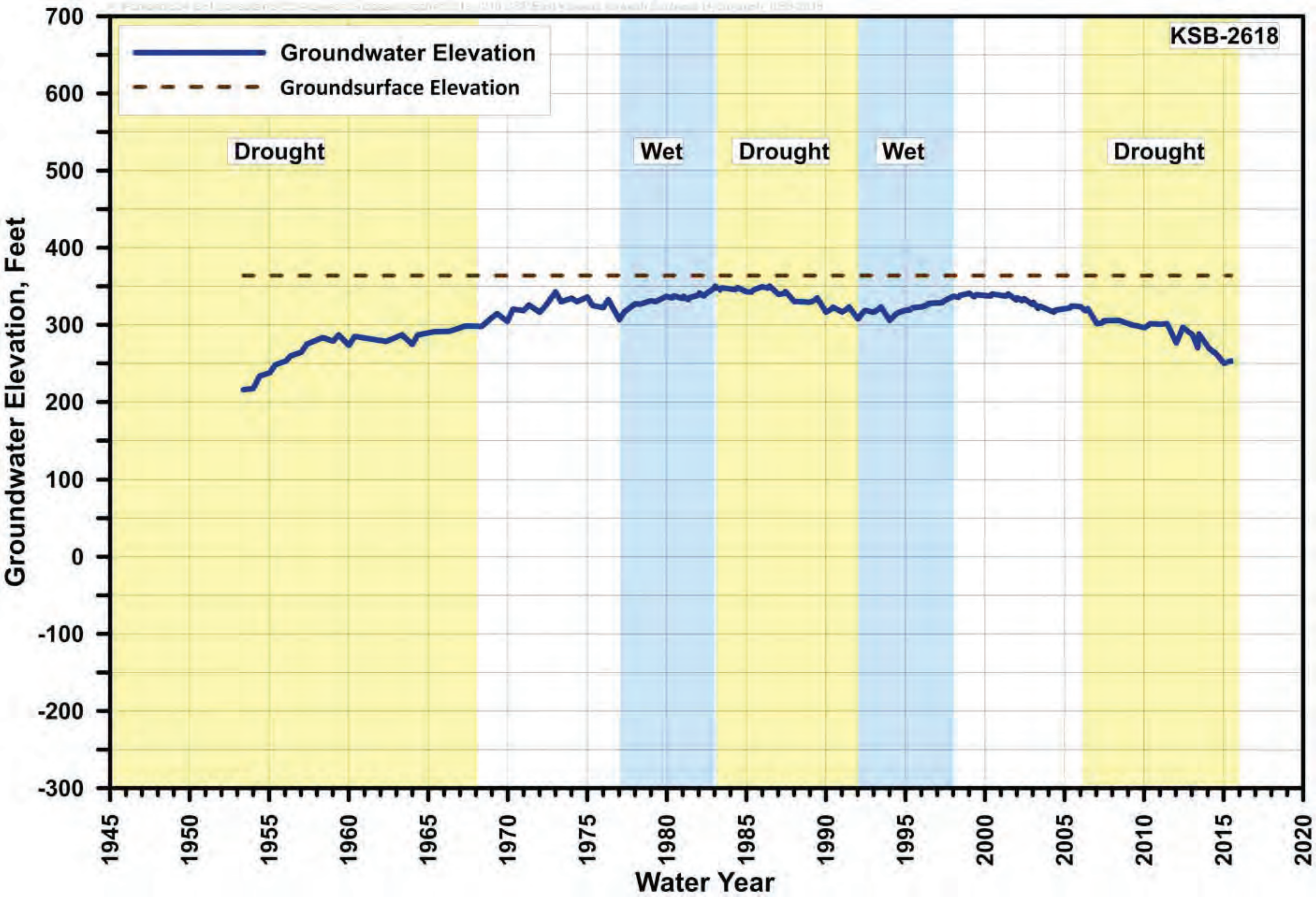
2015
2020
Water Year



KSB-2618
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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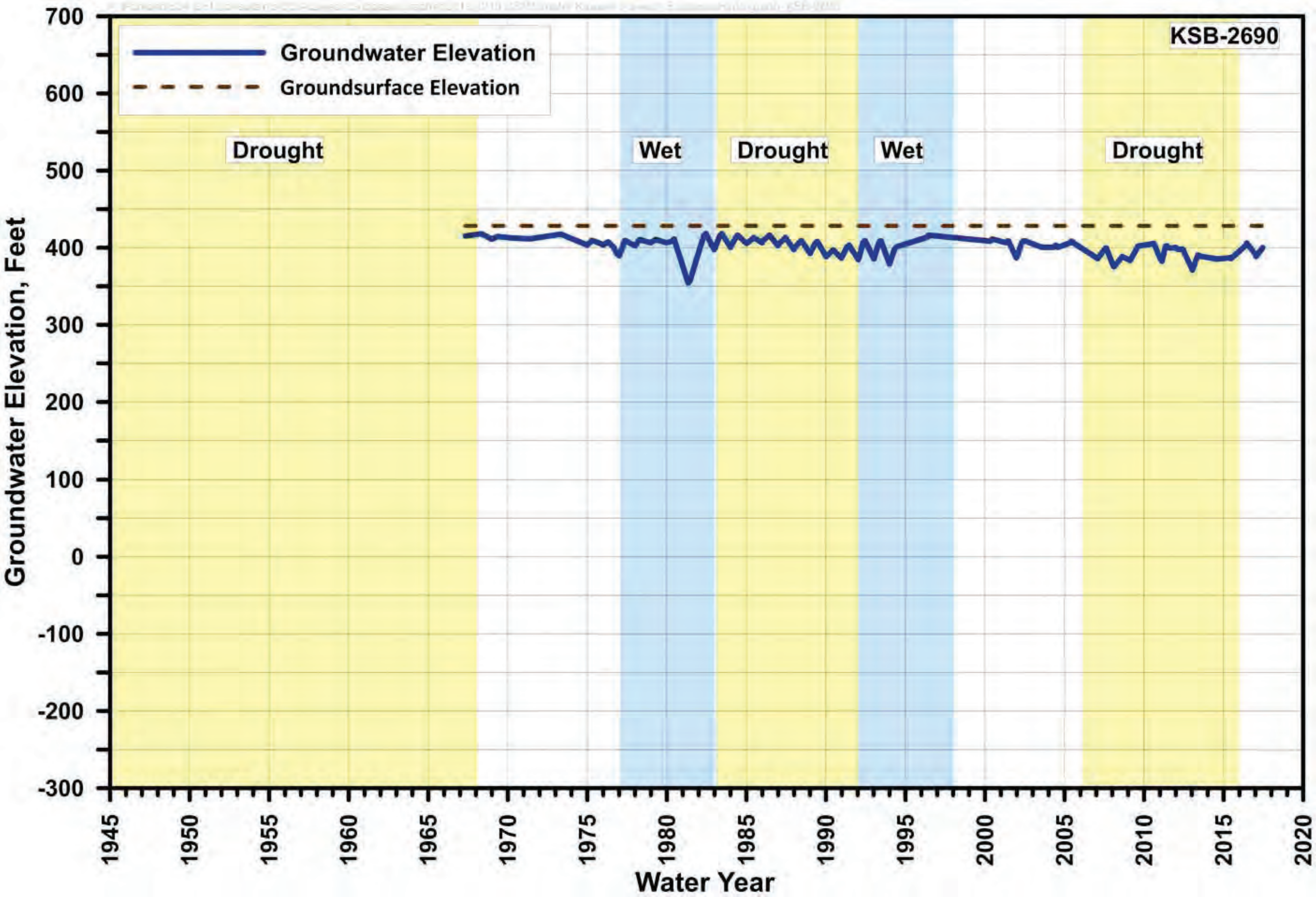
2015
2020
Water Year



Groundwater Elevation
Groundsurface Elevation
KSB-2690
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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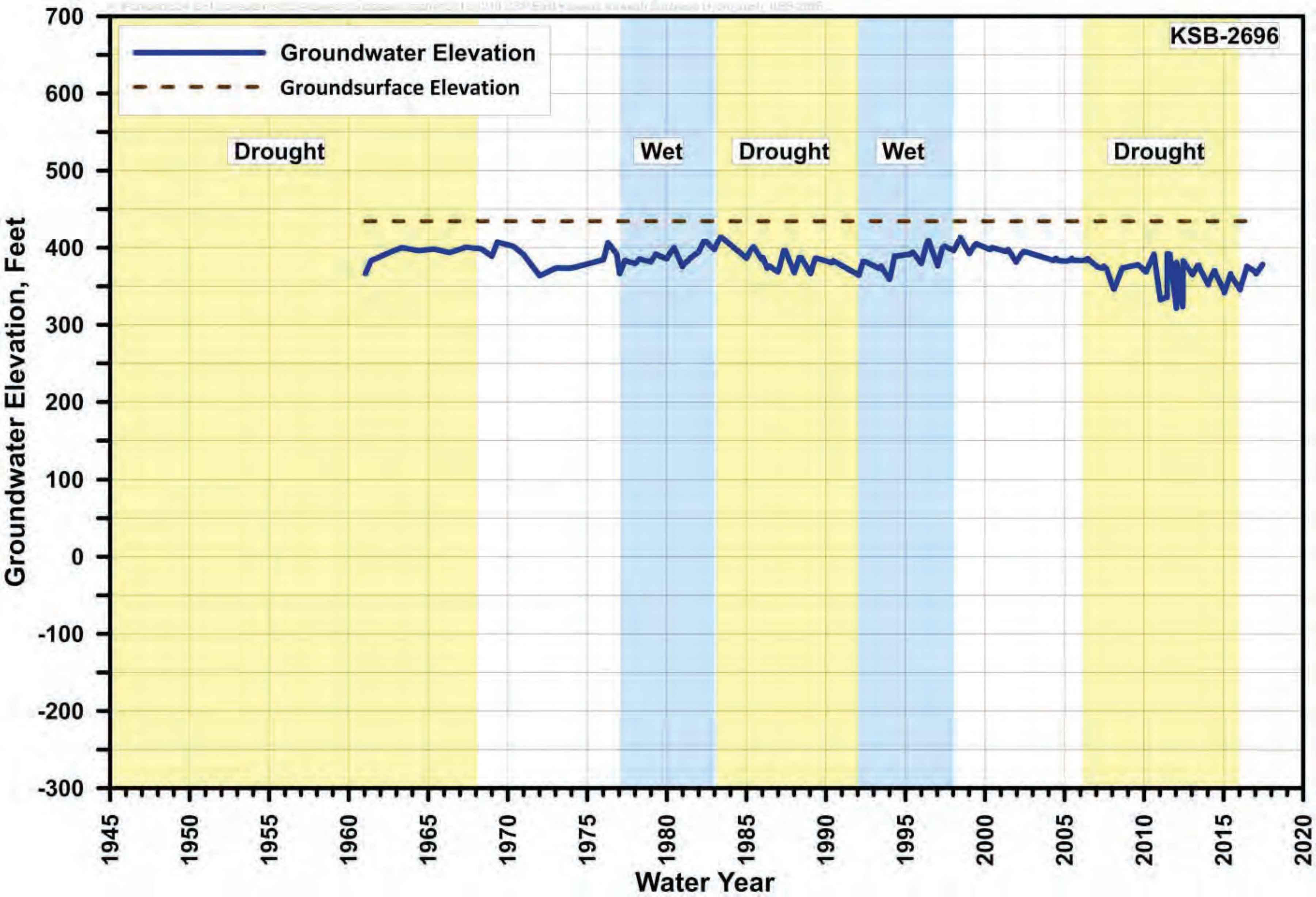
2015
2020
Water Year



KSB-2696
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
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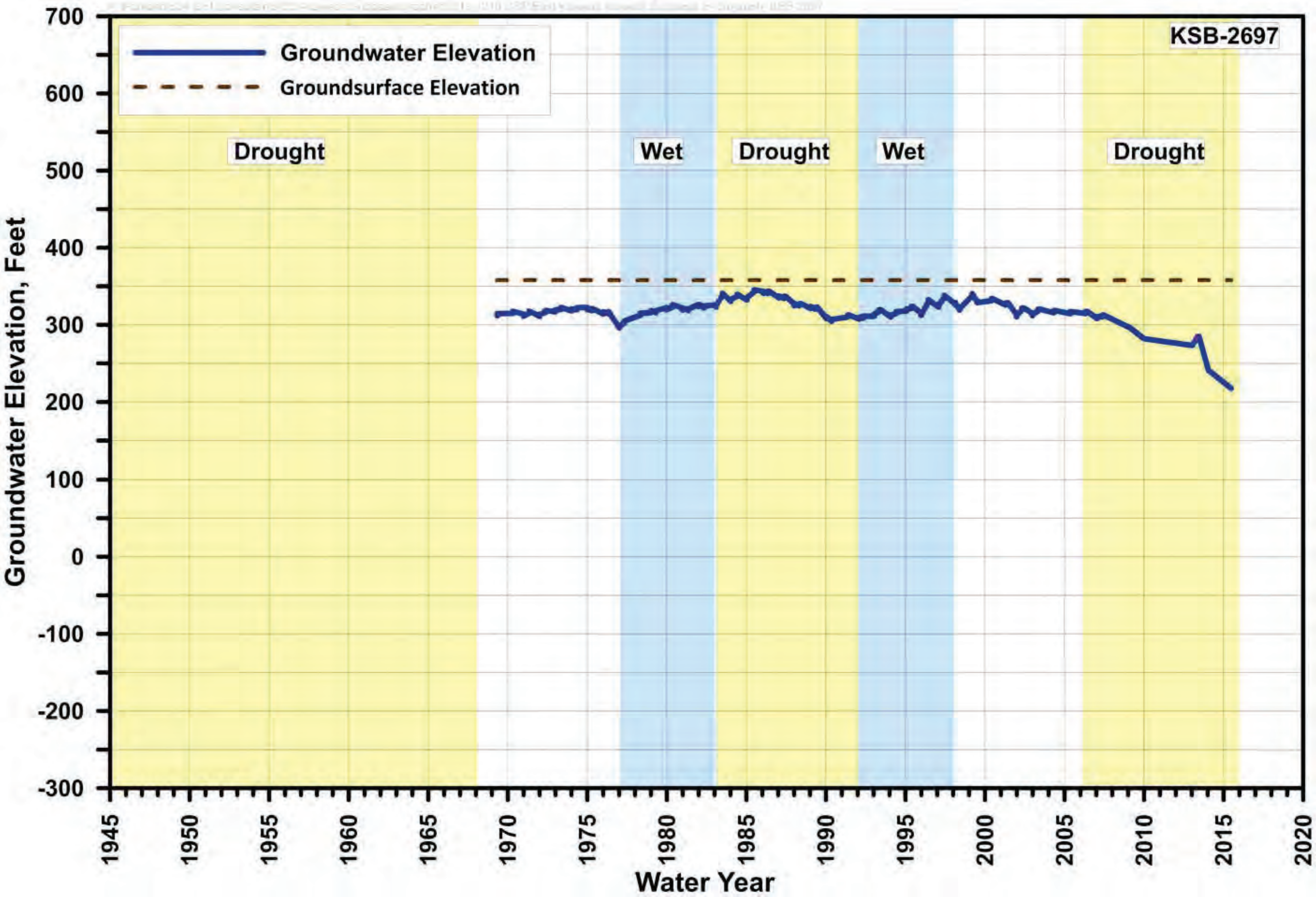
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Groundsurface Elevation
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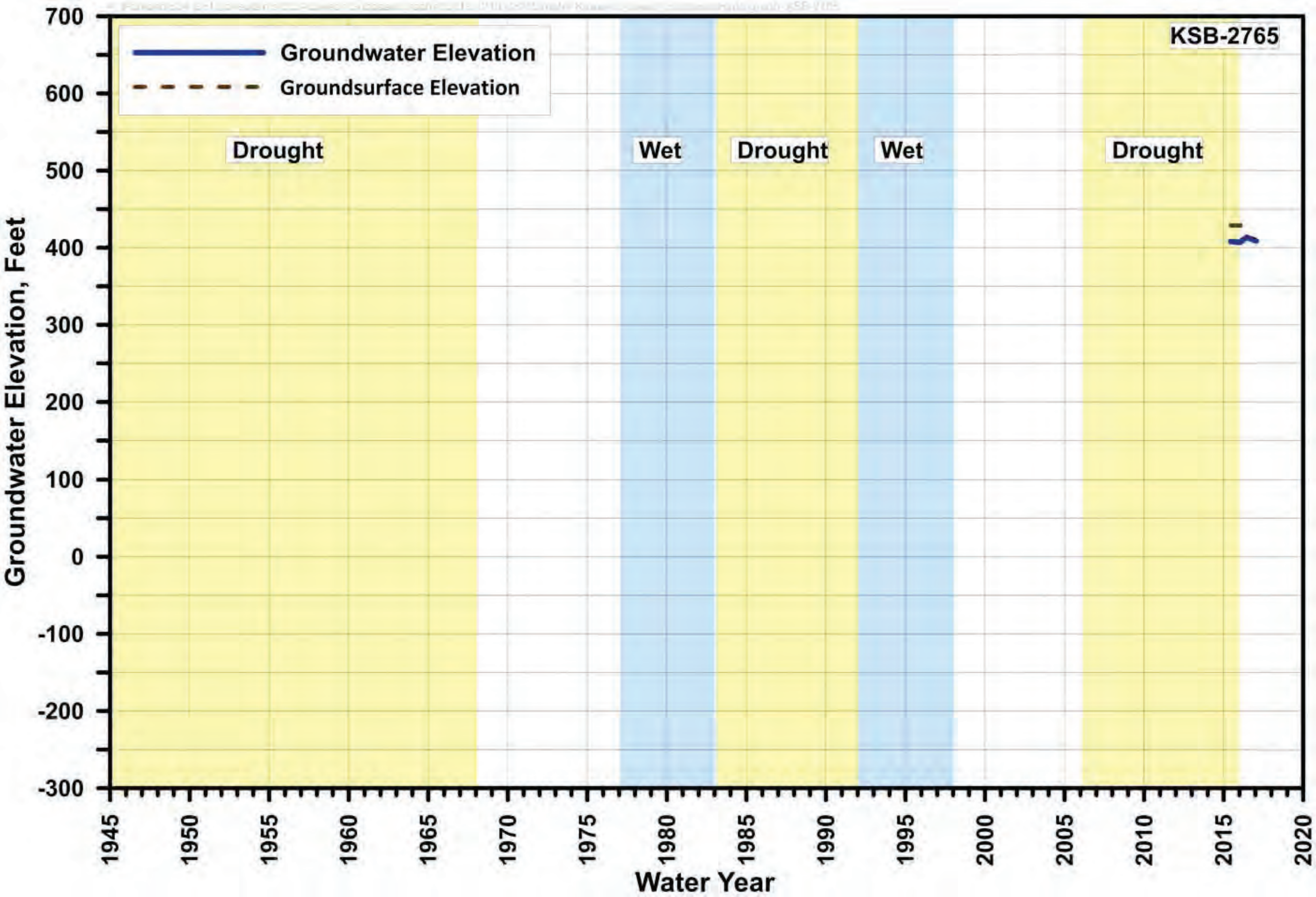

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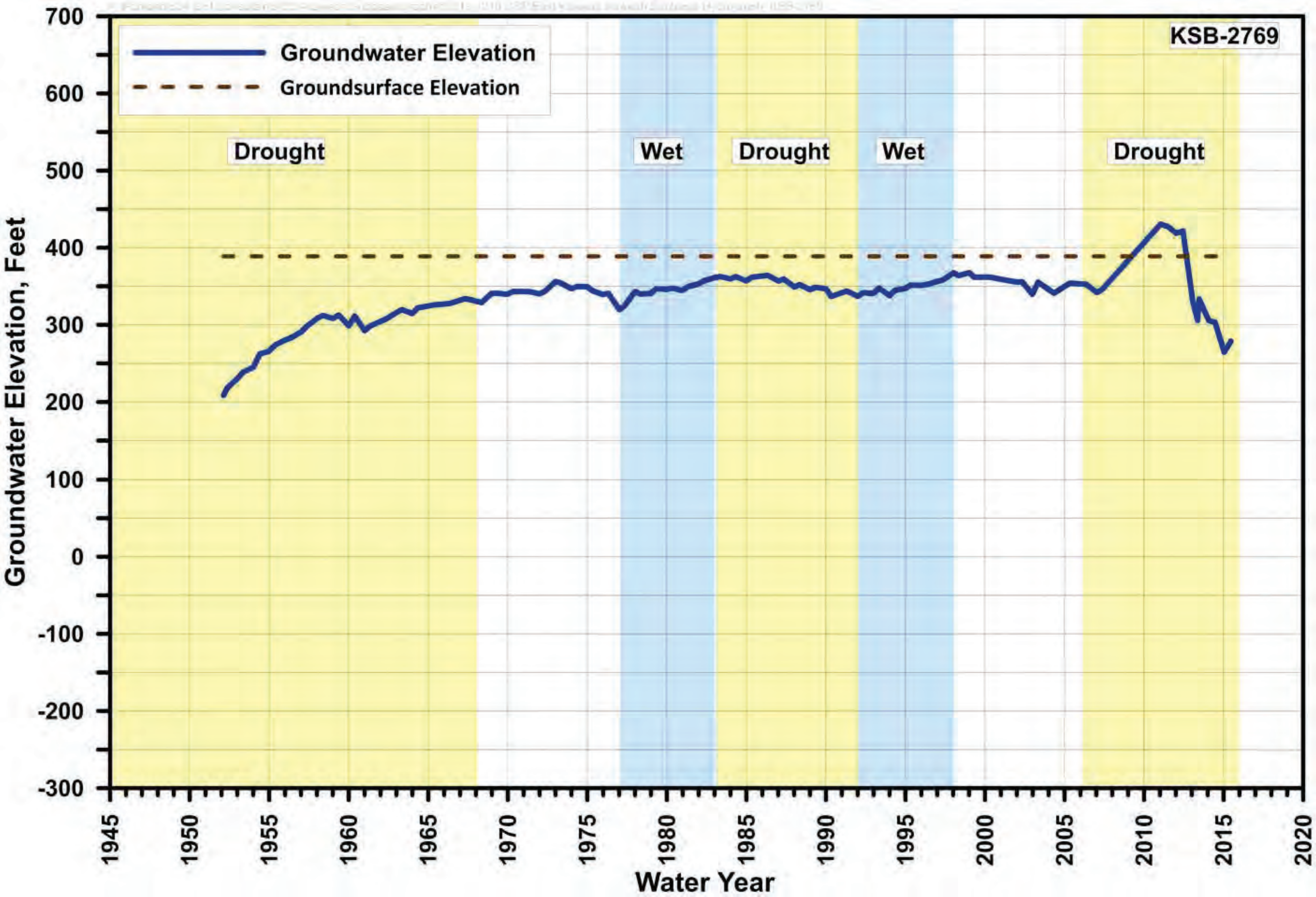

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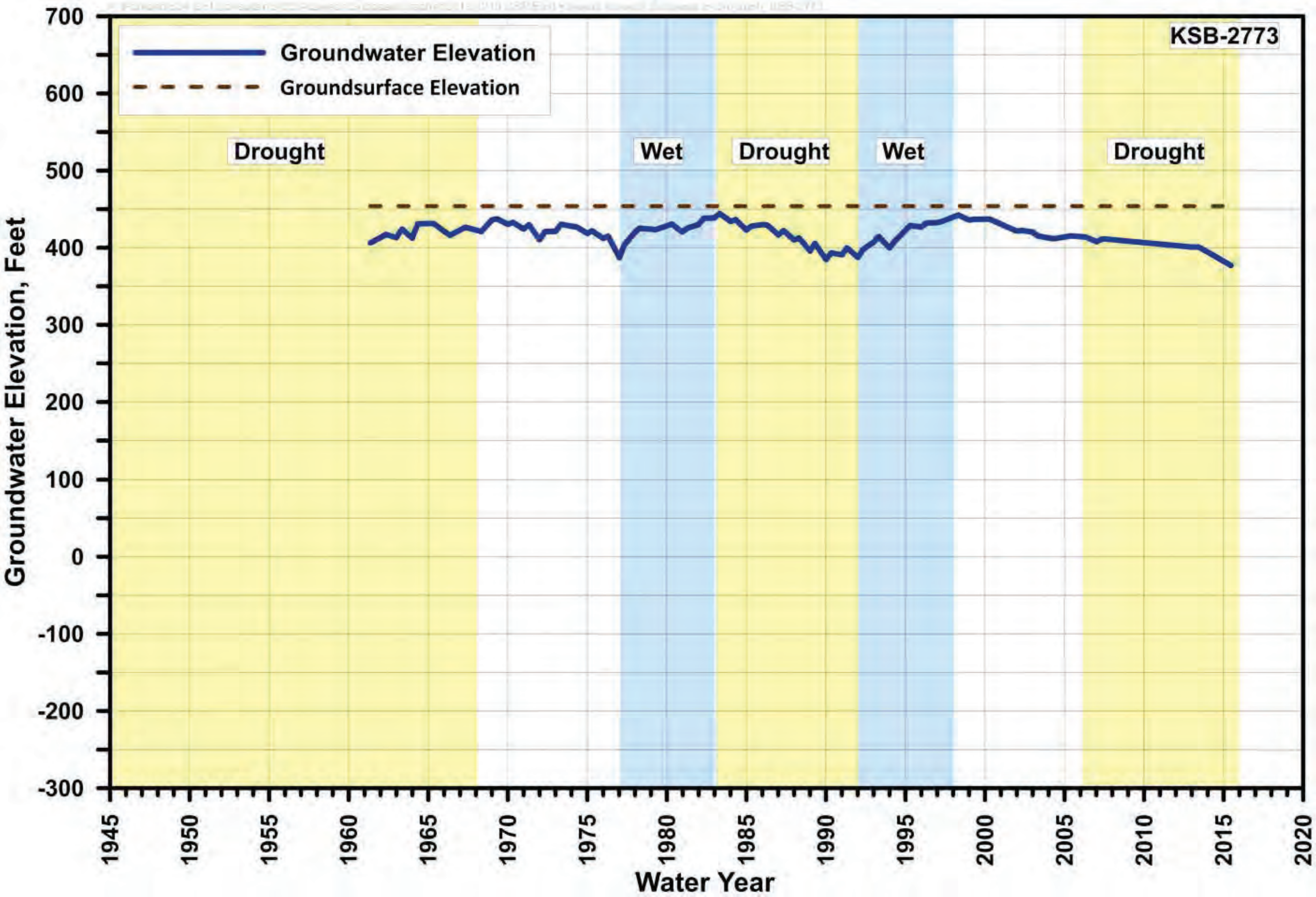

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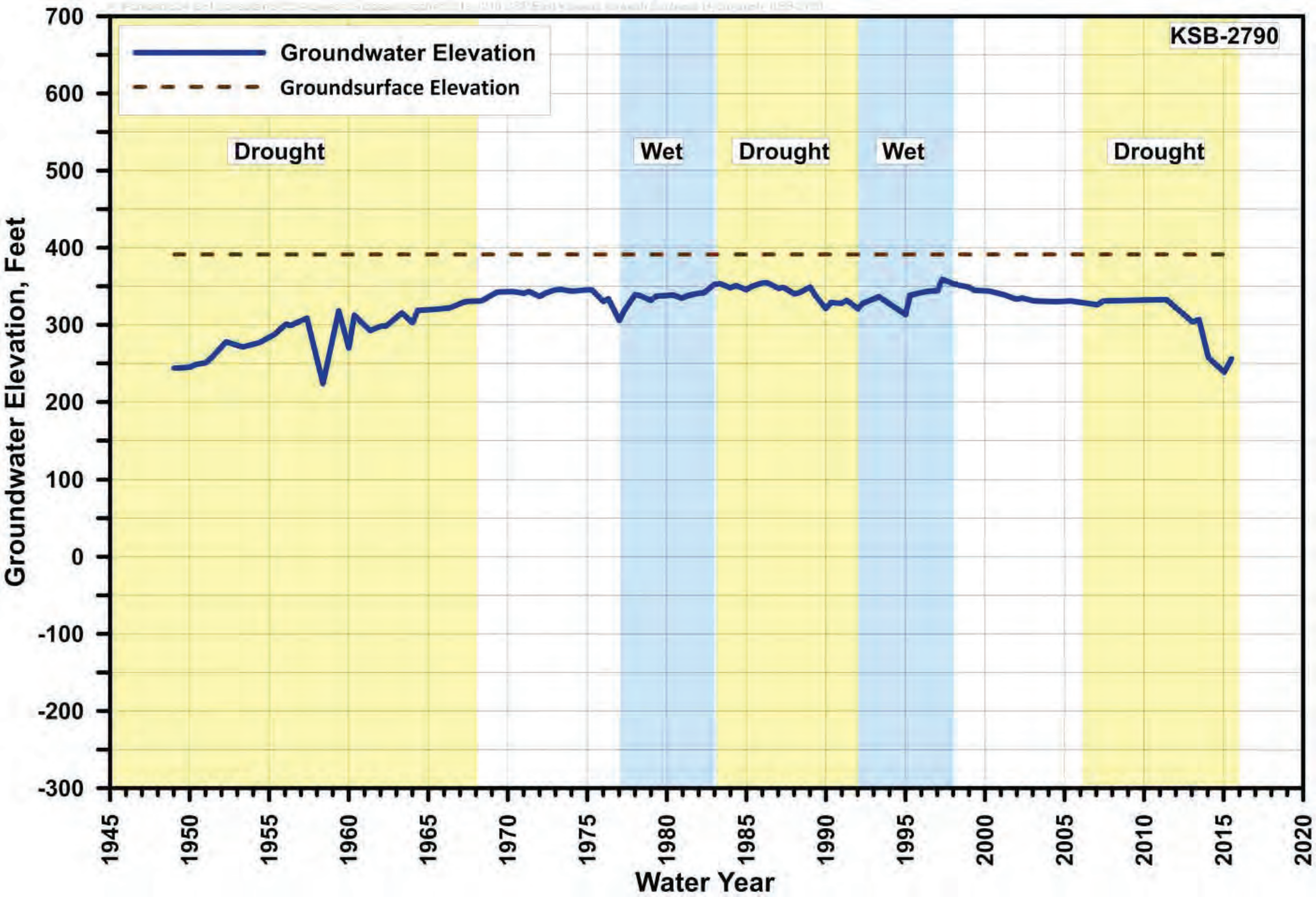

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Drought
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Water Year
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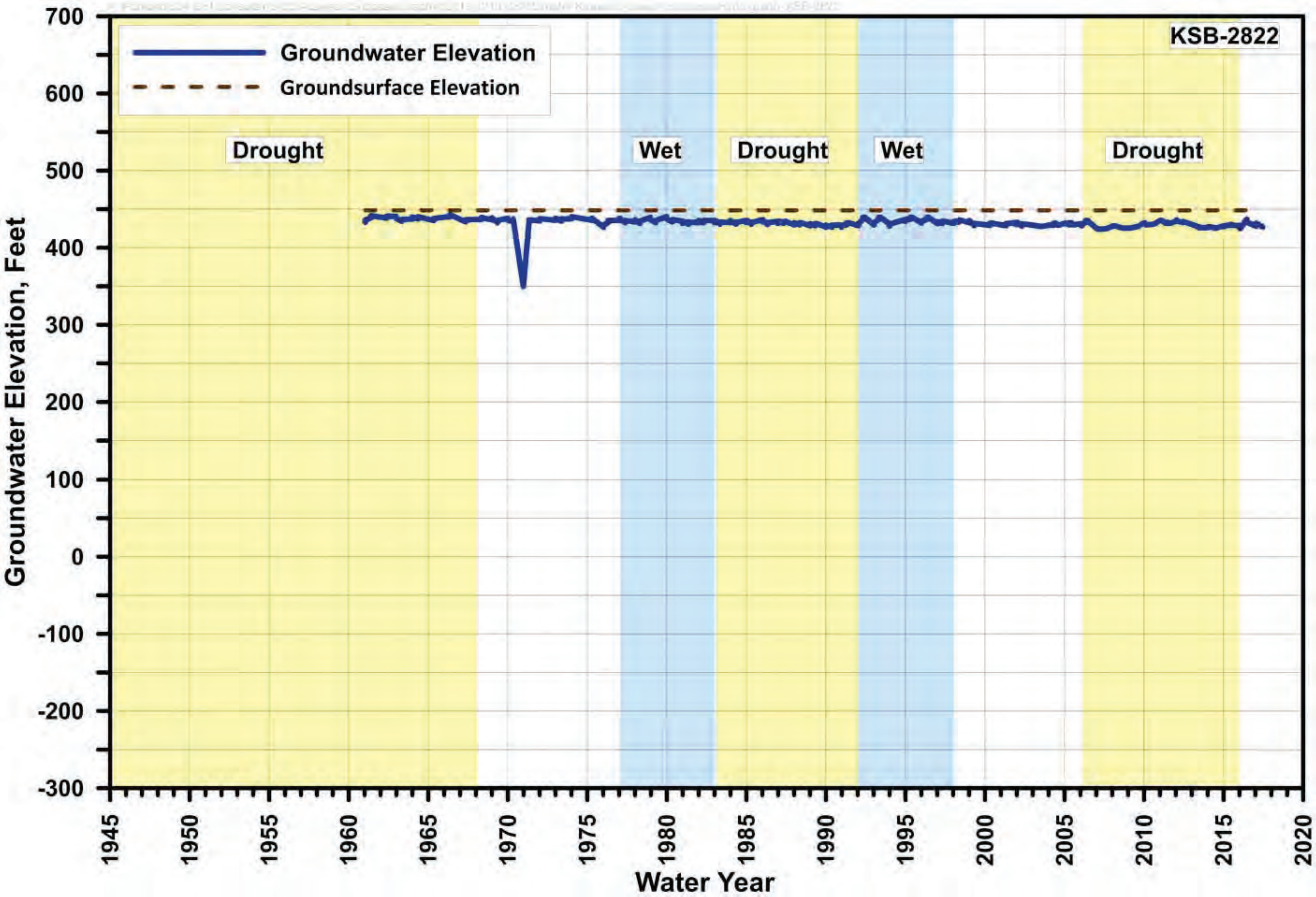
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Drought
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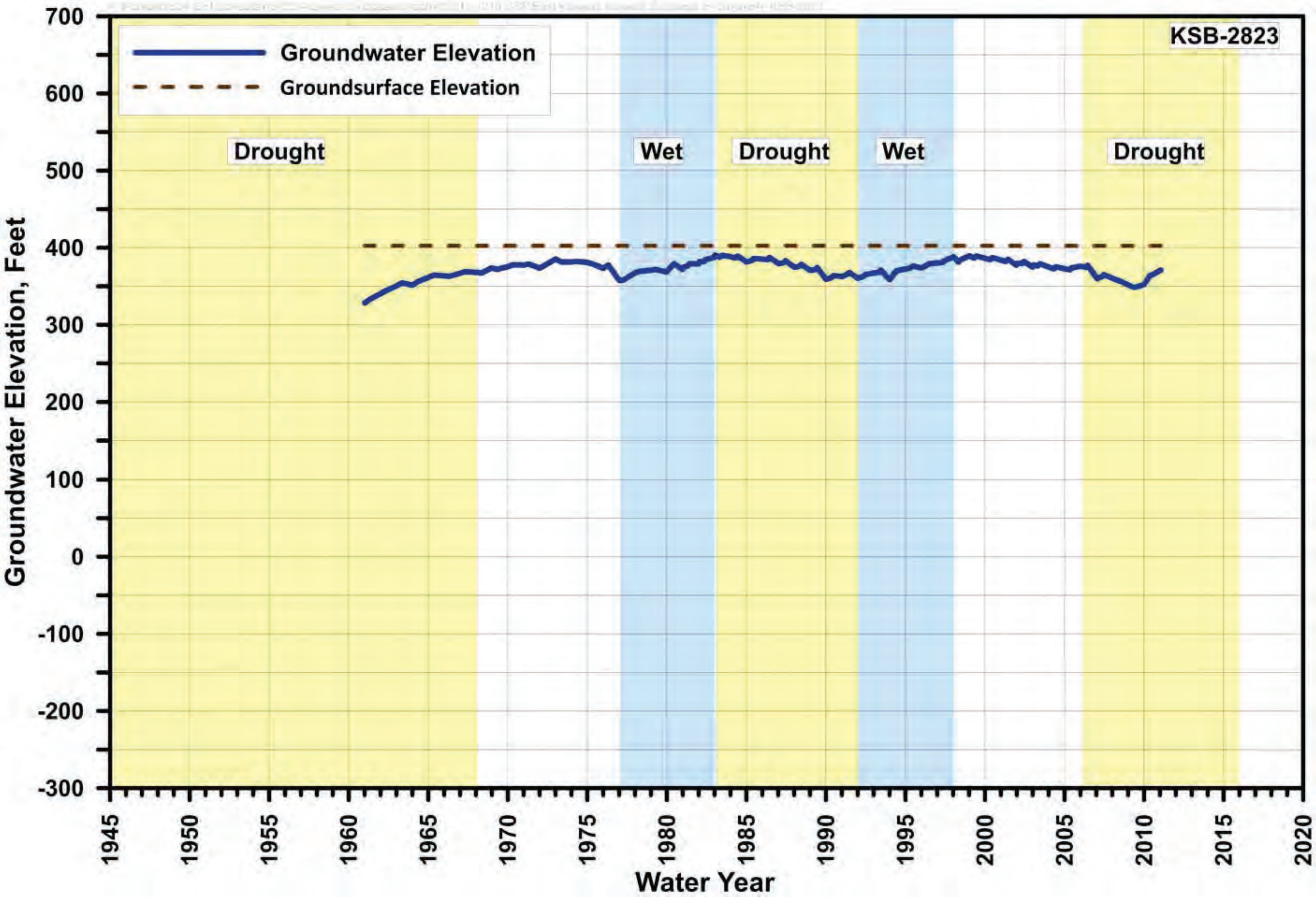

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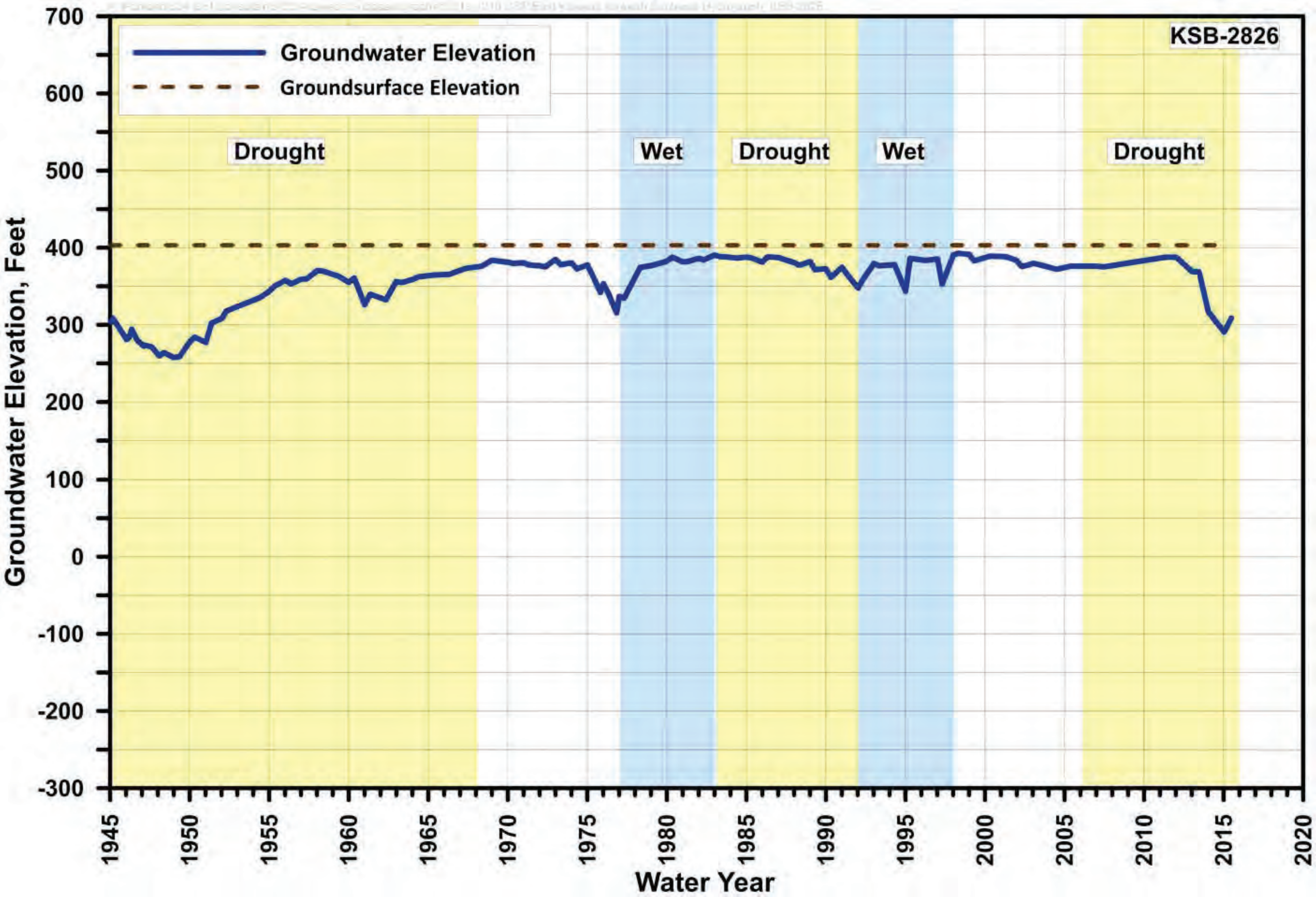

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Groundwater Elevation, Feet
Water Year
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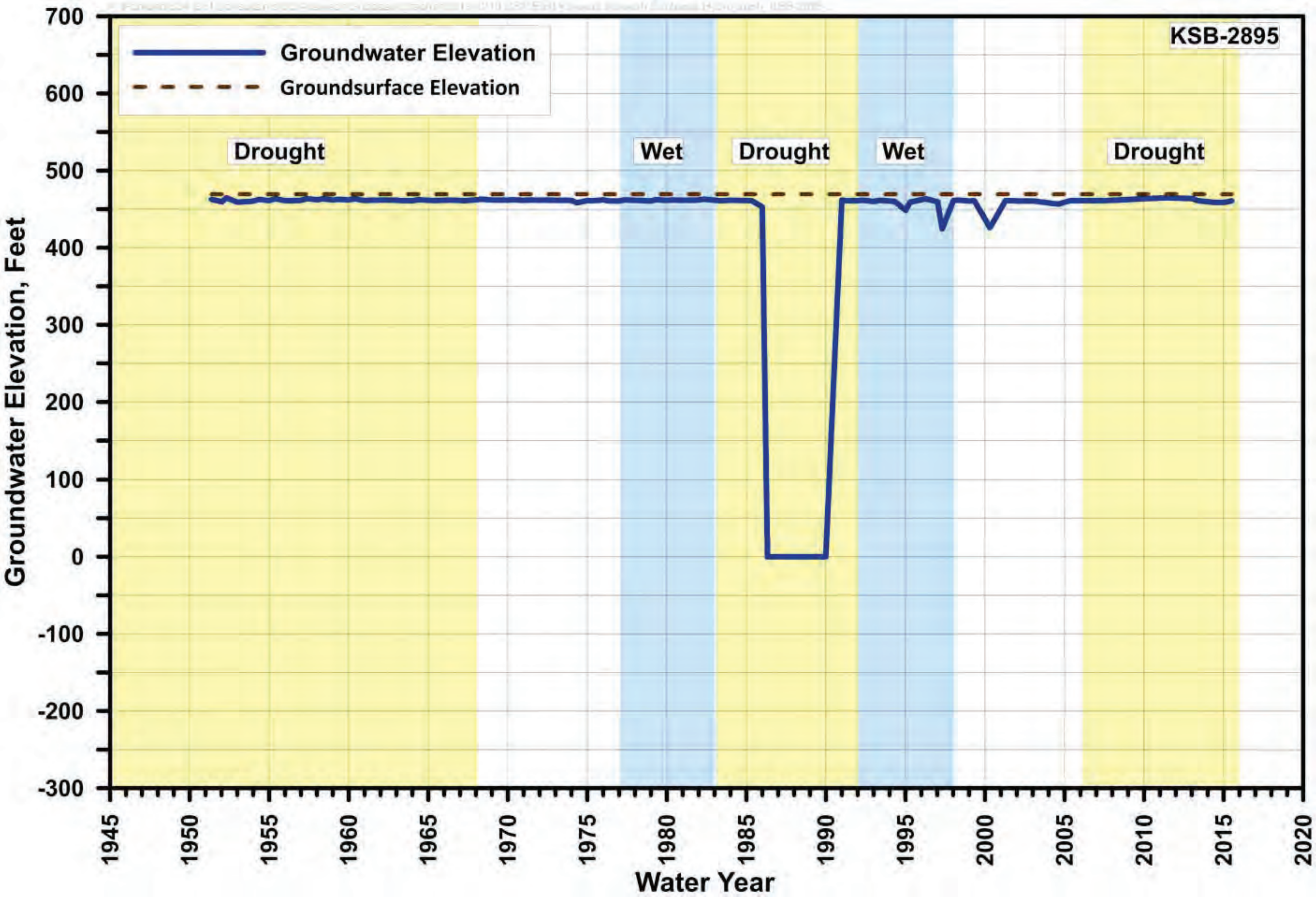
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Drought
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Water Year
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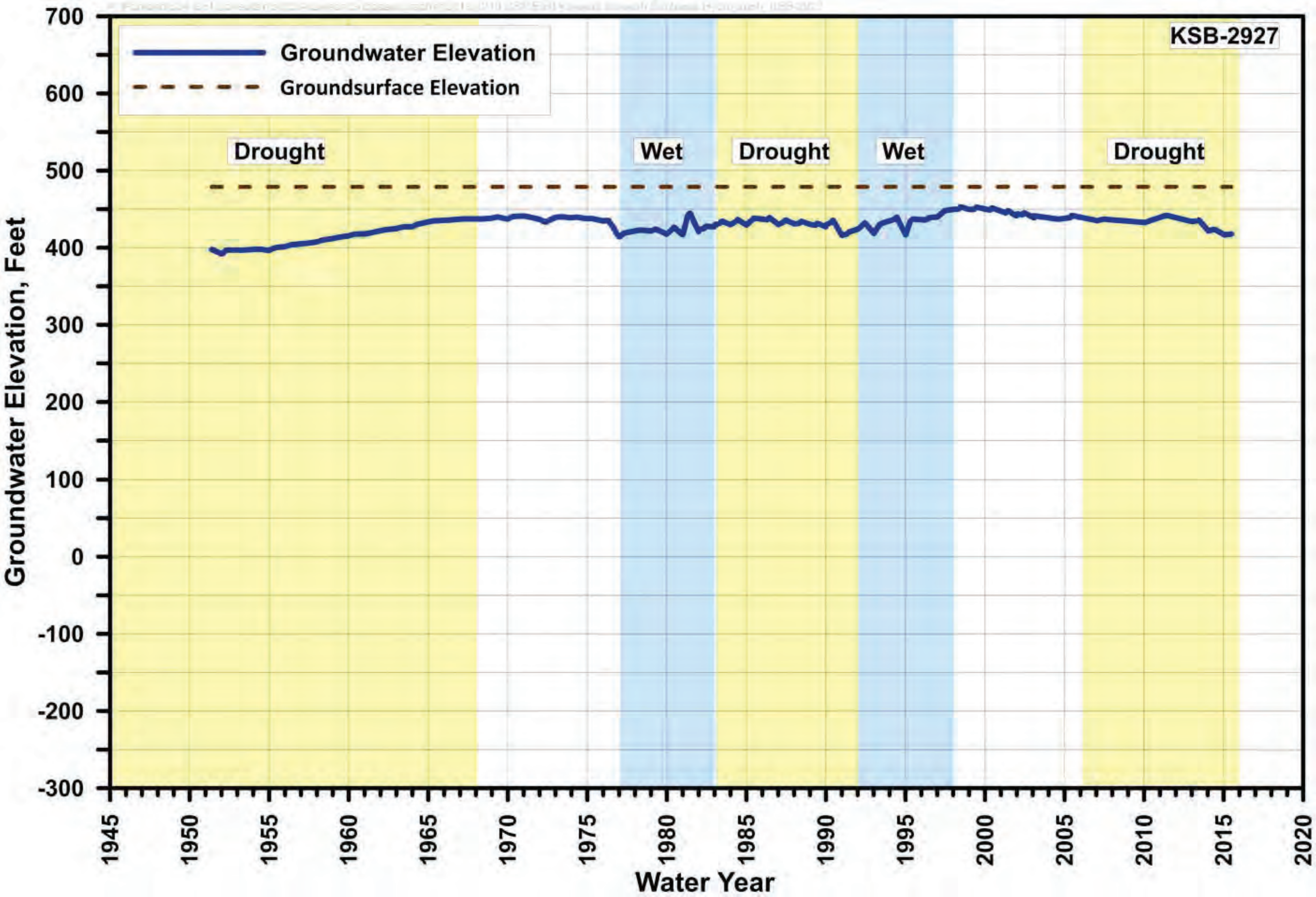

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# Appendix C

## Davids Engineering
## Evapotranspiration and Applied Water Estimates

## Technical Memorandum

# Technical Memorandum

**To:** GEI Consultants

**From:** Davids Engineering

**Date:** November 30, 2018

**Subject:** **Kaweah Subbasin Development of Evapotranspiration and Applied Water Estimates Using Remote Sensing**

## 1 Summary

The purpose of this effort is to develop time series estimates of agricultural water demands for the Kaweah Subbasin from 1999 through 2017. This effort updates a similar analysis previously completed for the Kaweah Delta Water Conservation District (KDWCD) from 1999 through 2016 to include the areas currently not included in the KDWCD area but lying within the Kaweah Subbasin and to extend the estimates through 2017.

The consumptive use of water (i.e., evapotranspiration) is the primary destination of infiltrated precipitation and applied irrigation water within the Kaweah Subbasin. Quantification of consumptive use was achieved by performing daily calculations of evapotranspiration (ET) for individual fields from October 1998 through December 2017. ET was separated into its evaporation (E) and transpiration (T) components. Transpiration was quantified using a remote sensing approach where Landsat satellite images acquired from USGS were used to calculate the Normalized Difference Vegetation Index (NDVI), which was subsequently translated to a basal crop coefficient and combined with referent ET to calculate transpiration over time.

A spatial coverage of field boundaries was developed for the Kaweah Subbasin, and individual field polygons were assigned cropping and irrigation method information over time based on available data. Field boundaries were delineated by combining polygon coverages in GIS format from the United States Department of Agriculture (USDA) and the California Department of Water Resources (DWR). The area encompassed by the field boundary GIS coverage includes the Kaweah Subbasin and the area immediately surrounding but outside of the subbasin.

Crop ET was calculated based on a combination of remote sensing data and simulation of irrigation events in a daily root zone water balance model. Due to the remote sensing approach crop ET estimates are relatively insensitive to crop type and irrigation method so detailed, accurate assignment of crop types and irrigation methods to each field is not critical to developing relatively reliable estimates of crop ET. Crop types and irrigation method were assigned to each field based on a combination of data from DWR and USDA. The amount of green vegetation present over time was estimated for each field polygon based on NDVI, which is calculated using a combination of red and near infrared reflectances as measured using multispectral satellite sensors onboard Landsat satellites. Following the preparation of NDVI imagery spanning the analysis period all images were quality controlled to remove pixels affected by clouds.

Mean daily NDVI values for each field were converted to basal crop coefficients based on cropping information from the 2007 Tulare County crop survey, combined with an analysis of actual evapotranspiration ($ET_a$) by crop conducted using the Surface Energy Balance Algorithm for Land (SEBAL®) for 2007 (Bastiaanssen et al., 2005; SNA, 2009). Daily precipitation was estimated based on assembly and review of data from the PRISM Climate Group at Oregon State University[1]. Daily reference evapotranspiration ($ET_o$) was estimated based on information from California Irrigation Management Information System (CIMIS) weather stations. Root zone parameters that influence the amount of available soil moisture storage were estimated based on crops and soils present in the Kaweah Subbasin.

A summary for the 1999 to 2017 analysis period of the annual ET of applied water ($ET_{AW}$), $ET_c$ (synonymous with $ET_a$), applied water (AW), deep percolation of applied water ($DP_{AW}$) and deep percolation of precipitation ($DP_{pr}$) estimates based on the root zone water balance model is given in the Results section.

Application of remote sensing combined with daily root zone water balance modeling (RS-RZ model) provides an improved methodology for estimation of surface interactions with the groundwater system including net groundwater depletion through estimation of ET of applied water and other fluxes.

# 2 Introduction

The purpose of this effort is to develop time series estimates of agricultural water demands for the Kaweah Subbasin from 1999 through 2017. Demand was estimated quantitatively at the field scale using a daily root zone water balance model and aggregated to monthly time steps. It is anticipated that these estimates will be used to support development of an integrated hydrologic model for the Kaweah Subbasin and water budget development for one or more Groundwater Sustainability Plans (GSPs). Crop evapotranspiration (ET), the primary driver of agricultural water demand, was estimated based on a combination of remote sensing and simulation of irrigation events using the water balance model.

This effort updates a similar analysis previously completed for the Kaweah Delta Water Conservation District (KDWCD) from 1999 through 2016 to include the areas currently not included in the KDWCD area but lying within the Kaweah Subbasin. In addition to adding the additional areas within the Kaweah subbasin, this analysis extends the estimates through the end of the 2017 calendar year.

# 3 Methodology

## *3.1 Daily Root Zone Simulation Model*

A conceptual diagram of the various surface layer fluxes of water into and out of the crop root zone is provided in Figure 3.1. The consumptive use of water (i.e., evapotranspiration or ET) is the primary destination of infiltrated precipitation and applied irrigation water within the Kaweah Subbasin. Quantification of consumptive use was achieved by performing daily calculations of ET for individual fields from October 1998 through December 2017. Evapotranspiration was separated into its evaporation (E) and transpiration (T) components. Additionally, each component was separated into the amount of E or T derived from precipitation or applied water.



[1] http://prism.oregonstate.edu/

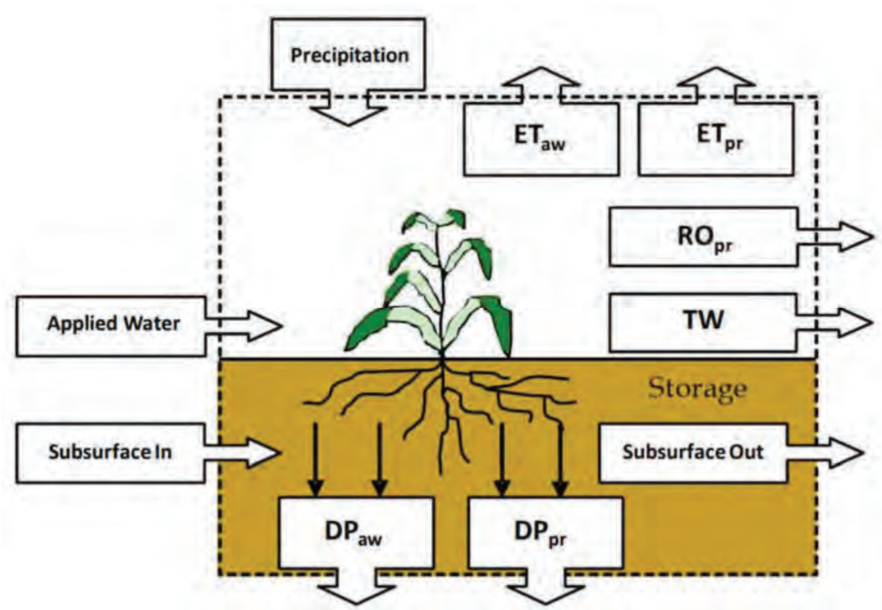


**Figure 3.1. Conceptualization of Fluxes of Water Into and Out of the Crop Root Zone**

Transpiration was quantified using a remote sensing approach whereby Landsat satellite images acquired from USGS were used to calculate the Normalized Difference Vegetation Index (NDVI), a measure of the amount of green vegetation present. NDVI values were calculated and interpolated for each field over time. NDVI values were then converted to transpiration coefficients that were used to calculate transpiration over time by multiplying daily NDVI by daily reference evapotranspiration ($ET_o$). Evaporation was quantified by performing a surface layer water balance for the soil based on the dual crop coefficient approach described in FAO Irrigation and Drainage Paper 56 (Allen et al. 1998). On a daily basis, evaporation was calculated based on the most recent wetting event (precipitation or irrigation) and the evaporative demand for the day ($ET_o$). This methodology is described in greater detail by Davids Engineering (Davids Engineering 2013).

## *3.2 Development of Field Boundaries*

A spatial coverage of field boundaries was developed for the Kaweah Subbasin, and individual field polygons were assigned cropping and irrigation method information. For each field polygon, daily water balance calculations were performed for the 1999 to 2017 analysis period, and irrigation events were simulated to estimate the amount of water applied to meet crop irrigation demands. This section describes the development of the field polygon coverage and assignment of cropping and irrigation method attributes.

### 3.2.1 Development of Field Boundaries

Field boundaries were delineated by combining publicly available polygon coverages in GIS format from the United States Department of Agriculture (USDA) and the California Department of Water Resources (DWR). For the original KDWCD study area, common land unit (CLU) coverages developed by the USDA Farm Services Administration (FSA) on a county by county basis were combined to develop the base field coverage. Gaps exist in the CLU field coverages for fields not participating in USDA farm programs. These gaps were filled by overlaying the FSA CLU data with field polygons from DWR land use surveys for Kings and Tulare counties.

For the expanded study area encompassing the full Kaweah Subbasin, the original field boundaries were retained, and additional fields were added based on DWR's 2014 statewide spatial cropping dataset.

The area encompassed by the field boundary GIS coverage includes the Kaweah Subbasin and the area immediately surrounding, but outside of, the subbasin. Fields outside of the subbasin were included to provide a more robust dataset for model calibration and validation. Ultimately, results specific to the subbasin as a whole include only those fields with their centroid located within the Kaweah Subbasin.

### *3.3 Assignment of Cropping and Irrigation Method*

As described previously, crop evapotranspiration (ET) was calculated based on a combination of remote sensing data and simulation of irrigation events in a daily root zone water balance model. A result of the remote sensing approach is that crop transpiration was estimated with little influence from the assigned crop type for each field. Additionally, crop transpiration is the dominant component of ET, meaning that ET estimates are likewise largely independent of the assigned crop type.

Crop evapotranspiration is driven to some extent by the characteristics of the irrigation method and its management, including the area wetted during each irrigation event and the frequency of irrigation. Surface irrigation methods typically wet more of the soil surface than micro-irrigation methods; however, surface irrigated fields are typically irrigated less frequently than their micro-irrigated counterparts. As a result, evaporation rates can be similar among surface and micro-irrigated fields and estimates of evaporation are likewise somewhat independent of the assigned irrigation method. Parameters related to irrigation method were assigned based the predominant irrigation method for each crop, as described by recent historical DWR land and water use surveys.

A key result of the relative insensitivity of the crop ET estimates to crop type or irrigation method (due to the remote sensing approach), is that detailed, accurate assignment of crop types and irrigation methods to each field is not critical to developing reliable estimates of crop ET at the field scale and, more importantly, at coarser scales due to the cancellation of errors in individual field estimates as they are aggregated.

Crop types were assigned to each field based on a combination of data from DWR and USDA. DWR data consisted of land use data from 2003 and 2014 for Kings County and from 1999, 2007, and 2014 for Tulare County. USDA data consisted of Cropland Data Layer coverages for 2008 to 2013 and 2015 to 2016. The source of land use data for each year is summarized in Table 3.1.

**Table 3.1. Land Use Sources by County and Year.**

| County | Year(s) | Source |
|---|---|---|
| Kings | 1999-2007 | DWR (2003) |
| | 2008-2013 | CDL |
| | 2014 | DWR (2014) |
| | 2015-2017 | CDL* |
| Tulare | 1999-2002 | DWR (1999) |
| | 2003-2007 | DWR (2007) |
| | 2008-2013 | CDL |
| | 2014 | DWR (2014) |
| | 2015-2017 | CDL* |

* CDL data for 2016 was used for 2017

## *3.4 NDVI Analysis*

The amount of green vegetation present over time was estimated for each field polygon based on the Normalized Difference Vegetation Index (NDVI), which is calculated using a combination of red and near infrared reflectances, as measured using multispectral satellite sensors onboard Landsat satellites. NDVI can vary from -1 to 1 and is typically varies from approximately 0.15 to 0.2 for bare soil to 0.8 for green vegetation with full cover. Negative NDVI values typically represent water surfaces.

### 3.4.1 Image Selection

Landsat images are preferred due to their relatively high spatial resolution (30-meter pixels, approx. 0.2 acres in size). A total of 682 raw satellite images were selected and converted to NDVI spanning the period from September 1998 to January 2018. Of the images selected, 230 were from the Landsat 5 satellite, 350 were from the Landsat 7 satellite (first available in 2001), and 102 were from the Landsat 8 satellite (first available in 2013). These images were used to process and download surface reflectance (SR) NDVI from the USGS Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA)[2].

An example time series of NDVI imagery for 2010 for the Kaweah Delta Water Conservation District (KDWCD) is shown in Figure 3.1 in Davids Engineering (2013). In the figure, areas with little or no green vegetation present are shown in brown, and areas with green vegetation are shown in green.

There was sufficient cloud-free Landsat imagery available that no cloud gap filling as in Davids Engineering (2013) was necessary. The number of days between image dates ranged from 5 to 56, with an average of 10 days. Generally, there was at least one image selected for each month.

### 3.4.2 Extraction of NDVI Values by Field and Development of Time Series NDVI Results

Following the preparation of NDVI imagery spanning the analysis period, all images were masked using the Quality Assessment Band (BQA) provided by ESPA to remove pixels affected by clouds. Then, mean NDVI was extracted from the imagery for each field for each image date. These NDVI values were then interpolated across the full analysis period from October 1, 1998 to December 31, 2017 to provide a daily time series of mean NDVI values for each field.

[2] USGS ESPA website: https://espa.cr.usgs.gov/

Top of Atmosphere (TOA) NDVI was calculated for several image dates and compared to SR NDVI on the same image dates to establish the following relationship ($R^2$=0.99):

$$(TOA\ NDVI) = 0.9224*(SR\ NDVI) - 0.0171 \qquad [3.1]$$

This regression was applied to all image dates to convert from SR to TOA NDVI to provide consistency with the relationship between NDVI and the transpiration coefficient developed by Davids Engineering (2013) **Error! Bookmark not defined.**.

Landsat 8 bandwidth was adjusted to be consistent with bandwidths from Landsat satellites 5 and 7 using the following empirical relationship:

$$(L7\ mean\ NDVI) = 0.984*(L8\ mean\ NDVI) - 0.0421 \qquad [3.2]$$

An example of time varying NDVI for individual fields over time is found in Section 3 of Davids Engineering (2013). Interpolated NDVI values for selected fields are provided for the period 1999 through 2010 on an annual basis, from January 1 to December 31 of each year. These figures illustrate the ability of the remote sensing approach to account for both changes in cropping over time and the presence of double- and triple-cropping.

### 3.4.3 Development of Relationships to Estimate Basal Crop Coefficient from NDVI

Basal crop coefficients ($K_{cb}$) describe the ratio of crop transpiration to reference evapotranspiration ($ET_o$) as estimated from a ground-based agronomic weather station. By combining $K_{cb}$, estimated from NDVI, with an evaporation coefficient ($K_e$), it is possible to calculate a combined crop coefficient ($K_c = K_{cb} + K_e$) over time[3]. By multiplying $K_c$ by $ET_o$, crop evapotranspiration ($ET_c$) can be calculated. For this analysis, $ET_o$, $K_{cb}$, $K_e$, and $ET_c$ (synonymous to actual ET, $ET_a$) were estimated for each field on a daily time step from October 1, 1998 to December 31, 2017.

Mean daily NDVI values for each field were converted to basal crop coefficients based on cropping information from the 2007 Tulare County crop survey conducted by DWR, combined with an analysis of actual evapotranspiration ($ET_a$) by crop conducted using the Surface Energy Balance Algorithm for Land (SEBAL®) for 2007 (Bastiaanssen et al., 2005; SNA, 2009). Specifically, a relationship between actual basal crop coefficients estimated using SEBAL and field-scale mean NDVI values developed by Davids Engineering (2013) was applied to calculate daily basal crop coefficients for each field over time[4].

## *3.5 Precipitation*

Daily precipitation was estimated based on assembly and review of data from the PRISM Climate Group at Oregon State University[5]. Specifically, each field was assigned estimated precipitation from the 4km PRISM grid cell within which its centroid fell. The update generally results in modest increases in estimated precipitation within the study area, with greater increases moving from west to east due to orographic effects.

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[3] The estimation of Ke is based on a daily 2-stage evaporation model presented in FAO Irrigation and Drainage Paper No. 56 (Allen et al. 1998).

[4] This relationship is developed based on comparison of the combined crop coefficient to NDVI for individual fields, but represents only the transpiration component of ET. Thus, the relationship developed predicts the basal crop coefficient, Kcb.

[5] http://prism.oregonstate.edu/

Annual precipitation totals, averaged over the study area for water years 1999 to 2017, are shown in Figure 3.1. Water year precipitation over the study period varied from 4.1 inches in 2014 to 16.1 inches in 2011, with an annual average of 9.1 inches.

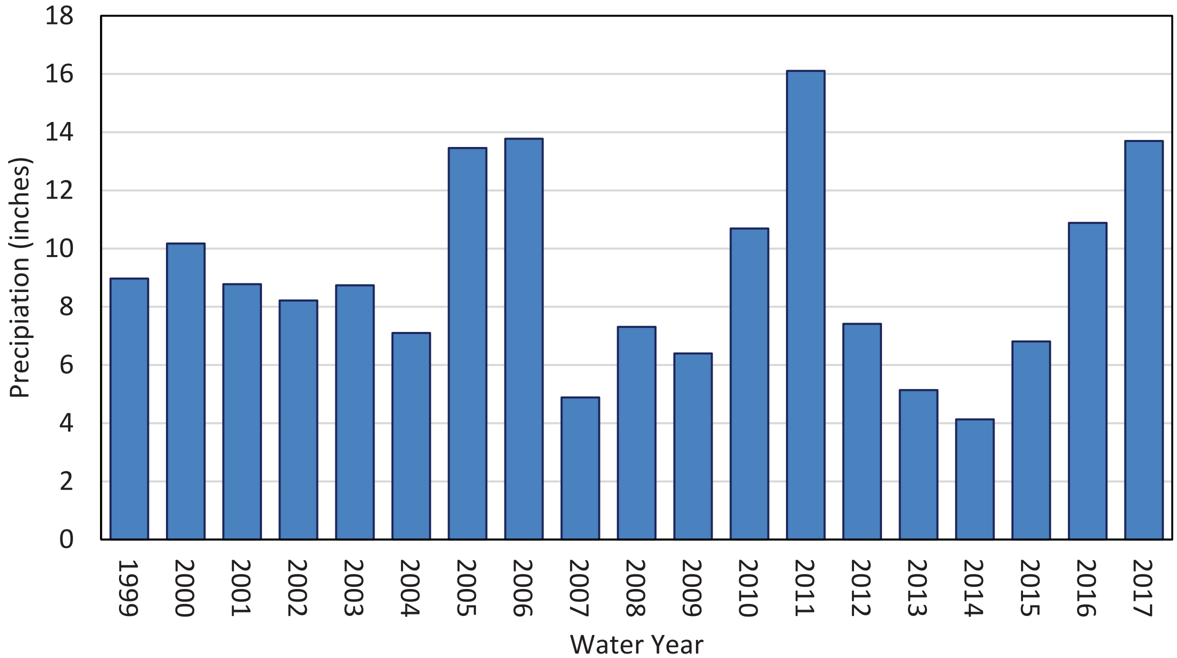



**Figure 3.2. Annual Precipitation Totals**

## *3.6 Estimation of Daily Reference Evapotranspiration*

Daily reference evapotranspiration ($ET_o$) was estimated based on information from California Irrigation Management Information System (CIMIS) weather stations. $ET_o$ provides a means of estimating actual crop evapotranspiration over time for each field. Based on review of nearby weather stations with data available during the period of analysis, the Porterville station (169) was selected based on it being relatively close to the Kaweah Subbasin, at a similar elevation to the Kaweah Subbasin, having relatively good fetch, and having available data for the majority of the analysis period.

Individual parameters from the available data including incoming solar radiation, air temperature, relative humidity, and wind speed were quality-controlled according to the procedures of Allen et al. (2005). The quality-controlled data were then used to calculate daily $ET_o$ for the available period of record.

CIMIS data for Porterville were not available prior to August 2000. As a result, it was necessary to estimate $ET_o$ for the period from October 1, 1998 to August 1, 2000. $ET_o$ for Porterville was estimated by developing a linear regression to estimate Porterville $ET_o$ using quality-controlled data from the Stratford CIMIS station for the period of overlapping data availability.

## *3.7 Estimation of Root Zone Water Balance Parameters*

Root zone parameters that influence the amount of available soil moisture storage were estimated based on crops and soils present in the Kaweah Subbasin. Crop parameters of interest include root depth, NRCS curve number[6], and management allowable depletion (MAD). Root depth was estimated by crop group based on published values and a representative mix of individual crops within each crop group for the Kaweah Subbasin. Curve numbers were estimated based on values published in the NRCS National Engineering Handbook, which provides estimates based on crop type and condition. MAD values by crop were estimated based on values published in FAO Irrigation and Drainage Paper No. 56 (Allen et al., 1998).

Soil hydraulic parameters of interest include field capacity (% by vol.), wilting point (% by vol.), saturated hydraulic conductivity (ft/day), total porosity (% by vol.), and the pore size distribution index (λ, dimensionless). These parameters were estimated by first determining the depth-weighted average soil texture (sand, silt, clay, etc.) based on available NRCS soil surveys. Then, the hydraulic parameters were estimated using hydraulic pedotransfer functions developed by Saxton and Rawls (2006). Next, hydraulic parameters were adjusted within reasonable physical ranges for each soil texture so that the modeled time required for water to drain by gravity from saturation to field capacity agreed with typically accepted agronomic values. Unsaturated hydraulic conductivity (e.g. deep percolation) within the root zone was modeled based on the equation developed by Campbell (1974) for unsaturated flow.

# 4 Results

## *4.1 Crop Evapotranspiration*

Estimated annual crop evapotranspiration volumes for fields with their centroid within the Kaweah Subbasin are shown in Figure 4.1. Estimated volumes of ET derived from applied water (ETaw) and precipitation (ETpr) are shown in thousands of acre-feet (taf). Annual ETaw ranged from 721 taf to 916 taf, with an average of 817 taf. Annual ETpr ranged from 87 taf to 260 taf, with an average of 174 taf. Total crop ET ranged from 899 taf to 1,056 taf, with an average of 991 taf.

[6] The curve number runoff estimation method developed the Natural Resources Conservation Service (NRCS) was used to estimate runoff from precipitation in the model. For additional information, see NRCS NEH Chapter 2 (NRCS, 1993).

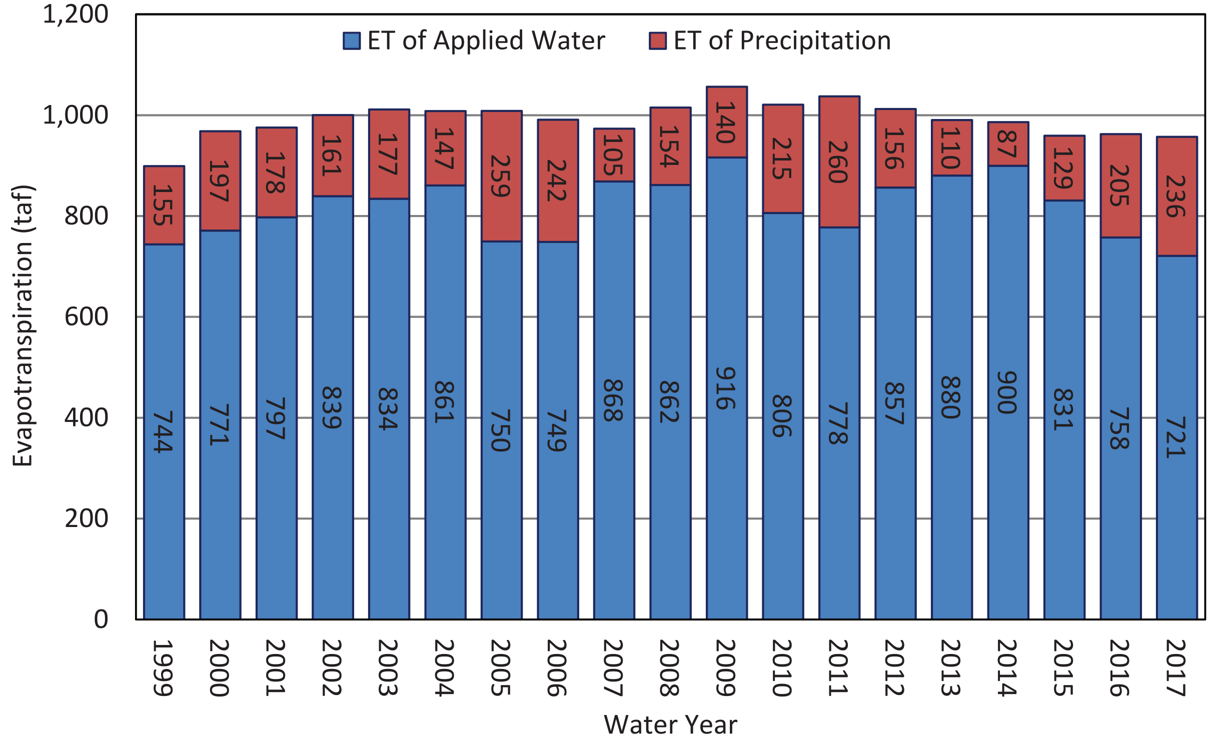



**Figure 4.1. Kaweah Subasin Crop ET by Water Year**

## *4.2 Irrigation Demands*

Annual estimated irrigation demands for fields with their centroid within the Kaweah Subbasin are shown in Figure 4.2 in thousands of acre feet. Annual demands ranged from 948 taf to 1,149 taf, with an average of 1,042 taf.

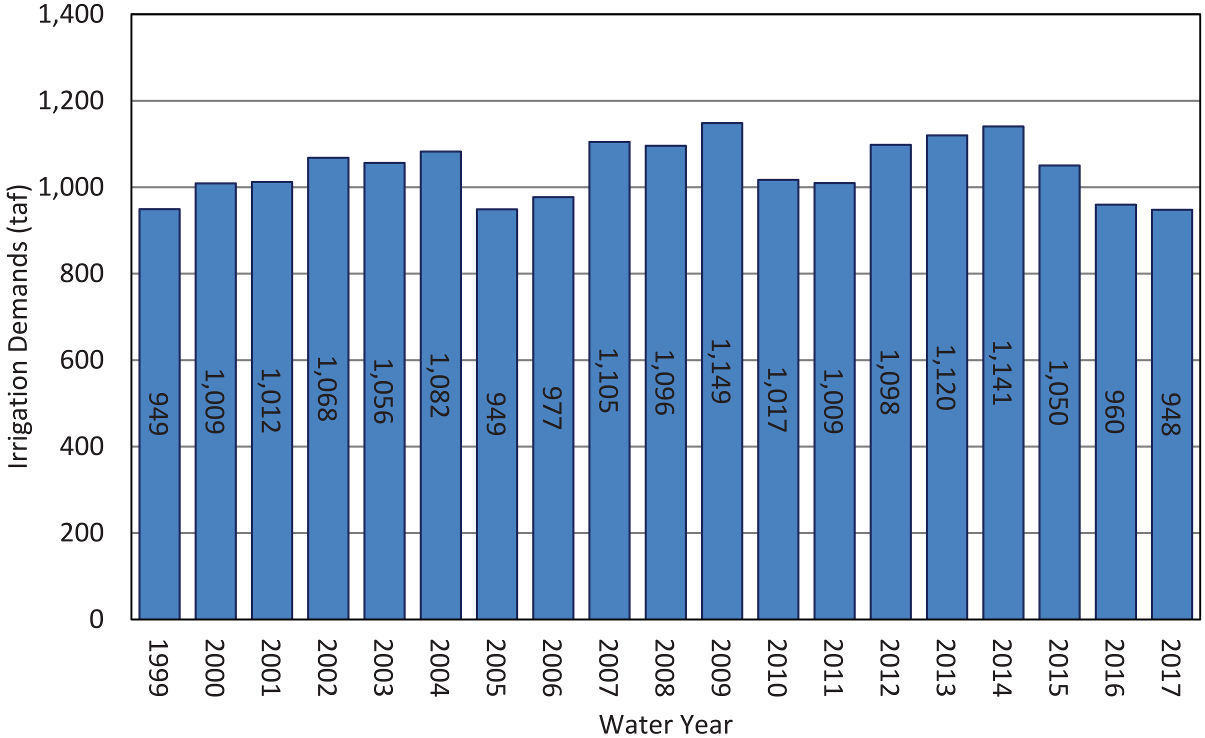



**Figure 4.2. Kaweah Subasin Irrigation Demands by Water Year**

## *4.3 Deep Percolation*

Estimated annual deep percolation volumes for fields with their centroid within the Kaweah Subbasin are shown in Figure 4.3. Estimated volumes of deep percolation derived from applied water (DPaw) and precipitation (DPpr) are shown in thousands of acre-feet. Annual DPaw ranged from 208 taf to 242 taf, with an average of 227 taf. Annual DPpr ranged from 24 taf to 130 taf, with an average of 60 taf. Total deep percolation ranged from 255 taf to 372 taf, with an average of 287 taf.

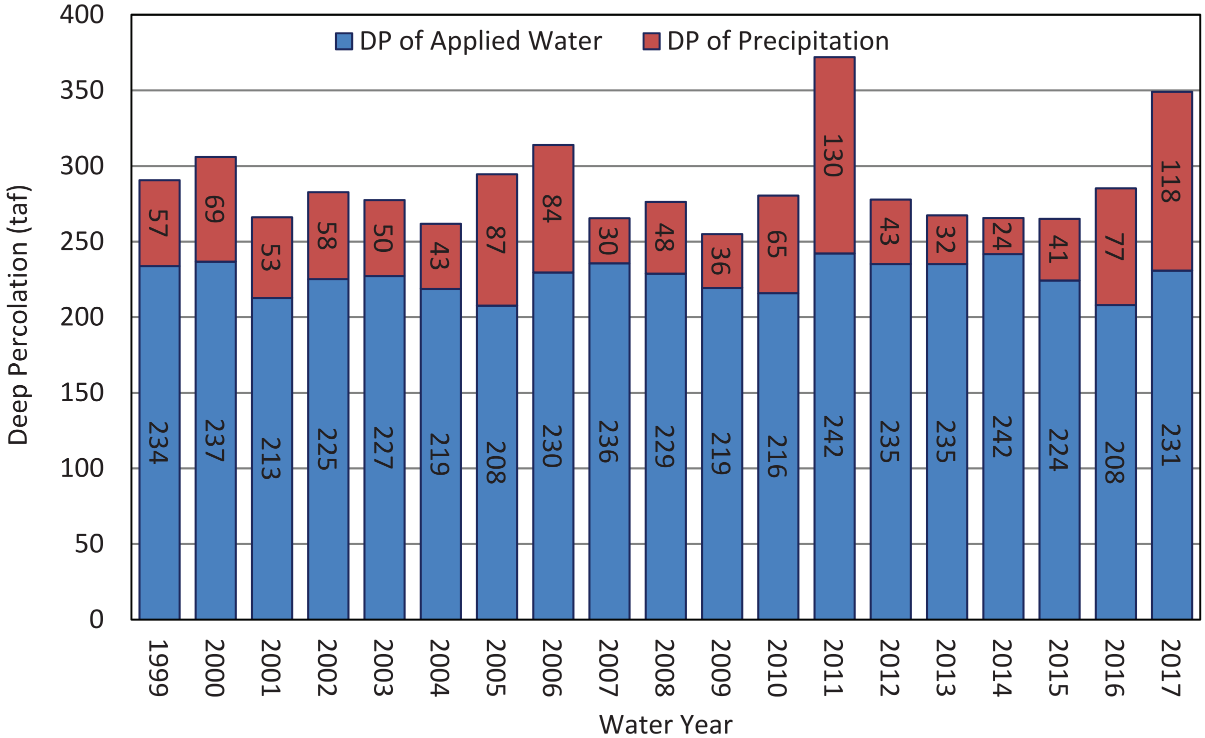



**Figure 4.3. Kaweah Subasin Deep Percolation by Water Year**

## *4.4 Annual Evapotranspiration by Crop for 2014*

Estimated annual average evapotranspiration by crop is shown in Figure 4.4, along with the estimated acreage for each crop. Figure 4.4 shows the estimated average total ET by crop in inches in 2014. Average ET ranges from 7 inches for miscellaneous grain and hay to 49 inches for walnuts. The primary crops are corn, citrus, alfalfa and walnuts, representing 82, 60,40, and 31 thousand acres, respectively.

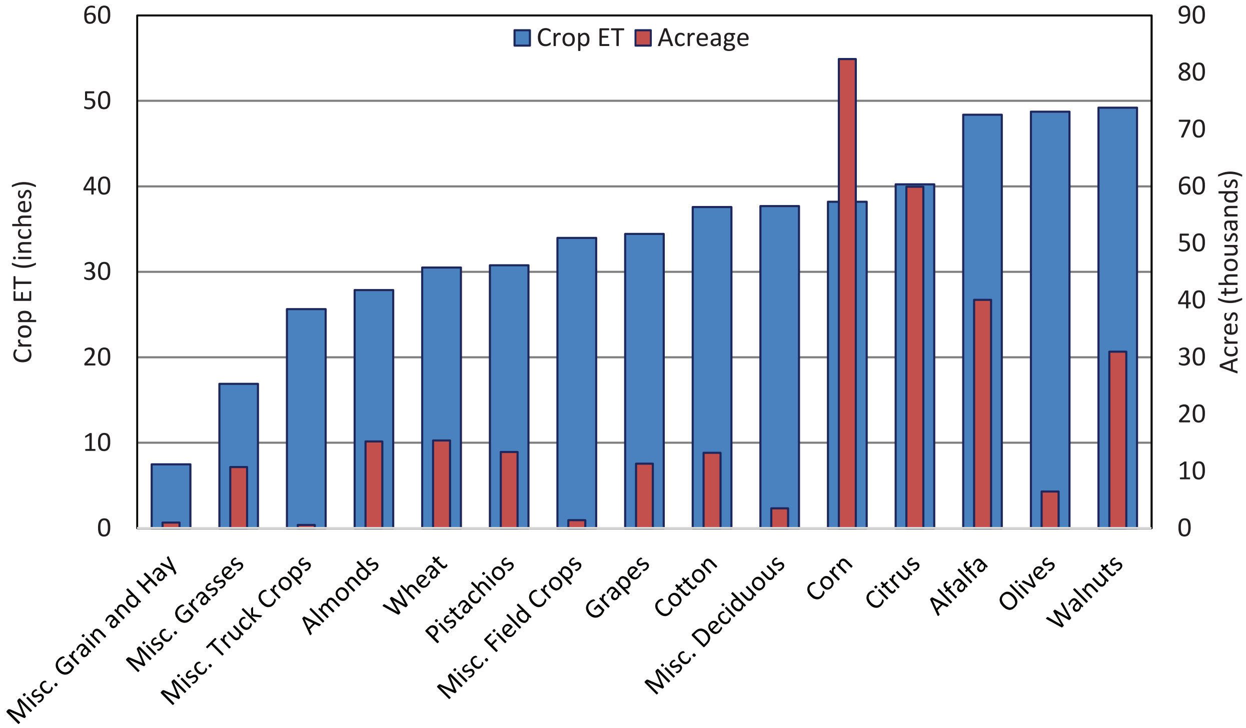



**Figure 4.4. Kaweah Subasin 2014 Average ET by Crop and Crop Acreage**

Additional monthly plots of $ET_{oF}$, $ET_a$ and AW by crop for 2014 can be found in the appendix.

# 5 References

Allen, R.G, L.S. Pereira, D. Raes, and M. Smith. 1998. Crop Evapotranspiration - Guidelines for Computing Crop Water Requirements. FAO Irrigation and Drainage Paper 56. FAO. Rome, Italy.

Davids Engineering. 2013. Time Series Evapotranspiration and Applied Water Estimates from Remote Sensing. Kaweah Delta Water Conservation District. http://www.kdwcd.com/wp-content/uploads/2018/07/KDWCD-NDVI-ET-Analysis-FINAL-REPORT-March-2013.pdf

NRCS. 1993. Chapter 2 - Watershed Project Evaluation Procedures. National Engineering Handbook Part 630, Hydrology.

Saxton, K.E. and W.J. Rawls. 2006. Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. Soil Sci. Soc. Am. J. 70:1569–1578.

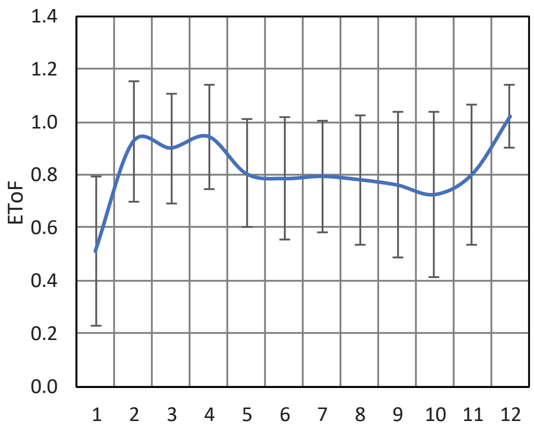
# 6 Appendix

This appendix includes the following figures:

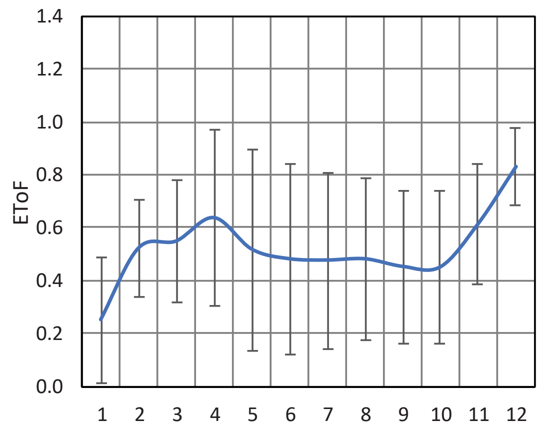
- Average monthly crop water use coefficients or “fraction of reference ET” (EToF) by crop, along with error bars depicting the standard deviation among fields.
- Average monthly crop ET by crop, along with error bars depicting the standard deviation among fields.
- Average monthly applied water by crop, along with error bars depicting the standard deviation among fields.

## *EToF 2014*

Alfalfa




Almonds

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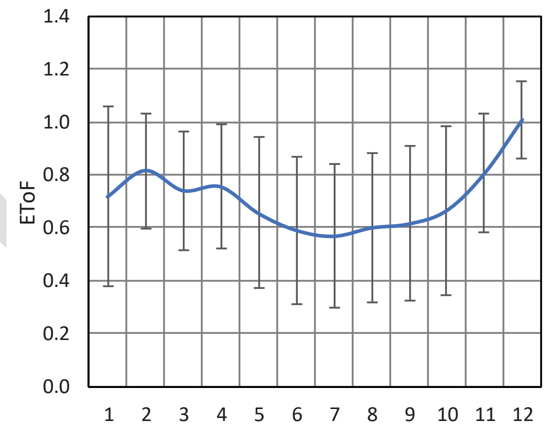


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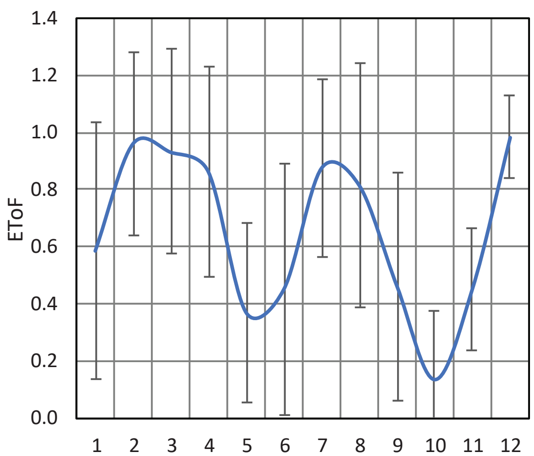


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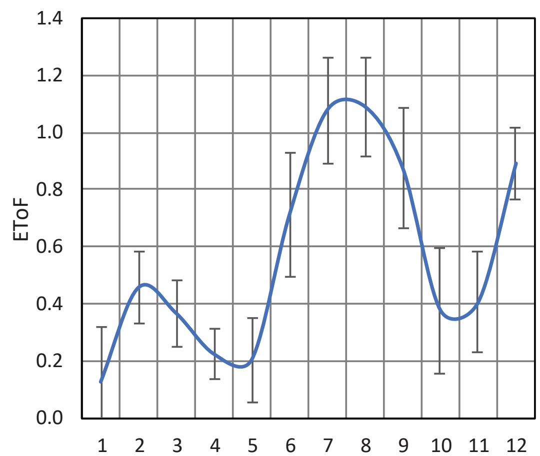


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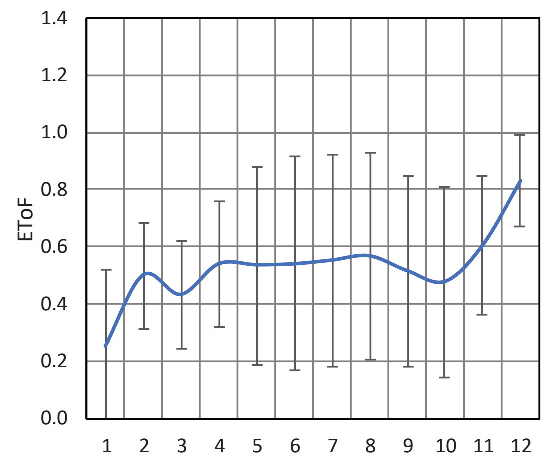

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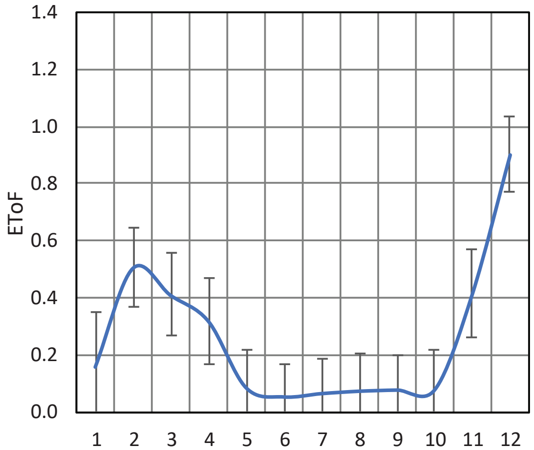


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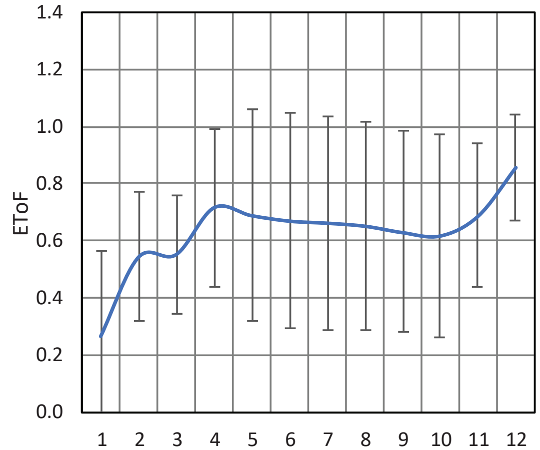


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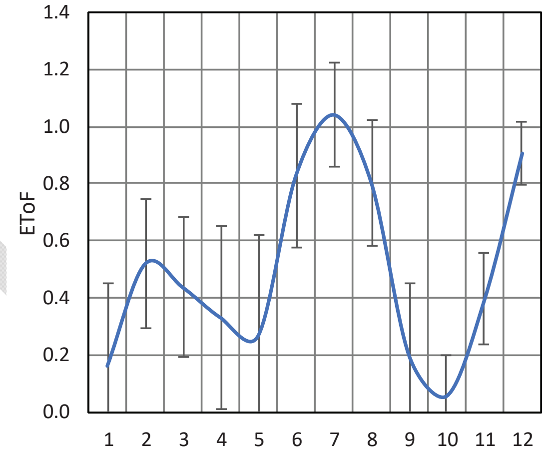


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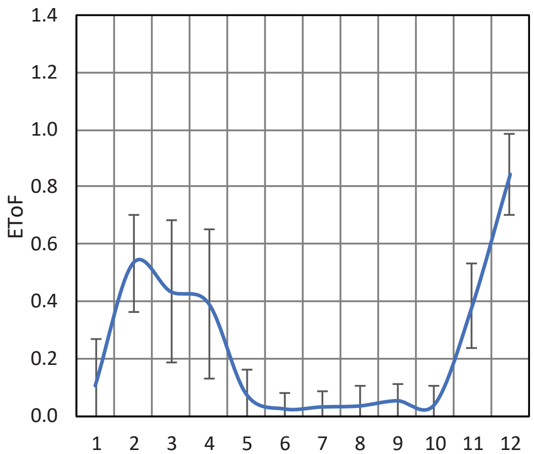


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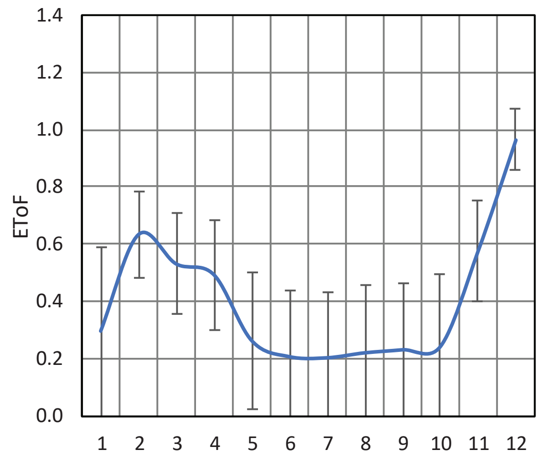


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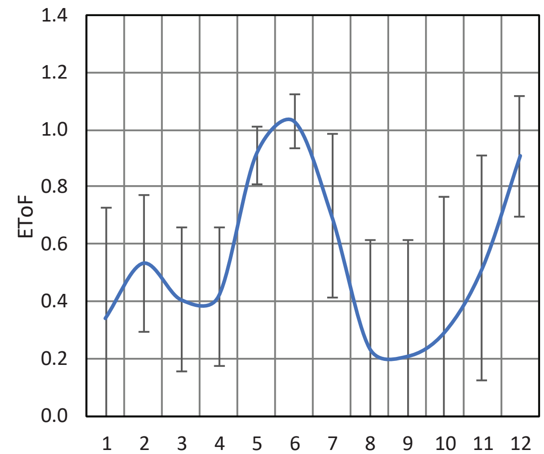

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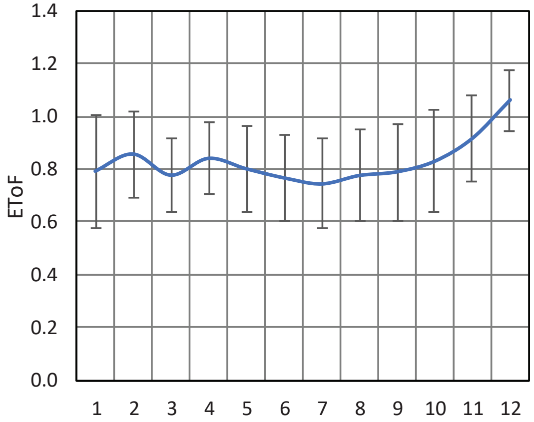


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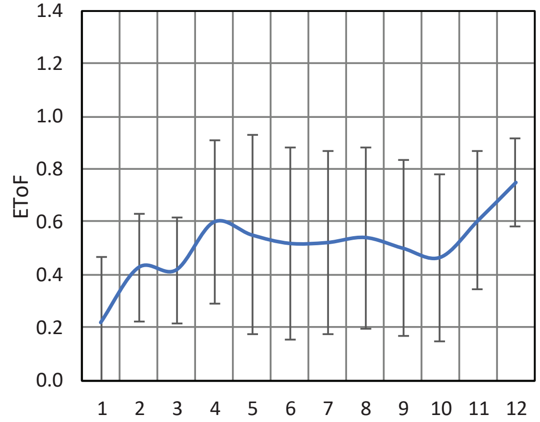


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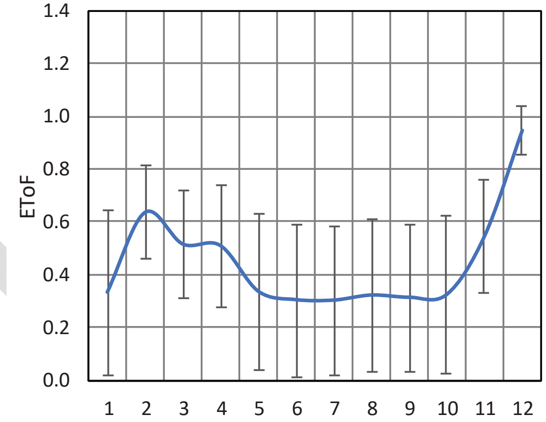


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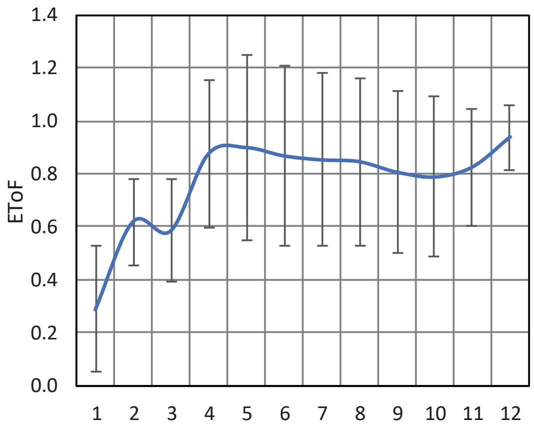


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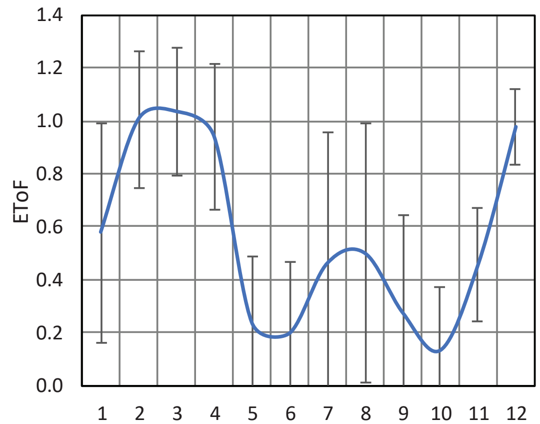

## *ETc 2014*

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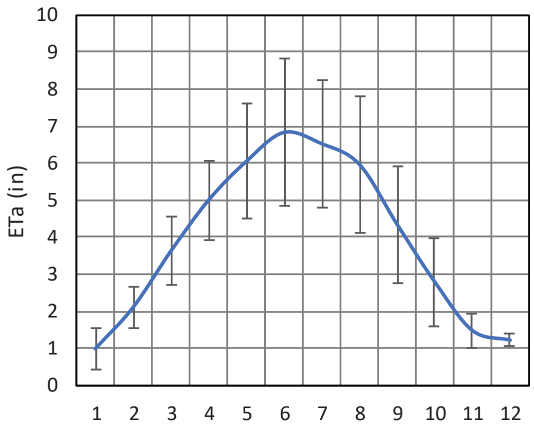


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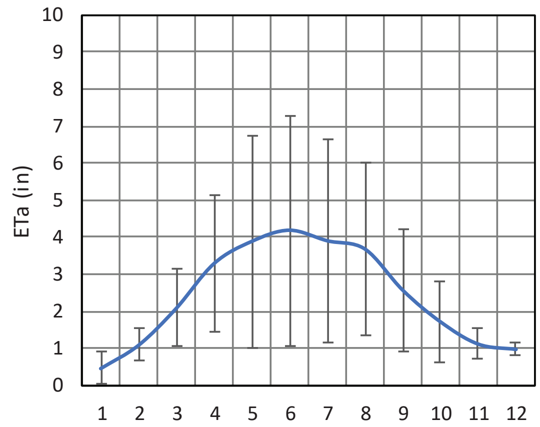


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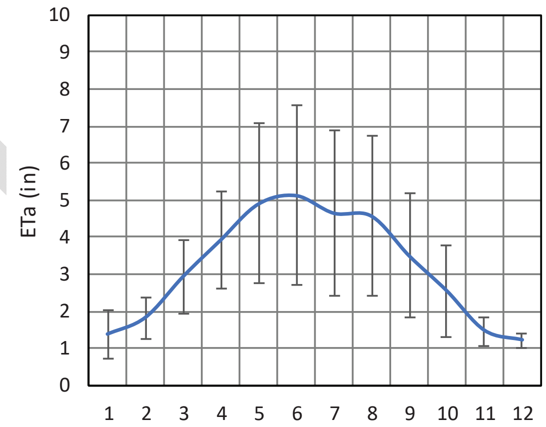


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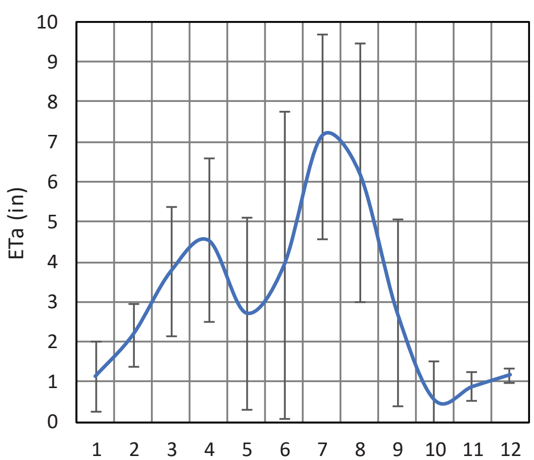


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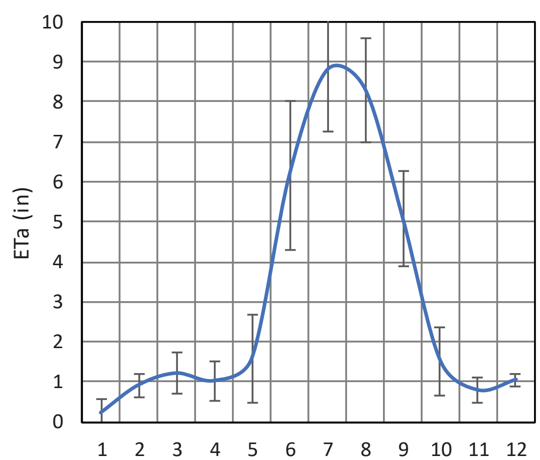


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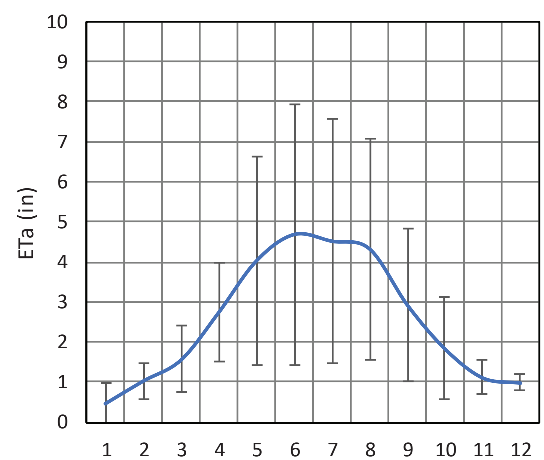

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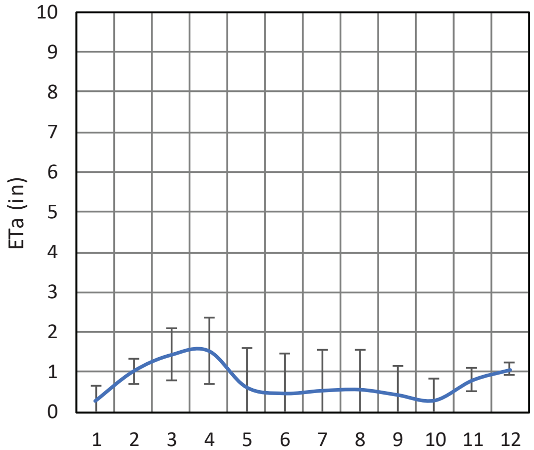


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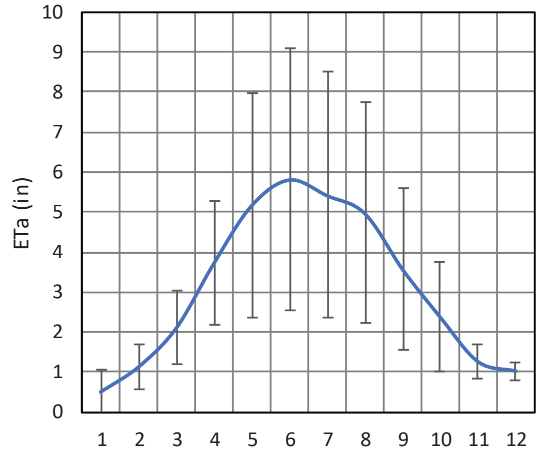


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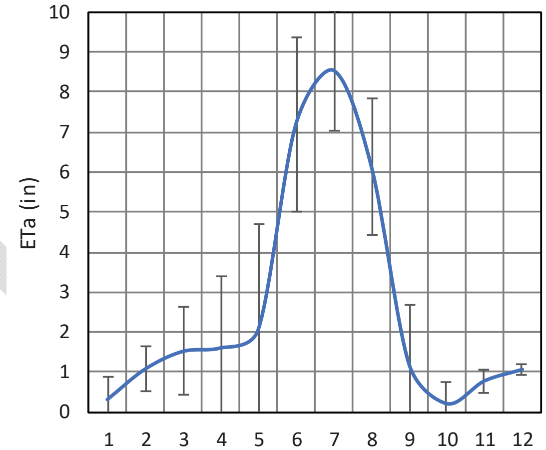


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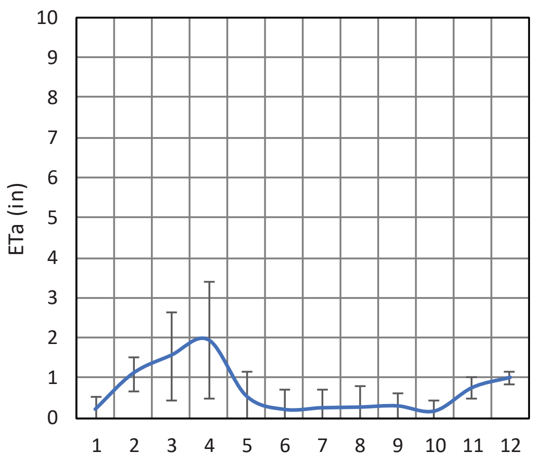


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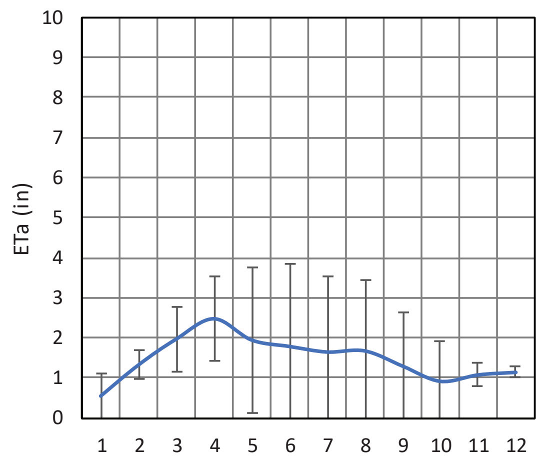


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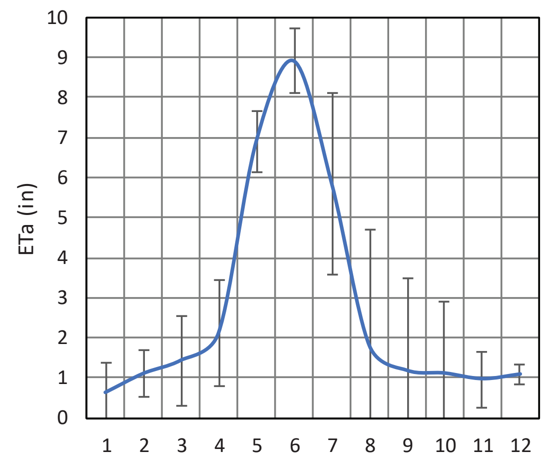

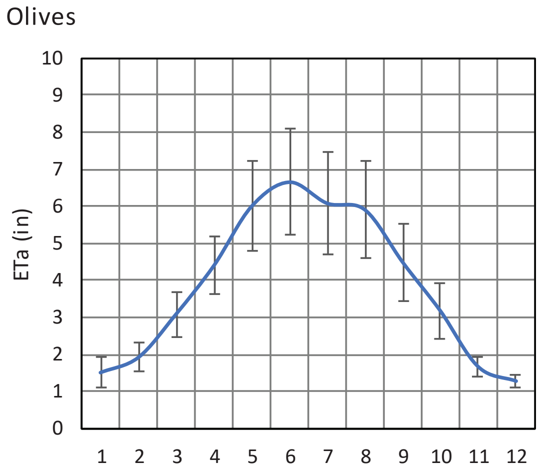
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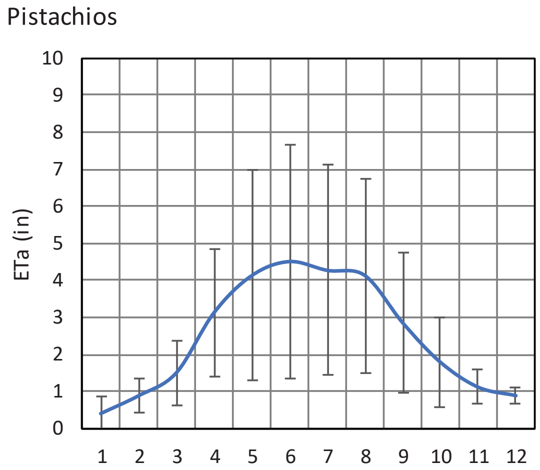
1 2 3 4 5 6 7 8 9 10 11 12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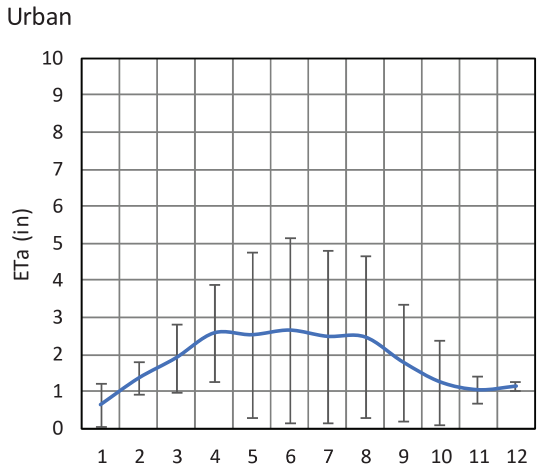
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ETa (in)
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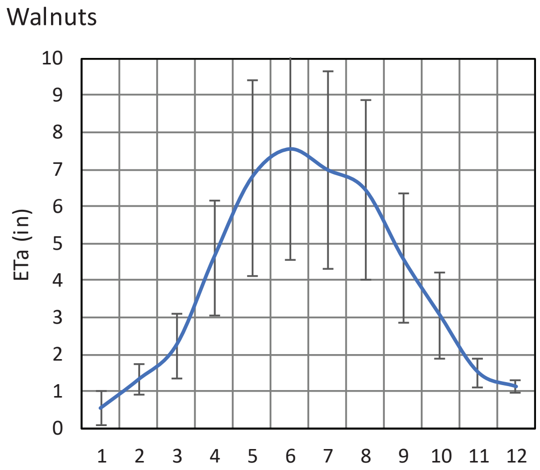
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ETa (in)
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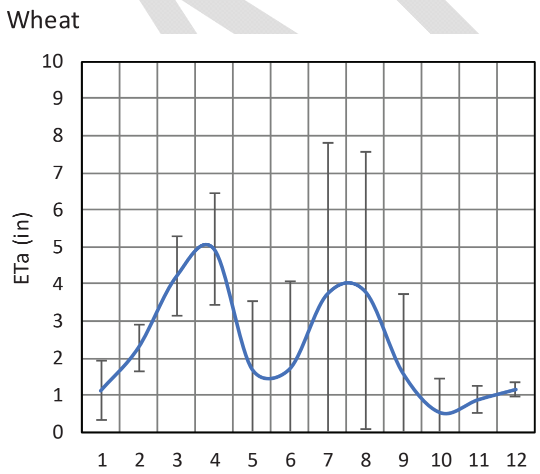
Wheat
ETa (in)
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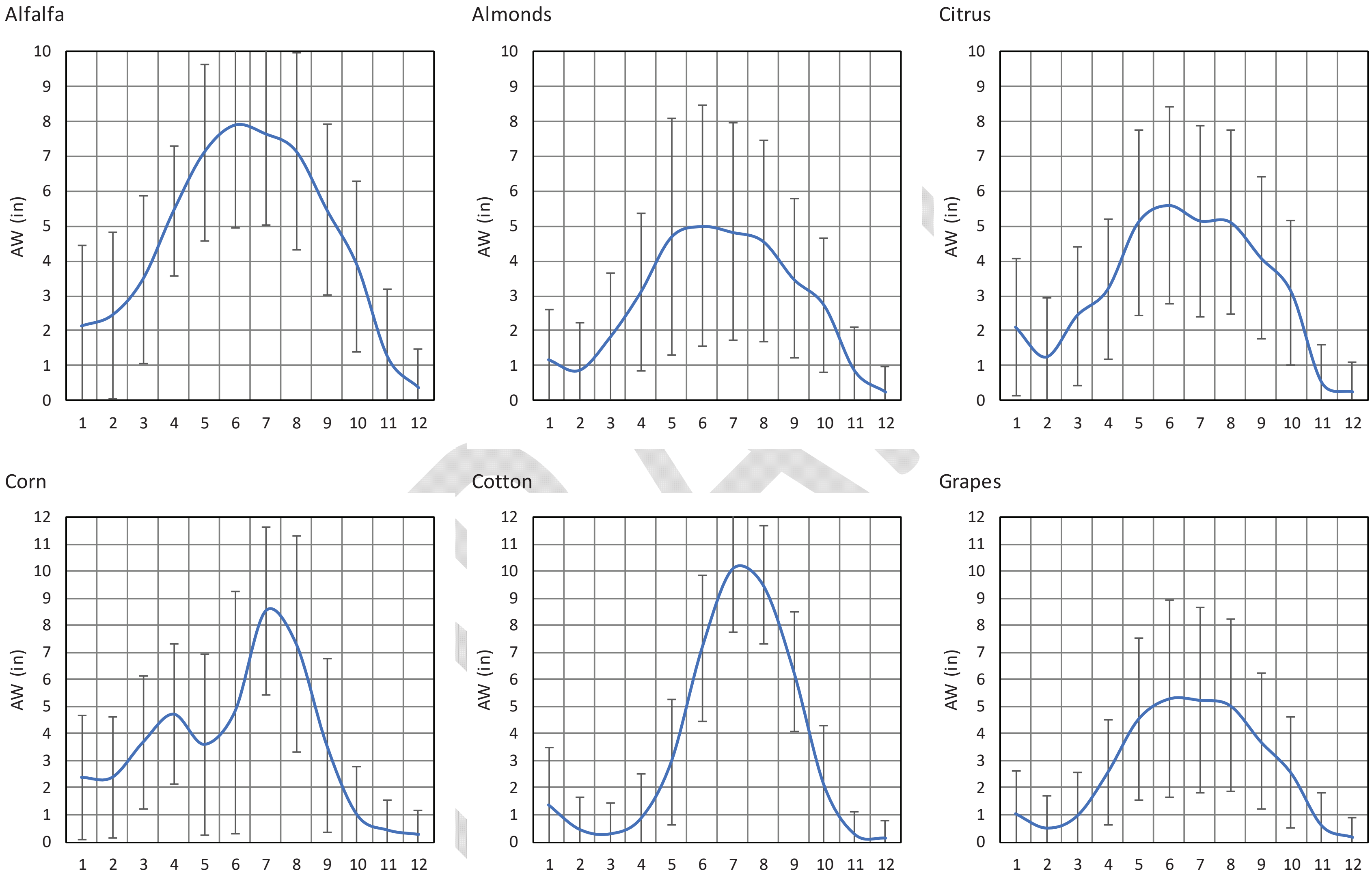
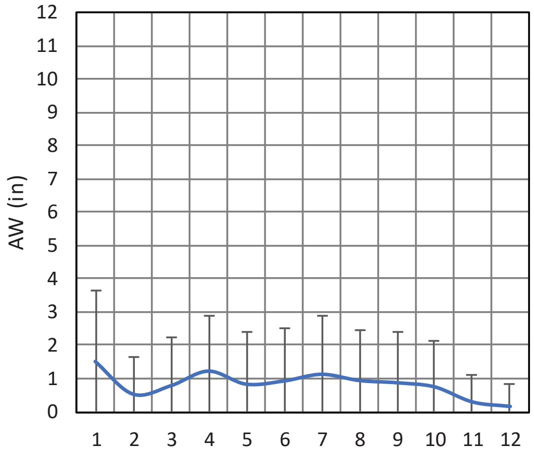
## *AW 2014*



Alfalfa
Almonds
Citrus
Corn
Cotton
Grapes
AW (in)
1 2 3 4 5 6 7 8 9 10 11 12

Idle

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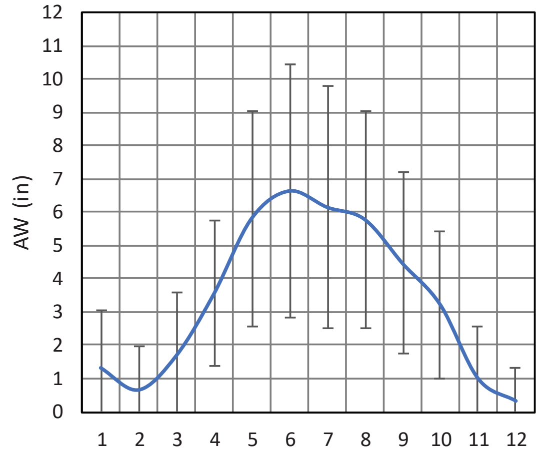


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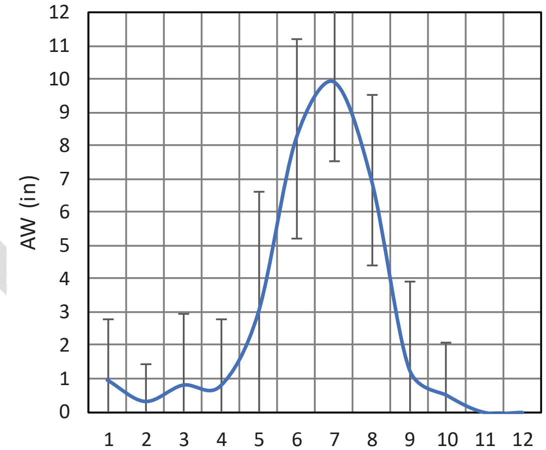


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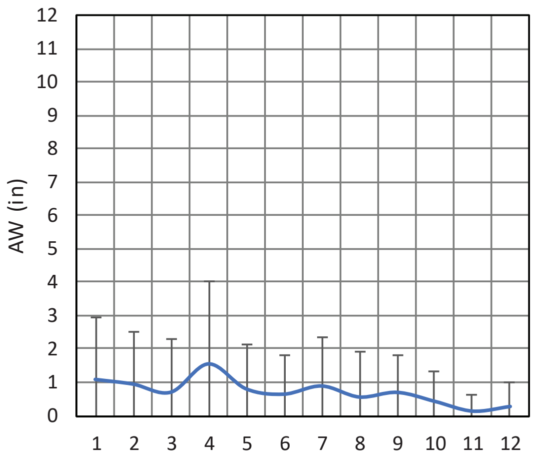


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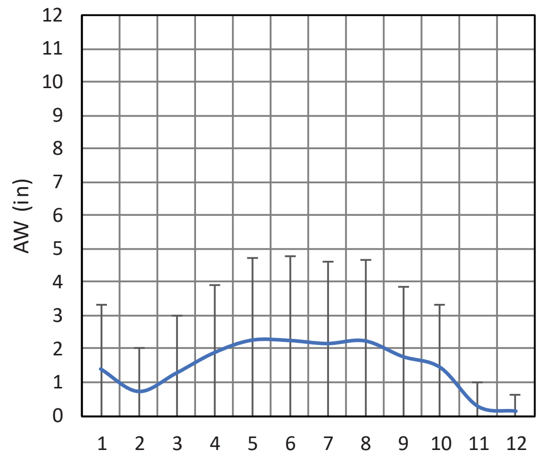


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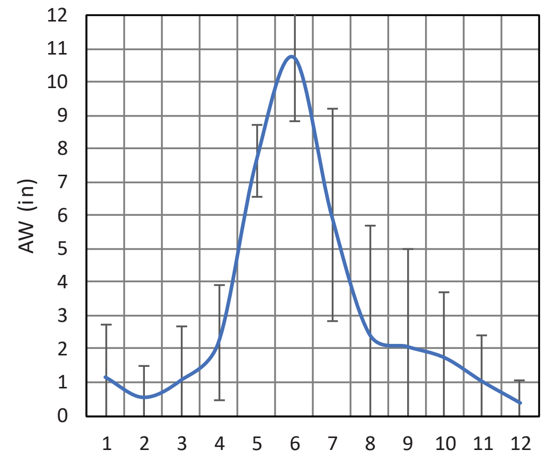

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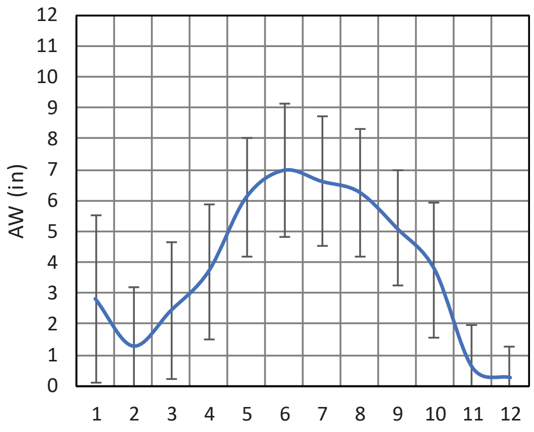


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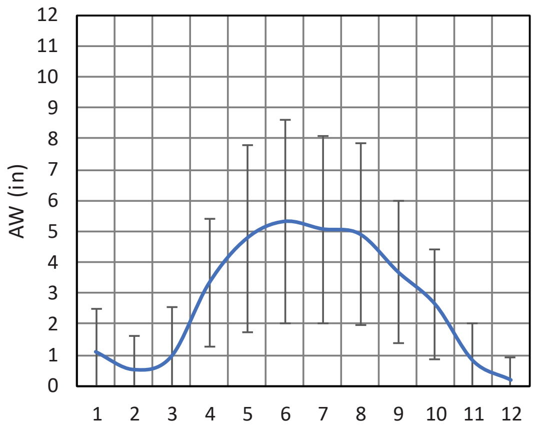


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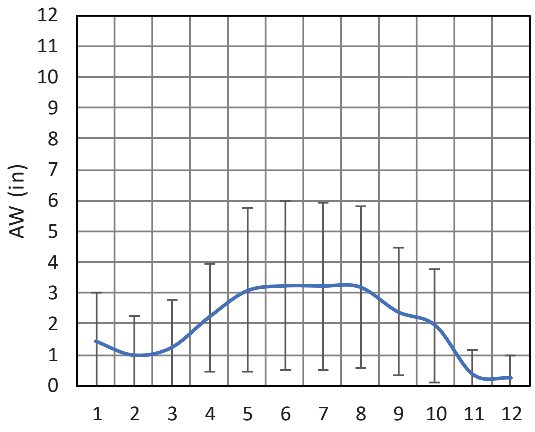


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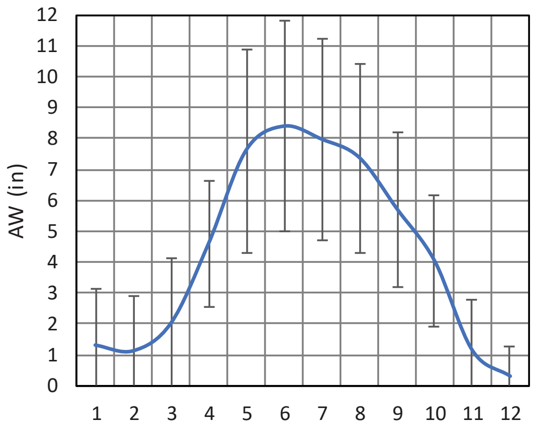


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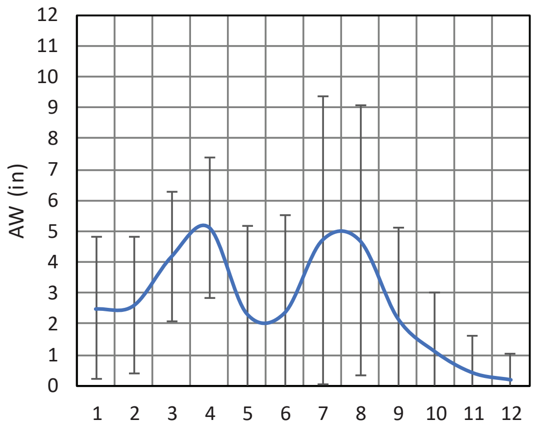

# Appendix D

## Friant Water Authority

## Future Water Supply Study

# Technical Memorandum

## Estimate of Future Friant Division Supplies for use in Groundwater Sustainability Plans, California

# CONTENTS



# FIGURES



# TABLES

# ACRONYMS

| | |
|---|---|
| CFS | cubic feet per second |
| CVP | Central Valley Project |
| CWC | California Water Commission |
| DEW | Drier/Extreme Warming |
| DWR | California Department of Water Resources |
| GSA | Groundwater Sustainability Agency |
| Friant | Friant Water Authority |
| Friant Contractors | Friant Division long-term contract holders |
| PEIS/R | Program Environmental Impact Statement/Report |
| Reclamation | U.S. Department of the Interior, Bureau of Reclamation |
| RWA | Recovered Water Account |
| SGMA | Sustainable Groundwater Management Act |
| SJRRP | San Joaquin River Restoration Program |
| SJRRS | San Joaquin River Restoration Settlement |
| SWP | State Water Project |
| TAF | thousand acre-feet |
| TM | Technical Memorandum |
| WMW | Wetter, Moderate Warming |
| WSIP | Water Supply Investment Program |

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# BACKGROUND

The Friant Water Authority (Friant) was approached by several Groundwater Sustainability Agencies (GSAs) for information about future water supply availability from the Central Valley Project (CVP) Friant Division. Those GSAs include the following, who were subsequently engaged during the development of analysis to meet their request:

- Mid-Kaweah GSA, represented by Paul Hendrix
- White Wolf Sub-basin GSA, represented by Jeevan Muhar
- Kern Groundwater Authority, represented by Terry Erlewine

This Technical Memorandum (TM) was prepared for use by those GSAs and others, in accordance with the expectations set by the Friant Board of Directors in their 2016 Strategic Plan to provide "accurate and up-to-date data needed to manage water supplies through modeling and data collection."

This TM presents five scenarios that were intended to represent a range of potential water supply conditions for the Friant Division through the end of the century, all of which were assembled from existing studies that were recently conducted using the CalSim-II computer model. These scenarios were assembled from pre-existing model runs and analysis and have been compiled and reviewed by Friant for use or consideration in plans developed by GSAs that receive Friant Contract surface water deliveries. The selected scenarios are summarized below and organized by their identification name in the accompanying "Summary_FutureFriantSupplies_Final" spreadsheet file.

1. **Model Run 2015.c (''2015.c'')** was designed to represent current conditions, where implementation of the San Joaquin River Restoration Settlement (SJRRS) is limited by downstream capacity limitations and the climate and hydrology are assumed to be most similar to historical hydrologic conditions.

2. **''2030.c''** was designed to represent near future climate conditions centered around 2030 and uses California Department of Water Resources (DWR's) central tendency climate projection. This scenario assumes implementation of the SJRRS, as described in the Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).

3. **''2070.c''** was designed to represent far-future climate conditions centered around 2070 and uses DWR's central tendency climate projection. This scenario assumes implementation of the SJRRS, as described in the Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).

4. **''DEW.c''** was included in this TM for completeness, as it represents an extreme climate condition (being: Drier/Extreme Warming, "DEW") that was produced by DWR for planning studies. The DEW scenario was developed by DWR as a means of bracketing the range of potential future climate conditions by 2070, which are highly uncertain. This scenario was modeled with implementation of the SJRRS, as described in the Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).

5. **''WMW.c''** was included in this TM for completeness, as it represents an extreme climate condition (being: Wetter/Moderate Warming, "WMW") that was produced by DWR for planning studies. The WMW scenario was developed by DWR as a means of bracketing the range of potential future climate conditions by 2070, which are highly uncertain. This scenario was modeled with implementation of the SJRRS, as described in the Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).

For questions, clarifications, or suggestions that will improve this TM or its application with the implementation of the Sustainable Groundwater Management Act (SGMA) for planning purposes, please contact Jeff Payne, Director of Water Policy at jpayne@friantwater.org

# STUDY SETTING

The Friant Division includes storage for waters of the San Joaquin River at Friant Dam (Millerton Lake), as well as conveyance and delivery facilities through the Friant-Kern and Madera canals that deliver water to 32 Friant Division long-term contract holders (Friant Contractors) and other water users. Figure 1 shows the location of the Friant Contractors in the San Joaquin Valley. Friant Contractors all have access to waters of the San Joaquin River through their contracts with Reclamation. However, most Friant Contractors have other supplies that include groundwater and surface water supplies that are local to their geography.

Combined, the facilities of the Friant Division span over 180 miles, crossing seven rivers, and conveying water between 16 GSAs as shown in Figure 2. All the basins connected by the Friant Division and its facilities are considered by DWR to be “critically overdrafted” and therefore are each a “high priority” for the implementation of SGMA. Table 1 lists the Friant Contractors with lands overlapping a GSA and 2014 Friant Contractor irrigated lands. A Friant Contractor may appear in more than one GSA. The 2014 irrigated acreage was obtained from remote sensing from DWR (DWR, 2017). Friant Division M&I contractors were assumed to have no agricultural demand. Kaweah-Delta Water Conservation District agricultural demands were not estimated in this analysis. Any agricultural demand within City of Fresno is represented as part of the Fresno Irrigation District.


*Figure 1: Location of Friant Contractors in the San Joaquin Valley*

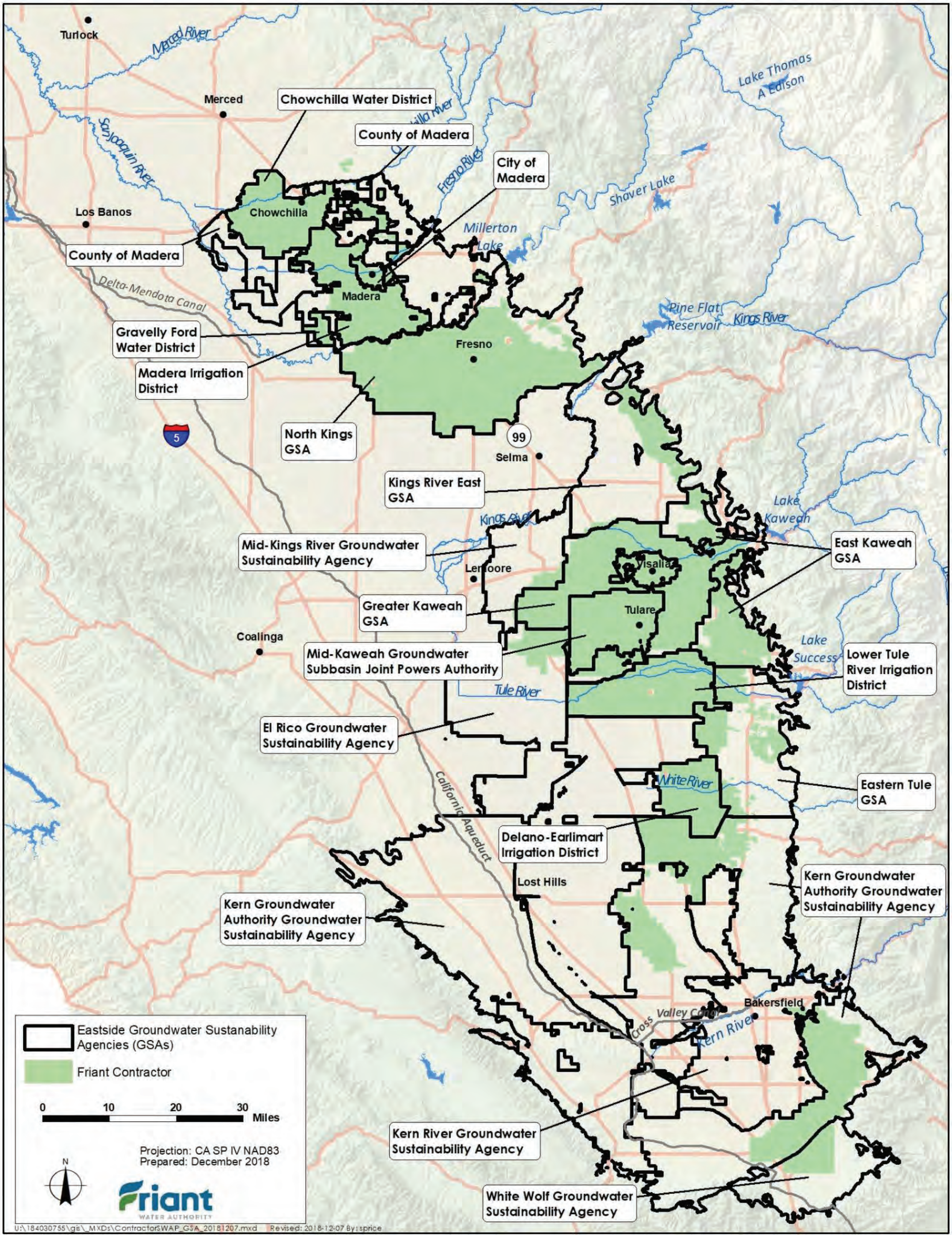


*Figure 2: Location of Friant Contractors relative to GSAs*

**Table 1. Friant Contractors and Estimated Irrigated Acreage relative to GSAs (DWR, 2017)**

| GROUNDWATER SUSTAINABILITY AGENCY | FRIANT CONTRACTOR[1] | FRIANT CONTRACTOR IRRIGATED LAND[2] (ACRES) |
|---|---|---|
| Chowchilla Water District | Chowchilla Water District | 67,170 |
| City of Madera | Madera Irrigation District | 910 |
| County of Madera | Chowchilla Water District | 30 |
| | Madera Irrigation District | 90 |
| Gravelly Ford Water District | Gravelly Ford Water District | 7,490 |
| Madera Irrigation District | Madera Irrigation District | 100,360 |
| North Kings GSA | Fresno Irrigation District[3] | 128,330 |
| | Garfield Water District | 1,160 |
| | International Water District | 540 |
| Kings River East GSA | Hills Valley Irrigation District | 2,830 |
| | Orange Cove Irrigation District | 24,360 |
| | Tri-Valley Water District | 1,040 |
| Mid-Kings River GSA | Kaweah Delta Water Conservation District[2] | NE |
| East Kaweah GSA | Exeter Irrigation District | 10,580 |
| | Ivanhoe Irrigation District | 9,630 |
| | Lewis Creek Water District | 1,010 |
| | Lindmore Irrigation District | 22,760 |
| | Lindsay - Strathmore Irrigation District | 10,880 |
| | Lower Tule River Irrigation District | 80 |
| | Stone Corral Irrigation District | 5,980 |
| Greater Kaweah GSA | Exeter Irrigation District | 500 |
| | Ivanhoe Irrigation District | 30 |
| | Kaweah Delta Water Conservation District[4] | NE |
| | Tulare Irrigation District | 60 |
| Mid-Kaweah Groundwater Subbasin Joint Powers Authority | Tulare Irrigation District | 58,160 |
| El Rico GSA | Kaweah Delta Water Conservation District[4] | NE |
| Lower Tule River Irrigation District | Lower Tule River Irrigation District | 80,480 |
| | Porterville Irrigation District | 70 |
| Eastern Tule GSA | Kern - Tulare Water District | 8,480 |
| | Porterville Irrigation District | 12,470 |
| | Saucelito Irrigation District | 18,060 |
| | Tea Pot Dome Water District | 3,090 |
| | Terra Bella Irrigation District | 9,110 |
| Delano - Earlimart Irrigation District | Delano - Earlimart Irrigation District | 49,960 |
| Kern Groundwater Authority GSA | Arvin - Edison Water Storage District | 84,280 |
| | Kern-Tulare Water District | 14,500 |
| | Shafter - Wasco Irrigation District | 30,190 |
| | Southern San Joaquin Municipal Utility District | 45,190 |
| Kern River GSA | Arvin - Edison Water Storage District | 190 |
| White Wolf GSA | Arvin - Edison Water Storage District | 20,830 |

Key:
GSA = Groundwater Sustainability Agency
NE = Not estimated
Notes:
[1]Only Friant Contractors with agricultural demands shown per GSA, Friant M&I contractors were assumed to have no agricultural demand.
[2] Irrigated lands rounded to nearest 10 acres
[3]Any agricultural lands within City of Fresno is represented as part of the Fresno Irrigation District
[4]Kaweah-Delta Water Conservation District agricultural lands were not estimated

# PREVIOUS STUDIES AND REPORTS

The potential range of future Friant Division water supplies from the San Joaquin River have been studied for several recent efforts. This TM relies on computer models, assumptions, and analysis that were initially developed for and reported by the following:

- San Joaquin River Restoration Settlement, and Program (SJRRS and SJRRP)
  - Settlement Agreement (2006)
  - Program Environmental Impact Statement/Report (PEIS/R; Reclamation, 2009)
- Temperance Flat Reservoir studies, including:
  - Federal Feasibility Study (Reclamation, ongoing)
  - Application to California Proposition 1, Water Storage Investment Program (Temperance Flat Reservoir Authority, 2017)

# FACTORS AFFECTING FRIANT SUPPLIES THROUGH YEAR 2100

Beyond the natural variability of annual precipitation in the headwaters of the San Joaquin River, several drivers are expected to greatly influence the water supplies of the Friant Division over the coming century. These include:

1. **Changes in the climate and hydrology**: These changes include a warming trend that is expected to reduce winter snow accumulation and hasten spring melt and runoff. Five climate conditions are considered in this report.
2. **Implementation of the SJRRS Restoration Goal:** The SJRRS Restoration Goal is currently limited in its implementation but is expected to be fully implemented by 2030, with the completion of river conveyance enhancements below Friant Dam. When completed, the impact of the SJRRS on Friant Contractor supplies will reach the extent anticipated in the SJRRS.
3. **Implementation of the SJRRS Water Management Goal**: The SJRRS Water Management Goal provides for several mechanisms to reduce or avoid water supply impacts on Friant Contractors. The water supply benefits of two SJRRS provisions are quantified in this analysis, being those described in Paragraphs 16(a) (i.e., recapture and recirculation) and 16(b) (i.e., water sold at $10 per acre foot during wet conditions).
   - Paragraph 16(a) is restricted at this time, being limited to the recapture of flows that can be released from Friant Dam. As implementation of the Restoration Goal progresses, so will recapture and recirculation.
   - Paragraph 16(b) is currently underutilized. At the time of the Settlement, a fixed $10 per acre foot price for wet year supplies was expected to stimulate investments in groundwater infiltration facilities. With subsequent water supply challenges imposed by SGMA on the Eastern San Joaquin Valley, the regional appetite for groundwater infiltration has grown dramatically. At this time, Friant Contractors anticipate considerable interest and ability to divert and infiltrate flows that may have spilled from Friant Dam under historical conditions. The upper end of implementation of 16(b) is expected to occur before 2030.

The technical representations of these conditions were taken from previous studies and reports, in the manner described below.

## INVENTORY OF MODEL SIMULATIONS PERFORMED

This report presents simulated operations that account for five climate conditions and the eventual full implementation of SJRRS Restoration and Water Management goals. Table 2 identifies 15 individual modeling runs compiled for this TM, along with the major assumptions for each.

The reader should note that each of the five climate conditions contain three model runs, denoted with a suffix of “a”, “b”, and “c”. To calculate the Restoration Goal for each of these climate conditions, model runs “a” and “b” were conducted to create comparisons that are necessary for explaining effect of SJRRS implementation. Calculation of the Water Management Goal requires a comparison of model runs “a” to model runs “b” and “c” to represent the expected recapture and recirculation for each level of SJRRS implementation. Model runs denoted with “c” are provided for comparative analyses that calculate recapture and recirculation, as well as additional groundwater recharge deliveries during wet conditions.

All simulations were performed using CalSim-II, the State of California’s premiere water supply planning and analysis tool. The primary use of the CalSim model is for estimating water supply exports from the Sacramento-San Joaquin Delta for delivery to CVP and State Water Project (SWP) water users. CalSim-II simulates statewide water supply operations using a continuous 82-year hydrology, traditionally based on the period of historic records beginning October 1921 and running through September 2003.

**Table 2. Fifteen model runs simulated for this Report**

| MODEL RUN | CLIMATE CONDITION | SJRRS SETTLEMENT RESTORATION GOAL | SJRRS SETTLEMENT WATER MANAGEMENT GOAL | BENCHMARK CALSIM-II MODEL USED |
|---|---|---|---|---|
| 2015.a | 2015 Conditions (historical modified for recent changes) | Pre-SJRRS | Pre-SJRRS | DWR Delivery Capability Report, 2015 climate |
| 2015.b | | Limited SJRRS | Limited Access | |
| 2015.c | | | Full Access | |
| 2030.a | Near-Future (DWR 2030 Central Tendency) | Pre-SJRRS | Pre-SJRRS | Water Commission, 2030 climate |
| 2030.b | | Full SJRRS | Limited Access | |
| 2030.c | | | Full Access | |
| 2070.a | Late-Future (DWR 2070 Central Tendency) | Pre-SJRRS | Pre-SJRRS | Water Commission, 2070 climate |
| 2070.b | | Full SJRRS | Limited Access | |
| 2070.c | | | Full Access | |
| DEW.a | Late-Future, 2070 Drier/Extreme Warming | Pre-SJRRS | Pre-SJRRS | Water Commission, 2070 DEW climate |
| DEW.b | | Full SJRRS | Limited Access | |
| DEW.c | | | Full Access | |
| WMW.a | Late-Future, 2070 Wetter/Moderate Warming | Pre-SJRRS | Pre-SJRRS | Water Commission, 2070 WMW climate |
| WMW.b | | Full SJRRS | Limited Access | |
| WMW.c | | | Full Access | |

Key:
DEW = Drier/Extreme Warming
DWR = California Department of Water Resources
SJRRS = San Joaquin River Restoration Settlement
WMW = Wetter/Moderate Warming

# CLIMATE CHANGES EVALUATED

The California Water Commission Water Supply Investment Program (CWC WSIP) developed baseline CalSim-II simulations using several levels of potential climate change to modify input hydrology of the entire system, including the San Joaquin River. These scenarios were developed using the 20 combinations of climate change models and representative concentration pathways recommended by DWR Climate Change Technical Advisory Group as being most appropriate for California water resource planning and analysis. Further details on the specific climate change included in each of the simulations is included in the CWC WSIP Technical Reference (CWC, 2016). The resulting climate change conditions used in this analysis include:

1. **2015 Conditions:** This represents a historical hydrology modified to match climate and sea level conditions for a thirty-year period centered at 1995 (reference climate period 1981 – 2010).
2. **Near-Future 2030 Central Tendency:** This represents a 2030 future hydrology with projected climate and sea level conditions for a thirty-year period centered at 2030 (reference climate period 2016 – 2045).
3. **Late-Future 2070 Central Tendency:** This hydrology represents a 2070 future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 (reference climate period 2056 – 2085).
4. **Late-Future 2070 Drier/Extreme Warming Conditions (DEW):** This hydrology represents a 2070 DEW future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 (reference climate period 2056 – 2085).
5. **Late-Future 2070 Wetter/Moderate Warming Conditions (WMW):** This hydrology represents a 2070 WMW future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 (reference climate period 2056 – 2085).

The seasonal timing of inflow to Millerton Lake is projected to change in response to climate change. Historical inflow to Millerton Lake generally peak during the month of June due to the delayed runoff from a large snow pack. The climate change scenarios for 2030 and 2070 are based on warmer conditions that will produce precipitation events with more rainfall and less snowpack than historically occurred, resulting in peak runoff earlier in the year. Peak runoff into Millerton Lake is projected to occur in May for the 2030 scenario, and in April for the 2070 scenario. Figure 3 shows the general trend of Millerton Lake inflow change due to climate change.

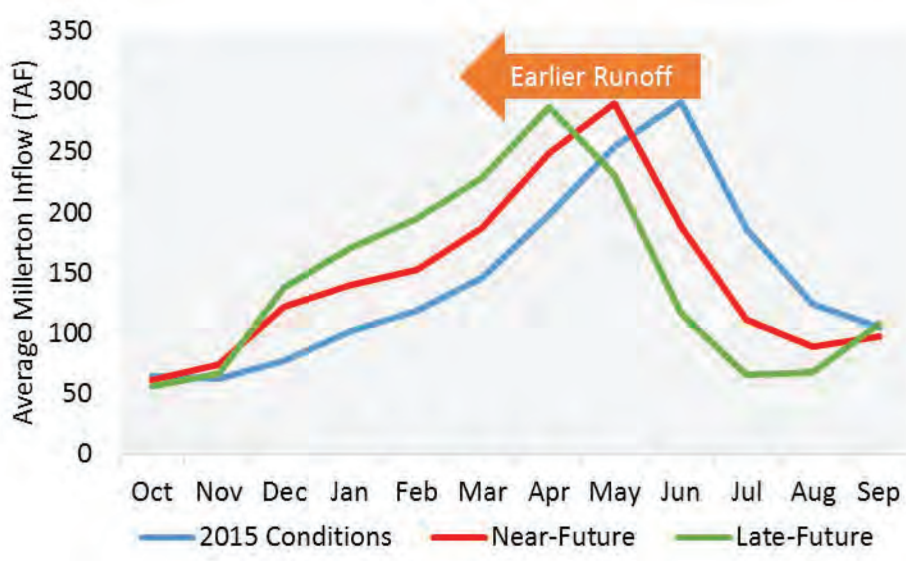


*Figure 3. Millerton Lake Inflow Change Due to Climate Change*

When analyzing CalSim-II outputs, the results are often summarized by water year type, which classifies groups of years with similar hydrologic characteristics. A water year starts October 1 of the preceding calendar year and ends September 30 of the current year. For example, water year 1922 starts October 1, 1921 and ends September 30, 1922. In this analysis the SJRRS water year type classification was used to summarize the estimated changes in Friant Division supplies. The SJRRS water year types are classified as follows: Wet, Normal-Wet, Normal-Dry, Dry, Critical High and Critical Low. For the CWC WSIP the SJRRP water year type classification remained unchanged between the five climate change conditions. In this TM, the SJRRS water year types were redefined based on Unimpaired Millerton Inflow (consistent with the SJRRS) from the CalSim II SV input files. This was done to update the SJRRS hydrographs to better reflect the anticipated climate change conditions. Table 3 summarizes the SJRRS water year types by climate condition. For reporting purposes, the designation of Critical water year type includes both Critical High and Critical Low SJRRS water year types.

**Table 3. SJRRS Water Year Types per Climate Condition by Number of Years and Percentage of Total Years**

| SJRRS WATER YEAR TYPE | 2015 CONDITIONS | NEAR-FUTURE, 2030 | LATE-FUTURE, 2070 | LATE-FUTURE, 2070 DEW | LATE-FUTURE, 2070 WMW |
|---|---|---|---|---|---|
| Wet | 16 (20%) | 18 (22%) | 19 (23%) | 21 (26%) | 35 (43%) |
| Normal-Wet | 25 (30%) | 21 (26%) | 20 (24%) | 12 (15%) | 21 (26%) |
| Normal-Dry | 24 (29%) | 25 (30%) | 20 (24%) | 11 (13%) | 15 (18%) |
| Dry | 12 (15%) | 11 (13%) | 16 (20%) | 20 (24%) | 9 (11%) |
| Critical[1] | 5 (6%) | 7 (9%) | 7 (9%) | 18 (22%) | 2 (2%) |
| **Long-Term[2]** | 82 | 82 | 82 | 82 | 82 |

Key:
DEW = Drier/Extreme Warming
DWR = California Department of Water Resources
SJRRS = San Joaquin River Restoration Settlement
WMW = Wetter/Moderate Warming
Note:
[1]For reporting purposes, the designation of Critical water year type includes both Critical High and Critical Low SJRRP water year types
[2]Long-Term average reflects the 82-year CalSim II simulation period (October 1921 thru September 2003)

# SJRRS IMPLEMENTATION

Implementation of the SJRRS includes actions to meet both the Restoration and Water Management Goals. Both goals have a direct effect on Friant Division water supplies, and both are expected to change in implementation over time.

Presently, both goals are implemented in a limited manner because of capacity restrictions in the San Joaquin River below Friant Dam (which constrict releases for the Restoration Goal) and the need for further buildout of groundwater infiltration facilities to take full advantage wet year supplies, when available (for the Water Management Goals). However, Reclamation has plans for implementation that will allow for virtually all SJRRS releases to be made by 2025 (SJRRP, 2018). Further, water users throughout the Friant Division are pursuing a broad array of facilities that will enhance the ability to implement Paragraph 16(b) water supplies, when available.

To represent the current and anticipated future implementation of the SJRRS, the following variations were constructed.

## Restoration Goal Implementation

Three levels of Restoration Goal implementation are considered, as follows:

1. **Pre-SJRRS:** This simulation sets the required minimum release from Millerton to the San Joaquin River to the values in the without project baseline conditions (SJRRP, 2009).
2. **Limited SJRRS:** This condition approximates current conditions, which are expected to remain limited until 2025. Simulations of this condition are based on the current channel capacity of 1,300 cubic feet per second (CFS) in Reach 2.
3. **Full SJRRS:** This condition represents the SJRRS hydrograph with capacities identified in the SJRRS Funding Constrained Framework. Under this plan, channel capacity will not exceed the identified 2025 channel capacity of 2,500 CFS in Reach 2. This hydrograph was used in the 2030, 2070, 2070 DEW, and 2070 WMW level of climate change simulations. Flow releases (Flow Schedules) for this condition were approximated with a spreadsheet developed by the SJRRP for the Framework Document (SJRRP, 2018). Table 3 shows the Full SJRRS Implementation hydrograph compared to the Funding Constrained Framework SJRRS hydrograph for the four climate change scenarios. The differences between the four climate change scenarios is due to the different number of years per SJRRS water year type, as shown in Table 3. Table 4 is not the impact of Friant Deliveries, but

represents the SJRRS releases under the Funding Constrained Framework under different climate change conditions.

**Table 4 Long-Term Average SJRRS Releases under Full SJRRS Implementation and the Funding Constrained Framework Four Climate Conditions**

| SJRRS WATER YEAR TYPE | FULL SJRRP IMPLEMENTATION (TAF/YEAR) | FUNDING CONSTRAINED FRAMEWORK | | | |
|---|---|---|---|---|---|
| | | NEAR-FUTURE, 2030 (TAF/YEAR) | LATE-FUTURE, 2070 (TAF/YEAR) | LATE-FUTURE, 2070 DEW (TAF/YEAR) | LATE-FUTURE, 2070 WMW (TAF/YEAR) |
| Wet | 674 | 633 | 633 | 628 | 633 |
| Normal-Wet | 474 | 434 | 433 | 428 | 432 |
| Normal-Dry | 365 | 365 | 364 | 363 | 357 |
| Dry | 302 | 297 | 296 | 296 | 300 |
| Critical High | 188 | 188 | 188 | 188 | 188 |
| Critical Low | 117 | 117 | 117 | 117 | 117 |
| **Long-Term**[1] | 438 | 417 | 414 | 376 | 483[2] |

Key:
DEW = Drier/Extreme Warming
DWR = California Department of Water Resources
SJRRS = San Joaquin River Restoration Settlement
TAF/year = thousand acre-feet per year
WMW = Wetter/Moderate Warming
Note:
[1]Long-Term average reflects the 82-year CalSim II simulation period (October 1921 thru September 2003)
[2] The Long-Term Average SJRRS release for 2070 WMW is higher than the Full SJRRP Implementation because, as Table 3 shows, the number of Wet water years increased from 16 years (20 percent) in the 2015 Condition to 35 years (43 percent) in the 2070 WMW Condition.

The quantification of SJRRS implementation impact is performed by comparing the with and without SJRRS water supplies diverted from Friant Dam.

In the course of compiling these model runs, it was discovered that previous studies had not correctly implemented SJRRS flows under climate change. SJRRS outflow requirements at Friant Dam are determined by the total annual hydrology, which can change enough under climate conditions to alter a given year's release requirements. All scenarios and results in this report have been adjusted to correctly set SJRRS flow requirements, including under climate change.

## Water Management Goal Implementation

Three levels of Water Management Goal implementation are considered, as follows:

1. **Pre-SJRRS**: This represents the without SJRRS condition.
2. **Limited Access:** This represents 16(a) supplies available to Friant Contractors as part of the SJRRS that provides for recapture and recirculation of flows released from Friant Dam for the purposes of meeting the Restoration Goal.
3. **Full Access:** This represents supplies anticipated with future ability to divert 16(a) and 16(b) supplies to Friant Contractors. 16(b) stipulates a Recovered Water Account (RWA) that represents water not required to meet SJRRS or other requirements be made available to Friant Contractors who experience a reduction in water deliveries from the implementation of the SJRRS. 16(b) water is made available to those Friant Contractors at $10 per acre-foot during wet condition.

The SJRRS and implementing documents identify several locations for recapture, however modeling conducted for the SJRRP PEIS/R only provided for estimated recapture as the incremental improvement in total Delta Exports that result from the SJRRS. The quantification of water supplies recaptured in the Delta in conformance with 16(a) is performed by comparing simulated Delta exports with and without the implementation of the SJRRS. The net improvement in export is identified as recapturable supply.

The CalSim-II model simulates 16(b) as an additional demand after Class 1 and Class 2 delivery allocations are met and before 215 ("Other") deliveries are made. The CalSim-II simulated 16(b) delivery via the Friant Kern and Madera canals is based on anticipated development of groundwater infiltration facilities throughout the Friant Division in response to SJRRS implementation.  These facilities are not identified and are represented as surrogate water demands in the CalSim-II model. As a result, use of 16(b) water supply availability must be viewed as total opportunity that has not been attributed among individual water users at this time.

The quantification of water supplies diverted from Friant Dam for 16(b) is performed by comparing the with and without SJRRS simulations that allow for added diversions. This required the additional simulation for each scenario, to provide for comparison.  The "#.b" scenarios are included in results for reference.

# GUIDANCE ON USE OF RESULTS

This TM provides descriptions of potential future water supplies for the Friant Division for five climate change conditions under different levels of SJRRS implementation.

The key outputs of this report are provided in tables by monthly and total volumes by contract year (which begins March 1 of the current calendar year and ends February 28 of the following year), except when noted, and summarized by SJRRS water year type classification and long-term average for each of the following:

- Millerton Lake Inflow
- Total Friant Division deliveries of:
  - Class 1
  - Class 2/Other
  - Paragraph 16(b) water (aka $10 water, or RWA water)
- Friant Dam Spill
- Potential Friant Division Delta Recapture (by year, only), for:
  - Class 1 Delta Recapture
  - Class 2 Delta Recapture
  - Total Delta Recapture

These data are provided in a spreadsheet, entitled: "Summary_FutureFriantSupplies_Final.xlsm"

Table 5 provides a portion of a tabulated output available in the spreadsheet. Tabulated information includes the average monthly and total volumes by SJRRS water year type classification and long-term average. For reporting purposes, the designation of Critical water year type includes both Critical-High and Critical-Low SJRRS water year types. Tabulated information also includes the monthly and total volumes per contract year (Mar-Feb). In the spreadsheet, the tables include the monthly and total volumes per contract year for the entire 82-year CalSim-II simulated period (October 1921 to September 2003).

**Table 5. Example Output Table for Class 1 Deliveries**

| | | Class 1 Delivery | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Total |
| | | TAF | TAF | TAF | TAF | TAF | TAF | TAF | TAF | TAF | TAF | TAF | TAF | TAF |
| | Wet | 16.1 | 28.1 | 51.6 | 123.4 | 189.9 | 181.5 | 106.3 | 48.5 | 12.2 | 6.4 | 6.3 | 29.8 | 800.0 |
| | Normal-Wet | 26.2 | 46.3 | 75.0 | 149.8 | 189.3 | 165.2 | 84.0 | 28.9 | 4.7 | 4.5 | 4.5 | 21.6 | 800.0 |
| | Normal-Dry | 32.9 | 56.7 | 92.1 | 158.6 | 184.4 | 152.5 | 67.9 | 20.9 | 3.6 | 3.6 | 3.4 | 19.7 | 796.3 |
| | Dry | 29.7 | 48.8 | 81.7 | 143.9 | 167.1 | 130.5 | 55.8 | 20.9 | 4.7 | 2.3 | 2.3 | 17.3 | 705.1 |
| | Critical | 16.7 | 19.9 | 36.4 | 86.6 | 111.5 | 65.2 | 31.0 | 19.9 | 6.6 | 0.0 | 0.0 | 9.9 | 403.8 |
| | Long Term | 26.1 | 44.6 | 74.1 | 142.4 | 179.9 | 153.4 | 76.2 | 28.7 | 6.0 | 4.0 | 3.9 | 21.3 | 760.4 |
| **2015** | | | | | | | | | | | | | | |
| **SJRRP** | Month | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Total |
| **WY Type** | Year | TAF | TAF | TAF | TAF | TAF | TAF | TAF | TAF | TAF | TAF | TAF | TAF | TAF |
| Normal-Wet | 1921 | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Normal-Wet | 1922 | 22.3 | 37.4 | 59.8 | 138.2 | 189.1 | 174.0 | 97.8 | 36.4 | 5.5 | 5.3 | 5.3 | 28.9 | 800.0 |
| Normal-Wet | 1923 | 25.6 | 42.7 | 64.4 | 146.7 | 187.1 | 170.7 | 95.2 | 33.8 | 4.9 | 4.6 | 4.6 | 19.7 | 800.0 |
| Critical | 1924 | 17.9 | 21.4 | 39.2 | 93.2 | 120.0 | 72.2 | 31.6 | 21.4 | 7.1 | 0.0 | 0.0 | 10.7 | 434.7 |
| Normal-Dry | 1925 | 32.8 | 56.4 | 89.7 | 158.4 | 188.2 | 152.0 | 70.7 | 21.0 | 3.9 | 3.9 | 3.3 | 19.7 | 800.0 |
| Normal-Dry | 1926 | 33.2 | 57.1 | 98.8 | 160.4 | 183.9 | 151.2 | 65.6 | 19.9 | 3.3 | 3.3 | 3.3 | 19.9 | 800.0 |
| Normal-Wet | 1927 | 25.7 | 47.4 | 80.6 | 151.2 | 191.4 | 163.5 | 79.8 | 26.8 | 4.8 | 4.6 | 4.6 | 19.8 | 800.0 |
| Normal-Dry | 1928 | 31.6 | 57.8 | 92.0 | 162.4 | 186.2 | 153.1 | 66.4 | 20.2 | 3.4 | 3.4 | 3.4 | 20.2 | 800.0 |
| Dry | 1929 | 26.8 | 48.2 | 80.3 | 132.2 | 148.5 | 124.8 | 53.0 | 16.1 | 2.7 | 2.7 | 2.7 | 16.1 | 654.0 |
| Dry | 1930 | 27.1 | 48.8 | 81.1 | 133.6 | 150.1 | 126.2 | 53.6 | 16.3 | 2.7 | 2.7 | 2.7 | 16.3 | 661.1 |
| Critical | 1931 | 12.9 | 15.5 | 28.3 | 67.4 | 86.9 | 52.3 | 22.9 | 15.5 | 5.2 | 0.0 | 0.0 | 7.7 | 314.5 |
| Normal-Wet | 1932 | 25.6 | 42.7 | 64.4 | 146.7 | 187.1 | 170.7 | 95.2 | 33.8 | 4.9 | 4.6 | 4.6 | 19.7 | 800.0 |
| Normal-Dry | 1933 | 32.8 | 56.4 | 89.7 | 158.4 | 188.2 | 152.0 | 70.7 | 21.0 | 3.9 | 3.9 | 3.3 | 19.7 | 800.0 |
| Dry | 1934 | 24.0 | 28.7 | 52.2 | 124.2 | 159.9 | 96.2 | 42.2 | 28.5 | 9.5 | 0.0 | 0.0 | 14.2 | 579.6 |
| Normal-Wet | 1935 | 28.2 | 47.3 | 80.4 | 150.7 | 190.7 | 162.9 | 79.5 | 26.7 | 4.7 | 4.6 | 4.6 | 19.7 | 800.0 |
| Normal-Wet | 1936 | 28.2 | 47.2 | 80.3 | 150.7 | 190.7 | 162.9 | 79.5 | 26.7 | 5.0 | 4.6 | 4.6 | 19.7 | 800.0 |
| Normal-Wet | 1937 | 28.7 | 48.0 | 81.6 | 159.5 | 191.1 | 160.7 | 74.5 | 24.0 | 4.0 | 4.0 | 4.0 | 20.0 | 800.0 |
| Wet | 1938 | 17.2 | 28.4 | 52.1 | 115.8 | 193.9 | 182.0 | 104.2 | 49.9 | 13.0 | 6.6 | 6.6 | 30.4 | 800.0 |

# CLASS 1 AND CLASS 2 SUPPLY PROJECTIONS

While CalSim-II does produce estimated deliveries of Class 1 water supplies with some confidence, the simulated "Class 2" and "Other" model outputs have always been problematic. This is because CalSim-II approximations of wet year operations were calibrated to mimic total releases – not actual deliveries of Class 2 or (separately) Other supplies. As a result, the modeling outputs provided with this TM do not distinguish between Class 2 and Other modeling categories. These two data outputs have been grouped to describe Class 2 behavior in aggregate. Through previous modeling conducted for SJRRS implementation, Friant Division managers have found the aggregation of Class 2 and Other model outputs performs closer to actual experience with Class 2 deliveries.

CalSim-II does not determine delivery by Friant Contractor, it simulates the annual allocations and then distributes them over the year on a monthly pattern. CalSim- II does approximate the division of flows between the Madera and Friant-Kern canals, but the actual final deliveries simulated in CalSim-II are not to specific Friant contractors or physical locations. Standard practice in interpreting deliveries to Friant Contractors has been to split Class 1 and Class 2/Other deliveries among individual contractors by contract quantity. For example, a district with an 80 thousand acre-feet (TAF) Friant Division Class 1 contract (i.e., 10 percent of total Class 1) and 70 TAF of Class 2 (i.e., five percent of total Class 2), would have access to 10 percent of the Class 1 supplies and five percent of the Class 2/Other supplies in a given year. Table 6 lists the Friant Contractors corresponding Class 1 and Class 2 contract amounts by volume and percentage. These have been incorporated into the spreadsheet to facilitate use.

NOTE: The reader may note that Section 215 water supplies are not discussed. While the factors that produce "215 water" are presumed to exist in the future, the frequency and magnitude of their availability is expected to be greatly diminished by implementation of the SJRRS, which has made available water supplies to Friant Contractors through Paragraph 16(b) of the Settlement. The assumed low availability of 215 water comports with recent experience, even with partial SJRRS implementation. As a result, this analysis makes no attempt to quantify future 215 water supply availability, which may be presumed to be nearly zero for planning purposes. "16(b)" or "RWA" or "$10" water (all the same) is discussed in a later section.

**Table 6. Friant Contractor Summary**

| FRIANT CONTRACTOR | CLASS 1 ACRE-FEET | CLASS 2 ACRE-FEET | CLASS 1 PERCENTAGE | CLASS 2/OTHER PERCENTAGE |
|---|---|---|---|---|
| Arvin-Edison Water Storage District | 40,000 | 311,675 | 5.0% | 22.2% |
| Chowchilla Water District | 55,000 | 160,000 | 6.9% | 11.4% |
| City of Fresno | 60,000 | 0 | 7.5% | 0.0% |
| City of Lindsay | 2,500 | 0 | 0.3% | 0.0% |
| City of Orange Cove | 1,400 | 0 | 0.2% | 0.0% |
| Delano-Earlimart Irrigation District | 108,800 | 74,500 | 13.6% | 5.3% |
| Exeter Irrigation District | 11,100 | 19,000 | 1.4% | 1.4% |
| Fresno County Water Works District No. 18 | 150 | 0 | 0.0% | 0.0% |
| Fresno Irrigation District | 0 | 75,000 | 0.0% | 5.4% |
| Garfield Water District | 3,500 | 0 | 0.4% | 0.0% |
| Gravelly Ford Water District | 0 | 14,000 | 0.0% | 1.0% |
| Hills Valley Irrigation District | 1,250 | 0 | 0.2% | 0.0% |
| International Water District | 1,200 | 0 | 0.2% | 0.0% |
| Ivanhoe Irrigation District | 6,500 | 500 | 0.8% | 0.0% |
| Kaweah Delta Water Conservation District | 1,200 | 7,400 | 0.2% | 0.5% |
| Kern-Tulare Water District | 0 | 5,000 | 0.0% | 0.4% |
| Lewis Creek Water District | 1,200 | 0 | 0.2% | 0.0% |
| Lindmore Irrigation District | 33,000 | 22,000 | 4.1% | 1.6% |
| Lindsay-Strathmore Irrigation District | 27,500 | 0 | 3.4% | 0.0% |
| Lower Tule River Irrigation District | 61,200 | 238,000 | 7.7% | 17.0% |
| Madera County | 200 | 0 | 0.0% | 0.0% |
| Madera Irrigation District | 85,000 | 186,000 | 10.6% | 13.3% |
| Orange Cove Irrigation District | 39,200 | 0 | 4.9% | 0.0% |
| Porterville Irrigation District | 15,000 | 30,000 | 1.9% | 2.1% |
| Saucelito Irrigation District | 21,500 | 32,800 | 2.7% | 2.3% |
| Shafter-Wasco Irrigation District | 50,000 | 39,600 | 6.3% | 2.8% |
| Southern San Joaquin Municipal Utility District | 97,000 | 45,000 | 12.1% | 3.2% |
| Stone Corral Irrigation District | 10,000 | 0 | 1.3% | 0.0% |
| Tea Pot Dome Water District | 7,200 | 0 | 0.9% | 0.0% |
| Terra Bella Irrigation District | 29,000 | 0 | 3.6% | 0.0% |
| Tri-Valley Water District | 400 | 0 | 0.1% | 0.0% |
| Tulare Irrigation District | 30,000 | 141,000 | 3.8% | 10.1% |
| **Total** | 800,000 | 1,401,475 | 100% | 100% |

## SJRRS WATER SUPPLY PROJECTIONS

The SJRRS Water Management Goal creates two new categories of supplies for Friant Contractors that are described in paragraphs 16(a) and (b) of the Settlement.

Delta recapture (Paragraph 16(a) is quantified in this analysis by taking the difference in Delta Exports between the with and without SJRRS implementation and crediting the net volume of improvement to the SJRRS recapture program. This does not account for the ability to recapture water supplies on the lower San Joaquin River. Delta recapture is reported as an annual quantity to overcome limitations in the simulation of monthly operations, which are not appropriate for use as monthly recapture volumes at this time. This supply represents an upper bound for potential recapture in the Delta. Discussions between Reclamation, DWR, and

Friant are ongoing to establish the availability of this water supply through Delta pumping. At the time of this report, no processes are in place to recapture in the Delta.

In recent practice, recaptured supplies have been split between Class 1 and 2 contractors, using recapture to back-fill for water contract allocations. For this analysis, Delta recapture has been split between Class 1 and Class 2 contractors, based on recent practices by Reclamation. At the request of Friant Contractors, recapture is provided first to Class 1 water users up to the point that the combination of Friant Division deliveries and recapture equal a 100 percent Class 1 allocation. Any volumes in excess are allocated to Class 2 contractors, proportional to their Class 2 contract volumes. The spreadsheet includes summary tables of total Delta recapture, and a breakout of Class 1 and Class 2 recapture by Friant Contractor proportional to their contract amounts as shown in Table 5. Users of this data are encouraged to apply contract quantities (Table 6) to attribute allocations among Friant Contractors.

The second SJRRS water category, Paragraph 16(b) supplies, are quantified in the CalSim II model by assuming a demand for this potential supply and meeting this demand, limited by availability of flood water and channel capacity for delivery.  Any remaining flood water is then assumed available for 215/other delivery in the simulation.  Specific patterns for the use of this supply do not yet exist and, thus, CalSim-II makes no assertion about anything except for the expectation and potential for these supplies to be delivered.

For consistency with previous efforts to interpret the CalSim II model and its output, 16(b) supplies have been divided among Friant Contractors in proportion to their share of impact from the SJRRS that accumulates to their water supplies. The impact from the SJRRS is estimated by comparison of the total C1 and C2/Other delivery in the Pre-SJRRS and "limited" CalSim II simulations.  The allocation to the individual contractors was done based on percentage of impact from the Proposed Implementation Agreement of the Friant Settlement (SJRRP, 2009) and from the percentage impact computed from the new CalSim II simulation performed for this analysis.  For example, a Friant Contractor with five percent of reduction in total Class 1 and Class 2/Other is and would have access to five percent of the 16(b) supplies. Table 7 and 8 shows impact of SJRRS under the five climate change conditions and computed impacts from the Mediator's Report for the Friant Contractors.

**Table 7. Summary of Friant Contractor Impacts per Climate Change and Mediator's Report (Volume)**

| FRIANT CONTRACTOR | LONG-TERM AVERAGE CLASS 1 AND CLASS 2/OTHER IMPACTS | | | | | |
|---|---|---|---|---|---|---|
| | MEDIATOR'S REPORT | 2015 CONDITION | NEAR-FUTURE, 2030 | LATE-FUTURE, 2070 | LATE-FUTURE, 2070 DEW | LATE-FUTURE, 2070 WMW |
| | TAF | TAF | TAF | TAF | TAF | TAF |
| Arvin-Edison Water Storage District | 30.342 | 28.13 | 28.88 | 26.54 | 18.69 | 28.41 |
| Chowchilla Water District | 17.661 | 15.76 | 16.58 | 15.75 | 12.59 | 16.04 |
| City of Fresno | 3.629 | 2.30 | 3.06 | 3.71 | 5.22 | 2.52 |
| City of Lindsay | 0.151 | 0.10 | 0.13 | 0.15 | 0.22 | 0.11 |
| City of Orange Cove | 0.085 | 0.05 | 0.07 | 0.09 | 0.12 | 0.06 |
| Delano-Earlimart Irrigation District | 13.255 | 10.53 | 11.96 | 12.47 | 13.10 | 10.97 |
| Exeter Irrigation District | 2.398 | 2.05 | 2.20 | 2.15 | 1.89 | 2.10 |
| Fresno County Water Works District No. 18 | 0.009 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Fresno Irrigation District | 6.719 | 6.40 | 6.46 | 5.79 | 3.66 | 6.43 |
| Garfield Water District | 0.212 | 0.13 | 0.18 | 0.22 | 0.30 | 0.15 |
| Gravelly Ford Water District | 1.254 | 1.19 | 1.21 | 1.08 | 0.68 | 1.20 |
| Hills Valley Irrigation District[1] | 0.000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| International Water District | 0.073 | 0.05 | 0.06 | 0.07 | 0.10 | 0.05 |
| Ivanhoe Irrigation District | 1.173 | 0.29 | 0.37 | 0.44 | 0.59 | 0.32 |
| Kaweah Delta Water Conservation District[1] | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Kern-Tulare Water District[1] | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Lewis Creek Water District | 0.088 | 0.05 | 0.06 | 0.07 | 0.10 | 0.05 |
| Lindmore Irrigation District | 3.967 | 3.14 | 3.58 | 3.74 | 3.94 | 3.28 |
| Lindsay-Strathmore Irrigation District | 1.663 | 1.06 | 1.40 | 1.70 | 2.39 | 1.16 |
| Lower Tule River Irrigation District | 25.024 | 22.66 | 23.62 | 22.16 | 16.94 | 22.99 |
| Madera County | 0.012 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 |
| Madera Irrigation District | 21.805 | 19.13 | 20.35 | 19.61 | 16.47 | 19.53 |
| Orange Cove Irrigation District | 2.371 | 1.50 | 2.00 | 2.42 | 3.41 | 1.65 |
| Porterville Irrigation District | 3.655 | 3.14 | 3.35 | 3.24 | 2.77 | 3.20 |
| Saucelito Irrigation District | 4.221 | 3.62 | 3.92 | 3.86 | 3.47 | 3.72 |
| Shafter-Wasco Irrigation District | 6.572 | 5.30 | 5.96 | 6.15 | 6.28 | 5.50 |
| Southern San Joaquin Municipal Utility District | 10.346 | 7.56 | 8.82 | 9.46 | 10.63 | 7.94 |
| Stone Corral Irrigation District | 0.605 | 0.38 | 0.51 | 0.62 | 0.87 | 0.42 |
| Tea Pot Dome Water District | 0.454 | 0.28 | 0.37 | 0.44 | 0.63 | 0.30 |
| Terra Bella Irrigation District | 1.754 | 1.11 | 1.48 | 1.79 | 2.52 | 1.22 |
| Tri-Valley Water District[1] | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Tulare Irrigation District | 14.447 | 13.18 | 13.67 | 12.74 | 9.49 | 13.36 |
| **Total** | **173.945** | **149.13** | **160.26** | **156.49** | **137.14** | **152.67** |

Key:
DEW = Drier/Extreme Warming
TAF = thousand acre-feet
WMW = Wetter/Moderate Warming
Note:
[1] Friant Contractor calculated impact as zero because they do not receive a proportion of 16(b) supplies.

**Table 8. Summary of Friant Contractor Impacts per Climate Change and Mediator's Report (Percentage)**

| FRIANT CONTRACTOR | LONG-TERM AVERAGE CLASS 1 AND CLASS 2/OTHER IMPACTS | | | | | |
|---|---|---|---|---|---|---|
| | MEDIATOR'S REPORT | 2015 CONDITION | NEAR-FUTURE, 2030 | LATE-FUTURE, 2070 | LATE-FUTURE, 2070 DEW | LATE-FUTURE, 2070 WMW |
| | % | % | % | % | % | % |
| Arvin-Edison Water Storage District | 17.444% | 18.864% | 18.020% | 16.958% | 13.630% | 18.611% |
| Chowchilla Water District | 10.153% | 10.571% | 10.347% | 10.066% | 9.183% | 10.504% |
| City of Fresno | 2.086% | 1.544% | 1.909% | 2.368% | 3.806% | 1.653% |
| City of Lindsay | 0.087% | 0.064% | 0.080% | 0.099% | 0.159% | 0.069% |
| City of Orange Cove | 0.049% | 0.036% | 0.045% | 0.055% | 0.089% | 0.039% |
| Delano-Earlimart Irrigation District | 7.620% | 7.063% | 7.464% | 7.970% | 9.553% | 7.183% |
| Exeter Irrigation District | 1.378% | 1.373% | 1.374% | 1.376% | 1.380% | 1.373% |
| Fresno County Water Works District No. 18 | 0.005% | 0.004% | 0.005% | 0.006% | 0.010% | 0.004% |
| Fresno Irrigation District | 3.863% | 4.292% | 4.030% | 3.701% | 2.669% | 4.213% |
| Garfield Water District | 0.122% | 0.090% | 0.111% | 0.138% | 0.222% | 0.096% |
| Gravelly Ford Water District | 0.721% | 0.801% | 0.752% | 0.691% | 0.498% | 0.786% |
| Hills Valley Irrigation District[1] | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% |
| International Water District | 0.042% | 0.031% | 0.038% | 0.047% | 0.076% | 0.033% |
| Ivanhoe Irrigation District | 0.675% | 0.196% | 0.234% | 0.281% | 0.430% | 0.207% |
| Kaweah Delta Water Conservation District[1] | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% |
| Kern-Tulare Water District[1] | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% |
| Lewis Creek Water District | 0.050% | 0.031% | 0.038% | 0.047% | 0.076% | 0.033% |
| Lindmore Irrigation District | 2.281% | 2.108% | 2.232% | 2.388% | 2.876% | 2.145% |
| Lindsay-Strathmore Irrigation District | 0.956% | 0.708% | 0.875% | 1.085% | 1.744% | 0.758% |
| Lower Tule River Irrigation District | 14.386% | 15.194% | 14.736% | 14.159% | 12.352% | 15.057% |
| Madera County | 0.007% | 0.005% | 0.006% | 0.008% | 0.013% | 0.006% |
| Madera Irrigation District | 12.536% | 12.831% | 12.699% | 12.532% | 12.011% | 12.791% |
| Orange Cove Irrigation District | 1.363% | 1.009% | 1.247% | 1.547% | 2.486% | 1.080% |
| Porterville Irrigation District | 2.101% | 2.103% | 2.089% | 2.072% | 2.019% | 2.099% |
| Saucelito Irrigation District | 2.427% | 2.430% | 2.446% | 2.467% | 2.531% | 2.435% |
| Shafter-Wasco Irrigation District | 3.778% | 3.553% | 3.719% | 3.927% | 4.581% | 3.602% |
| Southern San Joaquin Municipal Utility District | 5.948% | 5.071% | 5.504% | 6.048% | 7.754% | 5.201% |
| Stone Corral Irrigation District | 0.348% | 0.257% | 0.318% | 0.395% | 0.634% | 0.276% |
| Tea Pot Dome Water District | 0.261% | 0.185% | 0.229% | 0.284% | 0.457% | 0.198% |
| Terra Bella Irrigation District | 1.008% | 0.746% | 0.923% | 1.144% | 1.839% | 0.799% |
| Tri-Valley Water District[1] | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% |
| Tulare Irrigation District | 8.305% | 8.840% | 8.531% | 8.141% | 6.921% | 8.748% |
| **Total** | **100.00%** | **100.00%** | **100.00%** | **100.00%** | **100.00%** | **100.000%** |

Key:
DEW = Drier/Extreme Warming
WMW = Wetter/Moderate Warming
Note:
[1] Friant Contractor does not receive a proportion of 16(b) supplies.

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SJRRP, *see San Joaquin River Restoration Program*

# Appendix 2
# Monitoring Network Summary

Appendix 2

# Monitoring Network Summary

This appendix provides a summary of the monitoring networks for the management of groundwater resources within the Kaweah Subbasin in Tulare and Kings Counties. Groundwater management will be conducted by the Eastern Kaweah Groundwater Sustainability Agency (GSA), Greater Kaweah GSA, and the Mid-Kaweah GSA according to their respective groundwater sustainability plans (GSPs). Specific details of the monitoring networks can be found in the respective GSPs. This appendix will be revised periodically to reflect the expansion of the networks as data gaps are filled by ongoing management efforts.

The monitoring networks are focused on three of the six sustainability indicators, including Groundwater Levels, Water Quality, and Subsidence. Groundwater Storage will be addressed by Groundwater Levels by proxy. Seawater Intrusion is not applicable to the Kaweah Subbasin since the Pacific Ocean is located more than 80 miles to the west, beyond the Coast Mountains. Interconnected Surface Water has not been identified as applicable at this time in Mid-Kaweah and will be addressed by proxy via Groundwater Levels in the Eastern Kaweah GSA.

## Groundwater Levels

Figure A-2-1 illustrates the location of monitoring wells that will be used for semi-annual measurements of groundwater levels and estimates of groundwater storage. Selected wells may be monitoring monthly within the MKGSA by the Cities of Tulare and Visalia. The three GSAs will utilize a total of 126 wells, as summarized below.

| Purpose / GSA: | Greater Kaweah | Mid-Kaweah | Eastern Kaweah |
|---|---|---|---|
| Groundwater Levels | 40 | 43 | 43 |

## Groundwater Quality

Figure A-2-2 illustrates the location of wells that will be used for monitoring groundwater quality. The three GSAs will utilize a total of 285 wells, as summarized below. Most of these wells will be public supply wells which are sampled according to the requirements of the California Division of Drinking Water. Primary constituents of concern (COCs) as listed below.

| Metal | Anion | Organic Compound |
|---|---|---|
| Arsenic | Nitrate | DBCP (1,2-dibromo-3-chloropropane) |
| Chromium-VI | Perchlorate | TCP (1,2,3-trichloropropane) |
| Sodium | Chloride | PCE (perchloroethylene/tetrachloroethylene) |
| Total Dissolved Solids (TDS) | | |

The data management system will accumulate all available data from the various sources of data but will focus on the primary COCs and their respective measurable objective and minimum threshold. Data sources include the Groundwater Ambient Monitoring and Assessment Program (GAMMA), Irrigated Lands Regulatory Program (ILRP), Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS), and other programs as the data become available.

| Purpose / GSA: | Greater Kaweah | Mid-Kaweah | Eastern Kaweah |
|---|---|---|---|
| Groundwater Quality | 60 | 110 | 70 |

**Subsidence**

Figure A-2-3 illustrates the location of stations that will be used for monitoring subsidence. The three GSAs will utilize a total of 32 stations, as summarized below.

| Purpose / GSA: | Greater Kaweah | Mid-Kaweah | Eastern Kaweah |
|---|---|---|---|
| Subsidence | 14 | 8 | 10 |

**Figure A-2-1. Location Map for Monitoring Wells for Groundwater Levels**

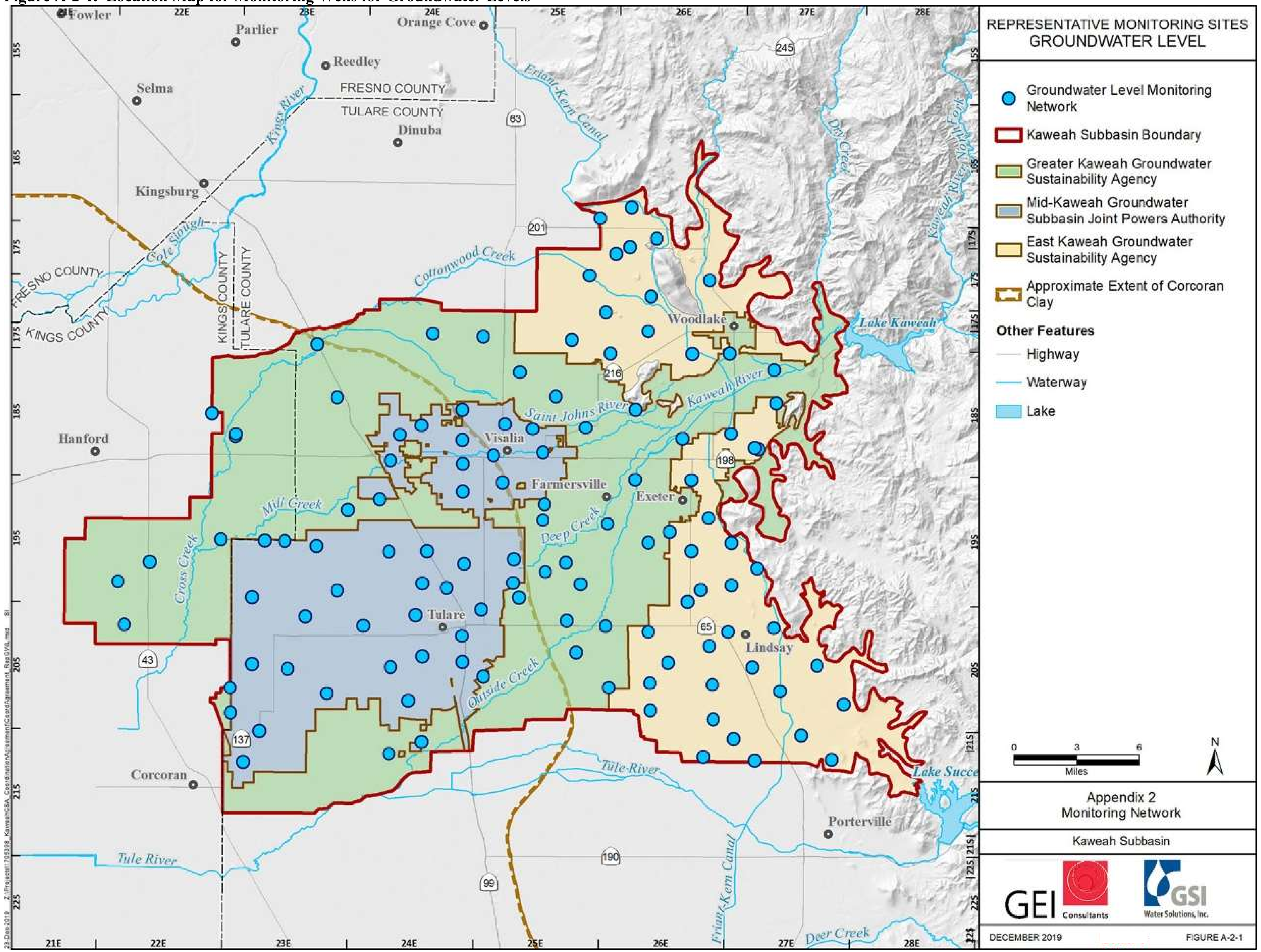


Figure A-2-2. Location Map for Supply Wells for Groundwater Quality Monitoring

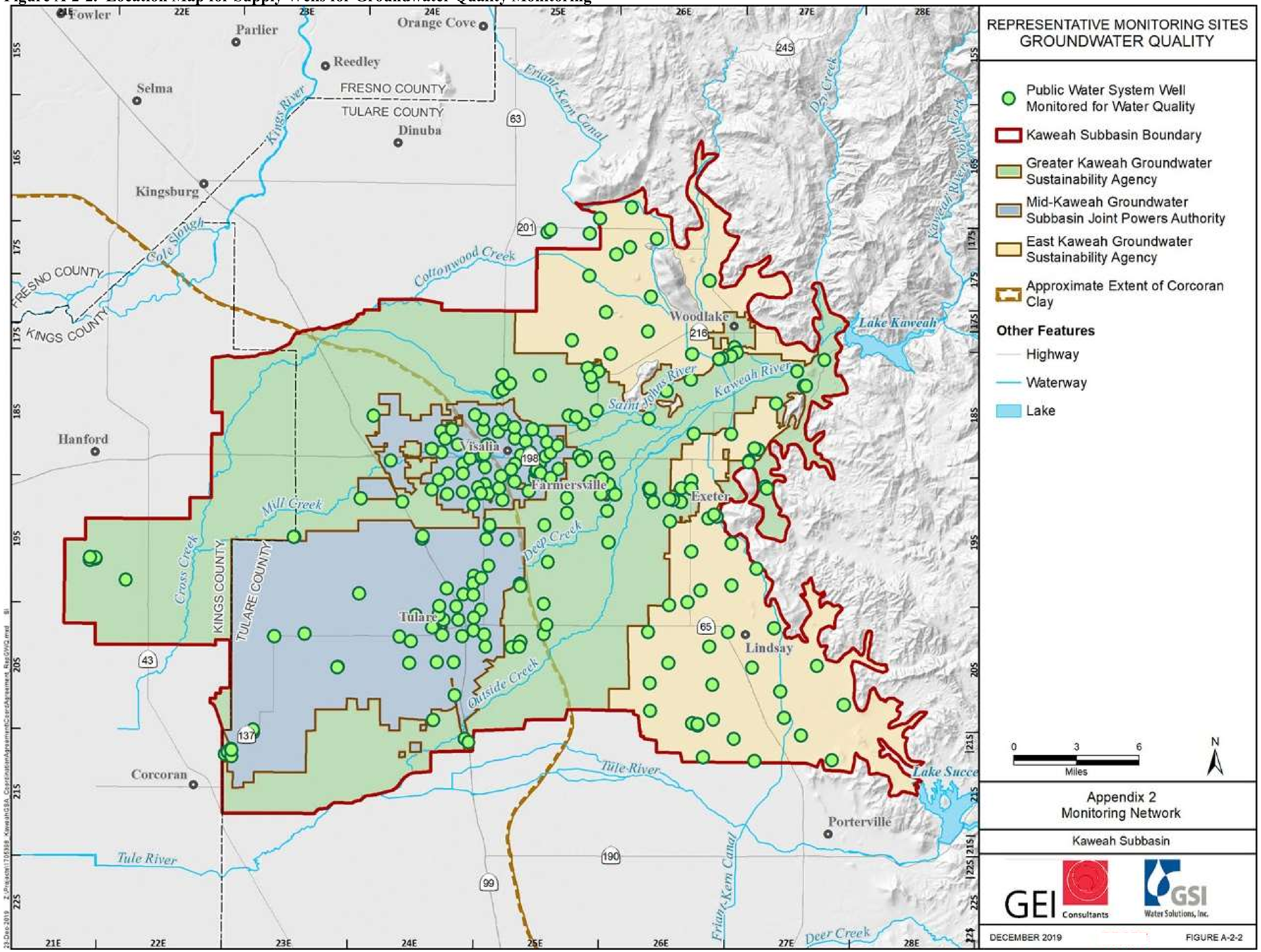
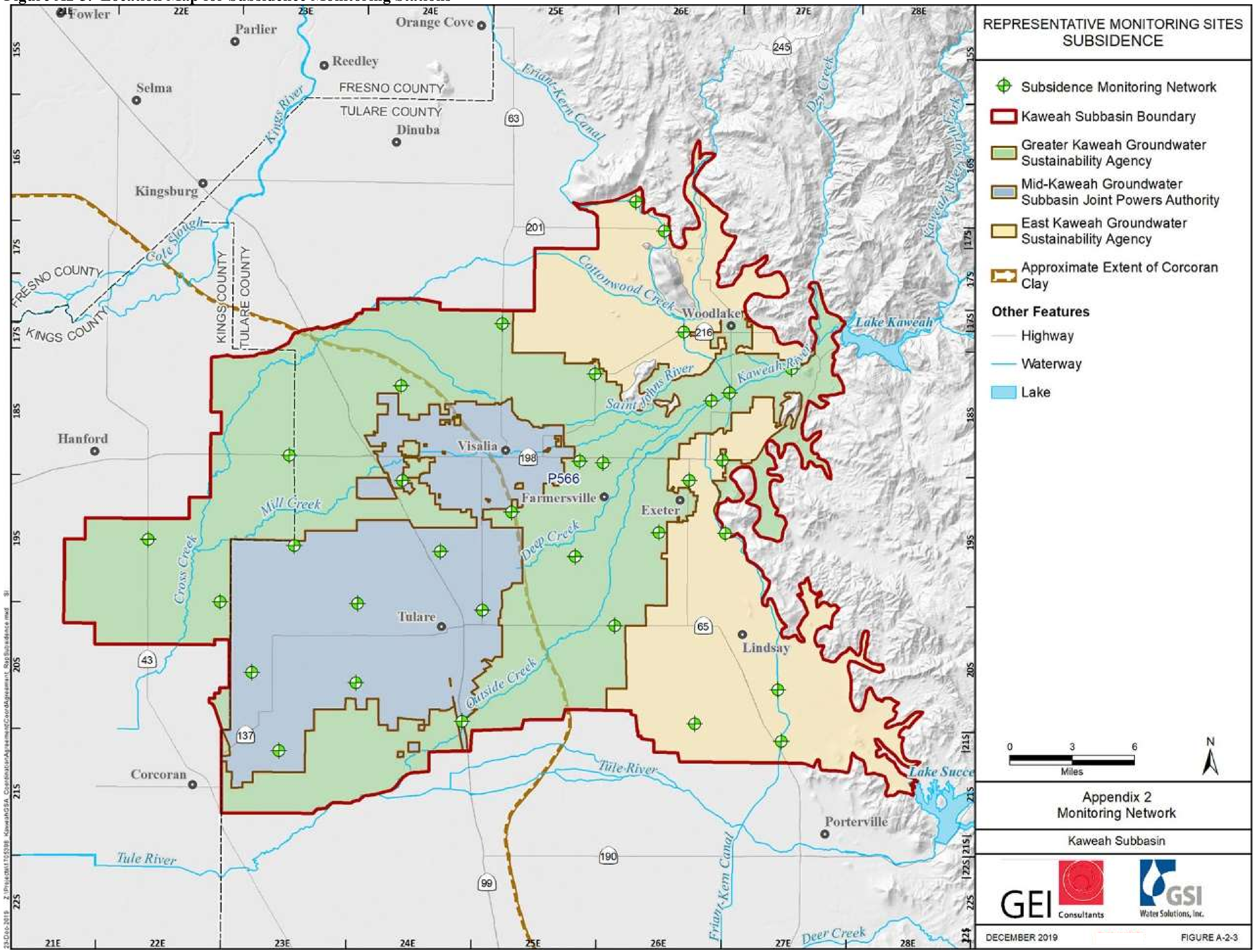


**Figure A2-3. Location Map for Subsidence Monitoring Stations**



# Appendix 3

# Water Accounting Framework Summary

# Water Accounting Framework

Appendix 3 to Kaweah Subbasin Coordination Agreement

For purposes of creating a water budget pursuant to 23 Cal. Code Regs. §354.18, the GSAs in the Kaweah Subbasin have agreed that the Sustainable Yield for the Subbasin shall be divided amongst the GSAs for purposes of development of their GSPs as described in the Kaweah Subbasin water budget. The water budget is not an allocation of final determination of any water rights. This understanding is consistent with § 10720.5(b) of SGMA, which provides that nothing in SGMA or in a plan adopted under SGMA determines or alters surface or groundwater rights under common law or any provision of law that determines or grants surface water rights.

The Subbasin GSAs have discussed water budgets and have developed a means to account for various components of the water budget. These discussions accounting also included recognition of water storage and conveyance infrastructure within the Subbasin as owned/operated by various water management entities within each GSA.

These discussions culminated in an agreed-to methodology to assign groundwater inflow components to each GSA consistent with categories that recognize a native, foreign and salvaged portion of all such components. In general, this methodology defines the native portion of groundwater inflows to consist of those inflows which all well owners have access to on a pro-rata basis; the foreign portion to consist of all imported water entering the Subbasin from non-local sources under contract by local agencies or by purchase/exchange arrangements; and the salvaged portion to consist of all local surface and groundwater supplies stored, treated and otherwise managed by an appropriator/owner of the supply and associated water infrastructure systems (e.g. storm water disposal systems and waste water treatment plants).

The methodology and apportionment of groundwater inflow components is as shown in Table 3.1:

**Table 3.1**

Components of Groundwater Inflow

Native
- Percolation from rainfall
- Streambed percolation (natural channels) from Kaweah River watershed sources
- Agricultural land irrigation returns from pumped groundwater
- Mountain front recharge

Foreign
- Streambed percolation from imported sources
- Basin recharge from imported sources
- Ditch percolation from imported sources
- Agricultural land irrigation returns from imported sources

Salvaged
- Ditch percolation from previously appropriated Kaweah River sources
- Additional ditch/field recharge from over-irrigation
- Captured storm water returns
- Waste water treatment plant returns
- Basin percolation from previously stored Kaweah River sources
- Agricultural land irrigation returns from Kaweah River watershed sources

*Except for mountain front recharge, sub-surface inflows in and out of the Subbasin are excluded from this accounting methodology and no ownership claims are asserted nor disavowed per this methodology.

*[this portion of the page intentionally left blank]*

Applying the accounting methodology in Table 6.1 to each GSA and their member entities that hold appropriative and contract water rights and/or salvaged water infrastructure systems results in the following quantification to each GSA, shown in Table 3.2:

**Table 3.2**

(values in acre-feet)

| | | | | |
|---|---|---|---|---|
| | **Native Water** | | | |
| | **East** | **Greater** | **Mid** | **Total** |
| Perc of Precip (Ag and 'Native' non-Ag land) | 23,666 | 44,213 | 20,974 | **88,854** |
| Streambed Perc from Kaweah River Sources | 16,767 | 31,324 | 14,860 | **62,952** |
| Irrigation Ret. Flow from Pumped GW | 41,484 | 77,501 | 36,766 | **155,752** |
| Mountain Front Recharge | 14,976 | 27,978 | 13,273 | **56,227** |
| **Total Native** | **96,894** | **181,017** | **85,874** | **363,784** |
| **GSA % of Total Native** | **27%** | **50%** | **24%** | |
| | | | | |
| | **Foreign Water** | | | |
| | **East** | **Greater** | **Mid** | **Total** |
| Streambed Perc from Imported Sources | 0 | 11,730 | 2,523 | **14,253** |
| Ditch Perc from Imported Sources | 0 | 1,204 | 21,745 | **22,949** |
| Basin Perc from Imported Sources | 0 | 1,050 | 14,305 | **15,355** |
| Irrigation Ret. Flow from Imported Sources | 12,073 | 1,241 | 7,140 | **20,453** |
| **Total Foreign** | **12,073** | **15,225** | **45,713** | **73,010** |
| **GSA % of Total Foreign** | **17%** | **21%** | **63%** | |
| | | | | |
| | **Salvaged Water** | | | |
| | **East** | **Greater** | **Mid** | **Total** |
| Ditch Perc from Kaw River Sources | 8,835 | 49,771 | 34,880 | **93,486** |
| Additional Recharge | 226 | 6,892 | 5,697 | **12,815** |
| Stormwater Return Flows | 508 | 2,370 | 8,491 | **11,368** |
| WWTP Return Flows | 1,470 | 3,129 | 13,878 | **18,477** |
| Basin Perc from Kaweah River Sources | 0 | 16,005 | 23,479 | **39,484** |
| Irrig. Ret. Flow from Kaweah River Sources | 4,555 | 31,039 | 11,981 | **47,574** |
| **Total Salvaged** | **15,593** | **109,205** | **98,406** | **223,205** |
| **GSA % of Total Salvaged** | **7%** | **49%** | **44%** | |
| | | | | |
| | **East** | **Greater** | **Mid** | **Total(*)** |
| **Grand Total** | **124,560** | **305,447** | **229,992** | **659,999** |
| **GSA % of Total** | **19%** | **46%** | **35%** | |

**(*) Excludes net sub-surface inflow of 60 taf/yr**

**Note: All data is derived from the Basin Setting and is based on water budget for the period Water Year 1997 to 2017 for the Kaweah Subbasin.**

As noted in Table 3.2, net sub-surface inflow is omitted from this quantification. Sub-surface inflows and outflows are discussed and quantified in the Basin Setting report (Appendix 1) and are embodied in scenarios of future groundwater conditions as simulated by application of the Subbasin computer model. As discussed in that report, the Subbasin's safe yield is estimated to be about 720,000 AF, which amount includes net sub-surface inflow. As defined in SGMA however, the Subbasin's sustainable yield may be additionally impacted when considering undesirable results for other sustainability indicators. The Parties therefore have preliminarily determined that the sustainable yield may be something less and have agreed that the total groundwater inflow of 660,000 AF identified in Table 3.2 will constitute the sustainable yield, which amount does not take into consideration net sub-surface inflow from adjacent subbasins. The estimated sustainable yield will continue to be revised pursuant to the monitoring of sustainability indicators and avoidance of undesirable results.

At this stage, inter-basin discussions concerning water budgets and associated credits for such sub-surface flows are not to the point of delineating Subbasin assignments thereof. The quantification as described serves primarily to shape future discussions among the Kaweah Subbasin GSAs concerning mutual responsibilities in achieving sustainability by 2040.

As additional data becomes available and water budget components are refined, the Subbasin water budget and estimates of sustainable yield will be periodically reevaluated, no less frequently than two years. Likewise, the individual GSA water balances will also be reviewed as this reevaluation occurs at the Subbasin level.

# Appendix 4
# DMS Summary



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# Appendix 4 -**DMS Summary**

# Memo

**To:** Kaweah Subbasin GSAs
Mike Hagman, East Kaweah GSA
Eric Osterling, Greater Kaweah GSA
Paul Hendrix, Mid-Kaweah GSA

**From:** Chris Petersen and Maria Pascoal, GEI Consultants

**Date:** [Status]

**Re:** Draft Specifications for the Kaweah Subbasin Data Management System

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The Sustainable Groundwater Management Act (SGMA) regulations, established by the California Department of Water Resources (DWR), require that a Groundwater Sustainability Plan (GSP) must have a Data Management System (DMS) capable of securely storing and displaying information relevant to the development and implementation of the GSP. The Kaweah Subbasin will be managed by three Groundwater Sustainability Agencies (GSAs) under three GSPs. To effectively and cost-efficiently share data, the GSAs will use one DMS to store the Subbasin's SGMA data.

The DMS for the Kaweah Subbasin is currently being developed by GEI Consultants, Inc. (GEI) with data and analytical support from GSI Water Solutions (GSI). The purpose of this memorandum is to describe the specifications of the DMS. These specifications were developed based on the DMS development meeting held with the three GSAs in April 2018 and supported by Task Order KSB-05.2018 Amendment 2, Task 1 – Data Management System. This memorandum includes the following sections:

1. SGMA DMS Requirements
2. Data Structure
3. Data Contents
4. Web Interface
5. DMS Hosting
6. Summary

# SGMA DMS Requirements

The Kaweah Subbasin DMS will be designed to meet the system and data requirements of SGMA.

## 1.1. System Requirements

The GSP Regulations (California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2) give broad requirements on data management, stating that a GSP must adhere to the following guidelines for a DMS:

> ***§ 352.6. Data Management System***
>
> *Each Agency shall develop and maintain a data management system that is capable of storing and reporting information relevant to the development or implementation of the [Groundwater Sustainability] Plan and monitoring of the basin.*
>
> *Note: Authority cited: Section 10733.2, Water Code.*
> *Reference: Sections 10727.2, 10728, 10728.2, and 10733.2, Water Code.*
>
> ***§ 352.4. Data and Reporting Standards***
>
> *(c) The following standards apply to wells:*
>
> *(3) Well information used to develop the basin setting shall be maintained in the Agency's data management system.*
>
> *Note: Authority cited: Section 10733.2, Water Code.*
> *Reference: Sections 10727.2, 10727.6, and 10733.2, Water Code.*
>
> ***§ 354.40. Reporting Monitoring Data to the Department***
>
> *Monitoring data shall be stored in the data management system developed pursuant to Section 352.6. A copy of the monitoring data shall be included in the Annual Report and submitted electronically on forms provided by the Department.*
>
> *Note: Authority cited: Section 10733.2, Water Code.*
> *Reference: Sections 10728, 10728.2, 10733.2, and 10733.8, Water Code.*

## 1.2. Data Requirements

SGMA defines sustainable groundwater management as "the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results."[1] Furthermore, SGMA outlines six undesirable results as follows:[2]

> *One or more of the following effects caused by groundwater conditions occurring throughout the basin:*
>
> *(1) Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic*

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[1] §10721(v)
[2] §10721(x)

*lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.*

*(2) Significant and unreasonable reduction of groundwater storage.*

*(3) Significant and unreasonable seawater intrusion.*

*(4) Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.*

*(5) Significant and unreasonable land subsidence that substantially interferes with surface land uses.*

*(6) Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.*

The presence or absence of the six undesirable results in a groundwater basin is determined by examining the sustainability indicator data for each. The Kaweah Subbasin DMS will store data relevant to each sustainability indicator as appropriate. There are multiple metrics by which the sustainability indicators may be observed. These metrics, as defined in the GSP Regulations and described by DWR in the Sustainable Management Criteria Best Management Practice (BMP) document,[3] are shown in **Figure 1**.

**Figure 1. DWR's Sustainability Indicator Metrics**

| **Sustainability Indicators** | Lowering GW Levels | Reduction of Storage | Seawater Intrusion | Degraded Quality | Land Subsidence | Surface Water Depletion |
|---|---|---|---|---|---|---|
| **Metric(s) Defined in GSP Regulations** | • Groundwater Elevation | • Total Volume | • Chloride concentration isocontour | • Migration of Plumes<br>• Number of supply wells<br>• Volume<br>• Location of isocontour | • Rate and Extent of Land Subsidence | • Volume or rate of surface water depletion |

[3] https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/BMP_Sustainable_Management_Criteria_2017-11-06.pdf.

The Kaweah Subbasin DMS is designed to store data for each of the six sustainability indicators. Each sustainability indicator may track one or more types of data, as shown in **Table 1**.

**Table 1. DMS Data Types to Monitor the SGMA Sustainability Indicators**

| Sustainability Indicator | Tracking Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | *Water Quality* | | | |
| | Water Level | Extensometer | GPS | InSAR | Chloride | ±10 constituents | Stream stages | Well* and/or Site Data |
| Subsidence | ✓ | ✓ | ✓ | ✓ | | | | ✓ |
| Water levels | ✓ | | | | | | | ✓ |
| Groundwater storage | ✓ | | | | | | | ✓ |
| Seawater intrusion | Not applicable (per GSP development) | | | | | | | |
| Surface water/ groundwater interaction | ✓ | | | | | | ✓ | ✓ |
| Water quality | ✓ | | | | ✓ | ✓ | | ✓ |

*May include aquifer, construction, lithology, and/or screen data

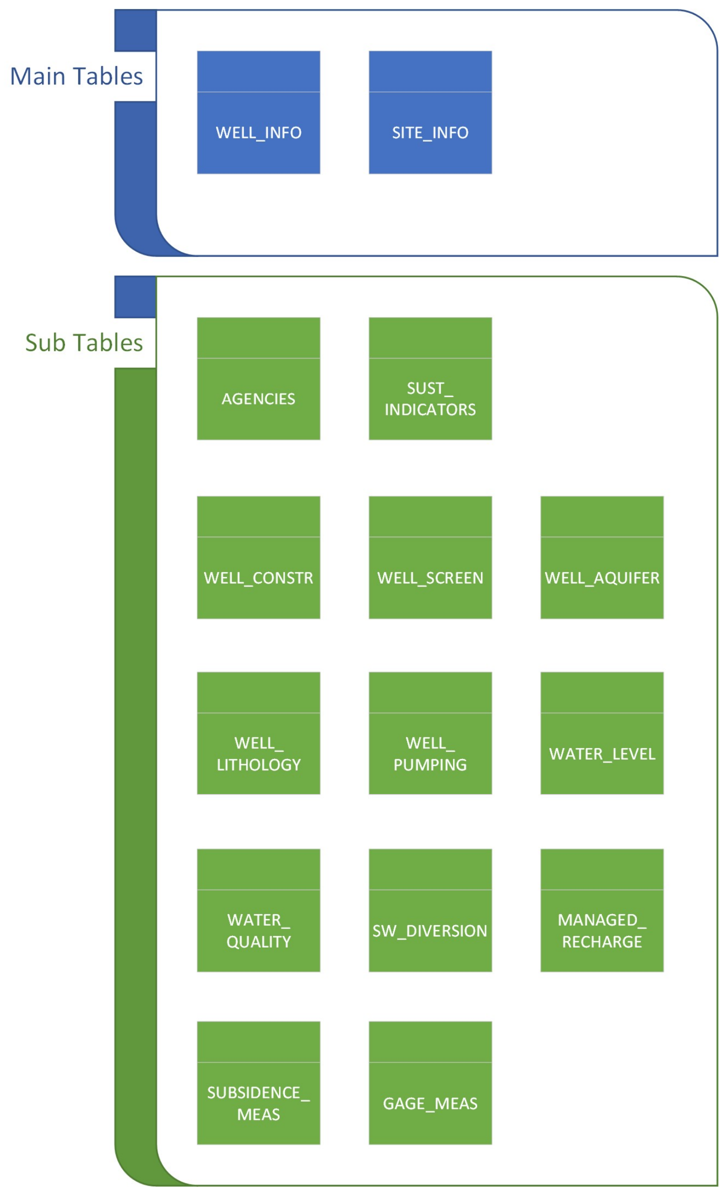
The Kaweah Subbasin DMS will accept the types of data shown in the columns of **Table 1**. However, the DMS will not necessarily be populated with historical data for each type. Data that was relied upon for 2020 GSP development is what will be uploaded in the DMS.

# Data Structure

The DMS will consist of a database plus an online web viewer. Data stored in the DMS is separated by categories into tables. The tables contain columns and rows of data. Each field holds a specific type of data, such as a number, text, or date. The primary DMS data tables are shown as **Figure 2**. The figure is color-coordinated to show the relationship between tables:

- **Blue Tables** – Main tables that include point data with a unique identification and unique point location to be added to the database (e.g., Well_Info and Site_Info)
- **Green Tables** – Sub tables related to the main table that hold additional details about the well or site (e.g., correlation of a well point with water level or water quality)

**Figure 2. Kaweah Subbasin DMS Tables – Main and Sub**



A brief description of each main and sub table is provided in **Table 2**. There are lookup tables within each of the main and sub tables, but the lookup tables are very detailed and not outlined here. The lookup tables can be found in the upload templates described in the next section of this document.

**Table 2. DMS Table Descriptions**

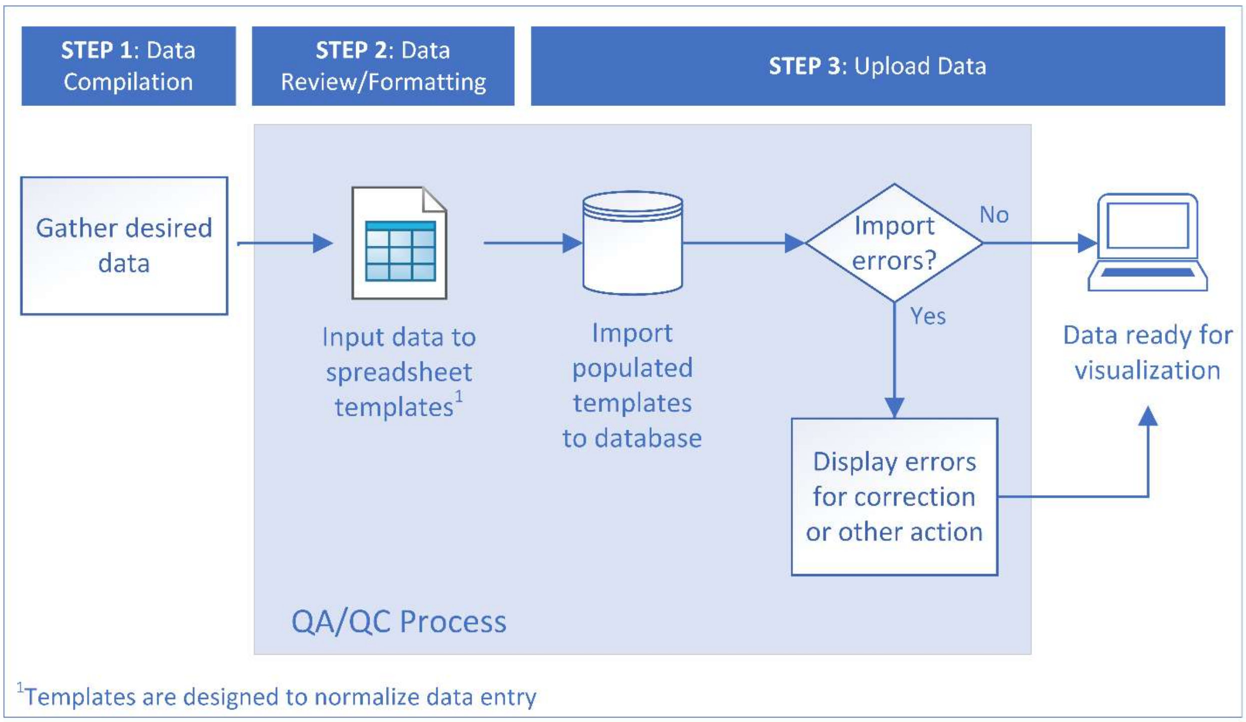
| Table | Description |
|---|---|
| ***Main Tables*** | |
| Site Info | Information about type of station (well, recharge site, diversion, gage, extensometer, GSP) and geographic location |
| Well Info | General information about well, including identifiers used by various agencies |
| ***Sub Tables*** | |
| Agencies | Agency associated with the well and/or site or the collection of data at a well or site |
| Sustainability Indicators | Minimum Thresholds and Measurable Objectives set for monitoring network sites tracking Sustainable Management Criteria for SGMA compliance |
| Well Construction | Well construction information including depth, diameter, etc. |
| Well Construction Screen | Supplements 'Well Construction' with well screen information (one well can have many screens) |
| Well Geologic Aquifer | Information about the aquifer parameters of the well such as pumping test information, confinement, and transmissivity |
| Well Geologic Lithology | Lithologic information at a well site (each well may have many lithologies at different depths) |
| Water Level | Water level measurements for wells |
| Well Pumping | Pumping measurements for wells, annual or monthly |
| Managed Recharge | Recharge measurements for a recharge site, annual or monthly |
| SW Diversion | Diversion volume measurements for a diversion site, annual or monthly |
| Water Quality | Water quality data for wells or any other type of site |
| Subsidence Measurement | Elevation measurements from stations tracking land subsidence |
| Gage Measurement | Stage or discharge water level measurements from stream gages |

## Data Contents

Historical data will be populated into the DMS as needed to support the 2020 GSPs. State and Federal data available via online public databases will be brought directly from the data source to the DMS by the DMS development team.

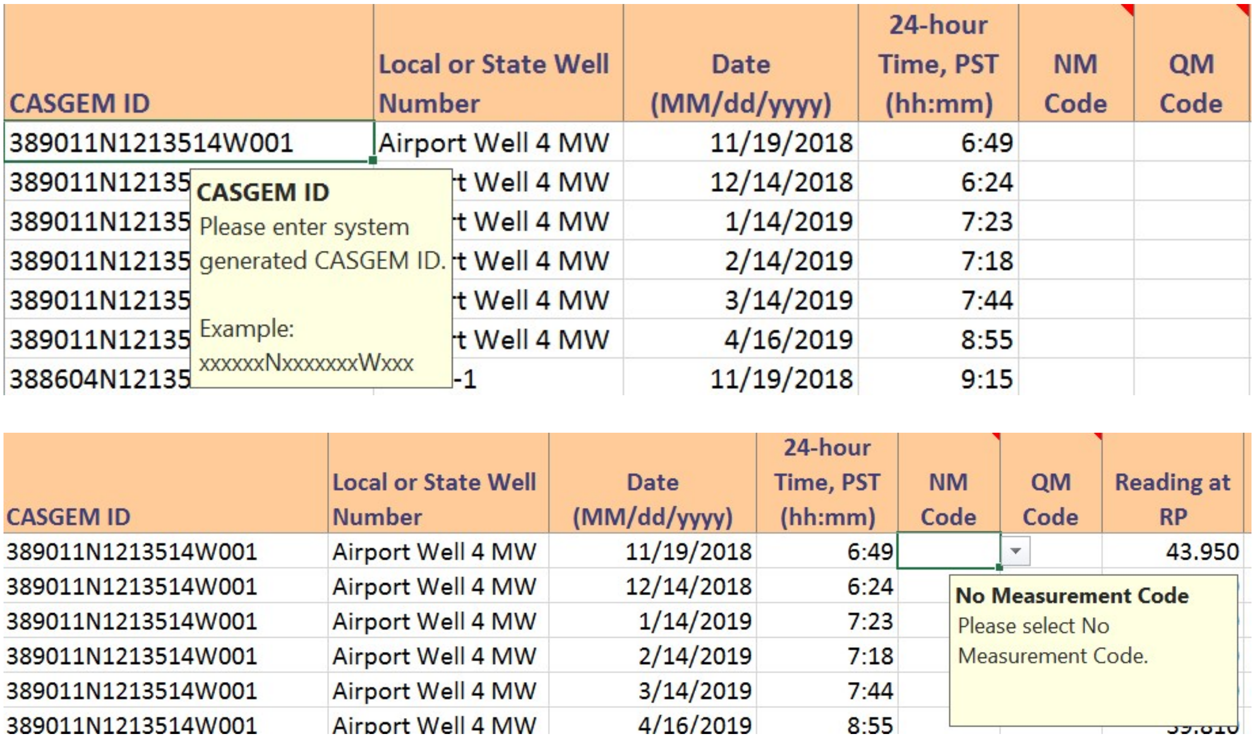
Local Kaweah Subbasin data used to support GSP development will be collected by GEI and put into spreadsheet templates designed to normalize data entry. The templates will include a set of rules restricting formatting, alphanumeric properties, and other filters. This template process is shown as **Figure 3**.

**Figure 3. Template Import Process for Local Data**




The templates include validation parameters similar to CASGEM templates. CASGEM templates are shown in **Figure 4** as an example. The templates will have pop-up windows to describe what should be filled in for each column. If a specific filter must be applied, only values that meet the criteria will appear in a drop-down list. GEI will upload data to the DMS using these templates.

**Figure 4. CASGEM Template Examples**




All the Main and Sub Tables listed in **Table 2** will have a template. The compiled data will be reviewed by GEI before it is migrated into the database. The data review process will be focused and limited in scope. It will include the following checks:

- Identifying outliers that may have been introduced during the original data entry process
- Removing or flagging questionable data

Once the data has been compiled, input to the templates, and reviewed, it will be uploaded to the DMS and displayed on a visualization tool (GIS map) interface.

Moving forward, the templates will be used by the Kaweah Subbasin GSAs to prepare future data for DMS input.

# Web Interface

The DMS begins with a database, stored locally or online, and is accompanied by a viewer that allows administrators to see the data in a user-friendly interface. The proposed Kaweah Subbasin DMS is a database built in Oracle plus a web application designed in JAVA.

The web application will display well and other instrument (e.g., extensometer) locations, identifying which wells or instruments are part of a representative monitoring network for the SGMA sustainability indicators.

- Clicking on a well site will display available historical water level or water quality data on a hydrograph
- Clicking on other monitoring points (e.g., extensometers) will display available historical data in tabular and chart format

The map displaying the DMS data will include additional geographic features such as GSA, local agency, and Bulletin 118 basin boundaries to provide context and facilitate interaction with the data.

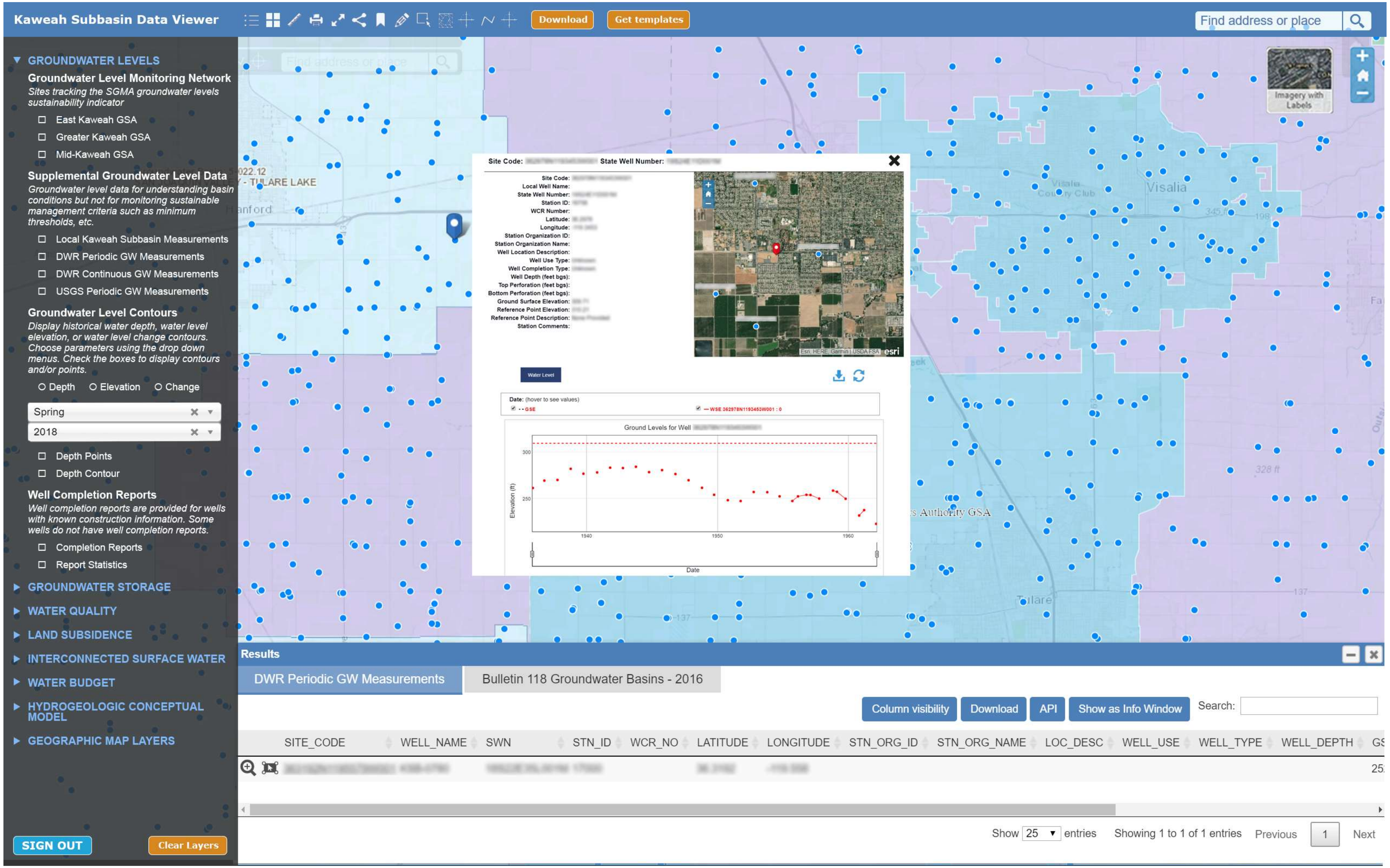
Representative monitoring network data will be made available for export to a spreadsheet format for analytical and reporting purposes. GSP Regulations Article 7 §356.2 outlines specific components to be reported annually (paraphrased):

- *General information including executive summary and location map (narrative)*
- Groundwater elevation contour maps (sourced by DWR) and hydrographs
- Groundwater extraction
- Surface water supply used or available for use, for groundwater recharge or in-lieu use
- *Total water use by water use sector and source (calculated)*
- Change in groundwater storage displayed in map and graph formats
- *Description of progress towards implementing the GSP (narrative)*

The items listed above are needed for each annual report to DWR. The Kaweah Subbasin DMS is designed to store all these items except for those shown in *italics*, which are either narratives or calculations that are done outside of the DMS.

See **Figure 5** for an example design for the Kaweah Subbasin data viewer.

**Figure 5. Example Design for Kaweah Subbasin Data Viewer**



# DMS Hosting

GEI will host the DMS for the duration of the amended Task Order – through December 2019. After that time, hosting will be transferred to either a Kaweah Subbasin GSA or a participating agency. As of the April 2018 DMS Development Meeting, the GSAs decided to postpone choosing where the DMS would be hosted from the year 2020 forward. If needed, GEI may continue to host the DMS for a nominal fee.

# Summary

The Kaweah Subbasin DMS will contain the information used to support GSP development. The data stored will be based on the requirements of SGMA and include relevant historical data collected during GSP development for each of the six sustainability indicators. The DMS will consist of an Oracle database with a web-based viewer designed using JAVA. Data will be available for export from the DMS using the web-based viewer. The DMS will be hosted on a GEI server through December 2019, after which time it will be hosted by a Kaweah Subbasin agency or stay with GEI for a fee.

# Appendix 5

# Data Gaps Summary

# Appendix 5

## Data Gaps Summary

This appendix provides a summary of the current data gaps in the Kaweah Subbasin. It represents the gaps that were identified at the time of 2020 GSP preparation by the Kaweah Subbasin GSAs: East Kaweah GSA (EKGSA), Mid-Kaweah GSA (MKGSA), and Greater Kaweah GSA (GKGSA).

The three abovementioned GSAs agreed to, at a minimum of every five years, provide an evaluation of data gaps and to make a good-faith effort to address data gaps. These commitments are documented in the Kaweah Subbasin Coordination Agreement.

In general, the Kaweah Subbasin GSPs identify a need for expanding the spatial extent and density of the monitoring networks for water levels, water quality, and subsidence. They also indicate a need for increased knowledge about the existing monitoring network including geological/hydrogeological information, well logs, and well construction information. Table A-5-1 provides a summary of the primary data gap topics.

**Table 5-1.** Primary data gap topics by GSP

| Data Gap Topic | EKGSA GSP | MKGSA GSP | GKGSA GSP |
|---|---|---|---|
| Geological/hydrogeological information | X | X | X |
| Well logs | X | X | X |
| Well construction information | X | X | X |
| Stream flow monitoring | X | | |
| Spatial extent and density of **water level** monitoring network | | X | X |
| Spatial extent and density of **water quality** monitoring network | | | X |
| Spatial extent and density of **subsidence** monitoring network | X | X | X |
| Groundwater-dependent ecosystems (GDEs) | X | | X |
| Subsurface inflows and outflows | X | | |
| Surface water deliveries | X | | |
| Recharge basin data collection | X | | |
| Irrigation demand | X | | |
| M&I demand | X | | |
| Accurate well count, type (domestic, irrigation, etc.), and status (active, inactive, abandoned[, destroyed]) | | X | X |
| Hydraulic parameters of principal aquifers based on pumping tests | | X | X |
| Water quality information for domestic and agricultural wells | | X | X |
| Interconnected surface water | | | X |
| Pumping records | | X | |
| Rocky Hill Fault: evaluation of flow | X | | |
| Intermontane Valley areas | X | | |
| Septic system contamination (Nitrate) | X | | |

Each of the three Kaweah Subbasin GSPs contain a list of the principal data gaps for its respective GSA area. The summary lists extracted from each GSP are provided below.

**East Kaweah**

From the EKGSA GSP, **Section 2.6 – Identification of Data Gaps**:

"Identification of data gaps will continue to be a work in progress. The principal data gaps are listed below, which are subject to revision during the course of completion of this GSP.

- Geological/hydrogeological information for all areas of the EKGSA.
    - The SkyTEM effort should assist in filling this data gap
    - New and/or better well logging for monitoring and production wells can also be informative in locations with little or no data
- Well construction information such as: depth of well, perforation intervals, casing diameter, and use
    - Strongly encourage the Kaweah Subbasin GSAs and Tulare County [to] initiate a well canvas of the area to develop a better data set
    - Potential Drinking Well Observation Plan can assist with gathering well data for specific drinking water wells in the region
- Stream flow monitoring on Cottonwood, Yokohl, Lewis, and Frazier Creeks
    - Gauges are proposed to be constructed, especially for the creeks potentially to be used for recharge activities
    - Specific watershed studies for these creek watersheds can be performed to better inform the estimations of creek flows and seepage
- Consistent subsidence monitoring
    - Likely remedied with more consistent InSAR data
    - Specific infrastructure to be surveyed for subsidence impacts
- Presence of GDE
    - Likely linked with the added stream flow monitoring
    - More consistent groundwater level monitoring in the intermontane valleys
- Water Budget Components
    - Further development of subsurface inflows and outflows from the mountain front and neighboring subbasins
    - Improved understanding of surface water deliveries within district boundaries
    - Retention/Recharge basin data collection and tracking as more recharge is developed
    - Improved understanding of irrigation demand and method for crop and soil types within the Subbasin and EKGSA
    - Improved tracking of M&I demands."

**Greater Kaweah**

From the GKGSA GSP, **Section 2. Basin Setting**:

"The following data gaps were identified for the GKGSA:

- Accurate count of wells in GKGSA area, including well type (domestic, irrigation, etc.) and status (active, inactive, abandoned, [destroyed]). A detailed reconnaissance survey is underway to verify location and operational status of wells within GKGSA's jurisdiction but was not yet complete to inform this plan).
- Construction details of wells, especially production/screen interval(s). This data gap is significant and limits a comprehensive understanding of groundwater level and groundwater quality conditions above and below the Corcoran Clay.
- Lithologic composition of aquifer, including geophysical logs at strategic locations.
- Hydraulic parameters of principal aquifers based on pumping tests.
- Water quality data for domestic and irrigation wells.
- Measurements of subsidence within the GKGSA. The historical record of measured subsidence is incomplete and provides no information to inform an understanding of subsidence with depth.
- Groundwater elevation monitoring in areas with shallower groundwater levels to confirm whether or not the potential interconnected surface water and/or GDEs are present."

**Mid-Kaweah**

From the MKGSA GSP, **Section 2. Basin Setting**:

"The following data gaps were identified for the MKGSA:

- Accurate count of wells in MKGSA area, including well type (domestic, irrigation, etc.) and status (active, inactive, abandoned[, destroyed])
- Construction details of wells, especially production/screen interval(s). This was a significant data gap that prevented a comprehensive understanding of groundwater level and groundwater quality conditions above and below the Corcoran Clay
- Groundwater production records from direct measurement and locally generated estimates of groundwater use in rural areas of the MKGSA. This information will improve the water budget.
- Lithologic composition of aquifer, including geophysical logs at strategic locations
- Hydraulic parameters of principal aquifers such as transmissivity, storativity and porosity based on pumping tests preferably. This information could then help with the interpretation of Aerial Electro-Magnetic (AEM) data recently collected.
- Water quality data for small rural community, domestic (rural residential home owners) and agricultural irrigation wells
- Understanding of groundwater quality trends with depth (i.e. between upper and lower principal aquifers and vertical changes within each principal aquifer). With this information, an improved understanding is possible regarding depth of base of freshwater throughout the MKGSA as well as the Kaweah subbasin as a whole.

- Measurements of subsidence within the MKGSA. The historical record of measured subsidence is incomplete and provides no information to inform an understanding of subsidence with depth. Correlation between subsidence and release of arsenic from clay mineralogy represents a data gap that needs to be filled through improved sampling and subsidence monitoring.
- Expanded monitoring of groundwater levels and groundwater quality in small rural communities and disadvantaged communities

A compilation of every reference to a data gap in any of the three Kaweah Subbasin GSPs or in the Kaweah Subbasin Basin Setting document is provided as **Table 5-2**. In general, the plan to fill a data gap is presented alongside or nearby the text where the gap is identified in the GSP or Basin Setting document.

**Table 5-2.** All Data Gap Reference Table

| GSP | Section | Page | Data Gap |
|---|---|---|---|
| GKGSA | 2.2 | 2-2 | **Summary List**<br>The following ***data gaps*** were identified for the GKGSA:<br>• Accurate count of wells in GKGSA area, including well type (domestic, irrigation, etc.) and status (active, inactive, abandoned[, destroyed]). A detailed reconnaissance survey is underway to verify location and operational status of wells within GKGSA's jurisdiction but was not yet complete to inform this plan).<br>• Construction details of wells, especially production/screen interval(s). This ***data gap*** is significant and limits a comprehensive understanding of groundwater level and groundwater quality conditions above and below the Corcoran Clay.<br>• Lithologic composition of aquifer, including geophysical logs at strategic locations.<br>• Hydraulic parameters of principal aquifers based on pumping tests.<br>• Water quality data for domestic and irrigation wells.<br>• Measurements of subsidence within the GKGSA. the historical record of measured subsidence is incomplete and provides no information to inform an understanding of subsidence with depth.<br>• Groundwater elevation monitoring in areas with shallower groundwater levels to confirm whether or not the potential interconnected surface water and/or GDEs are present.<br>The ***data gaps*** will be addressed as GKGSA implements the Management Actions designed to close such gaps, as described in Section 7.4 to establish a subbasin-wide Monitoring Network as described in Section 4 of this Plan. |
| GKGSA | 4 | 4-1 | In areas where existing monitoring does not meet the SGMA requirements, this section identifies the ***data gaps*** and proposed measures to address these ***data gaps*** during the SGMA implementation period, so the monitoring improves with time. Any such improvement will be implemented as recognized and the results will be evaluated during the 5-year updates. |
| GKGSA | 4.10.1 | 4-20 | **4.10.1: Data Gaps**<br>The following section describes ***data gaps*** for groundwater elevations, groundwater quality, and land subsidence. |

| GSP | Section | Page | Data Gap |
|---|---|---|---|
| GKGSA | 4.10.1.1 | 4-21 | **4.10.1.1: Groundwater Elevation and Storage**<br>As referenced in Regulation §352.4, "If an Agency relies on wells that lack casing perforations, borehole depth, or total well depth information to monitor groundwater conditions as part of a Plan, the Agency shall describe a schedule for acquiring monitoring wells with the necessary information, or demonstrate to the Department that such information is not necessary to understand and manage groundwater in the basin.<br>Well types and construction details will need to be determined to improve the monitoring network. Downhole well surveys and desktop surveys will be utilized for existing wells to fill in the well construction details gap. New dedicated monitoring wells and converted production wells will be utilized to fill in the monitoring network spatial extent and density. Improvement will occur during the initial few years of the implementation period, prior to the first 5-year update.<br>Currently, the Kaweah Subbasin has a total of 14 SGMA compliant, dedicated monitoring wells that may be used for groundwater level monitoring. An additional six monitoring wells are proposed through the DWR's Technical Support Services (TSS) program. Two of the proposed six wells are located within the GKGSA. While the reminder of the wells used in the interim have been identified as Key Wells in the Basin Setting, they are not dedicated SGMA compliant monitoring wells. To address this GKGSA, in coordination with EKGSA and MKGSA, plans to expand the spatial coverage of groundwater level monitoring wells by adding SGMA compliant wells at or near the locations of existing Key Wells as shown in Figure 4 3. The full development of the SGMA-compliant monitoring network is scheduled to take place over the SGMA implementation period of 2020 to 2040. |
| GKGSA | 4.10.1.2 | 4-21 | **4.10.1.2: Groundwater Quality**<br>Groundwater quality data are mostly available from the reoccurring sampling requirements for public water systems, primarily the Cities of Exeter, Farmersville, and Woodlake, but also for smaller systems within the GKGSA. Additional groundwater quality data will be available from the IRLP program and the upcoming CV-SALTS program and will provide further coverage in agricultural and rural areas. DWR will construct two new nested monitoring wells for the GKGSA as part of the Technical Services Support program. In addition, inactive production wells will be converted to monitoring wells to improve the spatial extent and density of the monitoring network. Improvement will occur during the initial few years of the implementation period, prior to the first 5-year review.<br>As described in Section 4.9, groundwater quality monitoring under existing regulatory programs for public water systems currently provide adequate coverage for the Constituents of Concern listed in the Basin Setting. For areas lacking a public water system, the IRLP and CV-SALTS programs can be used to provide groundwater quality data in the interim. Dedicated SGMA compliant monitoring wells are also eligible for use in groundwater quality sampling and can be brought in to the monitoring network as they are completed. |

| GSP | Section | Page | Data Gap |
|---|---|---|---|
| GKGSA | 4.10.1.3 | 4-21 | **4.10.1.3: Land Subsidence**<br>Land subsidence has been limited by the availability of data, notwithstanding the continuous GPS data for station P566 near Farmersville since 2005 and station CRCN near Corcoran since 2010, limited and variable coverage of InSAR data for 2007 to 2010 and 2015 to 2018, and the recent 2-year period (2016-2018) of KDWCD GPS data for various locations within and around GKGSA. The continued implementation of the KDWCD Land Surface Elevation Monitoring Plan will provide additional data on future subsidence at 12 locations within GKGSA and seven locations with MKGSA plus eight locations outside the Kaweah Subbasin. The GKGSA will coordinate with adjacent subbasins, especially in the southwestern portion of the subbasin where subsidence is greatest and could be affect surface infrastructure.<br>The KDWCD Land Surface Elevation Monitoring Network and InSAR are adequate to address the requirements of SGMA, in terms of spatial distribution. Additional refinement to KDWCD may be considered as part of interbasin coordination efforts for areas which experience higher rates of subsidence. |
| GKGSA | 4.10.1.4 | 4-21 | **4.10.1.4: Interconnected Surface Water**<br>As part of addressing the ***data gap*** of spatial distribution for SGMA-compliant groundwater level monitoring, the GKGSA and other GSAs of the Kaweah Subbasin will coordinate for the installation of SGMA-compliant groundwater level monitoring to validate existing data and confirm whether or not Interconnected Surface Waters are present in the Kaweah Subbasin in proximity to the Kaweah and St. Johns Rivers.<br>As part of addressing the data gap of spatial distribution for SGMA compliant groundwater level monitoring, the GKGSA and other GSAs of the Kaweah Subbasin will coordinate for the installation of SGMA compliant groundwater level monitoring to validate whether or not Interconnected Surface Streams are present in the Kaweah Subbasin in proximity to the Kaweah and St. Johns Rivers. |
| GKGSA | 5.5.1 | 5-15 | The minimum threshold for land subsidence will be a rate of annual decline in land surface elevation. Land subsidence will be measured at the representative land subsidence monitoring network, as shown on Figure 4-5.<br>In evaluating historic groundwater elevation data with subsidence data, an acceptable correlation was not evident, so the proxy use of groundwater levels is not possible. The absence of an acceptable correlation is notable because the mechanism for subsidence is relatively low groundwater levels and the associated compaction of clay units in response to the reduction in pore pressure. We believe the inability to establish this correlation stems from a high level of uncertainty due to:<br>• Incomplete subsidence records from existing monitoring stations.<br>• Insufficient number of subsidence monitoring stations.<br>• Lack of pumping records by well.<br>• Insufficient well construction and lithologic information to correlate pumping depths with subsidence depths.<br>• Subsidence is a more of a regional condition whereas groundwater levels are very local and can be quite variable due to local subsurface conditions.<br>These causes represent ***data gaps*** that will be filled through management actions during Plan implementation. |
| GKGSA | 8.1.2.1 | 8-3 | **8.1.2.1: Groundwater Elevations in GKGSA, last paragraph:** Groundwater contour maps submitted during the first five years may reflect a composite of the principal aquifers within the subbasin due to ***data gaps*** as discussed in the Basin Setting Report (Appendix 2A) of this Plan. As additional dedicated monitoring wells are installed, and as more knowledge is gained regarding subbasin hydrogeology, groundwater conditions within each separate aquifer will be better understood. The geophysical data collection project described in Section 7 will also aid in this regard. |

| GSP | Section | Page | Data Gap |
|---|---|---|---|
| GKGSA | 8.2 | 8-6 | In accordance with § 356.4 of the Regulations, the GKGSA will conduct a periodic evaluation of its Plan no less frequently than at five-year intervals and provide a written assessment to DWR of such evaluations. The assessments will include, but not be limited to, the following...<br>• Description of alterations to the monitoring network and its improvements to address ***data gaps***... |
| GKGSA | 8.2.1 | 8-7 | **8.2.1: Monitoring Network Assessment and Improvement**: The GKGSA recognizes that its initial monitoring network as described in Section 4 of this Plan includes existing monitoring sites lacking sufficient information such as well depth, screen intervals, and reliable well-log records, thereby reflecting significant ***data gaps***. Assessing these ***data gaps*** is a priority and will be conducted in accordance with § 352.2 and § 354.38 of the Regulations. Specific elements of such an assessment are to include:<br>• Targeting areas where an insufficient number of monitoring sites exist or where sites are considered unreliable or do not meet monitoring network standards<br>• Identifying ***data gap*** locations and reasons for their occurrence and surrounding issues that restrict monitoring and data collection<br>• Actions to be undertaken to close identified ***data gaps***, including the addition and/or installation of new monitoring wells or surface-water measuring facilities, closure of inadequate well density areas, and needed adjustments to monitoring and measurement frequencies |
| MKGSA | 1.4.3.1 | 1-12 | **1.4.3.1: County of Tulare General Plan**<br>The 2030 General Plan Update for the County of Tulare, adopted on August 28, 2018, does not have a specific update to address water usage and supply. However, the Tulare County 2012 General Plan has a Water Resources Element that requires the County to adopt ordinances and measures to:...• Encourage responsible agencies and organizations to install and monitor additional groundwater monitoring wells in areas where ***data gaps*** exist |

| GSP | Section | Page | Data Gap |
|---|---|---|---|
| MKGSA | 2.2 | 2-2 | **Summary List**<br>The following ***data gaps*** were identified for the MKGSA:<br>• Accurate count of wells in MKGSA area, including well type (domestic, irrigation, etc.) and status (active, inactive, abandoned[, destroyed])<br>• Construction details of wells, especially production/screen interval(s). This was a significant ***data gap*** that prevented a comprehensive understanding of groundwater level and groundwater quality conditions above and below the Corcoran Clay<br>• Groundwater production records from direct measurement and locally generated estimates of groundwater use in rural areas of the MKGSA. This information will improve the water budget.<br><br>• Lithologic composition of aquifer, including geophysical logs at strategic locations<br>• Hydraulic parameters of principal aquifers such as transmissivity, storativity and porosity based on pumping tests preferably. This information could then help with the interpretation of Aerial Electro-Magnetic (AEM) data recently collected.<br>    • Water quality data for small rural community, domestic (rural residential home owners) and agricultural irrigation wells<br>    • Understanding of groundwater quality trends with depth (i.e. between upper and lower principal aquifers and vertical changes within each principal aquifer). With this information, an improved understanding is possible regarding depth of base of freshwater throughout the MKGSA as well as the Kaweah subbasin as a whole.<br>    • Measurements of subsidence within the MKGSA. The historical record of measured subsidence is incomplete and provides no information to inform an understanding of subsidence with depth. Correlation between subsidence and release of arsenic from clay mineralogy represents a data gap that needs to be filled through improved sampling and subsidence monitoring.<br>    • Expanded monitoring of groundwater levels and groundwater quality in small rural communities and disadvantaged communities<br>•<br>The ***data gaps*** will be addressed as MKGSA implements the management actions designed to close such gaps, as described in Section 7.4. |
| MKGSA | 4 | 4-1 | **4. Monitoring Networks**<br>The following chapter describes both the existing groundwater monitoring within the MKGSA area and the representative monitoring required by SGMA. In areas where existing monitoring does not meet the SGMA requirements, this chapter identifies ***data gaps*** and proposed measures to address these ***data gaps*** during the SGMA implementation period so the representative monitoring improves over time. Plan updates will reflect new information regarding improvements to representative monitoring. This Section 4 includes all information in compliance with §354.32 through §354.40 of the Regulations. |
| MKGSA | 4.10.1 | 4-14 | **4.10 Monitoring Network Improvement Plan/ 4.10.1 Data Gaps**<br>The following section describes ***data gaps*** for groundwater elevations and storage, groundwater quality, and land subsidence. |

| GSP | Section | Page | Data Gap |
|---|---|---|---|
| MKGSA | 4.10.1.1 | 4-15 | **4.10.1.1: Groundwater Elevation and Storage Data Gaps**<br>As referenced in Regulation §352.4, "If an Agency relies on wells that lack casing perforations, borehole depth, or total well depth information to monitor groundwater conditions as part of a Plan, the Agency shall describe a schedule for acquiring monitoring wells with the necessary information or demonstrate to the Department that such information is not necessary to understand and manage groundwater in the basin."<br>Well types and construction details will need to be determined to improve the monitoring network. Downhole well surveys and desktop surveys will be utilized for existing wells to fill in the well construction details gap. New dedicated monitoring wells and converted production wells will be utilized to fill in the monitoring network spatial extent and density. Improvement will occur during the initial few years of the implementation period, prior to the first five-year update. |
| MKGSA | 4.10.1.2 | 4-15 | **4.10.1.2: Groundwater Quality Data Gaps**<br>Groundwater quality information is currently collected for public water systems, primarily Visalia and Tulare. The groundwater quality new dedicated monitoring wells and converted production wells will be utilized to fill in the monitoring network spatial extent and density. Improvement will occur during the initial few years of the implementation period, prior to the first 5-year update. DWR will be constructing new multilevel monitoring wells at the locations shown on Figure 4-7 (at the end of this Section) as part of their Technical Support Services program. These wells will be used for both groundwater level and quality monitoring. |
| | | | **4.10.1.3: Land Subsidence Data Gaps**<br>For the preparation of this initial plan, MKGSA lacked sufficient data to effectively correlate changes in groundwater levels within the MKGSA with historical land surface subsidence. This was problematic in developing accurate projections of potential future subsidence that may occur during the implementation period. Additionally, there was not sufficient data to find a good correlation between pumping and land surface subsidence. The implementation of KDWCD's Land Surface Elevation Monitoring Plan will provide additional data for future subsidence monitoring and evaluation of Sustainability Indicators. The MKGSA will explore other options for a secondary data source, especially where surface infrastructure in the southwestern portion of the subbasin could be affected. |
| MKGSA | 4 | 4-22 | Figure 4-7: Proposed New Multilevel Monitoring Wells to Fill ***Data gaps*** |
| MKGSA | 5.3.4.1 | 5-14 | In evaluating historic field-measured groundwater elevation data with field-measured subsidence data, an acceptable correlation was not evident. Such a technically defensible correlation was intended for the purpose of estimating the magnitude of future subsidence if groundwater levels were ever to reach minimum thresholds throughout the Subbasin. It was notable that an acceptable correlation did not emerge, since the mechanism for subsidence is declining groundwater levels below historic lows and the associated compaction of clay units in response to the reduction in pore pressure. We believe the inability to establish this correlation stems from a high level of uncertainty due to:<br>• Incomplete subsidence records from existing monitoring stations.<br>• Insufficient number of subsidence monitoring stations.<br>• Complete lack of pumping records by well. In some cases, pumping estimates were available by management area, but in most cases, there was no pumping data by well by year.<br>• Insufficient well construction information to correlate pumping depth with observed subsidence.<br>These causes represent significant ***data gaps*** that will be filled through management actions during Plan implementation. |

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| MKGSA | 8.1.2.1 | 8-2 | Groundwater contour maps submitted during the first five years may reflect a composite of the principal aquifers within the subbasin due to ***data gaps*** as discussed in Section 2 of this Plan. As additional dedicated monitoring wells are installed, and as more knowledge is gained regarding subbasin hydrogeology, groundwater conditions within each separate aquifer will be better understood. The geophysical data collection project described in Section 7 will also aid in this regard. |
| MKGSA | 8.2 | 8-5 | **8.2 Five-Year Assessments**<br>In accordance with §356.4 of the Regulations, the MKGSA will conduct a periodic evaluation of its Plan no less frequently than at five-year intervals and provide a written assessment to DWR of such evaluations. The assessments will include, but not be limited to, the following:<br>• Description of alterations to the monitoring network and its improvements to address ***data gaps***… |
| MKGSA | 8.2.1 | 8-5 | **8.2.1 Monitoring Network Assessment and Improvement**<br>The MKGSA recognizes that its initial monitoring network as described in Section 4 of this Plan includes existing monitoring sites lacking sufficient information such as well depth, screen intervals, and reliable well-log records, thereby reflecting significant ***data gaps***. Assessing these ***data gaps*** is a priority and will be conducted in accordance with §352.2 and §354.38 of the Regulations. Specific elements of such an assessment are to include:<br>• Targeting GSA areas where an insufficient number of monitoring sites exist or where sites are considered unreliable or do not meet monitoring network standards<br>• Identifying data gap locations and reasons for their occurrence and surrounding issues that restrict monitoring and data collection<br>• Actions to be undertaken to close identified ***data gaps***, including the addition and/or installation of new monitoring wells or surface-water measuring facilities, closure of inadequate well density areas, and needed adjustments to monitoring and measurement frequencies |
| EKGSA | 2.2.6.1 | 2-25 | According to DWR's Bulletin 118 (2003), there are no reported groundwater barriers restricting horizontal flow in and out of the Kaweah Subbasin. There is, however, the Rocky Hill fault zone that may affect groundwater flow inside of the Subbasin and potentially cross gradient of flow along the north and south boundaries. Located in the Eastern portion of the Subbasin, the Rocky Hill fault disrupts pre-Eocene deposits and may locally penetrate older alluvial deposits. The linearity of ridges in this area defines the fault line (Refer to Figure 2-4 for the Cross Section Location Map and Figure 2-7 and Figure 2-9 for Cross Sections DD' and gg'). The Rocky Hill fault does not offset younger alluvium based on water level data (Croft, 1968); however, lithology data from boreholes suggest that older alluvium may be offset or varied in thickness at the Rocky Hill fault. In addition, Fugro West (2007), suggested that the hydrologic connection of the oxidized alluvial aquifer may be restricted near the Rocky Hill fault; this represents a ***data gap*** in groundwater flow across the Rocky Hill fault, and should be evaluated in the future, both within the Subbasin and in association with the northern and southern boundaries of the Subbasin. |
| EKGSA | 2.3.3 | 2-42 | **2.3.3 Existing Land Subsidence Monitoring** Past, recent and potential future monitoring of land subsidence in the Kaweah Subbasin are summarized in Table 2-5. Much of the historical data does not cover the EKGSA area. Newer data sets (2015-2017) provide more coverage. The EKGSA will strive to keep these newer data sets active to avoid ***data gaps*** in the future. While land subsidence isn't believed to be a major concern in the EKGSA, it will be monitored to avoid Undesirable Results. |

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| EKGSA | 2.3.4 | 2-42 | **2.3.4 Existing Stream Flow Monitoring**<br>The most useful stream flow gauges monitored within the Subbasin are located outside the EKGSA. The closest water bodies regularly monitored are the Kaweah River, St. Johns River, and Yokohl Creek. The flow gauges are located in the GKGSA Kaweah GSA. Existing stream flow monitoring represents a ***data gap*** for the EKGSA to improve moving forward. Streams of interest for the EKGSA to improve monitoring data are: Cottonwood, Lewis, and Frazier Creeks. |
| EKGSA | 2.4.1.2 | 2-49 | **2.4.1.2 Well Hydrographs**<br>Hydrographs of individual wells in and around the EKGSA are presented in Appendix 2-D. Figure 2-21 is a map showing locations of these wells. These hydrographs depict the span of time between 1981 and 2017. Hydrographs outside the borders of the EKGSA were included to establish boundary conditions. It is difficult to identify wells with records that are complete for the entire base period. The wells depicted often contain ***data gaps*** but represent the most complete information available at this time. The dataset used to create these hydrographs associates water levels with a season/year format (e.g. Spr1990) rather than with a specific date. For the purposes of plotting, spring levels were considered to have been taken on March 1, while fall levels were plotted on October 1. Nevertheless, these hydrographs are a useful tool for tracking water level patterns through time across the EKGSA. |
| EKGSA | 2.4.1.2 | 2-50 | **Intermontane Valleys** – This classification is included to showcase wells on the Eastern border of the EKGSA with significant bedrock outcrop to their west. These wells are located in the small valleys interfingering with the mountain-front and are drilled into shallow alluvium veneering relatively shallow bedrock, with ready access to recharge coming from the mountain-front. They have consistently shallow DTW and low seasonal and hydrological deviation. Typical WSEs within these wells are consistently within 50 ft of the surface. Well 17S26E14L002M is nearly within the Valley proper and likely has deeper alluvium, less-direct recharge, and plentiful irrigation nearby. This well's hydrograph is more akin to wells in the Cottonwood Creek Interfan area as defined above, with GKGSA overall DTW and increased variation between seasons of wet and dry. Average DTW for this grouping of wells was 26.9 ft based on the years with data. There are significant temporal ***data gaps*** for this region, during which time none or only one well provided data. Between fall of 2008 and fall of 2012 no data is recorded for any of these wells. |
| EKGSA | 2.4.1.2 | 2-54 | **Well Depth:** Construction data for wells in the EKGSA was evaluated in a summarized format. Evaluating well logs confidently and accurately to match reports with the actual corresponding well in the field is difficult due to the current nature of the data sets available. This is a ***data gap*** that will be filled going forward. Figure 2-24, Figure 2-25, and Figure 2-26 display the average completed well depths per section for agricultural, domestic, and public wells respectively. Appendix 2-E provides more figures for these three well types, including minimum and maximum completed depths and number of wells per section. |

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| EKGSA | 2.4.3.3.4 | 2-62 | **Nitrate**: Sources and Spatial Distribution in the EKGSA - The historical and current predominate land use in the EKGSA is for commercial irrigated agriculture with some interspersed dairy farms. While Burton et. Al (2012) reports nitrate contaminations correlates to areas of agriculture classified as orchard and vineyard land uses, USGS finds that these regions also have medium to high density septic systems. GKGSA than 50 percent of the land use in hydrogeologic zones 7, 8 and 9 are orchards or vineyards. Septic-system density GKGSA than the Subbasin median value of 5 septic systems in a 500-meter radius around each selected GAMA well occurred hydrogeologic zones 4-9, with very high density of 11.8 septic systems within 500 meters of the selected wells in zones 7, and 11.0 septic systems in zone 9. USGS data was used for this evaluation to develop a clearer understanding of potential sources of nitrate contamination. While previous reports point towards orchard and vineyard land uses, septic system density is an unquantified source of contamination. While the existence of septic systems does not necessarily mean that they are a contributing source of nitrate contamination within the aquifer. However, leaky, poorly maintained septic systems can be a serious source of localized nitrate contamination. It is currently unknown the amount of contamination associated with poorly maintained septic systems. This represents a ***data gap*** that the EKGSA and Subbasin will need to evaluate going forward. Data gathered by USGS (Report 2011-5218) was determined from housing characteristics data from the 1990 U.S. Census. The density of septic systems in each housing census block was calculated from the number of tanks and block area. To more precisely identify the nitrate sources, current data should be compiled and evaluated with proximity to domestic water wells. This effort is being made through the Disadvantaged Community Involvement Program is trying to identify septic system density and condition in the Tulare-Kern Funding Area. |
| EKGSA | 2.4.4.3 | 2-67 | **2.4.4.3 Recent Land Subsidence**<br>Recent subsidence studies of the Central Valley have utilized satellite-based, remote sensing data from the Interferometric Synthetic Aperture Radar (InSAR) and aircraft-based L-band SAR or Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR) programs, led by NASA and Jet Propulsion Laboratory (JPL), as well as other international researchers. These datasets provide a continuous estimate of subsidence over a large portion of the Subbasin. Additionally, subsidence in the Subbasin and in the Tule Subbasin (to the south) can also be observed at point locations through continuous GPS (CGPS) stations and other land surface monitoring stations. Most of these are not located within the EKGA, representing a ***data gap***. These CGPS stations are monitored as a part of UNAVCO's Plate Boundary Observation (PBO), the California Real Time Network (CRTN) and California Spatial Reference Center (CSRC) of the Scripps Orbit and Permanent Array Center (SOPAC). Annual averages of CGPS or future extensometer data may permit a more meaningful comparison and/or calibration with InSAR data in the future.<br>Recent and historical subsidence data is summarized in Table 2-7. The data presented includes a summary of InSAR data published in a subsidence study commissioned by the California Water Foundation (LSCE, 2014) and by JPL (Farr et al., 2015 and 2016). The InSAR data was collected from a group of satellites (Japanese PALSAR, Canadian Radarsat-2, and European Space Agency's (ESA) satellite-borne Sentinel-1A and -1B), from 2006 to 2017, however there is a ***data gap*** for the EKGSA prior to 2015 due to the limit of study and absence of satellite data collection data prior to the ESA Sentinel satellites in 2014 (Farr et. al., 2016). |

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| EKGSA | 2.4.6 | 2-71 | **2.4.6 Groundwater Dependent Ecosystems** Where groundwater and surface water are separated by significant distances, as is the case with the majority of the EKGSA, the groundwater does not interact with the natural streams or manmade ditches, and therefore, no possibility exists for the presence of Groundwater Dependent Ecosystems (GDE). However, there are locations near the foothills of the Sierra Nevada where groundwater levels are closer to the surface.<br>Areas where groundwater is within 30 feet of the ground surface are located along the Kaweah River (primarily in GKGSA), the Stone Corral ID area, and near Lewis Creek in the Lindsay-Strathmore ID area. Figure 2-28 represents areas where groundwater elevations as of the Spring of 2015 were within 30 feet of the ground surface. Wetlands within these areas may be considered GDE, however additional study and data are necessary. This ***data gap*** will be addressed as part of further study going forward. |
| EKGSA | 2.5.3.2 | 2-82 | **2.5.3.2 Inflows to the Groundwater System - Natural Channels:** The EKGSA lacks reliable, long-standing stream gauges on the four major tributaries that flow into the area from the Sierra Nevada foothills. There is a single stream flow gauge on Yokohl Creek, while the other water bodies Cottonwood, Lewis, and Frazier Creeks do not have permanent gauges. In the absence of data, streambed percolation for the EKGSA was determined by an alternate method. The percolation from these creeks was assumed to be included in the mountain-front recharge accounted for in the Subsurface Flow. This is a ***data gap*** that will be further evaluated going forward. In addition to these creeks, a portion of the St. Johns River runs along the boundary between the EKGSA and GKGSA. It is assumed percolation over this stretch enters both the EKGSA and GKGSA. Per these estimates, the average annual natural percolation into the EKGSA is 2,000 AFY as shown in Table 2-10. |

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| EKGSA | 2.6 | 2-92 | **Summary List**<br>**2.6 Identification of *Data gaps*:** Identification of ***data gaps*** will continue to be a work in progress. The principal ***data gaps*** are listed below, which are subject to revision during the course of completion of this GSP.<br>• Geological/hydrogeological information for all areas of the EKGSA.<br>o The SkyTEM effort should assist in filling this data gap<br>o New and/or better well logging for monitoring and production wells can also be informative in locations with little or no data<br>• Well construction information such as: depth of well, perforation intervals, casing diameter, and use<br>o Strongly encourage the Kaweah Subbasin GSAs and Tulare County initiate a well canvas of the area to develop a better data set<br>o Potential Drinking Well Observation Plan can assist with gathering well data for specific drinking water wells in the region<br>• Stream flow monitoring on Cottonwood, Yokohl, Lewis, and Frazier Creeks<br>o Gauges are proposed to be constructed, especially for the creeks potentially to be used for recharge activities<br>o Specific watershed studies for these creek watersheds can be performed to better inform the estimations of creek flows and seepage<br>• Consistent subsidence monitoring<br>o Likely remedied with more consistent InSAR data<br>o Specific infrastructure to be surveyed for subsidence impacts<br>• Presence of GDE<br>o Likely linked with the added stream flow monitoring<br>o More consistent groundwater level monitoring in the intermontane valleys<br>• Water Budget Components<br>o Further development of subsurface inflows and outflows from the mountain front and neighboring subbasins<br>o Improved understanding of surface water deliveries within district boundaries<br>o Retention/Recharge basin data collection and tracking as more recharge is developed<br>o Improved understanding of irrigation demand and method for crop and soil types within the Subbasin and EKGSA<br>o Improved tracking of M&I demands |
| EKGSA | 3.4.2.2.1 | 3-28 | **Description of Minimum Thresholds:** Well monitoring data from Geotracker, and other sources, is currently not available at a granular enough level to allow for the mapping of specific contaminant plumes. Given these ***data gaps***, the current level of water quality monitoring for the identified COCs needs to be enhanced by a network to track regional trends and to serve as a warning system for changes in water quality. More details on the EKGSA's monitoring network is provided in Chapter 4. |
| EKGSA | 4.3.1 | 4-4 | **4.3 Groundwater Levels: 4.3.1 Monitoring Network Description**<br>Groundwater-level monitoring has been carried out for most of the past century. Existing groundwater wells with long monitoring histories make the best targets for continued monitoring. These wells are rare, and when they exist, their usefulness is often degraded by poor data quality. Most wells have incomplete temporal histories and lack consistent measurements for consecutive years throughout their operational lives. There is no recourse for historic temporal ***data gaps***, but the temporal quality of future measurements in these wells can be ensured. |

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| EKGSA | 4.3.1 | 4-5 | **4.3 Groundwater Levels: 4.3.1 Monitoring Network Description:** Private wells: In several parts of the EKGSA there are gaps in the current monitoring well coverage, therefore, records from private wells may be used to initially satisfy the monitoring network needs. Use of these wells would require landowners to execute agreements with the EKGSA to allow access and conduct and oversee the monitoring. This process is anticipated to be time intensive, so this option is not the most preferred method. |
| EKGSA | 4.3.1 | 4-5 | Figure 4-1 shows the proposed locations for the initial groundwater level monitoring network for the EGKSA, and the different types of wells to be utilized. The two wells notated with stars in the northern portion of the EKGSA are proposed dedicated monitoring wells that are anticipated to receive Technical Support Services (TSS) assistance through DWR. The seven locations notated with large circles are locations with ***data gaps***. The EKGSA will aim to obtain data from these regions (within half a mile) through agreement on private wells or through drilling dedicated monitoring wells during the first year(s) of implementation. It is understood that over the course of implementation the EKGSA will gradually convert the entire Monitoring Network to dedicated monitoring wells. |
| EKGSA | 4.3.3 | 4-9 | **4.3.3 Review and Evaluation of Monitoring Network:** The monitoring network will be assessed and reviewed for adherence to SGMA requirements at the end of each five-year period, with the first period beginning in 2020 and concluding in 2025. As the monitoring network currently stands there are a few ***data gaps*** that may affect the interim monitoring of the overall sustainability goal of the basin, however, these will be addressed within the first five years of monitoring. |
| EKGSA | 4.3.3.3 | 4-10 | **4.3 Groundwater Levels/Monitoring Network - Identification of Data Gaps:** Existing groundwater-level monitoring has provided data to prepare groundwater contour maps and identify groundwater level trends over the decades. The existing monitoring system relies heavily on the member irrigation districts, but this only provides data for a portion of the EKGSA. To better represent hydraulic gradient and flow direction within the EKGSA, about seven wells should be strategically placed for regular monitoring in the EKGSA. Figure 4-1 shows the approximate locations where additional monitoring wells are believed to be useful in accomplishing this goal and meeting the monitoring well density requirements set forth in the GSP. The EKGSA will try to fill these locations either through agreements with private landowners or by drilling new dedicated monitoring wells.<br><br>Other ***data gaps*** exist in the fact that most of the proposed monitoring network wells are privately owned production wells that are used for monitoring. Specific well construction information, including depth and perforated interval, are not known for many of the wells. Also, depending on how and when the data was collected, data points in some (or all) years may be skewed. Utilizing a production well as a monitoring well runs the risk of potential influence from recent pumping that may affect the 'static' reading aimed to be captured. It is believed that much of the recorded well data within the EKGSA is credible, however the EKGSA will continue to improve this data set going forward. |

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| EKGSA | 4.3.3.4 | 4-10 | **4.3 Groundwater Levels/Monitoring Network - 4.3.3.4 Plans to Fill Data Gaps**<br>The EKGSA will oversee the groundwater level monitoring network, including filling areas with data gaps. This will be especially useful for the regions that are not currently monitored, such as outside irrigation district boundaries. As previously stated, Figure 4-1 depicts the wells intended to fill spatial data gaps for initial implementation. The EKGSA will need to locate accessible private wells or drill new wells in the seven locations shown. Over time the EKGSA will transition to utilizing dedicated monitoring wells in its monitoring network.<br>To address data quality gaps related to unknown construction information, the EKGSA will utilize the following options:<br>• **Collect well completion reports.** Accurate well Completion Reports (WCRs) can potentially provide missing well construction and completion information. These records could be collected from landowners or DWR. Due to the way that data is collected and dispersed, it is often difficult to correlate WCRs with actual wells. Locations of wells as reported on WCRs are often subjective, as they are based on the drillers' ability to convey spatial location. Multiple wells may exist within the area a well's log leads to. In some cases, wells have been destroyed or lost without documentation. Obtaining well logs directly from owners bypasses this confusion, though this is not a perfect solution. Private well owners may be unable or unwilling to provide logs for their wells.<br>• **Perform a video inspection of each well to obtain construction information.** In the absence of verified well logs a video inspection can be performed on wells to determine the total completed depth and perforated interval(s). Each video inspection currently ranges in costs between $2,500 and as much as $15,000 if required to lift and reinstall a pump to obtain access in production wells. There would also be additional costs for administration and outreach to landowners. The EKGSA would need to enter into private agreements with individual well owners for the use of these wells; as an incentive for participation the EKGSA would cover the cost of the well video assessment.<br>• **Abandoned Wells.** The EKGSA will assess the likelihood of monitoring former wells that have been abandoned. Use of these wells will potentially bolster the density of the monitoring network in areas with minimal coverage, likely involve less stringent access requirements, and are cheaper than drilling new wells. Additionally, since these wells are no longer in production, the monitoring of abandoned wells allows for better potential in gaining a static water level reading and better fulfill the requirements of Sub-Article 4.<br>• **Replace monitoring point with a dedicated monitoring well.** Dedicated monitoring wells could be installed and used in place of private wells. The construction information would be known and since the EKGSA would locate these wells, access issues would not be an issue. Dedicated monitoring wells are expensive to construct, and their installation will depend on available funding.<br>Replace monitoring point with another private well. Private wells without documented construction information may potentially be replaced with other private wells that have verified well completion information. This option may be simpler and less costly than using video inspection and would be substantially less expensive than drilling new dedicated monitoring wells. This method of network repair would side-step the expense of drilling new wells but would still be subject to availability and limitations arising from the missing historical record. |
| EKGSA | 4.4.3.3 | 4-12 | **Groundwater Storage/Monitoring Network - 4.4.3.3 Identification of Data Gaps**<br>Gaps in current groundwater level monitoring networks have created corresponding inadequacies in the ability to calculate change in storage. ***Data gaps*** associated with aquifer characteristics, such as specific yield values used for storage estimates, are anticipated to be improved through the completion of different projects and studies undertaken by the Kaweah Sub-basin and the EKGSA (i.e. SkyTEM). |

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| EKGSA | 4.4.3.4 | 4-12 | **Groundwater Storage/Monitoring Network - 4.4.3.4 Plans to Fill Data Gaps**<br>Significant data gaps will be filled using the same methods used to address data gaps in the groundwater level network, as spatial data coverage is a critical component in the change in storage calculations. Aquifer evaluation at a Sub-basin scale was performed through a SkyTEM electromagnetic analysis. The results from this analysis were not ready in time for this initial GSP but will be available for future updates and modeling to improve the general knowledge of the aquifer characteristics moving forward. |
| EKGSA | 4.5.2 | 4-15 | **Water Quality/Monitoring Network - 4.5.2 Quantitative Values**<br>Threshold values for COCs are presented in Chapter 3. These values use MCL and prevalence data to provide minimum thresholds, measurable objectives, and interim milestones for each COC. Table 4-3 repeats the monitoring network wells table, but this time shows the baseline 10-year (2008-2017) COC averages for the wells in the network with water quality data available. By comparison, only 15 of the approximately 70 wells to be monitored for water quality have data for establishing a baseline. This represents a significant ***data gap***, however the intent of the EKGSA monitoring will strive to remedy this gap over the first years of implementation. Water quality degradation will be evaluated by determining if the actions of the EKGSA degrade the beneficial use of water in the Subbasin. |
| EKGSA | 4.5.3.3 | 4-16 | **Water Quality/Review of Monitoring Network - 4.5.3.3 Identification of Data Gaps**<br>The absence of groundwater level data across the entirety of the EKGSA is a ***data gap***. Future monitoring will need to address this ***data gap*** so the EKGSA can properly evaluate how groundwater management actions are impacting groundwater quality. |
| EKGSA | 4.5.3.4 | 4-16 | **Water Quality/Review of Monitoring Network - 4.5.3.4 Plans to Fill Data Gaps**<br>The EKGSA's proposal to monitor COCs across the groundwater level monitoring network intends to fill some of the significant data gaps with respect to groundwater quality data. Monitoring over the first five years of implementation should provide more insight on groundwater quality (location, trends, etc.) in the EKGSA. The EKGSA will also collaborate, where appropriate and feasible, with other agencies tasked with tracking and/or improving groundwater quality for additional assistance with data gaps. |
| EKGSA | 4.6.3.3 | 4-20 | **Land Subsidence/Monitoring Network - 4.6.3.3 Identification of Data Gaps**<br>Beyond the specific proposed monitoring points, no other ***data gaps*** were identified for the land subsidence monitoring network for the EKGSA. Subsidence has been an ongoing issue in portions of the Central Valley, thus monitoring systems have been put in place to evaluate the impacts. Over time these tools and data have improved and become more widespread. |
| EKGSA | 4.6.3.3 | 4-20 | **Land Subsidence/Monitoring Network - 4.6.3.4 Plans to Fill Data Gaps**<br>With the addition of survey points to critical infrastructure, and utilizing the InSAR data set as a backstop, the current subsidence monitoring network is believed to sufficiently cover the EKGSA. |
| EKGSA | 4.7.3.3 | 4-23 | **Depletion of Interconnected Surface Water/Monitoring Network - 4.7.3.3 Identification of Data Gaps**<br>Due to the absence of historic monitoring specifically related to groundwater-surface water connection, there are ***data gaps*** beyond that of local experience. The new proposed monitoring effort laid out in this GSP will likely shed light on the areas considered to be 'gaining' streams or connected due to perched groundwater. The new monitoring network may indicate other areas to have possible connection. In these instances, the EKGSA will adapt the monitoring to allow for further evaluation. |

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| EKGSA | 4.7.3.3 | 4-23 | **Depletion of Interconnected Surface Water/Monitoring Network - 4.7.3.4 Plans to Fill Data Gaps**<br>The proposed additions to the groundwater level monitoring network is expected to be a benefit to the understanding of interconnected surface water. This will be especially beneficial in the portions of the EKGSA adjacent the foothills and ephemeral streams. |
| EKGSA | 5.2 | 5-3 | **5.2 Projects:** Implementation through this first GSP will focus on bolstering data sets to fill ***data gaps***, and then projects fully developed based on current and projected conditions. |
| EKGSA | 5.3.2.6 | 5-36 | **5.3.2. Wellhead Requirements Management Actions - 5.3.2.6 Benefit Realization and Evaluation WH1 - WH-5 (Sec. 354.44.b.5)** - The expected benefits of water quality sample ports and analytical testing would fill ***data gaps*** and provide extractors with useful information. |
| EKGSA | 5.3.3 | 5-41 | **Groundwater Allocation Management Actions: GA-3 Groundwater Allocation "Adaptive Management" Approach**<br>The EKGSA may adopt a policy which states an adaptive management approach, whereby the groundwater allocation may be reviewed, changed, and reestablished periodically or during extreme drought as necessary to achieve long term sustainability. It is prudent for the EKGSA to acknowledge the current level of uncertainty in the available data and existing ***data gaps*** by providing flexibility in initial groundwater allocations as more data is gathered and analyzed in the upcoming years. Adaptive management is an approach to resource management that "promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes "learning while doing" (Environmental Defense Fund et al., 2017). |
| EKGSA | 6.1 | 6-1 | **Plan Implementation/6.1 Estimate of GSP Implementation Costs - Plan to Fill Data Gaps (One-Time Cost)**<br>Proper implementation of this GSP, especially as it relates to execution of projects and management actions, is contingent upon filling current ***data gaps***. This process will require determining which measures are necessary to build and maintain a comprehensive assessment of the water budget and ultimately verify groundwater sustainability. This plan to fill ***data gaps*** includes, but is not limited to, installing stream gauges, dedicated monitoring wells, and conducting a Proposition 218 vote. Costs are estimated to be approximately $1,230,000. |
| EKGSA | 6.2 | 6-3 | **6.2 Identify Funding Alternatives**: The EKGSA and/or its member agencies or other Kaweah Subbasin GSAs will apply for various grant funding opportunities to offset some of the capital costs associated with implementation of the GSP, whether it be a water supply project or to fill an existing **data gap**. The EKGSA will explore federal and state grant funding opportunities and low interest loans to help finance the initial steps of plan implementation. |

| GSP | Section | Page | Data Gap |
|---|---|---|---|
| Kaweah Subbasin Basin Setting | 2.3.1.1 | Q | **2.3.1.1 Key Wells:** The key wells were chosen as a subset of the entire water level monitoring database to adequately represent the Subbasin both laterally and vertically. These key wells were used along with the other monitored wells for the creation of water level contour maps and water level hydrographs. Most of the known wells in the Subbasin are either missing or have limited well construction information. Therefore, the **data gap** will be addressed with the following the steps below.<br>1. Further review of acquired well logs;<br>2. Conducting down-hole video surveys of wells; and<br>3. Installing additional monitoring wells as funds become available.<br>While there are limitations associated with using water level data from wells without construction information, we have performed an initial assessment of many of the available wells with a long period of record. This process allowed for the selection of wells that were used for developing an initial understanding of groundwater level variations throughout the Subbasin. It is understood that this snapshot of groundwater conditions is limited based on the unknown completion information about the wells and may change as construction data is obtained in the future. |
| Kaweah Subbasin Basin Setting | 2.3.4 | 50 | **2.3.4 Existing Stream Flow Monitoring:** The records of the stream groups impacting the facilities and stockholders of the ditch companies that they manage were acquired. Although ***data gaps*** exist, these may represent relatively small quantities of contributory flows. The records of the USGS are, for the most part, supplemental to the records of the Association and local agencies. The information that is published by the USGS, however, does fill some of the ***data gaps*** that exist in the information related to the local stream groups. Figure 20 shows the locations of stream flow gauges monitored within the Subbasin. |
| Kaweah Subbasin Basin Setting | 2.8.4 | 141 | **2.8.4 Recent Land Subsidence:** Recent and historical subsidence data are summarized in Table 43. It includes a summary of InSAR data published in a subsidence study commissioned by the California Water Foundation (LSCE, 2014), and by JPL. The InSAR data were collected from a group of satellites (Japanese PALSAR, Canadian Radarsat-2, and ESA's satellite-borne Sentinel-1A and -1B), from 2006 to 2017, with a ***data gap*** from 2011 to 2014 because there was a gap in satellite data collection until the ESA Sentinel satellites were launched in 2014. |

# Appendix 6
# Sustainability Goal and Undesirable Results

# SUSTAINABILITY GOAL AND UNDESIRABLE RESULTS

Appendix 6 to Kaweah Subbasin Coordination Agreement

## Table of Contents

# 6. Sustainability Goal and Undesirable Results

## 6.1 Introduction

This Section provides location-specific sustainable management criteria (SMC) for four of the six sustainability indicators, including establishing minimum thresholds and measurable objectives with integrated interim milestones. Section 3 of this GSP presents the Subbasin-scale SMC as required by 23 Cal. Code Regs. §§354.22-.26, i.e., the sustainability goal and a complete listing of undesirable results, including their causes, criteria and effects on beneficial uses and users. As discussed in Chapter 3, pursuant to 23 Cal. Code Regs §354.26(d) no sustainable management criteria need to set at this time for the undesirable results of Interconnected Surface Waters and Seawater Intrusion. Thus, pursuant to 23 Cal. Code Regs §354.26(e)[1], those undesirable results will not be discussed herein.

## 6.2 General Approach

As described later in this Section, the Subbasin identified minimum thresholds, based on declining groundwater levels (hereinafter "water level" or "level") that would otherwise occur during the 20-year SGMA implementation period devoid of any GSP projects and management actions (pre-SGMA floor). Measurable objectives are similarly based using this trend line. The relationship of these measurable objectives and the long-term success in achieving the objectives is discussed in the context of neighboring GSAs in the Subbasin and their respective actions undertaken during GSP implementation.

The Subbasin developed SMC within a framework of data, which currently has gaps. If SMCs (such as minimum thresholds and measurable objectives) vary substantially between adjacent GSAs, then the GSAs will coordinate and endeavor to adjust the particular SMC as additional data becomes available so that the GSAs eliminate any substantial variance which could inhibit a GSA from implementing its GSP and achieving sustainability within its jurisdictional area.

The metrics and approaches to be employed by the Subbasin for the six sustainability indicators are shown in **Table 6-1**.

## 6.3 Sustainability Goal

23 Cal. Code Regs. § 354.24. *Each Agency shall establish in its Plan a sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline. The Plan shall include a description of the sustainability goal, including information from the basin setting used to establish and sustainability goal, a discussion of the measures that will be implemented to ensure that*

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[1] 23 Cal. Code Regs §354.26(e) provides "An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators.

*the basin will be operated within its sustainable yield, and an explanation of how the sustainability goal is likely to be achieved within 20 years of Plan implementation and is likely to be maintained through the planning and implementation horizon.*

**Table 6-1: Sustainable Management Criteria by Sustainability Indicator**

| SMC Summary for GKGSA | | | |
|---|---|---|---|
| **Sustainability Indicators** | **Minimum Threshold** | **Measurable Objective** | **Optimal Objective [1]** |
| Water Level Declines | Pre-SGMA floor (2040 Intercept) [2] | 2030 Intercept [3] | Water Added (P&MA) [4] |
| Reduction in Storage | Calculated based on water levels[5] | Calculated based on water levels [5] | Calculated based on water levels [5] |
| Land Surface Subsidence | Benchmark Surveys | Benchmark Surveys | NA |
| Water Quality | Reference to other regulators [6] | Reference to other regulators [6] | NA |
| Seawater Intrusion | Establish non-applicability | Establish non-applicability | NA |
| Interconnected Surface Waters | Establish non-applicability | Establish non-applicability | NA |

[1] Per section 354.30(g) of the GSP Regulations re improving basin conditions
[2] Pre-SGMA floor as determined by representative monitoring sites in Hydrogeologic Zones
[3] 2030 intercept of Pre-SGMA floor projection as determined by representative monitoring sites in GSA
[4] Estimated with by the numerical model or empirical analysis incorporating projects and management actions
[5] Storage volume changes and associated SMC determined as function of water level changes
[6] e.g. SWRCB Division of Drinking Water requirements for public supply wells, RWQCB Irrigated Lands Regulatory Program

The broadly stated sustainability goal for the Kaweah Subbasin is for each GSA to manage groundwater resources to preserve the viability of existing agricultural enterprises of the region, domestic wells, and the smaller communities that provide much of their job base in the Sub-basin, including the school districts serving these communities. The goal will also strive to fulfill the water needs of existing and amended county and city general plans that commit to continued economic and population growth within Tulare County and within portions of Kings County.

This goal statement complies with §354.24 of the Regulations.
This Goal will be achieved by:

- The implementation of the EKGSA, GKGSA and MKGSA GSPs, each designed to identify phased implementation of measures (projects and management actions) targeted to ensure that the Kaweah Subbasin is managed to avoid undesirable results by 2040 or as may be otherwise extended by DWR.
- Collaboration with other agencies and entities to arrest chronic groundwater-level and groundwater storage declines, reduce or minimize land subsidence where significant and

unreasonable, decelerate ongoing water quality degradation where feasible, and protect beneficial uses.

- Application of the Kaweah Subbasin Hydrologic Model (KSHM) – incorporating the initial selection of projects and management actions by the Subbasin GSAs – and its simulation output is summarized in the Subbasin Coordination Agreement to help explain how the sustainability goal is to be achieved within 20 years of GSP implementation.
- Assessments at each interim milestone of implemented projects and management actions and their achievements towards avoiding undesirable results as defined herein.
- Continuance of projects and management action implementation by the three GSAs as appropriate through the planning and implementation horizon to maintain this sustainability goal.

## 6.4 Groundwater Levels

23 Cal. Code Regs § 354.26*(a). Each Agency shall describe in its Plan the processes and criteria relied upon to define undesirable results applicable to the basin. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin.*

The undesirable results are derived from the Basin Setting (Appendix 2A) and its characterization as described in the Hydrogeologic Conceptual Model, the historical, current, and projected groundwater conditions and trends, and stakeholder input. The three Subbasin GSAs have concurred with the undesirable results, their causes, determination criteria and effects, all as defined in this section. The sustainability indicators used to determine undesirable results are referenced herein. This section complies with §354.26 of the Regulations.

The terms "significant and unreasonable" are not defined by SGMA, and are left to GSAs to define within their GSPs. The process to define "significant and unreasonable" began with stakeholder and landowner discussions.

The GSAs within the Kaweah Subbasin have determined that undesirable results for groundwater levels may be significant and unreasonable when basinwide loss of industrial, municipal, and domestic pumping well capacity occurs due to lowering groundwater levels.

### *6.4.1 Causes leading to Undesirable Results*

23 Cal. Code Regs § 354.26 *(b). The description of undesirable results shall include the following: (1) The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results based on information described in the basin setting, and other data or models as appropriate.*

Undesirable results associated with groundwater level declines are caused by over-pumping or nominal groundwater recharge operations during drought periods such that groundwater levels fall and remain below minimum thresholds. Over-pumping and lack of recharge is area specific, and some GSA Management Areas experience greater adverse impacts than others.

### *6.4.2 Criteria to Define Undesirable results*

> 23 Cal. Code Regs § 354.26 *(b). The description of undesirable results shall include the following: (2) The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results for each applicable sustainability indicator. The criteria shall be based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin.*

With respect to water-level declines, undesirable results occur when one-third of the representative monitoring sites in all three GSA jurisdictions combined exceed their respective minimum threshold water level elevations. Should this occur, a determination shall be made of the then-current GSA water budgets and resulting indications of net reduction in storage. Similar determinations shall be made of adjacent GSA water budgets in neighboring subbasins to ascertain the causes for the occurrence of the undesirable result.

Groundwater elevations shall serve as the sustainability indicator and metric for chronic lowering of groundwater levels and, by proxy, for groundwater storage. Justification for use of groundwater elevations as a proxy in this instance is provided in Section 5.

It is the preliminary determination that the percentages identified herein represent a sufficient number of monitoring sites in the Subbasin such that their exceedance would represent an undesirable result for water-level declines, reduction in groundwater storage, land subsidence, and interconnected surface waters where applicable. Screen interval data for agricultural, municipal, and domestic wells, as identified in Section 5.3.2, has been scrutinized and a determination has been made that the percentage of wells completely dewatered by 2040 should the minimum thresholds not be exceeded would not constitute an undesirable result. Based on observed groundwater conditions in the future and not less frequently than at each five-year assessment, the GSAs will evaluate whether these percentages need to be changed.

### *6.4.1 Evaluation of Multiple Minimum Thresholds*

> 23 Cal. Code Regs § 354.26 *(c). The Agency may need to evaluate multiple minimum thresholds to determine whether an undesirable result is occurring in the basin. The determination that undesirable results are occurring may depend upon measurements from multiple monitoring sites, rather than a single monitoring site.*

The Subbasin, in coordination with other GSAs in the basin will utilize multiple wells to monitor and manage the GSA and basin. A detailed description of the GSA's monitoring network is included in Section 4 of this GSP.

## 6.5 Groundwater Storage

> 23 Cal. Code Regs § 354.26*(a). Each Agency shall describe in its Plan the processes and criteria relied upon to define undesirable results applicable to the basin. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin.*

The Groundwater Storage minimum thresholds are the same as groundwater levels and groundwater elevations across the GSA and subbasin were used to calculate the amount of groundwater in storage below the Minimum Thresholds to the base of the aquifer. An undesirable result in groundwater storage may be significant and unreasonable if the total amount of water in storage was less than the estimated amount of groundwater in storage below the Minimum Threshold or other factors identified in section 6.4 occur.

### *6.5.1 Causes leading to Undesirable Results*

> 23 Cal. Code Regs § 354.26 *(b). The description of undesirable results shall include the following: (1) The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results based on information described in the basin setting, and other data or models as appropriate.*

Undesirable results associated with groundwater storage are caused by the same factors as those contributing to groundwater level declines. Given assumed hydrogeologic parameters of the Subbasin, direct correlations exist between changes in water levels and estimated changes in groundwater storage.

### *6.5.2 Criteria to Define Undesirable results*

> 23 Cal. Code Regs § 354.26 *(b). The description of undesirable results shall include the following: (2) The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results for each applicable sustainability indicator. The criteria shall be based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin.*

The water-level sustainability indicator is used as the driver for calculated changes in groundwater storage. As such, when one-third of the Subbasin representative monitoring sites for water levels exceed their respective minimum thresholds, an undesirable result for storage will be deemed to occur. Given assumed hydrogeologic parameters of the Subbasin, direct correlations exist between changes in water levels and estimated changes in groundwater storage, and water levels are to serve as a metric for groundwater storage reductions as well. As discussed in Section 5.3.1, the current estimated volume of groundwater in storage in the Subbasin of 15 to 30 MAF is sufficient such that further depletion over the implementation period is not of a level of concern such that an undesirable results would emerge during the GSP implementation period.

#### *6.5.3 Potential Effects on Beneficial Uses and Users*

23 Cal. Code Regs § 354.26 *(b). The description of undesirable results shall include the following: (3) Potential effects on the beneficial uses and users of groundwater, on land uses and property interest, and other potential effects that may occur or are occurring from undesirable results.*

The potential effects to beneficial uses and users of reductions in groundwater storage are essentially the same as for declines in water levels. In most cases, the direct correlation is with declines in levels; however, some beneficial uses may be tied more specifically to loss of groundwater in storage.

## 6.6 Land Subsidence

23 Cal. Code Regs § 354.26*(a). Each Agency shall describe in its Plan the processes and criteria relied upon to define undesirable results applicable to the basin. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin.*

Land subsidence may be considered significant and unreasonable if there is a loss of a functionality of a structure or a facility to the point that, due to subsidence, the structure or facility cannot reasonably operate without either significant repair or replacement.

#### *6.6.1 Causes leading to Undesirable Results*

23 Cal. Code Regs § 354.26 *(b). The description of undesirable results shall include the following: (1) The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results based on information described in the basin setting, and other data or models as appropriate.*

Undesirable results associated with subsidence are caused by over-pumping or nominal groundwater recharge operations during drought periods such that groundwater levels fall and remain below minimum thresholds. Over-pumping and lack of recharge are area specific, and some GSA Management Areas experience greater adverse impacts than others. Over-pumping during drought periods, which may result in new lows in terms of groundwater elevations, is of particular concern based on current scientific understanding of subsidence trends in this region. Regional correlations of groundwater levels versus subsidence trends remain difficult to ascertain because groundwater levels occur at a local scale and subsidence occurs at a broader/regional scale.

#### *6.6.1 Criteria to Define Undesirable results*

23 Cal. Code Regs § 354.26 *(b). The description of undesirable results shall include the following: (2) The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results for each applicable sustainability indicator. The criteria shall be based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin.*

The primary criteria and metric will be the annual rate of reduction in land surface elevation and areal extent of such elevation changes. An undesirable result will occur when one-third of the Subbasin subsidence monitoring sites exceed their respective minimum thresholds. In addition, GKGSA will evaluate cumulative subsidence at each of the interim milestones as described in Section 5. The water-level sustainability indicator will be considered for differential land subsidence, although the current body of knowledge relative to subsidence and local and regional declines in water levels is limited. As set forth in Section 5.3.6, subsidence rates that represent minimum thresholds have been identified that reflect recent historical rates in the GKGSA region. Within the eastern portions of the Subbasin, the East Kaweah GSA has established minimum thresholds using a metric tied to loss of conveyance capacity in the Friant-Kern Canal which traverses from north to south through that GSA.

Subsidence becomes a land-surface problem when it is differential in nature i.e., elevation shifts across the areal extent of infrastructure deemed of high importance. For example, subsidence linearly along a major highway is manageable if gradual in its occurrence. In contrast, localized subsidence traversing across a highway, if sizable, would cause major cracking of the pavement surface and become a significant hazard to travelers. The same comparisons may be made for other infrastructure as well. For this reason, should an exceedance of a minimum threshold at a monitoring site occur, the applicable GSA will reach out to the County, cities, water districts, and others, both public and private, and inquire as to any infrastructure damages which may be occurring determine a corrective course of action if deemed necessary. A broad areal extent of land subsidence thus may not be of major concern, with the exception of the associated loss of aquifer system water storage capacity.

### *6.6.1 Potential Effects on Beneficial Uses and Users*

23 Cal. Code Regs § 354.26 *(b). The description of undesirable results shall include the following: (3) Potential effects on the beneficial uses and users of groundwater, on land uses and property interest, and other potential effects that may occur or are occurring from undesirable results.*

Differential land subsidence may impact surface infrastructure such as building foundations, paved streets/highways, and water conveyance systems. While not considered alarming within the Kaweah Subbasin, subsidence along the Friant-Kern Canal elsewhere along its alignment has been an ongoing concern impacting beneficial users of that water supply source. Groundwater deep wells may be adversely impacted due to casing and column failures. Loss of groundwater storage space in the aquifer system can occur with compaction of clay layers within; however, the volume of dewatered and available space existing within the aquifer system is considered extensive and adequate for future recharge during GSP implementation.

### *6.6.1 Evaluation of Multiple Minimum Thresholds*

23 Cal. Code Regs § 354.26 *(c). The Agency may need to evaluate multiple minimum thresholds to determine whether an undesirable result is occurring in the basin. The determination that undesirable results are occurring may depend upon measurements from multiple monitoring sites, rather than a single monitoring site.*

The Subbasin, in coordination with other GSAs in the basin will utilize multiple wells to monitor and manage the GSA and basin. A detailed description of the GSA's monitoring network is included in Section 4 of this GSP.

## 6.7 Degraded Water Quality

> 23 Cal. Code Regs § 354.26*(a). Each Agency shall describe in its Plan the processes and criteria relied upon to define undesirable results applicable to the basin. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin.*

An undesirable result may be significant and unreasonable if groundwater quality is adversely impacted by groundwater pumping and recharge projects and these impacts result in groundwater no longer being generally suitable for agricultural irrigation and domestic use.

### *6.7.1 Causes leading to Undesirable Results*

> 23 Cal. Code Regs § 354.26 *(b). The description of undesirable results shall include the following: (1) The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results based on information described in the basin setting, and other data or models as appropriate.*

Undesirable results associated with water quality degradation can result from pumping localities and rates, as well as other induced effects by implementation of a GSP, such that known plumes and contaminant migration could threaten production well viability. Well production depths too may draw out contaminated groundwater, both from naturally occurring and man-made constituents which, if MCLs are exceeded, may engender undesirable results. Declining groundwater levels may or may not be a cause, depending on location. In areas where shallow groundwater can threaten the health of certain agricultural crops, rising water levels may be of concern as well.

### *6.7.2 Criteria to Define Undesirable results*

> 23 Cal. Code Regs § 354.26 *(b). The description of undesirable results shall include the following: (2) The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results for each applicable sustainability indicator. The criteria shall be based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin.*

Should one-third of all Subbasin designated water quality monitoring sites exhibit a minimum threshold exceedance, and those exceedances are all associated with GSA actions, an undesirable result will be deemed to occur. Groundwater quality degradation will be evaluated relative to established MCLs or other agricultural constituents of concern by applicable regulatory agencies. The metrics for degraded water quality shall be measured by MCL compliance or by other constituent content measurements where appropriate. These metrics will include measurements for the following constituents where applicable:

- Arsenic
- Nitrate
- Chromium-6
- DBCP
- TCP
- PCE
- Sodium
- Chloride
- Perchlorate
- TDS

As explained in Section 5.3.4, in regions where agriculture represents the dominant use of groundwater, Agricultural Water Quality Objectives will serve as the metric as opposed to MCLs within public water supply jurisdictions. An exceedance of any of the MCL or agricultural metrics as defined herein at any representative monitoring sites will trigger a management action within the applicable Management Area or GSA, subject to determination that the exceedance was caused by actions of the GSA. MCLs and water quality objectives are listed in **Appendix 3A** and these are subject to changes as new water quality objectives are promulgated by the State of California and the Federal EPA. The Subbasin will provide updates in our annual reports and GSP Updates throughout the implementation periods of 2020 to 2040.

### *6.7.3 Potential Effects on Beneficial Uses and Users*

| |
|---|
| 23 Cal. Code Regs § 354.26 *(b). The description of undesirable results shall include the following: (3) Potential effects on the beneficial uses and users of groundwater, on land uses and property interest, and other potential effects that may occur or are occurring from undesirable results.* |

The potential effects of degraded water quality from migrating plumes or other induced effects of GSA actions include those upon municipal, small community and domestic well sites rendered unfit for potable supplies and associated uses, and/or the costs to treat groundwater supplies at the well head or point of use so that they are compliant with state and federal regulations. Potential effects also include those upon irrigated agricultural industries, as certain mineral constituents and salt build-up can impact field productivity and crop yields.

### *6.7.4 Evaluation of Multiple Minimum Thresholds*

| |
|---|
| 23 Cal. Code Regs § 354.26 *(c). The Agency may need to evaluate multiple minimum thresholds to determine whether an undesirable result is occurring in the basin. The determination that undesirable results are occurring may depend upon measurements from multiple monitoring sites, rather than a single monitoring site.* |

The Subbasin, in coordination with other GSAs in the basin will utilize multiple wells to monitor and manage the GSA and basin. A detailed description of the GSA's monitoring network is included in Section 4 of this GSP.

## 6.8 Interconnected Surface Waters

### *6.8.1 Undesirable results*

23 Cal. Code Regs § 354.26 *(d) An Agency that is able to demonstrate that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin shall not be required to establish criteria for undesirable results related to those sustainability indicators.*

No interconnected surface waters as defined in SGMA have been identified in any Kaweah Subbasin GSAs as described more thoroughly in the basin setting. Some of the Plans have identified this issue as a data gap and have committed to increasing monitoring.

## 6.9 Seawater Intrusion

### *6.9.1 Undesirable results*

23 Cal. Code Regs § 354.26 *(d) An Agency that is able to demonstrate that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin shall not be required to establish criteria for undesirable results related to those sustainability indicators.*

There is no potential for seawater intrusion to occur in the Kaweah Subbasin as described more thoroughly in the basin setting. Thus, no criteria need be established.

# Appendix 7

# Groundwater Modeling Technical Memorandum

# KAWEAH SUBBASIN
# GROUNDWATER MODELING REPORT

Final 12/31/19

# Contents

# Introduction

This memorandum describes the application of the Kaweah Subbasin Hydrologic Model (KSHM) to analysis of future conditions in the Kaweah Subbasin during the GSP implementation period from 2020 to 2040. The model is applied to estimate future water deficit and water levels under base no-action scenarios. It is also applied to assess the impacts of projects and management actions proposed by the Subbasin GSAs. The modeling results helped inform the GSAs in finalizing their sustainable management criteria including articulation of a basin wide sustainability goal statement and verifying the reasonableness of the measurable objectives, minimum thresholds, and interim milestones set at each groundwater level representative monitoring well for the 20-year GSP implementation period. The results are also intended to inform collaboration with other agencies and entities to arrest chronic water-level and groundwater storage declines, reduce or minimize land subsidence where significant and unreasonable, decelerate ongoing water quality degradation where feasible, and protect beneficial uses. The modeling approach and results of verification runs have been previously described in an earlier report which is provided in Appendix 1 of this report.

# Model Scenarios

The first modeling task initiated includes extending the duration of the model from the modeled period of water years 1999 to 2017 through the SGMA compliance period of water years 2020 to 2040. All modeling runs, from the no-action "Base Case" scenario through the projects and management action scenarios, incorporate climate change in accordance with DWR's climate change direction. The base case was used to identify measurable objectives and to facilitate planning for projects and management actions. The set of model runs to be performed was determined through iterative discussions and summarized in a presentation to the Kaweah Subbasin management team on April 17, 2019. The model runs implemented consisted of the following:

- Case 1, Base No-Action Scenario: Base Case Run with averaged water year repeated and adjusted to account for long term trend due to climate projections
- Case 2, Variable Base No-Action Scenario: Base case with historical sequence of wet and dry years
- Case 3, Reversed Variability Base No-Action Scenario: Base case with reversed historical sequence of wet and dry years
- Case 4, Future Management Actions Only: Built on the Base No-Action Scenario but with Pumping Reductions
- Case 5, Future Projects and Management Actions: Built on the Base No-Action Scenario but with Pumping Reductions and Projects

# Preparing Projected Hydrology

Projected climate conditions for the implementation period are important inputs for the determination of measurable objectives and ultimately the sustainability of the basin. The GSP Emergency Regulation which was issued by DWR to guide development of GSPs includes guidance for preparation of Project Hydrology for 2020 to 2040 implementation period. Section 354.18(c)(2)(B) of the GSP Emergency Regulation outlines the relevant requirements for preparing historical and projected water budgets.

For historical water budget, the regulation requires a quantitative assessment based on a minimum of 10 years of data including with the most recently available information. The 20-year current period (1997 to 2017) used for the Kaweah basin historical water budget meets and exceeds this requirement. For projected hydrology, the regulation requires future hydrology to be established using 50 years of historical precipitation, evapotranspiration, and streamflow information as a baseline. The regulation also requires projected hydrology information to be applied as the baseline condition used to evaluate future scenarios of hydrologic uncertainty associated with projections of climate change and sea level rise.

To support the development of a projected hydrology that meets the requirements of the regulation, DWR has provided a gridded, statewide dataset that contains over 89 years of detrended hydrologic time series (1922 to 2011) to capture variability. DWR has also computed the climate states at 1995, 2030 and 2070 using a combination of global climate models, and the climate states have been applied to the detrended time series to generate three future hydrologic time series. For estimation of imported water supplies such as those from the Friant-Kern system, DWR has simulated 82 years of future hydrologic time series using the CalSim model. Three climate time series, each 50 or more years long, were extracted from the DWR data and used to characterize projected hydrology in the Kaweah Basin under 1995, 2030 and 2070 conditions.

## Case 1: Base Case of Future with Averaged Conditions and No Projects

To meet the GSP Emergency Regulation requirements, a base case of projected hydrology covering the 20-year period for 2020 to 2040 is developed based on historical monthly averages. The average monthly hydrologic conditions experienced between 1997 through 2017 (the “current period”) are assumed for each year of the compliance period, and annual change factors are applied to account for the long-term trend due to climate change. Future water supply projections (including Class I, II and other water deliveries) from the Friant Water Authority are included in the base case. Detailed steps for generating the projected hydrology time series are described in the following steps:

- First Year (2020): Projected hydrology for the first year (2020) are computed as the monthly averages of the current hydrology (1997 to 2017). An implied change factor of 1 is used for the first year of projected hydrology.

- Early Years (2021 to 2030): Projected hydrology for subsequent years from 2021 to 2030 are computed by applying a set of change factors to account for climate change. Twelve climate change factors are computed using the percent change of the mean monthly values between two DWR-provided climate projection datasets centered around years 1995 and 2030, respectively. The linear trend is used to incremental apply the monthly change factors to each year between 2021 and 2030, and the change factors are applied to the monthly averages of the current (2020) hydrology to generate the projected hydrology.

- Later Years (2031 to 2040): Projected hydrology for the later years from 2031 to 2040 are computed by similarly applying factors to account for climate change. The climate change factors for later years is computed using the rate of change of the mean monthly values between DWR-provided climate projection datasets centered around years 2030 and 2070, respectively. The trend is applied incremental to the monthly values beginning with 2030 hydrology to generate projected hydrology for each year between 2031 and 2040.

Table 1 shows the monthly change factors computed for use in projecting future precipitation, evapotranspiration and water supply in the Kaweah Subbasin. Separate change factor values are provided for use in 2030 and 2040. Since a value of 100% is assumed for the first year 2020, change factors are easily interpolated for all intermediate years between 2020 and 2040 using a linear trend. Different change factors are computed in each of the three GSAs, and different change factors are also applied for water supplies from Kaweah Lake, Kings and the Friant Kern system.

*Table 1: Monthly Hydrologic Change Factors Derived from DWR-Provided Climate Change Projections.*

| | Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Precipitation (Percent of 2020 Values)** | | | | | | | | | | | | | |
| East Kaweah | 2030 | 92 | 102 | 98 | 108 | 104 | 109 | 103 | 85 | 88 | 101 | 109 | 105 |
| East Kaweah | 2040 | 89 | 97 | 97 | 111 | 104 | 109 | 99 | 80 | 87 | 104 | 112 | 111 |
| Greater Kaweah | 2030 | 92 | 101 | 97 | 108 | 105 | 108 | 103 | 87 | 88 | 101 | 112 | 105 |
| Greater Kaweah | 2040 | 90 | 96 | 97 | 110 | 105 | 108 | 100 | 83 | 87 | 101 | 113 | 110 |
| Mid-Kaweah | 2030 | 92 | 101 | 96 | 108 | 105 | 108 | 103 | 87 | 88 | 100 | 109 | 105 |
| Mid-Kaweah | 2040 | 90 | 96 | 95 | 110 | 105 | 108 | 100 | 83 | 87 | 100 | 110 | 110 |
| **Evapotranspiration (Percent of 2020 Values)** | | | | | | | | | | | | | |
| East Kaweah | 2030 | 104 | 103 | 103 | 105 | 103 | 103 | 102 | 104 | 104 | 103 | 103 | 103 |
| East Kaweah | 2040 | 105 | 105 | 106 | 106 | 105 | 104 | 103 | 105 | 105 | 104 | 104 | 104 |
| Greater Kaweah | 2030 | 104 | 103 | 104 | 105 | 103 | 103 | 102 | 104 | 104 | 103 | 103 | 103 |
| Greater Kaweah | 2040 | 105 | 105 | 106 | 106 | 104 | 103 | 103 | 105 | 105 | 104 | 104 | 104 |
| Mid-Kaweah | 2030 | 104 | 103 | 104 | 105 | 103 | 102 | 102 | 104 | 104 | 103 | 103 | 103 |
| Mid-Kaweah | 2040 | 105 | 105 | 106 | 107 | 104 | 103 | 103 | 105 | 105 | 104 | 104 | 104 |
| **Water Supply (Percent of 2020 Values)** | | | | | | | | | | | | | |
| Kaweah Lake | 2030 | 102 | 106 | 110 | 125 | 121 | 119 | 105 | 82 | 58 | 64 | 91 | 99 |
| Kaweah Lake | 2040 | 99 | 101 | 111 | 131 | 128 | 124 | 104 | 75 | 51 | 61 | 90 | 102 |
| Kings | 2030 | 100 | 111 | 118 | 135 | 131 | 127 | 115 | 96 | 64 | 58 | 84 | 96 |
| Kings | 2040 | 97 | 107 | 122 | 144 | 142 | 137 | 119 | 92 | 57 | 53 | 81 | 99 |
| Friant-Kern | 2030 | 85 | 97 | 146 | 152 | 116 | 110 | 101 | 97 | 85 | 90 | 85 | 85 |
| Friant-Kern | 2040 | 83 | 94 | 144 | 157 | 118 | 112 | 102 | 93 | 82 | 87 | 81 | 83 |

To generate the projected hydrology, the monthly change factors are applied to the fluxes from the calibrated model for the current period. The precipitation, evapotranspiration and water supply change factors are applied to different fluxes as follows:

- Mountain Front Runoff (precipitation change factors)
- Agricultural Pumping (evapotranspiration change factors)
- Agricultural Irrigation Return Flow (evapotranspiration change factors)
- Ditch Percolation (future estimated surface water allocations)
- Precipitation Percolation (precipitation change factors)
- River Recharge (water supply change factors)

## Case 2: Future with Interannual Variability and No Projects

The second modeling case is used to evaluate the impacts of interannual variability including extreme conditions such as wet and dry years and multi-year droughts which could impact water quality or induce subsidence. The projected hydrology is based on the historical hydrologic time series (1997 to 2017) with a climate adjustment applied to reflect climate conditions centered at 2030. This model run includes over 10 years of current hydrology and 50 years of projected hydrology as required by the GSP regulations. However, the results cannot be used for setting intermediate 5-year targets between 2020 and 2040 since the historical sequence of wet and dry years cannot be assumed to recur in the future. The results of this model run are used primarily to estimate the magnitude of uncertainty in future projections of performance targets.

## Case 3: Future with Interannual Variability Reversed and No Projects

The third modeling case also uses the historical time series used in Case 2 to evaluate the impacts of interannual variability and extreme wet and dry years. However, the sequence of historical time series is reversed such the model run begins with the most recent historical years of data while the oldest year of data enters the model last. The time series reversal changes the sequencing of hydrologic years but preserves the seasonal patterns that occurred within each year. To account for the impacts of climate change, a set of 12 monthly change factors is computed from the DWR climate projections centered at 2030 and applied to each year of the reversed time series.

The results of Case 3 run are useful for assessing the sensitivity of projected hydrology and sustainability indicators to the sequence of future annual droughts and wet years. However, the results cannot be used for setting intermediate 5-year targets between 2020 and 2040 since the sequence of years cannot be assumed to recur in the future. The results of this model run are also used to assess the magnitude of uncertainty in future projections of performance targets.

## Case 4: Altered Future with Management Actions

The fourth modeling case reflects a future scenario where only management actions would be employed to achieve sustainability. Management actions are to be implemented with the goal of reducing pumping and mitigating further decline in aquifer water levels. They include conservation and monitoring programs aimed at limiting extraction and reducing water use. They also include market-based mechanisms and external assistance programs to reduce the economic impact of reduced water use. Table 2 shows the list of near-term management actions to be implemented in the Kaweah Subbasin in Case 4 which does not include implementation of any projects, with the exception of relatively new and operating water exchanges within Mid-Kaweah GSA.

*Table 2: List of Management Actions included in Case 4*

| Region | Management Actions |
|---|---|
| East Kaweah GSA | • 5% Demand Reduction<br>• 2025 Demand Reduction Programs/Policies<br>• 2030 Demand Reduction Programs/Polices<br>• 2035 Demand Reduction Programs/Polices |
| Greater Kaweah GSA | • Modified Surface Water Deliveries<br>• Fallowing Program |
| Mid-Kaweah GSA | • Extraction Measurement Program<br>• Groundwater Extraction Allocation Implementation |

## Case 5: Altered Future with Management Actions and Projects

The fifth modeling case reflects a future scenario where projects and management actions would be employed to achieve sustainability. While management actions are aimed at reducing pumping, projects are proposed with the primary goal of increasing recharge. Table 3 shows the list of initial projects and management actions included in Case 5.  Case 5 is expected to generate the smallest water deficit since it reflects the combined impacts of recharge projects and pumping reduction from all the management actions previously listed in Case 4. Not all of the projects and management actions listed in table three

*Table 3: List of Projects and Management Actions included in Case 5*

| Region | Management Actions | Projects |
|---|---|---|
| East Kaweah GSA | • 5% Demand Reduction<br>• 2025 Demand Reduction Programs/Policies<br>• 2030 Demand Reduction Programs/Policies<br>• 2035 Demand Reduction Programs/Policies | • Lewis Creek Delivery<br>• Cottonwood Creek Delivery<br>• Yokohl Creek Delivery<br>• Micro-Basins<br>• Lindsay Recharge Basin<br>• Wutchumna Ditch Delivery<br>• Rancho de Kaweah |
| Greater Kaweah GSA | • Modified Surface Water Deliveries<br>• Fallowing Program | • Cross Creek Layoff Basin<br>• Improved LIWD Basins<br>• New LIWD Basins<br>• New Delta View Canal<br>• Deliveries to Delta View Landowners thru Lakeland<br>• On-Farm Recharge<br>• Kings River Floodwater Arrangement<br>• Buying Surplus Water in Wet Years<br>• Paregien Basin<br>• Basin No. 4<br>• Hannah Ranch<br>• Lewis Creek Water Conservation<br>• Ketchum Flood Control & Recharge<br>• St Johns River Water Conservation<br>• Peoples Recharge Expansion |
| Mid-Kaweah GSA | • Extraction Measurement Program<br>• Groundwater Extraction Allocation Implementation | • Cordeniz Recharge Basin<br>• Okieville Recharge Basin<br>• Tulare Irrigation District / GSA Recharge Basin<br>• On-Farm Recharge Programs<br>• McKay Point Reservoir<br>• Kaweah Subbasin Recharge Facility<br>• City of Visalia / Tulare Irrigation District Exchange Program<br>• Sun World International / Tulare Irrigation District Exchange Program<br>• City of Tulare / Tulare Irrigation District Catron Basin<br>• Packwood Creek Water Conservation Project<br>• Visalia Eastside Regional Park & Groundwater Recharge |

## Boundary Conditions

The Kaweah Subbasin numerical groundwater model is intended to be used as a valuable planning tool to guide groundwater managers in planning projects and management actions to achieve sustainability within the implementation period. To achieve this goal, particular attention is paid to how the head boundary conditions are specified in the model. Within the groundwater model, the General Head Boundary (GHB) surrounds the Kaweah Subbasin model at a distance of approximately 3 miles beyond the KSB boundary, located within the neighboring subbasins to the north, west and south. The area between the GHB and the Kaweah Subbasin is considered a “buffer zone,” the purpose of which is to evaluate subsurface inflow and outflow (underflow) between the adjacent subbasins. Figure 1 shows the model extent with the General Head Boundary represented by the line marking the edge of the model extent.

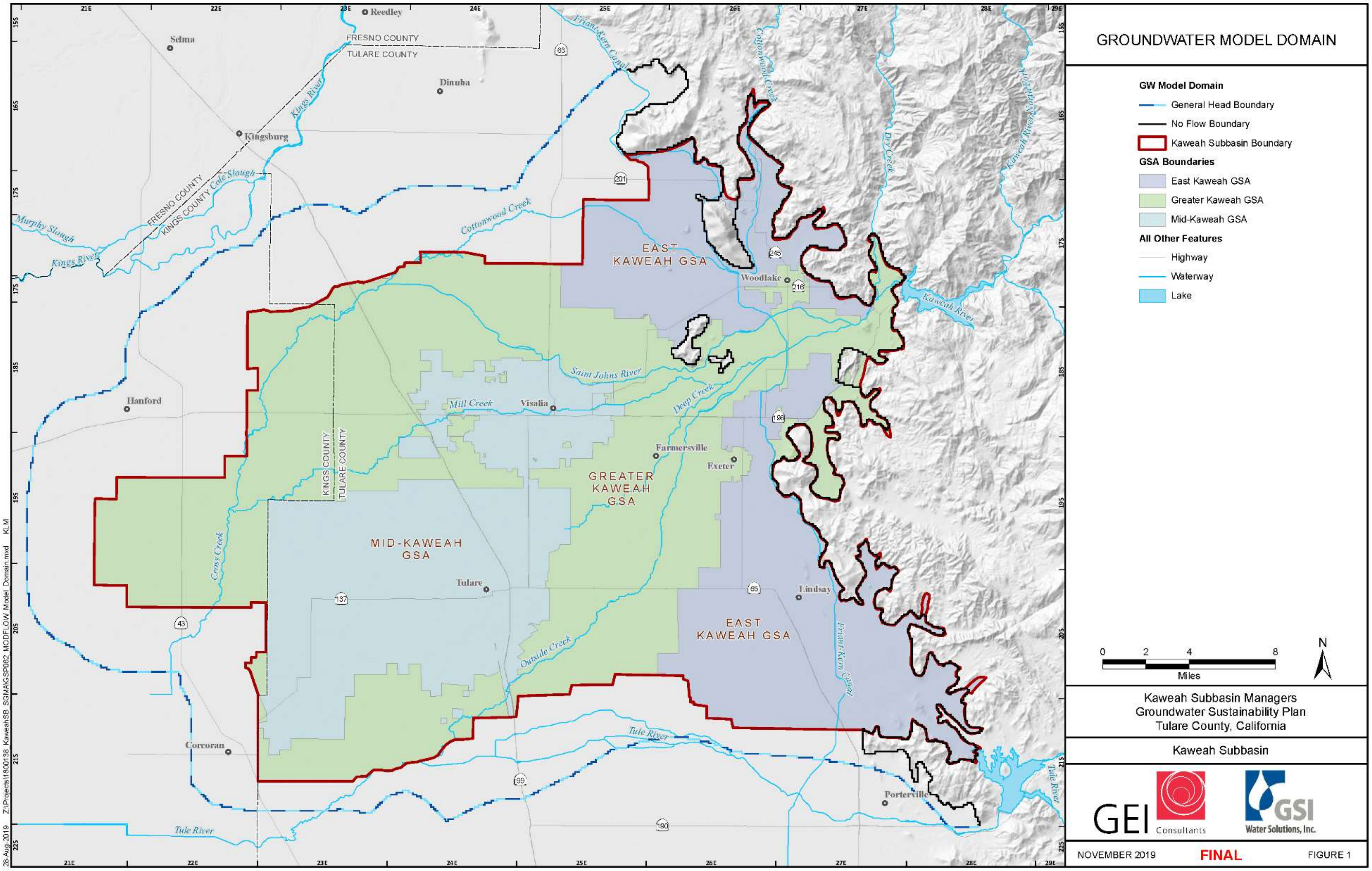



*Figure 1: Kaweah Subbasin Model Domain*

Head boundary conditions play an important role in modeling because, along with aquifer properties, they determine the magnitude of flows in and out of the subbasin. Boundary water levels for a modeling run must be specified for each month in the simulation period prior to each model run. They are difficult to specify accurately since they are based on water levels that respond to the change in fluxes due to actions in neighboring subbasins. However, they must be specified accurately enough to reflect changing fluxes entering and leaving the subbasin through the boundary.

In the Kaweah model, future water levels at the general head boundary are prescribed based on observed water elevations and simulated current hydrology (1997-2017) from the calibrated model. Future boundary water elevations from 2020 to 2040 were set by repeating the 12 average monthly values of the period from 1997 through 2017. This approach preserves the seasonal water level changes at boundary. It also ensures that the magnitude of underflow fluxes entering and leaving the basin for the base case are of the same order of magnitude as underflow fluxes for current hydrology. As projects and management actions are implemented within Kaweah and surrounding subbasins, the head boundary conditions and underflow will also change but these changes cannot be predicted without full knowledge of all projects and management actions in the region. The surrounding subbasins have the same modeling issues which can only be resolved in future by setting boundary conditions with modeled water levels from surrounding subbasins.

Figure 2 shows contours of the potentiometric surface for initial water levels at the start of the planning period in 2020. The elevation of the water table generally decreases from east to west. The highest water level elevations of between 300 and 400 ft occur in East Kaweah GSA at the transition from the Sierras to the valley floor. The lowest water levels of 40 ft or less occur along Cross Creak at the western edge of Greater Kaweah and Mid-Kaweah GSAs.

Figure 3 shows contours of the projected potentiometric surface changes between 2020 and 2040 under the base, no-project scenario. Contour values are generally negative indicating water levels in the Kaweah Subbasin would continue to decline without action to reduce extraction or increase supply. The largest declines would occur in the middle of the subbasin with declines exceeding 80 ft around Visalia. The region of decline is shaped like a cone centered around Visalia and extending over the entire subbasin.

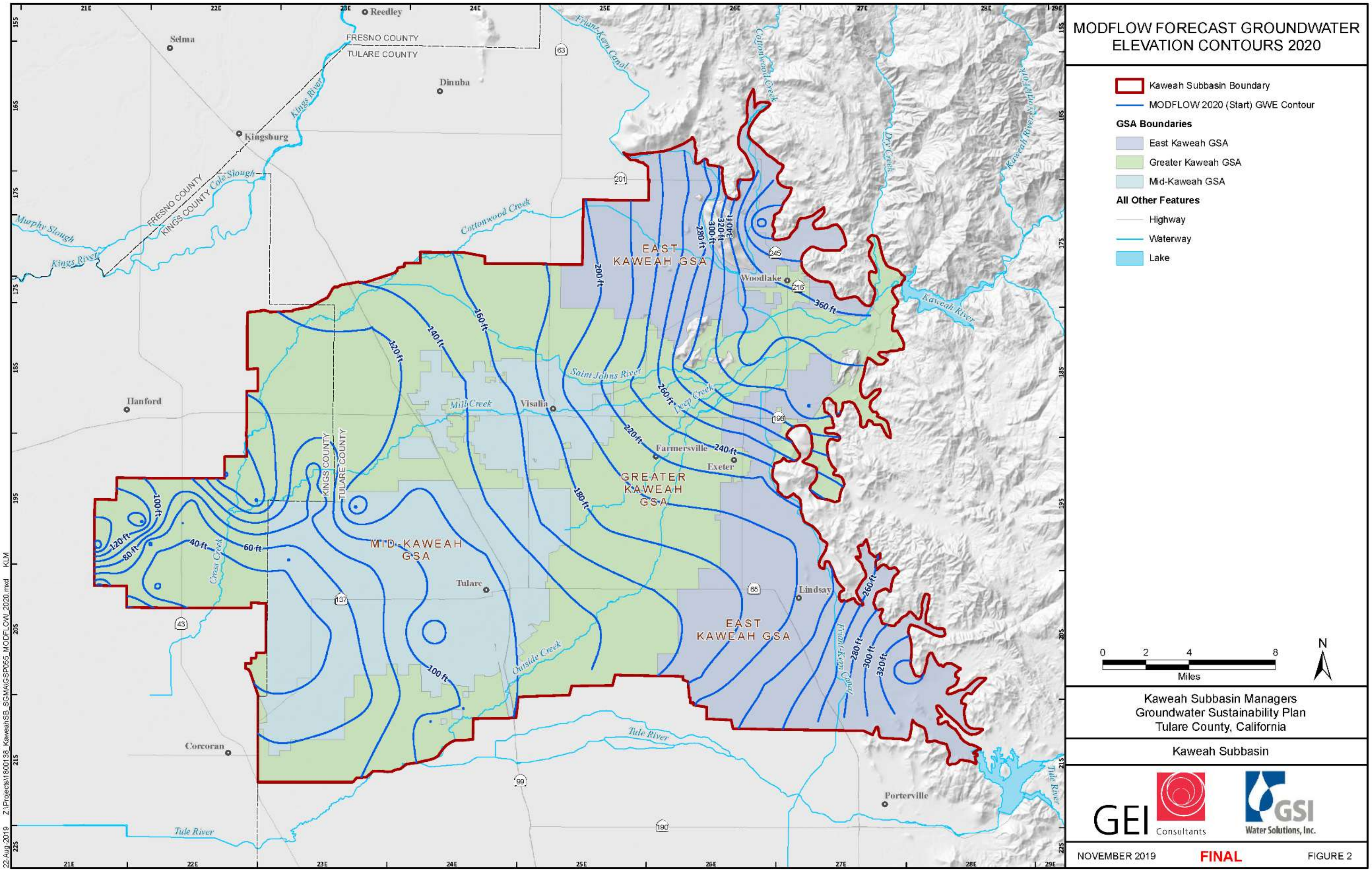



Figure 2: Potentiometric Surface Map showing Water Levels at the Beginning of the Simulation Period in 2020.

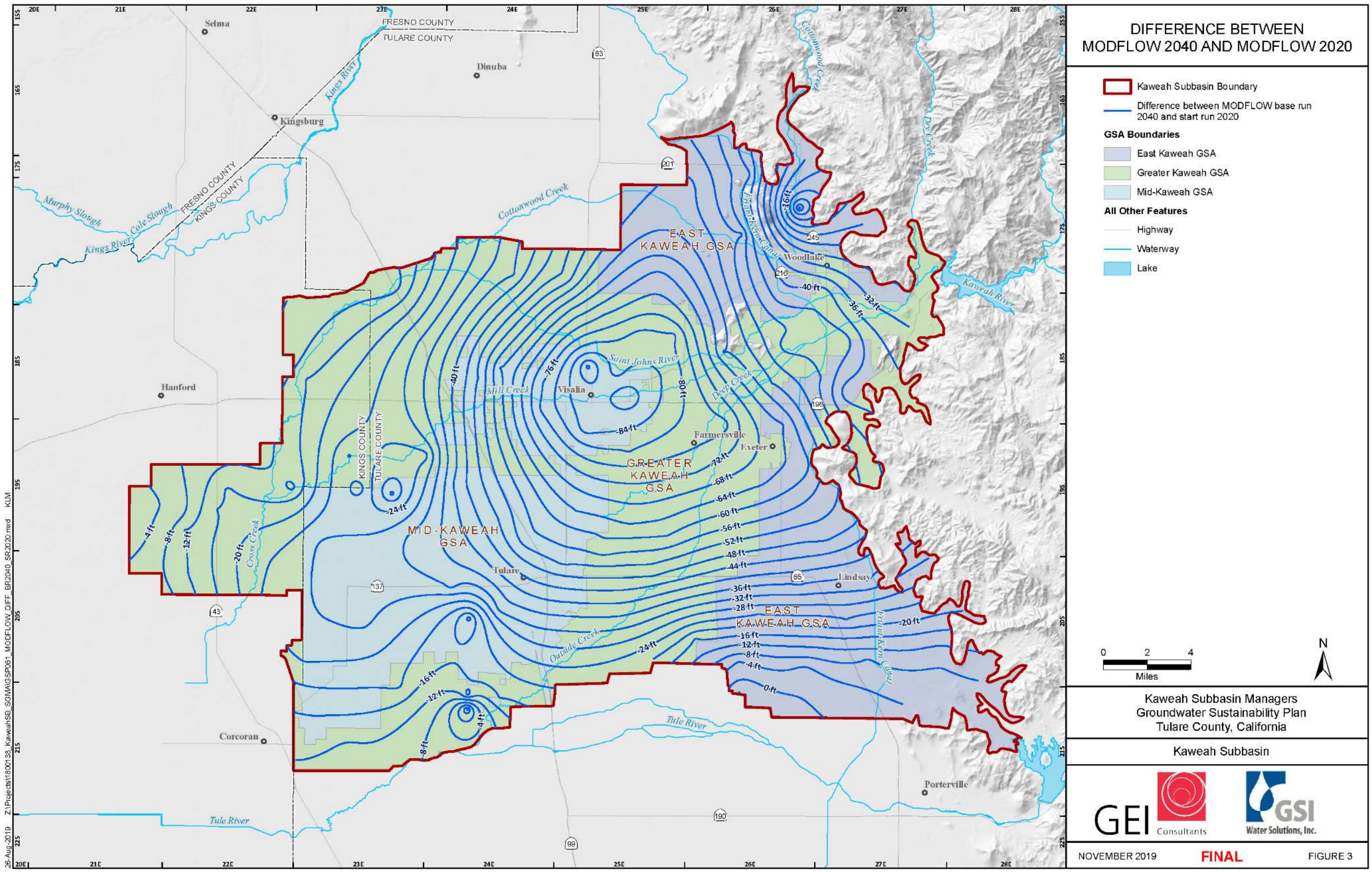



*Figure 3: Map of Potentiometric Surface Changes from 2020 to 2040 under the Base Case with No Projects.*

## Recharge and Pumping Projections

As shown in the Basin Setting chapter of the GSP for the Kaweah Subbasin, climate change is projected to increase temperatures and evapotranspiration, leading to an equivalent increase in crop demands and groundwater pumpage. Percolation also increases with increases in the volume of applied irrigation water. The increase in evapotranspiration coupled with shifts in the seasonal patterns of precipitation could also affect changes to the quantity and timing of deep percolation and groundwater storage. With projected demands anticipated to increase by approximately 10 percent by 2040 (Table 34 of the Kaweah Basin Setting Report), a combination of demand management and recharge programs are required to close the deficit in the Projected Water Budget.

Surface water availability changes are incorporated as presented in the Projected Water Budget section of the Basin Setting document. This availability affects surface water delivery to crops and, by extension, groundwater pumpage to satisfy crop requirements. Surface water availability also impacts recharge along streams, ditches and recharge basins. Additional recharge (on-farm recharge) and recharge basins are included as future projects in the basin. In the interest of maximizing the surface water supply during wet periods, the future projects evaluated in modeling case 5 include on-farm recharge or other large-scale recharge projects.

Municipal pumping within each city and overall agricultural pumping within each GSA are adjusted as percentages of the base case scenario. Municipal pumpage is modeled as documented in the Basin Setting, in accordance with anticipated pumpage documented in urban water management plans. For the base period, irrigated agriculture demand averaged 1,055,700 AF/WY, which was satisfied by a combination of surface water and groundwater. Recent crop survey data indicate that this demand is from a variety of crops including almonds, alfalfa, citrus, cotton, grapes, olives, truck crops, walnuts, wheat and several others (Davids Engineering, 2018). Crop ET was derived for each of these crops for each year during the recent period of 1999 to 2017, based upon trends in water use for each crop. During the period, total water demand related to the growing of almonds has increased by 14 percent, while total water demand to satisfy miscellaneous field crops has declined by 18 percent. By considering all of the trends for a total of 16 crop categories on a net basis, the average change in crop water ET demand has been relatively unchanged, increasing modestly each year between 1999 and 2018. Future projection of crop demand to 2040 and 2070 indicates that agricultural demand will increase to 1,138,200 AF/WY in 2030 and 1,239,500 AF/WY in 2070, which includes projected climate change effects.

Changes in agriculture water use are implemented through cropping changes, land fallowing or other land-use conversion alternatives. Cropping changes are included in the no-action model runs (Case 1, 2 and 3) as presented in the Projected Water Budget section of the Basin Setting document. Land retirement is included as a management action in the fourth and fifth scenarios.

Each GSA is able to model separate reduced pumpage "ramp downs" and specific projects and management actions in increments of 5 years or less. The results of the numerical modeling are summarized at a GSA-level along with water level changes, hydrographs, and water budget components in 5-year increments from 2020 through 2040. The 5-year summaries allow the GSAs to determine the anticipated effectiveness of projects and management actions.

Agricultural pumping reductions are incorporated into the groundwater model relative to the baseline run for many of the predictive scenarios. Reductions in pumpage are specified in areas smaller than the GSA such as the scale of an entitlement holder or a water district. Pumpage reductions are also allowed to vary temporally. To accommodate these spatial and temporal variations within the model, a shapefile is developed of the areas where pumpage reductions are proposed and used to assign a proportional reduction in pumpage for modeling areas. Likewise, reductions of pumpage are assigned evenly throughout the agricultural pumpage at the GSA scale. Temporally, these reductions are assigned in approximately 5-year periods (such as 2021 - 2025 or 2026 - 2030) to allow sufficient time for planning operational changes. A relative adjustment is also applied to irrigation return flows to maintain consistency with the prescribed agricultural pumping reductions.

Change in water levels from the baseline can readily be summarized over specified pumpage areas at the end of each 5-year period. However, the groundwater zone budget determining underflow, change in storage, other groundwater model fluxes, and objectives are only computed at the GSA level.

## Water from Management Actions and Projects

The impacts of Management Actions and Projects on reducing average annual water deficits in the Kaweah Subbasin over the implementation period 2020 to 2040 are shown in Table 4. The water deficit reductions are provided in thousands of acre-feet per year. Separate values are shown for the Management Actions (Case 4) and the combined impact of Projects and Management Actions (Case 5) for East Kaweah GSA, Greater Kaweah GSA and Mid-Kaweah GSA. Summary results for the full Kaweah Subbasin are also provided. For Mid-Kaweah GSA, the proposed Management Actions are included in Case 4 while Case 5 includes only proposed Projects without Management Actions. This is because Management Actions in Mid-Kaweah GSA include reoperation of existing projects such as capturing and storing local or regional flood flows that would otherwise leave the subbasin and operating existing Packwood Creek recharge facilities.

*Table 4: Water Deficit Reduction from Projects and Management Actions in Thousands of Acre-Feet per Year*

| | Water Deficit Reduction (1000 Acre-Feet/Year) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | East Kaweah GSA | | Greater Kaweah GSA | | Mid-Kaweah GSA | | Kaweah Subbasin | |
| Water Year | Case 4: Management Actions | Case 5: Total | Case 4: Management Actions | Case 5: Total | Case 4: Management Actions and Existing Projects | Case 5: Projects without Management Actions | Case 4: Management Actions | Case 5: Total |
| 2020 | 0 | 1.8 | 3.3 | 12.7 | 5 | 5 | 8.3 | 19.5 |
| 2021 | 1.5 | 5.1 | 4.5 | 14.2 | 5 | 5 | 11 | 24.3 |
| 2022 | 1.5 | 8.3 | 4 | 13.7 | 5 | 5 | 10.5 | 26.9 |
| 2023 | 1.5 | 8.3 | 8 | 77.4 | 5 | 5 | 14.5 | 90.6 |
| 2024 | 1.5 | 11 | 4 | 14.2 | 5 | 5 | 10.5 | 30.2 |
| 2025 | 7.5 | 14.5 | 4.5 | 14.7 | 5.6 | 10 | 17.6 | 39.2 |
| 2026 | 7.5 | 23.5 | 16.3 | 26.4 | 6.3 | 10 | 30 | 59.9 |
| 2027 | 7.5 | 23.5 | 16.3 | 99.3 | 6.9 | 10 | 30.6 | 132.8 |
| 2028 | 7.5 | 23.5 | 16.3 | 26.6 | 7.5 | 10 | 31.3 | 60 |
| 2029 | 7.5 | 23.5 | 16.3 | 26.6 | 8.1 | 10 | 31.9 | 60 |
| 2030 | 16.5 | 27 | 16.3 | 26.6 | 8.8 | 15 | 41.5 | 68.5 |
| 2031 | 16.5 | 27 | 36 | 130.1 | 9.4 | 15 | 61.9 | 172.1 |
| 2032 | 16.5 | 27 | 36 | 46.5 | 10 | 15 | 62.5 | 88.4 |
| 2033 | 16.5 | 27 | 36 | 46.5 | 10.6 | 15 | 63.1 | 88.4 |
| 2034 | 16.5 | 27 | 36 | 46.5 | 11.3 | 15 | 63.8 | 88.4 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2035 | 30 | 30.5 | 36 | 140 | 11.9 | 15 | 77.9 | 185.5 |
| 2036 | 30 | 30.5 | 65 | 75.6 | 12.5 | 15 | 107.5 | 121.1 |
| 2037 | 30 | 30.5 | 65 | 75.6 | 13.1 | 15 | 108.1 | 121.1 |
| 2038 | 30 | 30.5 | 65 | 75.6 | 13.8 | 15 | 108.8 | 121.1 |
| 2039 | 30 | 30.5 | 65 | 172.6 | 14.4 | 15 | 109.4 | 218 |
| 2040 | 30 | 30.5 | 65 | 75.6 | 15 | 15 | 110 | 121.1 |
| **Min** | **0** | **1.8** | **3.3** | **12.7** | **5** | **5** | **8.3** | **19.5** |
| **Max** | **30** | **30.5** | **65** | **172.6** | **15** | **15** | **110** | **218** |
| **Mean** | **14.6** | **21.9** | **29.3** | **58.9** | **9** | **11.4** | **52.9** | **92.2** |

The results show that proposed management actions (case 4) in the Kaweah Subbasin could yield approximately 52,900 acre-feet per year of reductions in water deficit. Case 5 results in a total water deficit reduction of 92,200 acre-feet annually on average and in the last five years the deficit reduction is 121,000 acre-feet which implies that the projects alone would yield 39,300 acre-feet per year. The Kaweah Subbasin Basin Setting Report estimates the basin Safe Yield at 720,000 acre-feet per year and the average annual groundwater pumping in the basin during the current water budget period is 798,000 acre-feet. Therefore, a reduction in deficit of 121,000 through the implementation of projects and management actions will ensure that we are operating within the safe yield of the basin. The Greater Kaweah GSA contributes to 64% of deficit reduction while East Kaweah and Mid-Kaweah contribute 24% and 12%, respectively. Implementation of most management actions increases gradually in each GSA over the 20-year planning horizon but with some stepped increases occurring approximate every five years. Projects in East Kaweah and Mid-Kaweah steadily reduce water deficits within their respective GSAs over the planning horizon. However, in Greater Kaweah, the projects yield gradually increasing volumes of water punctuated by large recharge volumes during wet years which are assumed to recur every four years.

Figure 4 shows contours of difference in 2040 water levels between the base no-action scenario and the scenario in which management actions are implemented but with no projects. The introduction of Management Actions would result in an overall rise in 2040 water levels relative to the no-action scenario. The largest improvements occur in the area between Cottonwood Creek and Saint Johns River with water levels rising up to 28 ft. Rises of over 20 ft are seen in other across the middle of the subbasin, stretching from areas along Mill Creek near Visalia to the Friant-Kern Canal near Lindsay.

Figure 5 shows contours of difference in 2040 water levels between the base no-action scenario and the scenario with full implementation of proposed projects and management actions. Under this scenario, the largest improvements in water levels of over 52 ft occur along Saint Johns River and Deep Creek, just west of Mckays Point. Improvements of over 40 ft are also seen between Mill Creek and Cross Creek near Remnoy.

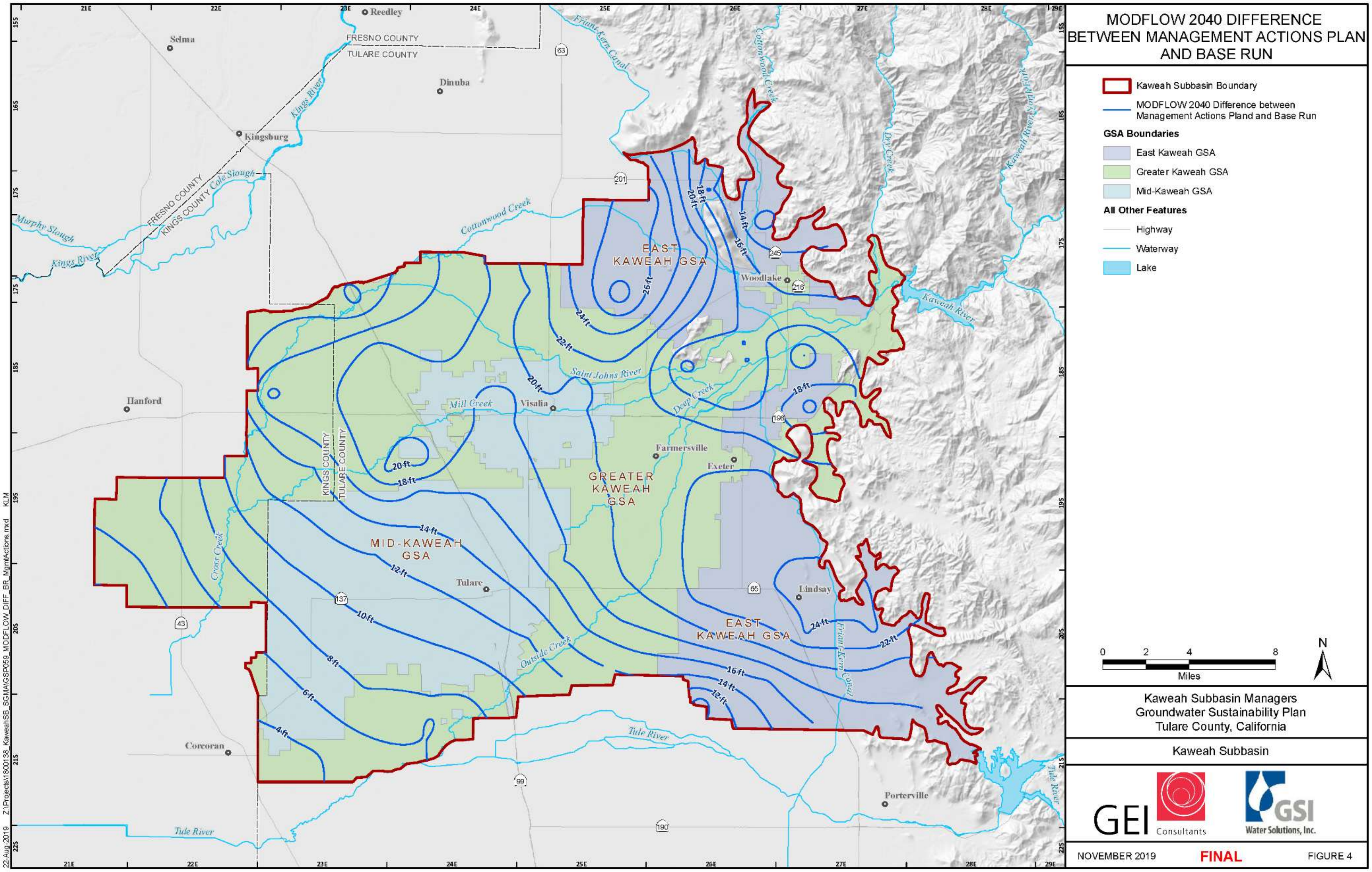



*Figure 4: Map of Differences in Potentiometric Surfaces between Base Case 1 with No Projects and Case 4 with Management Actions Only in 2040.*

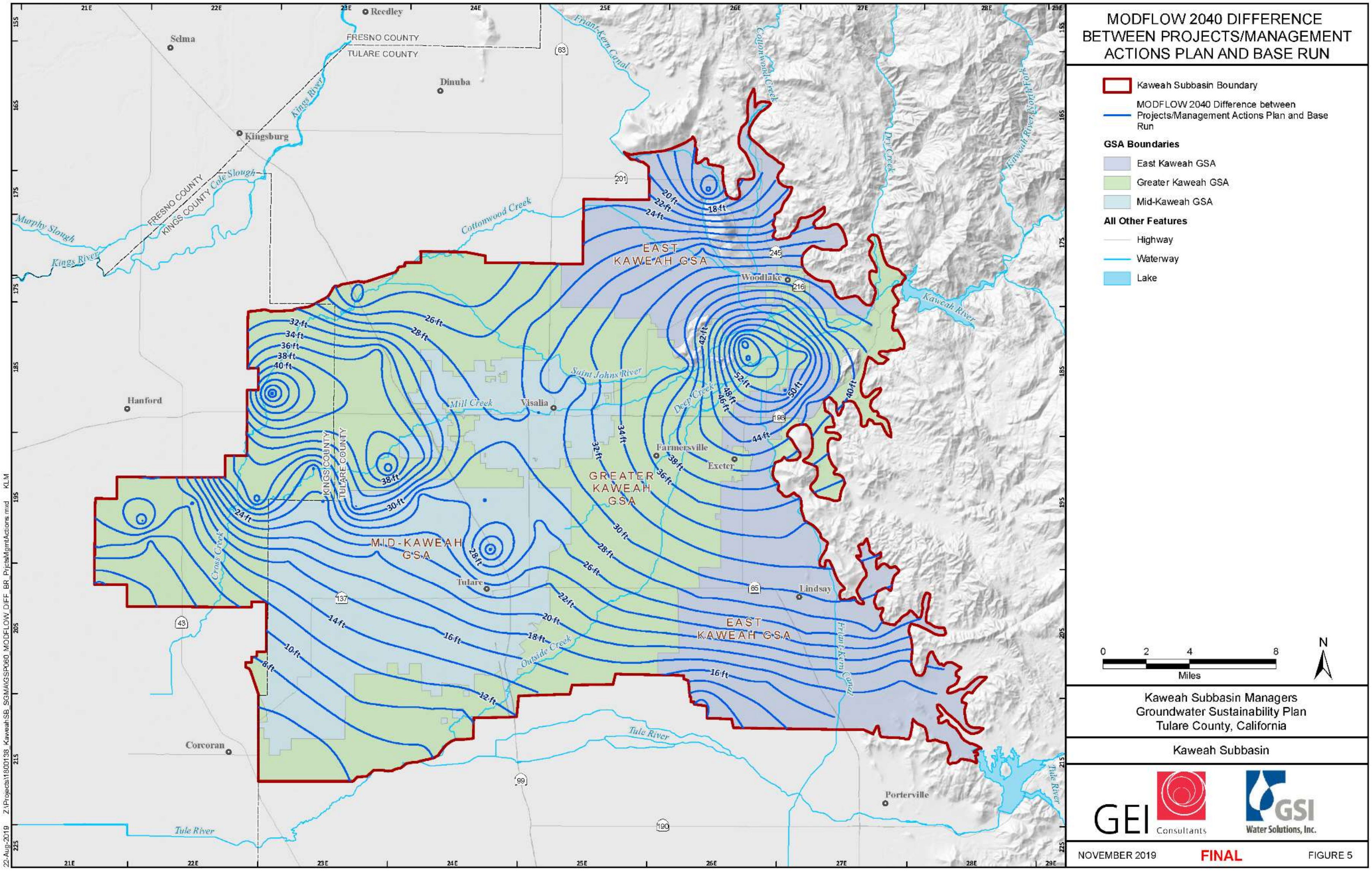



*Figure 5: Map of Differences in Potentiometric Surfaces between the Base Case 1 with No Projects and Case 5 with Management Actions and Projects in 2040.*

## Summary Results for Kaweah Subbasin

The impacts of the management actions and projects on groundwater fluxes and storage in the basin for the five modeling cases analyzed are summarized in Table 5. For each run, fluxes are presented for the initial water year (2020) followed by average fluxes for the next 5-year period. Inflow fluxes presented include recharge, underflow entering the Kaweah Subbasin from surrounding buffer zone, and total inflow fluxes. Outflow fluxes presented include pumping from agricultural wells, aquifer discharge to streams, pumping from non-agricultural wells, underflow discharged from the Kaweah Subbasin to the surrounding buffer zone, and total outflow. Annual rates of change in storage and cumulative storage changes at the end of each period are also presented.

The results show that for Base Case 1, water deficits would continue to increase steadily through the planning horizon, reaching a cumulative storage decline of 1.5 million acre-feet by 2040. The deficits increase during the period because total inflows increase by 7.7% while total outflows increase by 14.7%. While their total recharge fluxes are identical, simulations for the variable Case 2 and reversed variability Case 3 result in values of cumulative storage declines that are over 1.2 million acre-feet apart by 2040. The difference is mostly due to a difference in underflow into the Kaweah Subbasin of over 1 million acre-feet between the two cases. The reversal of fluxes also changes the water balance dynamics and results in intermediate storage deficits that are more severe in Case 3 than in Case 2. While future sequences of wet and dry water years cannot be predicted, the results suggest that Kaweah GSAs could benefit from contingency planning for interim deficits resulting from unfavorable water year sequences.

The results for Case 4 show that implementation of Management Actions could yield a 6% reduction in pumping from agricultural wells, resulting in a 4.4% reduction in total outflow relative to Case 1. Over the 20-year planning horizon, this translates to a 46% reduction in cumulative storage decline. The combination of Projects and Management Actions in Case 5 yields an 8.3% increase in recharge and a 2.8% reduction in total outflow. The net impact of the changes from Case 5 is a 79.9% reduction of the average annual storage decline from 71,500 acre-feet/year (or 1,501,901 acre-feet in 21 years) to 15,100 acre-feet/year (or 316,370 acre-feet in 21 years) from January 2020 to December 2040.

*Table 5: Impacts of Projects and Management Actions on Groundwater Fluxes and Storage in the Kaweah Subbasin.*

| Period in Water Years | Inflow (Acre-Feet/Year) Recharge | Inflow: Underflow Buffer to KSB | Inflow: Total Inflow | Outflow (Acre-Feet/Year) Ag Pumping | Outflow: Aquifer Discharge to Stream | Outflow: Non-Ag Pumping | Outflow: Underflow KSB to Buffer | Outflow: Total Outflow | Change in Storage (Acre-Feet/Year) | Cumulative Change in Storage (Acre-Feet) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Case 1: Base Case of Future with Averaged Conditions and No Projects** | | | | | | | | | | |
| 2020 | 676,105 | 185,429 | 861,534 | 726,105 | 0 | 101,360 | 60,420 | 887,886 | -26,352 | -26,352 |
| 2021 - 2025 | 674,117 | 206,914 | 881,031 | 747,316 | 0 | 108,481 | 62,235 | 918,032 | -37,001 | -211,359 |
| 2026 - 2030 | 674,117 | 218,869 | 892,987 | 783,289 | 0 | 120,729 | 64,877 | 968,895 | -75,908 | -590,899 |
| 2031 - 2035 | 674,106 | 236,257 | 910,364 | 803,716 | 0 | 132,728 | 64,898 | 1,001,341 | -90,977 | -1,045,786 |
| 2036 - 2040 | 674,566 | 253,312 | 927,878 | 813,133 | 0 | 141,028 | 64,940 | 1,019,101 | -91,223 | -1,501,901 |
| **Case 2: Future with Interannual Variability and No Projects** | | | | | | | | | | |
| 2020 | 927,137 | 157,959 | 1,085,096 | 503,909 | 0 | 94,915 | 68,183 | 667,008 | 418,089 | 418,089 |
| 2021 - 2025 | 709,912 | 206,077 | 915,990 | 680,497 | 521 | 99,663 | 57,998 | 838,678 | 77,311 | 804,646 |
| 2026 - 2030 | 653,687 | 203,723 | 857,410 | 765,822 | 229 | 123,965 | 71,984 | 962,000 | -104,590 | 281,694 |
| 2031 - 2035 | 666,604 | 225,936 | 892,540 | 810,017 | 213 | 143,603 | 88,081 | 1,041,913 | -149,373 | -465,173 |
| 2036 - 2040 | 618,801 | 274,083 | 892,883 | 945,506 | 55 | 135,831 | 81,597 | 1,162,989 | -270,106 | -1,815,704 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Case 3: Future with Interannual Variability Reversed and No Projects** | | | | | | | | | | |
| 2020 | 1,191,324 | 173,864 | 1,365,188 | 507,156 | 43 | 143,667 | 103,103 | 753,969 | 611,219 | 611,219 |
| 2021 - 2025 | 479,819 | 243,678 | 723,498 | 1,040,180 | 239 | 143,185 | 85,176 | 1,268,779 | -545,282 | -2,115,190 |
| 2026 - 2030 | 659,066 | 281,360 | 940,425 | 821,914 | 179 | 137,714 | 68,758 | 1,028,566 | -88,140 | -2,555,892 |
| 2031 - 2035 | 671,770 | 308,325 | 980,094 | 719,378 | 72 | 113,587 | 50,052 | 883,089 | 97,005 | -2,070,868 |
| 2036 - 2040 | 780,164 | 276,155 | 1,056,320 | 606,836 | 520 | 94,432 | 58,089 | 759,876 | 296,443 | -588,650 |
| **Case 4: Altered Future with Management Actions** | | | | | | | | | | |
| 2020 | 681,104 | 184,922 | 866,026 | 722,860 | 0 | 101,360 | 60,625 | 884,845 | -18,819 | -18,819 |
| 2021 - 2025 | 679,116 | 204,412 | 883,529 | 739,493 | 0 | 108,481 | 63,114 | 911,088 | -27,560 | -156,619 |
| 2026 - 2030 | 679,116 | 210,690 | 889,805 | 755,265 | 0 | 120,729 | 67,164 | 943,158 | -53,353 | -423,384 |
| 2031 - 2035 | 679,116 | 217,985 | 897,100 | 743,447 | 0 | 132,870 | 69,283 | 945,600 | -48,500 | -665,881 |
| 2036 - 2040 | 679,611 | 220,124 | 899,735 | 712,386 | 0 | 144,094 | 72,166 | 928,646 | -28,911 | -810,436 |
| **Case 5: Altered Future with Management Actions and Projects** | | | | | | | | | | |
| 2020 | 693,019 | 184,909 | 877,928 | 722,860 | 0 | 102,029 | 60,664 | 885,553 | -7,625 | -7,625 |
| 2021 - 2025 | 709,227 | 199,605 | 908,833 | 740,079 | 0 | 108,555 | 64,540 | 913,174 | -4,342 | -29,332 |
| 2026 - 2030 | 728,472 | 199,572 | 928,043 | 760,614 | 0 | 120,771 | 70,815 | 952,199 | -24,156 | -150,112 |
| 2031 - 2035 | 753,547 | 201,107 | 954,655 | 756,950 | 0 | 133,173 | 77,059 | 967,182 | -12,526 | -212,744 |
| 2036 - 2040 | 738,199 | 201,171 | 939,369 | 734,500 | 0 | 144,715 | 80,879 | 960,094 | -20,725 | -316,370 |

# Summary Results by GSA

## Summary Results for East Kaweah GSA

Table 6 is a summary of predictive modeling results for East Kaweah over the 20-year planning horizon. Case 4 and Case 5 result in the lowest annual water deficit (noted as "Change in Storage" in Table 6 and subsequent tables). The results indicated that implementation of Management Actions in Case 4 could reduce well pumping by 13,900 acre-feet/year and reduce the annual water deficit from 16,200 acre-feet/year to 6,600 acre-feet/year. The combination of Management Actions and Projects in Case 5 increases total inflow by 8,900 acre-feet/year, and the annual water deficit falls to 3,000 acre-feet/year.

*Table 6: Summary of Predictive Modeling Results for East Kaweah in Acre-Feet per Year*

| Summary Results for East Kaweah GSA | Base Case 1 | Variable Base Case 2 | Reversed Variable Case 3 | Management Actions Case 4 | Management & Projects Case 5 |
|---|---|---|---|---|---|
| **Recharge** | 118,096 | 118,064 | 117,445 | 118,107 | 126,632 |
| **Inflow from Buffer Zone** | 48,298 | 42,370 | 50,735 | 45,408 | 44,830 |
| **Inflow from Greater Kaweah** | 34,417 | 36,925 | 33,253 | 34,643 | 38,227 |
| **Total Inflow** | 200,811 | 197,360 | 201,434 | 198,159 | 209,689 |
| **Pumping from Ag Wells** | 166,025 | 166,324 | 164,666 | 152,120 | 159,167 |
| **Aquifer Discharge to Streams** | | 0 | 0 | | |
| **Pumping from Non-Ag Wells** | 2,842 | 2,669 | 2,652 | 2,842 | 2,796 |
| **Outflow to Buffer Zone** | 6,267 | 6,048 | 5,661 | 6,563 | 6,574 |
| **Outflow to Greater Kaweah GSA** | 41,843 | 44,553 | 42,017 | 43,278 | 44,121 |
| **Total Outflow** | 216,977 | 219,595 | 214,996 | 204,803 | 212,658 |
| **Annual Change in Storage** | -16,166 | -22,235 | -13,563 | -6,644 | -2,969 |

## Summary Results for Greater Kaweah GSA

Table 7 shows a summary of predictive modeling results for Greater Kaweah over the 20-year planning horizon. In Greater Kaweah, the Reversed Variable Case 3 achieves better reduction in water storage decline than the Management Actions Case 4. However, the results of Case 3 are unreliable for planning as the reductions occur due to significant increases in uncontrolled inflow from the buffer region relative to Case 2. The results for Case 4 indicate that implementation of Management Actions could reduce well pumping by 29,100 acre-feet/year relative to Case 1 and reduce the annual water deficit from 37,300 acre-feet/year to 20,800 acre-feet/year. The combination of Management Actions and Projects in Case 5 increases total inflow by 15,500 acre-feet/year relative to Case 1, and the annual water deficit falls to 5,400 acre-feet/year.

*Table 7: Summary of Predictive Modeling Results for Greater Kaweah in Acre-Feet per Year*

| Summary Results for Greater Kaweah GSA | Base Case 1 | Variable Base Case 2 | Reversed Variable Case 3 | Management Actions Case 4 | Management & Projects Case 5 |
|---|---|---|---|---|---|
| **Recharge** | 375,882 | 376,172 | 375,755 | 375,946 | 412,038 |
| **Inflow from Buffer Zone** | 177,354 | 180,487 | 219,638 | 165,516 | 153,823 |
| **Inflow from East Kaweah** | 41,843 | 44,553 | 42,017 | 43,278 | 44,121 |
| **Inflow from Mid-Kaweah** | 78,872 | 95,441 | 77,646 | 80,407 | 79,441 |
| **Total Inflow** | 673,950 | 696,653 | 715,056 | 665,148 | 689,424 |
| **Pumping from Ag Wells** | 469,694 | 470,276 | 468,868 | 440,620 | 440,625 |
| **Aquifer Discharge to Streams** | - | 242 | 242 | - | - |
| **Pumping from Non-Ag Wells** | 41,251 | 40,544 | 41,703 | 41,573 | 41,676 |
| **Outflow to Buffer Zone** | 48,322 | 58,435 | 53,653 | 51,085 | 55,910 |
| **Outflow to East Kaweah GSA** | 34,417 | 36,925 | 33,253 | 34,643 | 38,227 |
| **Outflow to Mid-Kaweah GSA** | 117,527 | 133,587 | 131,464 | 117,982 | 118,389 |
| **Total Outflow** | 711,211 | 740,010 | 729,182 | 685,903 | 694,826 |
| **Annual Change in Storage** | -37,261 | -43,357 | -14,126 | -20,755 | -5,402 |

## Summary Results for Mid-Kaweah GSA

Table 8 shows a summary of predictive modeling results for Mid-Kaweah over the 20-year planning horizon. In Mid- Kaweah, the Reversed Variable Case 3 achieves better reduction in water storage decline than Case 4 and Case 5. However, the results of Case 3 are unreliable for planning as the reductions occur due to significant reductions in uncontrolled outflows to Greater Kaweah. The results for Case 4 indicate that implementation of Management Actions could reduce well pumping by 4,000 acre-feet/year relative to Case 1 and reduce the annual water deficit from 18,100 acre-feet/year to 11,100 acre-feet/year. The combination of Management Actions and Projects in Case 5 increases total inflow by 5,300 acre-feet/year relative to Case 1, and the annual water deficit falls to 6,700 acre-feet/year.

*Table 8: Summary of Predictive Modeling Results for Mid-Kaweah in Acre-Feet per Year*

| Summary Results for East Kaweah GSA | Base Case 1 | Variable Base Case 2 | Reversed Variable Case 3 | Management Actions Case 4 | Management & Projects Case 5 |
|---|---|---|---|---|---|
| **Recharge** | 180,338 | 180,627 | 180,391 | 185,275 | 191,817 |

| | | | | | |
|---|---|---|---|---|---|
| **Inflow from Buffer Zone** | 1,120 | 1,288 | 2,077 | 1,027 | 975 |
| **Inflow from Greater Kaweah** | 117,527 | 133,587 | 131,464 | 117,982 | 118,389 |
| **Total Inflow** | 298,985 | 315,503 | 313,932 | 304,284 | 311,181 |
| **Pumping from Ag Wells** | 148,251 | 149,738 | 149,738 | 144,204 | 147,046 |
| **Aquifer Discharge to Streams** | - | - | - | - | - |
| **Pumping from Non-Ag Wells** | 80,488 | 81,083 | 78,895 | 80,930 | 81,152 |
| **Outflow to Buffer Zone** | 9,466 | 10,111 | 7,995 | 9,936 | 10,236 |
| **Outflow to Greater Kaweah GSA** | 78,872 | 95,441 | 77,646 | 80,407 | 79,441 |
| **Total Outflow** | 317,077 | 336,373 | 314,274 | 315,477 | 317,875 |
| **Change in Storage** | -18,092 | -20,870 | -342 | -11,193 | -6,694 |

## Conclusions and Recommendations

The Kaweah Subbasin Basin Setting Report estimates the basin Safe Yield at 720,000 acre-feet per year and the average annual groundwater pumping in the basin during the current water budget period is 798,000 acre-feet. Therefore, a reduction in deficit of 121,000 acre-feet through the implementation of projects and management actions will ensure that we are operating within the safe yield of the basin.

Through the five-year GSP assessment process and continued dialogue with neighboring subbasins as to their role in influencing the changes in storage within the Kaweah Subbasin, we expect to have improvements in our understanding of boundary conditions. Future updates to the groundwater model are expected to show stabilized groundwater levels through the implementation of the projects and management action considered in the GW modeling study. If residual storage reductions remain from these future modeling scenarios analyzed at the five year update, the GSAs will take further action to stabilize groundwater levels and reductions in storage with the implementation of additional projects and/or accelerated implementation of management actions designed to reduce groundwater extractions.

Under some modeling scenarios (such as the Reversed Variable Case 3), water levels within the buffer region can become misaligned with changing water levels within the subbasin. The misaligned water levels can significantly alter the amount of inflow or outflow moving across the buffer region or between neighboring GSAs, altering the patterns of water storage declines. Such transboundary flows are not sustainable over the long term and should not be relied upon to achieve sustainability targets. Future groundwater modeling efforts should identify approaches to account for transboundary flows to ensure reduction in water storage decline are achieved through sustainable approaches.

The Kaweah Subbasin groundwater model produced a fit between measured and model-generated data with a relative error of 3% in layer 1 and 10.7% in layer 3 during model calibration. This was determined to be an adequate fit for the planning model for GSP development. As the Kaweah Subbasin GSAs move from plan development to implementation, it is recommended that further resources be dedicated to the calibration of the model to enhance its accuracy and reliability as a decision-making tool.

# Appendix 1: Model Approach and Verification

## Introduction: Kaweah Groundwater Modeling

The purpose of this update is to communicate the current progress of the groundwater modeling efforts for Kaweah Subbasin. It was compiled from materials originally published on the Kaweah Subbasin website in March 2017 under the heading “Review of Existing Kaweah Subbasin GW Models and Approach for Model Development to Support GSP”.

Early in 2017, the GEI Consultants, Inc. (GEI) and GSI Water Solutions, Inc. (GSI) teams prepared a Technical Memorandum (TM) to evaluate the groundwater models available for use in development of the Groundwater Sustainability Plans (GSP) for the three Groundwater Sustainability Agencies (GSA) in the Kaweah Sub- Basin (Subbasin). That TM, dated March 8, 2017, presented the significant comparative details of three numerical groundwater flow models that cover the Sub- Basin, including:

- Kaweah Delta Water Conservation District (KDWCD) Groundwater Model,
- Central Valley Hydrologic Model (CVHM), and
- California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) coarse grid and fine grid variants.

The March 2017 TM identified the water budget from the most recent update of the KDWCD Water Resources Investigation (WRI) as an accounting "model", but it is essentially a water accounting analysis that uses water consumption and soil moisture models. It is not a three-dimensional, numerical groundwater flow model, but is a valuable analysis that will be used as primary inputs to the groundwater model. The March 2017 TM recommended use of the KDWCD Groundwater Model as the preferred tool for Sustainable Groundwater Management Act (SGMA) applications based upon its relative ability to address the potential model needs cited in SGMA regulations. Model selection criteria used in the TM included: model availability; cost of development and implementation; regulatory acceptance; suitability for GSP-specific analyses; and relative abilities to assess Subbasin water budget components, future undesirable results, and impacts of future management actions and projects.

More recently, the Kaweah Management Team, consisting of the East Kaweah, Greater Kaweah, and Mid-Kaweah Groundwater Sustainability Agencies (EKGSA, GKGSA, and MKGSA) approved a scope of work to develop a Subbasin wide numerical groundwater model to support GSP development and implementation. Efforts related to groundwater model development and use of the calibrated tool were generally defined within three tasks, as follows:

- Task 1 — Perform a technical assessment of existing groundwater models that cover the Kaweah Subbasin, with emphasis on the KDWCD Model, and develop an approach to update and revise the selected source model as required to support the objectives of the GSP.
- Task 2 — Perform model revisions and updates for the selected groundwater model as documented in Task 1, with a focus on supporting GSP objectives.
- Task 3 — Apply the updated model predictively for each GSA and cumulatively for the entire Subbasin to simulate future conditions, with and without potential management actions and projects proposed to support GSP implementation.

This TM documents the results of Task 1. GEI and GSI (the Modeling Team), as part of supporting Subbasin SGMA compliance, have evaluated the existing KDWCD Groundwater Model for update to simulate the entire Subbasin and relevant adjacent areas. The following presents technical details and performance aspects of the KDWCD Model and proposes a general approach for utilizing the model to support development of the GSP. Specifics of this approach may change over the course of model development as dictated by data constraints and improved conceptualization provided by the updated Subbasin Basin Setting developed through the Management Team. This TM and associated analyses satisfy Task 1 requirements, including:

- Perform a detailed evaluation of the existing KDWCD groundwater model inputs and outputs, including test runs and simulations, comparisons with water budget data, and a general comparison with regional C2VSim and CVHM models.
- Develop a plan to move forward with the model update, including assessment of status of required hydrogeologic data, updates to model area, parameters, fluxes, spatial framework, stress periods, validation periods, and calibration periods and general approach for the model domain.
- Prepare a TM summarizing the path forward for modeling support of the GSP, including technical coordination with adjacent basin GSA representatives regarding groundwater modeling methods and assumptions.

Additionally, the Modeling Team will present the key findings of this TM in a workshop for representatives of the Subbasin GSAs. This working session will allow GSA representatives to better understand the model design and capabilities as well as provide a forum for discussion of current, future, and outstanding data as well as planning needs for model development and predictive simulations.

After submittal of this proposed modeling approach and path forward, the Modeling Team will execute the recommended actions described in this document. Once updated, the Modeling Team is recommending adoption of the name Kaweah Sub- Basin Hydrologic Model (KSHM) for this new SGMA tool to differentiate it from the previous modeling efforts and to reflect the fact that it includes complex hydrologic analyses in addition to groundwater flow.

The Modeling Team previously performed a cursory review of pertinent aspects affecting the efficient use of the three major groundwater modeling tools that cover the Subbasin. This TM is built upon that analysis and includes a more in-depth assessment of the newly released beta version of the C2VSim model provided by the California Department of Water Resources (DWR). Although the results of the March 2017 analysis were reinforced with findings from this review, the Modeling Team also looked at the datasets contained within these valuable, regional modeling tools to see if they may be of use in the development of the KSHM.

CVHM is an 11-layer model that covers the entire Central Valley. It has a spatial resolution of one square mile and includes both a coupled lithologic model and Farm Process module (model) that are used to estimate hydraulic parameters and agricultural groundwater demand and recharge, respectively. The CVHM was previously deemed not to be a viable modeling alternative for the Subbasin analyses by the Modeling Team due to several factors. Most significant of these is the fact that the model data is only current to 2009, well before the SGMA-specified accountability date of 2015. The model resolution is also not suitable to reflect all water budget components at the precision required to assess past and current groundwater responses to water management within each GSA. The CVHM is also not suitably calibrated nor reflective of the hydrostratigraphy in the Subbasin and does not match the higher resolution and more accurate crop and related groundwater pumping estimates produced by Davids Engineering, Inc. (Davids Engineering) time-series analysis of evaporation and applied water estimates for the KDWCD; soon to be provided for the entire Subbasin through water year 2017.

Lastly, the use of the Farm Process is cost prohibitive, given the fact that it would have to be rigorously calibrated to the evapotranspiration and deep percolation estimates already provided by the Davids Engineering analysis.

The DWR-supported C2VSim Fine Mesh Beta Version was assessed in greater detail as part of the development of this modeling approach. Like CVHM, the C2VSim fine mesh does not include the high resolution of crop demands and surface water deliveries that are in the existing KDWCD model and can be easily updated with the KSHM. It also does not have the element resolution, flexibility to change fluxes, cost savings, and GSA-level accuracy of a sub-regional model designed to incorporate the highest resolution and locally accurate consumptive use and recharge information available. The Modeling Team assessed model layering, significant water budget components, storage change, and groundwater level elevation changes used in C2VSim relative to KDWCD monitoring well locations. The previous KDWCD model produced a better match for the data and estimates from the WRI, and at a significantly higher resolution. Simulated storage change within the Sub- Basin was greater than that estimated by C2VSim by over 20,000 acre-feet per year (AFY); without documentation of how the quantification of water budget components was performed. Calibration of regional flow directions and gradients were reasonable but not as accurate nor locally refined as that observed with the KDWCD modeling efforts.

The beta version of the C2VSim model is not currently considered to be calibrated in a quantitative sense, and no documentation is publicly available to assess the resolution or accuracy of the model inputs for the Subbasin. Because of our analysis and comparison of the C2VSim Fine Mesh Beta Model with the water budget and groundwater conditions from the WRI and the draft Basin Setting; the C2VSim was deemed to be a viable source of regional information to supplement development of the KSHM. However, relative to a modeling approach using the KSHM, the C2VSIM model would not provide a more accurate or cost-efficient option for satisfying SGMA regulations.

The KDWCD Groundwater Model was originally developed by Fugro Consultants, Inc. (Fugro) under the direction and sponsorship by KDWCD. Model development was documented in the report "Numerical Groundwater Flow Model for the Kaweah Delta Water Conservation District, Final Report" (April 2005). The objective of the model was to simulate the water budget estimates as refined under the WRI in 2003 and evaluate calibrated groundwater elevations, and modeled fluxes to and from adjacent subbasins.

In May 2012, the KDWCD model was expanded to the east and southeast by Fugro to include the service areas of the Cities of Lindsay and Exeter, and adjacent irrigation districts, including: the Lewis Creek Water District; some unincorporated land and significant portions of Exeter Irrigation District, Lindmore Irrigation District, and Lindsay-Strathmore Irrigation District. The purpose of this effort was to update only the geographic extent, and it did not include updates to the simulation period or the calibration. The model was intended to be updated, refined, and improved in the coming years to provide a rigorously calibrated model over this larger extent, but this proposed work was not performed prior to initiation of SGMA and GSP development efforts.

## Modeling Code and Packages

The KDWCD model was developed using MODFLOW 2000. MODFLOW, developed and maintained by the United States Geological Survey (USGS), is one of the most commonly used groundwater modeling codes in the world and is considered an industry standard. The pre- and post-processing of groundwater model data was performed using Groundwater Vistas, a third-party graphical user interface (GUI) that is among the most commonly used software in the groundwater industry to facilitate the use of MODFLOW.
The previous two KDWCD model variants used the following MODFLOW modules, or "packages":

- Well Package (WELL) Recharge
- Package (RCH)
- General Head Boundary (GHB) Package

MODFLOW utilizes large text files of numerical values as input files that provide the model with the values of various physical parameters and fluxes; all incorporated into the three-dimensional (3D) model structure. Much of the pre-processing and spatial organization of the data used to develop the MODFLOW input files was accomplished by Fugro using customized FORTRAN routines, as well as a geographic information system (GIS). Because of more recently available evapotranspiration and applied water estimates from Davids Engineering, the use of these FORTRAN routines is no longer necessary; providing a significant cost and time savings.

A summary of the construction and implementation of various water budget components into these model packages is discussed in following sections.

### Model Extent and Discretization

The spatial extent of the KDWCD model is presented in Figure 1. The figure displays the original model extent as well as the expanded extent to the east from the 2012 update. The model extends approximately twelve miles from east to west and 7.5 miles from north to south. It is composed of uniform 1,000 foot by 1,000- foot model cells for each layer.
There are some areas of the Subbasin that are not currently within the model domain (Figure 1), including much of what is now the EKGSA area. To evaluate the entire Subbasin area, in support of SGMA, it will be necessary to expand the model area to include all of the areas within the Subbasin. The updated model must also have shared boundaries and shared buffer zones with all adjacent groundwater sub- basins, as well as an evaluation of subsurface inflow and outflow (underflow) between the subbasins. Figure 2 shows the proposed, expanded model grid for the new KSHM extent.

### Model Layers

The KDWCD model is vertically discretized into three layers as shown on hydrogeologic cross sections shown on Figures 3, 4, and 5. These hydrogeologic cross sections show the principal aquifers, aquitard, and associated geologic units located throughout the Subbasin. Layer 1 represents the unconfined, basin sediments from the ground surface down to the Corcoran Clay in the western portion of the model domain or deeper; also including some older Quaternary alluvial deposits in the eastern portion of the domain. Layer 2 represents the Corcoran Clay, which is the primary aquitard in the Subbasin, where it is present in the western portion of the domain. In the eastern portion of the model area, where the Corcoran Clay pinches out, Layer 2 is simply represented with a minimal thickness and hydraulic parameters comparable to those of Layer 1. Layer 3 represents the largely confined basin sediments below the Corcoran Clay, where it is present, and deeper unconsolidated sediments to the east of the occurrence of this regional confining unit.

Although some of the regional models covering large areas of the Central Valley (i.e., CVHM and C2VSim) have a more highly discretized vertical layering, the Modeling Team believes that the three-layer conceptual model represented in the KDWCD model is justified given the available data and therefore suitable for the primary modeling objectives that support GSP development.

### Model Simulation Time Periods

The KDWCD model was originally set up with 38 6-month stress periods to simulate the 19-year (calendar) calibration period of 1981 through 1999. Water budget components as documented in the 2003 WRI were used as input into the model and spatially distributed to the degree feasible given the spatial resolution and precision of the data sources and model grid.

It is likely that, after any recommended changes to the KDWCD model are implemented into the KSHM, the Modeling Team will calibrate the model through water year 2017 and perform validation simulations to confirm that the previous calibration developed with the historic WRI information is a suitable starting point the new simulation period. After validation, additional model refinements and updates can proceed to further improve the predictive capabilities of the KSHM using the aforementioned recent, high-resolution datasets as well as updated Basin Setting information.

## Model Parameters

- **Hydraulic Conductivity/Transmissivity.** Hydraulic conductivity values are documented in the 2005 Model Report as well as in previous iterations of the WRI and conform with industry-standard literature values for the types of aquifer materials encountered at these depth intervals. Calibrated, horizontal hydraulic conductivities for Layer 1 (upper, unconfined aquifer) range from 50 feet/day (ft/d) to 235 ft/d, with the highest values in the southwest portion of the model area. Horizontal hydraulic conductivities for the portion of Layer 2 representing the Corcoran Clay were set at 0.024 ft/d. In the eastern area of Layer 2, where the Corcoran Clay pinches out, hydraulic conductivity values range from 50 to 150 ft/d and are essentially equal to the values assigned to the same area in Layer 1. Horizontal hydraulic conductivities for Layer 3 range from 25 ft/d to 125 ft/d. This distribution of hydraulic conductivity is consistent with previously published estimates from both the WRI and industry-standard literature estimates for the lithologies encountered.
- **Vertical Hydraulic Conductivity.** Vertical hydraulic conductivity in the model is set to a ratio of the estimated horizontal hydraulic conductivity, or an anisotropy ratio of 1:1. This means that the vertical hydraulic conductivity of the Corcoran Clay was assumed to be equal to its horizontal conductivity and was apparently based upon the extensive perforation of the Corcoran Clay and other aquifer units by fully penetrating wells. This perforation of the regional aquitard allows for greater hydraulic connection between the upper and lower aquifer units. The Modeling Team will assess the validity of this anisotropy ratio during the validation simulation and adjust where merited.
- **Storage Parameters.** Specific yields in the unconfined aquifer (Layer 1) range from approximately 8% to 14%. Storage coefficients for the confined areas were set at an order of magnitude of approximately 1 x 10-4. The storage coefficients used for the unconfined and the confined portions of the model are typical of those found in the basin and documented in the WRI as well as other commonly referenced literature for large basin fill valleys.

## Model Boundary Packages and WRI Water Budget Components

As mentioned previously, the KDWCD model uses three MODFLOW packages: WELL, RCH, and GHBs. A discussion of how those packages are used follows below.

- **Well Package (WELL).** As currently constructed, the KCWCD model represents the following WRI water budget components; which were calculated outside of the model Groundwater Vistas graphical user interface (GUI) using GIS and a FORTRAN routine that are unavailable to the Modeling Team. The flux values specified in the WELL package input files are essentially "lumped" fluxes representing the sum of the following water budget components:
  - Well pumpage (outflow)
  - Rainfall-based recharge (inflow)
  - Irrigation return flows (inflow)
  - Ditch loss (inflow)
  - Recharge basins (inflow)

The compilation of multiple water budget components into a single MODFLOW package makes tracking and assessment of the individual water budget components from model simulations difficult. Additionally, this model flux accounting approach and design makes evaluation of possible changes in the water budget because of management actions, changes in water demand or availability, and groundwater projects problematic. Because of this lumping of separate water budget components, every cell in Layer 1 is represented in the WELL Package. This makes the exact validation of the test runs and verification of the calibration with the WRI challenging. Without access to the spatial and temporal distributions of all water budget components utilized by Fugro, it is not possible to recreate the exact WELL package input file. However, the gross water budget inflow, outflow and storage values from the earlier WRI's match those simulated by the model and were reproduced by the Modeling Team.

- Recharge Package (RCH). The natural stream channels of the St. John's and the Lower Kaweah Rivers are represented in the model using the MODFLOW RCH Package. The RCH package applies a flux (ft/yr) in the surficial (shallowest) cells at the location where applied. The natural seepage flux values (or groundwater recharge) applied to the model correspond to the values of stream infiltration spatially estimated for these rivers and documented in the WRI.
- General Head Boundaries (GHB). The KDWCD model has GHBs assigned to all cells on the exterior perimeter of the model, as seen on Figure 1. GHBs are commonly used to represent the edges of a model domain within a larger aquifer extent. Reference heads (groundwater elevations) and "conductance" terms for adjacent aquifers just outside the model domain are used by this package to calculate fluxes in and out across the boundary. The Modeling Team generally agrees with the use of GHBs in the north, south, and west portions of the Subbasin. However, we propose the removal of the GHBs along the eastern portion of the subbasin at the Sierra Nevada mountain front. Conceptually, the eastern model boundary, especially with the expansion and inclusion of the EKGSA area, is not a head-dependent boundary, but a flux-dependent one based on mountain front recharge and seepage from natural drainages and streams adjacent to relatively impermeable material. Thus, this boundary is better represented using a no-flow condition coupled with a recharge or prescribed underflow component.

Previous WRIs have included estimates of inflow and outflow across the study boundaries, and comparisons between modeled and calculated values vary significantly both spatially and by magnitude. However, there are several variables that directly impact estimated underflow values that have not been sufficiently constrained, due to the focus of previous work being on the interior of the KDWCD area. Recently updated basin conditions, improved understanding of appropriate regional groundwater conditions adjacent to the Subbasin and use of an expanded model area will significantly improve the certainty of these underflow estimates.

- Model Calibration. Calibration of the KDWCD model for the historic simulation period of 1981-1999 is discussed in the April 2005 model report. These include charts of observed versus modeled water levels for three different time periods and transient hydrographs for 30 target well locations. The density of calibration targets was deemed adequate by the Modeling Team for a model of this area and with the resolution of the model input datasets. Detailed calibration statistics are not documented in the report, but qualitative inspection of the hydrographs indicates that the calibration is adequate for future use in predictive simulations. Additionally, an open-source and industry-standard parameter estimation and optimization algorithm and code (PEST) was used to enhance model calibration. This is a common and robust industry practice that typically improves model calibration statistics.

## Adequacy of the KDWCD Groundwater Model for GSP Development

Layering Scheme. The 3-layer model layering scheme incorporated into the KDWCD model was deemed adequate by the Modeling Team for use in GSP analyses, and likely does not need significant revision prior to use. This decision was based upon the agreement of the model layers with the hydrogeologic conceptual model for the Subbasin as well as the ability of the previous model to simulate historic fluctuations in groundwater elevations over an extensive spatial extent and temporal period. However, should the refinement of the lithologic and stratigraphic understanding of the basin and identification of specific pumping intervals require additional vertical resolution, both Layer 1 and Layer 2 can be split into two layers to improve the model's ability to match and describe key vertical gradients and changes in groundwater level elevations and pressures near prominent pumping centers. At present, this vertical refinement is not required nor supported by data.

Model Area. The model area will need to be expanded so that the entire Subbasin is included in the model. In addition, at the request of and in coordination with the technical groups for both Kaweah and adjacent subbasins, a buffer zone will be included outside the defined Subbasin boundaries so that adjacent models will overlap and share model input and monitoring data. This overlap will assist in reconciling differences between the direction and magnitude of groundwater gradients along subbasin boundaries. The preliminary extent of this buffer zone is proposed to be approximately 3 miles; however, this value will be revised in areas based on of the estimated locations of pervasive groundwater divides or apparent hydrologic boundaries.

Cell Size. The 1,000 feet square cell size appears to be adequate for the data density for most model inputs. However, due to improvements in computing speed and power, the Modeling Team recommends initially using a smaller cell size of 500 feet square to 1) accommodate improvements in assigning real world boundaries to the model grid, and 2) leverage the improved resolution of crop demand and evapotranspiration data available for this effort.

Parameters. Hydraulic conductivity and storage parameters will remain unchanged at the start of model revisions and calibration scenarios. These will be adjusted if the Modeling Team determines it is necessary during the model validation run or if model calibration standards require parameter refinements.

Stress Periods. The previous temporal discretization of the model incorporated 6- month stress periods. To appropriately characterize seasonal rainfall, surface water delivery and pumping patterns; one-month stress periods should be adopted for predictive simulations. This decision will be finalized after review and conditioning of the input groundwater demand and recharge datasets.

With these revisions to the model framework and geometry of the KDWCD model to support the development of the KSHM will be adequate for use to support GSP analyses. The following section summarizes additional, recommended revisions to the organization of the model inputs, parameters, boundary conditions, and MODFLOW packages.

### Proposed Revisions to KDWCD Groundwater Model and Model Approach

The Modeling Team concludes that the KDWCD model is suitable to support GSP development if the following revisions and refinements to the model are performed to develop the KSHM. As mentioned above, once updated, the Modeling Team is recommending adoption of the name Kaweah Subbasin Hydrologic Model for this new SGMA tool. This nomenclature is based upon that fact that this model incorporates more than simply a groundwater model in the final analysis. It also incorporates crop demand/evapotranspiration (with precipitation modeling) and applied water models.

The Modeling Team recommends that the relationships between the water budget components, as defined in the WRI (December 2003, revised July 2007), and the MODFLOW modeling packages currently available, be re-organized such that lumping of different water budget components within single MODFLOW packages is minimized. Some degree of aggregation may be unavoidable, but efforts will be made to apply unique water budget components from the updated WRIs and associated water budget components to more appropriate and recent MODFLOW packages.

Additionally, we will utilize features of MODFLOW and Groundwater Vistas that allow for tracking of unique components within a single model package when possible. The current and proposed revised conceptual assignments of water budget components to MODFLOW packages are summarized below.

A major change and advantage of this effort relative to previous modeling work involves the availability and use of time-series evapotranspiration and applied water estimates from 1999 through water year 2017, provided by Davids Engineering. This data set uses remote sensing imagery from Landsat satellites to estimate agricultural water demand throughout the Subbasin at a very high resolution (approximately 30 meters). This information was not available for previous model builds, and its use will not only improve the understanding and accuracy of agricultural water requirements relative to the previous land use and soil moisture balance calculations that have been used, but also enhance the spatial calibration and predictive capability of the updated and expanded KSHM. The Davids Engineering dataset also includes estimates of deep percolation of applied water and precipitation. During the review of the KDWCD model and development of this modeling approach, the Modeling Team performed testing of the use of this dataset and was able to readily develop crop requirements and associated pumping estimates at a resolution even finer than the proposed model resolution.

Well Pumping. Groundwater pumpage will be the dominant water budget component represented in the WELL package. Other, more limited fluxes may also be used to represent mountain front fluxes or other unforeseen fluxes that are specified but do not have a specific package that is appropriate. All pumpage will be coded within the WELL package input files to identify the pumping by source, use, or entity. Municipal wells will be specifically located and simulated when well permits and required data reports are accessible and provide data specific to each well. Agricultural well pumpage will likely be spatially averaged, or "spread across", irrigated areas because of the uncertainty associated with irrigation well location, construction, and monthly or seasonal pumping rates.

Precipitation-based recharge. The Modeling Team proposes to represent this water budget component using the Recharge package.

Natural channel infiltration. Infiltration of surface water in the natural stream channels of the St. John's and the Lower Kaweah Rivers is currently assigned to the Recharge Package. The Modeling Team proposes to maintain this data in the recharge package along the spatial location of the courses of the rivers. If deemed appropriate and more beneficial the latest version of the Stream Package (SFR2) may be used for localized reaches of continuously flowing water, where gages do not adequately monitor seepage that can be applied directly as recharge. The Stream package calculates infiltration (inflow) to the aquifer based on defined parameters regarding bed geometry and vertical conductivity, and this will likely involve some iterative re-definition of STREAM package components to accurately portray the calculated water budget component flux. Native evapotranspiration (ET), where relevant, will be subtracted from either the precipitation or natural channel infiltration modules. The inclusion of natural, riparian ET will be addressed specifically upon finalization of the water budget for the Subbasin.

Man-made channel recharge. (i.e., ditch and canal loss). This is currently incorporated with four other water budget components as a single summed value in the Well Package. The Modeling Team proposes to represent this water budget component using either the Recharge package or another Type 3 boundary condition type, such as a prescribed stage above land surface. Should another more advanced MODFLOW module prove to more effective in simulating this flux, it will be utilized, and the reasoning documented in the model development log.

Irrigation Return Flows. Irrigation return flows are the component of the water budget that infiltrates into the subsurface due to over-watering of crops. This is currently incorporated with four other water budget components as a single summed value in the Well Package. The Modeling Team proposes to represent this water budget component using the Recharge package, but to differentiate it from precipitation-based recharge within Groundwater Vistas by assigning zone identifiers that are different from the rainfall-based recharge.

Artificial Recharge Basins. This is currently incorporated with four other water budget components as a single summed value in the Well Package. Recharge basins are likely to be a common management strategy to help achieve sustainability in the Subbasin. As such, the model should be able to individually represent each recharge basin. These could be represented in the Recharge Package or other more sophisticated module if specifically merited.

Lateral Model Boundaries. These are currently simulated using the GHB Package. We will maintain this concept, but the locations of the GHBs will be moved to locations beyond the edge of the Subbasin up to the extent of the expanded model area. Assigned reference heads for the GHB cells will be based on observed groundwater elevations from historic groundwater elevation maps. GHB head assignments for predictive runs may be lowered over time if current trends indicate declining water levels over the next 20-40 years. These head assignments were finalized in consultation and coordination with adjacent subbasin technical groups as well as any regional modeling or State-derived predictive information.

Mountain Front Recharge. Currently, a GHB is assigned to the eastern edge of the Subbasin, along the front of the Sierra Nevada foothills. The modeling team will remove this GHB and represent mountain front recharge using the Recharge Package. Conceptually, mountain front recharge is not a head-dependent boundary, but a specified flux-dependent boundary.

Calibration Period and Validation Period. As discussed previously, the original model was calibrated to a 19-year calibration period using 6-month stress periods. The Modeling Team suggests that upon completion of the KSHM model, a validation run simulating the time period of 1999-2017 be made to assess that the model is still adequately calibrated. Upon assessment of the validation simulation, the KSHM will undergo the calibration process using both qualitative and quantitative measures, such as parameter estimation software (PEST), to produce the final calibrated simulation modeling tool to be used to refine the Subbasin water budget and be used for predictive simulations. Moving forward, the updated groundwater model for the Kaweah Subbasin will begin in 1999 and continue to be updated as new GSP updates are required and deemed necessary by the GSAs. This new start date is due to the substantially increased accuracy and spatial resolution of water budget features, primarily crop demand and surface water deliveries that result in agricultural pumping estimates, beginning with the first year that high quality satellite imagery and associated evapotranspiration/soil moisture balance models were provided by Davids Engineering. This modeling effort can be updated in the future with newer and more accurate local and regional data from neighboring GSAs to benefit required SGMA reporting, refinements, and optimization of the GSPs within the Subbasin.

Predictive Simulations. Predictive simulations through the SGMA timeframe of 2040 and beyond are performed using the same monthly stress period interval and are developed using the projected climate dataset provided by DWR. Correlations between this climatic projection and previously quantified groundwater demands and surface water deliveries are developed to produce a suitable baseline predictive simulation that will serve as a starting point for assessing the impacts of various adaptive management actions and groundwater projects.

Simulations are performed for individual GSAs, but also the cumulative effects of future groundwater management in the Subbasin are assessed relative to the baseline predictive simulation.

### Collaboration with Neighboring Subbasins

The Modeling Team collaborated with neighboring subbasin technical representatives during the update and application of the KSHM, with permission from the Kaweah Subbasin GSAs. The purpose for this coordination is to accomplish the following objectives:

- Receive input from GSAs' representatives on modeling tools and approaches in adjacent basins.
- Exchange data and information for consistency between tools.
- Agree on boundary conditions including both gradients and heads located at and outside of the boundaries of the Subbasin.
- Ensure that the KSHM integrates well, to the extent possible, with adjacent tools that our approaches for Kaweah Subbasin will not result in conflicting boundary conditions or water budgets.

The Modeling Team recommends that inter-basin model coordination meetings begin in August of 2018 and continue until the simulations required for use in developing the draft GSP is are completed. We anticipate the need for four (4) focused meetings on this approximate schedule:

1. KSHM Approach Meeting — Mid September 2018
2. KSHM Update Meeting — Late October 2018
3. KSHM Model Baseline Run and Boundary Flux Meeting — Late November 2018
4. KSHM Model Simulation Results Meeting — January 2019

The Modeling Team attended one meeting with the Tulare Lake Subbasin modeling group on June 15th, 2018 to facilitate data transfer between the two modeling efforts and improve agreement and conceptual consistency between the Sub- Basins. Upon request from the Kaweah Subbasin managers and committees, the Modeling Team will continue to collaborate and improve consensus with adjacent modeling groups to improve model agreement and sub-regional consistency between calibrated and predictive simulations. The Modeling Team is also prepared to develop and share baseline predictive simulation results with neighboring basins and accept in-kind data sharing to further improve predictive accuracy and understanding on adaptive management and project options and collaboration. These activities are approved by GSA representatives prior to the Modeling Team sharing any information or data.

## Conclusions and Recommendations Regarding Model Updates

In general, the Modeling Team believes that the KDWCD model provides an adequate precursor model that is suitable for use in GSP development if the following revisions and updates are incorporated.

Groundwater Vistas Version 7 will be the processing software package utilized. We will maintain MODFLOW as the basic code and will update to MODFLOW-USG or MODFLOW-NWT to take advantage of advances in numerical solution techniques that are available in these updated MODFLOW revisions.

1. **Extent.** The model will need to be expanded to fill the area between the general head boundary of the current model and the Subbasin boundary shown in Figure 1 to include the entire area of the Kaweah Subbasin.
2. **Layers.** The model layering scheme depicting two water-bearing layers above and below the Corcoran Clay is suitable for the objective of supporting the GSP development.
3. **Historical Simulations.** The KDWCD model has been calibrated to the 1981- 1999 hydrologic period. Based on inspection of the hydrographs presented in the 2005 modeling report and the 2012 Model update report, observed water levels are adequately simulated to consider this model effectively calibrated. The objective is to have a model suitable to simulate projected management actions through the entire Subbasin. No changes will be made to the inputs to the 1981-1999 run. Therefore, it is already calibrated to that period. We are just re-organizing the assignment of water budget components to different MODFLOW packages from 1999-2017, and beyond. Monthly stress periods will be used.

4. Assignment of water budget components to MODFLOW Packages. The Modeling Team proposes to revise the conventions used in the KDWCD model. This will be the most involved part of the model revision. The updated water budget values that have been generated by the GSA will continue to be the primary input as far as flux values go. However, we propose to organize them into more readily identifiable currently available MODFLOW packages to help with the analyses of potential water budget changes that may correspond to management actions in the future.
5. Recharge Components. Spatial distribution of such water budget components as percolation of precipitation, irrigation return flow, recharge basins, etc., will be updated based on the most currently available data.
6. Model Parameters. Hydraulic conductivity (horizontal and vertical) and storage coefficient will initially stay unchanged during the validation period simulation. If the calibration target hydrographs for the validation period indicate that a suitable match is retained between observed and modeled water levels, the existing parameters will be retained.
7. Flow Boundaries. In areas where the existing GHB boundaries are within the Kaweah Subbasin, they will be expanded approximately 1-2 miles, or at locations of any likely groundwater divides from the Subbasin boundary on the north, south, and west sides of the Subbasin. The assigned heads for these GHBs for the 1999-2017 verification run will be based on published groundwater elevations in the vicinity as depicted in contour maps published by DWR. Seasonal variability in assigned GHB heads can be incorporated.
8. No-Flow Boundaries. The eastern GHB along the base of the Sierra foothills will be removed. Instead, the flux in the Recharge Package will be increased along this boundary to represent mountain front recharge. The flux volume from the GHB will be evaluated, and this flux volume will be approximated using the Recharge Package.

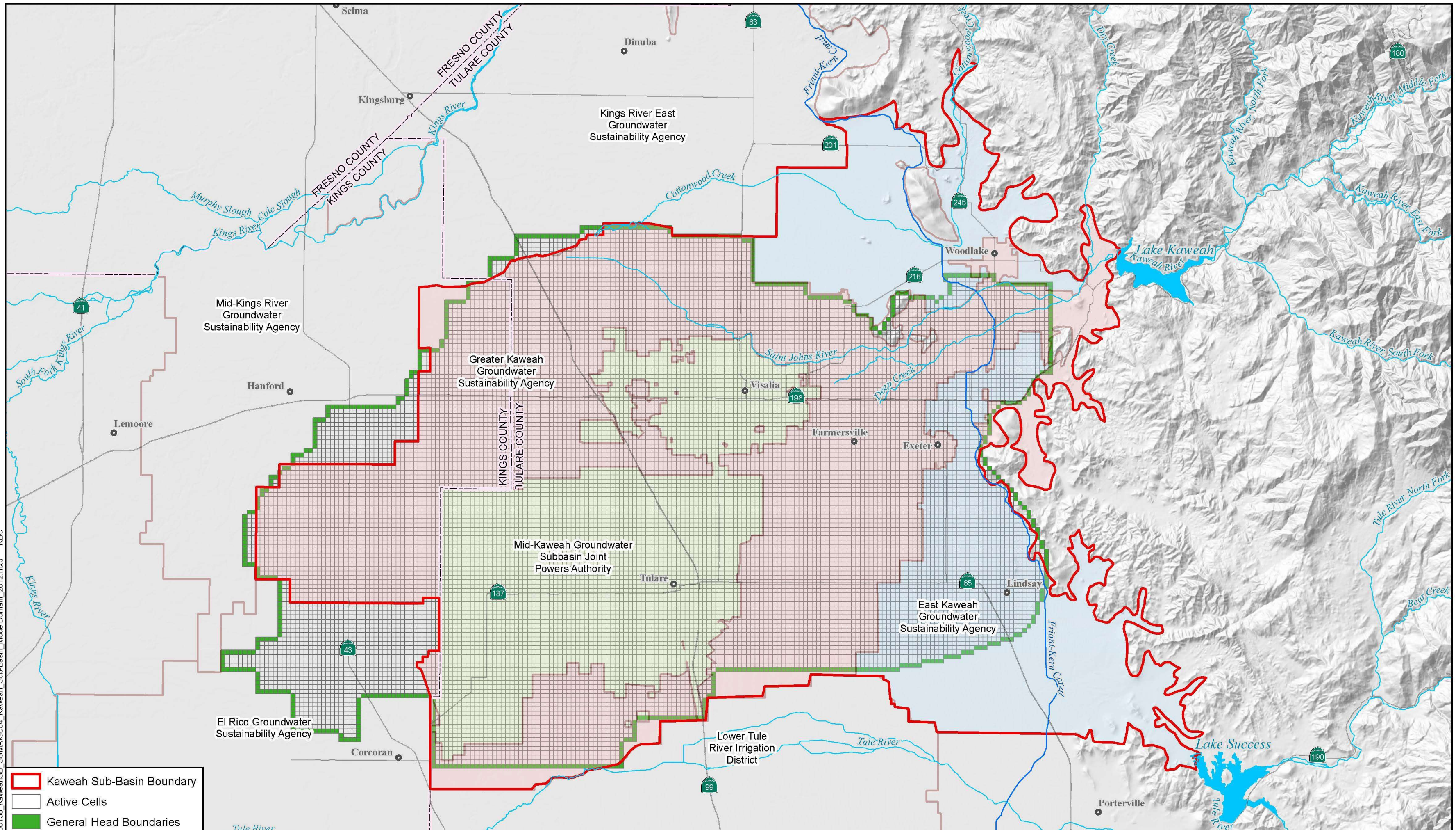
## Estimated Schedule of Model Update Activities

The Modeling Team proposes the following schedule for the major groundwater model update activities. Estimated timeframes for key inter-basin model coordination meetings and updates are also included in the following table to provide a more comprehensive schedule and to facilitate meeting planning. Specific model development and simulation tasks may shift to earlier or later timeframes, but it is the intention of the Modeling Team to comply with the overall schedule and satisfy deadlines for the final deliverable of the calibrated modeling tool and associated predictive scenarios. Should information not be available to the Modeling Team in time to use them in development of the calibrated model simulation or predictive simulations, the data will either not be included, or the schedule may be adjusted to accommodate their inclusion, per guidance from Sub- Basin GSA leadership.

Updates and presentations on the status of the groundwater modeling efforts will occur at regular intervals during Coordinated Subbasin and individual GSA meetings, per the scope of work for the groundwater modeling task order.

| Modeling Activity | Estimated Completion |
|---|---|
| Refinement and expansion of model domain and boundary conditions | Early September 2018 |
| Update water budget with David's Engineering and EKGSA data | Early September 2018 |
| Development of calibration targets | Mid-September 2018 |
| Parameterization of model layers | Mid-September 2018 |
| Refinement of groundwater fluxes | Mid-September 2018 |
| Inter-basin KSHM Approach Meeting (inter-basin) | Mid-September 2018 |

| | |
|---|---|
| Adjust boundary conditions, fluxes, and parameters using any new adjacent basin data | Late September 2018 |
| Initiate Formal Calibration Process | Early October 2018 |
| Inter-basin KSHM Update Meeting | Late October 2018 |
| Complete initial calibration process | Early November 2018 |
| Calibration and model refinements and preparation for predictive simulations | Late November 2018 |
| Inter-basin KSHM Calibrated Model and Boundary Flux Meeting | Late November 2018 |
| Develop predictive baseline scenario — Subbasin level | Early December 2018 |
| Develop GSA specific predictive simulations | Mid December 2018 |
| Cumulative Subbasin simulations | Early January 2019 |




Kaweah Sub-Basin
Groundwater Modeling Task 1
Tulare County, California

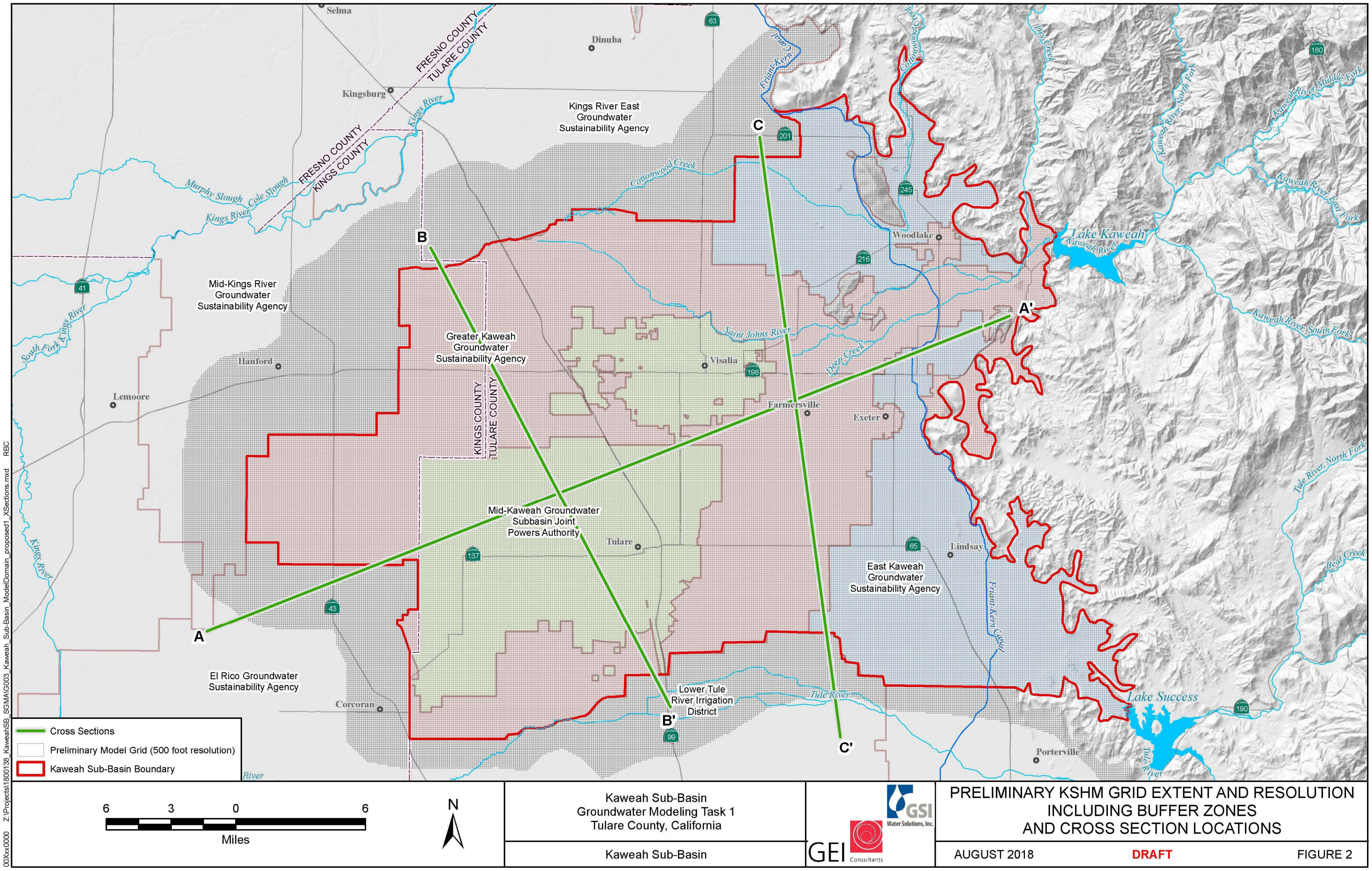
Kaweah Sub-Basin

GEI Consultants | GSI Water Solutions, Inc.

2012 KDWCD EXPANDED MODEL DOMAIN WITH GENERAL HEAD BOUNDARIES

AUGUST 2018 | DRAFT | FIGURE 1

00Xxx0000 Z:\Projects\1800138_KaweahSB_SGMA\G004_Kaweah_Sub-Basin_ModelDomain_2012.mxd RBC



Kings River East Groundwater Sustainability Agency
Mid-Kings River Groundwater Sustainability Agency
Greater Kaweah Groundwater Sustainability Agency
Mid-Kaweah Groundwater Subbasin Joint Powers Authority
East Kaweah Groundwater Sustainability Agency
El Rico Groundwater Sustainability Agency
Lower Tule River Irrigation District
FRESNO COUNTY
TULARE COUNTY
KINGS COUNTY
Selma
Dinuba
Kingsburg
Woodlake
Visalia
Farmersville
Exeter
Hanford
Lemoore
Tulare
Lindsay
Corcoran
Porterville
Lake Kaweah
Lake Success
Kings River
Saint Johns River
Tule River
Cottonwood Creek
Murphy Slough
Cole Slough
South Fork Kings River
Friant-Kern Canal
Kaweah River
A
A'
B
B'
C
C'
Cross Sections
Preliminary Model Grid (500 foot resolution)
Kaweah Sub-Basin Boundary
6 3 0 6
Miles
N
Kaweah Sub-Basin
Groundwater Modeling Task 1
Tulare County, California
Kaweah Sub-Basin
GSI Water Solutions, Inc.
GEI Consultants
PRELIMINARY KSHM GRID EXTENT AND RESOLUTION INCLUDING BUFFER ZONES AND CROSS SECTION LOCATIONS
AUGUST 2018
DRAFT
FIGURE 2

## Groundwater Model Modifications

Modifications were made to the Kaweah Subbasin Hydrologic Model (KSHM) by the groundwater modeling team during the period of July through September 2018. The modifications which were reported first reported in Progress Report Number 1- November 2018 include the following.

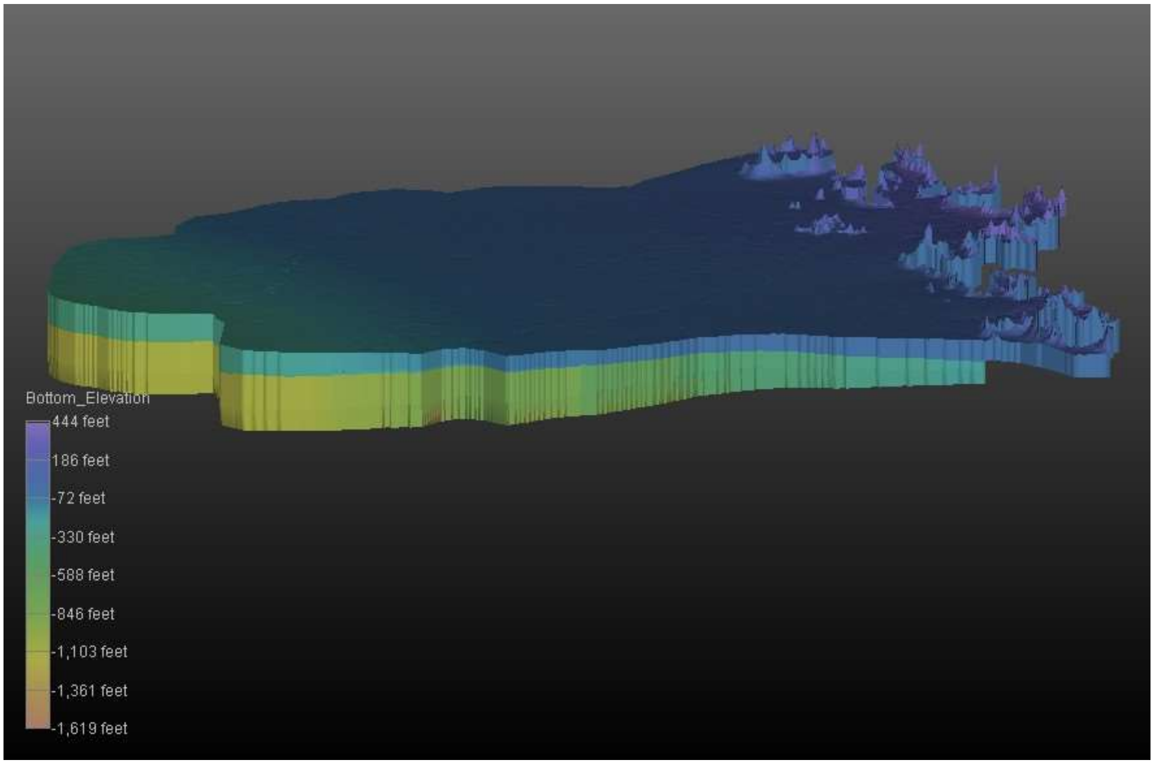
1. Added the general head boundaries
    a. What is a general head boundary? Water levels are fixed, and fluxes change

       - The General-Head Boundary package is used to simulate head-dependent flux boundaries. In the General-Head Boundary package the flux is always proportional to the difference in head.

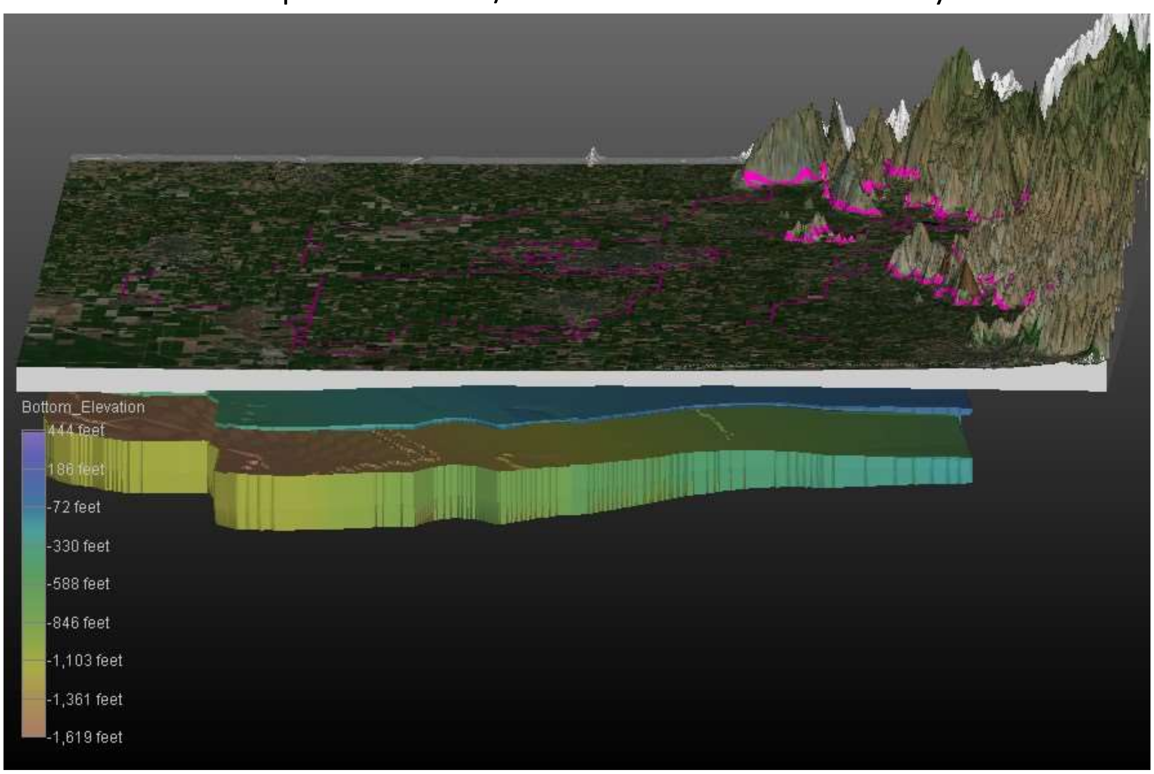
    b. The general head boundary condition is set on the north, west and south boundaries of the model and in model layers 1, 2, and 3.
2. Set the agricultural pumping based on Davids Engineering crop demand analysis for the period 1999 to 2017.
3. Distributed surface water delivery information spatially.
4. Refined the model grid from 1000 to 500-foot grids.
5. Refined stress periods from 6-month to 1-month step stress periods.
6. Expanded model layers into East Kaweah GSA area and up to the Eastern edge of the Kaweah Subbasin. Total model thickness in the east determined by the evaluation of the wells penetrating into the bedrock.
7. Added mountain front recharge and distributed recharge volumes proportionally based on upstream watershed size.
8. Increased the thickness of model layer three by lowering the base to near the bottom of the Tulare Formation.

### Exploded View of Groundwater Model Layers

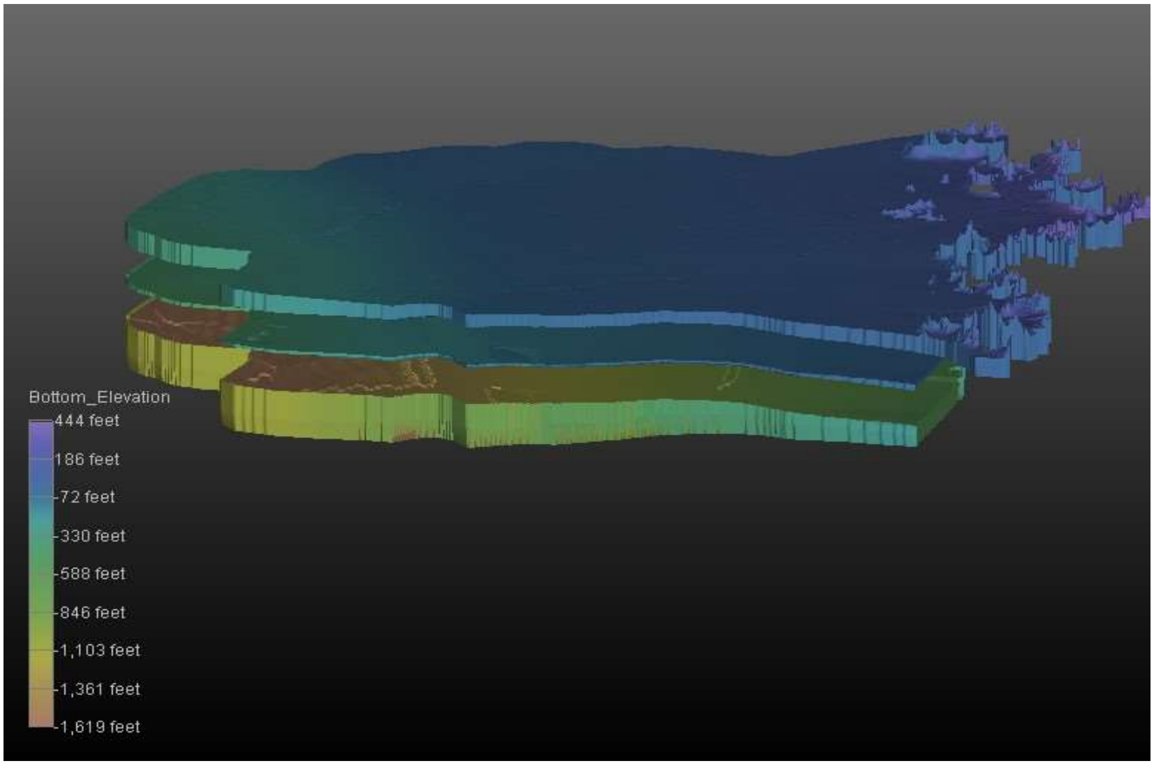
3-Dimensional Oblique Elevation of Entire Model Domain




3-Dimensional Oblique Elevation w/Aerial Photo and GSA Boundary Outlined

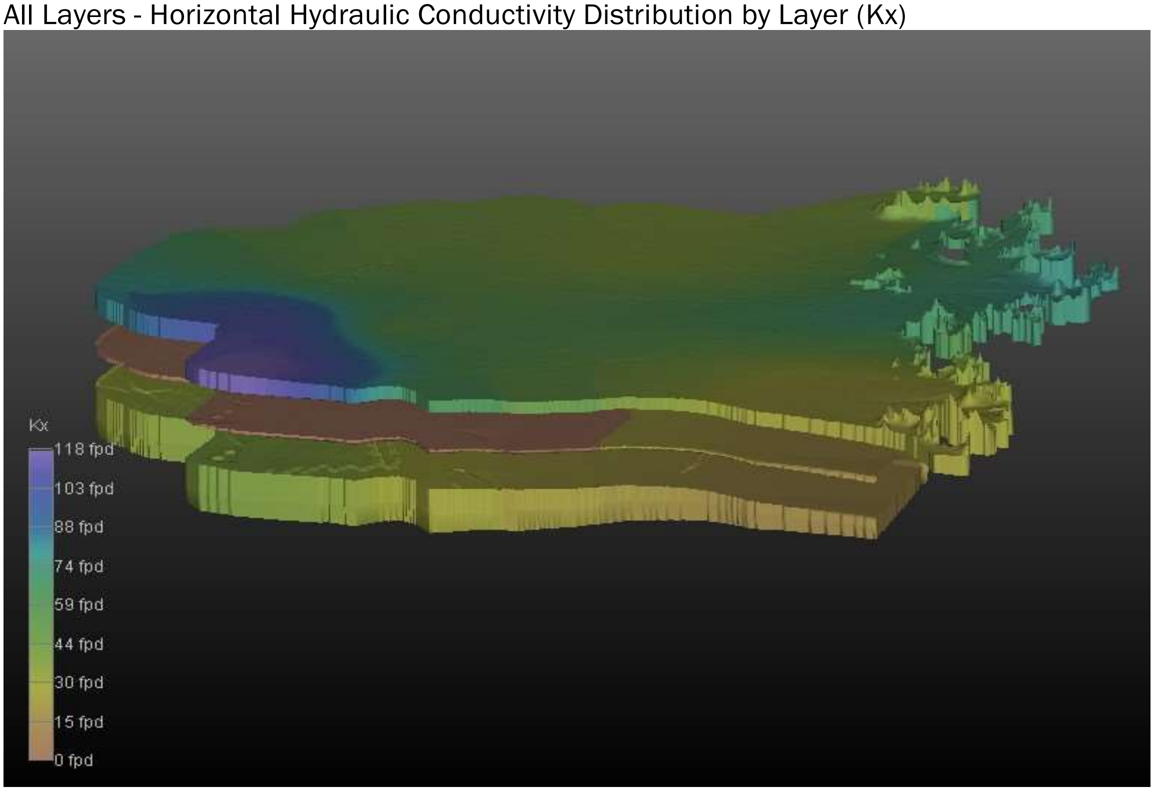



Exploded View of Groundwater Model Layers

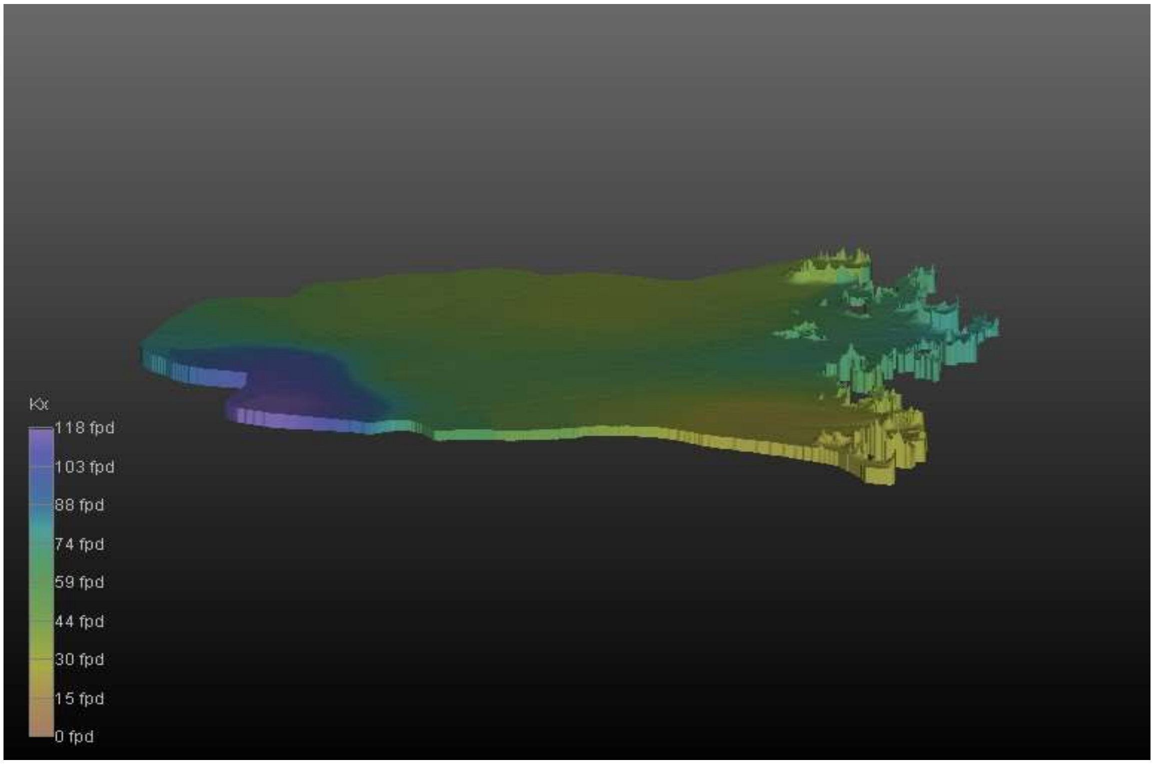



## Horizontal Hydraulic Conductivity Distribution by Layer (Kx)

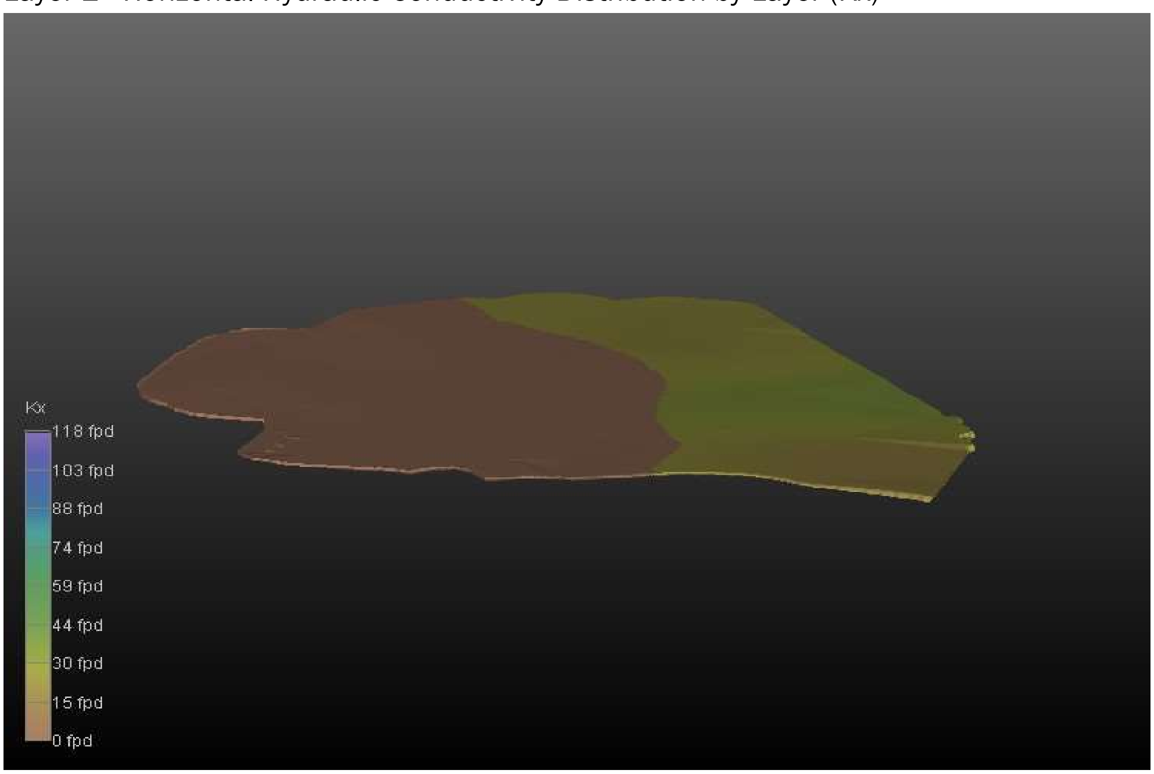
All Layers - Horizontal Hydraulic Conductivity Distribution by Layer (Kx)



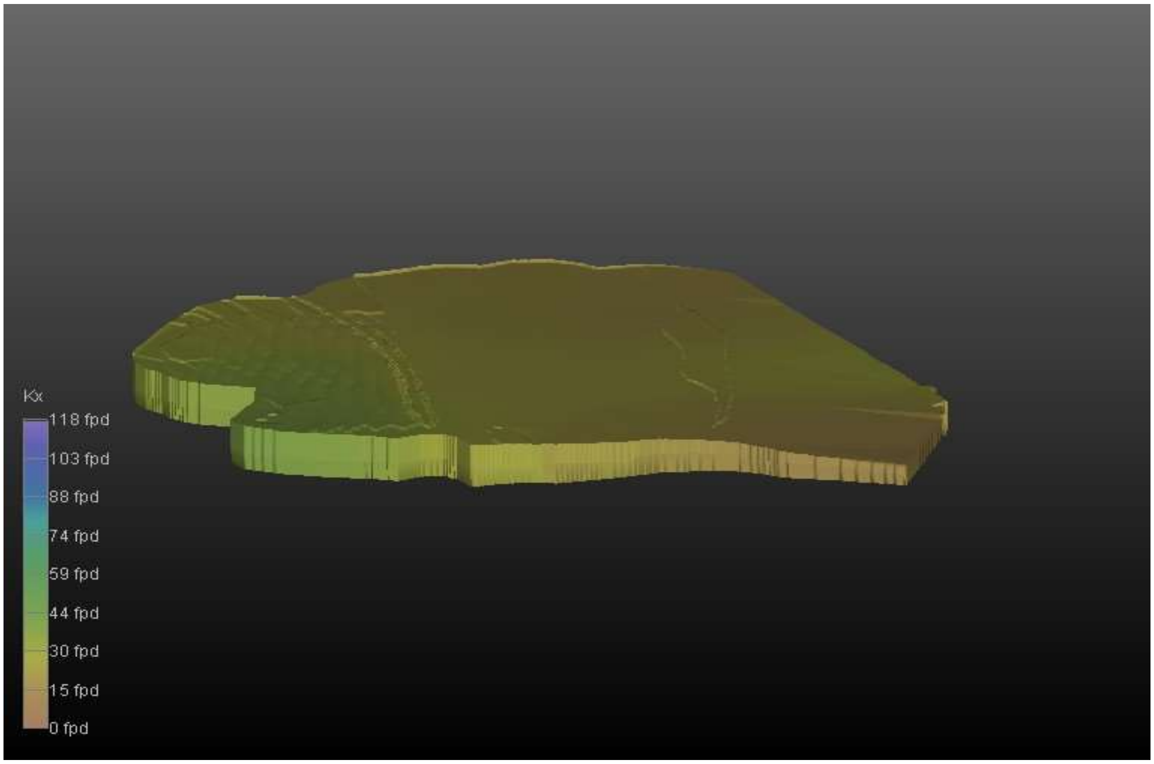
Layer 1 - Horizontal Hydraulic Conductivity Distribution by Layer (Kx)




Layer 2 - Horizontal Hydraulic Conductivity Distribution by Layer (Kx)

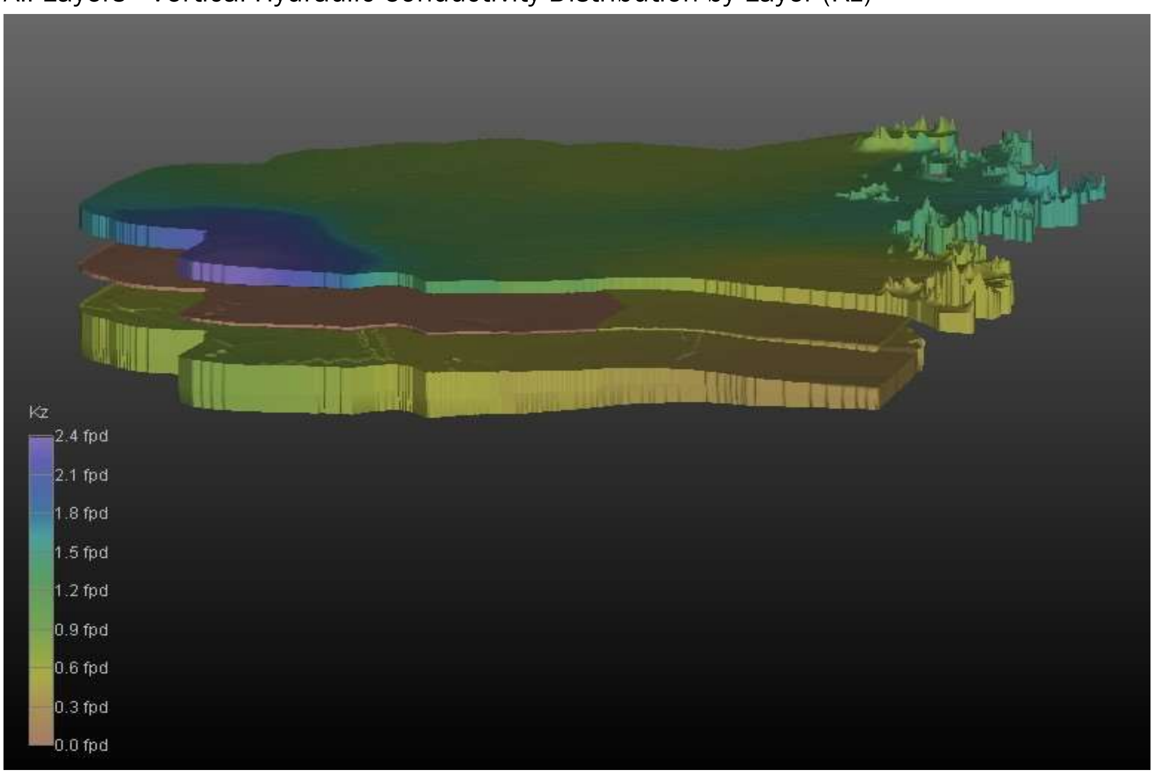


Layer 3 - Horizontal Hydraulic Conductivity Distribution by Layer (Kx)

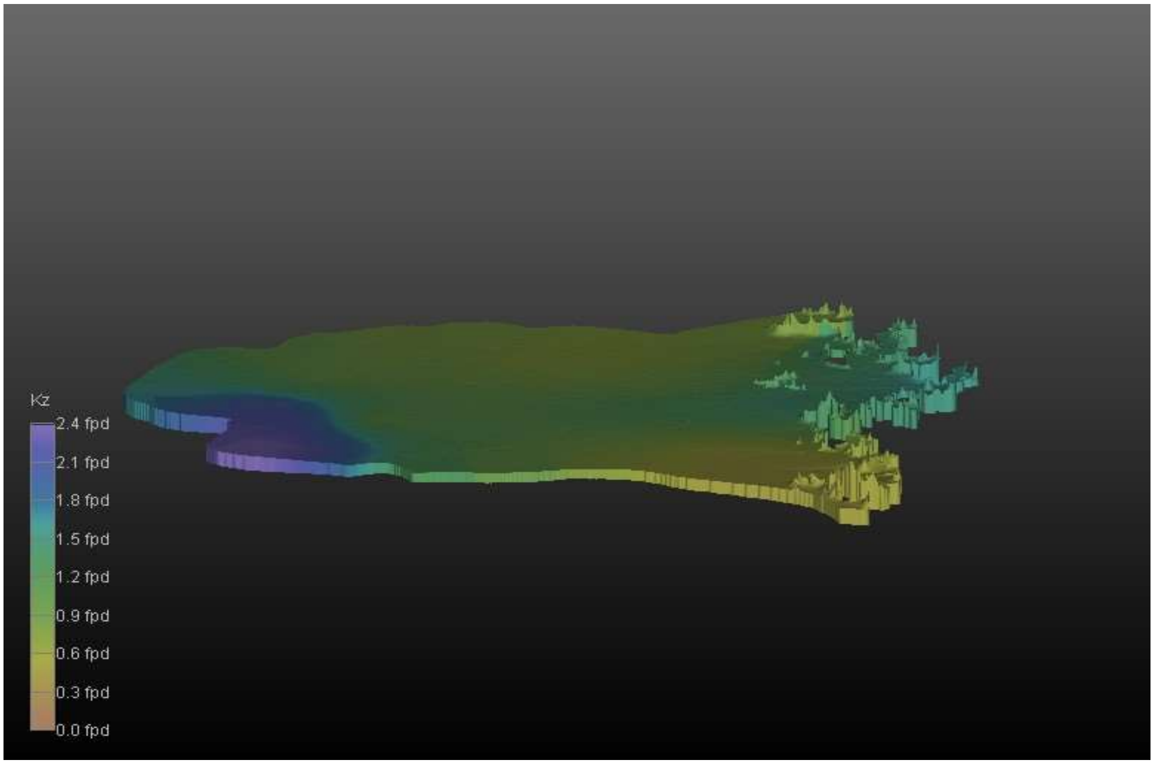



## Vertical Hydraulic Conductivity Distribution by Layer (Kz)

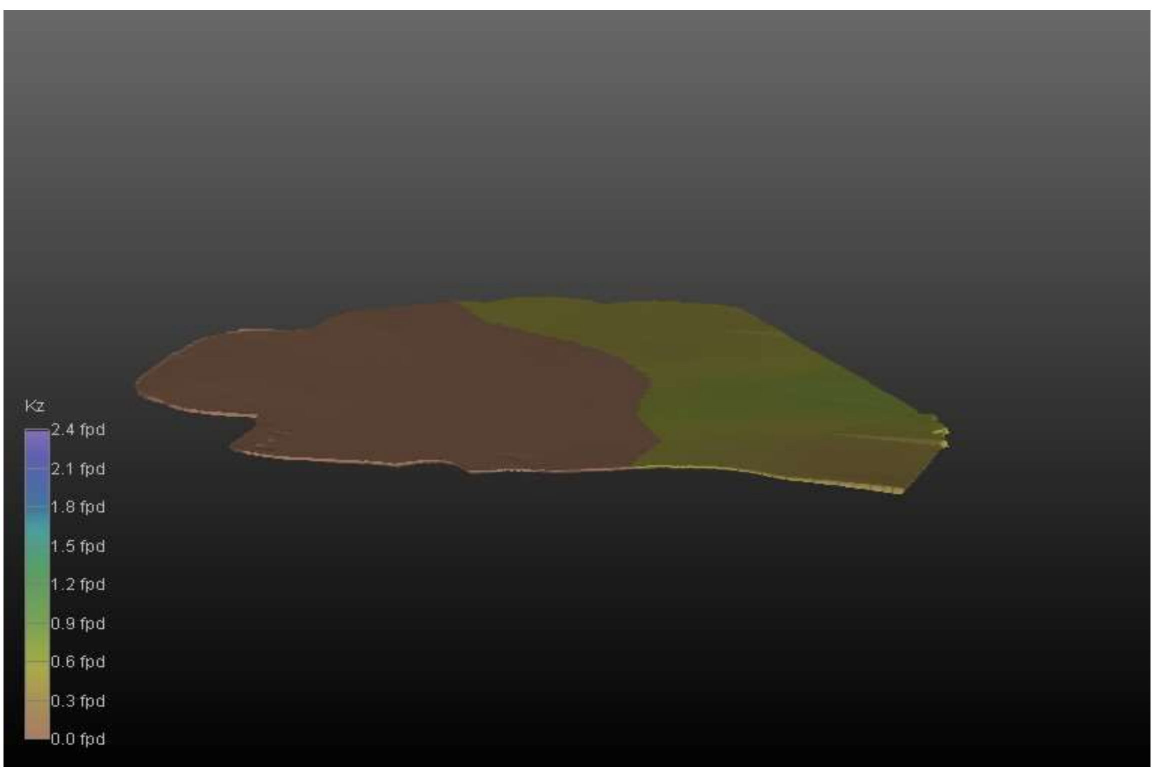
All Layers - Vertical Hydraulic Conductivity Distribution by Layer (Kz)



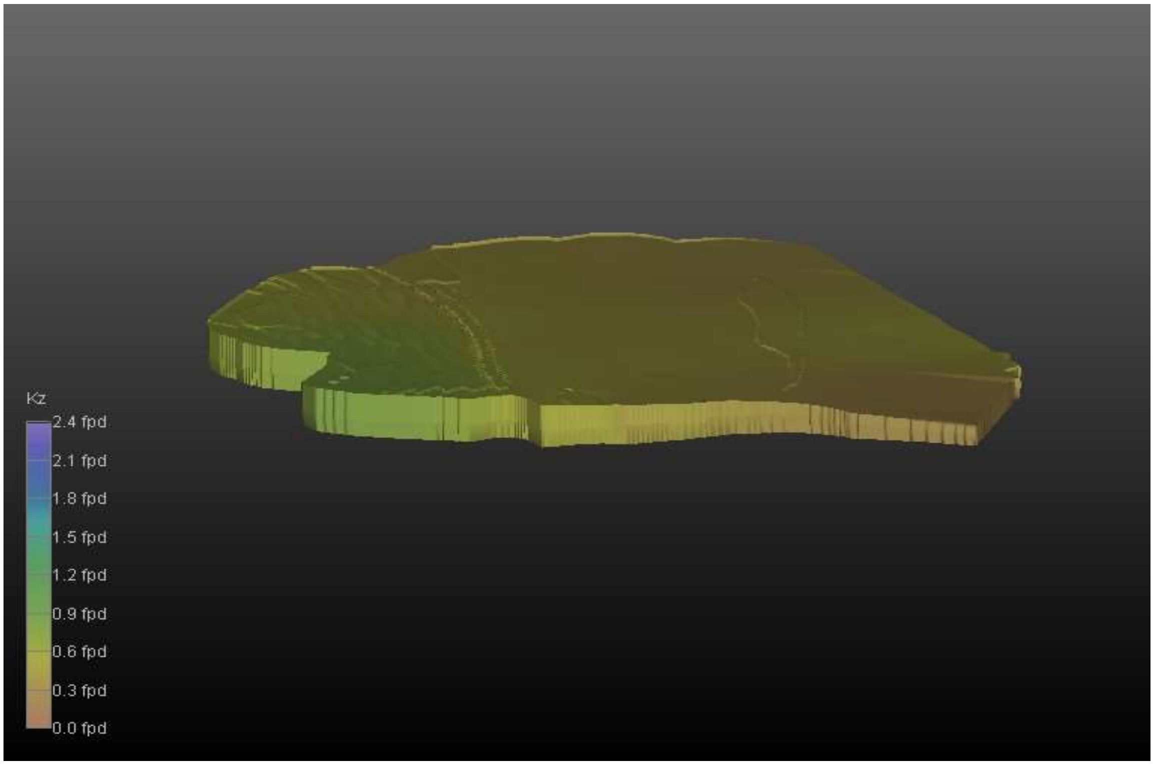
Layer 1 - Vertical Hydraulic Conductivity Distribution by Layer (Kz)




Layer 2 - Vertical Hydraulic Conductivity Distribution by Layer (Kz)



Layer 3 - Vertical Hydraulic Conductivity Distribution by Layer (Kz)




## Process of Model Verification

1. The groundwater modeling team performed verifications model runs from 1999 to 2017. The purpose of these simulations was to verify the accuracy of the model to match the new water budget and observed groundwater elevations throughout expanded grid area.
2. The modeling team adjusted the vertical hydraulic conductivity in all three layers to improve the match.
3. Storage values from the previous model were unchanged.

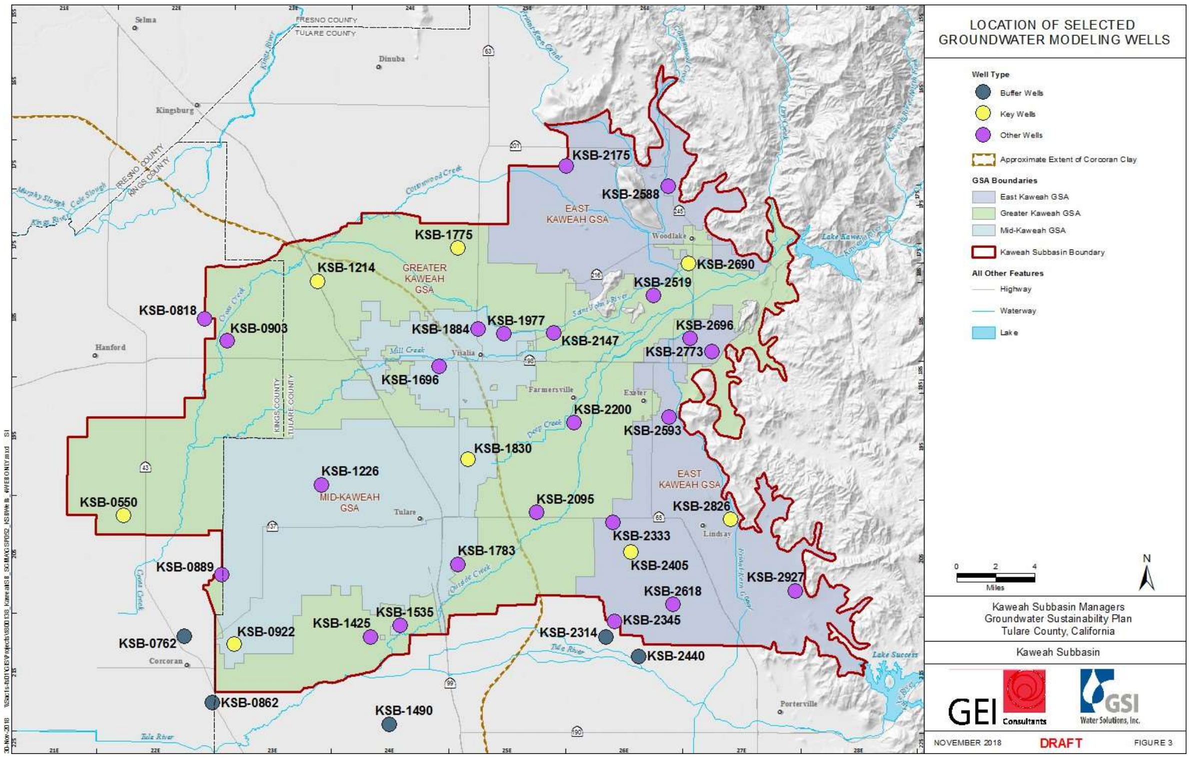
## Results of Verification

The groundwater modeling team increased the number of calibrated targets from 30 in the 2012 update to over 900 in the KSHM. All 900 of these targets have been included in the calibration statistics that follow the presentation of key well hydrographs.

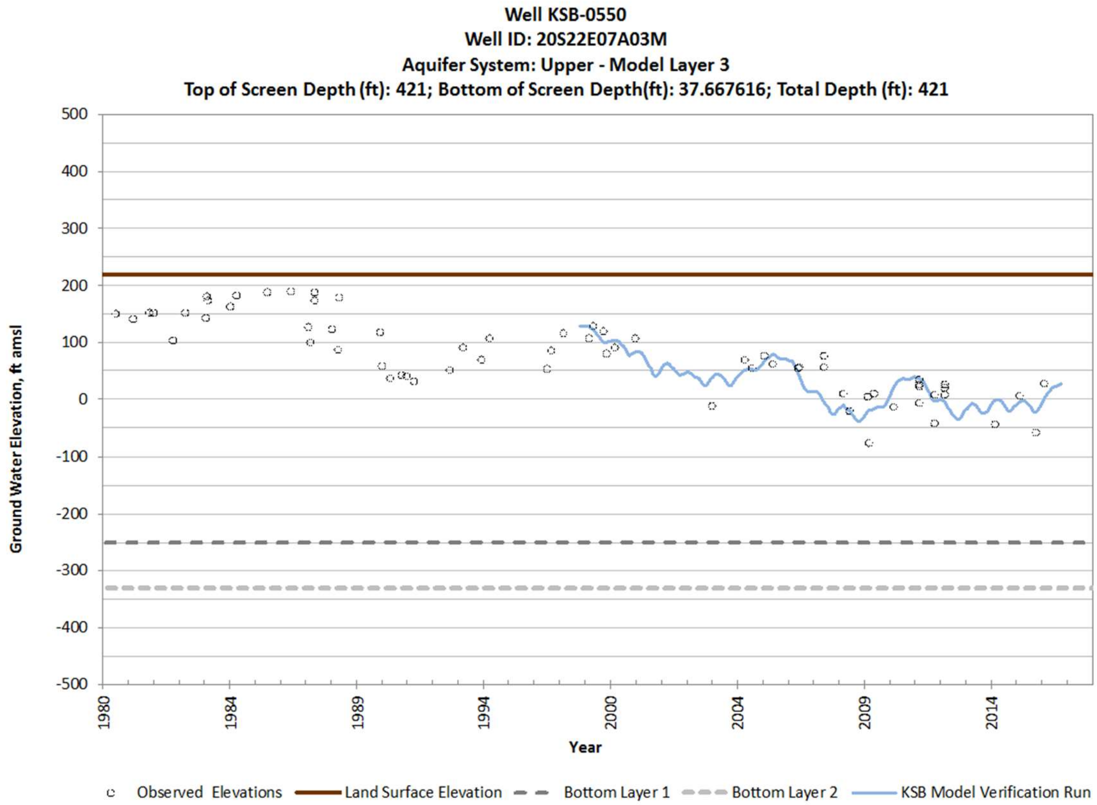
Included below is a map showing the locations of a group of key wells throughout the basin showing the match between observed and model simulated groundwater levels.

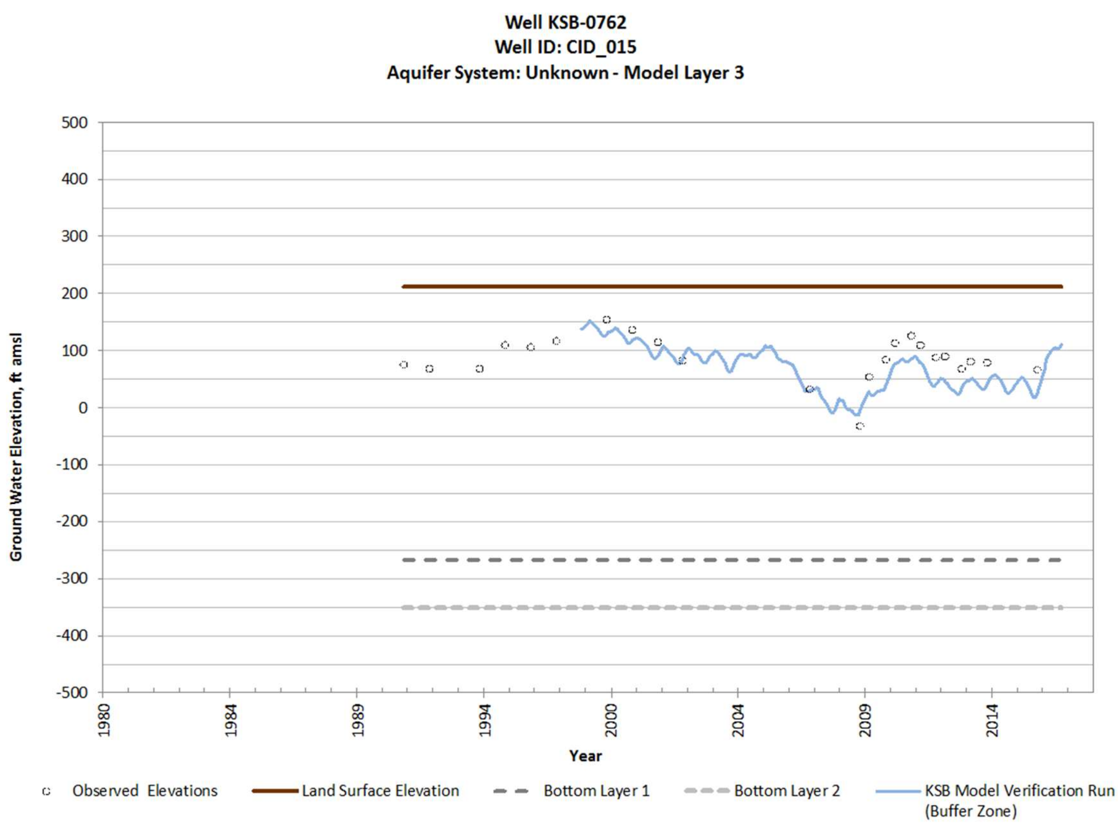
# Hydrograph Wells

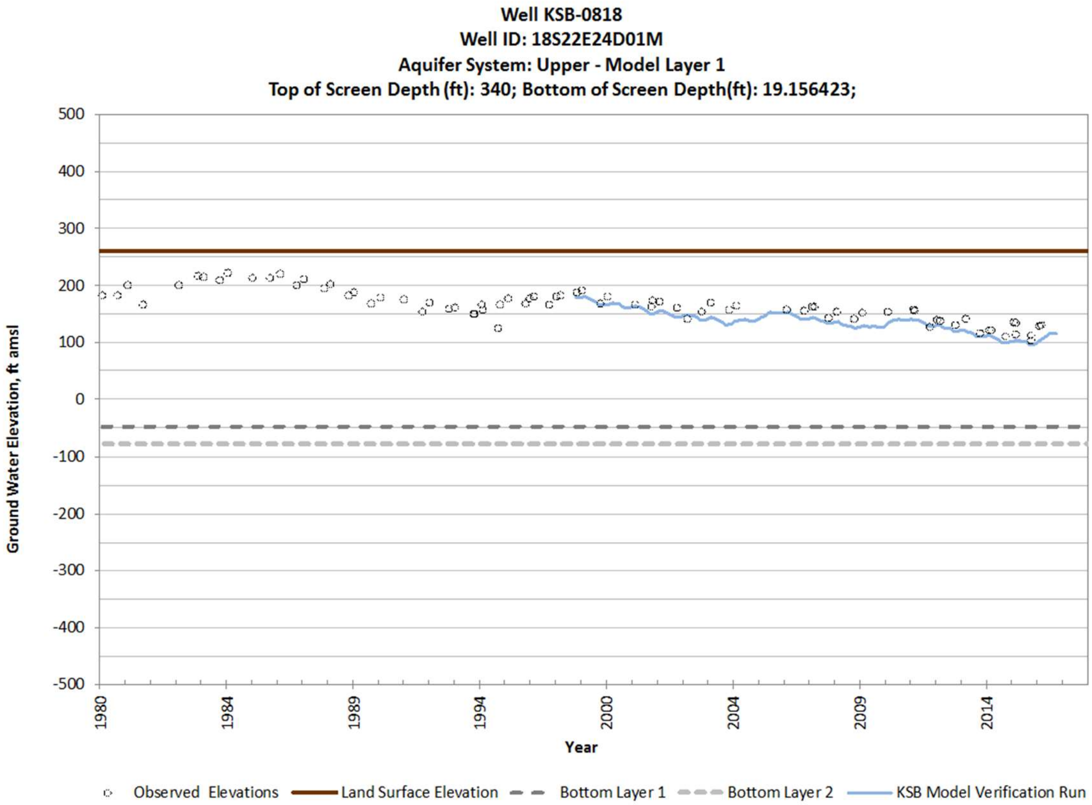
**WELL LOCATIONS**

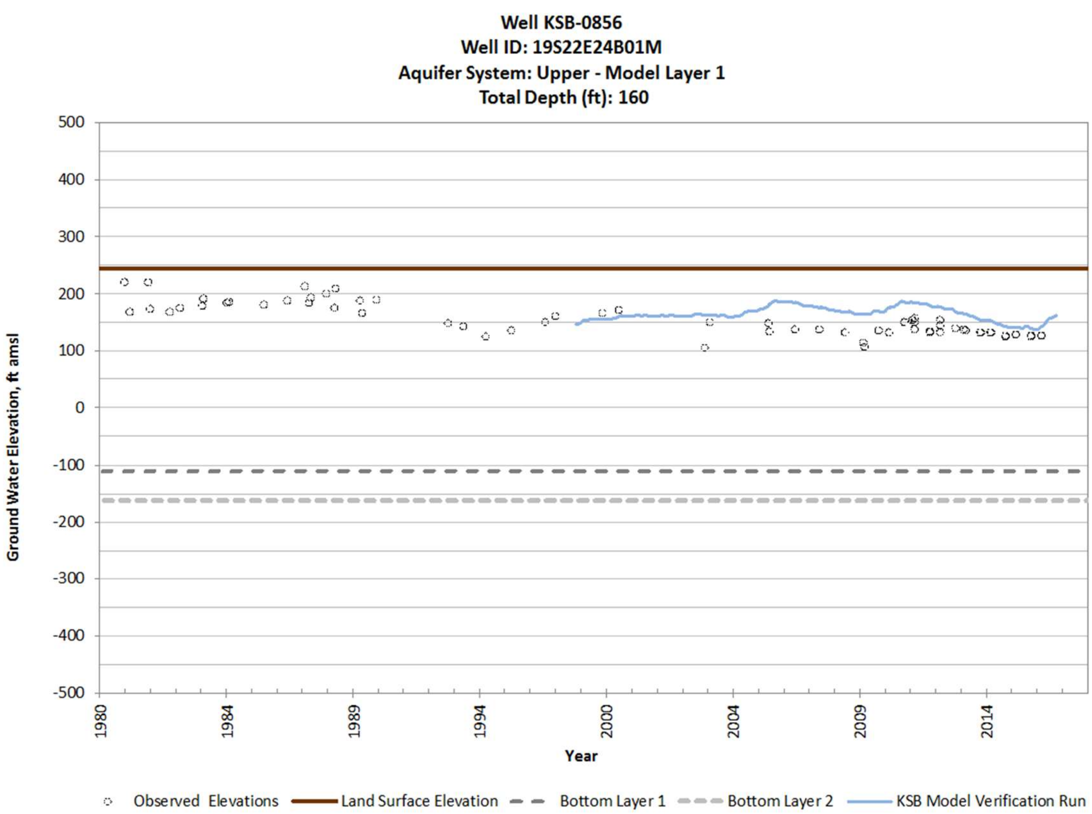


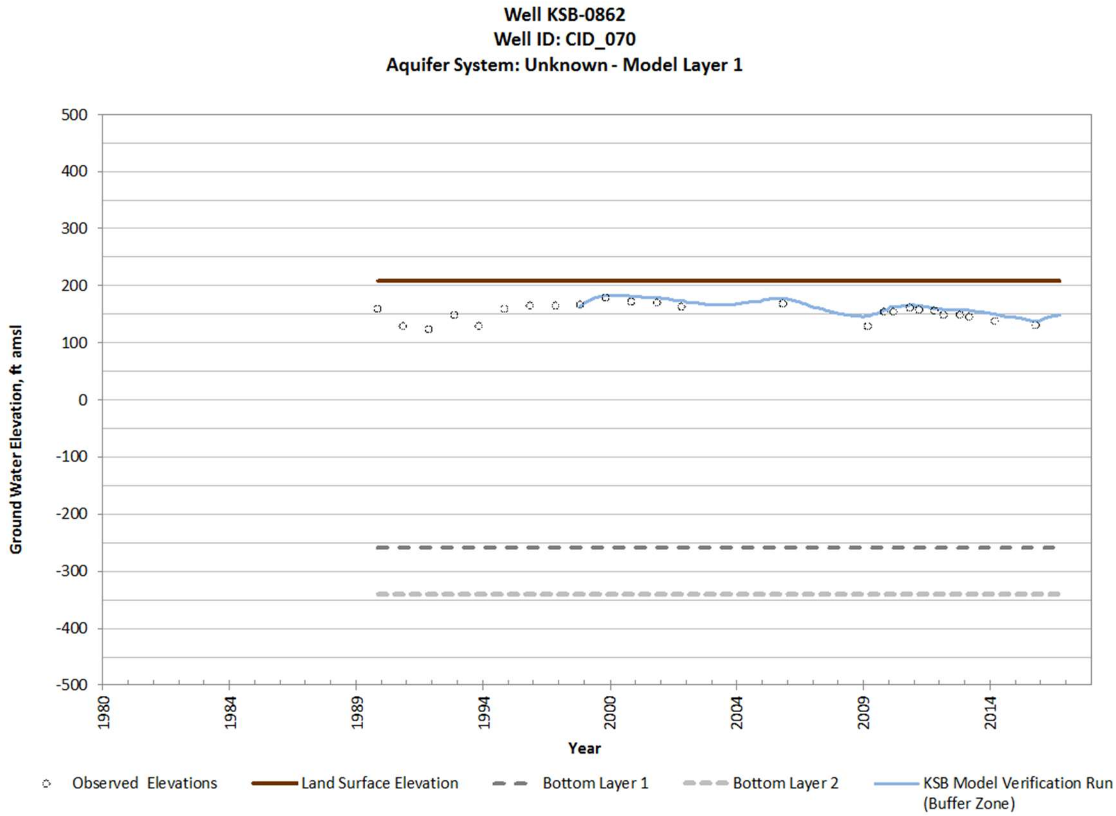

Hydrographs showing the match between observed and modeled groundwater elevations are presented for 37 key wells in the Kaweah Subbasin. Similar hydrographs have also been computed for over 900 wells within the subbasin and 200 wells within the model domain outside the subbasin. These additional hydrographs are available on demand but have been excluded from the report for brevity.

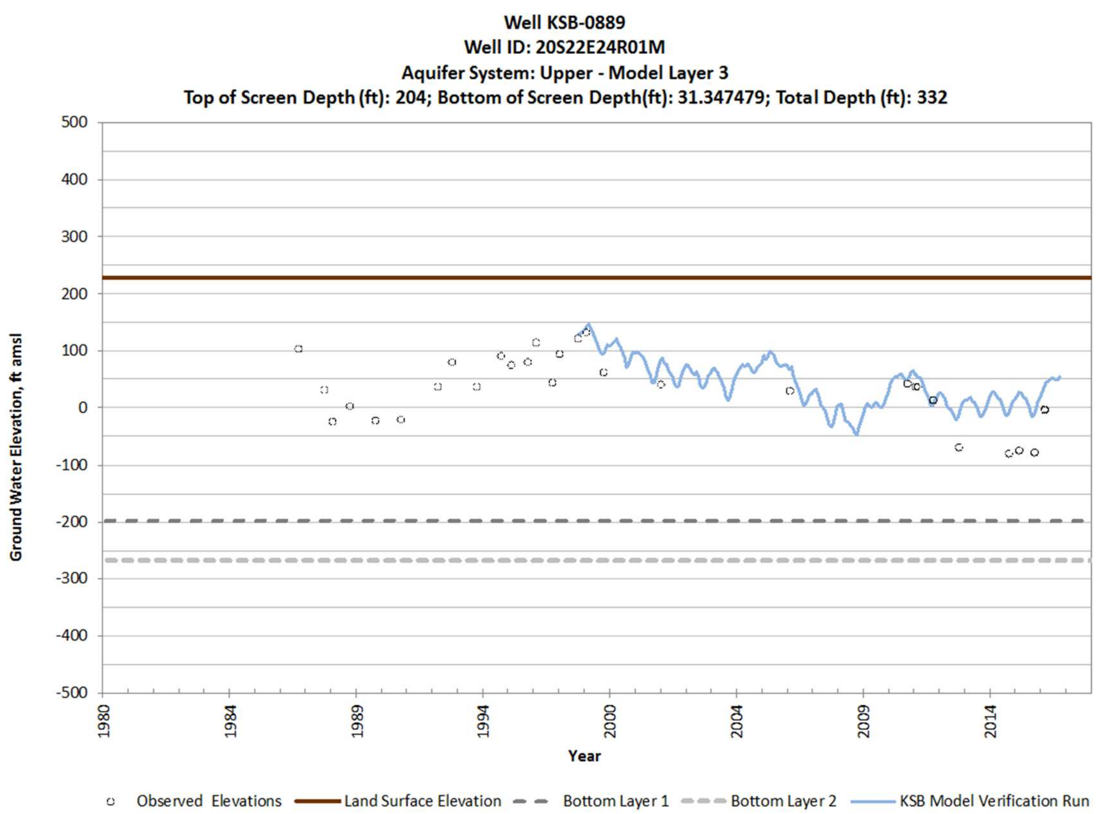

Well KSB-0550
Well ID: 20S22E07A03M
Aquifer System: Upper - Model Layer 3
Top of Screen Depth (ft): 421; Bottom of Screen Depth(ft): 37.667616; Total Depth (ft): 421
Ground Water Elevation, ft amsl
500
400
300
200
100
0
-100
-200
-300
-400
-500
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

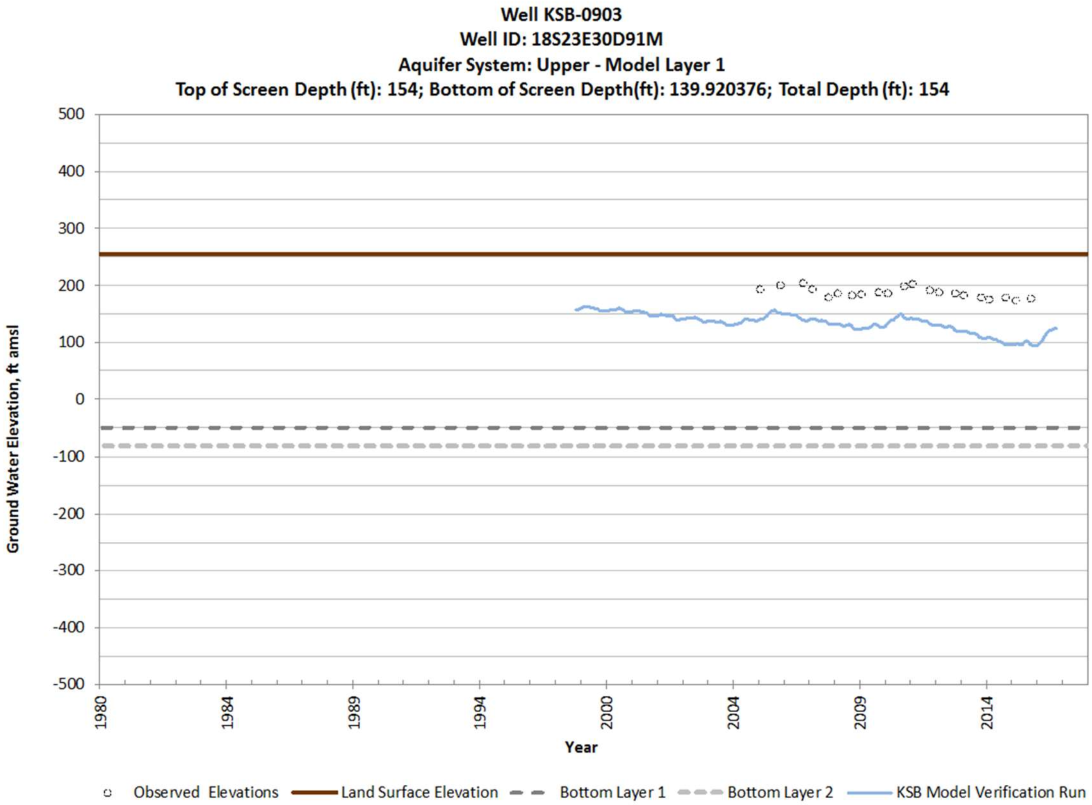

Well KSB-0762
Well ID: CID_015
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
500
400
300
200
100
0
-100
-200
-300
-400
-500
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run (Buffer Zone)

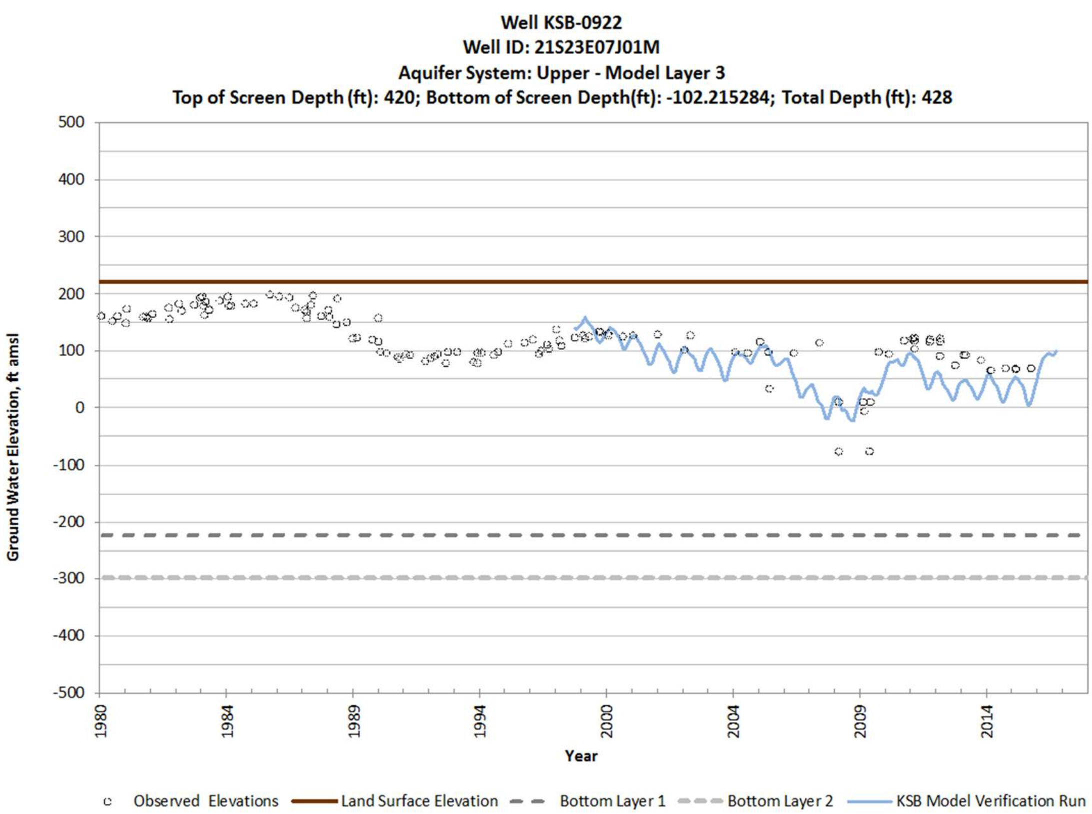

Well KSB-0818
Well ID: 18S22E24D01M
Aquifer System: Upper - Model Layer 1
Top of Screen Depth (ft): 340; Bottom of Screen Depth(ft): 19.156423;
Ground Water Elevation, ft amsl
500
400
300
200
100
0
-100
-200
-300
-400
-500
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

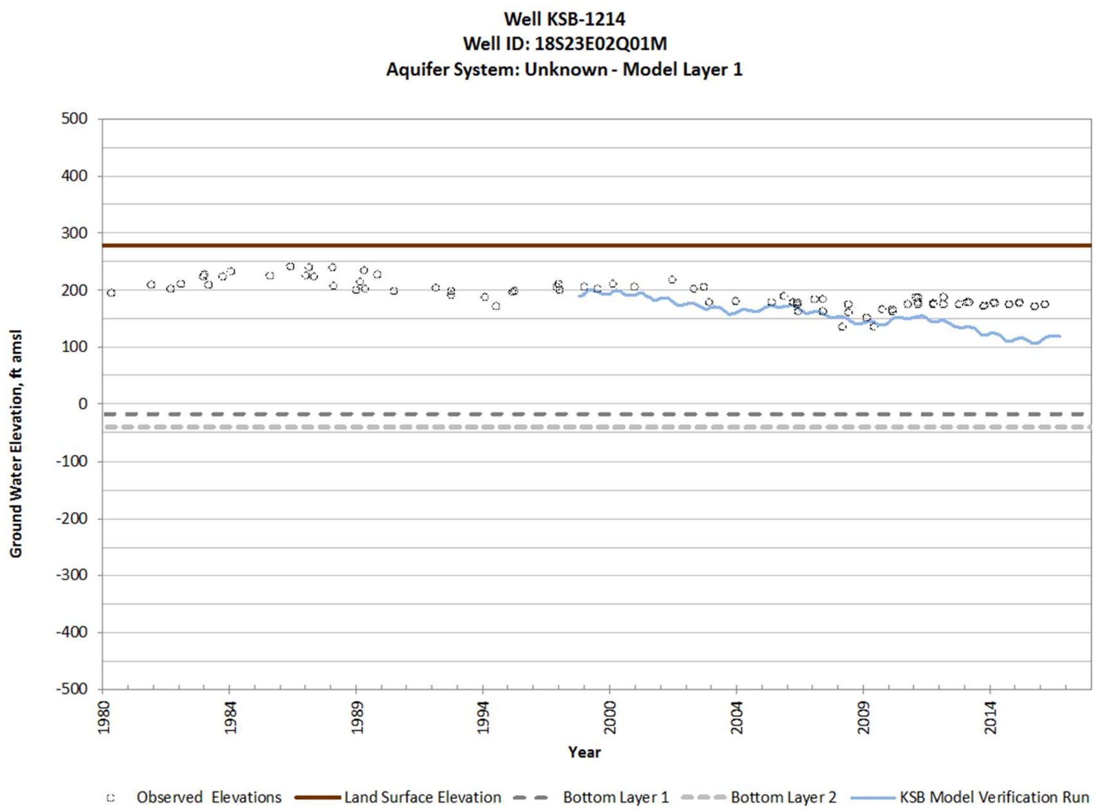

Well KSB-0856
Well ID: 19S22E24B01M
Aquifer System: Upper - Model Layer 1
Total Depth (ft): 160
Ground Water Elevation, ft amsl
500
400
300
200
100
0
-100
-200
-300
-400
-500
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run


Well KSB-0862
Well ID: CID_070
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run (Buffer Zone)

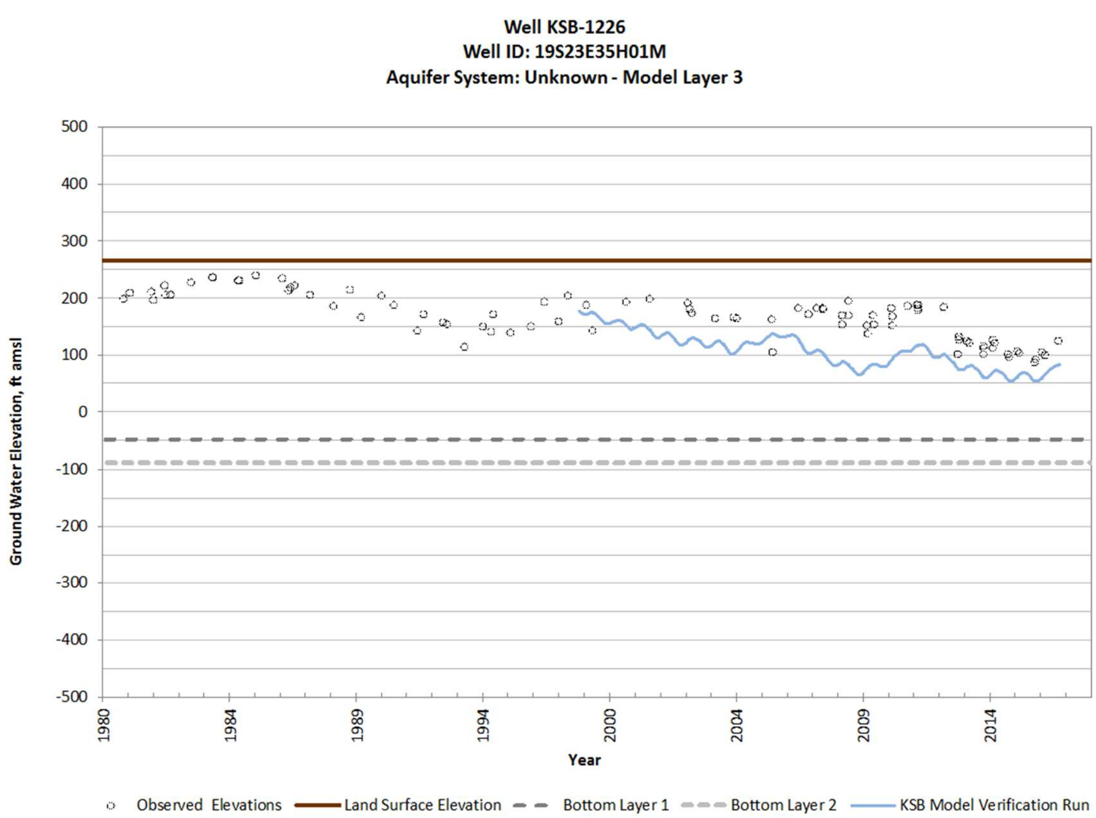

Well KSB-0889
Well ID: 20S22E24R01M
Aquifer System: Upper - Model Layer 3
Top of Screen Depth (ft): 204; Bottom of Screen Depth(ft): 31.347479; Total Depth (ft): 332
Ground Water Elevation, ft amsl
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run


Well KSB-0903
Well ID: 18S23E30D91M
Aquifer System: Upper - Model Layer 1
Top of Screen Depth (ft): 154; Bottom of Screen Depth(ft): 139.920376; Total Depth (ft): 154
Ground Water Elevation, ft amsl
500
400
300
200
100
0
-100
-200
-300
-400
-500
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

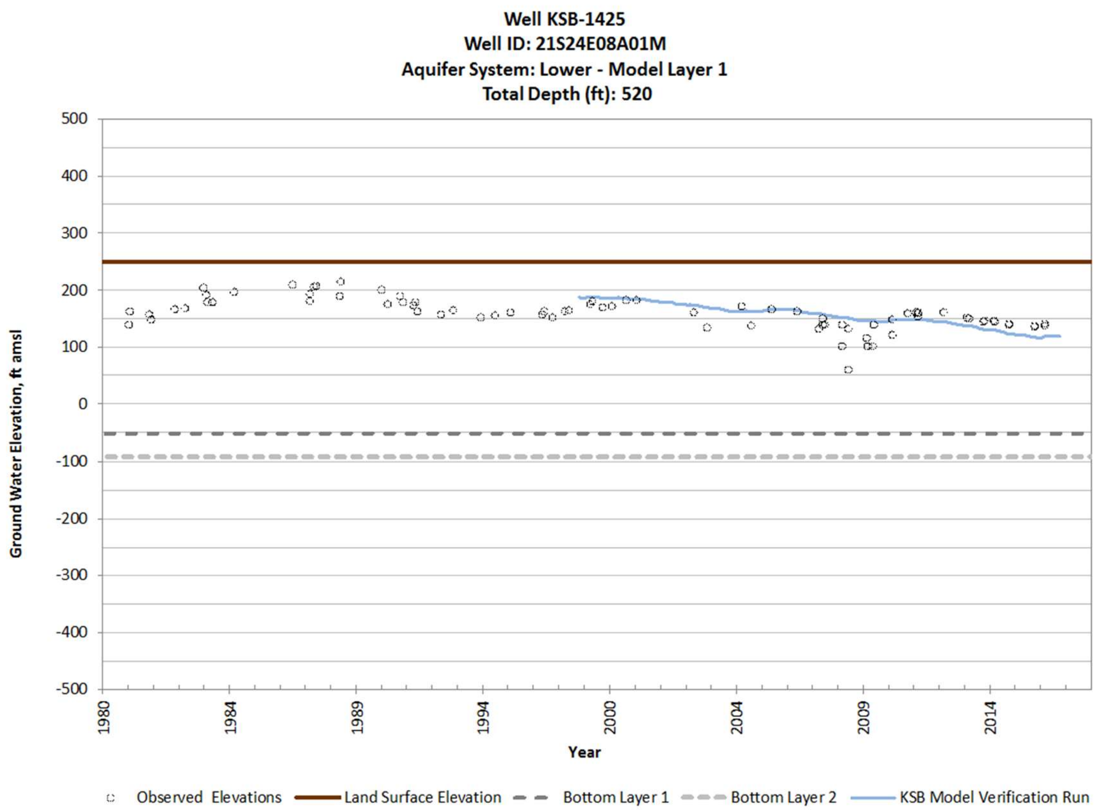

Well KSB-0922
Well ID: 21S23E07J01M
Aquifer System: Upper - Model Layer 3
Top of Screen Depth (ft): 420; Bottom of Screen Depth(ft): -102.215284; Total Depth (ft): 428
Ground Water Elevation, ft amsl
500
400
300
200
100
0
-100
-200
-300
-400
-500
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

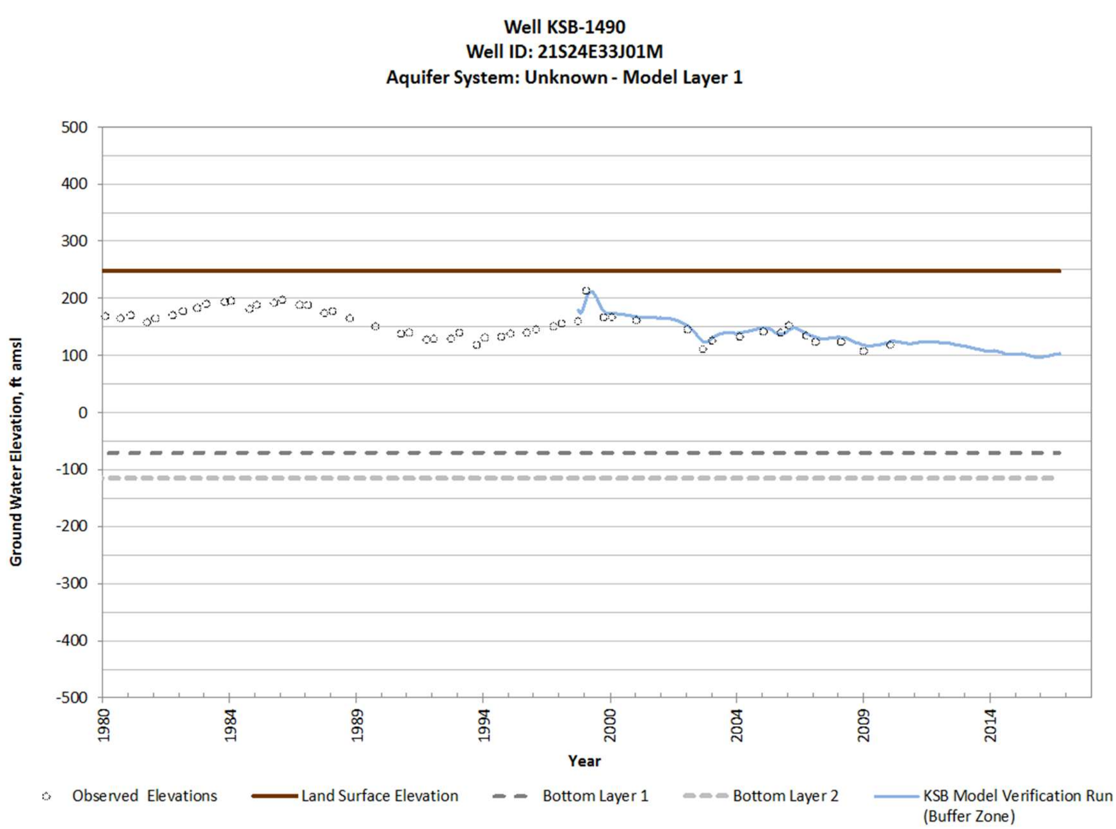


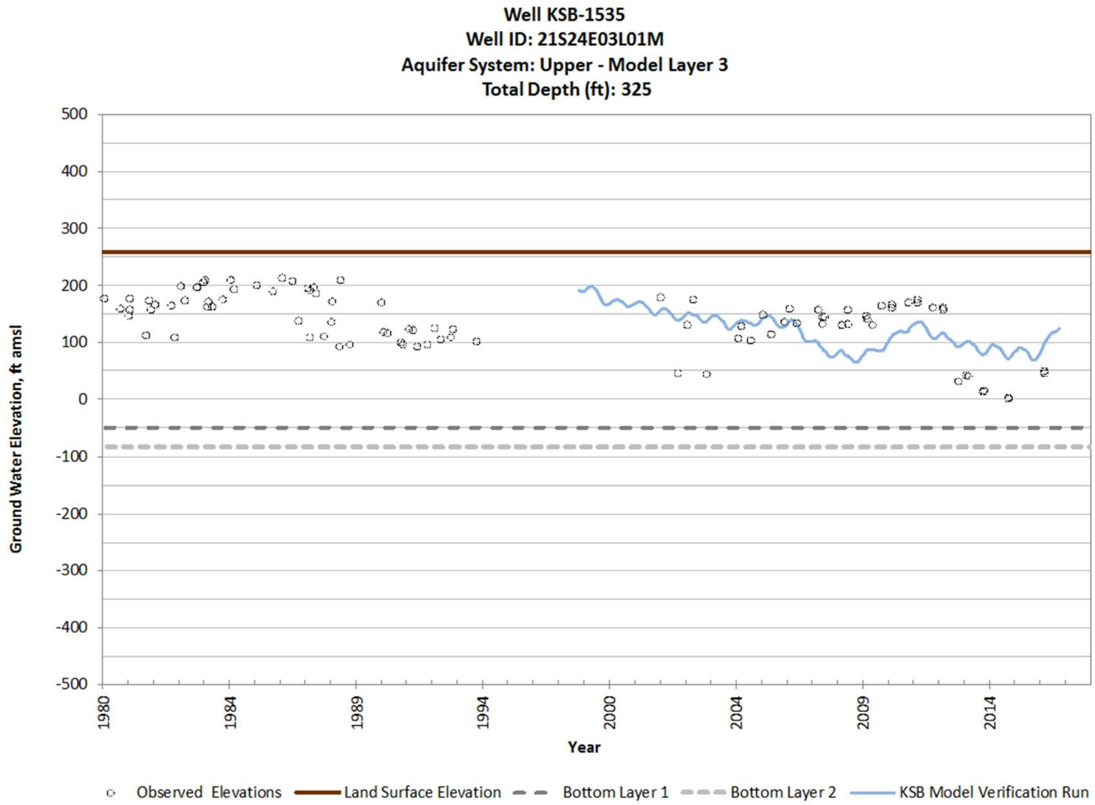
Well KSB-1214
Well ID: 18S23E02Q01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
500
400
300
200
100
0
-100
-200
-300
-400
-500
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

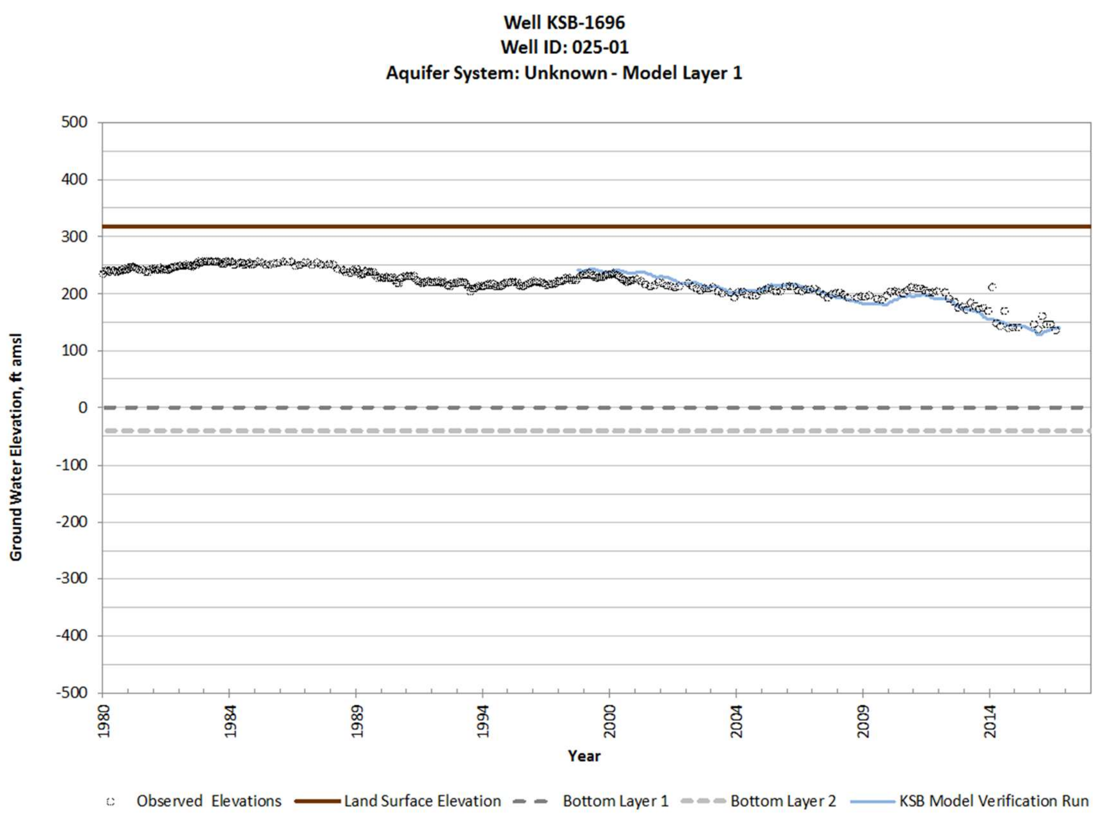



Well KSB-1226
Well ID: 19S23E35H01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
500
400
300
200
100
0
-100
-200
-300
-400
-500
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

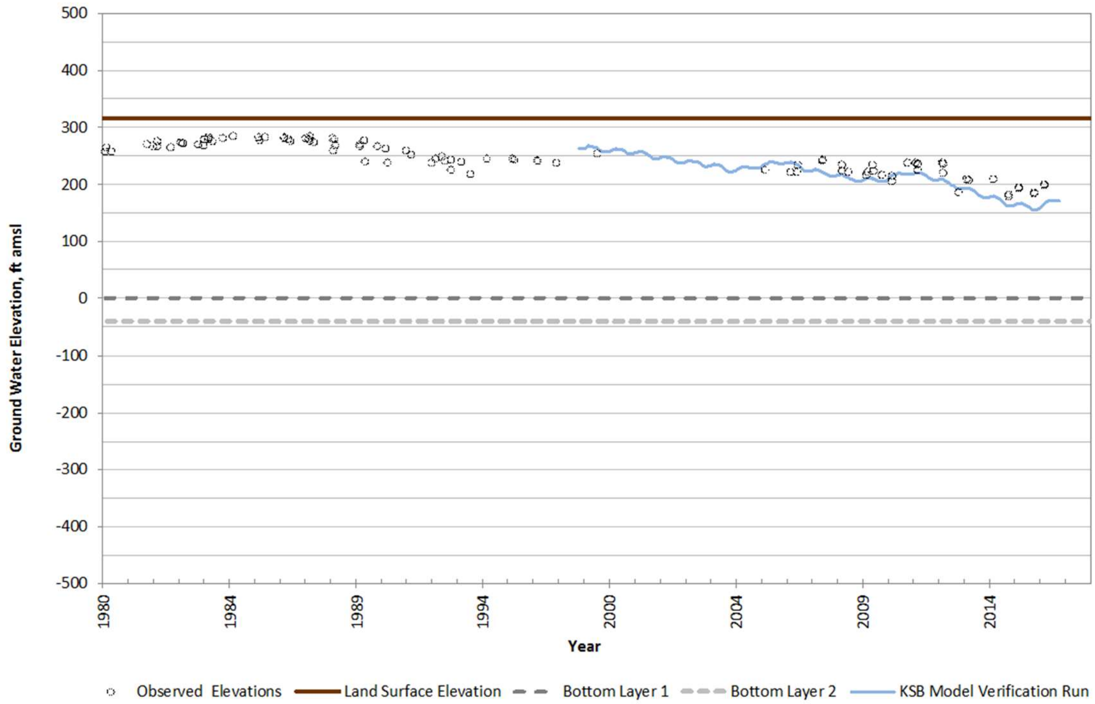

Well KSB-1425
Well ID: 21S24E08A01M
Aquifer System: Lower - Model Layer 1
Total Depth (ft): 520
Ground Water Elevation, ft amsl
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run


Well KSB-1490
Well ID: 21S24E33J01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run (Buffer Zone)

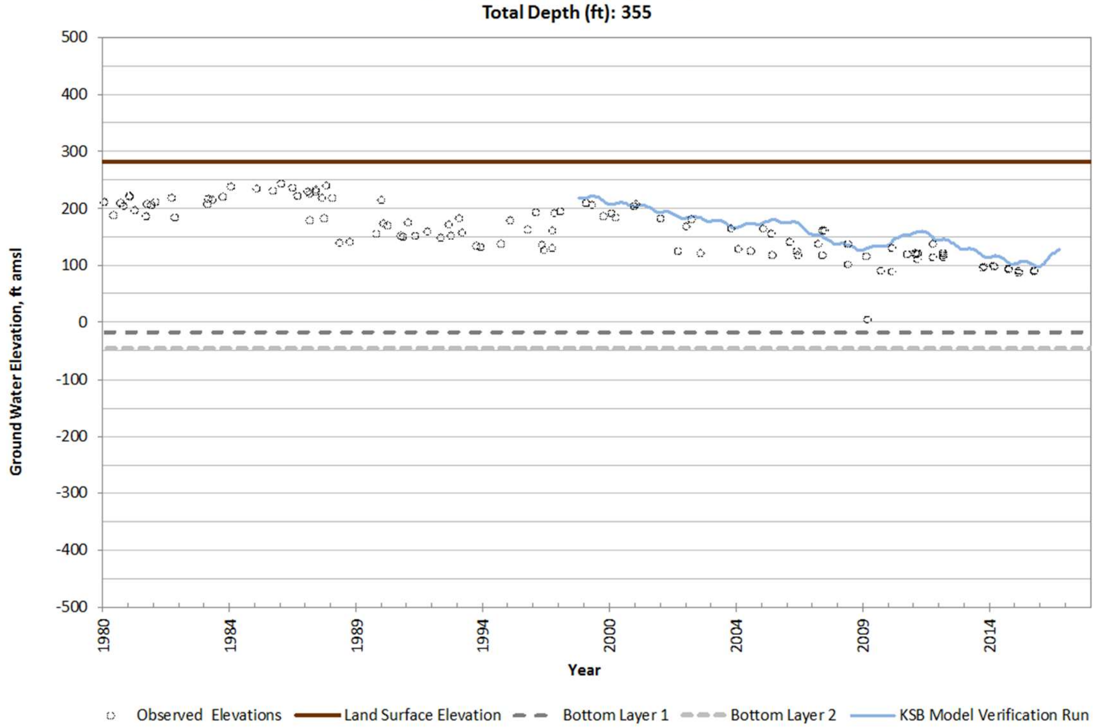

Well KSB-1535
Well ID: 21S24E03L01M
Aquifer System: Upper - Model Layer 3
Total Depth (ft): 325
Ground Water Elevation, ft amsl
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

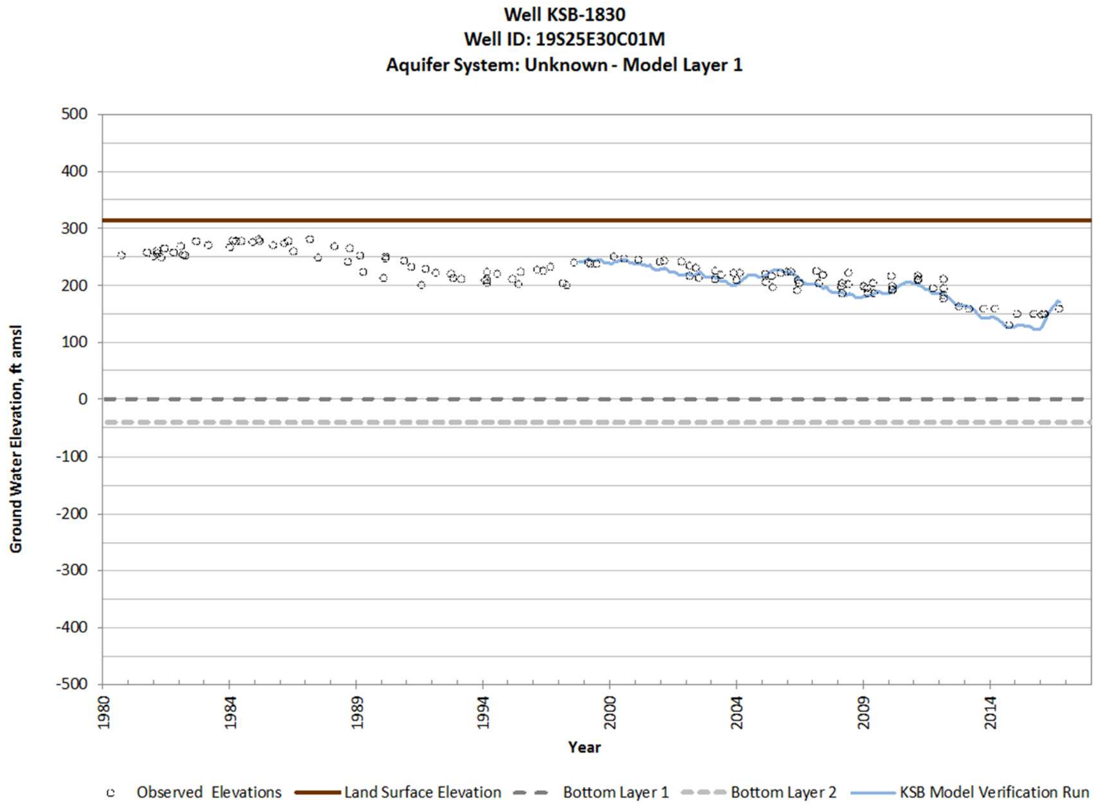

Well KSB-1696
Well ID: 025-01
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

**Well KSB-1775**
**Well ID: 17S24E36H03M**
**Aquifer System: Single - Model Layer 3**

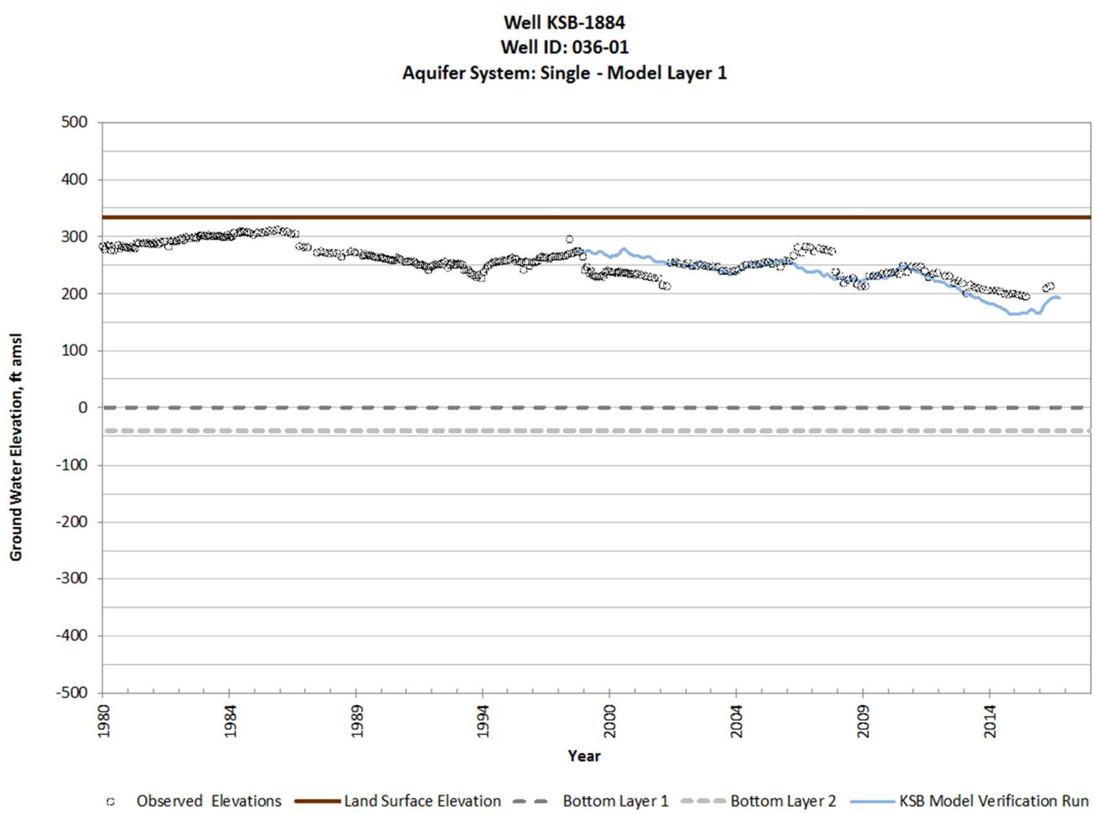



**Well KSB-1783**
**Well ID: 20S24E24H01M**
**Aquifer System: Upper - Model Layer 3**
**Total Depth (ft): 355**



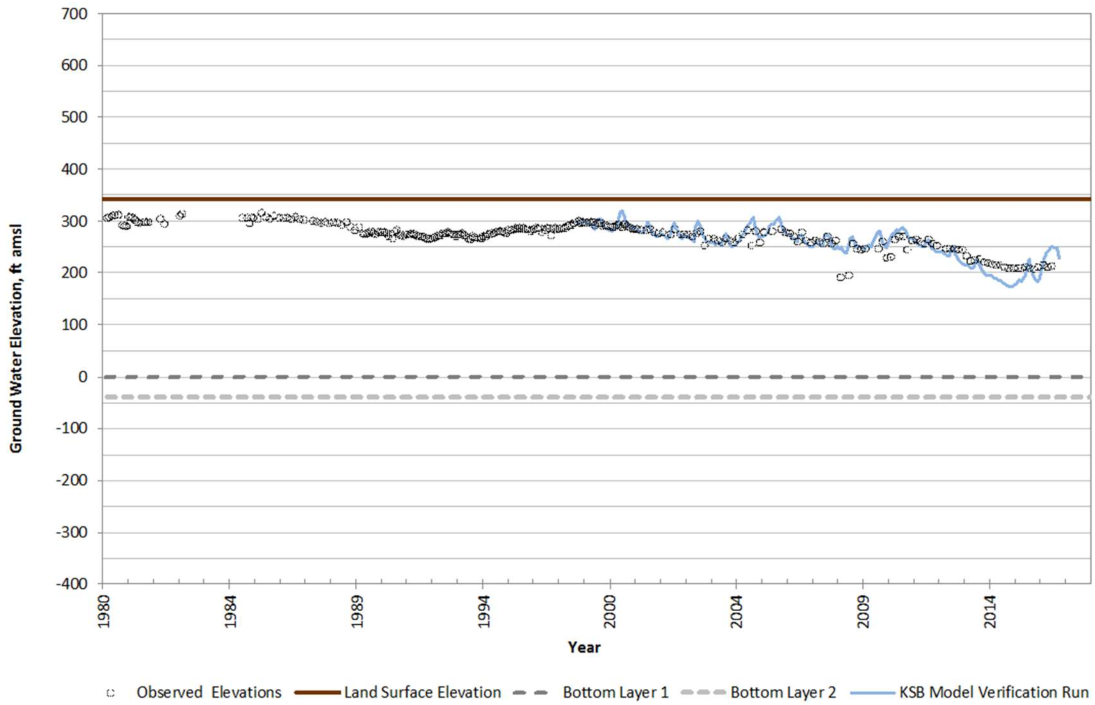


Well KSB-1830
Well ID: 19S25E30C01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
500
400
300
200
100
0
-100
-200
-300
-400
-500
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

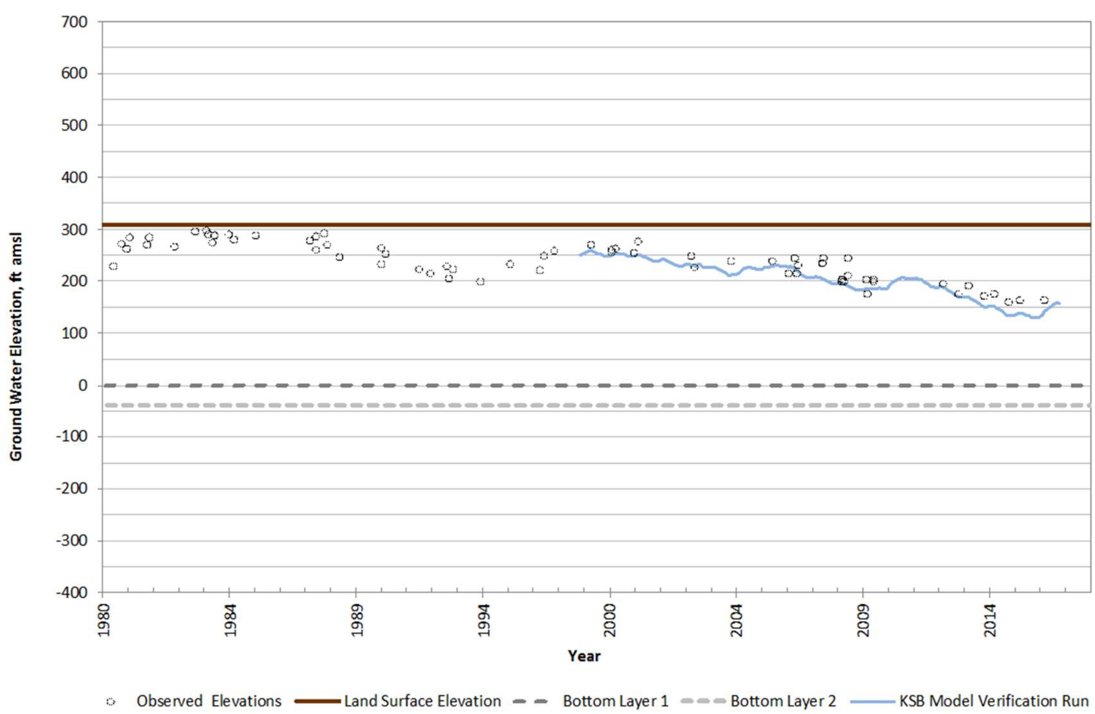



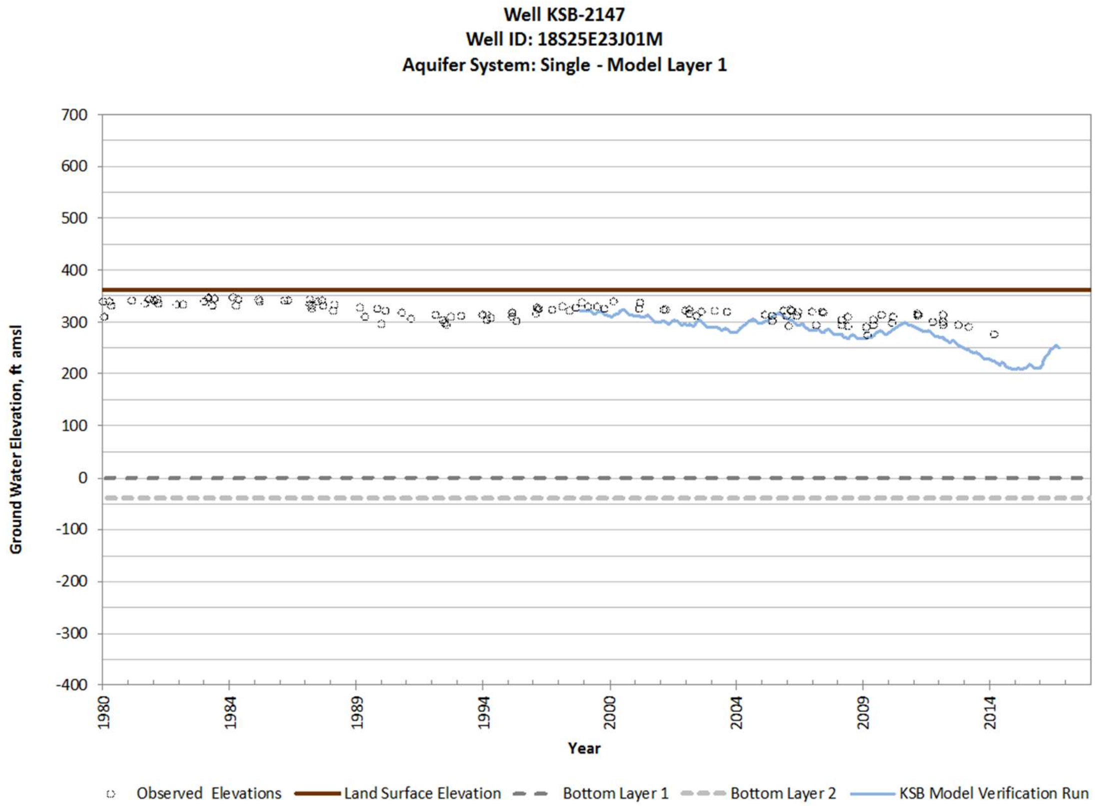
Well KSB-1884
Well ID: 036-01
Aquifer System: Single - Model Layer 1
Ground Water Elevation, ft amsl
500
400
300
200
100
0
-100
-200
-300
-400
-500
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

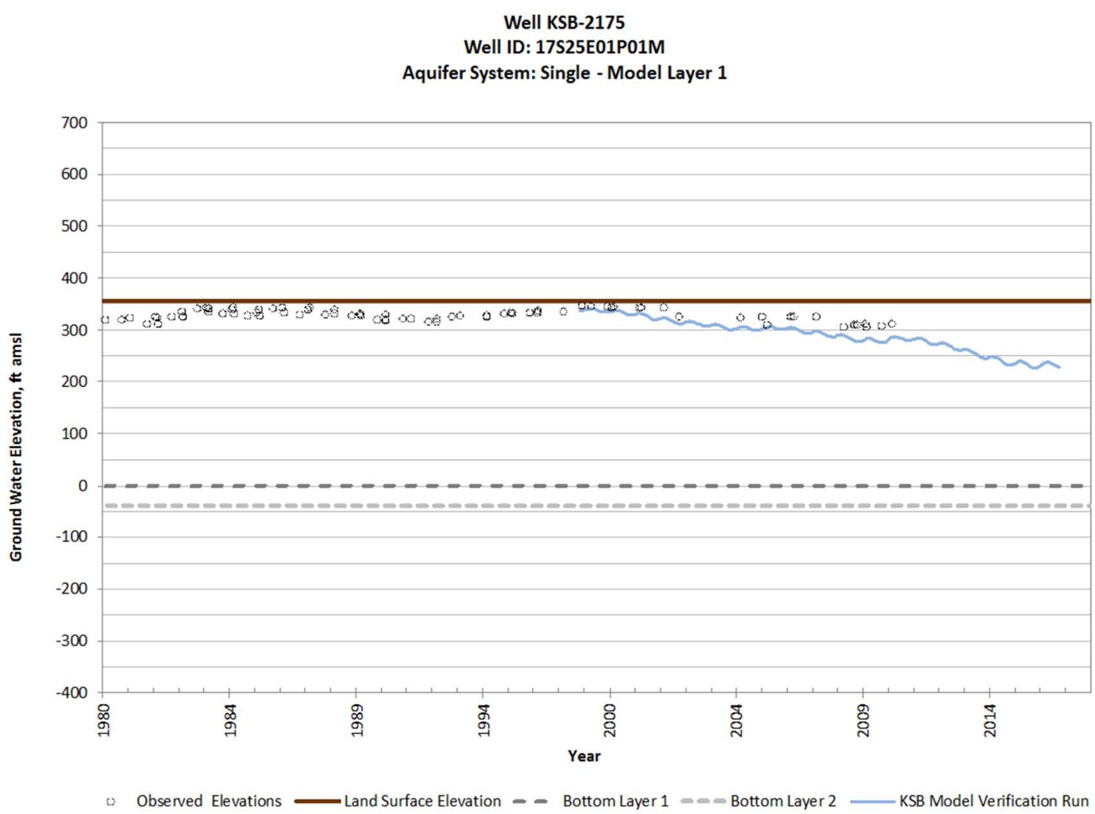
**Well KSB-1977**
**Well ID: 053-01**
**Aquifer System: Single - Model Layer 1**



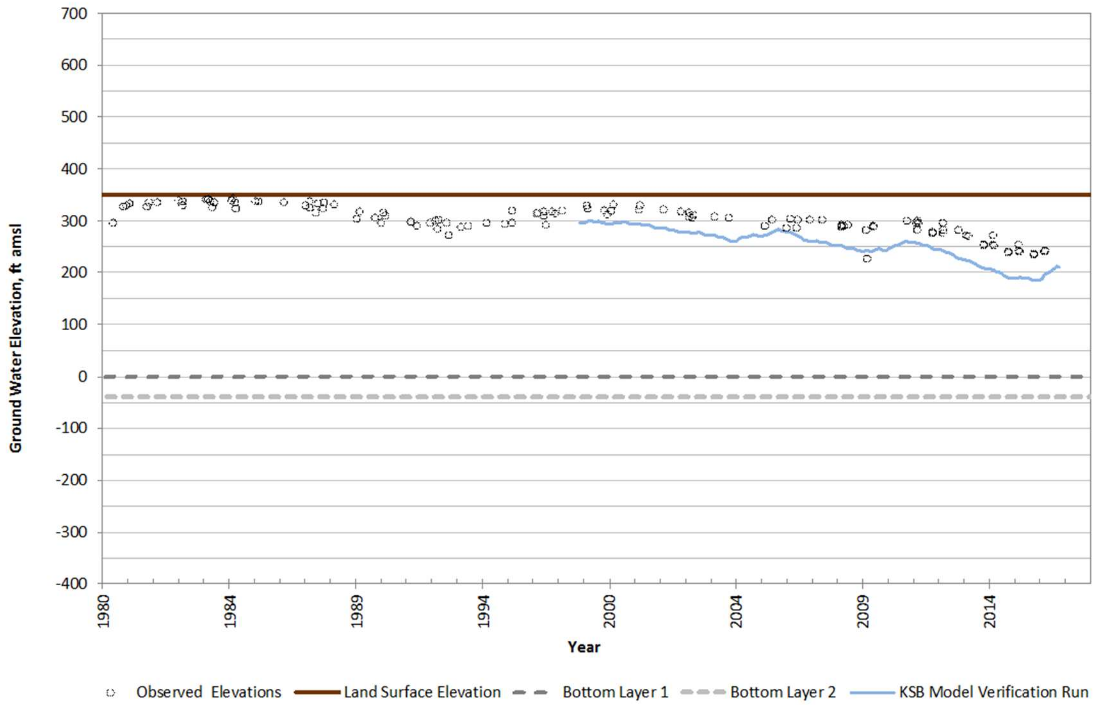

**Well KSB-2095**
**Well ID: 20S25E03R01M**
**Aquifer System: Single - Model Layer 1**



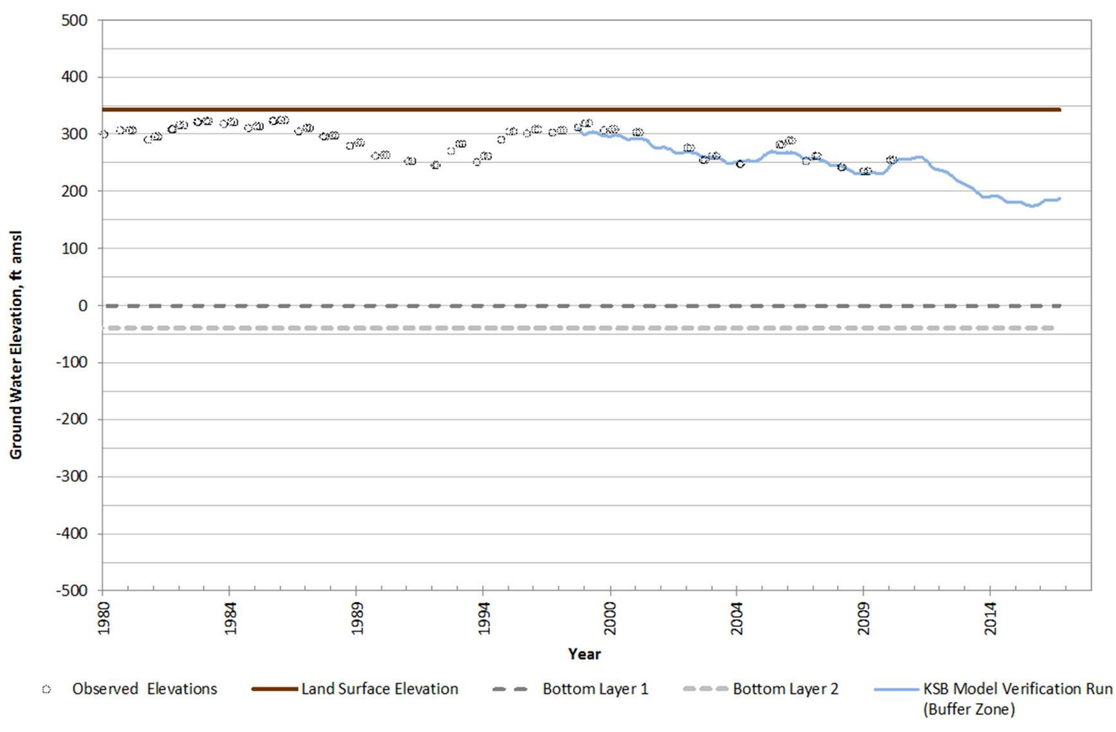

Well KSB-2147
Well ID: 18S25E23J01M
Aquifer System: Single - Model Layer 1
Ground Water Elevation, ft amsl
700
600
500
400
300
200
100
0
-100
-200
-300
-400
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run


Well KSB-2175
Well ID: 17S25E01P01M
Aquifer System: Single - Model Layer 1
Ground Water Elevation, ft amsl
700
600
500
400
300
200
100
0
-100
-200
-300
-400
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

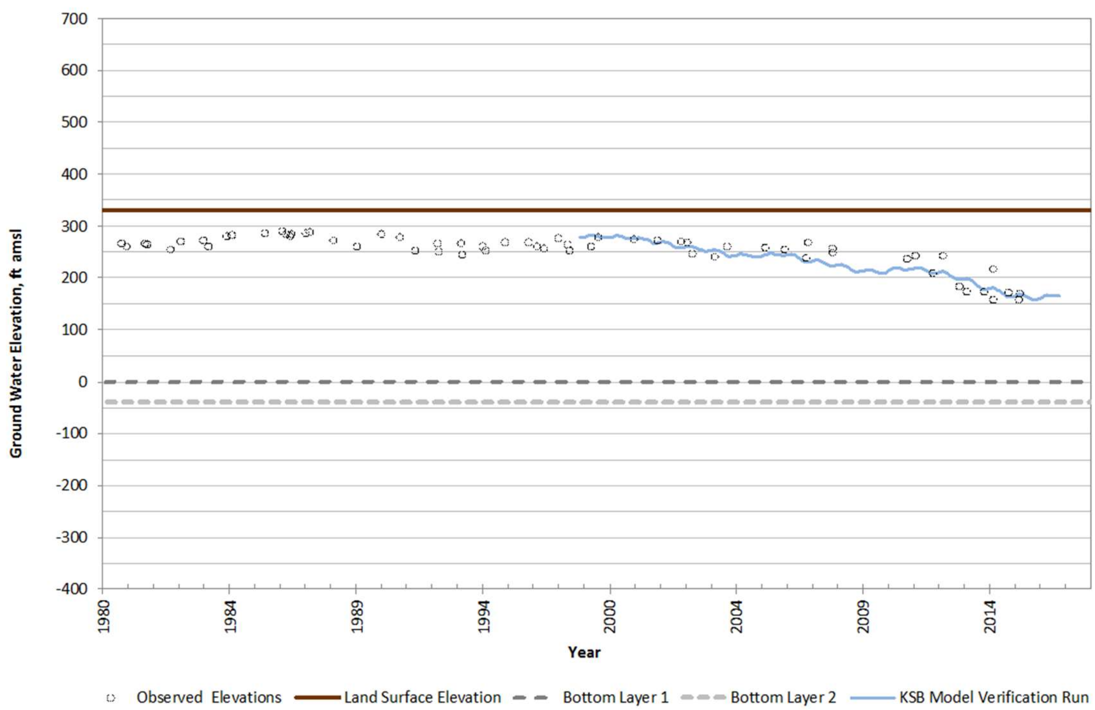
**Well KSB-2200**
**Well ID: 19S25E13A02M**
**Aquifer System: Single - Model Layer 1**



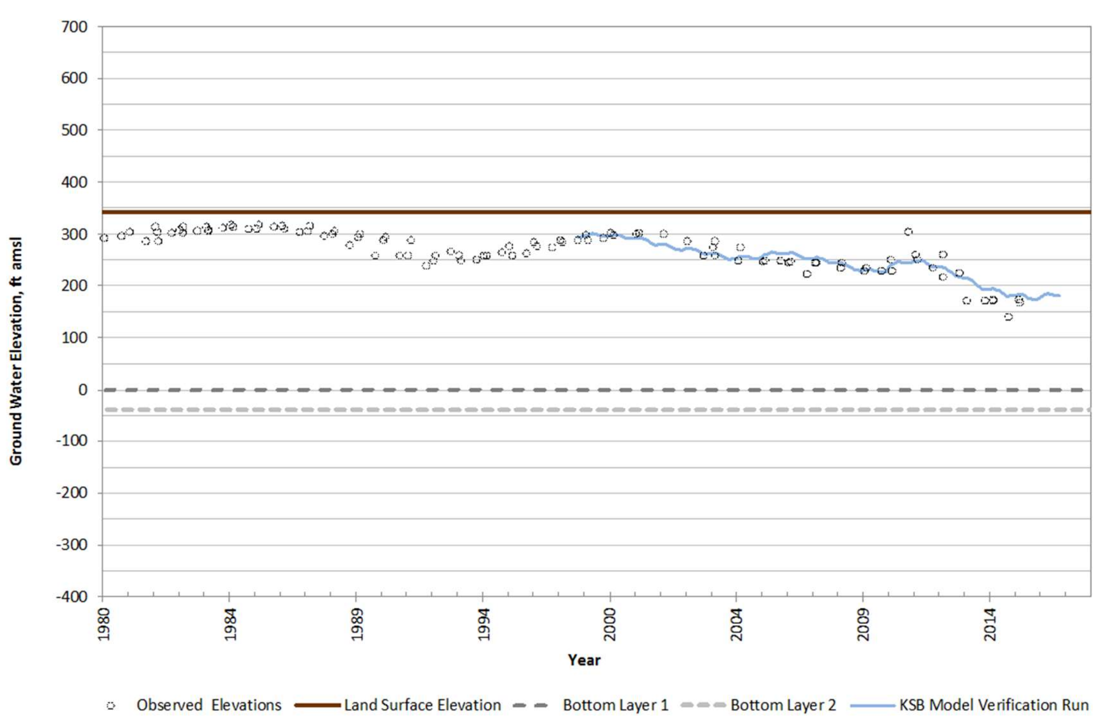

**Well KSB-2314**
**Well ID: 21S26E09D01M**
**Aquifer System: Single - Model Layer 1**

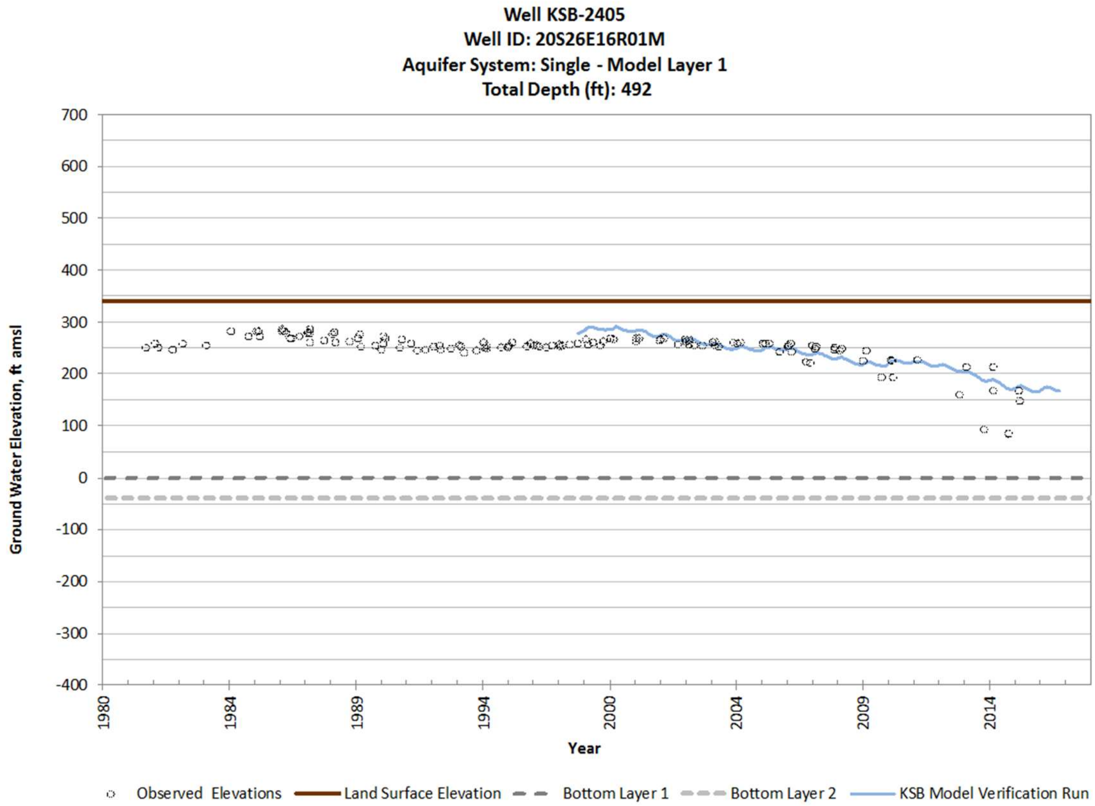


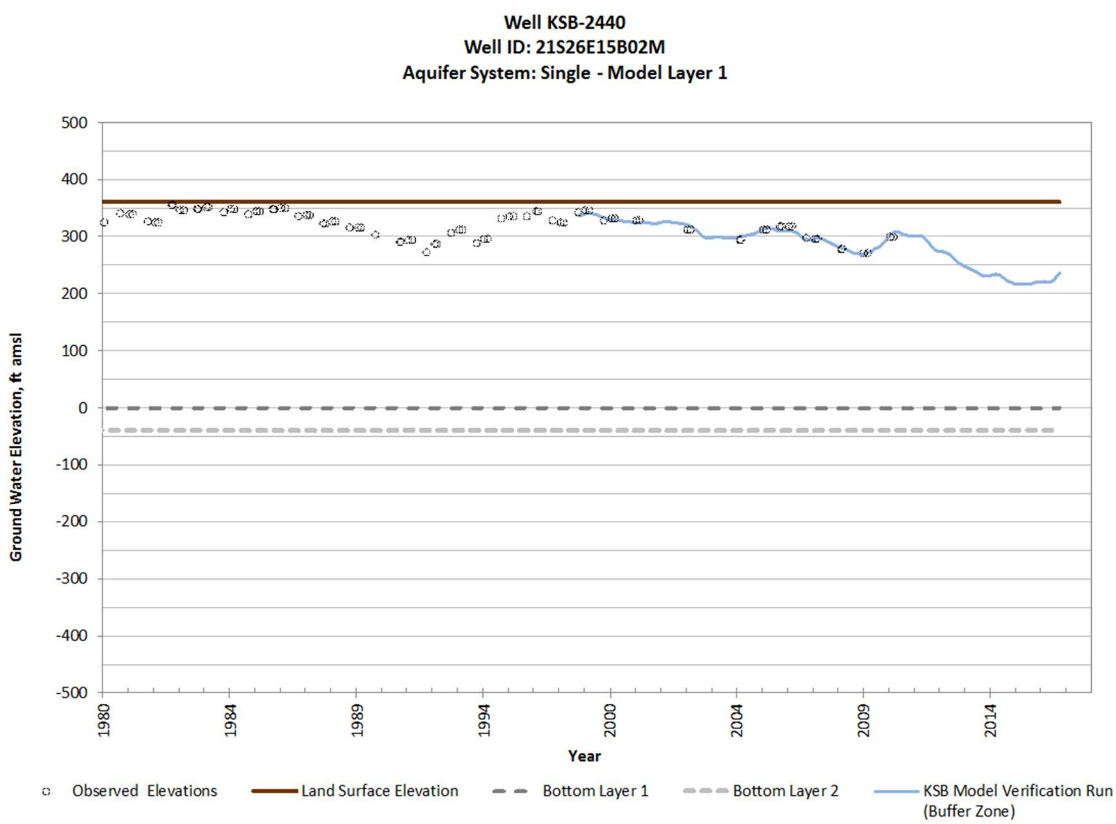
**Well KSB-2333**
**Well ID: 20S26E08H01M**
**Aquifer System: Single - Model Layer 1**

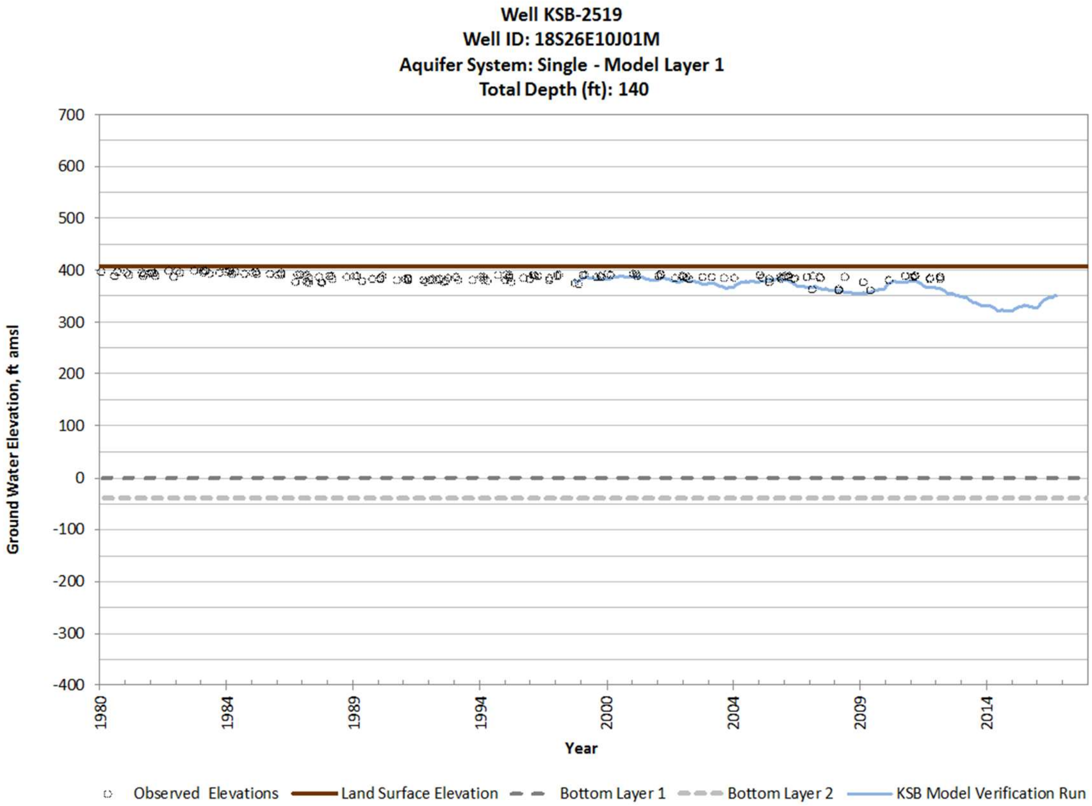


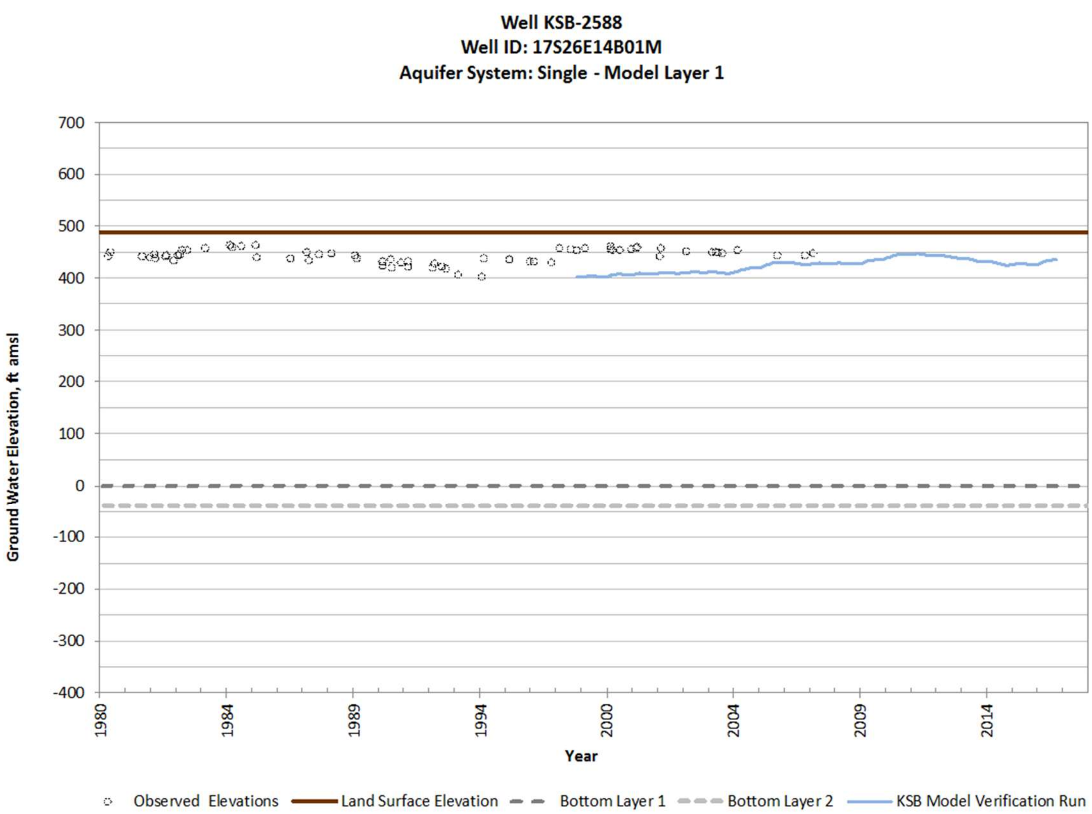

**Well KSB-2345**
**Well ID: 21S26E04F01M**
**Aquifer System: Single - Model Layer 1**

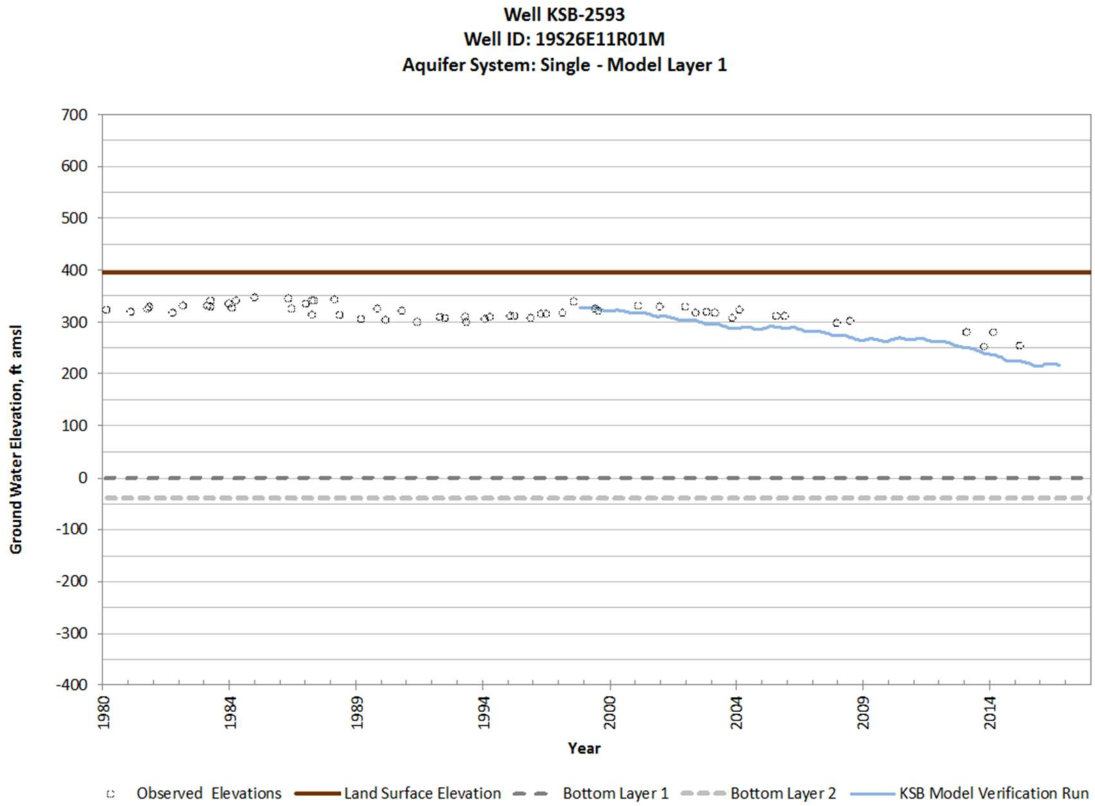


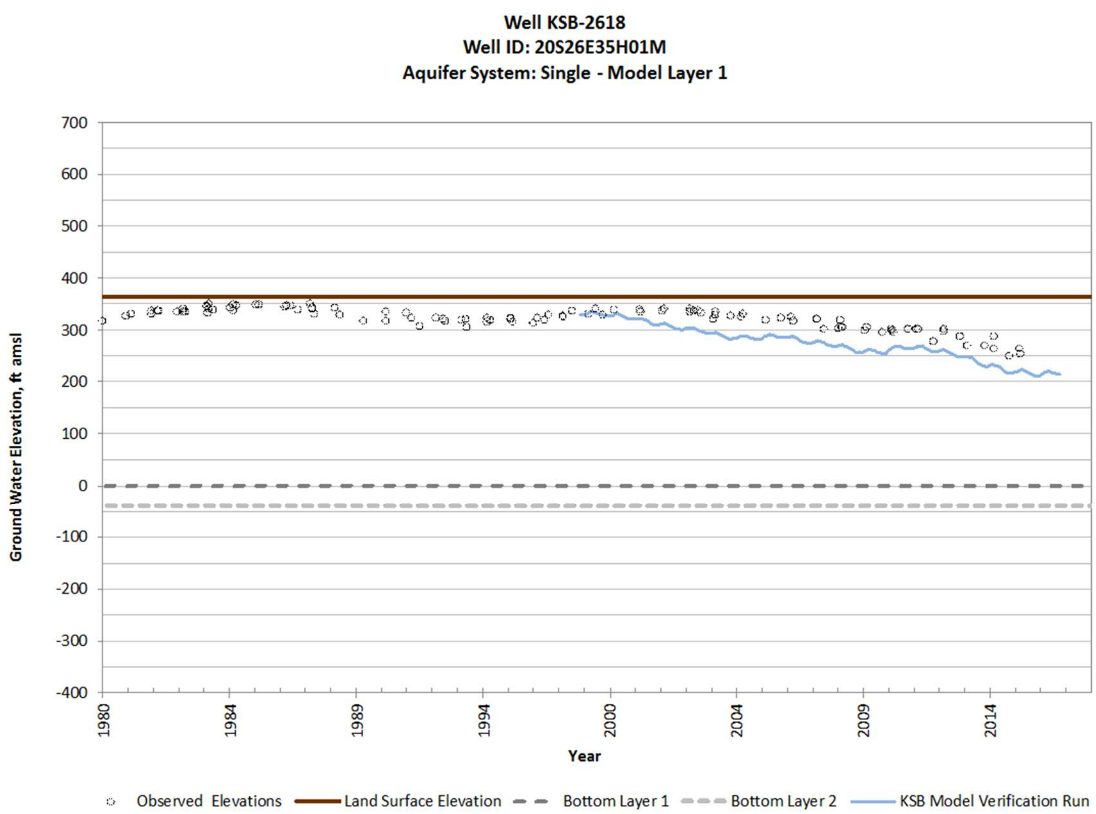

Well KSB-2405
Well ID: 20S26E16R01M
Aquifer System: Single - Model Layer 1
Total Depth (ft): 492
Ground Water Elevation, ft amsl
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

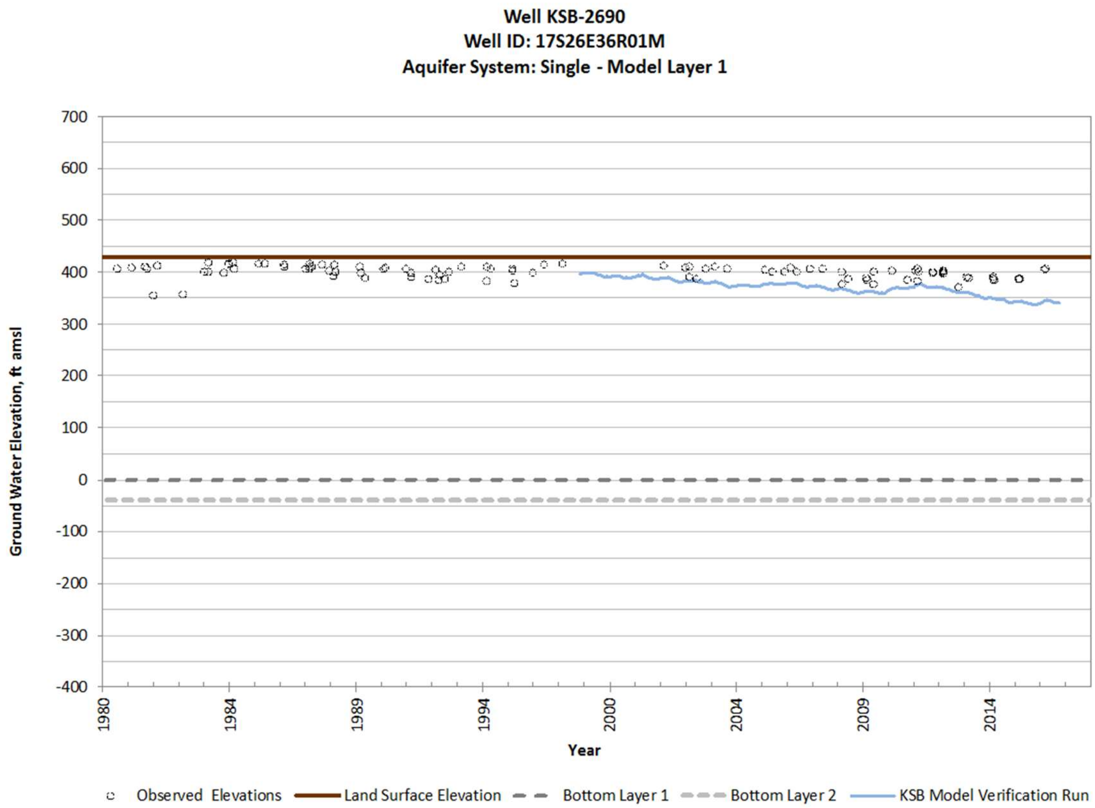

Well KSB-2440
Well ID: 21S26E15B02M
Aquifer System: Single - Model Layer 1
Ground Water Elevation, ft amsl
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run (Buffer Zone)

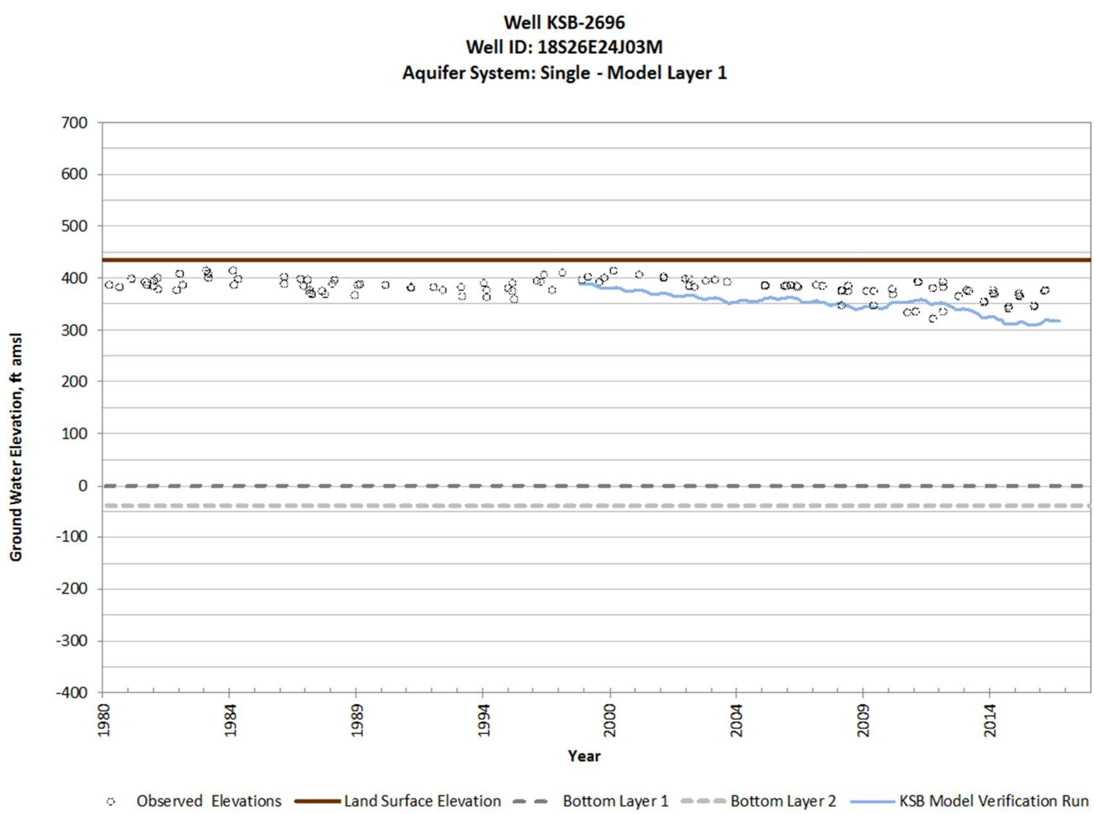

Well KSB-2519
Well ID: 18S26E10J01M
Aquifer System: Single - Model Layer 1
Total Depth (ft): 140
700
600
500
400
300
200
100
0
-100
-200
-300
-400
Ground Water Elevation, ft amsl
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

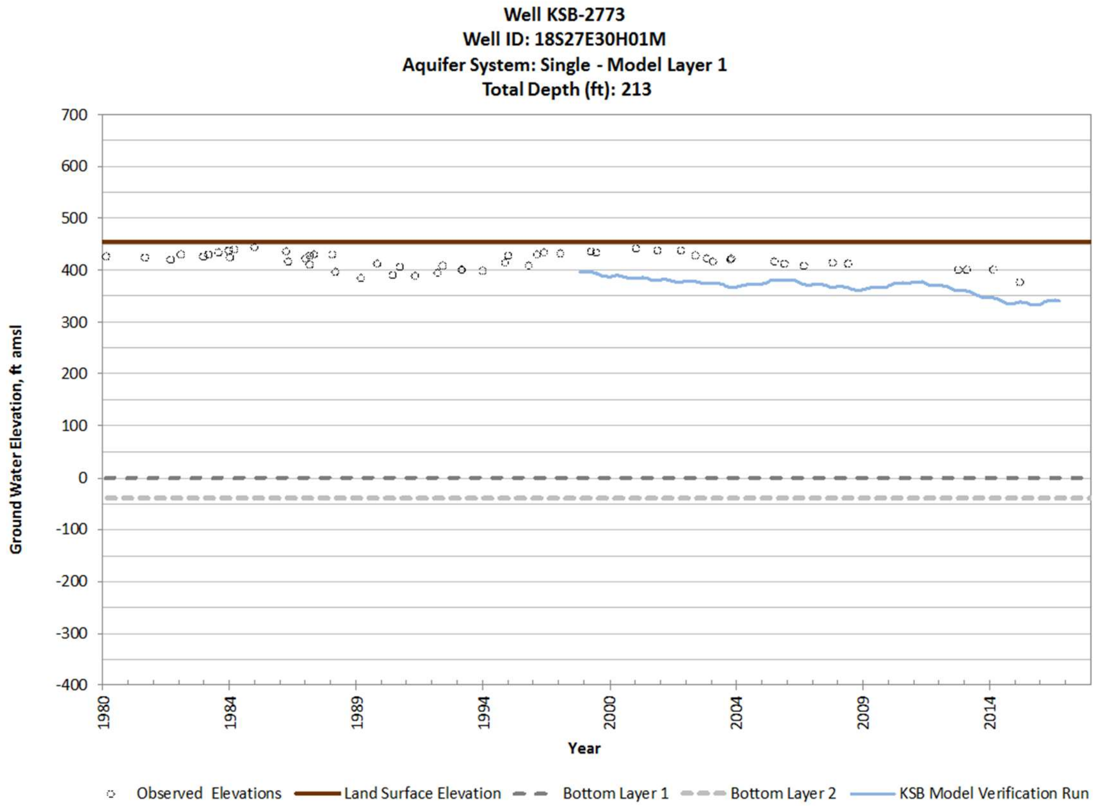

Well KSB-2588
Well ID: 17S26E14B01M
Aquifer System: Single - Model Layer 1
700
600
500
400
300
200
100
0
-100
-200
-300
-400
Ground Water Elevation, ft amsl
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

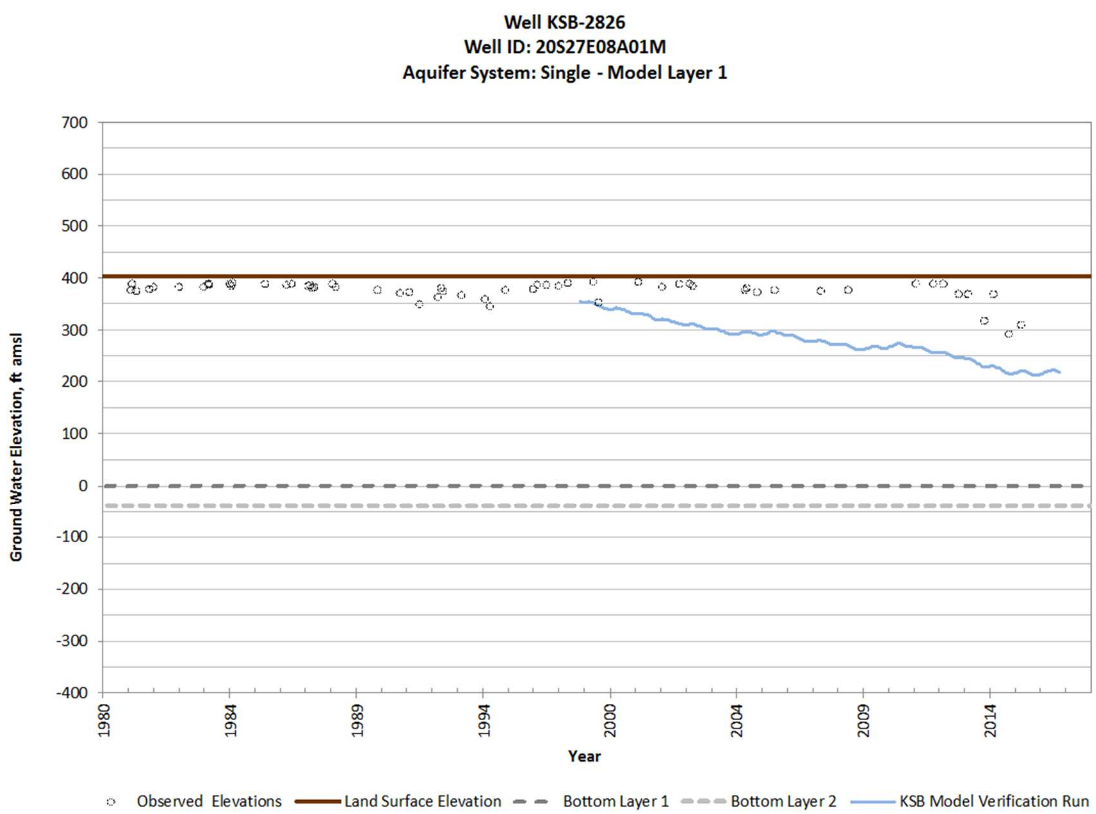

Well KSB-2593
Well ID: 19S26E11R01M
Aquifer System: Single - Model Layer 1
Ground Water Elevation, ft amsl
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run

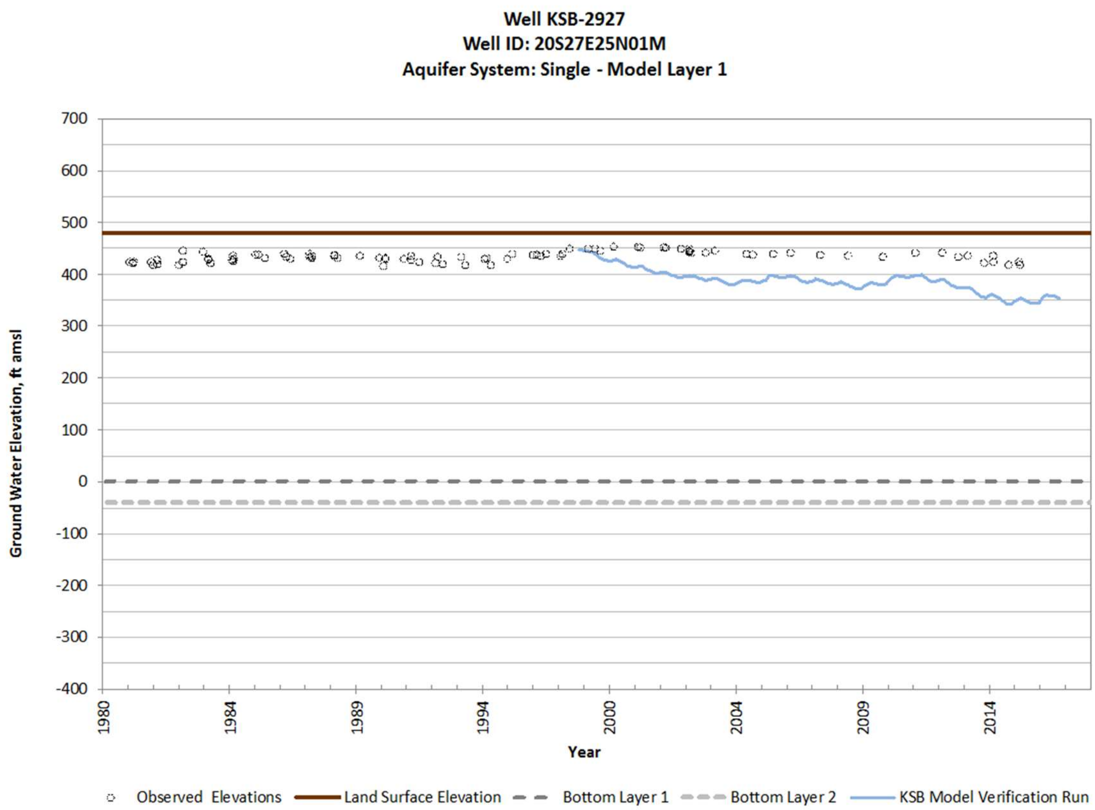

Well KSB-2618
Well ID: 20S26E35H01M
Aquifer System: Single - Model Layer 1
Ground Water Elevation, ft amsl
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run


Well KSB-2690
Well ID: 17S26E36R01M
Aquifer System: Single - Model Layer 1
Ground Water Elevation, ft amsl
700
600
500
400
300
200
100
0
-100
-200
-300
-400
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run


Well KSB-2696
Well ID: 18S26E24J03M
Aquifer System: Single - Model Layer 1
Ground Water Elevation, ft amsl
700
600
500
400
300
200
100
0
-100
-200
-300
-400
1980
1984
1989
1994
2000
2004
2009
2014
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run


Well KSB-2773
Well ID: 18S27E30H01M
Aquifer System: Single - Model Layer 1
Total Depth (ft): 213
Ground Water Elevation, ft amsl
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run


Well KSB-2826
Well ID: 20S27E08A01M
Aquifer System: Single - Model Layer 1
Ground Water Elevation, ft amsl
Year
Observed Elevations
Land Surface Elevation
Bottom Layer 1
Bottom Layer 2
KSB Model Verification Run



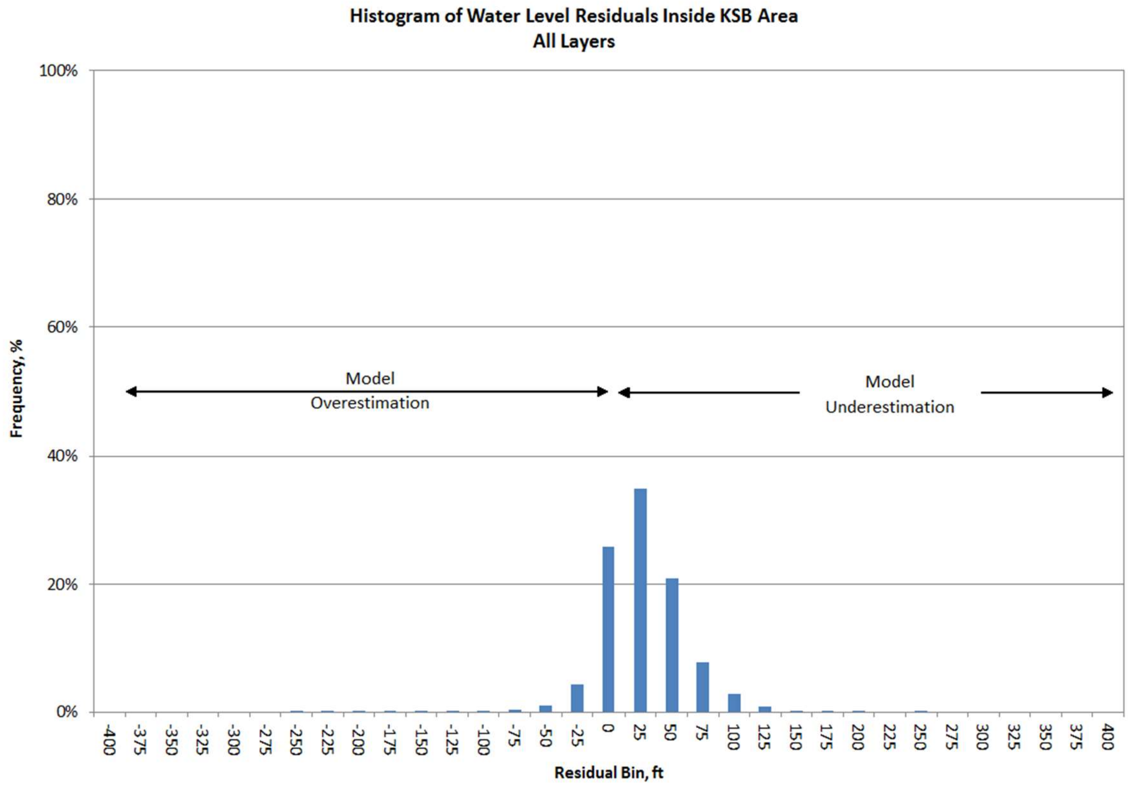

## Model Statistics

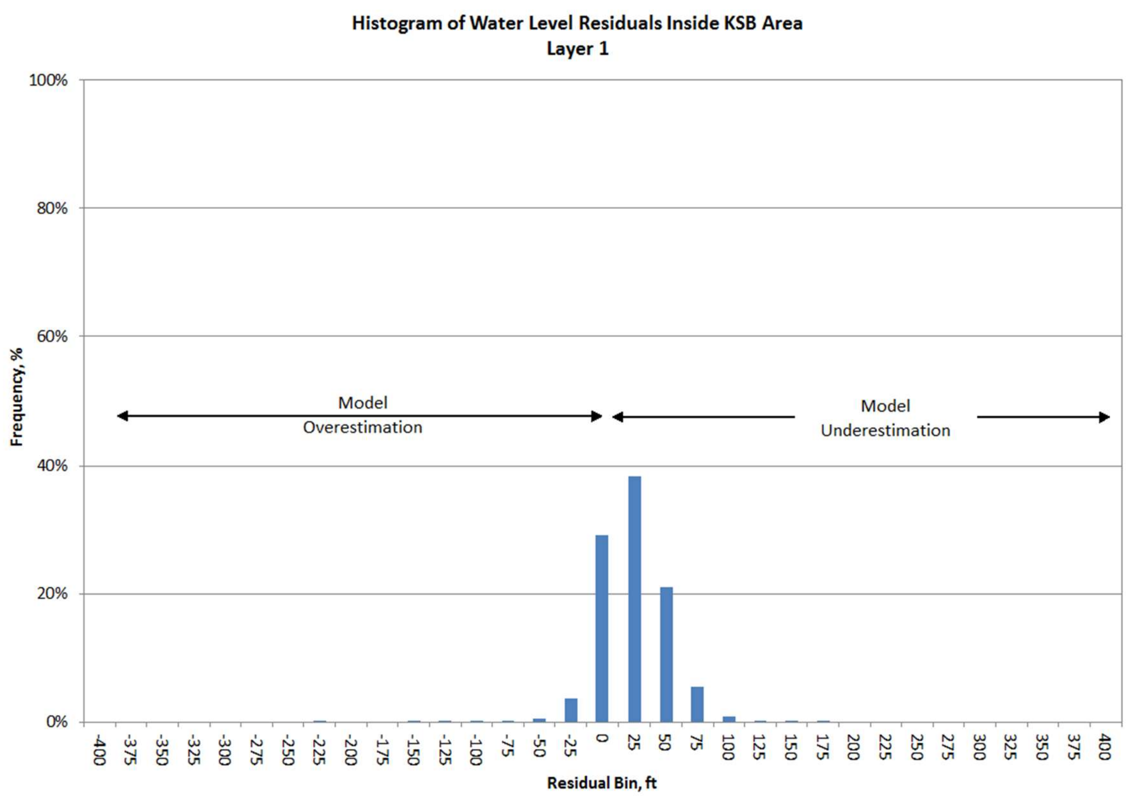
### Wells in Kaweah Subbasin

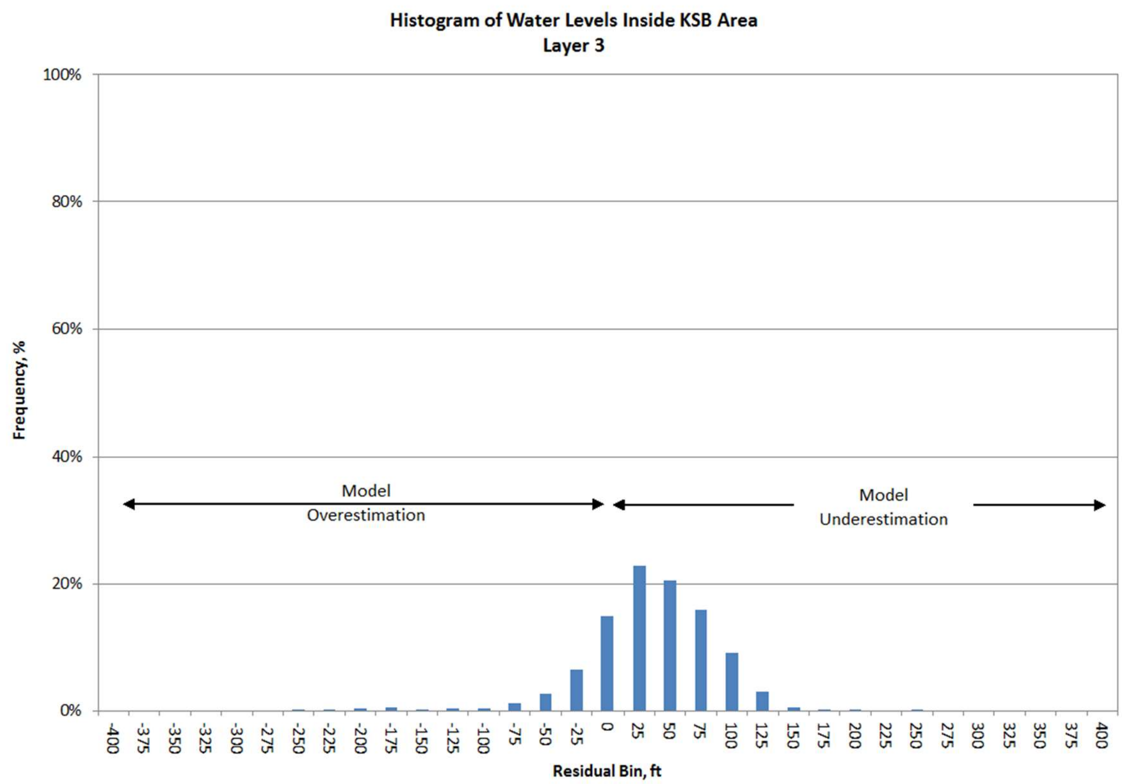
The graphs below show trends and comparisons of the groundwater model data. The data is shown for All Layers (all wells), Layer 1 (wells in layer 1), and Layer 3 (wells in Layer 3). The three main graphs in each section are as follows:

1. Histogram of Water Level Residuals
2. Temporal Distribution of Water Level Residuals
3. Measured vs Model- Calculated Water Levels

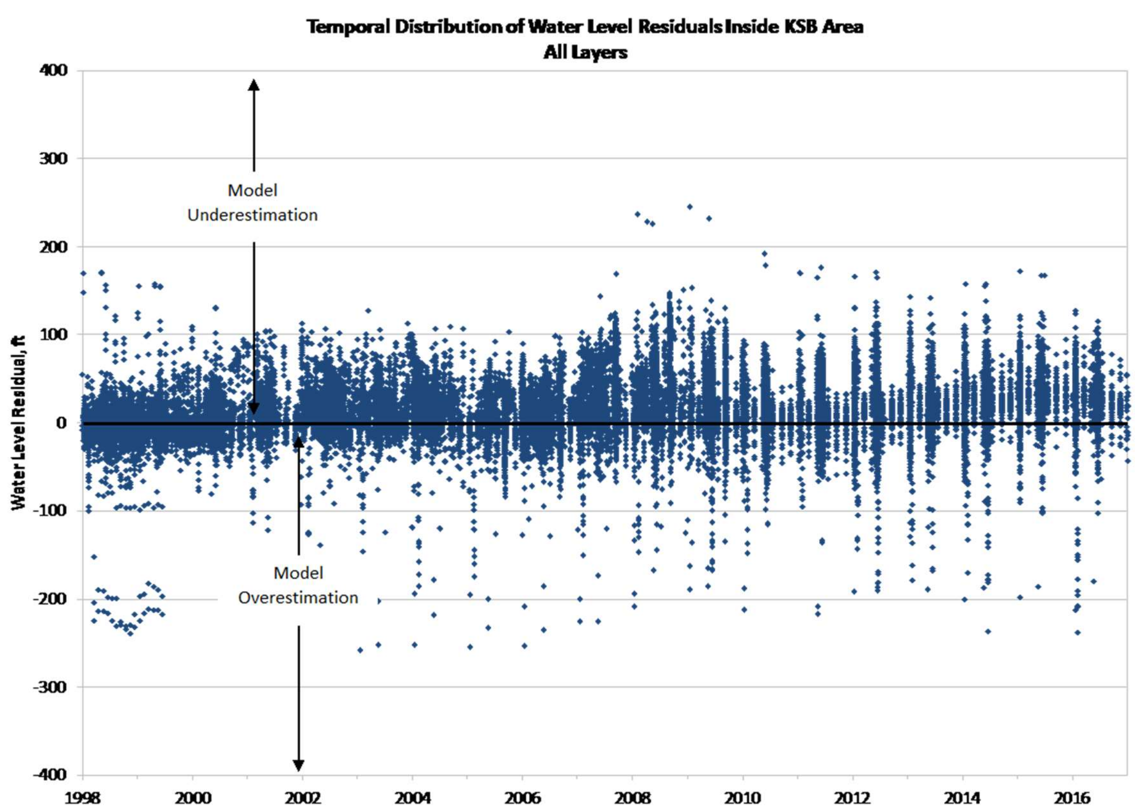
## Histogram of Water Level Residual

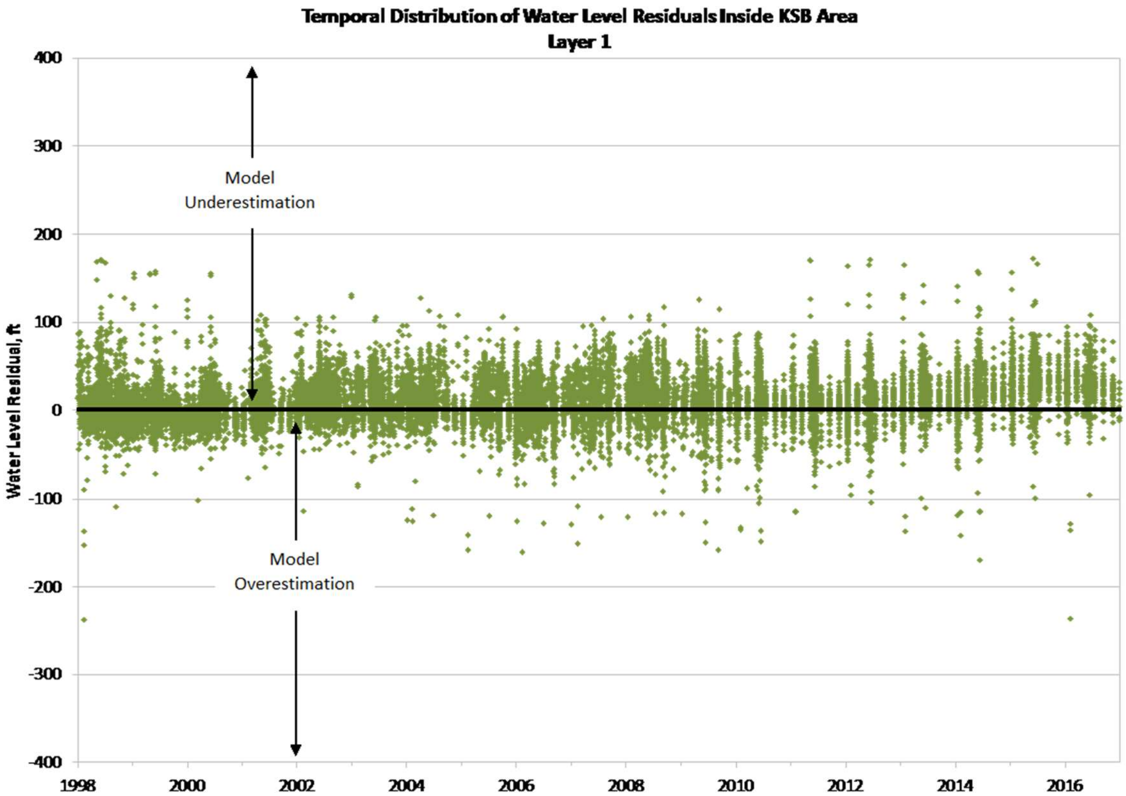


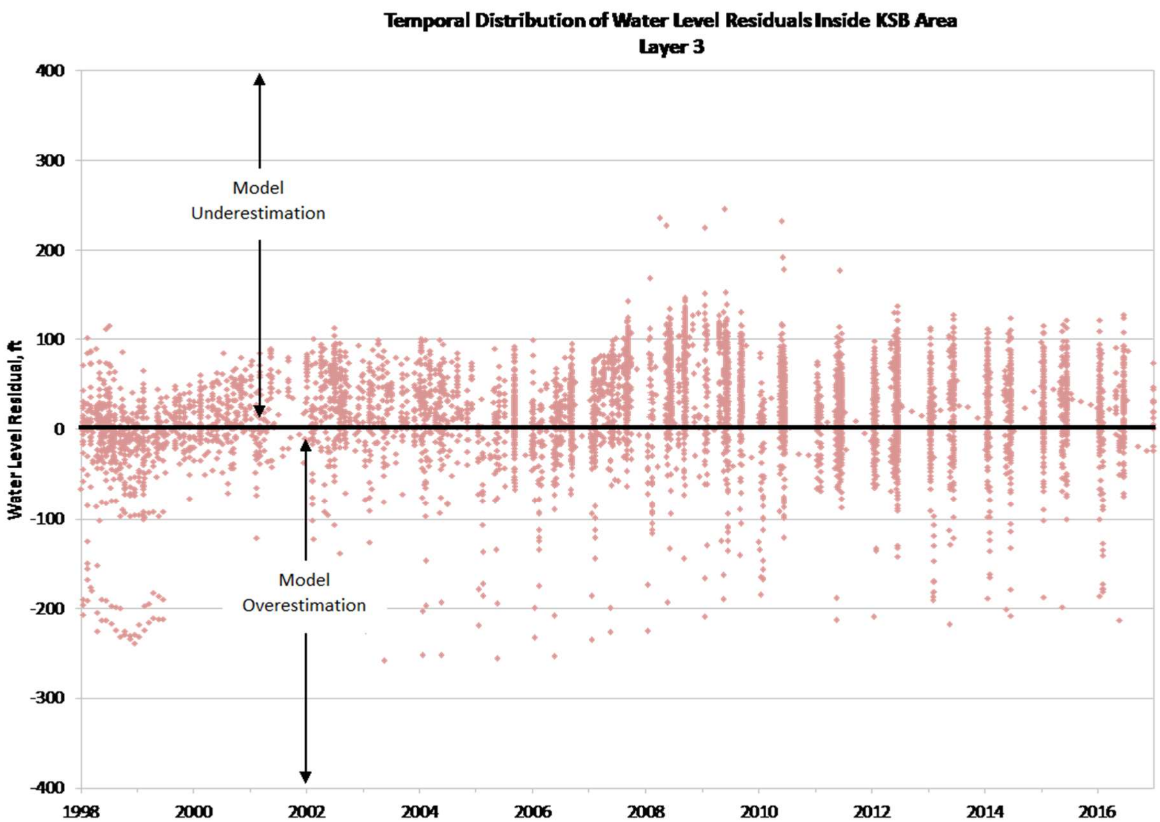





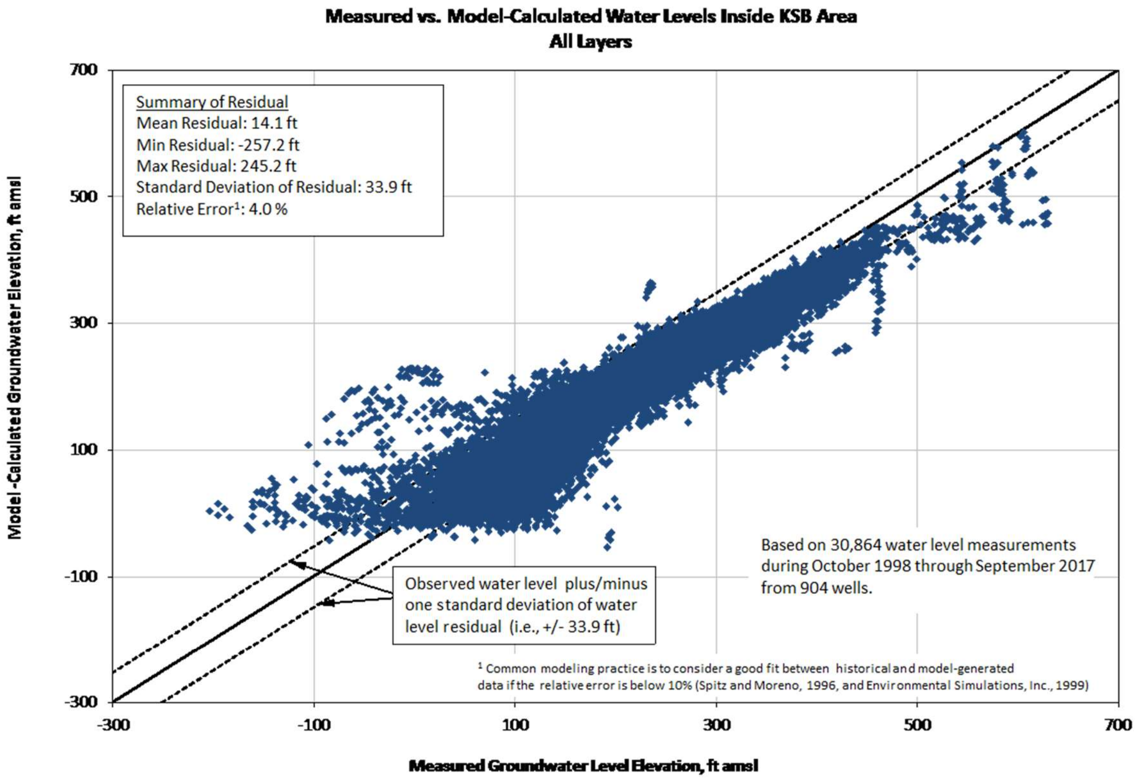

## Temporal Distribution of Water Level Residuals

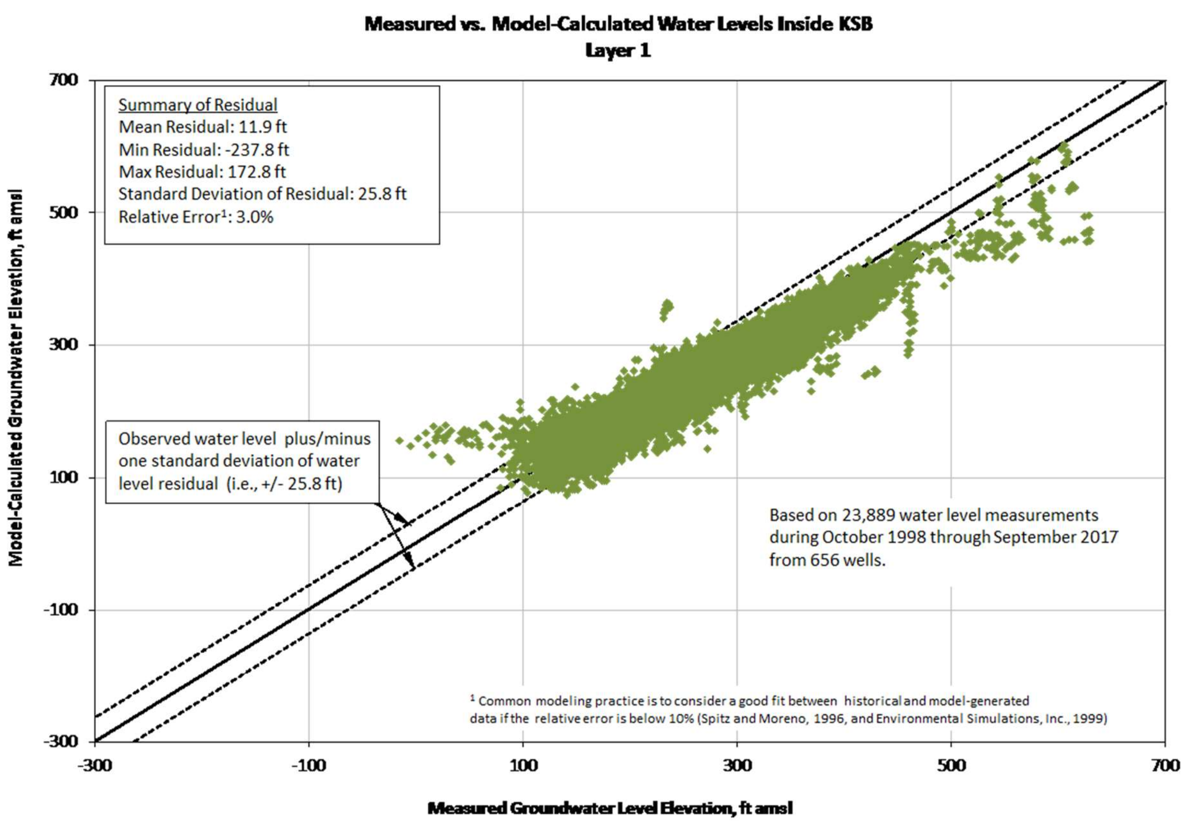


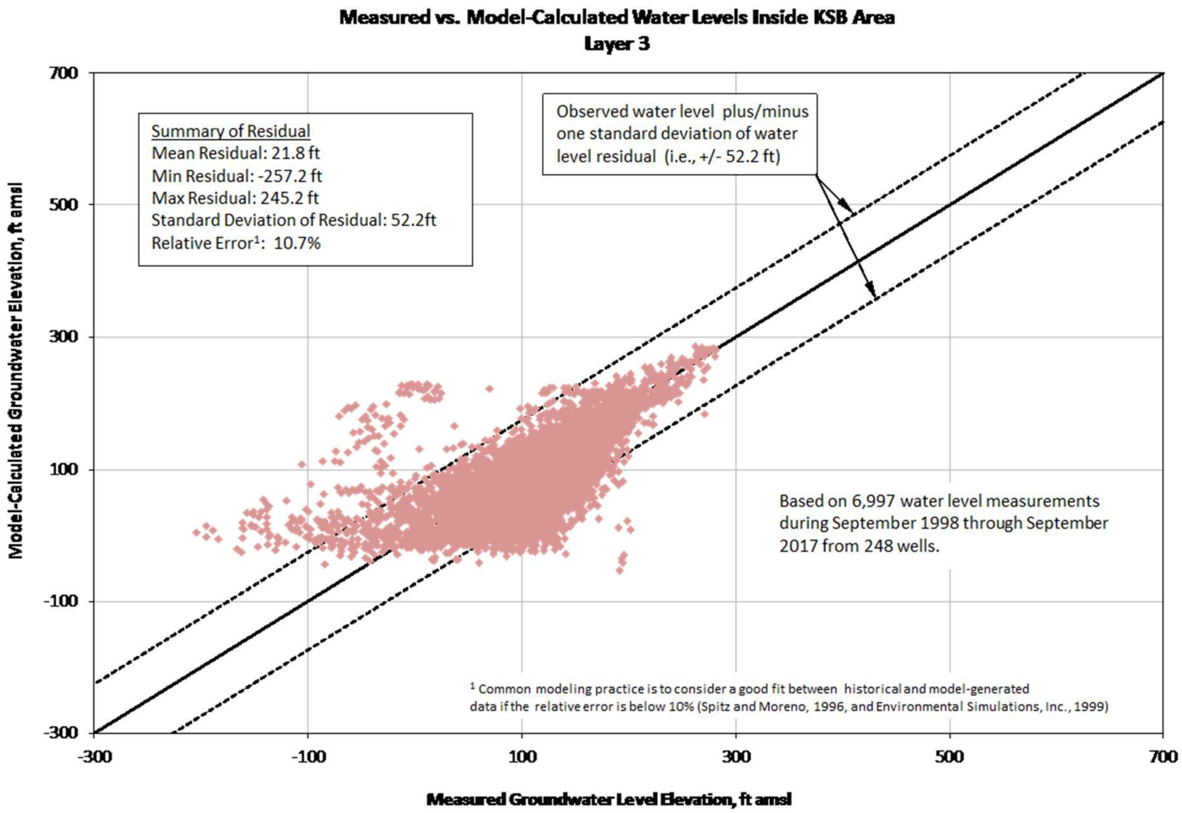

Temporal Distribution of Water Level Residuals Inside KSB Area
Layer 1
Model
Underestimation
Model
Overestimation
Water Level Residual, ft
400
300
200
100
0
-100
-200
-300
-400
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016


Temporal Distribution of Water Level Residuals Inside KSB Area
Layer 3
Model
Underestimation
Model
Overestimation
Water Level Residual, ft
400
300
200
100
0
-100
-200
-300
-400
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

Measured vs Model-Calculated Water Levels






## Comparing the Residual Layers

The residual from measured and modeling results are computed for 23,889 water level measurements from 656 wells between October 1998 through September 2017. Based on the values of relative error, we can conclude that there is a good fit between measured and model-generated data since the relative error is 3% in layer 1 and just over 10% in layer 3.

| Summary of Residual | KSB Layer 1 | KSB Layer 3 | All Layers |
|---|---|---|---|
| Mean Residual (ft) | 11.9 | 21.8 | |
| Min Residual (ft) | -237.8 | -257.2 | |
| Max Residual (ft) | 172.8 | 245.2 | |
| Standard Dev. of Residual (ft) | 25.8 | 52.2 | |
| Relative Error (%) | 3.0 | 10.7 | |

**Note common modeling practice is to consider a good fit between historical and model-generated data if the relative error is below 10%. (Spitz and Moreno, 1996, and Environmental Simulation, Inc., 1999)*

# Appendix 2: Full Kaweah Subbasin Results

## Full Results for Case 1: Base Case of Future with Averaged Conditions and No Projects

| Water Year | Inflow (Acre-Feet/Year) | | | Outflow (Acre-Feet/Year) | | | | | Storage | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Recharge | Underflow Buffer to KSB | Total Inflow | Ag Pumping | Aquifer Discharge to Streams | Non-Ag Pumping | Underflow KSB to Buffer | Total Outflow | Change in Storage (Acre-Feet/Year) | Cumulative Change in Storage (Acre-Feet) |
| 2020 | 676,105 | 185,429 | 861,534 | 726,105 | 0 | 101,360 | 60,420 | 887,886 | -26,352 | -26,352 |
| 2021 | 673,620 | 203,678 | 877,298 | 732,860 | 0 | 103,682 | 59,393 | 895,935 | -18,637 | -44,989 |
| 2022 | 673,620 | 205,414 | 879,035 | 739,458 | 0 | 106,216 | 61,291 | 906,965 | -27,930 | -72,920 |
| 2023 | 673,620 | 206,638 | 880,258 | 747,097 | 0 | 108,525 | 62,616 | 918,238 | -37,980 | -110,900 |
| 2024 | 676,105 | 208,646 | 884,751 | 755,303 | 0 | 110,849 | 63,749 | 929,901 | -45,151 | -156,050 |
| 2025 | 673,620 | 210,193 | 883,814 | 761,862 | 0 | 113,133 | 64,127 | 939,122 | -55,309 | -211,359 |
| 2026 | 673,620 | 212,602 | 886,222 | 768,886 | 0 | 115,649 | 64,536 | 949,071 | -62,849 | -274,208 |
| 2027 | 673,620 | 215,400 | 889,020 | 776,094 | 0 | 118,164 | 64,784 | 959,042 | -70,022 | -344,230 |
| 2028 | 676,105 | 218,919 | 895,024 | 782,900 | 0 | 120,927 | 65,156 | 968,984 | -73,960 | -418,189 |
| 2029 | 673,620 | 221,930 | 895,550 | 791,008 | 0 | 123,195 | 64,942 | 979,145 | -83,595 | -501,784 |
| 2030 | 673,620 | 225,496 | 899,117 | 797,556 | 0 | 125,708 | 64,967 | 988,231 | -89,114 | -590,899 |
| 2031 | 673,620 | 229,677 | 903,297 | 800,937 | 0 | 127,891 | 64,713 | 993,540 | -90,244 | -681,142 |
| 2032 | 676,099 | 233,290 | 909,388 | 801,646 | 0 | 130,418 | 65,071 | 997,136 | -87,747 | -768,890 |
| 2033 | 673,608 | 236,093 | 909,701 | 803,611 | 0 | 132,652 | 64,880 | 1,001,142 | -91,441 | -860,330 |
| 2034 | 673,606 | 239,534 | 913,140 | 806,077 | 0 | 135,154 | 64,870 | 1,006,100 | -92,960 | -953,291 |
| 2035 | 673,599 | 242,693 | 916,292 | 806,308 | 0 | 137,524 | 64,955 | 1,008,787 | -92,495 | -1,045,786 |
| 2036 | 676,068 | 246,934 | 923,002 | 811,192 | 0 | 138,989 | 65,077 | 1,015,258 | -92,256 | -1,138,041 |
| 2037 | 673,581 | 249,855 | 923,436 | 812,030 | 0 | 139,192 | 64,817 | 1,016,039 | -92,603 | -1,230,644 |
| 2038 | 673,578 | 253,266 | 926,844 | 813,739 | 0 | 141,351 | 64,797 | 1,019,887 | -93,044 | -1,323,688 |
| 2039 | 673,572 | 256,382 | 929,954 | 813,325 | 0 | 143,285 | 64,862 | 1,021,472 | -91,518 | -1,415,206 |
| 2040 | 676,029 | 260,125 | 936,154 | 815,379 | 0 | 142,321 | 65,149 | 1,022,849 | -86,695 | -1,501,901 |
| **Average 2020-2040** | **674,316** | **226,771** | **901,087** | **783,970** | **0** | **124,580** | **64,056** | **972,606** | **-71,519** | **-650,990** |

## Full Results for Case 2: Future with Interannual Variability and No Projects

| Water Year | Inflow (Acre-Feet/Year) | | | Outflow (Acre-Feet/Year) | | | | | Storage | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Recharge | Underflow Buffer to KSB | Total Inflow | Ag Pumping | Aquifer Discharge to Streams | Non-Ag Pumping | Underflow KSB to Buffer | Total Outflow | Change in Storage (Acre-Feet/Year) | Cumulative Change in Storage (Acre-Feet) |
| 2020 | 927,137 | 157,959 | 1,085,096 | 503,909 | 0 | 94,915 | 68,183 | 667,008 | 418,089 | 418,089 |
| 2021 | 1,186,432 | 212,662 | 1,399,094 | 450,049 | 44 | 97,438 | 47,322 | 594,852 | 804,242 | 1,222,330 |
| 2022 | 602,179 | 212,753 | 814,933 | 635,499 | 1,805 | 92,423 | 37,741 | 767,469 | 47,464 | 1,269,794 |
| 2023 | 688,052 | 195,456 | 883,509 | 677,926 | 548 | 92,275 | 56,153 | 826,902 | 56,607 | 1,326,401 |
| 2024 | 509,897 | 198,662 | 708,559 | 800,353 | 205 | 104,082 | 76,157 | 980,797 | -272,239 | 1,054,163 |
| 2025 | 563,000 | 210,854 | 773,854 | 838,657 | 2 | 112,096 | 72,617 | 1,023,371 | -249,517 | 804,646 |
| 2026 | 596,378 | 211,899 | 808,276 | 762,498 | 74 | 113,199 | 86,234 | 962,005 | -153,729 | 650,917 |
| 2027 | 474,937 | 220,772 | 695,709 | 913,175 | 282 | 127,425 | 80,387 | 1,121,269 | -425,560 | 225,356 |
| 2028 | 914,170 | 208,284 | 1,122,455 | 549,253 | 0 | 113,285 | 49,995 | 712,533 | 409,922 | 635,278 |
| 2029 | 820,036 | 183,763 | 1,003,799 | 564,464 | 0 | 119,950 | 47,269 | 731,683 | 272,116 | 907,394 |
| 2030 | 462,915 | 193,897 | 656,812 | 1,039,718 | 791 | 145,966 | 96,036 | 1,282,511 | -625,700 | 281,694 |
| 2031 | 597,824 | 195,972 | 793,796 | 894,045 | 0 | 149,384 | 107,367 | 1,150,796 | -357,000 | -75,306 |
| 2032 | 514,239 | 219,117 | 733,356 | 951,074 | 102 | 148,989 | 105,343 | 1,205,508 | -472,152 | -547,458 |
| 2033 | 774,102 | 230,418 | 1,004,520 | 658,256 | 3 | 140,618 | 82,814 | 881,690 | 122,830 | -424,628 |
| 2034 | 950,150 | 240,907 | 1,191,058 | 573,989 | 0 | 131,217 | 53,043 | 758,248 | 432,809 | 8,181 |
| 2035 | 496,704 | 243,265 | 739,969 | 972,719 | 959 | 147,809 | 91,836 | 1,213,323 | -473,354 | -465,173 |
| 2036 | 569,699 | 264,392 | 834,091 | 1,106,537 | 120 | 151,409 | 101,256 | 1,359,323 | -525,232 | -990,405 |
| 2037 | 407,524 | 274,466 | 681,990 | 1,185,193 | 99 | 144,434 | 80,170 | 1,409,897 | -727,907 | -1,718,312 |
| 2038 | 390,111 | 279,092 | 669,202 | 1,110,319 | 0 | 130,837 | 74,606 | 1,315,762 | -646,559 | -2,364,871 |
| 2039 | 536,273 | 259,803 | 796,076 | 822,968 | 15 | 125,676 | 82,866 | 1,031,525 | -235,449 | -2,600,320 |
| 2040 | 1,190,394 | 292,662 | 1,483,056 | 502,512 | 43 | 126,799 | 69,085 | 698,439 | 784,616 | -1,815,704 |
| **Average 2020-2040** | **674,864** | **224,146** | **899,010** | **786,339** | **242** | **124,297** | **74,594** | **985,472** | **-86,462** | **-104,663** |

## Full Results for Case 3: Future with Interannual Variability Reversed and No Projects

| Water Year | Inflow (Acre-Feet/Year) | | | Outflow (Acre-Feet/Year) | | | | | Storage | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Recharge | Underflow Buffer to KSB | Total Inflow | Ag Pumping | Recharge | Non-Ag Pumping | Underflow KSB to Buffer | Total Outflow | Change in Storage (Acre-Feet/Year) | Cumulative Change in Storage (Acre-Feet) |
| 2020 | 1,191,324 | 173,864 | 1,365,188 | 507,156 | 43 | 143,667 | 103,103 | 753,969 | 611,219 | 611,219 |
| 2021 | 536,675 | 139,383 | 676,058 | 825,712 | 15 | 138,916 | 128,162 | 1,092,805 | -416,747 | 194,472 |
| 2022 | 390,020 | 204,314 | 594,334 | 1,111,323 | 0 | 134,171 | 86,604 | 1,332,097 | -737,764 | -543,292 |
| 2023 | 407,240 | 252,324 | 659,565 | 1,185,336 | 99 | 145,928 | 73,509 | 1,404,873 | -745,308 | -1,288,600 |
| 2024 | 569,142 | 293,988 | 863,131 | 1,106,310 | 120 | 152,440 | 77,974 | 1,336,844 | -473,714 | -1,762,313 |
| 2025 | 496,017 | 328,383 | 824,400 | 972,217 | 959 | 144,469 | 59,633 | 1,177,277 | -352,877 | -2,115,190 |
| 2026 | 949,363 | 307,692 | 1,257,054 | 573,330 | 0 | 127,457 | 40,626 | 741,413 | 515,641 | -1,599,549 |
| 2027 | 773,345 | 238,922 | 1,012,267 | 657,424 | 3 | 135,945 | 85,382 | 878,754 | 133,513 | -1,466,036 |
| 2028 | 513,644 | 247,525 | 761,169 | 949,938 | 102 | 142,955 | 91,055 | 1,184,050 | -422,881 | -1,888,917 |
| 2029 | 596,916 | 276,709 | 873,624 | 892,780 | 0 | 141,484 | 73,496 | 1,107,761 | -234,136 | -2,123,053 |
| 2030 | 462,063 | 335,951 | 798,013 | 1,036,097 | 791 | 140,731 | 53,233 | 1,230,852 | -432,839 | -2,555,892 |
| 2031 | 818,253 | 341,336 | 1,159,589 | 559,479 | 0 | 115,896 | 30,396 | 705,771 | 453,818 | -2,102,074 |
| 2032 | 912,126 | 287,218 | 1,199,344 | 544,284 | 0 | 109,023 | 43,026 | 696,332 | 503,011 | -1,599,063 |
| 2033 | 473,254 | 287,541 | 760,795 | 905,896 | 282 | 123,092 | 66,352 | 1,095,623 | -334,828 | -1,933,891 |
| 2034 | 594,562 | 305,782 | 900,344 | 755,785 | 74 | 109,375 | 61,840 | 927,074 | -26,730 | -1,960,621 |
| 2035 | 560,653 | 319,746 | 880,399 | 831,448 | 2 | 110,548 | 48,648 | 990,645 | -110,247 | -2,070,868 |
| 2036 | 507,841 | 332,929 | 840,771 | 792,976 | 205 | 103,656 | 50,825 | 947,661 | -106,890 | -2,177,758 |
| 2037 | 684,705 | 338,231 | 1,022,937 | 670,552 | 548 | 91,453 | 36,860 | 799,412 | 223,524 | -1,954,233 |
| 2038 | 600,005 | 328,445 | 928,450 | 628,835 | 1,805 | 91,473 | 26,874 | 748,988 | 179,462 | -1,774,771 |
| 2039 | 1,183,943 | 215,572 | 1,399,515 | 443,711 | 44 | 94,145 | 75,152 | 613,051 | 786,464 | -988,307 |
| 2040 | 924,327 | 165,600 | 1,089,927 | 498,108 | 0 | 91,431 | 100,732 | 690,270 | 399,657 | -588,650 |
| **Average 2020-2040** | **673,591** | **272,450** | **946,042** | **783,271** | **242** | **123,250** | **67,309** | **974,073** | **-28,031** | **-1,508,923** |

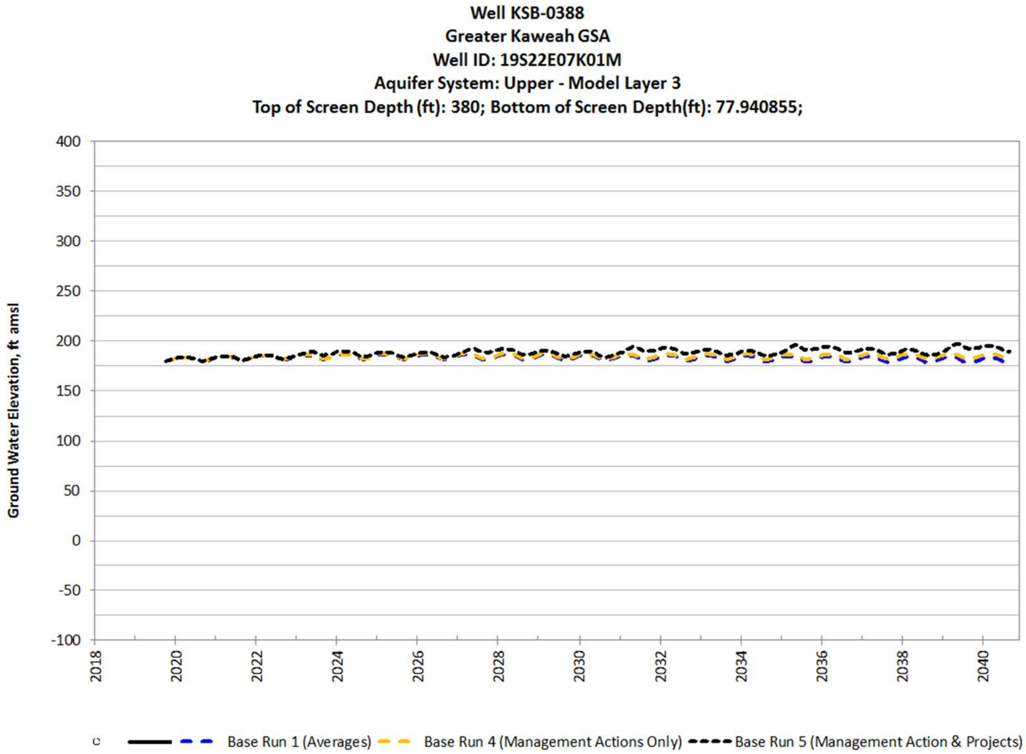
## Full Results for Case 4: Altered Future with Management Actions

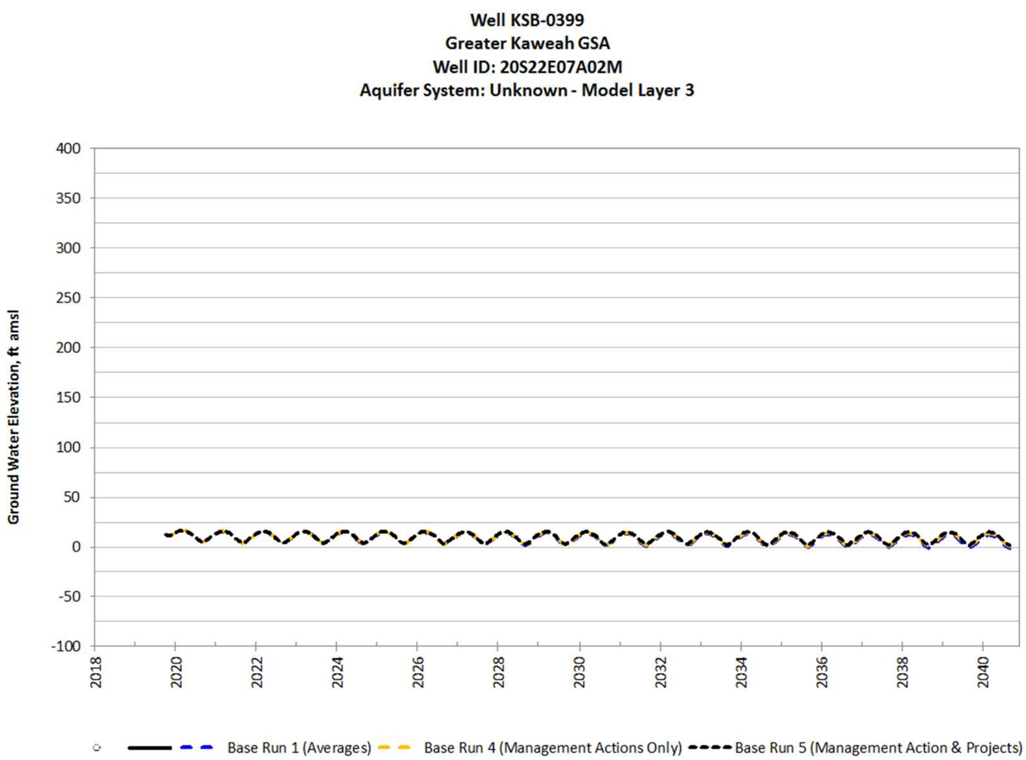
| Water Year | Inflow (Acre-Feet/Year) | | | Outflow (Acre-Feet/Year) | | | | | Change in Storage | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Recharge | Underflow Buffer to KSB | Total Inflow | Ag Pumping | Recharge | Non-Ag Pumping | Underflow KSB to Buffer | Total Outflow | Change in Storage (Acre-Feet/Year) | Cumulative Change in Storage (Acre-Feet |
| 2020 | 681,104 | 184,922 | 866,026 | 722,860 | 0 | 101,360 | 60,625 | 884,845 | -18,819 | -18,819 |
| 2021 | 678,620 | 202,314 | 880,934 | 726,854 | 0 | 103,682 | 59,930 | 890,466 | -9,533 | -28,351 |
| 2022 | 678,620 | 203,514 | 882,134 | 733,956 | 0 | 106,216 | 62,002 | 902,174 | -20,041 | -48,392 |
| 2023 | 678,620 | 203,884 | 882,504 | 737,608 | 0 | 108,525 | 63,549 | 909,682 | -27,178 | -75,570 |
| 2024 | 681,103 | 205,774 | 886,877 | 749,801 | 0 | 110,849 | 64,740 | 925,390 | -38,513 | -114,083 |
| 2025 | 678,619 | 206,575 | 885,194 | 749,246 | 0 | 113,133 | 65,350 | 927,730 | -42,536 | -156,619 |
| 2026 | 678,619 | 206,752 | 885,371 | 743,893 | 0 | 115,649 | 66,298 | 925,840 | -40,469 | -197,088 |
| 2027 | 678,619 | 208,208 | 886,826 | 750,498 | 0 | 118,164 | 66,838 | 935,499 | -48,673 | -245,761 |
| 2028 | 681,103 | 210,711 | 891,814 | 756,665 | 0 | 120,927 | 67,448 | 945,041 | -53,226 | -298,988 |
| 2029 | 678,619 | 212,763 | 891,381 | 764,160 | 0 | 123,195 | 67,480 | 954,835 | -63,454 | -362,441 |
| 2030 | 678,619 | 215,014 | 893,632 | 761,110 | 0 | 125,708 | 67,757 | 954,574 | -60,942 | -423,384 |
| 2031 | 678,619 | 215,454 | 894,073 | 744,144 | 0 | 128,224 | 68,307 | 940,675 | -46,602 | -469,986 |
| 2032 | 681,103 | 216,576 | 897,680 | 744,268 | 0 | 130,665 | 69,183 | 944,117 | -46,437 | -516,423 |
| 2033 | 678,619 | 217,589 | 896,208 | 745,654 | 0 | 132,652 | 69,351 | 947,657 | -51,450 | -567,872 |
| 2034 | 678,619 | 219,522 | 898,140 | 747,494 | 0 | 135,154 | 69,585 | 952,233 | -54,092 | -621,965 |
| 2035 | 678,619 | 220,782 | 899,400 | 735,676 | 0 | 137,654 | 69,988 | 943,317 | -43,917 | -665,881 |
| 2036 | 681,103 | 219,464 | 900,567 | 711,641 | 0 | 140,439 | 71,296 | 923,376 | -22,809 | -688,691 |
| 2037 | 678,617 | 218,732 | 897,349 | 711,957 | 0 | 142,655 | 71,750 | 926,363 | -29,014 | -717,705 |
| 2038 | 678,617 | 219,591 | 898,208 | 712,953 | 0 | 144,381 | 72,133 | 929,467 | -31,259 | -748,964 |
| 2039 | 678,617 | 220,552 | 899,169 | 711,698 | 0 | 145,124 | 72,518 | 929,340 | -30,171 | -779,135 |
| 2040 | 681,102 | 222,282 | 903,384 | 713,679 | 0 | 147,871 | 73,135 | 934,686 | -31,301 | -810,436 |
| **Average 2020-2040** | **679,328** | **211,951** | **891,280** | **736,944** | **0** | **125,344** | **67,584** | **929,872** | **-38,592** | **-407,455** |

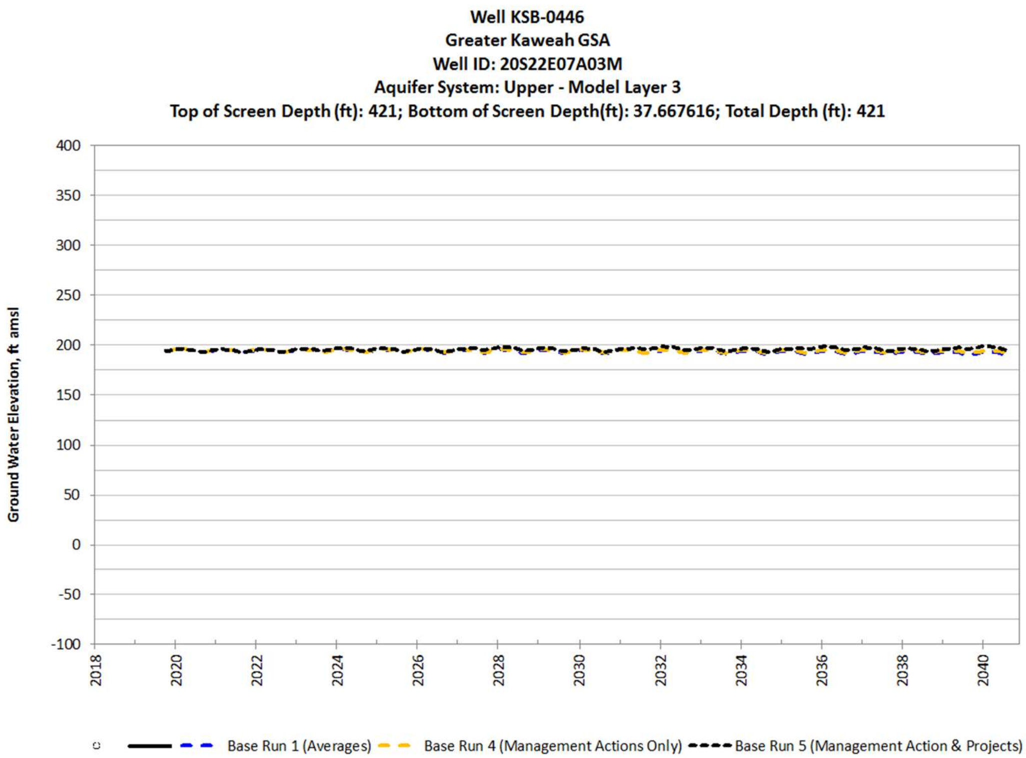
## Full Results for Case 5: Altered Future with Management Actions and Projects

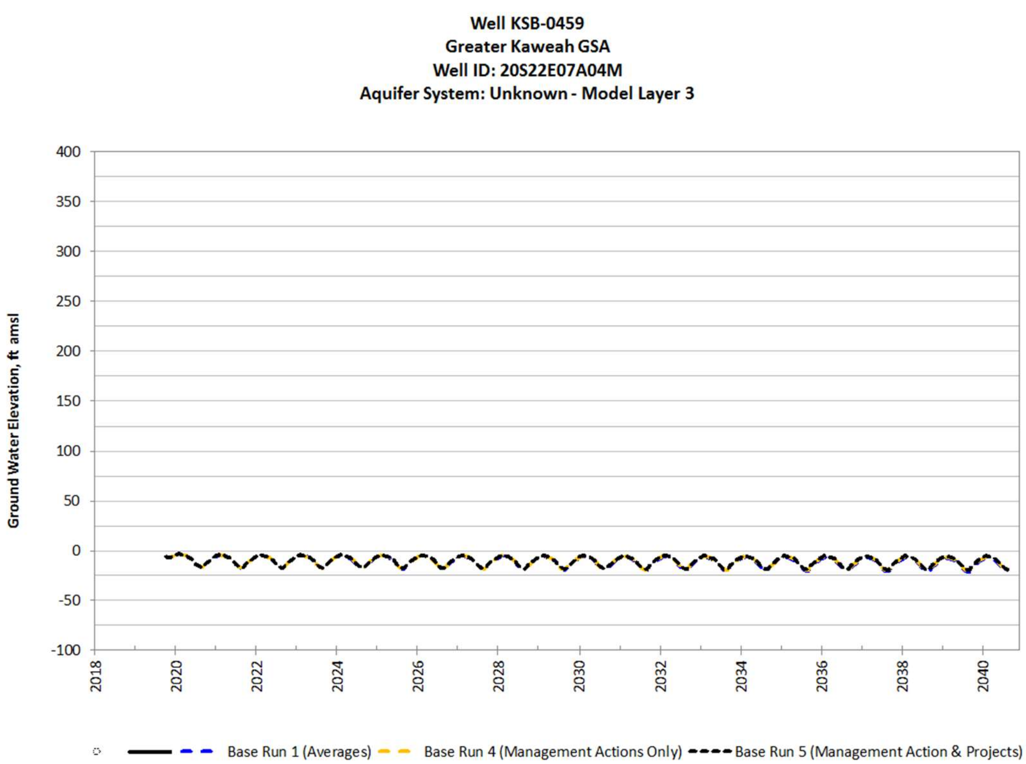
| Water Year | Inflow (Acre-Feet/Year) | | | Outflow (Acre-Feet/Year) | | | | Change in Storage (Acre-Feet/Year) | |
|---|---|---|---|---|---|---|---|---|---|
| | Recharge | Underflow Buffer to KSB | Total Inflow | Ag Pumping | Non-Ag Pumping | Underflow KSB to Buffer | Total Outflow | Change In Storage (Acre-Feet/Year) | Cumulative Change in Storage (Acre-Feet) |
| 2020 | 693,019 | 184,909 | 877,928 | 722,860 | 102,029 | 60,664 | 885,553 | -7,625 | -7,625 |
| 2021 | 692,081 | 201,840 | 893,921 | 726,854 | 103,847 | 60,091 | 890,792 | 3,129 | -4,496 |
| 2022 | 695,135 | 202,679 | 897,814 | 733,956 | 106,285 | 62,280 | 902,522 | -4,708 | -9,203 |
| 2023 | 754,786 | 195,768 | 950,555 | 737,608 | 108,573 | 66,823 | 913,005 | 37,550 | 28,347 |
| 2024 | 700,811 | 197,706 | 898,518 | 749,801 | 110,894 | 66,641 | 927,335 | -28,817 | -470 |
| 2025 | 703,322 | 200,034 | 903,356 | 752,178 | 113,174 | 66,866 | 932,218 | -28,862 | -29,332 |
| 2026 | 712,321 | 200,571 | 912,892 | 747,271 | 115,688 | 67,844 | 930,802 | -17,911 | -47,243 |
| 2027 | 785,165 | 194,160 | 979,325 | 754,312 | 118,204 | 73,946 | 946,461 | 32,864 | -14,379 |
| 2028 | 714,945 | 196,846 | 911,791 | 760,919 | 120,970 | 71,326 | 953,215 | -41,424 | -55,803 |
| 2029 | 712,463 | 201,420 | 913,883 | 768,855 | 123,239 | 70,436 | 962,530 | -48,646 | -104,449 |
| 2030 | 717,464 | 204,861 | 922,324 | 771,713 | 125,753 | 70,521 | 967,988 | -45,663 | -150,112 |
| 2031 | 801,229 | 197,492 | 998,722 | 755,179 | 128,271 | 78,944 | 962,394 | 36,328 | -113,784 |
| 2032 | 720,097 | 198,739 | 918,836 | 755,733 | 131,062 | 74,994 | 961,789 | -42,952 | -156,737 |
| 2033 | 717,619 | 202,972 | 920,591 | 757,560 | 133,316 | 73,816 | 964,691 | -44,100 | -200,837 |
| 2034 | 717,626 | 206,231 | 923,858 | 759,855 | 135,482 | 73,658 | 968,996 | -45,138 | -245,975 |
| 2035 | 811,166 | 200,103 | 1,011,270 | 756,425 | 137,733 | 83,881 | 978,039 | 33,231 | -212,744 |
| 2036 | 720,276 | 199,062 | 919,338 | 732,921 | 140,537 | 78,918 | 952,376 | -33,038 | -245,782 |
| 2037 | 717,812 | 202,242 | 920,054 | 733,653 | 142,773 | 77,386 | 953,812 | -33,758 | -279,540 |
| 2038 | 717,828 | 204,926 | 922,753 | 735,098 | 145,291 | 77,091 | 957,480 | -34,727 | -314,267 |
| 2039 | 814,808 | 199,028 | 1,013,835 | 734,198 | 147,012 | 88,871 | 970,081 | 43,754 | -270,513 |
| 2040 | 720,268 | 200,596 | 920,864 | 736,631 | 147,962 | 82,129 | 966,721 | -45,857 | -316,370 |
| **Average 2020-2040** | **730,488** | **199,628** | **930,116** | **746,837** | **125,624** | **72,720** | **945,181** | **-15,065** | **-131,015** |

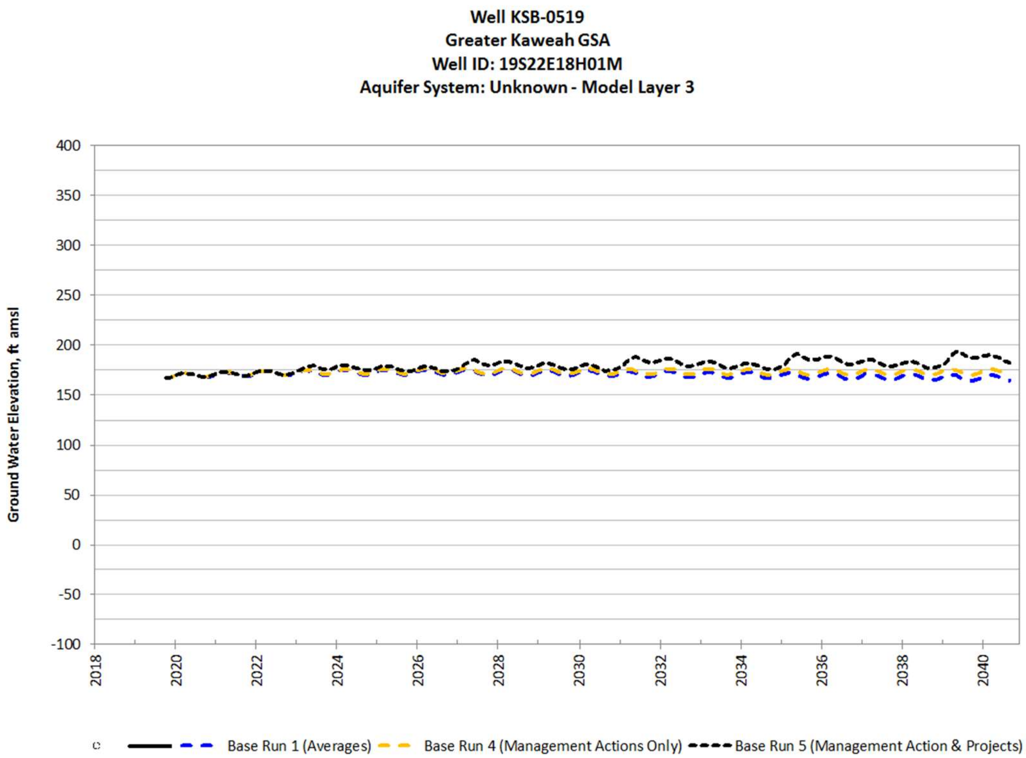
# Appendix 3: Modeling Results for Monitoring Wells

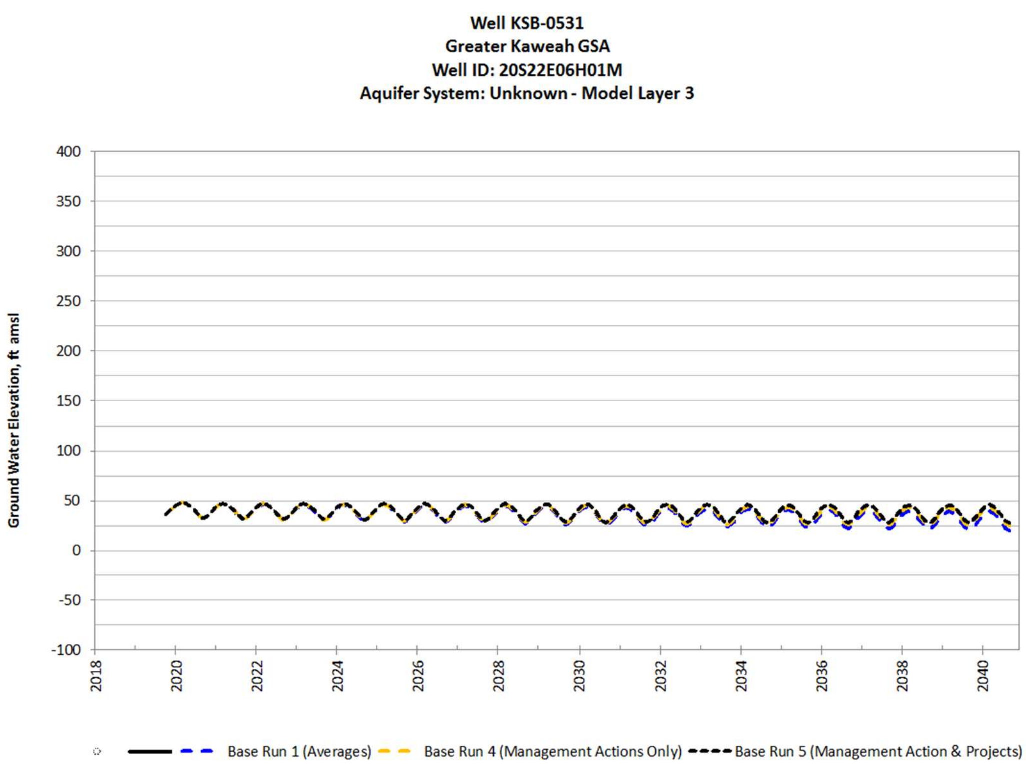


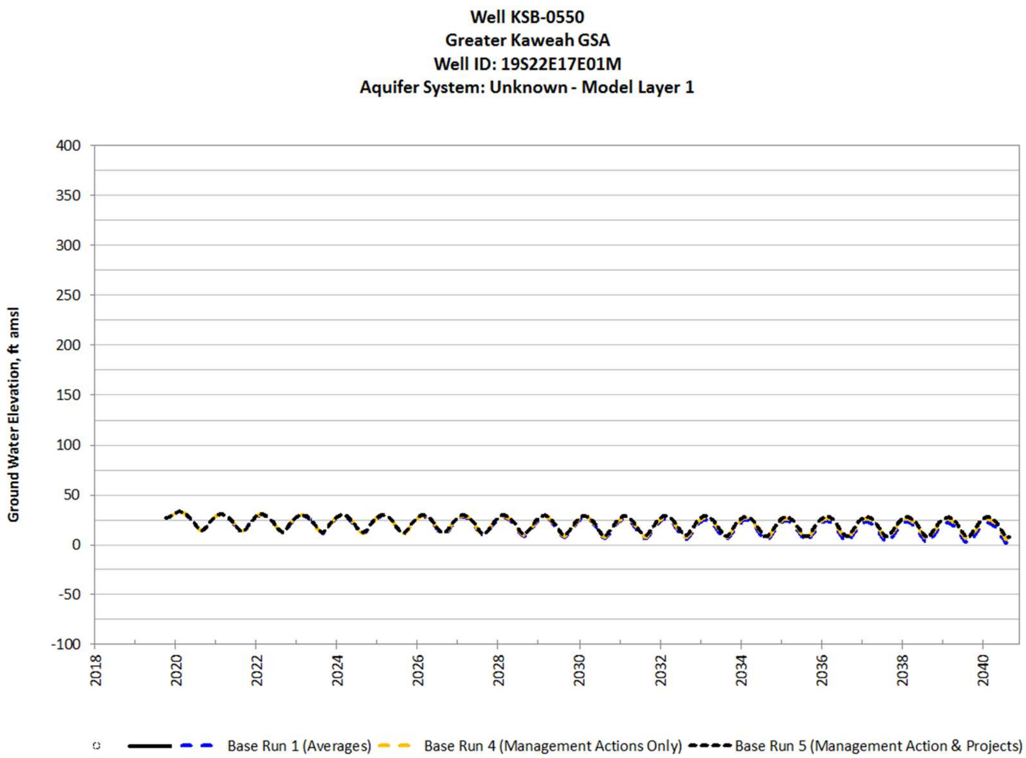



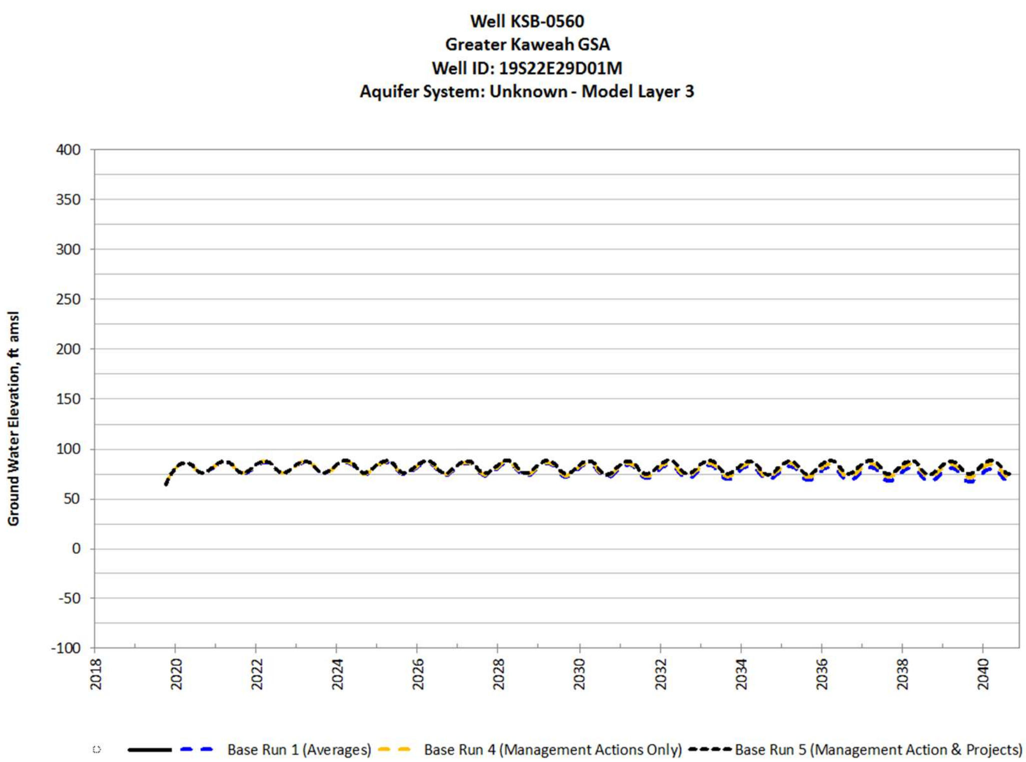

Well KSB-0446
Greater Kaweah GSA
Well ID: 20S22E07A03M
Aquifer System: Upper - Model Layer 3
Top of Screen Depth (ft): 421; Bottom of Screen Depth(ft): 37.667616; Total Depth (ft): 421
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-0459
Greater Kaweah GSA
Well ID: 20S22E07A04M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

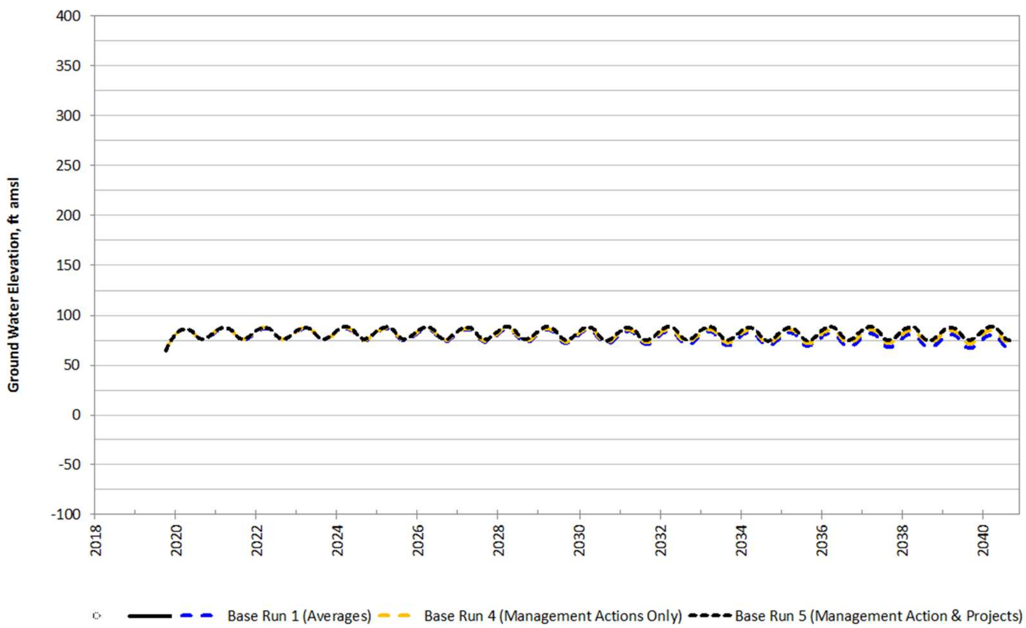

Well KSB-0519
Greater Kaweah GSA
Well ID: 19S22E18H01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-0531
Greater Kaweah GSA
Well ID: 20S22E06H01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

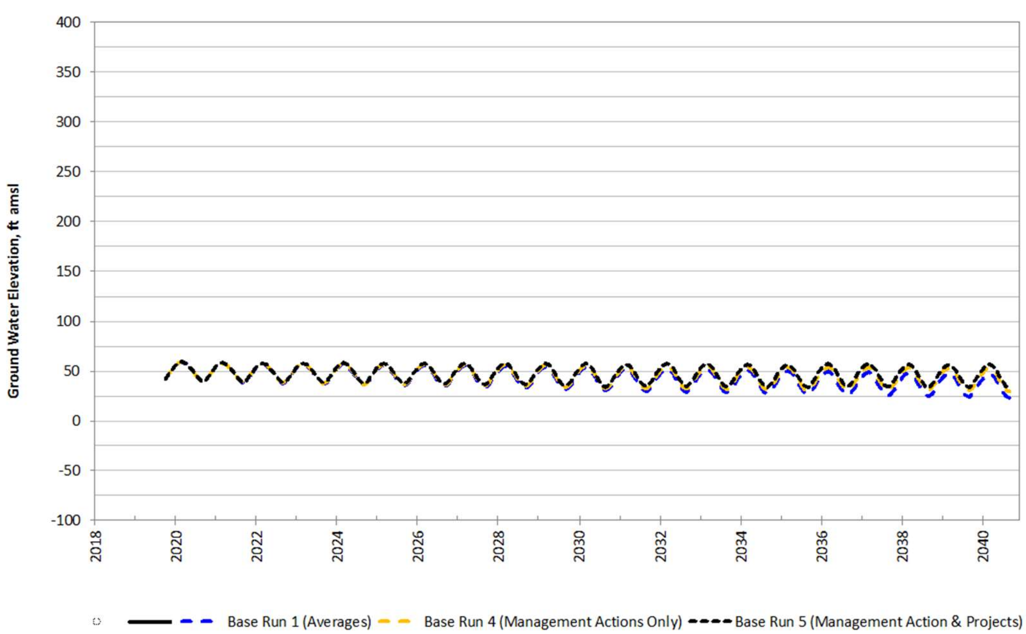

Well KSB-0550
Greater Kaweah GSA
Well ID: 19S22E17E01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

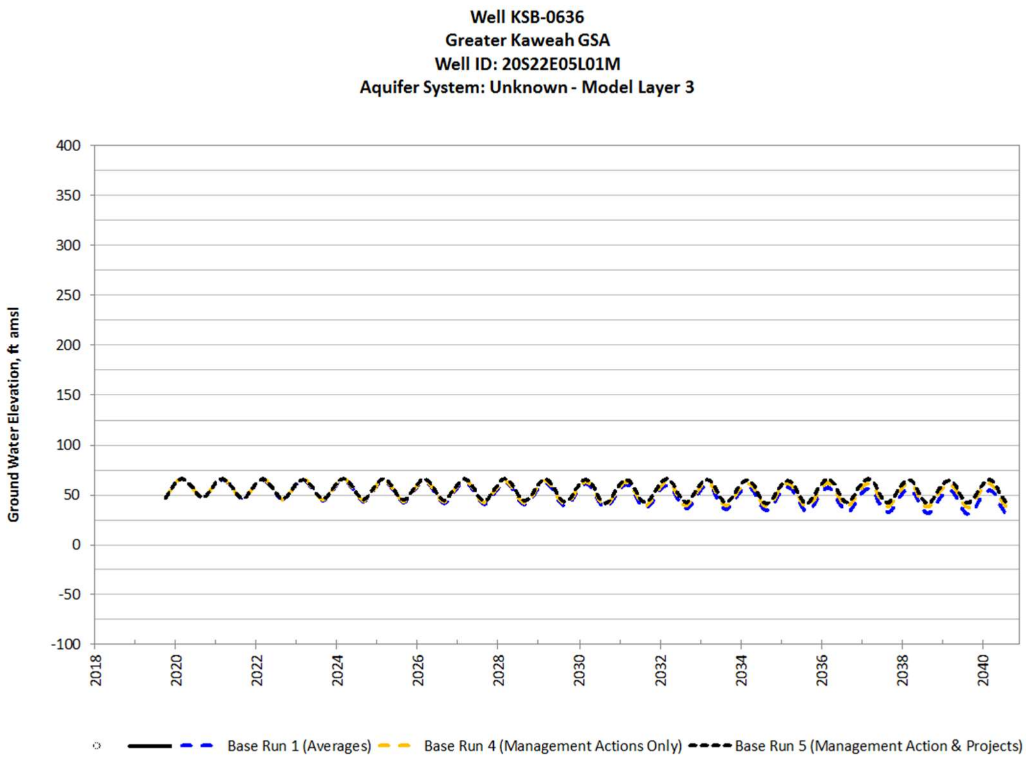

Well KSB-0560
Greater Kaweah GSA
Well ID: 19S22E29D01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

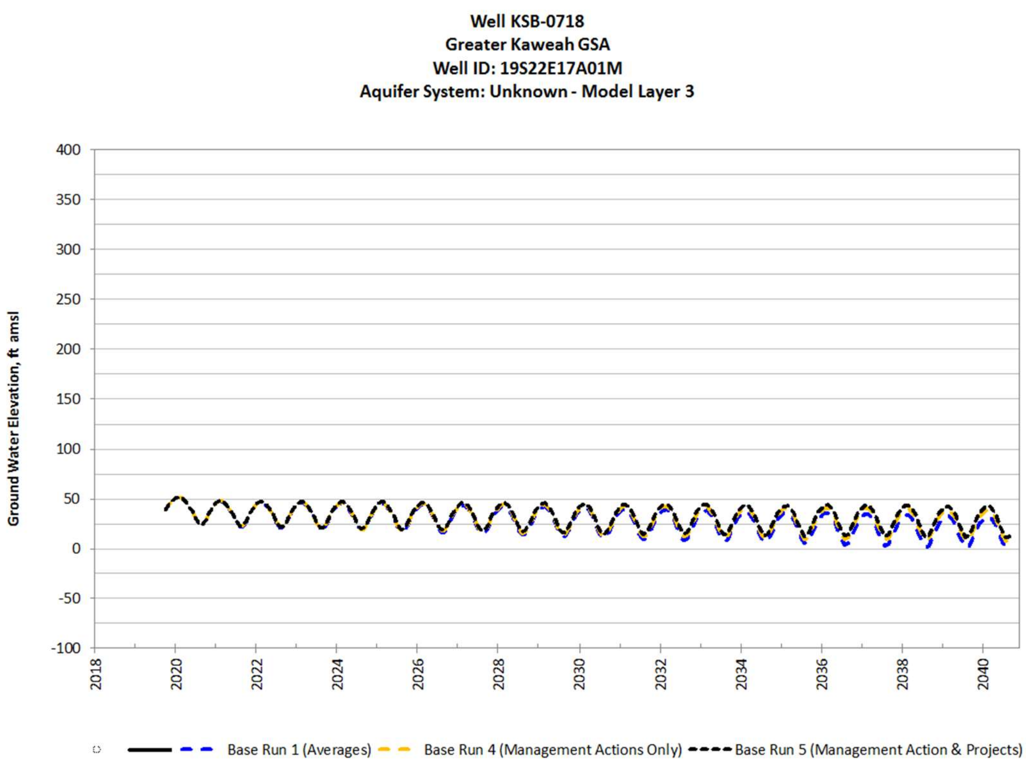
**Well KSB-0561**
**Greater Kaweah GSA**
**Well ID: 19S22E32D01M**
**Aquifer System: Unknown - Model Layer 3**

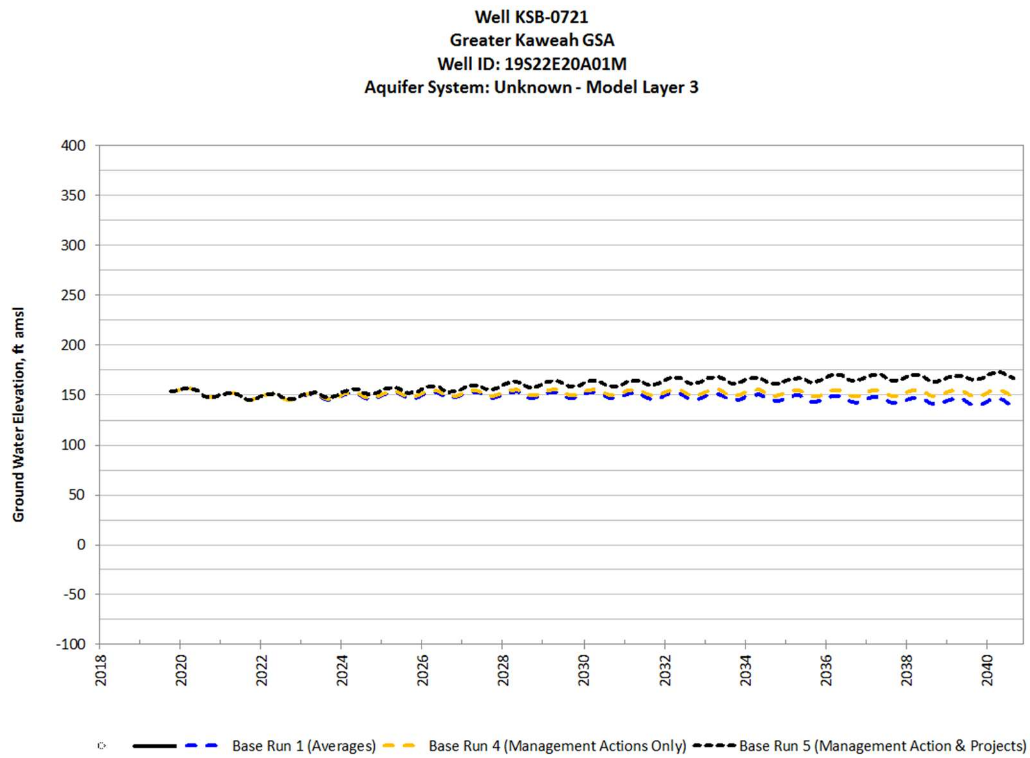


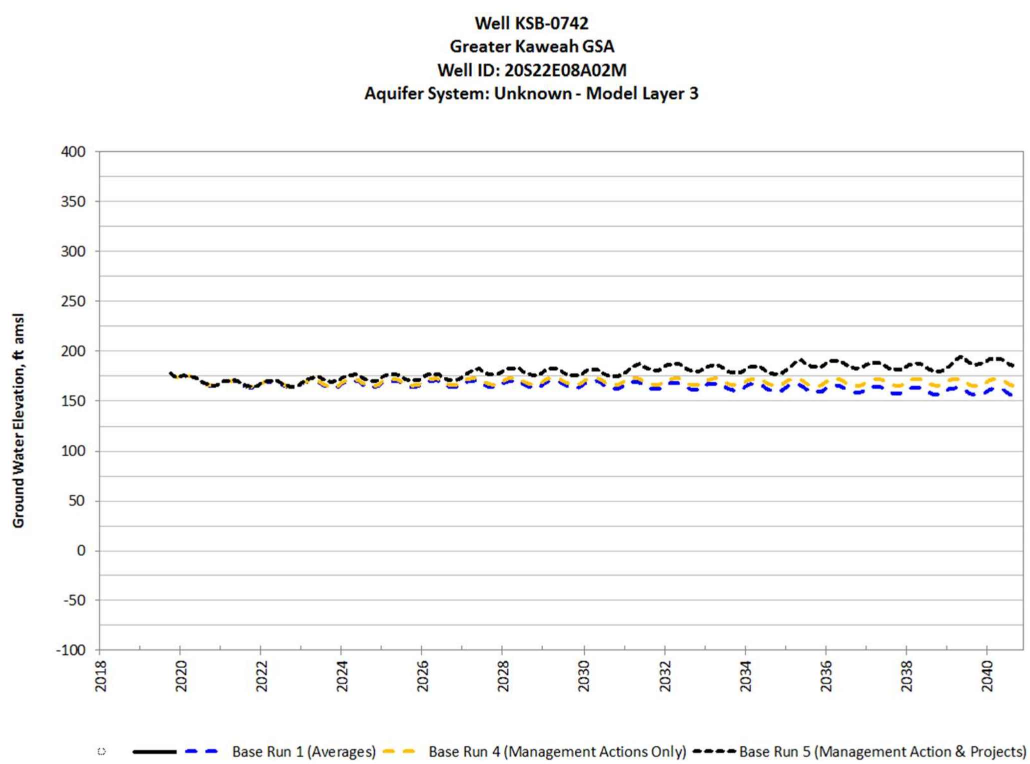

**Well KSB-0616**
**Greater Kaweah GSA**
**Well ID: 19S22E17L01M**
**Aquifer System: Unknown - Model Layer 1**

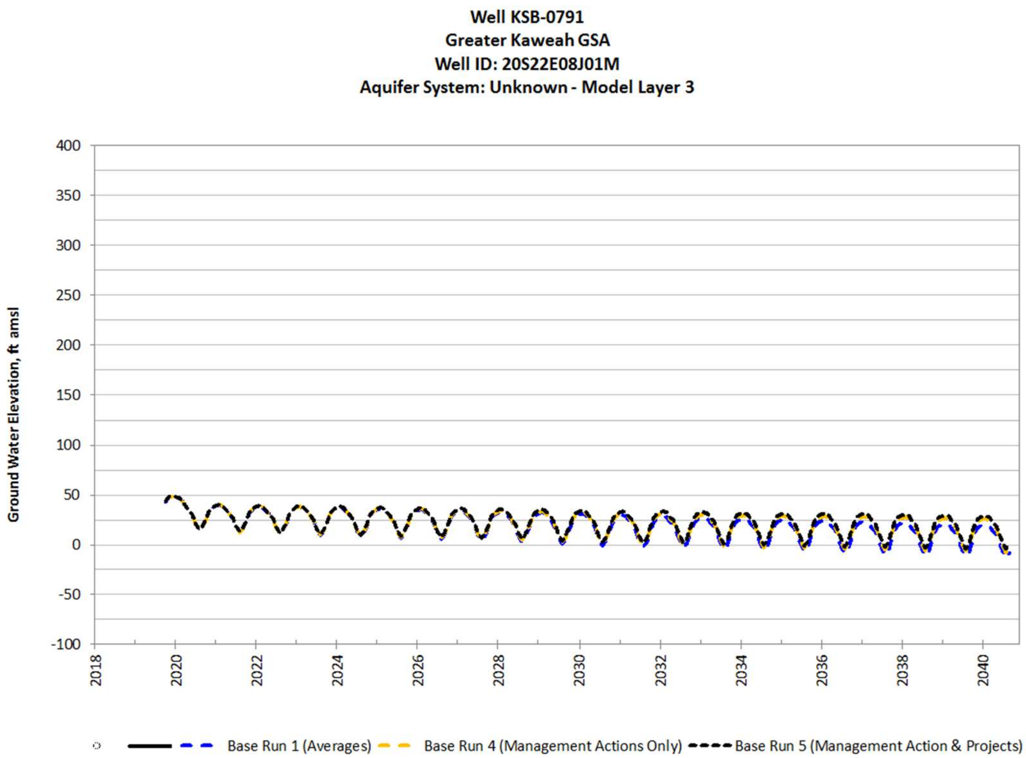


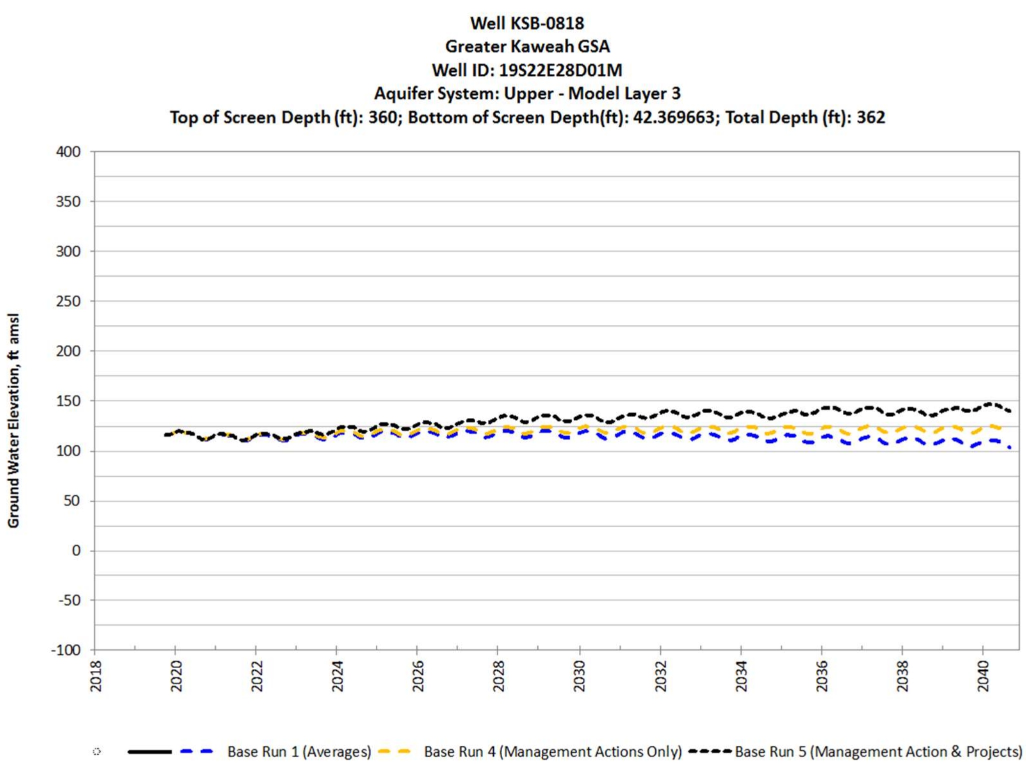

Well KSB-0636
Greater Kaweah GSA
Well ID: 20S22E05L01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

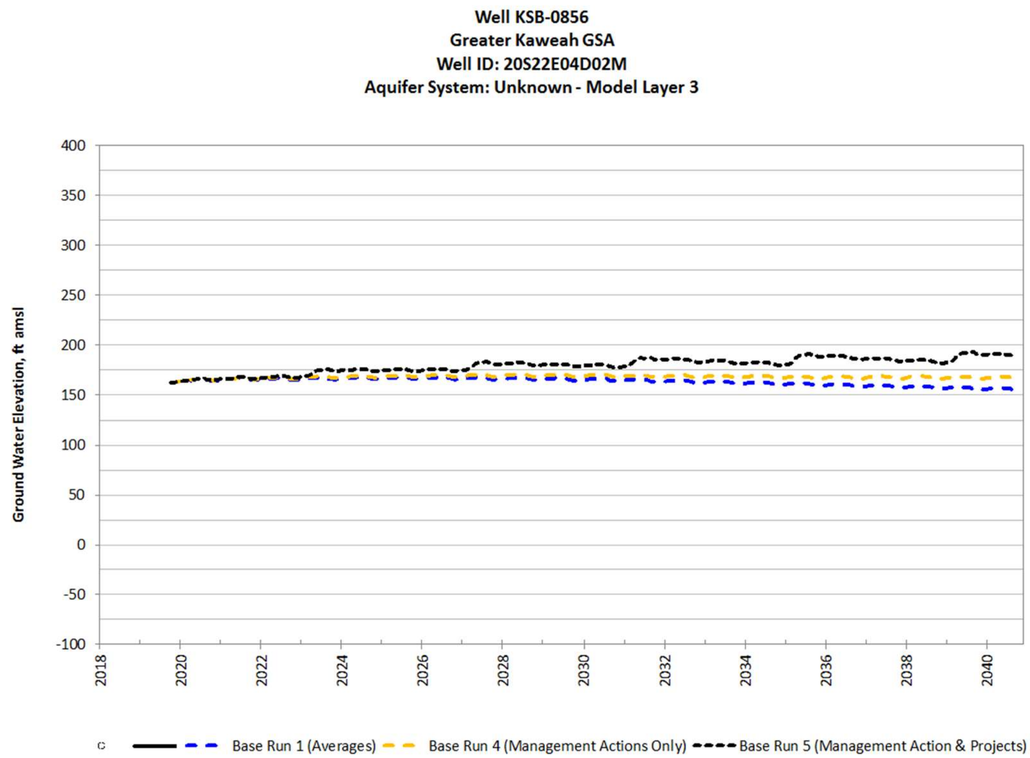

Well KSB-0718
Greater Kaweah GSA
Well ID: 19S22E17A01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

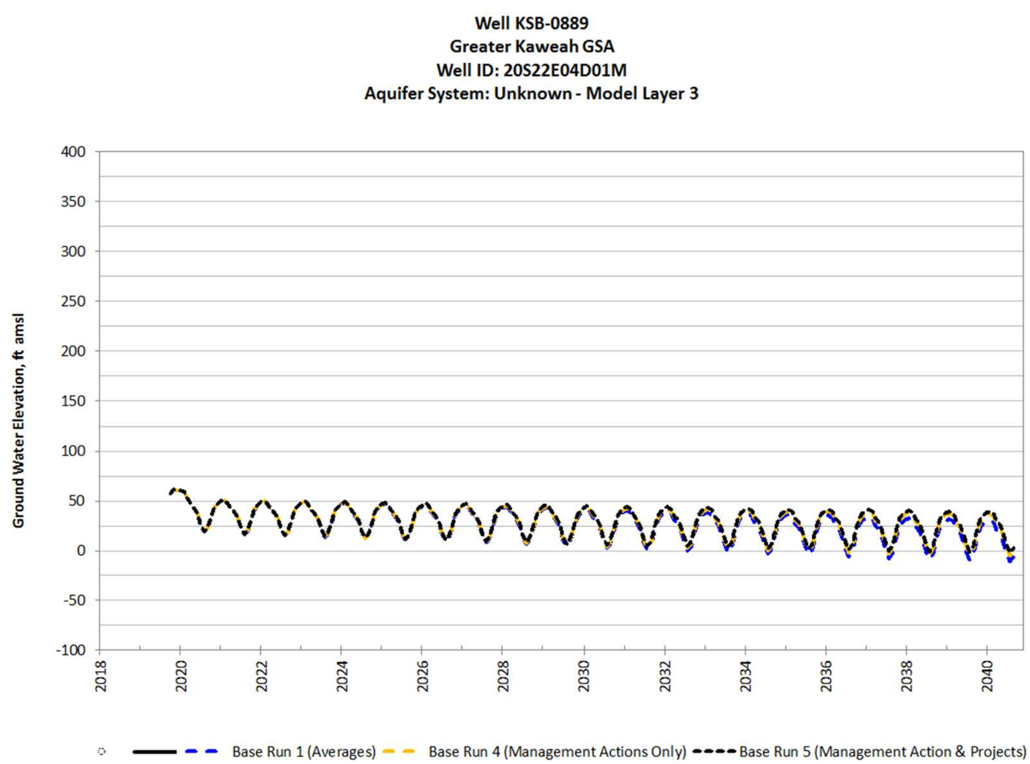

Well KSB-0721
Greater Kaweah GSA
Well ID: 19S22E20A01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-0742
Greater Kaweah GSA
Well ID: 20S22E08A02M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

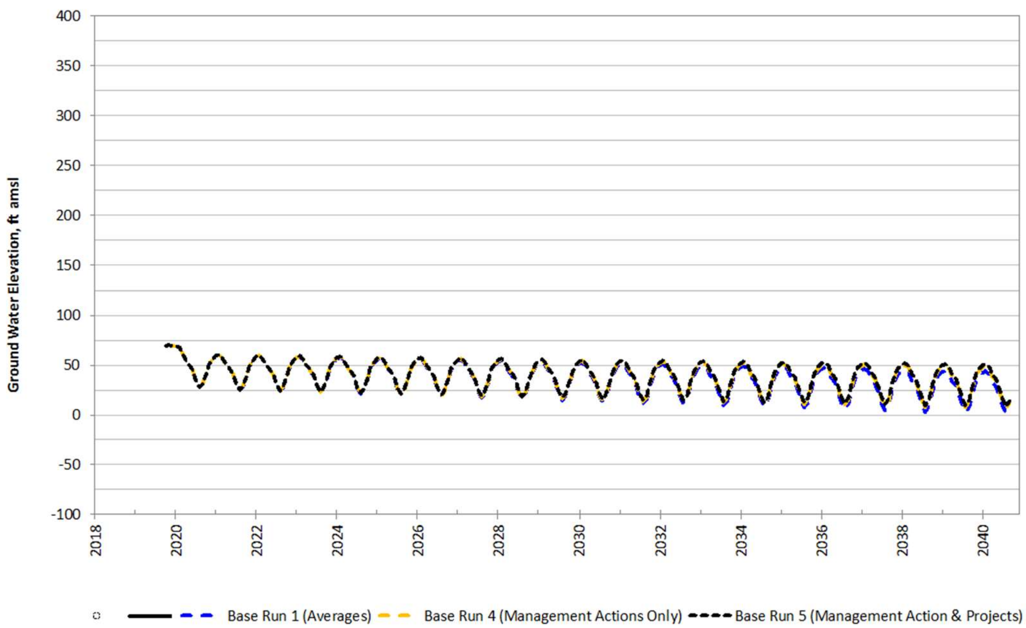

Well KSB-0791
Greater Kaweah GSA
Well ID: 20S22E08J01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-0818
Greater Kaweah GSA
Well ID: 19S22E28D01M
Aquifer System: Upper - Model Layer 3
Top of Screen Depth (ft): 360; Bottom of Screen Depth(ft): 42.369663; Total Depth (ft): 362
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

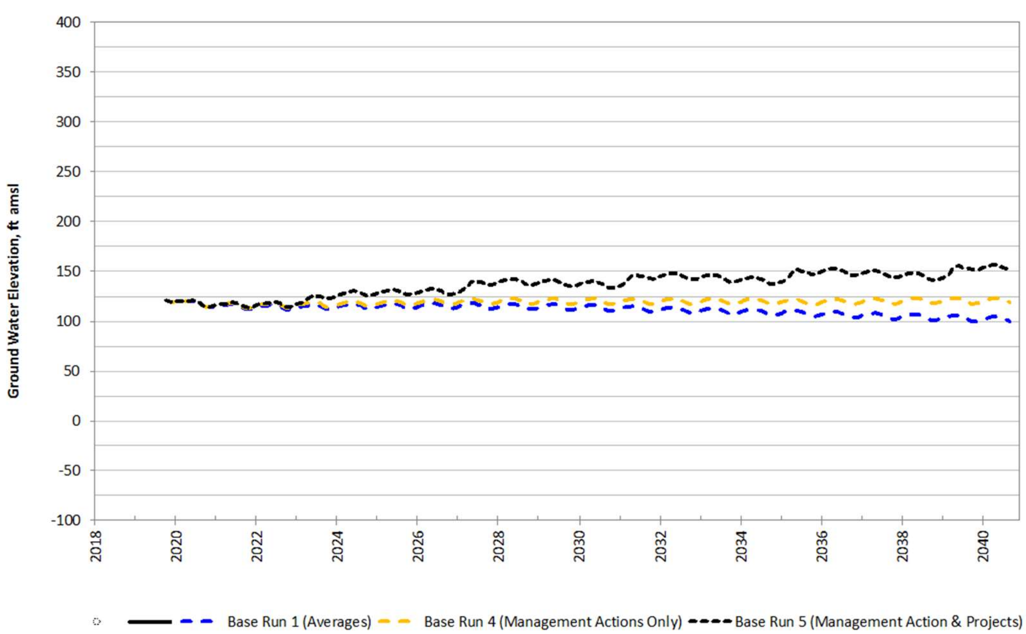

Well KSB-0856
Greater Kaweah GSA
Well ID: 20S22E04D02M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

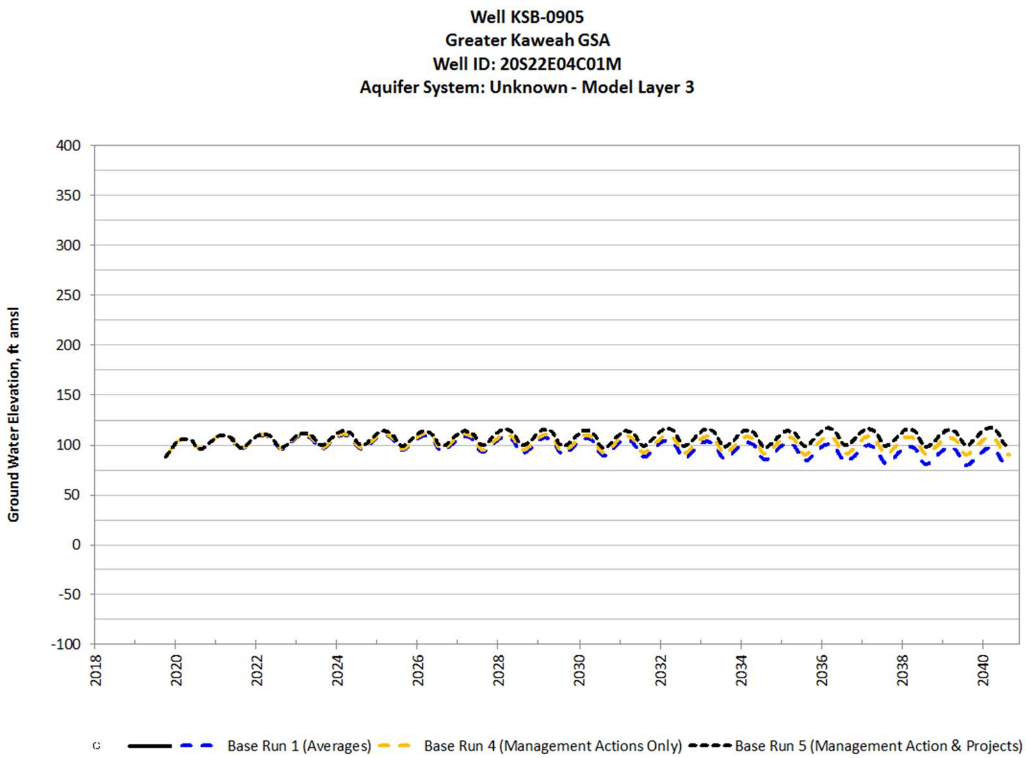

Well KSB-0889
Greater Kaweah GSA
Well ID: 20S22E04D01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

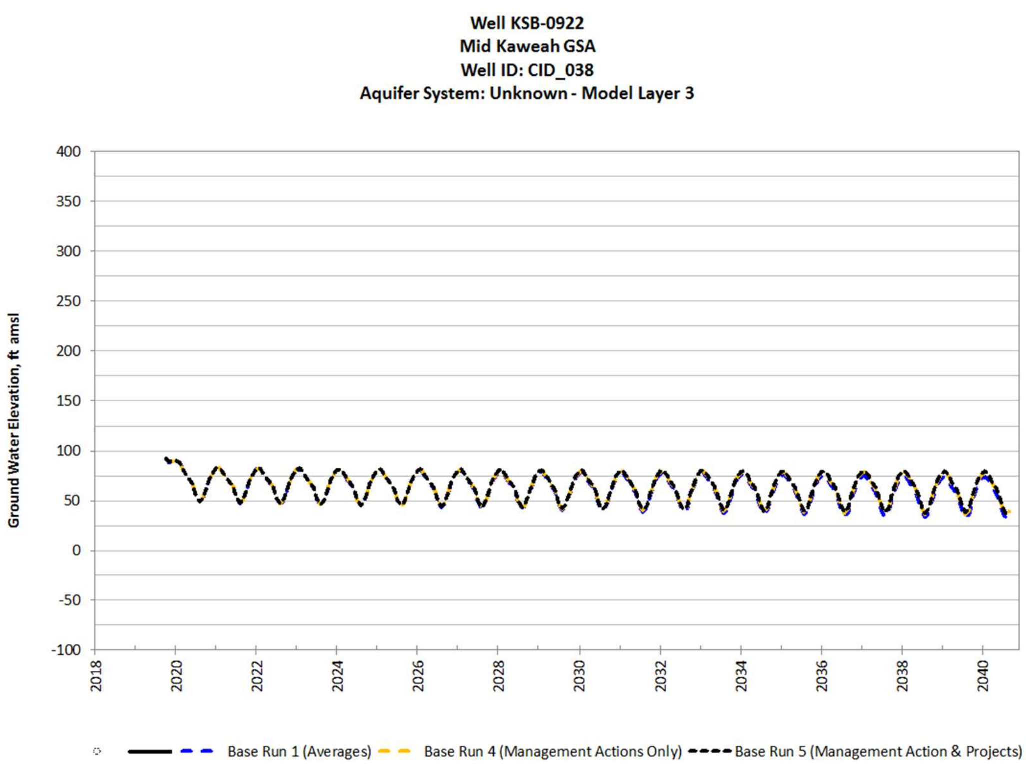
**Well KSB-0890**
**Greater Kaweah GSA**
**Well ID: 19S22E28C01M**
**Aquifer System: Unknown - Model Layer 3**

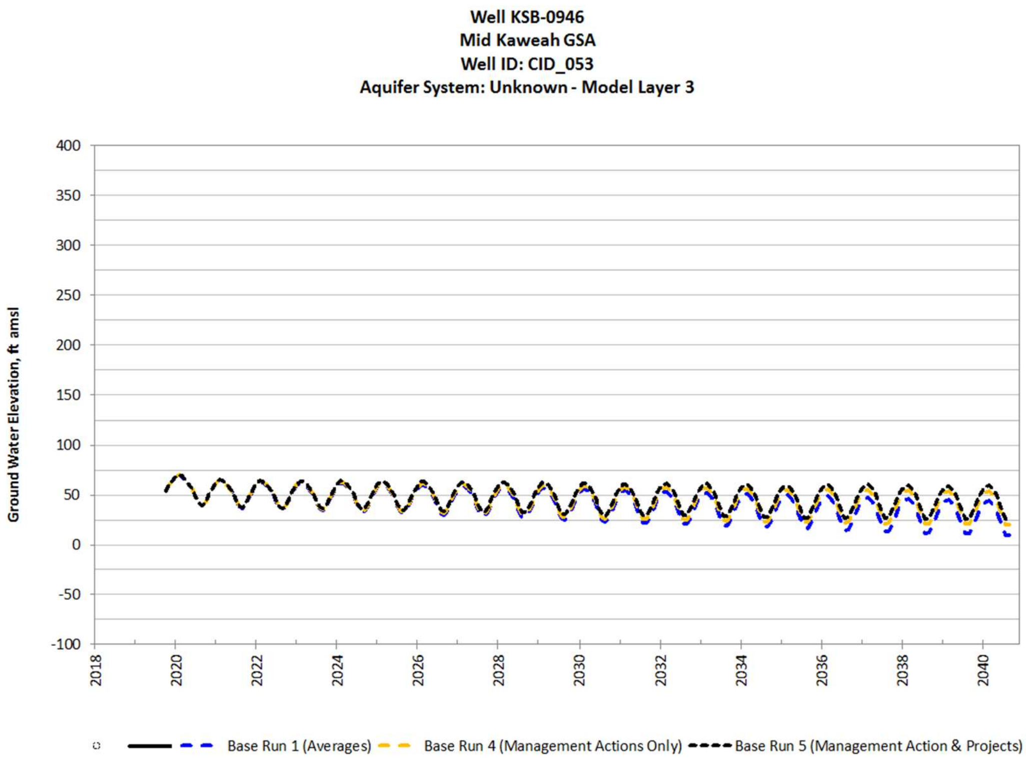


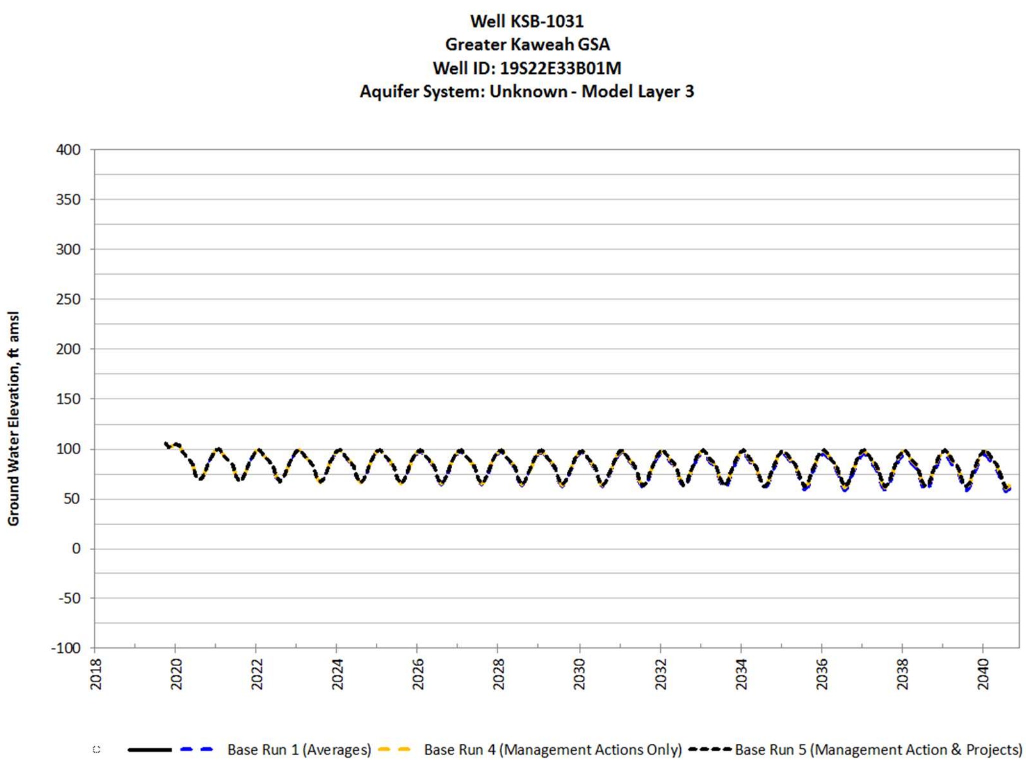

**Well KSB-0903**
**Greater Kaweah GSA**
**Well ID: 19S22E21C01M**
**Aquifer System: Unknown - Model Layer 3**



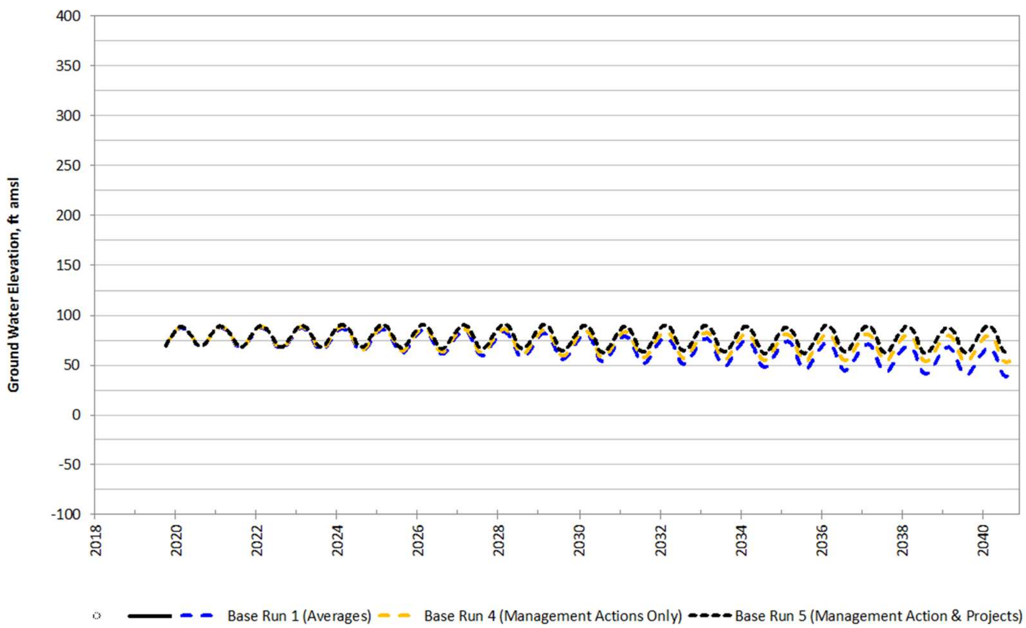

Well KSB-0905
Greater Kaweah GSA
Well ID: 20S22E04C01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-0922
Mid Kaweah GSA
Well ID: CID_038
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

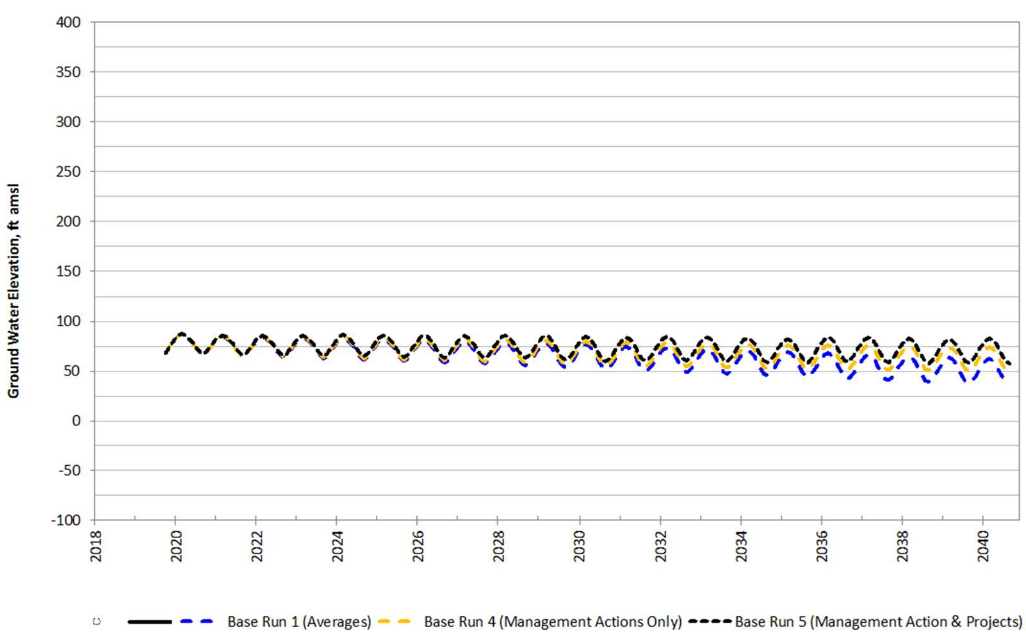

Well KSB-0946
Mid Kaweah GSA
Well ID: CID_053
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

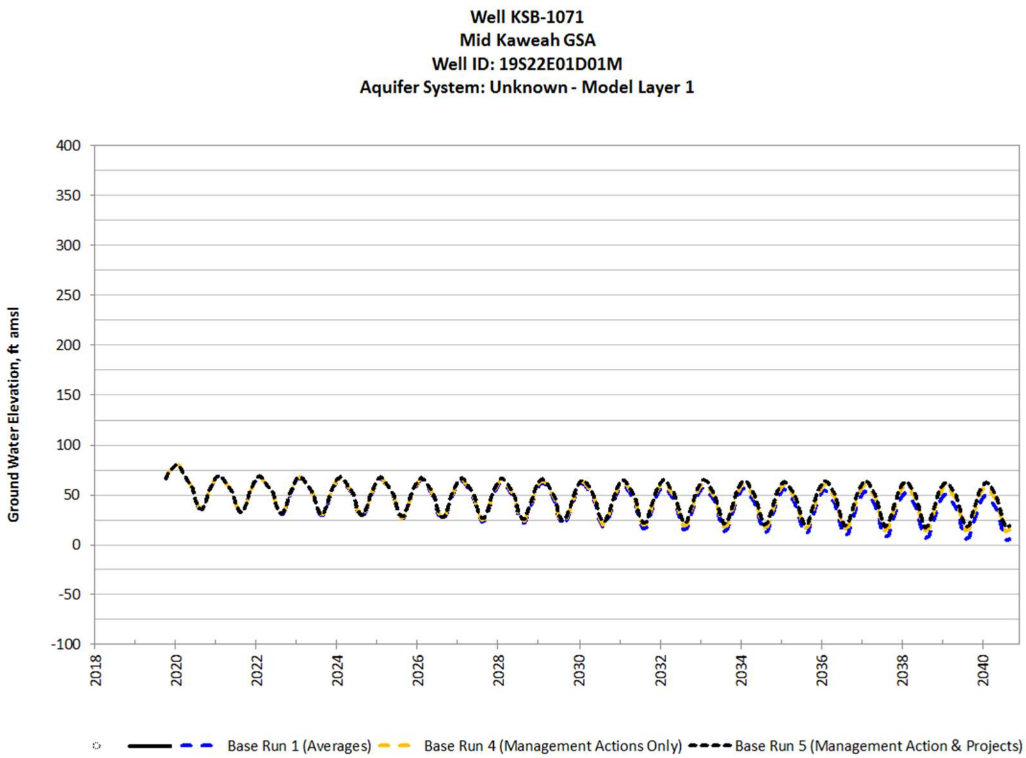

Well KSB-1031
Greater Kaweah GSA
Well ID: 19S22E33B01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

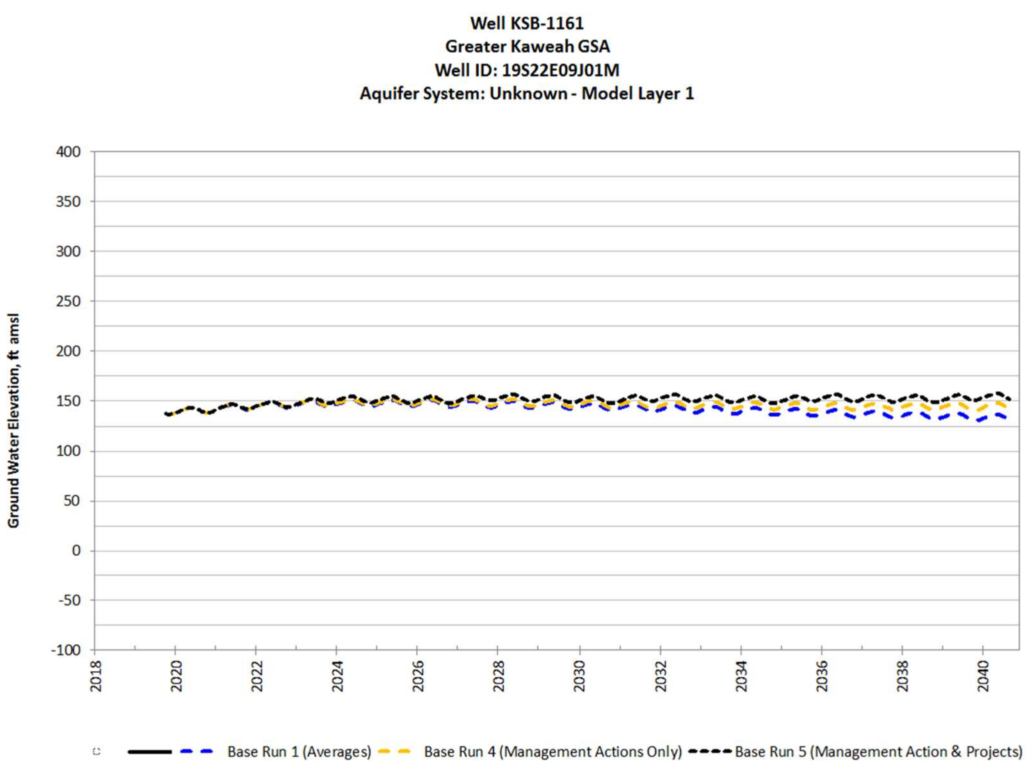
**Well KSB-1032**
**Greater Kaweah GSA**
**Well ID: 20S22E09H01M**
**Aquifer System: Unknown - Model Layer 3**



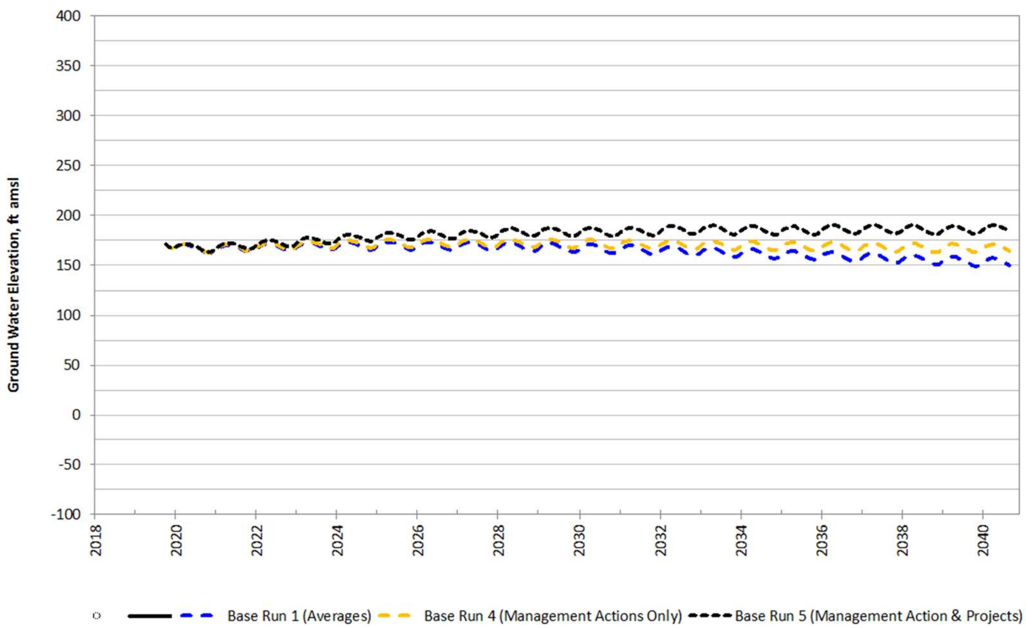

**Well KSB-1055**
**Mid Kaweah GSA**
**Well ID: CID_066**
**Aquifer System: Unknown - Model Layer 3**



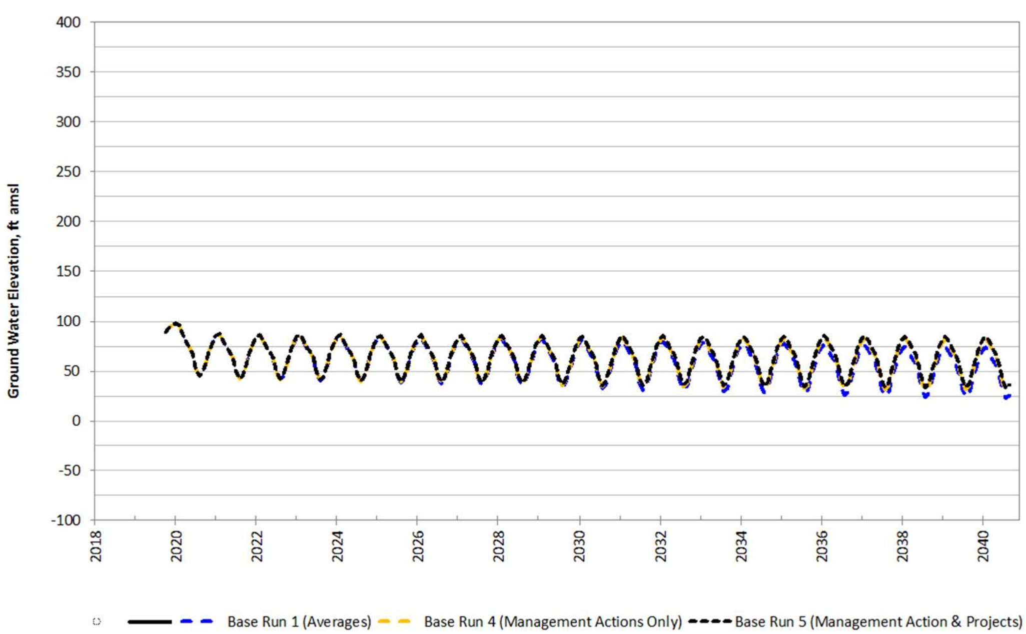

Well KSB-1071
Mid Kaweah GSA
Well ID: 19S22E01D01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-1161
Greater Kaweah GSA
Well ID: 19S22E09J01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

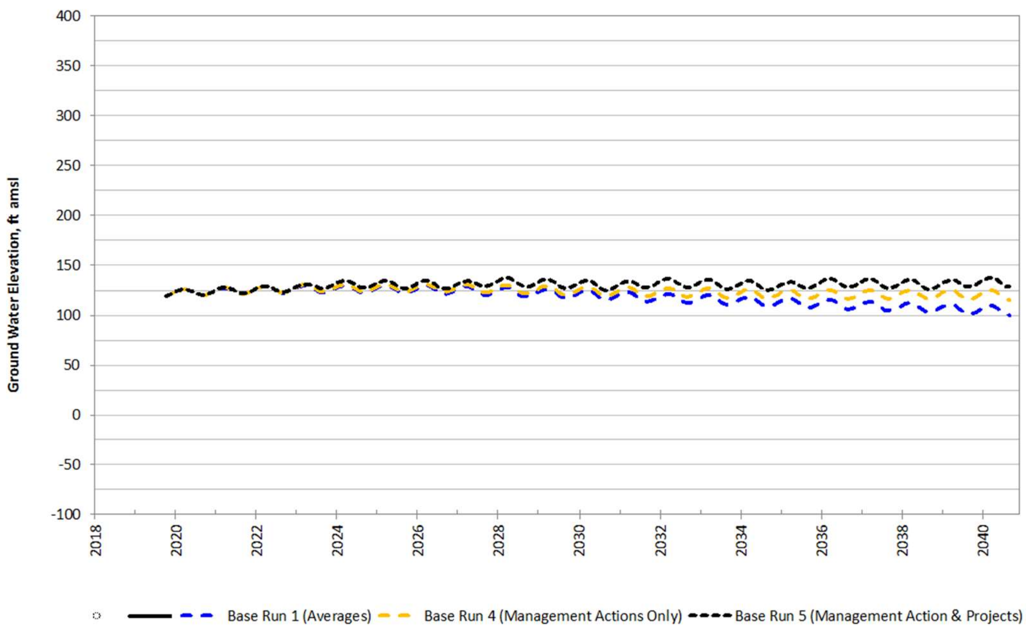
**Well KSB-1168**
**Mid Kaweah GSA**
**Well ID: CID_007**
**Aquifer System: Unknown - Model Layer 3**



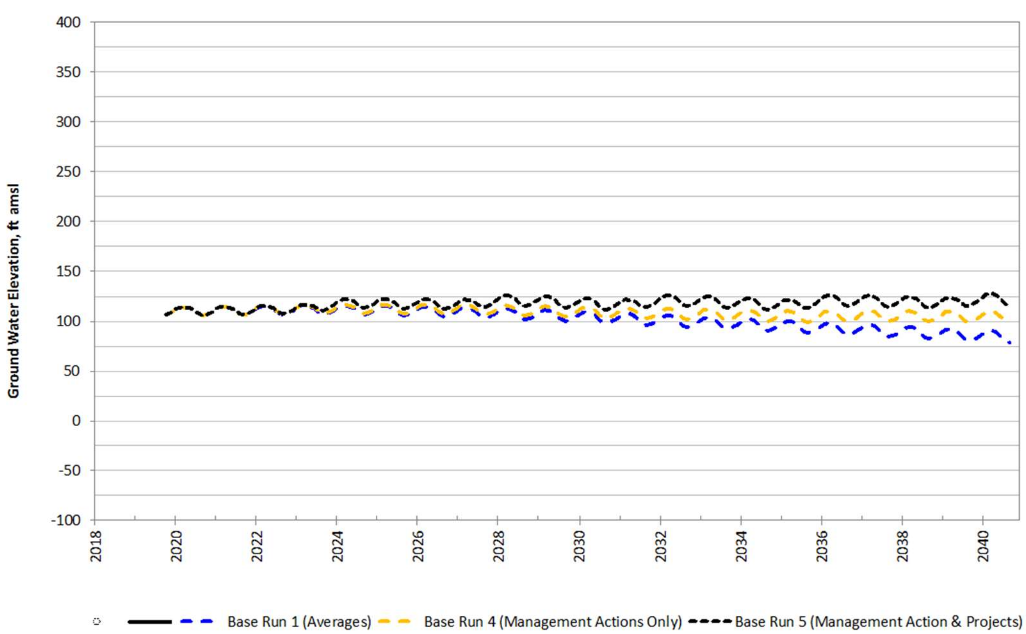

**Well KSB-1183**
**Greater Kaweah GSA**
**Well ID: 19S22E16A03M**
**Aquifer System: Unknown - Model Layer 3**



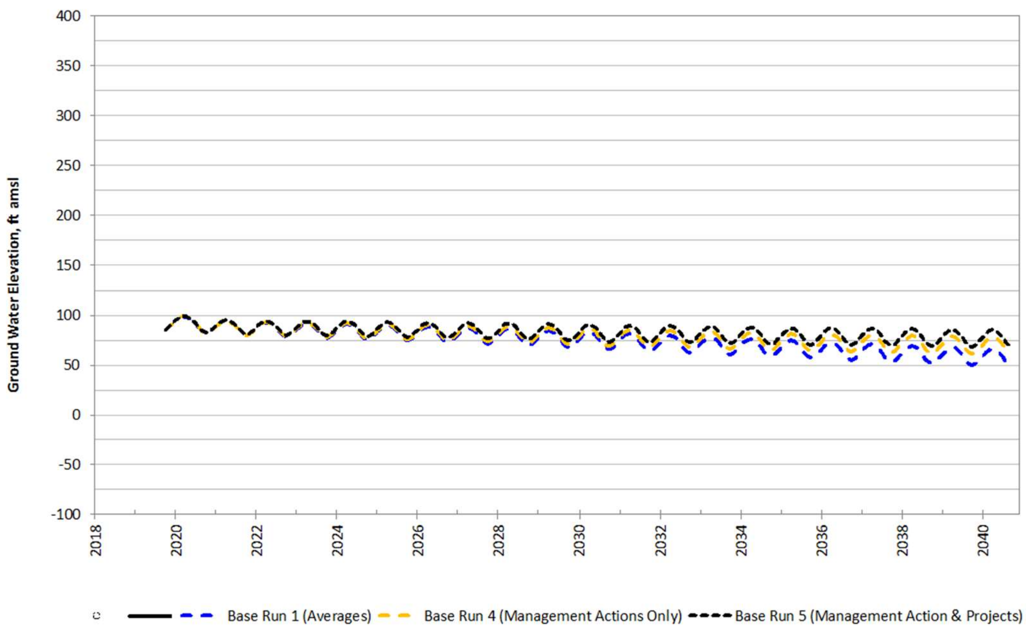
**Well KSB-1214**
**Greater Kaweah GSA**
**Well ID: 19S22E21J01M**
**Aquifer System: Unknown - Model Layer 3**



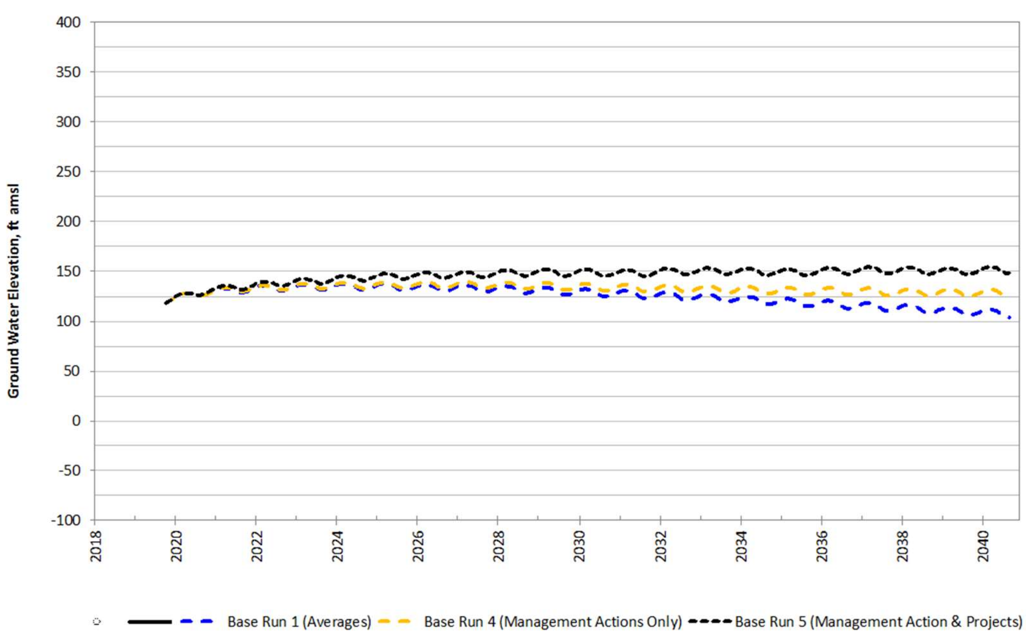

**Well KSB-1222**
**Greater Kaweah GSA**
**Well ID: 19S22E16A02M**
**Aquifer System: Unknown - Model Layer 1**



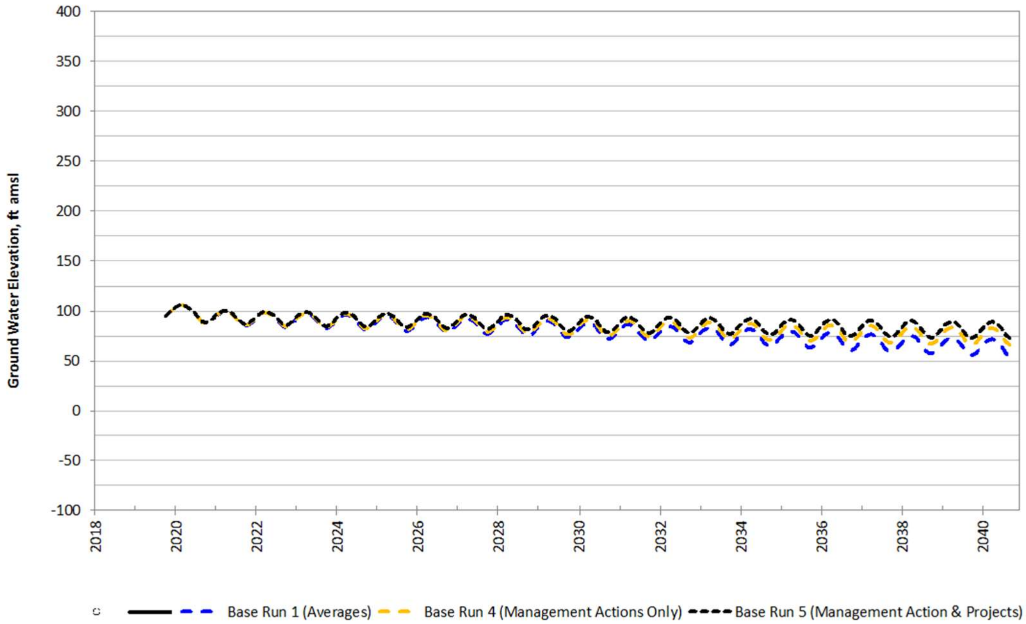
**Well KSB-1226**
**Mid Kaweah GSA**
**Well ID: CID_027**
**Aquifer System: Unknown - Model Layer 3**



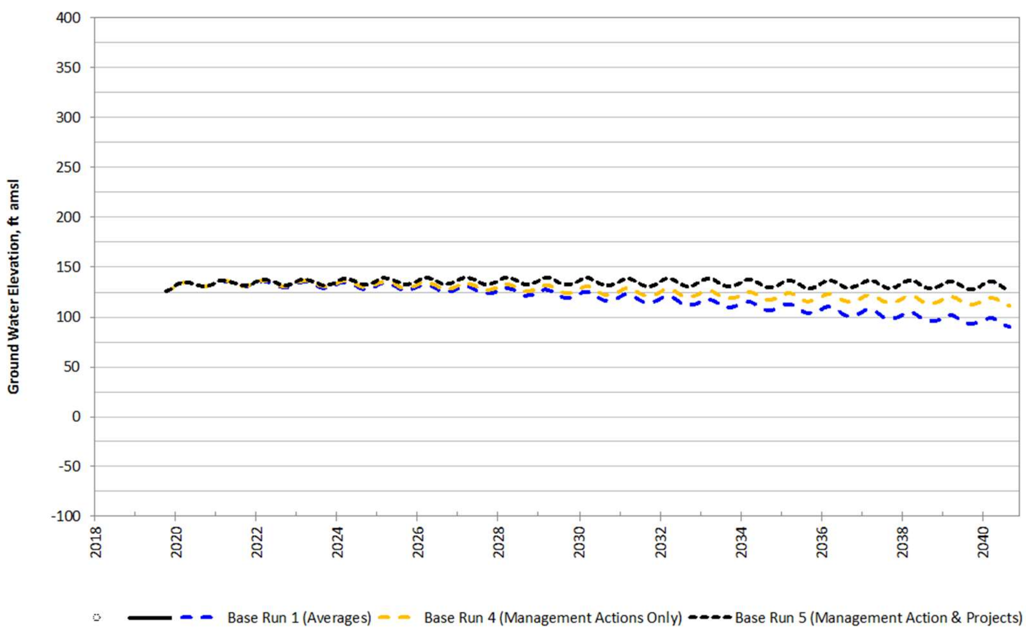

**Well KSB-1259**
**Greater Kaweah GSA**
**Well ID: 19S22E15M01M**
**Aquifer System: Unknown - Model Layer 3**

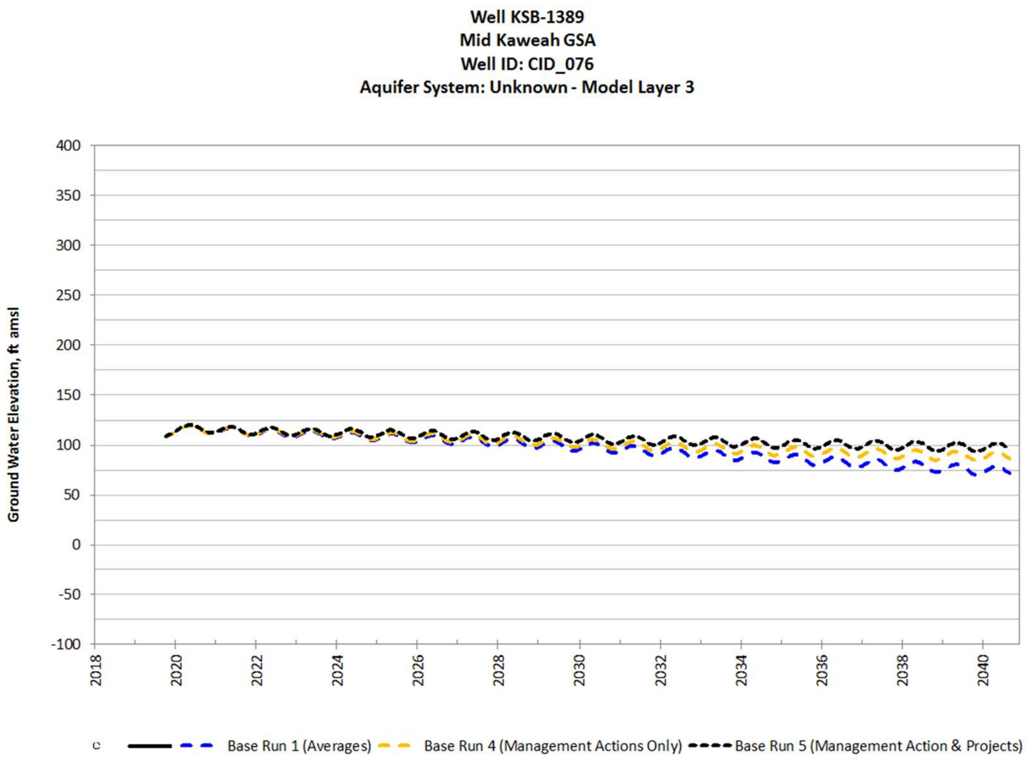


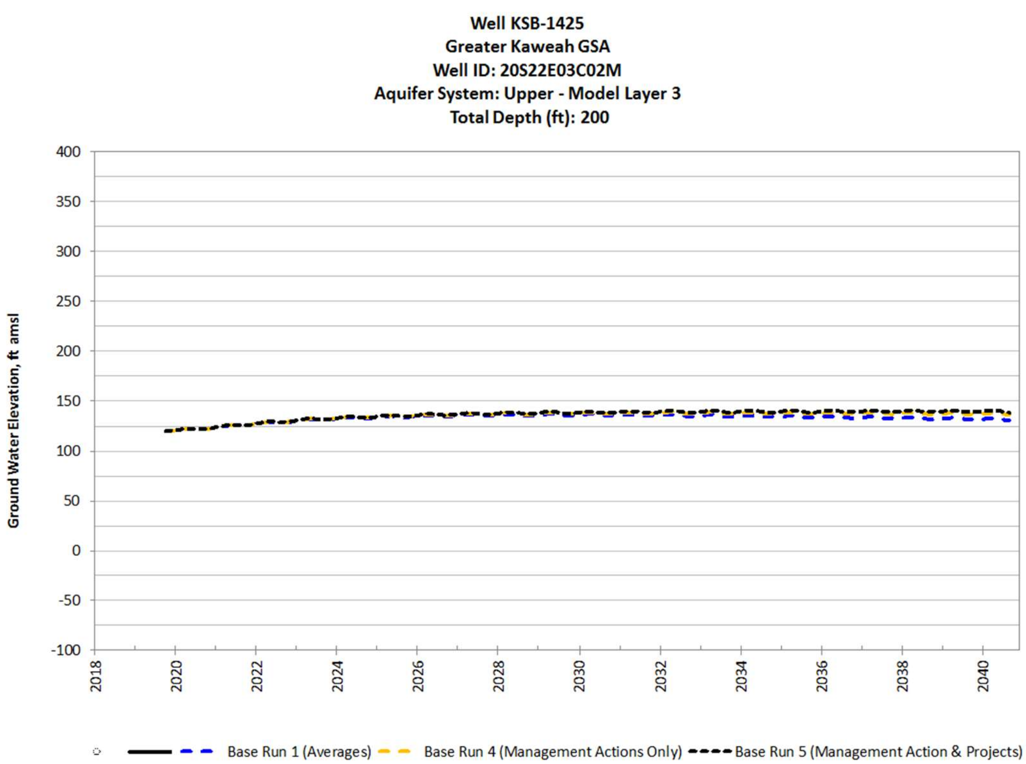
**Well KSB-1359**
**Mid Kaweah GSA**
**Well ID: CID_068**
**Aquifer System: Unknown - Model Layer 3**

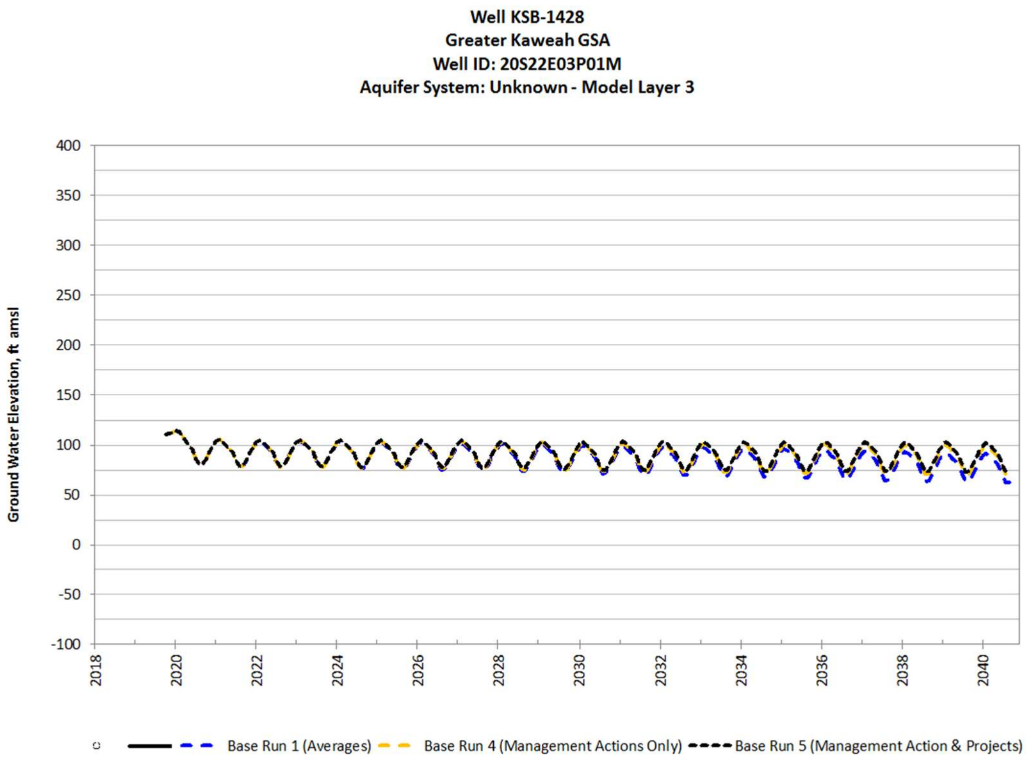


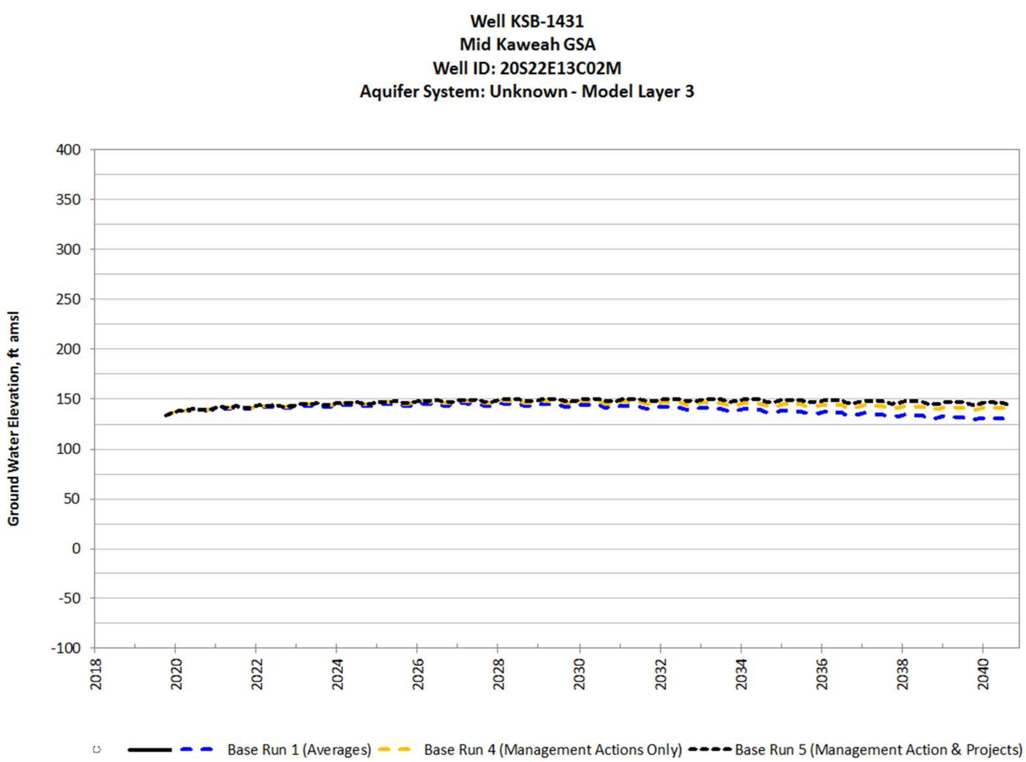

**Well KSB-1384**
**Greater Kaweah GSA**
**Well ID: 362000N1195800W001**
**Aquifer System: Unknown - Model Layer 3**

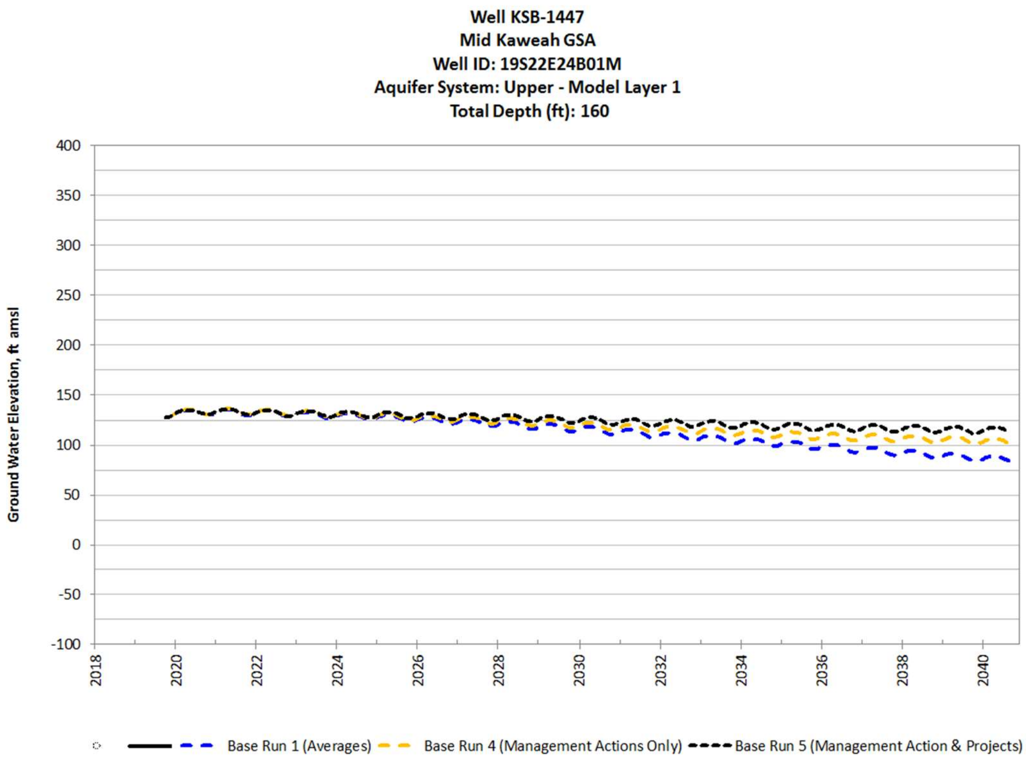


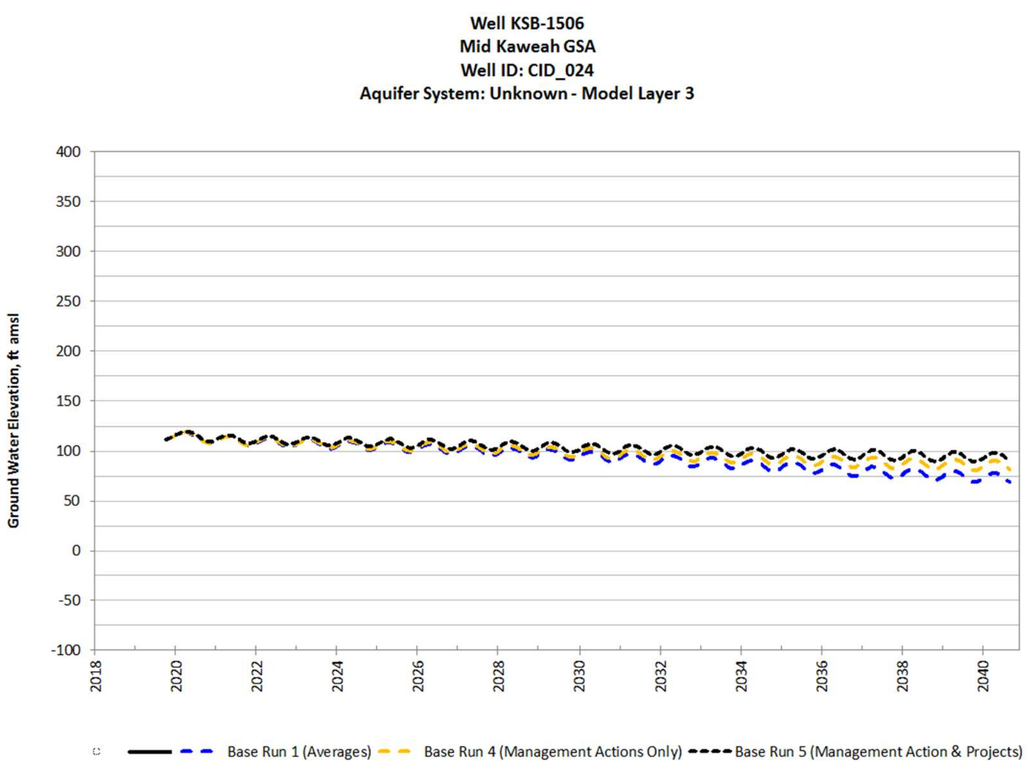

Well KSB-1389
Mid Kaweah GSA
Well ID: CID_076
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-1425
Greater Kaweah GSA
Well ID: 20S22E03C02M
Aquifer System: Upper - Model Layer 3
Total Depth (ft): 200
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

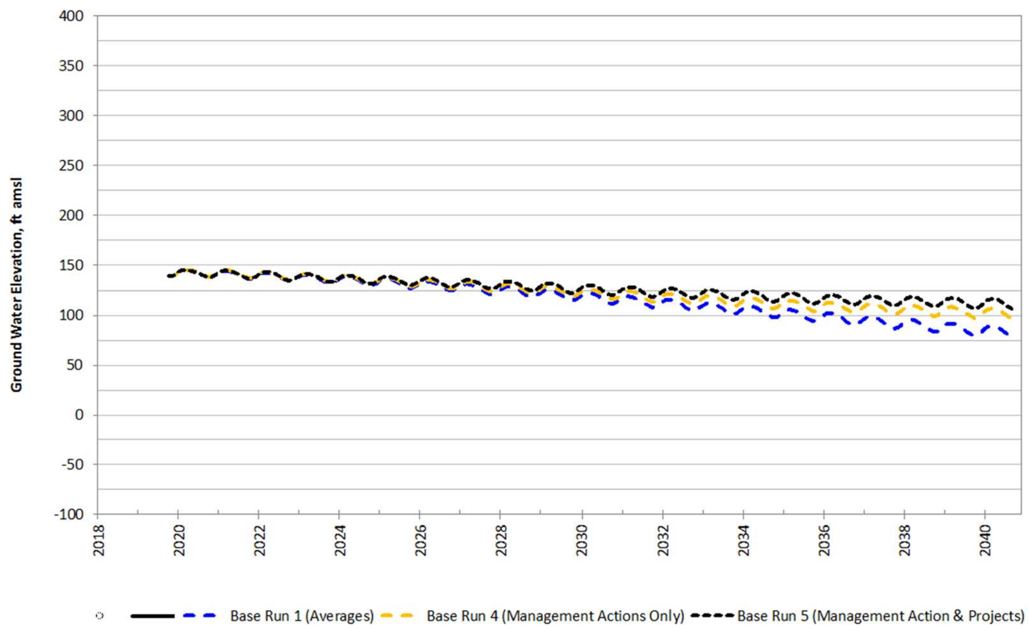

Well KSB-1428
Greater Kaweah GSA
Well ID: 20S22E03P01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-1431
Mid Kaweah GSA
Well ID: 20S22E13C02M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

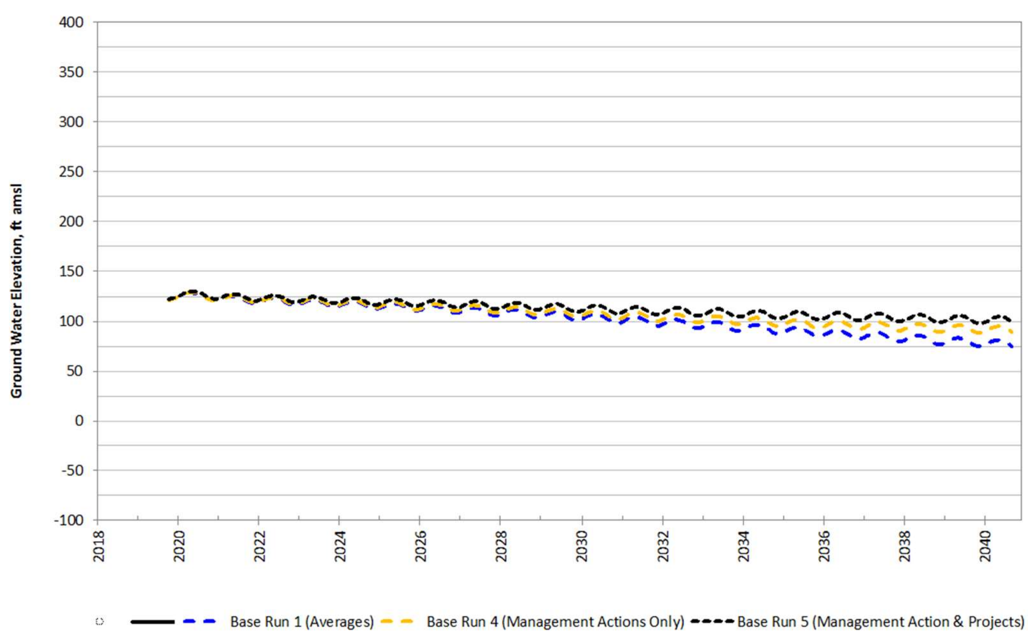

Well KSB-1447
Mid Kaweah GSA
Well ID: 19S22E24B01M
Aquifer System: Upper - Model Layer 1
Total Depth (ft): 160
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

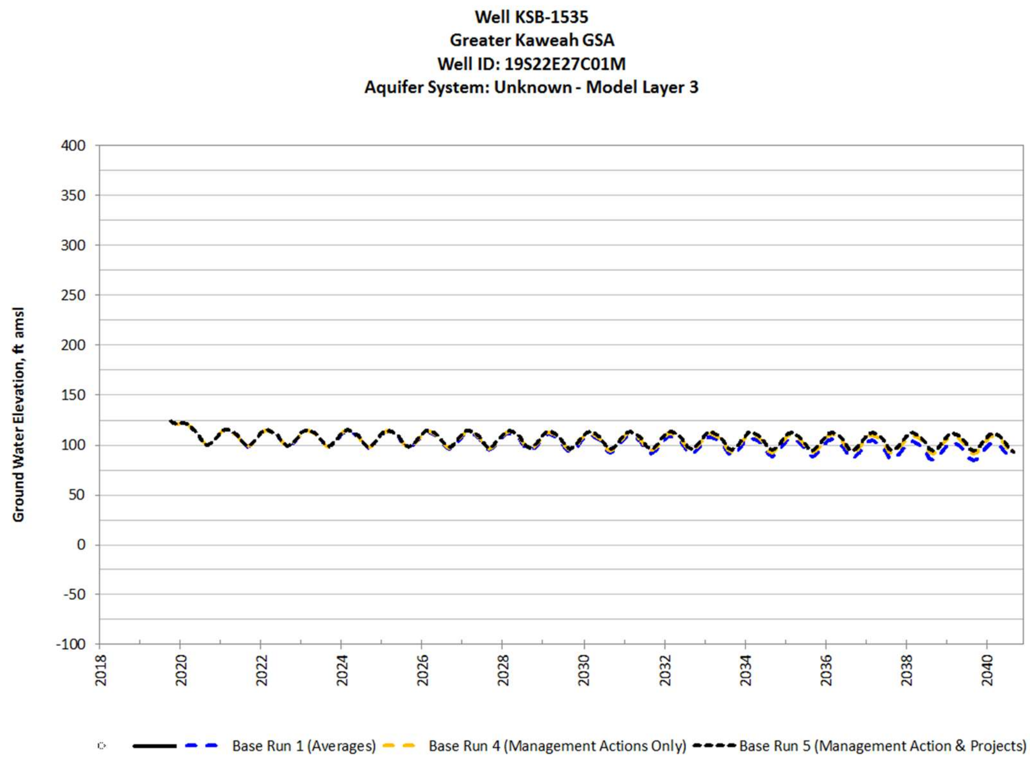

Well KSB-1506
Mid Kaweah GSA
Well ID: CID_024
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

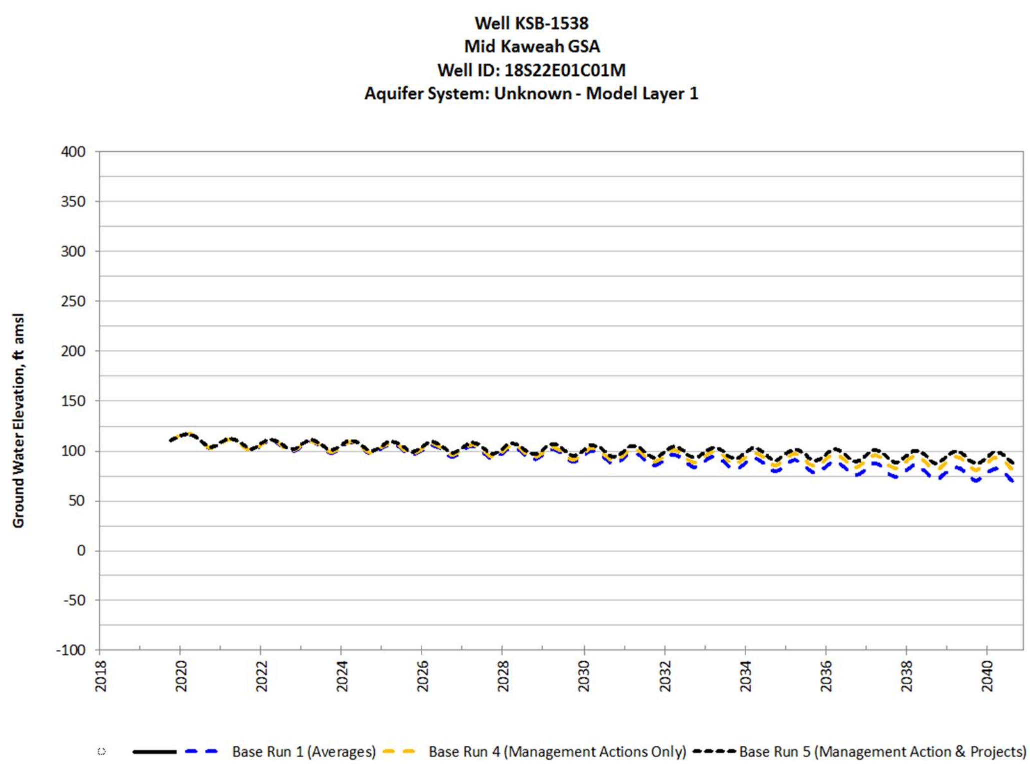
**Well KSB-1526**
**Mid Kaweah GSA**
**Well ID: CID_037**
**Aquifer System: Unknown - Model Layer 3**

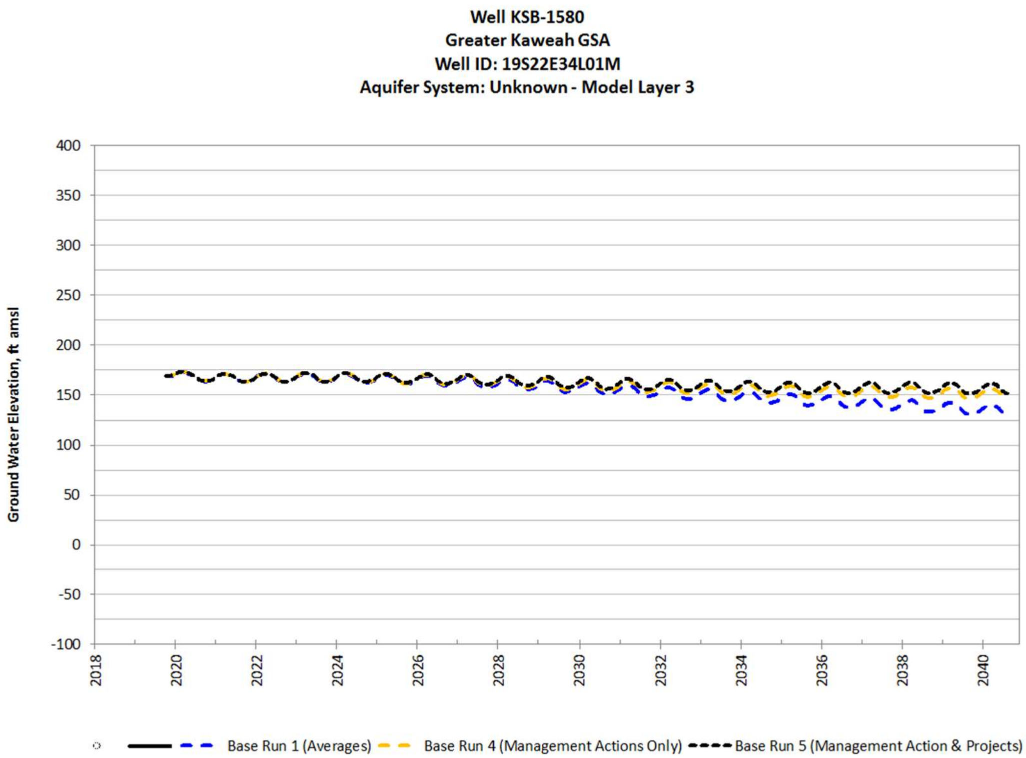


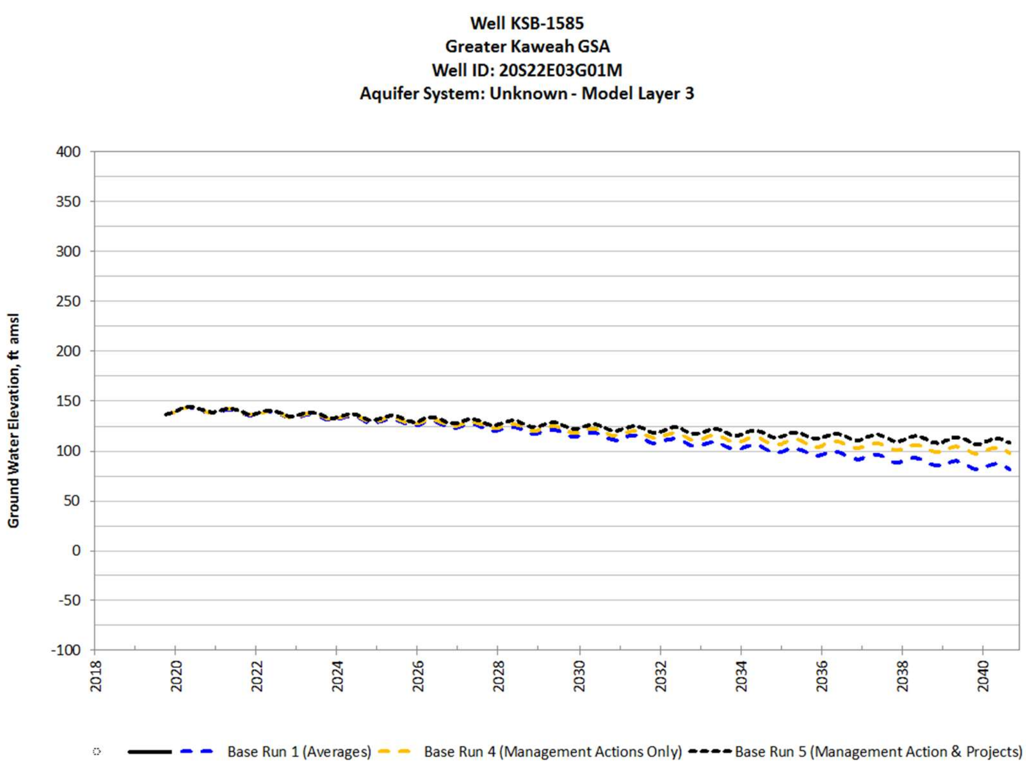

**Well KSB-1532**
**Mid Kaweah GSA**
**Well ID: CID_052**
**Aquifer System: Unknown - Model Layer 3**

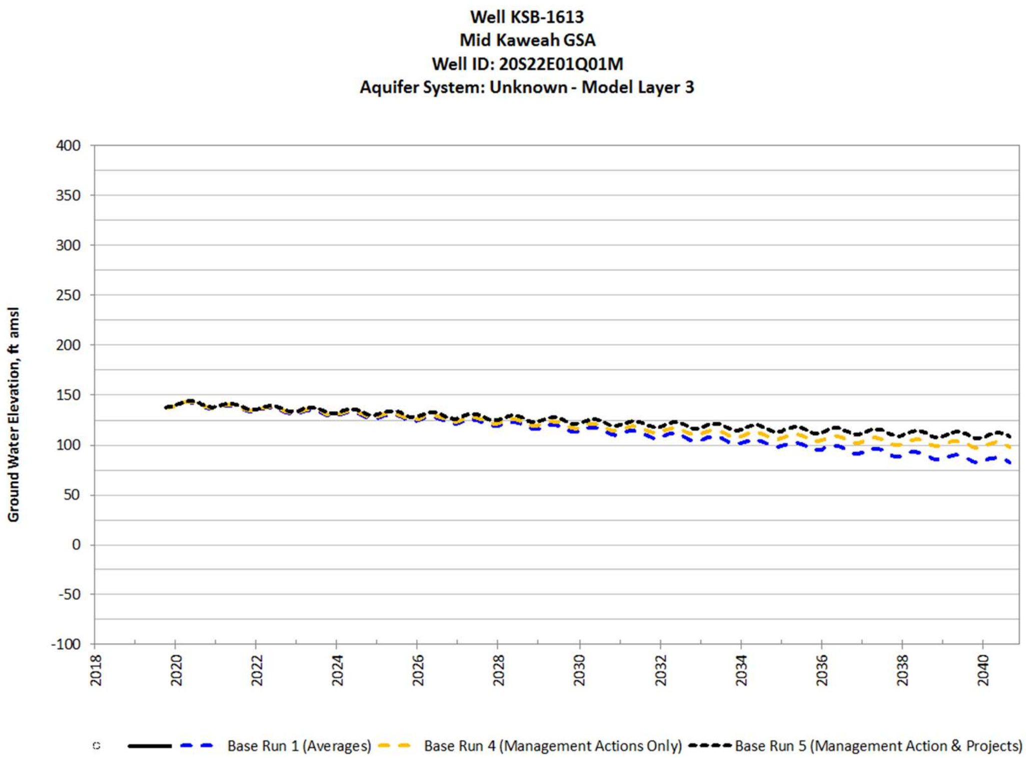


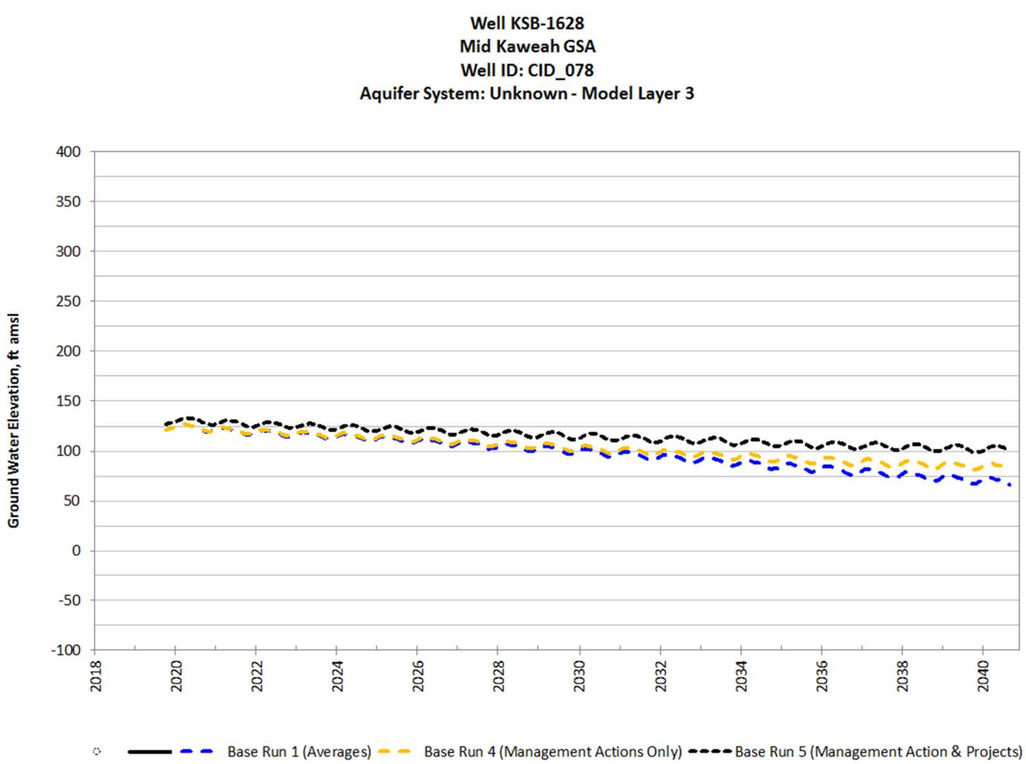

Well KSB-1535
Greater Kaweah GSA
Well ID: 19S22E27C01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-1538
Mid Kaweah GSA
Well ID: 18S22E01C01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

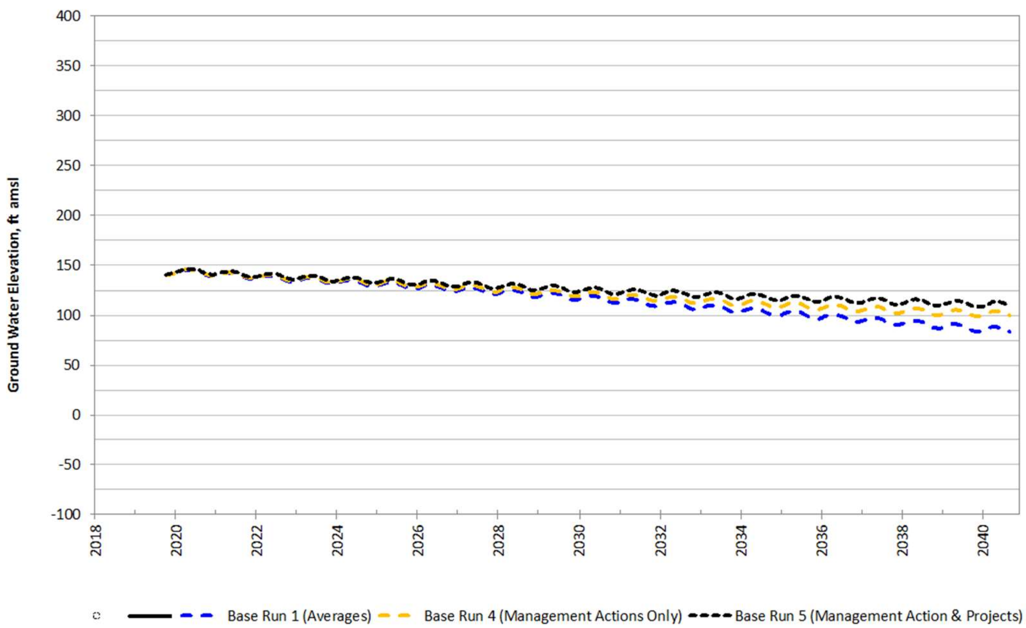

Well KSB-1580
Greater Kaweah GSA
Well ID: 19S22E34L01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-1585
Greater Kaweah GSA
Well ID: 20S22E03G01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

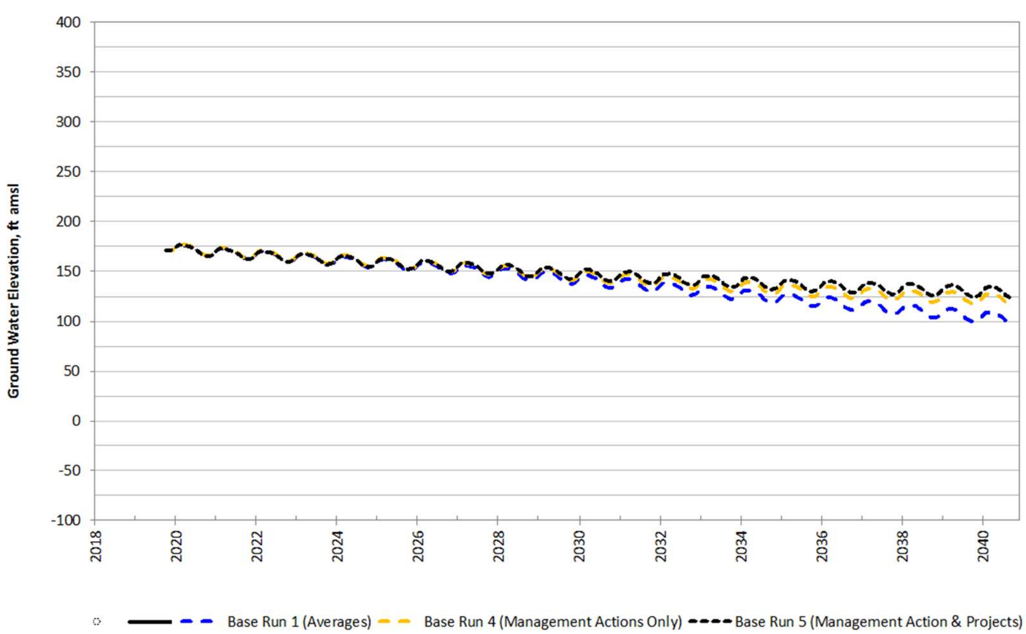

Well KSB-1613
Mid Kaweah GSA
Well ID: 20S22E01Q01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

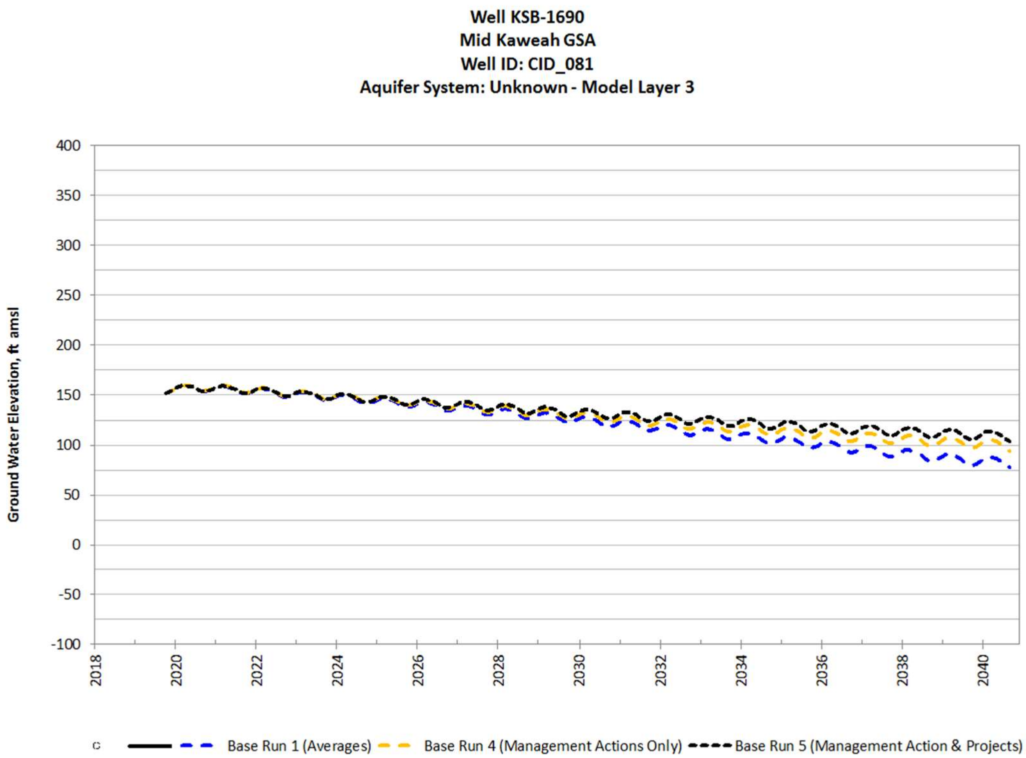

Well KSB-1628
Mid Kaweah GSA
Well ID: CID_078
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

**Well KSB-1634**
**Mid Kaweah GSA**
**Well ID: CID_079**
**Aquifer System: Unknown - Model Layer 3**

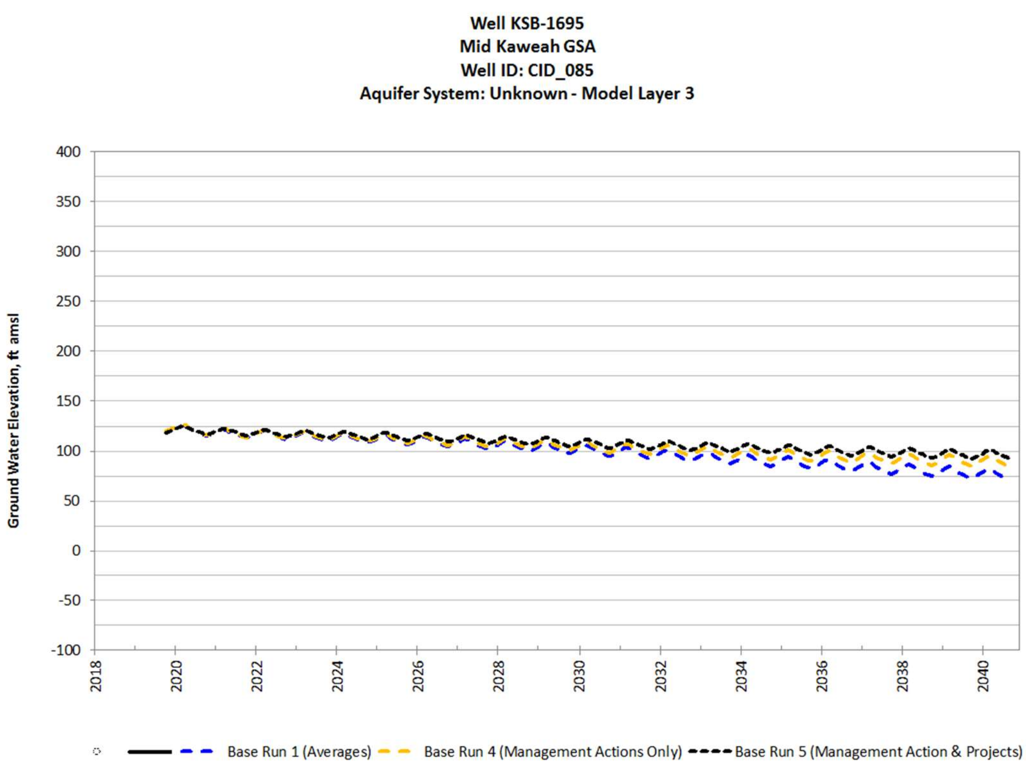



**Well KSB-1689**
**Mid Kaweah GSA**
**Well ID: CID_080**
**Aquifer System: Unknown - Model Layer 3**

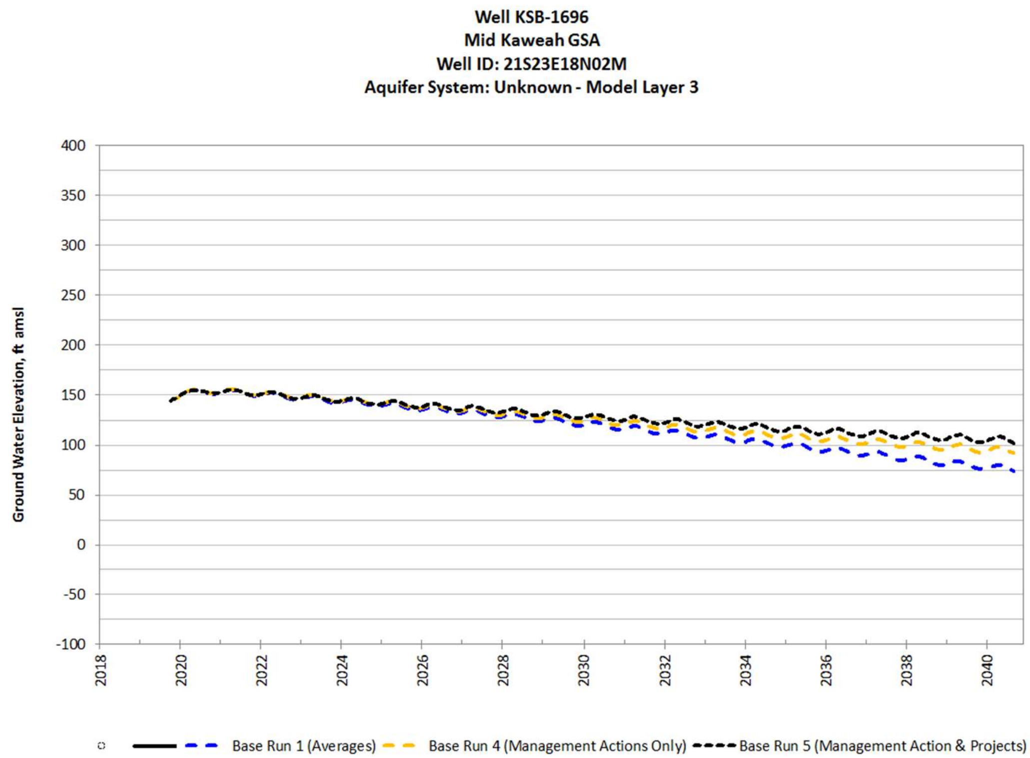


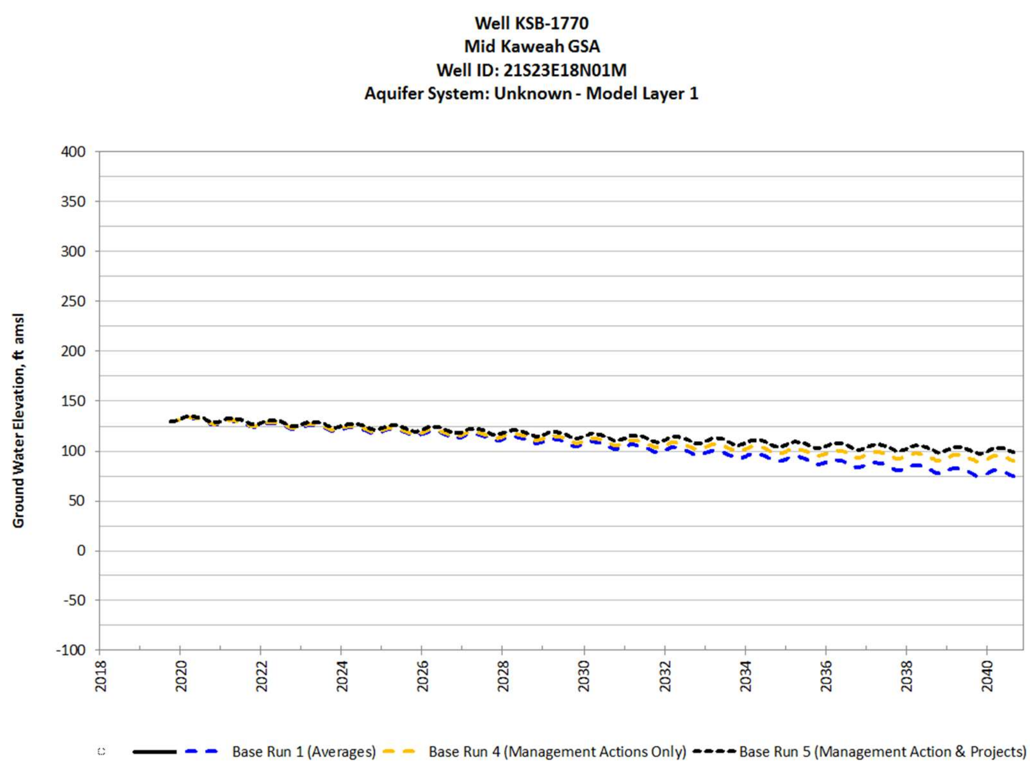


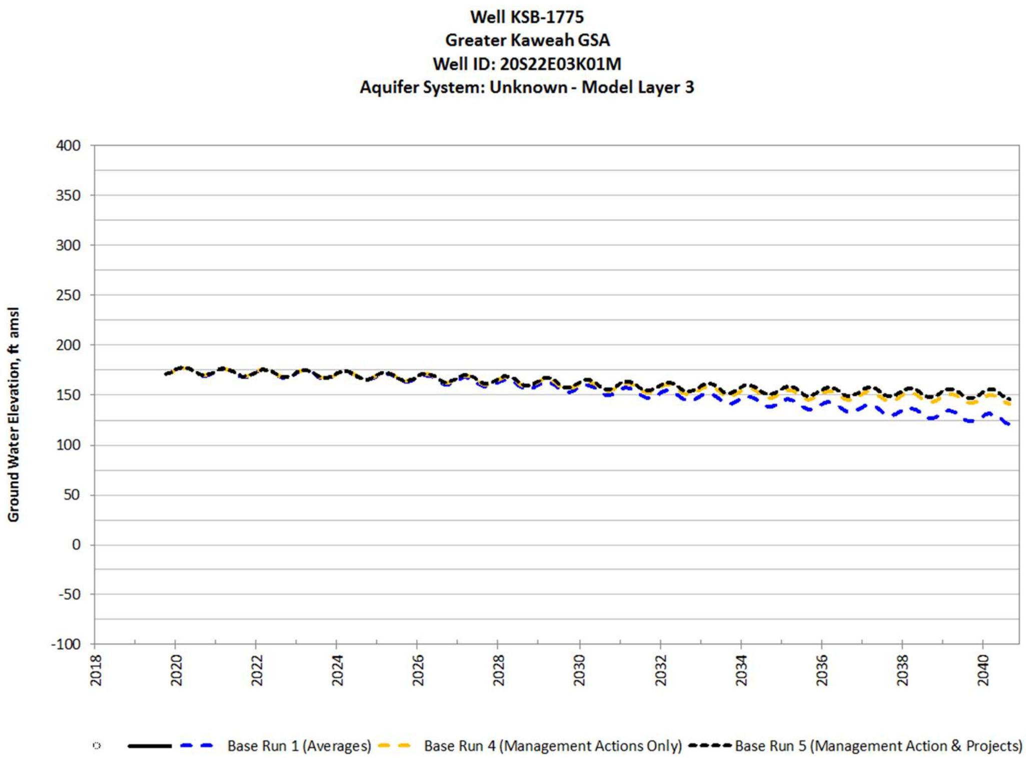
Well KSB-1690
Mid Kaweah GSA
Well ID: CID_081
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

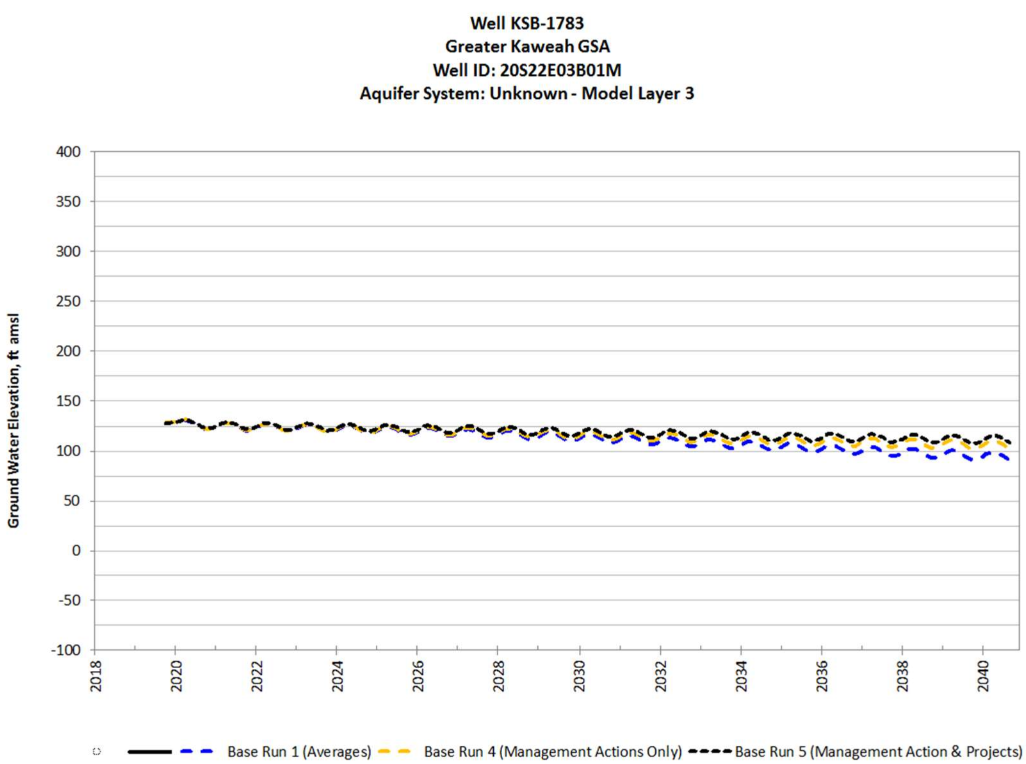



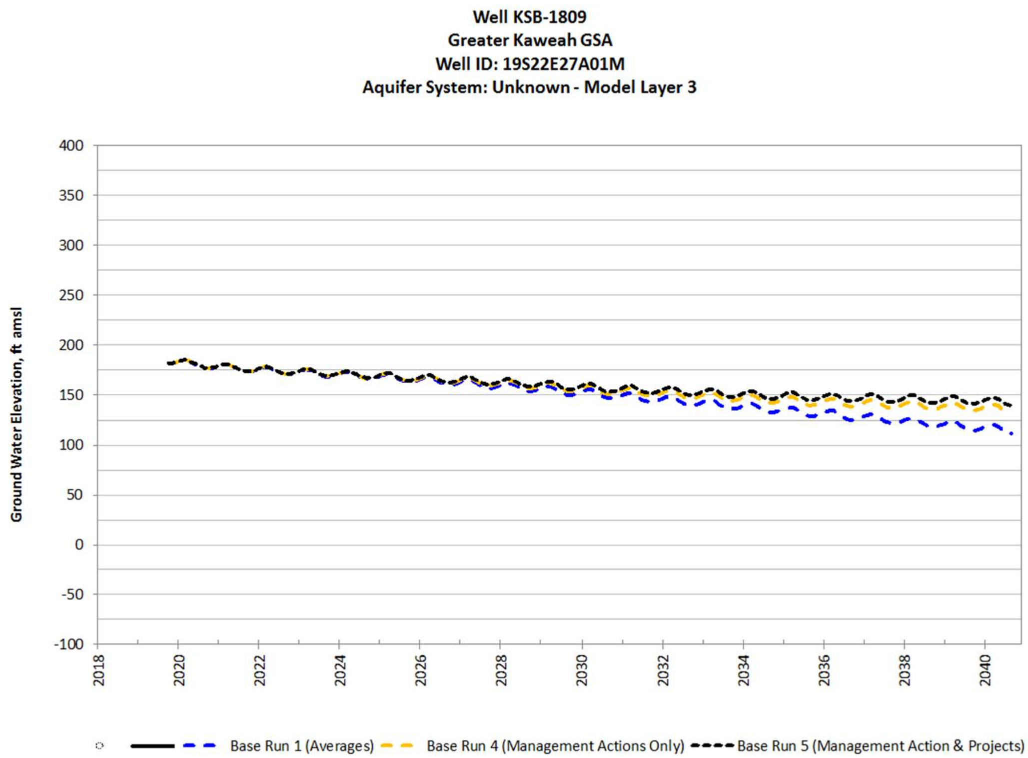
Well KSB-1695
Mid Kaweah GSA
Well ID: CID_085
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

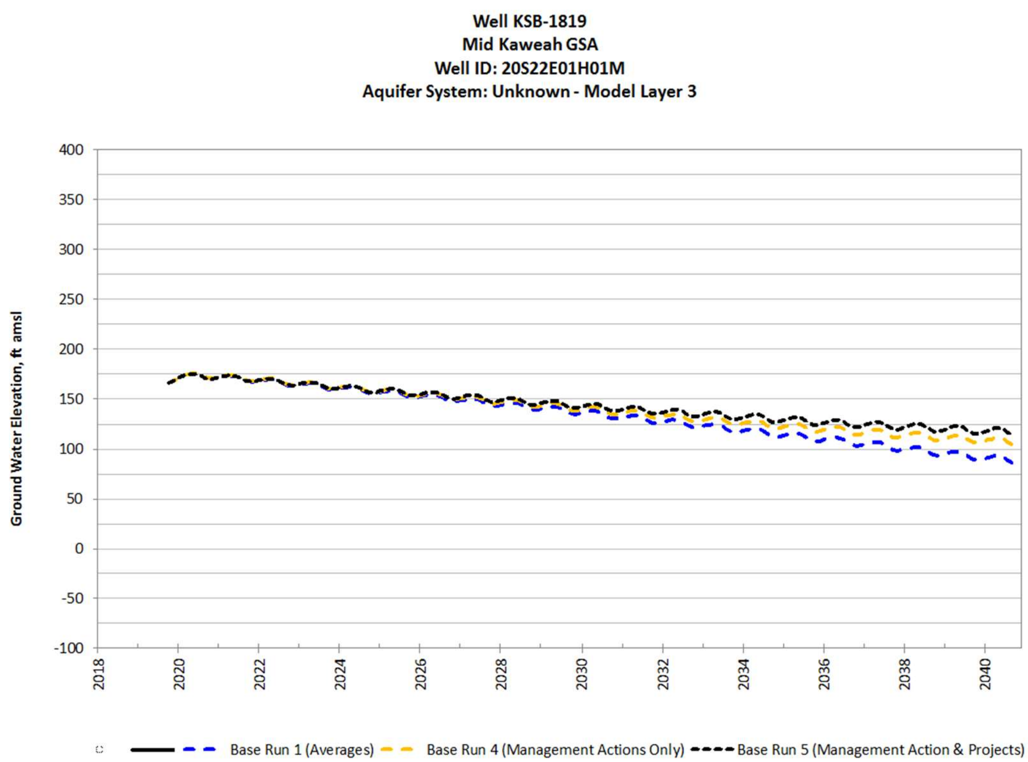

Well KSB-1696
Mid Kaweah GSA
Well ID: 21S23E18N02M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

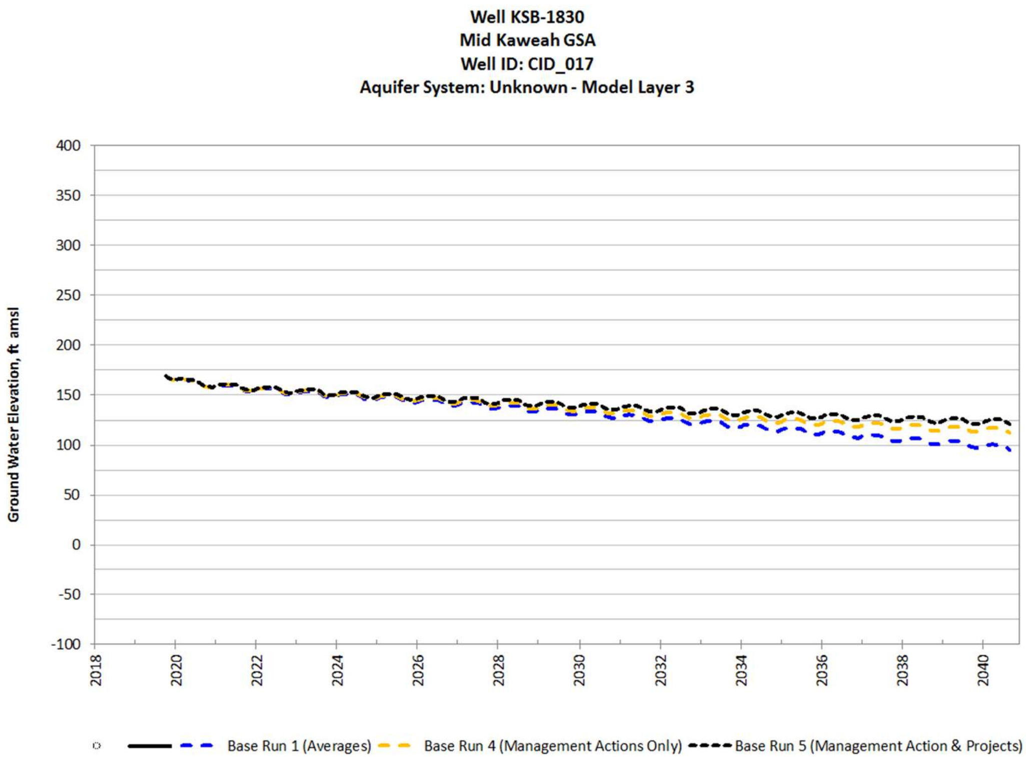

Well KSB-1770
Mid Kaweah GSA
Well ID: 21S23E18N01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

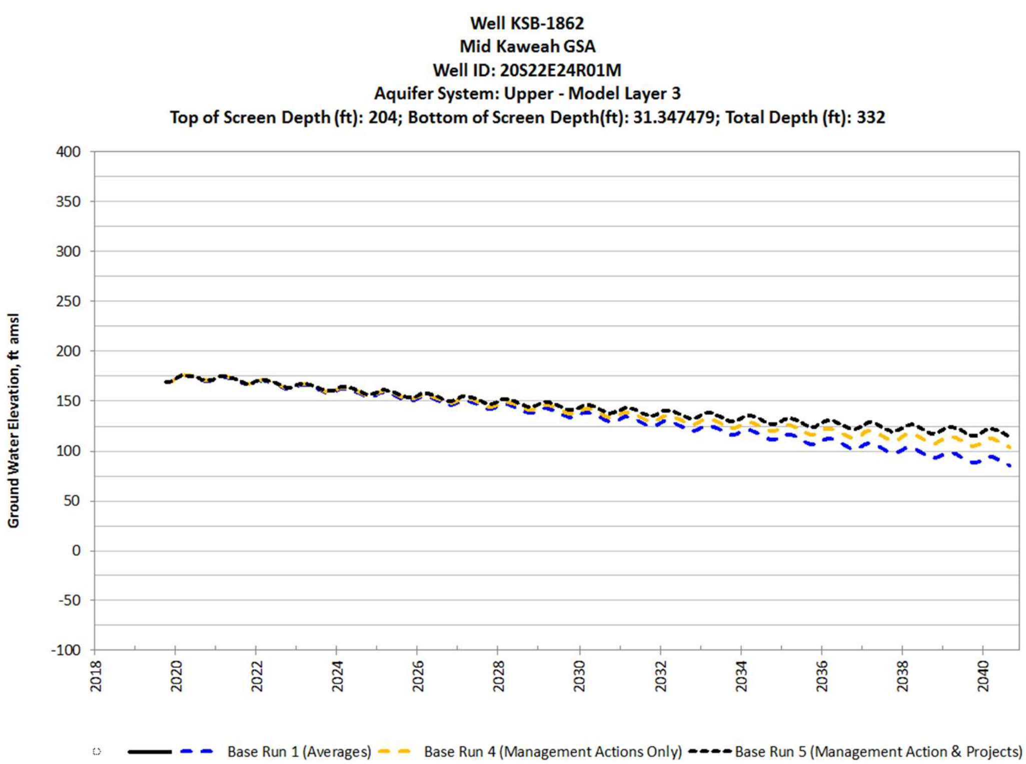

Well KSB-1775
Greater Kaweah GSA
Well ID: 20S22E03K01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-1783
Greater Kaweah GSA
Well ID: 20S22E03B01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

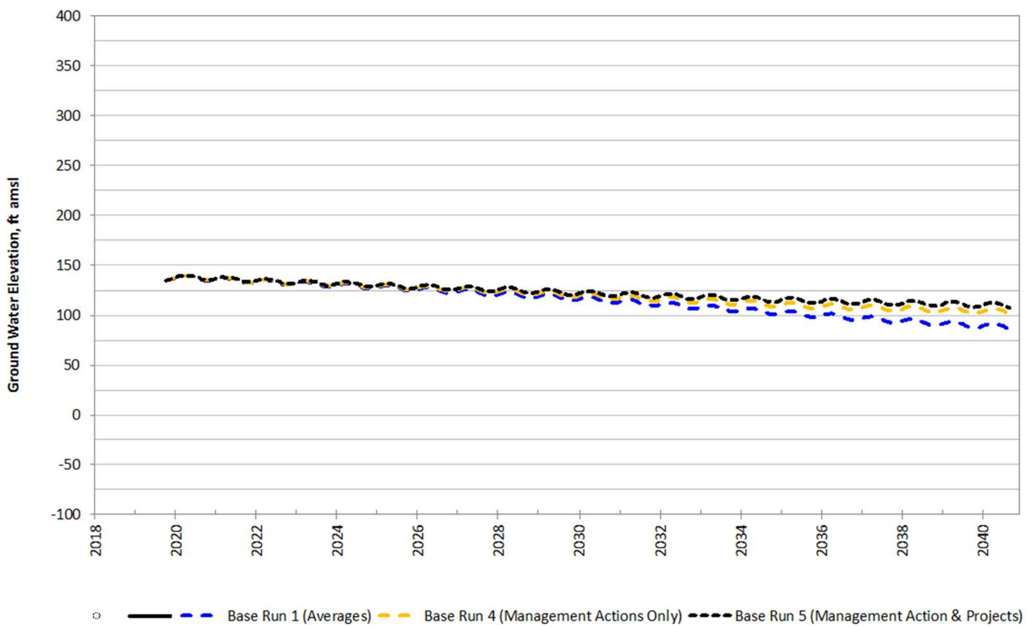

Well KSB-1809
Greater Kaweah GSA
Well ID: 19S22E27A01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-1819
Mid Kaweah GSA
Well ID: 20S22E01H01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

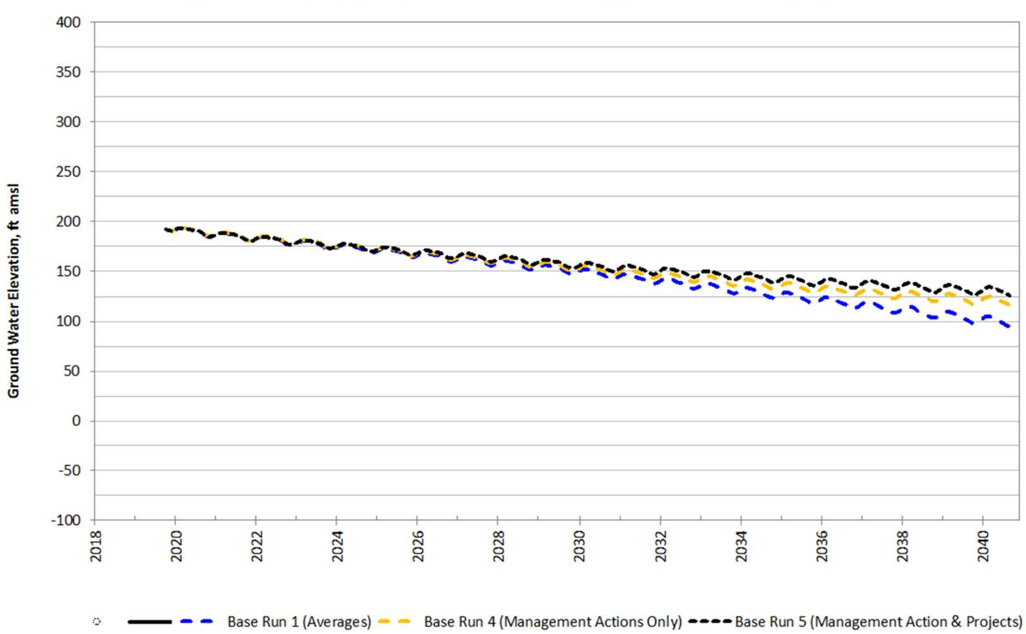

Well KSB-1830
Mid Kaweah GSA
Well ID: CID_017
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

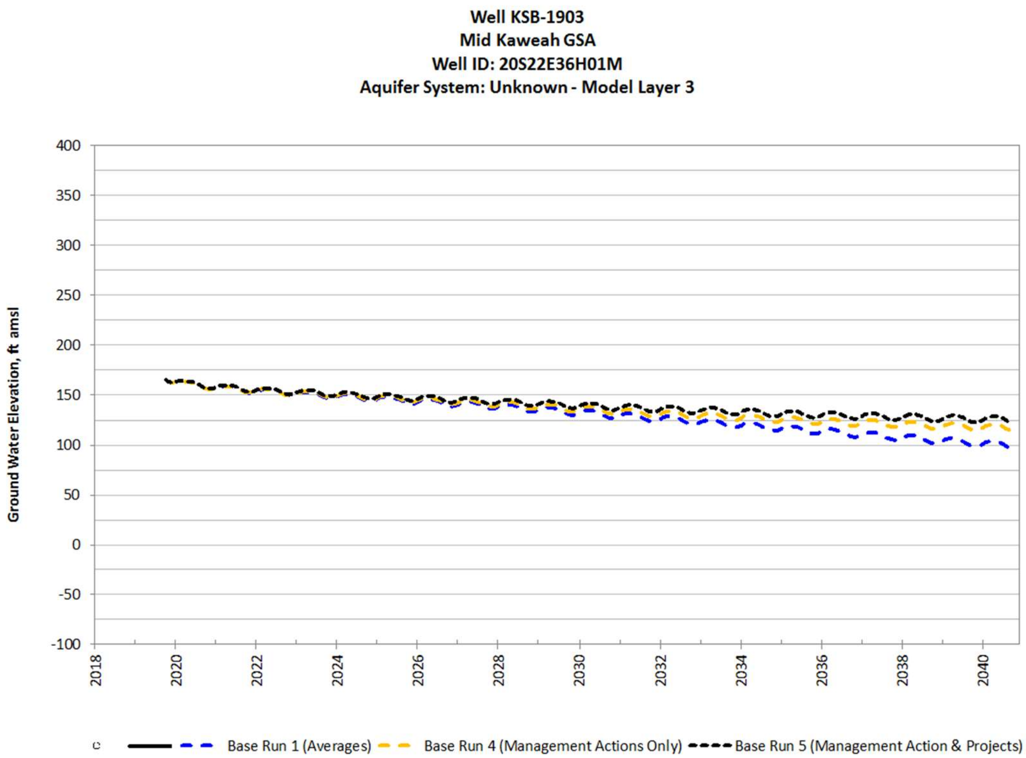

Well KSB-1862
Mid Kaweah GSA
Well ID: 20S22E24R01M
Aquifer System: Upper - Model Layer 3
Top of Screen Depth (ft): 204; Bottom of Screen Depth(ft): 31.347479; Total Depth (ft): 332
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

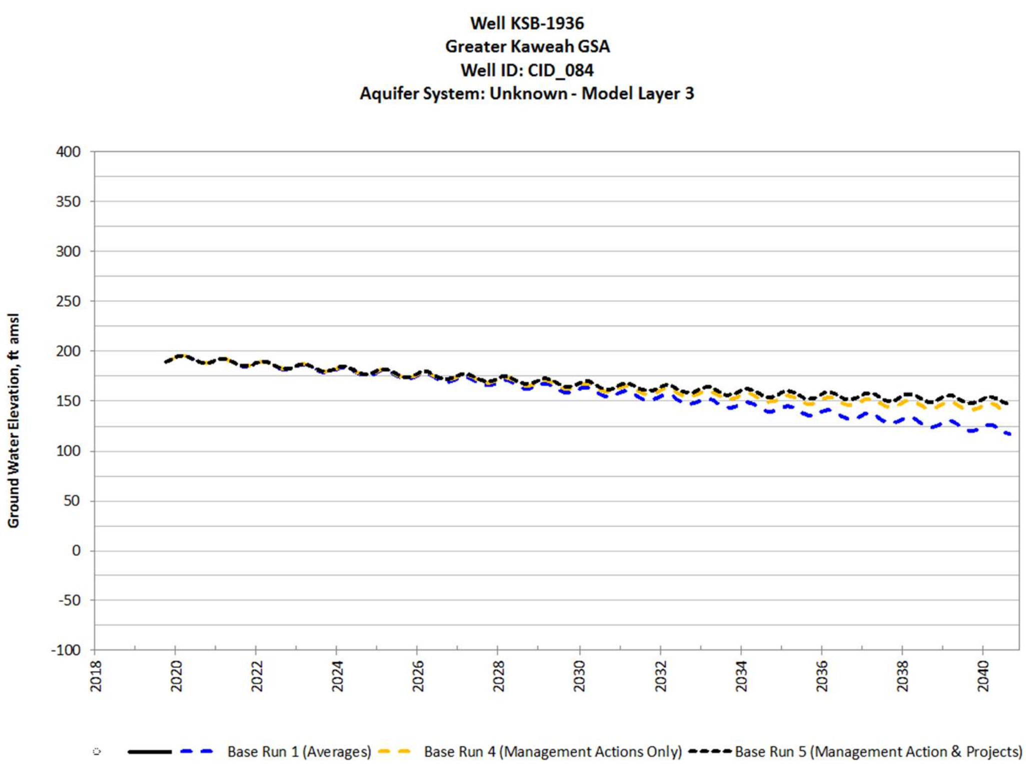
**Well KSB-1873**
**Greater Kaweah GSA**
**Well ID: CID_033**
**Aquifer System: Unknown - Model Layer 3**

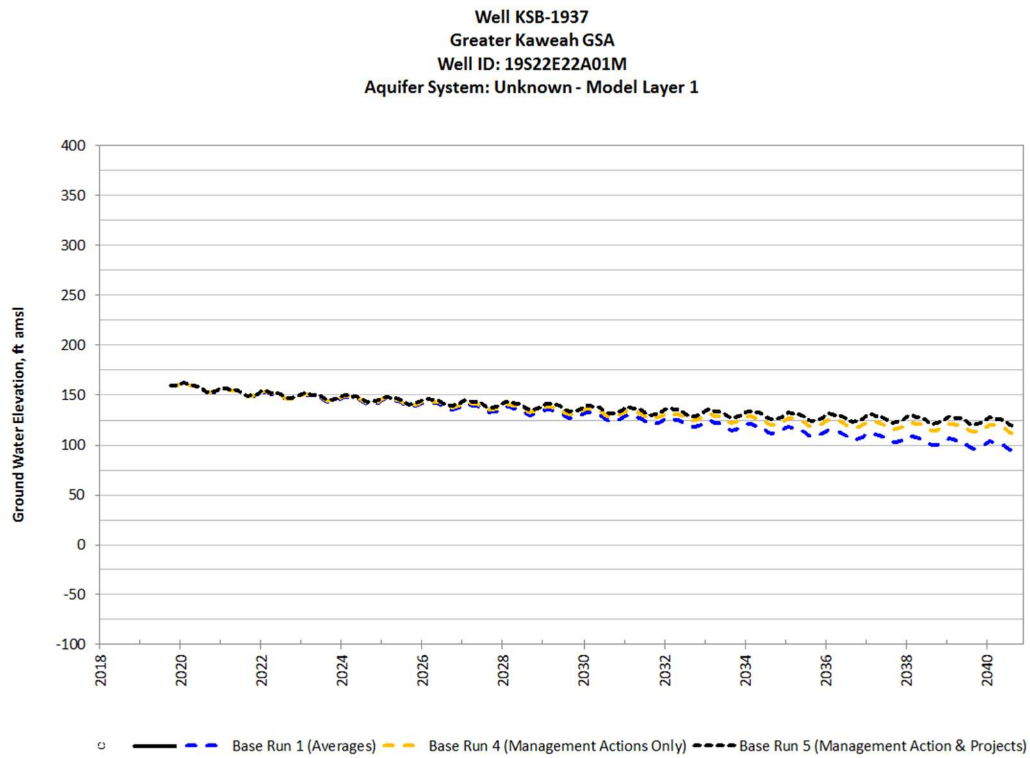


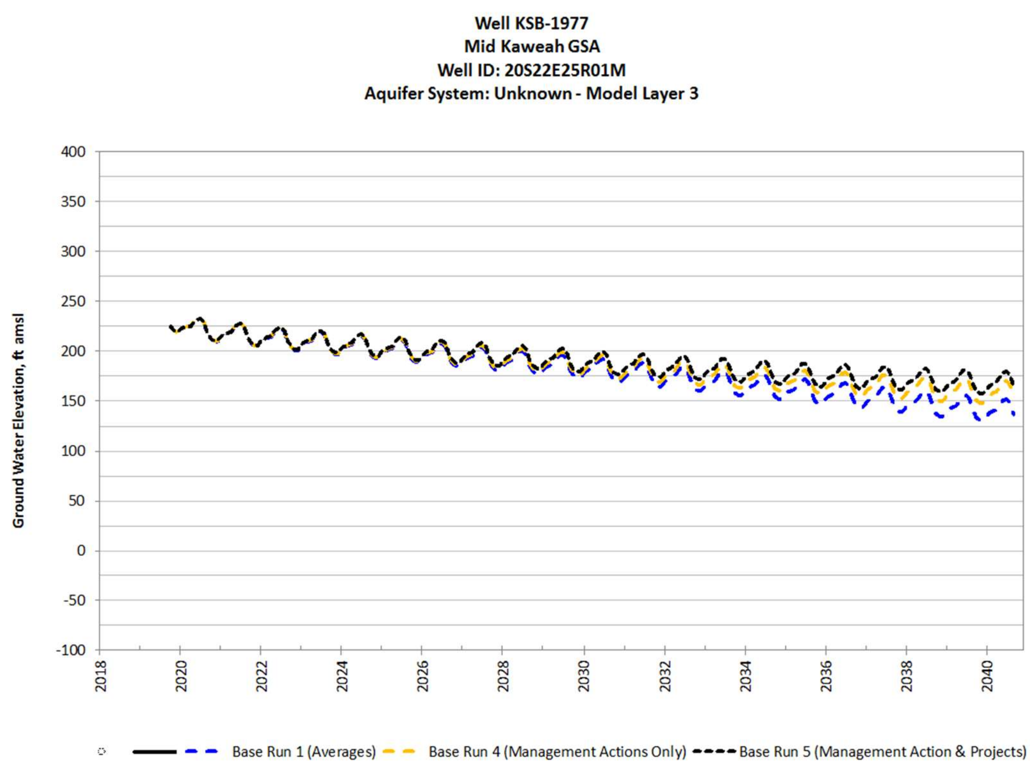

**Well KSB-1884**
**Mid Kaweah GSA**
**Well ID: 20S22E36A01M**
**Aquifer System: Upper - Model Layer 3**
**Top of Screen Depth (ft): 206; Bottom of Screen Depth(ft): 68.51899; Total Depth (ft): 210**



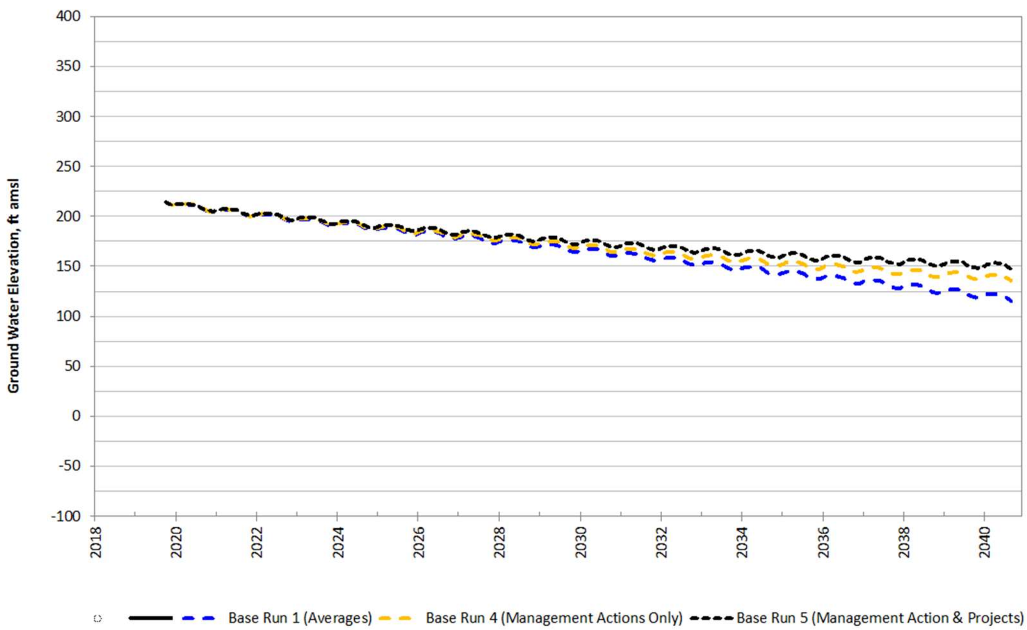

Well KSB-1903
Mid Kaweah GSA
Well ID: 20S22E36H01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-1936
Greater Kaweah GSA
Well ID: CID_084
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

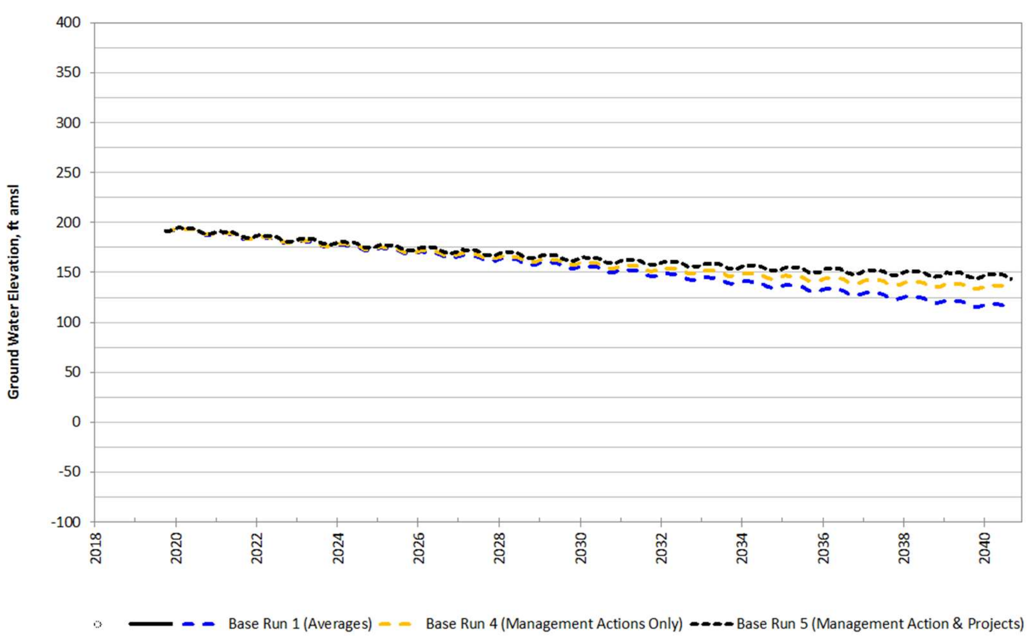

Well KSB-1937
Greater Kaweah GSA
Well ID: 19S22E22A01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

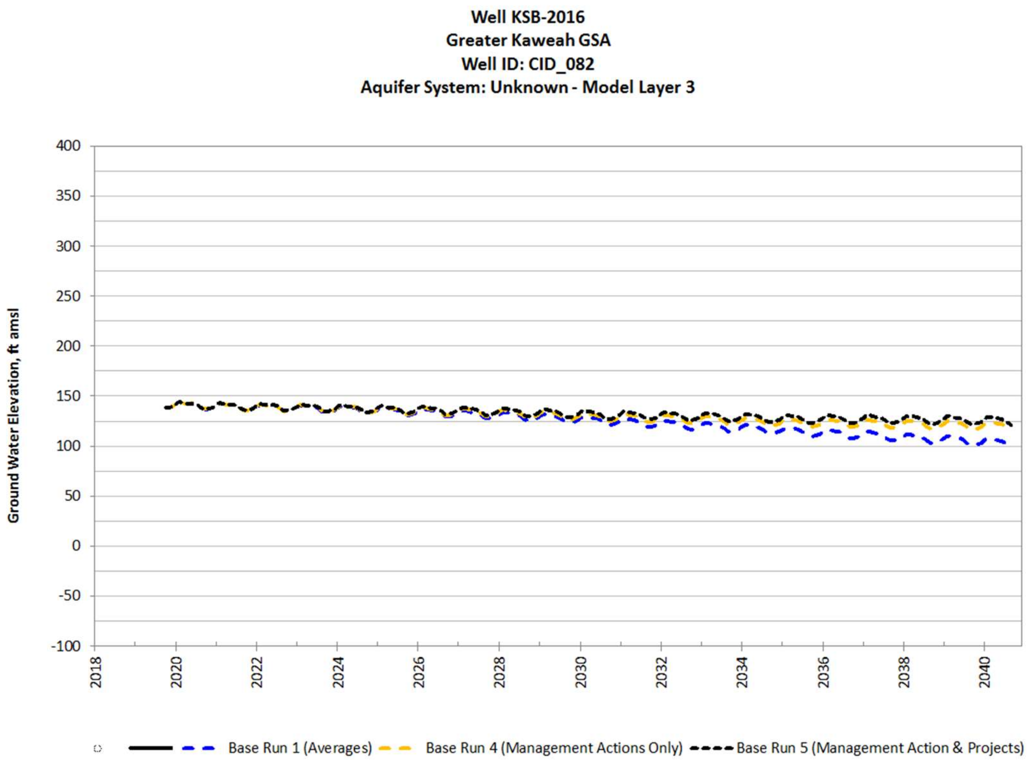

Well KSB-1977
Mid Kaweah GSA
Well ID: 20S22E25R01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

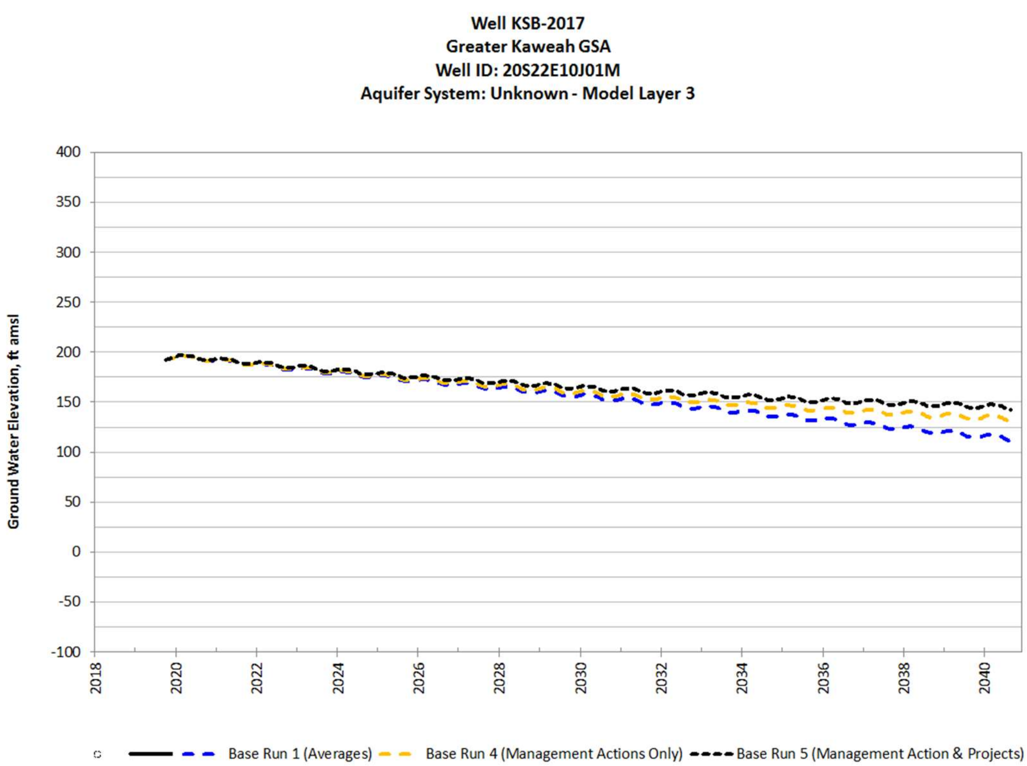
**Well KSB-2014**
**Mid Kaweah GSA**
**Well ID: CID_028**
**Aquifer System: Unknown - Model Layer 3**

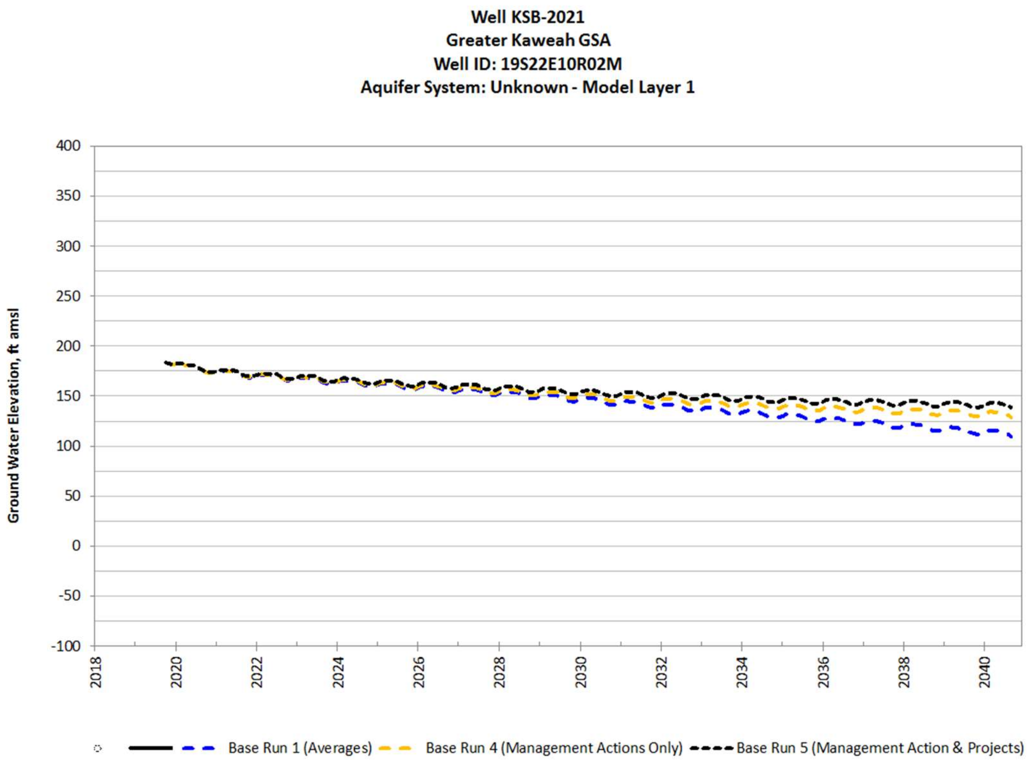


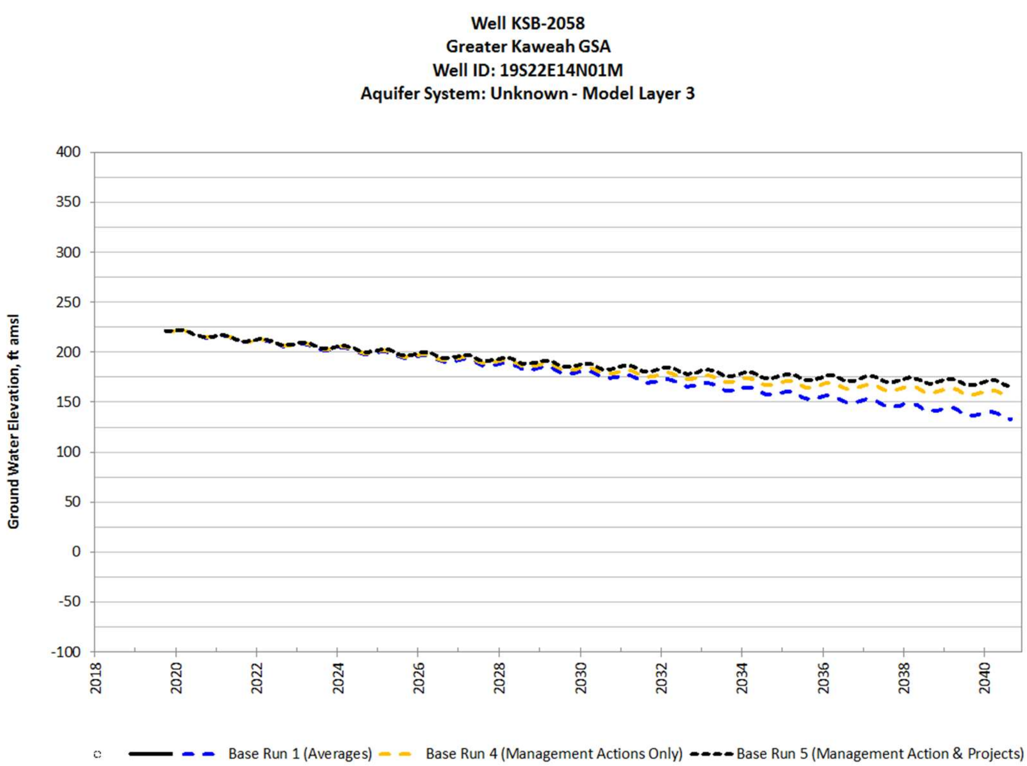

**Well KSB-2015**
**Greater Kaweah GSA**
**Well ID: CID_023**
**Aquifer System: Unknown - Model Layer 1**

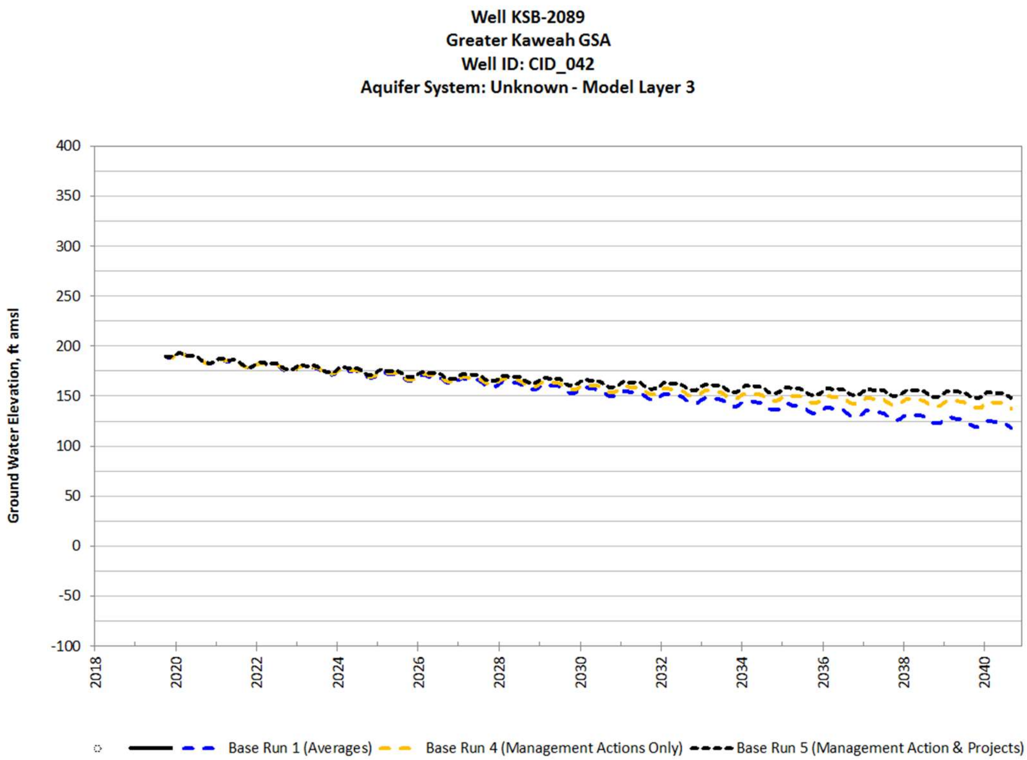


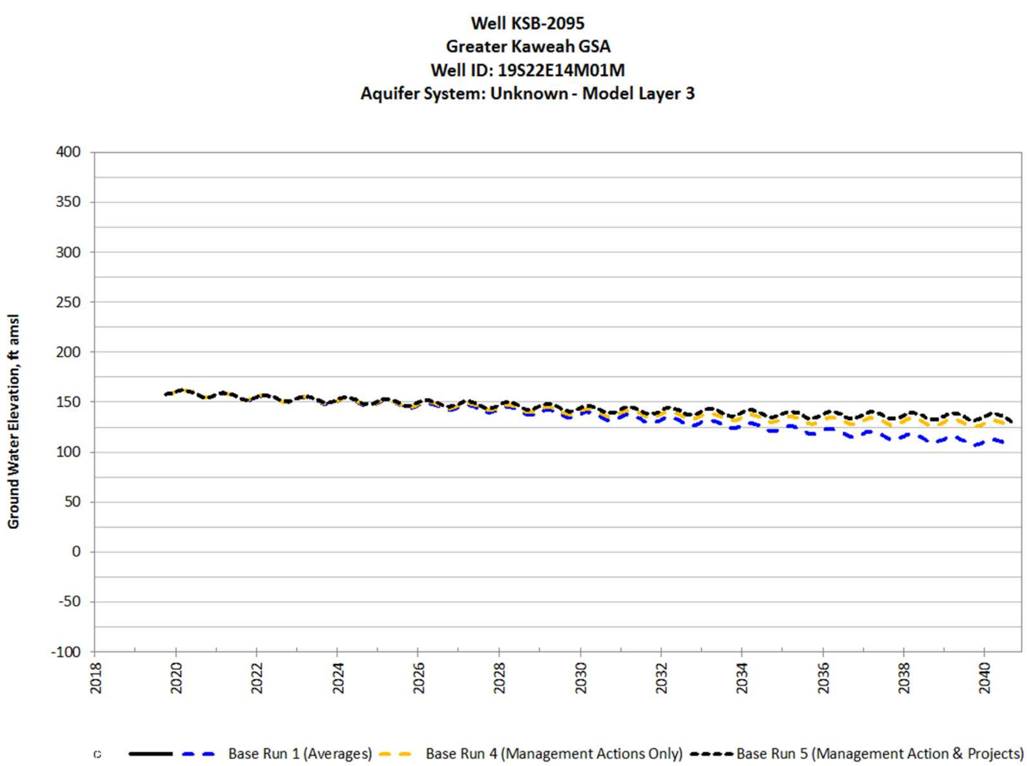

Well KSB-2016
Greater Kaweah GSA
Well ID: CID_082
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-2017
Greater Kaweah GSA
Well ID: 20S22E10J01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

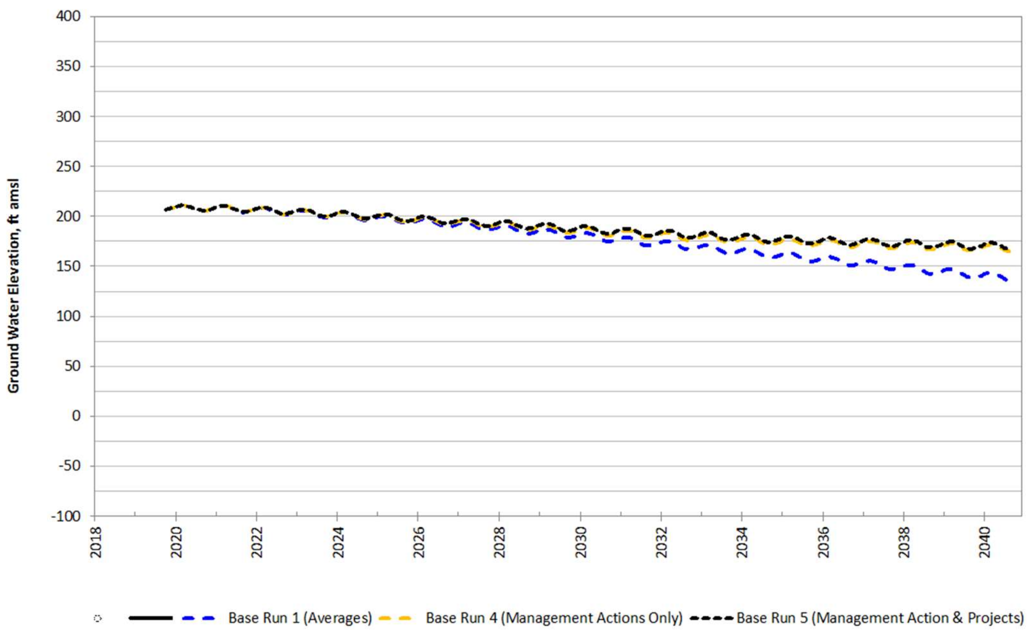

Well KSB-2021
Greater Kaweah GSA
Well ID: 19S22E10R02M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-2058
Greater Kaweah GSA
Well ID: 19S22E14N01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

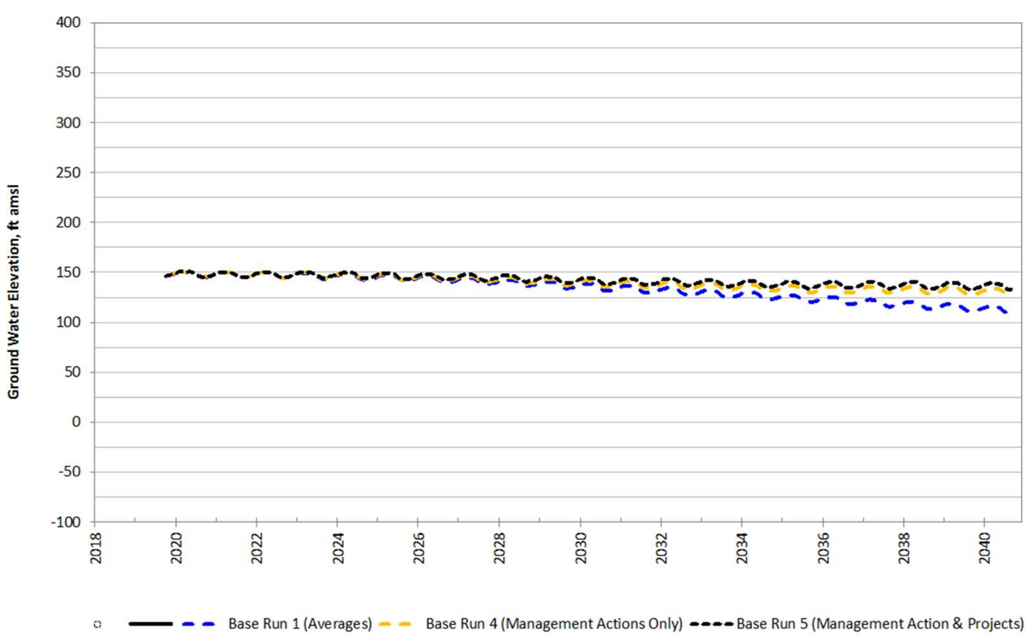

Well KSB-2089
Greater Kaweah GSA
Well ID: CID_042
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

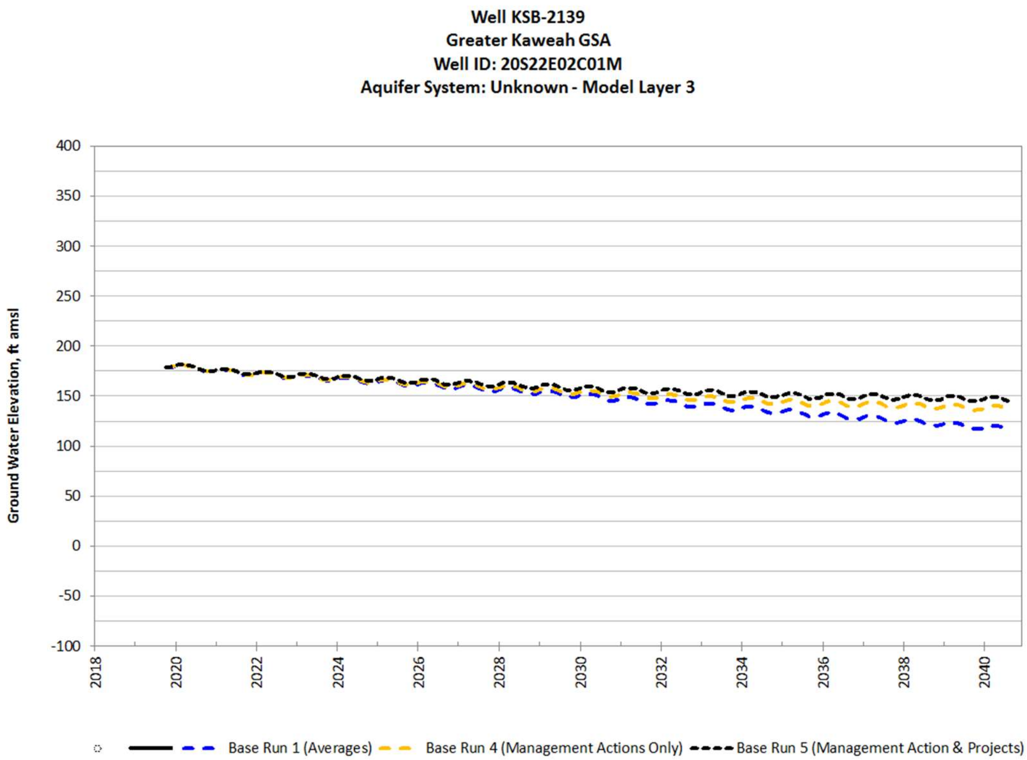

Well KSB-2095
Greater Kaweah GSA
Well ID: 19S22E14M01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

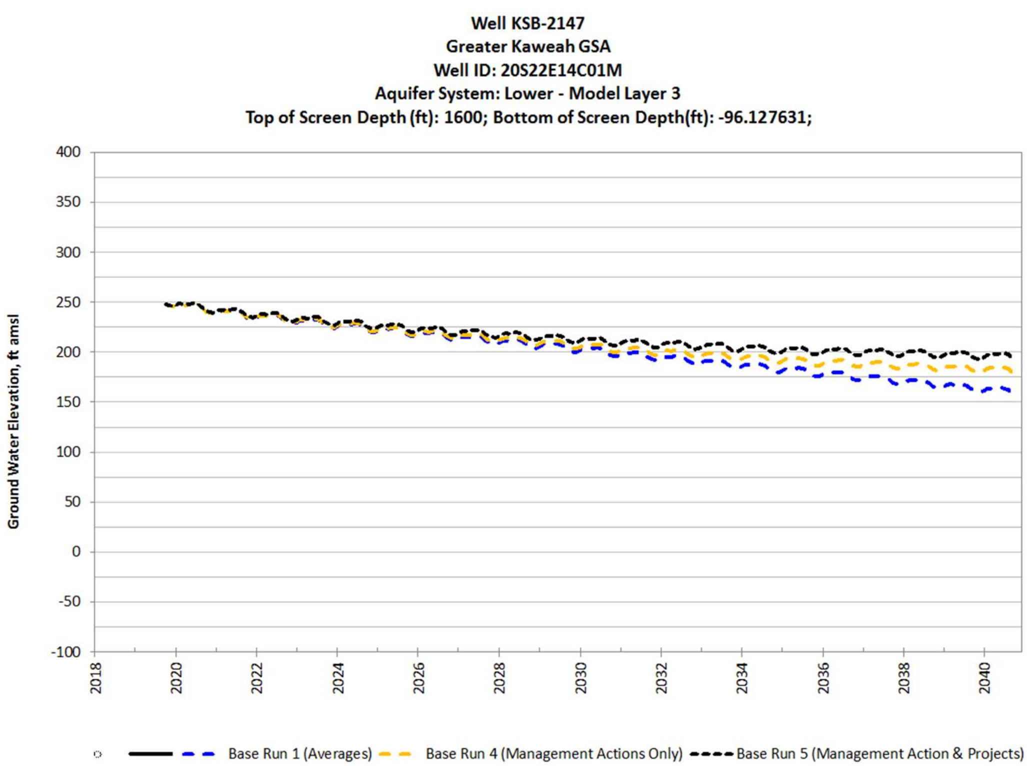
**Well KSB-2107**
**East Kaweah GSA**
**Well ID: 19S21E15R01M**
**Aquifer System: Unknown - Model Layer 1**



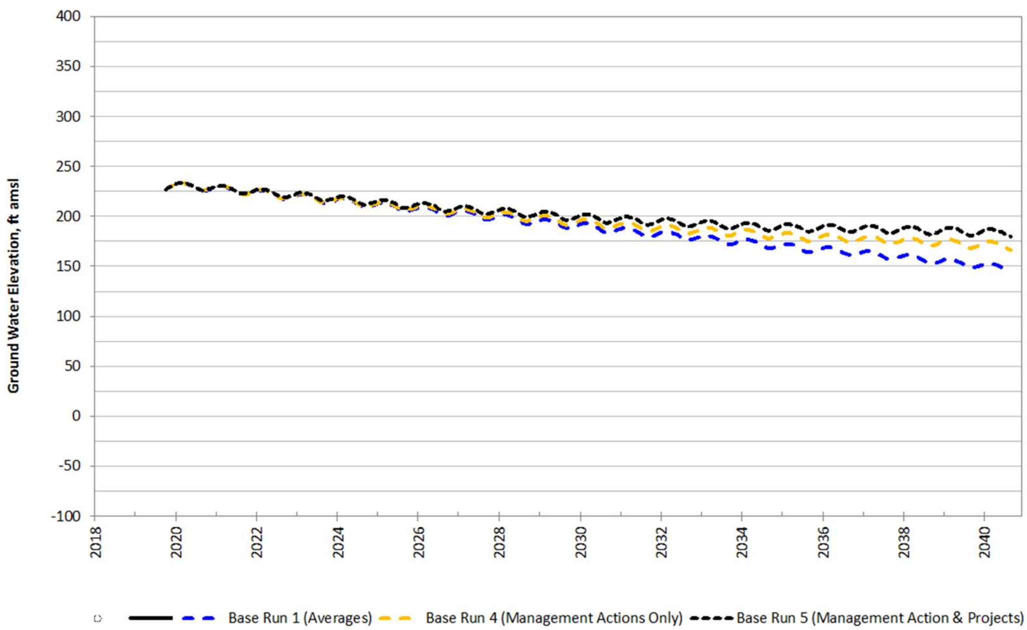

**Well KSB-2114**
**Greater Kaweah GSA**
**Well ID: CID_025**
**Aquifer System: Unknown - Model Layer 3**



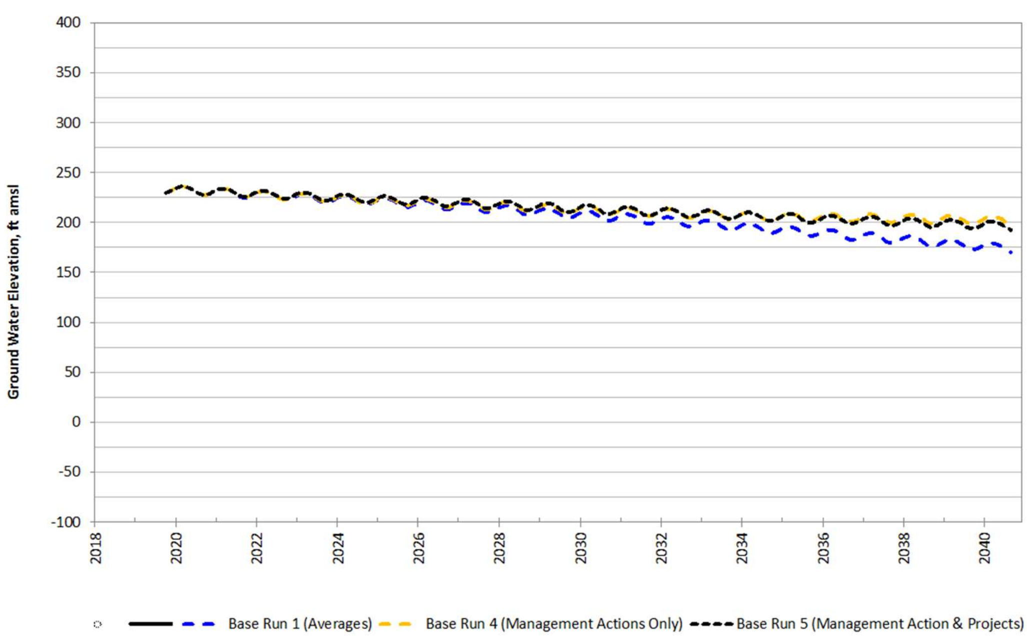

Well KSB-2139
Greater Kaweah GSA
Well ID: 20S22E02C01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

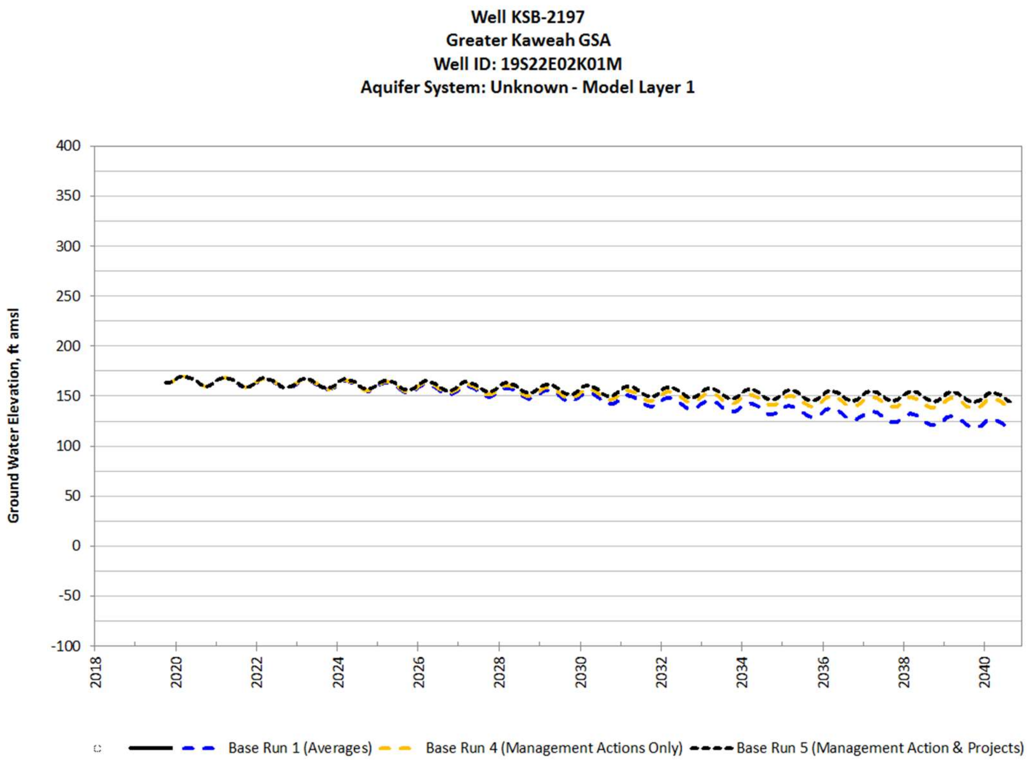

Well KSB-2147
Greater Kaweah GSA
Well ID: 20S22E14C01M
Aquifer System: Lower - Model Layer 3
Top of Screen Depth (ft): 1600; Bottom of Screen Depth(ft): -96.127631;
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

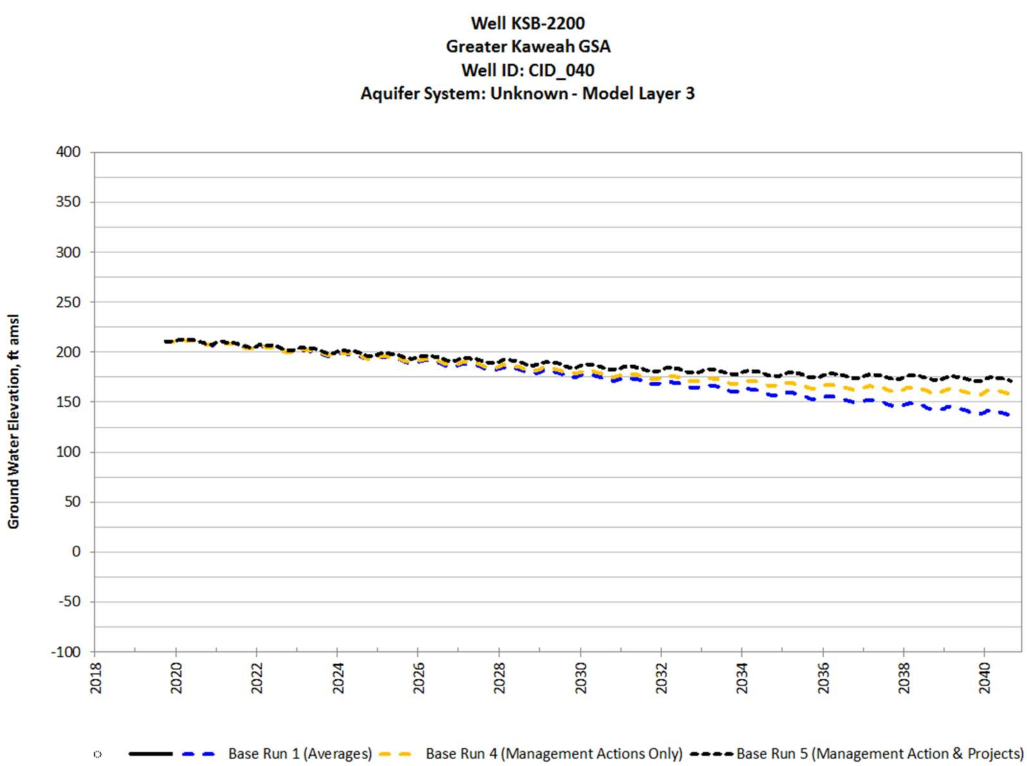
**Well KSB-2149**
**Greater Kaweah GSA**
**Well ID: CID_046**
**Aquifer System: Unknown - Model Layer 3**

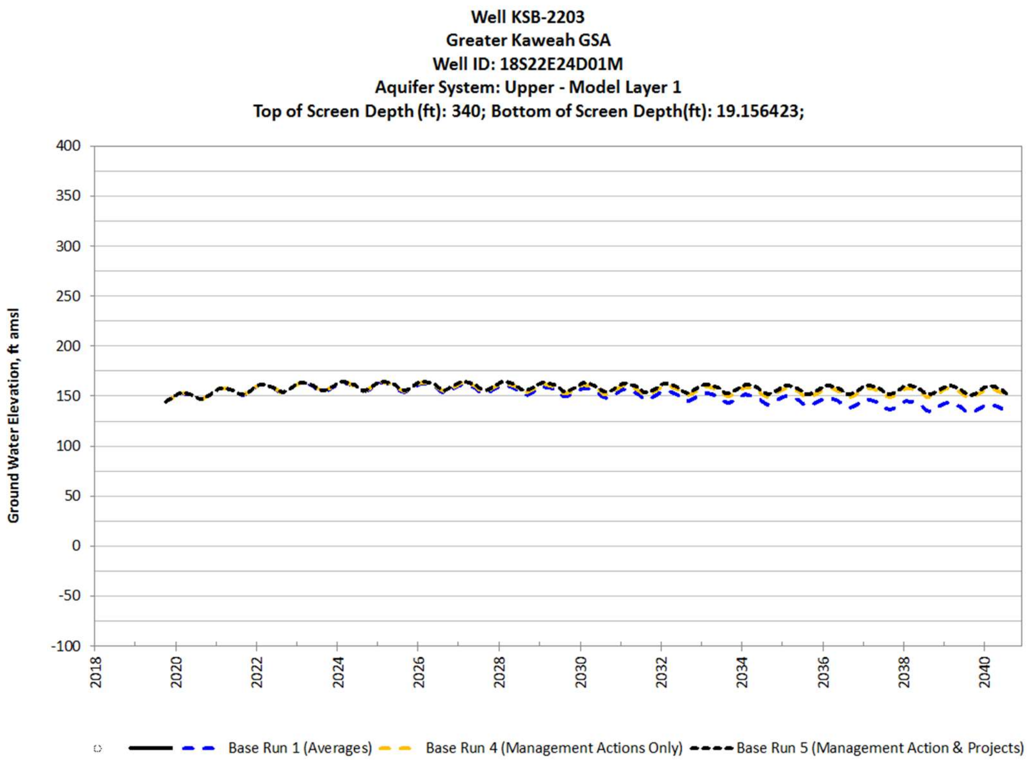


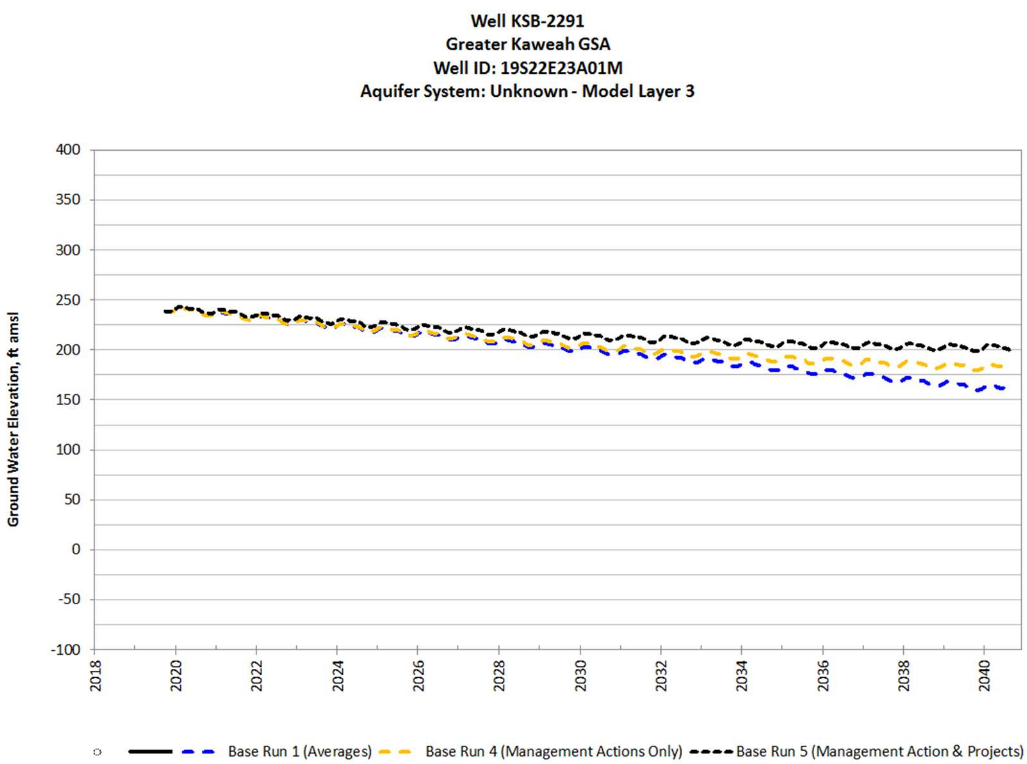

**Well KSB-2175**
**East Kaweah GSA**
**Well ID: 19S21E35D01M**
**Aquifer System: Unknown - Model Layer 1**

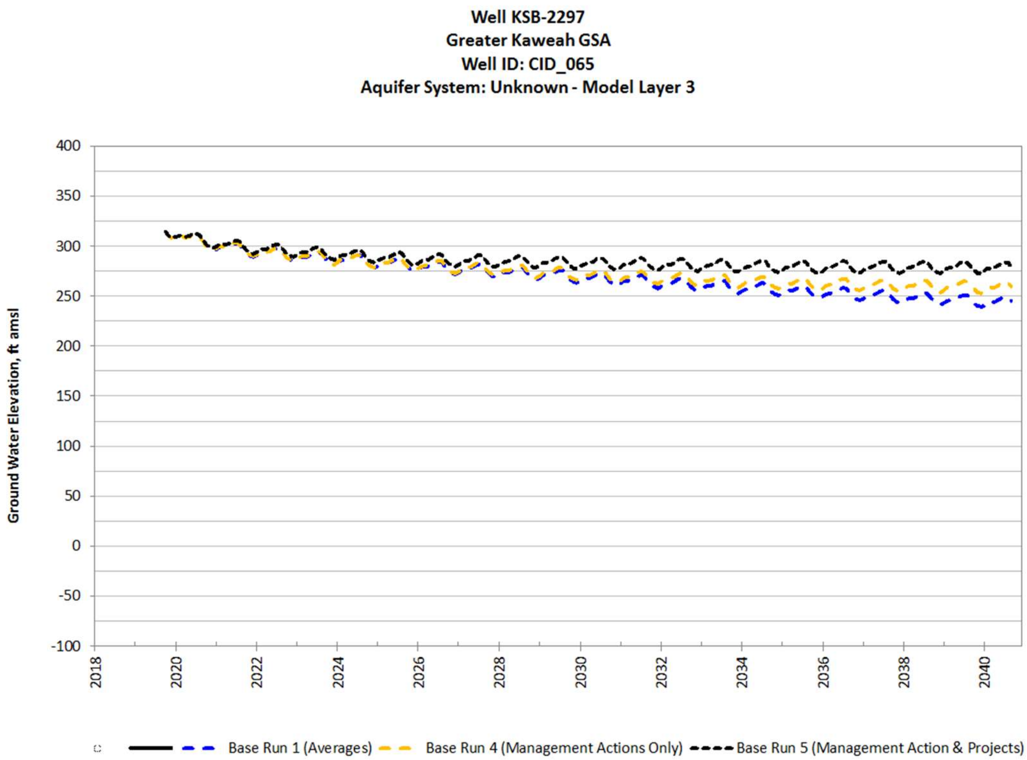


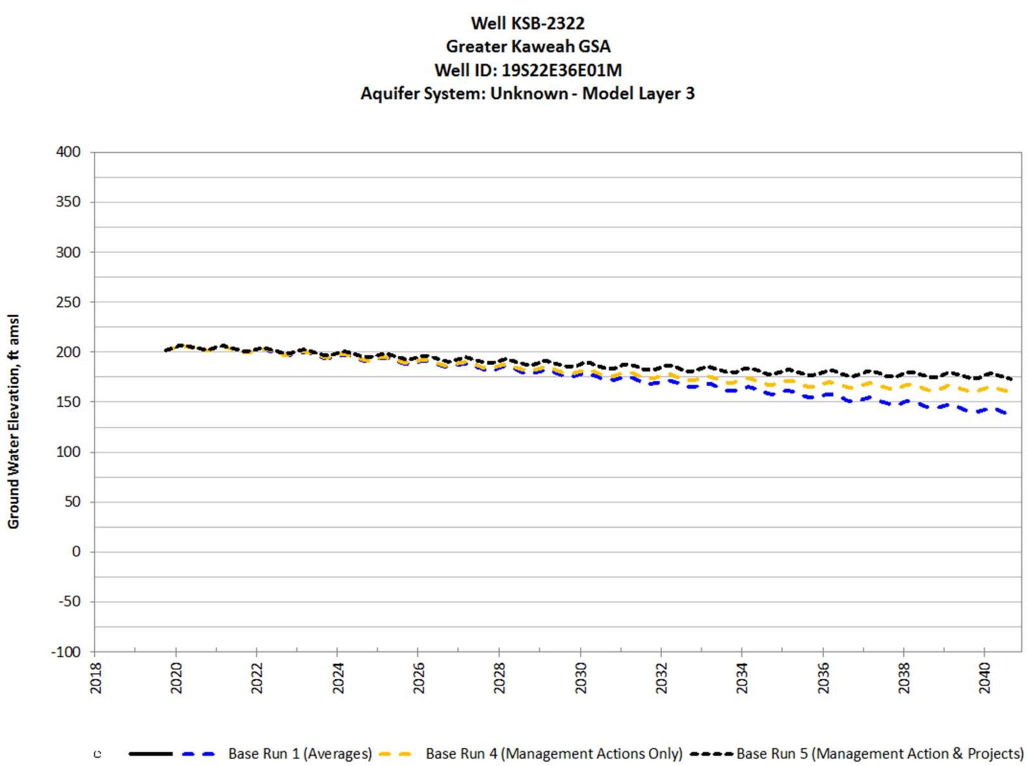

Well KSB-2197
Greater Kaweah GSA
Well ID: 19S22E02K01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

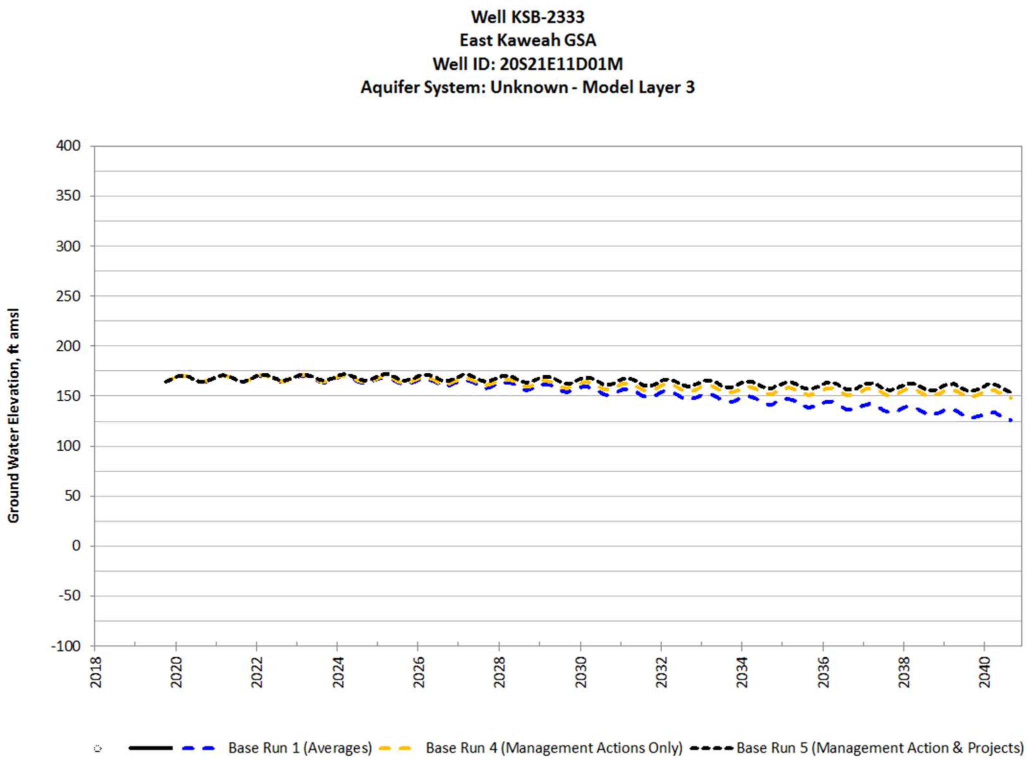

Well KSB-2200
Greater Kaweah GSA
Well ID: CID_040
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

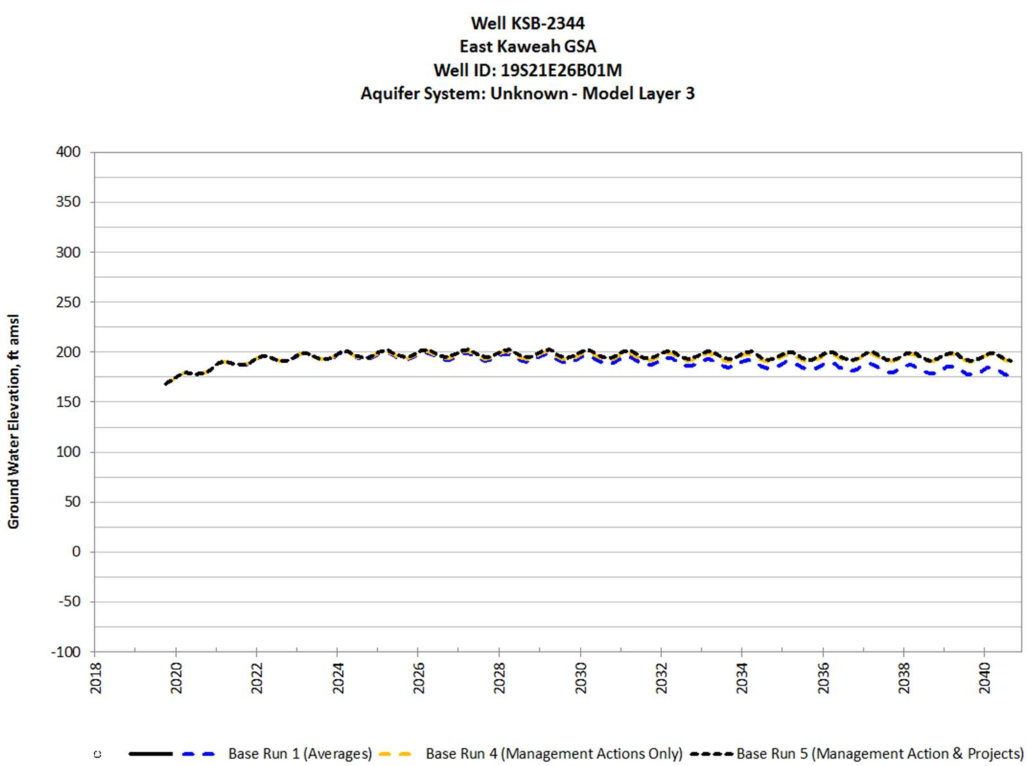

Well KSB-2203
Greater Kaweah GSA
Well ID: 18S22E24D01M
Aquifer System: Upper - Model Layer 1
Top of Screen Depth (ft): 340; Bottom of Screen Depth(ft): 19.156423;
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-2291
Greater Kaweah GSA
Well ID: 19S22E23A01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

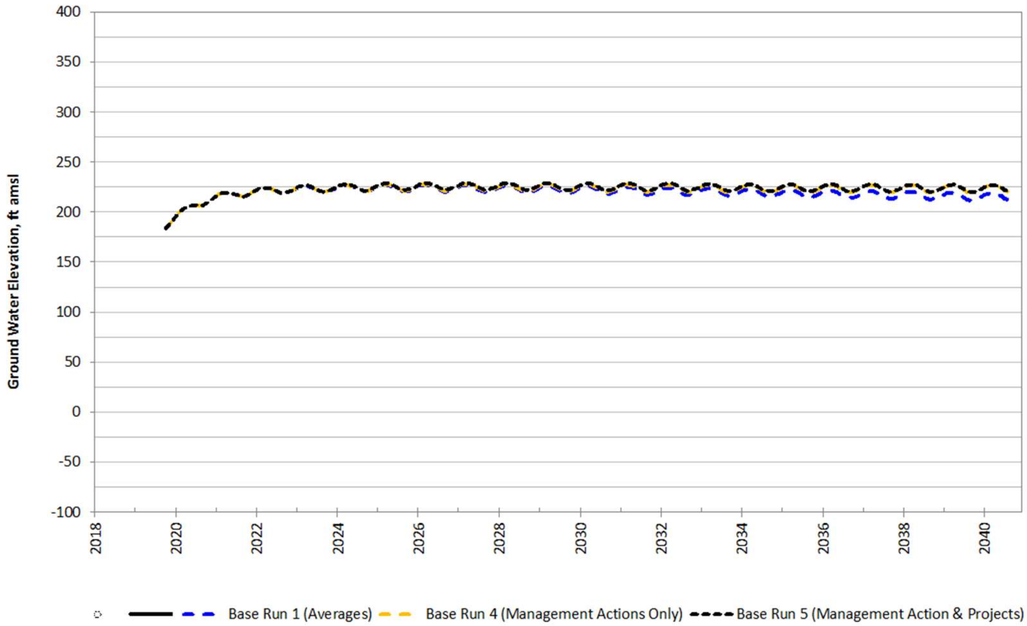

Well KSB-2297
Greater Kaweah GSA
Well ID: CID_065
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-2322
Greater Kaweah GSA
Well ID: 19S22E36E01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

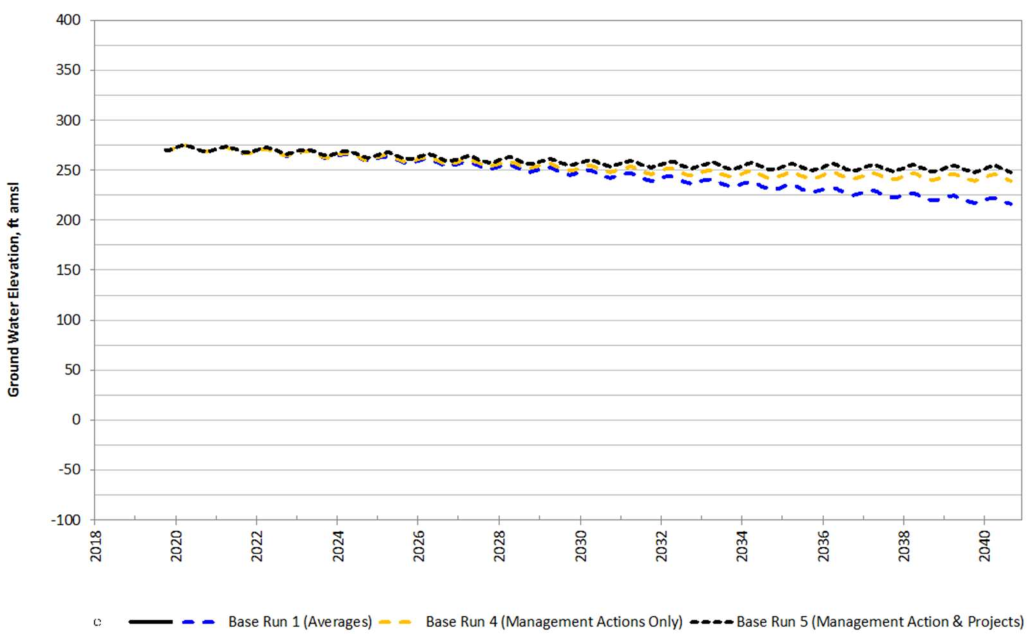

Well KSB-2333
East Kaweah GSA
Well ID: 20S21E11D01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-2344
East Kaweah GSA
Well ID: 19S21E26B01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

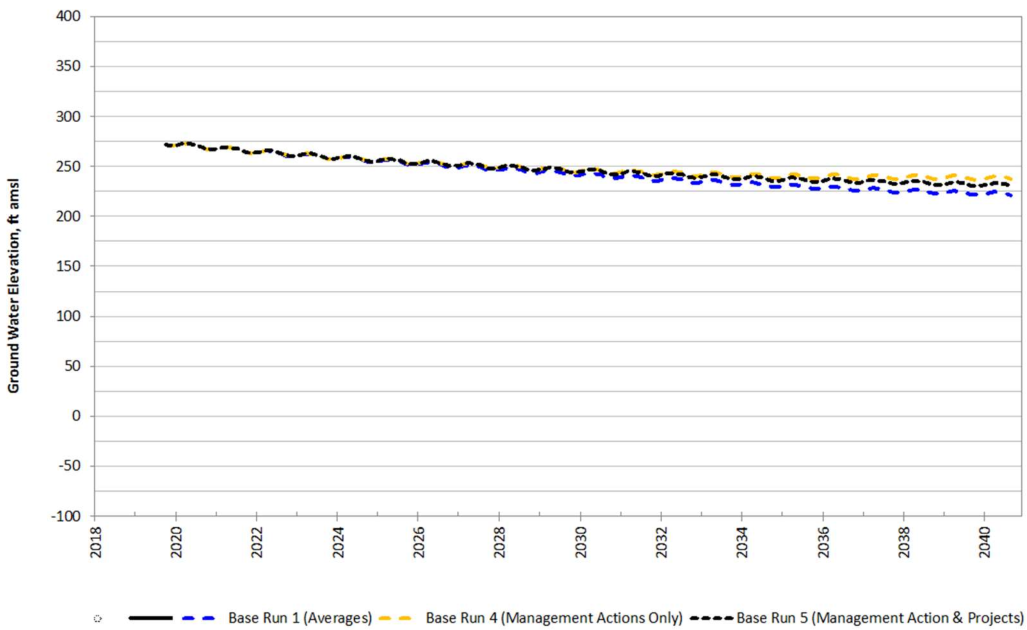
**Well KSB-2345**
**East Kaweah GSA**
**Well ID: 19S21E23J01M**
**Aquifer System: Unknown - Model Layer 3**



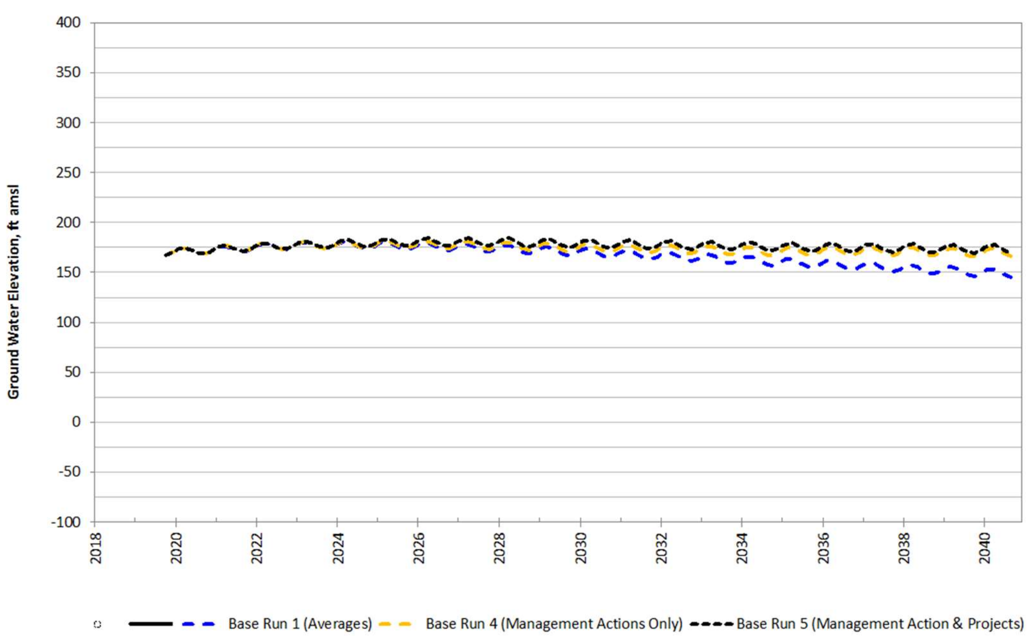

**Well KSB-2354**
**East Kaweah GSA**
**Well ID: 19S21E36M01M**
**Aquifer System: Unknown - Model Layer 1**

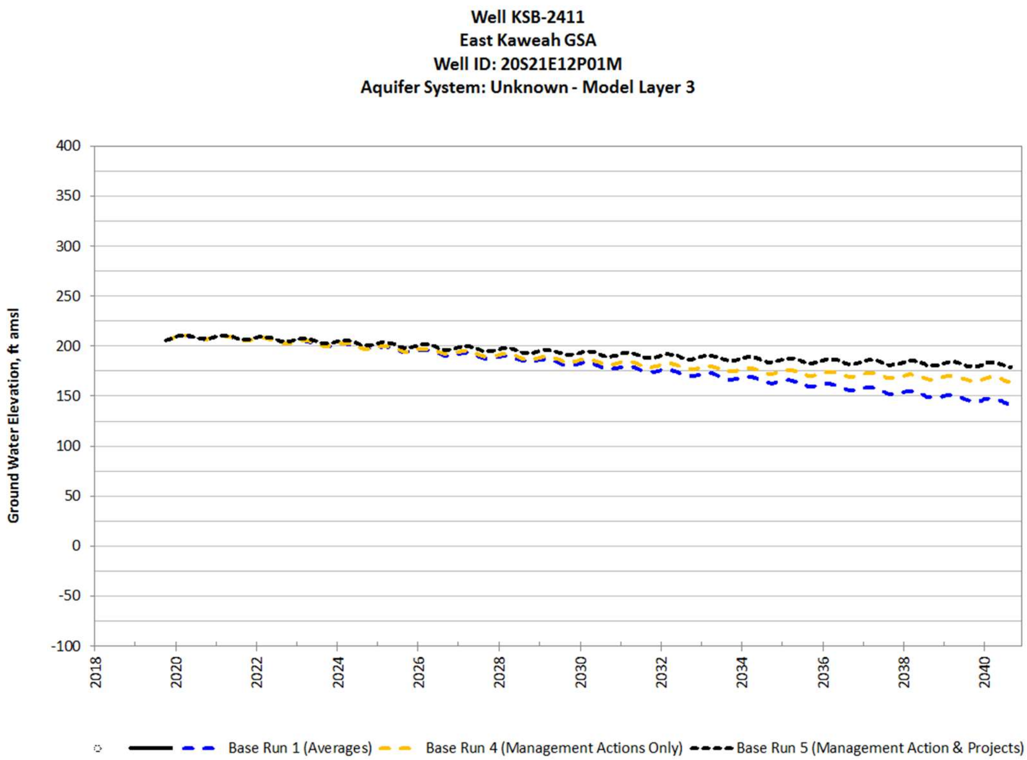


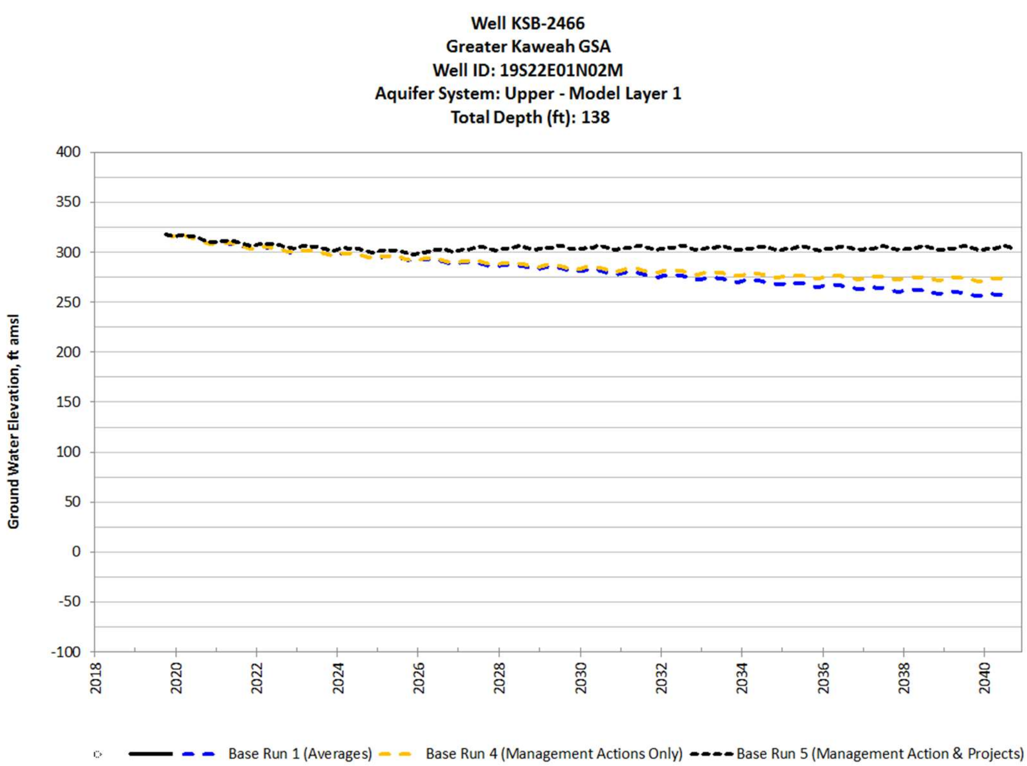
**Well KSB-2369**
**East Kaweah GSA**
**Well ID: 19S21E13C03M**
**Aquifer System: Unknown - Model Layer 3**

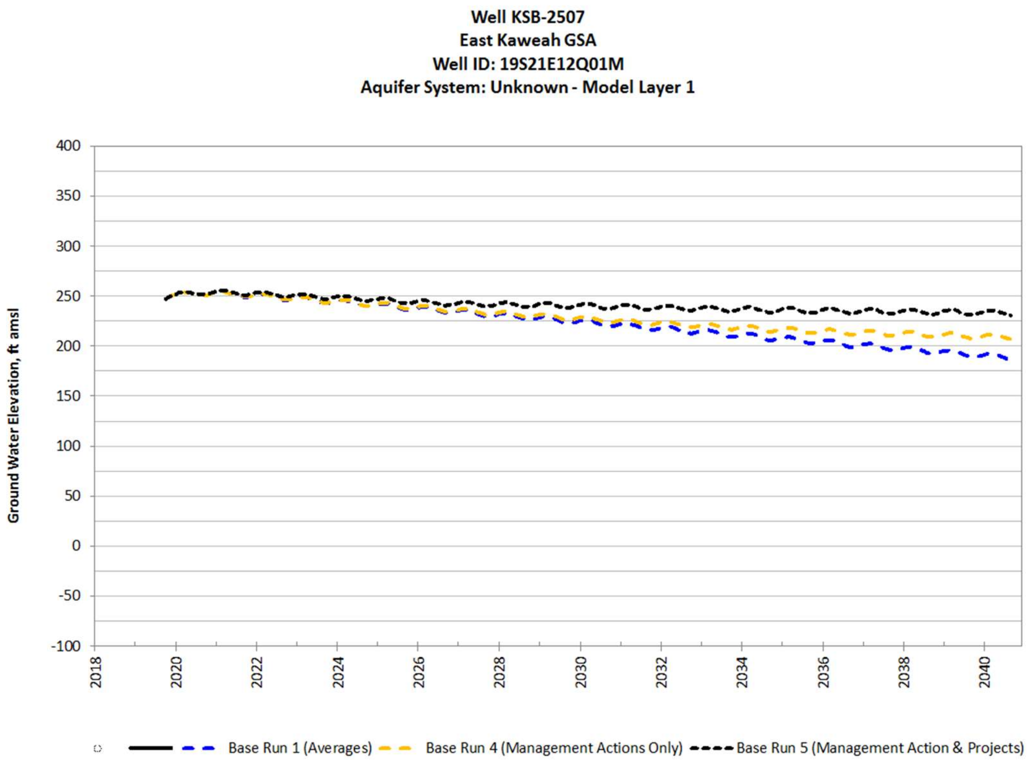


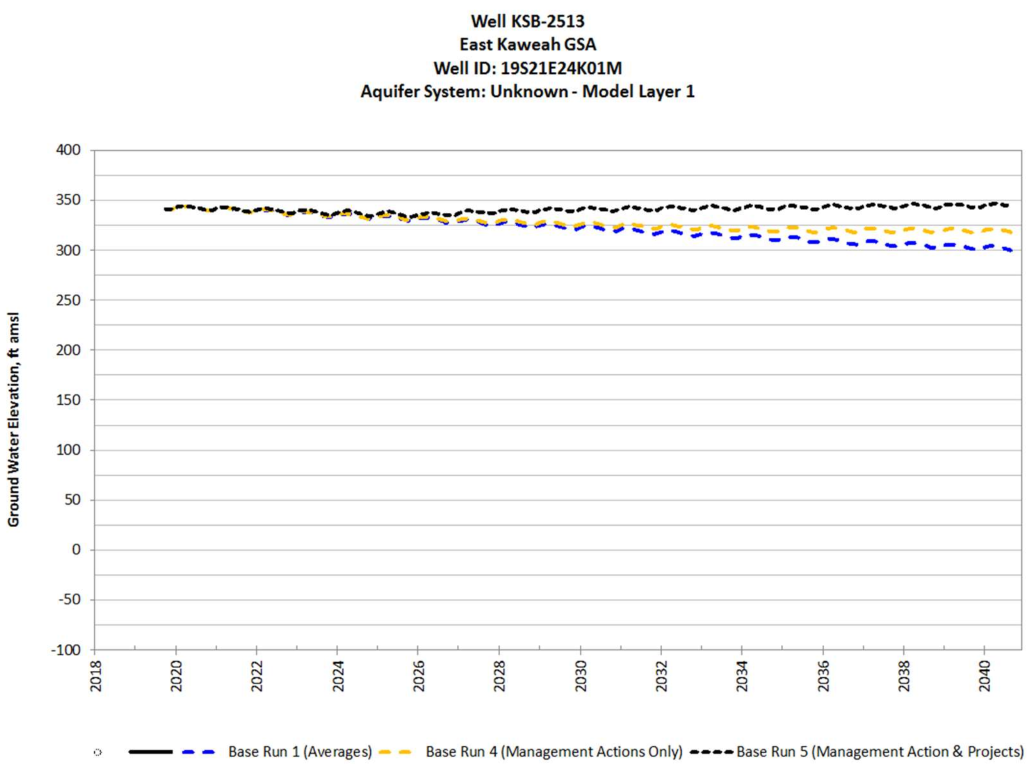

**Well KSB-2405**
**East Kaweah GSA**
**Well ID: 20S21E01L01M**
**Aquifer System: Unknown - Model Layer 3**

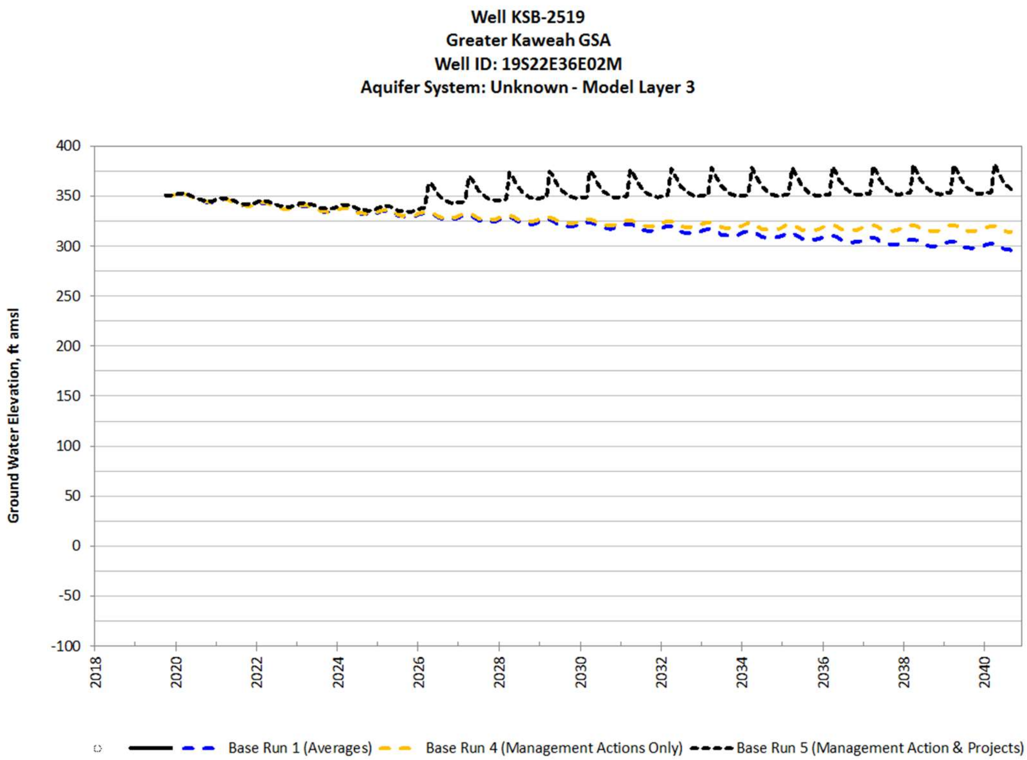


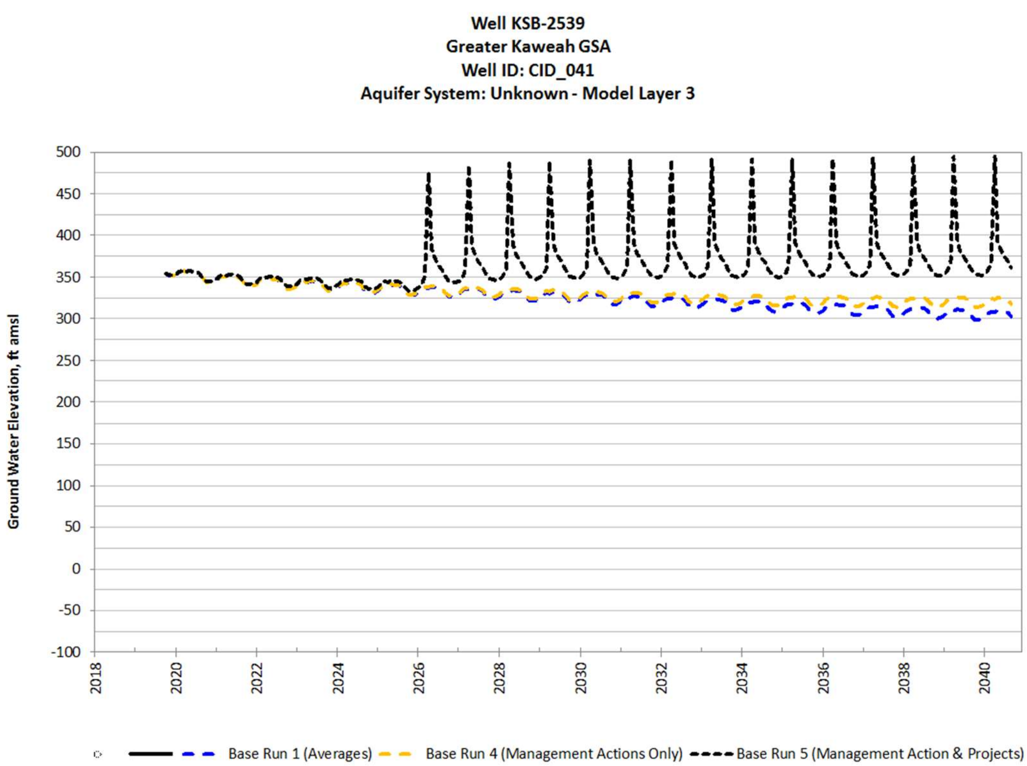

Well KSB-2411
East Kaweah GSA
Well ID: 20S21E12P01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

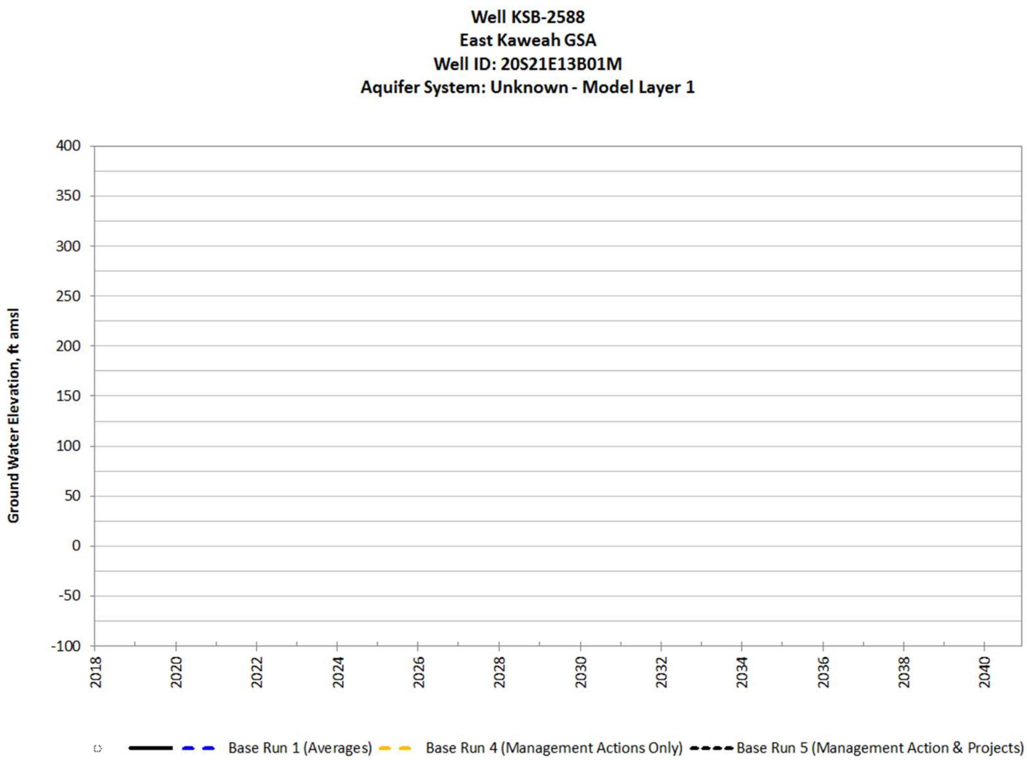

Well KSB-2466
Greater Kaweah GSA
Well ID: 19S22E01N02M
Aquifer System: Upper - Model Layer 1
Total Depth (ft): 138
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

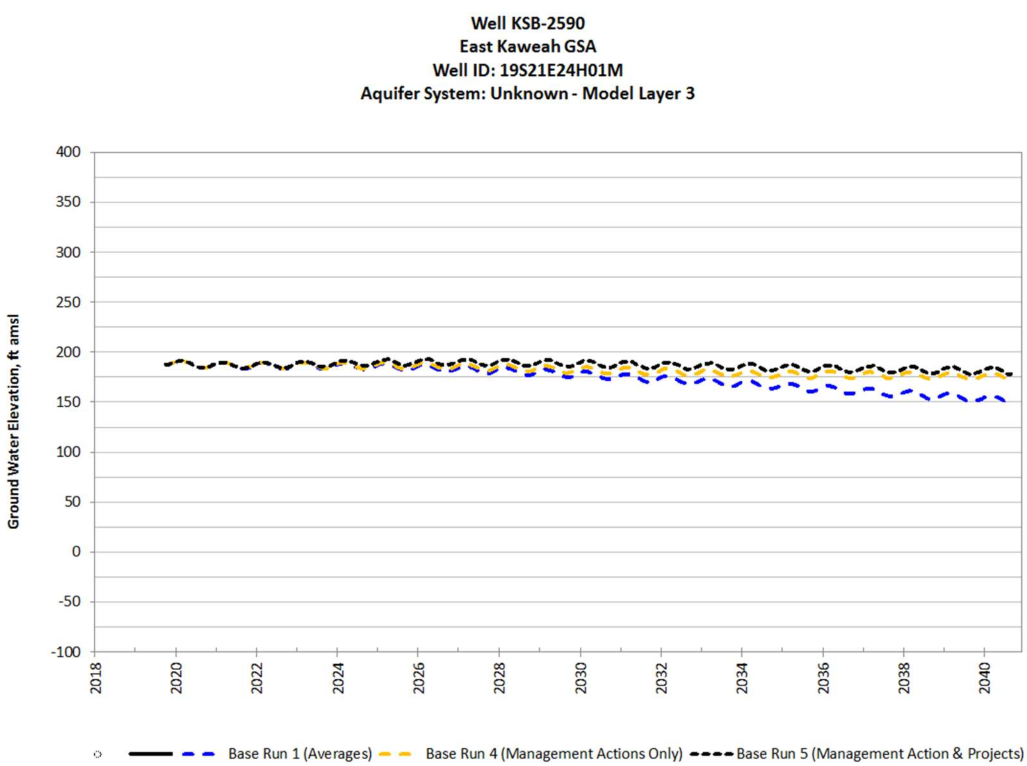

Well KSB-2507
East Kaweah GSA
Well ID: 19S21E12Q01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

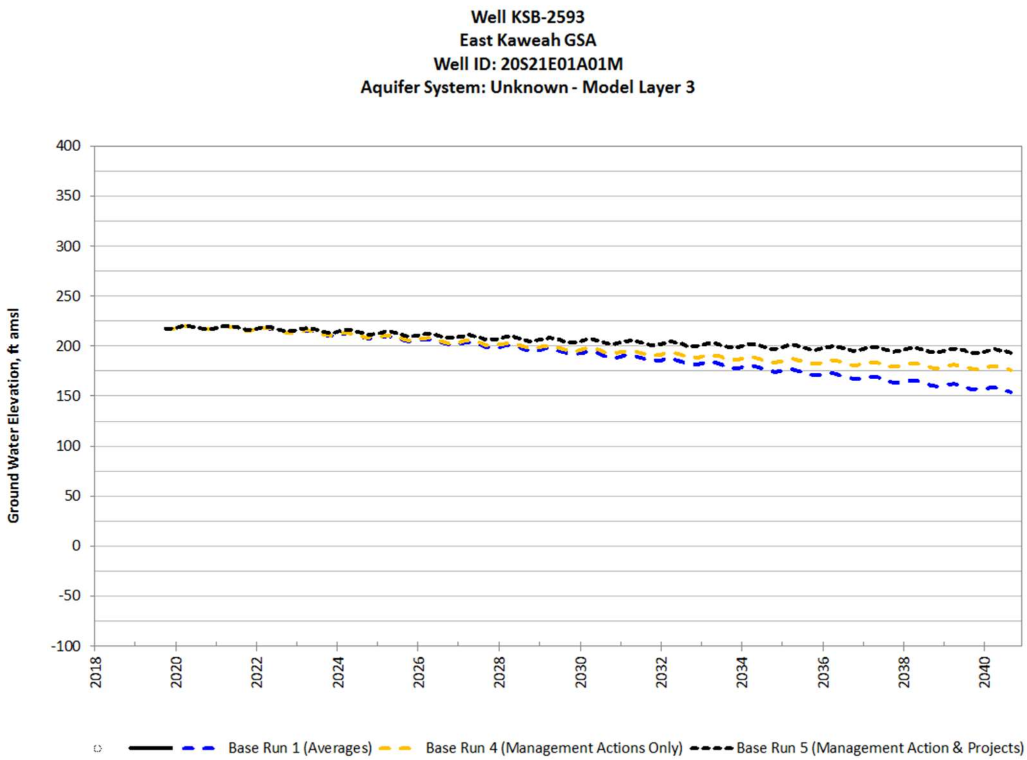

Well KSB-2513
East Kaweah GSA
Well ID: 19S21E24K01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

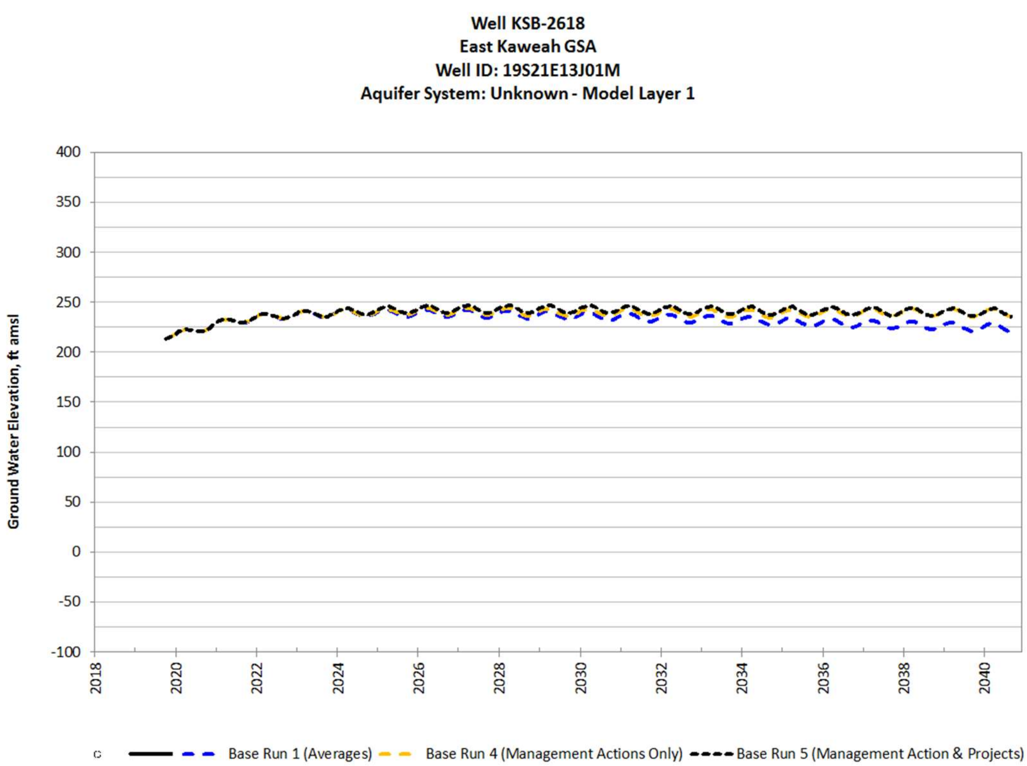

Well KSB-2519
Greater Kaweah GSA
Well ID: 19S22E36E02M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-2539
Greater Kaweah GSA
Well ID: CID_041
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
500
450
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

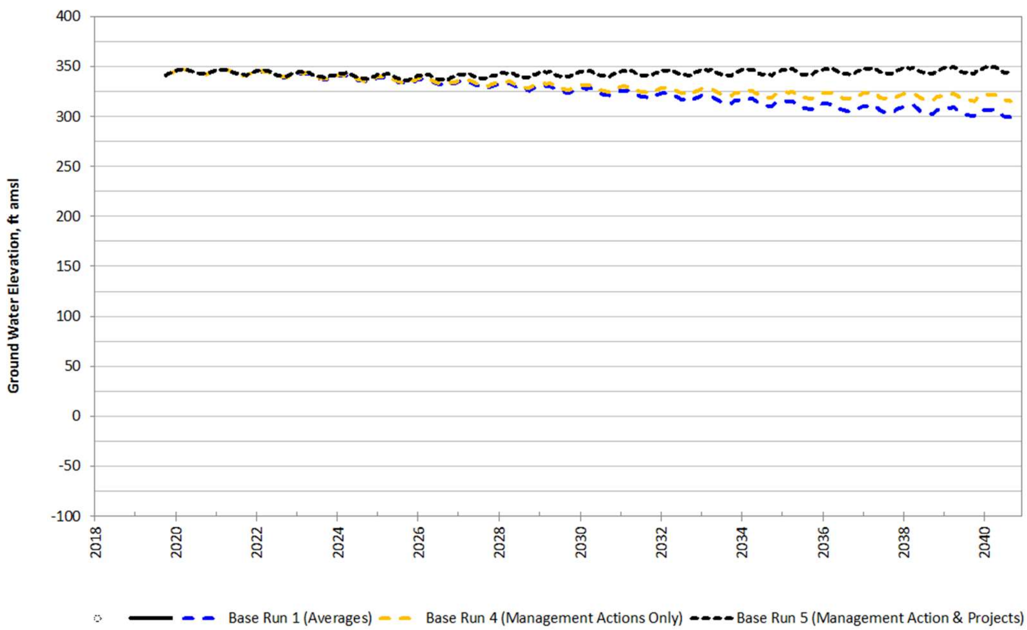

Well KSB-2588
East Kaweah GSA
Well ID: 20S21E13B01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-2590
East Kaweah GSA
Well ID: 19S21E24H01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

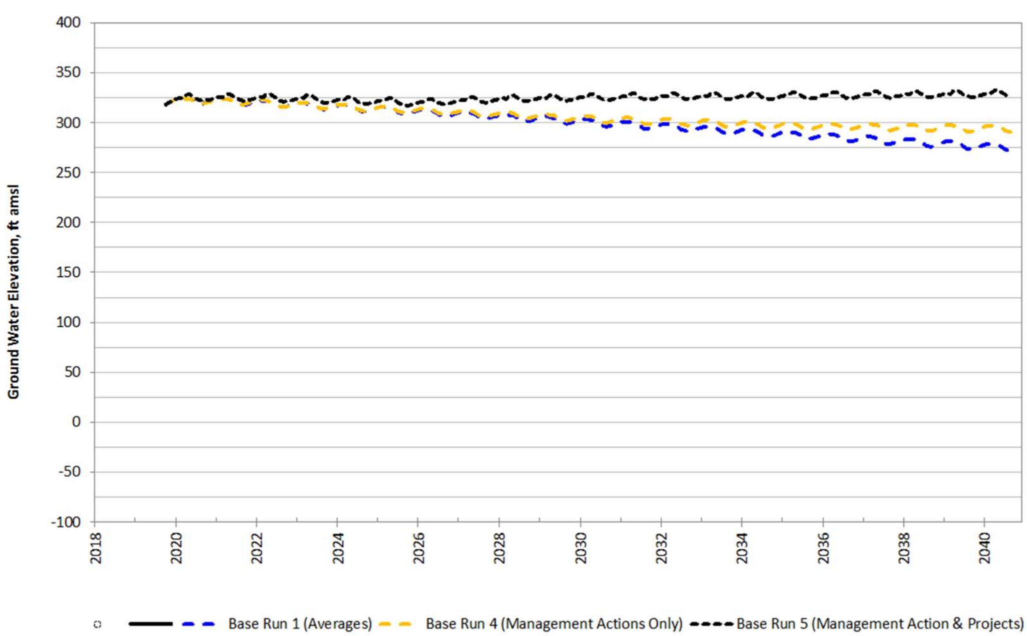

Well KSB-2593
East Kaweah GSA
Well ID: 20S21E01A01M
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-2618
East Kaweah GSA
Well ID: 19S21E13J01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

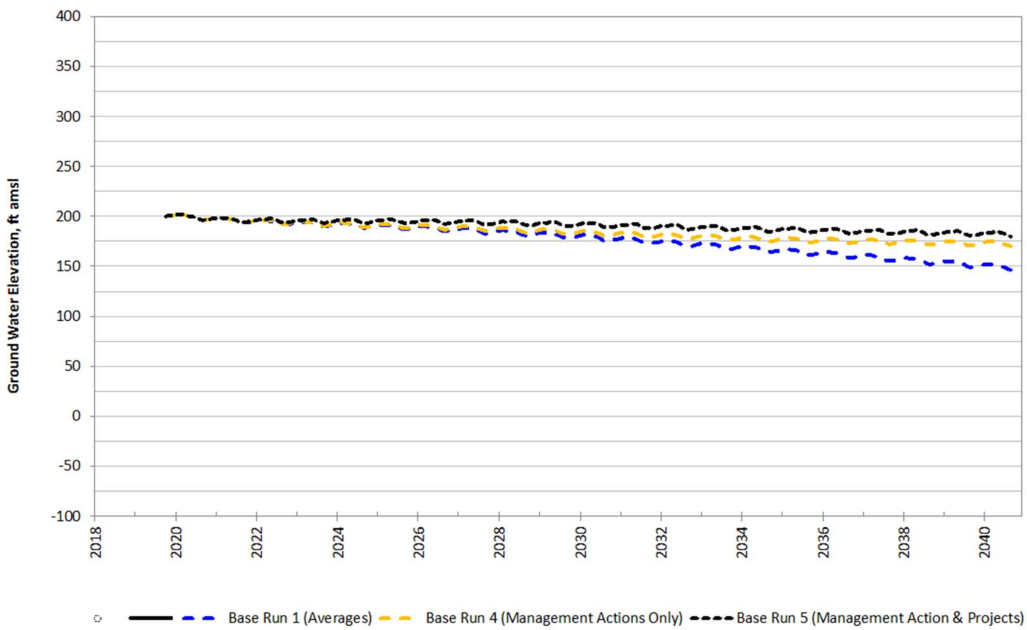
**Well KSB-2690**
**Greater Kaweah GSA**
**Well ID: CID_100**
**Aquifer System: Unknown - Model Layer 3**



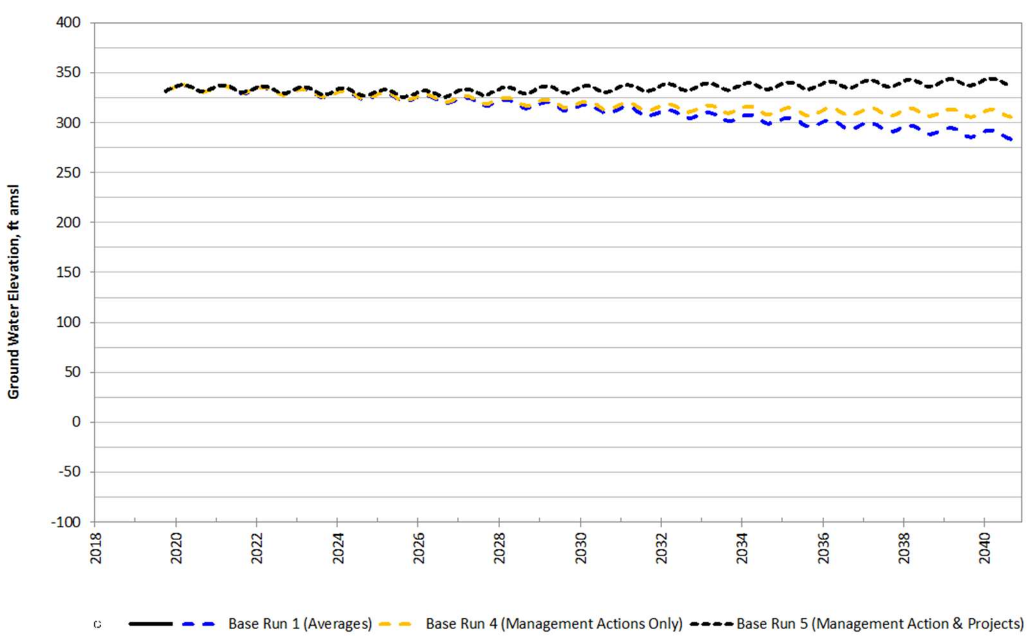

**Well KSB-2696**
**East Kaweah GSA**
**Well ID: 19S21E13A01M**
**Aquifer System: Unknown - Model Layer 3**



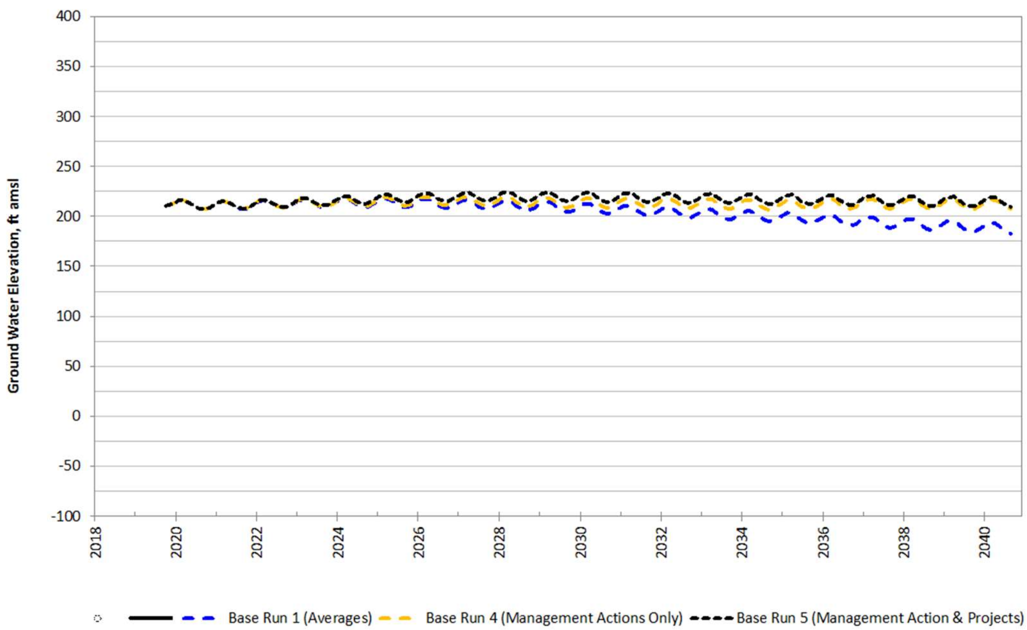
**Well KSB-2697**
**East Kaweah GSA**
**Well ID: 19S21E25J01M**
**Aquifer System: Unknown - Model Layer 3**



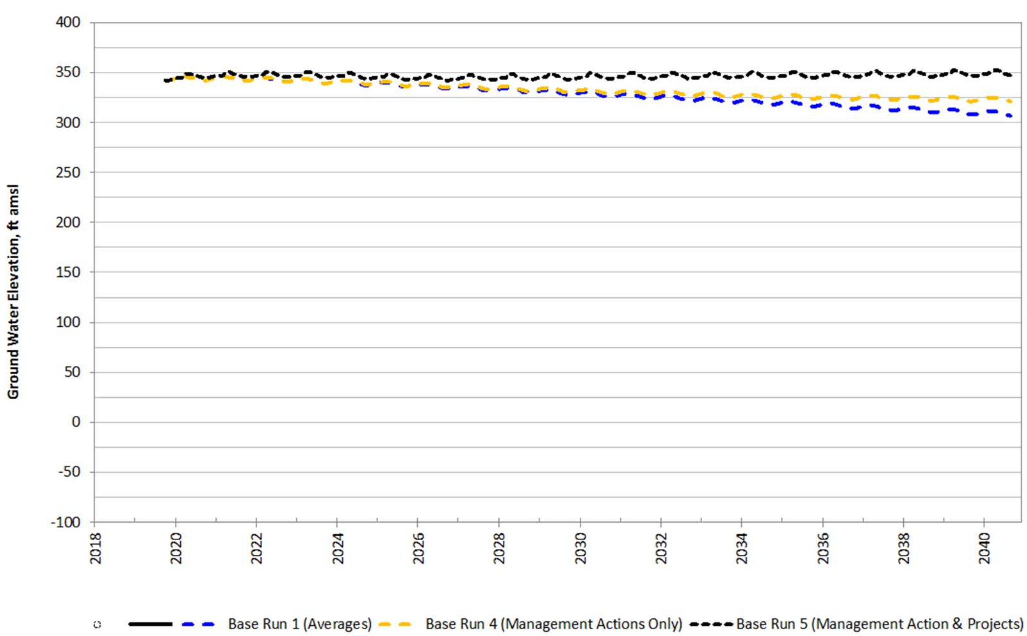

**Well KSB-2765**
**Greater Kaweah GSA**
**Well ID: CID_067**
**Aquifer System: Unknown - Model Layer 3**

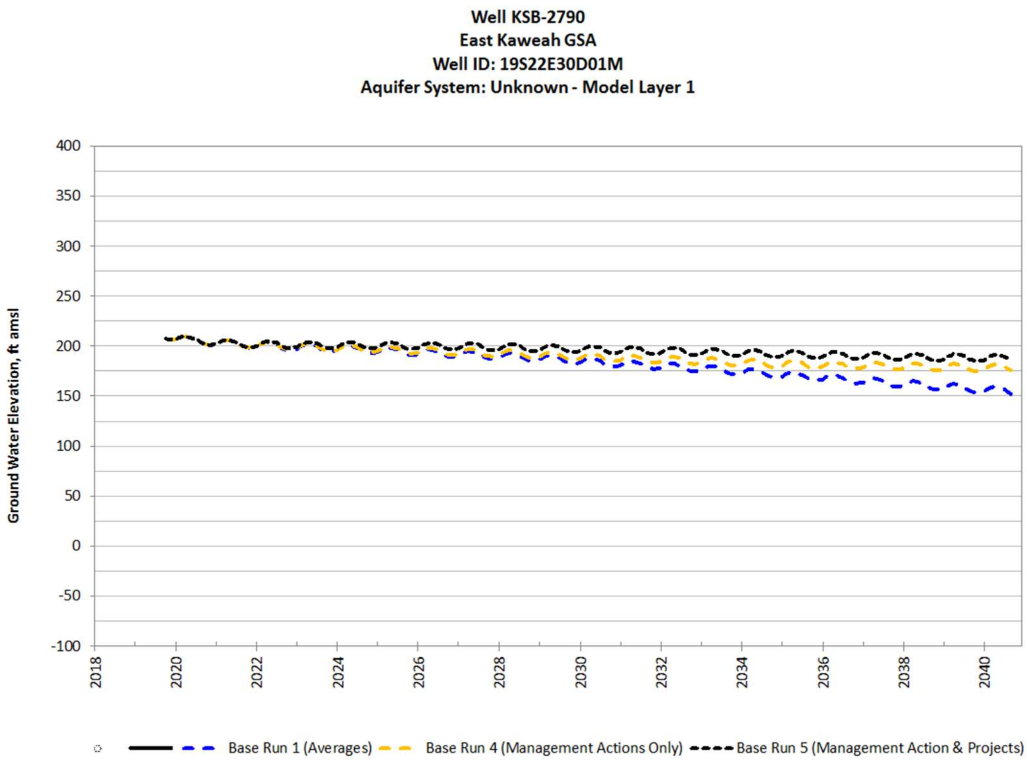


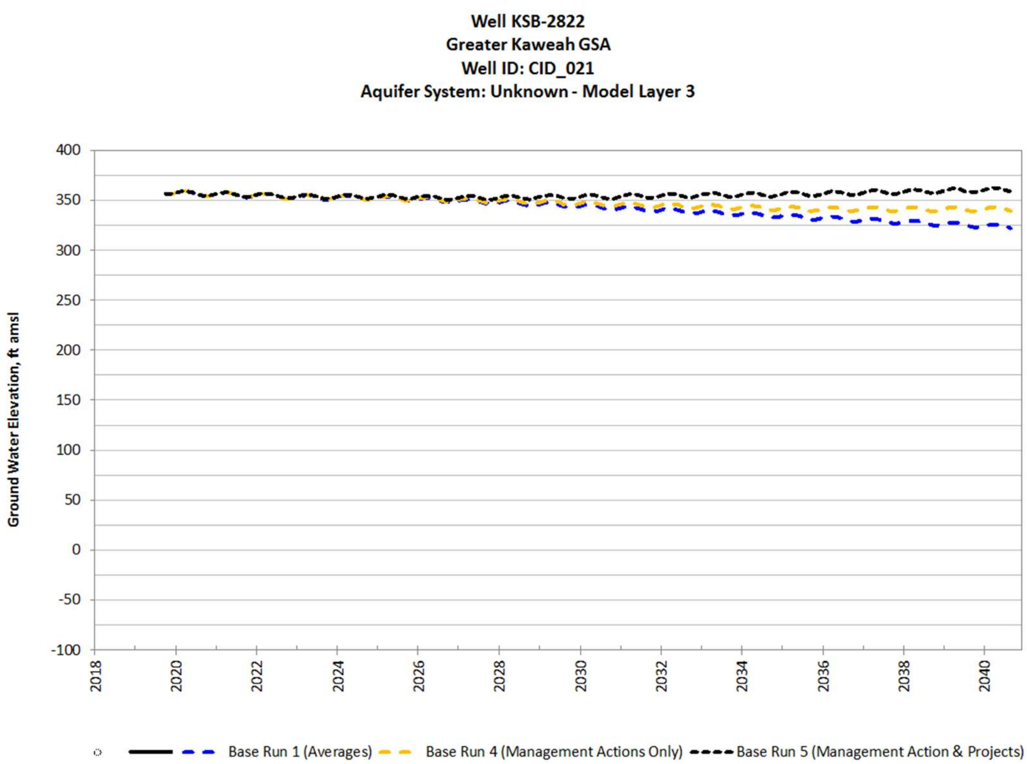
**Well KSB-2769**
**East Kaweah GSA**
**Well ID: 20S22E06N01M**
**Aquifer System: Unknown - Model Layer 3**



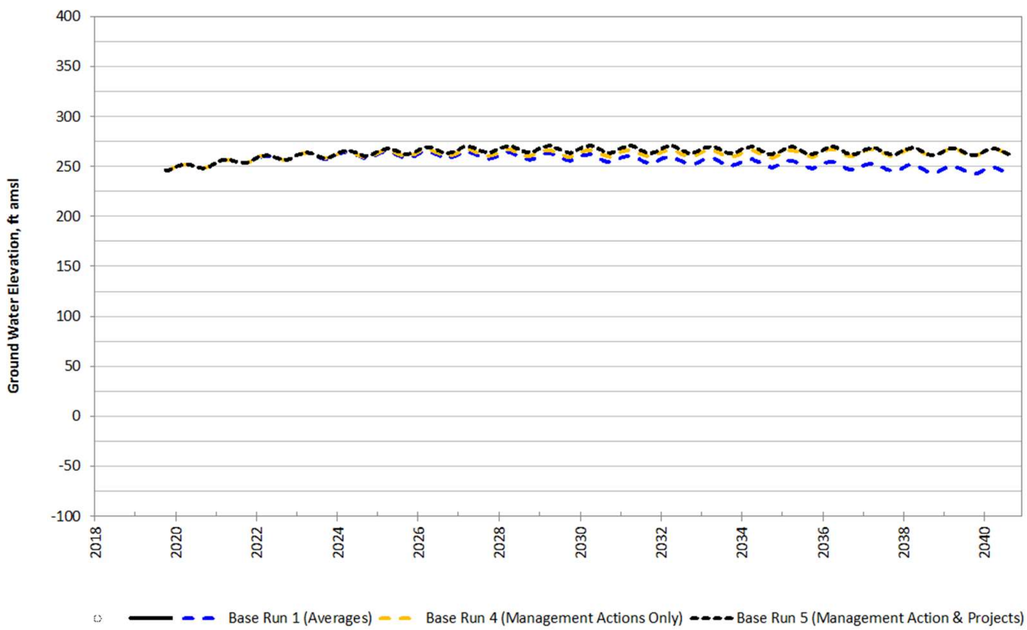

**Well KSB-2773**
**East Kaweah GSA**
**Well ID: 19S22E19M01M**
**Aquifer System: Unknown - Model Layer 3**



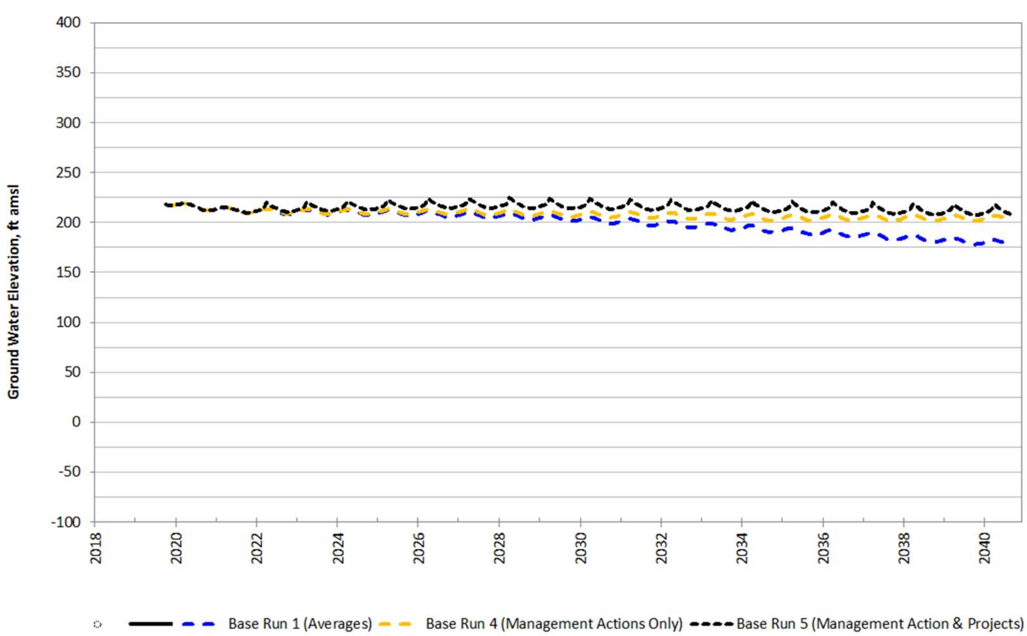

Well KSB-2790
East Kaweah GSA
Well ID: 19S22E30D01M
Aquifer System: Unknown - Model Layer 1
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)


Well KSB-2822
Greater Kaweah GSA
Well ID: CID_021
Aquifer System: Unknown - Model Layer 3
Ground Water Elevation, ft amsl
400
350
300
250
200
150
100
50
0
-50
-100
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Base Run 1 (Averages)
Base Run 4 (Management Actions Only)
Base Run 5 (Management Action & Projects)

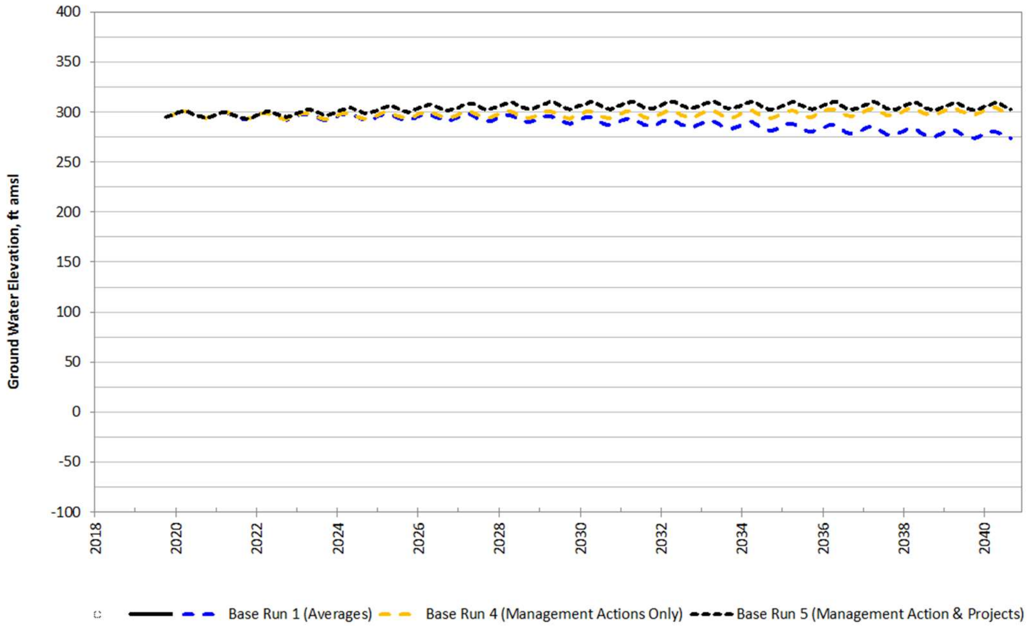
**Well KSB-2823**
**East Kaweah GSA**
**Well ID: 20S22E07M01M**
**Aquifer System: Unknown - Model Layer 1**




**Well KSB-2826**
**East Kaweah GSA**
**Well ID: 20S22E06C01M**
**Aquifer System: Unknown - Model Layer 3**



**Well KSB-2895**
**East Kaweah GSA**
**Well ID: 19S22E31B02M**
**Aquifer System: Upper - Model Layer 3**
**Top of Screen Depth (ft): 271; Bottom of Screen Depth(ft): -22.189495;**




**Well KSB-2927**
**East Kaweah GSA**
**Well ID: 19S22E31B03M**
**Aquifer System: Unknown - Model Layer 3**