

November 14, 2007

Mr. Lyn Garver
Kings River Conservation District
4886 East Jensen Avenue
Fresno, CA 93725

Subject: Kings Groundwater Basin Integrated Ground and Surface water Model
(KingsIGSM), Final Report

Dear Mr. Garver:

I am pleased to provide you with the final report on the "Kings Groundwater Basin Integrated Ground and Surface water Model (KingsIGSM)". This project was initiated to develop a comprehensive, defensible and robust analytical tool for (i) better representation of the physical conditions in the Kings groundwater basin, (ii) analysis of regional effects of various water management strategies and conjunctive use programs and projects on the surface and groundwater resources and environment in the basin.

The final report for the subject project documents the work performed to collect and analyze data, develop conceptual and numerical integrated hydrologic model, calibrate the model, and perform sensitivity analysis. Significant additional work were conducted prior to this document, including development of hydrogeologic characterization of the basin, development and analysis of water demand and water supply information, as well as water quality conditions in the basin. In addition, the model benefited from significant data and information available from various sources, including KRCD, the Kings River Water Agency (KRWA), the irrigation districts, the cities of Fresno and Clovis, and federal and state agencies, such as USGS and DWR. The model features specific details in the City of Fresno Sphere of Influence to provide the city with appropriate level of detail to support the planning and design goals of the Fresno Metroplan.

One of the important outcomes of the model development exercise, in my opinion, is the compilation and analysis of significant amount of data for the water years 1964-04, all in one location, including rainfall, streamflow, canal flows, surface water diversions, land use conditions and cropping patterns, municipal and agricultural groundwater pumping, municipal water use, agricultural water use estimates, stream accretions and depletions, artificial recharge, recycled water use, groundwater levels, lithologic logs, water quality data, and many other data. This data has been controlled and analyzed for quality, reviewed by experts in the area, including scientists, consultants, and stakeholders, and will be the basis for development of the Database Management System (DMS) that KRCD has initiated.

The model development process was conducted in close coordination with the Technical Analysis and Data (TAD) Workgroup of the Kings Basin Water Forum. The data, information,

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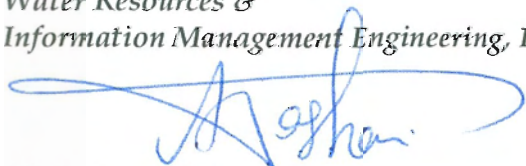
and analysis were presented in numerous meeting with TAD, and the draft model document was reviewed by the TAD as well as other Water Forum stakeholders. The comments were addressed and incorporated as appropriate to produce the final document.

Enclosed please find ten (10) copies of the final report, along with ten (10) copies of a CD containing a PDF version of the final report.

It was a great pleasure for the WRIME team to have worked with you and other KRCD staff, and stakeholders in the Kings Basin Water Forum on this project, and we look forward to providing consulting services to KRCD and the Water Forum stakeholders in the future. If you have any questions or need further information please do not hesitate to contact me.

Sincerely,

*Water Resources &
Information Management Engineering, Inc.*



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The Upper Kings Water Forum and Water Resources & Information Management Engineering (WRIME) would like to thank and acknowledge the following representatives from various stakeholder entities that have tirelessly attended the Water Forum's Technical Analysis and Data (TAD) Work Group meetings and supported the Kings IGSM model development efforts. These individuals were critical to the collection of data, review of draft and final work products, and the overall success of the model development. Special thanks are extended to:

- Gary Serrato, Fresno Irrigation District and TAD Work Group Chairman
- Brock Buche, City of Fresno
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- Ali Taghavi, WRIME, Inc.
- Rick Thaxton, Fresno County

1.1 PURPOSE

This purpose of this report is to presents the development and calibration of the Kings Integrated Groundwater and Surface water Model (Kings IGSM). The Kings IGSM model is developed to support the planning analysis required for the Upper Kings Basin Integrated Regional Water Management Plan (IRWMP) project.

As part of the cooperative efforts of local stakeholders, the Water Forum has evaluated structural and non- structural water management strategies that would help the Kings Region meet the IRWMP goals and objectives. The Water Forum recognized the need for a tool to quantitatively evaluate the nature and extent of the water resources problems and to compare potential future conditions and project effects.

The purpose, goals, and objectives for the Kings IGSM were defined by the Water Forum and documented in the (WRIME, 2006a). The purpose of the Kings IGSM are:

1. to provide an analytical tool for the Kings Basin area that can represent the groundwater and surface water flow systems and their interactions; and
2. to provide a regional planning level analytical tool that can provide quantitative information on a comparative basis to help answer different questions on the groundwater and surface water system characteristics and to evaluate alternative conjunctive water management strategies.

The Kings IGSM is a regional model that covers the entire Kings Basin and simulates the surface water and groundwater systems of Kings Basin, and is the first comprehensive model of the Kings Basin that incorporates the past four decades of detailed historic information of the Kings Basin. Hydrogeologic conditions, land use, crop pattern, major diversions of King River and major canals in the Kings Region are included in Kings IGSM. The Kings IGSM was calibrated using a representative 41-year period from 1964 to 2004. This period was selected because it contains an array of representative wet and dry periods and includes the operations of Pine Flat Reservoir under the final agreements as coordinated by the KRWA acting as the water master for allocating and managing Kings River surface water rights. It also follows importation of Friant-Kern water to Kings Basin.

The development of the Kings IGSM was coordinated by the TAD Work Group of the Water Forum. The Kings IGSM development process included a series of steps each of which was conducted and completed in cooperation with the TAD Work Group which provided technical review, guidance, and coordination to the Kings IGSM modeling team. TAD Work Group has

met ten times and participated in discussion, review, and decision-making regarding the technical assumptions and analysis, and data used in the Kings IGSM development. The specific meetings of TAD and Water Forum and Kings IGSM deliverables are shown in Figure 1-1.

The development of the model was supported by a series of technical studies that were reviewed by the TAD Work Group and included:

1. Modeling Objectives and Strategy (WRIME, 2006a);
2. Hydrogeologic Investigation (Brown and Caldwell, 2006);
3. Analysis of Water Demand Conditions (WRIME, 2006b);
4. Analysis of Water Supplies (WRIME, 2006c); and
5. State of Groundwater Quality in the Basin (WRIME, 2007a).

These technical studies were conducted to provide sufficient detail on the respective data to be used in the model. The following tasks were part of the Kings IGSM development:

1. Conceptual Model Formulation;
2. Model Development;
3. Model Calibration; and
4. Sensitivity Analysis.

1.2 PROJECT BACKGROUND

1.2.1 KINGS BASIN

Historically, the Kings Basin was primarily an agricultural area which relied on both surface water and groundwater for irrigation purposes, and groundwater for municipal water supply. The Kings River is the major source of surface water in Kings Basin. Pine Flat Reservoir regulates the flow of the Kings River and provides storage, flood control, and recreational benefits. The San Joaquin River defines the northern boundary of the Kings Basin and is a source of surface water supply and groundwater recharge in the Kings Basin. An extensive network of canals is used to deliver water to agricultural lands and to existing groundwater recharge facilities. Over the past twenty years there have been increases in population and municipal development; and in the use of treated surface water in lieu of groundwater by the cities of Fresno and Clovis.

Water use in Kings Basin exceeds the natural supply and the Basin is operated under overdraft conditions. Overdraft conditions have resulted in development of two groundwater depressions; one beneath the Fresno/Clovis metropolitan area, and the second larger and deeper depression in Lower Kings Basin in the area of the Raisin City Water District (RCWD). Over the past 40 years, water levels in Fresno area have dropped by an average of 40 feet. Some

of the wells in the Fresno area have been deepened and tap strata with lower hydraulic heads. Water levels drop in RCWD area has been more drastic and exceeds 150 feet.

The general movement of groundwater in the Kings Basin is from the northeast to the southwest direction. The primary drivers contributing to the changes in groundwater levels and overdraft are:

- groundwater pumping to meet agricultural water demand when surface water diversions are inadequate to fully meet the crop water requirements;
- development of new irrigated land;
- rural residential development relying solely on groundwater;
- high reliance on groundwater for all demands in much of the western parts of Kings Basin; and
- urban development and reliance on groundwater once lands are converted to urban use from agricultural uses, except recently in Fresno and Clovis.

Historical conditions in the Kings Basin and the expected future growth and changes in land use indicate that without corrective measures water levels will continue to drop, the existing depression areas will expand, and new depression areas will develop.

1.2.2 REGIONAL COOPERATION FOR WATER RESOURCES MANAGEMENT

The continued groundwater overdraft, competition for the available supplies, and the potential for conflicts in the region call for improved water resources management in the Kings Basin. As a result, the local agencies have initiated a process of regional cooperation in 2001 to address the overdraft problem and develop practical solutions. Kings River Conservation District (KRCD), Alta Irrigation District (AID), Consolidated Irrigation District (CID), and Fresno Irrigation District (FID) formed a Basin Advisory Panel (BAP); sought technical, facilitation, and financial support from the California Department of Water Resources (DWR); and signed a Memorandum of Understanding (MOU) that defined how they would work together to manage existing supplies and develop new supplies for the Kings Region. This water management group is formed pursuant to the IRWMP standards and guidelines (DWR, 2004).

The BAP members solicited wider stakeholder participation and the Water Forum was formed in 2004 to coordinate water resources planning in the Upper Kings Basin Region (Kings Region). The Water Forum embarked on developing an IRWMP for the Kings Region to improve water management, reduce conflicts, protect water quality, and ensure sustainable resources management through regional cooperation. The objective of the IRWMP is to identify and define different water management scenarios for the Kings Basin and evaluate alternatives to determine the most economical and best use of the water resources of the region as a whole.

The Upper Kings Basin IRWMP is the outcome of a two-year collaborative planning and facilitated process that included completion of a wide range of technical studies, preparation of briefings and technical memorandums, development of the Kings IGSM, extensive stakeholder involvement and community affairs process, and numerous meetings among various work groups and Water Forum participants. The IRWMP planning horizon extends 25 years into the future, until 2030.

1.2.3 ANTICIPATED USES AND APPLICATION OF THE KINGS IGSM

The Kings IGSM is expected to be used extensively for water resources planning and management in the Kings Basin. KRCD will continue to coordinate the use and application of the model and the TAD Work Group.

During the development of the Kings IRWMP, the model was used to conduct a Baseline Analysis. The Baseline Analysis evaluated the future without project conditions and is documented in the Upper Kings Basin IRWMP final report (WRIME, 2007b). A 2005 Existing Conditions scenario was performed to quantify the overdraft conditions assuming there are no changes to land use or no new water supply facilities constructed. The 2030 Baseline Conditions scenario was performed to evaluate the effects of land use at build out in the spheres of influence of the cities in the Kings Region. Both provide a basis for comparison of the benefits and impacts of any proposed water supply projects or other management actions. The Baseline analysis shows the cumulative effects of all of the land use changes that may occur or are currently planned within the spheres of influence of the cities. These analysis results can be incorporated by reference or used to meet any required California Environmental Quality Act (CEQA) or National Environmental Policy Act (NEPA) evaluations of cumulative impacts of proposed projects.

It is anticipated that the Kings IGSM will be used to further support the Water Forum in sizing capital projects and evaluating the IRWMP alternatives once these are firmly defined. The analysis of project alternatives will support any program or project level environmental evaluations that are needed to comply with the CEQA or NEPA should there be any federal involvement in proposed projects (funding, permitting, federal lands).

Stakeholders in the Kings Basin may also benefit by model analysis conducted as part of the IRWMP development or by using the Kings IGSM when it is necessary to quantify benefits or impacts of proposed actions. Contemporary examples of the model application within the Kings Basin include:

- The City of Fresno use of the model to support the development of the Metro Plan, a capital facilities plan for the city. The Kings IGSM will be used to size

projects, compare alternatives benefits and impacts, and support the preparation of any required program or project level environmental documents.

- Analysis of the groundwater impacts of the power plant being proposed by KRCD to support the permit application to the California Energy Commission.

The Kings IGSM may also be applied to circumstances which require quantification of project or program benefit and effects and comparison of alternatives. This could include:

- Preparing required engineering analysis for purposes of conducting a Proposition 218 electoral initiative;
- Integrating the model results with econometric models to evaluate and distribute project costs;
- Document project impacts and evaluating the nexus between a proposed project, mitigation costs, and impact fees and assessments;
- City or County General Plan updates and alternatives evaluation;
- City or special district capital facilities plans;
- Conjunctive use assessment;
- Historical benefits analysis;
- Project definition and design;
- EIR/EIS Support; and
- Water Quality Assessment.

The Kings IGSM does not currently include water quality modeling capabilities or operational modeling of the Pine Flat Reservoir or major CID, or AID distribution systems. The model, however, provides the fundamental data and information framework, as well appropriate level of spatial and temporal details for future development of additional features, such as the water quality simulation and river/reservoir operations. The development of these additional capabilities may be a potential future improvement to the Kings IGSM.

1.2.4 MODEL REFINEMENT FOR CITY OF FRESNO

The City is updating its Metro Plan to guide the development and management of the available water supply for current demands and future growth through 2060. The City was interested in developing an analytical tool to assist in:

- Better understanding the hydrologic and hydrogeologic conditions in Fresno area,
- Evaluation of no-project conditions as defined by the Metro Plan,
- Evaluation of Metro Plan project conditions, and
- Evaluation of local and regional effects of the projects.

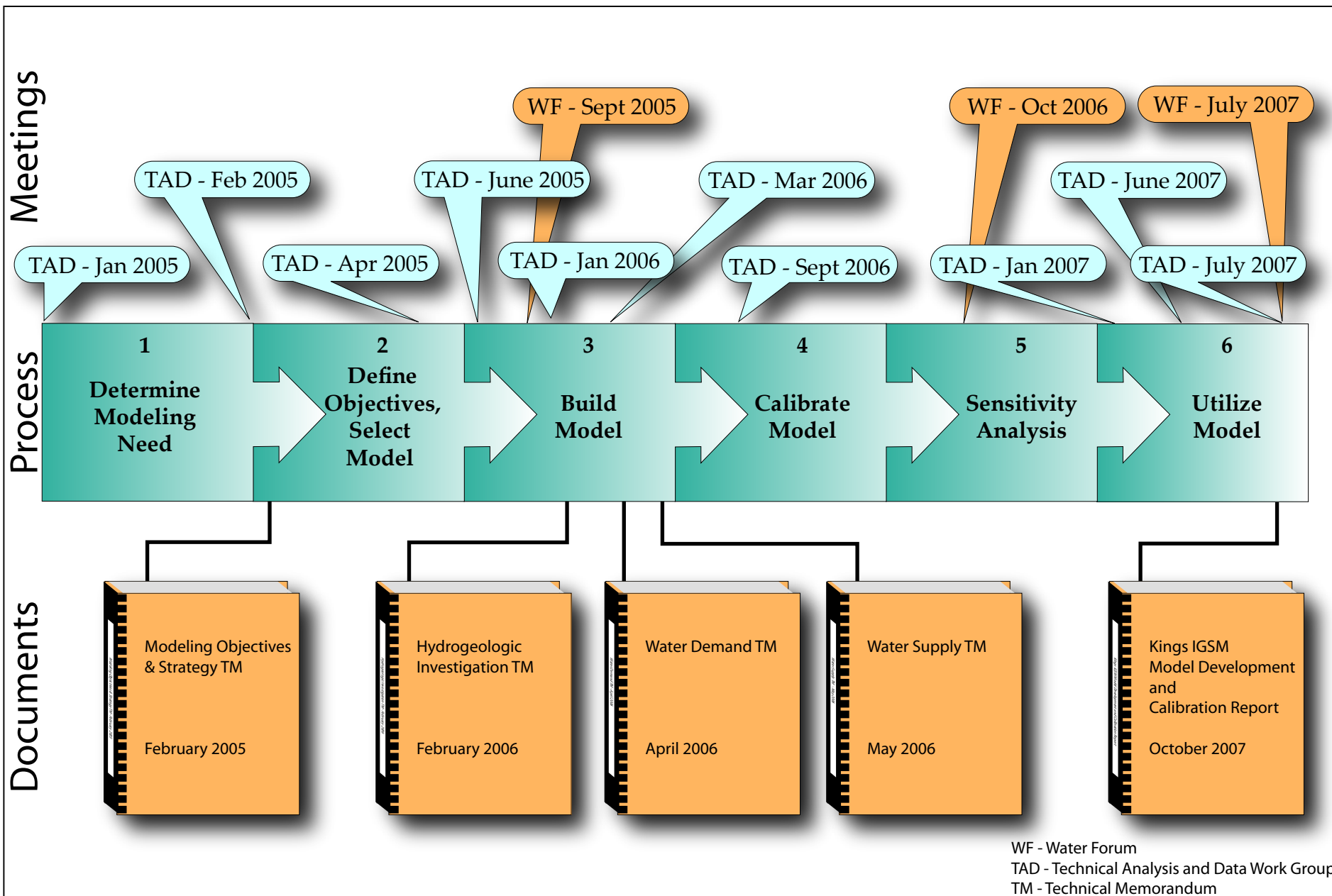
The City decided to use the Kings IGSM as an analytical tool for development of the Metro Plan and supported the enhancement of the model in Fresno area and incorporation of detailed data. Enhancement of the model in Fresno area supports the evaluation of proposed Metro Plan

facilities and alternatives at an appropriate level of resolution and detail required by the Metro Plan. Detailed model input data and analysis of model results for Fresno area are presented in this report.

1.3 ORGANIZATION OF THE REPORT

This report is organized as follows:

- **Section 1 - Introduction:** This section;
- **Section 2 - Model Area:** describes the area that is being modeled;
- **Section 3 - Model Data Requirements:** presents the model data requirements, key data sources and the simulation time period;
- **Section 4 - Model Characterization:** presents the model subregions, model grid and surface water configuration;
- **Section 5 - Model Input Data:** presents the data used in the input files of the model;
- **Section 6 - Model Calibration:** presents the calibration procedure and calibration results of Kings IGSM;
- **Section 7 - Sensitivity Analysis:** presents the results of the sensitivity analysis of the model parameters of the Kings IGSM;
- **Section 8 – Summary and Recommendations:** presents the summary of the report and provides recommendations for future course of action;
- **Section 9 - References:** lists the documents cited in the Kings IGSM Development and Calibration Report;
- **Appendix A – Characteristics of Municipal Wells in Fresno and Clovis:** presents location, capacity, screen interval, well depth, and assigned model layers for Fresno and Clovis Municipal Wells;
- **Appendix B – Calibration Well Hydrographs:** presents groundwater hydrographs for 1964 to 2004 at 240 calibration wells; and
- **Appendix C – Kings IGSM Sensitivity Analysis Results:** presents the results of Kings IGSM sensitivity analysis at selected impact areas.



	Model Development Process, Meetings, and Documents	July 2007
	Kings IGSM Model Development and Calibration	FIGURE 1-1

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The model area for the Kings IGSM is defined by the political, hydrologic and hydrogeologic settings of the study area and with due considerations for future applications of the Kings IGSM in the IRWMP area.

2.1 KINGS BASIN

The boundaries of the Kings IGSM are primarily based on the Kings groundwater basin, as defined by the DWR Bulletin 118. The Kings groundwater basin is located in the southern part of the San Joaquin Valley groundwater basin in the Central Valley of California (Figure 2-1).

The Kings Basin is bounded on the north by the San Joaquin River. The west boundary of Kings Basin is the eastern boundaries of the Westside and Delta-Mendota Basins. The southern boundary is the southern fork of the Kings River and the southern boundaries of Laguna Irrigation District, CID, and AID. The eastern boundary of the subbasin is the alluvium-granitic rock interface of the Sierra Nevada foothills.

The aquifer system consists of unconsolidated continental deposits of Tertiary and Quaternary age overlain by a younger series of deposits of Quaternary age. The Quaternary age deposits are divided into older alluvium, lacustrine and marsh deposits, younger alluvium, and flood-basin deposits. The older alluvium consisting of sand, gravel, cobbles, boulders, clay, silt, silty and sandy clay, and clayey and silty sand is an important aquifer in the Basin. The younger alluvium overlies the older alluvium and is interbedded with the flood-basin deposits. The younger alluvium is highly permeable beneath river channels.

Kings Basin is primarily an agricultural area, which has historically used both surface water and groundwater for irrigation purposes and primarily groundwater for municipal water supplies. Water use in Kings Basin exceeds the natural supply and the Basin has been operating under overdraft conditions for many years. The continued groundwater overdraft and the urban growth pressure in the region call for improved water resources management in the Kings Basin.

Historically, irrigation water supply in the basin has been provided by the surface water from the Kings River, supplemented by Friant-Kern water and Delta-Mendota Canal (DMC) water. Over the years, to further improve the agricultural productivity of the basin, the natural system has been modified by construction of canals, dams and reservoirs, and groundwater recharge ponds. To meet the water demands in the basin, the surface water supplies are supplemented

in dry years by groundwater pumping. In wet years, water may be intentionally applied in excess of the immediate irrigation demand to recharge groundwater.

Pine Flat Dam and Reservoir was constructed and began full operations in the early 1960s. The dam was constructed for both flood control and water conservation. The dam is operated by the US Army Corps of Engineers, however, the conservation pool is managed by the Kings River Watermaster, for the KRWA. The Watermaster is responsible for accounting and managing of the water released and delivered to the 28 member KRWA for irrigation and other beneficial uses. Pine Flat Dam has 1 million acre feet of storage and captures water in the winter for release in the summer irrigation season, and in wet years for release in dry years, when carry-over storage space is available. To alleviate depletion in the groundwater basin, recharge ponds have been built to store water in the groundwater basin, when surface water is available. Despite this and the other conjunctive use measures, groundwater overdraft continues.

2.1.1 SURFACE WATER SYSTEM

The primary source of surface water in the Kings Basin is the Kings River, including Pine Flat Reservoir releases, and stream inflows from Mills and Hughes Creeks, supplemented by imports from Friant Kern Canal of the Federal Central Valley Project (CVP) and Delta-Mendota Canal. The KRWA is the water master for the Kings River and includes 28 members that divert water and have rights to the Kings River. Based on streamflow data for water years from 1964 to 2004, the average annual total surface water inflow to the basin is about 1.85 million acre-feet (MAF). Of the total inflow, the Kings River on the average contributes 1.78 MAF, with a low of 500 thousand acre-feet (TAF) in dry years, and a high of 4.25 MAF in wet years. Much like the rest of California, the Kings Region observes the “average conditions” on a relatively infrequent basis, and water management activities must respond to wet or dry conditions. In addition, wet and dry periods can be prolonged and occur over multiple years.

2.1.2 LAND AND WATER USE SYSTEM

The primary water use in the Kings Basin is for irrigation purposes. The major water users in the Kings Basin include FID, CID, and AID that jointly hold rights and deliver roughly 65% of the total water of the Kings River. The major source of supply is the natural flow of the Kings River or the water stored in Pine Flat Dam and water from Friant-Kern and Delta-Mendota canals. The surface water supplies are supplemented by groundwater pumping during times when surface water is not available for diversion. Upper Kings Basin, with a total area of 585 thousand acres, has approximately 440 thousand acres of agricultural area. In contrast, Lower Kings Basin, with a total area of 335 thousand acres, has approximately 280 thousand

acres of agricultural area. Approximately 61% of Kings Basin agricultural area is in Upper Kings Basin and 39% in Lower Kings Basin. However, it is estimated that more than 50% of Kings Basin agricultural groundwater pumping is in Lower Kings Basin.

Urban demands are a smaller percentage of the overall water use in the Kings Basin and most municipal supplies are obtained through groundwater pumping. The cities of Fresno, Clovis, Orange Cove, and Friant treat surface water at surface water treatment plants and which do not rely exclusively on groundwater.

2.1.3 GROUNDWATER SYSTEM

The general movement of groundwater in the Kings Basin is from the northeast to the southwest direction from the Upper Kings Basin into Lower Kings Basin. Despite the availability of surface water for irrigation use, the long-term reliance on groundwater has caused significant overdraft on the basin. Average groundwater levels in Kings Basin have dropped by approximately 34 feet during the past 40 years, and continue to decline. The current average depth to water is 25 to 50 feet in AID, 50 to 75 feet in eastern areas of CID, 100 to 150 feet in western areas of CID, and 75 to 100 feet in western areas of FID. However, depth to water is greater in Fresno SOI (125 to 150 feet) and RCWD (225 to 250 feet). There are two water level depressions in Kings Basin; one beneath the Fresno/Clovis metropolitan area, and the second larger and deeper depression generally in the area of the Raisin City Water District.

The primary drivers contributing to the changes in groundwater levels and overdraft are:

- high reliance on groundwater for all demands in much of the western parts of Kings Basin;
- urban development and reliance on groundwater once lands are converted to urban use from agricultural uses; and
- groundwater pumping to meet agricultural water demand when surface water diversions are inadequate to fully meet the crop water requirements.

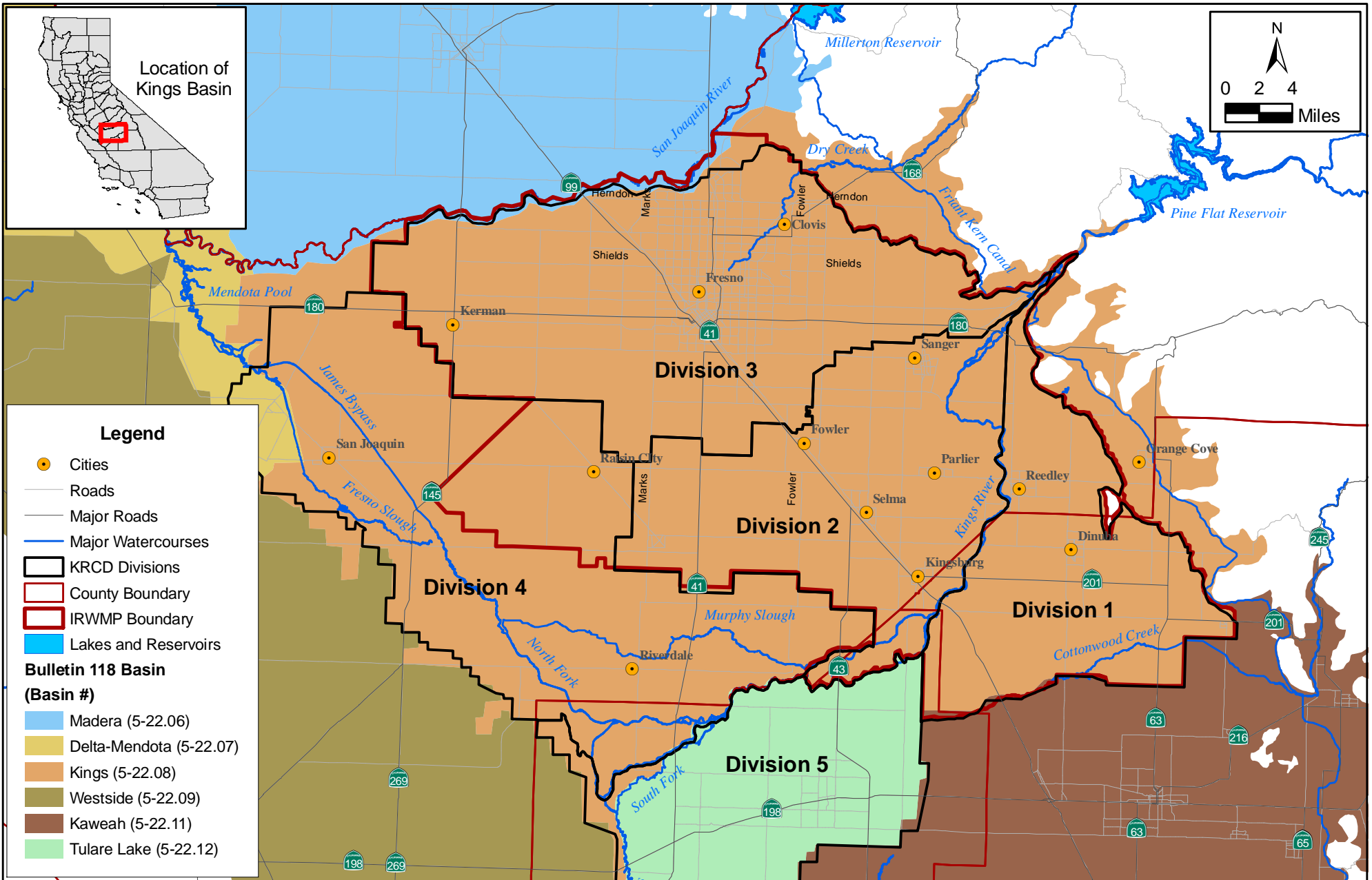
The cities of Fresno and Clovis have constructed surface water treatment plants that allow for use of surface water in-lieu of groundwater pumping and have recharged the groundwater for about 3.5 decades. This water management strategy leaves groundwater in storage and this will help recovery of the water table.

2.2 MODEL BOUNDARY

The model boundary, as shown in Figure 2-2, extends beyond the Kings groundwater basin area in the west and east to include the Mendota Pool area, Tranquility Irrigation District, and

urban and agricultural areas in the foothills. The model area extends about 50 miles from west to east and about 35 miles from north to south. The model area includes the Fresno-Clovis metropolitan and other urban areas, two major streams (Kings River and San Joaquin River), several major water distribution canals, and several small creeks.

The focus of the data collection and analysis effort as related to Kings IGSM development was limited to the IRWMP region (Figure 2-2). However, due to geologic and hydrologic interconnection of the IRWMP area and other areas, the readily available data on the neighboring areas outside the IRWMP area was also collected to facilitate the development of the Kings IGSM. The IRWMP area includes AID, CID, FID, and RCWD.



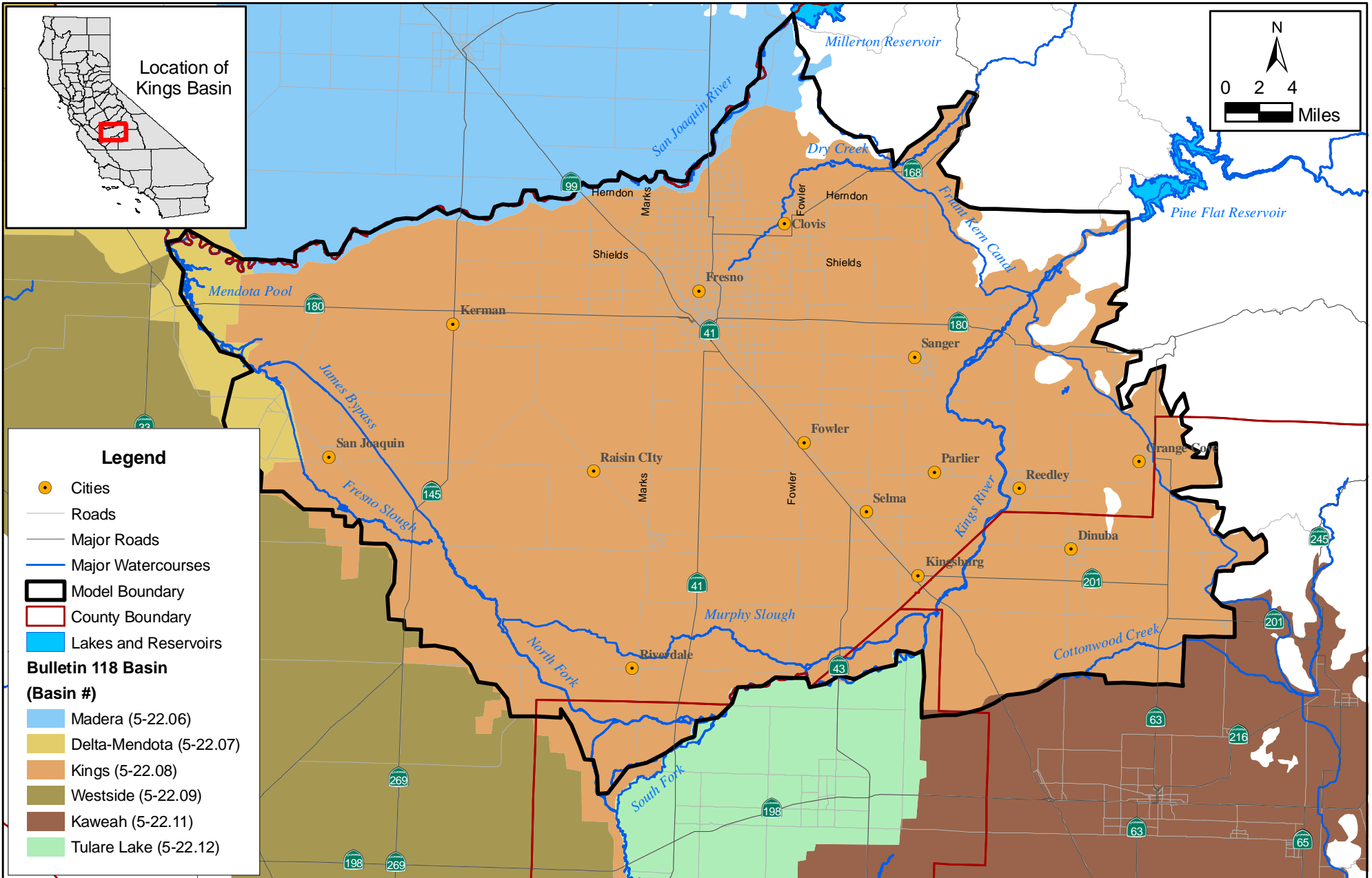
Groundwater Basin, IRWMP, and KRCD Divisions Boundaries

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Kings IGSM Model Development and Calibration

Figure 2-1





Groundwater Basin and Model Boundaries

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Kings IGSM Model Development and Calibration

Figure 2-2



This section describes the categories of data utilized to develop the Kings IGSM. A summary of input data used in the Kings IGSM is presented in Table 3-1. The data is organized into the following categories:

- Model characterization data;
- Geohydrology and geography data;
- Hydrology and climatology data;
- Land use and crop data;
- Water supply and demand data;
- Aquifer parameter data;
- Initial conditions data; and
- Boundary conditions data.

Model characterization data is described in Section 4. Other data categories are described in Section 5.

3.1 KEY DATA SOURCES

The key data sources used in the development of the Kings IGSM are listed below:

1. **Local Sources:**
 - a. Kings River Water Association (KRWA);
 - b. City of Fresno
 - c. City of Clovis;
 - d. County of Fresno;
 - e. Fresno Irrigation District (FID);
 - f. Consolidated Irrigation District (CID);
 - g. California State University – Fresno (CSUF);
 - h. Alta Irrigation District Integrated Groundwater and Surface water Model (AIDIGSM);
 - i. Alta Irrigation District (AID)
 - j. Kings River Conservation District (KRCD);
 - k. Fresno Metropolitan Flood Control District (FMFCD); and
 - l. Kenneth D. Schmidt and Associates;
2. **State Agencies:**
 - a. Department of Water Resources (DWR);
 - b. University of California, Davis (UCD);
 - c. Central Valley Groundwater and Surface water Model (CVGSM)
 - d. California Irrigation Management Information System (CIMIS); and

- e. Department of Health Services (DHS);
- 3. Federal Agencies:**
 - a. U.S. Bureau of Reclamation (USBR);
 - b. U.S. Geological Survey (USGS);
 - c. National Climatic Data Center (NCDC);
 - d. U.S. Army Corps of Engineers (Corps); and
 - e. U.S. Natural Resource Conservation Service (NRCS).

3.2 SIMULATION TIME PERIOD

The IGSM is a dynamic simulation model that simulates groundwater flow and stream flow for a continuous period of time. A time period, 1964–2004, was selected based on discussions with TAD Work Group. The features of the time period include:

- 1964 is the beginning of the Pine Flat Reservoir operation under contemporary guidelines (KRWA, 1997);
- Beginning of Friant-Kern Canal water deliveries to FID;
- Reasonable amount of data is available for this time period;
- A long (41-year) period that provides a reasonable basis for calibration of the model;
- The inclusion of wet, dry, normal, and extreme conditions of the regional hydrology in the basin, such as the 1976–1977 drought, and 1983 flood; and
- Significant changes in land and water use in the model area.

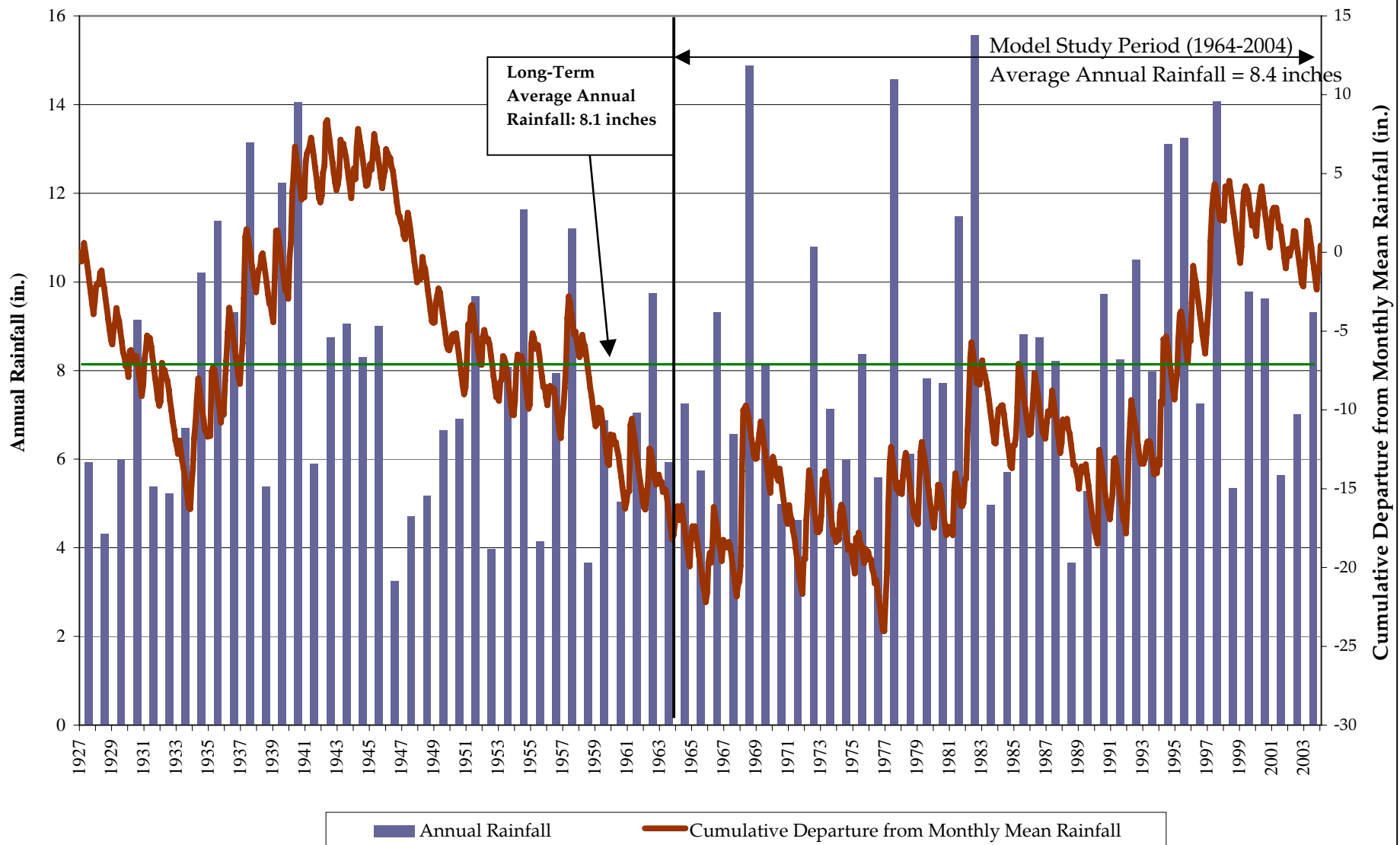
Figure 3-1 shows the annual rainfall total at Hanford, California for the 1927–2004 hydrologic period. Based on the isohyetal maps (based on U.S. Weather Service Data), the Hanford gage reasonably represents the long-term rainfall trends in the basin. Figure 3-1 indicates that the 77-year average annual rainfall (1927-2004) is 8.1 inches in the valley floor, while the average annual rainfall during the 41-year model simulation period (1964-2004) is 8.4 inches. The figure also shows the cumulative departure from average annual rainfall for Hanford station. This chart provides rainfall trend information in the valley floor, as the periods with falling cumulative departure curve represent dry conditions, and those with rising trends represent wet conditions. It is apparent that while the early part of modeling period is relatively average rainfall conditions, the latter part is relatively wet. At the same time, there are short-term dry and extreme dry conditions such as 1976-77 and 1987-92. Model simulations during these dry periods will assist in evaluation of potential project impacts for water supply reliability during drought conditions. On the other hand, the modeling analysis during relatively wet hydrologic periods, such as 1969 and 1983 can assist in evaluation of potential runoff capture and water availability for short-term and long-term conjunctive use opportunities. Kings River flow closely follows the rainfall trend in the valley floor. Table 3-2 shows rainfall averages for several selected hydrologic periods.

Table 3-1. Summary of Input Data used in the Model

Data Group	Data Item	Data Characteristics		Data Sources
		<i>Spatial Scale</i>	<i>Time Scale</i>	
Model Characterization	Element configuration	Element	Invariant	LAFCO, USGS, CASIL
	Node coordinates	Node	Invariant	LAFCO, USGS, CASIL
	Stream configuration	Stream node	Invariant	CASIL, FID, CID, AID
	Subregion definition	Element	Invariant	LAFCO, USGS, CASIL
Hydrogeology and Geography	Stratigraphy	Node	Invariant	USGS, DWR, Brown & Caldwell
	Stream cross-sections	Stream node	Invariant	USGS, CVGSM, CID IGSM, AID IGSM
	Drainage pattern	Element	Invariant	CASIL
	Well locations	Well	Invariant	City of Fresno, City of Clovis
	Well construction	Well	Invariant	City of Fresno, City of Clovis
	Well sizes/capacities	Well	Invariant	City of Fresno, City of Clovis
Hydrology and Climatology	Rainfall	Gaging station	Daily	NOAA, CIMIS
	Rainfall distribution	Element	Invariant	CASIL
	Soil classification	Element	Invariant	NRCS
	Evapotranspiration	Subregion	Monthly	CIMIS
	Upstream inflow	Stream node	Daily	USBR, DWR, KRWA
Land Use	Land use distribution	Element	Survey years	DWR, KRCD
	Crop acreage	Subregion	Annual	DWR, AgComm
Water Use	Surface water diversion	Subregion	Monthly	KRWA, FID, CID, AID
	Diversion locations	Subregion	Invariant	KRWA, FID, CID, AID
	Groundwater pumping	Subregion	Monthly	City of Fresno, City of Clovis, FID
	Pumping distribution	Element	Invariant	FID, CID, AID
	Urban water use	Subregion	Monthly	City of Fresno, City of Clovis, KRCD
	Canal facilities/layout	Element	Invariant	KRCD, KRWA, FID, CID, AID
Parameter Data	Hydraulic conductivity	Node	Invariant	USGS, FID, Ken Schmidt, David Cehrs
	Stream bed parameters	Stream node	Invariant	USGS, CVGSM, CID IGSM, AID IGSM
	Specific yield	Node	Invariant	KRCD, Ken Schmidt, David Cehrs
	Storage coefficient	Node	Invariant	Ken Schmidt, David Cehrs
	Runoff curve number	Subregion	Invariant	NRCS
	Soil percolation parameter	Subregion	Invariant	NRCS
	Initial conditions	Node	Invariant	DWR, Ken Schmidt
Other	Boundary conditions	Node	Invariant, daily	DWR
	Recharge facilities	Element	Invariant	FID, CID, AID, FMFCD
	Well hydrographs	Well	Monthly	DWR, Ken Schmidt
	Groundwater levels	Well, regional contours	Monthly	DWR, KRCD, Ken Schmidt
	Artificial recharge	Element	Monthly	FID, KRCD

AGComm = Agricultural Commissioner for Fresno County
 AID = Alta Irrigation District
 CASIL = California Spatial Information Library
 CID = Consolidated Irrigation District
 CIMIS = California Irrigation Management Information System
 CVGSM = Central Valley Groundwater and Surface Water Model
 DWR = Department of Water Resources
 FID = Fresno Irrigation District
 FMFCD = Fresno Metropolitan Flood Control District

KRCD = Kings River Conservation District
 KRWA = Kings River Water Association
 LAFCO = Local Agency Formation Commission for Fresno County and Tulare County
 NOAA = National Oceanic and Atmospheric Administration
 NRCS = Natural Resource Conservation Service
 USBR = United States Bureau of Reclamation
 SGS = United States Geologic Survey



Data Source: NOAA Hanford Station (43747)



Hanford Station Rainfall Data

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Figure 3-1

Table 3-2. Rainfall Averages for Different Hydrologic Periods

Hydrologic Period	Years	Average Rainfall (in/yr)
Long-Term Average	1928 - 2004	8.05
Model Period	1964 - 2004	8.41
Short Dry Period	1976 - 1977	6.98
Extended Dry Period	1987 - 1992	7.32
Short Wet Period	1982 - 1983	13.53
Extended Wet Period	1995 - 1998	11.93

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