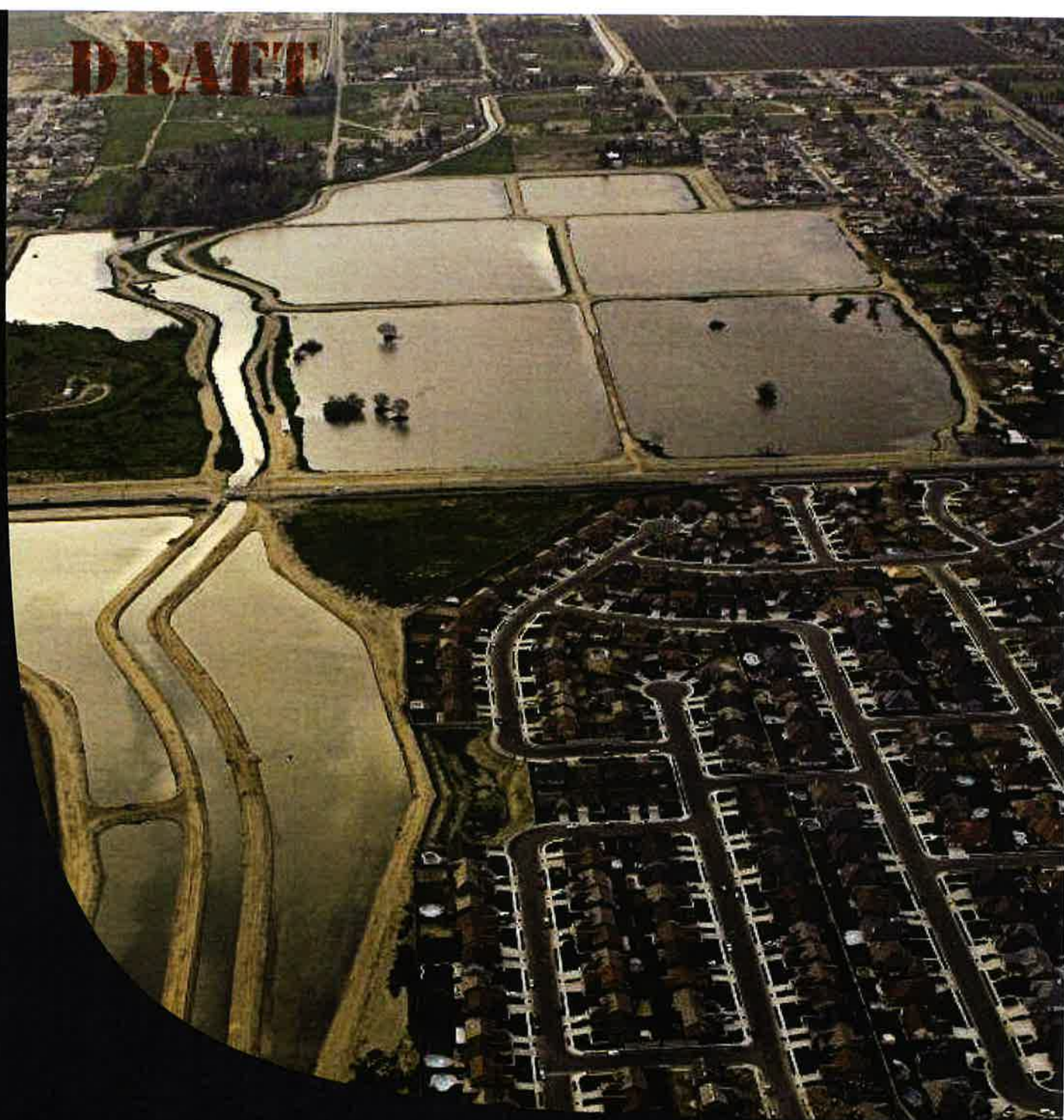


DRAFT



Prepared by Todd Engineers for Kern Fan Monitoring Committee

**Technical Memorandum No. 1
Site Conceptual Model
“With and Without Banking” Evaluation,
Kern Fan Area**

September 18, 2012

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TODD ENGINEERS

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List of Acronyms

AFY – acre feet per year

BVWSD – Buena Vista Water Storage District

cfs – cubic feet per second

COB – City of Bakersfield

CWD – Cawelo Water District

DWR – (California) Department of Water Resources

ET - evapotranspiration

gpm – gallons per minute

ID4 – KCWA Improvement District No. 4

KDWD – Kern Delta Water District

KFMC – Kern Fan Monitoring Committee

KCWA – Kern County Water Agency

KWB – Kern Water Bank

MGD – million gallons per day

MOU – Memorandum of Understanding

msl – mean sea level

NKWSD – North Kern Water Storage District

NORMWC – North of the River Municipal Water Company

NORSD – North of the River Sanitary District

SWID – Shafter-Wasco Irrigation District

SWP – State Water Project

Vaughn or VWC – Vaughn Water Company

WKWD – West Kern Water District

WWTP – wastewater treatment plant

1 Introduction

The Kern Fan Monitoring Committee (KFMC) is working cooperatively to monitor groundwater conditions in the alluvial aquifers beneath and in the lower area of the Kern River, generally referred to as the Kern Fan. In this area, favorable hydrogeologic conditions, the availability of imported and local water, and the cooperation of numerous water agencies and stakeholders have allowed for the subsurface storage of significant water supplies in the local groundwater basin. Although significant intentional recharge has occurred in the County for almost 50 years, more focused large-scale groundwater banks have operated along the apex of the Kern River Fan since the 1990s.

In compliance with various memoranda of understanding (MOUs) associated with groundwater banking projects, the KFMC is conducting an evaluation to assess potential groundwater impacts from various banking projects. The basis of the impacts evaluation is the groundwater conditions that would have occurred in the *absence* of banking. The comparison of conditions with groundwater banking to conditions without groundwater banking is referred to as a “with and without” evaluation by the KFMC and in this memorandum.

To assist in the *with and without* evaluation of various banking projects, the KFMC has retained Todd Engineers to construct, calibrate, and apply a numerical groundwater flow model (also referred to as the Kern Fan Model) based on an updated conceptual model. This memorandum presents the first step of the analysis – the development of the site conceptual model. The memorandum summarizes data sets and analyses to support the development of the numerical model with which to analyze potential impacts of certain recharge and banking projects along the Kern Fan.

1.1 Background

Numerous water districts, irrigation districts and banking entities have been formed in Kern County for the conjunctive management of local and imported surface water and groundwater, most of which are shown on Figure 1-1. Kern County Water Agency (KCWA) is the local contracting agency for imported water from the State Water Project (SWP) that supplements local surface water and groundwater for both agricultural and urban water supply. SWP enters the Study Area via the California Aqueduct (Figure 1-1). Urban SWP water is provided in the Study Area by KCWA which acts through Improvement District No. 4 (ID-4) as a wholesale supplier to portions of the Bakersfield urban area. KCWA also operates and participates in several of the groundwater banking projects along the lower Kern River, collectively shown in light blue on Figure 1-1.

In order to maintain groundwater levels and secure storage of surface water supplies when available, a large number of surface recharge facilities have been constructed along the Kern River and in various water districts north and south of the river as shown on Figure 1-2. Although many water districts manage intentional recharge projects for the primary benefit of local customers within their service area (e.g., North Kern Water Storage District), more formalized banking projects have also been developed that often involve storage and recovery of water for third parties outside of the banking areas (e.g., the

Kern Water Bank Authority) (Figure 1-3). The first such banking project was constructed in 1978 by the City of Bakersfield and involved about 2,800 acres of recharge facilities along the Kern River (referred to as the COB 2800 project). In 1984 the Berrenda Mesa project was constructed along the river and beginning in the mid- to late-1990s, the Kern Water Bank (KWB), and the smaller Pioneer project were also constructed in the river corridor. The approximate delineation of these and other more-recent banking projects are shown on Figure 1-3.

Participants in the larger banking projects (Project Participants) and water agencies in the vicinity (Adjoining Entities) recognized that banking could have potentially both beneficial and adverse impacts on water levels or water quality beyond the project boundaries. In 1995, Project Participants and Adjoining Entities associated with the Kern Water Bank signed a Memorandum of Understanding (MOU), forming the KPMC, to monitor and evaluate banking impacts on groundwater levels and quality. Since that time, a series of MOUs associated with other banking projects have been executed. The MOUs unite the signatory parties toward a shared goal of ensuring that both beneficial and adverse impacts from groundwater banking are identifiable and, to the extent practical, adverse impacts are mitigated.

In October 2011, the Kern County Water Agency (KCWA), on behalf of the KPMC, retained Todd Engineers to assist on the *with and without* evaluation for various banking projects. The contract was based on the scope of work presented in *Proposal to Provide Hydrogeological Consulting Services for the Development of an Aquifer Model for the With and Without Evaluations of the Kern River Alluvial Fan, Groundwater Banking Projects, Kern County, California* (Proposal) prepared by Todd Engineers and submitted to the KPMC in December 2010. Since October 2011, Todd Engineers has met with the Technical Subcommittee of the KPMC (Technical Subcommittee) on six occasions (including a technical workshop with selected members of the subcommittee) to refine the project scope, update the subcommittee on project status, discuss details of data collection and analysis, and obtain technical input for the development of the site conceptual model on which the numerical groundwater flow model will be based.

1.2 Project Objectives and Scope of Work

The goal of the project is to evaluate the changes to groundwater levels and flow that have occurred as a result of specific banking or recharge projects. To accomplish this goal, the following project objectives have been identified:

- Develop a site conceptual model and water balance of the groundwater system
- Construct and calibrate a numerical groundwater flow model
- Apply the numerical model to evaluate groundwater conditions without banking projects.

Based on meetings with the Technical Subcommittee, seven banking/recharge projects have been identified for a *with and without* evaluation including the Kern Water Bank (KWB), Pioneer Project, Berrenda Mesa Project, Buena Vista Water Storage District (BVWSD), City of Bakersfield 2800 Acres (COB 2800), West Kern Water District (WKWD) Storage Project, and Rosedale-Rio-Bravo Water Storage

District (RRBWSD), collectively referred to in this memorandum as “Banking Projects.” The project service areas of these seven projects are shown on Figure 1-3.

The objectives were incorporated into the scope of work for the project, which includes the following tasks:

1. Update Conceptual Model
2. Develop Numerical Flow Model
3. Simulate “With and Without” Banking Projects Scenarios
4. Identify Project Assumptions and Evaluation Accuracy
5. Prepare Technical Memoranda and Project Report
6. Conduct Conference Calls and Meetings.

Task 5 includes a series of memoranda to allow ongoing technical oversight from the KFMC. Four memoranda corresponding to Tasks 1 through 4 are included in the scope of work. Comments provided by the KFMC will be addressed and incorporated into the comprehensive Project Report. This memorandum is Technical Memorandum No. 1 (referred to herein as TM-1). TM-1 presents the results of Task 1 and introduces the proposed methodologies for translating the conceptual model into the numerical model (Task 2).

1.3 Study Area, Model Domain, and Study Period

The general Study Area, defined by the KFMC for the Proposal, generally includes the area from Poso Creek in the north to Kern Delta Water District (KDWD) in the south (Figure 1-1). In the initial stages of the project, hydrogeologic data were reviewed to delineate a preliminary model domain by Todd Engineers with assistance and input from the Technical Subcommittee.

The model domain (Model Area) covers approximately 454 square miles (about 290,500 acres) including portions of 23 townships/ranges north and south of the Kern River. Water districts included in the model domain are shown on Figure 1-1 and include all or portions of (from south to north): KDWD, ID-4, Kern River banking projects (collectively in blue), Buena Vista Water Storage District (BVWSD), Rosedale-Rio Bravo Water Storage District (RRBWSD), Semitropic Water Storage District (SWSD), Shafter-Wasco Irrigation District, North Kern Water Storage District, and the southwestern-most tip of Cawelo Water District (CWD). Purveyors supplying municipal and industrial supply (including groundwater pumping) are also located within the model domain as shown on Figure 1-4. The basis for the delineation of the model boundary and preliminary boundary conditions are described in more detail in Section 3 of this TM.

A Study Period has been selected to accommodate both wet and dry hydrologic cycles and to pre-date the major banking projects of interest, which began about 1995. Since data collection began prior to the end of 2011, data have been compiled through 2010. At the request of the Technical Subcommittee, data sets were collected from 1980 through 2010, when available. A review of data sets revealed that the amount and quality of data improved significantly beginning in about 1986. In particular, the primary water level database developed by Kern County Water Agency did not contain water level data prior to 1986, data on which the groundwater model would be calibrated. Remaining pre-1986 key data sets are

either non-existent or judged much less reliable including municipal pumping, imported water recharge, pre-banking area operations, and other data.

In addition, a review of hydrographs indicates that 1986 represented a time of relatively average hydrologic conditions and relatively stable water levels as documented in Section 2 of this memorandum. Stable groundwater levels provide benefits for developing initial conditions for the groundwater model. Further, the period between 1986 and the initiation of the major banking operations (1995) was judged sufficient time for the model to be calibrated to pre-banking conditions, recognizing that less formalized banking had already been developed in the region. For these reasons, the Study Period of calendar years 1986 – 2010 has been selected as the model time period (a period that is also consistent with the 2011 Proposal).

1.4 Data Sources

Numerous data sets have been compiled to support the conceptual and numerical models. Because monthly time steps are needed for the numerical model to allow for the analysis of seasonal variability in groundwater conditions, data have been collected on a monthly basis when available. For instances when data are available only on an annual basis, appropriate methodologies have been developed to allocate data monthly.

Data compilation has been coordinated through KCWA, but also has included direct communication and/or office meetings with individual water/irrigation districts, municipalities, mutual water companies, and the banking entities (including the Kern Water Bank Authority). KCWA also provided electronic scans of driller's logs and geophysical logs that covered the Study Area. Numerous datasets have been developed from the Kern River Hydrographic Annual Reports, referred to herein as the Kern River Annual Reports. These reports are prepared annually by the City of Bakersfield in cooperation with the Kern River Watermaster. Land use maps obtained from the County and DWR have been used in the estimation of agricultural irrigation, irrigation return flows, groundwater pumping, recharge from rainfall and other components of the conceptual model. Kern Fan Operations and Monitoring Reports prepared by the KFMC provide summary data for banking projects. All of these local documents and data have been supplemented by the vast amount of geologic and hydrogeologic technical publications prepared by state and federal agencies including the U. S. Geological Survey (USGS), California Department of Water Resources (DWR), University of California Bakersfield, and other investigators. These and other data sets and their use in the conceptual model are discussed in more detail throughout TM-1.

Data are available in either electronic (database or spreadsheet) formats or paper/pdf formats, which require either electronic manipulation for database consistency and/or hand-entry of data. A significant amount of data entry was undertaken by KCWA and Todd Engineers (and others) to develop an electronic database in a consistent format. The largest dataset developed by hand-entry of data has involved the thousands of records from the Kern River Annual Reports developed by the City of Bakersfield. These data include monthly records of flows in the Kern River, diversions from the river channel, use of diverted water for irrigation or recharge, movement of water among agencies, leakage along various reaches of the river channel, and estimates of canal losses. Well construction data from driller's logs have been hand-entered into the database for two of the larger water districts closest to

the banking projects; recovery well construction data associated with some of the banking projects also have been hand-entered. These well construction data supplemented well construction databases provided by several of the banking entities. In addition, municipal pumping from multiple purveyors (including CalWater, Oildale, and others) were hand-entered and added to the database.

Many of the spatial coverages of institutional boundaries or physical features were available from KCWA and others in formats compatible with the project's Database Management System and Geographical Information System (GIS), which can be readily imported into the pre-processor software of the numerical model. However, numerous data sets required digitizing and/or electronic conversion including pre-1997 land use data and geologic contours of regional clay layers. Details of these data sources and incorporation into the project are discussed in subsequent sections of TM-1.

Several data sources provided overlapping or similar data that were used for quality control and cross checking purposes. In several instances, duplicate data sources were in conflict and had to be reconciled. For example, annual banking data obtained from one source did not match monthly data provided from a separate source. In these instances of conflict, data sources were re-checked and assistance from the primary agency responsible for the data was obtained. In general, the primary entity responsible for collecting/compiling the data was considered the more reliable source.

Despite our best efforts, additional data and knowledge gaps remain. These are highlighted throughout this TM-1 along with the methods used to estimate values in the absence of data.

1.5 Use of the Technical Memorandum (TM-1)

TM-1 is the first in a series of technical memoranda to keep the KFMC informed of the incorporation of data and analysis into the project and to allow guidance and oversight for subsequent tasks. TM-1 is being provided to the KFMC and Technical Subcommittee for review and comment. Comments will be discussed in the meeting of the Technical Subcommittee in October 2012 with a focus on how comments should be addressed during development of the numerical model. Comments will be incorporated into the comprehensive Project Report at the end of the project.

2 Development of the Conceptual Model

The development of the site conceptual model has involved a review of the hydrologic and hydrogeologic conditions in the Study Area. This review has provided the foundational data to estimate the amounts and types of water moving through the groundwater system. These data are incorporated into the water balance and will be the basis for development of the numerical model.

2.1 Physical Setting

The Study Area is characterized by a relatively flat alluvial plain surrounded by the dissected uplands of the Coast Ranges to the west and the Sierra Nevada to the east. Within the Model Area, ground surface elevations range from about 600 feet mean sea level at the east-central edge to below 250 feet at the northwest corner. Ground surface elevations along the Kern River range from about 415 feet msl in the east to about 300 feet in the west across the Model Area, with an overall slope of about 6 feet per mile. Most of the Model Area has ground surface elevations between 300 feet and 400 feet msl.

2.1.1 Climate and Precipitation

The Model Area is characterized by cool, moist winters and hot, dry summers. The mean annual temperature is 65° F and summer highs frequently exceed 100° F. Average precipitation in the Model Area is about 6 inches per year.

Annual precipitation from 1890 through 2010 at the Bakersfield station is shown on the upper graph of Figure 2-1 with the Study Period of 1986 – 2010 highlighted on the graph. The period of record demonstrates the variability of rainfall in the Model Area ranging from less than 3 inches in extreme dry years to more than 10 inches in very wet years.

Figure 2-1 also shows monthly precipitation during the Study Period plotted on the lower graph with a cumulative departure curve (CDC). The CDC is used to more readily identify wet and dry periods in relation to average precipitation, which is shown as zero on the right-hand scale of Figure 2-1. When the curve is rising, conditions are wetter than average; a declining curve indicates dry conditions. Average precipitation for the Study Period is approximately 6.45 inches, slightly wetter than the long-term average. The cumulative departure curve also indicates a relatively wet period, but almost all of the change is controlled by the much wetter than normal conditions in December 2010, the last month of the Study Period. But for December rainfall, the Study Period would be very close to average hydrologic conditions.

With an average annual evapotranspiration (ET) rate of 57 inches, most of the rainfall evaporates, producing runoff only during intense rainfall events. Groundwater recharge from rainfall only occurs during wet years. Additional analysis of recharge from rainfall is presented in the Water Balance in Section 3.

2.1.2 Land Use

Land use data have been accessed from DWR and the Kern County Agricultural Commissioner's Office to better understand groundwater recharge and water supply and how those conditions have changed over the model period. The DWR land use maps identify areas of irrigated agriculture (including crop types), urban and industrial uses, native vegetation and numerous other uses. Land use data available from the Kern County Agricultural Commissioner's Office provide more detail on crop use because the maps are generated based on permit applications from growers. Both sources provide sufficient detail from which to estimate irrigation demand, the primary use of the maps for this project.

DWR land use maps are available for the years 1984, 1990, 1998, and 2006. The most recent DWR maps have been downloaded in electronic format and geo-referenced to the project GIS. The 1984 land use map was available in paper format only and has been digitized for use in the project. Electronic maps from the County are available in GIS format on an annual basis beginning in 1997, but 1997 and 1998 maps were found to be incomplete. A quality control check has been made by comparing DWR and County maps for overlapping time periods; this check indicates that acreages are generally within 15 percent and both sources are judged equally usable for the project. Because data are unavailable for each year of the model period, data have been reviewed for quality and representativeness over time for assignment to various years of the model. Based on this review, the following maps have been assigned to model years as summarized below in Table 2-1.

Table 2-1 Land Use Maps

Years in Model Period	Land Use Maps	Source
1986 - 1988	1984	DWR
1989 - 1995	1990	DWR
1996-1998	1998	DWR
1999 - 2010	1999 - 2010	Kern County

The 2010 crop map from Kern County is shown on Figure 2-2 to illustrate current land use conditions in the Model Area.

2.1.2.1 Agricultural Land

As seen on Figure 2-2, most of the Model Area contains irrigated agriculture. For recent years, irrigated agriculture has covered about 159,258 acres of the 290,500-acre Model Area, or about 55 percent. Another 6,790 acres have been determined to represent non-irrigated agriculture, or partially related to agricultural activities, adding another 2 percent to the agricultural coverage in the Model Area. Although the number of acres of irrigated agricultural acreage changes over the Model Period, it represents more than one-half of the acreage for all years in the model. In addition, cropping patterns, and resulting

irrigation demands, have changed significantly over the Model Period. In general, irrigation demand has increased from 1986 to 2010 based on changes in crops throughout the area.

Numerous water districts in the area develop internal district-specific crop surveys, which were requested during the data collection process for this project. However, these surveys are limited in a number of ways that restrict their use. Surveys are not available for most years of the model period. Most of the surveys are simple tables of annual acreage for particular crop groups and these categories vary from survey to survey. In addition, many surveys group similar-type crops together even when irrigation demands varied significantly among those crops. Most surveys are not location-specific and typically do not account for double-cropping. Further, many districts have now abandoned the crop surveys and have adopted use of the County land use maps, which are used in this project. To facilitate a comparison of the land use data against the crop survey tables, cropping acreages and irrigation demand have been developed on a district-basis. Most of the data compare relatively well (typically within about 15 to 20 percent) for time periods when data are sufficient for comparison. In general, the land use maps often indicate slightly larger acreages due to double-cropping and multiple crops grown on a parcel. Because the land use maps provide more detail on cropping patterns, are location-specific, are based on actual permits, and are available on an annual basis for most years of the Model Period, they are judged the more reliable source for analysis of irrigation demand.

2.1.2.2 Urbanized Areas

The Model Area includes much of the metropolitan area of the Cities of Bakersfield and Shafter, as well as several smaller communities. Urban areas have increased over time and currently represent about 75,266 acres of the Model Area, or about 26 percent of the area. This has increased from about 12 percent at the beginning of the Model Period.

2.1.2.3 Groundwater Banking Areas

As shown on Figures 1-2 and 2-2, the west-central portion of the Model Area contains most of the large banking projects located along the Kern River. Due to the permeable nature of the Kern River Fan sediments, almost all of the enhanced recharge projects both along the river and away from the river involve surface spreading through ponds, low-lying fields, or basins. These recharge areas, designated as “water” on the DWR land use maps, cover about 20,276 acres on recent maps, representing about 7 percent of the Model Area. With the exception of the COB 2800 banking area, most of these banking projects began after the mid- 1990s. Prior to that time, much of the land was irrigated agriculture, with only minor areas designated for intentional recharge (e.g., intentional flooding of open fields in the James Pioneer ID, where the KWB is currently located). Land use maps for pre-banking time periods (DWR 1984 and 1990) have been used to reflect conditions through 1995 (see Table 2-1 above).

2.1.3 Surface Water Features

The Kern River is the primary drainage of the Study Area and provides most of the water coming into the Model Area (Figure 1-1). The river is approximately 165 miles long and is fed by snowmelt and runoff in the Sierra Nevada, including areas near Mount Whitney, the highest peak in the contiguous United States. River flows are highly variable but have been regulated somewhat by operations at Isabella Dam

since its construction in 1953 (Figure 1-1). A stream gage downstream of the dam has recorded an average annual mean discharge of 946 cubic feet per second (cfs) (equivalent to about 680,000 acre feet per year (AFY)). Most of the river water is diverted into numerous canals (most unlined) for conveyance to agricultural fields, groundwater recharge facilities, and other uses. At a downstream gage west of Bakersfield, the river's average mean discharge is 312 cfs (about 226,000 AFY) or about one third of the discharge near the dam.

Prior to development, the Kern River terminated into a series of inland lakes (now dry), the largest of which is Tulare Lake located about 20 miles north of the model domain. In recent times, almost all of the river discharge is diverted for water supply or groundwater recharge prior to the drainage turning north at the western edge of the basin. Flood flows in the Kern River that cannot be used locally can exit the basin through the Kern River-California Aqueduct Intertie, located at the intersection of the lower Kern River and the aqueduct on the west-central boundary of the model (Figure 1-1).

River diversions are operated according to a complex system of water rights dating back to the 1800s. Three entities, Kern Delta Water District (KDWD), North Kern Water Storage District (NKWSD), and the City of Bakersfield (COB) hold various senior water rights determined by flows at a stream gage just east of the Model Area, referred to as First Point (Figure 1-1). The City of Bakersfield operates a system of stream gages and weirs along the channel and at diversion points to account for flows and losses (including groundwater recharge) throughout the area. The City reports these diversions and losses in annual hydrographic reports, referred to as Kern River Annual Reports. Canal losses and return flows from irrigated agricultures represent a large percentage of groundwater recharge in the Model Area.

2.2 Hydrogeologic Setting

The Study Area is located in the southern portion of the San Joaquin Valley, a long structural trough filled with more than 10,000 feet of marine and continental sediments. The continental sediments represent a variety of depositional environments including fluvial, deltaic, lacustrine, and alluvial fan sequences and form an alluvial wedge that thickens to the west across the valley.

Numerous investigators have described and mapped geologic units and water-bearing sediments throughout the valley for more than 100 years. That work has been presented and summarized in hundreds of publications and is not repeated here. Key elements of the geologic and hydrogeologic setting that describe the conceptual model and are relevant to the construction of the numerical model are summarized below.

2.2.1 Groundwater Basin

The Study Area is located within the Kern County Groundwater Subbasin, the southern-most portion of the San Joaquin Valley Groundwater Basin as defined by DWR. The subbasin covers approximately 3,040 square miles, 454 of which are in the Model Area. The subbasin has been estimated to contain approximately 40,000,000 AF of groundwater in storage with another 10,000,000 AF of storage capacity including areas where water levels have declined. A groundwater balance prepared by DWR and KCWA for a normalized year representing 1990 conditions included estimates for subbasin inflows and outflows. In that water balance, total subbasin inflows were estimated at 1,534,000 AFY with outflows

estimated at 1,400,300 AFY for a change in storage of 133,700 AFY under these conditions. The largest component of inflow was return flows from agricultural irrigation with both surface water and groundwater (843,000 AFY) and the largest outflow component was groundwater pumping for irrigation (1,600,000 AFY). A long-term water balance prepared by KCWA from 1970 to 1998 indicated a negative change in storage (average of -325,000 AFY), but did not consider all water balance components including subsurface inflow. A detailed water balance has been prepared for this project as a part of the conceptual model and is presented in Section 3 of TM-1.

2.2.2 Geology

A simplified geologic map is presented on Figure 2-3 that shows the Neogene and Holocene (late Tertiary and younger) basin sediments rimmed by Tertiary and pre-Tertiary bedrock to the east, south, and west. The Model Area is shown on the geologic map for reference. The Kern River bisects the area, underlain by recent channel deposits. The morphology of the recent alluvial fan sediments is indicated by the trajectory of the canal systems south of the river (Figure 2-3). The terminus of the ancestral river occurred at inland lakes including the Kern Lake and Buena Vista Lake beds, shown on the map. During long periods of large flows, the river drained north to the Tulare Lake Bed. These paleo-drainages are associated with the deposition of fine-grained sediments, shown on the map as flood-basin deposits and older lacustrine deposits. As shown by the Model Area, the presence of fine-grained sediments influenced the delineation of the boundaries of the model, especially along the southwestern edge.

Pleistocene-age lacustrine deposits have been mapped by numerous investigators including Croft (1972), who labeled the most prevalent units A – E. The most extensive unit is referred to as the E Clay, which has been mapped throughout much of the southern San Joaquin Valley. Recent work has either interpreted the E Clay to exist at different depths than previously estimated or has been correlated to non-time-stratigraphic units. In addition, others have indicated that the unit mapped as the E Clay is more correctly described as silt or silty clay.

Notwithstanding these qualifications, the unit mapped by Croft and others is evident in the hundreds of electric logs that have been reviewed for this project, and it represents a low-permeability surface that provides a reference for depicting hydrostratigraphic units in the area. It also appears to occur above or within a series of interbedded sands and clays that appear to be semi-confined based on water level data. The confining nature of the E Clay unit required consideration in the formation of the numerical model layers, discussed in Section 3 of this memorandum.

To investigate the stratigraphic nature of the E Clay and to incorporate it into the conceptual model, regional contour maps of the depth to the top of the unit and its thickness have been generated. These maps, generated from digitizing and interpreting information developed by Page, are shown on Figures 2-4 and 2-5.

2.2.3 Hydrostratigraphy and Aquifers

More than 220 electric logs have been reviewed to develop a hydrostratigraphic model on which to base numerical model layers. Regionally extensive low-resistivity units provide relatively reliable markers to assist in the interpretation. Low resistivity units are typically associated with low permeability sediments

such as silts or clays, with depositional environments that represent relatively slow deposition and often extend over large areas. The objective of the review was to identify aquifer packages that function as a hydraulic unit and are separated and delineated by relatively finer-grained aquitards. Using this methodology, three hydrostratigraphic units have been defined as illustrated by the electric log on Figure 2-6. The log was recorded in a well at the Pioneer Project, just north of the Kern River (for the general location, see the Pioneer Project on Figure 1-3).

As shown on the log, the Upper Unit is characterized by an approximate 300-foot sequence of primarily coarse-grained material (sands and gravels) as indicated by the higher resistivity readings. The geologic descriptions on the accompanying driller's logs indicate only minor amounts of silt and clay throughout this upper alluvial sequence. The character of the unit changes, especially to the northwest (beneath Semitropic WSD near the northwestern portion of the model) where the sand sequences are replaced by a thinner sequence of finer-grained sediments. The Upper Unit contains the water table throughout the model area and is variably saturated.

Below the upper 300 feet of sediments, a Middle Unit has been interpreted that is characterized by interbeds of sand/gravel and silt/clay with portions that vary throughout the model area. The upper portion of the Middle Unit is defined by the occurrence of lower resistivity units, typically below 20 ohm-meters on the Long Normal curve (RLN), which is the resistivity curve more representative of conditions in the aquifer away from the borehole. In the example well on Figure 2-6, the actual resistivity readings for these defining layers are below 10 ohm-meters in the upper portion of the Middle Unit (see scale at the bottom of the log). The top of the Middle Unit has been adjusted in some wells to accommodate construction data for representation in the model as described in Section 3 (e.g., the screen on Figure 2-5 is shown to extend from the Upper Unit into the Middle Unit.)

The lower-most unit (Lower Unit, Figure 2-6), has been defined at an approximate depth of 600 to 650 feet throughout the model area and is characterized by higher-resistivity, lower-permeability layers. The relatively high resistivity readings seen on most logs likely indicate more consolidated conditions. This unit is also typically characterized by discrete screens, as indicated by the third screen interval on the example log on Figure 2-6. Although the well on Figure 2-6 does not extend below about 740 feet, logs from several deeper wells in the area indicate that the nature of the sediments changes once again at about 800 feet, a depth used to define generally the bottom of the Lower Unit. For the few deep wells with available electric logs, this depth indicates more homogeneous consolidated units than seen in the upper intervals, with the Lower Unit functioning as a transition zone.

This methodology has been extended across the entire Model Area, recognizing that the textures and character of the units change significantly, especially with distance from the river. Changes in the character of the units will be accommodated in the model through the assignment of aquifer parameters, as discussed in Section 3.

2.3 Local Water Agencies and Institutional Framework

Surface water and groundwater are managed conjunctively throughout the Study Area to effectively match water supplies with demands; however, this complicates the tracking of water entering and

exiting the groundwater system. Although the site conceptual model focuses on the groundwater system, a brief description of local water agencies and the institutional framework provides some understanding as to which demands are met with each water source.

Several water sources are actively used and managed in the Kern Fan Area. Kern River water enters the Model Area through the river channel or from a series of unlined canals. Water is diverted from the river channel into lined or unlined canals in accordance with water rights administered by the Kern River Watermaster. Water is often transferred or re-directed to other destinations in real time when excess supplies are available. Most of the water is used for agricultural irrigation or groundwater recharge.

Local surface water is supplemented by imported water from the State Water Project (SWP) and Federal Central Valley Project (CVP). SWP water is conveyed into the Study Area via the California Aqueduct by KCWA, the local contracting agency. SWP water can be diverted into several canals on the west side of the Model Area or recharged in banking facilities on behalf of the agency or others. The Friant Water Users Authority operates the Friant-Kern Canal to convey CVP into the area. CVP water can be conveyed from the canal into a regional transmission canal (e.g., the Cross Valley Canal) or into the Kern River channel. CVP water enters the Study Area primarily through the Friant-Kern Canal. Local water and imported water are often involved in an exchange to facilitate conveyance.

A series of complex contracts, exchanges, and shared conveyance facilities offer Kern County water managers flexibility in water use, but complicate the ability to track the physical movement of water from various sources throughout the Model Period. The focus of the conceptual model has been to evaluate the inflows and outflows relating to the groundwater system regardless of water source while maintaining as detailed accounting as possible to minimize any double-counting in the water balance.

3 Conceptual Model of the Kern Fan Area

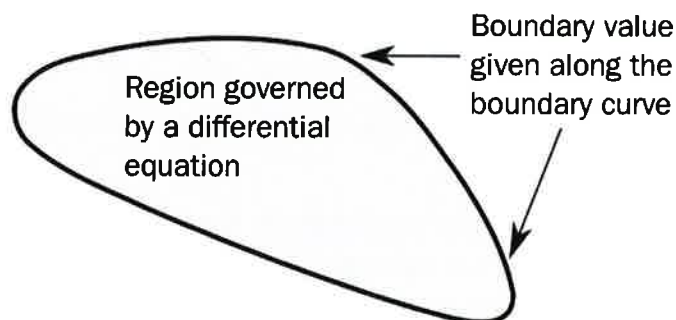
The conceptual model of the Kern Fan area provides a quantitative assessment of the hydrogeology of the Study Area by delineating aquifer systems into model layers, assigning aquifer parameters spatially and vertically, and providing a water balance for the study period. When the data analysis has involved multiple data sets and/or several analytical steps, details of the analysis are provided in a separate appendix and summarized in the text. Collectively, these data and analyses provide the basis on which the numerical model is being constructed.

3.1 Study Area and Model Area

Groundwater data throughout the Study Area have been used to characterize the numerical Model Area, which covers 454 square miles. The Study Area extends beyond the Model Area and its boundaries, which were identified and located on the basis of data over the larger study area.

3.1.1 Model Boundaries

Model boundaries are used in flow simulations of a large system (e.g., groundwater flow in the Southern Central Valley) by modeling a small part (e.g., the KWB area) that is far from its edge. Boundary conditions represent the dynamic sources of water (or no sources) that flow into or out of the model, and are used to constrain the mathematical solution of three-dimensional groundwater flow within the Model Area. The model domain (area) must have boundary conditions defined on all sides of the three-dimensional volume (top, bottom, and sides) as indicated by the schematic.



For the Kern Fan Model, a combination of time-varying specified head and time-varying specified flux (no flow and finite flow) conditions will be used for lateral boundaries in the numerical model. The top boundary for the model will be the land surface and/or water table with areal recharge over time. The sources and distribution of areal recharge which comprise the top boundary are discussed in detail in **Section 3.5**. The bottom boundary is discussed further in **Section 3.1.2** and will be defined as a no-flow boundary for the initial calibration simulations.

Lateral Boundaries

The lateral or side boundaries of the numerical model have been developed in conjunction with input from the KFMC, and were discussed at Project Meetings held on December 13, 2011 and April 18, 2012.

Model boundaries have been identified and constructed with consideration of geology/hydrogeology, regional groundwater flow directions throughout the study period, and have accounted for potential impacts on simulated flow from localized surface recharge from the river and canals. The lateral boundaries have been located at distances away from the KWB that minimize artificial influence on with and without predictions. Location of boundaries have been optimized to meet the multiple goals of properly constraining the flow model simulated with correct values of specified head or flux, and minimizing potential artificial influence of the boundaries on simulation of flow in the critical areas around the banking projects, while limiting the model and input data area to a manageable size.

To the degree possible, natural hydrologic boundaries in the study area such as persistent groundwater flowpaths and geologic boundaries have been selected so that simulated water levels could accurately respond to changing conditions without user-defined boundary condition heads or fluxes which would excessively constrain the simulations. Some boundaries have been located on the basis of both water levels and geology. Other boundaries have been selected on the basis of water level or flux irrespective of geology.

The available KCWA annual (spring) water level contour maps over 21 years (1980, 1987, 1991, 1993, 1995, and 1998 – 2010 - Appendix A) along with hydrographs for key study area wells have been reviewed to identify spatial and temporal trends in water levels. The individual spring maps between 1980 and 2010 also were digitally averaged to produce an average flow map (Figure 3-1). This map, along with the maps for individual years, has been used to assist the identification of consistent flowlines in some areas. Where contours and flowlines have been consistent over time, potential no-flow or other boundaries have been identified. However in some potential model boundary areas, local flow directions change from year to year in response to changing recharge and pumping patterns. Some model boundaries have been selected to be time-varying specified heads, to account for dynamic flux into and out of these boundaries. These boundaries have been aligned where heads were well-documented.

Figure 3-2 shows the Model Area and boundary types. Each boundary arc segment is numbered and color-coded by type for reference.

For time-varying specified head and specified flux boundaries, head and flux values will be assigned to multiple arc 'nodes' along each boundary arc. Different head or flux values can be assigned to different boundary nodes along a single arc segment, and can vary over time. Boundary heads or flux along the entire arc can then be extrapolated between the nodes. Using this approach, local variations in hydraulic gradient through the different sub-portions of the boundary arc segments can be simulated accurately. Head values used for the boundary arcs will be based on groundwater elevations measured in properly constructed wells adjacent or near to the arcs, along with regional water level maps and hydrographs. Vertical variations in boundary heads between model layers will be simulated if local water level data confirm the presence of vertical gradients between shallow and deep aquifers along the boundaries. Flux rates assigned to boundaries will be based on estimated inflows (or outflows) such as values canal leakage.

Note that during model calibration, some adjustments to boundary arc alignments, types, or values may be made in order to achieve proper calibration quality.

The lateral boundary conditions are described below. Beginning in the east, near the Kern River, boundary **Segment 1** was aligned with a generalized northwestern flowpath from the River to the north-northeast and may be represented as a no flow boundary. Average 1980 to 2010 water levels along this boundary (Figure 3-1) from south to north drop from around 280 to 160 feet msl. These are the average head values along the boundary arc; fluctuations in water levels over time occur along Segment 1 and many of the model boundaries as revealed on the annual water level contour maps (Appendix A) and KFMC hydrographs.

Segment 2 represents a time-varying head boundary along the northern edge of the model. This segment is also aligned roughly along a groundwater flow path from east-southeast to west-northwest. However, review of groundwater elevation contour maps indicates some groundwater flow occurs across this segment during some years. Dynamic flow directions occur in this area likely due to variable pumping and recharge over time. Accordingly, use of an 'open' boundary type as represented by time-varying specified heads is appropriate to allow inflow and outflow through the boundary segment. The head varies to be assigned to this boundary segment and the other time varying specified head segment will be developed based on groundwater elevations monitored over time in appropriately-constructed wells. Moderate differences in hydraulic heads are measured in between wells screened in shallow and deep aquifer zones in the vicinity of Buena Vista Water Storage District (BVWSD), Semitropic, and other areas in the northern portion of the proposed model domain. The vertical gradients reflect local recharge and pumping influences and the hydraulic resistance of the low permeability deposits including the E Clay and '300-foot Clay' present in the northern portions of the model. Vertical variations in time-varying heads may be assigned to the different model layers (see below) if head data support the presence of local vertical gradients. Average 1980 to 2010 Water levels along this boundary from range from around 160 to 100 feet msl.

Segment 3 continues west-northwest of Segment 2, and this arc represents a no-flow boundary aligned with a consistent east-southeast to west-northwest flowpath. Mapped flow directions along this boundary appear to be more consistent than in the area of Segment 2, therefore the arc alignment was parallel to the flow path. Average water levels along this boundary from east to west drop from around 100 to 70 feet msl.

Segment 4 represents a time-varying specified head boundary in the northwest portion of the model. The curvilinear arc alignment for this boundary was drawn parallel to relatively consistent groundwater elevation contours as presented on the KCWA Spring groundwater elevation maps. Based on water level data over time, groundwater outflow from the southeast to the northwest through this boundary occurs during most water years. However, during a few years inflow from the northwest to the southeast occurs. Recharge and pumping operations in the North Kern WSD and Semitropic Water Storage District (Semitropic) may affect heads along boundary Segments 2 and 4. The water banking and pumping activities of North Kern WSD and Semitropic that are outside of the Model Area can be accounted for by the time-varying heads assigned to the boundary arcs, which reflect the effects of these influences, without actually including the North Kern WSD and Semitropic activities inside the model domain. Average water levels along this boundary from range from around 80 to 60 feet msl.

Segment 5 represents a no-flow boundary in the northwest portion of the model. Groundwater flow directions along this boundary are to the northeast from the westside hills into the valley floor. Mapped flow directions along this boundary appear to be consistent over time; therefore the arc alignment was parallel to the flow path. Average water levels along this boundary from east to west drop from around 100 to 70 feet msl.

Segment 6 represents the western model boundary near Interstate 5. This boundary was created using ground surface elevations and geology and will be represented as a specified flux boundary. The flux rates represent leakage from canals and any mountain-front recharge from the southwest. Canals including the Outlet Canal, the Westside Canal, and the Kern River Flood Channel are a source of recharge that controls flow in that area. The fluxes assigned as inflow to this boundary will be based on the monthly canal losses along with natural recharge estimates. Note that water level data indicate there are some discontinuities in the area and that monitoring wells within one mile of each other on the western edge of the KWB record very different water level fluctuations (e.g., 19R and 19N). Faulting in the area may contribute to this head change. Average water levels along this boundary from range from around 170 to 200 feet msl.

Segment 7 represents the southwestern model boundary and is aligned with the northern edge of lower permeability sediments mapped as overbank and lacustrine deposits (Kern and Buena Vista Lake Beds). Mapped groundwater elevations and inferred flow directions in this area vary more than in most other areas within the model. Average water levels along this boundary range from around 160 to 220 feet msl. Large differences in hydraulic heads are measured in wells separated by relatively close distances, and between wells screened in shallow and deep aquifer zones. These head variations reflect local recharge and pumping influences and the hydraulic resistance of the low permeability deposits. Water level contour maps indicate that some groundwater is moving across the boundary. Moreover, there are transmissive sand units in this area (e.g., as logged in several wells in the Henry Miller Water District); therefore flow in this area may not be controlled by the local thick sequences of clay. Accordingly, the southern boundary was located south of the contact of the clay units to minimize the potential artificial influence of this boundary. As located, the low-permeability sediments are hypothesized to restrict the amount of flow through the southern boundary. The southern boundary is also aligned along a persistent flow divide between areas of high and low water levels. Potential revision of the southern boundary from a no-flow to specified head boundary may be considered during calibration. It should be noted that the boundary is relatively far away from the banking projects and likely will not affect model results near the KWB area.

Segment 8 represents the southeastern model boundary near the Central Branch Canal. The groundwater flow regime along with known canal loss rates at this location has been used to locate a logical boundary. Review of groundwater elevation data indicates that relatively minor groundwater inflow/outflow occurs beneath the Central Branch Canal. Water levels along this boundary range from around 180 to 280 feet msl. Heads also indicate that recharge from the canal losses creates local linear mounds with divergent groundwater flow beneath the canal. Therefore this boundary will be assigned time-varying specified flux boundary with 50 percent of monthly Canal losses assigned to the boundary arc.

Segment 9 represents a relatively short boundary segment perpendicular to the river near the Beardsley Canal and will be represented by time-varying specified flux or a time-varying specified head. Data and calculations to support the flux rates are provided in the Appendix E: Subsurface inflow and Outflow.

For the specified head and flux boundaries, estimates of associated volumetric flow into and out of the model have been made for the purposes of developing a conceptual model water balance. The methods used to quantify these and other water balance components are described further in Section 3.5.

3.1.2 Model Layers

The number and depths of layers for the numerical model have been developed with input from the KFMC, as discussed at the Project Meetings held April 18, 2012, May 10, 2012, and June 20, 2012.

Three-dimensional models like MODFLOW require discretization of the entire flow domain. The flow region is subdivided into model cells, both horizontally and vertically. The dimensions of the cells in the *x* and *y* directions are referred to as grid size. The grid size in the *x* and *y* directions should be sufficiently small to allow accurate simulation of areas of large hydraulic gradient, and the effects of sources and sinks. Vertical stacks of cells form model layers. Within each cell the various input parameters are maintained constant, but they may vary horizontally between the cells and vertically between layers.

Ultimately, the numerical model utilizes aquifer hydraulic properties (including layer top and bottom elevations, horizontal and vertical hydraulic conductivity, and storage properties) as key input parameters for each model cell and layer.

The numbers and thicknesses of constructed model layers should account for the objectives of the flow simulations (e.g., what is the depth interval of interest, what are the potential inflows and outflows from un-modeled deeper layers to the target depth interval of interest), depth of key facilities such as production wells, presence or absence of vertical hydraulic gradients, and available data. Model layers can sometimes represent major stratigraphic layers, if present. The top and bottom elevation surfaces of continuous geologic layers can be simulated, and aquifer hydraulic properties assigned to the layer. This approach can provide a relatively accurate numerical model if the hydraulic properties of the stratigraphic units are well known. If continuous stratigraphic layers are not present, model layers can be defined simply on the basis of aquifer hydraulic property distributions, well completion depths, or other parameters.

For the model, both geologic conditions and well depths have been used to define model layers. Most production wells in the study area have a maximum depth of around 700 to 800 feet. Appendix B lists the depths and perforated intervals of wells with known construction information. Figure 3-3 shows wells within the study area. Of the 3,786 wells in the study area, over 93 percent have total depths of less than 800 feet bgs. With a few exceptions, significant volumes of groundwater are not pumped below this depth.

The presence and distribution of relatively lower permeability stratigraphic layers has also been used to construct model layers. Some low-permeability confining units (such as the E Clay) appear to be laterally continuous or semi-continuous over portions of the Model Area, but the low-permeability units are generally not continuous in the KWB area. Figures 2-4 and 2-5 show the interpreted depths to the

top and thickness of the relatively low permeability unit(s) correlated to the E Clay. These relatively low permeability layers act to confine groundwater flow in deeper aquifer zones beneath the clays. Some vertical gradients are measured in the areas where the low permeability units are present, and in areas with recharge or pumping operations.

During the Project Meetings, comments were provided by KFMC members that the model layers should honor well construction and the presence of any continuous low permeability materials (e.g., the E Clay), as much as possible. Electric logs were subsequently reviewed and hydrogeologic cross sections developed to map the depths of confining units and, to the degree possible, build model layer geometries around these units. Because distribution of aquifer hydraulic properties is a critical input parameter for the numerical model, model layer development considered those wells that have high quality aquifer tests, recovery wells, and wells used for contouring depth discrete aquifer units.

At the May 2012 Project Meeting, Todd proposed an initial 3-layer model scheme with generalized layer depth ranges of approximately 0 to 300+, 300+ to 500+, and 500+ to 800 feet bgs. The elevations of the bottoms of Layers 1 and 2 would be refined based on presence and depths of confining units. Non-uniform elevations will be defined based on the depths of the lower permeability zones encountered in boreholes, to form elevation surfaces for the bottom of Layers 1 and 2. The bottom of Layer 3 will be set to a constant depth of 800 feet bgs. The upper layer will be unconfined and have variable saturated thickness. Layers 2 and 3 will be confined/convertible. Aquifer hydraulic properties will be assigned to each layer based on normalized hydraulic conductivities from high-quality pumping tests and specific sand intervals at locations with high quality lithologic information (see Section 3.2).

The hydrostratigraphy of the central Model Area can be conceptualized as a three-layer system. Geophysical and lithologic logs generally exhibit an upper higher permeability alluvial package that extends down to around 300 feet (Model Layer 1), a series of interbedded sands and silty clays down to about 550 feet or 600 feet (Model Layer 2) and a lower-permeability section extending to the bottom of most logs with total depths of around 700 feet (Model Layer 3). Deeper wells to the north indicate that the third zone transitions into a much higher resistivity zone at about 800 feet, providing the justification for the bottom of the model. Figure 3-4 shows locations of the hydrostratigraphic cross sections presented on Figures 3-5 through 3-10. These cross sections illustrate the locations of the model layer boundaries, the range of historical groundwater elevations along the cross sections, and the depth and distribution of the E Clay as reproduced from USGS contour maps. As illustrated on the cross sections, the three-layer model generally incorporates the lower permeability E Clay within model Layer 2. A small portion of the E Clay extends into Layer 3 near the southwestern boundary of the model.

In order to identify the specific depths of the contacts between the upper unconfined zone and middle confining zone, where present, geophysical resistivity logs and construction data have been reviewed for wells identified as having high-quality aquifer test information, and a methodology has been devised for developing model layers. Figure 2-6 shows an example geophysical log from the Pioneer Project annotated to show major changes in lithology. In addition, sand and clay intervals for these same wells were tabulated for use in characterizing hydraulic conductivities of the sands (Section 3.2).

Table 3-1 lists the depths of the three hydrostratigraphic zones identified in the geophysical logs evaluated for this project (including those wells with high quality aquifer test results available). Model

layer elevation surfaces (i.e., the bottom elevation of the upper unconfined alluvial sand zone, Model Layer 1, and the bottom of the interbedded lower permeability zone, Model Layer 2) were then constructed on the basis of these point elevations. Although the first approximation of model layers was based on connection and extrapolation of these hydrostratigraphic contact points, the model layer elevation surfaces were smoothed somewhat to provide layer bottom surfaces without large discontinuities. During this process a number of numerical interpolation methods were tested and some outlying contact elevation points were removed in order to construct layer surfaces. Ultimately, an inverse-distance weighted interpolation method was applied. The resulting layer elevation surfaces honor the hydrostratigraphic data and present functional surfaces for use in the numerical model.

Figures 3-11 through 3-13 show the final interpolated surfaces for the bottoms of Model Layers 1, 2, and 3, respectively. In all areas except near a portion of the northwestern boundary arc (Segment 4), the bottom of Layer 1 is located below the low water table, in order to maintain saturation during MODFLOW simulations (see below). Elevations of the bottom of Layer 1 (Figure 3-11) range from about -10 to 120 feet msl. Elevations of the bottom of Layer 2 (Figure 3-12) range from about -330 to -190 feet msl. Comparison of the top and bottom elevations of model Layer 2 with previous interpretations of the elevation of the E Clay (Figures 2-4 and 2-5) reveal that the confining unit is predominantly contained within Model Layer 2. The bottom of Layer 3 is set at a constant depth of 800 feet bgs. Elevations of the bottom of Layer 3 range from about -510 to -370 feet msl.

The thicknesses of each model layer have been calculated based on the top and bottom elevation surfaces. Layer 1 represents the unconfined alluvial zone and its saturated thickness fluctuates over time with the water table. To assess the approximate range of saturated thickness of Layer 1, the difference between the estimated "low" water table (representing historical low water levels as measured across the Model Area) and the Layer 1 bottom elevation surface was calculated. Similarly, the maximum thickness has been estimated as the difference between the "high" water table (representing historical high water levels as measured across the Model Area) and the Layer 1 bottom elevation surface.

Figures 3-14 and 3-15 show the saturated thickness of the shallow unconfined aquifer during these two periods. During dry conditions, the saturated thickness ranges from about 180 to 0 feet (Figure 3-14). Based on the estimated low water table, the area around the northwest model boundary (Segment 2) has minimal thickness. This may be due to the use of water levels from wells completed in the deep aquifer zone, which have lower hydraulic heads than the overlying shallow zone. Accordingly, higher boundary head values may be used and/or the bottom elevations for Layer 1 may be reduced slightly to maintain saturation of Layer 1 in this area. During wet periods, the saturated thickness of Layer 1 ranges from around 280 feet in the KWB area to 60 feet in the northern Model Area (Figure 3-15). Figures 3-16 and 3-17 show the thickness of Model Layers 2 and 3. The thickness of Layer 2 ranges from around 240 to 340 feet, while the thickness of Layer 3 ranges from around 260 to 160 feet. It is recognized that some newer production wells (e.g., Vaughn Water Company wells) north of the river have been drilled as deep as 1,200 feet to 1,400 feet. Because the maximum depth of the model is 800 feet, the portion of production from such deep zones below 800 will be excluded from the model.

These elevations and thickness will form the geometrical framework of the numerical flow model. Aquifer hydraulic properties including heterogeneous horizontal and vertical hydraulic conductivities, specific yields, and storage coefficients will be assigned to each model layer as discussed below.

3.1.3 Model Calibration Period

Selection of the historical model calibration period has been based on multiple considerations. These include the availability and reliability of key data sets compiled for the site conceptual model, and the need to simulate variable wet and dry conditions in order to validate the predictive model. In addition, the transient simulation period needs to be sufficiently long to simulate conditions before operation of the major banking projects (primarily beginning in about 1993) and is best initiated when water levels are relatively stable. Also, it may be beneficial to initiate the model after a relatively dry period that has allowed the vadose zone to drain. Finally, selection of a simulation period should account for uncertainties in model initial conditions, and allow sufficient model time for the simulation to 'attenuate' any errors caused by initial conditions.

The numerical flow model requires numerous input parameters, which are not well documented prior to 1986. The data sets improved significantly in 1986, another factor that entered into the model period recommendation. There are no water level data in the KCWA water level database prior to 1986; this database represents the most comprehensive compilation of consistently monitored wells in the basin and will be key data for model calibration. Prior to 1986 the only water level data available are from the Department of Water Resources (DWR) and these are sparse. Even in the (DWR) database, the number of wells appears to increase significantly in 1986.

Based on these criteria, a simulation period of 1986 through 2010 has been selected. Rationale for the 25-year period selection included the timing of banking projects, wet and dry hydrologic cycles, about three years of relatively stable water levels for initial conditions, and data availability. Recharge at the KWB and at other recharge facilities began in the mid-1990s, so inclusion of the earlier period beginning in 1986 allows evaluation of calibration quality before initiation of banking. Figure 2-1 shows annual precipitation data (presented on a calendar year basis) and a portion of the long-term (1890-2010) cumulative departure curve. Several wet and dry cycles occurred over the 25 year study period. The post-1986 time period precedes a major drought, with a very dry period occurring in 1990 and 1991, while relatively wet periods occurred in the late 1990's. Dry conditions returned in the late 2000's approaching the end of the historical simulation period. Simulation of these alternating dry and wet cycles allows validation of the model under differing recharge conditions.

3.2 Kern Fan Hydrostratigraphy

3.2.1 Distribution of Coarse and Fine-Grained Deposits

The distribution of coarse and fine-grained deposits across the study area has been characterized on the basis of lithologic and electrical logs, interpretations of stratigraphic and lithologic databases created by the KCWA and USGS, aquifer pumping test results, and published geologic studies, cross sections, and maps. The geologic information is summarized in Section 2, and references for the various stratigraphic studies and data are provided in Section 4. Several of the previous geologic studies have been used to

develop the model layer geometries for the numerical model. These data are also used to characterize and quantify aquifer hydraulic properties.

For this project, a methodology has been developed to simulate the distribution of coarse and fine grained deposits, and their aquifer hydraulic parameters in the numerical model. The distribution of these key model input parameters is based on the distribution of coarse and fine deposits more than 220 electrical resistivity logs from wells across the study area, along with aquifer hydraulic parameters from high quality pumping tests.

3.2.2 Aquifer Hydraulic Properties

Aquifer hydraulic properties are important input parameters for the numerical model. The key parameters are vertical and horizontal *hydraulic conductivity*, measures of the aquifer permeability, and *storage coefficients*, which affect the dynamic aquifer response to transient stresses such as recharge and pumping. These parameters, along with the aquifer and model layer thickness, form the physical framework or 'plumbing' of the groundwater system and the numerical model.

Some estimates of aquifer hydraulic properties within the study area previously were made from well pumping tests. Pumping test data and results have been obtained from KCWA, participating water Agencies and Districts. Additional estimates of hydraulic properties were made using undisturbed core samples from boreholes.

For most of the pumping tests, aquifer *transmissivity* was estimated. Transmissivity is the rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient. Transmissivity divided by the saturated thickness of aquifer is equal to the horizontal hydraulic conductivity. While a constant rate, long-term pumping test is the best method of determining transmissivity, it can also be estimated based on the ratio of pumping rate of the well and the observed drawdown (specific capacity). Storage properties of the aquifer include *specific yield* for unconfined aquifers and *confined storage coefficient* or *specific storage* (equivalent to storage coefficient divided by the saturated thickness of aquifer) for confined aquifers.

Aquifer hydraulic properties vary spatially across the study area because of the different sedimentary environments and dynamic geologic history of sediment deposition in the Central Valley. Well-sorted, coarse-grained sands have higher hydraulic conductivity and storage coefficients than fine-grained silts and clays. Because both types of geologic materials (coarse and fine-grained) are present in the Model Area and their distributions vary laterally and with depth (Section 2), an accurate representation of the distribution of these aquifer parameters must be developed. Representative three-dimensional distributions of these hydraulic properties allow accurate model predictions of the aquifer hydraulic response to dynamic recharge and pumping.

The approach and methodology for representing aquifer hydraulic parameters in the numerical model has been developed in conjunction with the KPMC, as discussed at the Project Meetings held April 18, 2012, May 10, 2012, and June 20, 2012. Each of the three model layers described in Section 3.1 will be 'populated' with hydraulic conductivities and storage parameters. The model will contain true-layer elevations for the top and bottom of each layer along with assigned hydraulic conductivities and storage parameters representing a composite value for the layer. Aquifer pumping test transmissivity results

along with borehole lithologies (sand and silt/clay intervals) at different locations within the Model Area will be used to estimate the distribution of horizontal hydraulic conductivities for each layer. Vertical hydraulic conductivities will be estimated initially on the basis of the presence or absence of clay layers and core sample permeameter tests. Storage coefficients will comprise specific yields for the uppermost aquifer and fully-confined or 'mixed' storage coefficients for the deeper layers.

The following sections describe the methodologies and results for estimating the distribution of hydraulic conductivities and storage parameters.

Aquifer Transmissivity and Horizontal Hydraulic Conductivity

Aquifer transmissivity values from high quality pumping tests were used to estimate horizontal hydraulic conductivities of the sand fraction at each test well location. Composite hydraulic conductivities at different locations were then developed based on the normalized hydraulic conductivities and actual percentages of coarse and fine aquifer materials at different locations.

Figure 3-3 shows the locations of wells in the study area, indicating those with pumping test data. The most accurate aquifer transmissivity values are from wells with high quality constant-rate pumping tests with observation wells and correct data analyses. The highest quality transmissivity values are from constant-rate pumping tests with observation wells performed on ID4 wells at Allen Road, Rosedale ENNS Pond Wells, Strand Ranch wells, and West Kern wells. For this set of tests, both drawdown and recovery data from pumping and observation wells were evaluated. Additional good quality tests were performed by KCWA on wells around the KWB. This set of tests involved single-well constant-rate pumping tests with 24-hour durations. Water level recovery data from the pumping wells were analyzed to estimate aquifer transmissivities. Of similar good quality were a third set of pumping tests and estimated aquifer transmissivities provided by the KFMC. Aquifer transmissivities for these high and good quality test wells range from 2,270 to 110,000 square feet per day (ft^2/day - Table 3-2). The average transmissivity is about 20,080 ft^2/day .

Figure 3-18 shows the distribution of transmissivity values estimated from high quality aquifer tests. Relatively high transmissivities are present in the center of the alluvial fan and KWB area; generally lower transmissivities are mapped in the northern and southern portions of the Model Area.

After discussion with the KFM, it was determined that aquifer transmissivities estimated from specific capacity values are of relatively lower quality, and would need to be normalized for the test duration and well screen interval. Therefore, these lower quality data have not been used to estimate horizontal hydraulic conductivities.

Using the reliable pumping tests as a baseline, hydraulic conductivity of the sand intervals for each test well has been estimated as follows. For each reliable pumping test, the electrical resistivity logs were reviewed and sand intervals identified. The total saturated sand thicknesses for each reliable test well were summed and the estimated transmissivities were divided by the total sand thickness to obtain a horizontal hydraulic conductivity for all sand layers at each well. This approach assumes that the inflow to the pumping well occurs via the sand intervals only, and that the horizontal hydraulic conductivity of each sand interval is the same. Using the normalized hydraulic conductivities and fractions of sand and lower permeability silts and clays, the hydraulic properties were further partitioned by model layer. The

horizontal hydraulic conductivity at each well for each layer was scaled based on the percentage of saturated sand logged in each depth interval. The resulting composite hydraulic conductivities for each model layer were reduced (scaled) based on the percentage of sand in each layer. Using this approach, the total aquifer transmissivity at each test well has been preserved and partitioned by model layer.

The analysis of sand fractions and calculation of hydraulic conductivities and scaled conductivities by layer is underway, but not complete. Representative values of horizontal hydraulic conductivity for the sand fraction from the analyses range from around 10 to 100 feet per day. The final analyses and hydraulic conductivity distribution used in the numerical model will be fully documented in Technical Memorandum No. 2.

Vertical Hydraulic Conductivity

Vertical hydraulic conductivities are generally lower than horizontal hydraulic conductivities. This is due to the stratified nature of alluvium: sediment grain imbrications that cause lower pore connectivity in the vertical direction as compared with horizontal, and the presence of discrete fine-grained silt and clay layers on both micro and macro scales. In areas where relatively continuous fine-grained stratigraphic layers (such as the E Clay shown in Figure 2-4) are present, vertical groundwater flow is impeded due to the low vertical permeability. The USGS has reported permeameter data from core samples of the E Clay; the average estimated vertical hydraulic conductivity of the E Clay is around 0.0004 feet per day. In such E Clay areas, vertical head differences exist between the shallow and deeper aquifer zones.

The numerical model must be able to simulate both horizontal and vertical groundwater flow. A three-dimensional distribution of vertical hydraulic conductivity will be developed during model calibration. Zones of vertical to horizontal hydraulic conductivity anisotropy ratios will be mapped, in part based on the distribution of coarse and fine grained deposits, and adjusted during calibration. In areas where coarse-grained deposit predominate, higher vertical-to-horizontal hydraulic conductivity anisotropy ratios will be simulated.

Storage Coefficients

Both unconfined and confined aquifer storage properties have been tabulated from published studies (USGS, DWR, and others), aquifer pumping tests, laboratory tests, and previous modeling of the KWB. Table 3-2 lists the storage coefficients estimated for high-quality pumping tests performed on West Kern and Strand Ranch wells. These confined or 'mixed' semi-confined storage coefficients range from around 0.0008 to 0.03 (unitless), and are appropriate for simulation of the semiconfined and confined model Layers 2 and 3. For the unconfined aquifer zones (Model Layer 1), specific yields will be used. Table 3-3 lists a range of specific yield values for different soil classifications (sand, clayey sand, etc.) in the Central Valley. Coarse-grained materials such as sand without fines have the highest specific yields (up to 35 percent), with lower values for finer-grained materials. The DWR has averaged measured specific yields in four Townships within the study area and reported averages of between 10 and 14 percent. Specific yields in the KWB area were also estimated as a part of the early DWR Kern Fan Groundwater Model. Heterogeneous distributions of specific yield were developed for that three-layer MODFLOW model; specific yields for the final model ranged from 12 to 21 percent. Note that a specific yield value of 0.15

has been used for the change in storage estimates developed for the preliminary water balance presented in Section 3.4.

As with hydraulic conductivity, three-dimensional distribution of specific yield and storage coefficients will be developed during model calibration. Zones of specific yield and storage coefficients will be mapped, in part based on the distribution of coarse and fine-grained deposits, and adjusted during calibration.

3.3 Groundwater Occurrence and Flow

Groundwater elevation data have been evaluated across the Study Area in order to assess horizontal and vertical hydraulic gradients, to define groundwater flow rates and directions, to estimate subsurface inflow and outflow, and to evaluate change in storage over time. Water level data also have been used to locate and align the model boundaries (Section 3.1.1). Water level data from a subset of these wells will be used to assess model calibration quality.

3.3.1 Groundwater Levels

Water level databases have been obtained from the KCWA and DWR. The KCWA began a water level monitoring program in 1980. Groundwater monitoring of selected wells in the study area has been conducted on a monthly or semi-annual basis, with creation by KCWA of annual (Spring) water level contour maps. These maps, along with hydrographs for key wells in the KWB area, are reported in the Annual Operations Reports prepared by the KPMC. Figure 3-3 shows wells in the study area; many of these wells have reported water level data and are used in the groundwater flow evaluation.

3.3.2 Groundwater Flow

Horizontal flow conditions are characterized with the KCWA Spring groundwater elevation contour maps. As described above, an average Spring water level map has been created to demonstrate overall flow conditions (Figure 3-1). Annual (spring) groundwater elevation contour maps for individual years are included in Appendix A.

As illustrated on the average and annual water level maps, groundwater generally flows from natural and artificial recharge areas toward discharge points. For any given period, the highest groundwater elevations generally occur near the eastern model boundary as a result of subsurface inflow from the river valley and infiltration from the River and adjacent canals. A divergent groundwater flow divide typically coincides with the Kern River channel with flow away from the river. Groundwater flow across the southern portion of the study area is generally from north to south, with local perturbations around local recharge and pumping sources particularly in the southernmost areas of the model. Groundwater flow through the northern portion of the study area is generally from southeast to northwest, away from the River and KWB and toward Semitropic Water Storage District.

Review of the annual water level contour maps reveals the fluctuations in water levels from year to year. Overall increases and decreases in basin storage are correlated to annual recharge fluctuations, and local changes in groundwater elevation occur that are associated with specific recharge and

pumping facilities. These groundwater elevation fluctuations have been used to estimate the changes in groundwater storage for comparison with the water balance (Section 3.4).

The range of groundwater elevations over the study period is illustrated on the cross sections (Figures 3-5 through 3-10). As illustrated on the cross sections, during periods of high groundwater, the water table is sometimes near the ground surface along the western and southern model boundaries, and depth to water beneath the KWB is less than 50 feet. In other areas and during dry periods, depth to water exceeds 300 feet. This range of water levels reflects the dynamic nature of recharge and pumping in the study area.

Water level changes over time are also documented on hydrographs prepared by the KFMC and included in the Kern Fan Area Operations and Monitoring Reports. Changes in water levels over time and by depth are documented in these hydrographs from key wells.

Vertical hydraulic gradients are present in several portions of the study area. Downward vertical gradients have been measured beneath and adjacent to some of the recharge ponds, and in other areas where fine-grained confining units are present. Vertical hydraulic gradients are present in several areas. These areas include the northernmost and southernmost portions of the model and generally correspond to locations where fine-grained confining units are present. At some locations, the magnitude of the vertical hydraulic gradient exceeds that of horizontal gradients. Vertical hydraulic gradients present near the KWB are measured in “nested” well pairs within and between the Shallow and Deep aquifer zones.

Water level elevation data will be used to assess model calibration. Maps and hydrographs of measured and simulated water levels in space and time will be developed, and some water balance elements including boundary inflow and outflow and change in storage will be compared with the estimates developed as a part of the conceptual model water balance.

3.4 Water Balance

In order to better understand the volumes of water moving through the groundwater system and to develop inputs for the numerical model, a water balance has been developed for the Model Area. The water balance presented in this section accounts for inflows and outflows to groundwater, the subtraction of which represents changes in groundwater storage over time. The balance presented herein does not provide for spatial variation, which will be handled in the numerical model by assigning appropriate portions of the inflows and outflows to the corresponding locations. The water balance represents a first approximation of changes in groundwater storage that will be further assessed during model development and calibration. A summary of water balance components are shown on Table 3-4.

Data have been compiled monthly for model input; annual totals are summarized here to illustrate the annual average and cumulative change in groundwater storage in the Model Area for the entire Study Period. The data and methodology are described for each of the water balance components below.

3.4.1 Inflows

Inflows into the groundwater system include subsurface inflow, deep percolation from precipitation, return flows from agricultural and municipal uses, canal losses, and managed recharge including groundwater banking. Each inflow component is described briefly below, followed by a presentation of the data from 1986 through 2010.

3.4.1.1 Subsurface Inflow

Groundwater flow occurs into and out of the model area through lateral boundaries. As described in Section 3.1.1, time-varying specified head and specified flux boundaries allow subsurface flow into the model. The areas of inflow and methodology used to calculate the amounts over time are provided in Appendix E. As summarized in Table 3-4, the estimated rate of inflow varies over time, with a range from zero (in 2000) to 15,556 AFY (in 1991).

3.4.1.2 Recharge from Rainfall

For the purposes of this water balance, recharge from rainfall has been subdivided into several different inflow components of the water balance. Percolation from rainfall on areas with native vegetation has been estimated using a simple soil moisture balance, as documented in Appendix C. Percolation occurs only in very wet years: 1995, 1998, and 2010, and as shown in Table 3-4, total volumes of rainfall recharge are small. It should be noted that rainfall on agricultural areas and municipal areas are included in the irrigation return flows and municipal return flows (see sections below).

3.4.1.3 Irrigation Return Flows

This inflow component accounts for the portion of irrigation water that is applied in excess of the evapotranspiration (ET) of the crop, as well as excess precipitation that either percolates directly or runoffs and percolates in nearby areas (defined herein as irrigation return flows). For agricultural areas, individual crops are associated with different amounts of return flows based on crop ET and irrigation efficiencies. The methodology used to develop agricultural demand including crop ET and documentation of irrigation efficiencies used in the analysis are described in more detail in Appendix D. Irrigation return flows include irrigation from both surface water and groundwater. The irrigation return flows for urban areas, including lawns and swimming pools used by individual homeowners, are developed separately based on municipal water demands and are summarized in a subsequent subsection as *municipal return flows*. Table 3-5 shows the estimated irrigation return flow for agricultural areas by Water District and service area. Figure 3-19 shows the Water Districts and Service Areas.

It is recognized that return flows do not recharge groundwater immediately upon application of irrigation, and various scenarios of vadose zone transport times have been evaluated. For accuracy in the groundwater model, the MODFLOW UZF package will be employed to develop an appropriate lag time for recharge of irrigation return flows over the Model Area. For the purposes of this water balance,

no lag has been incorporated. Recognizing that most of the Model Area has consisted of irrigated agriculture throughout the entire Study Period, a relatively steady state of recharge has likely been established, although actual amounts may vary temporally with changes in crop and irrigation patterns. The water balance is being used as a first approximation for the groundwater system that will be modified in the groundwater model. Therefore, an annual water balance that does not provide for a time lag of irrigation return flows is judged sufficient for the purposes of the water balance in this TM.

3.4.1.4 Municipal Return Flows

Some water supplies to municipal users are applied as urban irrigation and other recreational uses. Based on estimates in the Bakersfield area, 50 to 70 percent of municipal supply is used outdoors in some capacity. It is assumed that 12 percent of the outdoor use recharges the aquifer as return flow.

This evaluation of return flows addresses only municipal use of groundwater. It is recognized that river water and SWP water also provide a portion of the municipal supply. The water balance addresses the return of water used indoors through wastewater return flows. Percolation of outdoor uses of surface and imported water is small (on the order of 7 percent of surface water and imported water urban use) and has not been included in the water balance because of the level of complexity to estimate monthly returns compared to the order of magnitude of other components in the water balance. Municipal return flows (percolation) from outdoor uses are shown on Table 3-6.

3.4.1.5 Canal and River Seepage

Many of the canals and part of the Kern River used to transport water in the area are unlined, and leakage from these canals contributes to the underlying groundwater aquifer. Figure 3-20 shows the location of the major unlined canals.

Seepage losses have been calculated based on the difference of flow between various points less deliveries. Monthly canal losses are reported in the Kern River Annual Reports for the major canals in Kern Delta Water District, City of Bakersfield, North Kern Water Storage District, Rosedale Ranch, Cawelo, and the former James Pioneer Irrigation District. Losses along the Kern River are also reported in the Kern River Annual Reports for several reaches. Canal losses were also supplied by Semitropic Water Storage District and Buena Vista Water Storage District for canals in their service areas. The portion of the canal losses that occur within the Model Area have been estimated to be equivalent to the portion of the canal that overlies the Model Area. For the Kern Island Service Area of KDWD, canal losses for the entire service area were divided over the Kern Island canal and the Central Branch canal based on the total length of these canals. The Central Branch canal is located on the model boundary and it has been assumed that one half of losses occurring here recharge the model, while the remaining half does not enter the Model Area. Table 3-7 and Figure 3-21 show annual canal losses by major canals.

3.4.1.6 Enhanced Recharge and Banking

Enhanced recharge and banking is performed in the area by multiple water agencies through various mechanisms (canal spreading, recharge ponds, and in lieu supplies). For the purposes of this TM, no distinction is made between enhanced recharge conducted by water agencies and others to simply increase groundwater resources and more formal banking projects where water is recharged on behalf

of an outside party for the purposes of recovery. For future modeling of the groundwater condition without banking projects a distinction will be required. Because the array of recharge and banking projects covers the entire spectrum of recharge mechanisms, number of participating parties, and recovery methods, this distinction must be well defined and accepted by the technical committee.

Monthly recharge data have been received from the Kern Water Bank Authority for the KWB recharge by individual ponds from 1995 to 2011. Annual recharge data (along with recovery data) are shown on Figure 3-22. KCWA provided monthly recharge for the Pioneer Project and Berrenda Mesa Project from 1995 to 2011. Annual recharge data (along with recovery data) are shown on Figures 3-23 and 3-24, respectively. The Kern River Annual Reports contain monthly recharge volumes for COB projects with the Model Area (including the COB 2,800 facility, Truxtun Lakes, The Park at River Walk, and Aera Park); annual banking recharge volumes for the COB 2,800 facility are summarized on Figure 3-25. Kern River Annual Reports also contain monthly intentional recharge data for NKWSD, Rosedale Ranch ID, and KDWD banking data. Additional recharge data have been provided by various water districts for their respective recharge projects including KDWD, Semitropic WSD, RRBWSD, BVWSD, and WKWD. Annual recharge data for RRBWSD, BVWSD, and WKWD are summarized on Figures 3-26, 3-27, and 3-28, respectively. Table 3-8 shows the annual recharge by major project and Figures 1-2 and 1-3 show the general locations of the recharge facilities.

3.4.1.7 Wastewater Discharge

Several wastewater treatment plants (WWTP) serve the metro Bakersfield area. Two WWTPs are within the Model Area. These are the City of Bakersfield WWTP #3 and the North of the River Sanitary District #1 WWTP as shown on Figure 1-4. Discharge from these two WWTPs also occurs within the Model Area and is discussed in this section.

Other WWTPs operate within the metro Bakersfield region but are outside the Model Area. These include the City of Bakersfield WWTP #2 and the Kern Sanitation Authority WWTP, which are just east of the model's eastern boundary, and the Shafter-Minter Field WWTP which is just north of the model's northern boundary. Discharge from these WWTPs is not included in the water balance because it occurs outside the Model Area. Wastewater infiltration from individual septic systems may also occur within the model boundaries but volumes are likely to be small and inconsequential compared to the other water balance components. They were not included in the water balance.

City of Bakersfield WWTP #3

WWTP #3 serves the City of Bakersfield area that lies west of Highway 99 while WWTP #2 serves the area east of Highway 99. WWTP #3 is between McCutchen Road and Highway 119 to the north and south and between Ashe and Gosford roads to the east and west. During the 1986-2010 Study Period, plant capacity doubled from 8 million gallons per day (MGD) to 16 MGD. Since 1989, most effluent has been piped to a site called Green Acres Farm just west of Interstate 5 for irrigation. When irrigation demands are low in the winter, effluent is discharged to four onsite ponds for storage and percolation.

The City has provided monthly effluent flow data for 2000 through 2010. Annual effluent flows for 1986 through 1999 were estimated using population growth trends and a typical per capita effluent flow rate. Annual flows were divided evenly over each 12-month period.

Between 1986 and 1988, it was assumed that all effluent went to the onsite ponds. An onsite pond infiltration rate of 900 AF/month was estimated from a groundwater conditions study of WWTP #3 by Schmidt (July 2006). For 1989 through 2010, all effluent discharged between February and September went to Green Acres Farm. October through January effluent went to the onsite ponds first (up to a percolation rate of 900 AF/month) with the remainder going to Green Acre Farms. An irrigation efficiency of 80 percent was assumed for Green Acre Farm irrigation, the same as the rest of the Model Area irrigation. This results in 20 percent agricultural return flows for the applied effluent.

North of the River Sanitary District #1 WWTP

The North of the River Sanitary District #1 (NORS) WWTP is located within the City of Shafter and treats wastewater from the Oildale Mutual Water Company and the City of Shafter service areas. As of 1990, the City owns one-third of the plant's 7.5 MGD capacity. Wastewater is used to irrigate crops near the current plant location (Figure 1-4). Onsite ponds are used for winter storage and percolation.

Annual effluent volumes for 1998-2001 and 2008 are available from KCWA annual reports. Data for 2010 were obtained from the Tulare Lake IRWMP. Annual effluent flow between 2002 and 2009 was assumed to increase linearly. Effluent flows between 1986 and 1997 were estimated using population growth trends and a typical per capita effluent flow rate. Annual flow was then divided up evenly over each 12-month year. The effluent was then assumed to be available for local irrigation.

3.4.2 Outflows

The primary components of outflow from the Model Area include groundwater pumping and subsurface outflow. For the purposes of the water balance, several types of groundwater pumping are defined separately. Groundwater pumping amounts for recovery at the major banking projects have been documented by the operators of each project. Groundwater pumping for municipal and industrial purposes by the City of Bakersfield, Cal Water, and various smaller mutual water companies has been provided at various levels of detail by each purveyor. Groundwater pumping amounts by water districts for supplemental irrigation deliveries have been generally available from various data sources. The actual amount of agricultural irrigation groundwater pumping by private well owners in the Model Area is unknown and requires additional analysis.

Each component of outflow is described briefly below, followed by a presentation of the data from 1986 through 2010.

3.4.2.1 Groundwater Pumping for Banking Project Recovery

Groundwater that has been recharged or banked is recovered either by dedicated recovery wells or through increased production for municipal or agricultural supplies. For TM-1, recovery pumping includes only dedicated recovery wells. The banking projects with dedicated recovery wells include KWB (Figure 3-22), Pioneer Project (Figure 3-23), and Berrenda Mesa Project (Figure 3-24). Monthly pumping records by well have been provided by the KWB Authority and KCWA for these banking projects for 2001 through 2011 and annual data provided from 1996 to 2000. Table 3-9 shows the recovery pumping by general banking project. Other recharge projects (including COB 2800 acres and West Kern Water

District) do not differentiate banking recovery pumping from municipal use pumping and those amounts are included in the section on municipal pumping.

3.4.2.2 Agricultural Groundwater Pumping

The amount of groundwater pumped to satisfy agricultural demand has been estimated by first calculating the total crop demand for all agricultural irrigated areas. The amount of surface water used to meet a portion of this crop demand has been subtracted from the total (corrected for irrigation efficiencies) to estimate a remaining crop demand satisfied with groundwater. The sources of the surface water subtraction include all surface water deliveries to crops including local Kern River water, imported water, or groundwater pumped by agencies and delivered through surface facilities. Because this analysis has been conducted in several steps that involve numerous data types, the details of this analysis are presented in Appendix D.

The results of the analysis, the agricultural demand that is satisfied by private groundwater pumping, is shown by Water District and Service Area in Table 3-10 (Figure 3-19 shows the areas of these Water Districts and Service Areas). The estimated amount of irrigation demand supplied by groundwater and surface water in the Model Area is shown on Figure 3-29. The exact location of this local pumping is not well known. In most cases, a private well is used to supply a relatively small amount of water. Some water districts have inventories of private agricultural wells while others do not. For the purposes of the model, estimates on the distribution of pumping will be made based on the model cell size and magnitude of pumping per cell.

As noted above, additional groundwater is pumped by Water Districts and supplied to agricultural land through surface facilities. Total groundwater pumping by these districts (BVWSD, Semitropic WSD, and NKWSD) is available from BVWSD, Semitropic WSD, and the Annual Reports respectively. The amount of pumping within the Model Area has been estimated based on the percent of wells with the Model Area. The estimated groundwater pumping by District is shown on Table 3-11.

3.4.2.3 Municipal Groundwater Pumping

Municipal water is served in the Model Area by three major purveyors (California Water Company, City of Bakersfield, and Vaughn Water Company) and several smaller purveyors. The service areas of the water purveyors and water districts are shown on Figure 1-4. Municipal supplies include groundwater, surface water, and imported water sources. This section focuses on groundwater pumping for municipal use. Figure 3-30 presents annual municipal pumping by purveyor over the Study Period. For the purposes of this water balance, municipal groundwater pumping includes all groundwater uses other than agricultural irrigation. The water balance includes subtraction of pumped groundwater for municipal uses and addition of municipal use return flows (in the form of percolation) from wastewater (see Section 3.5.1.7) and through percolation of water used for irrigation of lawns, car washing, and other outside uses (see Section 3.5.1.4).

Most of the municipal pumping occurs in the eastern portion of the model. The water balance includes pumping from the purveyors listed below. Recent (2010) pumping is listed followed by the general range of groundwater pumping that occurred during the Study Period.

- California Water Company – 45,700 AFY (44,000-74,000 AFY)
- City of Bakersfield – 37,400 AFY (14,500-45,500 AFY)
- West Kern Water District – 21,700 AFY (9,600-28,300 AFY)
- Vaughn Water Company – 11,500 AFY (3,800-12,800 AFY)
- City of Shafter – 4,700 AFY (3,100-5,300 AFY)
- Greenfield County Water District – 2,300 AFY (870-2,600 AFY)
- North of the River Municipal Water Company – 400 AFY (0-1,000 AFY)
- Stockdale Mutual Water Company – 230 AFY (180-280 AFY)
- Buttonwillow County Water District – 210 AFY (160-210 AFY)
- Oildale Mutual Water Company – 150 AFY (0-2,100 AFY)
- Stockdale Annex Mutual Water Company – 120 AFY (90-140 AFY)

West Kern Water District municipal wells are within the Model Area, although almost all of the district lies outside the Model Boundaries. Recent pumpage has amounted to about 22,000 AFY. This pumping has been included in the water balance, but return flows have not because they occur outside the Model Area.

Some private domestic wells most likely pump within the Model Area but net consumption of this water is small and within the error of other water balance numbers. Because of the lack of documentation of this pumping and its likely insignificant volumes, it has not been included in the water balance.

Groundwater provides most of the area's municipal supply, which is replenished locally from natural recharge, canal seepage, spreading basins, and recycled water. The use of treated imported SWP water has increased in recent years with the expansion of local water treatment plants. The following text discusses groundwater pumping by purveyors within the Model Area.

California Water Service Company (Cal Water)

Cal Water is the largest municipal water supplier in Bakersfield. Their system serves a large portion of the City and segments of unincorporated lands adjacent to the City (encompassing about 49 square miles and a population of about 225,000) (Figure 1-4). Groundwater has historically supplied up to 80 percent of Cal Water's demands with surface and imported water making up the remainder. In 2011, Cal Water operated about 115 active wells with a design capacity of 142,000 AFY. About 14 percent of these wells are within the Model Area.

Cal Water has provided monthly production by well for the 2000 through 2010 time period. Data between 1986 and 1999 have been provided in the form of handwritten monthly production sheets. These data have been hand entered into the database and consist of over 28,000 lines of data. Only pumpage from wells within the Model Area have been used in the water balance. Also, only outside return flows from the 48 percent of the Cal Water service area that is inside the Model Area have been included. Inside return flows are incorporated within the wastewater return flows.

City of Bakersfield Water System (City Water System)

The City's Water System service area covers about 35 percent of the western portion of the Bakersfield (about 38 square miles) and provides water to a population of about 118,600 (Figure 1-4). Similar to Cal

Water, the City relies on a variety of water sources including groundwater, Kern River water, and imported SWP water. The City has contracted with Cal Water to operate its water distribution system. Groundwater supply is pumped from approximately 50 active groundwater wells within City boundaries. The City has provided monthly data by well for 1988 through 2010, while annual pumping totals are available for 1986 and 1987. The pumping distribution (by well and by month) in 1988 has been applied to 1986 and 1987.

Vaughn Water Company (VWC)

Vaughn Water Company has provided municipal water supply to the northwest portion of the City of Bakersfield and to areas of Kern County since 1928 and currently serves more than 9,300 connections (Figure 1-4). Groundwater is the only source of supply. In 2010, VWC pumped about 11,400 AFY from 12 production wells. VWC has provided monthly pumping data by well for 1992 through 2010. Only annual totals are available for 1987 through 1991, so pumping has been distributed to the same wells at the same percentages as in 1992. Pumping in 1986 is assumed the same as 1987.

West Kern Water District (WKWD)

WKWD has eight groundwater wells within the Model Area. WKWD provided monthly pumping by well from July 1998 through 2010 and monthly system totals from 1986 through 1998. While all of the WKWD wells are located within the Model Area, the service area lies almost entirely outside the Model Area. For this reason, municipal return flows are not included in the water balance.

City of Shafter (Shafter)

The City of Shafter is about 15 miles northwest of metropolitan Bakersfield and serves a population of about 18,200. Customers include those within Shafter City limits as well as some surrounding unincorporated County customers. Shafter currently has seven wells and groundwater is the sole source.

Shafter has provided 2002 through 2010 monthly totals but does not have monthly pumping by well information. Annual 1998 through 2001 data were obtained from its 2010 UWMP. For 1986 through 1997 data, an appropriate per capita use value was multiplied by estimated annual populations. Population estimates were obtained by assuming linear growth rates between known population values, accounting for those outside city limits as well. Annual 1986 through 2001 pumping totals were distributed monthly in the same monthly pattern as 2002 data.

Greenfield County Water District (Greenfield CWD)

Greenfield CWD supplies groundwater to a population of about 8,500 from five wells. Greenfield provided monthly pumping data for 2005 through 2010 and annual pumping totals for 2003 and 2004. Data from KCWA annual reports (1998-2001) provided annual pumping totals for those years. Pumping in 2002 was assumed as halfway between 2001 and 2003 values. For 1986 through 1997, pumping was estimated based on pumping increase rate data provided by Greenfield CWD. Monthly pumping averages from 2005 through 2010 were used to distribute 1986 through 2004 annual pumping.

North of the River Municipal Water District (NORMWD)

NORMWD is on the northern boundary of the Model Area and provides groundwater and ID4 water (surface and imported) to its customers. About 71 percent of NORMWD is within the Model Area. It

currently serves a population of about 6,000 and has five wells. KCWA provided pumping data in six-month intervals for 1989 through 2010. Pumping was divided up evenly between the six months in each time period. Data for 1989 were used for 1986 through 1988. All pumping and 71 percent of outside return flows were assumed to occur within the Model Area.

Stockdale Mutual Water Company (Stockdale MWC)

The Stockdale MWC is located in the City of Bakersfield (Figure 1-4). The mutual water company provides groundwater from two wells to about 80 connections. Stockdale MWC provided 1986 through 2010 pumping in six-month intervals. The pumping was divided evenly over each six-month period.

Buttonwillow County Water District (Buttonwillow CWD)

Buttonwillow CWD provides groundwater to a population of about 1,500 in the northwestern portion of the Model Area. The system has three wells. Data from KCWA annual reports (1998-2001 and 2008) provided annual pumping totals for those years. Data for the remaining years was estimated based on an appropriate per capita use value and estimated annual populations. Population estimates were obtained by assuming linear growth rates between known population values. Annual pumping was distributed monthly using the same average pumping percentages as those in Greenfield CWD.

Oildale Mutual Water Company (Oildale MWC)

Oildale MWC straddles the northern boundary of the Model, with 13 percent inside the Model Area. It serves a population of about 26,000. Oildale MWC supplies imported ID4 water and groundwater to its customers. Currently, groundwater provides about five percent of the supply from about nine wells, all located within the Model Area. Oildale provided 1986 through 2010 pumping in six-month intervals. This was divided up evenly over each six-month period. All pumping and 13 percent of outside return flows have been assumed to occur within the Model Area.

Stockdale Annex MWC (Stockdale Annex MWC)

Stockdale Annex MWC is next to Stockdale MWC within the City of Bakersfield but is operated as a separate entity. It has one active well and one standby/emergency well that supply water to about 140 connections. Pumping is not metered and not available from the mutual water company. However, the 2008 KCWA Annual Report listed annual pumping at about half of the Stockdale MWC pumping. Therefore, Stockdale Annex MWC pumping is assumed half of the Stockdale MWC pumping.

3.4.2.4 Subsurface Outflow

Groundwater flow occurs out of the model area through lateral boundaries. As described in Section 3.1.1, time-varying specified head and specified flux boundaries allow subsurface flow out of the model. The areas of outflow and methodology used to calculate the amounts over time are provided in Appendix E. The rate of outflow varies over time, and is estimated to range from zero to 8,361 AFY (Table 3-4). Additional outflow may occur out of the eastern boundary along the Kern River. This outflow is expected to be relatively small and has not been quantified for the water balance.

3.4.3 Inflow and Outflow Totals

Table 3-4 summarizes the annual inflows and outflows, which are illustrated in Figure 3-31, with inflows stacked above the zero line and outflows below the zero line. The most salient feature of Figure 3-31 is the variability of annual inflows relative to outflows. Total inflows range from less than 300,000 AFY to more than 1,500,000 AFY, while total outflows range between 500,000 AFY and about 1,000,000 AFY. Recharge and canal losses are the water balance components that vary the most from year to year. Less variation is seen in agricultural pumping and return flows as well as municipal pumping and return flows.

3.4.4 Changes in Groundwater Storage

Changes in groundwater storage can be derived in two ways. The first method is a simple accounting of the water balance elements described above and shown on Figure 3-31. Total inflows minus the total outflows is equal to the change in storage for the Model Area. The second method examines the change in groundwater elevations over time and applies a storativity coefficient (specific yield), which characterizes the volume of groundwater that an aquifer releases per unit volume of the aquifer.

Groundwater elevation maps from KCWA for spring water levels have been used to calculate changes in groundwater elevation with application of a storativity of 0.15 based on the published characterization of Model Area hydrogeology. The annual changes in storage from both methods are shown on Table 3-4 and on Figure 3-32. In brief, both methods capture the major trends in the Model Area and provide a reasonable check to the water balance.

Comparison of the change in storage calculated by each method indicates that the groundwater elevation method shows a more muted response in years with large volumes of managed recharge. This may reflect the timing and regional nature of water level monitoring and local nature of recharge. The water levels, generally measured in the spring, represent a regional snapshot in time. Managed recharge can result in mounding in the area of the recharge facilities that may not be captured in spring groundwater measurements. Accordingly, the lag between the two methods reflects possible differences between the surface recharge date and response in groundwater measurements.

Overall, the change in groundwater storage is reduced in years with less than average recharge and increased in years with more than average recharge. The average annual change in storage over the Model Period is a decrease of 45,000 AFY or 116,000 AFY, based on the water balance element calculation method or the groundwater elevation method, respectively. Because of the groundwater level lag response, the average change in storage based on groundwater levels would likely be closer to the water balance element method if early 2011 groundwater levels were included.

3.4.5 Model Water Budget

The previous sections have presented the water balance for the conceptual model. Development of this conceptual model is the first step of the analysis. This information will be used to construct, calibrate, and apply a numerical model, the Kern Fan Model, to analyze potential impacts of certain recharge and banking projects along the Kern Fan, also called the *with and without* evaluations. The change in storage graph (Figure 3-32), showing storage changes derived by two independent methods, affirms that the model water balance inflows and outflows reasonably represent the groundwater system and changes in groundwater levels.

4 References

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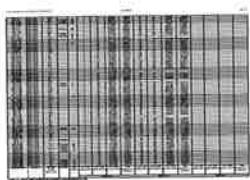
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TABLES

This image shows a close-up of a mechanical calculator, likely a Friden model. It features a complex arrangement of metal gears, levers, and a grid of numbers. The numbers are printed on a dark background, and the overall design is intricate and functional. The calculator is shown from a side-on perspective, highlighting its mechanical components.

DATE	DESCRIPTION	AMOUNT	BALANCE
1/1/11	OPENING BALANCE	100.00	100.00
1/15/11	PAYROLL	50.00	50.00
2/1/11	RENT	200.00	(150.00)
2/15/11	SALES	150.00	0.00
3/1/11	RENT	200.00	(200.00)
3/15/11	PAYROLL	50.00	(250.00)
4/1/11	RENT	200.00	(450.00)
4/15/11	SALES	150.00	(300.00)
5/1/11	RENT	200.00	(500.00)
5/15/11	PAYROLL	50.00	(550.00)
6/1/11	RENT	200.00	(750.00)
6/15/11	SALES	150.00	(600.00)
7/1/11	RENT	200.00	(800.00)
7/15/11	PAYROLL	50.00	(850.00)
8/1/11	RENT	200.00	(1050.00)
8/15/11	SALES	150.00	(900.00)
9/1/11	RENT	200.00	(1100.00)
9/15/11	PAYROLL	50.00	(1150.00)
10/1/11	RENT	200.00	(1350.00)
10/15/11	SALES	150.00	(1200.00)
11/1/11	RENT	200.00	(1400.00)
11/15/11	PAYROLL	50.00	(1450.00)
12/1/11	RENT	200.00	(1650.00)
12/15/11	SALES	150.00	(1500.00)
1/1/12	RENT	200.00	(1700.00)
1/15/12	PAYROLL	50.00	(1750.00)
2/1/12	RENT	200.00	(1950.00)
2/15/12	SALES	150.00	(1800.00)
3/1/12	RENT	200.00	(2000.00)
3/15/12	PAYROLL	50.00	(2050.00)
4/1/12	RENT	200.00	(2250.00)
4/15/12	SALES	150.00	(2100.00)
5/1/12	RENT	200.00	(2300.00)
5/15/12	PAYROLL	50.00	(2350.00)
6/1/12	RENT	200.00	(2550.00)
6/15/12	SALES	150.00	(2400.00)
7/1/12	RENT	200.00	(2600.00)
7/15/12	PAYROLL	50.00	(2650.00)
8/1/12	RENT	200.00	(2850.00)
8/15/12	SALES	150.00	(2700.00)
9/1/12	RENT	200.00	(2900.00)
9/15/12	PAYROLL	50.00	(2950.00)
10/1/12	RENT	200.00	(3150.00)
10/15/12	SALES	150.00	(3000.00)
11/1/12	RENT	200.00	(3200.00)
11/15/12	PAYROLL	50.00	(3250.00)
12/1/12	RENT	200.00	(3450.00)
12/15/12	SALES	150.00	(3300.00)
1/1/13	RENT	200.00	(3500.00)
1/15/13	PAYROLL	50.00	(3550.00)
2/1/13	RENT	200.00	(3750.00)
2/15/13	SALES	150.00	(3600.00)
3/1/13	RENT	200.00	(3800.00)
3/15/13	PAYROLL	50.00	(3850.00)
4/1/13	RENT	200.00	(4050.00)
4/15/13	SALES	150.00	(3900.00)
5/1/13	RENT	200.00	(4100.00)
5/15/13	PAYROLL	50.00	(4150.00)
6/1/13	RENT	200.00	(4350.00)
6/15/13	SALES	150.00	(4200.00)
7/1/13	RENT	200.00	(4400.00)
7/15/13	PAYROLL	50.00	(4450.00)
8/1/13	RENT	200.00	(4650.00)
8/15/13	SALES	150.00	(4500.00)
9/1/13	RENT	200.00	(4700.00)
9/15/13	PAYROLL	50.00	(4750.00)
10/1/13	RENT	200.00	(4950.00)
10/15/13	SALES	150.00	(4800.00)
11/1/13	RENT	200.00	(5000.00)
11/15/13	PAYROLL	50.00	(5050.00)
12/1/13	RENT	200.00	(5250.00)
12/15/13	SALES	150.00	(5100.00)
1/1/14	RENT	200.00	(5300.00)
1/15/14	PAYROLL	50.00	(5350.00)
2/1/14	RENT	200.00	(5550.00)
2/15/14	SALES	150.00	(5400.00)
3/1/14	RENT	200.00	(5600.00)
3/15/14	PAYROLL	50.00	(5650.00)
4/1/14	RENT	200.00	(5850.00)
4/15/14	SALES	150.00	(5700.00)
5/1/14	RENT	200.00	(5900.00)
5/15/14	PAYROLL	50.00	(5950.00)
6/1/14	RENT	200.00	(6150.00)
6/15/14	SALES	150.00	(6000.00)
7/1/14	RENT	200.00	(6200.00)
7/15/14	PAYROLL	50.00	(6250.00)
8/1/14	RENT	200.00	(6450.00)
8/15/14	SALES	150.00	(6300.00)
9/1/14	RENT	200.00	(6500.00)
9/15/14	PAYROLL	50.00	(6550.00)
10/1/14	RENT	200.00	(6750.00)
10/15/14	SALES	150.00	(6600.00)
11/1/14	RENT	200.00	(6800.00)
11/15/14	PAYROLL	50.00	(6850.00)
12/1/14	RENT	200.00	(7050.00)
12/15/14	SALES	150.00	(6900.00)
1/1/15	RENT	200.00	(7100.00)
1/15/15	PAYROLL	50.00	(7150.00)
2/1/15	RENT	200.00	(7350.00)
2/15/15	SALES	150.00	(7200.00)
3/1/15	RENT	200.00	(7400.00)
3/15/15	PAYROLL	50.00	(7450.00)
4/1/15	RENT	200.00	(7650.00)
4/15/15	SALES	150.00	(7500.00)
5/1/15	RENT	200.00	(7700.00)
5/15/15	PAYROLL	50.00	(7750.00)
6/1/15	RENT	200.00	(7950.00)
6/15/15	SALES	150.00	(7800.00)
7/1/15	RENT	200.00	(8000.00)
7/15/15	PAYROLL	50.00	(8050.00)
8/1/15	RENT	200.00	(8250.00)
8/15/15	SALES	150.00	(8100.00)
9/1/15	RENT	200.00	(8300.00)
9/15/15	PAYROLL	50.00	(8350.00)
10/1/15	RENT	200.00	(8550.00)
10/15/15	SALES	150.00	(8400.00)
11/1/15	RENT	200.00	(8600.00)
11/15/15	PAYROLL	50.00	(8650.00)
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12/15/15	SALES	150.00	(8700.00)
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1/15/16	PAYROLL	50.00	(8950.00)
2/1/16	RENT	200.00	(9150.00)
2/15/16	SALES	150.00	(9000.00)
3/1/16	RENT	200.00	(9200.00)
3/15/16	PAYROLL	50.00	(9250.00)
4/1/16	RENT	200.00	(9450.00)
4/15/16	SALES	150.00	(9300.00)
5/1/16	RENT	200.00	(9500.00)
5/15/16	PAYROLL	50.00	(9550.00)
6/1/16	RENT	200.00	(9750.00)
6/15/16	SALES	150.00	(9600.00)
7/1/16	RENT	200.00	(9800.00)
7/15/16	PAYROLL	50.00	(9850.00)
8/1/16	RENT	200.00	(10050.00)
8/15/16	SALES	150.00	(9900.00)
9/1/16	RENT	200.00	(10100.00)
9/15/16	PAYROLL	50.00	(10150.00)
10/1/16	RENT	200.00	(10350.00)
10/15/16	SALES	150.00	(10200.00)
11/1/16	RENT	200.00	(10400.00)
11/15/16	PAYROLL	50.00	(10450.00)
12/1/16	RENT	200.00	(10650.00)
12/15/16	SALES	150.00	(10500.00)
1/1/17	RENT	200.00	(10700.00)
1/15/17	PAYROLL	50.00	(10750.00)
2/1/17	RENT	200.00	(10950.00)
2/15/17	SALES	150.00	(10800.00)
3/1/17	RENT	200.00	(11000.00)
3/15/17	PAYROLL	50.00	(11050.00)
4/1/17	RENT	200.00	(11250.00)
4/15/17	SALES	150.00	(11100.00)
5/1/17	RENT	200.00	(11300.00)
5/15/17	PAYROLL	50.00	(11350.00)
6/1/17	RENT	200.00	(11550.00)
6/15/17	SALES	150.00	(11400.00)
7/1/17	RENT	200.00	(11600.00)
7/15/17	PAYROLL	50.00	(11650.00)
8/1/17	RENT	200.00	(11850.00)
8/15/17	SALES	150.00	(11700.00)
9/1/17	RENT	200.00	(11900.00)
9/15/17	PAYROLL	50.00	(11950.00)
10/1/17	RENT	200.00	(12150.00)
10/15/17	SALES	150.00	(12000.00)
11/1/17	RENT	200.00	(12200.00)
11/15/17	PAYROLL	50.00	(12250.00)
12/1/17	RENT	200.00	(12450.00)
12/15/17	SALES	150.00	(12300.00)
1/1/18	RENT	200.00	(12500.00)
1/15/18	PAYROLL	50.00	(12550.00)
2/1/18	RENT	200.00	(12750.00)
2/15/18	SALES	150.00	(12600.00)
3/1/18	RENT	200.00	(12800.00)
3/15/18	PAYROLL	50.00	(12850.00)
4/1/18	RENT	200.00	(13050.00)
4/15/18	SALES	150.00	(12900.00)
5/1/18	RENT	200.00	(13100.00)
5/15/18	PAYROLL	50.00	(13150.00)
6/1/18	RENT	200.00	(13350.00)
6/15/18	SALES	150.00	(13200.00)
7/1/18	RENT	200.00	(13400.00)
7/15/18	PAYROLL	50.00	(13450.00)
8/1/18	RENT	200.00	(13650.00)
8/15/18	SALES	150.00	(13500.00)
9/1/18	RENT	200.00	(13700.00)
9/15/18	PAYROLL	50.00	(13750.00)
10/1/18	RENT	200.00	(13950.00)
10/15/18	SALES	150.00	(13800.00)
11/1/18	RENT	200.00	(14000.00)
11/15/18	PAYROLL	50.00	(14050.00)
12/1/18	RENT	200.00	(14250.00)
12/15/18	SALES	150.00	(14100.00)
1/1/19	RENT	200.00	(14300.00)
1/15/19	PAYROLL	50.00	(14350.00)
2/1/19	RENT	200.00	(14550.00)
2/15/19	SALES	150.00	(14400.00)
3/1/19	RENT	200.00	(14600.00)
3/15/19	PAYROLL	50.00	(14650.00)
4/1/19	RENT	200.00	(14850.00)
4/15/19	SALES	150.00	(14700.00)
5/1/19	RENT	200.00	(14900.00)
5/15/19	PAYROLL	50.00	(14950.00)
6/1/19	RENT	200.00	(15150.00)
6/15/19	SALES	150.00	(15000.00)
7/1/19	RENT	200.00	(15200.00)
7/15/19	PAYROLL	50.00	(15250.00)
8/1/19	RENT	200.00	(15450.00)
8/15/19	SALES	150.00	(15300.00)
9/1/19	RENT	200.00	(15500.00)
9/15/19	PAYROLL	50.00	(15550.00)
10/1/19	RENT	200.00	(15750.00)
10/15/19	SALES	150.00	(15600.00)
11/1/19	RENT	200.00	(15800.00)
11/15/19	PAYROLL	50.00	(15850.00)
12/1/19	RENT	200.00	(16050.00)
12/15/19	SALES	150.00	(15900.00)
1/1/20	RENT	200.00	(16100.00)
1/15/20	PAYROLL	50.00	(16150.00)
2/1/20	RENT	200.00	(16350.00)
2/15/20	SALES	150.00	(16200.00)
3/1/20	RENT	200.00	(16400.00)
3/15/20	PAYROLL	50.00	(16450.00)
4/1/20	RENT	200.00	(16650.00)
4/15/20	SALES	150.00	(16500.00)
5/1/20	RENT	200.00	(16700.00)
5/15/20	PAYROLL	50.00	(16750.00)
6/1/20	RENT	200.00	(16950.00)
6/15/20	SALES	150.00	(16800.00)
7/1/20	RENT	200.00	(17000.00)
7/15/20	PAYROLL	50.00	(17050.00)
8/1/20	RENT	200.00	(17250.00)
8/15/20	SALES	150.00	(17100.00)
9/1/20	RENT	200.00	(17300.00)
9/15/20	PAYROLL	50.00	(17350.00)
10/1/20	RENT	200.00	(17550.00)
10/15/20	SALES	150.00	(17400.00)
11/1/20	RENT	200.00	(17600.00)
11/15/20	PAYROLL	50.00	(17650.00)
12/1/20	RENT	200.00	(17850.00)
12/15/20	SALES	150.00	(17700.00)
1/1/21	RENT	200.00	(17900.00)
1/15/21	PAYROLL	50.00	(17950.00)
2/1/21	RENT	200.00	(18150.00)
2/15/21	SALES	150.00	(18000.00)
3/1/21	RENT	200.00	(18200.00)
3/15/21	PAYROLL	50.00	(18250.00)
4/1/21	RENT	200.00	(18450.00)
4/15/21	SALES	150.00	(18300.00)
5/1/21	RENT	200.00	(18500.00)
5/15/21	PAYROLL	50.00	(18550.00)
6/1/21	RENT	200.00	(18750.00)
6/15/21	SALES	150.00	(18600.00)
7/1/21	RENT	200.00	(18800.00)
7/15/21	PAYROLL	50.00	(18850.00)
8/1/21	RENT	200.00	(19050.00)
8/15/21	SALES	150.00	(18900.00)
9/1/21	RENT	200.00	(19100.00)
9/15/21			



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
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The figure is a large, complex grid representing the results of a 2000 survey of 1000 respondents. The grid is organized into columns for various demographic and attitudinal variables, and rows for specific survey questions. The data is presented in a tabular format with numerical values and some categorical indicators.

Columns (Variables):

- Age
- Gender
- Marital Status
- Education
- Income
- Occupation
- Religion
- Political Affiliation
- Attitudes
- Values
- Beliefs
- Behaviors
- Opinions
- Preferences
- Needs
- Wants
- Goals
- Values
- Beliefs
- Behaviors
- Opinions
- Preferences
- Needs
- Wants
- Goals

Rows (Questions):

- Q1
- Q2
- Q3
- Q4
- Q5
- Q6
- Q7
- Q8
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The image displays a dense, rectangular grid of small, dark, and mostly illegible text fragments. These fragments are arranged in a structured, tabular format, suggesting they are remnants of a larger document or a corrupted scan of one. The fragments vary in size and orientation, but generally follow a grid-like pattern. Some fragments are more prominent than others, but none are clearly readable as full words or sentences. The overall appearance is that of a heavily degraded or corrupted digital document page.

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
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	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
1999													
5,956	126,139	81,854	133,402	190,178	102,676	245,494	200,003	59,292	67,985	78,417	230,318	3,355,605	134,224
7,856	150,682	30,992	37,151	159,210	81,605	1,466,726	1,111,271	82,802	7,418	41,881	378,203	8,363,758	334,550
2,207	164,128	169,852	160,238	142,031	138,183	141,747	149,264	140,139	158,718	160,583	164,572	4,104,686	164,187
140	5,277	5,818	6,000	5,913	5,909	5,667	6,032	6,586	6,743	6,399	5,983	134,306	5,372
086	9,086	9,084	9,149	9,214	9,279	9,528	9,093	9,473	9,538	10,209	10,881	234,564	9,383
	-	-	-	-	-	-	-	-	-	-	717	1,665	67
2,797	-	10,819	15,549	6,970	5,738	5,325	6,100	3,831	6,151	23,442	18,911	225,667	9,027
4,042	455,312	308,419	361,489	513,515	343,389	1,874,486	1,481,763	302,123	256,552	320,931	809,586	16,297,112	656,810
366	3,426	199,630	61,308	62,788	75,956	1,476	-	347,102	380,673	274,024	78,224	1,492,589	59,704
0,973	19,879	35,177	31,559	16,698	33,573	12,590	13,936	49,358	47,878	49,940	14,673	566,592	22,664
3,867	459,661	511,597	499,604	397,822	479,849	388,711	358,888	503,340	521,901	524,823	405,548	12,412,284	496,491
2,262	112,119	119,346	123,658	125,106	125,513	127,665	132,505	144,171	140,376	132,190	124,412	2,919,913	116,797
-	6,480	-	-	1,407	1,791	-	1,705	-	-	-	-	28,105	1,124
0,468	601,565	865,749	716,129	603,822	716,682	530,442	507,034	1,043,970	1,090,828	980,977	622,857	17,419,483	696,779
3,426	(146,253)	(557,330)	(354,640)	(90,307)	(373,293)	1,344,044	974,729	(741,847)	(834,276)	(660,046)	186,729	(1,122,371)	(39,969)
3,722	30,351	205,960	(669,044)	(490,514)	(51,814)	(118,414)	537,820	552,382	(1,292,567)	(918,784)	(291,609)	(2,897,331)	(115,893)

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
1,768	1,443	1,933	1,894	1,760	1,854	1,809	1,820	1,454	1,523	1,881	1,642	48,323	1,933
10,546	9,890	11,155	11,222	9,979	10,213	12,381	10,953	11,100	13,607	14,509	14,338	288,801	11,552
363	495	447	335	299	273	317	254	213	206	211	230	9,304	372
5,944	9,493	9,548	8,017	6,613	5,089	5,018	5,208	5,351	6,543	6,246	6,396	283,697	11,348
2,882	3,036	2,937	3,024	2,832	2,842	2,694	2,781	2,588	3,337	2,989	3,501	79,870	3,195
7,968	6,995	9,209	8,881	8,061	8,214	8,422	7,507	7,600	9,663	10,639	10,856	228,681	9,147
7,282	7,658	8,764	7,943	6,556	7,022	7,156	6,588	6,242	6,995	6,331	6,926	178,805	7,152
18,135	19,624	20,093	19,490	17,788	15,562	16,669	16,584	17,230	19,257	19,150	20,936	461,987	18,479
13,235	13,598	14,798	13,800	12,475	12,820	13,680	14,867	13,217	15,653	15,439	16,556	368,872	14,755
2,633	1,755	2,280	1,649	1,168	1,044	1,056	908	582	769	800	855	60,123	2,405
1,846	1,631	1,299	1,654	1,428	1,175	1,091	1,168	1,096	1,154	1,544	1,359	38,941	1,558
4,195	4,996	4,250	4,283	3,840	3,809	3,748	4,441	3,869	3,975	4,050	3,866	103,423	4,137
4,328	5,078	4,724	4,524	3,746	3,735	3,957	5,371	4,899	5,261	5,339	4,209	121,465	4,859
12,994	16,140	14,636	12,785	11,058	11,774	11,480	12,142	11,515	12,570	12,835	14,023	365,608	14,624
24,077	25,432	27,393	24,584	21,871	21,626	21,038	23,174	21,448	23,365	23,394	22,696	600,989	24,040
4,079	4,944	4,947	4,634	3,842	3,638	3,895	4,318	3,532	4,342	4,651	4,808	107,119	4,285
1,575	1,372	1,382	1,289	1,103	1,044	1,275	1,459	1,450	1,593	1,815	1,684	34,883	1,395
7,464	10,377	9,288	9,400	8,982	7,562	6,712	8,554	7,640	8,342	7,864	8,872	210,958	8,438
4,670	4,355	4,972	4,818	4,151	5,005	4,297	4,881	4,954	5,079	5,180	6,170	124,101	4,964
5,863	4,916	5,750	5,522	5,078	5,294	5,996	6,791	5,680	6,126	6,179	5,604	137,888	5,516
10,359	10,899	10,046	10,490	9,400	8,589	9,056	9,493	8,478	9,358	9,540	9,045	250,846	10,034
152,207	164,128	169,852	160,238	142,031	138,183	141,747	149,264	140,139	158,718	160,583	164,572	4,104,686	164,187

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
12	12	15	14	14	15	15	15	16	16	16	16	349	14
2,772	2,086	2,147	2,272	2,014	1,742	1,721	1,832	1,882	1,754	1,709	1,754	55,907	2,236
2,288	2,033	2,435	2,480	2,589	2,805	2,569	2,713	3,129	3,373	3,159	2,790	51,770	2,071
85	99	101	112	123	151	162	184	191	189	182	170	2,692	108
2	9	47	3	9		4	21	23	18	22	21	190	8
0	1	3	5	14	15	13	10	20	19	14	1	142	6
315	335	339	347	364	353	350	364	354	390	339	348	7,499	300
8	8	8	8	8	7	7	7	10	9	9	8	202	8
15	15	16	16	16	14	15	15	20	18	19	16	405	16
644	681	709	744	763	807	811	871	942	957	930	858	15,149	606
-	-	-	-	-	-	-	-	-	-	-	-	-	-
6,140	5,277	5,818	6,000	5,913	5,909	5,667	6,032	6,586	6,743	6,399	5,983	134,306	5,373

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
-	-	-	-	-	-	-	2,962	77	79	33	10	14,947	598
5,359	4,682	8,548	6,016	3,753	5,100	6,137	5,208	3,766	4,092	5,880	4,989	135,179	5,407
4	68	67	62	-	-	-	-	-	-	383	205	3,023	126
13,880	16,453	10,869	38,013	42,556	18,112	14,244	15,039	8,965	9,400	13,445	16,125	430,342	17,214
-	-	-	-	-	-	-	-	-	-	-	-	7,464	299
6,416	5,514	4,374	4,459	8,533	5,505	8,460	5,964	2,235	3,869	6,060	13,570	141,775	5,671
7,078	7,236	7,215	7,188	7,397	6,518	6,467	6,105	6,218	5,657	5,189	8,284	161,009	6,440
30	26	31	41	48	33	36	22	26	51	46	93	1,177	47
3,283	2,526	1,817	2,390	5,882	3,371	6,537	3,912	680	2,565	2,068	6,887	80,382	3,215
19,935	20,382	20,322	20,247	20,835	18,368	18,215	17,197	17,515	15,934	14,616	23,332	453,496	18,140
11,050	9,068	4,346	6,098	23,226	14,206	34,474	24,276	4,462	11,770	18,640	35,742	351,372	14,055
2,078	1,981	1,213	1,267	1,033	1,294	1,354	1,685	896	922	890	640	45,536	1,821
-	-	87	-	95	-	-	-	35	34	415	210	876	35
17,247	3,560	2,987	3,178	785	1,365	27,432	22,592	642	2,166	2,163	23,739	264,509	10,580
3,118	3,578	2,628	1,945	2,124	5,033	6,291	8,207	4,309	5,650	2,073	6,734	111,570	4,463
-	-	-	-	-	-	-	-	-	-	-	-	17,146	686
-	-	-	-	-	-	-	-	-	-	-	-	1,268	51
66,479	51,063	17,350	42,497	73,911	23,780	115,848	86,833	9,465	5,794	6,516	89,759	1,134,534	45,381
155,956	126,139	81,854	133,402	190,178	102,676	245,494	200,003	59,292	67,985	78,417	230,318	3,355,605	134,224

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
10,473	30,918	2,539	1,480	1,447	6,956	155,977	81,521	4,495	-	-	7,039	926,524	37,061
-	-	-	-	-	-	2,392	1,619	-	-	-	1,569	5,580	223
633	1,027	-	-	719	2,872	34,896	26,229	2,098	-	-	-	181,174	9,535
536	337	-	1,489	-	1,508	37,098	19,021	-	-	3,000	25,087	336,480	13,459
2,043	4,073	2,214	1,038	24,441	1,863	29,997	825	-	-	-	-	95,420	4,149
-	-	-	-	-	-	-	40,775	-	-	-	82,363	142,825	5,951
69,860	51,848	18,856	25,266	75,904	33,962	731,948	539,434	31,448	-	7,030	64,286	3,265,596	130,624
30,645	2,438	-	2,099	897	13,683	104,884	159,813	30,151	2,487	13,083	19,141	1,237,471	49,499
13,732	15,296	1,253	1,434	8,372	6,811	111,199	61,228	4,813	-	-	-	448,156	17,926
782	-	-	-	-	-	6,057	5,127	-	-	1,073	8,474	53,568	2,143
47,817	42,982	5,653	4,038	27,182	6,964	195,184	147,151	3,200	-	2,354	141,521	1,458,963	58,359
615	213	10	-	412	-	978	1,019	211	-	-	625	10,675	427
-	-	-	-	-	127	964	3,555	1,736	611	663	1,019	8,675	347
719	1,550	467	307	476	346	1,006	-	727	1,002	1,434	1,018	42,132	1,685
-	-	-	-	19,360	6,513	54,146	23,954	3,923	3,318	13,244	26,061	150,519	6,021
177,856	150,682	30,992	37,151	159,210	81,605	1,466,726	1,111,271	82,802	7,418	41,881	378,203	8,363,758	334,550

1999	3,366	3,426	199,630	61,308	62,788	75,956	1,476	-	347,102	380,673	274,024	78,224	1,492,589	59,704
-	-	-	-	-	-	-	-	-	2,302	9,429	4,042	-	15,773	631
-	-	-	33,511	9,919	2,914	8,928	378	-	51,958	65,283	61,059	17,479	251,429	10,057
-	-	-	-	-	-	-	-	-	33,345	33,889	29,846	11,845	108,925	4,357
-	-	-	-	-	-	-	-	-	52,752	53,003	35,838	10,825	152,418	6,097
-	-	-	-	-	-	-	-	-	56,889	55,213	-	10,365	122,467	4,899
-	-	-	-	-	-	-	-	-	3,134	5,067	2,839	1,322	12,362	494
-	-	-	-	-	-	-	-	-	55,484	54,378	37,515	9,985	157,362	6,294
-	-	-	-	-	-	-	-	-	24,537	24,132	48,643	3,171	100,483	4,019
-	-	-	88,695	24,904	46,350	48,641	-	-	-	-	-	-	208,590	8,344
-	-	-	-	1,892	3,345	-	-	-	8,052	9,717	4,536	861	28,403	1,136
3,366	3,426	31,334	17,688	8,808	13,267	-	-	-	18,634	12,548	7,127	2,287	123,099	4,924
-	-	6,464	-	-	-	-	-	-	-	-	-	-	6,464	259
-	-	22,918	-	-	-	589	-	-	23,245	36,604	29,594	6,291	119,241	4,770
-	-	16,708	6,906	1,371	4,531	1,098	-	-	16,770	21,410	12,985	3,793	85,573	3,423
Average	2001	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total		

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
7,619	6,332	7,386	7,618	7,046	8,440	7,636	7,286	6,786	6,700	7,766	5,660	193,164	7,727
14,451	14,756	17,655	18,685	16,655	25,159	16,435	11,056	20,385	26,020	27,573	16,090	426,421	17,057
908	1,343	1,674	956	594	774	726	534	755	756	730	651	25,731	1,029
14,101	22,470	23,488	19,562	14,240	10,813	10,860	5,864	10,685	13,471	12,117	8,387	877,106	35,084
12,663	11,973	11,134	11,816	11,381	12,721	11,438	11,102	11,983	14,371	12,646	12,006	321,451	12,858
25,692	22,120	29,932	29,531	20,535	30,881	20,815	14,960	30,855	32,486	36,707	24,314	680,065	27,203
25,189	22,751	29,751	27,237	18,936	25,168	19,685	16,510	27,299	21,137	20,314	15,602	565,659	22,626
25,140	21,842	24,046	28,081	12,593	21,043	12,248	6,321	24,813	22,105	25,600	12,371	551,730	22,069
48,199	42,210	52,327	50,708	41,723	48,345	43,984	37,567	58,260	59,701	57,870	40,479	1,275,430	51,017
2,867	138	1,035	198	75	58	681	691	69	367	679	847	92,758	3,710
8,146	6,188	5,469	6,777	5,860	5,336	4,840	4,630	5,123	5,122	6,729	5,286	163,364	6,535
8,059	7,256	5,376	4,763	4,491	6,242	3,299	6,533	7,032	6,199	7,335	6,768	132,170	5,287
13,333	14,087	13,812	14,877	11,704	11,203	8,141	9,666	12,881	12,972	12,378	8,620	354,689	14,188
56,124	63,458	56,309	51,812	45,013	54,048	50,783	48,492	54,065	56,008	55,692	53,103	1,525,794	61,032
105,775	101,288	105,536	99,621	88,268	99,513	94,527	90,727	101,251	106,550	103,985	90,441	2,527,001	101,080
13,589	16,190	19,732	19,006	14,782	15,208	14,492	17,460	16,327	20,080	20,449	17,198	384,539	15,382
845	3,179	4,810	5,736	3,249	4,540	23	139	6,720	6,865	7,777	804	87,674	3,507
27,380	38,725	37,699	40,043	36,828	36,019	25,540	26,475	36,295	38,928	36,316	35,627	794,533	31,781
20,470	17,432	19,215	19,537	16,773	22,562	18,563	19,535	23,027	22,131	21,669	21,423	513,878	20,555
5,084	1,218	17,947	13,884	5,892	15,145	2,650	4,696	16,737	20,063	20,800	10,584	264,321	10,573
28,232	24,704	27,262	29,156	21,184	26,631	21,344	18,643	31,994	29,869	29,689	19,285	654,805	26,192
463,867	459,661	511,597	499,604	397,822	479,849	388,711	358,888	503,340	521,901	524,823	405,548	12,412,284	496,491

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
10,973	13,410	14,712	12,413	10,016	11,322	12,590	13,492	15,558	13,427	12,318	10,708	258,644	10,346
-	4,116	13,981	15,387	4,765	12,810	-	444	23,022	21,606	23,084	1,488	226,096	9,044
-	2,352	6,485	3,759	1,918	9,442	-	-	10,777	12,845	14,538	2,477	81,852	3,274
10,973	19,879	35,177	31,559	16,698	33,573	12,590	13,936	49,358	47,878	49,940	14,673	566,592	22,664

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
161	161	199	186	191	196	200	205	210	212	212	212	4,689	188
72,111	52,021	53,872	58,348	51,953	45,566	45,590	49,249	50,417	46,783	44,781	45,747	1,423,560	56,942
30,599	27,417	32,675	33,362	35,056	37,829	34,554	36,558	42,291	45,517	42,603	37,414	697,642	27,906
1,140	1,329	1,360	1,507	1,653	2,026	2,169	2,486	2,574	2,554	2,445	2,282	36,205	1,448
30	178	939	52	181		82	416	443	364	434	414	3,792	158
39	62	277	501	1,488	1,629	1,377	992	2,091	1,955	1,419	151	15,055	627
4,219	4,488	4,539	4,653	4,881	4,727	4,688	4,887	4,770	5,258	4,578	4,663	100,612	4,024
107	106	109	111	109	100	102	102	140	123	131	115	2,838	114
214	212	218	221	218	199	204	204	280	246	263	230	5,676	227
8,600	9,095	9,433	9,929	10,194	10,776	10,812	11,668	12,666	12,825	12,481	11,447	202,089	8,084
15,042	17,050	15,724	14,789	19,182	22,465	27,888	25,737	28,290	24,538	22,843	21,735	427,755	17,110
132,262	112,119	119,346	123,658	125,106	125,513	127,665	132,505	144,171	140,376	132,190	124,412	2,919,913	116,797

FIGURES

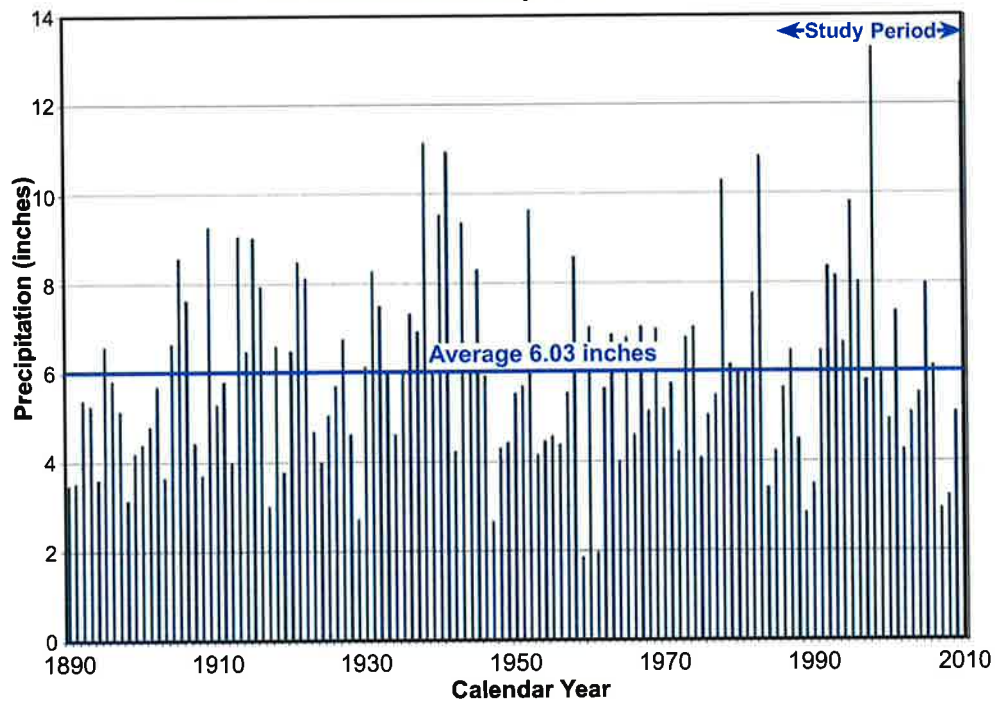




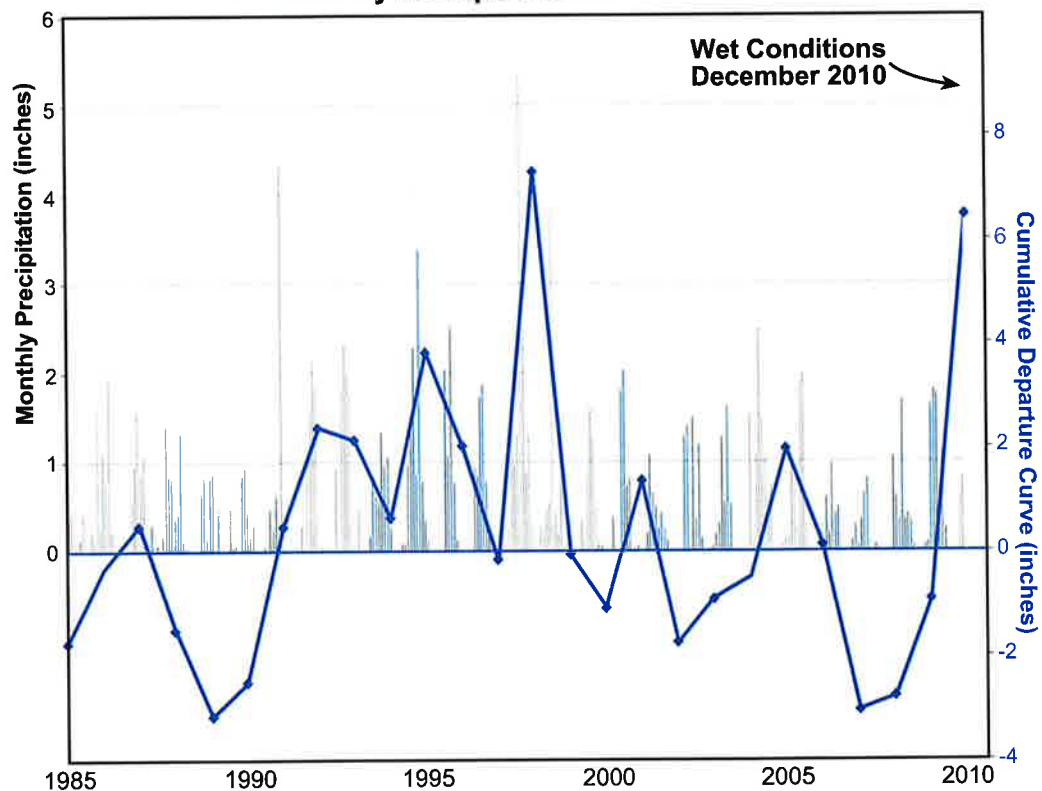




1890 - 2010 Annual Precipitation at Bakersfield



Study Period Cumulative Departure Curve and Monthly Precipitation at Bakersfield

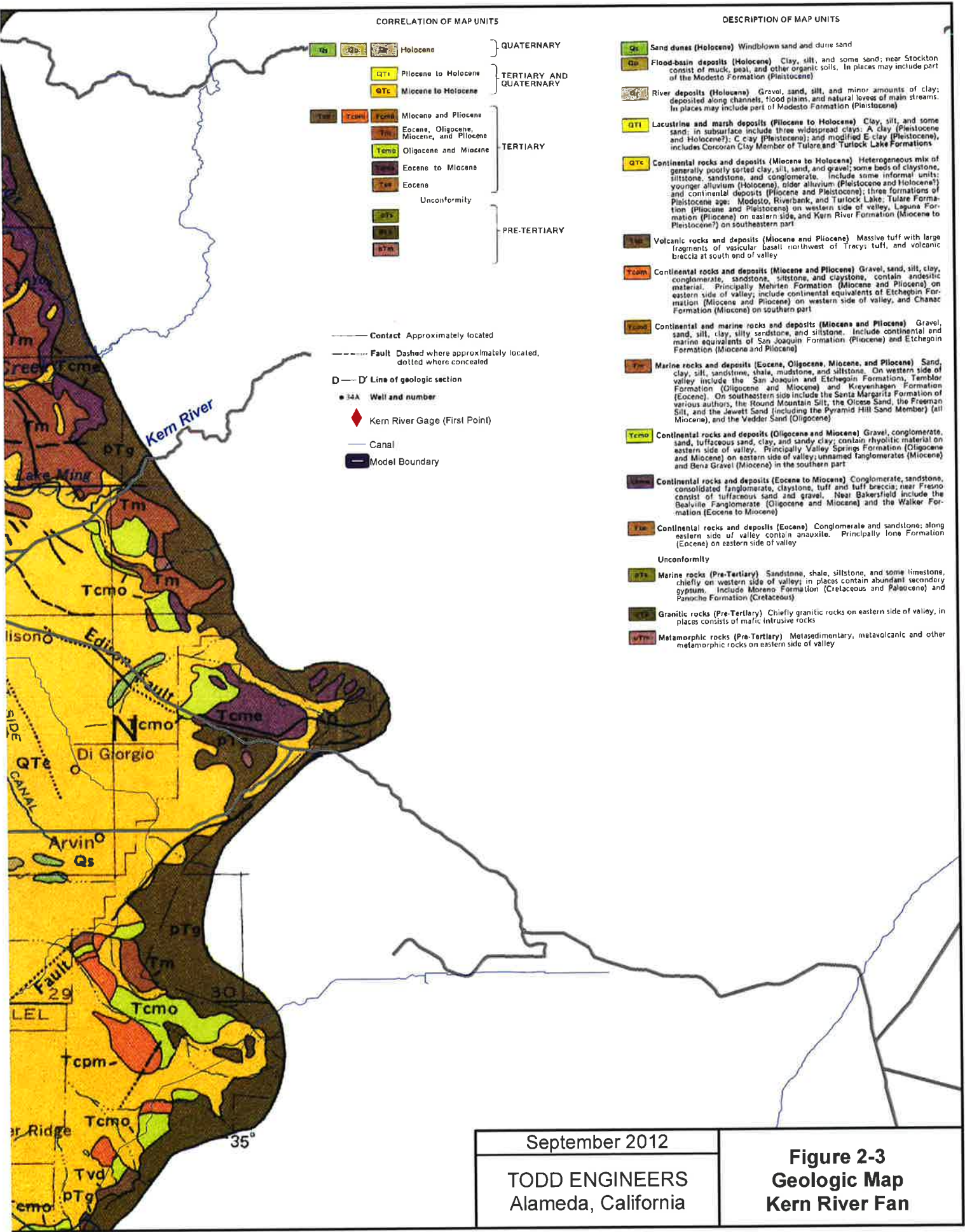


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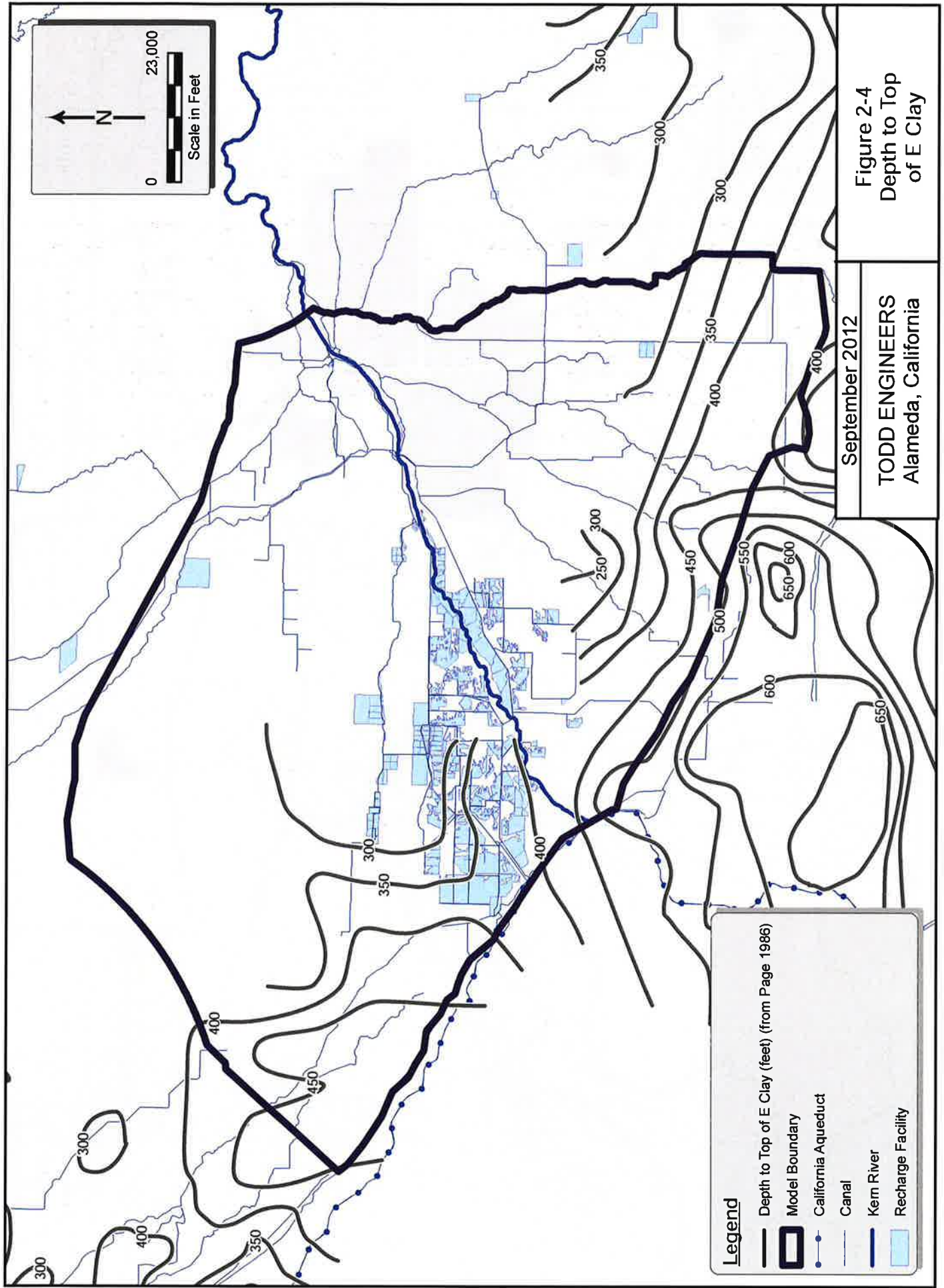
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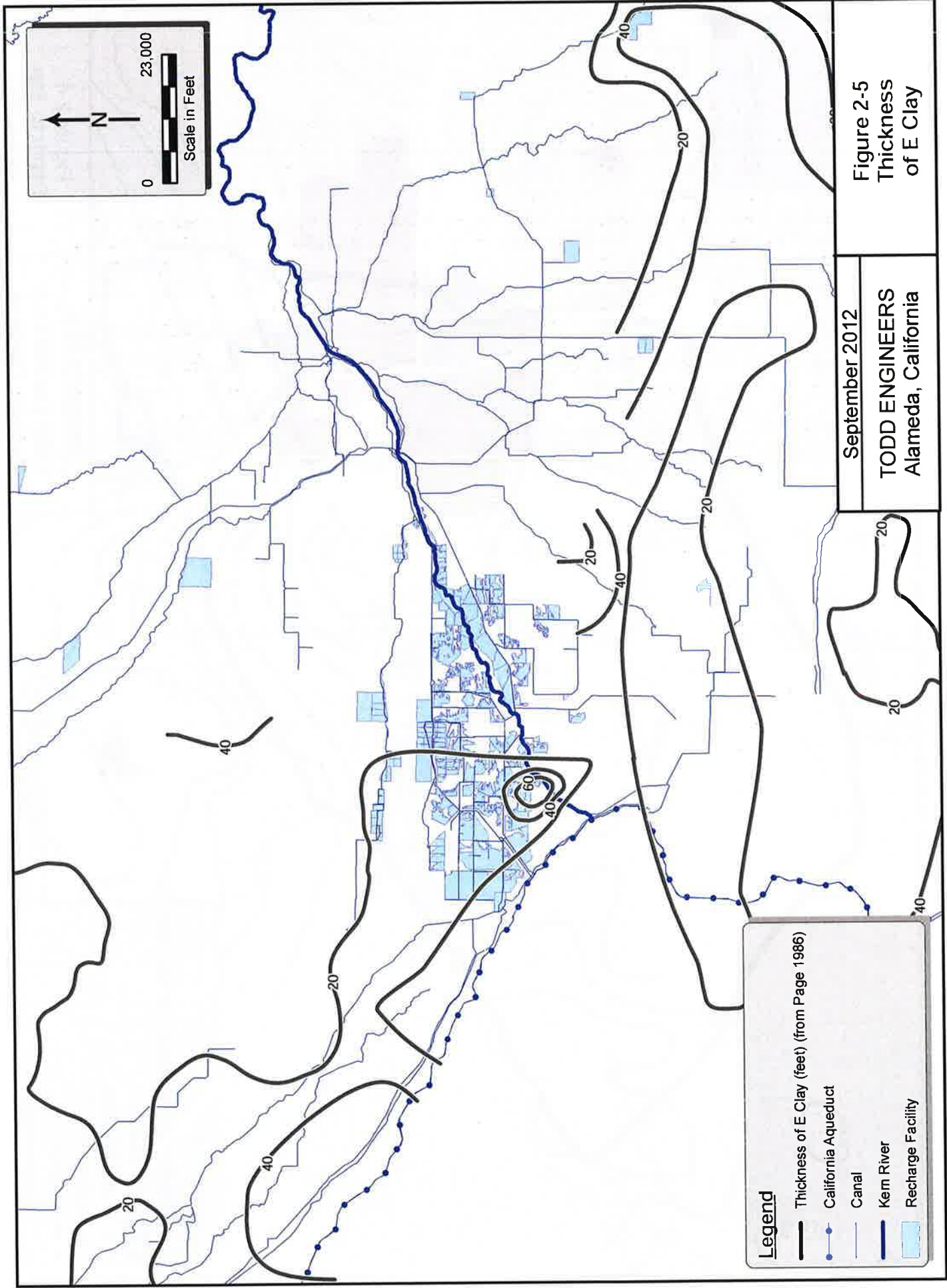
Figure 2-1
Precipitation and
Cumulative Departure
Curve





September 2012	Figure 2-3 Geologic Map Kern River Fan
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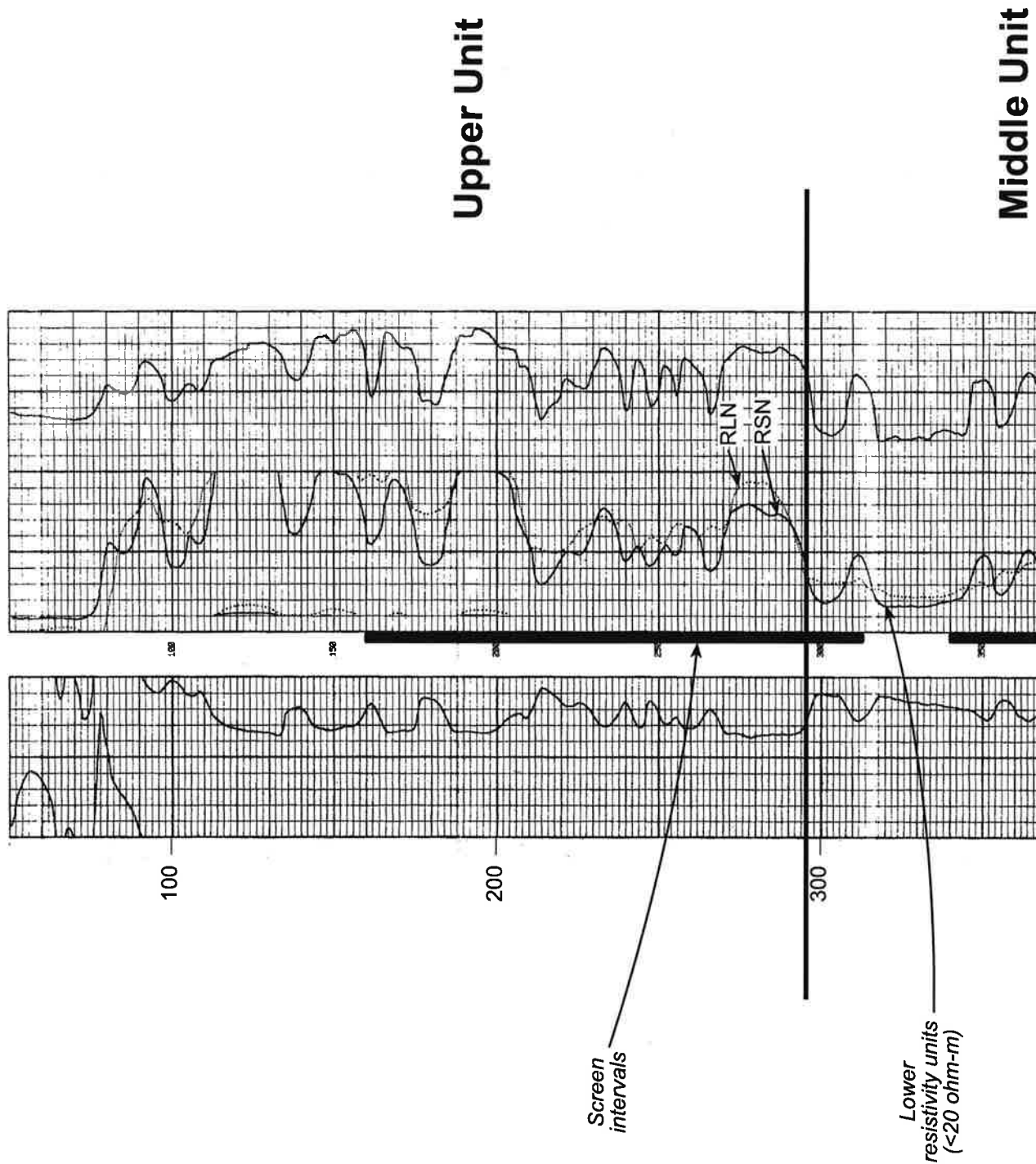
Legend

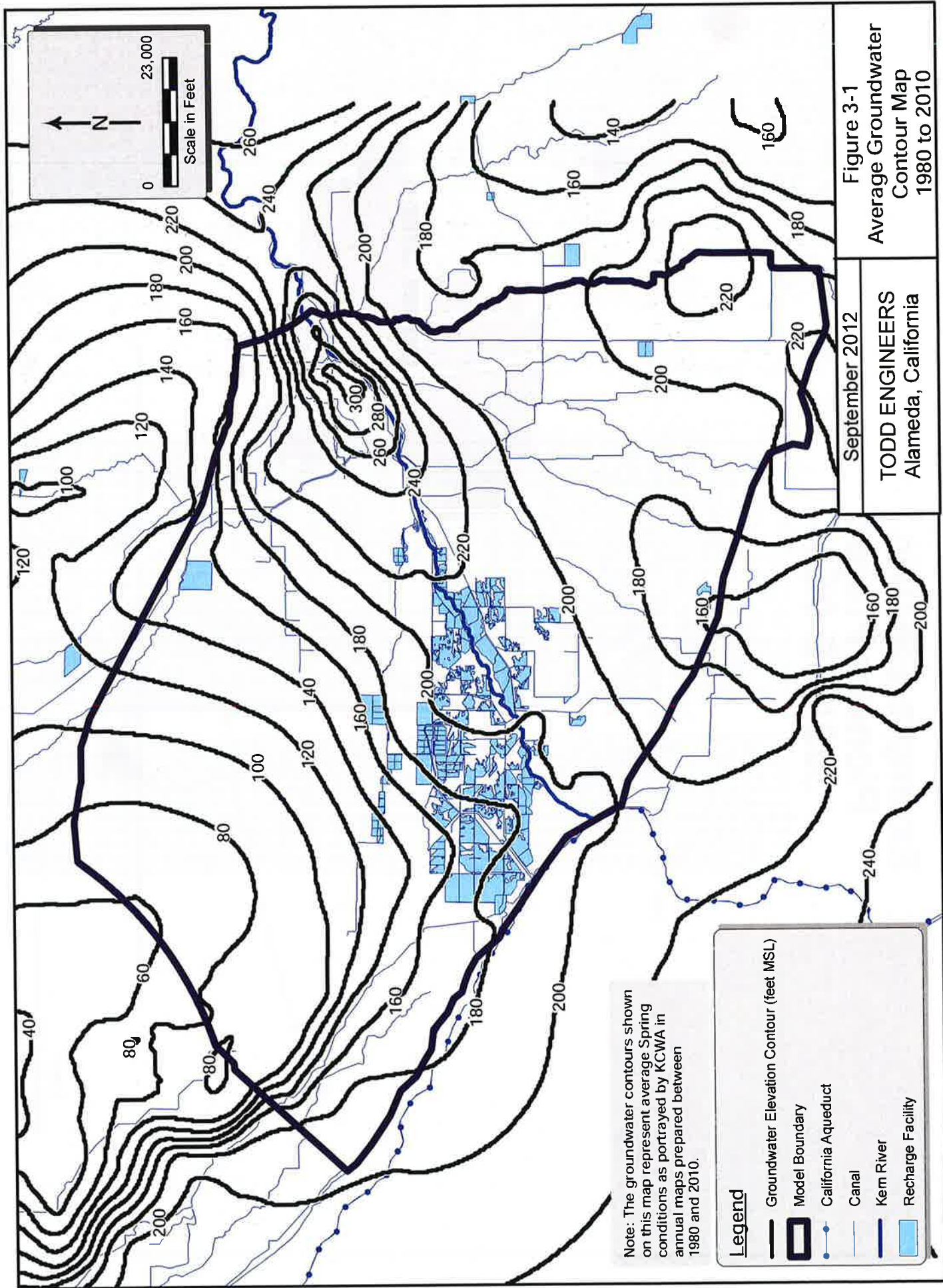
- Thickness of E Clay (feet) (from Page 1986)
- California Aqueduct
- Canal
- Kern River
- Recharge Facility

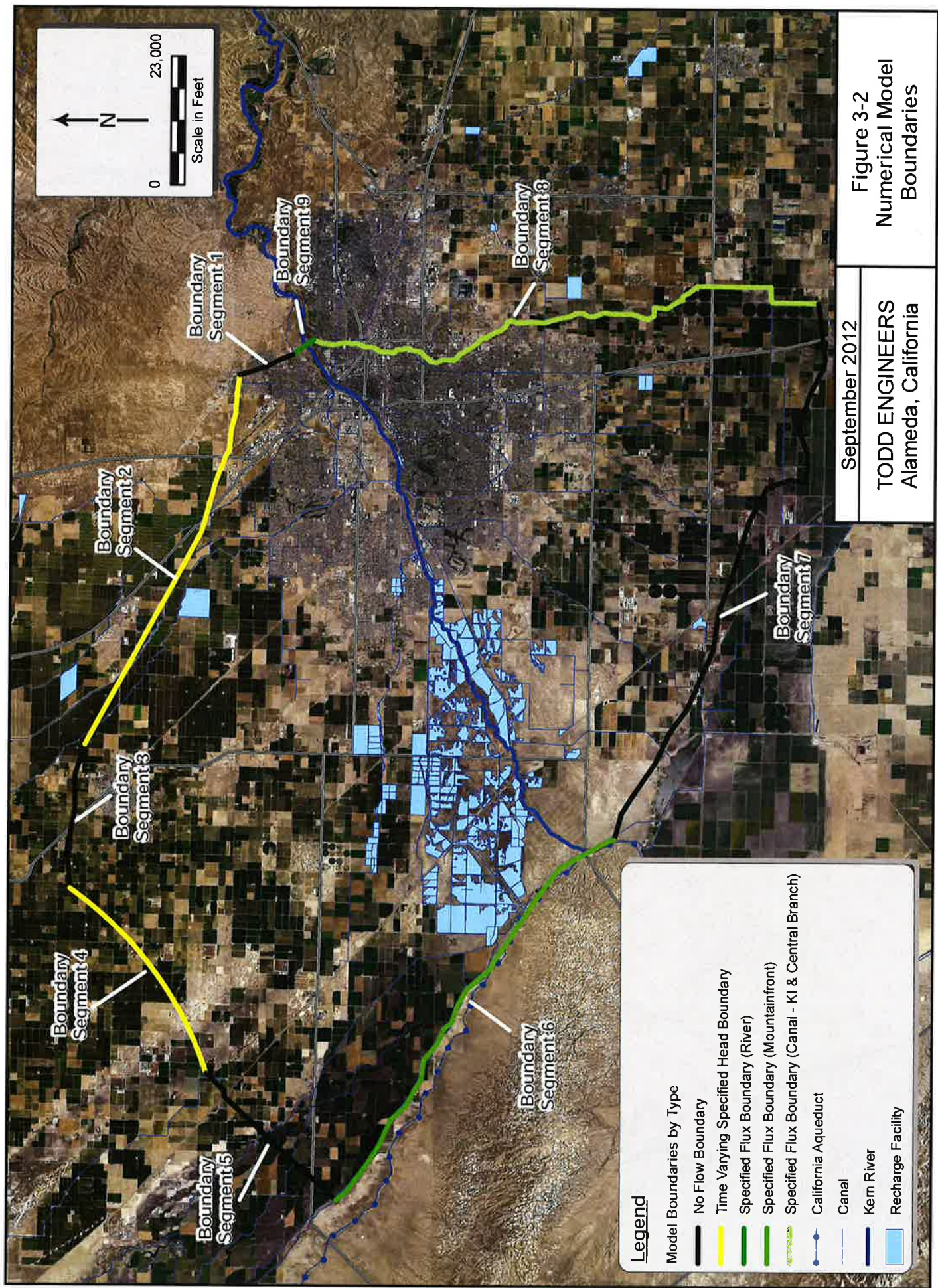
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Figure 2-5
Thickness
of E Clay

Example Electric Log Pioneer Project 30S/26E-9E01

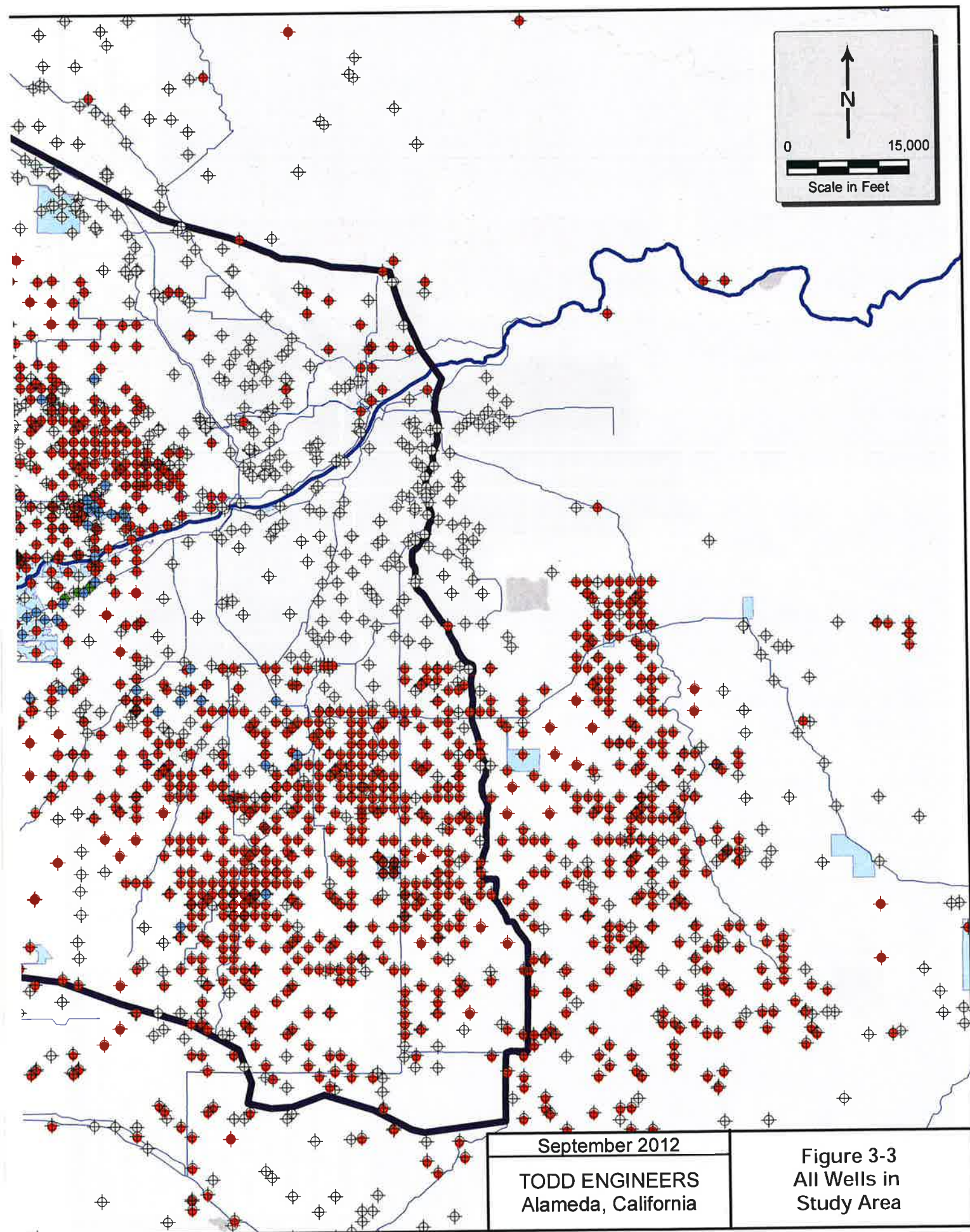


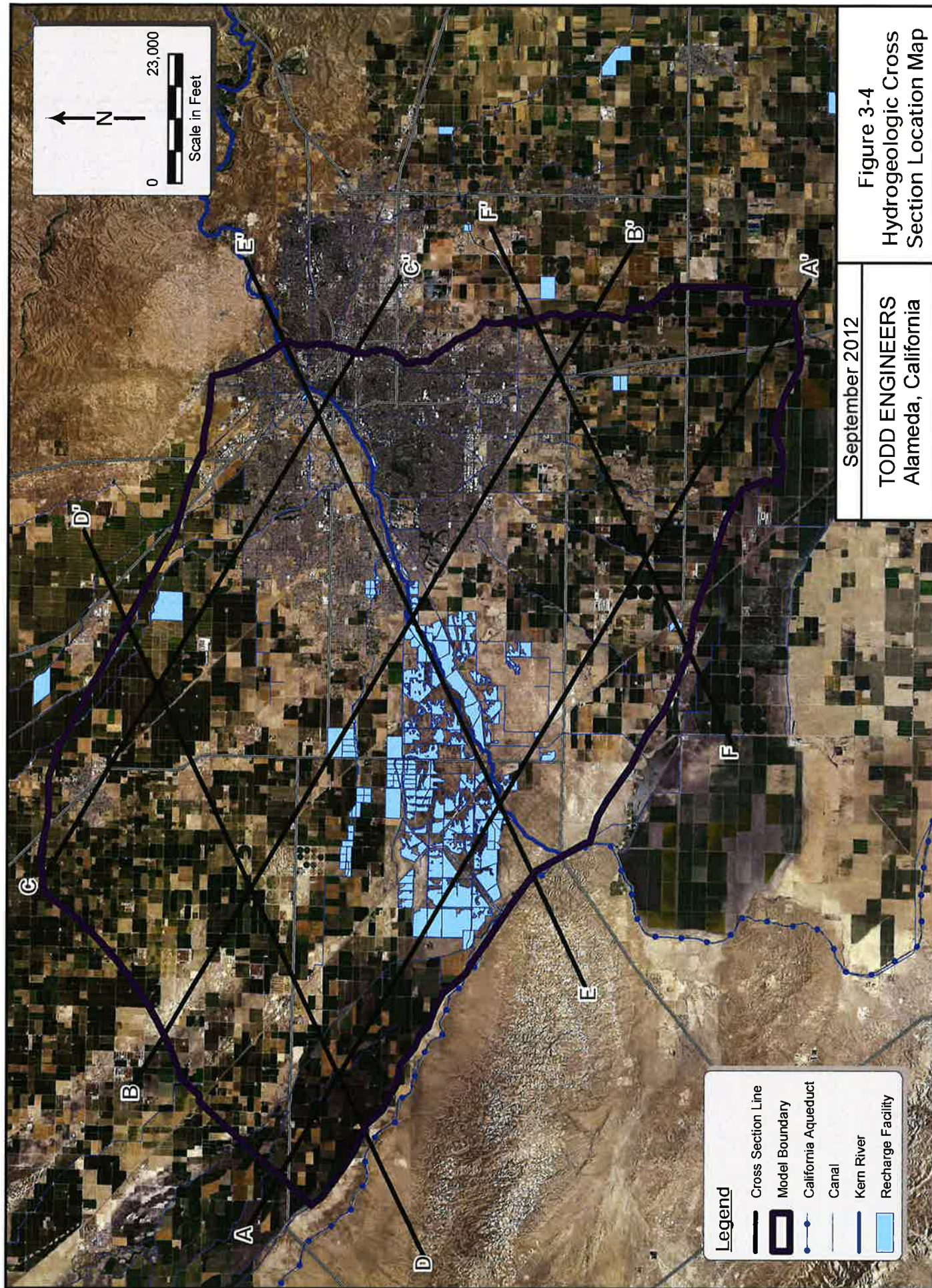


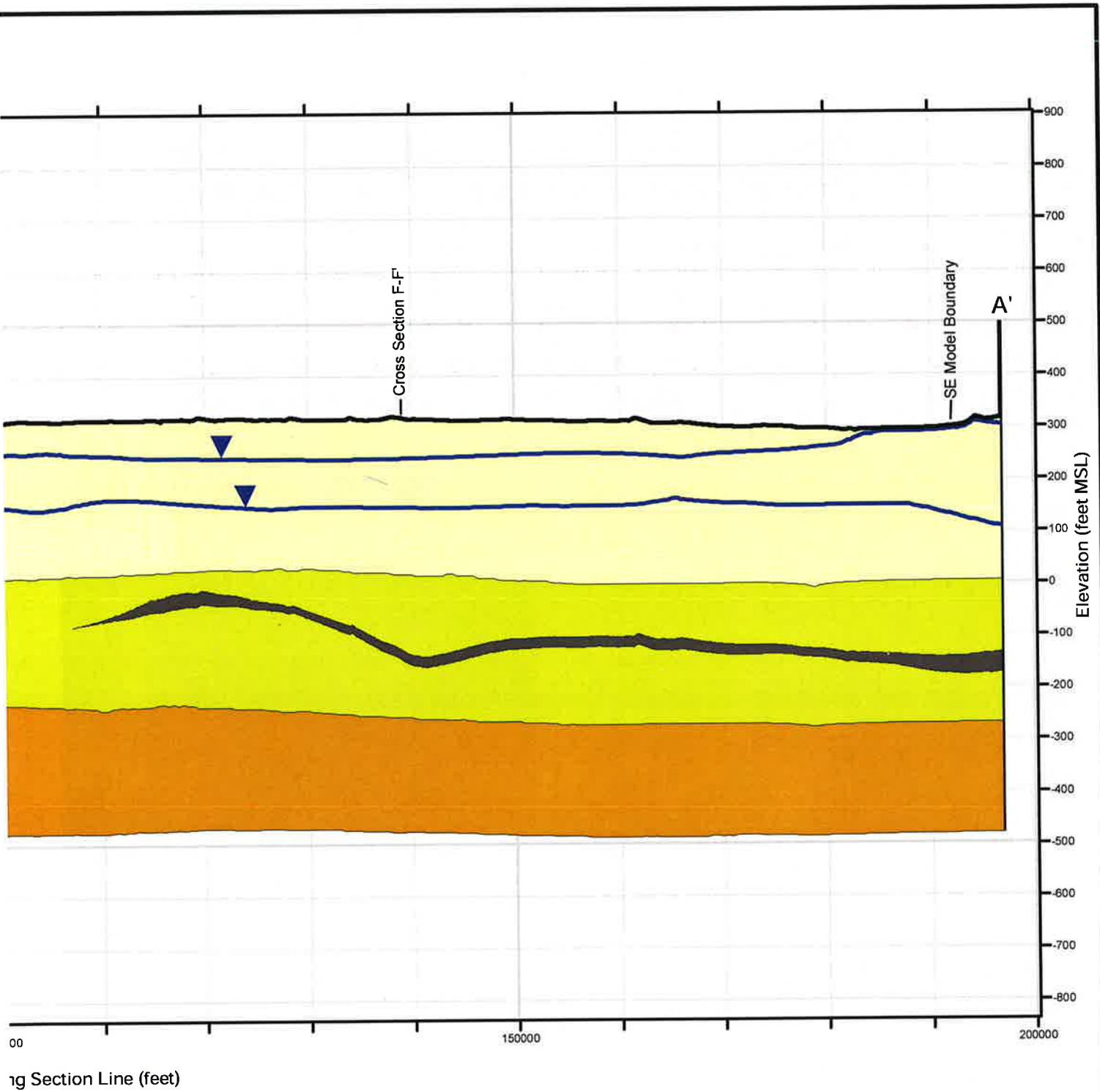


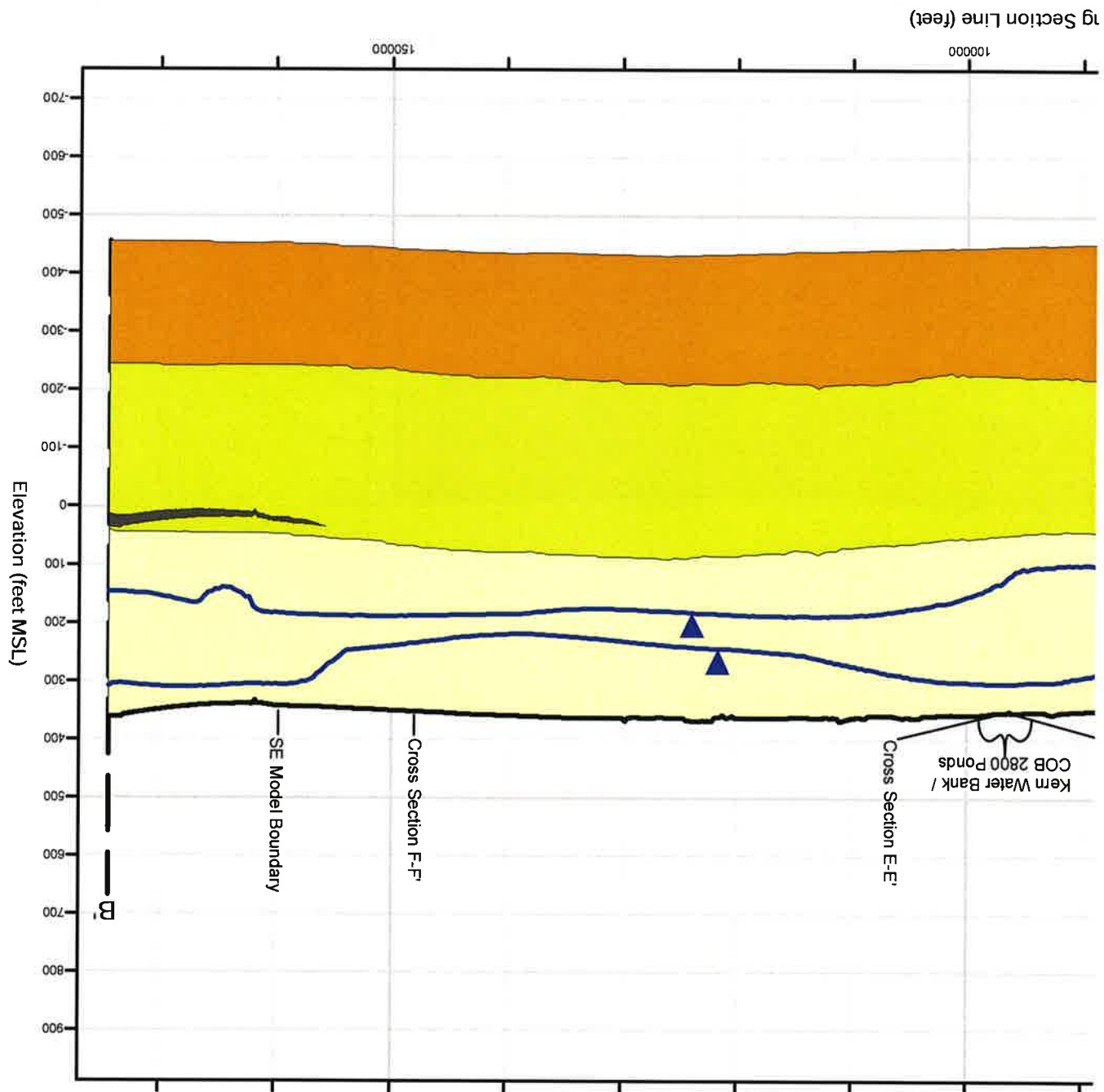
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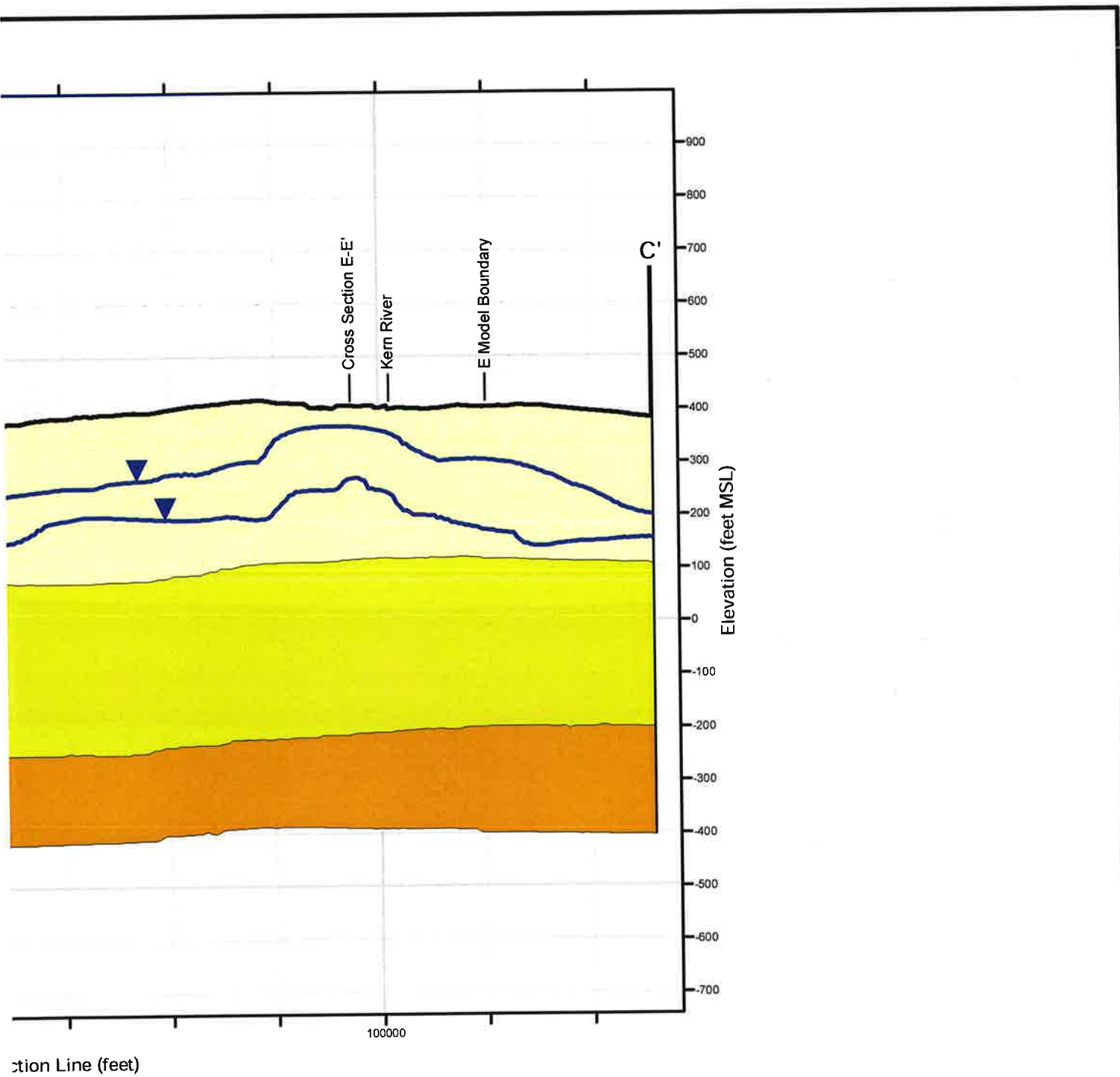
Figure 3-2
Numerical Model
Boundaries



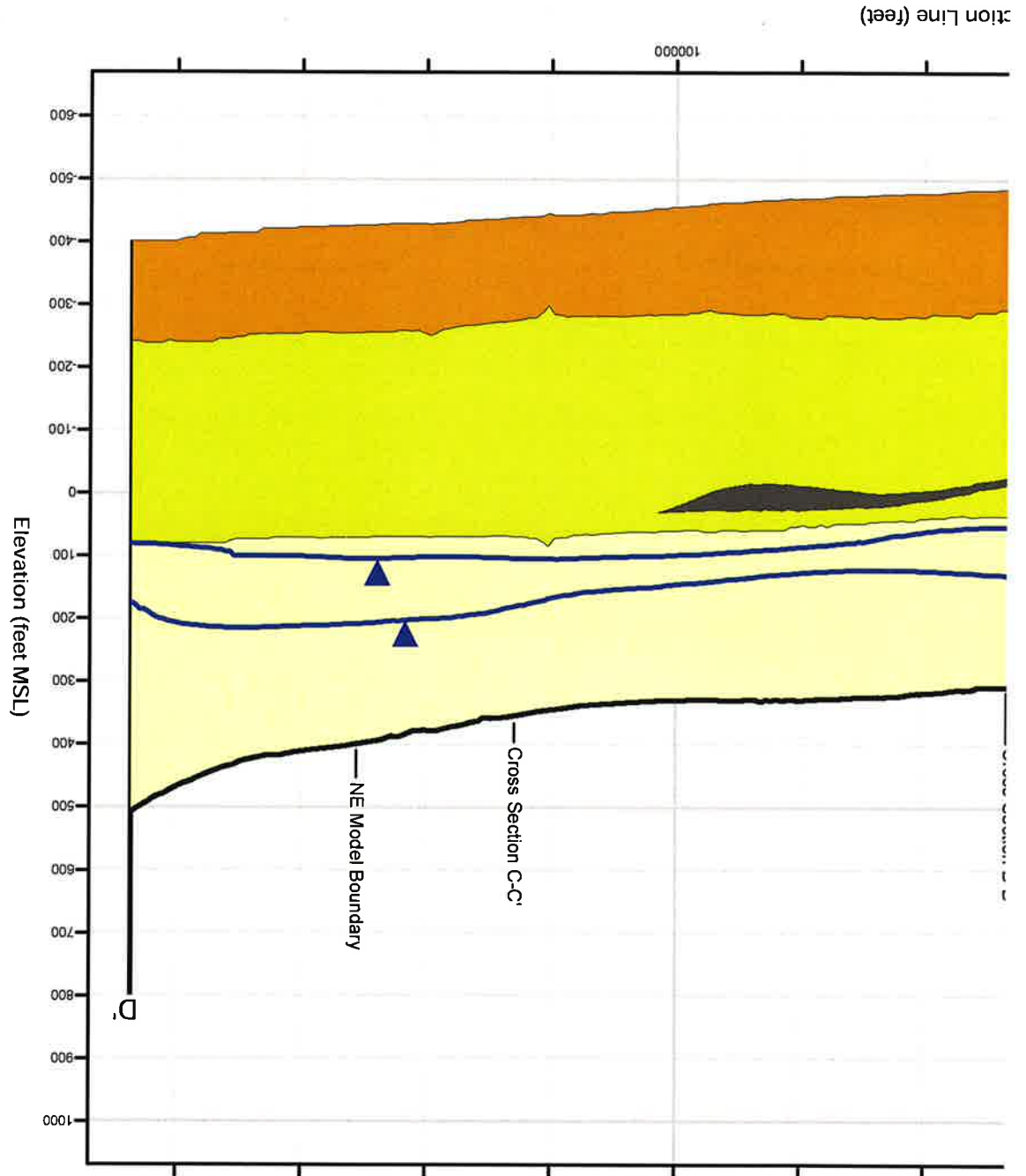


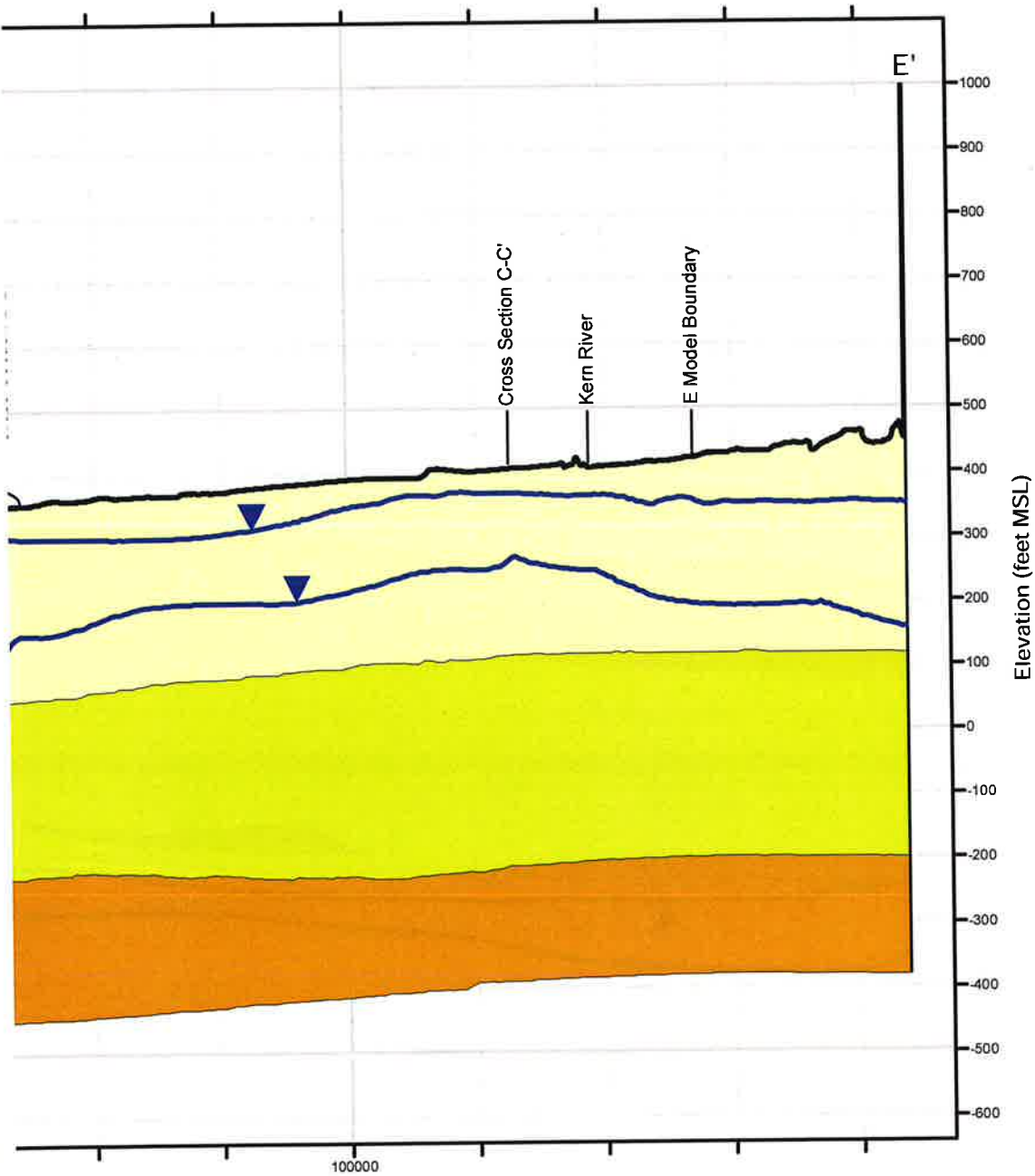






September 2012	Figure 3-7 Hydrogeologic Cross Section C - C'
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ction Line (feet)

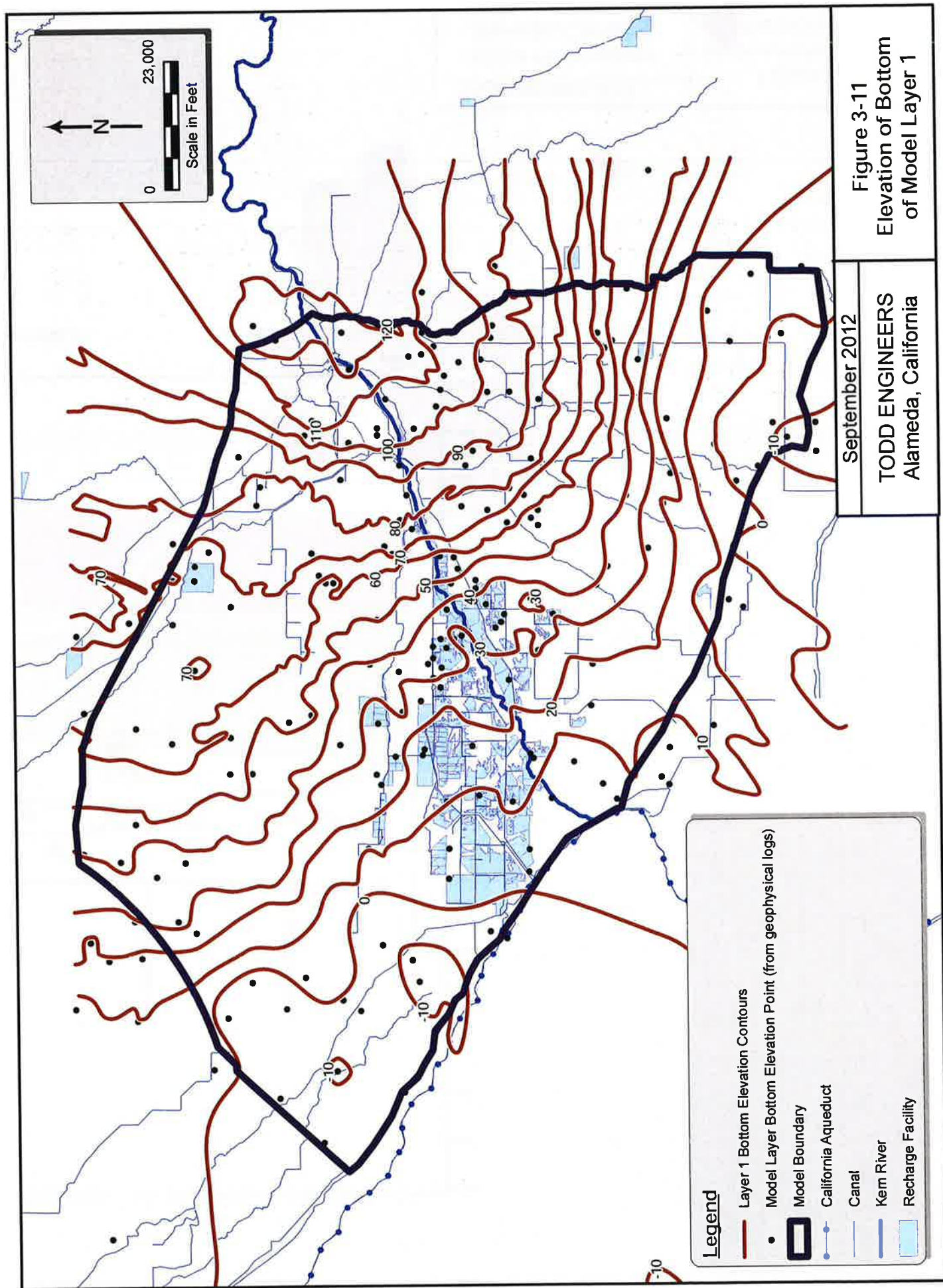
September 2012	Figure 3-9 Hydrogeologic Cross Section E - E'
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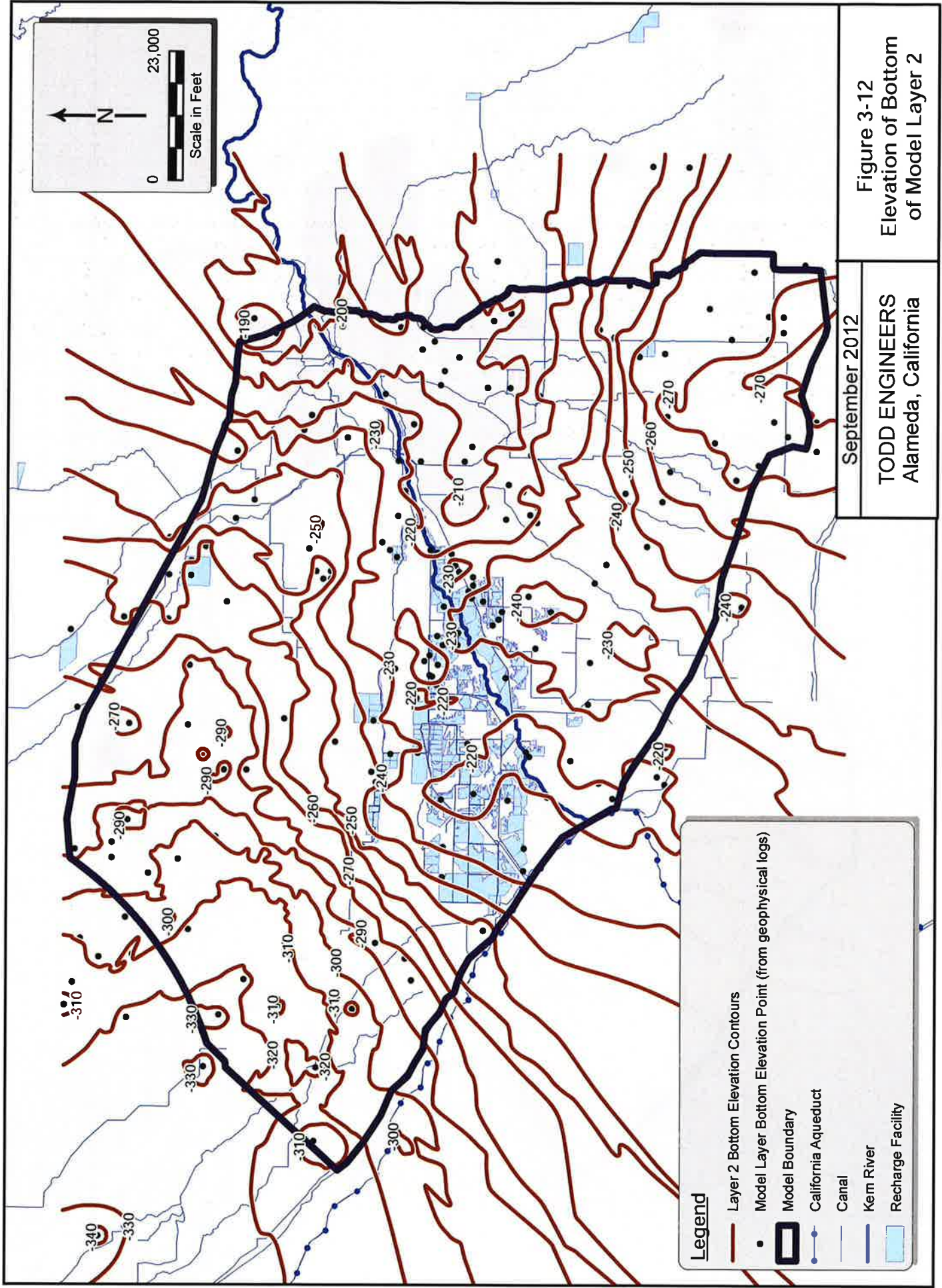
E Model Boundary

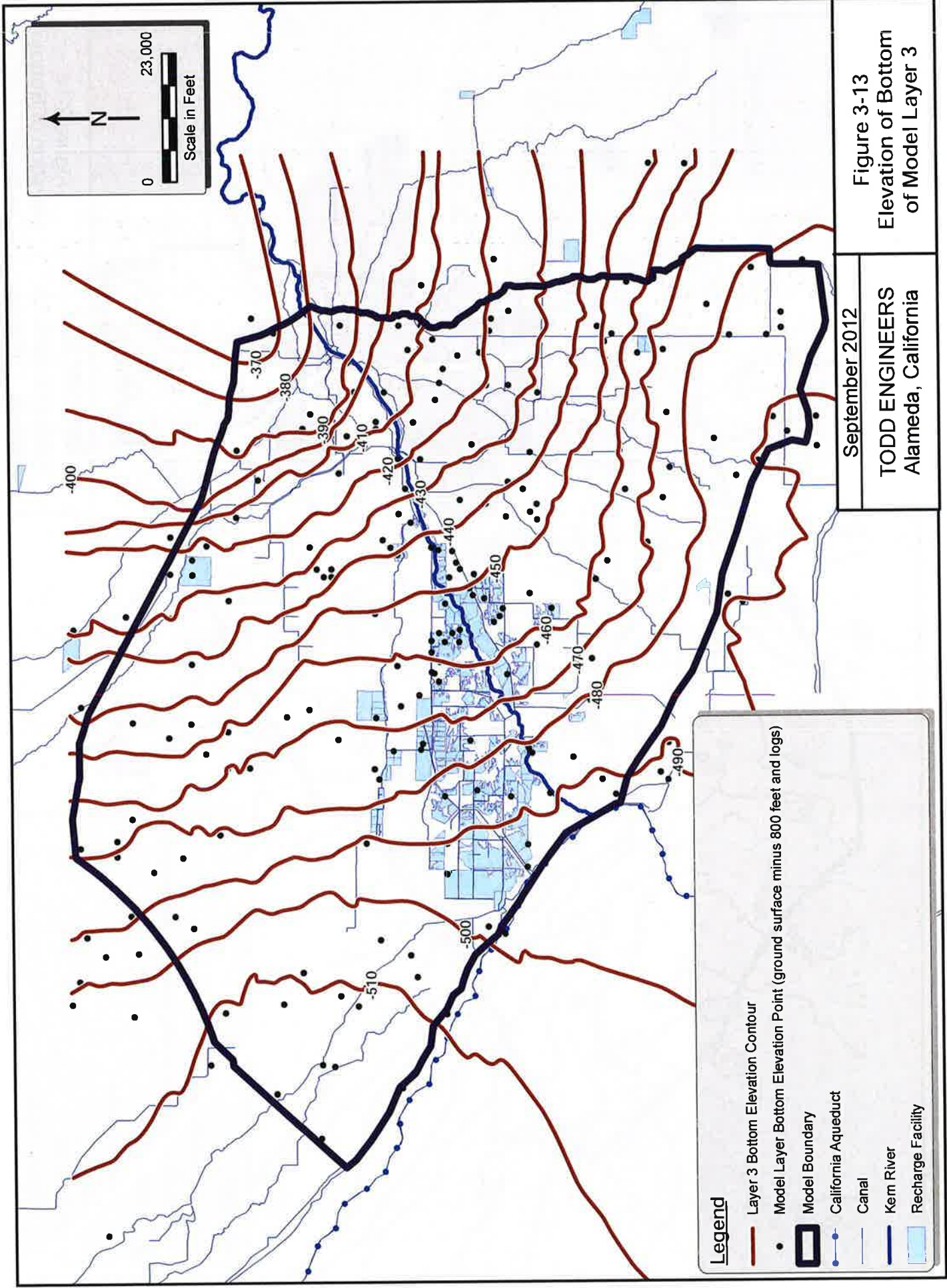
Cross Section B-B'

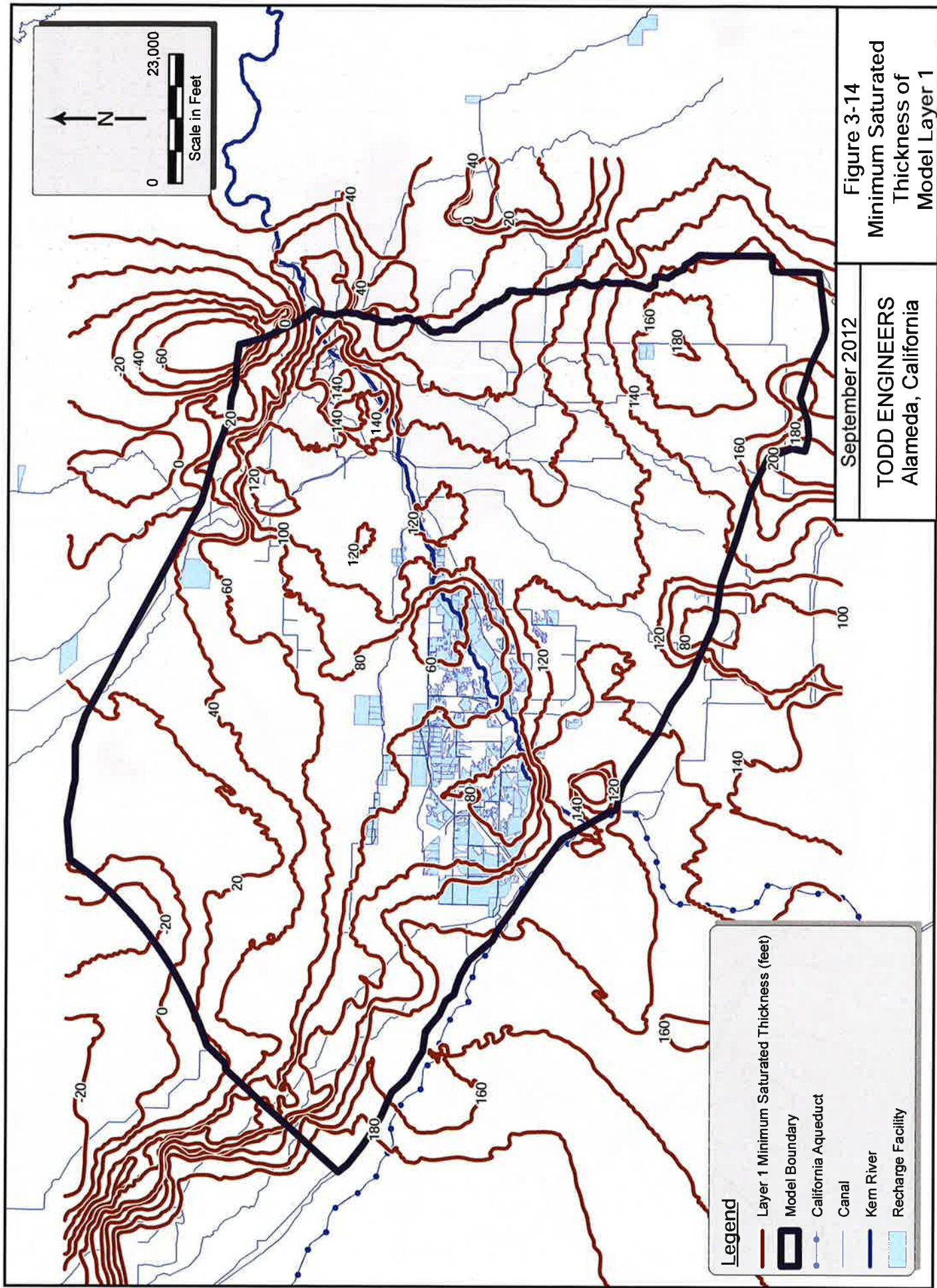
Elevation (feet MSL)

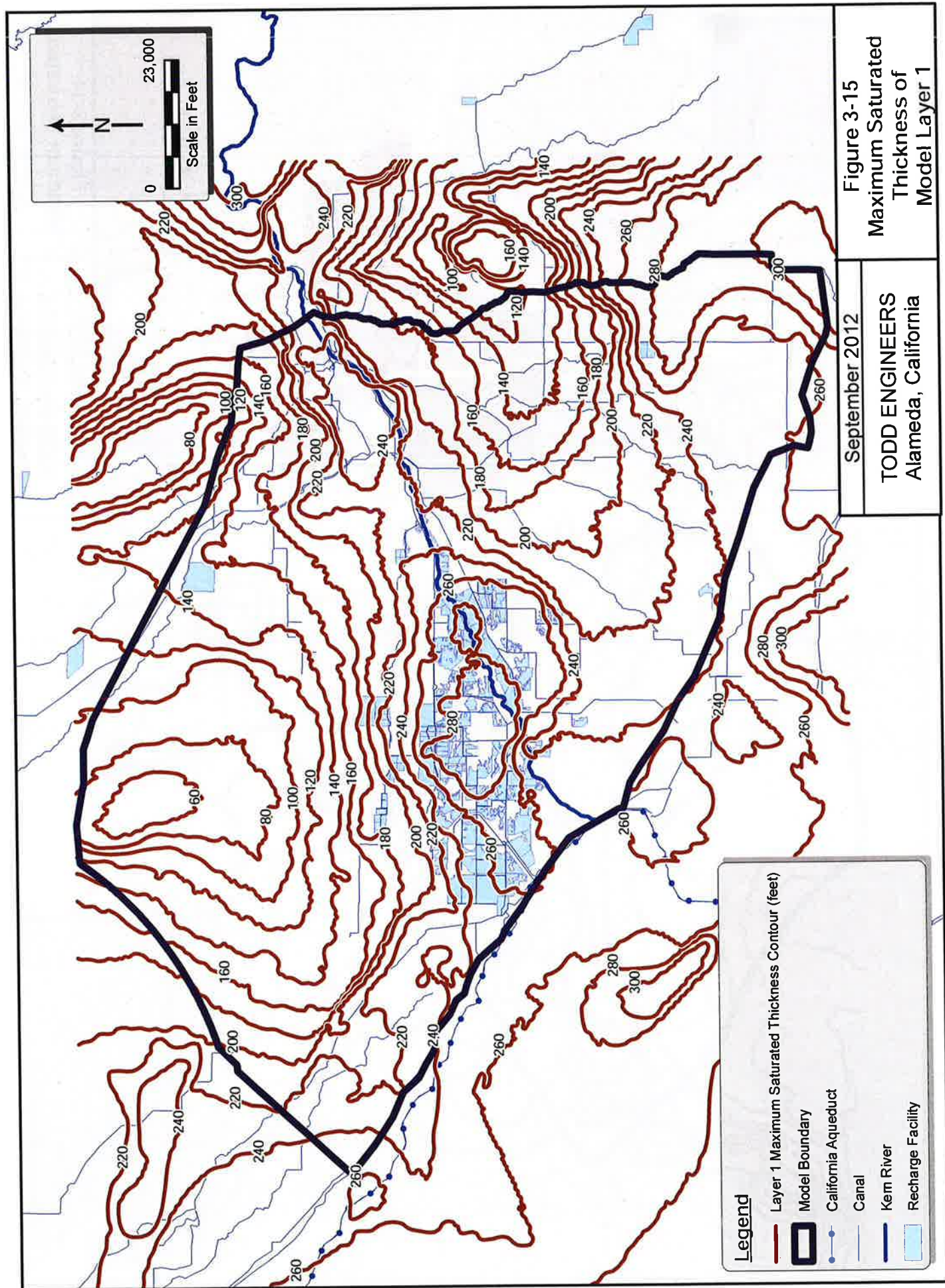
Figure 3-10
Hydrogeologic Cross
Section F - F'

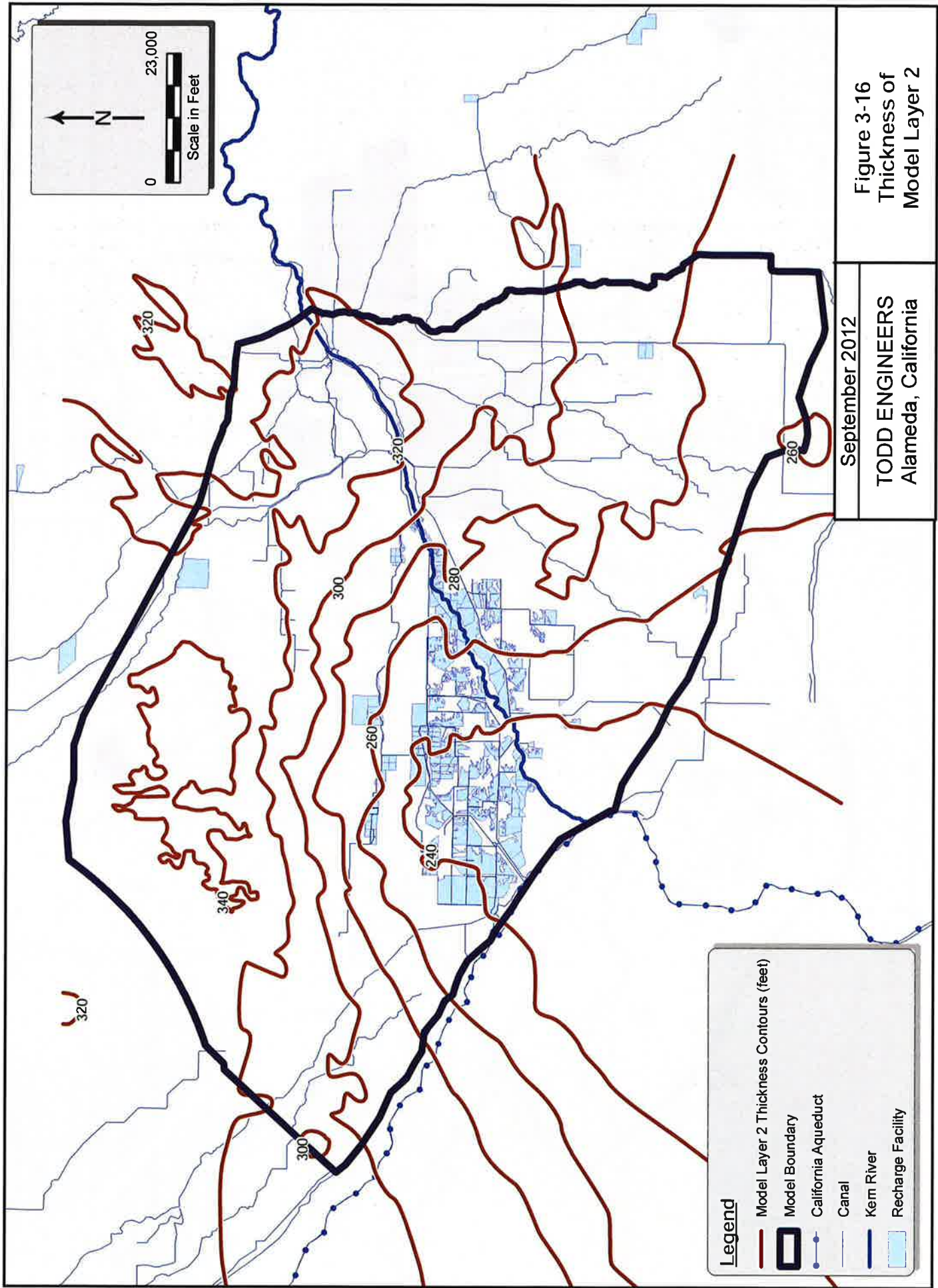






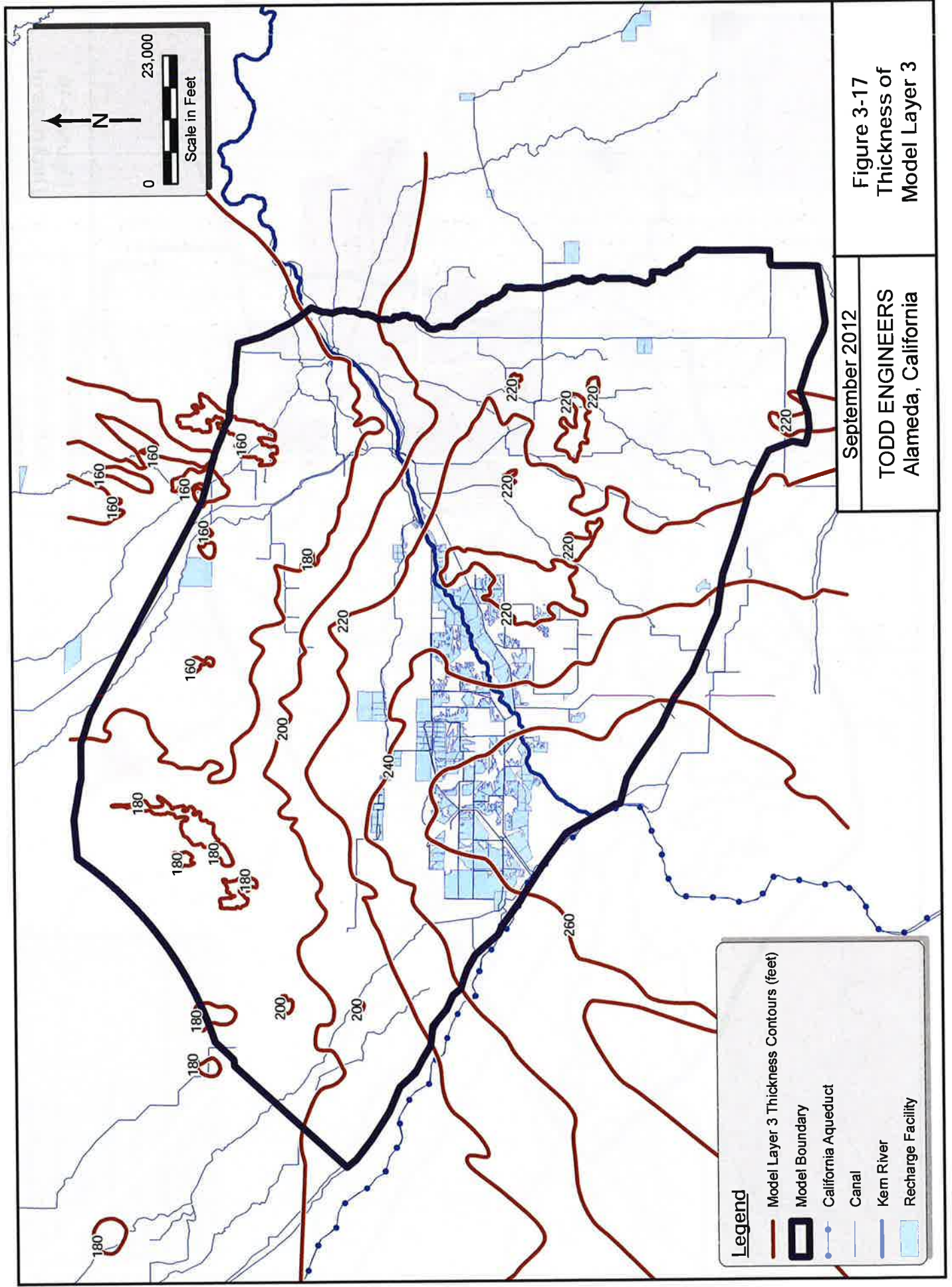


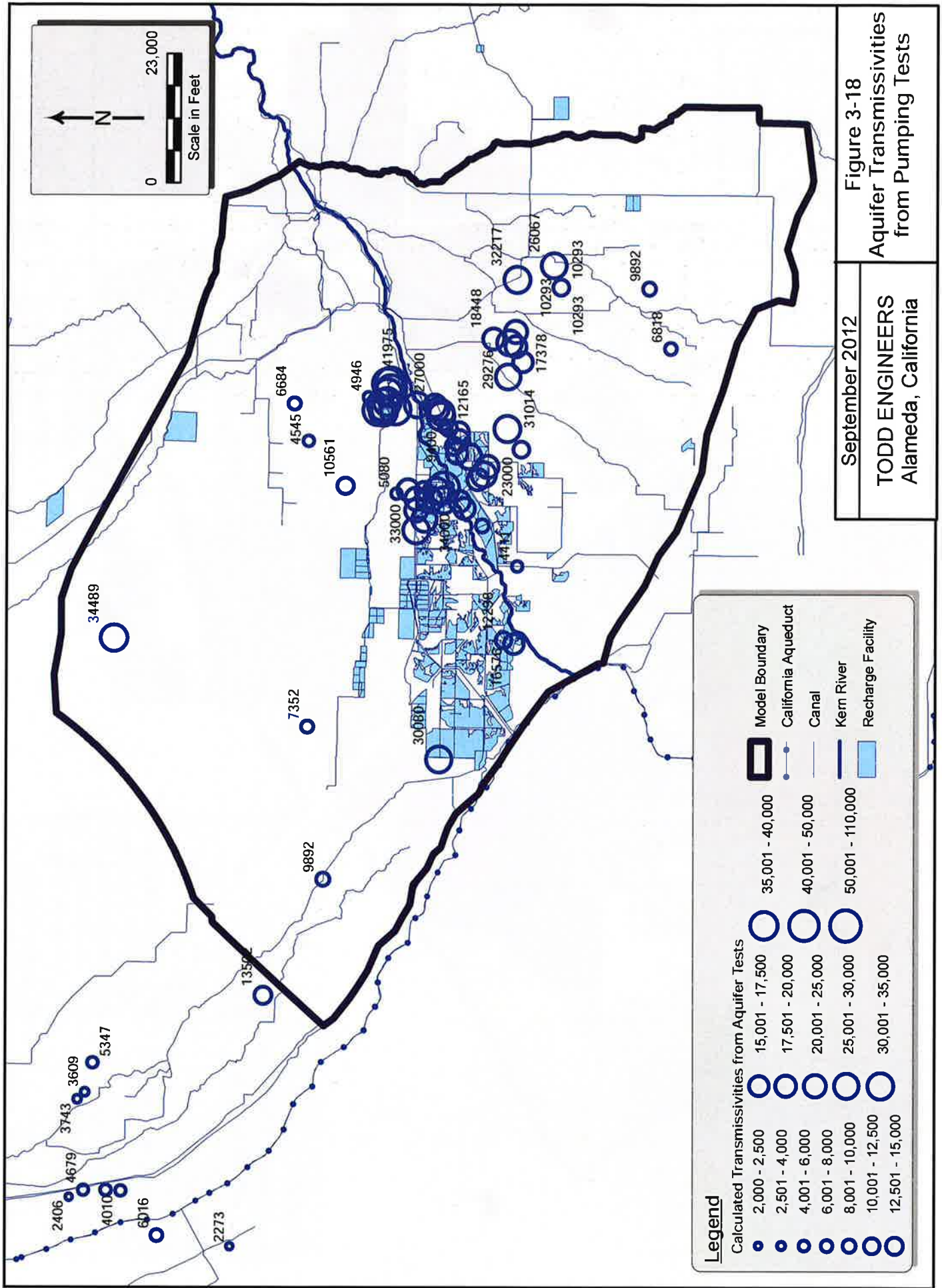


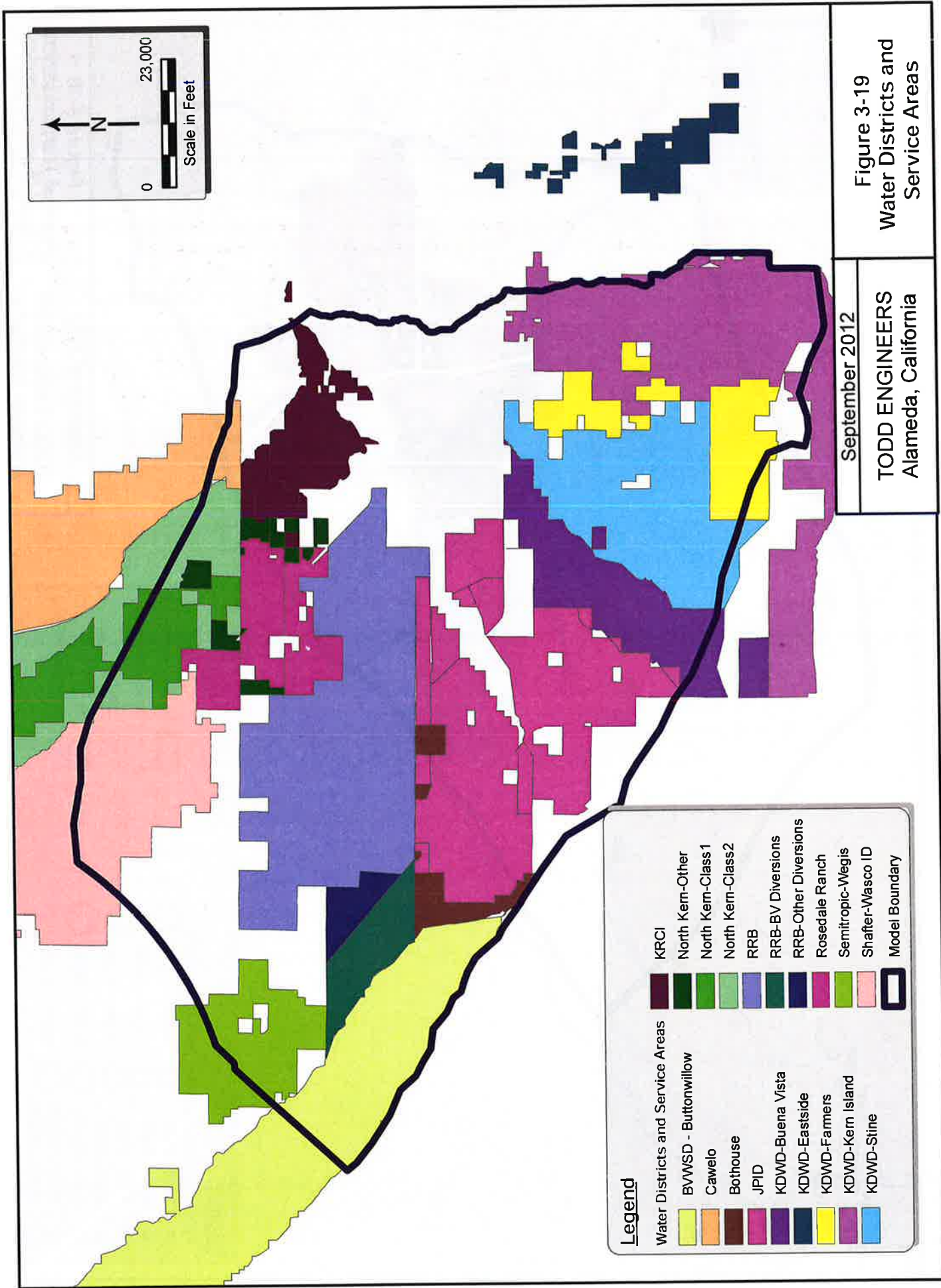


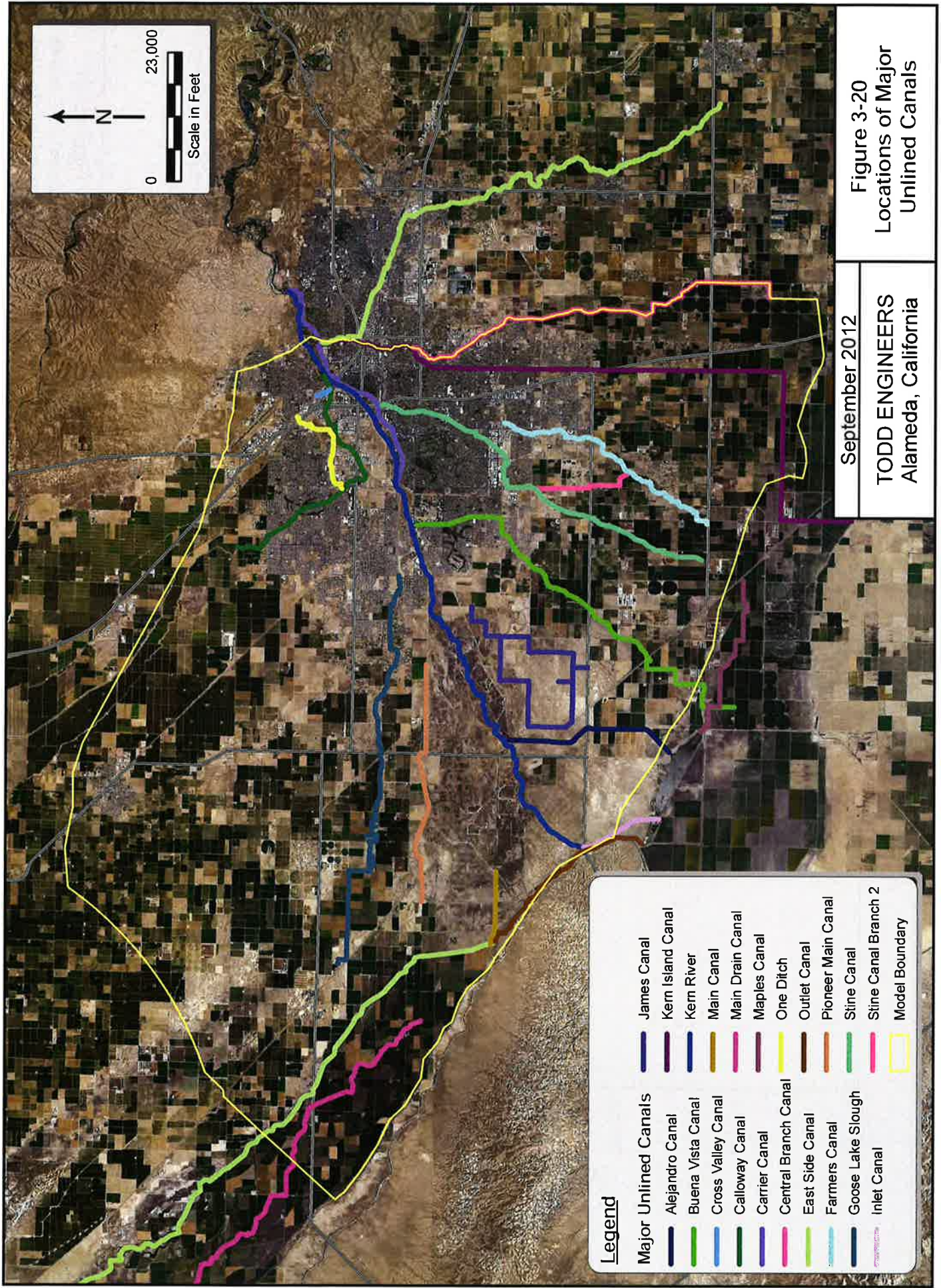
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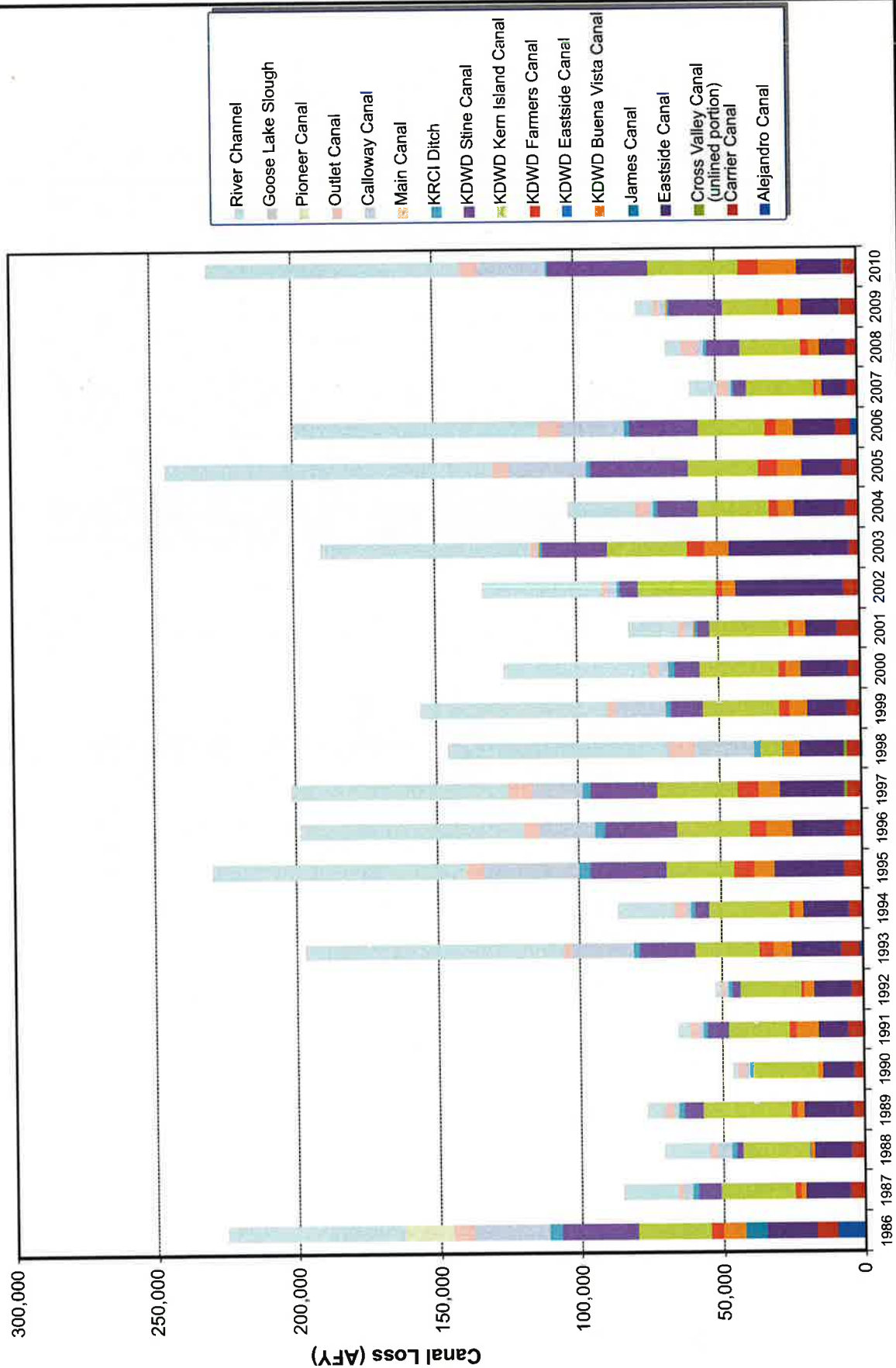
Figure 3-16
Thickness of
Model Layer 2







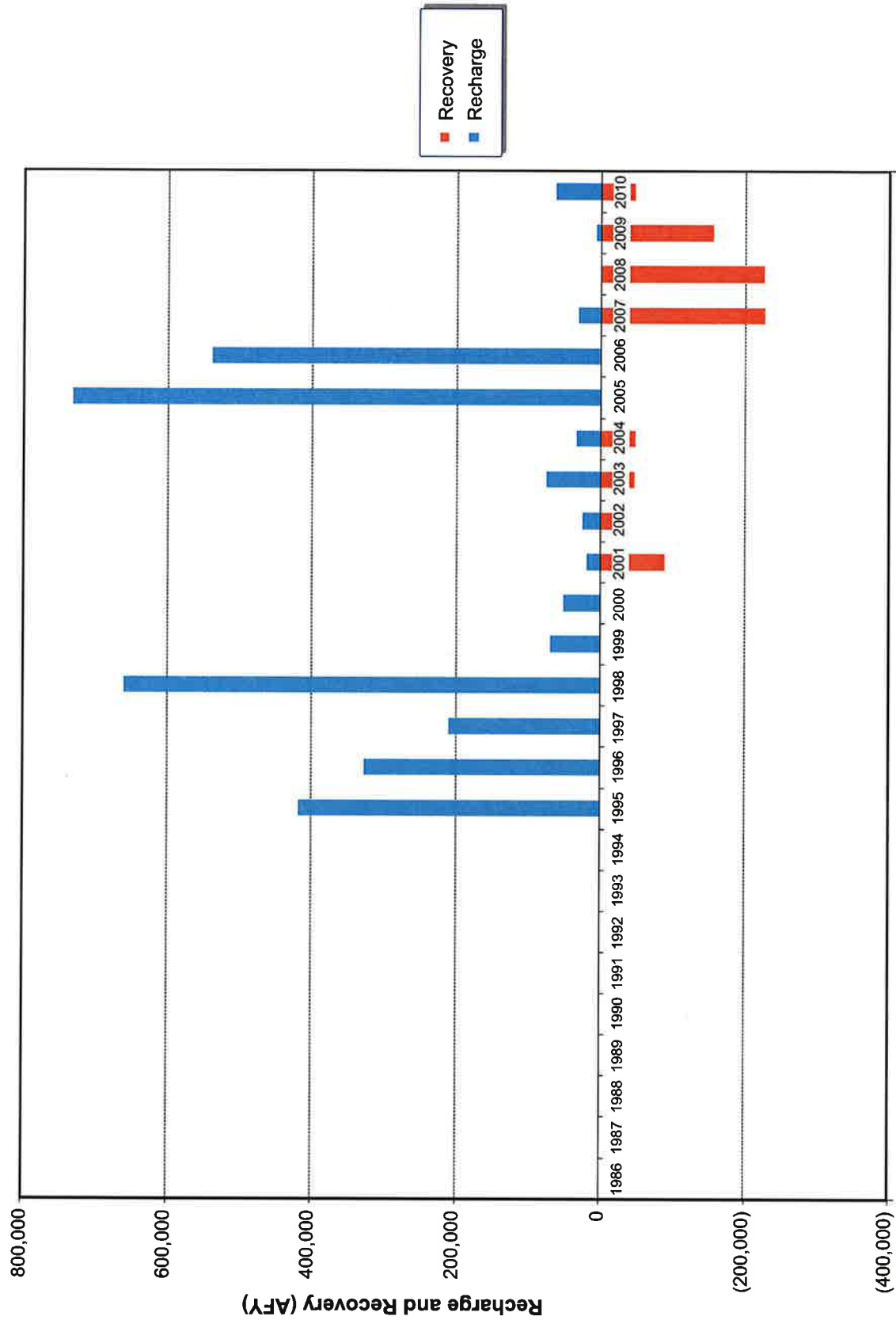




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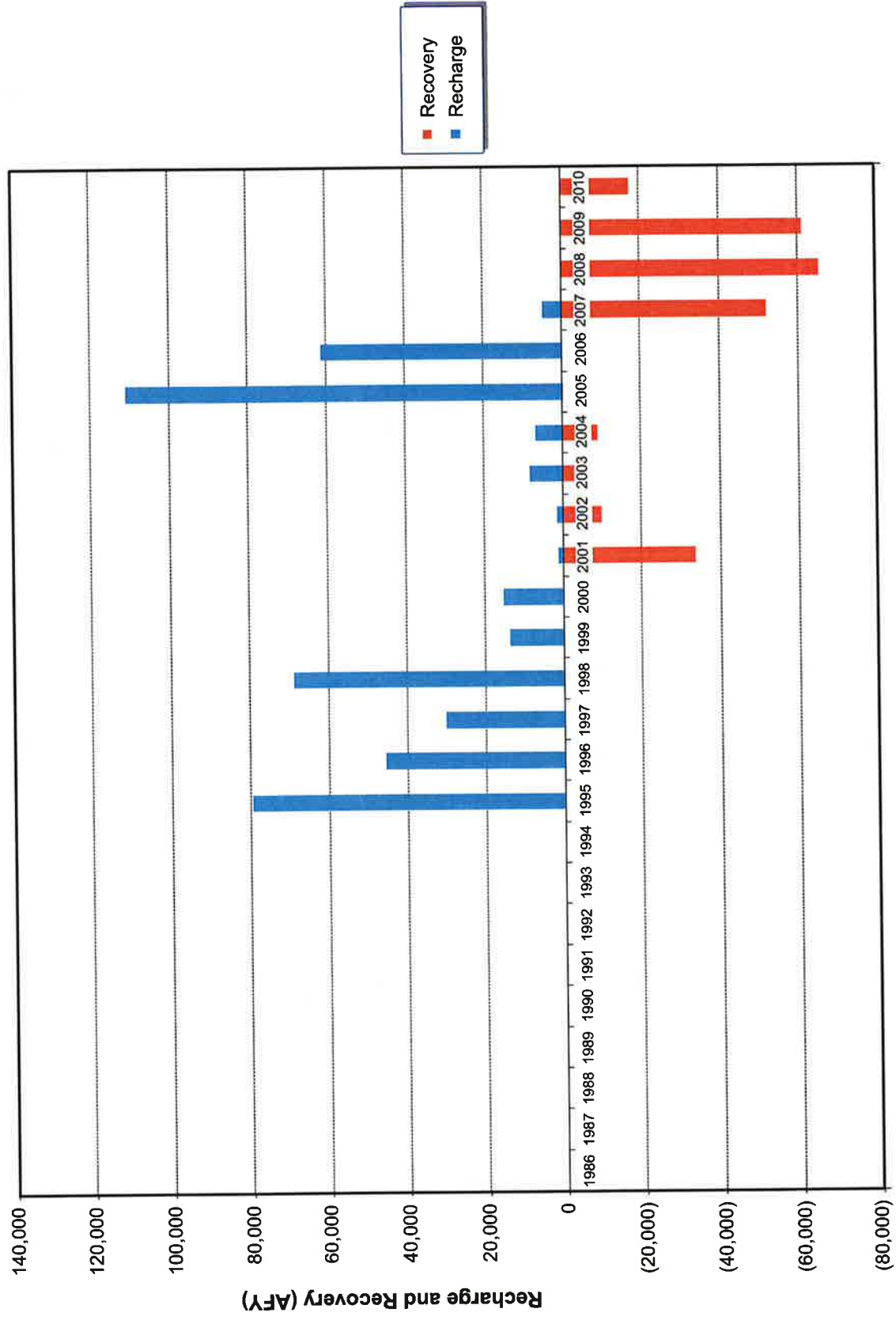
Figure 3-21
Estimated Losses
along Canals and
Kern River Channel



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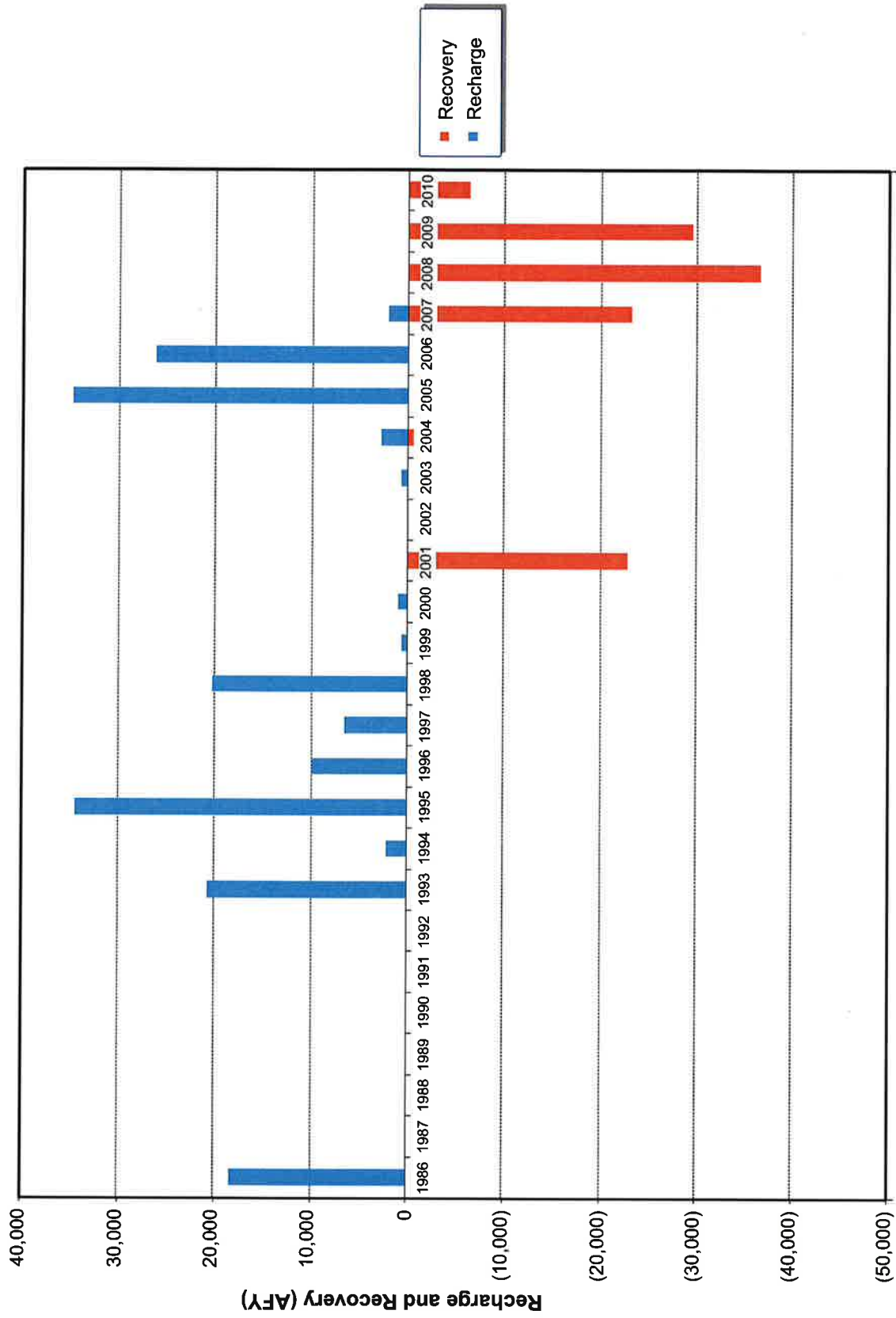
Figure 3-22
Groundwater Banking
Kern Water Bank

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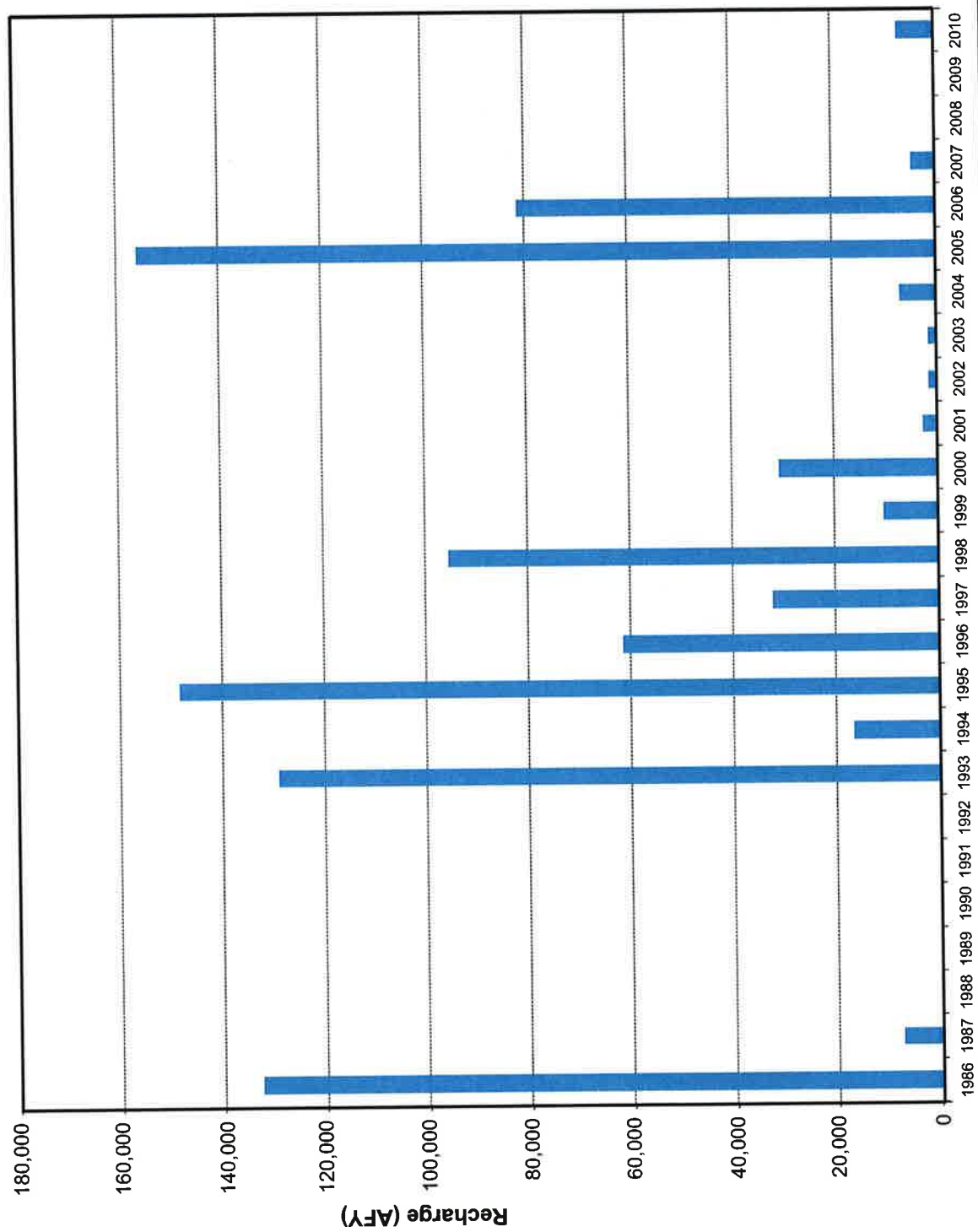
Figure 3-23
Groundwater Banking
Pioneer Project



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Figure 3-24
Groundwater Banking
Berrenda Mesa Project

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Figure 3-25
Groundwater Banking
COB 2800 Facility

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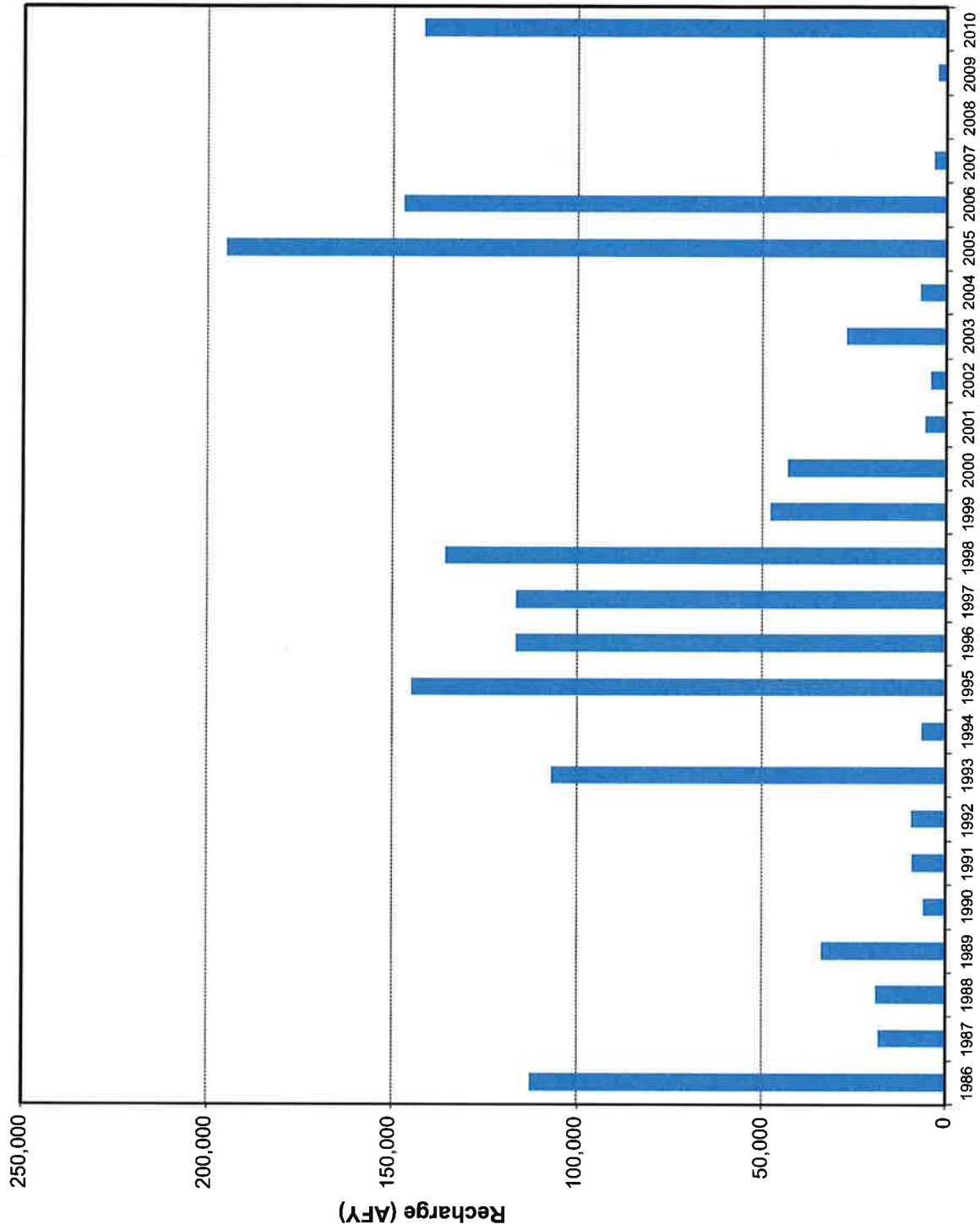
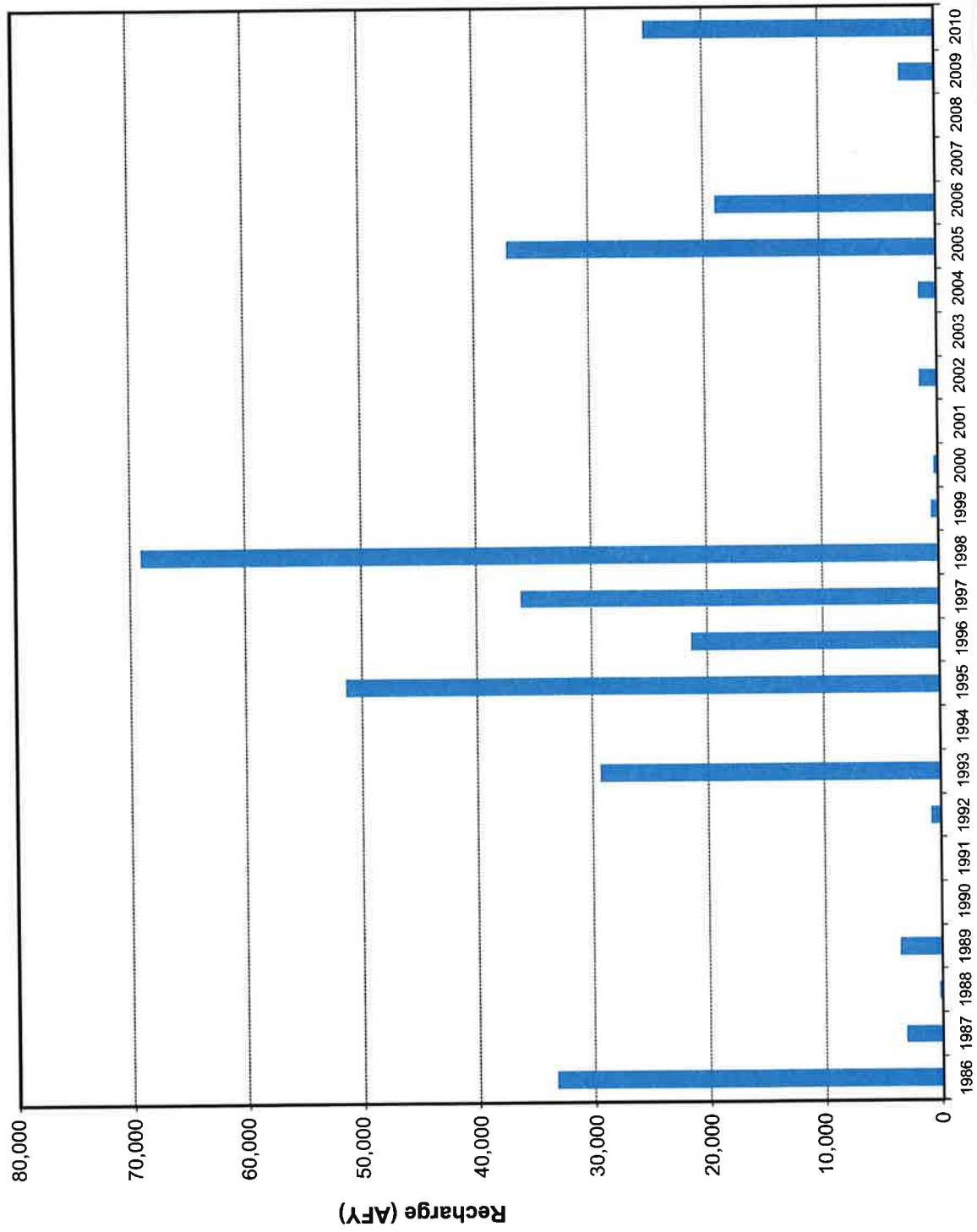


Figure 3-26
Groundwater Recharge
Rosedale
Rio Bravo WSD

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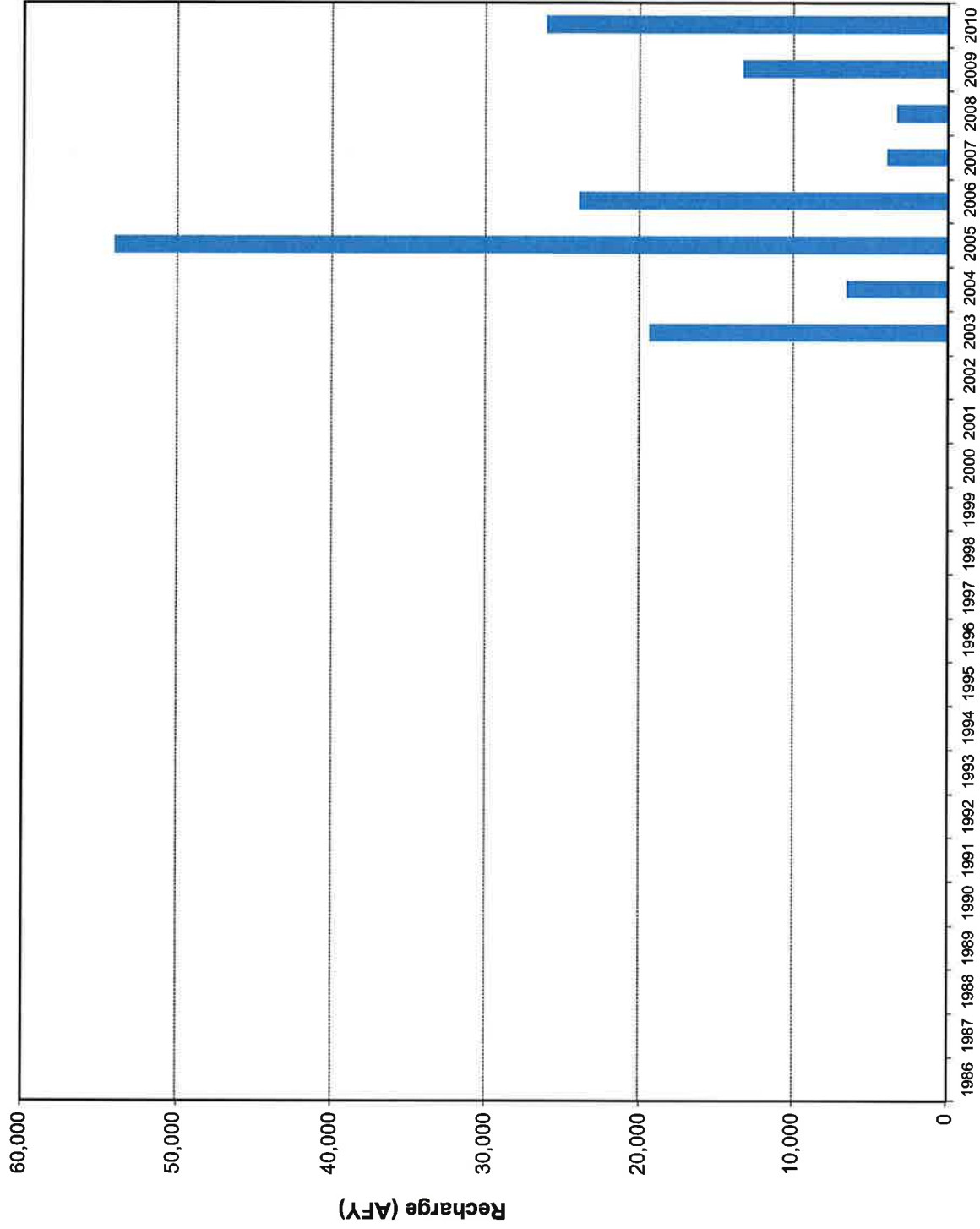
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Figure 3-27
Groundwater Recharge
Buena Vista WSD

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Figure 3-28
Groundwater Recharge
West Kern
Water District

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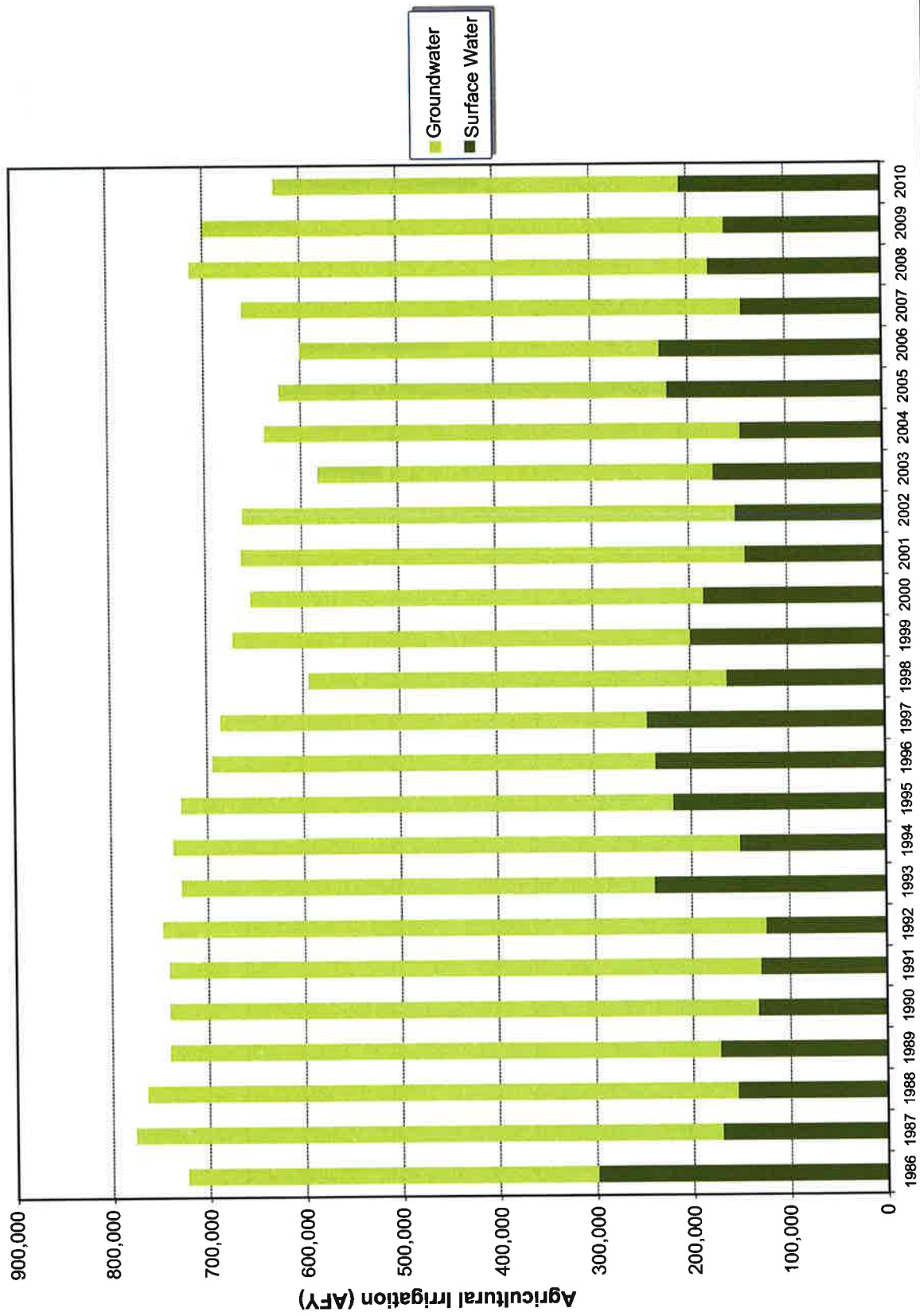


Figure 3-29
Agricultural Irrigation
by Source
Model Area

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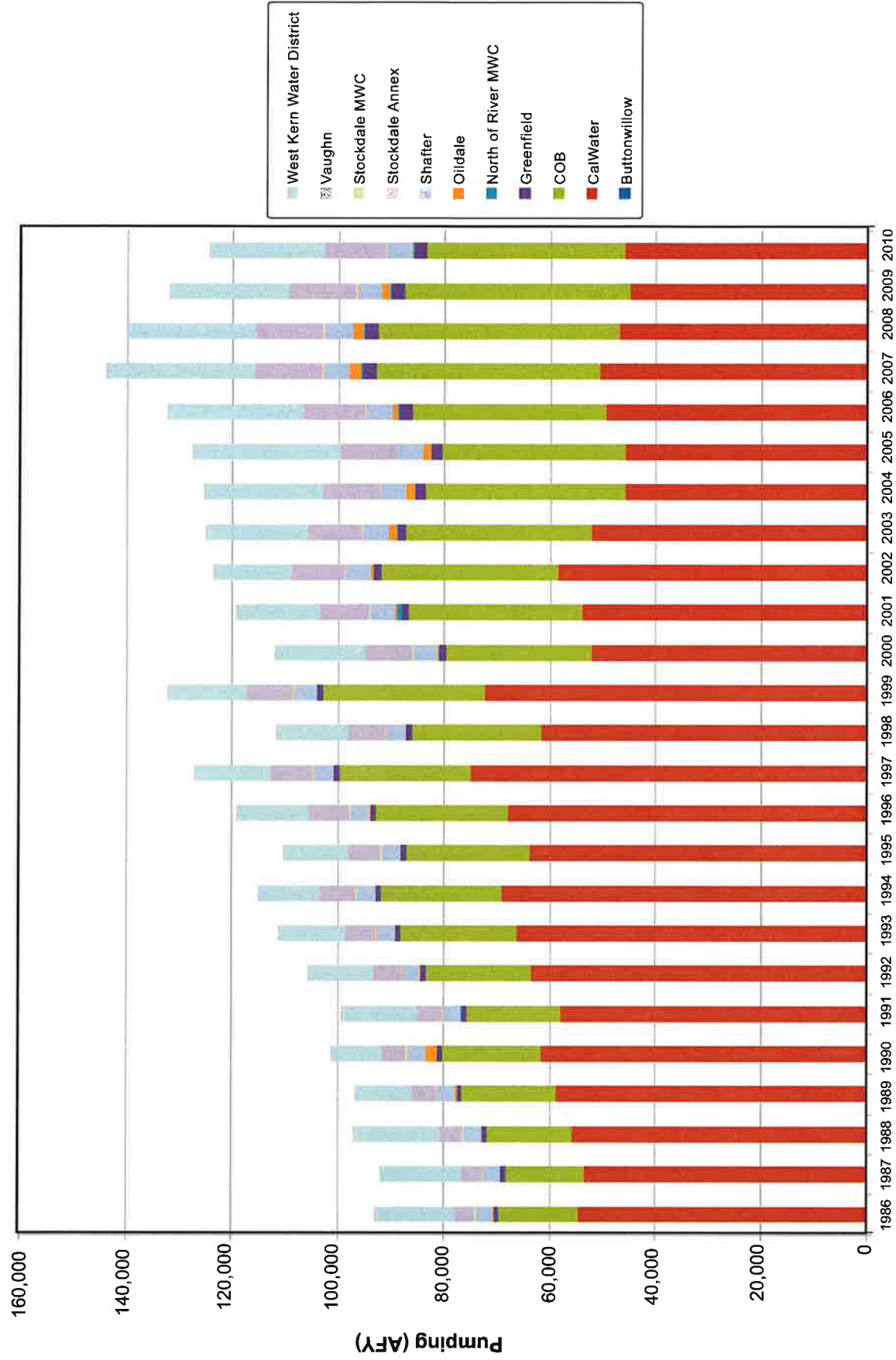
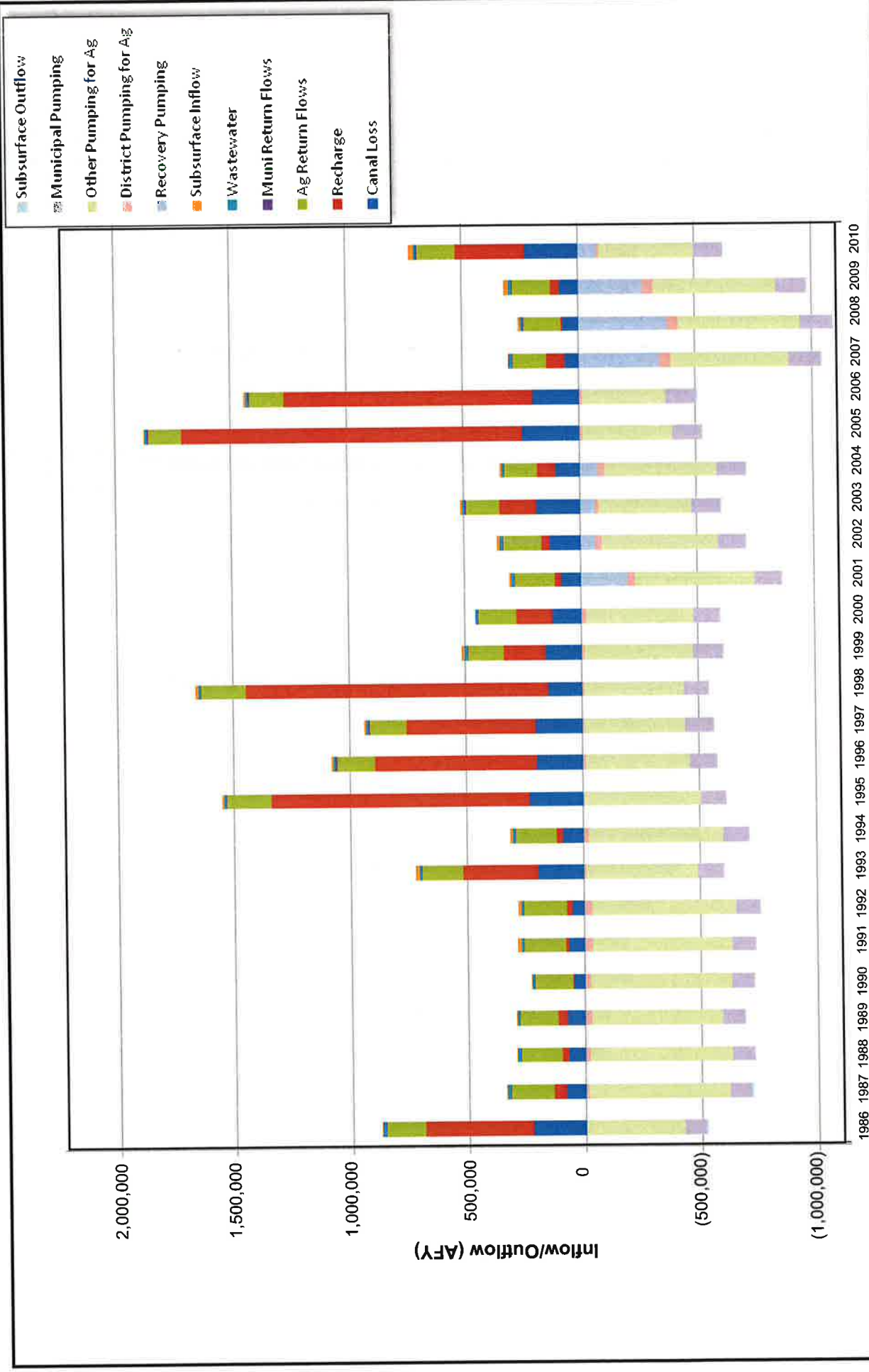


Figure 3-30
Municipal Pumping by
Purveyor
Model Area

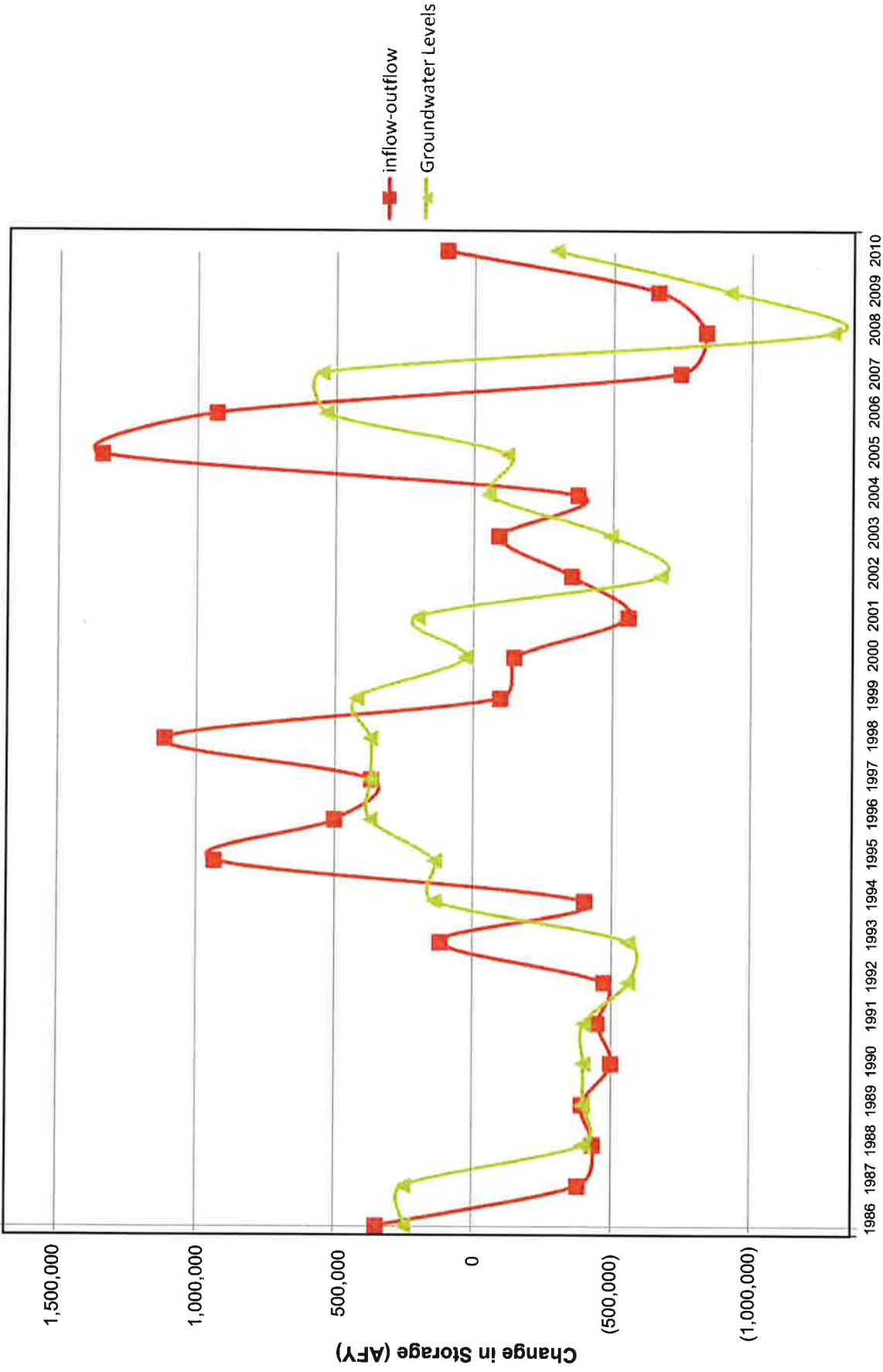
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Figure 3-31
Water Balance
Inflows and Outflows

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Figure 3-32
Change in
Groundwater Storage

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