KINGS BASIN INTEGRATED HYDROLOGIC MODEL

Technical Study No. 3

Analysis of Water Demands In Kings Basin

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Prepared for

Upper Kings Basin Water Forum

And

Kings River Conservation District

In Coordination with

Department of Water Resources

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PURPOSE AND INTRODUCTION

The purpose of this Technical Memorandum (TM) is to present the results of the analysis of historical agricultural and urban water demand in the Kings Basin. The objective of this analysis is to evaluate the historical land and water use conditions, and develop appropriate time series data to represent the agricultural and urban land use categories and water demand conditions in the Kings Basin to support the development of the Integrated Groundwater and Surface water Model (IGSM) in the basin. This hydrologic model is being developed to support the Upper Kings Basin Water Forum (Water Forum) and provide a robust analysis tool for evaluation of potential water supply and conjunctive use programs and projects that would be considered as part of the Upper Kings Basin Integrated Regional Water Management Plan (IRWMP). The historical hydrologic period selected for the model is 1964 to 2004 (Modeling Goals and Objectives Memorandum, WRIME, 2005).

The relevant water demand data for the 1964–2004 hydrologic period was collected from local, regional, and state agencies, and is presented in this TM. Specifically, the following data were collected and analyzed:

- Historical land use data;
- Historical crop acreage data;
- Irrigation efficiency;
- Agricultural water demand; and
- Urban water demand.

ORGANIZATION OF THE TECHNICAL MEMORANDUM

This Technical Memorandum is organized into following sections:

- **Project Background and Subsequent Tasks**: presents the background information on Water Forum, the study area, and previous studies;
- **Data Collection**: describes the data collection efforts as well as the data obtained from different public agencies;
- **Data Analysis**: presents a preliminary estimate of the agricultural and urban water demands; and
- **Conclusions**: provides a summary of the analysis results and how the results will be used for modeling.

PROJECT BACKGROUND AND SUBSEQUENT TASKS

The Kings River Conservation District (KRCD) and Water Forum participants are working together to develop the IRWMP. The California Department of Water Resources (DWR) is providing water management and technical support, as well as facilitation services to the Water

Forum to develop its water management strategies and conjunctive use programs. As part of this cooperation, the Water Forum has decided to develop an integrated hydrologic model for the following purposes (Integrated Hydrologic Modeling Goals and Objectives for Kings Basin, WRIME, 2005):

1. To develop for the Kings Basin area an analytical tool that can represent the groundwater and surface water flow systems and their interactions.
2. To develop a planning level analytical tool that can provide quantitative information on a comparative basis to help answer different questions on the groundwater and surface water system characteristics and to evaluate alternative conjunctive water management strategies.
3. To develop a tool that can be used in assessing management strategies consistent with the IRWMP goals and objectives.

The development of the IRWMP and the hydrologic model are supported by a series of Technical Studies:

1. Modeling Objectives and Strategy
2. Hydrogeologic Investigation
3. Analysis of Water Demand Conditions
4. Analysis of Water Supply Conditions; and
5. State of Groundwater Quality in the Basin

These Technical Studies are to provide sufficient detail on the respective data to support the development of the hydrologic model.

This TM documents the work performed for the first Technical Study, *Analysis of Water Demand Conditions*. The collection and preliminary analysis of the IRWMP Region's water demand will provide historical time series data. The detailed analysis of historical data will be completed during model development.

STUDY AREA

As the IRWMP is currently being developed by the Water Forum Participants which consists mostly of the irrigation districts and municipalities in the Upper Kings basin, the focus of the IRWMP region boundaries was defined by the Water Forum Participants. Therefore, the focus of the data collection and analysis effort as related to water demand was limited to the IRWMP region (Figure 1). However, due to geologic and hydrologic interconnection of the Upper Kings basin and other areas, the hydrologic model area covers more than the IRWMP region. As such, the readily available data on the neighboring area outside of the IRWMP region were also collected to facilitate the development of the model.

The model area boundary was delineated in collaboration with the *Technical Analysis and Data Work Group* of the Water Forum on the basis of hydrogeologic considerations (WRIME, 2006).

The IRWMP area includes the Alta Irrigation District (AID), the Consolidated Irrigation District (CID), the Fresno Irrigation District (FID), and the Raisin City Water District (RCWD) which are within Kings River Conservation District (KRCD) service area.

The AID covers an area of approximately 131,620 acres and includes the communities of Reedley, Dinuba, Orosi, and Cutler.

The CID encompasses an area of approximately 162,850 acres and includes the communities of Sanger, Del Rey, Fowler, Parlier, Selma, Caruthers, and Kingsburg. The remaining section of Division 2 is the Kings River Water District (KRWD), which covers an area of approximately 14,800 acres, and is primarily an agricultural area.

The FID covers roughly 259,140 acres and includes the Fresno/Clovis metropolitan area and the community of Kerman.

The RCWD covers an area of approximately 49,400 acres and is primarily an agricultural area; it also includes the community of Raisin City.

The KRCD covers an area of approximately 1,240,000 acres in the central San Joaquin Valley, including portions of Fresno, Kings, and Tulare Counties. The remaining areas within the KRCD covered by the model are the KRCD Coordinated Groundwater Management Plan areas 'A' and 'B,' including the members of the James Irrigation District, Tranquility Irrigation District, Laguna Irrigation District, Riverdale Irrigation District, and Liberty Water District. For details regarding the agencies applicable for coverage, refer to KRCD's plan adopted in July 2005.

PREVIOUS STUDIES

The following studies and reports were used to support the analysis performed in this Technical Study:

- Upper Kings Basin Assessment Report (WRIME, 2003): contains information on water demand in the IRWMP region, excluding the RCWD by evaluating the land use maps and applying a water duty for each of the different land use categories;
- Upper Kings Basin Summary of Land Use and Water Use (WRIME, 2004): contains additional information and confirmation on water demand and unit water duty factors;
- Bulletin 160-05: DWR California Water Plan Update, December 2005 contains hydrologic information for the Tulare Lake Hydrologic Region, including water demands;
- DWR Bulletin 166-4: Urban Water Use in California, August 1994, also contains urban water demand information for the Tulare Lake Hydrologic Region. The Tulare Lake Hydrologic Region is in the southern end of the San Joaquin Valley and includes all of the IRWMP area.

- Local Groundwater Management Plans and Urban Water Management Plans; Clovis, Dinuba, Selma, Sanger, Reedley UWMP Groundwater Annual Report present agricultural and urban water demand information in the IRWMP area for the specific agricultural areas, as well as urban communities.
- Miscellaneous reports and studies: AID Surface Water Study (1991), CID Surface Water Study (1993), FID Annual Report, FID efficiency impact study, KRCD On-Farm Irrigation Efficiency Study, etc.

The previous studies provided a good starting point for evaluating current data. The Kings Basin Assessment Report provided an estimate for water demand based on land use data for the years available when the study was conducted. The *DWR Bulletin 166-4* provided an analysis of the Tulare Lake Hydrologic Region. However, in order to compile the background and time series information required for the hydrologic model, an in-depth collection of data and analysis of historical water demands are required.

DATA COLLECTION

This section describes the data collection and inventory efforts. These activities were directed to obtain available data from local, state, and federal sources and to identify data gaps. Numerous meetings and/or phone calls with the KRCD and the Water Forum members were held to collect the following data:

1. Agricultural water demand
   - Surface water delivery data for agricultural use
   - Land use distribution
   - Crop acreage
   - Historical irrigation practices
   - Irrigation efficiency studies
2. Urban water demand
   - Surface water delivery data for urban use
   - Land use distribution
   - Water use per capita
   - Population estimates
   - Additional use and losses of water

A summary of the data needs and the collected data is provided in Table 1.

The project database includes an extensive collection of Geographic Information System (GIS) coverages. These coverages, along with their descriptions and sources, are presented in Table 2.

The geo-reference projection of these GIS map coverages vary, although most of them are in NAD 1927 UTM Zone 11 or NAD 1927 California State Plane Zone IV. All these coverages are converted into NAD 1983 UTM Zone 11 for the purposes of consistency and use in this project. The land use analysis was based on land area retrieved from the GIS files. In some instances

Table 1. State, Federal, and Water Forum Data Summary

Data Type	Data Need	Description	Data Sources
Artificial recharge studies and active programs	Water allocation for recharge	Design specifications; Diversion data; monthly; Percolation rates	FMFCD, FID, Fresno, Clovis, AID, CID
Crop Report	Agricultural water needs	Kings County, Tulare County, Fresno County	County Agricultural Commissioners, DWR
Environmental Uses	Water demand for environmental purposes	Stream flow requirement for fisheries program	KRCD
Irrigation Practices/ Efficiency Studies	Water demand analysis; calculate crop requirements;	Methods of irrigation and efficiency	KRCD
Land Use	Water demand and needs analysis	Kings County, Tulare County, Fresno County (1958–2000)	DWR Land & Water Use Database; Department of Conservation Farmland Mapping Program, Counties of Fresno, Tulare, Kings
Population	Historical water demand projection	General information and demographics	U.S. Census, City of Fresno, Clovis, Dinuba, Council of Governments
Recharge Basin Maps	Recharge distribution	Maps of ponding basins	FID, CID, AID, FMFCD
Recharge water deliveries	Water demand for groundwater recharge	Diversion for recharge	FID, CID, AID, Fresno, Clovis, FMFCD
Unit water requirements	Water demand and needs analysis	Requirements for crops specific to the Kings Basin	KRCD
Water Conveyance	Water deliveries for agriculture and urban; seepage losses	Canal map and description	FID, CID, AID, KRCD
Water Delivery	Evaluate groundwater recharge and delivery systems losses	Watermaster Report database 1964–2004	KRWA
Water Rights	Existing agreements and entitlements	Diversion and storage allocated to each water agency	SWRCB, KRWA, individual districts
Water Use	Urban water usage	Categorized water consumption and losses	DWR PWSS, DHS drinking water program, UWMP
Weather/Climate	Water demand analysis; calculate crop requirements	Evapotranspiration and precipitation	CIMIS
Wastewater Flows	Compare to total pumped and delivered to evaluate municipal consumptive use	Wastewater flows from treatment plants	Cities, SKF Sanitation District

Table 2. GIS and CAD Data

Coverage Type	Description	Data Sources
DWR Land Use	GIS layer for land use	DWR Division of Planning and Local Assistance Land & Water Use Database
Water Districts	Federal, state, and private water districts	California Spatial Information Library, Originator: USBR (2)
Public Land Survey System Grid	Grid showing township & range sections	California Spatial Information Library, Originator: DWR
Land Surface Elevation	30-meter digital elevation models (DEMs)	USGS Geographic Data Download.
KRCD Boundaries	KRCD Divisions and Lower Kings Management Areas	KRCD
Cities' Boundaries	Sphere of Influence	KRCD, City of Fresno, City of Clovis, LAFCO
Counties' Boundaries	Jurisdictional boundary reference layer	California Spatial Information Library, Originator: CDF (3)
Surface Hydrology	Detailed layer, generalized layer, and one polygon layer (reservoirs).	California Spatial Information Library, Originator: USBR & USGS
Roads	Both major and local roads	California Spatial Information Library, Originator: Tiger 2000 Transportation Layer
Recharge Basins	Recharge basins within irrigation district	FID, CID, AID, FMFCD, KRCD
Environmental Uses	Stream flow requirement for fisheries program	KRCD
Digital Air photos	Digital Orthophoto Quadrangle GeoTiff (DOQQ)	California Spatial Information Library, Originator: CaSIL, KRCD through Airphoto USA
Groundwater Basins	Basin boundaries as delineated by the State of California	California Spatial Information Library, Originator: DWR Bulletin 118

there were discrepancies on the total area calculated from the GIS map and previous data reported by an agency. This study used the GIS calculated land area as the most current and accurate data available.

During interviews and follow-up meetings with the local stakeholders, available data was obtained in digital and/or hard copy formats. However, it should be noted that often the requested data could not be made available to the project team typically because of limited staff time availability; lack of record maintenance protocols; or remote storage of unmarked boxes, which would made access available only to data-at-hand. A list of the data collected and the source of the data are summarized on Tables 1 and 2.

A brief discussion on the categories of data mentioned above is provided below.

AGRICULTURAL WATER DEMAND DATA COLLECTION

Water demand data for agricultural purposes are not directly available for the study area. Historically, there has not been any metering or record keeping of on-farm water use practices. However, a detailed accounting of Pine Flat storage and surface water deliveries through the main canals have been maintained and reported by the Kings River Water Agency (KRWA). The individual irrigation districts have varied methods of operation to meet agricultural water demands. Agricultural water demands are met primarily by surface water deliveries and groundwater pumping. The crop demands not met by surface water deliveries are assumed to be met by groundwater pumping.

AGRICULTURAL LAND USE

To estimate the agricultural water demand, an evaluation of the total cropped acres and types of crops grown is conducted. For cropping patterns, data from multiple sources were identified and collected from the county agricultural commissioner's annual report, the Department of Conservation Farmland Mapping Program, and the DWR Land and Water Use Division.

The DWR Land and Water Use Division performs land use surveys throughout California approximately every 6-8 years. The land use maps for Fresno, Kings and Tulare counties are processed, and summary tables for each county are organized by each DAU. The hard copy maps are available by 7 ½ minute Quad sheets, which are approximately 36 square miles in area. The DAUs that fall within the Kings Basin study area are #233 through #240, excluding #238 which lies south of the Kings River. A map of the DAUs and Quads is shown in Figure 2. A list of the county land use maps by DAUs and Quad numbering that cover the Kings Basin modeling area is found in Table 3. The land use maps available were collected from the DWR using the first survey in 1958. However, only the most recent years, identified in Table 3, are available in GIS format. Previous years are available as hard copy and/or scanned images by Quads. Each year contains approximately 36 Quads that cover the entire modeling area. The

KRCD is currently in the process of converting the scanned images to GIS files for the beginning of the study period for Fresno and Tulare Counties. Kings County land use maps were not readily available prior to 1991. The portion of the study area within Kings County is agricultural and contains approximately 4,100 acres within the CID. For the purpose of this study, it is assumed that the land use and harvested crop from this area has not significantly changed during the study period.

Table 3. Detailed Analysis Units for the Kings Basin Hydrologic Model Area

County Land Use Maps	DAUs	District/Area	Quads	Years Available
Fresno County	233 234 235 236 239	FID Academy Raisin CID AID	4138, 4139, 4140, 4235, 4236, 4237, 4238, 4239, 4240, 4241, 4242, 4334, 4335, 4336, 4337, 4338, 4339, 4340, 4341, 4342, 4436, 4437, 4438, 4439, 4440	1958, 1968, 1972, 1979, 1986*, 1994*, 2000*
Tulare County	237 239 240	Lower Kings CID Orange Cove	4441, 4442, 4443, 4541, 4542, 4543, 4538, 4539, 4540	1958, 1970, 1978, 1985, 1993*, 1999*
Kings County	236 239	CID AID	4539, 4540	1991*, 1996*, 2003*

*Available as GIS shape files

The land use data by DAU collected from DWR is used to estimate land use for the Kings Basin, because it provides a consistent method with reasonable accuracy throughout the study period.

In addition, the agriculture commissioner's offices for Fresno, Tulare, and Kings County publish an annual crop report. The annual crop reports are available and were collected in digital format for Tulare County from 2000 to present; for Fresno County from 1994 to present; and for Kings County from 1964 to present. The reports summarize the harvested acreage, the production per acre and a cash value for the harvested crop. These reports aggregate a lump sum of the harvested crops for the entire county without indication of where the crop was cultivated. The effort to apply the county-wide crop reports to the harvested crop mix within the study area was beyond the scope of current study. Therefore the Agricultural Commissioner crop reports were not directly included in the analysis. However, the county-wide annual crop trends will be incorporated in the annual crop acreage trend analysis for each DAU.

The Department of Conservation Farmland Mapping Program performs a land use survey and has produced maps in GIS format for every other year since 1984. The coverage areas available were for Fresno and Kings Counties. The Department does not conduct land use surveys within Tulare County. The files that were collected for the three counties do not contain specific

cropping data in formats required for modeling purposes and were not be helpful in assessing agricultural water demand.

Historical Irrigation Practices

The irrigation practices of individual farmers are not recorded by the counties or the irrigation districts. The study area has historically promoted the conjunctive use of agricultural irrigation waters. Historically, the predominant practice for irrigating crops has been by flood or furrow irrigation. Since 2001, the AID has required individuals to submit to the method of agricultural irrigation within their district boundaries. The intent is to focus on water conservation. The soil and groundwater conditions within the AID are not ideal conditions for recharge. The depth to groundwater within the AID is high with a relatively limited storage capacity. Within the past 10 years there has been an increased use of drip irrigation on permanent crops (orchards and vineyards). This trend is likely due to the increased energy and pumping costs. The practice is more limited in the IRWMP Region than in other areas of the state that are more reliant on groundwater. This is because of the primary reliance on surface water in the IRWMP Region and the increased costs associated with filtration, operation, and related equipment needed to use drip systems at farms served by surface water.

Irrigation Efficiency

No studies of regional irrigation efficiency were identified. The KRCD performed and published a final report for a three-year, on-farm irrigation efficiency study funded in part by DWR and USBR. The measurements were taken to include applied water, tail water, distribution uniformity, rainfall, and soil moisture. There were a total of four sites located with the FID and the CID. Site One was within the FID in the eastern portion of Fresno County and consisted of 36 acres of planted navel oranges irrigated by furrows. Site Two was in the CID and consisted of 28 acres of planted Ruby Seedless table grapes irrigated by a drip system. Site Three in the CID consisted of 35 acres of three varieties of stone fruit variety irrigated by a micro-sprayer system. Site Four within the FID was 30 acres of almonds irrigated using a border strip (flood) system. The finding of the study showed that Site One had an average seasonal irrigation efficiency of 68% using furrow irrigation. The sites with drip and micro-irrigation systems had an average seasonal irrigation efficiency of 96% and 89%, respectively. Site Four, irrigated by flood, recorded average season irrigation efficiency of 82%.

URBAN WATER DEMAND DATA COLLECTION

The urban water demand within the study area is primarily met by groundwater. For most cities, the production of groundwater is managed by the city's public works department or water districts. All municipalities are served by public utility departments, except for the City of Selma which is served by California Water Services, an investor-owned utility. Groundwater

production and delivery data were collected from the cities within the study area. Some cities were unable to provide historical water production and water use records and others only recently began maintaining groundwater pumping records.

Additional sources of data were sought since data available from urban water sources was limited. The DWR and the Department of Health Services Drinking Water Program collect water use information from the cities on a voluntary basis. The DWR has records for most of the cities and water production companies since the 1980s or mid-1990s. Additionally, water use records from the Department of Health Services Water Drinking Division were collected. Only current records, from 1999 to 2004, are maintained at the offices of DHS.

In order to get a better understanding of the quantity of water used, it is helpful to have a broad view of where the water is being produced. Below is a description of the water production facilities for the larger cities within the irrigation districts.

Fresno Irrigation District

There are two major cities within the FID boundary: the City of Fresno and the City of Clovis. Until 2004, when both cities brought surface water treatment plants on-line, groundwater was the sole source for drinking water. Groundwater is still a major source for water supply in Fresno. There are approximately 275 well sites, with 240 typically in operations, in the City of Fresno. Fresno's surface water treatment plant has a capacity of 30 million gallons per day (MGD) with a total build-out capacity of 60 MGD. In 2004, Fresno produced 52,148 million gallons (MG) of groundwater and 2,363 MG of surface water. The City of Clovis has 40 wells and a surface water treatment plan that can deliver 15 MGD of potable water, expandable to 45 MGD. In 2004, the City of Clovis produced 7,505 MG of groundwater and 527 MG of treated surface water.

Consolidated Irrigation District

The CID has five major urban areas within its boundaries: Selma, Fowler, Sanger, Parlier, and Kingsburg. Groundwater is the source of domestic water supply. The water demand for the City of Selma is met by annual groundwater production of 2,300 MG from a private company, California Water Service Company. The water department for the City of Fowler provides for the distribution of potable water from six well sites and produces 414 MG per year. The City of Sanger has seven wells with a current demand of 1,533 MG per year. The City of Parlier has a total of six active wells sites and an annual production of 1,059 MG. The City of Kingsburg produces 1,217 MG of groundwater per year.

Alta Irrigation District

Within the AID's boundaries are the City of Dinuba, the City of Reedley and the unincorporated areas of Cutler and Orosi. The primary source of water for the Cities of Dinuba

and Reedley is groundwater. Dinuba draws its water from eight groundwater wells all within the City limits. Over the last five years, the City of Dinuba has pumped an average volume of 1,474 MG per year. The Reedley Municipal Water System draws water from eight wells, with a total annual production of 1,750 MG. The annual production of the unincorporated areas of Cutler-Orosi was 818 MG.

Raisin City Water District

There is no information available from Raisin City at this time.

DATA ANALYSIS

This section presents the information collected and compiled to summarize a total historical water demand for the Kings Basin study area. The water demand is based on the available historical time series data that were collected. Historical time series tables were compiled based on readily available information. In this analysis, the agricultural water demand was estimated based on crop acreage for each DAU and crop-specific water duty. The total water consumed by urban areas was estimated based on per-capita water demands and population records. The following section will present the preliminary water demand estimates for agriculture and urban uses.

LAND USE

The land surveys started in 1958 and are completed roughly every seven years. The land survey is performed county wide by DAU and designated by year published. Neighboring counties' land use surveys typically do not occur in the same year. Some DAU cross over into multiple counties. For example, AID is represented by DAU 239 which extends into Fresno, Tulare and Kings Counties. The most recent land surveys were completed for Fresno County (2000), Tulare County (1999), and Kings County (2003). In order to estimate the crop acreage for AID, data from 1999, 2000, and 2003 was interpolated for the in-between years.

Figure 3 shows the current land use map for the Kings Basin region as compiled based on the latest available GIS coverage data. To have a time reference associated with this latest land use condition, the coverage is designated as 2000 level land use. Assuming the land use remained relatively unchanged during the survey years of 1999 to 2003, them map represent a reasonably accurate map of current land use. The riparian and total acreage were calculated from current GIS land use files. For consistency, it is assumed that the riparian acreage remained the same for the entire period of 1958 to 2004. For the land that was annexed by the irrigation districts during the study period, it is assumed that the land use classification has remained the same. Overall the assumption should be of minimal consequence to the overall Kings Basin water demand.

The land use and cropping data for 1964 to 2004 was linearly interpolated for Fresno, Tulare, and Kings Counties. The DAU-data is summarized below in Figure 4, which represents the total crop acreage of the Kings Basin study area for 1964 and 2004.

Based on this land use survey estimates for Year 2004, agriculture is the predominant land use in the Kings Basin. Approximately 77% (roughly 785,000 acres) of the study area is in agricultural use; 16% (165,000 acres) is in urban use; and 6% (65,000 acres) is in other uses (i.e., native vegetation, water surface) (Figure 5).

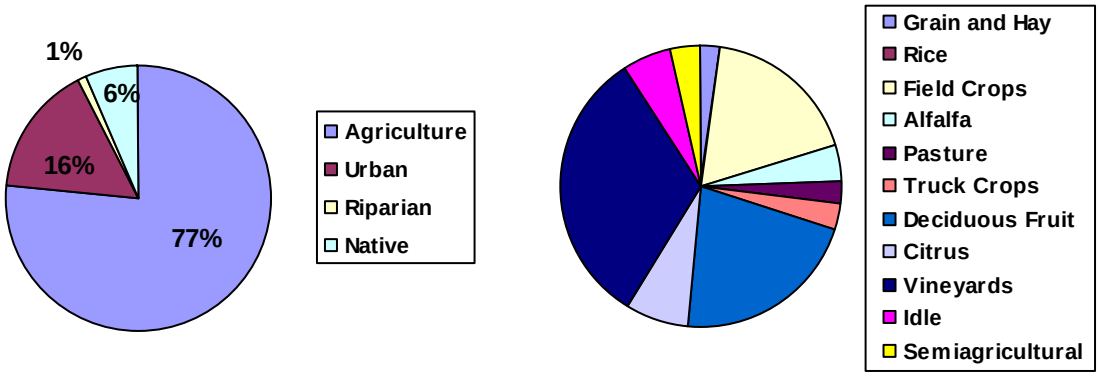

Figure 5. Land Use Percentage for 2004

The primary crop types include vineyards located in the CID, the FID and the RCWD, and deciduous fruits and nuts, which are present throughout the area but are located mostly in the AID and CID.

The Figures 6-12 show a graphical representation of the changes in land use from 1958 to 2004 for each DAU. The major land use categories are based on DWR classifications, as shown in Table 4.

Figure 6 represents the DAU 233 which, for the purpose of this study, contains the same land coverage as FID. The dominant crop acreage for the FID area since 1958 is vineyard. The chart shows the relationship between all agricultural crop acreage and the rapid urban growth. Urban growth has more than tripled during the period shown on the chart. Appendix A presents tables showing the change in urban acreage from 30,485 acres in 1958 to 107,376 in 2004. Perhaps, the most significant change in the agricultural crop mix is the reduction of land growing field crops, which is representative of the overall decline in agricultural acreage from 208,650 to 151,104 acres, and increase in urban land use.

Figures 7-12 show land use graphs for DAU 234 (Academy), DAU 235 (Raisin), DAU 236 (Consolidated), DAU 237 (Lower Kings), DAU 239 (Alta), and DAU 240 (Orange Cove). The total annual land use chart representing the King Basin region from 1958 to 2004 is shown in Figure 13 and in tabular form in Table A.8.b found in the Appendix A. Figure 13 clearly indicates that there has been an apparent decline in grains, alfalfa, and field crops along side a growth in urban and deciduous fruits and nuts, and citrus. As indicated in Table A.8.a in the

Figure 4. Total Annual Land Use Acreage

(Excel Figure)

Table 4. Standard Land Use Legend

GRAIN AND HAY CROPS			
1. Barley	2. Wheat	3. Oats	4. Miscellaneous and mixed grain and hay
RICE			
FIELD CROPS			
1. Cotton 2. Safflower 3. Flax	4. Hops 5. Sugar beets 6. Corn (field & sweet)	7. Grain sorghum 8. Sudan 9. Castor beans	10. Beans (dry) 11. Miscellaneous field 12. Sunflowers
PASTURE			
1. Clover native pasture 2. Mixed pasture	3. Native Pasture 4. Induced high water table	5. Misc. grasses (normally grown for seed)	6. Turf farms
ALFALFA & ALFALFA MIXTURES			
TRUCK CROPS			
1. Artichokes 2. Asparagus 3. Beans (green) 4. Cole crops (when further breakdown is not needed) 5. Carrots 6. Celery 7. Lettuce (all types)	8. Melons, squash, and cucumbers (all types) 9. Onions and garlic 10. Peas 11. Potatoes 12. Sweet Potatoes 13. Spinach	14. Tomatoes 15. Flowers, nursery & Christmas tree farms 16. Mixed (four or more) 17. Miscellaneous truck 18. Bush berries	19. Strawberries 20. Peppers (chili, bell, etc.) 21. Broccoli 22. Cabbage 23. Cauliflower 24. Brussels sprouts
DECIDUOUS FRUITS AND NUTS			
1. Apples 2. Apricots 3. Cherries	4. Peaches and nectarines 5. Pears 6. Plums	7. Prunes 8. Figs 9. Miscellaneous deciduous	10. Almonds 11. Walnuts 12. Pistachios
CITRUS AND SUBTROPICAL			
1. Grapefruit 2. Lemons 3. Oranges	4. Dates 5. Avocados 6. Olives	7. Miscellaneous subtropical fruits 8. Kiwis	9. Jojoba 10. Eucalyptus
VINEYARDS			
1. Table grapes	2. Wine grapes	3. Raisin grapes	
IDLE			
1. Land not cropped the current or previous crop season, but cropped within the past three years.		2. New lands being prepared for crop production.	
SEMIAGRICULTURAL & INCIDENTAL TO AGRICULTURE			
1. Farmsteads 2. Livestock feed lots	3. Dairies	4. Poultry farms	5. Urban Landscape*

*Similar water duties.

Figure 6. Annual Land Use Acreage for DAU 233 Fresno

(Excel Figure)

Figure 7. Annual Land Use Acreage for DAU 234 Academy

(Excel Figure)

Figure 8. Annual Land Use Acreage for DAU 235 Raisin

(Excel Figure)

Figure 9. Annual Land Use Acreage for DAU 236 Consolidated

(Excel Figure)

Figure 10. Annual Land Use Acreage for DAU 237 Lower Kings River

(Excel Figure)

Figure 11. Annual Land Use Acreage for DAU 239 Alta

(Excel Figure)

Figure 12. Annual Land Use Acreage for DAU 240 Orange Cove

(Excel Figure)

Figure 13. Annual Total Crop Water Demand

(Excel Figure)

Appendix A, during the 1958 to 2004, the study area has experienced an apparent increase in total agricultural acreage from approximately 751,000 to 785,000 acres and an increase in urban from 42,000 to 166,000 acres. The increase in urban acreage has resulted in conversion of agriculture to urban land, as well as encroachment of urban areas onto undeveloped land.

AGRICULTURAL WATER DEMAND

The agricultural water demand estimate were developed using DAU crop report summaries from DWR. The crop reports are compiled from the periodic county- wide land use surveys. The methodology for estimating crop water demand is detailed below.

Water Demand Calculation

Annual crop water demands in this TM are calculated from land use area by applying a water duty for each of the different land use categories. The water duties used are included in Table 4. The water duty factors were previously agreed upon and accepted by the members of the Upper Districts of the Kings Groundwater Basin and the Kings River Conservation District. These values are reported in the Upper Kings Basin Assessment Report (2003).

Table 4. Water Duties and Applied Water Use Coefficients for Agricultural Water Use

Agricultural Land Use	Water Duty (1) (Acre-Feet/Acre)
Citrus and Subtropical	3.5
Deciduous Fruit and Nut	4.0
Field Crops	2.5
Grain	1.5
Idle	0.0
Pasture and Alfalfa	5.1
Truck, Nursery and Berry	1.8
Vineyards	2.3
Semi Ag and Incidental to Ag	1.0

(1) WRIME Upper Kings Basin Assessment Report, 2003.

The annual agricultural water demands are calculated based on land use acreage data and estimates of the average annual "water duty" (expressed as AF per acre) for each crop category (Figure 13). Agricultural (irrigated crop) water duties range from 1.5 to 5.1 AF per acre. The results of the analysis of historical demand for the Kings Basin is presented in Table A.1.c in Appendix A. Based on this methodology, the annual changes in water demand is directly proportional to the annual changes in crop acreage. For the purpose of this study, the changes in hydrologic conditions, as well as, irrigation trends and efficiencies were not taken into consideration. The hydrologic model (IGSM) will include the irrigation practices, monthly

irrigation efficiencies for each crop type, antecedent soil moisture conditions, daily rainfall rates and patterns, and monthly potential evapotranspiration in calculating the detailed monthly water demand for each crop type.

URBAN WATER DEMAND

Urban water demand estimates are calculated by multiplying the time series per capita water use data by the historical population for each city. Following is a description of the data analysis to estimate urban water demand in the study area.

Population

Urban population data was collected from the U.S. Census Bureau and the Department of Finance. Table 5 shows the urban population listed by irrigation district. The data was linearly interpolated for the years in between the census as shown Table B.1.a in Appendix B. The estimated population growth trend is represented in Figure 14.

Table 5. Historical Urban Population by Irrigation District

		1960	1970	1980	1990	2000
FID	Clovis	5,546	13,856	33,021	50,323	68,468
	Fresno	133,929	165,972	218,202	354,202	427,652
	Kerman	1,970	2,667	4,002	5,448	8,551
	Subtotal	**141,445**	**182,495**	**255,225**	**409,973**	**504,671**
CID	Fowler	1,892	2,239	2,496	3,208	3,979
	Kingsburg	3,093	3,843	5,115	7,205	9,199
	Parlier	1,366	1,993	2,902	7,938	11,145
	Sanger	8,072	10,088	12,542	16,839	18,931
	Selma	6,934	7,459	10,942	14,757	19,444
	Subtotal	**21,357**	**25,622**	**33,997**	**49,947**	**62,698**
AID	Reedley	5,850	8,131	11,071	15,791	20,756
	Cutler	2,191	2,503	3,149	4,450	4,491
	Dinuba	6,103	7,917	9,907	12,743	16,844
	Orosi	1,048	2,757	4,076	5,486	7,318
	Subtotal	**15,192**	**21,308**	**28,203**	**38,470**	**49,409**

Figure 14. Population by Irrigation District

(Excel Figure)

Water Use Per Capita

Average water use per capita data were collected from 1980 to 2004. The data was available in a monthly an increment for select cities within the Kings Basin. For the time period between 1964 through 1979, an average water use per capita for the period of 1980 to 2004 was used. The average of the per capita water use does not take into account water conservation efforts, but it allows some flexibility to establish a preliminary estimate for historical water consumption. Figure 15 shows a graphical representation of the water use per capita by city. Figure 15 indicates that there is a noticeable fluctuation in water use per capita during the period of record from 1980 to 2004. In most recent years from 2001 to 2003, there was a general increase in water use per capita for most cities. There is an uncharacteristic increase for the Cities of Reedley and Fresno. As part of the work related to the Metro Plan update, additional information is expected from City of Fresno, which may help reconcile unusual trends. Appendix B presents monthly time series water use per capita for each city.

Water Demand Calculation

The urban water demand is calculated based on the historical population and estimates of per-capita water use. Figure 16 shows the total water demand by irrigation district for the period of 1964 to 2004. The chart clearly indicates a general increase in water demand for the urban areas within all irrigation districts. However, FID with the largest urban development has had an increase in water urban demand from approximately 47,000 AF in 1958 to 165,000 AF in 2004 with an average of 284 gallons per capita daily. The monthly time series water demand for the City of Fresno is found in Appendix B, Table B.2.b.

SUMMARY

This preliminary analysis of water demand in the IRWMP region indicates an increase in total water demand between 1964 and 2000. Water conservation programs implemented by the cities have reduced the overall per-capita water demand. However the population growth rate will be the dominant factor in the total urban water demand. The overall water demand for agricultural use has reduced primarily due to changes in land use from agricultural to urban land. An overall increase in agricultural water demand per acre is noticed, mainly because of a change in cropping patterns; reduction in vineyards, and increase in deciduous fruit and nut crops, which have a higher water duty.

The data compiled, analyzed, and prepared in this TM will be used as part of the input to the integrated hydrologic model. The model will use more detailed methodologies to further refine the data and include hydrologic variability in the water demand trends. In addition, this data will be available for inclusion in the Database Management System to be developed as part of the tools development for the IRWMP.

Figure 15. Annual Water Use per Capita

(Excel Figure)

Figure 16. Annual Urban Water Demand by Irrigation District

(Excel Figure)

APPENDIX A

AGRICULTURAL LAND USE DATA AND WATER DEMAND

APPENDIX B

URBAN POPULATION AND WATER DEMAND