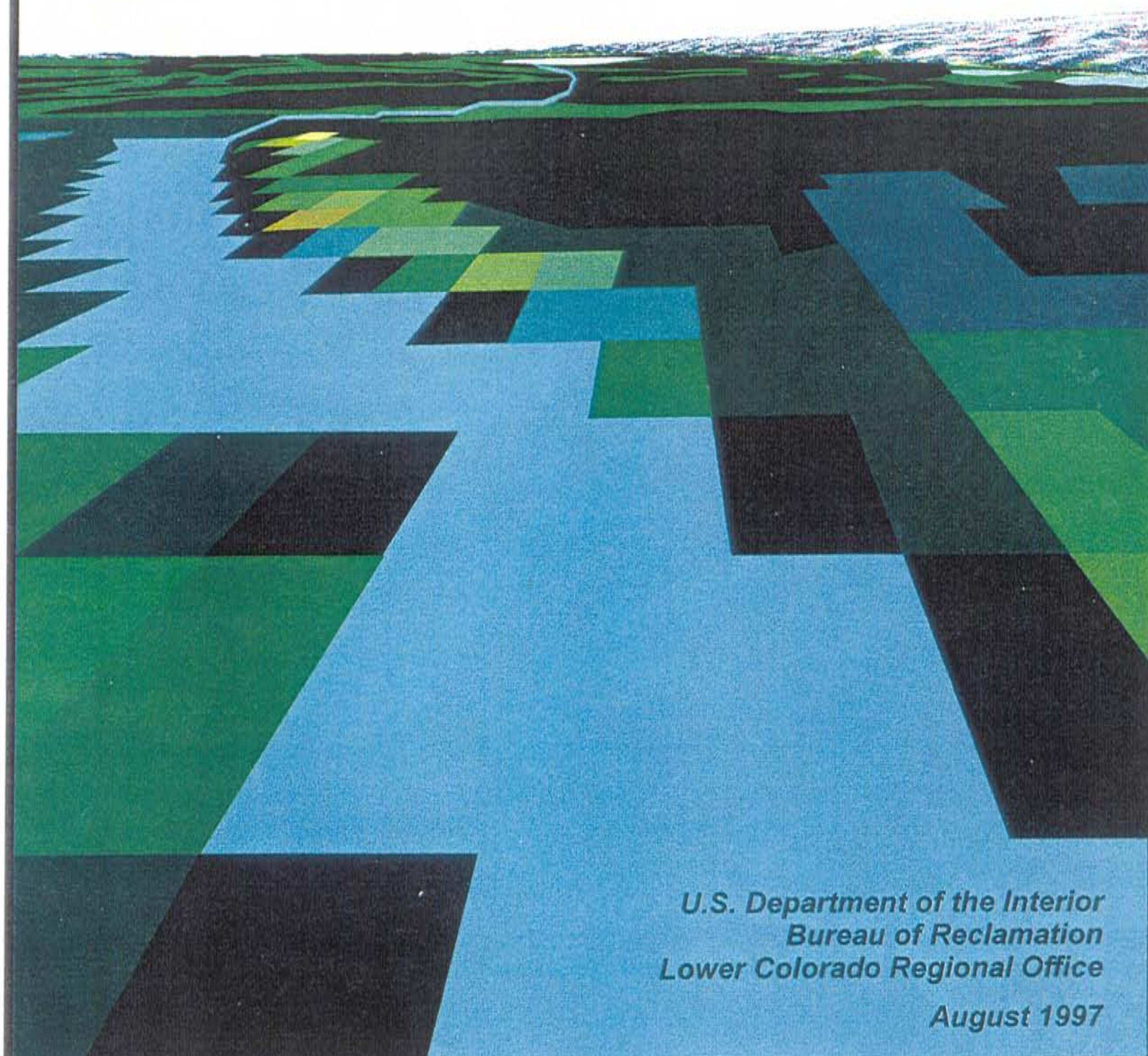
Lower Colorado River Accounting System

Demonstration of Technology

Calendar Year 1995



U.S. Department of the Interior
Bureau of Reclamation
Lower Colorado Regional Office

August 1997

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Demonstration of Technology

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U.S. Department of the Interior
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Boulder City, Nevada

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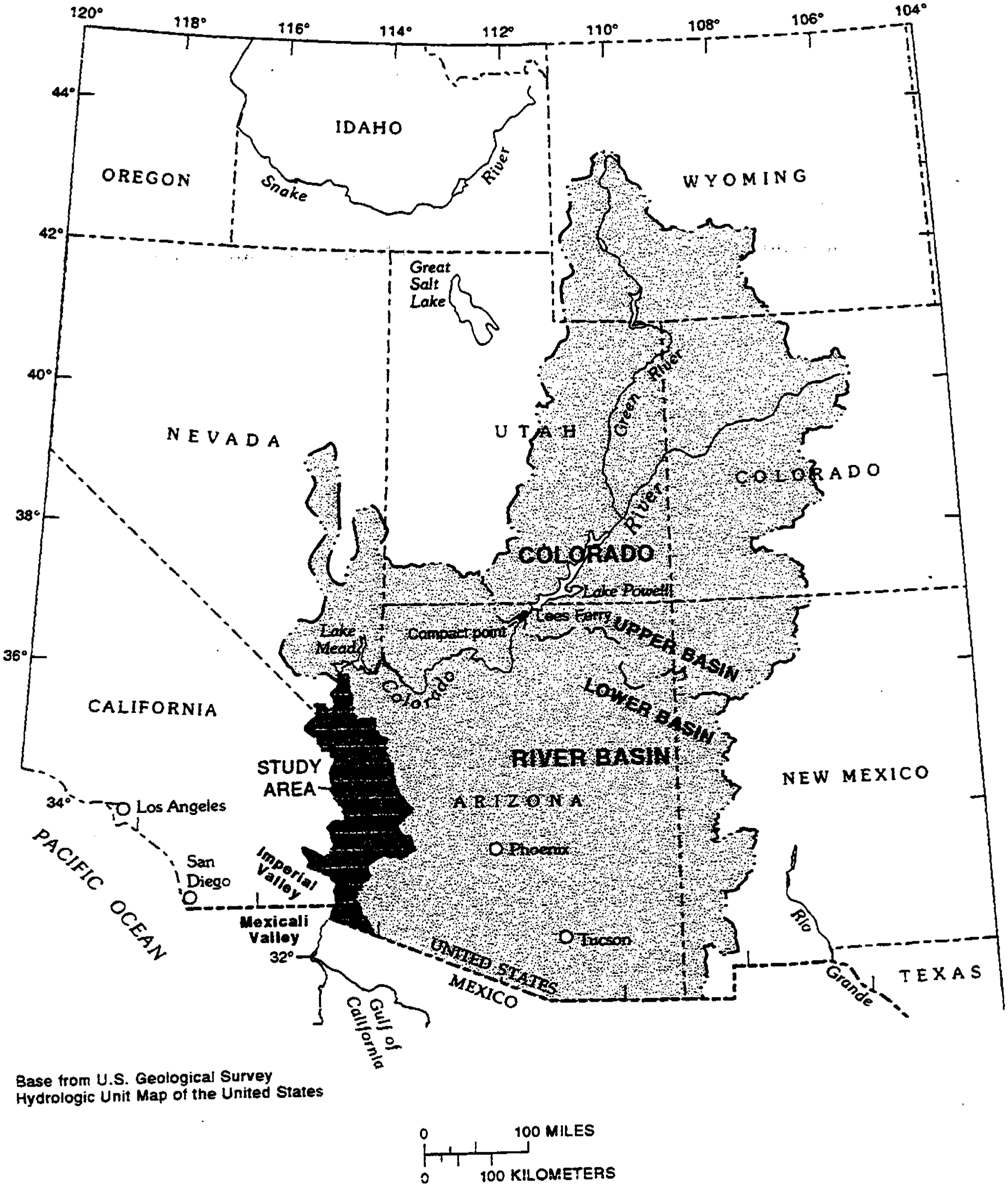

Colorado River basin and study area.

Executive Summary

The Colorado River is the principal source of water for agricultural, domestic, municipal, industrial, recreational, and hydroelectric purposes in Arizona, southern California, and southern Nevada. Within this area, accounting for the use and distribution of water from the Lower Colorado River is required by the U.S. Supreme Court Decree of 1964 (Supreme Court Decree) in *Arizona v. California*. In addition to its other requirements, the Supreme Court Decree dictates that the Secretary of the Interior (Secretary) provide detailed and accurate records of diversions, return flows, and consumptive use of water diverted from the mainstream "stated separately as to each diverter from the mainstream, each point of diversion, and each of the States of Arizona, California, and Nevada." This report focuses on determining values of consumptive use.

The Bureau of Reclamation (Reclamation) manages the water resources of the Lower Colorado River on behalf of the Secretary. In 1984, Reclamation joined with the U.S. Geological Survey (USGS), Lower Basin States, and Bureau of Indian Affairs to develop a method for estimating and distributing agricultural consumptive use to agricultural[1] water diverters between Hoover Dam and Mexico. This effort was in response to the States' request to account for return flows in addition to those measured as surface flows, a limitation of the water accounting method then in use.

The agencies agreed to develop the Lower Colorado River Accounting System (LCRAS), which addresses the requirements of the Secretary and responds to the States' request to account for both measured and unmeasured flows. The USGS finished its development of LCRAS in the late 1980s, but a final report was not published until 1995. In 1990, Reclamation took over responsibility for continuing development of LCRAS. Reclamation has modified LCRAS, and it is this modified method that was used for the LCRAS Demonstration of Technology for Calendar Year 1995.

[1] Agricultural consumptive use includes consumptive use by irrigation districts, wildlife refuges, and other reservations of land.

LCRAS Method as Developed by the U.S. Geological Survey

LCRAS, developed by USGS, was an accounting method that estimated and distributed consumptive use by vegetation to diverters along the Lower Colorado River. It was composed of two major parts. First, a water balance was used to estimate annual consumptive use by vegetation between Hoover Dam and Morelos Dam. Second, the annual consumptive use by vegetation was attributed to agricultural diverters by using remote sensing techniques and evapotranspiration (ET) calculations. Percentages of total ET were estimated for each diverter from the analysis of satellite images and estimated water-use rates of vegetation types within the boundaries of each diverter.

The LCRAS method combined the output from a water balance with the output from remote sensing techniques and ET to calculate annual consumptive use by vegetation of water from the Lower Colorado River by point of diversion, diverter, and State as required by the Supreme Court Decree.

Consultant Review and Recommendations

In 1994, Reclamation contracted with Dr. Marvin Jensen,[2] a water resources consultant, for an independent review of the LCRAS method. Dr. Jensen reviewed and provided recommendations for improving the LCRAS method through the application of state-of-the-art water resources technologies.

Dr. Jensen's recommendations included :

- Calculating ET using (1) reference values for short grass (ET_0) provided by the California Irrigation Management Information System

[2] Dr. Marvin Jensen: formerly Director, Colorado Institute for Irrigation Management, Colorado State University, Fort Collins, Colorado, 1987-92; and National Program Leader, Water Management Research, Agricultural Research Services, U.S. Department of Agriculture, Beltsville, Maryland, and Fort Collins, Colorado, 1979-87.

and Arizona Meteorological Network stations located in agricultural areas along the Colorado River and (2) vegetation-class-specific ET coefficients

- Incorporating these ET calculations into the water balance as a water use

Reclamation accepted these recommendations and incorporated them into LCRAS. The values presented in this report reflect these modifications, which are documented in Jensen (1994) and Jensen (1996b).

The incorporation of Dr. Jensen's recommendations yields a water balance equation in which all the inflows, outflows, and water uses are calculated or estimated. The residual reflects errors of estimate in all inflows, outflows, and water uses—not the vegetative consumptive use as in the USGS version of LCRAS. The residual is distributed to all inflows, outflows, and water uses in the water balance in proportion to the product of their magnitude and confidence interval.

Consumptive use by vegetation is now equal to the ET plus a proportion of the residual. The final value of consumptive use by vegetation can be either slightly larger or smaller than the ET, and the final value of domestic use can be slightly larger or smaller than initially estimated, because the residual can be either a positive or negative number.

Results

LCRAS calculated both agricultural and phreatophyte consumptive use for each agricultural diverter and domestic consumptive use along the mainstream of the Lower Colorado River. The amount, if any, of the phreatophyte consumptive use within a diverter's boundary that should be added to a diverter's total consumptive use is a question left open by this report.

A description and qualitative assessment of the results for the major components of LCRAS follows.

Image Classification Results

The image classification results show excellent potential for using Landsat V image data to satisfactorily discriminate agricultural vegetation classes. Reliable results were obtained for crops using single-date image classification techniques. Postclassification accuracy assessment shows that, overall, the crops can be mapped with an average accuracy of 93.0 percent.

Discrimination between phreatophytes, while not as well defined as crops, was successful. Phreatophytes were grouped into several classes. Postclassification accuracy assessment shows that, overall, the phreatophyte communities can be mapped with an average accuracy of 87.0 percent.

Image classification techniques were also used to quantify open water surface areas. Results were found suitable for use in estimating evaporation. Comparisons with published elevation/capacity/area data showed that the surface areas derived from image classification were within 3.0 percent of the published data.

Water Balance Results

The water balance closure was evaluated for each reach by comparing the value of the residual to the measurement error of the upstream inflow to the reach. Distributing the residual was considered optional if it was about equal to or less than the measurement error of the flow entering the reach. The residual was distributed in all reaches for this LCRAS Demonstration of

Technology to present the effect of the distribution, even though the residual was within the assumed measurement error of the upstream gauge in all reaches.

The residuals from the water balance for each reach are within 5 percent of the flow entering each reach. The overall residual for the entire Lower Colorado River (Hoover Dam to Morelos Dam) was less than 4 percent of the flow below Hoover Dam.

Table ES-1 presents the values used in the water balance and shows the closure of the water balance. All values are in annual acre-feet (acre-ft), unless otherwise declared.

Table ES-1.—Water balance summary
(Unit: acre-feet per year)

Water balance inflows, outflows, and water uses	Reach				
	Hoover Dam to Davis Dam	Davis Dam to Parker Dam	Parker Dam to Imperial Dam	Imperial Dam to Morelos Dam	Hoover Dam to Morelos Dam
Residual	125,815	-376,267	-180,481	106,064	-324,869
Residual as a percentage of the flow entering the reach	1.47	-4.52	-2.69	1.89	-3.80
Flow at the upstream boundary (Q_{us})	8,544,900	8,316,700	6,718,700	5,602,945	
Tributary inflow (T)	6,481	200,471	33,750	530,803	
Exported flow (Q_{ex})	0	1,779,635	0	3,776,675	
Evaporation (E)	123,307	106,973	75,416	8,570	
Domestic consumptive[1] use (C_{ud})	831	43,208	7,856	20,055	
Crop evapotranspiration (ET_{crop})	0	88,399	864,681	433,234	
Phreatophyte evapotranspiration (ET_{pht})	2,928	180,723	388,342	76,820	
Change in reservoir storage (ΔS_r)	-18,200	-24,200	-6,309	0	
Change in aquifer storage (ΔS_a)	0	0	0	0	
Flow at the downstream boundary (Q_{ds})	8,316,700	6,718,700	5,602,945	1,712,330	

[1] Domestic consumptive use includes municipal, industrial, recreational, and other consumptive uses not estimated by evapotranspiration.

Consumptive Use Results

Table ES-2 compares the crop, phreatophyte, and domestic consumptive use calculated by LCRAS to consumptive use as reported in the Decree Accounting Report as State totals.

The consumptive use estimates for most of the larger districts along the river were within 10 percent of consumptive use reported in the Decree Accounting Report.

The total water use by State from crops and domestic uses, as reported by LCRAS, also compared favorably to that reported in the Decree Accounting Report, with the differences between reported values being within 2 percent of each other.

Continued Development of LCRAS

LCRAS used the best and most complete data sources and analytic techniques available to produce the results presented in this report; however, improvements are possible, and some questions remain outstanding.

Specific areas identified for continued development include remote sensing, image processing, and geographic information system analysis tools; river gauging; incidental use factors in crop ET calculations; estimates of domestic uses as consumptive uses; open water surface evaporation and precipitation estimates; the appropriate assessment of phreatophyte use, if any, to diverters; accounting for estimates of underflow to Mexico across the Southerly International Boundary and the limitrophe section of the Colorado River in the water balance; and a method of estimating changes in groundwater storage.

Table ES-2.—Consumptive use
(unit: acre-feet per year)

LCRAS			Decree Accounting	
Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
Nevada				
Uses above Hoover Dam (from 1995 Decree Accounting Report)		199,407	199,407	Uses above Hoover Dam
Uses below Hoover Dam	21,792	19,048	18,032	Uses below Hoover Dam
			1,721	Unmeasured return flow credit
Nevada Total The difference in the values under the headings, "Decree Accounting Consumptive Use" and "LCRAS Crop and Domestic Consumptive Use" is double accounting for Big Bend Water District wastewater irrigation (1,384 acre-ft), distributed residual (-368 acre-ft), and Decree Accounting Report unmeasured return flow (1,721 acre-ft). 218,455 - 1,384 - (-368) - 1,721 = 215,718	21,792	218,455	215,718	Nevada Total
California				
			4,925,483	Sum of individual diverters
			88,679	Unmeasured return flow credit
California Total	200,207	4,878,487	4,836,804	California Total
Arizona				
Subtotal (below Hoover Dam, less Wellton-Mohawk Irrigation and Drainage District (Wellton-Mohawk IDD) and underflow to Mexico)	409,498	1,709,663	2,033,492	Sum of individual diverters below Hoover Dam, less Wellton-Mohawk IDD and returns from South Gila wells
Arizona uses above Hoover Dam (from the 1995 Decree Accounting Report)		178	178	Arizona uses above Hoover Dam
Wellton-Mohawk IDD (from the 1995 Decree Accounting Report)		247,409	247,409	Wellton-Mohawk IDD
Underflow to Mexico.[1] (21,000 acre-ft across the Limitrophe section + 67,000 acre-ft at SIB.		88,000	59,727	Pumped from South Gila wells (drainage pump outlet channels [DPOCs]): returns
			192,537	Unmeasured return flow credit
Arizona Total	409,498	2,045,250	2,028,815	Arizona Total
Lower Basin Total				
Total Lower Basin Use	631,497	7,142,192	7,081,337	Total Lower Basin Use

[1] Estimates made by the Yuma Area Office, Bureau of Reclamation.

Conclusions

Reclamation is directed to manage the Lower Colorado River. Currently, the demand for water exceeds the 7.5 million acre-ft apportioned for annual consumptive use. Because of the scarcity of this resource, Reclamation must manage the river in a manner that is fair for all diverters. To achieve this goal, Reclamation has taken the lead in the development of LCRAS. LCRAS can be characterized as a water accounting method that:

- Uses the best technology available
- Fulfills the Supreme Court Decree mandate to account for the consumptive use of water
- Provides consistent methods of determining water use for all diverters in the Lower Basin

The goal of the LCRAS program is to improve Decree Accounting using state-of-the-art technologies. Since its initial development by the USGS, Reclamation has improved and updated LCRAS with improved Geographic Information System data management tools and remote sensing procedures. As a result of recommendations from Dr. Jensen, LCRAS uses the reference ET method of calculating vegetative ET currently used internationally by the United Nations Food and Agriculture Organization. Reclamation will continue the process of refining each element of the LCRAS as technology develops and our understanding of the hydrologic system improves.

Reclamation is currently developing a public involvement process that will allow interested parties an opportunity to learn more about the method and provide input to improve it. We are interested in working with the State water agencies, Federal agencies, tribes, and diverters to make the method as consistent, accurate, and understandable as possible.

The accounting of water use in accordance with Article V of the Supreme Court Decree will proceed over the next few years as follows:

1. Reclamation will use the current Decree Accounting method to develop the official Decree Accounting Report until LCRAS is implemented.

2. Reclamation will calculate consumptive use using the LCRAS method in parallel with the current Decree Accounting method for calendar year 1996 and the next several years and compare the results of the two methods. The purpose of this exercise is to acquaint the users of the Decree Accounting Reports with LCRAS, as well as to examine any trends that may appear in the differences of the results provided by the two methods.

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Chapter 1

Introduction

The Colorado River, which has its headwaters as far north as Wyoming, discharges into the Gulf of California in Mexico (frontispiece location map). The Colorado River drainage basin includes about 246,700 square miles in the United States. The basin is divided into the upper and lower basins at Lee Ferry. The Lower Basin includes parts of Arizona, California, Nevada, New Mexico, and Utah.

The river is the source of water for a large distribution system that provides water to agricultural and densely populated areas in California, Arizona, and Nevada. Water is exported to parts of six counties in the coastal plain of southern California, including the cities of Los Angeles and San Diego, and to Phoenix in Arizona. Along the river, the dominant influence on the distribution of water is the diversion for irrigation.

In 1964, the U.S. Supreme Court decreed (U.S. Supreme Court, 1964) that a water use report for the Lower Colorado River Basin would be created at least annually (Decree Accounting Report). The most critical and controversial portion of the Decree Accounting Report is the calculation of consumptive use. Consumptive use is defined in Article I.(A) of the Supreme Court Decree of 1964 (Supreme Court Decree) which states,

> *'Consumptive use' means diversions from the stream less such return flow thereto as is available for consumptive use in the United States or in satisfaction of the Mexican treaty obligation.*

Since 1964, consumptive use has primarily been calculated as measured diversions from the stream less measured return flows back to the stream. A more extensive history and description of the Lower Colorado River and its legal framework can be found in attachment 1.

The Lower Basin States asked the Bureau of Reclamation (Reclamation), in 1969, to develop a method that would consider all return flows, measured and unmeasured, for each diverter in a consistent and equitable manner. The Lower Basin States, recognizing that groundwater return flows exist from domestic and municipal uses, considered the largest magnitude of groundwater return flows to come from irrigated areas along the mainstream of the Lower Colorado River. This is where Reclamation placed its emphasis.

The Task Force on Unmeasured Return Flow was established in 1970 and, after extensive discussion with the Lower Basin States and trials of other methods, chose, in 1984, to develop and apply a water balance approach to the Lower Colorado River. The proposal to develop and study the method was accepted by all the members of the task force, and the method was named the Lower Colorado River Accounting System (LCRAS). A history of events that led to the development of LCRAS and to the 1995 LCRAS Demonstration of Technology can be found in attachment 2.

The history of LCRAS and work that the U.S. Geological Survey (USGS) performed in developing it is presented in USGS Water Supply Paper 2407 (Owen-Joyce and Raymond, 1996). It contains a description of the original method developed by USGS. Reclamation has improved the method by incorporating state-of-the-art, remote sensing techniques and recommendations from Dr. Marvin E. Jensen, which include changing from Blaney-Criddle to the Penman-Montieth reference evapotranspiration (ET) method and altering the water balance equation.

Reclamation has also developed field border and diverter boundary Geographic Information System (GIS) coverage that allows the number of acres covered by each vegetation class, both crop and phreatophyte, to be calculated for each diverter.

This report documents the processes and data used to apply the LCRAS method to determine consumptive use for calendar year 1995 along the Lower Colorado River below Hoover Dam.

LCRAS Method as Developed by the U.S. Geological Survey

LCRAS, developed by USGS, was an accounting method that estimated and distributed consumptive use by vegetation to diverters along the Lower Colorado River. It was composed of two major parts. First, a water balance was used to estimate annual consumptive use by vegetation between Hoover Dam and Morelos Dam.

Second, this consumptive use was distributed to agricultural diverters by using remote sensing techniques and evapotranspiration calculations. Percentages of total ET were estimated for each diverter from the analysis of satellite images and estimated water-use rates of vegetation types within the boundaries of each diverter.

LCRAS combined the output from a water balance with the output from remote sensing techniques and ET calculations to calculate annual consumptive use of water from the Lower Colorado River by point of diversion, diverter, and State as required by the Supreme Court Decree.

Consultant Review and Recommendations

In 1994, Reclamation contracted with Dr. Marvin Jensen,[1] a water resources consultant, for an independent review of the LCRAS method. Dr. Jensen was tasked with reviewing and providing recommendations for improving the LCRAS method through the application of state-of-the-art water resources technologies.

[1] Dr. Marvin Jensen: formerly Director, Colorado Institute for Irrigation Management, Colorado State University, Fort Collins, Colorado, 1987-92; and National Program Leader, Water Management Research, Agricultural Research Services, U.S. Department of Agriculture, Beltsville, Maryland, and Fort Collins, Colorado, 1979-87.

Dr. Jensen's recommendations included:

- Calculating ET using (1) reference values for short grass (ET_0) provided by the California Irrigation Management Information System (CIMIS) and Arizona Meteorological Network (AZMET) stations located in agricultural areas along the Colorado River and (2) vegetation-class-specific ET coefficients

- Incorporating these ET calculations into the water balance as a water use

Reclamation accepted these recommendations and incorporated them into LCRAS. The values presented in this report reflect these modifications, which are documented in Jensen (1994) and Jensen (1996b).

The incorporation of Dr. Jensen's recommendations yields a water balance equation in which all the inflows, outflows, and water uses are calculated or estimated. The residual reflects errors of estimate in all inflows, outflows, and water uses, not the vegetative consumptive use as in the USGS version of LCRAS. The residual is distributed to all inflows, outflows, and water uses in the water balance in proportion to the product of their magnitude and confidence interval.

Consumptive use by vegetation is now equal to the ET plus a proportion of the residual. The final value of consumptive use by vegetation can be either slightly larger or smaller than the ET, and the final value of domestic use can be slightly larger or smaller than initially estimated, because the residual can be either a positive or negative number.

Water Balance

A water balance can be applied to an entire stream or a reach of a stream. A stream system boundary—inflow and outflow—and a knowledge of the flow and water uses of the stream system are required to compute a water balance. The knowledge of flow and water uses includes individual water uses, tributary inflows, exports from the system, changes in system storage, evaporation, etc.

A water balance performs a summation of all, or a selection of, inflows, outflows, and water uses of the stream system. The result of this summation is called a residual, and it represents water unaccounted for. In an ideal world, when all inflows, outflows, and water uses of a stream system have been summed, the residual is zero. In the real world, the residual of a water balance is seldom, if ever, zero. Depending on the purpose of the water balance, this residual can be explained in several ways:

- A known inflow, outflow, or water use that was not considered in the water balance because it is difficult to measure or estimate

- A postulated flow that was not considered in the water balance because it could not be measured or estimated or was not known to exist

- The summation of all errors of measurement and estimation for the entire water balance

- Some combination of the items listed above

The water balance applied to the Lower Colorado River in 1995 by LCRAS postulates that all inflows, outflows, and water uses can be measured or estimated with sufficient accuracy and resolution to meet the water accounting needs of the Supreme Court Decree. The residual of the water balance is considered to be the result of the impreciseness of measurement or estimation in some or all of the inflow, outflow, and water use values.

To determine a final value of crop, phreatophyte, and domestic consumptive use, the residual of the water balance is distributed (added or subtracted) to the original estimates for all inflows, outflows, and water uses in proportion to the product of their magnitude and standard error of the estimate (SEE).

Comparison of LCRAS with Decree Accounting Reports

Table A1, described in chapter 2, presents a comparison between the values of consumptive use compiled for the Decree Accounting Report and those calculated by LCRAS for all diverters. Below is a description of the conceptual differences in the way consumptive use is compiled for the Decree Accounting Report and calculated by LCRAS.

Agricultural Diverters

Decree Accounting Report

The Decree Accounting Reports are a compilation of measured diversions and measured return flows and can be used as an estimate of consumptive use for agricultural diverters, wildlife refuges, and other reservations of land. Beginning in 1991, in parallel with the continued development of LCRAS, the calculation of consumptive use for the Decree Accounting Report has been augmented with estimates of unmeasured return flow to address the question of unmeasured returns to the river.

These estimates of unmeasured return flow are based upon crop reports from 1990 and ET calculations using the Blaney-Criddle method. Unmeasured return flow factors, relating estimates of unmeasured return flow to diversions, were calculated in 1990 for large agricultural diverters along the river. These unmeasured return flow factors have since been applied to all agricultural diverters, wildlife refuges, and other reservations of land to estimate unmeasured return flow from each of these diverters. These estimates are then summed and reported as a total for each State.

LCRAS

The LCRAS method of calculating consumptive use by vegetation is an implicit expression of diversion less return, and it also assesses the availability of any return flows for downstream use. The LCRAS method calculates ET as an initial estimate of water use by vegetation, which allows such estimates to be made without measured diversions and measured return flows. This was done because the ability to measure all return flows was in question, and not all irrigated areas have measured diversions or return flows. LCRAS addresses the availability of return flows for downstream consumptive use by performing a water balance on the Lower Colorado River between the major dams.

LCRAS makes the final estimate of water use—consumptive use—by adding a proportionate share of the residual from the water balance to the ET calculated as an initial estimate of water use (distributing the residual). The final estimate of consumptive use can be either larger or smaller than the initial ET estimate because the residual from the water balance can be either a positive or a negative number.

Domestic Diverters

Decree Accounting Report

The consumptive use of domestic diverters has been compiled primarily using measured diversions and measured return flows in the Decree Accounting Reports. Beginning in 1991, in parallel with the continued development of LCRAS, the calculation of consumptive use for the Decree Accounting Report has been augmented with estimates of unmeasured return flow as an interim method of addressing the unmeasured-return-flow issue.

Estimates of unmeasured return flow for domestic diverters are derived from factors supplied by Arizona for Bullhead City and by California for the city of Needles in 1990. The return flow factor, which relates estimates of unmeasured return flow to diversion, has been applied to all domestic users. These estimates of unmeasured return flow are also summed and included in the unmeasured return flow totals reported for each State.

LCRAS

The initial estimate of consumptive use for domestic diverters can be made for use in LCRAS by any reasonable method. The initial estimates of consumptive use for domestic diverters used in the 1995 LCRAS Demonstration of Technology were compiled primarily as the reported diversions, or reported diversions less measured return flow, from the Decree Accounting Report for calendar year 1995. The exceptions are (1) domestic uses for which estimates are not required for the current Decree Accounting method but are required by LCRAS; (2) domestic uses that are implicitly included in the diversion less return flow measurements for irrigated areas; or (3) domestic uses that are required for water balance closure.

LCRAS makes the final estimate of domestic consumptive use by adding a proportionate share of the residual from the water balance to the initial estimate of domestic consumptive use described above (distributing the residual). The final estimate of domestic consumptive use can be either larger or smaller than the initial estimate because the residual from the water balance can be either a positive or a negative number.

Chapter 2

LCRAS in Calendar Year 1995

Reclamation's activities for the 1995 LCRAS Demonstration of Technology began on January 1, 1995, with the operation and maintenance of acoustic velocity meters to gauge large diversions from the Colorado River at Imperial Dam. As the year progressed, Reclamation finalized (cooperatively with a contractor) the image processing techniques that would be used in 1995, selected and purchased image data from the Landsat satellite, made onsite visits to selected fields to record the crop and field conditions (ground reference data collection), and began processing the image data. Reclamation also finalized the boundaries of each diverter that would be used in 1995.

Reclamation gathered ET rate and precipitation data from micro-meteorological stations along the Lower Colorado River and finalized (cooperatively with a contractor) the ET coefficients for each crop and phreatophyte class and open water evaporation that would be used in 1995. Reclamation compiled domestic uses and change in reservoir storage values during 1995 for Lakes Mohave and Havasu and Senator Wash Reservoir.

As calendar year 1995 came to a close, analysis of all the data for the year could begin. From the analysis of image data came the acreage of each crop grown, the acreage in the flood plain of each phreatophyte class, and the number of acres of open water between Hoover Dam and Mexico. This information, combined with the finalized diverter boundaries for 1995, allowed Reclamation to calculate the number of acres occupied by each crop and phreatophyte class for each agricultural diverter, wildlife refuge, or other reservation of land along the river.

With this information, the ET coefficients, and the ET rate and precipitation data from micrometeorological stations, Reclamation calculated the evapotranspiration of crops and phreatophytes within the boundaries of each agricultural diverter, wildlife refuge, or other reservation of land. Also, Reclamation compiled and analyzed the records of flow at the major dams and major diversion and delivery points.

Eventually, everything came into place for the water balance and the residual calculations. Reclamation finalized the form of the water balance that would be used in 1995 and calculated and proportionally distributed the residual to each water balance inflow and outflow, producing the final values of crop, phreatophyte, and domestic consumptive use.

The paragraphs below describe each of these activities and provide an assessment of their success and relative importance to the overall success of LCRAS for calendar year 1995.

Remote Sensing and Geographic Information Systems

Remote sensing and GIS techniques were developed and applied to the LCRAS process. These techniques were used to identify and map the vegetation class (crop and phreatophyte) and open water areas along the Lower Colorado River.

The flood plain boundary (shown in exhibits 1 through 7) used for this program was based upon the flood plain boundary described in Wilson and Owen-Joyce (1994). Additions to this flood plain boundary were needed, as the boundary was not identified in some narrow sections of the river. This flood plain boundary was used to identify areas from which phreatophytes should be included in the image data analysis. The crop areas included in this analysis are located within the flood plain boundary along the mainstream of the Lower Colorado River and upon the Palo Verde and Yuma Mesas. These areas were used to calculate the ET for each diverter and evaporation for each reach. The domestic diverters were not part of this GIS coverage. They, and their service areas, will be incorporated in the future.

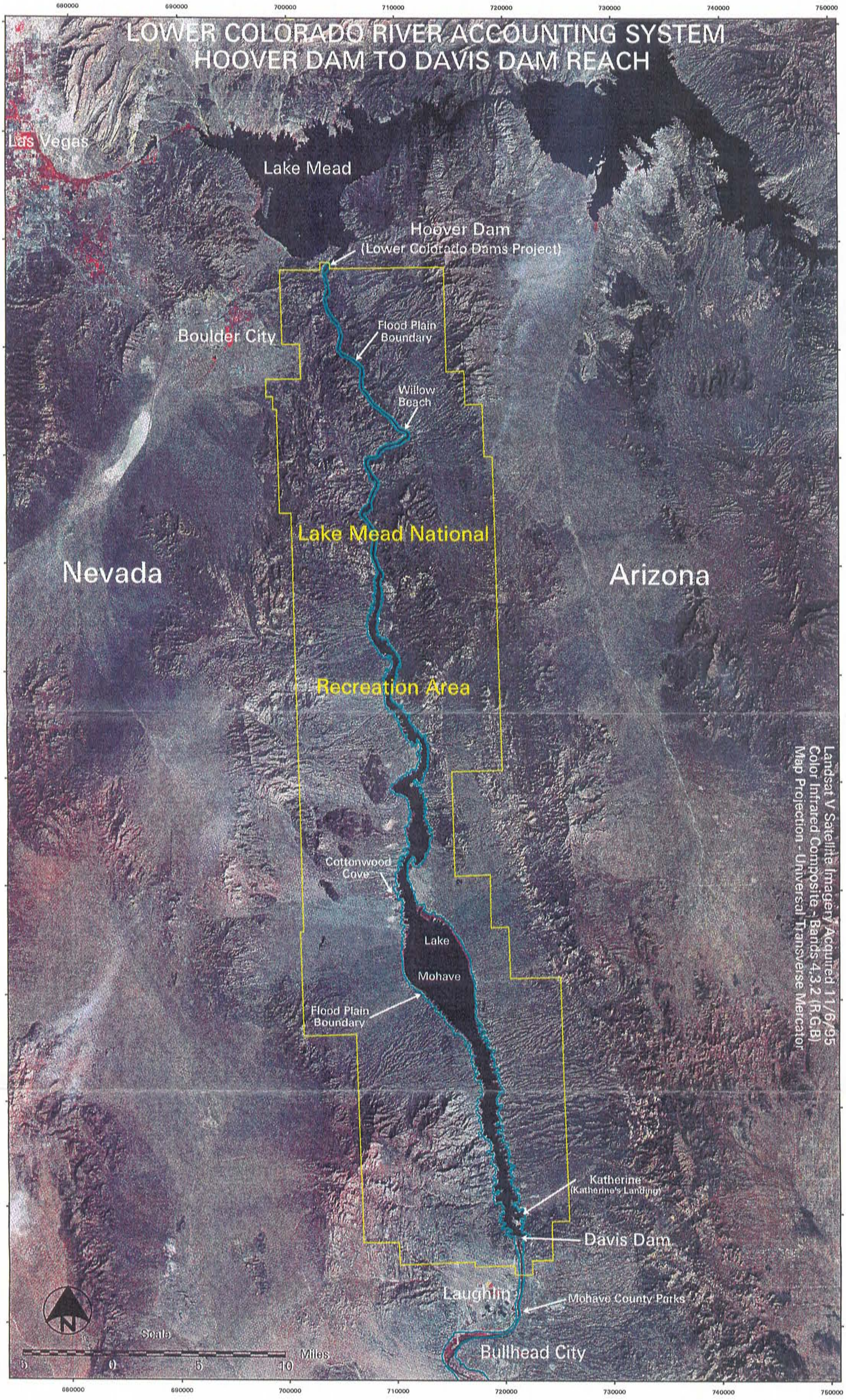

LOWER COLORADO RIVER ACCOUNTING SYSTEM
HOOVER DAM TO DAVIS DAM REACH
Las Vegas
Lake Mead
Hoover Dam
(Lower Colorado Dams Project)
Boulder City
Flood Plain Boundary
Willow Beach
Lake Mead National
Recreation Area
Nevada
Arizona
Cottonwood Cove
Lake
Mohave
Flood Plain Boundary
Katherine
(Katherine's Landing)
Davis Dam
Laughlin
Mohave County Parks
Bullhead City
Scale
5 0 5 10
Miles
N
Landsat V Satellite Imagery Acquired 11/6/95
Color Infrared Composite - Bands 4,3,2 (R,G,B)
Map Projection - Universal Transverse Mercator

Exhibit 1

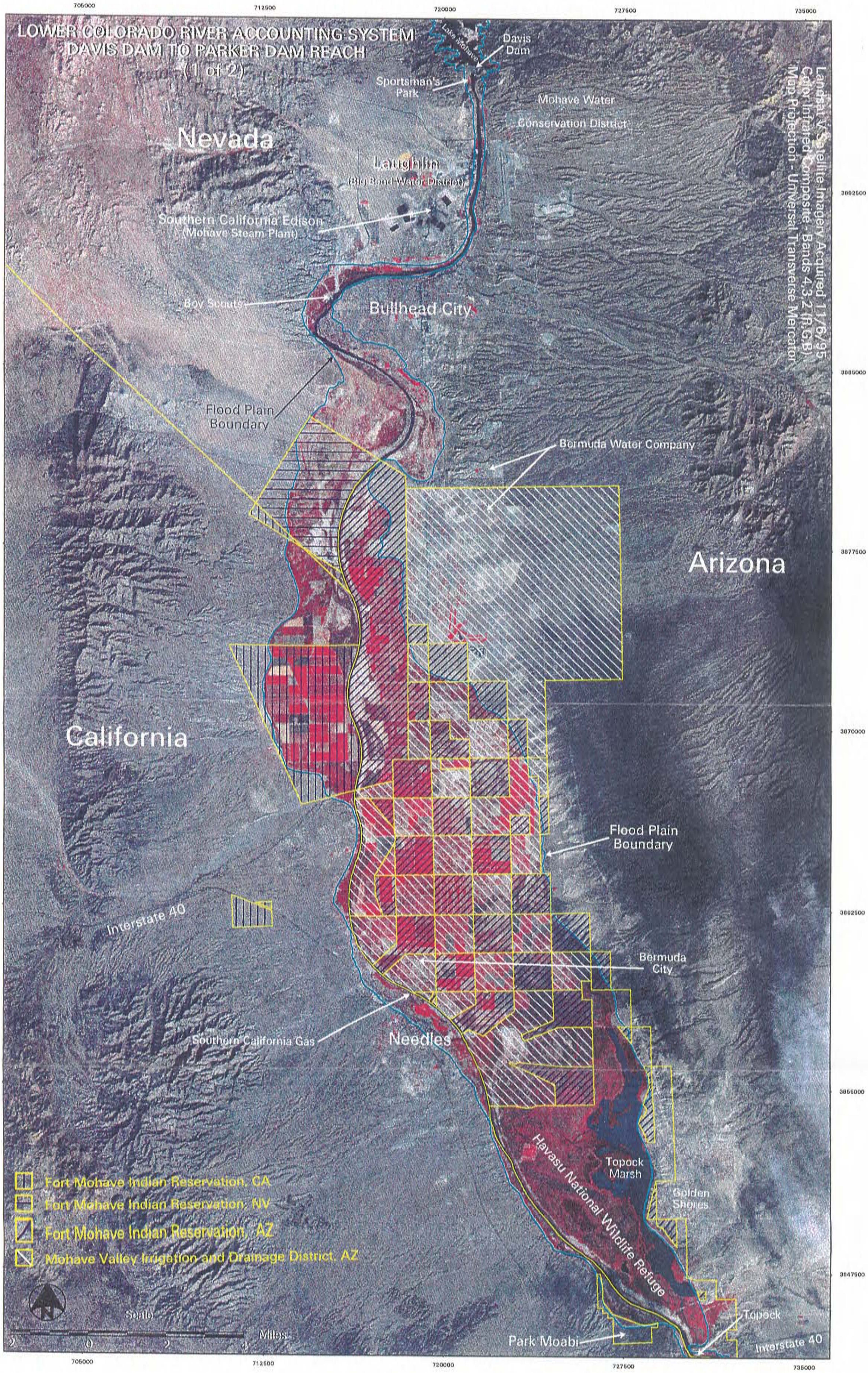

LOWER COLORADO RIVER ACCOUNTING SYSTEM
DAVIS DAM TO PARKER DAM REACH
(1 of 2)
Landsat V Satellite Imagery Acquired 11/6/95
Color Infrared Composite - Bands 4,3,2 (R,G,B)
Map Projection - Universal Transverse Mercator
705000
712500
720000
727500
735000
Lake Mohave
Davis Dam
Sportsman's Park
Mohave Water Conservation District
Nevada
Laughlin
(Big Bend Water District)
Southern California Edison
(Mohave Steam Plant)
Boy Scouts
Bullhead City
Flood Plain Boundary
Bermuda Water Company
Arizona
California
Flood Plain Boundary
Interstate 40
Bermuda City
Southern California Gas
Needles
Topock Marsh
Havasu National Wildlife Refuge
Golden Shores
Topock
Park Moabi
Interstate 40
Fort Mohave Indian Reservation, CA
Fort Mohave Indian Reservation, NV
Fort Mohave Indian Reservation, AZ
Mohave Valley Irrigation and Drainage District, AZ
Scale
Miles
2
0
2
4
3892500
3885000
3877500
3870000
3862500
3855000
3847500

Exhibit 2


Lower Colorado River Accounting System
Davis Dam to Parker Dam Reach
(2 of 2)
Fort Mohave Indian Reservation
Topock
Interstate 40
Park Moabi
Havasu
National
Wildlife
Refuge
Flood Plain Boundary
Arizona
Havasu Water Company of Arizona
CA
Chemehuevi Indian Reservation
Havasu Water Company of California
Lake Havasu
Lake Havasu City
Chemehuevi Indian Reservation
Lake Havasu State Park
Chemehuevi Indian Reservation
Flood Plain Boundary
Bill Williams River National Wildlife Refuge
Parker Dam
California
Colorado River
Indian Reservation
Earp
Parker
Scale
Miles
Landsat V Satellite Imagery Acquired 7/26/95
Color Infrared Composite - Bands 4,3,2 (R,G,B)
Map Projection - Universal Transverse Mercator

Exhibit 3

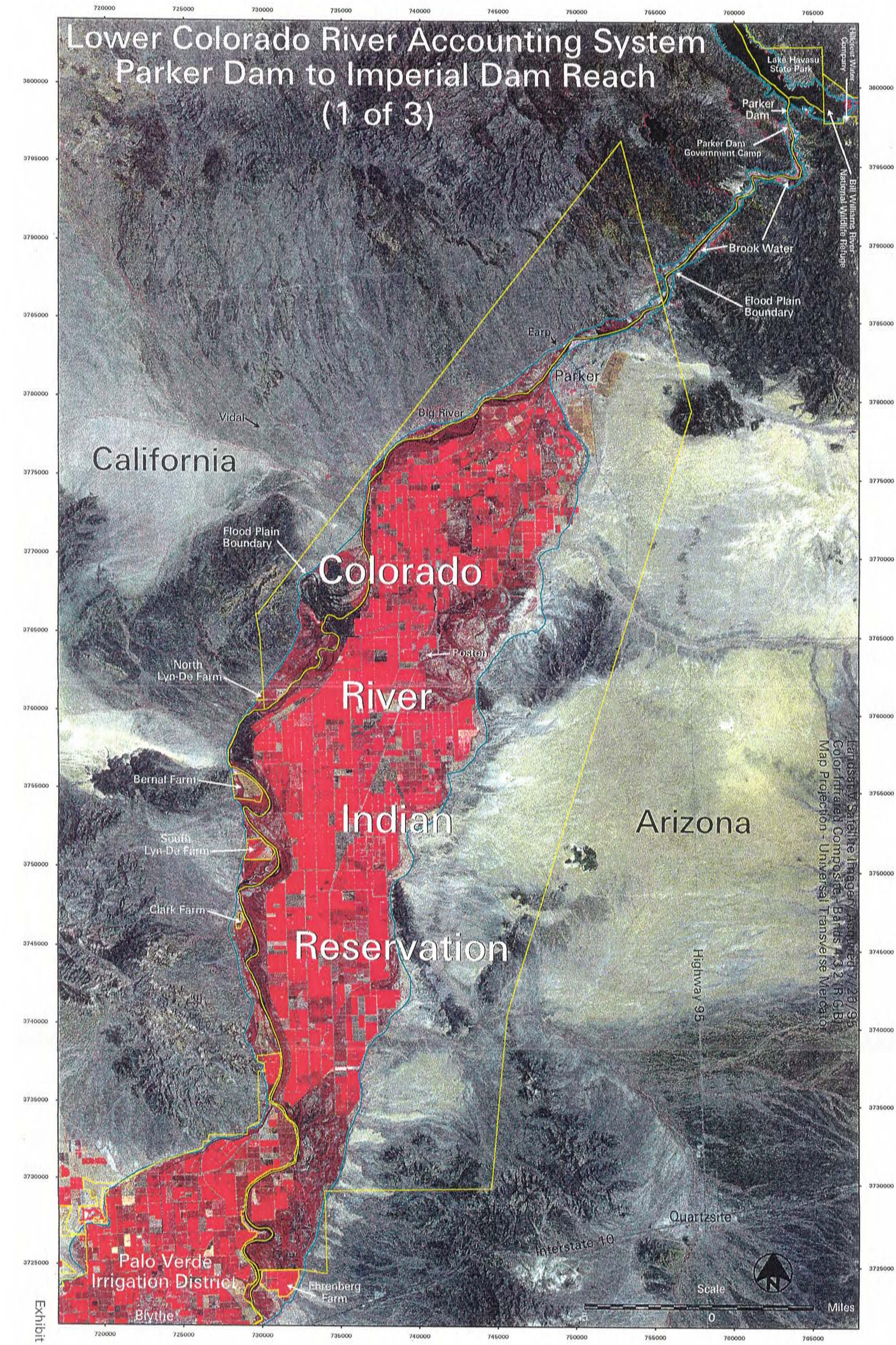
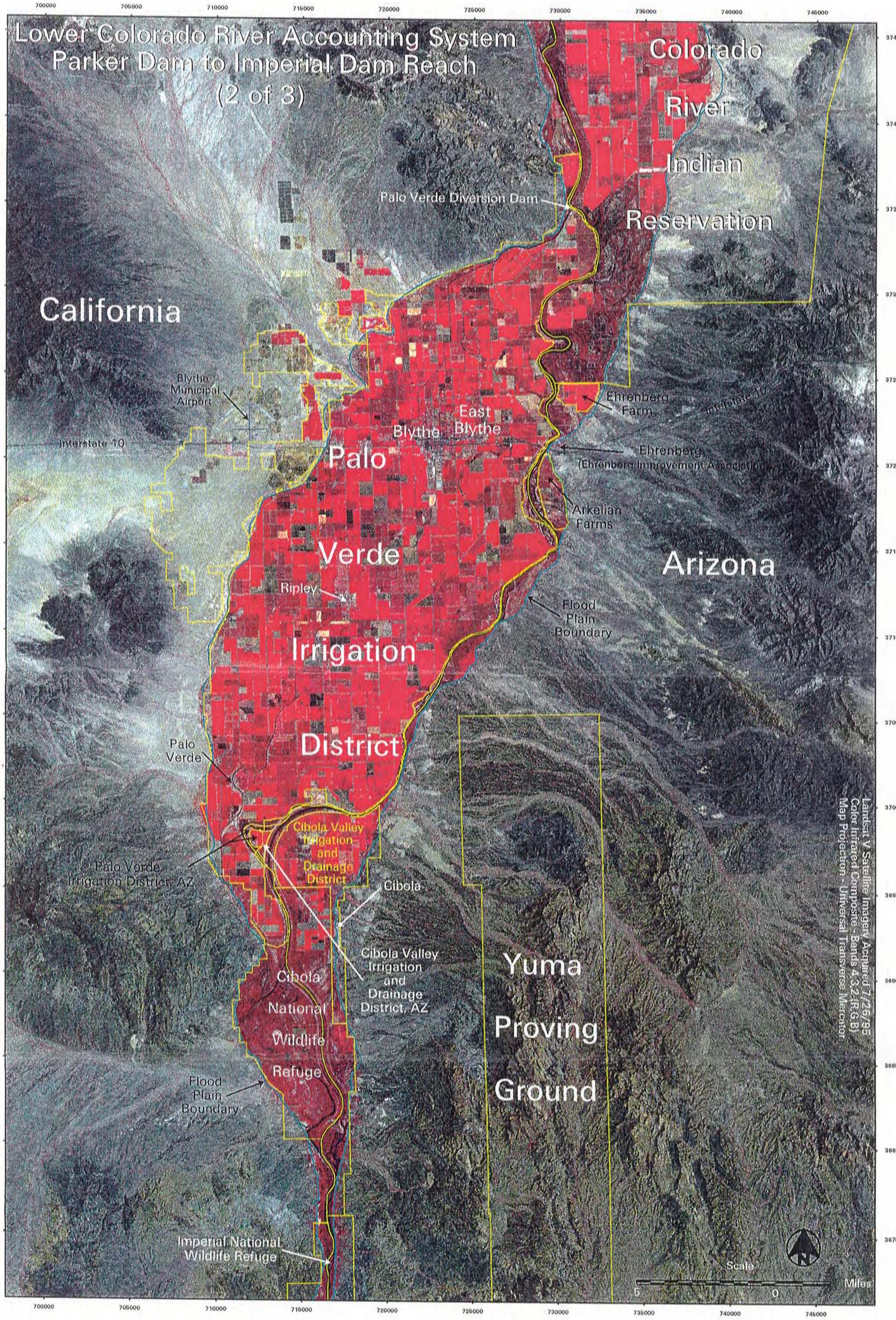
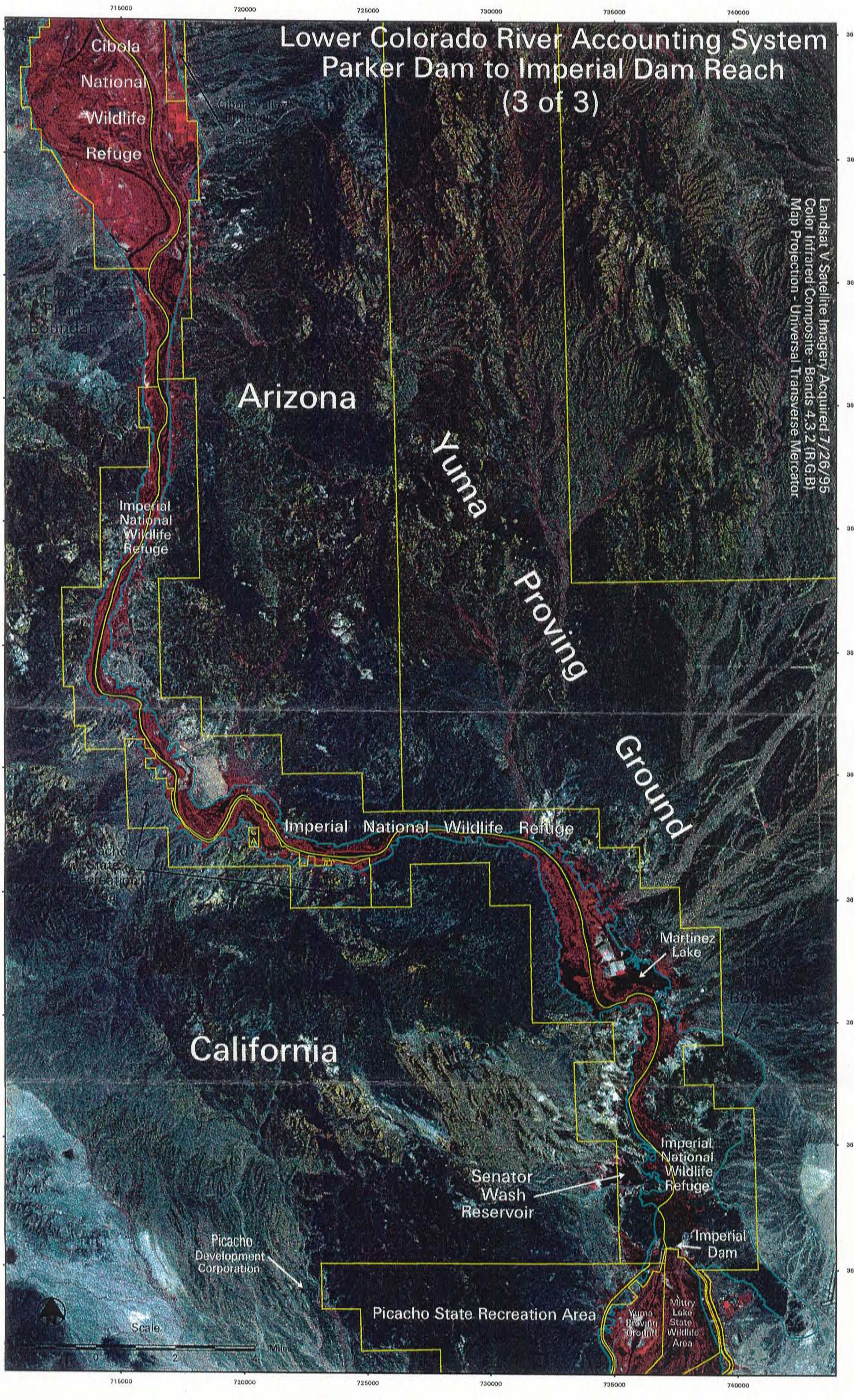

Lower Colorado River Accounting System
Parker Dam to Imperial Dam Reach
(1 of 3)
Lake Havasu State Park
Hillcrest Water Company
Parker Dam
Parker Dam Government Camp
Bill Williams River National Wildlife Refuge
Brook Water
Flood Plain Boundary
Earp
Parker
Big River
Vidal
California
Flood Plain Boundary
Colorado
River
Indian
Reservation
Poston
North Lyn-De Farm
Bernal Farm
South Lyn-De Farm
Clark Farm
Arizona
Highway 95
Color Infrared Composite - Bands 4,3,2 (R,G,B)
Map Projection - Universal Transverse Mercator
Quartzsite
Interstate 10
Palo Verde Irrigation District
Blythe
Ehrenberg Farm
Scale
5
0
Miles
N
720000
725000
730000
735000
740000
745000
750000
755000
760000
765000
3800000
3795000
3790000
3785000
3780000
3775000
3770000
3765000
3760000
3755000
3750000
3745000
3740000
3735000
3730000
3725000

Exhibit 4



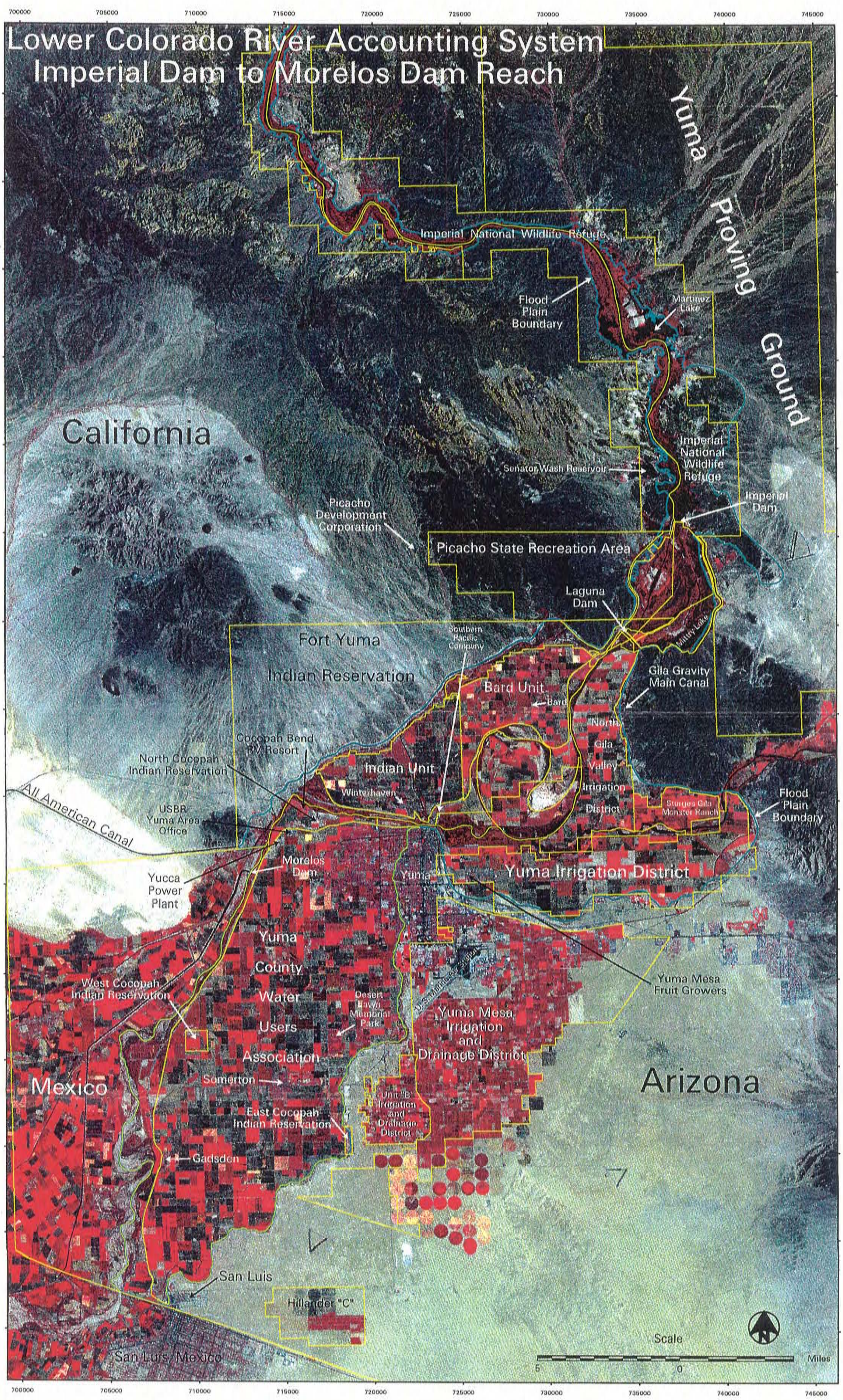
Lower Colorado River Accounting System
Parker Dam to Imperial Dam Reach
(2 of 3)
Colorado River Indian Reservation
Palo Verde Diversion Dam
California
Blythe Municipal Airport
Interstate 10
Ehrenberg Farm
Interstate 10
East Blythe
Blythe
Ehrenberg
(Ehrenberg Improvement Association)
Palo Verde Irrigation District
Arkelian Farms
Arizona
Ripley
Flood Plain Boundary
Palo Verde
Cibola Valley Irrigation and Drainage District
Palo Verde Irrigation District, AZ
Cibola
Cibola Valley Irrigation and Drainage District, AZ
Cibola National Wildlife Refuge
Yuma Proving Ground
Flood Plain Boundary
Imperial National Wildlife Refuge
Scale
5 0 Miles
Landsat V Satellite Imagery Acquired 7/25/95
Color Infrared Composite - Bands 4,3,2 (R,G,B)
Map Projection - Universal Transverse Mercator

Exhibit 5



Lower Colorado River Accounting System
Parker Dam to Imperial Dam Reach
(3 of 3)
Landsat V Satellite Imagery Acquired 7/26/95
Color Infrared Composite - Bands 4,3,2 (R,G,B)
Map Projection - Universal Transverse Mercator
Cibola National Wildlife Refuge
Flood Plain Boundary
Arizona
Yuma Proving Ground
Imperial National Wildlife Refuge
Imperial National Wildlife Refuge
Picacho State Recreation Area
Martinez Lake
California
Imperial National Wildlife Refuge
Senator Wash Reservoir
Imperial Dam
Picacho Development Corporation
Picacho State Recreation Area
Yuma Proving Ground
Mittry Lake State Wildlife Area
Scale
Miles
0
2
4
715000
720000
725000
730000
735000
740000
3690000
3685000
3680000
3675000
3670000
3665000
3660000
3655000
3650000
3645000
3640000

Exhibit 6



Lower Colorado River Accounting System
Imperial Dam to Morelos Dam Reach
Yuma Proving Ground
California
Imperial National Wildlife Refuge
Flood Plain Boundary
Martinez Lake
Senator Wash Reservoir
Imperial National Wildlife Refuge
Imperial Dam
Picacho Development Corporation
Picacho State Recreation Area
Laguna Dam
Mittry Lake
Fort Yuma Indian Reservation
Southern Pacific Company
Bard Unit
Bard
Gila Gravity Main Canal
North Gila Valley Irrigation District
Cocopah Bend RV Resort
North Cocopah Indian Reservation
Indian Unit
Winterhaven
Sturges Gila Monster Ranch
Flood Plain Boundary
All American Canal
USBR Yuma Area Office
Morelos Dam
Yuma
Yuma Irrigation District
Yucca Power Plant
Yuma County Water Users Association
West Cocopah Indian Reservation
Desert Lawn Memorial Park
Yuma Mesa Fruit Growers
Yuma Mesa Irrigation and Drainage District
Somerton
Mexico
Arizona
East Cocopah Indian Reservation
Unit "B" Irrigation and Drainage District
Gadsden
San Luis
Hillander "C"
San Luis, Mexico
Scale
5
0
Miles

Exhibit 7

Remote sensing involves the analysis of satellite imagery to identify the type and aerial extent of 14 crop classes, a fallow class, 12 phreatophyte communities, and open water surfaces along the Lower Colorado River.

GIS data base management tools were used to process and store large amounts of spacial and informational data, including ground reference data and data derived from the analysis of digital satellite imagery (image data). GIS data base management tools were used to calculate, summarize, and generate reports relating to the areal extent of each crop class and phreatophyte community for each diverter and to open water areas along the Lower Colorado River.

Satellite Image Analysis

Multispectral analysis was performed on image data to classify and map vegetation and open water areas along the mainstream of the Lower Colorado River for calendar year 1995. Vegetation and open water classification techniques have been developed for image data acquired by the Thematic Mapper (TM) sensor onboard the Landsat V satellite. This sensor detects and records reflected radiance (light) from the Earth's surface in seven regions of the electromagnetic spectrum. At any given instant, it focuses on only one small area of the surface, which corresponds to a single picture element or pixel. A pixel is the smallest unit composing a satellite image. The pixel size or spacial resolution of the Landsat TM data being used for image analysis is 25 meters. TM image data were acquired for analysis for the World Reference System[2] locations and on the dates shown below during calendar year 1995:

[2] Landsat V images are catalogued according to their location within the World Reference System (WRS). In this system, images can be uniquely defined by specifying a path, a row, and a date. The WRS for Landsat V has 233 paths corresponding to the number of orbits required to cover the earth in one 16-day cycle. Paths are numbered 001 to 233, east to west. The rows are numbered so that row 60 coincides with the equator on an orbit's descending node.

Path 38, rows 36 and 37	April 5, 1995	Path 39, row 35	February 23, 1995
Path 38, rows 36 and 37	May 23, 1995	Path 39, row 35	April 28, 1995
Path 38, rows 36 and 37	July 26, 1995	Path 39, row 35	August 18, 1995
Path 38, rows 36 and 37	December 1, 1995	Path 39, row 35	November 6, 1995

These image data were selected as they adequately covered the study area, were cloud free, and captured the variation in crop class and growth stage during the year.

TM image data were georeferenced to the Universal Transverse Mercator (UTM) map coordinate system. This process establishes and records the geographic location of each pixel in the image. Georeferencing was required to match map coordinates when image data were combined with other spatial data layers such as diverter boundaries. The image data were ordered from the vendor (EOSAT) user-ready in the UTM projection.

Ground Reference Data Collection

Correct identification of vegetation classes by image data analysis requires a detailed understanding of the spectral characteristics and agricultural practices of representative sites throughout the study area. TM image data contain information only about the spectral characteristics of a land cover type as detected and recorded by the TM sensor. The spectral characteristics of a land cover type measured by the sensor were recorded as digital representations of the Earth's surface, commonly referred to as "spectral signatures." Ground reference data were required to establish the unique relationship between the spectral signatures in the image data and the vegetation classes on the ground.

Ground reference data were collected for approximately 1,900 of the 12,800 agricultural fields in the study area. This represents about 15 percent of the total agricultural area. Half of the agricultural ground reference data were used in image data calibration, and the remaining half were used to assess the accuracy of the vegetation mapping. Selection of the calibration sites was based on the vegetation distribution in each major agricultural area along the mainstream of the Lower Colorado River. Agricultural fields were selected randomly from a data base of the agricultural fields and their borders. During 1995, ground reference data were collected four times. These times coincided with the acquisition of satellite imagery. Variability in planting and harvesting times for each crop was also considered in the selection of data collection dates during the year. Table 1 presents the crop classes sampled.

Table 1.—Crop classes

Alfalfa	Corn	Bermuda Grass	Sudan Grass	Fallow
Cotton	Lettuce	Citrus	Other Vegetables	Dates
Small Grains	Melons	Tomatoes	Crucifers	Safflower

The image classification results show that the spectral characteristics of the Landsat V image data are satisfactory for discriminating crop classes. Excellent results were obtained for crop classes listed in table 1, using a single-date image classification. Postclassification accuracy assessment shows that, overall, the crops can be mapped with an average accuracy of 93.0 percent.

Field reconnaissance was performed twice during 1995 to document field conditions of phreatophyte species, their density, and distribution. Several hundred sites were documented for use in image data calibration and postclassification accuracy assessment. The phreatophytes were divided into the classes shown in table 2.

Table 2.—Phreatophyte classes

Class name	Description
Marsh	40% cattail, bulrush, and phragmites
Barren	≤10% vegetation
Sc_low	11-60% salt cedar and ≤25% arrowweed
Sc_high	61-100% salt cedar and ≤25% arrowweed
Sc/ms	11-60% salt cedar, 11-60% mesquite, and ≤25% arrowweed
Sc_aw	≤75% sc and ≥25% arrowweed
Sc_ms_aw	15-45% sc, 15-45% mesquite, and 20-40% arrowweed
Ms_low	11-60% screwbean and honey mesquite, and ≤25% arrowweed
Ms_high	61-100% screwbean and honey mesquite, and ≤25% arrowweed
Ms_aw	21-60% mesquite, 31-60% arrowweed, and ≤20% salt cedar
Aw	51-100% arrowweed and ≤10% any trees
Cw	61-100% cottonwood and willow
Low veg	>10% and ≤30% any phreatophyte vegetation

Discrimination between phreatophyte classes was successful, although these classes were not as well-defined as crop classes due to the mixed nature of these areas and the highly variable density and vegetation growth patterns. A single-image classification technique was used to identify and determine the areas of phreatophytes in the Lower Colorado River flood plain. Postclassification accuracy assessment analysis indicated that the phreatophyte communities can be mapped with an average accuracy of 87.0 percent.

A separate class for open water was also developed, and image classification techniques were also used to quantify open water surface areas. A single-image classification technique was performed on the Landsat V image acquired April 5, 1995, for this purpose. Results were found suitable for use in estimating evaporation. Comparisons with published elevation/capacity/area data showed that the surface areas derived from image classification were within 3.0 percent of the published data.

A detailed description of the image processing and GIS techniques used for this LCRAS Demonstration of Technology will be available for review about January 1998.

Delineation of Total Vegetated Area

A relational data base (GIS coverage) was developed that delineates the field borders in all agricultural areas along the mainstream of the Lower Colorado River. All the ground reference data collected for calibration was linked to this field border data base. These borders were derived from Systemme Pour l'Observation de la Terre (SPOT) image data acquired in June and August 1992. All field borders were on-screen digitized at the 7-1/2-minute quadrangle level using the SPOT data as a backdrop. SPOT image data were used because it has a spatial resolution of 10 meters (Landsat V TM image data has a spatial resolution of 25 meters) and was projected onto the UTM map coordinate system at a scale of 1:24,000 (the same scale as a 7-1/2-minute USGS quadrangle map, the common standard for most spatial analysis). The 10-meter resolution of the SPOT image data provided an excellent backdrop for identifying and digitizing agricultural field borders. An example of a map with field borders highlighted is provided as exhibit 8.

All areas along the mainstream of the Lower Colorado River that divert or pump water were included in this analysis. The boundaries for these areas are shown in exhibits 1 through 7 and 9. This is also projected onto the UTM map coordinate system.

The Bill Williams River reach is shown as exhibit 10. This reach was used only to calculate the inflow to the Colorado River from the Bill Williams River. None of the water uses in the Bill Williams River reach are considered to be Colorado River water uses.

Water Balance Equation

In Jensen (1994), Dr. Jensen recommended the following water balance equation to replace that recommended by USGS and documented in Owen-Joyce and Raymond (1996). This is the basic equation that was applied to each reach of the river:

$$Q_{res} = Q_{us} + P + T - Q_{ds} - Q_{ex} - Q_{rf} - E - C_{ud} - ET_{pht} - ET_{crop} - \Delta S_r - \Delta S_a$$

Where:

Q_{res} = The residual.

Q_{us} = The flow at the upstream boundary of the reach.

P = Precipitation.

T = Tributary inflow to the reach.

Q_{ds} = The flow exiting the reach at the downstream boundary.

Q_{ex} = Water exported out of the basin.

Q_{rf} = Water diverted from one reach that returns to the river below the downstream boundary of that reach (off-stream outflow).[3]

E = Open water surface evaporation.

C_{ud} = Domestic, municipal, and industrial use.

ET_{pht} = The total estimated phreatophyte ET.

ET_{crop} = The total estimated crop ET.

ΔS_r = The change in reservoir storage.

Δs_a = The change in storage in the alluvial aquifer.

Some of the terms described above were combined for the LCRAS Demonstration of Technology for Calendar Year 1995. Flows entering Mexico

[3] This outflow was suggested for use in the revised water balance equation by Jensen (1994). It has been renamed from return flow to off-stream outflow for this report to avoid confusion with return flow as defined in the Supreme Court Decree.

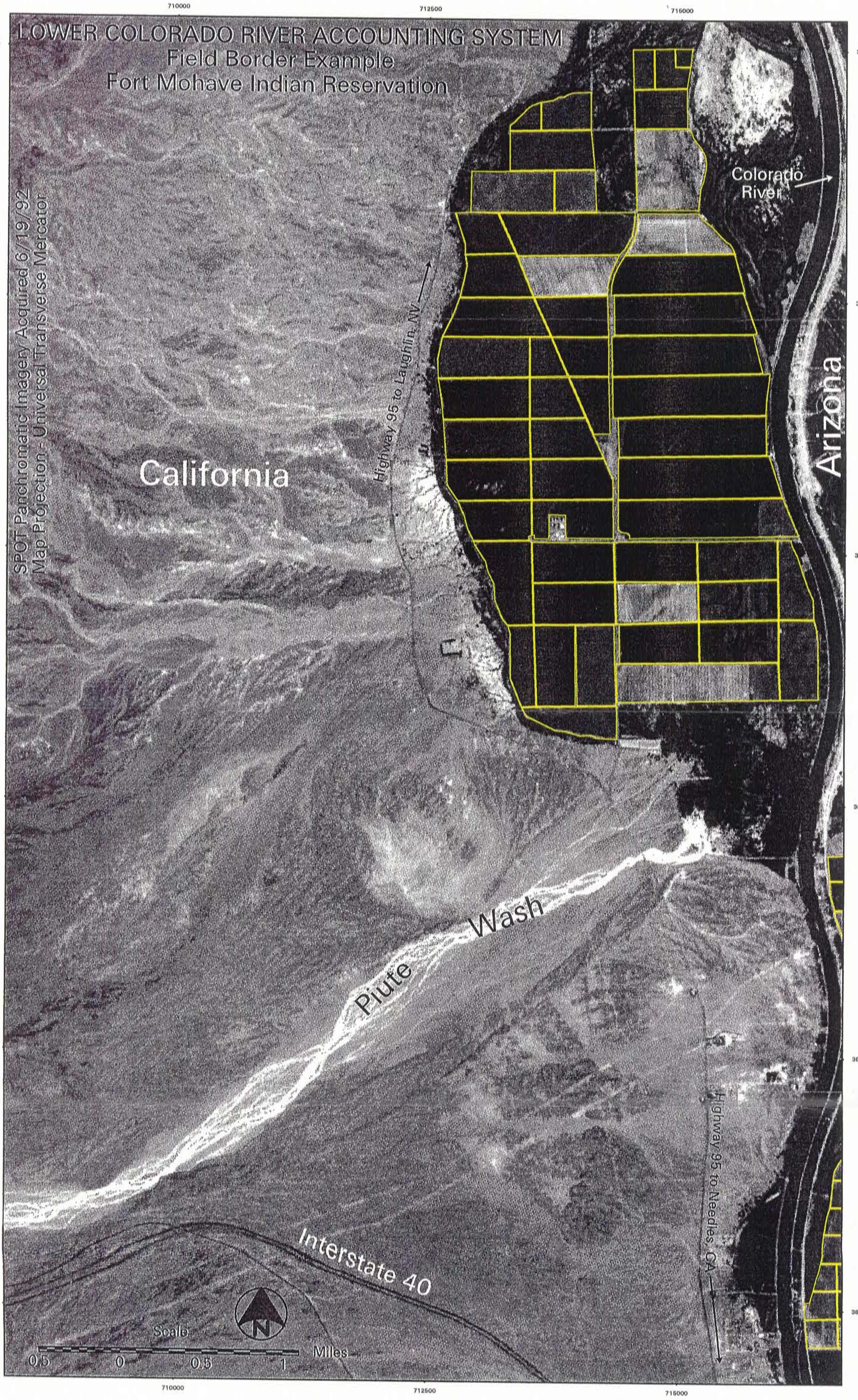
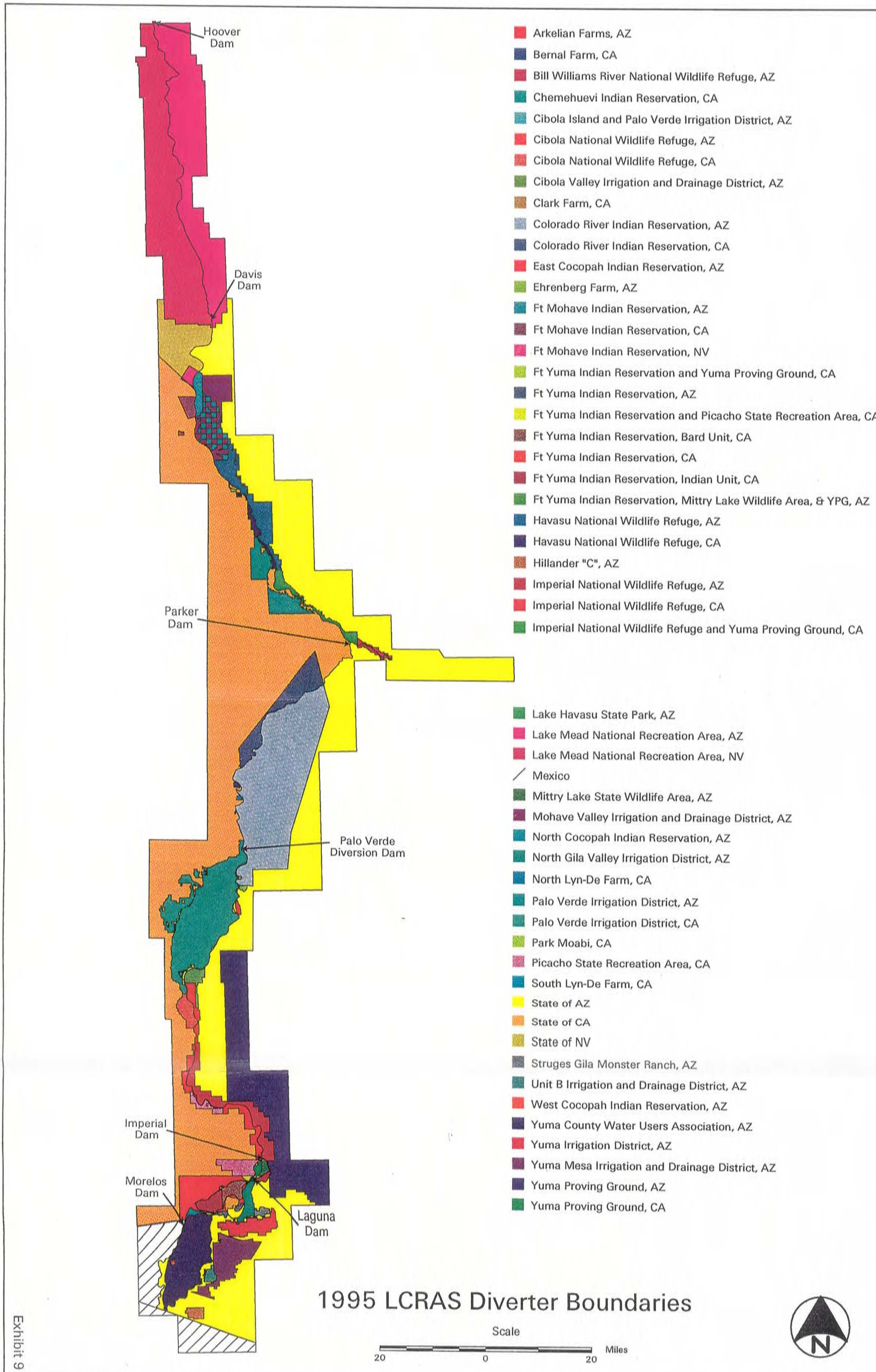
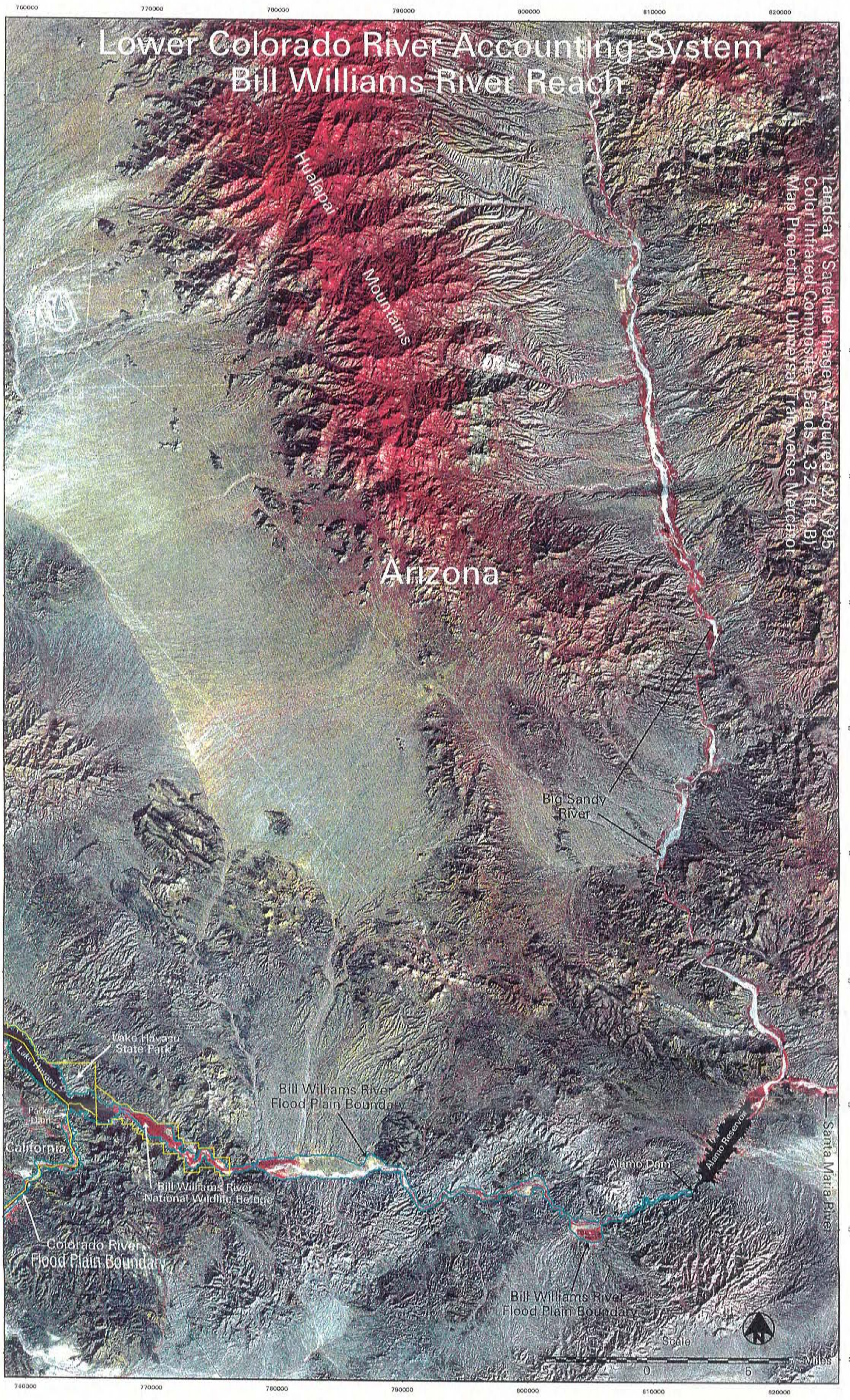


Exhibit 8

Note: Refer to Exhibit 2 for more detail.



1995 LCRAS Diverter Boundaries



Lower Colorado River Accounting System
Bill Williams River Reach
Hualapai
Mountains
Arizona
Landsat V Satellite Imagery Acquired 12/1/95
Color Infrared Composite Bands 4,3,2 (R,G,B)
Map Projection: Universal Transverse Mercator
Big Sandy River
Lake Havasu
Lake Havasu State Park
Parker Dam
California
Bill Williams River Flood Plain Boundary
Bill Williams River National Wildlife Refuge
Colorado River Flood Plain Boundary
Alamo Dam
Alamo Reservoir
Santa Maria River
Bill Williams River Flood Plain Boundary
Scale
0
5
Miles

Exhibit 10

at the Southerly International Boundary (SIB), initially identified as off-stream outflows, were modeled as part of the downstream flow. The effect of precipitation was modeled as a reduction in the magnitude of evaporation and crop ET.

This equation was applied to four reaches along the Lower Colorado River—Hoover Dam to Davis Dam, Davis Dam to Parker Dam, Parker Dam to Imperial Dam, and Imperial Dam to Morelos Dam.[4]

The data used in this LCRAS Demonstration of Technology are the most accurate and complete data that were available when the calculations were performed. Data were gathered from Reclamation records and reports and reports provided to Reclamation by other sources. The following sections of this report discuss the sources of data, calculations made with the data, and significant issues associated with the data.

Flow Data

Flow data include flows at upstream and downstream reach boundaries, exported water, measured tributary inflows, and changes in reservoir storage. Flow data were provided by USGS, Reclamation, the International Boundary and Water Commission (IBWC), Metropolitan Water District of Southern California (MWD), and the Central Arizona Project (CAP). An effort was made to use the same values for flow as presented in the Decree Accounting Report.

[4] The flow at the SIB near San Luis and other flows that enter Mexico below Morelos Dam are included in this reach.

Mainstream Flow (Q_{us}, Q_{ds})

The majority of the upstream (entering a reach) and downstream (exiting a reach) flow measurements were provided by USGS.[5] The exceptions—the downstream outflows and two of the upstream inflows of the Imperial Dam to Morelos Dam reach—are explained below.

The outflow from Imperial Dam to Morelos Dam reach (flows to Mexico at both the Northerly and Southerly International Boundaries) was measured and reported by IBWC using stage discharge relationships and standard flow measurement devices.

The inflow to the Imperial Dam to Morelos Dam reach (flow below Imperial Dam) was a summation of flow within the Colorado River channel, diversions to Mittry Lake, and flows in the All-American and Gila Gravity Canals. Flows in the Gila Gravity and Wellton-Mohawk Canals were measured by Reclamation using Acoustic Velocity Meters (AVMs).

For a more detailed explanation of the use of AVMs on the Lower Colorado River by Reclamation, see Madigan and Weiss (1996).

Most of the data reported by USGS were measured using stage-discharge relationships developed over the period of record for each gauge. An exception occurs at Hoover Dam, where flow through the dam was measured by closed conduit AVMs located in the penstocks. The devices conform to American Society of Civil Engineers[6] standards for AVM installations, and USGS reports the flow data annually.

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[5] USGS provided flow information in *U.S. Supreme Court Decree Stations of the Lower Colorado River, Diversions and Return Flows Data for Calendar Year 1995.*

[6] ASCE.

Export Flow (Q_{ex})

Flows into the California Aqueduct and the CAP were reported by MWD and Central Arizona Water Conservation District, respectively, from their own measurements. Consumptive use by MWD consists of diversions from Lake Havasu less return flows from the two reregulating reservoirs on the California Aqueduct, as reported by the Decree Accounting Report.

Diversions to the Wellton-Mohawk Irrigation and Drainage District (Wellton-Mohawk) were measured in the Wellton-Mohawk Canal by Reclamation, using open channel AVMs. Flows to the Imperial Irrigation District (IID) and the Coachella Valley Water District (Coachella) were measured in the All-American Canal below Pilot Knob by IID. The data measured by IID were reported by USGS .

The sum of the undistributed export flows compiled for calendar year 1995 was 5,556,310 acre-feet (acre-ft), or about 78 percent of the total Lower Colorado River Basin consumptive use. Distributed values for exports were not reported as results because these uses occur outside the Lower Colorado River mainstream.

The flow values for calendar year 1995 can be found in attachment 3.

Tributary Inflow Data (T)

Tributary inflows to the system were either measured or estimated. The flows of two tributaries were measured—the Gila River in southwestern Arizona and the Bill Williams River in west-central Arizona. Gila River flows were measured near Dome and reported by USGS. The Bill Williams River was measured near its headwaters below Alamo Dam and reported by USGS. Because the Bill Williams River flows many miles through established stands of phreatophytes before entering the Colorado River at Lake Havasu, LCRAS estimates the flow entering the Colorado River with a water balance, the same as for other reaches of the river.

The flow reported below Alamo Dam was the inflow to the Bill Williams reach. Evaporation and water uses were calculated using the same remote sensing and reference ET methods used along the mainstream of the Colorado River and subtracted from the flow below Alamo Dam to provide the inflow to the Colorado River. The phreatophyte and crop water use on the Bill Williams River between Alamo Dam and Lake Havasu were not considered to be Colorado River water uses.

Unmeasured tributary inflow values were taken directly from Owen-Joyce (1987). The flow values presented in this USGS report use a 10-year average flow estimate. These flow estimates have been reprinted in Owen-Joyce and Raymond (1996). The sum of the unmeasured tributary inflows was 88,320 acre-ft,[7] or about 1 percent of the flow below Hoover Dam. Unmeasured tributary flow values can be found in attachment 3. After the residual from the water balance was distributed, the final estimate of unmeasured flow to the Lower Colorado River increased to 90,990 acre-ft.

Evapotranspiration

The LCRAS method calculates evapotranspiration for all vegetation within the flood plain and on the Palo Verde and Yuma Mesas as an initial estimate of the consumptive use of water for each agricultural diverter. Evapotranspiration calculations require:

[7] Includes only unmeasured tributary inflows to the Colorado River. Not included are unmeasured tributary inflow estimates for the Bill Williams River between Alamo Dam and Lake Havasu presented in Owen-Joyce and Raymond (1996).

- Daily reference ET
- Daily vegetation class (crop or phreatophyte) ET coefficients
- Number of acres covered by each vegetation class

Daily reference ET values were obtained from AZMET and CIMIS stations; daily ET coefficients for each vegetation class were developed specifically for the LCRAS program and are documented in Jensen (1996); and Reclamation developed the area covered by each vegetation class through the analysis of remotely sensed data.

The CIMIS station and five AZMET weather stations located in irrigation districts within the flood plain continuously collect meteorological data to calculate hourly and daily reference ET (ET_0). Each station records maximum, minimum, and average temperature and relative humidity; 2- and 4-inch average soil temperature; windspeed; solar radiation (net radiation at CIMIS stations); and precipitation.

Evapotranspiration was calculated by multiplying the daily reference ET times each daily vegetation class ET coefficient, summing this product for a monthly total ET rate (in feet); and then multiplying this ET rate by the area (in acres) covered by each vegetation class. The ET for all vegetation classes within a diverter's area were summed to provide the total ET for the diverter.

In mathematical terms, the general equation for evapotranspiration by one vegetation class looks like this:

$$ET_v = [\sum_n (ET_0 \times K_c)] AC_c$$

Where:

ET_v = The total monthly or annual ET by one vegetation class for one diverter.

$\sum_n$ = Summation over an amount of time, typically 1 month or year.

ET_0 = Daily reference ET value calculated by AZMET or CIMIS stations.

K_c = Daily vegetation coefficient (Jensen, 1996).

AC_c = Acreage of one vegetation class for the diverter in question.

Crops (ET_{crop})

The first step in calculating the water use by crops within a diverter's area was to calculate an ET rate for each crop class. ET_0 values (inches) from the nearest AZMET or CIMIS station were multiplied by daily crop coefficients (dimensionless), unique to each crop class, to arrive at the daily ET rate for each crop class. The impact of rainfall on crop water use was considered by subtracting an estimate of effective precipitation (inches) from the ET rate for each crop class. The technique used to calculate effective precipitation is described below in the "Precipitation" section.

In parallel with the calculations of ET rate, the number of acres covered by each crop class within the diverter boundary must be calculated. This was done using remote sensing techniques. Satellite images were used to separately identify each crop class. GIS coverages were used first to identify the diverter area within which the crops fall, then to quantify the area covered by each crop class within a diverter's boundaries. There are 15 crop classes, some with numerous subclasses, for which this calculation was performed. These crop classes were listed in table 1 in the "Ground-Reference Data Collection" section.

Monthly ET for each diverter, in acre-feet, was calculated by summing the daily ET rate (feet, corrected for effective precipitation) for each month and multiplying by the area (acres) covered by each crop class within each diverter boundary. Monthly ET for each diverter was summed for the year to yield the annual ET for each diverter.

Using cotton as an example, the equation looks like this:

$$ET_{cotton} = \sum_n [(ET_0 \times K_{cotton}) - \text{Effective PPT}]AC_{cotton}$$

Where:

ET_{cotton}	=	The total monthly or annual ET by cotton for the diverter in question.
$\sum_n$	=	Summation for $_n$ time, either monthly or annually.
ET_0	=	Daily reference ET value calculated by AZMET or CIMIS stations.
K_{cotton}	=	Daily crop coefficient (Jensen, 1996) specific to cotton.
AC_{cotton}	=	Acreage of cotton for the diverter in question.
Effective PPT	=	Effective precipitation, which was the amount of ET reduced by rainfall.

The calculated ET for all crop classes within a diverter's boundary were summed to arrive at the total crop ET for the diverter. The summation of crop ET for all diverters, within a reach of the river, become the outflow, ET_{crop}, in the water balance equation described above.

The sum of the ET_{crop} compiled for calendar year 1995 was 1,386,314 acre-ft, or about 19 percent of the total Lower Colorado River Basin consumptive use. After the residual from the water balance was distributed, the final calculation of crop consumptive use dropped to 1,365,038.

Phreatophytes (ET_{pht})

Phreatophyte water use was calculated the same way as noted above in the section entitled "Crops (ET_{crop})," except that the ET rates for phreatophytes were not corrected for effective precipitation. Phreatophytes along the Lower Colorado River are mostly deep-rooted plants that benefit little from precipitation.

Using the same process applied to crop evapotranspiration, the summation of ET from all phreatophyte classes within a diverter's area yields the total phreatophyte ET for a diverter. The total phreatophyte ET for all diverters within a reach were summed to give the phreatophyte outflow ET_{pht} for the water balance equation.

Phreatophytes were grouped into several classes. The 14 phreatophyte classes used to calculate phreatophyte ET were listed in table 2 in the section "Ground Reference Data Collection." Remote sensing techniques were used to develop the number of acres covered by each phreatophyte class used to calculate ET_{pht}.

The sum of the ET_{pht} calculated for calendar year 1995 was 648,813 acre-ft, or about 8 percent of the combined Lower Colorado River Basin use and loss from crops, domestic uses, exports, evaporation, and phreatophytes. After the residual from the water balance was distributed, the final calculation of phreatophyte consumptive use dropped to 631,497 acre-ft.

Evaporation (E)

LCRAS calculates evaporation from the open water surfaces of Lake Mohave, Lake Havasu, Senator Wash, and the open water surfaces of the Colorado

River and adjacent backwaters (such as Topock Marsh and Mittry Lake) from Hoover Dam to Mexico. These values were used in the water balance of each reach.

LCRAS calculated monthly open water surface evaporation in 1995 as the product of the sum of daily AZMET and CIMIS ET_0 values times an average monthly evaporation coefficient. Monthly precipitation measured at the AZMET or CIMIS stations was subtracted from the evaporation rate to yield a corrected monthly evaporation rate. The corrected evaporation rate was multiplied by the open surface area (acres) to yield the monthly open water evaporation (acre-feet).

The open water surface area (acres) for Lakes Mohave and Havasu was derived from area estimates developed by analyzing a spring satellite image (more details are available in the section on remote sensing). This value was used to represent the annual open water surface area for each lake. The same procedure was used to develop the open water surface areas for the river below Hoover Dam to the Northerly International Boundary backwater areas and Senator Wash Reservoir.

The sum of the evaporation (below Hoover Dam) calculated for calendar year 1995 was 314,266 acre-ft, or about 4 percent of the combined Lower Colorado River Basin water use and loss from crops, domestic uses, exports, phreatophytes, and evaporation. After the residual from the water balance was distributed, the final calculation of evaporation dropped to 312,323 acre-ft.

Precipitation (P)

Precipitation was measured at each station in the AZMET and CIMIS networks by a recording rain gauge. The precipitation falling on each station was used in ET and evaporation calculations for the area surrounding it. An exception was made in 1995 for the Palo Verde Valley where the CIMIS station recorded approximately 19 inches of precipitation, a value deemed erroneous when compared with values from nearby stations. Reclamation chose to use precipitation data from the rain gauge located at the Palo Verde Irrigation District headquarters facility for calendar year 1995.

The effects of precipitation were treated in one of four ways, depending on the nature of the surface upon which it fell:

- Precipitation falling on open water surfaces was considered to be fully effective, and the total precipitation volume was considered an inflow to the system.
- Precipitation falling on crop areas was considered to be partially effective in reducing crop water demand.
- Precipitation falling on areas within the flood plain inhabited by adequately watered phreatophytes was not considered to reduce the water requirement of the phreatophytes. Neither was precipitation considered to run off in significant quantities from these areas. Precipitation falling over these areas, therefore, was not considered an inflow to the system.
- Precipitation falling on lands outside the flood plain, but within the basin, was presumed to be accounted for as part of the tributary inflow estimates reported by USGS in Owen-Joyce and Raymond (1996).

The amount of precipitation falling on crop areas that was considered to be partially effective in reducing crop water demand was called effective precipitation. Effective precipitation was subtracted from the ET rate calculated for crops to yield the final ET rate for crop areas, as described above in the "Crops (ET_{crop})" section. LCRAS calculates effective precipitation by multiplying the precipitation, recorded by the appropriate rain gauge, by an effective precipitation coefficient. The effective precipitation coefficients used for this LCRAS Demonstration of Technology were documented in Jensen (1993).

The equation used to calculate effective precipitation is:

Effective Precipitation = Precipitation × Effective Precipitation Coefficient

The depth of precipitation that fell over the Lower Colorado River Valley in 1995 ranged from 0.62 inch, measured at the Yuma, North Gila AZMET station, to 4.03 inches, measured at the Yuma Mesa AZMET station. The unweighted precipitation average recorded across the valley for 1995 was 2.78 inches.

Domestic Use (C_{ud})

Domestic use, in this report, means any use of Colorado River water that was not consumptive use by vegetation, or an export. Domestic use includes municipal use, industrial use, and individual household use.

The initial estimates of domestic use were compiled from two basic sources. The majority of domestic uses were taken directly from the Decree Accounting Report for 1995. These values were a mix of diversions less returns and diversions only. Where values from the Decree Accounting Report were not available, consumptive uses were calculated by applying the per capita consumptive use factors, used in Owen-Joyce and Raymond (1996), to updated population values from the 1990 census or from "Crop Production and Water Utilization Data for 1994" (the most recent values available). The estimated water use of a very few small municipalities was not changed from that shown by Owen-Joyce and Raymond (1996) because updated information was not available, and the water use values were very small.

The list of domestic diverters was compiled from those listed in Owen-Joyce and Raymond (1996) and in the Decree Accounting Report (both the main body and the miscellaneous users section), and from those identified as nonagricultural diverters in the Reclamation Water Contracts Data Base, so long as each diverter's continued existence could be verified and the source gave a reliable value for water use. Diverters in the Decree Accounting Report were identified as domestic diverters by discerning the type of water use from the name of the diverter because the type of use was not necessarily included.

There may be some domestic diverters that were not included, but their impact on the total consumptive uses calculated by this LCRAS Demonstration of Technology would be very small. Also, the fact that many of the domestic uses were reported as diversions has a tendency to exaggerate the true value of consumptive use. The diversions by MWD and CAP were not included here. These diversions were considered to be exports rather than domestic diverters.

The sum of the undistributed domestic uses compiled for calendar year 1995 was 71,949 acre-ft, or about 1 percent of the total Lower Colorado River Basin consumptive use. After the residual from the water balance was distributed, the final calculation of total domestic use dropped to 71,110 acre-ft. The table in attachment 4 lists the name, source of data, and value of consumptive use for each domestic diverter.

Change in Reservoir Storage (ΔS_r)

The change in reservoir storage in each reach must be considered in the water balance because an increase in reservoir storage reduces the flow at the downstream end of a reach (acts like an outflow), and a decrease in reservoir storage increases the flow at the downstream end of a reach (acts like an inflow). If there was no reservoir in a reach, the change in reservoir storage value was zero.

Storage calculations were performed by Reclamation daily on Lakes Mohave, Havasu, and Senator Wash using stage versus capacity tables. Reservoir storage values were reported monthly in Reclamation Reservoir Elevations and Contents tables, provided by the Lower Colorado Dams Facilities Office. The annual change in reservoir storage, used for LCRAS, was a summation of the difference between storage calculated on the first day of each month and the first day of the succeeding month.

A table showing the beginning- and end-of-month reservoir contents is included in attachment 5.

Change in Aquifer Storage (ΔS_a)

A value of zero was used for all reaches of the river for calendar year 1995 (as was done in Owen-Joyce and Raymond [1996]). Currently, no network of wells exists that would give consistent current water level data throughout the study area. A method for measuring changes in groundwater elevation in the Lower Colorado River Valley and the infrastructure for performing such measurements will be studied in the future.

Off-Stream Outflow[8] (Q_{rf})

Off-stream outflow, as used in the LCRAS water balance equation, refers to water that was diverted in one reach and returned to the river in a downstream reach, or that flows into Mexico. There was only one off-stream outflow considered in this water balance. This was the flow at the SIB near San Luis, where the water in the East and West Main Canals, the Main Drain, and the water pumped by the Protective and Regulatory Pumping Unit combine and flow into Mexico.

[8] This outflow was suggested for use in the revised water balance equation in Jensen (1994); it was originally named $Q_{\text{return flow}}$. The nomenclature has been changed for this report to avoid confusion with return flow as defined in the Supreme Court Decree.

These flow measurements were added to those at the Northerly International Boundary to form the downstream flow (Q_{ds}) for the Imperial Dam to Morelos Dam reach. The flow was measured and reported by the IBWC, and its values were presented in the flow data table found in attachment 3. The underflow to Mexico across SIB and the limitrophe section of the Colorado River will also be included in the Q_{ds} term for the Imperial Dam to Morelos Dam reach in future applications of LCRAS.

Residual (Q_{res})

The summation of all inflows and outflows in a water balance results in a residual. If inflows to a reach exceed outflows, the residual will be positive. If outflows exceed inflows, the residual will be negative. In the perfect mathematical modeling of a system, where all factors were accounted for and all measurements were absolutely accurate, the residual would be zero. In the real world conditions within which LCRAS operates, the residual cannot reasonably be expected to be zero. The residual values for each reach, along with the inflows, outflows, and water uses of the water balance, are displayed in table 3.

All residuals were less than 5 percent of the flow entering the reach, which Reclamation considers to be excellent for a large river system such as the Lower Colorado River. It was assumed that this was near the level of measurement accuracy for the river itself.

The residual of the LCRAS water balance was considered to be the summation of the errors of measurement and approximation associated with each inflow, outflow, and water use. The final value of crop, phreatophyte, and domestic consumptive use was realized when the residual was distributed to each of these terms. The undistributed values were known as

Table 3.—Water balance summary
(unit: acre-feet per year)

Water balance inflows, outflows, and water uses	Reach				
	Hoover Dam to Davis Dam	Davis Dam to Parker Dam	Parker Dam to Imperial Dam	Imperial Dam to Morelos Dam	Hoover Dam to Morelos Dam
Residual	125,815	-376,267	-180,481	106,064	-324,869
Residual as a percentage of the flow entering the reach	1.47	-4.52	-2.69	1.89	-3.80
Flow at the upstream boundary (Q_{us})	8,544,900	8,316,700	6,718,700	5,602,945	
Tributary inflow (T)	6,481	200,471	33,750	530,803	
Exported flow (Q_{ex})	0	1,779,635	0	3,776,675	
Evaporation (E)	123,307	106,973	75,416	8,570	
Domestic consumptive use (C_{ud})	831	43,208	7,856	20,055	
Crop evapotranspiration (ET_{crop})	0	88,399	864,681	433,234	
Phreatophyte evapotranspiration (ET_{pht})	2,928	180,723	388,342	76,820	
Change in reservoir storage (ΔS_r)	-18,200	-24,200	-6,309	0	
Change in aquifer storage (ΔS_a)	0	0	0	0	
Flow at the downstream boundary (Q_{ds})	8,316,700	6,718,700	5,602,945	1,712,330	

undistributed annual values (UAV); once the residual has been distributed, the revised values were termed distributed annual values (DAV). Distributed annual values of ET for vegetation and water use for domestic diverters were the values of consumptive use. Numerous proposals have been tendered as a method for distributing the residual. The distribution method that appears to have the best statistical validity overall when applied to a wide variety of conditions, distributes a portion of the residual based on the magnitude and accuracy of each inflow, outflow, and water use. This was done mathematically by distributing the residual based upon the product of the confidence interval and magnitude of each inflow, outflow, and water use (SEE × magnitude of measurement or estimate).

The water balance closure was evaluated for each reach by comparing the value of the residual to the measurement error of the upstream inflow to the reach. Distributing the residual was considered optional if it was about equal to or less than the measurement error of the flow entering the reach. The residual was distributed in all reaches for this LCRAS Demonstration of Technology to present the effect of the distribution, even though the residual was within the assumed measurement error of the upstream gauge in all reaches.

The USGS performed an evaluation of the measuring devices in use on the Colorado River and reported the results on pages 11-19 of Owen-Joyce and Raymond (1996). The devices were listed as E for excellent, G for good, and F for fair, meaning that 95 percent of the daily discharge measurements were within 5, 10, or 15 percent of the true value, respectively. Reclamation performed an evaluation of the AVMs at Hoover, Davis, and Parker Dams. The results were documented in Bureau of Reclamation (1995b).

The SEE for the water measurement from the closed conduit AVMs in use at Hoover Dam was approximately 2 percent. The SEE for each of the streamflow gauging stations below Davis and Parker Dams was approximately 5 percent. The SEE for streamflow gauging stations at Imperial Dam was approximately 5 percent[9] (the measurement at Imperial Dam was the sum of several measurements). As shown in table 3, the residual of each reach was less than the SEE of flow at the upstream boundary.

Sample Calculation

This sample calculation used data for the Colorado River Indian Reservation in Arizona (CRIR, AZ) as an example for calculating consumptive use by vegetation. This calculation was a four-step process.

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[9] The SEE used for the flow at Imperial Dam in the Parker Dam to Imperial Dam reach was 5 percent. The SEE used for the flow below Imperial Dam in the Imperial Dam to Morelos Dam reach was 3 percent. This inconsistency will be corrected in future applications of LCRAS.

First, the acreage of each crop and phreatophyte class was calculated using remotely sensed images and a GIS data base.

Second, the ET for each crop and phreatophyte class was calculated using reference ET, vegetation coefficients, and acreages from above. The ET for all vegetation classes were summed to provide the total crop and phreatophyte ET for the diverter.

Third, all inflows, outflows, and water uses for the reach within which the diverter resides were assembled and entered into the water balance equation, and the residual was calculated.

Fourth, the residual was distributed to the inflows, outflows, and water uses within the reach proportional to the product of their confidence interval and magnitude.

The process used to calculate the consumptive use of crops is presented below.

The tables, sheets, and values referred to in this sample calculation appear in appendix I, Part 1: Evapotranspiration Rate Calculations, and appendix I, Part 2: Water Balance and Consumptive Use Calculations. Since the tables in appendix I have identical formats, the reader can use this sample calculation as a basis for finding the calculations for any diverter. Readers will find that using the values listed may not yield exactly the same results as displayed on the tables. The values displayed on the tables in appendix I have been rounded.[10]

This sample calculation begins with the calculation of an ET rate and leads the reader through the calculation of the water balance and distribution of the residual.

[10] The crop acreage data used for this example and the LCRAS Run were calculated using Reclamation's remote sensing process; they were not provided by the districts in crop reports.

This sample calculation will proceed using alfalfa_1a as the sample crop, referred to hereafter simply as alfalfa. The daily ET rate for alfalfa at CRIR, AZ was calculated by multiplying the daily reference ET (ET_0), from the Parker AZMET station,[11] times the daily crop coefficient (K_c) for alfalfa; then subtracting the effective precipitation. The daily ET_0 values from the Parker AZMET station, for the month of January, are listed in Part 1, Sheet D, in the column under the January heading. Note that the ET_0 value for January 1 is 0.067 inch. The K_c for alfalfa on January 1 is 1.200 (listed on page 2 of 2, Sheet E). Since there was no rain that day, the product of the ET_0 and K_c values (0.08) is the ET rate, in inches, for alfalfa on January 1.

Let us look at January 3 for an example of an ET rate calculation when there was precipitation. The Parker AZMET station recorded 0.12 inch of precipitation on January 3. This value can be found in Part 1 on Sheet B in the column under the January heading. The effective precipitation (the portion of the precipitation that contributes to crop ET requirement) was the product of an effective precipitation coefficient and the amount of precipitation in inches. The effective precipitation coefficient for January was 0.4, which yields an effective precipitation of 0.05 inch (0.4 × 0.12). These values can be found on Part 1, Sheet C, in the column under the January heading.

Then we calculated the ET rate[12] as ($ET_0 \times K_c$) - effective precipitation. With ET_0 equal to 0.00 on January 3rd, K_c for alfalfa equal to 1.20, and effective precipitation equal to 0.05, the ET rate for January 3 was -0.05 inch (a negative ET rate means that the effective precipitation resulted in a net increase in soil moisture). Moderate rainfall events during the winter will frequently provide more moisture than the crop ET requirements during this time of the year.

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[11] The Parker AZMET station is the micrometeorological station closest to the CRIR in Arizona.

[12] The ET rate displayed in the tables of appendix I, Part 1 includes the effects of precipitation. These tables do not display an ET value that was not corrected for effective precipitation.

The ET rate for alfalfa was calculated for each day of January and summed to derive the monthly alfalfa ET rate for January (0.51 inch). This process was repeated for each month of the year. The daily values for each month are displayed in Part 1, Sheet E.

The monthly alfalfa ET for CRIR, AZ was obtained by multiplying the monthly ET rate for alfalfa by the number of acres in alfalfa within CRIR, AZ for each month. The crop acreage for CRIR, AZ is listed on page 2 of 3, Sheet Q.

To calculate the January ET for alfalfa, find the January ET rate for alfalfa (0.51 inch) and the acreage of alfalfa (45,222 acres) on pages 3 of 3 and 2 of 3, Sheet Q, respectively. Multiply these values and divide the product by 12 to produce the alfalfa ET (1,938 acre-ft) (shown on page 1 of 3, Sheet Q).

The equation for the calculation described above looks like this:

$$ET_{alfalfa} = \sum_m [(ET_0 \times K_{alfalfa}) - \text{Effective PPT}]\, AC_{alfalfa}$$

Where:

$ET_{alfalfa}$	=	The total monthly or annual evapotranspiration by alfalfa for CRIR, AZ.
$\sum_m$	=	Summation for the month or year.
ET_0	=	Daily reference ET value calculated by the Parker AZMET station.
$K_{alfalfa}$	=	Daily crop coefficient for alfalfa.
$AC_{alfalfa}$	=	Acreage of alfalfa grown at CRIR, AZ.
Effective PPT	=	Effective precipitation.

The process was repeated for all other crop and phreatophyte classes (except that effective precipitation was not subtracted from phreatophyte ET). The annual crop and phreatophyte ET for CRIR, AZ was calculated by summing the monthly ET for each crop and phreatophyte class.

The sample calculation, as described thus far, has provided the crop and phreatophyte ET (ET_{crop} and ET_{pht}) for CRIR, AZ. The same process was repeated for each diverter within the Parker to Imperial Dam reach to obtain their crop and phreatophyte ET.

The water balance was calculated for the Parker to Imperial Dam reach to produce the residual, a portion of which was distributed to the diverter's crop and phreatophyte ET, to yield the diverter's crop and phreatophyte consumptive use.

The water balance was performed in Part 2, Sheet A, using the water balance equation described previously.

Monthly values for each term were shown on tables in Part 2, and the monthly totals were carried over to Sheet B, the water balance sheet. For simplicity, this sample calculation will discuss the annual totals only.

The major inflow to the Parker Dam to Imperial Dam reach was provided by the mainstream of the Colorado River, measured as it entered the reach through Parker Dam (Q_{us}). This value, 6,718,700 acre-ft, is found in the total column of Sheet C.

The unmeasured tributary inflow values were provided by the USGS on page 46 of Owen-Joyce and Raymond (1996). There were no measured tributary inflows in the Parker Dam to Imperial Dam reach. The values are presented and summed on Sheet C. The total tributary inflow was 33,750 acre-ft.

Flow at the downstream boundary of this reach was the sum of four flows measured at and below Imperial Dam, shown on Sheet H. They were Station 60 on the All-American Canal, Station 30 on the Gila Gravity Main Canal, the inflow to Mittry Lake, and the Imperial Dam sluiceway. The annual flows were 4,569,600 acre-ft, 785,538 acre-ft, 10,407 acre-ft, and 237,400 acre-ft, respectively. The sum of these outflows resulted in the downstream outflow (flow at Imperial Dam). The value was 5,602,945 acre-ft.

There were no exports from the system in this reach. Therefore, the value used for export in the water balance was zero.

Evaporation was calculated by multiplying the average open water surface area, in acres, by the monthly evaporation rate minus precipitation. The evaporation rate was calculated as the monthly sum of daily ET_0, in inches, times a monthly evaporation coefficient. In equation form, it looks like this:

$$E = Area \times [(K_e \times ET_0) - PPT] \div 12$$

Where:

E	=	Open water surface evaporation between Parker and Imperial Dams (acre-feet).
Area	=	The total area of open water in this reach (acres).
PPT	=	The precipitation measured at the Parker AZMET station (inches).
$(K_e \times ET_0)$	=	The evaporation rate (inches):

Where:

K_e = The monthly evaporation coefficient, specific to the Parker Dam to Imperial Dam reach of the river.

ET_0 = The monthly reference ET, in inches, provided by the Parker AZMET station.

The January evaporation rate was derived by multiplying the monthly ET_0 (1.93 inches) times the evaporation coefficient (0.52) to yield a monthly evaporation rate of 1.00 inch. Precipitation in January from the Parker AZMET station was 2.48 inches. Subtract this from the evaporation rate to yield -1.48 inches. Divide by 12 to convert to -0.123 feet of evaporation. The area of open water in river section 1 was 4,505 acres. The product of open water surface area times the evaporation yields -554 acre-ft of evaporation from section 1 of the Parker to Imperial Dam reach of the river. The values noted above are presented in Part 2, Sheet H, for the month of January. The sum of open water surface evaporation for January in the Parker to Imperial reach totals -231 acre-ft, representing a net gain to the system (precipitation was greater than evaporation) and is presented in Part 2, Sheet B.

Domestic uses without measured diversions were estimated using the population given in the most recent census and a per capita use rate provided by each State.[13] For example, Poston has a population of approximately 480. The per capita use rate for that area was given as 0.03 acre-foot per person. The product of these values was 14 acre-ft of use for Poston. The domestic uses were calculated on Part 2, Sheet E. Domestic uses are described more fully in the section entitled "Domestic Use (C_{ud})."

Senator Wash is the only reservoir in the Parker Dam to Imperial Dam reach. The change in reservoir storage was calculated (on Sheet D) as the difference

[13] Per capita consumptive use rates were provided to USGS and are published in Owen-Joyce and Raymond (1996).

in water held in Senator Wash between the beginning and end of each month. The beginning-of-month value was the storage measured on the last day of the previous month. In January, the beginning-of-month storage (as measured December 31, 1994) was 8,599 acre-ft, the end-of-month storage (January 31, 1995) was 5,174 acre-ft. The difference was -3,425 acre-ft.

To this point, this sample calculation has described how the totals for each inflow, outflow, and water use in the water balance were calculated. Once the water balance equation has been used to calculate the residual and it has been distributed, the inflow, outflow, and water use values were termed DAVs. In the cases of crop, phreatophyte, and domestic water use, consumptive use was the DAV.

The water balance was calculated in Sheet A, yielding a residual of 180,480 acre-ft for the Parker Dam to Imperial Dam reach. The residual was distributed to each inflow, outflow, and water use in proportion to the magnitude of its UAV times its SEE (termed the Confidence Interval). Using the crop ET as an example, the distributed annual value was calculated as shown below:[14]

$$DAV_{ETcrop} = UAV_{ETcrop} + [\,(CI_{ETcrop} \div TCI) \times Q_{res}\,]$$

Where:

DAV_{ETcrop} = The distributed annual value of crop ET for the reach.

UAV_{ETcrop} = The undistributed annual value of crop ET.

CI_{ETcrop} = The confidence interval for crop ET.

[14] The DAV was added to outflows and subtracted from inflows. ET_{crop} was an outflow in the water balance.

TCI = The sum of all confidence intervals.

Q_{res} = The residual.

The UAV was 864,681 acre-ft, and the SEE was 10 percent, yielding a confidence interval of 86,468. The TCI was 636,549, and the residual was -180,480 acre-ft. Substituting these values into the equation results in:

$$DAV_{ETcrop} = 864{,}681 + [(86{,}468 \div 636{,}549) \times (-180{,}480)]$$

$$DAV_{ETcrop} = 840{,}164.8 \text{ acre-ft}$$

The residual was distributed to the crop ET of each diverter based on that diverter's proportion of the total UAV of crop ET. Continuing the sample calculation for CRIR, AZ, the equation for distribution is as follows:

$$DDET_{crop\ CRIT} = UAV_{crop\ CRIT} \div (UAV_{cropT} \div DAV_{cropT})$$

Where:

$DDET_{crop\ CRIT}$ = The distributed annual value of crop ET for CRIR, AZ.

$UAV_{crop\ CRIT}$ = The undistributed annual value for crop ET in CRIR, AZ.

UAV_{cropT} = The total of the undistributed annual crop ET value for all diverters.

DAV_{cropT} = The distributed annual value crop ET for all diverters, calculated as DAV_{crop} above.

Substituting values into the above equation yields the proportion of residual distributed to crop ET in CRIR, AZ:

$$DDET_{crop\ CRIT} = 423{,}794 \text{ acre-ft} \div (864{,}681 \text{ acre-ft} \div 840{,}165 \text{ acre-ft})$$

$$DDET_{crop\ CRIT} = 411{,}778 \text{ acre-ft}$$ [15]

The distributed value for phreatophytes for each diverter was calculated in the same fashion using the UAV and DAV for phreatophytes. The distributed annual phreatophyte ET for CRIR, AZ was 156,198 acre-ft. These values were considered to be the consumptive use by crops and phreatophytes at CRIR, AZ. The distributed values of domestic use (domestic consumptive use) were calculated in a similar manner.

An explanation of how the water balance calculations were performed is found in the beginning of Part 2 and is displayed on the tables of Part 2.

Results

The results of the LCRAS Demonstration of Technology for Calendar Year 1995 are presented in the numerous tables and charts found below and in the attachments. Table 4 presents a summary of consumptive use prepared by LCRAS and by the Decree Accounting method.

The results in table 4 show that the water use values calculated by LCRAS, and those reported by the Decree Accounting Report, compare favorably for some diverters, while others do not compare quite as well.

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[15] Differences between the results shown in the example and those displayed in appendix I are due to rounding.

Table 4.—Consumptive use
(Unit: flows in acre-feet per year)

LCRAS			Decree Accounting	
Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
		Nevada		
Uses above Hoover Dam (from 1995 Decree Accounting Report)		199,407	199,407	Uses above Hoover Dam
Uses below Hoover Dam	21,792	19,048	18,032	Uses below Hoover Dam
			1,721	Unmeasured return flow credit
Nevada Total The difference in the values under the headings, "Decree Accounting Consumptive Use" and "LCRAS Crop and Domestic Consumptive Use" is double accounting for Big Bend Water District wastewater irrigation (1,384 acre-ft), distributed residual (-368 acre-ft), and Decree Accounting unmeasured return flow (1,721 acre-ft). 218,455 - 1,384 - (-368) - 1,721 = 215,718	21,792	218,455	215,718	Nevada Total
		California.		
			4,925,483	Sum of individual diverters
			88,679	Unmeasured return flow credit
California Total	200,207	4,878,487	4,836,804	California Total
Arizona				
Subtotal (Below Hoover Dam, less Wellton-Mohawk IDD and underflow to Mexico)	409,498	1,709,663	2,033,492	Sum of individual diverters below Hoover Dam, less Wellton-Mohawk IDD and returns from South Gila wells
Arizona uses above Hoover Dam (from the 1995 Decree Accounting Report)		178	178	Arizona uses above Hoover Dam
Wellton-Mohawk IDD (from the 1995 Decree Accounting Report)		247,409	247,409	Wellton-Mohawk IDD
Underflow to Mexico.[1] (21,000 acre-ft across the Limitrophe section + 67,000 acre-ft at SIB.		88,000	59,727	Pumped from South Gila wells (DPOCs): returns
			192,537	Unmeasured return flow credit
Arizona Total	409,498	2,045,250	2,028,815	Arizona Total
		Lower Basin Total		
Total Lower Basin Use	631,497	7,142,192	7,081,337	Total Lower Basin Use

[1] Estimates made by the Yuma Area Office, Bureau of Reclamation.

Some of the differences can be attributed to consumptive uses by individual diverters, which were reported by LCRAS but not in the Decree Accounting Report. There were also several places where the consumptive use by some fields was reported by LCRAS as being charged to the State in which they are located and not to the adjacent irrigation district because these fields are not within known irrigation district boundaries. Figure 1 presents data for the States of California and Arizona and shows a good comparison between the total consumptive uses of crops and phreatophytes produced by LCRAS and the total consumptive uses reported by the Decree Accounting Report. These differences are also displayed and discussed in the bar chart section of attachment 6.

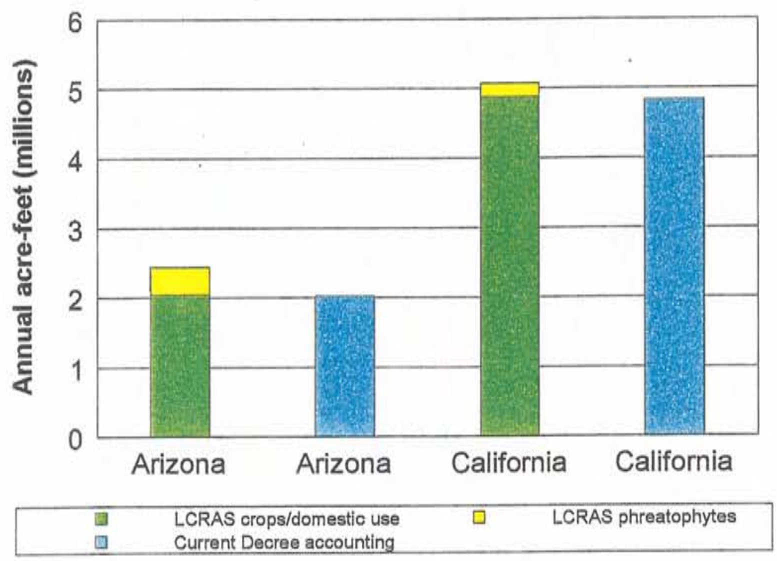
The table and bar charts found in attachment 6 present the results of the LCRAS Demonstration of Technology for Calendar Year 1995 and also present a comparison between the LCRAS results and the values published in the Decree Accounting Report. There are several notes on table A1 and the bar charts that assist in interpreting the results.

The differences in attachment 6 between consumptive uses reported by the Decree Accounting Report and those developed by LCRAS on a district-by-district basis have given rise to two outstanding questions:

1. Are the diverter boundaries used by LCRAS correct? Have the diverter boundaries used by LCRAS changed, or has water spreading been identified?

2. What portion, if any, of the consumptive use from phreatophytes within the boundary of a diverter should be considered part of the diverter's consumptive use?

The resolution of the two questions, as well as other questions and concerns learned during this LCRAS Demonstration of Technology, is addressed in the following chapter.



Decree Accounting values include estimates of unmeasured return flow

Figure 1.—State totals, Arizona and California (consumptive use for calendar year 1995).

Chapter 3

LCRAS Improvements

Improvements continue to be made to LCRAS, and that effort will continue into the future.

Diverter Boundaries

Reclamation has begun consultations with irrigation districts and other diverters to review and resolve any discrepancies in diverter boundaries that may exist between Reclamation's GIS coverage, used in 1995, and the most recently revised diverter boundaries. Meetings with diverters have taken place, and information gained through these meetings has been used to update the diverter boundaries used by LCRAS. The updated diverter boundaries will be used in future applications of LCRAS. Such information gathering will be an ongoing effort.

Phreatophyte Consumptive Use

What portion, if any, of the consumptive use from phreatophytes within the boundary of an agricultural diverter, a wildlife refuge, a State park, a domestic diverter, or other reservation of land should be added to the consumptive use calculated for the diverter?

Reclamation proposes the following outline for a solution to this question:

1. Water use from phreatophytes not located within any diverter boundary should be considered system loss,

2. Water use from phreatophytes growing within a diverter boundary, that are drawing water from a water table elevation that is equal to or less than the elevation of the Colorado River adjacent to the phreatophytes, should be considered system loss,

3. Water use from phreatophytes growing within a diverter boundary should be considered part of the consumptive use of the diverter if they are:

   a. Drawing water from a water table elevation that is above the elevation of the Colorado River adjacent to the phreatophytes, and

   b. Downgradient from the location of the diverter's primary use of the diverted water.

Reclamation will seek input from State water agencies and others knowledgeable in the Law of the River to derive a final solution to this question.

Remote Sensing, Image Processing, and Geographic Information System Analysis

LCRAS currently uses image data from the Landsat V satellite. This satellite is well beyond its service life, and its replacement is not scheduled to be launched until sometime in 1998. Reclamation is currently investigating other data sources to provide backup and/or replacement for Landsat V.

Reclamation will evaluate the potential for multispectral and multitemporal composite analysis to provide more accurate and, possibly, more timely annual crop summaries. Reclamation will also evaluate the potential for multidate open water surface classification to improve open water surface area estimates.

Change detection procedures are being developed for mapping phreatophyte areas. These procedures will eliminate the need to perform image classification each year to develop the phreatophyte acreages.

Reclamation will reinstate investigations into estimating ET using surrogate crop coefficients derived from a Normalized Difference Vegetation Index. Application of this technique would provide a means to check the ET estimates developed using single-date image classification.

River Gauging

A penstock modeling study at Hoover, Davis, and Parker Dams was performed by Reclamation to determine if:

- Closed conduit AVM installations conform to American National Standards Institute/American Society of Mechanical Engineers installation standards

- AVM installations were performing to manufacturer's specified accuracies of ±0.5 percent of true discharge

The resulting report (*Laboratory and Field Evaluations of Acoustic Velocity Meters at Davis and Parker Dams*) (Bureau of Reclamation, 1995b) shows that the installations in Davis and Parker Dams do not fully meet the installation standards due partially to the transducer orientation and their proximity to bends in the penstocks. The modeling study indicates that this has an adverse effect on the accuracy of the AVMs, which could be partially corrected with the installation of a second AVM path to create a crossflow path system.

Reclamation is reviewing how flow below the dams is calculated. The review includes a comparison of flow measurements taken by a Broad Band Acoustic

Doppler Current Profiler (BB ADCP) to those taken by the closed conduit AVM, turbine curve, and USGS stream-gauging method currently in progress. The BB ADCP is being used to rate the open-channel AVMs.

Incidental Use Factor

The ET figures used for calendar year 1995 did not apply an incidental use factor to account for consumptive uses of water by an irrigation district in addition to the use of water by the crops themselves. Such uses include evaporation from the canals and laterals, phreatophytes growing along the canals and fields, and other uses of the water outside the border of the field. An incidental use factor is currently envisioned as a fixed percentage added to the ET calculated for the crops alone. Reclamation will develop a process to calculate a fair, accurate, and equitable incidental use factor for each agricultural diverter along the mainstream of the Lower Colorado River.

Canal Losses

The losses from the All-American Canal, between Imperial Dam and Pilot Knob, and the Gila Gravity Main Canal are proportioned to the diverters that receive water from these canals by the current Decree Accounting method. This loss distribution is not included in the 1995 LCRAS Demonstration of Technology. This loss distribution will be included in LCRAS by the time LCRAS is used as the official Decree Accounting tool. The losses from the Gila Gravity main canal totaled 3,551 acre-feet (1,397 acre-feet of evaporation and 2,154 acre-feet of phreatophyte use), and the losses from the All-American Canal totaled about 5,800 acre-feet in 1995.

Domestic Use

The domestic use values presented in this report are mostly diversions from the Decree Accounting Report. (A complete description and listing of the domestic use values are included in attachment 5 in this report.) The use of diversions instead of consumptive uses overestimates domestic use by a factor of about 2.

Domestic uses must eventually be developed as consumptive use values. The total volume of water diverted by domestic users is small (about 72,000 acre-ft in 1995). Reclamation will provide estimates of consumptive use for domestic diverters currently reported as diversions in future applications of LCRAS.

Upon review of this Demonstration of Technology, Reclamation has discovered that some small domestic diverters were placed in the wrong reach and that some wells thought to be used for an industrial use (Huerta Packing) are probably used for irrigation. These errors will be corrected in subsequent applications of LCRAS.

Open Water Surface Evaporation and Precipitation

Evaporation calculations could be improved by the collection of more directly applicable meteorological information along the river. LCRAS currently uses meteorological data collected from the six AZMET and CIMIS stations noted in the section titled "Evapotranspiration" to calculate evaporation. Not all of the micrometeorology stations are close enough to the river to provide weather data fully representative of these conditions. Improved evaporation estimates require air and water temperature, relative humidity, and windspeed measurements representative of conditions over water. To provide the best possible evaporation estimates, Reclamation will investigate locating additional stations over water.

In the desert Southwest, precipitation generally occurs as rainfall events of high intensity, short duration, and local extent. As noted in the "Precipitation (P)" section above, rainfall occurring within the basin, yet outside of diverter boundaries, is currently accounted for in the water balance as unmeasured tributary inflow, which was estimated in Owen-Joyce (1987), using long-term average rainfall data.

Also, rainfall occurring over farmland and open water is currently measured only by the six CIMIS and AZMET stations. An increased density of precipitation gauges could potentially yield a more representative rainfall estimate. There are numerous other agencies, such as the National Park Service and National Weather Service, that record precipitation. Incorporating their data into LCRAS could potentially improve ET calculations. Reclamation will assess the appropriateness of incorporating these data into the LCRAS program.

Changes in Groundwater Storage

Currently, LCRAS has no mechanism to estimate the changes in aquifer storage. Reclamation and interested parties should investigate potential methods to acquire this information in the future. This item is currently assigned a low priority.

Modeling Program

The calculations required by LCRAS were performed by a multipage spreadsheet for calendar year 1995. A description of this spreadsheet can be found in the introduction pages to appendix I. Reclamation will investigate the potential application of the River Basin Modeling System, a specialized form of hydrologic modeling, to perform the calculations required by LCRAS and archive the required data. This system of modeling is currently being applied to the Colorado River Simulation System and the 24-Month Study, which are used for Colorado River reservoir operations and water supply studies.

Chapter 4

Conclusion and Future Activities

The goal of the LCRAS program is to improve Decree Accounting, using the technologies developed by LCRAS. Reclamation is currently developing a public involvement process that will allow interested parties an opportunity to learn more about the method and provide input to improve it. Reclamation is interested in working with the State water agencies, Federal agencies, tribes, and diverters to make the method as complete, consistent, and accurate as possible.

The accounting of water use in accordance with Article V of the Supreme Court Decree will proceed over the next few years as follows:

1. Reclamation will use the current Decree Accounting method in developing the official Decree Accounting Report until LCRAS is implemented.

2. Reclamation will calculate consumptive use using the LCRAS method in parallel with the current Decree Accounting method for calendar year 1996 and the next several years and compare the results of the two methods. The purpose of this exercise is to acquaint the users of the Decree Accounting Reports with LCRAS, as well as to examine any trends that may appear in the differences of the results provided by the two methods.

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Lower Colorado River Accounting System

Attachment 1

Colorado River History and Legal Framework

The Lower Colorado River is a critical part of the Southwest's environmental and economic structure. The Lower Colorado River and its tributaries have been extensively developed and used over the past 60 years, primarily to meet agricultural and domestic needs and to generate electric power. Urban dwellers in Las Vegas, Phoenix, Los Angeles, and San Diego also receive water from the Lower Colorado River.

Today, the waters of the Lower Colorado River are needed more than ever to meet the increasing needs of cities and suburbs, Native Americans, fish and wildlife, recreationists, and other interests. At the same time, the water needs of existing diverters must continue to be met.

The lower river is managed and operated under numerous compacts, Federal laws, court decisions and decrees, contracts, and regulatory guidelines and actions collectively known as the "Law of the River," comprised of five major components discussed below.

Colorado River Compact—The cornerstone of the "Law of the River," the Colorado River Compact (Compact) was negotiated by the seven Colorado River Basin States and the Federal Government in 1922. It defined the relationship between the Upper Basin States—where most of the river's water supply originates—and the Lower Basin States, where most of the water demands were developing. At the time, the Upper Basin States were concerned that plans for Hoover Dam and other water development projects in the Lower Basin would, under the Western water law doctrine of prior appropriation, deprive them of their ability to use the river's flows in the future.

The States could not agree on how the waters of the Colorado River Basin should be allocated among them, so the Compact simply divided the Colorado River Basin into an upper and a lower half and gave each basin the right to develop and use 7.5 million acre-feet of river water annually. This approach reserved water for future Upper Basin development and allowed planning and development in the Lower Basin to proceed.

Boulder Canyon Project Act of 1928—This act:

- Ratified the 1922 Compact
- Authorized the construction of Hoover Dam and related irrigation facilities in the Lower Basin
- Approved the development of an agreement among the Lower Basin States apportioning the Lower Basin's 7.5 million acre-feet among the States of Arizona (2.8 million acre-feet), California (4.4 million acre-feet), and Nevada (0.3 million acre-feet)
- Authorized and directed the Secretary of the Interior (Secretary) to function as the sole contracting authority for Colorado River water use in the Lower Basin

Mexican Water Treaty of 1944—Committed 1.5 million acre-feet of the river's annual flow to Mexico.

***Arizona* v. *California* Supreme Court Decision and Decree** —In 1963, the Supreme Court issued a decision settling a 25-year-old dispute between Arizona and California that stemmed from California's claim that Arizona's use of water from the Gila River, a Colorado River tributary, constituted use of its Colorado River apportionment, and that it had developed a historical use of some of Arizona's apportionment. The Supreme Court rejected California's arguments, ruling that Lower Basin States have a right to appropriate and use tributary flows before the tributary commingles with the Colorado River without such use being charged against the Lower Basin apportionments.

In 1964, the Supreme Court issued its decree. This decree enjoined the Secretary from delivering water outside the framework of apportionments defined by the law and mandated the preparation of annual reports documenting the uses of water in all three Lower Basin States.

1968 Colorado River Basin Project Act—This act authorized construction of a number of water development projects in both the Upper and Lower

Basins, including the Central Arizona Project. It also made the priority of the Central Arizona Project water supply subordinate to California's apportionment in times of shortage and directed the Secretary to prepare, in consultation with the Colorado River Basin States, long-range operating criteria for the Colorado River reservoir system.

Management is unique. The Secretary serves as the Lower Colorado River Watermaster. In the Lower Basin, the Secretary performs a role similar to that of a State engineer in administering water rights. Through the Bureau of Reclamation, the Secretary contracts for all water used in the Lower Basin, with the exception of certain Federal entitlements, and reports the use of water in a manner consistent with the law.

Attachment 2

History of Events That Led to the 1995 LCRAS Demonstration of Technology

Description

The objective of the Lower Colorado River Accounting System (LCRAS) program is to improve the Decree Accounting method. LCRAS fully addresses the Watermaster's role in determining consumptive use along the mainstream of the Lower Colorado River below Hoover Dam. LCRAS is unique in that it uses a water balance of the Lower Colorado River, as well as estimates of water use that are specific to individual diverters, to determine consumptive use.

Current Decree Accounting Reports use primarily measured diversions and measured return flows (where available) to determine consumptive use, recently augmented only by single year evapotranspiration estimates from a selection (not all) of the irrigation districts along the mainstream to estimate unmeasured returns.

History

A short history of events that led through the initial development of LCRAS and to the demonstration of the LCRAS method for calendar year 1995 is presented below:

- 1964 — Article V of the Supreme Court Decree in *Arizona* v. *California* mandated the Secretary of the Interior to prepare annual water use reports for the Lower Colorado River Basin.

- 1969 — The Lower Basin States requested that a method be developed to quantify unmeasured return flows. Three alternatives were identified:

1. Negotiate an agreement among the Lower Basin States.
2. Use a water balance.
3. Use a piezometer network.

- 1970 — The Task Force on Unmeasured Return Flow (Task Force) was established. The membership includes the Lower Basin States, the Bureau of Indian Affairs, the U.S. Geological Survey (USGS), and the Bureau of Reclamation (Reclamation).

The Task Force accepted a USGS proposal to quantify unmeasured return flows using a piezometer network.

- 1970-1983 — The piezometer network was installed, data were collected and analyzed, and reports were written. Unmeasured return flows were quantified by State, but not by diverter. The high flows of 1983 destroy much of the piezometer network.

- 1984 — The USGS proposed a cooperative project to the Task Force to develop a water-use accounting method utilizing a water balance and satellite imagery.

  The Task Force accepted the proposal, which was funded by Reclamation and called the Lower Colorado River Accounting System.

- 1986 — The Task Force chose not to repair the piezometer network damaged by floods in 1983 and to continue LCRAS.

- 1987 — The USGS published the first of three supporting reports for the LCRAS program - *Estimates of Average Annual Tributary Inflow to the Lower Colorado River, Hoover Dam to Mexico*, by Sandra Owen-Joyce, U.S. Geological Survey Water Resources Investigations Report 87-4078.

- 1988 — The USGS wrote the first LCRAS draft report. Initial results showed negative values of consumptive use between Davis and Parker Dams for calendar year 1984. The problem is thought to stem from inadequate river gauging and the unusually high flows in 1984 (the highest on record).

- 1989 — Reclamation accepted a USGS proposal to modify LCRAS to analyze the river as a single reach from Hoover Dam to Mexico. This modification mitigated the problem in the Davis Dam to Parker Dam reach.

- 1990 — The USGS completed a draft report documenting the single reach modification. Results were for calendar year 1984.

- 1991 — The USGS published the second supporting report for the LCRAS program, *Lower Colorado River Accounting System Computer Program and Documentation*, U.S. Geological Survey Open-File Report 91-179.

  The third USGS supporting report, documenting the procedures used to analyze satellite imagery, was not written. The specific procedures used were considered obsolete, and their reformulation was recommended.

- 1992 — Reclamation began to address improved open channel and closed conduit (penstock) gauging along the Lower Colorado River.

  Reclamation sought the assistance of a contractor to develop state-of-the-art remote sensing and Geographic Information System (GIS) procedures for the LCRAS program.

- 1994 — Reclamation awarded a contract to Pacific Meridian Resources (PMR) to develop state-of-the-art, remote sensing and GIS procedures for the LCRAS program.

  Reclamation contracted with Dr. Marvin Jensen to perform an assessment of the LCRAS method. Dr. Jensen recommended using an updated evapotranspiration technique and modifications to the water balance.

  Modifications to hardware and software for the closed conduit acoustic velocity meters installed in Hoover, Parker, and Davis Dam penstocks were completed.

The LCRAS team was formed and tasked with completing an evaluation of the LCRAS method of calculating consumptive use for irrigated agriculture along the Lower Colorado River mainstream for calendar year 1995.

- 1995 — The Technical Services Center in Denver published a report evaluating the accuracy and resolution of the acoustic velocity meters used in the penstocks at Davis and Parker Dams.

  The contract with PMR concluded successfully. Reclamation began to process remotely sensed data and build GIS products using methods and techniques developed jointly with PMR.

  The LCRAS team accepted Dr. Jensen's proposed modifications and proceeded to implement them for the 1995 evaluation.

- 1996 — The USGS published their LCRAS report (using 1984 data), *An Accounting System for Water and Consumptive Use Along the Colorado River, Hoover Dam to Mexico*, United States Geological Survey Water-Supply Paper 2407, and distributed it to the members of the Task Force.

  The LCRAS team completed the evaluation of the LCRAS method using Calendar Year 1995 data and began to identify and address remaining technical and policy issues.

Attachment 3

Measured and Unmeasured Flows for Each Reach

Measured Flows

Hoover Dam to Davis Dam Reach	Flow in acre-feet	Station number
Colorado River below Hoover Dam	8,544,900	9,421,500
Change in storage Lake Mohave !	-18,200	9,422,500
Davis Dam to Parker Dam Reach		
Colorado River below Davis Dam	8,316,700	9,423,000
Colorado River Aqueduct $	994,373	9,424,150
Bill Williams River below Alamo Dam	194,493	9,426,000
Central Arizona Project Canal $	785,262	9,426,650
Change in storage Lake Havasu !	-24,200	9,427,500
Parker Dam to Imperial Dam Reach		
Colorado River below Parker Dam	6,718,700	9,427,520
Change in storage Senator Wash !	-6,309*	
Colorado River above Imperial Dam	5,569,100	9,429,490
Imperial Dam to Morelos Dam Reach		
Diversion to Mittry Lake	10,407	9,522,400
All-American Canal	4,569,600	9,523,000
All-American Canal below Pilot Knob	3,391,440	9,527,500
Gila Gravity Main Canal **	785,537	9,522,500
Wellton-Mohawk Canal **	385,235	9,522,700
Colorado River below Imperial Dam	237,400	9,429,500
Gila River near Dome	527,803	9,520,500
Colorado River at NIB #	1,593,804	9,522,000
Eleven Mile wasteway #	766	9,525,000
Cooper wasteway #	1,241	9,531,850
Twenty-one Mile wasteway #	55	9,533,000
Main drain + 242 wells #	103,149	9,534,000
West Main Canal wasteway #	5,924	9,534,300
East Main Canal wasteway #	7,386	9,534,500

$ Provided by user, not U.S. Geological Survey
! U.S. Geological Survey - December 1994 minus December 1995
** Bureau of Reclamation open-channel acoustic velocity meter data
# Provided by International Boundary and Water Commission on a monthly basis
* Added to Colorado River above Imperial Dam table in the annual report
Remaining data is provided monthly and at end of year

Unmeasured Tributary Inflow Estimates

Hoover Dam to Davis Dam reach	Flow in acre-feet
Springs	3,080
Unmeasured runoff	2,100
Groundwater discharge	200
Eldorado Valley	1,100
Davis Dam to Parker Dam reach	
Unmeasured Runoff	
Davis Dam to Topock	12,000
Topock to Parker Dam	15,000
Whipple Mountains	1,150
Unmeasured Runoff From Tributary Streams	
Piute Wash	1,000
Sacramento Wash	2,500
Bill Williams River subarea[1]	4,000
Groundwater discharge	
Davis Dam to Topock	0
Topock to Parker Dam	880
Piute Valley	2,300
Sacramento Valley	10,000
Chemehuevi Valley	260
Bill Williams River subarea[1]	4,000
Parker Dam to Imperial Dam reach	
Unmeasured Runoff	
Whipple Mountains	1,150
Big Marie-Riverside Mountains	2,300
Palo Verde-Mule Mountains	1,200
Dome Rock-Trigo-Chocolate Mountains	16,200
Unmeasured Runoff in Tributary Streams	
Vidal Wash	1,300
Bouse Wash	4,800
Tyson Wash	2,600
McCoy Wash	800
Milpitas Wash	1,200
Groundwater Discharge	
Bouse Wash	1,200
Tyson Wash	350
Vidal Wash	250
Chuckwalla Valley	400
Imperial Dam to Morelos Dam reach	
Groundwater Discharge	
Gila River	1,000
Unmeasured runoff, Yuma area	2,000

[1] Not included in unmeasured inflows to the Lower Colorado River. These flows are used in the Bill Williams reach to estimate inflow to Lake Havasu from the Bill Williams River.

Reach/Diverter	Pumpage	Population	Use/ capita	State	Pop* use/capita	CU or Div	Data source	Notes	Domestic use after residual distribution
HOOVER TO DAVIS REACH	831								840
Cottonwood Cove	362	0	0.00	NV	0	Div	Decree		366
Katherine Landing	326	0	0.00	AZ	0	Div	Decree	Includes Willow Beach	330
Mohave County Parks	77	0	0.00	AZ	0	Div	Decree	Was diversion - Davis Dam	78
Lower Colorado Region Dams Project	66	0	0.00	AZ	0	Div	Decree		67
DAVIS TO PARKER REACH	43,208								42,299
Bullhead City	6,914	0	0.00	AZ	0	Div	Decree		6,769
Bermuda City	572	0	0.00	AZ	0	Div	B. Allan	See note	560
Big Bend Water District	4,367	0	0.00	NV	0	CU	Decree	Was Laughlin	4,275
Southern California Edison	13,281	0	0.00	NV	0	Div=CU	Decree	Was Mohave Steam Plant	13,002
Golden Shores	589	0	0.00	AZ	0	Div	Decree		577
Topock	0	900	0.03	AZ	27	CU	1990 census	Rand McNally atlas	28
Havasu Water Company of AZ	398	0	0.00	AZ	0	Div	Decree	Was Citizens Utilities	390
Needles	1,412	0	0.00	CA	0	CU	Decree		1,382
Havasu Water Company	58	0	0.00	CA	0	Div	Decree	Trailer park	57
Mohave Water Conservation District	564	0	0.00	AZ	0	Div	Decree	Was provider in addition to Bullhead City	552
Lake Havasu City	13,805	0	0.00	AZ	0	Div	Decree	Was Lake Havasu Irrigation and Drainage District	13,515
Brook Water	377	0	0.00	AZ	0	Div	Decree	Was Consolidated Water Utilities, Ltd.	369
Sportsman's Park	11	0	0.00	NV	0	Div	Decree	Was Clark County Parks and Recreation	11
Boy Scouts	10	0	0.00	NV	0	Div	Decree		10
Southern California Gas	59	0	0.00	CA	0	Div	Decree		58
BLM Permitees	764	0	0.00	AZ	0	Div	Decree		748

Reach/Diverter	Pumpage	Population	Use/capita	State	Pop* use/capita	CU or Div	Data source	Notes	Domestic use after residual distribution
PARKER TO IMPERIAL REACH	7,856								7,745
Picacho Development Corp.	115	0	0.00	CA	0	Div	Decree	Mine	113
Hillcrest Water Company	20	0	0.00	AZ	0	Div	Decree	Trailer park	20
Town of Parker	1,140	0	0.00	AZ	0	CU	Decree		1,124
Poston	0	480	0.03	AZ	14	CU	1990 census		14
Ehrenberg Improvement Association.	423	0	0.00	AZ	0	Div	Decree	City of Ehrenberg	417
Cibola	0	186	0.03	AZ	6	CU	1994 crop census	Population update from 1994 crop census; Cibola Valley Irrigation and Drainage District	6
Martinez Lake	0	10	0.03	AZ	0	CU		1984 data; needs population update	0
Earp	0	950	0.75	CA	713	CU	1990 census	Rand McNally atlas	703
Parker Dam/Govt Camp	237	0	0.00	CA	0	Div	Decree		234
Vidal	0	36	0.07	CA	3	CU		1984 data; needs population update	3
City of Blythe	0	8,428	0.29	CA	2,444	CU	1990 census		2,409
East Blythe	0	1,511	0.25	CA	378	CU	1990 census		373
Ripley	0	376	0.16	CA	60	CU	1990 census		59
Palo Verde	0	332	0.07	CA	23	CU		1984 data; needs population update	23
Big River	0	705	0.07	CA	49	CU	1990 census	Used CU factor from Palo Verde	48
Yucca Powerplant	323	0	0.00	AZ	0	Div	Decree		318
Huerta Packing 16S/22E	654	0	0	AZ	0	Div	Decree		645
Huerta Packing 16S/21E	914	0	0.00	AZ	0	Div	Decree		901
Cocopah Bend RV	340	0	0.00	AZ	0	Div	Decree		335

Reach/Diverter	Pumpage	Population	Use/ capita	State	Pop* use/capita	CU or Div	Data source	Notes	Domestic use after residual distribution
IMPERIAL TO MORELOS REACH	20,054								20,216
City of Yuma	14,902	0	0.00	AZ	0	CU	Decree		15,022
Yuma County	0	34,241	0.03	AZ	1,027	CU	1990 Census	Population estimated as Yuma County-(Somerton+Gadsden+San Luis+Yuma County+Fortuna Foothills)	1,035
Yuma Proving Ground	1,329	0	0.00	AZ	0	CU	Decree		1,340
Desert Lawn Memorial Park	112	0	0.00	AZ	0	Div	Decree	Listed as M&I user in contracts list	113
Bard	0	1,532	0.06	CA	92	CU		1984 data; needs population update	93
City of Winterhaven	129	0	0.00	CA	0	Div	Decree		130
Marine Corps Air Station	1,552	0	0.00	AZ	0	Div	Decree		1,565
Southern Pacific Company	48	0	0.00	AZ	0	Div	Decree	Wells used by gas company	48
Yuma Mesa Fruit Growers Association	12	0	0.00	AZ	0	Div	Decree		12
Yuma Union High School	150	0	0.00	AZ	0	Div	Decree		151
Yuma Area Office, Reclamation	402	0	0.00	AZ	0	CU	Decree		405
MORELOS TO SOUTHERLY INTERNATIONAL BOUNDARY									301
City of Somerton	0	5,282	0.03	AZ	158	CU	1990 Census		159
City of Gadsden	0	500	0.03	AZ	15	CU	1990 Census	Rand McNally atlas	15
City of San Luis	0	4,212	0.03	AZ	126	CU	1990 Census		127
Total domestic use (undistributed):	71,949							Total domestic use (distributed):	71,100

Notes: Div = diversion, CU = consumptive use, Decree = Decree Accounting Report for Calendar Year 1995, pop = population, cap = capita, cu = consumptive use.

Monthly storage values for Lakes Mohave and Havasu and Senator Wash, 1995

Reservoir		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Lake Mohave (acre-feet)	BOM	1,647,600	1,647,100	1,607,600	1,699,500	1,740,600	1,726,800	1,697,900	1,637,700	1,660,900	1,635,100	1,564,600	1,448,200	
	EOM	1,647,100	1,607,600	1,699,500	1,740,600	1,726,800	1,697,900	1,637,700	1,660,900	1,635,100	1,564,600	1,448,200	1,629,400	
	Change	-500	-39500	91,900	41,100	-13,800	-28,900	-60,200	23,200	-25,800	-70,500	-116,400	181,200	-18,200
Lake Havasu (acre-feet)	BOM	578,300	568,700	569,800	546,800	597,300	603,400	612,200	571,300	597,800	588,300	596,500	560,600	
	EOM	568,700	569,800	546,800	597,300	603,400	612,200	571,300	597,800	588,300	596,500	560,600	554,100	
	Change	-9,600	1,100	-23,000	50,500	6,100	8,800	-40,900	26,500	-9,500	8,200	-35,900	-6,500	-24,200
Senator Wash (acre-feet)	BOM	8,599	5,174	5,410	5,616	5,174	4,273	5,116	4,548	8,866	5,775	9,080	6,241	
	EOM	5,174	5,410	5,616	5,174	4,273	5,116	4,548	8,866	5,775	9,080	6,241	2,290	
	Change	-3,425	236	206	-442	-901	843	-568	4,318	-3,091	3,305	-2,839	-3,951	-6,309

This data was provided by the Bureau of Reclamation, Lower Colorado Dams Field Office, Operations Team.

Notes: Negative change values indicate that there was less water in the reservoir at the end of the month than at the beginning. Throughout 1995, there was a net decrease in the amount of water held in storage in these reservoirs.

BOM = beginning of month, EOM = end of month.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
Nevada				
Lake Mead National Recreation Area, NV (pht=1,555) + Cottonwood Cove (domestic use, after distribution of residual=366).	1,555	366	362	Lake Mead National Recreation Area, diversion from Lake Mohave (Cottonwood). Reported as a diversion.
Southern California Edison (domestic use, after distribution of residual).		13,002	13,281	Southern Nevada Water Authority (Southern California Edison), pumped from Sec 24 T32S R66E. Diversion = consumptive use.
Big Bend Water District (domestic use, after distribution of residual=4,275) + State of Nevada (pht=11,114; crops=1,384). **Note:** 1,384 acre-feet of crops should not be added to 4,367 acre-feet of domestic use. The crops are grown with waste water diverted for domestic use. This will be corrected in future applications of LCRAS.	11,114	5,659	4,367	Big Bend Water District Diversion Sec 12 T32S R66E. Reported as a consumptive use.
Sportsman's Park (domestic use, after distribution of residual).		11	12	Sportsman's Park. Reported as a diversion.
Boy Scouts (domestic use, after distribution of residual).		10	10	Boy Scouts of America. Reported as a diversion.
Ft. Mohave Indian Reservation, NV. Note: As long as crop use is 0, probably no need to report.	9,123	0		Not reported.
State of NV. **Note:** Crop and phreatophyte use included in Big Bend Water District. As long as crop use is 0, probably no need to report.	0	0		Not reported.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
Uses above Hoover Dam (from 1995 Decree Accounting).		199,407	199,407	Uses above Hoover Dam.
			1,721	Unmeasured return flow credit to Nevada.
Nevada Total **Note:** Difference is double accounting for Big Bend Water District, see above; and Decree Accounting Unmeasured Return Flow.	21,792	218,455	215,718	Nevada Total
California				
Fort Mohave Indian Reservation, CA.	5,025	16,544	21,364	Fort Mohave Indian Reservation, pumped from river and wells. Reported as a diversion.
Needles (domestic use, after distribution of residual).		1,382	1,412	City of Needles, 4 wells NW SW Sec 29 T9N R23E SBM. Reported as a consumptive use.
Colorado River Aqueduct (export).		994,373	994,373	Metropolitan Water District, diversion from Lake Havasu. Reported as a consumptive use.
Parker Dam/Govt. Camp (domestic use, after distribution of residual).		234	237	Parker Dam and Government Camp, diversion at Parker Dam. Reported as a diversion.
Colorado River Indian Reservation, CA (pht=40,799; crop=1,052) + North Lyn-De Farm, CA (portion not within Colorado River Indian Reservation boundary: pht=0; crop=1,777) + South Lyn-De Farm, CA (pht=0; crop=2,289) + Bernal Farm, CA (pht=1,284; crop=96) + Clark Farm, CA (pht=321; crop=0). **Note:** Some uncertainty exists concerning the southerly Colorado River Indian Reservation boundary in CA.	42,404	5,214	8,840	Colorado River Indian Reservation, pumped from 11 pumps and wells, 4 pumps from river. **Note:** Includes North Lyn-De Farm, CA; South Lyn-De Farm, CA; Bernal Farm, CA; and Clark Farm, CA. Some well locations near or in CRIR are questionable. Reported as a diversion.
Chemehuevi Indian Reservation, CA. **Note:** As long as crop use is 0, probably no need to report.	20	0		Not reported.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
Havasu National Wildlife Refuge, CA. **Note:** As long as crop use is 0, probably no need to report.	5,762	0		Not reported.
Park Moabi, CA. **Note:** As long as crop use is 0, probably no need to report.	179	0		Not reported.
Palo Verde Irrigation District, CA (pht=7,106; crop=386,360) + Palo Verde Irrigation District, AZ (pht=380; crop=208) + Cibola Island and Palo Verde Irrigation District, AZ (pht=19; crop=868) + Cibola Valley Irrigation and Drainage District in AZ on CA side of river; small use, probably less than 1,000 acre-feet, included in Cibola Irrigation District in AZ on AZ side of river + Blythe (city, domestic use=2,409) + East Blythe (domestic use=373) + Ripley (domestic use=59) + Palo Verde (domestic use=23). All domestic use values are after distribution of the residual. This result implies that about 28,794 acre-feet (less the use from Cibola) is probably unmeasured return flow.	7,505	390,300	426,599	Palo Verde Irrigation District, diversion from Palo Verde Dam. Reported as a consumptive use.
Cibola National Wildlife Refuge, CA. **Note:** There are no crops in the CNWR, CA. 190 acres of marsh (CU=583 acre-feet) were mistranscribed as safflower. No changes to image classification or ET calculation techniques are required. Corrected values would be pht=34,841; crop=0. This will be corrected in future applications of LCRAS.	34,258	583		Not reported.
Imperial National Wildlife Refuge, CA. **Note:** As long as crop use is 0, probably no need to report.	20,113	0		Not reported.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
Imperial National Wildlife Refuge and Yuma Proving Ground, CA. **Note:** As long as crop use is 0, probably no need to report.	138	0		Not reported.
Yuma Proving Ground, CA. **Note:** As long as crop use is 0, probably no need to report.	8,991	0		Not reported.
Ft. Yuma Indian Reservation and Yuma Proving Ground, CA .	902	262		Not reported.
Ft. Yuma Indian Reservation, Indian Unit, CA (pht=552; crop=19,295) + Ft. Yuma Indian Reservation, Bard Unit, CA (pht=920; crop=24,739) + Bard (domestic use, after distribution of residual= 93 acre-feet) + Fort Yuma Indian Reservation, CA (pht=14,090; crop=8,430).	15,562	52,557	55,368	Yuma Projects, Reservation Division Indian Unit, diversion at Imperial Dam (38,281 CU) + Yuma Projects, Reservation Division Bard Unit, diversion at Imperial Dam (52,260 CU) - Returns from Yuma Project, Reservation Division returns Sum Yuma Projects, Reservation Division use (40,373) + Ralf Land, 1 well, Sec 35 T15S R23E DDC=720 acre-feet + Living Earth Farm, 1 well, Sec 02 T16S R23E BBC=344 acre-feet + Berrymen, 1 well (C-16S-23E) 9CCA=992 acre-feet + Valdez, Mike, 1 well, Sec 22 T16S R23E BDD=864 acre-feet + Power, Pete, 1 well, Sec 14 T16S R23E CCB=2,040 acre-feet + Unknown, I.D., 1 well, 16S-22E 29DAD=240 acre-feet Indian and Bard units reported as consumptive use. Wells are reported as diversions.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
Winterhaven (domestic use, after distribution of residual).		130	129	City of Winterhaven, 1 well, SE SE NE Sec 27 T16S R22E SBM. Reported as a diversion.
Fort Yuma Indian Reservation and Picacho State Recreation Area, CA. **Note:** As long as crop use is 0, probably no need to report.	0	0		Not reported.
Picacho State Recreation Area, CA. **Note:** As long as crop use is 0, probably no need to report.	4,820	0		Not reported.
Picacho Development Corp., CA (domestic use, after distribution of residual).		113	115	Picacho Development Corp. Reported as a diversion.
All-American Canal below Pilot Knob (export, flow at gauge number 09527500).		3,391,440	3,397,279	Imperial Irrigation District, diversion at Imperial Dam (3,070,582) + Coachella Valley Water District, diversion at Imperial Dam (326,697). Reported as consumptive uses.
Earp (domestic use, after distribution of residual).		703		Not reported.
Vidal (domestic use, after distribution of residual).		3		Not reported.
Big River (domestic use, after distribution of residual).		48		Not reported.
Havasu Water Company (domestic use, after distribution of residual).		57	58	Havasu Water Company. Reported as a diversion.
Southern California Gas (domestic use, after distribution of residual).		58	59	Southern Cal Gas. Reported as a diversion.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS				**Decree Accounting**
State Of CA. Crop and phreatophyte consumptive uses not within known diverter boundaries.	54,528	24,486	19,650	Ida Cal, 3 wells, 11N/22W -31BAB=1,230 acre-feet, 11N/21E -36ADD=468 acre-feet, 11N/21E -36CDA=510 acre-feet. **Note:** These wells irrigate lands north of Fort Mohave ID in CA. Lye, C.L., 1 well, 1S/24E -16Gb=30 acre-feet Harp, P. (R. Harp), 1 well, (C-8-23) 13AAD=600 acre-feet Horizon Farms, 4 wells, (C-8-22) 6CDA=3,069 acre-feet, (C-8-22) 7BAB=950 acre-feet, (C-8-23) 1DCC=328 acre-feet, (C-8-23) 12CDB=332 acre-feet) Barett, 1 well (C-8-22) 6BBD=240 acre-feet) Living Earth Fm, 1 well, (C-8-23) 2ADC=19 acre-feet) Ed Weavers Farms, 4 wells (C-8-22) 6BCD=1,431 acre-feet, (C-8-22) 6CBA=1,546 acre-feet, (C-8-22) 1BBA=367 acre-feet, (C-8-23) 1BAD=168 acre-feet) Valdez, Mike, 2 wells, Sec T16S R23E 30ACC= 793 acre-feet, Sec T16S R23E 30ADD=2,730 acre-feet Power, O.L., 1 well, (C-8-23) 11DCA=1,156 acre-feet; Harp, Robert, 1 well, (C-8-23) 12DAC=960 acre-feet; Dees, Alex, 1 well, (C-8-23) 1DAC=2,491 acre-feet; Wilson Farms, 1 well, (C-8-23) 12BBA=35 acre-feet; Land, K. H., 1 well, (C-8-23) 2DDA=188 acre-feet. Note: The following wells have not been located, but are presumed to be within the State of CA polygons: Wetmore, Kenneth (1 well=5 acre-feet); Williams, Jerry (1 well=1 acre-feet); Lindeman, William H. and Hazel D., and Carney, Jerome D. (2 wells=1 acre-feet)
			88,679	Unmeasured return flow credit to California.
California Total	200,207	4,878,487	4,836,804	California Total

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
Arizona				
Lake Mead National Recreation Area, AZ (pht=1,795) + Katherine (domestic use, after distribution of residual). **Note:** Includes Willow Beach.	1,795	330	326	Lake Mead National Recreation Area, AZ, Diversions from Lake Mohave, (Katherine, Willow Beach). Reported as a diversion.
Lower Colorado Region Dams Project (domestic use, after distribution of residual).		67	66	Lower Colorado Region Dams Project (Davis Dam), Diversion at Davis Dam. Reported as a diversion.
Bullhead City (domestic use, after distribution of residual).		6,769	6,914	Bullhead City, Pumped from wells. Reported as a diversion.
Mohave County Parks (domestic use, after distribution of residual).		78	77	Diversion at Davis Dam, Mohave Co. Parks. Reported as a diversion.
Bermuda City (domestic use, after distribution of residual).		560		Not reported. Note: Check for pumpers.
Mohave Valley Irrigation and Drainage District, AZ (includes no municipal and industrial use).	32,903	24,748	38,398	Mohave Valley Irrigation and Drainage District, Pumped from wells. Reported as a diversion. **Note:** Includes 6,270 acre-feet of municipal and industrial use in 1995.
Fort Mohave Indian Reservation, AZ.	33,562	39,343	65,152	Fort Mohave Indian Reservation, 12 pumps and wells in flood plain. Reported as diversions.
Golden Shores (domestic use, after distribution of residual).		577	589	Golden Shores Water Conservation District, pumped from wells. Reported as a diversion.
Topock (domestic use, after distribution of residual).		26		Not reported.
Havasu Water Company, AZ (domestic use, after distribution of residual).		390	398	Havasu Water Co. of AZ (Citizens Utilities). Reported as a diversion.
Mohave Water Conservation District (Domestic use, after distribution of residual).		552	564	Mohave Water Conservation; pumped from wells. Reported as a diversion.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
Brook Water (domestic use, after distribution of residual).		369	377	Brook Water, (was Consolidated Water Utilities), pumped from river. Reported as a diversion.
Havasu National Wildlife Refuge, AZ. **Note:** Topock Marsh evaporation is estimated to be 12,889 acre-feet. This evaporation was assigned to system loss for this 1995 demonstration. Should evapotranspiration from Topock Marsh be included in estimates of consumptive use for the Havasu National Wildlife Refuge, AZ?	48,756	764	49,446	Havasu National Wildlife Refuge, Inlet-NW NE NW Sec 33 T9N RSSW, well 8N/23E-15Aa (Topock Marsh). Reported as a consumptive use.
Lake Havasu City (domestic use, after distribution of residual).		13,515	13,805	Lake Havasu City (Lake Havasu Irrigation and Drainage District; pumped from wells. Reported as diversions.
Central Arizona Project Canal (export).		785,262	785,262	Central Arizona Project; pumped from Lake Havasu. Reported as a diversion.
Town of Parker (domestic use, after distribution of residual).		1,124	1,140	Town of Parker; pumped from river, 1 well-NW NW NW Sec 7 T9N R19W G&SRM. Reported as a diversion.
Lake Havasu State Park, AZ. **Note:** May have missed a golf course.	3,424	0		Not reported.
Poston (domestic use, after distribution of residual).		14		Not reported.
Colorado River Indian Reservation, AZ.	156,198	411,779	425,102	Colorado River Indian Reservation; diversion at Headgate Rock Dam, 1 pump from river (B-04-22) 14BBD. Reported as a consumptive use.
Ehrenburg Improvement Association (domestic use, after distribution of residual).		417	423	Ehrenburg Improvement Association, 1 pump SW Sec 3 T3N R22W G&SRM. Reported as a diversion.
Cibola (domestic use, after distribution of residual).		6		Not reported.
Martinez Lake (domestic use, after distribution of residual. Use was less than 1 acre-foot).		0		Not reported.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
Ehrenberg Farm, AZ.	0	2,080	2,977	Jack Rayner (2 pumps; (B-04-22) 34 DCC(CDD)=2,781 acre-feet and (B-04-22)34 DCC(DCD)=196 acre-feet). Reported as a diversion.
Arkellan Farms, AZ. **Note:** Are there more Arkellan Farms pumps that are not reported?	2,554	2,446	2,208	George Arkellan (2 pumps; (B-03-22)16 DBD(DAD)=0 acre-feet and (B-03-22)16 DBD(DAD)=2,208 acre-feet). Reported as a diversion.
Bureau of Land Management permittees (domestic use, after distribution of residual).		748	764	Bureau of Land Management permittees. Reported as a diversion.
Hillcrest Water Company (domestic use, after distribution of residual).		20	20	Hillcrest Water Co. Reported as a diversion.
Yuma Proving Ground (domestic use, after distribution of residual). **Note:** Yuma Proving Ground polygons do not report any crop use.		1,340	1,329	Yuma Proving Ground, diversion at Imperial Dam, wells X,Y,M. Reported as a diversion.
Ft. Yuma Indian Reservation, Mittry Lake State Wildlife Area and Yuma Proving Ground, AZ. **Note:** As long as crop use is 0, probably no need to report.	930	0		Not reported.
Ft. Yuma Indian Reservation, AZ.	4,274	868	1,843	Dulin, A, 2 wells (C-8-22) 9CCC=1,569 acre-feet and (C-8-22) 7DAC=274 acre-feet. Reported as a diversion.
Ft. Yuma Indian Reservation and Yuma Proving Ground, AZ. **Note:** As long as crop use is 0, probably no need to report.	0	0		Not reported.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
Cibola Valley Irrigation and Drainage District, AZ. **Note:** Part is on CA side of river and probably reduces Palo Verde Irrigation District return flow.	5,894	9,836	29,210	Cibola Valley Irrigation District, 5 pumps Sections 20, 21, and 26T1N R23W. Reported as a diversion.
Cibola National Wildlife Refuge, AZ.	20,366	6,757	10,366	Cibola National Wildlife Refuge, 3 pumps. Reported as a diversion.
Cibola Island, AZ. **Note:** As long as crop use is 0, probably no need to report.	0	0		Not reported.
Imperial National Wildlife Refuge, AZ. **Note:** Some crops on north end and near Laguna Dam are included in phreatophyte use. This will be corrected in future applications of LCRAS.	33,737	0	10,000	Imperial National Wildlife Refuge, 2 wells, Sec 13 T5S R22W G&SRM. Reported as a diversion.
Imperial National Wildlife Refuge and Yuma Proving Ground, AZ. **Note:** As long as crop use is 0, probably no need to report.	0	0		Not reported.
Mittry Lake State Wildlife Area, AZ. **Note:** Some crops evident on imagery, included in phreatophyte use. Crop consumptive use will be isolated and reported in future applications of LCRAS.	11,130	0	360	Pumper L. Pratt Sec 14 T7S R22W ABC=360.
Mittry Lake State Wildlife Area and Yuma Proving Ground, AZ. **Note:** As long as crop use is 0, probably no need to report.	0	0		Not reported.
Sturges Gila Monster Ranch, AZ. **Note:** Some of the land within this polygon is State of AZ leased land, not Sturges Gila Monster Ranch. This will be corrected in future applications of LCRAS.	23	10,229	4,648	Sturges, diversions at Imperial Dam (Warren Act). Reported as a consumptive use.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
City of Yuma (domestic use, after distribution of residual).		15,022	14,902	City of Yuma, diversion at Imperial Dam (All-American Canal), diversion at Imperial Dam (Gila). Reported as a consumptive use.
Marine Corps Air Station (domestic use, after distribution of residual). **Note:** Located within Yuma Mesa Irrigation and Drainage District, AZ polygon.		1,565	1,552	Marine Corps Air Station (Yuma), diversion at Imperial Dam. Reported as a diversion.
Southern Pacific Company (domestic use, after distribution of residual).		48	48	Southern Pacific Company, diversion at Imperial Dam. Reported as a diversion.
Yuma Mesa Fruit Growers (domestic use, after distribution of residual).		12	12	Yuma Mesa Fruit Growers Association, diversion at Imperial Dam. Reported as a diversion.
Unidentified in LCRAS. An Ag diverter included in another user's total. Apparently more than 1 location; next to YDP and on Yuma Mesa or near Unit B. Need actual location and user boundaries.			905	University of Arizona, diversion at Imperial Dam (Warren Act). Reported as a diversion.
Yuma Union High School (domestic use, after distribution of residual).		151	150	Yuma Union High School, diversion at Imperial Dam. Reported as a diversion.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
Unidentified in LCRAS. Apparently an Ag user included in another user's total. Need actual location and user boundary.			34	Camille, Alec, Jr., diversion at Imperial Dam (Warren Act). Reported as a diversion.
Desert Lawn Memorial (Domestic use, after distribution of residual).		113	112	Desert Lawn Memorial, diversion at Imperial Dam. Reported as a diversion.
North Gila Valley Irrigation District, AZ.	930	19,618	17,925	North Gila Valley Irrigation District, diversion at Imperial Dam. Reported as a consumptive use.
Yuma Irrigation District, AZ.	536	32,413	56,403	Yuma Irrigation District, diversion at Imperial Dam. Pumped from private wells=49,981 acre-feet. Includes Glen Curtis Cit (2 wells (C-8-22) 24BDD=1,980 acre-feet (C-8-22) 24BDD=3,175 acre-feet) Cameron Bros (2 wells Sec 24 T08S R22W CCB=524 acre-feet, Sec 24 T08S R22W CAD=451 acre-feet) Judd T. Ott (1 well Sec 30 T08S R22W BAB=292 acre-feet) Yuma Irrigation District reported as a consumptive use, wells reported as diversions.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
Yuma Mesa Irrigation and Drainage District, AZ. **Note:** LCRAS crop and domestic consumptive use should be increased by the portion of the underflow to Mexico that is presumed to be from the application of water on the Yuma Mesa. This volume is about 57,000 acre-feet (85% of 67,000 acre-feet). See "Adjustments for underflow to Mexico," below. There are 5,720 acres of land adjacent to the district boundaries that are included in the Decree Accounting estimate of consumptive use. The consumptive use from these lands should be added to the crop and domestic consumptive use calculated by LCRAS for comparison with the consumptive use compiled by Decree Accounting. The consumptive use by these lands (about 25,000 acre-feet) is included in State of AZ consumptive use below. The water use of the Hillander C Irrigation District is included in the Decree Accounting estimate of consumptive use. Hillander C's water use should be added to the crop and domestic consumptive use calculated by LCRAS for comparison with the consumptive use compiled by Decree Accounting. Hillander C grew about 720 acres of citrus in 1995 for a consumptive use of about 2,800 acre-feet. The use by Hillander C is included in the State of Arizona consumptive use, below. The sum of these adjustments would yield a total crop and domestic consumptive use of 160,635 acre-feet (75,835+57,000+25,000+2,800).	0	75,835	201,021	Yuma Mesa Irrigation and Drainage District, diversion at Imperial Dam. Reported as a consumptive use.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (annual acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS				**Decree Accounting**
Unit B Irrigation and Drainage District, AZ. **Note:** LCRAS consumptive use should be increased by the portion of the underflow to Mexico that is presumed to be from the application of water on unit B. This volume is about 10,000 acre-feet (15% of 67,000 acre-feet). See "Adjustments for underflow to Mexico," below. The citrus acreage was mistranscribed into the water balance table as 1.004 acres. The acreage should have been entered as 1,004 acres. This error resulted in an underestimation of consumptive use by about 4,000 acre-feet. These adjustments would increase the crop and domestic consumptive use to 20,846 acre-feet (6,846 + 10,000 + 4,000).	0	6,846	25,734	Unit "B" Irrigation and Drainage District, diversion at Imperial Dam. Reported as a consumptive use.
Yuma County Water Users Association, AZ. **Note:** The LCRAS crop and domestic consumptive use should be increased by the underflow to Mexico that is presumed to be from the application of water within the Yuma County Water Users Association's boundaries (about 21,000 acre-feet, to the Limitrophe section of the Colorado River). See "Adjustments for underflow to Mexico," below. There are 2,070 acres of land between the Colorado River and the Yuma County Water Users' Association district boundary, in the Limitrophe section, that are included in the Decree Accounting estimate of consumptive use for the Yuma County Water Users Association. The water use from these lands should be added to the crop and domestic consumptive use calculated by LCRAS for comparison with the consumptive use compiled by Decree Accounting. The use by these lands (about 8,500 acre-feet) is included in the State of Arizona consumptive use, below. The water use of the cities of Somerton (159 acre-feet), Gadsden (15 acre-feet), and San Luis (127 acre-feet) are also included in the Decree Accounting estimate of consumptive use for the Yuma County Water Users Association. The water use from these cities should also be added to the crop and domestic consumptive use calculated by LCRAS for comparison with the consumptive use compiled by Decree Accounting. These adjustments would increase crop and domestic consumptive use to 214,770 acre-feet (184,969 + 21,000 + 8,500 + 159 + 15 + 127).	236	184,969	229,180	Yuma County Water Users Association, diversion at Imperial Dam and pumped from wells (surface water use reported as a consumptive use, includes return flows=225,292 acre-feet) + Burrell (1 well, Sec 33 T08S R24W BAB=300 acre-feet) + Farmland Management (3 wells, Sec 19 T09S R24W BAD=503 acre-feet, Sec19 T09S R24W BDD=534 acre-feet, Sec19 T09S R24W BDA=325 acre-feet) + Waymon Farms (1 Well, Sec 31 T09S R24W AAA=1,596 acre-feet) + W. Brand-D. Donnely (1 well, (C-9-25) 35ABA=630 acre-feet). YCWUA reported as a consumptive use, well use reported as diversion.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
West Cocopah Indian Reservation, AZ.	0	1,396	15,765	Cocopah Indian Reservation, diversion at Imperial Dam. Pumped from wells (includes return flows). Reported as a consumptive use. **Note:** Diversions from canal, 9 wells reported by U.S. Geological Survey in sections 25, 26, and 36 (off the reservation), and wells reported by Yuma Area Office, Bureau of Reclamation (locations unknown).
Yuma Area Office, Bureau of Reclamation (domestic use, after distribution of residual).		405	402	Yuma Area Office, diversion from Mode and Well No.8. Reported as a consumptive use.
Yucca Powerplant (domestic use, after distribution of residual). **Note:** Well location plots within the North Cocopah Indian Reservation.		318	323	Yucca Powerplant. Reported as a diversion.
North Cocopah Indian Reservation, AZ.	1,323	2,786	3,658	Texas Hill Farm (1 well, Sec 28 T16S R22E CDA=151 acre-feet) + Curry Family LTD (1 well, Sec 29 T16S R22E DAC=225 acre-feet) + R.E. & P. Power (1 well, Sec 30 T16S R22E ACC=2,850 acre-feet) + Ansil Hall (1 well, Sec 36 T16S R21E BCB=432 acre-feet). Reported as diversions.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
Huerta Packing (domestic use, after distribution of residual). **Note:** 2 wells (16S/22E-30CDA and 16S/21E-25ADD) located within North Cocopah Indian Reservation. These wells appear to be used for irrigation and will not be included as domestic diverters in future applications of LCRAS.		1,546	1,568	Huerta Packing, 2 wells; 16S/22E-30CDA=654 acre-feet and 16S/21E-25ADD=914 acre-feet. Reported as a diversion.
Cocopah Bend RV (domestic use, after distribution of residual). Located within North Cocopah Indian Reservation.		335	340	Cocopah Bend RV. 1 well, Sec 30 T16S R22E BDB=340 acre-feet. Reported as a diversion.
East Cocopah Indian Reservation, AZ. **Note:** A small trailer court should probably be in domestic use file.	0	0		Not reported.
Yuma County (domestic use, after distribution of residual).		1,035		Not reported.
Somerton (domestic use, after distribution of residual).		159		Not reported.
Gadsden (domestic use, after distribution of residual).		15		Not reported.
San Luis (Domestic use, after distribution of residual).		127		Not reported.
Hillander C, AZ. **Note:** Included in State of Arizona consumptive use, below.				Not reported.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
State of Arizona. **Note:** Includes lands just south of the Yuma Mesa Irrigation and Drainage District that are not within the district boundaries and lands between the Colorado River and the YCWUA district in the Limitrophe section. Includes other lands not within known diverter boundaries.	50,546	43,935	11,694	Ogram, George, 1 well, Sec 24 T08S R23W DCC=852 acre-feet + Peach, 1 well, Sec 22 T08S R23W DDC=396 acre-feet ; AZ prod, 1 well, Sec 23 T08S R23W CDA=373 acre-feet + Waymon Farms, 1 well (C-9-24) 31BBA=1,050 acre-feet + J.W. Cumings, 2 wells, (C-10-25) 1BBA=1,233 acre-feet, (C-10-25), 14ADB=519 acre-feet + P. Sibley, 1 well, (C-10-25) 2CDA=1,950 acre-feet + C & J Cummings, 1 well, (C-10-25) 26BAB=480 acre-feet + J. Barkley, 1 well, (C-10-25) 35CBA=480 acre-feet; Brown, Rodger S., 1 well, (C-11-25) 2BBA=587 acre-feet + Earl Huges, 1 well, (C-11-25) 3DAC=1,512 acre-feet + Glen Curtis Cit, 2 wells, (C-8-22) 18CAD=184 acre-feet, (C-8-22) 18DDD=207 acre-feet + Yowelman, R., 1 well, Sec 17 T08S R22W CSC= 960 acre-feet + Ott, Judd T., 1 well, (C-8-22) 19CCA=530 acre-feet + Glen Curtis Cit, 1 well, (C-8-22) 7CCD=381 acre-feet. Reported as diversions.

Table A1.—LCRAS and Decree Accounting consumptive uses by diverter (acre-feet)

Diverter name	Phreatophyte consumptive use	Crop and domestic consumptive use	Consumptive use	Diverter name
LCRAS			**Decree Accounting**	
Arizona Subtotal (Below Hoover Dam, less Wellton-Mohawk Irrigation and Drainage District, less underflow to Mexico).	409,498	1,709,663		
Underflow to Mexico. About 21,000 acre-feet flows into Mexico across the Limitrophe section and about 67,000 acre-feet flows into Mexico across the Southerly International Boundary for a total of about 88,000 acre-feet (estimates made by the Yuma Area Office, Bureau of Reclamation.)		88,000		
			-59,727	Pumped from South Gila Wells (drainage pump outlet channels): Returns.
Arizona Subtotal (Below Hoover Dam, less Wellton-Mohawk Irrigation and Drainage District, includes underflow to Mexico).	409,498	1,797,663	1,973,765	Arizona Subtotal (below Hoover Dam, less Wellton-Mohawk Irrigation and Drainage District, includes underflow to Mexico).
Arizona uses above Hoover Dam (from 1995 Decree Accounting).		178	178	Arizona uses above Hoover Dam.
Wellton-Mohawk Irrigation and Drainage District (from 1995 Decree Accounting Report).		247,409	247,409	Wellton-Mohawk Irrigation and Drainage District.
			-192,537	Unmeasured return flow credit to Arizona.
Arizona Total.	409,498	2,045,250	2,028,815	Arizona Total.
Total Lower Basin Use.	631,497	7,142,192	7,081,337	Total Lower Basin Use.

Notes:
pht = Consumptive use by phreatophytes
crop = Consumptive use by crops

Results in Graphic Form

A list of the bar charts included on the following pages and a short interpretation of the information displayed upon them are presented below:

Consumptive Use (State Totals, AZ and CA) and Consumptive Use, State of Nevada

Palo Verde Irrigation and Drainage District (CA) and Colorado River Indian Reservation (AZ)

Yuma County Water Users Association (AZ) and Yuma Mesa Irrigation and Drainage District (AZ)

Fort Mohave Indian Reservation (AZ) and Fort Mohave Indian Reservation (CA)

Cibola National Wildlife Refuge (AZ) and Cibola Valley Irrigation and Drainage District (AZ)

Colorado River Indian Reservation (CA) and Fort Yuma Indian Reservation, Bard and Indian Units (CA)

The following bar charts show the consumptive use reported by the Decree Accounting Report and the consumptive use of crops, phreatophytes, and domestic uses produced by LCRAS for State totals, and selected irrigation districts and wildlife refuges. These bar charts highlight two major points:

- Importance of determining the amount of phreatophyte use that should be reported as part of a diverters' consumptive use

- Comparison between the consumptive use of crops produced by LCRAS and the consumptive use reported by the Decree Accounting Report

The bar chart for the States of California and Arizona shows a good comparison between the total consumptive uses of crops and phreatophytes produced by LCRAS and the total consumptive uses reported by the Decree Accounting Report (with Decree Accounting estimates of unmeasured return flows to the States included). It also shows the small amount of water use by phreatophytes when compared to crops on a State-wide basis. The bar chart for the State of Nevada shows that there is no irrigation in Nevada and shows the minor impact that LCRAS has on calculations of consumptive use for Nevada.

The bar chart for the Palo Verde Irrigation and Drainage District shows the sum of consumptive uses from crops, phreatophytes, and domestic uses to be less than the measured diversion less measured return flow calculation used by the Decree Accounting Report. This appears to imply that the measured returns do indeed underestimate the actual return flows from the district.

The bar chart for the Colorado River Indian Reservation (AZ) shows the sum of consumptive uses from crops and phreatophytes to be close to the measured diversion less measured return flow calculation used by the Decree Accounting Report. This appears to imply that the measured returns do a reasonable job of estimating the actual return flows from the district.

The bar chart for the Yuma County Water Users Association compares the Decree Accounting Report value of consumptive use to the crop and phreatophyte consumptive use within the district boundaries developed by LCRAS, and an estimate of the underflow to Mexico that results from applied, but unconsumed, water. This underflow should be considered part of the Yuma County Water Users Association's consumptive use because it is not accountable as part of the Mexican delivery and is not available for other uses in the United States. Phreatophyte consumptive use does not appear to be displayed on the bar chart for the Yuma County Water Users Association because the value was very small.

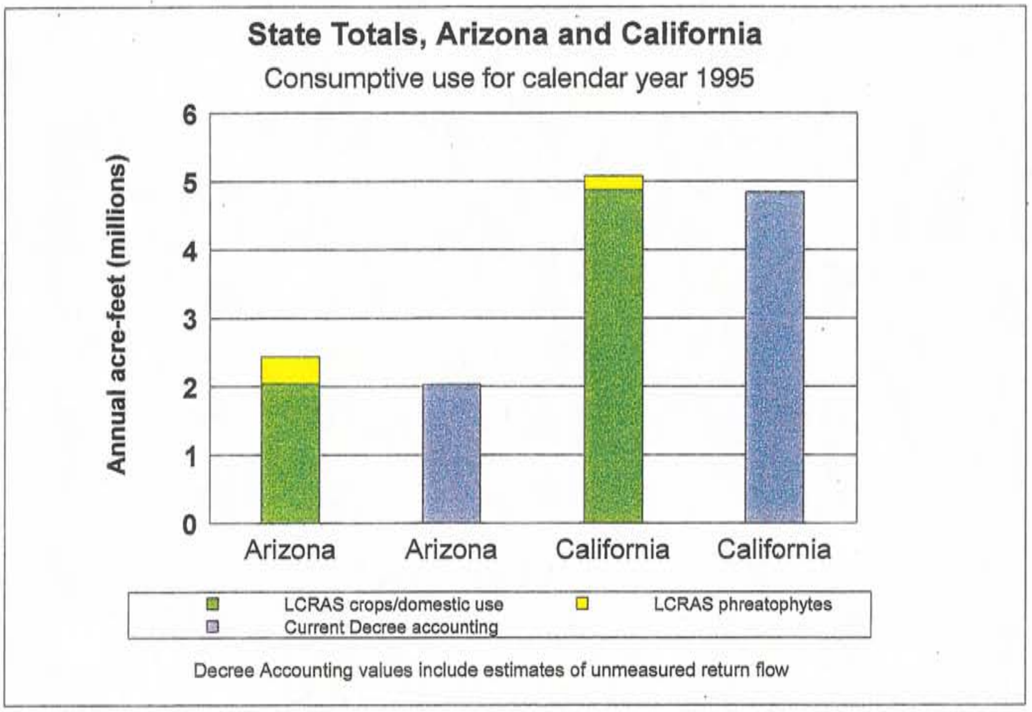
The bar chart for the Yuma Mesa Irrigation and Drainage District compares the Decree Accounting Report value of consumptive use to the crop use (both within the district boundaries and outside of the district boundaries on adjacent lands) developed by LCRAS, and an estimate of the underflow to Mexico that results from applied, but unconsumed, water on the Yuma Mesa. This underflow should be considered part of the Yuma Mesa Irrigation and Drainage District's consumptive use because it is not accountable as part of the Mexican delivery and is not available for other uses in the United States. Phreatophyte consumptive use is not displayed on the bar chart for the Yuma Mesa Irrigation and Drainage District because the value was very small. The nature of the situation occurring on the Yuma Mesa continues to be under study.

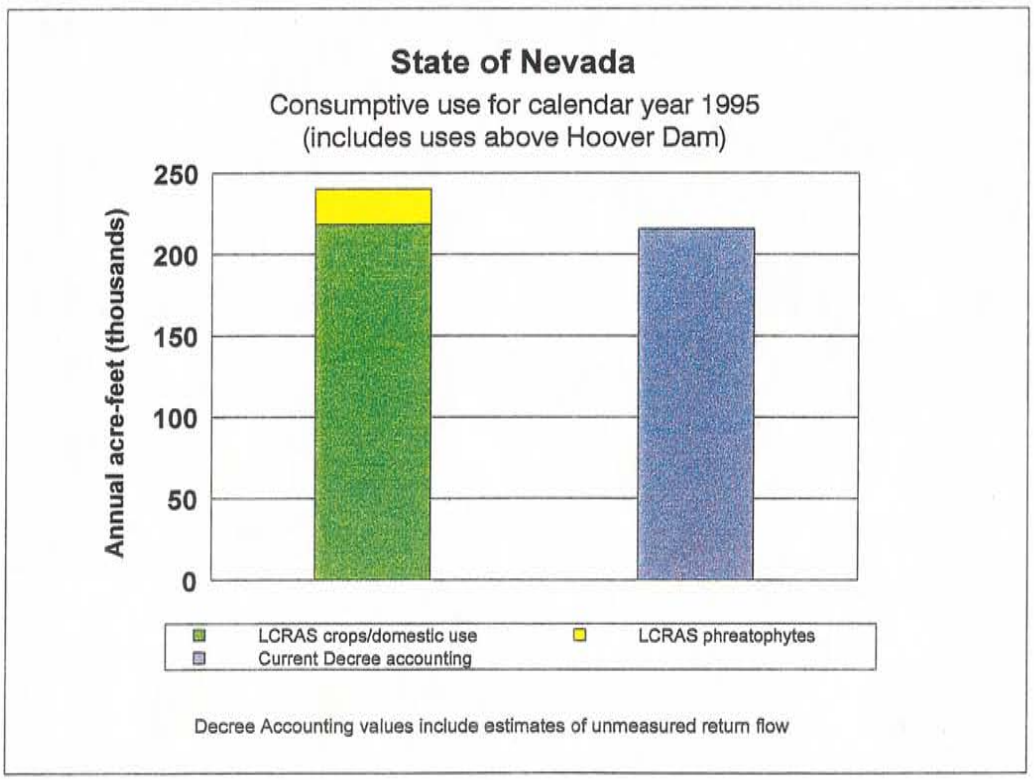
The bar charts for the Fort Mohave Indian Reservation (AZ) and Fort Mohave Indian Reservation (CA) show the consumptive use reported by the Decree Accounting Report and the crop and phreatophyte consumptive use produced by LCRAS. The consumptive use of crops produced by LCRAS is considerably less than that reported by the Decree Accounting Report. However, the sum of crop and phreatophyte consumptive use reported by LCRAS is somewhat greater than the consumptive use reported by the Decree Accounting Report. These are examples of situations where a determination of the amount of phreatophyte use that should be included in the consumptive use of a diverter is critical.

The bar chart for the Cibola National Wildlife Refuge shows the consumptive use reported by the Decree Accounting Report (a diversion with no return flow) and the crop and phreatophyte consumptive use produced by LCRAS. This is another example of a situation where a determination of the amount of phreatophyte use that should be included in the consumptive use of a diverter is critical.

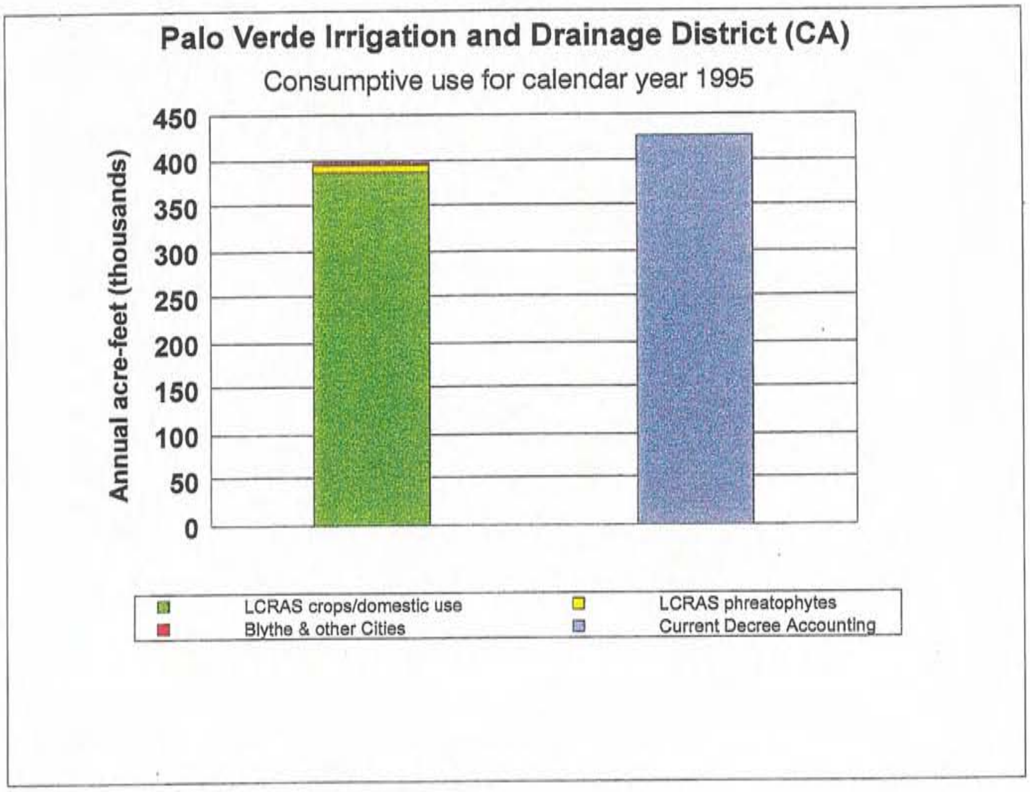
In some cases, such as the Cibola Irrigation and Drainage District, the crop (as well as the sum of crop and phreatophyte) consumptive use developed by LCRAS is less than the consumptive use reported by the Decree Accounting Report. In the case of the Cibola Irrigation and Drainage District, much of this difference can be attributed to the fact that the Decree Accounting Report only reports the water diverted by Cibola Irrigation and Drainage District; there are no return flows reported.

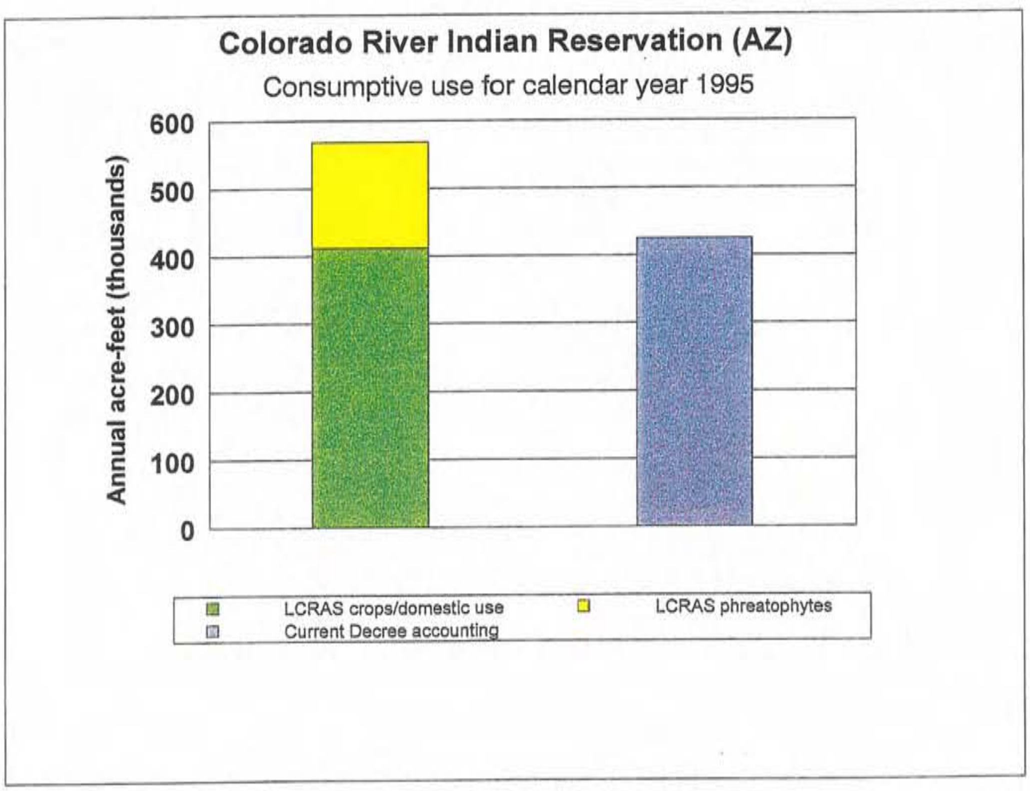
The bar charts for the Colorado River Indian Reservation (CA) and Fort Yuma Indian Reservation, Bard and Indian Units (CA) show the consumptive use reported by the Decree Accounting Report and the crop and phreatophyte consumptive use produced by LCRAS. This is another example of a situation where a determination of the amount of phreatophyte use that should be included in the consumptive use of a diverter is critical.





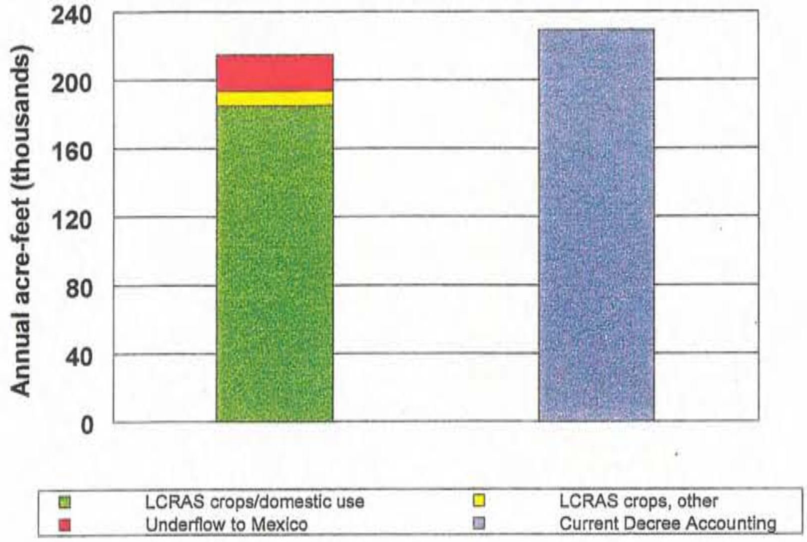
Some double accounting took place in the Big Bend area because of crops irrigated by gray water from the municipal diversion. The crop use was accounted for by the diversion less return value used for domestic use, and was also captured as an irrigation use by remote sensing. If this double accounting, the effect of redistributing the residual from the water budget, and the Decree Accounting estimate of unmeasured return flow is removed, the LCRAS Crop and Domestic Use and Current Decree Accounting values are identical. This is because there is no irrigation other than the gray water use; and little, if any, unmeasured return flow from this irrigation. The wastewater is discharged to the Colorado River from a municipal treatment plant.


Palo Verde Irrigation and Drainage District (CA)
Consumptive use for calendar year 1995
Annual acre-feet (thousands)
450
400
350
300
250
200
150
100
50
0
LCRAS crops/domestic use
Blythe & other Cities
LCRAS phreatophytes
Current Decree Accounting


Colorado River Indian Reservation (AZ)
Consumptive use for calendar year 1995
Annual acre-feet (thousands)
600
500
400
300
200
100
0
LCRAS crops/domestic use
Current Decree accounting
LCRAS phreatophytes

Yuma County Water Users Association (AZ)

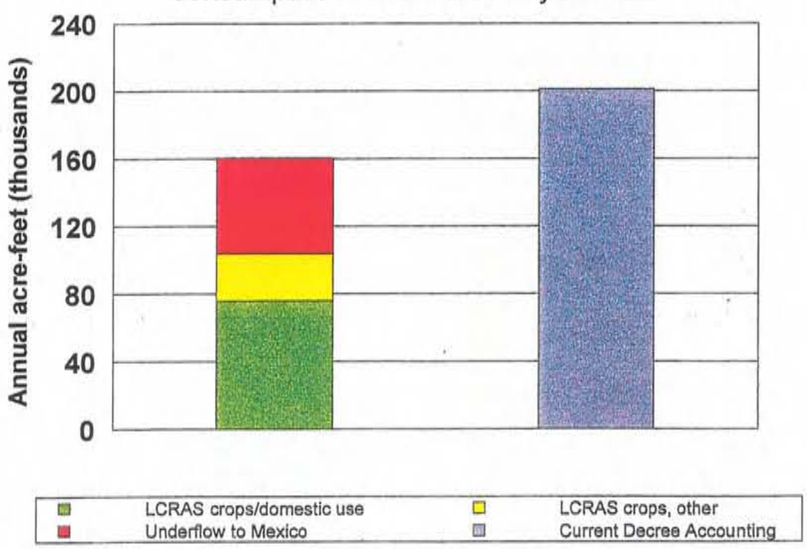
Consumptive use for calendar year 1995



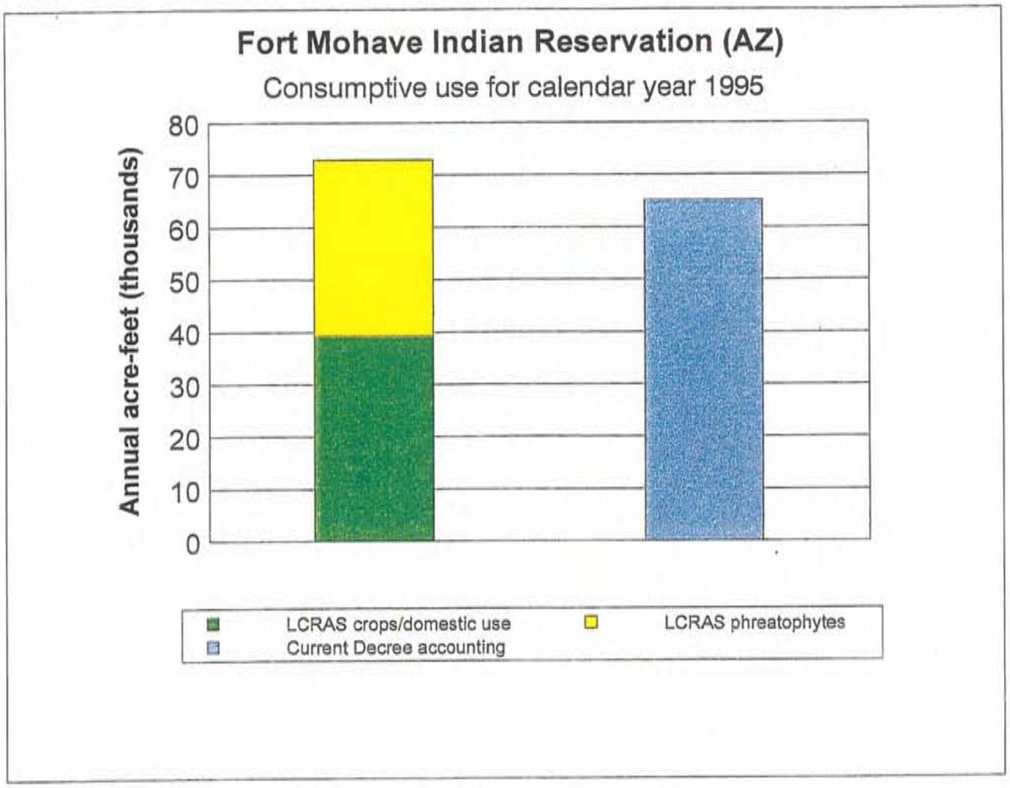
Note: "LCRAS crops, other" includes 8,500 acre-feet used adjacent to the district and 159 acre-feet by Somerton, 15 acre-feet by Gadsden, and 127 acre-feet by San Luis.

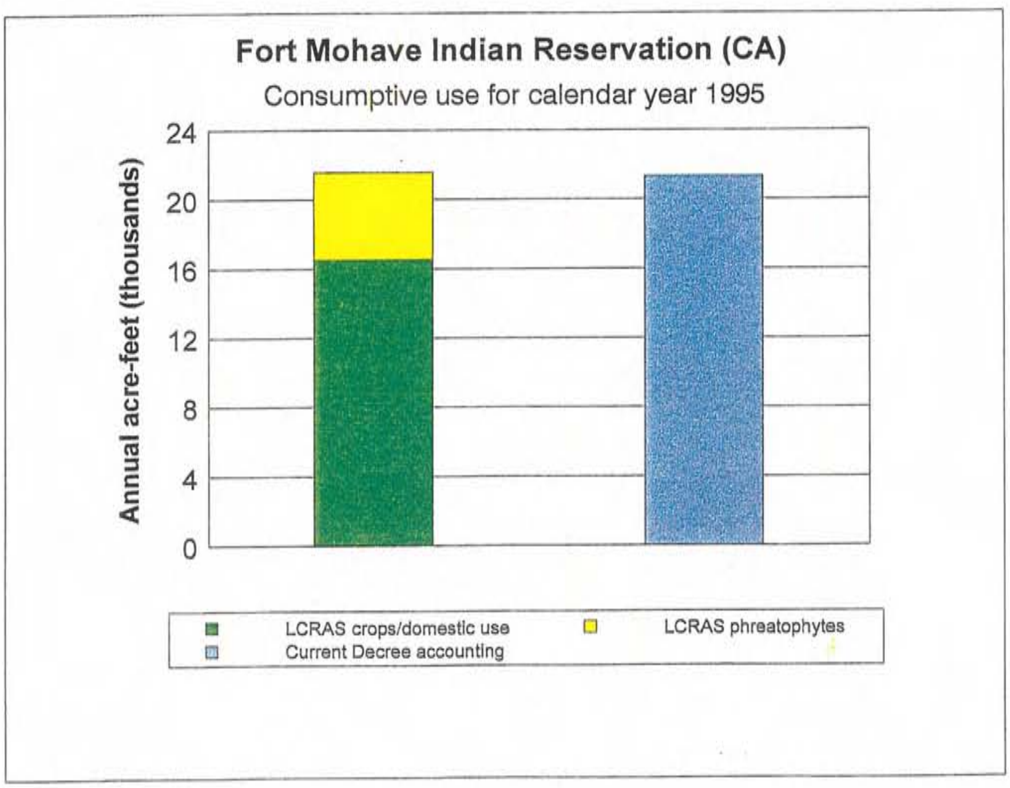
Yuma Mesa Irrigation and Drainage District (AZ)

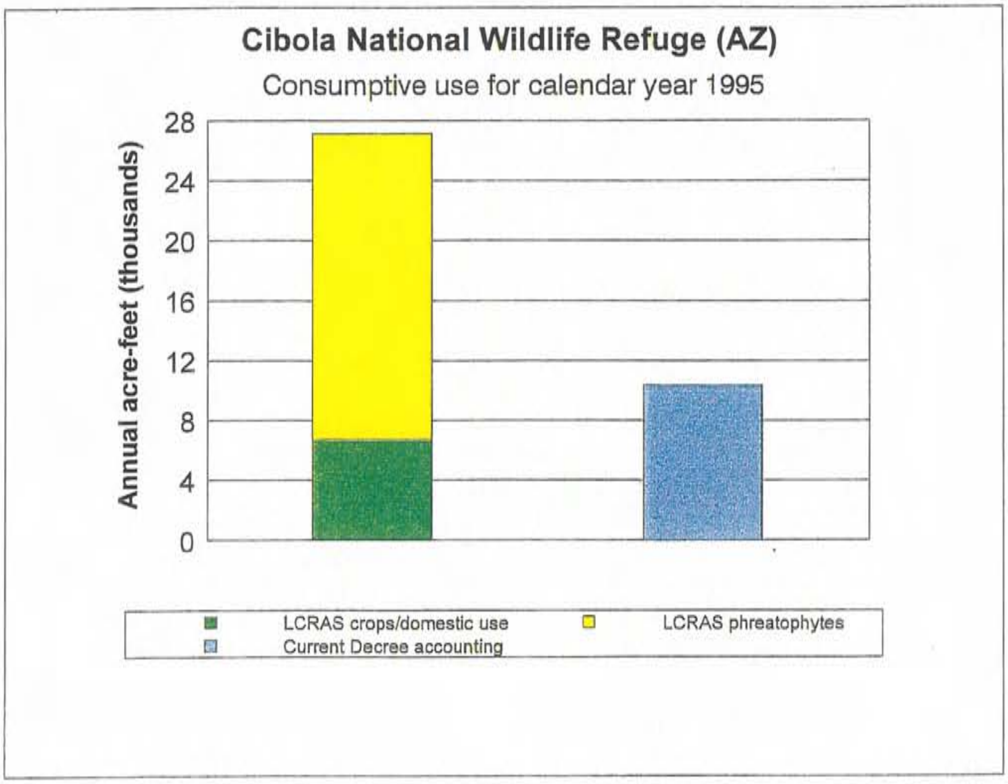
Consumptive use for calendar year 1995

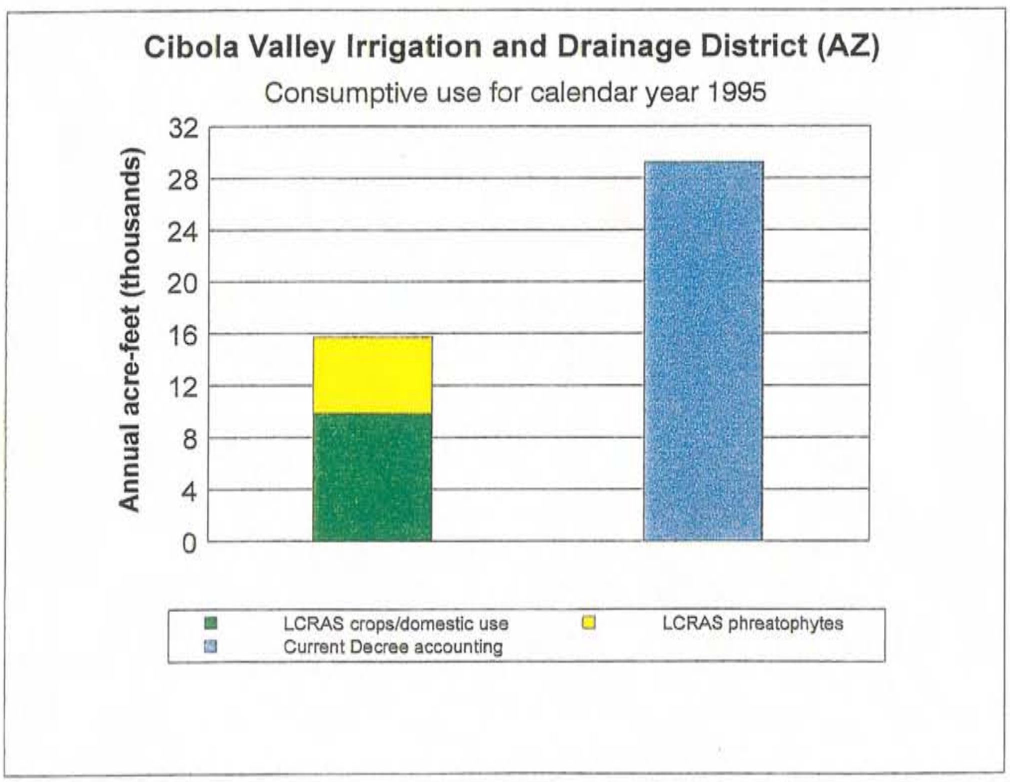


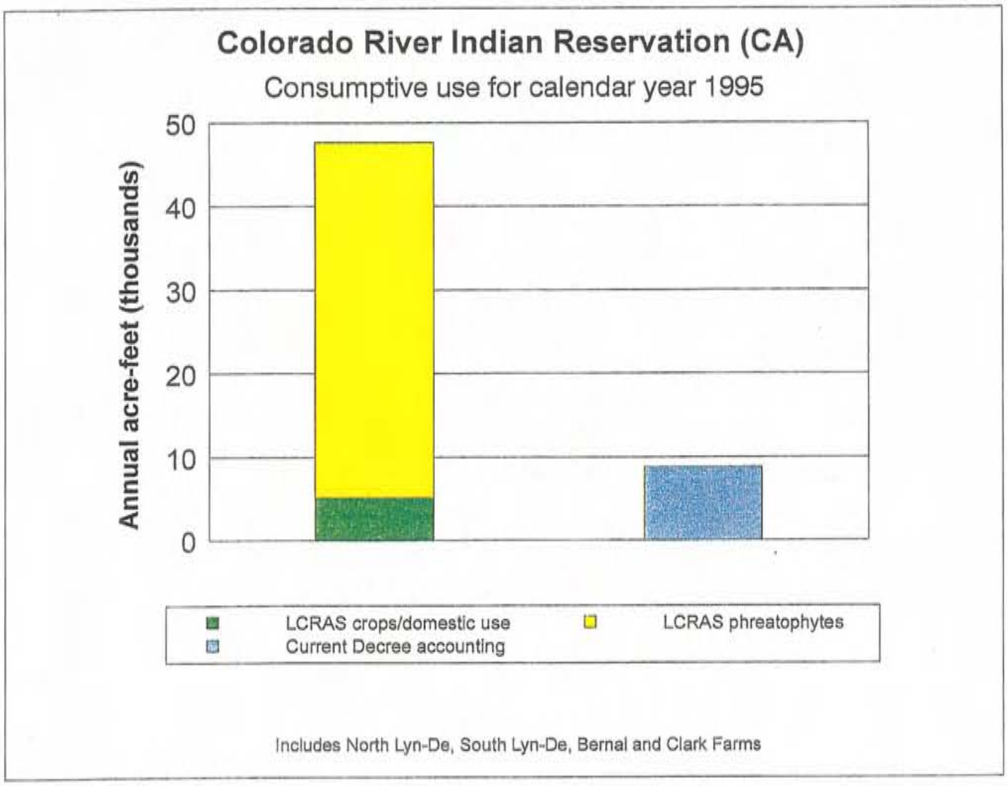
Note: "LCRAS crops, other" includes 25,000 acre-feet used adjacent to the district and 2,800 on Hillander C lands.

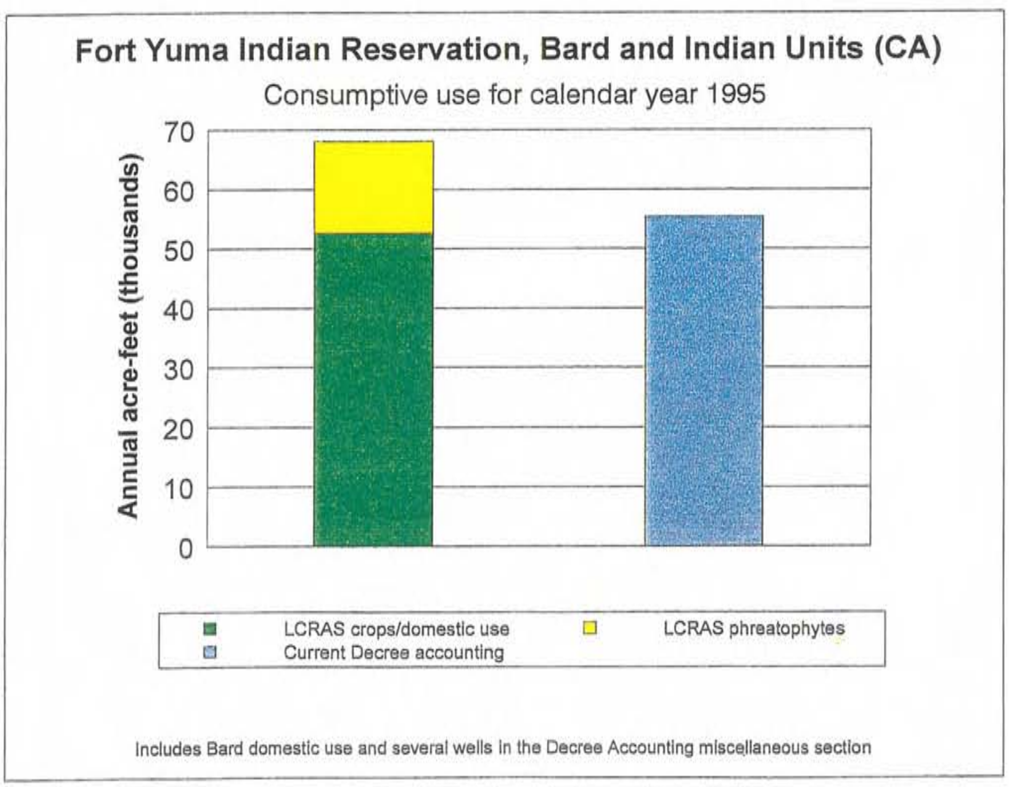

Fort Mohave Indian Reservation (AZ)
Consumptive use for calendar year 1995
Annual acre-feet (thousands)
80
70
60
50
40
30
20
10
0
LCRAS crops/domestic use
LCRAS phreatophytes
Current Decree accounting


Fort Mohave Indian Reservation (CA)
Consumptive use for calendar year 1995
Annual acre-feet (thousands)
24
20
16
12
8
4
0
LCRAS crops/domestic use
LCRAS phreatophytes
Current Decree accounting


Cibola National Wildlife Refuge (AZ)
Consumptive use for calendar year 1995
Annual acre-feet (thousands)
28
24
20
16
12
8
4
0
LCRAS crops/domestic use
LCRAS phreatophytes
Current Decree accounting


Cibola Valley Irrigation and Drainage District (AZ)
Consumptive use for calendar year 1995
Annual acre-feet (thousands)
32
28
24
20
16
12
8
4
0
LCRAS crops/domestic use
LCRAS phreatophytes
Current Decree accounting


Colorado River Indian Reservation (CA)
Consumptive use for calendar year 1995
Annual acre-feet (thousands)
50
40
30
20
10
0
LCRAS crops/domestic use
LCRAS phreatophytes
Current Decree accounting
Includes North Lyn-De, South Lyn-De, Bernal and Clark Farms


Fort Yuma Indian Reservation, Bard and Indian Units (CA)
Consumptive use for calendar year 1995
Annual acre-feet (thousands)
70
60
50
40
30
20
10
0
LCRAS crops/domestic use
LCRAS phreatophytes
Current Decree accounting
Includes Bard domestic use and several wells in the Decree Accounting miscellaneous section

MISSION STATEMENTS

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.