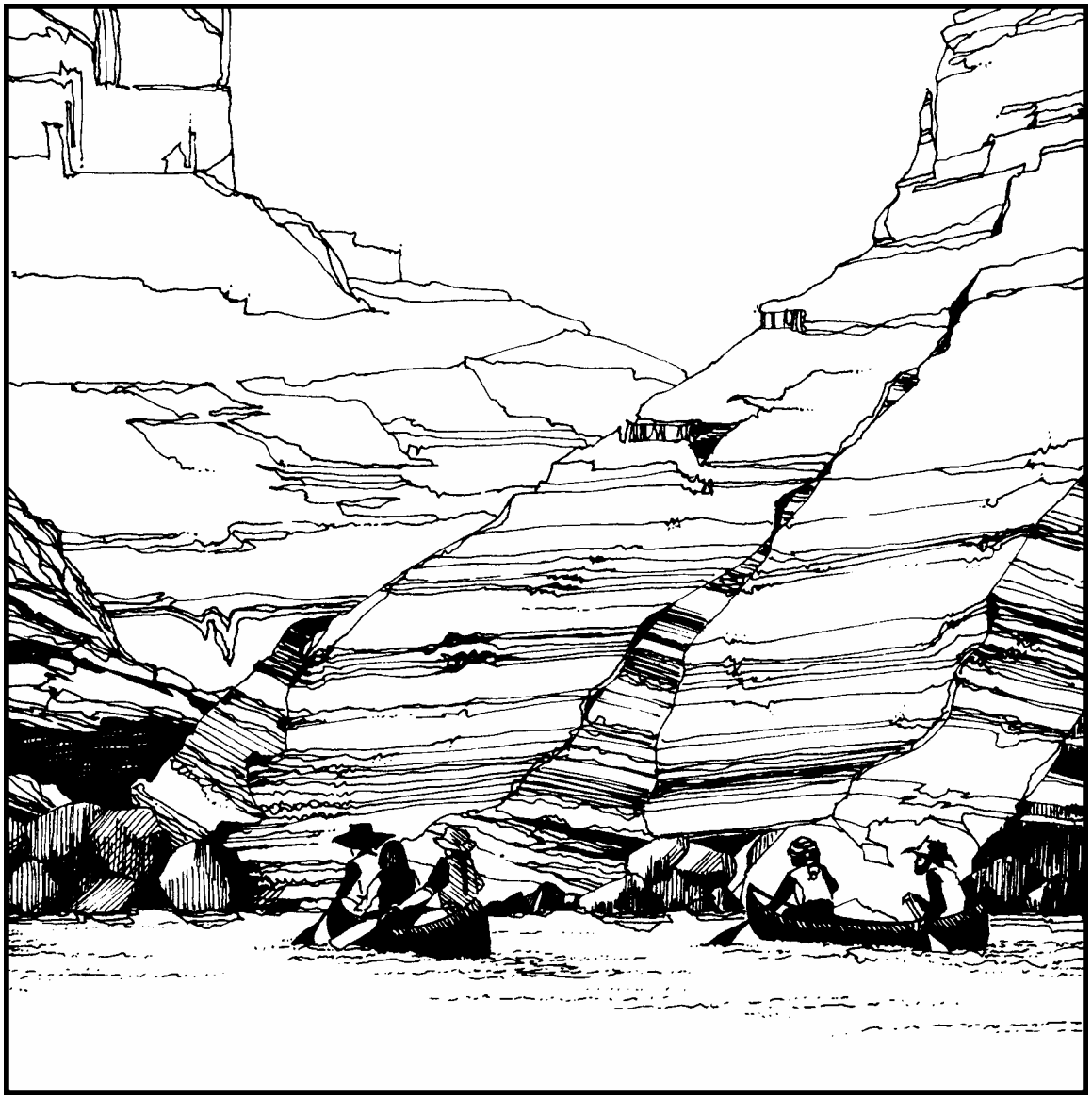
COLORADO RIVER SYSTEM
CONSUMPTIVE USES
AND
LOSSES REPORT
1991-1995



RECLAMATION'S MISSION

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.

DEPARTMENT OF THE INTERIOR'S MISSION

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural resources. This includes fostering wise use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. Administration.

COLORADO RIVER SYSTEM
CONSUMPTIVE USES
AND
LOSSES REPORT
1991-1995

September 2002

United States Department of the Interior
Bureau of Reclamation
Upper Colorado Region
Lower Colorado Region

COLORADO RIVER SYSTEM

CONSUMPTIVE USES AND LOSSES REPORT

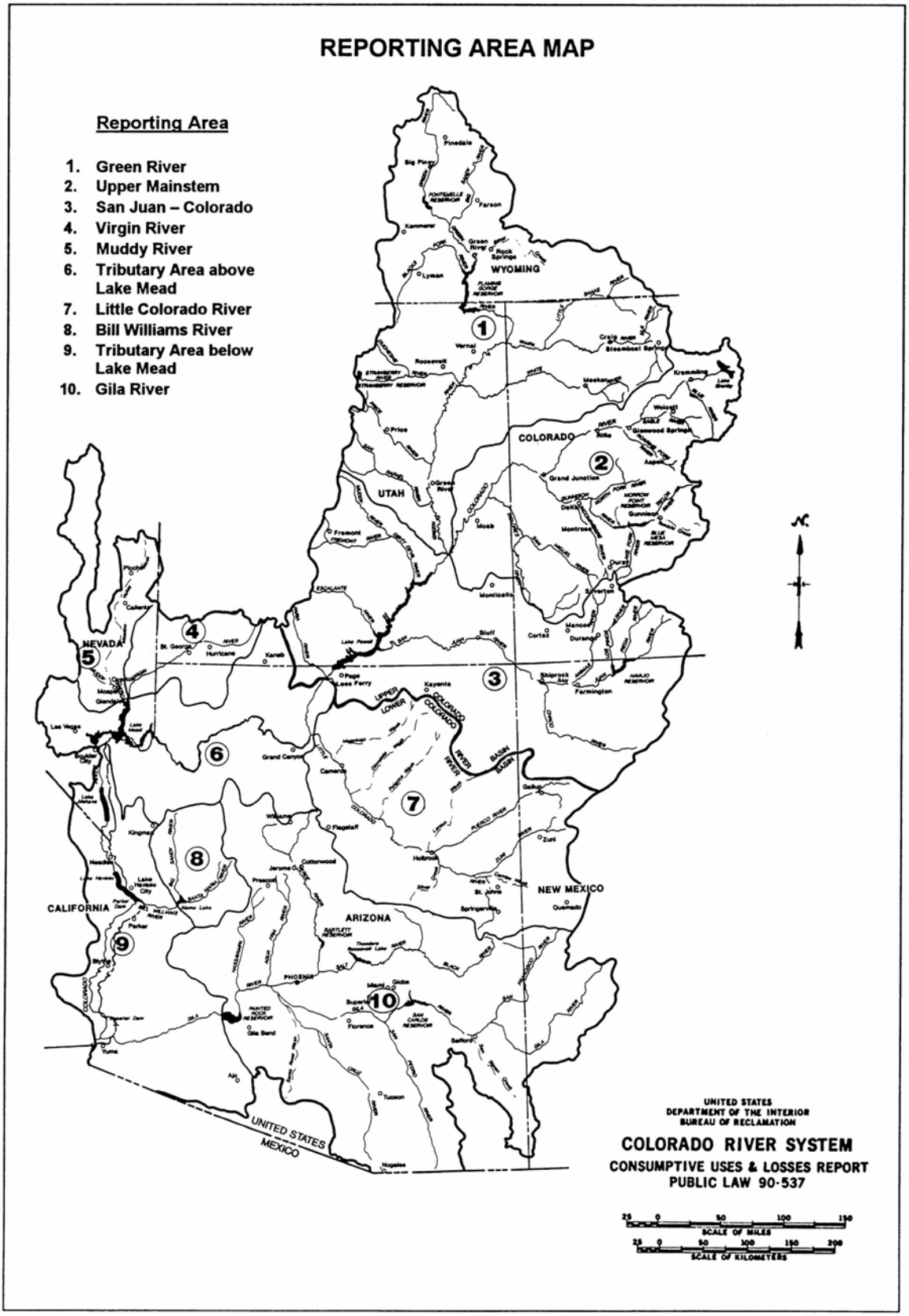
1991-1995

FOREWORD

This report was prepared pursuant to the Colorado River Basin Project Act of 1968, Public Law 90-537. The act directs the Secretary of the Interior to "make reports as to the annual consumptive uses and losses of water from the Colorado River System after each successive 5-year period, beginning with the 5-year period starting October 1, 1970 .... Such reports will be prepared in consultation with the States of the Lower Basin individually and with the Upper Colorado River Commission and will be transmitted to the President, the Congress, and to the Governors of each State signatory to the Colorado River Compact."

This report reflects the Department of the Interior's best estimate of actual consumptive uses and losses within the Colorado River Basin. The reliability of the estimate is affected by the availability of data and the current capabilities of data evaluation.

REPORTING AREA MAP



SUMMARY

This report presents estimates of the consumptive uses and losses from the Colorado River System for each calendar year from 1991 through 1995. It includes a breakdown of the beneficial consumptive use by major types of use, by major tributary streams, and, where possible, by individual States.

The Colorado River rises in the Rocky Mountains of Colorado, flows southwesterly about 1,400 miles and terminates in the Gulf of California. Its drainage area of 242,000 square miles in this country represents one-fifteenth of the area of the United States. Its water is used for irrigation, municipal and industrial purposes, electric power generation, mineral activities, livestock, fish and wildlife, and recreation. Large amounts are exported from the system to adjoining areas. The following table summarizes annual water use from the system by basins and States, including water use supplied by ground-water overdraft. Distribution of water use by types of use from the various reporting areas is contained within the body of the report.

Table: Summary

Colorado River System: Water Use by States, Basins, and Tributaries[1]
(1,000 acre-feet)

STATE AND BASIN OF USE	1991	1992	1993	1994	1995	Average 1991-95
ARIZONA						
Upper Basin	39	40	39	41	40	40
Lower Basin Mainstem	1,720	1,757	2,102	1,945	2,029	1,911
Lower Basin Tributaries	3,389	2,964	2,683	2,991	3,216	3,049
TOTAL	5,148	4,761	4,824	4,977	5,285	4,999
CALIFORNIA						
Lower Basin Mainstem	4,948	4,493	4,780	5,189	4,837	4,849
TOTAL	4,948	4,493	4,780	5,189	4,837	4,849
COLORADO						
Upper Basin	2,168	2,207	2,056	2,251	1,711	2,079
TOTAL	2,168	2,207	2,056	2,251	1,711	2,079
NEVADA						
Lower Basin Mainstem	180	178	208	226	216	202
Lower Basin Tributaries	102	126	126	145	134	127
TOTAL	282	304	334	371	350	329
NEW MEXICO						
Upper Basin	401	363	394	392	385	387
Lower Basin Tributaries	25	22	24	23	28	24
TOTAL	426	385	418	415	413	411
UTAH						
Upper Basin	821	868	823	957	791	852
Lower Basin Tributaries	87	96	98	105	110	99
TOTAL	908	964	921	1,062	901	951
WYOMING						
Upper Basin	442	544	420	604	437	489
TOTAL	442	544	420	604	437	489
OTHER[2]						
Upper Basin	475	499	550	597	625	549
Lower Basin	1,104	794	1,185	1,117	1,054	1,051
TOTAL	1,579	1,293	1,785	1,714	1,679	1,600
COLORADO RIVER SYSTEM						
Upper Basin	3,871	4,022	3,732	4,245	3,364	3,847
Lower Basin Mainstem	6,848	6,428	7,090	7,360	7,081	6,962
Lower Basin Tributaries	3,603	3,208	2,931	3,264	3,488	3,299
Other	1,579	1,293	1,735	1,714	1,679	1,600
TOTAL	15,901	14,951	15,488	16,583	15,612	15,708
WATER PASSING TO MEXICO						
Treaty	1,500	1,500	1,500	1,500	1,500	1,500
Minutes 218, 241, and 242	141	101	61	124	126	111
Regulatory Waste	21	81	3,693	26	212	807
TOTAL	1,662	1,682	5,254	1,650	1,838	2,418
COLORADO RIVER SYSTEM GRAND TOTAL	17,563	18,633	20,742	18,233	17,450	18,126

[1] Consumptive uses and losses; includes water uses satisfied by ground-water overdraft (Tables C-2 through C-6).
[2] Mainstem reservoir evaporation in the Upper and Lower Basins.

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COLORADO RIVER SYSTEM
CONSUMPTIVE USES AND LOSSES
REPORT
1991-1995

INTRODUCTION

The Colorado River System is composed of portions of seven States--Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming. It has a drainage area of about 242,000 square miles and represents about one-fifteenth of the area of the United States.

This report incorporates annual estimates of consumptive uses and losses of water from the system from 1991 through 1995. Wherever available, water use reports prepared in accordance with legal requirements concerning the operation of the Colorado River were utilized. Base data needed to estimate onsite consumptive uses were taken largely from existing reports and studies and from ongoing programs. Where current data were not available, estimated values were developed by various techniques and reasoned judgment. In general, methodology followed the techniques normally used within the system for estimating water use.

Nothing in this report is intended to interpret the provisions of the Colorado River Compact (45 Stat. 1057), the Upper Colorado River Basin Compact (63 Stat. 31), the Water Treaty of 1944 with the United Mexican States (Treaty Series 994; 59 Stat. 1219), the decree entered by the Supreme Court of the United States in Arizona vs. California, et al. (376 U.S. 340), the Boulder Canyon Project Act (45 Stat. 1057), the Boulder Canyon Project Adjustment Act (54 Stat. 774; 43 U.S.C. 618a), the Colorado River Storage Project Act, (70 Stat. 105; 43 U.S.C. 620), or the Colorado River Basin Project Act (82 Stat. 885; 43 U.S.C. 1501).

AUTHORITY

The authority for this report is contained in Public Law 90-537, the Colorado River Basin Project Act of 1968. Title VI, Section 601(b)(1) of the Act reads as follows:

(b) The Secretary is directed to:

(1) Make reports as to the annual consumptive uses and losses of water from the Colorado River System after each successive 5-year period, beginning with the 5-year period starting October 1, 1970. Such reports will include a detailed break down of the beneficial consumptive use of water on a State-by-State basis. Specific figures on quantities consumptively used from the major tributary streams flowing into the Colorado River shall also be included on a State-by-State basis. Such reports will be prepared in

consultation with the States of the Lower Basin individually and with the Upper Colorado River Commission, and shall be transmitted to the President, the Congress, and to the Governors of each State signatory to the Colorado River Compact.

PLAN OF STUDY

The Plan of Study and Methods Manual for the Colorado River System Consumptive Uses and Losses Report 1985-1990 was prepared and submitted in July 1992. These procedures were generally followed in the preparation of this report. Any changes in methodology are presented in the Methodology and Data Adequacy section of this report.

STUDY REPORTING AREAS

The drainage area of the Colorado River System in the United States is approximately 242,000 square miles. The river originates in the Rocky Mountains of Colorado and Wyoming, flows southwest about 1,400 miles, and terminates in the Gulf of California. The system consists of portions of seven states: Arizona, California, Colorado, New Mexico, Nevada, Utah, and Wyoming. The drainage area was divided into nine subbasins for the purposes of this report.

The Colorado River Compact, signed November 24, 1922, was established because the Upper Basin States were concerned that any storage on the river would be put to use more rapidly by the Lower Basin States, thus allowing them to claim prior appropriative rights. The Upper Basin States wanted provisions for their future development.

The term "Upper Basin States" refers to the States of Colorado, New Mexico, Utah, and Wyoming. "Lower Basin States" refers to the States of Arizona, California, and Nevada. However, the Upper Colorado River Basin refers to the hydrologic boundaries. Lee Ferry is the division point between the Upper Colorado River Basin and the Lower Colorado River Basin. Therefore, the hydrologic boundaries include portions of Arizona in the Upper Colorado River Basins and portions of Utah and New Mexico in the Lower Colorado River Basin. Hydrologic boundaries are shown on the map on page ii.

The major tributary streams selected as reporting areas in the Upper Colorado River Basin are: Green River (Wyoming, Colorado, Utah), Upper Main Stem (Colorado, Utah), and San Juan-Colorado (Colorado, New Mexico, Utah, Arizona).

Five tributary areas in addition to the main stem were selected in the Lower Colorado River Basin: Little Colorado River (Arizona, New Mexico), Virgin River (Utah, Arizona), Muddy River (Nevada), Bill Williams River (Arizona), Gila River (Arizona, New Mexico), and remaining areas in Arizona, Nevada, and Utah. The outflow point and drainage area for each is shown in table C-1. The boundaries of the reporting areas are shown on the map on page ii. A brief description of each reporting area follows.

Upper Colorado River Basin

Green River (Wyoming-Colorado-Utah)

The Green River reporting area comprises approximately 44,800 square miles in southwestern Wyoming, northwestern Colorado, and northeastern and east-central Utah.

Principal tributaries of the Green River are Blacks Fork, New Fork, and Big Sandy Creek in southwestern Wyoming, Yampa and White Rivers on the western slope of the Continental Divide in northwestern Colorado, and the Price, Duchesne, and San Rafael Rivers in eastern Utah. These streams are fed by numerous headwater lakes.

The largest towns in the reporting area are Rock Springs and Green River in Wyoming, Vernal and Price in Utah, and Craig, Steamboat Springs, and Meeker in Colorado.

Mineral production is the major industry. Oil and natural gas are of primary importance, as are coal, gilsonite, asphalt, and trona (soda ash). Thermal electric power production is becoming an increasingly important industry.

Agriculture ranks near mineral production in importance to the local economy. Agricultural development is centered around livestock production, primarily beef cattle and sheep. Because of a short growing season, crop production is limited largely to small grain, hay, and pasture. These crops are used as winter livestock feed and complement the vast areas of public grazing lands.

Irrigation consumptive use accounts for about 74 percent of the total water use in the Green River reporting area exclusive of any share of main stem evaporation. Nearly 705,000 acres of land are irrigated in an average year. Large exports of water are made to the Great Basin in Utah.

Upper Main Stem (Colorado-Utah)

The Upper Main Stem reporting area is drained by the Colorado River and its tributaries above the mouth of the Green River. Principal tributaries are the Roaring Fork, Gunnison, and the Dolores Rivers. The Upper Main Stem reporting area consists of 26,200 square miles, with about 85 percent of the area in Colorado and the remainder in Utah.

Grand Junction, Montrose, and Glenwood Springs are the principal towns in the Colorado portion of the upper main stem of the Colorado River. Moab is the only major community in the Utah portion of the upper main stem of the Colorado River.

Mineral production is the predominant industry. This area is the Nation's chief source of molybdenum and is a major source of vanadium, uranium, lead, zinc, coal, and gilsonite. On the Upper Main Stem reporting area, as in that of the Green River, agriculture centers around production of livestock which feeds on irrigated lands to complement the large areas of rangeland. Somewhat increased diversification of crops occurs in the Upper Main Stem, however, with some major land areas devoted to corn, beans, potatoes, table vegetables, and fruit. This diversification is made possible by climatic and topographic conditions that create favorable air drainage and minimize frost damage.

Irrigation consumptive use accounts for about 58 percent of the water use in the Upper Main Stem reporting area exclusive of any share of main stem evaporation. In an average year approximately 555,000 acres of land are irrigated. A considerable amount (30 percent) of water is exported to serve agricultural and municipal needs on the Eastern slope of the Continental Divide in Colorado.

San Juan-Colorado (Colorado-New Mexico-Utah-Arizona)

The San Juan reporting area is drained by the Colorado River and its tributaries below the mouth of the Green River and above Lee Ferry, Arizona. The largest of the tributary streams is the San Juan River which heads on the western slope of the Continental Divide in southwestern Colorado. Principal tributaries of the San Juan River are the Navajo, Piedra, Los Pinos, Animas, and La Plata Rivers. The other main tributaries in the basin are the Dirty Devil, Escalante, and Paria Rivers, which drain a portion of the Eastern slope of the Wasatch Plateau in Utah. The reporting area includes about 38,600 square miles in portions of Utah, New Mexico, Arizona, and Colorado.

The largest towns are Durango and Cortez in Colorado, Monticello and Blanding in Utah, Farmington in New Mexico, and Page in Arizona.

Mining and agriculture form the economic base for the San Juan-Colorado reporting area. The agricultural development is similar to that of the Upper Main Stem where most of the cropland is devoted to livestock feeds except for the production of diversified market crops on lands with favorable air drainage. The main market crops are fruit, vegetables, and dry beans. Oil, natural gas, and coal are the most important minerals produced. Thermal electric power production is increasingly important to the economy of the area.

Irrigation accounts for the largest use of water, about 77 percent of the San Juan reporting area use, exclusive of any share of main stem evaporation. About 310,000 acres of land are irrigated in an average year.

Lower Colorado River Basin

Main Stem Below Lee Ferry, Arizona-California-Nevada

The Colorado River has a length of more than 700 miles and a drainage area of 132,300 square miles within the Lower Colorado River System in the United States. The dividing point between the Upper and Lower Basin is Lee Ferry. Diversions are made at Lake Mead to the rapidly expanding North Las Vegas-Las Vegas-Henderson-Boulder City area for municipal and industrial purposes. The river below Lake Mead courses through canyons and broad alluvial valleys interspersed with bordering groups of mountains. Lakes Mohave and Havasu provide flood control and regulatory storage below Lake Mead. Lake Mohave reregulates Hoover Dam releases for power production and for deliveries to Mexico. Lake Havasu also provides a forebay for pumped diversions to the Central Arizona Project (CAP) in Arizona and export to the Metropolitan Water District of Southern California.

Lesser structures downstream include Senator Wash, Laguna, Headgate Rock, Palo Verde, Imperial, and Morelos Dams. Senator Wash and Laguna Dams provide very limited amounts of reregulation capacity, while the others are used principally for diversions.

Diversions below Lake Mead for agriculture, municipal and industrial, power, export, and other purposes are of the magnitude of six million acre-feet annually. A portion of these diversions is satisfied from upstream return flows. Yuma and Lake Havasu City in Arizona and Needles and Blythe in California are the major cities along the main stem below Lake Mead. Current irrigated lands adjacent to the main stem are estimated to cover approximately 275,000 acres.

Tributary Area Above Lake Mead, Arizona-Nevada-Utah

Development away from the Colorado River main stem is limited by the availability of water and the rugged terrain.

Most of the irrigated lands in this area are located in the lower reach of the Virgin River and Las Vegas Valley in Nevada, on Kanab Creek in Arizona and Utah. Reporting period irrigated land averaged approximately 12,000 acres.

North Las Vegas, Las Vegas, Henderson, and Boulder City in Nevada, are the leading cities in the area.

Tributary Area Below Lake Mead, Arizona

As discussed above, development away from the Colorado River main stem is limited by the availability of water and the rugged terrain.

Most of the irrigated lands in this area are located in the lower portions of the Gila and Bill Williams Rivers in Arizona. Kingman and Williams in Arizona, are the leading cities.

Little Colorado River, Arizona-New Mexico

The Little Colorado River drainage area occupies a large part of northern Arizona and a portion of west-central New Mexico. It originates on the north slopes of the White Mountains about 20 miles above Springerville, Arizona. The river has a main stem length of about 356 miles and joins the Colorado River on the east boundary of Grand Canyon National Park about 78 miles downstream from Glen Canyon Dam.

A series of saline springs near the mouth of the Little Colorado River produces an estimated 160,000 acre-feet of water annually. The U.S. Geological Survey (USGS) gauging station near Cameron, Arizona, is located on the Navajo Indian Reservation about 45 miles upstream from the mouth. Streamflow is undependable and erratic and is subject to flash floods of considerable magnitude. Flow at the gauging station during the 1991-95 period varied from 65,630 acre-feet in 1994 to 603,100 acre-feet in 1993. Only minor development of the ground water has occurred because of low yields and poor quality. Excessive erosion and sediment deposition plague the area.

Agriculture is concentrated along the main stem of the Little Colorado River in the upper reaches of the river, on Silver Creek, a southern tributary, and on the Zuni River in New Mexico. Current irrigated lands in the basin are estimated to average approximately 20,000 acres. Irrigated acreage in the basin is subject to variation because of frequent water shortages and inadequate storage facilities. Population is predominately rural with a relatively large Indian segment. Principal cities include Flagstaff, Winslow, and Holbrook in Arizona, and Gallup, Zuni, and Pueblo in New Mexico. Leading industries include tourism, recreation, manufacturing, mining, and forest management.

Virgin River, Arizona-Nevada-Utah

The Virgin River originates in western Kane County, Utah. It flows southwesterly through the southwest corner of Utah and the northwestern corner of Arizona and empties into the northern extremity of the Overton Arm of Lake Mead in Nevada. The selected outflow point is the long-term USGS gauging station at Littlefield, Arizona, which is about 36 miles upstream from Lake Mead and about 10 miles above the Arizona-Nevada State line. The river is fed chiefly from tributaries heading in the southern high plateaus and mountains in Utah. Several springs contribute water to the river at a relatively uniform rate. The two most significant of these springs are located near LaVerkin, Utah, and Littlefield, Arizona, and both are highly saline. Agricultural and municipal developments in Nevada below the selected outflow point are included in the "tributary area above Lake Mead".

The major irrigated areas are located in the LaVerkin-Hurricane-St. George-Santa Clara areas of Washington County, Utah, and in the Littlefield area of Mohave County, Arizona. Small irrigated areas are scattered throughout. Irrigated lands were estimated to average approximately 19,000 acres. Ground water has been developed to a limited degree. Population is predominately rural with St. George, Utah, being the principal city in the basin.

Muddy River, Nevada

The Muddy River, a tributary of the Virgin River prior to the existence of Lake Mead, originates from warm springs in northern Clark County, Nevada, about 10 miles northwest of Glendale. The river flows southeasterly about 30 miles and terminates at the northwestern extremity of the Overton Arm of Lake Mead near Overton, Nevada. Meadow Valley Wash, the major tributary of Muddy River, originates in northeastern Lincoln County and flows south to join the parent stream at Glendale. The USGS gauging station near Glendale is about 2.4 miles downstream from Meadow Valley Wash. The outflow varies little from year to year. Meadow Valley Wash, although perennial in the vicinity of Caliente, is normally dry in the last 50-mile reach above Glendale. Irrigated lands averaged approximately 20,000 acres. The entire basin is sparsely populated.

Bill Williams River, Arizona

The Bill Williams River is formed by the mergence of the Big Sandy and Santa Maria Rivers about 7.5 miles above Alamo Dam. The river above Alamo Dam drains an area of about 4,700 square miles from small, rough mountain ranges and intervening valleys in parts of Mohave, La Paz, and Yavapai Counties. Alamo Dam and Reservoir, primarily a

flood control structure completed in 1968, was built to protect downstream development along the Colorado River. A minimum pool is maintained for recreation and game management purposes. Releases up to a maximum of 2,000 ft/s from the allocated conservation pool above the minimum pool are coordinated with releases from main stem reservoirs. Releases from Alamo Dam and runoff from the intervening area flow westerly and enter at the lower end of Lake Havasu just above Parker Dam.

Irrigated lands are estimated to average approximately 5,000 acres. The limited development in the basin is dominated by copper mining at the unincorporated town of Bagdad. A large portion of the water supply in the basin is obtained from ground-water pumpage. Releases from Alamo Dam and Reservoir during the 1991-95 period varied from 20,310 acre-feet in 1994 to 701,500 acre-feet in 1993.

Gila River, Arizona-New Mexico

The Gila River is the largest tributary to the Colorado River in the Lower Colorado River System. The drainage area extends from the Continental Divide in New Mexico to the river's mouth near Yuma, Arizona. Elevations in the basin range from nearly 12,000 feet in the Eastern mountains to about 150 feet at the mouth. The selected outflow point for the basin is at Painted Rock Dam, a flood control structure located about 20 miles west of Gila Bend, Arizona. The drainage area above Painted Rock Dam is about 50,900 square miles, of which 5,600 square miles are in New Mexico, 44,200 square miles are in Arizona, and 1,100 square miles in Mexico. The dam was constructed to protect agricultural and urban developments downstream.

Nearly three-fourths of the population of the Lower Colorado River System reside in the Gila River Basin in the metropolitan Phoenix and Tucson areas. Industry and recreation play a large part in the economy. About two-thirds of the agricultural development in the Lower Colorado River System is located in the Gila River Basin. This development is concentrated in the central area of Maricopa, Pinal, and Pima Counties and is supported to a large degree by a long-term overdraft of the ground-water resources. Estimated irrigated lands ranged between 641,000 and 718,000 acres for the reporting period and averaged 664,000 acres. Nearly all of the surface water resources in the basin have been developed for decades.

TERMINOLOGY

The Colorado River is not only one of the most highly controlled rivers in the world, but is also one of the most institutionally encompassed. A multitude of legal documents, known collectively as the "Law of the River," effect and dictate its management and operation. Major documents include:

Colorado River Compact--1922
Boulder Canyon Project Act--1928
California Limitation Act--1929
California Seven Party Agreement--1931
Mexican Water Treaty--1944

Upper Colorado River Basin Compact--1948
Colorado River Storage Project Act--1956
United States Supreme Court Decree in Arizona vs. California--1964
Colorado River Basin Project Act--1968
Minute 242 of the International Boundary and Water Commission,
United States and Mexico--1973
Colorado River Basin Salinity Control Act--1974, amended 1984, 1995, and 1996

The Colorado River System is defined in the Colorado River Compact of 1922 as "...that portion of the Colorado River and its tributaries within the United States,", whereas the Colorado River Basin is defined as "...all of the drainage area of the Colorado River System and all other territory within the United States of America to which waters of the Colorado River System shall be beneficially applied.". The compact divided the Colorado River Basin into two subbasins--the "Upper Basin" and the "Lower Basin," with Lee Ferry as the division point on the river. Lee Ferry, located in Arizona, is a point in the main stem 1 mile below the mouth of the Paria River. For the purpose of this report, the Great Divide Basin, a closed basin in Wyoming, and the White River, also a closed basin, in Nevada have not been considered as part of the Colorado River System since flows from these basins never reach the Colorado River. Diversions from the system to areas outside its drainage area are considered herein as exports and have not been classified by types of use.

Beneficial consumptive use is normally construed to mean the consumption of water brought about by human endeavors and in this report includes use of water for municipal, industrial, agricultural, power generation, export, recreation, fish and wildlife, and other purposes, along with the associated losses incidental to these uses.

The storage of water and water in transit may also act as losses on the system although normally such water is recoverable in time. Qualitatively, what constitutes beneficial consumptive use is fairly well understood; however, an inability to exactly quantify these uses has led to various differences of opinion. The practical necessity of administering the various water rights, apportionments, etc., of the Colorado River has led to definitions of consumptive use or depletions generally in terms of "how it shall be measured." The Upper Colorado River Basin Compact provides that the Upper Colorado River Commission is to determine the apportionment made to each State by "...the inflow- outflow method in terms of manmade depletions of the virgin flow at Lee Ferry...".
There is further provision that the measurement method can be changed by unanimous action of the Commission. In contrast, article l(A) of the decree of the Supreme Court of the United States in Arizona vs. California defines, for the purpose of the decree, "Consumptive use means diversions from the stream less such return flows thereto as are available for consumptive use in the United States or in satisfaction of the Mexican Treaty obligation.". Nearly all the water exported from the Upper Colorado River System is measured; however, the remaining beneficial consumptive use, for the most part, must be estimated using theoretical methods and techniques. In the Lower Colorado River System tributaries to the main stem, similar methods must be employed to determine the amount of water consumptively used.

Reservoir evaporation loss is a consumptive use associated with the beneficial use of water for other purposes. For the purpose of this report, main stem reservoir evaporation is carried as a separate item for the Upper and Lower Basins.

Channel losses within the system are normally construed to be the consumptive use by riparian vegetation along the stream channel (or conveyance route) and the evaporation from the stream's water surface and wetted materials. Seepage from the stream normally appears again downstream or reaches a ground-water aquifer where it may be usable again. A decided lack of data and acceptable methodology, along with the intermittent flow characteristics of many Southwest streams, combine to make a reasonable determination of channel loss difficult. Channel losses have not been estimated for this report within the Upper and Lower Basins.

METHODOLOGY AND DATA ADEQUACY

This report is based almost entirely on data obtained from ongoing programs and current reports. Quantitative measurements of water use were used wherever available, but the majority of the basin water use was theoretically calculated. The following sections describe these calculations for both the Lower Colorado River Main Stem and the Upper and Lower Colorado River Basin tributaries.

Colorado River Basin Tributaries

In the tributary areas of the basin, records of diversions and return flows are not complete enough to allow direct calculation of consumptive water use. Theoretical and indirect methods of estimating consumptive use must then be relied upon. In the New Mexico portion of the Colorado River Basin, the annual consumptive use of water is reported by the New Mexico Interstate Stream Commission. For the Arizona, Colorado, Nevada, Utah and Wyoming portions of the Colorado River Basin, the annual consumptive use of water was estimated using the following methodologies.

Agriculture

The percentages of irrigation consumptive use range between 64 and 70 percent for the Upper Basin tributaries and between 67 and 73 percent for the Lower Basin tributaries. Both percent ranges exclude main stem evaporation. The annual irrigated acreage of most crops grown within each reporting area was estimated from information published in the yearly State Agriculture Statistics, 1987 National Census of Agriculture (since the State statistics do not include pasture land), and from Geographic Information System (GIS) irrigated acreage data available for Colorado, Utah, and Wyoming. The total irrigated acreage values for the Upper and Lower Basins are shown in tables UC-7 and LC-9, respectively.

Since most of these data were presented on a county basis, it was necessary to separate them into smaller reporting areas for computational purposes. This was accomplished

using land inventory maps and relationships developed for the comprehensive framework study.

These subbasins generally follow tributary stream basin and State boundaries. A representative climatic station was selected for each subbasin. Using historical records of temperature, precipitation, and frost dates, a consumptive use rate was computed for each major crop in each of the reporting years. For the purpose of this report, the consumptive use rates were computed using the modified Blaney-Criddle evapotranspiration formula in the version described in the Soil Conservation Service Technical Release No. 21, "Irrigation Water Requirements," revised September 1970. Irrigation consumptive rates were determined by subtracting the effective precipitation from the consumptive use rates. Effective precipitation for the Upper Basin was computed using the Soil Conservation Service method. This method is referenced in "SCS Technical Release No. 21." (It should be noted that this method estimates less effective precipitation than the Reclamation method. Previous reports used the Reclamation method of computing effective precipitation.) The values of irrigation consumptive use rates were applied to the estimates of irrigated acreage to yield the final values of irrigation consumptive use.

An exception to this procedure occurred in the Lower Basin in the "low desert" regions of Arizona where a regionally calibrated Blaney-Criddle formula was used to estimate the crop consumptive use. This departure was based on the research results of Leonard Erie, et al. Seasonal crop consumptive use factors ("K") for the lower elevation desert areas were selected from Conservation Research Report Number 29, “Consumptive Use of Water by Major Crops in the Southwestern United States”, issued May 1982 by the United States Department of Agriculture. Effective precipitation was derived from criteria developed for the area by Wayne D. Criddle, former Utah State Engineer.

These theoretical consumptive use calculations were based on the assumption of full water supply during the crop growing season. However, it is estimated that in an average year, about 37 percent of the irrigated lands in the Upper Basin receive less than a full supply of water, either due to lack of distribution facilities or junior water rights. The degree to which these lands suffer shortages varies widely from year to year, depending in large part on the magnitude of runoff. For this study, an estimate of the short supply service lands was made for each subbasin, primarily on the basis of reports and investigations collected for the comprehensive framework study. A streamflow gauging station was selected within each subbasin and the magnitude of the recessional portion of the annual hydrograph was used as an index to select the date at which consumptive use calculations should be terminated for the short supply lands.

Comprehensive framework studies of the incidental consumptive use of water associated with irrigation indicated that this use varied between 5 and 29 percent of the irrigation consumptive use, depending upon the location of the study area within the Colorado Basin. These percentages were used in the Upper Basin and an average value of 20 percent was used in the Lower Basin to adjust the calculated consumptive use.

The agricultural data is generally adequate for use in this report. Each state prepared annual county irrigated acreage estimates of the harvested crops during the reporting period. These statistics are assumed to be reliable. The irrigated pasture values were

based largely on the 1992 and 1997 National Census of Agriculture in the Lower Basin states since the State statistics do not include pasture land. Because of the length of time between reporting dates, this item needs to be considerably strengthened. In the Upper Basin states, GIS irrigated acreage data were used to estimate irrigated pasture lands. Other areas of agricultural data collection that need to be updated and verified are: (1) the consumptive water use of lands that receive less than a full seasonal supply of irrigation water and the areal extent of these lands, and (2) the amount of incidental seepage and phreatophytic losses associated with irrigation.

Reservoir Evaporation

A comprehensive listing was developed of all reservoirs in the Colorado River Basin which included the latitude, longitude, elevation, and surface area at total capacity for each reservoir.

Monthly content records were obtained for those reservoirs for which records are available. The average annual water-surface area was determined for each year of the reporting period. For those reservoirs lacking records, a "fullness factor" was estimated on the basis of reservoir use and historical hydrologic conditions. These "fullness factors" were then used to obtain estimates of average annual water surface area for the unreported reservoirs. For all of the basin, annual free water surface (FWS) evaporation rates were used to determine reservoir evaporation.

The FWS evaporation value was taken from NOAA Technical Report NWS 33, “Evaporation Atlas for the Contiguous 48 United States”, June 1982, Map 3 of 4 : Annual FWS Evaporation based on the reservoir location information. An account was taken of precipitation and runoff salvage to determine net evaporation rates. The net evaporation rates were applied to the estimates of average annual water-surface area to yield the values of annual reservoir evaporation.

An exception to this procedure was the determination of evaporation from what are called the main stem reservoirs shown in table UC-1. Predetermined average evaporation rates were applied to historical surface areas to yield values of evaporation on a monthly basis.

Ground Water

Currently, all ground-water pumpage is counted as consumptive use charged against the Colorado River Basin. Obviously, this is not necessarily true. Depending on the location and depth of the well and what types of soils are present in the area, it is possible that little or none of the water pumped would have contributed to the Colorado River System for hundreds or even thousands of years. It has recently been proposed that an interagency study team be put together consisting of personnel from various State Engineers Offices, Bureau of Reclamation, and any other pertinent agencies. This study team would establish guidelines for computing what amounts of ground water pumped should be charged against the Colorado River Basin. These guidelines will need to be established on an area by area basis rather than one set percentage for the entire basin. Results of this study will be incorporated in future Consumptive Uses and Losses Reports. However, until these guidelines are established, the Consumptive Uses and Losses Reports will continue to report all ground-water pumpage as depletion from the system.

Currently, the Arizona portion of the Upper Basin is the only part of the basin that reports ground-water pumpage as consumptive use. Although significant ground-water usage occurs in Arizona, Nevada, and New Mexico, for purposes of this report ground-water overdraft has not been taken into account in the computation of tributary consumptive use. It should be noted that present ground-water overdraft in Arizona has been estimated to be approximately 2.2 million acre-feet per year.

Stockpond Evaporation and Livestock

Stockpond surface areas were estimated from the May 1975 Soil Conservation Service (SCS) publication, "Livestock Water Use." The subbasin stockpond areas were subdivided by State and basin using the livestock population distribution. The same procedure used to calculate the unmeasured reservoir evaporation was used to estimate the stockpond evaporation.

Livestock population data was taken from annual State Agriculture Statistics and the 1992 and 1997 Census of Agriculture. Livestock population data included cattle, sheep, horses, and hogs. Consumption rates for the various livestock were derived from various reports, including the SCS publication, "Livestock Water Use," May 1975.

Stockpond and livestock data are adequate to prepare an estimate of this consumptive use. Considering the small amount of water use, any refuting effort would be best spent on the irrigation or evaporation categories.

Mineral Resources

Arizona leads the nation in the production of copper and the net water use for its production represents about 90 percent of the total water use for mineral resources in the Lower Basin. The Upper Basin uses water in the production of numerous minerals in addition to energy-related materials such as oil and natural gas.

Estimates of the water consumptively used were based largely on phone surveys conducted by the U.S. Geological Survey in 1990 and 1995 that quantified water use in the basin. Intermediate years were interpolated between 1990 and 1995. In some cases where, for privacy reasons, companies were unwilling to supply information, information was obtained from the U.S. Bureau of Mines.

Thermal Electric Power

The net use of water for the production of thermal electric energy from the tributaries of the Colorado River Basin was estimated from records obtained from the various power companies in the Basin. These records were complete and were judged to be accurate.

Municipal and Industrial

The basis for estimating municipal and industrial uses was the urban and rural population within the reporting areas. Preparation of annual population estimates was guided by

the 1990 census, various State and county statistical reviews, and reports that included population estimates for local areas. The yearly population estimates for the Upper and Lower Basins are shown in tables UC-8 and LC-10, respectively. Water supply withdrawal for urban, rural, commercial, industrial, and public uses were taken from data collected by the USGS and summarized in “Estimated Use of Water in the United States in 1990", USGS Circular 1081 and “Estimated Use of Water in the United States in 1995", USGS Circular 1200. This information was reported by hydrologic unit and state for 1990 and 1995. The estimates for 1991-94 were computed using a straight-line interpolation between the 1990 and 1995 values.

The population of the Colorado River System, estimated at nearly 5.1 million in 1990, has increased at an annual rate slightly more than 3 percent during this reporting period. A large portion of the population resides within Maricopa and Pima Counties, Arizona, and in Clark County, Nevada. Twenty percent of the Upper Basin and about 10 percent of the Lower Basin population was classified as rural with a significantly smaller per capita use of water. Both the urban and rural areas have the mutual problem of providing an adequate current and future water supply for a growing population in a water-short area. As a result of almost continuous studies concerning these problems, adequate production and effluent records are usually available to adequately assess water use.

Transbasin Diversions

Nearly all the transbasin diversions both out of and into the Colorado River System were measured and reported by the Geological Survey, or local water commissioners and users. The remainder were estimated on the basis of past records and capacity of facilities. Due to the high degree of measurement, this area of basin consumptive use is considered to be quite accurately determined.

Lower Colorado River Main Stem

The annual consumptive use of water from the Colorado River main stem by the States and exports from the system were taken from the Reclamation annual report entitled "Compilation of Records in Accordance with Article V of the Decree of the United States in Arizona vs. California."

Gross evaporation from Lake Mead is estimated by the USGS and published in its annual Water Resources Data reports. Net evaporation from Lake Mead is estimated by subtracting precipitation at nearby Boulder City, Nevada, from the gross evaporation. Net evaporation from Lake Mohave and Havasu and Senator Wash Reservoir was derived from evapotranspiration rates and evaporation factors developed by Dr. Marvin Jensen for the region.

The annual land use, water supply, and water use information being gathered for the operation, maintenance, and administration of the Colorado River main stem below Lee Ferry is believed to be generally adequate in quantity, quality, and extent. These data are under constant review and are being continually upgraded. Studies and programs are in progress to remedy a lack of data on return flows from main stem diversions.

BENEFICIAL CONSUMPTIVE USES AND LOSSES

A summary table of the Colorado River System total annual water uses, 1991 through 1995, by states and water flowing to Mexico is shown on page iv. Tables C-2 through C-6 show on a yearly basis the same information broken down by State, basin, and type of use. Water use within the selected reporting areas is discussed below.

Upper Colorado River Tributaries

Summaries of estimated annual consumptive uses and losses in the Upper Colorado River Basin for each of the reporting years, broken down by State, reporting area, and type of use are shown in tables UC-2 through UC-6.

Estimated main stem reservoir evaporation is shown in table UC-1. Technically, these are not all main stem reservoirs but are reservoirs that participate in the Colorado River Storage Project (CRSP). The Upper Colorado River Commission designates which reservoirs in the CRSP have evaporation losses charged to the State and which have losses charged to the basin as a whole. Reservoirs listed in table UC-1 are those to be charged to the basin as a whole. These reservoir evaporation losses amount to about 10 percent of all Upper Basin losses.

Upper Basin consumptive use varied between 3.4 million and 4.2 million and averaged 3.8 million acre-feet per year for the reporting period, 1991 through 1995. Agricultural uses accounted for about 67 percent of the total Upper Basin consumptive uses and losses. Irrigated acreage fluctuated very little during this period, ranging between 1.51 million acres and 1.65 million acres, and averaged 1.57 million acres per year. Variation in consumptive use during the reporting period was largely due to year-to-year changes in climatic conditions.

Transbasin exports, the second largest Upper Basin use, on the average accounted for 17 percent of Upper Basin total use, showed year by year variation during the reporting period ranging from a high of 868,700 acre-feet in 1993 to a low of 653,700 acre-feet in 1995. Water uses for thermal electric power generation remained fairly constant, averaging about 157,500 acre-feet per year, which represents about 4 percent of consumptive use in the Upper Basin.

Lower Colorado River Main Stem

Table LC-1 shows main stem reservoir evaporation and table LC-3 shows water uses along the lower Colorado River main stem and flood plain including water passing to Mexico. Water passing to Mexico is made up of deliveries in satisfaction of the Treaty,

deliveries made pursuant to Minute No. 242, Gila River flood releases, regulatory waste and anticipatory flood control releases from the main stem. The latter three are combined as excess releases in table LC-3 and for this reporting period totaled slightly more than 4.0 million acre-feet. Over 90 percent of this total was delivered in 1993.

Annual average main stem reservoir evaporation consumed approximately 1.0 million acre-feet.

Transbasin diversions continued to be the single highest consumer. For the current reporting period, as for the proceeding reporting period, transbasin diversions continued to account for approximately 64 percent of the Lower Colorado River main stem depletions.

Lower Colorado River Tributaries

Tables LC-4 through LC-8 show annual water uses within states by tributary and type of use. Lower Basin tributaries consumptive use was estimated to be about 2.9 million acre-feet in 1993, 3.4 million acre-feet in 1995, and 3.6 million acre-feet in 1991. The average for 1991-1995 was approximately 3.3 million acre-feet.

Significant ground-water usage occurs in Arizona, Nevada, and New Mexico. For the purpose of this report, ground-water overdraft has not been taken into account in the computation of tributary consumptive use. Also, tributary channel loss and salvage were not evaluated. However, it should be noted that present ground-water overdraft in Arizona has been estimated to be approximately 2.2 million acre-feet per year.

Consumptive use for the irrigation of crops represents between 67 and 73 percent of the total water use in the Lower Colorado tributary areas. Estimated annual consumptive use for the Lower Basin during the 5-year period averaged about 3.83 acre-feet per acre, varying from approximately 1.1 acre-feet per acre in parts of New Mexico to more than five acre-feet in the western portion of the basin. Estimated crop consumptive use varied considerably from year to year on the basis of climatic conditions, and acreage fluctuations, from a high of 3.1 million acre-feet in 1995 to a low of 2.7 million acre-feet in 1992. Irrigated lands for the reporting period averaged 750,000 acres.

The consumptive use of water for municipal and industrial purposes is estimated to have averaged about 0.8 million acre-feet or 20 percent of the total water use in the Lower Colorado tributary areas over the 1991-95 reporting period.

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