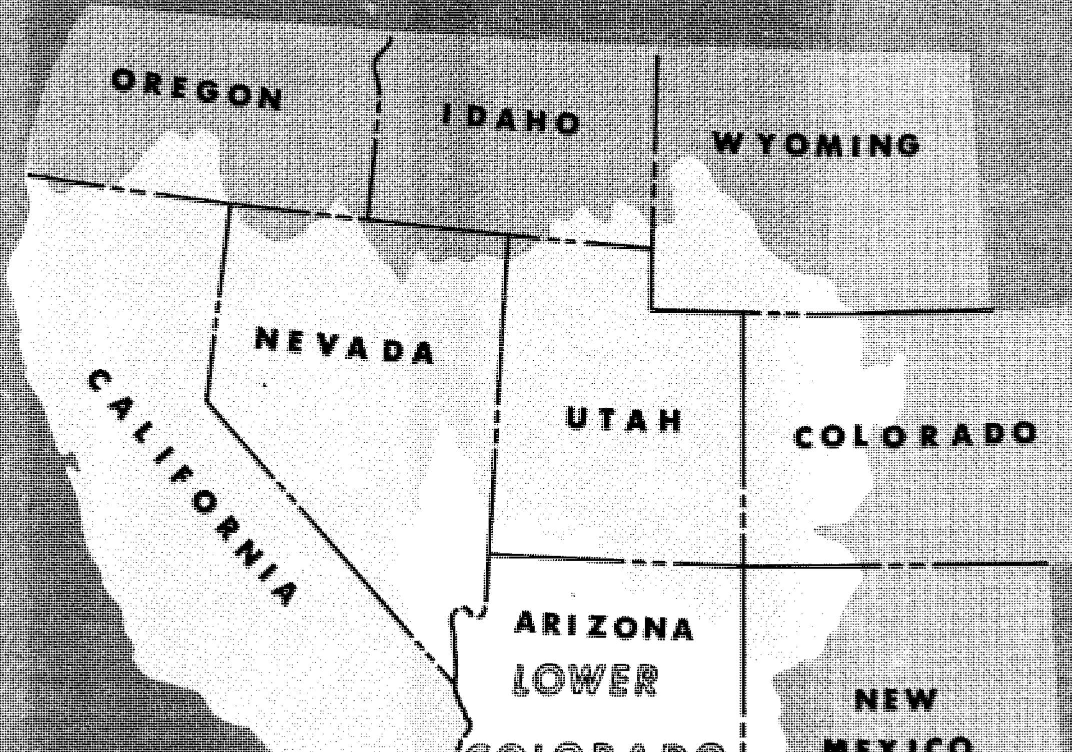
LOWER COLORADO REGION
Comprehensive Framework Study

APPENDIX X
IRRIGATION AND DRAINAGE
JUNE 1971



PREPARED BY:
LOWER COLORADO REGION STATE—FEDERAL
INTERAGENCY GROUP FOR THE
PACIFIC SOUTHWEST INTERAGENCY COMMITTEE

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LOWER COLORADO REGION

COMPREHENSIVE FRAMEWORK STUDY

APPENDIX X

IRRIGATION AND DRAINAGE

This report of the Lower Colorado Region Framework Study State-Federal Interagency Group was prepared at field-level and presents a framework program for the development and management of the water and related land resources of the Lower Colorado Region. This report is subject to review by the interested Federal agencies at the departmental level, by the Governors of the affected States, and by the Water Resources Council prior to its transmittal to the Congress for its consideration.

June 1971

This appendix prepared by the

IRRIGATION AND DRAINAGE WORK GROUP

of the

LOWER COLORADO REGION STATE-FEDERAL INTERAGENCY GROUP

for the

PACIFIC SOUTHWEST INTER-AGENCY COMMITTEE
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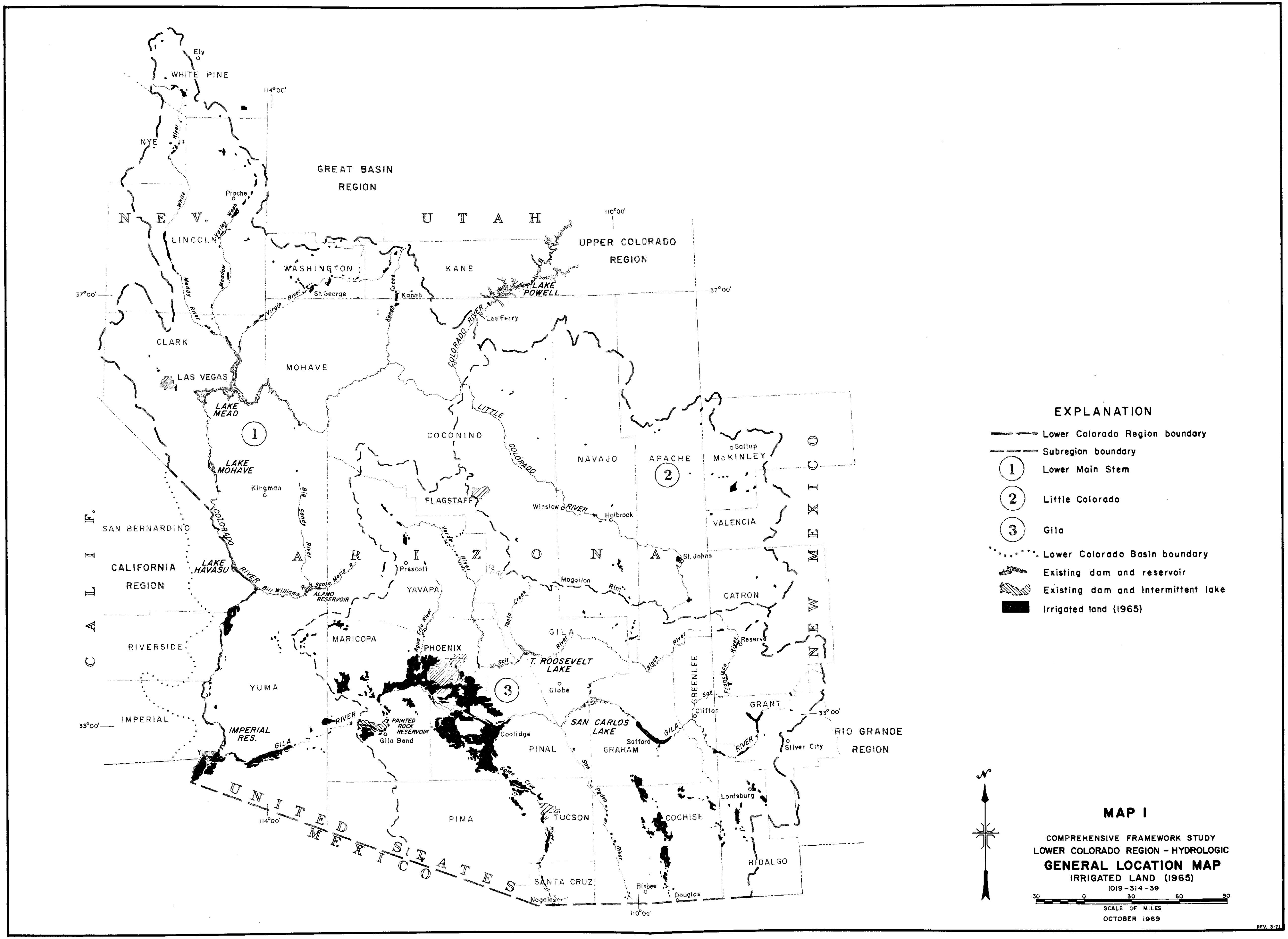

EXPLANATION
Lower Colorado Region boundary
Subregion boundary
1 Lower Main Stem
2 Little Colorado
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Existing dam and intermittent lake
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MAP I
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1019-314-39
30 0 30 60 90
SCALE OF MILES
OCTOBER 1969
GREAT BASIN REGION
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CALIFORNIA REGION
RIO GRANDE REGION
N E V.
U T A H
A R I Z O N A
N E W M E X I C O
C A L I F.
U N I T E D S T A T E S
M E X I C O
WHITE PINE
NYE
LINCOLN
CLARK
WASHINGTON
KANE
MOHAVE
COCONINO
NAVAJO
APACHE
McKINLEY
VALENCIA
CATRON
YAVAPAI
GILA
MARICOPA
YUMA
PINAL
GRAHAM
GREENLEE
GRANT
HIDALGO
COCHISE
PIMA
SANTA CRUZ
SAN BERNARDINO
RIVERSIDE
IMPERIAL
Ely
Pioche
St. George
Kanab
Lee Ferry
LAS VEGAS
LAKE MEAD
LAKE MOHAVE
Kingman
LAKE HAVASU
FLAGSTAFF
Prescott
Winslow
Holbrook
St. Johns
Gallup
PHOENIX
T. ROOSEVELT LAKE
Globe
Coolidge
SAN CARLOS LAKE
Safford
Clifton
Silver City
Lordsburg
TUCSON
Bisbee
Douglas
Nogales
Yuma
IMPERIAL RES.
PAINTED ROCK RESERVOIR
Gila Bend
ALAMO RESERVOIR
LAKE POWELL
COLORADO RIVER
LITTLE COLORADO RIVER
GILA RIVER
Virgin River
Muddy River
White River
Meadow Valley Wash
Kanab Creek
Big Sandy River
Bill Williams
Santa Maria R.
Verde River
Agua Fria River
Salt River
Tonto Creek
Black River
San Francisco River
San Pedro River
Santa Cruz River
Mogollon Rim
Reserve
37°00'
33°00'
114°00'
110°00'

Photo No. P-25-314-1 - Photograph showing typical irrigation operation as practiced in the Lower Colorado Region

SUMMARY OF FINDINGS

Irrigated land is expected to increase from the 1965 level of 1,315,000 acres to 1,613,000 acres by year 2020. Urbanization is expected to remove 204,000 acres from production. The total new irrigation development would be 502,000 acres. The program includes the completion of rehabilitation of existing distribution systems for 429,000 acres of presently irrigated lands and new distribution systems to serve 1,075,000 acres, a portion of which is presently irrigated exclusively by ground water. Drainage facilities are included to serve 188,000 acres.

The expected increase in irrigated land will necessitate development of lands not presently irrigated. A portion of this development will be included in areas that are now developed but idle, while the remainder will encompass new lands.

Augmentation schemes will be required to offset the existing shortages of water and to provide for future uses.

Development needs and costs based on the Modified OBE-ERS projections for the hydrologic area of the Lower Colorado Region are as follow:

Units: 1,000

	1965		1966-1980		1981-2000		2001-2020	
	Needs (ac)	Costs ($)	Needs (ac)	Costs ($)	Needs (ac)	Costs ($)	Needs (ac)	Costs ($)
Drainage								
L.M.S.	210	-	67	13,400	18	3,600	38	7,600
L.C.	-	-	-	-	1	200	1	200
Gila	2	-	1	1,000	13	10,840	49	37,700
Rehab. of Exist. Irrig. Dist. Sys.								
Acreage Served	293	-	429	-	-	-	-	-
L.M.S.	131	-	103	16,700	-	-	-	-
L.C.	2	-	6	970	-	-	-	-
Gila	160	-	320	52,000	-	-	-	-
Develop. of New Irrig. Dist. Sys.	-	-	346.8	-	596.2	-	132.0	-
L.M.S.	-	-	127	39,400	17.2	5,300	34.6	10,700
L.C.	-	-	6.8	2,100	3.0	800	0.4	200
Gila	-	-	213	66,000	576.0	178,000	97.0	29,800
OM&R								
Irrigation								
L.M.S.		-		2,100		2,200		2,380
L.C.		-		220		228		228
Gila		-		7,000		7,480		7,510
Drainage								
L.M.S.		-		277		293		337
L.C.		-		-		7		7
Gila		-		20		220		765

SUMMARY OF FINDINGS (continued)

A comparison of the OBE-ERS and Modified OBE-ERS for the projected Irrigated Area, Crop Irrigation Requirement, Diversion Requirement and Irrigation Development is shown in the following tabulation:

OBE-ERS

	1965	1980	2000	2020
Irrigated Area (1,000 ac)	1,315	1,374	1,414	1,449
Lower Main Stem	(293)	(288)	(321)	(345)
Little Colorado	(28)	(21)	(22)	(22)
Gila	(994)	(1,065)	(1,071)	(1,082)
Crop Irrigation Requirement (1,000 ac-ft)		4,348	4,373	4,430
Lower Main Stem		(996)	(1,088)	(1,152)
Little Colorado	(51)	(42)	(43)	(43)
Gila	(3,008)	(3,310)	(3,242)	(3,235)
Diversion Requirement (1,000 ac-ft)		8,730	7,678	7,603
Lower Main Stem		(2,264)	(2,134)	(2,086)
Little Colorado	(137)	(95)	(85)	(79)
Gila	(6,319)	(6,371)	(5,495)	(5,438)
Irrigation Development				
Lower Colorado Region (1,000 ac)		123.7	116.5	133.8
Lower Main Stem		(25.8)	(36.1)	(29.3)
Little Colorado		(0.5)	(0.4)	(0.4)
Gila		(97.4)	(80.0)	(104.1)

Modified OBE-ERS

	1965	1980	2000	2020
Irrigated Area (1,000 ac)	1,315	1,458	1,549	1,583
Lower Main Stem	(293)	(330)	(343)	(373)
Little Colorado	(28)	(34)	(36)	(36)
Gila	(994)	(1,094)	(1,170)	(1,174)
Crop Irrigation Requirement (1,000 ac-ft)		4,585	4,748	4,812
Lower Main Stem		(1,138)	(1,160)	(1,243)
Little Colorado	(51)	(62)	(66)	(66)
Gila	(3,008)	(3,385)	(3,522)	(3,503)
Diversion Requirement (1,000 ac-ft)		9,244	8,338	8,260
Lower Main Stem		(2,586)	(2,276)	(2,251)
Little Colorado	(137)	(141)	(129)	(120
Gila	(6,319)	(6,517)	(5,933)	(5,889)
Irrigation Development (1,000 ac)				
Lower Colorado Region		199.9	168.4	132.0
Lower Main Stem		(67.0)	(17.2)	(34.6)
Little Colorado		(6.3)	(1.6)	(0.4)
Gila		(126.6)	(149.6)	(97.0)

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INTRODUCTION

CHAPTER A - INTRODUCTION

Purpose and Scope

The purposes of the Irrigation and Drainage Appendix are to:

1. Identify the presently irrigated land and those lands suited for irrigation development in the Lower Colorado Region;

2. Tabulate the projected acreage of irrigated land required to satisfy the projected production requirements for food and fiber in the Lower Colorado Region for the years 1980, 2000, and 2020;

3. Assess the water needed to provide the irrigation water requirement for the projected acreage;

4. Assess the problems associated with present and future irrigation development and recommend possible solutions.

5. Identify the present and projected drainage problems.

6. Estimate the projected costs required to satisfy the needs and demands for irrigation and drainage.

This appendix summarizes the irrigation and drainage data for the three Subregions within the hydrologic boundaries, along with a Regional summary. The appendix has been divided into the following chapters:

Chapter A - Introduction--This chapter contains a brief discussion of the appendix, its purpose and scope, methodology, definitions, and history of the Region.

Chapter B - Present Status of Irrigation--This chapter contains a summary of the presently irrigated acreage by source and adequacy of the water supply, water requirements, and the contribution of the irrigated lands to the economy of the Region. This chapter also contains information on characteristics of the irrigated farms, crop production, value of products, and other benefits attributable to irrigation.

Chapter C - Irrigation Potential--This chapter contains a discussion, with maps and tables of land suited for irrigation and the associated water requirements that would be needed if these lands were irrigated.

Chapter D - Future Demands--This chapter contains projections of future irrigation developments for the years 1980, 2000, and 2020 based on a modification of the OBE-ERS projections. Additional data developed in this section include the water requirements for these developments and a description of the irrigation development as it pertains to the Lower Colorado Region.

Chapter E - Summary--This chapter presents summarized data on the OBE-ERS projections and relates this information to the Modified OBE-ERS plan of development.

Methodology and Definitions

One of the basic factors considered in Appendix X was the inventory of land resources of the Region to determine the total irrigated and potentially irrigable acreage. This was accomplished as a joint effort of several Federal agencies and appropriate States.

Presently irrigated land was inventoried for the base year 1965. By definition, irrigated land is land receiving water by artificial means for agricultural and recreational use purposes. Responsibility for inventorying irrigated acreage in the Region was assigned to the Irrigation and Drainage Work Group. Information was obtained from Federal and State agencies and these data were used directly or interpreted and adjusted to show their suitability for irrigation development.

Land suited for irrigation is land having soil, topography, and drainage conditions suitable for irrigation development. It may or may not be located where a water supply is or can be made available at costs presently conducive to development.

Studies concerning water utilization and irrigation practices were made in cooperation with appropriate Federal and State agencies. Data from all available sources were utilized and adjusted to Regional, State, and Subregional boundaries for the 1965 level of development. Crop consumptive use, crop irrigation requirements, farm delivery requirements, and diversion requirements were determined on the basis of the Blaney-Criddle Method, utilizing the latest available data on seasonal crop coefficients for the Lower Colorado Region. Irrigation requirements for the base year (1965) were based on farm efficiencies averaging 50 to 60 percent with deep percolation and surface waste taken into consideration. Projected efficiencies of 60 to 70 percent were based on the premise that distribution systems be constructed with impervious linings or enclosed in pipelines and other measures discussed later in this appendix. Specific information or details are available as supporting data.

Definitions pertaining to water utilization for irrigation as used in this appendix are listed below.

Land with a full supply is land with sufficient water available to satisfy the optimum water consumption requirements of crops produced.

Surface sources of water include streams, lakes, reservoirs, and drainage ditches. Ground-water sources relate to wells (pumped or flowing) and water taken directly from springs.

Water quality is a term used to describe the chemical and physical characteristics of water regarding its suitability for irrigation.

Drainage, as it pertains to irrigation, is the act, process, or mode of relieving lands of excess water and salt. Drainage water which has been collected by a drainage system may derive from surface water or from water passing through soil and may be of a quality suitable for reuse, or it may be of no further economic use at the time and place of its occurrence, therefore, is considered to be waste water.

Crop irrigation requirement for purposes of this study, is the amount of water required at the crop root zone to satisfy the optimum water consumption requirements of the crop. This requirement is based on the gross consumptive use less effective precipitation.

Farm delivery requirement, is the crop irrigation requirement divided by the farm efficiency based on present (1965) farm practices when farm efficiencies averaged between 50 and 60 percent. Leaching was not considered in the development of farm efficiencies, since deep percolation losses are considered adequate to meet leaching needs for most areas within the Region under existing water quality.

Diversion or withdrawal requirement was determined by dividing the farm delivery requirement by the weighted distribution system efficiency. This requirement was also based on the availability of a full water supply to meet optimum conditions.

Reference to OBE-ERS pertains to the Office of Business Economics, Department of Commerce, and the Economic Research Service, Department of Agriculture.

The section pertaining to the economic aspects of irrigated lands in regard to crop production, value of the products, and other benefits generated by irrigation, including economic projections of the Region's agricultural requirements for allocating future irrigation development, was prepared by the Economics Work Group, in cooperation with other Work Groups, Federal, and State agencies. Projections pertaining to the economic structure of the Region, as characterized by population, employment, personal income, gross output, and gross regional product, were made on the basis of county data which were aggregated so as to approximate the hydrologic Region and Subregions. Irrigation and drainage requirements were then projected, based on functional needs for food and fiber production derived from the economic projections. Data pertaining to characteristics of irrigated farms, livestock numbers, and value of crops, livestock, and livestock products were derived from U. S. Census of Agriculture, 1964, for the base year 1965. These data are for economic Subregions and Region.

Relationship to Overall Study

The Irrigation and Drainage Appendix is one of 12 appendixes to the Main Report providing basic data pertaining to water and related land development, use, or management. It presents a plan of analysis of the present situation and future requirements for irrigation and drainage to meet production requirements for food and fiber for the years 1980, 2000, and 2020. Combined with the other appendixes, it provides the data required for the formulation of framework plans and preparation of the Main Report.

Description of the Region

The Lower Colorado Region with an area of approximately 141,000 square miles includes most of Arizona and parts of southeastern Nevada, southwestern Utah, and western New Mexico. Geographically, it includes all drainage into the Colorado River below Lee Ferry, Arizona, except those in California and Mexico; several closed basins in Arizona, Nevada, and New Mexico; and some drainage basins in southern Arizona that flow into Mexico. Physiographically, the Region is comprised of (1) the Basin and Range Province and (2) the Colorado Plateau Province. The first is a hot and arid area of lower elevations containing a series of northwest-trending mountain ranges, intervening basins, and deserts. The geographic dividing line between the Basin and Range and the Colorado Plateau Province is the Mogollon Rim, an escarpment traversing central Arizona, and a series of other minor escarpments running from the head of Lake Mead, impounded by Hoover Dam, in a southeasterly direction to the Continental Divide in western New Mexico.

The Colorado Plateau Province which occupies the north and northeastern part of the Region is characterized by alternating cliffs and slopes. The entire province is drained by one master stream, the Colorado River.

The Region has been divided into three Subregions: (1) Lower Main Stem, (2) Little Colorado, and (3) Gila.

The Lower Main Stem Subregion, with approximately 50 organized irrigation districts and canal companies, encompasses a total of 56,544 square miles between Lee Ferry, Arizona, and Mexico, and includes western Arizona, a portion of southern Nevada, and the southwest corner of Utah.

The flow of the Colorado River within the Subregion is essentially controlled by Lake Mead (Hoover Dam) and by major reservoirs constructed as part of the Colorado River Storage Project.

Regulated releases from Lake Mead have provided the means for successful land development within the lower desert reaches of the Subregion.

Of the 1.7 million acre-feet of annual surface-water diversion for irrigation purposes within the Subregion, over 80 percent is for use along the river in Yuma County, Arizona. The three major surface-water diversions within this area are for the Yuma and Gila Projects and the Colorado River Indian Irrigation Project.

There are approximately 40 irrigation districts and canal companies serving agricultural lands in southern Nevada and Utah. These districts divert waters from the Muddy River system in Nevada, and the Virgin River system which drains portions of Nevada, Arizona, and Utah. Other tributaries with minor surface-water diversions within the Subregion include Kanab and Havasu Creeks and the Bill Williams River.

The Little Colorado Subregion with the Little Colorado River within its boundaries drains approximately 26,970 square miles in northeastern Arizona and northwestern New Mexico. The river rises on the north slopes of the White Mountains approximately 20 miles south of Springerville, Arizona, and flows in a general northwesterly direction to its junction with the Colorado River on the east boundary of Grand Canyon National Park. The Little Colorado River contributes an average of 0.42 million acre-feet annually (1914-1965) to the Colorado River. Nearly 40 percent of this supply is from the Blue Spring area located near the mouth of the river, however, this water is of a high saline content which significantly contributes to the Colorado River salinity problem.

Within the Little Colorado Subregion there are 13 organized irrigation districts and canal companies which use surface water as their major source of irrigation water supply. Five of these water users are located along the Little Colorado River in Arizona.

The Gila Subregion has approximately 80 irrigation districts and canal companies within its boundaries; and drains approximately 57,606 square miles in central and southeastern Arizona and southwestern New Mexico, bordering Mexico on the south and the Continental Divide on the east. Streams in the upper Gila River and Salt River systems are the most productive of the entire Lower Colorado Region, with many tributaries having perennial flows. Practically all the Subregion surface-water supplies originate from these upper watershed areas. The Salt River watershed in Arizona produces nearly 70 percent of the total Subregion surface-water irrigation diversions within the Subregion, over 85 percent is used in the central basin of Arizona. Major surface-water diversions within the central Arizona area are for the Salt River Project service area in the Phoenix area, and the San Carlos Project service area along the Gila River in Pinal County.

History and Background

The large-scale practice of irrigation in the Lower Colorado Region can be traced back to the Hohokam Indians who developed an impressive system of irrigation canals and a culture, about 300 B.C., capable of supporting a sizeable population. Faint evidences of these canal routes still exist.

The Spanish explorers of the mid-16th Century found the Indians in the southwest irrigating their land by diversions and canal systems. These explorers were followed by missionaries who reportedly aided the Indians by giving them new varieties of grain and vegetables. The first canal constructed in the Lower Colorado Region that started the present development was completed in March 1868 by Jack Swilling, a visionary of that period.

During the period 1880 to 1910, agriculture and associated industries expanded rapidly but spasmodically. The history of irrigation was one of alternate prosperity and failure.

The need for impounding runoff and sediment in the upper reaches of the watersheds for preventing flood damage and maintaining a continuous flow of irrigation water was recognized. After much effort, sufficient national attention to these problems was generated in the United States Congress to allow enactment of the Federal Reclamation Act of June 17, 1902. This legislation provided for the ultimate construction of the Salt River Project, as well as several other projects in the Region.

Between 1920 and 1930 several irrigation districts were organized. Although most of the irrigation organizations were established in the early 1920's, limited additional acreage was brought under irrigation until the latter part of the decade when electricity became more available. Ground-water pumping in the area began increasing about 1935. Instrumental factors in this increase were the advent of the deep turbine pump, the availability of lower cost power, and the substantial recovery of farm prices.

The increase in well drilling and the concurrent increase in pumping created concern over the gradual but continual lowering of the water table; however, no law or code existed to regulate well drilling and ground water was needed and therefore used to supplement the inadequate surface-water supply.

The period from 1946-1953 was one of increasing crop acreage, increasing water costs, and a definite overdraft of the reserve ground-water resources. Years of subnormal rainfall reduced the supply of surface water available for irrigation, thereby creating a need for additional water from the ground-water reservoirs. This shortage of water also prompted State legislatures in the Lower Colorado Region to enact legislation governing the extraction of water from underground supplies.

The period 1953-1965 was a leveling off period in which agriculture remained fairly stable with no significant increase in acreage.

PRESENT STATUS OF IRRIGATION

CHAPTER B - PRESENT STATUS OF IRRIGATION AND DRAINAGE

GENERAL

Agriculture

It is estimated that in 1965 approximately 1,530,000 acres were developed for irrigation in the Lower Colorado Region, of which about 1,190,000 acres were actually irrigated with 125,000 of these acres producing more than one crop in 1965. Approximately 370,000 acres of developed lands are currently out of production because of several factors including deficient water supplies, poor water quality, uneconomic pumping costs, and idle land developed for irrigation within urban areas. The locations of irrigated areas as of 1965 are shown on the General Map, Map No. 1 (Frontispiece).

About 77 percent of the irrigated lands are located in the Gila Subregion, and include large organized irrigation developments in Maricopa, Pinal, and Pima Counties in the central basin of Arizona. Most of the Region's remaining irrigation development (about 20 percent) is in the Lower Main Stem Subregion, which covers the western portion of the Region. The Little Colorado Subregion, which occupies northeastern Arizona and northwestern New Mexico, contains less than 3 percent of the Region's irrigated area. Although the Lower Colorado Region covers portions of southern Nevada and Utah and western New Mexico, about 94 percent of all irrigated lands are located within the State of Arizona. The distribution of these irrigated lands is given in table 1 and shown on Maps Nos. 2, 3, and 4.

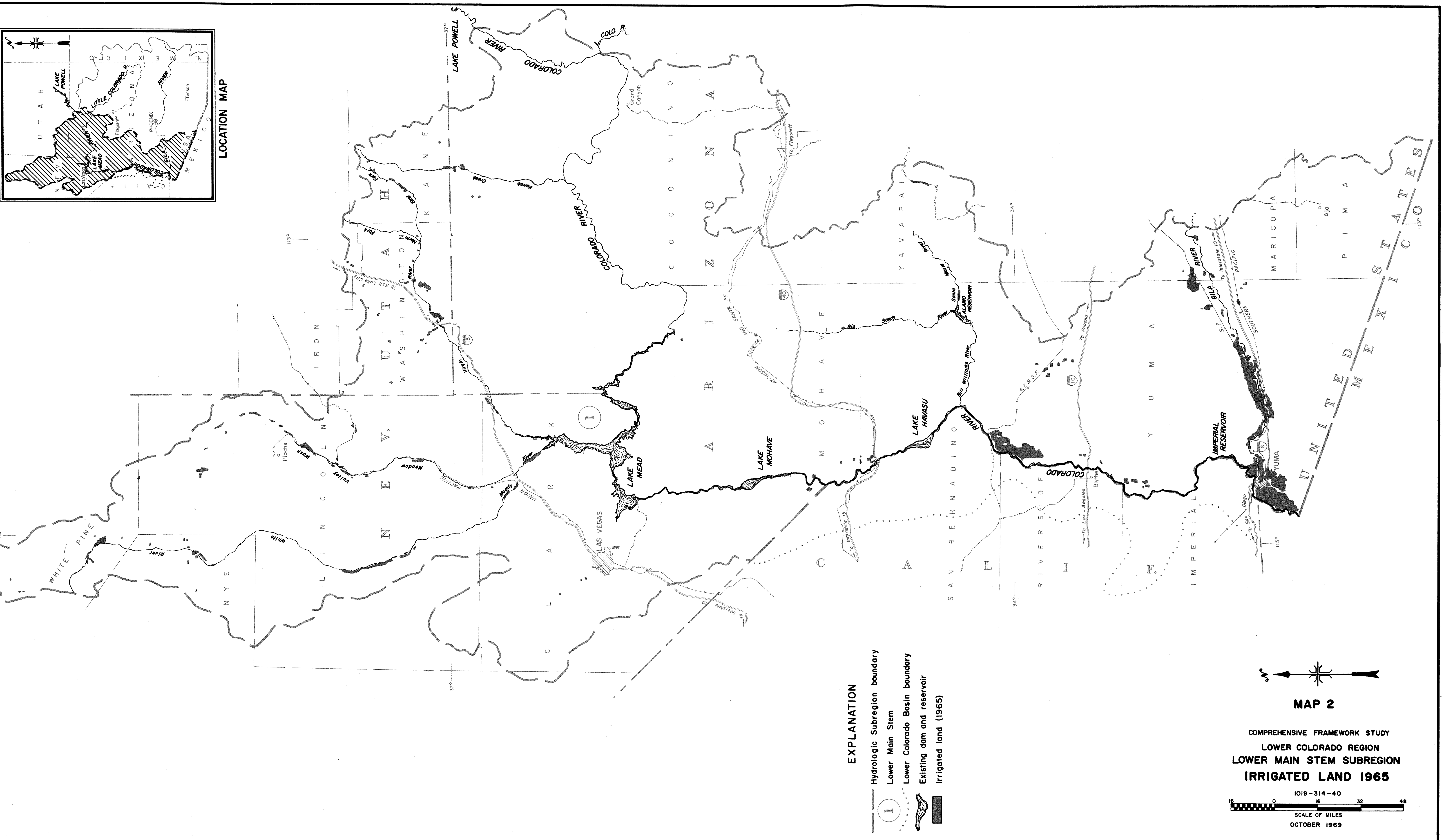
Table 1

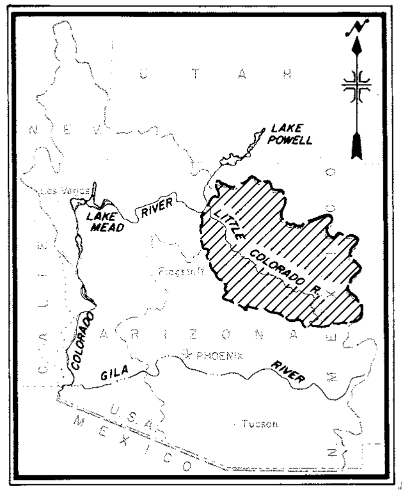
Total Irrigated Acres--1965 1/

Hydrologic Areas	Total (1,000 ac)
Subregion 1 (Lower Main Stem)	293
Arizona	(223)
Nevada	(49) 2/
Utah	(21)
Subregion 2 (Little Colorado)	28
Arizona	(22)
New Mexico	(6)
Subregion 3 (Gila)	994
Arizona	(961)
New Mexico	(33)
Total Region (Acres) 1/	1,315

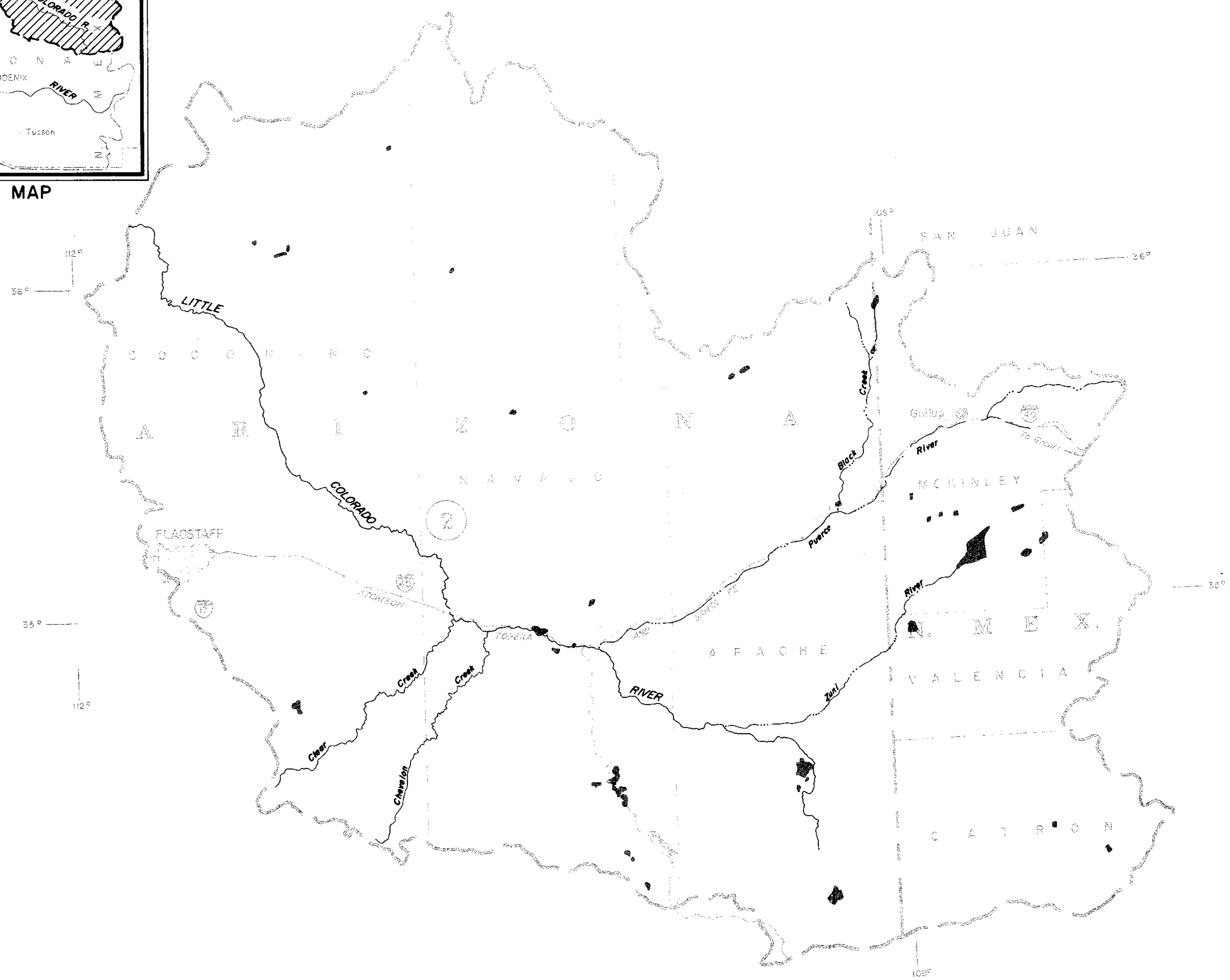
1/ Includes double cropping and failures.

2/ Includes 30,000 irrigated acres located on the White River system in White Pine, Nye, and Lincoln Counties; on Meadow Valley Wash in Lincoln County; and Jakes Valley in White Pine County.


MAP 2
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
LOWER MAIN STEM SUBREGION
IRRIGATED LAND 1965
1019-314-40
SCALE OF MILES
OCTOBER 1969
REV. 3-71
EXPLANATION
Hydrologic Subregion boundary
Lower Main Stem
Lower Colorado Basin boundary
Existing dam and reservoir
Irrigated land (1965)
LOCATION MAP
LAKE POWELL
COLORADO RIVER
LAKE MEAD
LAKE MOHAVE
LAKE HAVASU
IMPERIAL RESERVOIR
ALAMO RESERVOIR
GILA RIVER
Bill Williams River
Big Sandy River
Virgin River
Muddy River
White River
LAS VEGAS
YUMA
Blythe
Pioche
NEVADA
UTAH
ARIZONA
CALIFORNIA
UNITED STATES
MEXICO



LOCATION MAP



EXPLANATION

Hydrologic Subregion boundary

(2) Little Colorado

Irrigated land (1965)

MAP 3

COMPREHENSIVE FRAMEWORK STUDY

LOWER COLORADO REGION

LITTLE COLORADO SUBREGION

IRRIGATED LAND 1965

1019-314-41

16 0 16 32 48

SCALE OF MILES

OCTOBER 1969

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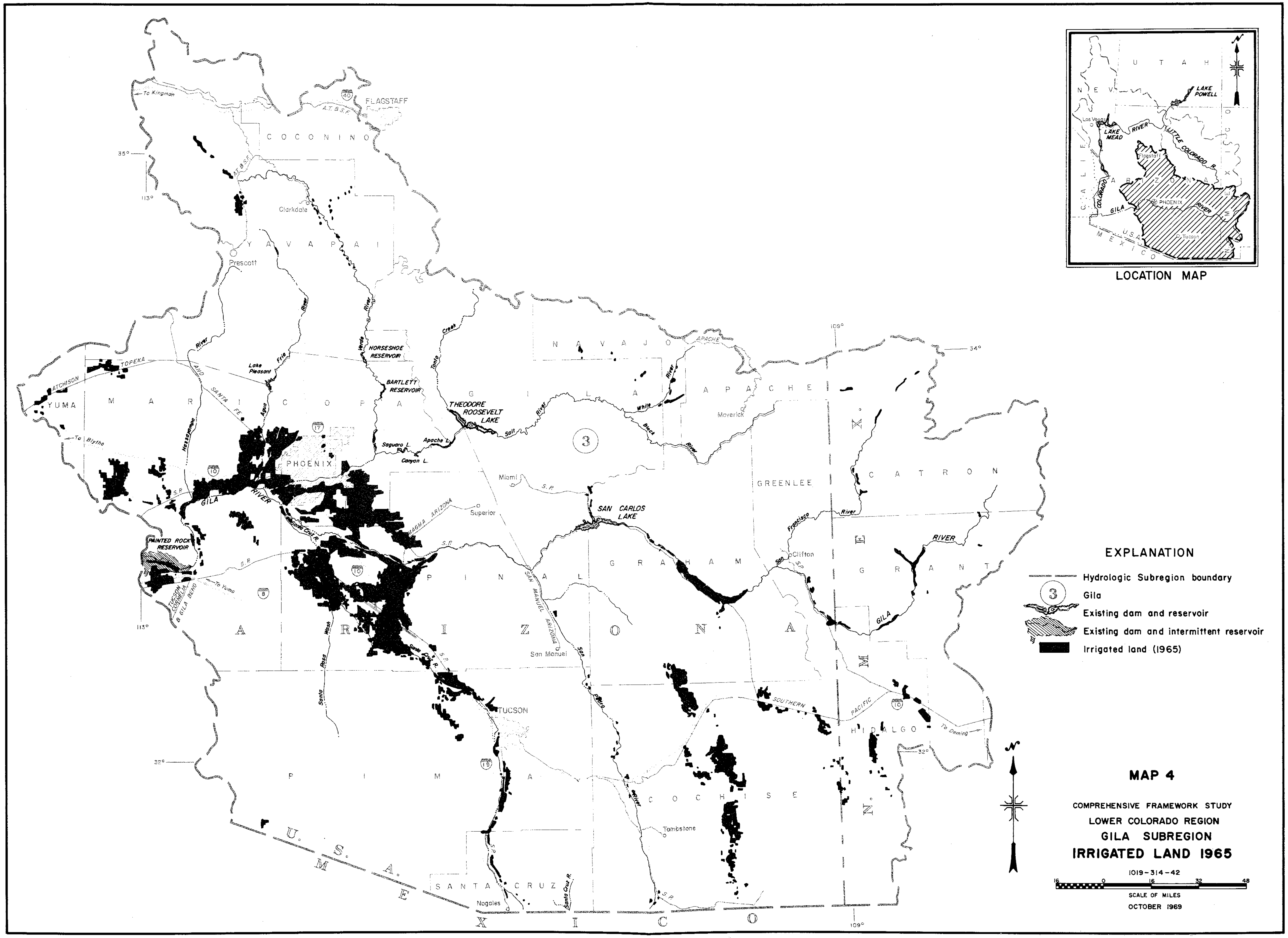

MAP 4

COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
GILA SUBREGION
IRRIGATED LAND 1965

1019-314-42

SCALE OF MILES

OCTOBER 1969

The long growing season available for portions of the Gila and Lower Main Stem Subregions allows double cropping of barley, forage crops, sorghum, and vegetables to increase total crop production. Of the 1,315,000 acres cropped in 1965 approximately 125,000 acres were double cropped. The ability to produce more than one crop in a year gives this area a unique advantage over many other irrigated sections of the United States.

About 90 percent of the total harvested acreage within the Region was accounted for by seven major crops. The following tabulation indicates these crops as a percentage of the harvested acreage.

Table 2--Major Crops - 1965

Crop	Acreage	Percent of Harvested Acreage
Alfalfa	207,880	18
Barley	170,230	15
Citrus	38,975	4
Cotton	344,810	31
Pasture	91,514	8
Sorghum	186,055	17
Vegetables	74,604	7

Major Bureau of Reclamation projects within the Region include the Salt River Project located in the Gila Subregion, and the Yuma and Gila Projects located within the Lower Main Stem Subregion. The Bureau of Indian Affairs has developed the Colorado River Indian Irrigation Project located in the Lower Main Stem Subregion and the San Carlos Project located in the Gila Subregion.

Within the Region there are approximately 140 irrigation districts and canal companies which encompass the majority of the irrigated lands.

Recreation and Fish and Wildlife

Lands irrigated for recreational use and production of crops for wildlife are about 2 percent of the total irrigated land in the Lower Colorado Region. Crops irrigated for wildlife use are estimated at about 1,300 acres and, except for minor acreage in New Mexico, are located in the Lower Main Stem Subregion.

Recreational lands consisting mainly of golf courses and miscellaneous city, State, and Federal parks are estimated at about 25,000 irrigated acres.

The irrigated pastureland used to board the show, racing, and riding horses is also recreation-oriented. The number of these animals is estimated to be 30,000 within the Region at the present time (1965).

Source of Water Supply

Surface--Early irrigation of arid lands in the Lower Colorado Region began with surface-water developments along the Virgin, Colorado, Gila, Salt, and Little Colorado River systems. However, by the 1930's essentially all the surface-water supplies within the Gila Subregion and Little Colorado Subregion, except for Clear and Chevelon Creeks and Blue Spring, had been appropriated for use so that further development was dependent upon ground water.

Of the 1,315,000 irrigated acres within the Region in 1965, only about 19 percent, or 250,000 acres, depend entirely on surface waters. The majority of these lands are within the Lower Main Stem Subregion, and include some irrigated lands in southwestern Utah, southeastern Nevada, and the irrigation developments along the Lower Colorado River.

Other small organized land developments with surface supplies are found throughout the upper Gila and Little Colorado River systems, most of which were developed for irrigation between 1890 and 1920. These are areas with decreed surface-water rights. With the exception of the San Carlos Project and the Salt River Indian Reservation, practically all irrigation on Indian reservations in the Gila and Little Colorado Subregions are supplied by diverting sporadic surface flows from minor tributaries. The total Indian lands irrigated each year varies depending upon the surface-water supply. The San Xavier, Chuichu, and Gila Bend Reservations depend entirely on ground water, while the San Carlos and Gila River Reservations depend partially on ground water for irrigation.

Within the Region almost two-thirds of all irrigated lands originally developed with surface-water supplies have been supplemented by pumped ground water. Currently there are approximately 418,000 acres of irrigated land, on which ground water is used to supplement surface-water supplies. A majority of the developed lands with supplemental ground-water supplies are found within the central basin of Arizona (Gila Subregion).

Ground Water--Since 1940 substantially all new irrigated land development in the Region has been supplied by pumping ground water excepting lands developed with Colorado River water. Under 1965 conditions over 47 percent of the total irrigated acreage was entirely dependent on ground water. Most of this development has taken place in the warmer southern desert area of the Region. Within Central Arizona about one-half million acres of land have been developed with ground-water supplies. Almost all of these developments pump far in excess of the recharge rate. In the south central Arizona area alone, annual ground-water levels are presently declining 1/ on an average of 8 to 10 feet per year and is believed to be the principal cause of land subsidence which has occurred in many areas. Several thousand acres of land that were developed for irrigation by ground water within central Arizona have gone out of production because of the decreased yield of the ground-water supply or high pumping costs.

Irrigated lands (1965 condition) within the Lower Colorado Region, tabulated by source of water supply are shown on table 3.

Table 3--Irrigated Acres by Water Source--1965

Hydrologic Area

Unit: 1,000 acres

Subregion	Total Irrigated Acres	Irrigated Lands by Water Source: Surface	Ground	Surface and Ground
Lower Main Stem	293	249	38	6
Arizona	(223)	(194)	(23)	(6)
Nevada	(49)	(36)	(13)	(0)
Utah	(21)	(19)	(2)	(0)
Little Colorado	28	16	4	8
Arizona	(22)	(10)	(4)	(8)
New Mexico	(6)	(6)	(0)	(0)
Gila	994	15	576	403
Arizona	(961)	(9)	(554)	(398)
New Mexico	(33)	(6)	(22)	(5)
Total Region (acres)	1,315 2/	280	618	417

1/ See Appendix V for map on ground-water decline due to pumping.

2/ Includes 125,000 acres double cropped.

Irrigation Practices

The long history of the scarcity of water and the increasing costs of pumping water have made the agricultural industry look critically at water management. Although much has been accomplished in efficient use of water supplies, the full potential has not yet been realized.

Within the boundaries of the Lower Colorado Region, some of the most modern techniques of water application are utilized. These include computers, remote control, telemetering, automatic gate operation, and other forms of irrigation system automation.

Table 4 indicates the type and quantity of some of the irrigation facilities and conservation measures that have been installed on the land as of 1965. As the table indicates, there has been a great deal of emphasis on good water management. The 7,377 miles of irrigation ditch lining, canal lining, and irrigation pipelines have considerably reduced the seepage loss.

Nearly 245,000 water-control facilities have been installed in the Lower Colorado Region. These facilities include major storage reservoirs, diversion dams, tailwater recovery facilities, pumping plants, and other water-control structures designed for better management in an irrigation system.

In many areas of the Lower Colorado Region, especially the Gila Subregion, ground water and surface water are incorporated in the same system. This allows a flexible operation as the pumps can be regulated to minimize system waste.

The following is an estimate of the percentage of land in the hydrologic Subregion irrigated by border, furrow, and sprinkler methods in the Lower Colorado Region.

Method	Subregion Lower Main Stem (%)	Little Colorado (%)	Gila (%)
Border	44	30	44
Furrow	55	70	54
Sprinkler	1	--	2

Table 4

Lower Colorado Region

Irrigation and Drainage Practices and Measures 1/

1965

Hydrologic Subregion

Practice or Measure	Unit	Lower Main Stem	Little Colorado	Gila	Total
Irrigation Water Storage Facilities	number	342	35	624	1,001
Irrigation Ditch and Canal Lining and Irrigation Pipeline	mile	955	28	6,394	7,377
Water Control Facilities (Diversion Dams, Pumping Plants, etc.)	number	94,069	4,160	146,483	244,712
Irrigation Water 2/ Management	acre	80,000	5,120	147,200	232,320
Land Leveling and Smoothing	acre	151,040	14,720	558,720	724,480
Tile Drains	mile	150	--	2	152
Tile System Structures (wells, etc.)	number	37	--	--	37
Drainage Ditch	mile	155	--	--	155

1/ Does not include all practices and measures that have been applied.

2/ The use and management of irrigation water--where the quantity of water used for each irrigation is determined by the moisture-holding capacity of the soil, the need of the crop, and where the water is applied at a rate and in such a manner that the crops can use it efficiently and significant erosion does not occur.

While there has been a slight increase in sprinkler systems in the Region, the emphasis is for more effective use of surface applications. Better water management and reduction of costs are main concerns of the irrigation farmer. Due to the high evaporation loss, sprinkler systems are not utilized as extensively as other systems in the Region.

Border irrigation is used for close growing crops, some row crops, and orchards where topography and soils are suitable. The three types of border irrigation are level, graded, and guide.

Furrow irrigation is used throughout the Region with about one-half of the acreage in the Gila and Lower Main Stem irrigated by this method. Furrow irrigation is used for nearly all row crops and is adaptable to great variations in land slopes and soil textures.

Corrugation irrigation is included in the furrow irrigation percentages. It is similar to furrow irrigation except that corrugations usually are smaller and closer together. This method is frequently used with borders when steep slopes and slow intake soils are encountered. The corrugations are used for irrigating close growing crops, such as hay and small grains. It is one of the least expensive irrigation methods to install.

Subirrigation is used on a very small acreage of the Lower Colorado Region.

In the Gila Subregion sprinklers are generally located in the area south of Tucson and Willcox. There are a few scattered throughout the remainder of the Region.

Use of Water for Irrigation

Diversions

The principal use of water within the Lower Colorado Region is for agricultural purposes. There are three sources of water supply: (1) Colorado River inflow from Upper Colorado Region, (2) streamflow originating within the Region, and (3) local ground-water reservoirs.

The current annual irrigation withdrawal in the Region is estimated as nearly 7.8 million acre-feet, representing an average gross diversion of over 6 acre-feet per irrigated acre. Annual irrigation withdrawals with the exception of the Phoenix-Casa Grande, Arizona, area and along the Colorado River average from 3 to 4 acre-feet per acre. About 62 percent of the present total irrigation withdrawal is supplied from ground-water pumpage.

The distribution by Subregion and States of the average annual surface diversion and ground-water pumping for irrigation purposes are shown below.

Table 5

Estimated Water Withdrawals for Irrigation - 1965

	Units: 1,000,000 ac-ft		
	Surface	Ground	Total
Subregion 1 (Lower Main Stem)	1.83	0.44	2.27
Arizona	(1.62)	(0.39)	(2,01)
Nevada	(0.12)	(0.04)	(0.16)
Utah	(0.09)	(0.01)	(0.10)
Subregion 2 (Little Colorado)	0.05	0.06	0.11
Arizona	(0.04)	(0.06)	(0.10)
New Mexico	(0.01)	--	(0.01)
Subregion 3 (Gila)	1.13	4.26	5.39
Arizona	(1.09)	(4.19)	(5.28)
New Mexico	(0.04)	(0.07)	(0.11)
Total	3.01	4.76	7.77

A large percentage of the 1,190,000 acres of irrigated land within the Region has an adequate water supply at the present time; however, this is not a firm supply as most of the diversions are from ground water and much of that is dependent on overdrafting the ground-water reserves.

The present (1965) use and diversion of essentially all surface water for irrigation within the Region is regulated by water right decrees. These decrees are (1) the Supreme Court Decree (Colorado River Water) of March 9, 1964, (2) the Gila Decree (Globe Equity No. 59) of June 29, 1935, (3) the Kent Decree (Salt and Verde Rivers) of March 1, 1910, (4) the Norviel Decree (Little Colorado River) of April 29, 1918, (5) the San Simon Creek Decree (New Mexico) of July 9, 1965, and five decrees in Utah. Other decrees, such as the Gila River System Decree of August 23, 1967, and the San Francisco River System Decree of May 9, 1968, also control the use and diversion of all surface and ground water, except for uses on certain Federal reservations.

The significance of these decrees is that they have established the priorities and water rights for a major portion of the appropriated surface-water supplies used for irrigation purposes within the Lower Colorado Region. More detailed information on these decrees may be found in the Legal and Institutional Appendix.

Lake Mead (Hoover Dam), together with major reservoirs constructed as part of the Colorado River Storage Project, almost completely controls the surface flow of the Colorado River within the Lower Main Stem Subregion. Lake Mead has a multipurpose storage capacity of nearly 30 million acre-feet, which in addition to providing conservation of water for irrigation also provides important flood protection and river regulation, conservation of water for M&I uses, generation of electrical energy, important outdoor recreation, and preservation of fish and wildlife. Regulated releases from Lake Mead have provided the means for successful land development within the lower desert reaches of the Subregion.

The three major surface-water diversions within this area are for the Yuma and Gila Projects and the Colorado River Indian Irrigation Project. Organized water users in the Yuma area include the Yuma Mesa Irrigation and Drainage District, the Yuma Irrigation District (South Gila Valley Unit), the Yuma County Water Users' Association, the North Gila Valley Irrigation District, the Unit "B" Irrigation and Drainage District, and the Wellton-Mohawk Irrigation and Drainage District.

Major irrigation diversion facilities include Imperial Dam, located 18 miles northeast of Yuma, and Headgate Rock Dam, located about 14 miles downstream from Parker Dam. Imperial Dam provides diversion facilities for Colorado River water for Arizona through the All-American and Gila Gravity Main Canals for delivery to the Yuma and Gila Projects, respectively. Headgate Rock Dam diverts water to irrigated lands on the Colorado River Indian Irrigation Project in Arizona. Although not directly connected with irrigation diversions within the Lower Main Stem Subregion, both Davis Dam, located 67 miles downstream from Hoover, and Senator Wash Dam, located about 2 miles northwest of Imperial Dam in California, provide additional regulation of riverflows arriving at Imperial Dam. Both these structures were built primarily to provide for regulation of Colorado River water delivered to Mexico as required by Part III of the Treaty of February 3, 1944. 1/

1/ The Mexican Water Treaty was consummated in 1944 (59 Stat. 1219) which allocated to Mexico 1.5 million acre-feet of Colorado River water annually.

Parker Dam and Palo Verde Diversion Dam were constructed primarily to provide diversion facilities for water users in California. However, Parker Dam is also one of the important control points in the operation of the Lower Colorado River.

In addition, flood control is provided by Alamo Dam, on the Bill Williams River in Arizona, which was completed in 1968.

Other minor diversions along the Colorado River main stem include diversions to the Cibola Valley Irrigation and Drainage District, located about 50 miles north of Yuma, and the Mohave Valley Irrigation and Drainage District near Bullhead City, Arizona.

Flow of the upper reaches of the Little Colorado River is partially controlled by Lyman Dam and Reservoir located about 9 miles south of St. Johns, Arizona, with a total storage capacity of about 31,000 acre-feet, and by numerous minor reservoirs in the upper tributaries.

Some of the smaller storage reservoirs include Daggs Reservoir and Mexican Lake on Silver Creek, Show Low and Lone Pine Reservoirs on Show Low Creek, and the Black Rock and Ramah Reservoirs on the Zuni River system in New Mexico.

Limited quantities of unappropriated and erratic surface flows occur throughout the lower reaches of the Little Colorado River. However, in most cases, relatively large storage reservoirs would be required to capture and utilize these flows. Streams having potential for future development include Clear, Chevelon, and Silver Creeks. The Puerco River and its major tributary Black Creek, in Arizona, and the upper reaches of the Zuni River system in New Mexico also have some potentials for future water resource development. Other tributaries of the Little Colorado River from the east and north include Nutrioso Creek and Leroux and Dinnebito Washes, and from the south and west, Canyon Diablo and San Francisco Washes.

Painted Rock Dam, located about 50 miles southwest of Phoenix, Arizona, was constructed as a flood control structure to control floodflows below existing structures on the Verde, Salt, Gila, and Agua Fria Rivers. It was selected as the lower (western) hydrologic control point of the Gila Subregion.

Major tributaries of the Salt River system include the Verde, Black, and White Rivers and Tonto Creek. Major water-producing tributaries of the upper Gila River are the San Francisco, San Carlos, San Pedro, and Salt Rivers.

All tributaries in the middle and lower reaches of the Gila River (below its confluence with the San Pedro River) are intermittent or ephemeral and are less productive. Almost all flows from these lower tributary systems are lost from the surface before reaching the main river. Major tributaries within the lower Gila River reach include the Santa Cruz River and Santa Rosa Wash draining from the south and the Agua Fria and Hassayampa Rivers and Centennial Wash draining from the north.

Within the huge central basin of the Gila Subregion (central Arizona area), most of the surface-water flows on major streams are controlled by single or multipurpose storage reservoirs. One of the primary purposes of these reservoirs is the conservation of water for irrigation.

Reservoir (Dam)	Date Completed	Stream	Operator
San Carlos (Coolidge Dam)	1928	Gila River	BIA
Roosevelt (Theodore Roosevelt Dam)	1911	Salt River	SRP
Apache (Horse Mesa Dam)	1927	Salt River	SRP
Canyon (Mormon Flat Dam)	1925	Salt River	SRP
Sahuaro (Stewart Mountain Dam)	1930	Salt River	SRP
Horseshoe (Horseshoe Dam)	1945	Verde River	SRP
Bartlett (Bartlett Dam)	1939	Verde River	SRP
Lake Pleasant (Waddell Dam)	1927	Agua Fria River	Maricopa County Municipal Water Cons. Dist. #1

The combined storage capacity of these eight multipurpose reservoirs is about 3.2 million acre-feet. The effectiveness of these reservoirs in controlling the stream runoff is indicated by the fact that the Salt-Verde Reservoir system of the Salt River Project has had only two major spills in the last 30 years. Lake Pleasant has spilled once in this time period and San Carlos Reservoir has never spilled.

The long-time average annual natural water supply from the Gila River system (undepleted flow) is estimated at about 1.8 million acre-feet. Under present conditions, very little surface flow leaves the Gila Subregion.

Major irrigation diversion facilities in this area include the Granite Reef Diversion Dam located about 20 miles northeast of Phoenix and the Ashurst-Hayden Diversion Dam located about 10 miles northeast of Florence, Arizona.

Other water service organizations using surface water for irrigation purposes within the central Arizona area include the Maricopa County Municipal Water Conservation District No. 1, the Roosevelt Water Conservation District, the Buckeye Water Conservation and Drainage District, St. Johns Irrigation District, and Peninsula Ditch Company. These five water user organizations are located adjacent to the Salt River Project in the Phoenix area. Also, Painted Rock Development Company (the Gila River Ranches, Inc.), and the Gila Water Conservation District (inactive) located in the Gila Bend area may divert water for irrigation purposes along the lower reaches of the Gila River.

Other minor surface irrigation diversions occur along the upper Gila River and also along the tributaries of the Salt and Gila Rivers. Although these surface-water diversion areas account for less than 15 percent of the total surface water used for irrigation purposes within the Gila Subregion, they include over 50 organized irrigation districts and canal companies.

Ground Water

In general, the history of ground-water development in the Lower Colorado Region has been a "mining operation." Beginning in the late 1920's and slowly increasing through the 1930's and the early 1940's, long accumulated ground-water reserves were drawn on to supplement insufficient, and in many cases overappropriated, surface supplies throughout the Gila Subregion in central Arizona. Since shortly before World War II, almost all new lands developed for irrigation have been supplied with water by pumping ground-water reserves. With increased pumpage, water levels declined and the annual overdraft steadily grew. Land subsidence and pumping costs have increased in response to the annual overdraft buildup and land retirement has increased due to increasing costs of pumping ground water and other economic factors.

Annual ground-water pumpage in the Region increased from less than 1,000,000 acre-feet in 1930 to 3,000,000 acre-feet following World War II, to nearly 5,000,000 acre-feet at the present time. Present annual overdraft is estimated as about 2.5 million acre-feet. In the central Arizona area alone, the average annual ground-water level decline is between 8 and 10 feet, with annual declines as much as 20 feet being reported in some wells.

The area of the greatest water demand, the desert lowlands of central Arizona, relies substantially on ground-water resources. Until the introduction of another source of water or, in some cases the economic means to better utilize and conserve the present source, the overdraft will continue.

Lower Main Stem Subregion--Under present conditions, annual ground-water pumpage for irrigation purposes within the Lower Main Stem Subregion is about 445,000 acre-feet. Most of the ground-water pumpage in the Subregion is within Arizona and, for the most part, adjacent to or within the flood plain area of the lower reaches of the Colorado River.

Although numerous shallow wells do pump underground water from the flood plain area, this water is recognized 1/ as Colorado River water (surface) and must be accounted for under Arizona's apportioned share of main stream river water. The major flood plain areas pumping Colorado River water with shallow wells are the Mohave Irrigation and Drainage District located south of Bullhead City, Arizona; Lake Havasu Irrigation and Drainage District and the Cibola Valley Irrigation and Drainage District, 50 miles north of Yuma; the Yuma Island area (unorganized district), located about 3 miles northeast of Yuma; and private lands located along the river between Yuma and the international boundary with Mexico.

The Yuma Irrigation District (Yuma Mesa Division-Gila Project) pumps some ground water, which it uses along with its surface-water supply for irrigation purposes. In addition, water is pumped for drainage purposes and is discharged from the area through a drainage system.

Minor areas where irrigation depends on ground water exist along the Gila River below Painted Rock Dam and in the Bouse and Cunningham Wash areas which are located about 30 miles southeast of Parker, Arizona.

Little Colorado Subregion--Ground-water development in the Little Colorado Subregion is extremely localized and represents a small percentage of the total ground water used for irrigation within the Lower Colorado Region. The Coconino Sandstone is probably the most important source of ground water within the Subregion. The aquifer is generally low yielding but is an important source of water along the Little Colorado River and major tributaries.

1/ Supreme Court Decree - Arizona v. California - March 9, 1964 - Article I(C).

Areas where ground-water wells have been installed to supplement surface supplies are in the Winslow-Holbrook and the St. Johns areas on the Little Colorado River and the agricultural areas around Snowflake and Woodruff on Silver Creek.

Gila Subregion--In the Gila Subregion, nearly 90 percent of the annual ground-water diversions within the Region are pumped. Almost all this ground-water pumpage is within Arizona, with the exception of a small amount along the upper Gila River and San Simon Creek in western New Mexico. More than 4,000 irrigation wells pump nearly 4.5 million acre-feet of ground water annually in the central Arizona area.

The principal areas using ground-water supplies to supplement surface-water supplies include the San Carlos Irrigation Project, the Salt River Project, and the Roosevelt Water Conservation District.

Other areas using ground water to supplement surface-water supplies are the upper Gila River Basin, the San Pedro River Basin, and the upper Verde River Basin in Arizona.

Crop Consumptive Use

Water use records for the Lower Colorado Region are generally not available. Since data were needed for specific crops, the theoretical consumptive use was determined on the basis of the Blaney-Criddle Method utilizing the latest available data on seasonal crop coefficients for the Lower Colorado Region. These derived values do not necessarily reflect actual historic, present, or future uses. The figures reflect the estimated amount of water which is lost by evaporation, transpiration, and the amount needed to build the plant tissue required to obtain optimum production.

The calculated results of the study are shown on tables 6 through 8, and indicate a requirement at the farm headgate of about 7.0 million acre-feet to meet the estimated 1965 demand for irrigation water. Of this amount, approximately 3.9 million acre-feet were computed as the ideal irrigation requirement for the crops (gross consumptive use less effective precipitation). Distribution losses from the diversion point to the farm headgate are estimated at an additional 1.9 million acre-feet.

Detailed information related to these studies are not included in this appendix. Specific information in this regard is available in the supporting data files.

Table 6

Type I Study
Lower Colorado Region
Hydrologic Areas
Crop Irrigation Requirements 1/

1965

Unit: 1,000 acre-feet

Subregion and State	Feed Crops	Food Crops	Oil, Fiber, and Seed Crops	Other Crops	Total
Lower Main Stem					
Arizona	381	141	198	34	754
Nevada	48	1	1	102	152
Utah	35	4	0	19	58
Subtotal	464	146	199	155	964
Little Colorado					
Arizona	23	2	--	17	42
New Mexico	8	--	--	1	9 2/
Subtotal	31	2	--	18	51
Gila					
Arizona	1,475	181	1,105	194	2,955
New Mexico	35	1	9	9	54 2/
Subtotal	1,510	182	1,114	203	3,009
Region Total	2,005	330	1,313	376	4,024

1/ Amount of water required at the crop root zone to satisfy the optimum water consumption requirements of the crop. (Gross consumptive use less effective precipitation.)

2/ Figures provided by New Mexico Interstate Stream Commission.

Table 7

Type I Study
Lower Colorado Region
Hydrologic Areas
Farm Delivery Requirements 1/

1965

Unit: 1,000 acre-feet

Subregion and State	Feed Crops	Food Crops	Oil, Fiber, and Seed Crops	Other Crops	Total
Lower Main Stem					
Arizona	762	282	395	68	1,507
Nevada	97	3	1	202	303
Utah	69	8	--	38	115
Subtotal	928	293	396	308	1,925
Little Colorado					
Arizona	46	4	--	35	85
New Mexico	16	--	--	1	17
Subtotal	62	4	--	36	102
Gila					
Arizona	2,530	305	1,915	340	5,090
New Mexico	66	1	16	19	102
Subtotal	2,596	306	1,931	359	5,192
Regional Total	3,586	603	2,327	703	7,219

1/ Crop Irrigation Requirement divided by the farm efficiency based on 1965 farm practices when farm efficiencies averaged between 50 and 60 percent with deep percolation and surface wastes considered.

Table 8

Type I Study
Lower Colorado Region
Hydrologic Areas
Diversion Requirements 1/

1965

Unit: 1,000 acre-feet

Subregion and State	Feed Crops	Food Crops	Oil, Fiber, and Seed Crops	Other Crops	Total
Lower Main Stem					
Arizona	1,053	392	548	91	2,084
Nevada	141	5	2	285	433
Utah	99	11	--	55	165
Subtotal	1,293	408	550	431	2,682
Little Colorado					
Arizona	60	6	--	46	112
New Mexico	21	--	--	3	24
Subtotal	81	6	--	49	136
Gila					
Arizona	3,110	376	2,306	418	6,210
New Mexico	72	1	17	20	110
Subtotal	3,182	377	2,323	438	6,320
Region Total	4,556	791	2,873	918	9,138

1/ Farm delivery requirement divided by the weighted distribution system efficiency also the availability of a full water supply to meet optimum conditions.

Return Flows

There is essentially no outflow from the Region excepting some return flows occurring near the Regional boundary in the vicinity of Yuma, Arizona, and that which is diverted to California and Mexico.

In addition, the portion of irrigation water that is returned by deep percolation and through seepage and has the potential of ground-water recharge and reuse is considered as return flow. An analysis by the Arizona Interstate Stream Commission indicates that in excess of 1 million acre-feet of water is recharged annually in the central Arizona area. This represents an addition to the water available for reuse.

Diversions

The renewable water supply available for use in the Region is inadequate to meet the needs of the existing economy. Virtually all dependable surface-water resources, exclusive of the mainstream of The Colorado River, are fully utilized and ground-water resources are being depleted.

Total water diversion for irrigated agriculture under current (1965) conditions totals about 7.9 million acre-feet, greatly exceeding the long-term natural supply. Diversions are provided by the following sources: Surface water about 3.0 maf, ground-water resources 4.8 maf, and sewage effluent 0.1 maf. Currently it is estimated that ground-water withdrawals exceed replenishment by approximately 2.4 million acre-feet per year.

Adequacy of Supply

In some locations the ground-water resource of the Lower Colorado Region is overdeveloped; over 60 percent of present withdrawals are from this source. The annual overdraft will eventually destroy the usefulness of this valuable resource. Several thousand acres of land in central Arizona that were developed for irrigation have already gone out of production because of deficient water supplies.

Increased pumping costs are making water from some aquifers prohibitively expensive for agricultural use and water from others is of unsuitable quality at the greater depths. In some aquifers the available water has already been exhausted.

Municipal and industrial water uses are competing with agricultural uses for the increasingly scarce supply.

WATER QUALITY

Suitability of Water Supply for Irrigation 1/

Although initial irrigation began in the Lower Colorado Region without consideration of water quality effects, increased water use with attendant water quality deterioration has emphasized the seriousness of such effects upon agricultural water users. Here, the arid and semiarid climatic conditions of the Region compound the problems associated with a highly mineralized supply. The high rates of evapotranspiration by plants, if combined with inadequate downward leaching, can cause the dissolved salts to accumulate in the root zone of the soil profile. Table 9 indicates the relative tolerance of crops to salinity and boron in the Lower Colorado Region.

The quality of the surface and ground water in the Region is, for the most part, suitable for irrigated agriculture. The total dissolved solids (TDS), boron, and suspended sediment concentrations and sodium adsorption ratios (SAR), though acceptable overall in the Region, do present some local problems, as do chlorides, sulfates, and residual sodium carbonates.

Surface water in the Region contains minimal concentrations of boron. However, ground water having boron concentrations greater than 0.5 mg/l occur in local areas of the southern half of the Region.

Suspended sediment in surface-water supplies causes local problems, including increased operation and maintenance costs and reduction of impoundment reservoir capacities. Impoundment capacities have been significantly reduced in Zion, Lyman, and Black Rock Reservoirs in the Little Colorado Subregion and in the small reservoirs formed by the Gillespie, Granite Reef, and Ashurst-Hayden Diversion Dams and Picacho Reservoir in the Gila Subregion.

Application of water, soil, and crop management practices account for the success of irrigated agriculture in the Region. Partial solutions to many of the local problems may be achieved by adding chemical amendments and providing for adequate drainage.

Surface Water--Surface water in the Region is classified on Map No. 5 according to a system developed by the U.S. Salinity Laboratory at Riverside, California. 2/ Overall, surface water is

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1/ Additional information on the effect of irrigation on surface- and ground-water quality is contained in Appendix XV.

2/ For explanation, see USDA Handbook No. 60.

Table 9

Type I Study
Lower Colorado Region
Relative Tolerance of Crops to Salinity and Boron 1/

Salinity 2/

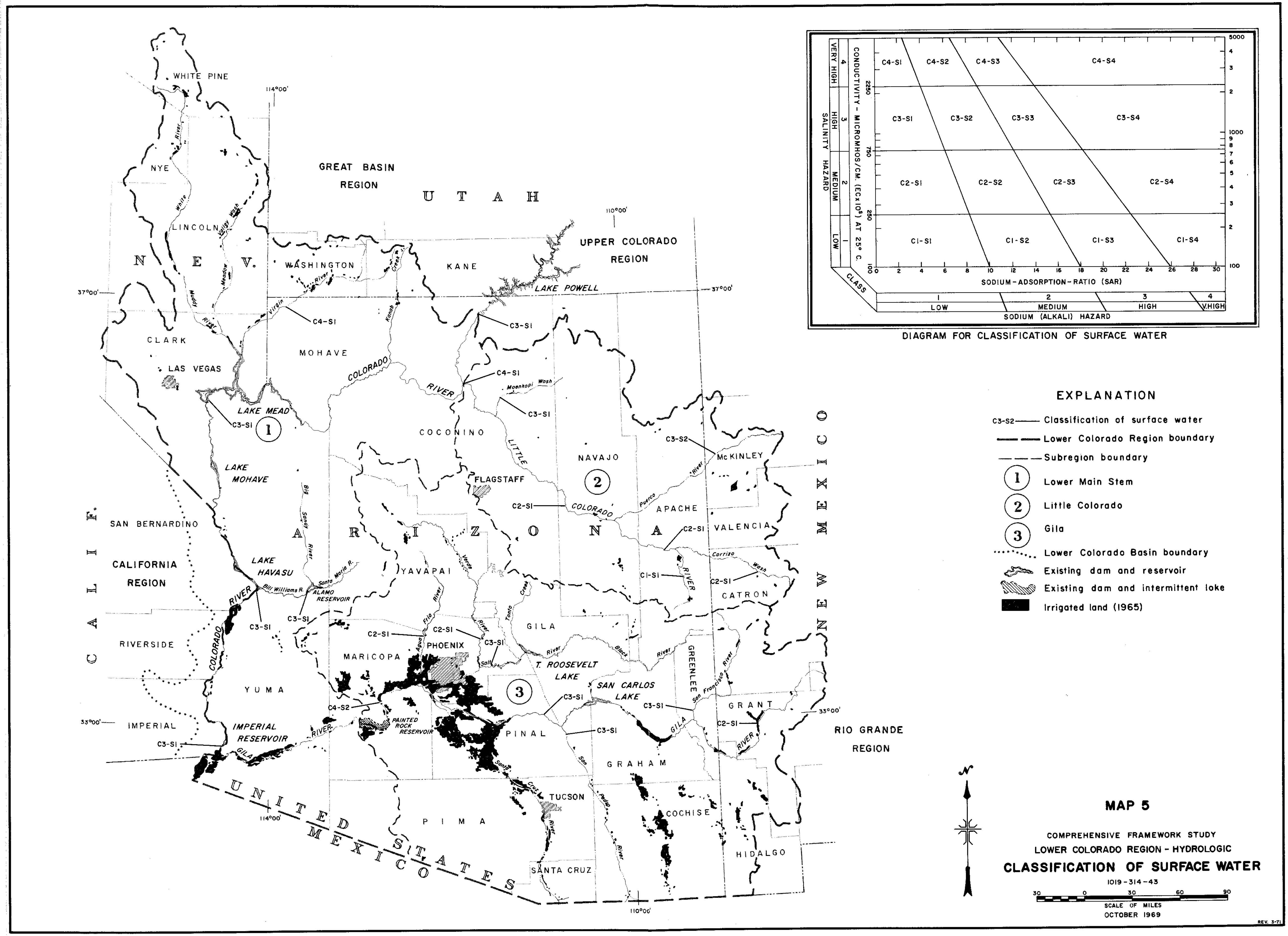
High Tolerance	Medium Tolerance	Low Tolerance
Vegetables	Pasture	Citrus
Beets	Vegetables	Orange
Asparagus	Lettuce	Grapefruit
Spinach	Onion	Lemon
Barley	Alfalfa	Vegetables
Cotton	Sorghum	Radish
		Celery
		Bean

Boron 2/

Tolerant	Semitolerant	Sensitive
Alfalfa	Cotton	Citrus
Vegetables	Barley	Orange
Onion		Grapefruit
Cabbage		Lemon
Lettuce		

1/ Source of data - USDA Handbook No. 60.

2/ In general, crops listed in each column show a decreasing tolerance from top to bottom.


MAP 5
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION - HYDROLOGIC
CLASSIFICATION OF SURFACE WATER
1019-314-43
SCALE OF MILES
30 0 30 60 90
OCTOBER 1969
REV. 3-71
EXPLANATION
C3-S2 Classification of surface water
Lower Colorado Region boundary
Subregion boundary
1 Lower Main Stem
2 Little Colorado
3 Gila
Lower Colorado Basin boundary
Existing dam and reservoir
Existing dam and intermittent lake
Irrigated land (1965)
DIAGRAM FOR CLASSIFICATION OF SURFACE WATER
CONDUCTIVITY - MICROMHOS/CM. (ECx10⁶) AT 25° C.
SALINITY HAZARD
VERY HIGH
HIGH
MEDIUM
LOW
SODIUM-ADSORPTION-RATIO (SAR)
SODIUM (ALKALI) HAZARD
CLASS
LOW
MEDIUM
HIGH
V.HIGH
C4-S1
C4-S2
C4-S3
C4-S4
C3-S1
C3-S2
C3-S3
C3-S4
C2-S1
C2-S2
C2-S3
C2-S4
C1-S1
C1-S2
C1-S3
C1-S4
GREAT BASIN REGION
UPPER COLORADO REGION
CALIFORNIA REGION
RIO GRANDE REGION
U T A H
N E V.
A R I Z O N A
C A L I F.
N E W M E X I C O
U N I T E D S T A T E S
M E X I C O
WHITE PINE
NYE
LINCOLN
CLARK
LAS VEGAS
WASHINGTON
KANE
MOHAVE
COCONINO
NAVAJO
APACHE
McKINLEY
VALENCIA
CATRON
SAN BERNARDINO
RIVERSIDE
IMPERIAL
YUMA
YAVAPAI
MARICOPA
PHOENIX
GILA
GREENLEE
GRANT
PINAL
GRAHAM
PIMA
TUCSON
COCHISE
SANTA CRUZ
HIDALGO
FLAGSTAFF
LAKE POWELL
LAKE MEAD
LAKE MOHAVE
LAKE HAVASU
ALAMO RESERVOIR
T. ROOSEVELT LAKE
SAN CARLOS LAKE
PAINTED ROCK RESERVOIR
IMPERIAL RESERVOIR
COLORADO RIVER
LITTLE COLORADO
GILA RIVER
Virgin River
White River
Meadow Valley Wash
Muddy River
Kanab Creek
Moenkopi Wash
Puerco River
Zuni River
Carrizo Wash
Big Sandy River
Santa Maria R.
Bill Williams R.
Agua Fria River
Verde River
Salt River
Tonto Creek
Black River
San Francisco River
Santa Cruz River
San Pedro River
114°00'
110°00'
37°00'
33°00'

classified as C3-S1, indicating that moderate leaching is required under average soil conditions and that there is little danger of developing harmful levels of sodium. However, water characteristics must also be equated with soil and drainage conditions and the type of crops to be grown before it can be determined whether the water should be used for irrigation.

In the Lower Main Stem Subregion, the Colorado River, which is the main supply for the Subregion, enters at TDS concentrations between 600 and 700 mg/l and increases to between 800 and900 mg/l at Imperial Dam, the last diversion point in the United States. Throughout this reach, the sodium adsorption ratio is consistently less than 3. According to the U.S. Salinity Laboratory system, this supply is classified as C3-S1, that is, having high salinity and low sodium hazards. High salinity hazards (C4) are found in the Virgin River at Littlefield, Arizona and the Las Vegas Wash.

Water quality (TDS) at the southerly international boundary is affected by three main factors: (1) the reduction of flow in the Colorado River by large diversions made upstream; (2) inflows from the Welton-Mohawk main outlet drain which are from ground-water drainage wells within the District; and (3) other irrigation return flows.

Water supplies in the Lower Main Stem Subregion contain minimal boron concentrations, except for the Colorado River at Yuma, Arizona, where concentrations have reached 0.4 mg/l, the critical level for citrus crops grown in that area.

The irrigated lands in the Little Colorado Subregion are located on the upper reaches of streams where applied water contains less than 500 mg/l of TDS and sodium-adsorption ratios pose no significant hazard. Thus, the supplies are classified as C2-S1. At the mouth of the Little Colorado River the flow is both augmented and degraded by Blue Spring and a group of smaller springs which drain more than 28,000 square miles of a saline ground-water aquifer. Classified as C4-S1, this water would pose high salinity hazard if used undiluted for irrigated agriculture. However, it enters the Little Colorado River downstream of any potential users and is diluted as it enters the Colorado River.

Most surface sources of irrigation water in the Gila Subregion are classified as C3-S1 or better; hence, only a moderate amount of leaching is required under average soil conditions, with little danger of development of harmful levels of sodium. The Verde and Agua Fria Rivers both contain less than 500 mg/l of TDS and have SAR's less than 3 at their major diversion points. At diversion points on the Salt and Gila Rivers the concentration of dissolved solids is somewhat higher--between 500 and 1,000 mg/l. The sodium adsorption ratios are generally less than 5. An exception is the quality at Gillespie Dam where total dissolved solids exceed 3,000 mg/l and SAR's exceed 10, thus indicating extremely high salinity and medium sodium hazard (C4-S2). This water, essentially return flows from the Salt River Valley, presents an appreciable sodium hazard in fine textured soils having high cation-exchange-capacity, especially under low leaching conditions. Furthermore, boron concentrations average more than 1 mg/l. Quantities of flow are small and they are used to augment pumped ground water. Potential deleterious effects are offset by this dilution, although yields of some crops are reduced.

Ground Water--Ground water in the Lower Colorado Region is generally less suitable for irrigation than is surface water. Regionally, the supply presently in use would be classified as C3-S1; the total ground-water resource available is of much poorer quality, however, and would be classified accordingly. The largest use of ground water is in the Gila Subregion.

Ground water in the Lower Main Stem Subregion generally contains less than 1,000 mg/l of dissolved solids and minimal amounts of sodium. Water classified as C3-S1 or poorer, requires moderate leaching. Water having more than 1,000 mg/l is limited chiefly to areas adjoining the Gila River, locally downstream from Parker Dam, and along the southermost reach of the Colorado River. Total dissolved solids concentrations exceeding 3,000 mg/l occur only locally near Las Vegas, Nevada, near Parker Dam, and in the Wellton-Mohawk Irrigation and Drainage District along the Gila River in Yuma County. Boron concentrations varying between 1 and 2 mg/l occur in ground water south of the Gila River for nearly its entire length in Yuma County.

In the Little Colorado Subregion the chemical quality of the ground water varies greatly; the dissolved solids content ranges from 90 to more than 60,000 mg/l. TDS concentrations exceeding 10,000 mg/l are widespread in multiple-aquifers located in the northern portion of the Subregion. Data available for the southern portion of the Subregion indicate that the ground water contains less than 1,000 mg/l TDS. Most of the water now pumped for irrigation in the Little Colorado Subregion is classified as C3-S1 or better. No boron-sensitive crops are grown in this Subregion.

As an average, ground water presently pumped for irrigation in the Gila Subregion is classified as C3-S1 or better, with some noted areas classified as C4-S2.

Ground water with SAR values greater than 10 occur in Graham County, near Casa Grande and Stanfield in Pinal County, and near Chandler in Maricopa County. Other areas of medium sodium hazard water in Maricopa County include Rainbow Valley, Hassayampa, Arlington, Tonopah, and Tolleson areas. Boron concentrations exceeding 1 mg/l occur near Palo Verde, a large area south of Gila Bend, and many small areas along the Salt and Santa Cruz Rivers. Many wells in the greater Phoenix area have boron concentrations varying between 0.5 mg/l and 1 mg/l.

Drainage

Under present conditions (1965), drainage problems in the Lower Colorado Region are generally associated with irrigation and are considered to be relatively minor. These problems have been caused by one of three factors (1) poor management of irrigation water, (2) restricted permeability of a layer or horizon in the soil, or (3) topographic relief of the area being irrigated. Each of these factors cause, in one way or another, water to accumulate in and/or on the soil faster than it can be used by plants, evaporate, or percolate through the soil. As a result, there is a salinity buildup, adequate aeration is precluded, and plant production is adversely affected.

Millions of dollars have been spent on correcting drainage problems. These problems generally become apparent after the land has been irrigated for some time.

Drainage problems by Subregions are described in the following paragraphs. Table 4 on page X-13 gives a summary of irrigation and drainage practices and measures that had been installed in the Lower Colorado Region as of 1965.

Lower Main Stem Subregion

The Lower Main Stem Subregion has several areas that have had or presently have some drainage problems.

At one time the area west and southwest of the city of Yuma, Arizona, had a system of open ditch drains which was adequate until additional lands were irrigated on the Yuma Mesa. However, drainage wells were later installed along the eastern side of this area to lower the water table which was rising due to percolation of irrigation water applied on the adjacent mesa. Under 1965 conditions, water from the drainage wells along the east side of Yuma Valley was pumped into the open drain system. The flow in these open drains terminated at the international boundary between the United States and Mexico where the water was pumped over the levee by the Boundary Pumping Plant for use in Mexico. The water thus delivered to Mexico was accounted as a portion of our treaty requirements for delivery of 1.5 million acre-feet annually to Mexico.

High water table and high salinity problems in the area directly east of Yuma are now controlled largely through the use of drainage wells and concrete lined ditches.

The area southeast of Yuma has had very few drainage problems. Some tile has been installed to drain land wet due to clay lenses. Seepage from unlined irrigation canals in the area northeast of Yuma has raised the water table under some land. It may be necessary to install drainage wells and line the main canals in the future.

In the Wellton, Arizona, area the installation of drainage wells, lining of canals, and the encouragement of better water management to avoid excess water penetration thereby preventing salinity and high water problems, have resulted in improved conditions.

Drainage problems in the Nevada portion of the Lower Main Stem Subregion are caused by one or more of the following: Relief, slow soil permeability, irrigation canal seepage losses, winter flows of water, artesian pressure, and poor quality (salinity and/or high content of silt) irrigation water. The effects have been waterlogging, salinization, and high water table. Canal lining, more efficient irrigation systems, surface drains, ground-water development, and sediment control structures have been applied or installed to reduce the problems.

Excess water has caused a drainage problem in a small area of Washington County, Utah. This high water table was created by subsoils having low permeability, by retarded surface runoff, and by seepage from irrigation canals. Open drains, canal lining, redesign of irrigation systems, and better water management have been applied as corrective measures.

Little Colorado Subregion

The Little Colorado Subregion has a few scattered drainage problems. There is a high water table problem in the St. Johns, Arizona, area.

Gila Subregion

Present drainage problems in the Gila Subregion are isolated and minor in nature.

By the late 1920's a major drainage problem which existed in the Salt River Valley was improved by the installation of drainage wells which lowered the water table. These same wells are now being used to supply a substantial part of the water used in the valley.

A high water table caused by overirrigation required the installation of drainage ditches and tile in the area south of Willcox, Arizona.

Drainage problems in the New Mexico portion of this Subregion are minor with overflow and seepage from irrigation canals the principal causes. This problem is being solved by concrete lining of canals and better water management.

The overapplication of irrigation water has been the contributing cause behind the high water table problem in the area southwest of Phoenix.

IRRIGATION AND ITS CONTRIBUTION TO THE ECONOMY
LOWER COLORADO REGION

Direct irrigation contributions to the economy of the Region are reflected in terms of crops produced. Indirect benefits arise from business activity associated with irrigated agriculture, from the tax base that is generated, and from recreation and related business activity associated with water storage reservoirs used for irrigation.

Number and Size of Irrigated Farms

There were approximately 5,600 irrigated farms (excluding Indian reservations) 1/ in the Lower Colorado Region in the mid-1960's according to the 1964 U.S. Census of Agriculture (table 10). The Lower Main Stem Subregion included 22 percent of these farms, the Little Colorado Subregion 6 percent, and the Gila Subregion 72 percent. In addition, there were 34 Indian irrigated reservation farms in the Region, 4 being in the Lower Main Stem Subregion, 15 in the Little Colorado Subregion, and 15 in the Gila Subregion.

Irrigated farms comprised about 70 percent of all farms in the Region, which (excluding Indian reservation) numbered 7,881 in 1964. In the Lower Main Stem Subregion 80 percent of the farms were irrigated, compared with about 60 percent for the Little Colorado Subregion and 70 percent for the Gila Subregion. (Indian reservation farm areas, classified as irrigated, comprised 67 percent of all reservation farm areas in the Region, 57 percent in the Lower Main Stem Subregion, 58 percent in the Little Colorado Subregion, and 83 percent in the Gila Subregion.)

1/ Indian reservations, or parts of reservations classified in the 1964 U.S. Census of Agriculture as single farms.

Table 10

Number and Size of Irrigated Farms in the
Lower Colorado Region
by
Subregion and State
1964 1/

Subregion and State	Irrigated Farms (number)	Proportion of All Farms (percent)	Average Size of Farm (acres)	Land Irrigated per Farm (acres)
Lower Colorado Region	5,603	71	1,236	213
Arizona	(4,693)	(73)	(1,120)	(237)
Nevada	(178)	(92)	(378)	(106)
New Mexico	(307)	(40)	(3,793)	(120)
Utah	(425)	(87)	(1,029)	(46)
Lower Main Stem	1,221	80	862	192
Arizona	(618)	(74)	(887)	(316)
Nevada	(178)	(92)	(378)	(106)
Utah	(425)	(87)	(1,029)	(46)
Little Colorado	303	60	5,248	56
Arizona	(273)	(65)	(5,233)	(59)
New Mexico	(30)	(34)	(5,378)	(34)
Gila	4,079	70	1,050	229
Arizona	(3,802)	(74)	(863)	(237)
New Mexico	(277)	(41)	(3,621)	(129)

1/ Source: 1964 U.S. Census of Agriculture. Excludes Indian reservations or parts thereof counted as single farms.

Irrigated farms in the Lower Colorado Region (excluding Indian reservations) averaged 1,200 acres in size according to the 1964 U.S. Census of Agriculture (table 10). Those in the Lower Main Stem Subregion averaged 860 acres, those in the Little Colorado Subregion 5,200 acres, and those in the Gila Subregion 1,050 acres. The irrigated Indian reservations in the Region averaged 526,200 acres in size, with those in the Lower Main Stem Subregion averaging 911,000 acres, those in the Little Colorado Subregion 656,700 acres, and those in the Gila Subregion 294,000 acres.

Only a small part of the land in irrigated farms is irrigated in the Lower Colorado Region. "Land irrigated in census year" (excluding Indian reservations) averaged 213 acres per farm in 1964 (table 10). This comprised only 17 percent of the land in these farms. Both the acreage irrigated and the percentage irrigated is largest in the Gila and Lower Main Stem Subregions and smallest in the Little Colorado Subregion. Only a very small part of the land in the Indian reservations classified as irrigated is irrigated. For the Region only one-twentieth of one percent (0.05 percent) is irrigated. The proportion ranges from 0.03 percent in the Lower Main Stem Subregion to 0.07 percent in the Little Colorado Subregion to .16 percent in the Gila Subregion.

Direct Contributions from Irrigation

Nearly half (47 percent) of the land irrigated in 1965 in the Lower Colorado Region was used for feed crops (barley, grain sorghum, corn, oats, hay, and silage (table 11)). Oil, fiber, and seed crops (cotton, safflower, peanuts, bermuda grass seed, and sugar beet seed) ranked second, with 28 percent of the acreage being used for these crops. Food crops (vegetables, fruits, nuts, wheat, potatoes, and dry beans) ranked third, with 14 percent of the acreage being used for these crops. The remainder of the land irrigated was used for irrigated pasture and "other" crops, the proportions being 7 percent and 4 percent, respectively.

Nearly half the land irrigated in 1965 was used for feed crops in each of the three Subregions, the proportions being 48 percent in the Lower Main Stem 47 percent in the Little Colorado, and 49 percent in the Gila. The situation was markedly different for the remaining crops, however. Oil, fiber, and seed crops accounted for one-third of the irrigated acreage in the Gila Subregion and for 16 percent in the Lower Main Stem, but the acreage of these crops was practically nil in the Little Colorado Subregion. Food crops were relatively important in the Lower Main Stem Subregion due to the relatively large fruit and vegetable acreage. They accounted for 27 percent of the irrigated acreage in that Subregion, compared with 11 percent in both the Little Colorado Subregion and the Gila Subregion. About 6 percent of the irrigated acreage was used for pasture in both the Lower Main Stem and Gila Subregions, while pasture accounted for 22 percent of the irrigated acreage in the Little Colorado Subregion.

Table 11

Irrigated Land and Its Use in the
Lower Colorado Region
by
Subregion and State
1965 1/

Hydrologic Area

Unit: 1,000 acres

Subregion and State	Feed Crops	Food Crops	Oil, Fiber, and Seed Crops	Irrigated Pasture	Other Crops	Total Acres Irrigated
Lower Colorado Region	615	183	369	92	56	1,315
Arizona	(565)	(179)	(364)	(73)	(25)	(1,206)
Nevada	(12)	(1)	--	(6)	(30)	(49)
New Mexico	(27)	(1)	(5)	(6)	--	(39)
Utah	(11)	(2)	--	(7)	--	(20)
Lower Main Stem	106	81	42	22	42	293
Arizona	(83)	(78)	(42)	(8)	(12)	(223)
Nevada	(12)	(1)	--	(6)	30	(49)
Utah	(11)	(2)	--	(8)	--	(21)
New Mexico	--	--	--	--	--	--
Little Colorado	16	1	--	10	1	28
Arizona	(10)	(1)	--	(10)	(1)	(22)
New Mexico	(6)	--	--	--	--	(6)
Gila	493	101	327	61	12	994
Arizona	(472)	(100)	(322)	(55)	(12)	(961)
New Mexico	(21)	(1)	(5)	(6)	--	(33)

1/ Items included in each commodity group are as follow:

Feed Crops : Irrigated acres of barley, corn, oats, and sorghum harvested for grain; alfalfa hay, miscellaneous tame hay, and irrigated wild hay, and corn and sorghum silage.

Food Crops : Irrigated acres of wheat, vegetables, fruit, nuts, potatoes, and dry beans.

Oil, Fiber, & Seed Crops: Irrigated acres of cotton, safflower, bermuda grass seed, sugar beet seed, and peanuts.

Other Crops : Miscellaneous irrigated crops, green manure crops, and irrigated crop failure or abandonment.

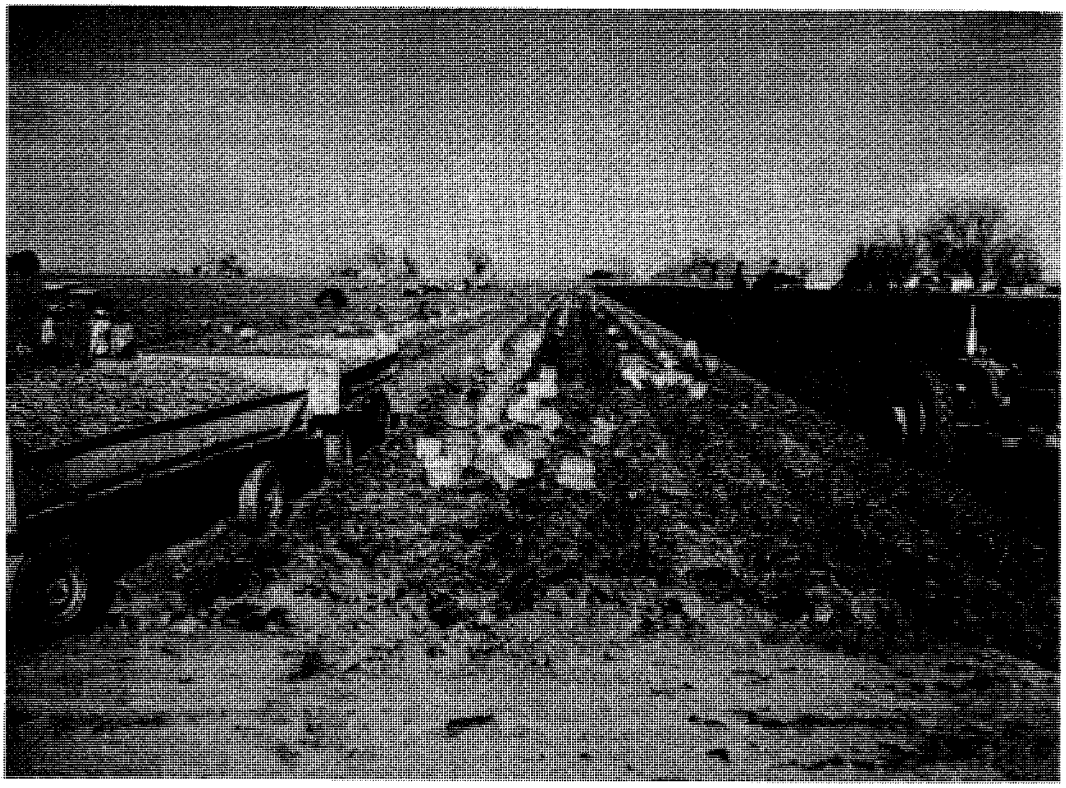


photo No. P-25-314-3 - View showing harvest of vegetables in the Lower Colorado Region

The estimated gross value of irrigated crops produced in the Region in 1965 (normalized) totalled $345 million (table 12). Of this amount, 25 percent was produced in the Lower Main Stem Subregion, 0.5 percent in the Little Colorado Subregion, and 74.5 percent in the Gila Subregion.

With cotton being the dominant crop in the Region, the "oil & fiber" crops as a group accounted for the largest proportion of the Regional crop income--38 percent. Food crops were second, accounting for 34 percent. Feed crops accounted for 26 percent, and other crops for about 2 percent of the total.

Due to the dominance of citrus and vegetable production in the Lower Main Stem Subregion, food crops as a group accounted for 60 percent of the gross value of crops produced in that Subregion in 1965. Food crop production was also relatively important in the Little Colorado Subregion due to its output of noncitrus fruits. However, since production of "oil & fiber" crops in the Little Colorado Subregion was nil, its production of feed crops and irrigated pasture accounted for a relatively large proportion of the value of its crop production. In the Gila Subregion the importance of cotton is indicated by the "oil & fiber" crop group accounting for nearly one-half the gross value of crops produced in 1965. Feed crops ranked second, accounting for nearly 30 percent of the value of crops produced. Food crops accounted for about 25 percent of the total.

Indirect Contributions of Irrigation

As indicated earlier, irrigation contributes indirectly to the economy in a number of ways. Indirect benefits arise from business activity associated with production of irrigated crops via the "multiplying" effects of purchases of inputs and sales of products. Firms supplying inputs required to produce irrigated crops, in turn, purchase their inputs from other firms. This process continues ad infinitum, thereby spreading the economic benefit of irrigation widely throughout the economy.

Similar indirect benefits are generated on the product side. The farmer producing the irrigated crops may "sell" them to a livestock enterprise on his farm. Or a separate business firm may purchase the products and use them to produce livestock or for other purposes. Products thus produced are, in turn, sold to other firms, and so on, thereby serving to create business activity and to multiply the benefits of irrigation.

Irrigation contributes indirectly to the economy of the Region through the tax revenue it helps generate. Irrigated land comprises a substantial real estate tax base. In 1965 the assessed value of

Table 12

Value of Irrigated Crops Produced in the Lower Colorado Region by Subregion 1965 (normalized) 1/ Economic Area

Subregion	Feed Crops 2/	Food Crops 2/	Oil and Fiber Crops 2/	Other Crops 2/	Total
	--------------------$1,000--------------------				
Lower Colorado Region	88,487	115,636	131,979	8,718	344,820
Lower Main Stem	14,174	51,988	15,497	4,662	86,321
Little Colorado	1,010	477	0	140	1,627
Gila	73,303	63,171	116,482	3,916	256,872
	----------Percentage Relationships-------------				
Lower Colorado Region	100.0	100.0	100.0	100.0	100.0
Lower Main Stem	16.0	45.0	11.7	53.5	25.0
Little Colorado	1.2	0.4	0.0	1.6	0.5
Gila	82.8	54.6	88.3	44.9	74.5
Lower Colorado Region	25.7	33.5	38.3	2.5	100.0
Lower Main Stem	16.4	60.2	18.0	5.4	100.0
Little Colorado	62.1	29.3	0.0	8.6	100.0
Gila	28.5	24.6	45.4	1.5	100.0

1/ Includes Government payments.

2/ Items included in each commodity group are as follow:
Feed Crops: Irrigated acres of barley, corn, oats, and sorghum harvested for grain; alfalfa hay, miscellaneous tame hay, and irrigated wild hay, irrigated pasture, and corn and sorghum silage.
Food Crops: Irrigated acres of wheat, vegetables, fruit, nuts, potatoes, and dry beans.
Oil and Fiber Crops: Irrigated acres of cotton, safflower, sugar beet seed, and peanuts.
Other Crops: Miscellaneous irrigated crops.

irrigated lands in the Region was approximately $50 million. Machinery and equipment used in irrigated agriculture also adds to the tax base. In addition, purchased inputs required for producing irrigated crops provide a source of sales tax revenue, and the income produced provides a base for income tax revenue.

Water based recreational activity and recreation on irrigated lands (hunting) in the Lower Colorado Region adds considerable benefits to the economy, both in monetary and nonmonetary terms. Monetary benefits are reflected in terms of employment created and licenses and fees collected, and indirectly through the associated business activity which is created. Nonmonetary benefits are reflected in the health and well being of participants, in the psychic value of the recreational activity, and in the enhancement of the Region as a place to live and to work.

Additional information pertaining to the relative contribution of agricultural industry sectors to the Region's economy is contained in the Appendix IV - Economic Base and Projections.

IRRIGATION POTENTIAL

CHAPTER C - IRRIGATION POTENTIAL

Lands

The Lower Colorado Region contains slightly over 36 million acres of land suited for irrigation development. About 13.4 million acres are of class 1 and class 2 quality. These lands are well suited for production of all crops climatically suited to the area where they are located. The remaining 22.8 million acres are of class 3 and 4 quality which have restrictive characteristics reducing crop suitability or production capacity of the land.

The scope and time schedule for the Framework Type I study were such that maximum use had to be made of all soil survey, land classification, and related data. Reasonable consistency in ranges of soil and land properties and their interpretation into irrigation land classes was essential for comparability between framework studies. Every effort was made to equate criteria used, and information available, by the several State and Federal agencies to achieve maximum use and coordination of existing soil and land data.

The irrigation land classes are defined as follow:

Class 1: Lands suitable for sustained high yields of most climatically adapted crops under sustained irrigation with minimum costs of development, and minimum cost of management associated with land.

Class 2: Lands moderately productive, or requiring moderate costs for development and management because of slight to moderate limitations in land characteristics.

Class 3: Lands of restricted productivity for most crops, or lands requiring relatively high costs for development and management, because of moderate to severe limitations in land characteristics.

Class 4: Lands adapted to few crops because of severe limitations in one or more land characteristics. These may include: (a) lands with steep or irregular topography with adequate soil for high income crops such as fruit, or with less favorable soils adapted to low income crops such as pasture, and (b) lands with slowly permeable, saline, sodic, shallow, or other adverse soil conditions adapted only to pasture and grain.

Class 6: Lands which because of extreme limitations in land or soil characteristics are unsuitable for sustained irrigation.

Irrigation land classes provide a ranking of land which, in adequate sized units and if properly provided with essential improvements of leveling, irrigation, and drainage, have sufficient productive capacity to support sustained irrigation and, where undeveloped, to warrant consideration for irrigation development.

Irrigation land classes are identical to irrigation soil classes with respect to permissible ranges of soil properties subject to minimum change, or those expressed on an equilibrium basis. They also include, however, a consideration of on-farm land development criteria such as drainage improvement, leveling or clearing of trees, brush, or stones. They do not include consideration of factors affecting the feasibility of service such as location, size, and distribution of lands with respect to other lands to be developed, the quantity and quality of available water supplies, or the costs of pumping and conveyance. The irrigable lands would be selected from within the irrigation land classes by considering the factors affecting feasibility of service.

The irrigation land classes are based upon those land characteristics that affect suitability for irrigation development and sustained productivity under irrigation. These include relatively stable characteristics such as the soil properties of effective depth, texture, water holding capacity and permeability, and topographic features of micro-relief and gradient, and in addition those factors subject to change in land development and farming operations such as rough micro-relief, removable rock or plant cover, shallow water tables, saline, and sodic conditions.

The criteria for the irrigation land classes permitted ready translation of existing data from land classification surveys by the U.S. Bureau of Reclamation and various State agencies and soil surveys by the U.S. Department of Agriculture into a comprehensive inventory of lands suitable for irrigation. The irrigation land classes are not expressed in terms of climatic factors, but differences due to climate are indicated by footnotes in the irrigation land class specifications.

Criteria used in the determination of the land classes are as follow:

<u>Soils</u>

1. Surface texture

2. Moisture retention in inches to depth of 48 inches

3. Effective depth (inches)

4. Salinity ($ECx10^3$ at equilibrium)

5. Sodic conditions (equilibrium)

   (a) Percent of area affected
   (b) Severity of problem (ESP)

6. Permeability (in place - inches per hour)

7. Permissible coarse fragments (percent by volume)

   (a) Gravel
   (b) Cobbles

8. Rock outcrops (distance apart in feet)

9. Soil Erosion

Topography (and related land development items)

1. Stone for removal (cu yds per acre)

2. Slope (percent)

   (a) Moderately to severely erodible soils
   (b) Slightly erodible soils

3. Surface leveling) In relative terms; quantitative units
) to be determined based on local
4. Tree removal) experience

As topographic criteria are dependent largely upon the method of irrigation, a provision is made for modifying the specifications where sprinkling is planned or applicable.

Drainage

1. Soil wetness - depth to water table during growing season (feet).

   (a) Loam or finer texture
   (b) Sandy soils

2. Depth to drainage barrier (feet)

3. Surface drainage (relative terms - permissible frequency of overflow to be determined by local conditions)

4. Air drainage - provisions for considering this factor where applicable.

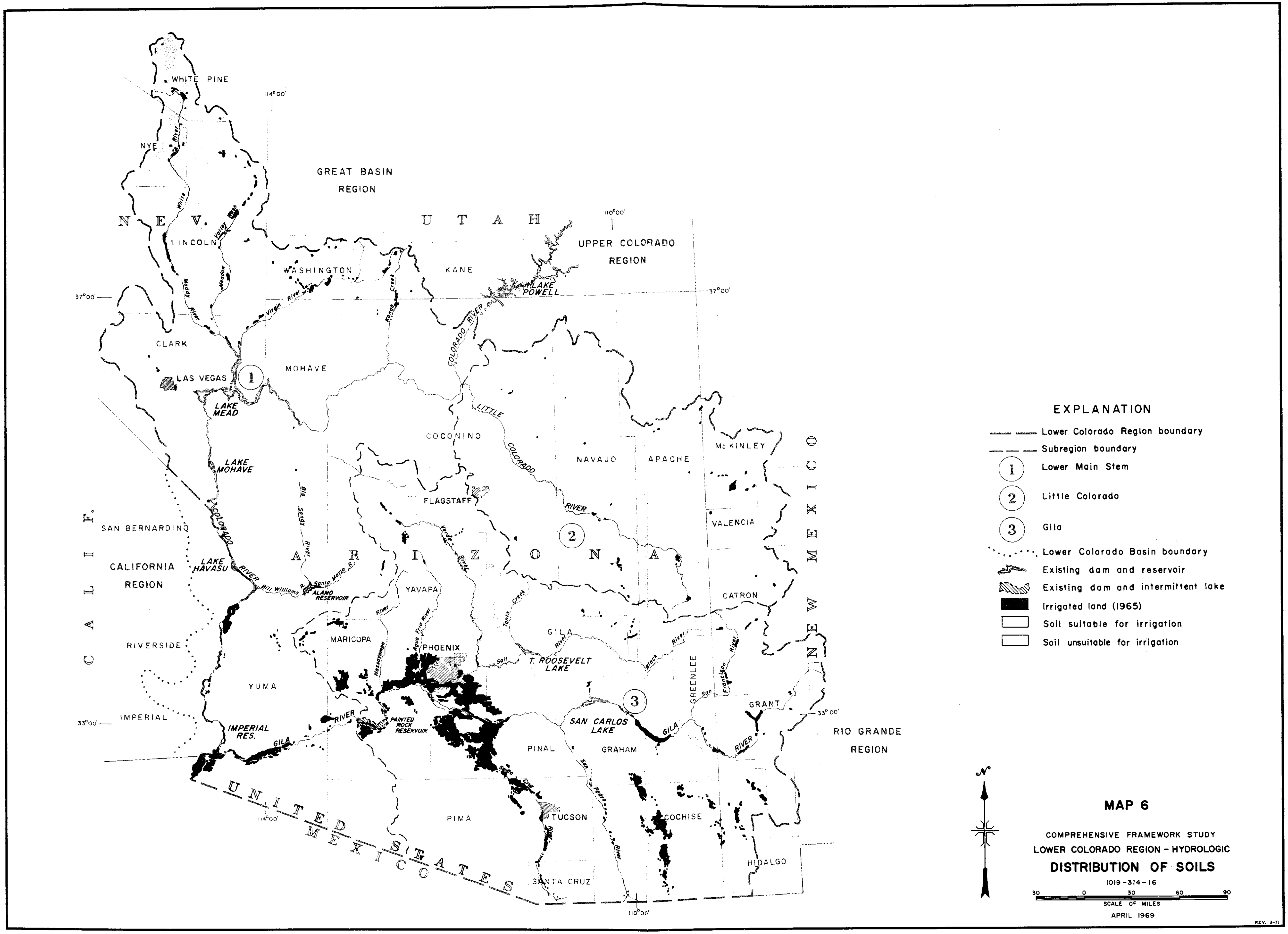
Maps Nos. 6, 7, 8, and 9 for the Region and Subregions show the areas considered suitable for irrigation development insofar as soil characteristics are considered. The maps do not show delineations by classes, but do delineate the areas suited from the unsuited areas.

Table 13 presents a summary of acreage data by land classes for each Subregion and State in the Lower Colorado Region. Presently irrigated or developed land is included in the totals. Figure 1 is a bar graph which presents percentage distributions of the land classes by Subregion and the Region. Additional information on descriptions and acreages of the irrigation soil classes is contained in the Land Suitability and Availability Section of the Land Resources and Use Appendix.

Water

The possibility of developing all of the land that is suited for irrigation in the Lower Colorado Region is, at best, remote. However, if restraints are ignored, the water requirements to develop the 36 million acres of land are shown in table 14. This indicates a crop irrigation requirement in excess of 100 million acre-feet and a withdrawal requirement of over 170 million acre-feet. 1/ These estimates were made by multiplying the average requirement per acre for the year 2020 as indicated in table 16 by the amount of land suited for irrigation development. It follows that these estimates would include the same efficiencies and practices that are anticipated for the year 2020.

1/ 1965 CIR = 4,023,000; 1965 withdrawal requirement = 9,138,000.



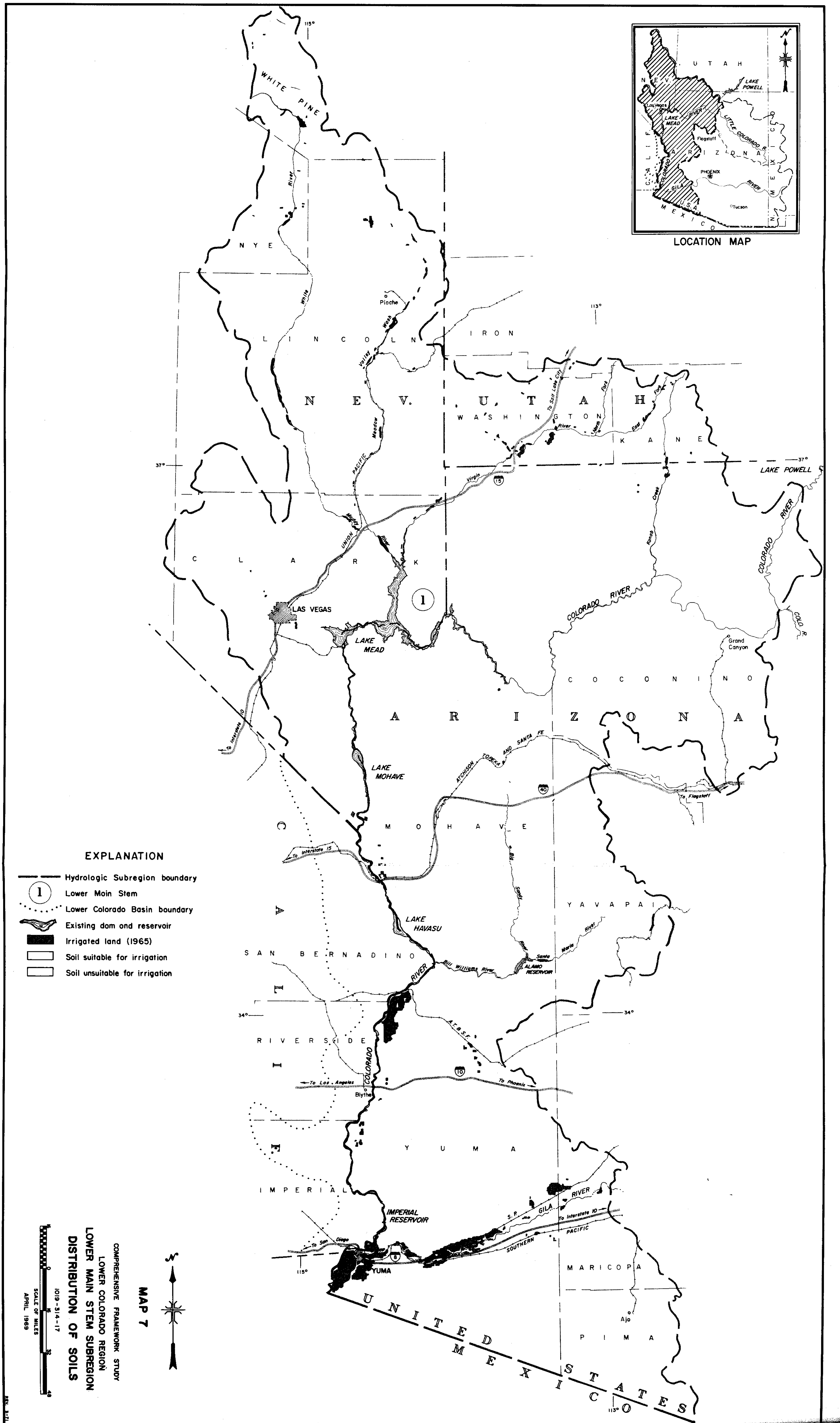
MAP 6

COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION - HYDROLOGIC

DISTRIBUTION OF SOILS

1019-314-16

APRIL 1969

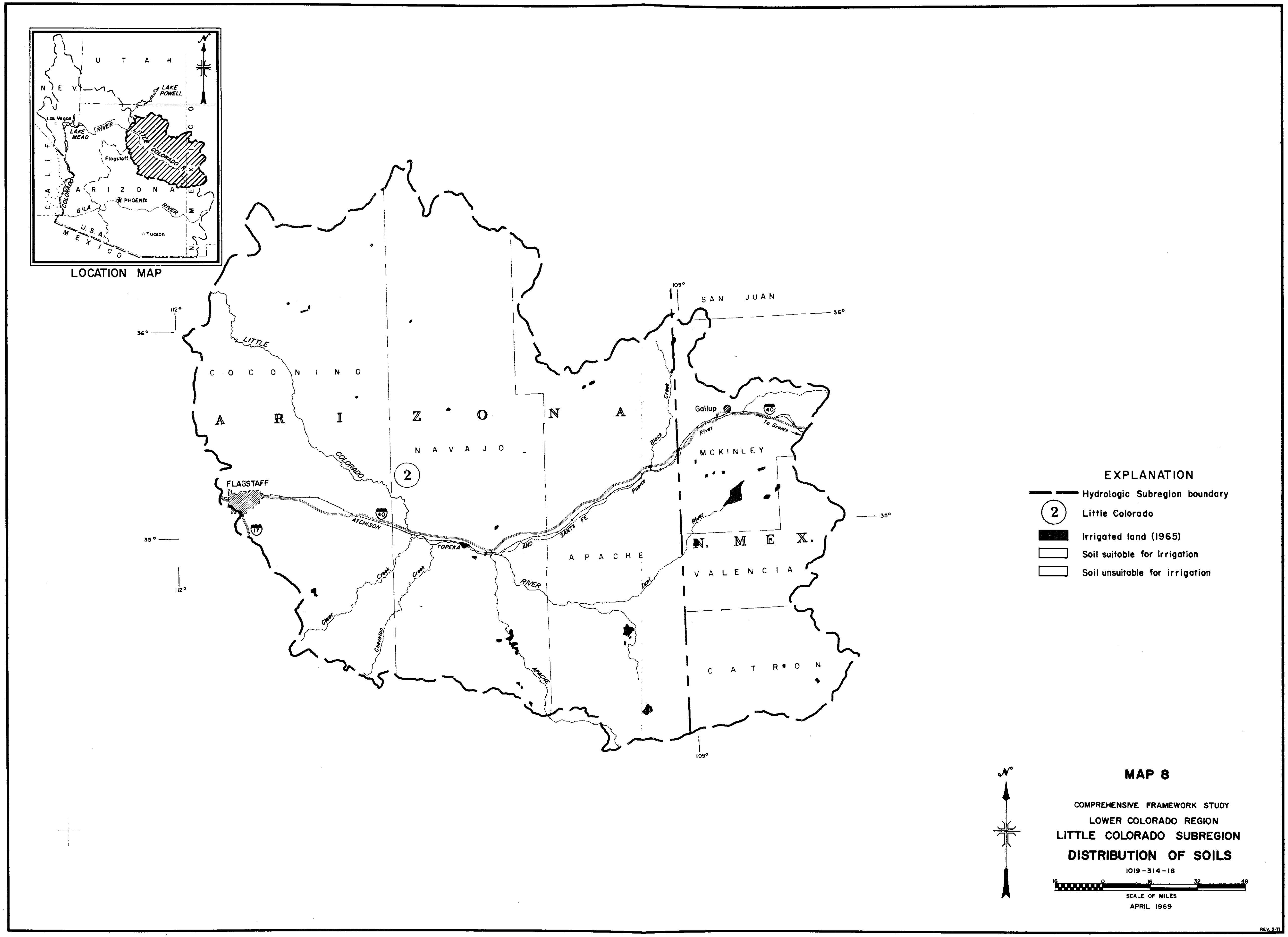


MAP 7

COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
LOWER MAIN STEM SUBREGION

DISTRIBUTION OF SOILS

1019-314-17
APRIL 1969



LOCATION MAP
UTAH
NEV.
LAKE POWELL
Las Vegas
LAKE MEAD
RIVER
LITTLE COLORADO R.
Flagstaff
CALIF.
COLORADO
ARIZONA
PHOENIX
GILA
RIVER
Tucson
U.S.A.
MEXICO
N. MEX.
COLO.
112°
36°
35°
109°
SAN JUAN
COCONINO
ARIZONA
NAVAJO
LITTLE
COLORADO
FLAGSTAFF
ATCHISON
40
17
TOPEKA
AND
SANTA FE
Gallup
To Grants
River
Black
Creek
Puerco
River
MCKINLEY
N. MEX.
APACHE
RIVER
Zuni
VALENCIA
Clear
Creek
Chevelon
Creek
APACHE
CATRON
EXPLANATION
Hydrologic Subregion boundary
2 Little Colorado
Irrigated land (1965)
Soil suitable for irrigation
Soil unsuitable for irrigation
MAP 8
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
LITTLE COLORADO SUBREGION
DISTRIBUTION OF SOILS
1019-314-18
16 0 16 32 48
SCALE OF MILES
APRIL 1969
REV. 3-71

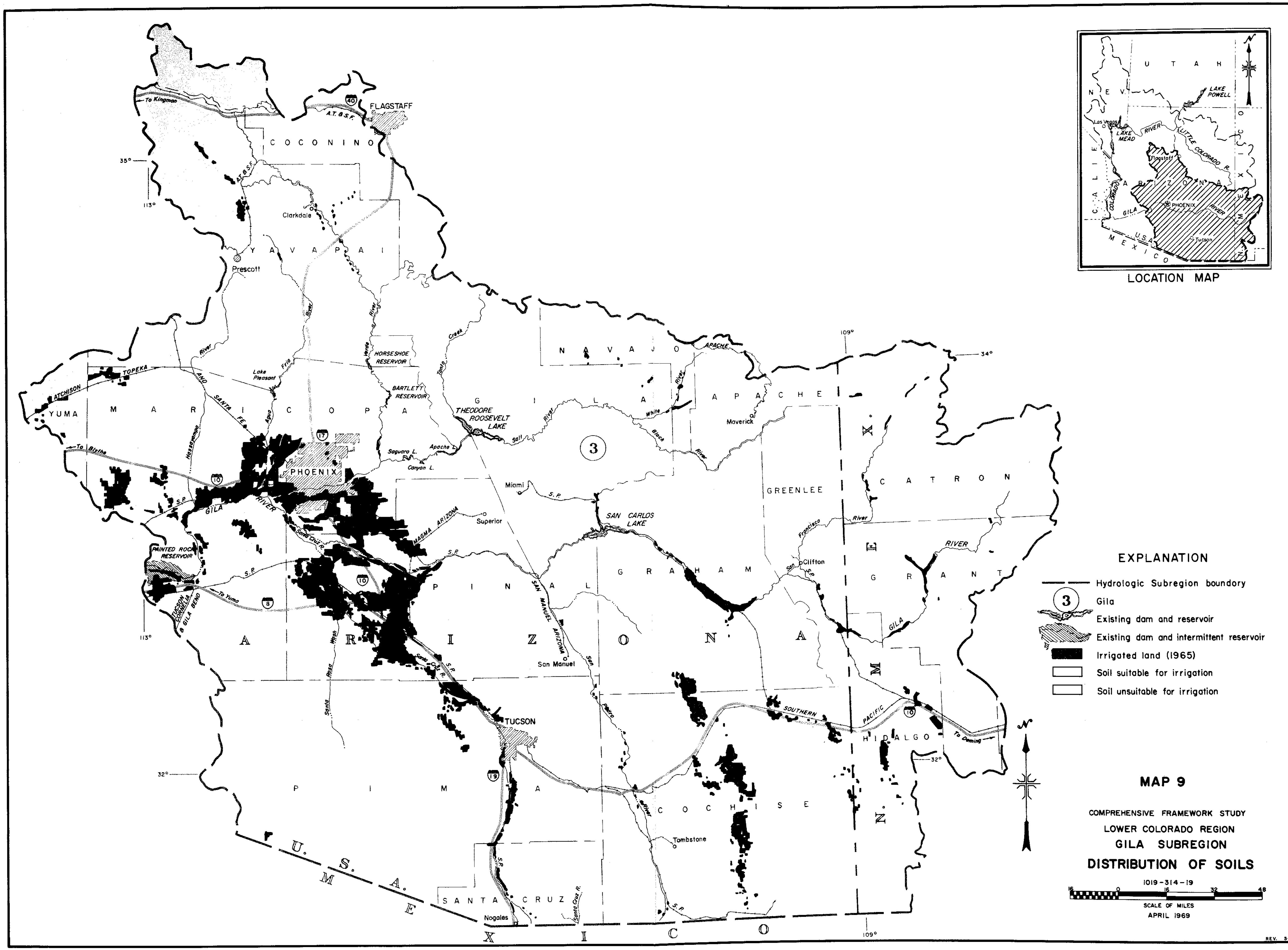

LOCATION MAP
UTAH
LAKE POWELL
Las Vegas
LAKE MEAD
RIVER
LITTLE COLORADO R.
Flagstaff
ARIZONA
PHOENIX
Tucson
GILA
U.S.A.
MEXICO
EXPLANATION
Hydrologic Subregion boundary
Gila
Existing dam and reservoir
Existing dam and intermittent reservoir
Irrigated land (1965)
Soil suitable for irrigation
Soil unsuitable for irrigation
MAP 9
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
GILA SUBREGION
DISTRIBUTION OF SOILS
1019-314-19
SCALE OF MILES
APRIL 1969
REV. 3-71
FLAGSTAFF
COCONINO
YAVAPAI
Clarkdale
Prescott
MARICOPA
YUMA
PHOENIX
GILA
NAVAJO
APACHE
GREENLEE
CATRON
GRANT
HIDALGO
PINAL
PIMA
COCHISE
SANTA CRUZ
ARIZONA
U.S.A.
MEXICO
HORSESHOE RESERVOIR
BARTLETT RESERVOIR
THEODORE ROOSEVELT LAKE
SAN CARLOS LAKE
PAINTED ROCK RESERVOIR
Lake Pleasant
Saguaro L.
Canyon L.
Apache L.
Miami
Superior
Maverick
Clifton
San Manuel
TUCSON
Tombstone
Nogales
To Kingman
To Blythe
To Yuma
To Deming
A.T. & S.F.
ATCHISON TOPEKA AND SANTA FE
SOUTHERN PACIFIC
MAGMA ARIZONA
SAN MANUEL ARIZONA
35°
34°
32°
113°
109°

Table 13

Lower Colorado Region Comprehensive Framework Study
(Type I)
Hydrologic Subregions
Classes of Land for Irrigation
Irrigation Land Classes

Unit: 1,000 acres

State	Subregion	1	2	3	4	Total 1-4	6 1/	Total 2/
Arizona	Lower Main Stem	895	2,433	3,344	2,621	9,293	13,476	22,769
	Little Colorado	541	836	2,349	2,100	5,826	8,031	13,857
	Gila	3,833	3,733	4,175	4,676	16,417	15,224	31,641
		5,269	7,002	9,868	9,397	31,536	36,731	68,267
New Mexico	Little Colorado	34	216	416	309	975	2,421	3,396
	Gila	207	385	363	684	1,639	3,510	5,149
		241	601	779	993	2,614	5,931	8,545
Nevada	Lower Main Stem	48	181	582	1,010	1,821	9,122	10,943
		48	181	582	1,010	1,821	9,122	10,943
Utah	Lower Main Stem	10	33	103	98	244	1,989	2,233
		10	33	103	98	244	1,989	2,233
Subregion								
Lower Main Stem		953	2,647	4,029	3,729	11,358	24,587	35,945
Little Colorado		575	1,052	2,765	2,409	6,801	10,452	17,253
Gila		4,040	4,118	4,538	5,360	18,056	18,734	36,790
Region Total		5,568	7,817	11,332	11,498	36,215	53,773	89,988

1/ Class 6 land not suited for irrigation development.

2/ Totals include presently developed land.

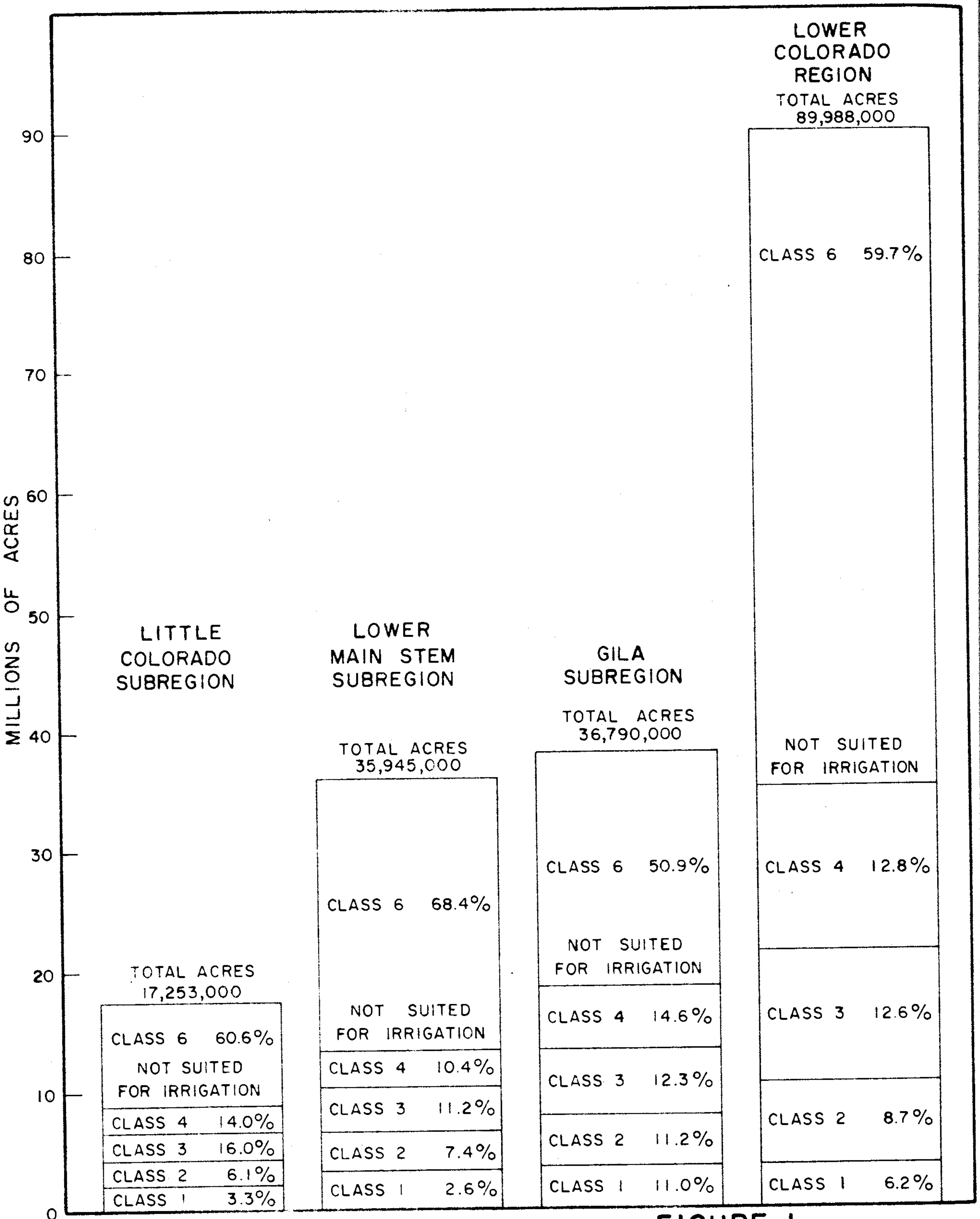


FIGURE I

COMPREHENSIVE FRAMEWORK STUDY

LOWER COLORADO REGION

IRRIGATION LAND CLASSES

HYDROLOGIC AREAS

1019-314-26

SEPTEMBER 1970

Table 14

Lower Colorado Region Comprehensive Framework Study
(Type I)
Hydrologic Subregions
Potential Land and Projected Water Requirements
2020

State	Subregion	Land Suited for Irrigation (1,000 ac)	Crop Irrigation Requirement (maf)	Withdrawal Requirement (maf)
Arizona	Lower Main Stem	9,293	26	44
	Little Colorado	5,826	16	28
	Gila	16,417	46	79
	Subtotal	31,536	88	151
New Mexico	Little Colorado	975	3	5
	Gila	1,639	5	8
	Subtotal	2,614	8	13
Nevada	Lower Main Stem	1,821	5	9
Utah	Lower Main Stem	244	-	1
Subregion				
Lower Main Stem		11,358	32	54
Little Colorado		6,801	19	33
Gila		18,056	50	86
Region Total		36,215	101	173

FUTURE DEMAND

CHAPTER D - FUTURE DEMAND

General

Agriculture has been historically a mainstay of the Region's economic growth and is vital to the stability of the Nation's future economy. To achieve this goal and to satisfy the requirements of the Modified OBE-ERS 1/ projections, it will be necessary to provide increased efficiencies and higher yields. Since the outlook is for continually rising input costs, the farmer will be provided the motive for accepting procedures that will allow him to continue to increase production to offset the higher operating costs.

The following paragraphs indicate the projected need for land and water to satisfy the Modified OBE-ERS projections.

Projections of Demands for Irrigated Land

In developing projections for future irrigated land requirements it was necessary to first derive data on acreage of harvested crops from the Modified OBE-ERS projected demands for the three study periods--1980, 2000, and 2020. These acreage values were provided by the Economic Work Group and a full discussion of the derivation of harvested crops by the economic Subregions is contained in the Economics Appendix.

These values were then computed for the hydrologic Subregions and the Region and are shown in table 15 for each of the projected years by groups of crops. A more detailed breakdown of the acreage by individual crops is available in the supporting data.

These data were then used to compute water requirements for each of the projected years which is discussed in the following section. In addition to the harvested acreage a certain portion of irrigated land is often planted and irrigated which does not get harvested due to economic circumstances of prices or other factors.

The double cropped land represents land from which two or more crops are harvested each year, such as spring lettuce and fall lettuce. However, it is not always the same crop. This value does not include double use of the same crop such as alfalfa harvested for hay and then pastured, or barley pasture and barley grain.

1/ Requirements were calculated originally to meet projections prepared by the Office of Business Economics and the Economics Research Service (OBE-ERS). These projections were subsequently modified by a Lower Colorado Region task force, largely of State representatives, to better reflect local planning. This led to the term "Modified OBE-ERS."

Table 15

Lower Colorado Region
Comprehensive Framework Study
Modified OBE-ERS Analysis
Projected Cropped Acres by Categories
Hydrologic Areas

Unit: 1,000 acres

Crop and Area	1965	Modified OBE-ERS Projected Acres 1980	2000	2020
Feed Crops 1/				
Region	629	637	582	488
Lower Main Stem Subregion	(123)	(133)	(107)	(94)
Little Colorado Subregion	(15)	(19)	(19)	(19)
Gila Subregion	(491)	(485)	(456)	(375)
Pasture				
Region	38	51	65	76
Lower Main Stem Subregion	(6)	(8)	(11)	(11)
Little Colorado Subregion	(2)	(2)	(3)	(4)
Gila Subregion	(30)	(41)	(51)	(61)
Food Crops 2/				
Region	178	335	423	509
Lower Main Stem Subregion	(69)	(120)	(146)	(174)
Little Colorado Subregion	(2)	(3)	(4)	(5)
Gila Subregion	(107)	(212)	(273)	(330)
Oil, Fiber, and Seed 3/				
Region	354	402	447	475
Lower Main Stem Subregion	(31)	(51)	(62)	(72)
Little Colorado Subregion	-	-	-	-
Gila Subregion	(323)	(351)	(385)	(403)
Other Crops 4/				
Region	43	45	46	50
Lower Main Stem Subregion	(41)	(42)	(42)	(44)
Little Colorado Subregion	(2)	-	(1)	(1)
Gila Subregion	-	(3)	(3)	(5)

Table 15

Lower Colorado Region
Comprehensive Framework Study
Modified OBE-ERS Analysis
Projected Cropped Acres by Categories
Hydrologic Areas

Unit: 1,000 acres

Crop and Area	1965	Modified OBE-ERS Projected Acres 1980	2000	2020
Acres Harvested	1,242	1,470	1,563	1,598
Acres Double Cropped 5/	125	142	151	154
Failures	73	18	16	15
Acres Irrigated	1,315	1,488	1,579	1,613
Net Acreage Cropped 6/	1,190	1,346	1,428	1,459

1/ Feed Crops: Barley, corn, oats, sorghum, alfalfa hay tame hay, and silage.

2/ Food Crops: Vegetables, citrus, non-citrus fruit, nuts, potatoes, and wheat.

3/ Oil, Fiber, and Seed Crops: Cotton, safflower, and flaxseed.

4/ Other Crops: Bermuda grass seed, sugar beets.

5/ Lower Main Stem Subregion and Gila Subregion harvested acreage X 10 percent.

6/ Acres irrigated less acres double cropped.

The total irrigated acreage in the Lower Colorado Region will be increased about 297,000 acres by the year 2020 if the Modified OBE-ERS projections are achieved. This will represent an increase of approximately 23 percent of the 1965 acreage.

"Acres Irrigated" as shown on table 15 were those used in computing water requirements.

Projections of Water Requirements

The crop irrigation requirement as shown on table 16 is based on the theoretical consumptive use as determined by the Blaney-Criddle Method utilizing the latest available data on seasonal crop coefficients. The total crop irrigation requirement will increase about 870,000 acre-feet by the year 2020 to satisfy the Modified OBE-ERS projections. This calculates to be a 22 percent increase over the existing theoretical crop irrigation requirement. This may be accomplished by increasing the farm efficiency through utilization of the conditions stated below.

The irrigation diversion requirement for each Subregion within the Lower Colorado Region is also shown on table 16. It should be noted that the total Regional withdrawal requirement of 9,138,000 acre-feet in 1965 (computed, based on full supply) decreases to 8,405,000 acre-feet in the projection year 2020. This indicates a decrease of 733,000 acre-feet or 8 percent less than the 1965 diversion requirement. Since these are theoretical figures based on a full water supply, it should not be construed that the decrease of 733,000 acre-feet is surplus and available for irrigation.

The following conditions must be satisfied by 2020 to allow the crop irrigation requirement to increase 22 percent while the diversion requirement decreases 8 percent overall for the Lower Colorado Region:

1. Every effort must be made to conserve the available water supply.

a. It is essential that all distribution systems be constructed with impervious linings or enclosed in pipelines.

b. It is necessary that farm practices and facilities be improved.

c. Irrigation efficiency must increase.

2. Soil, moisture, and plant management programs will be needed at an expanded basis.

Table 16

Lower Colorado Region
Modified OBE-ERS Hydrologic Area
Irrigation and Drainage
Projected Requirements

	1965	1980	2000	2020
Irrigated Area (1,000 ac)	1,315	1,488	1,579	1,613
Lower Main Stem	(293)	(360)	(373)	(403)
Little Colorado	(28)	(34)	(36)	(36)
Gila	(994)	(1,094)	(1,170)	(1,174)
Water Requirements 1/				
Crop Irrig. Req. (1,000 ac-ft)	4,024	4,666	4,829	4,893
Lower Main Stem	(964)	(1,219)	(1,241)	(1,324)
Little Colorado	(51)	(62)	(66)	(66)
Gila	(3,009)	(3,385)	(3,522)	(3,503)
Diversion Req. (1,000 ac-ft)	9,138	9,429	8,496	8,405
Lower Main Stem	(2,682)	(2,771)	(2,434)	(2,396)
Little Colorado	(137)	(141)	(129)	(120)
Gila	(6,319)	(6,517)	(5,933)	(5,889)

	1966-1980	1981-2000	2001-2020
Irrigation Development (1,000 ac)			
Lower Main Stem	67.0	17.2	34.6
Increased Irrig. Area	(66.2)	(14.1)	(29.3)
Urban Replacement	(0.8)	(3.1)	(5.3)
Little Colorado	6.3	1.6	0.4
Increased Irrig. Area	(5.8)	(1.2)	(0.)
Urban Replacement	(0.5)	(0.4)	(0.4)
Gila	126.6	149.6	97.0
Increased Irrig. Area	(100.2)	(75.6)	(3.9)
Urban Replacement	(26.4)	(74.0)	(93.1)
Lower Colorado Region	199.9	168.4	132.0
Increased Irrigation Area	(172.2)	(90.9)	(33.2)
Urban Replacement	(27.7)	(77.5)	(98.8)

1/ Does not include noncrop consumptive losses associated with irrigation. These losses have been estimated by and are included in Appendix V.

The above conditions will result in a decrease in return flows from irrigation in the Lower Colorado Region.

The adequacy of supply for the future of irrigation within the Lower Colorado Region is dependent on the plans that will be developed to provide water to meet the requirement for all uses. It is evident that some type of augmentation will be necessary to attain the Modified OBE-ERS goals.

Projections of Irrigation Economy

It is anticipated that landownership of irrigated lands will continue in the future at about the same level as existed in 1965. With the exception of development within Indian reservations, it is believed that public lands will be converted to private ownership either at the time or soon after irrigation development.

In addition to the land in the agricultural area used for harvested and/or irrigated land, there are other lands necessary within the farm for accomplishment of the program. Table 17 presents the Regional and Subregional distribution of this land for the three projected study periods. The derivation for each of the acreage values given is shown as footnotes in the table. The total as shown represents the land area developed that is required to meet the Modified OBE-ERS projection for the irrigated agricultural projections.

The total values shown represent the minimum acreage required in farms to meet the projected irrigation demands. In addition to this acreage, land will be required for highways, transmission lines, district canals, nonproductive land, and urban encroachment within the gross area of the farming community. Tables and discussion on these items are contained in the Land Resources and Use-Watershed Management Appendix.

Crop yield projections were made for these studies and were based upon judgment of agricultural technicians from State universities and Federal agencies involved in the Region, modified as necessary to achieve consistency among crops and among regions of the Pacific Southwest. The yield projections were based upon general criteria of the Type I study, supplemented by the following specific assumptions:

1. The projections reflect the average level of performance reasonably expected of all farm operators with the average level of management expected to prevail in each of the target years.

Table 17

Lower Colorado Region
Comprehensive Framework Study
Modified OBE-ERS Analysis
Distribution of Irrigated Farm Acreage by Uses
Hydrologic Area

Unit: 1,000 acres

	Year			
	1965	1980	2000	2020
Irrigated and Harvested 1/				
Lower Colorado Region	1,242	1,470	1,563	1,598
Lower Main Stem Subregion	278	358	371	401
Little Colorado Subregion	26	23	27	29
Gila Subregion	938	1,089	1,165	1,168
Crop Failures 2/				
Lower Colorado Region	73	18	16	15
Lower Main Stem Subregion	15	2	2	2
Little Colorado Subregion	2	11	9	6
Gila Subregion	56	5	5	7
Total Irrigated Area 3/				
Lower Colorado Region	1,315	1,488	1,579	1,613
Lower Main Stem Subregion	293	360	373	403
Little Colorado Subregion	28	34	36	35
Gila Subregion	994	1,094	1,170	1,175
Double Cropped 4/				
Lower Colorado Region	125	142	151	154
Lower Main Stem Subregion	26	33	34	37
Little Colorado Subregion	0	0	0	0
Gila Subregion	99	109	117	117
Net Irrigated Cropland 5/				
Lower Colorado Region	1,190	1,346	1,428	1,459
Lower Main Stem Subregion	267	327	339	366
Little Colorado Subregion	28	34	36	35
Gila Subregion	895	985	1,053	1,058
Farmsteads, Farmroads and Farm Canals 6/				
Lower Colorado Region	80	87	92	95
Lower Main Stem Subregion	14	20	20	22
Little Colorado Subregion	2	1	2	2
Gila Subregion	64	66	70	71

Table 17

Lower Colorado Region
Comprehensive Framework Study
Modified OBE-ERS Analysis
Distribution of Irrigated Farm Acreage by Uses
Hydrologic Area

Unit: 1,000 acres

	Year			
	1965	1980	2000	2020
Idle or Fallow 7/				
Lower Colorado Region	374	292	225	160
Lower Main Stem Subregion	41	32	25	18
Little Colorado Subregion	6	5	3	3
Gila Subregion	327	255	197	139
Total Developed Area in Farms 8/				
Lower Colorado Region	1,644	1,725	1,745	1,714
Lower Main Stem Subregion	312	379	384	406
Little Colorado Subregion	36	40	41	40
Gila Subregion	1,286	1,306	1,320	1,268

1/ Total harvested acres irrigated including double cropping.

2/ Cropland planted and irrigated but not harvested approximately 1% of irrigated and harvested for projected years.

3/ Summation of irrigated and harvested and crop failures.

4/ Ten percent of total harvested exclusive of Little Colorado Subregion.

5/ Total irrigated land less double cropped acreage.

6/ Six percent of harvested and failures (approx.) for projected years.

7/ Includes idle land in skip-row cotton production, plus a decrease of 1 percent per year from the 1965 base acreage of idle and fallow.

8/ Summation of net irrigated cropland, farmsteads, farmroads and farm canals, and idle or fallow.

2. Government programs in extension and research will continue at present levels and the average level of management of all farmers and ranchers will continue to improve.

3. The quality of land used in crop production will not change enough to have a significant effect on the level of yields.

4. The quality of water used for irrigation will not change enough to significantly affect the level of yields.

5. Water, fertilizer, insecticides, etc., required for crop production will be available at current normal price relationships.

6. Government programs are expected to exist during the projection period; however, market forces will be assumed to be the dominant factor in allocation of resources. This implies a gradual decrease in production restraints and greater market influence during the projection period.

7. Marketing and transportation facilities will be adequate to handle the projected agricultural production.

8. Current normal price relationships among inputs, and between inputs and outputs, will continue throughout the projection period.

9. Credit availability, tenure arrangements, zoning, and taxation policies will not interfere with agricultural adjustments, including farm consolidation or purchases of new technologies.

To provide a consistent base for the projections, yields for the 5-year period 1963-67 were averaged, to the extent data were available, to provide a normalized 1965 yield. Historical yields also were summarized to portray past trends.

Crop yields were first projected on an area basis to maintain consistency with location of crop production. These projections were then weighted by acres in deriving the projections for the Region and Subregions given in table 18. Projected shifts in location of production from lower to higher yielding areas naturally raised the projected yield. For example, the projected shift of cotton acreage to the Lower Main Stem Subregion caused the relative increase in yield for the Region in 2020 to exceed the relative yield increase for the Subregions.

A few crop yields were projected to approximately double by 2020 but most showed smaller increases. Three major crops--cotton, grain sorghum, and alfalfa--showed projected increases in the 80 to 90 percent range, while vegetable and citrus yields were projected to increase about 40 percent by 2020.

A number of factors have contributed to the dramatic increase in crop yields in the past 25 years, and are expected to contribute to that projected for the future. One is the high level of managerial ability of farmers in the Region and the level of financial resources at their command which permits quick adoption of technological developments and improved practices, both in solving production problems and in raising the level of production. Increased application of commercial fertilizers, herbicides, insecticides, and the like also contribute to increased yields. Increased application of fertilizers, insecticides, and herbicides will continue to be an important factor; however, due to the resulting adverse environmental effects produced by the increased usage, further study of the problem is recommended. Use of commercial nitrogen fertilizer in Arizona amounted to only about 10 thousand tons in 1950 but increased to nearly 65 thousand tons by 1965. This increase contributed materially to the rapid increase in crop yields. By 1965 commercial fertilizer was being applied on practically the entire acreage characterized by soil depletions. As a result it is not expected that continued fertilization will have the same yield-boosting effect in the future.

While projected yields were made for nearly all crops grown in the Lower Colorado Region, table 18 represents the yields for only the seven major crops. Other projected crop yields and details are available in Appendix IV, The Economic Base and Projections.

The problems inherent with providing 298,000 1/ acres of additional new irrigated land by year 2020 are compounded by the need to replace 204,000 acres of the presently irrigated area that will convert to municipal and industrial use during the same interval. Thus, it will be necessary by 2020 to irrigate 502,000 acres that were not in production in 1965. Much of the water used on the land that will be in future municipal and industrial areas will also convert to M&I usage. It follows that most of the 502,000 acres must assume a new water source if the Modified OBE-ERS projections are to be realized.

Water quality is emerging as a problem in the Lower Colorado Region. Particular concern is maintained for the Lower Main Stem Subregion as further degradation of quality is anticipated as the

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1/ Includes double cropping.

Table 18

Projected Yields for Major Crops
Type I
Lower Colorado Region

		Projected Yields 1/					
		Unit per Harvested Acre			Index (1965 = 100)		
Crop and Area	1965 Yield 2/	1980	2000	2020	1980	2000	2020
Alfalfa (in tons)							
Region	5.14	6.23	7.91	9.24	121	154	180
Lower Main Stem	5.38	6.41	8.07	9.46	119	150	176
Little Colorado	2.80	3.19	3.76	4.35	114	134	155
Gila	5.11	6.28	8.05	9.40	123	158	184
Barley (in lbs)							
Region	3,293	4,068	4,763	5,458	124	145	166
Lower Main Stem	3,178	3,903	4,577	5,250	123	144	165
Little Colorado	1,925	2,217	2,606	2,912	115	135	151
Gila	3,309	4,090	4,788	5,486	124	145	166
Citrus (in tons)							
Region	9.0 3/	9.6	11.2	13.0	106	124	144
Lower Main Stem	8.6 3/	9.1	10.7	12.4	106	124	144
Gila	9.7 3/	10.3	12.1	14.0	106	124	144
Cotton (in lbs)							
Region	1,007	1,233	1,511	1,808	122	150	180
Lower Main Stem	1,407	1,738	2,188	2,488	124	156	177
Gila	969	1,175	1,416	1,698	121	146	175
Pasture (in AUM)							
Region	9.0 4/	10.8	12.6	14.5	120	140	160
Lower Main Stem	6.7 4/	8.0	9.4	10.7	120	140	160
Little Colorado	5.7 4/	6.8	8.0	9.1	120	140	160
Gila	9.7 4/	11.6	13.6	15.5	120	140	160
Sorghum (in lbs)							
Region	4,297	5,506	6,690	7,766	128	156	181
Lower Main Stem	3,508	4,476	5,537	6,307	128	158	180
Gila	4,366	5,596	6,790	7,895	128	156	181
Vegetables (in cwt)							
Region	169 3/	196	212	235	116	125	139
Lower Main Stem	152 3/	163	171	195	107	112	128
Little Colorado	140 3/	170	200	220	121	143	157
Gila	183 3/	228	255	271	124	139	148

1/ The unrounded figures are not intended to imply preciseness in projections. The projections, originally made on an area basis, were rounded but this feature was lost when area projections were combined, weighted by acres, to obtain projections by Subregion and Region.

2/ Normalized as far as feasible. Arizona and New Mexico County yields were normalized by averaging 1963-67 yields published in Arizona Agricultural Statistics, Arizona Crop and Livestock Reporting Service and in New Mexico Agricultural Statistics, New Mexico Department of Agriculture cooperating with the U.S. Department of Agriculture. Yields for Nevada and Utah Counties were based primarily upon U.S. Census data and judgment of informed individuals.

3/ Arizona Fruit and Vegetable Standardization Service.

4/ Technician's estimate.

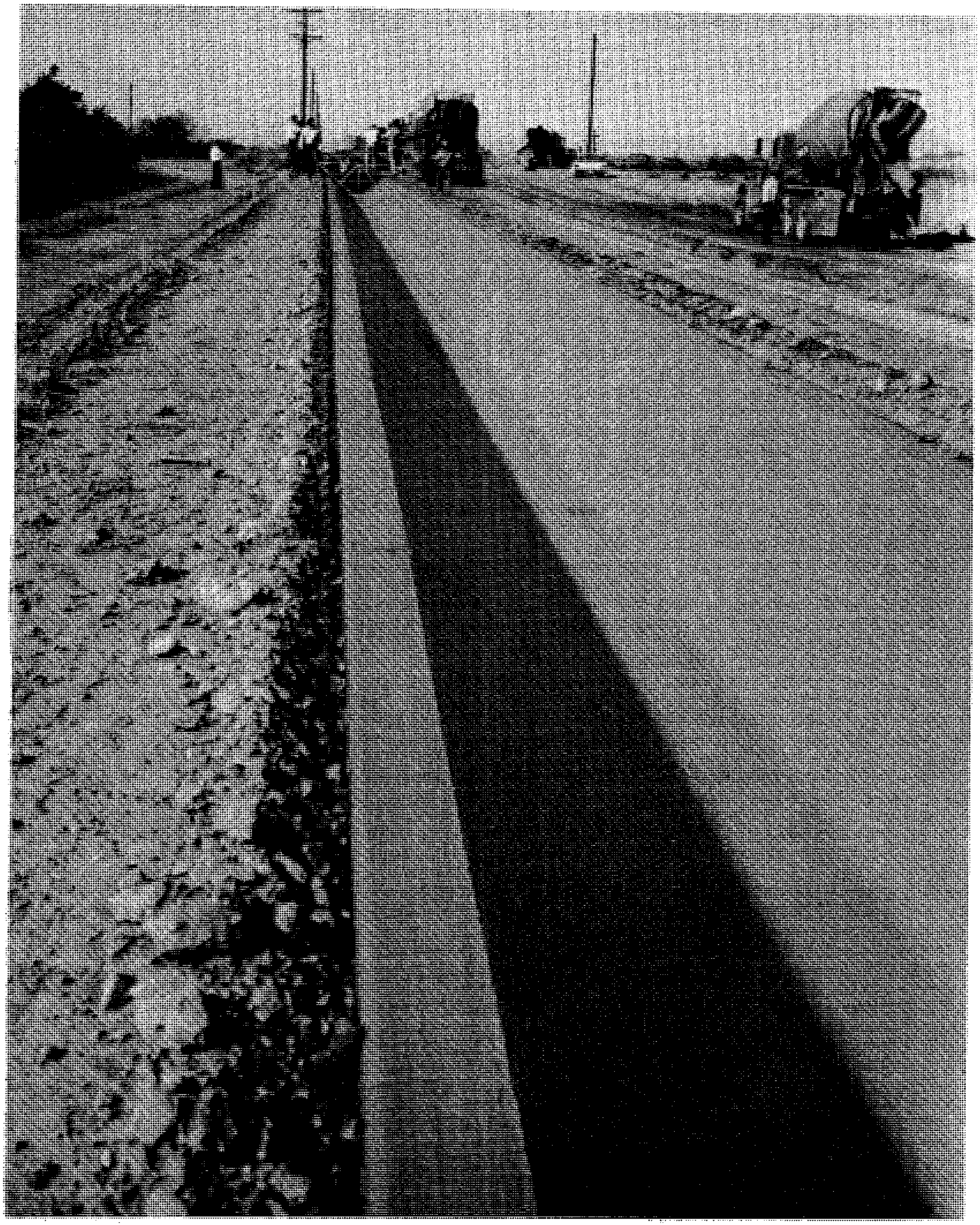

Photo No. P-885-314-74A

Picture of an existing lateral being rehabilitated with the installation of unreinforced concrete lining.

expected development in the Upper Colorado Region and in Indian reservations along the Colorado River occur. One preliminary study by the Water Quality, Pollution Control, and Health Factors Work Group indicated the likelihood of reduced yields as a result of increased salinity. Citrus production could be especially threatened since its tolerance to salts is limited.

Water quality of ground water will also become an increasing problem in some areas. Salt concentrations are known to exist in some aquifers at the greater depths. If the water levels continue to decline, it may eventually be necessary to abandon the pumping in some areas because of saline considerations.

Operating costs will continue to spiral as pumping lifts and well depths increase. The user faces increased power use, as well as the need to increase the size of motors and pumps. Perhaps the greatest problem in the Lower Colorado Region is to eliminate the overdraft of the ground-water reserves and, in doing so, partially stabilize the operating costs for the users.

The rights to use waters in many areas are being questioned in court cases. There are also indications that legislatures may be petitioned to enact laws that would grant preference to "higher use." Without the protection of existing water laws, the agricultural development would have insurmountable problems in stabilizing its economy.

Means to Satisfy Needs and Demands

To satisfy the needs and demands for irrigation that are indicated in the preceding paragraphs, it will be necessary to develop lands not presently irrigated. A portion of these will be included in areas that are now developed, but idle, while the remainder will encompass new lands. In the planning for agricultural use of lands not currently irrigated, consideration should be given to the values of the natural environments and the existing wildlife resource of the land. Actual location of these lands is not particularly germane to this reconnaissance study since development costs will be essentially the same assuming a water supply is available in the general area.

It is assumed that all existing distribution systems that are not now lined would be rehabilitated with concrete lining and/or pipelines. Much of the incentive for this construction will be provided by the authorized Central Arizona Project which requires impervious linings prior to delivery of project water. This activity will likely be completed by 1980. In addition, new irrigation distribution systems would be required to deliver water to areas that are now served by pumped water and to areas that will be needed for the projected irrigation increase and urban replacement.

Future augmentation will allow a decrease in pumping so that the ground-water overdraft will be curtailed. Agricultural drainage effluent will become available in increasing amounts. Drainage systems will be required to collect this water. It is anticipated that about 69,000 acre-feet of drainage flow will be available annually from the Gila Subregion by 1990. This figure may approach 309,000 acre-feet annually by the year 2020. A small desalting plant may prove to be beneficial in reclaiming this water.

Table 19 indicates the proposed development (in acres) to satisfy the drainage and distribution system needs.

Program costs were estimated for the off-farm irrigation and drainage development requirements by time frames assuming a water supply available locally. Feasibility estimates for the proposed Central Arizona Project were used as a basis for extending costs for this study. Table 20 provides the investment costs as well as operation, maintenance, and replacement costs. Implementation of the proposed programs will require an investment of $69,670,000 for rehabilitation and $107,500,000 for development of new irrigation distribution systems by 1980. Thereafter, about $225,000,000 will be required to complete the construction by 2020.

On-farm costs are presented in the Land Resources and Use-Watershed Management Appendix. These costs include development of new lands and rehabilitation of existing but idle lands.

The estimated costs of providing an adequate drainage collection system for the projected years is $14,400,000, $14,640,000, and $45,500,000 for the years 1980, 2000, and 2020, respectively, to be used on existing irrigated lands and drainage needs that may arise from development of new irrigated lands.

Conclusions

1. It will be necessary to provide 298,000 1/ acres of additional irrigated acreage in the year 2020 if the Modified OBE-ERS projections are to be realized.

2. At the present rate of urbanization of agricultural lands it is estimated that by the year 2020 it will be necessary to irrigate an additional 204,000 acres of land to offset 1965 acreage that could convert to municipal and industrial use during the 55-year period (1965-2020). In the interim period it is recommended that in-depth land use planning studies be undertaken to provide guidelines and policies for planned encroachment of agricultural lands by urbanization.

1/ Includes double cropping.

Table 19

LOWER COLORADO REGION
MODIFIED OBE-ERS - HYDROLOGIC AREA
DEVELOPMENT NEEDS 5/
(1,000 acres)

	1965	1966-1980	1981-2000	2001-2020
Drainage Needs (1,000 ac) 1/				
Lower Main Stem	210	67	18	38
Little Colorado	-	-	1	1
Gila	2	1	13	49
Rehabilitation of Existing Irrigation Dist. System 2/				
Acreage Served	293	429	-	-
Lower Main Stem 3/	(131)	(103)	-	-
Little Colorado 3/	(2)	(6)	-	-
Gila	(160)	(320)	-	-
Development of New Irrigation Distribution Systems 4/		346.8	596.2	132.0
Lower Main Stem 3/	-	(127)	(17.2)	(34.6)
Little Colorado 3/	-	(6.8)	(3.0)	(0.4)
Gila	-	(213)	(576.0)	(97.0)

1/ Group drainage needs

2/ Requirement to deliver water to farm.

3/ It is assumed that about 50 percent of the irrigated area will not be included in an organized district.

4/ Includes replacement for irrigated area utilized in urban expansion.

5/ Revised March 1970.

Table 20

LOWER COLORADO REGION
MODIFIED OBE-ERS - HYDROLOGIC AREA
DEVELOPMENT COSTS

Units: $1,000

PROGRAM COSTS 5/		1966-1980	1981-2000	2001-2020
INVESTMENT:				
Irrigation Develop. 1/	Fed.	75,500	172,100	32,700
	Non-Fed.	32,000	12,000	8,000
Lower Main Stem		(39,400)	(5,300)	(10,700)
Little Colorado		(2,100)	(800)	(200)
Gila		(66,000)	(178,000)	(29,800)
Rehab. of Existing 2/ Dist. Sys	Fed.	62,670	--	--
	Non-Fed.	7,000	--	--
Lower Main Stem		(16,700)	--	--
Little Colorado		(970)	--	--
Gila		(52,000)	--	--
Drainage	Fed.	13,400	13,640	44,500
	Non-Fed.	1,000	1,000	1,000
Lower Main Stem		(13,400)	(3,600)	(7,600)
Little Colorado		--	(200)	(200)
Gila		(1,000)	(10,840)	(37,700)
OM&R: 3/				
Irrigation				
Lower Main Stem		(2,110)	(2,200)	(2,380)
Little Colorado		(220)	(228)	(228)
Gila		(7,000)	(7,480)	(7,510)
Drainage 4/				
Lower Main Stem		(277)	(293)	(337)
Little Colorado		--	(7)	(7)
Gila		(20)	(220)	(765)

1/ Includes off-farm costs assuming a water supply available to the general area. It is assumed that 1965 acreage without distribution systems will be organized to provide economical distribution units.

2/ Includes 1965 acreage that is served by an existing distribution system.

3/ Average annual.

4/ Includes operation, maintenance, and replacement costs with power energy where applicable.

5/ Revised March 1970

3. Crop irrigation requirement will increase about 874,000 acre-feet, or 22 percent, to meet the Modified OBE-ERS projections for the 1965-2020 period.

4. The irrigation diversion requirement will decrease about 643,000 acre-feet, or about 8 percent, during the same period.

5. Quality considerations are emerging with increased importance. Some less salt tolerant crops may be affected particularly in the Lower Main Stem Subregion and some local areas.

6. Increased lining programs and other soil and moisture conservation programs are needed.

7. Estimated costs of providing the needed irrigation development are $177,170,000, $184,100,000, and $40,700,000 for the time periods 1980, 2000, and 2020, respectively.

8. Estimated costs of providing an adequate drainage collection system are $14,400,000, $14,640,000, and $45,500,000 for the time periods 1980, 2000, and 2020, respectively.

9. Augmentation schemes will be needed to offset the overdrafting of ground water and to provide for future uses.

10. Construction of authorized projects to utilize the Region's unused apportionment of Colorado River water will be required.

ALTERNATE PROJECTION

CHAPTER E

ALTERNATE PROJECTION

OBE-ERS Projections

As indicated in previous chapters, the original projections for these framework studies were made by the Office of Business Economics and the Economic Research Service. Modifications based on increased population projections furnished by the various States were made and used for the studies in the Lower Colorado Region. For ease of comparison, three tables are included to show the acreage requirements needed to satisfy the OBE-ERS projections. Since it was decided to not develop a framework plan for the OBE-ERS projections no data are available on costs associated with the irrigation and drainage portions of these projections. However, as the irrigated acreage and water requirements for the OBE-ERS projections are smaller than for the Modified OBE-ERS projections the costs would also be smaller. This would be true for each time frame but the difference would be slight. For example, for the Region, the difference in irrigated acreage in 2020 between the two projections is only 126,000 acres which is somewhat less than 10 percent of either projection.

Table 21 presents projected cropped acres by categories and is similar to table 16.

Table 22 lists the projected water and new land requirements for OBE-ERS and is comparable to table 16.

Table 23 presents a comparison with table 17 for the distribution of irrigated farm acreages by uses.

Table 21

Lower Colorado Region
Comprehensive Framework Study
OBE-ERS Analysis
Projected Cropped Acres by Categories
Hydrologic Areas

Unit: 1,000 acres

Crop and Area	1965	OBE-ERS Projected Acres 1980	2000	2020
Feed Crops 1/				
Region	629	494	491	476
Lower Main Stem Subregion	(123)	(111)	(112)	(108)
Little Colorado Subregion	(15)	(9)	(9)	(9)
Gila Subregion	(491)	(374)	(370)	(359)
Pasture				
Region	38	49	62	74
Lower Main Stem Subregion	(6)	(8)	(10)	(12)
Little Colorado Subregion	(2)	(2)	(3)	(3)
Gila Subregion	(30)	(39)	(49)	(59)
Food Crops 2/				
Region	178	233	264	293
Lower Main Stem Subregion	(69)	(94)	(113)	(125)
Little Colorado Subregion	(2)	(3)	(3)	(3)
Gila Subregion	(107)	(136)	(148)	(165)
Oil, Fiber, and Seed 3/				
Region	354	477	474	477
Lower Main Stem Subregion	(31)	(51)	(62)	(73)
Little Colorado Subregion	-	-	-	-
Gila Subregion	(323)	(426)	(412)	(404)
Other Crops 4/				
Region	43	144	147	152
Lower Main Stem Subregion	(41)	(52)	(53)	(55)
Little Colorado Subregion	(2)	(6)	(6)	(6)
Gila Subregion	-	(86)	(88)	(91)

Table 21

Lower Colorado Region
Comprehensive Framework Study
OBE-ERS Analysis
Projected Cropped Acres by Categories
Hydrologic Areas

Unit: 1,000 acres

Crop and Area	OBE-ERS Projected Acres 1965	1980	2000	2020
Acres Harvested	1,242	1,398	1,438	1,472
Acres Double Cropped 5/	125	135	139	142
Failures	73	6	6	6
Acres Irrigated	1,315	1,404	1,444	1,479
Net Acreage Cropped 6/	1,190	1,270	1,305	1,336

1/ Feed Crops: Barley, corn, oats, sorghum, alfalfa hay, tame hay, and silage.

2/ Food Crops: Vegetables, citrus, non-citrus fruit, nuts, potatoes, and wheat.

3/ Oil, Fiber, and Seed Crops: Cotton, safflower, and flaxseed.

4/ Other Crops: Bermuda grass seed, sugar beets.

5/ Lower Main Stem Subregion and Gila Subregion X 10 percent.

6/ Acres irrigated less acres double cropped.

Table 22

LOWER COLORADO REGION
OBE-ERS - HYDROLOGIC AREA
IRRIGATION AND DRAINAGE
PROJECTED REQUIREMENTS 1/

	1965	1980	2000	2020
Irrigated Area (1,000 ac)	1,315	1,404	1,444	1,479
Lower Main Stem	(293)	(318)	(351)	(375)
Little Colorado	(28)	(21)	(22)	(22)
Gila	(994)	(1,065)	(1,071)	(1,082)
Water Requirements 2/				
Crop Irrigation Requirement (1,000 ac-ft)	4,023	4,433	4,457	4,514
Lower Main Stem	(964)	(1,081)	(1,172)	(1,236)
Little Colorado	(51)	(42)	(43)	(43)
Gila	(3,008)	(3,310)	(3,242)	(3,235)
Diversion Requirement (1,000 ac-ft)	9,138	8,922	7,843	7,754
Lower Main Stem	(2,682)	(2,456)	(2,299)	(2,237)
Little Colorado	(137)	(95)	(85)	(79)
Gila	(6,319)	(6,371)	(5,459)	(5,438)

	1966-1980	1981-2000	2001-2020
Irrigation Development (1,000 ac)			
Lower Main Stem	25.8	36.1	29.3
Increased Irrig. Area	25.0	33.0	24.0
Urban Replacement	0.8	3.1	5.3
Little Colorado	0.5	0.4	0.4
Increased Irrig. Area	0	0	0
Urban Replacement	0.5	0.4	0.4
Gila	97.4	80.0	104.1
Increased Irrig. Area	71.0	6.0	11.0
Urban Replacement	26.4	74.0	93.1
Lower Colorado Region	123.7	116.5	133.8
Increased Irrigation Area	96.0	39.0	35.0
Urban Replacement	27.7	77.5	98.8

1/ Revised March 1970.

2/ Losses associated with irrigation are discussed in Water Resources Appendix V.

Table 23

Lower Colorado Region
Comprehensive Framework Study
OBE-ERS Analysis
Distribution of Irrigated Farm Acreage by Uses
Hydrologic Area

Unit: 1,000 acres

	Year			
	1965	1980	2000	2020
Irrigated and Harvested 1/				
Lower Colorado Region	1,242	1,398	1,438	1,472
Lower Main Stem Subregion	(278)	(316)	(350)	(373)
Little Colorado Subregion	(26)	(21)	(22)	(22)
Gila Subregion	(938)	(1,061)	(1,066)	(1,077)
Crop Failures 2/				
Lower Colorado Region	73	6	6	6
Lower Main Stem Subregion	(15)	(1)	(1)	(1)
Little Colorado Subregion	(2)	(0)	(0)	(0)
Gila Subregion	(56)	(5)	(5)	(5)
Total Irrigated Land 3/				
Lower Colorado Region	1,315	1,404	1,444	1,478
Lower Main Stem Subregion	(293)	(317)	(351)	(374)
Little Colorado Subregion	(28)	(21)	(22)	(22)
Gila Subregion	(994)	(1,066)	(1,071)	(1,082)
Double Cropped 4/				
Lower Colorado Region	125	135	139	142
Lower Main Stem Subregion	(26)	(29)	(32)	(34)
Little Colorado Subregion	0	-	-	-
Gila Subregion	(99)	(106)	(107)	(108)
Net Irrigated Cropland 5/				
Lower Colorado Region	1,190	1,269	1,305	1,336
Lower Main Stem Subregion	(267)	(288)	(319)	(340)
Little Colorado Subregion	(28)	(21)	(22)	(22)
Gila Subregion	(895)	(960)	(964)	(974)
Farmsteads, Farmroads and Farm Canals 6/				
Lower Colorado Region	80	87	89	91
Lower Main Stem Subregion	(14)	(16)	(16)	(16)
Little Colorado Subregion	(2)	(2)	(2)	(2)
Gila Subregion	(64)	(69)	(71)	(73)

Table 23

Lower Colorado Region
Comprehensive Framework Study
OBE-ERS Analysis
Distribution of Irrigated Farm Acreage by Uses
Hydrologic Area

Unit: 1,000 acres

	Year			
	1965	1980	2000	2020
Idle or Fallow 7/				
Lower Colorado Region	374	292	226	160
Lower Main Stem Subregion	(41)	(32)	(25)	(18)
Little Colorado Subregion	(6)	(5)	(4)	(3)
Gila Subregion	(327)	(255)	(197)	(139)
Total Developed Area in Farms 8/				
Lower Colorado Region	1,644	1,648	1,620	1,587
Lower Main Stem Subregion	(312)	(336)	(360)	(374)
Little Colorado Subregion	(36)	(28)	(28)	(27)
Gila Subregion	(1,286)	(1,284)	(1,232)	(1,186)

1/ Total harvested acres irrigated including double cropping.

2/ Cropland planted and irrigated but not harvested approximately 1 percent of irrigated and harvested for projected years.

3/ Summation of irrigated and harvested and crop failures.

4/ Ten percent of total harvested exclusive of Little Colorado Subregion.

5/ Total irrigated land less double cropped acreage.

6/ Six percent of harvested and failures (approx.) for projected years.

7/ Includes idle land in skip-row cotton production, plus a decrease of 1 percent per year from the 1965 base acreage of idle and fallow.

8/ Summation of net irrigated cropland, farmsteads, farmroads and farm canals, and idle or fallow.