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Riparian habitat changes in Cibola National Wildlife Refuge: 1959–1991

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RIPARIAN HABITAT CHANGES IN

CIBOLA NATIONAL WILDLIFE REFUGE: 1959 - 1991

by

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APPROVAL BY THESIS DIRECTOR

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ABSTRACT

In 1959, the Bureau of Reclamation proposed a channelization project through the Cibola Valley along the Lower Colorado River. The project entailed rerouting the river through a dry cut in order to lower groundwater levels in the Palo Verde Irrigation District upstream, thereby improving irrigation drainage. In conjunction with this, Cibola National Wildlife Refuge was created in 1964 to mitigate the effects of habitat loss from the channelization project. Aerial photographs of the Cibola Valley were analyzed for 1959, and vegetation community types were determined. A vegetation type map was developed for 1959 and compared with vegetation type maps for 1976 and 1986. Between 1959 and 1986, a lowering of the water-surface level in some parts of the refuge resulted in the draining of some lakes and the creation of slow-moving backwaters. Cottonwood-willow and marsh communities saw a significant reduction in area while the salt-cedar community saw rapid growth.

INTRODUCTION

Cibola National Wildlife Refuge, lying along the Lower Colorado River approximately 32 km south of Blythe, California, contains 67.2 km^2 of riverbottom land surrounded by desert. In 1964, two significant events affected the lands comprising the refuge: 1) intensive manipulation of the river channel through the refuge occurred under a channelization project undertaken by the Bureau of Reclamation between 1964 and 1970; 2) the land was acquired for fish and wildlife management in order to mitigate the effects of habitat loss from this channelization project, as well as for protection of the land from intensive development (primarily agriculture) characteristic of adjacent floodplain areas.

This paper attempts to establish and measure the types of changes that have occurred during the past 30 years within the ecosystem of the lands now occupied by the Cibola National Wildlife Refuge, and to analyze these changes with respect to the above events. Measurement of change was done through stereoscopic analysis of 1959 aerial photos, and these were compared with existing vegetation maps for 1976 and 1986. Changes relating to specific actions and events were analyzed based on correspondence in time and consideration of established ecological principles.

By 1964, ecological conditions on the lands within Cibola National Wildlife Refuge had already experienced nearly a century of accelerated human impact. The early exploitation of cottonwood and mesquite for fuelwood, the complete regulation of flows with the establishment of the first major dams in 1936, upstream withdrawals of water for irrigation, increased salinization, and changes in channel development due to alterations in sediment loads had all impacted the riparian and wetland communities along the Lower Colorado River (LCR) prior to creation of the refuge and the channelization project on its lands. One of the essential components of this study was to understand the relative stability of ecological conditions that prevailed just prior to the Bureau's channelization project through Cibola National Wildlife Refuge.

Ecological conditions within the refuge were relatively stable by 1964, having adjusted to the major hydrologic alterations of the previous several decades. Upon completion of the channelization project in 1970, and the diversion of the Colorado River into a new channel, the ecosystem began to undergo significant changes. As a result of the project, a lowering of the water-surface level occurred in portions of the refuge, as well as a drastically reduced rate of flow in the original channel. This lowering of the water-surface level, an expressed goal of the Bureau of Reclamation, drained the previous shallow Davis and Three Fingers lakes, resulting in the marshlands in these areas being replaced by the exotic salt cedar. In addition to lower water-surface levels, the stabilization of flows caused a reduction in number of riparian species reliant upon flooding for fertilization and reseeding. Cottonwood-willow communities have, in particular, been adversely affected not only within the refuge boundaries, but along the entire LCR.

The reduced water flow in the original channel affected the vegetation bordering the channel which experienced a visible increase in marsh species such as cattails. In order to mitigate the effects of marshland species encroaching into drained backwaters retaining shallow water, dredging operations, such as that in Cibola Lake, were implemented. This allowed for a deeper lake of permanent open water even in times of low water-surface levels.

Rapid native habitat loss in Cibola National Wildlife Refuge is now being mitigated through revegetation programs. Without these, the vegetation trends observed between 1959 and 1992 would most likely continue, increasing the probability of diverse vegetation communities eventually becoming dominated by salt cedar. This study hope to contribute to an understanding of the impact of water management projects on riparian ecosystems in an arid environment.

HISTORICAL BACKGROUND

From its headwaters in Wyoming and Colorado to its terminus at the Delta in the Gulf of California, the Colorado River is certainly one of the most dammed, diverted, and manipulated rivers in the world. Along the 453 km (281.5 miles) reach from Davis Dam to the Mexican border (Figure 1), the Lower Colorado River (LCR) supports 6 dams providing irrigation for nearly 1 million acres (Ohmart et al. 1988). California's net consumptive use of Colorado River water was approximately 5 million acre-feet in 1991, with 2.9 million acre-feet going to the Imperial Irrigation District and 1.2 million acre-feet to the Metropolitan Water District of Southern California. In addition, between 1.3 and 1.7 million acre-feet per year are diverted into central and southern Arizona along the newly opened Central Arizona Project canals (Bill Martin, Bureau of Reclamation, personal communication, 1992). In total, nearly 7.5 million acre-feet per year is allocated to California and Arizona--all coming from the waters of the Lower Colorado River.

The history of widespread human manipulation of the river's ecosystem, goes back to the mid-1800's when steamboats would ply the river with supplies for forts and mining camps. Fuel for these steamers and for the mines was provided from the dense stands of cottonwood and mesquite that lined the banks of the Lower Colorado River (LCR). Accounts by steamboat captains, passengers, and army personnel, in addition to photographs, attest to the fact that by the end of the steamboat era, in the late 1800's, number of cottonwoods had been seriously diminished. But the greatest impacts follow the building of the first modern dams at the turn of the century. These dams, and subsequent channelization projects, affected the vegetation along the LCR in many ways.

In order to better understand the ecological conditions which existed in Cibola National

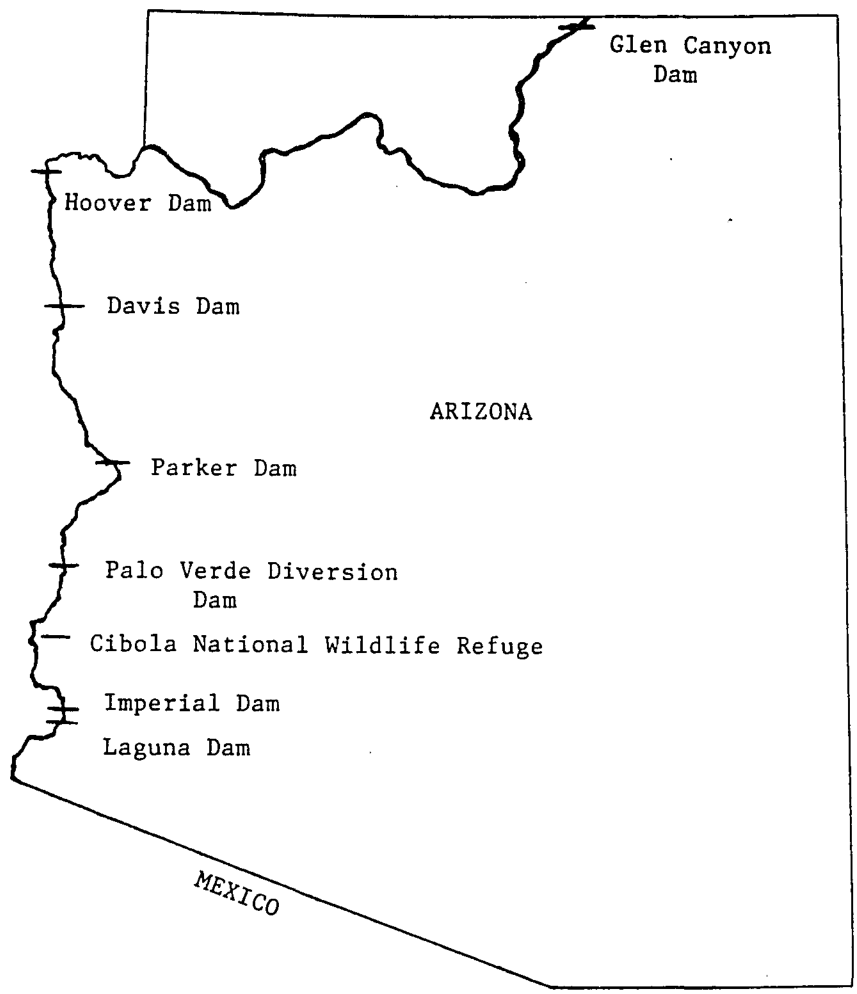


FIGURE 1: Location map of the Lower Colorado River.

Wildlife Refuge in the early 1960s, just prior to the channelization project and the creation of the refuge, it is important to understand the events which led up to and shaped the river and its adjacent lands within Cibola Valley. This section gives a brief overview of the condition of the Lower Colorado River and its ecosystem from the early 1900's until the present.

The Dams

Laguna Dam (1905-1909)

Located 13 miles above Yuma, Laguna Dam was the first dam to be built along the Colorado River by people other than the local Indians. Historically, the tribes along the river built temporary brush and earth-filled weirs to divert water for crops along the floodplain (Fradkin 1981). In addition to supplying irrigation water, Laguna was built in response to the devastating floods of 1905 which had obliterated crops and residences along the river's floodplain. The dam was designed to raise the level of the river and form a still pool in which sediment would settle and the remaining water could be diverted into canals for irrigation purposes. Perhaps the idea of a silt-trap seemed good at the time, but the engineers apparently hadn't calculated the carrying capacity of the river and within weeks of its completion, the reservoir behind Laguna Dam was filled to its lip by silt. Today, this dam mainly acts as protection for the toe of its upstream neighbor-- Imperial Dam, although some water is diverted to the Yuma Main Canal on the California side and to the Gila Irrigation District in Arizona.

The silting in of the reservoir has caused many changes in the ecosystem of this area. Silt continued to spread extensively behind the dam during the decade following its completion, and marsh vegetation--cattails, bulrush and cane--became dominant there as well as along the canals leading from the dam (Ohmart et al. 1988). An additional result of the creation of this marsh has been the northward migration of the Yuma Clapper Rail (*Rellus longirostris*), the only federally listed endangered bird species found in the Lower Colorado River Valley, from its original home in the Delta region into these newly-created marshes. This migration became more marked when the further building of upstream dams created a diminished flow, causing a drying up of the marshes within the Colorado River Delta south of the international border.

In 1912, Dr. Joseph Grinnell floated the LCR and wrote extensively on the ecological systems of that area. While in the vicinity of Laguna Dam, he observed the effects its creation had upon the landscape:

> The water level had been raised conspicuously for at least ten miles, and we saw evidence of deepening of the first-bottom deposits and slowing of current for fully thirty miles above the dam. The cottonwoods of the first-bottom had all been killed, evidently by the raising of the general surface around their trunks; and the mesquites and other vegetation of the second-bottom had all been drowned out, there thus being no trace of second-bottom conditions except for dead stalks. These were replaced by mudflats growing up to arrowweed. All of this change, of course, involved the birds and mammals of the area affected, in addition to the plant life (Grinnell 1914:61).

Imperial Dam (1935-1938)

Twenty miles north of Yuma lies the sprawling complex of Imperial Dam, which, along with Parker Dam and especially Boulder (later renamed Hoover), heralded the great dam building era along the Colorado River. These dams, constructed under the authorization of the Boulder Canyon Act of 1928, were seen as engineering wonders which would enrich both the soil and the economy of the arid lands straddling the river along its lower reaches, as well as creating an agricultural haven in Imperial Valley. Boulder Dam was revered. In his book on the building the dam, Simmons writes:

> Boulder Dam is the magnanimous wonder of modern civilization: a new era of development will follow this great triumph of man over America's most turbulent river and the present humanity and all generations to follow will experience

more rapid progress and a greater civilization (1936:1).

Under this sentiment, work began in earnest on dams and irrigation canals all along the the Lower Colorado River. Imperial Dam was built as a diversion dam primarily for the new All American Canal, the primary supplier for irrigation for Imperial Valley since 1942, with some water also being diverted to the Gila Gravity Main Canal which serves the Yuma area.

Almost as rapidly as Laguna's reservoir, the reservoir behind Imperial began to silt in. Today, the original capacity of 85,000 acre feet has shrunk to 1000 and the original vegetation has been supplanted by marshlands. Because the water diverted into the two canals is so heavily laden with sediment, three desilting basins are required to remove sand and silt before water enters these canals. This sediment is returned to the river through the California Sluiceway below the dam. Meanwhile, above the dam, dredging must be done to maintain surface flows and surface water for recreation (Ohmart et al. 1988). Since the completion of the dam in 1938, the river has been steadily aggrading from the lower reaches of what is now Cibola National Wildlife Refuge 39 miles down to Imperial Dam. Part of the 17,806 acres of the Imperial National Wildlife Refuge, the marshland behind Imperial Dam, provides an excellent variety of riparian and wetland habitats. Many backwater lakes in the refuge support large numbers of wintering waterfowl as well as nesting Yuma Clapper Rails (Rosenberg et al. 1991).

Parker Dam (1938)

Parker Dam, completed in 1938, required a 236-foot foundation to reach the bedrock lying under a deep layer of sand and gravel. With a storage capacity of approximately 648,000 acre-feet, Parker's Lake Havasu was created to entrap sediments, provide a basin for the intake of water to the Metropolitan Water District Aqueduct that serves Southern California, and provide hydroelectric power. From Lake Havasu, 3400 acrte-feet a day of water is diverted into the municipalities of Los Angeles and San Diego (Martin, Bureau of Reclamation, personal communication, 1992). Here, also, is located the Havasu Pumping Plant which began supplying water to Arizona along the Central Arizona Project in May of 1985.

In 1941, Havasu National Wildlife Refuge was created to mitigate effects of channelization and dam construction (Rosenberg et al. 1991). At first, Lake Havasu itself was included as a part of this refuge, but by the early 60s it became apparent that the recreational demands placed upon the reservoir by southern Californians were creating situations not compatible with the philosophy of a wildlife refuge. In 1965, Lake Havasu was taken out of the confines of the refuge in order to better meet the demands of a growing number of recreational users.

Headgate Rock Dam (1941)

Located 15 miles south of Parker Dam, Headgate Rock Dam was built to divert irrigation water for the Arizona portion of the Colorado Indian Reservation along the river (U.S. Bureau of Reclamation 1977). Under the control of the Bureau of Indian Affairs, Headgate Rock Dam slows the river to form Lake Moovalya, a sluggishly moving 14.4 mile stretch of river known as the Parker Strip. One of the nations most dangerous inland waterways, the Parker Strip receives a summer weekend visitation of roughly 125,000 people, many who come equipped with jet boats, jet skis, and a variety of other motor-powered watercraft (Fradkin 1981). Lining the banks of the Strip, are dockside bars, restaurants, homes, trailer parks, and campgrounds. Very little, if any, of the land immediately adjacent to the river lies undisturbed.

Davis Dam (1954)

The last of the great dams to be built on the LCR, and the largest since the building of Hoover, this earth and rock-filled dam backs up the river 67 miles to the foot of Hoover Dam and forms the 240-square-mile Lake Mojave. Although, like Parker Dam downstream, the site for Davis Dam lay on 200 feet of sediment overlying bedrock, the earth and rock structure was adapted for these conditions. Davis was built with three objectives in mind: river regulation, generation of electrical power, and the servicing of the Mexican Water Treaty of 1945 (Douglas and Asce 1947). In order to address the problem of high salinity and numerous residual pesticides arriving in Mexican fields, due primarily to the irrigation runoff of their northern neighbors, Davis Dam was built, in part, to act as a storage basin for water delivered to Mexico. The treaty promised to deliver 1.5 million acre-feet a year of water south of the border. In addition, at the time of construction, the Bureau of Reclamation felt that water released at Hoover Dam was in excess of current demand and was escaping "unused" to the Gulf and another reservoir was necessary to retain this water (Douglas and Asce 1947).

During construction of the dam, Bullhead Construction Camp was established to house the workers. Despite the belief that with completion of the dam, the camp would fold up and move away, it has become one of the centers for outdoor recreation along the river (Weir 1987). With the growing gambling city of Laughlin on the opposite bank, this area of the LCR has seen a steadily increasing population of both tourists and residents.

There is, of course, no way that an environment can be so altered without its ecosystem being highly impacted. In addition to the construction of dams along the Lower Colorado, extensive channelization projects have been undertaken. Today, from Davis Dam to the Mexican border-- a reach of 276 miles-- 144 miles are channelized, contained within artificial levees, or dredged. All but seven of these 144 miles are riprapped, a process with involves lining the river banks with rock and gravel to prevent bank erosion.

With the closing of the dams, the flow of the river has become a product of human manipulation, altering both water-surface levels and patterns of erosion and sedimentation patterns; with the changes in the flow, and agricultural return flows to the river, salinity has increased; with a change in flow characteristics and salinity levels, vegetation has made its adaptations, and under the influence of these changes both vegetation and animal communities have either immigrated to the LCR, migrated away, or ceased to exist (Rosenberg et al. 1991).

Flows

Perhaps the most dramatic change that has occurred as a result of flood control (including damming, dredging and riprapping) has been the loss of the historic floodplain. When Grinnell passed through the area between Needles and Yuma in 1912, he noted that the seasonal fluctuations in river volume ranged from approximately 4000 cfs in midwinter to 100,000 cfs in June, the height of the flood season (Grinnell 1914). Since the closing of Hoover Dam in 1935, the flows along the LCR have been regulated. No longer do natural seasonal fluctuations come into play; now, the pattern is primarily dependent on meeting the demands for electricity, from the urban sector, and agricultural crop demands. Data for 1960-1969 (Ohmart et al. 1988) show mean monthly water flow through Parker ranging from a low of 4342 cfs (260,000 acre-feet) in December to a high of 14,100 cfs (869,000 acre-feet) in July. For the same time period at Imperial Dam, the low was 4600 cfs in December and 12,000 in July (Table 1). The main repercussion of regulating the annual flows has been the realignment of vegetation both along the river's banks and in its floodplains, resulting in the alteration or elimination of riparian ecosystems.

A riparian association, according to Lowe (1964) is "one which occurs in or adjacent to drainageways and/or their floodplains and which is further characterized by species and/or life-forms different from that of the immediately surrounding non-riparian climax." Ewel (1978) found two essential ingrediants in riparian ecosystems: 1) laterally flowing water that rises and

Table 1

Monthly Water Flow Through Two Stations Along the Lower Colorado River*

Mean 1000 acre-ft ± SD

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Imperial Dam												
1941-1949	1,115 ± 853	1,014 ± 328	1,049 ± 256	867 ± 217	969 ± 216	964 ± 294	889 ± 145	877 ± 152	892 ± 245	974 ± 250	1,045 ± 258	1,191 ± 325
1950-1959	796 ± 364	683 ± 264	845 ± 323	654 ± 236	828 ± 247	795 ± 190	873 ± 126	849 ± 130	715 ± 183	644 ± 218	575 ± 228	655 ± 306
1960-1969	319 ± 65	373 ± 41	590 ± 43	638 ± 600	578 ± 42	629 ± 62	719 ± 68	699 ± 56	533 ± 57	424 ± 32	305 ± 62	277 ± 54
1970-1979	294 ± 71	355 ± 45	568 ± 57	656 ± 30	580 ± 44	578 ± 39	684 ± 46	648 ± 52	507 ± 63	397 ± 63	298 ± 33	326 ± 22
1980	317	343	858	979	861	922	1,066	986	864	808	727	698
1981	504	368	602	736	579	624	745	726	506	345	257	277
1982	331	378	539	708	535	497	590	562	415	367	247	238
1983	862	448	505	840	960	1,339	2,226	2,320	2,142	2,219	1,609	1,456
1984	1,649	1,577	1,607	1,514	1,510	1,705	1,844	1,716	1,535	1,501	1,428	1,521
1985	1,474	1,374	1,274	1,073	1,166	1,348	1,422	1,424	1,315	----	----	----
Parker Dam												
1941-1949	1,157 ± 355	1,030 ± 269	1,098 ± 237	955 ± 189	1,096 ± 236	1,062 ± 303	996 ± 135	970 ± 187	984 ± 245	1,052 ± 254	1,086 ± 269	1,216 ± 239
1950-1959	799 ± 364	676 ± 277	908 ± 308	907 ± 232	898 ± 251	911 ± 187	981 ± 118	934 ± 149	771 ± 200	652 ± 218	594 ± 245	660 ± 351
1960-1969	323 ± 71	441 ± 32	690 ± 53	696 ± 68	666 ± 49	768 ± 65	869 ± 67	794 ± 61	585 ± 55	423 ± 39	301 ± 72	267 ± 58
1970-1979	291 ± 88	428 ± 61	694 ± 63	793 ± 40	705 ± 48	739 ± 54	869 ± 61	759 ± 66	573 ± 92	400 ± 84	300 ± 34	338 ± 33
1980	304	387	1,056	1,121	964	1,145	1,247	1,164	982	879	760	715
1981	462	454	697	869	676	829	942	881	564	326	264	294
1982	330	492	653	851	658	618	763	638	501	380	219	264
1983	1,007	402	591	1,051	1,127	1,613	2,440	2,422	2,266	2,202	1,604	1,473
1984	1,728	1,657	1,741	1,609	1,662	1,932	2,012	1,835	1,668	1,595	1,498	1,527
1985	1,521	1,469	1,377	1,209	1,375	1,556	1,609	1,602	1,363	----	----	----

*Adapted form Ohmart et al., 1988.

falls at least once within a growing season; 2) a high degree of connectedness with other ecosystems. The most sensitive characteristic of riparian ecosystems, Ewel concluded, is the dependence of species composition on the amount of water-level fluctuations and the depth of flooding. Disturbance of water level fluctuations can drastically change the ability of a floodplain species to maintain dominance, as many flood-tolerant species found in riparian ecosystems can only withstand a short period of flooding. On rivers and streams allowed to run their natural course, flooding is the most ubiquitous form of disturbance in a riparian ecosystem (Stevens and Waring 1978).

Carothers and Brown (1991) documented changes occuring to riparian species in the Grand Canyon after the dam-released floods of 1983. Prior to the closing of Glen Canyon Dam in 1963, the vegetation in the Grand Canyon exhibited a "disclimax", a non-orderly succession of different vegetation types. Unlike communities in a stable environment, the species along this riparian corridor existed in a disturbed environment, due to great flucuations in annual water levels, and were adapted to constant, predictable natural change. After the closing of the dam, new riparian communities began to develope under the influence of the modified flows the river now exhibited. Annual flooding was no longer a pattern to which vegetation had to adapt. The flood of 1983, therefore, was unprecedented on a river corridor that had developed under stable conditions since 1963. The resulting vegetation scouring and sediment loss, caused by flows nearly tripled in volume, created more long term damage to the river ecosystem in the Grand Canyon than any single previous event. Fifty percent of all riparian vegetation below the flow level at 60,000 cfs was lost. Prior to the flood, maximum peak releases were 32,000 cfs while 1983 flood peaks were recorded at more that 92,000 cfs. The demise of this vegetation was attributed to drowning by continual inundation, burial under newly deposited sandbars, and washing away of entire stands of trees and shrubs. Only those plants with long taproots, such as salt cedar and mesquite, were able to resist removal by scouring. In addition, sustained flooding acted to leach nutrients from the soil, leaving the beaches through the Grand Canyon less fertile.

Today, dams trap sediment that would otherwise reseed riparian area after annual floods. Prior to damming, vegetative debris would accumulate over the year along the first terrace (essentially the floodplain for annual floods). Annual floods would carry this debris downstream, depositing it along the floodplain where it would decompose, adding nutrients and humus to the soil. In his study of two streams in Oklahoma, Barclay (1978) found that the reduction of flooding caused by channelization had negative effects on reproduction by a number of riparian tree species. Not only was tree reproduction lower along channelized sections, but species richness was relatively low in these areas. Along a portion of the Rio Grand River running between Mexico and Texas, Engle-Wilson and Ohmart (1978) found that upstream dams had halted the annual cycle of flooding, eliminating the deposition of fertile soil suitable for seed propogation. Schmidly and Ditton (1978) found that the most extensive riparian habitats in western Texas existed wherever periodic flooding occurred along the Rio Grande. In a study on two well-developed gallery forests along the Gila and San Pedro rivers in Arizona, Brady et al. (1985) determined that when light or moderate flooding occurs, establishment of many riparian species is favored through deposition of nutrient-rich sediments and increased soil mositure, and that major flooding is catastrophic, regardless of the developmental stage of a species. During the 1983, '84, and '86 floods along the LCR, the last remaining mature cottonwoods were drowned out due to excessive periods of inundation (Anderson, personal communication, 1992).

In addition to the demise of vegetation through catastrophic flooding and the elimination of fertile soils for reseeding, vegetation has been drowned along areas where low base flows previously occurred for much of the year. With the closing of dams along the LCR, base flows were raised in many areas, subsequently drowning species such as cottonwood and willow susceptible to prolonged periods of inundation (Ohmart et al. 1988). Consistently higher water levels have also resulted in the establishment of permenant marshes in some areas. One of the more spectacular examples of this occurred in what is now the 4000-acre Topack marsh just southeast of Needles, California.

Prior to the building of dams upriver from Needles, the annual high water flows resulted in a restriction of flow at the narrow entrance to Topock Gorge, a 17-mile exposed bedrock gorge downriver of Needles, creating a temporary marsh above the mouth of the gorge. During normal flood season, the inundated area often extended over 12,000 acres (Cowgill 1971). With the closing of Hoover Dam, higher base flows became the norm and a permanent marsh came into existence upriver from the gorge. Almost immediately the nature of the ecosystem began to change, with a notable increase in waterfowl simultaneously occurring with the transition to marshland vegetation. Then in 1948, the Bureau of Reclamation began to dredge a 9-mile stretch of the river between the town of Topock, at the head of the gorge, and Needles. In addition to this, the Bureau began a dry-cut (a new channel created through dry lands into which a river's flow is diverted) paralleling this section of river in order to mitigate the water losses through channel meandering. Within a few weeks the water table dropped five feet and began to drain the marsh.

From 1957 through 1960, the Bureau continued to dredge and and construct levees along the 40 mile reach between Needles and Davis Dam. As this dredging began to lower the water table in the area, threatening to drain the marsh, weekend visitors attracted to the marsh for its hunting and fishing possibilities brought their concerns to the attention of U.S. Secretary Udall. Udall initiated a secretarial order to build dikes and inlet canals to re-establish and maintain the marsh. In 1966, work began on the south dike and an inlet canal, subsequently permitting development of 4000 acres of marsh (Jim Goode, Havasu National Wildlife Refuge manager, personal communication, 1991).

Channelization projects often disrupt not only water-surface levels within a river, but its gradient, sediment load, and characteristics of sediment load distribution. In addition, constriction or straightening of a river channel can also cause significant rises in the stages of floods, resulting in more devastating floods (Belt 1975). In a 5-year study, Heede (1985) demonstrated the importance of the inter-relationship between vegetation and stream hydraulics in terms of water flow, sediment levels, geomorphology, and riparian species' ability to adjust to a river's flow, creating a dynamic equalibrium.

Dredging of channels, as with groundwater pumping, often results in a lowering of surface-water levels and can cause an overall lowering of groundwater levels. Reduced surface flows along the Gila River in Arizona resulted in the gradual loss of the riparian community (Rea 1983). Lowering of overall groundwater here, and in the Santa Cruz River to the southeast, caused the demise of dense mesquite bosques and cottonwood forests (Johnson and Carothers 1982; Rea 1983). In a revegetation study along the Rio Grande (Swenson and Mullins 1985), it was found that cottonwood saplings placed in holes dug to groundwater depth had high survival rates (40%-80%) while those placed in holes 2-4 feet above the water table had lower survival rates (0%-60%). Barclay (1958) found that of 54 wetlands orignally paralleling two streams in Oklahoma, all had disappeared by 1937 due to channelization projects. The dramatic disappearance of these wetlands was primarily due to the diversion of these rivers into dry-cuts leaving the wetlands without a water source. Barclay also noted that along the new channels, accelerated streambed erosion was occuring due to the absence of broad meanders in these channels. Due to increased flood control, as well as increasing demands for agricultural lands and the transporting of water from northern to southern California, riparian vegetation along the mainstream of the Sacramento River in California had been reduced from 775,000 acres (prior to human impact) to 12,000 acres in 1978--1.5% of the original total (Hehnke and Stone 1978; Haugen 1980).

An additional impact of impoundments and river channelization has been the increased loss of river water through evaporation. In the still-water area behind dams, and in the slow-moving water in canals, evaporation losses have been estimated along the Colorado River (Table 2). According to data from the U.S. Department of the Interior (1987), for the years 1976-1980, water

TABLE 2 Average water use in the Lower Colorado River Basin for 1976-1980 (in 1000 acre-feet). Data from Ohmart et al. 1988.

Type of Use	Lower Basin
Reservoir evaporation and channel losses	1,682
Irrigated agriculture	5,180
Municipal and industrial	453
Fish, wildlife, and recreation	50

loss through evaporation and bank seepage was second only to irrigated agriculture in total consumption of river water. The Colorado River Storage Project estimated water loss through evaporation and bank seepage at 3 million acre feet per year (Johnson and Simpson 1985). One result of this increased evaporation has been a paralleled increase in water salinity.

Salinity

One of the most serious problems concerning water managers in the Lower Colorado River Valley is that of salinity. Salinity increases significantly from the headwaters of the Colorado to Imperial Dam (Fradkin 1981). The Colorado River is naturally high in salts as it passes through regions of marine deposits in its meandering 1,360 mile descent to the Gulf in addition to receiving input from saline springs and tributary streams along the way. Yet, removal of high quality water through evaporation losses and irrigation return flows contribute to substantial increases in salinity. Coupled with this, the reduction in high peak flows (most commonly a result of late spring/early summer snowmelt) which formerly aided in flushing salt out of the system, further adds to the river's salinity levels. Along another southwest river, the Rio Grande, upstream uses of water for agriculture decreased both water availability and water quality within the study area (Engle-Wilson and Ohmart 1978). Due to these factors, increased salt accumulation left the soil in this area too saline for many crops as well as most native riparian species.

According to an environmental impact statement done in 1973 for the Havasu Intake Channel and Pumping Plant (U.S. Bureau of Reclamation 1973), the saline concentration of most surface and ground water in the Lower Colorado River Basin was approximately 500-1000 ppm. Salts from these sources, excluding irrigation returns, are of the calcium-sodium-sulfate type which predominates above Imperial Dam. Below Imperial Dam, however, agricultural return flows have produced a shift in salt type to predominantly chloride. This change in salts also goes hand in hand with the introduction of various pesticides and other introduced chemicals that have been leached out of irrigated fields. Agricultural returns containing pesticide/herbicide pollution have caused selenium, a naturally occurring toxin, to increase to the point where reproductive failure has been noted in some species of fish and birds (Ohmart et al. 1988). It also appears that increased sedimentation in reservoirs may also be influencing salinity and the mix of dissolved ions, as suspended sediments (through chemical and physical degradation) release salts and exchange ions (e.g., sodium for calcium).

Upstream of Cibola National Wildlife Refuge is the Palo Verde Irrigation District which receives water diverted at the Palo Verde Diversion Dam. Water from the river is moved through a network of canals to irrigate the 123,130 acres within the District, and returns to the river through an extensive drainage system. Since 1951, return flows from the District have shown an increase in salinity of about 10% over the water which enters the District on its northern end (Ohmart et al. 1988).

The problem of highly saline water was addressed in 1973 in an agreement between the United States and Mexico. The U.S., required to supply 1.5 million acre-feet a year to Mexico, was delivering water so high in salts that it was practically useless for agriculture. The 1973 agreement specified that waters reaching Mexico could be no higher than 115 + 30 ppm over the annual average salinity levels at Imperial Dam (Ohmart et al. 1988). The result of this agreement was the construction of the Yuma Desalinization Plant 6 miles west of Yuma. The purpose of the plant is to carry saline drainage water from upstream areas to the plant where it is desalted and returned back to the river for delivery to Mexico. Because the Yuma Desalinization Plant is located near the terminus of the Colorado River, it has little effect on upstream reaches and salinity remains a large problem on the LCR.

Vegetation

There is no doubt that the vegetation lining the Lower Colorado River Valley has changed both in composition and in magnitude. In 1912, Grinnell (1914) observed that riparian vegetation lined the banks for many kilometers and filled the broad alluvial valley. On the first terrace and in the braided channels, cottonwood (*Populous fremontii*) dominated, mixed among Goodding willow (*Salix gooddingii*). Plants along the first terrace are fast growing and relatively short-lived as adaptations to a frequently flooded environment. Cottonwood germination requires bare, sandy soils with a high water table (Mizoue 1984). Its existence depends upon the annual cycle of flooding to create new silt beds for seed germination. With the closing of Hoover Dam in 1935, 90% of the cottonwood forest along the LCR has been eliminated, the greatest loss occuring between 1940 and 1967 (Hoar and Erwin 1985). In another study, Johnson and Carothers (1982) estimated that less than 10% of cottonwoods remained in the southwest by 1982, and less than 5% of the phreatophytes in Arizona.

On the second terrace, that area which once received inundation from exceptionally high flows perhaps only once every 100 years, honey mesquite (*Prosopis glandulosa*) dominated. Long a fa,vorite for food both among Native Americans and cattle, the honey mesquite needed its long roots to reach the permanently moist soil near the water table. These plants cannot tolerate inundation for more than a few weeks. Thus, if either the first or second terrace receives prolonged inundation, they ultimately revert to marshland species such as cattails, bulrushes and tules: In addition, it is the second terrace that has been primarily used for agriculture along the LCR. In the Parker Division, just to the north of the Palo Verde Valley, Mizoue (1984) found that the second terrace had been cleared of native vegetation for agriculture, reducing honey mesquite cover from 91.5 km^2 in 1938 to 5.7 km^2 in 1982.

In addition to the impact of changing water levels on riparian vegetation, the introduction of the salt cedar (*Tamarix chinensis*) into the Lower Colorado River Valley has "forever" changed the vegetative character of this region (Ohmart et al. 1988.) Brought into this area in the 1920's to help promote bank stabilization, salt cedar took off like a wildfire. As of 1982, it was the major lowland woody riparian exotic species in the southwest (Johnson and Carothers 1982). With a high rate of seed production, this plant is both salt-tolerant and fire and flood adapted. With rising salinity levels affecting many plants in this area (all but saltbush (*Atriplex polycarpa*) and quail bush (*Atriplex lentiformis*) have low tolerance to salt), the salt cedar began to make its mark. One study has shown that salt cedar commonly invades riparian areas disturbed by reclamation projects (Potter 1970). Salt cedar normally out-competes, and can eliminate, native riparian vegetation such as cottonwood (Turner 1974; Engle-Wilson and Ohmart 1978; Schmidly and Ditton 1978; Carothers and Brown 1991). In his study of the channelized sections along the Gila River, Rea (1983) found most of these areas either barren or overgrown with salt cedar. Salt cedar has a deep tap root, grows quickly, produces large numbers of seeds, usually developes in single species stands with little or no intermixing of other species, and is extremely tolterant of inundation (Carothers and Brown 1991). It can survive burial by sediment deposits caused by flooding, and seedlings, whose densities have been found to increase after flooding, usually send up new shoots shortly after a flood has abated (Stevens and Waring 1985).

Salt cedar has the ability to colonize after summer rains because, unlike many native riparian species, its flowering and fruiting cycles allow for a continual supply of seeds to germinate whenever the soil is moist (Engle-Wilson and Ohmart 1978). Once a dense carpet of salt cedar seedlings has developed, little light penetrates to the soil for germinating other riparian species such as cottonwood and willow (Harris 1966). Along the San Pedro River, diversions, headwater impoundments, and depletion of underground aquifers have reduced the flow to that of an intermittent stream, with permenant flows occupying only 50 km of the river's total 250 km channel. Cut off from a perinneal flow, cottonwood numbers have declined and salt cedar increased (McNatt 1978).

With the completion of dams on the LCR, the absence of annual floods allowed deciduous debris to build up among the shoreline vegetation and these leaf-litter accumulations resulted in increasing frequency and intensity of fires. Studies estimate that salt cedar communities along the LCR now burn every 15 to 20 years and thus encourage dominance by the salt cedar over the less fire-adapted native species (Engle-Wilson and Ohmart 1978; Ohmart and Anderson 1988). By 1986, estimates were that roughly 40% of the available bottomland in the Lowere Colorado River Valley (land not built upon or under cultivation) was covered by pure salt cedar, while 43% was native vegetation mixed with salt cedar. An additional 16.3% was covered by honey mesquite and/or native shrubs, and only 0.7% was mature cottonwood or willow habitat, most of what was left having been eliminated in the floods of '83, '84, and '86 (Rosenberg et al. 1991).

In addition to the spread of salt cedar, other factors were acting to alter vegetation patterns. In late 1950's and early 60's, in an attempt to try and reduce both bank seepage and evaporation, control natural overbank flooding, and facilitate flow, a program of water salvaging was begun by the Bureau of Reclamation. The objective was to augment the current water supply with the approximately 350,000 acre-feet which the Bureau hoped to salvage with this program (Fradkin 1981). The nature of the undertaking was to streamline the river into a very effective canal. To accomplish this, the river was diverted into straightened dry-cuts, riprapped along its banks, dredged to remove sand and silt accumulations and evaporation-prone backwaters, and cleared of highly water-consumptive vegetation which lined its banks. In order to eliminate the vegetation, herbicides were used, fires were set, and plants were ripped out or buried by bulldozers. On the second terrace, much of the land was cleared for agriculture resulting in diminished numbers of honey mesquite. By the 1970's, virtually the only remaining tracts of native terrestrial vegetation were on the five Indian reservations and three national wildlife refuges. By 1988, productive agricultural land covered three-quarters of the LCR floodplain, about 310,734 acres (Ohmart et al. 1988).

Bird Communities

The changing vegetation has had profound effects on the make-up of bird and fish communities. Extensive research has been done in this area to gain a better understanding of how to manage the remaining as well as new species which inhabit the Lower Colorado River Valley. In evaluating wildlife habitats in lowland riverine environments, Schrupp (1978) found that these riparian areas were one of the most important habitat types for wildlife. Johnson and Carothers (1975) surveyed breeding avian populations along two channelized southwestern streams and found more than twice as many species and two to four times the number of birds on non-channelized sections of the same size and habitat. Of riparian vegetation species, the cottonwood-willow community appears to offer the best habitat to many bird species. Remaining cottonwood and willow along the Sacramento River in California, support a density and diversity of breeding birds equal to or greater than those in many other California habitats (Gaines 1974). Cottonwood-willow communities along the Rio Grande were found to contain higher densities and diversity of birds than surrounding areas (Engle-Wilson and Ohmart 1978). Studies in the Verde Valley of central Arizona (Carothers and Johnson 1985) showed a linear relationship between the number of cottonwood trees per acre and the number of nesting birds. Wildlife values are generally low in salt cedar (Engle-Wilson and Ohmart 1978; Carothers and Johnson 1982).

Within the avian communities along the LCR, three major changes have occurred. Species have 1) increased with conversion of the land to farmland or marshes, 2) declined with the loss of riparian habitats, or 3) expanded geographic ranges in recent years to include the Lower Colorado River Valley (Rosenberg et al. 1991). With the growth of marshes behind many reservoirs and among the backwaters, many waterbirds, such as the Yuma Clapper Rail, have benefitted. The expansion of wintering species associated with agriculture, open water and marsh lands has occurred, yet many of the original species dependent upon tall cottonwood-willow forest are in danger of disappearing altogether. Some of these birds, such as the Yellow Warbler (*Dendroica petechia*), and the Summer Tanager (*Piranga rubra*), considered abundant in these areas, are now found very locally and in small numbers along the river. At the same time, wildlife refuges such as Cibola have planted grain crops in order to insure a steady population of migratory and wintering birds such as geese, ducks and cranes.

Two studies have shown that in areas where agriculture is surrounded by riparian habitat, such as in Cibola National Wildlife Refuge, densities and diversities of birds were closely correlated to those of riparian areas. In agricultural areas not surrounded by riparian lands, 95% fewer birds and 32% fewer species were noted (Hehnke and Stone 1978). In one 14-month census done on riparian birds along the LCR Conine et al. (1978), found that agricultural situations did not support populations as large as those found in native riparian communities, yet more species preferred agricultural areas to those of salt cedar, although the introduced salt cedar has now become home to one of the largest concentrations of the Mourning Dove (*Zenaida macroura*), and White-winged Dove (*Zenaida asiatica*) in the region (Johnson and Carothers 1982). Conine et al. (1978) suggested by the above study that if strips of riparian vegetation were left around agricultural areas, high densities of riparian birds would be supported by these edges and venture into rarely used agricultural areas.

With all of the changes to the Lower Colorado River that have occurred since the late 1800's, perhaps Arleigh B. West, regional director of the Bureau of Reclamation in 1968, said it best when answering criticisms about the Bureau's river work:

> There has been controversy concerning our river program. The uninitiated assert that the river must be left in its natural state. The basic truth is that the lower Colorado River is now a stream wholly controlled by man...The river's flow can be manipulated in the same fashion as the garden hose on the tap outside your home, and is (Fradkin 1981:254).

Palo Verde and Cibola Valleys

Immediately north of the Cibola National Wildlife Refuge lies the Palo Verde Valley. The valley lands are comprised of an alluvial flood plain created as the Colorado River deposited its sediment while meandering between the bajadas and hills which border the valley. In 1988, approximately 123,130 acres were being irrigated under the control the Palo Verde Irrigation District. In 1959, just prior to the start of the channelization project in Cibola Valley downstream, 72,000 acres were under cultivation (Bureau of Reclamation 1959).

Permanent settlement in the Palo Verde Valley began in the 1870's when Thomas Blythe began to cultivate the northern third of the valley. By 1908 some 30,000 shares of stock certificates, each share representing water rights to one acre of land, had been sold, and by 1918 extensive artificial levees already lined the river (Bureau of Reclamation 1959). In 1923 the Palo Verde Irrigation District was formed.

Prior to the widespread agricultural development of the valley, the regime of the Lower Colorado River included heavy spring floods which inundated low-lying valleys such as Palo Verde. In a 1903 survey of the Colorado River through Palo Verde and Cibola valleys, the U. S. Geological Survey documented a meandering channel with many braided reaches. This reach of river was then approximately 50 miles in length with a slope of 1.6 feet per mile. This is considered the last record of this stretch of the river in its fairly natural state (Bureau of Reclamation 1959). In 1905, following a heavy flood that seriously damaged crops, increased agricultural activity demanded that levees be built to control the potentially devastating floods. Construction of the levees prevented the river from depositing sediment on the historic floodplain in Palo Verde Valley, causing deposition of sediment further downstream in Cibola Valley.

In order to improve the flow through the valley, sections of the river through Palo Verde were straightened resulting in a steeper gradient, creating in greater streambed erosion, and causing heavier loads of sediment to be transported downstream. By 1930, when the Yuma Project Office ran a profile of the river through Palo Verde and Cibola valleys, significant changes had occurred on the river since the 1903 study. Despite straightening of the channel in some sections, increased meandering had increased the channel length through this section by 5.5 miles. Due to this channel lengthening, the overall gradient had been reduced to 1.4 feet per mile, and increased aggradation downstream had caused the surface level of the river to raise nearly 7 feet at the Palo Verde Outfall drain in the northern end of Cibola Valley. The increased length of the channel as well as the change in gradient in the Palo Verde Valley were caused by a gradual westward shift of the river during this 27 year period, but the increased aggradation in Cibola Valley appears to be a result of both the presence of levees, and the decreased gradient of the river, in Palo Verde Valley (Bureau of Reclamation 1959). Although with the closing of Hoover Dam in 1935 the regime of the river changed drastically, it is important to recognize that alterations to the natural characteristics of the river in this area were already occurring.

After construction of both Hoover and Parker dams, regulated flows ranged anywhere from 700 to 15,000 cfs with the average being 10,000 cfs (Bureau of Reclamation 1987). By 1944 the water surface elevation for a flow of 15,000 cfs had been reduced by nearly 4 feet in the vicinity of the Palo Verde Irrigation District's intake. This rendered the gravity system used to convey water to the agricultural areas useless, and a temporary weir was created to raise the level at the intake. The weir was completed in 1945 and served its purpose until the completion of the Palo Verde Diversion Dam, located at the northern end of the Palo Verde Irrigation District, in November of 1957.

With the closing of this dam, further aggradation downriver in Cibola Valley was reduced, but by this time the accumulated sediment had caused the water surface to rise at the Palo Verde Outfall drain and serious drainage problems were occurring. To alleviate the problems in Palo Verde Valley caused by poor drainage at the outfall, the Bureau of Reclamation constructed a pilot cut across a bend in the river in order to move the river away from the drain. By 1948 the cut was complete and in 1949 the Bureau constructed a weir across the old channel diverting the river into the new cut. The drain now emptied into the old river channel which met the new channel at a confluence two miles further south. The desired result was achieved with a lowered water surface at the drain of approximately 2 feet.

In 1959, when the Bureau came out with its comprehensive plan for channelization in the Palo Verde and Cibola valleys, the river had been continually aggrading from the outfall drain through to the southern part of Cibola Valley since 1903. As a result, the water surface in the southern end of the valley had slowly risen until Cibola Lake was created. Land in the vicinity of the lake, previously used for agriculture, was made useless by the rising water table, which had now created numerous marshy areas. The Bureau, reacting to the complaints of landowners adjacent to the river's banks, recognized that something needed to be done to regulate the river through Palo Verde and Cibola valleys in order improve the agricultural capability of the land.

In 1959, the Bureau issued a comprehensive plan (Bureau of Reclamation 1959) on a channelization project for the Palo Verde and Cibola Valley Divisions. The goals of the project were:

1) to alleviate river bed scour, bank scour, and river meandering in the Palo Verde Valley thus reducing the amount of sediment being carried downstream,
2) to reduce the danger of floods through the creation of extensive levees,
3) to salvage water by lowering the water surface at the mouth of the Palo Verde Outfall drain, allowing the Irrigation District to further lower the water table over all the district lands and reduce the nonbeneficial use of water on unfarmed lands,
4) to prevent the continued loss of irrigated lands in the Palo Verde Valley through bank erosion.

The project proposed drainage and channelization of about 47 miles of the LCR through the Palo Verde and Cibola valleys with the primary channelization occurring in the lower part of this region-- what is today Cibola National Wildlife Refuge. In conjunction with the Bureau's plan, the U.S. Bureau of Sport Fisheries and Wildlife submitted their recommendations on how fish and wildlife resources could best be protected from damaging effects of the project. Their many suggestions on ways to mitigate wildlife losses ultimately resulted in the creation of Cibola National Wildlife Refuge in 1964.

The acquisition of land, both by the Bureau for channelization rights-of-way and by the Bureau of Sport Fisheries and Wildlife for the refuge, was not without controversy. The Cibola Valley Irrigation and Drainage District contained lands bordering the river from the Riverside-Imperial County line in the North to the southern end of Cibola Lake twelve miles to the south. By the early 1960's, about 7100 acres of these lands were in private ownership, with some 5500 acres in productive cultivation (Curtis 1966a). Lands in Cibola Valley had been actively farmed and grazed since 1899 when Lewis A. Bishop brought his family there from San Diego. By 1964, when dredging began in Cibola Valley for the channelization project, descendants of Bishop were still farming the land in the northern portion of the valley and grazing cattle around their ranch. Skip's Place, as the Bishop Ranch was called, was located at the point where the new channel was to split from the old channel. The subsequent raise in water surface level (in 1973 it was 218 feet [Bureau of Reclamation 1973]) would eventually cause the land upon which Skip's Place was located, (with elevations from 216-217 feet), to become swampy and no longer capable of supporting structures. In addition, those lands which were irrigated by pumps south of the future cut-off would no longer be functional due to the drop of water surface level in the old channel. Many legal battles between these farmers and ranchers and the Bureau of Reclamation were fought but ultimately the lands were acquired for channelization rights-of-way and Cibola National Wildlife Refuge.

Prior to the channelization project, farmers in Cibola Valley were having problems with both floods and the invasion of salt cedar. In an interview conducted in 1966 with Skip's Ranch resident Louis Bishop, great-nephew of Lewis Bishop, Bishop claimed that salt cedar trees had taken over the "river bank country" in Cibola ever since being introduced into the area in the '20s as an erosion control project. Bishop asserted that salt cedar used more acre-feet of water per year than the local crops which were primarily alfalfa and cotton (Curtis 1966b). In fact, one study (Gay 1985) found that dense salt cedar stands along the LCR lost 1700-1750mm yearly to evapo-transpiration-- nearly the equivalent of alfalfa.

With the opening of the new channel in March of 1970, the Bureau began to devote its entire dredging operation to improving fish and wildlife in Cibola National Wildlife Refuge. Nearly 120,000 feet of channel had been deepened in the Palo Verde Valley upstream, resulting in 151 acres of newly established backwater (Palo Verde Valley Times 1970a). The final stage of the project was the dredging of Cibola Lake in the southern end of the refuge. According to A.B. West the Bureau's regional director in Las Vegas, the river was expected to drop about two feet in the vicinity of Adobe Ruins located just south of Cibola Lake (Palo Verde Valley Times 1970b). Lower water levels would probably remain for six to eight years until aggradation began and subsequently raised the water surface level 2 feet above its 1970 level. The concern was that the lowered water level would drain the lake and adversely affect the wildlife living in its waters. Dredging of the lake began in February 1970, and was completed in November of that same year with the removal of nearly 2 million cubic yards of debris and the expansion of the lake to 600 acres. Prior to the dredging, aggradation in this area had caused an increase in the encroachment of emergent vegetation such as cattails and a reduction in fish numbers. The goal of the project was to create a deepened permanent lake, even at periods of low flow, thereby increasing its value as a fish and wildlife habitat (Palo Verde Valley Times 1970b).

Today Cibola National Wildlife Refuge encompasses 16,627 acres and includes, aside from the river and Cibola Lake, 785 acres of desert foothills and nearly 2,000 acres devoted to agricultural crops. These crops, including corn, milo, alfalfa, and wheat, are intended to supplement the diet of the 232 species of songbirds, upland species, and wintering waterfowl--

primarily Canadian Geese-- which are found within the refuge. The crops are planted and grown to maturity using regular farming methods and are not harvested, but instead mowed down with a large rotary mower and left as food for the birds. This practice is used to encourage waterfowl to remain for longer periods of time on the refuge and to discourage the destruction of surrounding crops outside the area. In addition to the farmlands, expanded marshes in the area have encouraged the presence of the endangered Yuma Clapper Rail, the only freshwater form of clapper rail. Also included in the refuge are approximately 140 acres which have been stripped of vegetation, primarily salt cedar, and revegetated with native riparian vegetation species. Two revegetation projects were completed in 1979 and 1980 and one is currently being worked upon. Changes in the completed projects have been monitered and these projects have resulted in integrative, high-quality wildlife habitats (Anderson and Ohmart 1984).

METHODS

In order to compare vegetation changes prior to the Cibola channelization project and since its completion, a vegetation map was created of the refuge from aerial photos. Black and white 1959 photo sets, produced at a nominal scale of 1:20000, were obtained from the Agriculture Stabilization and Conservation Service. Vegetation community types were determined by stereoscopic analysis of paired photos. Eleven community types were recognized, seven based on past research done on vegetative communities in the Lower Colorado River Valley by Anderson and Ohmart (1976; 1982). Mizoue (1984) used the same classification system in her work on quantifying the dynamics of vegetation communities in the Parker Division of the Lower Colorado River, lying to the north of Cibola National Wildlife Refuge. In 1986, another series of vegetation maps were made of the LCR between Davis Dam and the Mexican border again using the classification system originally formulated by Anderson and Ohmart (Younker and Andersen 1986). Both the 1976 and 1986 vegetation maps were interpreted from 1:6000 scale color aerial photography.

The eleven vegetation communities recognized on the 1959 vegetation map are:

1. Cottonwood-willow (CW): This community type consists of a mix of species dominated by cottonwood and willow trees. This community occurs primarily along the river's edge on the first terrace where annual flooding, prior to the channelization project, helped to reseed these species. They cannot survive periods of prolonged inundation and will drown if this occurs. Historically, these communities were much more extensive than the few remaining stands that exist today. Both plant species provide a high vertical profile at maturity on aerial photos (Mizoue 1984).
2. Salt cedar (SLC): This community type is predominantly the exotic salt cedar.

Brought to the United States from the Mideast in the 1800's for ornamental use, salt cedar was introduced into the Lower Colorado River Valley in the 1920's as part of a water salvaging program by the Bureau of Reclamation (Ohmart et al. 1988). Salt cedar, which is salt tolerant and resistant to fires, is an aggressive species that has gradually come to dominate most of the lands along the LCR (Johnson and Carothers 1982; Rosenberg et al. 1991). On the aerial photos, salt cedar appeared lighter in color than most other riparian species, most often providing a medium verticle profile.

3. Honey mesquite (HON): This community type occurs primarily on the second terrace and has drastically diminished over the years due to its replacement by agriculture. At maturity, honey mesquite may reach 6 to 8 meters in height and has a taproot which can reach several meters below the soil to tap the water table (Mizoue 1984). This commuinity was recognized on the aerial phots as being darker in color than salt cedar but also predominantly of medium canopy height.

4. Salt cedar-honey mesquite (HMS): Because of the proliferation of salt cedar, few pure stands of honey mesquite remain, most being mixed in with salt cedar communities in areas along the second terrace. The intermixing of light and dark colors and similar canopy heights made this community recognizable on the aerial photos.

5. Salt cedar-screwbean mesquite (SSC): Historically, communities of screwbean mesquite appear to have been restricted to small areas of stable soils along the lateral edge of the first terrace (Mizoue 1984). The screwbean mesquite recognized in the 1959 aerial photos, darker and denser than honey mesquite, was mixed with salt cedar.

6. Marsh (MA): This community type is located adjacent to slow moving backwaters

and lakes. It is composed predominantly of cattail, cane, and bulrush as well as dense areas of grasses. Marsh species appeared dark on the aerial photos, with a low verticle profile, and in association with areas of open water.

7. Agriculture (AG): This community is composed of land that is stripped of its native vegetation and is currently cultivated.

8. Abandoned agriculture (ABD): This community comprises lands that were previously cultivated, then abandoned, and are in the process of returning to natural vegetation, predominantly salt cedar. The regular pattern of abandoned fields made this community easily recognizable on the aerial photos.

9. Barren (B): These lands include little or no perceptible vegetation.

10. Unclassified (UNC): All areas in which vegetation communities could not be identified with any level of accuracy, or those areas where no vegetation was identified (1976 and 1986 maps), were termed unclassified.

11. Water (W): Any areas containing open water including the river, lakes, and backwaters that lie outside the new river channel.

12. Channel (CH): That portion of the river which runs through the new channel from the cutoff approximately one mile above the Palo Verde Outfall drain, until it rejoins with the old river channel just south of Cibola Lake.

To verify the communities recognized on the aerial photographs, field verification was done in April, 1992 within Cibola National Wildlife Refuge. Certain communities, or remnant communities recognized in 1959 still existed is some areas within the refuge. These field observations were cross-checked with the existing 1976 and 1986 vegetation maps as well as the 1959 aerial photos. Once the vegetation boundaries had been established on the aerial photos, a mylar copy was made of 1964 U.S.G.S. 1:24000 maps of lands containing the Cibola National Wildlife Refuge. The vegetation boundaries were then transferred to the mylar overlay. At this point, all three vegetation maps containing the refuge lands, 1959, 1976, and 1986 were digitized into the ARC/INFO geographic information system at the Arizona Remote Sensing Center.

ARC/INFO was used to help standardized the maps so as to be able to quantify the differences in the vegetation communities between the three different maps. Problems existed in that each map had been created by different interpreters and the amount of land represented in each map was arbitrary, dependent upon what areas each party either had the data for or wished to include. To alleviate this problem, all three maps were reduced to only those areas that lay within the Cibola National Wildlife Refuge boundary. This helped to reduce the areas of all three maps until they covered approximately the same area. Since the northeast portion of the refuge was only represented on two of the three maps, and was predominantly screwbean mesquite, this vegetative community was not analyzed.

Once the maps had been digitized using ARC/INFO, analysis included calculating the area, in square meters, for each vegetation community within each time period. The resulting area was converted to square kilometers and both the area and the percentage of total vegetation cover for each community occurring for each map was calculated and compared against the other two maps. From this, the amount and type of change occurring within the refuge between 1959, 1976, and 1986 could be deduced with a fair degree of accuracy.

In addition to the creation and comparison of the vegetation maps, interviews were held with researchers within the refuge as well as refuge personnel. Robert Ohmart of the Center for Environmental Studies at Arizona State University in Tempe, Arizona, and Bert Anderson, president of the Revegetation & Wildlife Management Center in Blythe, California have been monitoring vegetation and wildlife change along the LCR since 1973. Anderson's particular emphasis has been within Cibola National Wildlife Refuge for the past several years and the information he provided on the changes which have occurred in the refuge was of great help. Wes Martin, the refuge manager, answered many questions about current use of the land in the refuge and practices in maintaining vegetation and wildlife, and personnel at the Bureau of Reclamation in Boulder City, Nevada, supplied information on water management practices along the LCR.

RESULTS

The Cibola National Wildlife Refuge contains 13 miles of the Colorado River, of which approximately 11.5 miles are channelized, and unlike the Palo Verde and Parker districts to the north whose lands are mostly devoted to agriculture, consists of primarily riparian and upland vegetation. Even prior to the creation of the refuge, agriculture did not play a large role within the present refuge lands. Results from this study indicate that in 1959, five years before the dredge began its first cut in the Cibola Valley, less than 10 km² was land being irrigated for agriculture.

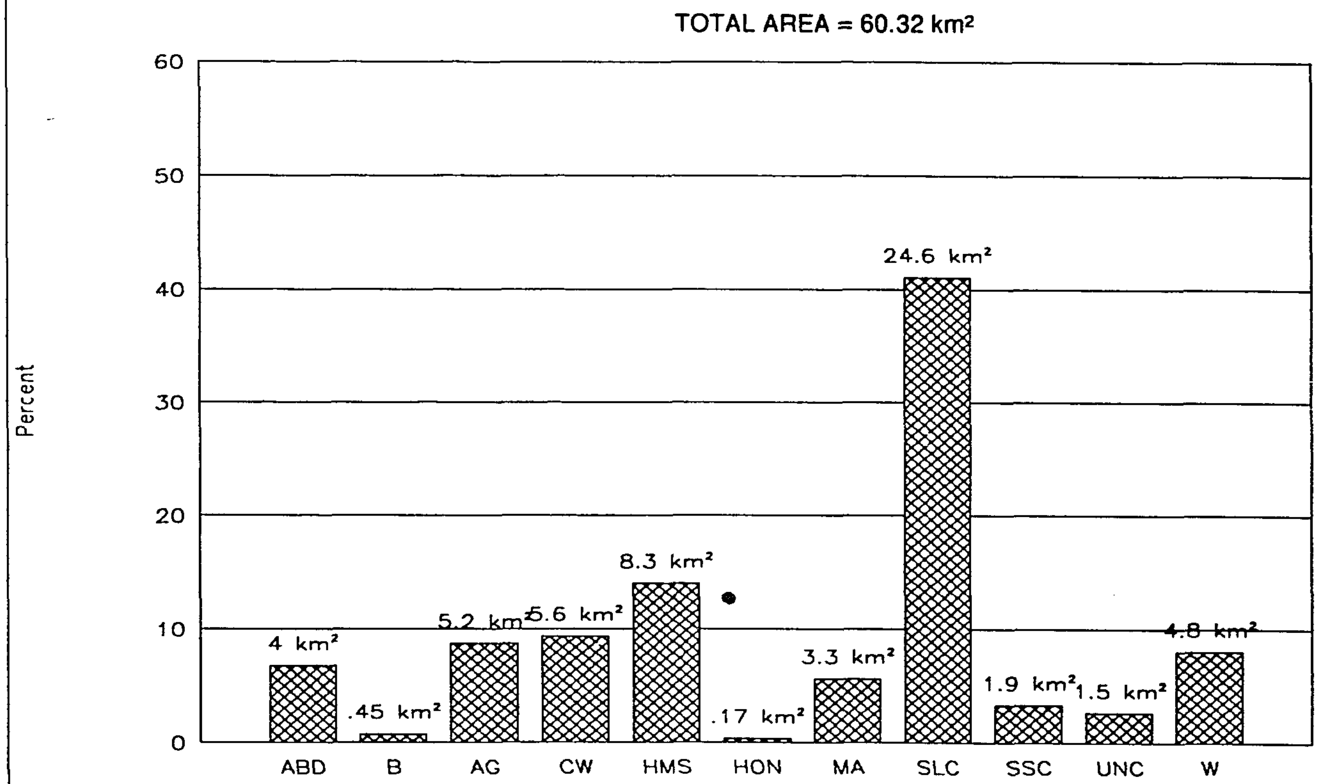
The vegetation map created for 1959 covers a total area of 60.3 km². The aerial photos used to produce the maps actually covered an area of 63.2 km² but the final map was reduced in area in order to correspond in shape and area with the existing 1976 and 1986 maps. The 3.1 km² that were eliminated were predominantly agricultural lands. The results for all three maps are given in percent of total land cover, and total area in kilometers for each vegetation category.

In 1959, the predominant vegetation type (Figure 2) was the exotic salt-cedar which covered 24.6 km² or 41% of the future refuge lands. The second most abundant category was that of the honey mesquite-salt cedar community which accounted for 8.3 km² or 14% of the total land cover. Cottonwood-willow communities were fairly abundant adjacent to the river and encompassed 5.6 km² (9.3%). As previously mentioned, agriculture was present in the area and accounted for 5.2 km² (8.7%), while abandoned agriculture totaled 4 km² (6.7%). Marshlands covered 3.3 km² (5.6%) while screwbean mesquite-salt cedar covered 1.9 km² (3.3%). Barren land accounted for 1.5 km² (2.6%), and lands that were unclassified made up .45 km² (.7%). Areas of open water, which at this time included the Colorado River, Davis, Three Fingers, and Cibola lakes, encompassed 4.8 km² (8%) of the total area.

The 1976 vegetation map was created six years after the river was diverted through the new channel and changes in vegetation communities which had occurred since 1959 are apparent. This map also encompassed 60.32 km^2 in area, all which lay inside the refuge boundary. The dominant vegetation community at this time (Figure 3) was still the salt-cedar but its area had increased to 30.9 km^2 (51.3%), an increase of 10.4% of the total land cover. The honey mesquite-salt cedar community had also increased by 2.8% to cover 10 km^2 (16.6%). Also gaining in area was the screwbean mesquite-salt cedar association which increased by 6.6% to now cover 5.9 km^2 (9.8%). The cottonwood-willow community, however, had begun its decline and accounted for 4.2 km^2 (7%) of the total area. Unclassified lands represented areas on the map that were not designated in any way, yet appeared to be predominantly agricultural lands, based on the location of those lands in 1959. Because they were not designated as such, the amounts in which agricultural lands may have changed was not quantified but the total coverage of barren lands was noted as being 3.7 km^2 (6.1%). The pure honey-mesquite community had seen an increase of 1.3% in area and was found on .97 km^2 (1.6%) of the land. Marsh communities had decreased substantially by 5% and now encompassed only .17 km^2 (.3%). Although the new channel covered 1.56 km^2, there was an overall decrease in the total amount of land covered by water of .7 km^2 (1.1%). If the channel area is subtracted from the total water area, water found in the old channel and lakes had been reduced by 2.1 km^2 (3.4%) and covered only 2.7 km^2 (4.4%).

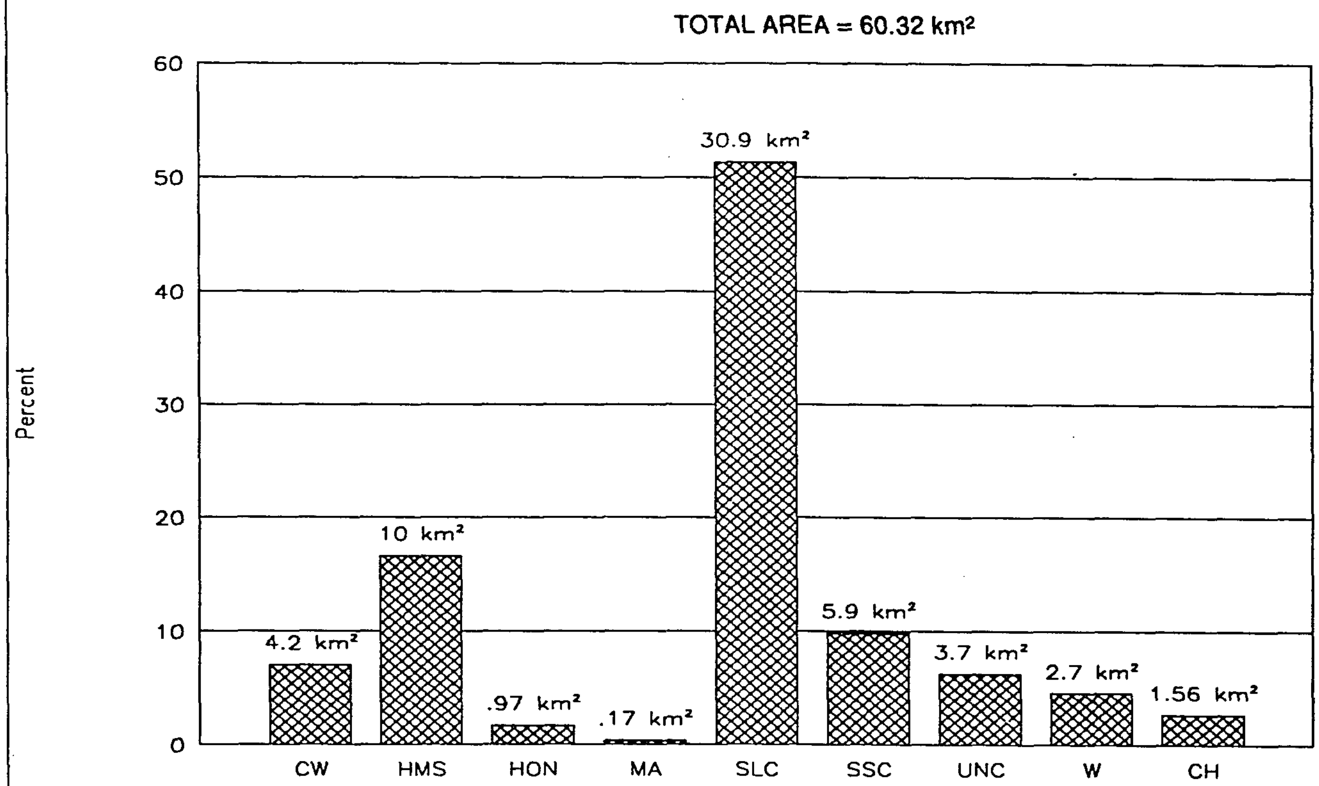
The 1986 vegetation map was created by a different organization than the 1976 map but was based on the classification system used in 1976. The total area included in this map (54 km^2) was less than in both the 1976 and 1959 maps due to the exclusion, in the northeast corner of the refuge, of an area that had been a large community of screwbean mesquite-salt cedar in 1976. For this reason, changes in the coverage of this community between 1976 and 1986 is not quantified. In addition, percentage of change between 1976 and 1986 for

Figure 2



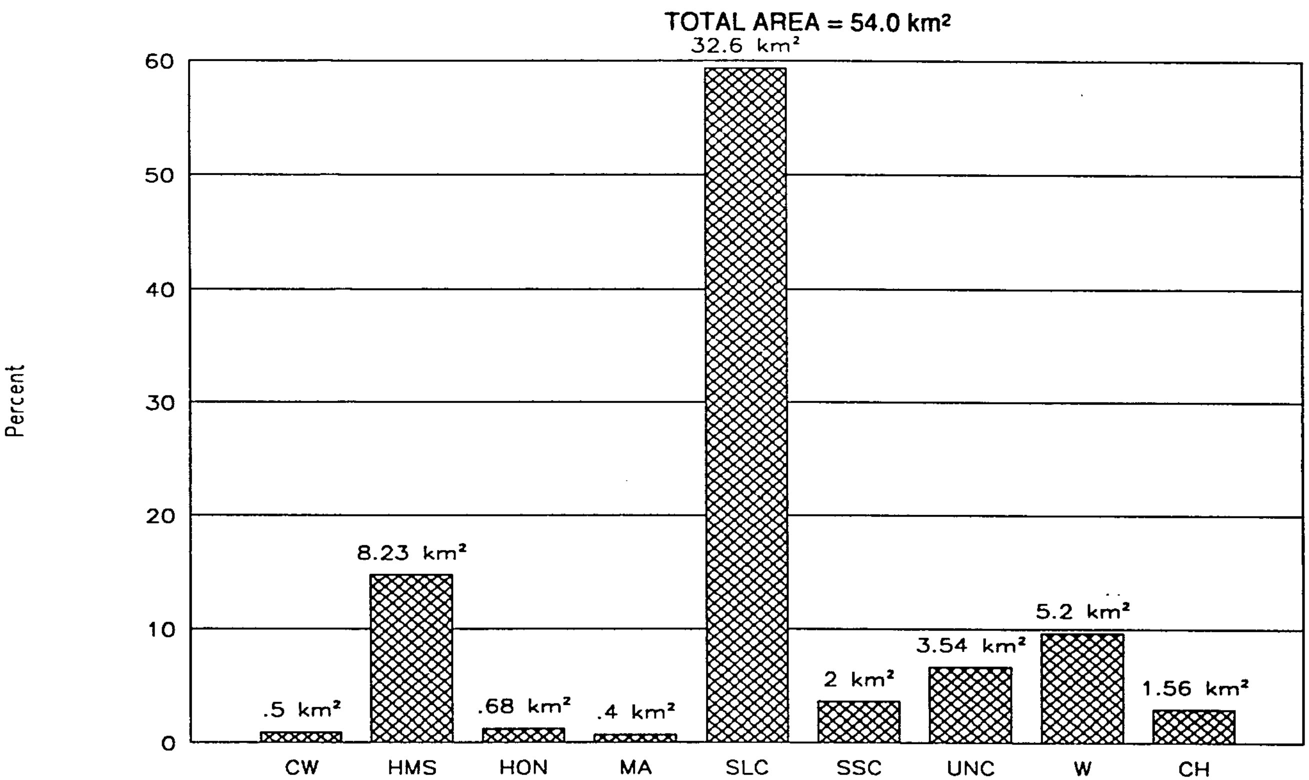
PERCENT OF VEGETATION COVER IN CIBOLA NATIONAL WILDLIFE REFUGE - 1959

Figure 3



PERCENT OF VEGETATION COVER IN CIBOLA NATIONAL WILDLIFE REFUGE - 1976

Figure 4



PERCENT OF VEGETATION COVER IN CIBOLA NATIONAL WILDLIFE REFUGE - 1986

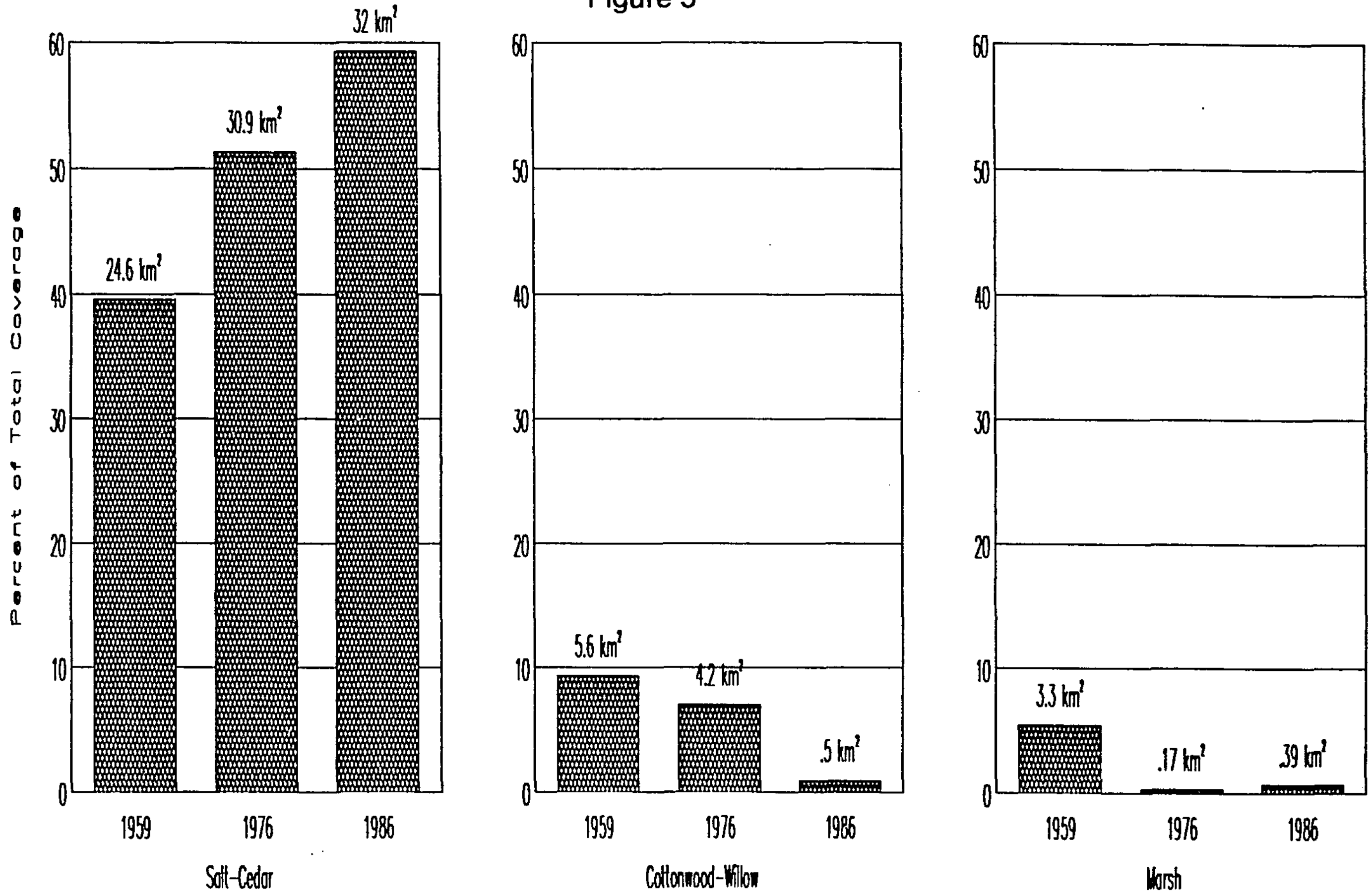
vegetation communities are not given as total land covered on the maps for the two years is not equal.

Once again, during this year, salt-cedar dominated the area (Figure 4) having increased its coverage by 1.7 km^2 to account for 32.6 km^2 (60%) of the total area covered by this map. With the exception of the salt cedar and marsh communities, all other vegetation communities noted on this map declined during this period. Honey mesquite-salt cedar was reduced by 2 km^2 to total 8 km^2 (14.8%). Unclassified lands, again representing undesignated areas, covered the next highest percentage of land totaling 3.34 km^2 (6.2%). The screwbean mesquite-salt cedar community decreased by 4 km^2 accounting for a total area of 1.9 km^2 (3.6%). Honey mesquite communities were reduced by .25 km^2 to total .64 km^2 (1.2%). The cottonwood-willow community saw a dramatic reduction in size by 3.7 km^2 to now cover on .5 km^2 (.9%). Marsh communities saw a slight increase of .23 km^2 to total .4 km^2 (.7%).

The 1986 map indicated that water existed in Davis and Three Fingers lakes, both of which were dry and overrun with salt cedar on the 1976 map. Cibola National Wildlife Refuge manager, Wes Martin, verified that both lakes had been dry since at least 1976. Therefore, those areas encompassed by the former Davis and Three Fingers lakes on the 1986 map were designated as "unclassified" when entered into the ARC/INFO system. The remaining areas of water outside the channel, both backwaters and lakes, accounted for 5.2 km^2 (9.6%), an increase of 2.5 km^2.

Overall, between 1959 and 1986 there was a substantial increase in salt cedar communities, a marked decrease in cottonwood-willow and marsh communities, and a slight increase in open water areas outside of the channel (Figure 5). Communities such as screwbean mesquite-salt cedar, and honey mesquite-salt cedar showed little change between these two years, although there was an increase in their areas in 1976 before a reduction to their 1986 coverages. Most of the former agricultural land (at least 5.8 km^2), that which was

Figure 5



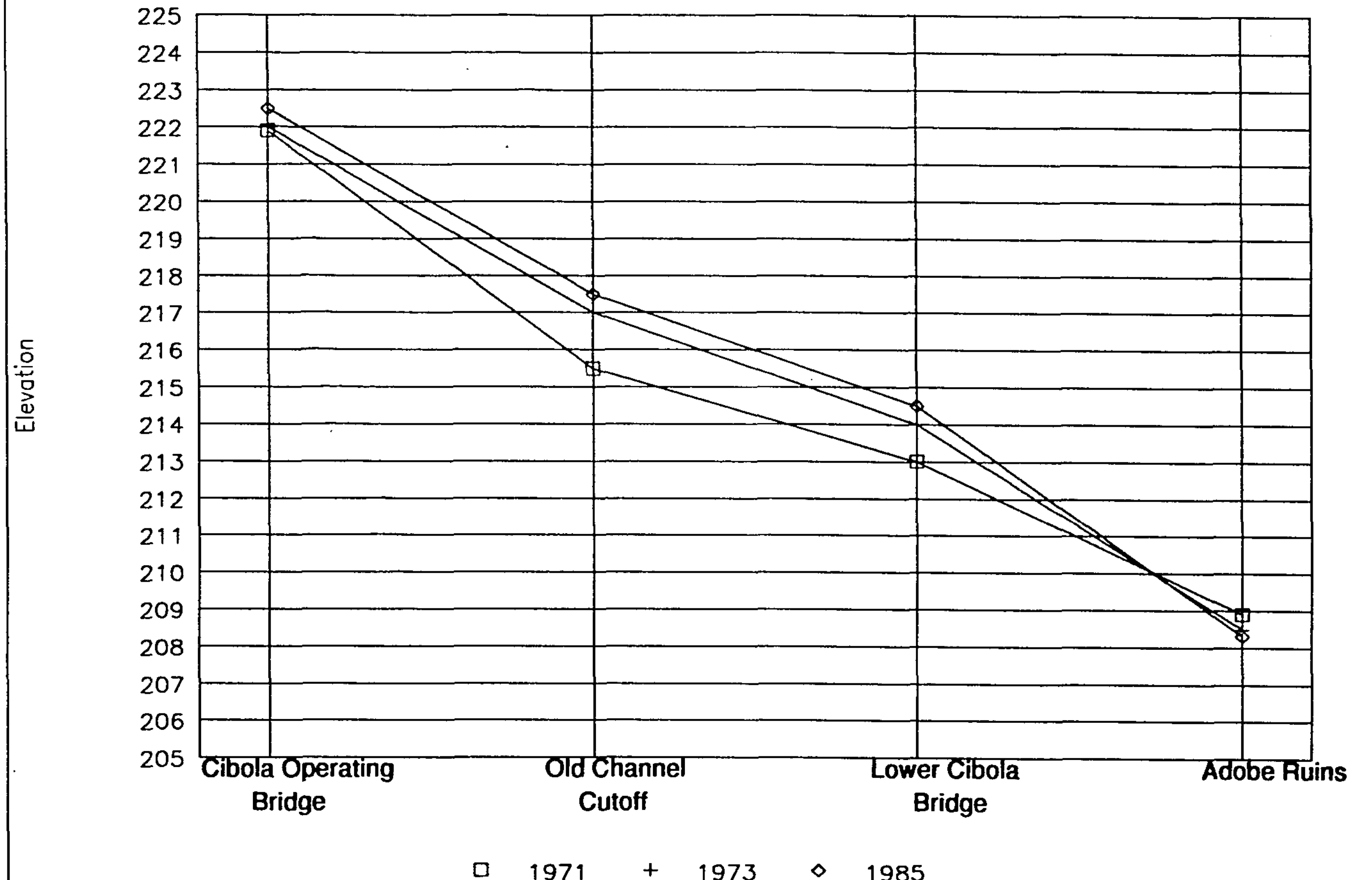
COMPARATIVE COVER FOR THREE VEGETATION COMMUNITIES
1959, 1976, 1986

under cultivation in 1959 and that which had recently been abandoned, was primarily salt cedar by 1986.

Data on water-surface levels from the Bureau of Recreation (1959, 1972, 1973, 1991) shows significant change in levels throughout the refuge between 1903, when Cibola Valley was first surveyed by the U.S. Geological Society, and 1985 (Figure 6). The initial degredation caused by the opening of the new channel slowly began to aggrade in the central portion of the refuge, while the southern portion shows continued degradation. Water surface levels in 1903 at what is now the Palo Verde Outfall drain (Figure 7), were approximately 212.5 feet for a river flow of 10,000 cfs. By 1930, water surface levels at the drain had risen dramatically to 223.7 feet, and dropped to 220 feet by 1959. Although water surface levels in the new channel have been monitored since 1971, data were not available for water in the old channel which acts today as simply an extension of the Palo Verde Outfall drain. The drop in water-surface level for the outfall drain, projected by the Bureau in 1959 as a result of the channelization project, was approximately 6 to 7 feet for an average flow of 500 cfs, the estimated flow through the backwaters of the old channel.

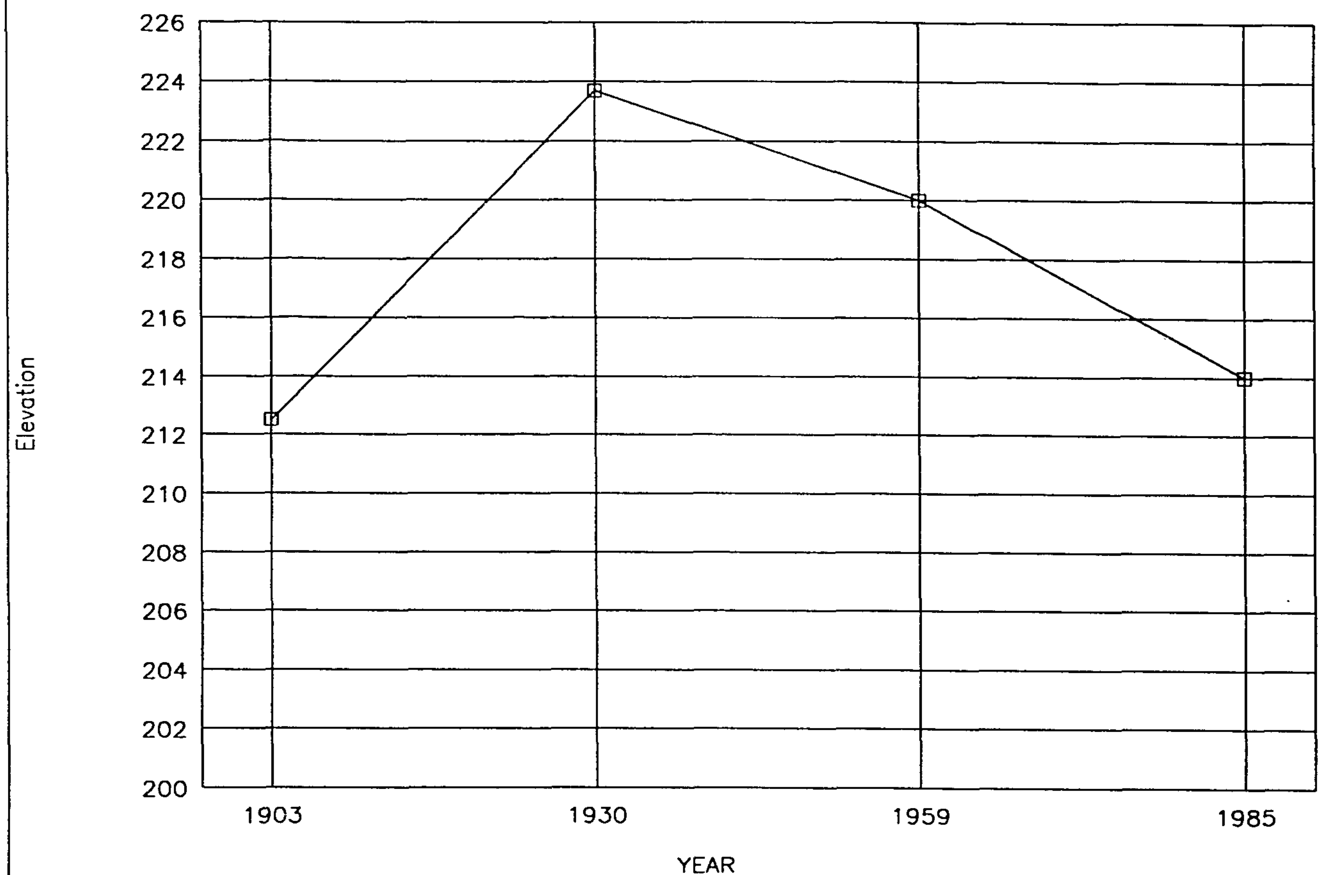
At the southern end of the refuge lies the Adobe Ruins gage, just south of Cibola Lake. Water surface elevations here have been monitored since just prior to the opening of the new channel in 1970 and have shown a steady decline in elevations at this point (Figure 8). In 1970, water surface elevations at Adobe Ruins for a flow of 10,000 cfs was 209.4 feet. After water was diverted into the dry cut, elevations dropped to 208.9 in 1971, 208.6 in 1972, and 208.5 in 1973. In 1973, estimates were that the water surface elevations were at or near a low point and that a rising trend would soon begin. Projections in 1973 were still in accordance with those made in 1959 for a rise to a high of 212 feet by the year 2020. Yet in 1985, surface elevations showed a continued drop and were measured at 208.31 feet for a flow of 10,000 cfs. These changes in water-surface levels have been instrumental in controlling the vegetation patterns in Cibola National Wildlife Refuge.

Figure 6



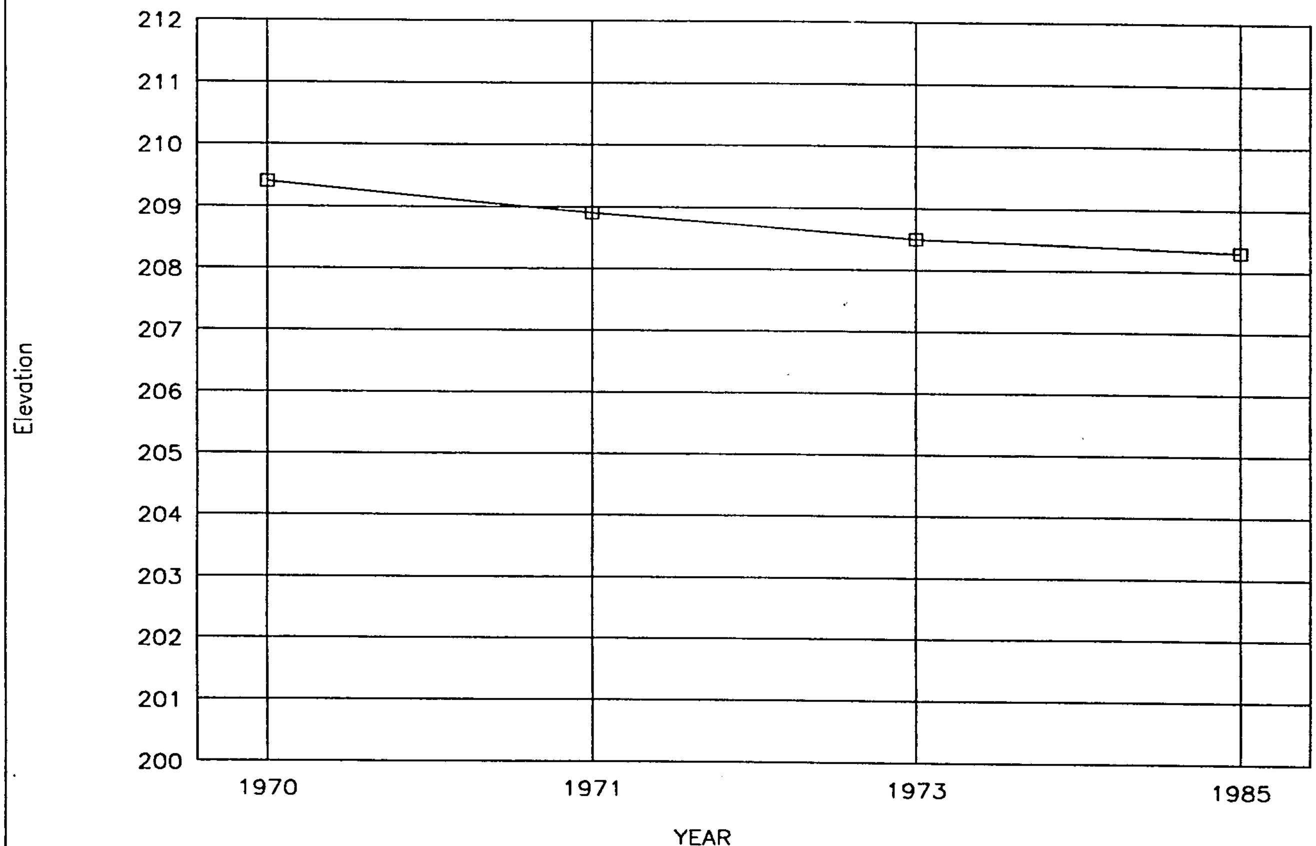
WATER SURFACE PROFILE THROUGH CIBOLA NATIONAL WILDLIFE REFUGE
(for a flow of 10,000 CFS)

Figure 7



WATER SURFACE ELEVATIONS - PALO VERDE OUTFALL

Figure 8



WATER SURFACE ELEVATIONS - ADOBE RUINS

DISCUSSION

Both the channelization project and the establishment of the wildlife refuge in Cibola Valley have had significant effects on the vegetation in this area. It is impossible to state that the ecosystem of Cibola Valley was in a "natural" state by 1959 but it can be assumed that the vegetation in this area had sufficient time to adapt to the river's regulated flows since the closing of Hoover Dam. As noted above, vegetation in upstream reaches, such as the Grand Canyon-- studied since the closing of Glen Canyon Dam-- had exhibited a pattern of relative stability with flows of minimal fluctuation (Carothers and Brown 1991). Likewise, it is resonable to assume that vegetation in Cibola Valley would have adapted to stable flows since the closing of Hoover Dam, and was susceptible to even slight changes in the hydraulics of the Lower Colorado River. This section attempts to correlate the impact of both the channelization project and the establishment of Cibola National Wildlife Refuge (CNWR), with the vegetation changes observed between 1959 and 1986.

Impacts of the Channelization Project

Cottonwood-willow community: One of the primary changes within this community occurred along the old channel of the LCR after the river had been diverted into the dry cut in 1970. One of the main objectives of the Bureau of Reclamation was to lower the water-surface level at the drain of the Palo Verde Outfall by approximately seven feet. In order to accomplish this, the river was diverted, in 1970, into a new channel split from the old channel about two miles above the drain. Since 1970, the only flow of water now feeding into the old channel has been the irrigation runoff from the Palo Verde Irrigation District-- approximately 500 cfs. This is a substantial drop from the previous average flow of 10,000 cfs through this area and by 1976, the repercussions of this change were evident. The cottonwood-willow community, particularly in the upper and mid-reaches of the old channel, had disappeared. By 1986, no remaining stands existed along the old channel.

Low flows and slow moving water within the old channel, allowing for greater evaporation, may have contributed to a rise in salinity levels. Return flows from the Palo Verde Irrigation District would also carry higher saline concentrations. In addition, the concentration of phosphate phosphorus in the backwaters of the refuge was .013mg/l greater than in the main channel when tested in 1975, presumably reflecting the influence of fertilizers in the Palo Verde Irrigation District (Minckley 1979). These changes might also have contributed to the demise of the cottonwood-willow community along the old channel, creating an environment too saline for its existance.

By 1986, the only cottonwood-willow communities left on the refuge occurred along a streambed adjacent to an agricultural area in the center of the refuge, and a small stand near the northern refuge boundary. What few mature cottonwoods remained in the refuge by the early 1980's were eliminated by the floods of '83, '84', and '86. These dam-controlled floods resulted in sustained periods of high water, and the drowning of the remaining mature cottonwoods in the refuge. When the floods receded, the soils contained higher saline concentrations not conducive to the regeneration of cottonwoods (Martin, CNWR manager, personal communication, 1992). The ability of the cottonwood-willow community in CNWR to eventually regenerate itself is improbable due to the elimination of annual flows of high water which formerly reseeded this area.

<u>Marshes:</u> Between 1959 and 1976, a dramatic decline in marsh cover occurred in CNWR. One of the areas of major loss for marshlands was in Davis and Three Fingers lakes. With a drop of nearly seven feet in water-surface levels at the Palo Verde Outfall drain, just to

the north of Davis Lake, and the severe reduction of flows in the old channel, both of these lakes were drained completely. By 1976, much of the marshland surrounding Cibola Lake had also disappeared. The most probable cause for this was the lowering of the water-surface level in the in the vicinity of Adobe Ruins, located at the southern end of Cibola Lake.

It was originally estimated by the Bureau of Reclamation that anticipated aggradation of the riverbed in the lower portion of Cibola Valley would result in a rise in water-surface levels in both Three Fingers and Cibola lakes. The design of the new channel was such that a gradient of 1.2 feet per mile would exist within the refuge allowing for slow aggradation to occur over the next 50 years, eventually raising the water-surface to design level (Bureau of Reclamation 1959). In the vicinity of Cibola Lake, lower than anticipated water-surface levels have occurred between 1970 and 1985 as a result of greater than anticipated degradation in the area of Adobe Ruins (Bureau of Reclamation 1973, 1985). According to the Bureau of Reclamation (1973), because of the greater-than-normal depth of flow, the dry-cut reach (designed to accommodate floods up to 80,000 cfs) acts as a settling basin for sediment, resulting in relatively sediment-free water arriving at Adobe Ruins and scouring the riverbed. It was anticipated by the Bureau in 1973 that this scour cycle was nearing completion and that water levels would begin to rise, but as of 1985, water-surface levels for 10,000 cfs at Adobe Ruins showed a continued drop in elevation. If this pattern is to continue, design water-surface levels for the year 2020 will not be reached.

Anticipating a drop in water-surface levels at Cibola Lake in the initial years after completion of the dry cut, and in order to combat the problem of "wildlife values [that] have gradually been reduced as a result of siltation and encroachment of emergent vegetation" (Palo Verde Valley Times, 1970a:7), a dredge began work shortly after the beginning of 1970 to deepen Cibola Lake. The dredge work, completed at the end of the same year, did succeed in deepening the lake in order to create a permanent area of marsh-free water. It also succeeded in halting the incursion of marsh species which had been increasing over the years due to increased sediment deposition in this area. In 1976, despite the dredging of Cibola lake, it was evident that the lake had diminished in area since 1959. One possible explanation for this, and for the reduction of marsh surrounding the lake, can be attributed to the dredging process involved with the dry cut.

The dredging operation began near Cibola Lake at the site where the new and old channels currently converge, and worked its way north to the point where the dry cut splits from the old channel. During this process, water from the river was gradually filling in that area of the dry cut which had already been removed. This water, plus that tapped from the groundwater table, kept the dredge afloat and supplied the necessary water needed to be mixed with the removed earth and pumped out of the dry cut. This would have resulted in a gradual dropping of water-surface levels both in the old channel and in the vicinity of Cibola Lake from the time the dredging of the dry cut began in 1964, until its completion in 1970 (Harlen Miller, River Development Branch, Bureau of Reclamation, person communication, 1992).

By 1986, it appeared that Cibola Lake had grown substantially in size despite the continual drop in water-surface levels (for a flow of 10,000 cfs) at Adobe Ruins. This discrepancy can most likely be attributed to the high flows associated with the '83 and '84 floods. Between 1970 and 1979, the maximum mean flow at Parker Dam, above the refuge, was 14,600 cfs, and 11,500 cfs at Imperial Dam downriver (Table 1). Although data was not available for November and December of 1985 (the year and months of the aerial photos on which the 1986 map was based), for January and February the *lowest* mean flow was 18,026 cfs, while November and December of 1984 saw minimum mean flows of 25,500 cfs. Floods in '83, '84, and '86 dramatically altered the stable flow patterns established since the late 1930's. For the first time since the closure of Hoover Dam in 1935, large amounts of water reached the Colorado River Delta (Ohmart et al. 1988). These heavy flows could account for the larger area of open water in Cibola Lake in 1986. In addition, Wes Martin, CNWR manager, stated that the floods brought a great deal of sediment into the lake, perhaps causing an additional rise in water surface levels. The decrease in marshlands surrounding Cibola Lake may also be attributed to this sustained rise in water-surface levels.

When the river was first diverted, marshes along the old channel quickly dried up, but by 1986, emergent marshland began to occur along the banks of the old channel. During field verification in 1992, it was evident that cattail, bulrushes, and other marshland species were common along this slow moving backwater. It is plausible that marsh communities will continue to expand along the old channel.

Salt Cedar: As communities such as cottonwood-willow and marsh diminished between 1959 and 1986, salt cedar began to replace them. The greatest loss of cottonwood-willow and marshlands occurred between 1964 and 1976 when water-surface levels were lowered, and after 1976 with the added impact of prolonged flooding and higher saline contents in the soil. As salt cedar is tolerant of floods, salt, and drought, the environment of CNWR after 1964 became increasingly suitable to the spread of salt cedar. Attesting to this fact is that by 1976 salt cedar occupied lands formerly covered by Davis and Three Fingers lakes , and the dominant species in areas of abandoned agriculture.

Today, salt cedar occupies most of the land within the refuge. The result of this spread of salt cedar is that few stands of honey and screwbean mesquite remain that are not intermixed with salt cedar. It is possible, as these species die out, that the ability of salt cedar for quick regeneration may result in a growing monoculture within the refuge. In addition, recent fires (1992) which burned 1700 acres in the southern portion of the refuge, are evidence that fires occur here and can further contribute to the spread of the fire-tolerant salt cedar. If current hydrological and ecological conditions were to continue, salt cedar might one day cover the entire refuge outside of agricultural areas.

In the Parker Division, adjacent to the northern boundary of the Palo Verde Irrigation District, extensive agricultural development and channelization have been undertaken. Compared with Mizoue's study (1984) of vegetation change between 1939 and 1982 in this area, Cibola's pattern of vegetation change has exhibited certain differences. Based on patterns of change between 1939 and 1982, Mizoue estimated probabilities of transition through time within the Parker Division if vegetation changes of 1982 were a stationary process, and predicted:

1) Although no reasons were given for the demise of the cottonwood-willow community in the Parker Division before 1982, it was found that what few remained along the levees at the time of her study, were being cleared for agriculture. Cottonwood, willows, honey and screwbean mesquite would all decline,
2) salt cedar would see an overall decrease in numbers throughout the Division, with increases only in those areas not being cleared for agriculture,
3) areas of open water and marshlands would decline.

In Cibola National Wildlife Refuge, the pattern of vegetation change contrasted with that of the Parker Division with the exception of the cottonwood-willow and mesquite communities:

1) cottonwood-willow and screwbean mesquite communities declined with a decline in honey mesquite after 1976,

2) salt cedar increased rapidly

3) marshlands saw an overall decline but after 1976 they began to increase,

4) an overall increase in open water (but a decline in backwaters outside of the new channel).

It may be argued that since the Parker District and the CNWR experienced similar hydraulic changes (channel straightening, dredging, leveeing etc.), the differences between these patterns of vegetation change in these two different divisions along the LCR can mainly be attributed to the establishment of Cibola National Wildlife Refuge in 1964.

Impacts of the Wildlife Refuge

Perhaps the most important impact the refuge has had on the growth of vegetation communities in this area is to control the growth of agriculture. Mizoue found that agricultural lands in the Parker District increased from .65 km^2 in 1939 to 132.4 km^2 in 1982, or 61% of the district's lands. In CNWR, agricultural lands account for only 8 km^2 or 10% of the refuge lands. These agricultural lands on the refuge are surrounded by riparian vegetation and are left unharvested as feeding and breeding grounds for waterfowl. The density and diversity of birds in this area are great, with at least 232 species occupying the refuge lands, and with Canadian goose numbers well over 13,000 at certain times of the year (U.S Fish and Wildlife Service 1984; Martin, personal communication, 1991). An added implication of land not being cleared for agriculture, is that the spread of salt cedar continues unimpeded. Mizoue found a decline in growth of salt cedar as more land was being converted to agriculture. Conversely, within CNWR, salt cedar has become the dominant species, accounting for nearly 60% of the refuge lands by 1986.

Open water areas in CNWR, unlike in the Parker Division, have seen an increase in area. The channelization project redistributed the open water within the refuge, with the majority of open water now existing in the new channel and Cibola Lake, while disappearing from other lakes and backwaters. What the refuge has done, however, is to maintain those open water areas which now exist. Not only has Cibola Lake been dredged and deepened, but stop-logs have been placed along its perimeter, acting to retain water within the lake during times of low flow. Water-surface levels can drop to as low as 201 feet during certain times of the year and these stop-logs prevent Cibola Lake from being completely drained for long periods of time (Martin, personal communication, 1992).

The effects of establishing both the agricultural lands and permanent areas of open water has been a reconfiguration of the bird species using the refuge. Historically, few waterfowl were found

in these areas, as was noted by Grinnell (1914:72) in his 1910 trip down the LCR:

> The little open water sometimes attracted a few transient ducks and mudhens, but so far as known no water bird outside of the Ardeidae remain to breed anywhere along the Colorado River.

Today, the refuge is utilized primarily by migratory and wintering waterfowl.

Perhaps one of the most promising effects CNWR has had on vegetation has been in the form of revegetation projects. Although accounting for only a few square kilometers as of 1992, the revegetation projects done within the refuge have the potential to restore the vegetation in this area to its original diversity, possibly encouraging a return of those native bird species which migrated due to a loss of prime habitat (primarily cottonwood-willow). In a study of two riparian areas re-established by wastewater on the Gila Indian Reservation in Arizona, Rea (1983) showed that with habitat amelioration, most locally extirpated bird species are still capable of recolonization. The success of these revegetation projects bodes well for a future which may see an eventual ecosystem, native in both vegetation and bird species, throughout portions of the refuge.

Implications for the Future

If patterns of vegetation change within CNWR were to remain stable, and management practices continue as they are today, the future of the refuge's ecosystem could be quite different from its upstream counterparts-- the Parker and Palo Verde Irrigation districts. Primarily, through continued revegetation projects, an increase in diversity of both vegetation and bird species can be expected. In the slow-moving backwater of the old channel, a continued increase in marshlands will occur leading to a possible increase in marshland wildlife. Regardless of the eventual sedimentation patterns at Adobe Ruins (which appear not to be aggrading as expected), Cibola Lake will retain areas of open water. Important as a sport fishing area, the lake will see continued maintenance through projects such as dredging and the placement of stop-logs, assuring open water year round. As a specified goal of the Bureau of Reclamation's channelization project is to maintain stable water-surface levels within the refuge, this could result in a stable pattern of vegetation change to occur along both the new and old channels, and should insure the success of revegetation projects developed around stable water-surface levels.

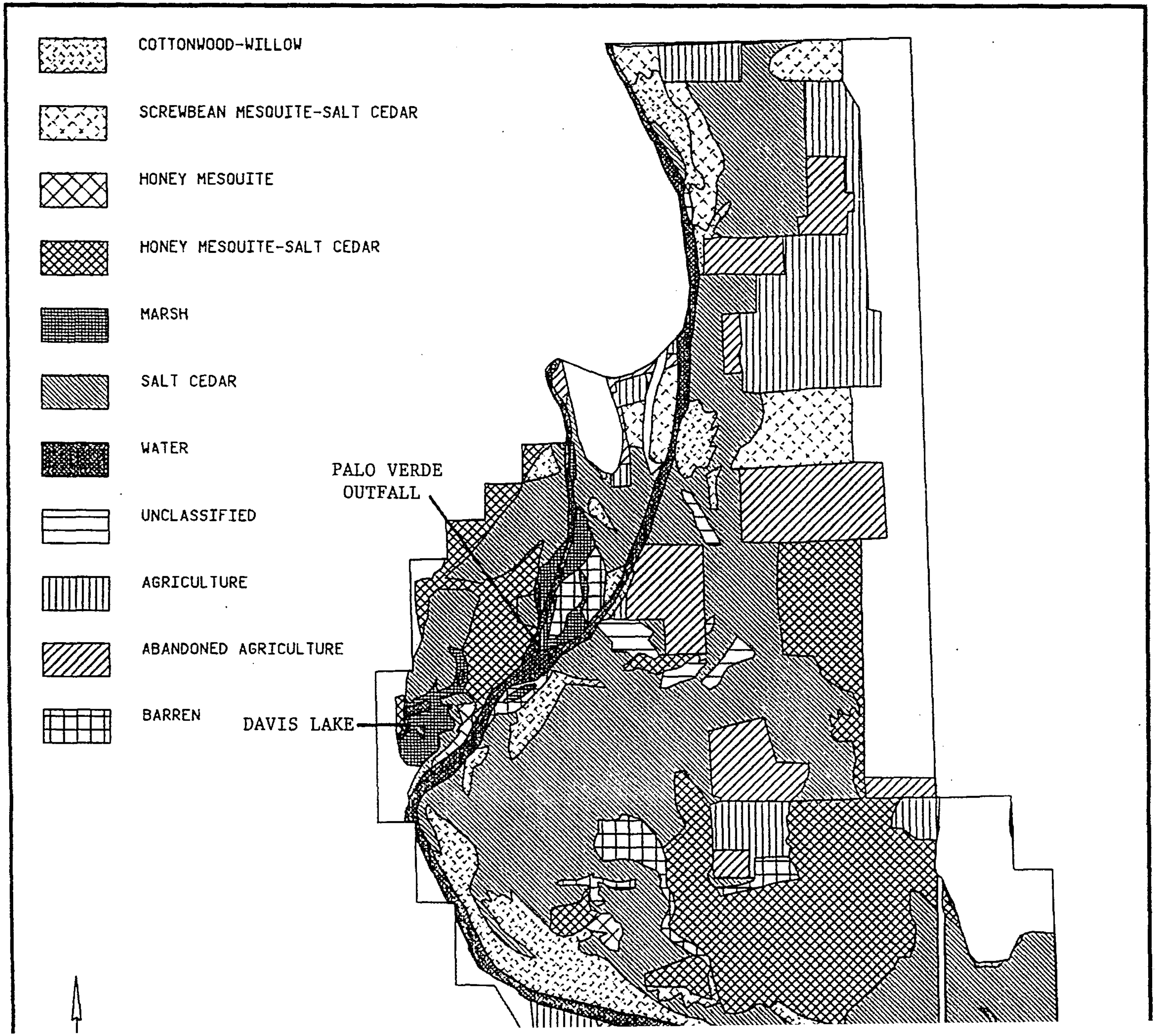
CONCLUSION

Although much of the ecosystem has undergone change on the refuge lands since the channelization project began, it is clear that human-induced changes had been occurring in this area since the turn of the century. It could be argued that the refuge acts as a sanctuary for both wildlife and native vegetation and although the Colorado River's waters will continued to be controlled, the refuge takes responsibility to minimize the effects of these controls and the channelization project in general. Although it cannot be maintained that wildlife refuges established along the Lower Colorado River are preserves of historically natural wildlife habitats, it could be argued that within these areas future change could head in this direction. With the incorporation of revegetation projects into refuge lands, native vegetation may have a better chance of making a comeback along the Lower Colorado. The diversity present in communities of native vegetation may result in the eventual return of certain of those wildlife species which have virtually disappeared from the Lower Colorado River Valley.

There is no doubt that the development and management of arid land water resources will continue. The Lower Colorado River represents an area that has seen the rapid and almost complete demise of its aquatic and riparian habitats. It is only recently that the Bureau of Reclamation has begun to slow its development of water resources along the Lower Colorado River, and it is now, in retrospect, that changes in the ecosystem must be carefully studied, By looking at the environmental impact of projects such as the channelization of the river through the arid environments of Palo Verde and Cibola valleys, we can better anticipate, and manage for, impacts of future projects in similar environments. By studying the effects that wildlife refuges have had on riparian habitats bordering the Lower Colorado River, we might be better able to create and manage future refuges in arid lands with similar ecosystems.

Without studies such as these, valuable riparian ecosystems could ultimately disappear from arid environments altogether.

APPENDIX A: VEGETATION MAPS FOR 1959, 1976, 1986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HONEY MESQUITE
HONEY MESQUITE-SALT CEDAR
MARSH
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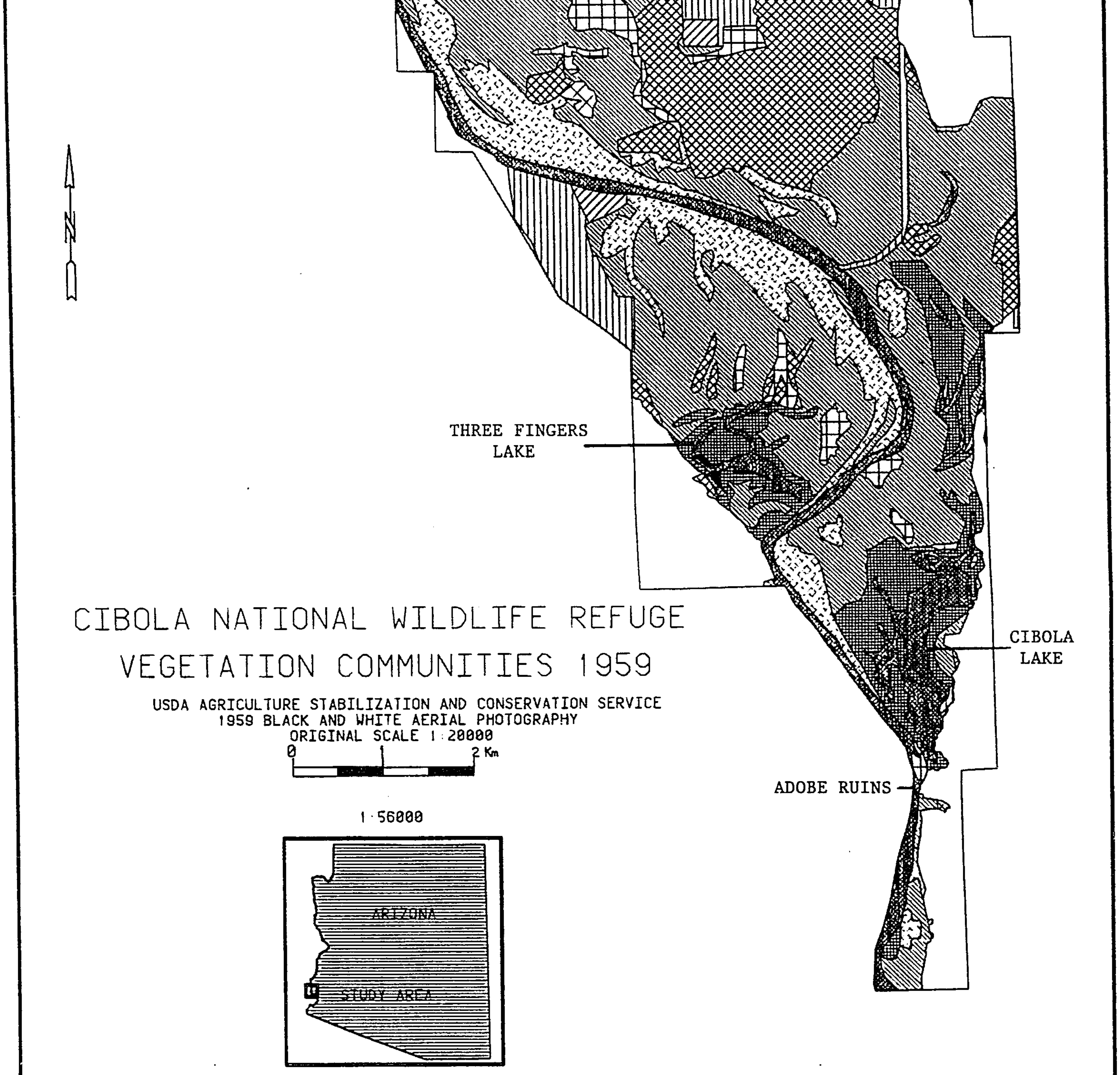
WATER
UNCLASSIFIED
AGRICULTURE
ABANDONED AGRICULTURE
BARREN
PALO VERDE
OUTFALL
DAVIS LAKE


N
THREE FINGERS LAKE
CIBOLA LAKE
ADOBE RUINS
CIBOLA NATIONAL WILDLIFE REFUGE
VEGETATION COMMUNITIES 1959
USDA AGRICULTURE STABILIZATION AND CONSERVATION SERVICE
1959 BLACK AND WHITE AERIAL PHOTOGRAPHY
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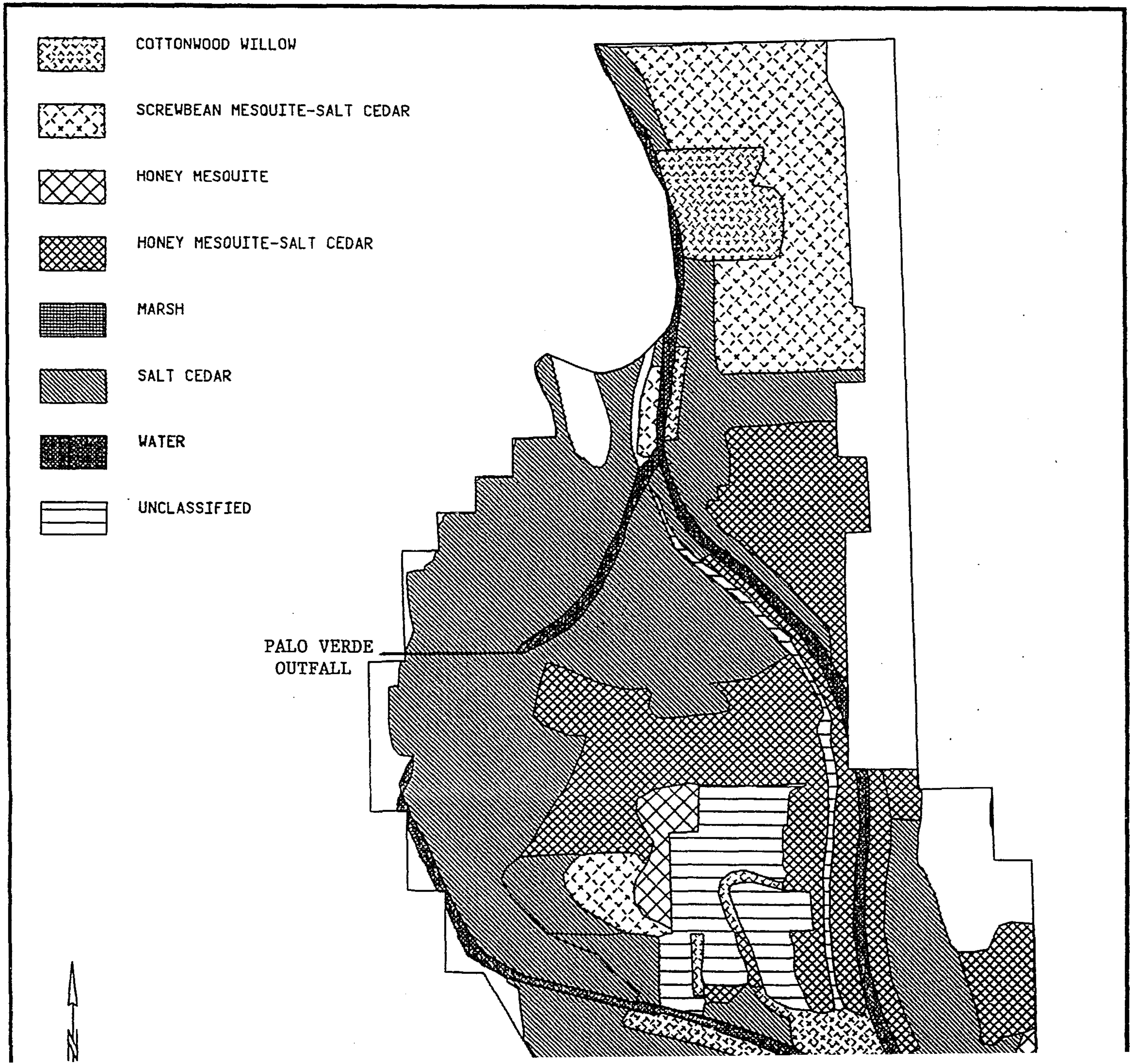
ARIZONA
STUDY AREA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SCREWBEAN MESQUITE-SALT CEDAR
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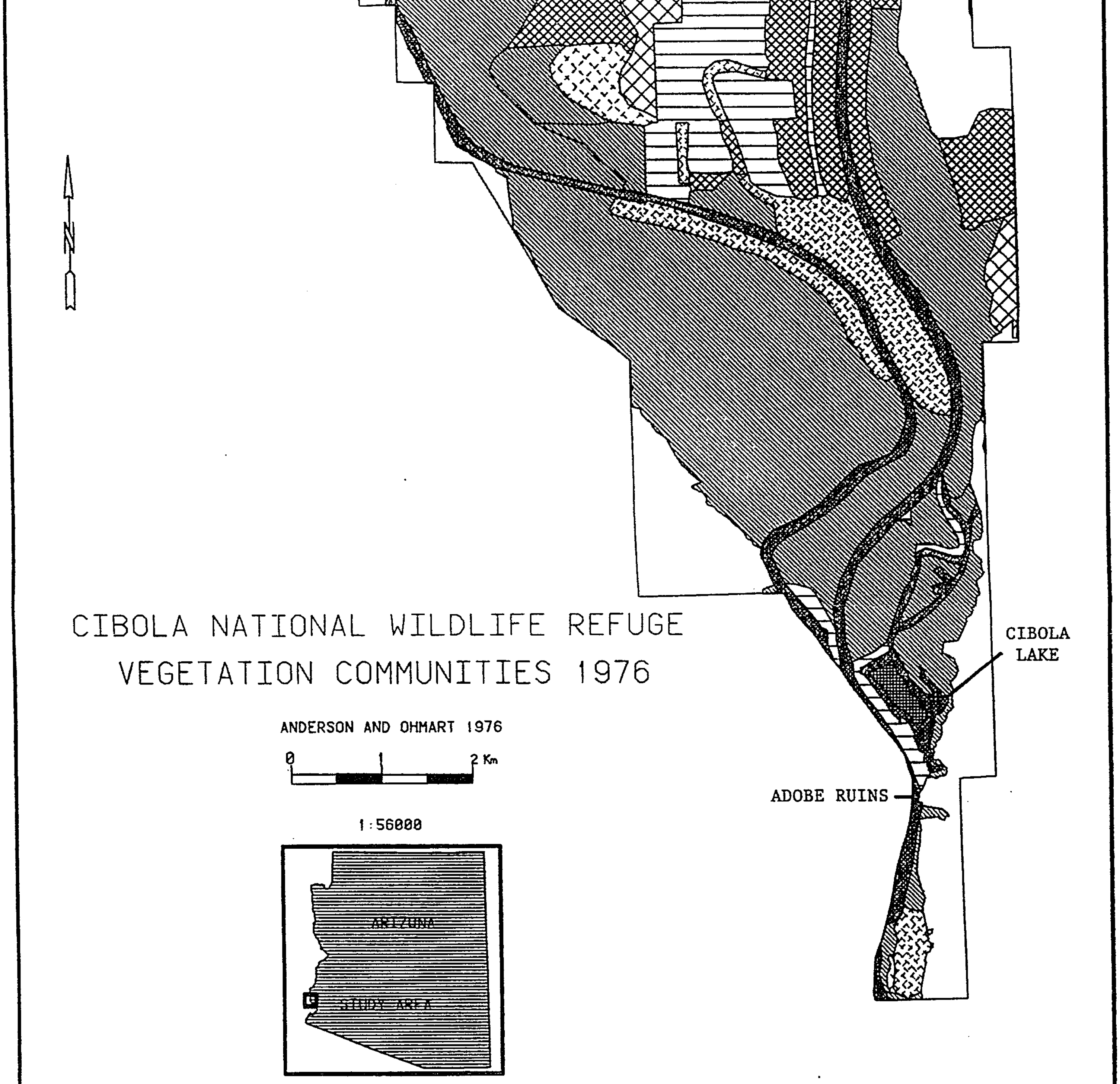
MARSH
SALT CEDAR
WATER
UNCLASSIFIED
PALO VERDE OUTFALL


CIBOLA NATIONAL WILDLIFE REFUGE
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ARIZONA
STUDY AREA
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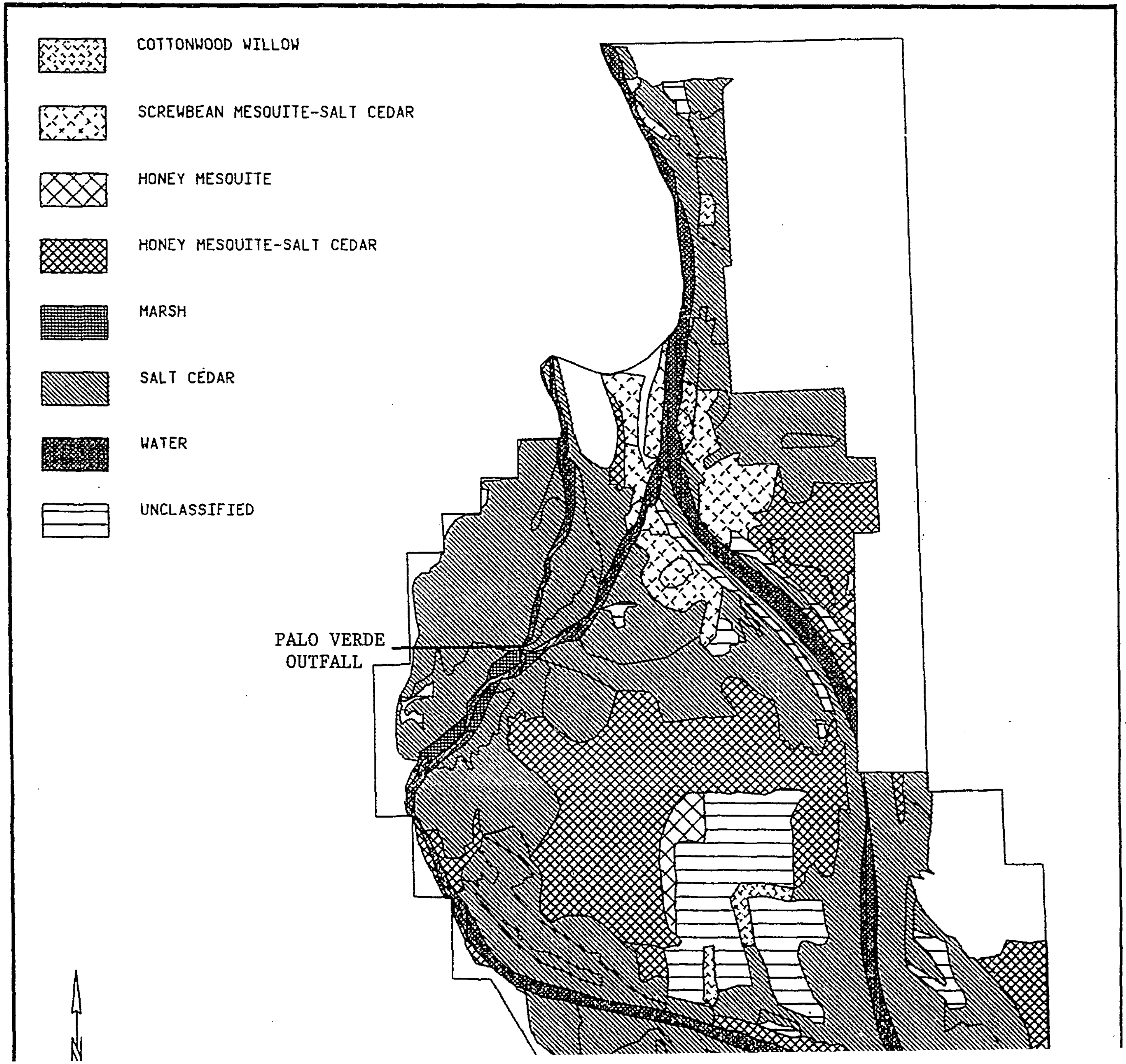
CIBOLA LAKE
ADOBE RUINS


COTTONWOOD WILLOW
SCREWBEAN MESQUITE-SALT CEDAR
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MARSH
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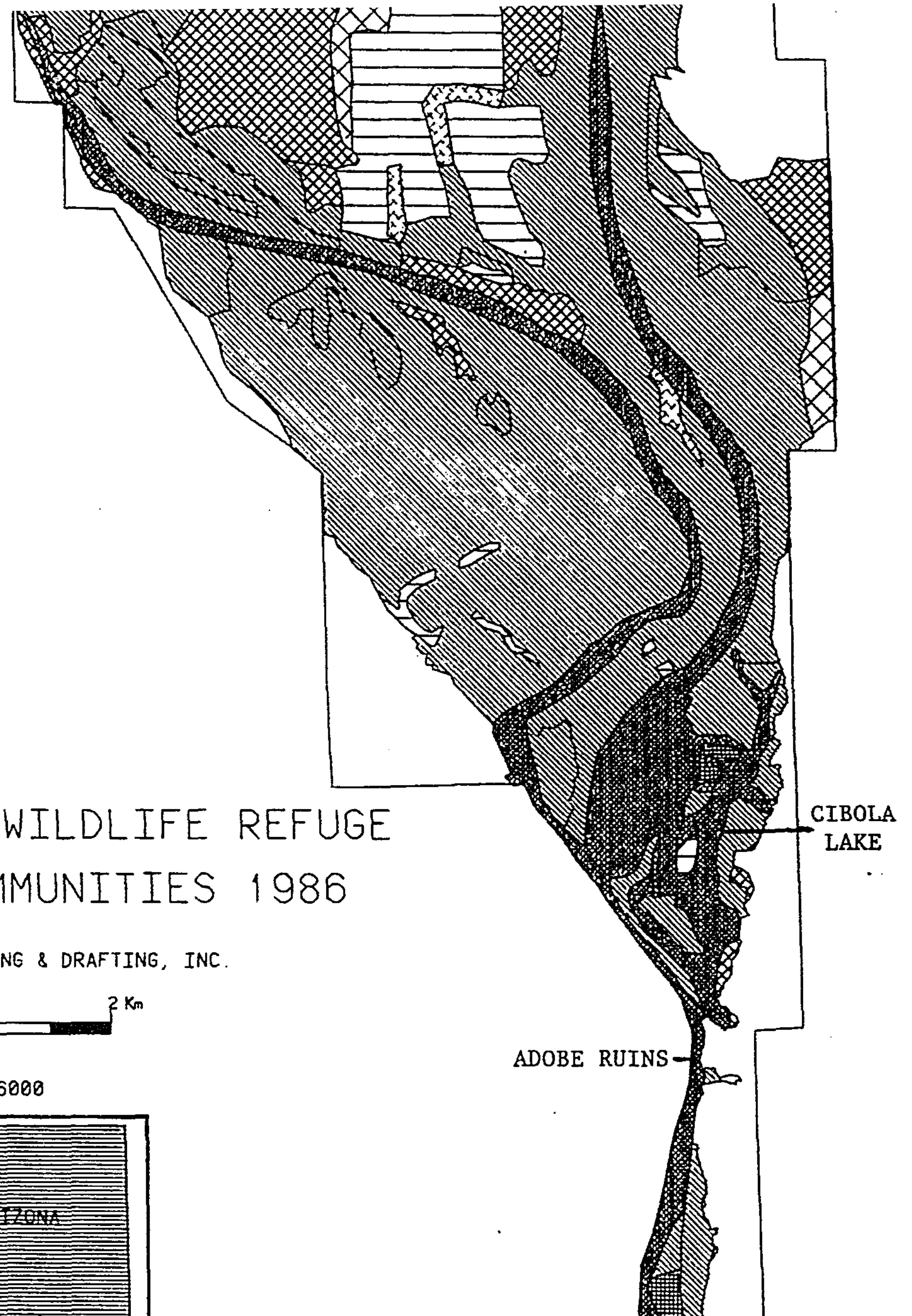
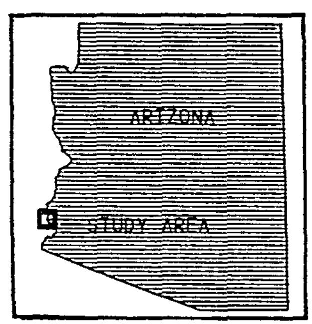
WATER
UNCLASSIFIED
PALO VERDE OUTFALL
N



CIBOLA NATIONAL WILDLIFE REFUGE
VEGETATION COMMUNITIES 1986

AAA ENGINEERING & DRAFTING, INC.

1:56000



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