# AN ASSESSMENT OF SURFACE WATER SUPPLIES OF ARKANSAS

## With Computations of Surplus Supplies and a Conceptual Plan for Import to Texas

Texas Water Development Board
Austin, Texas

# AN ASSESSMENT OF SURFACE WATER SUPPLIES OF ARKANSAS

## With Computations of Surplus Supplies and a Conceptual Plan for Import to Texas

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Contents

# List of Exhibits

## Purpose

The purposes of this study are to evaluate the surface water resources of the State of Arkansas to determine if there is water surplus to the needs of the State, both now and in the foreseeable future which could be exported to satisfy the needs of the water short areas in the State of Texas. And, if it is determined that surplus water does exist and will probably occur in the foreseeable future, to identify the locations where substantial quantities of water are in excess of the State's needs that might be available for export, and further, to develop a conceptual plan for delivery of this excess water to Texas.

## Summary

Mutual benefits can be derived by both Arkansas and Texas if surplus water is exported from Arkansas to the water short areas of Texas. Should New Mexico, Oklahoma and Louisiana join with Texas and Arkansas in a water transfer plan, the water supply and delivery system could probably be enlarged and a more cost effective system designed and constructed. The leadership to explore this concept could be provided by the Arkansas-White-Red Basins Inter-Agency Committee (AWRBIAC).

Large quantities of water in excess of the needs of the citizens of the State of Arkansas pass through or by the State.

The average annual discharge of the Mississippi River averages about 400 million acre-feet at the southeastern corner of Arkansas and the average annual outflows of the Arkansas tributaries average about 80 million acre-feet of which about 30 million acre-feet flows into the Mississippi and about 50 million acre-feet flows into the State of Louisiana.

The increased surface water needs of Arkansas to the year 2020 have been estimated to be 5.5 million acre-feet per year which, when deducted from the

average outflow of 76.5 million acre-feet per year of surface water from Arkansas for the period through 1975, leaves approximately 71 million acre-feet per year of excess and surplus surface waters flowing out of the State of Arkansas. Considering in addition to this, a requirement of bordering states to allow as much as 40 percent of all gauged surface water to flow over state lines, the projected 2020 excess and surplus water would be approximately 43 million acre-feet per year.

The Texas Water Development Board, the State agency in Texas responsible for planning the development of the State's water resources is currently writing a state-wide Water Plan. The Plan is expected to be completed in early 1977.

Preliminary information from this plan identifies several areas of Texas currently or in the foreseeable future which will need substantial quantities of water to maintain their present productivity. One such area is the High Plains of Texas where large quantities of water are currently being utilized in the production of food and fiber. Water for irrigation is currently being obtained from the Ogallala aquifer. Withdrawals from this aquifer greatly exceed the natural recharge rate; therefore, the aquifer is being mined and will ultimately be depleted.

Irrigation farmers in this area have demonstrated their ability to produce large quantities of food and fiber; however, food and fiber production is expected to decline as a result of the declining ground-water supplies. With the United State's increasing demand for agricultural products to help balance the world food shortages and offset the trade deficits resulting from energy depletion in the nation, the role of the High Plains in helping the nation to meet these agricultural needs is critical.

It has been estimated that six million acre-feet of water annually would be adequate to maintain current irrigation levels in the High Plains of Texas. This quantity could be provided from "excess and surplus" flows of the White, Arkansas, Ouachita and Little River systems in Arkansas. This represents less than 10 percent of the water leaving the State of Arkansas, not including the Mississippi. The actual export of water from Arkansas probably could be much greater and the State would still have adequate quantities of water remaining to satisfy all foreseeable needs.

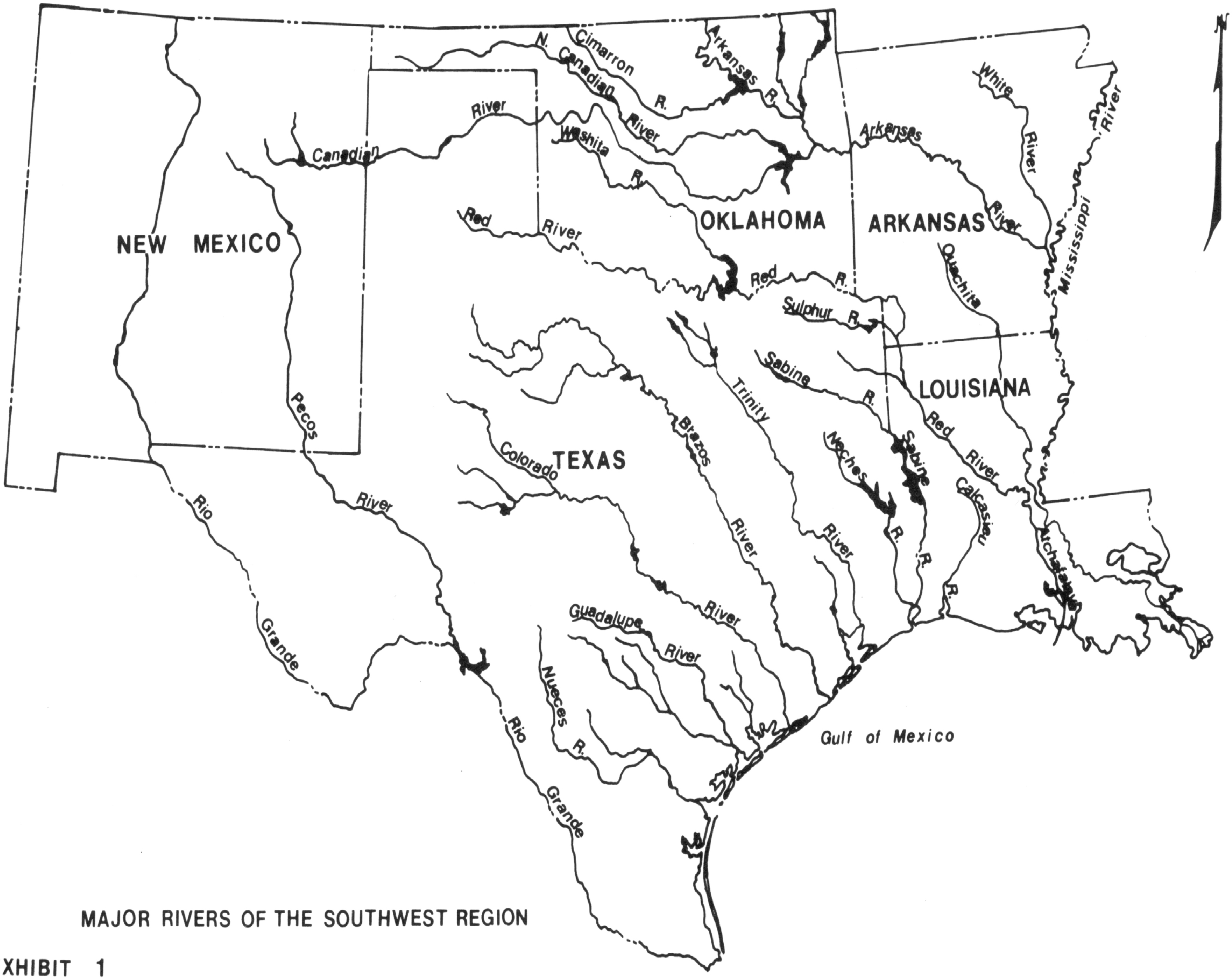
## Recommendations

Excess or surplus streamflows planned for exportation are currently being lost to surface runoffs to the Mississippi and ultimately to the Gulf of Mexico. A reevaluation of pumpage and storage practices should show that diversion and transport of water during wet season periods of moderate-to-high flow in the Mississippi tributaries will not normally interfere with firm yield capacities of surface reservoirs.

A region-wide education program of the public will be necessary to assure them that diversion of "excess and surplus" waters from the basins of origin will not interfere with any other present or projected use of water in the basins.

In Arkansas the abundance of water resources has precluded the necessity to establish a permit system or transfer water from one river basin to another. Legislation would have to be passed to enable interbasin and interstate transfer of water resources.

The Arkansas-White-Red Basins Inter-Agency, with the support of the Water Resources Council, could be requested to provide the leadership, coordination and guidance necessary to implement a southwest regional water diversion plan.




MAJOR RIVERS OF THE SOUTHWEST REGION

EXHIBIT 1

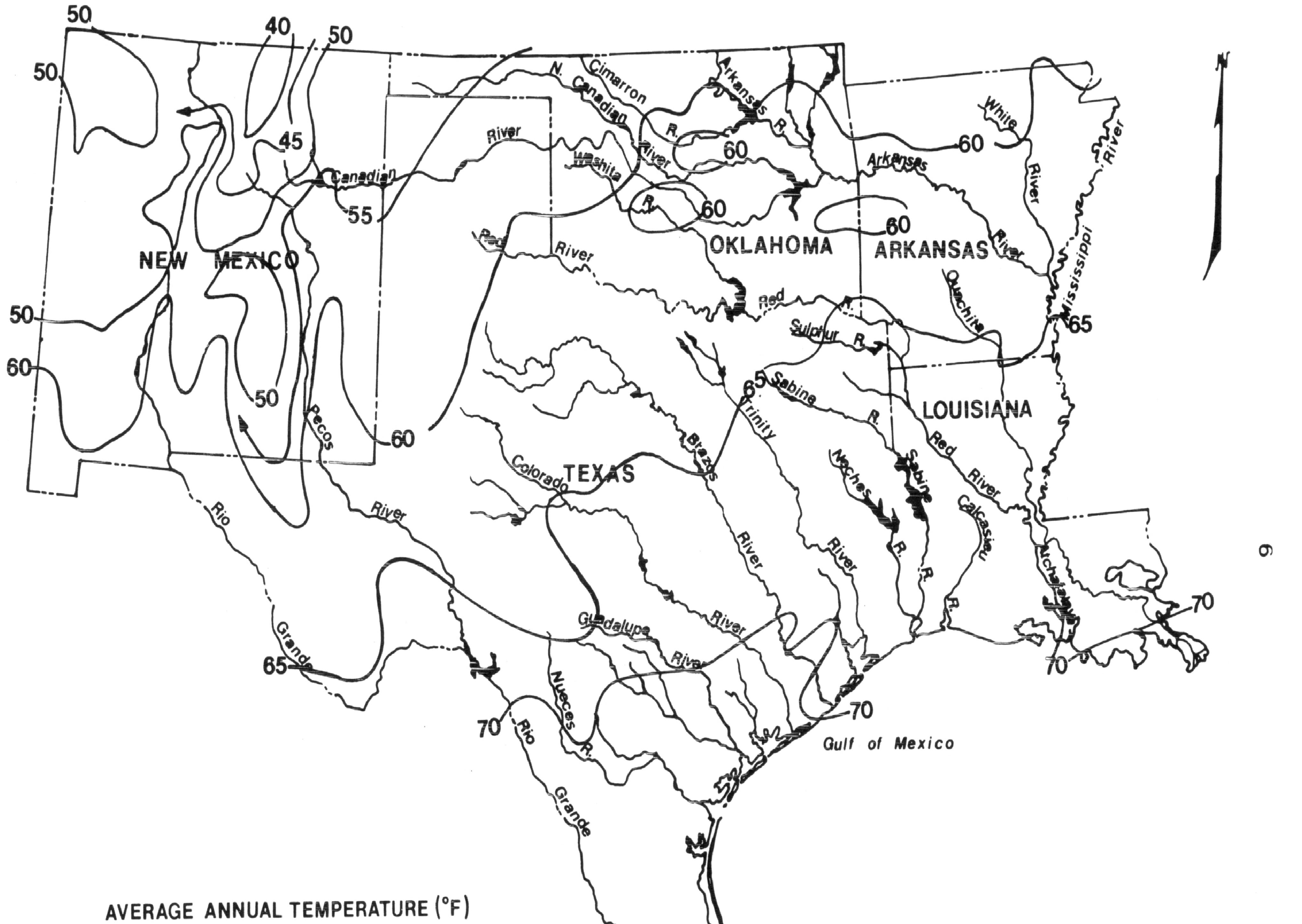
## Introduction

Water Resource Planning. Water resource planning was initially the activity of local municipalities and individual industries. Agricultural use of water was primarily determined by riparian rights with the agricultural interests bordering major streams having ready access to water supplies for agricultural use and those interests without access to the streams having no claim on the surface water resources. As the nation became more highly developed, the water resources have come under the jurisdiction of many agencies. These have included such agencies as water districts, irrigation districts, river compact commissions, municipal cooperative programs and interest in water planning on the part of state governments and the federal government.

Water resource planning evolved primarily at the state level with the assistance of river compact commissions, but this system has often failed to recognize the overall problems of water resource development on a regional basis because the boundaries of the river basins covered by the compact commissions do not closely coincide with state and local governmental boundaries.

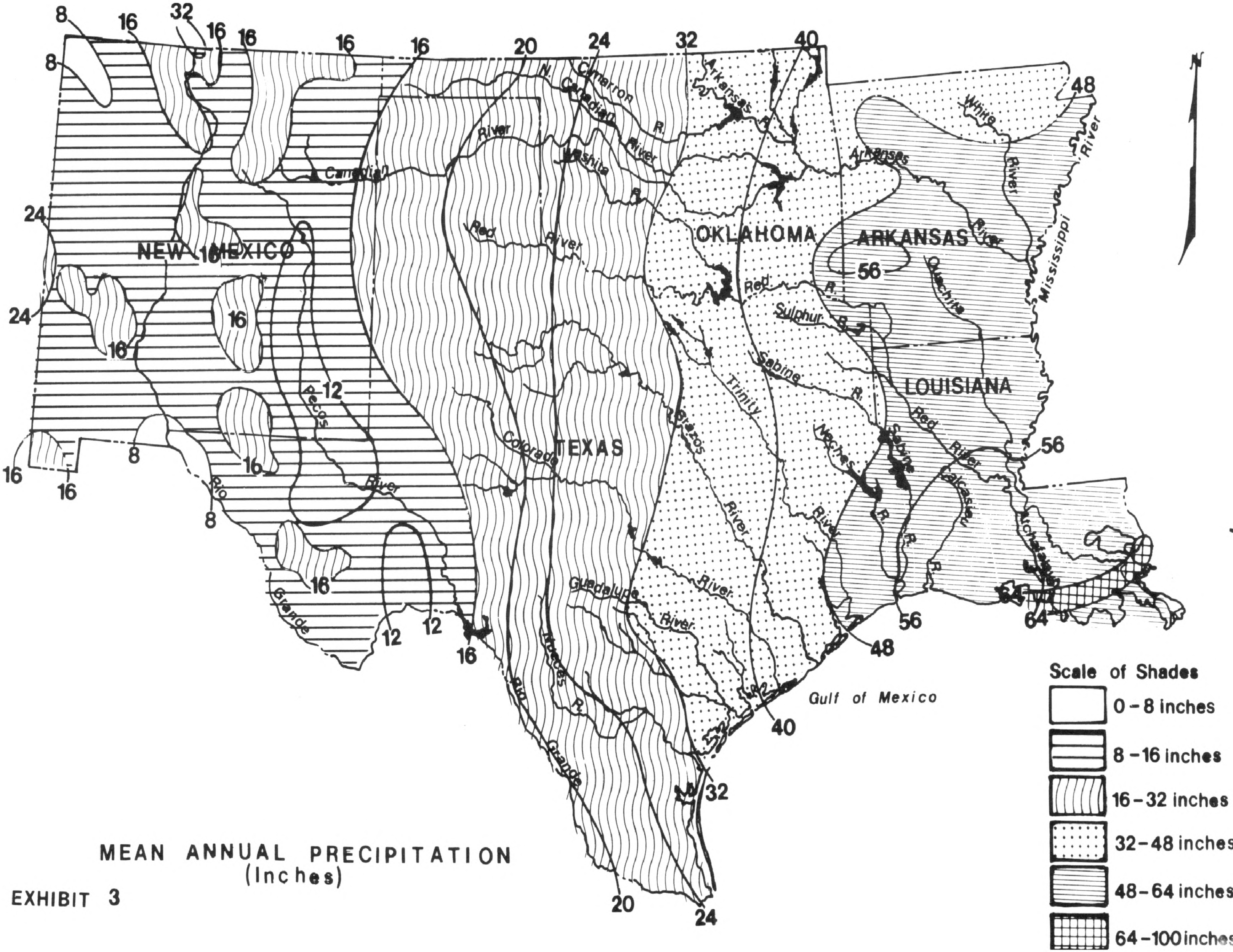
Recently there has been effort on the part of Texas to expand its state planning to a regional basis which would include the southwestern region of the United States, including the States of Arkansas, Louisiana, New Mexico and Oklahoma.

Climatological Effects. Examination of climatological and geographic data reveals that the water resources decline progressively westward from the Mississippi River. In the States of Arkansas and Louisiana, where the annual rainfall averages more than four feet per year and the evaporation is less than 44 inches per year, it is not unusual to find rainfall runoff of two feet into the tributary system and ultimately into the Mississippi River and Gulf of Mexico. By contrast, the Panhandle of Texas experiences as little as 20 inches of rainfall



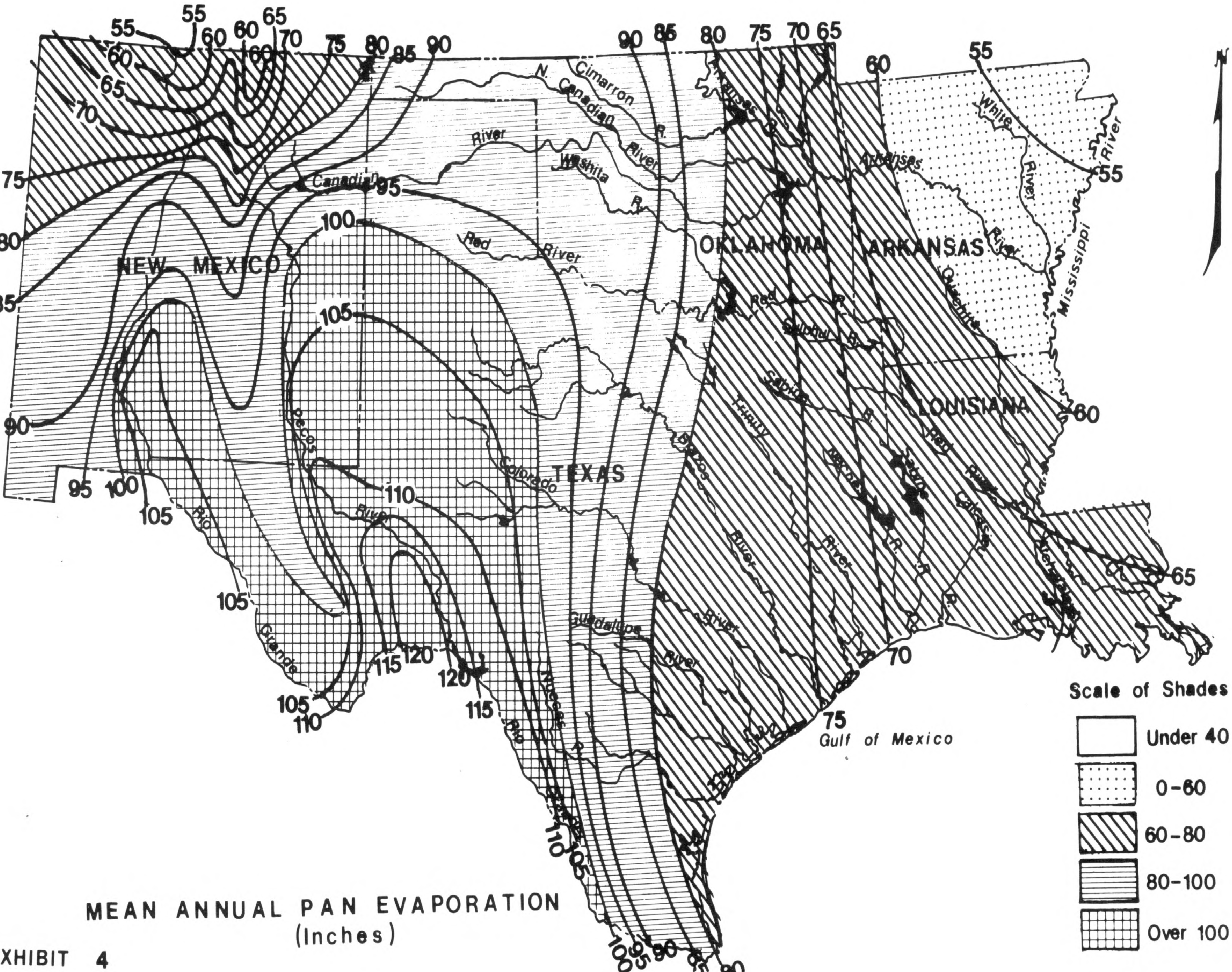

AVERAGE ANNUAL TEMPERATURE (°F)

EXHIBIT 2




MEAN ANNUAL PRECIPITATION
(Inches)

EXHIBIT 3




MEAN ANNUAL PAN EVAPORATION
(Inches)

EXHIBIT 4

in an average year while evaporation is 95 inches per year. The runoff in these areas averages one-half inch per year.

The net result of these facts is a westward progression of water deficiencies to the point that water for irrigation in some parts of central and western Texas and western Oklahoma is obtained from underground geological formations by irrigation wells. If it were not for the major aquifers in central and western Texas and western Oklahoma, almost all of the region would be limited to dryland farming. Because of the availability of underground water for irrigation in some areas, these areas have developed into extensive irrigated agricultural regions supplying national markets with large amounts of feed grains, cotton and wheat.

State Water Plans. The State of Texas has developed a water plan that was first published in 1968 and is presently being revised to update the information to present-day conditions.

The Oklahoma Comprehensive Water Plan, published in September 1975, does not show a need for the importation of water from Louisiana or Arkansas; however, the State of Oklahoma will be dependent on reservoirs in eastern Oklahoma that are on the tributaries of the Arkansas River and on the Little River which is tributary to the Red River. In order to develop a rational regional program, the requirements of Oklahoma in meeting its needs in the western part of the State must of necessity draw on the waters generated in these river basins to the extent that the water received by the State of Arkansas could be influenced.

Import Studies. The Oklahoma Water Plan envisions a transport system beginning in southeast Oklahoma near Hugo and transporting the water westward, primarily along the South Canadian and Washita rivers into southwestern Oklahoma.

There is the possibility that the most economical route for the transporting of Arkansas water to the High Plains of Texas would be through the Oklahoma system with compacted Arkansas waters that originate in Oklahoma being impounded and transferred westward. Also, waters that originate in Arkansas, such as the Ouachita and White rivers, could be diverted to Oklahoma for delivery to the High Plains of Texas and the western portion of Oklahoma.

The Mississippi River Commission made an extensive study of the diversion of water from southern Louisiana to east Texas for transport to west Texas. This study has suggested that the plan is not economically feasible. One of the reasons is that the waters must be moved several hundred miles from sea level at the Gulf Coast of Louisiana to east Texas before the transport to west Texas begins.

Problems. Since the water resources of any state are a valuable commodity for the municipal and industrial growth and agricultural production to the state, the movement of water across state lines can be very controversial and a question of political dissension. In order to accomplish the regional planning for the ultimate development of water resources, it is assumed that the economic and political consequences can be resolved to the benefit of all concerned.

One of the major questions to be resolved in the final development of a regional plan from an economic standpoint is the use of water for power generation versus the use of water for irrigation. If the water is allowed to flow through a hydroelectric facility and is then diverted and pumped back into an irrigation system, there will be a net loss of energy through the system. In many cases in the reservoirs of eastern Oklahoma and western Arkansas, the water is being used in the generation of electrcity; if this water could be diverted during the wet season from the flood control portion of the reservoir to an irrigation system, the energy saved could be substantial.

Of major importance to the understanding of a regional plan would be the definition of "excess and surplus" waters. Because there are local interests within Texas and within eastern Oklahoma that are concerned about the transfer of water from the basins of origin, it can well be understood that the people of

Arkansas and Louisiana will have the same concern. It is intended in the Oklahome Water Plan that the forecasted water needs within the basin of origin will be satisfied prior to any allocation and diversion of waters from a given river basin.

There are problems even within the states themselves where interbasin transfer of water can be controversial, but there is no doubt that in many instances interbasin transfer of water is needed to accomplish the maximum economic growth of the states within the region. An example of this is in southwest Arkansas where the quality of water in the Red River is such that the water cannot be utilized to the extent as that of Little River. It is apparent that the City of Texarkana should have access to the water in the Little River basin in order to avoid the quality problems of using Red River water. The same situation exists in central Arkansas in the Grand Prairie region where the aquifers are being depleted due to excessive pumpage. Much of these agricultural uses are in the Arkansas River basin but there is water available from the White River basin that could be distributed into the irrigation systems, serving both the White River basin and the Arkansas River basins with high quality water.

Concept of Transporting Water. One of the most important concepts that must be understood about the transfer of water westward is that the water would only be moved in periods of normal-to-high flows when the other priorities in the river basins are met. These priorities would be municipal use, industrial use, agricultural use, minimum flows to support navigation and minimum flows to maintain satisfactory water quality. It would only be during periods when the higher priority items had been met and the flows in the rivers are substantial that pumpage to the canal systems diverting water would be allowed. There is no conflict of interest between the transport of these excess and surplus waters through the conveyance system and the normal utilization of water throughout the normal seasons of water useage that would have the highest priority.

It is difficult to separate the provision of reservoir capacity designed for extreme drought conditions and the taking of water during normal-to-high flow periods because in the past most engineering works have been constructed based on the most severe drought cycles on record. Care must be taken to delineate a subnormal year and a normal year which will support the pumping programs.

There is another conventional operating practice which needs to be understood in the diversion of water from Arkansas to Texas. Under normal circumstances, the rivers in Arkansas are highly regulated as to normal and moderate flows. The regulation of the White, Arkansas, Ouachita and Little rivers in Arkansas actually prolongs the average flows in the rivers by storing water in the main reservoirs for power generation. These waters are retained for release when electricity loads are at their peak and when the rivers would normally have low flows. The release of water through the turbine generators provides moderate-to-heavy flows year round in the White and Ouachita rivers in particular. The location of the diversion points well downstream means that in the various river basins most of the utilization of the water for power generation that will take place has already been accomplished.

In the instance of the White River where the proposed diversion site is south of DeValls Bluff, there are no major users on the White, other than the nominal uses for irrigation, navigation and low-flow augmentation purposes; therefore, the diversion of water from this site would take place after most of the normal demands from the river have been satisfied. With the possible exception of a few industrial applications, navigation and low-flow augmentation south of Pine Bluff, most of the utilization of Arkansas River waters has taken place prior to the diversion point south of Little Rock and south of I-40. Again, in the case of the Ouachita River basin where the diversion point is below the confluence of the Caddo and Ouachita rivers, most of the utilization has been accomplished except for navigation, low-flow augmentation and the industrial and municipal use of water in south Arkansas. The diversion would be accomplished on the Little River below the three dams in Oklahoma and the three dams in Arkansas, with the possible exception of Millwood Reservoir as a transfer facility for the pumpage program. In this event, it is contemplated that the flow of pumped water would be near the dam area of the lake which is well downstream of the pumping stations that supply industry and municipalities.

Environmental Impact. The routing of conveyance systems in Arkansas has been selected in the lowest lying ridges between the river basins and by transferring through these ridge areas, the lowest pumping cost can be accomplished in concert with the least environmental impact. The environmental impact can be minimized with proper reclamation procedures.

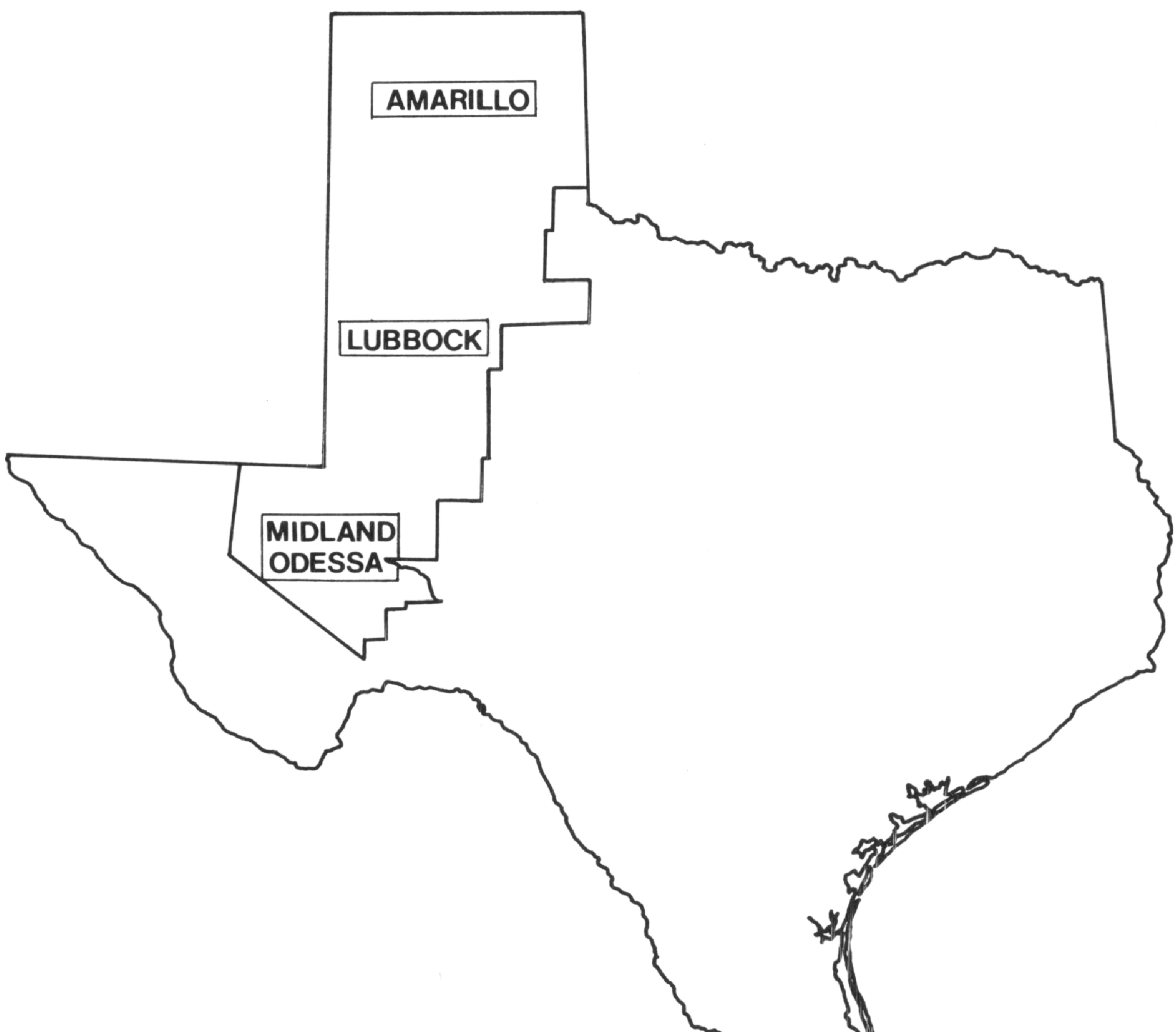
Summarization. While the scope of this study cannot answer all of the technical, economic and political considerations involved in interbasin and interstate transfer of waters originating in Arkansas, it is hoped that it can provide some concept that can be enlarged upon and developed for implementation to solve the water problems of western Texas and Oklahoma.

## Texas High Plains Water Problem

The principal irrigated area in west Texas and the Texas High Plains consists of 56 contiguous counties occupying the Texas Panhandle and extending southward as far as Pecos County. Total land area includes about 38,260,000 acres or approximately 22 percent of the total land area in the State. Elevation, soil texture and rainfall vary greatly from the southern to northern portions of the High Plains. Elevation ranges from 2,500 feet in the south to 4,000 feet in the north. Soils are more coarsely textured toward the south becoming finer in the north. On the average, annual rainfall in the High Plains totals 21 inches; however, some southern counties receive as little as eight inches per year.

High Plains Agriculture Industry. Agriculture is a major industry in the High Plains. The flat land is especially well suited to today's large scale, mechanized farming. With adequate water, the land is highly productive. During the past three decades the High Plains and west Texas have made a substantial contribution to the nation's food and fiber supplies. With the United States' increasing demand for agricultural products to help balance the world food shortages and offset the trade deficits resulting from energy depletion in the nation, the role of the High Plains in meeting the agricultural needs is critical and adequate supplies of water for irrigation are needed.

The Texas High Plains region represents a substantial portion of the U.S. agricultural market in several areas. The High Plains area contributed over 30 percent of the nation's production of grain sorghum in 1971; this was about two-thirds of the total production of the State. In the last eight years, the High Plains has produced 25 percent of the nation's grain sorghum. During the 1968 through 1975 period, the High Plains averaged 18 percent of the nation's output of cotton. Wheat production in this area accounted for 4 percent of the U.S. wheat production. In addition to the value of wheat as a food crop, it is also




TEXAS HIGH PLAINS REGION

EXHIBIT 5

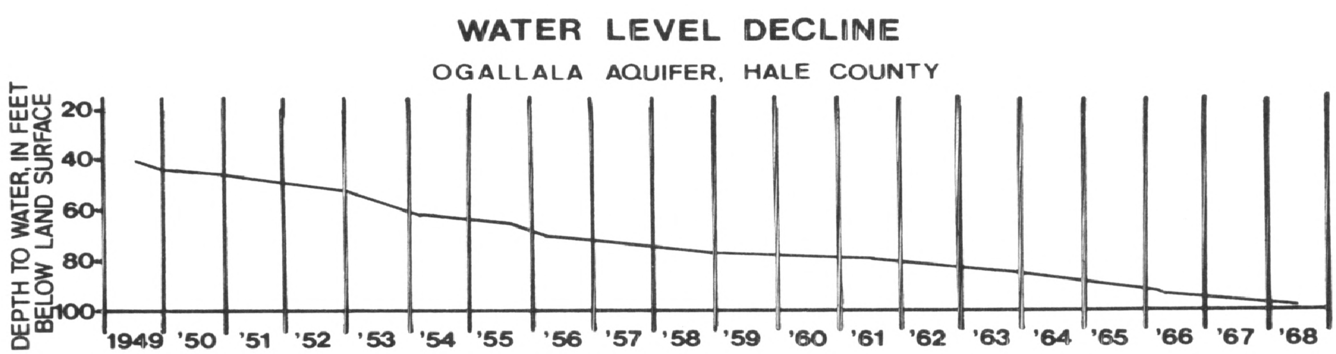
available for winter grazing. Corn has become one of the leading crops grown in the area in recent years. The 1975 crop accounted for 85 percent of the State's corn production.

Due to the abundance of feed grains grown in the area, the region has perhaps the heaviest concentration of fed cattle in the nation. From 1967 to 1973, the number of cattle fed in feedlots in Texas increased from 1 million to 3.8 million. In 1975, 77 percent of the fed cattle going to market in the State were produced in the High Plains. Exports ranged from 10 to 45 percent, with an average of 15 percent. Cattle production is projected to reach 12 million head by 1980, provided there is enough locally grown irrigated sorghum available. This would be enough beef to feed 40 million people.

Impact of Irrigation on Agriculture. This area of Texas accounts for over 65 percent of the irrigated acreage in the State. There are presently some 5.5 million acres of irrigated land in the region. This average represents 60 percent of the cropland in the region; however 82 percent of the High Plains agriculture was produced on this irrigated land in 1970. The growth of irrigated acreage has been steady, from less than one-half million acres in 1944 to the present figure. The potential in this region would be practically unlimited if there were an adequate supply of water for irrigation. There are over 13 million acres suitable for irrigation, more than double the current productive amount. Some formerly irrigated areas have been returned to dryland farming or lie idle because of the exhaustion of ground water supplies. Irrigated lands are projected to peak in 1985. After 1985, a steady reduction in ground water supplies is expected to reduce irrigated acreage. By 1985 if a supplemental surface supply of water has not reached the High Plains, the region will have begun an area-wide retrogression to dryland farming. The economic consequences, not only on a state level but on a national scale, will be severe.

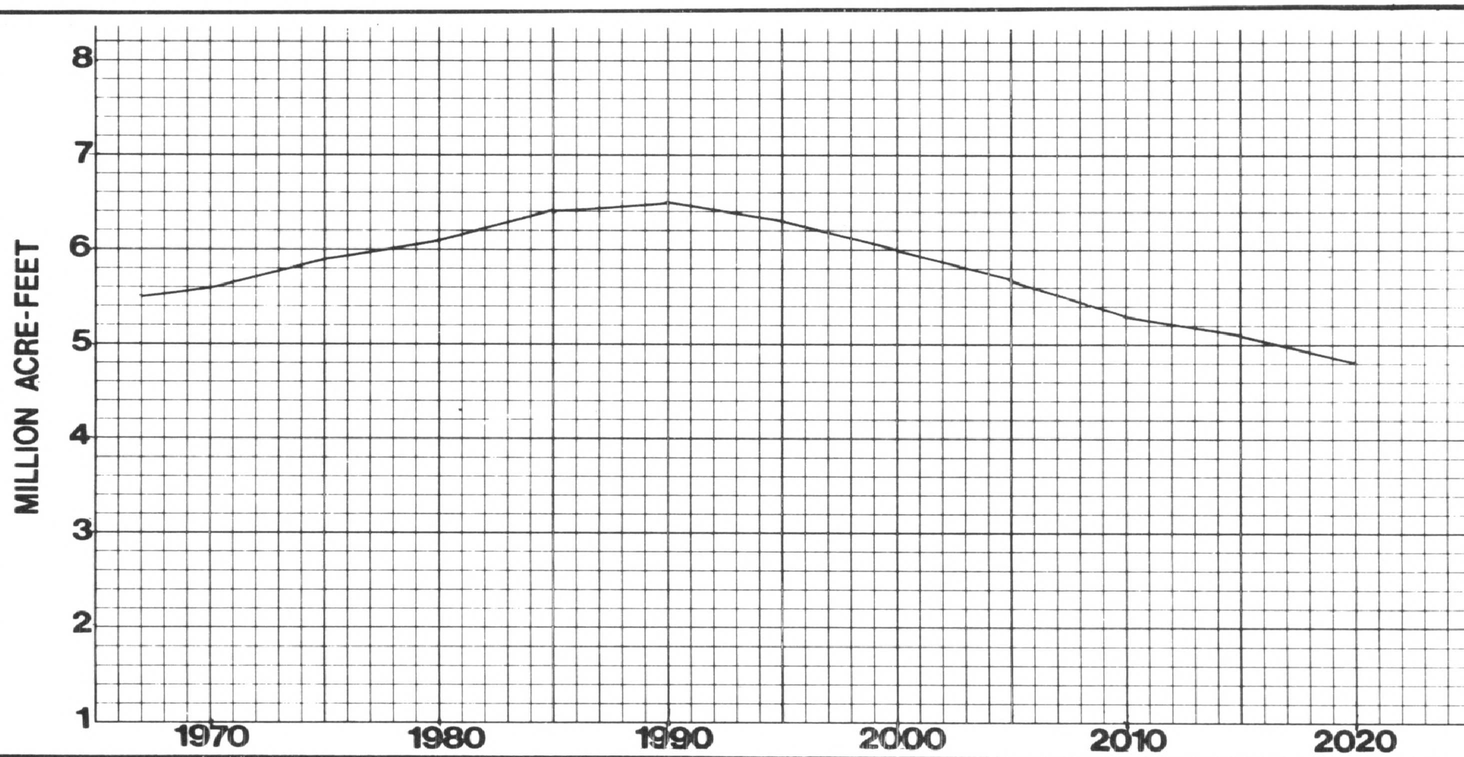
| TEXAS HIGH PLAINS vs. UNITED STATES CROP PRODUCTION | | | | | |
|---|---|---|---|---|---|
| CROP | UNIT | HIGH PLAINS | UNITED STATES | % TEXAS | % UNITED STATES |
| Cotton | Bale | 2,274,385 | 13,702,000 | 54 | 19 |
| Wheat | Bushel | 29,309,800 | 1,544,800,000 | 66 | 2 |
| Grain Sorghum | Bushel | 183,636,900 | 822,000,000 | 57 | 25 |
| Corn | Bushel | 26,915,400 | 5,573,320,000 | 68 | 1 |

EXHIBIT 6




TEXAS HIGH PLAINS OGALLALA AQUIFER

EXHIBIT 7




GROUND WATER AVAILABLE FOR IRRIGATION
TEXAS HIGH PLAINS

EXHIBIT 8

High Plains Petroleum Industry. Petroleum also plays a major part in the industry of the region. Texas has approximately 42 percent of the proved natural gas reserves of this country and 47 percent of the total liquid hydrocarbon reserves. Much of these reserves are in the High Plains area and to supply the demand for petroleum secondary recovery techniques by the use of water injection will be required. It is estimated that over one-half of all oil produced in Texas by 1980 will result from secondary recovery and 95 percent to be recovered by secondary techniques by 2020. Secondary recovery techniques by 2020 will require approximately 177 thousand acre-feet of water per year, which is about 3 percent of the six million acre-feet which possibly could be imported from Arkansas.

Summary of Water Problem. The Texas High Plains must have adequate water to support its economy and sustain production for national markets. The water available for all uses is being depleted at a much faster rate than it can be replenished. Water must be transported to the west Texas-High Plains region or the economic way of life will revert to that of dryland farming. This could be very detrimental not only to the local people of the High Plains but also to the nation and the free world.

## Excess and Surplus Surface Water to the Needs of Arkansas: 2020

Definition of Excess and Surplus Water. Defining "excess and surplus" water will, in the end, be a legal definition. For the purposes of this study, a modification has been developed to the definition found in the Oklahoma Comprehensive Water Plan of 1975 which stated "that water within the area of origin which is greater than the potential water development needed to meet the projected in-basin requirements for the next 50 years."

The time period for this study terminates at 2020; therefore, only 44 years are taken into consideration. This study deals only with surface water. A slight modification to the Oklahoma definition would result in stating that excess and surplus surface water is that surface water within the area of origin which is greater than the potential surface water development needed to meet the projected in-basin surface requirements to the year 2020.

All area surface water needs will be met before any surface water can be classified as excess and surplus surface water. The increased surface water needs of Arkansas to the year 2020 have been estimated to be 5.5 million acre-feet per year which, when deducted from 76.5 million acre-feet per year, which is the average outflow of surface water from Arkansas for the period of record through 1975, leaves approximately 71 million acre-feet per year which can be defined as excess and surplus waters in the year 2020 (see page 20, Exhibit 9).

Surface Water Needs: 2020. These increased surface needs are based on human needs and do not address obligations to bordering states based on compacts or other written legal documents. If, for the purpose of discussion, the State of Arkansas was required to allow at least 40 percent of all gauged surface water to flow over state lines (which is improbable), then the projected 2020 excess and surplus surface water would be approximately 43 million acre-feet per year. To give the reader some grasp for the magnitudes of water involved, all the flood

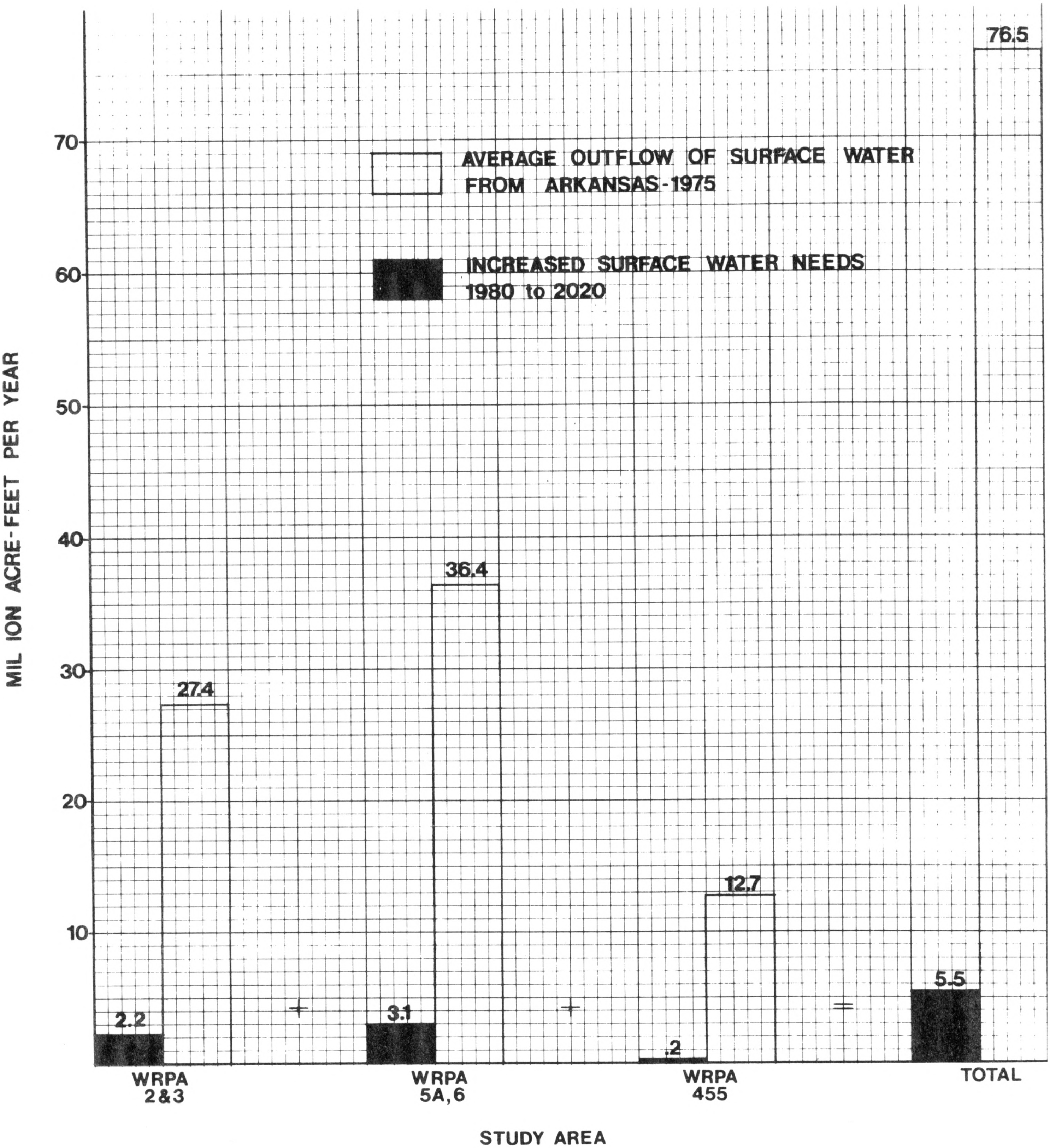

AVERAGE OUTFLOW OF SURFACE WATER FROM ARKANSAS-1975
INCREASED SURFACE WATER NEEDS 1980 to 2020
MIL ION ACRE-FEET PER YEAR
70
60
50
40
30
20
10
2.2
27.4
3.1
36.4
.2
12.7
5.5
76.5
WRPA 2&3
WRPA 5A,6
WRPA 455
TOTAL
STUDY AREA

EXHIBIT 9

pool storage of the Corps of Engineer dams in Arkansas amounts to 22.6 million acre-feet of water. To illustrate further, if the increased surface water needs were in error by a factor of two, the excess and surplus surface waters would be approximately 65 million acre-feet per year. Arkansas does have an excess and surplus of surface waters that flow out of the state every year and amount to at least 70 million acre-feet per year on the average.

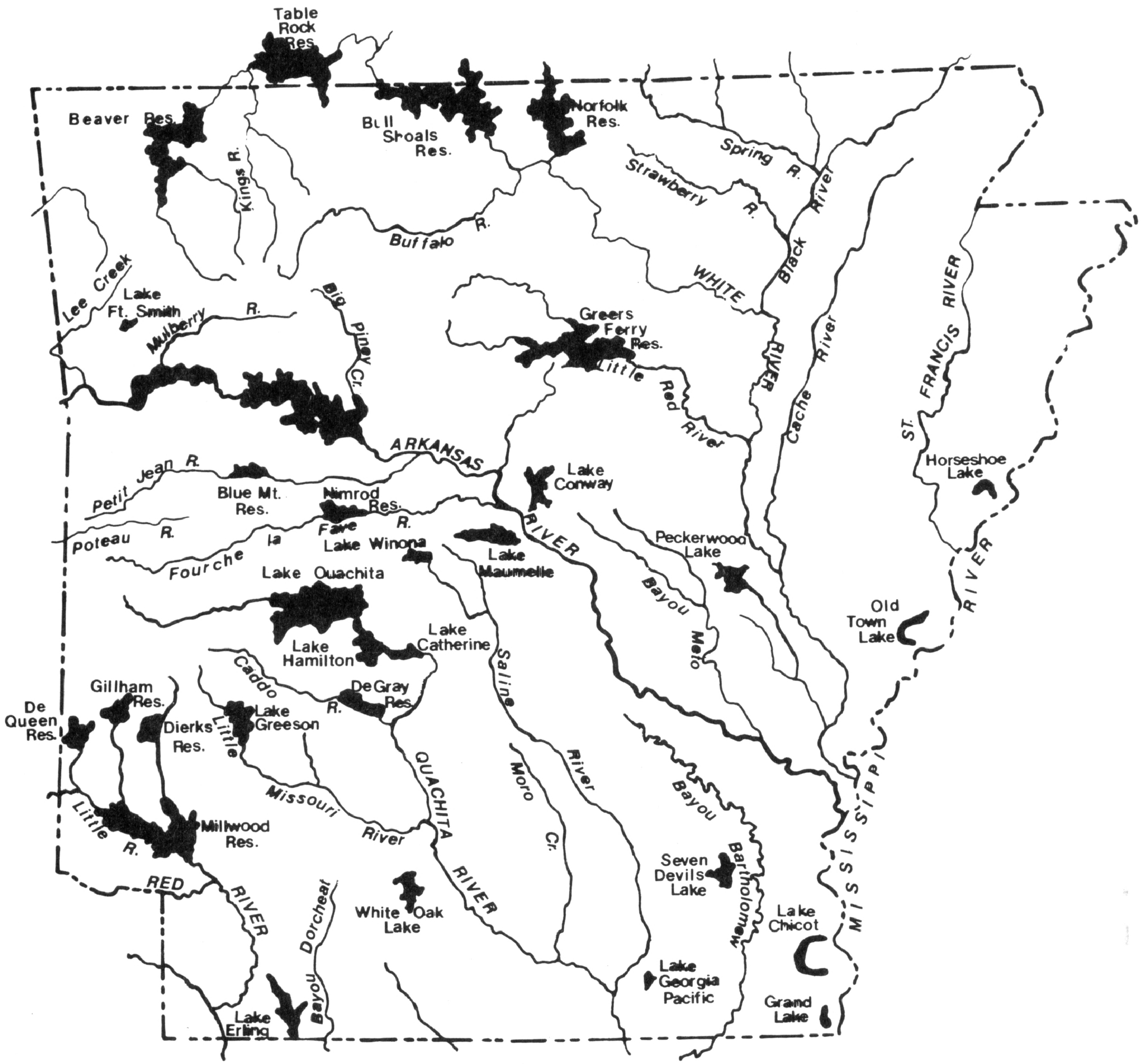
## Availability of Arkansas' River Waters for Diversion: 2020

Many factors can affect the determination of the availability of Arkansas' river waters for diversion to Texas. Some of these factors can be quantified with current available data while other factors require detailed research and engineering judgement. Consumptive, navigation, water quality and legal requirements can be identified while aquifer recharge, scouring, upstream and ecological balance requirements are much more difficult to determine and require lengthy study.

Consumptive Surface Water Requirements. The consumptive surface water requirements have been quantified by way of predicting the increased surface needs for the study area to the year 2020 (see Appendix C). This, in turn, was used to predict the average monthly flows of four selected streams in Arkansas for the year 2020 that are within three different water basins (see Appendix E). These streams were selected to allow an even distribution of water to be withdrawn throughout the selected study area.

Navigation Requirements. The navigation requirements are determined by the U.S. Corps of Engineers and future requirements for each river have been identified (see Appendix E).

Water Quality Requirements. Water quality requirements of a stream need to be defined before these requirements can be quanitified. By the year 2020, water




## ARKANSAS
## Major Lakes, Rivers & Streams

EXHIBIT 10

quality with reference to biological oxygen demand should not be a serious problem as there are government regulations and directives to accomplish this by 1983. The definition of water quality streamflow requirements that might best fit Arkansas' situation is that flow which allows a particular river or stream to keep itself at an acceptable pollution level during statistical low flows. Arkansas is currently using a statistical period of low flow that is seven continuous days during a ten-year period. This flow is different for every stream and all geographic locations on each stream. Statistical low flows for three of the rivers have been identified (see Appendix E). Little River flow data below Millwood Reservoir has not been developed due to the short period of record. The State of Arkansas has requested the Corps of Engineers to maintain at least 3,400 cfs streamflow in the Arkansas River to accommodate water quality requirements.

Legal Requirements. Arkansas is a member of the Red River Compact Commission and the Arkansas-Oklahoma Compact Commission and is bound to the legal agreements of these Commissions. The future use of surface water within Oklahoma could eventually affect the runoff into Arkansas, although this cannot be determined at this time. The Red River Compact Commission at this writing is attempting to negotiate guaranteed flows from Arkansas into Louisiana. These flows are not of a magnitude that would determine overall water availability, as they are less than the navigation or water quality flows which are considered to have precedence. The other legal requirements and committments of water within Arkansas have been thoroughly discussed in the Arkansas Water Plan of October 1975. Interstate basin transfer of water is not possible under current Arkansas law which would prevent the availability of any water for transfer for any reason unless a change was made.

Aquifer Recharge. Aquifer recharge can affect the flow of a stream. Generally if an aquifer is readily accessible to a stream hydrologically and water is being pumped out of the aquifer at an increasing rate, the stream tends to make up the difference. How much, where and when this happens throughout Arkansas has not been studied thoroughly.

Scouring and Upstream Needs. Scouring and upstream needs can be combined with ecological requirements. These, too, are indeterminate at this time; however, experience has shown that these requirements are most critical at low flows and usually are similar in quantity to water quality needs.

Assumptions for Diversion. In making a judgement as to the amount of water that is available for diversion, it was assumed that at least 60 percent of the year 2020 predicted mean monthly flow or the minimum navigation or minimum water quality flows would always remain, depending on which was greater. A percentage of the difference between the predicted mean monthly flow and the 60 percent amount was allocated for diversion. The 60 percent amount of streamflow is assumed to safely consider the aforementioned indeterminant factors. For example, the predicted mean monthly flow for January 2020 for the White River is 29,300 cfs and the amount available for diversion is 11,700 cfs (29,300 X .4), the amount needed to divert to Texas during January computes to be 3,300 cfs. The minimum navigation requirement was assumed to be 10,000 cfs; therefore, no water would be diverted during the months of August through November inclusive. These are modelized predictions and will not necessarily correlate to actual conditions, but should over a long period of time average out to approximate the predictions. The predicted water available for stream diversion in 2020 is tabulated on page 26. The predicted total surface water available for diversion based on the previous assumption amounts to 21.1 million acre-feet per year from Arkansas.

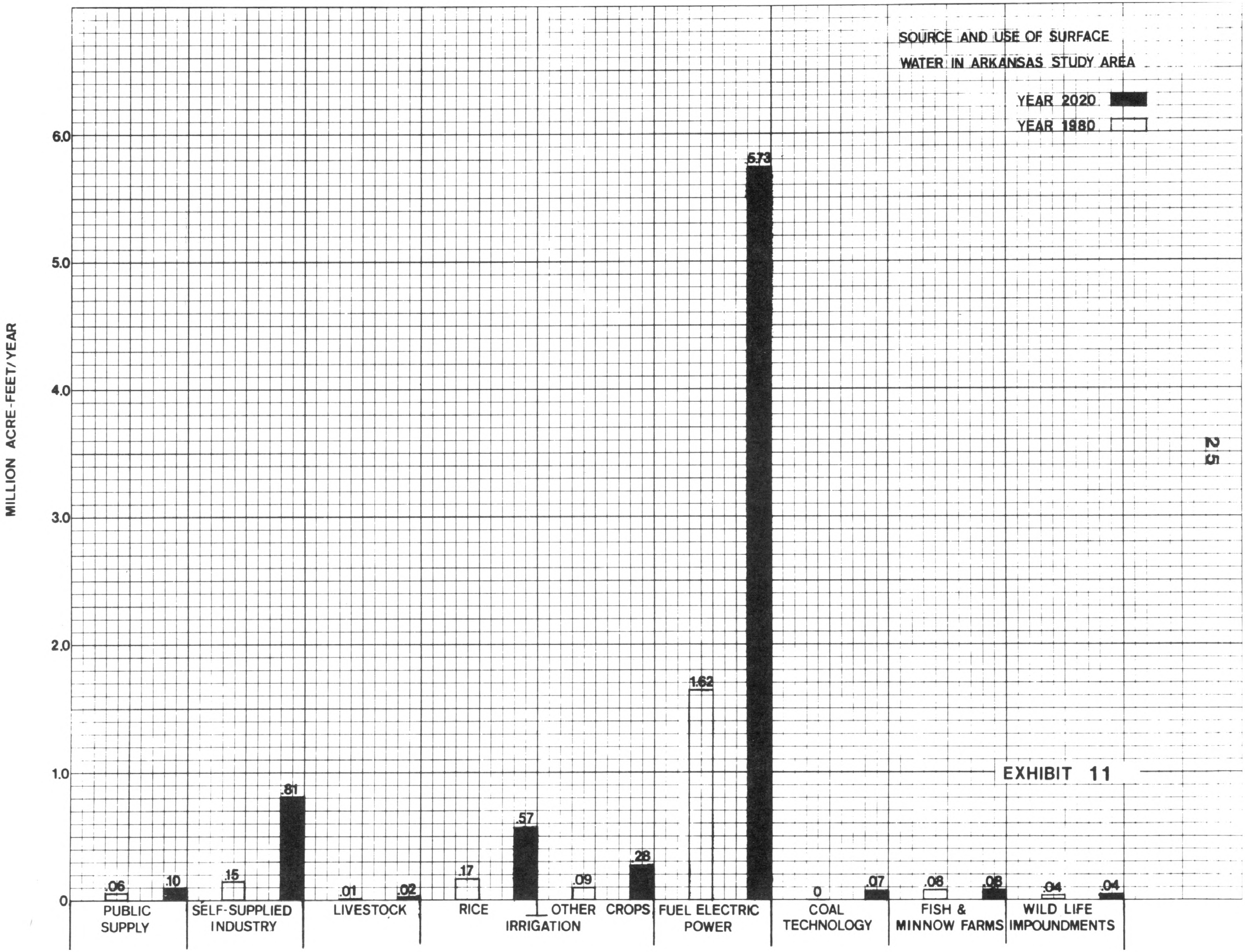

SOURCE AND USE OF SURFACE
WATER IN ARKANSAS STUDY AREA
YEAR 2020
YEAR 1980
MILLION ACRE-FEET/YEAR
6.0
5.0
4.0
3.0
2.0
1.0
0
.06
.10
.15
.81
.01
.02
.17
.57
.09
.28
1.62
5.73
0
.07
.08
.08
.04
.04
PUBLIC SUPPLY
SELF-SUPPLIED INDUSTRY
LIVESTOCK
RICE
OTHER CROPS
IRRIGATION
FUEL ELECTRIC POWER
COAL TECHNOLOGY
FISH & MINNOW FARMS
WILD LIFE IMPOUNDMENTS

EXHIBIT 11

PREDICTED WATER AVAILABLE FOR DIVERSION AND
PROPOSED WATER ALLOCATIONS FOR DIVERSION TO TEXAS: 2020

(000 cfs)

| | White River | | Arkansas River | | Ouachita River | | Little River | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Available | Allocable | Available | Allocable | Available | Allocable | Available | Allocable | Available | Allocable |
| JAN | 11.7 | 3.3 | 21.5 | 5.5 | 5.2 | 1.9 | 2.6 | 1.1 | 41.0 | 11.8 |
| FEB | 14.0 | 4.0 | 19.8 | 5.1 | 5.2 | 1.9 | 4.0 | 1.6 | 43.0 | 12.6 |
| MAR | 15.3 | 4.4 | 20.8 | 5.3 | 5.0 | 1.9 | 4.8 | 2.0 | 45.9 | 13.6 |
| APR | 16.4 | 4.7 | 18.9 | 4.9 | 5.2 | 1.9 | 3.8 | 1.6 | 44.3 | 13.1 |
| MAY | 17.7 | 5.0 | 20.4 | 5.2 | 5.5 | 2.1 | 5.7 | 2.4 | 49.3 | 14.7 |
| JUN | 10.4 | 3.0 | 14.6 | 3.8 | 1.7 | .6 | 3.0 | 1.2 | 29.7 | 8.6 |
| JUL | 7.4 | 2.1 | 8.3 | 2.1 | 0 | 0 | 0 | 0 | 15.7 | 4.2 |
| AUG | 0 | 0 | 5.0 | 1.3 | 0 | 0 | 0 | 0 | 5.0 | 1.3 |
| SEP | 0 | 0 | 5.4 | 1.4 | 0 | 0 | 0 | 0 | 5.4 | 1.4 |
| OCT | 0 | 0 | 9.3 | 2.4 | 0 | 0 | 0 | 0 | 9.3 | 2.4 |
| NOV | 0 | 0 | 23.6 | 6.1 | 1.6 | .6 | 2.0 | .8 | 27.2 | 7.5 |
| DEC | 8.3 | 2.4 | 19.3 | 5.0 | 2.7 | 1.1 | 3.2 | 1.3 | 33.5 | 9.8 |
| Yearly Averages (to nearest 100) | 8.4 | 2.4 | 15.6 | 4.0 | 2.7 | 1.0 | 2.4 | 1.0 | 29.1[1] | 8.4[2] |

[1]The total yearly average flow of 29,100 cfs for predicted water available for diversion equals approximately 21.1 million acre-feet per year.

[2]The total yearly average flow of 8,400 cfs for water allocations for diversion to Texas equals approximately 6 million acre-feet per year.

EXHIBIT 12

## Use of Arkansas' River Water for Irrigation

The river waters of concern in this study are the White, Arkansas, Ouachita and Little rivers. By inspecting the historical records, it can be determined that the waters of the White at DeValls Bluff, the Ouachita at Camden and the Little River at Millwood Reservoir have very low salinity and alkalinity hazards regarding use of the water for irrigation. Therefore, a rigorous justification of these waters is not considered necessary. The Arkansas River has had a history of elevated salinity and has not been considered adequate for irrigation purposes in the past. There has been a noticeable improvement of the water quality of the Arkansas River in recent years since completion of the McClellan-Kerr River Navigation System; therefore, the suitability of the Arkansas River water for irrigation warrants further discussion.

Arkansas River. By inspecting plots of 1970 and 1973 selected water quality data (see page 28), there does not seem to be a direct correlation between streamflows and dissolved solids in the Arkansas River near Little Rock. There are times when the salinity hazards are medium to high when streamflows are very high. There are also times when the salinity is not as hazardous when the flows are relatively low (less than 20,000 cfs). An explanation of these phenomena could be the runoff characteristics of the salt bed areas in the upper parts of the Arkansas River. It can be concluded that flows about 20,000 cfs will give a greater probability of acceptable irrigation water than flows of below 20,000 cfs. It should be noted in the 1970 to 1973 data that the alkali hazard was always considered to be low. However, the salinity hazard was high twice during 1970 and once in 1973 (see page 29). A detailed study of the Arkansas River water for irrigation was accomplished by L. H. Hileman of the University of Arkansas for the Arkansas Department of Commerce, Division of Soil and Water Resources in December 1974, wherein Mr. Hileman concluded that "Arkansas River

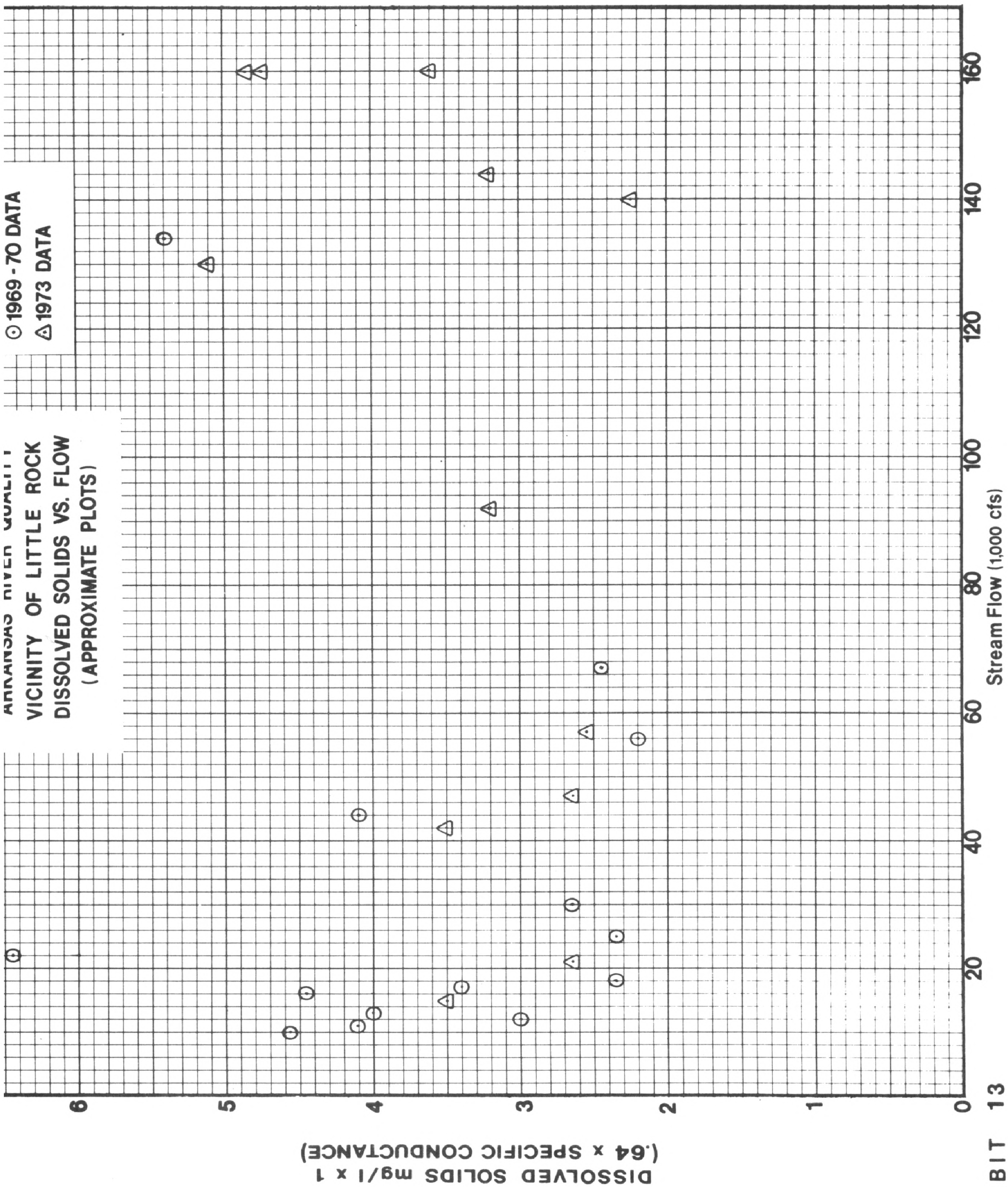

ARKANSAS RIVER QUALITY
VICINITY OF LITTLE ROCK
DISSOLVED SOLIDS VS. FLOW
(APPROXIMATE PLOTS)
⊙ 1969 - 70 DATA
△ 1973 DATA
0
20
40
60
80
100
120
140
160
Stream Flow (1,000 cfs)
0
1
2
3
4
5
6
DISSOLVED SOLIDS mg/l x 1
(.64 x SPECIFIC CONDUCTANCE)

EXHIBIT 13

ARKANSAS RIVER QUALITY FOR IRRIGATION
VICINITY OF LITTLE ROCK

| DATE | APPROXIMATE FLOW (000 cfs) | SODIUM ABSORPTION RATIO | SPECIFIC CONDUCTANCE MICROMHOS/CM | 64% OF SPECIFIC CONDUCTANCE* | IRRIGATION WATER HAZARD | |
|---|---|---|---|---|---|---|
| | | | | | ALKALI | SALINITY |
| 10-10-69 | 22.0 | 4.1 | 1,010 | 646 | low | high |
| 10-31-69 | 18.0 | 1.3 | 363 | 232 | low | medium |
| 11-24-69 | 16.7 | 2.3 | 533 | 341 | low | medium |
| 1- 5-70 | 30.1 | 1.9 | 417 | 267 | low | medium |
| 2-24-70 | 12.5 | 2.1 | 470 | 301 | low | medium |
| 3-20-70 | 56.9 | 2.1 | 340 | 218 | low | medium |
| 4-20-70 | 135.0 | 3.7 | 846 | 541 | low | high |
| 5-28-70 | 24.9 | 1.0 | 364 | 233 | low | medium |
| 6-15-70 | 67.4 | 1.3 | 383 | 245 | low | medium |
| 6-29-70 | 44.5 | 2.4 | 638 | 408 | low | medium |
| 7-13-70 | 11.2 | 2.3 | 639 | 409 | low | medium |
| 7-29-70 | 12.8 | 2.3 | 624 | 399 | low | medium |
| 8- 5-70 | 16.3 | 2.8 | 698 | 447 | low | medium |
| 9- 9-70 | 10.0 | 2.9 | 713 | 456 | low | medium |
| 1-24-73 | 144.0 | 1.2 | 500 | 320 | low | medium |
| 2-20-73 | 57.5 | 1.1 | 400 | 256 | low | medium |
| 3-20-73 | 170.0 | 1.2 | 420 | 267 | low | medium |
| 4-17-73 | 192.0 | 1.3 | 600 | 384 | low | medium |
| 5-22-73 | 169.0 | 1.3 | 600 | 384 | low | medium |
| 6-15-73 | 91.7 | 3.6 | 500 | 320 | low | medium |
| 7-20-73 | 21.1 | 1.1 | 420 | 267 | low | medium |
| 8-22-73 | 14.9 | 1.7 | 550 | 352 | low | medium |
| 10- 1-73 | 42.5 | 2.0 | 550 | 352 | low | medium |
| 10-15-73 | 130.0 | 3.2 | 800 | 512 | low | high |
| 11-14-73 | 46.7 | 1.9 | 420 | 267 | low | medium |
| 12-13-73 | 140.0 | 1.2 | 380 | 243 | low | medium |

*64% of specific conductance approximates the dissolved solids (Mg/1)

SOURCE: 1969-1970 Data -- USGS (Lock and Dam No. 6); 1973 Data -- Irrigation Using Arkansas River Water, p. 14; Alkali and Salinity Hazards -- USDA Circular 969.

EXHIBIT 14

## CLASSIFICATION OF IRRIGATION WATERS*

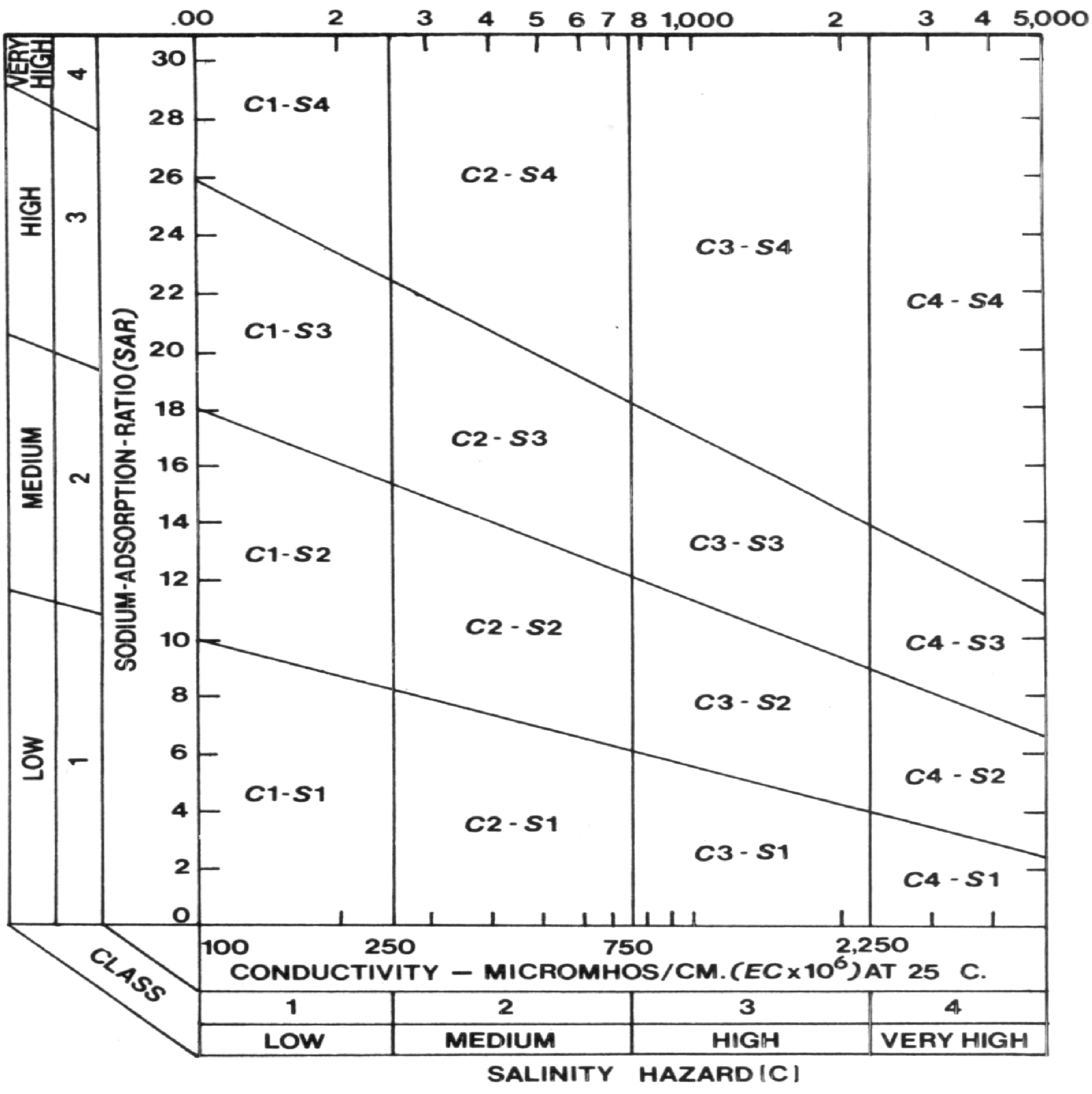



EXHIBIT 15

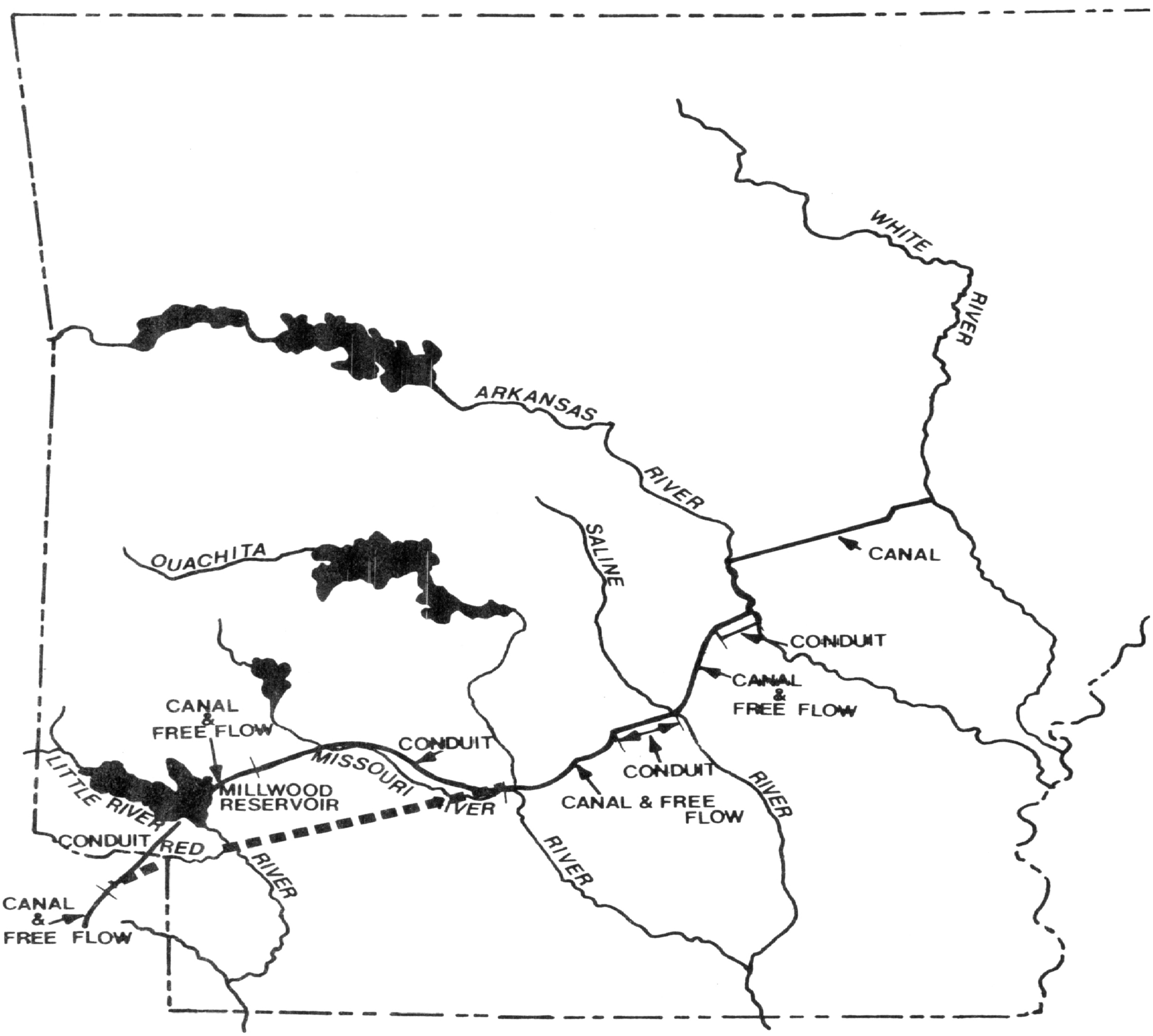
* USDA CIRCULAR 969 NOVEMBER 1955

water can be classed as 'fair' in overall condition for irrigation purposes." Inspection of the historical records depicting chloride concentration also shows a steady improvement and there can be times when occasional high chloride levels could create a hazard for irrigation purposes. The Arkansas River water can be used for irrigation as long as monitoring is accomplished in a scientific manner to minimize the possibility of withdrawing water that might be considered hazardous.

## The Export Plan

The exporting of water from Arkansas to Texas would require the construction of a series of canals and pressurized conduits to transport water from the White River below DeValls Bluff southwestward across Arkansas picking up additional waters from the Arkansas River, Ouachita River and Millwood Reservoir with final delivery to Wright-Patman Reservoir west of Texarkana.

Export Requirements. The yearly export requirements would be approximately six million acre-feet of water. Approximately 28 percent of this amount would come from the White River, 48 percent from the Arkansas River, 12 percent from the Ouachita River and 12 percent from Millwood Reservoir. Water would not be pumped continuously from each system as the reasoning behind this export plan is to capture excess and surplus surface water during high flows. From a historical point of view, water would not be pumped from the White River, Ouachita River or Millwood Reservoir during four summer months out of each year. The Arkansas River could be drawn from throughout the year but at much lower rates during the summer months (see Appendix E). Most water export plans are based on steady flow rates which allow for economies in pump and conveyance design. An export system based on maximum flows that occur approximately 30 percent of the time will be much more expensive, the difference being the cost to transport excess and surplus waters during high flows.




CONVEYANCE ROUTE

EXHIBIT 16

CONVEYANCE SYSTEM PROFILE

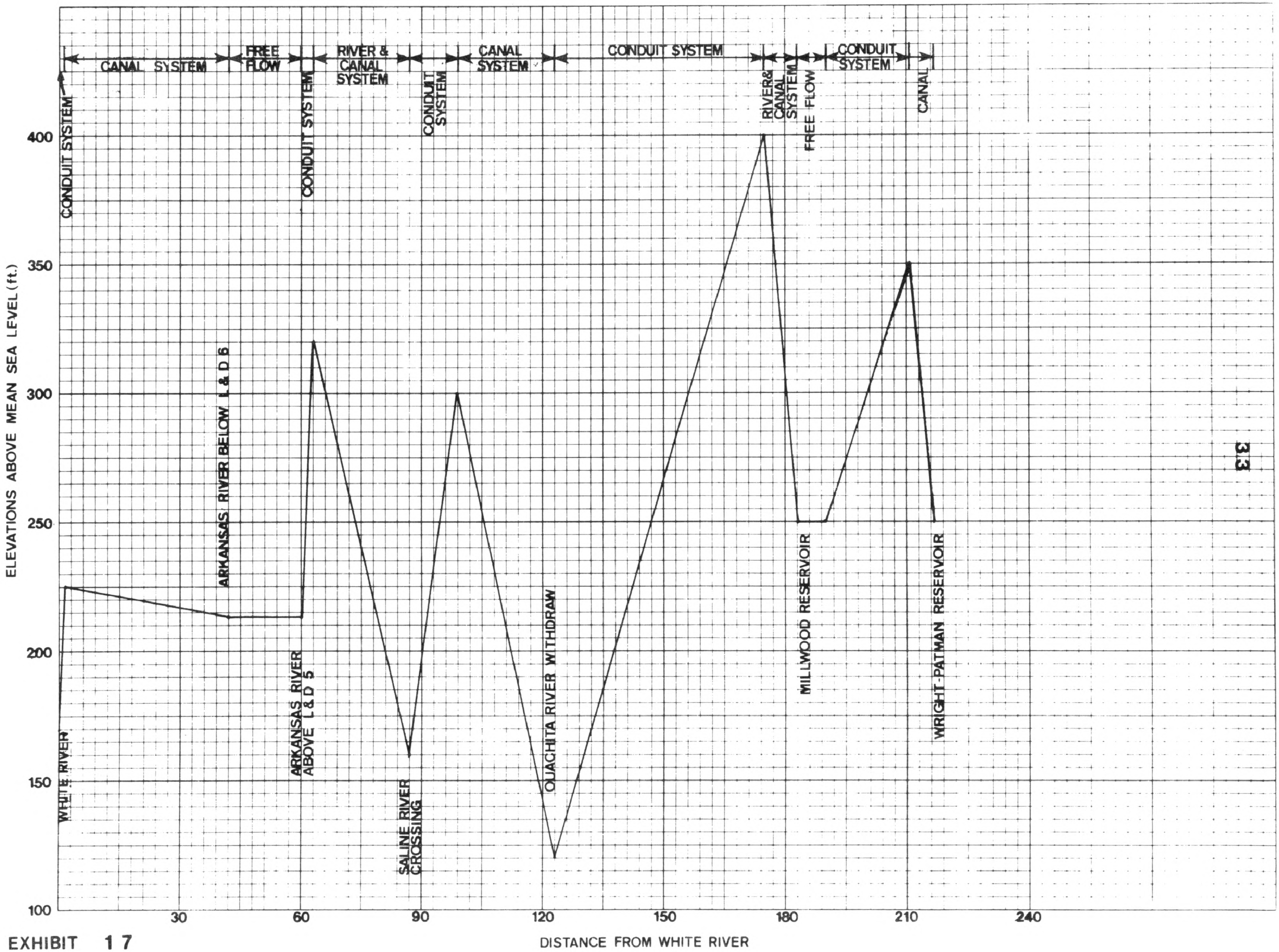



EXHIBIT 17

<u>The Route Location</u>. The conveyance system route is depicted on page 32. The proposed route would originate south of DeValls Bluff on the White River. Water would be pumped into a canal system for transport to the Arkansas River below Lock and Dam No. 6, southwest of Keo. The White River waters would be mixed with the Arkansas River waters, with the pool between Lock and Dam Nos. 5 and 6 to act as a storage for further pumping. Water would then be pumped from the Arkansas River just above Lock and Dam No. 5 on a westerly direction then dumped into Simpson Creek or a canal or combination thereof. The system then follows Hurricane Creek to the Saline River. The water would then be put into a pressurized system to run in a southwesterly direction approximately three miles south of Carthage then dumped into East Tulip Creek or canal or combination thereof. The system then follows East Tulip Creek to the intersection of Bushy Creek which is approximately 12 miles south of Sparkman. The system then flows westward withdrawing water from the Ouachita River then by a system of pressurized conduits further westward to a point approximately four miles south of Whelen Springs then northwest to a point approximately 13 miles northeast of Prescott. The pressurized system then proceeds westerly and eventually follows the South Fork of Ozan Creek and finally dumps into the Upper Plum Creek area being allowed to gravity flow to Millwood Reservoir. Millwood Reservoir would act as an enroute storage system to pump water by a pressurized system to Wright-Patman Reservoir by a route west of Texarkana and east of the Lone Star Ordnance Depot, allowing the water to gravity flow the final six miles.

For the purpose of this study, the import route is shown to pass through Millwood Rsservoir; however, a more detailed study of the effects on water quality in Millwood Reservoir and other environmental considerations may show a feasible alternate route below Millwood. The route from White River to near Whelen Springs would be the same as previously described. The alternate route from near Whelen Springs would follow Terre Rouge Creek and Pate Creek to a point near Hope, then parallel the railroad track to a point near McNab. The route would then proceed to Little River, then west and cross the Red River into Texas at a point near Ogden, Arkansas. The alternate route is shown as a dashed line on Exhibit 16, page 32.

Physical Description of Route. The Arkansas portion of the conveyance route crosses two large physiographic regions--Mississippi Alluvial Plain and West Gulf Coastal Plain.

The Mississippi Alluvial Plan is generally flat with elevations ranging from 500 to 100 feet, decreasing southward. The West Gulf Coastal Plain elevations vary from 500 to 100 feet above sea level with gently rolling hills.

Recent alluvium and terrace deposits provide the surface materials in the Mississippi Alluvial Plain and along the rivers and streams of the West Gulf Coastal Plain. The recent alluvium deposits are the results of floods and contain various water-washed materials, primarily silt. The terrace deposits are generally older. In the West Gulf Coastal Plain, the surface materials are poorly consolidated sand and clay with scattered deposits of lignite, quartzite and white limestone. Toward the southwestern portion of the State, there are scattered formations containing gypsum, lignite and clay.

Trees are the major natural vegetation in the state, occupying all but a few areas which are in natural prairies. The conveyance route originates in the natural prairie and traverses southwestward through a mixed hardwood forest which becomes more heavily concentrated with pine in the southern areas.

There are three major soils found along the route. Eastern Prairie Soils of the Grand Prairie have compacted clay subsoils with silt loam cultivated in rice, cotton, soybeans and pasture. Bottomland and Terrace Soils are found along all major streams but especially in the Red, Ouachita, Saline, Arkansas and Lower White river valleys. The soil varies from coarse to fine in texture and thus permeability varies from high to low. Chief agricultural uses are for cotton, rice, soybeans and pasture. The forested Coastal Plain Soils cover the largest portion of the route. The subsoils are sandy or silty clay loams with reddish, yellowish or brownish soils of sandy loam with some silt or clay. Forest harvestry is a major industry. Agricultural uses also include pasture, truck and field crops.

Construction of System. The construction of such a water conveyance system would be done in phases. The most probable phasing to start at Wright-Patman proceeding backward to the White River. The first phase would be to construct the conveyance system from Millwood to Wright-Patman followed by the system from the Ouachita River to Millwood in phase two. The third phase would be the system from the Arkansas River to the Ouachita River. The fourth phase would be from the White River to the Arkansas River. Phase three and four could be combined; however, a definite committment for phases one through three would be necessary because 48 percent of the water to be committed would come from the Arkansas River. It is very unlikely that the system would be constructed in its entirety under one continuous construction project.

## Benefits to Arkansas

The construction, operation and maintenance of the conveyance system to deliver water to Texas would require the employment of a large labor force, purchase of equipment and supplies, and provide a market for electricity generated in Arkansas. Additionally, the conveyance system could be designed to provide water for municipal, industrial and agricultural needs along the route within Arkansas both now and in the future. Construction of the conveyance route from the White River across the Grand Prairie region could interface with local citizens' plans to provide a system for surface water irrigation. The money obtained from the sale of water to Texas could be used to reduce taxes or at least maintain the low tax level being enjoyed by the citizens of the State.

## Benefits to Texas

The construction of a water transportation system would allow the agricultural economy of west Texas to continue and hopefully grow, thereby forestalling the displacements of people. The construction, operation and maintenance of the conveyance system would require the employment of a large labor force and purchase of equipment and supplies. The conveyance system could also be designed to provide water for all types of needs along the route. The redistribution of surface waters to west Texas would allow better utilization of arid lands that will otherwise be sparsely populated. This would help on a state and national level to relieve concentrations of people along waterways and large bodies of water which is more prevalent as time passes.

## Areas of Concern to Arkansas

Many questions will arise when considering such a project. Even though it can be proven that there is excess and surplus surface waters that could be exported to Texas, it is possible that such an undertaking would not be undertaken for other valid reasons. These social, economic, environmental and other scientific and legal questions must be answered by further detailed study and public discussion.

Environmental Impact. The exporting of water by the use of a cross-country conveyance system would have an impact on the environment of the areas from which surface water is diverted, as well as the area through which the water is transported. The conveyance system can be designed to minimize the degrading of the ecosystems along the route; however, there could be significant local socio-economic impacts on communities and landowners along the conveyance route. Impacts to the natural environment could occur at Millwood Reservoir. A merging of the existing Little River streamflows with the transported waters from the Arkansas River could have impacts on local as well as downstream aquatic and terresteral ecosystems. There would also be some changes in the quality of the water released downstream from Millwood. The conveyance system might interfere with the natural watersheds along the route enough to cause flooding of prime farmlands which could affect the wildlife balance and be an economic burden to landowners unless proper precautions are taken. A project of this nature could require substantial committment of land and alteration to roads, bridges, railroads and existing drainage structures.

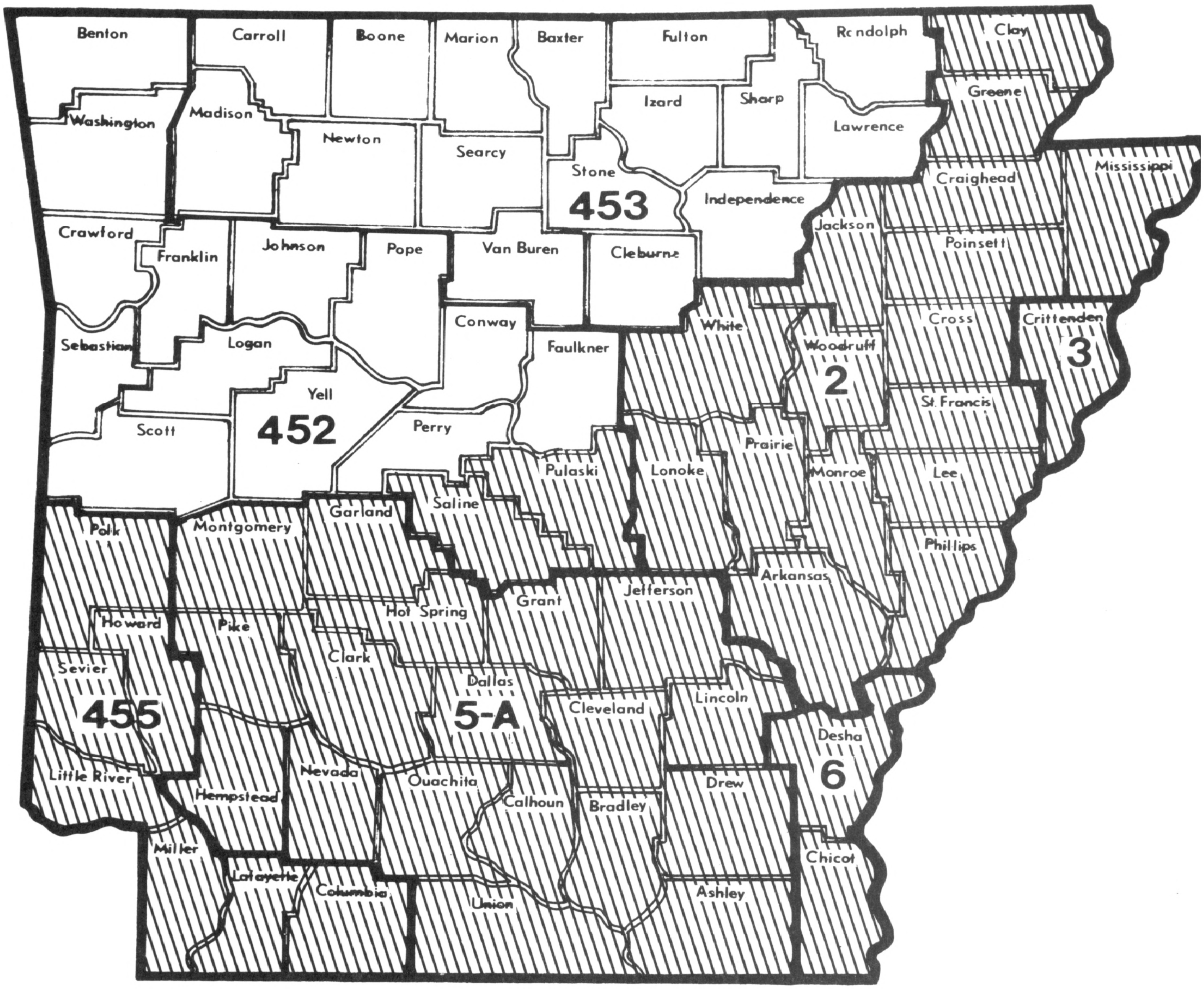
Bordering States' Water Policies. Water policy of bordering states that contribute to the surface water of Arkansas should not be overlooked. Oklahoma is committed by the Arkansas-Oklahoma Compact generally to allow 40 percent of the surface water at the borders to cross into Arkansas. Oklahoma's future surface needs and withdrawals might have an adverse effect on certain Arkansas surface waters. Arkansas has no agreements with Missouri. The Red River Compact Commission could also affect future Arkansas water policy.

The most important concern to the people of Arkansas could be what will be the consequences if Texas cannot transport water to the High Plains.

# Appendix A

## Description and Selection of the Study Area

The area selected within Arkansas for this study was based on the fact that the watershed patterns are generally to the south and east. The Water Resource Planning Areas (WRPA) that border the State to the south and east are 2, 3, 5-A, 6 and 455. The WRPAs were used as a study base because current acceptable data is available in this form and the results of this study can be correlated to other studies. Saline and Pulaski counties were included in the study area because the proposed conveyance route touches these counties and because these particular counties are among the most densely populated counties in Arkansas. WRPA 452 and 453 were excluded in identifying increased surface water needs because the surface water needs in northwestern Arkansas are satisfied before the southeastern surface needs. The physiography of WRPA 452 and 453 is such that it forms a natural border between northwest and southeast Arkansas; hence, the selection of the study area.




ARKANSAS STUDY AREA

EXHIBIT 18

## Appendix B

### Streamflow Data

Water Outflow from Arkansas to the South and East
(excluding Mississippi River)
Historical Monthly Mean Flows
(cfs)

The amount of surface water leaving the borders to the south and the east of Arkansas has been estimated by the Arkansas Divison of Soil and Water Resources to be approximately 80 million acre-feet which does not include the Mississippi River. Using data available from USGS and the computer system (AWRMIS) of the Arkansas Division of Soil and Water Resources, the tabulation of surface water outflow is 76.5 million acre-feet per year. These quantities compare favorably for this level of study. Not all outflow was taken into account since not all surface water leaving the state is gauged. Either value is conservative and represents a historical average.

# Appendix B

STREAM FLOW DATA
Water Outflow from Arkansas to the South and East (excluding Mississippi River)
Historical Monthly Mean Flows
(cfs)

| | | | | | | | | | | | | | | Mean Monthly Flow | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WRPA | STATION NO. | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | cfs | MM acre ft/year |
| 2 | 07047902 | 9,700 | 13,400 | 14,500 | 14,100 | 10,500 | 7,410 | 4,690 | 2,630 | 2,090 | 1,940 | 3,350 | 5,610 | | |
| 2 | 07047950 | 1,619 | 2,546 | 2,105 | 1,745 | 1,636 | 496 | 420 | 386 | 573 | 305 | 541 | 1,136 | | |
| 2 | 07077800 | 35,583 | 43,160 | 46,089 | 50,627 | 48,658 | 33,189 | 18,289 | 12,907 | 10,714 | 10,806 | 14,980 | 21,657 | | |
| 2 | 07264000 | 370 | 570 | 527 | 498 | 521 | 128 | 69 | 72 | 78 | 38 | 201 | 312 | | |
| | Subtotal | 47,272 | 59,676 | 63,221 | 66,970 | 61,315 | 41,223 | 23,468 | 15,995 | 13,455 | 13,089 | 19,072 | 28,715 | 37,789 | 27.36 |
| 5-A | 07363500 | 3,597 | 5,463 | 5,226 | 5,549 | 5,052 | 1,149 | 505 | 295 | 362 | 341 | 1,068 | 1,835 | | |
| 5-A | 07362500 | 236 | 438 | 513 | 517 | 464 | 33 | 29 | 14 | 7 | 10 | 64 | 161 | | |
| 5-A | 07365800 | 209 | 253 | 287 | 404 | 200 | 65 | 50 | 12 | 28 | 27 | 98 | 170 | | |
| 5-A | 07362000 | 12,949 | 12,945 | 12,562 | 13,128 | 13,711 | 4,306 | 2,231 | 1,667 | 2,000 | 1,898 | 3,910 | 6,762 | | |
| 5-A | 07362100 | 491 | 597 | 691 | 650 | 526 | 106 | 79 | 48 | 66 | 52 | 163 | 407 | | |
| | 07263450 | 53,775 | 49,416 | 51,878 | 46,965 | 51,109 | 37,019 | 21,432 | 13,113 | 14,164 | 23,310 | 58,972 | 48,278 | | |
| 6 | 07364150 | 914 | 1,468 | 1,392 | 1,236 | 1,204 | 371 | 169 | 124 | 153 | 167 | 282 | 547 | | |
| | Subtotal | 72,171 | 70,580 | 72,549 | 68,449 | 72,266 | 43,049 | 24,495 | 15,273 | 16,780 | 25,805 | 64,557 | 58,160 | 50,344 | 36.45 |
| 455 | 07341500 | 17,864 | 23,018 | 22,897 | 27,591 | 37,766 | 24,014 | 10,456 | 5,656 | 6,790 | 8,985 | 10,473 | 14,610 | 17,510 | 12.68 |
| | Total | 137,307 | 153,274 | 158,667 | 163,010 | 171,347 | 108,286 | 58,419 | 36,924 | 37,025 | 47,879 | 94,102 | 101,485 | 105,643 | 76.49 |

Source: U.S. Geological Survey and Arkansas Division of Soil and Water Resources

EXHIBIT 19

## Appendix C

## Source and Use of Surface Water in Arkansas Study Areas

The surface water needs for Arkansas were identified for Arkansas by Gulf South Research Institute in preparation of the Arkansas Water Plan. Since current year (1976) surface water needs were not identified, the Arkansas Water Plan projected data for the year 1980 was assumed to be the current data. The surface water needs for 2020 were based on population and economic growth forecasts made by the Water Resources Council for all sections of the U.S. The difference between these two groupings of data was considered to be the increased surface water needs from 1976 to 2020. Coal technology was considered in addition to the Arkansas Water Plan data since at the time of Gulf South's study more emphasis has been placed on future energy industry. Arkansas' lignite deposits are likely to bring coal technologies to Arkansas and the coal technology water projections were based on current coal technologies which will probably be less efficient than follow-on technologies. The Gulf South Research Institute's study also did not address the problem of declining ground water supplies in the Grand Prairie Aquifer. The predicitions for irrigation using surface waters in 2020 were based on conferences with personnel with the Arkansas Department of Commerce, Division of Soil and Water Resources and using the latest information available.

# Appendix C

SOURCE AND USE OF SURFACE WATER IN ARKANSAS STUDY AREAS
(mgd)[1]

| Year | Study Area by WRPA | Public Supply | Self-Supplied Industry | Livestock | Irrigation: Rice | Irrigation: Other Crops | Fuel-Electric Power | Coal Technology[4] | Fish & Minnow Farms | Wildlife Impoundments & Fish Hatcheries | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 | 2 and 3 | 2.35 | .65 | 2.75 | 105.24 | 44.54 | 613.85 | 0 | 55.52 | 34.48 | 859.38 |
| | 5-A, 6 and Saline & Pulaski | 48.54 | 101.92 | 4.52 | 49.19 | 34.40 | 836.51 | 0 | 14.12 | 3.57 | 1,092.77 |
| | 455 | 3.87 | 35.75 | 2.38 | .19 | 1.00 | 0 | 0 | 1.97 | 0 | 45.16 |
| | Total | 54.76 | 138.32 | 9.65 | 154.62 | 79.94 | 1,450.36 | 0 | 71.61 | 38.05 | 1,997.31 |
| | | (.06)[2] | (.15) | (.01) | (.17) | (.09) | (1.62) | (.00) | (.08) | (.04) | (2.237) |
| 2020 | 2 and 3 | 4.84 | 3.73 | 4.91 | 422.51 | 136.51 | 2,135.61 | 0 | 55.52 | 34.48 | 2,798.11 |
| | 5-A, 6 and Saline & Pulaski | 75.13 | 533.56 | 7.95 | 87.37 | 107.82 | 2,983.93 | 49.98 | 14.12 | 13.57 | 3,863.43 |
| | 455 | 8.43 | 190.04 | 4.23 | .19 | 1.18 | 0 | 16.16 | 1.97 | 0 | 222.70 |
| | Total | 88.40 | 727.33 | 17.09 | 510.07[3] | 245.51[3] | 5,119.54 | 66.64 | 71.61 | 38.05 | 6,884.24 |
| | | (.10) | (.81) | (.02) | (.57) | (.28) | (5.73) | (.07) | (.08) | (.04) | (7.712) |
| Increase 1980 to 2020 | 2 and 3 | 2.49 | 3.08 | 2.16 | 317.27 | 91.97 | 1,521.76 | 0 | 0 | 0 | 1,938.73 |
| | 5-A, 6 and Saline & Pulaski | 26.59 | 431.64 | 3.43 | 38.18 | 73.42 | 2,147.42 | 49.98 | 0 | 0 | 2,770.66 |
| | 455 | 4.56 | 154.29 | 1.85 | 0 | 1.18 | 0 | 16.66 | 0 | 0 | 177.54 |
| | Total | 33.64 | 589.01 | 7.44 | 355.45 | 165.57 | 3,669.18 | 66.64 | 0 | 0 | 4,886.93 |
| | | (.04) | (.66) | (.01) | (.40) | (.19) | (4.11) | (.07) | (.00) | (.00) | (5.475) |

Source: Arkansas Water Plan, Phase 1, Preliminary Water Use, p. 22.

[1]To convert mgd to acre-feet/year, multiply by 1120.22. To convert mgd to cfs, multiply by 1.547336.

[2]Numbers in parentheses are the totals in million acre-feet/year.

[3]Increased irrigation usage based on revised predictions due to declining ground water resources. Source material did not consider effects of declining ground water on irrigation.

[4]Source material did not take future coal technology into consideration.

EXHIBIT 20

## Appendix D

## Distribution of Increased Surface Water Needs

The increased surface water needs for Arkansas were distributed among the months of the years at the same ratios developed in the West Texas and Eastern New Mexico Water Import Study which was accomplished by the Mississippi River Commission. This data was developed to make a reasonable judgement as to how much each runoff area and stream might contribute to the increased surface water needs between 1976 and 2020.

# Appendix D

DISTRIBUTION OF INCREASED SURFACE WATER NEEDS: 2020*
MONTHLY AVERAGES
(cfs)

| MONTHLY AVERAGES | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEARLY AVERAGES | MM acre-ft/year | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WRPA 2 and 3 | | | | | | | | | | | | | | | |
| Public Supply | 3.85 | 3.85 | 3.85 | 3.85 | 3.85 | 3.85 | 3.85 | 3.85 | 3.85 | 3.85 | 3.85 | 3.85 | 3.85 | | |
| Self-Supplied Industry | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 | | |
| Livestock | .12 | .12 | .12 | 1.08 | 3.00 | 3.24 | 14.64 | 13.80 | 3.12 | .60 | .12 | .12 | 3.34 | | |
| Rice | 12.48 | 12.48 | 12.48 | 137.28 | 443.16 | 480.48 | 2,165.40 | 2,053.20 | 474.24 | 74.88 | 12.48 | 12.48 | 490.92 | | |
| Other Crops | 3.60 | 3.60 | 3.60 | 39.84 | 128.40 | 139.32 | 627.72 | 595.20 | 137.52 | 21.72 | 3.60 | 3.60 | 142.31 | | |
| Fuel-Electric Power | 0 | 0 | 0 | 0 | 0 | 7,064.04 | 7,064.04 | 7,064.04 | 7,064.04 | 0 | 0 | 0 | 2,354.68 | | |
| Coal Technology | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Subtotal | 24.82 | 24.82 | 24.82 | 186.82 | 583.18 | 7,695.70 | 9,880.42 | 9,734.86 | 7,687.54 | 105.82 | 24.82 | 24.82 | 2,999.98 | 2.14 | 40 |
| WRPA 5-A, 6 and Saline & Pulaski | | | | | | | | | | | | | | | |
| Public Supply | 41.14 | 41.14 | 41.14 | 41.14 | 41.14 | 41.14 | 41.14 | 41.14 | 41.14 | 41.14 | 41.14 | 41.14 | 41.14 | | |
| Self-Supplied Industry | 667.89 | 667.89 | 667.89 | 667.89 | 667.89 | 667.89 | 667.89 | 667.89 | 667.89 | 667.89 | 667.89 | 667.89 | 667.89 | | |
| Livestock | .24 | .24 | .24 | 1.32 | 4.20 | 5.64 | 22.44 | 21.00 | 5.52 | .24 | .24 | .24 | 5.31 | | |
| Rice | 1.56 | 1.56 | 1.56 | 16.56 | 53.28 | 57.72 | 260.52 | 246.97 | 57.12 | 9.00 | 1.56 | 1.56 | 59.08 | | |
| Other Crops | 2.88 | 2.88 | 2.88 | 31.80 | 102.60 | 11.24 | 501.12 | 475.08 | 109.68 | 17.28 | 2.88 | 2.88 | 113.60 | | |
| Fuel-Electric Power | 3,070.20 | 3,070.20 | 3,070.20 | 3,070.20 | 3,070.20 | 3,070.20 | 3,070.20 | 3,070.20 | 3,070.20 | 3,070.20 | 3,070.20 | 3,070.20 | 3,322.78 | | |
| Coal Technology | 77.34 | 77.34 | 77.34 | 77.34 | 77.34 | 77.34 | 77.34 | 77.34 | 77.34 | 77.34 | 77.34 | 77.34 | 77.34 | | |
| Subtotal | 3,861.25 | 3,861.25 | 2,861.25 | 3,906.25 | 4,016.65 | 4,031.17 | 6,156.13 | 6,115.09 | 4,028.89 | 3,883.09 | 3,861.25 | 3,861.25 | 4,287.14 | 3.10 | 56 |
| WRPA 455 | | | | | | | | | | | | | | | |
| Public Supply | 7.05 | 7.05 | 7.05 | 7.05 | 7.05 | 7.05 | 7.05 | 7.05 | 7.05 | 7.05 | 7.05 | 7.05 | 7.05 | | |
| Self-Supplied Industry | 233.04 | 256.08 | 233.04 | 232.92 | 232.92 | 256.08 | 232.92 | 232.92 | 256.08 | 232.92 | 233.04 | 232.92 | 238.74 | | |
| Livestock | .24 | .24 | .48 | .84 | 3.24 | 4.56 | 10.20 | 10.20 | 3.36 | .48 | .24 | .24 | 2.86 | | |
| Rice | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Other Crops | 0 | 0 | .24 | .24 | .24 | .36 | .84 | .84 | .36 | .24 | 0 | 0 | .28 | | |
| Fuel-Electric Power | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Coal Technology | 25.78 | 25.78 | 25.78 | 25.78 | 25.78 | 25.78 | 25.78 | 25.78 | 25.78 | 25.78 | 25.78 | 25.78 | 25.78 | | |
| Subtotal | 266.11 | 289.15 | 266.59 | 266.83 | 269.23 | 293.83 | 276.79 | 276.79 | 292.63 | 266.47 | 266.11 | 265.99 | 274.71 | .20 | 04 |
| Total | 4,152.18 | 4,175.22 | 4,152.66 | 4,359.99 | 4,869.06 | 12,020.70 | 16,313.34 | 16,126.74 | 12,009.06 | 4,255.38 | 4,152.18 | 4,152.06 | 7,561.72 | 5.47 | 100 |

*Distribution of increased needs at same ratios used in West Texas and Eastern New Mexico Water Import Study

EXHIBIT 21

# Appendix E

## WHITE RIVER (DE VALLS BLUFF)
## PREDICTED MEAN MONTHLY FLOWS YEAR 2020
(MEANS UP TO YEAR 1975 LESS SHARE OF INCREASED NEEDS TO YEAR 2020)

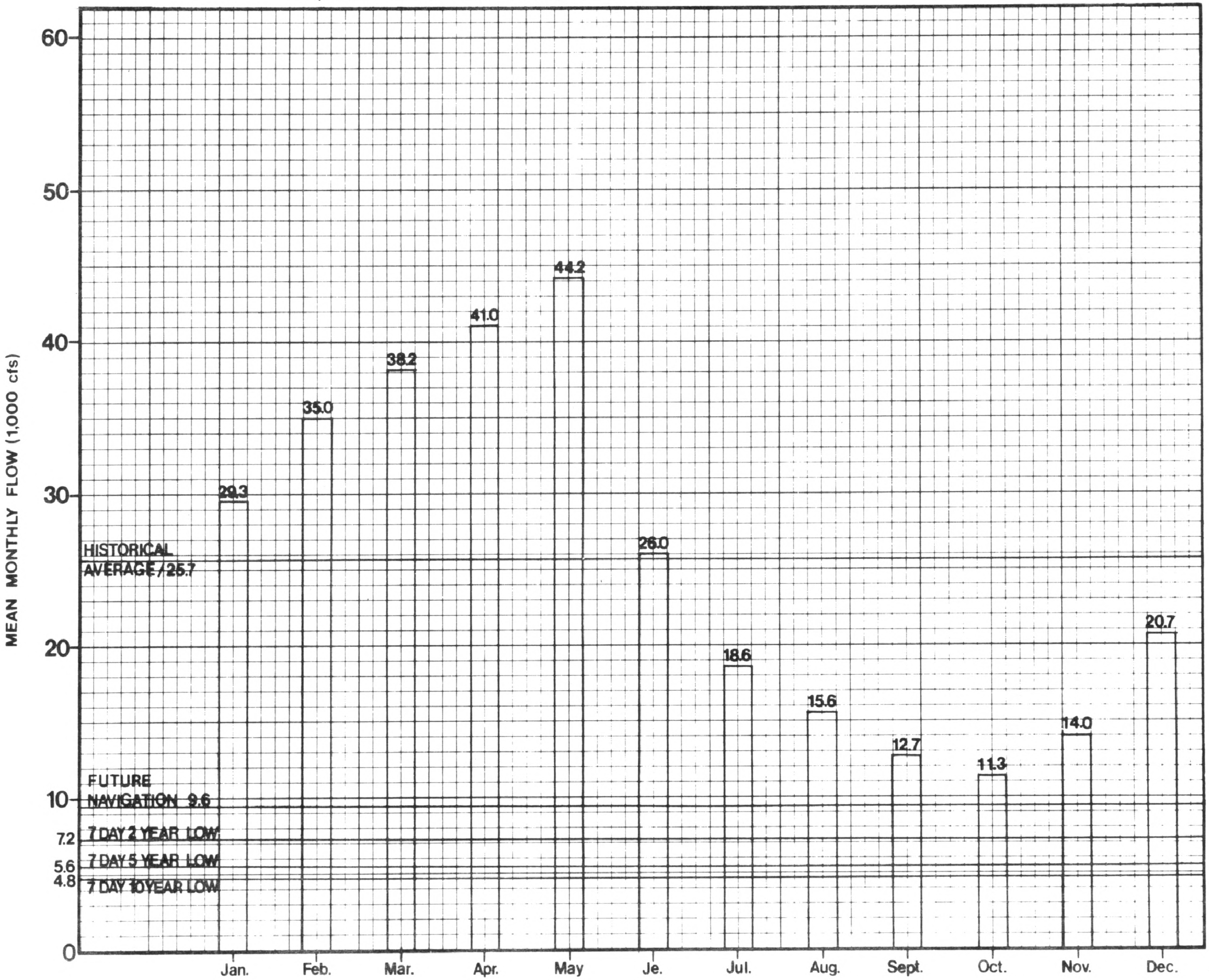



EXHIBIT 22

PREDICTED MEAN MONTHLY FLOWS: 2020
WHITE RIVER AT DeVALLS BLUFF
(cfs)

| | MEAN MONTHLY FLOWS 1975 | SHARE OF INCREASED SURFACE NEEDS 2020 | PREDICTED MEAN MONTHLY FLOW 2020 |
|---|---|---|---|
| JAN | 29,554 | 218 | 29,336 |
| FEB | 35,190 | 221 | 34,969 |
| MAR | 38,381 | 217 | 38,164 |
| APR | 41,181 | 217 | 40,964 |
| MAY | 44,463 | 216 | 44,247 |
| JUN | 26,229 | 220 | 26,009 |
| JUL | 18,855 | 300 | 18,555 |
| AUG | 15,852 | 299 | 15,553 |
| SEP | 12,921 | 220 | 12,701 |
| OCT | 11,484 | 218 | 11,266 |
| NOV | 14,234 | 218 | 14,016 |
| DEC | 20,930 | 218 | 20,712 |

OTHER DATA:

1951-1970 Historical Average -- 25,700 cfs

1951-1970 Seven Day, Two Year Low Flow -- 7,220 cfs
Seven Day, Five Year Low Flow -- 5,550 cfs
Seven Day, Ten Year Low Flow -- 4,830 cfs

Navigation Requirements (Future) -- 9,600 cfs (based on White River Navigation Study by Corps of Engineers)

Mean Monthly Flows -- Arithmetic Mean of USGS Data 1950-1970

EXHIBIT 23

## ARKANSAS RIVER (MURRAY DAM)
## PREDICTED MONTHLY FLOWS-YEAR 2020

(MEANS UP TO YEAR 1975 LESS SHARE OF INCREASED NEEDS TO YEAR 2020)

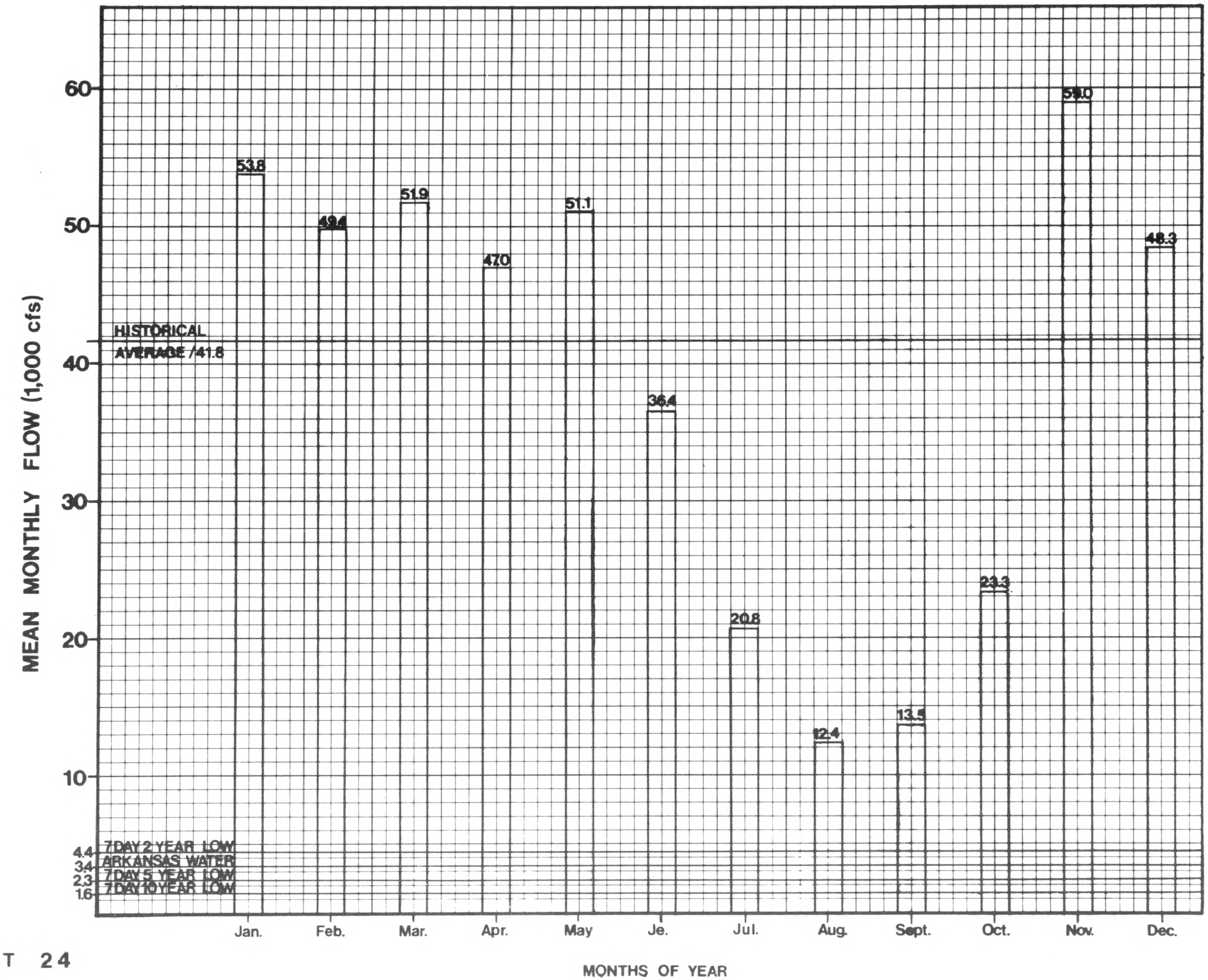



EXHIBIT 24

PREDICTED MEAN MONTHLY FLOWS: 2020
ARKANSAS RIVER AT MURRAY DAM
(cfs)

| | MEAN MONTHLY FLOWS 1975 | SHARE OF INCREASED SURFACE NEEDS 2020 | PREDICTED MEAN MONTHLY FLOW 2020 |
|---|---|---|---|
| JAN | 53,775 | 01 | 53,774 |
| FEB | 49,416 | 01 | 49,415 |
| MAR | 51,878 | 01 | 51,877 |
| APR | 46,965 | 01 | 46,964 |
| MAY | 51,109 | 01 | 51,108 |
| JUN | 37,019 | 660 | 36,359 |
| JUL | 21,432 | 663 | 20,769 |
| AUG | 13,113 | 662 | 12,451 |
| SEP | 14,164 | 660 | 13,504 |
| OCT | 23,310 | 01 | 23,309 |
| NOV | 58,972 | 01 | 58,971 |
| DEC | 48,278 | 01 | 48,277 |

OTHER DATA:

1927-1975 Historical Average -- 41,800 cfs

1929-1970 Seven Day, Two Year Low Flow -- 4,410 cfs
Seven Day, Five Year Low Flow -- 2,320 cfs
Seven Day, Ten Year Low Flow -- 1,610 cfs

Navigation Pool Requirements -- 1,600 cfs (1968 Corps of Engineers report)

Mean Monthly Flows -- Geometric Mean of USGS Data 1971-1974

Flow Requirement to Maintain Water Quality as Requested by Arkansas Department of Pollution Control and Ecology to the Corps of Engineers -- 3,400 cfs

EXHIBIT 25

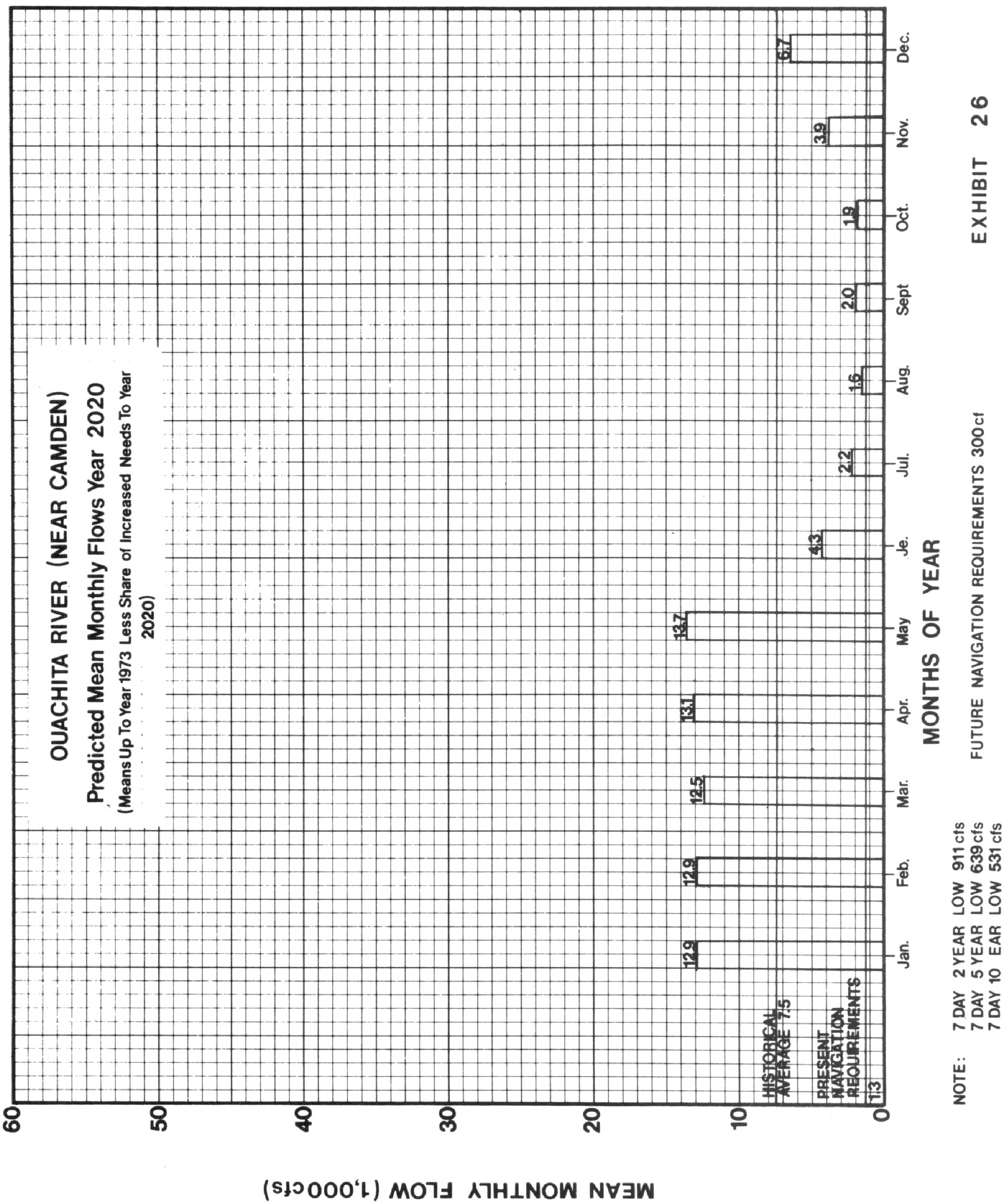

OUACHITA RIVER (NEAR CAMDEN)
Predicted Mean Monthly Flows Year 2020
(Means Up To Year 1973 Less Share of Increased Needs To Year 2020)
MEAN MONTHLY FLOW (1,000cfs)
0
10
20
30
40
50
60
HISTORICAL AVERAGE 7.5
PRESENT NAVIGATION REQUIREMENTS
1.3
12.9
12.9
12.5
13.1
13.7
4.3
2.2
1.6
2.0
1.8
3.9
6.7
Jan.
Feb.
Mar.
Apr.
May
Je.
Jul.
Aug.
Sept
Oct.
Nov.
Dec.
MONTHS OF YEAR
NOTE: 7 DAY 2 YEAR LOW 911 cfs
7 DAY 5 YEAR LOW 639 cfs
7 DAY 10 EAR LOW 531 cfs
FUTURE NAVIGATION REQUIREMENTS 300cf

EXHIBIT 26

PREDICTED MEAN MONTHLY FLOWS: 2020
OUACHITA RIVER AT CAMDEN
(cfs)

| | MEAN MONTHLY FLOWS 1973 | SHARE OF INCREASED SURFACE NEEDS 2020 | PREDICTED MEAN MONTHLY FLOW 2020 |
|---|---|---|---|
| JAN | 12,947 | 48 | 12,899 |
| FEB | 12,945 | 49 | 12,896 |
| MAR | 12,562 | 48 | 12,514 |
| APR | 13,128 | 48 | 13,080 |
| MAY | 13,711 | 48 | 13,663 |
| JUN | 4,306 | 48 | 4,258 |
| JUL | 2,231 | 66 | 2,165 |
| AUG | 1,667 | 66 | 1,601 |
| SEP | 2,000 | 49 | 1,951 |
| OCT | 1,898 | 48 | 1,850 |
| NOV | 3,910 | 48 | 3,862 |
| DEC | 6,762 | 48 | 6,714 |

OTHER DATA:

1929-1973 Historical Average -- 7,460 cfs

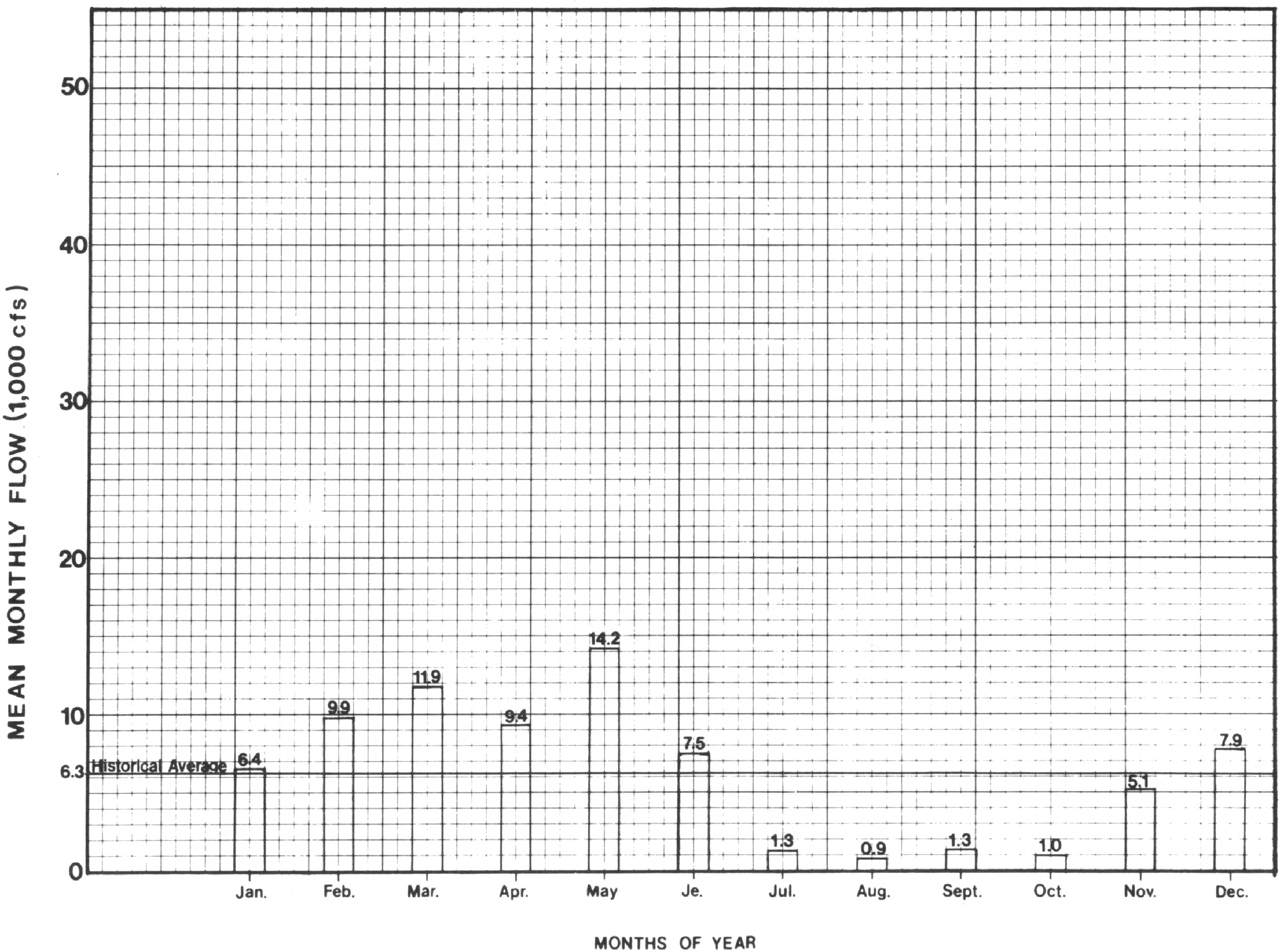
1955-1970 Seven Day, Two Year Low Flow -- 911 cfs
Seven Day, Five Year Low Flow -- 639 cfs
Seven Day, Ten Year Low Flow -- 531 cfs

Navigation Now -- 1,250 cfs
Future -- 300 cfs (based on revised Lock and Dam System, Corps of Engineers)

Mean Monthly Flows -- Arithmetic Mean of USGS Data 1929-1973

EXHIBIT 27

## LITTLE RIVER (BELOW MILLWOOD)
## PREDICTED MEAN MONTHLY FLOW YEAR 2020
(MEANS UP TO YEAR 1973 LESS SHARE OF INCREASED NEEDS TO YEAR 2020)



## PREDICTED MEAN MONTHLY FLOWS: 2020
## LITTLE RIVER BELOW MILLWOOD RESERVOIR
## (cfs)

| | MEAN MONTHLY FLOWS 1973 | SHARE OF INCREASED SURFACE NEEDS 2020 | PREDICTED MEAN MONTHLY FLOW 2020 |
|---|---|---|---|
| JAN | 6,374 | 08 | 6,366 |
| FEB | 9,918 | 09 | 9,909 |
| MAR | 11,888 | 08 | 11,880 |
| APR | 9,441 | 08 | 9,433 |
| MAY | 14,158 | 08 | 14,150 |
| JUN | 7,515 | 09 | 7,506 |
| JUL | 1,283 | 08 | 1,275 |
| AUG | 935 | 08 | 927 |
| SEP | 1,266 | 09 | 1,257 |
| OCT | 1,049 | 08 | 1,041 |
| NOV | 5,075 | 08 | 5,069 |
| DEC | 7,873 | 08 | 7,856 |

OTHER DATA:

1967-1973 Historical Average -- 6,320 cfs

Insufficient Data to Compute Low Flows

Mean Monthly Flows -- Arithmetic Mean of USGS Data 1967-1973

EXHIBIT 29

## Appendix F

## Probable Maximum Withdrawals and Conveyance System Flows Based on Predicted Mean Monthly Flows: 2020 (cfs)

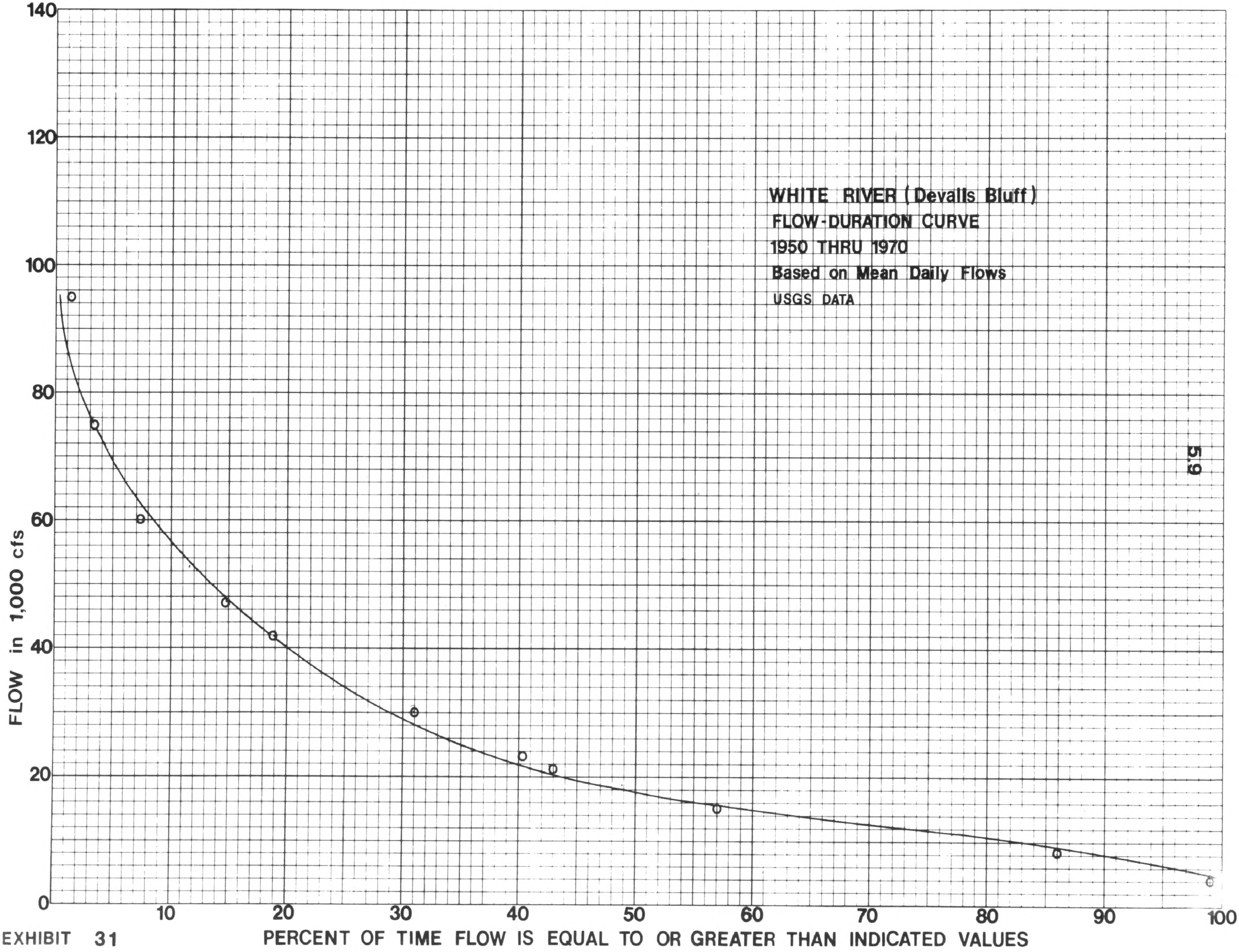
There are many factors which will determine the final design streamflow criteria to be used in designing the pump, canal and conduit sizes. It would not be practical to design for the probable maximum withdrawals as indicated on page 57 since these flows would occur for such a short overall time. In order to capture excess surface water during the eight month wetter cycles, the normal expected efficiencies in water transportation systems will have to be modified. The final determination of design flows will be a compromise based on engineering judgement. If 8,400 cfs is needed on a yearly average basis, then 12,600 cfs would be needed on an eight month average basis to provide six million acre-feet per year to Texas. The design considerations for the system from Millwood to Wright-Patman might be in the range of 12,600 to 14,700 cfs. The same reasoning could apply at each point within the system. Flow duration curves can help in making such judgements and the flow characteristics of the Arkansas and Ouachita have been changing in recent years. The flow seems to be more even, therefore, more predictable. This is probably a result of the Lock and Dam project on the Arkansas River and the hydroelectric flows from DeGray Reservoir on the Ouachita.

PROBABLE MAXIMUM WITHDRAWALS AND CONVEYANCE SYSTEM FLOWS
BASED ON PREDICTED MEAN MONTHLY FLOWS: 2020
(cfs)

| | (1) White River | (2) Arkansas River | (3) Cols. (1) + (2) | (4) Ouachita River | (5) Cols. (3) + (4) | (6) Millwood Reservoir | (7) Cols. (5) + (6) |
|---|---|---|---|---|---|---|---|
| JAN | 3,300 | 5,500 | 8,800 | 1,900 | 10,700 | 1,100 | 11,800 |
| FEB | 4,000 | 5,100 | 9,100 | 1,900 | 11,000 | 1,600 | 12,600 |
| MAR | 4,400 | 5,300 | 9,700 | 1,900 | 11,600 | 2,000 | 13,600 |
| APR | 4,700 | 4,900 | 9,600 | 1,900 | 11,500 | 1,600 | 13,100 |
| MAY | 5,000 | 5,200 | 10,200 | 2,100 | 12,300 | 2,400 | 14,700 |
| JUN | 3,000 | 3,800 | 6,800 | 600 | 7,400 | 1,200 | 8,600 |
| JUL | 2,100 | 2,100 | 4,200 | 0 | 4,200 | 0 | 4,200 |
| AUG | 0 | 1,300 | 1,300 | 0 | 1,300 | 0 | 1,300 |
| SEP | 0 | 1,400 | 1,400 | 0 | 1,400 | 0 | 1,400 |
| OCT | 0 | 2,400 | 2,400 | 0 | 2,400 | 0 | 2,400 |
| NOV | 0 | 6,100 | 6,100 | 600 | 6,700 | 800 | 7,500 |
| DEC | 2,400 | 5,000 | 7,400 | 1,100 | 8,500 | 1,300 | 9,800 |
| Average | 2,400 | 4,000 | 6,400 | 1,000 | 7,400 | 1,000 | 8,400 |

EXHIBIT 30

# Appendix G


WHITE RIVER (Devalls Bluff)
FLOW-DURATION CURVE
1950 THRU 1970
Based on Mean Daily Flows
USGS DATA
5.9
FLOW in 1,000 cfs
0
20
40
60
80
100
120
140
10
20
30
40
50
60
70
80
90
100
PERCENT OF TIME FLOW IS EQUAL TO OR GREATER THAN INDICATED VALUES
EXHIBIT 31

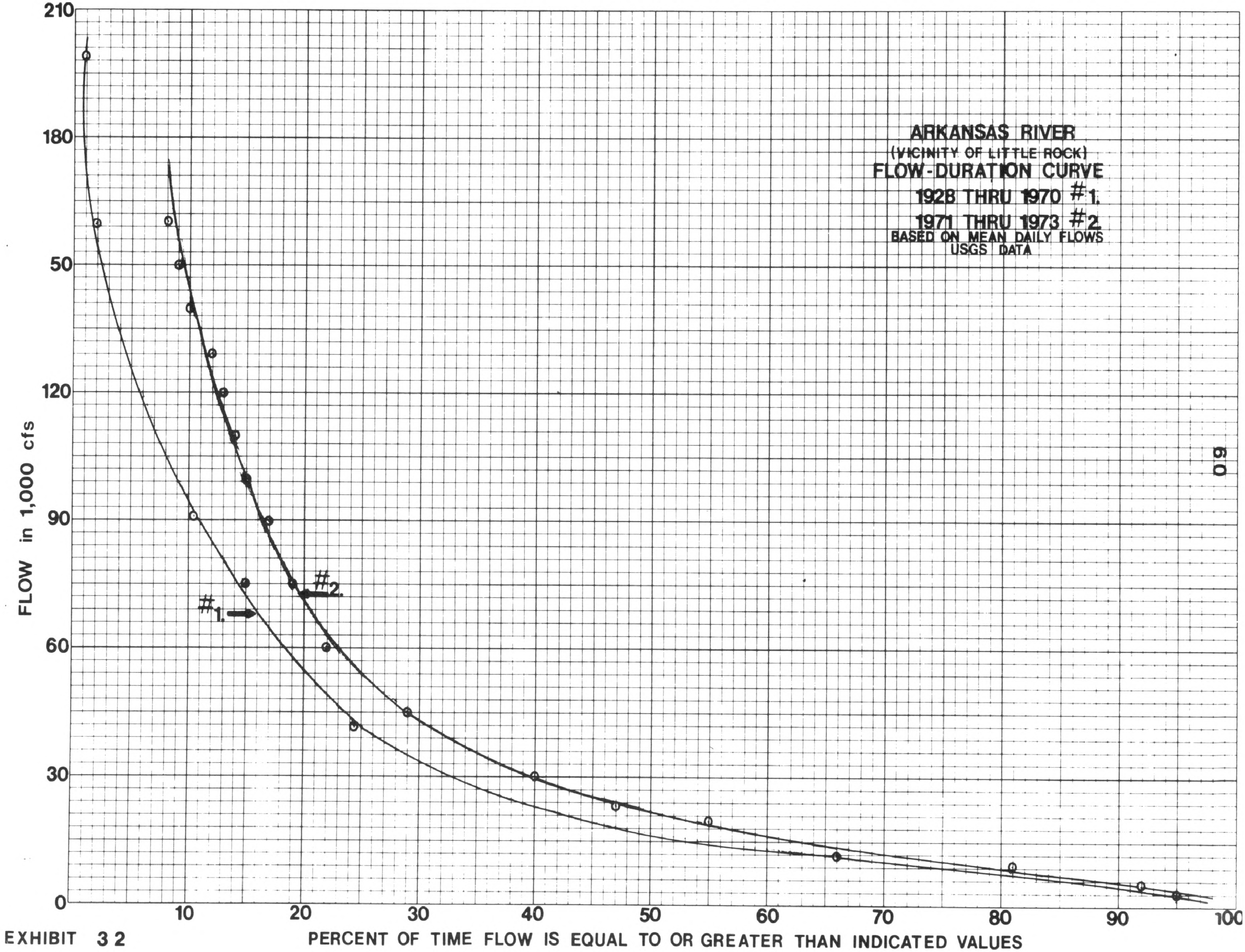

ARKANSAS RIVER
(VICINITY OF LITTLE ROCK)
FLOW-DURATION CURVE
1928 THRU 1970 #1.
1971 THRU 1973 #2.
BASED ON MEAN DAILY FLOWS
USGS DATA
FLOW in 1,000 cfs
0
30
60
90
120
50
180
210
10
20
30
40
50
60
70
80
90
100
#1.
#2.
PERCENT OF TIME FLOW IS EQUAL TO OR GREATER THAN INDICATED VALUES

EXHIBIT 32

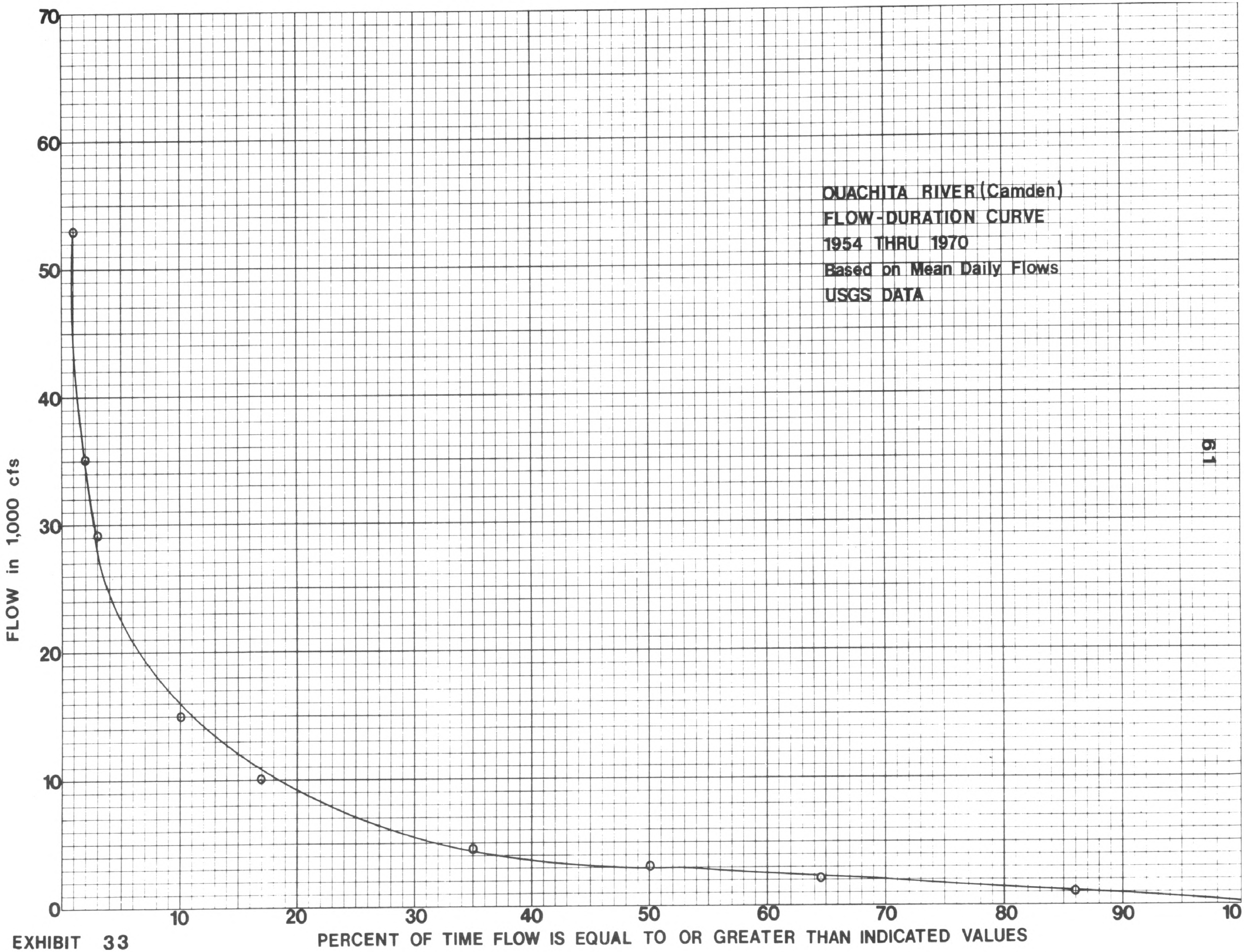

OUACHITA RIVER (Camden)
FLOW-DURATION CURVE
1954 THRU 1970
Based on Mean Daily Flows
USGS DATA
FLOW in 1,000 cfs
0
10
20
30
40
50
60
70
PERCENT OF TIME FLOW IS EQUAL TO OR GREATER THAN INDICATED VALUES
10
20
30
40
50
60
70
80
90
10

EXHIBIT 33

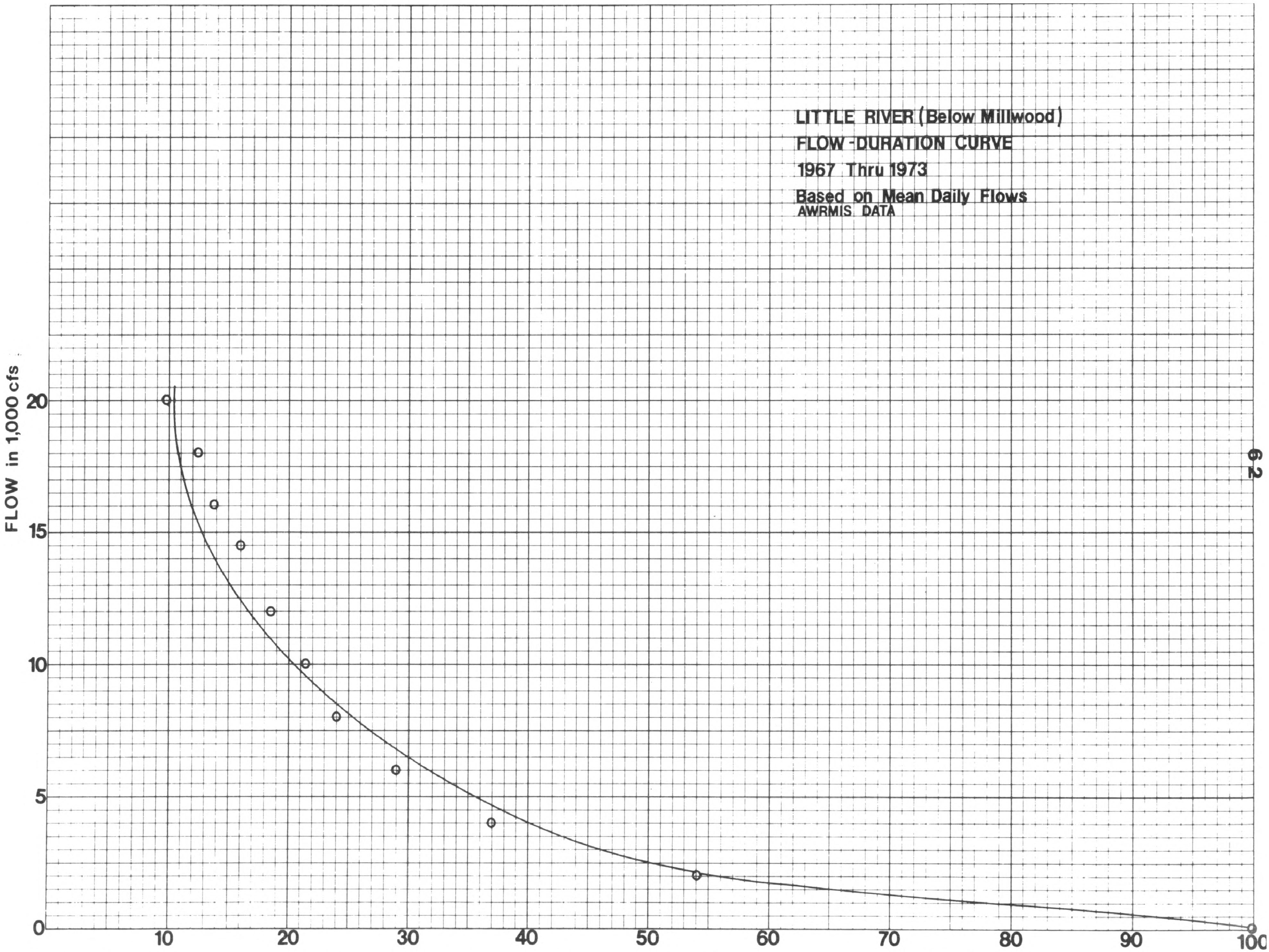
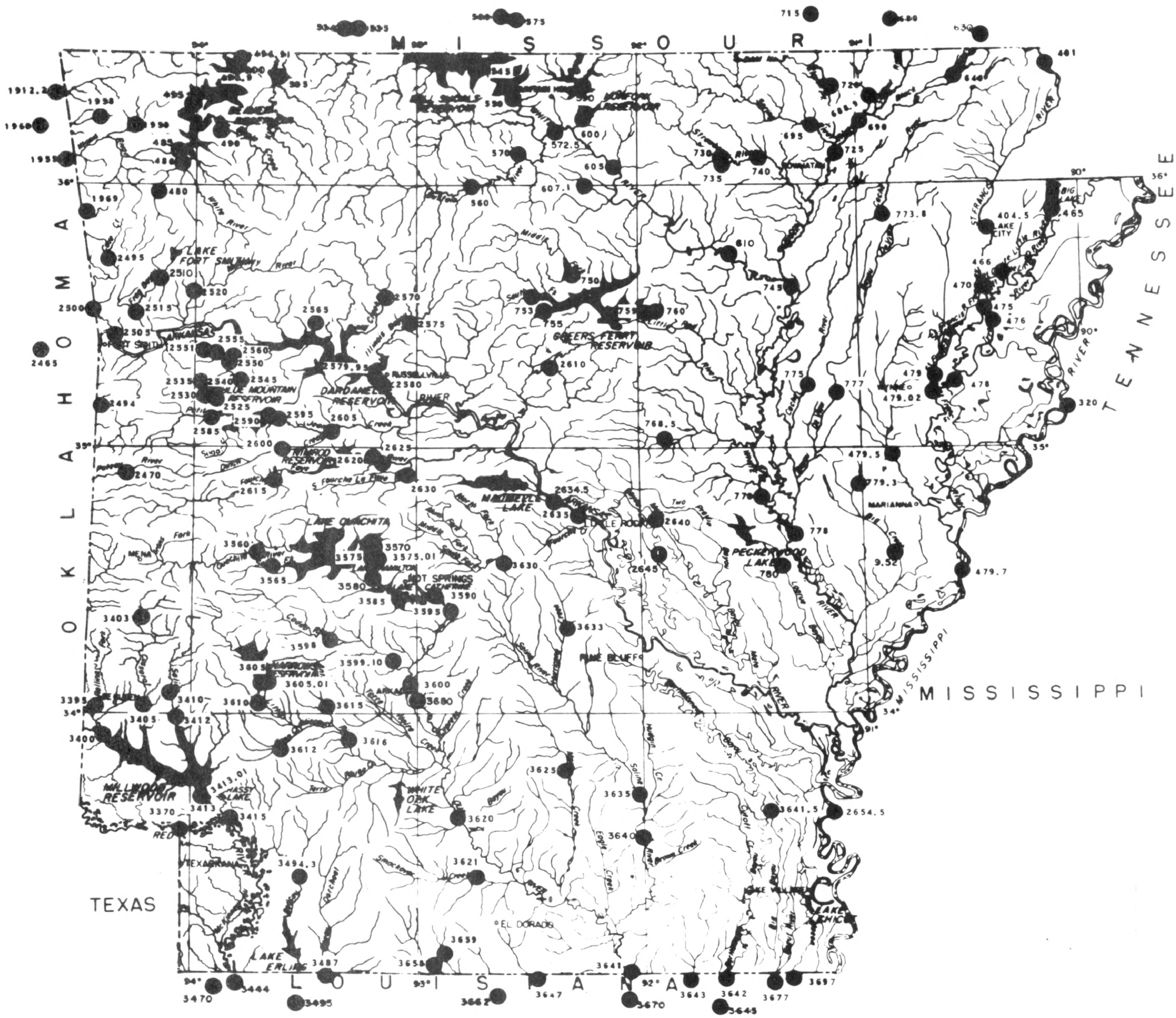



EXHIBIT 34

PERCENT OF TIME FLOW IS EQUAL TO OR GREATER THAN INDICATED VALUES

# Appendix H




USGS HYDROLOGIC DATA STATIONS

EXHIBIT 35

Appendix I

## U. S. CORPS OF ENGINEERS RESERVOIRS IN ARKANSAS

| NAME OF RESERVOIR | STREAM | MAXIMUM FLOOD POOL SURFACE AREA | MAXIMUM FLOOD POOL AC/FEET STORAGE | CONSERVATION POOL[1] SURFACE AREA | CONSERVATION POOL[1] AC/FEET STORAGE | INSTALLED KILLOWATT (000) | DAM HEIGHT | PURPOSE[2] |
|---|---|---|---|---|---|---|---|---|
| Bull Shoals | White | 71,240[3] | 5,408,000 | 45,400[3] | 3,048,000 | 342.0 | 258' | FC, P, R |
| Norfolk | North Fork | 30,700[3] | 1,983,000 | 22,000[3] | 1,251,000 | 70.4[4] | 222' | FC, P, W, R |
| Table Rock | White | 52,300[3] | 3,462,000 | 43,100[3] | 2,702,000 | 201.4 | 252' | FC, P, R |
| Greers Ferry | Little Red | 40,500 | 2,844,000 | 31,500 | 1,910,000 | 96.5 | 243' | FC, P, R |
| Lake Ouachita | Ouachita | 48,300 | 2,768,000 | 40,100 | 2,151,000 | 75.0 | 231' | FC, P, R |
| Millwood | Little | 95,200 | 1,858,000 | 29,200 | 206,600 | 0 | 88' | FC, W, R |
| Blue Mountain | Petit Jean | 11,000 | 258,000 | 2,900 | 25,000 | 0 | 115' | FC, R |
| Nimrod | Fourche La Fave | 18,300 | 336,000 | 3,600 | 29,000 | 0 | 97' | FC, R |
| Lake Greeson | Little Missouri | 9,800 | 407,900 | 7,260 | 279,700 | 25.5 | 190' | FC, P, R |
| Dardanelle | Arkansas | 0 | 0 | 36,600 | 486,000 | 124.0 | 68' | P, N, R |
| Gillham | Cossatot | 4,680 | 221,800 | 1,370 | 33,100 | 0 | 160' | FC, W, R |
| DeQueen | Rolling Fork | 4,050 | 136,100 | 1,680 | 34,900 | 0 | 160' | FC, W, R |
| Beaver | White | 31,700 | 1,952,000 | 28,220 | 1,652,000 | 112.5 | 228' | FC, P, W, R |
| Ozark | Arkansas | 0 | 0 | 10,600 | 148,400 | 100.5 | 58' | P, N, R |
| DeGray | Caddo | 17,000 | 881,900 | 13,400 | 654,700 | 86.0 | 243' | FC, P, W, R |
| Dierks | Saline | 2,970 | 96,800 | 1,360 | 29,700 | 0 | 134' | FC, W, R |
| TOTAL | | 437,740 | 22,613,500 | 318,330 | 14,641,100 | 1,233.3 | | |

[1] Bottom of Flood Control Pool
[2] FC-Flood Control; P-Power; W-Water Supply; N-Navigation; R-Recreation
[3] Some of area in the State of Missouri
[4] Proposed Project to Add More Generation by 1985

EXHIBIT 36

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For their help in providing data or water resources in Arkansas, we extend our thanks to the Corps of Engineers, U.S. Army, Little Rock District, Memphis District, Tulsa District and Vicksburg District; U.S. Geological Survey, Little Rock Office and Arkansas Department of Pollution Control and Ecology.

While the contributions of these individuals and agencies are acknowledged, the analysis, interpretation, conclusions and findings are solely the responsibility of Stephens Consultant Services Inc.