ARKANSAS, WHITE AND RED RIVER BASIN DEVELOPMENT WITH EMPHASIS ON (1) HYDROPOWER (2) WATER POLLUTION CONTROL (3) AGRICULTURE (4) FISH AND WILDLIFE AND (5) RECREATION

By

MOUNAGURUSWAMY GURUSWAMY

Bachelor of Engineering

University of Madras

India

1957

Submitted to the faculty of the Graduate School
of the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
August, 1962

Name: Mounaguruswamy Guruswamy Date of Degree: August 11, 1962

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: ARKANSAS, WHITE AND RED RIVER BASIN DEVELOPMENT WITH EMPHASIS ON (1) HYDRO POWER (2) WATER POLLUTION CONTROL (3) AGRICULTURE (4) FISH AND WILDLIFE AND (5) RECREATION

Pages in Study: 65 Candidate for Degree of Master of Science

Major Field: Civil Engineering

Scope of Study: An overall picture of the Arkansas, White and Red River Basin development with particular reference to hydro power, water pollution control, agriculture, fish and wildlife, and recreation is presented. This gives a general idea of all the pertinent investigations and factors to be considered for any multi-purpose river basin development scheme.

Findings and Conclusions: The plans and programs presented in this report are only tentative and will be subject to continued modification and refinement as more data become available and as changed economic conditions, technological improvements and other considerations may dictate. This report would be utilized by state and local agencies as a general framework within which the state and local agencies and state legislatures can decide what specific projects and programs should be initiated at a given time.

ADVISER'S APPROVAL_____

ARKANSAS WHITE AND RED RIVER BASIN DEVELOPMENT
WITH EMPHASIS ON (1) HYDROPOWER (2) WATER
POLLUTION CONTROL (3) AGRICULTURE
(4) FISH AND WILDLIFE AND
(5) RECREATION

Report Approved:

_____
Report Adviser

_____

_____
Dean of the Graduate School

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation and gratitude to the following individuals: To Professor Roger L. Flanders, who served as his major adviser, for his able guidance, constructive criticism and encouragement throughout the preparation of this report; to Professor D. M. Macalpine, who served as his second adviser for his help and encouragement; to his parents Mounaguruswamy Naidu and Manickam without whose cooperation and financial support it would not have been possible for the writer to continue his graduate work; and to his wife Jeyasantha, for her sacrifice and constant encouragement throughout the period of his studies. Finally, my appreciation is due to E. Grace Peebles for her careful and painstaking job of typing this report.

M. G.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

SYNOPSIS

The Arkansas - White - Red River Basin development scheme represents a typical long range plan for the development of the water and related land resources of the river basins. Any long range, multi-purpose river development scheme requires a systematic approach, so that the water potentials of the rivers can be utilized to the utmost efficiency.

An overall picture of the A. W. R. Basin development scheme is presented in this report and the following aspects of the scheme are dealt with in a detailed manner.

1. Hydro power.
2. Water pollution control.
3. Agriculture.
4. Fish and wildlife.
5. Recreation.

CHAPTER II

GENERAL INTRODUCTION

The Arkansas - White - Red River Basins area constitutes about 282 thousand square miles, or 180 million acres, in the south western portion of the United States. The three major rivers and their tributaries drain approximately one-eleventh of the nation"s land area, including all of Oklahoma and parts of Colorado, New Mexico, Kansas, Texas, Missouri, Arkansas and Louisiana.

The principal surface features of the A. W. R. basins are: a relatively small extent of high mountains in the west, a large area of low mountains which rise abruptly from the coastal and Mississippi alluvial plains in the east and between the two mountain areas, a broad expanse of interior lowland sloping gradually from west to east, broken locally by escarpments, hills, relics of old, eroded mountains. Rivers with sources in areas of precipitous slope, change from swiftly flowing to slow and sluggish streams meandering through wide alluvial valleys.

The annual precipitation averages about 55 inches in southeast Arkansas and eastern Louisiana, decreased rather uniformly westward to about 12 inches in the western great plains, then increased to 32 inches in the mountains of Colorado and New Mexico. In the great plains both monthly and annual rainfall are low, and serious defiencies in crop-season precipitation occur. In the eastern third of the

A. W. R. area, severe crop season deficiencies in precipitation occur less frequently.

About 7,172,000 people live in the A. W. R. basins. In 1950, 55.8 percent of the total population was classified as rural. Slightly more than half the rural population lived on farms while the remainder lived in towns and communities of less than 2,500 inhabitants.

The economy of the A. W. R. basins is dependent upon agriculture as a basic source of income and employment. Mining, the extraction of petroleum and natural gas, and initial processing and refining of the minerals constitute more important activities in this area than in most areas of the nation.

Agriculture is a major activity throughout the A. W. R. basins. In 1950, crops were harvested from 40 million acres, 29 percent of the farm land in the basins. About 77 million acres, 56 percent of the farm land acreage, were used for pasture, and about 7 million acres, 5 percent, were wood land not pastured. Cattle, wheat, cotton, and grain sorghums constitute major farm products.

Almost a third of the A. W. R. basins, 49 1/3 million acres is forest land, of which about 80 percent is commercial forest. These forest lands comprise 7.8 percent of the total forest lands of the United States and 8.6 percent of the commercial forest.

The most important mineral resources of the A. W. R. basins are the fuels. Petroleum and natural gas are produced from four areas. In 1952, about 469 million barrels of petroleum and 2,967 billion cubic feet of natural gas were produced. This was about 21 percent of the oil and 34 percent of the marketed natural gas for the United States.

Manufacturing represents a growing and increasingly important

segment of the A. W. R. basins economy. In 1950 nearly 300,000 persons were employed as manufacturing production workers as compared with 200,000 in 1940. Available data indicate that manufacturing in the region has continued to grow in importance since 1947.

2-1. Water Resources

With the exception of the higher elevations of the Rocky Mountains, the western half of the three basins suffers from moisture deficiencies so that the major concern in developing the water resources is to provide supplies for agricultural, domestic and industrial uses, although periodic floods damage numerous developed valley areas. In the eastern half of the basins, water run off is large, the Arkansas River increasing from an average annual flow of 323,000 acre-feet near Great Bend, Kansas, to 27,000,000 acre-feet at the Oklahoma-Arkansas state line, and 35,000,000 acre-feet near Little Rock, the Red River increasing from an average annual flow of 2,500,000 acre-feet at Gainesville, Texas to 21,000,000 acre-feet near Shreveport, Louisiana, and the White river having an acreage annual flow of about 22,000,000 acre-feet near Clarendon, Arkansas. In this eastern area floods constitute a serious problem, an enormous area of "wet-lands" could be improved for agricultural purposes through drainage measures, and even though precipitation rates are high, irrigation to counteract frequent drought periods is growing in importance.

Water resources development has been under way in the three basins for a century and a half. Domestic and industrial users have developed storage, pumping, treatment, and distribution facilities for the use of approximately 3.8 billion gallons of water a day. Hydroelectric power facilities existing or under construction have a total installed

capacity of 755,000 kilowatts and an annual generation of 2,730 million kilowatt hours. It is estimated that over two million acres of land are being irrigated and that drainage facilities serve approximately seven million acres. Dependable navigation facilities are currently being maintained from the mouth of the Red River to river mile 35-5 at the mouth of the Black River, and 351 miles up the Ouachita River to Camden, Arkansas.

The investigations conducted in the course of the A. W. R. Survey reveal that average annual flood damages to approximately 14,700,000 acres total $57,700,000 of which $29,500,000 are damages to crops and pastures. Several million acres of additional land could be irrigated, although availability of water is a limiting factor for much of this land. There are 14.7 million acres which have been classified as "wetlands." Finally an enormous increase in municipal and industrial water supplies will be required to meet the growing needs of the area, probably constituting a total increase in the neighborhood of seven billion gallons per day by the year 2000.

The framework plan set forth in this report, if completely implemented, would provide:

1. A reduction of flood losses of $19,700,000 per year.

2. Irrigation of 6,083,000 acres of new land and supplemental water supply or rehabilitation of existing facilities for 938,000 acres presently irrigated.

3. Drainage of 6.5 million acres for agricultural purposes.

4. Additional hydroelectric power facilities having a total installed capacity of 1,948,000 kilowatts which would produce 6.3 billion kilowatt hours of additional energy.

5. Storage facilities for municipal and industrial water supply in areas where surface supplies may be the best source.

6. Improved navigation facilities up the Arkansas River and its tributary the Verdigris, to Catoosa, Oklahoma; improved navigation facilities on the Red River from the Mississippi to the vicinity of Texarkana, Arkansas-Texas, and Lone Star, Texas.

The above discussion gives a general picture of the A. W. R. area and the water resources available and this forms the general introduction for this report.

2-2. Water Resources and Framework Plan

The discussion of the water resources and the framework plan is arranged in the following order: Upper Arkansas River Basin, Lower Arkansas River Basin, White River Basin, Red River Basin above Denison Dam, Red River Basin below Denison Dam and Ouachita River Basin.

(a) Upper Arkansas River Basin:

The long-range framework plan for water use and control for the Upper Arkansas Basin provides for

1. The irrigation of about 130,000 acres of additional land.

2. Rehabilitation of existing irrigation systems, or improved storage facilities for about 500,000 acres or both.

3. Improvement of drainage facilities for about 621,000 acres.

4. Flood control measures additional to those previously authorised provide average annual primary benefits of $4,814,800, of which $3,545,300 are damages prevented and $1,269,500 are changed land use. In addition, the estimated average annual damages prevented in the minor tributaries attributable to land treatment in the amount of $2,637,000.

5. Storage facilities at selected locations to meet prospective municipal and industrual water requirements where surface sources of supply may be needed.

6. Installation of 176,700 kilowatts of hydroelectric capacity in Colorado with an average annual generation of 642.4 million kilowatt hours.

(b) Lower Arkansas River Basin:

The long range plan of development of the water resources of the Arkansas River Basin below Keystone Dam includes a system of 33 major reservoirs for flood control, hydroelectric power, navigation, and other related purposes; 45 local flood protection projects and 840 water flow retardation structures. Nine of the major reservoirs and 22 local protection projects have been completed; 2 reservoirs are classified as under construction. Thirteen reservoir projects and 6 local protection projects have been authorized but not yet constructed.

The newly proposed projects in the plan include 9 multiple-purpose revervoir projects, 17 local flood protection projects, and the 840 water flow retardation structures.

(c) White River Basin:

The long range plan of development of the water resources of the White River Basin is based upon an integrated system of 16 reservoirs to be operated for the control of floods, development of hydroelectric power, and for other purposes. The existing flood control projects in the White River Basin have been effective in reducing flood losses, and further reduction will result from completion of projects now under construction. In addition to these projects, the long-range plan for flood control in the basin includes 9 previously authorized projects

and 21 additional projects including 5 multiple-purpose reservoirs, 9 local-protection projects, and 7 channel improvement projects. The flood control storage in the reservoirs will be effective in reducing peak discharges and flood damage on the White River and tributaries and in addition reduce floods on the Mississippi River. The local protection to about 112,000 acres lying along the White River and a number of its tributaries, including small urban areas in Harrison, Clinton, and Jud Sania, Arkansas. The channel-improvement projects, with the exception of Departee Creek, will be constructed as major outlets for local drainage projects in connection with flood control and will provide flood protection to about 399,000 acres of agricultural land and to a small urban area in Holly Grove, Arkansas. The primary flood control benefits that will result from the projects in the long-range plan, excluding those authorized for construction, will amount to about $4,991,000 annually, of which $2,575,400 is damages prevented and $2,415,600 is attributable to changed land use. In addition, the land-treatment program will reduce flood water and sediment damages in minor tributaries by $2,230,000 annually.

(d) Red River Basin Above Denison Dam:

The long-range plan of development for the water resources of the upper Red River Basin would reduce property damage through flood control and flood forecasting measures and would increase the agricultural productivity of the area through irrigation, drainage, flood control, and water flow retardation. In the plan it is recognized that the water resources should be protected from pollution and that a large part of the surface water resources which are of suitable quality should be used for municipal and industrial purposes.

In the Washita River Basin, the previously recommended Foss and Fort Cobb projects would supply municipal and industrial water to Anadarko, Chickasha, Clinton, and Elk City, and possibly to a number of additional smaller towns. Gracemont reservoir on Sugar Creek and Purdy Reservoir on Rush Creek are potential sources for municipal and industrial water.

The plan includes drainage facilities for 39,625 acres of land along the Washita River and its tributaries, about 72 percent of the total wet land area in that locality. Drainage works would consist generally of group and on-farm facilities discharging directly into adjacent streams. Flood control is prerequisite to drainage improvement in all these areas.

The plan includes hydroelectric generating facilities at the Gainsville Reservoir site, located on the Red River just above Lake Texoma. The Gainsville power plant with an installed capacity of 100,000 kilowatts would assist in meeting the future power needs of the area.

(e) Red River Basin Below Denison Dam:

Plan of Development: In addition to the projects already constructed or under construction, the flood control plan for the lower Red River includes several projects that have been authorized but not yet constructed, and a number of additional elements. The authorized projects include three reservoirs on major tributaties above Fulton, and two on major tributaries below Fulton, which, together with the completed and under construction reservoirs and the levee systems, will provide a high degree of protection to the Red River valley. Also authorized or previously recommended are Cooper reservoir on South Sulphur River, Texas, several levee and channel improvement projects, and

bank stabilization on Red River at locations where levee setbacks are not practicable. Other elements added to the flood control plan include Sandy Creek Reservoir on Blue River, Tupelo Reservoir on Clear Boggy Creek, Kisatchie Reservoir on Bayou Kisatchie, 7 reservoirs in the Little River Basin, 527, waterflow retardation structures, 28 local protection projects, and additional bank stabilization works along the Red River between Denison Dam and Boyee, Louisiana.

It is estimated, that the primary flood control benefits that will result from the projects in the long-range plan, excluding those previously authorized and recommended, will amount to $6,328,000 annually of which $3,119,000 will be flood losses prevented and $3,209,000 will be benefits from changed land use. In addition, the Department of Agriculture has estimated that the land-treatment program will reduce flood water and sediment damages in minor tributaries by $1,595,000 annually.

(f) Ouachita River Basin:

Plan of Development: Authorized flood control projects on which construction has not been initiated include the multiple-purpose Degray Reservoir, the Murfreesboro Flood Control Reservoir, the local protection project for Calion, Arkansas, extension of the Monroe, Louisiana flood wall, and the Bayou Bartholomew and tributaries channel improvement project. The existing, under construction, and authorized flood control projects in the Ouachita River Basin, together with the levees and other flood control improvements constructed under the Mississippi River and tributaties project, will provide considerable flood prevention benefits in the basin.

The primary flood control benefits that will result from the projects in the long range plan, excluding those previously authorized and recom-

mended, will amount to $389,000 annually, of which $145,000 will be flood losses prevented and $244,000 will be benefits from changed land use. In addition it has been estimated that the land-treatment program will reduce flood water and sediment damages in minor tributaries by $546,000.

CHAPTER III

HYDRO POWER

3-1. General

The object of this section of the report is to present information on the existing electric power supply of the region, including hydro electric power facilities; the need for additional power supply to serve the future power requirements of the region, and the hydroelectric power potential that may be utilized by 1975 in a comprehensive plan for multiple-purpose development of the Arkansas - White - Red river basins.

3-2. Development of Work Procedures

Shortly after organization of the Arkansas - White - Red basins Inter Agency Committee, this committee established the Hydroelectric Power Work Group with membership composed of state and federal agencies having an interest in power development and utilization, and with the federal power commission made responsible for coordination of the studies involved in this section of the report.

3-3. Investigations

(a) Prior Surveys and Reports: - There are many reports that have been prepared previously relating to various aspects of the power situation in the southwest and in portions of the A. W. R. basins, including power market surveys and hydroelectric power investigations, which have provided a source of information for studies in this section.

(b) Survey of Reported Hydro Power Potentialities: - This survey was initiated for the purpose of compiling engineering information on all reservoir projects which, by law or circumstances, were regarded as basic to the planning of A. W. R. reservoir systems and those which, having been previously studied, might become desirable components in the formulation of comprehensive river basin plans. In addition to projects in operation or under construction, the basic projects included those authorized for construction by Congress or state legislatures, and those that have been or may be hereafter approved or recommended at departmental level for presentation to the Congress. These latter type projects are hereafter referred to as proviso clause projects in accordance with the "proviso clause" in the 1950 flood control act.

3-4. Criteria

The survey of hydro-power potentialities in the three basins included detailed data on reservoirs having a total storage capacity of 5,000 acre-feet or more and only general data on the smaller reservoirs. Detailed data were also procured on those hydroelectric projects having a power installation of 100 kilowatts or more, without regard to the associated storage volume.

3-5. Results

As a result of the survey, pertinent data were procured on approximately 60 existing and potential hydro projects with installations of 100 kilowatts or more, approximately 100 non-power reservoir projects of 5,000 acre-feet or more of storage and over 700 reservoir projects with a storage of less than 5,000 acre-feet.

3-6. Investigations of Hydroelectric Potentialities

Criteria - Previously proposed projects: - The power features of

previously proposed hydroelectric projects throughout the A. W. R. Basins were reappraised in the interest of determining whether these projects would meet certain criteria established for projects to be included in the A. W. R. plan. This reappraisal took into account and included consideration of the following aspects which would affect the power features of the projects: new or supplementary project data; interstate water compacts, water use priorities, new operating criteria; multiple-purpose water uses; improvements in economic feasibility, and project modifications and alternatives.

3-7. New Projects

The aspects of the new power projects were examined to appraise economic necessity and feasibility, functional adequacy, hydraulic and electrical coordination, project design, project operation, and project costs.

3-8. Establishing the Need

The future need for additional dependable electric utility generating capacity in the A. W. R. Basins power market region has been developed for the years 1960, 1965, 1970, and 1975 by determining the differences between the estimated requirements of the load and the capacity available. The data indicate that there will be a need for additional dependable capacity amounting to 1,063,000 kilowatts by 1960 and 11,007,000 kilowatts by 1975.

3-9. Power Market Region

The power market region, which was selected as the logical outlet for power to be developed at proposed hydroelectric projects in the area, encompasses approximately 554,000 square miles or nearly twice the area within the physical boundaries of the basins considered. The market region

includes all of the states of Arkansas, Kansas, Missouri, Oklahoma and part of Colorado, Louisiana, Mississippi, New Mexico, and Texas as shown in Figure 3-1. Population of the market region was 16,566,691 in 1950 or 11 percent of the total United States Population.

3-10. Selection

Determination of the market region boundaries was governed largely by the following factors:

1. The magnitude and characteristics of the potential hydroelectric power supply available from existing, authorized, and proposed projects.

2. Location of the proposed multiple-purpose projects.

3. The location and size of future power loads and their distance from the proposed projects.

4. The extent to which the proposed projects would compete with projects in other regions.

5. The location and characteristics of the existing power production facilities and transmission facilities.

3-11. Subdivisions

Electric power supply and requirements data and estimates of future loads were prepared for each of the 22 power supply subareas shown in Fig. 3-1, each of which contains a rather closely interconnected group of electric utility systems for which detailed power data were available. In order to make a more comprehensive analysis of the data and estimates of future loads for areas that are closely related electrically and geographically to the proposed hydroelectric projects in the three river basins, the 22 subareas were grouped into eight areas designated A through H. The power supply subareas and principal states included in each area are given in Table 3-1.

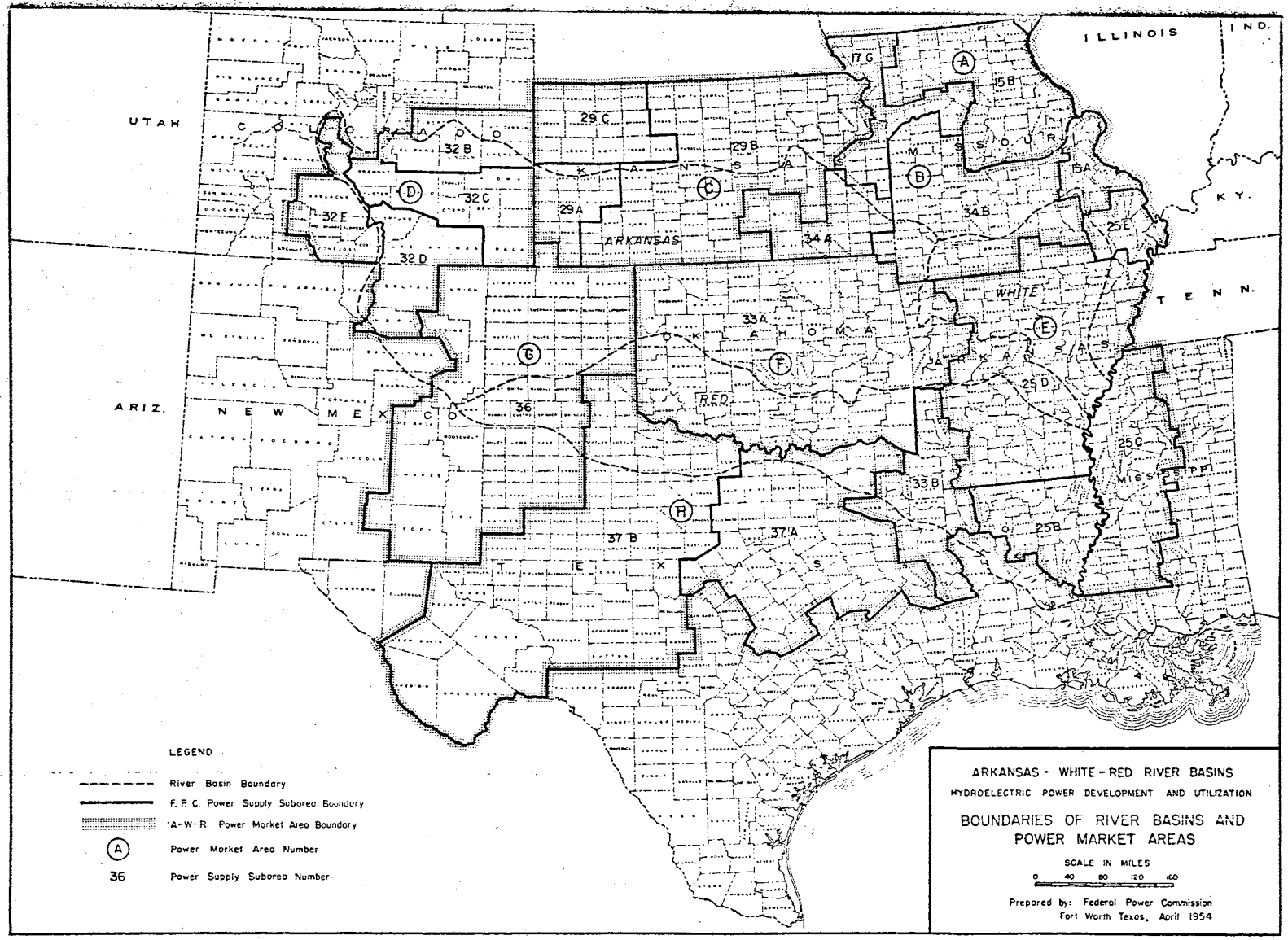

Figure 3-1. Boundaries of River Basins and Power Market Areas

TABLE 3-1

POWER SUPPLY SUBAREAS

Area	Power-Supply Subareas	Principal States
A	15-A, 15-B, 15-C	Missouri
B	17-G, 34-A, 34-B	Kansas, Missouri
C	29-A, 29-B, 29-C	Kansas
D	32-B, 32-C, 32-C, 32-E	Colorado
E	25-B, 25-C, 25-D, 25-E	Arkansas, Louisiana, Mississippi, S.E. Missouri
F	33-A, 33-B	Oklahoma, Texas, Western Arkansas, N.W. Louisiana
G	36	Texas, Eastern Mexico
H	37-A, 37-B	North central Texas

From page 16, Part II, section 7, A. W. R. Basins Inter-agency report on Hydro Power.

3-12. Market Areas for Proposed Hydro

Area D is considered to be the power market for proposed hydroelectric projects in the upper portion of the Arkansas River Basin. Power from hydroelectric projects in the lower portions of the A. W. R. Basins would be marketed primarily in areas B, E, F, and H, and to some degree in the fringe areas A, C. and G.

3-13. Inventory of All Existing Power Facilities

The inventory of electric generating plants in the A. W. R. market region included all electric utility generating plants and all industrial generating plants of 1,000 kilowatts capacity or more. In addition, all transmission lines of 22 kilovolts capacity or more were taken into account and firm power transfers into and out of the market region were

examined in this inventory.

3-14. Installed Capacity

The total installed capacity of electric utility system is shown to be 7,230,000 kilowatts. Classified by type of prime movers, 81.0 percent of the total installed capacity was steam electric, 8.7 percent internal combustion; and 10.3 percent hydroelectric.

3-15. Energy Transfers Over Regional Boundaries

The following tabulation lists the net transfer of energy over the regional boundary from each area during 1952:

TABLE 3-2

ENERGY TRANSFERS

Area	Exports Million Kilowatts	Area	Imports Million Kilowatts
A	160	D	50
B	94	H	4
E	530		

From page 20, Part II, Section 7, A. W. R. Basins Inter-agency report on Hydro Power.

3-16. Interconnection Between Areas

It is seen that each of the eight study areas A through H inclusive contains the electric facilities of one or more electric utilities which are closely tied together. The interconnections between adjacent areas have a carrying capacity capable of handling surplus generating capacity available for inter area flow except in the case of Area D. Area D is largely an isolated area.

(a) Effects of Fuel on Transmission Facilities:

The use of natural gas as a fuel in the market region under study has permitted the location of fuel electric generating stations within large market centers which in turn has brought the transmission line terminals of the market region within city limits.

3-17. Past and Estimated Future Power Requirements

Estimates of electric energy requirements are developed for the years 1960, 1965, 1970 and 1975. Independent estimates have been prepared for six major consumer groups by power supply subareas in order to give individual consideration to the type of consumer, the climate, and the economic conditions expected to prevail in each part of the A. W. R. market region. The aggregate estimated power use has been combined with appropriate allowance for energy losses to yield the total energy requirements by subareas, areas, and for the market region. The six energy use classifications considered are as follows: farm, residential, commercial, industrial, irrigation and other. Future use of electric energy has been related primarily to economic factors such as the location, climate, physical characteristics of the land, and natural and human resources.

3-18. Population

Population trends of farm and nonfarm residential persons and the number of farms were analyzed for each subdivision of the market region. Future estimates of this human resource were based on a study of the known natural resources such as farm land, timber, minerals, water, and the activity resulting from the processing of agricultural projects, the mining of minerals, and the industrial and commercial potentials accounted for by the manufacture of finished products needed in the region.

3-19. Energy Requirements

Total energy requirements for the market region were 25,753 million kilowatt hours in 1950 and 33,598 million kilowatt hours in 1952, or an increase of 30.5 percent in two years.

3-20. Peak Demands

An analysis was made of the 1950 and 1952 peak demands of each utility system, and the annual noncoincident and coincident peak demands were obtained for each power supply subarea and area. The noncoincident peak demand is the sum of the maximum annual demand on all utility systems in an area without regard to time of occurrence. The annual coincident peak demand is the maximum simultaneous demand of the utility systems of an area during the year. The average annual load factor may be determined from the coincident peak demand and the total energy requirements. The load factor of a system is the ratio of average demand to the maximum demand during a designated period. Future coincident peak demands have been calculated by applying an estimated annual load factor to the total energy requirements.

3-21. Load Characteristics

The annual peak demand on a utility system is greatly affected by climatic conditions. The peak demand occurs during a series of very hot summer days in Areas E. F. G. and H due to coincident operation of electrical air-conditioning equipment. Areas A, B, and C are in the northern part of the market region, and the historic peak demands have generally occurred during the winter. The seasonal occurrence of peak demands in different regions at different seasons may create an annual load diversity between areas. Greatest diversity occurs between Areas D and G where there is a winter peak in Area D, and a summer peak in Area A that is

caused by a combination of summer heat and irrigation pumping.

3-22. Projects Existing and Under Construction for Hydroelectric Power Generation and Transmission

Existing - All of the private hydroelectric developments in the A. W. R. Basins are in the category of existing equipment. There are no new capacity additions under construction or scheduled for construction at the present time. All of the privately owned stations were constructed for the main purpose of power generation and are, in main cases, located at favorable sites involving a rather inexpensive dam and reservoir and providing a substantial source of electrical energy in comparison to the investment. None of the privately owned reservoirs provide for flood control storage. The majority of the plants are considered as the run-of-river type and only three reservoirs have sizeable power storage as follows: Carpenter and Remmel on the Ouachita River with 119,560 and 20,000 acre-feet, respectively, and Ozark Beach on the White River with 11,000 acre-feet. The plants in Colorado are high head plants while the others are primarily low head plants - Carpenter and Remmel having the highest gross heads, of this latter category, of 95 and 50 feet, respectively. The only privately owned plant with sizeable units is the Carpenter plant with two 28,000 kilowatt units. Ozark Beach is next in size with four 4,000 kilowatt units.

3-23. Federal Hydroelectric Projects

Existing - There are six federal hydroelectric projects in service in the A. W. R. Basins as follows: Denison, Norfork, Narrows, Bull Shoals, Fort Gibson, and Tenkiller Ferry projects. These projects are operated by the corps of Engineers and the power is marketed by the Southwestern Power Administration, United States Department of the

Interior, under authority of the 1944 Flood Control Act.

3-24. Transmission Facilities

The Grand River Dam Authority has provided a transmission system which is a component of the regional interconnected system. It connects the pensacola project with Tulsa, Muskogee, and other load centers in northeastern Oklahoma. The two hydro plants owned by the city of Colorado Springs are connected by short lines to the municipal system which is, in turn, connected with Pueblo and Canon City.

3-25. The Plan of Improvement for Hydroelectric Power Development and Utilization

General Criteria - The plan of improvement for hydroelectric power development and utilization should be based upon the integration of existing and potential hydro and fuel-electric facilities. The potential hydroelectric development will be influenced by proper consideration of flood control, irrigation, industrial and municipal water, and other water uses from other sources, and power generation. Power utilization is dependent upon the power market with proper integration of hydro and fuel-electric facilities.

3-26. Power Studies

(a) Stream Flow:

Power studies were based upon the best official stream flow records available, correlated where necessary to establish stream flows at hydro plant sites for which no flow records are available. Actual or synthetic flows used are historical flows and therefore represent natural conditions except where regulated by existing upstream projects.

(b) Evaporation and Sedimentation:

In studies for the potential or non-proviso clause projects, allow-

ance was made for the effects of evaporation anticipated, downstream channel degradation, and the limitation placed on size of the hydro installation at several mountain stream sites by the downstream channel capacity.

(c) Power Releases:

All releases at the power sites could not advantageously be utilized through the turbines for power generation. It is contemplated that low-load factor peaking plants would not operate on Saturdays and Sundays. Therefore, small non-power releases were assumed to be made on these days to sustain minimum stream flows for pollution abatement and preservation of fishery resources.

(d) Power Drawdown Storage:

Whenever possible the power drawdown for an individual project or river system was based on an optimum value of QH (the product of net power discharge times available net head) using average values for the critical period. Concentration of regulatory storage in upstream reservoirs has been utilized in several of the river systems. It has the advantage of minimizing the drawdown at downstream reservoir projects or allowing the use of fixed head river-run plants, and in either case permits dependable operations at or near the installed capacity of the downstream projects.

3-27. Inter-Basin Coordination of Hydroelectric Projects

There are 45 existing, proviso clauses, and potential major hydro plants, all located within a radius of 200 miles and within an area composed of portions of the lower Arkansas Basin, White and Red River Basins, and lying in the states of Oklahoma, Texas, Missouri, and Arkansas. A number of these plants located in different river basins

are electrically interconnected or supply the same load area. The proximity of these three river systems to each other and the diversity in stream flow which has been shown to exist to some extent among them suggests that in a long range plan of power development and utilization there will be sufficient interconnection throughout the market areas which these plants will serve to justify an analysis of the 45 plants as a system. Consequently, a detailed ranking study was made for the 45 plants listed in the Table 3-3.

3-28. Coordination of Hydroelectric and Other Power Supply

To coordinate the hydroelectric supply, transmission facilities, and load area requirements, it is necessary to first consider the load area requirements and how they can be met by proper coordination of steam and hydro generation. This supply to the power market is transported by adequate transmission facilities.

3-29. Maximum or Ultimate Development Possibility

The estimated 1975 development would provide for utilization of the ultimate installation at all the existing and under construction, proviso clause, and potential projects (A. W. R. plan) in the three basins. It is emphasized that this is only a demonstration of the fact that, if constructed, the output of all these plants could be utilized.

3-30. Conclusions

The development of hydroelectric power from multiple-purpose projects in the A. W. R. Basins is generally contingent upon and related primarily to the use of water for municipal, industrial, agricultural, and navigation purposes, and to protection against floods.

It is the need for these other water uses that controls the development of hydroelectric power, except in the few instances where projects

TABLE 3-3

EXISTING PROVISO CLAUSE AND POTENTIAL MAJOR HYDROELECTRIC PROJECTS

Arkansas Basin	White Basin	Red Basin
Keystone	Beaver	Gainesville
Golagah	Grandview	Denison
Pensacola	Table Rock	Pine Creek
Markham Ferry	Ozark Beach	Lukfata
Fort Gibson	Bull Shoals	Sherwood
Webbers Falls	Colter	Broken Bow
Chewey	Buffalo City	De Queen
Tenkiller Ferry	Gilbert	Gillham
Eufaula	Lone Rock	Dierks
Short Mountain	Norfork	Blakely Mountain
Ozark	Wolf Bayou	Carpenter
Dardanelle	Hardy	Remmel
Nimrod	Greers Ferry	Rockport
	Judsonia	De Gray
		Narrows
		Riggs Bluff
		Kirkland
		Benton

From page 79, Part II, Section 7, A. W. R. Basins Inter-agency report on Hydro Power.

are recommended only for the generation of power in connection with related multiple-purpose systems.

CHAPTER IV

WATER POLLUTION CONTROL

4-1. Investigations

Investigations pertaining to water pollution control have been carried on by state and federal agencies for many years. Information on water uses, sources of pollution, effect of pollution, and other related information has been obtained and made a part of the records of the several state and federal agencies through the years. The federal water pollution control act of 1948 required the public health service to prepare or adopt comprehensive water pollution control programs in cooperation with the states.

4-2. Water Uses Affected by Pollution

The uses of water resources vary with the different geographic and climatic conditions, and the many diversified economic activities found across the basins. The important water uses pertinent to the subject of water pollution control are domestic and industrial water supplies; agricultural use, including irrigation and livestock watering; recreation, including bathing, boating, and other activities; production and utilization of fish and wild life, power development, navigation and ultimate waste disposal.

Throughout the arid and semiarid areas of the western third of the basins, extending from the Rockies to the 98th meridian, the available waters are used mainly for agricultural purposes although domestic

and municipal uses are important. Ground waters are intensively developed in local areas. In the central basins area, which supports the main centers of population and industrial activity, water resource developments have been initiated mainly to meet municipal and industrial needs. Other uses include the production and harvesting of fish and wildlife resources, and power generation. Ground waters are insufficient in quantity to supply many of the larger communities in the central area. In the eastern portion of the basins, although surface water is abundant, the majority of the smaller communities utilize ground water.

4-3. Sources of Pollution and Damages

Pollution contributed to the water resources of the basins may be listed under the following three general types according to source.

(a) Municipal Pollution: Sewage and other wastes discharged with or without treatment from incorporated or unincorporated municipalities, other legal bodies as sanitary districts, counties, towns, institutions, resorts, recreational centers or other population centers, and industrial wastes discharged into municipal sewer systems.

(b) Industrial Pollution: Industrial production or process wastes which are discharged with or without treatment to water courses through separate outlets not connected to municipal sewers, or which are discharged to underground aquifiers.

(c) Natural: Salinity exclusive of that resulting from man's activities and sediment resulting from erosion of lands.

Municipal Pollution

There are 759 source-systems of municipal pollution in the A. W. R. area serving about 3,360,000 people. Treatment of wastes is provided at 649 of these systems, serving approximately 2,650,000 people. The

total domestic waste load is reduced about one half by this treatment.

Data collected over decades have resulted in a high degree of understanding of municipal pollution problems. The major problems result from bacterial contamination which endangers municipal water supplies and bathing areas located downstream from sources of municipal pollution. In addition, other problems frequently created are those involving muisances, damages to aquatic life, lowered property values, potential health hazards, and aesthetic considerations.

Industrial Pollution

Industrial pollution results in considerably greater problems than does pollution from municipal sources. There are at least 460 industrial plants in the basins, exclusive of oil and gas fields, which are actual or potential sources of pollution.

Pollution problems in connection with the food, paper, and other industries producing organic wastes, are primarily of local importance because the streams have remarkable powers to assimilate such wastes after adequate treatment. Satisfactory abatement measures in most cases are known and can be applied. Nevertheless, the discharge of organic industrial wastes often results in serious pollution problems. Food industries frequently are located on small tributaries where water flows may be insufficient to prevent the occurrence of local nuisances. Then, too, this type of industry may operate intermittently or seasonally, and therefore may be reluctant to pay the cost necessary to provide adequate waste treatment.

The most important single type of industry in the basins area, both numerically and from the standpoint of pollution, is the oil and gas industry. There are more than 1,800 oil and gas fields in the

basins, some of which are sources of pollution. These fields are located principally throughout the central portion, in northern Louisiana, southern Arkansas, and in the panhandle of Texas. There are 172 counties in the basins in which oil and gas fields are located. This is approximately 52 percent of the counties in the basins.

Pollution problems associated with the oil and gas extraction industry, mining, chemical, and other industries producing inorganic waters are of an extremely serious nature. They are serious because of the toxic characteristics of some inorganic wastes, or because this type of waste is not readily assimilated by receiving waters. Inorganic wastes frequently damage many miles of receiving waters and only cease to be harmful when sufficiently diluted. Industrial wastes are often complex and variable. Treatment methods for certain wastes, for example, from the chemical industry, are difficult to determine and treatment may be expensive. Certain industrial wastes are much more deleterious than municipal sewage and some, besides having toxic or adverse taste and odor characteristics, use more of the normal oxygen content of the water than do municipal wastes. A single paper mill or meat packing plant may produce wastes equaling in strength the sewage from a city such as Tulsa, Oklahoma.

4-4. Pollution Control Facilities

Considerable progress in providing pollution control facilities for the protection of surface and ground water resources has been made in recent years. This has been achieved through the program activities of the State health departments, or water pollution control agencies, in cooperation with other state agencies, municipalities, industries, federal agencies, and other groups having interest in conservation of

water resources. Principal progress has been in the field of municipal waste treatment, and some progress has been made in treatment of industrial wastes.

The available data on oil field brine disposal facilities are not sufficiently uniform in nature to permit breakdown into numbers of units discharging untreated wastes or providing adequate brine disposal. However, brine disposal by reinjection into the oil-bearing strata or injection into salt water acquifers is being carried out in most fields developed since 1937 and also in some fields developed prior to that time. Subsurface injection is recognized as the most satisfactory method of brine disposal. In addition, when it is feasible to return the water to the oil-bearing strata the industry frequently benefits as the reinjection of water in many instances increases the ultimate oil recovery.

4-5. Required Facilities

Although most of the sewered municipalities in the three basins have some type of sewage treatment plant, there is indicated an immediate need for a number of plants where treatment is not now provided, and for the expansion or improvement of a substantial number of existing plants to render them adequate and effective for protection of the receiving waters. Eighty-two municipalities, with a sewered population of 298,600, need new plants for the treatment of wastes at present discharged raw. This number includes one municipality not now having a sewage collecting system. One hundred and eighty-six municipalities, with a sewered population of 907,600, need enlargements or additions to existing plants to increase capacities, improve operation, or to provide secondary treatment; 73, with a sewered population of 101,500,

need replacement of existing plants; 368, with a sewered population of 1,662,500, require no improvements; and the needs of 50 municipalities serving 384,800 persons are undetermined.

4-6. Other Needs

There are a number of pollution abatement needs other than physical needs which arise from the pollution control program itself. These include such items as new legislation, public education, financing, interstate compacts, and research.

In general, additional financial support needs to be provided by state legislatures. Additional financial support will enable existing programs to be carried on at a faster pace. It will permit agencies responsible for pollution control to build their staffs to adequate level, and to carry on additional surveys and investigations which are so necessary to adequate collection of data upon which control measures must be based.

Legislative changes are needed in several states to improve administration and financing of water pollution control programs. New problems may be expected to arise in the future, and periodic review of existing legislation should be made by interested agencies for the purpose of maintaining satisfactory control authority.

Although the problems of sanitation are as old as man, scientific research in the water pollution control field is relatively new. The advances in fundamental knowledge stemming from basic research makes possible applied and developmental progress in problem areas. Additional research on all phases of waste disposal is needed to hasten progress in pollution abatement.

Fields of research or investigations that are of major importance

in these basins include:

(a) More effective and economical ways to control pollution by oil field brines are needed, including ways to reduce the amount of brine produced and to lessen the problems of subsurface disposal.

(b) Feasibility investigations for abatement of natural pollution, particularly salinity, are needed.

4-7. Integration of Water Pollution Control with Other Programs

Additional development of projects which serve to control the flow of water in the basins continually enlarges the area of regulated streams and waterways. The changes in stream flow characteristics resulting from the construction and operation of stream regulating devices can be either a benefit or a damage to a water pollution control program. Many streams have widely varying natural flows and waste treatment works must be based upon critical low flow conditions. To be effective in preventing damages the development of water resources must be coordinated and integrated with pollution control programs. If this is done in the planning stage and continued as a part of the permanent operation, maximum economic benefits can be derived from the basin's development with minimum deleterious effects upon the health and physical welfare of the population.

Low-flow augmentation can also benefit water quality and hence, water users, by improving chemical and physical quality during low-flow periods. In some cases it is possible to reduce the degree of waste treatment required by storing flood waters for release during low-flow periods. In addition, augmented stream flows would benefit other water uses, such as recreation and fish and wildlife. Low-flow augmentation may be provided by seasonal use of flood control storage or by provision

of storage specifically for low-flow regulation.

In the final analysis, the best purpose will be served by the participation of the health agencies in the planning stages of water resource developments to insure that such developments will protect public health and, through pollution control, important water uses.

4-8. Administration of the Plan

Administering the program for controlling water pollution is primarily a responsibility of state pollution control agencies. In states where more than one agency has responsibilities related to water pollution control it is important that the programs of such agencies are properly coordinated in the over-all control program. Typical activities engaged in by these agencies include the following:

(a) Collect basic data to determine the source, type and amount of pollution.

(b) Hold public hearings regarding pollution problems.

(c) Promote construction of treatment facilities.

(d) Encourage recovery and use of waste products.

(e) Provide technical aid and research.

(f) Review and approve sewerage plans and specifications.

(g) Conduct inspections and provide operational assistance for sewage treatment facilities.

(h) Evaluate pollution problems and required remedial measures.

(i) Enforce pollution abatement laws.

(j) Promote, sponsor, and participate in municipal and industrial waste treatment short courses.

The solution of individual pollution problems and the provision of necessary waste treatment facilities for pollution abatement is the

responsibility of the communities, industries, or individuals producing and discharging the wastes causing pollution of public water courses.

4-9. Conclusions

Preservation and improvement of water quality is essential for the best utilization of available supplies, and for the prevention of nuisance conditions and protection of public health. Pollution control should be an integral part of comprehensive river basin programs, with full consideration given to this objective from the beginning of the planning process. In general, the overall plan for land and water resources development within the basins will have a beneficial effect on water pollution control principally through reduced salinity, increase in low flows, and sedimant reduction.

CHAPTER V

AGRICULTURE

5-1. Soils and Their Parent Materials

Variations in soil characteristics are very important fundamental considerations to the practical and effective solution of conservation and improvement problems and in the use and values of soils for agricultural purposes. In the formation of soils, the active forces are principally the climatic and vegetative elements of an area working on parent rock. These forces are conditioned by slope and act over long periods of time.

Rainfall, temperature, and humitidy all influence fertility and productivity of soil. Soils of the A. W. R. basins vary greatly because of the wide variation in the geological, climatic, and vegetative pattern.

5-2. Climate

One of the conditions that accounts for much of the variation in agriculture is climate, including temperature, frost-free season, wind, evaporation and transpiration, precipitation (rain and snow), rainfall intensities and humidity. Not only do climatic factors put natural limitations on kinds of agricultural enterprises, but they also require that solutions to agricultural problems be in keeping with these climatic limitations and adapted to natural conditions. Climate is a major determinant of natural vegetative patterns. In the A. W. R. area, climate

varies from semiarid to humid.

5-3. Precipitation

The annual precipitation ranges from about 60 inches, practically all as rainfall, at the mouth of the Red River in Louisiana, to only about 10 inches in parts of the New Mexico and Colorado plains area.

In the main humid climatic belt the 40 inches or more of annual precipitation provides normally sufficient to excessive moisture for adapted kinds of farming and for support of good forest growth. Vagaries in annual and growing season precipitation patterns, with an increasing proportion of quickly dissipated warm season rainfall, along the drier western fringe of the humid area, is an important limitation to farming and to good forest growth. Sleet storms occur frequently in north Arkansas and Missouri. Rainfall intensities with maximums up to 6-8 inches in 24 hours can be expected.

5-4. Temperature and Frost-Free Seasons

Temperature patterns in the A. W. R. area are directly related to elevation and distance from the Gulf of Mexico. Mild temperatures prevail in the low, moist areas of the lower watersheds in the southeast, while rigorous winter temperatures are experienced in the higher plains areas, the mountain areas, and in the northern Arkansas and White river basins in Colorado, Kansas, and southwestern Missouri. Extreme day to night fluctuations occur in the drier and higher western part, furthest from the Gulf (averaging about 30°F) while the low-lying moist southeastern part has a very small (10°F) average fluctuation. The spread between maximum and minimum temperatures is great in the interior north and western areas - up to 136°F - compared to only about 100°F in the southeast. All of these things have a bearing on the

agriculture of the A. W. R. Basins, including crop adaptation, farming methods, and need for special treatments for land and crops, the care and management of livestock, and other aspects.

5-5. The Agricultural Economy

Resource plans and programs being developed for the A. W. R. basins deal mostly with physical factors - land, water, and minerals. Land is a primary agricultural resource, but, as with water and minerals, it must be effectively developed and efficiently managed to provide for the needs of the people. About three-fourths of the land area in the basins is in farms and ranches. Thus, the basin's farm land area cannot be regarded simply as one vast tract for physical development. Economics enters into the management and organization of this land area and largely accounts for the way farms and ranches are operated, the intensity of use, and the enterprise combinations selected. Conservation of the land and its development, and the production from it, are directly tied to the independent decisions that will be made by the half million farmers and ranchers who farm the land. An effective plan must always give consideration to the economic status of the people of the area.

Programs and projects for waterflow retardation, irrigation drainage, farm forestry, conservation of farm land and range land and most flood-control projects depend largely upon agricultural land to produce the benefits that justify the plan. Therefore it is of utmost importance that the agricultural economy of the basins be given major consideration in developing plans that affect land use and production. To be successful in the long run, agricultural resource plans must be economically feasible as well as physically possible before farmers will adopt them

on a wide scale.

The economy of the Arkansas, White and Red Basins is primarily rural, with agriculture of major importance. About 29 per cent of the population within the basins was classed as "rural farm" by the 1950 census. Marketing of crops, livestock, and livestock products by the 519 thousand farmers and ranchers in the basins amounted to 1,776 million dollars in 1949 and comprised 8 per cent of the Nation's total agricultural product sales for that year. In addition to farm products sold, the basins' farmers are estimated to have used for home consumption products valued at about 225 million dollars. Thus, agriculture in the basins was more than a 2-billion dollar business in 1949. These data indicate the importance of agriculture in the economy of the basins and emphasize the reliance of the people upon farm land as a major primary resource from which they derive their living.

5-6. Major Uses of Public Land

In general, most of the land that is suitable for crop production is in private ownership. In most grazing areas land that is strategically located from the standpoint of water facilities is also privately owned. The ownership pattern of federal land greatly complicates its administration and creates many problems of utilization. For the country as a whole, federal ownership in 1950 included more than 3 thousand reserves and special-use areas and thousands of scattered tracts. Generally, the reservations and special-use areas are interspersed with private holdings. This complicates and intensifies the problems of managing the land in federal ownership.

5-7. Types of Farms

Type of farming is influenced by such factors as soils, topography,

climate, and availability of markets. Cotton farms were the most prevalent classified type in the A. W. R. Basins in 1950. Livestock farms were the next most important type with cattle and calves sold for beef the principal sources of income on these farms. Hogs in the eastern parts of the basins and sheep and wool in the western areas were also important income-producers on livestock farms. Of the cash-grain farms, wheat farms in the western parts of the basins, and rice farms in Arkansas, were of particular importance. Farms where no one source of sales amounted to as much as 50 per cent of the value of all farm products sold were classified as general farms. Non commercial farms and those unclassified accounted for over one-third of the total farms in the basins.

5-8. Conservation and Improvement of Farmland and Rangeland

The program of conservation and improvement of farmland and rangeland deals with needed treatment on all the croplands and grazing lands of the A. W. R. basins area, both public and private, except federally owned lands administered by the U. S. Forest Service.

In program formulation the basic soil conservation objective of the Department of Agriculture has been a guide - "the use of each acre of agricultural land within its capabilities and the treatment of each acre of agricultural land in accordance with its needs for protection and improvement." To accomplish this objective an endeavor was made to plan land use changes and treatment measures that would restore and improve the soil-resource base to the minimum point where it could be protected and soil losses controlled. This has automatically included the kinds and quantities of land-treatment measures desirable for water flow retardation and sediment control on the watersheds of the streams

of the A. W. R. basins. In addition there are measures which have little or no effect on the hydrology of a watershed but which are effective in stabilizing areas against wind erosion or water erosion in non-contributing areas, or in restoration of the soil-resource base to the required point for protection and control of soil losses.

5-9. Benefits Accruing from Application of Program

Table 5-1 shows the estimated increases in present annual agricultural-production values and net income obtainable from application of the program of conservation and improvement to the croplands and grazing lands of the A. W. R. area, by states and basins. In reviewing these estimated increased values, as well as other measured benefits, the following facts must be clearly associated:

(a) They are based upon crop and pasture production accruals estimated by the several state teams assisting on the conservation and improvement of farmland and rangeland phase of the A. W. R. study.

(b) They are based upon an assumption of completion of the remaining program, full participation by all owners and operators, and full and effective maintenance of all existing measures.

(c) They are based on the assumption that necessary amounts of technical services, educational assistance, credit and financial aid, materials, supplies, and equipment are readily available and are fully used; also, that reasonable and sufficient demand for the products exists.

(d) They are based upon continuing the application of recurring measures at proper rates and intervals.

(e) They are based upon an assumption of completely effective land use adjustments to fit land capabilities. The assumption that the poorest

TABLE 5-1

INCREASED ANNUAL AGRICULTURAL PRODUCTION VALUE AND NET INCOME FROM PROGRAMS[1]
(THOUSANDS OF DOLLARS - PROJECTED PRICE LEVEL)

States and Basins	Present Agricultural Production Value	Present Agricultural Production Net Income	Increases from Current Program Installation Rates		Increases Resulting from Full Program Installation	
			Production Value	Net Income	Production Value	Net Income
Colorado	65,440	24,513	8,432	2,678	15,977	5,074
New Mexico	22,850	10,837	2,481	1,687	4,758	3,260
Kansas	361,266	217,342	45,143	26,325	85,661	49,953
Oklahoma	485,127	174,768	70,655	38,939	187,571	103,526
Texas	251,135	96,695	26,540	22,111	72,100	59,672
Missouri	77,025	30,127	30,011	16,574	48,764	27,100
Arkansas	272,914	99,748	60,612	32,811	197,461	106,867
Louisiana	79,689	22,904	15,980	9,242	66,975	38,734
Arkansas Basin	914,938	433,663	140,045	77,973	321,753	177,726
White Basin	167,095	62,432	44,118	24,458	106,972	60,289
Red Basin	533,413	180,839	75,691	47,936	250,542	156,171
Total AWR	1,615,446	676,934	259,854	150,367	679,267	394,186

[1] Production from cropland and grazing land only. Only value of agricultural production increases included. Net income is obtained by deducting increased associated costs from increased production values in accordance with A-47 procedure.

From page 107, Part II, Section 11, A. W. R. Basins Inter-agency report on agriculture.

lands for growing certain crops will be diverted to other crops and use for which they are better adapted becomes one of the major ways in which production increases are obtainable.

5-10. Flood Damage Reduction

In addition to the agricultural production values that have been outlined, the conservation and improvement measures are also essentially the land treatment that would be required to effect flood-damage reduction, where such damage exists. Forestry measures would also be involved in flood-damage reduction.

A land-treatment program accomplishes flood-damage reduction by alleviation of sedimentation damage to land, crops and improvements, and by reducing damage from inundation, particularly in upstream tributaries and reaches.

5-11. Benefits Not Evaluated

There are many benefits that may accrue from conservation and improvement of farmland and rangeland, in addition to those measured in terms of agricultural production and flood damage reduction. Some of these are direct and tangible while others are secondary in nature, indirect or institutional.

5-12. Further Intensification for Increased Production

The fundamental task of the state teams was to develop needs for land treatment to protect the land resource base. The result of studies by the state teams indicated that an additional 31 per cent might be expected in present annual value of agricultural production, as a result of applying the additional measures. With the 42 per cent annual increase that could be expected from complete application of the planned program, the potential annual agricultural production value is 73 percent more than its present value.

CHAPTER VI

FISH AND WILDLIFE

6-1. Investigations

(a) Previous Investigations

Investigations pertaining to the abundance, distribution and development of fish and wildlife resources in the A. W. R. basins states have been carried on by state and federal agencies for many years. Also numerous studies have been conducted by colleges, universities, and various other organizations.

The extent of the investigations made by the Game and Fish Agencies of the A. W. R states is indicated by the fact that since 1938 under the federal aid programs they have conducted 81 research projects and 167 development projects on both fish and wildlife in addition to many other studies carried out during the same period as a part of their regular programs and in conjunction with several cooperative wildlife management research units. These studies have been of varying scope, and range from state wide inventories to life history studies of a single species. Reports of these studies either have been published or are a part of the permanent libraries of the Game and Fish Departments.

(b) A. W. R. Investigations

At the beginning of the A. W. R. study, the Fish and Wildlife Service placed personnel in the field to assist the states in the conduct of an inventory of fish and wildlife resources. Available inventory

materials from past studies were compiled and, where gaps in the information existed, field reconnaissances were made to obtain necessary data. The inventory data were recorded on a county basis for all states except Missouri, where zoo-geographic areas were used.

6-2. Fishery Resources

Fish Habitat Types

The subsequent listing of fish habitat types includes those broad separable environmental conditions which appear to bear a significant relationship to the existence and management of fishery resources. Turbidity, bottom conditions, water temperature, permanency of flow, and stream gradient form the basic criteria for the various habitat types in natural water. Physical factors such as size and average depth enter into the classification of artificial impoundments.

6-3. Mountain Streams and Lakes

Principal characteristics of mountain streams are alternate riffles and pools of clear, cool water flowing over bottoms of rock and gravel. Species of fish commonly occurring in the mountain streams of the Ozark plateaus and Ouchita provinces are smallmouth bass, spotted bass, warmouth, rock bass, various species of sunfishes, yellow walleye, channel catfish, several species of suckers, and freshwater drum.

6-4. Lowland Streams and Overflow Areas

In the lowland areas, principally the Mississippi alluvial plain of Arkansas and Louisiana, are numerous streams and lakes variously referred to as bayous, creeks, sloughs, oxbows, cut-offs, "old rivers," bays, and brakes.

A large commercial harvest is taken from lowland water areas, and market

fishing constitutes full or part time employment for a significant number of persons. Trammel nets, gill nets, hoopnets, hall seines, trot lines, and snag lines are typical of the tackle employed by commercial operators. Buffalo fishes, cat fishes, fresh water drum, carp, paddlefish, and gars are the principal species harvested.

6-5. Major Valley Streams

Habitat of this type is common in the arid and semiarid regions where stream flow is extremely erratic. It is usually comprised of small, shallow streams winding back and forth across a wide expanse of sandy beds. Few sport fish species are found in these waters except for channel catfish. Other common species are blue catfish, flat head catfish, bullheads, carp, freshwater drum, buffalo fishes, paddle fishes and gars.

6-6. Plains Streams

Plains streams are confined to the eastern part of the A. W. R. basins. They are varied in character and possess some of the distinguishing features of mountain streams, lowland streams and overflow areas, and major valley streams. Banks and bottom conditions are fairly stable and there is always water in the deeper holes to assure fish survival during drouth periods. In the foothills the plains streams are quite similar to mountain streams except for a lower gradient.

Species composition varies with the location of stream segments. In the foothills, largemouth bass, spotted bass, warmouth, rock bass, bluegill, and other sunfishes are common. Cat fishes, carp, freshwater drum, gars, and buffalo fishes make up a larger portion of the populations in the lower reaches.

Reservoir Lakes: Reservoir lakes may be superimposed upon any

of the natural water areas, creating a variety of fish habitats. The majority of impoundments falling in this category have been constructed for water use and control purposes. Generally, they are the larger impoundments, usually in public ownership.

6-7. Existing Fish and Wildlife Programs and Facilities.

State Activities

General: Resident fish and game are the property of the state, and except for certain migratory species, the administration of fish and wildlife resources is carried out by designated state fish and game agencies. Although administrative needs vary from state to state so that different organizational functions are required, most states are engaged in basic programs which are practically parallel. These programs include law enforcement, fish and game management, research education, and the control of damage by wildlife.

6-8. Administration of Laws and Regulations

Regulation of the fish and game harvest is accomplished by provisions governing creel and bag limits, the season and method of harvest, and related restrictions. Regulations are designed to permit the largest harvest possible consistent with the maintenance of adequate breeding populations of the species concerned. Enforcement of laws and regulations is carried out by a warden force. The game warden, game protector, conservation agent, or ranger, as he may be known in various states, is the representative of the game and fish agency who is in closest day to day contact with the public. His position in this respect is of great importance, as the manner in which he interprets the regulations and objectives of his agency to hunters, fishermen, and land owners is responsible to a large degree for the success of

the state program. The game warden force may also be called on to engage in any of the activities of the game and fish agency.

6-9. Control of Damage by Wildlife

Damage control activities are directed toward the elimination or reduction of wild animals which may become undesirable because of their inroads on cultivated crops, domestic livestock, or game species. Control activities may include trapping or poisoning carried on by state personnel, or a training program which encourages the landowners concerned to cope with their own particular problems.

6-10. Creation of New Habitat

Construction of new fishing waters is an important activity where a deficiency of habitat precludes the meeting of fishing needs of local anglers. These developments are usually impoundments which have been specifically improved for fishing before filling. Improvements include fish concentrating devices such as sunken brush piles, rock piles, and small uncleared areas; gravel and building tile for fishing spawning aids; and boat launching ramps and fishing piers. Waters developed primarily for fishing or operated by the state game and fish agencies are enumerated in Table 6-1.

6-11. Habitat Improvement

This type of development is usually carried out by the game and fish agency on public lands, and entails regulation of grazing by domestic stock, food and cover restoration, and control of undesirable vegetation. Where management units include forest lands, silvicultural practices may be modified to improve game habitat without causing any significant loss in timber production. Habitat improvement on private lands includes such measures as cover plantings in waste

TABLE 6-1

STATE WATERS DEVELOPED PRIMARILY FOR FISH, OR OPERATED BY STATE GAME AND FISH AGENCIES, AWR BASINS

Name	County	Area Acres	Type of Development	Type of Fishing
New Mexico				
Cimarron Canyon	Colfax	70	Stream	Cold water
Charette Lakes	Mora	520	Lakes	Cold water
Clayton Lake	Union	170	Lake	Cold water
Kansas				
Barber County State Lake	Barber	77	Lake	Warm water
Cheyenne Bottoms	Barton	13,000	Lake	Warm water
Butler County State Lake	Butler	232	Lake	Warm water
Clark County State Lake	Clark	337	Lake	Warm water
Cowley County State Lake	Cowley	80	Lake	Warm water
Crawford County State Lake	Crawford	60	Strip pits	Warm water
Crawford County State Lake	Crawford	150	Lake	Warm water
Finney County State Lake	Finney	324	Lake	Warm water
Grant County State Lake	Grant	44	Lake	Warm water
Kearney County Lake	Kearny	3,000	Lake	Warm water
Kingman County State Lake	Kingman	80	Lake	Warm water
Lyon County State Lake	Lyon	135	Lake	Warm water
McPherson County State Lake	McPherson	46	Lake	Warm water
Meade County State Lake	Meade	100	Lake	Warm water
Montgomery County State Lake	Montgomery	105	Lake	Warm water
Neosho County State Lake	Neosho	92	Lake	Warm water
State Forest	Crawford & Cherokee	205	Strip pits	Warm water
Woodson County State Lake	Woodson	179	Lake	Warm water
Chase County State Lake	Chase	109	Lake	Warm water
Oklahoma				
Boecher Lake	Blaine	18	Lake	Cold & warm water
Lake Dahlgren	Cleveland	42	Lake	Warm water
Waurika Lake	Jefferson	62	Lake	Warm water
Lake Hall	Harmon	40	Lake	Warm water
Louis Burtschi Lake	Grady	180	Lake	Warm water
Texas County Lake	Texas	130	Lake	Warm water
Lake Murray	Love-Carter	5,728	Lake	Warm water
Clayton Lake	Pushmataha	75	Lake	Warm water
Lake Carlton	Latimer	46	Lake	Warm water
Lake Lookout	Osage	17	Lake	Warm water
Greenleaf Lake	Muskogee	920	Lake	Warm water
Lake Carl Blackwell	Payne	3,380	Lake	Warm water
Stringtown Lake	Atoka	70	Lake	Warm water
Schooler Lake	Choctaw	26	Lake	Warm water

From page 83, Part II, Section 12 of A. W. R. Basins Inter-agency report on fish and wildlife.

places, planting of food and cover along field borders, crop residue management, and, sometimes, modification of land-use practices. Water control structures are used to create impoundments and manipulate water levels. In the more arid portions of the basins, watering places are provided, and waterfowl feeding and setting habitat are developed at suitable locations throughout the A. W. R. states.

Developments on private land are usually carried out by the land owner in conjunction with agricultural activities and soil conservation measures. Local civic or sportsmen's groups are active in this work from time to time. The states promote these activities by providing technical assistance and planting stock; in fact, most states maintain plant nurseries and furnish plants free of charge.

6-12. Non-Governmental Activities

Several national conservation organizations are active in the A. W. R. basins.

These include the national wildlife federation which is a conservation education association that also serves as the national service organization for affiliated state sportsmen groups. Among its many contributions to the furtherance of natural resources conservation is the financial assistance given for the establishment of conservation workshops to provide training for school teachers.

The Wildlife Management Institute is a non-profit, private organization supported by industries, organizations and individuals. Major objective of the Institute is to promote better use of natural resources.

The Sport Fishing Institute is another private, non profit organization. Its objective is to further sport fishing in order to effect " a shorter time between bites."

Throughout the A. W. R. basins are numerous fish and wildlife facilities that have been developed by private enterprise. Fishing lakes, game preserves, hunting clubs, game and fur farms, and impoundments for commercial fish production are typical of the types of private developments.

6-13. Needs for Fishing and Hunting Opportunities and Associated Problems

The needs for the development and maintenance of fish and wildlife resources are based on the demand of the public for fishing and hunting opportunities and the contributions made by these resources in supporting and diversifying our economic structure and in supplying food and fiber. These needs are an expression of values--social, esthetic, and economic, tangible and intangible, all of which contribute to man's well being.

Millions of Americans are seriously concerned about maintaining the fish and wildlife resources in the relative abundance and variety which exist today. They are concerned because the demand for these resources is rapidly increasing while, for many species, the supply is decreasing. They are concerned because they realize the importance of the various recreational activities based upon fish and wildlife resources in the life of the average American man, woman or child.

It is only natural that a rapidly growing population such as ours would exert an increasing pressure upon existing resources, but the increased demand for fish and wildlife experienced in recent years goes far beyond what might be attributed to population growth alone. Part of the answer is to be found in analysis of leisure time.

6-14. The Extension of Leisure

Never before in the history of America has there been a period during which leisure has been so extensive as at the present time. In 1900 the work week in industry averaged 56 hours, by 1930 it averaged only 44 hours,

and in 1950 it has dropped to 40.5 hours. Based on this trend, and taking cognizance of the current rate of increase in the national population, it has been predicted that the work week in another 5 years may be as low as 35 hours. The standard vacation in industry is lengthened, in contrast with shortened work weeks.

6-15. Leisure and Recreation

There are problems inherent in the increase of leisure which society, for its own good, cannot afford to ignore. Although people use their free time in a variety of ways, activities of a recreational nature are the most frequently engaged in because recreation is a basic human need. Therefore, it should be the objective of society to foster and encourage the more desirable recreational outlets.

6-16. Fishing and Hunting in Recreation

Among active outdoor recreational pursuits, few are more popular than fishing and hunting. They furnish opportunity for physical exercise, development of coordination, and relief from tension. They are an integral part of nature and outing activities which studies have demonstrated as being the most effective type of family recreation.

6-17. Economic Need for Fish and Wildlife

In addition to the great number of people participating in hunting and fishing, the amount of money spent by anglers, and hunters is an indicator of the popularity of these activities. Reliable estimates indicating the economic importance of fishing and hunting are being compiled throughout the country. The school of economics and Business Bureau of Economic and Business Research, Washington State College, reports that approximately 400,000 resident licensees in the state of Washington spent $80,000,000 in the pursuit of sport hunting and fishing during 1950.

considering the additional $21,000,000 paid to commercial fishermen, the estimated total of $101,000,000 was more than one-third as large as the total payroll of $288,427,000 reported by all retail establishments in the state of Washington for 1950.

6-18. Value of Commercial Harvest of Fur and Fish

The annual value of furs harvested from the A. W. R. basins exceeds one million dollars. Economically, this amount is of considerable importance since it represents supplemental sources of revenue for people in a low income group.

6-19. Meat Value of Game Harvested

In addition to the large financial expenditures in harvesting the fish and game crop, the value of the meat obtained is considerable. The value can be considered equal at least to the price at the neighborhood store for meat of comparable quality.

6-20. Economic value in Multiple-Purpose Development

Important collateral economic benefits in recreation and fishing and hunting result from large multiple-purpose reservoirs. This is evident from the large scale of investment of private money in developments catering to tourists, fishermen, and hunters around such projects. Total investment of private money directly attributable to such projects runs into millions of dollars.

6-21. Plan of Improvement for Fish and Wildlife

The plan of improvement for fish and wildlife consists of existing programs which will be continued in the future, projects and programs previously formulated for future initiation, and possible solutions to existing and anticipated needs and problems. The division between state and federal plans is based on traditional programing only, and

is not to be interpreted as a criterion for financing. Although the plan takes due cognizance of the sphere of activity for which the federal government has a legal responsibility, it is not anticipated that the projects and programs included herein will be financed or carried out by any particular agency. The plan will be varied in detail from time to time in the future as a result of additional studies and to meet changing conditions.

CHAPTER VII

RECREATION

7-1. Factors Influencing the Plan

From the headwaters of the Arkansas River in the Rocky Mountains to the mouth of the Red River in the Louisiana bayou country, there is a wide diversity of scenery, climate and opportunities for outdoor recreation. Nature omitted only large water areas and these are being created by man primarily for other purposes, but they provide the one missing recreation feature. At present the largest and most important, recreationally, is Lake Texoma in the Red River valley between Texas and Oklahoma.

Major factors that have increased and are continuing to increase outdoor recreation uses and needs for additional reserves and facilities are population, urbanization, and leisure time.

7-2. Population

National population has about doubled in the last half century and the rate of population increase doubled in the last decade. While the population increase in the A. W. R. basins has been below the national average, the large increase for the nation results in increased use of the recreation resources within the basins by people from other parts of the country.

Millions of visitors come into the basins every year seeking recreation. Their expenditures are the major source of revenue for many enterprises which serve the travel and recreation industry and in addition have

indirect effects on related lines of business.

7-3. Urbanization

The number of people living in urban and suburban concentrations has increased out of proportion to overall population increase. It is the people living in urban and suburban concentrations who feel most the need for, and contribute the largest per capita ratio to the use of public recreation reserves.

Although the total population of the basins increased less than one-tenth of one per cent between 1930 and 1950, there was an increase of nearly 30 per cent in urban population between 1940 and 1950. Eleven cities with populations over 25,000 showed increases ranging from 28.5 per cent to 136.3 percent. Now, nearly half of the people in the basins, which until recently was predominantly an agricultural region, are urban dwellers.

7-4. Leisure Time

The growing custom in industry to grant vacations with pay; the five-day week increasing the practicable radius of week-end recreation trips; and the increase in longevity with corresponding increase in the number of people in retirement from business with unlimited opportunities to make use of recreation areas result in ever increasing demands for non urban recreation opportunities.

7-5. Recreation Areas

Within the A. W. R. basins there are 51 state parks, 13 state monuments, 11 state reservoir areas and 4 wildlife refuges in which there are recreation facilities. In Oklahoma, Texas, Missouri, Arkansas, and Louisiana the state parks are areas of outstanding scenic and recreation value, generally with facilities for picnicking, camping, swimming and boating.

The state lake parks in Kansas have been developed around artificial lakes created primarily for fishing. Facilities are limited to those for fishing, boating and picnicking. The one state park in New Mexico is located on Conchas Reservoir. It contains camp and picnic areas, trailer park, lodge, cabins, coffee shop, stores and boating facilities.

7-6. Appraisal of Existing Developments

Although the total number of existing public recreation areas in the basins might be considered adequate, they are distributed in such a way that many segments of the basins are not adequately served. This is due primarily to the fact that in the majority of cases where recreation is associated with a man-made feature such as a reservoir, recreation was not a primary purpose of the project and was not a factor in determining the location. In some sections of the basins, recreation potentialities other than those associated with man-made features are very limited.

Publicly owned recreation areas are, in general, adequately distributed over the state of Kansas. The development of these areas, however, does not provide for diversified recreation. Deficiencies occur in such facilities as approach roads, drinking water systems, and comfort stations.

7-7. Basis for Selection of Proposed Reservoir Recreation Areas

The A. W. R. basins are, in general, devoid of natural lakes, and only the eastern half of the basins and the Rocky Mountain section have streams of recreational value. However, within the past two decades man-made reservoirs have created new water recreation areas. Recreation associated with water is extremely popular, not only with the people living within the basins but with those outside. Since the advent of the reservoir construction program coincided generally with the advent

of an increasing need and demand for public recreation areas, it was inevitable that recreation interests should recognize the value of this timely creation of new recreation resources. It was equally apparent, in seeking a solution for the increasing needs for day-use, weekend, and vacation areas, that proposed reservoir projects in many instances offer the most economical and practical solution.

However, since recreation is not a major purpose of any of the proposed reservoirs included in the plan, it follows that they may not be operated ideally for recreation. Flood control, irrigation, power, and other major uses result in a fluctuating water level which may adversely affect recreation development and use of the reservoir area depending on the magnitude and frequency of fluctuations, and the character of the shore line, but this does not preclude recreational use and enjoyment of the water. Throughout the basins, there seems to be no possibility, in the foreseeable future, of developing any great number of single-purpose water recreation areas.

In the selection of sites for recreation areas, location in relation to the population to be served is a major consideration. Therefore, the location of a proposed reservoir in relation to an area of need was the first criterion in singling out projects warranting special study.

7-8. Proposed Developments

The areas proposed fall generally into two broad types. The first are areas of intrinsic scenic, scientific or cultural value which should be preserved in the public interest, the second are areas needed to provide adequate nonurban recreation opportunities within convenient travel distance of all the people. Areas of the latter type are subdivided into day-use areas and weekend and vacation areas.

The developments proposed for areas of scenic, scientific and historic

interest are limited to construction and alterations essential for the preservation and use of the area. Facilities usually provided are those required for the safety and comfort of the visitor, and for the protection, preservation and interpretation of the area. Picnic facilities and other recreation facilities may at times be developed if compatible with the primary attraction of the areas.

The day-use recreation area is designed to provide opportunity for outdoor recreation when travel time is limited. Such areas should be within 25 to 35 miles of the users so that they may be easily reached in one hour's driving time.

The weekend and vacation recreation area is planned to meet the needs of visitors desiring to remain for more than one day. Outstanding natural features coupled with development to serve the greatest variety of recreation interests are desirable. In addition to the development recommended for the day-use area, facilities for overnight users such as campgrounds, lodges, and cabin developments with attendant service establishments, should be provided.

7-9. Recreation Developments on Federal Reservoir Projects

(a) Development on Existing Reservoirs: It is proposed that the initiated programs on 14 existing federal reservoirs in the A. W. R. basins be augmented by additional developments which will include further provision of minimum basic facilities. It is proposed that public-use facilities be provided on 4 other reservoirs, Lake Ouachita, Texarkana, Table Rock, and Toronto now under construction. The estimated cost to the federal government for these facilities is $3,177,900. Other facilities such as boat dock and boat rental, restaurants, overnight and vacation accommodations, group camps, club sites and private cabin sites, where presently

inadequate, will be provided by appropriate state or local agencies under lease, or by investors in commercial enterprise.

(b) Proposed Reservoir Recreation Areas: In the selection of sites for public recreation areas to serve those sections of the basins lacking such areas, first consideration was given to the potentialities of the reservoir projects included in the A. W. R. framework plan.

7-10. Problems

Within recent years, the demand for outdoor recreation facilities has grown tremendously throughout the nation. Since the basic recreation resources are land and water, every organization or agency from village to federal government which possesses land has to a greater or lesser degree, entered the recreation field. With such a multiplicity of agencies engaged in the same activity, it is inevitable that some confusion as to responsibility for recreation planning and for provision and administration of recreation areas and facilities has resulted.

Within A. W. R. basins at least five federal agencies have important responsibility in the recreation field. Differences in basic legislation authorizing the individual federal agencies to plan and administer recreation areas and differences in interpretation of law applicable to all agencies was evident throughout the formulation of the plan.

7-11. Programs for Continued Planning and Investigations

Recreation Studies of Water Use and Control Projects

In general the studies necessary to assure the best utilization of the recreation potentialities of a federal reservoir project fall into two phases. The first phase is the determination, in the early planning stage well in advance of construction, of the importance of the project in the overall system of recreation areas necessary to answer the present

and predicted future recreation needs of the locality, the state, and the nation.

The next phase of the program is the detailed recreation study of individual projects. These studies will be developed as part of the detail project plan after authorization and in the period immediately preceding construction. They result in detailed plans for the development of individual projects to insure that each will adequately provide the recreation opportunities with which it was charged in the overall basin plan.

7-12. Studies of Historic and Scientific Features in Water Use and Control Project Areas

There are two general phases in investigations of the archaeological and historic features of proposed water use and control project areas. The first is to determine whether archaeological or historic sites worthy of preservation are endangered by proposed construction programs. This has been accomplished for projects proposed in A. W. R. plan.

The second is the salvage program which will be undertaken preceding construction to assure that all archaeological or historic material obtainable from search and excavation of the lands to be disturbed or inundated is recovered. Salvage programs have been accomplished on four of the proposed projects and others should be scheduled to proceed concurrently with the programs of construction agencies. At the time funds are appropriated for construction of water use and control projects, funds should be appropriated for the national park service to carry on cooperative salvage work based on estimates submitted and justified by the Department of the Interior.

7-13. Studies of Water Flow Retardation Structures

Water flow retardation projects were not considered in the formulation of the recreation plan due to present policies affecting their development and operation. Such structures are planned so that all or most of the water stored will be released automatically. Also, public rights-of-way are not acquired at federal cost.

7-14. Other Studies

The recreation plan has been directed toward presenting a basin-wide analysis of the needs for public recreation areas and water use control. Detail planning for the development of the recreation resources and specific areas is required.

CHAPTER VIII

CONCLUSIONS

This report dealing with the projects and programs is expected to constitute only a general guide to the agencies in planning their annual programs to be covered by their budgets and to the Congress in relating agency budgets to the problems, needs and potentialities of the Arkansas, White and Red River Basins. Since all the suggestions are only tentative, it is likely to be subjected to alterations during actual execution of the projects.

The plan has been devised on the basis of information and basic data available during investigations and is intended to show resource development potentialities for meeting needs and problems that may develop during the range of the plan. It includes projects and programs for which the responsibility for development may rest with the federal government, state or local governments, private interests, or combinations thereof. It is contemplated that the plan will be subject to continued modification and refinement as more data become available and as changed economic conditions, technological improvements, and other considerations may dictate.

For example, the agricultural programs and measures outlined on the report are those which appeared at the time of preparation of the report, to be most desirable for application over the years immediately ahead. An application period of 20 years was used for presenting quantities of

measures and computing costs. The actual rate at which the various phases will be applied will depend on several factors including general economic changes which may influence the financial status of individual farmers and woodland operators and the comparative profits or savings to come from applying certain measures at specific times. Another influencing factor will be the intensity of effort exerted by public agencies, governed largely by the public financial participation that may be forthcoming.

Regarding hydro power it is concluded that all projects require further study, and that other multiple purpose uses will dictate scheduling of most hydroelectric construction, and that scheduling should be as far in advance as possible so as to permit early correlation with required fuel - electric plant construction.

The plan is intended to provide a framework within which state and federal agencies and, where applicable, private interests may progressively develop and implement their action programs relating to resource conservation and development.

Although the plan emphasizes activities normally undertaken by governmental agencies, it is assumed that private interests will carry out specific projects or programs by themselves or in cooperation with appropriate state and federal agencies should they so desire.

Finally, a continued coordination of planning and developmental activities among the interested agencies is assumed.

BIBLIOGRAPHY

Reports of Arkansas-White-Red Basins Inter-Agency Committee.

1. A Report on the Conservation and Development of the Water and Land Resources. Part I.
2. Hydroelectric Power Development and Utilization. Part II, Section 7.
3. Water Pollution Control. Part II, Section 9.
4. Agriculture. Part II, Section 11.
5. Fish and Wildlife. Part II, Section 12.
6. Recreation. Part II, Section 13.

VITA

Mounaguruswamy Guruswamy

Candidate for the Degree of

Master of Science

Report: ARKANSAS, WHITE, AND RED RIVER BASIN DEVELOPMENT WITH EMPHASIS ON (1) HYDROPOWER (2) WATER POLLUTION CONTROL (3) AGRICULTURE (4) FISH AND WILDLIFE AND (5) RECREATION

Major Field: Civil Engineering

Biographical:

Personal Data: Born in S. V. Puram, Coimbatore, India, April 6, 1936, the son of Mounaguruswamy Naidu and Manickam.

Education: Received the Bachelor of Engineering degree in Civil Engineering from University of Madras, India, in 1957.

Experience: Junior engineer, public works Department, Government of Madras, India, from June 1957 to August 1961.