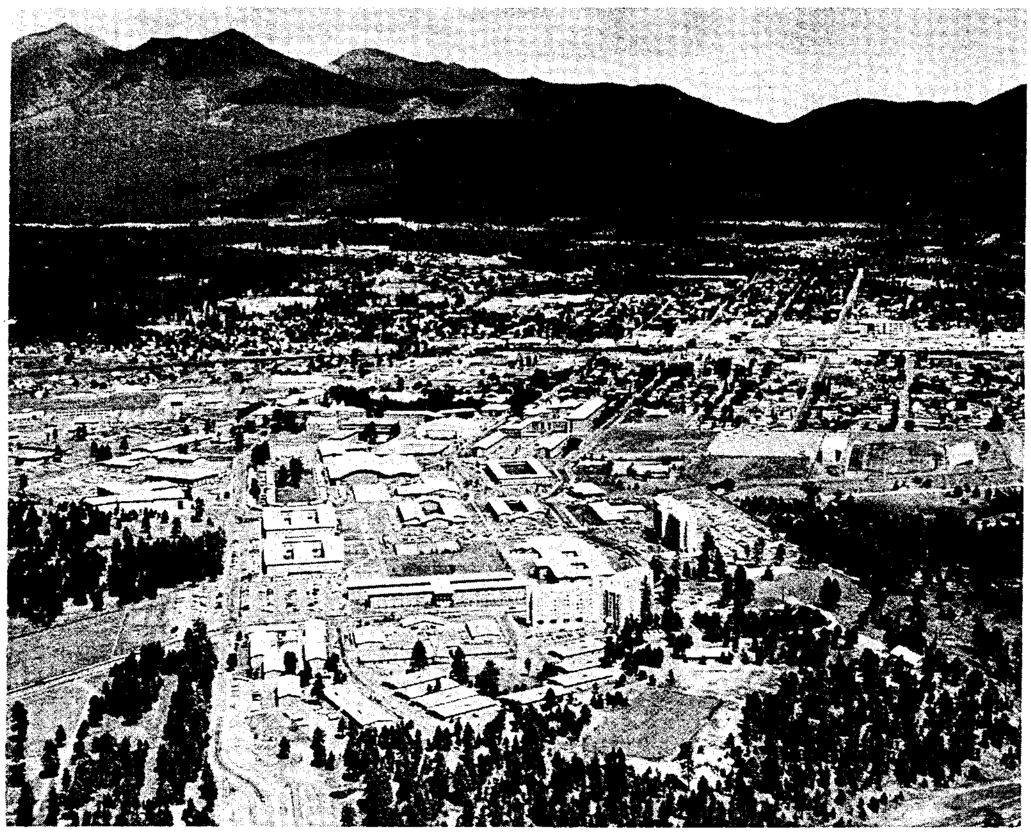
MOGOLLON MESA PROJECT Arizona

Concluding Report

DECEMBER

1977



UNITED STATES DEPARTMENT OF THE INTERIOR

Bureau of Reclamation

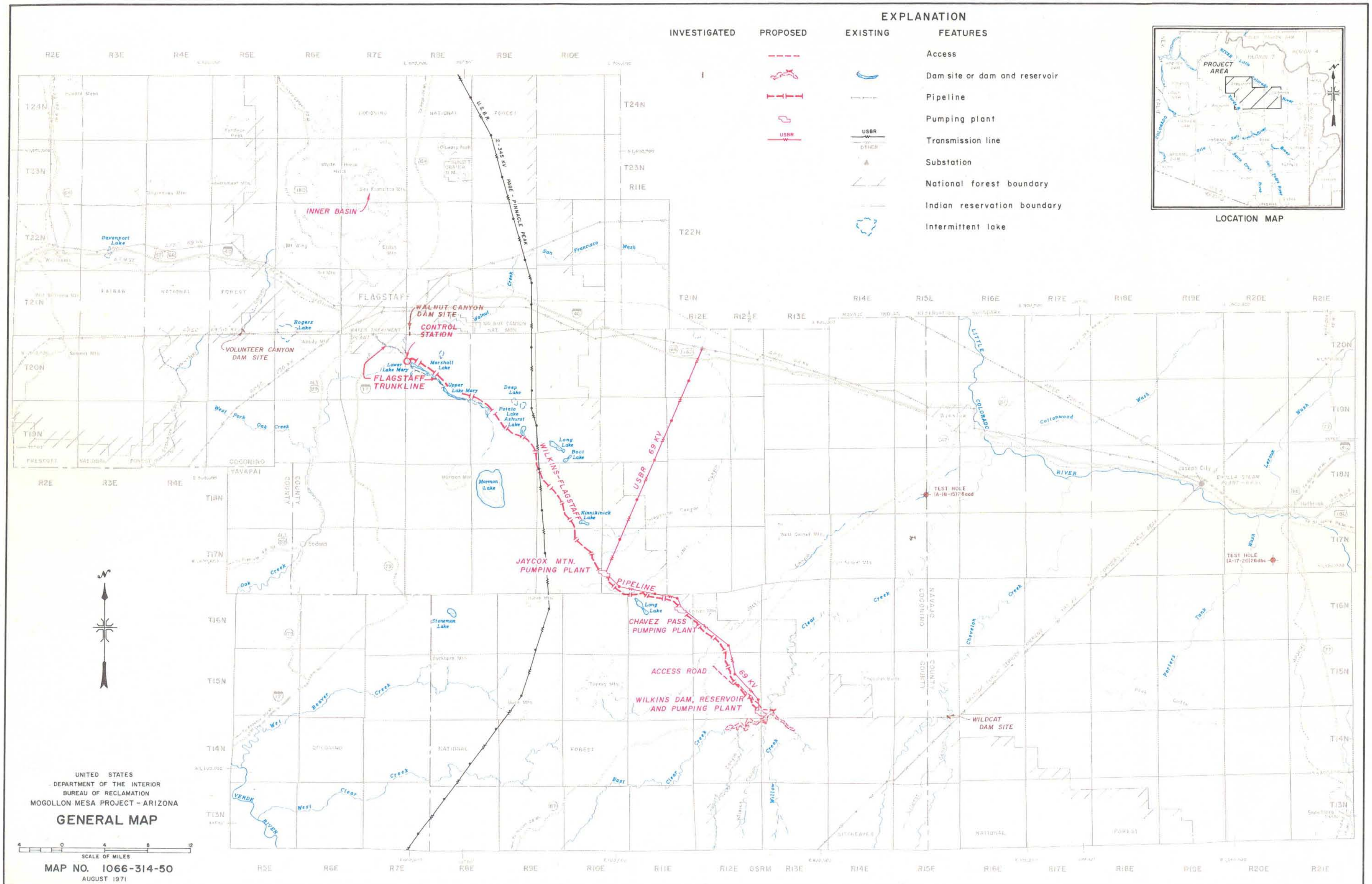
MOGOLLON MESA PROJECT, ARIZONA

Concluding Report

December 1977

This report was prepared pursuant to the Act of June 17, 1902. Publication of the findings and recommendations herein should not be construed as representing either the approval or disapproval of the Secretary of the Interior. The purpose of this report is to provide information and alternatives for further consideration by the Bureau of Reclamation, the Secretary of the Interior and other Federal agencies.

R. Keith Higginson, Commissioner
Manuel Lopez, Jr., Regional Director, Lower Colorado Region
Bureau of Reclamation



Interior-Reclamation, B.C., Nev. 12-72

PREFACE

Flagstaff is the principal trade center of northern Arizona. It is experiencing population growth and economic expansion caused by the annual increase in tourism and enrollment at the Northern Arizona University.

The local water supply on which the city is dependent for its municipal and industrial use comes from three ground-water well fields in the area and from surface water developed on Walnut Creek. The city plans to fully develop the well fields prior to developing additional surface water and could, therefore, defer the requirement for the water developed by the installation of the Mogollon Mesa Project for many years. Although development of the ground water is quite expensive on a unit cost basis, it does not require as much immediate capital layout as would be required to construct the Mogollon Mesa Project. Based on the city's expressed preference, a decision was made to prepare a concluding report to cover the feasibility investigations at this time.

The Mogollon Mesa Project is a multipurpose proposal which would provide a supplemental municipal and industrial water supply to the city of Flagstaff, fish and wildlife benefits, and recreation opportunities. The project as presented in the concluding report would be developed in two stages. The first stage would consist of the Wilkins Dam and Reservoir on Clear Creek, and an aqueduct system to deliver supplemental municipal and industrial water to Flagstaff. The second stage would consist of lining and enlarging the existing Upper Lake Mary on Walnut Creek. The logistics of maintaining a viable water supply during construction dictate the sequence.

Studies of all phases of the investigation except for the enlargement of the Upper Lake Mary and transmission line location were conducted on a feasibility level. Designs and estimates for the rehabilitation and enlargement of Upper Lake Mary are of appraisal level.

The environmental quality plan was developed to comply with Procedure No. 1 for planning and water related land resources. This plan would provide 14,000 acre-feet of water annually to Flagstaff, Arizona, and 4,400 acre-feet annually for waterfowl refuges. In addition water not needed initially for M&I uses would be used temporarily for lake stabilization and maintaining full streams in Clear Creek and Walnut Creek.

The project is in compliance with Executive Order No. 11296. Protection against dam failure due to flooding has been provided for by designing the spillway and reservoir surcharge with capacity to pass the design floods without overtopping the dam.

A preliminary study of the archeology of the Wilkins Reservoir site was made by the Department of Anthropology, Museum of Northern Arizona in 1969 for the Bureau of Reclamation. The National Park Service prepared an evaluation report based on the Museum's findings.

The project investigations were conducted under the traditional procedures for planning. Under these procedures the plan of project development was found to be engineeringly and environmentally feasible and economically justified, as demonstrated by the economic rate of return of 7.8 percent. This concluding report on the Mogollon Mesa Project, Arizona, was prepared in accordance with Procedure No. 1, Level C of the Water Resources Council's Notice of Establishment of

Schedule and Application of Principles and Standards to Implementation Studies in Progress, published in the Federal Register, Volume 39, No. 143, July 24, 1974. Any future investigations of this project will be made to comply with the Water Resources Council's Principles and Standards for Planning Water and Related Land Resources and in accordance with the Office of Management and Budget's Circular No. A-97, as supplemented and amended, or any other policy or procedure that may be enforced at that time.

SUMMARY SHEETS

SUMMARY SHEETS

Mogollon Mesa Project, Arizona

LOCATION: The project is located in Coconino County, Arizona. Wilkins Dam and Reservoir would be located on Clear Creek, a tributary to the Little Colorado River. An aqueduct system would extend from Wilkins Dam northwestward to the city of Flagstaff's existing trunkline near Lower Lake Mary. A proposed storage and regulating reservoir would be located on Walnut Creek at Upper Lake Mary, about 11 miles south of Flagstaff, Arizona.

AUTHORITY FOR REPORT: Federal Reclamation Law (Act of June 17, 1902, 32 Stat. 388, and Acts amendatory thereof or supplementary thereto). Authority to engage in feasibility investigation was authorized by Public Law 89-561, September 7, 1966, and Public Law 90-254, February 13, 1968.

PLAN: The plan would provide a supplemental municipal and industrial water supply to the city of Flagstaff, fish and wildlife benefits, and recreation opportunities.

The Mogollon Mesa Project would be developed in two stages. The first stage would consist of Wilkins Dam and Reservoir and the aqueduct system to deliver supplemental municipal and industrial water to Flagstaff, Arizona. The second stage would consist of lining and enlarging Upper

Lake Mary when required to meet Flagstaff's future water demands. It is estimated that first stage facilities would provide the city with 11,900 acre-feet of water and would meet estimated water requirements until about 2003. This is based on the premise that the local water supply available to the city is 2,400 acre-feet until Upper Lake Mary is taken out of operation for reconstruction at which time the local supply will be reduced to 1,000 acre-feet, in addition to the 11,900 acre-feet made available by the first stage.

In the first stage the pipeline of the aqueduct would connect Wilkins Reservoir to the existing Flagstaff trunkline of Lower Lake Mary and project water would be diverted directly to existing treatment facilities. In the second stage a bifurcation would be constructed on the aqueduct near the upper end of Upper Lake Mary and additional pipeline and structures would be constructed to divert Wilkins Reservoir water directly into Upper Lake Mary. The second stage of construction would make possible an increase of 6,500 acre-feet of firm water supply.

TOTAL PROJECT COSTS: (April 1976 prices) $85,390,000

First Stage

Feature	Cost	
Wilkins Access Road	$ 6,830,000	
Wilkins Dam and Reservoir	16,550,000	
Wilkins Pumping Plant	2,600,000	
Chavez Pass Pumping Plant	1,225,000	
Jaycox Mountain Pumping Plant	1,225,000	
Pipeline and Structures	34,410,000	
Transmission System	2,270,000	
Communication Equipment	767,000	
Fish and Wildlife	1,191,000	
Recreation Activities		
Subtotal (First Stage)	$67,068,000	$67,068,000

Second Stage

Pipeline and Structures	$ 400,000	
Upper Lake Mary Dam and Reservoir	15,460,000	
Fish and Wildlife and Recreation Facilities	2,462,000	
Subtotal (Second Stage)	$18,322,000	$18,322,000
Investigation Costs 1/		$(1,250,000)
Total Project Costs		$85,390,000

1/ Included in the Total Project Costs

CONSTRUCTION PERIOD: Approximately 4 years

ANNUAL OPERATION, MAINTENANCE, AND REPLACEMENT COSTS:

First Stage

Feature	OM&R Cost	Total OM&R Cost
Wilkins Dam and Reservoir	$ 56,000	
Access Road	98,000	
Aqueduct	73,000	
Algae Control in Pipeline	3,000	
Pumping Plants	287,000	
Transmission System	40,000	
Communication Equipment and Remote Control System	14,000	
Pumping Energy	695,000	
Fish and Wildlife and Recreation Facilities	58,000	
Subtotal (First Stage)	$ 1,324,000	$ 1,324,000

Second Stage

Feature	OM&R Cost	Total OM&R Cost
Upper Lake Mary Dam and Reservoir	30,000	
Pumping Energy	205,000	
Fish and Wildlife and Recreation Facilities	181,000	
Subtotal (Second Stage)	$ 416,000	416,000
Total Project		$ 1,740,000

PROJECT INVESTMENT:

	First Stage	Second Stage	Total
Construction Costs 1/	$66,068,000	$18,072,000	$84,140,000
Interest During Construction	6,157,000	1,323,000	7,480,000
Total	$72,225,000	$19,395,000	$91,620,000

ANNUAL EQUIVALENT COSTS:

	First Stage	Second Stage	Total
Project Investment	$ 4,614,000	$ 385,000	$ 4,999,000
Project OM&R Costs	1,155,000	79,000	1,234,000
Total	$ 5,769,000	$ 464,000	$ 6,233,000

ANNUAL EQUIVALENT BENEFITS:

	First Stage	Second Stage	Total
Municipal and Industrial Water	$ 6,631,000	$ 421,000	$ 7,052,000
Recreation	23,000	85,000	108,000
Fish and Wildlife	180,000	93,000	273,000
Total	$ 6,834,000	$ 599,000	$ 7,433,000

ANNUAL EQUIVALENT COSTS FOR BENEFIT-COST ANALYSIS:

	First Stage	Second Stage	Total
Annual Equivalent Investment Costs	$ 4,445,000	$ 48,000	$ 4,493,000
Annual Equivalent OM&R Costs	1,324,000	416,000	1,740,000
Total	$ 5,769,000	$ 464,000	$ 6,233,000
NET BENEFITS:	$ 1,065,000	$ 135,000	$ 1,200,000

1/ Investigation costs of $1,250,000 ($1,001,000 first stage and $249,000 second stage) are excluded.

ALLOCATION OF COST:

	Project Construction Cost	Construction 1/	Interest During Construction	OM&R Costs At Full Project Development
First Stage				
Municipal and Industrial (Reimbursable)	$ 64,019,000	$ 64,019,000	$ 5,364,000	$ 1,264,000
Recreation and Fish and Wildlife (Nonreimbursable)	2,048,000	2,048,000	137,000	60,000
Total	$66,067,000	$66,067,000	$ 5,501,000	$ 1,324,000
Total Project				
Municipal and Industrial (Reimbursable)	$77,772,000	$77,772,000	$ 6,286,000	$ 1,480,000
Recreation and Fish and Wildlife (Nonreimbursable)	6,368,000		425,000	260,000
Total	$84,140,000	$77,772,000	$6,711,000	$1,740,000
Project Total	$ 84,140,000			
Investigation Costs	1,250,000 1/			
	$ 85,390,000			

REPAYMENT OF PROJECT COSTS:

	First Stage	Total Project
Reimbursable Costs Allocated to M&I Water		
Construction Costs 1/	$64,019,000	$77,772,000
Interest During Construction	5,364,000	6,286,000
Total	$69,383,000	$84,058,000

1/ Investigation costs of $1,250,000 ($961,000 first stage) are excluded and are comprised of $80,734 contribution by the State of Arizona, $290,787 from the Colorado River Development Fund, and $878,479 General Investigations Fund, which are nonreimbursable under the provision of Public Law 92-149.

Municipal and industrial water users would repay the first stage costs allocated to this purpose with interest at 4.371 percent on the unpaid balance during a 50-year period. Costs allocated to municipal and industrial water for the second stage development would be repaid with interest in a 50-year period starting the first year of operation of the second stage.

The water charge to Flagstaff, including repayment of investment costs with interest and payment of annual OM&R costs, would be about $390 per acre-foot the first year, gradually reducing to about $314 per acre-foot in the 21st year. Annual OM&R charges would be about $91 per acre-foot in the 10th year of project operation and about $68 when the full first stage water supply is used.

PROJECT FEATURES:

Dams and Reservoirs

Wilkins Dam--Thin, double curvature, concrete structure

Location: On Clear Creek in Sections 31 and 32, T. 15 N., R. 13 E., G&SRM, about 32 miles southwest of Winslow, Arizona.

	Unit	
Elevation at top of parapet	feet	6219.5
Elevation at top of dam	feet	6215
Elevation at top of active conservation storage	feet	6194
Height of dam above streambed	feet	228
Crest length	feet	790
Volume of dam	cubic yards	96,350
Spillway capacity	cubic feet per second	57,200
Reservoir capacity, top of active conservation	acre-feet	34,600

Reservoir capacity, inactive storage . . .	acre-feet	4,400
Reservoir capacity, top of dead storage	acre-feet	6,000
Total reservoir capacity	acre-feet	45,000
Sediment storage, 100 years	acre-feet	7,260
Reservoir area, top of conservation storage capacity	acres	568

Wilkins Reservoir Pool Evaluations and Water Surface Areas

	Pool Evaluation (feet msl)	Water Surface (acres)
Maximum Water Surface	6215	650
Top of Active Conservation Capacity	6194	568
Top of Inactive Conservation Capacity	6104	220
Dead Storage	6080	167

Upper Lake Mary Dam--Rolled earthfill

Location: On Walnut Creek, a tributary to the Little Colorado River in Section 27, T. 20 N., R. 8 E., G&SRM, about 11 miles southeast of Flagstaff, Arizona.

	Unit	
Elevation at top of dam	feet	6855
Elevation at top of active conservation storage	feet	6842.6
Height of dam above streambed	feet	65
Crest length	feet	1,500
Volume of dam	cubic yards	253,000
Spillway capacity	cubic feet per second	6,150
Reservoir capacity, top of active conservation	acre-feet	24,060
Reservoir capacity, inactive storage	acre-feet	4,840
Total reservoir capacity	acre-feet	29,500
Reservoir area, top of conservation storage capacity	acres	1,089

Upper Lake Mary Reservoir Storage Allocation (acre-feet)

Second Stage	Initial Condition
Surcharge Pool	7,300
Active Conservation Pool	24,060
Minimum Pool	5,440
Total Capacity	29,500

Upper Lake Mary Reservoir Pool Elevations and Water Surface Areas

	Pool Evaluation (feet msl)	Water Surface (acres)
Maximum Water Surface	6849	1,202
Top Active Conservation Capacity	6842.6	1,089
Top Inactive Capacity	6815	596
Dead Storage	6800	155

Aqueduct System

Pumping Plants

Wilkins Pumping Plant

Type of pumps--electric driven
Number--3 with 1 standby
Capacity total--37 cubic feet per second
Maximum head (feet)--560

Chavez Pumping Plant

Types of pumps--electric driven
Number--3 with 1 standby
Capacity total--37 cubic feet per second
Maximum head (feet)--435

Jaycox Pumping Plant

Type of pumps--electric driven
Number--3 with 1 standby
Capacity total--37 cubic feet per second
Maximum head (feet)--435

Pipeline

Wilkins Reservoir to Lake Mary

Type--Concrete or equivalent
Length (miles)--51 (applicable to first stage construction)
Diameter (inches)--30 to 42
Normal design capacity (cubic feet per second)--37

Hydrology

Wilkins Reservoir

Contributing drainage area above Wilkins gage	321	square miles
Historic average annual runoff (1947-1969)	56,000	acre-feet
Maximum annual runoff	142,200	acre-feet
Minimum annual runoff	12,700	acre-feet
Inflow design flood		
4-day volume	116,800	acre-feet
Peak discharge	61,500	cubic feet per second

Upper Lake Mary Reservoir

Contributing drainage area above Lake Mary Dam	53.5	square miles
Historic average runoff (1947-1969)	8,700	acre-feet
Maximum runoff	21,400	acre-feet
Minimum runoff	1,200	acre-feet
Inflow design flood		
4-day volume	12,920	acre-feet
Peak discharge	20,760	cubic feet per second

MOGOLLON MESA PROJECT, ARIZONA
Concluding Report

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I. SUMMARY

I. SUMMARY

A. Introduction

This is a Concluding Report on the findings of the feasibility investigations of the multiple-purpose Mogollon Mesa Project in the Little Colorado River Basin in Coconino and Navajo Counties, Arizona. It presents a plan for the development of storage on Clear Creek, a tributary to the Little Colorado River, and a system of pumping plants and pipeline for supplying municipal and industrial water to the city of Flagstaff, Arizona. It includes development of offstream storage by enlarging and lining present Upper Lake Mary for the purpose of increased total project yields. The plan would also provide fish and wildlife benefits and recreation opportunities.

The development of local ground-water supplies in the project area for the purpose of providing supplemental water for the future growth of the cities of Winslow and Holbrook is evaluated in the report. The project area and main features of the plan are shown on the frontispiece, General Map, Drawing 1066-314-50.

B. Authority for the Report

The report has been prepared under the general authority of the Federal Reclamation Laws (Act of June 17, 1902, 32 Stat. 388) and acts amendatory thereof or supplementary thereto. Authorization for feasibility investigations of the Project is contained in Public Law 89-561, dated September 7, 1966, and Public Law 90-254, dated February 13, 1968. A portion of the costs of the feasibility investigations was provided by funds contributed by the State of Arizona under terms of Contracts Nos. 14-06-300-1490 dated October 24, 1964;

14-06-300-1757 dated January 27, 1966; and 14-06-300-2077 dated December 11, 1969, between the United States and the Arizona Interstate Stream Commission 1/.

C. Purpose and Scope of Investigations

Investigations of the Mogollon Mesa Project were oriented toward the most economical development of the water resources to meet the increasing multiuse needs of the area. The project plan as proposed contemplates the regulation and delivery of Clear Creek flows to meet increasing demands for municipal and industrial water and provides facilities for fish and wildlife and recreation use. The report also presents an analysis of the ground-water resources in the Winslow-Holbrook and Flagstaff areas.

Studies of all phases of the investigation except for the enlargement of Upper Lake Mary were conducted on a feasibility level. Designs and cost estimates are of feasibility level for the storage and diversion facilities pertaining to Wilkins Dam and Reservoir and the pipeline and pumping plants system. Estimates for the rehabilitation and enlargement of Upper Lake Mary are of reconnaissance level.

D. Present Conditions

Flagstaff, Arizona, is the principal trade center of northern Arizona. It is located at the junction of Interstate 40 and U.S. Highway No. 89, both important intercontinental highways. Winslow and Holbrook, Arizona, lying 65 miles and 87 miles east, respectively, and Williams lying 20 miles west of Flagstaff on Interstate 40, are

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1/ Name changed to Arizona Water Commission on April 13, 1971.

also important trade centers of northeastern Arizona. All four cities are served by the Santa Fe Railroad and a number of motor freight lines. Tourism is an important industry common to all four cities. Lumbering, manufacturing, and the increasing growth of Northern Arizona University are additional important factors of Flagstaff's economic base.

Flagstaff depends upon surface water storage, a limited and expensive ground-water source southwest of the city, and relatively inexpensive springs and wells in the Inner Basin of the San Francisco Peaks for its municipal and industrial water supply. All of these possess limited potential for expansion; therefore, there is a need to develop outside sources of water to meet the projected population growth.

The cities of Winslow and Holbrook are totally dependent upon ground-water sources providing fair to good quality water for their municipal and industrial purposes. Water requirements for their projected population can be adequately met from the ground-water reserves available for development. Williams depends upon surface storage of runoff from several small drainages of Bill Williams Mountain for its water supply. This supply, although erratic, is generally adequate.

E. Local Development Plans

As a result of studies made and testing done by the Bureau of Reclamation in the Inner Basin, the city of Flagstaff drilled one production well in 1968. Drilling on a second well was initiated in 1969 and completed in 1970. Also in 1970, drilling was commenced on a third well and completed in 1971. Production from the first two wells has been tested with each well capable of producing about 800 gallons per minute (gal/min). During the latter part of the summer of 1971, the third well was also equipped for pumping. The Inner Basin well field would not undergo further development in the near future since any additional wells would have to be drilled into bedrock. This well field is only used in the summer to help the city meet the peak requirements.

Six wells are producing in the Woody Mountain Well Field. These wells have a maximum capacity of about 3.7 million gallons per day (Mgal/d). A seventh well will be in production in 1977. The average water quality of this well field is total dissolved solids (TDS) 142 and hardness 110.

Five wells have been drilled in the Lake Mary Well Field. Two are used only for observation, and two are connected to the city's water system. The two producing wells provide about 2 Mgal/d. The estimated yield of the well not connected is 1.5 Mgal/d.

The city is waiting until additional wells have been drilled to determine the size of pipe that will be required to deliver water from the existing unconnected well and future wells to the city's system. The average quality of water from this well field is TDS 271 and hardness 250.

With all well fields in production, it is estimated that about 7 Mgal/d of water could be produced. The city is doing more work to determine the rate of recharge of the well fields and plans full development of its ground-water resources prior to the importation of water supplies from Clear Creek.

F. Project Plan of Development

The plan of development of the Mogollon Mesa Project would involve the construction of Wilkins Dam, a 228-foot high concrete thin-arch structure, an aqueduct system involving about 51 miles of 30- to 42-inch-diameter reinforced concrete pipe, and three pumping plants having capacity to divert 37 cubic feet per second (ft^3/s) of water from Wilkins Reservoir to Flagstaff, Arizona.

The total storage at the Wilkins Reservoir site is limited by the poor water-holding capacity of the Kaibab limestone to elevation 6194 or 45,000 acre-feet by the existence of a contact zone between the Coconino sandstone formation, which forms the lower portion of the canyon wall, and the Kaibab limestone formation which occurs about 125 to 200 feet above the canyon floor. In order to obtain better utilization of the Clear Creek flows, the plan also contemplates the lining and enlargement of Upper Lake Mary to a capacity of 29,500 acre-feet. This would provide for more effective regulation of Clear Creek flows, as well as conserve the historically large seepage losses from Upper Lake Mary. Facilities for recreation would be constructed at both reservoirs, and benefits to fish and wildlife, as well as recreation, would result from the plan of development.

Projected municipal water requirements of the city of Flagstaff can be met by diversions from Wilkins Reservoir for many years. Therefore, the plan of development contemplates stage construction in which the enlargement and rehabilitation of Upper Lake Mary would be deferred with consequent savings in interest and operation costs. The financial analysis of the project was based on the premise that local water in the amount of 2,400 acre-feet would be available until Upper Lake Mary is taken out of operation for construction, at which time the local water supply would be reduced to 1,000 acre-feet annually.

Under this concept the enlargement and rehabilitation of Upper Lake Mary would be deferred for a period of about 21 years after construction of the first stage.

It is contemplated that the city of Flagstaff would operate the project facilities after construction. The city would have the responsibility for providing the necessary connection facilities between the terminal point of the project pipeline and the city's trunkline, and for providing additional treatment facilities when needed. Maintenance of, and additions to, the distribution system would also be the responsibility of the city of Flagstaff.

G. Project Costs and Benefits

1. Project Costs. The estimated total construction cost of the Mogollon Mesa Project under stage development is $85,390,000 based on April 1976 prices ($67,068,000 for the first stage and $18,322,000 for the second stage) and $1,250,000 for investigation. Estimated annual operation, maintenance, and replacement costs at full project development are $1,740,000 ($1,324,000 for the first stage and $416,000 for the second stage). The plan contemplates that the city of Flagstaff would operate and maintain all project works except recreational facilities. Operation and maintenance of the recreational and fish and wildlife facilities would be managed by the U.S. Forest Service.

The annual equivalent Federal project costs for a 100-year period of analysis are estimated to be $5,769,000 for the first stage development and $6,233,000 for full project development.

2. Project Benefits. The first stage project benefits are estimated to be $6,834,000 annually. The benefits under full project development are estimated to be $7,433,000 annually.

The first stage is economically justified with annual equivalent net benefits of $1,065,000. The total project, consisting of the first and second stages, is economically justified with annual equivalent benefits of $1,200,000.

3. Project Investment (Excluding Investigation Costs). The estimated Federal investment, including construction costs and interest during construction, is $72,224,000 for first stage development and $91,620,000 for full project development. Reimbursable costs allocated to municipal and industrial water supply, repayable with interest at 6.375 percent, are $69,383,000 and $84,058,000 for first stage development and full project development, respectively. Costs allocated to fish and wildlife and recreation are estimated to be $6,368,000 for full project development and are nonreimbursable.

H. Support for the Project

Community and civic leaders of Flagstaff are interested in long-range development of the Mogollon Mesa Project. They have also expressed reservations about commitment to repayment until additional assessments of the ground-water supplies have been made and points on the city's estimated growth curve be confirmed.

I. <u>Other Investigations and Reports</u>

Supplemental funds for investigation use were contributed to the Bureau of Reclamation for northern Arizona water studies by the State of Arizona through a series of contracts beginning in 1960. The first of these studies made under cooperative contract (No. 14-06-300-1008) presented an inventory of water resource data and served as a guide for water resources planning in Coconino and Navajo Counties. A report entitled "Cooperative Water Resource Inventory, Arizona," published by the Bureau of Reclamation in 1965, summarized these water resource data.

In 1962 reconnaissance investigations of potential water resource developments were initiated on the basis of a contract (No. 14-06-300-1214) between the United States and the Arizona Interstate Stream Commission. A second contract (No. 14-06-300-1416) with the Arizona Interstate Stream Commission, dated November 12, 1963, provided additional funds for completion of the reconnaissance investigation. These contracts with the State were for the purpose of defining alternative water resource plans either by direct diversion of water from the Colorado River, by water exchanges, by interbasin transfers, or by developing unappropriated tributary water in areas of the State outside the Central Arizona Project.

In the reconnaissance report entitled "Arizona-Colorado River Diversion Projects, Little Colorado River Basin and Adjacent Counties," dated September 1966 (revised June 1968), plans were presented for the development of municipal and industrial water supplies for the cities of Winslow and Holbrook by construction of a dam on Chevelon Creek at the Wildcat site and a pipeline and pumping plant system. The report also included plans for developing new water supplies for Flagstaff, Williams, and Ashfork by constructing a reservoir on Clear Creek at the Wilkins site and a system of pipelines and pumping plants to serve the cities. This report was used as a basis and guide to initiate feasibility investigations on the Flagstaff-Williams Division and the Winslow-Holbrook Division of the Mogollon Mesa Project.

J. Cooperation and Acknowledgments

The data and services of several Federal, State, and local government agencies, as well as private consulting firms and individuals, were used in the preparation of this report. The State of Arizona, through the Arizona Interstate Stream Commission, contributed funds to assist in the investigations for the Mogollon Mesa Project. The National Park Service, Bureau of Outdoor Recreation, Fish and Wildlife Service, Environmental Protection Agency, and the Forest Service have contributed consultative services and data and have also prepared reports on their cooperative studies of the project potentialities. The Geological Survey and the Soil Conservation Service also provided consultative services and data in the preparation of this report.

Special acknowledgment is made to city officials of Flagstaff for their continued and strong support of the project investigations, and to the College of Business, Northern Arizona University, for its special report on the population growth of Coconino and Navajo Counties.

II. GENERAL DESCRIPTION

II. GENERAL DESCRIPTION

A. Location

The Mogollon Mesa Project area is located in southern Coconino County and southwestern Navajo County, Arizona, as shown on Drawing 1066-314-50. Wilkins Dam and Reservoir would be on Clear Creek in Sections 31 and 32, T. 15 N., R. 13 E., G&SRM. An aqueduct system consisting of a pipeline, pumping plants, and other appurtenant works would extend from Wilkins Reservoir northwestward to deliver municipal and industrial water supplies for Flagstaff, Arizona.

The city of Flagstaff, county seat of Coconino County and northern Arizona's largest city, is located at about elevation 6900 on the southern slopes of the San Francisco Peaks. The city lies 137 miles north of Phoenix at the major crossroads of northern Arizona.

The cities of Williams lying 32 miles west of, and Winslow and Holbrook lying 58 and 87 miles east of Flagstaff, respectively, while not proposed for physical connection with project facilities could benefit from use of the studies made during investigations of the project and through receipt of indirect benefits made possible by development of the project.

B. Physiography

1. Topography. The Mogollon Mesa Project area comprises the southwestern portion of the Little Colorado River Basin of the Arizona-Colorado Plateau Province of Arizona. The Grand Canyon, Kaibab Plateau, San Francisco Plateau, and Echo Cliffs are notable features of this province while individual plateaus, together with

valleys, buttes, painted deserts, and flat-topped mesas, occur as well. Probably the most outstanding features of the western portion of the area are the 12,680-foot high San Francisco Peaks, the highest point in Arizona. South of Williams, Bill Williams Mountain, an extinct volcanic cinder cone, rises to 9,250 feet.

The Mogollon Rim, the southern boundary of the project area, separates the Colorado Plateau physiography from the Central Highlands Zone of Arizona. The major portion of the project is on the Mogollon slope, a subdivision of the Colorado Plateau Physiographic Province. The plateau is a relatively smooth rolling area. Locally major streams have cut narrow canyons as much as hundreds of feet deep, and a few prominent buttes and ridges rise abruptly from the regional ground level.

2. Regional Geology. The geology of the area comprises a thick sequence of near-horizontal sedimentary and volcanic strata. The rolling plains are mostly developed on relatively resistant formations by the erosion of overlying softer formations. The ridges and mesas generally represent local remnants of an overlying sequence of soft formations with an erosion-resistant layer at the top. A few of the mesas are due to vertical displacement along faults. Local drainage is mostly through shallow, low-gradient, dry channels, but the larger creeks and rivers of the area are mostly in narrow, steep-walled canyons.

Several significant geologic units occur at or near the surface in the project area. From oldest to youngest, they are as follows:

The Coconino sandstone is exposed in the lower walls and bottoms of several deep canyons. It is a uniform unit of fine-grained, weakly to moderately cemented, cross-bedded, quartz sandstone. Its thickness ranges from 200 to 1,000 feet, but only the upper portion is exposed in the canyons of the project area. The Coconino is in part saturated with water and is the principal aquifer of the region.

The Coconino sandstone is the principal aquifer in the Flagstaff study area and in combination with the upper 200 to 300 feet of the underlying Supai formation supplies most of the water to deep wells. Water quality ranges between 100 and 575 milligrams per liter (mg/l) total dissolved solids.

The Kaibab limestone in the Flagstaff area, overlying the Coconino sandstone, is mostly silty or sandy limestone that varies in color from yellowish or light gray to white and averages about 300 feet in thickness. It is above the water table throughout the area so is not a significant aquifer; however, because it is strongly jointed and fractured, it is important as a recharge medium to underlying rocks.

The Moenkopi formation is composed of red or reddish-brown siltstones, mudstones, and sandstones and where present in the Flagstaff area ranges from a few feet to 300 feet or more in thickness. Within the study area it is above the regional water table. Because of its less permeable nature, however, the Moenkopi may impede the downward percolation of ground water, creating perched water bodies that locally contribute small amounts of water to wells or springs.

Alluvial deposits in the area consist of coalescing fans at the base of San Francisco Mountain and of thin silt, sand, and gravel deposits along washes or underlying the valleys. These deposits vary in thickness. Wells in the Flagstaff area usually penetrate less than 50 feet of alluvium while some wells south of the area penetrate up to 300 feet of alluvium. Limited data on quality of water from the alluvium indicate total dissolved solids range from 150 to 390 mg/l.

Large areas of the plateau surface are capped with volcanic rocks consisting of flat-lying basalt flows with interflow zones of cinders and tuff.

The proposed project is involved to some degree with all of the described geologic formations and topographic features. In the Wilkins Reservoir impoundment area, Clear Creek and its tributaries flow through deep narrow canyons. The damsite is in a 500-foot-deep canyon which penetrates the Kaibab limestone and about 200 feet of the underlying Coconino sandstone.

The pipeline route is along the rolling plateau surface. Along the first several miles of the route, the surface is formed on the Kaibab limestone. At the Chavez Pass Pumping Plant site, the alinement extends up a steep slope on the Moenkopi formation to a basalt-capped higher plateau, which continues on to the Upper Lake Mary area. Much of the volcanic plateau is a poorly drained area and the alinement passes within a short distance of several small shallow lakes.

Upper Lake Mary, the terminus for the proposed pipeline, is in a long, narrow, flat-bottomed valley formed by the depression of a crustal block between two parallel fault zones. The valley floor is covered with an unknown thickness of clayey alluvium overlying volcanic rocks.

The soil cover in the area reflects climatic factors, parent materials, and the topography. Generally, the soil is thin and rocky and interspersed with frequent rock exposures. The steeper slopes, especially canyon walls, are almost bare, but the soil thickness reaches several feet in the broader, poorly drained plains and meadows. Over the Kaibab limestone the soils are sandy and calcareous with minor organic content. Over the volcanic rocks the soils are mostly clay, with a large percentage of rock fragments and low to moderate organic content. The clayey soils typically are subject to swelling and cracking because of fluctuations in moisture levels during the year.

No minerals of commercial value are known in the project vicinity. Sandstone and basalt suitable for building stone and similar uses, and limestone for making portland cement are available in large quantities. However, these low-value materials have not been developed since the regional market is adequately supplied by less remote deposits.

3. Climate. The higher elevation of the project area, the Mogollon Rim, Flagstaff, and Williams have typical mountain climate with mild cool summers and moderately cold winters. At Flagstaff there are only 3 days a year, on the average, when temperatures rise to 90°F. or above, and there are only 9 days a year, on the average, when the temperature falls to zero or below. Precipitation during the summer is in the form of thunderstorms, while winter precipitation is generally in the form of snow. The annual average snowfall at

Flagstaff is 80 inches and the total annual average precipitation is about 18 inches. The average annual growing season is 120 days, with the longest and shortest on record being 164 and 73.

At Winslow and Holbrook, in the lower elevations of the project area, the climate is arid with warm summers and moderately cold winters. Precipitation averages less than 8 inches a year. Mean monthly temperatures and precipitation are given in Table 1.

4. Vegetation. The project area is found in the Transitional Life Zone of the Colorado Plateau Physiographic Province consisting of mostly pinon-juniper community. Some ponderosa pine may be found along the western reach of the pipeline route in the Upper Lake Mary area; and Douglas fir in the inner gorge and on the north facing canyon slopes of Clear Creek. The flood plain is riparian community consisting of mostly cottonwood-ash-boxelder association. There is a wide diversity of biotic habitats resulting in a wide range of mesophytic and xerophytic plants and their associated fauna. The vegetation at the top of the plateau is typically pinon and juniper, with scattered shrubs and subshrubs such as snakeweed, prickly pear, and mendora. Limestone outcrops support fernbush and rockmat.

C. Historical or Archeological Sites

A preliminary study of the archeology of the Wilkins Reservoir site was made by the Department of Anthropology, Museum of Northern Arizona, in 1969, for the Bureau of Reclamation. Nine archeological sites consisting of six rock shelters and three areas with petroglyphs were investigated and recorded. The report sets out

Table 1
NORMAL MONTHLY TEMPERATURES 1/
Mogollon Mesa Project, Arizona

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Williams	31.0	33.2	38.5	46.9	54.8	63.6	68.7	66.6	61.4	51.0	40.4	34.4	49.2
Flagstaff	27.3	29.6	35.6	43.3	50.9	59.5	65.5	63.9	58.5	47.0	36.1	30.4	45.6
Winslow	31.0	37.5	45.6	55.6	64.8	74.3	80.2	77.8	70.7	57.4	41.3	32.5	55.7
Holbrook	33.4	38.8	45.7	54.3	62.4	71.5	77.6	75.5	69.1	57.1	42.6	34.8	55.2

AVERAGE RAINFALL 1/

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Williams	1.89	2.15	1.85	1.38	0.66	0.54	2.59	3.73	1.85	1.32	1.06	2.23	21.25
Flagstaff	1.83	1.78	1.45	1.18	0.51	0.69	2.28	2.84	1.58	1.52	1.00	1.65	18.31
Winslow	0.43	0.48	0.39	0.45	0.32	0.26	1.02	1.43	0.91	0.66	0.36	0.52	7.23
Holbrook	0.47	0.54	0.46	0.45	0.28	0.33	1.16	1.46	1.01	0.68	0.41	0.49	7.74

1/ From *Arizona Climatological Data*, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environment Data Service. Normals for all stations are climatological means based on the period 1931-1960.

several recommendations with regard to future archeological investigations to be made before construction of Wilkins Reservoir. These are:

1. Further study and analyses of the art work of the three petroglyph sites.

2. Excavation of four of the six rock shelter sites to gain knowledge of settlement, subsistence, and cultural-temporal affinities within the locality of the impoundment area.

The National Park Service concurs with these recommendations.

There are additional sites along or adjacent to the aqueduct right-of-way. As a matter of policy for preservation of archeological sites from vandals, pot hunters, and other unauthorized excavators, the locations of these sites are disclosed to properly accredited persons or institutions.

No historical sites, as listed in the National Register of Historic Places, are found within the project area.

D. History of Settlement

1. Flagstaff. Flagstaff, located in central Coconino County, was established during the early 1870's to serve as a work camp for construction crews building the Atlantic and Pacific Railroad. In 1880, there were only a few people living in Flagstaff, but the building of the railroad improved accessibility and by 1890 the population had reached nearly 1,000. In 1882, the first sawmill was established to furnish ties for the railroad under construction, which eventually became Santa Fe's main transcontinental line through Arizona. From that time lumbering and more recently wood products manufacturing have continued to play an important part in Flagstaff's economy.

Northern Arizona University was founded in 1899 as the Arizona State College of Flagstaff. The university has experienced accelerated growth in recent years. In 1970, enrollment was about 9,000. In 1894, Lowell Observatory was founded and in 1908 the U.S. Forest Service established its first experimental station in the newly created Coconino National Forest.

Astronomy, astrophysics, and astrogeology have become important in recent years and Flagstaff has been established as a major center for astronomical space and other scientific research.

The Navajo Ordnance Depot was constructed 12 miles west of Flagstaff in the early 1940's. Although the depot underwent a drastic reduction in force in 1971, it has been one of the county's largest employers.

2. Williams. Williams, located in western Coconino County, is the only early settlement besides Flagstaff that has maintained status throughout the years as an incorporated city in Coconino County. First settled in 1876, the post office was established in June 1881.

The town grew as an early division point on the Santa Fe Railroad and lumbering and cattle and sheep raising in the surrounding area contributed to its growth. Later it achieved importance as a tourist center and today Williams is known as the "Gateway to the Grand Canyon."

3. Winslow. By 1882, the construction of the Atlantic and Pacific Railroad had progressed westward to the Little Colorado River. Here the available water supply fixed a division point, and the city of Winslow was established at the western edge of central Navajo County.

Prior to this time the Mormons had established agricultural settlements on the Little Colorado River, but these proved unsuccessful because of the settlers inability to control the Little Colorado River for irrigation purposes.

With the establishment of the railroad, the cattle industry in northern Arizona began to thrive, and in 1884 the Aztec Land and Cattle Company established what became known as the famous Hash Knife Outfit on the banks of the Little Colorado River. The railroad, cattle, tourism, and more recently lumbering have been the chief industries of Winslow.

4. Holbrook. Holbrook was founded in 1882 as a new railroad station on the north bank of the Little Colorado River at about its present site. A post office and Wells Fargo station were established in Holbrook in 1882 and 1885, respectively. Holbrook became the Navajo County seat in 1895. Today it is the trading center for numerous ranches, and the employment center for approximately 100 Federal employees engaged in forestry, conservation, geology, and Indian affairs. There are many additional employees in motels and restaurants which support the tourist industry.

E. General Economy

1. Employment. Total employment in Coconino County provided mostly by government manufacturing, and services located in Flagstaff, increased from 13,900 in 1960 to 19,675 (annual average) in 1970, an increase of 41.5 percent 1/.

1/ Source: Arizona Statistical Review by Valley National Bank, September 1971.

According to records of 1970 almost 70 percent of the total employment is in the services, wholesale, and retail trade, and government sectors of the economy.

Logging and the manufacturing of timber into wood and paper products have accounted for most of the manufacturing employment. In Flagstaff alone, over 400 persons are so employed. The services industry, catering largely to tourists, comprises about 18 percent of the total employment. Government and services account for about 30 percent and 18 percent, respectively 1/.

Comparable employment figures for Navajo County during the past decade are not available. However, total annual average employment in 1970 was 11,600 2/, an increase of about 19 percent over 1967.

It is reported that the labor supply in Navajo County is generally adequate to meet all needs. Employment reaches annual highs during July and August and is lowest during December and January. This is true for services supporting tourism, manufacturing, and in highway and railway maintenance.

Indians living on the Navajo, Hopi, and Fort Apache Indian Reservations constitute a large, untapped labor resource. A recent survey made on the Navajo Indian Reservation by the Arizona State Employment Service showed that there are a great number of unemployed Indians who desire employment. The major barriers which present

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1/ Arizona State Employment Service.
2/ Source: Arizona Statistical Review by Valley National Bank, September 1971.

ready employment are: isolation (poor transportation and communication facilities on the reservations); low occupational skills; low educational attainment; and language. As these barriers are removed, a large labor reserve in the county can be utilized.

2. Tourism and Recreation. Tourism has been important to Coconino County since the time of early settlement when William Boss discovered an Indian trail into the Grand Canyon and set up tent houses to accommodate guests. It has been a major economic factor to the cities of Flagstaff and Williams in recent years because of the proximity to such attractions as Oak Creek Canyon, Walnut Creek National Monument, Sunset Crater National Monument, Wupatki National Monument, the skiing areas on the San Francisco Peaks and Bill Williams Mountain, the Coconino National Forest, and Lake Powell, in addition to the Grand Canyon.

Visitors to the National Park areas numbered about 3,623,300 in 1970, an increase of about 56 percent over the numbers registered in 1965. Passenger cars entering the northern Arizona area numbered about 2,523,000 in 1970, an increase of about 20 percent over those entering in 1966.

In addition to the scenic attractions, the higher wooded areas of the project area offer fishing, boating, swimming, and water skiing in lakes near Flagstaff and Williams.

Additional planned development of recreational areas can be expected to provide for continued employment growth in this economic sector of the project area cities.

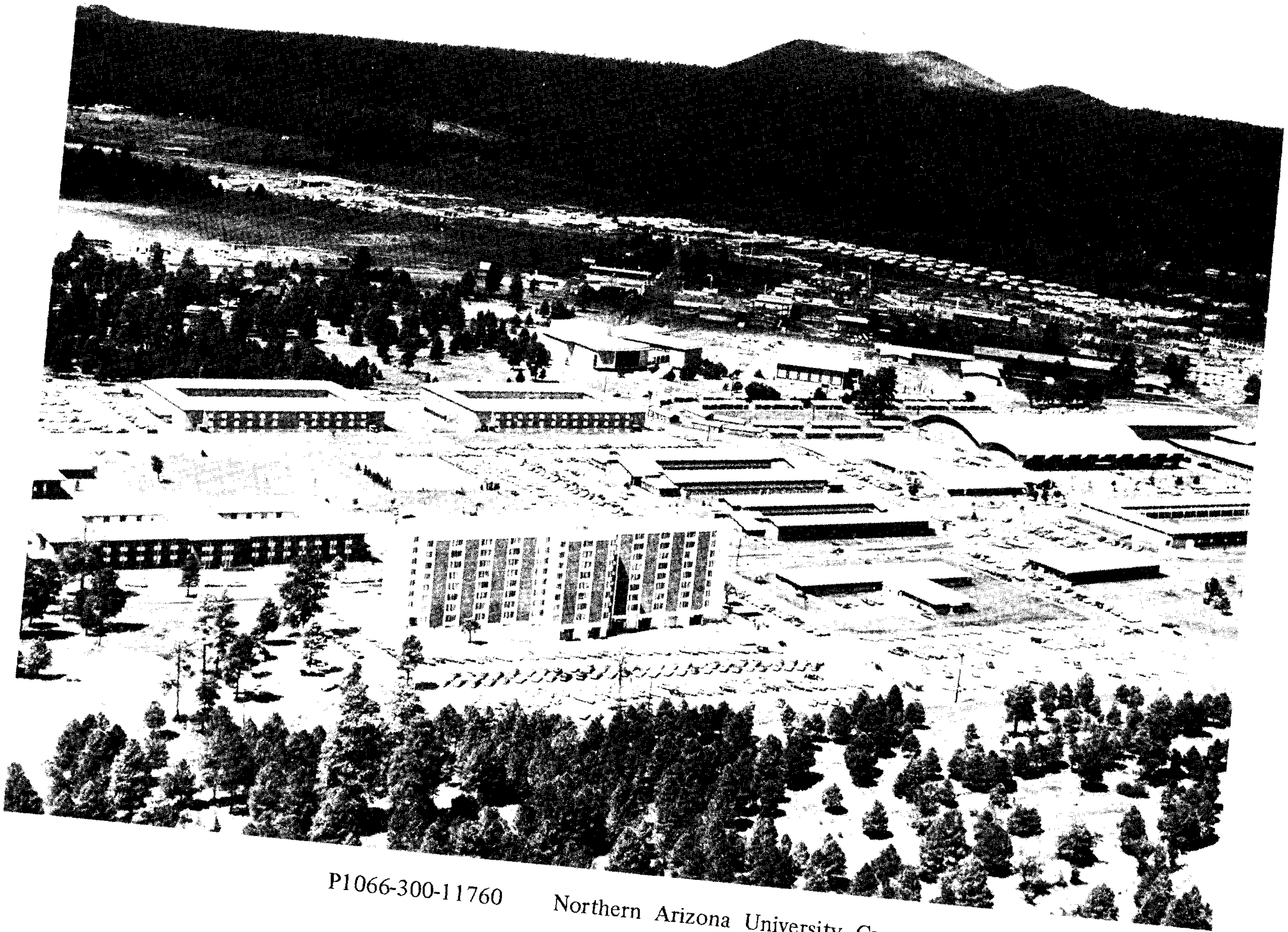
Winslow and Holbrook lie in close proximity to areas of scenic interest including Meteor Crater, Canyon de Chelly National Monument, Painted Desert, and the Petrified Forest National Park. Visitation to Canyon de Chelly and Petrified Forest numbered about 1,520,500 in 1970, an increase of about 45 percent over the numbers registered in 1965.

3. Education. The following description is exclusive of the school on the Navajo and Hopi Indian Reservations. In the 1969-70 school term, Coconino County had an attendance of 7,926 pupils in elementary schools and 3,217 pupils in high schools. Williams with one junior and senior high school and one elementary school had a total enrollment of 758.

Flagstaff is served by eight elementary schools, three junior high schools, two high schools, and two Roman Catholic elementary schools. Enrollment in the elementary and junior high schools totaled 4,673 and enrollment in Flagstaff high schools totaled 2,017 during the 1969-70 school year.

Northern Arizona University is located at Flagstaff. It has five colleges--The College of Arts and Sciences, the College of Business Administration, the College of Creative Arts, the College of Education, and the Graduate College. The university also includes the School of Forestry and the School of Applied Science and Technology (see Photo No. P-1066-300-11760).

The fall semester enrollment at Northern Arizona University is given for the following years:



P1066-300-11760 Northern Arizona University Campus

Fall Semester Enrollment--NAU

1963	1965	1967	1968	1969	1970	1975
4,800+	6,000+	7,473 1/	8,151 1/	8,704 1/	8,984 1/	10,956 2/

The Flagstaff school district provides vocational-technical education programs for adult and high school student training. Vocational training facilities in the city include two beauty schools.

The city of Winslow's educational system is comprised of four elementary schools, one junior high, and one high school. A parochial elementary school also serves the community. The total average enrollment during the 1969-70 school term was 2,750 students.

The public school system in the city of Holbrook is comprised of four elementary schools, one junior high school, and one senior high school with a total enrollment of 2,050 students, according to records as of June 30, 1970.

4. Retailing. The retail and wholesale trade industry probably ranks second in importance in the economy of the Flagstaff area. Today, as in the past, Flagstaff serves as the major trading center for all of northern Arizona. The other nearest trade centers of consequence are: Phoenix, Arizona, 137 miles south; Gallup, New Mexico, 186 miles to the east; and Las Vegas, Nevada, 263 miles west of Flagstaff. Employment in this industry is concentrated most heavily in order of importance in eating and drinking places, gasoline service stations, grocery stores, and general merchandise

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1/ Arizona Statistical Review by Valley National Bank, September 1971.

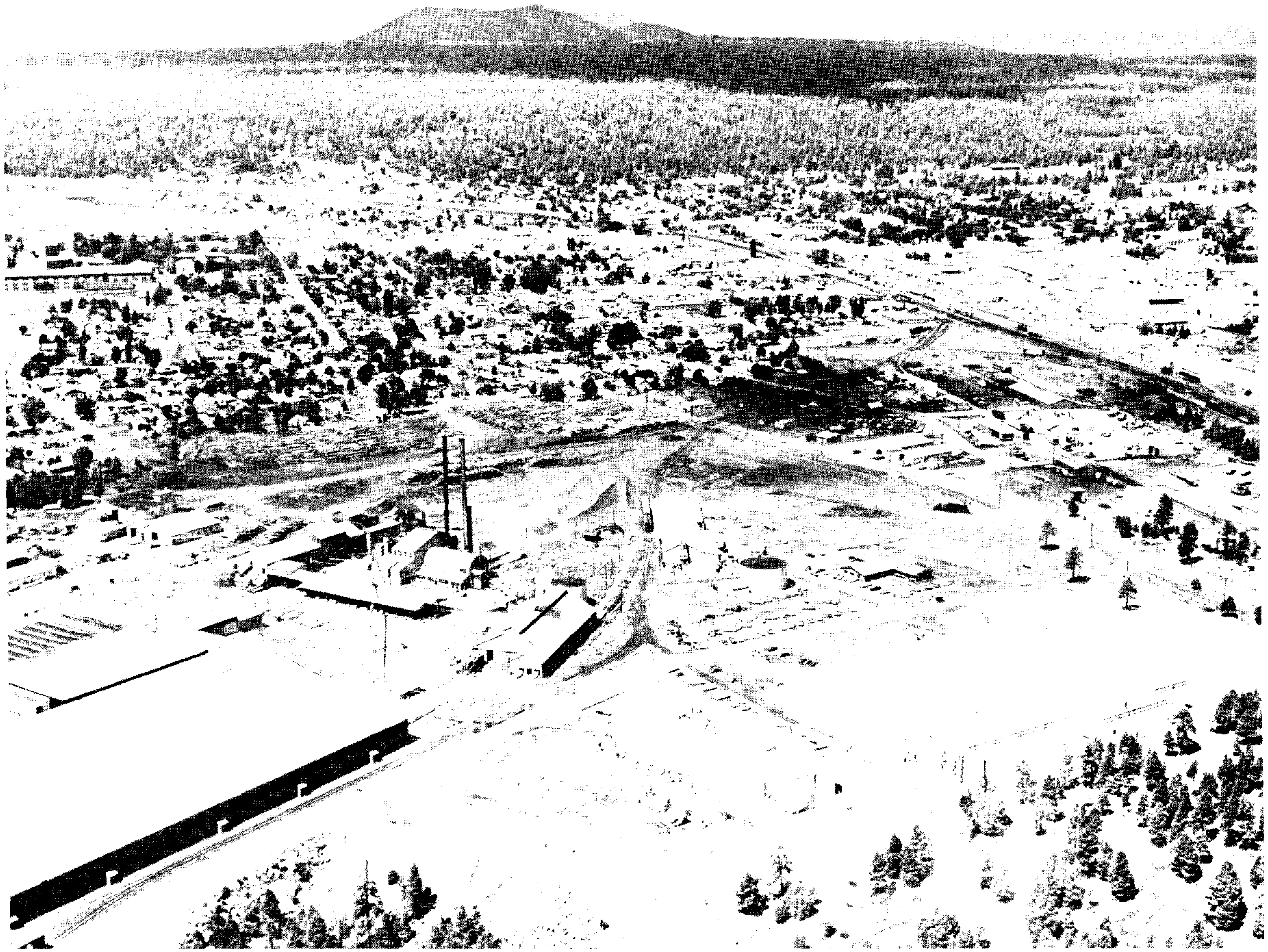
2/ Arizona Statistical Review by Valley National Bank, September 1976.

stores. Retail sales in Coconino County have grown 56 percent between 1962 and 1969.

The retail trade industry is the second most important source of employment in the Winslow-Holbrook area. Total retail sales in Navajo County have grown 33 percent between 1962 and 1969.

5. Manufacturing. Manufacturing is becoming an increasingly important factor in the economic base of both the Flagstaff and the Winslow-Holbrook areas (see Photo No. P-1066-300-11758). It is now Flagstaff's fourth most important industry. Timbering, log milling, planing, wood paper products, and processing of wood waste products account for over three-quarters of manufacturing employment in the area. The industry has become more diversified recently with the addition of two new companies, W. L. Gore and Associates, Inc., wire and cable manufacturers, and E-Z Mills, Inc., an apparel manufacturer.

Manufacturing in Winslow is becoming increasingly diversified. In addition to lumbering, food processing and apparel manufacturing plants are operating in the area. The Coca Cola Bottling Company of northern Arizona employs approximately 70 persons and is ranked as the second largest in the State. Western Superior Corporation, a division of the BVD Company, opened a new 120,000-square-foot plant in September 1968 with the latest equipment for cutting, sewing, and finishing apparel. The plant is currently manufacturing mens and boys tee shirts and underwear and ladies lingerie. Approximately 135 persons are currently employed and there are plans for plant expansion which would increase employment to about 400 persons.



P1066-300-11758 Wood Products Manufacturing–Flagstaff

6. Agriculture. Agricultural activities in the project area are devoted primarily to sheep raising and cattle ranching. Some cultivated areas exist on the alluvial lands of the Little Colorado River in the valley between Winslow and Holbrook. These areas are devoted chiefly to the raising of alfalfa, small grains, and feed crops.

The U.S. Census of Agriculture for year 1964 indicated the following values for agricultural production for the counties embracing the project area:

County	Crops	Livestock	Total
Coconino	$ 385,000	$2,825,000	$3,210,000
Navajo	2,810,000	2,814,000	5,624,000

7. Mining. Mining and quarrying are of minor importance in the economic base of Flagstaff and Williams in Coconino County. Sand and gravel, pumice, stone, copper, and uranium (listed in order of value of production) are the minerals which are mined in the county.

8. Transportation. The Atchison, Topeka, and Santa Fe Railroad, main line from Chicago to Los Angeles, serves the cities of Williams, Flagstaff, Winslow, and Holbrook. Winslow is headquarters for the Albuquerque Division. Here the railroad industry is the single largest employer in the city, employing nearly 1,000 persons.

Several trucking companies, including ICX, REA Express, Santa Fe Trail Transporation Company, Valley Copperstate Lines, Schade Refrigerated Lines, Watson-Wilson (Yellow Freight), and H&R Transfer and Storage, serve Flagstaff via Interstate Highway 17 from Phoenix and Interstate Highway 40 from Los Angeles.

Both Continental Trailways and Greyhound Bus Lines serve Flagstaff, Winslow, and Holbrook on transcontinental routes. Williams is served by Greyhound Bus Lines. Daily commercial air travel and freight service are provided by Frontier Airlines to Flagstaff and Winslow from Phoenix, Arizona, and from Denver, Colorado.

F. Population Growth

Population growth in Coconino County and Navajo County has increased an average of about 38 percent and 25 percent, respectively, each decade since 1930. In 1970 Coconino County had a population of 48,326 and by 1975 the population had reached 65,200 or an increase of over 35 percent in 5 years; Navajo County, with a population of about 47,559 in 1970 had increased to 58,500 by 1975. The two counties comprised about 6 percent of the total State population of approximately 2,224,000. Historic population of the two counties is shown in Table 2.

Table 2
POPULATION OF COCONINO AND NAVAJO COUNTIES, ARIZONA 1/
Mogollon Mesa Project, Arizona

	1930	1940	1950	1960	1970	Est. 1975
Coconino County	14,064	18,770	23,910	41,857	48,326	65,200
Navajo County	21,202	25,309	29,446	37,994	47,559	58,500
State	435,523	499,261	749,587	1,302,161	1,772,482	2,224,000

1/ Arizona Statistical Review. 32nd Annual Edition, September 1976, Valley National Bank.

The census of population for the project cities for 1970 with net change since the 1960 census is given in Table 3.

Table 3
POPULATION CENSUS OF PROJECT CITIES
Mogollon Mesa Project, Arizona

City	Census Period 1/ 1960	1970	% Change 1/	1975 2/	% Change
Williams	3,559	2,386	-33.0	2,700	+ 1.3
Flagstaff	18,214	26,117	+43.4	31,320	+19.9
Winslow	8,862	8,066	- 9.0	7,663	- 5.0
Holbrook	3,438	4,759	+38.4	5,093	+ 7.0

The Bureau of Reclamation entered into two contracts with Northern Arizona University, Flagstaff, dated November 16, 1966, and June 30, 1967, for population projection studies of the project cities and two other northern Arizona cities. Some adjustments were made in the projections following actual net changes which had occurred in population statistics during the interim period between the time when the studies were completed and the 1970 census. Table 4 shows the projected population for each of the project cities used in computing future water requirements.

Table 4
PROJECTED POPULATION OF PROJECT CITIES 1/
Mogollon Mesa Project, Arizona

Year	Williams	Flagstaff	Winslow	Holbrook
1980	3,100	36,770	9,870	6,650
1990	3,830	48,950	12,010	8,675
2000	4,560	62,480	14,510	10,875
2010	5,290	77,620	17,415	13,270
2020	6,020	94,320	20,715	15,860
2030	6,750	112,750	24,440	18,655

1/ Arizona Statistical Review, 27th Annual Edition, September 1971, Valley National Bank.
2/ Arizona Statistical Review, 32nd Annual Edition, September 1976, Valley National Bank.

III. PROBLEMS AND NEEDS OF THE AREA

III. PROBLEMS AND NEEDS OF THE AREA

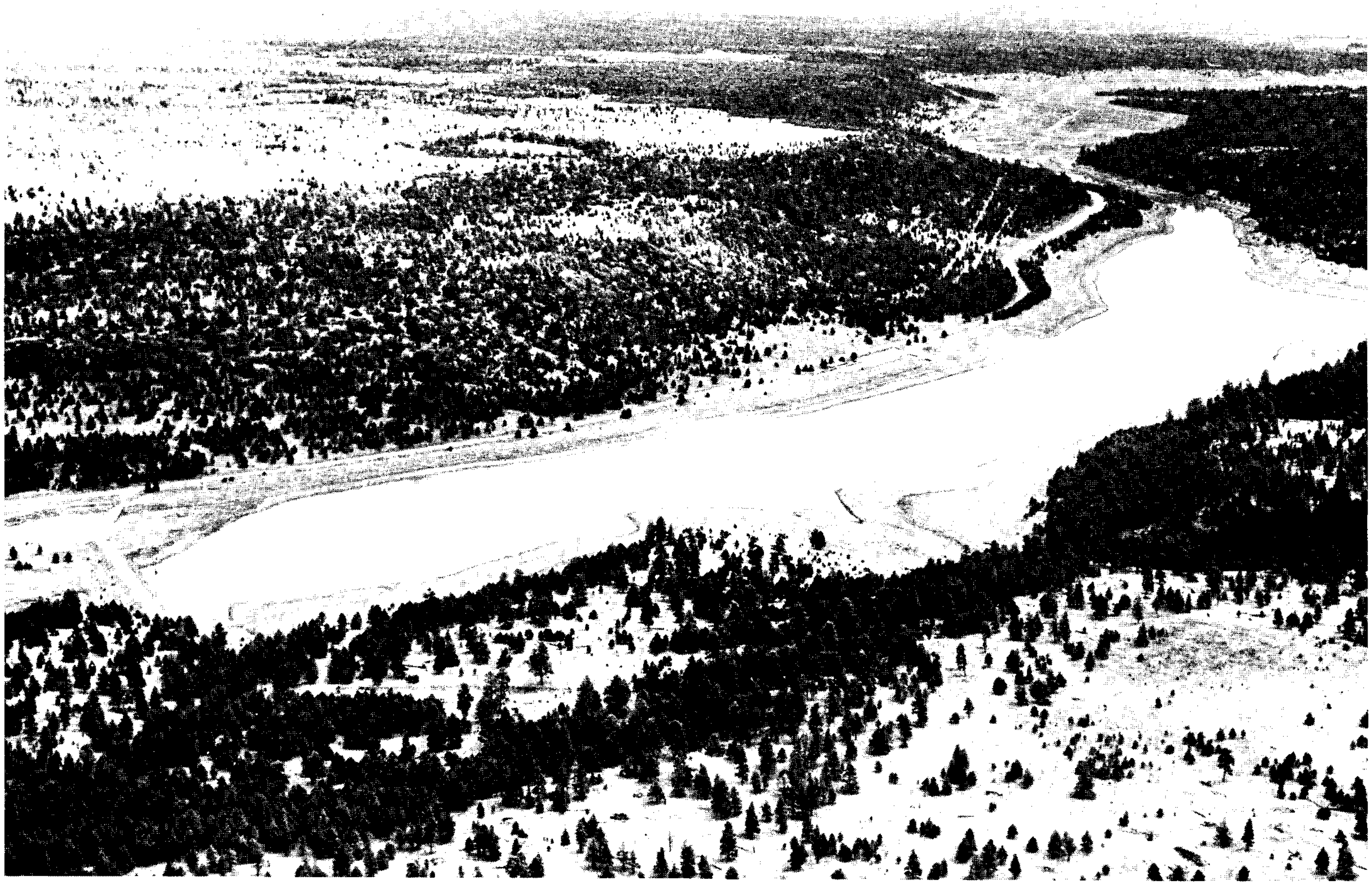
A. Need for Development

1. General. Flagstaff, Arizona, with a present population of approximately 26,000, is northern Arizona's largest city and leading trade center. Science and education are important culturally, while timbering, tourism, and increasing manufacturing activity are important factors in its present economy. Ideally located with respect to transportation facilities and with an unusually mild and totally enjoyable alpine climate, the Flagstaff area is poised for a promising future. Immediate areas of need are the expansion of industry and manufacturing to smooth out seasonal employment patterns, the provision of adequate low-cost housing, expanded facilities for training a skilled labor force, development of guidelines and policies for dealing with environmental issues, continued land use planning, providing for increasing demands for recreation brought on by increased population and leisure time, and early development of supplemental municipal and industrial water supplies. Deficiencies in local fresh water supplies and the availability of sources for future urban growth and industrial expansion constitute major problems in the further development of Flagstaff. While surface supplies are of good quality and generally adequate for the present population, there are times in years of less than average precipitation when dependability becomes a major concern. The ground-water sources of supply present problems of quality, high production costs, and concern for the potential that can be attained.

The undependable nature of the Williams water supply could be a contributing factor limiting community growth of the city as the high cost of importing water during periods of drought discourages establishment of potential industry. The development of a dependable, moderately priced source of water could be expected to stimulate community growth.

There are approximately 15,500 acres of arable land in the valley of the Little Colorado River in the Winslow-Holbrook area, but only about 1,620 acres of this have a history of irrigation. Irrigation water for the area is furnished by diversions from Clear and Chevelon Creeks and the Little Colorado River, and some pumping from private wells. Agricultural development of the available arable lands has been limited for a number of reasons including streamflow that seasonally is inadequate, high cost of developing streamflow regulatory storage, correspondingly high costs of distribution system development, and the short growing season.

2. Municipal and Industrial Water. The principal source of Flagstaff's present water supply is Upper Lake Mary, which controls about 54 square miles of drainage area on Walnut Creek (see Photograph No. P-1066-300-11772). Water yield from the lake is limited because of the small drainage area and because a large part of the water that is stored, especially in high flow years, is lost by seepage. The lake lies on basalt flows which overlie the Kaibab limestone. Both formations are probably highly fractured since the Anderson Mesa Fault passes along Walnut Creek Valley. As a result, high seepage rates have been experienced from the lake since its original



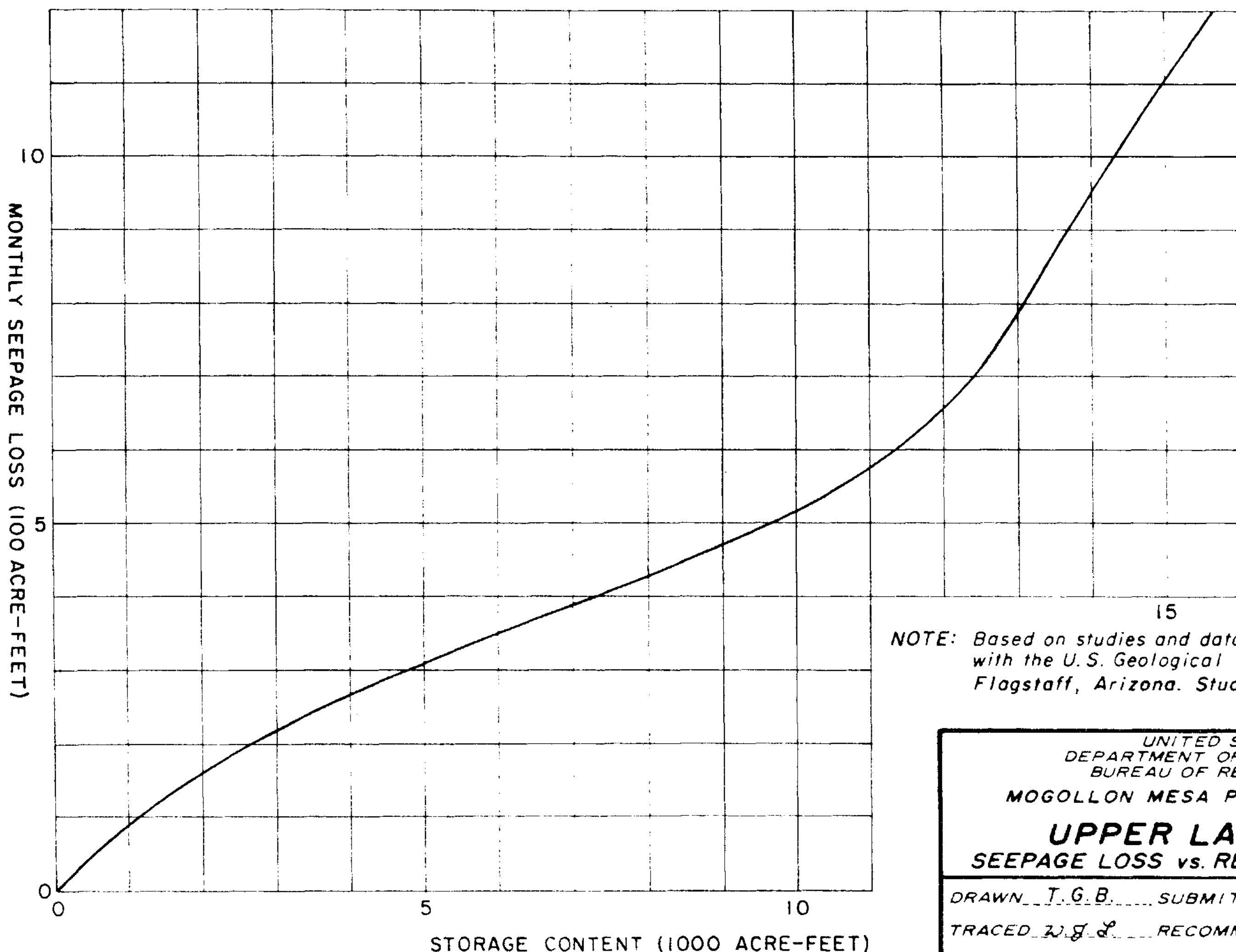
P1066-300-11772 Upper Lake Mary on Walnut Creek construction in 1941. After the dam was raised in 1952 to a storage capacity of about 15,600 acre-feet, even higher seepage rates have occurred.

A seepage study covering the period 1961 through 1966 was made to estimate seepage loss. Through a water budget analysis, it was estimated that seepage for the period of study averaged about 4,400 acre-feet annually. For the same period of study (1961-1966), Upper Lake Mary contributed an average annual supply of about 1,700 acre-feet to the city's water requirement. A graph of estimated seepage losses versus reservoir content is shown on Drawing No. 1066-314-70.

There is immediate need by the city of Flagstaff to develop the full potential of the San Francisco Mountain Inner Basin water supply, which is estimated to average about 3,000 acre-feet per annum for both the well field and the infiltration system. Attaining this potential would insure against critical shortages prior to the importation of water from Wilkins Reservoir.

The potential of the Lake Mary well field and the Woody Mountain well field needs to be examined at the earliest practical date to determine what portion these ground-water sources will be able to contribute to future water demands.

The city of Williams relies upon limited and erratic surface runoff from the northern slopes of Bill Williams Mountain for its municipal water supply. The city has always experienced water problems. In 1888, railroad engineers recommended abandonment of the station as a division point because of an unreliable and insufficient water supply.



NOTE: Based on studies and data prepared in cooperation with the U.S. Geological Survey and the city of Flagstaff, Arizona. Study period 1961-1966.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

MOGOLLON MESA PROJECT—ARIZONA

UPPER LAKE MARY
SEEPAGE LOSS vs. RESERVOIR CONTENT

DRAWN T.G.B.	SUBMITTED
TRACED W.G.L.	RECOMMENDED
CHECKED	APPROVED
PHOENIX, ARIZ. SEP. 17, 1971	1066-314-70

Beginning the period 1890-1900 water was hauled by rail from Del Rio Springs in Chino Valley during times of critical shortages. Since that time a total of seven small reservoirs has been built to contain runoff, but excessive quantities of stored water are lost through leakage. On the average of about once every 4 years, the city of Williams has to haul water by tank car from Del Rio Springs.

Efforts by the city to develop ground-water supplies in the vicinity have not met with success although exploration by deep well drilling has been made. Wells drilled 1,020 feet into the Coconino sandstone formation and 2,500 feet and 2,340 feet into the Supai formation were all dry holes.

The city of Williams needs to continue its program of water salvage through lining of existing reservoirs. The degree of success experienced in the sealing of Dogtown Fork Reservoir completed in 1970 will dictate the course of action to be taken regarding a similar program on Kaibab Reservoir.

3. Outdoor Recreation. Population growth, combined with the advent of increasing leisure time, places increasing demands for planning and developing new facilities for fishing and recreation. The forested lands within and surrounding the project area are ideally suited to these purposes. Augmenting the natural resources with fresh water lakes and live streams would provide additional facilities to accommodate the needs for fishing, swimming, and boating.

B. Existing Water Supply Systems

1. Flagstaff. Municipal and industrial water for the city of Flagstaff is currently supplied from four sources: Upper and Lower

Lake Mary on Walnut Creek (surface runoff), Lake Mary well field, Woody Mountain well field, and the Inner Basin area of the San Francisco Mountain.

Upper Lake Mary, located about 11 miles southeast of Flagstaff, has a present capacity of about 15,600 acre-feet at spillway crest elevation. It is the primary source of water supply. The lower lake has a capacity of about 8,600 acre-feet, but it is shallow and leaks badly and is used only in case of emergencies. Water is released from Upper Lake Mary through a 36-inch concrete pipeline to a pumping station at Lower Lake Mary. Two pumps, with a combined capacity of 8.0 million gallons per day, lift water from the pumping station through a 27-inch main to the filter plant from which point the water is pumped into the distribution system network and two 50-million-gallon terminal storage reservoirs.

Upper Lake Mary has been developed to essentially its full potential for local surface water without lining and rehabilitation. Upper Lake Mary Dam was constructed by the city in 1941, and in 1952 the dam was raised 12 feet to provide additional reservoir capacity. Since that date, the reservoir spilled once in 1952 and once in 1969, and three times in 1966 for short durations. Over the period of record the lake has supplied from a low of 8.5 percent to a high of 92 percent of the city's annual water requirement. The average is about 63 percent.

The Lake Mary well field located north of Lower Lake Mary (based on 1976 data) consists of five wells, drilled to depths ranging from 1,050 to over 1,300 feet. Depths of pumping range from 400 feet to

600 feet. Two wells are equipped for production, two are used for observation, and one is not connected. They furnish additional water to the city during periods of heavy demand and emergencies. The potential capacity of this well field is not known, but the city and the Geological Survey have been working together to obtain pump tests that will form the basis for an estimate of the potential yield. One major drawback to heavier use from this source is that the quality of water is inferior to that from the other developed sources as it contains about 650 parts per million total dissolved solids and relatively high levels of iron and manganese. Although it has not been determined what the concentration of iron might be under continued pumping, preliminary analyses indicate the water can be brought within acceptable levels through treatment. Very rough preliminary estimates made to date indicate an annual yield of about 3,200 acre-feet might be attained with the well field fully developed.

The Woody Mountain well field is located about 7 miles southwest of Flagstaff. The system consists of six drilled wells ranging in depth from 1,540 to 1,746 feet. These wells are in production with a maximum capacity of about 3.7 million gallons per day. The seventh well is being drilled and will be in production in 1977. A 16-inch-diameter pipeline carries the water into Flagstaff. This source is expensive, being utilized during periods of peak demands and in seasons of drought when Upper Lake Mary supplies are inadequate.

The safe yield of the Woody Mountain well field has never been determined, but the six wells already constructed probably define the field's areal extent. The city is presently considering plans to fully test the field under sustained pumping in an effort to obtain more definite data on yield, drawdown, recovery, power costs, and other operations and maintenance data. Over the period of record, 1956-1970, this source has been furnishing an annual average quantity of about 380 acre-feet. In 1964, the well field supplied 1,200 acre-feet, the maximum of record. Existing data indicate a potential annual yield of about 3,200 acre-feet. The quality of water is excellent.

The Inner Basin is the original source of municipal water for Flagstaff. As of 1972, facilities of the Inner Basin consisted of three drilled wells, a tunnel infiltration system, a pipe collection system, and a pipeline extending from the basin to the city. During the period 1956 through 1969 the Inner Basin furnished, on the average, about 22 percent of the city's annual water requirement making it the second most important source of water supply. Since 1959, the city and Federal agencies have been cooperating in the exploration and development of the Inner Basin water source. During the period 1968-1971, the city drilled three production wells to tap the ground water supplies. These wells have been operated during the summer months since their completion to help the city meet its peak requirements. Further development of this well field is not expected in the near future since any additional wells would have to be drilled into bedrock. During the period 1956 through 1969, the Inner Basin furnished on an average annual basis only about 570 acre-feet or approximately 20 percent of the basin's apparent potential. Existing data indicate a potential average annual yield of about 3,000 acre-feet. Water quality is excellent. Present sources of water supply and the potential for Flagstaff are indicated in Table 5.

As indicated in Table 5, the estimated average annual potential yield from existing sources of supply is 12,500 acre-feet. In any one year the yield could be substantially less because of the direct dependence of Upper Lake Mary and the Inner Basin on the available precipitation and runoff. Long-term pumping tests (4 to 6 months) would be required in the Woody Mountain and Lake Mary well fields to obtain information on ultimate sustained yield.

Production wells in the Inner Basin were pumped at high capacity during the summer of 1971 following a subnormal year of precipitation. Ground-water levels in the basin were drawn down extensively and as of the spring of 1972 these levels were not recovering. It will take several years of record comparing pumped withdrawals with average years of precipitation to indicate the degree of sustained yield that would be available from this source.

In addition to the Woody Mountain well field being an unproven source as to the degree of ultimate water yield obtainable, it is a very expensive source of supply. Because of the extreme pumping depths and the corresponding high power costs, the estimated cost of water production at the wellhead is in excess of $300 per acre-foot. Consequently, this source is used sparingly and only as emergencies dictate.

The estimate of the average annual potential yield for Upper Lake Mary is shown in Table 5.

Table 5
PRESENT AND POTENTIAL SOURCES OF WATER SUPPLY
Flagstaff, Arizona
Mogollon Mesa Project, Arizona

Unit: 1,000 Acre-Feet

Source	Average Annual Supplied 1947-1969	Supplied in 1969	Estimated Average Annual Potential
Upper Lake Mary (as is)	1.40	2.65	3.1 2/
Lake Mary Wells	0	0	3.2
Woody Mountain Wells	0.38 1/	0.34	3.2
Inner Basin	0.57	1.23	3.0
Total	2.35	4.22	12.5

1/ Woody Mountain well field was constructed in 1955. Figure represents average water supplied to the city for the period 1956 through 1969.

2/ Potential yield under projected demands for the year 2000.

Data which would permit reasonable estimates of the local potential development that could be depended upon are presently unavailable. John Carollo Engineers recently published a report for the city of Flagstaff entitled "Water Resources Report, City of Flagstaff, Arizona, 1972." The report concludes, in part, that the potential capacity of presently developed sources with existing facilities, and facilities under construction is approximately as tabulated.

Source	Annual Capacity (Acre-Feet)
Woody Mountain Wells	2,790
Lake Mary Wells	2,240
Inner Basin Wells and Springs	120-1,230
Lake Mary Surface Water	300-3,070
	5,450-9,510
Mean	7,480

The report recommends, in part, that a "first phase, 5-year program" be carried out by the city to include testing and developing data to support the estimate in the above tabulation. Should the results of an executed "first phase" program indicate that local sources of supply can be relied upon to furnish the mean yield estimated in the above tabulation on a sustained basis, the city would have sufficient water to meet estimated requirements until about 1980.

2. Winslow. Winslow obtains its municipal water supplies of suitable quality from a well field located about 6 miles southwest of Winslow in Section 13, T. 18 N., R. 14 E. Current development comprises five wells. A sixth well in this field has been abandoned.

Pertinent data for these wells are contained in Chapter IV of this report.

Annual pumpage from the well field averaged about 1,400 acre-feet during the 1950-1963 period, increased to about 1,800 acre-feet in 1968, and decreased to about 1,600 acre-feet in 1970. Although short-term year-to-year water level declines have occurred, the records indicate no significant water level decline for the period of record 1953-1968. There has been no reported decrease in well yields.

The available ground-water source can be expected to fulfill the needs estimated for long-range growth and expansion of Winslow.

Early water supplies for the Winslow area were met from Clear Creek. Early irrigators constructed a concrete diversion dam and irrigation ditch on Clear Creek in 1897. These facilities and the water rights were purchased by the Santa Fe Railroad Company in 1912. Santa Fe developed a municipal water supply by constructing a pumping plant at the diversion dam reservoir, a filter treatment plant, a pipeline system, and storage tanks. These two waterworks systems were given to the city in 1953. The erratic supply and inferior quality from saline springs in lower Clear Creek forced the city to develop the ground-water sources, and the surface system as eventually abandoned.

3. <u>Holbrook</u>. Municipal and industrial water supplies of suitable quality for Holbrook are obtained from a well field located about 2 miles southwest of the city in Section 10, T. 17 N., R. 20 E. Current development comprises three wells. Pertinent data for these wells are contained in Chapter IV of this report.

Annual pumpage from the well field averaged about 550 acre-feet during the 1959-1963 period, which was increased to about 650 acre-feet in 1970. Although short-term, year-to-year water level declines have occurred, the records indicate no significant water level declines for the period 1952-1968. There has been no reported decrease in well yields.

The available ground-water source can be expected to fulfill the needs estimated for long-range growth of Holbrook.

4. Williams. The existing water supply system consists of seven reservoirs which impound surface runoff from the northern slopes of Bill Williams Mountain. The total storage capacity of the combined reservoir system is about 2,700 acre-feet. About 2,000 acre-feet or 74 percent of the total capacity is contained in Dogtown Fork and Kaibab Reservoirs, both on the drainage of Dogtown Fork. Dogtown Fork Reservoir is the largest of the seven with a storage capacity of about 1,100 acre-feet. Kaibab Reservoir has a storage capacity of about 900 acre-feet. About 20 percent of the total storage capacity available, 540 acre-feet, is contained in the Santa Fe and Cataract Reservoirs. The total storage capacity of the seven reservoirs is several times the city's annual need, but shortages occur periodically because of lack of sufficient holdover storage to allow for years of subnormal precipitation and because of excessive reservoir seepage.

The sealing of Dogtown Fork Reservoir with a polyvinyl chloride (PVC) plastic membrane of 10 mil thickness, protected by an 18-inch earth covering, was completed in 1970 by the city of Williams under a program financed in cooperation with the Department of Housing and

Urban Development. Preliminary reports of the reservoir operation since rehabilitation indicate the lining has successfully sealed the reservoir. The city is now seeking a source of financing to undertake a similar lining program on Kaibab Reservoir.

During the period 1957 through 1970 the city's annual water use for all purposes averaged about 275 acre-feet.

C. Future Water Requirements

The future water requirements for the cities in the project area have been projected for a 50-year period of analysis, 1980 to 2030.

Winslow and Holbrook have historically had adequate water supplies; so use has increased with time and the future projects reflect this historical trend. Even using the increasing per capita use and increasing populations the available supply is adequate to meet future needs. This is not the case for Flagstaff and Williams, which have historically had shortages. A new plan of development should at least maintain under future conditions the past and present water consumption; so the standard of living would not be degraded.

If the project is reinvestigated in the future, operation studies will be made using both existing and project facilities with projected future water requirements in order to estimate when project facilities are needed and to better evaluate project benefits.

Population projections and future municipal and industrial water requirements for the cities of Flagstaff, Winslow, Holbrook, and Williams are shown in Tables 6, 7, 8, and 9, respectively.

Table 6
PROJECTED POPULATION AND WATER REQUIREMENTS
Flagstaff, Arizona
Mogollon Mesa Project, Arizona

Year	Population Projection	Projected Use (gallons per capita per day)	Annual Consumption (acre-feet)	Annual Requirement 1/ (acre-feet)
1960	18,214 2/			
1970	26,117 3/	150	4,400	5,200
1980	36,770	150	6,200	7,300
1990	48,950	150	8,200	9,600
2000	62,480	150	10,500	12,400
2010	77,620	150	13,000	15,300
2020	94,320	150	15,800	18,600
2030	112,750	150	18,900	22,200

1/ Includes 15 percent for distribution system losses.

2/ 1960 census.

3/ 1970 census.

Table 7
PROJECTED POPULATION AND WATER REQUIREMENTS
Winslow, Arizona
Mogollon Mesa Project, Arizona

Year	Population Projection	Projected Use (gallons per capita per day)	Annual Consumption (acre-feet)	Annual Requirement 1/ (acre-feet)
1960	8,862 2/			
1970	8,066 3/	145	1,310	1,540
1980	9,870	155	1,720	2,020
1990	12,010	165	2,218	2,610
2000	14,510	175	2,850	3,345
2010	17,415	185	3,610	4,245
2020	20,715	195	4,525	5,325
2030	24,440	205	5,610	6,600

1/ Includes 15 percent for distribution system losses.

2/ 1960 census.

3/ 1970 census.

Table 8
PROJECTED POPULATION AND WATER REQUIREMENTS
Holbrook, Arizona
Mogollon Mesa Project, Arizona

Year	Population Projection	Projected Use (gallons per capita per day)	Annual Consumption (acre-feet)	Annual Requirement 1/ (acre-feet)
1960	3,438 2/			
1970	4,759 3/	140	750	880
1980	6,650	150	1,115	1,315
1990	8,675	160	1,555	1,830
2000	10,875	170	2,075	2,440
2010	13,270	180	2,680	3,150
2020	15,860	190	3,375	3,970
2030	18,655	200	4,180	4,920

1/ Includes 15 percent for distribution system losses.

2/ 1960 census.

3/ 1970 census.

Table 9
PROJECTED POPULATION AND WATER REQUIREMENTS
Williams, Arizona
Mogollon Mesa Project, Arizona

Year	Population	Population Forecast by Northern Arizona University	Adjusted Population Forecast	Per Capita Water Use Rate (gallons)	Projected 1/ Annual Water Requirement (acre-feet)
1960	3,559 2/				
1970	2,386 2/	4,209	2,386	150	470
1980		4,923	3,100	150	610
1990		5,660	3,830	150	760
2000		6,366	4,560	150	900
2010		7,116	5,290	150	1,050
2020		7,845	6,020	150	1,190
2030		8,600	6,750	150	1,330

1/ Includes 15 percent allowance for losses in city distribution system.

2/ Census.

IV. WATER RESOURCES

IV. WATER RESOURCES

A. Surface Water

1. General. Clear Creek rises along the Mogollon Rim in southeastern Coconino County in central Arizona and flows northeasterly through the Coconino and Sitgreaves National Forests. It has cut a deep narrow canyon into the high plains of the Colorado Plateau to its confluence with the Little Colorado River several miles east of Winslow, Arizona. Runoff from Clear Creek is extremely erratic, both seasonally and annually, with periods of up to 10 consecutive months of no flow being recorded at the Wilkins Dam site. Maximum monthly flows exceeding 60,000 acre-feet have occurred on several occasions. Annual runoff at the dam site has varied from a recorded low of 12,700 acre-feet in 1956 to a maximum recorded high of 142,200 acre-feet in 1952.

A portion of the Clear Creek runoff is produced by summer thunderstorms, usually in August and September. The major runoff, however, is from winter and spring snowmelt during the period February through May. June, July, and October generally produce little, if any, runoff.

Walnut Creek originates in southeastern Coconino County about 30 miles southeast of Flagstaff, Arizona. This area is characterized by many small, natural depressions or closed drainages occupied by intermittent lakes. The upper reaches of Walnut Creek drain into one of the largest of these closed basins which forms Mormon Lake. The creek reappears north of Mormon Lake and flows northwest through Lake Mary, then northeast into San Francisco Wash. San Francisco

Wash flows eastward into Canyon Diablo which enters the Little Colorado River near Leupp, Arizona, about 40 miles east of Flagstaff.

Runoff from Walnut Creek at Upper Lake Mary is erratic and subject to long periods of only minor streamflow. Many months of no flow have been experienced. The maximum monthly runoff from the 53.5-square-mile drainage area above Upper Lake Mary is estimated to be 10,600 acre-feet in April 1952. Annual volumes are estimated to vary from 1,200 acre-feet in 1956 to 21,400 acre-feet in 1952. No estimates of runoff were made for Walnut Creek for the period prior to 1947.

The origin of streamflow in Walnut Creek is much the same as discussed above for Clear Creek. Snowmelt occurs predominantly in January through April, followed by low streamflow from May through November. Runoff response to summer thunderstorms is much less pronounced on Walnut Creek than on Clear Creek due to much higher rates of infiltration. The infiltrating rainfall produces delayed runoff, primarily from drainage of the upper soil profile, which yields streamflow of sustained low volume rather than of short duration and high peak.

The study period selected to evaluate water supply and to test operating conditions is water years 1947-1969. This period corresponds to the availability of streamflow records at the Wilkins Dam site and of operating records for Upper Lake Mary from which historic inflow to that reservoir was estimated.

2. Inflow to Project Reservoirs. The proposed water supply for the Mogollon Mesa Project would be supplied by Clear Creek and by Walnut Creek.

The average annual historical runoff for Wilkins Reservoir for the entire study period (1947-69) is 56,000 acre-feet. This record is based on the Geological Survey records from the gaging station, Clear Creek below Willow Creek, near Winslow, located about a mile below the proposed dam site. All data prior to 1965 are essentially undepleted or virgin streamflow records. In December 1964, Blue Ridge Reservoir began storing waters of Clear Creek for exporting to the Verde River system. Data for the years 1965-1969 were adjusted to virgin conditions based on records of operation for Blue Ridge Reservoir.

Blue Ridge Reservoir, owned and operated by the Phelps Dodge Corporation, is located on East Clear Creek about 12 miles above the proposed Wilkins Dam site. It has a storage capacity of about 15,000 acre-feet and controls 75 of the 321 square miles of drainage area above Wilkins. Water is pumped from Blue Ridge Reservoir out of the Little Colorado River drainage into the Verde River system. First exports were made in October 1965. Since that time diversions have averaged 12,150 acre-feet annually for the period 1966 to 1970. Since the operation of Blue Ridge Reservoir affects inflow to the proposed Wilkins Reservoir, it was necessary to include Blue Ridge in the overall analysis of the operations of the project system. The estimated virgin inflow of East Clear Creek to Blue Ridge Reservoir for the study period 1947-1969 averages 18,000 acre-feet annually.

Upper Lake Mary, formed by an earthfill dam built in 1941 and raised in 1952, is used for municipal water supply for the city of Flagstaff, Arizona, and is located on Walnut Creek about 11 miles southeast of Flagstaff. The present structure has a usable capacity of about 15,600 acre-feet. No records of inflow are available. Water supply records for Flagstaff do include, however, weekly stage readings on Upper Lake Mary and Lower Lake Mary and releases or pumpage from the lake for the period 1947-1969. These data were used to develop monthly estimates of inflow for the 1947-1969 study period using a weekly water budget analysis. The estimated virgin natural inflow from Walnut Creek is 8,700 acre-feet annually. The inflow design flood for Upper Lake Mary has a peak discharge of 20,760 acre-feet with a 4-day volume of 12,920 acre-feet.

a. Evaporation. Project operation studies include an average annual allowance for water-surface evaporation of 400 acre-feet for Blue Ridge Reservoir, 1,400 acre-feet for Wilkins Reservoir, and 3,100 acre-feet for Upper Lake Mary.

b. Seepage. Operation studies include an average annual allowance for seepage of 3,800 acre-feet at Blue Ridge Reservoir and 8,900 acre-feet at Wilkins Reservoir. It is assumed that Upper Lake Mary would be fully lined thereby making seepage losses negligible.

Wilkins Reservoir would lie within a narrow, nearly vertical-walled canyon about 500 feet deep which exposes about 300 feet of Kaibab limestone overlying about 200 feet of the Coconino sandstone. The top of the active conservation storage pool, elevation 6194, in the 45,000-acre-foot reservoir would be just below the contact zone of these formations. The Kaibab-Coconino contact zone does, however, dip into the proposed reservoir in the left abutment upstream from the dam. In this area a grout curtain would be required from elevation 6194 (top of active conservation storage) down to the contact between the limestone and sandstone to minimize leakage.

A seepage analysis of Wilkins Reservoir under the above conditions indicated a seepage rate of about 34 cubic feet per second (ft^3/s) at the end of 1 year of operation and about 24 ft^3/s at the end of 2 years of operation. The reservoir seepage loss after several cycles of filling and emptying was computed to approximate a maximum of 20 ft^3/s. This seepage rate was used in the feasibility-grade operation study. The enlargement and lining of Upper Lake Mary under future project conditions are necessary in order to make the lake into a regulatory and carryover storage reservoir for diverted Clear Creek flows. Without lining, much of the water imported from Wilkins Reservoir would be lost by seepage, thereby reducing the project yield significantly.

3. Sedimentation. Sediment inflow to Blue Ridge Reservoir was not evaluated. The reservoir is assumed to retain the sediment inflow from its 75-square-mile drainage, leaving 246 square miles contributing to Wilkins Reservoir. No commensurate reduction in storage capacity of Blue Ridge was, however, considered in the operation studies. The effects of assuming some storage reduction in Blue Ridge would be to increase the average flow to Wilkins Reservoir during high flow periods. However, little, if any, of this would accrue during the critical flow period.

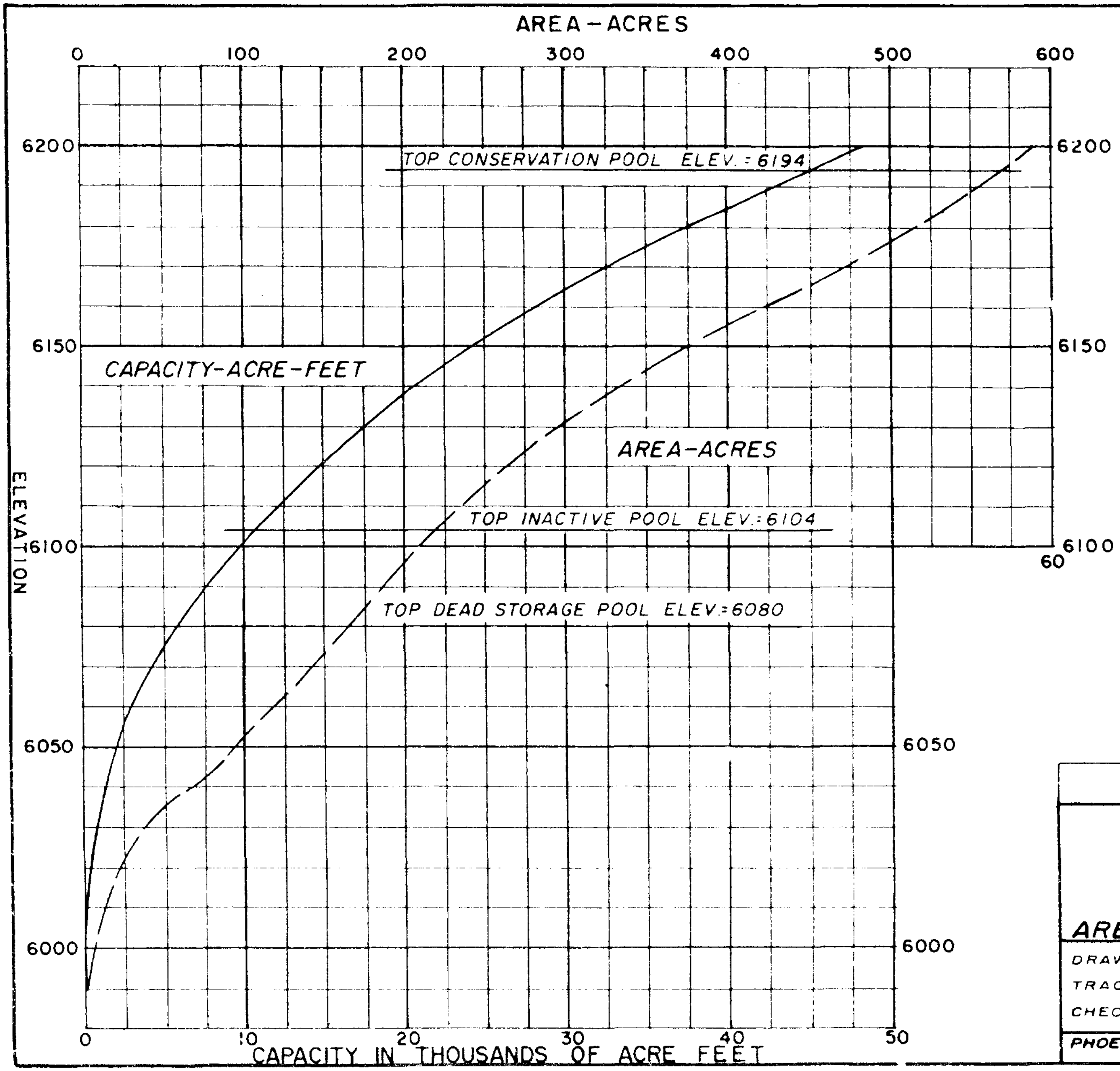
Based on visual inspection and evaluation of the sediment-producing characteristics of the basin, an annual sediment yield rate of 0.3 acre-foot per square mile was adopted for Wilkins Reservoir. The mean annual sediment inflow to Wilkins Reservoir is estimated to be 72.6 acre-feet, yielding 50- and 100-year sediment accumulations of 3,630 and 7,260 acre-feet, respectively.

The 50- and 100-year sediment volumes were distributed in the 45,000-acre-foot capacity reservoir following the Emperical Area-Reduction Method. The resulting sediment elevations at the dam after 50 and 100 years are elevations 6009 and 6033.5, respectively. Area and capacity relationships for initial conditions are shown on Drawing No. 1066-314-27.

An estimated annual deposition of about 10 acre-feet in Upper Lake Mary is based upon a unit annual yield being less than 0.2 acre-foot per square mile. 1/ This low unit value is substantiated by a hydrographic survey made by the Geological Survey during September 1967 which, when compared to the preconstruction surveys of 1940-41, showed no deposition of sediments in the midstorage range. Since the anticipated quantity of sediment inflow involved amounts to less than 5 percent of the active reservoir capacity, detail sediment deposition studies were not initiated.

Deposition at the dam was not evident except for materials which appear to have resulted from organic decomposition during summer months when the lake was stratified.

1/ Pacific Southwest Inter-Agency Committee, Water Resources Council, June 1971, Main Report, Lower Colorado Region Comprehensive Framework Study, Map following page 42, Irrigated Lands, 1965, Drawing No. 1019-314-39.



AREA-CAPACITY TABLE		
ELEV.	AREA	CAPACITY
5987	—	—
6000	7	46
6025	28	484
6050	94	2009
6075	155	5121
6100	211	9696
6125	279	15821
6150	377	24021
6175	490	34859
6200	591	48371

NOTE

These curves are based on 1" = 1000' contour interval 25', Wilkins Reservoir Site Topography Drawing No. 1066-314-5.

ALWAYS THINK **SAFETY**

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOGOLLON MESA PROJECT

WILKINS RESERVOIR
CLEAR CREEK
AREA AND CAPACITY CURVES 1968

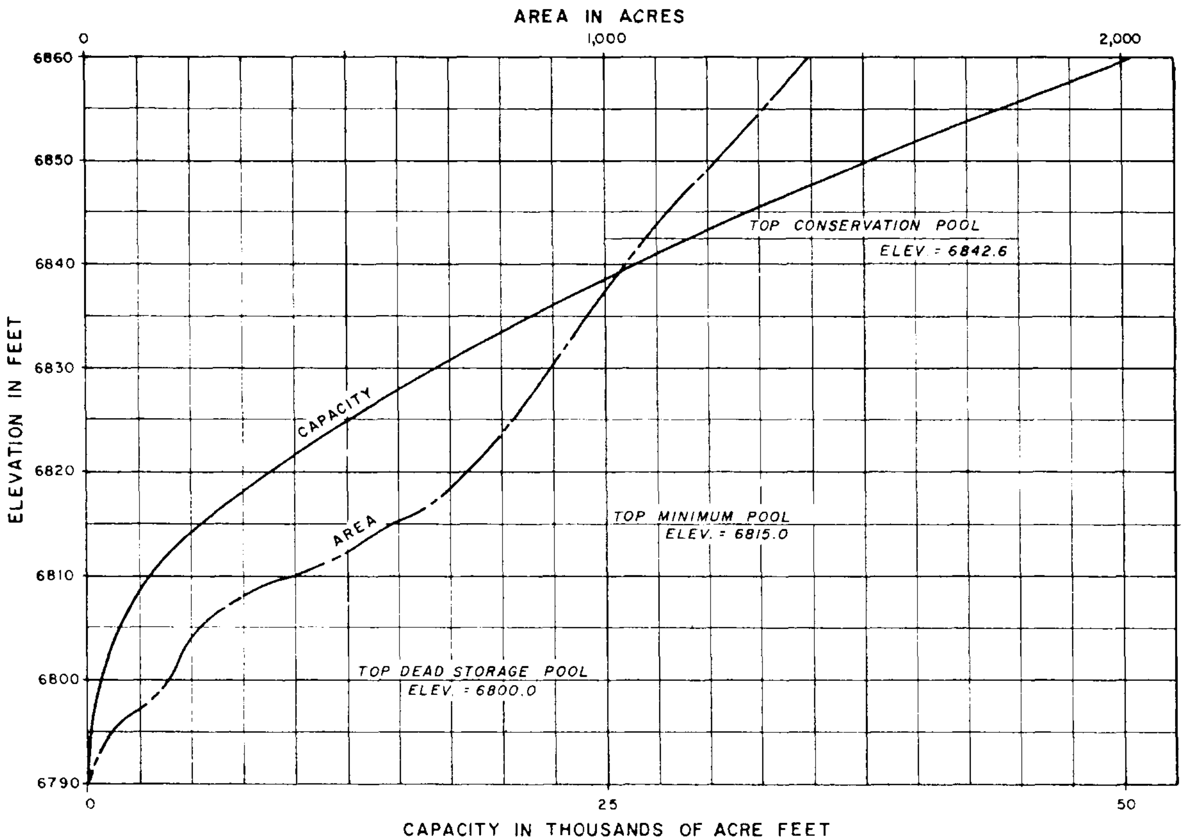
DRAWN C.W.W. M.D.M. SUBMITTED ______
TRACED T.K.C. RECOMMENDED ______
CHECKED ______ APPROVED ______

PHOENIX, ARIZ. MAY 26, 1969 | 1066-314-27

A minimum depth of 10 feet above the existing streambed at the dam is recommended for protection of the lowest outlet, allowing for the possibility of increased sediment yields due to forest fires, construction activity, etc. Area-capacity curves for the enlarged Upper Lake Mary are shown in Drawing No. 1066-314-47.

4. Reservoir Operation Studies. A detailed monthly operation study depicting the first stage development of the project (Wilkins Reservoir and the aqueduct system) was prepared for the 1947-1969 study period. The analysis, assuming 50 years of sediment accumulation in Wilkins Reservoir, indicates a first stage delivery capability of 12,300 acre-feet annually to the aqueduct and 11,900 acre-feet annually to Flagstaff. Table 10 summarizes these studies.

A detailed operation study for full project development was prepared for the study period 1947-1969 and is contained in the Hydrology Appendix. This study, which represents conditions of 50 years of sediment accumulation in project reservoirs, indicates that a firm annual delivery of 18,400 acre-feet can be supplied to the city of Flagstaff from the combined storage of Wilkins Reservoir and the enlarged Upper Lake Mary. The project plan would function satisfactorily during the historically most critical period occurring during the middle 1950's and also operate effectively during periods of more favorable water supply. Table 11 shows a water budget representing average annual conditions for the period 1947-1969. The budget shows that on the average a considerable amount of water would be spilled and seeped from Wilkins Reservoir. The spills result from physical and economic reservoir design limitations which preclude



AREA-CAPACITY TABLE		
ELEV.	AREA	CAPACITY
6790	0	0
6795	40	80
6800	155	600
6805	215	1,510
6810	394	2,950
6815	596	5,440
6820	731	8,805
6825	816	12,670
6830	895	16,970
6840	1043	26,600
6850	1220	37,910
6860	1398	51,000

NOTE

Based on data from Geological Survey, Water Resources Division, Flagstaff, Arizona and 7.5 minute quadrangle maps, Lower Lake Mary and Ashurst Lake.

FIGURE 15

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOGOLLON MESA PROJECT—ARIZONA

UPPER LAKE MARY

RESERVOIR AREA & CAPACITY CURVES

DRAWN J.R.M. ...... SUBMITTED ....
TRACED G.F.O. ..... RECOMMENDED ....
CHECKED M.D.M. .... APPROVED ....

PHOENIX, ARIZ. JAN. 22, 1971 1066-314-47

Table 10
AVERAGE ANNUAL WATER BUDGET
First Stage
1947-1969
(50-Year Reservoir Sedimentation Condition)
Mogollon Mesa Project, Arizona

	Unit: Acre-Feet
Blue Ridge Reservoir	
Virgin Inflow	18,000
Outflow	
Evaporation Losses	400
Seepage Losses	3,800
Pumped Releases to Verde River Basin	11,000
Spills	2,500
Change in Storage	+300
	18,000
Wilkins Reservoir	
Inflow	
Virgin Sectional Inflow--Blue Ridge to Wilkins	41,900
Spills from Blue Ridge	2,500
Seepage Returns from Blue Ridge	1,300
	45,700
Outflow	
Evaporation Losses	1,400
Seepage Losses	10,300
Pumped Releases to Flagstaff Pipeline	12,300
Spills	21,300
Change in Storage	+400
	45,700
Flagstaff Pipeline	
Pumped Deliveries to Pipeline from Wilkins	12,300
Pipeline Losses	400
Firm Water Supply for City of Flagstaff	11,900

Table 11
AVERAGE ANNUAL WATER BUDGET
Full Project Development
1947-1969
(50-Year Reservoir Sedimentation Condition)
Mogollon Mesa Project, Arizona

	Unit: Acre-Feet
Blue Ridge Reservoir	
Virgin Inflow	18,000
Outflow	
Evaporation Losses	400
Seepage Losses	3,800
Pumped Releases to Verde River Basin	11,000
Spills	2,500
Change in Storage	+300
	18,000
Wilkins Reservoir	
Inflow	
Virgin Sectional Inflow--Blue Ridge to Wilkins	41,900
Spills from Blue Ridge	2,500
Seepage Returns from Blue Ridge	1,300
	45,700
Outflow	
Evaporation Losses	1,400
Seepage Losses	8,900
Pumped Releases to Flagstaff Pipeline (Firm Water Supply)	15,700
Spills	19,300
Change in Storage	+400
	45,700
Upper Lake Mary	
Inflow	
Virgin Natural Inflow from Walnut Creek	8,700
Pipeline Inflow from Wilkins, Less Pipeline Losses	15,400
	24,100
Outflow	
Evaporation Losses	3,100
Seepage Losses	0
Releases to City of Flagstaff	18,400
Spills	2,100
Change in Storage	+500
	24,100

a more optimum control of Clear Creek flows. During critical water supply periods, maximum use would be made of the conservation storage capacities in the two reservoirs without shortage in delivering the water supply of 18,400 acre-feet annually.

5. Future Depletions. Future depletions above Wilkins Reservoir and Upper Lake Mary are expected to be limited to increased recreational use during the summer. In addition to Blue Ridge Reservoir and Knoll Lake, both located on upper tributaries of Clear Creek, there are a few small ponds which presently provide water-oriented recreation in the Clear Creek drainage. Maximum lake surface area is about 400 acres. Mormon Lake at the head of Walnut Creek is a closed basin and its drainage area has not been considered as a source of water supply for Lake Mary. No plans for further development of the water resources are known to exist. Future additional depletions, if they occur, would probably be small and should not affect the available water supply as formulated.

Future potential augmentation to the streamflow above Wilkins Reservoir could be possible through the emerging programs of the Bureau of Reclamation, Soil Conservation Service, Forest Service, and others. These programs are aimed at increasing runoff by precipitation, watershed and vegetative management. The heavily forested Mogollon Mesa, of which the Clear Creek drainage is a part, appears to offer significant potential as a vegetative treatment area. Weather modification, or precipitation management, is also a future possibility for increasing the available water resources of the project area. The Mogollon Mesa would seem to hold some potential as an application area in light of the favorable results obtained by the Bureau of Reclamation in its 1971 Arizona emergency cloud seeding program. Neither of these potentials were considered, however, in assessing the water supply available to the Mogollon Mesa Project.

6. Water Quality. The city of Flagstaff is endowed with some sources of water which are of the best quality in the State of Arizona. The Inner Basin and Lake Mary surface water supplies are of excellent quality. From the analysis of limited water samples and other indications available, project water from Wilkins Reservoir will continue the city's position in this regard. Table 12 shows the chemical analysis of samples taken at both the Wilkins Dam site and at Upper Lake Mary.

At the start of any future investigations a water quality program for chemical, organic, and trace elements of the surface and groundwater resources under consideration for project water supply will be initiated.

a. Clear Creek. The runoff of Clear Creek at the Wilkins Dam site is of excellent quality well suited for municipal and industrial purposes. Results of the few samples analyzed indicate a salt concentration of about 100 p/m (TDS) or less. Downstream from the dam site near the mouth of Clear Creek, saline springs contribute to the stream. Low flows near Winslow are very poor in quality. Except for the normal runoff period, February through May, runoff from the upper drainage areas of Clear Creek is insufficient to dilute the spring flow to produce good quality water in the lower reach.

Table 12
CHEMICAL QUALITY OF WATER
Mogollon Mesa Project, Arizona

Date	Total Soluble Salts (p/m)	Calcium (p/m)	Magnesium (p/m)	Sodium (p/m)	Chloride (p/m)	Sulfate (p/m)	Carbonate (p/m)	Bicar-bonate (p/m)	Fluoride (p/m)	Hardness as $CaCO_3$ (p/m)
Upper Lake Mary										
1951 1/	74	10	4	3	4	6	0	45	0.2	43
2-57 2/	84	7	3	1	2	9	0	30	0.1	30
7-57 2/	137	10	3	1	1	11	0	36	0.2	37
11-60 2/	88	17	3	1	2	17	0	34	0.0	55
7-26-71 1/	54	5	3	2	2	6	0	30	0.2	25
Clear Creek Near Wilkins Dam Site										
5-4-43 3/	90	17	8	2						75
5-26-43 3/	90	22	11	2						100
6-29-43 3/	114	23	10	2						99
3-11-66 1/	59	7	4	2	1	8	0	34	0.1	34
5-17-66 4/	172	31	6	3	7	3	0	121	0.1	121

1/ U.S. Geological Survey, Flagstaff, Arizona.

2/ Quality of Arizona Domestic Water, Report 217, November 1963, The University of Arizona, Tucson, Arizona.

3/ Little Colorado River Basin Survey, 1942-1943, Bureau of Reclamation Quality of Water.

4/ Bureau of Reclamation, Arizona Projects Office, Phoenix, Arizona.

b. Walnut Creek. The city of Flagstaff has used the runoff of Walnut Creek stored in Upper Lake Mary since 1941. Analyses of water samples from Upper Lake Mary show these waters to be of good quality. Total dissolved solids range from 100 p/m to 200 p/m. A minor problem in the past has been encountered with the presence of iron and manganese in solution.

B. Ground Water

1. General. Several ground-water studies were conducted as integral parts of the Mogollon Mesa Project investigations. These studies were made to evaluate the effects of water impoundment by the proposed Wilkins Reservoir on the ground-water regimen of downstream areas and to quantify and qualify the local ground-water resource for future municipal and industrial supplies for the cities of Winslow, Holbrook, and Flagstaff.

The ground-water studies were initiated in 1966 and completed by 1971. The studies were done in part in cooperation with the State of Arizona under terms of Contract No. 14-06-300-2077 between the United States and the Arizona Interstate Stream Commission (currently known as the Arizona Water Commission). These studies included the collection of all readily available hydrogeologic data, a well measuring program to supplement available water level data, geophysical programs in the Flagstaff area, and a test-hole drilling program comprising one deep hole in the Winslow and Holbrook areas, respectively, and nine holes in the Flagstaff area.

The following narrative discusses these studies in two parts: the Winslow-Holbrook and Flagstaff Divisions.

2. <u>Winslow-Holbrook Area</u>.

a. <u>Geologic Setting</u>. The Winslow-Holbrook area as discussed in this report lies on the middle and lower portions of the Mogollon slope, part of the Colorado Plateau Physiographic Province of north-eastern Arizona. The upper (southern) portion of the Mogollon slope terminates at the Mogollon Rim, a spectacular fault scarp. The Mogollon slope dips gently northward from the Mogollon Rim to the Little Colorado River. The slope is dissected by the rugged canyons of most major streams traversing it.

Stratigraphic units pertinent to this study area are, in descending order, alluvium of the Little Colorado River, the Moenkopi formation, Kaibab limestone, Coconino sandstone, and Supai formation. The Permian Kaibab limestone forms the surface over much of the upper and middle portions of the Mogollon slope. The Moenkopi formation forms much of the slope's surface along the lower portions. The Coconino sandstone crops out within and sometimes adjacent to the deep canyon areas and in local areas related to major geologic structures. The Supai formation does not crop out within the study area.

The Mogollon slope is a plateau whose ground surface roughly conforms to the regional gentle dip of the underlying formations. Numerous northwest or northeast trending low-dip and plunging anticlines and synclines occur on the slope. The major structural features in the study area are the Holbrook anticline and the Dry Lake syncline.

Faults on the Mogollon slope typically trend both northeast and northwest. They are generally of small displacement and essentially vertical.

b. Hydrogeology.

(1) General. The Mogollon slope constitutes the southern flank of the Black Mesa Basin which has its center in northern Navajo County. The regional movement of ground water for almost all of northern Arizona is toward the center of this basin and thence to the Colorado River. Most of the ground water along the Mogollon slope moves generally northward into the Black Mesa Basin. Ground-water recharge to the Mogollon slope is from direct infiltration of precipitation and percolation of streamflow. Natural discharge of ground water along the Mogollon slope is largely from springs that occur south of the Little Colorado River in the Joseph City and Holbrook area. Natural discharge of ground water from the Black Mesa Basin occurs at Blue Spring and other springs near the confluence of the Little Colorado and Colorado Rivers.

(2) The Coconino Sandstone. The primary aquifer of the Mogollon slope is the Coconino sandstone, which is white to buff, fine- to medium- grained, and quartzitic. It is characteristically crossbedded, massive, and is variably to tightly cemented with silica. Its thickness ranges from 200 to about 1,000 feet, with the maximum thicknesses occurring along the Mogollon Rim. The inherent permeability of the Coconino is generally low; however, fracturing, jointing, and variable degrees of cementation significantly increase this inherent permeability. Permeabilities in the Coconino range from less

than 1 gallon per day per square foot (gpd/ft^2) up to 70 gpd/ft^2. Available data indicate a wide scatter of transmissibilities (permeability X saturated aquifer thickness) ranging from about 1,500 to 3,000 gpd/ft along the upper and middle portions of the Mogollon slope to over 150,000 gpd/ft in wells in the Joseph City-Holbrook area. Well capacities range from under 5 to over 2,000 gallons per minute (gal/min). Water levels in the Coconino range from about 1,100 feet below land surface in the upper portions of the Mogollon slope to a few feet above land surface along the Little Colorado River where the aquifer is under artesian pressure.

The quality of water in the Coconino is highly variable. Generally the total dissolved solids are minimal along the upper portions of the Mogollon slope, increasing in content northward toward the Little Colorado River. Ground water north and east of the Little Colorado River is commonly highly mineralized. At any given location salinity also generally increases with depth.

(3) Supai Formation. The Supai formation comprises sandstone, siltstone, claystone, limestone, gypsum, and halite. Thick sections of halite have been penetrated at depths ranging from 600 to 1,000 feet in the Holbrook area. The sandstone unit commonly directly underlies the Coconino sandstone and appears to have similar hydrologic characteristics. In some areas it is considered part of the Coconino aquifer.

In most of the earlier reports on the Winslow-Holbrook area the Supai water was considered to be too salty for any use. The objectives of the test hole drilling program were to define the base of the fresh water and determine the geologic environment of the fresh water/salt water interface, as well as the quality of water above and below the interface.

The Winslow test hole (A-18-15) 28aad penetrated 870 feet of Coconino sandstone encountering the Supai at a depth of 1,020 feet. Depth to ground water from land surface in the Coconino was about 266 feet. Water samples were collected for chemical analyses at selected intervals with a double-packer drill-stem tool to define subtle or marked quality changes with depth. Table 13 presents these data. The saline water body occurs toward the bottom section of the Coconino sandstone between the 814- and 914-foot depth intervals. All waters encountered were of the sodium chloride type, in contrast to the waters southward which are of the bicarbonate type. While collecting water samples at the bottom of the test hole, a water level was also determined for the saline water body. This salt water level stood at a depth of 330 feet below ground surface, about 64 feet below the top surface of the upper water body.

The Holbrook test hole (A-17-20) 26dbc penetrated 315 feet of Coconino sandstone before encountering the Supai at a depth of 355 feet. Depth to ground water from land surface in the Coconino was about 297 feet. Water samples were collected for chemical analyses as in the Winslow test hole. Table 14 presents these data. It is significant that in this hole the saline water was encountered at more than 200 feet into the Supai in contrast to the Winslow test hole. The fresh water is of the bicarbonate type, more typical of the upper Mogollon slope water. There was no measurable difference in water level between the fresh and salt water bodies.

Table 13
CHEMICAL ANALYSES OF WATER FROM TEST WELL (A-18-15) 28aad
Chemical Analyses of Water Samples Collected by the Bureau of Reclamation
Analyzed by the U.S. Salinity Laboratory, Riverside, California
Mogollon Mesa Project, Arizona

Lab. No.	Sampled By	Source	Date Sampled	Temp. °F.	Date Received	Date Analyzed	Collector's Number	Zone 1/2/ Sampled	Intake 1/ Valve	Quantity Pumped 3/ Before Sample (gal.)
32104	Bureau of Reclamation	Test Well(A-18-15)28aad	7-31-69	64	9-9-69		1	1,210 to 1,076	1,176	250
32105	Bureau of Reclamation	Test Well(A-18-15)28aad	8-1-69	64	9-9-69		2	946 to 846	934	240
32106	Bureau of Reclamation	Test Well(A-18-15)28aad	8-4-69	64	9-9-69		3	826 to 726	814	720
32107	Bureau of Reclamation	Test Well(A-18-15)28aad	8-5-69	64	9-9-69		4	716 to 616	704	630
32108	Bureau of Reclamation	Test Well(A-18-15)28aad	8-6-69	64	9-9-69		5	606 to 506	594	1,350
32109	Bureau of Reclamation	Test Well(A-18-15)28aad	8-7-69	64	9-9-69		6	496 to 396	482	900

Lab. No.	Temp. °F.	pH	ECx10⁶ @ 25° C.	Dissolved Solids		% Na	SAR	Units	Cations				Anions					Total		Minor Elements ppm				
				ppm	t.a.f.				Na	K	Ca	Mg	CO_3	HCO_3	Cl	SO_4	NO_3	Cations Meq./L	Anions Meq./L	B	F	Fe	SiO_2	PO_4
32104		7.4	116,000	109,500	149	96	312	Meq./L ppm	1,749	2.19	42.92	20.08	0	1.81	1,790	50.07	trace	1,814	1,842	3.29	0.04		4	
32105		7.5	27,800	17,740	24.1	94	97	Meq./L ppm	279.0	0.42	10.28	6.26	0	3.01	284.5	11.94	trace	296.0	299.4	0.51	trace		4	
32106		7.9	4,380	2,434	3.31	89	25	Meq./L ppm	36.68	0.12	2.21	1.99	0	4.88	32.06	4.76	trace	41.00	41.72	0.12	0.02		8	
32107		8.2	4,740	2,690	3.66	91	29	Meq./L ppm	41.20	0.16	2.05	2.09	0.28	5.03	34.21	6.15	0.01	45.50	45.70	0.13	0.02		10	
32108		7.8	4,420	2,517	3.42	87	23	Meq./L ppm	37.20	0.12	2.68	2.56	0	4.65	32.38	5.83	trace	42.56	42.88	0.21	0.02		10	
32109		7.8	2,880	1,674	2.28	84	16	Meq./L ppm	23.31	0.10	2.50	1.81	0	4.71	15.39	7.67	trace	27.72	27.79	0.09	0.02		12	

1/ Feet below ground surface.

2/ Zone isolated by inflatable packers.

3/ Pumped by airlift.

Table 13 (Continued)

CHEMICAL ANALYSES OF WATER FROM TEST WELL (A-18-15) 28aad
Chemical Analyses of Water Samples Collected by the Bureau of Reclamation
Analyzed by the U.S. Salinity Laboratory, Riverside, California
Mogollon Mesa Project, Arizona

Lab. No.	Sampled By	Source	Date Sampled	Temp. °F.	Date Received	Date Analyzed	Collector's Number	Zone 1/2/ Sampled	Intake 1/ Valve	Quantity Pumped 3/ Before Sample (gal.)
32110	Bureau of Reclamation	Test Well (A-18-15)28aad	8-8-69	64	9-9-69		7	424 to 265	410	1,100
32111	Bureau of Reclamation	Test Well (A-18-15)28aad	8-11-69	64	9-9-69		8	926 to 826	914	2,400
32112	Bureau of Reclamation	Test Well (A-18-15)28aad	8-11-69	64	9-9-69		9	926 to 826	914	1,050

Lab. No.	Temp. °F.	pH	ECx10⁶ @ 25° C	Dissolved Solids ppm	Dissolved Solids t.a.f.	% Na	SAR	Units	Cations Na	Cations K	Cations Ca	Cations Mg	Anions CO_3	Anions HCO_3	Anions Cl	Anions SO_4	Anions NO_3	Total Cations Meq./L	Total Anions Meq./L	Minor Elements ppm B	F	Fe	SiO_2	PO_4	
32110		7.7	3,020	1,932	2.63	74	11	Meq./L	22.30	0.15	5.99	1.68	0	3.83	13.51	12.85	0.01	30.12	30.23	0.02	0.03		14		
								ppm																	
32111		7.9	18,800	11,380	15.5	94	79	Meq./L	180.1	0.30	4.96	5.37	trace	5.26	182.4	5.83	trace	190.7	193.5	0.48	trace		8		
								ppm																	
32112		8.0	12400	7,234	9.84	93	58	Meq./L	114.7	0.25	3.85	3.89	trace	5.51	112.3	5.43	trace	122.7	123.3	0.24	0.02		7		
								ppm																	
								Meq./L																	
								ppm																	
								Meq./L																	
								ppm																	
								Meq./L																	
								ppm																	

1/ Feet below ground surface.

2/ Zone isolated by inflatable packers.

3/ Pumped by airlift.

Table 14

CHEMICAL ANALYSES OF WATER FROM TEST WELL (A-17-20) 26dbc

Chemical Analyses of Water Samples Collected by the Bureau of Reclamation

Analyzed by the U.S. Salinity Laboratory, Riverside, California

Mogollon Mesa Project, Arizona

Lab. No.	Sampled By	Source	Date Sampled	Temp. °F.	Date Received	Date Analyzed	Sample Number	Zone Tested
32209	Bureau of Reclamation	Test Well (A-17-20)26dbc	11-4-69		1-6-70		2	554 feet to 615 feet
32210	Bureau of Reclamation	Test Well (A-17-20)26dbc	11-5-69		1-6-70		3	436 feet to 546 feet
32211	Bureau of Reclamation	Test Well (A-17-20)26dbc	11-6-69		1-6-70		4	W.S. to 446 feet
32212	Bureau of Reclamation	Test Well (A-17-20)26dbc	11-25-69		1-6-70		6	Bailer sample from 722 feet

Lab. No.	Temp. °F.	pH	EC×10^6 @ 25° C.	Dissolved Solids ppm	Dissolved Solids t.a.f.	% Na	SAR	Units	Cations Na	Cations K	Cations Ca	Cations Mg	Anions CO_3	Anions HCO_3	Anions Cl	Anions SO_4	Anions NO_3	Total Cations Meq./L	Total Anions Meq./L	Minor Elements ppm B	F	Fe	SiO_2	PO_4	
32209		7.9	635	383	0.52	39	1.8	Meq./L	2.49	0.06	1.90	1.88	trace	3.05	1.48	1.85	trace	6.33	6.40	0.01	0.02		13		
								ppm																	
32210		7.9	626	375	0.51	37	1.7	Meq./L	2.32	0.06	1.90	2.00	trace	3.03	1.47	1.71	trace	6.28	6.23	0.02	0.02		13		
								ppm																	
32211		8.0	724	476	0.65	47	2.5	Meq./L	3.49	0.07	1.94	1.85	trace	3.33	1.53	2.48	0.01	7.35	7.37	0	0.02		13		
								ppm																	
32212		7.4	24,800	16,300	22.2	90	66	Meq./L	242.8	0.28	21.78	5.07	0	3.42	247.9	22.35	trace	269.9	273.7	0.14	0.02		9		
								ppm																	
								Meq./L																	
								ppm																	
								Meq./L																	
								ppm																	

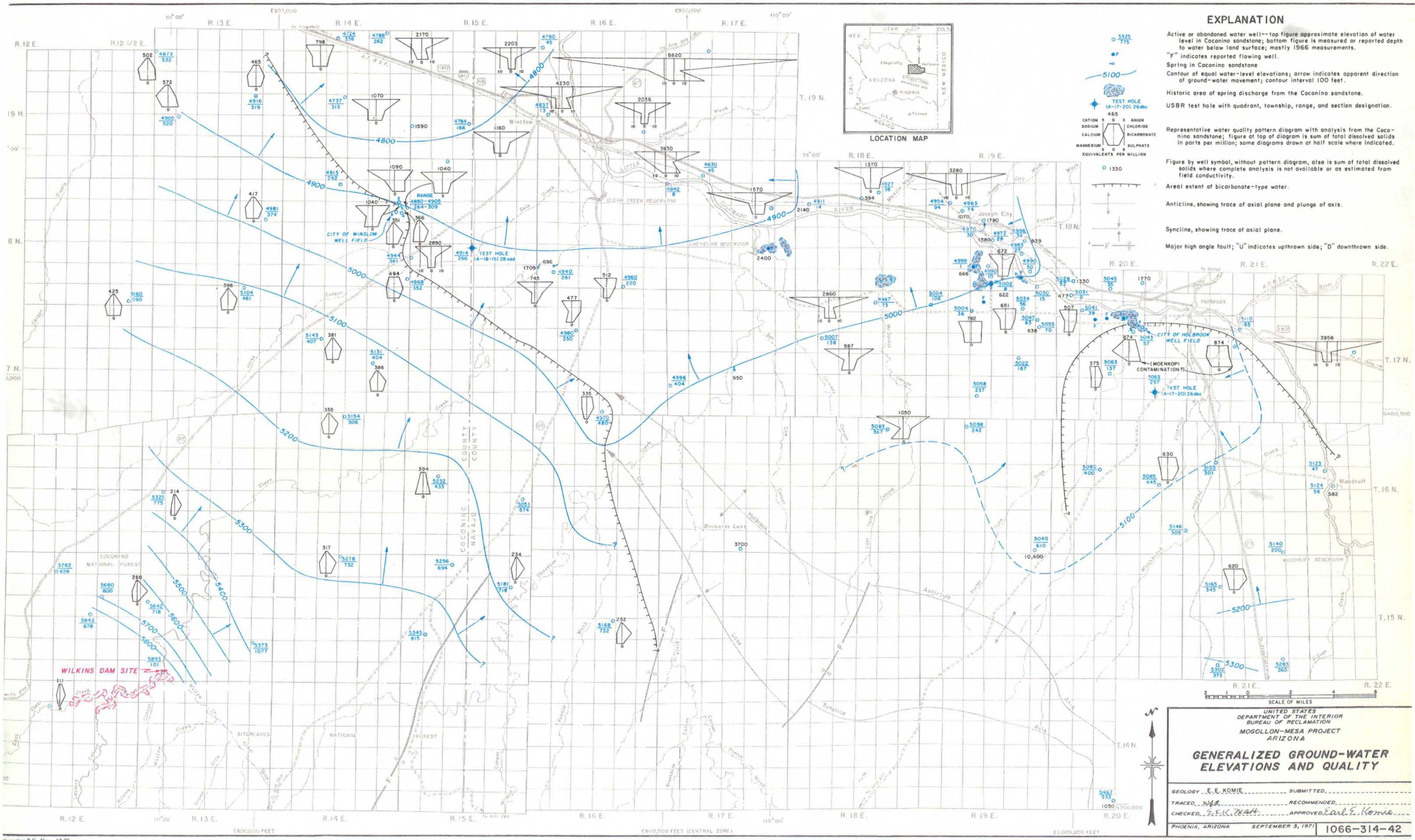
BR Test Well (A-17-20) 26dbc. Located approximately 5 miles SW of Holbrook on Heber Highway in Navajo County, Arizona, in the NW¼, SE¼, Sec. 26, T. 17 N., R. 20 E. G&SRM. Six-inch casing to 310 feet.

(4) Kaibab Limestone. Along most of the Mogollon slope the Kaibab is not saturated and acts only as a recharge medium to underlying rocks. In the Hay Hollow-Snowflake area, it is reported to be saturated and is considered as part of the Coconino aquifer system. It cannot be considered a source of water to Winslow. It does not occur in the Holbrook area.

(5) Moenkopi Formation. The Moenkopi comprises sandstone, siltstone, claystone, mudstone, limestone, and gypsum members. In the Hay Hollow-Snowflake area, it is considered a secondary aquifer, supplying good quality water to shallow domestic and stock wells. In the Winslow-Holbrook area the Moenkopi, in general, contains very poor quality water and is commonly "cased off" in wells that penetrate the underlying Coconino sandstone. Typically, this water is high in calcium and sulphate, indicative of a gypsum environment. It cannot be considered as a significant source of water to either Winslow or Holbrook.

(6) Little Colorado River Alluvium. Although these materials are partially saturated, the waters are commonly highly mineralized. Numerous wells have been abandoned because of poor quality water. These materials cannot be considered as a source of potable water for either Winslow or Holbrook.

c. Ground-Water Movement. Drawing No. 1066-314-42 presents the elevation contours on the regional ground-water body, essentially within the Coconino sandstone. These contours represent the water table conditions prevalent in the Coconino along the upper portions of the Mogollon slope as well as the artesian conditions


EXPLANATION
Active or abandoned water well--top figure approximate elevation of water level in Coconino sandstone; bottom figure is measured or reported depth to water below land surface; mostly 1966 measurements.
"F" indicates reported flowing well.
Spring in Coconino sandstone
Contour of equal water-level elevations; arrow indicates apparent direction of ground-water movement; contour interval 100 feet.
Historic area of spring discharge from the Coconino sandstone.
USBR test hole with quadrant, township, range, and section designation.
TEST HOLE (A-17-20) 26dbc
CATION
SODIUM
CALCIUM
MAGNESIUM
ANION
CHLORIDE
BICARBONATE
SULPHATE
EQUIVALENTS PER MILLION
Representative water quality pattern diagram with analysis from the Coconino sandstone; figure at top of diagram is sum of total dissolved solids in parts per million; some diagrams drawn at half scale where indicated.
Figure by well symbol, without pattern diagram, also is sum of total dissolved solids where complete analysis is not available or as estimated from field conductivity.
Areal extent of bicarbonate-type water.
Anticline, showing trace of axial plane and plunge of axis.
Syncline, showing trace of axial plane.
Major high angle fault; "U" indicates upthrown side; "D" downthrown side.
LOCATION MAP
UTAH
COLO.
NEV.
CALIF.
ARIZONA
NEW MEXICO
MEXICO
PHOENIX
Tucson
Flagstaff
Winslow
Holbrook
CITY OF WINSLOW WELL FIELD
CITY OF HOLBROOK WELL FIELD
Joseph City
WILKINS DAM SITE
CLEAR CREEK RESERVOIR
CHEVELON RESERVOIR
WOODRUFF RESERVOIR
Richards Lake
COCONINO NATIONAL FOREST
SITGREAVES NATIONAL FOREST
COCONINO COUNTY
NAVAJO COUNTY
LITTLE COLORADO RIVER
(MOENKOPI) CONTAMINATION
TEST HOLE (A-18-15) 28 ccd
RANGE 4880-4905 264-309
Anticline
Syncline
R. 12 E.
R. 12 1/2 E.
R. 13 E.
R. 14 E.
R. 15 E.
R. 16 E.
R. 17 E.
R. 18 E.
R. 19 E.
R. 20 E.
R. 21 E.
R. 22 E.
T. 19 N.
T. 18 N.
T. 17 N.
T. 16 N.
T. 15 N.
T. 14 N.
4800
4900
5000
5100
5200
5300
5400
5500
5600
5700
5800
E800,000 FEET
E900,000 FEET (CENTRAL ZONE)
E1,000,000 FEET
SCALE OF MILES
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOGOLLON-MESA PROJECT
ARIZONA
GENERALIZED GROUND-WATER ELEVATIONS AND QUALITY
GEOLOGY E. E. KOMIE
SUBMITTED
TRACED
RECOMMENDED
CHECKED
APPROVED Earl E. Komie
PHOENIX, ARIZONA
SEPTEMBER 3, 1971
1066-314-42

prevalent along the Little Colorado River. Generally, the contours indicate that the movement of ground water is essentially toward the Little Colorado River northward from the high recharge areas along the Mogollon Rim. A large ground-water trough, corresponding roughly to the trend of Chevelon Creek, is the major feature of ground-water movement on the Mogollon slope area. This feature essentially funnels most of the recharge from that southeastern portion of the Mogollon slope into the general Winslow vicinity. The ground-water trough appears to be related to the Holbrook anticline and Dry Lake syncline and/or the major regional faults that may act as ground-water barriers.

d. Ground-Water Quality. The ground water that occurs in sedimentary rocks of the Mogollon slope varies from saturated brines to water of about 100 p/m total dissolved solids. Some of the saturated brines are probably connate waters. In any event, flushing of this saline water has been, and is presently, occurring. Essentially, there is a lens of fresh water floating on a salt water body along the Mogollon slope. The fresh water/salt water interface is not sharp. There is a zone of dispersion, or mixed waters, between the fresh water and salt water. In areas at greater distances from points of recharge the fresh water does not occur and wells commonly initially penetrate the zone of dispersion which is immediately underlain by the salt water.

The configuration of the ground-water contours showing direction of movement and the pattern diagrams characterizing the chemical types of waters appear to be strongly influenced by the

Holbrook anticline and Dry Lake syncline. While these major geologic structures are indicated to have a dominant effect upon ground-water movement and water quality, it is apparent that other geologic structures probably occur in the study area which would have similar effects. The configuration of the top surface of the salt water body is also virtually unknown; only widespread point data are available.

e. Winslow Well Field. The Winslow well field is located about 6 miles southwest of Winslow in Section 13, T. 18 N., R. 14 E., G&SRM. Current development comprises five wells. A sixth well in this field has been abandoned. Pertinent data for these wells are as follows:

Location	City Number	Total Depth (ft)	Depth to Water (ft)	Pump (hp)	Yield (gal/min)	Draw-down (ft)
(A1814) 13abd(2)	1	620	269 (1953)	75	550	50
(A1814) 13baa	2	700	265 (1954)	125	950	22
(A1814) 13cab	3	900	309 (1964)	60	400	104
(A1814) 13dbb	4	1,000	305 (1964)	75	400	142
(A1814) 13bad	5	1,100	300 (1962)	75	880	240
(A1814) 13abd(3)	aband.	350	270 (1968)	--	--	--

Annual pumpage from the well field averaged about 1,400 acre-feet during the 1959-1963 period, increased to about 1,800 acre-feet in 1968, and decreased to about 1,600 acre-feet in 1970. The Geological Survey utilizes well (A-18-14) 13abd(3) as an observation well on a semiannual basis. Although short-term, year-to-year water level declines have occurred, the records indicate no significant water level decline for the period of record 1953-1968. There has been no reported decrease in well yields.

The only reported problem associated with long-term pumping has been a deterioration of water quality in selected wells. From Drawing No. 1066-314-42, it is apparent that wells Nos. 3 and 4 wholly penetrate the fresh water body, while the others are within the dispersed zone. The quality changes in individual wells that have occurred with respect to time are dominantly the result of pumping.

Water quality problems similar to that of the Winslow well field are prevalent in the Joseph City area. In this area a high concentration of irrigation wells has induced salt water intrusion from the north leading to the abandonment of several wells.

f. Holbrook Well Field. The Holbrook well field is located about 2 miles southwest of Holbrook in Section 10, T. 17 N., R. 20 E., G&SRM. Current development comprises three wells. Pertinent data for these wells are as follows:

Location	City Number	Total Depth (ft)	Depth to Water (ft)	Pump (hp)	Yield (gal/min)	Draw-down (ft)
(A-17-20) 10dab	1	120 1/	18 1/	40	450	24 2/
(A-17-20) 10acc	2	120 1/	18 1/	60	700	16 2/
(A-17-20) 10cdc	3	120 1/	18 1/	100	1,000	6 2/

1/ As reported by the city of Holbrook.

2/ In 1963 the city reports a pump test on all three wells with the reported drawdown shown above. The wells were then pumped an additional 5 hours producing 1 million gallons, during which the drawdown in each well increased at a rate of 1 foot per hour.

Annual pumpage from the well field averaged about 550 acre-feet during the 1959-1963 period, which has increased to about 650 acre-feet in 1970. The Geological Survey utilizes well (A-17-20) 10dba as an observation well to monitor water level trends in the Holbrook well field. Although short-term, year-to-year water level declines have occurred, the records indicate no significant water level declines for the period 1952-1968. There has been no reported decrease in well yields. There have not been any reported water quality problems. The water is indicated to be of the fresh water body, of the bicarbo-sulphate type, with about 850 p/m total dissolved solids.

g. The Ground-Water Resources.

(1) General. Recharge to the Winslow-Holbrook area is primarily from the south, along the high elevation-high precipitation portions of the Mogollon slope. Normal annual precipitation along the upper Mogollon slope ranges as high as 35 inches and averages between 16 to 25 inches. This area represents the most prolific recharge zone to the consolidated rocks of northern Arizona.

The discharge from Blue Spring represents a large portion of the total discharge from Black Mesa Basin, about 160,000 acre-feet annually. This is natural discharge occurring under present levels of ground-water development and also represents surplus recharge to Black Mesa Basin. Much of this recharge originates along the Mogollon slope. It is extremely doubtful if present or future projected levels of ground-water development would approach a major fraction of this indicated recharge.

(2) Winslow Area. No significant water level decline has occurred within the general area of the Winslow well field since its

inception, inferring that recharge is adequate to replenish discharge at historic and present levels of development. The quality of water deterioration can be attributed to the salt water body that underlies the well field and the zone of dispersion that lies immediately to the north and east. The data suggest that, with a given pumping pattern, well interference intensifies individual well drawdown effects allowing a cone of salt water to intrude the overlying fresh water. This drawdown would also induce lateral subsurface inflow from the higher mineralized waters to the north and east.

Projected M&I water requirements for Winslow by the year 2030 are about 6,600 acre-feet annually. There are no data to indicate that this requirement cannot be met by ground water. It is recommended, however, that future ground-water development not be concentrated in the present well field. There are sufficient data on quality of water with which to identify the areas underlain by the fresh water body. Future development should be oriented to a new well field site optimumly located as to quality and designed so as to minimize potential well interference. Individual well yields should not differ drastically from those prevalent in the present well field.

(3) Holbrook Area. No long-term water level decline has occurred within the general area of the Holbrook well field, although there is significant pumping for irrigation nearby. A marked increase in irrigation pumpage is not projected; therefore, ground-water conditions should remain as they are now. Projected water requirements for Holbrook by the year 2030 are about 4,800 acre-feet annually. There are no data to indicate that this requirement cannot be supplied

by ground water. There is no quality of water problem at the present time, nor is one anticipated. Any new well development should be located eastward or southeastward from the present well field to minimize inflow of poor quality water from the east and/or north.

h. Proposed Wilkins Dam--Its Effect on the Ground-Water Regimen. A comparison of historic streamflow records at Wilkins Dam site and the Winslow gage indicates that Clear Creek, in this reach, is a losing stream. Data are not available with which to estimate Clear Creek Channel percolation losses with any degree of confidence. However, an evaluation of streamflow records from Wilkins to the Winslow gage during the 1947-1969 period indicates annual losses ranging from less than 1,000 acre-feet to about 19,000 acre-feet, averaging about 4,500 acre-feet.

Reservoir seepage-loss studies have been made at proposed Wilkins Dam which indicate that with impoundment of water and with successive cycles of filling, losses could range from about 9,000 acre-feet to 15,000 acre-feet annually depending upon the method of reservoir operation and the degree of seepage control attained in the developed reservoir. Most of these losses would migrate into the regional ground-water body and would become an active increment of recharge to the Coconino sandstone. The reservoir seepage losses would reappear in Clear Creek downstream from the dam. The continuous seepage and the recurring reservoir spills would result in significantly increased recharge from the stream compared to the recharge from the intermittent historic flow.

Drawing No. 1066-314-42 illustrates the direction of ground-water movement away from proposed Wilkins Reservoir. The arrows indicate that recharge to the Winslow well field originated primarily from the southwest and south and that the most direct path of movement to the well field is from the general area of proposed Wilkins Reservoir. A very minor amount, if any, of percolation losses in Clear Creek has any direct influence on the well field.

The permeability of the Coconino sandstone is very low, and is calculated to be about 0.1 foot per day or about 37 feet per year. It is expected that reservoir percolation losses would create a ground-water mound. When the mound reaches downstream streambed levels there will be a temporary pickup in the stream below the reservoir. The rate of reservoir seepage loss would be in equilibrium with pickup in the stream. Most of this pickup would again be lost to the Coconino sandstone aquifer. The water in this aquifer is moving in the general direction of the Winslow well field. The time required for ground water to move from the reservoir to the stream recharge area would prevent the project from having any practical effect on the Winslow area during the life of the project.

3. Flagstaff Area.

a. General. The following narrative has been divided into two sections. Section A discusses the regional ground-water reservoir, primarily the Coconino aquifer system, and Section B discusses the unique ground-water occurrence in the Interior Valley (Inner Basin) on San Francisco Mountain.

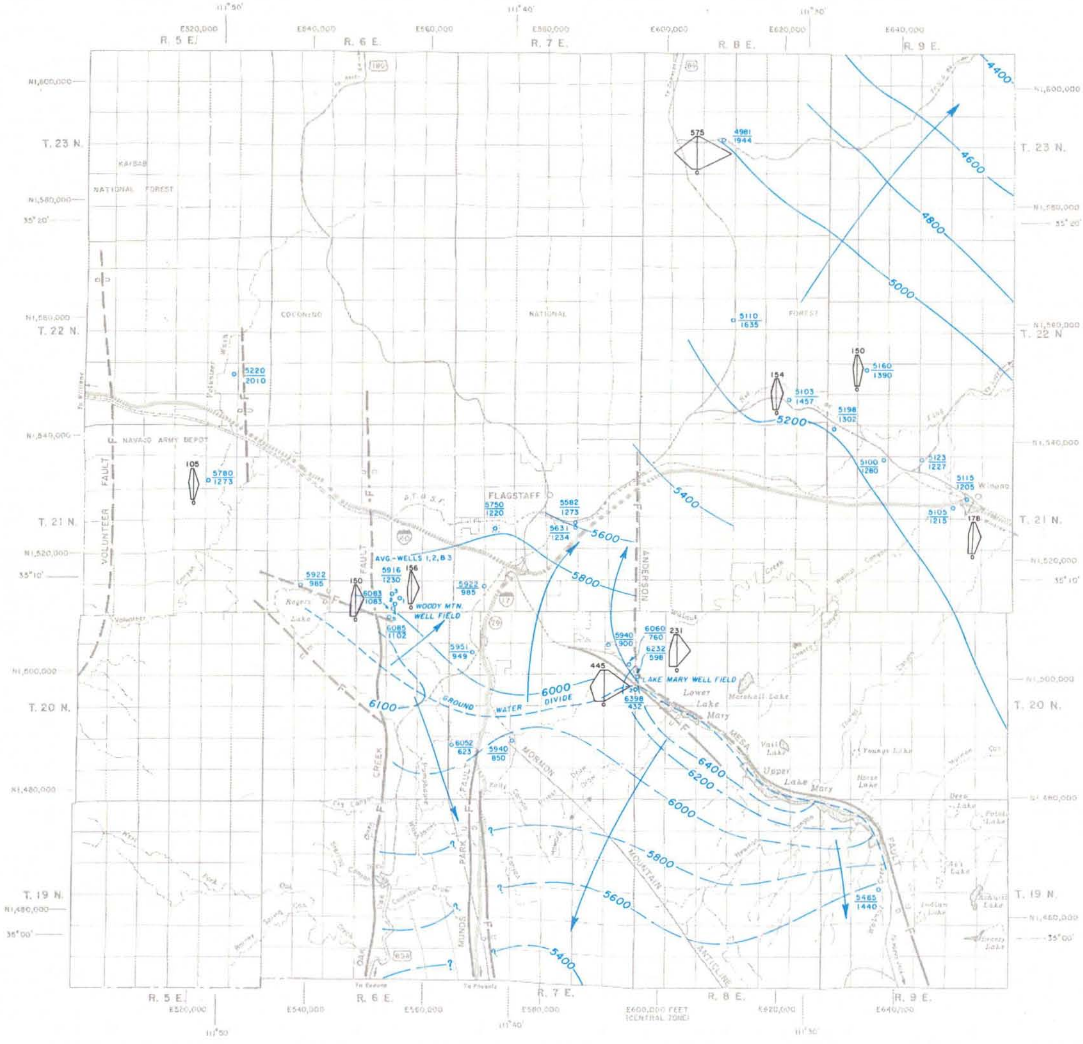
SECTION A

b. <u>Geologic Setting</u>. The Flagstaff study area (see Drawing No. 1066-314-67) lies on the San Francisco Plateau, about midway between the Little Colorado and Verde Rivers, within the Colorado Plateau Physiographic Province of northeastern Arizona. The San Francisco Plateau is bounded on the southwest by the Mogollon Rim, a spectacular fault scarp, and merges to the southeast with the Wupatki Bench, a westward extension of the broad Mogollon slope. The San Francisco volcanic field is superimposed upon this plateau. The plateau is dissected by deep canyons of several traversing streams.

Volcanic rocks cover most of the San Francisco Plateau. The Kaibab limestone is extensively exposed south and east of Flagstaff. The Moenkopi, Coconino, and sediments underlying the volcanics crop out as isolated exposures. Alluvial deposits, including fan deposits, the fill in small interior valleys or parks, and channel deposits make up a significant part of the surface. The Supai formation does not crop out in the study area.

Throughout much of the area geologic structure in the major sedimentary units is masked by extensive volcanics and/or alluvium at the surface. The regional dip is to the northeast, usually less than 3 degrees; however, this dip is reversed to the southwest at the crest of the Mormon Mountain anticline.

There are numerous faults within the study area which generally trend north northeasterly and northwesterly. Most of them are high-angle faults with less than 50-foot displacement although maximum displacement is as much as 500 feet.



LOCATION MAP

EXPLANATION

CATION 10 0 10 ANION; SODIUM, CALCIUM, MAGNESIUM; CHLORIDE, BICARBONATE, SULPHATE; 575; EQUIVALENTS PER MILLION	Representative water quality pattern diagram with analysis from the Coconino sandstone; figure at top of diagram is sum of total dissolved solids in parts per million.
o 6060/760	Active or abandoned water well--top figure approximate elevation of water level in Coconino sandstone; bottom figure is measured or reported depth to the water below land surface; mostly 1966 measurements.
5600	Contour of equal water-level elevations; arrow indicates apparent direction of ground-water movement; contour interval 200 feet.
U/D F	Major high angle fault; "U" indicates upthrown side; "D" is downthrown side; dashed where approximate.
	Anticline, showing trace of axial plane and plunge of axis.

2 0 2 4 6
SCALE OF MILES

N

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOGOLLON MESA PROJECT
ARIZONA

GENERALIZED GROUND-WATER ELEVATIONS AND QUALITY

GEOLOGY G. D. FORD SUBMITTED
TRACED W.J.L. RECOMMENDED
CHECKED E.A.K.man APPROVED Earl E. Komie
PHOENIX, ARIZONA SEPTEMBER 17, 1971 1066-314-67

c. Hydrogeology.

(1) General. The Flagstaff study area as discussed in this report lies partly along the extreme southwestern flank of the Black Mesa Basin, the principal hydrologic basin south of the Colorado River in northern Arizona. The ground-water divide (Drawing No. 1066-314-67) separates that part of the area related to the Black Mesa Basin to the northeast from the Verde River Basin to the southwest. North of the divide ground-water movement is generally to the northeast toward the Little Colorado River and south of the divide it is to the southwest toward the Verde River.

Ground-water recharge to the San Francsico Plateau is from infiltration of precipitation and streamflow primarily as snowmelt. Natural discharge from the plateau occurs through springs that discharge to the Little Colorado and Verde Rivers.

Ground water in the deep aquifers beneath the San Francisco Plateau ranges from fresh to brackish. With increasing distance from the prime recharge area along the Mogollon Rim, the flushing of connate water in the consolidated sedimentary rocks has been less effective, and ground water a few miles northeast of the study area is classed as brackish.

(2) The Coconino Sandstone. The Coconino sandstone is the principal aquifer in the Flagstaff study area and, in combination with the upper 200 and 300 feet of the underlying Supai formation, supplies most of the water to deep wells. It is light orange to white in color, quartzitic, very fine- to medium-grained, crossbedded, and is variably cemented with silica. Logs of wells in the study area

indicate thicknesses of the Coconino sandstone (including equivalents of the Toroweap formation) range from about 450 to nearly 900 feet.

Transmissibilities in undisturbed Coconino are generally less than 1,000 gallons per day per foot. Aquifer tests of the wells at the Woody Mountain well field adjacent to the Oak Creek fault indicated transmissibilities from 5,000 to 50,000 gpd/ft, with the highest transmissibilities occurring nearest the fault. Specific capacities of most of the Flagstaff city wells range from 2.5 to 8.6 gallons per minute per foot of drawdown, while wells in the Coconino unrelated to faulting often have specific capacities of less than 1 gal/min/ft of drawdown. Capacities of wells in the Coconino sandstone (including the upper portion of the Supai) range from less than 10 gal/min to more than 600 gal/min. Depths to water in the Coconino sandstone are between 1,000 and 1,944 feet below land surface throughout most of the Flagstaff study area. In proximity to the ground-water divide, however, water levels are often slightly less than 1,000 feet and are probably less than 500 feet below land surface in the vicinity of the Lake Mary reservoirs where seepage has created a ground-water mound.

(3) Supai Formation. The Supai formation comprises sandstones, siltstones, mudstones, thin limestones, and conglomerates. In other areas along the Mogollon slope to the east it includes thick evaporite units but these are not encountered by wells in the Flagstaff area nor are they reported in the Verde Valley area south of Flagstaff where nearly 1,600 feet of Supai rocks are exposed. The top few hundred feet of the Supai, which contribute water to some deep wells

in the Flagstaff study area, are lithologically similar to the Coconino. It comprises very fine to fine-grained sandstones or silty sandstones which are distinguished from the Coconino only by their reddish-brown color.

The top of the Supai is encountered from 1,050 to nearly 1,600 feet below land surface by wells in the Flagstaff area.

It is impossible to isolate the aquifer characteristics of the upper part of the Supai from those of the Coconino as the two act as a single hydrologic unit in most wells in the Flagstaff area. Some wells south and west of Flagstaff draw water mostly or entirely from the Supai, and yields from these wells are from 7 to 40 gal/min. Other wells completed in the Supai have been reported as "dry." Specific capacities of wells in the Supai are often less than 1 gal/min/ft of drawdown.

(4) Kaibab Limestone. The Kaibab limestone in the Flagstaff area is mostly silty or sandy limestone that varies in color from yellowish or light gray to white and averages about 300 feet in thickness. It is above the water table throughout the area so is not a significant aquifer; however, because it is strongly jointed and fractured it is important as a recharge medium to underlying rocks.

(5) Moenkopi Formation. The Moenkopi formation is composed of red or reddish-brown siltstones, mudstones, and sandstones, and where present in the Flagstaff area ranges from a few feet to 300 feet or more in thickness. Within the study area it is above the regional water table. Because of its less permeable nature, however, the Moenkopi may impede the downward percolation of

ground water, creating perched water bodies that locally contribute small amounts of water to wells or springs.

(6) Sediments Underlying the Volcanics. Sediments comprising claystones and mudstones, siltstones, silty sandstones, and conglomerates underlie the volcanics in parts of the study area. These sediments have been recognized in widely separated areas of the San Francisco Plateau in thicknesses ranging up to 300 feet. The materials usually do not contain water but do impede the downward movement of ground water creating perched water zones that contribute small amounts of water to wells or springs.

(7) Volcanic Rocks. The volcanic rocks in the Flagstaff area consist of numerous lava flows of basaltic to silicic composition with interbedded zones of cinders, gravel, and residual soils. Deep wells in the Woody Mountain area have penetrated more than 600 feet of this volcanic series and the Sunset Crater well penetrates 700 feet. Numerous cinder cones are scattered throughout the northern half of the study area. Although the volcanics are above the regional water table throughout the study area, they often contain perched water zones which support some small capacity wells used for domestic and/or stock purposes. Capacities of these wells range from less than 1 gal/min to 60 gal/min. Specific capacities reported from a few of these wells are from 1.4 to as high as 15 gal/min/ft of drawdown, although it is doubtful that the higher yields could be maintained with sustained pumping.

The large area of highly permeable cinders exposed at the surface and the fractures and jointed nature of many of the lavas make them highly effective recharge media, where underlain by permeable sedimentary rocks. It is thought that much of the recharge to the major aquifers in the Flagstaff area is through this means. Impermeable sediments within or underlying the volcanics impede the downward percolation creating perched water bodies or causing the water to move laterally to discharge areas.

(8) Alluvial Deposits. Alluvial deposits in the study area consist of coalescing fans at the base of San Francisco Mountain, and of thin silt, sand, and gravel deposits along washes or underlying the valleys and parks. Water in the alluvium is derived from precipitation and snowmelt, and its storage is limited by the thickness and areal extent of the deposits. Just south of the study area some wells penetrated up to 300 feet of alluvium underlying the parks with well yields up to 450 gal/min. Logs of wells in the Flagstaff study area usually show less than 50 feet of alluvium. Those which are completed in the alluvium are often reported as "dry" or yield small amounts of water.

d. Ground-Water Movement. The major feature in the Flagstaff study area which controls ground-water movement in the Coconino and upper Supai aquifer is the ground-water divide south of Flagstaff. As shown on Drawing No. 1066-314-67, the divide extends through both Lower and Upper Lake Mary and is probably, in large part, controlled by the Anderson Mesa Fault in this area. To the west the divide is south of the Woody Mountain well field and extends to the Roger's Lake area. Regional ground-water movement is away from the divide to the south and the northeast. High reservoir seepage losses are indicated by the ground-water mound under Lower and Upper Lake Mary.

e. Ground-Water Quality. Ground water in the Coconino-Supai aquifer system underlying the Flagstaff area is the calcium bicarbonate type and within the study area is of excellent quality, ranging between 100 and 575 parts per million total dissolved solids. The quality worsens northeast of the study area. A well at Wupatki Ruins (about 28 miles northeast of Flagstaff) yields sodium chloride-type water with 1,030 parts per million total dissolved solids from the Coconino sandstone.

Available data indicate that perched water in the Flagstaff area is calcium bicarbonate type and of excellent quality reflecting its direct derivation from precipitation. Water from the volcanics adjacent to the study area has between 150 and 200 p/m total dissolved solids. Limited data to water from the alluvium indicate total dissolved solids range from 150 to 390 p/m. The Moenkopi formation and the sediments underlying the volcanics supply very limited quantities of water and data are not available to define the quality.

f. Woody Mountain Well Field. In June of 1954, the city of Flagstaff began development of a well field in the Woody Mountain area about 2 miles southwest of the city limits. The well field was located to take advantage of increased transmissibilities of the fractured zone associated with the Oak Creek Fault. Based on data furnished in 1976 by the city of Flagstaff, six deep wells have been completed and are producing. The seventh well is being constructed and will be in operation in 1977. Pertinent data on six of the wells are as follows. Data on the seventh well are not available.

Location	City No.	Depth	Casing	Perforated	Pump (hp)	Yield (gpm)	Specific Capacity	Pump Lift (ft)
(A-21-6) 35cba	1	1,600	0-1588	1330-1588	240	380	1.6	1,457
(A-21-6) 35ccb	2	1,746	0-1600	1200-1600	250	350	6.8	1,293
(A-21-6) 35bcc	3	1,602	--	--	250	400	4.1	1,295
(A-21-6) 35ccc	4	1,540	0-1518	1213-1518	250	500	2.5	1,283
(A-20-6) 2bbc	5	1,600	0-1600	1050-1600	300	600	4.6	1,179
(A-21-6) 35caa	6	1,503	--	--	300	300	--	--

Well No. 2 was interpreted to have completely penetrated the Coconino sandstone and the upper 161 feet of the Supai formation. The other wells bottomed in Coconino sandstone. Since initial pumping in 1956, the annual total pumpage from the well field has ranged from a low of less than 35 acre-feet in 1967 to a high of about 1,200 acre-feet in 1964. Measurements of well No. 1 show that the water level has varied about 13 feet since the well field began production in response to high or low production. The lowest water level occurred in 1964 and subsequently returned to its original level in 1968. There has been no noticeable decline in well yields or deterioration of quality thus far, although "sanding" has occurred in individual wells. The coincidence of the maximum annual pumpage with the water level low indicates the need for more protracted pumping to determine a probably safe yield for the well field.

g. Lake Mary Well Field. Development of the Lake Mary well field was begun in 1962 and by 1976 five deep wells had been drilled. The site just north of Lower Lake Mary, near the Anderson Mesa Fault, was chosen because of its geologic similarity to the Woody Mountain well field location. The Lake Mary well field is essentially recharged by seepage losses from Lower Lake Mary and depths to water in the Coconino are the shallowest recorded in the study area. Lake Mary well No. 1 was drilled through the Coconino sandstone and 200 feet into the Supai. It did not produce up to expectation as sanding problems were encountered so has not been equipped for production. Lake Mary well No. 2 was located farther from the Anderson Mesa Fault and bottomed in the Coconino sandstone. It is presently a producing well equipped to deliver 700 gal/min. Operational problems with air entrainment might limit this capacity to about 500 gal/min. Water from this well contains about 650 p/m total dissolved solids and relatively high levels of iron and manganese. The city is implementing programs to solve this quality problem. Lake Mary well No. 3 was drilled by Ponderosa Paper Products Company and deeded to the city in exchange for water used by that company from city mains. Its production has never exceeded 50 gallons per minute and consequently the well has not been used by the city. Stimulated by the concern of the shortage of surface-water supplies during 1972, the city drilled Lake Mary well No. 4 during the latter part of 1972 and early part of 1973. The well was drilled to a depth of 1,340 feet and tested 800 gal/min. Water level during the test was 780 feet. Static water level was 423 feet. Difficulties have been encountered making pipe connections from the well to the city's supply line and power connections have not been completed. The two wells connected to the city water system produce about 2.0 million gallons per day. The one not connected to the city's system has an estimated yield of 1.5 million gallons per day. Two wells are used for observation purposes.

h. Ground-Water Resource.

(1) General. Recharge to the Flagstaff study area is derived from rainfall, runoff, and snowmelt in natural channels, and seepage losses from Lower and Upper Lake Mary. Normal annual precipitation in the area is above 20 inches. Extensive surface exposures of permeable volcanic rocks and the Kaibab limestone probably transmit portions of this precipitation to the Coconino aquifer, but ground-water contours in the area indicate that the largest part of the recharge probably occurs along major fault structures.

The Flagstaff area lies astride a regional ground-water divide where movement of water is constantly away from the immediate area toward the Verde River to the southwest and the Little Colorado River to the northeast. This area is located in a somewhat unfavorable hydrogeologic area because the primary aquifer is a consolidated sedimentary rock with inherently low hydrologic properties, and depths to ground water are extreme. Any development is costly both from a capital cost and annual power cost standpoint.

Available data indicate there has been no general water level decline in the Flagstaff study area. This would infer that ground-water withdrawals, under current levels of development, have not exceeded long-term recharge. While this fact is apparent, it is based upon minimal pumpage and cannot be projected to significantly larger withdrawals.

(2) Woody Mountain Well Field. The potential of this well field has not been fully established. It may be that it can never be established because of the extremely fractured nature of the aquifer,

however, the city is considering conducting sustained pumping in an effort to fully appraise its potential. Average annual pumpage in the well field for the period 1956-1969 was about 380 acre-feet. Because of the deep wells, very high pump lifts, and corresponding high power costs, the estimated cost of water production at the pump head is in excess of $300 per acre-foot.

The Geological Survey estimates the potential of the well field as being between 2 to 4 million gallons per day or about 2,150 to 4,300 acre-feet annually. The present installed capacity probably represents the full potential. There is the possibility that additional well fields can be located southward along the Oak Creek Fault. Any additional ground-water development, however, would be as costly, if not more costly, than the Woody Mountain field and would necessitate higher pump lifts to Flagstaff.

(3) Lake Mary Well Field. The potential of this well field has not been established. Five wells have been drilled. Two are in current production. The quality of water from these wells is inferior to that of the other existing sources. Other than the iron and manganese problem, the water is extremely hard and excessive nitrates also occur.

The Geological Survey estimates the potential of the well field as being at least 3 million gallons per day or about 3,200 acre-feet annually. Since this well field probably derives much of its recharge from seepage from Lower and Upper Lake Mary, any implementation of lining these reservoirs would in effect negate most of the above potential.

(4) Other Potential Areas. There appears to be little potential for additional large-scale ground-water development within the study area. Any new large-scale development would have to be located east or northeast of the study area toward the Little Colorado River. Even in these areas, however, quality of water is inferior to local supplies, total pump lifts to Flagstaff would be greater than the surface water alternative from Wilkins Reservoir, and there would be the danger of inducing salt water intrusion (like the Winslow area) if development were too concentrated.

SECTION B

a. Geologic Setting. San Francisco Mountain is an ancestral composite volcano built of flows, comprised mainly of andesite and dacite with some rhyolite and pyroclastics. The Inner Basin is thought to lie astride the center of the volcanic cone representing an area of subsidence later modified by fluvial and glacial erosion and deposition. Most recent investigators in the area have defined three periods of glaciation. Each glacial period has left its inherent moraines and glaciofluvial outwash. The depression was ultimately breached during an early period of glaciation. A large terminal moraine subsequently was deposited at this breach. The moraines are unconsolidated to poorly consolidated, unstratified to crudely stratified, silty and gravelly clays interbedded with poorly sorted fine to coarse sand and gravel, and boulders up to 3 feet in diameter. The outwash consists of unconsolidated to semiconsolidated, poorly stratified, poorly sorted fine to coarse sand and gravel, interbedded with admixtures of silt, cobbles, and boulders. Steep volcanic rock slopes enclose the Inner Basin on three sides, and minor slope wash and a thin mantle of soil occur along the bottom of these rock slopes.

The composite volcano is superimposed on the classic Colorado Plateau sedimentary sequence, probably covering Moenkopi, Kaibab, and Coconino rocks.

b. Hydrogeology. The glacial and glaciofluvial deposits constitute the ground-water reservoir underlying the Inner Basin. These deposits have an indicated maximum aggregate thickness in excess of 500 feet. Inherently, glacial and glaciofluvial deposits exhibit a very wide range of grain sizes both horizontally and vertically. These deposits are of heterogeneous and lenticular nature. Pumping tests indicate this heterogeneity by extreme variability in transmissibilities and storage coefficients.

The areal distribution of the outwash deposits in the Inner Basin is long and narrow. Typically, the filling of a valley such as the Inner Basin takes place more rapidly near the center than along the sides. Accordingly, the greatest thicknesses are along the valley axis. The outwash deposits are indicated to be younger than, and probably overlie and interfinger with, contemporaneous colluvium and older glacial and outwash deposits which crop out below the Inner Basin. The outwash deposits probably contain the most prolific aquifers, as will be discussed under a subsequent section.

Ground-water recharge to the Inner Basin is accomplished primarily by infiltration of snowmelt runoff and secondarily by infiltration of runoff from late summer rainfall.

The occurrence of ground-water in these deposits ranges from perched (semiperched) to artesian. The city of Flagstaff's shallow infiltration system essentially draws from several local perched water bodies. Other minor semiconfined to confined water bodies occur above the primary deep water body. These water bodies are only local.

The primary water body underlies the entire basin. This water body is mostly semiconfined, but exhibits artesian conditions. Initial static depths of the top of the deep water body ranged from 70 to 173 feet (see Table 15). Generalized water level contours are shown on Drawing No. 1066-314-48. These contours indicate the general direction of ground-water movement and apparent gradients.

The quality of ground water in the Inner Basin is remarkably low in total dissolved solids, perhaps reflecting its rapid transient state, both laterally and vertically. Several analyses averaged about 36 p/m total dissolved solids, primarily calcium bicarbonate.

c. Test Hole Drilling Program.

(1) 1966. This program consisted of wells Nos. 1 and 2 (see Drawing No. 1066-314-48). Dacite bedrock was penetrated in No. 1 at 329 feet. Well No. 2 was terminated at 245 feet before reaching bedrock because of extremely difficult drilling conditions in boulders and loose gravels. A pump test was conducted on well No. 2 for about 24 hours during which time the total drawdown was about 4 feet with constant pumping of about 300 gal/min. The test pump used precluded a larger pumping capacity. A transmissibility of about 95,000 gpd/ft was computed from the drawdown data. There

Table 15
SUMMARY OF WELL DATA--INNER BASIN
Mogollon Mesa Project, Arizona

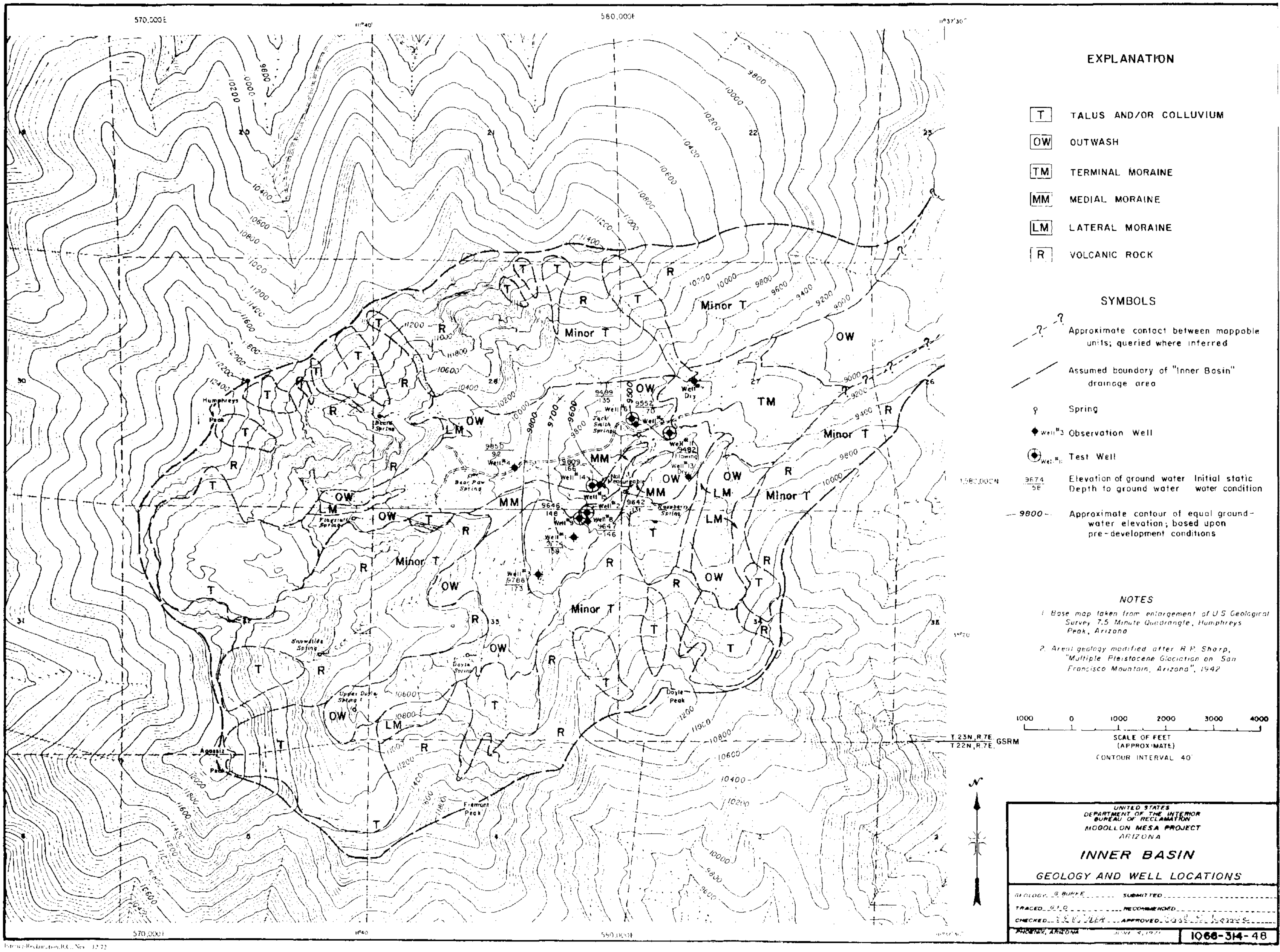
Location Number	City Number	Year Completed	Depth Drilled (feet)	Depth Completed (feet)	Initial Static Water Level (Depth) (feet)	Depth to Bedrock (feet)	Elevation Average Land Surface (feet)	Elevation Water Surface (feet)
(A-23-7) 33aab$_1$	1 - obs. well	1966	356	340	158	329	9832	9674
(A-23-7) 33aab$_2$	2 - test well	1966	248	245	131	1/	9773	9642
(A-23-7) 33aca	3 - obs. well	1967	253	253	173	195	9961	9788
(A-23-7) 28dcb	4 - obs. well	1967	350	191	92	170	9943	9850
(A-23-7) 27cbc$_1$	5 - obs. well	1967	224	224	70	210	9622	9552
(A-23-7) 27cbc$_2$	6 - test well	1967	220	220	135	1/	9634	9499
(A-23-7) 27 bad	7 - obs. well	1967	290	215	2/	200	9440	--
(A-23-7) 33aab$_3$	8 - obs. well	1968	332	330	146	280	9792	9647
(A-23-7) 33aab$_4$	9 - test well	1968	352	352	148	340	9793	9646
(A-23-7) 27cbd$_3$	11 - test well	1971	485	485	Flowing	470 3/	9482±	4/
(A-23-7) 27cdb	13 - obs. well	1969	370	--	2/	345 3/	--	--
(A-23-7) 28ddd$_2$	14 - test well	1970	500	490	166	1/	9775±	9609
(A-23-7) 28ddd$_1$	15 - obs. well	1969	450	--	15	1/	9775±	--

1/ Bedrock not encountered.

2/ Dry hole when drilled.

3/ Reported by driller.

4/ Artesian head, not measured.


EXPLANATION
T TALUS AND/OR COLLUVIUM
OW OUTWASH
TM TERMINAL MORAINE
MM MEDIAL MORAINE
LM LATERAL MORAINE
R VOLCANIC ROCK
SYMBOLS
Approximate contact between mappable units; queried where inferred
Assumed boundary of "Inner Basin" drainage area
Spring
Observation Well
Test Well
9674 / 58 Elevation of ground water / Depth to ground water Initial static water condition
9800 Approximate contour of equal ground-water elevation; based upon pre-development conditions
NOTES
1. Base map taken from enlargement of U.S. Geological Survey 7.5 Minute Quadrangle, Humphreys Peak, Arizona
2. Areal geology modified after R.P. Sharp, "Multiple Pleistocene Glaciation on San Francisco Mountain, Arizona", 1942
SCALE OF FEET (APPROXIMATE)
CONTOUR INTERVAL 40'
T.23N, R.7E. / T.22N, R.7E. GSRM
Humphreys Peak
Agassiz Peak
Fremont Peak
Doyle Peak
Minor T
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOGOLLON MESA PROJECT
ARIZONA
INNER BASIN
GEOLOGY AND WELL LOCATIONS
GEOLOGY G. BURKE
SUBMITTED
TRACED
RECOMMENDED
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PHOENIX, ARIZONA
1066-314-48

was no measurable drawdown in well No. 1 with which to compute a storage coefficient.

(2) 1967. To further outline the subsurface extent of the ground-water reservoir and its saturated configuration, wells Nos. 3 through 7 were drilled in 1967. Depths to bedrock in these wells are shown on Table 15. A pump test was conducted on well No. 6 utilizing well No. 5 as an observation well. This test was run for about 45 hours during which time the total drawdown was about 48 feet with constant pumping of about 400 gal/min. A transmissibility of about 20,000 gpd/ft was computed from the data. From the plotted drawdown data, it was apparent that two hydrologic boundaries were encountered during the test. The water level in well No. 5 did not react to pumping in well No. 6, although it was only 75 feet away. Either the well was improperly constructed or it indicated a total lack of hydraulic continuity with well No. 6.

In any event, this pump test indicated less permeable materials in the general area of well No. 6 as compared to well No. 2 and also indicated a more restricted aquifer, in a lateral sense, than that aquifer in the general area of well No. 2. The lack of drawdown data in well No. 5 precluded a computation of storage coefficient.

(3) 1968. Wells Nos. 8 and 9 were drilled in 1968. Well No. 9 was constructed as a potential high capacity production well with wells Nos. 1, 2, and 8 acting as observation wells during an extended pump test. This test was run for about 40 hours during which time the total drawdown was about 38 feet with constant pumping of about 1,400 gal/min. An average estimated transmissibility of

about 150,000 gpd/ft was indicated from data plotted for all four wells (Nos. 1, 2, 8, and 9). Transmissibilities computed from the four wells ranged from about 145,000 gpd/ft to 264,000 gpd/ft. Storage coefficients computed from these wells ranged from about 0.07 in well No. 1 to .004 in wells Nos. 2 and 8, indicating an increasing degree of confinement in a northeasterly direction through the basin. It is emphasized that these storage coefficients are based upon short-term calculations and are probably not indicative of long-term values.

Three apparent hydrologic boundaries were encountered during the pump test. Calculations indicated that the boundaries ranged from about 800 feet to about 1,600 feet from the immediate pumped area.

This pump test, while confirming the excellent hydraulic properties of the aquifer apparent in well No. 2 in 1966, also indicated the limited nature of the ground-water reservoir. The storage coefficient calculations also indicated the limited storage capacity of the reservoir. The apparent increasing degree of confinement in a downslope direction also suggested that artesian conditions might be encountered further downslope. This was to be confirmed in later drilling. The Bureau of Reclamation's drilling program terminated in 1968.

(4) 1969-1971. The city of Flagstaff continued drilling test wells during the 1969-1971 period, primarily oriented toward establishment of a well field in the Inner Basin. Four wells were drilled, Nos. 11, 13, 14, and 15. Wells Nos. 11 and 14 were completed as production wells, well No. 13 was a dry hole, and well No.

15 was the pilot hole for No. 14. There were no pump tests conducted on these wells. Limited city of Flagstaff pumping data indicate that well No. 14 has a potential of 400 to 600 gal/min and well No. 11 has a potential of 800 to 1,000 gal/min. Well No. 11 exhibited an artesian head of about 15 feet above ground surface, as estimated by city of Flagstaff personnel, confirming confined conditions near the Inner Basin outlet. It is believed that the finer materials associated with moraine deposition in this area, with greatly reduced permeabilities, have created such a confined condition.

d. Recharge Analysis. The Inner Basin drainage area comprises about 2,650 acres, with elevations ranging from 9440 at the outlet to 12,610 at Humphreys Peak. The mean elevation is about 10,725 feet. The predominant vegetation of the basin is spruce intermingled with aspen. Pine, fir, and juniper occur only locally. Meadow grasses cover much of the basin floor.

Annual precipitation is estimated to range from 17 to 47 inches (by correlation with Flagstaff records, adjusted for elevation differences). Average annual precipitation is estimated at about 36 inches. Snowfall comprises about one-half this total. Periodic snow surveys were initiated in the Inner Basin in 1967 in order to better estimate annual precipitation. Data collected to date are excellent but the period of record is yet too short to significantly change the above estimates.

Consumptive use by vegetation is estimated to average 10 inches per year, or about 2,200 acre-feet. Estimates of consumptive use were based upon vegetational types and densities determined from aerial photograph.

Loss of precipitation through sublimation of the snowpack is estimated to average 5.8 inches annually. This sublimation was estimated by correlation with effective pan evaporation of selected stations in Arizona, adjusted for elevation.

The annual average quantity of precipitation available for recharge is as follows:

Recharge--Precipitation, 35.6 inches			7,900 a.f.
Discharge--Consumptive use, 10.0 inches -	2,200 a.f.		
Sublimation, 5.8 inches	1,300 a.f.	3,500 a.f.	
Average Annual Gross Recharge			4,400 a.f

Over the long term this annual gross recharge is estimated to range from 800 to 6,500 acre-feet.

There is another increment of discharge which must be considered to be able to quantify the net recharge which would be available for ground-water development. This increment is subsurface outflow, both laterally under the surface outlet and vertically through the volcanic rocks.

Several rough calculations were made to establish the magnitude of subsurface outflow. The first calculation involved the confirmation of a storage coefficient. In 1968, well No. 9 was pumped for about 40 days at a rate varying from 1,100 to 1,400 gal/min, with a total discharge of about 225 acre-feet. Total water level decline at the end of the pumping period was 70 feet in well No. 9, and about 60 feet in wells Nos. 2 and 8, located 100 and 200 feet, respectively, from No. 9. Total decline in well No. 1 located about 370 feet from No. 9 was about 3 feet with no pumpage effect noted in well No. 3, about 1,500 feet from well No. 9. These declines, with an arbitrary delineation of the areal extent of the pumping cone, indicated a dewatered volume of about 3,000 acre-feet. This dewatered volume, compared with the total discharge of 225 acre-feet, indicates a storage coefficient of about 0.075, roughly in agreement with selected pumping test data. This also would indicate that with signficant withdrawals the confining characteristics of the aquifer is negated and the aquifer assumes water table or semiconfined characteristics.

A second calculation involved prepumping water level declines that occurred naturally after the snowmelt recharge. In most of the observation wells this water level decline consistently averaged about 0.1 foot per day. The surface area of the usable ground-water reservoir was estimated at about 500 acres. Using a storage coefficient of 0.07 this would suggest that reservoir losses to subsurface outflow approximate about 1,300 acre-feet throughout the year.

A third calculation attempted to inventory the increments of recharge and discharge and compare that inventory to the total recharge indicated from the snow surveys. The water level rises that occurred during the spring of 1968 were quantified by using a storage coefficient of 0.07 and a surface area of 500 acres. This computation indicated a net incremental recharge volume of about 700 acre-feet. The shallow infiltration gallery produced about 600 acre-feet during that 1968 snowmelt season. Using other estimated discharge increments as discussed previously, the inventory for 1968 is as follows:

	Acre-Feet
Water increment to storage	700
Water produced from infiltration system	600
Consumptive use by vegetation	2,200
Subsurface outflow	1,300
Total gross recharge	4,800

The Soil Conservation Service, which conducted the snow surveys, estimated that the water yield from snowmelt that year was about 5,000 acre-feet. This apparent agreement would suggest that the inventory items are in a correct order of magnitude.

e. Conclusions. This investigation indicated the following conclusions:

1. The Inner Basin is a significant local supply of low cost, excellent quality water to the city of Flagstaff.

2. This supply is estimated over the long term to average about 3,000 acre-feet annually.

3. Due to losses resulting from subsurface outflow and the relatively small storage capacity, the ground-water reservoir should not be considered as a storage reservoir. Its function should be considered on only "a pumped when available" basis.

4. Well development should have no effect on water production from the infiltration system.

C. Water Rights

1. General. Although the respective water rights of the Lower Colorado River Basin States to the water of the Colorado River were

defined in the Supreme Court suit Arizona vs. California, et. al., the decree of March 9, 1964 (376 U.S. 340) does not adjudicate the waters of the tributaries above Lake Mead. The Little Colorado River, an interstate stream, serves irrigated acreage in Arizona and New Mexico. There is presently no formal agreement between these states as to their respective rights in the stream.

The State of Arizona can act unilaterally in the matter of water rights in the Little Colorado River only within her rights to the Colorado River system water as it may be apportioned and allocated by the Colorado River Compact. The Compact apportions and/or allocates the water to the Upper and Lower Basins, and does not extend to the division of the water among states. The presently unused water of the Little Colorado River constitutes a part of the inflow to Lake Mead in the Lower Basin.

2. Surface Water. The doctrine of appropriative rights was firmly established in Arizona during the latter portion of the last century. Section 45-101, Arizona Revised Statutes, reads in part:

> "The waters of all sources, flowing in streams, canyons, ravines or other natural channels, or in definite underground channels, whether perennial or intermittent, flood, waste or surplus water, and of lakes, ponds and springs on the surface, belong to the public and are subject to appropriation and beneficial use as provided in this chapter. Beneficial use shall be the basis, measure, and limit to the use of water."

Section 45-147 sets forth a relative value to the public as follows:

> Domestic and municipal uses, irrigation and stock watering, power and mining uses, and recreation and wildlife including fish.

An application for water must be filed with the Arizona State Land Department for a permit to appropriate intra-State water.

The Bureau of Reclamation on August 5, 1966, filed an application for a permit (R-2504) to appropriate 20,400 acre-feet of water per year from Clear Creek at the Wilkins Dam site. The proposed use is for a municipal supply for the northern Arizona cities of Flagstaff, Williams, Ashfork, and possibly other urban areas. The city of Flagstaff hold a permit, granted many years ago, to use 1 billion gallons (about 3,000 acre-feet) per year from Walnut Creek at Upper Lake Mary.

The Phelps Dodge Corporation holds the permit (No. A-2634) granted to divert from Clear Creek an average 11,000 acre-feet per year into the East Verde River from existing Blue Ridge Reservoir. This transbasin diversion is used as a basis for exchange with Salt River Project for Black River water diverted by the corporation for mining and municipal purposes near Morenci, Arizona. Diversions are limited to no more than 18,000 acre-feet per year when available. A minimum pool of 2,000 acre-feet is provided by Blue Ridge Reservoir affording fishing and recreation opportunity.

In 1953, the Santa Fe Railroad gave the city of Winslow its water right, property, and water works used in the diversion of water to the city. The water right (No. C-114) held by the railroad was for the diversion of 500 miner's inches (about 8,800 acre-feet) per year from Clear Creek.

In 1959, the city of Winslow filed an application for 2,852,500,000 gallons (about 8,750 acre-feet) of water per annum to be delivered from a reservoir of 1,100 acre-feet total capacity constructed on Clear Creek. Under Permit No. 1298, granted by the State Land Department on April 16, 1959, the city has until 1985 to complete construction of the proposed dam and to put the water to domestic use.

On the basis of Permit No. R-2143, the Arizona Game and Fish Commission constructed Knoll Lake on Leonard Creek, a tributary of Clear Creek. Completed in 1963, Knoll Lake has a maximum surface water area of 77 acres and a total storage of 3,450 acre-feet. It provides fishing and recreation opportunities.

Several small early rights for stock watering purposes also exist along Clear Creek.

The city of Winslow has used small amounts of water from Clear Creek for many years. The lack of storage facilities in the vicinity has made utilization of these rights difficult. Poor water quality at low flows and heavy silting during spring runoff have added to these difficulties. Prior to 1966, the city changed the Clear Creek diversion from the Santa Fe pumping plant to an open ditch and concrete pipe system using water from the old settlers dam near Winslow. At that time the water was to be used principally for irrigation of 475 acres belonging to the city, since the development of the present well field supplying Winslow with a good quality water at low cost had, for the most part, negated the need for supplementing water for the domestic and municipal need. On the basis that about 300 acres have been actually irrigated, the full irrigation water requirement would be about 1,000 acre-feet per year.

Should Winslow desire to exercise its present rights to Clear Creek water, opportunity would still exist under project conditions. The physical limitation of 45,000 acre-feet of conservation storage at the proposed Wilkins Dam site necessitates spilling (or releasing in anticipation of spilling) down Clear Creek nearly half of the available Wilkins Reservoir inflow under conditions of full development. The projected water requirements of the city of Flagstaff indicate that the full system yield of 18,400 acre-feet per year would not be utilized until 20 or more years after the turn of the century. This would result in even greater bypass quantities prior to that time. Also, sizable reservoir seepage losses are expected to return, at least in part, to the main channel of Clear Creek. Therefore, the opportunity to divert Clear Creek water at Winslow with present facilities would not be eliminated by the Wilkins Dam and Reservoir; however, a change in flow regime and the diminution of total flow volume in lower Clear Creek can be expected.

3. Ground Water. State court rules have firmly established that percolating subterranean waters belong to the surface landowner. They are not subject to appropriation procedures under Arizona water laws unless it can be definitely shown the subterranean flow is in a natural underground stream channel between well defined banks. Flows in an underground stream are subject to appropriation under the same rule as a surface stream.

In order to protect its diminishing ground-water supplies, the Arizona Legislature passed the Ground-Water Act in 1945 and later, in 1948, created "critical ground-water areas" mainly in the central agricultural portion of the State. These areas have been enlarged by the State Land Commissioner over the past few years. The constitutionality of the Ground-Water Act has been upheld by the Arizona

Supreme Court. This act was further strengthened by legislation during 1968. There are no designated "critical ground-water areas" in the project area.

In principle, Arizona's ground-water code provides a means by which those agricultural areas not having a reasonable firm supply at current rates of withdrawal could be determined to be critical ground-water areas. Drilling of additional wells for agricultural purposes is prohibited after the making of a critical area determination by the State Land Commissioner.

V. PLAN OF DEVELOPMENT

V. PLAN OF DEVELOPMENT

A. General

The Mogollon Mesa Project plan proposes the construction of Wilkins Dam and Reservoir on Clear Creek in Sections 31 and 32, T. 15 N., R. 13 E., G&SRM, Coconino County, Arizona, to provide for the regulation and diversion of Clear Creek flows for the principal purpose of municipal and industrial water supply for the city of Flagstaff, Arizona.

The project plan also includes the construction of a pipeline and pumping facilities to deliver water from Wilkins Reservoir to Flagstaff, the rehabilitation of Upper Lake Mary Dam, and lining the enlarged Upper Lake Mary Reservoir. It is contemplated that the project would be constructed in two stages with the rehabilitation of Upper Lake Mary being deferred until such time as Flagstaff's future water demands require the additional water made available through the combined operation of the project reservoirs. Enlargement of Upper Lake Mary Dam and lining of the reservoir would provide an additional 6,500 acre-feet of firm water yield to Flagstaff. This increased water yield would come partly from additional water pumped from Wilkins Reservoir, partly from increased yield from Walnut Creek and partly from converting Flagstaff's present fluctuating water yield from Upper Lake Mary to a firm supply.

Stage construction would permit the deferral of costs associated with the reconstruction of Upper Lake Mary.

Operation studies of Wilkins Reservoir operating alone in the first stage development, without the benefit of offstream storage, indicate a firm yield of 12,300 acre-feet annually. Assuming about 3 percent losses in conveyance to Flagstaff, this would provide about 11,900 acre-feet per year of municipal and industrial water to the Flagstaff trunkline and would meet the city's estimated water requirements until about year 2003. This is based on the premise that the local water supply available to the city is 2,400 acre-feet until Upper Lake Mary is taken out of operation for reconstruction, at which time the local water supply would be reduced to 1,000 acre-feet annually in addition to the 11,900 acre-feet made available by the first stage. About year 2000 the second stage of construction involving the rehabilitation and enlargement of Upper Lake Mary could be initiated.

By lining and enlarging Upper Lake Mary more efficient utilization of Walnut Creek water would also be possible through elimination of present large seepage losses amounting to about 4,400 acre-feet annually. Operated jointly with a 37 ft^3/s interconnected pipeline, the two reservoirs could attain a combined firm yield of 18,400 acre-feet annually. This would require a delivery of about 15,400 acre-feet annually from Wilkins Reservoir. Table 16 presents an average annual summary of reservoir operations when operating at the above firm yield conditions.

Facilities for treating and distributing the import water are considered to be the responsibility of the city of Flagstaff.

The first stage of the project plan provides for the development of recreation facilities in accordance with recommendations of the Bureau of Outdoor Recreation and the expansion of fishing opportunities through creation of Wilkins Reservoir on Clear Creek. In the

Table 16
WATER REQUIREMENT SCHEDULE
City of Flagstaff, Arizona
Mogollon Mesa Project, Arizona

Unit: Acre-Feet

Project Year	Fiscal Year	Flagstaff Water Requirement	Local Water Supply Available	Project Water Required	Project Water From: Stage I From Wilkins Reservoir	Stage II From Upper Lake Mary	Stage II From Wilkins Reservoir
1	1982	7,770	2,400	5,370	5,370	0	0
2	83	7,990		5,590	5,590		
3	84	8,220		5,820	5,820		
4	85	8,450		6,050	6,050		
5	86	8,680		6,280	6,280		
6	87	8,910		6,510	6,510		
7	88	9,140		6,740	6,740		
8	89	9,370		6,970	6,970		
9	1990	9,600		7,200	7,200		
10	91	9,880		7,480	7,480		
11	92	10,160		7,760	7,760		
12	93	10,440		8,040	8,040		
13	94	10,720		8,320	8,320		
14	95	11,000		8,600	8,600		
15	96	11,280		8,880	8,880		
16	97	11,560		9,160	9,160		
17	98	11,840		9,440	9,440		
18	99	12,120	2,400	9,720	9,720		
19	2000	12,400	1,000	11,400	11,400		
20	01	12,690		11,690	11,690		
21	02	12,980		11,980	11,900 1/	0	
22	03	13,270		12,270	9,270	3,000	0
23	04	13,560		12,560	9,560		
24	05	13,850		12,850	9,850		
25	06	14,140		13,140	10,140		
26	07	14,430		13,430	10,430		
27	08	14,720		13,720	10,720		
28	09	15,010		14,010	11,010		
29	2010	15,300		14,300	11,300		
30	11	15,630		14,630	11,630		0
31	12	15,960		14,960	11,900		60
32	13	16,290		15,290			390
33	14	16,620		15,620			720
34	15	16,950		15,950			1,050
35	16	17,280		16,280			1,380
36	17	17,610		16,610			1,710
37	18	17,940		16,940			2,040
38	19	18,270		17,270			2,370
39	2020	18,600		17,600			2,700
40	21	18,960		17,960			3,060
41	22	19,320		18,320			3,420
42	23	19,680		18,400			3,500
43	24	20,040					
44	25	20,400					
45	26	21,760					
46	27	21,120					
47	28	21,480					
48	29	22,840					
49	2030	22,200					
50	31	22,560	1,000	18,400	11,900	3,000	3,500

1/ The water supply is 80 acre-feet short of the water requirement.

second stage of construction, involving the lining and rehabilitation of Upper Lake Mary, additional recreational facilities and fishing opportunities would be made available.

No power production facilities would be included in the project as there is insufficient water supply to support a hydroelectric powerplant and use of full reservoir capacity for municipal and industrial use would preclude provision of a permanent pool for power generation. The project plan does not include storage space for water quality control as any scheduled releases from the reservoirs for downstream use other than for municipal and industrial purposes would decrease the firm yield project water supply.

Flood control regulation would not be provided in Wilkins Reservoir as a project function. There are no cultivated lands or improvements of any significance downstream from Wilkins Dam site on Clear Creek that would receive any benefit from such regulation. Some minor flood regulation would occur by reason of operating the reservoir within the surcharge pool provided for passing the design flood.

Flood control regulation would not be provided in Upper Lake Mary.

B. Statement of Compliance with Executive Order 11296

Downstream from Wilkins Dam site Clear Creek is entrenched in a well defined canyon throughout its length to its confluence with the Little Colorado River. There is little or no opportunity for building within the flood plain.

Lands lying adjacent to Clear Creek are in private ownership for the most part and use is devoted chiefly to grazing.

Protection against dam failure due to flooding has been provided by designing the spillway and reservoir surcharge with a capacity to pass the design floods without overtopping the dam.

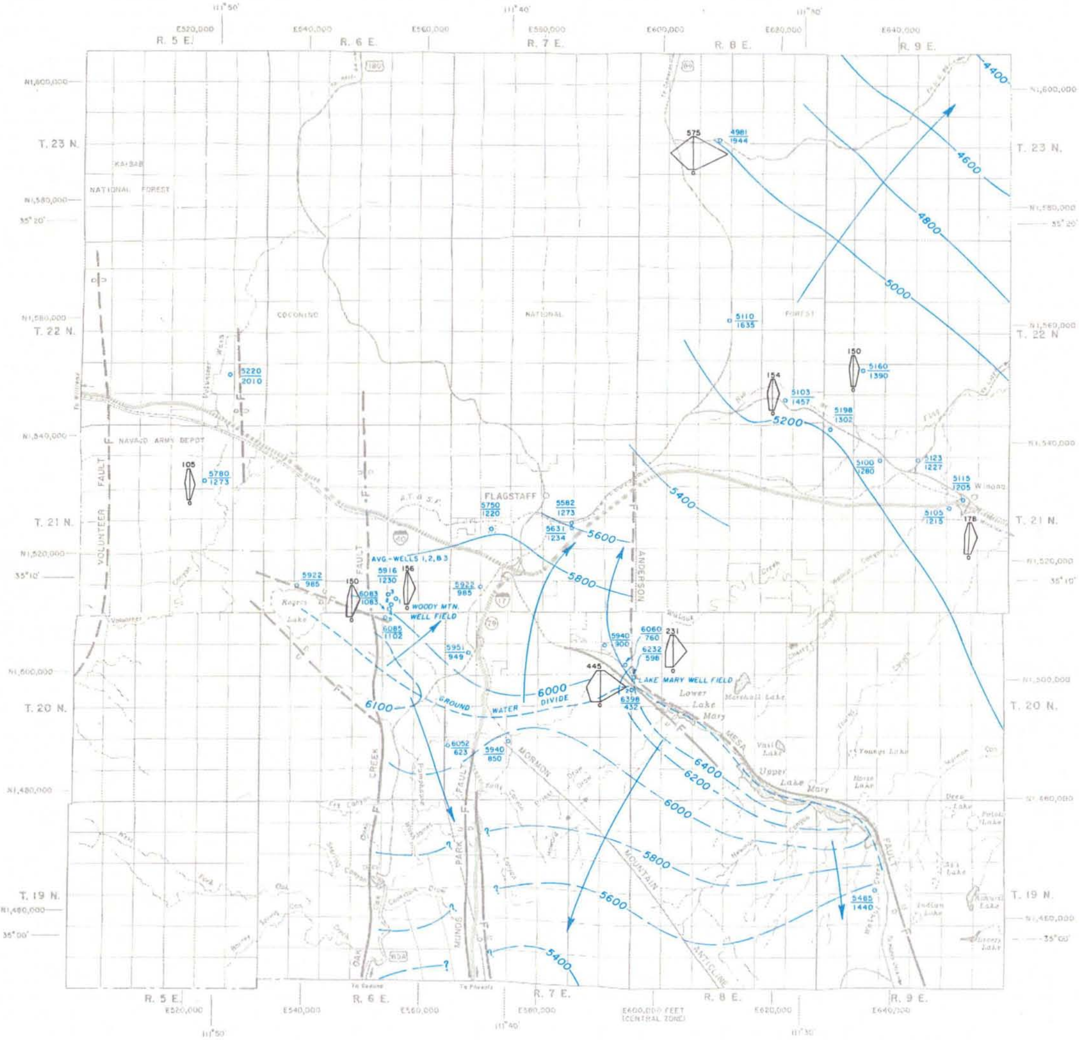
The flood plain and channel of Walnut Creek from Upper Lake Mary to its junction with San Francisco Wash lie entirely within the boundaries of the Coconino National Forest. Both San Francisco Wash, below its confluence with Walnut Creek, and Canyon Diablo, tributary to the Little Colorado River, are in extremely rough terrain and are bordered by lands devoted chiefly to grazing.

Development within the flood plain or channel of Walnut Creek has not occurred for two reasons: (1) the presence of existing Upper Lake Mary and its operation with infrequent spills which would discourage building within the flood plain and channel without imposed restrictions, and (2) the U.S. Forest Service policy of controlling development within the National Forest. The rehabilitation and enlargement of Upper Lake Mary contemplated under ultimate project development would not change these conditions.

Protection against dam failure due to flooding has been provided for by designing the spillway and reservoir surcharge with capacity to pass the design floods without overtopping the dam.

C. Plan of Operation

The basic operation of the first stage of the project would be to divert Clear Creek water via the pumping plants and pipeline system from Wilkins Reservoir to a control station at Lower Lake Mary (see Map No. 1066-314-74). The control station would connect to a 49-foot diameter by 27-foot-high terminal tank which would eliminate a direct



LOCATION MAP

EXPLANATION

CATION 10 575 10 ANION
SODIUM — CHLORIDE
CALCIUM — BICARBONATE
MAGNESIUM 10 0 10 SULPHATE
EQUIVALENTS PER MILLION

Representative water quality pattern diagram with analysis from the Coconino sandstone; figure at top of diagram is sum of total dissolved solids in parts per million.

6060 / 760 — Active or abandoned water well-- top figure approximate elevation of water level in Coconino sandstone; bottom figure is measured or reported depth to the water below land surface; mostly 1966 measurements.

5600 — Contour of equal water-level elevations; arrow indicates apparent direction of ground-water movement; contour interval 200 feet.

U F D — Major high angle fault; "U" indicates upthrown side; "D" is downthrown side; dashed where approximate.

Anticline, showing trace of axial plane and plunge of axis.

2 0 2 4 6
SCALE OF MILES

N

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOGOLLON MESA PROJECT
ARIZONA

GENERALIZED GROUND-WATER ELEVATIONS AND QUALITY

GEOLOGY G. D. FORD ____ SUBMITTED ____
TRACED ____ RECOMMENDED ____
CHECKED ____ APPROVED Earl E. Kornie
PHOENIX, ARIZONA SEPTEMBER 17, 1971 | 1066-314-67

connection between the Flagstaff trunkline and aqueduct, thereby protecting the latter line from unknown changes that may occur in the Flagstaff system. Diversions would be made from the terminal tank directly to the city of Flagstaff's treatment facilities center via the existing pipeline connecting Lower Lake Mary and the present treatment plant.

In later years when municipal water requirements demand additional water supply, the second stage of the project plan could be implemented. A bifurcation would be constructed on the existing aqueduct near the upper end of Upper Lake Mary with additional pipeline and structures to connect the aqueduct with Upper Lake Mary. After the lining and rehabilitation of Upper Lake Mary are completed, diversions from Clear Creek would then be released directly into Upper Lake Mary and the reservoir would be operated in combination with Wilkins Reservoir to attain the project firm yield of 18,400 acre-feet. The aqueduct below the bifurcation would remain available as an emergency bypass facility.

The water requirement schedule for the plan of operation is displayed in Table 16. It is based on the premise that the project would supplement existing supplies from Upper Lake Mary (1,400 acre-feet) and Inner Basin and other sources (1,000 acre-feet). The 1,400 acre-feet average supply from Upper Lake Mary would not be available during the construction period of the second stage. After completion of the second stage, the average yield of 1,400 acre-feet would become part of the firm project water supply.

D. Description of Project Works

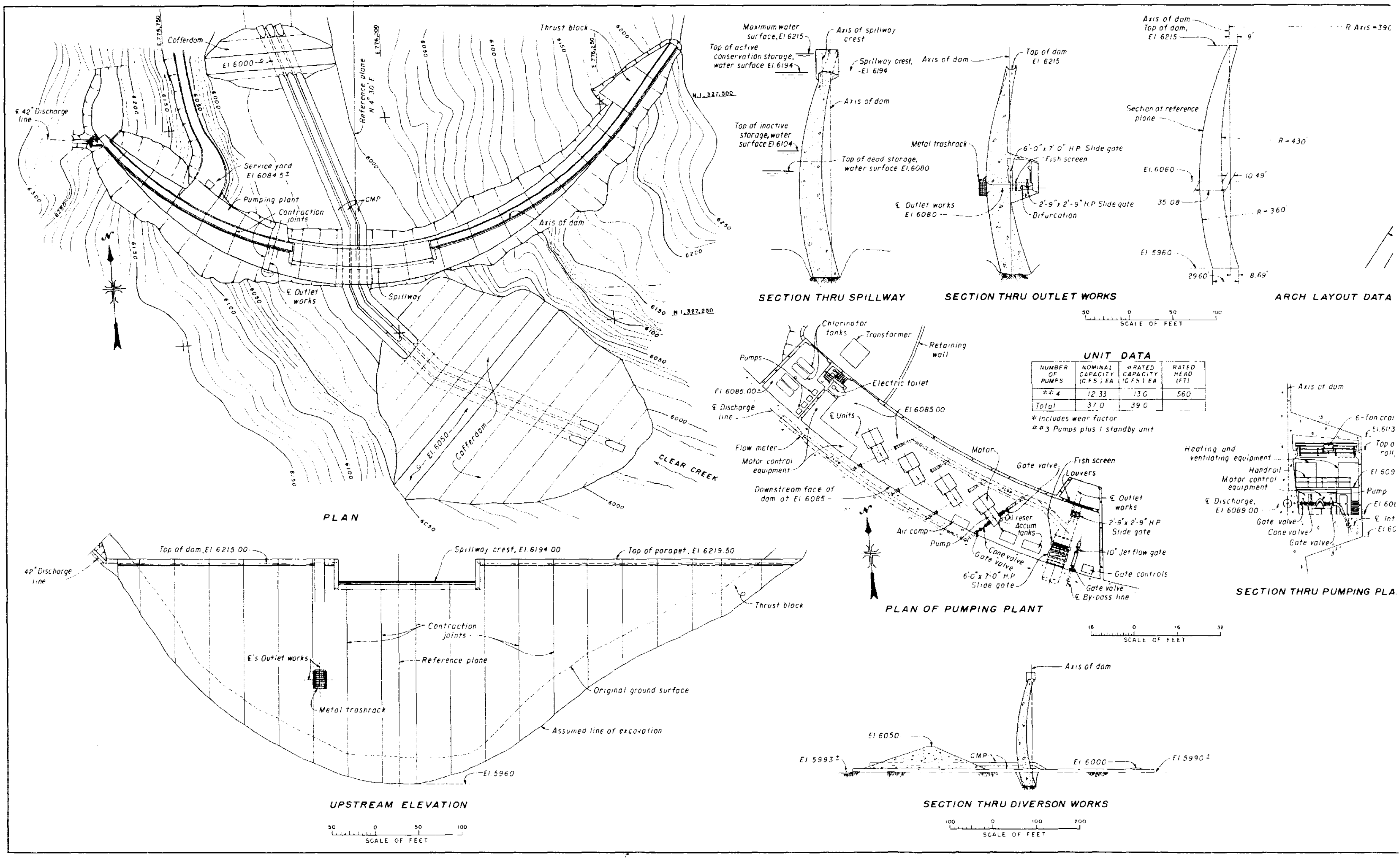
1. Wilkins Dam. Wilkins Dam would be located in a deeply incised canyon of Clear Creek in Sections 31 and 32, T. 15 N., R. 13 E., G&SRM (see Photograph No. P-420-300-7156). It would be a thin, double curvature, concrete-arch structure rising about 228 feet above streambed. The dam would have a crest length of 790 feet. The drainage area upstream from the dam site is 321 square miles. The general plan and section for the dam are shown on Drawing No. 1066-D-5. The spillway would be an uncontrolled ogee crest located in the center of the dam. It would have a discharge capacity of 57,200 ft^3/s to protect against an inflow design flood for a general winter rain or snow storm with a peak of 61,500 ft^3/s and a 4-day volume of 116,800 acre-feet.

The dam proper would contain 94,500 cubic yards of mass concrete. The spillway crest, piers, gatehouse, curbs, parapets, and walls would contain another 1,850 cubic yards of concrete for a total concrete volume of 96,350 cubic yards.

Access to the site for the construction of Wilkins Dam would be obtained by the construction of a two-lane, 30-foot wide oil surfaced roadway from State Highway 87 to the damsite. The total length of the road would be about 9.6 miles, with the grade and alinement following the natural ground contours, wherever possible, to avoid excessive cut and fill sections.

2. Outlet Works and Diversion Facilities. The facilities required to divert water from Wilkins Reservoir, consisting of a bifurcation in the outlet works and Wilkins Pumping Plant, are incorporated within

P420-300-7156 Clear Creek and Site of Proposed Wilkins Dam

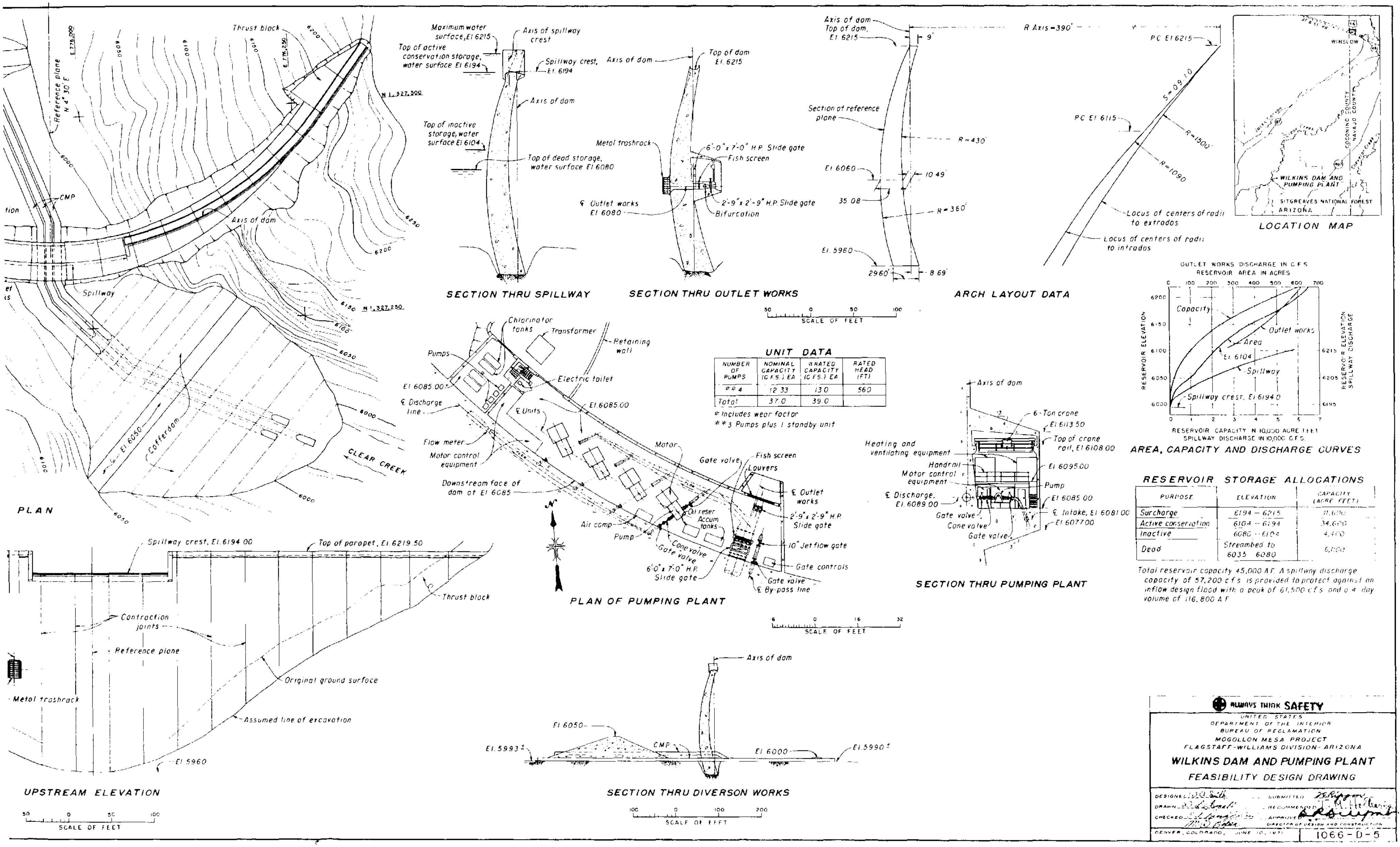


UNIT DATA

NUMBER OF PUMPS	NOMINAL CAPACITY (C.F.S.) EA	*RATED CAPACITY (C.F.S.) EA	RATED HEAD (FT)
** 4	12.33	13.0	560
Total	37.0	39.0	

* Includes wear factor

** 3 Pumps plus 1 standby unit



UNIT DATA

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**4	12.33	13.0	560
Total	37.0	39.0	

* Includes wear factor

** 3 Pumps plus 1 standby unit

RESERVOIR STORAGE ALLOCATIONS

PURPOSE	ELEVATION	CAPACITY (ACRE-FEET)
Surcharge	6194 – 6215	11,600
Active conservation	6104 – 6194	34,600
Inactive	6080 – 6104	4,400
Dead	Streambed to 6035 6080	6,000

Total reservoir capacity 45,000 A.F. A spillway discharge capacity of 57,200 c.f.s. is provided to protect against an inflow design flood with a peak of 61,500 c.f.s. and a 4-day volume of 116,800 A.F.

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOGOLLON MESA PROJECT
FLAGSTAFF-WILLIAMS DIVISION - ARIZONA

WILKINS DAM AND PUMPING PLANT

FEASIBILITY DESIGN DRAWING

DESIGNED ___ SUBMITTED ___
DRAWN ___ RECOMMENDED ___
CHECKED ___ APPROVED ___
DIRECTOR OF DESIGN AND CONSTRUCTION

DENVER, COLORADO, JUNE 10, 1971 | 1066-D-5 the dam. By means of the bifurcation and gate control, releases can be made from the reservoir for either delivery to the Flagstaff area or to the stream below the dam or to both.

Releases to Clear Creek would be controlled by a 2-foot 9-inch wide by 2-foot 9-inch high pressure slide gate in the pumping plant on the downstream face of Wilkins Dam. The outlet has a capacity of 550 ft^3/s at the top of the active conservation storage, elevation 6194. A 12-inch bypass line controlled by a 10-inch jet flow gate provides nominal releases to Clear Creek during inspection or servicing of the intake.

Diversion of releases for municipal and industrial water purposes would be effected by means of Wilkins Pumping Plant. The magnitude of such releases would be controlled by the capacity of the Wilkins-Flagstaff pipeline designed at 37 ft^3/s.

3. Diversion Scheme. The streamflows would be diverted through the construction area using corrugated metal pipes. The 5-year flood was used in the design of the diversion scheme. After completion of construction, bulkhead gates would be placed over the pipes at the face of the dam and the portion of the pipes in the dam plugged with concrete. The downstream cofferdam would be removed after construction.

4. Visitor Facilities. Specific visitor facilities have not been incorporated in the design of the dam. However, it is recommended that a visitor overlook be incorporated with the Wilkins Pumping Plant surge tank area. This area is located on the left abutment of and above the dam providing an excellent view of the construction site and the finished structure.

5. Wilkins Reservoir. The Coconino sandstone forms the lower portion of the canyon walls, and the Kaibab limestone forms the upper portion. The maximum height of the reservoir is governed by the permeability of the contact between the Coconino sandstone and the Kaibab limestone, which occurs about 125 to 200 feet above the canyon floor. The conservation pool elevation (6194) generally is below the Coconino-Kaibab contact. However, gentle warping of the strata results in the contact dipping below that elevation along a 2,000- to 3,000-foot portion of the west side of the reservoir area. The lowest point of the contact is 25 feet below the top of the conservation pool. It will be necessary to construct a grout curtain along the contact zone where it dips to control seepage from the side of the reservoir at full storage.

Maximum water surface elevation during the design flood (about 6215) is above the contact in a large part of the reservoir. Since the spillway is at elevation 6194, there will be no storage above that elevation.

The reservoir formed by the dam would have a capacity of 45,000 acre-feet at a normal water surface elevation 6194 and would have a water surface area of 568 acres.

The reservoir capacity would consist of 34,600 acre-feet for active conservation storage, 4,400 acre-feet of inactive storage, and 6,000 acre-feet of dead storage (see Reservoir Capacity Allocations and Photograph No. P-698-300-10010).

Although an outlet works is designed as an integral part of the dam to accomplish releases from the reservoir to the stream below,

7-1088 (8-72)
Bureau of Reclamation

RESERVOIR CAPACITY ALLOCATIONS

TYPE OF DAM: Thin, double curvature, concrete	REGION: LC — STATE: Arizona
OPERATED BY: Bureau of Reclamation	RESERVOIR: Wilkins
CREST LENGTH: 790 FT. CREST WIDTH: FT	DAM: Wilkins
VOLUME OF DAM: 96,350 CU YD	PROJECT: Mogollon Mesa
CONSTRUCTION PERIOD: 5 years	DIVISION:
STREAM: Clear Creek	UNIT:
RES AREA: 568 ACRES AT EL 6,194	STATUS OF DAM:
ORIGINATED BY: (Initials) (Code) (Date)	APPROVED BY: (Initials) (Code) (Date)

CREST OF DAM (without camber)	EL 6215 (3)
MAXIMUM WATER SURFACE	EL 6215
TOP OF EXCLUSIVE FLOOD CONTROL	EL —
TOP OF JOINT USE	EL —
USES: F.C.	—
TOP OF ACTIVE CONSERVATION	EL 6194
USES:	
TOP OF INACTIVE (2)	EL 6104
TOP OF DEAD	EL 6080
STREAMBED AT DAM AXIS	EL 5987
LOWEST POINT OF FOUNDATION EXCAVATION	EL 5960

FREEBOARD	— FT.
SURCHARGE	11,600 A.F.
EXCLUSIVE FLOOD CONTROL	0 A.F.
JOINT USE	0 A.F.
ACTIVE CONSERVATION	34,600 A.F.
INACTIVE	4,400 A.F.
DEAD	6,000 A.F.

Maximum height (structural height): 255 (4) ft.
Height above streambed: 228 ft.
Total capacity (1): 45,000 a.f.
Live capacity: 39,000 a.f.
Active capacity: 34,600 a.f.

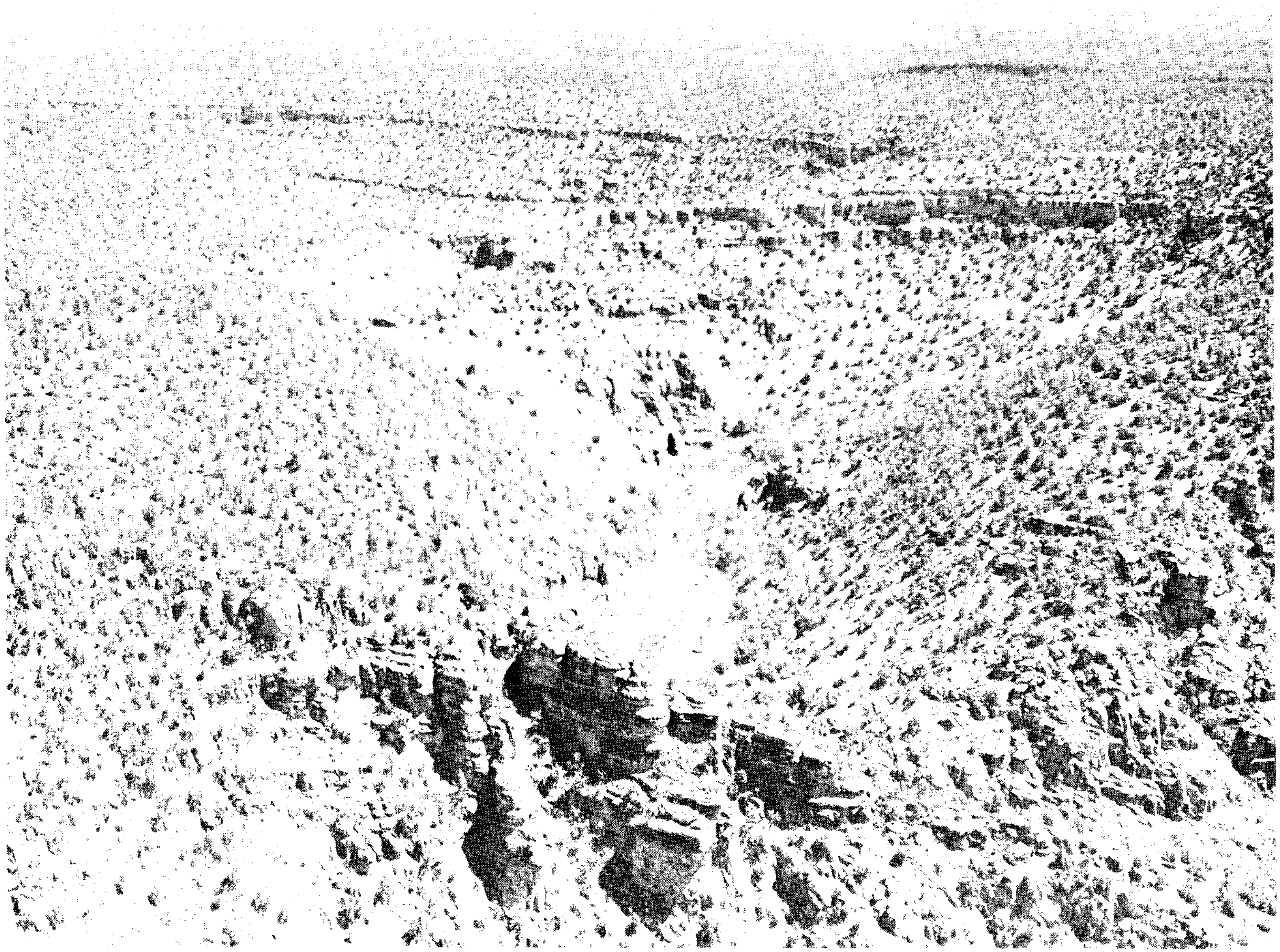
(1) Includes 7,260 a.f. allowance for 100 year sediment deposition between streambed and El 6194, of which 2,260 a.f. is above El 6112.5.
(2) Established by Fish and Wildlife

REFERENCES AND COMMENTS:

Minimum pool, top of inactive capacity corresponding to 200 surface acres to be maintained for fish and wildlife purpose.

(3) Top of parapet, elevation 6219.5.

(4) Elevation 5960 to 6215.



P698-300-10010 Clear Creek in Vicinity of Proposed Wilkins Reservoir the project plan does not contemplate scheduled releases for downstream uses as such releases would decrease the firm yield of the project water supply for municipal and industrial uses. Under these conditions, the channel immediately below the dam would become a live stream for a short distance but stream losses further downstream would result in continued intermittent streamflow that is activated by reservoir spills and by natural runoff from the area below the reservoir.

6. The Aqueduct System. Municipal and industrial water deliveries to Flagstaff trunkline would be accomplished by diversions from Wilkins Reservoir by means of a pipeline and three pumping plants. The pipeline would vary in size from 30 inches to 42 inches in diameter, would be about 51 miles in length (first stage construction) and would have a design discharge capacity of 37 ft^3/s. The three pumping plants would lift the diverted water through a total maximum head of 1,430 feet. Wilkins Pumping Plant would be incorporated within the dam. Chavez Pass Pumping Plant would be located at Station 690+40, or about Mile 13.1 along the pipeline from the dam. Jaycox Pumping Plant would be located at Station 1100+60, or about Mile 20.8 along the pipeline from the dam. Both Chavez Pass and Jaycox Pumping Plants would be identical in architectural and physical plant design. Table 17 gives the design criteria for each of the pumping plants.

A communication system would be incorporated in the aqueduct system to provide status monitoring of the various pumping plants and control structures. A communication cable along with low voltage

Table 17
DESIGN CRITERIA
Pumping Plants
Mogollon Mesa Project, Arizona

Pumping Plant	No. of Units	Standby Units	Total Maximum Head (feet)	Rated Quantity Each Unit (ft^3/s)	Normal Quantity Each Unit (ft^3/s)	Horsepower Each Unit	Percent Efficiency: Motor	Percent Efficiency: Pump	Percent Efficiency: Over-all	kW Required All Units
Wilkins	3	1	560	13	12.33	1,250	95	84	75	3,000
Chavez Pass	3	1	435	13	12.33	900	95	84	75	2,200
Jaycox	3	1	435	13	12.33	900	95	84	75	2,200

power cables would be buried along the pipeline right-of-way connecting the pumping plants with the operations office in the city of Flagstaff.

7. <u>The Transmission Line System</u>. The power transmission system proposed for operating the project pumping plants would consist of a 69-kV Federal line of wood H-frame construction extending from an existing substation located on the Arizona Public Service Company 69-kV line between Flagstaff and Winslow, Arizona, to Jaycox Pumping Plant. The line would then extend along the pipeline right-of-way to serve Chavez Pass and Wilkins Pumping Plants. Its total load would be 7,400 kW and its total length would be 52 miles.

8. <u>Upper Lake Mary Dam and Reservoir</u>. Upper Lake Mary is Flagstaff's present source of surface water supply. Under the second stage of the proposed plan of development, the reservoir would be enlarged from its present capacity of 15,600 acre-feet to 29,500 acre-feet to provide for offstream storage and reregulation of diverted Clear Creek flows.

The reservoir would be lined throughout with a PVC membrane of 20-mil thickness to prevent seepage of the developed water supply. A covering of earth material over the membrane will be required for protection and stability. The earth material would be placed to a depth of 12 inches in the reservoir area below the inactive pool elevation of 6815 and 18 inches in the reservoir area above the inactive pool elevation. With proper installation and the protection afforded by the earth covering, it is estimated the lining membrane would last the life of the project.

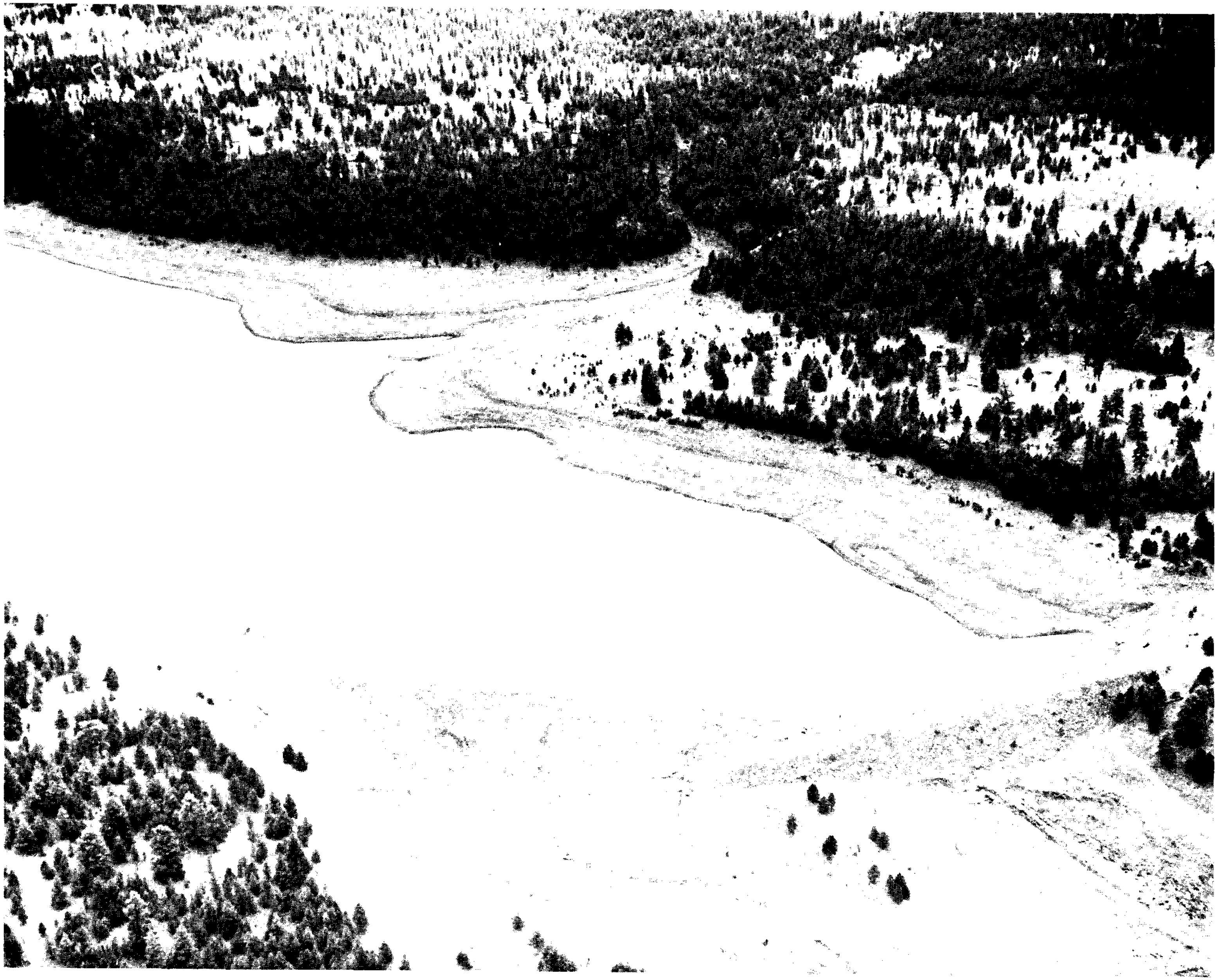
At top of inactive storage, elevation 6815, the reservoir would have a capacity of 5,440 acre-feet and a surface area of 596 acres. At the top of the active conservation pool, elevation 6842.6, the reservoir would have a capacity of 29,500 acre-feet and a surface area of 1,089 acres.

The present dam located on Walnut Creek in Section 27, T. 20 N., R. 8 E., G&SRM, would be removed and replaced with a rolled earth-filled structure about 65 feet high above streambed and 1,500 feet in length. The new dam would have an embankment of 253,000 cubic yards. An uncontrolled ogee crest spillway would be located on the left abutment. It would have a discharge capacity of 6,150 ft^3/s to protect against an inflow design flood with a peak of 20,760 ft^3/s and a 4-day volume of 12,920 acre-feet.

A bifurcation structure at Station 2198+91 would be constructed on the Wilkins-Flagstaff pipeline to divert water to Upper Lake Mary. A pipeline extending 1,750 feet from the bifurcation structure would release water through a baffled outlet structure into the reservoir (see Photograph No. P-1066-300-11775). For data on the reservoir see the Reservoir Capacity Allocations.

9. Recreation and Fish and Wildlife Facilities. The Bureau of Outdoor Recreation furnished costs of the recreation facilities including camp units, boat launch ramps, swimming and picnicking areas (only at Upper Lake Mary in which swimming is permitted) and supporting parking, circulatory roads, water, and sanitation facilities.

The Public Health Service of the State of Arizona has no regulations concerning full body contact sports in reservoirs even though



P1066-300-11775 Upper Lake Mary Dam and Spillway on Walnut Creek

7-1686 (2-72)
Bureau of Reclamation

RESERVOIR CAPACITY ALLOCATIONS

TYPE OF DAM Rolled Earthfill	REGION LC STATE Arizona
OPERATED BY	Upper Lake Mary (Enlarged) RESERVOIR
CREST LENGTH 1,500 FT. CREST WIDTH FT	Upper Lake Mary DAM
VOLUME OF DAM 253,000 CU YD	Mogollon Mesa PROJECT
CONSTRUCTION PERIOD	DIVISION
STREAM Walnut Creek	UNIT
RES AREA 1,089 ACRES AT EL 6,842.6	STATUS OF DAM
ORIGINATED BY: (Initials) (Code) (Date)	APPROVED BY: (Initials) (Code) (Date)

Maximum height (structural height) 65 ± ft
Height above streambed 65 ± ft ①
Total capacity 29,500 a.f.
Live capacity 28,900 a.f.
Active capacity 24,060 a.f.

CREST OF DAM (without camber)	EL 6855	FREEBOARD	6 FT
MAXIMUM WATER SURFACE	EL 6849	SURCHARGE	7,300 A.F.
TOP OF EXCLUSIVE FLOOD CONTROL	EL —	EXCLUSIVE FLOOD CONTROL	0 A.F.
TOP OF JOINT USE	EL —	JOINT USE	0 A.F.
USES: F.C.			
TOP OF ACTIVE CONSERVATION	EL 6842.6	ACTIVE CONSERVATION	24,060 A.F.
USES:			
TOP OF INACTIVE ②	EL 6815	INACTIVE	4,840 A.F.
TOP OF DEAD	EL 6800	DEAD	600 A.F.
STREAMBED AT DAM AXIS	EL 6790		
LOWEST POINT OF FOUNDATION EXCAVATION	EL —		

① Includes 0 a.f. allowance for ____ year sediment deposition between streambed and El ____, of which ____ a.f. is above El ____.

② Established by Fish and Wildlife – about 200 acres minimum pool required

REFERENCES AND COMMENTS:

Reconnaissance design.

Annual deposition of sediment estimated to be about 10 acre-feet per year. The 100-year sediment inflow is less than 5 percent of active capacity. Detailed sediment distribution studies have not been made.

domestic water would be diverted directly from the reservoir. However, any purveyor under the State jurisdiction must provide complete treatment of all water taken from reservoirs and distributed for domestic purposes.

Development costs for Upper Lake Mary are based on available standards and are in line with recent Forest Service experience on the Coconino National Forest. Because of the extremely rough terrain and unusual condition in the Wilkins Reservoir area, Bureau of Outdoor Recreation standards were not considered applicable to the boat launch construction at Wilkins Reservoir. Consequently, the cost estimate for this facility was prepared from design data available by the Bureau of Reclamation. The kind and number of each facility are tabulated below.

Facility	At Full Development: Upper Lake Mary	At Full Development: Wilkins Reservoir
Camp Units	215	60
Picnic Units	90	-
Boat Access and Launch Ramp	8	1
Swimming Area	1	-
Sightseer and Shore Fisherman Parking Space	80	-

E. Geology and Construction Materials

1. General Geology. The proposed Wilkins Dam and Reservoir and the Wilkins Dam-Flagstaff pipeline route are on the Mogollon slope, a subdivision of the Colorado Plateau Physiographic Province. Generally the plateau surface is relatively smooth and rolling, but locally major streams and their tributaries have cut narrow canyons as much as hundreds of feet deep. A few prominent buttes and ridges rise abruptly from the regional ground level.

The Mogollon slope comprises sedimentary and volcanic strata in a gentle regional dip to the northeast. The rock units influencing project features are, in descending order, Tertiary to Quaternary volcanic rocks, Triassic Moenkopi formation, Permian Kaibab limestone, and Permian Coconino sandstone.

2. Engineering Geology. Wilkins Dam site is located in the 500-foot deep canyon of Clear Creek which penetrates the Kaibab limestone and about 200 feet of the underlying Coconino sandstone. The foundation of the dam would largely comprise the Coconino sandstone, with the crest of the dam extending up into the overlying Kaibab limestone. The elevation at the top of the active conservation pool, 6194 feet, is about 25 feet above the sandstone-limestone contact on the left abutment and about 5 feet below the contact on the right abutment.

The rock at the dam site has been determined to have adequate strength and stability to support a thin-arch concrete dam.

The pipeline alinement crosses a succession of sedimentary and volcanic rock types, essentially the Kaibab limestone, the Moenkopi, and the volcanic formations.

The relative proportions of rock to common cut in excavation for the pipe trench vary from place to place. Excavation would be dry and for the overall alinement would be about 45 percent rock cut and 55 percent common. All foundation materials along the alinement have adequate bearing capacity and stability for the pipeline.

Wilkins Pumping Plant as presently designed would be incorporated within Wilkins Dam. The discharge line would be partly on a 1/2:1

slope on the lower part of the canyon wall and would then continue up a gentler, irregular slope to the surge tank located on a low knoll on the canyon rim. Coconino sandstone forms the steep lower canyon wall. Above about elevation 6170 the canyon wall and rim are in Kaibab limestone. Foundation stability and bearing capacity are adequate for the pipeline and surge tank.

The Chavez Pass Pumping Plant structure would be underlain by the Moenkopi formation. The surge tank site and the major part of the discharge alinement are underlain by volcanic rocks. Bearing strength and stability of the shale in the Moenkopi formation in this area are relatively low, but are considered adequate for the size of the structure design. Bearing strength and stability of the volcanic rock are adequate. Excavation would be dry. At the pumping plant site it is estimated that the excavation would be 70 percent common cut and 30 percent rock cut. Excavation for the discharge line would be about 70 percent rock cut and 30 percent common cut. Any required excavation at the surge tank would be rock cut.

The Jaycox Mountain Pumping Plant structure would be near the base of Jaycox Mountain, a small isolated volcanic knob. The discharge line would be located up the side of the mountain. Bedrock is Quaternary-Tertiary volcanic rock. Slope wash and residual soil cover the surface, except for scattered small outcrops near the top of the mountain. The soil consists of silty to clayey sand with gravel boulders, and ranges in depth from about 8 feet at the pumping plant to a few inches at the end of the discharge line. Bearing strength and stability are adequate for the proposed structure. Excavation would be dry. At the pumping plant excavation would be common cut to about 8 feet and rock cut below. Along the discharge line excavation would be about 30 percent common cut and about 70 percent rock cut.

Upper Lake Mary Dam is located on Tertiary to Quaternary basalt. The basalt overlies a sequence of nearly flat-lying Paleozoic to Mesozoic sedimentary rocks, Moenkopi formation, Kaibab limestone, Coconino sandstone, and older formations. Bearing strength and stability are considered adequate for the proposed new structure.

3. Seismicity. Severe earthquakes that would damage the structures are improbable.

To evaluate the potential occurrence of damaging earthquakes, the following data have been considered. Arizona is designated as an area of moderate seismic risk by Dr. S.T. Algermissen 1/ where moderate damage from earthquakes may be expected. During the period of historical record from around the turn of the century to 1970, 14 earthquakes with intensities of V or greater on the Modified Mercalli Scale were recorded that had epicenters within Arizona. Thirty-nine other earthquakes with epicenters elsewhere were felt in Arizona during that period. 1/ The principal active area within the State is in the Flagstaff area and northward to the Utah border where half of the reported earthquakes occurred and intensities as high as VII have been reported. This activity is probably associated with younger faults and volcanism in the area.

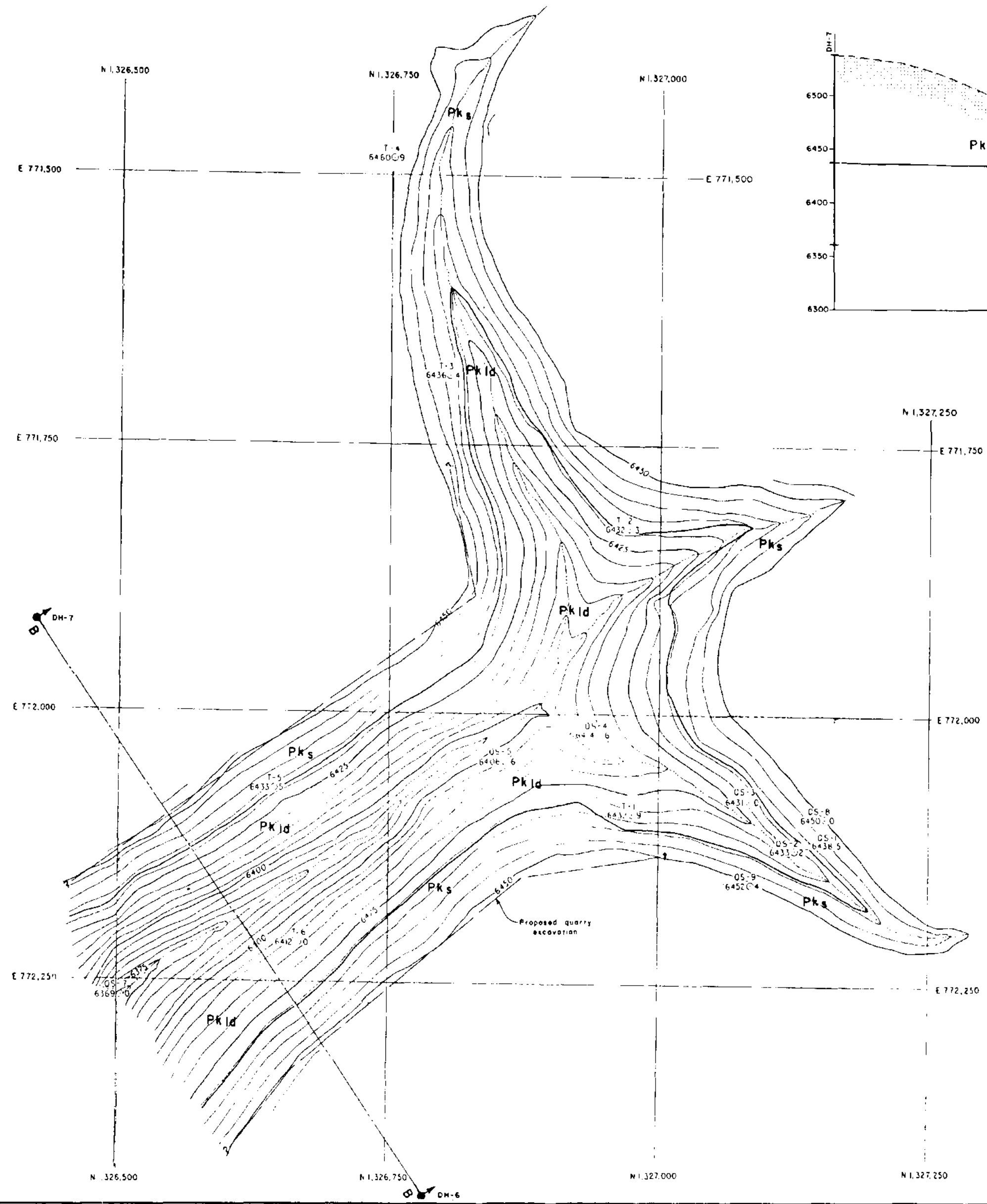
1/ Earthquake History of the United States: Publication 41-1, Revised Edition (through 1970), 1973, National Oceanic and Atmospheric Administration.

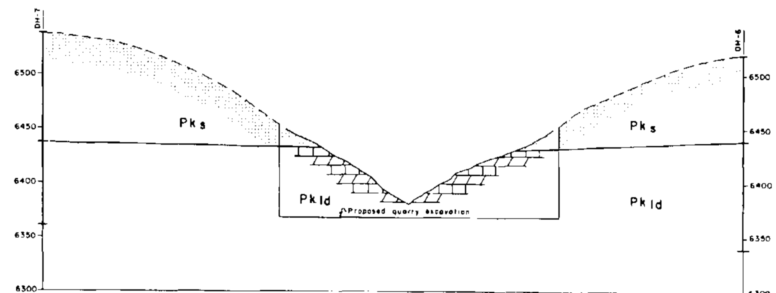
4. Construction Materials.

a. Wilkins Dam. Suitable natural aggregate is not available in the vicinity of the dam site. The nearest known suitable aggregate source is in Rye Creek, a tributary to Tonto Creek, about 75 miles south of the dam site on the Phoenix-Payson highway. The deposit is in the broad channel of an intermittent stream and it consists of sand, gravel, and cobbles derived from various igneous, metamorphic, and sedimentary rocks.

A quarry could be established in the Kaibab limestone near the dam site to provide crushed-rock aggregate. A suitable site was selected about 4,000 feet west of the dam site (see Drawing No. 1066-314-38). In this area a 400-foot-long portion of the canyon contains about 90,000 cubic yards of exposed usable rock. By excavating about 12,000 cubic yards of inferior rock overburden, the usable quantity available could be increased to about 160,000 cubic yards, or the quarry could be extended upstream and downstream to obtain a similar volume without stripping.

b. Pipeline. Precast concrete pipe or other equivalent types of pipe would be used in construction of the pipeline, and only small quantities of concrete would be required for pipeline structures. Aggregate could be obtained from the proposed crushed aggregate quarry near Wilkins Dam site or from commercial sources in Flagstaff. Suitable materials for bedding that would require no processing could be obtained from existing cinder quarries at Sunset Pass (Sections 3 and 4, T. 17 N., R. 13 E.) and at Flagstaff. Crushed rock from the proposed aggregate quarry at Wilkins Dam site would also be available.





SECTION B-B

EXPLANATION

PERMIAN

Pks	SANDSTONE: Fine to medium-grained, moderately cemented by carbonate and silica, massive bedding
Pkld	LIMESTONE AND DOLOMITE: Hard, dense with minor vuggy zones along some bedding planes, massively bedded

SYMBOLS

● DH-6 Location of vertical drill hole

REFERENCE DRAWING

SCALE OF FEET
CONTOUR INTERVAL 5'

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOGOLLON MESA PROJECT
ARIZONA

QUARRY SITE
GEOLOGY

GEOLOGY: R.H.Rozmond ..... SUBMITTED: ....
TRACED: D.D.D. RECOMENDED: ....
CHECKED: S.F.Groy APPROVED: Carl E Kowe

PHOENIX, ARIZONA JANUARY 15, 19[illegible]
SHEET 1 OF 1

1066-314-38

Backfill material could be obtained from required excavation except in places of extensive rock cut. Where these areas occur, quantities of suitable material could be obtained within a mile of the alinement.

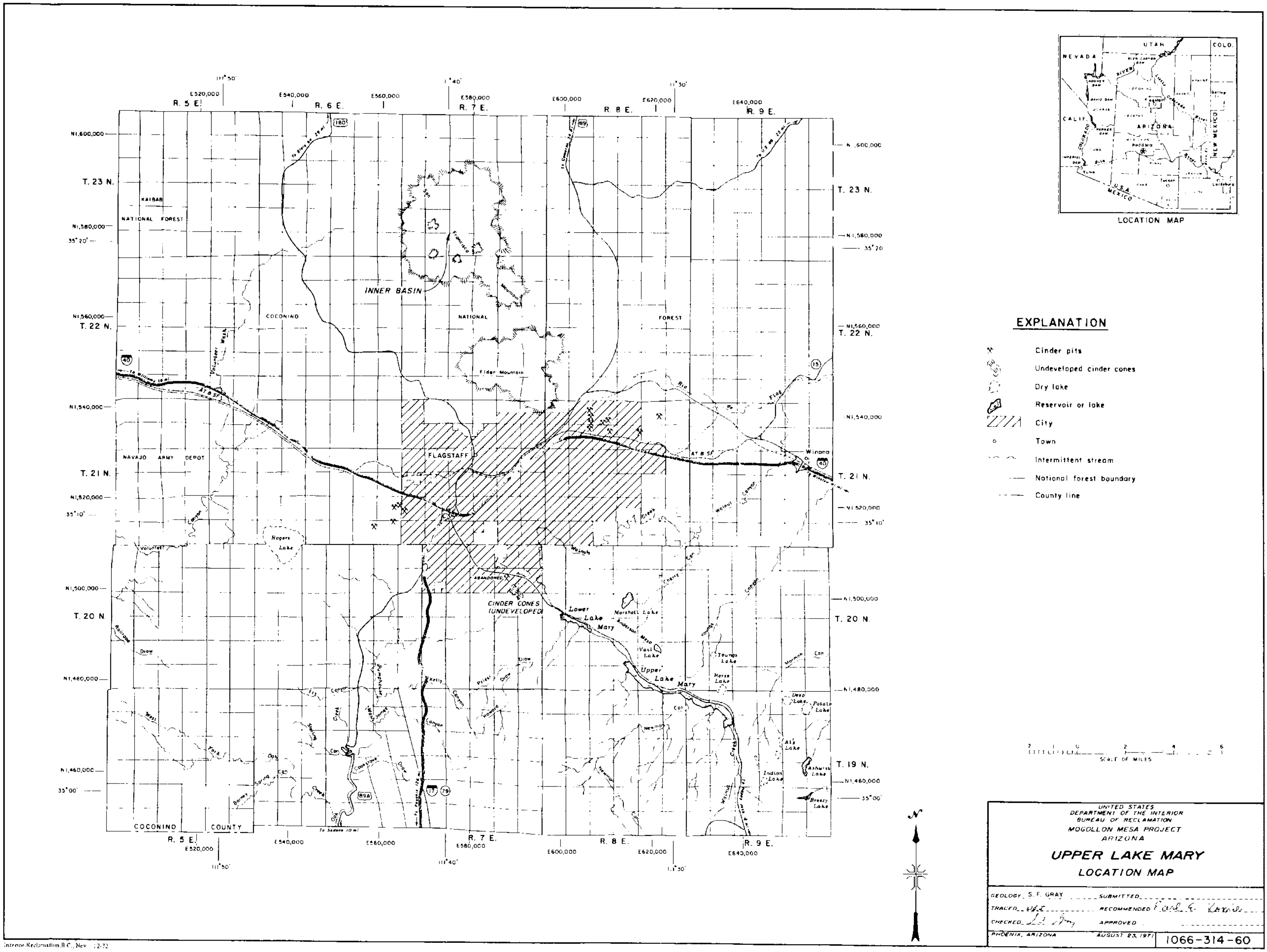
c. Pumping Plants. Crushed aggregate for concrete would be available from the proposed aggregate quarry for Wilkins Dam, or concrete could be obtained from commercial plants in Flagstaff. Backfill could be supplied from required common excavation. Construction water could be obtained from lakes and streams in the project area.

d. Upper Lake Mary Dam. Construction of a new, higher dam to replace the existing dam would probably be accomplished by removing the present embankment and reusing part of it in the new fill. Additional materials could be obtained from within the limits of the present reservoir area upstream from the existing dam. Riprap is available from the basalt flows along the south shore and within the limits of the present reservoir area. Commercial aggregate is available in Flagstaff about 11 miles from the dam (see Map No. 1066-314-60).

e. Lining of Upper Lake Mary Reservoir. The most suitable and available cover material for the 20-mil PVC membrane is volcanic cinders. Existing cinder pits with large quantities of material available occur southwest of Flagstaff about 15 miles from the reservoir. These pits are used commercially and by the Arizona Highway Department.

F. Construction Problems

1. Accessibility. Access to all features of the proposed plan of development, including the pipeline and pumping plants, is relatively easy except for Wilkins Dam and Reservoir. The first order of



Interior-Reclamation B.C., Nev. 12-72

construction on the dam would be to build about 8 miles of all-weather road from State Highway 87 to the canyon rim. It would also be necessary to construct a road from the canyon rim along the near vertical canyon wall for access to Wilkins Dam Pumping Plant. A separate access road from the canyon rim to the reservoir would be required for fishing and recreation purposes.

2. Rights-of-Way. Wilkins Dam and Reservoir site occupies lands within the Coconino and Sitgreaves National Forests, plus a few private parcels. The takeline for the proposed reservoir right-of-way constitutes about 1,233 acres of private holdings. Additional right-of-way for the proposed enlargement of Upper Lake Mary Reservoir is entirely within the Coconino National Forest. Right-of-way for the aqueduct system involves 516 acres of Forest Service land and 61.5 acres of private land.

3. Relocation. Under the proposed plan for enlarging Upper Lake Mary Reservoir, approximately 2-1/2 miles of paved county road along the northeast shore would require relocation to a higher elevation.

G. Project Cost

1. Construction Costs. The estimated total cost of the two-stage Mogollon Mesa Project is $85,390,000 including investigation costs of $1,250,000. Construction costs of the various features of the project are summarized in Table 18. The first stage and the second stage construction is shown on the Project Cost Estimate.

Estimates for the cost of constructing the project features are based on April 1976 price levels, indexed from July 1971. In addition

Table 18
ESTIMATED CONSTRUCTION COSTS 1/
Mogollon Mesa Project, Arizona

Feature	Cost
Stage I	
Wilkins Dam and Reservoir	$23,380,000 2/
Pumping Plants	5,050,000
Pipeline and Structures	34,410,000
Communication System	767,000
Transmission System	2,270,000
Fish and Wildlife and Recreation Facilities	1,191,000
Subtotal	$67,068,000
Stage II	
Pipeline and Structures	$ 400,000
Upper Lake Mary Dam and Reservoir	15,460,000
Fish and Wildlife and Recreation Facilities	2,462,000
Subtotal	$18,322,000
Total Construction Cost	$85,390,000 3/

1/ April 1976 price levels.

2/ Includes $6,830,000 for the Wilkins access road.

3/ Includes investigation costs of $1,250,000.

7-1720 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1 Summary

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

WILKINS DAM, WILKINS PUMPING PLANT, WILKINS-FLAGSTAFF PIPELINE, CHAVEZ PASS PUMPING PLANT

PROJECT COST ESTIMATE

Feasibility Estimate, Stage I

OFFICE PREPARED BY: Lower Colorado Regional Office

PROJECT MOGOLLON MESA
Date of Estimate June 25, 1976
Prices as of April 1976 (Indexed from July 1971)

Previous Estimate Prices as of

Sheet 1 of 4

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	DESCRIPTION	CCE SHEET NUMBERS	LABOR AND MATERIALS BY CONTRACTOR Cost	LABOR AND MATERIALS BY GOVERNMENT Cost	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property	TOTAL COST Property Class	TOTAL COST Identified Property
1			2	3	4	5	6	7	8	9	10	11
			TOTAL COST - STAGE I								67,068,000	
01			RESERVOIRS AND DAMS								23,380,000	
	01		WILKINS DAM--CREST ELEVATION 6215					18,408,000	4,972,000	23,380,000		
		100	Land and Rights	1			410,000					
		140	Roads and Road Structures	1			5,380,000					
		151	Dams		12,618,000		12,618,000					
			(1) Dam Structure	1	(12,060,000)							
			(2) Spillway	2	(248,000)							
			(3) Outlet Works	2	(310,000)							
03			PUMPING AND PUMPING-GENERATING PLANT								2,600,000	
	01		WILKINS PUMPING PLANT					2,020,000	580,000	2,600,000		
		130	Structures and Improvements	3			790,000					
		152	Waterways	4			760,000					
		160	Pumps and Prime Movers	4			290,000					
		170	Accessory Electric Equipment	4			156,000					
		199	Miscellaneous Equipment	4			24,000					
05			CANALS AND CONDUITS								36,860,000	
	01		WILKINS-FLAGSTAFF PIPELINE - WILKINS PUMPING PLANT TO CHAVEZ PASS PUMPING PLANT					7,824,000	2,176,000	10,000,000		
		100	Lands and Rights	5			24,000					
		152	Waterways	6			6,400,000					
		153	Waterway Structures	10			1,400,000					
	02		CHAVEZ PASS PUMPING PLANT					957,000	268,000	1,225,000		
		130	Structures and Improvements	10			410,000					
		153	Waterway Structure	11			132,000					
		160	Pumps and Prime Movers	11			242,000					
		170	Accessory Electric Equipment	11			152,000					
		199	Miscellaneous Equipment	11			21,000					
	03		WILKINS-FLAGSTAFF PIPELINE, CHAVEZ PASS PUMPING PLANT TO JAYCOX MOUNTAIN PUMPING PLANT					4,630,000	1,300,000	5,930,000		
		152	Waterways	13			4,100,000					
		153	Waterway Structures	14			530,000					

7-1720 (6-72)
Bureau of Reclamation
Formerly Basic Estimate Cost Summary

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS.

JAYCOX MOUNTAIN PUMPING PLANT, WILKINS-FLAGSTAFF PIPELINE TRANSMISSION SYSTEM, AND GENERAL PROPERTY

PROJECT COST ESTIMATE

Feasibility Estimate, Stage I

OFFICE PREPARED BY: Lower Colorado Regional Office

PROJECT: MOGOLLON MESA
Date of Estimate: June 25, 1976
Prices as of: April 1976 (indexed from July 1971)

Previous Estimate Prices as of

Sheet 2 of 4

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	DESCRIPTION	CCE SHEET NUMBERS	LABOR AND MATERIALS BY CONTRACTOR Cost	LABOR AND MATERIALS BY GOVERNMENT Cost	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property	TOTAL COST Property Class	TOTAL COST Identified Property
1			2	3	4	5	6	7	8	9	10	11
05			CANALS AND CONDUITS (continued)									
	04		JAYCOX MOUNTAIN PUMPING PLANT					957,000	268,000	1,225,000		
		130	Structures and Improvements	15			410,000					
		153	Waterway Structure	15			132,000					
		160	Pumps and Prime Movers	16			242,000					
		170	Accessory Electric Equipment	16			152,000					
		199	Miscellaneous Equipment	16			21,000					
	05		WILKINS-FLAGSTAFF PIPELINE, JAYCOX MOUNTAIN PUMPING PLANT TO PINE HILL REGULATING TANK					6,380,000	1,770,000	8,150,000		
		152	Waterways	17			5,900,000					
		153	Waterway Structures	19			480,000					
	06		WILKINS-FLAGSTAFF PIPELINE, PINE HILL REGULATING TANK TO LOWER LAKE MARY					8,070,000	2,260,000	10,330,000		
		152	Waterways	21			6,440,000					
		153	Waterway Structures	25			1,630,000					
13			TRANSMISSION LINES, SWITCHYARDS, AND SUBSTATION								2,27[illegible],000	
	01		WILKINS SUBSTATION	26				195,000	55,000	250,000		
	02		JAYCOX SUBSTATION	26				173,000	52,000	225,000		
	03		CHAVEZ SUBSTATION	26				173,000	52,000	225,000		
	04		TRANSMISSION LINE TO ARIZONA PUBLIC SERVICE COMPANY SUBSTATION AND APS SUBSTATION	26				1,230,000	340,000	1,570,000		
15			GENERAL PROPERTY								1,9[illegible],000	
	01		MASTER CONTROL SYSTEM					590,000	177,000	767,000		
		180	Communication Equipment				590,000					
	02		FISH AND WILDLIFE FACILITIES (WILKINS RESERVOIR)					850,000	230,000	1,080,000		
	03		RECREATION FACILITIES (WILKINS RESERVOIR)					87,000	24,000	111,000		
			GENERAL INVESTIGATIONS						(1,001,000)		(1,001,000)	

7-1720 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1 Summary

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS.

UPPER LAKE MARY DAM, UPPER LAKE MARY FLOW CONTROL TO ULM, AND GENERAL PROPERTY

PROJECT COST ESTIMATE

Reconnaissance and Feasibility Estimate, Stage II

OFFICE PREPARED BY: Lower Colorado Regional Office

PROJECT MOGOLLON MESA
Date of Estimate June 25, 1976
Prices as of April 1976 (Indexed from Oct. 1971)
Sheet 3 of 4

Previous Estimate Prices as of

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	DESCRIPTION	CCE SHEET NUMBERS	LABOR AND MATERIALS BY CONTRACTOR Cost	LABOR AND MATERIALS BY GOVERNMENT Cost	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property	TOTAL COST Property Class	TOTAL COST Identified Property
	1		2	3	4	5	6	7	8	9	10	11
			TOTAL COST - STAGE II								18,322,000	
01			RESERVOIRS AND DAMS								15,460,000	
	02		UPPER LAKE MARY DAM					12,370,000	3,090,000	15,460,000		
		110	Relocation of Property of Others				590,000					
		151	Dams		11,780,000		11,780,000					
			(1) Dam Structure	27	(1,370,000)							
			(2) Spillway	28	(1,100,000)							
			(3) Outlet Works	28	(560,000)							
			(4) Reservoir Lining	29	(8,750,000)							
05			CANALS AND CONDUITS								400,000	
	01		UPPER LAKE MARY FLOW CONTROL STATION TO UPPER LAKE MARY					313,000	87,000	400,000		
		152	Waterways				310,000					
		153	Waterway Structures		3,000		3,000					
			(1) Baffled Outlet at Upper Lake Mary		(3,000)							
15			GENERAL PROPERTY								2,462,000	
	01		FISH AND WILDLIFE FACILITIES (UPPER LAKE MARY)					1,350,000	350,000	1,700,000		
	02		RECREATION FACILITIES (UPPER LAKE MARY)					600,000	162,000	762,000		
			GENERAL INVESTIGATIONS						(249,000)		(249,000)	

TABLE 15a (Continued)

7-1720 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1 Summary

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

STAGE I AND STAGE II TOTALS

PROJECT COST ESTIMATE

Reconnaissance and Feasibility Estimates, Stages I and II

OFFICE PREPARED BY: Lower Colorado Regional Office

PROJECT MOGOLLON MESA
Date of Estimate June 25, 1976
Prices as of April 1976 (Indexed from July 1971 and October 1971)
Sheet 4 of 4

Previous Estimate Prices as of

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	DESCRIPTION	CCE SHEET NUMBERS	LABOR AND MATERIALS BY CONTRACTOR Cost	LABOR AND MATERIALS BY GOVERNMENT Cost	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property	TOTAL COST Property Class	TOTAL COST Identified Property
1			2	3	4	5	6	7	8	9	10	11
			TOTAL PROJECT COST									
			STAGE I - TOTALS					52,544,000	14,524,000	67,068,000		
			STAGE II - TOTALS					14,633,000	3,689,000	18,322,000		
			COMBINED TOTALS					67,177,000	18,213,000	85,390,000		
			GENERAL INVESTIGATIONS						(1,250,000)			

to direct construction costs, the estimates include costs for service facilities, preparation of designs and specifications, award of contracts, supervision of construction, and other items of overhead.

The engineering designs and cost estimates for all project features except Upper Lake Mary Dam are of feasibility level. Costs of rehabilitating and raising Upper Lake Mary Dam are of reconnaissance level.

2. Project Operation, Maintenance, and Replacement Costs. Estimated operation, maintenance, and replacement costs for the Mogollon Mesa Project for full project development are $1,324,000 for the first stage and $1,740,000 under full project development, based on current prices and on the assumption that the city of Flagstaff will be the operating entity.

Arizona Public Service Company is the only available source of power and energy in the Flagstaff-Winslow area. Power and energy for project pumping would be supplied by the Arizona Public Service Company in accordance with its large industrial rate for high voltage distribution. The estimated power cost is $900,000 per year at full development, based on a total pump lift of 1,340 feet and a delivery of 15,400 acre-feet annually. The resulting unit cost for pumping energy is $58.44 per acre-foot.

Table 19 itemizes the total annual operation, maintenance, and replacement costs for the project features.

3. Schedule of Construction. The schedule of construction for the first stage presented on the Control Schedule (Form PF-2) provides one year for advance planning and preconstruction activities

Table 19
OPERATION, MAINTENANCE, REPLACEMENT AND POWER COSTS 1/
Full Project Development
6-3/8 Percent Interest
Mogollon Mesa Project, Arizona

Feature	Costs	Replacement Costs	OM&R Costs
	Stage I		
Wilkins Dam and Reservoir	$ 56,000	--	$ 56,000
Access Road	--	$98,000	98,000
Pipeline	73,000	--	73,000
Algae Control in Pipeline	3,000	--	3,000
Pumping Plants	284,000	3,000	287,000
Transmission System	36,000	4,000	40,000
Communication Equipment and Remote Control System	--	14,000	14,000
Pumping Energy	695,000	--	695,000
Recreation and Fish and Wildlife	39,000	19,000	58,000
Total Stage I			$1,324,000
	Stage II		
Upper Lake Mary	$ 30,000	--	$ 30,000
Pumping Energy	205,000	--	205,000
Recreation and Fish and Wildlife	133,000	$48,000	181,000
Total Stage II			$ 416,000
Project Total			$1,740,000

1/ April 1976 price levels.

LEGEND Types of Activity

[illegible] and Other [illegible] — Construction

TABLE 19a

LINE NO	PROGRAM ITEM	QUANTITY	ESTIMATED TOTAL 1/	Estimated TOTAL TO SEPT. 30, 1976	FISCAL YEARS First	Second	Third	Fourth	3/	[illegible]	BALANCE TO COMPLETE	LINE NO
	1	2	3	4	5	6	7	8	9	10	11	
1	PROJECT GOALS											1
2	Municipal and Industrial Water	18,400 acre-feet						11,900 acre-feet			6,500 acre-feet	2
3												3
4												4
5	CONSTRUCTION PROGRAM											5
6	Wilkins Access Road		6,830,000	84,000	1,900,000	4,846,000						6
7	Wilkins Dam and Reservoir		16,550,000	297,000	250,000	2,900,000	8,460,000	4,643,000 ← Initial Storage				7
8	Wilkins Pumping Plant		2,600,000	39,000			1,000,000	1,561,000 ← Initial Water				8
9	Chavez Pass Pumping Plant		1,225,000	18,000			450,000	757,000				9
10	Jaycox Mountain Pumping Plant		1,225,000	18,000			450,000	757,000				10
11	Pipeline and Structures		34,810,000	498,000	130,000	7,500,000	15,000,000	11,282,000	70,000	300,000	30,000	11
12	Transmission System		2,270,000	35,000			700,000	1,535,000				12
13	Upper Lake Mary Dam and Reservoir		15,460,000	249,000					130,000	9,800,000	5,281,000	13
14	General Property		767,000	12,000			150,000	605,000				14
15	Fish and Wildlife and Recreation Facilities		3,653,000					1,191,000	70,000	1,140,000	1,252,000	15
16												16
17	TOTAL CONSTRUCTION COST		85,390,000	1,250,000 2/	2,280,000	15,246,000	26,210,000	22,331,000	270,000	11,240,000	6,563,000	17
18												18
19	TOTAL PROJECT COST		85,390,000	1,250,000	2,280,000	15,246,000	26,210,000	22,331,000	270,000	11,240,000	6,563,000	19
20	Consolidated Expenditures and Credits		-1,250,000	-1,250,000								20
21	TOTAL EXPENDITURES		84,140,000									21
22												22
23	TOTAL OBLIGATIONS		84,140,000									23
24												24
25												25

NOTES

1/ April 1976 price levels.
2/ Includes $80,734 contributed by the State of Arizona and $[illegible] from the Colorado River Development Funds.
3/ Construction of the Second Stage will be deferred until the additional supplemental water is required by Flagstaff.

RECOMMENDED ____ Operating Office Head ____ Date

RECOMMENDED ____ Regional Director ____ Date

RECOMMENDED ____ Chief, Division of [illegible] ____ Date

APPROVED ____ Commissioner ____ Date

REVISED ____ Date

SHEET [illegible] OF [illegible] SHEETS

UNITED STATES
DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

CONTROL SCHEDULE

MOGOLLON MESA PROJECT-ARIZONA

Boulder City, Nevada (OFFICE) — June 2[illegible], 197[illegible] (DATE) — LC (REGION)

☐ GENERAL INVESTIGATIONS ☐ LOAN PROGRAM
■ CONSTRUCTION ☐ OTHER

and 3 years for construction. The first contract could be awarded near the end of the first year after authorization. Municipal and industrial water deliveries could be initiated near the end of the fourth year after authorization.

A construction schedule for the second stage is also presented on the PF-2 Control Schedule.

H. Alternative Plan

1. General. The reconnaissance report entitled "Arizona-Colorado River Diversion Projects, Little Colorado River Basin and Adjacent Counties," dated September 1966 (revised June 1968), outlined plans for developing M&I water supplies to serve the future demands of the cities of Winslow and Holbrook under the Winslow-Holbrook Division, and plans for developing M&I water supplies to serve the cities of Flagstaff and Williams and the town of Ashfork under the Flagstaff-Williams Division.

a. The Winslow-Holbrook Division. Project features initially considered for the Winslow-Holbrook Division included a dam and reservoir on Chevelon Creek at the Wildcat site in Section 1, T. 14 N., R. 15 E., on the Navajo and Coconino County line, and a pipeline and pumping plant system from the Wildcat Reservoir to divert municipal and industrial water supplies to the cities of Winslow and Holbrook.

These features were abandoned because of unfavorable geologic conditions in the Wildcat Reservoir area. Studies were then oriented toward seeking alternate sources to provide the future water requirements of the cities of Winslow and Holbrook. The ground-water study of the Winslow-Holbrook area, carried forward as a part of the feasibility investigations, evaluates the ground-water reservoir and demonstrates that it is the most economical source for future development.

b. <u>The Flagstaff-Williams Division</u>. Project features originally contemplated for the Flagstaff-Williams Division, conceived as a result of reconnaissance investigations, included a dam and reservoir on Clear Creek at the Wilkins site and a pipeline and pumping plant system from Wilkins Reservoir serving the cities of Flagstaff and Williams and the town of Ashfork. With the advancement of feasibility investigations and the collection of more detailed data, particularly with respect to population projections, it became progressively clear that Ashfork could not support the cost of import water and that additional development of the available local supplies could satisfy requirements of the city of Williams, Arizona, for the present and future at less cost than an import plan. Ashfork, Arizona, has applied to the Farmers Home Administration for a grant and loan to construct a ground-water supply system for its requirements.

The Northern Arizona University population projection study showed a much slower growth rate for Williams than was estimated in the reconnaissance study. In fact, Williams lost population in the last decade, dropping about 33 percent from 3,559 in 1960 to 2,386 in 1970.

With the realization of the infeasibility of receiving water from Wilkins Reservoir, the city commenced studies for further developing local water sources, concentrating on prevention of seepage from the main reservoirs, and enlarging present conservation storage facilities.

Just prior to November 1967 the city contracted with a consultant to design an impermeable lining for Dogtown Reservoir and to develop engineering plans for raising Cataract Dam 2 feet. In 1968, Cataract Dam and spillway were raised 2 feet in elevation to gain an additional 24 million gallons of storage. Then during the summers of 1969 and 1970 the city lined the Dogtown Reservoir financed with city funds and a matching grant from the Department of Housing and Urban Development.

Other major improvements which could be considered by the city when the need for additional water arises include the lining of Kaibab Reservoir and the possibility of raising Santa Fe Dam to gain additional storage.

2. The Leupp Corner Area. The Leupp Corner area, lying about 8 miles northwest of Winslow and about 42 miles southeast of Flagstaff adjacent to Interstate 40, has been an area of interest as being a possible ground-water source of M&I water supply for the city of Flagstaff.

Ground-water data collected and evaluated for the Winslow area, described in Chapter IV, were utilized as a basis of consideration for this alternative. However, this ground-water alternative was not studied in detail because of two primary constraints, economic and quality of water.

The apparent total dynamic pump lift (from a ground-water pumping level to Flagstaff) would be approximately 1,400 feet greater than the comparable Wilkins Reservoir to Flagstaff pump lift. This additional pump lift would result in significantly greater annual cost.

Pumping of a quantity comparable to the yield of Wilkins Reservoir would probably result in salt water intrusion. Furthermore, the current quality of ground water in the Leupp-Winslow area is about 500-600 p/m greater in total dissolved solids than Clear Creek surface water.

These constraints served to eliminate any detailed study of this ground-water alternative.

3. Walnut Creek Canyon. Local interests at Flagstaff proposed that consideration be given to the possibility of developing project offstream storage at a site in Walnut Creek Canyon, downstream from Lower Lake Mary and about 5 miles southeast of Flagstaff, as an alternate to the proposed enlargement of Upper Lake Mary.

The chief reasons for advancing the proposal were (1) the possibility of developing a reservoir of less surface area than can be obtained at Upper Lake Mary, thereby reducing annual evaporation losses; and (2) the advantage obtained by having the project off-stream storage facility closer to the city and point of use.

A geologic inspection indicated that the reservoir site is in a faulted limestone environment having a poor water-holding capability. Appropriate remedial treatment of the reservoir was considered to be uneconomic.

4. Volunteer Canyon. Volunteer Canyon Dam and Reservoir site, located in Section 34, T. 21 N., R. 5 E., in western Coconino County about 12 miles southwest of Flagstaff, has long been considered by some local interests as being a possible source of municipal water supply for Flagstaff and Williams.

A geologic inspection indicated that the reservoir site is in a limestone environment exhibiting extensive solution cavities. This type of environment is poor in water-holding capability. Appropriate remedial treatment of the reservoir was considered to be uneconomic. A stream gaging station was installed at the site in July 1965. The streamflow records now available also indicate that this site does not hydrologically warrant further consideration. The site was abandoned for further study.

5. Blue Ridge Reservoir. Preliminary studies were made to include existing Blue Ridge Reservoir, located on East Clear Creek above Wilkins Reservoir site, with operation of the proposed Wilkins Reservoir under the principles of exchange of water with the Central Arizona Project. Under this concept it was assumed that Blue Ridge Reservoir would be allowed to remain full except as needed to fill in the Wilkins Reservoir water supply. Studies showed that normal evaporation and seepage losses would cause Blue Ridge Reservoir to draw down extensively during periods of little or no runoff. Operation studies indicated that Blue Ridge Reservoir would not increase Wilkins Reservoir yields during a critical dry period.

6. Further Development of Local Supplies. Table 5, page 36, portrays an estimate of the potential water supply that additional development might make available from existing sources. As noted in Chapter 3, the safe yield of the well fields has not been determined, although in 1972 some prolonged pumping in the Woody Mountain well field was accomplished and a new well in the Lake Mary well field was drilled.

The city plans on fully developing these well-field sources prior to the development of the Mogollon Mesa Project.

Depending upon the productivity of the local well fields under continued development, the city at some point in the future will have to reach a decision whether to develop Clear Creek surface supplies or limit population growth to that which can be accommodated by the then developed existing sources.

The lining and improvement of Upper Lake Mary as a separate development from the Mogollon Mesa Project were given consideration as an alternate source of development for interim water supplies. By itself this improvement would only generate an estimated additional 1,600 acre-feet of water annually. As described in Chapter 4, page 67, the Lake Mary well field is essentially recharged by seepage losses from Upper and Lower Lake Mary and implementation of lining Upper Lake Mary would in effect negate most of the potential of the Lake Mary well field.

I. Plan Formulation

As previously described, the proposed Wilkins Reservoir would lie within a narrow, nearly vertical-walled canyon about 500 feet deep, which exposes about 300 feet of Kaibab limestone overlying about 200 feet of the Coconino sandstone. The top of the conservation pool, elevation 6194, would be generally just below the contact zone of these formations. Excessive losses to seepage in the Kaibab limestone prevent consideration of storage space above the contact zone. In order to gain effective conservation capacity lost by the limitation of Wilkins Reservoir, offstream reservoir storage to develop additional yield from Clear Creek flows is required. No suitable sites for developing offstream storage exist between the proposed Wilkins Dam and Upper Lake Mary, the source of Flagstaff's present surface water supply. Consideration was therefore given to the practicability of increasing the storage capacity of the present lake by rehabilitating and raising the existing dam to accommodate increased diversions from Wilkins Reservoir.

A computer program was developed to explore alternate possibilities for combining the conservation pools of Wilkins Reservoir and an enlarged Upper Lake Mary. The alternatives were analyzed based on storage at Wilkins Reservoir of 45,000 acre-feet, and on five different sizes of pump diversion facilities of 17, 27, 31, 37, and 46 ft^3/s. Monthly pump diversion rates were varied based on adopted operating rules governed by the end-of-month storage capacity of Wilkins Reservoir.

Pumping rates varied from maximum pipe design capacity during high storage levels in Wilkins Reservoir to zero during minimum storage levels. Each different aqueduct system size required a certain amount of incremental conservation storage in Upper Lake Mary to firm increased diversions and make nearly uniform project water deliveries. Six different incremental reservoir sizes were studied for Upper Lake Mary, ranging from 8,500 acre-feet to 26,000 acre-feet.

Of the several different alternatives studied, five plans were selected for a preliminary incremental economic analysis. A brief description of the five plans, all including Wilkins Dam with a total capacity of 45,000 acre-feet, follows:

1. Plan 1. Aqueduct system sized at 17 ft^3/s. No offstream storage considered.

2. Plan 1A. The existing Upper Lake Mary would be used for offstream storage. The conservation pool water surface would be raised 15 feet to elevation 6845 and the reservoir would be lined with polyvinyl chloride to the same elevation to prevent seepage.

3. Plans 2A and 3A. Same as Plan 1A, except with aqueduct system sized at 31 and 37 ft^3/s, respectively.

4. Plan 4A. The existing Upper Lake Mary would be used for offstream storage. The conservation pool water surface would be raised 20 feet to elevation 6850.

Based on preliminary operation studies, Plans 1 through 4A would produce the following average yields from project reservoirs:

Plan	Acre-Feet per Year
1	12,300
1A	15,500
2A	16,800
3A	18,400
4A	18,500

The result of the preliminary incremental analysis examination showed the net benefit and benefit-cost ratio increment between Plans 2A and 3A to be the greatest, indicating Plan 3A to be the best for economic development of Clear Creek water resources.

Detailed monthly operation studies made for the project plan as presented in the Hydrology Appendix, included the basic concepts of Plan 3A (Wilkins Reservoir capacity 45,000 acre-feet; aqueduct capacity 37 ft^3/s), plus inflow to Upper Lake Mary from Walnut Creek.

The results of the combined operation study established the requirement for 24,100 acre-feet of conservation storage in an enlarged Upper Lake Mary to yield a firm annual project water supply of 18,400 acre-feet. Providing inactive storage of 5,400 acre-feet for fish and wildlife and recreation purposes requires a total capacity of an enlarged Upper Lake Mary of 29,500 acre-feet. This would require raising the top of the conservation pool 14 feet above its present elevation.

VI. ENVIRONMENTAL CONSIDERATIONS

VI. ENVIRONMENTAL CONSIDERATIONS

A. General

The proposed Mogollon Mesa Project would structurally, economically, and ecologically influence the human and natural environment.

Generally, the human aspects would be enhanced by the development. The natural environment would be altered somewhat by construction of project facilities and influenced by an expanding population and use.

The Bureau of Reclamation has outlined policy and basic requirements for developing a program which embraces planning, construction, and operation for improving the function, appearance, and environmental compatibility of all project works, lands, and waterways under its jurisdiction. The Mogollon Mesa Project and its associated structures have been planned and would be constructed in accordance with this policy on environmental quality, preservation, and enhancement.

B. Beneficial and Adverse Effects

1. Water Quality. Clear Creek water is of excellent quality with total dissolved solids averaging less than 100 parts per million. Impoundment of these waters would cause an undetermined, but not detrimental, increase in salinity because of evaporation and dissolution of minerals found in the formations of the area which would be inundated. During a low runoff year, the water quality change has been estimated to be about 10 percent.

2. Streamflow Regimen. An 8-mile portion of the existing intermittent stream would be inundated by Wilkins Reservoir. The aquatic life that exists in the natural stream found in the proposed reservoir

area would be replaced by plant and animal species typical of cold water reservoirs of the southwestern United States.

No scheduled releases from the reservoir to the stream below the dam are planned under ultimate project operation. Annual seepage from the reservoir is estimated to amount to about 8,900 acre-feet and spills averaging about 19,900 acre-feet are expected to occur in most years. During the first 30 years of the project (the M&I buildup), water from the reservoir would be available for release. This, along with a uniform seepage flow, would improve the overall streamflow requirement below the dam for a distance of up to 5 miles.

The stream is subject to seasonally heavy flooding. With the floods, which occur mostly in the spring and late summer, come silt loads. Wilkins Dam would pose a barrier to these floods, causing an accumulation of sediment in the reservoir. The 100-year sediment accumulation is estimated at 7,260 acre-feet and storage space has been allocated for this purpose.

3. General Recreation and Fishing. The deep, cold waters of Wilkins Reservoir would enhance and expand Arizona's overall cold water fishery program, and would contribute in relieving public pressure on existing cold water streams and lakes in northern Arizona. Access to the lake from the rim and minimum basic visitor and recreational facilities would be provided to enhance the area for public use. Table 20 shows the estimated number of mandays of fishing and recreation which would be provided by this reservoir.

Table 20
GENERAL RECREATION AND FISHING USE
Wilkins Reservoir
Mogollon Mesa Project, Arizona

Unit: Man-Days

Project Year	With Project		Without Project	
	Recreation	Fishing	Recreation	Fishing
1	5,000	60,000	100	100
5	15,000	60,000	100	100
100	15,000	60,000	100	100

The reservoir is in an area where it would provide a trout fishery similar to that found at Blue Ridge Reservoir which is located upstream from the proposed Wilkins Reservoir. The general area currently attracts many people and the recreation pressure will undoubtedly increase in the future. Wilkins Reservoir would have the potential to absorb much of this pressure. Coordination with the Forest Service to determine means of handling the recreation pressure and ways of minimizing adverse impacts on the National Forests would continue as advance project planning progresses.

At Upper Lake Mary, the minimum pool would be stabilized at about 600 acres under second stage project conditions. This stabilized body of water would provide a considerable increase in annual man-days of recreation and fishing as shown in Table 21.

Table 21
GENERAL RECREATION AND FISHING USE
Upper Lake Mary
Mogollon Mesa Project, Arizona

Unit: Man-Days

Project Year	With Project		Without Project	
	Recreation	Fishing	Recreation	Fishing
1	50,000	300,000	40,000	200,000
100	165,000	300,000	40,000	200,000

The increase would be primarily through development of a permanent trout-northern pike fishery and improved public outdoor recreation facilities.

The stabilization and lining of Upper Lake Mary would have an adverse impact on Lower Lake Mary since much of the lower lake's water supply results from seepage from the upper lake. More detailed studies would be required to determine the extent of this impact.

Increased recreation use by man would have some unavoidable adverse impact on the natural surroundings at both Wilkins and Upper Lake Mary Reservoirs. With increased activity, some of the solvable problems that would arise are litter, water pollution, and noise. Problems associated with destruction of natural vegetation and landscape, increased danger of forest fires, and displacement of some wildlife species that do not tolerate human interference would also occur because of increased use of the area. The magnitude of these adverse impacts can be minimized, however, with proper management of the recreational areas.

4. Impacts on Plant and Animal Life. At Wilkins Reservoir, an area of approximately 600 acres would be cleared of riparian vegetation. This includes the cottonwood-ash-box elder riparian community and isolated stands of douglas fir. Every reasonable effort would be made to channel marketable timber into beneficial use. There are no known rare or endangered species of plants in the area. The alinement of temporary construction and access roads would be selected in a manner that would preserve natural beauty and minimize erosion. Trees, brush, and stumps would be cleared as necessary in compliance

with present Forest Service policy, to provide suitable construction and permanent recreation access, a straight swath appearance would be avoided. The road would be provided with side drainage ditches and culverts across the road to prevent soil or road erosion. The road grade and alinement would follow the general contour of the land whenever possible to avoid excessive cut and fill sections. Construction scars would be restored where feasible by replacing topsoil in borrow areas, and by blending both borrow and waste disposal areas with the natural terrain.

The natural fauna of a portion of the canyon and stream would be displaced and modified because of Wilkins Reservoir. Removal of vegetative cover and inundation of the existing canyon would cause the species of animals found in the area to be displaced. These species may include cottontail, squirrel, chipmunk, beaver, mice, rats, mole, bear, raccoon, skunk, deer, and elk. Most animals would be lost since existing nearby habitat is occupied. However, similar habitat may develop along the shoreline of Wilkins Reservoir and the population of these species may return to former levels. No rare or endangered terrestrial animal species are known in the area.

Inundation of eight miles of the natural intermittent stream would result in alteration of the existing fresh water fauna. A number of native fish species such as speckled dace, sucker, and spinedace are found in deep pools. Some of these species would not survive in a reservoir environment, and with the subsequent introduction of game species.

The rare and endangered species, Little Colorado spinedace (Lepidomeda Vittata), would be further endangered by the project. The reservoir would inundate the confluence of East Clear Creek and Willow Creek which some ichthyologists consider to be good habitat for the spinedace in drought conditions. The seepage and spills from the reservoir may improve Clear Creek below the dam to provide habitat for the spinedace. Published reports indicate this species has an ability to reinhabit its range when precipitation and other conditions improve. Sampling in September of 1973 showed the Little Colorado spinedace was present at several locations upstream from Blue Ridge Reservoir and more than 15 miles upstream from the proposed Wilkins Reservoir. The fish was absent at two other sites sampled, one about a mile above and the other about seven miles above the reservoir. These two sites are downstream from Blue Ridge Reservoir. This fish is found in other tributaries of the Little Colorado River. The species would be transplanted and protected in selected reaches above and below the dam, or on other similar streams in the area. Introduced species would include rainbow and brown trout.

There could be some adverse impact on big game migration routes (elk and deer) around the pumping plants due to the noise of the pumps. The traffic of occasional operation and maintenance personnel and vehicles would cause a minor impact.

At Upper Lake Mary (second stage), there would be some loss of present waterfowl area in terms of nesting and low marsh areas due to the stabilizing effect of a higher water surface elevation. A cinder covering to protect the membrane lining of the enlarged Upper Lake

Mary would provide a medium for reestablishing the bottom biota necessary for fish life.

Clearing for the larger reservoir impoundment would require removal of about 25 acres of ponderosa pine forest.

5. Archeologic Sites. The Southwest Archeological Center, National Park Service, prepared a reconnaissance report on the archeological resources of the Wilkins Reservoir site. The report indicates there are nine known archeological sites in the proposed reservoir area and recommends that salvage work be done in and adjacent to the impoundment area. There would be provisions in the project for salvage work.

Of great archeological significance is the "early man" ruins found near the Chavez Pass Pumping Plant site. The actual area was purposely avoided in planning the pipeline route and pumping plant location. The Chavez Pass area is frequently vandalized by souvenir hunters and its scientific value for future research and salvage is endangered under present conditions. A salvage and/or preservation program for this archeological site would be included in the project as a mitigation measure if it is found to be needed because of the project.

6. Esthetics and Construction Scars. Clearing, blasting, ripping, and earthmoving would be required during construction in order to prepare the Wilkins Dam site for construction. An area in the canyon of approximately 15 acres would be disturbed by this activity. A temporary construction camp and equipment storage areas would be needed near the dam site and would require several acres of natural terrain to be wholly or partially cleared and fenced for security

reasons. After construction, the campsite and storage areas would be restored as nearly as possible to the original condition.

Wherever possible, borrow areas, quarry sites, batching plants, roads, and equipment storage areas would be located in the reservoir area below the proposed normal waterline.

The access road grades and alinement would follow the general contour of the land to avoid excessive cut and fill sections. Construction scars would be restored where feasible by replacing topsoil in borrow areas, and by blending both borrow and waste disposal areas with the natural terrain.

To minimize visual impact, physical consolidation of the necessary functions has been considered in the design of Wilkins Dam. The spillway, outlet works, pumping plant, and discharge manifold and penstocks were all incorporated into the design of the dam, which would produce one graceful double curvature-arch structure esthetically more pleasing and compatible to the surrounding landscape.

A minimum pool will be maintained initially at 10,400 acre-feet and 200 surface acres at reservoir elevation 6104 for fish and wildlife purposes. Maximum reservoir drawdown under extreme conditions will be 90 feet with a minimum evacuation period of about 17 months. Under normal operations, yearly fluctuation will average about 50 feet. Water spills from Wilkins Reservoir will be large and frequent, averaging over 19,000 acre-feet annually and occurring on the average of every other year. Drawdown to the minimum pool will occur on an average of about once in every 5 years of operation. The reservoir setting itself would possess, to many people, high scenic value.

The impact of the pipeline would be temporary since it would be buried underground and the disturbed areas would be restored and reseeded to natural conditions. All borrow and waste disposal areas would be restored and seeded to conform with the surrounding terrain.

Each of the pumping plants at Jaycox Mountain and Chavez Pass would be designed to be situated partially below grade to reduce the height of superstructure and lessen the visual impact of the facility upon the environment. The switchyards and forebay tanks would be placed so as to mask their silhouettes against the transition slopes on the uphill side of the site.

About 3 million cubic yards of noncohesive material would be needed to cover the plastic lining of Upper Lake Mary. The most practical material available in the area is volcanic cinders. The nearest source of this material is about 5 miles northwest of Upper Lake Mary and would necessitate leveling of two small hills of about 100 acres covered by ponderosa pine forest with its associated biota. There would be a visual impact from removing these hills. Existing commercial cinder pits with large quantities of material available occur southwest of Flagstaff about 15 miles from the reservoir. Coordination with Forest Service personnel would precede final planning to determine the best location.

Material for construction of the new earthfill dam would come from existing borrow pits in the area and from a new borrow area one mile southwest of the present dam. Existing dam embankment would also be removed and reused as part of the new fill section. Riprap in the form of basalt cobbles and boulders would be available from below the proposed high waterline.

The general esthetic and scenic value of Upper Lake Mary would improve by providing a more stable reservoir condition. Annual reservoir drawdown would not be severe, but waterline marks would occur much as they do under present conditions.

All used equipment and construction materials not necessary for project operation would be dismantled and removed from each of the sites after construction.

Preservation and enhancement measures would be used for transmission systems location and design during the advance planning and construction stage. Location of transmission lines would take advantage of existing utility corridors within the area, mountain background, ridges, and tree lines to shield and mask towers from skylines. In areas of high scenic values, transmission towers would utilize new low-profile design concepts and coloring schemes to blend with the background landscape.

7. Human Environment and Economy. The project would provide an assured water supply for the city of Flagstaff. During construction of project features, a maximum of about 1,000 construction workers would be required and these workers may establish residence near the project area. Community services and housing facilities in the Flagstaff area appear adequate to accommodate the additional population during one year of preconstruction and the 3-year first stage construction period. Also, the community service and housing should be adequate for the construction of the second stage which will require about 3 years to install.

With an assured water supply, the current trend of population growth and industrial expansion is expected to continue into the foreseeable future. Chapter II describes past trends and the extent of population growth is forecasted. The substantial population increase is based on additional industrial development and continued increase in retirement residences.

Additional community service facilities, including transportation network, schools, and municipal services, would be required. Additional land would be occupied by buildings, roads, and related facilities. Other problems common to urban environments, such as noise and air contaminants, would increase but would be no worse than what occur in cities of similar size. Attendant with this increased population growth and economic expansion are the additional opportunities made available in the Flagstaff area which could alleviate future pressure on highly populated urban centers.

C. Draft Environmental Statement

1. Consultation and Coordination. Throughout the period of feasibility studies, there has been reliance upon interdepartmental coordination procedures with the Fish and Wildlife Service, Bureau of Outdoor Recreation, and the National Park Service to utilize their delegated jurisdiction and environmental expertise. The above bureaus and the Department of Agriculture, Forest Service, and the Bureau of Reclamation have coordinated their activities with the Arizona Game and Fish Department and the Arizona State Highway Department in order to obtain the basic additional information for a draft environmental statement.

2. Preparation and Submission. A preliminary draft environmental statement was prepared in accordance with the National Environmental Policy Act of 1969, Public Law 91-190, but was not released to the many affected agencies, organizations, and individuals for comments because no Federal action is proposed on the project at this time.

VII. ECONOMIC AND FINANCIAL ANALYSIS

VII. ECONOMIC AND FINANCIAL ANALYSIS

A. Introduction

The Mogollon Mesa Project is a potential municipal and industrial water supply project with planned development for fish and wildlife and recreation. Development of the project is contemplated for stage construction. Wilkins Dam and Reservoir and the aqueduct system would be constructed in the first stage. It is estimated that first stage facilities would provide Flagstaff with up to 11,900 acre-feet. This supplemental water supply along with the available local supply would meet the city's estimated water requirements until about year 2003.

Enlargement of Upper Lake Mary Dam and lining of the reservoir would be done in the second stage. This would provide an additional 6,500 acre-feet of firm water yield to Flagstaff. This increased water supply would come partly from additional water pumped from Wilkins Reservoir, partly from increased yield from Walnut Creek and Upper Lake Mary, and partly from converting Flagstaff's present fluctuating water yield from Upper Lake Mary to a firm supply.

B. Project Benefits

Construction and operation of the Mogollon Mesa Project would result in benefits accruing to municipal and industrial water, recreation, and fish and wildlife enhancement.

1. Municipal and Industrial Water Benefits

a. First Stage. The first stage would supply 11,900 acre-feet of water annually to Flagstaff's trunkline near Lower Lake Mary Dam. Benefits are evaluated from the cost of providing the same amount of water from a single-purpose alternative project most likely to be developed in the absence of the Federal project. The alternate water development was considered to be the same as the Federal project with the recreation and fish and wildlife facilities deleted. Annual costs were based on amortizing investment costs in 50 years at 7½ percent interest. Annual equivalent benefits for the first stage are $6,631,000.

b. Total Project. The project would supply 18,400 acre-feet of water annually to Flagstaff. Benefits are evaluated from the cost of providing the same amount of water from a single-purpose alternative project most likely to be developed in the absence of the Federal project. The alternate water development was considered to be the same as the Federal project with recreation and fish and wildlife facilities deleted. Annual costs were based on amortizing investment costs in 50 years at 7½ percent interest. Annual equivalent benefits for 100 years for the total project would be $7,433,000.

2. Recreation Benefits. The Bureau of Outdoor Recreation estimated the recreation benefits on both reservoirs based on the projected visitor-day use at each reservoir.

a. First Stage. Annual benefits at the Wilkins Reservoir were estimated to increase from $8,625 the first year of operation to $25,875 in the fifth year and remain at this rate for the rest of the period of analysis. Annual equivalent recreation benefits for the 100-year period of analysis at 6.375 percent interest are $23,000.

b. Total Project. Annual recreation benefits of the enlarged and lined Upper Lake Mary were based on the increased population of the area and begin accruing in year 2003.

The total project annual equivalent recreation benefits based on a 100-year period of analysis beginning in 1984 would be $108,000.

3. Fish and Wildlife Benefits. The Fish and Wildlife Service estimated the fish and wildlife benefits.

a. First Stage. Annual fish and wildlife benefits on Wilkins Reservoir were estimated to be $180,000 beginning the first year the reservoir is operational.

b. Total Project. The annual equivalent benefits based on a 100-year period beginning in 1982 for the total project would be $273,000.

4. Summary of Project Benefits. Annual equivalent benefits from all project purposes would be $7,433,000 and are summarized in Table 22.

C. Project Costs

The total cost to construct the Mogollon Mesa Project's first stage is estimated to be $67,068,000 and the cost of the total project is $85,390,000.

Investigation costs of $1,001,000 for the first stage and $1,250,000 for the total project are nonreimbursable by authority of Public Law 92-149. These costs are excluded for net benefit analysis, cost allocation, and repayment. The remaining costs are $66,067,000 for the first stage and $84,140,000 for the total project.

The interest during construction on the first stage and the total project would be about $6,157,000 and $7,480,000, respectively.

The annual operation, maintenance, and replacement costs for full project development are estimated to be $1,324,000 for the first stage

Table 22
SUMMARY OF ANNUAL EQUIVALENT PROJECT BENEFITS
Mogollon Mesa Project, Arizona

	Annual Equivalent Benefits at Beginning of Second Stage	Factor	Annual Equivalent Benefits at Beginning of First Stage
First Stage			
Municipal and Industrial Water			$6,631,000
Recreation			23,000
Fish and Wildlife			180,000
Total			$6,834,000
Second Stage			
Municipal and Industrial Water	$1,362,000	.3091 1/	$ 421,000
Recreation	274,000	.3091 1/	85,000
Fish and Wildlife	300,000	.3091 1/	93,000
Total	$1,936,000		$ 599,000
Project Total			$7,433,000

1/ Present worth of one for 19 years at 6-3/8 percent interest.

and $1,740,000 for the total project. Negotiations will be made with Coconino County, the State of Arizona, or the Forest Service to take over operation and maintenance of the access road to Wilkins Dam and Reservoir after construction is completed. If one of those agencies takes over operation and maintenance of the access road, the Mogollon Mesa Project will be relieved of the cost.

The total annual equivalent costs of the first stage at 6.375 percent interest for the 100-year period of analysis are $5,769,000 and for the total project are $6,233,000. Federal economic costs are summarized in Table 23.

D. Net Benefits

The first stage of the Mogollon Mesa Project is economically justified with annual equivalent net benefits of $1,065,000 for the 100-year period of analysis. Annual equivalent benefits are $6,834,000 and annual equivalent costs are $5,769,000.

The total Mogollon Mesa Project economically justified with annual equivalent net benefits of $1,200,000. Annual equivalent benefits are $7,433,000 and annual equivalent costs are $6,233,000.

E. Economic Rate of Return

The economic rate of return for the Mogollon Mesa Project is 7.8 percent for the first stage and for the total project.

F. Cost Allocation

The investigation costs of the project amounting to $1,250,000 were assigned directly to nonreimbursable and prepaid categories.

The remaining construction costs with appropriate interest during construction and OM&R costs at full project development were allo-

Table 23
SUMMARY OF FEDERAL ECONOMIC COSTS 1/
Mogollon Mesa Project, Arizona

Item	Unadjusted Cost	Annual Equiv. Cost at Beginning of Second Stage	Factor	Common Time Value
First Stage				
Construction Costs				
Wilkins Dam and Reservoir	$22,999,000			$22,999,000
Pumping Plants	4,975,000			4,975,000
Pipeline and Structures	33,912,000			33,912,000
General Property	755,000			755,000
Transmission System	2,235,000			2,235,000
Fish & Wildlife & Rec.Facilities	1,191,000			1,191,000
SUBTOTAL	$66,067,000			$66,067,000
Interest During Construction	6,157,000			6,157,000
Investment Cost	$72,224,000			$72,224,000
Annual Equivalent Investment Cost				$ 4,614,000
Annual OM&R Cost at Full Development	$ 1,324,000			
Annual Equivalent OM&R Cost				$ 1,155,000
TOTAL ANNUAL EQUIVALENT COST				$ 5,769,000
Second Stage				
Construction Costs				
Upper Lake Mary Dam and Reservoir	$15,211,000			
Inlet Structure to Upper Lake Mary	400,000			
Fish & Wildlife & Recreation Fac.	2,462,000			
SUBTOTAL	$18,073,000			
Interest During Construction	1,323,000			
Investment Cost	$19,396,000			
Annual Equivalent Investment Cost		$1,245,000	.3091 2/	$ 385,000
Annual OM&R Cost at full Development	$ 416,000			
Annual Equivalent OM&R Cost		255,000	.3091 2/	79,000
TOTAL ANNUAL EQUIVALENT COST		$1,500,000		$ 464,000
TOTAL PROJECT ANNUAL EQUIVALENT COST				$6,233,000

1/ The investigation costs amounting to $1,250,000 have been excluded and are comprised of $80,734 contribution by the State of Arizona, $290,787 from the Colorado River Development Fund, and $878,479 which is nonreimbursable under the provision of Public Law 92-149.

2/ Present worth of one for 19 years at 6-3/8 percent interest.

cated among the project purposes using the separable costs-remaining benefits methods. Separate allocations were made for the first stage and the total project.

The allocation of cost for the first stage and total project is presented in Tables 24 and 25.

A summary of costs allocated to project purposes is presented in Table 26.

G. Repayment

The schedule of Flagstaff's projected M&I water requirements, local supply, and project water deliveries for the first stage and full project development used in project repayment is presented in Tables 27 and 28, respectively.

1. Municipal and Industrial. First stage costs allocated to M&I water are $69,383,000. This includes $64,019,000 of construction costs and $5,364,000 of interest during construction.

Total project costs allocated to M&I water are $84,058,000. This includes $77,772,000 of construction costs and $6,286,000 of interest during construction.

Costs allocated to M&I water are reimbursable in 50 years with interest at 5.683 percent on the unpaid balance. The Water Supply Act of 1958 provides for a 10-year interest-free period for the unused portion of storage costs allocated to M&I water. Deferrable investment amounts as authorized by the Water Supply Act of 1958 were determined for the first 10 years for the first stage and the total project.

Table 24
ALLOCATION OF COSTS
100-Year Analysis - 6-3/8 Percent Interest
First Stage
Mogollon Mesa Project, Arizona

	Municipal & Industrial	Recreation & Fish & Wildlife	Total
Benefits			
Annual Equivalent	$ 6,631,000	$ 203,000	$ 6,834,000
Capitalized	103,800,000	3,178,000	106,978,000
Single-Purpose Alternate Cost	88,183,000	1/	
Construction	64,876,000		
Interest During Construction	6,119,000		
OM&R - Capitalized	17,188,000		
OM&R - Annual	1,098,000		
Justifiable Expenditure	88,183,000	3,178,000	91,361,000
Separable Costs (Common Time Basis)	71,970,000	2,121,000	74,091,000
Construction	50,826,000	1,191,000	52,017,000
Interest During Construction	4,488,000	38,000	4,526,000
OM&R - Capitalized	16,656,000	892,000	17,548,000
OM&R - Annual	1,064,000	57,000	1,121,000
Remaining Justifiable Expenditure	16,213,000	1,057,000	17,270,000
Allocation Percentage	93.9	6.1	100.0
Separable Costs			
Construction	50,826,000	1,191,000	52,017,000
Interest During Construction	4,488,000	38,000	4,526,000
OM&R - Annual	1,231,000	58,000	1,289,000
Joint Costs			
Construction	13,193,000	857,000	14,050,000
Interest During Construction	1,532,000	99,000	1,631,000
OM&R - Annual	33,000	2,000	35,000
Total Allocated Costs			
Construction	64,019,000	2,048,000	66,067,000
Interest During Construction	6,020,000	137,000	6,157,000
OM&R - Annual	1,264,000	60,000	1,324,000
Reimbursable Costs			
Construction	64,019,000		
Interest During Construction	5,364,000 2/		
Total	$69,383,000		

1/ Single-purpose alternate costs exceed capitalized benefits.

2/ Interest during construction for repayment is reduced from $6,020,000 to $5,364,000 because repayment is made at 5.683 interest and the cost allocation is made using 6-3/8 percent interest. The adjustment factor is .891.

Table 25
ALLOCATION OF COSTS
100-Year Analysis - 6-3/8 Percent Interest
Total Project
Mogollon Mesa Project, Arizona

	Municipal & Industrial	Recreation & Fish & Wildlife	Total
Benefits			
Annual Equivalent	$ 7,052,000	$ 381,000	$ 7,433,000
Capitalized	110,391,000	5,964,000	116,355,000
Single-Purpose Alternate Cost	93,726,000	1/	
Construction	69,701,000		
Interest During Construction	6,479,000		
OM&R - Capitalized	17,546,000		
OM&R - Annual	1,121,000		
Justifiable Expenditure	93,726,000	5,964,000	99,690,000
Separable Costs (Common Time Basis)	70,755,000	3,808,000	74,563,000
Construction	50,235,000	1,952,000	52,187,000
Interest During Construction	4,537,000	87,000	4,624,000
OM&R - Capitalized	15,983,000	1,769,000	17,752,000
OM&R - Annual	1,021,000	113,000	1,134,000
Remaining Justifiable Expenditure	22,971,000	2,156,000	25,127,000
Allocation Percentage	91.4	8.6	100.0
Separable Costs			
Construction	48,915,000	3,653,000	52,568,000
Interest During Construction	4,645,000	198,000	4,843,000
OM&R - Annual	1,252,000	239,000	1,491,000
Joint Costs			
Construction	28,857,000	2,715,000	31,572,000
Interest During Construction	2,410,000	227,000	2,637,000
OM&R - Annual	228,000	21,000	249,000
Total Allocated Costs			
Construction	77,772,000	6,368,000	84,140,000
Interest During Construction	7,055,000	425,000	7,480,000
OM&R - Annual	1,480,000	260,000	1,740,000
Reimbursable Costs			
Construction Cost	77,772,000		
Interest During Construction	6,286,000 2/		
Total	$84,058,000		

1/ Single-purpose alternate costs exceed capitalized benefits.

2/ Interest during construction for repayment is reduced from $7,055,000 to $6,286,000 because repayment is made at 5.683 interest and the cost allocation is made using 6-3/8 percent interest. The adjustment factor is .891.

Table 26
REIMBURSABLE AND NONREIMBURSABLE
ALLOCATED PROJECT COSTS
Mogollon Mesa Project, Arizona

	Project Investment Costs	Reimbursable			Nonreimbursable		
		Construction	Interest During Construction 5.683 percent	OM&R at Full Project Development	Construction	6-3/8 Percent Interest During Construction	OM&R
First Stage							
Municipal & Industrial	$64,019,000	$64,019,000	$5,364,000	$1,264,000	$2,048,000	$137,000	$60,000
Recreation, Fish & Wildlife	2,048,000						
Total	$66,067,000						
Project Total							
Municipal & Industrial	$77,772,000	$77,772,000	$6,286,000	$1,480,000	$6,368,000	$425,000	$260,000
Recreation, Fish & Wildlife	6,368,000						
Total	$84,140,000						
Investigation Costs	1,250,000 1/						
	$85,390,000						

1/ The investigation costs of $1,250,000 have been excluded and are comprised of $80,734 contribution by the State of Arizona, $290,787 from the Colorado River Development Fund, and $878,479 which is nonreimbursable under the provisions of Public Law 92-149.

Table 27
SCHEDULE OF FLAGSTAFF PROJECTED MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS, LOCAL SUPPLY AND PROJECT WATER DELIVERIES, FIRST STAGE
Mogollon Mesa Project, Arizona

Project Year	Fiscal Year	Flagstaff Water Requirement Acre-feet	Local Water Supply Acre-feet	Project Water Delivery Acre-feet
1	1984	8,220	2,400	5,820
2	85	8,450		6,050
3	86	8,680		6,280
4	87	8,910		6,510
5	88	9,140		6,740
6	89	9,370		6,970
7	1990	9,600		7,200
8	91	9,880		7,480
9	92	10,160		7,760
10	93	10,440		8,040
11	94	10,720		8,320
12	95	11,000		8,600
13	96	11,280		8,880
14	97	11,560		9,160
15	98	11,840		9,440
16	99	12,120	2,400	9,720
17	2000	12,400	1,000	11,400
18	1	12,690		11,690
19	2	12,980		11,900
20	3	13,270		
21	4	13,560		
22	5	13,850		
23	6	14,140		
24	7	14,430		
25	8	14,720		
26	9	15,010		
27	2010	15,300		
28	11	15,630		
29	12	15,960		
30	13	16,290		
31	14	16,620		
32	15	16,950		
33	16	17,280		
34	17	17,610		
35	18	17,940		
36	19	18,270		
37	2020	18,600		
38	21	18,960		
39	22	19,320		
40	23	19,680		
41	24	20,040		
42	25	20,400		
43	26	21,760		
44	27	21,120		
45	28	21,480		
46	29	21,840		
47	2030	22,200		
48	31	22,560		
49	32	22,920		
50	33	23,280	1,000	11,900

Table 28
SCHEDULE OF FLAGSTAFF PROJECTED MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS, LOCAL SUPPLY, PROJECT WATER DELIVERIES, AND WATER TO BE PUMPED, FULL PROJECT DEVELOPMENT
Mogollon Mesa Project, Arizona

Project Year	Fiscal Year	Flagstaff Water Requirement Acre-feet	Local Water Supply Acre-feet	Project Water Delivery Acre-feet	Project Water from Lake Mary Acre-feet	Project Water to be Pumped from Wilkins Acre-feet
1	1984	8,220	2,400	5,820	0	5,820
2	85	8,450		6,050		6,050
3	86	8,680		6,280		6,280
4	87	8,910		6,510		6,510
5	88	9,140		6,740		6,740
6	89	9,370		6,970		6,970
7	1990	9,600		7,200		7,200
8	91	9,880		7,480		7,480
9	92	10,160		7,760		7,760
10	93	10,440		8,040		8,040
11	94	10,720		8,320		8,320
12	95	11,000		8,600		8,600
13	96	11,280		8,880		8,880
14	97	11,560		9,160		9,160
15	98	11,840		9,440		9,440
16	99	12,120	2,400	9,720		9,720
17	2000	12,400	1,000	11,400		11,400
18	1	12,600		11,690		11,690
19	2	12,980		11,900	0	11,900
20	3	13,270		12,270	3,000	9,270
21	4	13,560		12,560		9,560
22	5	13,850		12,850		9,850
23	6	14,140		13,140		10,140
24	7	14,430		13,430		10,430
25	8	14,720		13,720		10,720
26	9	15,010		14,010		11,010
27	2010	15,300		14,300		11,300
28	11	15,630		14,630		11,630
29	12	15,960		14,960		11,960
30	13	16,290		15,290		12,290
31	14	16,620		15,620		12,620
32	15	16,950		15,950		12,950
33	16	17,280		16,280		13,280
34	17	17,610		16,610		13,610
35	18	17,940		16,940		13,940
36	19	18,270		17,270		14,270
37	2020	18,600		17,600		14,600
38	21	18,960		17,960		14,960
39	22	19,320		18,320		15,320
40	23	19,680		18,400		15,400
41	24	20,040				
42	25	20,400				
43	26	20,760				
44	27	21,120				
45	28	21,480				
46	29	21,840				
47	2030	22,200				
48	31	22,560				
49	32	22,920				
50	33	23,280	1,000	18,400	3,000	15,400

The schedule of interest-bearing investment for the first stage and total project is presented in the following tabulation:

Year	First Stage and Total Project Cost
1	$ 61,403,000
11	69,383,000
19	84,058,000

The wholesale water charge to Flagstaff based on paying through water charges only would be about $670 per acre-foot the first year. Water charges per acre-foot could be gradually reduced each year to a water charge of about $390 per acre-foot. These water charges include repayment of investment costs with interest and payment of annual OM&R costs. Annual OM&R charges would be about $129 per acre-foot in the tenth year of project operation and about $106 when the full first stage water supply is used.

The variable and reducing water charge rate schedule is used to prevent many years of deficit payment of interest charges with increased cost to Flagstaff and the United States. The initial high rate of $670 per acre-foot is needed to keep interest deficits within a reasonable period of 5 years.

A repayment schedule for first stage municipal and industrial water costs is presented in Table 29.

Costs allocated to M&I water for the first stage development would be repaid with interest at the rate of 5.683 percent in a 50-year period starting the first year of operation. Unused storage costs would be deferred for interest payments under the Water Supply Act of 1958.

TABLE 29
FIRST STAGE
REPAYMENT OF PROJECT COSTS ALLOCATED TO MUNICIPAL AND INDUSTRIAL WATER
MOGOLLON MESA PROJECT, ARIZONA

77/01/03.

NO	YEAR	ANNUAL WATER DEL AC.FT.	COST PER AC.FT.	GROSS REVENUE	OM AND R COSTS	NET OPERATING REVENUE	PAYMENT TO PRINCIPAL	INTEREST ON UNPAID BAL 5.683 PRCNT	UNPAID BALANCE	PLANT IN SERVICE	SURPLUS
0	1983								61403000	61403000	
1	1984	5820	670	3899400	909121	2990279	-499253	3489532	61902253		
2	1985	6050	670	4053500	922562	3130938	-386967	3517905	62289220		
3	1986	6280	670	4207600	936003	3271597	-268299	3539896	62557519		
4	1987	6510	670	4361700	949444	3412256	-142888	3555144	62700407		
5	1988	6740	670	4515800	962886	3552914	-10350	3563264	62710757		
6	1989	6970	670	4669900	976327	3693573	129721	3563852	62581036		
7	1990	7200	670	4824000	989768	3834232	277752	3556480	62303284		
8	1991	7480	660	4936800	1006131	3930669	369973	3540696	61913311		
9	1992	7760	650	5044000	1022494	4021506	502973	3518533	61410338		
10	1993	8040	640	5145600	1038858	4106742	616792	3489950	68773546	69383000	
11	1994	8320	630	5241600	1055221	4186379	277978	3908401	68495568		
12	1995	8600	620	5332000	1071584	4260416	367813	3892603	68127755		
13	1996	8880	610	5416800	1087947	4328853	457153	3871700	67670602		
14	1997	9160	600	5496000	1104310	4391690	545970	3845720	67124632		
15	1998	9440	590	5569600	1120674	4448926	634233	3814693	66490399		
16	1999	9720	580	5637600	1137037	4500563	721914	3778649	65768485		
17	2000	11400	570	6498000	1235216	5262784	1525161	3737623	64243324		
18	2001	11690	560	6546400	1252164	5294236	1643288	3650948	62600036		
19	2002	11900	550	6545000	1264436	5280564	1723004	3557560	60877032		
20	2003	11900	540	6426000	1264436	5161564	1701922	3459642	59175110		
21	2004	11900	530	6307000	1264436	5042564	1679642	3362922	57495468		
22	2005	11900	520	6188000	1264436	4923564	1656097	3267467	55839371		
23	2006	11900	510	6069000	1264436	4804564	1631213	3173351	54208158		
24	2007	11900	500	5950000	1264436	4685564	1604914	3080650	52603244		
25	2008	11900	490	5831000	1264436	4566564	1577122	2989442	51026122		
26	2009	11900	480	5712000	1264436	4447564	1547749	2899815	49478373		
27	2010	11900	470	5593000	1264436	4328564	1516708	2811856	47961665		
28	2011	11900	460	5474000	1264436	4209564	1483903	2725661	46477762		
29	2012	11900	450	5355000	1264436	4090564	1449233	2641331	45028529		
30	2013	11900	440	5236000	1264436	3971564	1412593	2558971	43615936		
31	2014	11900	430	5117000	1264436	3852564	1373870	2478694	42242066		
32	2015	11900	430	5117000	1264436	3852564	1451947	2400617	40790119		
33	2016	11900	420	4998000	1264436	3733564	1415462	2318102	39374657		
34	2017	11900	420	4998000	1264436	3733564	1495902	2237662	37878755		
35	2018	11900	420	4998000	1264436	3733564	1580914	2152650	36297841		
36	2019	11900	420	4998000	1264436	3733564	1670758	2062806	34627083		
37	2020	11900	420	4998000	1264436	3733564	1765707	1967857	32861376		
38	2021	11900	420	4998000	1264436	3733564	1866052	1867512	30995324		
39	2022	11900	420	4998000	1264436	3733564	1972100	1761464	29023224		
40	2023	11900	420	4998000	1264436	3733564	2084174	1649390	26939050		
41	2024	11900	420	4998000	1264436	3733564	2202618	1530946	24736432		
42	2025	11900	420	4998000	1264436	3733564	2327793	1405771	22408639		
43	2026	11900	420	4998000	1264436	3733564	2460081	1273483	19948558		
44	2027	11900	420	4998000	1264436	3733564	2599887	1133677	17348671		
45	2028	11900	410	4879000	1264436	3614564	2628639	985925	14720032		
46	2029	11900	410	4879000	1264436	3614564	2778025	836539	11942007		
47	2030	11900	400	4760000	1264436	3495564	2816900	678664	9125107		
48	2031	11900	400	4760000	1264436	3495564	2976984	518580	6148123		
49	2032	11900	390	4641000	1264436	3376564	3027166	349398	3120957		
50	2033	11900	390	4641000	1264436	3376564	3120957	177364			78243
TOTAL		526860		260852300	59239699	201612601	69383000	132151358			

Municipal and industrial water second stage costs would be added to the unpaid balance of the first stage when the second stage becomes operational and repayment would be made in an additional 50 years.

A repayment schedule for the total project municipal and industrial water costs is presented in Table 30.

2. Recreation and Fish and Wildlife. Costs allocated to recreation and fish and wildlife are nonreimbursable under authority of Section 1 of Public Law 89-72. Wilkins Reservoir and Upper Lake Mary Reservoir are located in the Coconino and Sitgreaves National Forests and the facilities are appropriate for administration by a Federal agency as a part of the National Forest system.

TABLE 30
TOTAL PROJECT
REPAYMENT OF PROJECT COSTS ALLOCATED TO MUNICIPAL AND INDUSTRIAL WATER
MOGOLLON MESA PROJECT, ARIZONA

77/08/01.

NO	YEAR	ANNUAL WATER DEL AC.FT.	COST PER AC.FT.	GROSS REVENUE	OM AND R COSTS	NET OPERATING REVENUE	PAYMENT TO PRINCIPAL	INTEREST ON UNPAID BAL 5.683 PRCNT	UNPAID BALANCE	PLANT IN SERVICE	SURPLUS
0	1983								61403000	61403000	
1	1984	5820	670	3899400	909121	2990279	-499253	3489532	61902253		
2	1985	6050	670	4053500	922562	3130938	-386967	3517905	62289220		
3	1986	6280	670	4207600	936003	3271597	-268299	3539896	62557519		
4	1987	6510	670	4361700	949444	3412256	-142888	3555144	62700407		
5	1988	6740	670	4515800	962886	3552914	-10350	3563264	62710757		
6	1989	6970	670	4669900	976327	3693573	129721	3563852	62581036		
7	1990	7200	670	4824000	989768	3834232	277752	3556480	62303284		
8	1991	7480	660	4936800	1006131	3930669	389973	3540696	61913311		
9	1992	7760	650	5044000	1022494	4021506	502973	3518533	61410338		
10	1993	8040	640	5145600	1038858	4106742	616792	3489950	68773546	69383000	
11	1994	8320	630	5241600	1055221	4186379	277978	3908401	68495568		
12	1995	8600	620	5332000	1071584	4260416	367813	3892603	68127755		
13	1996	8880	610	5416800	1087947	4328853	457153	3871700	67670602		
14	1997	9160	600	5496000	1104310	4391690	545970	3845720	67124632		
15	1998	9440	590	5569600	1120674	4448926	634233	3814693	66490399		
16	1999	9720	580	5637600	1137037	4500563	721914	3778649	65768485		
17	2000	11400	570	6498000	1235216	5262784	1525161	3737623	64243324		
18	2001	11690	560	6546400	1252164	5294236	1643288	3650948	62600036		
19	2002	11900	550	6545000	1264436	5280564	1723004	3557560	75552032	84058000	
20	2003	12270	530	6503100	1121739	5381361	1087739	4293622	74464293		
21	2004	12560	520	6531200	1138686	5392514	1160708	4231806	73303585		
22	2005	12850	440	5654000	1155634	4498366	332523	4165843	72971062		
23	2006	13140	440	5781600	1172582	4609018	462073	4146945	72508989		
24	2007	13430	440	5909200	1189529	4719671	598985	4120686	71910004		
25	2008	13720	440	6036800	1206477	4830323	743677	4086646	71166327		
26	2009	14010	410	5744100	1223424	4520676	476294	4044382	70690033		
27	2010	14300	410	5863000	1240372	4622628	605313	4017315	70084720		
28	2011	14630	410	5998300	1259657	4738643	755728	3982915	69328992		
29	2012	14960	410	6133600	1278942	4854658	914691	3939967	68414301		
30	2013	15290	380	5810200	1298228	4511972	623987	3887985	67790314		
31	2014	15620	380	5935600	1317513	4618087	765563	3852524	67024751		
32	2015	15950	380	6061000	1336798	4724202	915185	3809017	66109566		
33	2016	16280	380	6186400	1356083	4830317	1073310	3757007	65036256		
34	2017	16610	350	5813500	1375368	4438132	742122	3696010	64294134		
35	2018	16940	350	5929000	1394654	4534346	880510	3653836	63413624		
36	2019	17270	350	6044500	1413939	4630561	1026765	3603796	62386859		
37	2020	17600	350	6160000	1433224	4726776	1181331	3545445	61205528		
38	2021	17960	320	5747200	1454262	4292938	814628	3478310	60390900		
39	2022	18320	320	5862400	1475301	4387099	955084	3432015	59435816		
40	2023	18400	320	5888000	1479976	4408024	1030287	3377737	58405529		
41	2024	18400	320	5888000	1479976	4408024	1088838	3319186	57316691		
42	2025	18400	310	5704000	1479976	4224024	966716	3257308	56349975		
43	2026	18400	310	5704000	1479976	4224024	1021655	3202369	55328320		
44	2027	18400	310	5704000	1479976	4224024	1079716	3144308	54248604		
45	2028	18400	310	5704000	1479976	4224024	1141076	3082948	53107528		
46	2029	18400	310	5704000	1479976	4224024	1205923	3018101	51901605		
47	2030	18400	310	5704000	1479976	4224024	1274456	2949568	50627149		
48	2031	18400	310	5704000	1479976	4224024	1346883	2877141	49280266		
49	2032	18400	310	5704000	1479976	4224024	1423426	2800598	47856840		
50	2033	18400	310	5704000	1479976	4224024	1504320	2719704	46352520		

TABLE 30 (Continued)
TOTAL PROJECT
REPAYMENT OF PROJECT COSTS ALLOCATED TO MUNICIPAL AND INDUSTRIAL WATER
MOGOLLON MESA PROJECT, ARIZONA

77/08/01.

NO	YEAR	ANNUAL WATER DEL AC.FT.	COST PER AC.FT.	GROSS REVENUE	OM AND R COSTS	NET OPERATING REVENUE	PAYMENT TO PRINCIPAL	INTEREST ON UNPAID BAL 5.683 PRCNT	UNPAID BALANCE	PLANT IN SERVICE	SURPLUS
51	2034	18400	310	5704000	1479976	4224024	1589810	2634214	44762710		
52	2035	18400	310	5704000	1479976	4224024	1680159	2543865	43082551		
53	2036	18400	310	5704000	1479976	4224024	1775643	2448381	41306908		
54	2037	18400	300	5520000	1479976	4040024	1692552	2347472	39614356		
55	2038	18400	300	5520000	1479976	4040024	1788740	2251284	37825616		
56	2039	18400	300	5520000	1479976	4040024	1890394	2149630	35935222		
57	2040	18400	300	5520000	1479976	4040024	1997825	2042199	33937397		
58	2041	18400	300	5520000	1479976	4040024	2111362	1928662	31826035		
59	2042	18400	300	5520000	1479976	4040024	2231350	1808674	29594685		
60	2043	18400	300	5520000	1479976	4040024	2358158	1681866	27236527		
61	2044	18400	300	5520000	1479976	4040024	2492172	1547852	24744355		
62	2045	18400	300	5520000	1479976	4040024	2633802	1406222	22110553		
63	2046	18400	300	5520000	1479976	4040024	2783481	1256543	19327072		
64	2047	18400	300	5520000	1479976	4040024	2941666	1098358	16385406		
65	2048	18400	300	5520000	1479976	4040024	3108841	931183	13276565		
66	2049	18400	290	5336000	1479976	3856024	3101517	754507	10175048		
67	2050	18400	290	5336000	1479976	3856024	3277776	578248	6897272		
68	2051	18400	290	5336000	1479976	3856024	3464052	391972	3433220		
69	2052	18400	280	5152000	1479976	3672024	3433220	195110			43694
TOTAL		1013670		385270000	90283875	294986125	84058000	210884431			

VIII. CONCLUSIONS

VIII. CONCLUSIONS

Studies and investigations leading up to this concluding report provide the basis for the following conclusions:

1. The city of Flagstaff plans full development of the ground-water resources in the Inner Basin, Woody Mountain, and Lake Mary well fields prior to the development of the Mogollon Mesa Project.

2. Flagstaff is experiencing population growth and economic expansion but at a slower rate than originally projected, possibly contributed by inverse pricing.

3. The investigations were completed under the traditional guidelines for investigating the feasibility of a project and were found to be engineeringly and environmentally feasible and economically justified.

4. The city desires to hold its surface water rights on Clear Creek in reserve in order to meet the city's long-term need.

5. The Flagstaff City Council and Water Commission have expressed strong interest in the project. They have also expressed reservations about commitment to repayment and proposed that the construction of the project be delayed until some time into the future after additional assessments and development of the ground-water resources and the city confirms points on its estimated growth curve.

6. The fish and wildlife benefits were substantially reduced and the mitigation costs to the project were significantly increased as the result of the Fish and Wildlife Service's reevaluation of the Mogollon Mesa Project. This drastic change from the Fish and Wildlife Service's original evaluation report would probably eliminate fish and wildlife as a purpose of the project.

7. The approach to planning was changed following the completion of the project investigations. If any future studies of the project are undertaken, they would be made under the Water Resources Council's Principles and Standards for Planning and the Fish and Wildlife Service would be contacted to reevaluate the project benefits and mitigation plan at that time.

APPENDED MATERIAL

MOGOLLON MESA PROJECT, ARIZONA

PROCEDURE NO. 1 ADDENDUM

MOGOLLON MESA PROJECT, ARIZONA
PROCEDURE NO. 1 ADDENDUM

CONCLUDING REPORT

December 1977

Manuel Lopez, Jr., Regional Director, Lower Colorado Region
Bureau of Reclamation

PREFACE

The Water Resources Council established a schedule for application of Principles and Standards for Planning Water and Land Resources. Procedure No. 1, which was published in the Federal Register on July 24, 1974, and amended February 12, 1975, establishes a schedule for application of the Principles and Standards to implementation studies in process.

The completion of the Mogollon Mesa Project feasibility studies was accomplished under Level C of Procedure No. 1, as amended, which states:

> C. Level C (implementation) plans on which field studies analyses and evaluation were completed as of October 25, 1973, and which were formulated in accordance with Senate Document No. 97 as supplemented and amended, and which are either transmitted to OMB between July 1, 1974, and June 30, 1975, or which are in the review process on June 30, 1975, specifically designated and listed by the agencies, and transmitted to OMB between July 1, 1975, and June 30, 1976, will require supplemental analyses. A list of the plans in this review process will be filed on July 1, 1975, by the agencies with the Water Resources Council. 1/ Plans in Section C will include an addendum providing the following information.
>
> 1. Changes in Benefits and Costs: An evaluation of the plan without reformulation, using current normalized prices, current construction costs, and current recreation values.
>
> 2. Environmental Quality Plan: An abbreviated environmental quality plan consistent with the intent of the "Principles and Standards," but which is abridged in detail.
>
> 3. Regional Development and Social Well-being: An abbreviated display of the regional development and social well-being impacts consistent with the intent of the "Principles and Standards," but which is abridged in detail.
>
> 4. Need for Reformulation: If the plan has unresolved environmental problems, a careful examination of the plan will be undertaken by the responsible Federal agency, and reasons that reformulation of a plan is not needed prior to authorization will be set forth.

1/ The Water Resources Council of Representatives approved an action to extend the period of time transmitting certain Level C implementation study plans utilizing a modified multiobjective planning approach. The action taken on June 9, 1976, extended the date of submittal to the Office of Management and Budget to June 30, 1977.

MOGOLLON MESA PROJECT, ARIZONA
PROCEDURE NO. 1 ADDENDUM
CONCLUDING REPORT
August 1977

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LIST OF DRAWINGS

I. CHANGES IN BENEFITS AND COSTS

I. CHANGES IN BENEFITS AND COSTS

The recommended plan and the alternative plan presented in the concluding report have been evaluated using construction costs and recreation values of April 1976. Fish and wildlife benefits were developed by the Fish and Wildlife Service and presented as part of the Bureau of Outdoor Recreation evaluation report of September 24, 1971. The following changes have been effected:

1. Project costs were indexed to April 1976 price level from prices of April 1974 (indexed from July 1971).

2. The OM&R costs were indexed to April 1976 prices.

3. Municipal and industrial water benefits were recalculated using April 1976 prices. Recreation benefits were increased by 50 percent to account for the increase in recreation values provided in the Water Resources Council's Principles and Standards for Evaluation of Water and Land Resources.

4. The economic evaluation was made using 6-3/8 percent interest rate instead of the 5-7/8 percent interest rate.

5. Repayment of interest bearing investment cost was made using 5.683 percent interest rate instead of 4.371 percent interest rate.

6. Investigation costs are nonreimbursable and are no longer paid by project beneficiaries.

7. Cost allocated to recreation and fish and wildlife is nonreimbursable under authority of Section 1 of Public Law 89-72. Wilkins Reservoir and Upper Lake Mary are located within the National Forest and would be administered as part of the National Forest System.

II. ENVIRONMENTAL QUALITY PLAN

II. ENVIRONMENTAL QUALITY PLAN

A. Introduction

Presented in this part of the Addendum is an abbreviated Environmental Water Quality (EQ) plan which was formulated consistent with the intent of Procedure 1 of the Principles and Standards and accordingly abridged in detail. The abbreviated EQ plan was formulated to reflect national, regional, state and local needs or problems consistent with the EQ objectives.

B. Problems and Needs

Since surface-water resources are limited in the desert southwest, any natural flowing stream or lake will have high potential for public use and will usually possess outstanding scenic, fish and wildlife, and recreational values. This is especially true in the forested plateau and mesa areas of northern Arizona, the upper tributary system of the Little Colorado River Basin.

Although this forested area has an annual precipitation of about 20 inches, many mountain lakes dry up during late summer and most streams are intermittent. These problems stem from the geophysical and geological characteristics of the watershed area.

Surface streamflows are very erratic, fluctuating widely from year to year and month to month. Summer thunderstorms of moderate to high intensities and short durations usually cover small areas and runoff percolates quickly through the many volcanic caps and other pervious cover material. Spring runoff from snowmelt and early rains, representing over one-half of the annual runoff, usually occurs before the middle of May, at which time a three- to four-month dry period is not uncommon. A record 10-month no-flow period has been recorded on Clear Creek.

The many mountain lakes, including Upper and Lower Lake Mary, Mormon, Ashurst, and Long Lakes, are annually confronted with the possibility of midsummer dry up. Most are located atop the pervious Kaibab formation or within volcanic sinkholes which account for the high seepage rates.

The primary objectives under the EQ plan would be to establish waterfowl refuges and to enhance and stabilize natural and manmade lakes and flowing streams in the project area.

The projected increase in the water requirement of the city of Flagstaff would be met for 25 years by the EQ plan.

On a short-term basis, 13 years, there would be about 8 miles of flowing stream in Clear Creek. This flowing stream would start just below the Wilkins Dam and extend downstream for about 8 miles. Its purpose would provide habitat for the Little Colorado spinedace and to be consistent with Sections 7 and 9 of the Endangered Species Act. Long Lake would be stabilized for 13 years with 3,500 acre-feet per year and then partially stabilized for 12 more years with a decreasing amount of water. This stabilization of Long Lake would provide additional water recreation for the area.

The long-term environmental uses would be the Al's and Post Lake wildfowl refuge and the Lower Lake Mary-Walnut Creek area. The project would provide water for the establishment of permanent wildfowl areas and a scenic flowing stream. Long-term recreational use of the area will increase either with or without the project. The increase would be faster with the project than without, due to increased accessibility and recreation potential.

A preliminary study of the archeology of the Wilkins Reservoir site was made by the Department of Anthropology, Museum of Northern Arizona, in 1969. Nine archeological sites consisting of six rock shelters and three petroglyphs were investigated and recorded. Two of the several recommendations, with regard to future archeological investigations, to be made before construction of Wilkins Reservoir are as follow:

1. Further study and analyses of the art work of three petroglyph sites.

2. Excavation of four of the six rock shelter sites to gain knowledge related to problems of settlement, subsistence, and cultural-temporal affinities within the locality of the impoundment area.

The Mogollon Mesa Plateau and Rim country, which encompasses the study area, is rich in "early man" ruins. Within the project area alone, Coconino National Forest, it has been estimated that upwards of 1,000 sites probably exist, most of which have not been surveyed for their archeological significance and salvage value. "Early man" ruins have been estimated to cover about 400,000 acres within this area.

C. Plans and Estimates

1. General. Features of the proposed EQ plan which are common with the proposed NED plan include Wilkins Dam and Reservoir, the

enlargement and lining of Upper Lake Mary, and the Wilkins-Flagstaff pipeline and pumping plant system. The EQ plan also includes the development of Lower Lake Mary waterfowl refuge, and provisions for a full supply of water delivered to Clear Creek and Long Lake for 15 years and a partial supply for the next 12 years. Construction of the EQ plan would be in a single stage, which differs from the two-stage schedule of the NED plan.

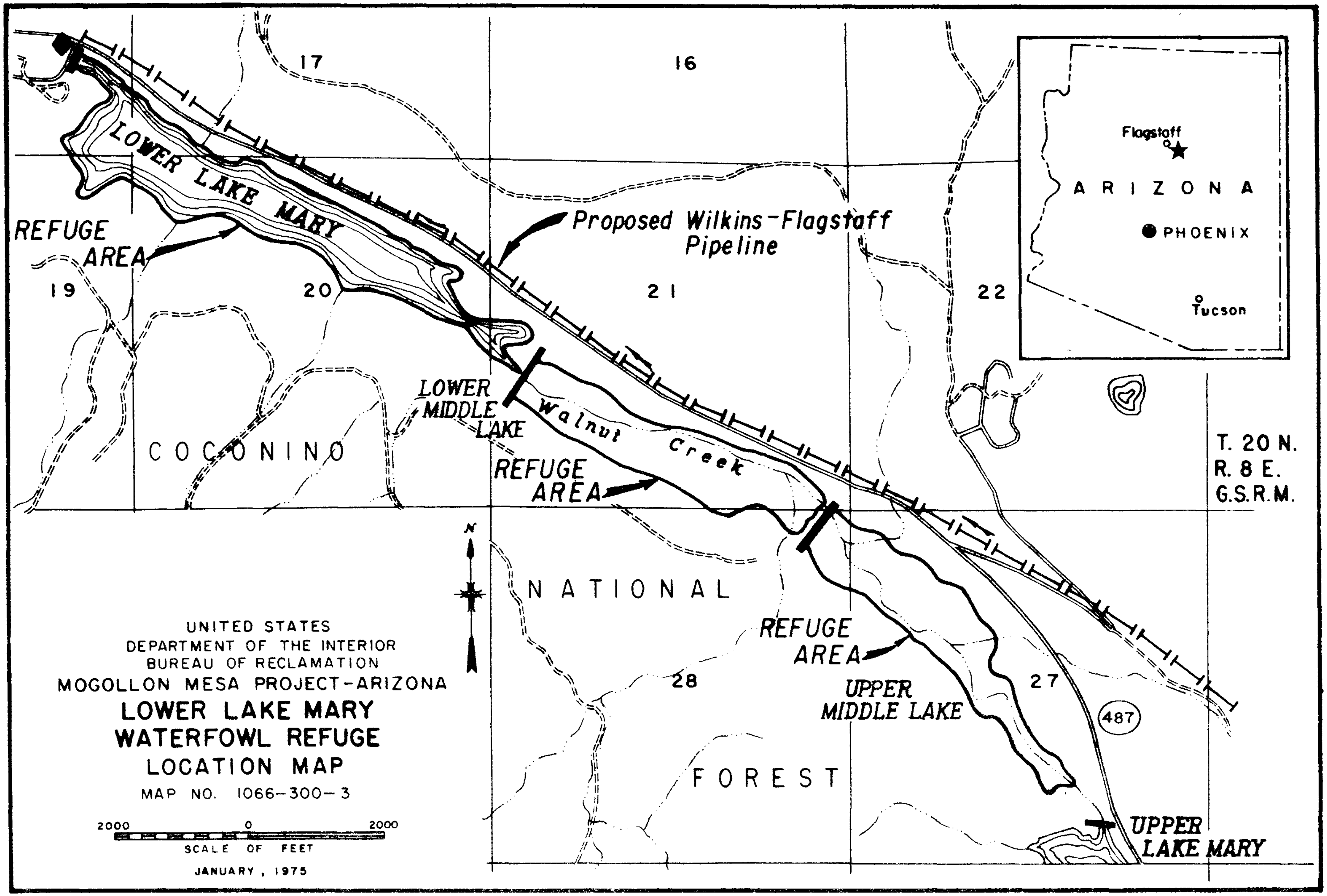
The main difference between the water supply of the EQ plan and the NED plan is the reallocation of 4,400 acre-feet of project water among the above EQ features, based primarily on preservation, enhancement, and stabilization of flowing streams and natural and man-made lakes, and also to establish highly manageable waterfowl refuges. The EQ plan would allocate 3,700 acre-feet per year to the Lower Lake Mary refuge and 700 acre-feet per year to Al's and Post Lake refuge. The 3,700 acre-feet would also provide a flowing stream in Walnut Creek. The EQ plan would furnish 14,000 acre-feet of M&I water to Flagstaff, as compared to 18,400 acre-feet in the NED plan.

2. Physical Features of the Recommended Plan.

a. Wilkins Dam and Reservoir and Upper Lake Mary. Physical description of these features would be the same as for the NED plan.

b. Wilkins-Flagstaff Pipeline System. The system would be designed at 37 ft^3/s capacity the same as the NED plan.

c. Lower Lake Mary Waterfowl Refuge and Walnut Creek Fishery. This waterfowl refuge would consist of stabilizing three shallow ponds (lakes) in a series as shown on Map No. 1066-300-3.


17
16
LOWER LAKE MARY
REFUGE AREA
Proposed Wilkins-Flagstaff Pipeline
19
20
21
22
Flagstaff
ARIZONA
PHOENIX
Tucson
LOWER MIDDLE LAKE
Walnut Creek
REFUGE AREA
COCONINO
T. 20 N.
R. 8 E.
G.S.R.M.
N
NATIONAL
REFUGE AREA
UPPER MIDDLE LAKE
28
27
487
FOREST
UPPER LAKE MARY
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOGOLLON MESA PROJECT-ARIZONA
LOWER LAKE MARY
WATERFOWL REFUGE
LOCATION MAP
MAP NO. 1066-300-3
2000
0
2000
SCALE OF FEET
JANUARY, 1975

The 11 ft^3/s turnout from Upper Lake Mary would provide 3,700 acre-feet of water annually to stabilize this waterfowl operation and provide a flowing stream in Walnut Creek.

The present Lower Lake Mary would be maintained at its normal pool of about 200 acres at elevation 6787. A lower middle lake would be maintained by the construction of a low weir section to cover about 92 acres at a normal water surface of 6790 feet, and the upper middle lake with construction of a similar weir would cover about 88 acres at 6795 feet. In total, the waterfowl refuge would contain about 380 acres.

The dams to impound water in the two upper ponds would be low earthfill section with crest lengths of 825 and 740 feet, respectively, and structural heights above natural ground of about 5 and 8 feet. Crest widths were estimated at 10 feet with both sideslopes at 3:1

These three ponds would back water up to Upper Lake Mary and would be located generally in Sections 20, 21, and 27, T. 20 N., R. 8 E., G&SRM. Lower Lake Mary Dam (existing) is located about one mile southeast of the Flagstaff city limits.

The 3,700 acre-feet would also provide a flowing stream in Walnut Canyon averaging about 5 ft^3/s. The live creek would begin at Lower Lake Mary Dam and would extend for about 5 miles downstream. This reach would be open to public fishing.

d. Long Lake Stabilization (Fishery). The Wilkins-Flagstaff pipeline will pass within about 1,000 feet of Long Lake, which is a popular trout-northern pike fishery even though it is subject to severe annual drawdown and occasional dry up periods in some years.

Long Lake is about 350 acres at normal full capacity with an estimated volume of about 5,000 acre-feet. The present average lake area is about 175 acres. It is estimated that about 3,500 acre-feet of project water per year would be available to stabilize Long Lake for a period of about 13 years. A decreasing amount of water would be available for an additional 12 years to reduce the annual drawdown of Long Lake.

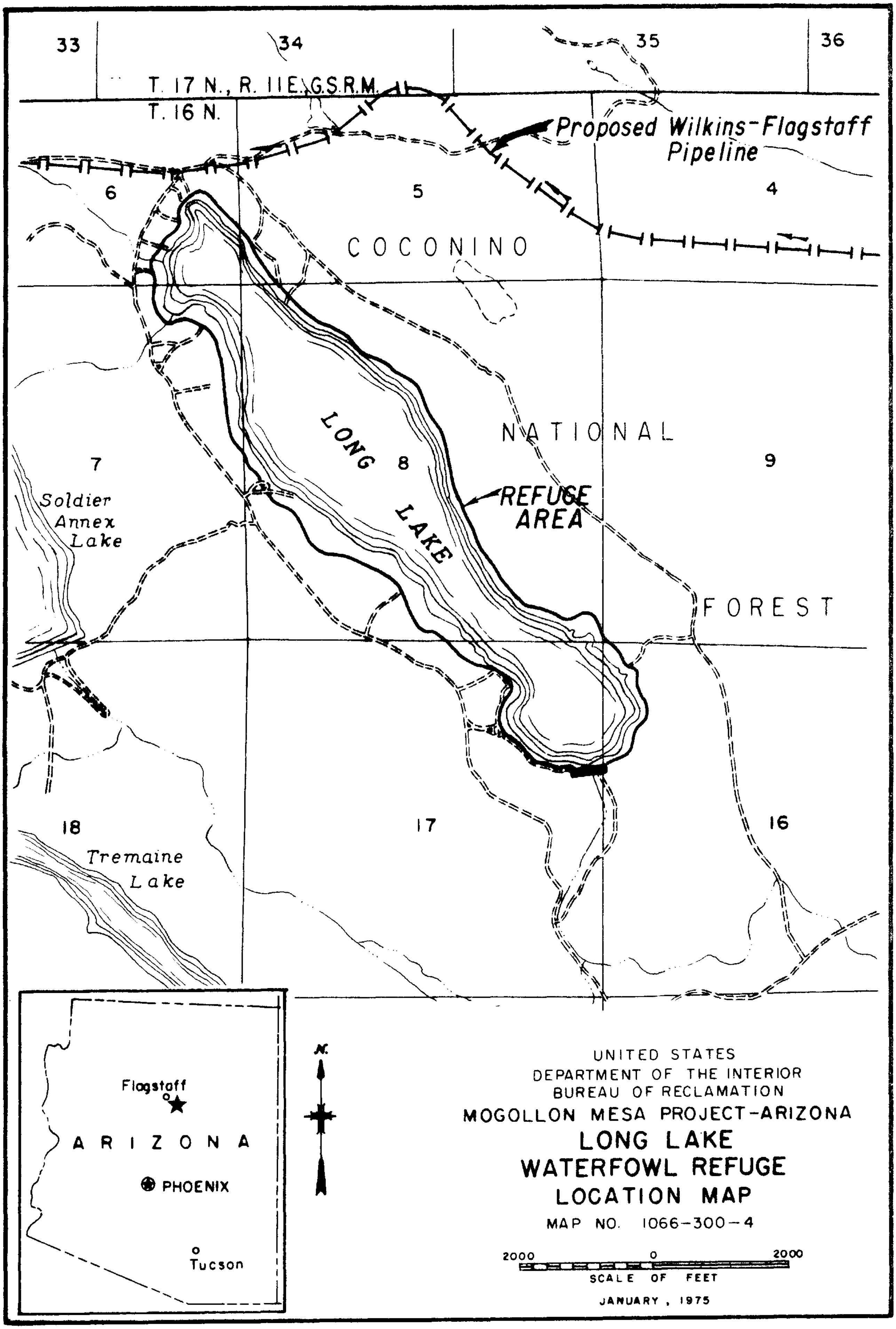
A 10 ft^3/s turnout at elevation 7120 would discharge project water from the Wilkins-Flagstaff pipeline into a natural drain for flow into Long Lake (see Map No. 1066-300-4).

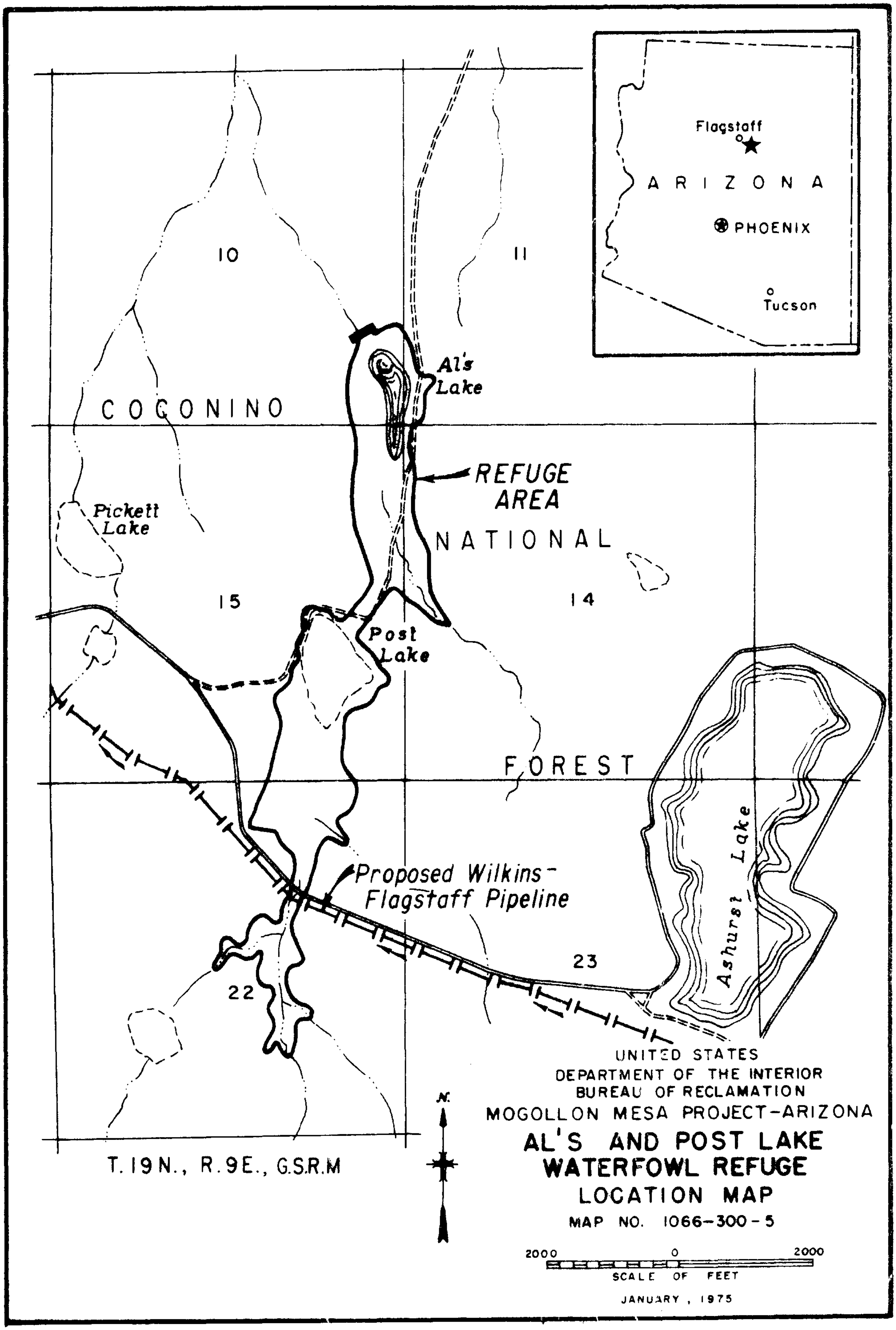
e. Al's and Post Lake Waterfowl Refuge. This major EQ feature, along with Lower Lake Mary, will provide the entire area around Upper Lake Mary with waterfowl refuge system, one above and one below the lake, making for an excellent flyway pattern.

Al's and Post Lake waterfowl refuge would consist of two sinkhole (volcanic) lakes joined together by a small channel and contained by a small earthfilled dam structure (see Map No. 1066-300-5).

Al's Lake would contain about 87 acres of shallow water and Post Lake about 125 acres, for a combined total of 212 acres. The surface elevation of the combined lakes would be 7100 at the stabilized normal pool.

To prevent excessive seepage losses, this waterfowl refuge would be lined with two feet of selected earth (clay) materials from a borrow area five miles distant.


33
34
35
36
T. 17 N., R. 11 E. G.S.R.M.
T. 16 N.
Proposed Wilkins-Flagstaff Pipeline
6
5
4
COCONINO
NATIONAL
FOREST
7
8
9
LONG LAKE
REFUGE AREA
Soldier Annex Lake
18
17
16
Tremaine Lake
Flagstaff
ARIZONA
PHOENIX
Tucson
N.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOGOLLON MESA PROJECT-ARIZONA
LONG LAKE
WATERFOWL REFUGE
LOCATION MAP
MAP NO. 1066-300-4
2000
0
2000
SCALE OF FEET
JANUARY, 1975


Flagstaff
ARIZONA
PHOENIX
Tucson
10
11
Al's Lake
COCONINO
REFUGE AREA
Pickett Lake
NATIONAL
15
14
Post Lake
FOREST
Proposed Wilkins-Flagstaff Pipeline
Ashurst Lake
23
22
T. 19 N., R. 9 E., G.S.R.M
N.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOGOLLON MESA PROJECT-ARIZONA
AL'S AND POST LAKE
WATERFOWL REFUGE
LOCATION MAP
MAP NO. 1066-300-5
2000 0 2000
SCALE OF FEET
JANUARY, 1975

The small earthfilled dam to impound this refuge would be located in Section 10, T. 19 N., R. 9 E., G&SRM. It would have a crest length of about 200 feet and a maximum height above natural ground of 17 feet. The crest width and elevation would be 10 and 7105 feet, respectively.

The Wilkins-Flagstaff pipeline would pass through a high ridge on Post Lake at which point a 2 ft^3/s turnout would make an annual delivery of 700 acre-feet to stabilize this refuge on a 100-year sustained basis.

f. Clear Creek Flowing Stream. A varying amount of water would be available to establish a flowing stream in Clear Creek below Wilkins Dam for 13 years. The amount of water available would be 3,280 acre-feet and 2,960 acre-feet for the first two years and then decrease to 2,820 acre-feet the third year. After the third year, the amount of water available would decrease yearly with only 220 acre-feet available the thirteenth year. This would provide a flowing stream in a scenic canyon and would provide a limited amount of water-oriented recreation.

g. Archeological Survey, Salvage, and Preservation Program. The EQ plan would include an archeological survey of all areas affected by the project.

h. Cost Estimates. Table 1 shows a breakdown by features of the estimated EQ construction and OM&R costs.

i. Benefits. The following tabulation presents the benefits of the various functions:

Table 1
SUMMARY OF COST ESTIMATES 1/
Environmental Quality Plan
Mogollon Mesa Project, Arizona

Wilkins Dam and Reservoir, Pipeline, Etc.	
Construction	
Wilkins Dam and Reservoir	$23,380,000
Pumping Plants	5,050,000
Pipeline and Structures	34,810,000
Transmission System	2,270,000
Communications Equipment	767,000
Lake Stabilization Turnouts	38,000
Post and Al's Lake Waterfowl Refuge	1,346,000
Subtotal	$67,661,000
Upper Lake Mary Dam and Reservoir, Etc.	
Construction	
Upper Lake Mary Dam and Reservoir	$15,460,000
Fish and Wildlife and Recreation Facilities	3,720,000
Middle Lake Mary Waterfowl Refuge	51,000
Subtotal	$19,231,000
Total Construction Cost	
Investment Cost	$86,892,000
Operation, Maintenance and Replacement 2/	1,681,000

1/ April 1976 price levels.

2/ Annual OM&R costs at full development are $248,000 for fish and wildlife and recreation facilities and $1,433,000 for the rest of the project.

Category	Benefits ($1,000)
Municipal and Industrial	6,886
Fish and Wildlife	445
Recreation	196
Total	7,527

3. Alternate Plans.

a. Permanent Allocation of Additional Water To Environmental Quality Enhancement. This alternative would construct the same basic features as the proposed plan, but more water would be permanently allocated to EQ features. The number and size of additional features would depend on the amount of water allocated to EQ features. Some features that could be included are the establishment of a permanent flowing stream in Clear Creek below Wilkins Dam and the permanent stabilization of Long Lake.

The impacts related to construction would not vary significantly from the proposed plan since most features are the same. Additional study would be required to assess what the impacts of this alternative would be on the environment. The impact on the environment would depend on the amount of water allocated to EQ plans.

b. Permanent Allocation of No Water to Environmental Quality Enhancement. This alternative would require construction of most of the features of the proposed project; however, the AI's and Post Lake refuge feature would most likely be deleted. This plan would give priority of water use to municipal purposes and provide no long-term environmental enhancement. Since the only EQ enhancement would be short term using excess water, this is not considered a viable EQ alternative. This alternative corresponds to the NED plan.

c. Other Sources of Water. This alternative would seek augmentation of the water supply in the Flagstaff area. Some possible sources of augmentation include Blue Ridge Reservoir through agreement with Phelps Dodge Corporation, precipitation management, and importation from the Colorado River. These are mentioned as possibilities and would require a great deal more study and time before they could be accomplished. The city of Flagstaff is proceeding with the development of the ground water in the area to supplement the water supply.

d. Nondevelopment of the Proposed Project. With no action, the population and economic growth of the Flagstaff area would be curtailed by 1980. Growth could continue at a controlled rate if per capita use of water were tightly restricted and if local water supplies were developed, regulated, and recycled to their maximum potential.

There would be no commitment of resources or energy to construction activities. Visitor use of the area would still increase but at a rate slower than with the project. There would be no enlargement or enhancement of waterfowl habitat or stabilization of Long Lake. Clear Creek would continue to have uncontrolled, intermittent flows.

The city of Flagstaff would not be precluded from building the project without Federal funds.

D. Evaluation of Environmental Impacts

1. Open and Green Spaces. The EQ plan would not change the quality of existing "open and green" spaces except where clearing would be involved. Quality is reduced principally by intrusion of the powerline and by the effect produced by clearing rights-of-way. The quality of green space would be enchanced by about 5 miles of flowing streams in Walnut Creek and about 8 miles in Clear Creek.

2. Flowing Streams. Neither Walnut Creek nor Clear Creek contain continuous flowing streams. Under the EQ plan beginning in the third year, Walnut Creek would receive about 5 ft^3/s to provide a flowing stream for five miles. During the first 13 years of the project, there will be sufficient water available to provide a flowing stream in Clear Creek. There are no other sustained free-flowing streams in the project area; however, the scenic Oak Creek Canyon is adjacent to the project area.

3. Lakes. A new reservoir will be created behind Wilkins Dam. This reservoir would have a maximum of 568 acres and will provide additional fishing and other water-oriented recreation in the project area. The project would also improve Upper Lake Mary by providing a more stable water supply. Fishing in Long Lake would be improved by providing water for stabilization of the water surface. Thirty-five hundred acre-feet of water would be available for this use in these lakes for about 13 years and a decreasing amount of water would be available for an additional 12 years.

4. Wetland Area (Waterfowl Refuges). The EQ plan would increase the amount of waterfowl refuge area by improving some existing

areas and by adding some new area. About 1,100 acres of permanent standing water would be added under the EQ plan.

5. Other Areas of Natural Beauty (Canyons). Two canyons are involved in this category. The canyon at Clear Creek is spectacular, and under any of the alternatives, eight miles would be lost to inundation by Wilkins Reservoir. The EQ plan would provide a decreasing amount of water to create a flowing stream in Clear Creek for 13 years.

Beginning in the third year of the project, 3,700 acre-feet of water will be available for the Lower Lake Mary refuge and to maintain about five miles of flowing stream in the scenic Walnut Canyon.

6. Archeological Survey, Salvage, and Preservation Program. The Mogollon Mesa and Rim country is considered to be an area of archeological transition. It has been estimated that thousands of early man ruins and sites are located within the study area.

An archeological survey of the Wilkins Dam and Reservoir site, Upper Lake Mary Dam and Reservoir site, the aqueduct rights-of-way, and all other areas affected by construction of the project would be completed prior to construction. Any archeological or historical property found, prior to or during construction, will be evaluated by an archeologist or other appropriate professional who will make a determination in consultation with the Arizona State Historic Preservation Officer regarding the property's eligibility for inclusion in the National Register of Historic Places. Should the property be determined eligible for inclusion in the National Register of Historic

Places, the Bureau of Reclamation will follow the procedure outlined in 36 CFR 800.

7. Biological Resources.

a. Fauna. There would be a loss of eight miles of stream-bank habitat and fauna, but it would be replaced by an aquatic ecosystem. The construction of Wilkins Dam would alter the aquatic habitat of the Little Colorado River spinedace (Lepodomeda Vittata). The effect the project would have on this fish requires more study.

There would be no permanent loss of habitat or fauna as the result of constructing the aqueduct since it would be buried 3 feet in the ground and the disturbed areas would be restored and reseeded to near natural conditions. About 580 acres would be required for the pipeline. Construction of the pipeline would cause temporary damage to vegetation and disturb wildlife along the route. Elk, deer, antelope, and other animals would be disturbed by noise from the pumping plants and increased activity in the area.

The enlargement of Upper Lake Mary would require about 2½ miles of paved county road which would require about 9 acres of land resulting in a permanent disturbance of the habitat and a loss of the fauna.

Clearing of the enlarged Upper Lake Mary would require removal of several stands of ponderosa pine forest (about 25 acres). The remainder of the area (about 1,190 acres) is covered with grass and shrubs. By lining Upper Lake Mary, seepage to Lower Lake Mary would be reduced. There would be sufficient project water in the early years of operation and in a high percentage of the latter years of operation to furnish water for fishing and hunting needs in Lower Lake Mary. It is possible in some later years for Lower Lake Mary to dry up and sustain some fishing and hunting loss. There would be a commitment of 2,154,000 cubic yards of cinder to cover the lining of Upper Lake Mary. This cinder will be quarried from sites to be chosen later in cooperation with the Forest Service.

Areas within the reservoir (Upper Lake Mary) would be used to the maximum extent possible to obtain borrow material for the Dam. Areas outside of the lake will be restored and seeded to blend with the natural terrain.

b. Flora. About 600 acres within the Wilkins Reservoir, some areas along the aqueduct route, and the increase in lake areas would be permanently lost to native flora. Other areas would be disturbed during construction and then returned to native vegetation.

8. Air Quality. In theory, the air quality at Flagstaff and in the project area will generally decrease under any plan or with no plan because of the continued growth of industry, residential areas, and auto use. The decrease would occur faster with the plan than without the plan.

9. Sound Quality. There will be an increase in the noise level with the project. The pumping plants on the aqueduct line will raise the sound level in the area. The area affected would be small in relation to the total. During construction, there would be a temporary increase in the noise level in the area due to the increase in traffic.

10. Visual Quality. The visual quality of the area will be altered by the project features. The pumping plants and other permanent structures will be designed to harmonize with the natural environment as much as possible. Wilkins Dam will alter the visual aspect of Clear Creek Canyon. A portion of the canyon vista will be replaced with a water vista.

The Wilkins Reservoir would have a maximum fluctuation of 90 feet, which would leave waterline marks on the lower canyon walls. The maximum drawdown would occur on the average of once in five years.

11. Mitigating Measures. The increase in waterfowl refuge area created by the project would mitigate the loss of terrestrial habitat caused by the project.

The threatened Little Colorado spinedace could be transplanted and protected in selected reaches of Clear Creek and in Walnut Creek. This program would require cooperation with various Federal and State agencies and could result in enhancement of this species.

12. Adverse Effects. There would be some loss of terrestrial habitat and stream areas with the native biota. Some potential habitat of the threatened Little Colorado spinedace would be inundated by the reservoir, but additional habitat may be created or enhanced below Wilkins Dam and in Walnut Creek for this fish.

There would be a watermark on the canyon walls of the reservoir as a result of the fluctuating water level. The degree this watermark would affect the visual esthetics of the area is a subjective evaluation.

Evaporation from the reservoir would cause a decrease in the quality of water during the life of the project.

As a result of the project, accessibility to the area will be improved resulting in an increased use by man. This increase in use and the noise from the pumping plants could cause relocation of any wildlife migration routes in the area.

13. Commitment of Resources. A small amount of land would be committed as a result of the pumping plants associated with the pipeline. There would be a commitment of a borrow area located about five miles north of Upper Lake Mary and the ponderosa pine forest that occupies that area. The area consists of cinders which would be used to place on top of the proposed lining in Upper Lake Mary. About eight miles of the natural canyon at Clear Creek and its component geological formation, some archeological ruins, and native terrestrial and aquatic biota would be committed to the reservoir. The archeological ruins would be treated in compliance with the procedures outlined in "36 CFR 800."

Some of the water resource, that under natural conditions flows in Clear Creek and contributes to the flow of the Little Colorado River watershed, will be committed to other uses, including a municipal supply for Flagstaff, stabilization of Long Lake, and development of a flowing stream in Walnut Creek below Lower Lake Mary.

The land used to increase the size of Upper Lake Mary would be removed from terrestrial habitat and added to the marsh and aquatic habitat. The permanent roads built for the project would commit land from the natural state.

The resources and energy used to construct the project would be irretrievably committed.

Table 2 shows an abbreviated comparison of the national economic development and the recommended environmental quality plans.

E. Economic and Financial Analysis

1. Introduction. The EQ plan for the Mogollon Mesa Project would provide 14,000 acre-feet of municipal and industrial water annually for Flagstaff, and 4,400 acre-feet of water for waterfowl refuges and 5 miles of flowing stream on Walnut Creek. For about 26 years, water will be provided for stabilization of Long Lake, and for about 13 years, water will be provided for a flowing stream on Clear Creek below Wilkins Dam. The enlargement of Upper Lake Mary Dam and lining of the reservoir would be completed in about 3 years after Wilkins Dam and the Wilkins-Flagstaff pipeline are completed.

2. Project Benefits. Construction and operation of the EQ plan would result in benefits accruing to municipal and industrial water users, recreation, and fish and wildlife enhancement.

a. Municipal and Industrial Water Benefits.

(1) Flagstaff would receive 14,000 acre-feet of water annually from Wilkins Dam and Reservoir and from Upper Lake Mary. Benefits are evaluated from the cost of providing the same amount of water from a single-purpose alternative project most likely to be developed in the absence of the Federal project. The alternative water development was considered to be the same as the Federal project, but with the Wilkins-Flagstaff pipeline reduced to 28 ft^3/s and with

Table 2
COMPARISON OF NATIONAL ECONOMIC DEVELOPMENT AND ENVIRONMENTAL QUALITY PLANS
Mogollon Mesa Project Arizona

Component	EQ Plan	NED Plan	Difference (NED Plan minus EQ Plan)
National Economic Development			
Beneficial Effects	$7,527,000	$7,433,000	$- 94,000
Adverse Effects	7,425,000	6,233,000	-1,192,000
Net Beneficial Effects	102,000	1,200,000	+1,098,000
Environmental Quality			
Beneficial and Adverse Effects			
A. Open and Green Space	Create Wilkins Reservoir with 568 surface acres high quality water and 1 access point.	Create Wilkins Reservoir with 568 surface acres high quality water and 1 access point.	No Difference
	Enlarge Upper Lake Mary and provide an additional water supply and a minimum pool.	Enlarge Upper Lake Mary and provide an additional water supply and a minimum pool.	No Difference
	Inundate 8 miles of intermittent mountain stream.	Inundate 8 miles of intermittent mountain stream.	No Difference
	Noise level will be increased at 3 pumping plants.	Noise level will be increased at 3 pumping plants.	No Difference
B. Biological	Provide lake habitat for fish at Wilkins Reservoir and a minimum pool at Upper Lake Mary.	Provide lake habitat for fish at Wilkins Reservoir and a minimum pool at Upper Lake Mary.	No Difference
	Destroy natural habitat along 8 miles of intermittent stream.	Destroy natural habitat along 8 miles of intermittent stream.	No Difference
	Provide 380 acres of waterfowl refuge on Lower Lake Mary.		380 acres of waterfowl refuge
	Provide 5 miles of flowing stream on Walnut Creek.		5 miles of flowing stream
	Provide 212 acres of waterfowl refuge at Al's and Post Lake.		212 acres of waterfowl refuge
	Provide water for stabilization of Long Lake for 25 years.		Stabilization of Long Lake for 25 years.
	Provide some water for about 8 miles of flowing stream in Clear Creek for 13 years.		Water for 8 miles flowing stream on Clear Creek for 13 years.
	Disrupt 51 miles of habitat for pipeline and transmission line.	Disrupt 51 miles of habitat for pipeline and transmission line.	No Difference

the recreation and fish and wildlife facilities deleted. Annual cost was based on amortizing investment cost in 50 years at 7½ percent interest. Annual equivalent benefits for 100 years are $6,886,000.

b. Recreation Benefits. The Bureau of Outdoor Recreation estimated the recreation benefits on both reservoirs based on the projected visitor-day use at each reservoir.

(1) Annual benefits at the Wilkins Reservoir were estimated to increase from $8,625 the first year of operation to $25,875 in the fifth year and remain at the $25,875 rate for the rest of the period of analysis. Annual equivalent recreation benefits for the 100-year period of analysis at 6-3/8 percent interest are $23,000.

(2) Annual recreation benefits at the enlarged Upper Lake Mary were estimated on the basis that 1986 would be the first year of operation. Benefits were estimated to be $41,250 the first year and to increase to $274,125 annually in 20 years. The benefits were based on the increased population of the area and the Nation.

The annual equivalent recreation benefits based on a 100-year period of analysis beginning in 1984 would be $173,000.

c. Fish and Wildlife Benefits. The Fish and Wildlife Service estimated the fish and wildlife benefits.

(1) Annual fish and wildlife benefits on Wilkins Reservoir were estimated to be $180,000 beginning the first year the reservoir is operational.

(2) Annual fish and wildlife benefits on the enlarged and lined Upper Lake Mary were estimated to be $300,000 beginning the first year the reservoir is operational.

d. Summary of Project Benefits. Annual equivalent benefits from the project purposes are summarized in Table 3.

3. Project Costs. The total cost to construct the EQ plan of the Mogollon Mesa Project is estimated to be $86,892,000.

Investigation cost of $1,250,000 for the project is nonreimbursable by authority of Public Law 92-149. This cost is excluded for net benefit analysis, cost allocation, and repayment. The remaining cost is $85,642,000 for the project.

The interest during construction for the project would be about $7,619,000.

The annual equivalent operation, maintenance and replacement costs of the project for the 100-year period of analysis are estimated to be $1,609,000. Negotiations will be made with Coconino County, the State of Arizona, or the U.S. Forest Service to take over operation and maintenance of the access road to Wilkins Dam and Reservoir after construction is completed. If one of those agencies takes over operation and maintenance of the access road, the Mogollon Mesa Project will be relieved of the cost.

The total equivalent cost at 6-3/8 percent interest for the 100-year period of analysis is $7,425,000. Federal economic costs are summarized in Table 4.

4. Net Benefits. The EQ plan of the Mogollon Mesa Project is economically justified with a net benefit of $102,000. Annual equivalent benefits are $7,527,000 and annual equivalent costs are $7,425,000.

5. Cost Allocation. For purposes of cost allocation, only the costs included in the national economic development account are

Table 3

SUMMARY OF ANNUAL EQUIVALENT
PROJECT BENEFITS AT 6-3/8 PERCENT
Environmental Quality Plan
Mogollon Mesa Project, Arizona

	Unadjusted	Factor	Common Time Value
Municipal & Industrial Water	$ 6,886,000		$ 6,886,000
Wilkins Dam & Reservoir			
Recreation	23,000		23,000
Fish & Wildlife	180,000		180,000
Upper Lake Mary Dam & Reservoir			
Recreation	274,000	.63139 1/	173,000
Fish & Wildlife	300,000	.88373 2/	265,000
TOTAL BENEFITS			$ 7,527,000

1/ Benefits at full development are $274,000 and common time value = $173,000. $173,000 ÷ $274,000 = .63139.

2/ Present worth of one for two years at 6-3/8 percent interest.

Table 4

SUMMARY OF ECONOMIC COSTS
Environmental Quality Plan
Mogollon Mesa Project, Arizona

	Unadjusted Cost	Factor	Common Time Value
Wilkins Dam & Reservoir, Pipeline, etc.			
Construction			
Wilkins Dam and Reservoir	$ 22,999,000		
Pumping Plants	4,975,000		
Pipeline and Structures	34,312,000		
Transmission System	2,235,000		
General Property	755,000		
Lake Stabilization Turnouts	38,000		
Post & Al's Lake Waterfowl Refuge	1,346,000		
Subtotal	$ 66,660,000		$ 66,660,000
Interest During Construction	6,302,000		6,302,000
Upper Lake Mary Dam & Reservoir, etc.			
Construction			
Upper Lake Mary Dam & Reservoir	$ 15,211,000		
Fish & Wildlife & Recreation Facilities	3,720,000		
Middle Lake Mary Waterfowl Refuge	51,000		
Subtotal	$ 18,982,000	.8837 1/	$ 16,774,000
Interest During Construction	1,490,000	.8837 1/	1,317,000
Total Project Costs			
Construction Costs			$ 83,434,000
Interest During Construction			7,619,000
Investment Cost			$ 91,053,000
Annual Equivalent Investment Cost 2/			$ 5,816,000
Operation, Maintenance & Replacement	$ 1,681,000 3/		1,609,000
Total Annual Equivalent Cost			$ 7,425,000

1/ Present worth factor of one for 2 years at 6-3/8 percent interest.

2/ Annual equivalent investment cost at 6-3/8 percent interest for 100 years (.06388).

3/ Annual OM&R Costs at full development are $239,000 for Fish and Wildlife and Recreation Facilities and $1,442,000 for the rest of the project.

allocated between the national economic development objective and the environmental quality objective.

In allocating between NED and EQ objectives, the allocation becomes a two-stage process involving the allocation of costs between objectives and then the further allocation of costs among components of the two objectives.

Table 5 presents the allocation of NED costs between objectives. The allocation of the NED costs of the EQ plan to NED objective components using the separable costs-remaining benefit method is presented in Table 6.

A summary of reimbursable and nonreimbursable project costs allocated to project components is presented in Table 7.

6. Repayment. The schedule of Flagstaff's projected M&I water requirements, local supply, project water deliveries, and water to be pumped is presented in Table 8.

With the EQ plan, Flagstaff's projected project water deliveries are greater by 1,400 acre-feet annually for the first 16 years compared to the NED plan. This occurs because all of the EQ plan is constructed in one stage compared to two-stage construction of the NED plan. After construction of Upper Lake Mary Dam and Reservoir, 1,400 acre-feet of average annual water yield from Walnut Creek is converted from an average water supply to a firm water supply and is considered to be project water.

a. Municipal and Industrial. The costs allocated to M&I water are $72,172,000. This includes $66,704,000 of construction costs and $5,468,000 of interest during construction.

Table 5

ALLOCATION OF NATIONAL ECONOMIC DEVELOPMENT COSTS BETWEEN OBJECTIVES
Environmental Quality Plan
Mogollon Mesa Project, Arizona

	NED Plan	EQ Plan	Difference
NED Objective			
Benefits	$116,355,000	$117,826,000	$ 1,471,000
Costs	97,536,000	116,240,000	18,704,000
Net Benefits	18,819,000	1,586,000	-17,233,000
Net Incremental NED Costs	= $ 11,011,000		
Allocation of NED Costs of EQ Plan			
Total NED Costs of EQ Plan			$116,240,000
Less Net Incremental NED Costs of EQ Plan			-17,233,000
Allocation of NED Costs of EQ Plan to NED Objective			$ 99,007,000 1/

1/ The common time value of costs, $99,007,000 is computed to unadjusted construction cost, interest during construction cost, and annual OM&R costs at full project development for allocation to project purposes. The unadjusted costs are:

Construction Cost	$72,946,000
Interest During Construction	6,636,000
OM&R Costs, Annual	1,431,000

Table 6

ALLOCATION OF COSTS
100-Year Analysis - 6-3/8 Percent Interest
Environmental Quality Plan
Mogollon Mesa Project, Arizona

	Municipal and Industrial	Recreation and Fish & Wildlife	Total
Benefits			
Annual Equivalent	$ 6,886,000	$ 641,000	$ 7,527,000
Capitalized	107,792,000	10,034,000	117,826,000
Single-Purpose Alternate Cost	92,218,000	1/	
Construction	69,261,000		
Interest During Construction	6,474,000		
OM&R - Capitalized	16,483,000		
OM&R - Annual	1,058,000		
Justifiable Expenditure	92,218,000	10,034,000	102,252,000
Separable Costs (Common Time Basis)	28,279,000	8,612,000	36,891,000
Construction	18,396,000	4,716,000	23,112,000
Interest During Construction	1,680,000	358,000	2,038,000
OM&R - Capitalized	8,203,000	3,538,000	11,741,000
OM&R - Annual	524,000	226,000	750,000
Remaining Justifiable Expenditure	63,939,000	1,422,000	65,361,000
Allocation Percentage	97.8	2.2	100.0
Separable Costs			
Construction	18,396,000	5,155,000	23,551,000
Interest During Construction	1,674,000	399,000	2,073,000
OM&R - Annual	606,000	248,000	854,000
Joint Costs			
Construction	48,308,000	1,087,000	49,395,000
Interest During Construction	4,463,000	100,000	4,563,000
OM&R - Annual	564,000	13,000	577,000
Total Allocated Costs			
Construction	66,704,000	6,242,000	72,946,000
Interest During Construction	6,137,000	499,000	6,636,000
OM&R - Annual	1,170,000	261,000	1,431,000
Reimbursable Costs			
Construction Cost	66,704,000		
Interest During Construction	5,468,000 2/		
TOTAL	$72,172,000		

1/ Single-Purpose alternate costs exceed capitalized benefits.

2/ Interest during construction for repayment is reduced because repayment is made at 5.683 interest and the cost allocation is made using 6-3/8 percent interest. The adjustment factor is .891.

Table 7

REIMBURSABLE AND NONREIMBURSABLE
ALLOCATED PROJECT COSTS
Environmental Quality Plan
Mogollon Mesa Project, Arizona

		Reimbursable			Nonreimbursable		
	Project Construction Costs	Construction	Interest During Construction 5.683 Percent	OM&R at Full Project Development	Construction	Interest During Construction 6-3/8 Percent	OM&R
Municipal & Industrial	$ 66,704,000	$ 66,704,000	$ 5,468,000	$ 1,170,000			
Recreation, Fish & Wildlife	6,242,000				$ 6,242,000	$ 499,000	$ 261,000
TOTAL	$ 72,946,000	$ 66,704,000	$ 5,468,000	$ 1,170,000	$ 6,242,000	$ 499,000	$ 261,000
Environmental Quality	$ 12,696,000				$ 12,696,000	$ 1,156,000	250,000
Project Total	$ 85,642,000	$ 66,704,000	$ 5,468,000	$ 1,170,000	$ 18,938,000	$ 1,655,000	$ 511,000
Investigation Costs	$ 1,250,000 1/						
	$ 86,892,000						

1/ The investigation costs amounting to $1,250,000 have been excluded and are comprised of $80,734 contribution by the State of Arizona, $290,787 from the Colorado River Development Fund, and $838,519 which is nonreimbursable under the provisions of Public Law 92-149.

Table 8

SCHEDULE OF FLAGSTAFF'S PROJECTED MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS,
LOCAL SUPPLY, PROJECT WATER DELIVERIES AND WATER TO BE PUMPED
Environmental Objective Plan
Mogollon Mesa Project, Arizona

				Project Water Delivery							
Project Year	Fiscal Year	Flagstaff Water Requirement Acre-feet	Local Water Supply Acre-feet	Flagstaff Acre-feet	Walnut Cr. Fishery & Waterfowl Refuge Acre-feet	Al's and Post Lake Acre-feet	Long Lake Stabiliza. Acre-feet	Clear Cr. Flowing Stream Acre-feet	Total	Project Water from Lake Mary Acre-feet	Project Water to be pumped from Wilkins Reservoir Acre-feet
1	84	8,220	1,000	7,220		700	3,500	3,280	18,400	0	11,420
2	85	8,540		7,540	0			2,960		3,000	11,740
3	86	8,680		7,680	3,700			2,820			12,580
4	87	8,910		7,910				2,590			12,810
5	88	9,140		8,140				2,360			13,040
6	89	9,370		8,370				2,130			13,270
7	90	9,600		8,600				1,900			13,500
8	91	9,880		8,880				1,620			13,780
9	92	10,160		9,160				1,340			14,060
10	93	10,440		9,440				1,060			14,340
11	94	10,720		9,720				780			14,620
12	95	11,000		10,000				500			14,900
13	96	11,280		10,280			3,500	220			15,180
14	97	11,560		10,560			3,440	0			15,400
15	98	11,840		10,840			3,160				
16	99	12,120		11,120			2,880				
17	2000	12,400		11,400			2,600				
18	01	12,690		11,690			2,310				
19	02	12,980		11,980			2,020				
20	03	13,270		12,270			1,730				
21	04	13,560		12,560			1,440				
22	05	13,850		12,850			1,150				
23	06	14,140		13,140			860				
24	07	14,430		13,430			570				
25	08	14,720		13,720			280				
26	09	15,010	1,000	14,000	3,700	700	0	0	18,400	3,000	15,400
50	2031	21,840	1,000	14,000	3,700	700	0	0	18,400	3,000	15,400

Costs allocated to M&I water are reimbursable in 50 years with interest at 5.683 percent on the unpaid balance. The Water Supply Act of 1958 provides for a 10-year interest-free period for the unused portion of storage costs allocated to M&I water. Deferrable investment amounts, as authorized by the Water Supply Act of 1958, were determined for the first 10 years of the project.

The schedule of interest-bearing investment for the project repayment schedule is shown in the following tabulation:

Beginning of Year	Interest Bearing Investment Costs
1	$ 60,996,000
11	11,176,000
Total	$ 72,172,000

The required water charge to Flagstaff would be about $525 per acre-foot the first year, based on paying all M&I water costs through water charges. Water charges per acre-foot could be gradually reduced each year to a water charge of about $400 per acre-foot. These water charges include repayment of investment costs with interest and payment of annual OM&R costs. Annual OM&R charges would be about $97 per acre-foot in the tenth year of project operation and about $84 when the full water supply is used.

The variable and reducing water charge rate schedule is used to prevent many years of deficit payment of interest charges with increased cost to Flagstaff and the United States. The initial high rate of $525 per acre-foot is needed to keep interest deficits within a reasonable period of six years.

A repayment schedule for municipal and industrial water costs is presented in Table 9.

b. Recreation and Fish and Wildlife. Costs allocated to recreation and fish and wildlife are nonreimbursable under authority of Section 1 of Public Law 89-72. Wilkins Reservoir is located in the Coconino and Sitgreaves National Forests and Upper Lake Mary is in the Coconino National Forest, and the facilities are appropriate for administration by a Federal agency as part of the National Forest system.

TABLE 9

ENVIRONMENTAL QUALITY PLAN

REPAYMENT OF PROJECT COSTS ALLOCATED TO MUNICIPAL AND INDUSTRIAL WATER

MOGOLLON MESA PROJECT, ARIZONA

77/08/02.

NO	YEAR	ANNUAL WATER DEL AC.FT.	COST PER AC.FT.	GROSS REVENUE	OM AND R COSTS	NET OPERATING REVENUE	PAYMENT TO PRINCIPAL	INTEREST ON UNPAID BAL 5.683 PRCNT	UNPAID BALANCE	PLANT IN SERVICE	SURPLUS
0	1983								60996000	60996000	
1	1984	7220	525	3790500	871372	2919128	-547275	3466403	61543275		
2	1985	7540	525	3958500	890073	3068427	-429077	3497504	61972352		
3	1986	7680	525	4032000	821698	3210302	-311587	3521889	62283939		
4	1987	7910	525	4152750	833386	3319364	-220232	3539596	62504171		
5	1988	8140	525	4273500	845074	3428426	-123686	3552112	62627857		
6	1989	8370	525	4394250	858515	3535735	-23406	3559141	62651263		
7	1990	8600	525	4515000	870203	3644797	84326	3560471	62566937		
8	1991	8880	525	4662000	884813	3777187	221508	3555679	62345429		
9	1992	9160	525	4809000	901176	3907824	364733	3543091	61980696		
10	1993	9440	525	4956000	915786	4040214	517851	3522363	72638845	72172000	
11	1994	9720	525	5103000	932149	4170851	42785	4128066	72596060		
12	1995	10000	520	5200000	946759	4253241	127607	4125634	72468453		
13	1996	10280	515	5294200	961369	4332831	214449	4118382	72254004		
14	1997	10560	510	5385600	977733	4407867	301672	4106195	71952332		
15	1998	10840	505	5474200	992343	4481857	392806	4089051	71559526		
16	1999	11120	500	5560000	1008706	4551294	484566	4066728	71074960		
17	2000	11400	495	5643000	1025069	4617931	578741	4039190	70496219		
18	2001	11690	490	5728100	1040263	4687837	681537	4006300	69814682		
19	2002	11980	485	5810300	1057211	4753089	785521	3967568	69029161		
20	2003	12270	475	5828250	1072405	4755845	832918	3922927	68196243		
21	2004	12560	470	5903200	1089353	4813847	938255	3875592	67257988		
22	2005	12850	460	5911000	1104547	4806453	984182	3822271	66273806		
23	2006	13140	460	6044400	1121495	4922905	1156565	3766340	65117241		
24	2007	13430	460	6177800	1138443	5039357	1338744	3700613	63778497		
25	2008	13720	460	6311200	1153637	5157563	1533031	3624532	62245466		
26	2009	14000	430	6020000	1170000	4850000	1312590	3537410	60932876		
27	2010	14000	430	6020000	1170000	4850000	1387185	3462815	59545691		
28	2011	14000	430	6020000	1170000	4850000	1466018	3383982	58079673		
29	2012	14000	430	6020000	1170000	4850000	1549332	3300668	56530341		
30	2013	14000	420	5880000	1170000	4710000	1497381	3212619	55032960		
31	2014	14000	420	5880000	1170000	4710000	1582477	3127523	53450483		
32	2015	14000	420	5880000	1170000	4710000	1672409	3037591	51778074		
33	2016	14000	420	5880000	1170000	4710000	1767452	2942548	50010622		
34	2017	14000	420	5880000	1170000	4710000	1867896	2842104	48142726		
35	2018	14000	420	5880000	1170000	4710000	1974049	2735951	46168677		
36	2019	14000	420	5880000	1170000	4710000	2086234	2623766	44082443		
37	2020	14000	420	5880000	1170000	4710000	2204795	2505205	41877648		
38	2021	14000	420	5880000	1170000	4710000	2330093	2379907	39547555		
39	2022	14000	420	5880000	1170000	4710000	2462512	2247488	37085043		
40	2023	14000	420	5880000	1170000	4710000	2602457	2107543	34482586		
41	2024	14000	420	5880000	1170000	4710000	2750355	1959645	31732231		
42	2025	14000	420	5880000	1170000	4710000	2906657	1803343	28825574		
43	2026	14000	420	5880000	1170000	4710000	3071843	1638157	25753731		
44	2027	14000	420	5880000	1170000	4710000	3246415	1463585	22507316		
45	2028	14000	420	5880000	1170000	4710000	3430909	1279091	19076407		
46	2029	14000	410	5740000	1170000	4570000	3485888	1084112	15590519		
47	2030	14000	410	5740000	1170000	4570000	3683991	886009	11906528		
48	2031	14000	400	5600000	1170000	4430000	3753352	676648	8153176		
49	2032	14000	400	5600000	1170000	4430000	3966655	463345	4186521		
50	2033	14000	400	5600000	1170000	4430000	4186521	237920			5559
TOTAL		608500		275357750	53563578	221794172	72172000	149616613			

III. REGIONAL DEVELOPMENT AND SOCIAL WELL-BEING

III. REGIONAL DEVELOPMENT AND SOCIAL WELL-BEING

A. General

This part of the Addendum presents an abbreviated display of the regional development and social well-being impacts consistent with the intent of the Principles and Standards, but which is abridged in detail. A complete display of beneficial and adverse effects for all components for the regional development and social well-being accounts has not been directed for this project.

B. Impacts

The Regional Development and Social Well-Being impacts for the recommended and alternative plans would result from:

1. Construction of facilities for the impoundment and delivery of municipal and industrial water.
2. Operation and maintenance of project facilities.
3. By an expanding population.
4. By a change in land use.

The impact area for construction and operation of facilities would be on Coconino and Navajo Counties designated as Region 1.

The installation of the project features would assure Flagstaff, Arizona with a firm water supply for over 40 years, fishery and recreation activities would be expanded.

Existing socioeconomic conditions in Coconino County are characterized as follows:

1. The county is classified as rural with small towns, Indian villages, and a low population density.

2. In recent years northern Arizona has experienced rapid population growth.

3. The income per capita is low. This is due in part to the high concentration of low income Indian population in the area. Most of the employment is associated with services, wholesale and retail trade, and in government sections. The economic expansion from an early base of small agriculture and railroad settlements and mining camps to a new economy based on tourism, timbering, new manufacturing, mining, educational and research activities.

4. Present socioeconomic services are those commonly found in tourist oriented communities.

Arizona State agencies and the Arizona Valley National Bank have made the following projections relative to socioeconomic conditions:

1. Population will probably continue to grow.

2. Employment in all categories will probably continue to expand.

Regional development and social well-being account for the proposed project are displayed in Tables 10 and 11. These tables present a graphic illustration in quantitative and qualitative terms of beneficial and adverse effects.

A display of the regional development and social well-being impacts for the alternative EQ Plan has not been prepared.

Table 10

SOCIAL WELL-BEING EFFECTS
Mogollon Mesa Project, Arizona

A. Real Income Distribution	1. Reimbursement from region 1 totals $294,942,000 including interest on the interest bearing obligation.
B. Life, Health, and Safety	1. Provision of emergency water supply in case of any interruption of water supply from well fields.
C. Recreation & Educational Opportunities	1. Create diversity of recreational opportunities of $297,000 of annual benefits of general recreation (b) $480,000 of annual benefits of fish and wildlife at full development.
	2. Construction would cause minor influx of children into the project area. These children would have little effect on the schools because they would be distributed between Winslow and Flagstaff, Arizona in commuting distance of the construction site.
D. Emergency Preparedness	1. Provision of flexible water supply reserves.

Table 11

BENEFICIAL AND ADVERSE EFFECTS
Regional Development Account, Mogollon Mesa Project, Arizona

Unit: $1,000

Components	Region I. (Planning Area)					Rest of Nation	Summary
		Direct Users					
	Total	Farm	City	Recreation	Other		
First Stage							
A. Beneficial Effects 1/							
1. Benefits to Regional Users							
a. Municipal & Industrial Water	103,800		103,800				103,800
b. Recreation	360			360			360
c. Fish & Wildlife	2,818			2,818			2,818
2. Unemployed & Underemployed Labor Resources Employed During Construction, Wages	540				540		540
TOTAL BENEFICIAL EFFECTS	107,518		103,800	3,178	540		107,518
B. Adverse Effects 1/, 2/							
1. Reimbursement, Flagstaff M&I Water							
a. Construction Cost	64,019		64,019				64,019
b. Interest During Construction 3/	5,364		5,364				5,364
2. Nonreimbursable Costs							
a. Construction Cost						2,048	2,048
b. Interest During Construction 4/						137	137
TOTAL ADVERSE EFFECTS	69,383		69,383			2,185	71,568
Total Project							
A. Beneficial Effects 1/							
1. Benefits to Regional Users							
a. Municipal & Industrial Water	125,121		125,121				125,121
b. Recreation	4,649			4,649			4,649
c. Fish & Wildlife	7,514			7,514			7,514
2. Unemployed & Underemployed Labor Resources Employed During Construction, Wages	670				670		670
TOTAL BENEFICIAL EFFECTS	137,954		125,121	12,163	670		137,954
B. Adverse Effects 1/, 2/							
1. Reimbursement, Flagstaff M&I Water							
a. Construction Cost	77,772		77,772				77,772
b. Interest During Construction 3/	6,286		6,286				6,286
2. Nonreimbursable Costs							
a. Construction Cost						6,368	6,368
b. Interest During Construction 4/						425	425
TOTAL ADVERSE EFFECTS	84,058		84,058			6,793	90,851

1/ Capitalize values for 100 years at 6-3/8 percent interest.

2/ Values are capital payments during 50-year repayment period.

3/ Interest at 5.683 percent.

4/ Interest at 6-3/8 percent.

IV. NEEDS FOR REFORMULATION

IV. NEEDS FOR REFORMULATION

In event that the project investigations are again undertaken, it would be necessary to reformulate the project plan under the Water Resources Council's Principles and Standards for Planning. Also the Fish and Wildlife Service would need to be contacted to reevaluate the project fish and wildlife benefits and to reanalyze its mitigation plan. Studies of alternative transmission line location that would have less impact than the alinement proposed in the Concluding Report would be required.

Other data needed to be updated and any reevaluation would be land use, landownership, water operation studies, population estimates, recreation demands in the area, and reevaluation of the environmental impacts.

ACTING REGIONAL DIRECTOR'S MEMORANDUM TO
FISH AND WILDLIFE SERVICE ON DRAFT REPORT

United States Department of the Interior
BUREAU OF RECLAMATION
LOWER COLORADO REGIONAL OFFICE
P.O. BOX 427
BOULDER CITY, NEVADA 89005

IN REPLY REFER TO: LC-700
123.8b

August 22, 1977

Memorandum

To: Field Supervisor, Division of Ecological Services, Fish and Wildlife Service, Room 247A, Downtown Post Office Building, 522 North Central Avenue, Phoenix, Arizona 85004

From: Acting Regional Director

Subject: Mogollon Mesa Project, Arizona--Fish and Wildlife Service Draft Report

The subject report shows significant changes in fish and wildlife benefits and mitigation requirements from your earlier reports. Since fish and wildlife was considered a project purpose, these changes would require reevaluation and considerable effort in modifying the project planning reports.

Although we are currently preparing a concluding report on the Mogollon Mesa Project, the data from the subject report will not be included as we still have questions about the fish and wildlife benefits and mitigation proposals. We do not feel that it would be advantageous to spend additional time and money to resolve those questions now since a concluding report is being prepared. In addition, any future studies of the project that are undertaken would be made under the Water Resources Council's Principles and Standards, and the Service would be contacted to reevaluate the project benefits and mitigation plan at that time. Therefore, we do not see a need to finalize the existing draft report.

/S/ Roy D. Gear

In duplicate

FISH AND WILDLIFE REPORT

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Ecological Services
2934 W. Fairmount Avenue
Phoenix, Arizona 85017

November 25, 1977

Memorandum

To: Regional Director, Bureau of Reclamation,
Lower Colorado Region, Boulder City, Nevada 89005

From: Field Supervisor, FWS, Phoenix, Arizona

Subject: Final Fish and Wildlife Report, Mogollon Mesa Project,
Coconino County, Arizona (BR)

This memorandum constitutes the report of the U. S. Fish and Wildlife Service on fish and wildlife resources in relation to the proposed Mogollon Mesa Project, Coconino County, Arizona. The project was authorized for study under general authority of the Federal Reclamation Laws (Act of June 17, 1902, 32 Stat. 388, and Acts amendatory thereof and supplementary thereto).

This report has been prepared under the authority of and in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). It is intended to accompany your feasibility-grade report on the Mogollon Mesa Project. The Arizona Game and Fish Department has cooperated in the preparation of this report and concurs in its content as indicated by the enclosed letter from Director Robert A. Jantzen, dated March 1, 1977, signed by John Carr, Supervisor, Planning and Evaluation Branch.

PROJECT DESCRIPTION

The Mogollon Mesa Project would be a multipurpose project which would include the development of municipal and industrial water for the City of Flagstaff, and also provide for fish and wildlife and recreation development. The project would be developed in two stages. The principal features of the first stage would be Wilkins Dam and Reservoir on East Clear Creek; pumping plants at Jaycox Mountain, Chavez Pass, and Wilkins; and a pipeline and other appurtenant works required to deliver water to Flagstaff, Arizona. The second stage would consist of lining Upper Lake Mary with a membrane lining and raising the dam about 15 feet. This stage of the project would be delayed until such time as Flagstaff's water demands dictate its need.

The project is located in Coconino County, Arizona, with much of the project area being within the Coconino and Apache-Sitgreaves National Forests. Wilkins Dam and Reservoir would be constructed on East Clear Creek, a tributary to the Little Colorado River. A pipeline system would extend from Wilkins Dam northwestward to the city of Flagstaff's existing trunkline near Lower Lake Mary. Upper Lake Mary on Walnut Creek, about 11 miles south of Flagstaff, would be used as a storage and regulating reservoir.

The proposed site of Wilkins Dam is a deeply incised canyon of East Clear Creek. The dam would be a thin, double curvature, concrete-arch structure rising about 228 feet above streambed. Crest length of the dam would be 790 feet. The reservoir would be about 8 miles long, have a storage capacity of 45,000 acre-feet, and a surface area of 568 acres at conservation pool elevation 6,194.[1/] At the top of the inactive pool the reservoir would have a surface area of 220 acres and a capacity of 10,400 acre-feet. Maximum reservoir fluctuation would be 90 feet with a yearly average of 50 feet. Water spills into East Clear Creek would be an estimated 19,000 acre-feet annually.

Water deliveries to Flagstaff from Wilkins Reservoir would be accomplished by means of a pipeline and three pumping plants. The pipeline would vary in size from 30 to 42 inches in diameter, would be 51 miles in length, and have a design capacity of 37 cubic feet per second. The three pumping plants would lift the water a total of 1,430 feet. Wilkins Pumping Plant would be incorporated in the dam. Chavez Pass and Jaycox Pumping Plants would be located 13 and 21 miles from the dam, respectively.

A 69-KV power transmission system proposed for operating the pumping plants would extend from an existing substation between Flagstaff and Winslow on an Arizona Public Service 69-KV line to the Jaycox Pumping Plant and then all along the pipeline to the Wilkins Dam. An alternate power system, starting at the intersection of the pipeline and the Bureau of Reclamation's 345-KV line, could be constructed along the pipeline right-of-way to the pumping plants.

The second stage of the proposed plan would involve enlargement of Upper Lake Mary Reservoir from its present capacity of 15,600 acre-feet to 29,500 acre-feet to provide for offstream storage and regulation of diverted Clear Creek flows. With this increase in capacity, the reservoir would have a surface area of 1,089 acres. At minimum pool elevation the reservoir would have a capacity of 5,440 acre-feet and a surface area of 596 acres. Normal reservoir drawdown would be from 5 to 10 feet annually.

1/ All elevations are in feet and refer to mean sea level.

The reservoir would be lined throughout with a PVC membrane to prevent seepage. This membrane would have to be covered with volcanic cinders for protection and stability. The present dam would be removed and replaced with a rolled, earthfilled structure 1,500 feet in length and rising about 65 feet above streambed.

Pertinent data for Wilkins and Upper Lake Mary Reservoirs are given in the following table:

Mogollon Mesa Project Reservoirs

Storage Allocation	Pool Elevation (feet MSL)	Capacity (acre-feet)	Water Surface (acres)
Wilkins Reservoir			
Dead Storage	6,080	6,000	167
Inactive	6,104	10,400	220
Conservation	6,194	45,000	568
Upper Lake Mary			
Dead Storage	6,800	600	155
Inactive	6,815	5,440	596
Conservation	6,842.6	29,500	1,089

Projections of fish and wildlife trends and public use of these resources are based on a 100- year period of analysis.

FISH

Without the Project

The area of project influence on aquatic resources would include Upper and Lower Lake Mary, and Walnut and East Clear Creeks.

Fish species found within the project area include both native and introduced. The native fish fauna occur primarily in Clear Creek which is typical of the Little Colorado River drainage. Native species include the rountail chub Gila robusta grahami, speckled dace Rhinichthys osculus, Little Colorado sucker Pantosteus discobolis, and the Little Colorado spinedace Lepidomeda vittata. Both the roundtail chub and Little Colorado spinedace are listed in the Arizona Game and Fish Department's "Threatened Wildlife of Arizona," January 1976. The following introduced species also occur in Clear Creek: rainbow trout Salmo gairdneri, brown trout Salmo trutta, golden shiner Notemigonus crysoleucas, fathead minnow Pimephales promelas, southwestern plains killifish Fundulus zebrinus and green sunfish Lepomis cyanellus.

Stocking records of the Arizona Game and Fish Department and Arizona State University show that cutthroat trout Salmo clarki, Arctic grayling Thymallus arcticus, brook trout Salvelinus fontinalis, Apache trout Salmo apache, channel catfish Ictalurus punctatus, and longfin dace Agosia chrysogaster have been stocked in the Clear Creek drainage in recent times and may occur in the project area.

During good water years when flows in East Clear Creek are maintained, populations of the native fish increase and spread throughout the drainage. During low water conditions habitat becomes minimal and population densities are reduced. Isolated pools within the streambed sustain the fish population during these low water conditions. One of these pools is located at the junction of East Clear Creek and Willow Creek just above the proposed dam site. The Little Colorado spinedace normally occurred there; however, during the recent aquatic inventory of the project area carried out by the Arizona Game and Fish Department this particular species was not found.

The fish fauna of Upper Lake Mary is entirely introduced. The Lake supports rainbow trout, northern pike Esox lucius, and channel catfish, which provide the main fishery. The lake also supports the golden shiner, fathead minnow, southwestern plains killifish, green sunfish, bluegill, Lepomis macrochirus; black crappie, Pomoxis nigromaculatus; yellow perch, Perca flavescens; and walleye, Stizostedion vitreum vitreum, the latter having been recently introduced by the Arizona Game and Fish Department. The Department presently plants 100,000 trout annually and supplements the viable northern pike population when needed.

Fishing within the project area is confined mostly to Upper Lake Mary which presently supports about 20,000 man-days of fishing annually for trout, northern pike, and channel catfish. With the anticipated future increase in human population, mostly in the Flagstaff and Phoenix areas, the demand for fishing opportunities will increase. However, Flagstaff growth will place increased water demands on Lake Mary resulting in lower lake levels and poorer fishing conditions. Under future conditions fishing pressure is expected to remain near present levels during wet periods and to increase during the drier years.

Within the proposed Wilkins Reservoir site, East Clear Creek supports about 100 man-days of stream fishing for rainbow and brown trout per year. Fluctuating streamflows, including periods of near dry conditions, limit fish production and survival. Difficulty in reaching the stream also helps account for the small amount of fishing. The flow conditions of East Clear Creek and low fishing pressure are not expected to change significantly without the project.

With the Project

Wilkins Reservoir would inundate about 8 miles of East Clear Creek including some of the small pools which are known to sustain residual populations of native fish during drouth periods. Native fish species found within this stream segment would be replaced by species more adaptable to reservoir conditions. The present stream fishery would be eliminated.

It is anticipated that seepage from the dam, estimated at 8,900 acre-feet annually, would reappear immediately downstream of the dam. This seepage would improve the downstream flow regimen resulting in 2 to 3 miles of flowing stream and pool maintenance for an additional 2 miles. Habitat for native fish within these reaches would be improved.

Wilkins reservoir would be relatively unproductive due to its steep sides and small littoral zone. Wide fluctuations would further inhibit productivity. The minimum pool would be capable of maintaining fish populations; however, low productivity and difficult access would limit fisherman use. Annual use of the reservoir during the 100-year period of analysis is estimated at 5,000 man-days valued at $15,000. A fish stocking program would be necessary to sustain the fishery.

Dewatering of Upper Lake Mary during the construction stage would cause a temporary loss of the existing fishery. However, as productivity and fish populations within the reservoir are reestablished, the reservoir would support increased fishing pressure. Average annual fisherman-use is estimated at 50,000 man-days valued at $150,000. Use estimates are based on continued management of the fishery as presently being carried out by the Arizona Game and Fish Department.

WILDLIFE

Without the Project

The project area contains a variety of vegetative types. Cover within Wilkins Reservoir site is composed mainly of broadleaf riparian woodlands including cottonwood, ash, box elder, and Arizona walnut. Ponderosa pine and Douglas fir also occur along the canyon bottom. The canyon slopes support pinon-juniper together with various shrubs and grasses. Along the pipeline route three vegetative types can be found: grassland, pinon-juniper or oak woodlands, and ponderosa pine-Douglas fir. Cover near Lake Mary consists of ponderosa pine and grassland. Several small lakes occur along the pipeline route across Anderson Mesa.

Present access to the project vicinity is limited to primitive dirt roads with the exception of that area around Lake Mary and the northern portion of Anderson Mesa where good access to some of the fishing lakes is available. Lands for the most part are under federal ownership. However, several scattered tracts of private land exist near the southeast end of the pipeline route. Two of these tracts have been subdivided, greatly increasing human intrusion into the area.

The riparian habitat found along East Clear Creek supports the greatest variety of wildlife species. Elk, mule deer, white-tail deer, turkey, black bear, and mountain lion are the big-game species using this area. It is the primary habitat of the white-tailed deer and is used heavily by elk during severe winters. An estimated 50 elk are now dependent on this area during such periods, and this population is increasing.

Upland-game species using the reservoir site include the mourning dove, band-tailed pigeon, cottontail rabbit, and squirrel. Waterfowl use of East Clear Creek is minor. The beaver, ringtail cat, and raccoon are the furbearers found in the area.

The riparian community along East Clear Creek also supports a large variety of nongame birds, mammals, reptiles, and amphibians. Particularly noteworthy is the large number of bats which inhabit caves and crevices along the steep canyon walls.

Species of big-game animals listed for the Wilkins Reservoir site are also found along the pipeline route and in the vicinity of Lake Mary except that white-tailed deer are less prevalent. Also, about 300 pronghorn antelope inhabit Anderson Mesa. The project area is within the best big-game range in Arizona; concentrations of big-game animals, other than deer, are among the highest in the state.

The cottontail rabbit, Abert's squirrel, Gambel's quail, Mearns' quail, mourning dove, and band-tailed pigeon, are upland-game species found in the Lake Mary area and along the pipeline route.

Waterfowl use along the pipeline route and at Lake Mary is substantial particularly during the spring and fall migration periods. Also, some nesting takes place in the numerous small lakes and ponds on

Anderson Mesa and in Upper and Lower Lake Mary. Species nesting within the area are the mallard, pintail, cinnamon teal, redhead, ruddy duck, and coot. Other species occurring in migration are the shoveler, canvasback, blue-winged teal, green-winged teal, lesser scaup, ring-necked duck, bufflehead, American wigeon, gadwall, common goldeneye and Canada geese.

Nongame animals include a large variety of bird species. Of particular significance is the number of bald eagles wintering at Mormon Lake. During the last two or three years from 10 to 14 bald eagles have been observed annually. The area also supports numerous nongame mammals such as the badger, rock squirrel, bobcat, and pocket gopher.

Wildlife habitat conditions are expected to remain essentially the same over the project life. No specific plans have been developed by the Forest Service for habitat improvement now or in the future. However, the habitat is expected to degrade somewhat through increased human use of the area and the possible further subdivision of private lands.

Estimated annual man-days of hunting without the project are: big game, 21,000; upland, 7,500; waterfowl, 3,500; and nongame, 1,500. Hunter use is expected to remain relatively stable over the project life.

With the Project

The construction of Wilkins Dam and Reservoir will result in the clearing of about 600 acres of broadleaf riparian habitat from the conservation pool area. Included will be 8 miles of streamside habitat. This area is used for winter range by mule deer, turkey, and most heavily, by elk. Whitetail deer and bear are year-round residents of the canyon. The big game and other species using the area will be forced to compete with those animals in the surrounding area of suitable habitat. Therefore, the end result will be a reduction in wildlife numbers equivalent to the numbers presently dependent upon the reservoir area. The reservoir also would cut off established migration routes for deer and elk isolating approximately 7,000 acres of key winter range. Browse in the area is currently receiving maximum use and could not stand increased pressure without severely damaging range conditions. The anticipated increase in human activities due to the attraction of Wilkins Reservoir and to improved access would result in degradation of much of the surrounding area for big game, particularly elk, wild turkey, and bear.

The loss or degradation of habitat within the Wilkins Reservoir basin would cause a decrease in populations of upland game as habitat decreases and increased recreational use occurs.

The presence of Wilkins Reservoir would not benefit waterfowl materially. The reservoir would provide a resting and limited feeding area during the spring and fall migration periods, but few waterfowl are expected to remain in the area for any extended time.

Wilkins Dam and Reservoir would have an adverse impact on many nongame animals, especially birds. The destruction of the riparian woody vegetation along the river would reduce or eliminate bird populations that it shelters, particularly nesting species. Conditions for water-oriented birds would be improved with the reservoir.

It can be expected that most species of reptiles and amphibians inhabiting the reservoir area would decrease in numbers as they are displaced to compete for the remaining habitat with other animals.

Construction of the underground pipeline itself would not significantly affect big-game animals. However, the increased access provided by construction and maintenance roads would have a damaging effect on wildlife along the proposed pipeline, particularly elk and antelope. The pumping station to be located in Chavez Pass would be in a migration route for elk and deer, and the pumping station at Jaycox Mountain would be in some of the best elk range in the area. The raising of the dam and lining of the reservoir basin at Upper Lake Mary, during the second stage of the project, would have an insignificant effect on big-game species.

The pipeline would reduce upland-game habitat somewhat; however, populations would remain near their present level. The second stage of the project would have an insignificant effect on upland game.

Waterfowl populations along the pipeline route would be little affected by the construction of the proposed pipeline. However, improved access to the many small lakes and ponds located along the pipeline route across Anderson Mesa would decrease in value as waterfowl habitat because of increased human usage of the area for hunting and other outdoor recreation. The raising of Upper Lake Mary would have an insignificant effect on the waterfowl habitat in the lake area. The lining of the lake basin, on the other hand, would cut off the seepage loss which now helps sustain Lower Lake Mary thereby adversely affecting waterfowl habitat. The lower basin is dependent on this seepage loss for maintenance of its water levels; thus, the lower lake could be greatly reduced in size. Additional study is needed to define this impact.

Losses of nongame animals resulting from construction of the pipeline and second stage work on Upper Lake Mary would be insignificant.

That portion of the power transmission system from the existing Arizona Public Service Company substation to Jaycox Pumping Plant would pass through excellent habitat for antelope and elk. Construction of this new line would result in the loss of additional wildlife habitat. In part, the losses would be temporary as disturbed areas revegetate. However, some permanent habitat loss would be attributable to the maintenance roads and towers. The additional access provided by construction and maintenance roads would open the area to increased human usage thereby degrading habitat conditions. From the Jaycox Pumping Plant to the Wilkins Pumping Plant, the transmission line would follow the pipeline right-of-way so that adverse impacts would be minimized.

Estimated annual man-days of hunting with the project are: big game, 19,000; upland game, 7,500; waterfowl , 4,000; and nongame, 1,000.

DISCUSSION

One purpose of the Mogollon Mesa Project is fish and wildlife development. In fulfillment of this objective, a fish and wildlife plan has been formulated. This plan includes measures for obtaining an acceptable level of mitigation for project-induced losses and also for achieving a feasible level of enhancement.

In order to mitigate for the loss of about 8 miles of East Clear Creek which would be inundated by Wilkins Reservoir, controlled releases should be made to augment the seepage flow from the dam to insure a flowing stream for a distance of about 5 miles downtream of the dam with maintenance of pools for an additional 3 miles. This would provide habitat for those native fish, particularly the Little Colorado spinedace and roundtail chub that would not survive in the lentic environment of Wilkins Reservoir. This stream segment should be maintained for native fish species.

Fish production facilities would be needed to sustain a fishery in Wilkins reservoir. Management of a trout fishery would require the annual stocking of 50 catchables per acre. Production of these fish could best be accomplished through expansion of an existing facility.

At present all of the Arizona Game and Fish Department's coldwater facilities are operating at full capacity. Because of the lack of sites with water of sufficient quality, the construction of a new coldwater hatchery is not possible at this time. The Department is presently negotiating for the purchase of the Silver Creek Hatchery, a private coldwater facility near Show Low, Arizona. This hatchery employs a canal system for the propagation of fish and could be renovated and modernized to increase production. This option may be available at the time of project construction; if not, expansion of a federal hatchery should be considered. Costs of providing the necessary fish are estimated at $35,000 for capital construction and $10,000 for annual operation and maintenance. Rehabilitation of the proposed reservoir should be planned at 5-year intervals at an annual cost of $6,000. These would be fishery enhancement measures and would be subject to provisions of the Federal Water Project Recreation Act (79 Stat. 213).

In Upper Lake Mary the present management program involving fish plants of trout, northern pike and, if the new introduction is successful, walleye is expected to continue. The cost of reestablishing the northern pike fish population in the lake, following reconstruction of the dam and lining of the reservoir, is estimated at $1,500. Planting stock for this purpose could be obtained from nearby lakes. This program should be conducted by the Arizona Game and Fish Department.

The construction and operation of the Wilkins Dam and Reservoir would result in the loss of riparian wildlife habitat along East Clear Creek and Willow Creek. This riparian vegetation and its bordering plant communities provide for maximum species diversity and constitute the most productive wildlife habitat within the project area.

Compensation for the loss of riparian wildlife habitat would require the acquisition of comparable replacement habitat. Acquisition of the Bullpen Ranch on West Clear Creek, a 90-acre parcel within the Coconino National Forest (portions of Sections 2, 3, and 11, T. 13 N., R. 6 E.) would partially fulfill this purpose. This area is relatively flat with good access and therefore has high potential for subdivision or other intensive land use development. Any such development also would adversely affect wildlife values on the adjacent National Forest. The area has been partially cleared and, if purchased, could be returned to native vegetation. This would help mitigate some of the wildlife losses at Wilkins Reservoir but would not provide winter range. Costs of acquiring this area are estimated at $225,000.

Another tract of private land, also located within the Coconino National Forest, would serve as partial replacement of winter range losses. This tract, comprising about 640 acres, is in section 31, T. 14 N., R. 13 E. It, too, is subject to subdivision so that acquisition for mitigation purposes would not only protect its wildlife value but eliminate possible undesirable impacts on the National Forest. The estimated acquisition cost is $250,000.

If acquired, both areas would be incorporated into the National Forest and would be administered by the U. S. Forest Service in accordance with Section 3(f) of the Fish and Wildlife Coordination Act. Under Forest Service management, the two areas would have the capacity to mitigate about 50 percent of the project-induced wildlife losses.

Additional study should be undertaken to determine the impact of lining Upper Lake Mary on Lower Lake Mary. Should this impact greatly alter waterfowl habitat conditions at the lower lake, mitigation measures then should be investigated. Mitigation could be provided through a project-funded waterfowl management program at Mormon Lake which would be implemented by the Forest Service. This program could include the construction of dikes, water control structures, and nesting islands. The extent of project participation in such a program would be determined following further delineation of project impacts on Lower Lake Mary.

Construction of the proposed pipeline and maintenance roads from Wilkins Dam site to the Lake Mary area would result in a reduction of habitat values in the area. To minimize this loss the right-of-way should be kept to a width of 30 feet or less. Also, the exact alignment of the pipeline should be determined on site by representatives of the Bureau of Reclamation, Arizona Game and Fish Department, Forest Service, and Fish and Wildlife Service. Maintenance roads associated with the pipeline should be managed in accordance with Forest Service guidelines and plans for the area.

Adverse impacts on wildlife associated with construction of a power transmission system from the Arizona Public Service Company's substation between Flagstaff and Winslow to the Jaycox Pumping Plant could be reduced if the proposed alternate system originating at the intersection of the pipeline and Bureau of Reclamation's 345-KV line near Long Lake were used. This alternate would not require construction of additional access roads since it would follow the pipeline right-of-way.

To meet the mitigation needs and enhancement potential described in the above fish and wildlife plan, we recommended that:

1. Releases from Wilkins Dam be sufficient to maintain a continuous downstream flow in East Clear Creek for a minimum of 5 miles, and to sustain pools in the streambed for 3 additional miles. These releases are considered to be mitigation for the loss of native fish habitat.

2. Hatchery facilities be constructed to produce the rainbow trout to be annually stocked in Wilkins Reservoir. The facilities would require an estimated capital expenditure of $35,000 and annual operation, maintenance, and replacement costs of $10,000. These costs should be assigned to fishery enhancement and, therefore, would be subject to the cost-sharing provisions of the Federal Water Project Recreation Act (79 Stat. 213, as amended). Location of hatchery facilities should be determined cooperatively by the Arizona Game and Fish Department, Fish and Wildlife Service, and the Bureau of Reclamation at the time of project construction and should be accomplished if possible through expansion or renovation of an existing State facility.

3. Project funds in the amount of $1,500 be made available to the Arizona Game and Fish Department for the purpose of reestablishing a northern pike population in Upper Lake Mary. This cost should be funded as a project expense.

4. An area of 90 acres of riparian habitat on West Clear Creek, known as the Bullpen Ranch, located in sections 2, 3, and 11, T. 13 N., R. 6 E., and 640 acres of winter range habitat, located in section 31, T. 14 N., R. 13 E., be acquired as partial compensation for project-caused wildlife habitat losses. Acquisition costs, estimated at $475,000, should be funded as a project expense. These lands should be incorporated into the National Forest and administered by the U. S. Forest Service in accordance with Section 3(f) of the Fish and Wildlife Coordination Act. The acquired areas should be managed primarily for wildlife under a plan cooperatively developed by the Arizona Game and Fish Department, Forest Service, Bureau of Reclamation, and the Fish and Wildlife Service.

5. Additional hydrological studies be undertaken to determine what impact the lining of Upper Lake Mary will have on Lower Lake Mary. If the study shows that waterfowl habitat would be adversely affected in Lower Lake Mary, mitigative measures should be employed to offset the loss of waterfowl habitat. Such measures could include a project-funded waterfowl management program at Mormon Lake of sufficient magnitude to offset the losses. This program should be implemented by the Forest Service. Such a program might consist of the construction of dikes, water control structures, and nesting islands. The cost incurred should be funded as a project expense.

6. The right-of-way for the pipeline be kept to a width of 30 feet or less and the final alignment of the route be determined cooperatively by a team from the Arizona Game and Fish Department, Fish and Wildlife Service, Forest Service, and Bureau of Reclamation.

7. The alternative transmission system route from the intersection of the pipeline and the Bureau of Reclamation's 345-KV line be used to lessen the impacts on wildlife habitat attributable to the additional access roads required for construction and maintenance should the route from the Arizona Public Service Company substation be followed.

8. All capital and OM&R costs associated with project mitigation measures be treated in the same manner as other project joint costs and allocated among the beneficial purposes of the project.

9. All capital and OM&R costs associated with project enhancement measures be treated in the manner specified within the Federal Water Project Recreation Act (79 Stat. 213).

The opportunity to report on fish and wildlife aspects of the Mogollon Mesa Project is appreciated. Please advise us and the Arizona Game and Fish Department of any changes in project plans so that project effects may be re-evaluated and revisions made in this report if necessary. We look forward to continued cooperation in detailed planning if the project should be authorized for construction.

Gilbert R. Nef

MEMORANDUM FROM THE FISH AND WILDLIFE SERVICE

ARIZONA GAME & FISH DEPARTMENT

2222 West Greenway Road Phoenix, Arizona 85023 942-3000

March 1, 1977

Mr. Richard Morgan, Field Supervisor
U.S. Fish and Wildlife Service
522 North Central Avenue, Room 247A
Phoenix, Arizona 85004

Dear Dick:

The Arizona Game and Fish Department has reviewed the Draft Fish and Wildlife Service Coordination Report dated February 1, 1977, regarding the U.S. Bureau of Reclamation's Mogollon Mesa Project. The Department concurs with the contents of the report with the following exceptions.

Page 8: We object to use of the term "minor" regarding the present stream fishery of East Clear Creek. In Arizona, 8 miles of self-sustaining primitive stream is not "minor", it is a significant amount of relatively pristine and unique habitat which many years provides extremely high quality fishing.

Page 9: The currently applied value of $3 per fishing day should be considered low. Martin, W. E., R. L. Gum, and A. H. Smith of the University of Arizona prepared Agricultural Experiment Station's Technical Bulletin 211 in 1974. The publication entitled "The Demand for and Value of Hunting, Fishing and General Rural Outdoor Recreation in Arizona" estimates that in Arizona Game and Fish Department's Region II, which includes the project area, the consumer surplus value of an average cold water fishing trip was $27.89. Consumer surplus value is a monetary estimate of the satisfaction a consumer receives from a commodity above the price he actually paid for that commodity.

Page 11: Gambel's and Mearns' quail, if present, are marginal.

Page 11: Also, we do not believe waterfowl use of East Clear Creek should be considered insignificant. We think a better term would be unknown since we have seen eight broods of ducks in four trips into the Canyon during the past two years.

Page 12: The waterfowl species list is incomplete. It should include red heads as nesters and the following as migrants: blue-winged teal, green-winged teal, lesser scaup, ring-necked duck, bufflehead, American widgeon, gadwall and common goldeneye. Canada geese are also common migrants.

Page 12: The second paragraph suggests that only 10-14 bald eagles winter in the Mormon Lake-Lake Mary areas. Seventeen eagles have been seen in one area on Mormon Lake alone. The total winter eagle population fluctuates but we believe it may be as high as 40 birds plus during certain peaks of eagle migration. Lake Mary is also important to wintering bald eagles.

Page 13: The canyon bottom is winter range for mule deer, elk, and turkey. Whitetail and bear are year-round residents of the canyon.

Page 15: Lining and raising water levels in Upper Lake Mary will reduce shallows and islands and associated emergent vegetation, resulting in a decrease in waterfowl habitat quality of the area.

Page 17: Due to the lack of productivity in lakes such as the proposed Wilkins reservoir, annual fingerling plants will not provide an adequate fishery. A more realistic plan involves annual plants of 50 catchables per acre at an approximate cost of $10,000. Rehabilitation of the lake should be planned at 5-year intervals at an annual cost of at least $6,000.

We appreciate the opportunity to comment on this report. If further comments or coordination are required, please do not hesitate to contact us.

Sincerely,

Robert A. Jantzen, Director

By: John N. Carr, Supervisor
Planning & Evaluation Branch

JNC:dd

Distribution

(5) Regional Director, Bureau of Reclamation, Boulder City, NV
(5) Director, Arizona Game and Fish Department, Phoenix, AZ
(1) Regional Administrator, Environmental Protection Agency, San Francisco, CA
(3) Regional Forester, U.S. Forest Service, Albuquerque, NM
(1) Forest Supervisor, Coconino National Forest, Flagstaff, AZ
(1) Forest Supervisor, Sitgreaves National Forest, Springerville, AZ
(1) Regional Director, National Park Service, San Francisco, CA
(1) Regional Director, Bureau of Outdoor Recreation, San Francisco, CA
(1) Regional Director, FWS, Albuquerque (ES)
(1) Area Manager, FWS, Phoenix, AZ

LETTER FROM CITY MANAGER, FLAGSTAFF, ARIZONA

CITY OF FLAGSTAFF

P. O. BOX 1208 • FLAGSTAFF, ARIZONA 86001

November 2, 1971

123.86 - MM

Bureau of Reclamation
135 North Second Avenue
Phoenix, Arizona

Attention: Mr. Keith Pinkerton

Gentlemen:

The Flagstaff City Council has gone on record as strongly urging the Bureau of Reclamation to complete the feasibility study on the proposed Wilkins Dam Project just as soon as possible. They are supported in this position by the Flagstaff Water Use and Utilization Commission and the Coconino County Task Force for Water Development. A copy of the Task Force resolution is enclosed.

The Council feels that at this time, the Wilkins Dam Project offers the only known long range solution to the City's water problem. Since water is such a major concern to Flagstaff it is anticipated that based on a favorable feasibility report, the necessary steps will be taken immediately to implement the Project.

Very truly yours,

Leland C. McPherson
City Manager

LCM/lb
Enclosure

R E S O L U T I O N

WHEREAS, the proposed Wilkins Dam on East Clear Creek would greatly aid in developing a water availability supply for the City of Flagstaff and other communities in Northern Arizona;

AND, WHEREAS, the Bureau of Reclamation has commenced a study to determine the feasibility of the proposed Wilkins Dam;

NOW, THEREFORE, BE IT RESOLVED by the Coconino County Task Force for Water Development that they recommend that the City Council for the City of Flagstaff go on record as strongly urging the United States Government to proceed with the feasibility study.

DATED AT FLAGSTAFF, ARIZONA this 2nd day of November, 1971.

Tio A. Tachias

Tio A. Tachias, Chairman Coconino County Task Force for Water Development

MEMORANDUM FROM THE BUREAU OF OUTDOOR RECREATION

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF OUTDOOR RECREATION
PACIFIC SOUTHWEST REGIONAL OFFICE
BOX 36062
450 GOLDEN GATE AVENUE
SAN FRANCISCO, CALIFORNIA 94102

IN REPLY REFER TO:

D6427 LCO
Your ref: 3-700/123.8b

September 24, 1971

Memorandum

To: Regional Director, Region 3, Bureau of Reclamation

From: Acting Regional Director

Subject: Mogollon Mesa Project, Arizona

This memorandum provides planning aid recreation information based on the currently proposed plan of development and is intended for your use in economic studies for the subject project. It should be noted that this information is subject to formal review by a number of interested and affected governmental agencies and, consequently, may require future revision.

The following assumptions have been made in developing these recreation estimates:

1. Operation of reservoir units would be essentially as indicated in hydrographs forwarded this office by your memorandum of June 25, 1971.

2. Use restrictions at Upper Lake Mary for protection of water quality would not be a limiting factor on recreation use.

3. A reservoir zoning plan would be instituted at Lake Mary to protect angling use from high-speed boating activities.

4. High-speed boating activities would be prohibited on Wilkins Reservoir.

5. An improved access road to Wilkins Reservoir will be provided at project cost.

6. Net project-induced fishing use at Upper Lake Mary and Wilkins Reservoir would be 100,000 and 50,000 man-days annually, respectively.

The recreation plan developed for this project is conceptual in nature, providing only sufficient detail for an evaluation of the potential for realizing recreation benefits and the specific costs required for such realization. For example, although it was ascertained that sufficient suitable land is available for the recommended levels of development, no specific sites have been selected. Detailed site selection and planning of recreation areas should be performed during advanced planning stages by the Forest Service, which will have responsibility for the project's recreation administration.

Benefits

General recreation benefits are based on the net change in the quantity and quality of recreation use resulting from project construction, and are estimated in accordance with the procedures and range of values prescribed in Supplement #1 to Senate Document 97. Table 1 summarizes general recreation use and benefits over the life of the project. It should be noted that net use and benefits attributable to project units are based on projected increases in water-dependent uses only.

Angling use and benefits have been developed by the Bureau of Sport Fisheries and Wildlife.

Costs

Cost estimates include provision of facilities for general recreationists, fishermen, and hunters and are based on providing for net project-induced use. Costs relating to fishery stocking and management are not included and will be estimated by the Bureau of Sport Fisheries and Wildlife.

Costs will be incurred for the development of recreation facilities to include camp units, boat launch ramps, swimming and picnicking areas (Lake Mary only), and supporting parking, circulatory roads, water, and sanitation. Tables 2 and 3 summarize facility development and investment costs required for development of Upper Lake Mary and Wilkins Reservoir respectively. (Facilities at Upper Lake Mary would actually be developed in two stages, the first occurring during project construction, and the final stage in approximately project year 10 in response to the anticipated growth in visitation.) No land acquisition for recreation purposes is required; existing lands in Federal ownership and lands within the Bureau of Reclamation's joint-purpose takeline will be sufficient.

Development costs for Upper Lake Mary are based on available standards and are in line with recent Forest Service experience on the Coconino National Forest. A factor of 30 percent has been added to cover contingencies, planning and engineering. Standards were not considered applicable to launching ramp construction at the Wilkins site due to extremely difficult terrain, and consequently a separate cost estimate for this facility has been developed by the Bureau of Reclamation. With the exception of launching ramps at Wilkins Reservoir, replacement costs are based on the complete replacement of facilities every 25 years during the project life. O,M&R costs for the ramps at Wilkins are based on Bureau of Reclamation estimates. Operation and maintenance costs for Lake Mary and the Wilkins Lake Campground are based on an average expenditure of $0.45 per Recreation Day. Table 4 summarizes costs incurred over the life of the project.

Comparison of Benefits and Costs

Tables 1 and 4 provide information required for your feasibility evaluation. We recommend the combining of general recreation and fish and wildlife uses of project reservoirs as a single project purpose inasmuch as this approach more realistically represents the interrelated activities of reservoir users. In the event, however, that separate evaluations of the functions should be desired, the dual-use cost estimates contained in this memorandum may be suballocated to the separate functions based on the ratio of each function's dollar benefits to combined benefits.

Least Cost Alternative

For purposes of cost allocation, it can be assumed that there is no less costly means of providing equivalent recreation benefits which would be precluded by the project's recreation function. Potential demand for water-oriented recreation opportunities in this region far exceeds the potential supply.

We hope this will provide sufficient data for your economic studies. We will be happy to assist you in its interpretation if necessary.

George W. Webber

Enclosures

cc:
Projects Manager, Phoenix Development Office, Phoenix, Arizona
by transmittal slip 9/27/71

Table 1

General Recreation Use and Benefits

Mogollon Mesa Project

Upper Lake Mary

Project Year	1/ Without Project Use	2/ Without Project Benefits	1/ With Project Use	3/ With Project Benefits	Net Benefits
1	40,000	$40,000	50,000	$ 67,500	$ 27,500
5	40,000	40,000	100,000	135,000	95,000
15	40,000	40,000	150,000	202,500	162,500
20	40,000	40,000	165,000	222,750	182,750
100	40,000	40,000	165,000	222,750	182,750

Wilkins Reservoir

Project Year	1/ Use	4/ Benefits
1	5,000	$ 5,750
5	15,000	17,250
100	15,000	17,250

Notes: 1/ Annual Use in Recreation Days.
2/ Annual benefits @ $1.00 per RD.
3/ Annual benefits @ $1.35 per RD.
4/ Annual benefits @ $1.15 per RD.

Table 2

Recreation Development Costs

Upper Lake Mary

Facilities	Initial Development Units	Initial Development Cost	Subsequent Development (Year 10) Units	Subsequent Development (Year 10) Cost	Total Development Units	Total Development Cost
CAMP UNITS: @$3,500 - Include table, grill, parking spur, and pro-rata share of circulatory roads, water and sanitation.	155	$542,500	60	$210,000	215	$752,500
PICNIC UNITS: @$2,500 - Include tables, grills, with pro-rata share of supporting water, parking and sanitation.	65	162,500	25	62,500	90	225,000
BOAT LAUNCHING RAMPS: @$40,000 - Concrete ramp 12' x 150' with supporting parking for cars and trailers and Sanitation.	5	200,000	3	120,000	8	320,000
SWIMMING AREA: @$25,000 - Instantaneous capacity of 100. Includes parking and Sanitation.	1	25,000	0	-------	1	25,000
SIGHTSEER & SHORE FISHERMAN PARKING SPACES @ $300.00	60	18,000	20	6,000	80	24,000
Subtotal		$948,000		$398,500		$1,346,500
Contingency, Planning, & Engineering - 30%		284,400		119,550		403,950
Total		$1,232,400		518,050		$1,750,450
Round		$1,230,000		$520,000		$1,750,000

Table 3

Recreation Development Costs

Wilkins Reservoir

Facilities	Units	Cost
CAMP UNITS: @$3,500 - Include table, grill, parking spur, and pro-rata share of circulatory roads, water and sanitation.	60	$210,000
	30% Planning & Contingency	63,000
		$273,000
BOAT ACCESS UNIT: Includes road connection to joint purpose access road and 3 land launch ramp between El. 6140 and 6194.	1	$414,000*
	Total	$687,000
	Round	$685,000

*BR Estimate: Includes planning, engineering and contingency factors.

Table 4

Summary of Recreation Costs[1/]
Mogollon Mesa Project

Upper Lake Mary

Project Year	Development Costs	Replacement Costs[2/]	Annual O&M Costs[3/]
-1	$1,230,000		
1			$ 49,500
5			72,000
10	520,000		
15			94,500
20			101,250
25		$1,230,000	
30			
35		520,000	
50		1,230,000	
60		520,000	
75		1,230,000	
85		520,000	
100			101,250

Project Year	Development Costs	Wilkins Reservoir Campground Replacement Costs[2/]	Annual Campground O&M Costs[3/]	Annual Boat Access O,M&R[4/]
-1	$685,000			
1			$24,750	$42,000
5			29,250	42,000
25		$273,000	29,250	42,000
50		273,000	29,250	42,000
75		273,000	29,250	42,000
100			29,250	42,000

Notes:
1/ Costs include facilities for both general recreationists, fishermen and hunters.
2/ Replacement costs based on complete facility replacement every 25 years.
3/ O&M Costs based on $0.45 per Recreation Day, including administrative overhead.
4/ BR estimate for boat access unit.

THE ARCHEOLOGICAL, BIOLOGICAL, AND GEOLOGICAL RESOURCES OF THE PROPOSED WILKINS RESERVOIR, LOCALITY, COCONINO AND SITGRAVES NATIONAL FOREST. BY THE MUSEUM OF NORTHERN ARIZONA, DEPARTMENT OF ANTHROPOLOGY

MUSEUM OF NORTHERN ARIZONA
DEPARTMENT OF ANTHROPOLOGY

THE ARCHAEOLOGICAL, BIOLOGICAL, AND GEOLOGICAL RESOURCES OF THE PROPOSED WILKINS RESERVOIR LOCALITY COCONINO AND SITGREAVES NATIONAL FORESTS COCONINO COUNTY, ARIZONA

NATIONAL PARK SERVICE - BUREAU OF RECLAMATION
ORDER NO. 931-21

Final Report

Alexander J. Lindsay, Jr.

Project Coordinator

Sections Prepared by:

James W. Mueller

Archaeologist

Steven W. Carothers

and

R. Roy Johnson

Biologists

George Billingsley

Geologist

Submitted by:

Alexander J. Lindsay, Jr.

Curator of Anthropology

December 31, 1969

FOREWORD

In July, 1969, the Bureau of Reclamation office in Flagstaff contacted the Museum with respect to conducting an antiquities clearance for the Wilkins Reservoir Project. Liaison with the National Park Service followed and shortly after a cost estimate was prepared for the project, with the assistance of Mr. Sid Saunders the Bureau representative, and submitted to the National Park Service for consideration.

Approval of the project was given, and field work began and was completed in the fall of 1969. The various disciplines represented worked together during the planning stages, but independently in the field, with some exceptions, due to the nature of each discipline's goals and methods for collecting data.

The reports which form this study were written by the primary field workers in consultation with one another and with an awareness of the needs of one another's studies.

Each report offers its own recommendations for future work. We propose that the anthropological and biological studies be given major consideration for support. The geological studies appear to involve a need only to investigate the alluvial sedimentation along East Clear Creek as it relates to the archaeological picture and modern ecological circumstances. At a time near the conclusion of the proposed salvage anthropological and biological projects, a period of field work in which the two disciplines coordinate their efforts on the problem of human ecology should be arranged. The focus of this interdisciplinary study should include the historical and prehistoric aspects.

In summary, it is recommended that the salvage work be done in and adjacent to the impoundment area. A combined anthropological and biological project complemented with a sedimentation study is proposed. A cost estimate for this project has been prepared and can be submitted upon request.

Alexander J. Lindsay, Jr.
Project Coordinator

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
Southwest Archeological Center
Box 1562, Gila Pueblo
Globe, Arizona 85501

IN REPLY REFER TO:
770.

001.-

April 27, 1970

Memorandum

To: Assistant Regional Director, Region 3, Bureau of Reclamation, Phoenix, Arizona

From: Acting Chief, Southwest Archeological Center

Subject: Report of Interdisciplinary Investigations in Wilkins Reservoir

Enclosed are two copies of an interdisciplinary report entitled "The Archaeological, Biological, and Geological Resources of the Proposed Wilkins Reservoir Locality Coconino and Sitgreaves National Forests Coconino County, Arizona." Under the direction of Dr. Alexander J. Lindsay, Jr., of the Museum of Northern Arizona, it represents the work of three authors. We are very pleased with the results and have accepted the report as final fulfillment of the terms of our Purchase Order No. 931-21 between the Museum and the National Park Service.

You will note Dr. Lindsay's recommendations for further scientific investigations in the project area. We concur with his recommendations and with those of the authors. He has offered, upon request, to provide cost estimates for additional work.

Thank you very much for providing the funds which covered the costs of this significant research. We especially thank Mr. J. S. Saunders for arranging helicopter support for the field work and for his many other courtesies to the Museum staff.

/s/ Rex. L. Wilson

Rex L. Wilson

Enclosure

A PRELIMINARY STUDY OF THE ARCHAEOLOGY OF THE PROPOSED WILKINS RESERVOIR LOCALITY

James W. Mueller

Museum of Northern Arizona

Wilkins Reservoir Project

Museum of Northern Arizona

Flagstaff

1969

ARCHAEOLOGY - CONTENTS

LIST OF FIGURES

A PRELIMINARY STUDY OF THE ARCHAEOLOGY OF THE PROPOSED WILKINS RESERVOIR LOCALITY

James W. Mueller
Museum of Northern Arizona

Introduction

Purpose

An archaeological reconnaissance of the proposed impoundment area for the Wilkins Reservoir Project was conducted at the request of the Bureau of Reclamation and the National Park Service on October 15-17 and October 27-29, 1969. The purpose of the survey was to provide antiquity clearance for the project.

Location

The reconnaissance occurred in East Clear Creek Canyon, a drainage which forms the boundary between Coconino and Sitgreaves National Forests in Coconino County, Arizona.

Procedures

The Museum of Northern Arizona was represented by James W. Mueller and Peter J. Pilles, Jr., Salvage Archaeologists. The archaeological investigations during the period of October 15-18 were conducted contemporaneously with the geological reconnaissance.

The survey was conducted on foot and by helicopter; the latter mode being a most useful method to locate rock shelters. The helicopter was also used to search out shelters suspected of habitation which, if found, were later reached on foot. This project's geologist located several archaeological sites in the course of his investigations in the inner gorge.

The entire impoundment area was investigated from a helicopter from as low an altitude as safety considerations would permit. The portion of the impoundment area that was most thoroughly investigated on foot lies on the south-facing wall of Clear Creek Canyon between its confluence with Willow Creek and Leonard's Canyon. That portion of the west-facing wall of Wilkins Canyon between its first right-angle bend and its confluence with Clear Creek was also thoroughly reconnoitered on foot. Willow Creek was not foot-reconnoitered due to the rarity of shelters in that tributary drainage.

Two clusters of three-to-five rock shelters each were observed aerially but were not investigated for the presence of cultural remains. These features are located on the south-facing wall of East Clear Creek and Leonard's Canyon, approximately 1 mi. upstream from their confluence. A more complete study of the impoundment area should include an investigation of these shelters.

The platform area between the junction of Arizona Highway 87 and National Forest Service Road 319 and the entire length of the impoundment area were casually and sporadically surveyed both from the air and from a ground vehicle. This reconnaissance was performed incidental to travel to and from the canyon.

Archaeological Inventory

Nine archaeological sites were recorded in the proposed impoundment area. These are plotted on Map 1. The numerical designations in the following summary descriptions of the nine sites refer to the Museum of Northern Arizona system of nomenclature. All sites are located in Coconino National Forest unless otherwise noted. The petroglyph sites are located in the inner gorge. The rock shelter sites are located at the contact of the Kaibab limestone and the underlying Coconino sandstone on the south- or west-facing slope of the canyon walls.

The Sites

NA10,711-Ariz. 0:8:2 (MNA). A rock shelter site with a storage room (Fig. 2) and a possible living room constructed of sandstone masonry (Fig. 3). Two prehistoric bows were found, but neither pottery nor blackened ceilings were encountered. Recommended for complete excavation.

Figure 2. View of NA10,711, Unit B. A small storage room of dry masonry walls that has been crudely plastered and contains handprints; frontal entranceway.

Figure 3. View of NA10,711 Unit A. Apparently dry sandstone masonry forming, with the rear of the rock shelter, a living room or work area enclosed on three sides.

NA10,712-Ariz. 0:8:3 (MNA). Two rock shelters with blackened ceilings yielded a wooden shake (specimen submitted for dendrochronological analysis) in NA10,712A (Fig. 4), and a complete mano, a mano fragment, and a dry-laid sandstone block wall in NA10,712B (Fig. 5). Both shelters lacked pottery. Recommended for complete excavation.

NA10,713-Ariz. 0:8:4 (MNA). One blackened ceiling rock shelter with a mano fragment, surface charcoal, and nonhuman bones that are either burned or fossilized. No pottery or architecture was found. A test trench 1.00 by 0.25 m. was dug into the shelter deposits. Cultural debris was found to be surficial.

NA10,714-Ariz. 0:8:5 (MNA). A rock shelter (Fig. 6) with blackening of the ceiling and surface charcoal, but without pottery. A 50 cm. square test pit was dug near the center of the cave which revealed a lens of moderately dense ash and charcoal. Recommended for complete excavation.

NA10,715-Ariz. 0:8:6 (MNA). A small petroglyph site consisting of several animal figures and a preparation area. Evidence for other utilization of the site was not found. Recommended for test excavation.

NA10,716-Ariz. 0:8:7 (MNA). A large petrograph site consisting of a 5.0 by 1.5 m. panel of petroglyphs and pictographs (Fig. 7). The figures are frequently superimposed and the designs include the reutilization of existing figures in the same and mixed media. A panel of large, recent pictographs is located about 50 yd. downstream from the main, prehistoric panel. No evidence for additional utilization was recovered. Recommended for test excavations below and adjacent to the petroglyph panel.

NA10,717-Ariz. 0:8:8 (MNA). A small petrograph site (Fig. 8) consisting entirely of zoomorphic and geometric forms in petroglyphs and black and yellow pictographs. (Sitgreaves National Forest). Recommended for test excavation below the pictograph panel.

NA10,718-Ariz. 0:8:9 (MNA). A rock shelter with a rock outline built on bedrock and forming a possible living room (Fig. 9). Blackened ceiling, corn cobs, charcoal, burned wood and a nonhuman unmodified bone were also found. No pottery. (Sitgreaves National Forest). Recommended for complete excavation.

NA10,719-Ariz. 0:8:10 (MNA). A rock shelter with surface charcoal, an unidentified long bone fragment, another burned or fossilized bone, and blackened ceiling. Neither pottery nor architecture.

Figure 4. View of NA10,712A. A very small rock shelter with blackened ceiling and possible building rubble.

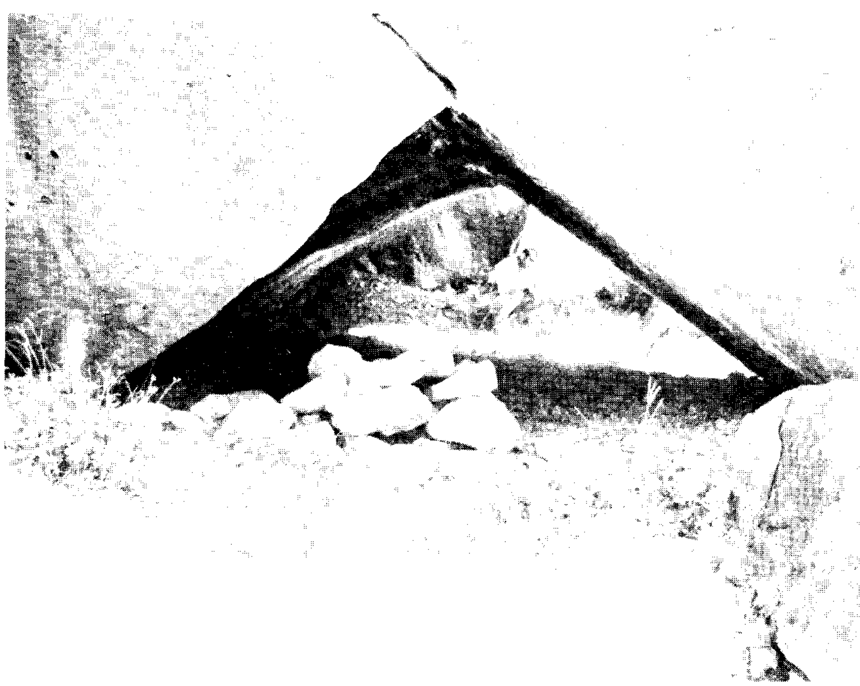


Figure 5. View of NA10,712B. A rock shelter formed by collapse of canyon sandstone and partially sealed at west end by low, dry masonry wall.

Figure 6. View of NA10,714. A rock shelter with scarce cultural debris and no architecture.

Figure 7. View of NA10,716. A large petrograph site consisting of distinct and superimposed petroglyphs and pictographs depicting animals and various geometric forms.

Figure 8. View of NA10,717. A small petrograph site with subject matter similar to NA10,716. Art work also occurs on the roof of the small shelter and on almost inaccessible walls above.

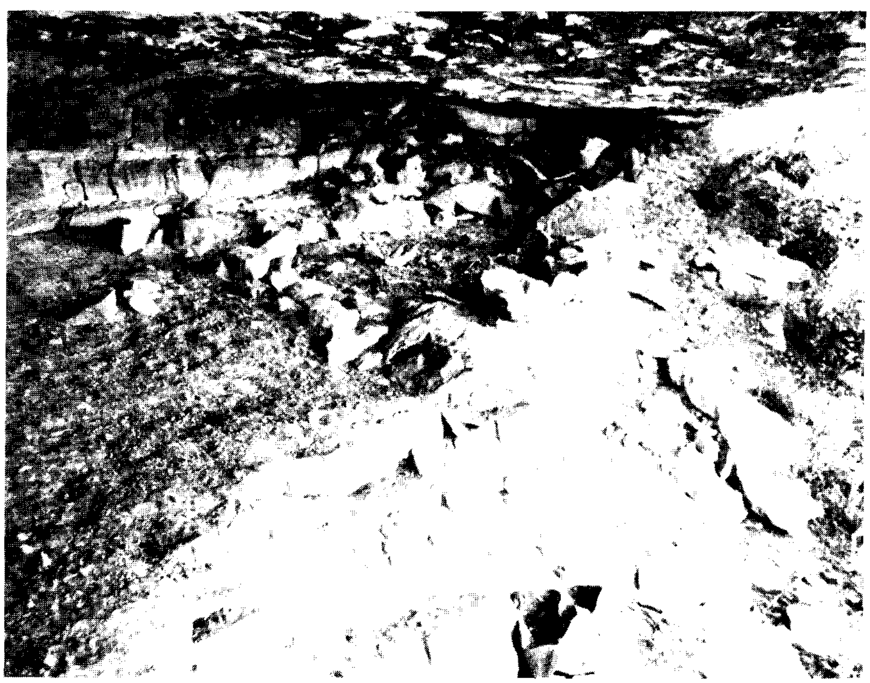


Figure 9. View of NA10,718. A shelter site with a low rock outline that possibly forms a living room.

In addition to the above sites, several finds of isolated artifacts were encountered. A bone awl formed from the ulna of an elk, Cadus cadensis, was found in the fluvial gravels and sands in the inner gorge in the area of NA10,715, a petroglyph site. A foot reconnaissance to nearby suspicious shelters was negative; no occupied shelter was found in the immediate area. Two horseshoes with nails in place were found along the canyon walls. One was found in the area between NA10,716 and NA10,719. The second horseshoe was found in the vicinity of NA10,713.

Many shelters where occupation would be expected revealed no evidence for occupation. This is especially true for the surveyed area of Wilkins Canyon and for some of the larger shelters in the reconnoitered area of Clear Creek.

No prehistoric sites were observed from the air or from the ground during travel to and from the canyon. The plateau between the impoundment area and Arizona State Highway 87 seems to be a prehistorically unoccupied area.

Previous Research in the Clear Creek Region

The most recent archaeological investigation in the general region of the impoundment area is the survey of John Wilson (1969). The nearest permanent occupation in the area is the NA9032 community (see Map 1 for location). This community consists of four sites containing permanent, residential pueblo units, a defensible fort on a promontory in a gooseneck of East Clear Creek, and several small, seasonally-occupied pueblo units. The sites are located about 5 mi. upstream from the proposed dam site. All the sites in the community date in the 12th century.

In addition to the NA9029 community, nine sites are located along East Clear Creek. Eight of these are clustered 2 mi. north of the NA9029 community (Map 1) or about 7 mi. north of the dam site. A fort site is located about 1 mi. south of the NA9029 community. Another site is located 0.75 mi. west of Clear Creek midway between the dam site and the northern cluster of sites.

Wilson's reconnaissance was oriented toward defining the southern and eastern boundaries of the Sinagua culture area. His work included the area east and west of the middle East Clear Creek drainage. The region between East Clear Creek and Chevelon Creek to the east is virtually unoccupied. This area forms the boundary of the southeastern limits of Sinagua culture. From this spatial criterion, Wilson concludes that the NA9032 community can be assigned to the Sinagua culture. The diagnostic Alameda Brownware is not present.

Wilson opines that the smaller pueblos were occupied only during the summertime by peoples other than the residents of the permanently-occupied pueblo. It is not known from where the seasonal occupants came. The large rectangular inclosures may have served as an integrating nucleus for the first occupants to arrive. Wilson assumes an agricultural subsistence base for this in the absence of reasonable alternatives.

Petrographs

Dating

The most helpful work concerning petrograph dating is Turner's (1963) study of rock art of the Glen Canyon region. Turner distinguishes five petrographic styles that are dated on the basis of their association with ceramics and their state of weathering. A brief summary of the styles and their characteristic features will be helpful to an analysis of the petroglyphs.

Style 1 (1850-present): Cultural traits that show an easily recognizable Western influence.

Style 2 (1300-present): Proto-historic and recent Hopi work. Shallow dinting and incising, variable line-width, circular layout, facial features on kachina forms, close affinities between pottery designs and petroglyph designs.

Style 3 (A.D. 1200-1300): Poorly executed outline forms with broad, irregular edged lines, direct percussion (not hammerstone and chisel), horns originating from the neck of sheep, drooping nasal region in sheep, nonnaturalistic representation, qualitatively inferior to Style 4, hammerstone pecking, paucity of element variation.

Style 4 (A.D. 1050-1250): Well-executed pecking, variable subject matter, equidistant dints, hammerstone-chisel technique, and seven characteristic designs.

Style 5 (A.D. pre-1050): Rectilinear, highly obliterated, broad and straight incised lines, cross-hatching, deepest and well-placed dints, solid pecked areas being rare, sheep with large rectangular bodies and reduced appendages, squiggle maze.

Sinagua Petrographic Studies

Turner has additionally described the distribution of these style classes throughout the Southwest. Table 1 summarizes the frequencies of occurrence of each style class in the Sinagua area. Included in this table are sites in the southern Sinagua area and sites within the Sinagua area that manifest extra-Sinaguan influences.

Table 1
Stylistic Frequencies
Within the Sinagua Area

Style One	Omitted
Style Two	4
Style Three	8
Style Four	18
Style Five	4

Conclusions

The rock shelter sites, with the exception of NA10,711 and possibly NA10,712, are probably best interpreted as temporary shelters utilized during hunting and gathering activities. The evidence that supports this contention is the paucity of artifacts, the lack of architecture, the lack of permanent storage vessels as indicated by the absence of potsherds, the nearness to permanent spring-fed water in the upper portion of Clear Creek, and the rich, exploitable flora and fauna that exist in the canyon today. The several grinding tools suggest that some food was being prepared in rock shelters. The present animal trails suggest that the shelters may have been used as "blinds" wherein the occupants waited for the approach of an animal (deer or elk probably) to be killed. The use of fire in these shelters would be expected for warmth or even possibly for cooking. The empirical evidence for fire is questionable; the blackened ceilings may have been caused by nonhuman agents such as patination or plant action. Although there is no evidence to support the idea, it is possible that the shelters may have been "stopover" points used en route to or return from the subsistence activities in the inner gorge.

In addition to their putative use as "stopovers" or "blinds," NA10,711 and NA10,712 may have been minimally used as residential units. The primary evidence for this hypothesis is the presence of architecture. The presence of bows and architecture at NA10,711 strongly supports this hypothesis of the dual hunting and residential use of the site.

The corn cobs found in the rock shelter at NA10,718 suggest that corn was being grown, processed or eaten at the site. Corn agriculture is possible on the raised alluvial terrace at the confluence of Leonard's and Clear Creek Canyons. The ground stone fragment allows for the possibility of corn processing, as well as the grinding of gathered plants. There is no surface evidence that relates to the eating of corn.

The NA9029 community of John Wilson's survey is the nearest prehistoric occupation that can place these temporary, hunting-gathering shelters in a broader cultural context. It will be recalled that Wilson suggested an agricultural base in the absence of a reasonable alternative. The sites discovered during the Wilkins Reservoir Project would appear to constitute a reasonable supplement (not alternative) to the agricultural base. It is hypothesized that the agriculturally-based pueblos at NA9029 and the hunting-gathering rock shelters in Clear Creek form part of the same subsistence-settlement system in the Clear Creek area. The pueblos formed a permanent, agriculturally-based residential unit from which parts of the community occasionally fragmented in order to harvest the rich flora and fauna of the inner gorge. The rock shelters constituted a temporary, campsite, satellite unit to which the hunter-gatherer specialists repaired in order to exploit the canyon bottoms.

The explanation of the location of the temporary shelters is completely speculative. It is possible that high populations at the downstream sites resulted in the overuse of the inner gorge immediately adjacent to the communities. The occupants of the pueblos, suffering from a slight subsistence stress, may have turned upstream in Clear Creek to exploit an area that was previously undisturbed. A superficial conjecture suggests that the biotic communities upstream in the inner gorge are richer than those downstream. This speculation would explain the location of the temporary rock shelters upstream from the permanently-occupied pueblo units. Much empirical data is missing to support or refute these speculations. It is suggested that an initial step would be to determine the presence and distribution of rock shelter sites along the canyon wall in the area of the residential pueblos.

The above subsistence hypothesis relates to the dating of the canyon shelter sites. If these sites are part of the same cultural system, they would necessarily have to be contemporary with the NA9029 community. Wilson has dated the latter sites to the 12th century A.D. Thus, one probably interpretation would be to assign the rock shelters to the 12th century A.D. also.

The cross-dating of petroglyphs from Clear Creek and from Turner's work presents a less clear date of prehistoric occupation. The petroglyphs from Clear Creek manifest several attributes that characterize all of Turner's styles. These attributes are broad, incised lines and squiggle maze (Style 5); variable subject matter, well-executed dints, and two out of seven characteristic designs (Style 4); broad, irregular-edged lines (Style 3); variable line width, shallow dinting and incising (Style 2). Thus, there are suggestions that the petroglyphs date from the A.D. pre-1050 period to the present. This dating does not eliminate an Early Man or Desert horizon date.

Some, but not all of the attributes that characterize this extended time period are present. The absence of the remaining characteristics from the petrographs is difficult to explain. It is possible to speculate a cultural difference as an explanation. Turner's work and dating was based on the petroglyphs in the Anasazi area. The Clear Creek petroglyphs, as will be shown shortly, are not located in the Anasazi area.

The one characteristic that most ,summarily describes the Clear Creek petrographs may be the variation in the subject matter. This attribute characterizes Turner's Style

4. This single attribute approach thus results in a date between A.D. 1050 and 1250, which agrees generally with the 12th century date obtained by the above subsistence-based cross-dating.

A final problem concerns the cultural affiliation of the petroglyph and rock shelter sites. The absence of pottery forces an indirect approach based on spatial criterion. The sites lie within the Sinagua boundary as defined by Wilson, who used this spatial criterion to assign the NA9029 community to the Sinagua area. It seems probable that the sites in the Wilkins impoundment area on East Clear Creek may also be assigned to the Sinagua area.

There is also evidence for an historic use of the Clear Creek Canyon. The isolated occurrences of horseshoes and the pictographs (Style 1), 50 yd. downstream from the main panel at NA10,716, document the historic occupation of the inner gorge. Several abandoned cabins that are located on the plateau west of Clear Creek support the historic use of the Clear Creek area.

Recommendations

Additional survey of suspected occupied sites near the confluence of Clear Creek and Leonard's Canyon is necessary to complete the preliminary reconnaissance that was begun by this project.

Three petrograph sites in the inner gorge will be inundated by the proposed impoundment. Further study and analyses of the art work are necessary to supplement the preliminary photography and recording of this project. Excavation in the riverine sands at the base of these sites is recommended to investigate for the possible utilization of the area adjacent to the rock art.

Six rock shelter sites are located at the rock unit contact zone near the water level of the proposed impoundment. It is expected that these sites may answer some of the problems of settlement, subsistence, and cultural-temporal affinities within and outside of the locality. It is therefore recommended that four of the shelter sites be excavated prior to inundation. Minimum considerations for the choice of sites to be excavated include two sites with architecture (NA10,711 and NA10,712), one site with a blackened ceiling and a minimum amount of artifactual content (NA10,714), and one site with evidence of agriculture (NA10,718). Excavations in the riverine terrace at the confluence of Leonard's and Clear Creek Canyons are proposed in order to test for the possible practice of agriculture in the canyon's gorge.

Stabilization or protective measures at NA10,711 and NA10,712 should be taken after excavation to prevent the destruction of the existing walls by tourism or vandalism.

It is also recommended that consideration be given to broaden the archaeological reconnaissance and excavation programs, to find and investigate prehistoric and historic sites outside of the impoundment zone. Within the limits of what might be termed a recreation area or use area, some sites are already known and others may exist. These sites should be inventoried and excavated, if necessary, to prevent loss of these resources through time as the area is used for recreation and water development.

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A PRELIMINARY STUDY OF THE BIOTA OF THE PROPOSED WILKINS RESERVOIR LOCALITY

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and
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Prescott College

Wilkins Reservoir Project
Museum of Northern Arizona
Flagstaff

1969

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A PRELIMINARY STUDY OF THE BIOTA OF THE PROPOSED WILKINS RESERVOIR LOCALITY

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Introduction

Purpose

The purpose of this study was to collect and record the characteristic features of the flora and fauna in a small area of East Clear Creek and some of the lesser tributaries that drain into it. It was our intention to examine the flora and fauna in a short period of time and extract from that a general description of the ecological relationships occurring within the canyon in the area to possibly be inundated by the proposed Wilkins Reservoir.

Location

The exact location of the Wilkins Dam and Reservoir Site is illustrated on the Department of Interior location map (Fig. 1). The area surveyed during the present study is indicated by the black dashed line.

Procedures

A total of five days was spent on the biological survey of the area to be impounded studying and collecting the associated flora and vertebrate fauna. No attempt was made to study the invertebrate fauna as time would not allow a detailed survey of these life forms. Our report is based almost exclusively on data collected in relation to vascular plants, mammals and birds. On 4 and 5 October 1969 the two principal investigators made observations and collections in the area of Willow Creek and the actual dam site. At this time there were five field assistants used in plant collecting and vertebrate trapping, four from the Museum of Northern Arizona and one from Prescott College. On 17, 18, and 19 October one principal investigator (S. W. Carothers) and three field assistants from the Museum of Northern Arizona traversed the area of proposed impoundment from the dam site south-southwest to Leonard Canyon and back again, collecting pertinent biological data within this area.

The vascular plants were identified by Walter B. McDougall, Museum of Northern Arizona and R. Roy Johnson, Prescott College. The bryophytes were identified by Ardith B. Johnsen, Museum of Northern Arizona.

Ecological Description of Area

The wide diversity of habitat in and around East Clear Creek and Willow Creek illustrates the extent to which microclimatic variations and subsequent vegetational partitioning result from difference in slope exposure and cold air drainage. These microclimatic differences result in a wide range of mesophytic and xerophytic plants and their associated fauna. Figure 2 illustrates the great vegetational differences found on the opposing canyon slopes.

In the area that the Wilkins Dam will impound, East Clear Creek bisects the Kaibab Plateau, having cut through the Kaibab Limestone into the underlying Coconino Sandstone.

Vascular Plants

The vegetation at the top of the plateau is typically pinyon *Pinus edulis* and juniper *Juniperis* spp., with scattered shrubs and subshrubs such as snakeweed *Gutierrezia sarothrae*, prickly pear *Opuntia* sp. and menodora *Menodora scabra* (Fig. 3). Limestone outcrops support fern-bush *Chamaebatiaria millefolium* and rock-mat *Petrophytum caespitosum*.

Of more concern, at present, is the flora in that portion of the canyon that will eventually be inundated once the construction of the dam is completed. Tree species along colder side canyons include ponderosa pine *Pinus ponderosa*, Douglas fir *Pseudotsuga menziesii* and Gambel oak *Quercus gambelii*. Riparian trees consist mainly of narrow-leaf

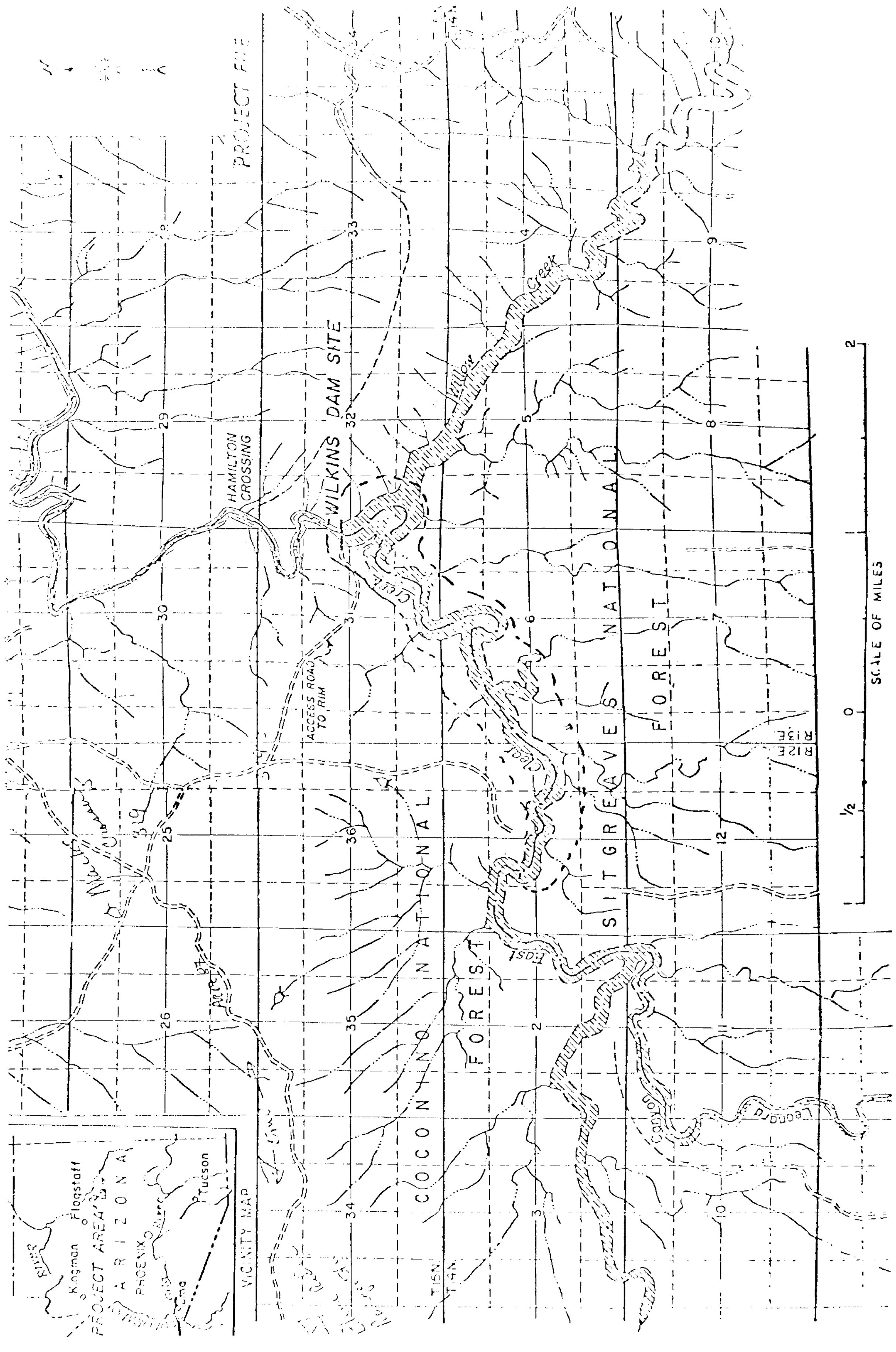

Figure 1. Map of Area Studied.

Figure 2. Willow Creek from the west side of the actual dam site, looking southeast. Note the three main vegetational types, semiarid pinyon-juniper-scrub community on the south-facing slope, the deciduous riparian vegetation on the canyon bottom and the dense coniferous forest on the north-facing slope. The elevational range at this point is from ca. 5900 ft. at the stream bed to 6400 ft. on the canyon rim.

Figure 3. View of the pinyon-juniper woodland on the rim of the canyon.

cottonwood Populus angustifolia, velvet ash Fraxinus veluntina, Arizona walnut Juglans major and boxelder Acer negundo (Fig. 4). It was not uncommon in some areas of the canyon bottom to encounter towering Douglas firs and ponderosa pines. Some of these measured as high as 120 ft. (Fig. 5). Shrubs and woody vines include willow Salix lasiolepis, Arizona grape Vitis arizonica, virginia creeper Parthenocissus inserta, elderberry Sambuscus coerulea, dogwood Cornus stolonifera, gooseberry Ribes sp., and Arizona rose Rosa arizonica. Other trees and shrubs in the stream bottom, but not strictly riparian are rocky mountain juniper Juniperis scopulorum, New Mexican locust Robinia neo-mexicana, poison ivy Rhus radicans and false-indigo Amorpha fruticosa.

Native herbaceous plants which are in evidence along the stream bottom include coneflower Rudbeckia laciniata, wild geranium Geranium sp., meadow rue Thalictrum fendleri, skyrocket Gilia aggregata, cocklebur Xanthium saccharatum, scarlet beardtongue Penstemon bridgesii, goldenrod Solidago altissima, brickellia Brickellia grandiflora, tansy mustard Descuriania richardsonii, and scouring rush Equisetum hiemale.

Introduced weedy species include common plantain Plantago major. white clover Melilotus alba, bug-seed Corispermum nitidum, Russian thistle Salsola kali, knotweed Polygonum persicaria and curley dock Rumex crispus.

Native weedy species include asters Aster spp., bur-sage Franseria acanthicarpa and parasitic dodder Cuscuta campestris. Also collected during our survey were several species of grasses and sedges. These are listed in Appendix I (Biology) along with all the other plants collected during this study.

Generally, the dry east- and south-facing slopes of the canyon support the pinyon-juniper woodland with scattered red mahonia Berberis haematocarpa, cacti Opuntia sp. and century plants Agave sp. (Fig. 6). The steep sandstone cliffs near the base of the west-facing slopes harbor an entirely different vegetation composed of shrubs such as rock spiraea Holodiscus dumosus, percome Pericome caudata, adelia Forestiera neomexicana and mock orange Philadelphus microphyllus.

Bryophytes

Several bryophytes were collected near the dam site in the area to be inundated. Two species of particular interest were found. Rhytidium rugosum, a large moss which

Figure 4. Riparian trees on south side of canyon bottom. The dominant tree species here are narrow-leaf cottonwood, velvet ash and boxelder. This is an example of the habitat in which Microtus mexicanus and Neotoma mexicana were taken.

Figure 5. Isolated stands of mature Douglas fir and Ponderosa pine trees found in the canyon bottom. These trees were known to be utilized by many bird species, particularly Clark's Nutcrackers, Saw Whet Owls and Sharp-shinned Hawks.

Figure 6. Riparian trees on the bottom and semiarid scrub and pinyon-juniper found on the east and south-facing slopes of the canyon. Trees in the foreground are Gambel oak. This is an example of the type of habitat in which Peromyscus boyei and Neotoma albigula were taken.

grows in thick mats, was collected near one of the temporary pools of water. This collection represents the northern-most record of known occurrence of this species in the state. It was known only from Cochise County before. The other moss, Abietinium abietinella, collected with R. rugosum, is known to be endemic in Arizona to the canyon walls of East Clear Creek.

Mammals

Of the many species of mammals seen or trapped in East Clear Creek a few are of special interest. The White-throated wood rat Neotoma albigula, is generally known to inhabit the arid to semiarid plains and deserts (Hall and Kelson 1959: 686). A map (Fig. 7) taken from the most recent work on the distribution of the four subspecies of N. albigula in Arizona (Cockrum 1960: Fig. 76; 193) seems to bear this fact out. The map illustrates that there have been no previous records of this species occurring in a large portion of the state ranging from ca. 30 to 100 mi. wide and 300 mi. long. This area very closely parallels the ponderosa pine-Doublas fir vegetation zone given by Nichol (1937, 1952). On 5 October 1969, three male specimens of this species were captured near the Wilkins Dam Site, which is in the area where they have never been recorded. At this time their subspecific designations are unknown. All were taken on the south- and east-facing slopes of the escarpment. On these slopes the vegetation is typical of arid or semiarid zones. These narrow, but continuous escarpments provide arid to semiarid microhabitats which could serve as dispersion corridors for certain animal, and possibly plant, species. These dispersion corridors would provide species such as Neotoma albigula, xeric avenues through the mesic ponderosa pine-Douglas fir belt. This would allow species, or subspecies, adapted to the more arid regions to the north and south of this coniferous forest barrier to move back and forth through otherwise unsuitable mesic habitat.

The wood rat most commonly associated with the coniferous forest belt is the Mexican wood rat Neotoma mexicana. Two specimens of this species were taken on the north-facing slope of the canyon where the habitat is consistently pine and Douglas fir.

Other mammals captured in the canyon which, to a certain extent, reflect this habitat partitioning are the meadow vole, Microtus mexicanus, and the brush mouse, Peromyscus

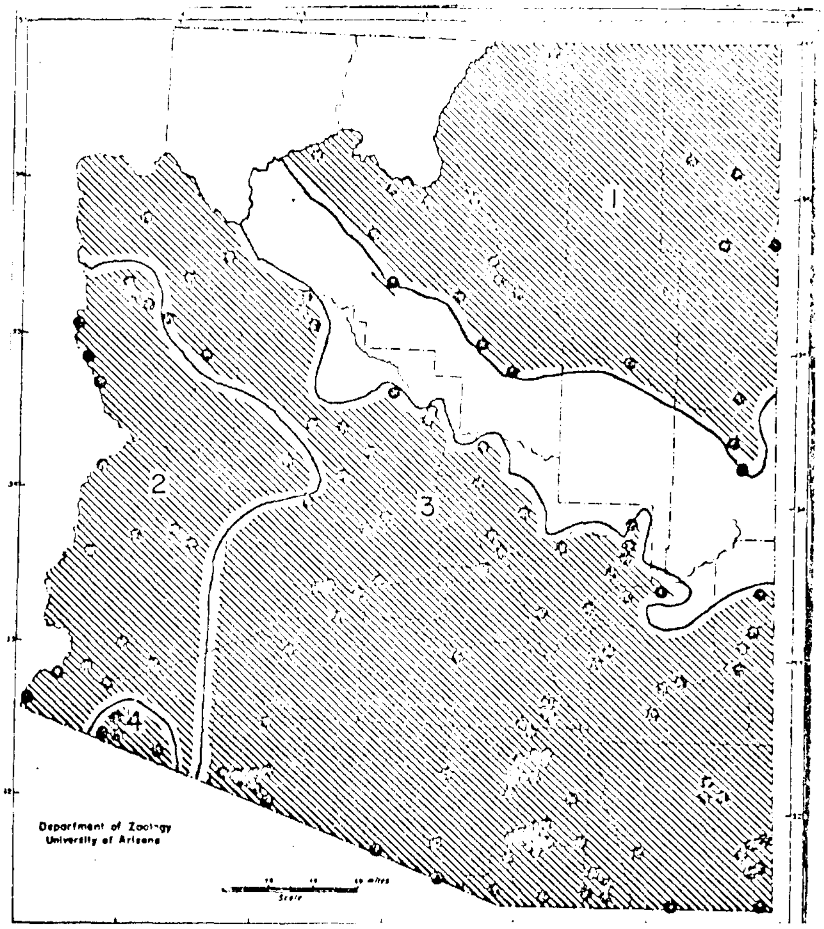

Figure 7. Map showing the distribution of Neotoma albigula in Arizona (from Cockrum 1960: Fig. 76; 193). Black dot represents East Clear Creek collection area. 1, N. a. laplataenis; 2, N. a. venusta; 3, N. a. albigula; 4, N. a. mearnsi.

boylei. These two species are generally separated by elevational differences which reflect habitat changes, the meadow vole being found in mesic montane meadows and the brush mouse occurring in the more arid lowlands. In the inner gorge of East Clear Creek these two habitats exist within 100 vertical ft. of each other, as thus do the two mammals.

The beaver, Castor canadensis, was also found in the study area. According to the distribution map of C. canadensis presented by Cockrum (1960: Fig. 60; 55) the beaver has not previously been reported within 40 mi. of this area. Figure 8 shows a small beaver dam constructed across the dry creek bottom. Dams such as this were found throughout the canyon area and fresh cuttings and tracks were seen around many of the standing pools of water. This is a unique situation in that the beaver are apparently active in dam building beginning at the spring thaw and continuing until the flow subsides, whereupon they then dig into the banks around the standing pools and await the next season's runoff. To our knowledge this behavioral characteristic has not been reported before.

Big game mammals found using the canyon are as follows: mule deer Odocoileus hemionus, Elk Cervus canadensis and the black bear Euarctos americanus. The skeletons of five dead elk were found in the study area. Whether or not these were killed or wounded during the past hunting season could not be determined on analysis of the remains. They had, however, all died at about the same time, which was estimated to be within a year from the time we found them.

A complete list of all mammal species found in the area during this study is found in Appendix I (Biology).

Birds

In another northern Arizona Canyon, Walnut Canyon, Haldeman and Clark (1969)found that the altitudinal distribution of several species of birds was affected by the reversed zonation of plants, i.e., Douglas fir on the bottom of the canyon and pinyon-juniper on the rim. From a precursory examination of the avifauna in East Clear Creek, the same phenomenon probably holds true there. On our late October survey several birds were found using the fir trees in the inner gorge and the north-facing slopes of

Figure 8. Small beaver dam constructed across the dry stream bottom. After each spring flood, the beaver construct new dams until the creek flow subsides, forcing them to dig into the banks around the few standing pools of water found throughout the canyon.

the canyon that are typically found in higher mountains. Examples of these are the Saw Whet Owl, Red-breasted Nuthatch, Brown Creeper, Hermit Thrush, Townsend's Solitaire and Clark's Nutcracker.

Birds usually associated with the more arid lowlands that were seen on the canyon rim, and south and east-facing slopes were the Scrub Jay, Screech Owl and Canyon Wren.

A complete list of the avifauna observed and/or collected in the study area is given in Appendix I (Biology). This list, like the plant and mammal lists, is by no means definitive, and more research is needed during the spring and summer to determine the occurrence of the bulk of the species using the canyon.

Fish

Figure 9 illustrates an isolated pool of water measuring ca. 30 by 60 m. This pool appeared to be quite typical of the many encountered during the course of our investigation. Even though there was no stream flow in the portion of East Clear Creek that we surveyed, the water in the majority of the small pools was quite clear and fresh. Some seemed to remain constant in water supply and were probably spring fed, while others dried up.

Rainbow Trout Salmo gairdneri ranging from 20 to 30 cm. in size were abundant in the small pools. Over 30 individual trout were removed from pools throughout the study area and in some cases the fish seemed to be suffering from malnutrition. When this was the case, it was presumed to have been caused by overpopulation in a pool that was drying up. At the remains of one small pool we found one rainbow trout and one sucker Catostomus sp. in water so shallow that they were not completely submerged.

Judging from the number of mammal tracks found around them, the drying pools afford an important source of food for skunks, raccoons and bears.

Conclusions and Recommendations for Further Study

East Clear Creek Canyon, as a deep, relatively steep-sided canyon, displays a wide variety of habitat which allows a high species diversity of both flora and fauna. This

Figure 9. A typical standing pool of water, the likes of which were common throughout the impoundment area. The pool here measured ca. 30 by 60 m. and the water was quite fresh. As many as 10-15 mature Rainbow trout were seen in pools like this.

wide diversity of habitat is, for the most part, the result of degree and facing slope exposure and cold air drainage, a commonly occurring and well-known phenomenon.

Before all final conclusions can be drawn regarding the ecological relationships between the various species of plants and animals found in the canyon, further research should be done in the spring and summer seasons. Particular emphasis should be placed on a breeding bird study and dependence of breeding birds on the varying vegetational communities occurring in East Clear Creek.

One apparently unique situation that occurs in the canyon that merits further study is the occurrence of Neotoma albigula on the south- and east-facing escarpment. The occurrence of N. albigula here is unique in that this location lies in the middle of the narrow pine-Douglas fir zone that cuts a large path through most of central Arizona. On either side of this coniferous forest zone N. albigula is known to occur, N. a. laplataensis to the north and N. a. albigula to the south, but there has never, until now, been a record of the species occurring within this zone. The specimens found here may represent intermediate forms and may indicate the lack of geographic isolation between the two aforementioned subspecies.

The life history of the beaver in this section of the canyon may also merit further study. To our knowledge it has not been recorded that beaver will become established and thrive in the absence of running water, as they apparently do in areas of East Clear Creek Canyon where the stream flow is intermittent.

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APPENDIX I - BIOLOGY

A Checklist of Plants, Mammals, Birds, and Fish Observed and/or Collected in the Study Area During October, 1969

Vascular Plants

1. Acer Negundo L. Box-elder
2. Agave sp. Century-plant
3. Amorpha fruticosa L. False-indigo
4. Artemisia ludoviciana Nutt. Sagebrush
5. Aster canascens Pursh. Aster
6. Bahia dissecta (Gray) Britton. Yellow-ragweed
7. Berberis haematocarpa Wooton. Barberry
8. Brickellia grandiflora (Hook) Nutt. Brickellia
9. Chamebatiaria millefolium (Torr.) Maxim.
10. Chenopodium album L. Goosefoot
11. Chrysopsis villosa (Pursh) Nutt. Golden-aster
12. Clematis liqusticifolia Nutt. Clematis
13. Corispermum nitidum Kit. Bug-seed
14. Cornus stolonifera Michx. Dogwood
15. Cuscuta campestris Yuncker. Dodder
16. Cyperus ferax L. C. Rich. Flat-sedge
17. Descurainia richardsonii (Sweet) O. E. Shultz. Tansy-mustard
18. Echinochloa crusgalli (L.) Beauv. Barnyard grass
19. Elymus canadensis L. Wild-rye
20. Epilobium adenocaulon Hausskn. Willow-weed
21. Equisetum hiemale L. Scouring rush
22. Erigeron divergens Torr. & Gray. Fleabane
23. Eriogonum alatum Torr. Wild-buckwheat

Vascular Plants (cont.)

24. Eriogonum jamesii Benth. Wild-buckwheat
25. Forestiera neomexicana Gray. Adelia
26. Franseria acanthicarpa (Hook.) Coville
27. Fraxinum veluntian Torr. Velvet ash
28. Geranium sp. Geranium
29. Gilia aggregata (Pursh.) Spreng. Skyrocket
30. Gilia multiflora Nutt. Gilia
31. Gnaphalium grayi Nels. & Macbr. Cud-weed
32. Gnaphalium macounii Greene. Cud-weed
33. Gutierrezia sarathrae (Pursh.) Britt. & Rusby. Snakeweed
34. Holodiscus dumosus (Nutt.) Heller. Fern-bush
35. Humulus americanus Nutt. Hop
36. Juglans major (Torr.) Heller. Walnut
37. Juncus tenuis Willd. Rush
38. Juniperus scopulorum Sarg. Rocky mountain juniper
39. Juniperus sp. Juniper
40. Melilotus alba Desr. White sweet-clover
41. Menodora scabra Gray. Menodora
42. Oenothera laciniata Hill. Evening-primrose
43. Opuntia sp. Prickly pear
44. Panicum bulbosum H. B. K. Panicum
45. Parthenocissus inserta (kerner) K. Fritsch Virginia creeper
46. Penstemon bridgesii Gray. Beardtongue
47. Pericome caudata Gray. Pericome
48. Petrophytum caespitosum (Nutt.) Rydb. Rock-mat
49. Philadelphus microphyllus Gray. Mock-orange
50. Pinus edulis Engelm. Pinyon pine
51. Pinus ponderosa Lawson. Ponderosa pine
52. Plantago major L. Plantago

Vascular Plants (cont.)

53. Polygonum persicarpa L. Knotweed
54. Populus angustifolia James. Narrow-leaf cottonwood
55. Pseudotsuga menziesii (Poir.) Britton. Douglas-fir
56. Psilostrophe sparsiflora (Gray.) A. Nels. Paperflower
57. Quercus gambelii Nutt. Gambel oak
58. Rhus radicans L. Poison-ivy
59. Ribes sp. Currant
60. Robinia neomexicana Gray. New Mexican locust
61. Rosa arizonica Rydb. Wild-rose
62. Rubus neomexicanus Gray. Rubus
63. Rudbeckia laciniata L. Coneflower
64. Rumex crispus L. Curly-leaf dock
65. Salix lasiolepis Benth. Arroyo willow
66. Salsola kali L. var. tenuifolia Tausch. Russian thistle
67. Sambucus glauca Nutt. Elderberry
68. Sisymbrium altissimum L. Tumble-mustard
69. Solidago altissima L. Goldenrod
70. Sporobolus cryptandrus (Torr.) Gray. Sand dropseed
71. Thalictrum sp. Meadow-rue
72. Vitis arizonica Engelm. Canyon grape
73. Xanthium saccharatum Wallr. Cocklebur

Bryophytes

1. Abietinium abietinella
2. Rhytidium rugosum

Mammals

1. Bat Myotis sp.
2. Cottontail Sylvilagus sp.

Mammals (cont.)

3. Rock squirrel Citellus variegatus
4. Cliff chipmunk Eutamias dorsalis
5. Beaver Castor canadensis
6. Western harvest mouse Reithrodontomys megalotis
7. Deer mouse Peromyscus maniculatus
8. Brush mouse Peromyscus boylei
9. Pinyon mouse Peromyscus truei (Possibly on rim)
10. White-throated wood rat Neotoma albigula
11. Mexican wood rat Neotoma mexicana
12. Mexican vole Microtus mexicanus
13. Black bear Euarctos americanus
14. Raccoon Procyon lotor
15. Striped skunk Mephitis mephitis
16. Elk Cervus canadensis
17. Mule deer Odocoileus hemionus

Birds

1. Sharp-shinned Hawk Accipiter striatus
2. Golden Eagle Aquila chrysaetos
3. Turkey Meleagris gallopavo
4. Spotted Sandpiper Actitis macularia
5. Screech Owl Otus asio
6. Saw Whet Owl Aegolius acadicus
7. Red-shafted flicker Colaptes cafer
8. Hairy Woodpecker Dendrocopos scalaris
9. Acorn Woodpecker Melanerpes formicivorus
10. Yellow-bellied Sapsucker Sphyrapicus varius
11. Stellers Jay Cyanocitta stelleri
12. Scrub Jay Alphelocoma coerulescens

Birds (cont.)

13. Clarks Nutcracker *Nucifraga columbiana*
14. Common Crow *Corvus brachyrhynchos*
15. Mountain Chickadee *Parus gambeli*
16. White-breasted Nuthatch *Sitta carolinensis*
17. Red-breasted Nuthatch *Sitta canadensis*
18. Pygmy Nuthatch *Sitta pygmaea*
19. Brown Creeper *Certhia familiaris*
20. Canyon Wren *Catherpes mexicanus*
21. Robin *Turdus migratorius*
22. Townsend's solitaire *Myadestes townsendi*
23. Hermit Thrush *Hylocichla guttata*
24. Western Bluebird *Sialia mexicana*
25. Ruby-crowned kinglet *Regulus calendula*
26. Lesser Goldfinch *Spinus psaltria*
27. Pine Siskin *Spinus pinus*
28. Rufous-sided Towhee *Piplio erythropthalmus*
29. Oregon Junco *Junco oreganus*
30. Gray-headed Junco *Junco caniceps*
31. Chipping Sparrow *Spizella passerina*

Fish

1. Sucker *Catostomus* sp.
2. Rainbow Trout *Salmo gairdneri*

A PRELIMINARY STUDY OF THE GEOLOGY OF THE PROPOSED WILKINS RESERVOIR LOCALITY

George H. Billingsley, Jr.
Northern Arizona University

Wilkins Reservoir Project
Museum of Northern Arizona
Flagstaff

1969

GEOLOGY - CONTENTS

LIST OF FIGURES

A PRELIMINARY STUDY OF THE GEOLOGY OF THE PROPOSED WILKINS RESERVOIR LOCALITY

George H. Billingsley, Jr.
Northern Arizona University

Introduction

Purpose

The purpose of this report is to describe briefly the geology of Clear Creek Canyon, determine what stratigraphic formations are present, and if they deserve further investigation.

Location

The area of study is situated approximately 34 mi. southwest of Winslow, Arizona, in the following townships:

Township 15 North, Range 13 East, Sections 31 and 32.

Township 14 North, Range 13 East, Sections 4, 5, 6, and 9.

Township 14 North, Range 12 East, Sections 1, 2, 3, 10, and 11.

The damsite is located 0.25 mi. north of the junction of East Clear Creek and Willow Creek. The area of study includes the following tributary canyons of East Clear Creek: 1.5 mi. of Leonard Canyon. 0.5 mi. of Wilkins Canyon, 4.5 mi. of Willow Creek, and 9.0 mi. of Clear Creek upstream from the proposed damsite.

Discussion

General Information

The structural geology, mainly fractures and joints, of the Clear Creek region has already been studied. However, the writer feels that the anticline in the proposed damsite area has some structural significance pertaining to the damsite.

Willow Creek Anticline

The regional dip of all the stratified units of the area is in a northeasterly direction about one degree. At the present damsite locality, there is a small anticline with an axial strike, South 49 degrees East. The axis of the anticline is about 0.25 mi. below the damsite location and trends in a southeasterly direction. The damsite is on the southwest limb or flank of the anticline. (No measurement of the dip was taken, but the slope should not exceed 10 degrees.) Because the regional dip is nearly perpendicular to the axial trend of the anticline, a shallow syncline has developed and lies parallel to the anticline on the southwest flank. Willow Creek appears to follow the synclinal trough as if it were structurally controlled by the anticline. Clear Creek seems to have been either superimposed upon the structure, or the anticline was uplifted or rejuvenated into Clear Creek. Clear Creek cuts through the anticline nearly perpendicular to the axis (Fig. 3). The dam will be nearly parallel to the axis of the anticline and updip from the syncline. This position should cut down seepage of water along the bedding planes in the sandstone. Although the bedding planes between cross-beds are not continuous over long distances, the gentle dip southwest still helps to retain water in the impoundment area (Fig. 1).

Many small fractures are present in the lower sandstone formation and parallel the strike of the structures. However, most of these fractures seem very tightly closed and water probably would not penetrate them extensively.

Kaibab Formation

General Statement

The type locality for the Kaibab Formation is located at Kaibab Gulch, Paria River, Southern Utah and was named by Darton (1910). McKee (1938: 13) divided the Kaibab Formation into three members. These members were informally named in ascending order: the Gamma, Beta, and Alpha Members.

The Gamma Member is slope-forming and consists of sandy limestone, thin-bedded and forming a slope. The Beta Member is composed of sandstones, limestones, and

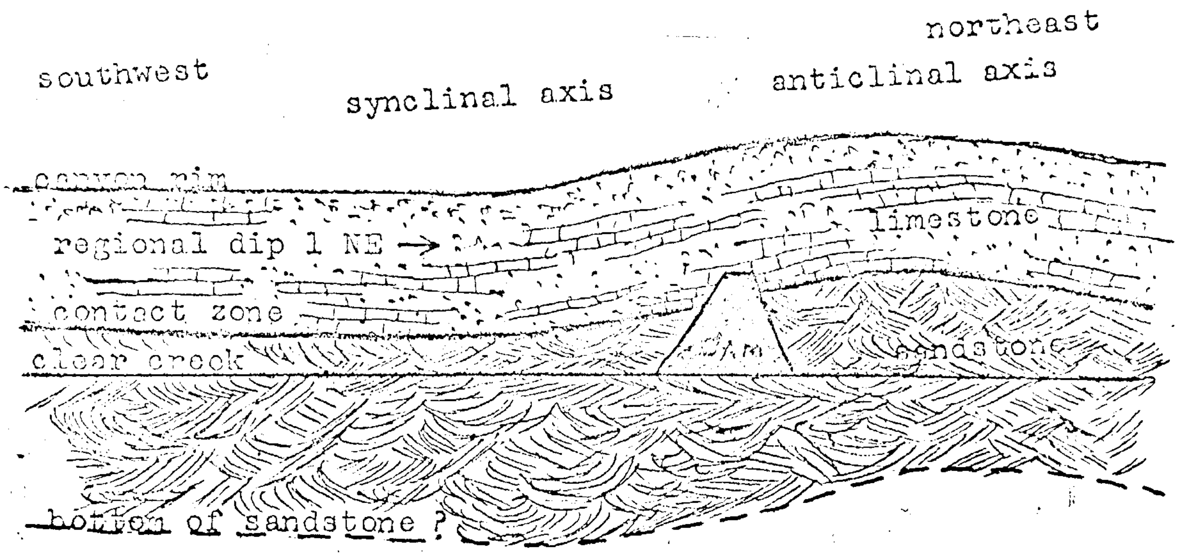

Figure 1. Cross section A-A southwest to northeast through anticline and syncline showing position of dam in relation to the structures. Not to scale.

Figure 2. Aerial view of the junction of Willow Creek and Clear Creek showing the Willow Creek Anticline and Syncline. The view was taken looking east, South 80 degrees, East, at an altitude of about 400 ft. and 1.5 mi. west of the dam site.

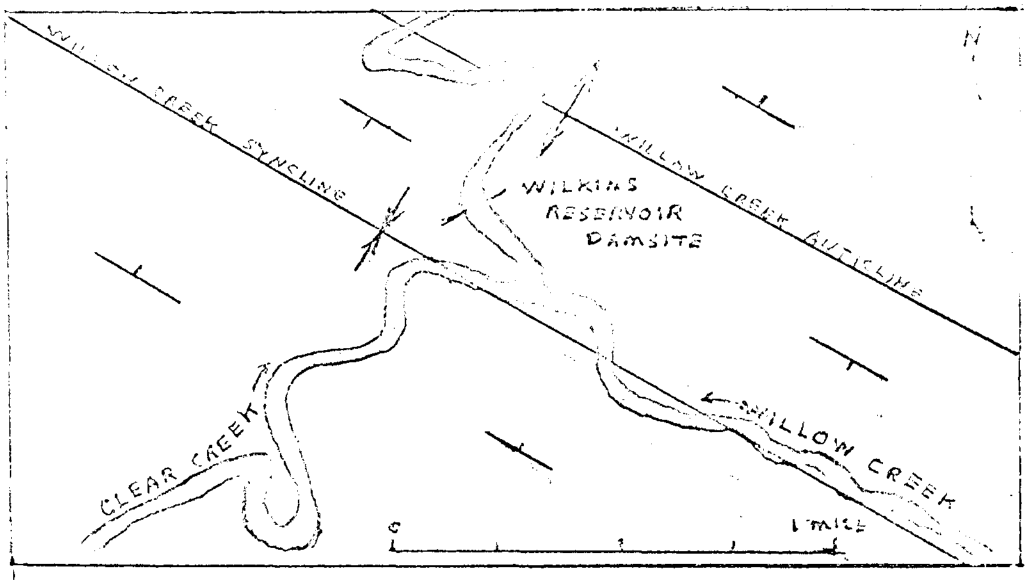

Figure 3. Map showing position of anticline and syncline in relation to Clear Creek and Willow Creek.

interbedded chert and forms the main slope of receding, step-like ledges of the formation. The Alpha Member is formed of alternating thin-bedded limestones and red beds with gypsum.

Kaibab Formation in Clear Creek Area

All three members are present in the Clear Creek area. One section was measured at Mile 4.5 on East Clear Creek (Fig. 3). The Gamma Member measured 136 ft.; the Beta Member measured 191 ft.: and the Alpha Member measured 26 ft. Total thickness for the Kaibab Formation is 353 ft.

The Gamma Member consists mainly of light yellowish-gray to light gray sandy limestone and dolomite with well-rounded quartz sand grains. This member forms a steep slope with a resistant ledge in the lower part.

The Beta Member is the typical ledge-and-cliff forming unit of the Kaibab Formation. Interbedded limestones and sandstones are commonly seen as medium gray, step-like ledges in a very steep angle slope. The sand grains are fine to medium in size and usually well-rounded. Some quartz grains have a frosted appearance as if they were deposited by wind in shallow waters.

The Alpha Member in the Clear Creek region consists of a fine- to medium-grained, well-rounded orthoquartzite sandstone with a calcareous matrix. The sandstone is well-sorted and is a yellowish-white color.

The Gamma Member is noticed only in the north central area of Arizona. The Beta Member in eastern Arizona consists of sandstone and forms an important part of the formation. The Alpha Member changes from red beds and thin-bedded limestones in the west to limestones and sandstones in the east (Brown 1969).

Coconino Sandstone

General Statement

The type locality for the Coconino Sandstone was not designated by Darton (1910) who proposed the name Coconino Sandstone. McKee (1934) also did not specify a type locality for the formation in his study of the Coconino Sandstone. Sorauf (1962: 105) designated the Hermit Basin as the type locality of the Coconino Sandstone from a photograph taken by McKee in that area.

The Coconino Sandstone is an areally-extensive blanket in central and north central Arizona. Throughout the Grand Canyon country it is characteristically white to buff in color, has an almost uniform grain size, a clean, well-sorted sandstone, is cliff-forming, and is almost uniformly cross-bedded. The formation is about 1,000 ft. thick near Pine, Arizona, but thins rapidly to the north, northwest and west. The most distinctive structure in the Coconino is the large-scale, wedge planar, cross-stratification. The inclined laminae have dips of as much as 34 degrees, and have gently curving surfaces that in places are 60 to 70 ft. long. Essentially all of the high-angle foreset beds dip in a southerly direction, indicating the sand was transported by wind from the north (Reiche 1938).

Coconino Sandstone in Clear Creek Area

Typically, the sandstone is a well-sorted, fine-grained to medium size, nearly pure orthoquartzite sandstone. The matrix consists dominantly of silica while carbonate seems to appear in the extreme upper part. The grains are well-rounded to rounded and have a frosted surface. This sandstone is massive and cross-stratified on a large scale.

Fresh rock surfaces are dull white to buff in color. Weathered surfaces have a light gray, dull white color and commonly have a nearly black coating of desert "varnish" which gives a somber appearance to outcrops of this sandstone in distant view, mainly in overhanging areas.

Bedding in the sandstone is characterized by massive cross-stratified units that locally attain a thickness of 195 ft. Cross-stratification on planes is steeply dipping, averaging 23 degrees. The cross strata are generally concave upward and in randomly oriented wedge-shaped sets that give the bedding an erratic appearance. Wherever observed, this cross-bedding has been found to consist of long, sweeping layers averaging about 40 ft. with maximum length about 65 ft. Thick units of cross-bedded sandstone were observed up to 30 ft. per unit. Some of the low-angle slopes in the sandstone show a direction reverse to the normal. This probably means that they represent either depositional or erosional surfaces on the windward sides of the dunes. In general, dip of the foreset beds is to the south and partly southeast, indicating the sandstone was probably transported from a northerly direction. The sandstone is uniform in lithology throughout the investigated area (Fig. 4).

The origin for the sandstone is eolian. Evidence is supplied by very large scale parallel wind ripples, 4 to 6 in. between crests, with rounded flat crests and oriented with axes parallel to the dip slope. Ripples are found mainly on the windward-slope where the load probably exceeded the transporting power of the wind. Frosted quartz grains, the shape and type of cross-bedding, and the dune-like structures are characteristic of eolian deposition.

Conclusion

Because of close similarities of stratigraphy between the strata in Clear Creek and those of the type locality of Coconino Sandstone and the Kaibab Formation, the writer has designated the sandstone of Clear Creek Canyon to be equivalent to, or the same as, the Coconino Sandstone. Furthermore, the upper strata of the canyon are equivalent to the Kaibab Formation.

Since a small area of Clear Creek and its tributaries will be effected by the waters of Wilkins Dam, further geological investigation is not necessary, since there is little change in lithology of strata above and below the impoundment area.

Figure 4. Section of Coconino Sandstone at Mile 1.0 showing the cross-bedding and general appearance. View is looking east and downstream. Photo taken near noon in bottom of canyon.

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APPENDIX I - GEOLOGY
WILKINS RESERVOIR PROJECT
DESCRIPTIONS OF MEASURED SECTIONS

Section #1

Coconino Sandstone

Section was measured at one and a half miles upstream from the damsite on Clear Creek. Start of section is at water level in Clear Creek (Appendix I - Geology, Fig. 1).

Coconino Sandstone:

Sandstone, pure orthoquartzite. Well-rounded to rounded, well-sorted, and medium- to fine-grained. Dull white interior and dull white to buff color on weathered surfaces. In upper part of section, bedding planes have a pale yellow weathered appearance in some locations. Large tabular cross-bedding planes in wedge-shaped units are typical throughout the section averaging slightly smaller units in upper part. Dip of bedding planes is dominantly in a south-southeasterly direction. Measured dips from bottom to top of section are 25, 26, 23, 22, 26, 20, 21, 26, 20, 22, 19, 23 degrees. Average dip is 23 degrees. Forms cliff or very steep angle-resistant slope. 195 ft.

Total for Coconino Sandstone, section #1 is 195 ft.

Section #2

Coconino Sandstone

Section was measured at four and a half miles upstream from the damsite on Clear Creek. Start of section is at water level in Clear Creek (Appendix I - Geology, Fig. 2).

Coconino Sandstone:

Sandstone, same description as in section #1 above. Same type of cross-bedding and forms sheer cliff or very resistant, steep slope. Measured dips or cross-bedding planes from bottom to top are 19, 26, 23, 22, 25, 20, 28, 18, 20, and 23 degrees. Average dip is 22 degrees. 192 ft.

Total for the Coconino Sandstone, section #2 is 192 ft.

Appendix I - Geology, Figure 1. Section #1. View of area of measured section #1 of Coconino Sandstone. Note cross-bedding. Photo taken looking east from west side of Clear Creek at Mile 1.5.

Appendix I - Geology, Figure 2. Section #2. View of the measured section of Coconino Sandstone at Section #2. Note cross-bedding and contact zone. 192 ft. of Coconino Sandstone. Photo taken across Clear Creek looking northwest at Mile 4.5.

Section #2

Kaibab Formation

Section was measured at four and a half miles upstream from the damsite on Clear Creek. Description starts with the Coconino Sandstone and proceeds upward through the Kaibab Formation.

Sandstone, pale yellow to white, well-rounded and fine-grained. Ninety-nine per cent quartz. Tabular cross-bedding with steep dip (24 degrees).

Unconformity:

Horizontal thin laminated sandstone of yellowish-orange color marks the "contact zone" between the two formations. The cross-bedded sandstone has been beveled to a nearly flat surface. Beginning of Kaibab Formation (Appendix I - Geology, Fig. 3).

Kaibab Formation:

Gamma Member:

Calcareous sandstone, nearly level, thinly laminated orthoquartzite, well-rounded, well-sorted, and very fine- to fine-grained. Light yellowish color both interior and exterior. Calcite matrix. 3 ft.

Sandy limestone, yellowish light gray, very sandy. Contorted bedding making irregular surfaces in top part. Forms weathered out caves and overhangs. Crumbly. 3 ft.

Sandy limestone, light yellowish gray both interior and exterior. Sand is very fine and well-rounded. Sand grains are quartz only. Massive bedding. Forms resistant cliff for overhangs above soft contact zone. 19 ft.

Cherty limestone, brownish-white, contains chert nodules in concretionary forms. Forms weathered ledge, easily eroded. 2 ft.

Sandy limestone, massive beds, forms resistant ledge. Light gray surface, very light gray interior. Well-rounded sand grains. 17 ft.

Sandy limestone and limestone, alternating beds. Thin bedded (2 to 6 in.). Light olive gray to very light olive gray. Contains some thin layers of silty limestone. Forms slope. 20 ft.

Sandy limestone, massive bed. Light gray, forms a resistant ledge. 2 ft.

Appendix I - Geology, Figure 3. Contact zone at the lower portion of the Kaibab Formation and upper portion of Coconino Sandstone. Upper part of photograph is the base of the Gamma Member, Kaibab Formation. Lower part is Coconino Sandstone showing cross-bedding beveled at contact zone. Photo taken at top of section #1 at contact zone, top of Coconino Sandstone.

Sandy limestone, light gray exterior, creamy light gray interior. Thin bedded (4 to 10 in.). Some layers are aphanitic dolomite and limestone. Small ledges near top part. Forms slope. 70 ft.

Total for the Gamma Member is 136 ft.

Beta Member:

Sandy limestone, contains calcite geodes and crystals. Uniform bedding of 2 ft. layers. Light gray exterior and very light gray interior. Forms resistant ledge. 27 ft.

Limestone, somewhat dolomitic. Medium olive gray exterior, light olive gray interior. Thick bedding of about 2 ft. average. Forms receding step-like slope. 26 ft.

Limestone, massive, somewhat dolomitic. Forms resistant cliff. Light olive gray interior and exterior. 24 ft.

Sandstone, calcite matrix. Medium grain, well-rounded, orthoquartzite. Thinly laminated, horizontal bedding. Weathers a medium olive gray, very light gray interior. Forms a weak ledge. 4 ft.

Limestone, somewhat dolomitic, 4 ft. massive beds. Olive gray to light olive gray both exterior and interior. Slight trace of very small fossils near top part. Forms resistant cliff. 13 ft.

Sandy limestone, medium gray exterior, light gray interior. Very sandy, interbedded thin layers of orthoquartzite sandstone, yellowish-white interior and light gray exterior. Forms receding ledges. 14 ft.

Limestone, medium gray exterior, light brown gray interior. Slightly fossiliferous near top part. Very small fossils. Forms step-like slope. 13 ft.

Sandy limestone, light gray exterior, very light gray interior. Forms slope. 22 ft.

Calcareous sandstone, weathers medium gray to light gray, yellowish white interior. Horizontal bedding, thin bedded, forms resistant ledges. Sand grains are well-rounded quartz and fine-grained. 19 ft.

Limestone, dark gray exterior, medium gray interior. Thin-bedded, highly calcareous limestone with alternating thick massive limestone beds (6 in. to 4 ft.). Forms step-like ledges. 29 ft.

Total for the Beta Member is 190 ft.

Alpha Member:

Sandstone, very light yellowish-gray to dull white on both exterior and interior surfaces. Fine- to medium-grained, well-rounded to rounded quartz grains. Horizontal bedding, thinly laminated. Medium sorting, calcareous matrix. Forms ledges and slope. Also top of canyon rim. 26 ft.

Total for the Alpha Member is 26 ft.

Total for the Kaibab Formation is 353 ft.