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THE RESOURCES AGENCY

Department of Water Resources

BULLETIN No. 22

SHASTA COUNTY INVESTIGATION

JULY 1964

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
Department of Water Resources

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ACKNOWLEDGMENT

Valuable assistance and data used in this investigation were contributed by agencies of the State and Federal Governments, Shasta County, public districts, and private companies and individuals. This cooperation is gratefully acknowledged.

Special mention also is made of the helpful cooperation of the following:

California Department of Fish and Game, Region I
California Division of Forestry
California Division of Mines, Redding Office
California Division of Highways, District II
Shasta-Trinity National Forest Headquarters
Shasta County Department of Water Resources
Shasta County Water Resources Board
Farm Advisor and Agricultural Commissioner of Shasta County
Pacific Gas and Electric Company

ATE OF CALIFORNIA—RESOURCES AGENCY

WILLIAM E. WARNE, *Director*

EPARTMENT OF WATER RESOURCES

. BOX 388
RAMENTO

May 13, 1964

Honorable Edmund G. Brown, Governor,
and Members of the Legislature
of the State of California

Gentlemen:

I have the honor to transmit herewith Department of Water Resources final edition of Bulletin No. 22, "Shasta County Investigation". The investigation leading to this report was conducted under terms of cooperative agreements between the State of California and Shasta County.

The bulletin contains basic data on surface and groundwater supplies in Shasta County, and estimates of present and future water requirements for the county. The report presents a general plan for developing local water supplies as well as utilization of major works constructed in and adjacent to Shasta County.

The preliminary edition of Bulletin No. 22 was published in December, 1960. A public hearing on the preliminary edition was held on December 27, 1963, in Redding, California, to receive comments from interested agencies, groups, and individuals. Comments received from Shasta County have been included as an appendix to the final edition.

Basic data and other information contained in this bulletin have been reported by officials of Shasta County to have been of great value to local interests and districts in recent implementation of developments of the water resources of that county to meet their water needs.

Sincerely yours,

William E. Warne

Director

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

EDMUND G. BROWN, Governor
HUGO FISHER, Administrator, The Resources Agency of California
WILLIAM E. WARNE, Director, Department of Water Resources
ALFRED R. GOLZE, Chief Engineer
JOHN R. TEERINK, Assistant Chief Engineer

NORTHERN BRANCH

John M. Haley . . . . Chief
Stuart T. Pyle . . . . Chief, Planning Section

The Shasta County Investigation was conducted and the preliminary edition of the report dated May 1960 was prepared under the direction of

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Porter A. Towner . . . . Chief Counsel
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Isabel C. Nessler . . . . Coordinator of Reports

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NORRIS POULSON, La Jolla[3/]

MARION R. WALKER, Ventura

----0----

WILLIAM M. CARAH
Executive Secretary

ORVILLE ABBOTT[4/]
Engineer

Changes in membership of California Water Commission after publication of preliminary edition of Bulletin No. 22.

1/ Appointed January 19, 1961, succeeding James K. Carr, Sacramento.
2/ Appointed February 14, 1963, succeeding George Fleharty, Redding.
3/ Appointed April 4, 1962, succeeding Samuel B. Morris, Los Angeles.
4/ Appointed December 1, 1963, succeeding George Gleason.

ORGANIZATIONAL CHANGES

The Shasta County Investigation was conducted from 1955-56 under the direction of the State Water Resources Board by the former Division of Water Resources, Department of Public Works, and from 1956-59 by the State Department of Water Resources.

A. D. Edmonston (now deceased) was State Engineer and Secretary of the former Water Resources Board at the time of his retirement up to November 1, 1955. He was succeeded by H. O. Banks who served as State Engineer until that office was abolished by June 5, 1956; at which time the Department of Water Resources was created and Mr. Banks was appointed as Director.

William E. Warne succeeded Mr. Banks, who resigned from the Department to enter private consulting business on January 1, 1961.

In July, 1962, the Department of Water Resources was placed organizationally in the newly created The Resources Agency of California. Mr. Warne was appointed Acting Administrator to The Resources Agency in addition to continuing as Director of the Department of Water Resources. Mr. Hugo Fisher was appointed Administrator of The Resources Agency on January 7, 1963.

This investigation was carried out under the general direction of William L. Berry who was in charge of planning in the former Division of Water Resources and Chief of the Division of Resources Planning in the Department of Water Resources subsequent with July 5, 1956.

PUBLIC HEARING
ON
Preliminary Edition
of
Bulletin No. 22, Shasta County Investigation

In accordance with the Water Code and the Department of Water Resources' policy, a public hearing was held on March 27, 1964, in Redding, California, to receive comments from interested agencies, groups, and individuals on the preliminary edition of Bulletin No. 22, "Shasta County Investigation."

Eight persons in addition to the staff from the Department of Water Resources attended the meeting, including representatives from federal, state, and local governmental agencies

Two persons made comments at the hearing. Mr. John Perez, Chairman of the Shasta County Board of Supervisors, introduced Mr. Arnold Rummelsburg, Director of Shasta County Department of Water Resources, who gave verbal comment on the bulletin at the hearing. Mr. Rummelsburg's statement discussed several water projects that have been initiated since issuance of the preliminary edition of Bulletin No. 22. He referred to Shasta County's written comments on the technical aspects of the investigation that have been included as an appendix to this bulletin.

On the basis of review of oral and written comments received at the hearing, and written comments received by mail subsequent to release of the preliminary edition of Bulletin No. 22, it appears that the objectives of the investigation have been reasonably accomplished. It was found, however, that some disagreements exist over the results of estimates of present and future water requirements for Shasta County. Local interests apparently feel that the state's estimates set forth in Bulletin No. 22 are too low. An analysis of our most recent (1964) studies indicate that possibly some of the values shown in Bulletin No. 22 may be slightly low. However, since these water use studies are not as yet complete there is no sound basis upon which to change estimates shown in the bulletin.

It was therefore concluded that no technical and only minor editorial revisions were necessary prior to the publication of the final edition of Bulletin No. 22. Moreover, it was anticipated that future Coordinated Statewide Planning studies by the Department of Water Resources will include updating of estimates on water use and water requirements, based on more refined data.

Copies of the transcript of the March 27, 1964, hearing are on file with the Department of Water Resources in Sacramento and are available for review by the public.

Verbal comments were made at the hearing by the following persons:

Mr. John Perez, Supervisor, Shasta County

Mr. Arnold Rummelsburg, Director of Water Resources, Shasta County

Written comments were received from the following:

Department of Fish and Game, State of California

Federal Power Commission Regional Office, San Francisco

Shasta County Department of Water Resources

CHAPTER I. INTRODUCTION

Shasta County, one of the great water-producing areas of California, is confronted with mounting demands for its water resources as a result of the rapid increase of state and county populations during recent years. The water resources of the county far exceed the present demands, as well as the estimated future demands for water to meet local needs. Because of this factor, Shasta County is faced with important decisions regarding the development of its water resources for both local and statewide use.

The people of Shasta County have shown increasing interest in the ultimate disposition of the local water resources; there is concern that appropriation of water for use in areas outside the county could jeopardize future local development.

Although active in obtaining water for its present needs, the county has realized the necessity of formulating a long-range plan for developing supplemental water supplies for future local needs. It has become of paramount importance to Shasta County to have a water plan that would serve to guide and coordinate the activities of the county in the future development and utilization of its water resources.

Authorization for Investigation

The Shasta County Board of Supervisors, in a letter dated November 24, 1954, requested the State Water Resources

Board to make a preliminary survey of the county's potential water supply with a view toward a program for a comprehensive investigation. The State Water Resources Board referred the request to the State Engineer with instructions to examine the content of the request, to make a report on the need for the investigation, and, if the need existed, to estimate the scope, duration, and cost of such an investigation.

On April 1, 1955, the State Water Resources Board approved a three-year cooperative investigation, recommended by the State Engineer as a result of the preliminary findings, and authorized negotiation of an agreement between the State of California and Shasta County. The agreement, effective as of July 1, 1955, provided that the proposed study:

> "... shall consist of a three-year program of investigation and a report directed toward the formulation of plans for the orderly development of the surface and underground water resources of Shasta County. The investigation shall embrace all aspects of water development including, but not necessarily limited to, irrigation, urban, industrial, and mining use, hydroelectric power, flood control, fish, wildlife, and recreation. The investigation shall also include consideration of imported water supplies and their integration with local plans of water development. Problems of water quality shall be considered where pertinent."

This agreement also authorized the provision of funds to meet the costs of the investigation for one year. A previous interim agreement between the parties, effective as of May 1, 1955, provided funds for preliminary studies during the months of May and June 1955. A supplemental agreement, effective as of July 1, 1956, authorized funds to meet the costs of the investigation for the second year. A second supplemental agreement, effective as of July 1, 1957, authorized funds to complete the investigation and the report.

For the 1957-58 fiscal year, funds were provided under the California Water Development Program by the Budget Act of 1957, Item 263 (a). These funds were utilized to expand the investigation to include work of statewide interest. During the 1958-59 fiscal year, funds provided by the Budget Act of 1958, Item 257, were utilized to continue work on the report.

Copies of the agreements between the cooperating agencies are included in Appendix A, entitled "Agreements Between the State Department of Water Resources, or its Predecessors, and the County of Shasta".

Objective and Scope of Investigation

The objective of the Shasta County Investigation was the collection and cataloging of basic information relating to the surface and ground water resources of Shasta County and to formulate plans for their orderly development. To attain this objective, it was necessary to make inventories of the water resources and water requirements of the county before determining a general plan of physical works for development of water for local use. The physical works were considered not only as individual projects, but also as developments that might be coordinated with the Trinity River Division of the Central Valley

Project and with features of The California Water Plan. Moreover, in accordance with multipurpose planning concepts, consideration was given to combined development of the water conservation, flood control, power development, fish, wildlife, and recreational aspects of each project.

The Shasta County Investigation required extensive field and office studies, as well as review of data developed in previous investigations. Field work for the investigation commenced in May 1955, and, as data accumulated, office studies were initiated to formulate plans for development of the water resources. Although studies of proposed water supply projects were limited to a preliminary determination of engineering feasibility, these studies were in sufficient detail to identify projects worthy of further consideration.

Hydrologic studies, including the collection and compilation of precipitation and stream flow data, were made to evaluate the surface water supplies available to Shasta County. This work involved cooperation among the Department of Water Resources, Shasta County, and agencies of the Federal Government in the installation and maintenance of eight additional stream gaging stations.

Field work also included studies of geologic features of the valley fill areas in order to determine and define the characteristics of the ground water basins. Geologic exploration of foundation conditions was conducted at five dam sites.

Construction materials and borrow areas were located, and soil samples were tested in the laboratory.

At each dam site, two or more plans of development, incorporating different reservoir storage capacities, were formulated. Preliminary engineering designs and estimates of capital and annual costs were prepared for each plan. Operation studies were made to estimate water yield of each project.

Estimates of recreational benefits in Shasta County, as determined for the Northeastern Counties Investigation, were reviewed and are included in this bulletin.

Related Investigations and Reports

Many prior investigations and reports were reviewed in connection with the Shasta County Investigation. Of particular importance are two recent investigations summarized in the following paragraphs.

The State-Wide Water Resources Investigation, initiated in 1947 and completed in 1957, was conducted under direction of the State Water Resources Board by the Division of Water Resources of the Department of Public Works. Three bulletins were published containing the results of this investigation. State Water Resources Board Bulletin No. 1, entitled "Water Resources of California", published in 1951, contains a compilation of data on precipitation, unimpaired stream runoff, flood flows and frequencies, and quality of water throughout the State. State Water Resources Board Bulletin No. 2, entitled "Water Utilization and Requirements of California", published in June 1955, includes determinations of the present use of water throughout the State for all consumptive purposes and presents forecasts of probable ultimate water requirements, based in general on the capabilities of the land to support further development. The third and concluding phase of the State-Wide Water Resources Investigation was reported in Department of Water Resources Bulletin No. 3, entitled "The California Water Plan", published in May 1957. This bulletin presents preliminary plans for the full practicable development of the water resources of the State to meet the ultimate water needs for the benefit of all areas of the State and for all beneficial purposes.

The Northeastern Counties Investigation, conducted during the period 1954 through 1957, was a detailed study of land uses and water needs covering 15 northeastern counties of California, including Shasta County. A report on the investigation, Department of Water Resources Bulletin No. 58, entitled "Northeastern Counties Investigation", was published in June 1960.

Area Under Investigation

Shasta County, with an area of about 3,847 square miles, is located in the northcentral part of the State at the northern extremity of the floor of the Sacramento Valley. West of the Sacramento River, the southern boundary of the county follows in part the main stem and Middle Fork of Cottonwood Creek. East of the Sacramento River, the southern boundary follows the main stem and North Fork of Battle Creek and Digger Creek, a tributary of North Fork of Battle Creek. The southern boundary extends entirely across the drainage basin of the Sacramento River. The western boundary follows the watershed divide between the Sacramento and Trinity Rivers. The northern and eastern boundaries do not follow natural features. The northern boundary is an east-west line lying slightly more than 1 mile south of Dunsmuir, while the eastern boundary lies almost 4 miles east of McArthur and extends along north-south section lines. The area under investigation is shown on Plate 1, entitled "Location of Shasta County".

To facilitate reference to its many parts and to aid in hydrologic analysis, Shasta County, a portion of the Sacramento River Basin of the Central Valley Hydrographic Area, has been subdivided into 17 hydrographic units. The hydrographic unit boundaries were determined from considerations of water supply and related water service. Hydrographic units in the mountainous and upland areas were separated on natural drainage lines of the larger tributary streams and at convenient stream gaging stations. Boundaries of hydrographic units on the valley floor were established with consideration of those water-using units having similar physical and operational characteristics. Principal factors considered were present and potential sources of water supply, and the facilities of existing water service agencies. Boundaries and numbers of the hydrographic units described in this bulletin are shown on Plate 2, entitled "Hydrographic Units". Numbers and names of hydrographic units used in the Shasta County Investigation and the Northeastern Counties Investigation are cross-indexed with those used in State Water Resources Board Bulletin No. 2, entitled "Water Utilization and Requirements of California", as presented in Table 1 of this bulletin.

Natural Features

The northern portion of the Sacramento Valley floor extends into the southcentral portion of Shasta County. This area, with the adjacent foothills, constitutes the core of the county, a region of alluvium-filled bottom lands and low flat-topped ridges, 400 to 1,000 feet in elevation, covered with brush and trees.

The topography surrounding the core area, except for Fall River Valley in the northeastern part of the county, is characterized by volcanic plateaus, rugged mountains, and deep stream-cut channels. Between elevations of 1,500 and 2,000 feet, oak and digger pine growth becomes more dense and gradually merges with coniferous forests of pine, fir, and cedar.

The northeastern part of Shasta County lies in the Modoc Plateau area, characterized by brush-covered lava beds

TABLE 1

CROSS-INDEX OF HYDROGRAPHIC UNITS

Bulletin No. 2, "Water Utilization and Requirements of California"		Shasta County and Northeastern Counties Investigations	
Number:	Name	Number:	Name
5A-2	Pit River	16	McArthur
		17	Hat Creek
		18	Montgomery Creek
		21*	Shasta Lake
5A-3	McCloud River	19	McCloud River
		21*	Shasta Lake
5A-4	Sacramento River above Shasta Dam	20	Dunsmuir
		21*	Shasta Lake
5A-5	West Side, Shasta Dam to Cottonwood Creek	22	Clear Creek
		23*	Keswick
		24	Cottonwood Creek
		25	Olinda
5A-6	East Side, Cow Creek to Paynes Creek	23*	Keswick
		32	Stillwater Plains
		33	Cow Creek
		34	Bear Creek
		35	Battle Creek
5A-8	Antelope to Mud Creek	38	Mill Creek
5A-12	Feather River	42	North Fork Feather River
5A-17	Anderson-Cottonwood	50	Anderson

*Contained within more than one Bulletin No. 2 Hydrographic Unit.

with hills and ridges of low relief. Fall River Valley, a portion of this area, is an ancient lake bed at an elevation of about 3,300 feet.

The southeastern portion of Shasta County is also of volcanic origin with numerous volcanoes, extinct cinder cones, and lava flows. This area contains a large portion of Lassen Volcanic National Park.

<u>Drainage Basins</u>

The three principal drainage basins of Shasta County are those of the Pit, McCloud, and upper Sacramento Rivers. These streams join in Shasta Lake, as shown on Plate 2. With the exception of the Modoc Plateau portion of the Pit River Basin, the area drained by these three streams within Shasta County is almost entirely mountainous. The total area of these drainage basins above Shasta Dam is about 6,620 square miles, of which some 2,150 square miles are in Shasta County.

Drainage basins of two major creeks are situated entirely within Shasta County. West of the Sacramento River, Clear Creek drains a rugged mountainous area of about 245 square miles. To the east of the Sacramento River, Cow Creek drains about 426 square miles of the Cascade Range.

Drainage basins of two other major creeks are situated partly within Shasta County and partly within Tehama County. To the west of the Sacramento River, Cottonwood Creek drains an area of about 945 square miles, of which 371 square miles lie within Shasta County. With its headwaters in Lassen Volcanic National Park, Battle Creek drains an area of about 365 square miles, of which 184 square miles are within Shasta County. Many lesser creeks are tributary to the Sacramento River between Shasta Dam and the southern boundary of the county.

About 5 square miles of the headwaters of Mill Creek and about 21 square miles of the upper watershed of the North Fork Feather River are situated entirely within Lassen Volcanic National Park, in the southeastern corner of Shasta County. Water originating in these two stream basins flows south and away from the county.

Climate

Shasta County has a diverse physiography. Hence, the discussion of climate in this section will be only of a general nature. Table 2 summarizes pertinent climatological data for 13 stations in and adjacent to Shasta County and indicates the wide variety of climatic conditions in the county.

The valley area of Shasta County adjacent to the Sacramento River has a climate that is generally characteristic of the Sacramento Valley floor. It is a mild two-season climate with moderate, wet winters and warm, dry summers. The average frost-free period in this area is about nine months. About 85 percent of the seasonal precipitation occurs during the months of November through April. The average of mean seasonal precipitation in the valley area is about 36 inches.

Climatic conditions in the mountains surrounding the valley area are similar to those of the Sierra Nevada. At

TABLE 2

CLIMATOLOGICAL DATA FOR SELECTED STATIONS
IN OR ADJACENT TO SHASTA COUNTY

Station	Elevation, in feet	Frost-free period, in days	Maximum and minimum temperatures for period of record, in degrees Fahrenheit		Mean* seasonal precipitation, in inches
			Maximum	Minimum	
Shasta County					
Redding Fire Station No. 2	577	284	114	17	37.87
Lakeshore	1,075	207	115	12	66.36
Shasta Dam	1,076	283	114	25	56.05
Turntable Creek	1,080	274	114	22	60.86
Volta Power House	2,200	227	110	14	31.90
Hat Creek Power House No. 1	3,015	111	113	-17	17.38
Burney	3,127	58	105	-20	26.88
Fall River Mills Intake	3,340	125	106	-18	17.00
Manzanita Lake	5,850	95	94	-13	42.82
Tehama County					
Red Bluff Airport	341	277	115	17	20.12
Mineral	4,901	80	100	-13	51.79
Siskiyou County					
McCloud	3,300	92	107	-11	49.24
Mount Shasta	3,544	129	108	-9	35.51

*The mean period is the 50-year period from 1897-98 to 1946-47. (The locations of these stations are shown on Plate 4.)

higher elevations the frost-free periods decrease to three months or less, and even in mid-summer the nights are cool. Mean seasonal precipitation in some areas is as much as 90 inches. Much of the precipitation occurs as snowfall which, at higher elevations, does not appear as runoff until late spring. In southeastern Shasta County snow often is seen on the slopes of Mount Lassen in the late summer and fall months.

The Modoc Plateau area in the northeastern portion of the county lies generally between the elevations of about 3,000 and 3,500 feet. Minimum winter temperatures are much lower than those in the valley area and frost-free periods range from two to four months. Much of the seasonal precipitation occurs as rainfall and varies from a mean of about 17 inches at Fall River Mills to a mean of 27 inches near Burney.

Geology

Shasta County is geologically unique in that it occupies portions of 5 of the 11 geomorphic provinces defined on the Geomorphic Map of California published by the California Division of Mines in 1938. Geomorphic provinces are major land areas of similar geologic and land-form features. These provinces in Shasta County include the Klamath Mountains, northern Coast Range, Great Valley of California or Central Valley, Cascade Range, and Modoc Plateau.

The Klamath Mountains province occupies the entire northwestern portion of the county, extending on the west to the southern county line. This region comprises the most rugged terrain of the county. Elevations range from 500 feet near Redding to some peaks of more than 6,000 feet along the drainage divide on the west and northwest which separates Shasta County from Trinity County. The area is underlain by a wide variety of rock types including sedimentary, igneous, and metamorphic rocks of Paleozoic, Triassic, and Jurassic ages. Primarily because of the heavy precipitation, the rocks are deeply weathered, forming thick soils which support a dense growth of vegetation.

Southwest of Redding, in the area between Beegum and Gas Point, a small portion of the northern Coast Range province extends into Shasta County. The rocks of this region abut into the Klamath Mountains and extend eastward beneath the younger sediments of the Central Valley province. The topography of this area consists of low to moderately high, rounded hills and north-trending ridges, all of which are composed of sandstone and shale. The hills and ridges are nearly barren of soil but in places support a sparse growth of brush and trees.

The Central Valley province extends into Shasta County from the south to a northern boundary about 3 miles north of U. S. Highway 299. It occupies an area of low topographic relief, between an approximate boundary on the west extending northerly from the confluence of Cottonwood Creek and its North Fork, and a boundary on the east trending northerly through the town of Millville. This area is essentially a plain, interrupted by the valleys of the Sacramento River; of Cow Creek and its tributaries; and of Clear, Churn, Stillwater, and Cottonwood Creeks. It is partially surrounded by mountainous terrain on the west, north, and east. Thus, the Central Valley province in Shasta County is an interior dissected plain. To the south, the topographic continuity with the main portion of the Central Valley is interrupted by an east-west structural uplift known as the Red Bluff arch.

The Cascade Range province in Shasta County is the southern end of a chain of volcanic cones dominated in California by Mt. Shasta and Mt. Lassen, the latter the southernmost cone. Elevations along the crest of the volcanic chain in Shasta County vary from approximately 4,000 feet to a maximum of over 10,000 feet at Mt. Lassen. Beyond the main alignment of peaks the province continues south into Tehama County. In Shasta County, the province extends westward as far as the Sacramento River. West of the 122° meridian, the province is much dissected by westward and southwestward-trending canyons in which the streams of the Cow Creek drainage system flow. These streams, Little Cow, Swede, Oak Run, Clover, South Cow, and Old Cow Creeks, have eroded through the lava cover, thus exposing older sediments and metamorphic rocks.

The Modoc Plateau province is situated in the northeastern portion of the county and is bounded on the west and the south by the Cascade Range province. The Modoc Plateau province is an extension of the great Columbia lava plateau which occupies large areas of Washington, Oregon, and southern Idaho. The province consists of vast accumulations of predominantly basaltic lava and fragmental volcanics with interbedded water-laid sediments. The elevation of this region in Shasta County averages between 3,000 and 4,000 feet, but many peaks and ridges extend above this general level to elevations of over 5,000 feet. Structurally, the province is characterized by north trending tilted, fault blocks, some of which contain dry lake beds. Fall River Valley in the extreme northeastern corner of Shasta County is a notable example of a dry former lake bed which occupies such a depressed fault block. Hat Creek Valley, southwest of Fall River Valley, is an eastward tilted, down-dropped fault block into which Recent lavas have flowed partially filling the trough. The flat areas along Burney Creek north of the town of Burney have been formed by the deposition of flood plain materials in a depression along the western edge of a westward tilted fault block.

Streams and permanent lakes are rare in the Modoc Plateau province because of high permeability of the lavas. However, perennial streams such as Rising River, Hat Creek, Burney Creek, Pit River, and Fall River and a number of perennial lakes owe their existence chiefly to large springs which feed them. Pit River, the principal stream of the province, has cut well below the once level floor of Fall River Valley and now flows through a deep gorge cutting across a series of fault blocks to Lake Britton and eventually to Shasta Lake.

Soils

The soils of Shasta County have been derived from a variety of materials including volcanic, granitic, sedimentary, and metamorphic rocks. Generally, the volcanics predominate in the eastern portion of the county, while rocks of the western part consist of granitics, sediments, and metamorphics. The soils may be divided into three broad groups: residual soils, old valley-filling soils, and Recent alluvial soils. A delineation of the three soil groups is presented on Plate 3, entitled "Generalized Soils of Shasta County".

Soils of the residual group are formed in place by weathering and decomposition of the parent rock material. These soils vary widely in color, texture, depth, and structure, according to the parent material and the climatic influences to which they have been subjected. Although the most extensive of the three general groups, the residual soils are of minor agricultural significance. The soils occupy the upper foothill slopes and much of the area of the mountainous regions.

The old valley-filling soils are derived from materials transported and deposited by water and subsequently weathered and modified in profile. The soils are very fine-grained and normally consist of well-defined zones of compaction or cementation. The old valley-filling soils usually occupy intermediate positions between the more elevated residual soil group and the lower-lying Recent alluvial soil group. They are located almost entirely within the core area in the southcentral part of the county, although the lacustrine deposits found in the Modoc Plateau area are also included in this group. Where depth is adequate, the soils have some agricultural importance; however, they are generally thin and support only medium or shallow-rooted crops.

Of the three soil groups, only the Recent alluvial soils are of major agricultural importance. They include the deposits of both intermittent and perennial streams, either in the level bottoms or in the sloping fans which have been built up at the foot of slopes bordering the valleys. These deposits have not yet been modified in profile through the processes of weathering and are usually still in process of accumulation. Normally, the Recent alluvial soils vary in color and texture according to the kind of material from which the soils were derived. Most of the agricultural development of the county has taken place in areas containing these soils.

Present Development

Agricultural, timber, and mining industries, hydro-electric power development, and in recent years recreational pursuits have contributed significantly to the economy of Shasta County.

Agriculture. The mainstay of the agricultural development of Shasta County is the livestock industry. Hay and irrigated pasture lands combined with the summer range areas form an integrated livestock management unit. Of the average annual total farm income of $6,000,000, the livestock industry provides $4,900,000.

Field crops, horticultural crops, and specialty crops have contributed materially to the gross farm income. During the past three or four years, the value of strawberry plant production has increased greatly, even though the acreage (about 200 acres) is small. The apiary industry is a large contributor to the gross farm income for specialty crops. The town of Cottonwood is one of the largest bee shipping centers in the United States. Honey and wax are produced, queen bees are sold, and entire colonies are rented for pollination.

Statistics compiled by the California Department of Agriculture indicate that agricultural production of the county has not increased greatly since the early 1920's. Almost all irrigated lands are now being served from water supply systems developed before 1920. In 1955, the date of the last survey of irrigated lands, there were about 46,500 irrigated acres in Shasta County. Since that time, there has been only a minor increase. The magnitude of the livestock industry is evident from the data pertaining to irrigated crops. About 43,400 acres of the total irrigated acreage are devoted to production of feed and pasture. Of the remaining 3,100 acres, 1,300 acres are planted in field crops also used for stock feeding; 1,400 acres are devoted to orchards, of which about 900 are in relatively low-yielding olive trees; and 400 acres produce truck crops (including berry crops).

Industry. Industry in Shasta County is dominated by lumbering which began when gold was discovered, but grew very slowly over the years until the construction boom that started in the late 1930's caused a rapid expansion in the number of mills and in the total production. In recent years the lumber industry, with 94 listed establishments, has been the principal contributor to the economy of the county. The average annual gross value of the products of the lumber industry during recent years has been about $18,000,000.

Other types of establishments listed in the 1954 Census of Manufacture of the United States Bureau of the Census are: seven manufacturers of food and kindred products; six plants engaged in printing and publishing; one manufacturer of stone, clay, and glass products; two plants producing fabricated metal; and two machinery manufacturers.

Although mining was for many years of major importance to the economy of Shasta County, the gross value of mineral production has declined appreciably in recent years. From 1896 until the end of World War I, Shasta County led the State in total value of mineral production, exclusive of petroleum. The average annual value for the period from 1880 to 1951 was over $3,000,000, and for the period from 1955 through 1957 was $1,600,000.

Existing hydroelectric power facilities within Shasta County have a total installed capacity of 845,000 kilowatts, an amount which exceeds the installed capacities of any other county of the State. Two additional major hydroelectric power plants will be constructed in the near future as a part of the Trinity River Division of the Central Valley Project of the United States Bureau of Reclamation. These facilities will then increase the installed capacity to a total of 1,118,000 kilowatts.

Recreation. Due to the accessibility of the county and the wide range of topographic, geologic, and climatic conditions found within its boundaries, many outdoor recreational activities are possible in Shasta County. Development of the recreation potential is encouraged by the numerous areas reserved for public use. These areas include Lassen Volcanic National Park, Shasta National Forest, Trinity National Forest, and Lassen National Forest. Within the national forests are the Thousand Lakes Valley Wild Area, Shasta Lake Recreation Area, the McArthur-Burney Falls Memorial State Park, Castle Crags State Park, Shasta State Historical Monument, and Latour State Forest Reserve.

Fishing is one of the most popular recreational activities. Some of the State's best known trout streams are located in Shasta County. Fish are also caught in the many lakes, ponds, and reservoirs. Game fish include: steelhead, salmon, rainbow and german-brown trout, black bass, crappie, and catfish.

Hunting is another of the popular recreational activities of Shasta County. The deer population attracts most of the hunters, but sportsmen also seek bear and smaller animals, as well as valley and upland game birds.

Shasta Lake has become the center of recreational activity in the county. The lake provides a habitat for both warmwater and coldwater fish, and is used by hunters as a means of reaching areas which were previously of difficult access. Swimming, boating, and water skiing have become very popular, and camp grounds and home sites have been established around the lake. As the pressure of sportsmen and those seeking recreation has mounted, additional access roads and facilities have been constructed.

CHAPTER II. WATER SUPPLY

The water resources of Shasta County are comprised of direct precipitation, surface runoff and ground water within the county, surface and subsurface inflow to the county, and imported water. A portion of this water is used within the county, but most of it flows from the area as surface and subsurface outflow.

Definitions

The following terms are defined for use in the following discussion:

Annual--The 12-month period from January 1 of a given year through December 31 of the same year, sometimes termed the "calendar year".

Seasonal--Any 12-month period other than the calendar year.

Precipitation Season--The 12-month period from July 1 of a given year through June 30 of the following year.

Runoff Season--The 12-month period from October 1 of a given year through September 30 of the following year.

Mean Period--A period of time chosen to represent conditions of water supply and climate during a long period of years. As it relates to runoff, the mean period is the 53-year period from 1894-95 to 1946-47. As it relates to precipitation, the mean period is the 50-year period from 1897-98 to 1946-47.

Base Period--A period of years for which monthly estimates of stream flow are compiled. For purposes of this investigation, the water-deficient years of the 1920's and 1930's were included; therefore, the base period chosen was the 36-year period from 1920-21 through 1955-56. Average seasonal natural runoff for this period was about 90 percent of the mean seasonal natural runoff.

Mean--The arithmetical average of quantities occurring during the mean period.

Average--The arithmetical average of quantities occurring during other than the mean period.

Unimpaired or Natural Runoff (Flow)--The flow of a stream as it would be if unaltered by upstream diversion, storage, import, export, or change in upstream consumptive use caused by development. Unimpaired runoff is reconstructed from measured historical runoff by adjusting for the quantitative effect of alterations in stream flow above the point where the flow is measured.

Historical Runoff (Flow)--The flow of a stream as it has occurred and was or would have been recorded by measuring devices.

Present Impaired Runoff (Flow)--The flow of a stream as it would have been if the present development had existed throughout the period of study.

Free Ground Water--A body of ground water which can be replenished by direct percolation of overlying surface waters and moves in direct relation to the slope of the water table.

Confined Ground Water--A body of ground water overlain by material sufficiently impervious to sever hydraulic connection with overlying water and moving under pressure caused by the difference in elevation between intake and discharge areas of the confined water body.

Specific Yield--The ratio of the volume of water a saturated soil will yield by gravity to the total volume of the soil. It is commonly expressed as a percentage.

Ground Water Storage Capacity--The product of the specific yield and the volume of material in the depth intervals considered.

Specific Capacity--The number of gallons of water per minute per foot of drawdown produced by pumping from a well under steady flow conditions.

Precipitation

Shasta County lies within the path of storms which periodically sweep inland from the Pacific Ocean during the winter and spring months. The precipitation from these storms ranges from moderate to heavy and generally increases with elevation, falling as rain on the lower levels and usually as snow on the higher slopes and mountains. During summer months, precipitation generally occurs as a result of thunderstorms, particularly on the Cascade Range and Modoc Plateau areas.

Precipitation Stations and Records

Forty-three precipitation stations in or adjacent to Shasta County, with unbroken records of 10-year periods or longer, were considered in this investigation. In addition, data were obtained for 32 stations with records of less than 10 years. Of the 75 precipitation stations, 12 could not be used in the precipitation studies because of insufficient or unreliable data, or because of questionable location of discontinued stations. The remaining 63 stations were fairly well distributed over the area of investigation, and the records provided adequate data to determine the pattern of precipitation. Records of precipitation at most of these stations have been published in bulletins of the United States Weather Bureau. Seasonal precipitation data for stations with previously published records, and monthly precipitation data for stations with unpublished records are available in the files of the Department of Water Resources. The locations of 60 of the 63 precipitation stations and the distribution of mean seasonal precipitation are shown on Plate 4, entitled "Lines of Equal Mean Seasonal Precipitation".

Precipitation Characteristics

Because of large differences in quantity or precipitation from location to location in Shasta County, no single station record is truly indicative of precipitation elsewhere in the county. Nevertheless, the precipitation data gathered at Redding, where records have been kept since 1875, give an approximate indication of seasonal and monthly variations that have occurred throughout the county. Recorded seasonal precipitation at Redding is presented graphically on Plate 5A, entitled "Recorded Seasonal Precipitation at Redding". Mean monthly distribution of precipitation as recorded at Redding is presented in Table 3.

Precipitation at lower elevations of the county consists almost entirely of rainfall. Moderate to heavy snowfall can generally be expected in the winter at elevations above 3,500 feet,

TABLE 3

MEAN MONTHLY DISTRIBUTION
OF
PRECIPITATION AT REDDING

Month	Precipitation	
	In inches	In percent of mean seasonal total
July	0.10	0.3
August	0.09	0.2
September	0.66	1.7
October	2.21	5.8
November	4.18	11.0
December	6.69	17.7
January	7.35	19.4
February	5.93	15.7
March	5.02	13.3
April	2.94	7.8
May	1.83	4.8
June	0.87	2.3
TOTALS	37.87	100.0

and it it not unusual to experience temporary closing of roads because of heavy snowfall at elevations below 3,500 feet. Heavy snowpacks are common in the southeastern portion of the county in the vicinity of Mt. Lassen, and in the northwestern area between the Sacramento and Pit Rivers. A snow course and storage precipitation gage at Stout's Meadow, in the northcentral area of the county, has a recorded mean seasonal precipitation of about 84 inches. There are indications that areas of higher elevation in that vicinity probably have mean seasonal depths of precipitation in excess of 90 inches.

Precipitation varies over wide limits from season to season. At Redding, it ranges from about 41 percent to about 182 percent of the seasonal mean of 37.87 inches. Maximum seasonal precipitation at Redding occurred in 1940-41 when 68.87 inches were recorded. This amount was closely approached in 1889-90 when 68.55 inches of precipitation were measured. In 1897-98 and 1923-24 only 15.66 and 15.68 inches of rain fell at Redding. Long-term trends in precipitation are indicated on Plate 5B, entitled "Accumulated Departure from Mean Seasonal Precipitation at Redding". On the average, nearly 85 percent of the seasonal precipitation in Shasta County falls during the six-month period of November through April.

Quantity of Precipitation

To provide a means for estimating runoff and a check on stream flow estimates made by other methods, mean seasonal depth and total mean seasonal quantity of precipitation were determined for each hydrographic unit. The results of these determinations are presented in Table 4. As indicated in the table, the mean seasonal depth of precipitation in Shasta County as a whole is about 50.4 inches, corresponding to 10,330,000 acre-feet of water. Table 4 also shows the wide range of precipitation within the county, ranging from a seasonal mean of about 25 inches in the McArthur Hydrographic Unit to over 81 inches in the McCloud River Hydrographic Unit.

Stream Flow

Runoff of precipitation from watersheds of its mountainous regions constitutes the most important source of water supply available to Shasta County. Within the county are portions of the watersheds of the Pit, McCloud, and Sacramento Rivers, and of four major creeks (Clear, Cow, Cottonwood, and Battle Creeks), plus the watersheds of numerous minor streams lying entirely within the county. A substantial portion of the flow in these streams is unregulated and undeveloped, and comprises a potential source of water to meet future requirements in Shasta County as well as those in water-deficient areas in other parts of California.

Stream Gaging Stations and Records

There are several gaging stations with excellent continuous records of the flow of streams within Shasta County. The stations having the longest and most important records are located on the Pit, McCloud, and Sacramento Rivers. At the present time there are five continuous recording stations on these streams, and four additional important stations were flooded by the creation

TABLE 4

ESTIMATED WEIGHTED SEASONAL DEPTH AND TOTAL
QUANTITY OF PRECIPITATION BY HYDROGRAPHIC UNITS
TOTALLY OR PARTIALLY IN SHASTA COUNTY
1897-98 TO 1946-67

Hydrographic unit		Area, in acres			Mean seasonal depth, in inches		Mean seasonal quantity, in acre-feet	
Number	Name	Inside Shasta County	Outside Shasta County	Total	Inside Shasta County	Outside Shasta County	Inside Shasta County	Outside Shasta County
16	McArthur	156,100	623,100	779,200	25.08	33.30	326,300	1,729,100
17	Hat Creek	487,500	121,900	609,400	40.12	36.64	1,629,900	372,200
18	Montgomery Creek	234,000	0	234,000	68.34	0	1,332,600	0
19	McCloud River	116,400	267,100	383,500	81.17	56.32	787,400	1,253,600
20	Dunsmuir	138,500	136,200	274,700	68.40	56.54	789,500	641,700
21	Shasta Lake	244,500	0	244,500	67.26	0	1,370,400	0
22	Clear Creek	147,000	0	147,000	56.71	0	694,700	0
23	Keswick	29,900	0	29,900	59.84	0	149,100	0
24	Cottonwood Creek	233,400	368,200	601,600	41.74	40.49	811,800	1,242,400
25	Olinda	51,200	0	51,200	36.68	0	156,500	0
32	Stillwater Plains	80,500	0	80,500	41.94	0	281,300	0
33	Cow Creek	272,700	0	272,700	43.77	0	994,700	0
34	Bear Creek	103,700	0	103,700	34.53	0	298,400	0
35	Battle Creek	117,400	114,200	231,600	55.66	38.50	544,500	366,400
38	Mill Creek	3,500	114,800	118,300	67.00	*	19,500	*
42	North Fork Feather River	13,400	757,800	771,200	58.50	*	65,300	*
50	Anderson	32,600	28,000	60,600	29.56	*	80,300	*
	TOTALS	2,462,300	2,531,300	4,993,600			10,332,200	

* Not determined, because does not affect water supply of Shasta County.

of Shasta Reservoir. However, the records of these latter stations remain usable and provide valuable supplementary data. The flows of most of the major creeks below Shasta Dam were not recorded until 1940.

Runoff records of the principal streams of Shasta County are adequate, and sufficiently reliable for the hydrographic studies conducted during this investigation. Records of runoff of many smaller streams, however, are nonexistent or considered to be unreliable. During the investigation eight new stream gaging stations were constructed on minor streams of the county in cooperation with the United States Bureau of Reclamation, the United States Geological Survey, and Shasta County.

Appendix B, entitled "Stream Gaging Stations in and Adjacent to Shasta County" contains the names and numbers of the gaging stations, and the hydrographic unit in which each is located, their elevations, the drainage area of each hydrographic unit, the periods, type and source of record, and the average seasonal runoff for the period of record. Minima and maxima of seasonal runoff in acre-feet are also shown. Data upon which this information was based are available in the files of the Department of Water Resources.

Runoff Characteristics

Stream flow in Shasta County is the result of direct contributions from rainfall and melting snows and of accretions from ground water. These sources differ greatly from one another in their uniformity of discharge. Accordingly, the relative proportions of flows from these several origins largely determine the variation in seasonal patterns of runoff in the county. Streams that are rain-fed to a significant extent experience the greatest variation of flow with high peaks of relatively short duration during the rainy season. Snowmelt runoff occurs over a longer period than that from rainfall, and streams sustained largely from this source are characterized by long periods of uniformly high flow, without extreme peaks, during the spring and early summer. Runoff in spring-fed streams flows largely from ground water stored in pervious volcanic materials, and has the most uniform seasonal distribution of the three sources.

Seasonal runoff characteristics of major streams of the county are indicated on Plate 6, entitled "Accumulated Departure from Mean Seasonal Natural Runoff of Streams in Shasta County". Plate 6 depicts the fact that major streams of the county have quite similar seasonal flow characteristics. It further illustrates the modifying effect of uniform ground water flow from the prevailing volcanic formations on extreme variations in the seasonal runoff pattern. The flows of the Pit River, McCloud River, and Battle Creek originate in basins which are almost entirely of volcanic origin. As a result, the accumulated departure curves of these streams exhibit less departure from the normal than those of the other streams represented on Plate 6 which drain basins having proportionally less volcanic areas in their watersheds.

Churn and Stillwater Creeks have the runoff characteristics of many of the minor rain-fed streams that do not flow through volcanic formations. These streams commence flowing shortly after the first appreciable rains in the fall and cease flowing about one month after the last significant rains in the spring. The total quantity of flow in these minor streams correlates very closely with seasonal precipitation and, therefore, varies widely from season to season. On the other hand, Fall and Rising Rivers have the characteristics of spring-fed streams. These two streams are fed almost entirely by seeps and springs located at the edge of the volcanic flows, and their flows show very slight seasonal change.

Plate 7A, entitled "Estimated Seasonal Natural Runoff of Cow Creek near Millville", and Plate 7B, entitled "Accumulated Departure from Mean Seasonal Natural Runoff of Cow Creek near Millville", are presented to further illustrate seasonal variations in stream flow. As shown on Plate 7A, the mean seasonal natural runoff in Cow Creek was 473,000 acre-feet. Its average seasonal natural flow was 415,000 acre-feet during the 36-year base period. In the 1923-24 and 1930-31 water years, the seasonal flow was about 110,000 acre-feet, or only 26 percent of the average flow of the base period. On the other hand, in 1903-04 and 1906-07, the estimated seasonal flow was about 1,080,000 acre-feet, or almost 10 times that occurring in the minimum years. Both Plates 7A and 7B clearly show the generally deficient period of runoff that occurred between 1921-22 and 1936-37.

Quantity of Runoff

Shasta County is one of the great water producing areas of California. The mean seasonal natural runoff that originates within the county is estimated to be about 5,800,000 acre-feet, or slightly over one-fourth of the surface water resources of the Sacramento River Basin as measured at Sacramento.

Available records of stream flow, including those obtained from measurements made in connection with this investigation, provided sufficient data to estimate the amount of runoff at unmeasured locations or of ungaged streams. However, in some instances the records were of such short duration that the estimates could be subject to some error.

The average seasonal runoff for the base period was estimated for each hydrographic unit. The runoff of 10 of the 17 hydrographic units was derived from records of runoff at stream gaging stations which measured runoff of the drainage areas of these units. The estimates of runoff in certain hydrographic units which lie partially outside Shasta County were proportioned by the estimated mean seasonal precipitation to the estimated mean seasonal precipitation occurring inside and outside the county.

Accretions to flow of the Sacramento River between Shasta Dam and the southern boundary of Shasta County are in excess of surface runoff to this reach. Studies of ground water movement indicate that these accretions are attributable to effluent flows into the river from the Redding ground water basin. The amount of these effluent flows was estimated by comparing the average seasonal natural surface runoff from hydrographic units between Shasta Dam and the gaging station of the Sacramento River near Red Bluff, with that of the Sacramento River in the same reach, estimated from records of runoff measured at Shasta Dam and at the gaging station near Red Bluff. The resultant estimate of seasonal accretion from ground water was approximately 252,000 acre-feet. This value was apportioned by river miles between the City of Redding and the gaging station near Red Bluff to obtain an estimated accretion within Shasta County of 131,000 acre-feet seasonally. Since any errors in estimates of the large values of runoff involved reflect in these results, the value of 131,000 acre-feet should be considered only indicative of the approximate magnitude of the accretions from ground water. The natural runoff at the gaging station near Red Bluff for the 36-year base period (1920 through 1955-56) was estimated to be 89.7 percent of the mean seasonal natural runoff during the mean period (1894-95 through 1946-47). During the base period it was estimated that there were 5,217,000 acre-feet of runoff originating in Shasta County. The factor of 89.7 percent was then applied to obtain an estimate of 5,800,000 acre-feet for natural runoff during the mean period. This amounts to over one-fourth of the estimated runoff of the Sacramento River Basin. It must be added, however, that the 89.7 percent relationship is not applicable to the individual hydrographic units because of different runoff characteristics of each unit.

A summary of the estimates of average seasonal natural runoff in and adjacent to Shasta County is presented by hydrographic units in Table 5.

TABLE 5

ESTIMATED AVERAGE SEASONAL NATURAL RUNOFF
BY HYDROGRAPHIC UNITS TOTALLY OR PARTIALLY
IN SHASTA COUNTY
1920-21 TO 1955-56

Hydrographic unit		Precipitation, in percent of total for the hydrographic unit		Average seasonal natural runoff, in acre-feet		
Number	Name	Inside Shasta County	Outside Shasta County	Inside Shasta County	Outside Shasta County	Total
16	McArthur	1/	1/	734,000	156,000	890,000
17	Hat Creek	81.4	18.6	632,000	144,000	776,000
18	Montgomery Creek	100.0	0	791,000	0	791,000
19	McCloud River	1/	1/	487,000	666,000	1,153,000
20	Dunsmuir	1/	1/	323,000	379,000	702,000
21	Shasta Lake	100.0	0	652,000	0	652,000
22	Clear Creek	100.0	0	236,000	0	236,000
23	Keswick	100.0	0	85,000	0	85,000
24	Cottonwood Creek	39.5	60.5	212,000	324,000	536,000
25	Orlinda	100.0	0	56,000	0	56,000
32	Stillwater Plains	100.0	0	115,000	0	115,000
33	Cow Creek	100.0	0	415,000	0	415,000
34	Bear Creek	100.0	0	101,000	0	101,000
35	Battle Creek	59.8	40.2	181,000	122,000	303,000
38	Mill Creek	1/	1/	12,000	2/	2/
42	North Fork Feather River	1/	1/	37,000	2/	2/
50	Anderson	48.7	51.3	17,000	18,000	35,000
--	Accretions 3/	1/	1/	131,000	121,000	252,000
	TOTALS			5,217,000	1,930,000	7,333,000

1/ Precipitation not used to apportion runoff inside and outside of Shasta County.
2/ Not determined.
3/ Accretions to the Sacramento River between Shasta Dam and the gaging station near Red Bluff not attributable to surface flow. Runoff apportioned by river miles between the City of Redding and the gaging station near Red Bluff.

Runoff at Dam Sites

There were no records available of stream flow at any of the dam sites studied in this investigation. Natural runoff at the dam sites was usually derived for the base period, 1920-21 through 1955-56, by multiplying the nearest reliable estimated natural runoff value for the stream by an area-precipitation factor. The area-precipitation factor was derived by dividing the total mean seasonal precipitation on the drainage basin above the dam site by the total mean seasonal precipitation on the drainage basin above the nearest point of reliable estimated natural runoff.

Values of present impaired runoff and ultimate impaired runoff at dam sites were also estimated for the base period. Present impaired runoff was determined by deducting estimated present consumptive use of applied water above the dam site from estimated full natural runoff at the dam site. Present water use was estimated on the basis of present water-using developed areas above the dam site, assuming a full available water supply. Ultimate impaired runoff was estimated in a similar manner, after determining probable ultimate upstream water use.

Imported and Exported Water

Present imports of water into Shasta County are minor in amount. The only appreciable quantities of water imported are conveyed from below the Inskip Power Plant on the South Fork of Battle Creek to the Coleman Power Plant on Battle Creek. Not all of the water thus conveyed originates outside the county, because the waters of upper Battle Creek are diverted from Shasta

County to Tehama County for use in the South and Inskip Power Plants and returned to the Coleman Power Plant for use in Shasta County.

In the future, large quantities of water will be imported into Shasta County from the Trinity River Division of the Central Valley Project, which is presently under construction by the United States Bureau of Reclamation. In addition to importing water, features of the Trinity River Division will develop and control the flow of Clear Creek in Whiskeytown Reservoir. The major portion of the imported water from the Trinity River Division will pass through the county for use in water-deficient areas elsewhere in the State, after being combined in Keswick Reservoir with water released from Shasta Reservoir.

The major present export of water from Shasta County consists of regulated releases from Shasta Reservoir. This water flows down the Sacramento River for use elsewhere in the Sacramento and San Joaquin Valleys and in the San Francisco Bay area. The Anderson-Cottonwood Irrigation District exports water from the county to serve a portion of the district situated in Tehama County.

Ground Water

Because many ground water basins in Shasta County are only partially developed and others are completely undeveloped, many of the hydrologic data necessary for their analyses are not available, and it was not possible to evaluate all the items generally considered in ground water studies. Studies of the ground water hydrology of the county were, therefore, limited to the Redding ground water basin and to certain areas of potential ground water development in the Modoc Plateau area.

Redding Ground Water Basin

The principal ground water reservoir of Shasta County is the Redding ground water basin, which lies partly in south-central Shasta County and partly in northcentral Tehama County. The basin is bounded on the north by the Klamath Mountains, on the east by the foothills of the Cascade Range, and on the west by the foothills of the Klamath Mountains and northern Coast Range. The southern boundary is formed by the Red Bluff arch, a structural uplift trending east-northeast across the Sacramento Valley. The geography of the basin is shown in Plate 8, entitled "Redding Ground Water Basin".

Geology. The five water-bearing geologic formations recognized in the basin are alluvium of Recent age; Red Bluff formation of Pleistocene age; Tehama and Tuscan formations, both of upper Pliocene and possibly lower Pleistocene age; and Nomlaki tuff of upper Pliocene age. The Tehama and Tuscan formations comprise the principal water-bearing materials in the basin. The water-bearing formations are sedimentary deposits which are underlain either by nonwater-bearing or salt water-bearing rocks of Cretaceous age. The water-bearing sediments occupy a north-south trough formed by a synclinal structure in the Cretaceous rocks. The Cretaceous rocks are deeply buried in the southcentral portion of the basin, but are at or near the surface in the west, north, and east margins of the basin. Pre-Cretaceous, nonwater-bearing rocks outcrop in the Klamath Mountains and underlie the

Cretaceous rocks at great depth beneath the basin. Late Tertiary and Quaternary volcanic rocks, some of which are water-bearing, overlie pre-Cretaceous and Cretaceous rocks and Pliocene formations on the east side.

The base of the fresh water-bearing sediments is defined by the upper surface of the Chico formation of Cretaceous age. This formation consists chiefly of consolidated sandstone and shale of marine origin. The fresh water-bearing sediments in the basin vary irregularly from a negligible thickness near the west and north margins and part of the east margin to about 3,000 feet in thickness in the vicinity of U. S. Highway 99, six miles south of Cottonwood.

Ground Water Levels and Movement. Data on ground water levels in the Redding ground water basin prior to 1955 are largely unavailable. However, ground water levels were measured during the three-year period of this investigation. Approximately 330 wells were measured, including nearly all operating and nonoperating irrigation wells, municipal wells, and certain domestic and abandoned wells in areas where the latter were the only possible source of information. Water stage recorders were installed on several wells for varying periods of time to obtain continuous records of water levels under various conditions of draft, replenishment, and daily cyclic fluctuations. Lines of equal depth to ground water for the spring and fall seasons of 1956 are shown on Plate 9, entitled "Lines of Equal Depth to Ground Water, Redding Ground Water Basin".

Knowledge of ground water movement in the Redding ground water basin was made possible from data provided by the measurements of depth to water in wells. Maps showing lines of equal elevation of ground water for each spring and fall season during the period of measurement were prepared. These maps exhibit similar contour patterns, and give an indication of the direction of ground water movement. Maps representing spring and fall elevations of the ground water surface for 1956 are shown on Plate 10, entitled "Lines of Equal Elevation of Ground Water, Redding Ground Water Basin". Because the Redding ground water basin is completely bordered by nonwater-bearing rocks along its north and west boundaries, subsurface inflow from these areas was considered to be negligible. Measurements at a limited number of wells on the east side of the Redding ground water basin, combined with a knowledge of the geologic formations, indicate that most of the subsurface inflow to the basin probably occurs in this area.

Very little information is available on the extent and location of areas of subsurface outflow. The direction of ground water movement generally follows the surface drainage pattern of the area. The Red Bluff arch, which is cut through by the Sacramento River, blocks the southerly flow of lesser surface streams, and also presents an effective barrier to the southerly movement of ground water. Ground water probably moves northward from this southern boundary of the basin toward Cottonwood Creek and the Sacramento River. This condition is indicated on Plate 10 by higher elevations of water levels in a few wells near the Red Bluff arch.

Yield of Existing Wells. Large yields of water are derived in the southeastern and extreme southern parts of the Redding ground water basin from irrigation wells, with the larger wells yielding from 400 to over 1,000 gallons per minute. These yields are generally adequate for agricultural and municipal purposes. In other portions of the basin, north of the mouth of Clear Creek, including a portion of Anderson Valley and northern Stillwater Plains, the yields are less consistent. In the late summer months some wells in this area dry up or yield a negligible quantity of water. In the extreme northern portion of the basin, wells yield only enough water for domestic use and irrigation of small acreages.

This decrease in ground water yield in a general south-north direction in the Redding Basin is partly due to a gradual thinning of and reduction in permeability of the water-bearing formation.

Data obtained from pump and well tests in portions of the Redding ground water basin are summarized in Table 6. This table presents average depth, average and maximum yields, and average specific capacity of wells in each area where data were available.

Modoc Plateau Ground Water Area

Studies were made of five principal areas of present and potential sources of ground water in the Modoc Plateau area in northeastern Shasta County: Fall River Valley, Goose Valley, Clayton Valley, Burney Basin, and Hat Creek Valley. Because the entire Modoc Plateau area is underlain by volcanic materials, the

TABLE 6

WELL DATA FOR VARIOUS GEOGRAPHIC UNITS
REDDING GROUND WATER BASIN

Use of wells	Number of wells tested	Average depth of well, in feet	Yield of wells,* in gallons per minute: Average	Yield of wells,* in gallons per minute: Maximum	Average specific capacity, in gallons per minute per foot of drawdown
Cottonwood Creek					
Irrigation, industrial, and municipal	22	345	525	2,000	32
Anderson Valley					
From vicinity of Anderson north to Clear Creek					
Industrial and municipal	11	290	610	1,555	25
Southern portion, from Bear Creek to southern boundary of basin					
Irrigation	4	310	1,550	2,150	30
North of Clear Creek to Redding					
Industrial and municipal	5	140	45	50	1
Churn Creek Bottoms					
Irrigation	4	58	680	2,070	67
Cow Creek Bottoms					
South of Palo Cedro					
Irrigation	11	180	620	1,070	25
Stillwater Plains					
South of Old Alturas Road					
Irrigation	12	250	480	1,062	25

* Computed from pump tests made by Pacific Gas and Electric Company and various pump companies.

occurrence of ground water is not limited to the five principal areas. However, throughout the entire Modoc Plateau area, this volcanic material has highly variable water-bearing capabilities. The delineation of all areas underlain by water-bearing materials was not attempted during this investigation because of limited time and funds. The locations of the principal present and potential areas of ground water use are shown on Plate 11, entitled "Modoc Plateau Ground Water Area".

There is relatively little development of ground water in the five principal areas of present and potential ground water use. Therefore, data on ground water and on characteristics of water-bearing materials are limited, and only general information concerning geology, ground water levels and movement, and yields of existing wells is available.

Geology. Ground water in the Modoc Plateau area occurs chiefly in volcanic rocks which underlie most of the area. These volcanic rocks occur generally at the surface in the Burney Basin and Hat Creek Valley, and beneath the lacustrine or lake-bed deposits in Fall River Valley, Goose Valley, and Cayton Valley. Water moves through these lavas by means of the interconnection of crevices and cavities, often of considerable size, within and between the lava flows.

The only other water-bearing materials of significance in the Modoc Plateau area are the aforesaid lacustrine deposits. The most extensive and deepest of these deposits occur in Fall River Valley, where they are the principal source of water to many domestic wells and a few irrigation wells in the valley.

Small amounts of ground water may occur, as a result of infiltration of precipitation and irrigation water, in the alluvial deposits of the Burney Basin. There are also three small alluvial areas along Hat Creek. The alluvial deposits in all areas, and the lacustrine deposits in Goose and Cayton Valleys, are shallow and provide very little ground water storage. However, the volcanic rocks adjacent to and underlying these valleys are generally water-bearing, and are often highly permeable.

Ground Water Levels and Movement. During this investigation, water levels of seven wells in the Burney Basin and 106 wells in Fall River Valley were measured semiannually. Depths to water in these wells for the fall of 1957 and the spring of 1958 are shown on Plate 12, entitled "Lines of Equal Depth to Ground Water, Modoc Plateau Ground Water Area".

Elevations of ground water at wells were determined and are indicated on Plate 13, entitled "Lines of Equal Elevation of Ground Water, Modoc Plateau Ground Water Area". Only limited data are available for analyzing ground water movement. Plate 13 indicates that ground water generally moves toward the Pit River from both sides of Fall River Valley. Ground water also apparently moves toward other major streams of the area, as is illustrated by Burney Falls on Burney Creek, by Rising River on Hat Creek, and by the numerous large springs forming Fall River and its tributaries. In addition to these more spectacular occurrences, numerous lesser springs and seeps add to the flows of surface streams in the area.

Yield of Existing Wells. Wells in the Modoc Plateau area usually yield adequate water for most domestic needs, and irrigation supplies can generally be obtained from volcanic rocks. Data from nine wells in Burney Basin and from one in Goose Valley indicate that yields vary from 90 to 4,300 gallons per minute, and that specific capacities vary from 10 to over 1,000 gallons per minute per foot of drawdown.

Yields of wells drilled into the Fall River Valley lake sediments are low, generally less than 300 gallons per minute. However, wells drilled through the lake sediments into the underlying volcanic rocks produce from 200 to 1,000 gallons per minute. Flows of artesian wells range from a few gallons per minute to about 100 gallons per minute.

It should be emphasized that the water-bearing properties of volcanic rocks are extremely variable, and it is difficult to predict whether an adequate water supply will be obtained from a well drilled in an untested area of volcanics.

Quality of Water

The principal objective of the water quality studies conducted during this investigation was to ascertain the quality of surface and ground waters with respect to their beneficial uses.

The surface water supplies of Shasta County are excellent in mineral quality, and in this respect are well suited for irrigation, fish habitat, and other benefitical uses. Water of good to excellent mineral quality occurs commonly throughout the ground water basins of the county, except in wells in the northern and northwestern portions of the Redding Basin. Data used to determine the quality of waters in Shasta County included mineral analyses of 183 surface and ground water samples.

Quality of Surface Waters

Analyses of 55 samples from 27 streams of Shasta County give evidence of the excellent mineral quality of its surface waters. These samples were collected during the five-year period, 1952 through 1956, to obtain data regarding the mineral characteristics of streams during both spring and fall seasons.

Since most of the streams of the county drain mountain areas composed of igneous and consolidated sedimentary rocks, most of the surface waters are low in dissolved solids. There appears to be little difference in mineral character of composition of water between streams in the eastern and western portions of the county. Waters are generally of a calcium-magnesium bicarbonate or magnesium bicarbonate type. There also appears to be little variation in dissolved mineral composition between high and low flows. Minor rain-fed streams, such as Churn and Stillwater Creeks which traverse outcrops of marine sediments, tend to have waters with higher chloride concentrations than other streams, but their waters are still of excellent mineral quality. Some few streams which drain mining areas have waters with high concentrations of sulfate and metallic elements. Water from such streams is generally of good to poor mineral quality for irrigation, but generally does not meet the recommended standards of the United States Public Health Service for drinking water, and is sometimes toxic to fish life.

Quality of Ground Waters

In general, ground water in Shasta County is good to excellent in quality and suitable for most beneficial uses, as indicated by the analyses of 128 samples from 110 wells. However, saline ground water which is unsuitable for any beneficial use underlies some areas of the county. These saline ground waters are found in wells in the northern and northwestern portions of the Redding ground water basin and are mostly sodium chloride in type. The source of the saline ground waters is apparently the Chico formation, which is of marine origin.

Since data collected during this investigation indicate that poor quality ground waters occur extensively in the basal section of the water-bearing sediments, lateral and upward movement of poor quality ground waters may be taking place in areas presently containing ground waters of suitable quality for beneficial uses. The deeper, poor quality waters are believed to be under sufficient pressure to be forced upward to underlying zones of usable ground water through defective or improperly constructed wells.

As indicated heretofore, ground water in the Modoc Plateau area is pumped principally from volcanic materials and, to some extent, from the lake sediments in Fall River Valley. Analyses of water samples from volcanic materials in widely scattered locations show similar mineral composition. These waters are either of the calcium-magnesium bicarbonate type or of the magnesium-calcium bicarbonate type. Analyses of water from both artesian and nonartesian wells in Fall River Valley indicate fairly uniform overall mineral composition, except that the total dissolved solids and nitrate content are somewhat higher in the nonartesian waters. Degradation of the quality of ground water is not believed to be a serious problem in the Modoc Plateau area.

CHAPTER III. WATER UTILIZATION AND REQUIREMENTS

Present water utilization and future requirements for water in Shasta County are relatively small when compared with the water supply originating within the county. Even under assumed ultimate conditions of development, the net depletion of the water supply by all uses in the county would be less than 15 percent of the natural runoff originating in the county.

The estimates of consumptive use and requirements for water, presented in this chapter, were evaluated on the basis of the employments of land, water, and timber as they relate to water use. Estimates of ultimate water use were based on the premise that full development of irrigable land and other natural resources will eventually occur.

Definitions

The following terms are used as defined:

Water Utilization--In a broad sense, includes any employment of water by nature or man, either con_umptive or non-consumptive, as well as irrecoverable losses of water incidental to such employment. This term is synonymous with the term "water use".

Water Requirement--The amount of water needed for all beneficial uses and for irrecoverable losses incidental to such uses.

Consumptive Use of Water--The quantity of water consumed by vegetative growth in transpiration and building of plant tissues and water evaporated from adjacent soil, from water surfaces, and from foliage. It also refers to water similarly consumed and evaporated by urban and nonvegetative types of land use.

Applied Water--The water delivered to a farmer's headgate for irrigation use or to an individual's meter, or its equivalent, for urban use. It does not include direct precipitation.

Effective Precipitation--That portion of the direct precipitation which is consumptively used and which does not run off or percolate below the root zone.

Farm Irrigation Efficiency--The ratio of the amount of the consumptively used applied irrigation water to the total amount of such applied water. It is commonly expressed as a percentage.

Water Service Area Efficiency--The ratio of the amount of consumptively used applied water in a given service area to the total amount of water delivered to the area. It is commonly expressed as a percentage.

Present--This term is used generally in reference to land use and water supply conditions prevailing during the period from 1952 to 1956.

Ultimate--This term refers to conditions after an unspecified but long period of years in the future when development of natural resources would be at a maximum and essentially stabilized. Its use is related to long-range resources planning and development that is not only physically possible on the basis of land and water resources but is also practicable and reasonable on the basis of foreseeable economic conditions.

Other terms are needed to express more precisely the factors that pertain to the various beneficial employments of water. "Requirement" is a general term that expresses need for beneficial use of water. It is customary to employ with it certain modifying words that by implication define the exact nature of the requirement. For example, "diversion requirement" is the amount of water needed at the point of diversion on a stream system to provide for losses in conveyance of water to places of use, for the necessary irrigation head to distribute the water in the fields, for the wetting of the soil volume, and for deep percolation. A "service area requirement" includes all the foregoing uses of water in a specified service area, measured, however, at the point or points of entrance of the water to the service area, or the equivalent, rather than at a point of diversion on a stream system. Any re-use of return flows from irrigation or other employments of the water within the service area is taken into account.

Water requirements associated with consumptive use refer to the net utilization of water in a given area or stream basin. Requirements for water that cause an impairment in either the quantity or quality of the water supply available for other purposes are termed "requirements for consumptive use". In general, they include irrigation, municipal, industrial, and domestic requirements.

Only a portion of the water that is applied to agricultural, municipal, industrial, or recreational areas is utilized. The remaining part of the applied water percolates into the ground or returns to streams, where it is available for re-use. That portion of the applied water or requirement that is utilized in evaporation and transpiration is known as "consumptive use of applied water".

Nonconsumptive requirements for water refer to the use of water for fish propagation, power production, or aesthetic purposes. The water is put to beneficial use and then returned to the natural channels. In most instances the regimen of flow of the stream is affected, but not the quantity or quality of the water.

Methods which are fairly reliable, although still subject to much improvement, have been developed for estimating unit values of consumptive use of water by irrigated crops. The quantity of water consumptively used by the crops is largely independent of the amount of water supplied, provided a sufficient quantity is available to the crops at the proper time to maintain good growing conditions. Although this basic use of water can be reasonably estimated, the quantities involved in conveyance, methods of application and application losses, use and amount of return flow, type of soil, etc., are difficult to evaluate accurately, for they depend upon the details of works and operation of projects. Irrigation heads will vary with topography and soil characteristics. For these reasons, only an approximation can be made of either the diversion requirement or the service area requirement prior to the construction and operation of a project.

One phase of the hydrologic analysis of a stream basin or a portion thereof is an evaluation of future changes in runoff resulting from future uses of land and water. The change may be either an increase or a decrease in quantity of flow. Conversion of brush land to dry-farmed grazing land may cause an increase in runoff and water supply, while its conversion to irrigated crop production may cause an increase in consumptive use and a decrease in water supply. The reclamation of a native marsh and its transformation into a well-managed irrigated pasture may cause a decrease in consumptive use of water and an increase in the water supply. Conversely, a change in agricultural practice from grain production to irrigated pasture may result in greater consumptive use of water and in a decrease in the water supply.

Normally, as native lands are brought under irrigation, the regimen of downstream flows is changed. For the most part, the amount of the change in downstream flow is determined by the difference both in consumptive use of water and irrecoverable losses between any two stages of development. An analysis based on these factors was utilized in this investigation to evaluate ultimate available stream flow at proposed dam sites.

In general, the present and probable ultimate consumptive uses of applied water in Shasta County were determined by application of appropriate unit values of consumptive use of water to the present and probable ultimate patterns of land use. In determining the probable ultimate patterns of land use, due consideration was given to the nature and extent of the present agricultural, urban, and industrial development; to indications of trends in such development; to the availability of the water supply; and to those natural features of the basin such as climate, topography, and soils as they affect the use and re-use of water. Evaluations of ultimate water service area requirements were made by considering efficiencies in use of the water which are presently realized or would ultimately be achieved by operating agencies.

Certain possible nonconsumptive requirements for water in Shasta County, such as those for hydroelectric energy generation, conservation of fish and wildlife, and recreation, may be of varying significance in the design of works for the development of the water resources of the county. In most instances, the magnitudes of such nonconsumptive requirements would be dependent upon such factors as the feasibility of various multipurpose uses, public interest, and economics in the planning of future projects.

Present Water Resources Development

Although extensive development of the water resources of Shasta County has occurred, there remains a large amount of water susceptible of development for irrigation, production of hydroelectric energy, domestic and municipal use, recreation, and other beneficial purposes. Irrigation, involving the principal consumptive use of water in the county, has increased only slightly during the last quarter-century, and no sizable irrigation projects have been constructed since about 1920.

Most of the water now used in Shasta County is obtained by direct diversion from streams. Small quantities of ground water are pumped for municipal, industrial, domestic, and irrigation purposes.

The major existing reservoirs in the county, other than Shasta Lake, are operated primarily for the production of hydroelectric energy. However, the reservoir storage capacity provided for hydroelectric energy production is small, and operation of the power plants is largely dependent upon direct diversion of stream flow. Shasta Lake, the largest reservoir in California and a major feature of the Central Valley Project, is a multipurpose development for irrigation, production of hydroelectric energy, domestic and municipal use, recreation, and other beneficial purposes.

The locations of existing water supply developments and boundaries of public water service agencies in Shasta County are shown on Plate 14, entitled "Existing Water Supply Developments and Public Water Service Agencies in Shasta County". Power plants in the county are listed in Table 7. The principal water service agencies in Shasta County, both public and private, and pertinent data regarding sources of water supply and type of use are listed in Table 8.

Drainage Area Above Shasta Dam

The drainage area above Shasta Dam within Shasta County consists of portions of the watersheds of the Pit, McCloud, and upper Sacramento Rivers and all of the Squaw Creek watershed. The area encompasses 1,377,000 acres, or 56 percent of the area of the county. It produces an average of 3,619,000 acre-feet of surface runoff seasonally, or about 69 percent of the runoff originating within the county. The drainage area, except for the Modoc Plateau, is entirely mountainous and land suitable for irrigation is found only in relatively small, scattered parcels. Most of the major existing physical works for water development in Shasta County are within this area and all of these works, with the exception of Shasta Lake, are for the primary purpose of producing hydroelectric energy.

The principal areas of irrigation above Shasta Dam are in the Modoc Plateau portion of Shasta County. These irrigated areas are in Fall River, Cayton, and Goose Valleys, the Burney Basin, and lands adjacent to Hat Creek. Present consumptive use of applied water for irrigation and domestic

TABLE 7

HYDROELECTRIC POWER PLANTS
IN SHASTA COUNTY

Name of plant	Source of water	Hydrographic unit	Operator 1/	Installed capacity, in kilowatts
Hat Creek No. 1	Hat Creek	Hat Creek	PG&E	10,000
Hat Creek No. 2	Hat Creek	Hat Creek	PG&E	10,000
Pit No. 1	Fall River	Hat Creek	PG&E	56,000
Pit No. 3	Pit River	Hat Creek	PG&E	72,900
Pit No. 4	Pit River	Montgomery Creek	PG&E	90,000
Pit No. 5	Pit River	Montgomery Creek	PG&E	128,000
Clear Creek 2/	Trinity River	Clear Creek	--	130,000 3/
Spring Creek 2/	Trinity River and Clear Creek	Keswick	--	143,000 3/
Shasta	Sacramento River	Keswick	USBR	379,000
Keswick	Sacramento River	Keswick	USBR	75,000
Kilarc	Old Cow Creek	Cow Creek	PG&E	3,000
Cow Creek	South Cow Creek	Cow Creek	PG&E	1,200
Volta	North Fork Battle Creek	Battle Creek	PG&E	6,400
Coleman	Battle Creek	Battle Creek	PG&E	13,800
TOTAL				1,118,300

1/ PG&E -- Pacific Gas and Electric Company.
USBR -- United States Bureau of Reclamation.
2/ Under construction.
3/ Presently planned capacity.

TABLE 8

PRINCIPAL WATER SERVICE AGENCIES IN SHASTA COUNTY

Name of agency	Source of supply	Area serviced	Hydrographic unit	Primary type of service
Anderson-Cottonwood Irrigation District	Sacramento River	Anderson Valley and Churn Creek Bottoms	Anderson	Irrigation
Bella Vista Water District*	Sacramento River, Cow Creek, and ground water (proposed)	Stillwater Plains and Cow Creek Bottoms	Stillwater Plains and Cow Creek	Irrigation
Buckeye County Water District	Shasta Lake	Buckeye	Stillwater Plains	Domestic
Enterprise Public Utility District	Ground water	Enterprise	Stillwater Plains	Domestic
Wonderland-Mountain Gate Community Services District	Ground water	Mountain Gate	Stillwater Plains	Domestic
Shasta Dam Area Public Utility District	Shasta Lake	Central Valley and Project City	Stillwater Plains	Domestic
Summit City Public Utility District	Shasta Lake	Summit City	Stillwater Plains	Domestic
City of Redding	Sacramento River	Redding	Anderson	Domestic
Anderson Water Company	Ground water	Anderson	Anderson	Domestic
Cottonwood County Water District	Ground water	Cottonwood	Anderson	Domestic
Anderson Heights Water Company	Ground water	Anderson Heights	Olinda	Domestic
Verde Vale Water Company	Ground water	Verde Vale (Anderson Valley)	Anderson	Domestic
Happy Valley Water Company	North Fork Cottonwood Creek and tributaries	Igo, Ono, and Olinda	Cottonwood Creek and Olinda	Irrigation
Citizens Utilities Company	Ground water	Burney, Fall River Mills, and McArthur	Hat Creek and McArthur	Domestic
Burney County Water District	Ground water	Burney	Hat Creek	Domestic

*Recently formed, not yet an operating agency.

purposes above Shasta Dam is estimated to be about 41,000 acre-feet per season, or about 36 percent of total consumptive use of water in the county.

Irrigation water supplies in the Modoc Plateau area are obtained by diversion of stream flow, supplemented, in some places, by pumping from ground water. Domestic water supplies are generally obtained from wells or springs.

The Pit-Hat hydroelectric power system of the Pacific Gas and Electric Company comprises six power plants with attendant diversion structures, conduits, and transmission lines, located in the Pit River Basin above Shasta Lake. The six plants, having a combined installed capacity of 366,900 kilowatts, are: Hat Creek Nos. 1 and 2, and Pit Nos. 1, 3, 4, and 5. The power plants of the Pit-Hat system are all basically run-of-the-river plants, because the relatively uniform flow characteristics of the Pit River and its Shasta County tributaries are well-suited to hydroelectric power development. Some peaking of power generation is realized from small amounts of reservoir storage capacity within the system.

<u>Westside Area below Shasta Dam</u>

The westside area below Shasta Dam comprises the drainage basins of all streams west of the Sacramento River between Shasta Dam and the south county line and includes the Churn Creek bottoms, which is that portion of the Anderson-Cottonwood Irrigation District lying to the east of the

Sacramento River. The major streams of the area are Clear and Cottonwood Creeks. The area covers approximately 494,000 acres, or 20 percent of Shasta County. An average of approximately 606,000 acre-feet per season of stream flow, or 12 percent of that originating within Shasta County, drains from this area.

Three public water service agencies and several privately owned water companies provide water for agricultural, municipal, industrial, and domestic uses in the Westside area. Most water development works in this area do not store water, but divert the available stream flows. Rainbow Lake on Cottonwood Creek (a conservation reservoir), Keswick Reservoir on the Sacramento River (a reregulation reservoir), and Shasta and Keswick hydroelectric power plants on the Sacramento River are located in the area. Whiskeytown Reservoir on Clear Creek, and the Clear Creek and Spring Creek Power Plants will soon be added to the physical works of this area as parts of the Trinity River Division of the Central Valley Project.

The principal areas of water use in the Westside area are in the Anderson-Cottonwood Irrigation District, the lands served by the Happy Valley Water Company, the City of Redding, and some lands along Cottonwood Creek. The present consumptive use of applied water in the Westside area by crops and for domestic purposes is estimated to be about 50,000 acre-feet seasonally, or about 43 percent of the present consumptive use of applied water in the county.

The Anderson-Cottonwood Irrigation District diverts water from the Sacramento River by means of a dam located a few hundred feet upstream from U. S. Highway 99 East. The water is conveyed by canal for irrigation of lands within the district, including some lands in Tehama County. In addition, the district pumps water from the Sacramento River for irrigation in the Churn Creek Bottoms. Municipal, industrial, and domestic water supplies needed within the district are generally obtained by wells pumping from ground water. The City of Redding obtains its water supply by pumping from the Sacramento River. Prior to the construction of Shasta Dam, both the district and the city obtained their water supplies from the Sacramento River by the same means presently employed.

The water supply of the Happy Valley Water Company is obtained by diversion of natural stream flow from the North Fork of Cottonwood Creek and several of its tributaries, supplemented by water stored in Rainbow Lake on the North Fork of Cottonwood Creek. The company serves irrigation water to lands in the vicinity of Igo and Ono and to the Happy Valley area. Domestic water supplies for the Happy Valley area are, in most instances, pumped from ground water at relatively shallow depths, although several wells now in use are over 200 feet in depth.

The rest of the Westside area, comprising the irrigated lands along Cottonwood Creek from its north fork to the west boundary of the Anderson-Cottonwood Irrigation District, obtain water by diversion of stream flows, supplemented by ground water pumping. During the past few years, some wells have been drilled which provide full irrigation water supplies.

Rainbow Lake, Keswick Reservoir, and the Shasta and Keswick Power Plants are the major water development works in the Westside area. Rainbow Lake, which is formed by Musselbeck Dam, a hydraulic fill structure 110 feet in height on the North Fork of Cottonwood Creek has a maximum storage capacity of 4,800 acre-feet. Keswick Reservoir is formed by Keswick Dam on the Sacramento River and is used to reregulate power releases of water from Shasta Lake. Keswick Reservoir is an integral unit of the Shasta Division of the Central Valley Project, as are the Shasta and Keswick hydroelectric power plants. These two plants have a combined installed capacity of 454,000 kilowatts, and both use water stored in Shasta Lake to generate power.

The Trinity River Division of the Central Valley Project, presently under construction by the United States Bureau of Reclamation, is scheduled to be completed about 1963. Trinity Reservoir, on the Trinity River west of Shasta County, will have a storage capacity of 2,500,000 acre-feet. Releases of water from this reservoir will be utilized by a power plant having a capacity of 96,000 kilowatts, and will be reregulated in Lewiston Reservoir about 7 miles downstream. Lewiston Dam will contain outlets to release water to meet downstream requirements of the Trinity River Basin, including those of the important fishery. Water not needed in the Trinity River Basin will be diverted into

Shasta County through the Clear Creek Tunnel to the Clear Creek Power Plant, having a capacity of 130,000 kilowatts, and thence into the 250,000 acre-foot Whiskeytown Reservoir on Clear Creek, a tributary of the Sacramento River. From this point the Trinity River water and surplus water from Clear Creek will flow through the Spring Creek Tunnel to the Spring Creek Power Plant, with a capacity of 143,000 kilowatts, and then into Keswick Reservoir on the Sacramento River. Flows from the Spring Creek Power Plant, as well as the Shasta Power Plant, will be reregulated in Keswick Reservoir and released to meet requirements of the Central Valley Project.

Eastside Area Below Shasta Dam

The Eastside area below Shasta Dam comprises the drainage basins of all streams on the east side of the Sacramento River between Shasta Dam and the southern Shasta County line, excluding the Churn Creek Bottoms. The two principal streams of the area are Cow and Battle Creeks. Minor streams of the area include Churn, Stillwater, Bear, and Ash Creeks. The area covers about 574,000 acres, or 23 percent of that of Shasta County. An average stream flow of 812,000 acre-feet per season, or 16 percent of the runoff originating within the county, drains from this area. The Cow-Battle hydroelectric power system of the Pacific Gas and Electric Company is the only major water development in the Eastside area.

The Cow Creek Bottoms, comprising lands adjacent to Cow Creek and its tributaries below an elevation of about 600 feet, is the principal area of water utilization. However, scattered parcels of land at higher elevations in the Cow, Bear, Ash, and Battle Creek drainage basins are also irrigated, as well as some lands on the Stillwater Plains. The estimated present consumptive use of applied water by crops and for domestic purposes in the Eastside area below Shasta Dam is about 24,000 acre-feet seasonally, or 21 percent of that for the entire county. Almost all of the presently applied water is obtained by direct diversion from streams. In the Cow Creek Bottoms ground water supplies are used occasionally to supplement stream flow, and on the Stillwater Plains there are some lands irrigated with ground water. However, amount of ground water used is small when compared with the quantity of water obtained from surface sources.

There are four public water service agencies delivering domestic water in the Eastside area below Shasta Dam. These agencies are located in the Stillwater Plains hydrographic unit and are: the Summit City Public Utility District, the Shasta Dam Area Public Utility District, the Buckeye County Water District, and the Enterprise Public Utility District. The first three listed districts obtain water from Shasta Lake. The Enterprise Public Utility District obtains its supply by pumping ground water from gravels adjacent to the Sacramento River. The Wonderland-Mountain Gate Community Services District, recently formed, proposes to develop ground water in the area north of Central Valley and Project City.

The Cow Creek Unit of the Trinity River Division of the Central Valley Project was authorized to provide water service to the Bella Vista Water District. This unit will serve the Cow Creek Bottoms and potential agricultural areas on the Stillwater Plains. The plan is to pump water from the Sacramento River to supply the northern half of the Stillwater Plains, and to furnish water to supplement stream flow in Cow Creek. In addition, the plan envisions ground water as a source of supply for the southern half of the Stillwater Plains, and as a supplement to stream flow in the lower Cow Creek Bottoms. The Bella Vista Water District and the Bureau of Reclamation are negotiating a water service contract.

Major water development works in the Eastside area below Shasta Dam comprise the Cow-Battle hydroelectric power system of the Pacific Gas and Electric Company. The system consists of North Battle Creek and Macumber Reservoirs, and six small power plants, with their conduits and forebays. Four of the plants are in Shasta County: Kilarc, Cow Creek, Volta, and Coleman, with a total installed capacity of 24,400 kilowatts. South and Inskip Power Plants, in Tehama County, add another 10,000 kilowatts to the installed capacity of the system. The power plants are essentially run-of-the-river plants, with North Battle Creek Reservoir used to supplement late summer stream flows. Macumber Reservoir is no longer utilized as a regulating reservoir because of excessive leakage. However, it still has a retarding effect on the flows of North Battle Creek, and contributes to the effectiveness of the Cow-Battle hydroelectric power system.

Land Use

The initial steps in estimating water requirements of Shasta County were to determine the annual and probable ultimate pattern of land uses. The present pattern of land use was determined by field surveys. The probable ultimate pattern of land use was estimated from land classification data.

Present Pattern of Land Use

The lands upon which water was utilized during 1955 and 1956 were classified according to type of use. Summaries of the results of this present land use classification, within hydrographic units and service areas, are, respectively, presented in Tables 9 and 10. Present water-using lands are shown on Plate 15, entitled "Irrigated and Irrigable Lands, and Potential Service Areas".

The predominant use of irrigated lands in Shasta County is for livestock production. Alfalfa, improved pasture, and grain and grain-hay crop classifications total 44,600 acres, or approximately 95 percent of the present lands irrigated in Shasta County.

Probable Ultimate Land Use Pattern

An estimate of the probable ultimate pattern of land use for irrigated agriculture and urban and suburban development, and the ultimate areas to be used for recreational development and reservoir purposes, was determined as a basis for estimates of ultimate water requirements.

TABLE 9

PRESENT PATTERN OF LAND USE IN SHASTA COUNTY BY HYDROGRAPHIC UNITS

(In acres)

Hydrographic unit		Type of land use											
		Irrigated lands									Other water-using areas		
Reference number	Name	Alfalfa	Improved pasture	Grain and grain hay	Truck	Miscellaneous field crops	Deciduous orchard	Sub-tropical orchard	Vineyard	Total irrigated	Urban lands	Meadow pasture[1]	Average area of reservoirs
16	McArthur	1,460	5,610	30	--	--	--	--	--	7,100	250	8,540	230
17	Hat Creek	970	3,140	590	--	60	10	--	--	4,770	390	5,970	1,170
18	Montgomery Creek	--	1,340	60	40	--	70	--	--	1,510	10	50	60
19	McCloud River	--	610	--	--	--	--	--	--	610	--	60	--
20	Dunsmuir	--	140	10	10	--	10	--	--	170	40	--	--
21	Shasta Lake	--	--	--	50	--	--	--	--	50	--	--	27,500
22	Clear Creek	--	60	--	--	10	--	--	--	70	50	--	2,600[2]
23	Keswick	--	--	--	--	--	--	--	--	--	--	--	600
24	Cottonwood Creek	60	1,050	--	80	--	10	410	--	1,610	10	--	60
25	Olinda	10	650	--	30	--	--	470	--	1,160	470	--	20
32	Stillwater Plains	80	350	--	30	--	30	--	--	490	1,810	40	30
33	Cow Creek	260	7,010	--	30	--	50	--	--	7,350	--	110	--
34	Bear Creek	80	2,040	--	--	--	120	--	--	2,240	30	70	10
35	Battle Creek	--	350	--	--	--	40	--	--	390	140	630	90
38	Mill Creek	--	--	--	--	--	--	--	--	--	--	--	--
42	North Fork Feather River	--	--	--	--	--	--	--	--	--	--	10	--
50	Anderson	650	17,440	560	100	150	140	--	10	19,050	3,320	--	--
	TOTALS	3,570	39,790	1,250	370	220	480	880	10	46,570	6,520	15,480	32,370

1/ A portion of these lands is naturally irrigated.
2/ Whiskeytown Reservoir (under construction).

TABLE 10

PRESENT PATTERN OF LAND USE IN SHASTA COUNTY BY SERVICE AREAS
(In acres)

Service area		Type of land use										
		Irrigated lands									Other water-using areas	
Name	Hydrographic unit	Alfalfa	Improved pasture	Grain and grain hay	Truck	Miscellaneous field crops	Deciduous orchard	Subtropical orchard	Vineyard	Total irrigated	Urban lands	Meadow[1/] pasture
Fall River Valley	16-17	1,460	5,580	30	--	--	--	--	--	7,070	250	8,230
Hogback Ridge	17-16	--	--	--	--	--	--	--	--	--	--	60
Hat Creek	17	660	1,620	340	--	60	--	--	--	2,680	--	330
Burney Creek	17	200	560	--	--	--	--	--	--	760	360	910
Goose Valley	17	--	20	--	--	--	--	--	--	20	--	3,570
Cayton Valley	17	20	280	180	--	--	--	--	--	480	--	680
Montgomery Creek	18	--	390	--	--	--	30	--	--	420	--	--
Igo-Ono	24-22-25	--	400	--	--	--	--	--	--	400	--	--
Bee Creek	24	--	140	--	--	--	--	--	--	140	--	--
Cottonwood Creek	24	60	250	--	80	--	--	--	--	390	--	--
Happy Valley	25-24	10	700	--	30	--	10	880	--	1,630	--	--
Stillwater Plains	32	20	40	--	30	--	10	--	--	100	--	--
Bella Vista	32-33	130	430	--	--	--	20	--	--	580	--	--
Cow Creek Bottoms	33	90	1,710	--	--	--	10	--	--	1,810	--	--
Little Cow Creek	33	--	440	--	--	--	--	--	--	440	--	--
Round Mountain	18-33	--	550	--	--	--	10	--	--	560	30	--
Bullskin Ridge	33	--	40	--	--	--	--	--	--	40	--	10
Oak Flat	33	--	730	--	--	--	--	--	--	730	--	--
Oak Run	33	60	120	--	--	--	--	--	--	180	--	--
Clover Creek	33	--	680	--	--	--	--	--	--	680	--	--
Old Cow Creek	33	--	1,410	--	--	--	--	--	--	1,410	--	--
Whitmore	33	--	790	--	--	--	20	--	--	810	--	--
Hagaman Gulch	33-34	--	20	--	--	--	--	--	--	20	--	--
South Cow Creek	33	150	260	--	--	--	--	--	--	410	--	--
Urban Center	25-50	60	2,110	--	--	--	--	--	10	2,180	3,670	--
North Suburban	32	--	40	--	--	--	--	--	--	40	900	--

TABLE 10 **(Continued)**

PRESENT PATTERN OF LAND USE IN SHASTA COUNTY BY SERVICE AREAS
(In acres)

Service area		Type of land use										
		Irrigated									Other water-using areas	
Name	Hydrographic unit	Alfalfa	Improved pasture	Grain and grain hay	Truck	Miscellaneous field crops	Deciduous orchard	Subtropical orchard	Vineyard	Total irrigated	Urban lands	Meadow pasture 1/
Millville Plains	33-34	60	90	--	--	--	--	--	--	150	--	--
Anderson-Cottonwood	50	580	13,390	560	10	150	70	--	--	14,760	1,100	--
Black Butte	34-35	--	--	--	--	--	--	--	--	--	--	--
Inwood	34	--	720	--	--	--	30	--	--	750	--	20
Manton	35	--	40	--	--	--	30	--	--	70	--	--
TOTALS		3,560	33,550	1,110	150	210	240	880	10	39,710	6,310	13,810

1/ A portion of these lands is naturally irrigated.

Irrigated Lands. Irrigability and crop adaptability were basic considerations in classifying the agricultural lands of Shasta County. The land classification survey indicated that the ultimate gross irrigable area of the county is about 259,000 acres. In addition, some 277,000 acres meet the physical requirements for irrigable lands, but are best suited for forest or range management.

Not all of the gross irrigable area of 259,000 acres would require water service. To estimate the probable ultimate net irrigable area requiring water service, factors of reduction were applied to the gross irrigable area. These factors accounted for farm lots, roads, canals, fallow lands, and incidental non-irrigable areas and other considerations such as difficulty of development and size, shape, and location of the lands. As a result, there was obtained a probable ultimate net irrigable area of about 208,000 acres.

The ultimate crop pattern within the net irrigable area was estimated by considering the growth and development not only of Shasta County, but also of surrounding counties and the remainder of the State. The methods, procedures, and results of studies leading to the probable ultimate crop pattern are presented in the following paragraphs.

(1) Standards for Land Classification. The suitability of land for irrigation is influenced by numerous factors. The physical characteristics of the land and the inherent conditions of the soil directly affect the adaptability of land for

irrigation. Some indirect factors are those related to the production and marketing of climatically adapted crops, location of land with respect to adequate water supplies, and regional climatic conditions. For this investigation all pertinent factors relating to land classification, direct and indirect, were considered in evaluating the probable ultimate requirements for water.

On the basis of land classification surveys, the extent and location of irrigable lands were determined and the lands were divided into various crop adaptability classes. Lands classified as suitable for irrigation development were segregated into three broad topographic groups: smooth-lying valley lands, slightly sloping and undulating lands, and steeper and more rolling lands. Where other conditions limited the suitability of the lands to produce climatically adapted crops, the three broad classes were further subdivided in accordance with the nature of the limitations. In Shasta County such limiting conditions include shallow soil depths, rockiness, high-water tables, and coarse soil textures with low moisture-holding capacities.

In the mountain and foothill areas of Shasta County, lands are found with soils and physical characteristics which make them suitable for irrigation. However, due to climate and other factors associated with their present use, they were classified as best suited to remain under some type of forest or range management. In general, these areas lie at elevations where the length of the growing season limits crop adaptability.

It appears reasonable that these marginal lands would remain as grazing lands under general forest management. Another example of irrigable lands best suited to forest management are those adjacent to mountain lakes and streams which are potentially valuable for recreational activities. These lands were not considered as potential agricultural lands, but were assumed to remain under forest management.

Table 11 contains a description of the land classification standards adopted by the Department of Water Resources and used in the survey of Shasta County.

(2) Gross Irrigable Area. Results of the land classification survey of Shasta County are presented in Table 12. This table shows that the gross irrigable area of the county is about 259,000 acres. Of this area, about 136,000 acres, or 52 percent, were classified as irrigable valley land. Most of these irrigable valley lands are composed of Recent alluvial and lacustrine (lake-formed) soils, the greater portion being of excellent quality for agricultural purposes.

The irrigable hill lands are mostly composed of residual soils or old valley terrace soils. The best of the irrigable hill lands, those which have adequate soil depth and reasonably smooth topography, comprise about 39,000 acres, or approximately 15 percent of the gross irrigable area of Shasta County. The remainder of the irrigable hill lands, totaling some 84,000 acres, or about 33 percent of the gross irrigable area, are limited in their crop adaptability by inadequate soil depths, presence of rock, or excessive ground slopes.

TABLE 11

LAND CLASSIFICATION STANDARDS

Land class	Characteristics
	Irrigable Valley Lands
V	Smooth-lying valley lands with slopes up to 6 percent in general gradient, in reasonably large-sized bodies sloping in the same plane; or slightly undulating lands which are less than 4 percent in general gradient. The soils have medium to deep effective root zones, are permeable throughout, and free of salinity, alkalinity, rock, or other conditions limiting crop adaptability of the land. These lands are suitable for all climatically adapted crops.
Vw	Similar in all respects to Class V, except for the present condition of a high water table, which in effect limits the crop adaptability of these lands to pasture crops. Drainage and a change in irrigation practice would be required to affect the crop adaptability. For the purpose of this investigation, it was assumed that there would be no further change in use of these lands.
Vl	Similar in all respects to Class V, except for having fairly coarse textures and low moisture-holding capacities, which in general make these lands unsuited for the production of shallow-rooted crops because of the frequency of irrigations required to supply the water needs of such crops.
Vp	Similar in all respects to Class V, except for depth of the effective root zone, which limits use of these lands to shallow-rooted crops, such as irrigated grain and pasture.
Vr	Similar in all respects to Class V, except for the presence of rock on the surface or within the plow zone in sufficient quantity to prevent use of the land for cultivated crops. These lands are suitable for irrigated pasture crops.
Vpr	Similar in all respects to Class V, except for the limitations set forth for Classes Vp and Vr, which restrict the crop adaptability of these lands to irrigated pasture.

TABLE 11 (Continued)

LAND CLASSIFICATION STANDARDS

Land class	Characteristics
	Irrigable Hill Lands
H	Rolling and undulating lands with slopes up to a maximum of 20 percent for rolling large-sized bodies sloping in the same plane and grading down to a maximum slope of less than 12 percent for undulating lands. The soils are permeable, with medium to deep effective root zones, and are suitable for the production of all climatically adapted crops. The only limitation is that imposed by topographic conditions, which affect the ease of irrigation and the extent of these lands that may ultimately be developed for irrigation.
Hp	Similar in all respects to Class H, except for depth of the effective root zone, which limits use of these lands to shallow-rooted crops.
Hr	Similar in all respects to Class H, except for the presence of rock on the surface or within the plow zone in sufficient quantity to restrict use of the land to noncultivated crops.
Hpr	Similar in all respects to Class H, except for depth of the effective root zone and the presence of rock on the surface or within the root zone in sufficient quantity to restrict use of these lands to noncultivated crops.
M	Similar in all respects to Class H, except for topographic limitations. These lands have smooth slopes up to 30 percent in general gradient for large-sized bodies sloping in the same plane, and slopes up to 20 percent for rougher and more undulating topography. These lands will probably never become as highly developed as "H" classes of land and are best suited for irrigated pasture.
Mp	Similar in all respects to Class M, except for depth of the effective root zone, which limits use of these lands to shallow-rooted crops.
Mr	Similar in all respects to Class M, except for the presence of rock on the surface or within the plow zone in sufficient quantity to restrict use of these lands to noncultivated crops.

TABLE 11 (Continued)

LAND CLASSIFICATION STANDARDS

Land class	Characteristics
Mpr	Similar in all respects to Class M, except for depth of the effective root zone and the presence of rock on the surface or within the root zone, which limits use of these lands to noncultivated shallow-rooted crops.
F	Presently forested lands, or lands subject to forest management, which meet the requirements for irrigable land but which, because of climatic conditions and physiographic position, are better suited for timber production or some type of forest management program rather than for irrigated agriculture.
U	Urban lands presently used for residential, commercial, resort, and industrial purposes.
N	Includes all lands which fail to meet the requirements of the above classes.

Plate 16, "Classification of Irrigable Lands", delineates these irrigable lands into broad groups as follows: valley lands with crop adaptability not limited by depth of effective root zone or by presence of rock in plow zone, valley lands with limited crop adaptability due to depth of effective root zone, hill lands with crop adaptability not limited by depth of effective root zone or by presence of rock in plow zone, hill lands with limited crop adaptability due to depth of effective root zone, valley and hill lands with limited crop adaptability due to presence of rock in plow zone, and other irrigable lands best suited to forest or range management.

TABLE 12

CLASSIFICATION OF IRRIGABLE LANDS
IN SHASTA COUNTY BY HYDROGRAPHIC UNITS

(In acres)

Hydrographic unit		Irrigable valley land classes						Irrigable hill land classes								Gross irrigable area	Irrigable lands best suited to forest management
Reference number	Name	V	Vw	Vl	Vp	Vr	Vpr	H	M	Hp	Mp	Hr	Hpr	Mr	Mpr		
16	McArthur	17,400	8,380	---	12,320	320	---	2,960	1,450	690	390	---	30	80	---	44,020	32,770
17	Hat Creek	9,060	5,730	180	30	1,330	150	2,280	600	1,340	590	440	530	20	40	22,320	129,060
18	Montgomery Creek	830	70	---	---	100	---	2,190	2,730	---	---	510	---	520	---	6,950	35,680
19	McCloud River	780	50	---	---	---	---	100	30	---	---	---	---	---	---	960	960
20	Dunsmuir	390	---	---	---	270	---	540	430	20	40	50	---	---	---	1,740	20
21	Shasta Lake	90	---	---	---	10	---	800	700	560	10	10	---	---	---	2,180	---
22	Clear Creek	10	---	---	---	10	---	50	50	20	90	110	---	30	---	370	---
23	Keswick	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
24	Cottonwood Creek	5,440	---	210	2,270	60	40	1,020	1,730	7,000	5,940	170	850	---	---	24,730	---
25	Olinda	6,140	---	---	700	---	20	620	---	1,480	830	---	450	---	---	10,240	---
32	Stillwater Plains	7,100	40	---	12,720	100	---	3,840	210	11,080	2,100	260	---	---	---	37,450	---
33	Cow Creek	10,380	160	---	950	1,210	60	14,310	4,830	2,550	790	9,120	840	4,550	130	49,880	17,370
34	Bear Creek	3,820	30	---	1,940	1,520	210	5,300	950	1,690	---	4,490	1,480	220	---	21,650	16,930
35	Battle Creek	1,840	670	---	---	910	---	1,820	650		---	3,400	150	1,470	80	10,990	44,190
38	Mill Creek	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
42	North Fork Feather River	---	40	---	---	---	---	---	---	---	---	---	---	---	---	40	50
50	Anderson	13,650		450	5,060	70	250	2,860	---	3,070	30	10	80	---	---	25,530	---
	TOTALS	76,930	15,170	840	35,990	5,910	730	38,690	14,360	29,500	10,810	18,570	4,410	6,890	250	259,050	277,030

(3) Factors Determining Net Irrigable Area. Certain factors reducing the full utilization of land classified as irrigable have been determined and probable limits established. Even in the most intensively developed areas of irrigated agriculture, not all irrigable lands receive water every season. Since the results of the land classification survey were in terms of gross area, it was necessary to estimate the net acreage that might ultimately be irrigated in an average season.

To determine net irrigable area, the gross irrigable area of each class of land was adjusted by applying appropriate factors. These factors, which are the products of the individual factors discussed below, are presented in Table 13. The net irrigable acreages by hydrographic units and service areas are presented in Tables 14 and 15, respectively.

Crop Rotation--Permitting land to lie fallow is an agricultural practice for both high and low quality lands. The practice is particularly followed in farming low quality lands when the price of a product is low. Permitting land to lie fallow, whatever the reason, is known as crop rotation.

It is anticipated that, in the future, the higher quality irrigable lands will be intensively developed for irrigation and will remain in relatively continuous operation, whereas lands of poorer quality and of limited crop adaptability will be in production only when favorable economic conditions permit. Even though it is assumed that all net irrigable lands will receive water service, the effect of crop rotation will reduce the acreage irrigated seasonally.

TABLE 13

FACTORS USED TO CONVERT GROSS IRRIGABLE ACRES TO NET IRRIGABLE ACRES

(In percent)

Hydrographic unit		Irrigable valley land classes						Irrigable hill land classes							
Reference number	Name	V	Vw	Vl	Vp	Vr	Vpr	H	M	Hp	Mp	Hr	Hpr	Mr	Mpr
16	McArthur	88	89	--	80	79	--	82	74	75	68	--	67	64	--
17	Hat Creek	87	89	85	82	80	75	79	73	73	66	70	65	63	58
18	Montgomery Creek	87	89	--	--	80	--	79	71	--	--	72	--	64	--
19	McCloud River	87	89	--	--	--	--	81	74	--	--	--	--	--	--
20	Dunsmuir	84	--	--	--	79	--	80	73	73	67	71	--	--	--
21	Shasta Lake	88	--	--	--	81	--	81	73	75	--	72	--	--	--
22	Clear Creek	88	--	--	--	80	--	78	72	72	65	70	--	63	--
23	Keswick	--	--	--	--	--	--	--	--	--	--	--	--	--	--
24	Cottonwood Creek	88	--	86	81	80	75	81	73	75	67	72	66	--	--
25	Olinda	88	--	--	82	--	76	81	--	77	67	--	66	--	--
32	Stillwater Plains	88	89	--	80	79	--	82	74	75	68	72	--	--	--
33	Cow Creek	87	89	--	80	79	74	81	73	75	66	71	66	64	58
34	Bear Creek	87	89	--	80	79	74	82	73	75	--	72	67	64	--
35	Battle Creek	87	89	--	--	79	--	82	73	--	--	73	68	64	58
38	Mill Creek	--	--	--	--	--	--	--	--	--	--	--	--	--	--
42	North Fork Feather River	--	89	--	--	--	--	--	--	--	--	--	--	--	--
50	Anderson	88	--	82	82	81	78	83	--	77	69	73	69	--	--

TABLE 14

CLASSIFICATION OF NET IRRIGABLE
LANDS IN SHASTA COUNTY BY HYDROGRAPHIC UNITS

(In acres)

Hydrographic unit		Irrigable valley land classes						Irrigable hill land classes										Total
Reference number	Name	V	Vw	Vl	Vp	Vr	Vpr	H	M	Hp	Mp	Hr	Hpr	Mr	Mpr	net irrigable areas
16	McArthur	15,310	7,460	--	9,860	250	--	2,430	1,070	520	260	--	20	50	--	37,230
17	Hat Creek	7,880	5,100	150	20	1,060	110	1,800	440	980	390	310	340	10	20	18,610
18	Montgomery Creek	720	60	--	--	80	--	1,730	1,940	--	--	370	--	330	--	5,230
19	McCloud River	680	40	--	--	--	--	80	20	--	--	--	--	--	--	820
20	Dunsmuir	330	--	--	--	210	--	430	310	10	30	40	--	--	--	1,360
21	Shasta Lake	80	--	--	--	10	--	650	510	420	--	10	--	--	--	1,680
22	Clear Creek	10	--	--	--	10	--	40	40	10	60	80	--	20	--	270
23	Keswick	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
24	Cottonwood Creek	4,790	--	180	1,840	50	30	830	1,260	5,250	3,980	120	560	--	--	18,890
25	Olinda	5,400	--	--	570	--	20	500	--	1,140	560	--	300	--	--	8,490
32	Stillwater Plains	6,250	40	--	10,180	80	--	3,150	160	8,310	1,430	130	--	--	--	29,730
33	Cow Creek	9,030	140	--	760	960	40	11,590	3,530	1,910	520	6,480	550	2,910	80	38,500
34	Bear Creek	3,320	30	--	1,550	1,200	160	4,350	690	1,270	--	3,230	990	140	--	16,930
35	Battle Creek	1,600	600	--	--	720	--	1,490	470	--	--	2,480	100	940	50	8,450
38	Mill Creek	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
42	North Fork Feather River	--	40	--	--	--	--	--	--	--	--	--	--	--	--	40
50	Anderson	12,010	--	370	4,150	60	200	2,370	--	2,360	20	10	60	--	--	21,610
	TOTALS	67,410	13,510	700	28,930	4,690	560	31,440	10,440	22,180	7,250	13,260	2,920	4,400	150	207,840

TABLE 15

CLASSIFICATION OF NET IRRIGABLE LANDS
IN SHASTA COUNTY BY SERVICE AREAS

(In acres)

Service area		Irrigable valley land classes						Irrigable hill land classes								Total
Name	Hydro-graphic unit	V	Vw	Vl	Vp	Vr	Vpr	H	M	Hp	Mp	Hr	Hpr	Mr	Mpr	net irrigable areas
Fall River Valley	16-17	14,450	7,180	--	9,940	230	--	2,420	950	910	260	--	20	50	--	36,410
Hogback Ridge	17-16	1,180	40	--	--	50	--	590	250	380	370	--	--	--	--	2,860
Hat Creek	17	2,950	290	160	--	440	--	120	--	--	--	10	--	--	--	3,970
Burney Creek	17	1,720	810	--	--	250	--	60	--	--	--	10	--	--	--	2,850
Goose Valley	17	190	3,040	--	--	--	--	--	--	--	--	--	--	--	--	3,230
Cayton Valley	17	580	600	--	--	--	--	50	--	--	--	--	--	--	--	1,230
Montgomery Creek	18	40	--	--	--	--	--	330	500	--	--	60	--	110	--	1,040
Igo-Ono	24-22-25	120	--	--	--	--	--	220	550	480	2,170	--	310	--	--	3,850
Bee Creek	24	--	--	--	--	--	--	--	--	90	520	--	--	--	--	610
Cottonwood Creek	24	3,150	--	130	730	--	30	150	50	1,850	--	--	10	--	--	6,100
Happy Valley	25-24	6,350	--	--	1,300	--	--	590	--	320	--	--	--	--	--	8,560
Stillwater Plains	32	660	--	--	6,770	--	--	460	--	2,660	--	190	--	--	--	10,740
Bella Vista	32-33	4,580	--	--	4,040	--	--	2,430	130	4,040	510	140	--	--	--	13,730
Cow Creek Bottoms	33	3,920	--	--	50	10	--	1,230	--	620	--	170	--	--	--	6,000
Little Cow Creek	33	520	--	--	--	170	--	400	90	160	--	350	--	140	--	1,830
Round Mountain	18-33	500	--	--	--	20	--	720	500	--	--	10	--	--	--	1,750
Bullskin Ridge	33	70	10	--	--	--	--	920	390	--	--	590	--	250	--	2,230
Oak Flat	33	220	--	--	--	--	--	1,010	40	--	--	1,610	--	400	--	3,280

TABLE 15 (Continued)

CLASSIFICATION OF NET IRRIGABLE LANDS
IN SHASTA COUNTY BY SERVICE AREAS

(In acres)

Service area		Irrigable valley land classes						Irrigable hill land classes								Total
Name	Hydrographic unit	V	Vw	Vl	Vp	Vr	Vpr	H	M	Hp	Mp	Hr	Hpr	Mr	Mpr	net irrigable areas
Oak Run	33	1,160	--	--	--	--	--	690	60	--	--	10	--	--	--	1,920
Clover Creek	33	550	--	--	--	--	--	930	1,560	30	--	240	--	560	--	3,870
Old Cow Creek	33	70	--	--	--	550	--	340	20	90	450	620	--	330	70	2,540
Whitmore	33	650	--	--	--	80	40	3,400	30	--	--	2,400	280	870	--	7,750
Hagaman Gulch	33-34	--	--	--	--	--	--	720	--	--	--	--	--	--	--	720
South Cow Creek	33	480	--	--	--	40	--	260	490	--	20	100	--	20	--	1,410
Urban Center	25-50	3,640	--	--	1,970	40	140	70	--	620	--	--	40	--	--	6,590
North Suburban	32	320	30	--	1,100	50	--	670	20	1,290	520	--	--	--	--	4,000
Millville Plains	33-34	250	--	--	1,600	170	50	--	--	1,190	--	--	70	--	--	3,330
Anderson-Cottonwood	50	10,000	--	370	4,190	30	70	2,390	--	3,060	50	--	20	--	--	20,180
Black Butte	34-35	--	--	--	--	--	--	1,490	200	--	--	640	--	10	--	2,340
Inwood	34	1,230	20	--	--	590	70	2,930	530	--	--	2,690	360	30	--	8,450
Manton	35	1,410	--	--	--	640	--	870	300	--	--	2,010	60	180	--	5,470
TOTALS		60,960	12,020	660	29,690	3,360	400	26,460	6,660	17,860	4,870	11,850	1,170	2,950	70	178,840

Nonagricultural Use--It is anticipated that there will always be a portion of the irrigable lands that will be occupied by urban types of development such as farm lots, highways, railroads, canals, and industrial establishments. The nature of the agricultural development will, in some degree, determine the extent of certain of these nonagricultural land uses. For example, orchard and truck farming areas ordinarily include more land use for roads and farm lots than in areas where field crops are dominant. A factor based on the above effect was determined to vary between 95 and 93 percent.

Nonirrigable "Island" Areas--It was not possible to delineate all of the small areas of nonirrigable land which occur within the lands classed as irrigable. The occurrence of these small plots of nonirrigable lands varies generally with the detail of the survey and classes of lands being surveyed. The occurrence is greatest in the marginal classes. A factor based on this effect was determined to vary between 99 and 92 percent.

Size, Shape, and Location--It is apparent that small, irregularly shaped plots of land, particularly when isolated from other irrigable lands, cannot be irrigated as readily or completely as large, regularly shaped, compact units. Ownership boundaries also exert an influence, since many small, isolated ownerships may never be developed. A factor based on these effects was determined to vary between 100 and 92 percent.

Adverse Topography--The inherent difficulties encountered in developing and serving water to those lands with the more adverse topographic conditions will tend to prevent them from being utilized completely. This is particularly true of lands with hilly topography which could not be served completely by a gravity irrigation system and which require numerous pump lifts. A factor based on this effect was determined to vary between 100 and 92 percent.

Economic Conditions--The economic effect of profit or loss on the production of crops is recognized as one of the most influential factors in determining the amount of seasonal irrigated acreage and the resultant water requirements. It is probable that there will always be a tendency to withdraw land from production in years of economic adversity. Inasmuch as the concept of ultimate development, adopted for purposes of the present studies, presupposes maximum land use within physical limitations and water supply availability, economic effects were not given consideration in determining the probable ultimate net irrigated area. This assumption is conservative in relation to water requirements, because the estimated future requirements are thus maximized. Consequently, the factor for this effect was considered to be 100 percent.

(4) Probable Ultimate Crop Pattern. The projection of a probable ultimate crop pattern that could be sustained on the irrigable lands of Shasta County was an important step in evaluating ultimate water requirements. The present development of irrigated agriculture was used as a base of departure in projecting the ultimate crop pattern. The Shasta County Farm

Advisor, the Shasta County Agricultural Commissioner, and other agricultural leaders throughout the area furnished valuable information which aided in the forecast of future agricultural development.

Any projection of a probable ultimate crop pattern must be generalized. For instance, since the raising of livestock is presently the dominant segment of the agricultural industry in Shasta County, it appeared reasonable that the ultimate crop projection should be weighted heavily in favor of crops necessary in raising livestock. Similarly, as the population of California increases, it is expected that urban encroachment on those deciduous orchard and truck crops now grown adjacent to metropolitan areas of the State will increase, and the production of deciduous orchard and truck crops will shift to suitable lands in areas such as Shasta County. For this reason, a moderate acreage of these crops was included in the estimated ultimate crop pattern of the county.

The various crop categories included in the probable ultimate crop pattern are the same as those in the present pattern of land use, with the exception of subtropical orchard which is omitted in the probable ultimate crop pattern. Olives in the Olinda area comprise the major portion of the present subtropical orchard category. Yields of these olive orchards are low when compared to the major olive-producing areas of the State, and it is believed that in the future they will be replaced by more productive crops with higher monetary returns.

The projected future crop pattern may vary considerably during any given year or series of years because of economic conditions or other unforeseen factors. However, the primary purpose of projecting an ultimate crop pattern for this investigation was to provide a means for estimating ultimate water requirements. The pattern as projected appears reasonable and adequate for this purpose. The probable ultimate crop pattern projected for Shasta County is presented by hydrographic units and by service areas in Tables 16 and 17, respectively.

Urban and Suburban Lands. Urban and suburban lands, as considered in this report, include the gross developed areas of the cities and towns, sawmills, small communities, industrial areas, and resorts. These urban areas are not limited by municipal boundaries or by any specific density of development. The acreages of present urban lands for each hydrographic unit in Shasta County are tabulated in Table 9 and are shown on Plate 15.

Forecasts of future population were used to estimate future urban and suburban use of water. These forecasts were based on the assumption that full development of all natural resources would be attained in Shasta County. Agriculture and timber resources now support, either directly or indirectly, about two-thirds of the population. Under ultimate conditions, it is expected that employment in agriculture and forest products industries will double, while the population will increase

TABLE 16

PROBABLE ULTIMATE CROP PATTERN ON IRRIGATED LANDS IN SHASTA COUNTY BY HYDROGRAPHIC UNITS

(In acres)

Hydrographic unit		Irrigated lands							
Reference number	Name	Alfalfa	Improved pasture	Grain and grain hay	Truck	Miscellaneous field crops	Deciduous orchard	Total irrigated	Meadow pasture*
16	McArthur	12,000	11,100	4,200	500	2,000	----	29,800	7,500
17	Hat Creek	5,200	6,200	2,800	---	500	----	14,700	4,000
18	Montgomery Creek	800	2,600	400	100	---	1,300	5,200	100
19	McCloud River	300	500	---	---	---	----	800	---
20	Dunsmuir	100	700	---	100	100	400	1,400	---
21	Shasta Lake	200	900	---	400	---	200	1,700	---
22	Clear Creek	---	200	---	---	---	---	200	---
23	Keswick	---	---	---	---	---	---	---	---
24	Cottonwood Creek	1,400	11,600	1,400	400	900	3,200	18,900	---
25	Olinda	700	5,000	700	100	400	1,500	8,400	---
32	Stillwater Plains	2,300	19,700	2,900	500	1,500	2,800	29,700	---
33	Cow Creek	8,000	18,900	2,000	400	1,600	7,500	38,400	100
34	Bear Creek	2,100	10,500	1,300	200	900	1,900	16,900	---
35	Battle Creek	600	5,100	400	100	500	1,200	7,900	600
38	Mill Creek	---	---	---	---	---	---	---	---
42	North Fork Feather River	---	---	---	---	---	---	---	---
50	Anderson	4,600	13,400	900	300	1,000	1,400	21,600	---
	TOTALS	38,300	106,400	17,000	3,100	9,400	21,400	195,600	12,300

*A portion of these lands is naturally irrigated.

TABLE 17

PROBABLE ULTIMATE CROP PATTERN
ON IRRIGATED LANDS IN SHASTA COUNTY
BY SERVICE AREAS

(In acres)

Service area		Irrigated lands							
Name	Hydro-graphic unit	Alfalfa	Improved pasture	Grain and grain hay	Truck	Miscel-laneous Field crops	Total irrigated	Total irrigated	Meadow pasture*
Fall River Valley	16-17	11,450	11,320	4,110	500	1,850	----	29,230	7,180
Hogback Ridge	17-16	1,000	1,150	550	---	120	----	2,820	40
Hat creek	17	1,720	980	790	---	190	----	3,680	290
Burney Creek	17	700	780	460	---	100	----	2,040	810
Goose Valley	17	100	90	---	---	---	----	190	3,040
Cayton Valley	17	310	180	140	---	---	----	630	600
Montgomery Creek	18	---	590	100	---	---	350	1,040	---
Igo-Ono	24-22-25	100	3,650	100	---	---	----	3,850	---
Bee Creek	24	---	610	---	---	---	----	610	---
Cottonwood Creek	24	900	2,100	400	400	300	2,000	6,100	---
Happy Valley	25-24	300	5,260	300	300	300	2,100	8,560	---
Stillwater Plains	32	300	8,440	1,400	100	100	400	10,740	---
Bella Vista	32-33	1,700	8,530	500	300	1,000	1,700	13,730	---
Cow Creek Bottoms	33	2,200	1,200	500	300	1,000	800	6,000	---
Little Cow Creek	33	380	1,060	90	---	---	300	1,830	---
Round Mountain	18-33	350	600	300	---	---	500	1,750	---
Bullskin Ridge	33	370	1,300	100	---	---	450	2,220	10
Oak Flat	33	400	2,280	100	---	---	500	3,280	---
Oak Run	33	700	620	100	---	---	500	1,920	---
Clover Creek	33	600	2,120	150	---	---	1,000	3,870	---
Old Cow Creek	33	170	2,220	50	---	---	100	2,540	---
Whitmore	33	1,400	4,400	600	---	---	1,350	7,750	---
Hagaman Gulch	33-34	200	220	100	---	---	200	720	---
South Cow Creek	33	320	560	130	---	---	400	1,410	---

TABLE 17 (Continued)

PROBABLE ULTIMATE CROP PATTERN
ON IRRIGATED LANDS IN SHASTA COUNTY
BY SERVICE AREAS

(In acres)

Service area		Irrigated lands							
Name	Hydrographic unit	Alfalfa	Improved pasture	Grain and grain hay	Truck	Miscellaneous field crops	Total irrigated	Total irrigated	Meadow pasture*
Urban Center	25-50		N E G L I G I B L E						
North Suburban	32		N E G L I G I B L E						
Millville Plains	33-34	50	2,630	550	---	50	50	3,330	---
Anderson-Cottonwood	50	4,000	12,580	900	300	1,000	1,400	20,180	---
Black Butte	34-35	350	1,140	150	50	150	500	2,340	---
Inwood	34	1,100	5,230	400	100	500	1,100	8,430	20
Manton	35	450	3,420	300	50	400	850	5,470	---
TOTALS		31,620	85,260	13,370	2,400	7,060	16,550	156,260	11,990

*A portion of these lands is naturally irrigated.

nearly four-fold. It is anticipated that a substantial portion of the population, at the time of ultimate development, will be supported by recreational activities and their attendant services. Industries in urban areas, other than the forest products industry, are expected to support the population to a minor extent only.

Although ultimate urban water requirements were determined on a population basis, the area of lands expected to become predominantly urban and suburban in character was determined in order to refine the estimates of population distribution. This area was done on the basis of assumed population densities. The densities assumed were 8.5 persons per acre in urban areas and 4.25 persons per acre in rural communities and suburban areas. The resultant estimates of ultimate urban and suburban areas are presented in Table 18.

Future population growth of the county was estimated for the Department of Water Resources in connection with the Northeastern Counties Investigation by Harold F. Wise and Associates, consultants in planning and urban economics. The estimates considered not only the future growth of Shasta County but also the future growth of the 15 northeastern counties, the State of California, and the nation. The results were published in Appendix A of Department of Water Resources Bulletin No. 58, entitled "Future Population, Economic, and Recreation Development of California's Northeastern Counties". The estimates indicated that the ultimate population of Shasta County would probably

TABLE 18

PROBABLE ULTIMATE AREAS OF URBAN AND SUBURBAN LANDS, RECREATIONAL LANDS, AND RESERVOIR WATER SURFACES IN SHASTA COUNTY BY HYDROGRAPHIC UNITS

(In acres)

Hydrographic Unit		Urban and suburban areas	Recreational areas			Average area of principal reservoirs
Reference number	Name		High intensity	Medium intensity	Low intensity	
16	McArthur	1,200	33,200	42,000	17,800	3,700
17	Hat Creek	2,400	190,100	22,500	203,600	1,300
18	Montgomery Creek	--	117,600	--	51,900	1,200
19	McCloud River	--	54,100	2,000	3,500	1,700
20	Dunsmuir	--	73,100	16,800	3,100	--
21	Shasta Lake	--	256,300	--	400	27,500
22	Clear Creek	--	124,500	--	400	5,900
23	Keswick	--	23,900	--	--	600
24	Cottonwood Creek	--	66,200	16,000	127,300	2,400
25	Olinda	--	5,700	--	13,200	1,700
32	Stillwater Plains	8,900	2,400	--	--	*
33	Cow Creek	1,200	178,600	--	10,100	4,800
34	Bear Creek	--	35,100	--	31,700	*
35	Battle Creek	--	58,300	--	19,700	400
38	Mill Creek	--	3,000	--	--	--
42	North Fork Feather River	--	12,700	--	--	--
50	Anderson	12,700	9,100	--	800	6,000
	TOTALS	26,400	1,243,900	99,300	483,500	57,200

*Represents less than 50 acres.

reach 195,000. More recent studies by the Department of Water Resources indicate that this population may be reached by about the year 2010. However, the estimates of ultimate water requirements for urban and suburban lands, presented herein, are based on a forecasted population of 195,000. Wise and Associates further subdivided this estimate into the following categories: urban and suburban -- 140,400 persons; rural nonfarm -- 46,400 persons; and rural farm -- 8,200 persons. The breakdown into these three categories was based on estimates of the future potential of recreation, agriculture, and industry and on the direct and related employment in each category.

In order to estimate the ultimate water requirements by hydrographic units, the county population was apportioned as a part of this investigation among the units by considering present population centers to represent the pattern for future growth. This apportionment of the population among hydrographic units is presented in Table 19.

Forest Lands and Uses. Various federal and state agencies, assisted by timber companies, have estimated the extent and productivity of commercial forest land in Shasta County. They have determined commercial forest land to be about 1,263,000 acres, or more than half the total area of the county, and the sustained annual timber yield of these lands to be 303,000,000 board feet (international scale).

In Department of Water Resources Bulletin No. 58 the annual production of forest products on a sustained yield

TABLE 19

ESTIMATED DISTRIBUTION OF ULTIMATE POPULATION OF SHASTA COUNTY BY HYDROGRAPHIC UNITS

(In numbers of persons)

Hydrographic unit: Reference number	Hydrographic unit: Name	Urban and suburban	Rural, non-farm	Rural, farm	Total
16	McArthur	5,000	2,000	1,400	8,400
17	Hat Creek	10,000	2,000	700	12,700
18	Montgomery Creek	---	2,000	200	2,200
19	McCloud River	---	---	2/	2/
20	Dunsmuir	---	1,500	100	1,600
21	Shasta Lake	---	2,500	100	2,600
22	Clear Creek	---	1,500	2/	1,500
23	Keswick	---	900	---	900
24	Cottonwood Creek	---	2,000	800	2,800
25	Olinda	---	5,000	300	5,300
32	Stillwater Plains	49,000	10,000	1,200	60,200
33	Cow Creek	5,000	5,500	1,600	12,100
34	Bear Creek	---	2,500	700	3,200
35	Battle Creek	---	3,000	300	3,300
38	Mill Creek 1/	---	---	---	---
42	North Fork Feather River 1/	---	---	---	---
50	Anderson	71,400	6,000	800	78,200
	TOTALS	140,400	46,400	8,200	195,000

1/ Entirely within Lassen Volcanic National Park.
2/ Less than 50.

basis was estimated on the assumption that production of pulp, paper products, and fiberboard will be confined generally to the counties of Shasta, Tehama. Butte. Yuba, and Siskiyou. Furthermore it was assumed that some of the timber from neighboring counties would be processed in Shasta County. The resulting estimated sustained annual production of major forest products industries for Shasta County is:

Lumber	417 million board feet (lumber tally)
Plywood . . .	66.61 million square feet (3/8-inch basis)
Pulp	431 thousand tons
Fiberboard and paper products.	276 thousand tons

These quantities were used in estimating ultimate water requirements for the forest products industry in the county.

Recreational Lands and Uses. Historically, the economy of Shasta County has depended on lumbering, agriculture, mining, and related service industries. In recent years, however, recreational activity has rapidly increased to a position of major importance in the county's economy.

The firm of Harold F. Wise and Associates in its studies for the Department of Water Resources previously reported that the future rate of recreational development can be expected to exceed the rate of population growth in the State by a considerable degree.

Harold F. Wise and Associates delineated potential recreational areas, and further separated the areas into broad classifications of high, medium, and low intensity of use. High intensity recreational use includes lands of prime recreational potential which are accessible by motor vehicle during the entire vacation season. Most future development is expected to occur in these areas. Medium intensity use includes lands of prime recreational value which are not readily accessible by motor vehicles. These areas will be developed to some extent, but their greatest use will probably be for fishing, hunting, hiking, camping, and similar activities. Low intensity recreational areas are generally of inferior scenic and topographic qualities, although they may be important for hunting. These classifications were selected so that user-days of recreation on these lands could be estimated. The studies indicated that over 1,800,000 acres, or almost 75 percent of the total area of Shasta County, has some recreational potential. Data on lands included in the various classifications of recreational use are set forth in Table 18.

For each of the three broad classifications of recreational lands, user-days were estimated in four general categories. These are (1) permanent and summer residences, (2) commercial resorts and motels, (3) organizational camps, and (4) camping and picnic areas. The estimated user-days for each of the four categories of recreational activity in Shasta County are listed by hydrographic units in Table 20.

Large quantities of water may, therefore, be expected to evaporate from reservoir surfaces within the county.

Reservoir Areas. The California Water Plan envisions Shasta County as the hub of surface water development of the upper Sacramento River Basin, and the plan further indicates possible future projects in the county which could regulate waters imported from the Klamath and Trinity Rivers.

The estimated ultimate average reservoir water surface area within Shasta County, derived from existing and possible future projects shown in The California Water Plan, is about

TABLE 20

ESTIMATED ULTIMATE ANNUAL USER DAYS ON RECREATIONAL LANDS IN SHASTA COUNTY BY HYDROGRAPHIC UNITS

Hydrographic unit		Category of recreational activity				
Reference number	Name	Permanent and summer residences	Commercial resorts and motels	Organizational camps	Camping and picnic areas	Totals
16	McArthur	1,179,000	176,000	125,000	1,987.000	3.467.000
17	Hat Creek	5,276,000	789,000	557,000	8,893,000	15,515,000
18	Montgomery Creek	2,149,000	321,000	227,000	3,622,000	6,319,000
19	McCloud River	756,000	113,000	80,000	1,274,000	2,223,000
20	Dunsmuir	1,179,000	176,000	125,000	1,987,000	3,467,000
21	Shasta Lake	3,254,000	487,000	344,000	5,485,000	9,570,000
22	Clear Creek	1,583,000	237,000	167,000	2,669,000	4,656,000
23	Keswick	303,000	45,000	32,000	511,000	891,000
24	Cottonwood Creek	2,656,000	397,000	281,000	4,476,000	7,810,000
25	Olinda	240,000	36,000	25,000	404,000	705,000
32	Stillwater Plains	30,000	4,000	3,000	51,000	88,000
33	Cow Creek	2,392,000	358,000	253,000	4,032,000	7,035,000
34	Bear Creek	847,000	127,000	89,000	1,427,000	2,490,000
35	Battle Creek	989,000	148,000	104,000	1,667,000	2,908,000
38	Mill Creek	38,000	6,000	4,000	64,000	112,000
42	North Fork Feather River	161,000	24,000	17,000	271,000	473,000
50	Anderson	126,000	19,000	13,000	212,000	370,000
	TOTALS	23,158,000	3,463,000	2,446,000	39,032,000	68,099,000

57,200 acres. This value was computed by an analysis of the operation of proposed reservoirs under ultimate conditions of development, which indicated that the average area upon which evaporation would occur probably would be about 79 percent of the total normal pool area of these reservoirs, amounting to 72,300 acres. The distribution of this total reservoir surface area is presented by hydrographic units in Table 18.

Unit Values of Use of Applied Water

In the evaluation of present and probable ultimate applied water use in Shasta County, studies of the extent and types of water-using lands were followed by a determination of unit values of consumptive use of applied water for each of the classes and types of lands requiring water service. Unit values of consumptive use of applied water were estimated for irrigated lands, urban and suburban developments and rural domestic areas, the forest products industry, recreational activities, and evaporation from reservoir surfaces.

Irrigation Water Use

Mean seasonal unit values of consumptive use of applied water for irrigated crops in Shasta County were determined by an empirical method originally developed by Harry F. Blaney and Wayne D. Criddle of the Soil Conservation Service, United States Department of Agriculture. By this method, measured values of monthly consumptive use are correlated with climatological influences expressed in terms of mean monthly temperatures and monthly percent of annual daylight hours. The mean seasonal unit values of consumptive use are obtained from the monthly values.

The derived unit values of applied water applicable to Shasta County represent mean conditions of water supply and climate, and are based on the assumption that sufficient moisture is available in the root zone at all times to maintain good growing conditions and to produce optimum crop yields. The mean seasonal values obtained by this method are presented in Table 21. Although representative of the best currently available information, these values should be considered as subject to verification and modification by long-term field studies of evapotranspiration and soil moisture depletion. Such studies are currently being made by the Department of Water Resources at several locations in Shasta County.

Urban, Suburban, and Rural Water Use

Urban and suburban water use was taken to include water service to business and commercial establishments, residences, and industries other than the major forest products industry which is discussed separately. However, domestic water use was considered to be the primary use of water in urban and suburban areas of the county. Rural domestic water use was taken to include water service to rural farm and nonfarm homes.

Ideally, unit values of water use would be based on measurements made in the area of use. Data secured within the area under consideration would reflect the varying climatic and operational influences and season-to-season variations in use. However, in the absence of adequate data available for the specific area of investigation, it was necessary to supplement

TABLE 21

ESTIMATED MEAN SEASONAL UNIT VALUES OF
CONSUMPTIVE USE OF APPLIED WATER BY IRRIGATED CROPS
IN HYDROGRAPHIC UNITS OF SHASTA COUNTY

(In feet of depth)

Hydrographic unit		Irrigated crops						
Reference number	Name	Alfalfa	Improved pasture	Grain and grain hay	Truck	Misc. field crops	Deciduous orchard	Meadow pasture
16	McArthur	1.4	1.6	0.7	0.4	0.5	---	2.0
17	Hat Creek	1.4	1.6	0.7	---	0.5	---	2.0
18	Montgomery Creek	1.4	1.6	0.7	0.4	---	0.8	2.0
19	McCloud River	1.4	1.5	---	---	---	---	---
20	Dunsmuir	1.4	1.7	---	0.5	0.6	0.9	---
21	Shasta Lake	1.4	1.6	---	0.4	---	0.9	---
22	Clear Creek	---	2.5	---	---	---	---	---
23	Keswick	---	---	---	---	---	---	---
24	Cottonwood Creek	2.5	2.5	0.4	0.8	0.9	1.4	---
25	Olinda	2.4	2.5	0.4	0.8	0.9	1.4	---
32	Stillwater Plains	2.0	2.2	0.7	0.8	0.7	1.4	---
33	Cow Creek	2.0	2.2	0.7	0.8	0.7	1.4	2.8
34	Bear Creek	2.0	2.2	0.7	0.8	0.7	1.4	---
35	Battle Creek	2.0	2.2	0.7	0.8	0.7	1.4	2.8
38	Mill Creek	---	---	---	---	---	---	---
42	North Fork Feather River	---	---	---	---	---	---	---
50	Anderson	2.1	2.3	0.4	0.8	0.9	1.4	---

Note - Where a unit value of consumptive use is not shown, that particular crop is not grown in the hydrographic unit.

the results of studies made in Shasta County with the results of investigations in other areas of the State.

Estimates of unit values of water use for present and ultimate urban and suburban development and rural domestic areas were determined on a per capita basis, rather than on a unit area basis. Data pertaining to population and water use per capita are more readily available and more reliable than data on unit use of domestic water based on areas of urban and suburban land. Furthermore, under ultimate development of the natural resources of Shasta County and adjacent counties, the ultimate population can be more accurately forecast than the growth and final disposition of urban and suburban lands.

Estimates of per capita domestic water use based on records of delivered water from eight representative towns in mountainous regions and ten towns and cities in the Sacramento Valley, including two in Shasta County, provided a broad base for estimating the present and ultimate domestic water requirements of the county. Analysis of water use records from the 18 communities indicated that the present urban and suburban average water use is 250 gallons per capita per day in valley areas and 160 gallons per capita per day in upland areas. It was estimated that present rural domestic water use is about 200 gallons per capita per day in the valley area and 130 gallons per capita per day in the upland.

Estimates of per capita water use under ultimate conditions of development included consideration of two assumptions:

(1) that per capita water use increases as the size and level of development of urban centers increase, and (2) that per capita water use increases as the standard of living increases. It was estimated that urban and suburban use in valley communities would increase to about 390 gallons per capita per day, and in upland communities would increase to about 250 gallons per capita per day. The estimated values of domestic water use under ultimate conditions for rural areas were 300 gallons per capita per day in the valley areas and 200 gallons per capita per day in upland areas.

The foregoing unit values of water use refer to delivery requirements at points of use. Consumptive use was estimated to be 50 percent of the delivery requirement. Estimated unit values of consumptive use of applied water delivery requirement for urban and suburban uses and for rural domestic uses are presented in Table 22.

TABLE 22

ESTIMATED UNIT VALUES OF WATER DELIVERY REQUIREMENT AND CONSUMPTIVE USE OF APPLIED WATER FOR URBAN AND SUBURBAN AND FOR RURAL DOMESTIC USES IN SHASTA COUNTY

(In gallons per capita per day)

Development	Water delivery requirement		Consumptive use	
	Present	Ultimate	Present	Ultimate
Urban and suburban				
Valley communities	250	390	125	195
Upland communities	160	250	80	125
Rural domestic				
Valley communities	200	300	100	150
Upland communities	130	200	65	100

Major Forest Products Industry Water Use

Because of the volume of the forest products industry in Shasta County, the amount of water utilized by this industry is significant. The major categories of forest products are lumber, plywood, fiberboard, paper products, and pulp. Unit values of water use for these categories were obtained from information made available by the United States Forest Service and various companies of the industry. Consumptive use of applied water in the production of lumber and plywood was considered to be the same as the water requirement. Consumptive use of applied water in the production of fiberboard and paper products, and pulp was estimated to be 10 percent of the gross requirement. The unit values used in this bulletin to determine total water requirements and consumptive use of applied water are presented in Table 23. Since requirements and consumptive use are fairly constant, the table can be read for present and future values.

TABLE 23

ESTIMATED UNIT VALUES OF WATER REQUIREMENT
AND CONSUMPTIVE USE OF APPLIED WATER
FOR THE FOREST PRODUCTS INDUSTRY IN SHASTA COUNTY

Item	Basis of measurement	Water requirements	Consumptive use of water
Lumber	Gallons per board foot of product	1.0	1.0
Plywood	Gallons per board foot of logs used	1.0	1.0
Fiberboard and paper products	Gallons per ton of chips	10,000	1,000
Pulp	Gallons per ton of chips	60,000	6,000

Water Use Associated With Recreation

Unit values of water use for recreation in Shasta County were determined in terms of user-days. The four water-using categories considered were permanent and summer residences, commercial resorts and motels, organizational camps, and camping and picnic areas. The unit values of water were derived from studies by the Department of Water Resources in other areas of the State, and represent both consumptive use of applied water and delivery requirement. The unit values of recreation water use are presented in Table 24.

TABLE 24

ESTIMATED UNIT VALUES OF CONSUMPTIVE USE OF APPLIED WATER AND DELIVERY REQUIREMENT OF WATER FOR RECREATIONAL ACTIVITIES IN SHASTA COUNTY

(In gallons per user-day)

Category of use	Unit value of consumptive use and delivery requirements
Permanent and summer residences	150
Commercial resorts and motels	100
Organizational camps	50
Camping and picnic areas	10

Evaporation From Reservoir Surfaces

Unit values of net monthly evaporation from reservoir surfaces were estimated as the amount of evaporation in excess of precipitation during those months when evaporation is greater than precipitation.

Net seasonal evaporation from reservoir surfaces was derived by the summation of the monthly excess of evaporation over precipitation and was expressed in terms of depth of water. Net reservoir surface evaporation generally occurs during the 7-month period of April through October.

For this investigation, gross evaporation from reservoir surfaces was estimated from pan evaporation records and records from other devices. Precipitation records were obtained for reliable stations at or near the locations of evaporation measurements. Net seasonal evaporation from reservoir surfaces was found to range in Shasta County from 20 to 38 inches.

Consumptive Use of Applied Water

Estimates were made of the present and probable ultimate consumptive use of applied water in Shasta County. These estimates were generally based on the unit values of consumptive use of applied water and on the present and estimated ultimate land use and population values previously discussed.

Present Consumptive Use of Applied Water

The amount of applied water consumptively used on irrigated lands was obtained as the product of the estimated acreage devoted to each irrigated crop and its estimated mean unit value of consumptive use of applied water. Consumptive use of applied water was evaluated under assumed full water supply conditions, such that sufficient moisture would be available in the root zone to maintain active plant growth.

The amount of consumptive use of applied water in urban and suburban developments and rural domestic areas was estimated as the product of population for each category and the appropriate derived value of per capita consumptive use of water. The estimate of present consumptive use for urban and suburban developments and rural domestic purposes includes the water used for industrial, including the forest products industry, and recreational purposes.

Net evaporation from reservoir surfaces represents an approximation of the quantity of water that is lost to use over and above the amount of water previously consumed on the lands in the reservoir before construction. To derive consumptive use from reservoir water surfaces, average areas exposed to evaporation for each of the hydrographic units were multiplied by unit net seasonal evaporation from reservoir surfaces. Approximately 95 percent of the present reservoir evaporation occurs at facilities constructed primarily to provide water for export purposes.

Estimates of mean seasonal consumptive use of applied water in areas of water use in Shasta County are presented in Tables 25 and 26, by hydrographic units and service areas, respectively. These estimates were based on the existing water supply development. Consumptive use of applied water by lands located outside the service areas and amounts of reservoir evaporation are not included in Table 26.

TABLE 25

ESTIMATED PRESENT MEAN SEASONAL CONSUMPTIVE USE
OF APPLIED WATER IN SHASTA COUNTY BY HYDROGRAPHIC UNITS

(In acre-feet)

Hydrographic unit		Class of use				
Reference number	Name	Irrigated lands	Meadow pasture	Urban and suburban, and rural domestic	Net reservoir evaporation	Totals
16	McArthur	11,000	12,000	200	400	23,600
17	Hat Creek	6,900	7,200	200	2,700	17,000
18	Montgomery Creek	2,200	---	*	100	2,300
19	McCloud River	900	---	*	---	900
20	Dunsmuir	300	---	*	---	300
21	Shasta Lake	*	---	*	69,700	69,700
22	Clear Creek	200	---	*	6,500	6,700
23	Keswick	---	---	*	1,600	1,600
24	Cottonwood Creek	3,400	---	*	100	3,500
25	Olinda	2,300	---	300	100	2,700
32	Stillwater Plains	1,000	---	1,300	100	2,400
33	Cow Creek	16,000	*	*	---	16,000
34	Bear Creek	4,800	---	*	*	4,800
35	Battle Creek	800	400	100	200	1,500
38	Mill Creek	---	---	---	---	---
42	North Fork Feather River	---	---	---	---	---
50	Anderson	40,900	---	2,500	---	43,400
	TOTALS	90,700	19,600	4,600	81,500	196,400

*Less than 50 acre-feet.

TABLE 26

ESTIMATED PRESENT MEAN SEASONAL CONSUMPTIVE USE
OF APPLIED WATER IN SHASTA COUNTY BY SERVICE AREAS

(In acre-feet)

Name	Hydro-graphic unit	Class of use			
		Irrigated lands	Meadow pasture	Urban and suburban, and rural domestic	Totals
Fall River Valley	16-17	11,000	11,500	200	22,700
Hogback Ridge	17-16	*	---	*	*
Hat Creek	17	3,800	100	100	4,000
Burney Creek	17	3,000	1,100	100	4,200
Goose Valley	17	*	4,300	*	4,300
Cayton Valley	17	600	800	*	1,400
Montgomery Creek	18	600	---	*	600
Igo-Ono	24-22-25	1,000	---	*	1,000
Bee Creek	24	400	---	*	400
Cottonwood Creek	24	800	---	*	800
Happy Valley	25-24	3,000	---	*	3,000
Stillwater Plains	32	200	---	*	200
Bella Vista	32-33	1,200	---	*	1,200
Cow Creek Bottoms	33	3,900	---	*	3,900
Little Cow Creek	33	1,000	---	*	1,000
Round Mountain	18-33	1,200	---	*	1,200
Bullskin Ridge	33	100	*	*	100
Oak Flat	33	1,600	---	*	1,600
Oak Run	33	400	---	*	400
Clover Creek	33	1,500	---	*	1,500
Old Cow Creek	33	3,100	---	*	3,100
Whitmore	33	1,700	---	*	1,700
Hagaman Gulch	33-34	*	---	*	*
South Cow Creek	33	900	---	*	900
Urban Center	25-50	7,000	---	3,000	10,000
North Suburban	32	100	---	600	700
Millville Plains	33-34	300	---	*	300
Anderson-Cottonwood	50	39,900	---	500	40,400
Black Butte	34-35	---	---	*	*
Inwood	34	1,600	---	*	1,600
Manton	35	100	---	*	100
TOTALS		90,000	17,800	4,500	112,300

*Less than 50 acre-feet.

Probable Ultimate Consumptive Use of Applied Water

The probable ultimate seasonal consumptive use of applied water by irrigated lands, urban and suburban developments, rural areas, recreational activities, the forest products industry, and the evaporation from principal reservoirs was estimated as the product of the forecasted level of development for each category and the corresponding unit value of consumptive water use. The procedures utilized in estimating ultimate consumptive use of applied water in Shasta County were similar to those employed to estimate present use.

The amount of water to be used seasonally on ultimately irrigated lands was estimated as the product of the forecasted ultimate acreage for each crop type and its respective unit value of consumptive use of applied water. The estimates were based on the assumption that a full seasonal water supply would be available to the net crop acreage that might ultimately be irrigated in any one season.

The probable ultimate consumptive use of applied water for urban and suburban developments and rural domestic purposes was obtained as the product of the appropriate population estimate and the unit value of per capita consumptive use of water.

The probable ultimate consumptive use of applied water for recreational purposes was determined as a product of the estimated user-days for each type of use in the recreational areas and the appropriate unit value of water use per user-day.

The probable ultimate consumptive use of applied water for the forest products industry was estimated as the product of the estimated annual production that would ultimately be processed in the county on a sustained yield basis and the appropriate average unit values of water consumed in processing.

The amount of evaporation from reservoir surfaces under ultimate conditions of development was estimated as the product of the average surface area in acres for both existing reservoirs and those planned to be located in Shasta County under The California Water Plan and the net seasonal depth of evaporation from reservoir surfaces in each area.

Estimates of probable ultimate mean seasonal consumptive use of applied water in Shasta County, by hydrographic units and service areas, are presented in Tables 27 and 28, respectively. Ultimate water use by lands located outside the service areas and amounts of reservoir evaporation are not included in Table 28.

Water Requirements

The various types of water requirements in Shasta County are considered and evaluated in this section under the general headings of "Probable Ultimate Consumptive Water Requirements", "Probable Ultimate Nonconsumptive Water Requirements", and "Supplemental Water Requirements".

Probable Ultimate Consumptive Water Requirements

The probable ultimate consumptive water requirements for each hydrographic unit in Shasta County were estimated for

TABLE 27

PROBABLE ULTIMATE MEAN SEASONAL CONSUMPTIVE USE
OF APPLIED WATER IN SHASTA COUNTY
BY HYDROGRAPHIC UNITS

(In acre-feet)

Hydrographic unit		Class of use						
Reference number	Name	Irrigated lands	Meadow: pasture	Urban and suburban and rural domestic	Forest products industry	Recreational areas	Net reservoir evaporation	Totals
16	McArthur	38,700	15,000	1,100	*	700	10,000	65,500
17	Hat Creek	19,400	8,000	1,700	400	3,000	3,400	35,900
18	Montgomery Creek	6,600	200	200	200	1,200	2,700	11,100
19	McCloud River	1,200	---	*	100	400	3,900	5,600
20	Dunsmuir	1,800	---	200	100	700	---	2,800
21	Shasta Lake	2,100	---	300	100	1,900	69,700	74,100
22	Clear Creek	500	---	200	100	900	15,400	17,100
23	Keswick	---	---	100	*	200	1,600	1,900
24	Cottonwood Creek	38,700	---	300	100	1,500	7,100	47,700
25	Olinda	17,000	---	900	*	100	5,300	23,300
32	Stillwater Plains	55,300	---	12,600	---	*	100	68,000
33	Cow Creek	70,900	300	1,500	100	1,400	14,100	88,300
34	Bear Creek	31,700	---	300	*	500	*	32,500
35	Battle Creek	14,800	1,200	400	100	600	1,100	18,200
38	Mill Creek	---	---	---	---	*	---	*
42	North Fork Feather River	---	---	---	*	100	---	100
50	Anderson	45,300	---	16,800	8,800	100	19,000	90,000
	TOTALS	344,000	24,700	36,600	10,100	13,300	153,400	582,100

*Less than 50 acre-feet.

TABLE 28

PROBABLE ULTIMATE MEAN SEASONAL CONSUMPTIVE USE OF
APPLIED WATER IN SHASTA COUNTY BY SERVICE AREAS

(In acre-feet)

Service area		Class of use					
Name	Hydrographic unit	Irrigated lands	Meadow pasture	Urban and suburban and rural domestic	Forest products industry	Recreational areas	Totals
Fall River Valley	16-17	38,100	14,400	1,000	*	400	53,900
Hogback Ridge	17-16	3,700	100	*	0	--	3,800
Hat Creek	17	4,600	600	300	*	1,300	6,800
Burney Creek	17	4,100	1,300	1,400	300	600	7,700
Goose Valley	17	300	6,100	*	--	--	6,400
Cayton Valley	17	800	1,200	*	--	--	2,000
Montgomery Creek	18	1,300	--	100	--	200	1,600
Igo-Ono	24-22-25	9,400	--	*	--	--	9,400
Bee Creek	24	1,500	--	*	--	--	1,500
Cottonwood Creek	24	11,100	--	200	--	--	11,300
Happy Valley	25-24	17,400	--	500	--	--	17,900
Stillwater Plains	32	20,900	--	2,100	--	--	23,000
Bella Vista	32-33	25,800	--	2,100	--	--	27,900
Cow Creek Bottoms	33	9,500	--	1,400	--	--	10,900
Little Cow Creek	33	3,600	--	*	--	100	3,700
Round Mountain	18-33	2,900	--	100	100	100	3,200
Bullskin Ridge	33	4,300	*	*	--	--	4,300
Oak Flat	33	6,600	--	*	--	--	6,600
Oak Run	33	3,500	--	*	--	--	3,500
Clover Creek	33	7,400	--	*	--	200	7,600
Old Cow Creek	33	5,400	--	*	--	--	5,400
Whitmore	33	15,100	--	200	--	300	15,600
Hagaman Gulch	33-34	1,200	--	*	--	--	1,200
South Cow Creek	33	2,500	--	*	--	--	2,500

TABLE 28 (Continued)

PROBABLE ULTIMATE MEAN SEASONAL CONSUMPTIVE USE OF APPLIED WATER IN SHASTA COUNTY BY SERVICE AREAS

(In acre-feet)

Service area		Class of use					
Name	Hydro-graphic unit	Irrigated lands	Meadow pasture	Urban and suburban and rural domestic	Forest products industry	Recreational areas	Totals
Urban Center	25-50	--	---	14,000	2,800	--	16,800
North Suburban	32	--	--	5,600	--	--	5,600
Millville Plains	33-34	6,400	--	*	--	--	6,400
Anderson-Cottonwood	50	49,500	--	5,600	6,000	--	61,100
Black Butte	34-35	4,200	--	*	--	--	4,200
Inwood	34	15,900	*	200	--	300	16,400
Manton	35	10,100	--	200	--	200	10,500
TOTALS		287,100	23,700	35,000	9,200	3,700	358,700

*Less than 50 acre-feet.

irrigated lands, urban and rural populations, the forest products industry, recreational activities, and evaporation from reservoir surfaces. Estimates of probable ultimate mean seasonal water requirements to meet consumptive demands are summarized by hydrographic units and service areas in Tables 29 and 30, respectively. Water requirements of lands located outside the service areas and amounts of reservoir evaporation are not included in Table 30.

Irrigation Water Requirements. To estimate ultimate seasonal water requirements for irrigated lands in Shasta County, the derived values of seasonal consumptive use of applied water for each hydrographic unit were divided by appropriate water service area efficiency factors. The resulting estimates represent the amounts of water which would be required for delivery to each hydrographic unit. Based on studies made for the Northeastern Counties Investigation and published in Department of Water Resources Bulletin No. 58, the weighted average water service area efficiency for each hydrographic unit was estimated to be 50 percent, except in McArthur and Hat Creek Hydrographic Units where the efficiencies were 60 percent and 55 percent. respectively.

Farm irrigation efficiencies, conveyance losses, and monthly demands as they affect water requirements in the county, are discussed in the following paragraphs. These factors were used to estimate water service area efficiencies and to study the yields of various reservoirs described in the next chapter.

TABLE 29

PROBABLE ULTIMATE MEAN SEASONAL WATER
REQUIREMENTS IN SHASTA COUNTY BY HYDROGRAPHIC UNITS

(In acre-feet)

Hydrographic unit		Class of use						
Reference number	Name	Irrigated lands	Meadow: pasture	Urban and suburban and rural domestic	Forest products industry	Recreational areas	Net reservoir evaporation	Totals
16	McArthur	64,500	15,000	2,200	*	700	10,000	92,400
17	Hat Creek	35,300	8,000	3,400	400	3,000	3,400	53,500
18	Montgomery Creek	13,200	200	500	200	1,200	2,700	18,000
19	McCloud	2,500	---	*	100	400	3,900	6,900
20	Dunsmuir	3,600	---	400	100	700	---	4,800
21	Shasta Lake	4,100	---	600	100	1,900	69,700	76,400
22	Clear Creek	1,000	---	300	100	900	15,400	17,700
23	Keswick	---	---	200	*	200	1,600	2,000
24	Cottonwood Creek	77,300	---	600	100	1,500	7,100	86,600
25	Olinda	34,000	---	1,800	*	100	5,300	41,200
32	Stillwater Plains	110,700	---	25,200	---	*	100	136,000
33	Cow Creek	141,800	300	3,000	100	1,400	14,100	160,700
34	Bear Creek	63,300	---	700	*	500	*	64,500
35	Battle Creek	29,600	1,200	700	100	600	1,100	33,300
38	Mill Creek	---	---	---	---	*	---	*
42	North Fork Feather River	---	---	---	*	100	---	100
52	Anderson	90,600	---	33,500	87,800	100	19,000	231,000
	TOTALS	671,500	24,700	73,100	89,100	13,300	153,400	1,025,100

*Less than 50 acre-feet.

TABLE 30

PROBABLE ULTIMATE MEAN SEASONAL WATER
REQUIREMENTS IN SHASTA COUNTY BY SERVICE AREAS

(In acre-feet)

Service area		Class of use					
Name	Hydrographic unit	Irrigated lands	Meadow pasture	Urban and suburban and rural domestic	Forest products industry	Recreational areas	Totals
Fall River Valley	16-17	63,500	14,400	2,000	*	400	80,300
Hogback Ridge	17-16	6,700	100	*	--	--	6,800
Hat Creek	17	8,400	600	600	*	1,300	10,900
Burney Creek	17	7,400	1,300	2,800	300	600	12,400
Goose Valley	17	500	6,100	*	--	--	6,600
Cayton Valley	17	1,500	1,200	*	--	--	2,700
Montgomery Creek	18	2,600	--	200	--	200	3,000
Igo-Ono	24-25-22	18,800	--	100	--	--	18,900
Bee Creek	24	3,000	--	*	--	--	3,000
Cottonwood Creek	24	22,200	--	400	--	--	22,600
Happy Valley	25-24	34,800	--	1,000	--	--	35,800
Stillwater Plains	32	41,800	--	4,200	--	--	46,000
Bella Vista	32-33	51,600	--	4,200	--	--	55,800
Cow Creek Bottoms	33	19,000	--	2,800	--	--	21,800
Little Cow Creek	33	7,200	--	*	--	100	7,300
Round Mountain	18-33	5,800	--	200	100	100	6,200
Bullskin Ridge	33	8,600	*	*	--	--	8,600
Oak Flat	33	13,200	--	*	--	--	13,200
Oak Run	33	7,000	--	*	--	--	7,000
Clover Creek	33	14,800	--	*	--	200	15,000
Old Cow Creek	33	10,800	--	*	--	--	10,800
Whitmore	33	30,200	--	400	--	300	30,900
Hagaman Gulch	33-34	2,400	--	*	--	--	2,400
South Cow Creek	33	5,000	--	*	--	--	5,000

TABLE 30 (Continued)

PROBABLE ULTIMATE MEAN SEASONAL WATER REQUIREMENTS IN SHASTA COUNTY BY SERVICE AREAS

(In acre-feet)

Service area		Class of use					
Name	Hydrographic unit	Irrigated lands	Meadow pasture	Urban and suburban and rural domestic	Forest products industry	Recreational areas	Totals
Urban Center	25-50	--	--	28,000	28,800	--	56,800
North Suburban	32	--	--	11,200	--	--	11,200
Millville Plains	33-34	12,800	--	*	--	--	12,800
Anderson-Cottonwood	50	99,000	--	11,200	58,000	--	168,200
Black Butte	34-35	8,400	--	*	--	--	8,400
Inwood	34	31,800	*	400	--	300	32,500
Manton	35	20,200	--	400	--	200	20,800
TOTALS		559,000	23,700	70,100	87,200	3,700	743,700

*Less than 50 acre-feet.

(1) Farm Irrigation Efficiency. Farm irrigation efficiency has been defined heretofore as the ratio of the amount of consumptive use of applied irrigation water to the total amount of such applied water. The ratio is commonly expressed as a percentage. Studies of irrigation efficiency in and adjacent to Shasta County were used to estimate farm irrigation efficiencies that might be realized in the future. Probable ultimate farm irrigation efficiencies for various crops are presented in Table 31.

TABLE 31

ESTIMATED ULTIMATE FARM IRRIGATION EFFICIENCIES IN SHASTA COUNTY

(In percent)

Crop	Agricultural region	
	Redding Basin and foothill areas	Modoc Plateau area
Alfalfa	55	55
Improved pasture	50	50
Grain and grain hay	60	60
Truck	50	40
Field crops	50	40
Deciduous orchard	55	--

(2) Conveyance Losses. Direct estimates of overall conveyance losses were not made for projects in Shasta County, since conveyance losses were considered in deriving water

service area efficiencies. Because of the wide range of geologic conditions found in Shasta County, detailed estimates of conveyance losses for specific projects were considered beyond the scope of this investigation. Losses of this nature depend primarily on the selected types, locations, and sizes of the conduits, and whether the conduits are lined or unlined.

(3) Monthly Demands for Irrigation Water. Because of differences in water utilization by various crops, and differences in climatic conditions in the several agricultural regions of Shasta County, there is considerable variation in both the rate and period of demand for irrigation water. On the average, the irrigation demand in the Redding Basin and surrounding foothills occurs during the months of March through October. Studies in the upper Pit River Basin in Modoc, Lassen, and Shasta Counties indicate that in the Modoc Plateau area the irrigation season extends from May through September. Values derived for the McArthur Hydrographic Unit were used to represent conditions in that portion of the Modoc Plateau situated in Shasta County. The estimated average monthly distribution of demand for irrigation water in the Redding Basin and foothill areas and Modoc Plateau area is presented in Table 32.

Urban, Suburban, and Rural Domestic Water Requirements. Seasonal water requirements for urban and suburban developments and rural domestic uses were estimated as the products of the estimated population in each category within each

TABLE 32

ESTIMATED AVERAGE MONTHLY DISTRIBUTION OF SEASONAL DEMAND FOR IRRIGATION WATER IN SHASTA COUNTY

(In percent of seasonal total)

Month	Agricultural region: Redding Basin and foothill areas	Agricultural region: Modoc Plateau area
March	2	--
April	6	--
May	13	19
June	16	25
July	21	30
August	19	15
September	14	11
October	9	--
TOTALS	100	100

hydrographic unit and corresponding unit values of water delivery requirements.

The monthly distribution of seasonal demands for urban water supplies must be considered in planning of water development projects. It is anticipated that present monthly distribution of urban water demands in Shasta County will probably change only slightly in the future. Monthly distribution of demand for urban water for five communities in Northern California is presented in Table 33. These communities are Woodland and Davis, which are representative of valley communities; Redding, in the Shasta County core area; and Fall River Mills and Susanville, representative of upland or mountain communities. The monthly distribution of urban water demand at Redding was used in all planning studies for this investigation, since it appears to be a reasonable intermediate value between valley and upland communities, and because it is representative of a major portion of urban and domestic water use in Shasta County.

TABLE 33

MONTHLY DISTRIBUTION OF SEASONAL DEMAND FOR URBAN WATER SUPPLIES IN NORTHERN CALIFORNIA

(In percent of seasonal total)

Month	Davis (1954)	Woodland (1952)	Redding (1945-56)	Fall River Mills (1953)	Susanville (1953)
January	4	4	5	6	4
February	3	4	4	5	4
March	4	4	5	6	4
April	7	6	7	6	7
May	12	11	9	8	7
June	14	12	12	15	7
July	16	16	16	15	12
August	13	14	15	12	16
September	11	11	11	9	16
October	8	9	7	6	11
November	4	5	5	6	7
December	4	4	4	6	5
TOTALS	100	100	100	100	100

Forest Products Industry Water Requirements. Seasonal water requirements for the forest products industry were computed by multiplying the estimated quantity of each forest product manufactured within each hydrographic unit by the corresponding unit value of seasonal water requirement. For fiberboard, paper products and pulp, only a minor amount of the processing water is actually consumed. The unconsumed portion returns to the stream system.

It was assumed that the water requirement for lumber production would be in proportion to the commercial forest lands within the hydrographic units. The water use of this phase of the forest products industry is relatively small, and the water requirement was assumed to be equal to the consumptive use. As previously stated, it is expected that the forest products industry of Shasta County will fully utilize the county's timber resources and to some extent those of surrounding counties.

Present information available on monthly distribution of seasonal water demands by the forest products industry indicates some monthly variation due to present methods of seasonal operation. However, analysis of probable forest products industry operations under ultimate conditions of sustained yield production indicated that the distribution of monthly demands for water would be essentially uniform. Therefore, for the purpose of project studies, it was assumed that forest products industry water demands would be distributed uniformly throughout the year.

Water Requirements Associated With Recreation. Estimates of water requirements for probable ultimate recreational areas were determined to be the products of the estimated user-days for each of the four categories of recreational activities and the corresponding water consumption per user-day. The four water-using categories are permanent and summer residences, commercial resorts and motels, organizational camps, and camping and picnic areas. Because of the small quantities of water required for this classification of use, it was assumed that all water delivered would be consumed.

Evaporation From Reservoir Surfaces. Water requirements for reservoir evaporation in the county were derived as the products of average areas of evaporation and unit net seasonal reservoir evaporation values. These requirements were assumed equal to the consumptive uses from the reservoir water surfaces, which have been discussed previously. Evaporation from the surfaces of reservoirs providing water for export purposes was estimated to be 128,000 acre-feet seasonally, or approximately 85 percent of the total amount of evaporation. Since these reservoirs would be utilized primarily for supplying water to areas outside Shasta County, only 15 percent of the total amount of evaporation, or 19,200 acre-feet, should be considered as a water requirement of the county.

Probable Ultimate Nonconsumptive Water Requirements

Certain nonconsumptive requirements for water, such as those for hydroelectric power generation, and for conservation of fish and wildlife, were considered to be significant in the design of works for development of the water resources of Shasta County. Project use for flood control purposes was also assumed to be important. In most instances, the magnitude of the non-consumptive water requirements is relatively indeterminate, and depends upon allocation of water supply during design of the works. Water requirements for hydroelectric power production and conservation of fish and wildlife, as well as flood control requirements, are discussed in general terms in this section. Stream flow maintenance and stream flow enhancement requirements for the lower reaches of Cow Creek and Cottonwood Creek, as evaluated by the California Department of Fish and Game, are also presented in this section.

Hydroelectric Power Production. The principal non-consumptive requirement for water in Shasta County is that which pertains to the generation of hydroelectric energy. No plans for hydroelectric power generation were developed as a part of this investigation. However, a number of projects for power production in the drainage basins of the McCloud and Pit Rivers have been proposed by other agencies and are discussed in Chapter IV. Other streams which now are, or soon will be, developed for hydroelectric power generation in Shasta County include Clear, Cow, and Battle Creeks and the Sacramento River.

Although this requirement generally does not result in the consumption of water nor in the depletion of runoff, except in evaporation from reservoir surfaces, it does affect the variations in stream flow below the power plants. This variation in stream flow was considered in evaluating projects.

Recreation and Fish and Wildlife. By virtue of its climatic advantages and wide variety of natural attractions, Shasta County enjoys an outdoor recreational opportunity of great importance to its growth and economy, and of significant importance to the State as a whole. With anticipated continued growth in population, it is expected that the public demand for preservation and enhancement of recreational facilities will be sufficient to assure the provision of water supplies necessary for such purposes.

Consumptive use of water for recreational activities has been previously evaluated. In addition, there are a number of nonconsumptive uses of water which would enhance the recreational potential and improve fish and wildlife conditions. These uses consist first of maintaining reservoir water surfaces at levels which would provide an adequate water supply for fish and wildlife and which would enhance recreation. Secondly, stream fisheries could be maintained or enhanced by release of appropriate flows from future reservoirs.

The California Department of Fish and Game has studied the streams of Shasta County, and has determined that stream flow maintenance releases would be required from future developments in the lower reaches of Cow and Cottonwood Creeks. The report by the Department of Fish and Game on these creeks is included as Appendix D of this bulletin. Flows needed to maintain the present fishery, as well as flows which should increase the fishery potential, are discussed in this appendix.

Flood Control. Any portion of the available reservoir storage capacity that is operated wholly or partially for flood control purposes may reduce the capacity available for conservation.

Historically, flood damages in Shasta County from the Sacramento River have been relatively slight. Since the construction of Shasta Dam, extensive urban and suburban development has taken place on the flood plain of the Sacramento River. In some locations development has even encroached upon the anticipated flow line of maximum expected flood releases from Shasta Dam. During the floods of February 1958, when the maximum flood releases were first made, some damage was sustained by these developments. Flood damages in the county on streams other than the Sacramento River have been generally limited to damage sustained by roads, bridges, and minor erosion of agricultural lands.

Supplemental Water Requirements

The probable ultimate supplemental water requirements represent the quantities of water necessary to satisfy future demands for water in Shasta County, over and above presently required quantities. These requirements, therefore, establish the scale of need for water conservation development necessary to meet local demands for water supplies.

To estimate the ultimate supplemental water requirements for irrigated lands of Shasta County, the difference between probable ultimate and present consumptive use of applied water on irrigated lands was divided by water service area efficiencies. Since the estimated present consumptive use of water in urban, suburban, and rural areas includes present forest-products-industry and recreational uses, the supplemental requirements for these categories are the same as the water requirements shown in Tables 29 and 30. Inasmuch as urban, suburban, and rural water delivery requirements are equivalent to twice the consumptive use of these categories, the difference between ultimate and present consumptive use of water was doubled. The supplemental water requirements for evaporation from reservoir surfaces was assumed to be equal to the difference between the probable ultimate and present net reservoir evaporation requirements presented in Tables 25 and 27. The resulting estimates of ultimate supplemental water requirements in Shasta County are presented in Tables 34 and 35, by hydrographic units and service areas, respectively. The supplemental water requirements by lands located outside the service areas and amounts of reservoir evaporation are not included in Table 35.

TABLE 34

ESTIMATED ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENTS IN SHASTA COUNTY BY HYDROGRAPHIC UNITS

(In acre-feet)

Hydrographic Unit		Class of use						
Reference number	Name	Irrigated lands	Meadow pasture	Urban and suburban and rural domestic	Forest products industry	Recreational areas	Net reservoir evaporation	Totals
16	McArthur	46,200	3,000	1,800	*	700	9,600	61,300
17	Hat Creek	26,000	800	3,000	400	3,000	700	33,900
18	Montgomery Creek	9,200	200	400	200	1,200	2,600	13,800
19	McCloud River	400	--	--	100	400	3,900	4,800
20	Dunsmuir	3,000	--	400	100	700	--	4,200
21	Shasta Lake	4,200	--	600	100	1,900	--	6,800
22	Clear Creek	600	--	400	100	900	8,900	10,900
23	Keswick	--	--	200	*	200	--	400
24	Cottonwood Creek	71,600	--	600	100	1,500	7,000	80,800
25	Olinda	30,000	--	1,200	*	100	5,200	36,500
32	Stillwater Plains	108,800	--	22,600	--	*	--	131,400
33	Cow Creek	109,800	300	3,000	100	1,400	14,100	128,700
34	Bear Creek	53,400	--	600	*	500	--	54,500
35	Battle Creek	28,000	800	600	100	600	900	31,000
38	Mill Creek	--	--	--	--	*	--	*
42	North Fork Feather River	--	--	--	*	100	--	100
50	Anderson	8,800	--	28,600	87,800	100	19,000	144,300
	TOTALS	500,000	5,100	64,000	89,100	13,300	71,900	743,400

*Less than 50 acre-feet.

TABLE 35

ESTIMATED ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENTS IN SHASTA COUNTY BY SERVICE AREAS

(In acre-feet)

Service area		Class of use					
Name	Hydrographic unit	Irrigated lands	Meadow pasture	Urban and suburban and rural domestic	Forest products industry	Recreational areas	Totals
Fall River Valley	16-17	45,200	2,900	1,600	**	400	50,100
Hogback Ridge	17-16	6,700	100	**	--	--	6,800
Hat Creek	17	1,400	500	400	**	1,300	3,600
Burney Creek	17	2,000	200	2,600	300	600	5,700
Goose Valley	17	500	1,800	**	--	--	2,300
Cayton Valley	17	400	400	**	--	--	800
Montgomery Creek	18	1,400	--	200	--	200	1,800
Igo-Ono	24-22-25	16,800	--	100	--	--	16,900
Bee Creek	24	2,200	--	**	--	--	2,200
Cottonwood Creek	24	20,600	--	400	--	--	21,000
Happy Valley	25-24	28,800	--	1,000	--	--	29,800
Stillwater Plains	32	41,400	--	4,200	--	--	45,600
Bella Vista	32-33	49,200	--	4,200	--	--	53,400
Cow Creek Bottoms	33	11,200	--	2,800	--	--	14,000
Little Cow Creek	33	5,200	--	**	--	100	5,300
Round Mountain	18-33	3,400	--	**	100	100	3,600
Bullskin Ridge	33	8,400	--	**	--	--	8,400
Oak Flat	33	10,000	--	**	--	--	10,000
Oak Run	33	6,200	--	**	--	--	6,200
Clover Creek	33	11,800	--	**	--	200	12,000
Old Cow Creek	33	4,600	--	**	--	--	4,600
Whitmore	33	26,800	--	400	--	300	27,500
Hagaman Gulch	33-34	2,400	--	**	--	--	2,400
South Cow Creek	33	3,200	--	**	--	--	3,200

TABLE 35 (Continued)

ESTIMATED ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER
REQUIREMENTS IN SHASTA COUNTY BY SERVICE AREAS

(In acre-feet)

Service area		Class of use					
Name	Hydrographic unit	Irrigated lands	Meadow pasture	Urban and suburban and rural domestic	Forest products industry	Recreational areas	Totals
Urban Center	25-50	--	--	22,000	28,800	--	50,800
North Suburban	32	--	--	10,000	--	--	10,000
Millville Plains	33-34	12,200	--	**	--	--	12,200
Anderson-Cottonwood	50	19,200	--	10,200	58,000	--	87,400
Black Butte	34-35	8,400	--	**	--	--	8,400
Inwood	34	28,600	--	200	--	300	29,100
Manton	35	20,000	--	200	--	200	20,400
TOTALS		398,200	5,900	60,500	87,200	3,700	555,500

* Reservoir evaporation is not included.
**Less than 50 acre-feet.

CHAPTER IV. PLANS FOR WATER DEVELOPMENT

The Shasta County Investigation, although authorized primarily to study means of developing waters of the county for local use, has contributed materially to the California Water Planning Program.

This program, authorized by the Legislature to study details of The California Water Plan, first announced in Bulletin No. 3, in May 1957, confines its planning to two fields: (1) the development of water for local needs, and (2) where there is a surplus, the development of water for export to areas of deficiency. Since a portion of the water developed primarily for export, either within or adjacent to Shasta County, may also be used locally, the Shasta County Investigation included both aspects of the California Water Planning Program and constitutes one of its many integral parts.

Insofar as development of the water resources of Shasta County is concerned, The California Water Plan, as presented in Bulletin No. 3 and modified under the California Water Planning Program, provides for development of the water resources of the county to meet the county's probable ultimate water requirements, as well as to provide supplemental water supplies for water-deficient areas of the State. In general, the plan gives consideration to water conservation and reclamation, to flood control and flood protection, to the use of water for agricultural, domestic, and industrial purposes, to hydroelectric power development, to protection of the quality of fresh waters, and to the interests of fish, wildlife, and recreation.

In the Shasta County Investigation, formulation of plans for local water development was based on the conservation of surface water resources and the development of ground water supplies. The major source of water supply available to Shasta County is runoff from the highly productive watersheds of the mountainous regions of the county. Part of this runoff is being utilized in the county by direct diversion from streams. Since runoff always diminishes during the summer and fall months, often to the point where it is insufficient for watershed requirements, some areas of the county have developed supplemental yields by means of small surface reservoirs and from ground water. Plans for the development of local water resources were made on the premise that summer and fall flows are fully utilized.

To aid in the discussion of plans for local water development, the present and potential water-using areas of Shasta County were grouped into 31 possible service areas as shown on Plate 15, entitled "Irrigated and Irrigable Lands and Potential Service Areas", and on Plate 30, entitled "Plans for Water Development in Shasta County". These service areas were delimited on the basis of areas served by existing water service agencies and their probable future extensions, areas having common interests in water supply (namely, watermaster service areas), and areas of irrigable lands that could be served from a common source of water. In addition to these 31 service areas, there are several thousand acres of irrigable land in scattered locations in the foothills and mountains of the county. Planning of water development for these scattered irrigable lands was considered to be beyond the scope of this investigation. Furthermore, brief studies of water supplies for these lands indicated that most of them could be served by the construction of small farm reservoirs.

In general, the planning studies indicate that the Bella Vista, Happy Valley, and Urban Center service areas could best be served by water from the Trinity River Division of the Central Valley Project of the United States Bureau of Reclamation. The future water requirements of the Cottonwood Creek service area, and the six service areas in the Modoc Plateau area (Fall River Valley, Hogback Ridge, Hat Creek, Burney Creek, Goose Valley, and Cayton Valley service areas) could probably best be met by developing ground water, generally through the efforts of individual farmers. Above an elevation of about 600 feet in the watersheds of Cow, Bear, Ash, and Battle Creeks, and the North Fork of Cottonwood Creek, there are a number of service areas which could be served from projects included herein among the plans for future water resource development in Shasta County.

Although the primary concern in planning local water development was for domestic, municipal, irrigation, and other beneficial consumptive uses, consideration was also given to the production of hydroelectric power, flood control, recreation, and the preservation and enhancement of fish and wildlife.

Water Development for Service Areas

Whenever applicable, the ensuing discussion of service areas includes the following items in order: a brief description of the area; its location and physical characteristics; acres now irrigated and source of supply; acres potentially irrigable and their probable supplemental water requirements; possible sources to meet supplemental water requirements; and an appraisal of possible supplemental water developments, including a description, discussion of adequacy, and estimate of costs. The conclusions as to suitable sources of water for the various service areas are summarized on Plate 29, entitled "Probable Sources of Future Supplemental Water Supply for Service Areas". Locations of features considered in plans for water development are shown on Plate 30.

General Procedures

In evaluating the types of water developments appropriate for the various service areas, several assumptions as to supplemental water requirements were made. For service areas in Modoc Plateau, the values of supplemental water requirements for meadow pasture were omitted because it was believed that they could be met by return flow from water used on other irrigated lands. For the remaining service areas, supplemental water requirements for urban and suburban and rural domestic uses, for the forest products industry, and for recreational areas, which were less than about 500 acre-feet per season, were also omitted because it was felt that these requirements would be met by small projects or wells constructed by individual users.

At the beginning of the Shasta County Investigation, brief studies were made of numerous available surface reservoir sites which appeared to have possibilities for water development. As the investigation progressed, however, only 16 of these sites seemed to justify close analysis, the remainder being rejected because of topographic, geologic, or hydrologic limitations.

The sites which were selected as having potential were further evaluated, and only the more promising of these were subjected to more detailed analysis, involving preliminary estimates of cost and water yield.

Estimates of capital costs were based on prices prevailing in the spring of 1958, and included the costs of dam, spillway, outlet works, land acquisition, and where necessary, land clearing and road relocation. To this subtotal, a 10 percent engineering and administration cost and a 20 percent contingency cost were added. Interest during construction, computed at four percent per annum for one-half the estimated number of months required to complete the project, was also added.

Estimates of annual costs were considered to include costs of operation and maintenance, replacement of physical elements having an expected life span of less than 50 years, retirement of the indebtedness over a 50-year period, and interest on the debt, computed at four percent per annum.

Certain terms used in this chapter pertaining to reservoir yield are used in a special sense, as defined below.

Safe Yield--The maximum sustained rate of draft from a reservoir that could be maintained through a critically dry water supply period to meet, without deficiency, a given demand for water.

Irrigation Yield--The maximum sustained rate of draft from reservoir that could be maintained through a critical water supply period to meet with an allowable deficiency, a given demand for irrigation water.

For purposes of this study, the average deficiency was assumed to be 2 percent per year, and the maximum deficiency was assumed to be 35 percent during one year of the base period.

In general, the yields of the various reservoirs were computed on the basis of full flows of the streams at the dam sites without reduction for uses of water that may be made under existing water rights. Exceptions to this procedure were made on some streams where water rights exist by not including summer flows in computation of reservoir yields. Yields of new water, to meet supplemental water requirements of the service areas would, therefore, be somewhat lower than the values presented herein if downstream uses were fully accounted.

After reservoir sites were determined, studies of possible conduit routes were made where appropriate. Seven conduit routes are described in this chapter.

In many service areas in Shasta County, relatively small farm reservoirs could be an important means of developing water supplies. Such small farm reservoirs are herein defined as storage facilities of less than 2,500-acre-foot capacity. Because of the large number of potential sites for this type of development, and because such reservoirs are usually an individual or small group enterprise, no plans for this type of development were studied during this investigation.

Fall River Valley Service Area

The Fall River Valley service area includes the irrigable lands of Fall River Valley, located in the northeastern portion of Shasta County in the Modoc Plateau, as shown on Plate 30. About 7,100 acres in the area are presently irrigated with water diverted from the Pit River and from Fall River and its tributaries, and with water pumped from ground water. Another 7,200 acres of meadow pasture land are subirrigated from high ground water. It is estimated that an additional net irrigable area of 22,100 acres would require a water supply in the future. The estimated ultimate supplemental water requirement for agricultural, domestic, industrial, and recreational purposes would be about 47,200 acre-feet annually.

The water rights of the Pacific Gas and Electric Company greatly restrict utilization of the Pit and Fall River stream flows as sources of water supply for this area. Energy and plant capacity components are determining factors in evaluating the cost of water that might be purchased from the Pacific Gas and Electric Company and diverted upstream from the power development to the Fall River Valley service area. Cost of water flowing through Pit Power Plants Nos. 1, 3, 4, and 5, if evaluated for energy component only, was estimated to be approximately $4.20 per acre-foot, and about $5.10 per acre-foot when Pit Power Plants Nos. 6 and 7 are added to the existing power developments on the Pit River. Lack of pertinent data precluded evaluating the cost of water from the standpoint of reduction in dependable capacity of these plants, if this reduction were attributable to the upstream diversion of water to the service area. In practice, the cost of such water would be subject to negotiation with the company.

In general, ground water occurs in this service area in lake sediments and underlying volcanic rocks. The lake sediments are tight, fine-grained materials which cannot produce sufficient quantities of water to meet the future needs of Fall River Valley. Wells drilled into the lake sediments generally yield less than 300 gallons per minute. On the other hand, it is believed that the water within the volcanic rocks under Fall River Valley is derived from volcanic formations of great areal extent surrounding the valley. Wells drilled into these volcanic rocks usually yield from 200 to over 1,000 gallons per minute. Hence, ground water stored in underlying volcanic rocks may be the potential source of water to meet most of the future water needs of the Fall River Valley service area.

Hogback Ridge Service Area

The Hogback Ridge service area is located in the Modoc Plateau area directly south of Fall River Valley, as shown on Plate 30. There are no irrigated lands within the service area at the present time, although about 2,900 acres are classified as irrigable lands. The estimated water requirement for these lands is about 6,700 acre-feet annually.

Local streams, water pumped from the Pit River, and ground water were considered as possible sources of water supply for this service area. Lack of suitable sites precluded studies of surface storage reservoirs on local streams. Preliminary estimates indicated that the cost of water pumped from the Pit River would be excessive, including as it would the cost of pumping against an approximately 300-foot head and the cost of purchasing water from the Pacific Gas and Electric Company.

No water wells are known to exist in the Hogback Ridge service area. Consequently, knowledge of the geology and hydrologic characteristics of the underlying formations was not attainable. Lack of this information precluded an appraisal of the ground water resources. However, from general knowledge of the geology of the area, it would appear that ground water may be contained within the underlying volcanic rocks. Test drilling would be required to investigate the practicability of developing this source.

Hat Creek Service Area

The Hat Creek service area includes irrigable lands adjacent to Hat Creek, as shown on Plate 30. It is situated between the upper reaches of Hat Creek and Rising River in the Modoc Plateau area. The service area essentially encompasses the lands of the Hat Creek Watermaster service area. About 2,700 acres in the area are now irrigated by direct diversion of stream flow, under terms of an adjudication of water rights. It is estimated that another 1,000 acres of irrigable lands will need a water supply in the future. The estimated future supplemental water requirement for agricultural, domestic, and recreational purposes is about 3,100 acre-feet annually.

Since there are no reservoir sites for surface storage in the area, ground water is the only apparent source of supplemental water supply. It appears from the small amount of available data that it might be a practical source. There are a few wells in Hat Creek Valley, a lava-flow fill of a depression in older volcanic rocks. Two wells in the valley, for which some information is available, penetrate the volcanic rocks and obtain water from the underlying older volcanics. Experience at these wells indicates that the overlying Recent volcanics are probably barren of water, and the older volcanics probably constitute the most promising potential source of water to meet supplemental requirements of the service area. This observation should be verified by test drilling.

Burney Creek Service Area

The Burney Creek service area in the Modoc Plateau consists of lands lying adjacent to Burney Creek, situated between approximately three miles west and about six miles north of the town of Burney. The location of this service area is shown on Plate 30. Approximately 800 acres, or about 27 percent of the estimated ultimate net area of irrigable lands, are irrigated at the present time by direct diversion of the flows of Burney Creek. Present municipal and industrial water supplies are obtained by pumping from ground water. The Citizens Utilities Company provides water service to the town of Burney from ground water sources. In addition to the acreage now irrigated, an estimated 2,100 irrigable acres will need a water supply in the future. The ultimate supplemental water requirement for agricultural, domestic, industrial, and recreational purposes is estimated to be about 5,500 acre-feet annually.

The probable source of water to meet future needs of the area is ground water, for no feasible surface storage sites were found during this investigation. Most existing wells in the Burney Creek service area produce adequate quantities of water for municipal, industrial, or irrigation needs. It is believed that ground water underlies the entire service area. However, because of the highly variable water-bearing characteristics of the volcanic rocks, low-yielding wells may be encountered. Present depths to water in the wells range from about 200 feet in the southwestern portion of the area to about 85 feet in the extreme northern portion.

Goose Valley Service Area

Goose Valley is located in the northeastern portion of Shasta County, north of the town of Burney and west of Burney Creek, as shown on Plate 30. The service area includes a 3,600-acre continuous expanse of meadow pasture and marsh, subirrigated from high ground water. On the fringes of the meadow pasture and marsh lands, there are about 200 acres of potentially irrigable land containing residual volcanic soils. The estimated ultimate seasonal water requirement of this land is about 500 acre-feet. In addition, some of the higher meadow pasture land would require supplemental water in the latter part of the irrigation season.

Ground water was considered as a possible source of water to meet future needs of this service area. Goose Valley is an ancient lake basin filled with water-bearing lacustrine deposits. Practically no data on ground water are available at the present time. The only known well in the valley was drilled in 1956 for irrigation purposes. It was reported that the well was tested at over 3,000 gallons per minute with 9 feet of drawdown. A well such as this could provide sufficient water to meet the estimated ultimate supplemental water requirement of Goose Valley.

<u>Cayton Valley Service Area</u>

Cayton Valley is situated in the Modoc Plateau area, about 3 miles north of Lake Britton, as shown on Plate 30. In the center and lower portions of the valley, about 700 acres of meadow pasture land are subirrigated from high ground water. Almost 500 acres of residual volcanic soils surrounding the meadow pasture land are irrigated by diversion from Cayton Creek, which flows through the valley. The remaining 100 acres of irrigable land will require an estimated 400 acre-feet of supplemental water annually.

Cayton Creek and its tributaries lack suitable reservoir sites to provide for development of a surface water supply. Only a few shallow wells exist in the valley, and consequently, data required to evaluate ground waters as a potential water source are lacking. However, observations of surface geology suggest that Cayton Valley is underlain with lake deposits. Sediments of this type may yield water, as at Goose Valley. Test wells would be required to appraise this potential water source.

Montgomery Creek Service Area

The Montgomery Creek service area consists of irrigable lands in the vicinity of the town of Montgomery Creek. The location of this service area is shown on Plate 30. About 420 acres of the area are now irrigated by diversion from Montgomery Creek and from springs. Another 580 acres of irrigable land in the service area will eventually require an estimated 1,400 acre-feet of supplemental water annually.

Because the irrigable lands of the Montgomery Creek service area are located mostly on ridges and hillsides away from and above Montgomery Creek, these lands could not be readily served by a single surface storage project. Therefore, small farm reservoirs would be the best means of meeting the future supplemental water needs of the service area.

Round Mountain Service Area

The Round Mountain service area includes irrigable lands in the vicinity of the town of Round Mountain, as shown on Plate 30. The service area consists of lands included in the Cedar Creek water rights adjudication and contiguous irrigable lands. Of an estimated 1,750 net irrigable acres, about 560 acres are irrigated at the present time. The estimated ultimate supplemental water requirement is about 3,400 acre-feet annually.

The irrigable lands of the Round Mountain service area are widely separated and could not be readily served from one surface storage project. Field reconnaissance of the service area disclosed several locations where small farm reservoirs could develop additional water supplies. This type of project would appear to be the best method of developing water to meet future needs of the area.

Little Cow Creek Service Area

The Little Cow Creek service area encompasses lands in the North Cow Creek water rights adjudication (except lands within the Bella Vista Water District) and adjacent lands. The location of this service area is shown on Plate 30. Of an estimated 1,830 net irrigable acres in the service area, about 440 are irrigated at the present time. The estimated ultimate supplemental water requirement for the irrigable lands is about 5,200 acre-feet annually.

The irrigable lands of the Little Cow Creek service area are widely separated. A field reconnaissance of the area indicated that construction of a number of small farm reservoirs on Little Cow Creek and its tributaries would develop sufficient water to meet the ultimate supplemental water requirement.

Bullskin Ridge Service Area

The Bullskin Ridge service area consists of irrigable lands lying generally on the ridge between Little Cow and Oak Run Creeks, as shown on Plate 30. About 40 acres of an estimated 2,230 net irrigable acres are irrigated by direct diversion from streams at the present time. The estimated ultimate supplemental water requirement for the remaining irrigable lands is about 8,400 acre-feet annually.

Oak Run, Clover, and Mill Creeks were considered as potential sources of water to supply this service area. The flows of these streams are used under adjudicated rights, and usually there are no surplus flows during the irrigation season. Therefore, storage of surplus winter flows would be required to meet future water needs in the area. A field reconnaissance and detailed study of topographic maps and aerial photographs of the three streams revealed no practical surface storage sites of 2,500-acre-foot capacity or over. Minor storage that could be developed on these streams would require long ditches to deliver water to the service area. Therefore, the best means of future water development would probably be small farm reservoirs constructed within the service area.

Oak Flat Service Area

The Oak Flat service area is situated on a broad ridge between Oak Run and Clover Creeks, and consists of lands in the Oak Run water rights adjudication and adjacent irrigable lands. The location of this service area is shown on Plate 30. About 730 acres of an estimated 3,300 net irrigable acres are irrigated at the present time. The estimated ultimate supplemental water requirement for the irrigable lands is about 10,000 acre-feet annually.

Surface waters stored by means of small farm reservoirs were considered to be the most probable sources of water supply for this service area. However, there is a scarcity of adequate sites within the service area to develop sufficient water to meet future supplemental needs. Farm reservoir sites which could be utilized to provide a major portion of the needed water were found outside the service area on Oak Run and Clover Creeks.

Consequently, it appears that small farm reservoir development on Oak Run and Clover Creeks, supplemented by farm reservoirs within the service area, would probably constitute the best means of meeting future water demands in the Oak Flat service area.

Oak Run Service Area

The Oak Run service area, east of the Bella Vista Water District, includes irrigable lands in the lower reaches of Oak Run Creek. About 180 acres of an estimated 1,900 net irrigable acres are irrigated at the present time by direct diversion from streams. The estimated ultimate supplemental water requirement of the irrigable lands is about 6,200 acre-feet annually.

Two types of surface storage development were considered as possible sources of water supply for this service area. A number of sites suitable for small farm reservoirs were found on streams tributary to Oak Run Creek. Farm reservoirs on these streams could be planned to provide most of the supplemental water required. On the other hand, a single reservoir, that of Oak Flat on Oak Run Creek, could be planned to provide over 85 percent of the supplemental water needed by the service area. Features of Oak Flat Dam and Reservoir are outlined in the following section.

Oak Flat Dam and Reservoir. This reservoir would be created by construction of a dam on Oak Run Creek west of Oak Flat. The dam would be located in Section 25, Township 33 North, Range 2 West, MDB&M. Stream bed elevation at the axis of the dam is about 1,425 feet.

Maps of the dam site and reservoir site were prepared by the United States Bureau of Reclamation, at a scale of 1 inch equals 100 feet with a contour interval of 5 feet, and 1 inch equals 1,000 feet with a contour interval of 10 feet, respectively. The latter map was used to obtain reservoir area and capacity data shown on Plate 23, entitled "Area, Capacity, Cost and Yield Relationships-Oak Flat Reservoir".

The United States Bureau of Reclamation investigated the geologic characteristics of the Oak Flat Dam site and reservoir area. Geologic exploration indicated that the dam site would be suitable for construction of a rockfill dam not exceeding about 100 feet in height. The foundation consists of jointed and vesicular basalt. On the left abutment the basalt is overlain with residual soil to a depth of about 2 feet. On the right abutment it is overlain with about 6 feet of tuff breccia, 18 feet of sandstone, and 2 feet of topsoil.

Watertightness of foundation and abutment rock was tested by injecting water under pressure into three exploratory core holes and noting the rate of water loss. These tests indicated no appreciable loss in the sandstone, tuff breccia, and basalt, suggesting that dam leakage would be negligible. Foundation preparation would entail removal of top soil, and excavation into the underlying materials to a depth of about 2 feet.

Cost estimates were prepared for three heights of rockfill dam that could be built at the site, and cost curves were developed, as shown on Plate 23. In each case the dam would have a crest width of 25 feet, upstream slope of 2.5 to 1, and downstream slope of 2 to 1. The impervious core would have a crest width of 10 feet, and slopes of 0.5 to 1 on the upstream and downstream sides. Adequate quantities of construction materials for the impervious core are available in the reservoir area. Salvage materials from the spillway excavation and quarried basalt rock might prove suitable for use in the embankment as rockfill.

In each size of dam, a lined, side-channel spillway with an ogee weir, having a discharge capacity of 11,000 second-feet, would be constructed in the ridge forming the right abutment. Since the rocks underlying the topsoil are erosion resistant, it would be necessary to line only a short section of the spillway chute.

The maximum depth of water over the spillway crest would be 5 feet, which would provide 5 feet of freeboard between the high-water elevation of the reservoir and the crest of the dam.

The estimated average seasonal runoff at the Oak Flat Dam site, for the 36-year period from 1920-21 through 1955-56, is about 11,000 acre-feet. Results of the yield studies are presented on Plate 23. For a reservoir storage capacity of 10,000 acre-feet, discussed below, the seasonal irrigation yield would be about 5,400 acre-feet.

The estimated capital and annual costs, and costs per acre-foot of irrigation yield for the Oak Flat Dam and Reservoir are shown on Plate 23. For a 10,000-acre-foot reservoir, these costs would be, respectively, about $3,000,000, $153,000, and $28.70.

These costs include the acquisition of lands of four cattle ranches in the reservoir area, utilized at the present time for meadow hay or pasture.

The general physical features of an Oak Flat Dam which would impound 10,000 acre-feet of water are illustrated on Plate 18, entitled "Salt Creek Dam on Salt Creek, Mistletoe Dam on Churn Creek, and Oak Flat Dam on Oak Run Creek". Pertinent data on general features of Oak Flat Dam and Reservoir are presented in Table 36.

Clover Creek Service Area

The Clover Creek service area includes lands in the Clover Creek Basin that receive water under adjudicated water rights (from Clover Creek) and additional irrigable lands in the area. The location of this service area is shown on Plate 30. Of an estimated 3,870 net irrigable acres, about 680 acres are now irrigated. The estimated ultimate supplemental water requirement for the irrigable lands is about 11,800 acre-feet annually.

Surface waters that could be stored in reservoirs on Clover Creek and its tributaries were considered as possible sources of water supply for this service area. Since Clover Creek and its tributaries usually have no surplus flows during the irrigation season, storage of winter flows would be required for additional needs. A field reconnaissance and detailed study of topographic maps and aerial photographs indicated that the best means of providing supplemental water for this service area would be through construction of small farm reservoirs on Clover Creek and its tributaries. Sites for reservoirs of larger storage capacity were not found.

TABLE 36

GENERAL FEATURES OF A POSSIBLE OAK FLAT DAM AND RESERVOIR ON OAK RUN CREEK

Dam Site	
Location	Sec. 25, T33N, R2W, MDB&M
Stream	Oak Run Creek
Elevation of stream bed, in feet	1,425
Dam	
Type	rockfill
Crest elevation, in feet	1,515
Crest length, in feet	5,380
Crest width, in feet	25
Height above stream bed, in feet	90
Freeboard above spillway crest, in feet	10
Side slopes, upstream	2.5:1
downstream	2:1
Volume of fill, in cubic yards	606,000
Reservoir	
Drainage area, in square miles	11.2
Storage capacity, in acre-feet	
Normal pool	10,000
Minimum pool	500
Elevation, in feet	
Normal pool	1,505
Minimum pool	1,458
Surface area, in acres	
Normal pool	365
Minimum pool	40
Type of spillway	side channel
Spillway discharge capacity, in second-feet	11,000
Type of outlet	welded steel pipe encased in concrete

Old Cow Creek Service Area

The Old Cow Creek service area, as shown on Plate 30, includes irrigable lands adjacent to Old Cow Creek. Over 1,400 acres of an estimated 2,500 net irrigable acres are presently irrigated with water obtained by direct diversion from Old Cow Creek, and with water obtained by conservation of flows of tributaries in existing small farm reservoirs. The estimated ultimate supplemental water requirement for the irrigable lands is about 4,600 acre-feet per season.

Surface waters available for storage in potential reservoirs on Old Cow Creek and its tributaries were considered as possible sources of supply for this service area. A project on Old Cow Creek above the service area could provide water for irrigable lands and for the existing Kilarc Powerhouse. Water for the service area could also be stored in a reservoir on Glendening Creek. Furthermore, additional small farm reservoirs on lesser tributaries of Old Cow Creek could meet a portion of the supplemental water requirements.

Of the reservoir sites studied, only the Cutter and Glendening sites were found to be engineeringly feasible. Possible dams and reservoirs at these sites are described in the following sections.

Cutter Reservoir. This reservoir would be created by construction of a dam on Old Cow Creek about 4 miles above the Kilarc diversion dam, and south of Dan Hunt Meadows. The dam would be located in Section 28, Township 33 North, Range 2 East, MDB&M. Stream bed elevation at the dam site is about 4,640 feet.

Cutter Reservoir could provide water to meet the ultimate supplemental water needs of the Old Cow Creek service area, or a portion of the water needs of the Whitmore service area. Releases from this reservoir could also be used to enhance the hydroelectric generating capacity of the Kilarc Power Plant prior to downstream use.

Topography of the dam and reservoir sites was taken from the United States Geological Survey Whitmore quadrangle map, supplemented by data from field surveys to locate 10-foot contours. A summary of area and capacity data for Cutter Reservoir is presented in Table 37.

TABLE 37

AREAS AND CAPACITIES OF CUTTER RESERVOIR

Depth of water, in feet	Water surface elevation, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	4,640	0	0
40	4,680	40	390
80	4,720	70	2,590
120	4,760	150	7,070
160	4,800	260	15,200
200	4,840	470	29,800

Preliminary geologic reconnaissance indicated that the Cutter Dam site is suitable for a rockfill dam constructed to a height of 200 feet. Bedrock at the site is a hard, massive, fine-grained volcanic rock. The channel section is filled with about 2 feet of cobbles and gravel overlying the bedrock. The lower 100 feet on both abutments is covered by overlay deposits. Slightly jointed and weathered bedrock is exposed in the upper 100 feet of the abutments. Stripping and shaping in the channel section and the lower 100 feet of the abutments would require removal of 6 to 8 feet of soil, rock rubble, and weathered bedrock. About 4 feet of stripping would be required in the upper portions of the abutments.

A saddle on the right abutment would provide a suitable spillway location for a 160-foot high dam, with crest elevation at approximately 4,800 feet. Should a lower dam be constructed, an excessive amount of spillway excavation would be required. Although rock is not exposed in the saddle, bedrock is estimated to lie within 10 to 15 feet of the surface.

Adequate construction materials are available in the vicinity of the dam site. Impervious fill materials would consist of residual soils. These soils were sampled and tested, and the maximum density was determined to be about 91 pounds per cubic foot. The soils contain particles over 1 inch in size, and removal of these large particles would provide a better gradation of material for use in an impervious section. The predominant hard material in the area (the massive, fine-grained volcanic rock) would generally be suitable for rockfill, riprap, and if crushed, aggregate.

The estimated mean seasonal flow (1897-98 to 1946-47) from the 13.4 square miles of drainage basin above the dam site is 19,600 acre-feet. Monthly operation studies were made to determine the relationship between safe yield and storage capacity.

A preliminary analysis was made of a 160-foot rock-fill dam, which would create a reservoir with storage capacity of 10,500 acre-feet. Crest elevation of the dam would be 4,800 feet, and the crest of the spillway would be at an elevation of 4,790 feet. The upstream slope would be 2.5 to 1, and the downstream slope would be 1.4 to 1. The sloping earth core would have a 10-foot top width, upstream slope 1.5 to 1, and downstream slope 1.25 to 1. It would extend into a 10-foot deep cutoff trench excavated into the sound volcanic rock formation. The total volume of fill would be about 710,000 cubic yards.

An unlined spillway excavated in the right abutment would discharge flood flows into Hunt Creek, which enters Old Cow Creek about 3,000 feet below the dam site. A concrete ogee weir with a short paved apron would provide control for the spillway. The spillway discharge capacity would be 16,000 second-feet, with a maximum depth of water of 6 feet above the spillway crest. This would provide 4 feet of freeboard between the maximum water surface elevation and the crest of the dam.

The capital cost of Cutter Dam and Reservoir was estimated to be $4,310,000. The estimate of annual cost is about $219,000. The safe seasonal yield on an irrigation demand schedule was estimated to be about 7,900 acre-feet, including present rights to water. Seasonal irrigation yield for the same conditions would be about 8,500 acre-feet. The estimate of annual cost per acre-foot of irrigation yield is about $26.

Glendening Reservoir. This reservoir would be created by construction of a dam on Glendening Creek, a major tributary of Old Cow Creek, about 2 miles east of Whitmore and about 2 miles south of the Kilarc Powerhouse. The reservoir area is moderately timbered and contains no improvements other than fencing. The dam would be located in Section 9, Township 32 North, Range 1 East, MDB&M. Stream bed elevation at the dam site is about 2,370 feet.

Glendening Reservoir could provide a portion of the supplemental water required by either the Old Cow Creek service area, or the Whitmore service area discussed subsequently.

Topography of the dam and reservoir sites was taken from the United States Geological Survey Whitmore quadrangle map, supplemented by field surveys to locate intermediate 10-foot contours. A summary of area and capacity data for Glendening Reservoir is presented in Table 38.

Preliminary geologic reconnaissance indicated that the Glendening site is suitable for a rockfill dam up to 130 feet in height. Abutments and channel section consist of hard volcanic rock. Although vesicular in part, the rock is of sufficient strength to support a dam of the size and type under consideration.

Table 38

AREAS AND CAPACITIES OF GLENDENING RESERVOIR

Depth of water, in feet	Water surface elevation, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	2,370	0	0
30	2,400	7	70
70	2,440	26	730
110	2,480	66	2,570

Foundation preparation of the site would entail stripping the entire left abutment to an estimated depth of 8 feet, removal of 6 to 8 feet of soil and rubble from the lower 40 feet of the right abutment, and excavation of about 5 feet of material from the channel section.

Construction materials near the Glendening Dam site are generally similar to those at the Cutter Dam site. The residual soils tested are light but impervious, and could be used in the impervious core of a dam. The volcanic lava rocks could be used for rockfill, riprap, or aggregate.

Mean seasonal runoff (1897-98 to 1946-47) from the 11.5 square miles of drainage area above the dam site was estimated to be about 14,000 acre-feet. The safe seasonal irrigation yield obtainable from the size of reservoir considered would be essentially equal to the storage capacity.

A preliminary analysis was made of a 110-foot high rockfill dam forming a reservoir with storage capacity of 1,700 acre-feet. The dam crest would be at an elevation of 2,480 feet, and the crest of the spillway would be at an elevation of 2,470 feet. The crest length and width of the dam would be 600 feet and 20 feet, respectively. The slopes of the dam would be 2.5 to 1 upstream, and 1.5 to 1 downstream. The earth core would have a 10-foot top width and upstream and downstream slopes of 0.75 to 1. The core would extend into a 10-foot deep cutoff trench excavated into the sound volcanic rock foundation. The total volume of fill was estimated to be about 292,000 cubic yards. A spillway of about 5,000-second-foot discharge capacity would be excavated across a ridge at the upper end of the reservoir. Spillway flows would discharge into a draw, and then back into Glendening Creek several thousand feet below the dam site.

The capital cost of Glendening Dam and Reservoir was estimated to be about $1,360,000. The corresponding estimated annual cost would be about $69,000. The safe seasonal yield on an irrigation demand pattern was estimated to be about 1,900 acre-feet. Thus, the cost of water per acre-foot of safe yield from the reservoir would be about $36.

Whitmore Service Area

The Whitmore service area consists of lands lying generally on the ridge between Old Cow and South Cow Creeks. About 800 acres of an estimated 7,750 net irrigable acres are irrigated at the present time by diversion of flows from South Cow Creek. The estimated ultimate supplemental irrigation water requirement is about 26,800 acre-feet per season.

Surface storage reservoirs were considered as possible means of developing a water supply for this service area. One potential site, the Bateman Reservoir site, was found on Atkins Creek. Cutter and Glendening Reservoirs, previously discussed, and Bateman Reservoir could collectively provide about 19,000 acre-feet of water seasonally on an irrigation demand schedule to the Whitmore and Old Cow Creek service areas, including amounts of water presently used. The estimated ultimate supplemental irrigation water requirement of these two service areas is about 41,000 acre-feet per season. This requirement could be met by supplementing the yields from the three aforementioned reservoirs by construction of small farm reservoirs.

Bateman Reservoir. This reservoir would be created by construction of a dam on Atkins Creek about one-half mile above its confluence with South Cow Creek. The dam would be located in Section 24, Township 32 North, Range 1 East, MDB&M. Stream bed elevation at the dam site is about 2,980 feet.

Bateman Reservoir could provide water to meet a portion of the ultimate supplemental water requirement of the Whitmore service area. A portion of its yield could also be used to meet the ultimate supplemental water requirement of the Hagaman Gulch service area discussed later in this bulletin.

Topography of the dam site was taken from the United States Geological Survey Whitmore quadrangle map, supplemented by field surveys to locate intermediate 10-foot contours.

A summary of area and capacity data for Bateman Reservoir is presented in Table 39.

TABLE 39

AREAS AND CAPACITIES OF BATEMAN RESERVOIR

Depth of water, in feet	Water surface elevation, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	2,980	0	0
20	3,000	4	40
60	3,040	30	760
100	3,080	110	3,560
140	3,120	230	10,300

Reconnaissance geologic investigation indicated that the Bateman Dam site is suitable for an earth or rockfill dam up to 150 feet in height. The foundation and abutments consist of fine-grained, volcanic rock, which is exposed on the right abutment at elevations greater than 60 feet above stream channel, but which is covered elsewhere on the foundation. In the unweathered state this rock is hard and massive.

The channel section measures 135 feet in width. The present stream bed occupies a gravel and cobble laden channel, 60 feet in width, located along the right side of the site. The left bank of the channel is a flood plain, 75 feet in width, standing about 5 feet higher than the stream bed.

Foundation preparation of the site would entail removal of sediments from the channel section to an estimated average depth of 5 feet, and stripping of residual soil and rubble from the abutments to an estimated average depth of 15 feet from the left abutment and 10 feet from the lower slopes of the right abutment.

A spillway could be constructed on either of the abutments. However, the depth of residual soils to firm volcanic rock on the ridge forming the left abutment may be excessive, and, therefore, a heavy lining might be required for the spillway.

Adequate quantities of suitable construction materials are available in the immediate vicinity of the Bateman Dam site. These materials consist of light, residual soils and fine-grained, hard volcanic rocks, similar to those found at the Cutter Dam site.

The estimated mean seasonal runoff (1897-98 to 1946-47) from the 12.5 square miles of drainage area above the dam site is about 17,700 acre-feet.

An analysis of a 140-foot dam was made to obtain preliminary cost information. The dam would form a reservoir having a storage capacity of 8,500 acre-feet. A rockfill dam with an impervious earth core was selected for analysis. The crest of the dam would be at an elevation of about 3,120 feet, and the crest of the spillway at 3,110 feet. Crest length and width would be 920 feet and 20 feet, respectively. The upstream and downstream slopes of the dam would be 2 to 1. An impervious core, with an upstream slope of 1 to 1 and a downstream slope of 0.5 to 1, would have a 5-foot top width and a 10-foot cutoff trench at the upstream toe. The total volume of fill in the embankment would be about 815,000 cubic yards.

A spillway with a concrete ogee weir would be constructed on the right abutment. The spillway would be lined for a distance of 450 feet downstream from the weir. The spillway discharge capacity would be 5,000 second-feet, with a 5-foot maximum depth of water above the crest of the weir.

The capital cost of the Bateman Dam and Reservoir project was estimated to be about $4,350,000. The corresponding annual cost would be $221,000. The safe yield on an irrigation demand schedule would be about 7,300 acre-feet per season, including water that must be released to satisfy the vested rights at the Cow Creek Power Plant during winter and spring months. Seasonal irrigation yield was found to be nearly equal to the storage capacity of the reservoir, or 8,500 acre-feet. The estimated cost per acre-foot of irrigation yield was about $26.

Hagaman Gulch Service Area

The Hagaman Gulch service area consists of irrigable lands on a ridge south and east of the town of Whitmore, and between South Cow Creek and Dickerson Creek, as shown on Plate 30. About 20 acres of an estimated 720 net irrigable acres in the area are irrigated at the present time by direct diversion from streams. The estimated ultimate supplemental water requirement is about 2,400 acre-feet annually.

Bateman Reservoir, previously discussed, would be a possible source of supply to meet the future water needs of the service area. However, it is believed that small farm reservoir development on South Cow Creek or Dickerson Creek might prove to be a more economical source of water.

South Cow Creek Service Area

The South Cow Creek service area includes irrigable lands in South Cow Creek Valley lying above the confluence of South Cow and Old Cow Creeks and below the existing South Cow Power Plant. The location of this service area is shown on Plate 30. About 400 acres of an estimated 1,400 net irrigable acres are irrigated at the present time by direct diversion from South Cow Creek. The estimated ultimate supplemental water requirement for the irrigable lands is about 3,200 acre-feet per season.

Surface storage reservoirs were considered as possible means of developing a water supply for this service area. Water released from Bateman Reservoir, previously discussed, could be used downstream in the South Cow Creek service area. However, a reservoir on South Cow Creek above the service area could also provide a water supply to the area. Since this reservoir would be located above the Cow Creek Power Plant, its releases could be used to enhance the hydroelectric generating capacity of the plant. Furthermore, surplus water from the reservoir could also be utilized in the Cow Creek Bottoms, although a less costly water supply for the Cow Creek Bottoms could be obtained from Millvillito Reservoir, discussed later in the section on the Bella Vista service area.

A possible dam and reservoir site, the Wagoner site, was found on South Cow Creek above the service area. Wagoner Dam would be located in Section 33, Township 32 North, Range 1 West, MDB&M, above the diversion to South Cow Power Plant. Water conserved in this reservoir could enhance hydroelectric energy generation and could be used for irrigation in the service area. Permission to inspect the Wagoner Dam and Reservoir site could not be obtained from the landowner. Consequently, the geologic and topographic details of this site are not known. However, as a result of field inspection of areas upstream and downstream, it was assumed that the foundation at this site would be suitable for an earthfill dam. Aerial photographs and the Whitmore quadrangle map of the United States Geological Survey were used in studies of a project at the site. Stream bed elevation at the dam site is about 1,570 feet.

The height of a dam at the Wagoner site would be about 120 feet, and the crest length would be about 1,300 feet. A reconnaissance cost estimate for a Wagoner Dam and Reservoir with a gross storage capacity of 8,400 acre-feet indicated a total capital cost of about $1,850,000. The corresponding annual cost would be $95,000. For capacities up to about 10,000 acre-feet, the new seasonal irrigation yield would be about equal to the storage capacity. Therefore, the cost per acre-foot of new irrigation yield would be about $11.50.

Inwood Service Area

The Inwood service area includes irrigable lands situated on the ridge between Bear and Ash Creeks, as shown on Plate 30. About 750 acres of an estimated 8,450 net irrigable acres are irrigated at the present time, mostly from streams and springs. The estimated ultimate supplemental water requirement for irrigation is about 28,600 acre-feet per season.

Ground water and surface storage reservoirs were considered as possible sources of water supply for this service area. A field reconnaissance disclosed that yields of most wells in the area are generally limited to amounts sufficient only for domestic use. Feasible surface storage reservoir sites for features larger than those of farm reservoirs were not found in the service area. A field reconnaissance indicated that there are a number of sites suitable for small farm reservoirs on Bear Creek and its tributaries, both above and within the service area. Because of the variable characteristics of the volcanic formations of the area, farm reservoir sites would require engineering and geologic appraisals. However, it is believed that farm reservoirs would be the best means of developing water to meet a portion of the ultimate supplemental water requirement of the Inwood service area.

Black Butte Service Area

The Black Butte service area includes irrigable lands adjacent to Ash Creek in Township 30 North, Range 1 West, MDB&M, as shown on Plate 30. There is no irrigation within the service area at the present time. However, about 2,300 acres constitute the net area of irrigable lands. The estimate of the ultimate supplemental water requirement for irrigation is about 8,400 acre-feet per season.

Surface storage reservoirs were considered as a possible means of developing a water supply for this service area. The Ash Creek Reservoir project on Ash Creek, described in this section, could yield a portion of the water needed. Stream flow diverted into Ash Creek from the North Fork of Battle Creek near Shingletown could provide an additional supply. However, diversion of this flow would affect the Battle Creek power development of the Pacific Gas and Electric Company, and the cost of the water could only be determined by negotiation between the potential water user and the company. The total static head of the Volta, South, Inskip, and Coleman Power Plants in the system is 2,404 feet (Volta, 1,063 feet; South, 516 feet; Inskip, 378 feet; and Coleman, 479 feet).

Estimates based on the energy component only indicate that the value of water flowing through these plants is about $5.80 per acre-foot. The additional value of the water, based on the reduction of dependable power capacity of these plants due to upstream diversions, was not estimated because of a lack of data.

Ash Creek Reservoir. Ash Creek Reservoir would be created by construction of a dam on Ash Creek about 1.5 miles northeast of Black Butte. The dam would be located in Section 9, Township 30 North, Range 1 West, MDB&M. Stream bed elevation at the site is about 2,160 feet.

Dam and reservoir site topography was taken from the United States Geological Survey Manton quadrangle map, supplemented sufficiently by field surveys to locate intermediate 10-foot contours.

Preliminary geologic investigation indicated that the Ash Creek Dam site is probably suitable for an earthfill dam up to 110 feet high. The right abutment and lower 90 feet of the left abutment consist of tuff breccia; whereas the upper 20 feet of the left abutment consist of lava. Of some concern is the tuff breccia-lava contact, which constitutes a possible avenue of leakage through the left abutment.

The site will require further investigation, including laboratory testing to determine the strength of the foundation rock, and field testing to explore the possibilities of abutment leakage and the susceptibility of the foundation to grouting should leakage pose a problem.

Foundation preparation would entail stripping of overlying materials to an estimated average depth of 8 feet throughout.

The spillway could be excavated through the ridge of tuff breccia forming the right abutment, and would require lining. Spillway flows would return to Ash Creek well below the downstream toe of the dam.

Construction materials for Ash Creek Dam would be the deep residual volcanic soils available within 1.5 miles of the dam site, and the volcanic flow rocks adjacent to the site. The soils appear to be similar to the impervious soils tested in the upper Cow Creek Basin. The volcanic rocks appear to be suitable for rockfill or riprap.

Mean seasonal runoff from the 4.6 square miles of drainage area above the dam site was estimated to be about 3,400 acre-feet. However, topography of the site limits the reservoir storage capacity to about 3,000 acre-feet, and the yield from this amount of storage would meet only a portion of the future water requirements of the Black Butte service area.

A preliminary analysis was made of a 110-foot homogeneous earthfill dam forming a reservoir with a capacity of 3,000 acre-feet. Crest elevation of the dam would be about

2,270 feet, and the elevation of the spillway would be 2,260 feet. Crest length and width of the dam would be 890 feet and 20 feet, respectively. The upstream and downstream slopes of the embankment would be 2.5 to 1. A 10-foot cutoff wall would be required in the foundation. The total volume of fill would be about 550,000 cubic yards.

A lined spillway with an ogee weir would be constructed across the ridge forming the right abutment. The spillway discharge capacity would be about 2,000 second-feet, with a maximum depth of water of about 5 feet above the spillway crest.

The reservoir area has no improvements, other than fences, and is mostly covered with brush, oak, and pine.

The capital cost of the Ash Creek Dam and Reservoir was estimated to be about $1,400,000. The corresponding annual cost would be about $71,000. The safe yield on an irrigation demand schedule was estimated to be about 1,500 acre-feet per season, and the irrigation yield about 2,800 acre-feet per season. The cost of water in the reservoir would be about $25 per acre-foot of irrigation yield.

Millville Plains Service Area

The Millville Plains service area includes irrigable lands between the lower reaches of Cow and Bear Creeks and lands adjacent to these streams, as shown on Plate 30. About 150 acres of an estimated 3,300 net irrigable acres in the service area are irrigated at the present time by direct diversion from streams. The estimated ultimate supplemental water requirement for irrigation is about 12,200 acre-feet per season.

Ground water and surface storage reservoirs were considered as possible sources of water supply for this service area.

The ground water potential of the Millville Plains service area was not evaluated because pertinent data were not available. However, data available elsewhere in the Redding ground water basin indicate that ground water is probably present under the Millville Plains. It is also probable that this water is moving from the east toward Cow Creek and the Sacramento River. Before commitment is made to an alternative surface water development for this service area, ground water test drilling should be conducted to determine depth to water, expected yields, rates of flow, and other pertinent factors.

Millville Reservoir or Millvillito Reservoir on South Cow Creek could provide water to the Millville Plains service area. These reservoirs are discussed in the section on the Cow Creek Bottoms service area. Water would be delivered from South Cow Creek by means of a conduit, such as a Millvillito-Millville Plains canal, which could be located above most of the irrigable lands of the service area. A branch pressure conduit could deliver water to irrigable lands in the Cow Creek Bottoms lying south of South Cow Creek and east of Cow Creek.

Millvillito-Millville Plains Canal. This canal would extend from Millvillito Dam (discussed under Cow Creek Bottoms service area), along the edge of the bluff south of Millville, and southwest of Millville in a southerly direction to the Millville Plains service area. Southwest of Millville, a branch from the main canal would continue along the bluffs to a terminus at Switzars Gulch in the Cow Creek Bottoms, which would be in Section 16, Township 31 North, Range 3 West, MDB&M. The total length of the canal and branch would be about 11.5 miles. The initial discharge capacity of the canal would be about 72 second-feet, and would decrease to 32 second-feet at Switzars Gulch. The capital cost of the canal was estimated to be $563,000, and the corresponding annual cost, $34,000.

Manton Service Area

The Manton service area includes irrigable lands adjacent to the southern boundary of Shasta County, as shown on Plate 30. About 70 of an estimated 5,470 net irrigable acres in the service area are irrigated at the present time by direct diversion from streams. There are numerous springs in the area, and many tributaries to Battle Creek and several ditches of the Pacific Gas and Electric Company traverse it. The estimated ultimate supplemental water requirement for irrigation is about 20,000 acre-feet per season.

The feasibility of surface reservoir storage, and of purchase of water from the Pacific Gas and Electric Company were considered as possible sources of supplemental water. Although surplus flows occur in Battle Creek and its tributaries during winter and spring months, two obstacles are in the way of developing reservoir storage. One is that the topography of the area is not suitable for reservoir sites.

Even if engineeringly feasible, future storage projects almost anywhere in the Manton service area would be subject to restrictions by existing water rights. Use of water in the Battle Creek Basin is based on riparian rights, pre-1914 appropriative rights, and post-1914 appropriative rights and applications.

There are four power plants in the Battle Creek power system of the Pacific Gas and Electric Company, Volta and Coleman in Shasta County, and South and Inskip in Tehama County. The Volta plant is located above the elevation of most of the service area, and, consequently, would not be affected by use of water in the area. However, energy and power generation at the South, Inskip, and Coleman plants would be impaired by use of water in the service area. The total static head of the latter three power plants is 1,373 feet. The estimated value of the energy component of the water flowing through these plants is about $3.20 per acre-foot. The total value of this water, including that for dependable power capacity, was not estimated because of lack of pertinent data, and cost of the water, if purchased, would have to be determined by negotiation between the potential water user and the company.

North Suburban Service Area

The North Suburban service area is located north of Redding between U. S. Highway 99 and the Sacramento River, and is composed entirely of urban and suburban lands. The location of this service area is shown on Plate 30. The estimated ultimate supplemental water requirement for urban and domestic purposes is 10,000 acre-feet per season. The service area encompasses the Buckeye County Water District, the Summit City Public Utility District, the Shasta Dam Area Public Utility District, and the Wonderland-Mountain Gate Community Services District. The first three of these districts now receive a treated domestic water supply from a distribution system of the United States Bureau of Reclamation. This water is pumped from Shasta Lake at Shasta Dam to a water tank located near Toyon, between Summit City and Central Valley.

The Wonderland-Mountain Gate Community Services District, recently formed, is attempting to develop ground water supplies from a relatively shallow valley fill area in the southern part of the district. This district also has considered the possibility of pumping water from the Bridge Bay arm of Shasta Lake, which is less than 1 mile north of the district.

Studies of the four districts disclosed four possible means of obtaining future surface water supplies for domestic purposes: (1) pumping from Shasta Lake at Shasta Dam; (2) pumping from Shasta Lake at Bridge Bay; (3) pumping from Keswick Reservoir at a point about 3 miles north of Keswick Dam; and (4) pumping from the Sacramento River near Redding. Depending upon the rate and pattern of growth within the North Suburban service area, any one or all four of these methods might be used.

Enlargement of the present facilities for pumping from Shasta Lake at Shasta Dam would probably provide the best means of obtaining a supplemental water supply, if growth within the service area should be an expansion of the towns of Central Valley and Project City, the present urban core of the area. The terminus of the existing conduit is centrally located at an adequate elevation to provide a water supply by gravity to most of the area. Should an early expansion occur in the northern portion of the service area, its water needs could readily be met by pumping from Shasta Lake at Bridge Bay.

Future water needs due to expansion in the southern half of the Buckeye County Water District could be met by an enlargement of the existing system. However, pumping water from Keswick Reservoir would also constitute a means of meeting supplemental water requirements in this area.

Supplemental water requirements of the eastern portion of the service area could be met from distribution laterals included in a current plan of the United States Bureau of Reclamation to pump water from the Sacramento River near Redding and to convey it to the Bella Vista service area. These laterals would terminate near the eastern boundary of the North Suburban service area.

Stillwater Plains Service Area

The Stillwater Plains service area includes irrigable lands of the elevated plains between Cow Creek and the Sacramento River lying south of the Bella Vista service area, as shown on Plate 30. About 100 acres of an estimated 10,700 net irrigable acres are irrigated at the present time. The estimated ultimate supplemental water requirement for agricultural and domestic purposes is about 45,600 acre-feet seasonally.

Ground water, surface water pumped from reservoirs on Cow Creek or the Sacramento River, and surface water stored in reservoirs on Churn and Stillwater Creeks, were considered as possible sources of supply for this service area. Studies of these sources indicated that ground water would provide the most economical water supply. The adequacy of ground water supplies and of well yields within the service area was confirmed by studies conducted by the United States Bureau of Reclamation in 1957. The average depth to ground water is about 100 feet, and it is probable that the average pumping lift would not exceed 150 feet.

From the results of reconnaissance studies, it was estimated that the cost of water pumped from the Sacramento River and from Cow Creek would be several times the cost of ground water. Studies and search for reservoir storage sites were made on Churn and Stillwater Creeks. One site suitable for a reservoir larger than 2,500 acre-feet in storage capacity was found on Churn Creek. This site, designated Mistletoe Reservoir, is described in the following section.

Mistletoe Dam and Reservoir. Mistletoe Reservoir would be created by construction of a dam on Churn Creek, about one-fourth mile upstream from the Old Alturas Highway, in Section 32, Township 32 North, Range 4 West, MDB&M, within the Bella Vista service area. The stream bed elevation at the dam site is about 540 feet.

A topographic map of the reservoir and dam site area was prepared for the United States Bureau of Reclamation by the United States Geological Survey, at a scale of 1 inch equals 800 feet, with a contour interval of 10 feet. Reservoir area and capacity data obtained from this map are shown on Plate 17, entitled "Area, Capacity, Cost and Yield Relationships-Mistletoe Reservoir".

Geologic exploration indicated that the Mistletoe Dam site would be suitable for construction of a zoned earthfill dam up to 100 feet in height. The foundation rock consists of intercalated beds of semiconsolidated tuffaceous-sandy clay and clayey-sandy gravel of the Tuscan-Tehama formation. This material forms the main part of both abutments and underlies the valley floor.

A weakly cemented silty and clayey gravel of the Red Bluff formation caps the Tuscan-Tehama formation on both abutments. On the valley floor the Tuscan-Tehama formation is overlain by about 10 feet of alluvial deposits which are relatively pervious. An exploratory drill hole in the channel indicated that about 10 feet of loose pervious gravels are underlain by 23 feet of impervious clay. Another drill hole on the left abutment showed the Red Bluff formation to be 15 to 20 feet thick above the Tuscan-Tehama formation. Stripping of about 5 feet of material on the abutments and 10 feet in the valley floor and channel section would be required.

Cost estimates were prepared for three heights of earthfill dam at the Mistletoe site, and the cost-yield curves shown on Plate 17 were developed. In each case the dam would have a crest width of 25 feet, an upstream slope of 3 to 1, and a downstream slope of 2.5 to 1. Adequate quantities of impervious construction materials are available from the Red Bluff formation within 1 mile of the dam site. Materials salvaged from the spillway excavation would be suitable for use in the semipervious zones of the dam.

A lined chute spillway with an ogee weir, having a discharge capacity of 11,000 second-feet, would be located in the left abutment. The maximum depth of water above the spillway crest would be 7 feet, with an additional 5 feet of freeboard to the crest of the dam.

Since stream flow records of Churn Creek were not available, seasonal runoff was estimated by direct correlation with seasonal precipitation at Redding. Results of the yield studies, presented as a curve on Plate 17, are based on estimated seasonal flows varying from 5,600 to 88,000 acre-feet, with an average seasonal runoff of 23,000 acre-feet during the 18-year period from 1920-21 through 1937-38.

Estimates of capital and annual costs for a 5,400-acre-foot Mistletoe Reservoir, one of the three sizes studied, with an estimated seasonal irrigation yield of about 4,500 acre-feet, are $1,500,000 and $80,000, respectively. The yield of the reservoir would cost an estimated $17.50 per acre-foot. The estimate of capital cost includes acquisition of land and dwellings in the vicinity of U. S. Highway 299 which would be inundated when the reservoir was filled. A reservoir of greater storage capacity than 5,400 acre-feet would involve, in addition to the foregoing costs, those for construction of a bridge on U. S. Highway 299 at the upper end of the reservoir.

The general physical features of Mistletoe Dam are illustrated on Plate 18, entitled "Salt Creek Dam on Salt Creek, Mistletoe Dam on Churn Creek, and Oak Flat Dam on Oak Run Creek". Pertinent data on the general features of Mistletoe Dam and Reservoir are presented in Table 40.

TABLE 40

GENERAL FEATURES OF A POSSIBLE
MISTLETOE DAM AND RESERVOIR ON CHURN CREEK

Dam site	
Location	Sec. 32, T32N, R4W, MDB&M
Stream	Churn Creek
Elevation of stream bed, in feet	540
Dam	
Type	earthfill
Crest elevation, in feet	600
Crest length, in feet	1,860
Crest width, in feet	25
Height above stream bed, in feet	60
Freeboard above spillway crest, in feet	12
Side slopes, upstream	3:1
downstream	2.5:1
Volume of fill, in cubic yards	586,000
Reservoir	
Drainage area, in square miles	27
Storage capacity, in acre-feet	
Normal pool	5,400
Minimum pool	1,000
Elevation, in feet	
Normal pool	588
Minimum pool	569
Surface area, in acres	
Normal pool	370
Minimum pool	100
Type of spillway	chute on left abutment
Spillway discharge capacity, in second-feet	11,000
Type of outlet	welded steel pipe encased in concrete

Bella Vista Service Area

The Bella Vista service area includes most of the irrigable lands in the Stillwater Plains and Cow Creek Bottoms lying north of State Highway No. 44, as shown on Plate 30. It would encompass essentially the same area as the recently revised boundaries of the Bella Vista Water District. Of an estimated 13,700 net irrigable acres, about 600 acres are irrigated at the present time. Present water supplies are obtained from ground water, from storage in farm reservoirs, and by direct diversion of stream flow. The estimated ultimate supplemental water requirements in the service area are about 49,000 acre-feet per season for irrigation purposes, and about 4,200 acre-feet per season for domestic purposes.

The four potential water sources considered for future needs of the Bella Vista service area were diversion from streams, surface water storage projects, ground water, and water from the Trinity River Division of the Central Valley Project. Studies of alternative plans utilizing these potential sources indicated that the Cow Creek Unit plan, developed by the United States Bureau of Reclamation, and authorized on August 12, 1955, as a part of the Trinity River Division of the Central Valley Project, would be the best plan for initial water development in the service area. Ground water could be used to supplement the Cow Creek Unit plan in portions of the service area. Additional water to meet future requirements could be obtained by enlarging features of the Cow Creek Unit plan or by constructing a reservoir or reservoirs on Cow Creek.

The Cow Creek Unit plan of development would consist of a pumping plant, a main conduit, and a distribution system. The pumping plant on the Sacramento River near Redding, with a capacity of 93 second-feet and a lift of 294 feet, would discharge water into the main pressure conduit, which would extend to the vicinity of Bella Vista. Distribution pressure laterals would extend north and south from the main conduit to the vicinities of Churn Creek, Stillwater Creek, and Cow Creek. The costs and benefits of the plan for the Bella Vista Water District have not yet been published by the United States Bureau of Reclamation.

It is probable that future development of ground water within the Bella Vista service area will be limited. The underlying Cretaceous rocks, which are generally salt water-bearing, lie at maximum depths of about 400 feet along State Highway No. 44, and are exposed at the surface in the vicinity of U. S. Highway 299. The limited depths of sediments containing fresh water, and the generally low yields of wells experienced, relegate ground water to a minor position as a potential source of water supply.

The three reservoirs studied as possible sources of future supplemental water supplies for the Bella Vista service area were Bella Vista Reservoir on Little Cow Creek, a large reservoir which could provide water for both local use and export; Vacacilla Reservoir on Little Cow Creek, which could provide water for local use only; and Salt Creek Reservoir on Salt Creek, a minor reservoir which could provide a limited amount of water for local use. As has been stated, these reservoirs constitute possible sources of supplemental water in excess of that provided by the Cow Creek Unit plan.

Bella Vista Reservoir. Bella Vista Reservoir would be created by construction of a dam on Little Cow Creek just upstream from its confluence with Dry Creek. The dam would be located in Section 20, Township 32 North, Range 3 West, MDB&M. Stream bed elevation at the dam site is 488 feet.

Water from the reservoir could meet a portion of the ultimate supplemental needs of the Cow Creek Bottoms and the northern Stillwater Plains. However, most of the reservoir yield would be new regulated water for export and use outside Shasta County. The reservoir would be operated for flood control.

A topographic map of the Bella Vista Dam site was prepared by the Department of Water Resources at a scale of 1 inch equals 200 feet, with a contour interval of 5 feet. A map of a portion of the reservoir area was available from the United States Bureau of Reclamation at a scale of 1 inch equals 800 feet, with a contour interval of 10 feet. The Department of Water Resources prepared a map of the remainder of the reservoir area at a scale of 1 inch equals 400 feet, with a contour interval of 10 feet. The reservoir maps were used to obtain the area and capacity data shown on Plate 19, entitled "Area, Capacity, Cost and Yield Relationships-Bella Vista Reservoir".

Geologic exploration indicated that the dam site would be suitable for construction of an earthfill dam about 180 feet in height. Foundation materials at the site are flat-lying, semi-consolidated, tuffaceous silt and clay, and lenticular volcanic gravels of the Tuscan-Tehama formation. Above an elevation of about 645 feet on the right abutment, and 670 feet on the left abutment, the Tuscan-Tehama formation is capped with a consolidated andesitic agglomerate, or Tuscan mudflow. The channel section and flood plain, about one-half mile wide, consist of Recent alluvium comprised of loose, pervious, sandy gravel.

Stripping in the channel would consist of removal of 10 to 15 feet of Recent alluvium. Approximately 5 feet of soil and weathered material would be removed from both abutments.

Cost estimates were prepared for several heights of homogeneous earthfill dam that could be built at the site. In each case the dam would have a crest width of 30 feet, upstream slope of 3.5 to 1, and downstream slope of 2.5 to 1. Adequate quantities of construction materials are situated within 2.5 miles of the dam site, in the reservoir area and on the surrounding terraces. The embankment would consist of materials derived from the Recent alluvium and the Tuscan, Tuscan-Tehama, Red Bluff, and Chico formations. Aggregate would be obtained by processing the Recent alluvium, or by hauling from gravel plants near Redding. Quarried sandstone of the Chico formation would be used for riprap.

A lined chute spillway with an ogee weir would be constructed on the left abutment. The spillway discharge capacity would be 30,000 second-feet. Maximum depth of water above the spillway crest would be 10 feet, providing 7 feet of freeboard on the dam. The spillway flood flows would be discharged into a stilling basin, and then guided by means of an unlined channel to the stream channel about 1,500 feet below the dam.

Results of yield studies for Bella Vista Reservoir are presented as curves on Plate 19. For a reservoir with storage capacity of 196,000 acre-feet, as described herein, the safe seasonal yield would be about 76,000 acre-feet, including a mandatory release of 11,000 acre-feet for fish and wildlife. Since yield of the reservoir would be primarily used outside Shasta County, the schedule of releases from Bella Vista Reservoir would be integrated with other reservoirs in the Sacramento Valley.

General physical features of a Bella Vista Dam which would impound 196,000 acre-feet of water are illustrated on Plate 20, entitled "Vacacilla Dam on Little Cow Creek and Bella Vista Dam on Little Cow Creek". Pertinent data on general features of Bella Vista Dam and Reservoir are presented in Table 41. Estimates of capital costs, annual costs, and costs per acre-foot of safe yield of Bella Vista Reservoir are shown on Plate 19. These estimates for a 196,000-acre-foot reservoir are, respectively, $16,300,000, $840,000, and $12.80.

TABLE 41

GENERAL FEATURES OF A POSSIBLE
BELLA VISTA DAM AND RESERVOIR ON LITTLE COW CREEK

Dam site	
Location	Sec. 20, T32N, R3W, MDB&M
Stream	Little Cow Creek
Elevation of stream bed, in feet	488
Dam	
Type	earthfill
Crest elevation, in feet	630
Crest length, in feet	3,160
Crest width, in feet	30
Height above stream bed, in feet	142
Freeboard above spillway crest, in feet	17
Side slopes, upstream	3.5:1
downstream	2.5:1
Volume of fill, in cubic yards	7,100,000
Reservoir	
Drainage area, in square miles	123
Storage capacity, in acre-feet	
Normal pool	196,000
Minimum pool	5,000
Elevation, in feet	
Normal pool	613
Minimum pool	517
Surface area, in acres	
Normal pool	4,400
Minimum pool	420
Type of spillway	converging chute with stilling basin
Spillway discharge capacity, in second-feet	30,000
Type of outlet	welded steel pipe encased in concrete

Vacacilla Project. The Vacacilla Project would include Vacacilla Reservoir on Little Cow Creek, and the Vacacilla-Palo Cedro Canal which would convey water to the Cow Creek Bottoms on the west side of Cow Creek.

(1) Vacacilla Reservoir. This reservoir would be created by construction of a dam on Little Cow Creek about 2 miles east of Bella Vista. Vacacilla Dam would be located in Section 9, Township 32 North, Range 3 West, MDB&M. Stream bed elevation at the dam site is about 540 feet.

Vacacilla Reservoir would be an alternative to Bella Vista Reservoir as a source of local water supply, and could meet a portion of ultimate water requirements of the Cow Creek Bottoms.

A topographic map of the reservoir and dam site areas was prepared for the United States Bureau of Reclamation by the United States Geological Survey at a scale of 1 inch equals 800 feet, with a 10-foot contour interval. Reservoir area and capacity data obtained from this map are shown on Plate 21, entitled "Area, Capacity, Cost and Yield Relationships-Vacacilla Reservoir".

Geologic exploration indicated that the dam site would be suitable for construction of an earthfill dam not exceeding about 80 feet in height. A number of saddles exist along the west side of the reservoir area. One saddle has an elevation of 618 feet, and two others about 619 feet. The axis of the dam would be in a wide flat valley where the channels of

Little Cow Creek and Salt Creek approximately parallel each other. The foundation rock is hard, medium-grained sandstone, with minor occurrence of interbedded clayey shale of the Chico formation. Volcanic clayey gravel and semiconsolidated andesitic mudflow of the Tuscan formation overlie the Chico formation above an elevation of about 575 feet on both abutments, and form the hills and terraces in the vicinity of the site.

An estimated average depth of 8 feet of alluvium and 2 feet of weathered bedrock would require removal from beneath the channel section of the dam. About 3 feet of loose surface material of the Chico formation, and about 15 feet of deeply weathered material of the Tuscan sediments would have to be stripped from the right abutment. Stripping in the flat portion of the lower left abutment would include removal of about 5 feet of flood plain material and about 2 feet of sandstone. Stripping depth would decrease to about 2 feet near the contact between the Chico and Tuscan sediments. A minimum of 5 feet of soil and rock rubble of the overlying Tuscan sediments on the left abutment would be stripped under the impervious section of the dam.

Cost estimates were prepared for several heights of earthfill dam at the Vacacilla site, and yield-cost curves were developed. In each case the dam would have a crest width of 20 feet, upstream slope of 3 to 1, and downstream slope of 2.5 to 1. Adequate quantities of construction materials, consisting of gravels, sands, and clays of the Tuscan sediments, are available in the reservoir area within 1.5 miles of the dam site. Aggregate would be obtained by processing materials of the Tuscan sediments, or by hauling it from gravel sources near Redding. Small quantities of riprap could be quarried from sandstone of the Chico formation.

A side channel spillway would be located in the ridge forming the right abutment. A concrete ogee weir would control the spillway flows, which would be discharged into a gully below the dam. A moderate amount of riprap would be required on the toe of the dam to prevent erosion caused by backwater from the spillway. The spillway discharge capacity would be 37,000 second-feet. The maximum depth of water above the spillway crest would be 8 feet, allowing an additional 5 feet of freeboard to the crest of the dam.

Studies were made of the relationship between safe yield and storage capacity for releases of water on an irrigation demand schedule. Results of yield studies are presented as curves on Plate 21. For a reservoir with storage capacity of 12,500 acre-feet, one of the sizes studied, the estimated safe seasonal yield is about 13,100 acre-feet.

Several cattle ranches would be inundated by Vacacilla Reservoir. Improvements in the area include residences, barns, miscellaneous farm buildings, and approximately 250 acres of land devoted to irrigated pasture. It would be necessary to relocate about 0.5 mile of U. S. Highway 299.

The general physical features of a Vacacilla Dam, which would create a reservoir of 12,500-acre-foot storage capacity, are illustrated on Plate 20. Pertinent data on general features of the dam are presented in Table 42.

TABLE 42

GENERAL FEATURES OF A POSSIBLE
VACACILLA DAM AND RESERVOIR

Dam site	
Location	Sec. 9, T32N, R3W, MDB&M
Stream	Little Cow Creek
Elevation of stream bed, in feet	540
Dam	
Type	rockfill
Crest elevation, in feet	610
Crest length, in feet	1,120
Crest width, in feet	20
Height above stream bed, in feet	70
Freeboard above spillway crest, in feet	13
Side slopes, upstream	3:1
downstream	2.5:1
Volume of fill, in cubic yards	374,000
Reservoir	
Drainage area, in square miles	101
Storage capacity, in acre-feet	
Normal pool	12,500
Minimum pool	500
Elevation, in feet	
Normal pool	597
Minimum pool	561
Surface area, in acres	
Normal pool	650
Minimum pool	80
Type of spillway	side channel
Spillway discharge capacity, in second-feet	37,000
Type of outlet	welded steel pipe encased in concrete

Estimates of capital costs, annual costs, and cost per acre-foot of safe yield of Vacacilla Reservoir are shown on Plate 21. For a 12,500-acre-foot reservoir, these estimates are, respectively, about $2,140,000, $110,000, and $7.70.

(2) Vacacilla-Palo Cedro Canal. The Vacacilla-Palo Cedro Canal could deliver most of the water needed to meet ultimate requirements of irrigable lands in the Cow Creek Bottoms lying west of Cow Creek between Vacacilla Dam and the Sacramento River. The alignment of the canal would extend from Vacacilla Dam to Spring Creek near Palo Cedro. The canal would have a discharge capacity of 55 second-feet at Vacacilla Dam, and 25 second-feet at its terminus near Palo Cedro. The capital cost of the canal was estimated to be $370,000.

The area south of Palo Cedro would obtain its future water supply by means of an extension of the Vacacilla-Palo Cedro Canal.

Salt Creek Reservoir. Salt Creek Reservoir would be created by a dam on Salt Creek about 1 mile north of U. S. Highway 299. The reservoir would be within the sites of Vacacilla or Bella Vista Reservoirs. Salt Creek Dam would be located in Section 34, Township 33 North, Range 3 West, MDB&M. The stream bed elevation at the dam site is about 590 feet.

Salt Creek Reservoir could be a source of supplemental water for irrigable lands in the Cow Creek Bottoms north of Palo Cedro, and could be a minor alternative to Vacacilla Reservoir as a source of water.

A topographic map of the Salt Creek Dam site and reservoir area was prepared by the Department of Water Resources at a scale of 1 inch equals 400 feet, with a contour interval of 10 feet. Area and capacity data for the reservoir obtained from this map are presented on Plate 22, entitled "Area, Capacity, Cost, and Yield Relationships-Salt Creek Reservoir".

Geologic exploration indicated that the Salt Creek Dam site would be suitable for construction of a rockfill dam not exceeding 75 feet in height. Bedrock at the dam site consists of sandstone of the Chico formation with thin intercalated beds of shale. The bedrock dips about 7 degrees downstream. Sandstone is exposed in the stream channel and in places on the abutments. Average stripping depth on the abutments would be about 5 feet, and stripping in the channel section would be about 2 feet.

Cost estimate studies were prepared for three heights of rockfill dam at the Salt Creek site, and yield and cost curves were developed. In each case the dam would have a crest width of 25 feet, upstream slope of 2.5 to 1, and downstream slope of 2 to 1. Adequate quantities of impervious and semipervious alluvial materials are available from extensive flats in the reservoir area and downstream from the dam. Materials for filters, pervious sections, and aggregate would be obtained by processing the semipervious materials, or from gravel sources in the vicinity of Redding. Riprap would be quarried from the hard, massive sandstone found at the dam site and in the reservoir area.

An unlined spillway with an ogee weir would be located on the right abutment. The spillway discharge capacity would be 6,000 second-feet. The maximum depth of water above the spillway crest would be 4 feet, which would allow 4 feet of freeboard between high water elevation and the crest of the dam.

Diversion of stream flows during the construction period would not be required, since Salt Creek is an intermittent stream and would be dry for a period of at least four months. There are no improvements in the reservoir area.

The general physical features of a Salt Creek Dam which would impound 4,000 acre-feet of water, one of the sizes studied, are illustrated on Plate 18. Pertinent data on general features of Salt Creek Dam and Reservoir are presented in Table 43.

Estimates of capital costs, annual costs, and costs per acre-foot of irrigation yield of Salt Creek Reservoir are shown on Plate 22. These estimates for a 4,000-acre-foot reservoir are, respectively, about \$550,000, \$28.400, and \$8.00. The estimated seasonal irrigation yield of a reservoir of that capacity would be about 3,600 acre-feet.

TABLE 43

GENERAL FEATURES OF A POSSIBLE
SALT CREEK DAM AND RESERVOIR

Dam site	
Location	Sec. 34, T33N, R3W, MDB&M
Stream	Salt Creek
Elevation of stream bed, in feet	590
Dam	
Type	rockfill
Crest elevation, in feet	650
Crest length, in feet	2,211
Crest width, in feet	25
Height above stream bed, in feet	60
Freeboard above spillway crest, in feet	8
Side slopes, upstream	2.5:1
downstream	2:1
Volume of fill, in cubic yards	172,600
Reservoir	
Drainage area, in square miles	13
Storage capacity, in acre-feet	
Normal pool	4,000
Minimum pool	500
Elevation, in feet	
Normal pool	642
Minimum pool	613
Surface area, in acres	
Normal pool	202
Minimum pool	50
Type of spillway	chute
Spillway discharge capacity, in second-feet	6,000
Type of outlet	welded steel pipe encased in concrete

Cow Creek Bottoms Service Area

The Cow Creek Bottoms service area includes irrigable lands adjacent to Cow and South Cow Creeks, lying approximately between Millville and Palo Cedro and the Sacramento River, as shown on Plate 30. About 1,800 acres of an estimated 6,000 net irrigable acres are irrigated at the present time, by direct diversion from streams and pumping from ground water. The estimated ultimate supplemental water requirement for domestic and agricultural purposes is 14,000 acre-feet annually.

Ground water and surface stream flows were considered as potential sources of water for future needs of the Cow Creek Bottoms service area. Although present ground water development in the area is minor, the limited data available indicate that the supplemental water requirements could be met from ground water sources. However, subsurface conditions in the area are highly variable, and yields of individual wells are uncertain. Well data for eleven irrigation wells in the Cow Creek Bottoms have previously been presented in Table 6.

Surface storage projects were considered as alternatives to ground water sources for this service area, as well as for primary sources to be supplemented by ground water. Reservoirs on Little Cow Creek, discussed under the Bella Vista service area, could readily provide water to meet requirements of lands adjacent to the main stem of Cow Creek lying south of Palo Cedro. Reservoir sites were also considered on South Cow, Old Cow, and Clover Creeks. Water developed on these streams could be utilized within the entire service area. Discussion of two potential reservoirs on South Cow Creek, Millville, and Millvillito Reservoirs, follows.

Millville Reservoir. This reservoir would be created by construction of a dam on South Cow Creek, approximately

1 mile above its confluence with Old Cow Creek. Millville Dam would be located in Section 17, Township 31 North, Range 2 West, MDB&M, about 0.5 mile upstream from a dam site considered by the United States Bureau of Reclamation in 1945. Stream bed elevation at the axis of the dam is about 600 feet.

The reservoir could regulate flows of South Cow Creek and water diverted from Old Cow and Bear Creeks. It could provide a water supply to the Cow Creek Bottoms and the Millville Plains, as well as to areas outside the county. The reservoir would be an alternative project to Millvillito Reservoir, planned to provide water for use within the county only.

A topographic map of the dam site was prepared by the Department of Water Resources at a scale of 1 inch equals 200 feet, with a contour interval of 10 feet. The reservoir area is shown on the United States Geological Survey Millville quadrangle at a scale ratio of 1 to 62,500, with a contour interval of 40 feet. Reservoir area and capacity data shown on Plate 24, entitled "Area Capacity, Cost, and Yield Relationships-Millville Reservoir", were determined from a manuscript copy of a portion of the United States Geological Survey Millville quadrangle, at a scale ratio of 1 to 15,360, with a contour interval of 40 feet.

Geology of the Millville Dam site was investigated by the Department of Water Resources in 1959, and was found to be suitable for a rockfill dam up to about 270 feet in height. Shales, sandstones, and conglomerates of the Chico formation outcrop on both abutments and extend beneath the channel. The Chico formations are overlain by semiconsolidated clays, silts, sands, and gravels of the Tuscan and Tehama sediments. About 30 feet of Nomlaki tuff occur near the base of these sediments. A basalt lava flow caps the Tuscan-Tehama sediments on both abutments. The shallow alluvium in the stream channel consists of soil, sand, and gravel.

Stripping on both abutments and shaping in the channel section would be necessary. Average stripping on the abutments and in the channel section would be about 10 feet under impervious materials, and less than 5 feet under pervious materials. Soil cover and weathered sediments would comprise most of the material to be removed on the abutments. Alluvium and weathered Chico sediments would be removed from the channel section.

Cost estimates were prepared for several heights of earthfill at the site, and yield and cost curves were developed. In each case the dam would have a crest width of 30 feet and upstream and downstream slopes of 2 to 1. Adequate quantities of impervious materials are available from gravel deposits downstream from the dam site, and additional quantities of impervious and semipervious materials are available in the reservoir area. Riprap or rockfill could be quarried from basalt flows near the dam site. Aggregate could be obtained from the Sacramento River near Redding or by processing the Tuscan-Tehama sediments.

A lined spillway with an ogee weir would be located on the ridge forming the left abutment. To dissipate energy of the spillway flows, a flip bucket would be provided at the end of the spillway chute. A spillway discharge capacity of 6,000 second-feet would be provided. The maximum depth of water above the spillway crest would be about 19 feet, leaving 6 feet of freeboard to the crest of the dam.

Results of the yield studies are presented as curves on Plate 24. For a reservoir with a storage capacity of 124,000 acre-feet, the safe seasonal yield would be about 47,500 acre-feet, including about 11,000 acre-feet for stream flow releases to maintain the resident fishery.

The reservoir would inundate eight ownerships. In the reservoir area which is used for the raising of cattle, sheep, and hogs, there are residences, barns, and farm buildings.

The general physical features of a Millville Dam which would impound 124,000 acre-feet of water are illustrated on Plate 25, entitled "Millvillito Dam on South Cow Creek and Millville Dam on South Cow Creek". Pertinent data on general features of Millville Dam and Reservoir are presented in Table 44.

Estimated capital and annual costs, and costs per acre-foot of safe yield of Millville Reservoir are shown on Plate 24. These costs for a 124,000-acre-foot reservoir would be, respectively, about $7,500,000, $390,000, and $10.80.

TABLE 44

GENERAL FEATURES OF A POSSIBLE
MILLVILLE DAM AND RESERVOIR

Dam site	
Location	Sec. 17, T31N, R2W, MDB&M
Stream	South Cow Creek
Elevation of stream bed, in feet	600
Dam	
Type	rockfill
Crest elevation, in feet	785
Crest length, in feet	1,650
Crest width, in feet	30
Height above stream bed, in feet	185
Freeboard above spillway crest, in feet	25
Side slopes, upstream	2:1
downstream	2:1
Volume of fill, in cubic yards	2,014,000
Reservoir	
Drainage area, in square miles	78
Storage capacity, in acre-feet	
Normal pool	124,000
Minimum pool	5,000
Elevation, in feet	
Normal pool	760
Minimum pool	649
Surface area, in acres	
Normal pool	1,790
Minimum pool	310
Type of spillway	chute
Spillway discharge capacity, in second-feet	6,000
Type of outlet	steel pipe in diversion tunnel

Millvillito Reservoir. This reservoir would be created by construction of a dam on South Cow Creek about 0.5 mile below its confluence with Old Cow Creek. The dam would be located in Section 18, Township 31 North, Range 2 West, MDB&M. Stream bed elevation at the axis of the dam is about 535 feet. Millvillito Reservoir could provide water to the Cow Creek Bottoms and Millville Plains.

A topographic map of the dam site was prepared by the Department of Water Resources in 1957, at a scale of 1 inch equals 200 feet, with a contour interval of 5 feet. The reservoir area-capacity data shown on Plate 26, entitled "Area, Capacity, Cost, and Yield Relationships-Millvillito Reservoir", were estimated from the United States Geological Survey Millville quadrangle, at a scale ratio of 1 to 62,500, with a contour interval of 40 feet.

Geologic exploration indicated that the dam site would be suitable for a rockfill dam of the heights under consideration. However, further exploration of the foundation would be required to determine the probable extent of leakage in the abutments and in the foundation. Rock exposed in the steep slopes of both abutments consists of hard, vesicular, olivine basalt. The basalt flow is underlain by firm Tuscan and tuffaceous clay and clayey gravel, and overlain by a thin layer of Quaternary terrace gravel. The average thickness of the basalt is about 35 feet. The contact between the basalt and the Tuscan sediments is at an elevation of about 575 feet.

Stripping would be necessary in the stream channel and on both abutments. About 10 to 15 feet of loose sand and gravel would need to be stripped in the channel section, about 5 feet of basalt rubble and float on the lower slopes of the abutments, and about 3 feet of soil, rock rubble, and jointed basalt on the upper slopes of the abutments. In general, although the Tuscan sediments in the area are semi-pervious, permeable gravel and sand beds within the sediments might cause at least moderate seepage in the foundation. In the abutments, seepage through the Tuscan sediments and along their contact with the basalt flow would probably occur.

Cost estimates were prepared for several heights of rockfill dam at the Millvillito site, and yield and cost curves were developed. In each case, the dam would have a crest width of 25 feet, and upstream and downstream slopes of 2 to 1. Adequate amounts of construction materials for the dam are available from borrow areas south of Millville, and from smaller areas located about 0.25 mile southwest on the left abutment.

A lined chute spillway would be constructed across the ridge forming the right abutment. The spillway discharge capacity would be about 55,000 second-feet, with a maximum depth of water of 11 feet above the spillway crest, leaving 5 feet of freeboard between high water and the crest of the dam. The spillway flows would be discharged into a ravine and guided into the channel of South Cow Creek.

Results of the yield studies are presented as a relationship of safe yield and storage capacity on Plate 26.

For purposes of illustration, general features of a dam with a crest elevation of 640 feet are shown on Plate 25, entitled "Millvillito Dam on South Cow Creek and Millville Dam on South Cow Creek", and pertinent data on the general features of the dam are presented in Table 45.

TABLE 45

GENERAL FEATURES OF A POSSIBLE
MILLVILLITO DAM AND RESERVOIR

Dam site	
Location	Sec. 18, T31N, R2W, MDB&M
Stream	South Cow Creek
Elevation of stream bed, in feet	535
Dam	
Type	rockfill
Crest elevation, in feet	640
Crest length, in feet	760
Crest width, in feet	25
Height above stream bed, in feet	105
Freeboard above spillway crest, in feet	16
Side slopes, upstream	2:1
downstream	2:1
Volume of fill, in cubic yards	268,000
Reservoir	
Drainage area, in square miles	159
Storage capacity, in acre-feet	
Normal pool	12,700
Minimum pool	1,000
Elevation, in feet	
Normal pool	624
Minimum pool	576
Surface area, in acres	
Normal pool	300
Minimum pool	70
Type of spillway	chute
Spillway discharge capacity, in second-feet	55,000
Type of outlet	welded steel pipe encased in concrete

Estimated capital and annual costs, and costs per acre-foot of safe yield of Millvillito Reservoir are shown on Plate 26. For a 12,700-acre-foot reservoir, these costs would be, respectively, about $1,300,000, $67,000, and $6.10.

Urban Center Service Area

Although the Urban Center service area is shown with definite boundaries on Plate 30, it should not be considered as being delineated precisely. In general, it embraces the anticipated expansion of the population centers of Redding and Enterprise, and comprises about 20,000 to 25,000 acres of urban and suburban lands. The service area extends from 2 miles north of Redding to Clear Creek, with the expected development taking place on both sides of the Sacramento River. In the year 2010 the population of the service area is expected to be about 83,000. The estimated supplemental water requirement for domestic and industrial purposes is about 51,000 acre-feet annually.

At present the City of Redding pumps its water supply from the Sacramento River. The Enterprise Public Utility District pumps ground water from gravels adjacent to the Sacramento River, and from the ground water basin underlying the Churn Creek Bottoms. In the valley area between Redding and Clear Creek, water supplies are generally obtained from ground water sources.

One means of obtaining supplemental water to meet future municipal and industrial needs of the service area would be by diversion of water from the Spring Creek Tunnel of the Trinity River Division of the Central Valley Project. Alternative methods would include pumping water from the Sacramento River to supply the City of Redding, and pumping ground water to supply Enterprise and the valley areas south of Redding. However, ground water production is uncertain in the Enterprise area, and the quality of ground water in the valley area south of Redding is questionable because of water pollution by sewage.

Spring Creek-Redding Conduit. The Spring Creek-Redding Conduit would divert water from the Spring Creek Tunnel, about 2 miles north of the town of Shasta, to a terminal about 0.5 mile west of the Redding city limits, in Section 32, Township 32 North, Range 5 West, MDB&M.

The terminal elevation of the Spring Creek-Redding Conduit was taken for study purposes to be 1,000 feet, to provide for anticipated future westward movement of population into areas above the 750-foot contour, the present elevation of the Redding settling reservoir. Water would flow through the Spring Creek Tunnel and the Spring Creek-Redding Conduit under the pressure head developed by the pool elevation in Whiskeytown Reservoir.

With a normal minimum pool elevation of 1,190 feet in Whiskeytown Reservoir, a 36-inch reinforced concrete pipe would carry 42,000,000 gallons per day, enough to meet the average daily water requirements of 60,000 persons during the month of maximum demand. This population is about 72 percent of the anticipated 2010 figure. Operation studies by the United States Bureau of Reclamation show that if the drought period of the 1920's and 1930's occurred in the future, the minimum pool elevation of Whiskeytown Reservoir would drop to about 1,100 feet for a few months. Even under these short-term adverse conditions, the conduit would carry 32,000,000 gallons per day. This reduced capacity would result in a deficiency of 10,000,000 gallons per day in the month of maximum demand, and lesser deficiencies in three other months of summer and fall.

The estimated cost of the Spring Creek-Redding Conduit, including a branch line to the town of Shasta, is $1,050,000. The estimated annual cost, at a 4 percent interest rate, including operation and maintenance, is about $69,000.

The City Council of Redding and the Board of Supervisors of Shasta County sponsored a feasibility study of the Spring Creek-Redding Conduit. The study was conducted by Clair A. Hill and Associates, a consulting engineering firm, who prepared a detailed feasibility report on this project for the Shasta County Water Agency. The alignment and the estimated cost of the Redding Conduit presented in the feasibility report are essentially in agreement with the alignment and the estimated cost of the project obtained during the Shasta County Investigation. In addition, the following statements are made in the conclusions and recommendations of the above-described feasibility report in regard to the Spring Creek-Redding Conduit:

"F. From the standpoint of quantity, quality, and cost, the Trinity Project as a source of water for the Service Area is entirely feasible.

"G. It is recommended that the project be undertaken."

Anderson-Cottonwood Service Area

The Anderson-Cottonwood service area, as shown on Plate 30, consists of the present area of the Anderson-Cottonwood Irrigation District, and irrigable lands contiguous to the district's western boundary, less the district's present lands lying north of Clear Creek. The present water supply of this service area is obtained from the Sacramento River by gravity diversion to serve lands on the west side of the river, and by pumping from the river to serve lands on the east side. The estimated ultimate supplemental water requirement of the area for agricultural, domestic, and industrial purposes is about 87,000 acre-feet annually.

Studies of the Anderson-Cottonwood service area indicated that the present water supply diverted into the main canal of the Anderson-Cottonwood Irrigation District is adequate to meet future needs of the service area.

Happy Valley Service Area

The Happy Valley service area, as shown on Plate 30, includes the irrigable lands on the ridge tops between the lower reaches of Clear and Cottonwood Creeks. Of an estimated 8,560 net irrigable acres within the service area, about 1,630 acres were irrigated in 1955. At the present time the area receives water service from the Happy Valley Water Company. Supplemented with water stored in Rainbow Lake, the present sources of water are flows diverted from the North Fork of Cottonwood Creek and tributaries, and flows of the South Fork of Clear Creek. The need for a more dependable water supply in the service area was established in 1957 by the State Public Utilities Commission in Decision No. 55447.

The estimated ultimate seasonal water requirement in the service area is about 34,800 acre-feet for irrigation purposes and 1,000 acre-feet for domestic purposes.

Studies of the Happy Valley service area indicated that the existing water system does not meet present demands of the area, and that construction of new reservoirs to provide supplemental water to be delivered by the existing system would not be economically justified. Consequently, in planning for future water service, it was assumed that the present system would be abandoned below Igo, and that water presently being used in Happy Valley would be used in the Igo-Ono service area. The ground water resources of the Happy Valley service area are limited, and are estimated to be only partially sufficient to supply domestic demands in the area.

Studies were made of plans to obtain a water supply for the Happy Valley service area from Hulen Reservoir on the North Fork of Cottonwood Creek. However, delivery of water to Happy Valley from Hulen Reservoir would require an extensive conveyance system and a 230-foot pump lift.

It was found that the cost of water from the Trinity River Division of the Central Valley Project would be less than the estimated cost of water from Hulen Reservoir. Hulen Reservoir is discussed in more detail in the section on the Cottonwood Creek service area.

Trinity River Division of the Central Valley Project. Studies were made of means of obtaining a water supply for the Happy Valley service area from the Trinity River Division of the Central Valley Project currently under construction by the United States Bureau of Reclamation. The three means considered were: (1) diversion of water from Whiskeytown Reservoir and a gravity conduit to Happy Valley; (2) release of water from Whiskeytown Reservoir into Clear Creek and pumping from Clear Creek near Happy Valley; and (3) pumping of water from an enlarged Saeltzer Reservoir on Clear Creek. The first two plans were found to be comparable, and superior to the plan for pumping water from the enlarged Saeltzer Reservoir. Because the United States Bureau of Reclamation is currently conducting project planning studies for the Happy Valley service area, and because economic analysis of such a project would require integration with the whole of the Central Valley Project, only general descriptions of the first and second plans for utilization of Trinity River Division water are presented in this section.

(1) Whiskeytown-Happy Valley Conduit. This conduit, with a capacity of 130 second-feet, would extend from

Whiskeytown Dam to Harbison Reservoir, an existing regulating reservoir at the upper end of the Happy Valley distribution system. The conduit would be 15.4 miles long, and would consist of 12.5 miles of canal, 1.9 miles of flume, and 1 mile of siphon. From Whiskeytown Dam the conduit would be located on the east side of Clear Creek to a point about 1.5 miles north of Igo. It would then cross Clear Creek and would continue southward to a point slightly east of Igo. The conduit would then essentially follow the alignment of the existing Happy Valley ditch to Harbison Reservoir. The conduit could deliver 25,000 acre-feet of water annually on an irrigation demand schedule. A conduit of this capacity would be a partial solution to the water problems in Happy Valley. Allowance could be made for future construction of storage enroute, so that the ultimate water needs could be met.

The estimated capital cost of the Whiskeytown-Happy Valley Conduit is about $1,930,000, and the annual costs about $122,000. The charge for water at Whiskeytown Reservoir by the Bureau of Reclamation would have to be added to this annual cost. However, if the conduit were built by the Bureau of Reclamation and incorporated into the Central Valley Project, all annual costs would be covered by an overall water service charge.

(2) <u>Pumping from Clear Creek</u>. Water from the Trinity River Division of the Central Valley Project could be

released from Whiskeytown Reservoir into Clear Creek, and could be lifted about 250 feet from Clear Creek near Saeltzer Reservoir to the service area distribution system. This supply would be available to all but the most westerly higher lands of the service area. These higher lands could utilize the present water supply from the North Fork of Cottonwood Creek until this supply is needed in the Igo-Ono area, at which time water from Clear Creek could be relifted to supply the higher lands.

The plan to pump water of the Trinity River Division from Clear Creek lends itself to staged development, and consequently would entail lesser initial capital expenditures.

Igo-Ono Service Area

The Igo-Ono service area, as shown on Plate 30, consists of irrigable lands in the North Fork Cottonwood Creek Basin, between the Happy Valley Canal and the North Fork of Cottonwood Creek. About 400 acres of an estimated 3,800 net irrigable acres are irrigated at the present time. The present water supply is obtained by means of the Happy Valley Canal and a few small farm reservoirs. The estimated ultimate supplemental water requirement for irrigation of this service area is about 16,800 acre-feet per season.

Studies indicated that the 6,100 acre-feet of water per season exported to Happy Valley by means of the Happy Valley Canal, could be used to meet a portion of the supplemental water requirements of the Igo-Ono service area, if the Happy

Valley service area could obtain water from another source. Farm reservoirs in the Igo-Ono service area could also develop water to meet a portion of the supplemental requirement. In addition, several potential reservoir sites, ranging from 5,000 to 10,000 acre-feet in storage capacity, were found on streams intersected by the Happy Valley Canal.

Reconnaissance cost estimates indicated that Shoemaker Reservoir would be suitable for initial construction to increase the yield of the existing system, as shown on Plate 14. Petty Butte Reservoir could provide supplemental domestic water supplies to either the Igo-Ono or Happy Valley service areas.

Shoemaker Reservoir. Shoemaker Reservoir would be located on the North Fork of Cottonwood Creek upstream from Rainbow Lake. Shoemaker Dam would be located in Section 20, Township 31 North, Range 7 West, MDB&M. Stream bed elevation at the dam site is 2,040 feet.

It was estimated that about 10,000 acre-feet of storage capacity on the North Fork of Cottonwood Creek would provide an irrigation yield of about 10,000 acre-feet per season on an irrigation demand schedule. Of this amount, it was assumed that approximately 3,000 acre-feet would be available in the existing Rainbow Lake, leaving 7,000 acre-feet to be created by a dam at the Shoemaker site.

A preliminary cost estimate was made of a reservoir at the Shoemaker site with a net storage capacity of 7,000 acre-feet. It would be created by an earthfill dam 180 feet in height, with side slopes of 4 to 1 upstream and 2.5 to 1 downstream. The crest length and width of the dam would be 1,440 feet and 30 feet, respectively. The total volume of fill would be about 3,500,000 cubic yards. The spillway discharge capacity would be about 8,500 second-feet. The capital cost of this project was estimated to be $4,700,000. The corresponding annual cost was estimated to be about $239,000. The annual cost per acre-foot of irrigation yield from the reservoir would be about $34.00.

Petty Butte Reservoir. Petty Butte Reservoir would be located on the South Fork of Clear Creek near the town of Igo. The dam site would be in Section 20, Township 31 North, Range 6 West, MDB&M. Stream bed elevation at the dam site is about 1,070 feet.

A preliminary cost estimate was made of an earthfill dam 100 feet in height, with side slopes of 4 to 1 upstream and 2.5 to 1 downstream. The capital cost of this project, with 2,400 acre-feet of storage capacity, which was determined to essentially equal the firm seasonal yield, was estimated to be about $757,000. The corresponding annual cost was estimated to be about $39,000. The annual cost per acre-foot of firm yield from the reservoir would be about $16.00.

Bee Creek Service Area

The Bee Creek service area, as shown on Plate 30, includes irrigable lands situated between the Bee Creek Ditch and the North Fork of Cottonwood Creek. Prior to December 1955 there was a small diversion structure on the North Fork that raised the stream level enough to divert water into the Bee Creek Ditch. Land use studies show that about 140 acres were irrigated from this ditch. In the flood of 1955 the diversion structure washed out and at last report has not been replaced. There are about 600 net irrigable acres in the service area, and it is estimated that the ultimate supplemental water requirement is about 2,200 acre-feet seasonally.

The source of water considered for future needs of the service area was stream flow conserved by reservoirs. Several sites suitable for surface storage were found on the North Fork of Cottonwood Creek, as well as on its tributaries, Jerusalem, Moon Fork, and Ducket Creeks. Studies indicated that a single development, Bee Creek Reservoir, could meet the ultimate water requirements of the service area.

Bee Creek Dam would be located on the North Fork of Cottonwood Creek in Section 9, Township 30 North, Range 7 West, MDB&M, approximately 2 miles west of Ono. Stream bed elevation at the dam site is 1,070 feet. A preliminary cost estimate was made for a rockfill dam 90 feet in height, which would create a reservoir with 3,300 acre-feet of storage capacity. The capital cost of this project was estimated to be about $722,000.

The corresponding annual cost would be about $37,000, and the annual cost per acre-foot for the estimated 3,300 acre-feet of seasonal irrigation yield would be about $11.00.

Cottonwood Creek Service Area

The Cottonwood Creek service area, as shown on Plate 30, includes irrigable lands on the north side of Cottonwood Creek, and extends from the boundary of the Anderson-Cottonwood Irrigation District to the junction of the North and Middle Forks of Cottonwood Creek. Of an estimated 6,100 net irrigable acres, approximately 400 acres are irrigated at the present time by direct diversion of stream flows and by pumping from a few wells in the area. The estimated ultimate supplemental water requirement of the service area is about 20,600 acre-feet seasonally.

Delivery of water to the Cottonwood Creek service area was found to be possible from Hulen Reservoir or from Whiskeytown Reservoir, a feature of the Clear Creek Unit of the Trinity River Division of the Central Valley Project. However, available data indicated that ground water is probably the best source to meet most of the ultimate water requirements of the service area.

Hulen Project. The Hulen Project would include Hulen Reservoir on the North Fork of Cottonwood Creek, and the Hulen-Cottonwood Creek Conduit which would convey water from the reservoir to the service area.

(1) Hulen Reservoir. Hulen Reservoir would be created by construction of a dam on the North Fork of Cottonwood Creek, about 5 miles north of its confluence with the Middle Fork of Cottonwood Creek. The dam would be located in Section 16, Township 30 North, Range 6 West, MDB&M. Stream bed elevation at the dam site is about 660 feet. A saddle dam on the east side of the reservoir, less than 1 mile northeast of the main dam, would be required at an elevation of about 835 feet.

Hulen Reservoir could provide an irrigation water supply to the Cottonwood Creek service area, and could enhance flows of the North Fork and main stem of Cottonwood Creek during normally low-flow summer and fall months. Any regulated yield that might prove to be surplus to the local requirements could be utilized in areas south of Shasta County.

Topographic maps of the dam site and reservoir area were prepared by the United States Bureau of Reclamation in 1945, at a scale of 1 inch equals 200 feet and with a contour interval of 10 feet, and at a scale of 1 inch equals 500 feet with a contour interval of 10 feet, respectively. Area and capacity data for Hulen Reservoir, derived from the map of the reservoir area, are presented on Plate 28, entitled "Area, Capacity, Cost, and Yield Relationships-Hulen Reservoir".

Surface geologic mapping and limited subsurface exploration of the dam site were made in the fall of 1945 by the United States Bureau of Reclamation. The surface mapping was reviewed by the Department of Water Resources during the Shasta County Investigation. In addition, analyses of soil samples were made to ascertain the suitability of soils for use as construction materials.

Based on the foregoing geologic studies, the Hulen Dam site was found to be suitable for an earthfill dam over 200 feet in height. Foundation rocks are shales, sandstones, and conglomerates of the Chico formation. The rocks strike across the channel of the North Fork of Cottonwood Creek and dip about 20 degrees downstream. Alluvium in the channel area is believed to be less than 10 feet deep throughout the foundation area of the dam. Small remnants of terrace gravels are found in the canyon walls.

Stripping would be required under both the pervious and impervious fill in the abutments and channel section. On the abutments an estimated average depth of 5 feet of soil would be stripped under the pervious fill, and an average of 35 feet of weathered and jointed bedrock would be stripped under the impervious fill. Less than 10 feet of alluvial materials would be removed from the channel section. Moderate grouting would probably be required along the axis of the dam.

Designs and cost estimates were prepared for several heights of earthfill dam at the site, and yield and cost curves were developed. In each case, the dam would have a crest width of 30 feet, upstream slope of 3 to 1, and downstream slope of 2.25 to 1. The impervious core would have a crest width of 10 feet and side slopes of 0.5 to 1 upstream and downstream. The impervious fill would consist of old terrace deposits available less than 2 miles northeast of the dam site, and the pervious fill would be obtained from dredger tailings and stream gravels in the vicinity of Gas Point, less than 3 miles from the dam site. Materials from the spillway were considered for the pervious fill, but were found to be unsuitable. The small quantities of riprap needed in the embankment could be quarried from granodiorite deposits near Igo, less than 3 miles north of the dam site.

A lined side-channel spillway would be constructed on the right abutment. The spillway discharge capacity would be about 32,000 second-feet, with a maximum depth of water of 7 feet above the spillway crest, providing an additional 6 feet of freeboard between maximum water elevation and the crest of the dam.

Preliminary yield studies of Hulen Reservoir indicated that a storage capacity of 92,000 acre-feet would provide yield to meet the water needs of the Cottonwood Creek service area and the requirements for stream flow maintenance. Results of yield studies are presented as curves on Plate 28. For a 92,000-acre-foot reservoir, the estimated safe seasonal irrigation yield would be about 21,200 acre-feet, and an additional 7,200 acre-feet per season would be provided for stream flow maintenance. However, recent records of stream flow near the Hulen Dam site, obtained by the department subsequent to the Shasta County Investigation, indicate runoff values higher than the estimates used in these studies.

The general features of a dam 200 feet in height, impounding 92,000 acre-feet of water, are shown on Plate 27, entitled "Hulen Dam on North Fork Cottonwood Creek". Pertinent data on general features of the dam and reservoir are presented in Table 46. Estimates of the capital and annual costs of Hulen Dam and Reservoir, as well as the annual costs per acre-foot of safe yield, are shown as curves on Plate 28. These costs, for the reservoir of 92,000-acre-foot storage capacity, are, respectively, about $5,644,000, $297,000, and $14.

(2) Hulen-Cottonwood Creek Conduit. For purposes of planning studies, the irrigable lands of the Cottonwood Creek service area were subdivided into five subareas. These subareas are shown on Plate 14. A lined canal starting at Hulen Dam, with an initial capacity of 93 second-feet, would convey water to the service area. The conduit capacity would then decrease in passing through each subarea. The last section of the main conduit would have a capacity of 16 second-feet, and would terminate at a creek about 2.5 miles east of Cottonwood. The main conduit would have a total length of about 19 miles, and would convey water along the upper and northern side of the service area. The estimated capital cost of the main conduit is about $1,570,000, and the corresponding estimate of annual costs, including operation and maintenance, is about $89,000.

TABLE 46

GENERAL FEATURES OF A POSSIBLE
HULEN DAM AND RESERVOIR

Dam site	
Location	Sec. 16, T30N, R6W, MDB&M
Stream	North Fork Cottonwood Creek
Elevation of stream bed, in feet	660
Dam	
Type	zoned earthfill
Crest elevation, in feet	860
Crest length, in feet	1,190
Crest width, in feet	30
Height above stream bed, in feet	200
Freeboard above spillway crest, in feet	13
Side slopes, upstream	3:1
downstream	2.25:1
Volume of fill, in cubic yards	2,249,800
Reservoir	
Drainage area, in square miles	864
Storage capacity, in acre-feet	
Normal pool	92,000
Minimum pool	1,000
Elevation, in feet	
Normal pool	847
Minimum pool	715
Surface area, in acres	
Normal pool	1,990
Minimum pool	20
Type of spillway	side channel
Spillway discharge capacity, in second-feet	32,000
Type of outlet	welded steel pipe encased in concrete

Enlarged Whiskeytown-Happy Valley Conduit. Enlargement and extension of the potential Whiskeytown-Happy Valley Conduit would be a possible method of delivering water to the Cottonwood Creek service area. Preliminary estimates indicated that the increased capital cost of an enlarged Whiskeytown-Happy Valley Conduit, and the capital cost of a Happy Valley-Cottonwood Creek Conduit, which would make water available along the upper edge of the service area, would total about $1,956,000. The corresponding annual cost would be about $133,000. The latter value does not include charges by the United States Bureau of Reclamation for water at Whiskeytown Reservoir.

Ground Water Development. As indicated heretofore, ground water development appears to be the best source of water to meet future needs of the Cottonwood Creek service area. The five subareas of the irrigable lands used in planning the Hulen-Cottonwood Creek Conduit were also utilized in making ground water studies. Theoretical pumping analyses indicated that each subarea could supply an amount of ground water equal to its ultimate seasonal requirement without overdraft. Based on the data available, well yields of 1,000 gallons per minute were assumed for two of the subareas, and of 500 gallons per minute for the remainder of the service area, as shown in Table 47. The table also shows data pertinent to present and future ground water use and cost of ground water development in the service area. Information on the costs of pumping from ground water, including amortization of the wells, pumps, and motors, and annual charges for power, operation, and maintenance, was taken from a 1956 publication of the Shasta County Water Resources Board, entitled "What is Water Worth?". The seasonal costs per acre for ground water development were

TABLE 47

ESTIMATED FUTURE GROUND WATER DEVELOPMENT AND COSTS
COTTONWOOD CREEK SERVICE AREA

Sub-area number	Net irrigable acres	Seasonal water requirement, in acre-feet	Well yield, in gallons per minute	Number of wells	Average static depths to ground water, in feet: Present: Spring	Present: Fall	Future: Spring	Future: Fall	Average pumping depths, in feet: Present	Future	Future average annual cost per acre*	Future total annual cost**
1	950	3,500	500	12	60	60	65	100	no wells	130	$16.80	$16,000
2	1,800	6,500	500	22	50	50	55	70	80	100	13.30	23,900
3	2,200	8,000	1,000	14	50	50	55	65	105	115	13.40	29,500
4	900	3,300	1,000	6	50	50	55	65	75	90	11.30	10,200
5	250	900	500	4	60	60	65	80	85	105	13.90	3,500
TOTALS	6,100	22,200	---	58	--	--	--	--	--	---	----	$83,100

*Based on costs in the 1956 publication of the Shasta County Water Resources Board, entitled "What is Water Worth?".

**Does not include additional pumping head required for sprinkler irrigation.

estimated on the assumptions that the average applied water requirement is about 4 acre-feet per acre seasonally, and that average pumping lifts are as presented in Table 47.

Hydroelectric Power Developments

The streams in Shasta County which would be affected by projects for the primary purpose of generating hydroelectric power are the Pit and McCloud Rivers. A discussion of such developments is presented in this section. Tables in Appendix C describe features of existing (1958) power developments.

Pit River Development

The existing hydroelectric power generating facilities on the Pit River are the Pit Nos. 1, 3, 4, and 5 plants of the Pacific Gas and Electric Company. The proposed generating facilities are the Pit Nos. 2, 6, and 7 plants planned by the same agency. The Pacific Gas and Electric Company system utilizes water of the Pit River and its tributaries, Fall River and Hat Creek, and, when completed, will develop the power head between Fall River and Shasta Lake. The Pit Nos. 6 and 7 power plants will also utilize water conveyed from the McCloud River to the Pit River.

Pit No. 2 Project. The basic features of the proposed Pit No. 2 Project will be a forebay located below the Pit No. 1 plant, a conduit to convey Pit and Fall Rivers waters from the forebay to the Pit No. 2 plant, and this new plant to be located at the upstream end of Lake Britton. The static head of the power plant will be 98 feet, and the installation will have a capacity of 14,000 kilowatts and an average annual power generation of about 95,000,000 kilowatt-hours.

Pit No. 6 Project. The proposed Pit No. 6 Project will be located downstream from the Pit No. 5 and McCloud-Pit power plants. The basic features will be a dam and reservoir on the Pit River, and the new Pit No. 6 power plant at the base of the dam. The concrete gravity dam will be 165 feet in height, and will create a reservoir with gross storage capacity of about 15,700 acre-feet, and net storage capacity of about 11,600 acre-feet. The static head of the power plant will be 155 feet. The two-generator installation will have a capacity of 74,000 kilowatts, and an average annual power generation of 323,000,000 kilowatt-hours.

Pit No. 7 Project. The proposed Pit No. 7 Project will be located upstream from the Pit River arm of Shasta Lake. Its basic features will consist of a dam and reservoir on the Pit River, the Pit No. 7 power plant at the base of the dam, and an afterbay dam and reservoir. The concrete gravity dam will be 230 feet in height, and will create a reservoir with gross capacity of about 34,000 acre-feet, and net storage capacity of about 16,500 acre-feet. The static head of the power plant will be about 205 feet. The installation will have a capacity of 100,000 kilowatts, and an average annual power generation of 449,000,000 kilowatt-hours. The afterbay below the Pit No. 7 plant will be inundated by Shasta Lake when the lake is full.

McCloud-Pit Development

The McCloud-Pit Development, proposed by the Pacific Gas and Electric Company, will make use of McCloud River waters to develop power through the 1,615 feet of head between the proposed McCloud River Reservoir and Shasta Lake. The power head will be developed by operating the new McCloud-Pit power plant in conjunction with the Pit Nos. 6 and 7 projects. The total installed capacity of the McCloud-Pit and Pit Nos. 6 and 7 power plants will be 330,000 kilowatts.

The principal features of the McCloud-Pit Development will consist of the McCloud Diversion Dam and Reservoir on the McCloud River, the McCloud Tunnel between McCloud and Iron Canyon Reservoirs, the Hawkins Creek Diversion Dam and Feeder (an intake structure) on Hawkins Creek, the Iron Canyon Dam and Reservoir on Iron Canyon Creek, the Iron Canyon Tunnel between Iron Canyon Reservoir and the McCloud-Pit power plant, and the McCloud-Pit power plant on the Pit River.

The McCloud Diversion Dam will be located in Section 27, Township 38 North, Range 2 West, MDB&M, upstream from the junction of the McCloud River and Lizard Creek. The concrete arch dam will be about 235 feet in height above stream bed, and will impound approximately 35,300 acre-feet of water. The effective storage capacity of the reservoir will be about

31,000 acre-feet, between the normal pool elevation of 2,680 feet and the minimum water surface elevation of 2,578 feet (Pacific Gas and Electric Company datum).

The McCloud Tunnel will be a pressure tunnel about 7.7 miles in length. The intake structure will be located immediately upstream from the McCloud Diversion Dam. The maximum flow capacity of the tunnel will be about 1,750 second-feet. A shaft will divert Hawkins Creek water into the McCloud Tunnel at the Hawkins Creek Diversion Dam. The outlet portal of the tunnel will be at Iron Canyon Reservoir.

The Hawkins Creek Diversion Dam, a timber crib structure, will be located on Hawkins Creek, in Section 36, Township 38 North, Range 2 West, MDB&M, about 1 mile southeast of the junction of Hawkins Creek and the McCloud River. The diversion dam will be about 16 feet in height above the stream bed. Hawkins Creek water will be diverted through an intake structure upstream from the dam into the McCloud Tunnel by means of an inclined shaft.

Iron Canyon Dam will be on Iron Canyon Creek, a tributary of the Pit River, in Section 21, Township 37 North, Range 1 West, MDB&M, about 4 miles north of the existing Pit No. 5 power plant. The dam will be an earthfill structure about 175 feet in height above stream bed, and will impound approximately 24,400 acre-feet of water. The effective storage capacity of the reservoir will be about 24,000 acre-feet.

The Iron Canyon Tunnel will be a pressure tunnel about 2.4 miles in length. The intake structure will be immediately upstream from Iron Canyon Dam. At the terminus of the tunnel about 3,000 feet of penstock will extend to the McCloud-Pit power plant. The maximum flow capacity of the tunnel will be about 1,800 second-feet.

The McCloud-Pit power plant will be on the right bank of the Pit River, in Section 3, Township 36 North, Range 1 West, MDB&M, about 1.5 miles upstream from the existing Pit No. 5 power plant. The maximum static head of 1,217 feet will be developed between the water surface of Iron Canyon Reservoir at spillway crest elevation of 2,665 feet, and the McCloud-Pit power plant tailwater on the Pit River at an elevation of 1,448 feet. The installation will have a capacity of 156,000 kilowatts, and an average annual power generation of 640,000,000 kilowatt-hours.

Export Developments

Proposals for developing the water resources of several streams in Shasta County for export to other areas of the State were included in The California Water Plan. The Millville and Bella Vista proposals on Cow Creek and the Hulen proposal on Cottonwood Creek, have export potential and were discussed in connection with water resources developments for Shasta County. Other projects having potential for developing water for export purposes are found on Clear and Battle Creeks and the Sacramento River. Discussions of these proposals are presented in this section.

Clear Creek Development

The Clear Creek Development would be an integral part of a system of works designed to conserve surplus water of the Klamath, Trinity, Van Duzen, and Mad Rivers, and the South Fork of the Smith River, and to convey these waters to the Sacramento Valley. The works would also be operated for generation of hydroelectric energy, flood control, preservation of fish and wildlife, and recreation. This system would consist of a series of dams, reservoirs, power plants, and conveyance facilities, and their operation would be coordinated with that of the Trinity River Division of the Central Valley Project. The Clear Creek Development was contemplated primarily to utilize the available power head between Whiskeytown Reservoir of the Central Valley Project and Iron Canyon Reservoir, the dam for which would be located on the Sacramento River about 10 miles south of the Shasta County line.

The Clear Creek Development would involve construction of Kanaka and Saeltzer Dams on Clear Creek in the Sacramento River Basin and an appurtenant power plant at each of the dams. Kanaka Dam and Reservoir, impounding water delivered from

Burnt Ranch Reservoir, as well as runoff from Clear Creek, would be located on Clear Creek about 8 miles east of Redding. Water released from Kanaka Reservoir would flow through the Kanaka power plant, located near the base of the dam, into Saeltzer Reservoir located immediately downstream. Saeltzer Diversion Dam, about 6 miles upstream from the confluence of Clear Creek with the Sacramento River, and would function primarily for development of the remainder of the power head on Clear Creek below Kanaka Dam. The final generation of energy in this system of works would be accomplished by the Saeltzer power plant, located at the base of Saeltzer Dam.

Alternative plans for projects on north coastal streams are currently under intensive study by the Department of Water Resources.

Battle Creek Development

The Battle Creek Diversion Works on Battle Creek would be part of conservation and flood control development, involving the regulation of Battle and Paynes Creeks flows and construction of Wing Reservoir on Inks Creek for offstream storage. Except for stream flow maintenance for fish on lower reaches of the stream channels, there would be no local use of developed water supplies of Battle and Paynes Creeks. Spills from Battle Creek and winter runoff from Paynes Creek would be diverted through large-capacity flood channels into Wing Reservoir.

The Battle Creek Diversion Works would consist of a 230-foot dam located about 6 miles upstream from the Coleman Fish Hatchery. The reservoir created by construction of the dam would have a net storage capacity of about 36,000 acre-feet. The diversion flood channel would be 2.5 miles in length, and would divert maximum flows of about 60,000 second-feet.

The Paynes Creek Diversion Works would consist of a dam, 100 feet in height, located about 9 miles upstream from the Sacramento River. The reservoir created by construction of the dam would have no operating storage. The diversion flood channel would be 1.5 miles in length, and would divert maximum flows of about 30,000 second-feet.

Wing Reservoir would have a storage capacity of about 240,000 acre-feet. All releases from Wing Reservoir would flow into Iron Canyon Reservoir for further downstream regulation and use, including generation of electrical energy.

Sacramento River Development

The Sacramento River development, as described in The California Water Plan, would provide conservation of water, flood control, and would develop the available power head between Keswick Dam and Red Bluff. The development would consist of Redding Diversion Dam and Reservoir near Redding, and the Redding Conduit; Girvan Reservoir, and the Anderson Conduit; and Iron Canyon Dam and Reservoir, and the appurtenant power plant. The Redding Diversion Dam, a structure 50 feet in height, would be constructed and operated to divert the stream flow southward through the Redding Conduit to Girvan Reservoir on Clear Creek, where a junction would be made with the imported waters of the Klamath-Trinity Division. From Girvan Reservoir the combined flow would be further conveyed about 11 miles southerly through the Anderson Conduit to the Cottonwood power plant, located about 2 miles northeast of the town of Cottonwood. Releases from the Cottonwood power plant would enter the Cottonwood Creek arm of Iron Canyon Reservoir through an excavated tailrace channel about 1 mile in length. The water would then flow about 18 miles through the 950,000-acre-foot reservoir to Iron Canyon Dam, and through the Iron Canyon power plant near the base of the dam, into the proposed Redbank Diversion Reservoir of the United States Bureau of Reclamation, all on the Sacramento River near Red Bluff.

Water Rights

Shasta County is the site of large-scale water resources development for export to water-deficient areas of the State. As a consequence, the county is concerned with protection and reservation of water to meet its own future needs. The laws that provide such protection and reservation, and their applicability to Shasta County are discussed in this section. In addition, existing water rights that affect planning for local water development are discussed.

County of Origin and Watershed Protection Statutes

The county of origin law, Section 10505 of the Water Code, relates only to state water right applications. A state application is one that is filed by the State for water which may be required to develop or complete any part of a general or coordinated plan looking toward the development, utilization, or conservation of the water resources of the State (Section 10500, Water Code, 1959).

Section 10505 provides:

> "10505. No priority under this part shall be released nor assignment made of any application that will in the judgment of the commission, deprive the county in which the water covered by the application originates of any such water necessary for the development of the county."

The areas in which water originates are afforded further protection by the provisions of Section 11460 of the Water Code. This section provides:

> "11460. In the construction and operation by the department of any project under the provisions of this part a watershed or area wherein water originates, or an area immediately adjacent thereto which can conveniently be supplied with water therefrom shall not be deprived by the department directly or indirectly of the prior right to all of the water reasonably required to adequately supply the beneficial needs of the watershed area, or any of the inhabitants or property owners therein."

The only state applications that affect water supplies for Shasta County are those that were assigned to the Bureau of Reclamation for the Federal Central Valley Project. They are Applications Nos. 5625, 5626, and 9363 through 9368. Together these applications seek the appropriation of up to 6,500,000 acre-feet of water per annum by storage at Shasta Dam, and between 22,000 and 24,000 cubic feet per second by direct diversion from the Sacramento River and channels of the Sacramento-San Joaquin Delta. These applications were assigned to the United States in two groups in 1938 and 1952. Since very substantial quantities of water originate in Shasta County that are physically available to satisfy these applications, the reservations that were made in the assignments for the benefit of the counties of origin are significant.

Applications Nos. 5625, 5626, 9364, and 9365 were assigned to the United States for the Federal Central Valley Project on September 3, 1938. The following reservation was included in the assignment:

> ". . .subject to depletion of the stream flow above Shasta (formerly Kennett) Dam by the exercise of lawful rights to the use of water for the purpose of development of the counties in which such water originates, whether such rights have been heretofore or may be hereafter initiated or acquired, such depletion not to exceed in the aggregate four million five hundred thousand (4,500,000) acre-feet of water in any consecutive ten-year period, and not to exceed a maximum depletion in any one year in excess of seven hundred thousand (700,000) acre-feet."

This reservation applies to the drainage area above Shasta Dam, including portions of Modoc, Lassen, Shasta, and Siskiyou Counties.

The quantities of water reserved are such that the portion of Shasta County located above Shasta Dam appears to be fully protected as against the operator of the Central

Valley Project. The drainage area located below the dam is not protected by this reservation. It is, however, included in the reservation contained in the assignment of Applications Nos. 9363, 9366, 9367, and 9368, made on March 6, 1952. This reservation is as follows:

> ". . .subject, however in conformity with Section 10505 of the Water Code of the State of California, to any and all rights of any county in which the water sought to be appropriated originates to the extent that any such water may be necessary for the development of such county."

Shasta County's interests are affected by operation of the Central Valley Project. By its terms, Section 11128 of the Water Code makes the watershed protection statute applicable to the United States. It reads:

> "11128. The limitations prescribed in Section 11460 and 11463 shall also apply to any agency of the State or Federal Government which shall undertake the construction or operation of the project, or any unit thereof, including, besides those specifically described, additional units which are consistent with and which may be constructed, maintained, and operated as a part of the project and in furtherance of the single object contemplated by this part."

Shasta Dam is, of course, a feature of the Federal Central Valley Project. The Trinity River Division, consisting of Trinity and Whiskeytown Dams and Reservoirs and related works, is also part of the Federal Central Valley Project. However, the Trinity River Division has never been made a part of the State Central Valley Project. This fact creates an ambiguity as to whether the county of origin law is applicable to this portion of the federal project. A portion of Shasta

County is capable of being served from the Trinity River Division of the federal project.

Appropriative and Adjudicated Water Rights

There are many water rights along the Sacramento River and its tributaries in Shasta County. Those rights which have been adjudicated and those held by the Pacific Gas and Electric Company are discussed in this section.

Drainage Area Below Shasta Dam. Certain tributaries of Cow Creek and the North Fork of Cottonwood Creek are included in two state watermaster service areas. The Cow Creek tributaries are Cedar Creek, North (Little) Cow Creek, Clover Creek, and Oak Run Creek. Adjudications cover the water rights on these streams.

The water rights of the Pacific Gas and Electric Company for two power plants on Cow Creek and four power plants on Battle Creek were established before the effective date of the Water Commission Act in 1914. Any development above these plants would either have to be operated so as not to impair these rights, or arrangements would have to be made to purchase rights from the company, or to compensate for impairment of such rights, under applicable state and federal laws. However, if projects above these power plants could be used to enhance the hydroelectric generating capacity of the plants, the company might be expected to compensate the constructor of a project for such enhancement.

Pit River Drainage Area. As has been described, an extensive development of the power resources of the Pit River below Fall River Valley has been under construction in stages by the Pacific Gas and Electric Company. Four power plants have been completed, and the company has obtained water rights for its proposed Pit Nos. 6 and 7 power plants. The status of water rights applications on file with the State Water Rights Board in support of this development are shown in the following tabulation:

Application	Date	Plant	Amount: Direct diversion, in second-feet	Amount: Storage, in acre-feet	Status
1891	July 2, 1920	Pit No. 3	3,000		License
1892	July 2, 1920	Pit No. 4	3,000		Permit
3650	September 26, 1923	Pit No. 3	25		License
14743	April 7, 1952	Pit No. 6	4,500	40,000	Permit
14928	July 28, 1952	Pit No. 4	500		Permit
15407	July 9, 1953	Pit No. 7	4,850		Permit

Use of water at the Pit No. 5 plant is under claim of riparian right.

The Pit No. 1 project utilized substantially the entire flow of Fall River, just above its junction with the Pit River. The Supreme Court of California has determined that the rights to divert water for this plant are riparian rights. /Fall River Valley Irrigation District v. Mt. Shasta Power Corp., 202 Cal. 56, 71-72, 259 Pac. 444 (1927); Crum v. Mt. Shasta Power Corp., 117 Cal. App. 586, 600, 4 p. 2d 564 (1931)/.

Much of the existing and potential use of water in Fall River Valley is from ground water which may be interconnected with and affect the flow of Fall River. Under such circumstances, overlying landowners have correlative rights to utilize ground water on their overlying land in relation to riparian uses such as that of the Pacific Gas and Electric Company. [McClintock v. Hudson, 141 Cal. 275, 281, 74 Pac. 849 (1903)].

In addition to the power plants on the Pit River, the Pacific Gas and Electric Company is operating two small power plants on Hat Creek, located approximately 2 miles and 4 miles upstream from the confluence of Hat Creek with the Pit River. Water Rights on Hat Creek and Burney Creek have been adjudicated. These streams are included in two state watermaster service areas.

CHAPTER V. CONCLUSIONS AND RECOMMENDATIONS

The Shasta County Investigation included an inventory of surface and ground water resources of the county, an evaluation of present beneficial uses of water, an estimate of future local water requirements based on the capability of the land to support further development, and an appraisal of water resource development possibilities. The beneficial uses of water considered were those for irrigation, municipal purposes, industry, recreation, fish and wildlife, and hydroelectric power generation.

Conclusions

As a result of field investigations and analyses of available data pertaining to the water resources and water problems of Shasta County, a number of conclusions have been reached. These are summarized as follows:

1. Runoff from the highly productive watersheds of the Cascade, Klamath, and Coast Ranges, and ground water supplies of the Redding ground water basin and of the Modoc Plateau ground water area constitute generally adequate sources of water supply for present and future requirements in Shasta County. The estimated mean seasonal natural runoff from Shasta County is about 8,200,000 acre-feet. Of this amount, about 5,800,000 acre-feet originate within the county, and about 2,400,000 acre-feet are contributed from watersheds outside the county.

2. Both surface and ground water supplies of Shasta County are generally of good to excellent mineral quality and

are well suited for most beneficial uses. Exceptions are waters of certain minor streams, the most notable of which is Spring Creek, which are degraded by drainage flows from mines and mining residues and are of poor mineral quality for either irrigation or domestic use. Degradation of the ground water from ancient entrapped brines occurs in wells in the northern and northwestern portions of the Redding ground water basin.

3. The area irrigated in Shasta County at the present time totals about 46,600 acres. Other developed water-using areas include about 6,500 acres of urban lands, 15,500 acres of meadow pasture, and an average of 32,400 acres of reservoir water surface subject to evaporation.

4. The estimated present mean seasonal consumptive use of applied water on irrigated lands in Shasta County is about 90,700 acre-feet. It is estimated that in addition about 19,600 acre-feet of water per season are consumed by meadow pasture, and about 4,600 acre-feet for urban and suburban and for rural domestic purposes. The estimated net mean seasonal reservoir evaporation in the county is about 81,500 acre-feet. Thus, the total present mean seasonal consumptive use of applied water in Shasta County is about 196,400 acre-feet.

5. The gross irrigable area within Shasta County is about 259,000 acres. Of this amount, irrigable valley lands comprise about 136,000 acres and irrigable hill lands about 123,000 acres. In addition, there are approximately 277,000 acres of potentially irrigable land classified as best suited to forest management.

6. It is estimated that under conditions of ultimate development, a net area of about 195,600 acres could be irrigated in Shasta County, if adequate water supplies were developed. Another 12,300 acres could be devoted to meadow pasture, 26,400 acres to urban and suburban use, and 1,827,000 acres to various intensities of recreational use. Under such conditions, the average water surface area of the principal reservoirs would total about 57,200 acres.

7. The estimated ultimate mean seasonal consumptive use of applied water for all purposes in Shasta County is about 582,000 acre-feet.

8. The estimated ultimate mean seasonal water requirement to meet consumptive demands in Shasta County is about 1,025,000 acre-feet.

9. The estimated ultimate mean seasonal supplemental water requirement to meet consumptive demands in Shasta County is about 743,000 acre-feet.

10. An immediate source of supplemental water available to portions of Shasta County is ground water. The Redding ground water basin is the principal ground water source, and large yields from irrigation wells occur in the southeastern and southern parts of this basin. In general, however, relatively minor use is now made of the Redding ground water basin.

The Modoc Plateau ground water area includes five principal localities of potential ground water supply, which are virtually undeveloped at present. These are Fall River Valley, Goose

Valley, Cayton Valley, Burney Basin, and Hat Creek Valley The entire Modoc Plateau area is underlain by volcanic material with variable water-bearing characteristics.

Ground water could probably meet the ultimate supplemental water needs within the Modoc Plateau area and in the southerly portion of the Stillwater Plains. Ground water could probably provide most of the ultimate supplemental water required by the lands adjacent to Cottonwood Creek and the Cow Creek Bottoms. Specifically, the future water requirements of the following service areas could be met largely in this manner:

Fall River Valley	Goose Valley
Hogback Ridge	Burney Creek
Hat Creek	Stillwater Plains
Cayton Valley	Cottonwood Creek

11. A second source of supplemental water available to Shasta County is the surface water presently flowing out of the area. Development of surface waters for use in the county would require construction of water storage, conveyance, and distribution facilities. A number of the reservoirs would be of capacity in excess of 2,500 acre-feet, appropriate for development by a group of water users of by a public water agency. The future needs of the following service areas could be met largely by water conserved in such reservoirs of substantial storage capacity:

Cow Creek Bottoms	South Cow Creek
Millville Plains	Black Butte
Old Cow Creek	Igo-Ono
Whitmore	Bee Creek

Water developed from ground water and by the construction of smaller farm reservoirs could also meet portions of the future demands in some of these service areas. The Manton service area could obtain a part of its future water supply, as could the Black Butte service area, from facilities of the Pacific Gas and Electric Company or from tributaries of Battle Creek, subject to water rights of that company and providing that satisfactory agreements could be reached by negotiation. Millville Reservoir is one of the proposed surface storage projects that could be used to supply water to the Millville Plains and Cow Creek Bottoms service areas. The existing Happy Valley Canal could supply a part of the supplemental water needed by the Igo-Ono service area.

In the higher foothill and mountain areas of Shasta County, most of the future water needs would probably be met with supplies from farm reservoirs of less than 2,500-acre-foot storage capacity. Specifically, the needs of the following service areas could be met largely in this manner:

Montgomery Creek	Oak Run
Round Mountain	Clover Creek
Little Cow Creek	Hagaman Gulch
Bull Skin Ridge	Inwood
Oakflat	

Alternatively, the Oak Run service area could obtain a part of its future water supply from surface reservoirs and the Hagaman Gulch service area could meet all of its requirements from such sources.

12. A third source of supplemental water which could be made available to Shasta County is the yield of existing and proposed surface storage projects, planned primarily to develop water for export to areas of the State to the south. This source is of primary importance to the valley and mesa area of the county below Shasta Dam.

Shasta, Trinity, and Whiskeytown Reservoirs of the Central Valley Project, operated by the United States Bureau of Reclamation, could meet the future supplemental water requirements of the Redding-Enterprise area, the service areas of organized water agencies between Redding and Shasta Lake, the Bella Vista Water District, and Happy Valley. The future needs of the following service areas could be met largely in this manner:

Bella Vista	Urban Center
North Suburban	Happy Valley

Recommendations

To further development of the water resources in Shasta County for all beneficial uses, it is recommended that the county, acting through the Shasta County Water Agency or appropriate public districts:

1. Continue its study of local water problems and encourage, when found needed and feasible, the planning, financing, construction, and operation of local water projects.

2. Encourage inclusion of local service areas of the county in the service from major water development projects constructed in or adjacent to the county primarily for export purposes.

3. Urge the development and use of ground water in those areas of the county where ground water is the logical source of future supplemental water supplies.

4. Encourage cooperation of local individuals and agencies with appropriate state and federal agencies in the proper construction of farm reservoirs for water service to those potential water-using lands of the county which are best suited to this type of development.

5. Maintain continuous records of stream flow at strategic points on those streams of the county which have the possibility of being utilized for water conservation works. Such records will permit reliable determination of future water project yields and facilitate the most economic design of essential features.

6. Continue regular periodic observations of ground water levels and sampling of ground water for quality analyses in the Redding ground water basin, in order to permit more reliable determination of potential ground water yield and future ground water conditions.

7. Conduct periodic surveys of land use in the county as it relates to water utilization, in order to permit evaluation of future water demands and, in turn, to facilitate meeting the demands as they occur.

APPENDIX A

AGREEMENTS BETWEEN THE STATE DEPARTMENT OF WATER RESOURCES, OR ITS PREDECESSORS, AND THE COUNTY OF SHASTA

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AGREEMENTS BETWEEN THE STATE DEPARTMENT OF WATER RESOURCES, OR ITS PREDECESSORS, AND THE COUNTY OF SHASTA

INTERIM AGREEMENT BETWEEN
THE STATE WATER RESOURCES BOARD,
THE COUNTY OF SHASTA,
AND THE DEPARTMENT OF PUBLIC WORKS

THIS INTERIM AGREEMENT, executed in quintuplicate, entered into as of May 1, 1955, by the State Water Resources Board, hereinafter referred to as the "Board"; the County of Shasta, hereinafter referred to as the "County", and the Department of Public Works of the State of California, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer":

W I T N E S S E T H

WHEREAS, it is proposed by the parties hereto to enter into a co-operative agreement, on or about July 1, 1955, for conducting a three-year comprehensive program of investigation of the water resources of Shasta County at an estimated total cost of One Hundred Thousand Dollars ($100,000); and

WHEREAS, the Board has received reasonable assurances of favorable consideration by the Legislature of a Fifteen Thousand Dollar ($15,000) item in the Budget Act of 1955 to match a like amount to be contributed by the County for the first year program of work under said investigation; and

WHEREAS the parties hereto desire to initiate work on said investigation in advance of passage of said Budget Act of 1955; and

WHEREAS, State personnel and certain State funds remaining in Item 260 of the Budget Act of 1954, are or can be made available to initiate work on said program in advance of July 1, 1955; provided that matching funds in a like amount are contributed by the County; and provided further that the County give assurances of its intention to match additional funds made available by the Budget Act of 1955 and by subsequent Budget Acts; and

WHEREAS, the County by resolution dated March 24, 1955, has made Two Thousand Dollars ($2,000) available for the purpose of initiating the work with matching State funds: and further has indicated its willingness and intent to match State funds made available in the Budge Act of 1955 and in subsequent Budget Acts; provided that the total County contribution of matching funds shall not exceed Fifty Thousand Dollars ($50,000);

NOW, THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the Board, the County, and the State Engineer do hereby mutually agree as follows:

ARTICLE I - WORK TO BE PERFORMED

The work to be performed under this interim agreement shall consist primarily of the establishment and staffing of a field office in Redding; the collection, cataloging and review of available data relating to the water resources of the County: and preliminary consideration, as time permits, of alternative plans for the development of water to be imported into the County from the Trinity River.

It is understood and agreed that the purpose of this interim agreement is to inaugurate a three-year program of investigation and a report directed toward the formulation of plans for the orderly development of the surface and underground water resources of Shasta County.

ARTICLE II - FUNDS:

On execution of this interim agreement, the County shall transmit the sum of Two Thousand Dollars ($2,000) to the State Engineer for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury, for expenditure by the State Engineer in performance of the work provided for in this interim agreement. Also upon execution of this interim agreement, the Board shall request the Director of Finance to approve the transfer of the sum of Two Thousand Dollars ($2,000) from funds appropriated to the Board by Item 260 of the Budget Act of 1954 to the Water Resources Revolving Fund for expenditure by the State Engineer in performance of work provided for in this interim agreement.

Notwithstanding anything contained in this interim agreement contrary hereto or in conflict herewith, this interim agreement is made contingent upon the funds being deposited in or transferred to the Water Resources Revolving Fund as provided herein for expenditure by the State Engineer in performance of the work provided for in this interim agreement. In the event any of the funds are not transferred to the Water Resources Revolving Fund by the Director of Finance as provided for herein within 30 days after the Board requests such transfer, this interim agreement shall terminate and the unexpended balance of any funds deposited by the County shall be returned, provided that neither the Board nor the State Engineer shall be obligated to the County for any portion of the funds already expended.

Furthermore, this interim agreement is made contingent upon receipt by the Board of assurances from the County of its willingness and intent to match State funds made available in the Budget Act of 1955 and in subsequent budget acts to insure continuity and completion of the entire investigational program as hereinbefore specified.

The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for under this interim agreement any amount in excess of the funds made available hereunder.

Upon completion and final payment for the work provided for in this interim agreement, or of the agreement for conducting the entire three-year program of investigation if it be then in force, the State Engineer shall furnish to the Board and to the County a statement of all expenditures made. One-half of the total amount of all said expenditures shall be deducted from the sum advanced from funds appropriated to the Board, and one-half of the total amount of all said expenditures shall be deducted from the sum advanced by the County and any balance which may remain shall be returned to the Board and to the County in equal amounts.

Notwithstanding anything herein contained to the contrary, this agreement may be terminated and the provisions of this agreement may be altered, changed, or amended, by mutual consent of the parties hereto.

ARTICLE III - EFFECTIVE DATE

This agreement shall become effective immediately upon its execution by all the parties hereto.

IN WITNESS WHEREOF, the parties hereto have executed this agreement to be effective as of the date hereinabove first written.

Approved as to Form and Procedure

/s/ Randall J. Presleigh
District Attorney
County of Shasta

Approved as to Form and Procedure

/s/ Henry Holsinger
Attorney for Division of Water Resources

APPROVED AS TO FUNDS

/s/ E. R. Higgins
Comptroller

COUNTY OF SHASTA

By /s/ Andrew T. Jessen
Chairman, Board of Supervisors

S E A L

/s/ Ruth A. Presleigh
Clerk, Board of Supervisors

STATE WATER RESOURCES BOARD

By /s/ Clair A. Hill
Clair A. Hill, Chairman

State of California
Department of Public Works

FRANK B. DURKEE
Director of Public Works

S E A L

By /s/ A. H. Henderson
A. H. Henderson
Deputy Director of Public Works

/s/ A. D. Edmonston
A. D. Edmonston
State Engineer

S.H.Y. Form	L.F.H. Budget	Value	Descript.

DEPARTMENT OF FINANCE
APPROVED
May 23, 1955

JOHN M. PEIRCE, Director

By /s/ Louis J. Heinzer
Administrative Adviser

AGREEMENT BETWEEN THE STATE WATER RESOURCES BOARD, THE COUNTY OF SHASTA AND THE DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in quintuplicate, entered into as of July 1, 1955, by the State Water Resources Board, hereinafter referred to as the "Board"; the County of Shasta, hereinafter referred to as the "County"; and the Department of Public Works of the State of California, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer":

W I T N E S S E T H

WHEREAS, by the State Water Resources Act of 1945, as amended, the Board is authorized to make investigations, studies, surveys, hold hearings, prepare plans and estimates, and make recommendations to the Legislature in regard to water development projects, including flood control plans and projects; and

WHEREAS, by said Act, the State Engineer is authorized to cooperate with any county, city, state agency, or public district on flood control and other water problems and when requested by any thereof may enter into a cooperative agreement to expend money in behalf of any thereof to accomplish the purposes of said act; and

WHEREAS, the County by letter dated November 24, 1954, requested the Board to enter into a cooperative agreement for conducting a comprehensive investigation of the water resources of Shasta County with special reference to plans for immediate or near future development; and

WHEREAS, the State Engineer has determined that, because of the rapidly expanding agricultural and industrial economy of the area and because of the special situation created by the need for integrating local developments with federal plans for the importation of water, a cooperative investigation is warranted and within the scope and intent for which matching funds are allocated by the

State Water Resources Board; and

WHEREAS, the Board on April 1, 1955, directed the State Engineer to cooperate in conducting a comprehensive investigation of the water resources of Shasta County in accordance with Article I hereof and to render a report thereon;

NOW, THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the Board, the County, and the State Engineer do hereby mutually agree as follows:

ARTICLE I - WORK TO BE PERFORMED

The work to be performed under this agreement shall consist of a three year program of investigation and a report directed toward the formulation of plans for the orderly development of the surface and underground water resources of Shasta County. The investigation shall embrace all aspects of water development including, but not necessarily limited to, irrigation, urban, industrial, and mining use, hydroelectric power, flood control, fish, wildlife, and recreation. The investigation shall also include consideration of imported water supplies and their integration with local plans of water development. Problems of water quality shall be considered where pertinent.

The results of the investigation, including plans and estimates of cost, together with other supporting data, shall be summarized in the report.

The Board by this agreement authorizes and directs the State Engineer to cooperate with the County in making said investigation and report.

During the progress of said investigation and report all maps, plans, information, data, and records pertaining thereto which are in the possession of any party hereto shall be made fully available to any other party hereto for the due and proper accomplishment of the purposes and objectives hereof.

The work under this agreement shall be diligently prosecuted with the objective of completion of the investigation and report on or before June 30, 1958, or as nearly thereafter as possible.

ARTICLE II - FUNDS:

The County, upon execution by it of this agreement, shall transmit to the State Engineer the sum of Fifteen Thousand Dollars ($15,000) for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury, for expenditure by the State Engineer in performance of the work provided for in this agreement. Also, upon execution of this agreement by the Board, the Director of Finance will be requested to approve the transfer of the sum of Fifteen Thousand Dollars ($15,000) from funds appropriated to the Board by Item 213 of the Budget Act of 1955, for expenditure by the State Engineer in performance of the work provided for in this agreement and the State Controller will be requested to make such transfer.

If the Director of Finance, within thirty (30) days after receipt by the State Engineer of said Fifteen Thousand Dollars ($15,000) from the County, shall not have approved the deposit thereof into said Water Resources Revolving Fund, together with the transfer of the sum of Fifteen Thousand Dollars ($15,000) from funds appropriated to the Board by Item 213 of the Budget Act of 1955, for expenditure by the State Engineer in performance of the work provided for in this agreement, said sum contributed by the County shall be returned thereto by the State Engineer.

It is understood by and between the parties hereto that the sum of Thirty Thousand Dollars ($30,000) to be made available as hereinbefore provided is adequate to perform that portion of the above specified work during the first year of said three-year investigation. It is the further understanding that the County will make a further sum of Fifteen Thousand Dollars ($15,000) available at the commencement of the second year of said investigation which will be subject to a matching or contribution in an equal sum by the Board to defray expenses incurred during the second year thereof, and will make a further sum of Twenty Thousand Dollars ($20,000) available at the commencement of the third year of said investigation which will be subject to a matching or contribution in an equal sum by the Board for the completion of said investigation and report, contingent upon availability of County and Board funds for such purposes.

The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for under this agreement any amount in excess of the sum of Thirty Thousand Dollars ($30,000) as made available hereunder and when said sum is exhausted, the Board and the State Engineer may discontinue the work provided for in this agreement and shall not be liable or responsible for the resumption and completion thereof until further sums as specified in the preceding paragraph are made available.

Upon completion of and final payment for the work provided for in this agreement, the State Engineer shall furnish to the Board and to the County a statement of all expenditures made under this agreement. One-half of the total amount of all said expenditures shall be deducted from the sum advanced from funds appropriated to said Board, and one-half of the total amount of all said expenditures shall be deducted from the sum advanced by the County and any balance which may remain shall be returned to the Board, and to the County, in equal amount.

ARTICLE III - EFFECTIVE DATE

This agreement shall become effective immediately upon its execution by all the parties hereto.

IN WITNESS WHEREOF, the parties hereto have executed this agreement to be effective as of the date hereinabove first written.

Approved as to Form and
Procedure

/s/ Randall J. Presleigh
District Attorney
County of Shasta

Approved as to Form and
Procedure

/s Henry Holsinger
Attorney for Division of
Water Resources

APPROVED AS TO FUNDS

/s Wm. S. Cully,
Assistant Comptroller

:S.H.Y.:	L.F.H. :	:	:
: Form :	Budget :	Value :	Descript:

: DEPARTMENT OF FINANCE :
: A P P R O V E D :
: Jun 23 1955 :
: JOHN M. PEIRCE, Director :
: By /s Louis J. Heinzer :
: Adminstrative Adviser :

COUNTY OF SHASTA (SEAL)

By Andrew T. Jessen
Chairman, Board of Supervisors

/s/ Ruth A Presleigh
Clerk, Board of Supervisors

STATE WATER RESOURCES BOARD

By /s/ Clair A. Hill
Clair A. Hill, Chairman

State of California
Department of Public Works

FRANK B. DURKEE
Director of Public Works
(SEAL)

By /s A. H. Henderson
A. H. Henderson
Deputy Director of Public
Works

/s A. D. Edmonston
A. D. Edmonston
State Engineer

SUPPLEMENTAL AGREEMENT BETWEEN THE STATE WATER RESOURCES BOARD,
THE COUNTY OF SHASTA,
AND THE DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in quintuplicate, entered into s of July 1, 1956, by the State Water Resources Board, hereinafter eferred to as the "Board"; the County of Shasta, hereinafter reerred to as the "County"; and the Department of Public Works of he State of California, acting through the agency of the State ngineer, hereinafter referred to as the "State Engineer":

W I T N E S S E T H

WHEREAS, by agreement heretofore entered into as of uly 1, 1955, which was preceeded by an interim agreement heretoore entered into as of May 1, 1955, by and between the County, the oard, and the State Engineer, it was provided that the work to e performed by the State Engineer thereunder shall consist of an nvestigation and report on the water resources of Shasta County, s outlined more particularly in said prior agreement; and

WHEREAS, under said agreements the County made available he total sum of Seventeen Thousand Dollars ($17,000) which was atched in an equal amount by the Board for expenditure by the State ngineer in the performance of the work provided for in said agreeents; and

WHEREAS, it was the expressed intention of said agreeents that at the commencement of the second year of said investiation the County would make available a further sum of Fifteen housand Dollars ($15,000) subject to a matching or contribution n equal amount by the Board for the continuation of said investiation, and that the County will make a further sum, of such amount hat the total County contribution of matching funds will not exceed

Fifty Thousand Dollars ($50,000) in accordance with the terms of the Interim Agreement of May 1, 1955, available at the commencement of the third year of said investigation which will be subject to a matching or contribution in an equal sum by the Board for the completion of said investigation and report, contingent upon availability of County and Board funds for such purposes; and

WHEREAS, funds are required to continue said investigation, and it is the desire of the parties hereto that an additional sum of Thirty Thousand Dollars ($30,000) shall be provided, Fifteen Thousand Dollars ($15,000) thereof by the County, and Fifteen Thousand Dollars ($15,000) thereof by the Board;

NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each of the parties hereto as hereinafter set forth, the Board, the County, and the State Engineer do hereby mutually agree as follows:

1. The County, upon execution by it of this agreement, shall transmit to the State Engineer the sum of Fifteen Thousand Dollars ($15,000) for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental.

2. Upon execution of this agreement by the Board, the Director of Finance will be requested to approve the transfer of the sum of Fifteen Thousand Dollars ($15,000) from funds appropriated to the Board by Item 224 of the Budget Act of 1956 for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental, and the State Controller will be requested to make such transfer.

3. The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for in said prior agreement to which this agreement is supplemental any amount in excess of the sum of Sixty-Four Thousand Dollars ($64,000) as made available under said prior agreement, said prior interim agreement, and this supplemental agreement; and if such funds so made available are exhausted before completion of said work, the Board and the State Engineer may discontinue said work and shall not be liable or responsible for the resumption or completion thereof until further funds are made available at the commencement of the thir year as provided in said prior agreements and this supplemental agreement.

4. Insofar as consistent herewith and to the extent adaptable hereto, all of the terms and provisions of said prior agreements are hereby made applicable to this agreement and are hereby confirmed, ratified, and continued in effect.

IN WITNESS WHEREOF, the parties hereto have executed this agreement to be effective as of the date hereinabove first written.

Approved as to Form and
Procedure

/s/ Randall J. Presleigh
District Attorney
County of Shasta

Approved as to Form and
Procedure

/s Henry Holsinger
Attorney for Division of
Water Resources

DEPARTMENT OF FINANCE
APPROVED
Jul 12 1956

John M. Peirce, Director
By /s/ Louis J. Heinzer
Administrative adviser

COUNTY OF SHASTA

By /s/ Andrew T. Jessen
Chairman, Board of Supervisors

/s/ Ruth A. Presleigh
Clerk, Board of Supervisors

STATE WATER RESOURCES BOARD

By /s/ Clair A. Hill
Clair A. Hill, Chairman

State of California
Department of Public Works

FRANK B. DURKEE
Director of Public Works

SEAL

By /s/ A. H. Henderson JUN 15 195
A. H. Henderson
Deputy Director of Public
Works

/s/ Harvey O. Banks
Harvey O. Banks
State Engineer

SUPPLEMENTAL AGREEMENT BETWEEN THE DEPARTMENT OF WATER RESOURCES AND THE COUNTY OF SHASTA

THIS AGREEMENT, executed in quintuplicate, entered into ıs of July 1, 1957, by the State of California, Department of Water Resources, hereinafter referred to as the "Department," and the County of Shasta, hereinafter referred to as the "County":

W I T N E S S E T H:

WHEREAS the Department, on July 5, 1956, assumed the duties ınd responsibilities of the State Water Resources Board, hereinafter referred to as the "Board", and the Department of Public Works of he State of California, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer"; and

WHEREAS by agreement entered into as of July 1, 1955, which vas preceded by an interim agreement entered into as of May 1, 1955, ınd supplemented by an agreement entered into as of July 1, 1956, by ınd between the County, the Board, and the State Engineer, it was provided that the State Engineer would make an investigation and report on the water resources of Shasta County; and

WHEREAS under said agreements the County made available he total sum of Thirty-two Thousand Dollars ($32,000) which was matched ın an equal amount by the Board for expenditure by the State Engineer ın the performance of the work provided for in said agreements; and

WHEREAS it was the express intent of the parties that at he commencement of the third year of said investigation the County vould make available a further sum of Eighteen Thousand Dollars $18,000), subject to a matching, or contribution, in an equal amount y the Department for the completion of said investigation and report; nd contingent upon availability of County and Department funds for uch purposes; and

WHEREAS Thirty-six Thousand Dollars ($36,000) is now required to continue the investigation;

NOW, THEREFORE, it is mutually agreed as follows:

1. The County, upon execution by it of this agreement, shall transmit to the Department the sum of Eighteen Thousand Dollars ($18,000) for deposit in the Water Resources Revolving Fund in the State Treasury for expenditure by the Department in continuing the work provided for in said agreements.

2. Upon execution of this agreement by the Department, the Director of Finance will be requested to approve the transfer of Eighteen Thousand Dollars ($18,000) from funds appropriated to the Department by Item 265 of the Budget Act of 1957 to said Water Resources Revolving Fund for continuance of the work provided for in said agreements.

3. The Department shall not be obligated to spend more than One Hundred Thousand Dollars ($100,000) for the work provided for in said agreements and in this supplemental agreement, and if such funds are exhausted before completion of the investigation and report, the Department may discontinue said work and not be liable for the completion thereof.

4. Except as amended hereby all of the terms and provisions of said prior agreements are continued in full force and effect.

IN WITNESS WHEREOF, the parties hereto have executed this agreement to be effective as of the date hereinabove first written.

Approved as to Form and
Procedure

/s/ Randall J. Presleigh
District Attorney
County of Shasta

Approved as to Form and
Procedure

/s/ Mark C. Nosler
Attorney for Department
of Water Resources

COUNTY OF SHASTA

By /s/ Andrew T. Jessen
Chairman, Board of Supervisors

/s/ Ruth A. Presleigh
Clerk, Board of Supervisors

State of California
Department of Water Resources

HARVEY O. BANKS
Director

By /s/ Paul L. Barnes
Paul L. Barnes, Chief
Division of Administration

Form	Budget	Value	Descipt.

DEPARTMENT OF FINANCE
A P P R O V E D

Aug 23 1957

JOHN M. PEIRCE, Director

By /s/ Louis J. Heinzer
Adminstrative Adviser

APPENDIX B

STREAM GAGING STATIONS IN AND ADJACENT TO SHASTA COUNTY

TABLE B-1

STREAM GAGING STATIONS IN AND ADJACENT TO
SHASTA COUNTY

Name and number of hydrographic unit and name of gaging station	Reference number	Elevation, in feet	Drainage area, in square miles 1/	Period of record	Type of record 2/	Source of record 3/	Average, in acre-feet	Maximum: Season	Maximum: Acre-feet	Minimum: Season	Minimum: Acre-feet
McARTHUR - 16											
Pit River near Bieber	5-38	4,100	2,970	1904-08 1914 1922-26 1929-31 1952-present	D	USGS	312,000	1903-04	1,230,000	1930-31	25,800
Horse Creek at Little Valley near Pittville	5-39	4,180	203	1928-31	D	USGS	---	1929-30	10,000	1930-31	5,000
McArthur Drainage Canal at McArthur	5-40	3,350	---	1923-32	I	PGE USGS	35,000	1924-25	41,000	1930-31	29,000
Bear Creek near Dana	5-41	4,000	80+	1921-26	I	PGE USGS	18,000	1921-22	30,000	1923-24	2,000
Fall River near Glenborn	5-42	3,380	---	1922	I	USGS	---	---	---	---	---
Fall River at Fall River Mills	5-43	3,300	---	1912-13 1921-22	D	PGE USGS	---	1912-13	1,020,000	1921-22	916,000
Pit River at Fall River Mills	5-44	3,230	4,150	1923-51	D	PGE USGS	332,000	1937-38	1,189,000	1930-31	76,000
HAT CREEK - 17											
Lost Creek near Bald Mountain	5-45	3,900	---	1929-30	D	USGS	40,000	(one season only)			
Hat Creek near Hat Creek	5-46	4,300	122	1926-29 1930-present	D	USGS	93,000	1955-56	126,000	1933-34	59,000
Hat Creek at Browns Ranch	5-47	3,800	173	1926	I	USGS	---	---	---	---	---
Hat Creek at Hawkins Ranch	5-48	3,760	184	1911-13	D	USGS	138,000	(1911-12 only)			
Hat Creek at Wilcox Ranch	5-49	3,670	202	1921-22	D	USGS	96,000	(one season only)			
Hat Creek at Hat Creek	5-50	3,290	222	1910-17	I	USGS	---	1911-12	99,000	1912-13	82,000
Rising River near Cassel	5-51	3,180	---	1911-14 1921-22	D	USGS	---	1911-12	277,000	1921-22	216,000
Hat Creek above No. 2 Power Plant	5-52	3,100	627	1931-32	I	USGS	---	---	---	---	---
Hat Creek at Carbon	5-53	2,720	634	1921-22	I	PGE USGS	384,000	(one season only)			
Burney Creek above Burney	5-54	4,090	58	1921-22	D	USGS	29,000	(one season only)			
Burney Creek at Haynes Ranch	5-55	3,280	---	1927-29	I	DWRWA	---	---	---	---	---
Burney Creek near Burney	5-55A	3,160	86	1958-present	D	DWR	29,000	(1958-59 only)			
Burney Creek near Burney	5-56	3,190	87	1911-13 1921-22	I	USGS	---	1912-13 1921-22	36,000	1911-12	28,000
Burney Creek at Burney	5-56A	---	---	1911-12	D	USGS	28,000	(one season only)			
Burney Creek at Burney Falls	5-57	2,700	183	1921-22	D	USGS	132,000	(one season only)			
Pit River near Pecks Bridge	5-58	2,690	4,800	1922-24	D	USGS	1,620,000	(1922-23 only)			
Pit River at Lindsay Flat	5-59	2,440	4,860	1922-27	D	USGS	1,640,000	1925-26	2,170,000	1923-24	1,310,000
Pit River No. 3 Powerhouse Discharge at Lindsay Flat	5-60	2,440	---	1927-39	D	USGS	---	---	---	---	---
Pit River below Pit No. 4 Dam	5-61	2,345	4,860	1927-present	D	USGS	1,929,000	1951-52	2,952,000	1933-34	1,230,000

STREAM GAGING STATIONS IN AND ADJACENT TO
SHASTA COUNTY

Name and number of hydrographic unit and name of gaging station	Reference number	Elevation, in feet	Drainage area, in square miles 1/	Period of record	Type of record 2/	Source of record 3/	Seasonal runoff for period of record: Average, in acre-feet	Maximum: Season	Maximum: Acre-feet	Minimum: Season	Minimum: Acre-feet
MONTGOMERY CREEK - 18											
Pit River at Big Bend	5-62	1,674	4,920	1910-present	D	USGS	2,090,000	1955-56	3,048,000	1933-34	1,292,000
Kosk Creek near Henderson	5-63	1,800	55	1910-16	D	USGS	---	1915-16	249,000	1912-13	106,000
Pit River below Pit No. 5 Power Plant	5-63A	---	---	1944-49	D	USBR	---	---	---	---	---
Pit River above Hatchet Creek	5-64	1,280	5,040	1925-37	D	USGS	1,843,000	1926-27	2,650,000	1930-31	1,370,000
Montgomery Creek at Montgomery Creek	5-65	2,125	22	1911-13	D	USGS	---	1912-13	37,000	1911-12	30,000
Pit River near Montgomery Creek	5-66	1,075	5,170	1944-present	D	USGS	2,715,000	1955-56	4,014,000	1946-47	1,924,000
Squaw Creek above Shasta Lake	5-67	1,170	65	1944-present	D	USGS	166,000	1955-56	306,000	1954-55	86,000
McCLOUD RIVER - 19											
Mud Creek near McCloud	5-70	3,325	13	1927-32	D	USGS	---	1928-29	7,600	1929-30 1930-31	5,400
Angel Creek near McCloud	5-70A	2,739	17	1955-59	D	COPCO USGS	---	1955-56	51,000	1956-57	26,000
McCloud River below Big Springs near McCloud	5-70B	2,951	340	1955-present	D	COPCO USGS	---	1955-56	690,000	1956-57	580,000
McCloud River near McCloud	5-71	2,750	389	1931-present	D	USGS	634,000	1955-56	868,000	1932-33	438,000
McCloud River above Panther Creek near McCloud	5-71A	2,492	420	1955-present	D	COPCO USGS	---	1955-56	1,008,000	1956-57	835,000
McCloud River above Shasta Lake	5-72	1,110	622	1945-present	D	USGS	1,196,000	1955-56	1,747,000	1949-50	878,000
DUNSMUIR - 20											
Sacramento River at Castella	5-1	1,950	257	1910-22	D	USGS	494,000	1914-15	791,000	1919-20	214,000
Sacramento River at Delta	5-2	1,075	427	1944-present	D	USGS	800,000	1955-56	1,224,000	1946-47	459,000
SHASTA LAKE - 21											
Sacramento River at Antler	5-3	934	461	1910-11 1919-41	D	USGS	793,000	1940-41	1,990,000	1923-24	192,000
Squaw Creek at Ydalpom	5-68	800	100	1911-13	I	USGS	---	1912-13	198,000	1911-12	169,000
Pit River near Ydalpom	5-69	735	5,350	1910-43	D	USGS	2,960,000	1937-38	4,984,000	1930-31	1,550,000
McCloud River near Gregory	5-73	950	652	1902-08	D	USGS	1,742,000	1903-04	2,400,000	1907-08	1,240,000
McCloud River at Baird	5-74	700	690	1910-43	D	USGS	1,289,000	1940-41	2,205,000	1930-31	631,000
Sacramento River at Kennett	5-75	618	6,580	1925-42	D	USGS	5,023,000	1937-38	9,427,000	1930-31	2,530,000
Shasta Lake near Redding	5-75A	550	6,665	1942-present	R	USGS	---	---	---	---	---
CLEAR CREEK - 22											
Clear Creek near Shasta	5-78	1,085	172	1911-13	D	USGS	---	1911-12	143,000	1912-13	134,000
Clear Creek at French Gulch	5-78A	1,320	115	1950-present	D	USGS	161,000	1955-56	234,000	1954-55	65,000
Clear Creek near Igo	5-79	700	231	1940-present	D	USGS	290,000	1940-41	791,000	1943-44	93,000
KESWICK - 23											
Sacramento River at Keswick (upstream)	5-76	490	---	1938-42	D	USGS	---	---	---	---	---
Sacramento River at Keswick (downstream)	5-77	480	6,710	1938-present	D	USGS	5,955,000	1940-41	8,821,000	1943-44	2,760,000

TABLE B-1 (Continued)

STREAM GAGING STATIONS IN AND ADJACENT TO
SHASTA COUNTY

Name and number of hydrographic unit and name of gaging station	Reference number	Elevation, in feet	Drainage area, in square miles 1/	Period of record	Type of record 2/	Source of record 3/	Average, in Acre-feet	Maximum: Season	Maximum: Acre-feet	Minimum: Season	Minimum: Acre-feet
COTTONWOOD CREEK - 24											
North Fork Cottonwood Creek near Ono	5-88	2,050	12	1919	I	USGS	---	---	---	---	---
Moon Fork Cottonwood Creek near Ono	5-89	1,980	10	1919	I	USGS	---	---	---	---	---
North Fork Cottonwood Creek at Ono	5-90	780	52	1907-13	D	USGS	92,000	1908-09	178,000	1912-13	48,000
North Fork Cottonwood Creek near Igo	5-90A	650	89	1956-present	D	DWR	---	1957-58	349,000	1958-59	318,000
Middle Fork Cottonwood Creek near Ono	5-90B	550	249	1956-present	D	USGS	108,000	(one year only)			
Cottonwood Creek near Cottonwood	5-91	370	945	1940-present	D	USGS	592,000	1940-41	1,658,000	1943-44	172,000
Dry Fork South Fork Cottonwood Creek near Cottonwood	5-91A	525	---	1958-present	D	DWR	---	---	---	---	---
South Fork Cottonwood Creek near Cottonwood	5-91B	532	---	1958	D	DWR	---	---	---	---	---
STILLWATER PLAINS - 32											
Clover Creek near Anderson	5-86A	---	---	1956-?	D	USBR	---	---	---	---	---
COW CREEK - 33											
Little Cow Creek at Palo Cedro	5-80	490	145	1911-14	D	USGS	---	1912-13	138,000	1911-12	83,000
Oak Run Creek near Round Mountain	5-81	2,620	---	1927-32	I	DWRWA	---	---	---	---	---
Oak Run Creek near Oak Run	5-81A	1,400	11	1957-present	D	USGS	---	---	---	---	---
Little Cow Creek near Ingot	5-81B	1,360	61	1957-present	D	DWR	---	1957-58	182,000	1958-59	56,000
Clover Creek at Fern Bridge	5-82	2,650	---	1930-32	I	DWRWA	---	---	---	---	---
Clover Creek near Oak Run	5-82A	1,930	19	1957-59	D	USGS	---	---	---	---	---
Old Cow Creek at Kilarc Diversion	5-82B	---	24	1920-present	W	PGE	---	---	---	---	---
Clover Creek at Millville	5-83	500	53	1911-14	D	USGS	---	1912-13	43,000	1911-12	29,000
Salt Creek near Bella Vista	5-83A	600	---	1957-present	D	DWR	---	---	---	---	---
Cow Creek at Millville	5-84	490	166	1911-14	D	USGS	---	1912-13	138,000	1911-12	109,000
South Cow Creek near Millville	5-84A	610	79	1956-present	D	USGS	54,000	(one year only)			
South Cow Creek at Power Plant Diversion	5-84B	---	---	1921-present	W	PGE	---	---	---	---	---
Cow Creek near Millville	5-85A	400	427	1949-present	D	USGS	484,000	1955-56	749,000	1954-55	262,000
BEAR CREEK - 34											
Bear Creek near Millville	5-85	500	---	1911-14	D	USGS	---	1912-13	54,000	1911-12	50,000
BATTLE CREEK - 35											
North Fork Battle Creek below North Battle Creek Reservoir	5-46A	---	---	---	W	PGE	---	---	---	---	---
North Fork Battle Creek above Macumber Reservoir	5-46B	---	---	---	W	PGE	---	---	---	---	---
North Fork Battle Creek below Macumber Reservoir	5-46C	---	---	---	W	PGE	---	---	---	---	---

TABLE B-1 (Continued)

STREAM GAGING STATIONS IN AND ADJACENT TO SHASTA COUNTY

Name and number of hydrographic unit and name of gaging station	Reference number	Elevation, in feet	Drainage area, in square miles 1/	Period of record	Type of record 2/	Source of record 3/	Seasonal runoff for period of record: Average, in acre-feet	Maximum: Season	Maximum: Acre-feet	Minimum: Season	Minimum: Acre-feet
BATTLE CREEK - 35 (continued)											
Battle Creek near Cottonwood	5-87	420	362	1940-present	D	USGS	332,000	1940-41	504,000	1946-47	198,000
North Fork Battle Creek at Eagle Canyon Diversion Dam	5-87A	---	---	1920-present	W	PGE	---	---	---	---	---
Cross Country Canal	5-87B	---	---	1919-present	W	PGE	---	---	---	---	---
Soap Creek at Diversion Dam	5-87C	---	---	1937-present	W	PGE	---	---	---	---	---
South Battle Creek at Diversion Dam	5-87D	---	---	1921-present	W	PGE	---	---	---	---	---
PAYNES CREEK - 36											
Paynes Creek near Red Bluff	5-92A	360	92	1949-present	D	USGS	53,000	1955-56	93,000	1956-57	20,000
ANDERSON - 50											
Sacramento River near Redding	5-77A	440	---	1945-52 1954-present	D	USBR DWR	---	---	---	---	---
Sacramento River at Balls Ferry	5-86	375	---	1945-52 1954-present	D	USBR DWR	---	---	---	---	---
Sacramento River at Jellys Ferry	5-92	310	9,090	1895-1902	D	USGS	8,088,000	1895-96 1896-97	10,200,000	1897-98	4,960,000
Sacramento River near Red Bluff	5-93	250	9,300	1902-present	D	USGS	8,080,000	1903-04	15,900,000	1923-24	2,970,000
Sacramento River at Red Bluff	5-94	240	---	1894-96 1957-present	S	USGS DWR	---	---	---	---	---

1/ As reported by the agency

2/ D - Daily
I - Intermittent
W - Weekly
S - Seasonal
R - Reservoir contents

3/ USGS - United States Geological Survey
PGE - Pacific Gas and Electric Company
DWRWA - Department of Water Resources Water Rights Adjudication
DWR - Department of Water Resources
USBR - United States Bureau of Reclamation
COPCO - California-Oregon Power Company

APPENDIX C

EXISTING DAMS AND HYDROELECTRIC POWER PLANTS

IN SHASTA COUNTY, 1958

TABLE OF CONTENTS

EXISTING DAMS AND HYDROELECTRIC POWER PLANTS
IN SHASTA COUNTY, 1958

TABLES

TABLE C-1

EXISTING DAMS IN SHASTA COUNTY, 1958

Name of dam	Owner	Stream	Location[1] MDB&M Section	Township	Range	Type of dam	Crest length, in feet	Crest Height, in feet	Elevation: crest above sea level	Maximum storage capacity, in acre-feet	Year completed	Use
Anderson-Cottonwood	Anderson-Cottonwood Irrigation District	Sacramento River	35	32N	5W	Flashboard and buttress	455	20	490	100	1917	Irrigation
Musselbeck	Happy Valley Water Company	North Fork Cottonwood Creek	31	31N	7W	Hydraulic fill	470	110	2,024	4,800	1920	Irrigation
Coleman Forebay	Pacific Gas and Electric Company	Tributary Battle Creek	32	30N	2W	Earth	2,600	20	870	73	1911	Power
Macumber	Pacific Gas and Electric Company	North Battle Creek	15	31N	2E	Earth and rock	2,425	27	4,100	425	1907	Power
North Battle Creek	Pacific Gas and Electric Company	North Battle Creek	20	32N	3E	Rockfill	439	46	5,246	1,016	1909	Power
Pit No. 3	Pacific Gas and Electric Company	Pit River	30	37N	3E	Gravity	494	120	2,770	40,600	1925	Power
Pit No. 1	Pacific Gas and Electric Company	Fall River	25	37N	4E	Gravity	600	15	3,327	50	1922	Power
Pit No. 4	Pacific Gas and Electric Company	Pit River	8	36N	2E	Slab and buttress	415	74	2,458	2,000	1927	Power
Pit No. 5 Diversion	Pacific Gas and Electric Company	Pit River	9	36N	1E	Gravity	320	52	2,056	390	1943	Power
Pit No. 5 Conduit Embankment	Pacific Gas and Electric Company	Sugar Pine Creek	5	36N	1E	Earth	2,825	61	2,046	1,147	1943	Power
Hat Creek No. 2 Diversion	Pacific Gas and Electric Company	Hat Creek	29	36N	4E	Gravity	120	19	2,980	620	1942	Power
Pit No. 1 Forebay	Pacific Gas and Electric Company	Fall River	25	37N	4E	Earth	520	40	3,330	2,800	1947	Power
False Lake	C.D. and Mary A. Pelletier	North Fork Jenney Creek	4	31N	5W	Earth	600	21	750	100	1851	Irrigation
Reese Reservoir	Arnold Sargent	Tributary Tadpole Creek	20	31N	5W	Earth	350	26	900	98	1876	Irrigation, municipal
James Montgomery	James L. Montgomery	Flat Creek	19	31N	5W	Earth	240	24	850	65	1869	Irrigation
Null	Dr. John W. Null	Rock Creek	16	30N	2E	Earth	400	54	3,206	188	1954	Domestic, irrigation, and recreational
Ross	Wayne K. Ross	Tributary Stillwater Creek	10	32N	4W	Earth	740	30	730	709	1957	Irrigation
Ross No. 2	Wayne K. Ross	Tributary Stillwater Creek	10	32N	4W	Earth	760	29	725	243	1957	Irrigation
Keswick	United States Bureau of Reclamation	Sacramento River	21	32N	5W	Gravity	1,046	119	596	23,800	1950	Power, stream flow reregulation
Shasta	United States Bureau of Reclamation	Sacramento River	15	33N	5W	Gravity	3,460	487	1,078	4,492,700	1949	Irrigation and power
Whiskeytown[2]	United States Bureau of	Clear Creek	28	32N	6W	Earth and rock	2,150	278	1,228	250,000		Irrigation, municipal, domestic, power, and recreational

1/ Locations of dams are shown on Plate 14.
2/ Under construction.

TABLE C-2

EXISTING HYDROELECTRIC POWER PLANTS IN SHASTA COUNTY, 1958

Name of power plant	Owner	Stream	Location MDB&M: Section	Location MDB&M: Township	Location MDB&M: Range	Installed power capacity, in kilowatts	Average static head, in feet	Elevation of tailrace U.S.G.S. datum, in feet
Hat Creek No. 1	Pacific Gas and Elec. Co.	Hat Creek	32	36N	4E	10,000	217	2,969
Hat Creek No. 2	Pacific Gas and Elec. Co.	Hat Creek	20	36N	4E	10,000	198	2,770
Pit No. 1	Pacific Gas and Elec. Co.	Pit River	10	36N	4E	56,000	454	2,850
Pit No. 3	Pacific Gas and Elec. Co.	Pit River	9	36N	2E	72,900	315	2,417
Pit No. 4	Pacific Gas and Elec. Co.	Pit River	10	36N	1E	90,000	382	2,040
Pit No. 5	Pacific Gas and Elec. Co.	Pit River	9	36N	1W	128,000	615	1,410
Kilarc	Pacific Gas and Elec. Co.	Old Cow Creek	33	33N	1E	3,000	1,192	2,648 1/
Cow Creek	Pacific Gas and Elec. Co.	South Cow Creek	6	31N	1W	1,200	715	920 1/
Coleman	Pacific Gas and Elec. Co.	Battle Creek	32	30N	2W	13,800	482	383 1/
Volta	Pacific Gas and Elec. Co.	North Fork Battle Creek	16	30N	1E	6,400	1,254 1,204	2,200 1/
Shasta	U.S. Bureau of Reclamation	Sacramento River	15	33N	5W	379,000	478	587
Keswick	U.S. Bureau of Reclamation	Sacramento River	21	32N	5W	75,000	101	486
Spring Creek 2/	U.S. Bureau of Reclamation	Spring Creek	17	32N	5W	143,000	623	587
Clear Creek 2/	U.S. Bureau of Reclamation	Clear Creek	11	32N	7W	130,000	692	1,210

1/ Pacific Gas and Electric Company datum.
2/ Under construction.

BULLETIN NO. 22

SHASTA COUNTY INVESTIGATION

APPENDIX D

THE EFFECTS ON FISHERIES RESOURCES BY POTENTIAL WATER DEVELOPMENT PROJECTS OF COTTONWOOD AND COW CREEKS, SHASTA COUNTY, CALIFORNIA

Prepared under the supervision of

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Fisheries Biologist IV

by

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Fisheries Biologist I

STATE OF CALIFORNIA
DEPARTMENT OF FISH AND GAME

June, 1958

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EDMUND G. BROWN
GOVERNOR

COMMISSIONERS
M. P. ELSER, PRESIDENT
SAN DIEGO
E H. SMITH, VICE PRESIDENT
LOS ANGELES
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NRY E. CLINESCHMIDT
REDDING

W. T. SHANNON
DIRECTOR

STATE OF CALIFORNIA

Department of Fish and Game

May 23, 1960

Honorable Harvey O. Banks
Department of Water Resources
1120 N Street
Sacramento, California

Dear Mr. Banks:

Transmitted herewith is a report entitled "The Effects on Fisheries Resources by Potential Water Development Projects of Cottonwood and Cow Creeks, Shasta County, California". This report was prepared as part of the work performed under Inter-agency Agreement 8-213-51.

The report is an evaluation of the effects of potential water development projects on fisheries and wildlife resources of the Cottonwood and Cow Creek basins. It also contains flow recommendations for the protection and maintenance of these resources.

W T Shannon
Director

Attachment

INTRODUCTION

This report has been prepared for use by the Department of Water Resources in connection with its Shasta County Investigation. It is intended to provide planning engineers with sufficient information to evaluate the effects of potential water development projects on fisheries and wildlife resources, and to recommend measures for the protection of these resources under conditions of project operation. This report represents a portion of the services provided in fulfillment of Inter-Agency Agreement 8-213-S1 between the Departments of Fish and Game and Water Resources.

The Shasta County Investigation is a cooperative study intended primarily to determine the most feasible means of developing supplies of water to satisfy requirements within Shasta County. Cottonwood and Cow Creeks are suitable sources of water. Various dam sites on both of these streams could be developed to sizes sufficient to meet water requirements within Shasta County. However, most of these same sites have been included in The California Water Plan as projects to supply water for both local needs and for export to water deficient areas. Consequently, the sites would be developed with much larger dams, and operations would differ greatly from those for smaller developments.

Both Cottonwood and Cow Creeks support fish populations which would be affected by projects constructed on these streams, regardless of whether the projects would be of large or small size. These effects could be either beneficial or detrimental, depending upon the degree of compatibility of project operations with fisheries requirements.

In scope, this report is limited to Cottonwood and Cow Creeks, and considers the development of potential sites to either large or small sizes. Other related major features of The California Water Plan, although not in either of these basins, are also considered.

FISHERIES AND WILDLIFE RESOURCES
OF COTTONWOOD AND COW CREEKS

Both Cottonwood and Cow Creeks presently support runs of king salmon and steelhead rainbow trout. In addition, smallmouth bass are found in certain areas of each stream and resident rainbow trout are present in Cow Creek. Silver salmon have recently been introduced into Mill Creek, Tehama County, and could possibly spread to these streams.

Cottonwood Creek

Cottonwood Creek rises in the rugged inner coast range at an altitude of about 4,000 feet. It consists of three branches, the North, Middle, and South Forks. The direction of flow is generally east, entering the Sacramento River near the town of Cottonwood. The drainage area is 929 square miles, and length of stream is over 100 miles. Natural barriers reduce the available spawning area for anadromous fish to about 83 miles. In the upper reaches, the stream flows over hard shale and conglomerate, which is of little value for spawning purposes. (Hanson, et al, 1940)

The lower section of the main stem is wide, shallow, and meandering. Bank vegetation is generally sparse; giving little protection to fish and no shade to reduce water temperatures. Gravel is plentiful and of a suitable size for spawning purposes.

The South Fork has the better gravel of the Cottonwood drainage and could produce large numbers of salmon if supplementary water were supplied to augment the normal flows in the summer and fall.

Flow Records

Flow records for Cottonwood Creek have been maintained since 1941 by the U. S. Geological Survey. The gaging station is located two miles east of the town of Cottonwood. Mean and minimum monthly flows from 1941 through 1955 are listed in Table I. The average annual runoff is 900,000 acre-feet.

Table I

Flow in Cottonwood Creek Near Cottonwood, 1941-1955
(in second-feet)

	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
Mean	105	214	1,510	2,062	1,998	1,589	1,213	594	319	112	61	64
Minimum 1/	37	40	42	44	105	156	224	111	76	30	20	15

1/ Lowest monthly flows recorded.

Fish Population

King salmon ascend Cottonwood Creek in the fall to spawn when flows are adequate. In many years flows are too low for fish passage until December or later. Since the bulk of the Sacramento River fish spawn in November, very often Cottonwood Creek provides no substantial spawning access.

Steelhead spawn in unknown numbers in the stream. Their spawning migration is later than that of salmon and they usually have sufficient water to move upstream successfully.

The mean king salmon spawning population in Cottonwood Creek is estimated to be about 850 fish. Assuming a sex ratio of two males per female, approximately 280 females use the stream. With increased flows in early fall, many more fish would be attracted to the stream.

The major factors limiting king salmon at present are irrigation diversions, hard bottom areas upstream, wide flood-plain type channels in lower reaches, and low flows with attendantly high temperatures during summer and fall.

Cow Creek

Cow Creek is composed of five tributary streams which flow southwest down the foothills of the Cascade Range. From north to south the tributaries are: Little Cow Creek, Oak Run, Clover Creek, Old Cow Creek, and South Cow Creek. The main stem enters the Sacramento River east of Anderson. The drainage area encompasses 527 square miles. The distance from mouth to the source of the longest tributary, South Cow Creek, is 40 miles. Total length of streambed in the drainage is approximately 66 miles. Stream gradient in upper reaches is quite steep, but gradually lessens to produce a sluggish section near the mouth. The lowest portion of the stream is submerged by backwater from the Sacramento River during periods of high flow.

Both the upper and lower portions of the stream are unsuitable for king salmon spawning. The upper reaches flow through bedrock gorges in many places. This generally limits upstream migrants, and is unsuitable for spawning. Good spawning conditions exist in the central portions of the stream and its tributaries. The gravel is of acceptable size and is utilized by anadromous fishes for spawning purposes.

Flow Records

Flow records for Cow Creek have been maintained since 1950 by the U. S. Geological Survey. The gaging station is located three miles downstream from the mouth of Little Cow Creek. Mean and minimum monthly flows from 1950 through 1955 are given in Table II. The mean annual runoff is 517,500 acre-feet.

Table II

Flow in Cow Creek near Millville, 1950-1955
(in second-feet)

	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept
Mean	140	386	1,441	2,044	1,607	1,141	806	606	283	72	42	47
Minimum 1/	27	42	90	81	327	281	358	177	55	17	14	11

1/ Lowest monthly flows recorded.

Fish Populations

Important resident fish in Cow Creek include smallmouth bass and rainbow trout. The bass maintain a population by natural reproduction. Trout are maintained to a certain extent by natural reproduction and, in addition, some are stocked by the Department of Fish and Game.

Seasonal residents in the stream include steelhead trout and fall-run king salmon. These fish enter the stream usually in fall and winter. Flows are too low and water temperatures too high to accommodate spring-run fish, the adults of which must remain in the stream all summer.

Unpublished estimates by the Department of Fish and Game indicate the average king salmon spawning run to be about 1,460 fish, based on ten years of observation. The largest run, in 1956, was over 3,000 while the lowest, in 1949, was estimated at 200. No estimates have been made on numbers of steelhead entering the stream.

Much of the potential spawning ground in Cow Creek is presently unavailable to anadromous fish because of natural barriers, power developments, and irrigation diversions. All tributaries except Clover Creek have natural barriers in their upper reaches which prevent upstream migration. The areas above barriers are considered relatively unimportant, however, because of poor stream bottom characteristics.

Irrigation diversions are present on all tributaries of Cow Creek. These seriously reduce normal flows during the summer, and entirely bar any migration of spring-run salmon.

Power developments exist on Old Cow and South Cow Creeks. The Kilarc plant on Old Cow Creek is considered to have no effect on salmon because of an impassable natural barrier below the power station. The South Cow Creek installation diverts water from near the head of Wagoner Canyon to Hooten Gulch, a distance of four miles. During low flows this stretch becomes completely dry. This is considered a serious obstacle, since good spawning areas exist in and above Wagoner Canyon.

Mine drainage waters enter North Cow Creek near the town of Ingot. Copper and zinc, both toxic to fish when in sufficient quantities, enter the stream. It is not known at the present time if this condition adversely affects the fish populations.

PROPOSED WATER DEVELOPMENT PROJECT

The California Water Plan (California Department of Water Resources Bulletin No. 3, 1957) proposes five reservoirs and one re-regulation structure on Cottonwood Creek and its tributaries. Water provided by this plan would be used locally in Cottonwood Valley and the Reeds Creek area.

Flood protection for the downstream areas and regulated flows would improve and enhance stream flows for the maintenance of fish life.

Table III

Summary of Cottonwood Creek Works

Dam and Reservoir	Stream	Dam Height in feet	Normal Pool Elevation	Storage Gross acre-feet	Capacity Active acre-feet
Dippingvat	South Fork	205	1,150	55,000	51,300
Rosewood	Dry Creek	200	783	200,000	196,000
Fiddlers	Middle Fork	310	1,050	310,000	270,000
Hulen	North Fork	205	850	96,400	93,400
Fiddler Afterbay*	Middle Fork	73	750	5,400	1,000

* A re-regulation structure for Fiddlers Reservoir.

The California Water Plan proposes the development of Cow Creek and its tributaries. Two dams and three diversion structures would conserve and regulate the flows of these streams.

The place of water use would be local Redding area and Sacramento Valley. Regulated flows would improve and enhance stream flows for the maintenance of fish life.

Table IV

Summary of Cow Creek Works

Dam and Reservoir	Stream	Dam Height in feet	Normal Pool Elevation	Storage Gross acre-feet	Capacity Active acre-feet
Bella Vista 1/	Little Cow	110	600	146,000	138,000
Millville 2/ 3/	South Cow	215	800	206,000	200,000
Oak Flat 1/	Oak Run	80	1,490	5,300	5,000
Old Cow Cr. 2/	Old Cow Creek	145	815	18,000	10,000
Bear Creek	Bear Creek	140	1,180	---	---

1/ Oak Flat Reservoir will divert Oak Run Cr. to Bella Vista Res.
2/ Old Cow Creek Reservoir will divert to Millville Reservoir.
3/ Bear Creek Reservoir will divert to Millville Reservoir.

Shasta County Cooperative Investigation

The Shasta County Cooperative Investigation between State and County is primarily interested in determining the most feasible means of developing supplies of water to satisfy requirements of Shasta County. Two reservoirs are proposed for Cow Creek. They are Millvillito Dam, a half mile west of the junction of South Cow and Old Cow Creeks and Vacacilla Dam, two miles east of the town of Bella Vista on Little Cow Creek. The stream areas that would be blocked by the structures have little value for anadromous fish. Conservation and regulation of flows with streamflow maintenance would improve and enhance these streams.

One reservoir is planned for Cottonwood Creek. Hulen Reservoir would be located on the North Fork Cottonwood Creek, approximately four miles from the main stream junction. The stream bed above the project is unsuitable for anadromous fish spawning. Conservation and regulation of continuous flows would enhance the downstream areas for fisheries.

EFFECT OF THE PROPOSED PROJECTS ON FISHERIES AND WILDLIFE

Present flows in these two stream systems are almost completely unregulated. Some small diversions are present, but few larger scale attempts have been made to store the heavy winter runoff for use during the summer. Characteristically, the flow pattern is one of extremes; high in winter and spring, low in summer and fall. The low flows approximate only one-half to one per cent of those occurring during the winter runoff. It should be obvious that such a pattern while natural, is not so desirable as more nearly uniform annual flows with some increase during periods of anadromous fish migration and spawning.

Previous Reports

Cow and Cottonwood Creeks have been considered in three federal reports which are cited in the list of references at the end of this report. The streams were described in reference to fish salvage and enhancement for possible federal water projects. Salmon spawning capacities were estimated for each tributary of the creeks at different constant flows, and estimated capacities at various selected flows drawn from these reports are presented in Tables V and VI. Also listed is the estimated sport catch, commercial catch, and angler use of the resources at the various population levels. Assumptions used are a catch-to-escapement ratio of 3:1, that the flows indicated would be measured at the U. S. Geological Survey stations mentioned previously, and that increased flows would allow spring-run fish to live through the summer and spawn in the streams.

Table V

Possible use by King Salmon of the Main Stem Cottonwood Creek at Selected Flows

Flow in Second-Feet	Present 1/ Conditions	80cfs 2/	100cfs 2/	300cfs 2/
Number of spawners	850	10,380	15,570	30,000
Number sport caught	459	5,605	8,408	16,200
Number commercially caught	2,091	25,535	38,302	73,800
Angler-days use	1,056	12,891	19,338	37,260

1/ Mean minimum flow at spawning time (1941-1955): October, 60 cfs; November, 90 cfs; December, 190 cfs.
2/ Entire year.

Table VI

Possible use by King Salmon of the Main Stem Cow Creek at Selected Flows

Flow in Second-Feet	Present 1/ Conditions	50cfs 2/	100cfs 2/
Number of spawners	985	3,400	10,200
Number sport caught	532	1,836	5,548
Number commercially caught	2,423	8,364	25,052
Angler-days use	1,223	4,223	12,760

1/ Mean minimum flow at spawning time (1950-1955): October, 40 cfs; November, 90 cfs; December 240 cfs.
2/ Entire year.

Possible Advantages to Fisheries by Projects

The projects as planned for these streams are primarily for irrigation of local areas. They have, if properly managed, considerable potential value for fish, mammals, birds, and streamside recreation. Present flows support populations of fish. With regulation of flows to produce slightly higher flows in periods of normal low water and regulated flows through the winter, the potential use by king salmon spawning numbers would increase. The figures in Tables V and VI seem high but habitat improvement in addition to attraction of spring-run fish make them acceptable. One note of caution to be expressed is that these predictions are of the maximum potential use under optimum conditions. Actual use can be determined only after operation at recommended flows for several years.

King salmon are temporary users of the stream at spawning time for egg deposition. Time spent by young in streams of the size of Cow and Cottonwood Creeks is rarely more than one month. Adults simply ascend the stream when adequate water becomes available, select a nest site, build the nest, spawn, and die. The young usually migrate downstream shortly after emergence from the gravel.

Resident fish in these streams would gain also from stabilized annual flows. Rainbow trout and smallmouth bass could be expected to increase in numbers and in average size from the improved living conditions resulting from controlled water releases.

Steelhead and silver salmon enter streams later than king salmon and are not usually affected by conditions of low flow at spawning time. The young produced spend a few months to a year or more in the parent stream. Constant flows would improve conditions for them. Low summer flows, resulting in high temperatures and decreased food supplies, limit the number of juvenile salmon and steelhead surviving to migrate to the ocean in their second spring. Since a suitable stabilized flow would eliminate most of these limiting factors, steelhead and silver salmon may be expected to show population increases under stable flow conditions.

Disadvantages of Regulated Stream Flows

Periodic flood of the streams scours the stream bed free of silt. The removal of silt facilitates free water circulation through the bottom material which insures a good oxygen supply to nests on the bottom.

Generally, the most serious objection to regulation of streamflows is the obstruction the dams will produce across the stream. In this instance, the proposed projects are upstream from the spawning grounds, and could help maintain a high productive level without interfering with migration.

Probable Use of Reservoirs

Shasta County has a great amount of diversified outdoor water recreation. The planned reservoirs on Cottonwood Creek and Cow Creek will add to the County's recreation potential. Tentative plans are to draw the reservoirs down to minimum pool each year. This drawdown would limit the amount of water available for maintenance of fish populations in the late summer and fall. Warm water is generally found in low altitude reservoirs and if the minimum pool is shallow a dissolved oxygen deficiency might exist during certain periods of the year. This would cause heavy fish die-offs which would limit population size. Spring and early summer water levels of reservoirs would support local water recreation but high air temperatures and low water levels in the latter part of the year would decrease the appeal for water recreation use. The majority of people using these areas during the initial period after construction would be from local sources, and would be expected to utilize the areas for short periods of time only. During later years, increased pressure for recreation on the lakes might be expected as the populations of the local metropolitan areas increase.

MAINTENANCE OF PRESENT CONDITIONS

The amount of water which flows in a stream is one factor that determines the size of resident fish populations. Other information lacking, requisite maintenance flows may be calculated from the typical flows during the period when fish populations are most vulnerable to the effects of low flows. In the case of salmonids, this period is generally late summer, fall, and early winter, or September through December. A summary of monthly average, minimum recorded, and modal flows of Cottonwood Creek near Cottonwood and Cow Creek near Millville is shown on Plate D-1.* Typical flows for Cottonwood Creek are as follows: August, 40-50 cfs; September, 40-50 cfs; October 50-60 cfs; November, 80-90 cfs; (1941-1955 data). Cow Creek typical flows are as follows: August, 20-30 cfs; September, 50-60 cfs;

* Plate D-1 effectively summarizes the results of statistical analysis of the recorded flow data of Cottonwood and Cow Creeks for the casual reader. Plates from which the summary data were obtained are on file with the Department of Fish and Game.

October, (bi-modal) 30-40 cfs, 100-110 cfs; November, 100-110 cfs; (1949-1955 data). The above flows may be considered to maintain the existing resident populations of fish.

Calculating the typical flows for December and January was impossible because of the wide dispersion of these flows. The next best calculation would be a mean drawn from 36-year average computed historic flows and recorded monthly flows. In Cottonwood Creek, the 36-mean flows for December are 1,250 second-feet and for January are 1,675 second-feet. In Cow Creek, the 36-year mean flows for December are 1,215 second-feet and for January are 1,315 second-feet.

RECOMMENDATIONS FOR DOWNSTREAM FLOWS BELOW TENTATIVE DAMS ON COTTONWOOD AND COW CREEK DRAINAGES

Cottonwood Creek

Table V describes utility for salmon at selected flows in the main stem of Cottonwood Creek. One hundred second-feet minimum flow is recommended to accommodate the largest number of spawners in proportion to the amount of water. Fifteen thousand, five hundred spawners could be accommodated with this regulated flow. The minimum water releases, which are recommended to maintain fish life in the three forks of Cottonwood Creek, should satisfy the main stem flow requirements.

The South Fork of Cottonwood Creek has the largest potential of the three forks of Cottonwood Creek for anadromous fish production. Minimum flows would need to be larger than in the other forks because of the width of the gravel beds. During the months of October, November, and December the runs of fall spawning salmon would utilize the gravel beds if 100 second-feet were available. Storage water would have to be utilized for stream flow maintenance during October and part of November, and natural runoff during the following month and a half. To maintain this stream during the rest of the year for the production of young salmon and for maintenance of a resident fish population, 50 second-feet minimum flow should be adequate. Gaging of these flows could be made at the junction of the South Fork of Cottonwood Creek and the main stem. With the recommended flows, there would be made available gravel for 8,100 spawners (Moffett, et al, 1945). At present, salmon seldom utilize the gravels of South Cottonwood Creek. The average width of this fork is 54 feet (Hanson, et al, 1940). Artificial channeling in the wide areas would help considerably in better water utilization.

The Middle Fork of Cottonwood Creek has the second largest potential for salmon production of the Cottonwood forks. Maintenance of 50 second-feet minimum flow below the proposed dam would accommodate 2,200 spawners (Moffett, et al, 1945), and an increased population of resident fish. Gaging of this stream should also be at its junction with the main stem. Present plans contemplate power releases from a proposed dam, therefore, water of greater amounts than the minimum fish flow would be released. It is recommended that continuous, non-fluctuating flows be released from the power plant, either by operation without peaking, or by adding a re-regulating reservoir.

North Fork Cottonwood Creek has the least value of the three tributaries for anadromous fish production. A release of

30 second-feet minimum flow should be adequate to maintain resident fish and for the production of salmon. The minimum flows recommended for the South Fork Cottonwood Creek (100 cfs), Middle Fork (50 cfs), and North Fork (30 cfs), would be more than adequate for the recommended main stem flow of 100 cfs. These flows would accommodate approximately 15,000 salmon on the main stem, and a total of approximately 10,000 salmon in the three tributaries.

Cow Creek

At the present, the major salmon spawning areas of Cow Creek are located in the lower 14 miles of the main stream and South Cow. Recommended flows for this section are presented in Table VI. A flow of 100 second-feet minimum would provide a potential for 10,200 spawners annually and support a resident fish population as well (Moffett, et al, 1947). Oak Run, a tributary to Cow Creek, has a potential of 9,033 spawners annually (Hanson, et al, 1940). The limiting factors of this stream now are intermittent flows and irrigation diversions. Tentative plans are to divert Oak Run and Clover Creek to Little Cow Creek. The recommended release would have to be from the diversion dam on Oak Run. The successful downstream migration of young fish would be difficult unless the many diversions were screened. The total potential utilization of the main stream Cow Creek and Oak Run would be approximately 20,000 salmon yearly in addition to a resident population of game fish.

The reservoirs, which are planned for both the Cottonwood Creek drainage and Cow Creek, would be primarily for local irrigation purposes. Their sizes are of such magnitude, that each year the lakes would be drawn down to the minimum pool size. Winter and spring runoff would be expected to fill these reservoirs and spill some uncontrolled water each year. Minimum flows in streams below dams should be maintained when stream flow falls below the values quoted in the recommendations by added releases from storage. If at any time the minimum flow requirements are exceeded, no additional water for fish would be needed from storage. Minimum annual flows would permit utilization of the streams by spring-run, as well as fall-run salmon. The controlled flows would also allow a high survival of eggs and young fish, and would facilitate their downstream migration.

Cottonwood and Cow Creeks join the Sacramento River above the site of the proposed Iron Canyon Dam. After its construction the continued success of these streams as producers of anadromous fish would depend upon passage of adults upstream and young fish downstream past this large dam and reservoir.

SUMMARY

Proposed water conservation projects on Cottonwood and Cow Creeks are analyzed in order to give planning engineers facts regarding the present fisheries resources in these streams, and to make recommendations for protection and enhancement with water development projects.

Cottonwood Creek now supports an estimated annual king salmon spawning run of 850 fish. It is estimated that with adequate annual minimum flows this drainage could accommodate

approximately 25,000 spawners. These flows would also increase steelhead and smallmouth bass populations.

Cow Creek annually accommodates approximately 985 king salmon. An estimated 20,000 kings could utilize this drainage if minimum annual flows were adequate. Reservoirs would be fluctuated over a wide range each year, and would not be particularly suited to water-associated recreation or fishing. However, it is probable that during part of the year they would receive rather heavy recreation use from nearby centers of population.

Flows to maintain fisheries were calculated from historic data. Average daily flows in Cottonwood Creek ranged from August, 40-50 cfs to 1,675 cfs in January. Cow Creek ranged from August, 20-30 cfs to January 1,315 cfs.

Three federal reports considered enhancement flows in these Creeks. A minimum flow of 100 cfs in both Cow and Cottonwood Creeks was selected as the level which would produce the highest potential of king salmon production.

Water conservation and suitable flow regulation of Cottonwood and Cow Creeks would improve and enhance the streams for maintenance of fish life. Recreation potentials also could be expected to be increased by the creation of reservoirs and regulated streamflows. Anadromous fish production would not be adversely affected by structures because the majority of the spawning areas are found downstream from the proposed structures.

REFERENCES

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1940. An investigation of fish-salvage problems in relation to Shasta Dam. U.S.D.I., Bureau of Fish, Spec. Sci. Rept. No. 10, 200 pages.

Moffett, James W. et al

1947. Potential salmon production in relation to the Upper Sacramento River Tributary Plan (alternate to Iron Canyon Dam). U.S.D.I., Fish and Wildlife Service, 18 pages. (mimeo.)

U. S. Fish and Wildlife Service

1947. A preliminary evaluation report on the fish and wildlife aspects of the Upper Sacramento River Tributary Plan (alternate to Iron Canyon Dam) Sacramento River Basin, California. U.S.D.I., Fish and Wildlife Service, 6 pages. (mimeo.)

California Department of Water Resources

1957. The California Water Plan Bulletin Number Three, 246 pages, plus 8 plates.

State of California | The Resources Agency

M E M O R A N D U M

To : Honorable William E. Warne
Director
Department of Water Resources
1120 N Street
Sacramento, California

Date: March 24, 1964

From : Department of Fish and Game

Subject: WP - State of California, Department of Water Resources Shasta County Investigation, Bulletin No. 22

The Department of Fish and Game has received notice of the proposed public hearing on the above subject bulletin and we wish to make the following comments in connection therewith.

We understand Bulletin No. 22 is directed primarily towards the presentation of basic water supply data and its probable present and future consumptive use in Shasta County. Although a very general plan of water development is provided in connection with local water requirements, Bulletin No. 150 will largely supersede Bulletin No. 22 and treat water development in Shasta County on a much more comprehensive basis.

This Department, through the Contract Services Section, prepared Appendix D to Bulletin No. 22 which summarized the probable effects of several dams on Cow and Cottonwood Creeks. Since completion of that Appendix considerable additional study has been conducted in the area in connection with the Upper Sacramento River Basin Investigation. Following informal consultation with DWR personnel and in line with the present investigation of the Upper Sacramento River Basin the more recent fish and wildlife studies are proposed for inclusion in the fish and wildlife appendix to your Bulletin No. 150.

In view of the above circumstances the Department of Fish and Game does not propose to make an oral presentation at the hearing scheduled for March 27 on Bulletin No. 22. However, we suggest that this letter be incorporated in the final edition of Bulletin No. 22.

/s/ Harry Anderson

Deputy Director

APPENDIX E

COMMENTS OF SHASTA COUNTY

ON THE PRELIMINARY EDITION OF BULLETIN NO. 22 "SHASTA COUNTY INVESTIGATION"

PUBLIC HEARING
Joint Hearing of California Water Commission
and Department of Water Resources
Held at Courthouse, Redding, California
March 27, 1964

Statement by
Mr. Arnold Rummelsburg, Director
Shasta County Department of Water Resources

Some time ago Shasta County submitted, in writing, comments on Bulletin 22 with a request that these comments be included in the final published edition of the report. For this reason our statement today will be very brief.

We are all aware of the time factor involved in this study and the fact that the preliminary edition of the Bulletin was published in December of 1960. There has been a great deal of progress in water development in Shasta County since that time and I would like to call to your attention some of these accomplishments, many of which were recommended in Bulletin 22.

Approximately a year ago the Clear Creek Community Services District entered into a repayment contract with the Bureau of Reclamation for the Clear Creek unit of the Trinity River Project to serve the Happy Valley area. Designs are well under way and it is expected that construction of this feature will start this summer. Just last Tuesday the voters of the Bella Vista Water District by a 98 percent majority approved a repayment contract for the Cow Creek Unit of the Trinity River Project to serve the Bella Vista Water District and it is expected that construction of this feature will begin this summer as well.

A Shasta Community Services District is currently constructing a water system to take water from the Trinity River Project. The Cascade Community Services District, located south of Redding will commence construction of a domestic water system in the very near future. The Keswick Community Services District is attempting to obtain a loan for a water system through the Davis-Grunsky program and just yesterday the subcommittee of the California Water Commission was up here inspecting the Keswick area.

The Centerville Community Services District, located west of Redding is attempting to obtain financing for a water system. In the Igo-Ono area the landowners are concerned over their water problems and just last week submitted a petition for the formation of a district to the local agency formation commission. People in the Cottonwood area are concerned over water and erosion problems and have organized the Cottonwood Creek Watershed Association. Because of the competition for water in the Cow Creek area an adjudication is under way covering all portions of the Cow Creek watershed which have not already been adjudicated.

The State Water Rights Board has informed us that in all streams tributary to the Sacramento River there is no unappropriated water during the months of July and August. The Shasta County Water Agency is actively negotiating a contract with the Bureau of Reclamation to obtain water for potential water users along these streams on an exchange basis from the Central Valley Project facilities.

I call these to your attention to point out some of the things which have transpired since the preliminary edition of Bulletin 22 was published.

Since that time we know a great deal of additional data has been developed. Your department studies in the upper Sacramento River basin have refined the cost estimates on some of the projects included in Bulletin 22. From this study and your North Coastal Investigation additional information affecting Shasta County has been developed.

As stated in our formal comments which have previously been submitted, we are quite anxious that Bulletin 22 be published in its final form and that our comments be included. We feel that it is important that basic data developed in the Shasta County Investigation be made available to all those who are interested. Therefore, we feel that the various appendices to the report should be printed in several copies and be made available. We feel that this basic data has been very helpful so far and will continue to be valuable as future water projects are considered in the area.

SHASTA COUNTY

DEPARTMENT OF WATER RESOURCES

Written Comments* on

BULLETIN 22
SHASTA COUNTY INVESTIGATION

GENERAL

Bulletin 22, The Shasta County Investigation, is a cooperative study financed jointly by the County of Shasta and the State of California and conducted by the State Department of Water Resources. The major objective of the investigation is the collection and cataloging of basic information relating to the surface and ground water resources of Shasta County. It is believed that this objective has reasonably been accomplished. In the course of the study a great deal of information was developed and put together in one place and in such a manner so as to make it useful to those concerned with water development and water development projects. A summary of this information is contained in the report itself. However, much additional valuable information is contained in the various appendices to the report which we feel should be made readily available to all who could profit by it. This could be done by having this information published in accompanying reports and made available to county officials and private engineers in the area.

CHAPTER I

Soils. The report states that of the three major soil groups in Shasta County, only the recent alluvial soils are of

* Comments received 8-16-62.

major agricultural importance. Although the recent alluvial soils are the major ones developed to irrigations use at the present time, the lacustrine deposits in the Fall River area are significant, as are many of the old valley-filling soils, particularly in the Happy Valley area. According to Plate 15, a large percentage of the lands classified as potentially irrigable consist of the old valley-filling soils.

Present Development. It is stated that the average annual total farm income is $6,000,000 of which the livestock industry provides $4,900,000. It should be noted that the year 1960, showed the total income is estimated to be $11,500,000 of which $5,600,000 is attributable to livestock industry.

Industry. Since the development of this report there has been established the Calaveras Cement Plant located north of the City of Redding. This plant will be in full production by 1963, and will have a production of 1,000,000 barrels. In addition to this there is now being constructed a pulp and paper mill by the Kimberly-Clark Corporation located near Anderson. This plant will ultimately have capacities as follows:

150	tons	per	day	of	ground wood pulp
300	"	"	"	"	bleached sulfate pulp
400	"	"	"	"	printing paper
75	"	"	"	"	tissue paper.

CHAPTER II

Water Supply. Chapter 2 of the report's discussion of water supply begins by saying that the water resources of Shasta are comprised of direct precipitation, surface runoff and ground water within the county, surface and subsurface inflow to the county and imported water. It goes on to say that a portion of this water is used within the county but most of it flows from the area as surface and subsurface outflow. This is a true statement but it is certainly an understatement. We feel this point should be emphasized more specifically. As a matter of fact, farther on in the report it is stated that the mean seasonal natural runoff that originates within the county is estimated to be 5,800,000 acre-feet a year or slightly over one-fourth of the surface water resources of the Sacramento River basin. It is further stated that when contributions from watersheds outside the county are added, the estimated mean seasonal natural runoff from Shasta County is about 8,200,000 acre-feet. This is over 10 percent of the mean seasonal runoff of the entire State of California.

Under the sections of water utilization and requirements it is estimated that the present consumptive use due to the present level of development is in the order of 200,000 acre-feet. In other words, Shasta County apparently utilized approximately 2½ percent of all of the water passing the southern boundary and 3½ percent of all water which originates in the county.

Precipitation Stations. Of the 75 precipitation stations listed in the report there are only approximately 28 active at the present time. These are well distributed through the county with one exception, and that is in the Sacramento Valley core section of the county. There is a precipitation station in Redding and one in Red Bluff but nothing along the valley floor in between at the present time. It would seem then that one of the recommendations that should be made as a result of this investigation would be that a precipitation station be installed in the Anderson-Cottonwood area.

Steam Gaging Stations. One appendix which is included in the report as Appendix B is concerned with the various stream gaging stations in and adjacent to Shasta County. This appendix lists approximately 90 locations for stream gaging stations in the county. Although the information from all of these stations is quite valuable, such a large list tends to be somewhat misleading, in that many of these stations are based on weekly records, many were maintained for only a short period of time and many are not maintained at the present time. It should be pointed out that of all of those listed, there are approximately 23 active gaging stations in Shasta County at the present time. Partially as a result of this investigation, certain of these gaging stations were installed in the county and these stations are already beginning to develop valuable information.

Ground water. Any discussion of ground water is quite difficult to follow without a geologic map and geologic cross sections and this information in the form of a plate has not been included in the report. The plate showing well location and depth and elevation of ground water for the Redding ground water basin, Plates 8, 9, and 10 indicate thereon that four geologic cross sections have been made; however, they are not found at any point in the report. It is strongly recommended in the final publication of Bulletin 22, that maps showing the geology of the area, and adequate cross sections as well, be included. It is stated in the study that maps for both ground water depth and elevation were prepared for spring and fall of each year of the study. However, these maps for only one year were found in the report. It would be interesting and, we think, valuable to have this information for each year for which it was developed. In addition, more specific data on well yields would be helpful. The averages shown in Table 6 for each of the general areas can be misleading, and perhaps, there is enough information to indicate more specifically at least where certain wells of adequate yield have been developed in the past.

Quality of Ground Water. On page 47 the problem of saline ground water is discussed very briefly. This however, is a very important and serious problem in Shasta County and one which concerns us very much. It is believed that it warrants major consideration and further discussion in a report of this nature. Perhaps those areas which are general problem areas with respect to saline ground waters could be delineated on a map. It is believed however, that if the geologic map and geologic cross sections previously referred to were included in the report, this would provide sufficient information.

CHAPTER III

Water Utilization and Requirements. This chapter discusses the water utilization and requirements both under present and future conditions and states that even under ultimate conditions the net depletion of the water supply by all county uses would be a relatively small percentage of the total natural runoff originating in the county. This was referred to in previous comments. Present water resources developments are discussed in this chapter and on Table 8 the principle water service agencies in the county are delineated. This information is shown as well on Plate 14. It should be pointed out that the Burney County Water District, which serves domestic water to the Burney area was left off of Plate 14.

Present Pattern of Land Use. The pattern of land use of Shasta County has been developed by hydrographic units and summarized for the county as a whole on Table 9. This is exactly the same as Table 32 of Bulletin 58, the Northeast County Investigation. This is based on crop survey conducted during 1955 and 56. A comparison of the county totals on Table 9 with the figures published in the 1956 report of the Shasta County Agricultural Commissioner seems however, to indicate certain discrepancies. It should be noted, however, that land use figures in the agricultural commissioners report are based on all productive land, whether or not it is irrigated.

Net Irrigable Land. All of the land in Shasta County was classified as to its suitability and a factor was applied to each class of land to determine the percentage which would be irrigated and developed at some time in the future. Except for changes in the classification heading, Table 12 which indicates classification of the irrigable lands of Shasta County by topographic units is exactly the same as Table 35 in Bulletin 58. This information is shown on Plate 16. It is noted that in the legend for this plate two classifications of hilly land are indicated, one to represent hilly lands with crop adaptability not limited by the depth of effective root zone or rock in plow zone and the other with those limitations. The colors used appear to be identical and it is impossible to tell them apart on the map.

Ultimate Land Use Pattern. As stated in the report, any projection of probable ultimate crop pattern must be generalized and we, of course, recognized this. It is reasonable that crop projections at the present time would be weighted heavily in favor of the type of development currently found on the land; however, it should be pointed out that if such a projection had been made in the early 20's it is conceivable that a much larger percentage of the land would have been forecast to orchard crops and the like. In addition, we recognize that forecasts of urban and suburban land use must be general and are somewhat of a guess. We would like to suggest however, that it is very likely that considerable urban and suburban development will occur in the Olinda hydrographic unit, as this covers much of the area immediately adjacent to the City of Redding. As indicated in Table 18 of the report, no land was forecast for development in this manner. In addition, it is very likely that considerable urban and suburban development will occur in hydrographic unit 23, the Keswick hydrographic unit, particularly the area east of the river as this adjoins the Buckeye and Central Valley areas. Table 17 on page 87, "Probable Ultimate Crop Pattern" appears to contain a typographic error in the 8th column heading. This should read "Deciduous Orchard."

Recreational Land Uses. This section covers the use of land for recreation including permanent summer residences and commercial resorts and the like, and organizational camps and camping and picnicking areas and discusses the user days for these catagories. The last sentence of this section states that "large quantities of water may therefore be expected to evaporate from reservoir surfaces from within the county." This implies that substantial reservoir evaporation is caused by recreational use. Actually, recreation use of reservoirs in Shasta County is in most cases incidental to the major purposes of the reservoir and such evaporation is not caused by or a result of recreation use.

Unit Values of Use of Applied Water. The discussion of water use requirements goes into some detail regarding urban, suburban and rural water use and discusses the requirements of forest products industries and water use associated with recreation. The determination of the consumptive use of water for agricultural crops however, is discussed very briefly. This seems a bit out of proportion in that these consumptive use figures are of major importance and are, perhaps, one of the keys in determining the total water requirement for the area. A review of the literature indicates that the consumptive use figures here utilized are substantially the same as those of Bulletin 58 and Bulletin 2. We feel that this point is particularly important because of past disagreements over the unit values used for consumptive use. It is noteworthy that at the hearings held on Bulletin 58, the Northeast Counties

Investigation, Shasta County made a rather strong point of its objection to the figures for consumptive use of applied water and felt that larger values should be used. In addition to this, comments along the same lines were made by Siskiyou, Plumas, Butte and Yolo Counties and several others.

Unit Value of Consumptive Use. Because of the differences of opinion previously expressed regarding the values used for consumptive use of applied water, this has been gone into in some detail. Working very closely with the University of California Agriculture Extension Service, figures have been developed that we feel to be a satisfactory indication that the consumptive use figures should be higher than are indicated in the report. This information is attached to these comments. Although this is based on limited data and is not purported to be exact, we feel that this does provide adequate information to indicate that the figures used in Bulletin 22 should be significantly increased except for deep rooted crops in the general Redding area where precipitation is high. When appropriately modified figures have been applied to the projected crop pattern, the figure for consumptive use of applied water obtained for irrigation is approximately 400,000 acre-feet, up approximately 16 percent from the figure of 344,000 acre-feet contained in Table 27 of the report.

Reservoir Evaporation. All of the tables in the report regarding consumptive use and water requirements for Shasta County contain a column for reservoir evaporation. This would seem to indicate that this evaporation is a water requirement of

Shasta County as such. On page 104 of the report however, it is stated that approximately 95 percent of the present reservoir evaporation occurs at facilities constructed primarily to provide water for export purposes. This will also be true of a very large percentage of the evaporation which occurs under ultimate conditions. It would seem rather misleading then, to consider reservoir evaporation as a water requirement of the county but rather would seem more appropriate to set this figure up as a separate item. It is recalled that the treatment of reservoir evaporation was strongly objected to by Shasta County in its comments on Bulletin 58. This item should be considered separately from the county's water requirements, or at least covered by a footnote in the tables.

Water Requirements. When the same factors for irrigation efficiency are applied to the 400,000 acre-foot consumptive use figures that were applied to the figures shown in Table 27 a total water requirement for irrigation purposes of 780,000 acre-feet is obtained. If the county total for Table 27, Probable Ultimate Mean Seasonal Consumptive Use of Applied Water, and Table 29, Probable Ultimate Mean Seasonal Water Requirements of Shasta County are revised accordingly the results would be as follows:

Estimate Mean Seasonal
Consumptive Use & Water Requirements for Shasta County

	Consumptive Use of Applied Water	Water Requirements
Irrigated Lands	400,000	780,000
Meadow Pasture	25,000	25,000
Urban, Suburban & Rural Domestic	37,000	73,000

Estimate Mean Seasonal
Consumptive Use & Water Requirements for Shasta County
(Cont. 1)

	Consumptive Use of Applied Water	Water Requirements
Forest Products Industries	10,000	89,000
Recreation Areas	13,000	13,000
TOTAL	485,000	980,000
Net Reservoir Evaporation (Not a Shasta County Water Requirement)	153,000	153,000
TOTAL	638,000	1,133,000

Bulletin 22 shows water requirements 872,000 acre-feet per year plus reservoir evaporation of 153,000 acre-feet per year. It should be pointed out that while ultimate water requirements for irrigation purposes may be determined in a relatively straightforward manner, industrial requirements (as forest products) could easily be much different from the estimate figures. We believe that the total ultimate water requirements could easily be at least 10 percent to 15 percent greater than those indicated in Bulletin 22.

CHAPTER IV

Plans for Water Development. This chapter discusses possible sources of water supply to meet the future demands for each of the 31 service areas delineated within the county. For each potential service area there is a brief description together with a discussion of the probable water needs and suggestions are made as to where this water could be obtained. There appears to be a discrepancy for many of the service areas between the figures quoted in the text for supplemental water requirements and the total delineated on Table 35 of this report. An analysis indicates that in the case of 12 service areas, the water requirements for either domestic or recreation uses were not included in the text. In the case of another six or seven service areas the item shown on Table 35 for the meadow pasture was not included in the text. It would seem that the supplemental requirement discussed for each service area would agree with the figures delineated in the table which was developed in Chapter III.

Reservoir Yield Studies. The report states that in general the yields of the various reservoirs were computed on the basis of full flows of the stream at the damsite without reduction of uses of water that can be made under existing rights. If this is the case, then the yield developed at any reservoir site would be the yield of the entire reservoir-stream system rather than that of the reservoir itself. In order to determine the cost of new water provided by the reservoir it would be necessary to divide the total project cost by the project yield rather than the yield of the project-stream system.

Ground Water. Ground water is recommended as the source of supply for eight of the service areas in the county. Six of these are located in the mountainous regions, the Modoc plateau, Hat Creek and Burney areas. In the case of three of these service areas the report recommends test drilling in order to varify the ground water potential of the area. Perhaps some suggestions or guides to an appropriate test drilling program should be suggested.

Ground water is also recommended as the most suitable source of supply for the Cottonwood Creek service area. There may be some question about this however, as although ground water appears to be available in the eastern section of the Cottonwood Creek basin, it is questionable whether it can be developed satisfactorily in the area west of Dry Creek.

Major Storage Projects. The reports list 16 different possibilities for major storage projects within the county which are considered to be feasible from a physical point of view. For each of these projects estimates were made of the cost of the project and the cost per acre-foot of yield for what was considered to be the optimum sized project for the particular site under consideration. As previously mentioned, it was stated that yields were determined without reductions for prior rights, and consequently the cost of new water developed by the project would be higher than the figures shown in the report.

The department's progress report on their Upper Sacramento River Basin Investigation which was published in May of 1961 has considered three of these reservoir sites; Hulen, Millville and Bella Vista. This report showed cost figures considerably different from those indicated in Bulletin 22 for these reservoirs. Following is a comparison:

Project	Capacity Acre-Ft.	Yield Acre-Ft.	Cost Per Acre Feet of Yield
Bulletin 22			
Millville	124,000	47,500	$10.80
Bella Vista	196,000	76,000	12.00
Hulen	92,000	21,200	14.00

Project	Capacity Acre-Ft.	Yield Acre-Ft.	Cost Per Acre Feet of Yield
Upper Sacto. Investigation			
Millville	72,000	40,000	$ 7.30
Bella Vista	229,000	82,000	10.50
Hulen	94,000	60,000	4.90

Because of the differences in cost obtained, particularly of the Hulen and Millville sites, the lower costs should be a least noted in the final report. From a practical standpoint, it is doubtful if either Bella Vista Reservoir or Mistletoe Reservoir on Churn Creek should receive consideration simply because of their location with respect to present and future suburban type land use.

All of the costs presented are based on financing projects with an interest rate of 4 percent. Somewhere it should be pointed out that it is at times possible to obtain financing for irrigation projects through federal programs under more favorable terms. It should also be pointed out that multiple purpose projects may be possible, through the Davis-Grunsky program or other means by which the cost of water could be reduced.

It is noted that the Iron Canyon Reservoir, together with other projects which are export in nature are included on Plate 30. If these projects are included on the plate, there should be some discussion of them in the body of the report.

COMMENTS ON CONSUMPTIVE USE OF WATER IN SHASTA COUNTY

The term "consumptive use" is defined as the total amount of water taken up by vegetation for transpiration or building of plant tissue plus the evaporation of soil moisture, snow or intercepted precipitation. A proper evaluation of consumptive use is of cardinal importance in developing the water requirement for any area which may be under study.

The total amount of water required by a given crop and consumptively used thereby is generally supplied from two sources. The first of these is from precipitation and consists of both the precipitation used during the period of its occurrence and that precipitation which is stored in the soil within the root zone of any particular crop under consideration, and later withdrawn from the soil. When precipitation does not occur at the times and in the quantity needed, the additional water required to satisfy the demand of crops must be applied by artificial means and the amount which must be applied is fundamental in determining the water requirements of any crop or area.

Bulletin 22, the Shasta County Investigation, which was published by the State Department of Water Resources in December of 1960, contains on Table 21, estimates of unit values of consumptive use of applied water for various irrigated crops, for each hydrographic unit of the county. These figures were obtained by using the Blaney-Criddle method which, simply stated, is a correlation of consumptive use with the climatic factors of mean monthly temperature and monthly percentage of daylight hours, with an allowance for effective precipitation. This is the same data as that contained in Table 44 or 58, the Northeast Counties Investigation. Subsequent to the publishing of the preliminary edition of Bulletin 58, and at the public hearings held on it, there was considerable objection to the values used for consumptive use of applied water, both on the part of Shasta County and several others, and the opinion was expressed that the values were considerably lower than they should be.

It is the purpose of this report to attempt to look into the consumptive use figures for the major crops of this area, primarily to have some objective basis for determining whether or not we agree with the values used by the State.

For this analysis two crops were selected, alfalfa and irrigated pasture. These two crops represent about 70 percent of the total ultimate irrigated land use in Shasta County as projected in Bulletin 22. Consumptive use was determined on the basis of the difference in evaporation between black and white atmometers, which in effect is a correlation of consumptive use with the climatic factor of solar radiation. The atmometer data was obtained from the State Department of Water Resources. The coefficient applied to the atmometer readings was obtained from work done at the University of California at Davis.

Table 1 shows a compilation of the atmometer data for the seven month growing season for several stations which have been designated the "Redding Group" and indicates the monthly consumptive use for this group and a total consumptive use during the growing season of 3.7 feet for either alfalfa or irrigated pasture. This is identical to the total consumptive use figure shown for these crops in Table 113 of Bulletin 2. Table 2 shows the consumptive use for the same crops for the "Fall River Group" stations for a five month growing season, and indicates a seasonal value of 2.9 feet. This agrees quite well with the comparable figure of 3.0 feet shown in Table 113 of Bulletin 2.

After determining the total consumptive use during the growing season, the breakdown between effective precipitation and consumptive use of applied water is obtained by working out a "water balance" for a particular crop, and for a particular type of soil for the entire year. In order to do this the average precipitation, soil moisture capacity, root depth, and an estimate of consumptive use during the non-cultural period must be determined. Precipitation at Redding and Fall River are shown on Table 3 and were obtained from climatological data of the United States Weather Bureau. The other items mentioned were estimated on the basis of discussions with representatives of the Shasta County Farm Advisors office and the extension irrigationist of the University of California Agricultural Extension Service at Davis.

Table 6 through 9 are "water balances" for the two crops under consideration for both the Redding and Fall River areas which are based on typical conditions for the crops and areas under consideration. A summary of the results, compared with the consumptive use and effective precipitation figures used by the State in Bulletin 2, 58 and 22 (all three state bulletins have identical figures), for comparable crops in comparable areas, is as follows:

AREA	ALFALFA Effective Precipitation	ALFALFA C. U. of Applied Water	ALFALFA Total Cumulative Use	PASTURE Effective Precipitation	PASTURE C. U. of Applied Water	PASTURE Total Cumulative Use
Redding Area						
This Study	1.6	2.1	3.7	1.1	2.6	3.7
State Bulletins	1.7	2.0	3.7	1.5	2.2	3.7
Fall River Area						
This Study	1.0	1.9	2.9	0.7	2.2	2.9
State Bulletins	1.6	1.4	3.0	1.4	1.6	3.0

It is seen that although there is a satisfactory agreement with respect to total consumptive use, there is significant disagreement as to the portion of this consumptive use which is satisfied by normal precipitation and that which must be satisfied by applied water. In the case of alfalfa growing in the Redding area, there is satisfactory agreement for all figures.

It appears from an analysis of the data that in the case of a deep-rooted crop such as alfalfa growing in an area where there is sufficient precipitation, the method of analysis used here and that used by the State gives satisfactory agreement with respect to the amount of precipitation which can be utilized. In the case of the Fall River area, and with crops of limited root depth, there is not a satisfactory agreement and values approximately 1/3 greater than those contained in the state bulletins are indicated.

State Water Resources Board. Bulletin 2 Water Utilization and Requirements in California. 1955.

Veihmeyer, Halkins and Hendrickson. Determining Water Needs for Crops from Climatic Data. Hilgardia Vol. 24 No. 9 Dec. 1955.

State Department of Water Resources. Bulletin 58. Northeast Counties Investigation. December 1957 (Preliminary Draft).

State Department of Water Resources. Agroclimatic Monitoring Program in California. March 1960.

TABLE 1

ATMOMETER DATA for STATIONS in REDDING GROUP

		Monthly Black minus White Atmometer Evaporation (in milliliters)							
Station	Year	March	April	May	June	July	Aug	Sept	Oct
Redding 6 SE	1955	-	-	578	613	640	691	490	195
" "	1956	-	-	464	564	607	548	430	-
" "	1957	-	432	461	622	597	485	379	252
" "	1958	-	-	506	510	571	457	-	-
Redding Stayer	1958	-	-	-	-	-	-	500	397
" "	1959	-	449	491	633	739	602	456	396
" "	1960	-	373	470	632	677	567	463	316
Redding Airport	1957	-	418	427	474	-	554	324	275
Redding Ranger Sta.	1955	-	345	529	576	607	538	477	387
TOTAL Redding Group Number of years		- -	2287 6	3926 8	4624 8	4438 7	4442 8	3519 8	2218 7
Average Redding Group		-	381	491	578	634	555	440	317

Consumptive Use for Month (inches) (Factor = 0.0134)	5.1	5.6	7.7	8.5	7.4	5.9	4.3

Total 3.7 ft.

TABLE 2

ATMOMETER DATA for STATIONS in FALL RIVER GROUP

		Monthly Black minus White Atmometer Evaporation (in milliliters)						
Station	Year	March	April	May	June	July	Aug	Sep
Fall River Intake	1956	-	-	-	512	575	497	51
" " "	1957	-	-	408	581	-	-	-
Fall River R. S.	1955	-	-	474	534	594	628	47
" " "	1956	-	-	-	536	612	563	45
" " "	1957	-	-	493	554	508	513	41
Fall River 4NW	1958	-	-	-	-	-	384	38
" " "	1959	-	-	-	577	596	503	37
McArthur 2SF	1955	-	-	-	-	-	619	51
" "	1956	-	-	428	503	591	540	44
Pittville 1S	1956	-	-	-	-	-	537	43
" "	1957	-	-	448	626	641	549	45
" "	1958	-	-	-	474	579	602	-
" "	1959	-	-	-	606	659	646	48
TOTAL Fall River Group		-	-	2251	5503	5355	6581	495
Number of years		-	-	5	10	9	12	1
Average Fall River Group		-	-	450	550	595	548	45

Consumptive use for month (inches) (Factor = 0.0134): May 6.0, June 7.4, July 8.0, Aug 7.4, Sep 6.

Total 2.9 ft

TABLE 3

Mean Monthly Precipitation

Shasta County Stations

Month	Redding	Fall River
January	7.4	2.6
February	5.4	3.0
March	5.1	2.3
April	3.1	1.7
May	1.7	1.3
June	1.1	0.7
July	0.1	0.2
August	0.2	0.2
September	0.3	0.4
October	2.2	1.5
November	4.1	2.0
December	7.9	3.1
TOTAL	38.6	19.0
Years of Record	86	22

TABLE 4

Estimated Moisture Holding Capacities of Soils

Type of Soil	Moisture Holding Capacity (in. per ft. of soil)
Sand	1
Sandy Loam	1½
Clay Loam	2
Clay	2½

TABLE 5

Estimated Depth of Root Zones

Crop	Depth of Root Zone
Irrigated Pasture (Ladino Clover)	2-3 ft.
Alfalfa	7 ft.

TABLE 6

COUNTY of SHASTA

DEPARTMENT of WATER RESOURCES

Water Balance

Crop Alfalfa Root Depth 7.0 ft.

Soil Type Sandy Loam Moisture Capacity 1.5 in. per ft.

Total Storage Capacity of Soil 10.5 inches.

Precipitation Station Redding

Consumptive Use Station Redding Group

Growing season 4/1 to 10/31

C.U. During noncultural period 2.0 in. per month when available

Month	Precipitation	Soil Storage at end of month	Consumptive Use	Effective Precipitation	Deficiency During Month	Cumulative Deficiency
Jan	7.4	10.5	2.0	4.5		
Feb	5.4	10.5	2.0	2.0		
Mar	5.1	10.5	2.0	2.0		
Apr	3.1	8.5	5.1	3.1		
May	1.7	4.6	5.6	1.7		
June	1.1	0	7.7	1.1	2.0	2.0
July	0.1	0	8.5	0.1	8.4	10.4
Aug	0.2	0	7.4	0.2	7.2	17.6
Sept	0.3	0	5.9	0.3	5.6	23.2
Oct	2.2	0	4.3	2.2	2.1	25.3
Nov	4.1	2.1	2.0	4.1		
Dec	7.9	8.0	2.0	7.9		
TOTAL	38.6		54.5	29.2	25.3	

C.U. of applied water	2.1 ft
Effective precipitation used during cultural period	1.6 "
Total C.U. during cultural period	3.7 "

TABLE 7

COUNTY of SHASTA

DEPARTMENT of WATER RESOURCES

Water Balance

Crop Irrigated Pasture Root Depth 2.5 ft

Soil Type Clay Loam Moisture Capacity 2.0 in. per ft

Total Storage Capacity of Soil 5.0 inches.

Precipitation Station Redding

Consumptive Use Station Redding Group

Growing Season 4/1 to 10/31

C.U. During noncultural period 2.0 inches per month when available

Month	Precipitation	Soil Storage at end of month	Consumptive Use	Effective Precipitation	Deficiency During Month	Cumulative Deficiency
Jan	7.4	5.0	2.0	2.0		
Feb	4.5	5.0	2.0	2.0		
Mar	5.1	5.0	2.0	2.0		
Apr	3.1	3.0	5.1	3.1		
May	1.7	0	5.6	1.7	0.9	0.9
June	1.1	0	7.7	1.1	6.6	7.5
July	0.1	0	8.5	0.1	8.4	15.9
Aug	0.2	0	7.4	0.2	7.2	23.1
Sept	0.3	0	5.9	0.3	5.6	28.7
Oct	2.2	0	4.3	2.2	2.1	30.8
Nov	4.1	2.1	2.0	4.1		
Dec	7.9	5.0	2.0	4.9		
TOTAL	38.6		54.5	23.7	30.8	

C.U. of applied water 2.6 ft
Effective precipitation used during cultural period 1.1 "

Total C.U. during cultural period 3.7 "

TABLE 8

COUNTY of SHASTA

DEPARTMENT of WATER RESOURCES

Water Balance

Crop Alfalfa Root Depth 7.0 ft.

Soil Type Sandy Loam Moisture Capacity 1.5 in. per ft.

Total Storage Capacity of Soil 10.5 inches.

Precipitation Station Fall River

Consumptive Use Station Fall River Group

Growing Season 5/1 to 9/30

C.U. During noncultural period 1.0 in. per month when available

Month	Precipitation	Soil Storage at end of month	Consumptive use	Effective Precipitation	Deficiency During Month	Cumulative Deficiency
Jan	2.6	5.2	1.0	2.6		
Feb	3.0	7.2	1.0	3.0		
Mar	2.3	8.5	1.0	2.3		
Apr	1.7	9.2	1.0	1.7		
May	1.3	4.5	6.0	1.3		
June	0.7	0	7.4	0.7	2.2	2.2
July	0.2	0	8.0	0.2	7.8	10.0
Aug	0.2	0	7.4	0.2	7.2	17.2
Sept	0.4	0	6.0	0.4	5.6	22.8
Oct	1.5	0.5	1.0	1.5		
Nov	2.0	1.5	1.0	2.0		
Dec	3.1	3.6	1.0	3.1		
TOTAL	19.0		41.8	19.0	22.8	

C.U. of applied water	1.9 ft
Effective precipitation used during cultural period	1.0 "
Total C.U. during cultural period	2.9 "

TABLE 9

COUNTY of SHASTA

DEPARTMENT of WATER RESOURCES

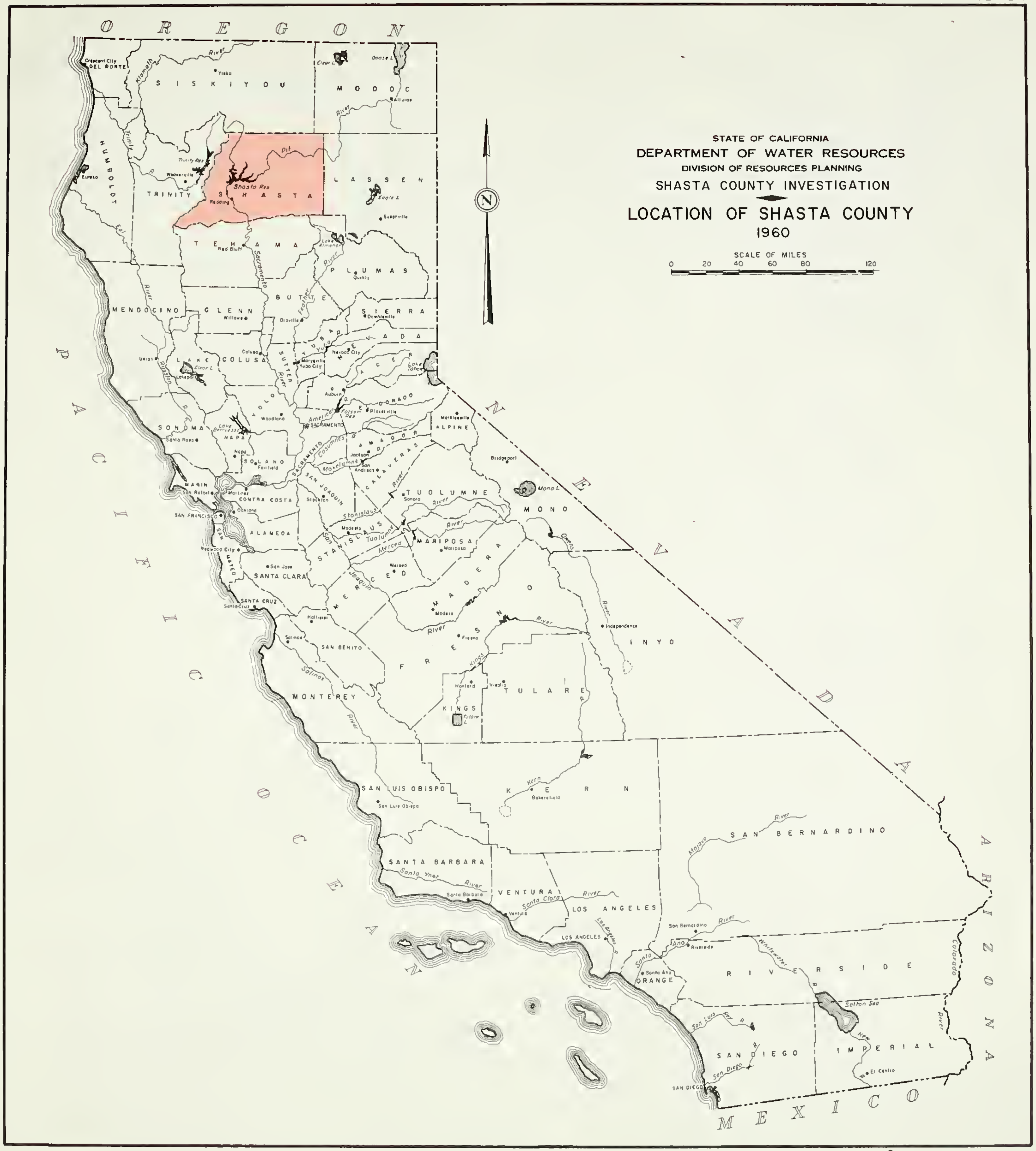
Water Balance

Crop ___Irrigated Pasture___ Root Depth ___2.5___ ft.
Soil Type ___Clay Loam___ Moisture Capacity ___2.0___ in. per ft.
Total Storage Capacity of Soil ___5.0___ inches.
Precipitation Station ___Fall River___
Consumptive Use Station ___Fall River Group___
Growing Season 5/1 to 9/30
C. U. During noncultural period 1.0 in. per month when available

Month	Precipi-tation	Soil Stor-age at end of month	Consump-tive Use	Effective Precipi-tation	Deficiency During Month	Cumula-tive De-ficiency
Jan	2.6	5.0	1.0	2.4		
Feb	3.0	5.0	1.0	1.0		
Mar	2.3	5.0	1.0	1.0		
Apr	1.7	5.0	1.0	1.0		
May	1.3	0.3	6.0	1.3		
June	0.7	0	7.4	0.7	6.4	6.4
July	0.2	0	8.0	0.2	7.8	14.2
Aug	0.2	0	7.4	0.2	7.2	21.4
Sept	0.4	0	6.0	0.4	5.6	27.0
Oct	1.5	0.5	1.0	1.5		
Nov	2.0	1.5	1.0	2.0		
Dec	3.1	3.6	1.0	3.1		
TOTAL	19.0		41.8	14.8	27.0	

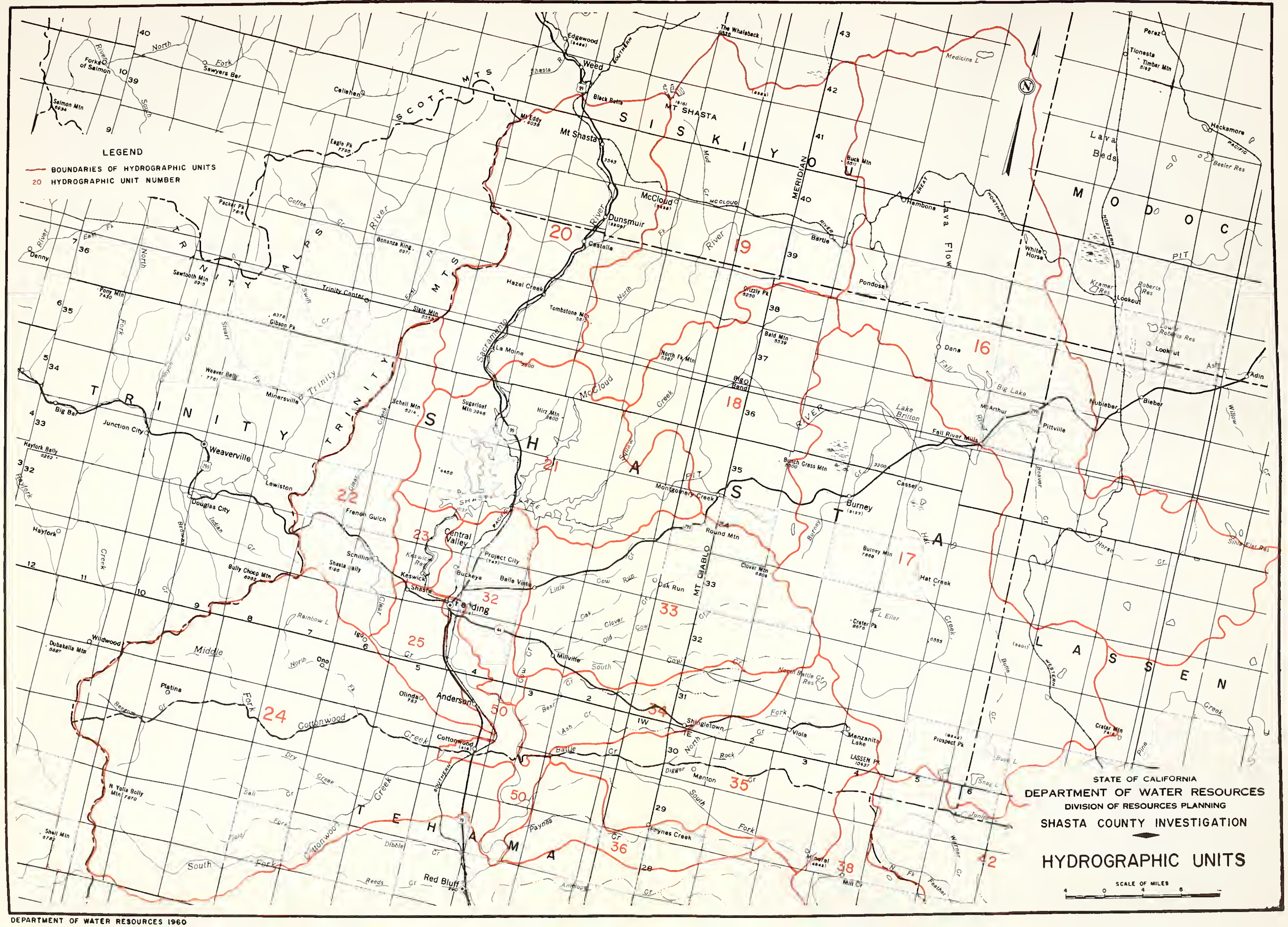
C.U. of applied water 2.2 ft
Effective precipitation used during cultural period 0.7 "

Total C.U. During Cultural Period 2.9 "

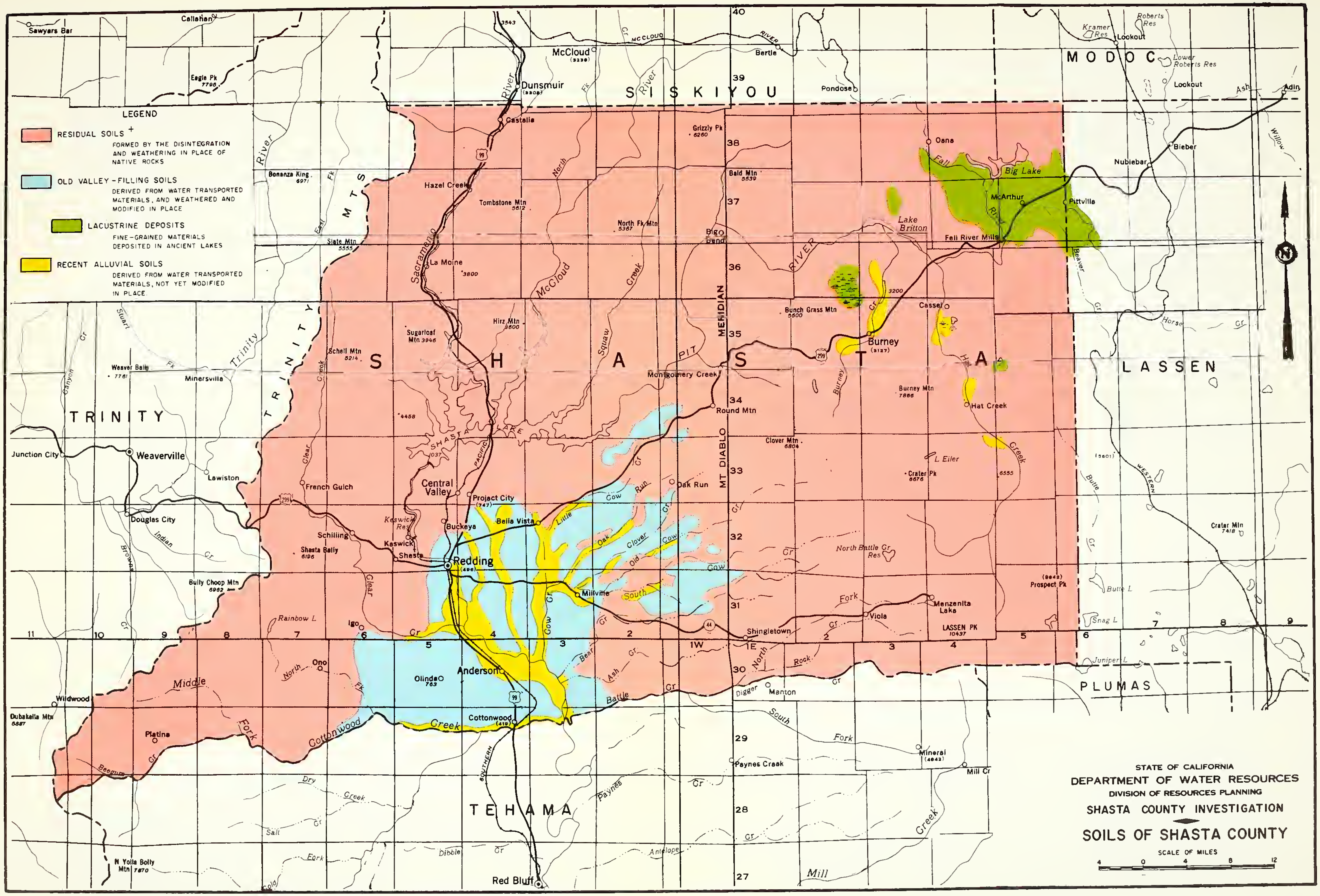

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA COUNTY INVESTIGATION
LOCATION OF SHASTA COUNTY
1960
SCALE OF MILES
0 20 40 60 80 120
N
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
LAKE
COLUSA
SUTTER
YUBA
NEVADA
PLACER
YOLO
EL DORADO
SONOMA
NAPA
ALPINE
SOLANO
SACRAMENTO
AMADOR
CALAVERAS
MARIN
CONTRA COSTA
SAN JOAQUIN
TUOLUMNE
MONO
ALAMEDA
STANISLAUS
MARIPOSA
SAN MATEO
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
FRESNO
INYO
SAN BENITO
MONTEREY
KINGS
TULARE
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
SAN FRANCISCO
Shasta Res
Redding
Pit
Sacramento
Feather
Salton Sea
Colorado
Lake Tahoe
Mono L

HYDROGRAPHIC UNITS

16 MC ARTHUR
17 HAT CREEK
18 MONTGOMERY CREEK
19 MC CLOUD RIVER
20 DUNSMUIR
21 SHASTA LAKE
22 CLEAR CREEK
23 KESWICK
24 COTTONWOOD CREEK
25 OLINDA
32 STILLWATER PLAINS
33 COW CREEK
34 BEAR CREEK
35 BATTLE CREEK
38 MILL CREEK
42 NORTH FORK FEATHER RIVER
50 ANDERSON



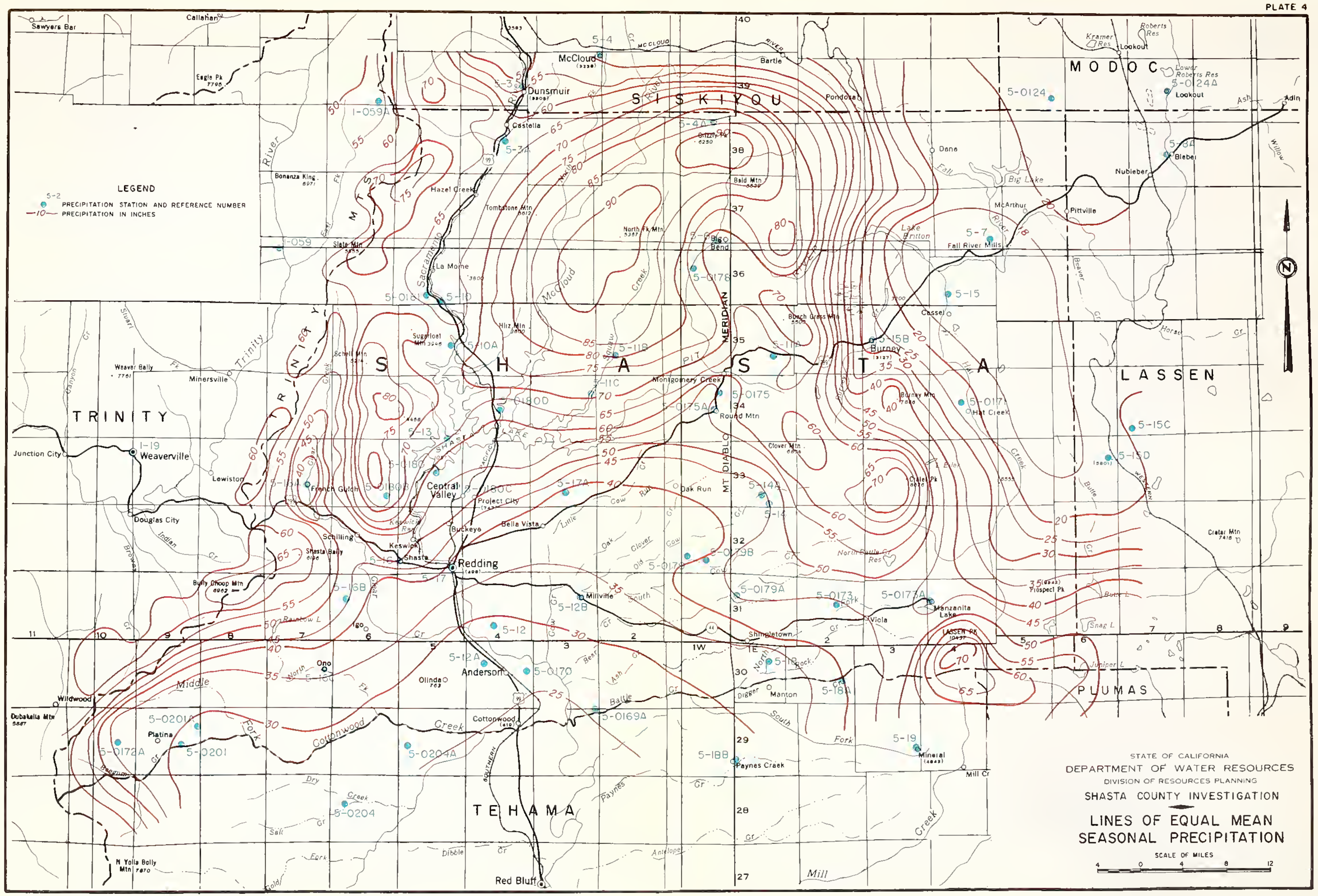
DEPARTMENT OF WATER RESOURCES 1960


LEGEND
RESIDUAL SOILS +
FORMED BY THE DISINTEGRATION AND WEATHERING IN PLACE OF NATIVE ROCKS
OLD VALLEY-FILLING SOILS
DERIVED FROM WATER TRANSPORTED MATERIALS, AND WEATHERED AND MODIFIED IN PLACE
LACUSTRINE DEPOSITS
FINE-GRAINED MATERIALS DEPOSITED IN ANCIENT LAKES
RECENT ALLUVIAL SOILS
DERIVED FROM WATER TRANSPORTED MATERIALS, NOT YET MODIFIED IN PLACE
S H A S T A
S I S K I Y O U
M O D O C
L A S S E N
P L U M A S
T E H A M A
T R I N I T Y
T R I N I T Y M T S
MT DIABLO MERIDIAN
Redding
Anderson
Cottonwood
Burney
McArthur
Fall River Mills
Big Lake
Dunsmuir
McCloud
Castella
Weaverville
Red Bluff
Shasta Lake
LASSEN PK 10437
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA COUNTY INVESTIGATION
SOILS OF SHASTA COUNTY
SCALE OF MILES
4 0 4 8 12

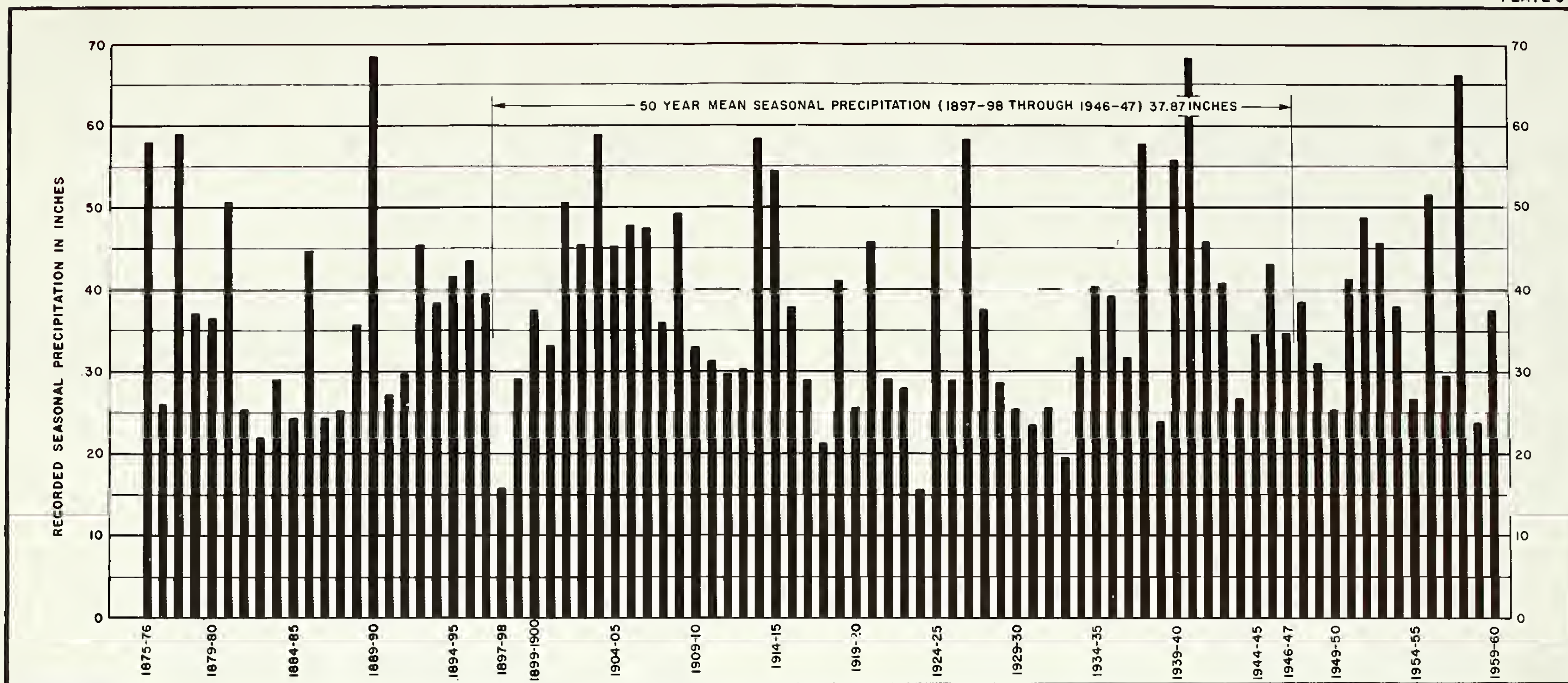
PRECIPITATION STATIONS

1-059	TRINITY CENTER RANGER STATION	5-4	MC CLOUD
1-059A	MUMBO BASIN	5-4A	STOUT'S MEADOW
1-19	WEAVERVILLE RANGER STATION	5-6	BIG BEND
5-0124	DAY	5-7	FALL RIVER MILLS INTAKE
5-0124A	LOOKOUT	5-8A	BIEBER (CORY)
5-0169A	COLEMAN FISH HATCHERY	5-10	DELTA
5-0170	GILMAN RANCH	5-10A	LAKESHORE
5-0171	HAT CREEK RANGER STATION	5-11A	BUCKHORN
5-0172A	HARRISON GULCH RANGER STATION	5-11B	SQUAW CREEK GUARD STATION
5-0173	MACUMBER	5-11C	SQUAW CREEK RANGER STATION
5-0173A	MANZANITA LAKE	5-12	CHURN CREEK
5-0175	MONTGOMERY CREEK #2 SSW	5-12A	ANDERSON (BARRY)
5-0175A	ROUND MOUNTAIN	5-12B	MILLVILLE
5-0178	PIT RIVER POWERHOUSE #5	5-13	KENNETT
5-0179	ST. VRAIN RANCH	5-14	KILARC FOREBAY
5-0179A	INWOOD	5-14A	KILARC POWERHOUSE
5-0179B	SEITZ	5-15	HAT CREEK POWERHOUSE #1
5-0180	SHASTA DAM	5-15B	BURNEY
5-0180B	IRON MOUNTAIN #2	5-15C	BLACK'S MOUNTAIN
5-0180C	TOYON (GOVERNMENT CAMP)	5-15D	BLACK'S MOUNTAIN BRANCH
5-0180D	TURNTABLE CREEK	5-16	SHASTA
5-0181	VOLLMERS	5-16A	FRENCH GULCH
5-0201	BEEGUM	5-16B	IGO (NORTHWEST)
5-0201A	WILLIAMS RANCH	5-16C	ONO
*5-0201B	SADDLE CAMP RANGER STATION	5-17	REDDING FIRE STATION #2
5-0204	ROSEWOOD	5-17A	BACKBONE
5-0204A	FERGUSON RANCH	5-18	VOLTA POWERHOUSE
*5-2	MT. SHASTA SLOPE	5-18A	FORWARD MILL
*5-2A	MT. SHASTA SLOPE	5-18B	PAYNES CREEK
5-3	DUNSMUIR RANGER STATION	5-19	MINERAL
5-3A	CASTELLA	*5-20	CHESTER
		*5-24	RED BLUFF AIRPORT

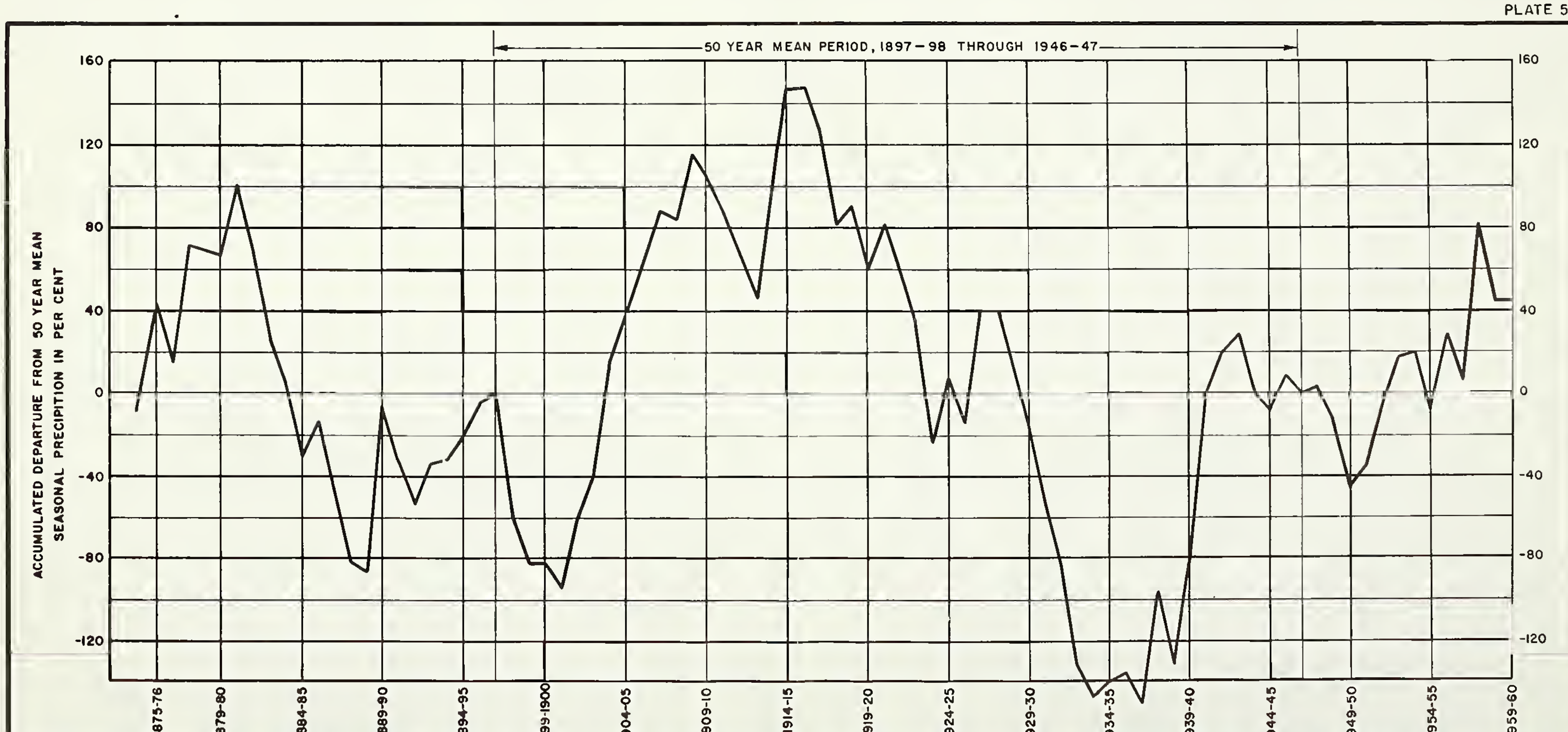
* THESE STATIONS ARE NOT DELINEATED.



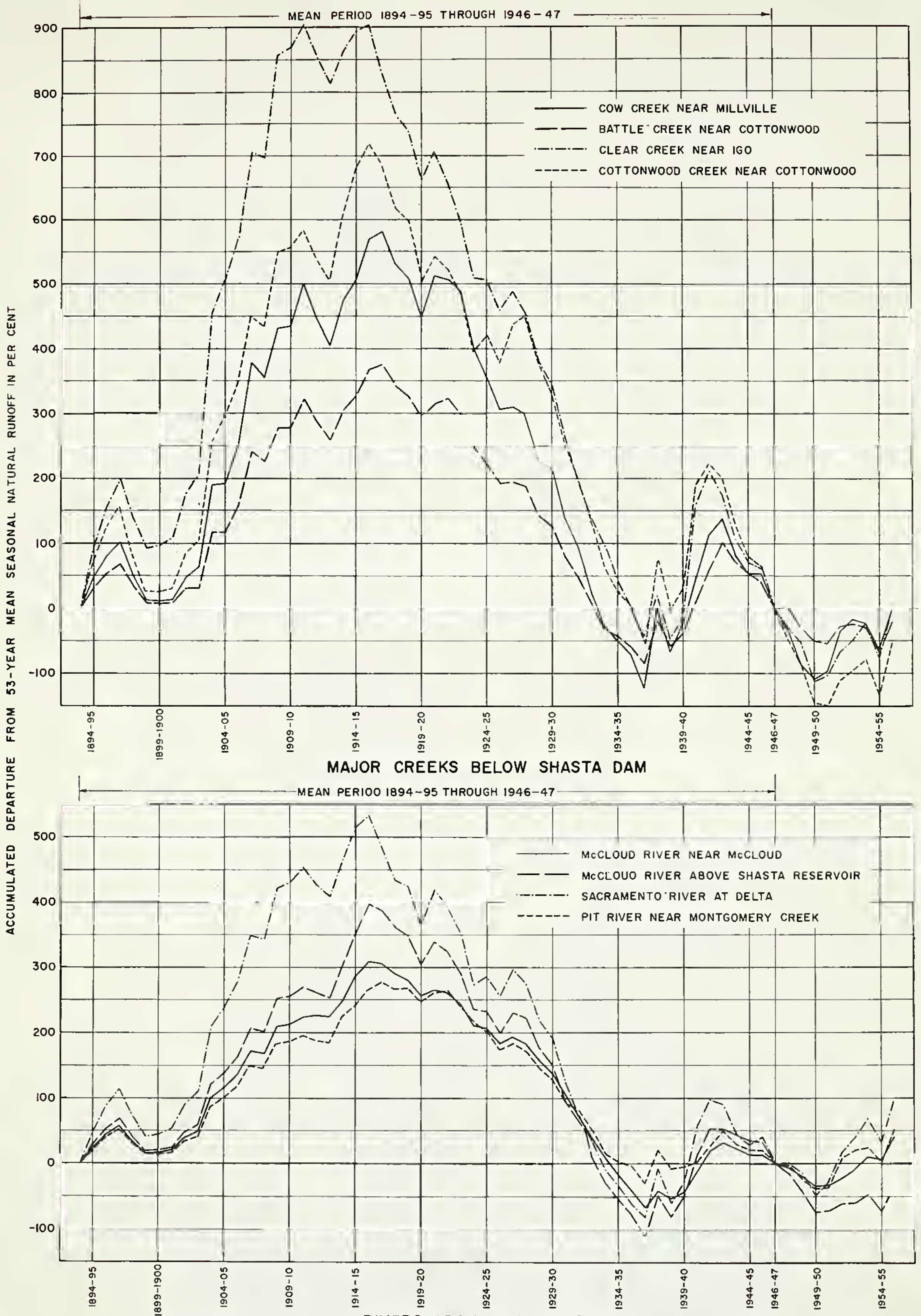
DEPARTMENT OF WATER RESOURCES 1960



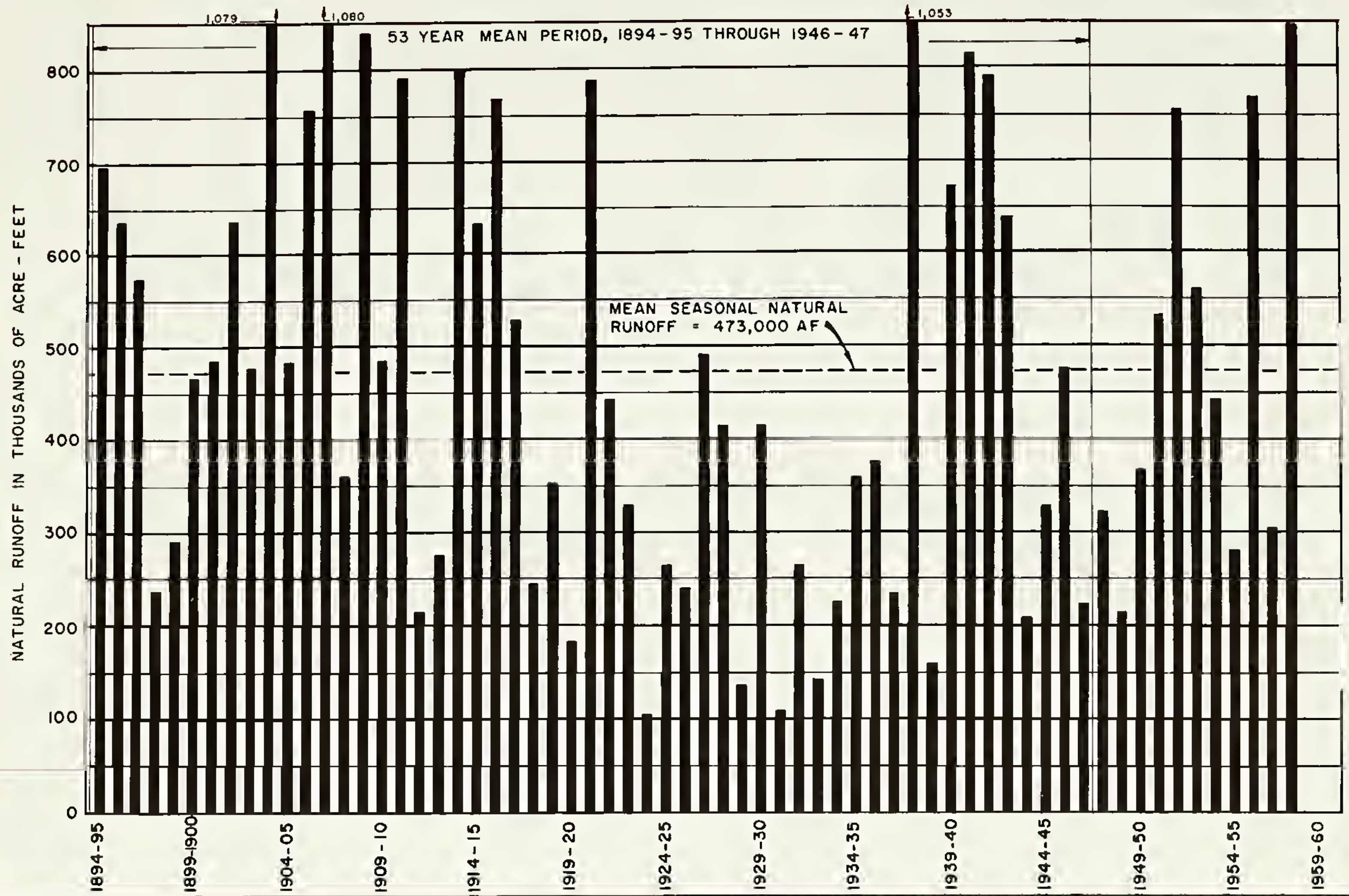
RECORDED SEASONAL PRECIPITATION AT REDDING



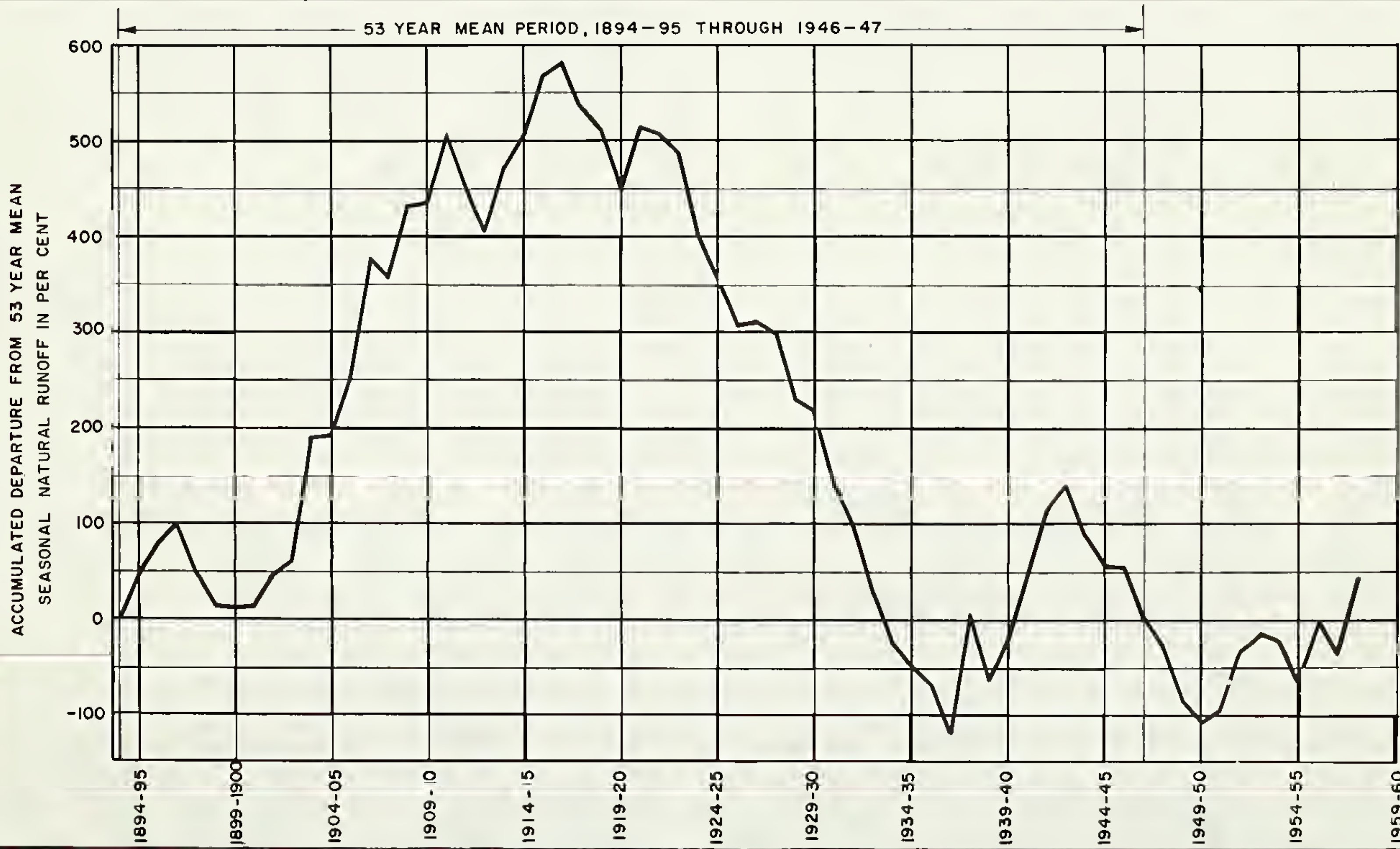
ACCUMULATED DEPARTURE FROM MEAN SEASONAL PRECIPITATION AT REDDING



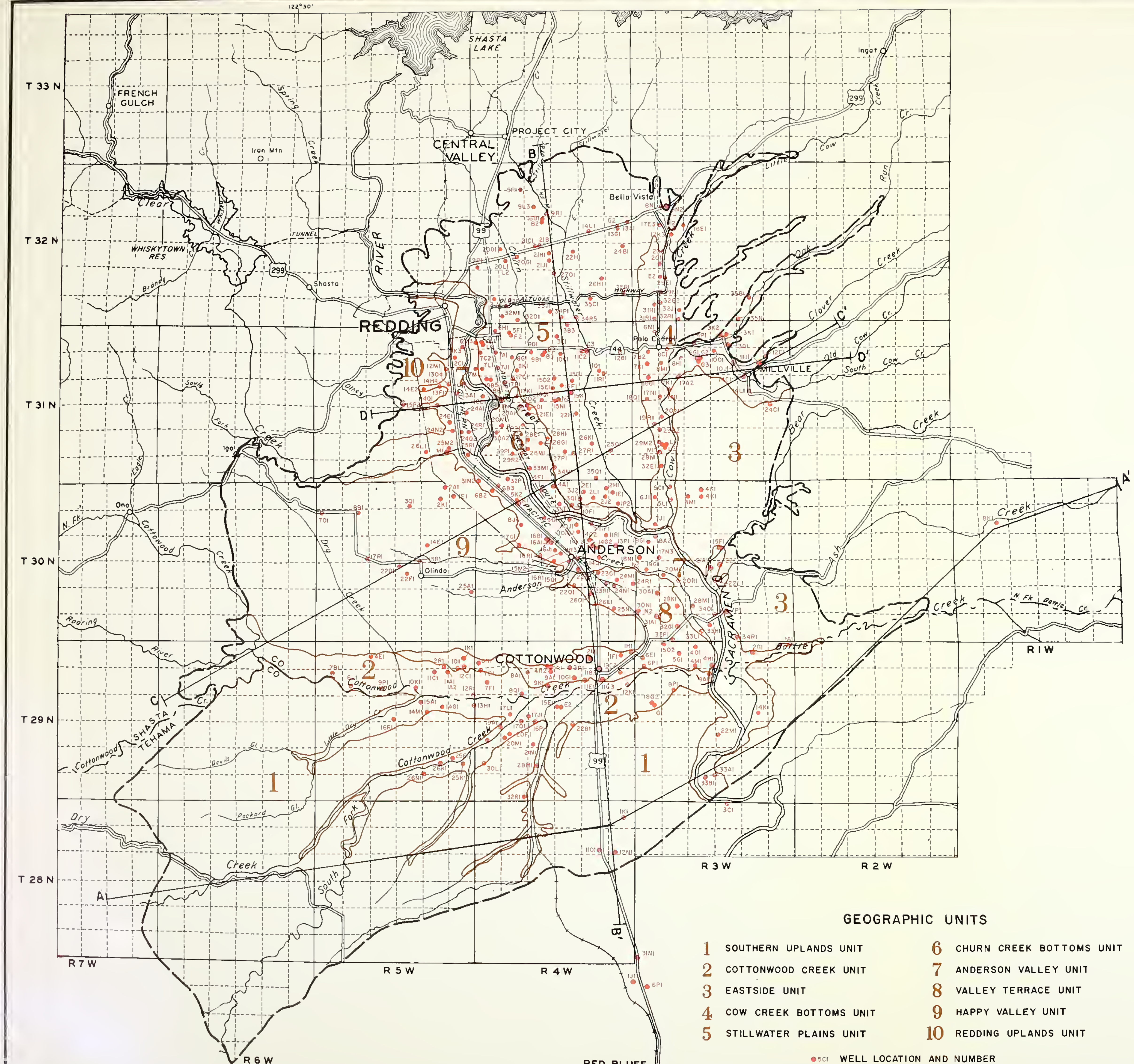
ACCUMULATED DEPARTURE FROM MEAN SEASONAL NATURAL RUNOFF
OF STREAMS IN SHASTA COUNTY

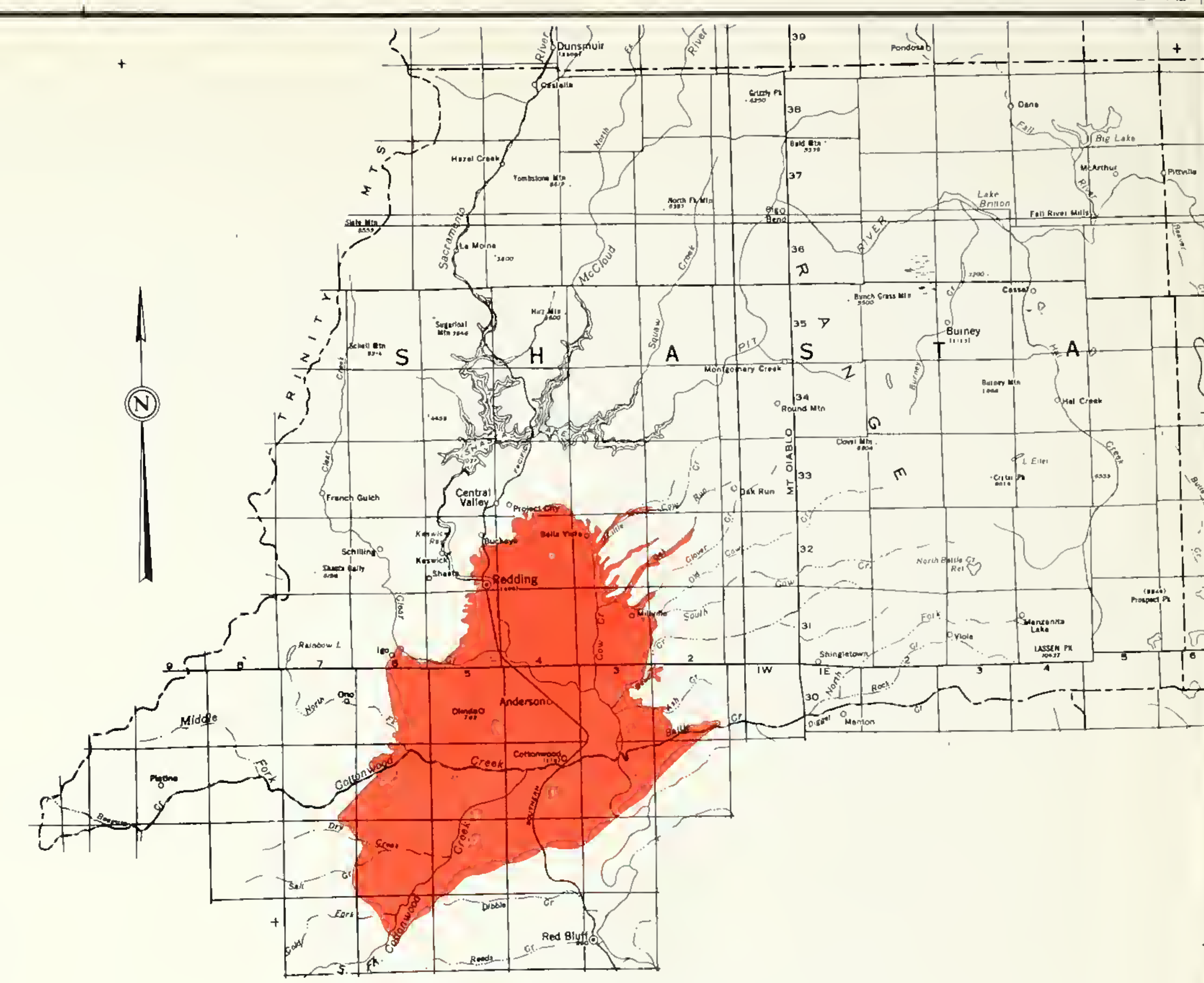


ESTIMATED SEASONAL NATURAL RUNOFF OF COW CREEK NEAR MILLVILLE



ACCUMULATED DEPARTURE FROM MEAN SEASONAL NATURAL RUNOFF OF COW CREEK NEAR MILLVILLE





LOCATION MAP

GEOGRAPHIC UNITS

1 SOUTHERN UPLANDS UNIT
2 COTTONWOOD CREEK UNIT
3 EASTSIDE UNIT
4 COW CREEK BOTTOMS UNIT
5 STILLWATER PLAINS UNIT
6 CHURN CREEK BOTTOMS UNIT
7 ANDERSON VALLEY UNIT
8 VALLEY TERRACE UNIT
9 HAPPY VALLEY UNIT
10 REDDING UPLANDS UNIT

5CI WELL LOCATION AND NUMBER
A—A' LOCATION OF GEOLOGIC CROSS SECTION

KEY TO WELL LOCATION NUMBERS

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

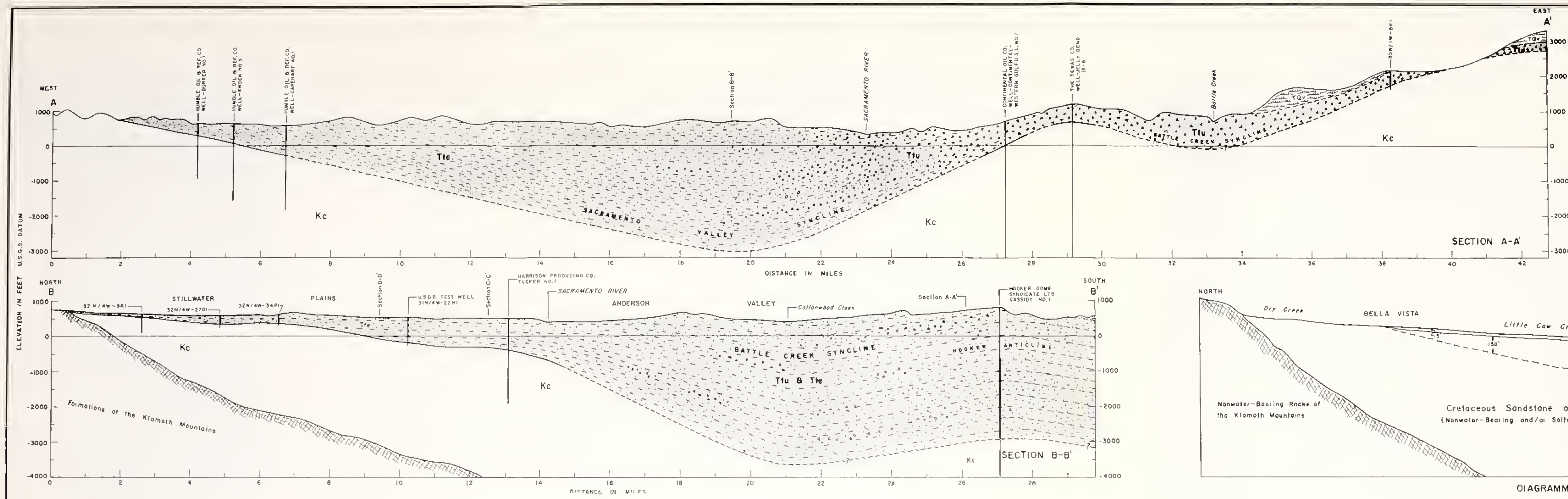
Location Numbers are designated by Township, Range, Section and 1/16 Section. Sixteenth sections are indicated by letters in accordance with diagram above. Points within the same sixteenth section are numbered serially (ie: 1, 2, 3, etc.). Thus a point having the following location number, 16N./1W.-28F2, is the second point located in the the S.E. 1/4 of the N.W 1/4 of section 28, Township 16 North, Range 1W.

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SHASTA COUNTY INVESTIGATION

REDDING GROUND WATER BASIN

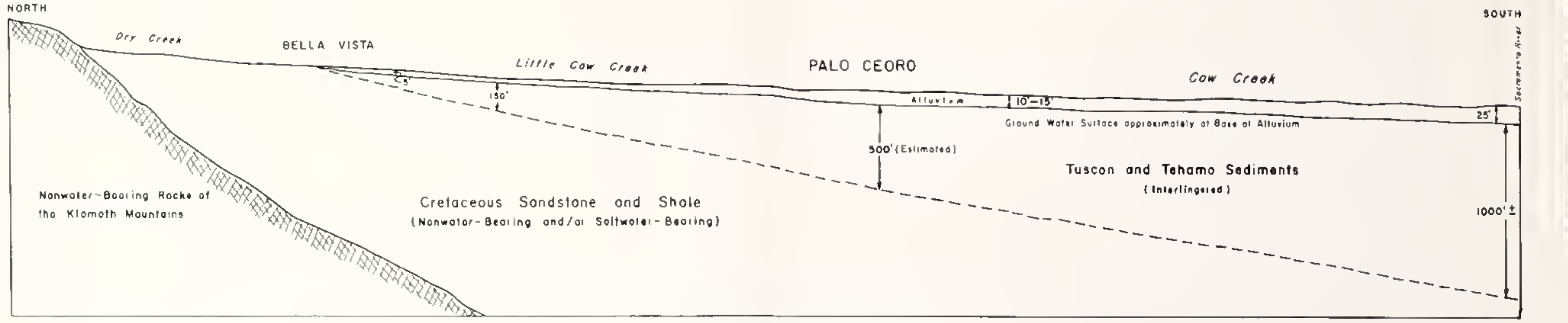
SCALE OF MILES
2 0 2 4 6



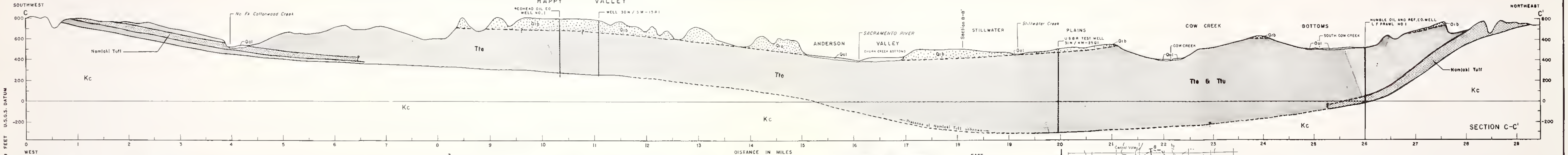
GENERALIZED CROSS SECTIONS A-A' and B-B'

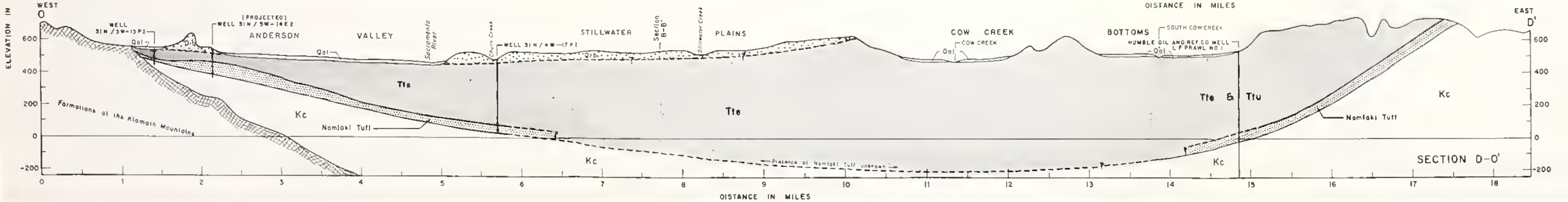
LEGEND

QUATERNARY	RECENT	Qal	ALLUVIUM — UNCONSOLIDATED GRAVEL, SAND, SILT, AND CLAY. STREAM CHANNEL AND FLOOD PLAIN DEPOSITS.
	PLEISTOCENE	Qrb	RED BLUFF FORMATION — COARSE GRAVELS, OFTEN WITH LARGE BOULDERS IN A RED SANDY CLAY MATRIX.
		TQv	BASALT AND ANDESITE LAVA FLOWS
TERTIARY	PLIOCENE	Tte Ttu	TEHAMA (Tte) AND TUSCAN (Ttu) FORMATIONS — SEMI-CONSOLIDATED MIXTURES OF CLAY, SILT, SAND, AND GRAVEL (TEHAMA) INTERFINGERING WITH VOLCANIC SEDIMENTS AND TUFF BRECCIA (TUSCAN).
		Tn	NOMLAKI TUFF — PUMICEOUS DACITE TUFF NEAR OR AT THE BASE OF THE TUSCAN AND TEHAMA FORMATIONS.
CRETACEOUS		Kc	CHICO FORMATION — CONSOLIDATED SEDIMENTARY ROCKS INCLUDING SANDSTONE, SHALE AND CONGLOMERATE.

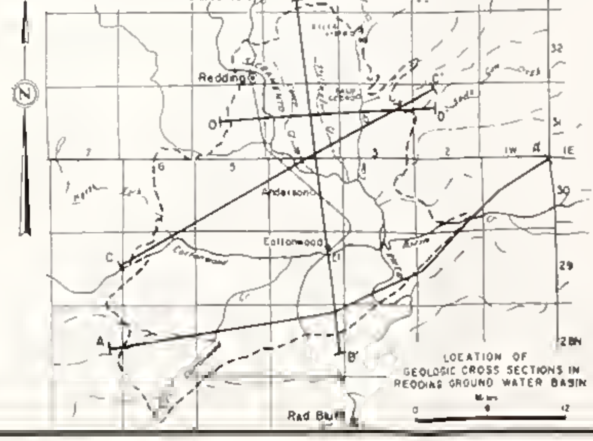


DIAGRAMMATIC CROSS SECTION ALONG COW CREEK
(Not specifically located)
Scale approximate





DETAILED CROSS SECTIONS C-C' and D-D'

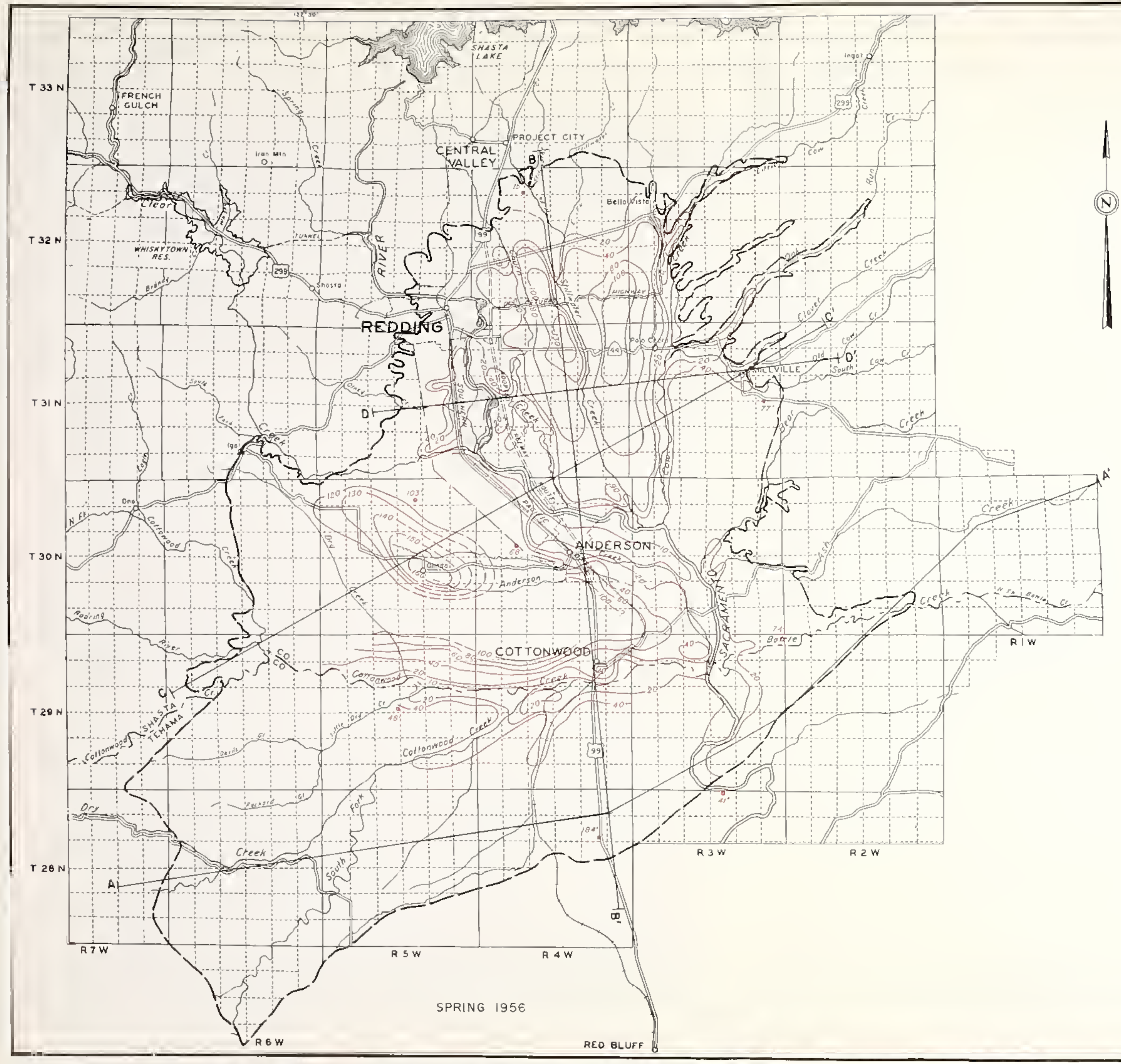


NOTE: LINES OF GEOLOGIC SECTIONS ALSO SHOWN ON PLATES C-1 AND 8

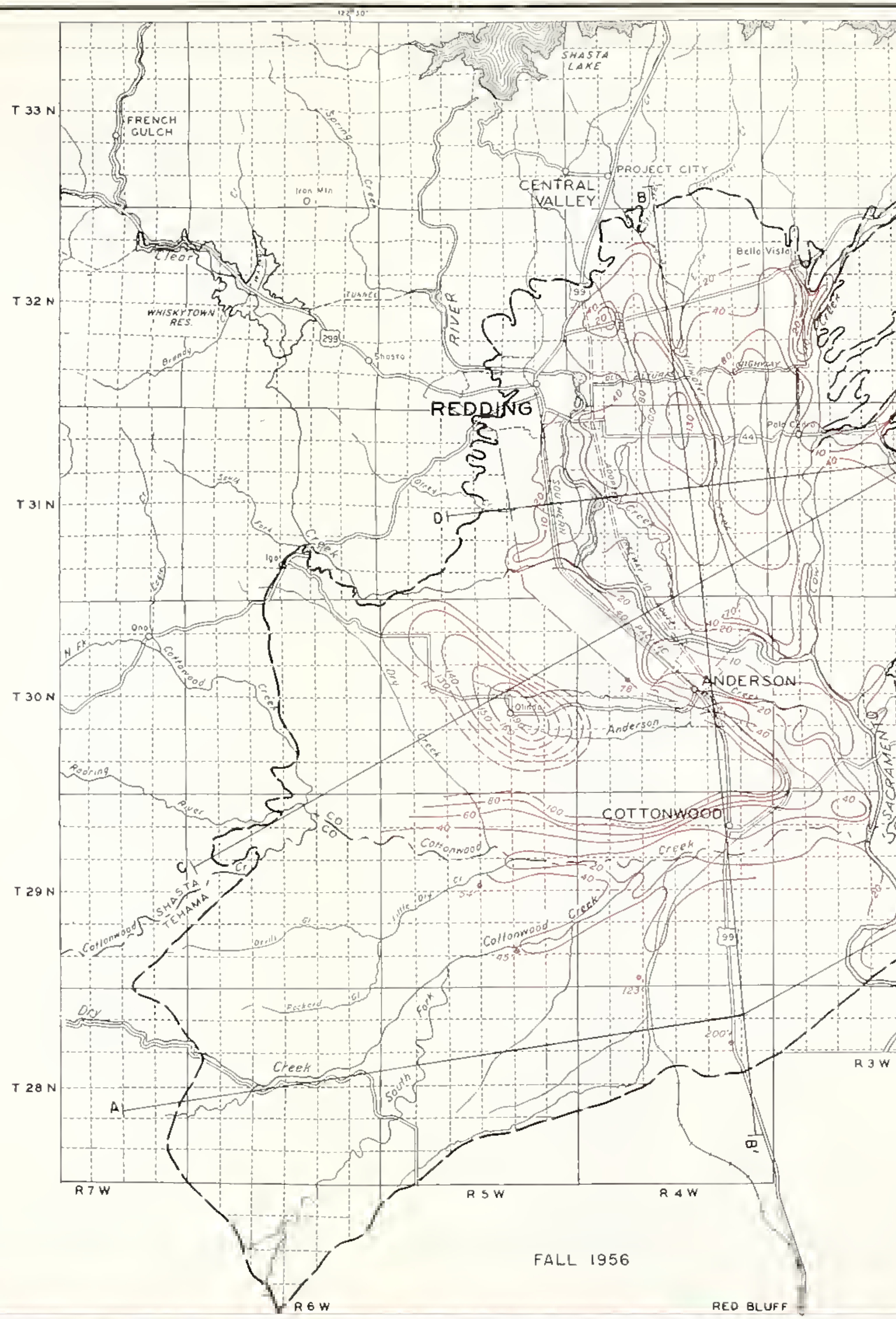
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA COUNTY INVESTIGATION

GEOLOGIC CROSS SECTIONS REDDING GROUND WATER BASIN

DEPARTMENT OF WATER RESOURCES 1960



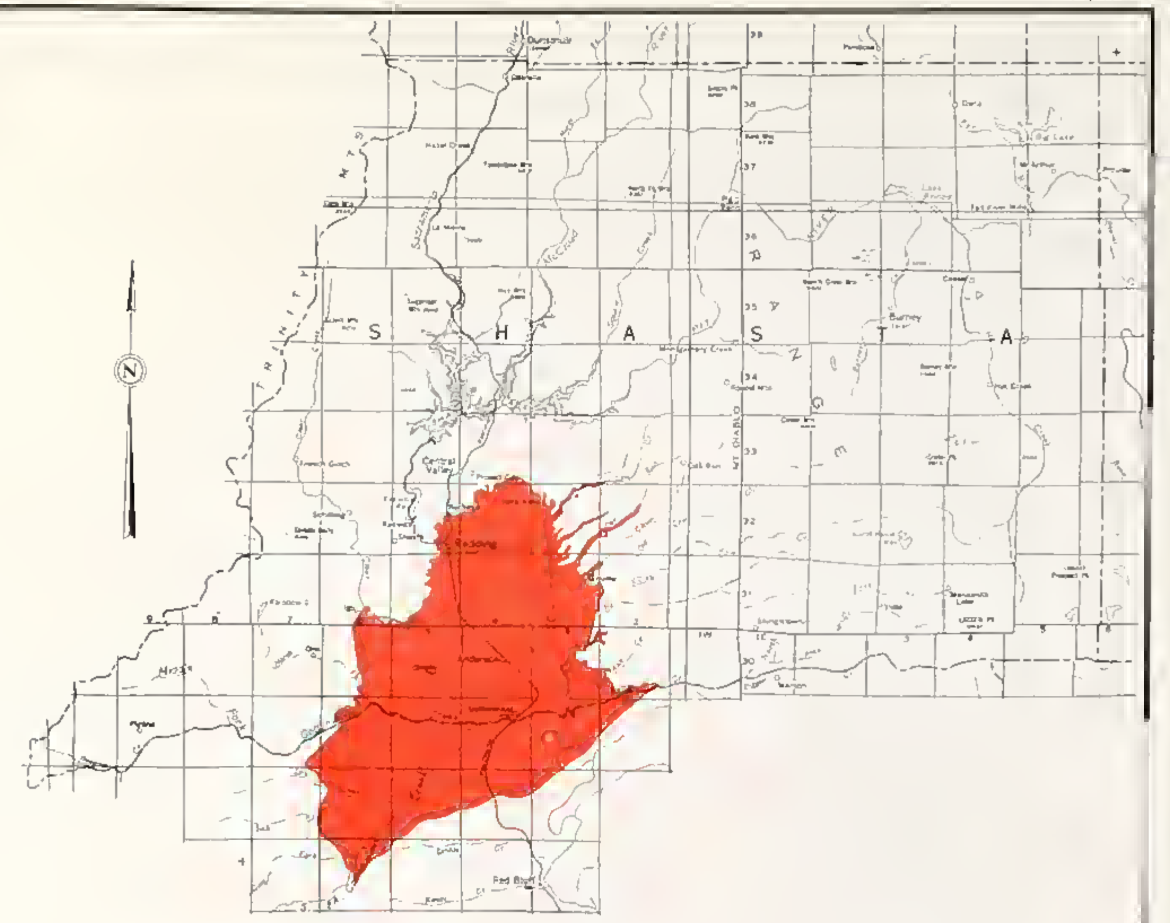
SPRING 1956



FALL 1956

LEGEND

- 10 — LINES OF EQUAL DEPTH TO GROUND WATER IN FEET
- 150 — PROJECTED LINES OF EQUAL DEPTH TO GROUND WATER IN FEET
- ● 79' ISOLATED MEASURED WELLS WITH APPROPRIATE DEPTH TO GROUND WATER IN FEET



LOCATION MAP

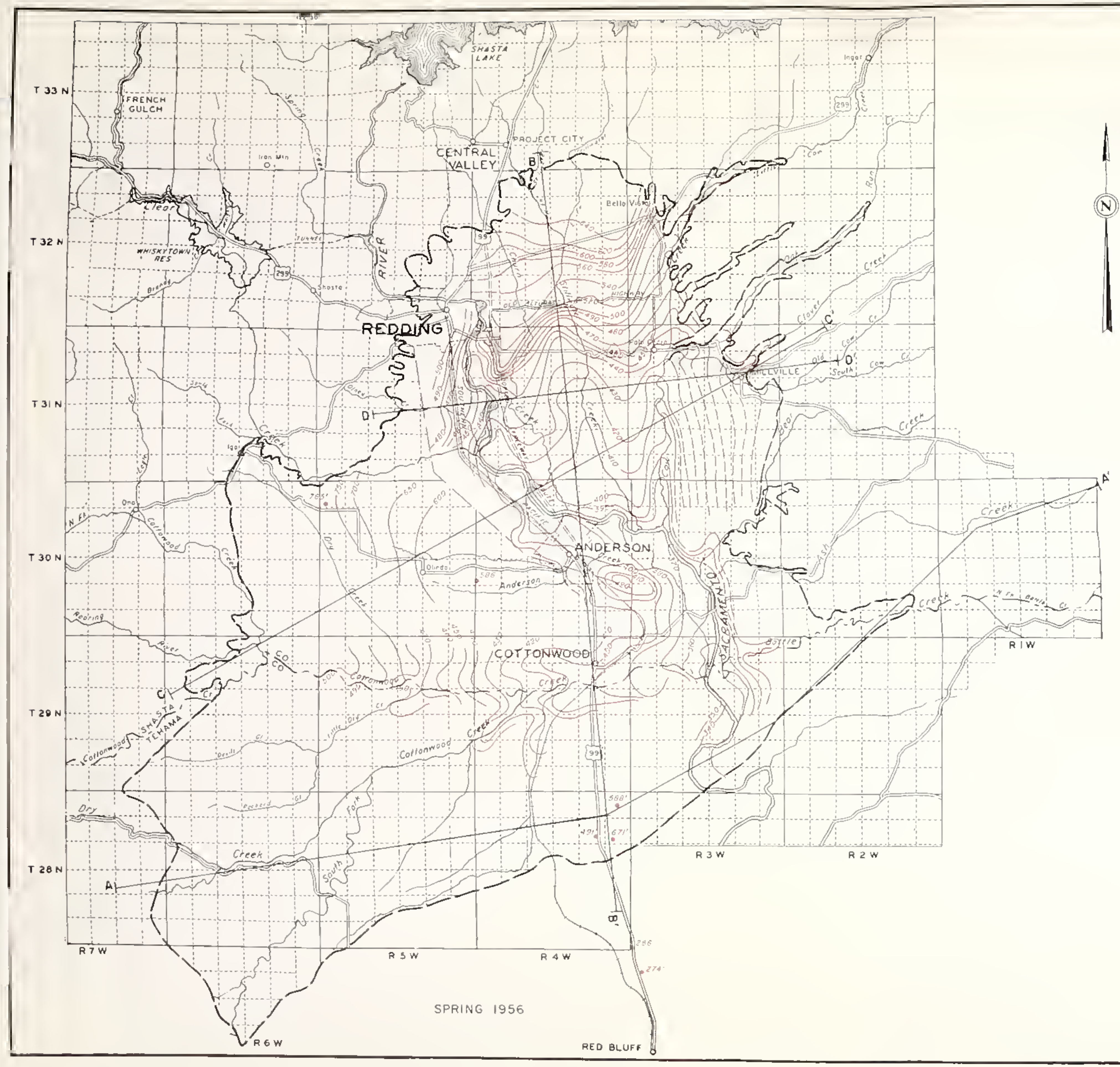
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SHASTA COUNTY INVESTIGATION

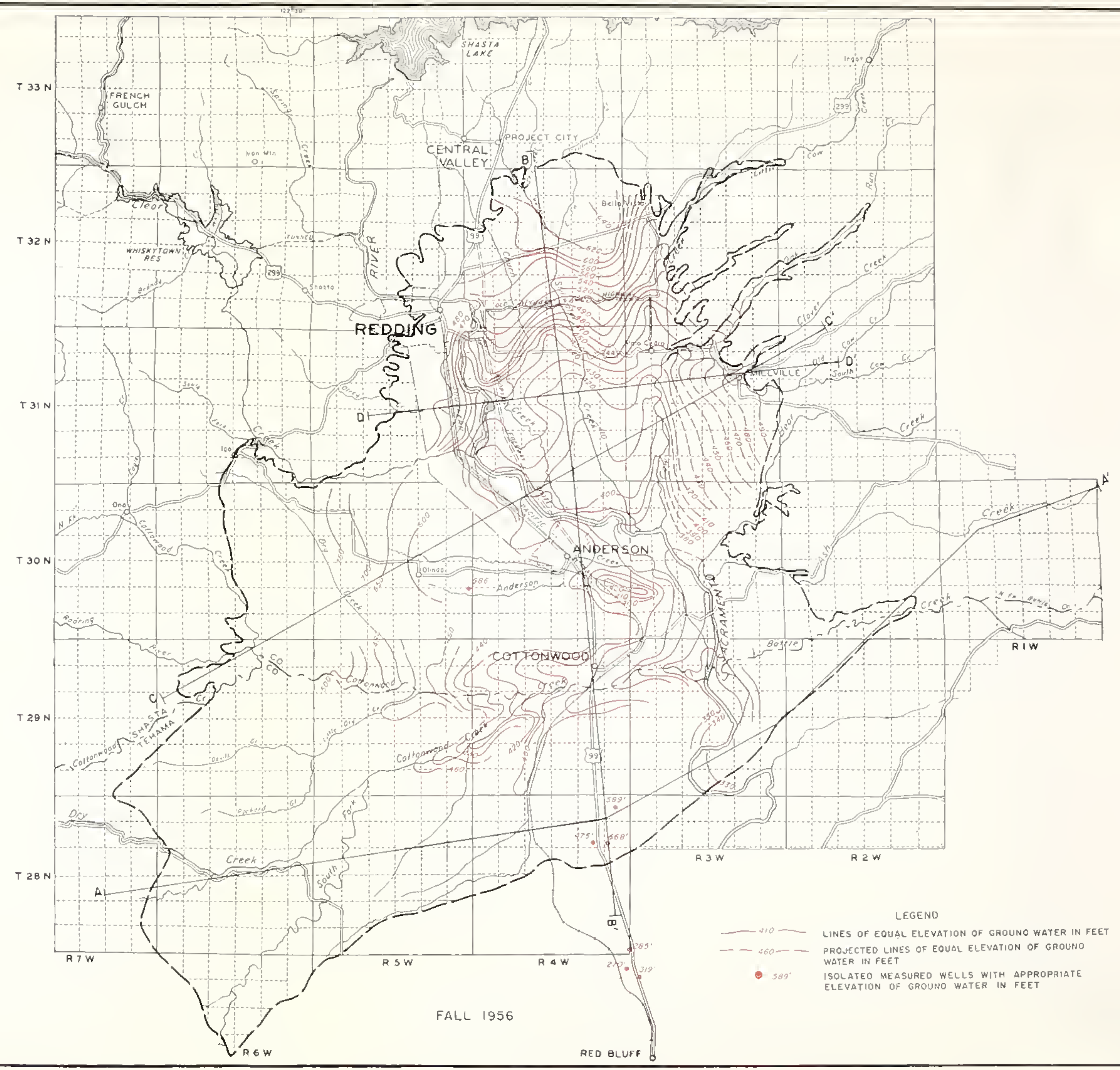
LINES OF EQUAL DEPTH TO GROUND WATER REDDING GROUND WATER BASIN

SPRING 1956 , FALL 1956

SCALE OF MILES
2 0 2 4 6



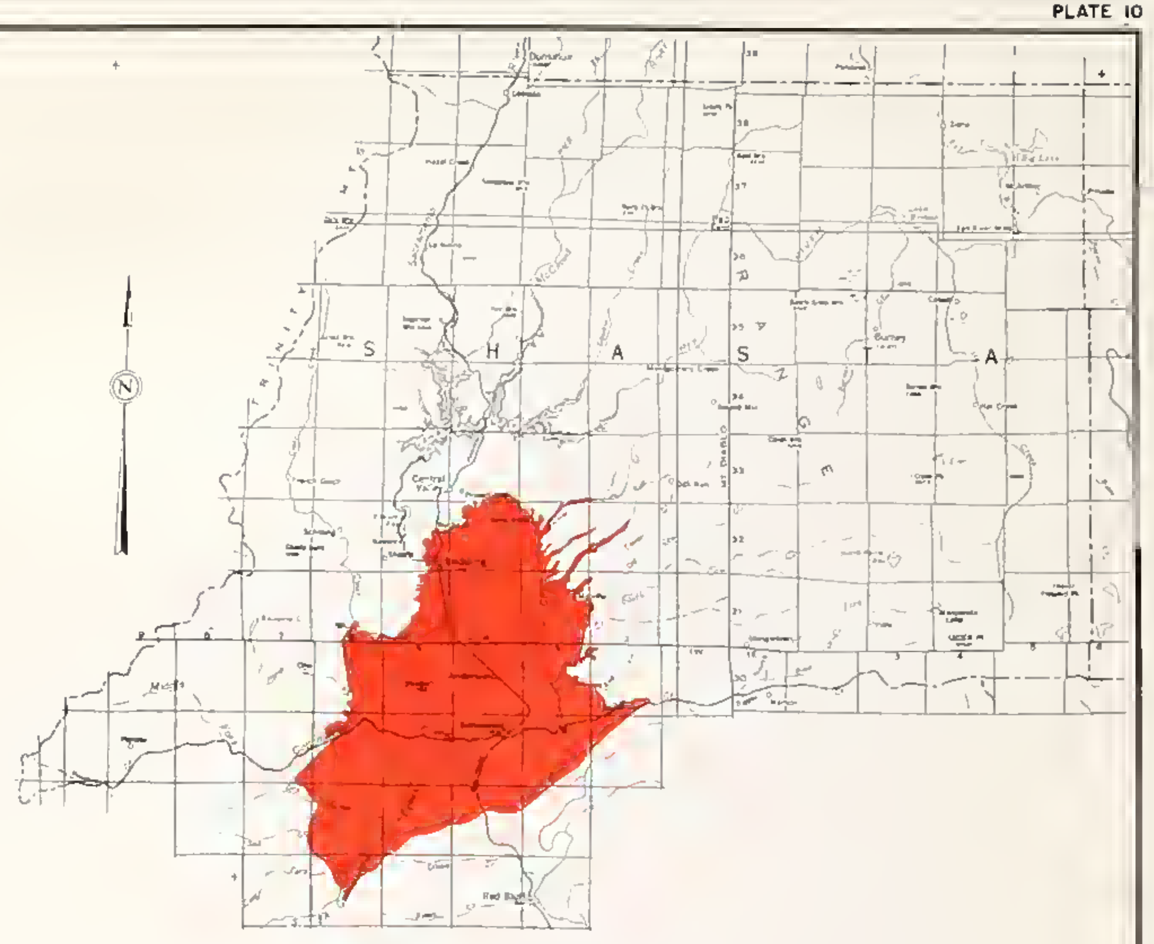
SPRING 1956



FALL 1956

LEGEND

- LINES OF EQUAL ELEVATION OF GROUND WATER IN FEET
- PROJECTED LINES OF EQUAL ELEVATION OF GROUND WATER IN FEET
- ISOLATED MEASURED WELLS WITH APPROPRIATE ELEVATION OF GROUND WATER IN FEET



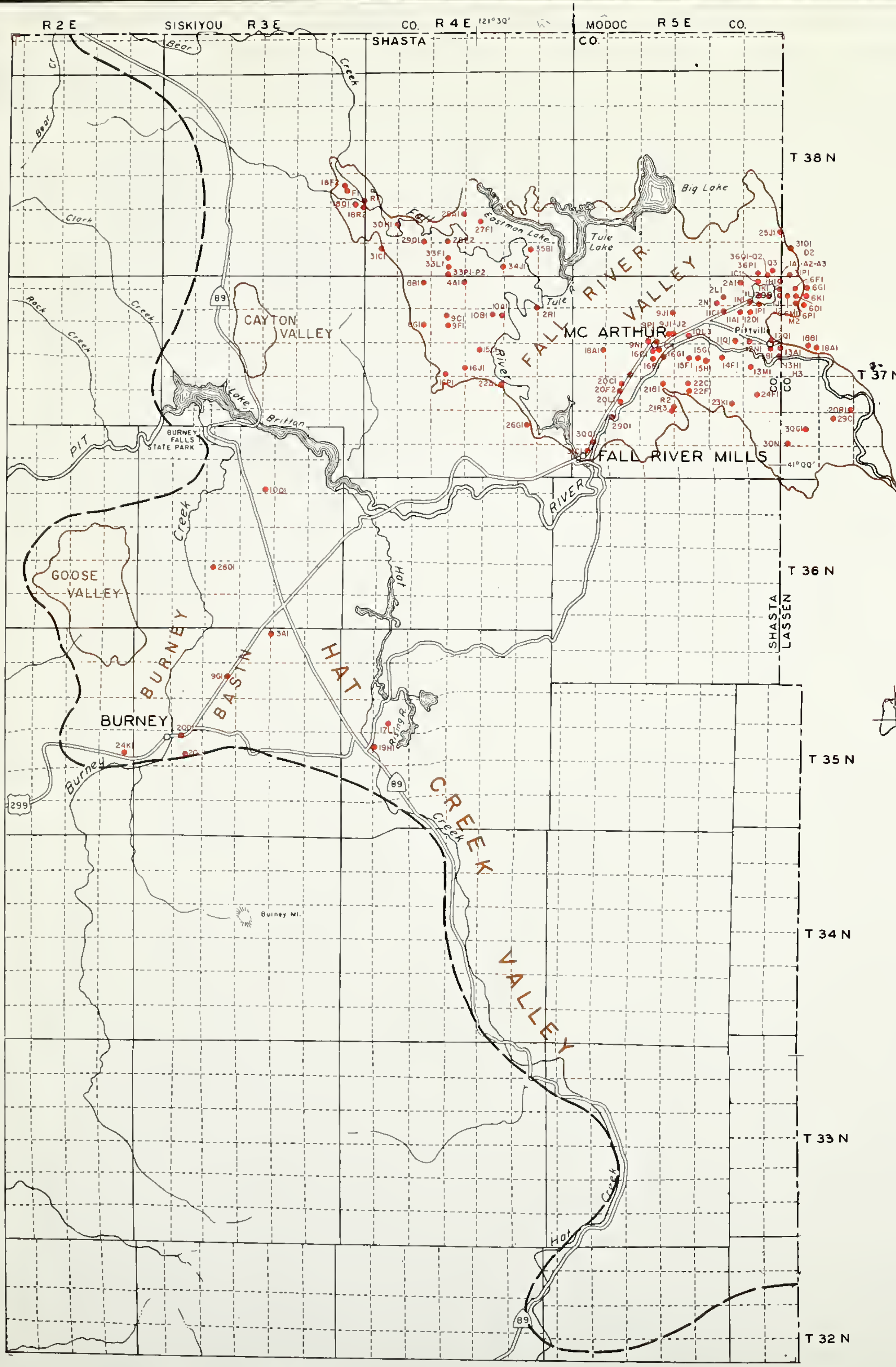
LOCATION MAP

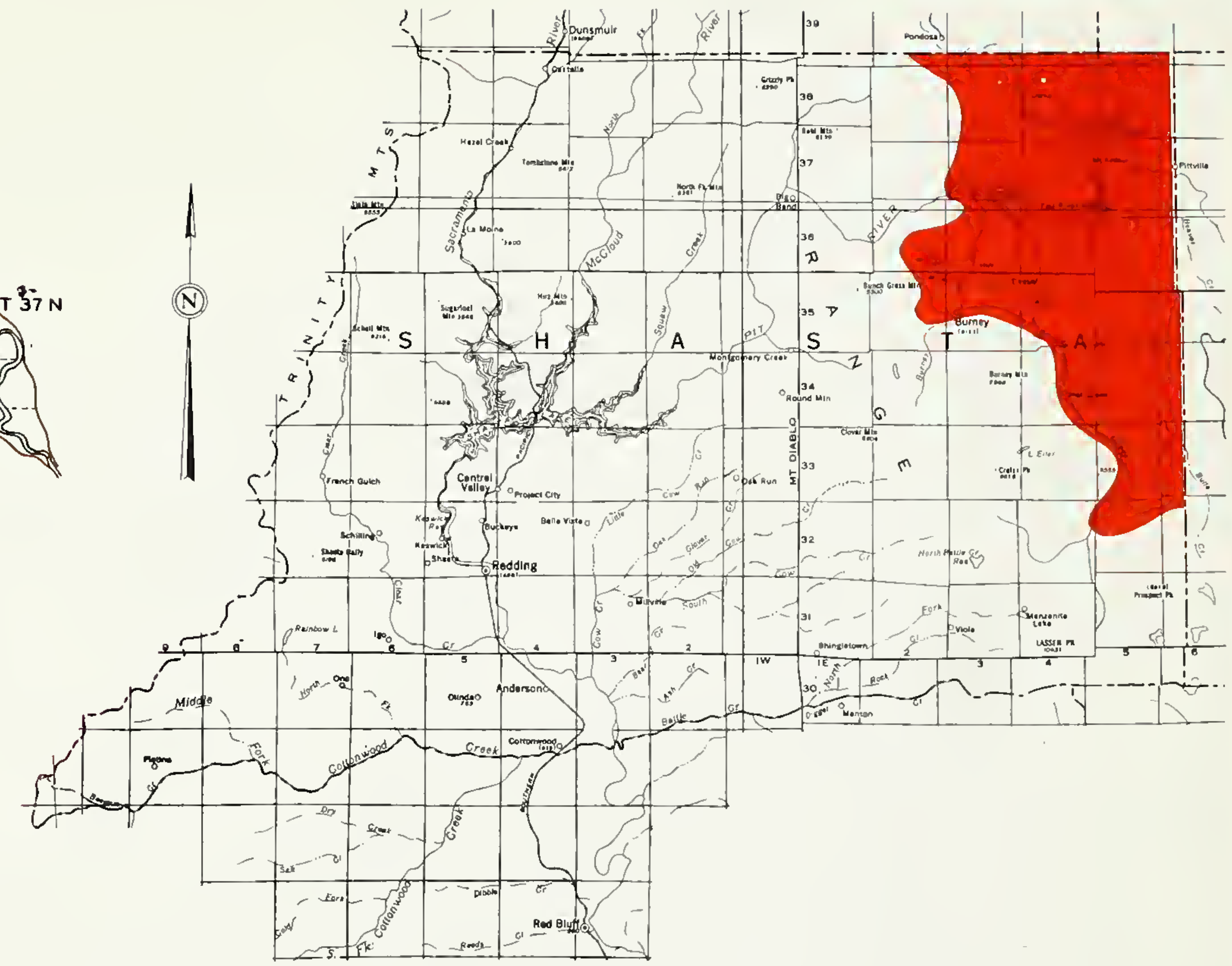
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA COUNTY INVESTIGATION

LINES OF EQUAL ELEVATION OF GROUND WATER REDDING GROUND WATER BASIN

SPRING 1956, FALL 1956

SCALE OF MILES





LOCATION MAP

KEY TO WELL LOCATION NUMBERS

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Location Numbers are designated by Township, Range, Section and 1/16 Section. Sixteenth sections are indicated by letters in accordance with diagram above. Points within the same sixteenth section are numbered serially (ie: 1, 2, 3, etc.) Thus a point having the following location number, 16N/1W-28F2, is the second point located in the the S.E. 1/4 of the N.W 1/4 of section 28, Township 16 North, Range 1W,

5C1● WELL LOCATION AND NUMBER

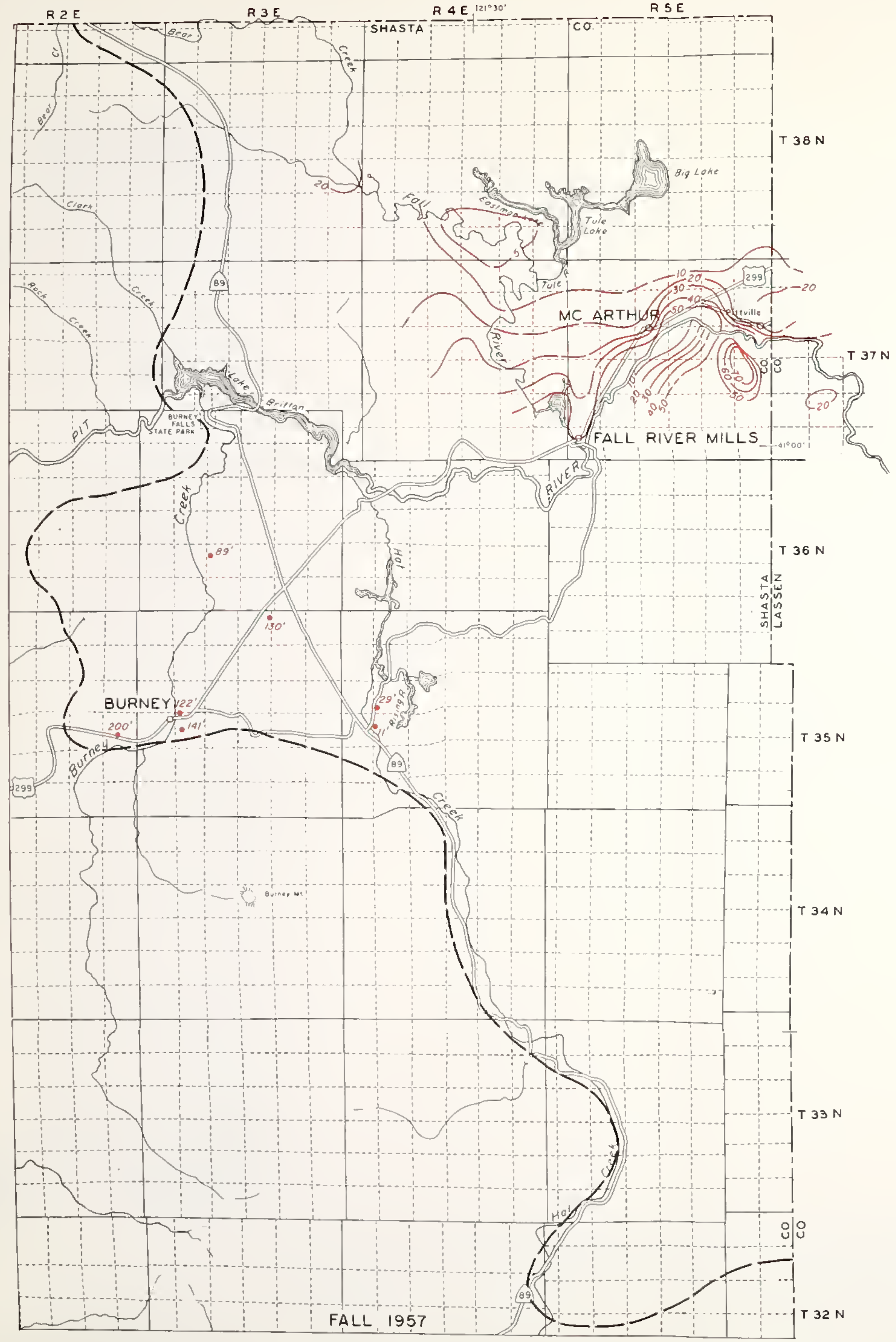
GROUND WATER AREA BOUNDARY

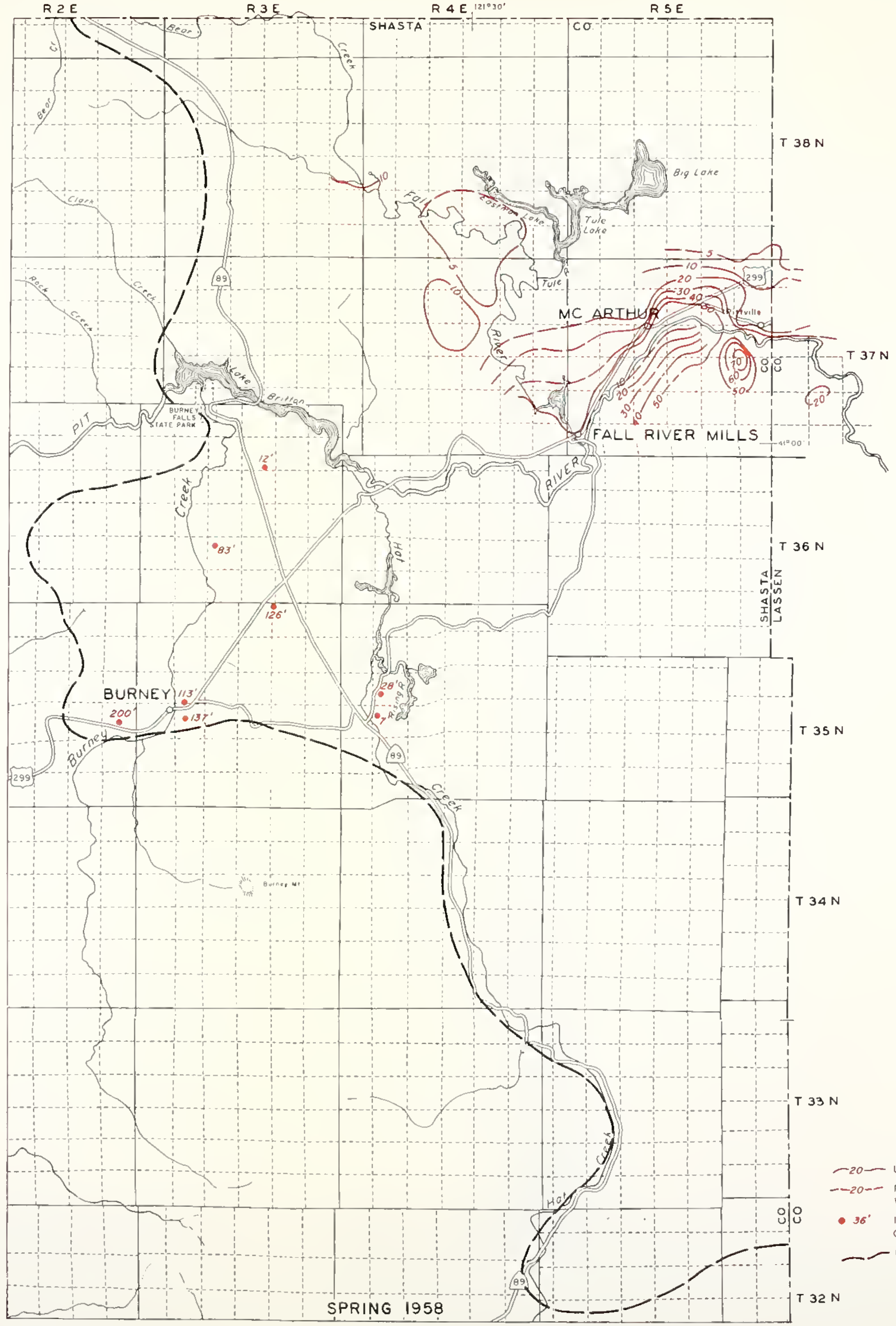
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

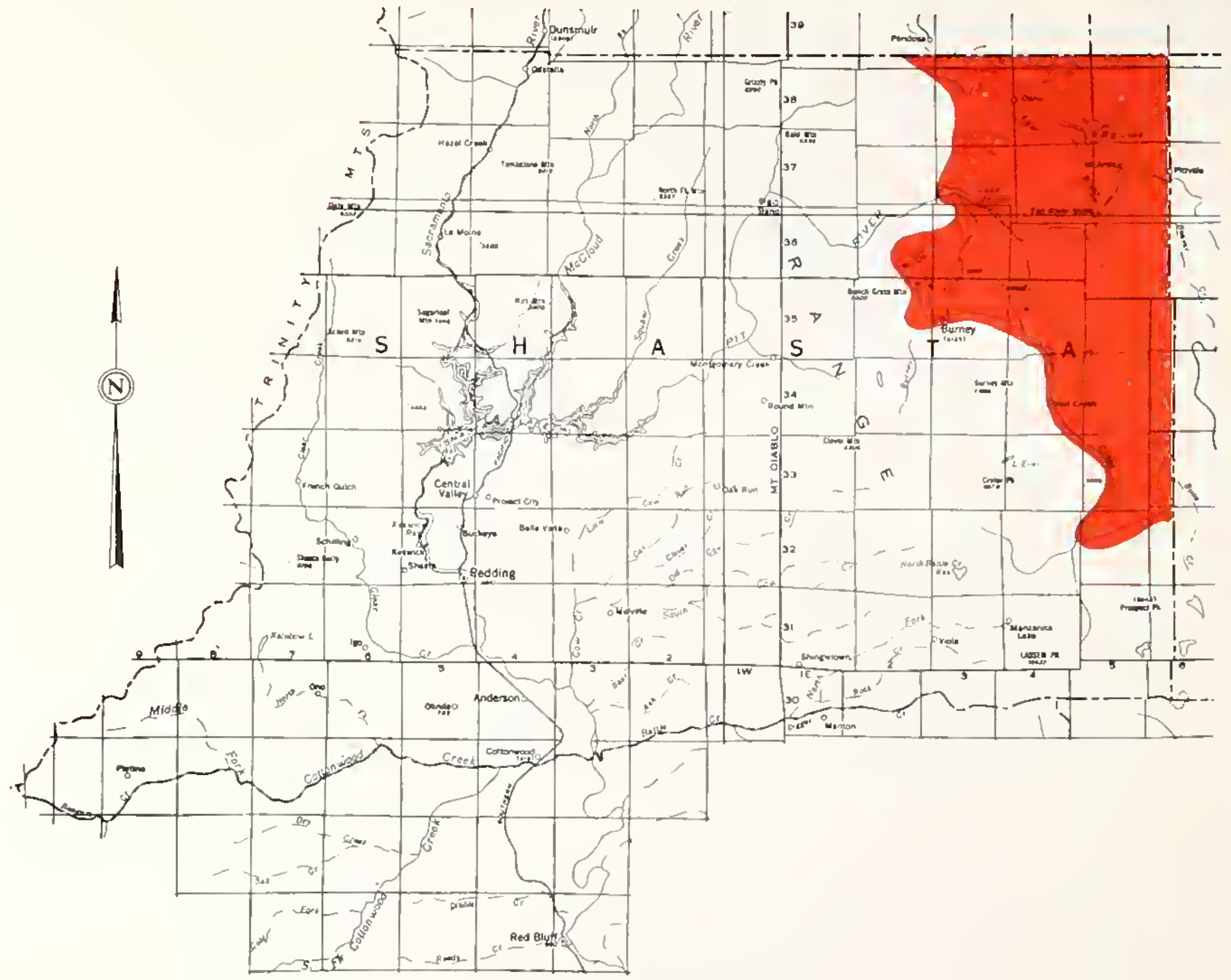
SHASTA COUNTY INVESTIGATION

MODOC PLATEAU GROUND WATER AREA

SCALE OF MILES
2 0 2 4 6







LOCATION MAP

LEGEND

—20— LINES OF EQUAL DEPTH TO GROUND WATER IN FEET

—20— PROJECTED LINES OF EQUAL DEPTH TO GROUND WATER IN FEET

● 36' ISOLATED MEASURED WELLS WITH APPROPRIATE DEPTH TO GROUND WATER IN FEET

— — GROUND WATER AREA BOUNDARY

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

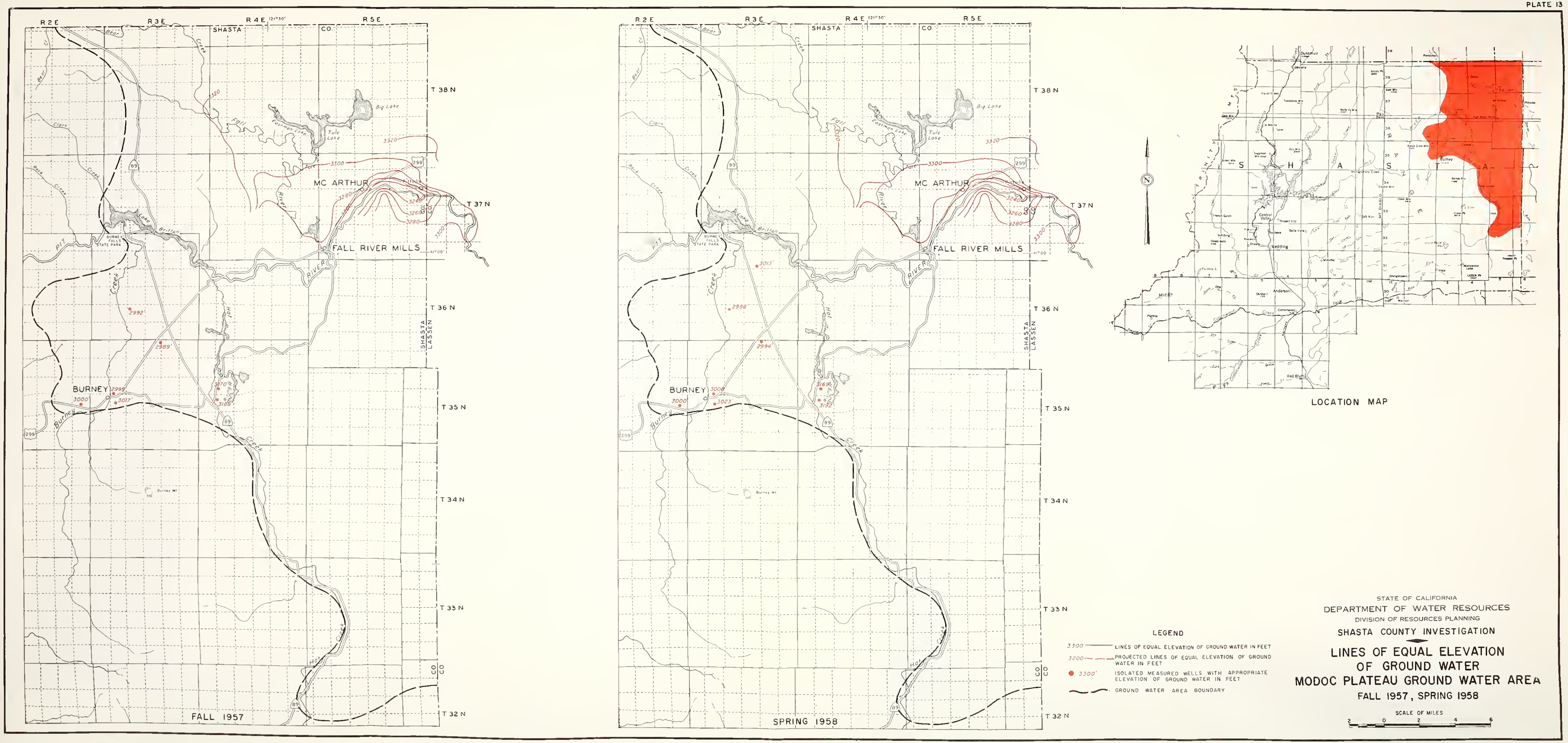
SHASTA COUNTY INVESTIGATION

LINES OF EQUAL DEPTH TO GROUND WATER MODOC PLATEAU GROUND WATER AREA

FALL 1957, SPRING 1958

SCALE OF MILES

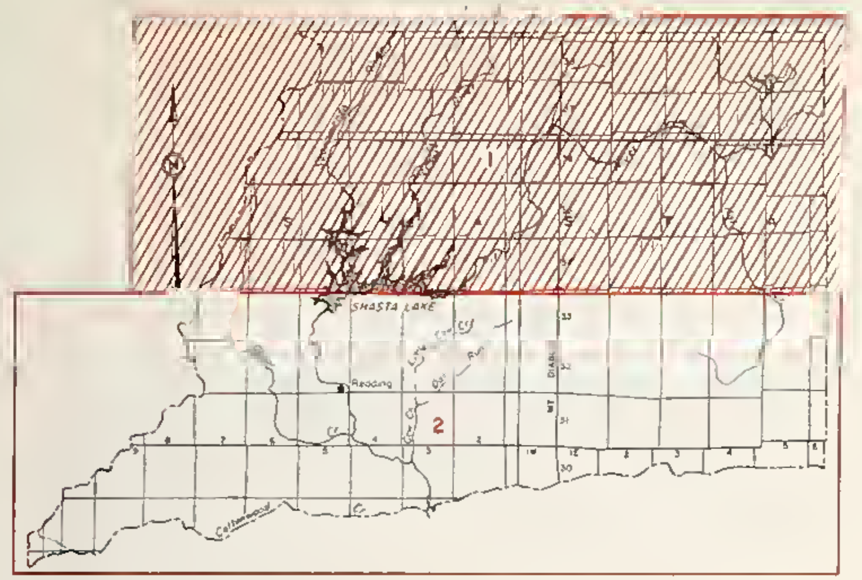
2 0 2 4 6



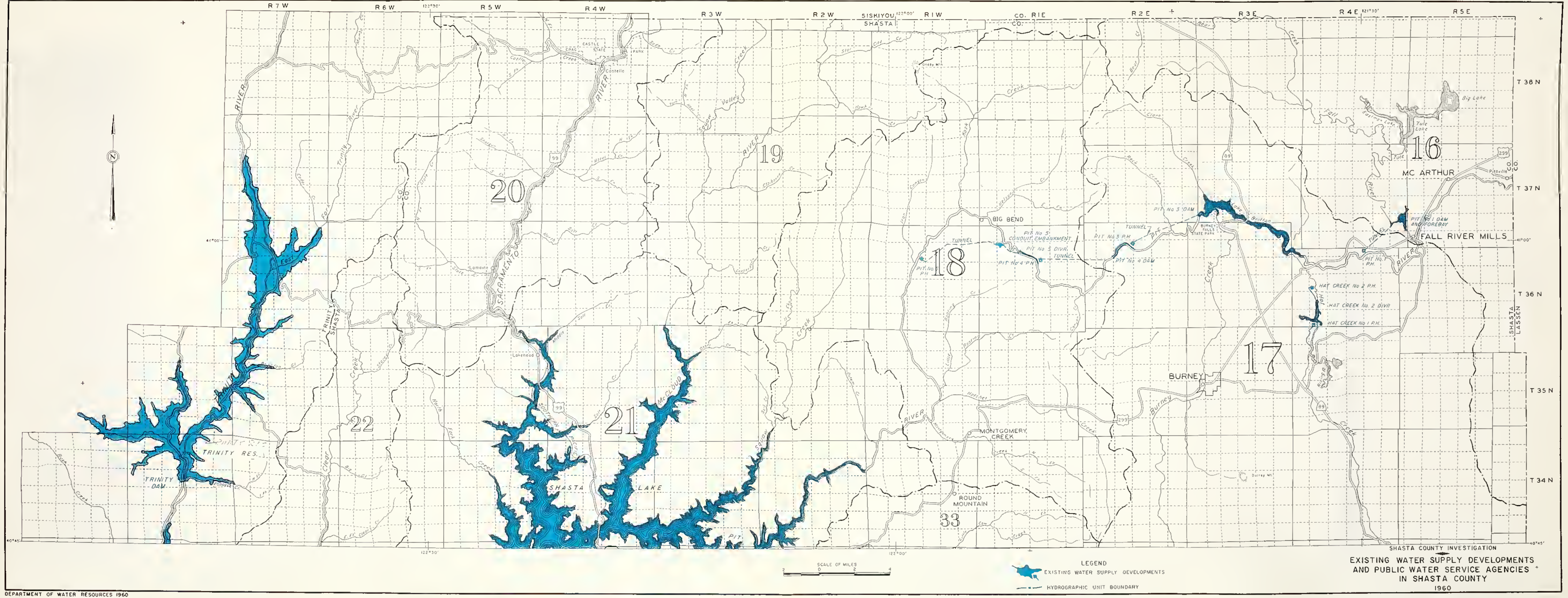
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SHASTA COUNTY INVESTIGATION

LINES OF EQUAL ELEVATION OF GROUND WATER
MODOC PLATEAU GROUND WATER AREA
FALL 1957, SPRING 1958



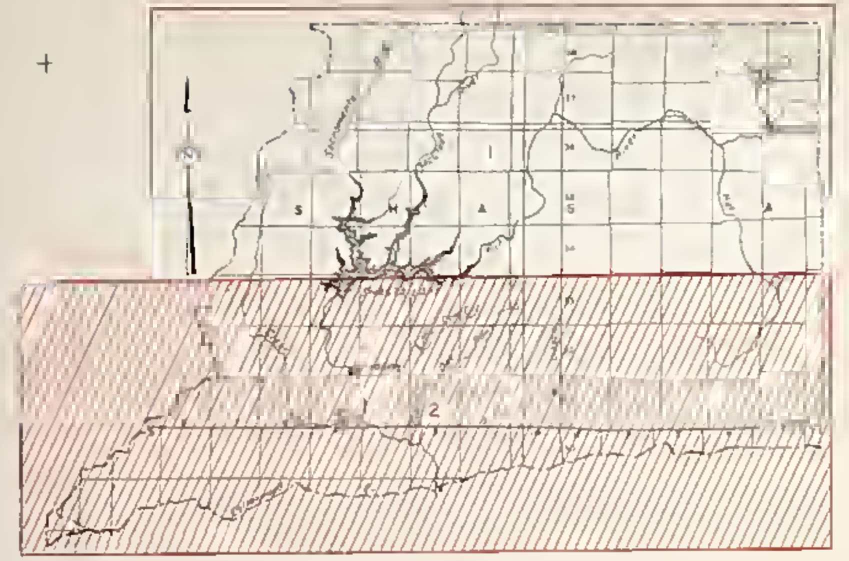
INDEX OF SHEETS



SHASTA COUNTY INVESTIGATION

EXISTING WATER SUPPLY DEVELOPMENTS
AND PUBLIC WATER SERVICE AGENCIES
IN SHASTA COUNTY
1960

DEPARTMENT OF WATER RESOURCES 1960



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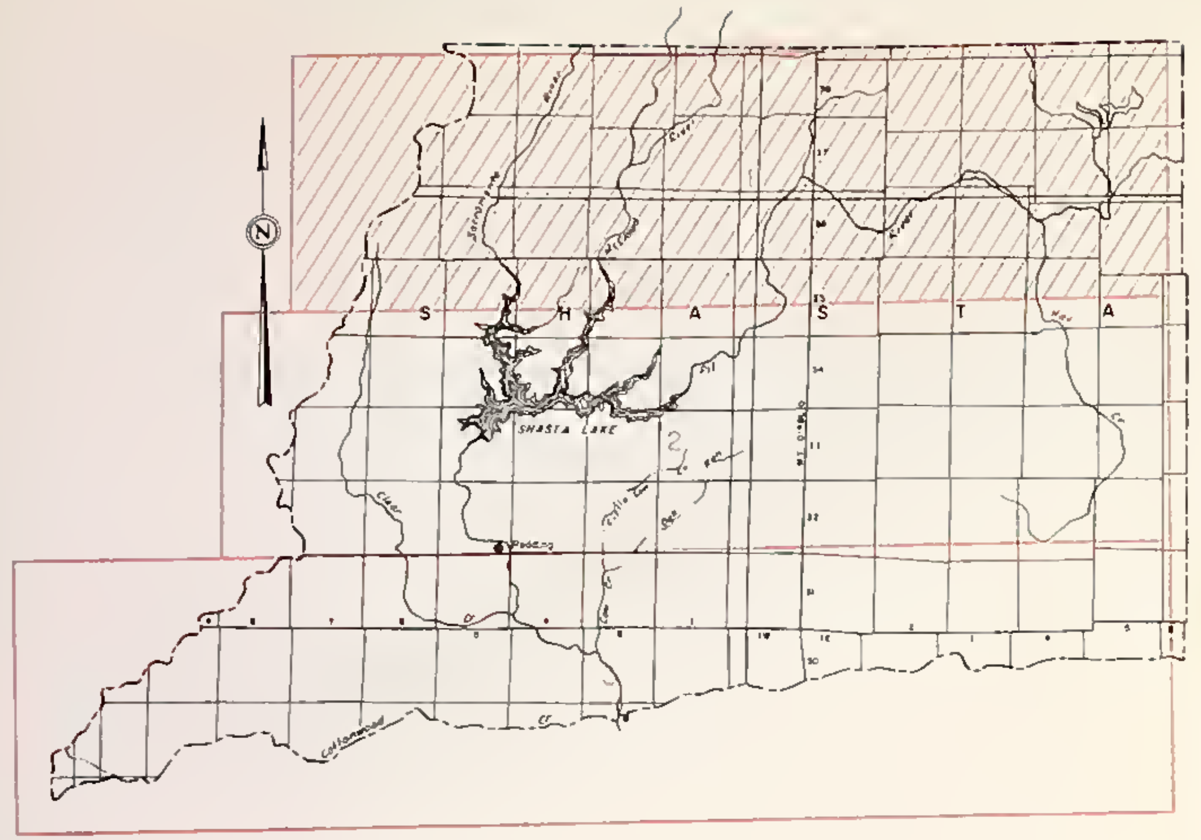

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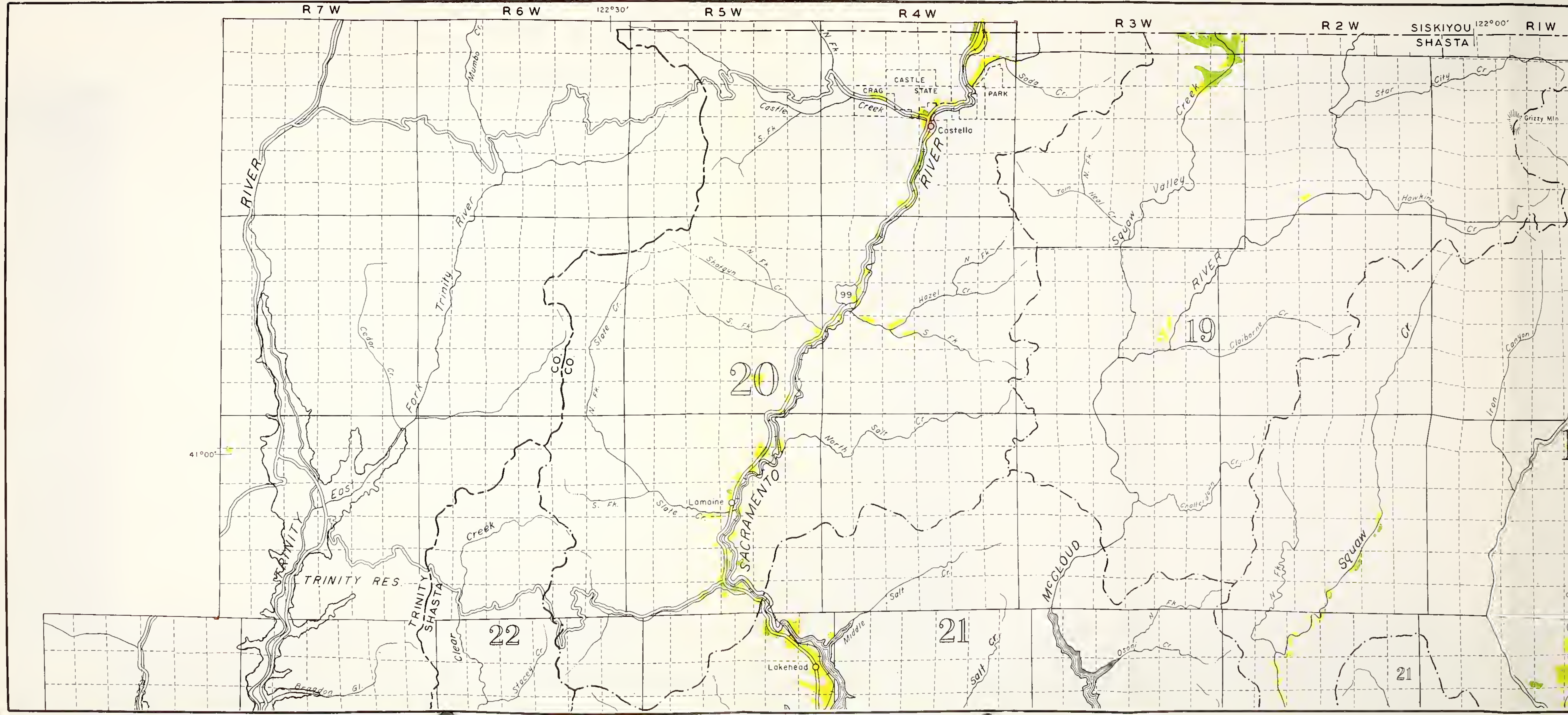


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BURNEY FALLS STATE PARK
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GOOSE VALLEY
HOGBACK RIDGE
HAT CREEK
Grizzly Mtn
Big Lake
Tule Lake
Eastman Lake
Lake Britton
PIT
RIVER
MCCLOUD
Squaw Valley Creek
Star City Cr.
Hawkins Cr.
Clark
Rock Creek
Kosk
Nelson
Iron Canyon
Bear Cr.
Bear Creek
Claiborne Cr.
Roaring Cr.
Little
Hat Cr.
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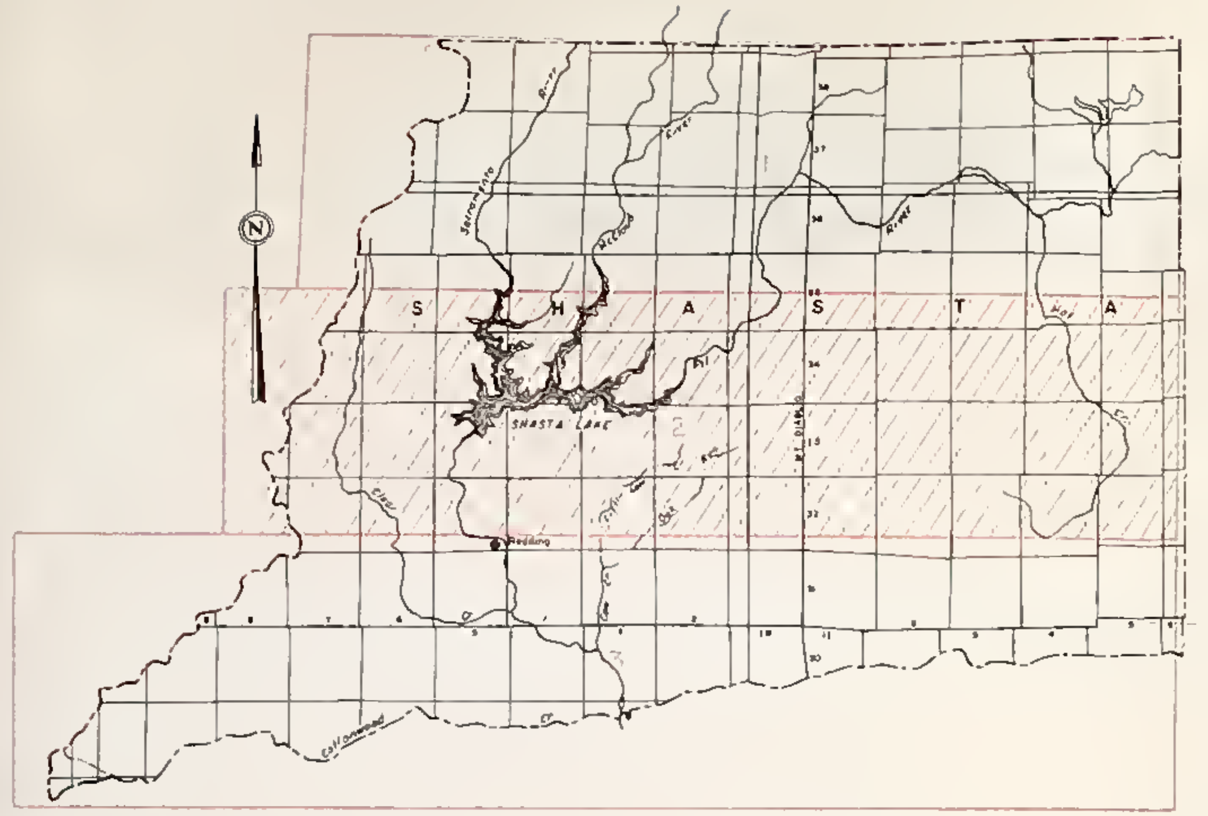

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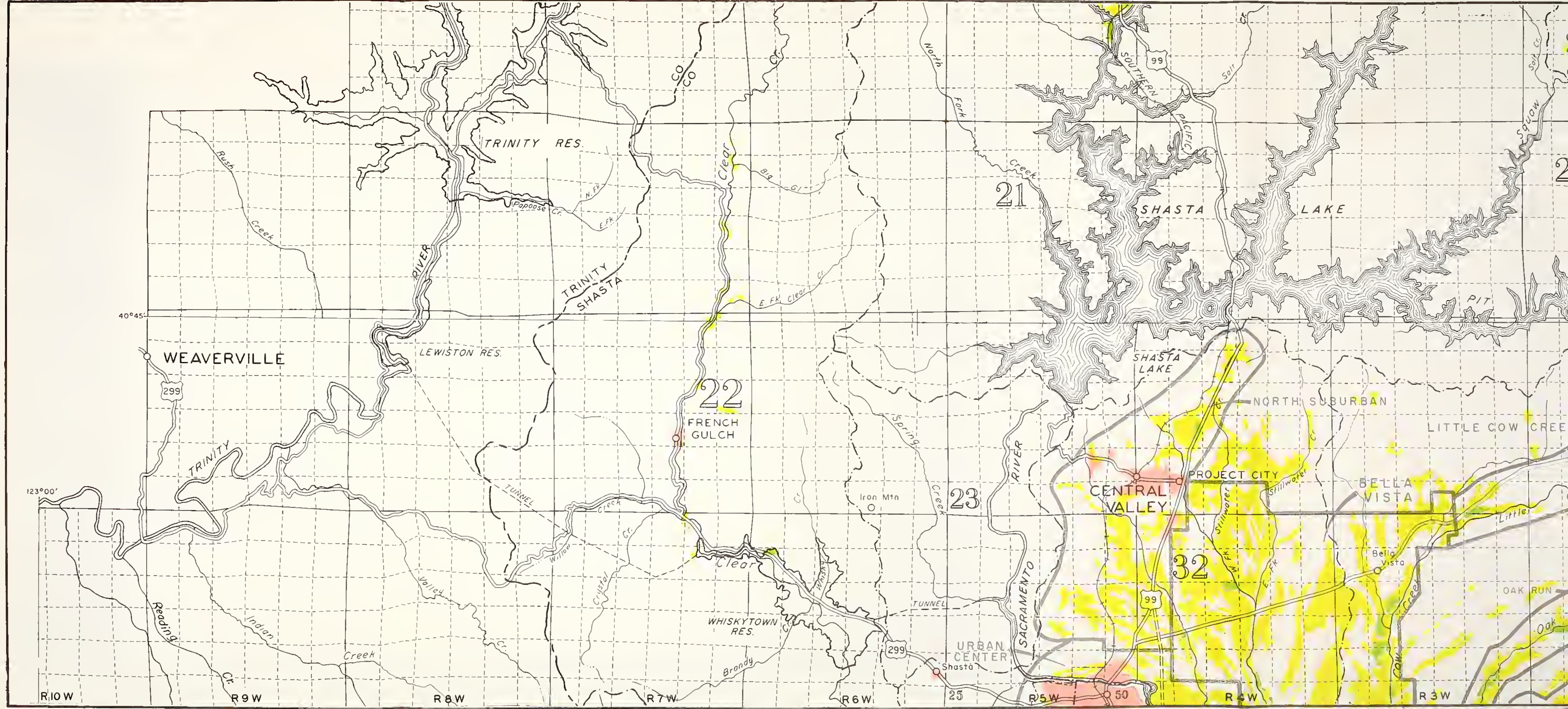


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ROUND MOUNTAIN
ROUND MOUNTAIN
HAT CREEK
BULLSKIN RIDGE
OAK FLAT
NORTH SUBURBAN
LITTLE COW CREEK
CLOVER CREEK
BELLA VISTA
Bella Vista
OAK RUN
WHITMORE
Whitmore
HAGAMAN GULCH
Ingot
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LAKE
PIT
RIVER
Hatchet
Burney Cr.
Hat Creek
Hot Creek
Little Cow Creek
Oak Run
Clover Creek
Old Cow Creek
South Cow Creek
Stillwater Cr.
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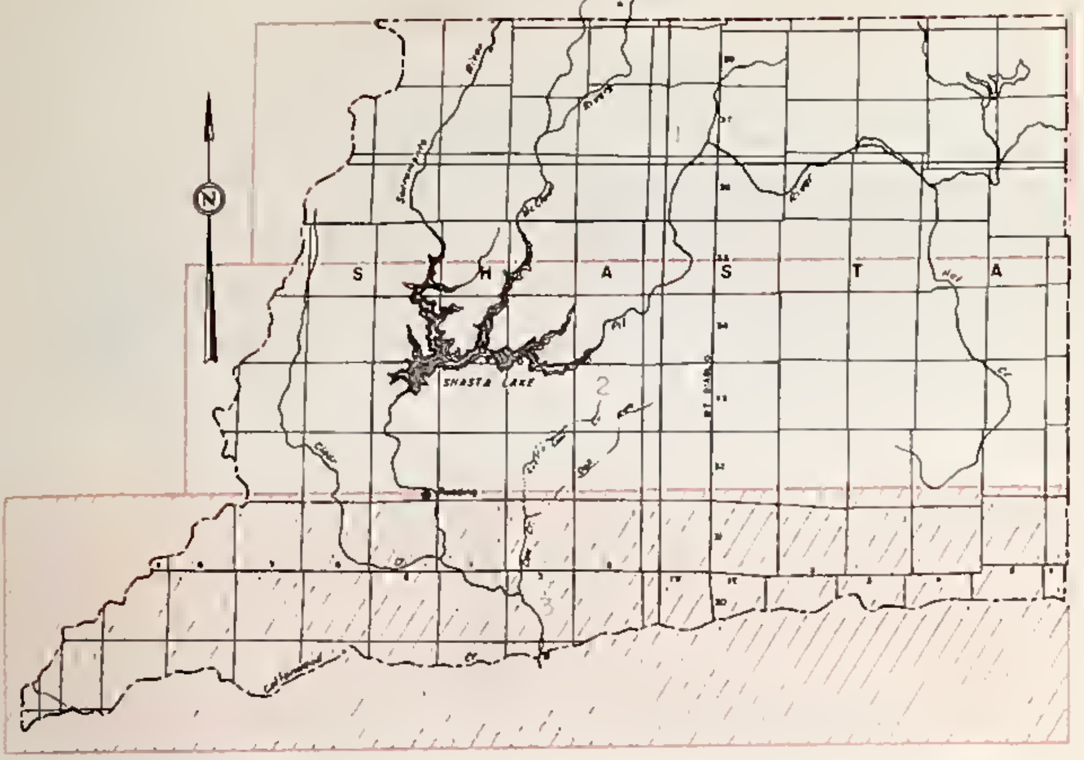

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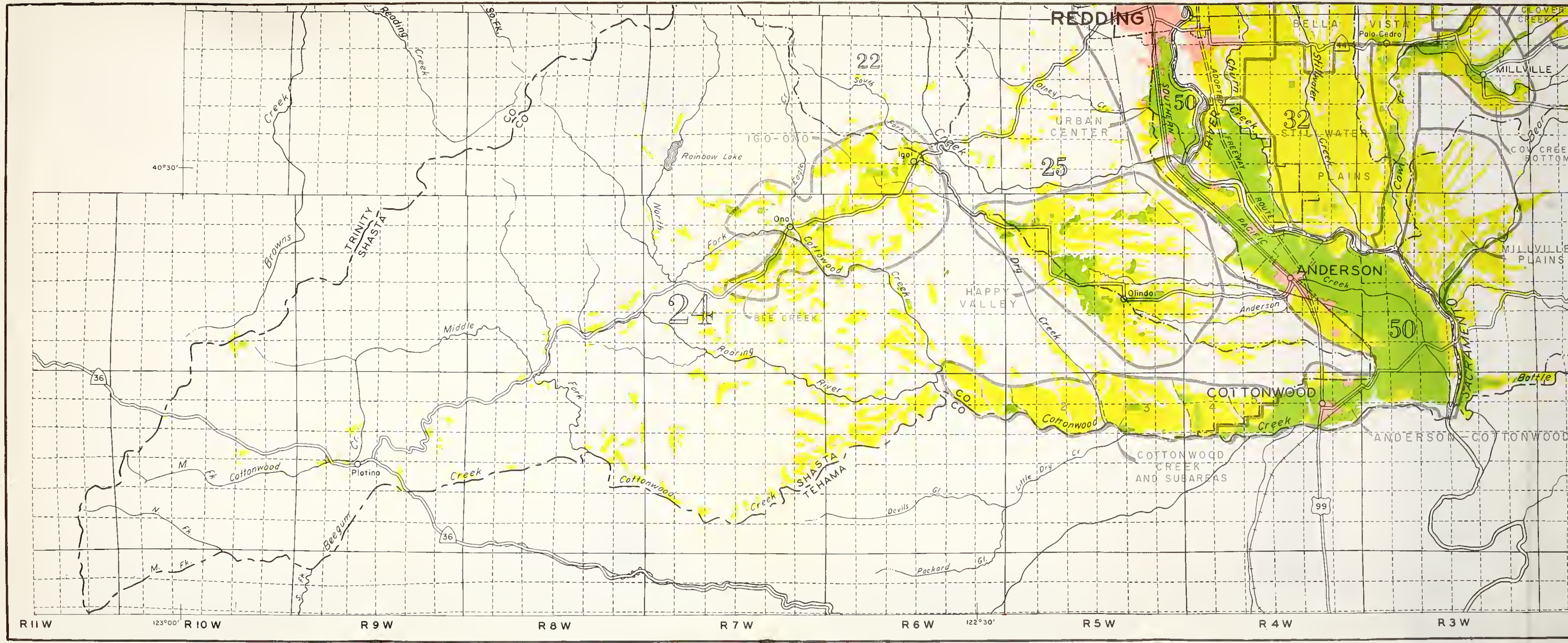

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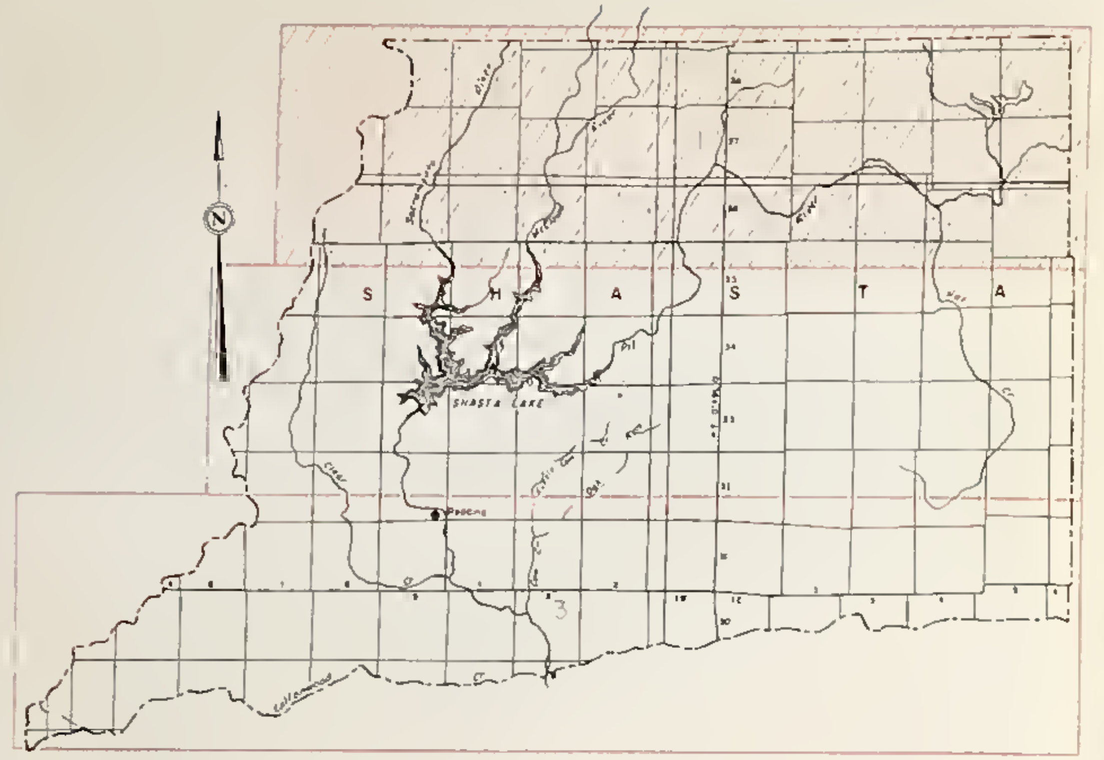
SHASTA COUNTY INVESTIGATION

IRRIGATED AND IRRIGABLE LANDS AND POTENTIAL SERVICE AREAS

1960



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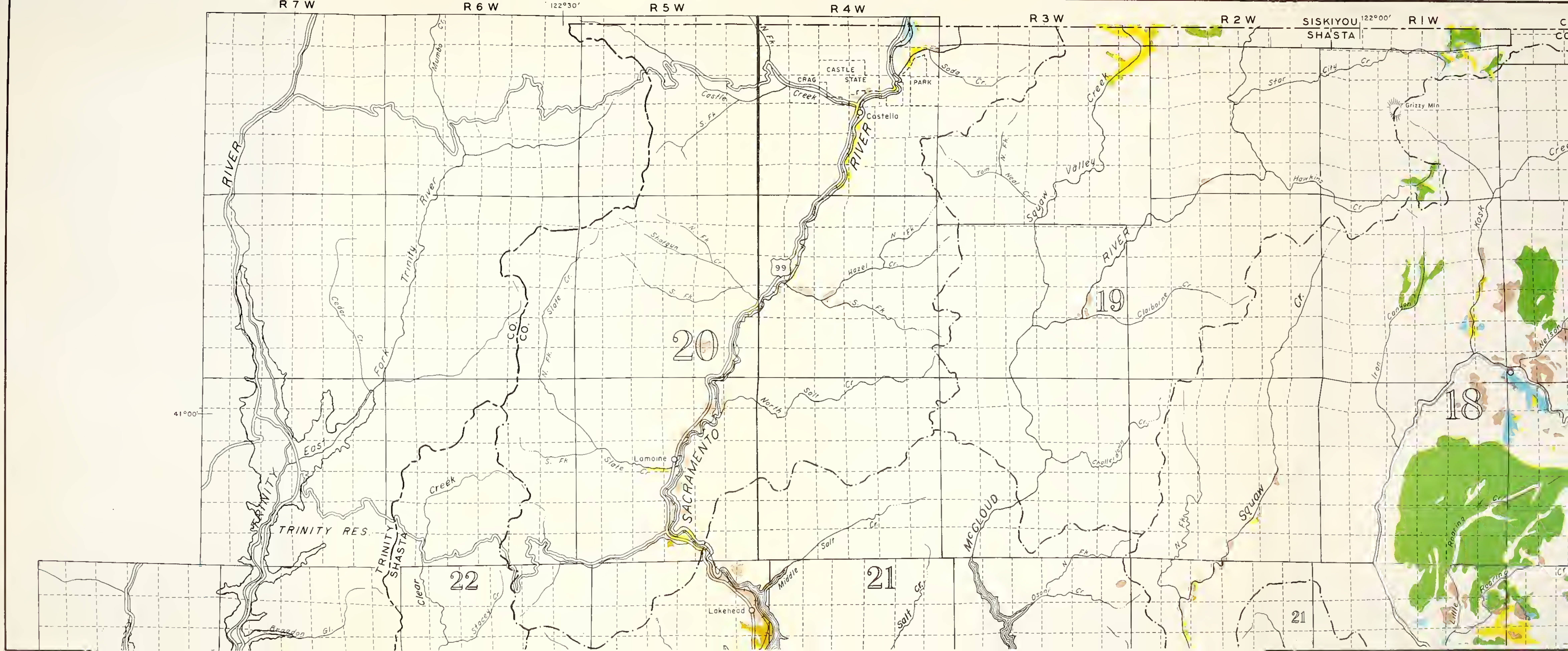

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Eastman Lake
Tule Lake
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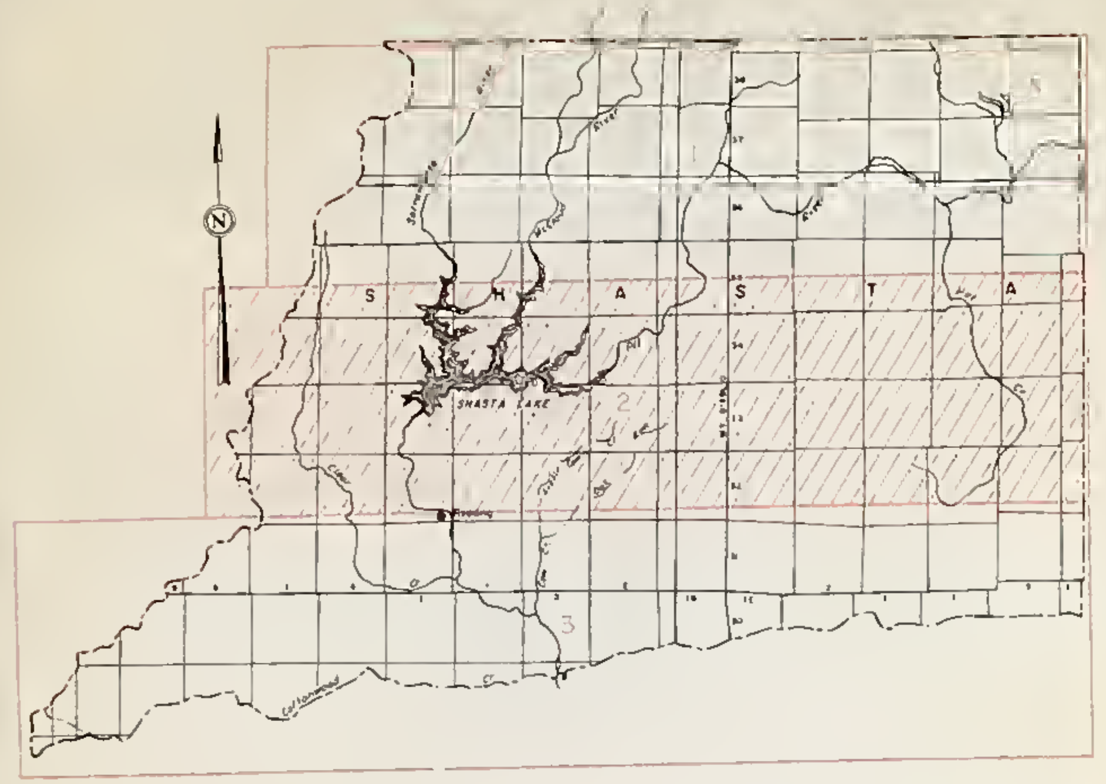

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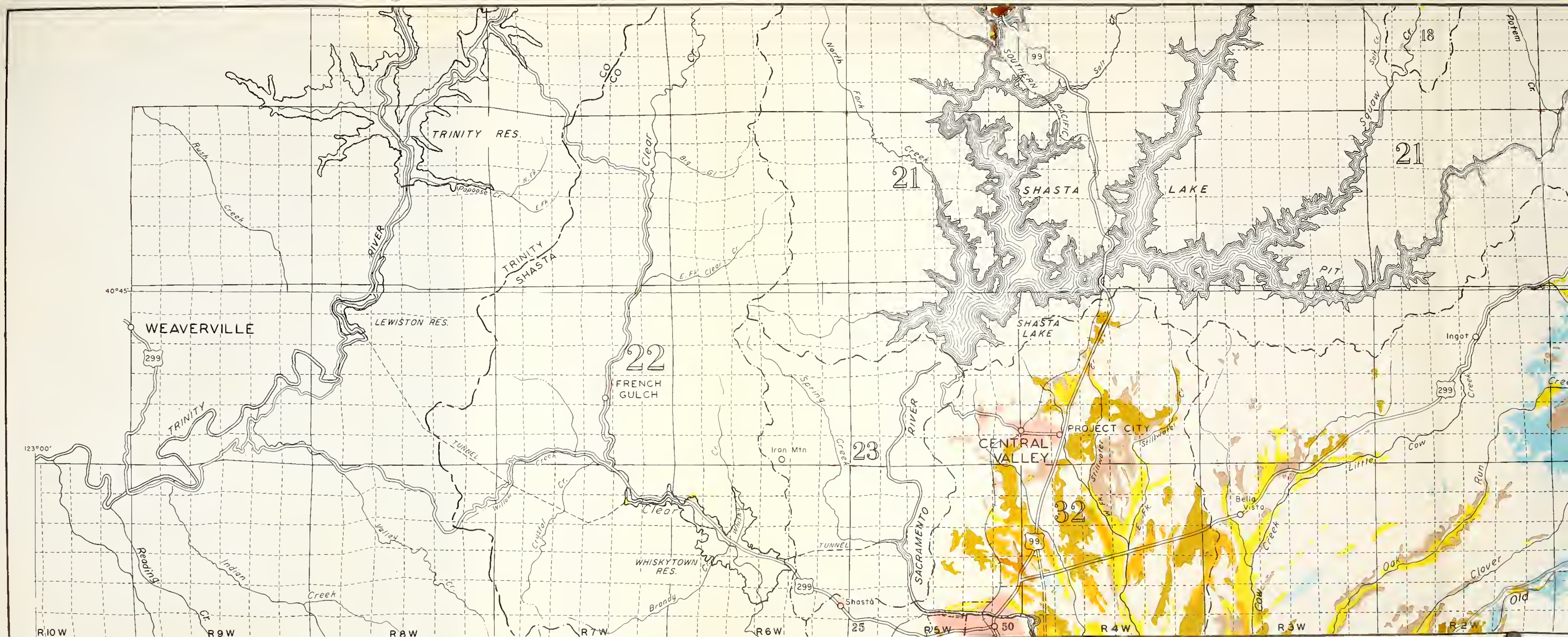


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Bella Vista
Ingot
Whitmore
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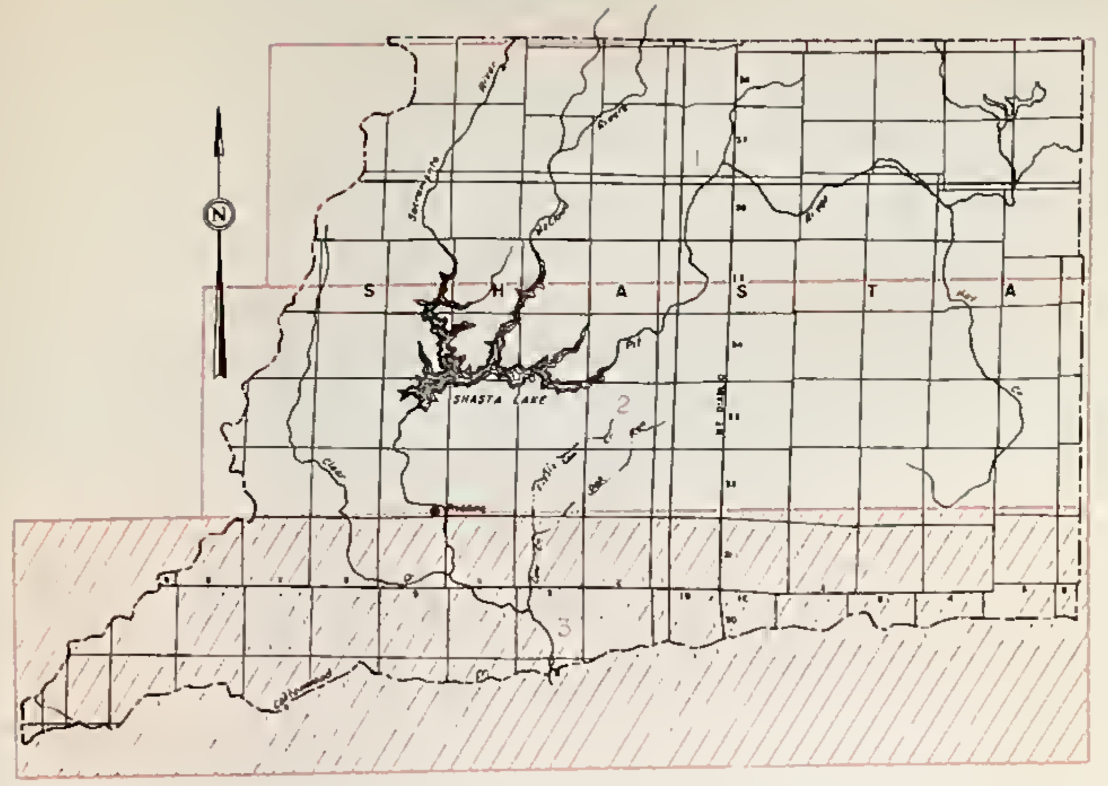

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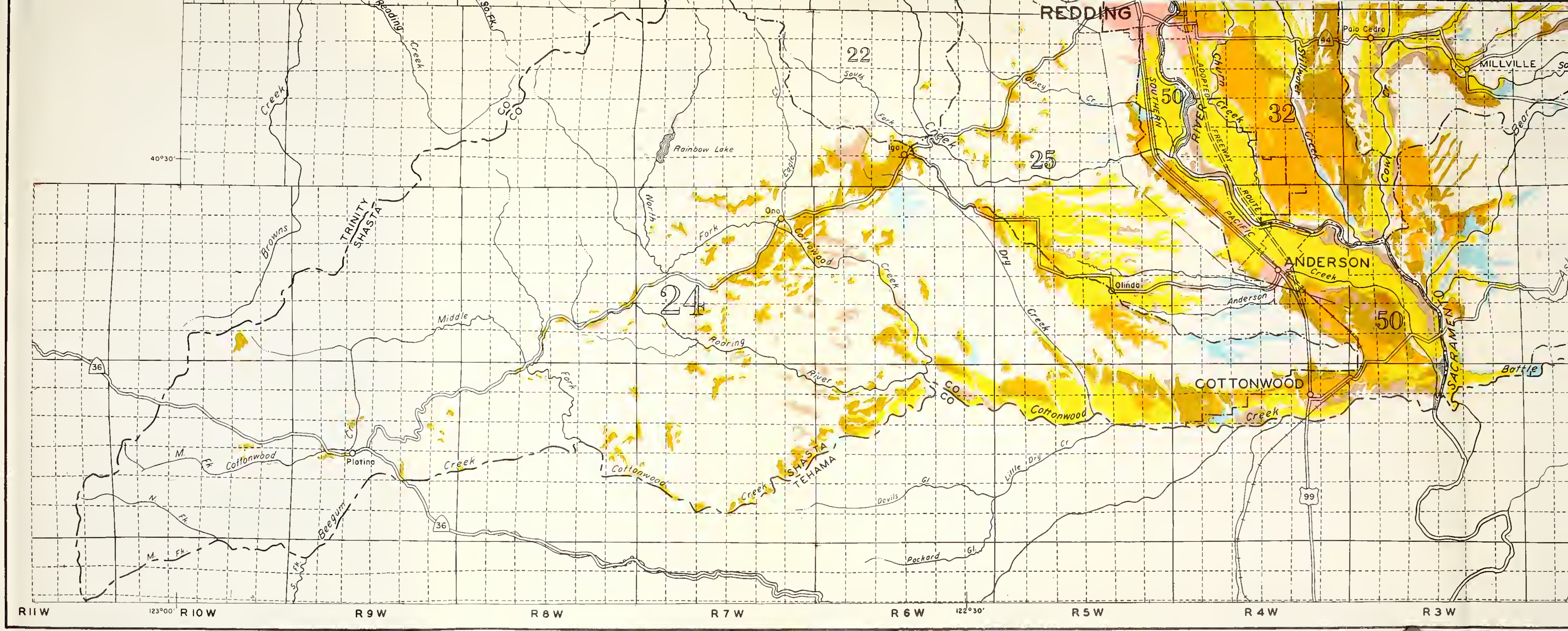


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Shingletown
Manton
Viola
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PACIFIC
FREEWAY
ROUTE
Churn Creek
Stillwater Creek
Cow Cr.
Cow Creek
Bear Creek
Battle Creek
North Fork
South Fork
Digger Creek
Onion Creek
Rock Creek
Ash Creek
Anderson Creek
Cottonwood Creek
Dry Cr.
Clover Cr.
Lost Creek
Manzanita Creek
Bailey Creek
West Fk.
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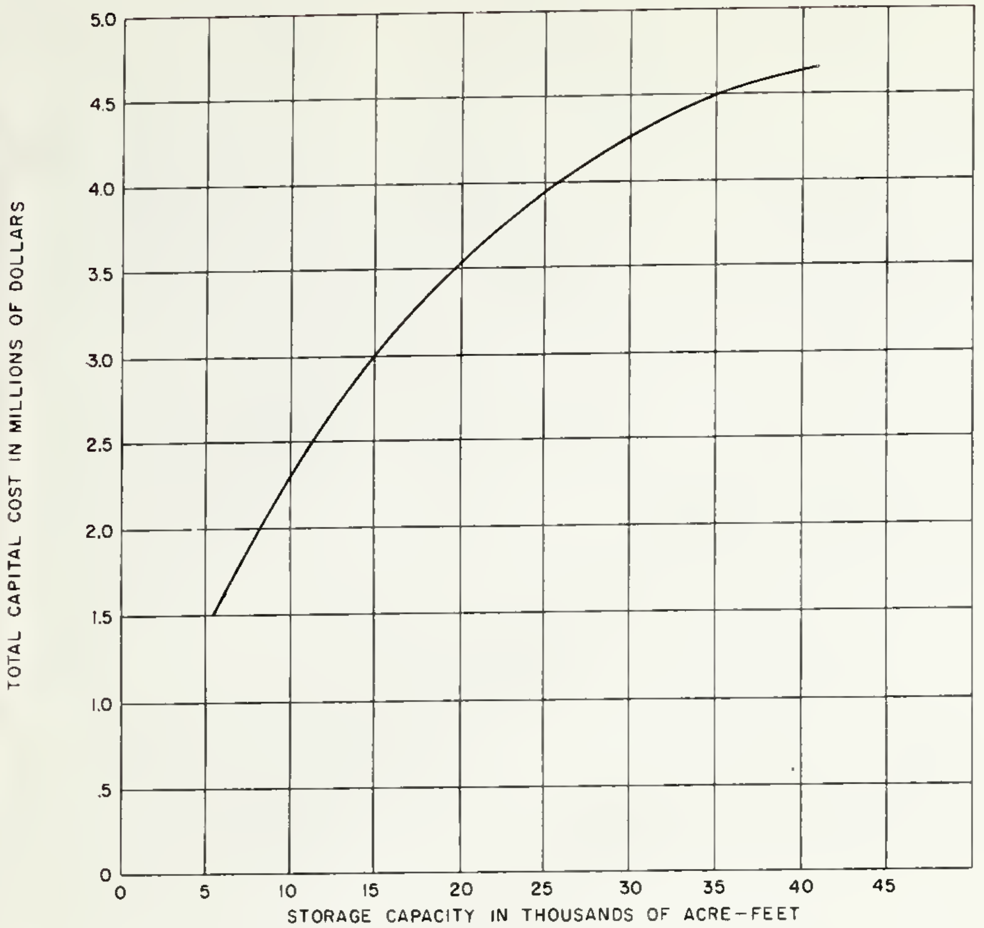

Fig. 1. TOTAL CAPITAL COST

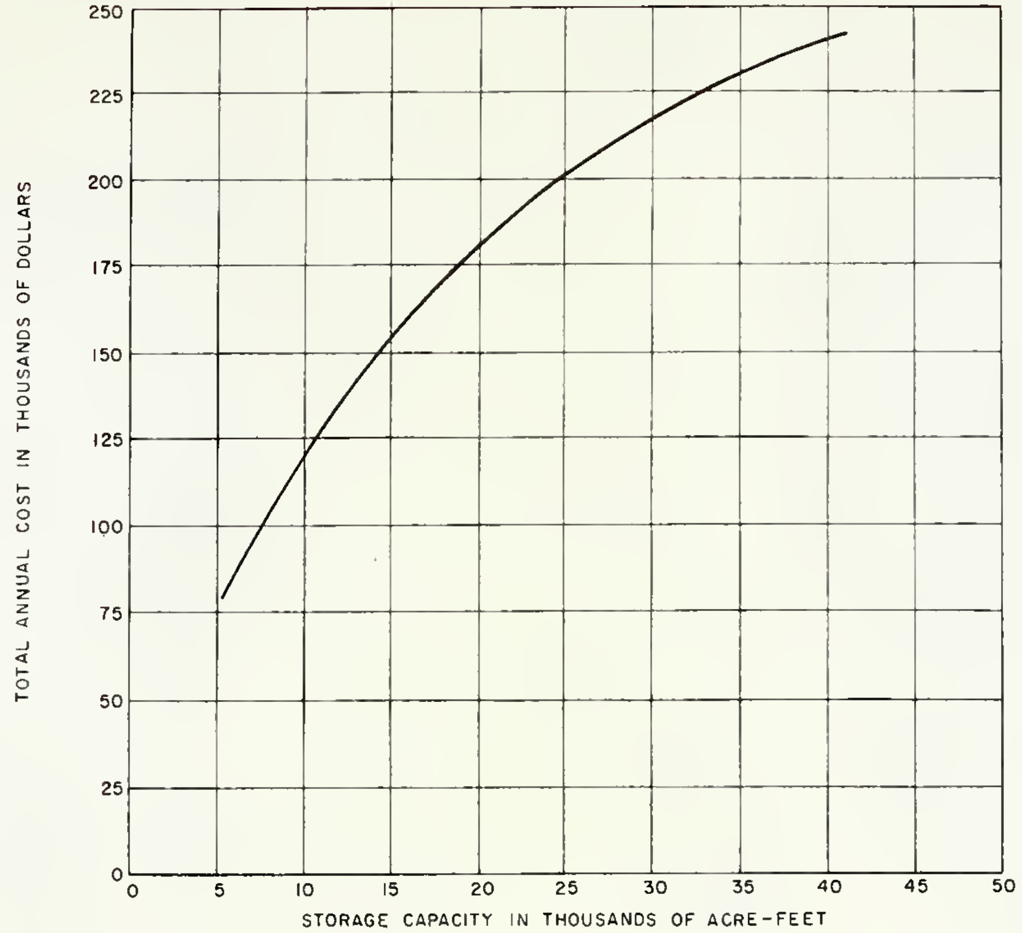

Fig. 2. TOTAL ANNUAL COST

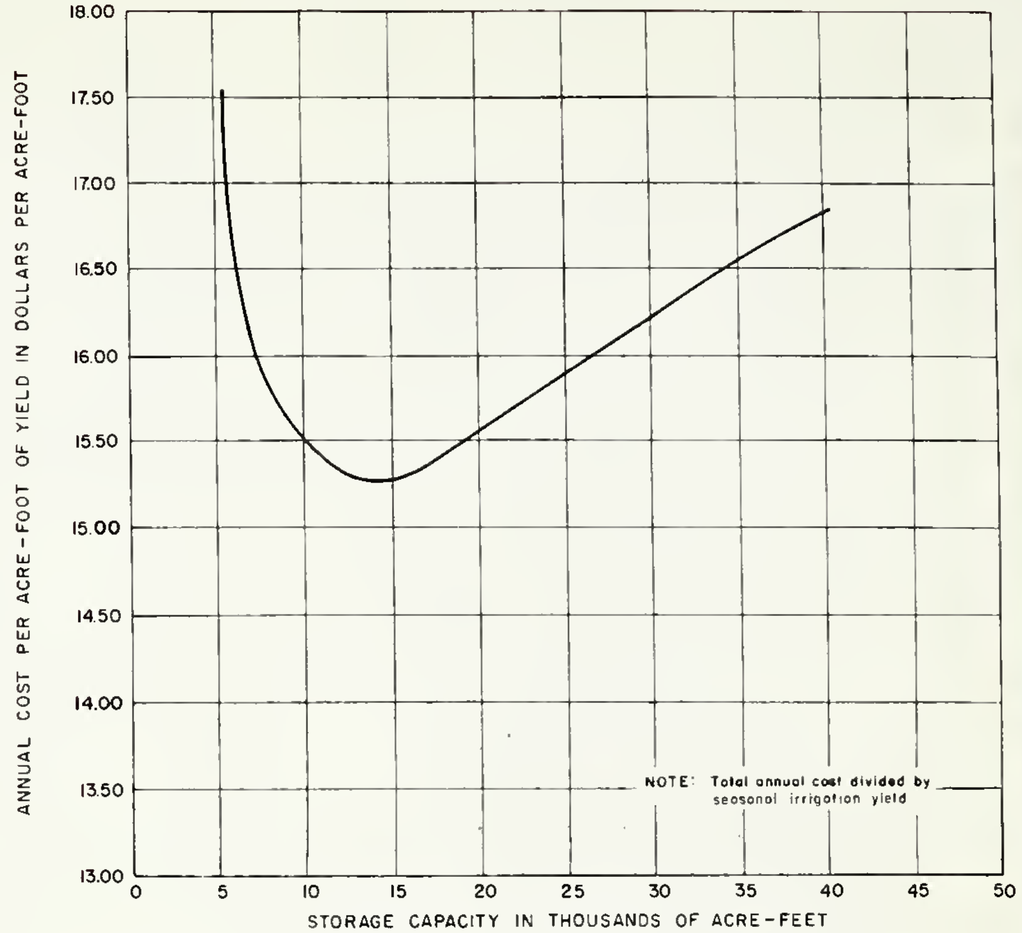

Fig. 3. ANNUAL COST PER ACRE-FOOT OF YIELD

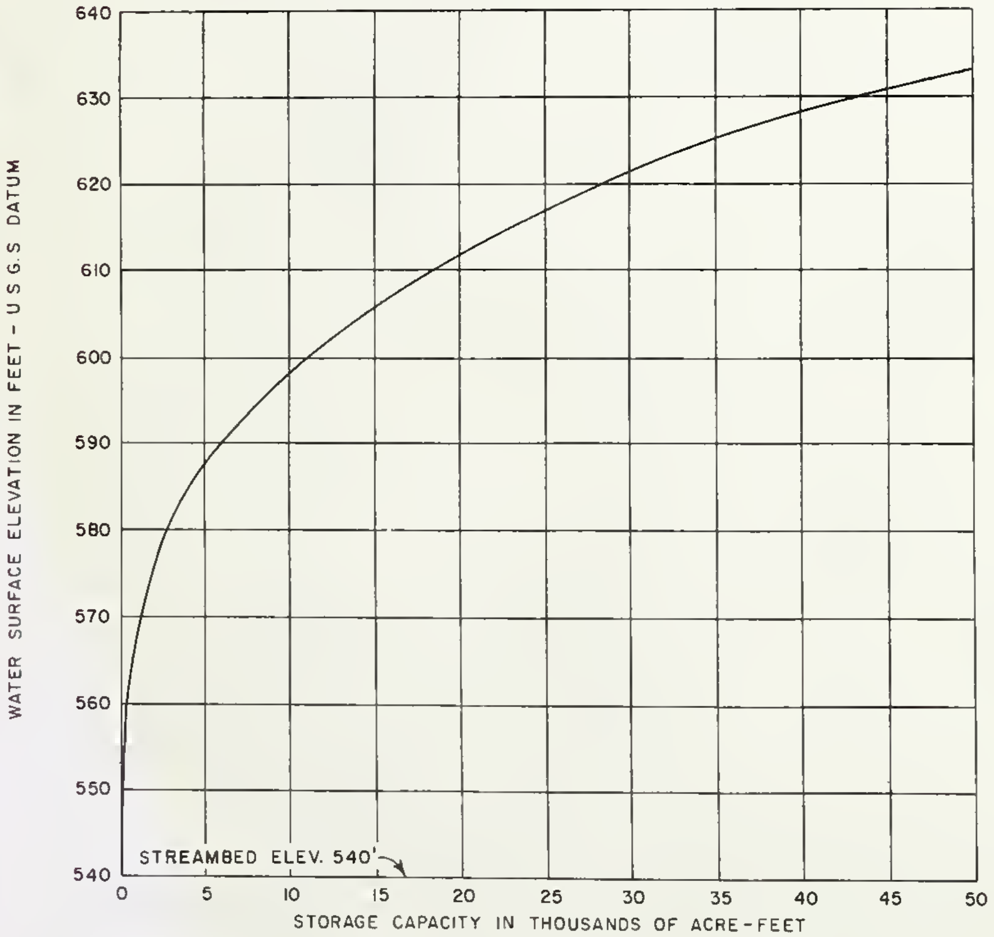

Fig. 4. WATER SURFACE ELEVATION VS. STORAGE CAPACITY

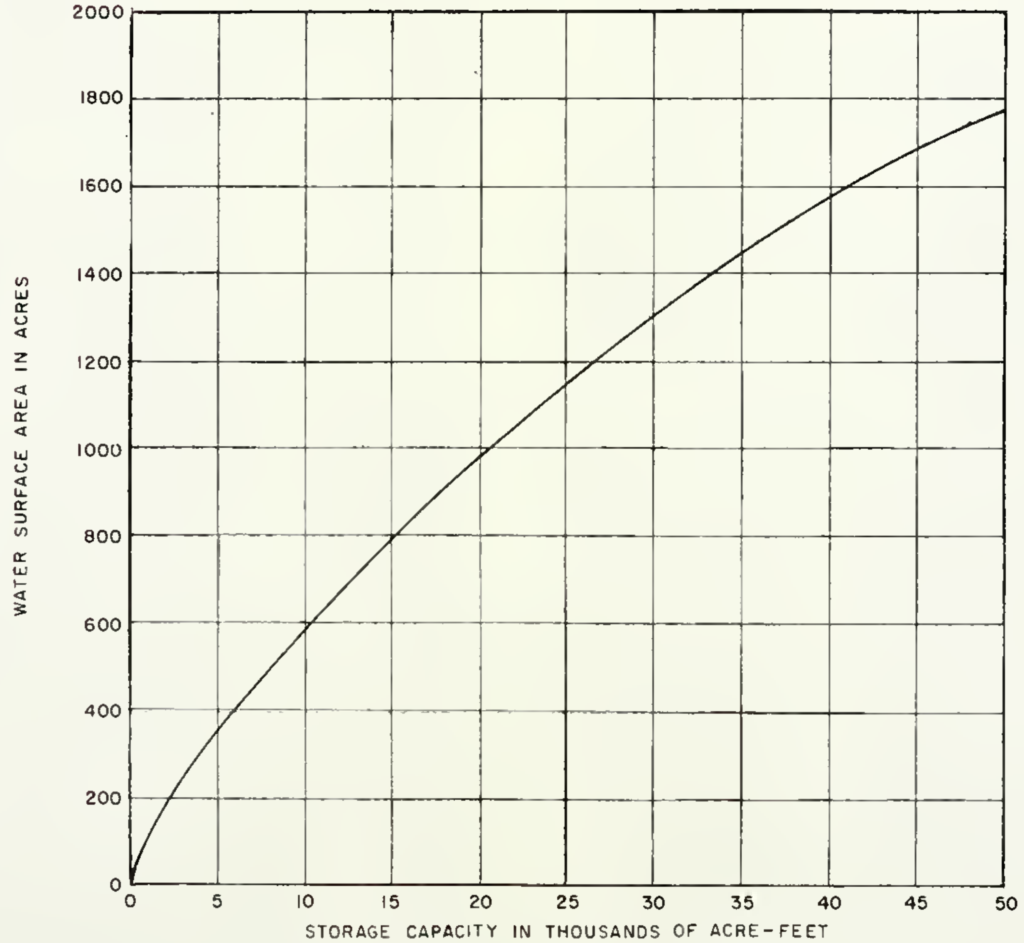

Fig. 5. WATER SURFACE AREA VS. STORAGE CAPACITY

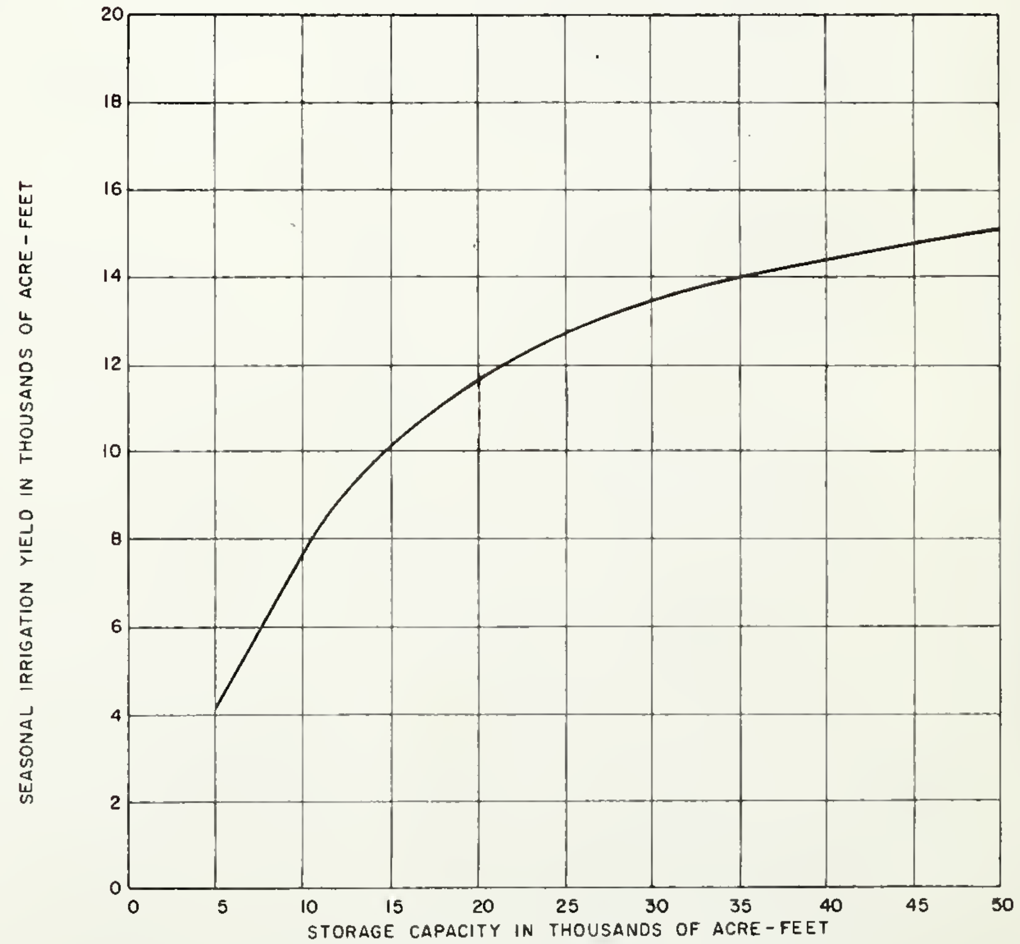

Fig. 6 SEASONAL IRRIGATION YIELD

AREA, CAPACITY, COST AND YIELD RELATIONSHIPS-MISTLETOE RESERVOIR

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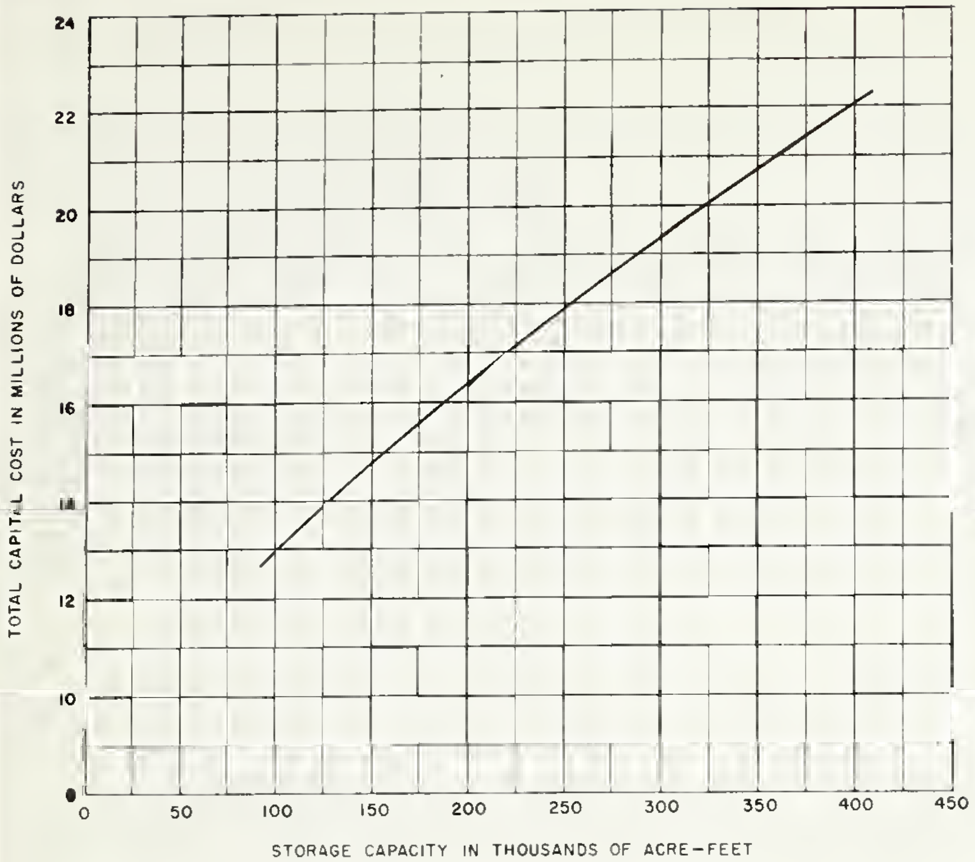
SALT CREEK DAM ON SALT CREEK
MISTLETOE DAM ON CHURN CREEK
AND
OAK FLAT DAM ON OAK RUN CREEK

1960



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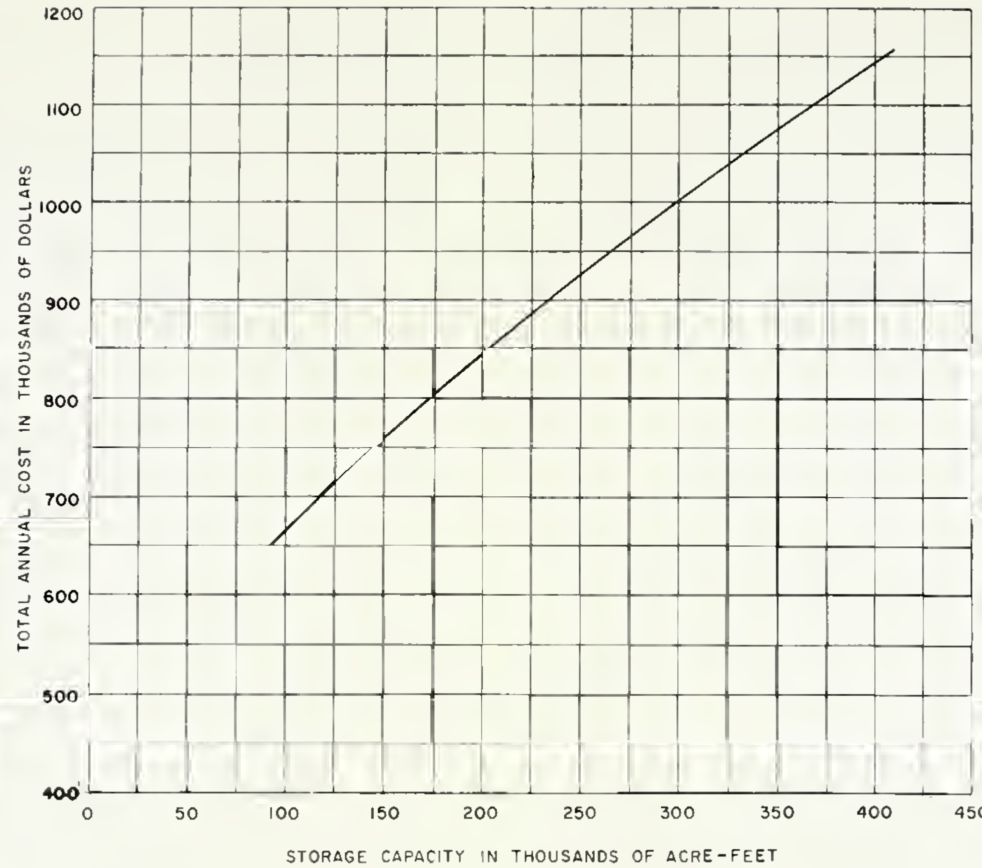


Fig. 2. TOTAL ANNUAL COST

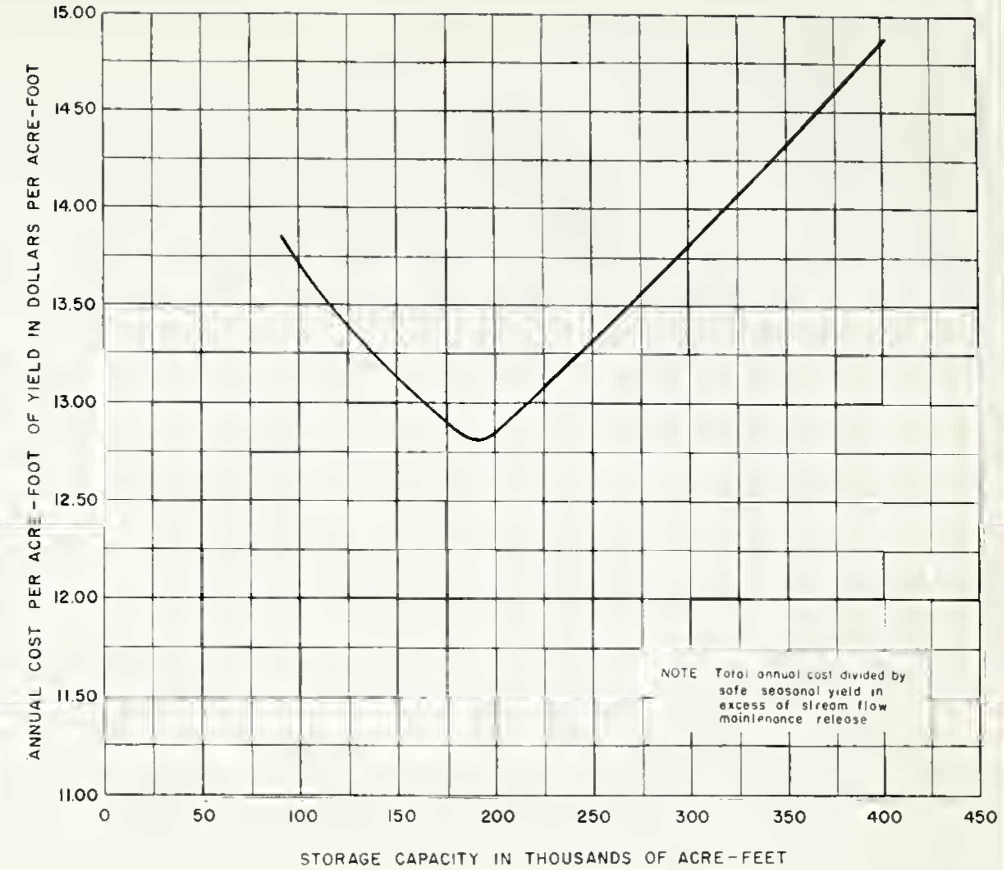


Fig. 3. ANNUAL COST PER ACRE-FOOT OF YIELD

Fig. 4. WATER SURFACE ELEVATION VS. STORAGE CAPACITY

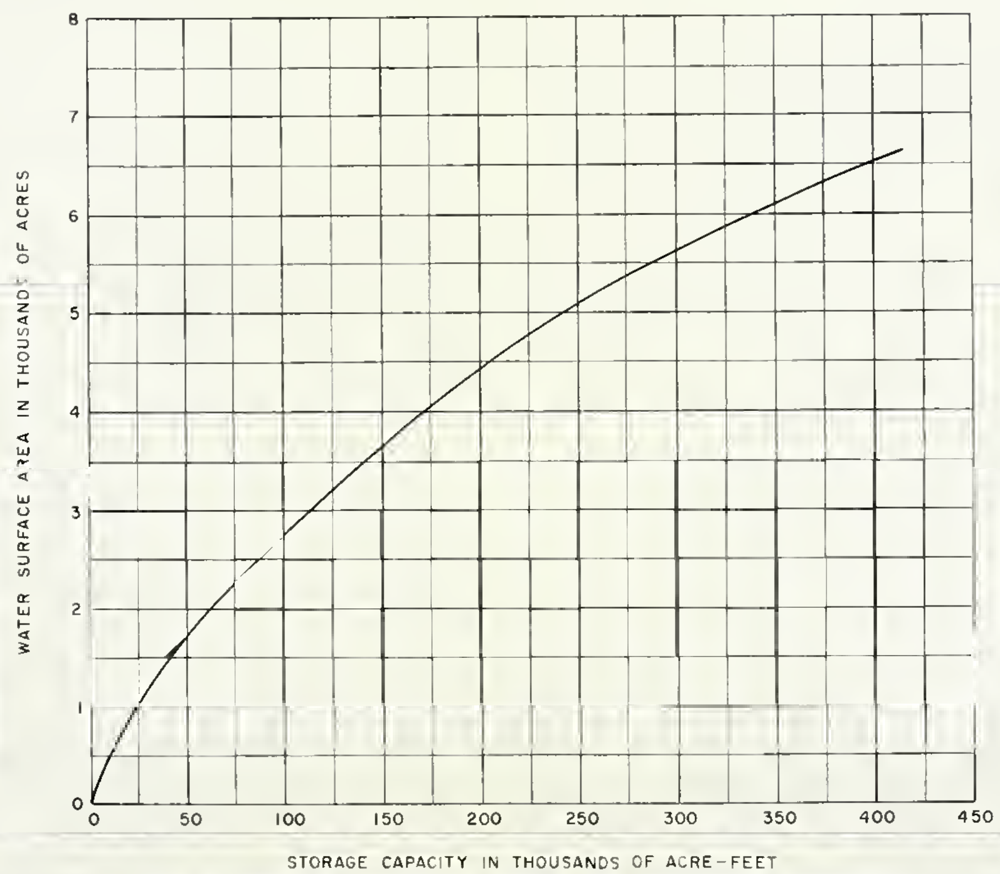


Fig. 5. WATER SURFACE AREA VS. STORAGE CAPACITY

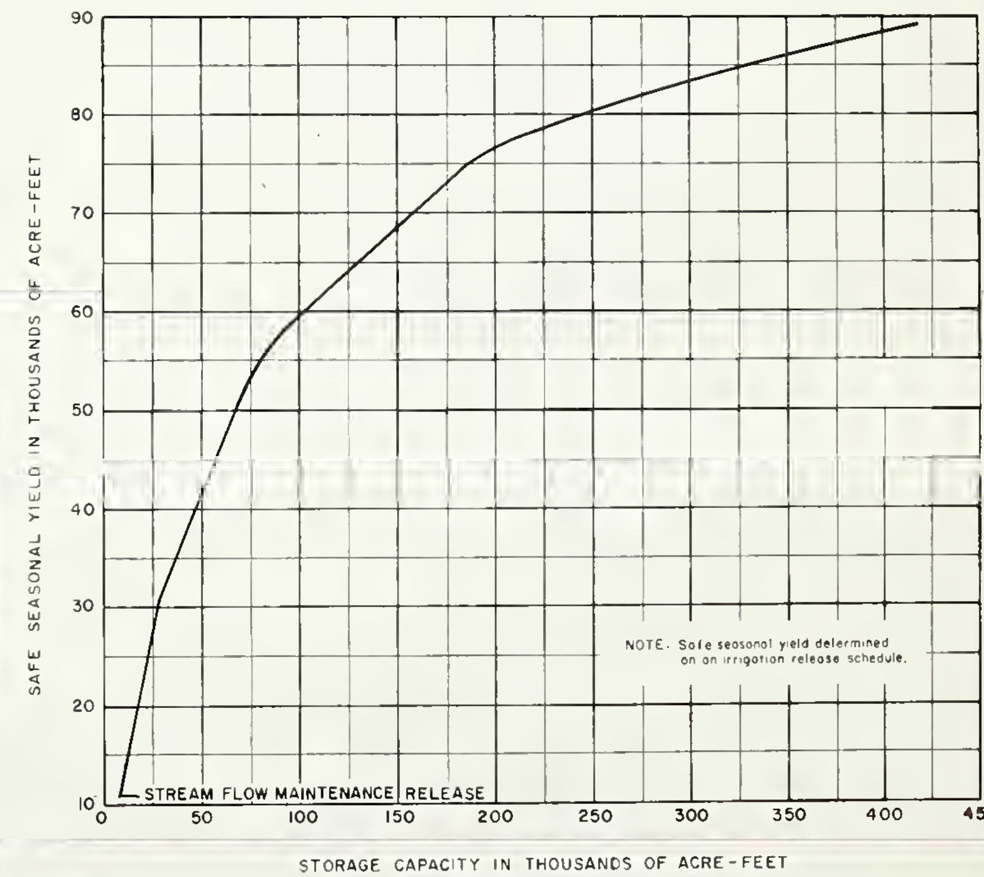
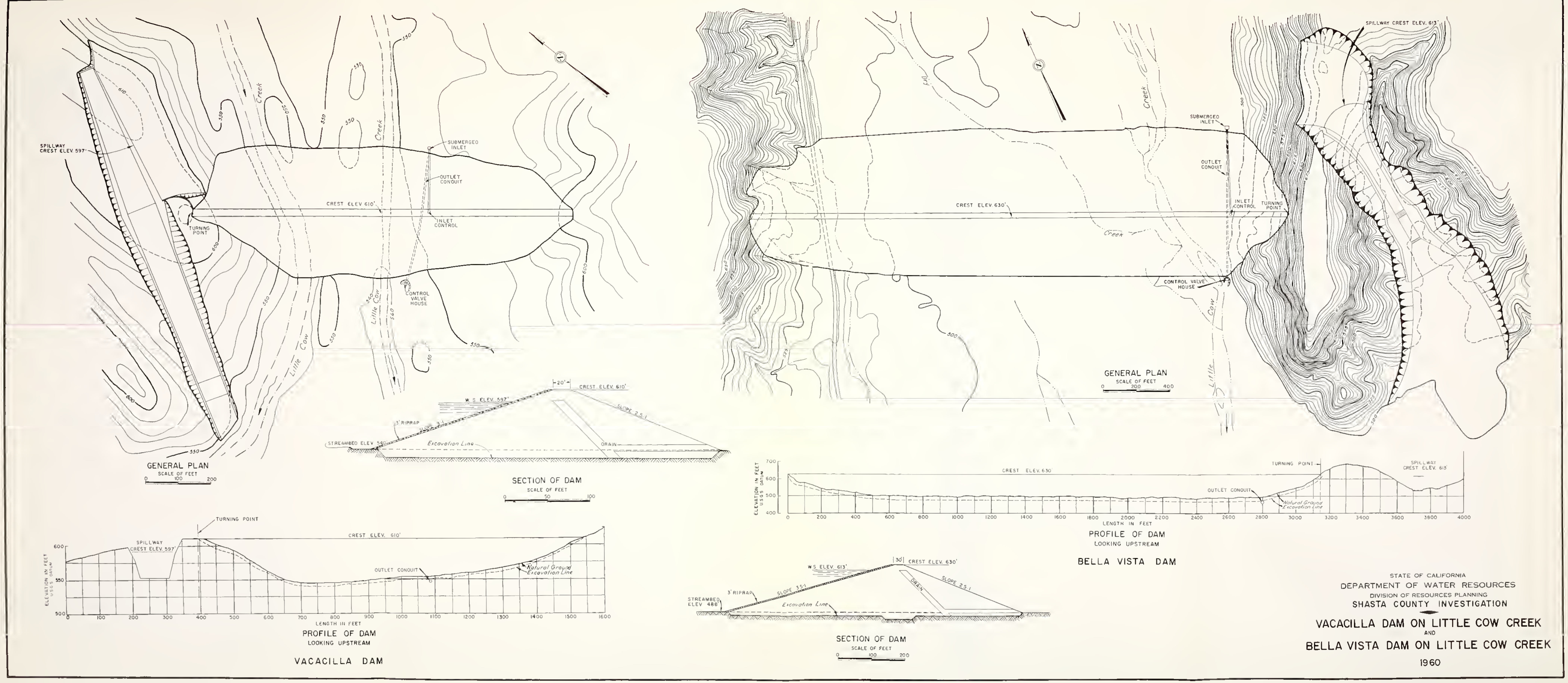


Fig. 6. SAFE SEASONAL YIELD

AREA, CAPACITY, COST, AND YIELD RELATIONSHIPS - BELLA VISTA RESERVOIR



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VACACILLA DAM ON LITTLE COW CREEK
AND
BELLA VISTA DAM ON LITTLE COW CREEK

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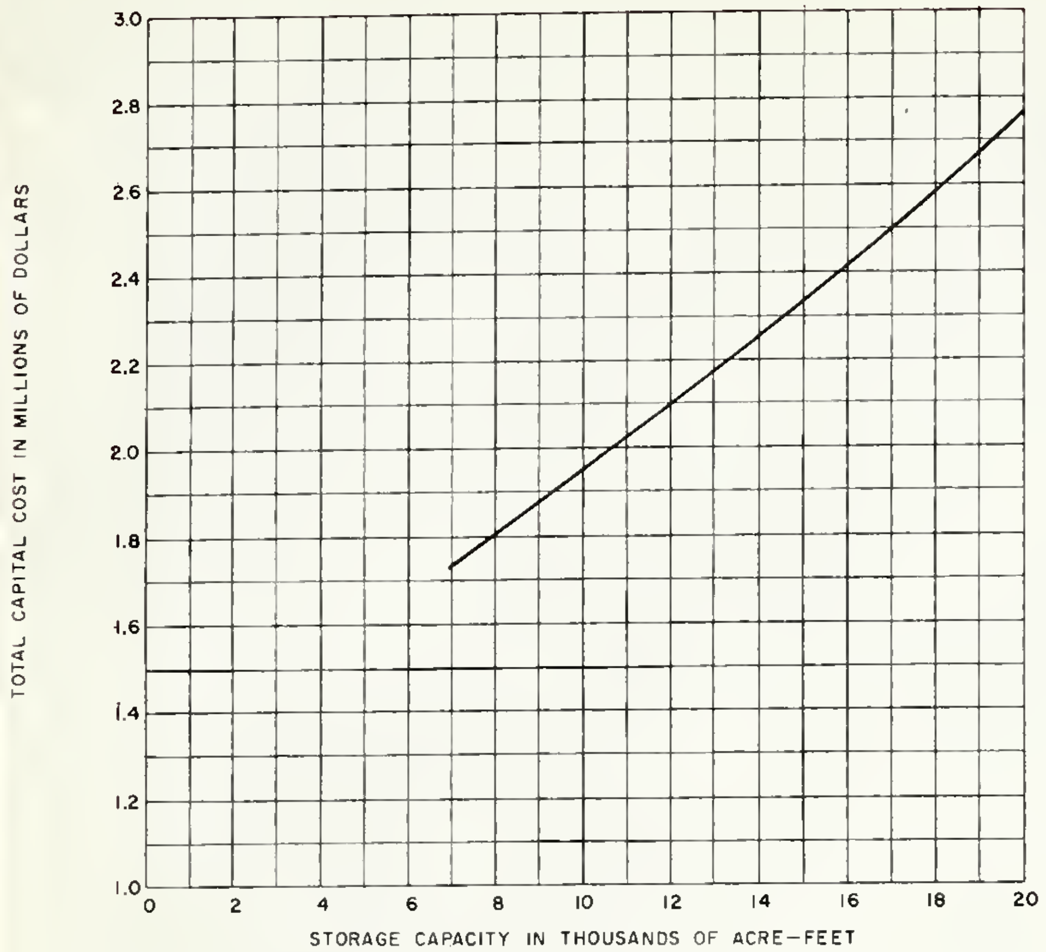


Fig. 1. TOTAL CAPITAL COST

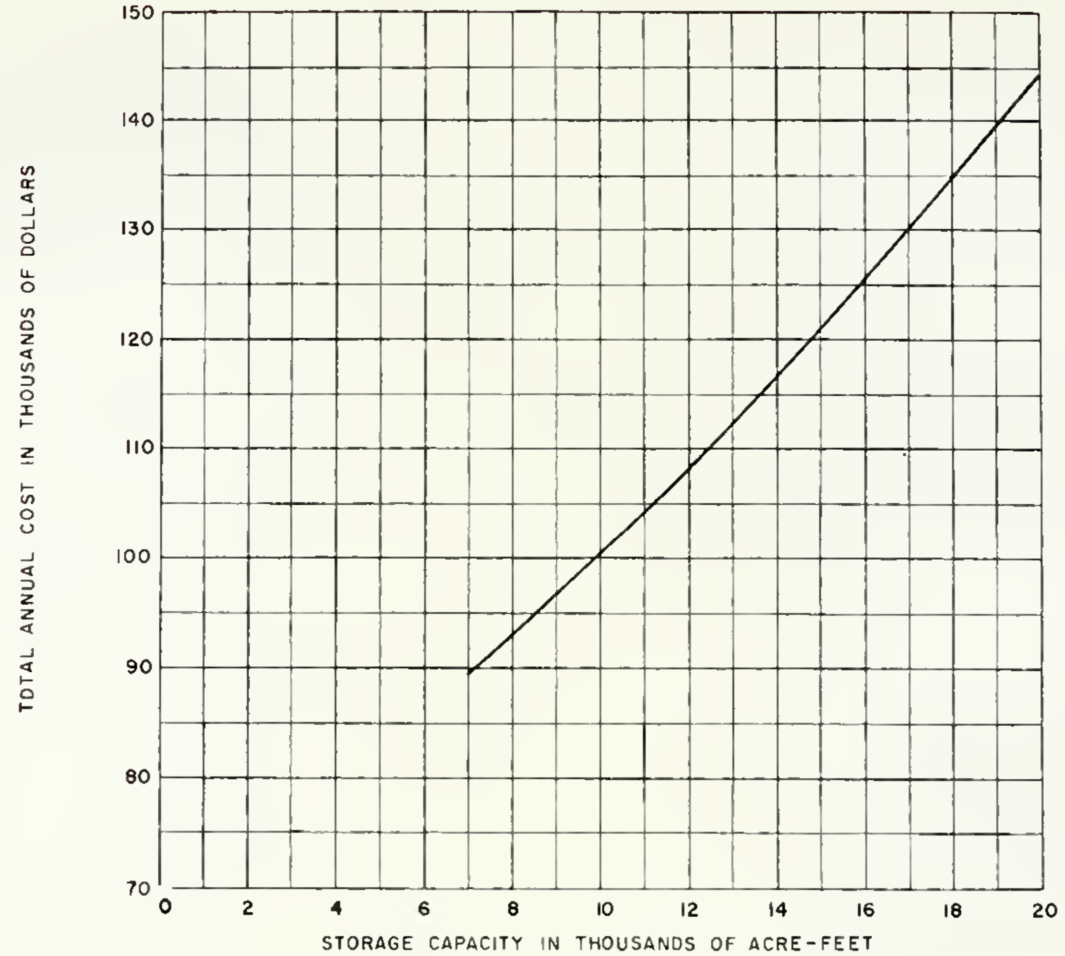


Fig. 2. TOTAL ANNUAL COST

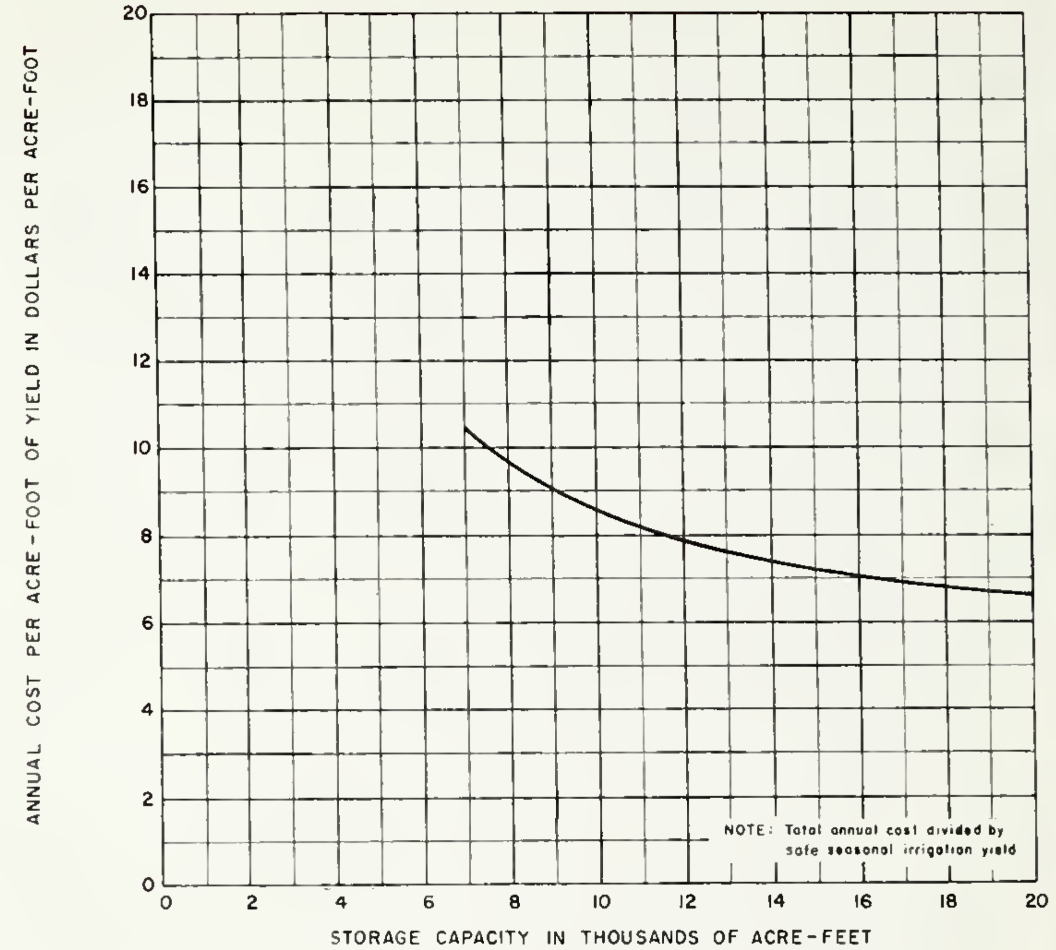


Fig. 3. ANNUAL COST PER ACRE-FOOT OF YIELD

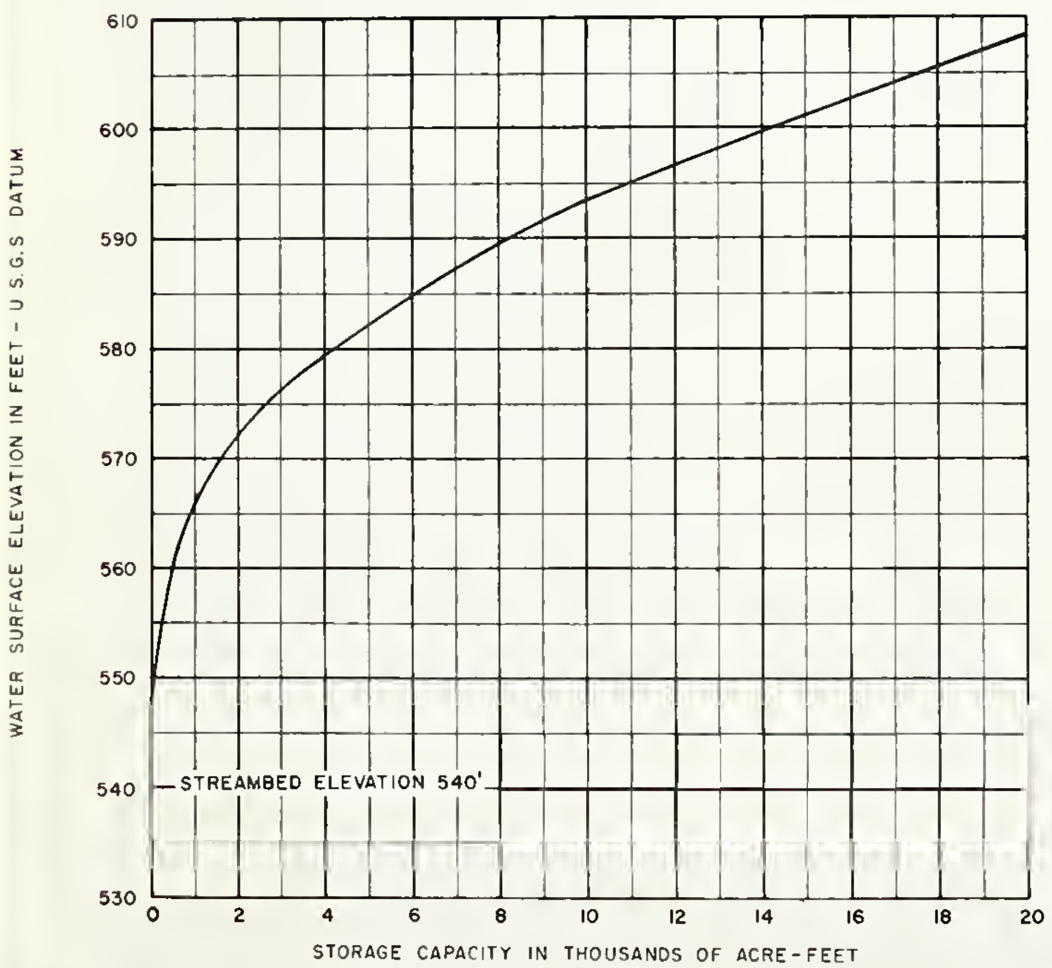


Fig. 4. WATER SURFACE ELEVATION VS. STORAGE CAPACITY

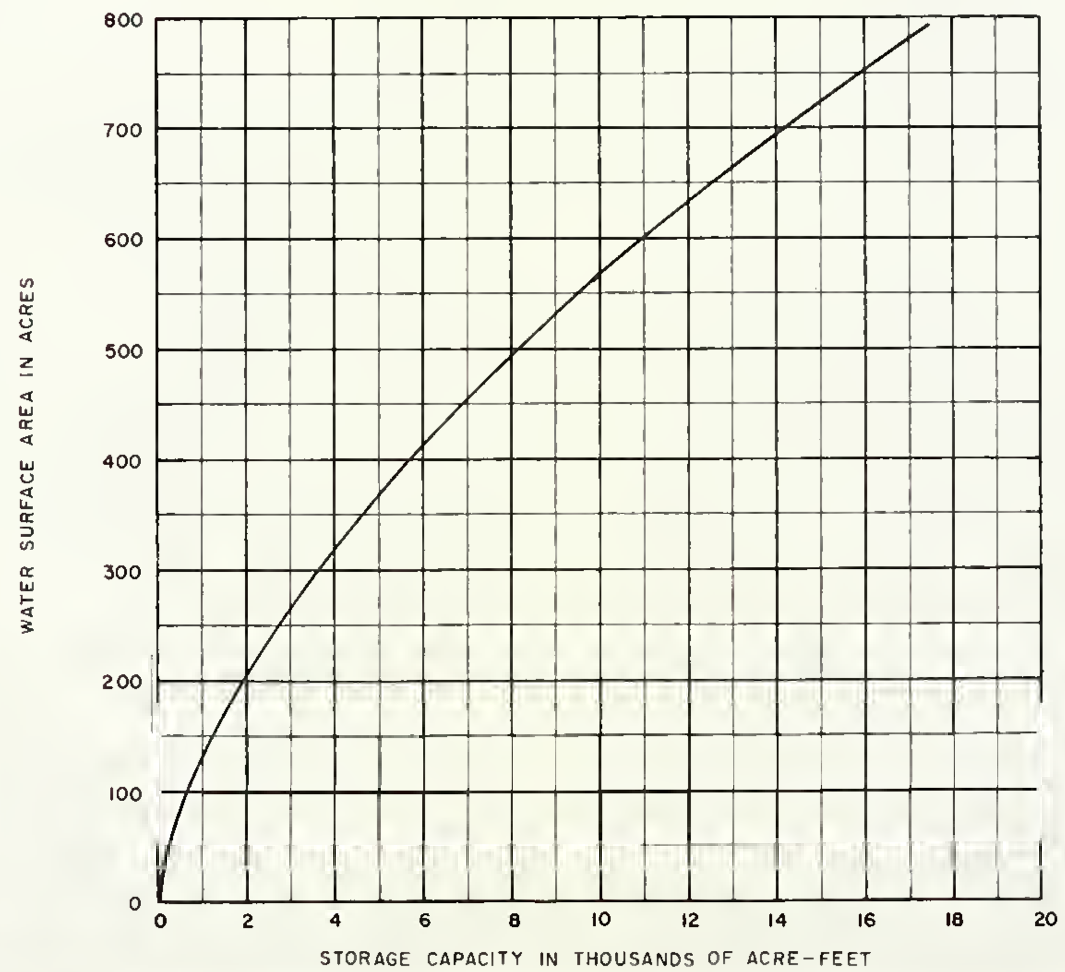


Fig. 5. WATER SURFACE AREA VS. STORAGE CAPACITY

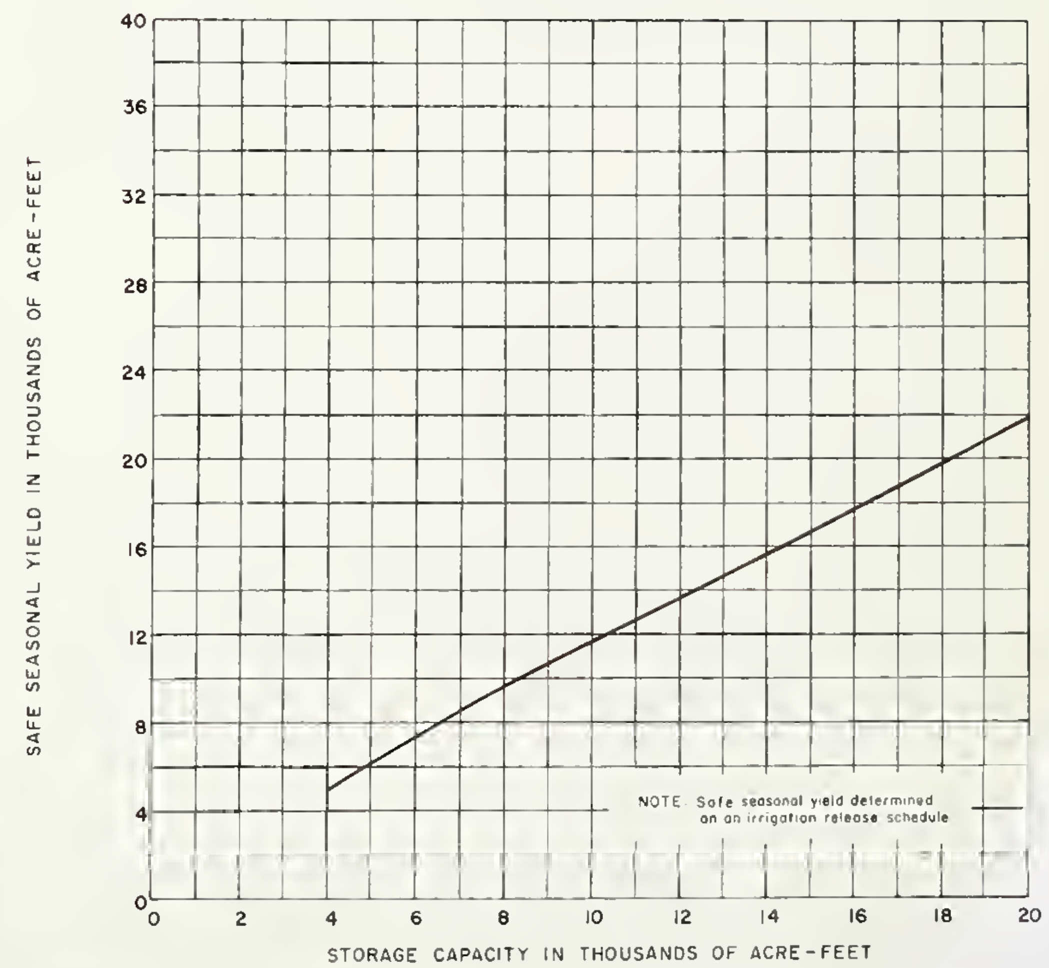
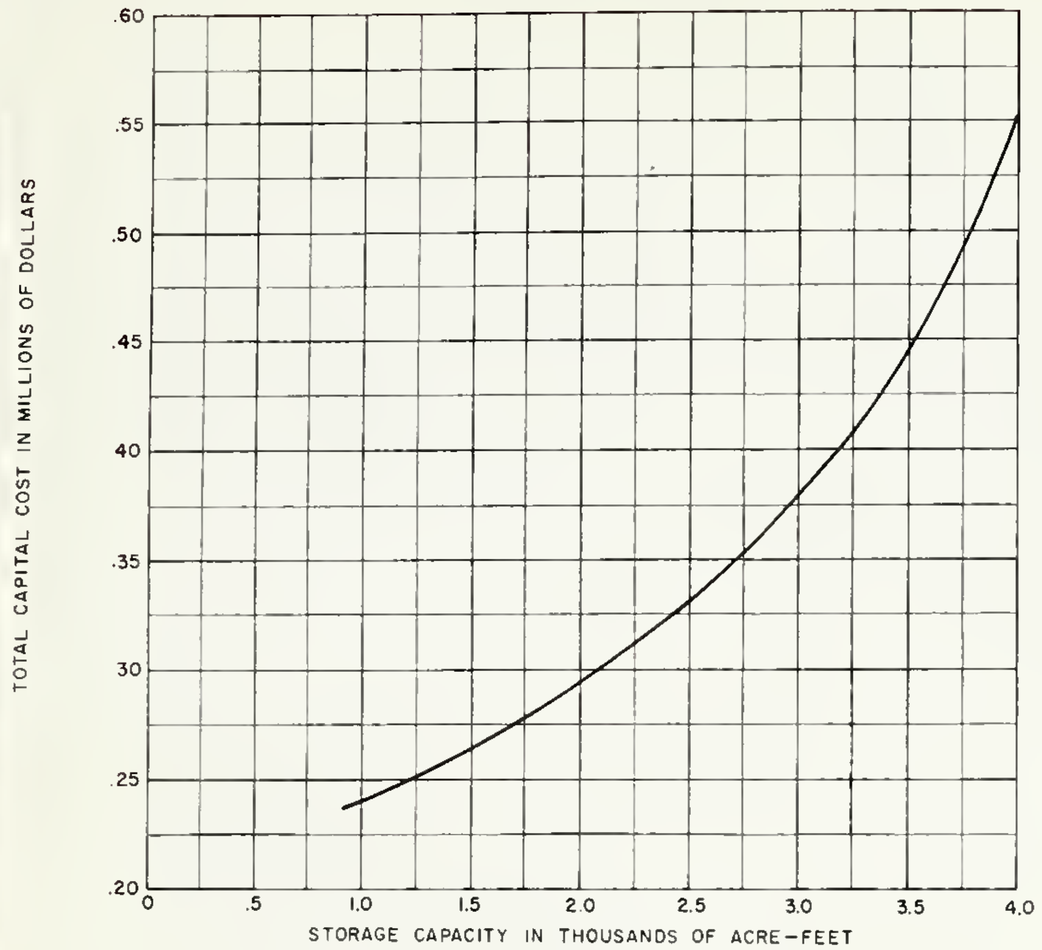


Fig. 6. SAFE SEASONAL YIELD

AREA, CAPACITY, COST, AND YIELD RELATIONSHIPS-VACACILLA RESERVOIR



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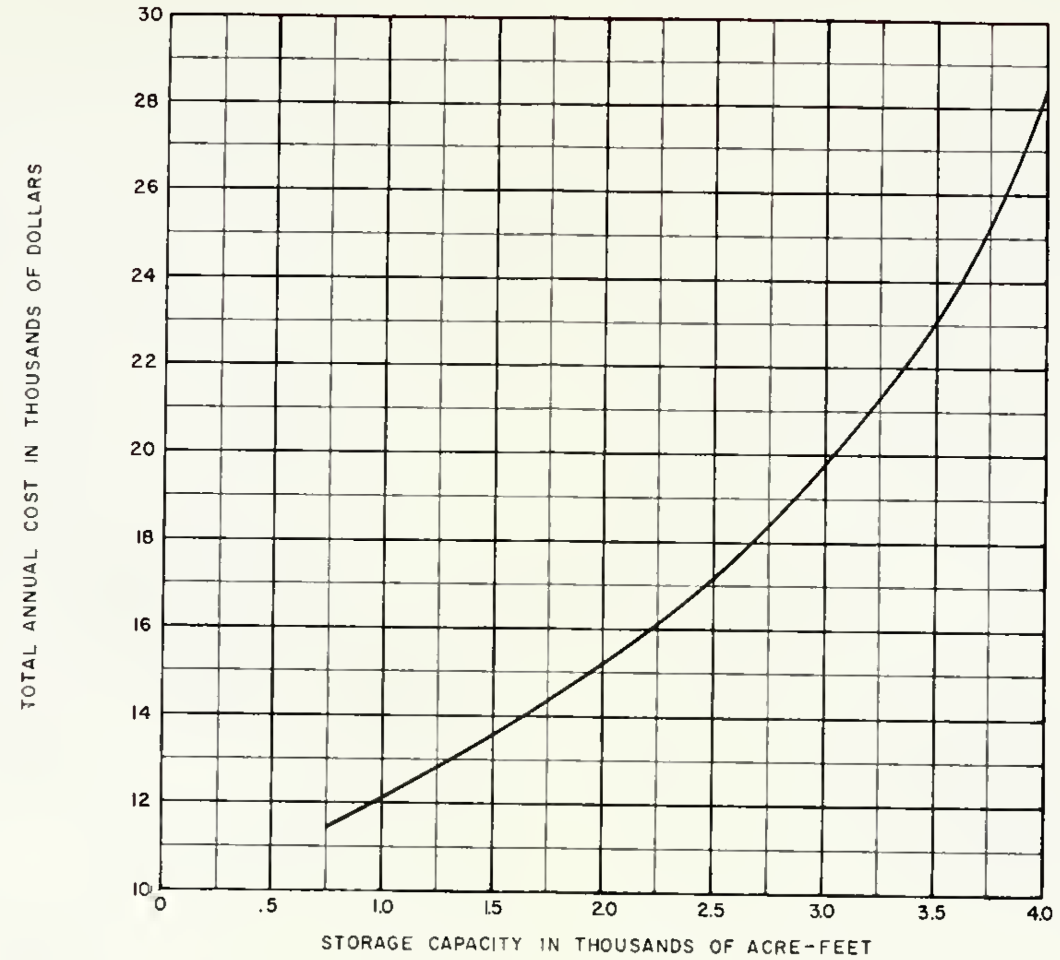


Fig. 2. TOTAL ANNUAL COST

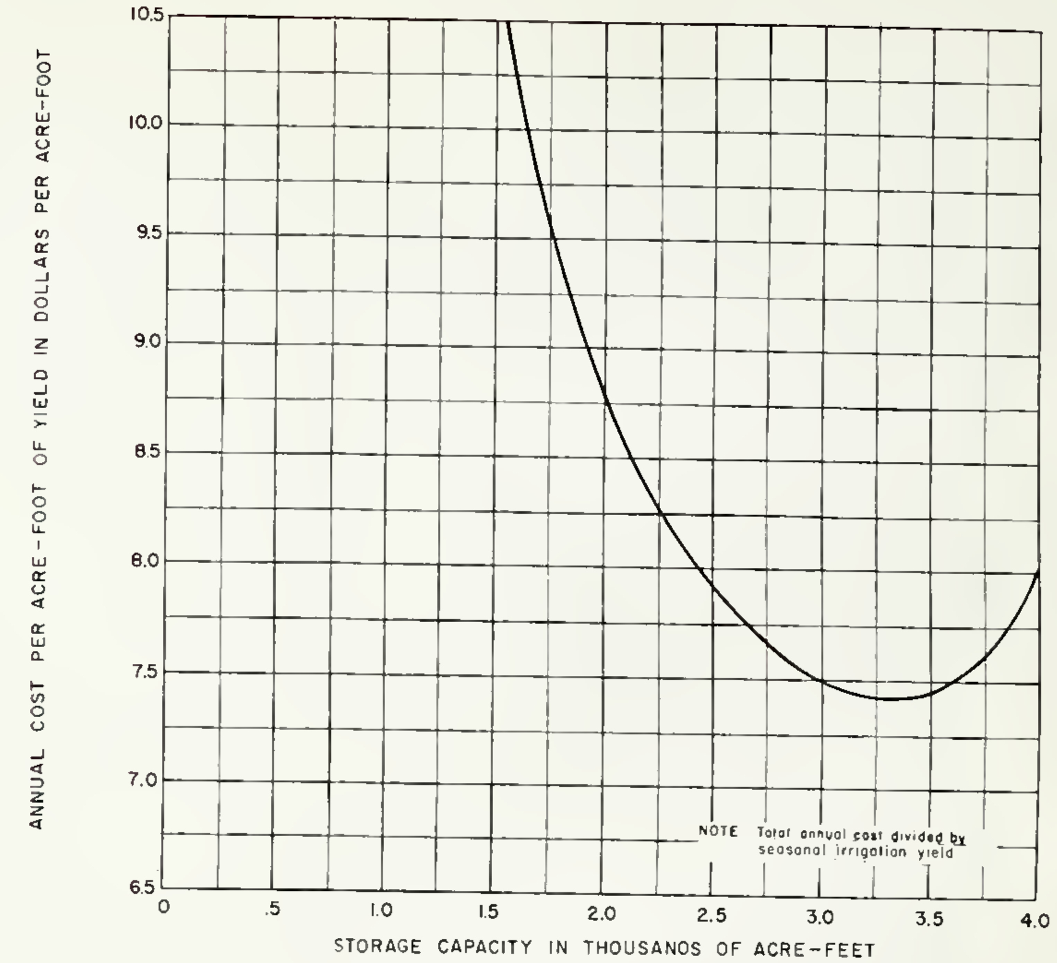


Fig. 3. ANNUAL COST PER ACRE-FOOT OF YIELD

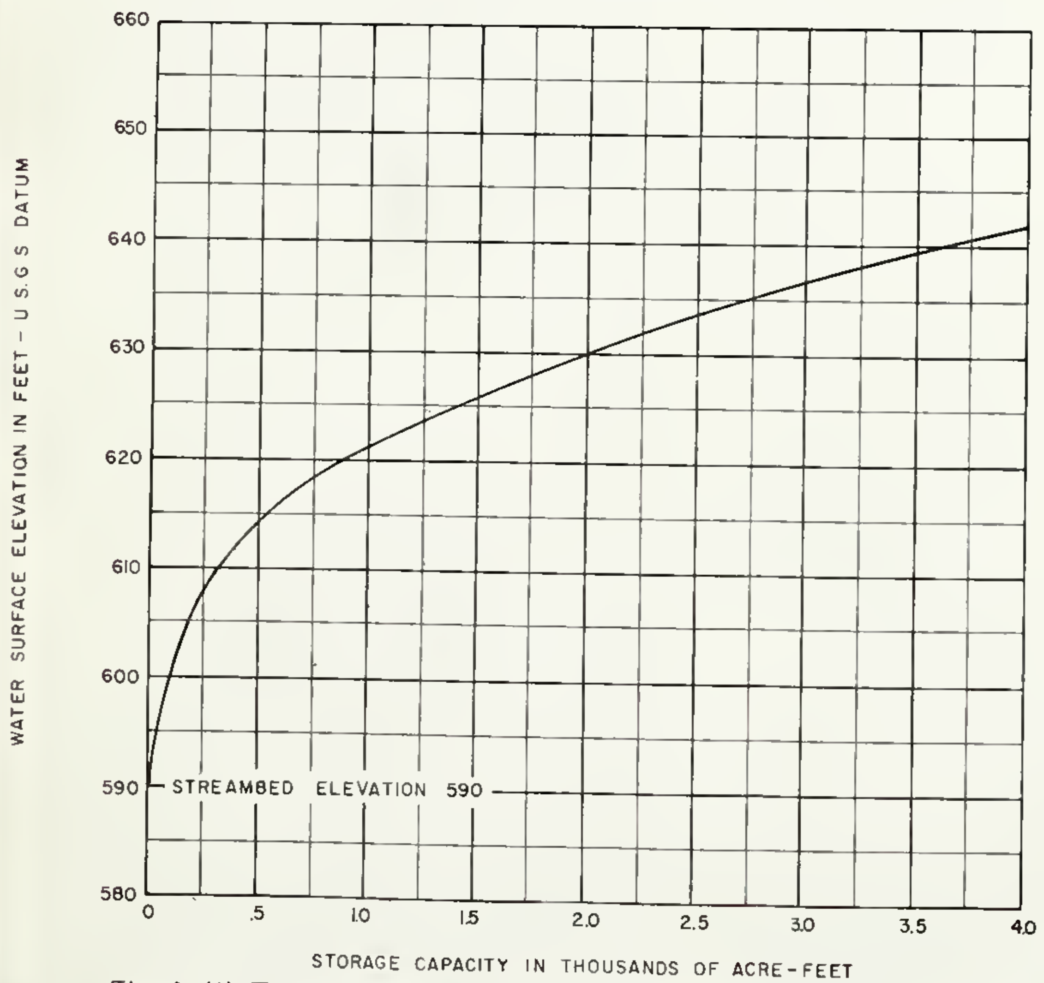


Fig. 4. WATER SURFACE ELEVATION VS. STORAGE CAPACITY

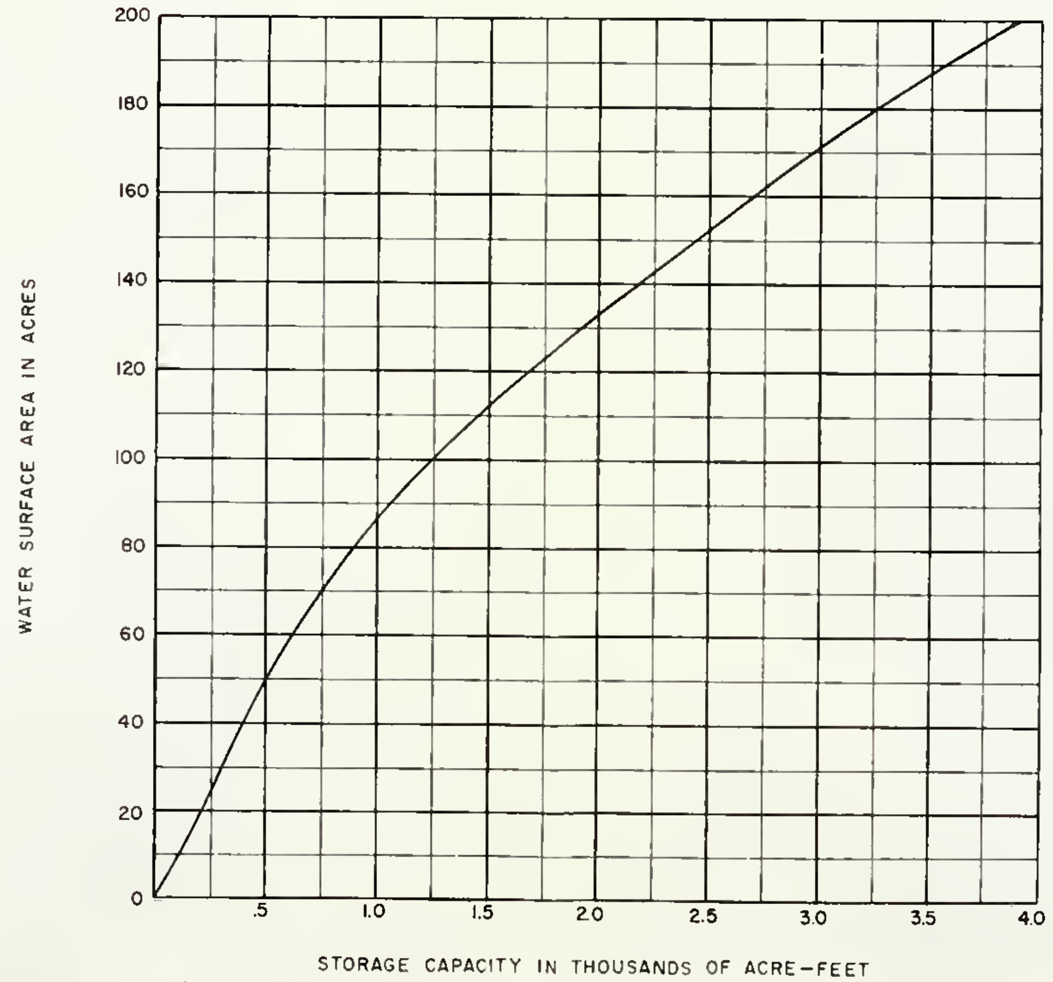


Fig. 5. WATER SURFACE AREA VS. STORAGE CAPACITY

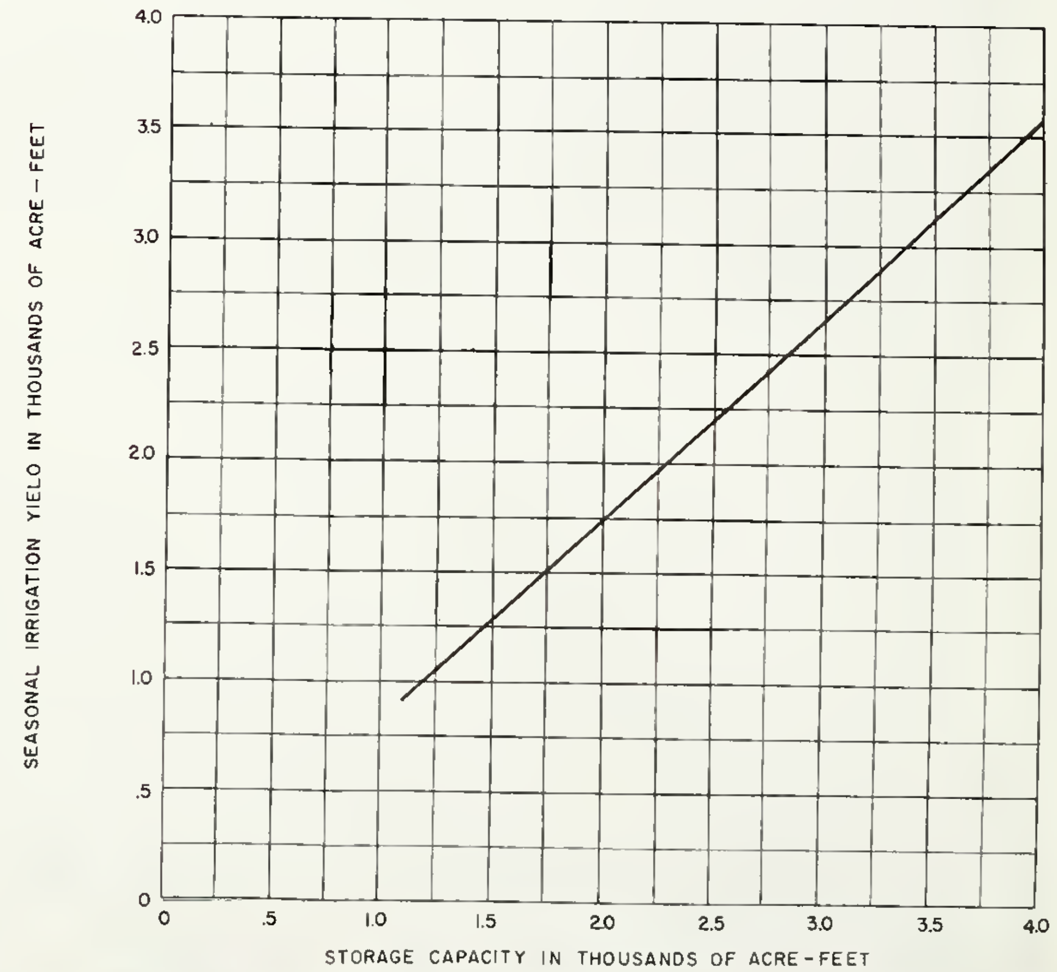
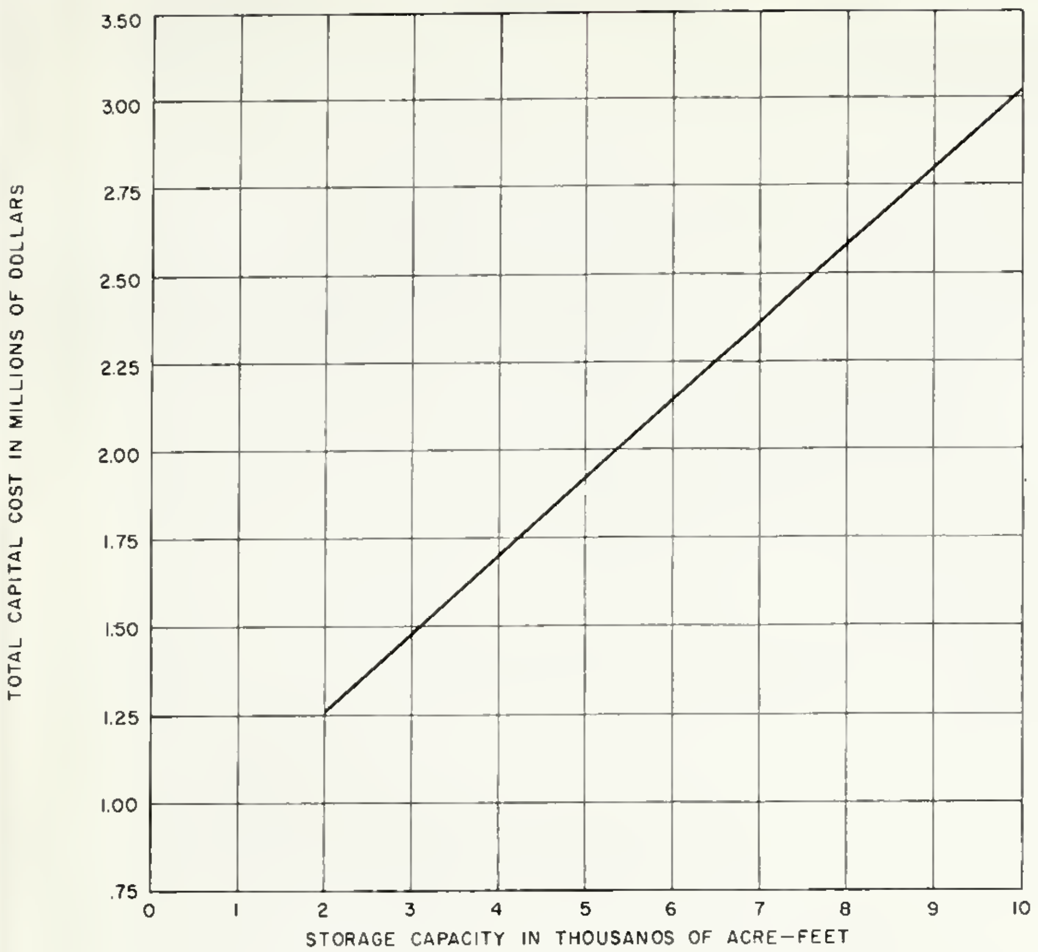


Fig. 6 SEASONAL IRRIGATION YIELD

AREA, CAPACITY, COST AND YIELD RELATIONSHIPS-SALT CREEK RESERVOIR



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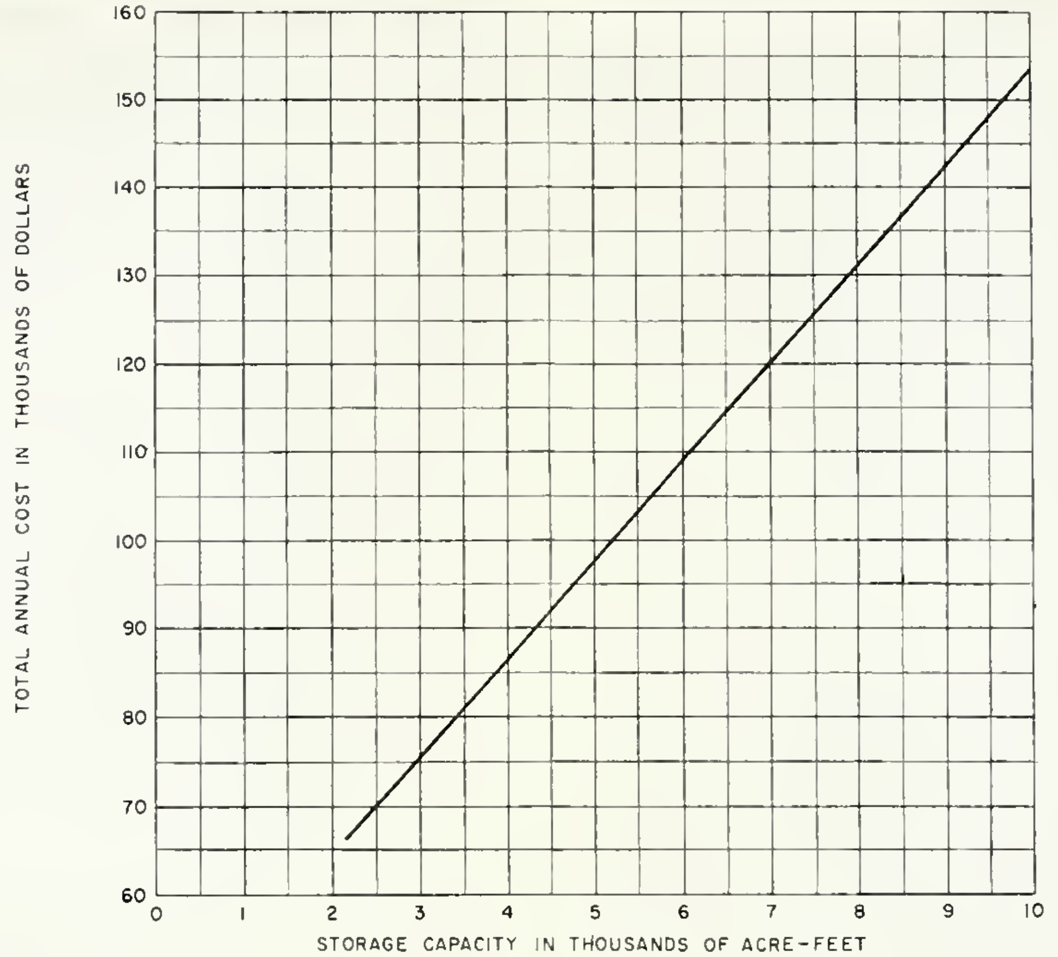


Fig. 2. TOTAL ANNUAL COST

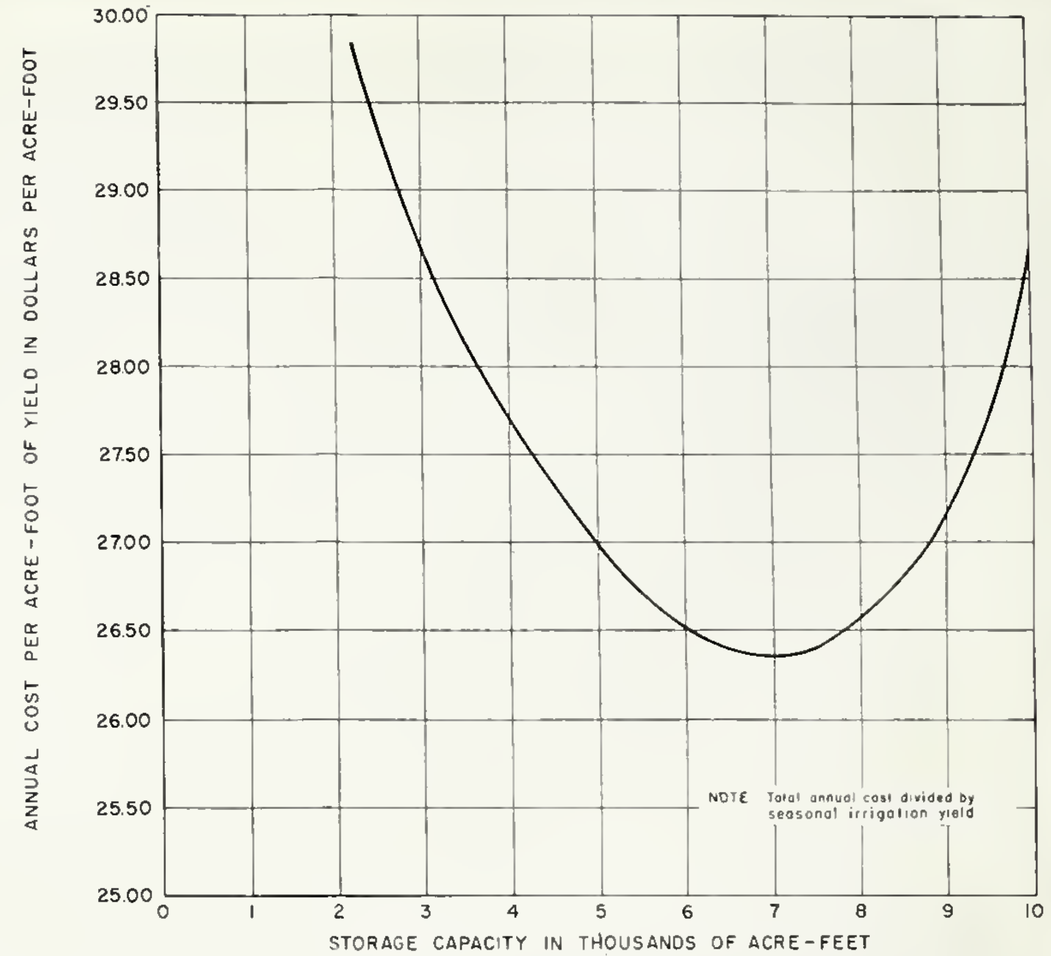


Fig. 3. ANNUAL COST PER ACRE-FOOT OF YIELD

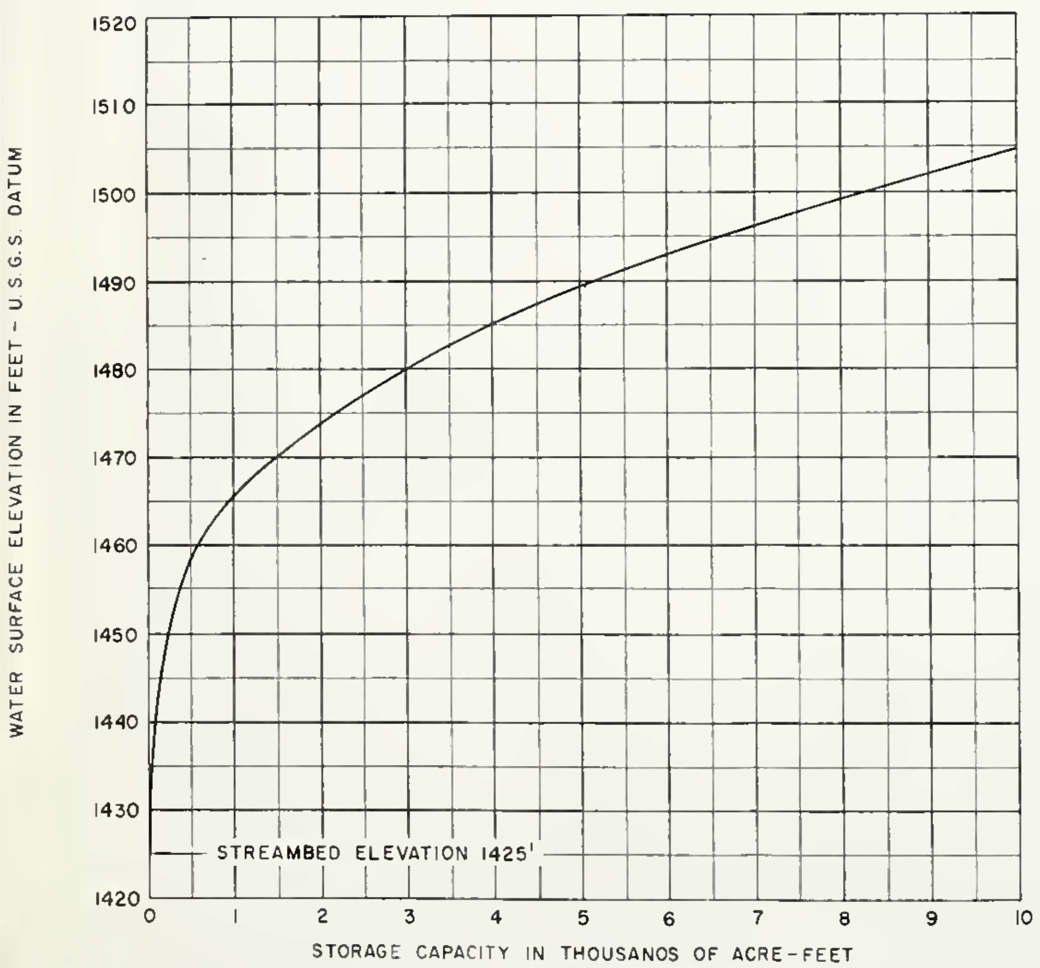


Fig. 4. WATER SURFACE ELEVATION VS. STORAGE CAPACITY

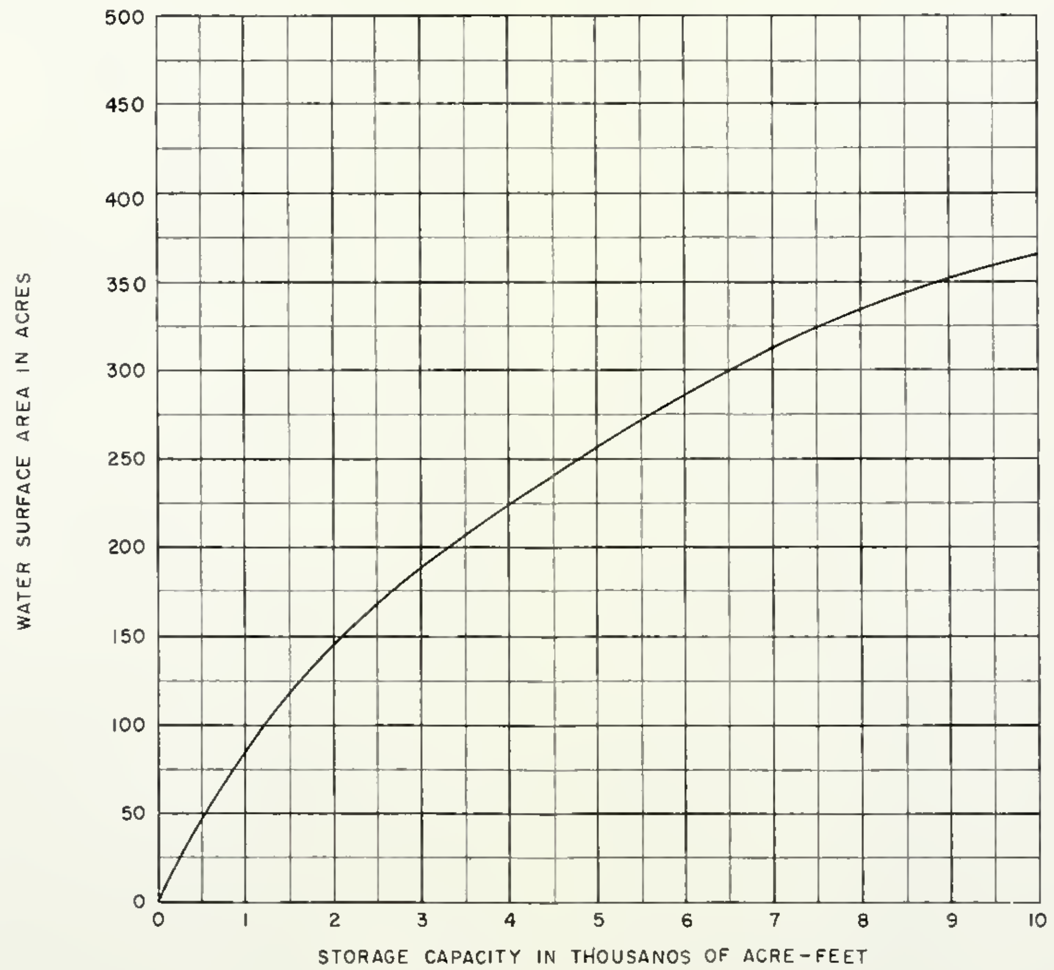


Fig. 5. WATER SURFACE AREA VS. STORAGE CAPACITY

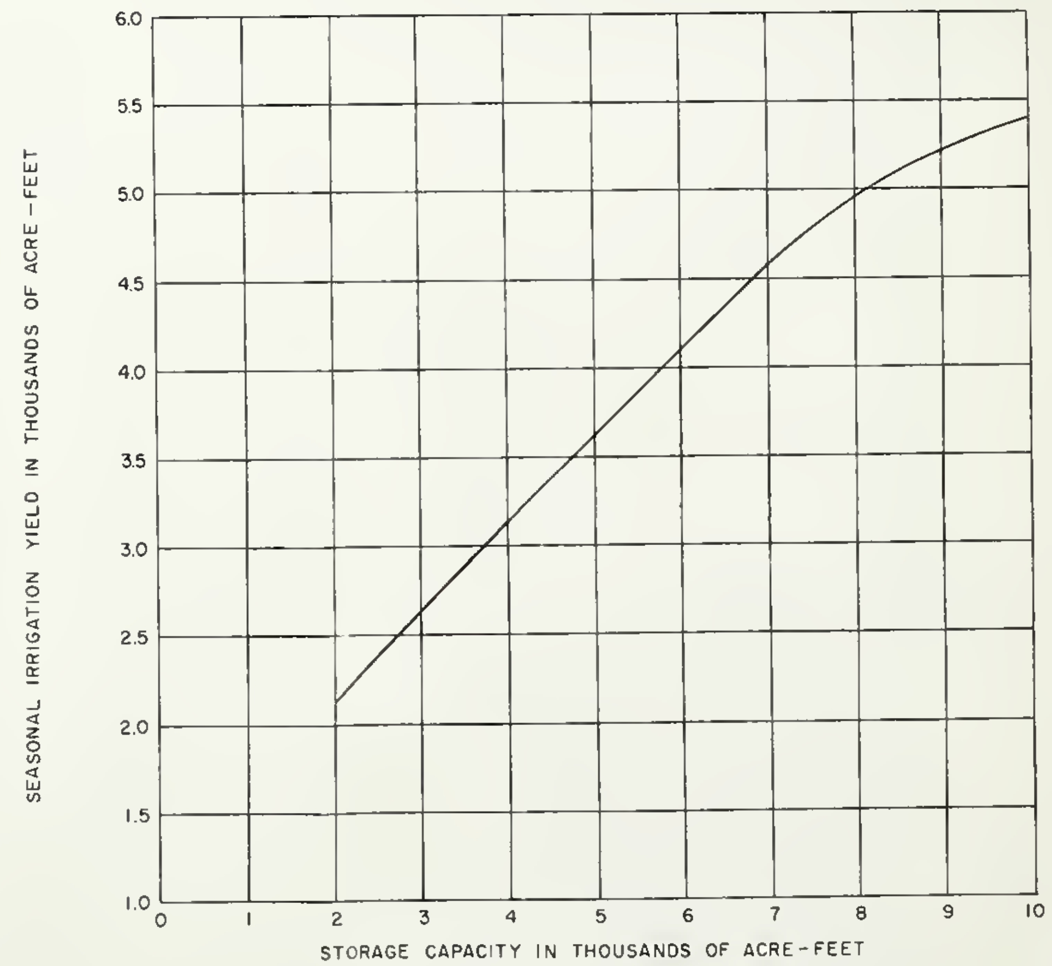


Fig. 6 SEASONAL IRRIGATION YIELD

AREA, CAPACITY, COST, AND YIELD RELATIONSHIPS—OAK FLAT RESERVOIR

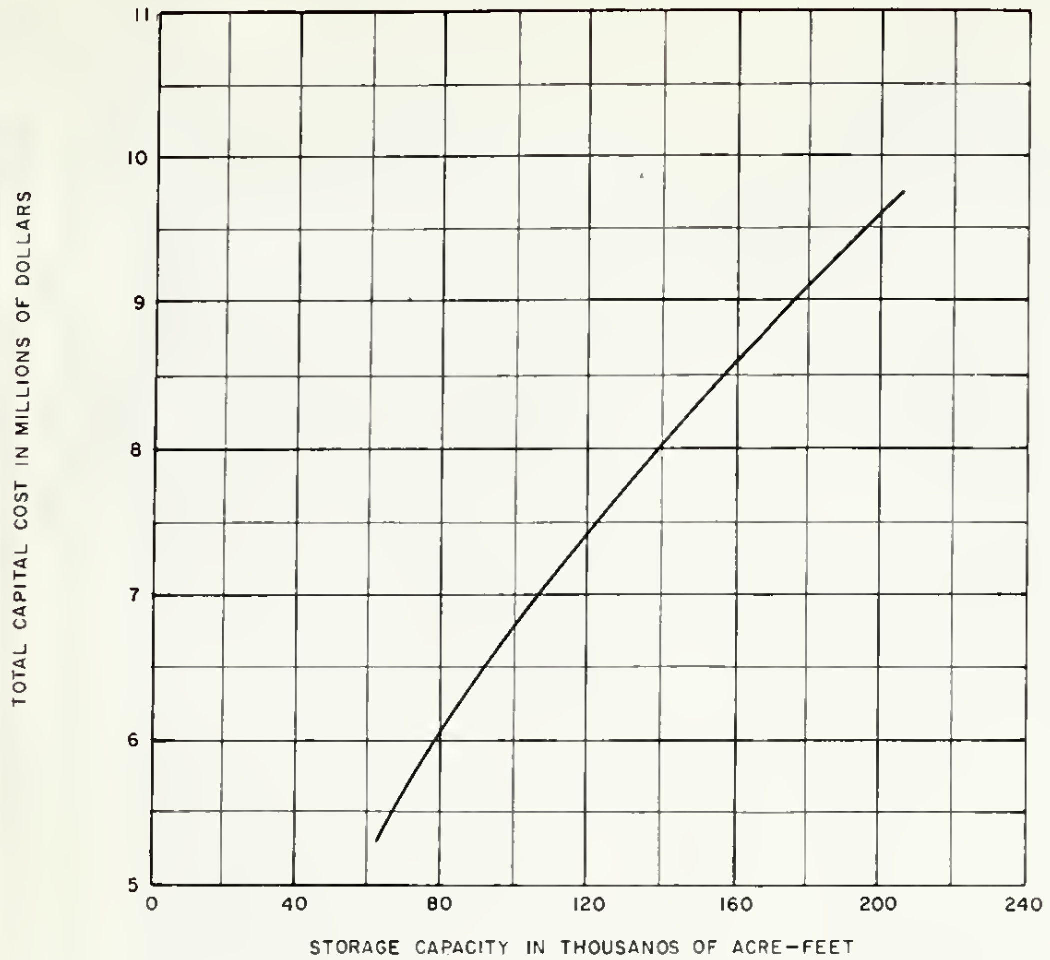


Fig. 1. TOTAL CAPITAL COST

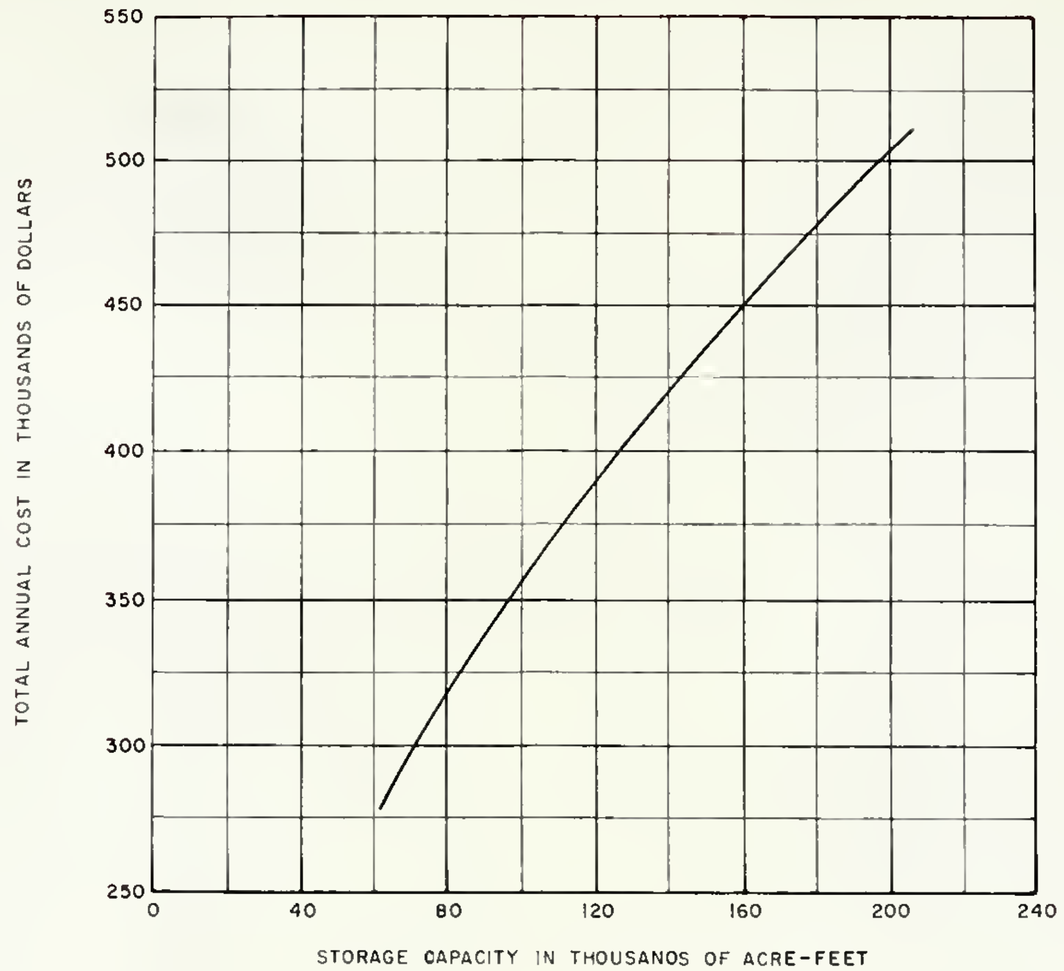


Fig. 2. TOTAL ANNUAL COST

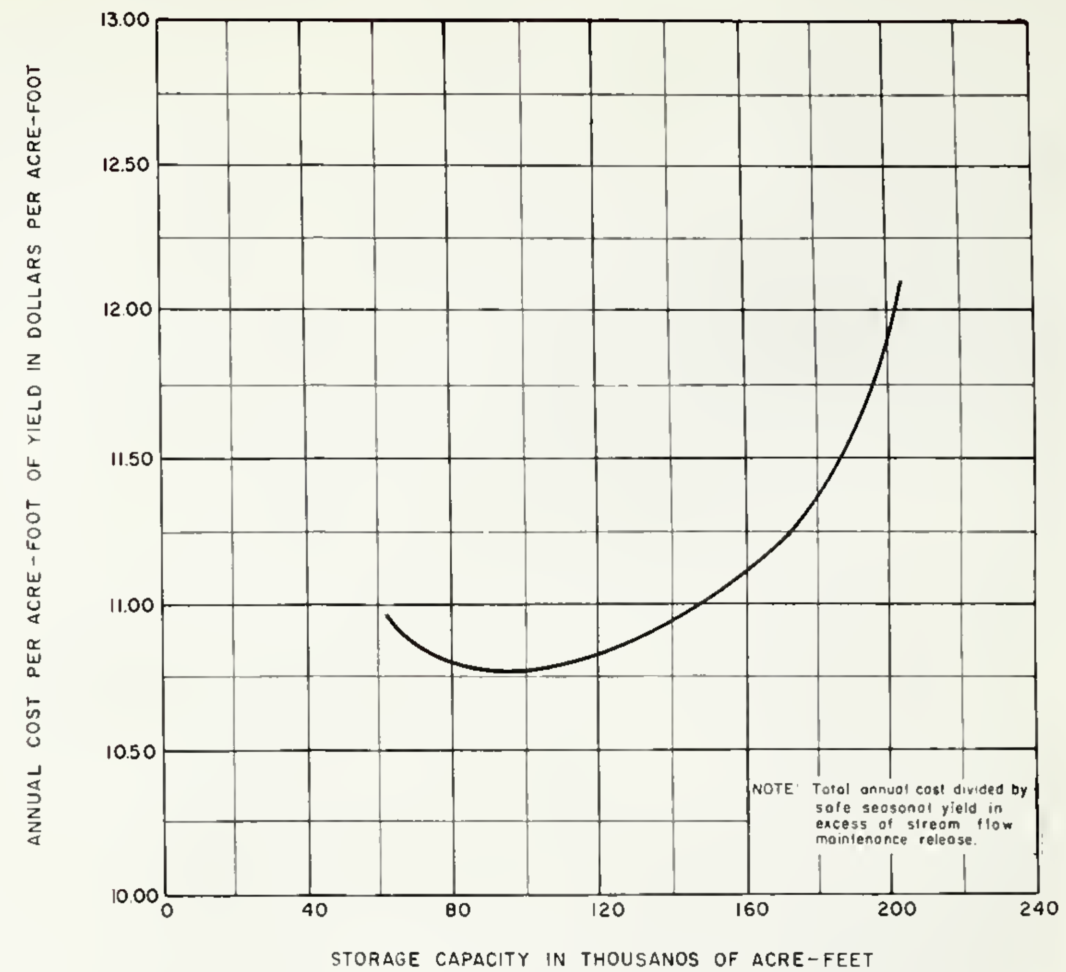


Fig. 3. ANNUAL COST PER ACRE-FOOT OF YIELD

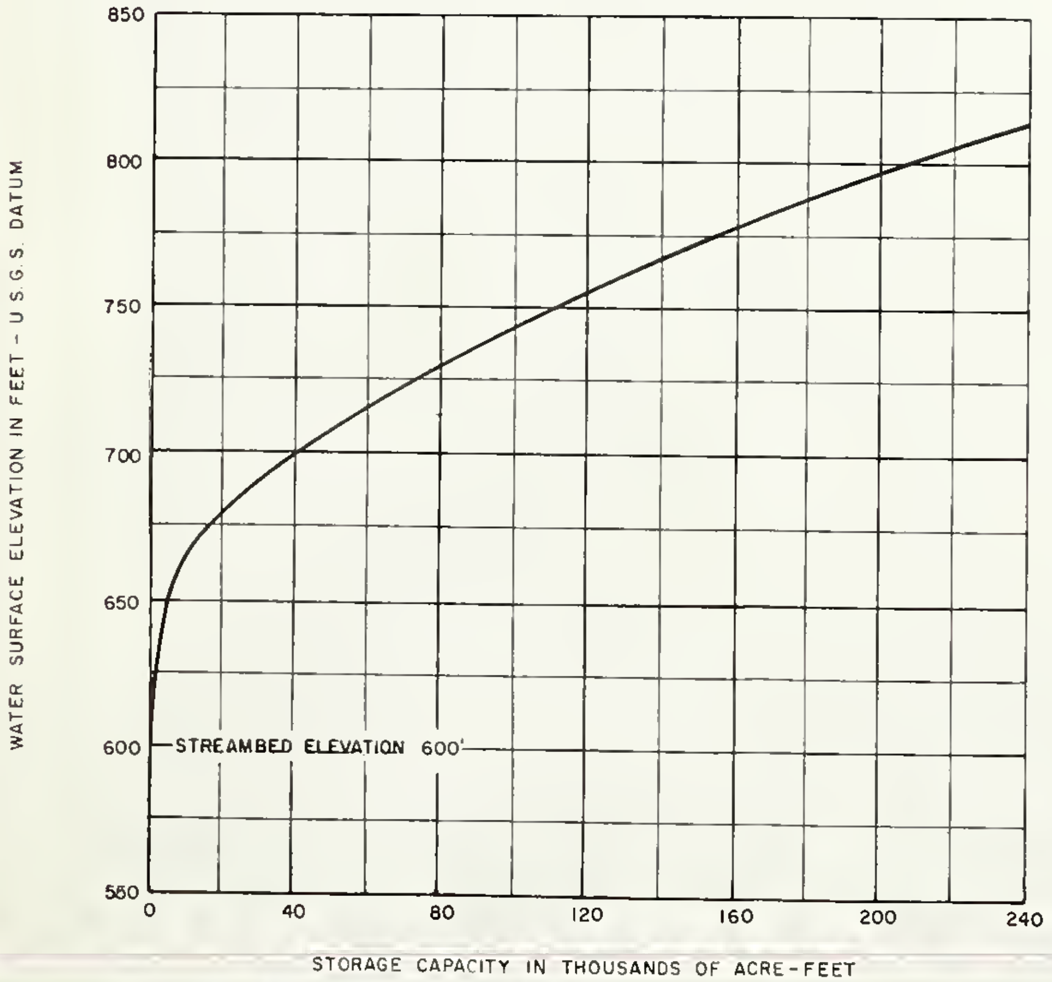


Fig. 4. WATER SURFACE ELEVATION VS. STORAGE CAPACITY

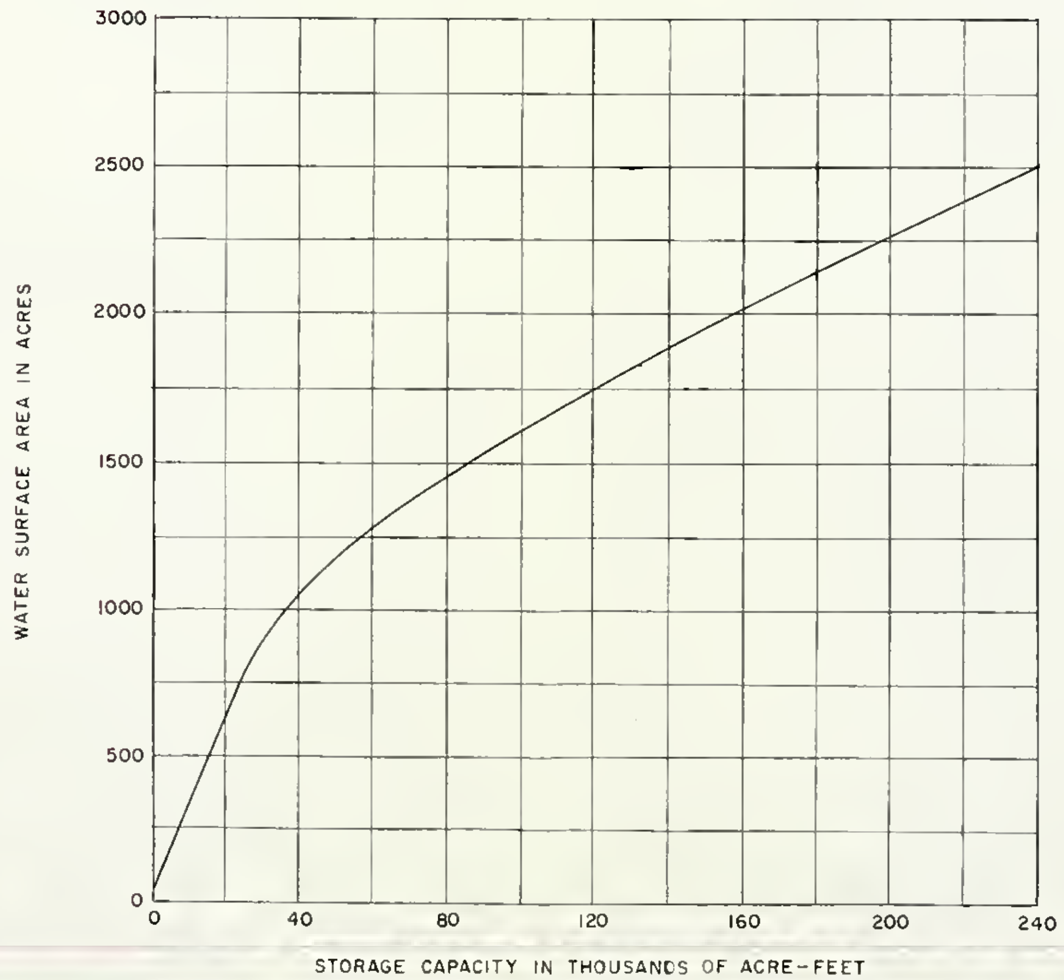


Fig. 5. WATER SURFACE AREA VS. STORAGE CAPACITY

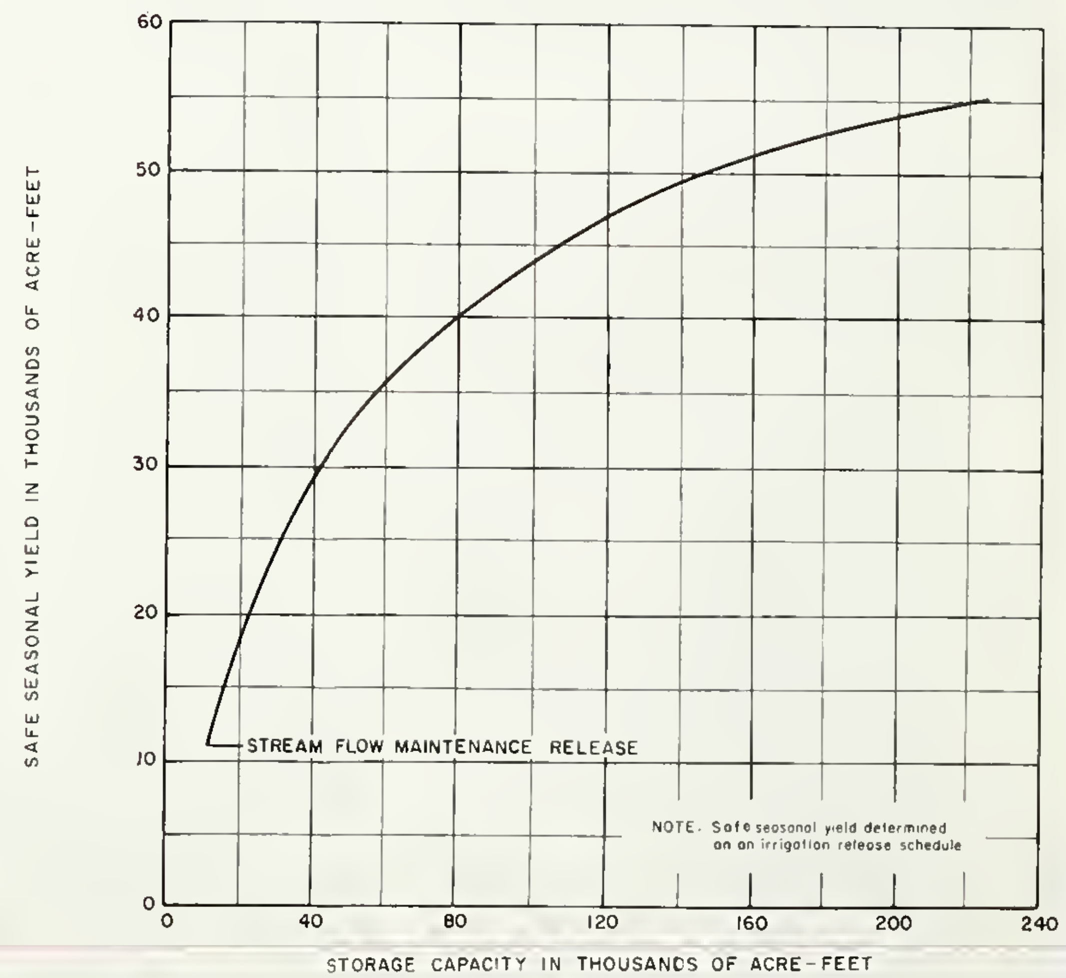
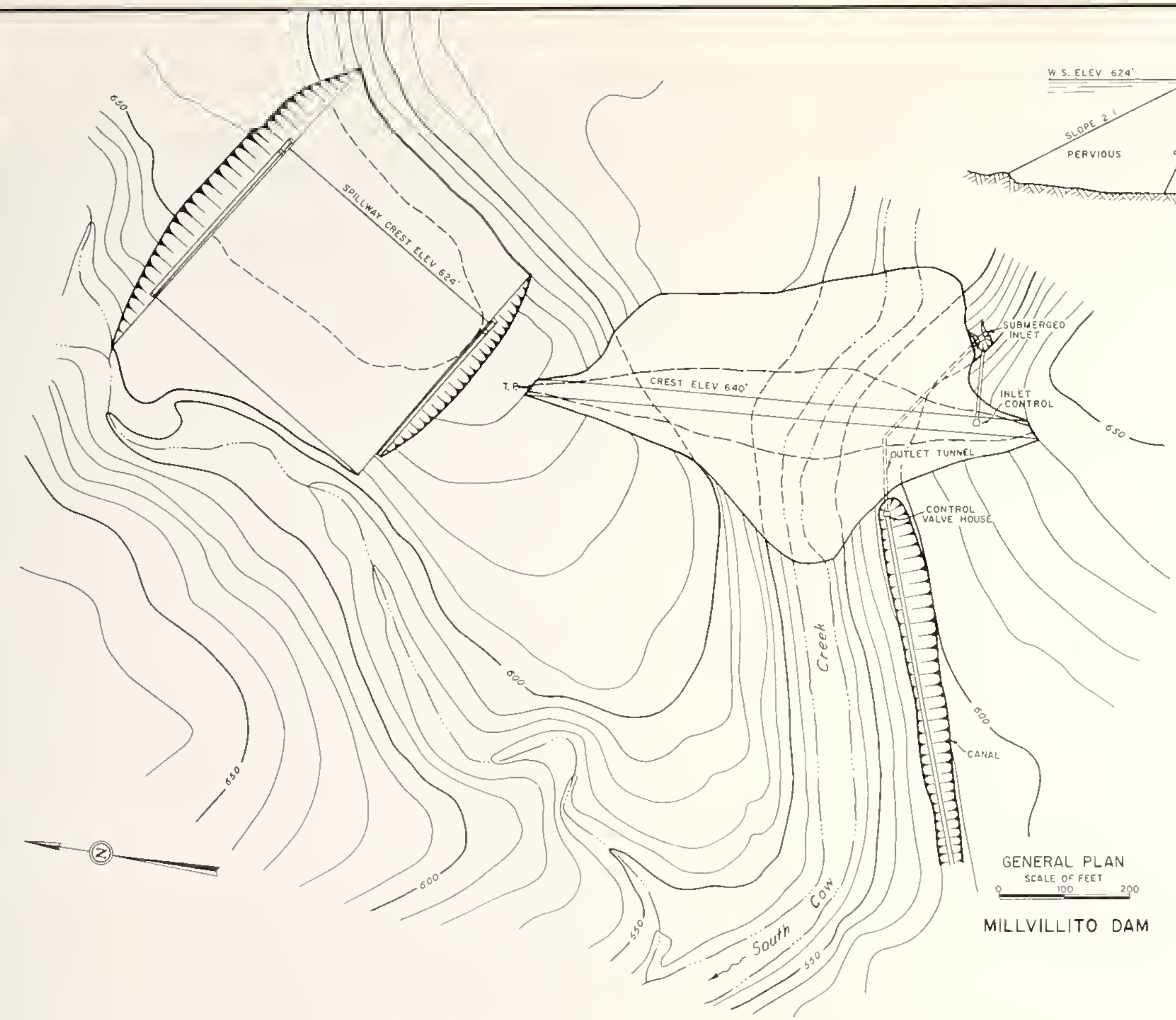


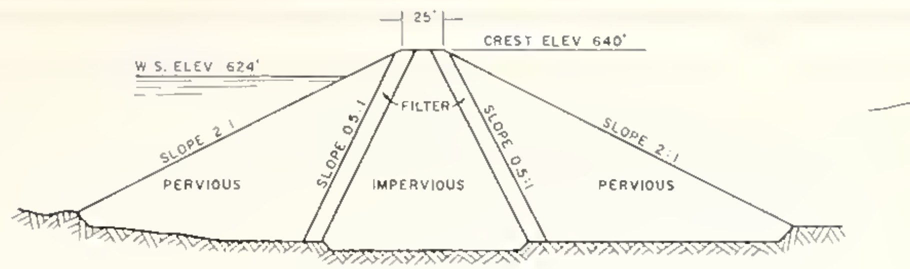
Fig. 6. SAFE SEASONAL YIELD

AREA, CAPACITY, COST, AND YIELD RELATIONSHIPS-MILLVILLE RESERVOIR

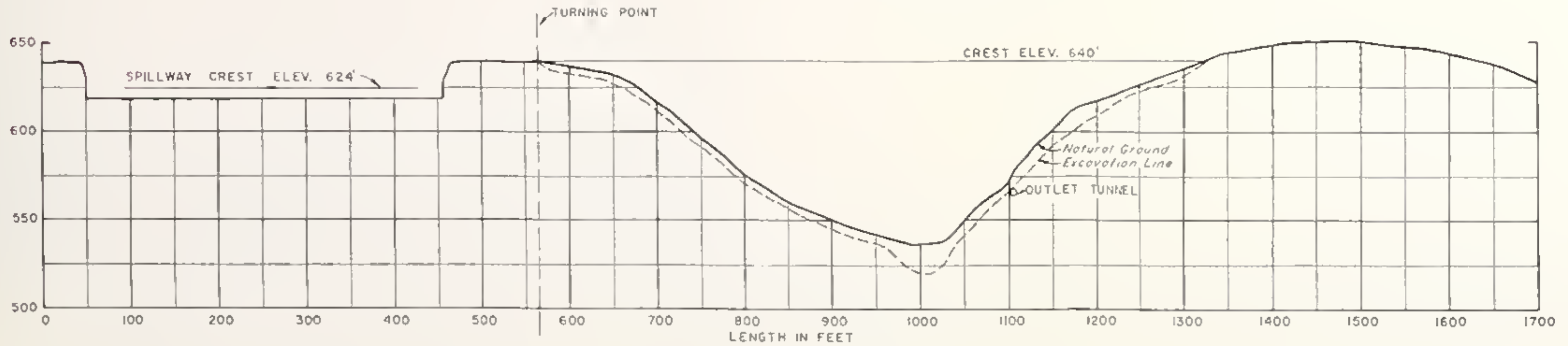


GENERAL PLAN
SCALE OF FEET 0 100 200

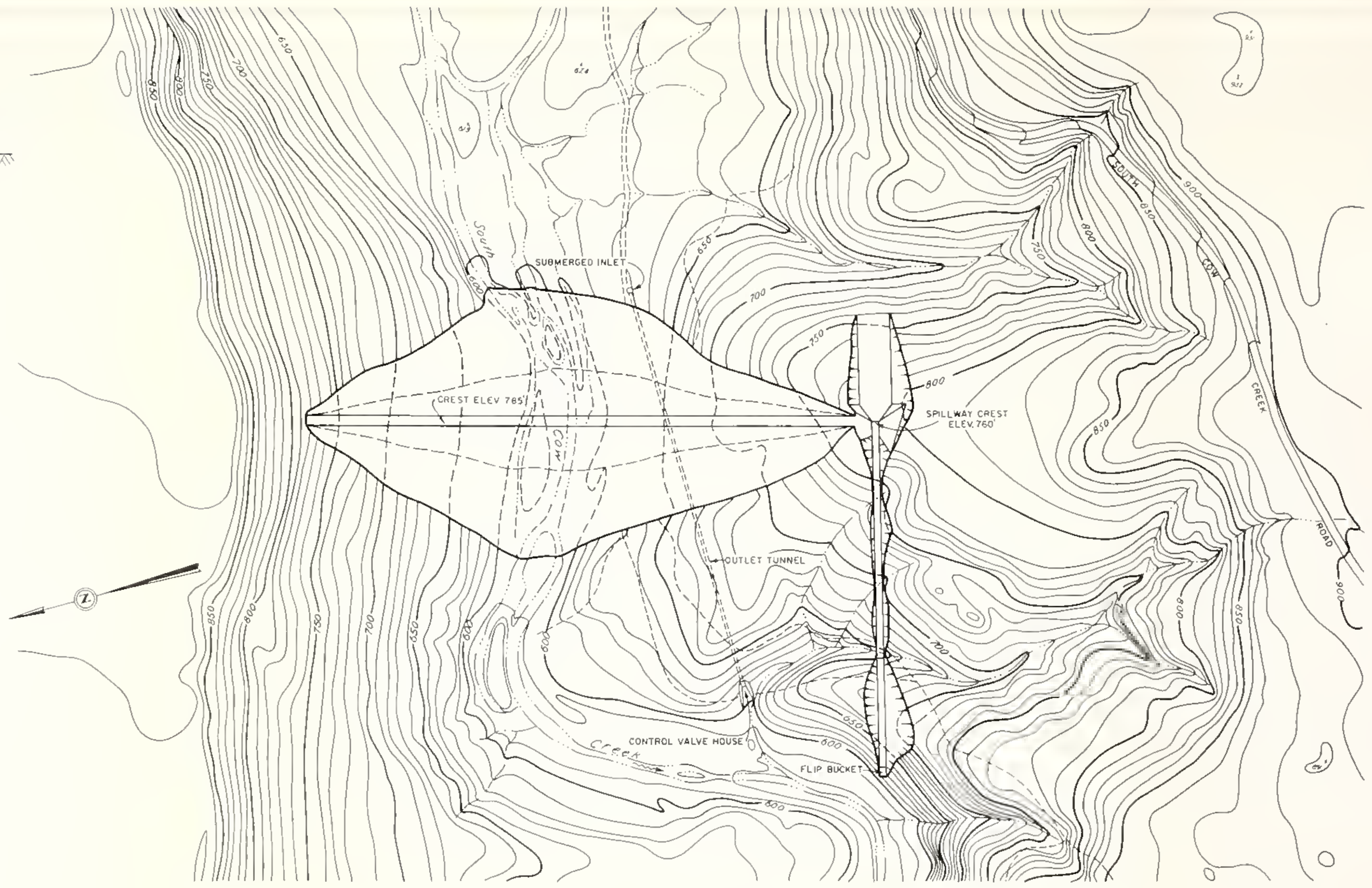
MILLVILLITO DAM



SECTION OF DAM
SCALE OF FEET 0 50 100

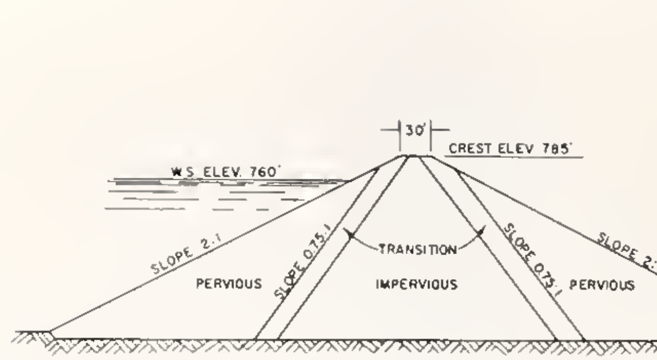


PROFILE OF DAM
LOOKING UPSTREAM

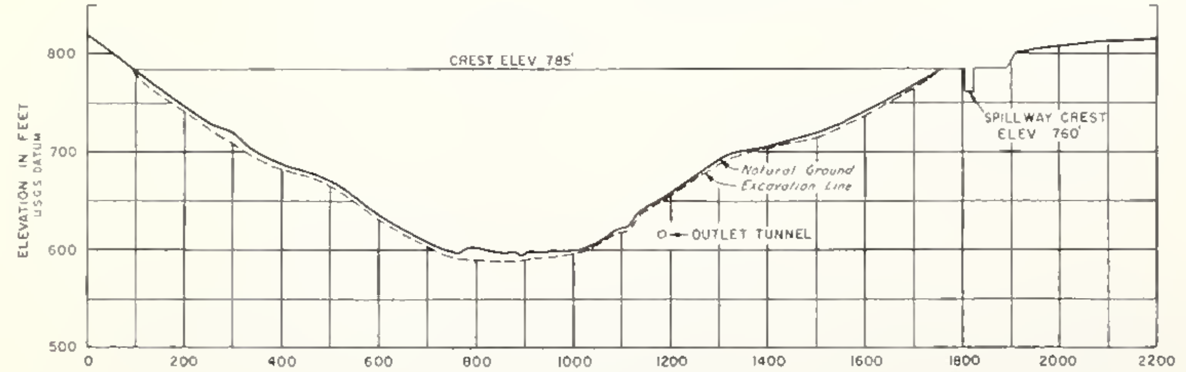


GENERAL PLAN
SCALE OF FEET 0 200 400

MILLVILLE DAM



SECTION OF DAM
SCALE OF FEET 0 100 200



PROFILE OF DAM
LOOKING UPSTREAM

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA COUNTY INVESTIGATION

MILLVILLITO DAM ON SOUTH COW CREEK
AND
MILLVILLE DAM ON SOUTH COW CREEK
1960

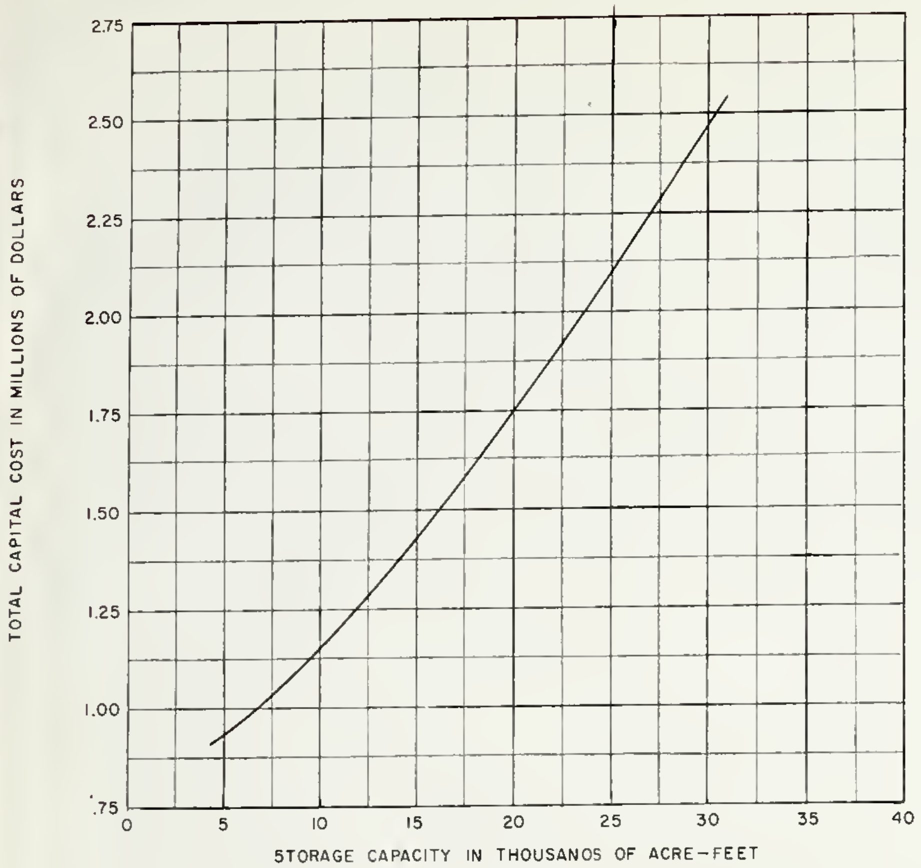


Fig. 1. TOTAL CAPITAL COST

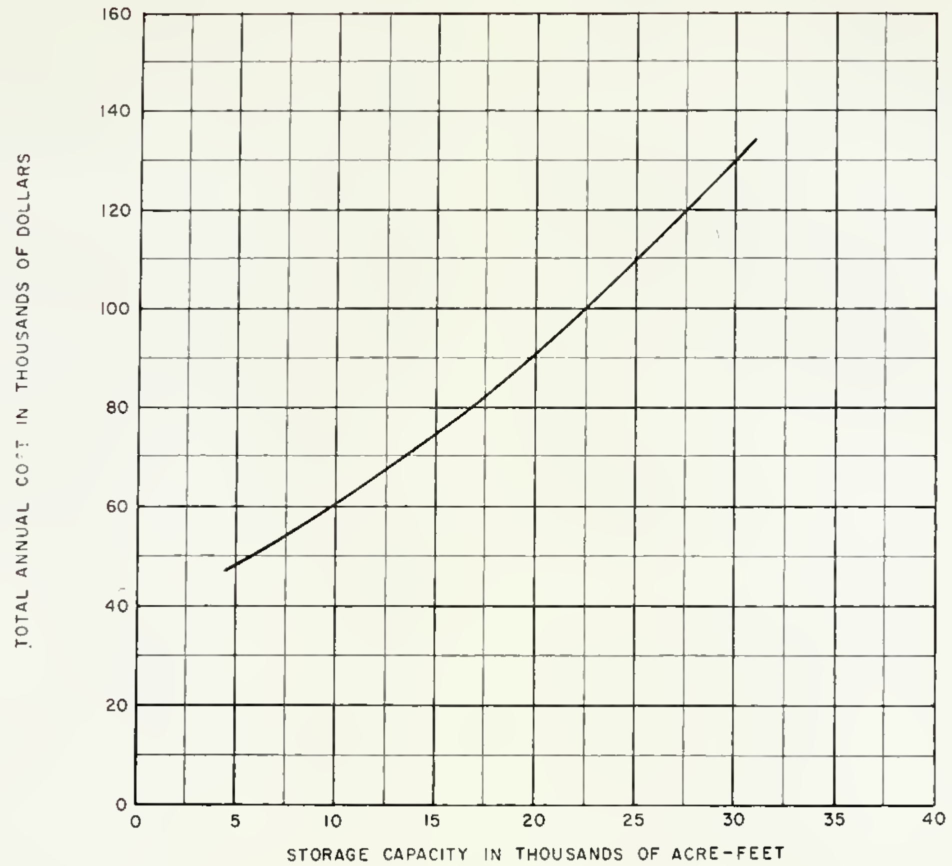


Fig. 2. TOTAL ANNUAL COST

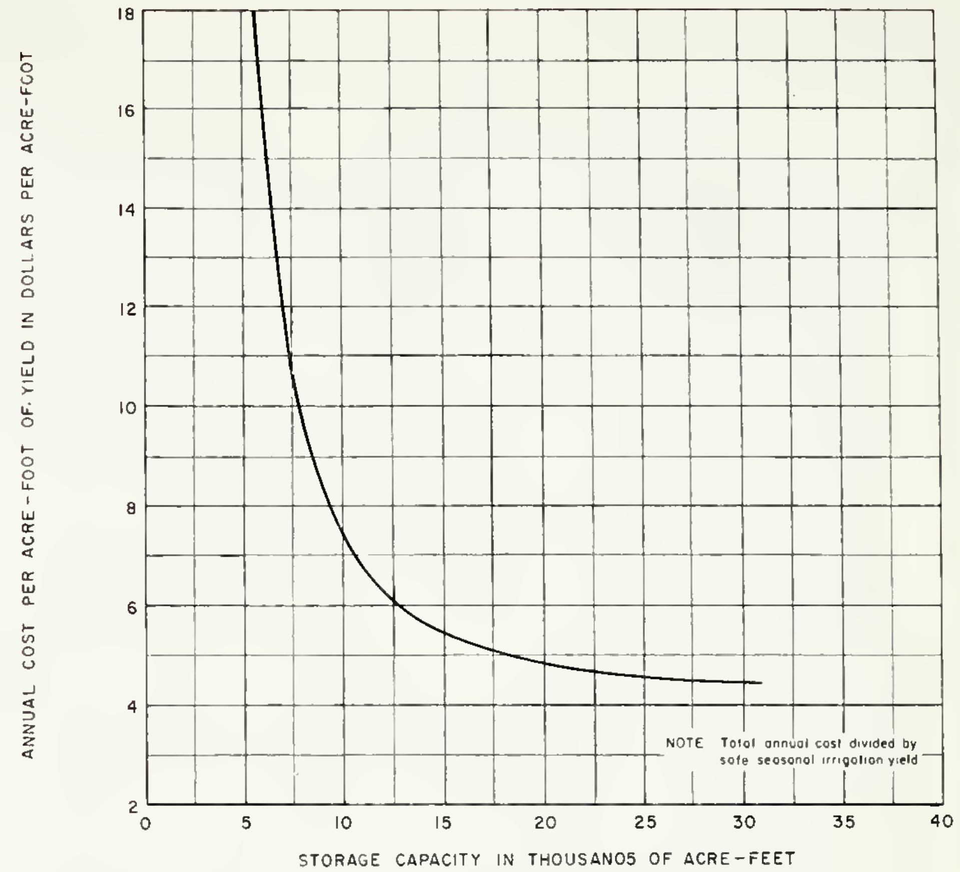


Fig. 3. ANNUAL COST PER ACRE-FOOT OF YIELD

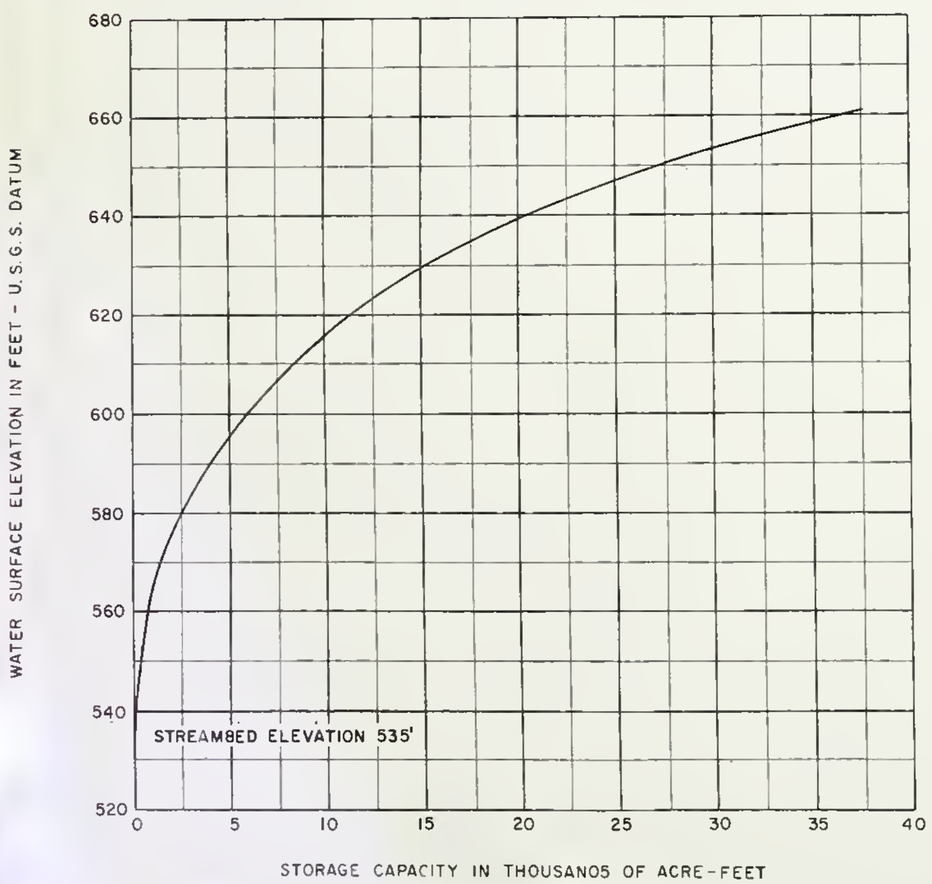


Fig. 4. WATER SURFACE ELEVATION VS. STORAGE CAPACITY

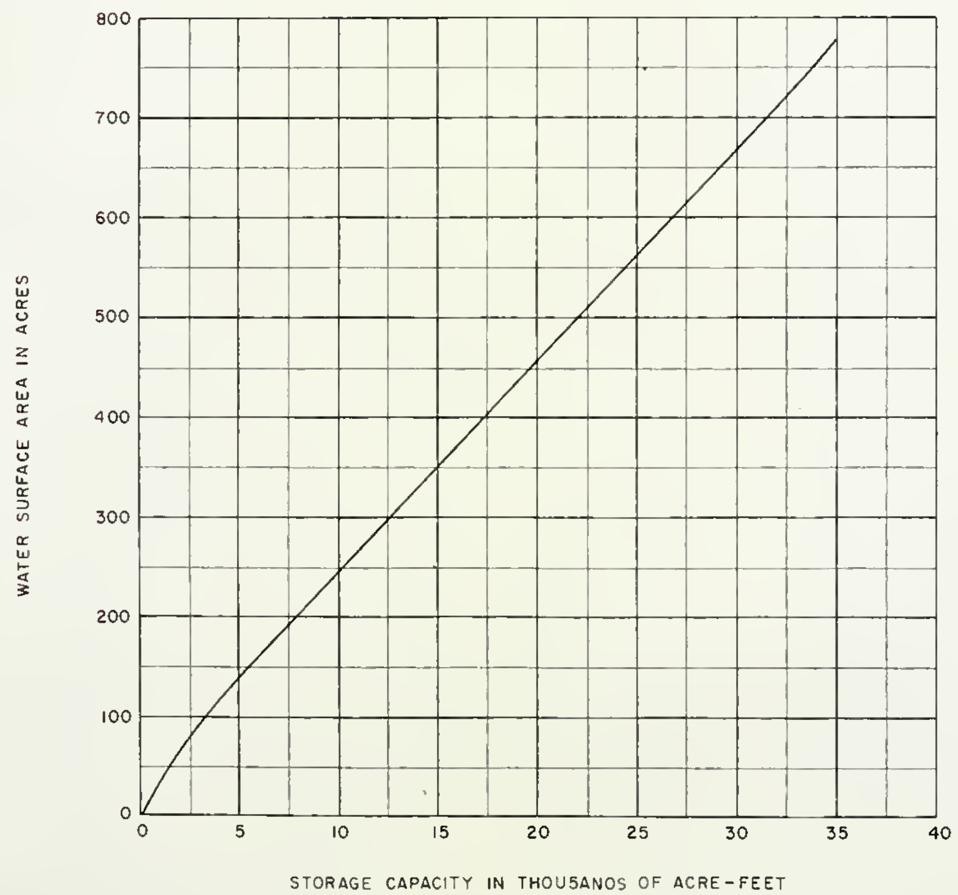


Fig. 5. WATER SURFACE AREA VS. STORAGE CAPACITY

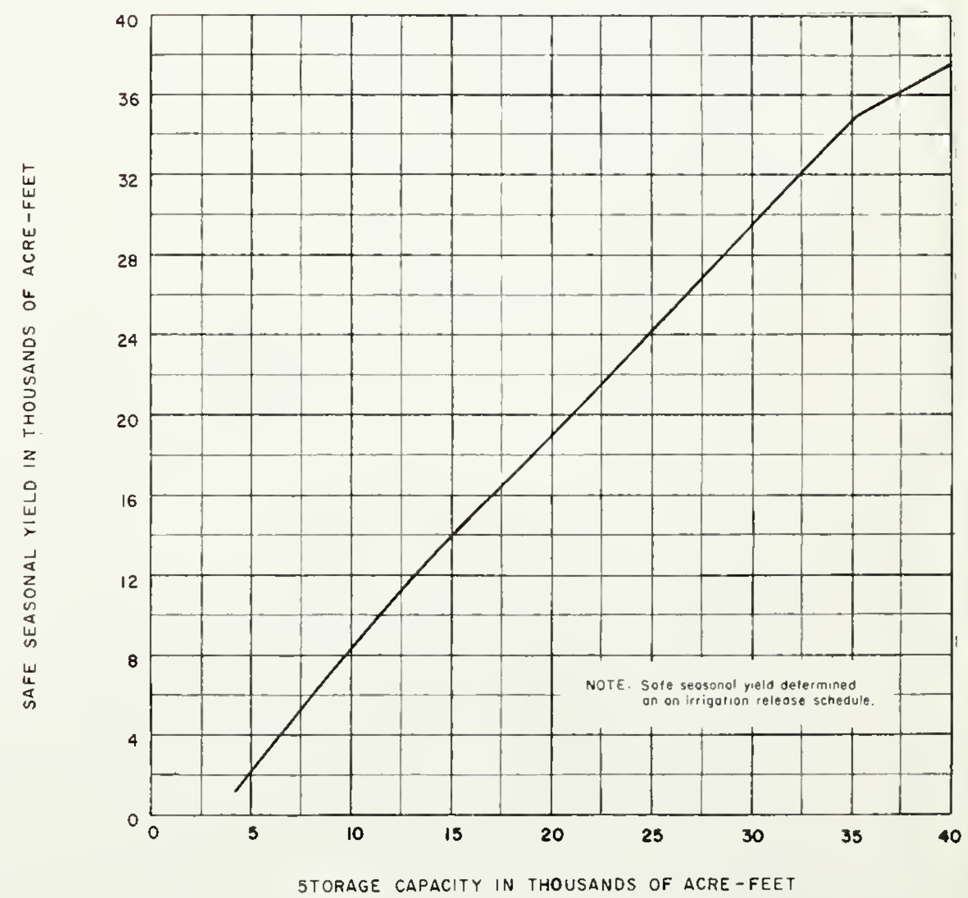
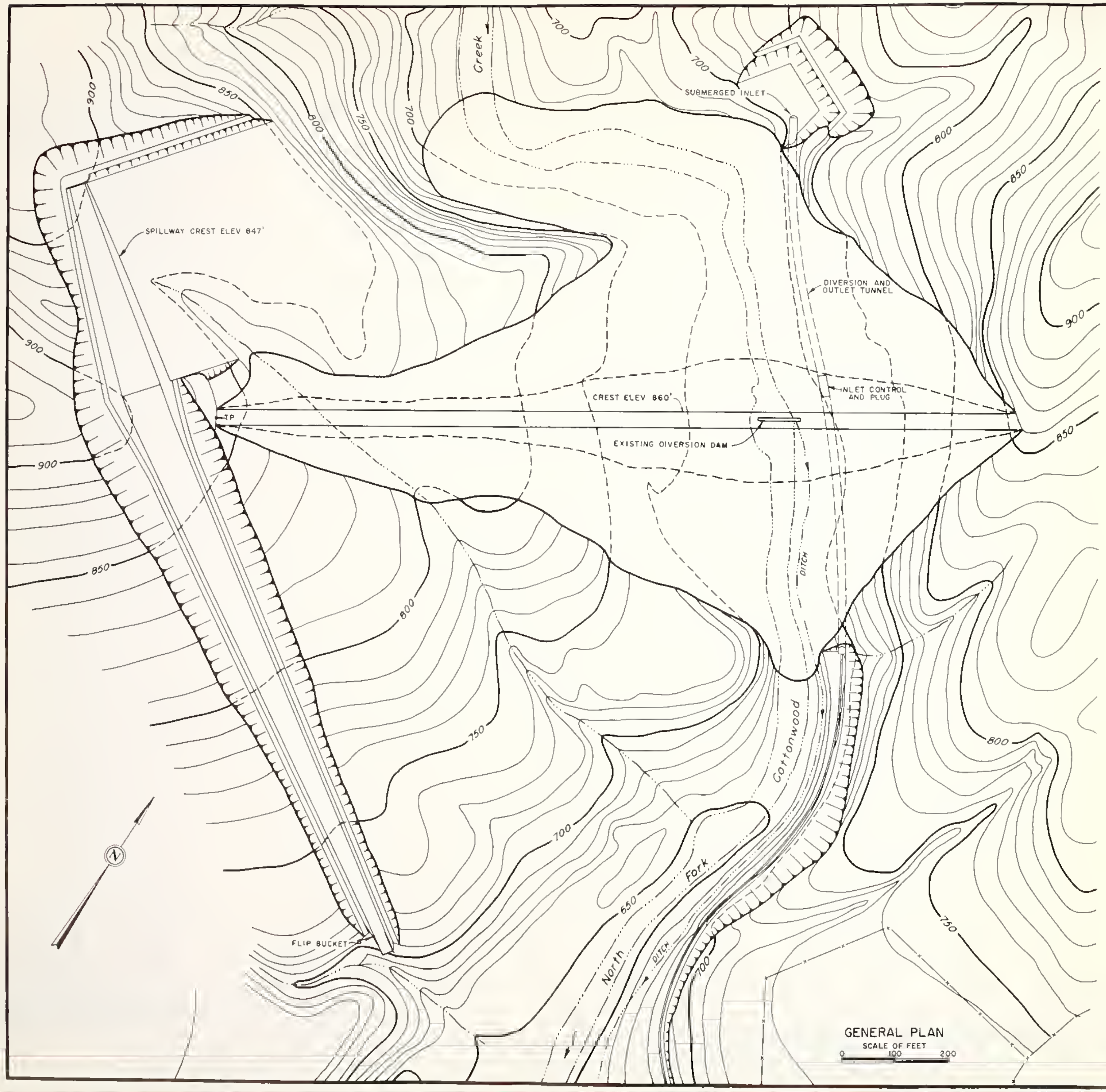
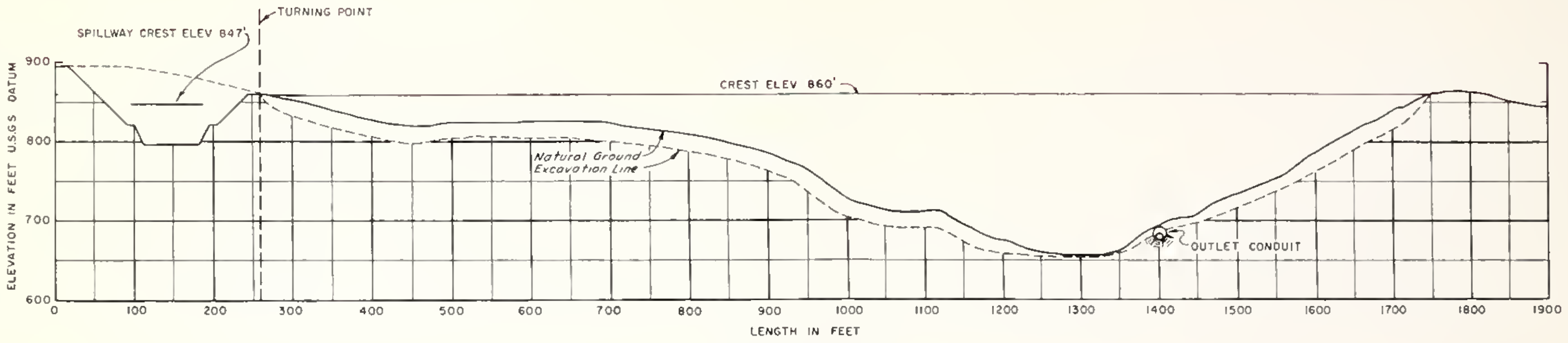


Fig. 6. SAFE SEASONAL YIELD

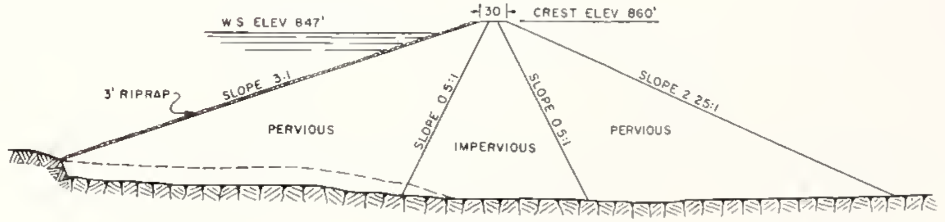
AREA, CAPACITY, COST, AND YIELD RELATIONSHIPS-MILLVILLITO RESERVOIR



GENERAL PLAN
SCALE OF FEET
0 100 200



PROFILE OF DAM
LOOKING UPSTREAM



SECTION OF DAM
SCALE OF FEET
0 100 200

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA COUNTY INVESTIGATION

HULEN DAM ON NORTH FORK
COTTONWOOD CREEK
1960

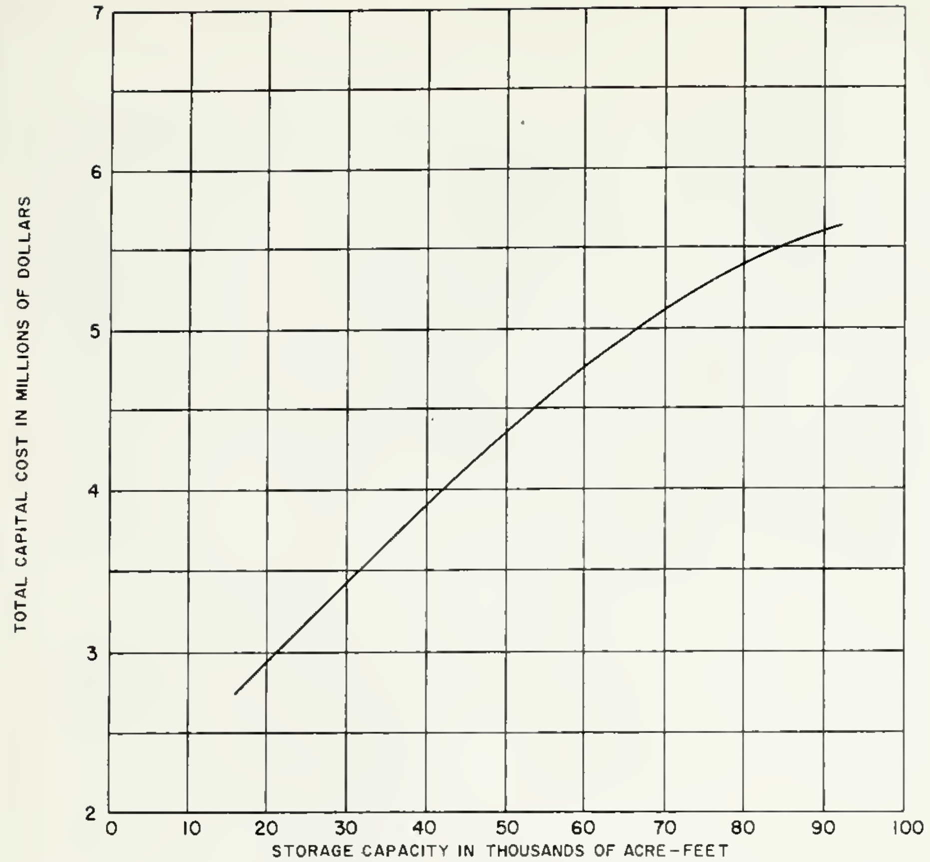


Fig. 1. TOTAL CAPITAL COST

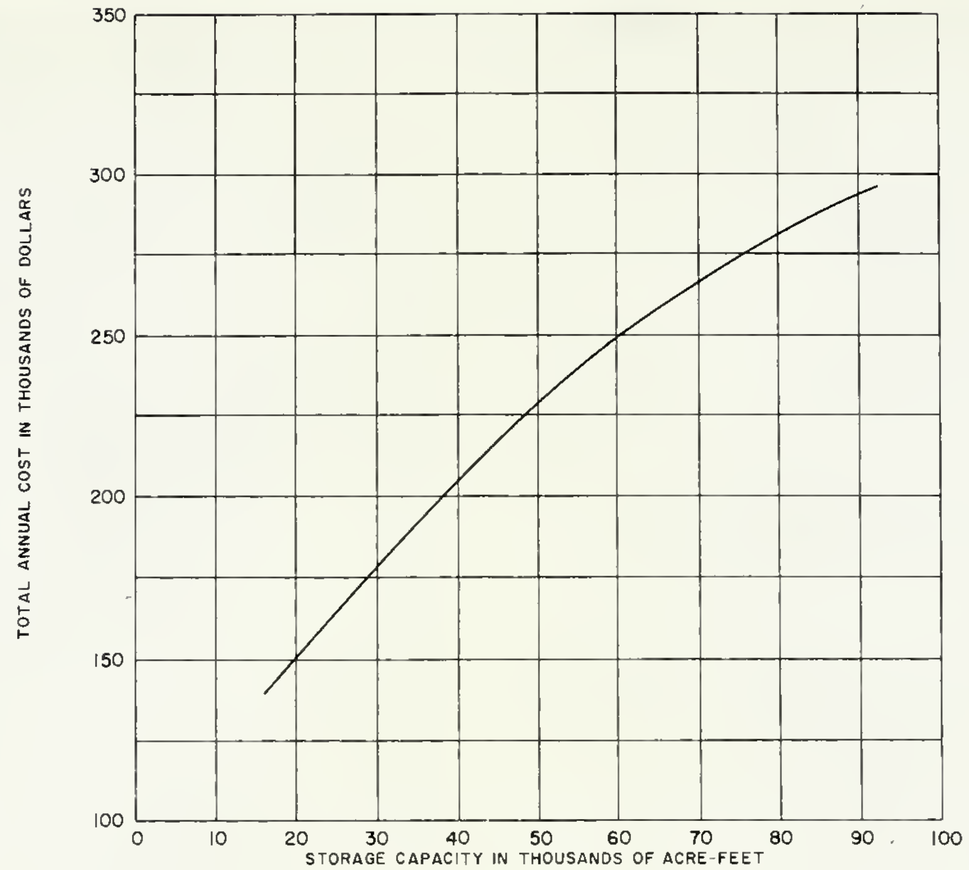


Fig. 2. TOTAL ANNUAL COST

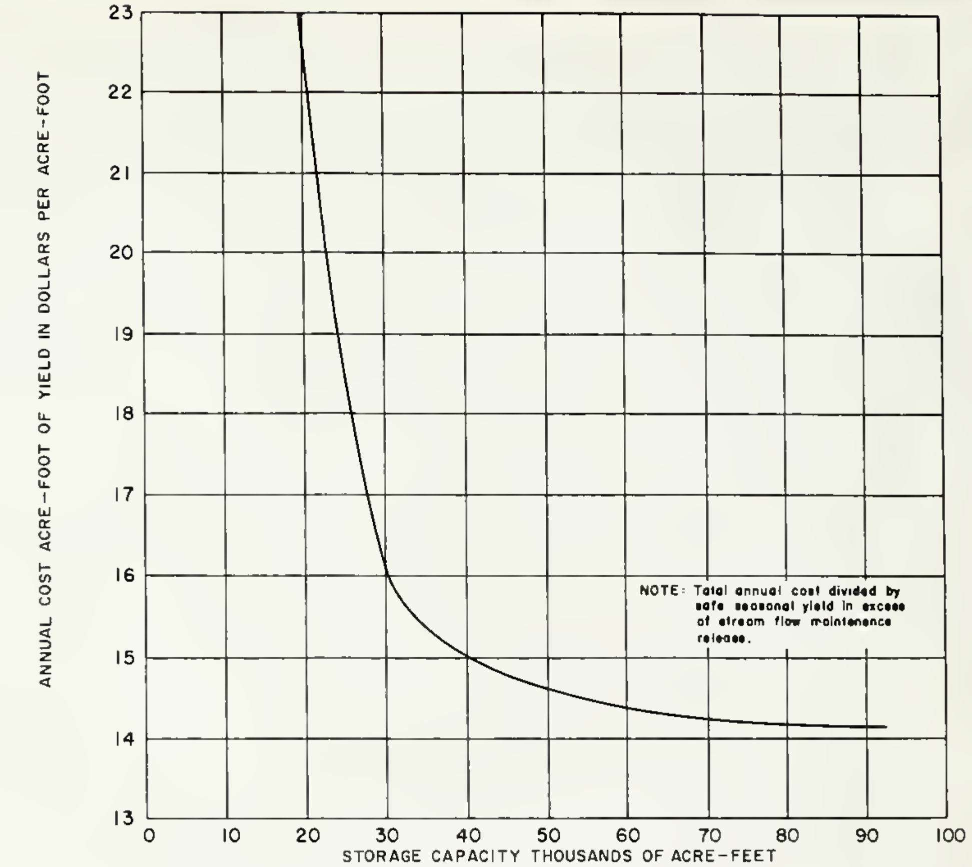


Fig 3. ANNUAL COST PER ACRE-FOOT OF YIELD

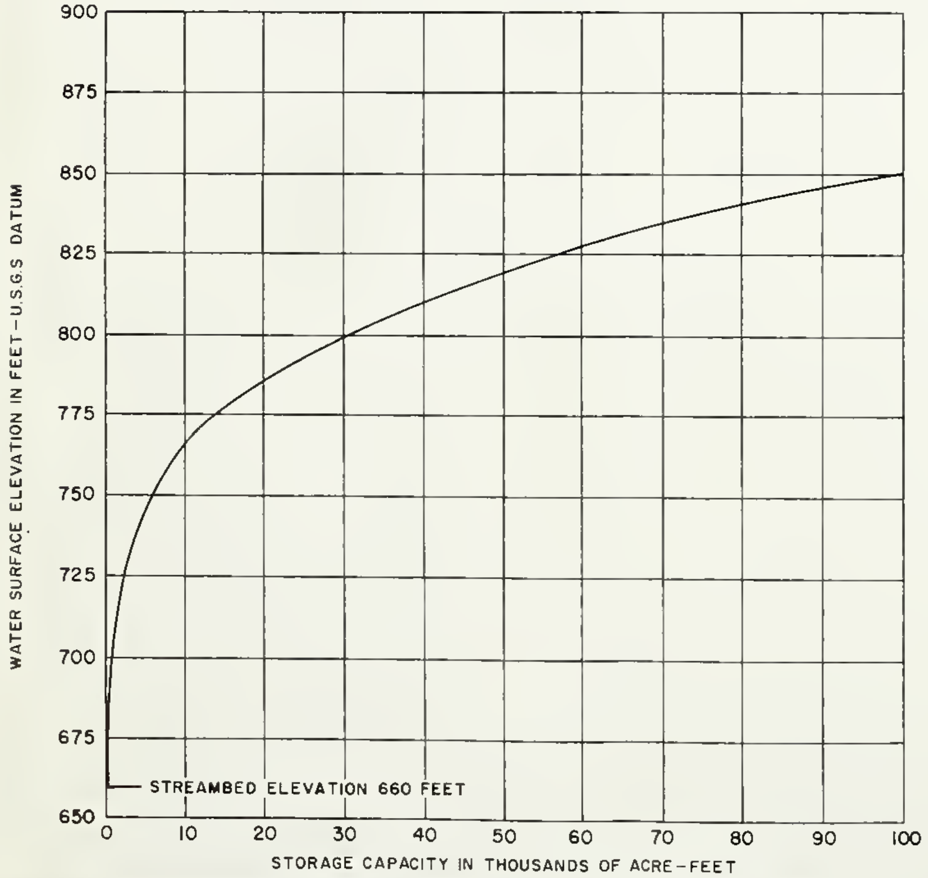


Fig. 4. WATER SURFACE ELEVATION VS. STORAGE CAPACITY

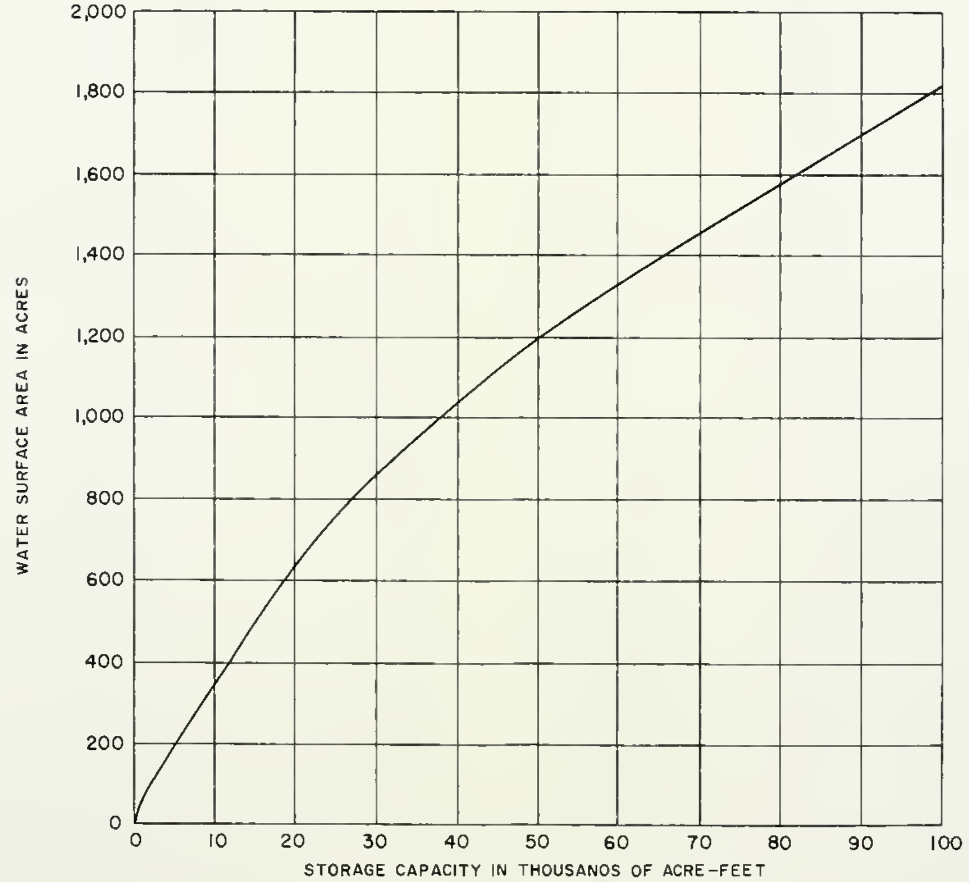


Fig. 5. WATER SURFACE AREA VS. STORAGE CAPACITY

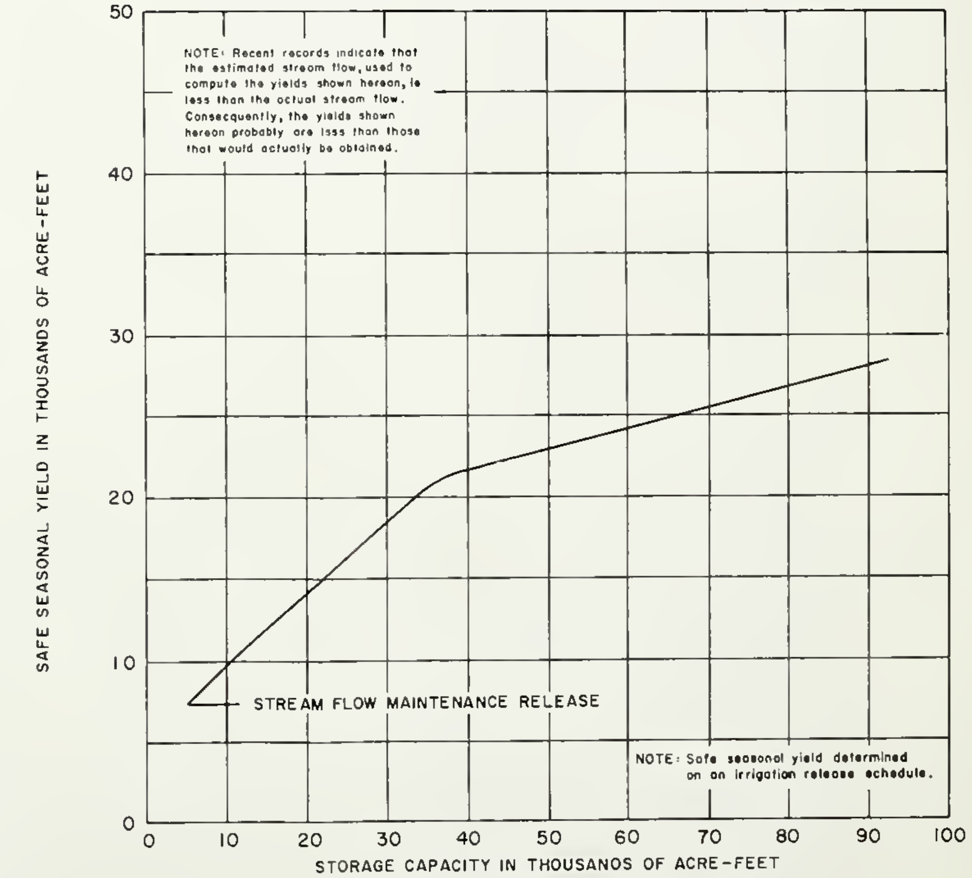
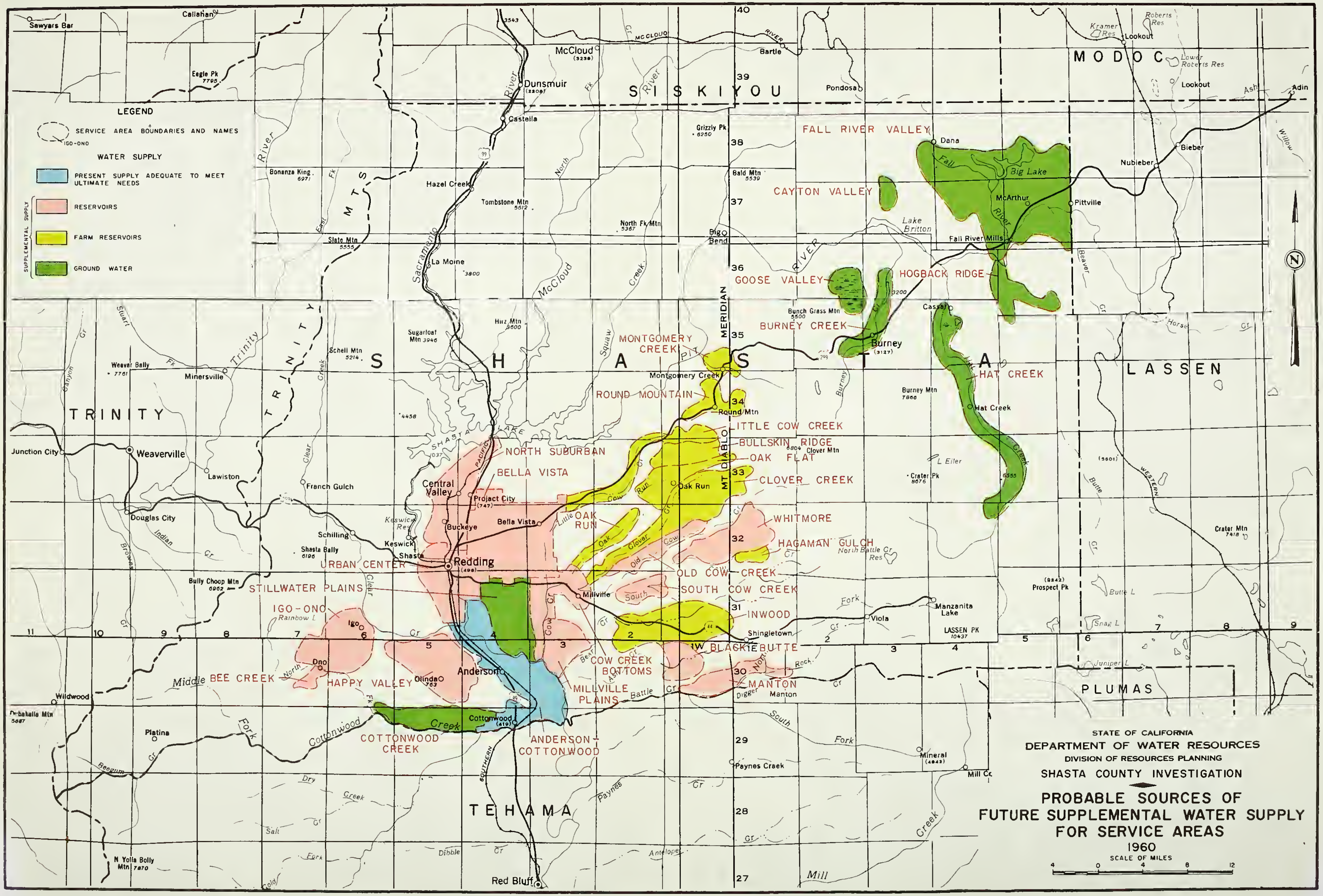
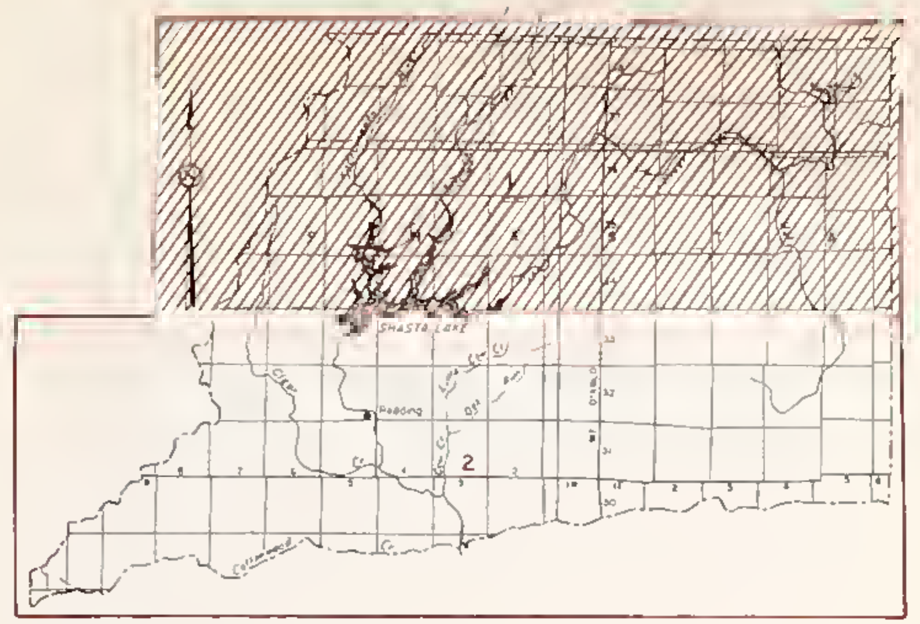


Fig. 6. SAFE SEASONAL YIELD

AREA, CAPACITY, COST, AND YIELD RELATIONSHIPS-HULEN RESERVOIR


LEGEND
SERVICE AREA BOUNDARIES AND NAMES
IGO-ONO
WATER SUPPLY
PRESENT SUPPLY ADEQUATE TO MEET ULTIMATE NEEDS
SUPPLEMENTAL SUPPLY
RESERVOIRS
FARM RESERVOIRS
GROUND WATER
SISKIYOU
MODOC
TRINITY
SHASTA
LASSEN
PLUMAS
TEHAMA
FALL RIVER VALLEY
CAYTON VALLEY
GOOSE VALLEY
HOGBACK RIDGE
BURNEY CREEK
HAT CREEK
MONTGOMERY CREEK
ROUND MOUNTAIN
LITTLE COW CREEK
BULLSKIN RIDGE
OAK FLAT
CLOVER CREEK
NORTH SUBURBAN
BELLA VISTA
LITTLE OAK RUN
WHITMORE
HAGAMAN GULCH
URBAN CENTER
STILLWATER PLAINS
OLD COW CREEK
SOUTH COW CREEK
IGO-ONO
INWOOD
BLACK BUTTE
COW CREEK BOTTOMS
MANTON
MILLVILLE PLAINS
BEE CREEK
HAPPY VALLEY
COTTONWOOD CREEK
ANDERSON-COTTONWOOD
Redding
Anderson
Cottonwood
Red Bluff
Weaverville
Burney
MT DIABLO MERIDIAN
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA COUNTY INVESTIGATION
PROBABLE SOURCES OF FUTURE SUPPLEMENTAL WATER SUPPLY FOR SERVICE AREAS
1960
SCALE OF MILES



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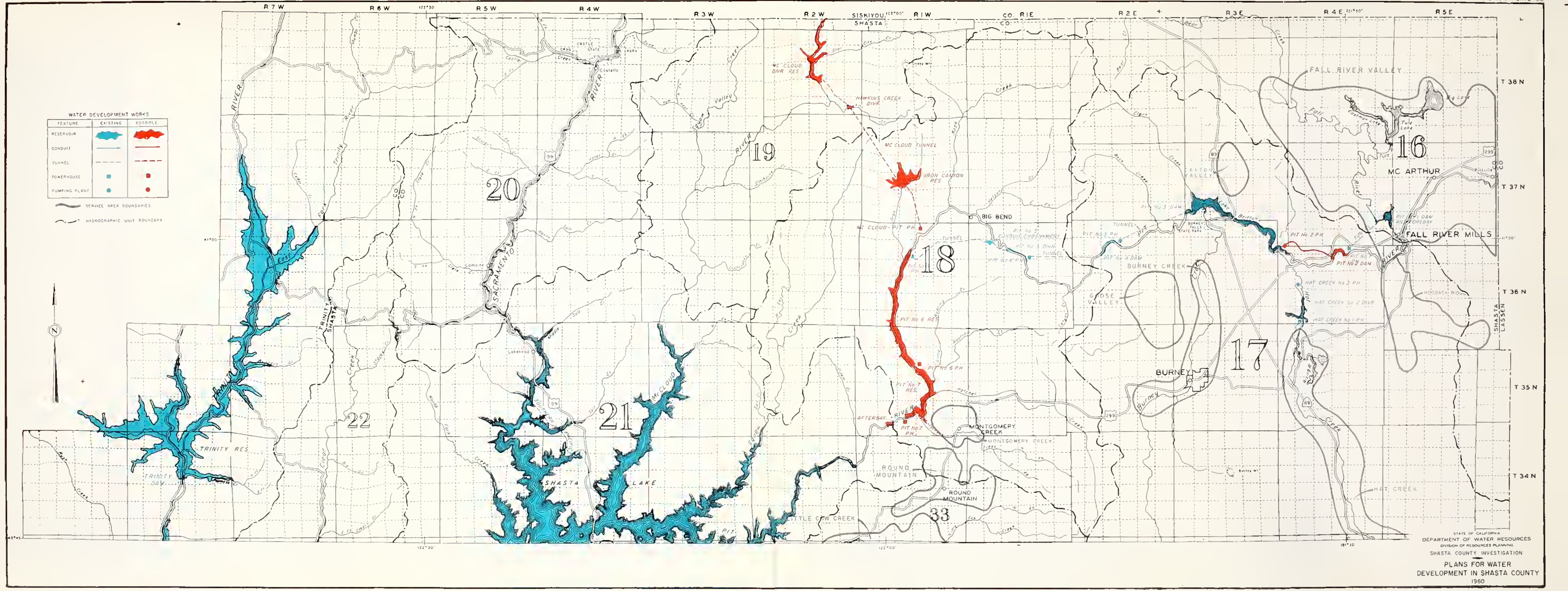

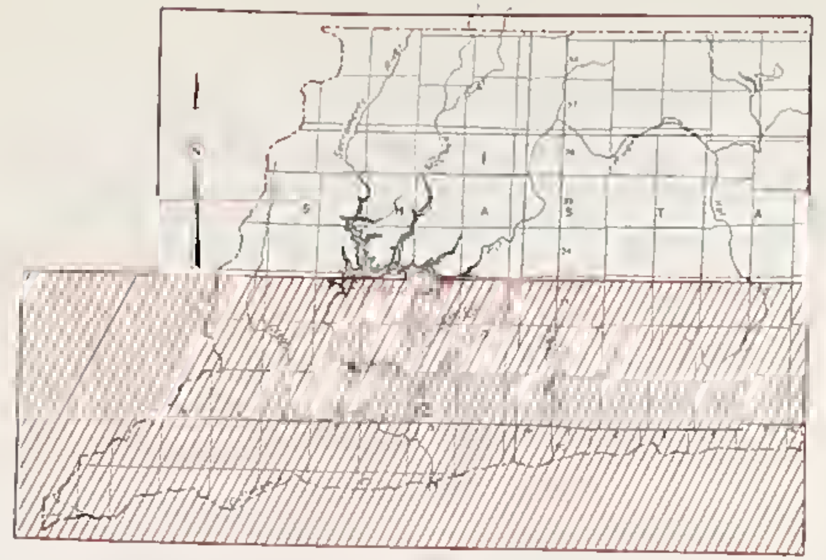

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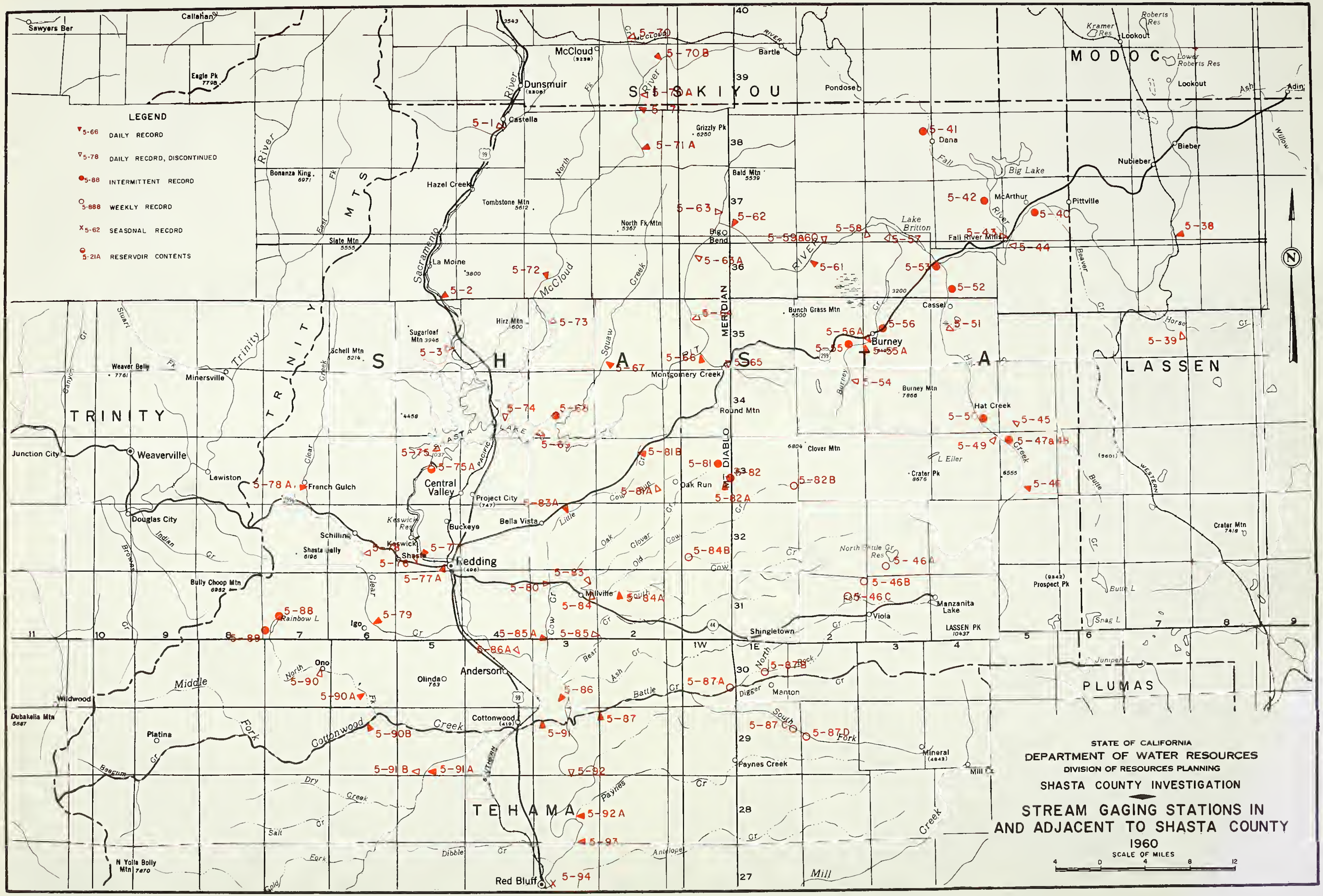
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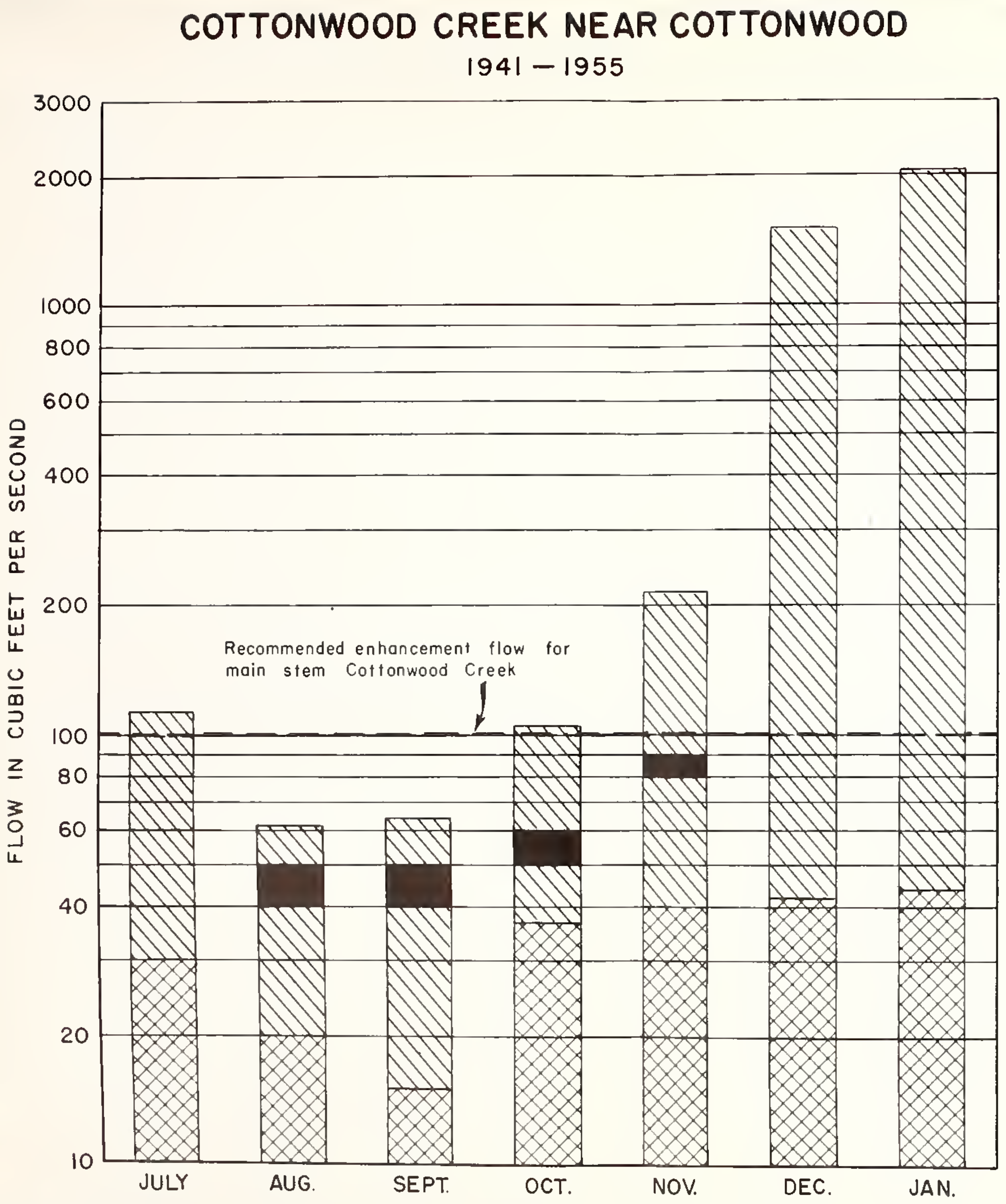
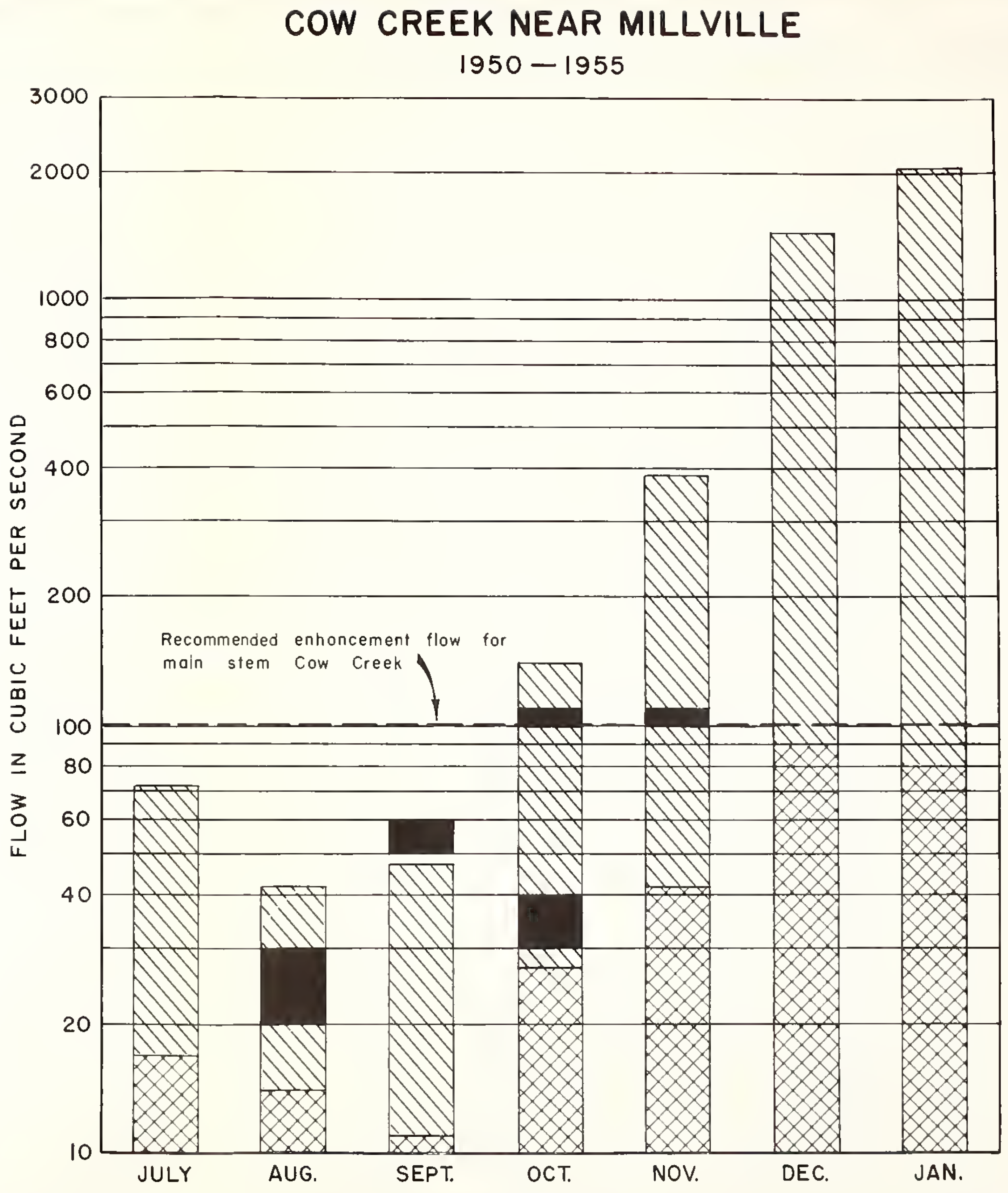
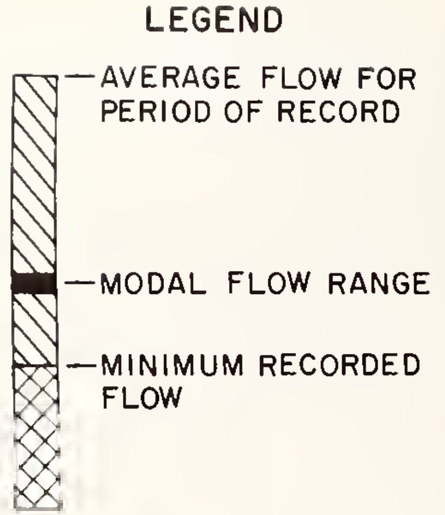
5-78 DAILY RECORD, DISCONTINUED
5-88 INTERMITTENT RECORD
5-888 WEEKLY RECORD
5-62 SEASONAL RECORD
5-21A RESERVOIR CONTENTS
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SHASTA COUNTY INVESTIGATION
STREAM GAGING STATIONS IN AND ADJACENT TO SHASTA COUNTY
1960
SCALE OF MILES
4 0 4 8 12
SISKIYOU
MODOC
SHASTA
LASSEN
TRINITY
PLUMAS
TEHAMA
TRINITY MTS
MERIDIAN
MT DIABLO
Redding
Red Bluff
Burney
Weaverville
Dunsmuir
McCloud
Anderson
Cottonwood
Central Valley
Shasta Lake
Fall River Mills
McArthur
Adin
Bieber
Nubieber
Lookout
Manton
Shingletown
Millville
Castella
Big Bend
Montgomery Creek
Round Mtn
Oak Run
Hat Creek
Cassel
Lake Britton
Big Lake
Pittville
Dana
Pondosa
Bartle
Hazel Creek
La Moine
Project City
Buckeye
Bella Vista
Keswick
Shasta
Igo
Ono
Platina
Wildwood
Olinda
Viola
Manzanita Lake
Mineral
Paynes Creek
Junction City
Lewiston
Douglas City
Minersville
French Gulch
Schilling
Callahan
Sawyers Bar
LASSEN PK 10437
N Yolla Bolly Mtn 7870
Bully Choop Mtn 6962
Sacramento River
McCloud River
Pit River
Fall River
Cottonwood Creek
Battle Cr
Clear Cr
Cow Cr
Hat Creek







STATE OF CALIFORNIA
DEPARTMENT OF FISH AND GAME
SHASTA COUNTY INVESTIGATION

SUMMARY OF MONTHLY AVERAGE, MINIMUM RECORDED, AND MODAL FLOWS OF COTTONWOOD CREEK NEAR COTTONWOOD AND COW CREEK NEAR MILLVILLE

DEPARTMENT OF WATER RESOURCES 1960

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