State of California

THE RESOURCES AGENCY

Department of Water Resources

BULLETIN No. 150

UPPER SACRAMENTO RIVER BASIN INVESTIGATION

Preliminary Edition

MARCH 1965

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
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FOREWORD

Bulletin No. 150, preliminary edition of the "Upper Sacramento River Basin Investigation", gives the results of a comprehensive six-year study of the Sacramento River and its tributaries between Shasta Dam and Red Bluff.

The objective of this investigation was to develop a plan for economic development of the water resources in the Upper Sacramento River Basin. The Legislature approved this investigation by Item 257 of the Budget Act of 1958. Further legislative direction was given to this investigation in March 1958 by enactment of Assembly Concurrent Resolution No. 33, which named specific reservoir sites for consideration, and also extended the geographic scope of the original investigation by requiring consideration of Paskenta Reservoir, a potential storage site on Thomes Creek.

Included in the investigation were extensive studies of an Iron Canyon Project on the Sacramento River near Red Bluff. As a result of the investigation, however, it was concluded that the Iron Canyon Project is not economically justified under present economic conditions. It was further concluded that four tributary reservoir projects, Hulen and Dippingvat on Cottonwood Creek, Millville on Cow Creek, and Paskenta on Thomes Creek, are economically justified. These reservoirs should be the initial developments toward full utilization of the water resources of the Upper Sacramento River Basin.

Director

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California State Department of Parks and Recreation

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California Public Utilities Commission

Pacific Gas and Electric Company

Shasta County Department of Water Resources

Tehama County Flood Control and Water Conservation District

California State Board of Reclamation

CHAPTER I. INTRODUCTION

The Sacramento River and its tributaries form the largest stream system lying entirely in California. From its headwaters in the extreme north central part of the State, the Sacramento flows down through California's great Central Valley and out the Golden Gate to the Pacific. More than 30 percent of the State's average annual runoff originates in this river system. Several major rivers and numerous smaller streams draining into the Sacramento River from the rugged mountain ranges in northeastern and northwestern California contribute to this runoff.

Various plans for controlling and developing this tremendous resource have been considered since the turn of the century. During the past 30 years, several major steps have been taken. Shasta, the largest single reservoir in the State, was built in the 1940's on the main stem of the Sacramento River near the northern edge of the Sacramento Valley. In addition, several major storage reservoirs have been constructed on tributary streams to aid in control of the runoff. Whiskeytown Reservoir on Clear Creek, Black Butte Reservoir on Stony Creek and Folsom Reservoir on the American River have been completed within the last ten years. At the present time, construction is well under way on the nation's highest earthfill structure, Oroville Dam. Oroville is on the Feather River, the largest single tributary to the Sacramento.

This bulletin reports on an investigation of a portion of the Sacramento River Basin, which prior to completion of Whiskeytown Reservoir in 1963, contained no major storage structures. The area consists of 2,600 square miles tributary to the Sacramento River between Shasta Dam and the City of Red Bluff, and the 188 square miles of the Thomes Creek watershed above Paskenta. The entire area is designated in this report as the Upper Sacramento River Basin. This basin presently delivers an average uncontrolled runoff of more than 2 million acre-feet annually into the Sacramento River system.

Although the water resources of the Upper Sacramento River Basin are presently almost undeveloped, the bountiful water supply has, over the years, led to several studies of possible projects on the main stem

Sacramento River, and of possible developments on the several tributary streams within the basin. This investigation comprised for the first time a comprehensive study of the basin in which the project purposes of recreation and fishery enhancement were considered as having equal priority with the more familiar purposes of hydroelectric power production, flood protection, and conservation of water for irrigation, municipal, and industrial uses. Shasta and Tehama Counties, in which these projects would be located, presently depend on the recreation industry as a significant source of income. A major accomplishment of the water projects described in this report would consist of increasing the recreational attractiveness of the basin and expansion of this important industry.

Objectives of Investigation

The objectives of this investigation were to (1) determine the water supply available for development, (2) determine the present and probable future local water requirements, (3) develop a comprehensive basin-wide plan for full beneficial control and utilization of the waters of the Upper Sacramento River Basin, and (4) present economic evaluations of those projects which have possibilities for construction in the immediate or near future.

Scope of Investigation

The Upper Sacramento River Basin Investigation gave comprehensive and detailed consideration to the full development and possible enhancement of all water and water-associated resources. Assembly Concurrent Resolution No. 33 requested the Department to investigate the possible development of certain specific storage sites in the basin. In addition, it was found necessary to examine a number of alternative development possibilities to fulfill the overall objectives of the investigation.

The investigation encompassed virtually all aspects of water development, control, and utilization. Studies ranged from cursory examinations through reconnaissance evaluations to semidetailed estimates and projections. Project units were designed to meet economic demands for local agricultural and industrial water service, reduce flood flows within and from the area, provide for recreational benefits, protect and enhance the fishery resources, develop the hydroelectric power potential of the basin, and, to the extent possible, sustain an export supply in the Sacramento-San Joaquin River Delta.

Engineering and related technical investigations were made for a possible large reservoir on the main stem of the Sacramento River and for alternative reservoirs on tributaries to the Sacramento River. A major phase of the investigation involved the engineering and economic aspects of the main stem Iron Canyon Project. This investigation included problems associated with damsite geology, foundation conditions, structural design, and the effect of the dam and reservoir on the Sacramento River salmon fishery. Another major effort was directed toward planning multiple-purpose reservoirs on the tributary streams to either supplement or replace the main stem reservoir. The potential for development of ground water to supply local demands was also studied.

The study was begun in July 1958 and completed in June 1964. During this period the investigation was carried on by three state agencies. The Department of Water Resources conducted the investigation and prepared the report. Fish and wildlife aspects, including estimates of water requirements for maintenance of fishlife and for various conditions of possible enhancement, were prepared by the Department of Fish and Game for each project under consideration for initial construction. Water-associated recreation use of each potential project was estimated by the Department of Parks and Recreation through its Division of Beaches and Parks.

This report represents the combined efforts of these agencies to develop projects that would maximize the net benefits to the people of the State of California.

Related Investigations and Reports

For many years, plans have been made to develop and put to beneficial use the waters of the Upper Sacramento River Basin. A review of related reports, both published and unpublished, provided much of the background and data for this investigation. Information on the history and reclamation of the Upper Sacramento River Basin was obtained from the Reclamation Board of the State of California. Streamflow and flood data were obtained from publications of the U. S. Geological Survey (USGS), the U. S. Corps of Engineers, the U. S. Bureau of Reclamation, and the State of California Department of Water Resources.

The U. S. Corps of Engineers has made numerous studies in connection with the flood problems in the Upper Sacramento River Basin and in Butte Basin. Several of their reports were useful in evaluating the flood problems and possible solutions in the Upper Sacramento River Basin.

The U. S. Bureau of Reclamation, in connection with its responsibilities for the Central Valley Project, has published much information that was used in evaluating the problems and potential of the Upper Sacramento River Basin. Their reports were useful in evaluating the possibilities of constructing a reservoir on the main stem of the Sacramento River in the vicinity of the Iron Canyon site near Red Bluff.

The State's overall water plan, published in 1957 as Department of Water Resources Bulletin No. 3, provided a general plan for the development of the waters of the Upper Sacramento River Basin. Subsequent plans such as Bulletin No. 22, "Shasta County Investigation", carried the general plans further by making them more definite.

Many of the publications studied during this investigation are listed in Appendix E, Bibliography.

Area of Investigation

The area under investigation comprises the drainage basin of the Sacramento River between Shasta Dam and Red Bluff, the Thomes Creek watershed above Paskenta, and related agricultural service areas downstream from Red Bluff. The basin extends about 80 miles from the crest of the coast range on the west to the crest of the Cascades on the east, and about 35 miles from Shasta Dam on the north to Red Bluff on the south. The location of the area is shown on Plate 1, "Location of Area of Investigation".

The area contains about 2,800 square miles of which 1,900 are comprised of fairly rugged mountains varying in elevation from a few hundred feet to over 10,000 feet. The valley lands, in contrast, are relatively flat. At Red Bluff, the southernmost city within the basin, the elevation is 305 feet, whereas at Redding, 30 miles north, the elevation is 496 feet, only 191 feet higher.

Principal tributary streams within the basin are Clear, Cottonwood, and Thomes Creeks on the west side, and Cow, Bear, Battle, and Paynes

Creeks on the east side. The wedge-shaped northern tip of the valley intrudes into mountainous areas. To the east and northeast lie the Cascade Mountains. The Klamath Mountains, to the northwest, join with the Cascades at the northern extremity of the area. To the west, the Trinity and Coast Ranges form the western limit of the basin. The Coast Range consists of several subparallel ranges which have elevations generally ranging between 4,000 and 6,000 feet above sea level.

The Cascades consist of a volcanic chain flanked by irregular volcanic flows, and include Lassen Peak which, at an elevation of 10,457 feet, is the highest point adjacent to the basin.

The Klamath Mountains on the northwest are characterized by rugged peaks which rise from about 6,000 to over 8,000 feet above sea level.

Soils

A great variety of rock formations occur in the basin. The west side soils are of relatively recent origin with deep, fine-textured soils along the valley bottoms, underlain by coarse gravel and sand. The benches and ridges that form the foothills have red gravelly soils with some local areas containing a high percentage of red clay which are often underlain by hardpan at various depths. The hardpan generally restricts the use of foothill lands to irrigated pasture or dry range operation.

Tertiary and Quaternary volcanic rocks extend from the eastern divide to the east edge of the valley. Cretaceous and Eocene sedimentary rocks underlie the volcanics at lower elevations, and occur at the surface in some areas. Various older metasedimentary and metavolcanic rocks extend northward from the northern part of the area. The east side soils are generally medium textured; however, some small areas have coarse stream and colluvial deposits, partially derived from volcanic materials. A large part of the area has subsoils comprised of red clay and coarse gravel.

A broad belt of upper Pleistocene and Quaternary sediments, up to 22 miles wide, occupies the central portion of the basin. Along the Sacramento River and other principal streams, Recent alluvium is present. In general, the valley or bottom soils are deep and fine-textured, and are suitable for a wide variety of field and orchard crops. Crops presently grown are corn, milo, sugar beets, safflower, strawberry plants, alfalfa, and hay. Orchards are planted to apples, olives, walnuts, almonds, prunes, and peaches. In addition, large farming areas are devoted to the raising of beef and dairy cattle. The intermediate slopes and benches have shallow soil depths which restrict crop adaptability; the top benches are quite rocky and are often underlain with hardpan and parent materials which generally restrict their use to irrigated pasture or dry range land operation. Many of the soils in the intermediate and higher bench lands are relatively low in fertility.

Climate

The climate of the basin is typical of the Central Valley of California. The winters are cool and wet and the summers are hot and dry. Virtually all precipitation falls in the winter months, generally in the form of rain. The average seasonal precipitation for the basin is approximately 40 inches. High temperatures are common during the summer months, frequently exceeding 100 degrees Fahrenheit. The high temperature, dry atmosphere, and long summers with occasional hot winds are conducive to high evaporation from water surfaces. The average frostfree period is from the latter part of March to the middle of December. Average growing season is therefore approximately 260 days. Minimum temperatures rarely fall below 28 degrees Fahrenheit, although killing frosts have been recorded in Red Bluff as late as April 12 and as early as November 11. In general, the climate in the Upper Sacramento River Basin is suitable for a wide range of crops commonly grown throughout the Sacramento Valley. It is also very conducive to water-associated recreational uses.

Transportation

The Upper Sacramento River Basin is served by four major all-weather paved highways. U. S. Highway 99, the main north-south highway through the area, runs in a general southeasterly direction from the Canadian to the Mexican border and serves the principal cities in the Central Valley of California. The largest cities in the basin, Redding, Red Bluff, Anderson, and Cottonwood, are on or near U. S. Highway 99. U. S. Highway 299 starts at U. S. Highway 101 near the Pacific Coast and extends eastward to Redding. From Redding, it extends northeastward and ends at Alturas about 30 miles from the Nevada border. State Highway 44 extends southeastward from Redding and terminates at State Highway 89 near Manzanita Lake. State Highway 36 runs east and west from Red Bluff, ending at Susanville on the east and at U. S. Highway 101 on the west. In addition, numerous improved and unimproved county roads transect the area and make connections with the main federal and state highways. The highway system provides ready access by automobile, bus, and truck to markets and centers of commerce in other parts of California.

The Southern Pacific is the only railroad that serves the basin. Its main line roughly parallels U. S. Highway 99 as it passes through the basin. In addition to serving the main centers of population in the Upper Sacramento River Basin, it provides access to markets in Los Angeles, San Francisco, Sacramento, Portland, and Seattle.

There are municipal airports in Redding and Red Bluff capable of handling medium-sized jet aircraft. Pacific Airlines presently provides four nonjet flights daily from Redding and Red Bluff to San Francisco and Portland.

Existing transportation facilities adequately meet present requirements and could be readily expanded to handle the greater volume of passenger and freight service that is anticipated on the basis of population projections and future economic expansion.

The West Side

From the Sacramento River, the land rises toward the west in parallel, narrow, alluvial valleys separated by moderately high granitic ridges. Through these valleys, many streams empty into the Sacramento River. Cottonwood Creek, the largest tributary in the basin, drains an area of approximately 950 square miles and enters the Sacramento River about 4 miles east of the town of Cottonwood.

In the valleys along the watercourses of the Cottonwood Creek area, agriculture is highly developed. Toward the foothills, where the soil thins out and becomes rocky, cattle raising is almost the only use made of the land. In the extreme western sections of the area at the higher elevations, pines grow in profusion. In the central section at the lower elevations, the natural forest consists of sparse cottonwood, scrub oak, and manzanita. Ground water may be either abundant or sparse. The valley and lower foothill area is underlain by Continental and Marine sediments of the Chico formation which dips toward the east, forming the base for an almost continuous ground water basin. The higher elevation lands, in contrast, are very nearly devoid of ground water. This lack of water has precluded major development in the upper areas. However, in the few areas along the higher ridges and terraces where water is available, one-half to five acre homesites are rapidly being developed.

Clear Creek, the second largest tributary on the west side of the basin, drains into the Sacramento River between Redding and Anderson. The only developed agricultural areas within the Clear Creek area are concentrated in Happy Valley about 2 miles west of Anderson and 4 miles northwest of Cottonwood. The Happy Valley area has recently been assured a water supply by forming into a public water district and contracting with the U. S. Bureau of Reclamation of receive water from Whiskeytown Reservoir.

Thomes Creek, in the southwestern portion of the area of investigation, drains into the Sacramento River 15 miles south of Red Bluff. The Thomes Creek drainage area west of U. S. Highway 99 is only sparsely settled and presently is devoted to cattle raising and to the growing of olives and citrus crops.

The East Side

Eastward from the Sacramento River the land slopes steadily upward. As the elevation increases the landscape takes on a less productive appearance. This is largely due to the change from irrigated pasture to dry range land operation. For a few weeks following the winter rains the shallow soils support enough grass for cattle grazing. Within a short time, however, the soil moisture is depleted and the vegetation becomes sparse and brown. Here and there patches of coniferous forest mixed with manzanita survive on local pockets of ground water.

The lower foothill lands are largely devoted to cattle raising, with spots of irrigated meadow supplied by ground water. Forested areas of Douglas fir and pine lie in scattered parcels along the higher foothill elevations, usually along intermittent or ephemeral streams which interlace the area.

The upper edge of the area is heavily forested with pine and fir. Lumbering is one of the major activities in this area, and many small mills dot the landscape.

Agriculture in the area consists largely of pasture, but also includes small acreages of walnuts and strawberry plants. Much of the pasture is grown on irrigated lands adjacent to the creeks running through the area. Most of the irrigation is done by direct diversion from the creeks, although a limited use is made of ground water in the Stillwater Plains area. Very little irrigable land exists in the northeastern portion of the area of investigation. In this area the land is hilly and rocky, leaving only scattered patches of irrigable land. For a part of the year cattle can be grazed in the mountains, but as the soil moisture is depleted and the grasses die out, the cattle are moved to better pasturage.

History of Economic Development

Exploration of the Upper Sacramento River Basin by Spanish explorers occurred between 1821 and 1823. Next came the American explorer and trail blazer Jedediah Strong Smith in 1828. In his footsteps a stream of hunters and trappers came from both the north and south. Between the time of early exploration and settlement, the area was inhabited mainly by hunters, trappers, and resident Indian tribes.[1/]

The explorations of Peter Lassen and General John Bidwell in 1843 helped attract settlers to the area. In 1844, the population consisted of less than 50 ranch owners and workers on large Mexican land grants along the Sacramento River. In all, about a dozen large ranches were established before the gold rush. In 1848, Marshall's discovery at Coloma prompted Major Pierson Barton Reading to prospect for gold on his 26,000-acre ranch in Shasta County. He discovered gold on Clear Creek and on the Trinity River in 1848. From this time on, there was a steady migration of settlers

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1/ For an account of the history of local Indian tribes, see "Ishi". T. Kroeber. University of California Press, 1961.

to Shasta and Tehama Counties. At first, the newcomers were mainly interested in mining, but as the mines played out, their attention turned to other economic pursuits.

Economic development of the basin did not take place on a substantial scale until after 1890. By this time a population of about 26,000 persons was scattered throughout Tehama and Shasta Counties, primarily in rural areas. Redding, the largest city, had only 1,800 inhabitants.

By the turn of the century, a trend toward urbanization had begun. Redding and Red Bluff had grown to a combined population of nearly 6,000 out of a total population of 28,300. Population projections of Shasta and Tehama Counties indicate that this trend toward urban living is continuing at an ever-increasing rate. The Department's estimates show that the population will increase from 97,400 persons in 1963 to 440,000 by the year 2020. About 380,000, or more than 85 percent of the population in the year 2020, will be living in cities and towns.

The present economy is based largely on agriculture and supporting business and lumbering and forest products industries, although it is becoming more and more dependent on business catering to the recreation and tourist trade. Several of the small towns such as Anderson and Cottonwood are in transition from agricultural service centers to commercial centers. Small business establishments dot the eastern side of Highway 99 from Cottonwood to Redding. The Kimberly Clark Corporation recently built a new pulp mill plant at Anderson that employs an estimated 400 persons. The United States Plywood Corporation plant at Anderson is one of the largest in the United States, with a production of about 50,000 sheets per day.

Because of their numerous motels and restaurants, and because of the considerable distance to other large towns, Redding and Red Bluff have become stop-over points for many travelers in Northern California. The construction of Shasta Reservoir particularly has stimulated the tourist industry in Redding. With the recent completion of Trinity and Whiskeytown Reservoirs, it is anticipated that tourist and recreational activity will increase further in the region surrounding Redding.

History of Water Development

The Sacramento Valley and its upper basin have been plagued by damaging floods and droughts for many years. Early plans for flood control included: drainage in the Sacramento Valley by opening of the river mouth; construction of adequate levees; construction of "escapeways" at strategic points to allow the surplus waters of major floods to be stored in the various basins; and retention of as much water as possible between the levees so as to ultimately scour a satisfactory river channel. Consideration was given to a plan to divert water near Chico Landing, and to conduct it through Butte Basin by a bypass channel. However, such a channel would not have sufficient storage capacity, and consequently would deliver flood waters too rapidly to the lower river.

In February and March 1904, notable floods occurred in the Sacramento Valley streams. These floods, which produced record flows at the Sacramento River near Red Bluff, resulted in great damage. Following the floods of 1904, a committee of engineers known as the Dabney Commission was appointed to evolve a comprehensive plan for controlling the Sacramento River floods.

Additional flooding occurred in March 1907, and in January and February 1909. The occurrence of these floods, and the interest developed by the Dabney Commission, brought the matter of flood control in the Sacramento Valley to the attention of the federal government. Efforts by local, state, and federal agencies to develop a general Sacramento Valley flood control project have resulted in the construction of the extensive, but inadequate, flood channels, levees, and other flood relief systems that exist today.

In 1931, the state engineer made a report to the California Legislature on the State Water Plan. This comprehensive plan discussed the physical and economic aspects of state water distribution problems. Investigations and reports of federal, state, and local agencies culminated in passage by the Legislature of the Central Valley Project Act of 1933, intended to implement the initial features of the State Water Plan in the Central Valley. The project, originally intended for construction utilizing state funds, was subsequently set up for federal financing through the U. S. Bureau of Reclamation, as a feature of the Public Works Administration's program to alleviate the depression then existing throughout the country.

Shasta Dam was constructed by the U. S. Bureau of Reclamation in the early 1940's for river regulation, navigation, flood control, irrigation, domestic water supply, and power generation. Control of water quality, recreation, and fish conservation are also recognized purposes of Shasta Reservoir. This multiple-purpose reservoir, a key unit of the Central Valley Project, has a reservoir surface area of 29,000 acres, and a storage capacity of 4.5 million acre-feet including 1.3 million acre-feet specifically reserved for flood control purposes.

The need for additional flood control, the ever-increasing demand for electrical energy, and the desirability of conserving water for use in the thirsty valleys of California have caused the U. S. Bureau of Reclamation, the Corps of Engineers, the State, and local agencies to persist in the development of plans for additional storage on the main stem of the Sacramento River. These proposals have met with mild approval from some landowners below the proposed sites, and vigorous objections from upstream landowners and from local and state fisheries interests.

As a result of the strong opposition to main stem developments, studies were made to determine the feasibility of constructing tributary reservoirs in lieu of an Iron Canyon or Table Mountain Reservoir.

In 1945, the California Legislature, after holding extensive hearings, enacted into law Chapter 1912, now codified as Chapter 12649 of the Water Code. This chapter, quoted below, gave legislative approval to the search for suitable tributary reservoir sites.

> "12649. It is the intention of the Legislature that, if a feasible plan can be found which will provide adequate flood control in the upper Sacramento Valley without the necessity of constructing a dam across the Sacramento at the Table Mountain site, or any other site in the same general vicinity, and thereby prevent the necessity of flooding valuable agricultural land and at the same time prevent damage to the fishing resources of the Sacramento River, such alternative plan should be adopted."

Independent studies by the U. S. Bureau of Reclamation, the Corps of Engineers, and the State had previously concluded that a tributary reservoir flood control plan did not constitute a satisfactory alternative to a main stem reservoir. These early investigations considered only flood protection, water supply, and power production as major project purposes. During recent years, however, the multiple-purpose concept has become more and more important, and benefits attributable to many diversified functions are now included in economic evaluations.

Since 1947, when the Statewide Water Resources Investigation, "The California Water Plan", was started, factors affecting water development within the Upper Sacramento River Basin have been changing at an accelerated pace. These factors not only include physical development, but the basic criteria of evaluation. For example, since the inception of the Upper Sacramento River Basin Investigation in 1958, recreation and fish and wildlife enhancement have gained greater prominence, and the monetary values ascribed to these benefits have been more thoroughly evaluated and are assuming a more important position in the ultimate formulation of comprehensive multiple-purpose projects. This recent emphasis on recreation and fisheries enhancement has greatly increased the economic potential of tributary reservoir developments. At the same time recent advancements in the development of large, highly efficient steam-electric powerplants have reduced the costs of power production, and have therefore reduced the economic value of hydroelectric power projects. This reduction of hydroelectric power benefits has greatly reduced the economic potential of a dam and reservoir on the main stem of the Sacramento River.

Influence of Future Water Projects

The Upper Sacramento River Basin will eventually become an integrated part of a complex of water control and supply covering the entire State. Studies of the North Coastal area, now in progress, may greatly influence the eventual decision as to the control and disposition of waters within the Upper Sacramento River Basin. The principal influence of the North Coastal Investigation on the Upper Sacramento River results from the method and time of import of additional North Coastal water to the Sacramento Valley. This future import water could be brought in by either of two practical routes. They are: (1) a diversion tunnel into Clear Creek, then through a series of reservoirs and powerplants into the Sacramento River above the Iron Canyon damsite; (2) a diversion tunnel into Cottonwood Creek, then through the West Side Conveyance System to a large Glenn Reservoir Complex on Thomes and Stony Creeks.

The route selected may therefore have a very pronounced effect on future water projects within the Upper Sacramento River Basin. It is not possible at this time to determine which of the above alternatives will finally be constructed.

Other studies of the Upper Sacramento River area are now being made by local agencies and by the State and federal governments. The results of these studies will continue to affect future water development projects in the Upper Sacramento River Basin.

Arrangement of This Report

The water supply and water requirements for the basin are presented in Chapter II; Iron Canyon Project is discussed and evaluated in Chapter III; tributary reservoir development projects are discussed and evaluated in Chapter IV; ground water development possibilities are discussed in Chapter V; and conclusions and recommendations are contained in Chapter VI.

CHAPTER II. WATER SUPPLY AND WATER REQUIREMENTS

The water resources of the Upper Sacramento River Basin consist of direct precipitation on the lands of the area, natural surface and subsurface inflow to the basin, and imported water. A portion of this resource is used locally, but the majority flows from the basin as surface or subsurface outflow. The water supply of the basin is considered and evaluated in this chapter under the general headings "Precipitation", "Streamflow", "Imported and Exported Water", "Ground Water", and "Water Quality".

Present and predicted future water requirements in the Upper Sacramento River area are relatively small when compared with the water supply originating in the basin. Even under conditions of expected maximum development, the net depletion of water supply by all local uses will be substantially less than the available natural runoff. The water requirements are discussed in this chapter under the general headings "Present Water Resources Development", "Service Areas", "Land Use", and "Water Requirements".

Precipitation

Winter precipitation results from storms and their associated fronts moving into the Upper Sacramento River area from the Pacific Ocean. In basinwide storms, rainfall is generally heavy in the area just west of Shasta Dam and along the western and eastern drainage divides. The orographic lifting of moist air masses over the Cascade Mountains releases precipitation on the windward slope, resulting in heavy precipitation in the eastern part of the basin. This orographic precipitation is in addition to the precipitation resulting from the convergence process operating in low pressure systems and along fronts. The lowest rainfall occurs on the valley floor near Red Bluff. Although precipitation in the form of rain is predominant, considerable snow falls at higher elevations, notably on the slopes of Mount Lassen.

For purposes of this investigation, the 50-year period from July 1905 to June 1955 was used to estimate mean annual precipitation.

Precipitation Stations

There are 29 precipitation stations in and adjacent to the study area with continuous records of 10 years or longer. These stations, together with others with shorter periods of record were used as a basis for plotting lines of equal mean annual precipitation shown on Plate 2, "Lines of Equal Mean Annual Precipitation". Table 1 presents the station name, location, elevation, period of record, source of record, and estimated average seasonal precipitation for the period 1905-1955. All records of precipitation used in the study have been published in bulletins of either the U. S. Weather Bureau or the Department of Water Resources.

Precipitation Characteristics

The precipitation pattern is historically one of wet winters and extremely dry summers. Approximately 85 percent of the seasonal precipitation occurs from November through April. The remaining 15 percent generally occurs in late spring and early fall with virtually no precipitation occurring during the summer months. Extreme seasonal variability of precipitation is evidenced by the record at Redding which shows a maximum of 69 inches and a minimum of 16 inches. Average seasonal precipitation in the basin varies from 76 inches at Iron Mountain to 19 inches at Red Bluff. The average for the entire study area is approximately 40 inches. Snow depths up to 300 inches have been recorded on Mount Lassen.

The lines of equal mean annual precipitation developed from precipitation data were used in flood hydrology studies and in estimating the natural runoff from drainage areas that do not have streamflow measurements available.

Streamflow

Runoff from the basin and releases from Shasta Reservoir constitute the present sources of surface water originating within the Sacramento River Basin. Imports from the recently completed Trinity River Division, federal Central Valley Project, have increased this runoff by about 850,000 acre-feet annually. Natural runoff from the basin not

TABLE 1

PRECIPITATION STATIONS IN OR ADJACENT TO THE
UPPER SACRAMENTO RIVER BASIN

Station	Latitude and Longitude	Elevation Above Mean Sea Level, in Feet	Period of Record*	Source of Record	Estimated Mean Annual Precipitation, in Inches
West Side					
Trinity R. S.	41° 00' 122° 41'	2,295	1941-	USWB	45.51
Minersville Rock Rch.	40° 50' 122° 51'	2,400	1949-58	USWB	44.46
Weaverville R. S.	40° 44' 122° 56'	2,050	1871-	USWB	34.89
French Gulch	40° 42' 122° 38'	1,100	1951-	USWB	37.50
Iron Mountain No. 2	33N-6W-35	2,750	1949-	Private	76.50
Buckhorn Summit	40° 38.4' 122° 43.9'	3,100	1952-	USBR	
Shasta	40° 36' 122° 29'	1,148	1896-1912	USWB	50.75
Igo 3 N.W.	40° 32.5' 122° 34.0'	1,620	1940-	Private	47.70
Ono	40° 29' 122° 37'	980	1951-	USWB	36.01
Ono Exp. Range	30N-8W	1,500	1939-	UC	
Harrison Gulch R. S.	40° 22' 122° 57'	2,710	1943-	USWB	34.94
Beegum	40° 21' 122° 51'	1,291	1940-48 1951-54	USWB	27.70
Ferguson Ranch	40° 21' 122° 27'	800	1951-	USWB	27.69
Beegum 2 SW	40° 19.0' 122° 52.9'	3,450	1952-	USBR	30.44
Rosewood	40° 17' 122° 33'	865	1894-1904	USWB	25.04
Saddle Camp R. S.	40° 10' 122° 48'	3,850	1945-	USWB	31.44
Ball Mtn. Look Out	39° 56' 122° 47'	6,500	1948-	USWB	38.07
Paskenta 6 WNW	39° 55.2' 122° 39.5'	3,700	1952-	USBR	36.43
Paskenta R. S.	39° 53' 122° 33'	755	1938-	USWB	21.52
Flournoy	39° 55.3' 122° 26.2'	580	1953-	Private	21.53

* Dash following year indicates continuous record.

TABLE 1 (Continued)

PRECIPITATION STATIONS IN OR ADJACENT TO THE UPPER SACRAMENTO RIVER BASIN

Station	Latitude and Longitude	Elevation Above Mean Sea Level, in Feet	Period of Record*	Source of Record	Estimated Mean Annual Precipitation, in Inches
West Side (Continued)					
Corning Houghton Rch.	39° 54' 122° 22'	487	1946	USWB	19.51
Corning 7 WNW	39° 57' 122° 18'	395	1955-	DWR	
Corning 1 W	39° 56' 122° 12'	288	1958-	DWR	20.92
Main Stem					
Turntable Creek	40° 46' 122° 18'	1,067	1947-	USWB	61.72
Shasta Dam	40° 43' 122° 25'	1,076	1943-	USWB	55.90
Redding Fir Sta. No.2	40° 35' 122° 24'	577	1875-	USWB	37.45
Churn Creek	40° 28' 122° 18'	450	1915-27	USWB	29.07
Anderson-Gilman Rch.	40° 27' 122° 16'	234	1934-39	Private	25.19
Red Bluff W.B.A.P.	40° 09' 122° 15'	341	1877-	USWB	19.41
Los Molinos 3 N	40° 04' 122° 06'	245	1954-	Private	23.00
Tehama	40° 02' 122° 08'	220	1871-1916	USWB	
Los Molinos	40° 01' 122° 06'	219	1910-13, 1924-39, 1942-54	Private	23.00
Vina Monastery	39° 56' 122° 04'	202	1916-54, 1958-	Private	21.27
East Side					
Montgomery Cr. 2 SSW	40° 49' 121° 56'	2,100	1911-19, 1941-	USWB	52.13
Round Mountain	40° 48' 121° 57'	2,010	1951-	USWB	55.52
Kilarc P.H.	40° 01' 121° 52.3'	2,700	1921-	PG&E	42.33
St. Vrain Ranch	40° 36' 121° 59'	1,600	1924-28	Private	

* Dash following year indicates continuous record.

TABLE 1 (Continued)

PRECIPITATION STATIONS IN OR ADJACENT TO THE UPPER SACRAMENTO RIVER BASIN

Station	Latitude and Longitude	Elevation Above Mean Sea Level, in Feet	Period of Record*	Source of Record	Estimated Mean Annual Precipitation, in Inches
East Side (Continued)					
Whitmore 4 ESE	40° 36.1' 121° 50.8'	2,900	1952-	USBR	
Millville	40° 23' 122° 10.5'	510	1952-	Private	33.04
Macumber	40° 32' 121° 44'	4,000	1922-30	PG&E	44.00
Manzanita Lake	40° 32' 121° 34'	5,850	1941-	USWB	42.25
Coleman F. H.	40° 24' 122° 09'	420	1943-	USWB	25.19
Darrah Springs F. H.	40° 25.9' 121° 59.7'	975	1937-43, 1957	DFG	25.55
Volta P. H.	40° 27' 121° 52'	2,200	1919-	USWB	32.90
Manton 1 E	40° 26.2' 121° 50.8'	2,395	1955-58	Private	
Forward Mill	40° 26' 121° 44'	3,300	1951-	USWB	36.72
Dales	40° 18.8' 122° 09.2'	600	1952-	Private	27.23
Paynes Creek	40° 20' 121° 54'	1,850	1951-	USWB	28.51
Lassen Lodge 2 W	40° 20.9' 121° 45.1'	3,600	1952-	USBR	
Mineral	40° 21' 121° 36'	4,850	1909-	USWB	48.91
Campbellville	40° 02' 121° 43'	4,000	1951-	USBR	49.37

* Dash following year indicates continuous record.

Abbreviation	Agency
DWR	California Department of Water Resources
USWB	United States Weather Bureau
USBR	United States Bureau of Reclamation
PG&E	Pacific Gas and Electric Company
UC	University of California
DFG	Department of Fish and Game

presently serving beneficial purposes, plus water spilled from Shasta Reservoir, comprise the water that is available for development as new conservation yield.

Stream Gaging Stations and Records

The flow of most major streams in the basin has been measured for many years under a cooperative program of the U. S. Geological Survey and the Department of Water Resources, and by other public and private agencies. Long-term records are available on the Sacramento River and near the mouths of most major tributaries. Table 2 lists the stream gaging stations in and near the basin and gives the Department of Water Resources' index number, the drainage area of the station, the period of record at each station, and the source of record. Locations of the gages used in hydrologic studies for this investigation are shown on Plate 2.

Runoff Characteristics

The distribution of runoff in the west side streams is closely related to the precipitation pattern. Many of the smaller west side streams dry up entirely during the summer months, while flow in the main streams is substantially reduced. The contribution of snowmelt to runoff from these streams is not appreciable, since more than 90 percent of the area is below 5,000 feet in elevation. Streams on the east side have high runoff peaks of longer duration than west side streams, and usually carry sustained flow throughout the summer months. The sustained flows are attributable to two factors: first, snow at the higher elevations tends to defer a portion of the runoff to the spring months; and second, the porous volcanic soil acts as a regulator by allowing the winter precipitation to penetrate into its pervious structure and then slowly return to the stream systems.

Quantity of Runoff

Estimates of natural and impaired runoff of the streams in the Upper Sacramento River Basin were made from available streamflow records, and from correlations with precipitation in the tributary stream basin. The estimated full natural runoff originating in the basin for the selected base period is about 2 million acre-feet annually.

The 20-year period from October 1, 1921, through September 30, 1941, was chosen as the base period for reservoir operation studies to

TABLE 2

STREAM GAGING STATIONS IN OR ADJACENT
TO THE UPPER SACRAMENTO RIVER BASIN

DWR Index Number	Station	Drainage Area, in Square Miles	Period of Record*	Source of Record
Main Stem				
2 3050	Pit River near Ydalpom	5,350	1911-43	USGS
2 3050	McCloud River at Baird	665	1911-43	USGS
2 1200	Sacramento River at Antler	461	1910-11, 1919-41	USGS
2 1060	Sacramento River at Kennett	6,580	1925-42	USGS
2 1050	Shasta Lake near Redding	6,665	1942-	USBR
2 1010	Sacramento River at Keswick (downstream)	6,710	1938-	USGS
0 2835	Sacramento River near Redding		1945-52, 1954-	DWR
0 2815	Sacramento River at Balls Ferry		1945-52, 1954	USBR DWR
0 2790	Sacramento River at Jellys Ferry	9,090	1895-1902	USGS
0 2780	Sacramento River at and near Red Bluff	9,300	1902	USGS
0 2770	Sacramento River at Red Bluff		1957-	DWR
0 2760	Sacramento River at Redbank Creek		1951-	USBR
West Side				
3 6230	Clear Creek at French Gulch	115	1950-	USGS
3 6180	Clear Creek near Shasta	172	1911-13	USGS
3 6130	Clear Creek near Igo	228	1940-	USGS
3 5160	North Fork Cottonwood Creek near Ono	12	1919	USGS
3 5170	Moon Creek near Ono	9.6	1919	USGS
3 5150	North Fork Cottonwood at Ono	52	1907-13	USGS
0 3545	North Fork Cottonwood near Igo	88.7	1956-	DWR
0 3580	Middle Fork Cottonwood near Ono	250.7	1956-	USGS
0 3565	Dry Fork of South Fork Cottonwood near Cottonwood	148.1	1958-	DWR
0 3595	South Fork Cottonwood near Cottonwood	219.1	1958-	DWR
0 3520	Cottonwood Creek near Cottonwood	945	1940-	USGS
0 3460	Redbank Creek at Foothills	89	1948-	DWR
0 3320	Elder Creek at Gerber	136	1949-	USGS
0 3350	Elder Creek near Henleyville	130	1930-41	USGS
3 3110	Elder Creek near Paskenta	92.9	1948-	USGS
3 2120	Thomes Creek at Paskenta	188	1920-	USGS

* Dash following year indicates continuous record.

TABLE 2 (Continued)

STREAM GAGING STATIONS IN OR ADJACENT
TO THE UPPER SACRAMENTO RIVER BASIN

DWR Index Number	Station	Drainage Area, in Square Miles	Period of Record*	Source of Record
East Side				
4 8400	Little Cow Creek near Ingot	60.6	1957-	DWR
4 8375	Salt Creek near Bella Vista	14.0	1957-	DWR
4 8350	Little Cow Creek at Palo Cedro	145	1911-14	USGS
4 8200	Oak Run Creek near Oak Run	11.2	1957-	USGS
4 8250	Clover Creek near Oak Run	19.0	1957-59	USGS
4 8160	Clover Creek at Millville	53.4	1911-14	USGS
4 8450	Old Cow Creek at Kilarc Diversion	24	1921-	PG&E
4 8550	South Cow Creek at Wagoner Canyon	50	1920-	PG&E
4 8500	South Cow Creek near Millville	78.7	1956-	USBR
4 8300	Cow Creek at Millville	166	1911-14	USGS
4 8110	Cow Creek near Millville	427	1949-	USGS
4 0750	Bear Creek near Millville	75.6	1959-	DWR
4 0730	Bear Creek near Millville	83.0	1911-14	USGS
4 7300	South Fork Battle Creek near Mineral	33.0	1959-	DWR
4 7110	Battle Creek near Cottonwood	362	1940-	USGS
0 4620	Paynes Creek near Red Bluff	92.5	1949-	USGS
4 5110	Antelope Creek near Red Bluff	124	1940-	USGS
4 4180	Mill Creek near Mineral	24.5	1928-32	USGS
4 4110	Mill Creek near Los Molinos	135	1909-13 1928-	USGS
4 3110	Deer Creek near Vina	200	1911-15, 1920-37, 1939-	USGS

* Dash following year indicates continuous record.

Abbreviation	Agency
DWR	California Department of Water Resources
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
PG&E	Pacific Gas and Electric Company

determine yields through the critical dry period. This period coincides with the period selected by the U. S. Bureau of Reclamation for their Central Valley Project Operation Studies; it includes the critical dry period of record; and it also includes a series of above normal runoff years to provide for reservoir filling before and after the dry period. The average seasonal runoff for the base period is approximately 75 percent of the estimated 50-year mean.

For convenience of presentation, principal streams of the basin were divided into three major groups: (1) the main stem of the Sacramento River; (2) the west side tributary streams; and (3) the east side tributary streams. The main stem is that portion of the Sacramento River between Keswick Dam and the City of Red Bluff. The major west side tributary streams are Clear, Cottonwood, and Thomes Creeks. The major east side tributary streams are Cow, Bear, Battle, and Paynes Creeks. The combined runoff from these major east and west side tributary streams supplies approximately 85 percent of the more than 2 million acre-feet of the annual runoff originating within the basin.

Table 3 presents estimated or recorded annual runoff at selected locations in the basin and Table 4 shows the average monthly distribution of runoff at selected locations within the basin.

Flood Hydrology

Studies were made to determine the magnitude of the probable maximum flood at each reservoir site and to determine the frequency of flooding in areas downstream from the reservoir sites.

The probable maximum flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the particular hydrologic region. This flood discharge was computed for each reservoir site and used to determine the required spillway design capacity.

Flood frequency analyses were made for flood damage study areas for conditions of "with" and "without" the project. These frequency analyses were used in conjunction with flood damage estimates to determine flood control benefits which would accrue to a project.

TABLE 3

RECORDED OR ESTIMATED HISTORIC ANNUAL RUNOFF
AT SELECTED LOCATIONS IN THE UPPER SACRAMENTO RIVER BASIN
(In thousands of acre-feet)

Water Year	Sacramento River at[1] Shasta Dam	Sacramento River near[2] Red Bluff	Thomes Creek at[2] Paskenta	Cottonwood Creek near[1] Cottonwood	Cow Creek near[1] Millville	Battle Creek near[1] Cottonwood
1921-22	4,622	6,328	193	506	445	393
1922-23	3,648	5,009	146	364	330	280
1923-24	2,479	2,972	33	82	107	205
1924-25	5,065	7,739	284	806	266	279
1925-26	3,728	5,352	144	366	242	268
1926-27	6,987	10,657	337	1,003	491	373
1927-28	5,120	7,317	257	712	415	344
1928-29	3,208	4,122	55	141	138	219
1929-30	4,190	5,815	142	361	416	314
1930-31	2,539	3,080	54	136	110	202
1931-32	3,694	4,823	113	287	266	271
1932-33	3,471	4,359	88	224	144	231
1933-34	3,321	4,375	74	189	227	236
1934-35	4,917	7,164	154	393	360	333
1935-36	4,673	6,667	190	497	377	313
1936-37	4,125	5,778	112	285	236	283
1937-38	9,548	14,396	446	1,440	1,053	589
1938-39	3,465	4,109	65	164	160	230
1939-40	7,030	10,256	285	810	673	437
1940-41	8,716	13,957	432	1,658[2]	814	504[2]
20-year average	4,727	6,714	180	521	364	315

1/ Estimated
2/ Recorded

TABLE 4

ESTIMATED MEAN MONTHLY DISTRIBUTION OF NATURAL RUNOFF
AT SELECTED LOCATIONS IN THE UPPER SACRAMENTO RIVER BASIN
(In percent of seasonal total)

Location	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Sacramento River at Red Bluff	3.4	5.5	9.3	11.6	17.7	16.0	14.0	8.3	4.9	3.4	3.0	2.9	100.0
Thomes Creek at Paskenta	0.3	3.6	9.5	11.6	20.8	19.6	19.0	11.4	3.4	0.6	0.1	0.1	100.0
Cottonwood Creek near Cottonwood	0.5	3.2	11.8	14.6	23.2	20.7	13.8	6.9	3.1	1.0	0.5	0.7	100.0
Cow Creek near Millville	0.8	4.0	16.7	15.3	20.6	18.6	10.3	6.6	3.2	1.6	1.3	1.0	100.0
Battlecreek near Cottonwood	4.9	6.7	9.5	9.9	13.6	12.6	11.1	11.0	7.5	5.0	4.2	4.0	100.0

Imported and Exported Water

Large quantities of water are being imported to the basin from the recently constructed reservoirs of the Trinity River Division of the federal Central Valley Project. This import has increased the flow into the Upper Sacramento River Basin by about 850,000 acre-feet annually. Trinity River water comes into the basin via Clear Creek. Whiskeytown Reservoir regulates this water and the natural runoff of Clear Creek and diverts it via the Spring Creek conduit and powerhouse into Keswick Reservoir on the Sacramento River. The major portion of this water passes through the Upper Sacramento River Basin for use in water-deficient areas elsewhere in the State.

Other large imports of water from the North Coastal area may pass through the basin in the future enroute to water deficient areas of the State. The Westside Conveyance System, which would divert additional Trinity River water into the Sacramento Valley, is being studied by this Department and by the federal government as an alternative to an enlarged Clear Creek Diversion. The Westside Conveyance System would transport large quantities of water through the basin into a large Glenn Reservoir Complex on Thomes and Stony Creeks. Future imports from the Middle Fork Eel River might also be diverted into the Glenn Reservoir Complex.

All of these possible future imports plus natural basin surpluses will be conveyed by the Sacramento River and diverted downstream for use in water-deficient areas.

Ground Water

Most of the ground water resources of the Upper Sacramento River Basin have not yet been fully developed. Due to the ready accessibility of high quality surface water, ground water has only recently begun to be of major importance for agricultural use. However, most local, municipal, and industrial water requirements are presently satisfied by ground water pumping. Because of the lack of need, little geologic and geohydrologic data have been collected. However, available data indicate that large quantities of high quality ground water may be obtained economically throughout extensive areas of the Upper Sacramento River Basin.

The Redding ground water basin contains most of the usable ground water in the Upper Sacramento River area. This basin lies partly in south central Shasta County and partly in north central Tehama County. It is bounded on the north by the Klamath Mountains, on the west by the foothills of the Klamath Mountains and the northern Coast Range, and on the south by the Red Bluff arch, a structural uplift which trends northeasterly across the Sacramento Valley in the vicinity of Red Bluff. The eastern boundary is arbitrarily defined as being at the foothills of the Cascade Range although it is recognized that a small part of the basin extends further to the east.

Important fresh-water-bearing geologic formations in the basin are alluvium, the Red Bluff formation, and the Tehama and Tuscan formations. The Tuscan and Tehama formations comprise the principal water-bearing deposits in the basin.

Recharge of the ground water is accomplished mainly by percolation of water at higher elevations followed by slow subsurface movement to the valley. Some direct recharge occurs in the valley. The recharge has been sufficient in the past to allow only minor seasonal fluctuations in the level of the water table.

No determination of the safe ground water yield was made. However, since the average annual water table elevation has remained essentially constant since 1955, it is believed that the safe ground water yield is greater than present extractions. Waters imported from the Trinity River to the Happy Valley area and the Bella Vista Water District will provide additional recharge to the Redding ground water basin. A detailed discussion of ground water studies in the Upper Sacramento River Basin Investigation are presented in Chapter V.

Water Quality

The objectives of the water quality study made in connection with this investigation were: (1) to determine present quality conditions of surface and ground water; (2) to detect any water quality problems; and (3) to evaluate water quality aspects of proposed water development projects.

Quality of Surface Waters

Surface waters in the Upper Sacramento River area are of excellent mineral quality suitable for most beneficial uses. Most of the water can be classed as calcium-magnesium bicarbonate in type. Exceptions to this classification include waters in the upper reaches of Churn and Stillwater Creeks, which are classed as magnesium-sodium bicarbonate, and Clear Creek, which are classed as calcium-sodium bicarbonate. Detrimental concentrations of minerals have not been detected in any of the major streams or their tributaries.

The range and average value of mineral constituents of surface streams in this area are as follows:

Constituent	Range	Average
Boron, in parts per million	0.00-0.30	0.09
Chlorides, in parts per million	0.0-57.0	8.2
Hardness, in parts per million	16-168	60
Total dissolved solids, in parts per million	41-229	104
Sodium, in percent of base constituents	11-40	23

Water with the above characteristics is considered Class 1 (excellent to good) for irrigation purposes. This water is slightly hard, but would generally require no softening. A comparison of characteristics of the surface water in the investigational area with criteria contained in the U. S. Public Health Service Drinking Water Standards of 1962 shows that the water would generally be of satisfactory mineral quality for domestic and municipal uses. Under ultimate development of irrigated lands in this area, irrigation return flows could have a deleterious effect upon surface water quality. The extent and magnitude of this problem cannot be thoroughly evaluated until a pattern of development has become established.

Extensive timber resources in the mountains surrounding the Upper Sacramento River area provide a definite possibility for future development of timber by-product industries. Wastes from these industries could create a source of water quality impairment, unless the disposal of these wastes is suitably controlled. The responsibility for exercising such control, pursuant to Division 7 (commencing with Sec. 13,000) of the Water Code, is vested in the Central Valley Regional Water Pollution Control Board (No. 5).

A few miles northwest of Redding, just outside the area of investigation, lies the Iron Mountain region containing metallic ore deposits, some of which are presently being mined. Water draining from this area, especially via Spring Creek, is frequently acidic and has undesirable concentrations of copper, zinc, iron, aluminum, and other toxic salts which are leached from tailings of both operating and abandoned mines. Waters thus polluted are sometimes lethal to fish, and adversely affect animal and plant organisms on which fish feed. To alleviate this problem the U. S. Bureau of Reclamation recently constructed the Spring Creek debris dam near the mouth of Spring Creek.

Quality of Ground Waters

Ground water in the area of investigation is generally of excellent mineral quality. Poor quality water, however, does exist in the basin fringe area near the base of the foothills where the salt-water-bearing Chico formation rises near the surface. Except for these local areas of inferior quality, the ground water can generally be classed as magnesium-calcium bicarbonate type with a range and average value of mineral constituents as follows:

Constituent	Range	Average
Boron, in parts per million	0.00-0.74	0.07
Chlorides, in parts per million	0.5-30.0	10.5
Hardness, in parts per million	8-246	78
Total dissolved solids, in parts per million	66-300	162
Sodium, in percent of base constituents	10-48	28

Water with the average characteristics listed above is Class 1 irrigation water and is generally suitable for domestic and industrial uses.

Present Water Resources Development

Although extensive development of the surface water resources of the Upper Sacramento River Basin has occurred, there remains a large amount of water available for development for irrigation, production of hydroelectric energy, domestic and municipal use, recreation, and other beneficial purposes. Many new water resources developments have occurred in the basin in recent years, and several new water service agencies have been formed to take advantage of these developments.

The locations of existing water supply developments in the basin are shown on Plate 4, "Plans for Initial Development". These developments are described in the following sections under West Side Area and East Side Area.

West Side Area

The west side area comprises the drainage basins of all streams west of the Sacramento River between Shasta Dam and Red Bluff, plus the Thomes Creek drainage area above the USGS stream gaging station near Paskenta. The major streams of the area are Clear Creek, Cottonwood Creek, and Thomes Creek.

Several public water service agencies and privately owned water companies provide water for agricultural, municipal, industrial, and domestic uses. The principal areas of water use are the Anderson-Cottonwood Irrigation District, the cities of Redding and Red Bluff, some lands along Cottonwood Creek, and the lands served by the Happy Valley Water Company.

The Anderson-Cottonwood Irrigation District diverts water from the Sacramento River by means of a dam located just north of the City of Redding. The water is conveyed by canal for irrigation of lands within the district, including some lands in both Shasta and 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 from ground water pumping.

Redding obtains its water supply by pumping from the Sacramento River. The water supply for Red Bluff comes from ground water pumping, supplemented by diversions from Antelope Creek.

The water supply of the Happy Valley Water Company is obtained by diversion of natural streamflow 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. The people of this area have recently formed the Clear Creek Community Services District and have entered into a contract with the Bureau of Reclamation to serve the Happy Valley area with water imported from the Trinity River. In addition, four other community service districts have recently been formed in the west side area. These are Keswick, Shasta, Centerville, and Cascade.

The rest of the west side area, comprising the irrigated lands along Cottonwood Creek between its North Fork and the southern boundary of the investigational area, obtain water by diversion of streamflows, and by ground water pumping.

Rainbow Lake, Whiskeytown Reservoir, Keswick Reservoir, and the Clear Creek, Spring Creek, Shasta and Keswick Powerplants are the major water development works in the west side area. Rainbow Lake, with a maximum storage capacity of 4,800 acre-feet is formed by Misselbeck Dam on the North Fork of Cottonwood Creek.

Keswick Reservoir, with a storage capacity of 23,800 acre-feet, 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 powerplants. These two plants have a combined installed capacity of 454,000 kilowatts, and both use water stored in Shasta Lake to generate power. Surplus waters of the Trinity River Basin are diverted into the Upper Sacramento River Basin through the Clear Creek Tunnel to the 130,000 kilowatt Clear Creek Powerplant, and thence into the 250,000 acre-foot Whiskeytown Reservoir on Clear Creek. From this point, Trinity River water, along with the natural runoff of Clear Creek, flows through the Spring Creek Tunnel to the 143,000 kilowatt Spring Creek Powerplant and then into Keswick Reservoir. Flows from Spring Creek Powerplant, as well as Shasta Powerplant, are reregulated in Keswick Reservoir and released to meet requirements of the Central Valley Project. The U. S. Bureau of Reclamation has recently completed a diversion structure on the Sacramento River near Red Bluff. This structure, called the Red Bluff Diversion, will release water into a Tehama-Colusa Canal and into the existing Corning Canal. These canals will convey water southward for use on the west side of the Sacramento Valley.

East Side Area

The east side area comprises the drainage basins of all streams on the east side of the Sacramento River between Shasta Dam and the City of Red Bluff. The two principal streams of the area are Cow and Battle Creeks. Minor streams of the area include Churn, Stillwater, Bear, and Paynes Creeks. The Cow-Battle hydroelectric power system of the Pacific Gas and Electric Company comprises the only major existing water development on east side streams.

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 present water use. However, scattered parcels of land at higher elevations in the Cow, Bear, and Paynes Creek drainage basins are also irrigated, as well as some lands in the Stillwater Plains. In the Cow Creek Bottoms, ground water supplies are used occasionally to supplement surface diversions. Some lands in the Stillwater Plains are also irrigated with ground water. However, the amount of ground water used is small when compared with the quantity of water obtained from surface sources.

There are five public water service agencies delivering domestic water in the east side area below Shasta Dam. These are: the Summit City

Public Utility District, the Shasta Dam Area Public Utility District, the Buckeye County Water District, the Enterprise Public Utility District, and the recently formed Wonderland-Mountain Gate Community Services District. The first three 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, and the Wonderland-Mountain Gate Community Services District is developing 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 agricultural water service to the Bella Vista Water District. In 1964, the voters of the Bella Vista Water District approved a repayment contract to obtain Trinity River water.

Major water development works in the east side area comprise the Cow-Battle hydroelectric power system of the Pacific Gas and Electric Company. The system consists of North Battle Creek (1,016 acre-feet) and Macumber (425 acre-feet) Reservoirs, and six small power plants and attendant conduits and forebays. Four of the powerplants, Kilarc, Cow Creek, Volta, and Coleman, with a total installed capacity of 24,400 kilowatts, are in Shasta County. South and Inskip Powerplants, in Tehama County, add another 10,000 kilowatts to the installed capacity of the system. The powerplants are essentially run-of-the-river plants, with North Battle Creek Reservoir used to supplement late summer streamflows. 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.

Service Areas

Five potential irrigation service areas were studied during the course of this investigation. These are the Cow Creek, Cottonwood Creek, Happy Valley, Thomes Creek, and Los Molinos-Vina Service Areas. The Thomes Creek and Los Molinos-Vina Service Areas lie outside of the area of investigation but could be served from surface water developments within the Upper Sacramento River Basin. Since initiation of this study, the Happy Valley Service Area has become the previously described Happy Valley Water District and will be served water from Whiskeytown Reservoir. The other four potential service areas are shown on Plate 3, "Possible Plans for Development and Agricultural Service Areas under Initial Consideration", and described in the following sections.

Cow Creek Service Area

The Cow Creek Service Area is located to the east and southeast of Redding in Shasta County. The area contains about 28,800 acres, which is divided into three subareas; Stillwater Plains, Cow Creek Bottoms, and Millville Plains. Stillwater Plains, the largest of the subareas, comprises moderately dissected terraces between Churn Creek on the west, Cow Creek on the east, Highway 44 on the north and the Sacramento River floodplain of Cow Creek, but includes some lower terraces of the Stillwater Plains area on the west. Millville Plains consists of moderately dissected high terraces between the floodplains of Cow Creek, Bear Creek and the Sacramento River.

Cottonwood Creek Service Area

The Cottonwood Creek Service Area is located west and southwest of the adjoining Anderson-Cottonwood Irrigation District. The service area is located in both Shasta and Tehama Counties. It contains 22,600 acres and is divided into three subareas: Gas Point Road, Evergreen Road, and Bowman Road. The Gas Point Road subarea lies along the main stem of Cottonwood Creek between the junction of the North and Middle Forks and the mouth of the South Fork. The Bowman Road subarea lies along the South Fork of Cottonwood Creek. The Evergreen Road subarea lies parallel to and northwest of the Bowman Road subarea.

Thomes Creek Service Area

The Thomes Creek service area adjoins Thomes Creek and is located west of Corning. The eastern boundary adjoins the Corning Canal service area of the Bureau of Reclamation. There are 39,500 acres in the Thomes Creek service area.

Los Molinos-Vina Service Area

The Los Molinos-Vina service area lies between the cities of Chico and Red Bluff on the east side of the Sacramento River. It is bounded by Rock Creek on the south, the valley floor line on the east and north, and a combination of the Southern Pacific Railroad, U. S. Highway 99E, and the Chico Canal service area on the west. This service area was considered for service from surface waters developed within the Upper Sacramento River Basin but it was determined that it could more economically be served from underlying ground water, and by development of surface supplies from east side streams.[1/] Consequently, this area was eliminated from further consideration.

Land Use

The initial steps in estimating water requirements of the potential project service areas were to determine the present and future patterns of land use. The present pattern of land use was determined by field surveys. The future pattern of land use was estimated from land classification data and economic forecasts. Present and projected land use patterns are tabulated for each potential project service area at the end of this section (Tables 5, 6, and 7).

Present Pattern of Land Use

Land use surveys were conducted in the potential project service areas during 1961. The predominant use of irrigated lands in the potential project service areas is for livestock production. Alfalfa, improved pasture, and grain and grain-hay crops make up approximately 85 percent of the presently irrigated lands in these areas.

Probable Future Land Use Pattern

The predicted future pattern of land use for irrigated agriculture and urban and suburban development was used for estimating the future water requirements of the potential project service areas.

1/ The Possibility of developing surface supplies from east side streams is being studied as a part of the Department's "Sacramento Valley East Side Investigation", to be published in 1966 as Bulletin No. 137.

Irrigability and crop adaptability were basic considerations in classifying agricultural lands. Not all of the gross irrigable area would require water service. To estimate the future net irrigable areas requiring water service, factors of reduction were applied to the gross irrigable area. These factors accounted for farm lots, roads, canals, and other incidental nonirrigable areas determined by considering difficulty of development, size, shape, and location of the lands.

Any projection of future crop patterns must be generalized. For instance, since the raising of livestock is presently the dominant segment of the agricultural industry in the basin, it appears reasonable that the 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 these crops will shift to suitable lands in areas like the Upper Sacramento River Basin. For this reason, a moderate acreage of these crops was included in the estimated future crop pattern of the basin.

Crop patterns may vary considerably during any given year or series of years because of economic conditions or other unforeseen factors. The primary purpose of projecting future crop patterns for this investigation was to provide a means for estimating future water requirements and to provide data required to estimate benefits from increased crop production. The patterns as projected appear reasonable and adequate for this purpose. It was assumed that project development in each area would be completed in 1970 and that the buildup period required to reach near maximum irrigated acreage would be about 10 years.

Forecasts of future population were used to estimate amount and type of lands urbanized during each decade. These forecasts were based on the assumption that full development of all natural resources would be attained in the basin. 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 nearly four-fold. It is anticipated that a substantial portion of the population,

TABLE 5

COW CREEK SERVICE AREA
PROJECTED LAND USE, IN ACRES
1960-2020

Land Use	1960	1970	1980	1990	2000	2010	2020
1. Irrigated Lands							
Orchard	100	200	600	800	700	500	400
Field	100	100	1,900	1,800	1,600	1,300	1,000
Truck	300	300	600	600	300	200	200
Grain	*	*	800	600	500	400	200
Alfalfa	200	400	1,300	1,300	1,000	600	400
Pasture	1,600	1,800	6,100	6,400	6,000	5,000	3,800
Subtotal	2,300	2,800	11,300	11,500	10,100	8,000	6,000
2. Urban Lands	300	1,600	3,900	6,900	9,400	12,200	15,000
3. Nonirrigated, Irrigable Lands	17,300	15,600	5,200	2,400	1,700	1,600	1,000
4. Nonirrigable and Other Miscellaneous Lands **	8,900	8,800	8,400	8,000	7,600	7,000	6,800
Total	28,800	28,800	28,800	28,800	28,800	28,800	28,800

* Less than 50 acres.
** Other miscellaneous lands include farm lots, roads, canals, and other incidenta
nonirrigable areas.

TABLE 6

COTTONWOOD CREEK SERVICE AREA
PROJECTED LAND USE, IN ACRES
1960-2020

Land Use	1960	1970	1980	1990	2000	2010	2020
1. Irrigated Lands							
Orchard	100	200	1,000	1,400	1,500	1,500	1,500
Field	0	*	1,300	1,500	1,600	1,600	1,600
Truck	0	*	500	600	700	800	800
Grain	0	*	600	600	500	500	500
Alfalfa	100	300	2,300	2,300	2,100	2,000	2,000
Pasture	900	2,900	5,300	5,100	5,100	5,100	5,100
Subtotal	1,100	3,400	11,000	11,500	11,500	11,500	11,500
2. Urban Lands	*	*	*	*	*	*	*
3. Nonirrigated, Irrigable Lands	11,500	9,200	1,600	1,100	1,100	1,100	1,100
4. Nonirrigable and Other Miscellaneous Lands **	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Total	22,600	22,600	22,600	22,600	22,600	22,600	22,600

* Less than 50 acres.
** Other miscellaneous lands include farm lots, roads, canals, and other incidental nonirrigable areas.

TABLE 7

THOMES CREEK SERVICE AREA
PROJECTED LAND USE, IN ACRES
1960-2020

Land Use	1960	1970	1980	1990	2000	2010	2020
1. Irrigated Lands							
Orchard	0	200	1,100	1,700	1,900	1,900	1,900
Field	*	*	3,000	3,100	3,200	3,300	3,400
Truck	*	*	600	600	600	600	600
Grain	*	*	800	600	500	400	300
Alfalfa	100	200	2,700	2,700	2,600	2,600	2,600
Pasture	800	1,000	7,100	8,100	8,800	9,500	10,200
Subtotal	900	1,400	15,300	16,800	17,600	18,300	19,000
2. Urban Lands	100	100	100	100	100	100	100
3. Nonirrigated, Irrigable Lands	21,000	20,500	6,600	5,100	4,300	3,600	2,900
4. Nonirrigable and Other Miscellaneous Lands **	17,500	17,500	17,500	17,500	17,500	17,500	17,500
Total	39,500	39,500	39,500	39,500	39,500	39,500	39,500

* Less than 50 acres.
** Other miscellaneous lands include farm lots, roads, canals, and other incidenta
nonirrigable areas.

at the time of full 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.

Water Requirements

Requirements for irrigation water supplies in the potential project service areas were estimated by applying appropriate irrigation efficiency factors to estimated unit consumptive use of applied water data published in Department of Water Resources Bulletin No. 58, "Northeastern Counties Investigation". The resulting estimates represent the gross quantity of water which must be delivered to the farm headgate to supply the projected crop requirements.

Water requirements for urban lands were also estimated for each service area. Urban water requirements were determined on the basis of estimated unit water requirements and the projected population.

The estimated current unit water requirements are based upon the evaluation and adjustment of applicable historical urban water use data. Unit water requirements for each future decade were determined by estimating the year 2020 unit water requirements, and then assuming a constant rate of increase from the time of project completion to the year 2020. Some of the factors considered in evaluating the year 2020 unit water requirements are (1) character of the anticipated urban complex, (2) irrigated land area, (3) unit consumptive use, (4) irrigation efficiency pertinent to lawn area, and (5) internal household use.

Cow Creek Service Area

Present water use in the Cow Creek service area is supplied from ground water and surface diversions. The Stillwater Plains subarea is supplied entirely from ground water; the Cow Creek Bottoms and Millville Plains subareas are supplied by surface diversions supplemented by ground water pumping during the later part of the irrigation season when streamflows become inadequate.

Ground water satisfies all domestic needs in the Cow Creek service area as well as a substantial portion of the present irrigation requirements. Even so, much of the ground water reservoir remains almost untapped. Available data indicate that little change in depth to ground water has taken place during recent times even though ground water extractions have increased considerably. Consequently, available ground water supplies appear to be more than adequate to meet foreseeable future demands.

Most of the future agricultural utilization of water in the Cow Creek service area will probably be for crops associated with livestock production. When ultimate development is reached the water requirement for the entire service area will be about 47,500 acre-feet per year. Of this amount 28,400 acre-feet, or about 60 percent of the total requirement, will supply urban demands resulting from encroachment by the City of Redding and its suburbs. In estimating per capita rates of urban water use under future conditions, consideration was given to the following: (1) per capita water use increases as the size and level of urban centers increase, and (2) per capita water use increasesaas the standard of living increases. The projected water requirements for this service area are presented in Table 8.

TABLE 8

PROJECTED WATER REQUIREMENTS
IN THE COW CREEK SERVICE AREA
IN ACRE-FEET

Use	1960	1970	1980	1990	2000	2010	2020
Orchard	200	400	1,100	1,500	1,400	1,000	800
Field	200	200	2,700	2,500	2,200	1,800	1,300
Truck	400	500	1,000	900	500	400	300
Grain	*	*	400	300	300	200	100
Alfalfa	800	1,600	4,700	4,600	3,400	2,300	1,500
Pasture	6,500	7,200	24,600	25,800	23,800	19,800	15,100
Total Irrigation Requirement	8,100	9,900	34,500	35,600	31,600	25,500	19,100
Urban Requirement	200	1,400	4,500	8,700	13,900	21,000	28,400
Total Requirement	8,300	11,300	39,000	44,300	45,500	46,500	47,500

* Less than 50 acre-feet

Cottonwood Creek Service Area

Most of the water presently used in the Cottonwood Creek service area is supplied from ground water. In addition to satisfying all domestic needs, ground water provides most of the water for lands presently irrigated in the service area, although some of the irrigation requirements are met by diversions from Cottonwood Creek.

Most of the future agricultural utilization of water in the service area will be for crops associated with livestock production. No significant amounts of urban or suburban water requirements are projected for this service area. The small farm domestic water requirement is included in the agricultural requirement presented in Table 9.

TABLE 9

PROJECTED WATER REQUIREMENTS
IN THE COTTONWOOD CREEK SERVICE AREA
IN ACRE-FEET

Use	1960	1970	1980	1990	2000	2010	2020
Orchard	200	400	2,000	2,800	3,000	3,000	3,000
Field	0	*	2,300	2,700	2,900	2,900	2,900
Truck	0	*	800	1,000	1,200	1,300	1,300
Grain	0	*	300	300	200	200	200
Alfalfa	400	1,000	8,100	8,000	7,300	7,000	7,000
Pasture	3,600	11,600	21,200	20,400	20,400	20,400	20,400
Total Irrigation Requirement	4,200	13,000	34,700	35,200	35,000	34,800	34,800
Urban Requirement	*	*	*	*	*	*	*
Total Requirement	4,200	13,000	34,700	35,200	35,000	34,800	34,800

* Less than 50 acre-feet

Thomes Creek Service Area

The Thomes Creek service area has less than 5 percent of its irrigable lands presently irrigated. The major source of supply to the presently irrigated lands is by surface diversion from Thomes Creek. Generally, the ground water supply in the service area is inadequate, although it might be possible to develop limited economic supplies in the eastern portion of the area.

Nearly the entire future use of water in the service area will be for agricultural purposes, most of which will be dedicated to crops associated with livestock production. Since no significant amounts of urban or suburban water requirements are projected for the service area, the small domestic uses are included in the agricultural requirements presented in Table 10.

TABLE 10

PROJECTED WATER REQUIREMENTS
IN THE THOMES CREEK SERVICE AREA
IN ACRE-FEET

Use	1960	1970	1980	1990	2000	2010	2020
Orchard	0	400	2,200	3,300	3,700	3,700	3,700
Field	*	*	5,400	5,600	5,800	5,900	6,100
Truck	*	*	1,000	1,000	1,000	1,000	1,000
Grain	*	*	400	300	200	200	100
Alfalfa	400	700	9,400	9,400	9,100	9,100	9,100
Pasture	3,200	4,000	28,400	32,400	35,200	38,000	40,800
Total Irrigation Requirement	3,600	5,100	46,800	52,000	55,000	57,900	60,800
Urban Requirement	*	*	*	*	*	*	*
Total Requirement	3,600	5,100	46,800	52,000	55,000	57,900	60,800

* Less than 50 acre-feet

CHAPTER III. IRON CANYON PROJECT

The possibility of constructing a major dam on the Upper Sacramento River has been under intermittent investigation for more than 60 years. During this period numerous studies covering several sites have been conducted by various federal, state, and local agencies. Reservoirs ranging in size from a few hundred thousand to several million acre-feet have been considered.

Selection of a favorable damsite on the Upper Sacramento River was considered as early as 1904 by the U. S. Reclamation Service. In a report to the Legislature in 1931, the Division of Water Resources recommended construction of Shasta Reservoir at a capacity of 2,940,000 acre-feet. Studies were nonetheless continued in the 1930's at other sites. The Bureau of Reclamation investigated a site at Table Mountain in considerable detail, as an alternative to Shasta as the initial reservoir on the Sacramento River. Finally, the Shasta site was selected, and Shasta Dam was constructed in the 1940's with a storage capacity of 4,500,000 acre-feet.

Throughout all of these investigations, it was generally recognized that a reservoir somewhere in the vicinity of Red Bluff would be able to provide substantial control for the runoff produced between Red Bluff and Shasta Dam.

In 1944, the Chief of Engineers, U. S. Army, transmitted to the Congress an interim report recommending Table Mountain Dam and Reservoir. In Public Law 534, 78th Congress, a modified version of Table Mountain Reservoir was authorized with this proviso:

> "... that this modification of the project shall not be construed to authorize the construction of a high dam at Table Mountain site but shall authorize only the low-level project to approximately the elevation of four hundred feet above mean sea level, said low-level dam to be built on a foundation sufficient for such dam and not on a foundation for future construction of a higher dam."

This reservoir would store only 553,000 acre-feet.

In 1945, the Corps of Engineers urged the substitution of an Iron Canyon Reservoir, about 15 miles downstream, as an alternate to the low Table Mountain Reservoir, since it could be constructed at approximately the same cost, it would interfere less with existing irrigation development and it would fit in better with the high Table Mountain project proposed for ultimate construction by the U. S. Bureau of Reclamation. The Corps concluded from its studies that an earthfill dam could be built at the site. In a letter dated December 4, 1947, the Sacramento District Engineer reported:

> "All the field surveys and exploration work necessary for preparation of contract drawings and specifications have been substantially completed, the size of the powerplant has been determined and approved by the Federal Power Commission, and the type and location of the dam and its appurtenances have been decided upon."

But plans and specifications, and even the design report, were never completed, and no money was appropriated by the Congress.

Several circumstances contributed to deferment of the Iron Canyon Project at that time.

1. Any reservoir which approaches an economically optimum capacity would inundate certain agricultural and potential industrial lands within Shasta County in the vicinity of the communities of Anderson and Cottonwood.

2. An anadromous fishery of considerable value may be undesirably affected.

3. Foundation conditions at the damsites are adverse and questions had been raised relative to the structural feasibility of constructing a safe dam.

To meet the above objections and at the same time attempt to develop the Upper Sacramento River Basin, additional studies were initiated by both the Bureau of Reclamation and the Corps of Engineers. These studies considered a system of reservoirs on tributary streams as an alternative to a main stem reservoir, primarily for flood control purposes. Both agencies found such a plan to be infeasible under then current conditions. During these investigations the Bureau found that a high degree of flood protection for Butte Basin, the area to be protected, could be obtained by the construction of Black Butte Reservoir and additional levees and channel improvements within Butte Basin.

In 1948, a Division of Water Resources publication titled "Alternative Plans for Control of Floods in the Upper Sacramento Valley", also recommended substitution of a bypass and levee system to protect Butte Basin, and deferral of Iron Canyon or alternative storage systems to a later date. However, Bulletin No. 3, "The California Water Plan", published in 1957, included an Iron Canyon Reservoir and several tributary reservoirs in its ultimate plans for development of the Upper Sacramento River Basin.

The Iron Canyon Project presented in this chapter was analyzed first on the basis of physical feasibility and second on the basis of economic justification. Since foundation conditions at all of the several possible dam locations are far from ideal, there has been considerable concern as to whether or not a safe dam could be built at any of the sites. Consequently, a major objective of this investigation was to select the most favorable damsite and to make final determinations as to whether or not a safe dam could be constructed.

The Department of Water Resources, with the help of a board of world famous consultants, concluded from existing data and geologic subsurface explorations conducted during the investigation that a safe dam at the Iron Canyon site, about 4.5 miles above Red Bluff, could definitely be built. The consultants, geologist Roger Rhoades and engineers B. E. Torpen and Phillip C. Rutledge, concluded in September 1960 that:

> "... we are convinced that a safe dam with crest at or below elevation 420 and a spillway capable of passing the maximum probable flood can be built at Iron Canyon in the general area between Plans Nos. 1 and 4 prepared by the department."

However, they requested additional exploratory work and testing to confirm their conclusion.

After the necessary testing and exploratory work was completed, the board of consultants met in May 1961, and again concluded that a safe dam could be built. At that time they also set forth various suggestions concerning the type of dam to consider and the methods of construction to employ. The complete consultants' report is reproduced as Appendix C of this report.

The Iron Canyon Project presented herein would meet several multiple-purpose water needs of the State of California. It would provide a measure of flood control protection to more than 100,000 acres of land along the east side of the Sacramento River between Red Bluff and Colusa; it would produce 153,000 kilowatts of dependable hydroelectric power capacity, and about 715,000,000 kilowatt hours of electric energy annually for use within and outside the basin; it would support an average water-associated recreational use of about one million visitor days annually; and it would develop about 130,000 acre-feet of new export yield to the Sacramento-San Joaquin River Delta.

The Iron Canyon Project that was selected to meet the above needs would consist of the following project features: Iron Canyon Dam, Powerplant, and Reservoir on the Sacramento River about 4.5 miles above Red Bluff; Iron Canyon Afterbay Dam and Reservoir on the Sacramento River in the vicinity of the existing Red Bluff Diversion Reservoir below Red Bluff; fish hatchery facilities below the afterbay dam; fish conveyance and passage facilities from the afterbay dam to Iron Canyon Reservoir; and recreation facilities at both of the project reservoirs. Each of these features is discussed in detail in the following sections of the report.

Iron Canyon Dam, Powerplant, and Reservoir

Economic considerations restrict the height of dam which can be constructed at the Iron Canyon site. Above an elevation of about 420 feet serious inundation of urban areas in the vicinity of Anderson and Cottonwood would occur. Therefore, the maximum water surface elevation of an Iron Canyon Reservoir at extreme flood stage was limited in this investigation to approximately 415 feet. The inundation of productive lands could be considerably reduced by a smaller reservoir, but the savings in land costs would not offset the resulting decrease in benefits. Similarly, the severity of the anadromous fisheries problem associated with a large reservoir, and costs of such items as the spillway and diversion during construction, would not be reduced proportionately with a smaller development. Consideration of these factors resulted in the selection of a reservoir having a normal water surface elevation of 401 feet, a storage capacity of 1,000,000 acre-feet, and a surface area of 27,000 acres, as the optimum size.

Flow in the Sacramento River at the Iron Canyon damsite consists of natural runoff, releases of stored water from Shasta Reservoir, and water imported from the Trinity River. This flow may be further increased by future imports from the North Coastal area.

Although runoff originating within the Upper Sacramento River Basin study area is essentially uncontrolled, it is, to some extent, presently serving beneficial purposes in the Sacramento River and in the Sacramento-San Joaquin Delta.

Under the existing operation of the Central Valley Project by the Bureau of Reclamation and the future operation of the State Water Project by the Department of Water Resources, releases from Shasta Reservoir complement uncontrolled downstream accretions of flow to fulfill irrigation, domestic, and navigation requirements. Therefore, the amount of water available for control, regulation, and distribution as new conservation yield at Iron Canyon Reservoir would be that portion of the natural runoff of the basin not presently serving beneficial purposes, or designated to serve beneficial uses, plus uncontrolled spills from Keswick Reservoir.

The average annual flow available for power generation at Iron Canyon Reservoir would be about 7,260,000 acre-feet. Of this amount, 4,540,000 acre-feet would be committed to downstream use and the remaining 2,720,000 acre-feet would be available for development of conservation yield. Some of this water, if controlled and regulated by storage reservoirs in the Upper Sacramento River Basin during periods of excess flows, and released during periods of need, could produce new export yields for water deficient areas in Central and Southern California. The average annual natural runoff originating in the area between Shasta Dam and Red Bluff is approximately 2,000,000 acre-feet. Of this amount east side tributaries contribute about 900,000 acre-feet, west side tributaries contribute about 800,000 acre-feet, and the remaining 300,000 acre-feet originates on the valley floor.

Dam

The damsite selected is located in a broad, steep-walled canyon carved by the Sacramento River. It is located about 1,600 feet downstream from the U. S. Geological Survey stream gaging station, "Sacramento River near Red Bluff". The foundation is composed of the Tuscan formation capped by a thin gravel deposit known as the Red Bluff formation which is also known locally as the High Terrace deposits. All of the beds in the Tuscan formation dip downstream at a shallow angle of 3 to 4 degrees in the vicinity of the damsite. The Tuscan formation is made up of five members which can be subdivided in order of their age from youngest to oldest as: the Sacramento tuff and sand, the Iron Canyon agglomerate, the Seven Mile tuff and sand, Bald Hill agglomerate, and the Supan tuff and sand. The Sacramento tuff and sand and the Iron Canyon agglomerate were intensively studied during this investigation since they would comprise most of the dam foundation.

As a result of the preliminary study, which evaluated data from prior investigations, the department undertook further exploration to fill the gaps in accumulated knowledge. In 1959-1960, 21 shallow auger holes were drilled to explore and test possible borrow materials at shallow depth. One deep core hole was also drilled to obtain samples of the Iron Canyon agglomerate. During this program several field and laboratory tests were made on the shallow and deep foundation materials to determine their strength and permeability. In 1960, after presenting the results of these explorations to the board of consultants, the department conducted further exploration as recommended by the board. This work comprised drilling of additional diamond drill holes and a field permeability test on the Seven Mile tuff and sand to determine if uplift pressures in permeable zones would be a serious problem. The results of geologic investigations are contained in an office report, "Engineering Geology of Iron Canyon Dam Site on the Sacramento River", in the files of the Department of Water Resources.

After evaluating all data, it was concluded by the board of consultants that the foundation would be of sufficient strength to withstand loads imposed by an earthfill dam and appurtenant structures to the proposed heights. Consequently, a zoned earthfill dam with a fairly extensive concrete ogee weir spillway section and power intake structure was selected at this site. Typical sections of the main dam embankment, dike, spillway, and power intake structure are presented on Plate 5, "Iron Canyon Dam".

The dam would be about 175 feet high, 5,800 feet long, and 40 feet wide at the crest. It would consist of an earthfill embankment across the Sacramento River channel; a gravity concrete power intake structure connecting the right abutment of the main dam and the left abutment of the spillway; an extensive concrete ogee weir spillway and radial gates connecting the power intake structure with a wing dam; and a long, low wing dam connecting with the spillway weir and the right abutment of the dam foundation.

A gated spillway was selected primarily on the basis that it would allow the reservoir to be filled to its full capacity during non-flood periods, while still assuring passage of the tremendous design flood flows with a much lower dam crest elevation than would be required with an ungated spillway.

Dam Design. The section for the main embankment would consist of three main zones, as shown on Plate 5. The impervious core section would be constructed from terrace deposits. These deposits, which are composed of well-graded materials ranging in size from gravel through clay, are described in detail in the Department's unpublished office geology report. They are located east of the left abutment of the main dam. The estimated usable quantity of these terrace deposits, which average 6 feet in thickness, is about 1,000,000 cubic yards.

The Iron Canyon agglomerate would be used in the outer zone (Zone 2) of the embankment section. These deposits consist of volcanic mudflows composed of large angular blocks of lava in a tuffaceous sand and clay matrix. Approximately 1,600,000 cubic yards of this agglomerate could be salvaged from excavation in the spillway and outlet works area. In addition, an unlimited source of this material could be obtained from the right bank of the river, approximately 2,000 feet upstream from the dam axis.

Drain material and aggregate would be obtained from stream deposited sand and gravels (Zone 3) located along Dibble Creek, three and one-half miles southwest of the dam axis. These deposits have an average depth of 12 feet and are estimated to contain 1,500,000 cubic yards.

The downstream toe and the upstream face of the dam would be constructed of rockfill. This riprap and rock material would be obtained from spillway excavation and from basalt material located about 4 miles northeast of the dam axis. It is estimated that spillway excavation would provide about 200,000 cubic yards of agglomerate boulders which might be usable for riprap. Additional rock would be obtained by quarrying in Zone 4.

Embankment details would include: (1) a chimney drain to prevent erosion of the core material and to lower the elevation of the saturation line, (2) a three-foot layer of riprap on the upstream face to prevent erosion by wave action and (3) a rock toe to provide protection against maximum tailwater from power releases and spillway discharges.

The wing dam, which would connect the concrete spillway section to the right abutment, would be a homogeneous section consisting of agglomerate excavated from the spillway channel, with a gravel chimney drain.

The locations of possible borrow materials are shown on the materials location map on Plate 5.

Spillway. Comparative cost studies were made on various spillway designs. The use of gated spillways with and without auxiliary spillways was considered. In order to successfully provide all possible storage and still maintain a maximum flood control release of 150,000 second-feet, a spillway with fourteen 45- by 35-foot radial gates placed on a massive concrete ogee weir section was selected. In addition, a concrete-lined chute and approach channel would be required.

The spillway would be located on the right abutment in dipping beds of agglomerate with overlying tuff and sand. This site was selected in order to meet requirements of the consulting board that there be a minimum thickness of 50 feet of agglomerate under the concrete control structure. A stilling basin would be provided to eliminate erosion.

Flood routing studies to determine the relationship between dam height and spillway capacity were based on (1) the probable maximum flood (PMF) hydrograph having a peak discharge of 1,070,000 second-feet and a 4-day volume of 4,050,000 acre-feet, and (2) the standard project flood (SPF) having a peak discharge of 550,000 second-feet and a 4-day volume of 2,040,000 acre-feet.

The control structure was designed to meet both normal and emergency discharge requirements in accordance with the following operation criteria:

1. Under normal flood operations, water would be released at a rate equal to the inflow up to a maximum of 150,000 second-feet whenever the reservoir water surface is between elevation 384

feet and 401 feet. As soon as the reservoir elevation would exceed 401 feet, the gates would be opened completely.

2. Under emergency operations, it was assumed that the gates would be completely closed until the water surface reached elevation 401 feet. They would then operate at a 1:1 ratio rate of gate travel to rate of reservoir rise above elevation 401 feet.

Reservoir flood routing studies indicated that under emergency operations the spillway would pass the probable maximum flood inflow of 1,070,000 second-feet with a maximum spillway discharge of 870,000 second-feet and a maximum water surface elevation 14 feet above normal pool elevation. This would leave a freeboard of 5 feet, which was considered adequate. Under normal operating conditions the spillway would pass the standard project flood inflow of 550,000 second-feet with a spillway discharge of 430,000 second-feet. With this flow the maximum water surface elevation would be at elevation 403 feet, or only 2 feet above the normal pool elevation.

The <u>Control Structure</u> would be 760 feet long, 120 feet high, and 115 feet wide at the base. The maximum foundation pressure was found to be 8.5 tons per square foot which was well within the allowable limit of 12 tons per square foot recommended by the Board of Consultants. In order to provide a tie into the embankment the gravity concrete section was extended into the earthen embankment a distance of 180 feet. Retaining walls would be provided to prevent the embankment material from spilling into the spillway approach channel or the chute.

The <u>Chute</u> slab would be 2 feet thick throughout its 600-foot length. It would have a maximum width of 760 feet at the top, narrowing to 500 feet at the stilling basin.

The <u>Stilling Basin</u> would be a reinforced concrete structure 500 feet wide and 230 feet long located about 700 feet downstream from the spillway control structure. It was designed to pass the standard project flood outflow of 430,000 cubic feet per second. Chute blocks and an end sill would be provided to effect a hydraulic jump. A zone of riprap would be provided for a distance of 100 feet beyond the basin to protect the channel against scour.

Outlet Works (Penstocks)

Four 22-foot-diameter penstocks would be installed in the concrete gravity power intake structure to supply stream releases and to meet the demands of the powerplant. Semicircular trashrack structures would be provided at the entrance of each penstock from elevation 310 feet to elevation 415 feet. Closure of the penstocks would be effected by four fixed-wheel gates which would be mounted on the face of the structure. A gantry crane would be provided for erection, installation, and maintenance of the penstock gates and installation and removal of penstock stoplogs.

Bypass conduits past the turbine or other auxiliary outlet works are not included in this plan since it was assumed that low level outlets would not be required. Dewatering of the reservoir to about elevation 333 feet could be accomplished by discharging through the powerplant. Below that point the reservoir could not be lowered.

Powerplant

A powerplant would be constructed at the base of Iron Canyon Dam and would consist of four reaction turbines. It would be designed to operate efficiently at heads ranging from a maximum of 145 feet to a minimum of 92 feet. Its design head would be 111 feet. This powerplant would have an installed and a dependable power capacity of 153,000 kilowatts and would generate an average of approximately 715,000,000 kilowatt-hours of electric energy annually.

Reservoir

Studies were made of Iron Canyon Reservoir sizes ranging between 600,000 and 1,000,000 acre-feet, with various flood control storage reservations and with various sizes of hydroelectric power development. The best reservoir from an economic standpoint was found to have a storage capacity of 1,000,000 acre-feet, including 400,000 acre-feet of flood control storage reservation. At maximum storage pool elevation, 401 feet USGS datum, the reservoir would inundate about 27,500 acres of land. In addition to the reservoir lands, a perimeter strip approximately 300 to 500 feet beyond the water surface, and additional water-associated recreation lands would be required. A total of 36,000 acres would be sufficient to satisfy all requirements for the project. This land area is presently used for farming, stock ranches, orchards, rural homesites and subdivisions, and small businesses along the river catering to fishermen.

Construction of the project would require relocation of about 40 miles of power transmission lines. In addition, access to Coleman Fish Hatchery would require about 10 miles of new road construction. Other road relocations would also be required around portions of the reservoir perimeter.

Natural vegetation is sparse within the reservoir area so clearing costs would be nominal.

Diversion During Construction

Diversion during construction would be a major problem at Iron Canyon damsite. A 25-foot diameter concrete-lined circular tunnel approximately 1,150 feet long would be driven under the right abutment near the channel section. Flows up to about 21,000 second-feet would be diverted through the tunnel by means of a cofferdam built to elevation 330 feet. The cofferdam would consist of agglomerate derived primarily from the spillway excavation and a blanket of terrace material laid on the upstream slope. Although normal summer streamflows could be diverted with a much lower cofferdam, the necessity to divert winter flows during one season would require the higher dam, which would allow an additional flow of about 60,000 second-feet to be passed over the partially completed spillway weir with no significant damage.

Construction Schedule

The construction of Iron Canyon Dam would require four years to complete. During the first two years, the river would not be diverted since all major construction except the earth embankment across the river channel, part of the intake structure, and the spillway weirs and piers above elevation 305 feet could be constructed without dewatering the river channel. Summer flow during the third construction season would be diverted through the diversion tunnel and the uncompleted spillway. During this phase of construction the main embankment and the intake structure would be completed.

The stream would be diverted through the power penstocks during the final construction phase which would consist of raising the spillway weir to its final height, constructing the gate piers, and installing the spillway crest gates.

General Features

General features of Iron Canyon Dam, Powerplant, and Reservoir, are summarized in Table 11.

TABLE 11

IRON CANYON DAM, POWERPLANT, AND RESERVOIR

Item	Description
<u>General Data</u>	
Location	Sacramento River, Sec. 3, T27N, R3W, MDB&M and Sec. 34, T28N, R3W, MDB&M
Drainage area	
Total	9,300 square miles
Below Shasta	2,635 square miles
Runoff	
Natural mean annual	
1906-1955	8,050,000 acre-feet
1922-1941	7,000,000 acre-feet
<u>Reservoir Data</u>	
Water surface elevations (USGS Datum)	
Minimum power pool	358 feet
Maximum storage pool	401 feet
Spillway design flood pool	415 feet
Storage capacity (elevation, 401 feet)	1,000,000 acre-feet
Surface area	
elevation, 401 feet	27,000 acres
elevation, 415 feet	36,000 acres
Flood control reservation	400,000 acre-feet
<u>Dam</u>	
Type	Zoned earthfill and gravity concrete
Height above streambed	175 feet
Elevation of crest	420 feet
Total volume, in cubic yards	5,530,000
<u>Spillway</u>	
Type	Gated ogee weir and chute with stilling basin
Design capacity	870,000 second-feet
Elevation of weir crest	366 feet
Length of weir crest	630 feet (net)
Gate type	Counter-balanced radial
Gates, number and size	Fourteen, 45 by 35 foot

TABLE 11 (Continued)

IRON CANYON DAM, POWERPLANT, AND RESERVOIR

Item	Description
<u>Outlet Works and Penstocks</u>	
Conduit type	Steel penstocks in concrete gravity section
Conduit size	Four 22-foot-diameter pipes
Control, size and type	Four 17 by 35 foot fixed wheel gates with stoplog protection
<u>Powerplant</u>	
Installed capacity	153,000 kilowatts
Turbines, number, and type	Four, reaction
Maximum static head	145 feet
Net design head	111 feet
Minimum net head	92 feet

Iron Canyon Afterbay Dam and Reservoir

The Iron Canyon Afterbay Dam and Reservoir would consist of an offstream storage reservoir on the right side of the Sacramento River, and an enlargement of the existing Red Bluff Diversion Reservoir immediately east of Red Bluff. With a total active capacity of 32,000 acre-feet, it would provide sufficient storage to regulate the releases from Iron Canyon Reservoir and Powerplant. The Iron Canyon Afterbay Dam and Reservoir would consist of the following major features: (1) A dike extending from the right abutment of Red Bluff Diversion Dam along the west side of the Sacramento River to Mooney Island, then extending northwestward to the vicinity of Tyler Road where the natural ground surface would form the right abutment; (2) a modified Red Bluff Diversion Dam to allow the water surface to be raised from its present normal pool elevation of 252.5 feet to 260 feet; (3) a channel connecting Red Bluff Reservoir to the offstream reservoir formed by the dike; (4) a canal outlet to connect with the Bureau of Reclamation's planned Tehama-Colusa Canal. A plan showing the above features, with typical cross sections of the dike and connecting channel, is presented on Plate 6 "Iron Canyon Afterbay on Sacramento River".

Dike

The dike would consist of an earthfill section having an impervious earth core and a pervious outer shell, riprapped on the upstream face to prevent erosion. It would have a total length of about 7 miles, a crest width of 20 feet, and side slopes of 3.0 to 1 on the upstream face and 2.5 to 1 on the downstream face. It would vary in height between 0 and 42 feet with an average height of about 27 feet. The total embankment volume would be about 3.5 million cubic yards.

The impervious core material would be taken from the Tehama soils along the west edge of the reservoir. Pervious materials and riprap would be obtained from the floodplain and channel deposits within the reservoir.

Modified Red Bluff Diversion

A very preliminary estimate was made of the modification that would be required in the Red Bluff Diversion Dam to allow the normal water surface to be raised to 260 feet. It was assumed that this could be accomplished by increasing the size of gates from 18 to 28 feet, and modifying the dam to support the higher water surface. In the event that this modification is not possible, it may be desirable to increase the size of the offstream storage reservoir by extending the dike downstream.

Connecting Channel

A channel would be necessary to convey water between the afterbay area and the diversion reservoir. This channel would have a bottom width of 225 feet, side slopes of 2 to 1, and a constant bottom elevation of 240 feet. It was designed to convey up to 9,000 second-feet in either direction. The total excavation would be about 1.4 million cubic yards.

A fish screen would be constructed at the upstream end of the channel to prevent downstream migrating salmon and steelhead from entering the lower reservoir.

Tehama-Colusa Canal Extension

An outlet structure and canal would be constructed from the afterbay reservoir to connect with the Tehama-Colusa Canal, which would be inundated at its upper end by construction of the afterbay. The outlet structure would consist of two 13-foot wide, top seal radial gates, with a capacity of 2,000 second-feet, at the minimum reservoir pool elevation of 250 feet. The canal would extend from the outlet structure a distance of about 1,250 feet to join the Tehama-Colusa Canal in the vicinity of Tyler Road.

General Features

General features of Iron Canyon Afterbay Dam and Reservoir are shown on Table 12.

TABLE 12

GENERAL FEATURES OF IRON CANYON AFTERBAY DAM AND RESERVOIR

Item	Description
Reservoir	
Location	West floodplain of Sacramento River between Red Bluff Diversion Dam and Mooney Island
Maximum water surface elevation	260 feet
Minimum water surface elevation	250 feet
Active storage	32,000 acre-feet
Water surface area	4,000 acres
Dam	
Dike	
Type	Zoned earthfill
Crest elevation	267 feet
Maximum height	42 feet
Length	36,300 feet
Total embankment volume	3,500,000 cubic yards
Modified Red Bluff Diversion Dam	
Spillway crest elevation	235 feet
Spillway crest length	660 feet
Spillway capacity w/water surface elevation at 261 feet	200,000 cfs
Gate type	Fixed wheel
Connecting Channel	
Capacity	9,000 cfs
Bottom width	225 feet
Invert elevation	240 feet
Length	15,000 feet
Excavation	1,400,000 cubic yards
Tehama-Colusa Canal Extension	
Capacity at minimum water surface elevation	2,000 cfs
Gates	Two, 13 by 12 foot radial
Bottom width	24 feet
Length	1,250 feet

Fisheries Protection Facilities

The need for providing adequate protection for the existing fisheries resources of the Upper Sacramento River was of utmost importance in determining the economic potential of the Iron Canyon Project. In order to properly evaluate the facilities needed to protect this resource, several problems were considered and evaluated, and solutions (or presumed solutions) were found. The most significant problems consisted of the following:

1. Determination of the size of salmon runs occurring above and within the proposed reservoir sites.

2. Selection and design of fish passage facilities for both upstream and downstream migrating fish.

3. Determination of size and type of artificial facilities needed to replace the spawning gravels which would be inundated by the project.

4. Determination of whether or not fish spawned in the gravels upstream from the reservoir would migrate downstream through the reservoir and return to the ocean.

5. Predicting water temperature changes resulting from the project, and evaluating their effects on the fisheries resources.

Extensive studies were made by the Department of Water Resources, the Department of Fish and Game, Mr. George J. Eicher, fisheries consultant, and Mr. Jerome Raphael, a specialist in reservoir water temperature predictions, in an attempt to solve these problems.

The Department of Fish and Game made estimates of the number of salmon that spawn in the Sacramento River above the proposed project. These estimates, which are presented in the Fish and Game appendix, Appendix B, indicated that about 50 percent of the presently used spawning gravels above Iron Canyon Afterbay would be inundated by the Iron Canyon

Project. On this basis the hatchery and the fish passage facilities were each designed to support one-half of the fall salmon run.

Mr. Eicher prepared a plan to protect the fisheries of the Upper Sacramento River. In his report, entitled, "Fish Protection at the Iron Canyon Project, Sacramento River, California", June 1961, Mr. Eicher stated the purpose of his investigation as follows:

> "... to describe as factually as possible the conditions of the fisheries that may be expected after such a project is constructed with and without the inclusion of various provisions for fish protection. Possible effects of the proposed Iron Canyon Project upon fishery resources of the Sacramento River will be evaluated, and means proposed by which such effects may be modified in order to preserve such resources at their highest level of abundance."

As the result of his investigations, Mr. Eicher concluded as follows:

> "Iron Canyon Dam can be a factor in the reduction of runs of anadromous fish to the Sacramento River, or it can be the means of perhaps enhancing them.
>
> "The result will depend to a large extent on the degree and accuracy of planning for the protection and development of the populations of such fish. A potential will exist for rearing of young salmonoids on a basis somewhat comparable to that of controlled rearing lakes now being developed. The only difference will be that power will be produced at the dam. With proper facilities there should be no reason why the fish cannot be bypassed around the powerplant without injury. The structure and layout of the dams and powerhouse lend themselves well to planning for good fish passage.
>
> "It cannot be emphasized too strongly, however, that full effort to provide for fish is necessary to extract the greatest degree of fish production from the Sacramento River. Funds spent for maximum protection necessary will yield commensurate returns in terms of fish and associated benefits to the well being and economy of the region."

Designs of facilities for the passage of fish presented in this report incorporated the features suggested by Mr. Eicher, but include some modifications suggested by the Department of Fish and Game.

Fish passage facilities consisting of a series of fish ladders and transportation canals were designed to extend from the left abutment of the modified Red Bluff Diversion Dam to a main fish ladder on the left abutment of Iron Canyon Dam, as shown on Plate 6. These facilities were designed to accommodate a maximum of 150,000, and an average of 80,000 upstream migrating salmon annually.

A fish hatchery of sufficient size to provide for a maximum spawning run of 150,000 mature salmon was used for computing construction costs of the hatchery facilities. Annual operation costs of the hatchery were computed for the average fall run estimated to be about 80,000 salmon annually. This hatchery would compensate for the loss of natural spawning gravels which would be inundated by Iron Canyon Reservoir.

The provision of fish passage facilities and a fish hatchery assumes that young downstream-bound salmon would find their way through the reservoir and be delivered into the river below the project without significant loss, and that water temperatures in the reservoir, hatchery, fish ladder, and the river downstream from Iron Canyon would be suitable for both mature and juvenile salmon and steelhead.

Studies to determine whether or not young salmon and steelhead, on their downstream migration toward the ocean, could successfully negotiate a large reservoir without becoming residual or unduly delayed, were made by the Department of Fish and Game at Shasta Reservoir. This study was not carried to a successful conclusion because of budget reductions, but the information obtained indicated "... that a grave problem of residualism may exist when fall-run king salmon fingerlings are forced to negotiate a large, warmwater, fluctuating reservoir on their way to the sea." A report on this investigation entitled, "Observations on Downstream Migrant Salmonoids, Shasta Reservoir, California", was published by the Department of Fish and Game in October 1963. Before any project such as Iron Canyon is proposed for construction, a study to determine whether or not small salmon could or would migrate through a large reservoir should be undertaken.

Mr. Jerome Raphael, a professor at the University of California and a specialist in water temperature predictions in reservoirs, determined the probable temperatures that would occur in the Sacramento River below Iron Canyon Afterbay Dam if the project were constructed. The text of Mr. Raphael's report, which is included as Appendix D of this bulletin, concludes that under project conditions summer and early fall temperatures would be increased substantially over nonproject conditions, and that winter and spring water temperatures would be lowered. His predicted temperatures below Iron Canyon Dam for a typical year of project operation are shown on Figure 1. The Department of Fish and Game has indicated that these temperatures would have a tremendous detrimental effect on salmon and steelhead populations in the Sacramento River. A solution to this problem would therefore have to be found before construction of this project could be undertaken. The predicted water temperature study indicates that inclusion of a low-level outlet structure may provide a solution, but that this would necessitate a new temperature prediction study.

Wildlife Mitigation Facilities

Studies were made by contract personnel of the Department of Fish and Game to determine the effects construction of the Iron Canyon Project would have on wildlife. These studies show that 1,200 acres of land would have to be purchased and operated for waterfowl management purposes to mitigate for damages caused by the project. Other minor damages to quail and pheasants would also require mitigation. The results of these studies are included in the Fish and Game Appendix.

Costs, Benefits, and Benefit-Cost Ratio

The costs and benefits of the Iron Canyon Project are discussed in the following pages in terms of average annual equivalent and present worth values under the headings of costs, benefits, and benefit-cost ratio.

The average annual equivalent is a figure used to establish, for

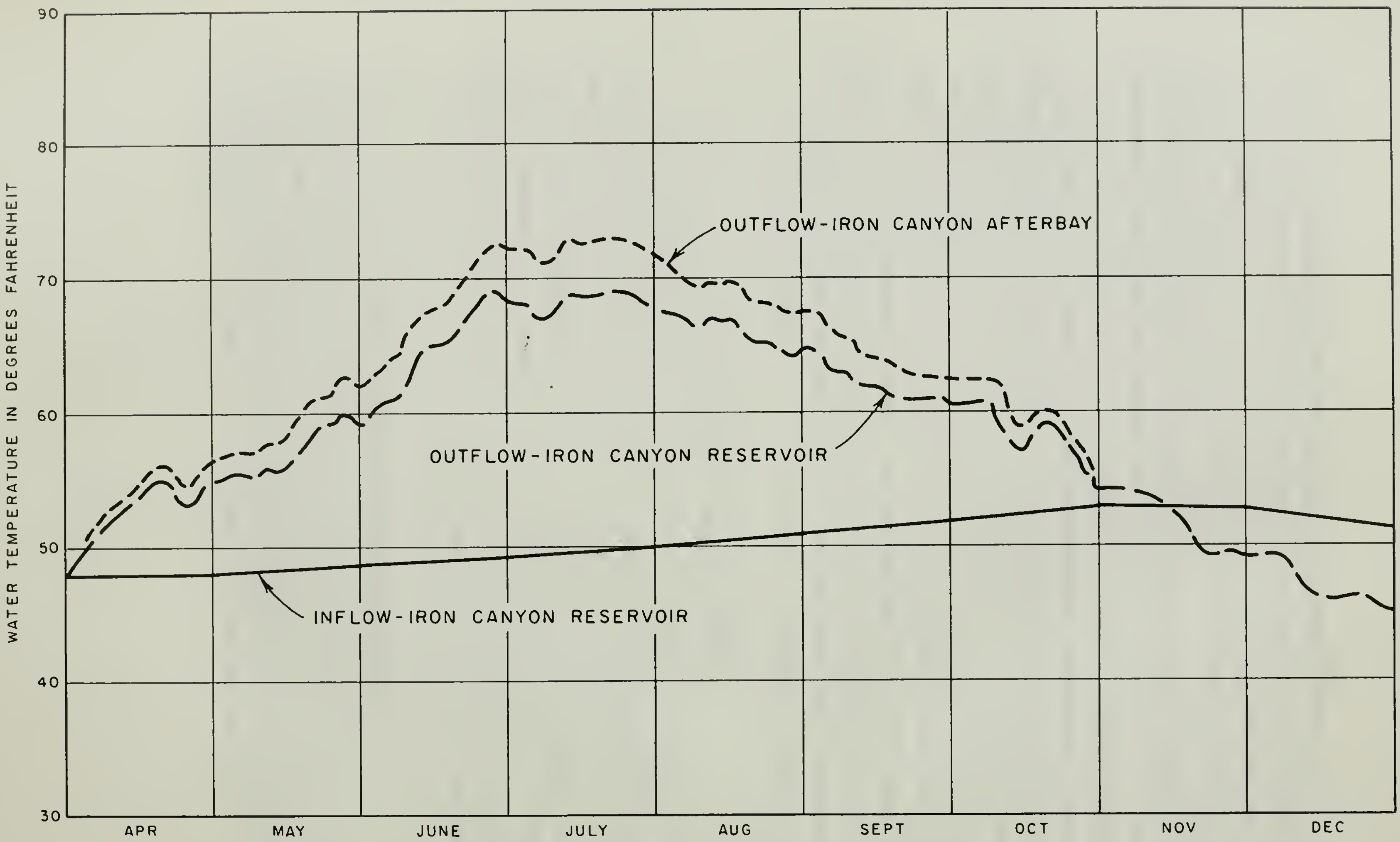

FIGURE I

PREDICTED EFFECTS OF THE IRON CANYON PROJECT ON WATER TEMPERATURES IN THE SACRAMENTO RIVER FOR A TYPICAL RUNOFF YEAR comparative purposes, a uniform annual cost or benefit throughout the full project repayment period. Average annual equivalent costs are computed as the annual costs of operation, maintenance, and replacement of the project, plus the product of the capital cost and a capital recovery factor of 0.04655. The capital recovery factor represents an amount of a total debt which, when paid in equal annual installments over a 50-year repayment period, at a four percent interest rate, would repay the entire capital cost of the project.

The present worth value represents the present amount of money, invested at current interest rates (in this case four percent), that would be required to meet a future project expenditure, or series of expenditures. For instance, the present worth value of total annual operation, maintenance, and replacement cost would be that amount of money which if invested now, at four percent interest rates, would be sufficient to pay these costs each year of the 50-year repayment period.

Costs

Costs of the Iron Canyon Project were determined on the basis of construction prices existing in the fall of 1963, a repayment period of 50 years, and an annual interest rate of four percent.

The estimated average annual equivalent cost of the project would be $10,500,000. The total economic cost would be $225,000,000. This cost represents the total construction cost (capital cost), plus the present worth of annual operation, maintenance, and replacement costs. Capital costs of Iron Canyon Dam and Reservoir and Iron Canyon Afterbay Dam and Reservoir are summarized in Tables 13 and 14. Costs of Iron Canyon Project features not included in these tables are summarized in Table 15, "Iron Canyon Project Costs, Benefits, and Benefit-Cost Ratio".

TABLE 13

SUMMARY OF CAPITAL COSTS OF IRON CANYON DAM AND RESERVOIR

Reservoir Capacity = 1,000,000 Acre-Feet

Item	Quantity	Costs	
Dam			
Diversion and Care of Stream			
Cofferdam	350,000 cubic yards	$ 640,000	
Tunnel (20-foot diameter)	Lump sum	1,200,000	
Miscellaneous	Lump sum	260,000	
			$ 2,100,000
Main Dam			
Stripping	200,000 cubic yards	420,000	
Embankment	3,100,000 cubic yards	6,210,000	
Miscellaneous	Lump sum	870,000	
			7,500,000
Wing Dam			
Stripping	100,000 cubic yards	100,000	
Embankment	2,100,000 cubic yards	4,800,000	
			4,900,000
Spillway			
Excavation	3,800,000 cubic yards	1,600,000	
Concrete; includes cement and steel	290,000 cubic yards	11,300,000	
Radial gates and hoists	Lump sum	1,700,000	
Miscellaneous	Lump sum	200,000	
			14,800,000

TABLE 13 (Continued)

SUMMARY OF CAPITAL COSTS OF IRON CANYON DAM AND RESERVOIR

Reservoir Capacity = 1,000,000 Acre-Feet

Item	Quantity	Costs	
Dam (Continued)			
Outlet Works			
Excavation	940,000 cubic yards	$ 400,000	
Concrete	240,000 cubic yards	8,800,000	
Penstocks	Lump sum	1,340,000	
Foundation, drill, and grout	Lump sum	60,000	
			$10,600,000
Subtotal			39,900,000
Engineering and administration			6,000,000
Contingencies			6,900,000
Interest during construction			4,200,000
TOTAL COST OF DAM			57,000,000
Reservoir			
Clearing		$ 1,400,000	
Land and improvements		25,600,000	
Relocations		11,300,000	
Subtotal			38,300,000
Engineering and administration			5,740,000
Contingencies			6,610,000
Interest during construction			2,350,000
TOTAL COST OF RESERVOIR			53,000,000
TOTAL COST OF DAM AND RESERVOIR			110,000,000

TABLE 14

SUMMARY OF CAPITAL COSTS OF
IRON CANYON AFTERBAY DAM AND RESERVOIR

Item	Quantity	Costs	
Dam			
Dike			
Stripping	700,000 cubic yards	$ 110,000	
Enbankment	3,500,000 cubic yards	3,140,000	
			$ 3,250,000
Modification of Red Bank Diversion	Lump sum		2,000,000
Connecting Channel			
Excavation	1,400,000 cubic yards	280,000	
Fish screen	Lump sum	100,000	
			380,000
Tehama-Colusa Canal Extension			
Excavation	16,000 cubic yards	10,000	
Embankment	18,000 cubic yards	10,000	
Outlet	Lump sum	20,000	
			40,000
Subtotal			5,670,000
Engineering and administration			850,000
Contingencies			980,000
Interest during construction			300,000
TOTAL COST OF DAM			7,800,000
Reservoir			
Land and improvements			1,900,000
Engineering and administration			300,000
Contingencies			400,000
Interest during construction			100,000
TOTAL COST OF RESERVOIR			2,700,000
TOTAL COST OF DAM AND RESERVOIR			10,500,000

Benefits

The Iron Canyon Project would produce flood control, hydroelectric power, export, and recreation benefits. Local irrigation benefits were also computed but found to be less than their estimated costs. Each of the project benefits are discussed in detail in the following paragraphs.

Flood Control Benefits. Two basic flood hydrology studies were completed by the Department and subsequently used as a basis for the evaluation of flood control benefits from Iron Canyon Reservoir: (1) "Flood-Control Hydrology, Sacramento River Basin above Iron Canyon Damsite", August 1959, and (2) "Upper Sacramento River Basin Investigation Flood Hydrology Study", October 1960.

Standard project and probable maximum floods were developed during the first study for the Iron Canyon site and for sites on major tributaries between Shasta Dam and Red Bluff. A flood storage reservation diagram for Iron Canyon Reservoir was also developed during this study. The second study was made to develop preproject and project frequency-flow relationships for the Sacramento River at the Iron Canyon site and at Ord Ferry.

Corps of Engineers flow-damage data presented in "Master Manual of Reservoir Regulation", March 1959, were used as a basis for evaluation of flood control benefits from Iron Canyon Reservoir. In the manual, the area of flood damage is divided into zones; the peak flow for each of these zones is identified with a specific stream gage or gages. In order to utilize the data, relationships between peak flows at gages identified with each zone and peak flows at either the Iron Canyon site or the Ord Ferry gate were established. Damage in each of the zones, corresponding to peak flows at Ord Ferry or Iron Canyon was compiled into two general flow-damage curves: Sacramento River from Red Bluff to Rice Creek and Sacramento River from Rice Creek to Colusa Weir including Butte Basin. These two curves were used in conjunction with the frequency-flow relationships at Iron Canyon and at Ord Ferry to determine flood damages.

Hydrology and damage data studies determined the dollar value of flood control benefits. Flood control benefits from Iron Canyon Reservoir would accrue from three sources: (1) prevention of the loss of goods or services that would otherwise occur as a result of floods; (2) increased land values that result from changes in agricultural, industrial, or commercial land use patterns because of reduction or elimination of the flood hazard; and (3) annual savings in levee and weir construction and maintenance costs.

These latter benefits were derived from the Corps of Engineers Comprehensive Flood Control Survey Report dated February 1, 1945, indexed up to reflect current prices, and from the state Division of Water Resources report, "Alternative Plans for Control of Floods in Upper Sacramento Valley", dated September 1948, wherein a levee system in conjunction with reservoir storage was used. Flood reduction benefits were computed as the difference in expected average annual damages, with and without the project, which would be realized over the life of the project. Land enhancement benefits and the benefits resulting from annual savings in levee and weir construction and maintenance costs were also computed on a "with" and "without" project basis. The following tabulation shows average annual benefits adjusted to allow for future economic development over the life of the project.

Item	Sacramento River Rice Creek to Colusa Weir Including Butte Basin	Sacramento River Red Bluff South to Rice Creek	Total
Prevention of future flood damages	$565,000	$270,000	$ 835,000
Increased land values	25,000	--	25,000
Savings in levee and weir	100,000	100,000	200,000
Total annual benefit	690,000	370,000	1,060,000

Hydroelectric Power Benefits. The annual value of benefits attributable to the generation of hydroelectric power from a project is the estimated cost of producing equivalent power from the most likely alternative source expected to develop in the absence of the proposed development, with appropriate adjustment for transmission costs and losses and other technical factors. The assumption is made, based upon the industry trend over the past few decades, that the most likely alternative source for the Iron Canyon Powerplant would be a modern, privately financed steam-electric plant.

Based on an analysis of a steam-electric plant, the capacity component was determined to have a value of $15.40 per kilowatt-year and the energy component, 2.75 mills per kilowatt-hour. The benefit value therefore consists of the capacity component multiplied by the dependable capacity of the plant, plus the energy component multiplied by the average annual energy production of the plant. The following tabulation presents the estimated annual benefits of the Iron Canyon Powerplant.

Dependability Component - 153,000 KW x $15.40	=	$2,360,000
Energy Production Component - 715,700,000 KWH x $.00275	=	1,970,000
Total Annual Benefit	=	4,330,000

<u>Export Water Benefits</u>. Export benefits to be derived from an Iron Canyon Reservoir cannot be accurately determined without incorporating this reservoir into a coordinated operation study of the Sacramento-San Joaquin River System at the Delta. This extremely complex operation is being prepared by the Department's Division of Operations in cooperation with the U. S. Bureau of Reclamation. Unfortunately, it was not completed at the time this report was prepared. Since estimated export benefits from Iron Canyon required an estimate of new yield, an empirical method had to be developed to provide an interim estimate, pending completion of a fully coordinated operation of the Sacramento-San Joaquin Delta.

Review of several predicted water supply studies by the State and the Bureau of Reclamation shows that varying amounts of water will be wasted from the Delta during its critical water supply period. The frequency of this waste varies depending upon the staging of future projects and the estimated buildup in demand for water. Yields from Iron Canyon

Reservoir for export from the Delta range between a low of 50,000 acre-feet and a high of 150,000 acre-feet of firm annual new yield, depending on which water supply is used. For this study, a firm yield of 130,000 acre-feet per year was determined to be the most reasonable value. The estimated average annual equivalent benefit of this yield would be $1,400,000. This value was derived by multiplying the new yield by the benefit value of an acre-foot of water at the Delta.1/ The derivation of export water benefits is presented in the following tabulation.

PRESENT WORTH AND AVERAGE ANNUAL EQUIVALENT EXPORT BENEFITS
IRON CANYON PROJECT

Decade	Present Worth of Benefit
1970 - 1980	*
1980 - 1990	$14,430,000
1990 - 2000	7,310,000
2000 - 2010	4,930,000
2010 - 2020	3,330,000
Total Present Worth	$30,000,000
Average Annual Equivalent	1,400,000

*No demand for export water from the Upper Sacramento River Basin is anticipated prior to 1980.

Recreation Benefits. If the Iron Canyon Project were constructed, numerous areas adjoining the reservoir could be developed for recreation. Most of these areas would be located on the right bank or westerly portion of the reservoir. Detailed studies of the recreational use that would result from an Iron Canyon Project were made by the Department of Parks and Recreation. The results of this study are presented in their recreation report, included as Appendix A of this Bulletin.

1/ A detailed discussion of the method used to estimate export yields and export benefits is contained in the following chapter under planning considerations.

Total recreation use of the Iron Canyon Project was computed for each decade during the economic life of the project. From this total was deducted the projected recreation use that would have occurred without the project. The difference represented the net recreation use attributable to the Iron Canyon Project.

Monetary values of recreation benefits were derived by assigning a value of $1.80 to each visitor-day of use. The $1.80 represents a weighted average recreation value for the basin area determined by application of the consumer surplus theory.1/

The decade net recreational use in visitor-days was then multiplied by $1.80 to obtain the total benefits for each decade. These benefits were then brought back to present worth and converted to average annual equivalent benefits in order to facilitate comparison of benefits and costs. The estimated average annual equivalent recreation benefits would be $900,000. The following tabulation presents these values for the period 1970-2020.

PRESENT WORTH AND AVERAGE ANNUAL EQUIVALENT
RECREATION BENEFITS 1970-2020

Decade	Estimated Net Visitor-Day Use	Benefit
1970 - 1980	1,400,000	$ 2,088,000
1980 - 1990	3,700,000	3,693,000
1990 - 2000	6,400,000	4,350,000
2000 - 2010	10,100,000	4,640,000
2010 - 2020	14,800,000	4,563,000
Total Net Visitor-Days	36,400,000	
Total Present Worth		$19,334,000
Average Annual Equivalent		$900,000

1/ Measurement of Recreation Benefits; Journal of Land Economics, Volume 34, August 1958, by A. H. Trice and S. E. Wood.

Local Irrigation Benefits. The only local area suited for the service of irrigation water from Iron Canyon Project would be the Los Molinos-Vina area. This area consists of about 25,000 irrigable acres contiguous to the left bank of the Sacramento River, extending eastward to the foothills and from Red Bluff to Rock Creek. Portions of this area are presently irrigated from diversion of local surface runoff and from ground water. Alternate sources of water for this area would consist of additional development of the extensive ground water reservoir which underlies this area, and development of surface supplies from tributary streams on the east side of the Sacramento Valley. Preliminary cost estimates showed that ground water could be supplied to this area at a lower cost than could be supplied by the Iron Canyon Project. Consequently, no local irrigation benefits would be derived from the Iron Canyon Project. The possibility of serving this area from surface developments on east side streams is being studied as a part of the current "Sacramento Valley East Side Investigation", results of which will be published by the Department in 1966 as Bulletin No. 137.

Benefit-Cost Ratio

The estimated annual equivalent costs of the Iron Canyon Project would be $10,480,000. Estimated total annual equivalent benefits would be $7,690,000. The resultant ratio of benefits to costs would be about 0.73 to 1. The project is therefore economically unjustified at the present time. Table 15 presents a summary of the economic costs, benefits, and benefit-cost ratio of the Iron Canyon Project.

Additional Imports

In the event that water from future North Coastal developments on the Lower Trinity River is brought into the Sacramento River above the Iron Canyon damsite, additional power benefits could be produced which might make the Iron Canyon Project economically justifiable. This possibility will be considered further by the Department in its continued investigations of the North Coastal area.

TABLE 15

IRON CANYON PROJECT COSTS, BENEFITS, AND BENEFIT-COST RATIO

Feature	Annual Costs at 4% 50 Year			50-Year Repayment Period Costs		
	Capital Recovery	Operation, Maintenance, and Replacement	Totals Av. Annual Equivalent Costs	Capital	Present Worth of Operation, Maintenance, and Replacement	Total
Project Costs						
Iron Canyon Dam	$ 2,650,000	$ 80,000	$ 2,730,000	$ 57,000,000	$ 1,700,000	$ 58,700,000
Iron Canyon Reservoir	2,470,000	40,000	2,510,000	53,000,000	900,000	53,900,000
Iron Canyon Powerplant	1,540,000	410,000	1,950,000	33,000,000	8,800,000	41,800,000
Fish Passage Facilities	260,000	170,000	430,000	5,700,000	3,600,000	9,300,000
Fish Hatchery	560,000	1,130,000	1,690,000	12,100,000	24,100,000	36,200,000
Recreation Facilities	290,000	310,000	600,000	6,200,000	6,700,000	12,900,000
Iron Canyon Afterbay Dam	360,000	10,000	370,000	7,800,000	200,000	8,000,000
Iron Canyon Afterbay Res.	130,000	20,000	150,000	2,700,000	400,000	3,100,000
Wildlife Mitigation Facilities	20,000	30,000	50,000	500,000	600,000	1,100,000
Totals	8,280,000	2,200,000	10,480,000	178,000,000	47,000,000	225,000,000

Project Benefits

Project Purpose	Av. Annual Equivalent	Present Worth
Recreation	$ 900,000	$ 19,300,000
Flood Control	1,060,000	22,700,000
Hydroelectric Power	4,330,000	93,000,000
Export Water	1,400,000	30,000,000
Total	7,690,000	165,000,000

Benefit Cost Ratio

$$\frac{165,000,000}{225,000,000} = 0.73:1$$

Summary and Discussion

As a result of the present investigation, it is concluded that:

1. A safe dam can be constructed at the Iron Canyon site.

2. Some of the problems relating to protection of the salmon and steelhead resources of the Upper Sacramento River due to construction of the Iron Canyon Project remain to be resolved.

3. Considerable additional study to develop adequate solutions to problems relating to fish would be required before the Department of Fish and Game and sport and commercial fishery interests could be persuaded that the Iron Canyon Project would not cause irreparable damage to the salmon populations of the Sacramento River.

4. The costs of lands, rights-of-way, and easements are increasing rapidly and will soon exceed the dam costs.

5. Under present economic conditions, the costs of an Iron Canyon Project exceed the benefits by a substantial margin. The present economic benefit-cost ratio is only 0.73 to 1.

In view of the unfavorable benefit-cost ratio, it was determined that possible plans for near future water development within the Upper Sacramento River Basin could only come from construction of tributary reservoir projects and from ground water development. A detailed discussion of plans for the development of tributary reservoirs is presented in Chapter IV of this report. Ground water development possibilities are presented in Chapter V.

CHAPTER IV. PLANS FOR DEVELOPMENT OF TRIBUTARY STREAMS

Development of water storage and conservation facilities on tributary streams was considered in planning for full utilization of the water resources in the Upper Sacramento River Basin. Many potential water storage sites located in the stream basins tributary to the Sacramento River were investigated. Of the seven sites that preliminary investigation indicated might warrant further study, four appear to be economically justified at the present time. These are Hulen on North Fork Cottonwood Creek, Dippingvat on South Fork Cottonwood Creek, Paskenta on Thomes Creek, and Millville on South Cow Creek. Those sites not presently economically justified are Fiddlers on Middle Fork Cottonwood Creek, Rosewood on Dry Fork Cottonwood Creek, and Bella Vista on Little Cow Creek.

This chapter discusses the physical and economic considerations that were used to produce water development plans on the tributary streams. Plans for development of the seven reservoir sites listed above are discussed according to the stream basins, Cottonwood Creek, Cow Creek, and Thomes Creek, in which they exist.

Preliminary planning studies of reservoir storage projects in Battle, Paynes, and Clear Creek Basins indicated that none were economically justified under present economic conditions. Therefore, no plans are presented for these stream basins.

Planning Considerations

In the past, plans for development of the Sacramento River tributary stream basins have been mainly oriented to water conservation for local use and to provide flood protection in Butte Basin. In recent years, conservation for export to outside areas of water deficiency, and conservation for the purposes of recreation and the preservation and enhancement of fish and wildlife resources have become increasingly important. Use of water for the last named purposes is recognized as a beneficial use of water in California. The State Water Rights Board is required to take into account, whenever it is in the public interest, the amounts of water required for such purposes in determining the amount of water available for appropriation for other beneficial uses.[1] It is, moreover, the declared policy and intent that in both state and federal water conservation projects recreational development and the enhancement of fish and wildlife be included in project purposes wherever feasible.[2]

The fact that recreation and fishery enhancement can now be included as nonreimbursable features of local, state, and federal projects, coupled with the finding brought out in Chapter III -- that a main stem Sacramento River development at the Iron Canyon site is not economically justified at this time -- has changed somewhat the criteria under which possible tributary development projects in the Upper Sacramento Basin are formulated from that of a decade ago. The basis used in formulating tributary reservoir projects is discussed below as project operation and planning and sizing criteria.

Project Operation Criteria

The general criteria for operation of tributary reservoirs during the study period were similar for all of the projects. Reservoirs were operated to provide for annual local irrigation requirements, to regulate flows to provide for downstream fishery enhancement, to provide water for export to the Sacramento-San Joaquin Delta, to develop reservoir recreation, and to provide flood control.

Local irrigation water demands were determined from land classification and land use studies for the several possible service areas presented in Chapter II of this report and shown on Plate 3. Project water requirements were then determined by dividing the service areas into subservice areas that could be most economically served from a given water development project.

In determining local irrigation water requirements, the following assumptions were made:

1/ Water Code Section 1243.
2/ Davis-Dolwig Act, Water Code Sections 11900 to 11925; Fish and Wildlife Coordination Act of March 10, 1934, as amended, 16 U.S.C. 661 to 666c (1958 ed).

1. Project water will be delivered by 1970 and will be available throughout the project service area.

2. Water will be delivered at a cost within the average payment capacity of crops projected, and within the landowner's willingness to pay.

3. The project buildup period will occur within 10 years after project completion.

4. Present and preproject water requirements will continue to be met from existing sources.

The Department of Fish and Game conducted studies to determine the fishery enhancement that could be realized from increased and controlled flows in the tributary streams. The amount of enhancement provided by various streamflow releases was estimated for each of the tributary streams below the proposed reservoir sites. A monthly percentage distribution of annual fisheries water requirements for Cottonwood, Cow, and Thomes Creeks is presented in Table 16. These distributions were used in reservoir sizing and in estimating fishery enhancement benefits.

Inflows to tributary reservoirs were considered to be available for storage whenever there are surplus flows in the Delta. Water stored during these periods would be released during periods of deficiency. Since surpluses in the Delta generally occur during February, March, and April, and since the major part of fisheries enhancement flows occur during other months, fish releases would generally produce increased yields to the Delta.

Reservoir storage sufficient to insure protection of reservoir fishlife was maintained at each reservoir. In addition, the storage of water in project reservoirs to meet downstream fisheries demands in the fall and winter months insures the maintenance of a large reservoir pool during the summer recreation season.

Inherent in the economic potential of the proposed tributary reservoir projects is the assumed ability of these reservoirs to maintain water temperatures that will assure the survival of adult salmon, their eggs, and their fry. Water temperature prediction studies for these reservoirs were not within the scope of this reconnaissance investigation.

TABLE 16

MONTHLY DISTRIBUTION OF ANNUAL FISHERY
ENHANCEMENT AND LOCAL IRRIGATION WATER DEMANDS

(In percent)

Month	Fishery Demand				Local Irrigation Demand
	Cottonwood Creek		Cow Creek	Thomes Creek	
	Main Stem 1/ (Hulen Res.)	South Fork (Dippingvat Res.)	(Millville Res.)	(Paskenta Res.)	Entire Area of Investigation
January	30	8.5	13	13	0
February	0	8.5	10	8	0
March	0	8.5	7	8	1
April	0	7	7	8	5
May	0	7	5	2	16
June	0	7	5	2	20
July	0	2	3	2	22
August	0	2	3	2	20
September	0	6	8	2	12
October	10	14.5	13	2	4
November	30	14.5	13	30	0
December	30	14.5	13	21	0

1/ In months when no fisheries water release is required, it was assumed that natural runoff was sufficient to satisfy the fishery requirement.

However, such studies should be included as an integral part of future feasibility investigations of those projects which show indications of economic justification.

Reservoir flood control space, to be effective, must be available during periods of high flow. Due to the nature of proposed project operations for local irrigation and for fisheries enhancement, the reservoirs would normally be drawn down to minimum levels when the flood season occurs, thus providing sizable flood control benefits. The development of a detailed flood operation schedule was not considered warranted for this investigation, although such a schedule would be needed prior to final design of a project.

In determining local and export yields, deficiencies in water supply, including fishery enhancement demands, were allowed during dry years. When the yield is less than the annual demand, Department policy is to allow a percentage deficiency up to 50 percent in any one year, but not more than 100 percent within any consecutive 7-year period.

Many operation studies were made to select the reservoir size for each site that would maximize net benefits for the several possible project purposes using criteria discussed in the preceding paragraphs.

Project Planning and Reservoir Sizing Criteria

The multiple-purpose concept of reservoir use was used in analyzing all potential reservoir storage projects. The following criteria were followed in all project planning studies within the tributary stream basins:

1. The water supply period 1921-22 through 1940-41 was used to evaluate reservoir water yields.
2. Downstream users with prior rights are fully protected by preservation of present impaired streamflows during periods of use.
3. Areas of origin of water were given first consideration in development of new water supplies.
4. Only primary tangible benefits were used in economic evaluations.
5. All economic analyses were based on a 50-year repayment period (1970-2020), using an annual interest rate of 4 percent.

6. Each reservoir was sized to produce maximum net project benefits.

Maximum net benefits are realized when the scale of development is extended to the point where the benefits added by the last increment of enlargement are equal to the costs of adding that increment.

Development of Costs and Benefits for Possible Project Purposes

The principles and methods used in evaluating the costs and benefits connected with a specific project purpose are presented in this section. As discussed herein, specific costs are those costs which can be identified with a specific physical project purpose, such as recreation facilities. The separable cost for each project purpose is the difference between the cost of the multiple-purpose project and the cost of the project with that purpose omitted. For a purpose to be included in a project, separable costs incurred by that purpose must be less than the benefits that would be derived. Costs of dam, reservoir, and appurtenances for each project were distributed among the various project purposes in accordance with the "separable costs -- remaining benefits" method of analysis.[1/] A preliminary cost allocation is shown for each of the economically justified tributary reservoir projects.

Recreation

Benefits. Estimates of the number of visitor-days of recreation use experienced at a particular recreation site were based on the attractiveness of the recreation pursuit, proximity of similar recreation functions, accessibility to the recreation area, and number of recreationists able to participate. The difference in recreation use (in visitor-days) under "project" and "nonproject" conditions represents the recreation use attributable to each project.

Benefits attributable to each project are determined by multiplying the dollar value of a day's recreation activity by the net number of visitor-days of use. A visitor-day value of $1.80 was established for all types of recreation activity for each of the tributary reservoirs. This value was determined as the difference in cost of travel for a long distance recreation seeker (90 percentile) as opposed to the cost of travel

1/ This method distributes multiple-purpose project costs equitably among the purposes served. It assigns to each purpose its separable cost and a share of the remaining joint costs in proportion to the remaining benefits.

for the average recreation seeker (50 percentile). This difference reflects the "consumer's surplus" or net benefit derived by the median recreationist.[1/]

Costs. Specific costs of recreation facilities were estimated using construction standards and expenditure estimates of the State Department of Parks and Recreation. The number of facilities required were determined by estimating the total recreation use for each project and constructing sufficient new facilities each decade to meet the predicted increase in recreation user demand for that decade. Operation, maintenance, and replacement costs were also determined by using Department of Parks and Recreation standards.

Fisheries Enhancement

Benefits. The area of stream gravels suitable for salmon spawning was determined for various streamflow releases below each proposed reservoir by field personnel of the Department of Fish and Game. From these gravel surveys, an estimate was made of the numbers of salmon that could be accommodated below each project reservoir.

For each 100 adult salmon that reach the spawning beds it was estimated by Department of Fish and Game biologists that 400 of their progeny would live to reach maturity. Of these, 240 would be caught commercially, 60 would be caught by sports fishermen, and 100 would return to perpetuate the spawning cycle.

Net fisheries benefits attributable to each project were computed by multiplying the increase in numbers of fish caught, both commercially and by sports fishermen, by the estimated net value of the fish.

The benefit accruing from commercially caught salmon is based upon an average dockside price per pound of 56¢, less the cost of harvesting by a reasonably efficient commercial operation, 22¢ per pound, leaving a benefit value of 34¢ per pound. On the basis of this value, and an average weight of commercially caught salmon of 12 pounds, the net commercial benefit value per fish is $4.08.

Benefits from sport salmon fishing, both in the rivers and in the ocean, are based on the estimated number of fisherman days needed to catch

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1/ "Measurement of Recreation Benefits", Journal of Land Economics, Volume 34, August 1958, by A. H. Trice and S. E. Wood.

a salmon, multiplied by the value of a day's fishing, which was estimated to be $1.80. This is the same value used for other types of recreational activities.

Creel census studies conducted by the Department of Fish and Game show that the time needed to catch each salmon is three days for ocean sport fishing, and seven days for river sport fishing. The resulting benefit values are $5.40 for ocean-caught salmon and $12.60 for a river-caught salmon. The composite sport value, weighted on the basis of 69 percent being ocean caught, and 31 percent being river caught, is $7.65. Because the life cycle of a king salmon averages four years, it was assumed that fisheries enhancement benefits would begin to accrue on the fifth year following project completion.

Costs. Two items of specific costs would be incurred by the fishery enhancement purpose. The first would consist of costs of acquiring access rights-of-way along the stream channels for management purposes; the second would consist of costs of planting fingerling salmon until the salmon runs become established by natural propagation. The cost of acquiring access rights-of-way to each stream was estimated from recent comparable land sales. The cost of stocking the stream with fingerlings was based on planting 200 fingerlings for each potential returning spawner at a cost of 1¢ per fingerling for the first four years following project completion.

Flood Control

Benefits. Flood control benefits accruing from projects constructed on tributary streams were divided into two general categories: (1) benefits based on reduction of local damages along the tributaries between the damsite and the streams' confluence with the Sacramento River, and (2) those benefits derived from reducing or preventing losses due to flooding of "remote" lands along the Sacramento River between Red Bluff and Colusa.

Benefits on tributaries were determined by first assessing all available actual flood damage data compiled by the Corps of Engineers and the Department of Water Resources and converting the damages from floods of record to average annual damages. A rough reconnaissance estimate of local flood damages was then made under proposed project conditions. The difference in damages "with" and "without" the project represent the local flood control benefits to the project.

It has been shown in previous studies that if flood control storage is provided on Sacramento River tributary streams, some measure of flood control will result between Red Bluff and Colusa. Detailed studies to determine the effectiveness of flood control provided by seven reservoirs on Cow, Cottonwood, and Thomes Creeks indicated that about twice as much storage would be needed on the tributaries to provide the same degree of flood protection between Red Bluff and Colusa as would be supplied by Iron Canyon Reservoir. The annual flood control benefits related to active storage capacity at Iron Canyon were found to be about $1.40 per acre-foot. Therefore, a conservative value of 50¢ per acre-foot of active storage capacity was assigned as a "remote" incremental flood control benefit to each of the tributary reservoirs considered.

Costs. Since no specific flood control features were included in the tributary reservoir plans, no specific costs were determined.

Conservation for Local Irrigation

Benefits. Increased productivity would result from the application of project water to lands presently dry farmed or receiving only a partial water supply. The procedure utilized in determining benefits involves the subtraction of all farm costs, except annual land and water costs, from the gross farm income to obtain the net return to land and water. Benefits are the difference between the returns to land and water resulting with the project and those which will accrue in the area during the analysis period if no project is built.

Costs. Specific costs of the irrigation features of a project are those costs connected with the distribution of water. For the purpose of this study the initial costs of facilities required to move the water from the storage site to the main body of the service area were estimated and included. Annual operation and maintenance costs of the main canal and appurtenant structures were also included as specific costs.

Conservation for Export

Benefits. A demand for additional export water at the Sacramento-San Joaquin Delta above that developed by the initial State Water Facilities is expected to develop by 1980. Benefits resulting from replenishment and augmentation of the Delta water supply were estimated to be $20 per acre-foot for the period 1980-1990, and $15 per acre-foot thereafter. These benefits were derived as the net benefits to service areas of the State Water Facilities after deducting the costs of water delivery from the Delta to the service area. The urban water supply benefits were estimated on the basis of the most favorable alternative supply, including anticipated reductions in the cost of sea water conversion in Southern California.

At this stage of planning, it was not possible to perform operation studies of the tributary reservoirs conjunctively with all other storage facilities in the Sacramento-San Joaquin River system. Therefore, the following empirical method was developed to estimate the Delta yield produced from tributary reservoir projects.

New yield to the Sacramento-San Joaquin Delta from any size reservoir was determined by the following formula:

$$Y = \frac{S_t - S_1 + I - R - S}{6} - E$$

Where:
- Y = Annual firm export yield at the Delta
- S_t = Active reservoir storage
- S_1 = Storage required to produce local yield requirement
- I = Inflow to reservoir during months of surplus flows in the Delta during the critical water supply period
- R = Release for project purposes during months of Delta surplus
- S = Uncontrolled reservoir spill during months of Delta surplus
- E = Average annual evaporation from the reservoir

The critical water supply period at the Delta was estimated to be seven years; however, when an allowance is made for two 50 percent deficiencies in delivery in critically short years of water supply, the effective critical period becomes six years. Consequently, six was used as the denominator in the above formula.

Costs. No specific costs would be incurred when benefits from conservation of water for export are determined in the manner described above.

Municipal and Industrial Uses

A study of the present municipal and industrial water supplies in areas that could be served from any tributary reservoir revealed that existing supplies are adequate, both in quantity and quality, to meet both present and future requirements. Consequently, no municipal or industrial water will be supplied from project reservoirs.

Hydroelectric Power

Preliminary studies of the hydroelectric power potential at tributary reservoir sites showed that cost of power development would be greater than expected revenues. Therefore, the purpose of power development was not included in any of the tributary reservoir projects.

Economic Justification Studies

Comparison of the present worth of primary project benefits and the present worth of project costs is commonly expressed in the form of a ratio, called the benefit-cost ratio. A project may be considered to be economically justified if its tangible primary benefits exceed its costs of design, construction, operation, maintenance, and replacement; in other words, if its benefit-cost ratio exceeds unity. The fact that this ratio does not reflect intangible or secondary benefits should be kept in mind, however, when making economic comparisons between projects.

Cost Allocation Studies

Cost allocation is the process of apportioning costs of a multiple-purpose project equitably among the various purposes served by the project. This is an essential step in the economic evaluation process since it provides the basis for determining the amount to be paid by each of the project beneficiaries for the various project services. The allocation embraces all project costs, including costs of construction, operation, maintenance and replacement. The concept of cost allocation assumes that the total cost of combining several purposes in a comprehensive project is substantially less than the sum of the costs of separate projects provided for each purpose, and that the savings derived through use of multiple-purpose structures should be shared by all purposes.

While there are several available methods of allocating costs of a project, the separable costs -- remaining benefits method is generally considered to be superior. Consequently, this method, which has been recommended by the Federal Interagency Committee on Water Resources for general use in allocating costs of federal multiple-purpose river basin projects, is used by the Department of Water Resources. Briefly, the separable costs remaining benefits method involves:

1. Determination of justifiable costs through evaluation of the benefits accruing to each purpose, such benefits limited by the least costly alternative.

2. Determination of the separable costs of each purpose.*

3. Subtraction of the separable costs from the justifiable costs.

4. Assignment to each purpose of a share of the residual or remaining joint costs in proportion to the remaining benefits.

Plans for Development of Cottonwood Creek Basin

Cottonwood Creek, the largest tributary stream system in the Upper Sacramento River Basin, drains an area of about 950 square miles, and produces a mean annual runoff of about 520,000 acre-feet. Its major tributaries are the North, Middle, Cold, Dry, and South Forks. Other smaller tributaries include Beegum and Salt Creeks.

During this investigation potential dam and reservoir sites were studied on each of the major tributaries of Cottonwood Creek. Those sites that were found to warrant detailed investigation consist of the following:

1. Hulen on North Fork Cottonwood Creek, 4 miles upstream from the confluence with the Middle Fork, and 15 miles west of the town of Cottonwood.

2. Fiddlers on Middle Fork Cottonwood Creek, 9 miles upstream from the confluence with the North Fork.

3. Rosewood on Dry Fork, 7 miles upstream from the confluence with the South Fork.

4. Cold Fork Diversion on Cold Fork Cottonwood Creek, 8 miles upstream from the confluence with South Fork.

5. Dippingvat on South Fork Cottonwood Creek, 27 miles upstream from the junction with Cottonwood Creek, and 20 miles west of Red Bluff.

Each of these projects is discussed in detail in the following sections.

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* Separable costs represent the difference in cost between the multiple-purpose project with all purposes included, and the project cost with that purpose excluded.

Hulen Project

The Hulen Project is located in Shasta County and consists of a dam and reservoir on North Fork Cottonwood Creek, downstream irrigation canals, recreation and wildlife habitat development facilities, and improvement of the stream channel of Cottonwood Creek below the confluence with the North Fork. The drainage area tributary to Hulen damsite is about 86 square miles. The estimated average annual runoff for the period 1921-22 through 1940-41 was 121,000 acre-feet when corrected for maximum future upstream water use.

Project Analysis

A reservoir formed by a dam at the Hulen site would provide downstream releases for irrigation in the Gas Point Road subservice area and improve the salmon spawning areas in the main stem of Cottonwood Creek. The reservoir would also provide excellent areas for recreation development, a small measure of flood control in the areas along Cottonwood Creek and along the Sacramento River, and new water to increase the export yield from the Sacramento-San Joaquin Delta. Preliminary studies of the Hulen Project indicated that a demand would exist for each of the above project purposes. Detailed studies were then made to determine whether or not each of these purposes were economically justified for inclusion in the project. Results indicated that the specific costs of each of these project purposes were less than the benefits that would be derived; consequently, each purpose was included in the project sizing analysis. In this study, local project purposes were given first consideration in project formulation.

Reservoir Sizing. Project costs and benefits were estimated for a range of reservoir sizes which varied from a smaller reservoir capable of supplying only local water demands to a large reservoir limited only by water supply or demand for project services and including all possible project purposes. Comparable costs and benefits were studied to determine the size that would yield maximum net benefits. This study revealed that a multiple-purpose reservoir with a storage capacity of 136,000 acre-feet at a normal pool elevation of 869 feet above sea level provided maximum net benefits.

The project would provide annual yields of 38,000 acre-feet for fisheries enhancement, 24,000 acre-feet for local irrigation use, and would increase the firm yield at the Delta by about 34,000 acre-feet annually.

General Features. The Hulen Project as proposed would consist of the following project features: (1) dam and appurtenant structures, (2) reservoir, (3) stream improvement for salmon spawning, (4) main irrigation canal, and (5) recreation facilities. General project features are shown in Figure 2.

Project Operation. Project water yields were determined from operation studies completed in accordance with the operation criteria set forth at the beginning of this chapter. The reservoir was operated to supply maximum requirements for local irrigation, and to provide for maximum salmon enhancement. Consideration was also given to development of water for export and to flood control protection. Table 17 presents an annual summary of the monthly operation study of the Hulen Project.

Geology

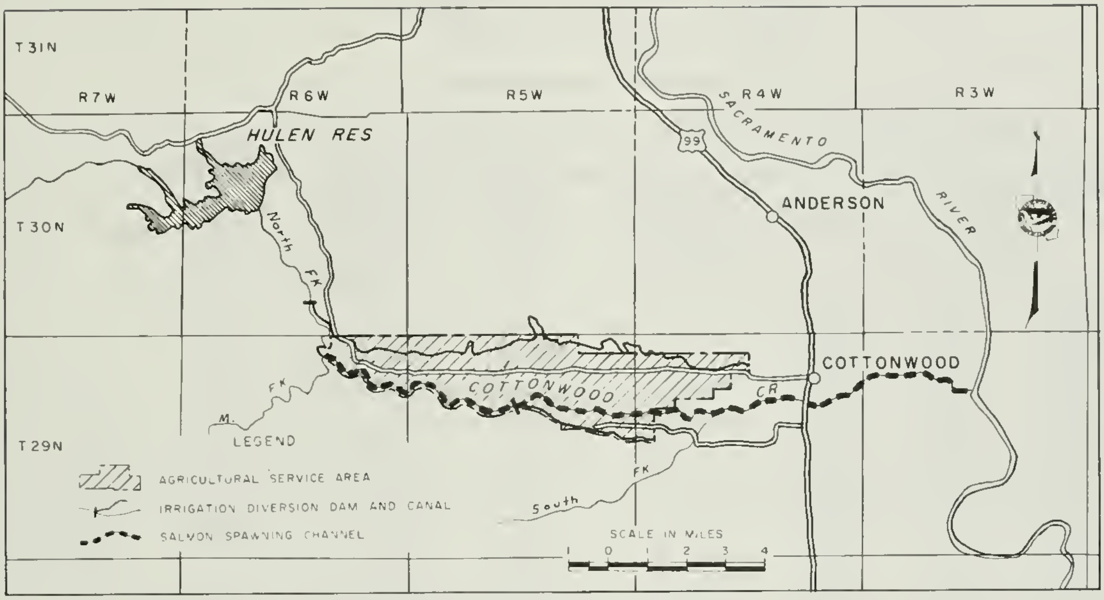
Geologic studies at Hulen damsite included a review of all available information from previous investigations. No foundation exploration at the damsite was performed by the Department of Water Resources; however, information from explorations conducted by the U. S. Bureau of Reclamation in 1945 was utilized. At that time four diamond drill holes (two on the right abutment, one on the left abutment, and one in the stream channel) were drilled to explore foundation conditions at the damsite.

Geologic surface mapping of the damsite was completed by the Department during this investigation and several auger holes were drilled to explore and obtain samples of possible impervious construction materials. Plate 7, "Hulen Dam and Reservoir on North Fork Cottonwood Creek", shows the geologic structure of the damsite and the location of construction material borrow areas.

Damsite Geology. Hulen damsite is located in an area of moderate relief with rounded hills rising about 400 feet above the streambed on both abutments. Several terrace levels have been formed where the stream in former geologic times meandered in a broad valley and deposited gravel on a flood plain. Downcutting action has since formed a narrow, steep-walled

FIGURE 2

HULEN PROJECT



General Project Features
(All elevations are USGS datum)

Dam

Location	Section 16, T30N, R6W, MDB&M
Type	Zoned earthfill
Height Above Streambed, in Feet	222
Crest Elevation, in Feet	882
Volume of Fill, in Cubic Yards	2,470,000

Reservoir

Drainage Area, in Square Miles	86
Water Surface Elevation at Normal Pool, in Feet	869
Storage Capacity, in Acre-Feet	136,000
Water Surface Area, in Acres	2,740

Spillway

Type	Gated weir with three 20' x 20' gates
Weir Crest Elevation, in Feet	849
Design Capacity, in Second-Feet	30,000

Outlet Works

Type	36-inch steel pipe in concrete-lined diversion tunnel

Project Accomplishments

Local Irrigation Yield, in Acre-Feet Per Year	24,000
Salmon Enhancement, in Numbers of Increased Annual Catch	63,000
Yield to Sacramento-San Joaquin Delta, in Acre-Feet Per Year	34,000

TABLE 17

SUMMARY OF MONTHLY OPERATION
STUDY OF HULEN RESERVOIR

(In 1,000 Acre-Feet)

Runoff Year	Storage on Oct. 1	Inflow a/	Water Releases and Losses					
			Release b/ for Prior Rights	Local Irrigation	Fishery Enhancement	Evaporation	Spill	Total
1921-22	36.0	117.3	7.4	24.0	38.0	5.9	0	75.3
22-23	78.0	80.7	2.5	24.0	38.0	6.3	0	70.8
23-24	87.9	14.7	0	12.0 c/	19.0 c/	5.0	0	36.0
24-25	66.6	189.4	11.1	24.0	38.0	7.5	57.8	138.4
1925-26	117.6	83.2	2.4	24.0	38.0	7.4	25.3	95.1
26-27	105.7	239.9	8.2	24.0	38.0	7.7	153.6	231.5
27-28	114.1	169.4	4.8	24.0	38.0	7.4	102.1	176.3
28-29	107.2	27.7	1.1	24.0	38.0	5.3	0	68.4
29-30	66.5	83.0	2.4	24.0	38.0	6.0	0	68.4
1930-31	81.1	26.9	0	12.0 c/	19.0 c/	5.0	0	36.0
31-32	72.0	62.3	4.9	24.0	38.0	4.9	0	71.8
32-33	62.5	46.9	8.2	24.0	38.0	3.8	0	74.0
33-34	35.4	40.1	0	12.0 c/	19.0 c/	3.6	0	34.6
34-35	40.9	89.0	7.2	24.0	38.0	4.4	0	73.6
1935-36	56.3	114.7	1.4	24.0	38.0	7.0	0	70.4
36-37	100.6	61.9	8.2	24.0	38.0	6.1	0	76.3
37-38	86.2	348.7	9.2	24.0	38.0	7.6	236.0	314.8
38-39	120.1	32.8	0	24.0	38.0	6.4	0	68.4
39-40	84.5	193.0	3.8	24.0	38.0	7.3	97.5	170.6
1940-41	106.9	403.1	8.9	24.0	38.0	7.7	314.6	393.2
Average	81.3	121.2	4.4			6.1		

a/ Estimated future impaired flow at Hulen damsite under future upstream depletions.

b/ Additional release in May, June, July, and August to satisfy prior downstream rights.

c/ Deficiency of 50 percent in release during 1924, 1931, and 1934.

NOTE: Storage at normal pool is 136,000 acre-feet. Storage on October 1 plus inflow minus water releases and losses equals storage on following October 1. A minimum storage of 13,800 acre-feet was reached on January 1, 1935. Normal pool storage of 136,000 acre-feet was reached during the winter months of each year in which spills occurred.

canyon where resistant layers of sandstone and conglomerate are present. Downstream from the axis of the dam, the canyon broadens where less resistant shale and mudstone occur.

The layers containing conglomerate and sandstone are the strongest rock types and will provide good foundation for almost any type of dam. The mudstone and shale are not nearly as strong, but nevertheless would provide a suitable foundation for a fill-type dam.

Reservoir Geology. The rock types in the reservoir are tight sandstones and shales. Consequently, leakage from the reservoir should be negligible. Landslides will not be a problem since the rocks are not deeply weathered and stable rocks are generally present close to the surface. Characteristics of the soil and rock in the drainage area above Hulen damsite indicate that deposition of silt in the reservoir would be negligible.

Construction Materials. A number of possible borrow areas for impervious and pervious materials and riprap were located by the U. S. Bureau of Reclamation in their study of the site in 1945. However, none of the materials were sampled or tested at that time. In 1958, as part of the Shasta County Investigation conducted by the Department of Water Resources, three samples from a road cut in the Tehama formation were collected and tested for grading, compaction, and shear strength.

Exploration for the current investigation included drilling 20 auger holes in two borrow areas located east and north of the site. Samples from seven drill holes were collected for testing. Quarry and pervious material borrow areas were mapped but no subsurface explorations were performed.

Practically unlimited quantities of suitable impervious construction materials are available within 1 to 1-1/2 miles of the site. In the proposed impervious borrow area, which lies between Ridge Road and Gas Point Road, the maximum thickness may be more than 100 feet but no deep holes have been drilled to substantiate this possibility. Twelve auger holes were drilled in this area, but due to presence of cobbles the depth of drilling was limited to less than 25 feet.

Approximately 2,000,000 cubic yards of gravel, a sufficient quantity for the pervious portions of the proposed dam embankment, are available from dredger tailings located downstream from the confluence of North Fork Cottonwood Creek and Cottonwood Creek. These gravels are hard and well-rounded but appear to contain fines in sufficient quantities to necessitate processing.

Several excellent sources of rock for rockfill or riprap are available within 2-1/2 miles of the site. Massive sandstone beds occur just north of the Ono-Igo Road in Section 5, Township 30 North, Range 6 West. Two other suitable quarry areas are present along Huling Creek south of the Ono-Igo Road.

Project Designs and Costs

The designs and costs of the Hulen Project are presented in the following paragraphs under the headings of Dam and Appurtenant Structures, Reservoir, Irrigation Distribution System, Stream Management for Fishery Enhancement, Recreation, and Preservation of Wildlife.

Dam and Appurtenant Structures. A zoned earthfill dam consisting of pervious dredger tailings and an impervious earth core was selected for Hulen damsite as the most efficient use of construction materials available near the site. The dam would be 222 feet high, would have a crest width of 30 feet, and a crest length of about 1,550 feet. The crest elevation would be at 882 feet USGS datum. Plate 7 presents the plan, profile, and maximum section of Hulen Dam.

The Embankment section was designed to be placed in two zones to take maximum advantage of the physical characteristics of the construction materials available. Zone one would be constructed from materials suitable to form an impervious central core having side slopes of 1 to 1. Suitable materials could be acquired about 1 mile east of the damsite.

The pervious material in zone two would support the impervious core. Side slopes of 2.5 to 1 on the upstream slope and 2 to 1 on the upper portion and 3 to 1 on the lower portion of the downstream slope were found to be adequate. Suitable pervious materials can be obtained from dredger tailings located about 4-1/2 miles downstream from the damsite. The total volume of embankment is estimated to be 2,470,000 cubic yards.

Riprap for the upstream face of the dam would come from excavation for the spillway and from a quarry site about 2 miles north of the damsite.

Clearing and foundation preparation are not considered to be expensive items at this damsite. Stripping, which was estimated to average 4 feet under the entire embankment, can be accomplished by common excavation with some light blasting. In addition, a cutoff trench about 20 feet deep would be required under the central half of the impervious zone to reduce seepage. A grout curtain would also be provided along the axis by a single line of grout holes about 10 feet apart and averaging 75 feet deep.

<u>The Spillway</u> would be located on the right abutment in an area which is predominantly shale, with occasional sandstone beds having thicknesses of up to 15 feet.

Cost studies revealed that the least total cost of dam and appurtenant structures would be realized by using a gated spillway consisting of (1) a 75-foot wide approach channel, concrete-lined for 40 feet in front of the control structure, (2) a control structure having a 7-foot high concrete overflow weir founded on firm rock, and three counterweighted, automatic operating, radial gates, each 20 feet long and 20 feet high, and an 800-foot concrete-lined chute section, 71 feet wide at the weir and narrowing to 45 feet at streambed.

The spillway was designed to meet the following conditions: (1) it must pass the probable maximum flood without damage to the dam, and (2) it must pass the maximum flood of record over the spillway gates with the gates closed. The spillway was designed to pass the probable maximum flood inflow of 35,000 second-feet with a maximum water surface elevation of 7 feet above normal pool. The maximum flood of record, 8,700 second-feet, was routed over the top of the spillway gates as a check on the safety of the dam against overtopping in the event of failure of the gate operating mechanism. On the basis of the second condition, the height of the dam was increased to provide 13 feet of surcharge elevation above the top of the gates instead of the 7 feet required to pass the probable maximum flood.

The spillway gates would normally be operated by electrically powered hoists. In addition, a float chamber would be provided to ensure automatic opening at a rate of approximately 5 feet of gate rise to 1 foot of water surface rise at stages above normal pool. This device would function without any external source of power.

The Outlet Works would utilize a 6-foot diameter tunnel through the right abutment of the damsite. The tunnel would be used for diversion of the streamflow during construction. The tunnel would be driven through shale, sandstone, conglomerate, and mudstone. Tunneling conditions should be relatively good throughout, with light to moderate support required during the tunneling operation. Lining would be required for its entire length.

The outlet works would consist of (1) an intake structure containing two 36-inch hydraulically operated slide gates to draw water from a high and a low level in the reservoir to provide some control of water temperatures below the dam, (2) a 36-inch welded steel pipe, about 1,275 feet long, installed inside the diversion tunnel, and (3) a 30-inch Howell-Bunger valve to dissipate energy and to assist in flow regulation. The outlet works was designed to release 150 second-feet with a gross head of 90 feet.

A Saddle Dam about 45 feet high and containing about 130,000 cubic yards of fill would be required just north of the main dam. The embankment would be a homogeneous earthfill with riprap on the upstream face.

Reservoir. Approximately 4,900 acres of land would be acquired for the reservoir and for areas suitable for recreation development. The majority of this land is uncleared brush and range land with scattered oak trees. About 2,800 acres would be within the normal reservoir area. This land would require at least partial clearing.

Relocation of County roads around the reservoir would require about one-fourth mile of new road. In addition, 2 miles of existing road would be improved and used for access roads.

Table 18 presents a summary of costs of the Hulen Dam, Reservoir, and appurtenances.

TABLE 18

SUMMARY OF COSTS OF HULEN DAM, RESERVOIR, AND APPURTENANCES

Item	Construction Cost	Engineering, Administration, Contingencies, and Interest During Construction	Total Capital Cost
Dam and Appurtenances			
Embankment	$3,150,000		
Spillway	760,000		
Outlet Works	420,000		
Saddle Dam	180,000		
Subtotal	4,510,000	$1,650,000	$6,160,000
Reservoir			
Land Acquisition and Clearing	470,000		
Relocation of Roads and Utilities	210,000		
Subtotal	680,000	250,000	930,000
Total	5,190,000	1,900,000	7,090,000

Irrigation Distribution System. The Gas Point Road subservice area shown on Plate 4 and in Figure 2 could be served by water released from Hulen Reservoir. The water could be diverted from the North Fork of Cottonwood Creek approximately 2-1/2 miles downstream from Hulen Dam, and from the main stem of Cottonwood Creek about 3 miles downstream from the confluence with the North Fork. A canal leading from the North Fork diversion at an elevation of approximately 600 feet could deliver water by gravity flow to the portion of the service area north of Cottonwood Creek. This canal would be concrete-lined, about 13 miles long, and would have a maximum capacity of 80 second-feet. The canal leading from the diversion point on Cottonwood Creek at an elevation of about 500 feet would deliver water to the portion of the service area south of Cottonwood Creek. It would be concrete-lined, about 5 miles long, and would have a capacity of 10 second-feet.

Estimated construction cost of the canals and diversion structures is $1,120,000. The total capitalized cost including operation and maintenance over the 50-year period of analysis would be $1,230,000. The average annual equivalent cost would be $57,200.

Stream Management for Fishery Enhancement. The entire length of the main stem of Cottonwood Creek from the confluence of the Middle and North Forks to the Sacramento River could be improved for salmon spawning with water released from Hulen Reservoir. In order to properly manage the stream channel and improve some areas for maximum spawning capacity it would be necessary to acquire rights to manage and operate the channel. The area required would be about 600 acres and would cost about $180,000.

It is estimated that the present annual spawning salmon runs in Cottonwood Creek average 1,000 fish. With enhanced flows provided by this project, the spawning run could be increased to 23,000 fish, or an increase of 22,000. This would increase the adult salmon catch by about 66,000 annually.

It was estimated that to initiate the increased spawning runs, the stream should be stocked with fingerling salmon at the rate of 200 fingerlings per adult spawner for each of the first four years following project construction. This would cost about $44,000 per year for four years.

Maintenance of the stream channel would be minor, and could be carried out by the Regional Headquarters of the Department of Fish and Game. Therefore, no annual cost was assigned to the project for operation and maintenance of the spawning gravels.

The total estimated initial cost of improving the salmon runs in the main stem of Cottonwood Creek would be $320,000. The average annual equivalent cost would be $14,900.

Recreation. Estimates of the recreation facilities needed to meet projected recreation demands were made to determine if the site could be developed to meet the demands and to estimate the cost of recreation facilities. Estimated recreation demands would require about 60 recreation units during the first decade of project operation. These units were designed only for day use because of the overnight facilities provided at existing nearby water projects. The number of recreation units required to meet future demands was also estimated on the basis of recreation use projections.

Costs of the recreation facilities were based on state park experiences and were estimated to be $2,100 per recreation unit. This unit cost would include water supply and sanitary facilities and interior recreation roads. Costs of other recreation facilities such as boat launching areas and swimming beaches were estimated separately.

Costs of operation, maintenance, and replacement of the recreation facilities were estimated from costs incurred at similar existing recreation areas. This cost was found to be about 30¢ per visitor day of use. Appendix A includes a discussion of the recreation potential of the Hulen Project.

The total present worth cost of recreation facilities, including operation, maintenance, and replacement during the 50-year period of analysis, is $1,180,000. The average annual equivalent cost is $54,900.

Preservation of Wildlife. Department of Fish and Game studies show that development of the Hulen Project would cause loss of habitat for deer and quail. These studies indicate that control and improvement of about 620 acres of land above maximum reservoir pool elevation on the south side of the reservoir would be required to compensate for loss of deer range.

New quail habitat could be provided on a 40-acre tract located on the north side of the reservoir below Ono Road.

A detailed description of the lands and improvements required for wildlife mitigation is presented in Appendix B, "Fish and Wildlife".

Initial habitat development costs are estimated to be $30,000. Deer range habitat manipulation is estimated to cost $20,000 at 10-year intervals. The total present worth value of wildlife preservation costs would be $130,000. The equivalent average annual cost would be about $6,000.

Summary of Project Costs. A summary of the estimated project costs during the 50-year period of analysis is presented in Table 19. The capital cost of the project is estimated to be $8,830,000. Present worth of total expenditures is estimated to be $10,380,000. The average annual equivalent cost would be $483,000.

TABLE 19

SUMMARY OF HULEN PROJECT COSTS

Project Feature	Present Worth			Average Annual Equivalent Cost
	Capital Cost	Operation, Maintenance, Replacement, and General Expenses	Total	
Dam, Reservoir, and Appurtenances	$7,090,000	$430,000	$ 7,520,000	$350,000
Irrigation Canals	1,120,000	110,000	1,230,000	57,200
Access Rights and Stream Improvements for Salmon Spawning	320,000	0	320,000	14,900
Recreation Facilities	510,000*	670,000	1,180,000	54,900
Preservation of Wildlife	30,000	100,000	130,000	6,000
Total	9,070,000		10,380,000	483,000

* Includes present worth value of future facilities.

Project Accomplishments and Benefits

Both the local and statewide economy would benefit from construction of the Hulen Project as proposed herein. The accomplishments and benefits from each project purpose, due to construction of a reservoir with a storage capacity of 136,000 acre-feet, are discussed in this section.

Local Irrigation. The Gas Point Road subservice area as shown on Plate 4 contains 7,000 acres of land classified as irrigable. Of this area, 6,600 acres, having a maximum annual water requirement of 20,000 acre-feet, could be served by this project.

The proposed project would provide a firm annual yield of 24,000 acre-feet at the reservoir on an irrigation schedule. This would meet projected maximum future demands for irrigation water in the Gas Point Road subservice area and would allow 4,000 acre-feet of transportation losses.

Irrigation benefits would average about $187,000 annually. The present worth value of this benefit would be about $4,020,000.

Fishery Enhancement. Department of Fish and Game studies show that gravels in 19 miles of the main stem of Cottonwood Creek would be excellent for salmon production if water is provided in the proper amounts at the proper time and temperature. Illustration 1 shows two typical sections of these potential spawning gravels. Hulen Reservoir as proposed herein would provide near optimum water requirements for fish. A firm water supply of about 38,000 acre-feet made available on a fisheries demand schedule would produce about 22,000 adult salmon spawners annually. The monthly distribution of this demand is shown in Table 16. Historical streamflow records indicate that in other months flow requirements for incubation of eggs and transportation of fry would be supplied by natural streamflow from the remainder of the Cottonwood Creek drainage basin.

Figure 3 shows the flow in Cottonwood Creek during the spawning season under project conditions, as compared to the median impaired flow for the period 1922 to 1941. Recorded monthly flows for a typical dry year are also shown. Regulation of North Fork Cottonwood Creek at times of high flow during the spawning season will also be an accomplishment of the project, since a reduction of high flows in the stream channel will allow more productive use of available gravels.

An annual increase of 22,000 adult spawners in Cottonwood Creek would produce an increase in the ocean commercial catch of about 52,000. The sport catch would be increased by about 14,000.

Annual benefits from this increased salmon catch would be about $241,000. The capitalized value would be about $5,180,000. The method used to compute these benefits was presented earlier in this chapter. A more detailed description of the salmon potential and possible production is presented in Appendix B.

Recreation. Water-associated recreation in the form of boating, picnicking, reservoir fishing, and swimming would be provided at Hulen Reservoir. Provision of water for fishery enhancement would be especially compatible with reservoir recreation since water stored for fishery enhancement purposes would not be released until after the recreation season (June through September). With adequate facilities provided for the predicted demand, it is estimated that about 40,000 recreation visitor-days of use would occur annually at the beginning of project operation, increasing to 270,000 visitor-days annually by year 2020. Appendix A presents the total estimated visitor-day use by decades at Hulen Reservoir.

Illustration 1

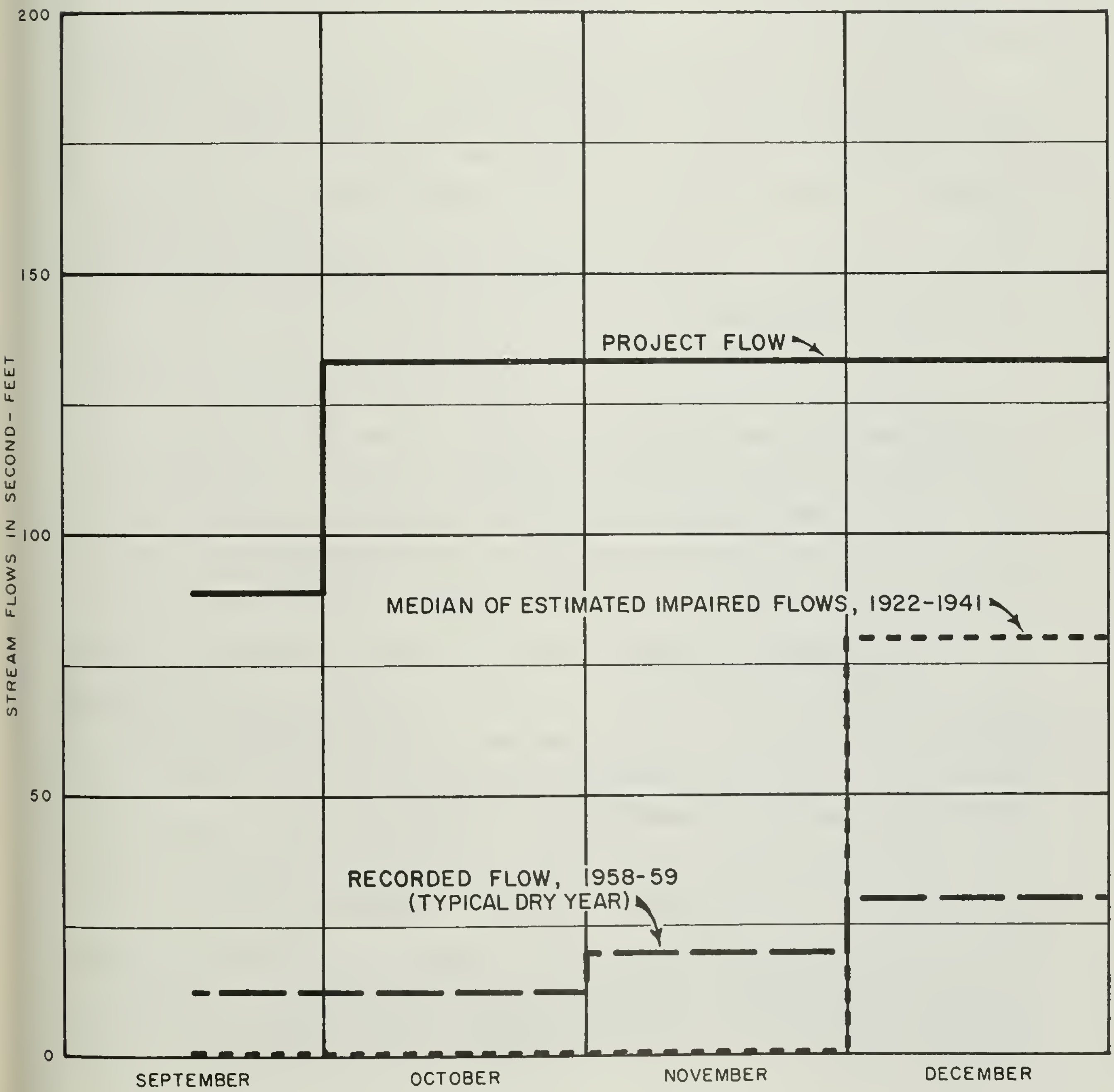
Potential Salmon Spawning Gravels in Main Stem Cottonwood Creek

Looking upstream at Department of Fish and Game study section located about 17 miles from the Sacramento River. Note the excellent spawning gravels and riffles.

Looking downstream from U. S. Highway 99 bridge about 5 miles from the Sacramento River. Note the abundance of suitable salmon spawning gravels.

FIGURE 3

COMPARISON OF AVERAGE MONTHLY STREAM FLOWS
IN NORTH FORK COTTONWOOD CREEK
BELOW HULEN DAM DURING THE SALMON SPAWNING SEASON



Total recreation benefits for this project were estimated to have a capitalized value of about $4,000,000. The equivalent average annual benefit would be $186,000.

Flood Control. Under present conditions, agricultural lands along the main stem of Cottonwood Creek suffer flood damages at frequent intervals. Damages come from inundation of farming land and from stream bank erosion. There is occasionally some damage to public facilities, such as roads and bridges and very infrequently some residential and commerical property is damaged.

Because Hulen Reservoir would be operated to supply irrigation and fishery enhancement water during the summer and fall months, there would generally be at least 40,000 acre-feet of reservoir storage available on December 1 to impound flood waters. Reduction in flood damages in the lower Cottonwood Creek area due to this flood reservation storage was estimated at $20,000 annually. The capitalized value of this amount would be $430,000.

As stated earlier, an annual flood control benefit of 50 cents per acre-foot of active storage was assigned to each tributary reservoir for flood reduction in the Sacramento Valley between Red Bluff and Colusa. This remote benefit would total about $65,000 annually. The capitalized value of this amount would be $1,400,000.

Total capitalized value of flood control benefits would be $1,830,000. The equivalent average annual value is $85,000.

Conservation for Export. Since Hulen Reservoir would be operated largely for fishery enhancement, water which previously would have reached the Delta during periods of spill would now be delivered during periods of deficiency. It is estimated that water conserved by this project would increase the annual Delta yield by about 34,000 acre-feet.

Benefits from this water would have an average annual equivalent value of $365,000. The capitalized value would be $7,850,000.

Summary of Project Benefits. A summary of the estimated project benefits during the 50-year period of analysis is presented in Table 20. The present worth value of the total benefits which would accrue over the

50-year period is estimated to be $22,880,000. The equivalent average annual benefit would be $1,064,000.

TABLE 20

SUMMARY OF HULEN PROJECT BENEFITS

Project Purpose	Present Worth of Total Benefits	Average Annual Equivalent Benefits
Local Irrigation	$ 4,020,000	$ 187,000
Fishery Enhancement	5,180,000	241,000
Recreation	4,000,000	186,000
Flood Control	1,830,000	85,000
Conservation for Export	7,850,000	365,000
Total	22,880,000	1,064,000

Economic Justification

For a project to be economically justified, the primary tangible benefits from the project must exceed the total project cost when reduced to a similar time basis. In other words, the benefit-cost ratio must be greater than unity.

The present worth value of the project benefits was estimated to be $22,880,000. The total capitalized cost of the project, based on 1963 price levels and including the present worth value of future expenditures for additions and for operation and maintenance, was estimated to be $10,380,000. The resulting comparison of benefits and costs indicate that the project is economically justified by a ratio of 2.2 to 1.0.

Allocation of Project Costs

A preliminary cost allocation was made to determine the proportions of the cost of the multiple-purpose project that should be charged to each of the various project purposes. The separable costs -- remaining benefits method of analysis was used. For each of the purposes, the benefits set forth above would be limited by the least costly alternative method of providing the service. Table 21 presents a summary of the preliminary cost allocation. This allocation shows that the cost of producing new water supplies to the Delta would be only $114,000 for 34,000 acre-feet of yield. Since it was assumed that the demand for additional Delta water will not

TABLE 21

PRELIMINARY ECONOMIC COST ALLOCATION FOR HULEN PROJECT

(Based on average annual equivalent values in dollars)

	Local Irrigation	Fishery Enhancement	Recreation	Flood Control	Conservation for Export	Total
Benefits	$187,000	$241,000	$186,000	$85,000	$365,000	$1,064,000
Alternative Costs	120,000	216,000	1/	1/	212,000	--
Total Justifiable Costs 2/	120,000	216,000	186,000	85,000	212,000	819,000
Separable Costs 3/	77,000	54,000	55,000	0	41,000	227,000
Remaining Benefits 4/	43,000	162,000	131,000	85,000	171,000	592,000
Percentage Distribution of Remaining Benefits	7.3%	27.4%	22.2%	14.3%	28.8%	100.0%
Total Project Cost						483,000
Total Separable Costs						227,000
Total Remaining Joint Costs						256,000
Allocated Remaining Joint Costs 5/	19,000	70,000	57,000	37,000	73,000	256,000
Separable Costs	77,000	54,000	55,000	0	41,000	227,000
Total Allocated Costs	96,000	124,000	112,000	37,000	114,000	483,000

1/ Assumed to be in excess of benefits.
2/ The justifiable cost is the smaller of the two values, benefits and alternative costs.
3/ Separable costs are the difference between the total project cost, and the cost with a given purpose excluded.
4/ Remaining benefits represent the difference between total justifiable costs and the separable costs.
5/ Remaining joint costs are allocated in accordance with the percentage distribution of remaining benefits.

occur until 1980, water would be delivered only during the last 40 years of the period of project analysis. Based on this assumption, the cost per acre-foot of water delivered would be about $5.30. The additional cost of conveyance facilities to the area of use would increase the cost to the user.

The allocated costs of developing local agricultural water requirements is $95,000 for 20,000 acre-feet of yield, or about $4.80 per acre-foot. This cost is only slightly less than the alternative cost of ground water development which was estimated to be $6 per acre-foot. The possibility therefore exists that local interests might elect to develop ground water to satisfy the demand for irrigation water in the Gas Point Road subservice area rather than to develop a surface supply from the Hulen Project.

In the event that local water demands might be developed from another source, an alternative Hulen Project was analyzed which excluded local irrigation as a project purpose. A summary of the costs and accomplishments of this alternative project is presented in the following section of the report.

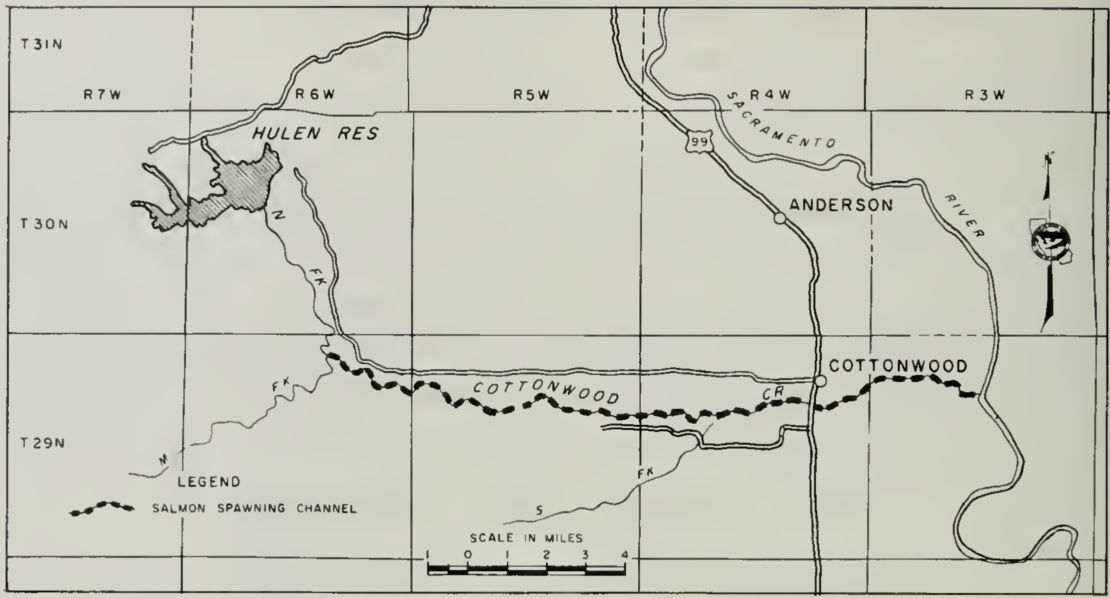
Alternative Hulen Project

In view of the possibility that ground water development for irrigation might be more desirable from the local users' standpoint than a surface supply, or that the local agency may elect to delay development of irrigable lands, this section presents a Hulen Project which excludes local irrigation as a project purpose.

Reservoir sizing studies for a multiple-purpose fishery enhancement, recreation, flood control, and export project indicated that a reservoir with 132,000 acre-feet of storage capacity would maximize net project benefits. Figure 4 presents the project features and accomplishments of the Alternative Hulen Project. The total capitalized cost of the project would be $9,040,000. Project benefits accruing over the 50-year period and reduced to present worth values are $19,300,000. The average annual equivalent costs and benefits are $421,000 and $900,000, respectively. The resulting benefit-cost ratio of 2.1 to 1.0 indicates an economic justification that is only slightly lower than that of the previously described Hulen Project. Consequently, a Hulen Project with or without local irrigation development is economically justified at the present time.

FIGURE 4

ALTERNATIVE HULEN PROJECT



General Project Features
(All elevations are USGS datum)

Dam

Location . . . . Section 16, T30N, R6W, MDB&M
Type . . . . Zoned Earthfill
Height Above Streambed, in Feet 220
Crest Elevation, in Feet 880
Volume of Fill, in Cubic Yards 2,400,000

Reservoir

Drainage Area, in Square Miles 86
Water Surface Elevation at Normal Pool, in Feet 867
Storage Capacity, in Acre-Feet 132,000
Water Surface Area, in Acres 2,640

Spillway

Type . . . . Gated weir with three 20' x 20' gates
Weir Crest Elevation, in Feet 847
Design Capacity, in Second-Feet 30,000

Outlet Works

Type . . . . 36-inch steel pipe in concrete-lined diversion tunnel

Project Accomplishments

Local Irrigation Yield, in Acre-Feet Per Year 0
Salmon Enhancement, in Numbers of Increased Annual Catch 75,000
Yield to Sacramento-San Joaquin Delta, in Acre-Feet Per Year . . . 35,000

Dippingvat Project

The Dippingvat Project consists of a dam and reservoir on South Fork Cottonwood Creek, recreation facilities around the reservoir, stream improvement for salmon spawning, and wildlife habitat development. The damsite is in Tehama County about 27 miles upstream from the confluence of South Fork Cottonwood Creek and the main stem of Cottonwood Creek. The drainage area tributary to the damsite is about 127 square miles. The estimated average annual runoff from 1921-22 through 1940-41 was 102,000 acre-feet.

Almost the entire length of the South Fork channel has excellent gravels suitable for salmon spawning. However, during the spawning season streamflow is generally inadequate and only a few fish utilize the stream in its natural condition. Illustration 2 shows the available gravels at two sections of South Fork Cottonwood Creek below Dippingvat Reservoir. A reservoir formed by a dam at the Dippingvat site would conserve high winter runoff for release down the channel at the proper time to provide substantial enhancement to the present salmon runs. In addition the reservoir would provide suitable environment for water-associated recreation development; it would provide some flood control, both in the area along Cottonwood Creek and along the Sacramento River; and it would increase the export yield from the Sacramento-San Joaquin Delta.

Project Analysis

Preliminary study of the Dippingvat Project indicated that there would be a demand for each of the following project purposes: local irrigation, fishery enhancement, recreation, flood control, and conservation for export. Studies were then made to determine if each of these purposes were economically justified for inclusion as project functions. Results indicated that the specific costs of each purpose were less than the benefits that would be derived; consequently, each purpose was included in the project sizing analysis.

Reservoir Sizing. Net benefits for all proposed project purposes were estimated for reservoirs with various storage capacities. Two multiple-purpose projects were sized to maximize the net project benefits. One project, which included the purposes of local irrigation, fishery enhancement, Illustration 2

Potential Salmon Spawning Gravels in South Fork Cottonwood Creek

Looking downstream from Oxbow Bridge about 5 miles below Dippingvat damsite. Even this far upstream (22 miles from Main Stem Cottonwood Creek) good spawning gravels are available.

Looking across the stream channel about 5 miles upstream from Main Stem Cottonwood Creek. Note the wide expanse of potential spawning gravels.

recreation, flood control, and conservation for export, was found to have maximum net project benefits with a reservoir having a storage capacity of 74,000 acre-feet. A similar project which included all proposed purposes except local irrigation was also studied. This project would produce maximum net benefits with a reservoir having a storage capacity of 71,000 acre-feet.

In order for a given purpose to be included in a project, the separable costs of including that purpose must be less than the justifiable cost. The justifiable cost represents either the estimated benefits or the least costly alternative which could provide the services, whichever is less.

A preliminary analysis was made to determine if all of the proposed project purposes could be economically included in the project. The minimum annual cost of including local irrigation as a project purpose was found to be $65,000 annually, whereas the alternative cost of ground water development was only $54,000 annually. Therefore, local irrigation was excluded as a project purpose for Dippingvat Reservoir. The separable cost of all other purposes was less than the justifiable cost, so the project which maximized net benefits for these purposes was formulated. Dippingvat Reservoir was, therefore, sized with a storage capacity of 71,000 acre-feet.

General Features. The Dippingvat Project as proposed would consist of the following project features: (1) dam and appurtenant structures, (2) reservoir, (3) stream improvement for salmon spawning, and (4) recreation facilities. General project features are shown in Figure 5.

Project Operation. Operation studies of the reservoir to determine project water yields were completed in accordance with the operation criteria set forth at the beginning of this chapter. The reservoir was operated to provide maximum salmon enhancement, reservoir recreation, export yield, and flood control. Table 22 presents an annual summary of the monthly operation study of the Dippingvat Project with a storage capacity of 71,000 acre-feet. No yield was supplied for local irrigation since ground water could be developed at a lower cost.

FIGURE 5

DIPPINGVAT PROJECT

General Project Features
(All elevations are USGS datum)

Dam

Location	Section 36, T27N, R7W, MDB&M
Type	Earth and Rockfill
Height Above Streambed, in Feet	210
Crest Elevation, in Feet	1,183
Volume of Fill, in Cubic Yards	1,420,000

Reservoir

Drainage Area, in Square Miles	127
Water Surface Elevation at Normal Pool, in Feet	1,169
Storage Capacity, in Acre-Feet	71,000
Water Surface Area, in Acres	975

Spillway

Type	Gated weir with two 40' x 30' radial gates
Weir Crest Elevation, in Feet	1,139
Design Capacity, in Second-Feet	62,000

Outlet Works

Type	6-foot-diameter concrete horseshoe tunnel with slide gates

Project Accomplishments

Local Irrigation Yield, in Acre-Feet Per Year	0
Salmon Enhancement, in Numbers of Increased Annual Catch	127,000
Yield to Sacramento-San Joaquin Delta in Acre-Feet Per Year	22,000

TABLE 22

SUMMARY OF MONTHLY OPERATION STUDY OF DIPPINGVAT RESERVOIR
71,000 Acre-Feet of Storage

(In acre-feet)

Runoff Year	Storage on Oct. 1	Inflow[a]	Water Releases and Losses				
			Fishery Enhancement	Evaporation	Release for Prior Rights[b]	Spill	Total
1921-22	17,100	99,300	56,000	3,300	4,000	0	63,300
22-23	53,100	71,500	56,000	3,000	0	3,500	62,500
23-24	62,100	16,100	28,000[c]	2,400	0	0	31,200
24-25	47,800	157,900	56,000	3,100	8,200	70,300	137,600
1925-26	68,100	71,900	56,000	2,900	0	23,300	82,200
26-27	57,800	196,700	56,000	3,100	4,100	125,000	188,200
27-28	66,300	139,700	56,000	3,100	600	83,900	143,600
28-29	62,400	27,600	56,000	2,000	0	0	58,000
29-30	32,000	70,800	56,000	2,300	0	0	58,300
1930-31	44,500	26,800	28,000[c]	2,300	0	0	30,300
31-32	41,000	56,200	56,000	2,300	1,400	0	59,700
32-33	37,500	43,900	56,000	1,300	3,600	0	60,900
33-34	20,500	37,100	28,000[c]	1,700	0	0	29,700
34-35	27,900	77,100	56,000	2,300	3,200	0	61,500
1935-36	43,500	97,500	56,000	2,900	0	21,300	80,200
36-37	60,800	55,900	56,000	2,600	3,300	0	61,900
37-38	54,800	282,400	56,000	3,100	6,600	204,000	269,700
38-39	67,500	32,200	56,000	2,400	0	0	58,400
39-40	41,300	159,000	56,000	2,900	900	78,100	137,900
1940-41	62,400	325,000	56,000	3,100	5,300	256,900	321,300
Average	48,600	102,200		2,600	2,100		

a/ Estimated future impaired flows at Dippingvat damsite.
b/ Additional release in May, June, July, and August to satisfy prior downstream rights.
c/ Deficiency of 50 percent in release in 1924, 1931, and 1934.
NOTE: Storage at normal pool is 71,000 acre-feet. Storage on October 1, plus inflow, minus water releases and losses, equals storage on following October 1. A minimum storage of 8,300 acre-feet was reached on March 1, 1933. Normal pool storage of 71,000 acre-feet was reached during the winter months of each year in which spills occurred.

Geology

Dippingvat damsite is located in an area of moderate relief and northwest-trending ridges and valleys. The damsite was formed by the South Fork Cottonwood Creek which has cut a V-shaped notch in Rocky Ridge. This ridge consists of resistant layers of sandstone and conglomerate which dip northeastward at angles of 35 to 45 degrees.

Damsite Geology. The rock which forms the foundation for the proposed dam is composed of downstream dipping beds of mudstone, conglomerate, and sandstone of various thicknesses. The mudstone is firm and compact, but it is brittle and slakes rapidly when exposed to air. The conglomerate is hard, well cemented, massive, and composed of pebbles and small cobbles in a matrix of sand. Competent sandstone occurs near the toe of the proposed dam in beds which vary from a few inches to several feet in thickness.

Several faults exist at the damsite as shown on Plate 8, "Dippingvat Dam and Reservoir on South Fork Cottonwood Creek". The most significant fault, which cuts directly through the V-notch, has experienced about 75 to 100 feet of apparent horizontal displacement. Some gouge or sheared shale appears in a narrow zone along the fault but otherwise there has been little disturbance of the rock adjacent to the fault. Some special treatment and cleaning out of the sheared material will be necessary but the fault does not appear to be a serious defect in the foundation and would not jeopardize the safety of the dam.

No subsurface foundation exploration nor rock testing has been conducted at the damsite. However, similar rock exists at the Fiddlers damsite and results of extensive tests made on the mudstone, the weakest rock unit, indicate that rock at this site would provide a suitable foundation for a fill-type dam.

The spillway would be founded on beds of shale, sandstone, mudstone, and conglomerate. Because of the erodible nature of the mudstone, complete lining of the spillway would be necessary.

The stream diversion and outlet works tunnel would be located in the left abutment. Tunneling conditions should be good, and only light support would be required. However, lining would be required to prevent erosion.

Reservoir Geology. The reservoir area is underlain by beds of mudstone, sandstone, and siltstone. Formations of this type should not present any problem of leakage from the reservoir or landslides into the reservoir. Reservoir silting would be very minor.

Construction Materials. Exploration for construction materials that could be used for Dippingvat dam was very limited. Four auger holes were drilled in a possible impervious borrow area about 2-1/2 miles east of the damsite and several samples of the material were tested in the laboratory. These tests indicated that the practically unlimited quantities of material available from this source would be suitable for impervious fill.

Pervious materials suitable for a transition between an impervious core and a rock shell would be available about 2-1/2 miles downstream from the damsite at McCartney Place. The material consists of an estimated 180,000 cubic yards of stream-deposited sand and gravel.

An excellent source of rockfill material is available one-half mile downstream from the site. The rock is well cemented, medium-grained sandstone which occurs in several beds ranging in thickness between 30 and 80 feet. Each of these beds is overlain by layers of sandstone and mudstone.

An additional source of rockfill can be obtained by selective quarry operations at a site located south of the stream, although considerable waste, consisting of mudstone and thin sandstone beds, will probably be necessary.

Possible sources of fill material are shown on the materials location map on Plate 8.

Project Designs and Costs

The designs and costs of the Dippingvat Project are presented in the following paragraphs under the headings of dam and appurtenant structures, reservoir, stream management for fishery enhancement, preservation of wildlife, and recreation.

Dam and Appurtenant Structures. A composite earth and rockfill dam consisting of quarried rock and an impervious earth core was selected for Dippingvat damsite. This type of dam was chosen to make the best economic use of available construction materials while assuring adequate safety of the dam structure.

The dam would be 210 feet high, would have a crest width of 30 feet, and a crest length of about 650 feet. The crest would be at elevation 1,183 feet, USGS datum. Plate 8 presents the plan, profile, and maximum section of Dippingvat dam.

The embankment section was designed to be placed in four zones. Zone 1 would be an impervious central core having side slopes of 0.75 to 1.0. Sufficient material suitable for the impervious section is available about 2-1/2 miles east of the damsite.

The sandstone beds one-half mile downstream from the damsite would supply sufficient material for the rockfill section, designated as Zone 2 on Plate 8. The outside slopes of the dam would be placed at 2.5 to 1 on the upstream face and at 2 to 1 on the downstream face.

Stream-deposited sands and gravels would be used for Zone 4, the transition between the impervious and rockfill sections.

Clearing and foundation preparation would not be expensive items at this damsite. An estimated average depth of stripping of 6 feet would be necessary under the entire structure with an additional 10-foot cutoff trench under the impervious section to reduce seepage. Seepage through the abutments would be controlled by placing a grout curtain under the impervious section of the embankment.

The total embankment volume for Dippingvat Dam would be about 1,420,000 cubic yards.

The Spillway would be excavated through the ridge which forms the right abutment. Excavation would be through beds of shale, conglomerate, and sandstone. Most of the shales could be ripped, but blasting would be necessary in the conglomerate and sandstone.

Cost studies indicated that the least total cost of dam and appurtenant structures would be realized by using a gated spillway. The spillway structure would consist of (1) a 90-foot-wide approach channel which would be entirely concrete-lined to prevent erosion, (2) a control structure consisting of a 9-foot-high conc ete overflow weir founded on firm rock, with three counterweighted, automatic-operating radial gates, each 40 feet long and 20 feet high, and (3) a 650-foot-long, concrete-lined chute section with a constant bottom width of 80 feet.

The spillway was designed to meet the following conditions: (1) it must pass the probable maximum flood without damage to the dam, and (2) it must pass the maximum flood of record over the spillway gates with the gates closed. The spillway was designed to pass the probable maximum flood inflow of 62,000 second-feet with a maximum spillway discharge of 60,000 second-feet and a maximum water surface elevation 7 feet above normal pool. The maximum flood of record, 15,000 second-feet, was routed over the top of the spillway gates as a check of the safety of the dam against overtopping in the event of failure of the gate operating mechanism. On the basis of this flood routing study, the height of the dam was increased to provide 14 feet of surcharge elevation above normal pool.

The spillway gates would normally be operated by electrically powered hoists. In addition, a float chamber would be provided to ensure automatic opening at a rate of approximately 5 feet of gate rise to 1 foot of water surface rise at stages above normal pool. This device would function without any external source of power.

A Tunnel through the left abutment of the damsite would serve a dual purpose. It would be used for diversion of the streamflow during construction and would house the outlet conduit after the dam had been constructed. The tunnel would require only minor support, but would be completely concrete lined.

The outlet works would consist of (1) an intake structure which would contain two 36-inch hydraulically operated slide gates to draw water from a high and a low level in the reservoir to provide some control of water temperatures below the dam, (2) a 30-inch welded steel pipe installed in the downstream 60 feet of the diversion tunnel, and (3) a 30-inch Howell-Bunger valve which would be used to dissipate energy and to regulate flow. The outlet works was designed to release 150 second-feet at minimum pool elevation.

Reservoir. Approximately 2,200 acres of land must be acquired for the reservoir and areas suitable for recreation development. The majority of this land is uncleared brush and range land with scattered oak trees. About 980 acres would be within the proposed reservoir area. This area would require at least partial clearing. There are no roads or utilities in the reservoir area.

Table 23 presents a summary of capital costs of Dippingvat dam, reservoir, and appurtenances.

TABLE 23

SUMMARY OF COSTS OF DIPPINGVAT DAM, RESERVOIR, AND APPURTENANCES (In Dollars)

Item	Construction Cost	Engineering, Administration, Contingencies, and Interest During Construction	Total Capital Cost
Dam and Appurtenances			
Embankment	2,460,000		
Spillway	1,880,000		
Outlet Works	380,000		
Subtotal	4,720,000	1,780,000	6,500,000
Reservoir			
Land Acquisition and Clearing	90,000		
Construction Facilities and Access Roads	200,000		
Subtotal	290,000	110,000	400,000
Total	5,010,000	1,890,000	6,900,000

Stream Management for Fishery Enhancement. The entire length of South Fork Cottonwood Creek below Dippingvat damsite and that portion of the main stem Cottonwood Creek below the confluence with the South Fork could be improved for salmon spawning with water released from Dippingvat Reservoir. In order to properly manage the stream channel and improve some areas for maximum spawning capacity, it would be necessary to acquire rights to manage the entire length of the channel. The area required would be about 900 acres and would cost about $270,000.

It was estimated that the present average annual salmon run in this reach of stream is about 1,000 fish. With improved flows provided by the proposed project, the annual run could be increased to 44,000 fish, or an increase of about 43,000.

In order to initiate the salmon runs the stream should be stocked with fingerling salmon at the rate of 200 fingerlings per adult spawner for each of the four years following project construction. The costs of these fish would be about $88,000 per year for four years.

Minor maintenance of the stream channel could be carried out by the Regional Headquarters of the Department of Fish and Game; consequently, no annual costs were assigned to the project for operation and maintenance of the spawning gravels.

Total estimated initial cost of increasing the salmon runs in South Fork Cottonwood Creek would be $590,000. The average annual equivalent cost would be $27,500.

Preservation of Wildlife. Department of Fish and Game studies show that development of the Dippingvat Project would cause loss of habitat for deer and quail. Their estimates indicate that control and improvement of about 580 acres of land above the maximum reservoir pool elevation on the south side of the reservoir would be required to compensate for deer range and quail habitat losses.

Initial development costs of this land are estimated to be $27,500. Deer range habitat manipulation is estimated to cost $12,800 at 10-year intervals. The total present worth value of wildlife preservation costs would be $110,000. The equivalent average annual cost would be $5,100.

Recreation. Estimates of the recreation facilities needed at the Dippingvat Project to meet the projected recreation demand were made to determine if the site could be developed to meet the demand and to estimate the cost of providing recreation facilities. Estimated demands would support about 15 recreation units during the first decade of project operation. These recreation units were designed for day use only. The number of recreation units required to meet the future demand was also estimated on the basis of recreation use projections.

Costs of the recreation facilities were based on state park experiences and were estimated to be $2,100 per recreation unit. This unit cost would include water supply and sanitary facilities and interior recreation roads. Costs of other recreation facilities such as boat launching areas and swimming beaches were estimated separately.

Costs of operation, maintenance, and replacement of the recreation facilities were estimated from costs incurred at similar recreation areas. This cost was found to be about 30¢ per visitor day of use.

The total present worth cost of recreation facilities including present worth of operation, maintenance, and replacement is $350,000. The average annual equivalent cost is $16,300.

Summary of Project Costs. A summary of the estimated project costs during the 50-year period of analysis is presented in Table 24. Capital cost of the project is estimated to be $7,700,000. The estimated present worth of the total expenditures is $8,290,000. The average annual equivalent cost would be $386,000.

TABLE 24

SUMMARY OF DIPPINGVAT PROJECT COSTS

Project Feature	Present Worth			Average Annual Equivalent Cost
	Capital Cost	Operation, Maintenance and Replacement	Total	
Dam, Reservoir, and Appurtenances	$6,900,000	$340,000	$7,240,000	$337,100
Access Rights and Stream Improvement for Salmon Spawning	590,000	0	590,000	27,500
Recreation Facilities	180,000*	170,000	350,000	16,300
Preservation of Wildlife	30,000	80,000	110,000	5,100
Total	7,700,000		8,290,000	386,000

* Includes present worth value of future expenditures.

Project Accomplishments and Benefits

Both the local and statewide economy would benefit from the Dippingvat Project as proposed herein. The accomplishments and benefits from each project purpose, due to construction of a reservoir with a storage capacity of 71,000 acre-feet, are discussed in this section.

Fishery Enhancement. Figure 6 shows the flow in South Fork Cottonwood Creek during the spawning season for project conditions compared to the median impaired flow for 1922 through 1941. Recorded monthly flows for a typical dry year are also shown. Regulation of South Fork Cottonwood Creek at times of high flow during the spawning season will also be an accomplishment of the project. By reducing the high flows in the spawning channel, more productive use can be made of the available gravels.

The assured fishery enhancement releases provided by the Dippingvat Project would make sufficient gravels available for an estimated 43,000 adult salmon. This would provide an annual increase in the ocean commercial catch of about 102,000 salmon. The sport catch would be increased by about 25,000 salmon annually. Benefits from increased production produced by these salmon would have a capitalized value of $10,400,000. This is equivalent to an average annual benefit of $484,000.

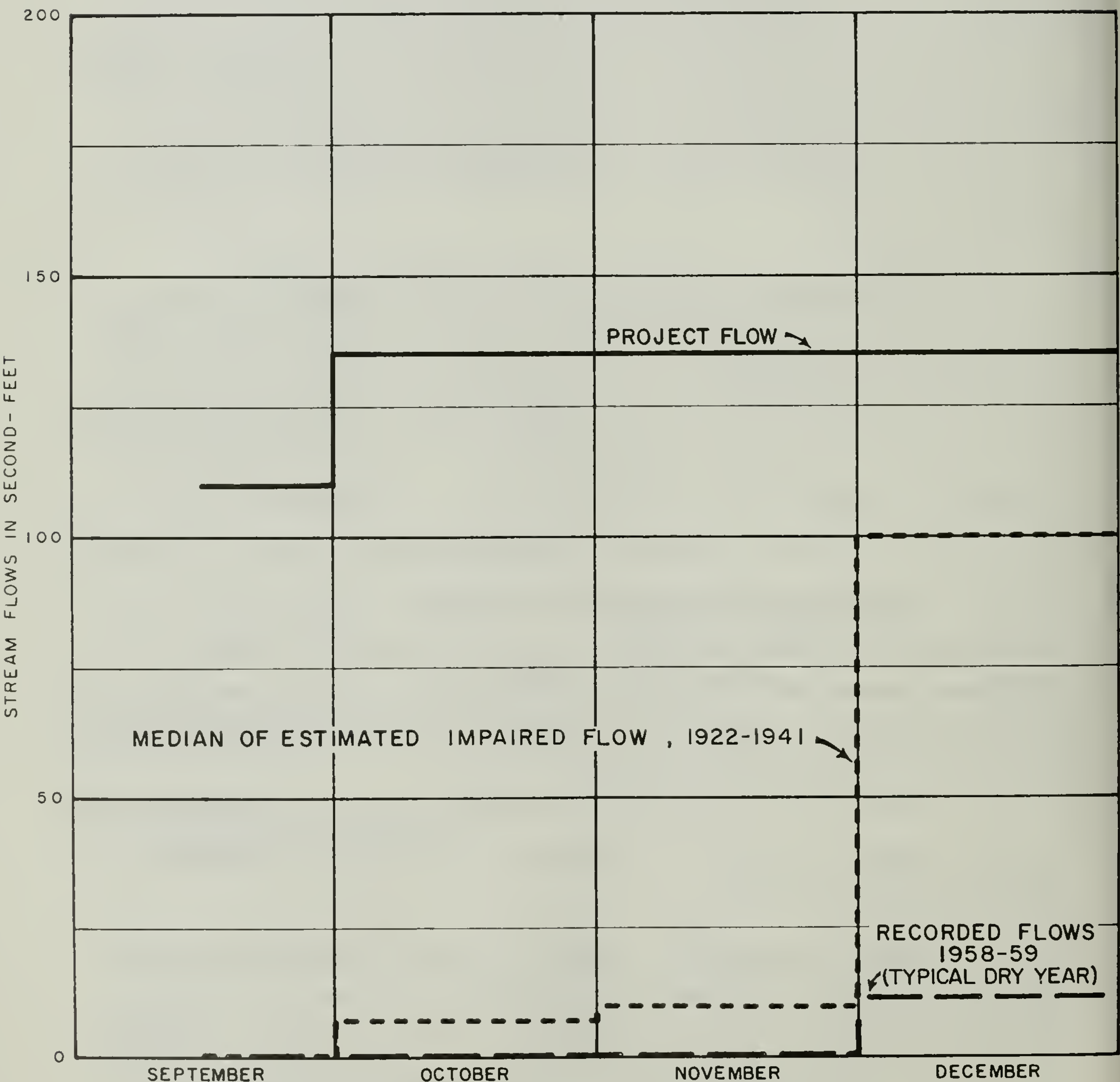
Recreation. Water-associated recreation in the form of boating, picnicking, reservoir fishing, and swimming would be provided at Dippingvat Reservoir. An estimated use of about 10,000 visitor-days would occur annually at the beginning of project operation, increasing to 70,000 visitor-days annually by year 2020.

Total recreation benefits for this project were estimated to have a capitalized value of about $1 million. The equivalent average annual benefit would be $46,000.

Flood Control. Under present conditions, agricultural lands along the main stem of Cottonwood Creek downstream from the confluence with the South Fork suffer flood damages at frequent intervals. Damages come from inundation of farming land and from streambank erosion. There

FIGURE 6

COMPARISON OF AVERAGE MONTHLY STREAM FLOWS
IN SOUTH FORK COTTONWOOD CREEK
BELOW DIPPINGVAT DAM DURING THE SALMON SPAWNING SEASON



is occasionally some damage to public facilities, such as roads and bridges, and very infrequently some residential and commercial property is damaged.

Because Dippingvat Reservoir would be operated to supply fishery enhancement releases during the summer and fall months, about 30,000 acre-feet of reservoir storage would generally be available on December 1 to impound flood waters. The annual reduction in flood damages in the lower Cottonwood Creek area due to this flood reservation storage was estimated to be about $20,000 annually.

As stated earlier, an annual flood control benefit of 50¢ per acre-foot of active storage was assigned to each tributary reservoir for flood reduction in the Sacramento Valley between Red Bluff and Colusa. This remote benefit would total about $33,000 annually. Annual flood control benefits would, therefore, total about $53,000. The capitalized value of this amount would be $1,140,000.

Conservation for Export. By virtue of Dippingvat Reservoir being operated to provide water for fishery enhancement, water which previously would have reached the Delta during periods of spill would instead be regulated and released during periods of deficiency. Water conserved by this project would increase the annual Delta yield by about 22,000 acre-feet.

Benefits from this water would have an average annual equivalent value of $240,000. The capitalized value of this benefit is $5,150,000.

Summary of Project Benefits. A summary of the estimated project benefits during the 50-year period of analysis is presented in Table 25. The present worth value of the total benefits which would accrue to the project is $17,690,000. The average annual equivalent value is $823,000.

TABLE 25

SUMMARY OF DIPPINGVAT PROJECT BENEFITS

Project Purpose	Present Worth of Total Benefits	Average Annual Equivalent Benefit
Fishery Enhancement	$10,400,000	$484,000
Recreation	1,000,000	46,000
Flood Control	1,140,000	53,000
Conservation for Export	5,150,000	240,000
TOTAL	17,690,000	823,000

Economic Justification

The present worth value of project benefits was estimated to be $17,690,000. The total capitalized cost of the project, based on 1963 price levels and including the present worth value of future expenditures for additions and for operation and maintenance, was estimated to be $8,290,000. The resulting comparison of benefits and costs indicate that the project is economically justified by a ratio of 2.1 to 1.

Allocation of Project Costs

A preliminary cost allocation was made to determine the proportions of the multiple-purpose project costs that should be borne by each of the various project purposes. These costs were apportioned according to the separable costs -- remaining benefits method of analysis. For each of the purposes the benefits set forth above would be limited by the least costly alternative of providing the service. Table 26 presents the results of the preliminary cost allocation.

The allocation to the 22,000 acre-feet of export yield was estimated to be $86,000 annually. Since it was assumed that the demand for additional water in the Delta will not occur until 1980, water would be delivered only during the last 40 years of the period of project analysis. Based on this assumption, the cost per acre-foot of water delivered would be $6.30.

TABLE 26

DIPPINGVAT PROJECT
PRELIMINARY ECONOMIC COST ALLOCATION
(Based on average annual equivalent values in dollars)

	Fishery Enhancement	Recreation	Flood Control	Conservation for Export	Total
Benefits	$484,000	$46,000	$53,000	$240,000	$813,000
Alternative Costs	359,000	1/	1/	137,000	---
Total Justifiable Costs 2/	359,000	46,000	53,000	137,000	595,000
Separable Costs 3/	57,000	16,000	0	12,000	85,000
Remaining Benefits 4/	302,000	30,000	53,000	125,000	510,000
Percentage Distribution of Remaining Benefits	59.2	5.9	10.4%	24.5	100.0%
Total Project Cost					386,000
Total Separable Cost					85,000
Total Remaining Joint Costs					301,000
Allocated Remaining Joint Costs 5/	178,000	18,000	31,000	74,000	301,000
Separable Costs	57,000	16,000	0	12,000	85,000
Total Allocated Costs	235,000	34,000	31,000	86,000	386,000

1/ Assumed to be in excess of benefits.
2/ The justifiable cost is the smaller of the two values, benefits and alternative costs.
3/ Separable costs are the difference between the total project cost, and the cost with a given purpose excluded.
4/ Remaining benefits represent the difference between total justifiable costs and the separable costs.
5/ Remaining joint costs are allocated in accordance with the percentage distribution of remaining benefits.

Fiddlers Project

Fiddlers Project in Shasta County would consist of Fiddlers dam, reservoir, and appurtenances on Middle Fork Cottonwood Creek; recreation facilities around the reservoir, and 29 miles of improved stream channel in the Middle Fork and main stem of Cottonwood Creek.

Fiddlers damsite is located about 10 miles upstream from the confluence of the Middle and North Forks of Cottonwood Creek. The drainage area above the site is 222 square miles. Estimated annual runoff for 1921-22 through 1940-41 averaged about 137,000 acre-feet.

Fiddlers Project could develop 20,000 acre-feet of local agricultural water for use in the Gas Point Road subservice area, and increase the salmon population in the Middle Fork and main stem Cottonwood Creek by about 30,000 fish annually. In addition it could provide substantial water-associated recreation benefits, provide a measure of flood control in the area along Cottonwood Creek and along the Sacramento River, and develop 37,000 acre-feet of new yield for export to the Sacramento-San Joaquin Delta.

Studies were made to determine if each of the above purposes were justified for inclusion in the project analysis. Results indicated that each purpose could be considered since the specific cost attributed to each purpose would be less than the benefits derived.

Reservoir Sizing

Project costs and benefits were estimated for reservoirs which varied in size from 20,000 to 175,000 acre-feet. Projects including various combinations of purposes were studied to determine the project size which would provide maximum net benefits. During this study it was found that no project could be formulated in which the benefits would exceed the costs.

For illustrative purposes a Fiddlers Project which includes a 170,000 acre-foot reservoir is discussed herein.

Project Operation

Project water yields were determined by operation studies completed under operation criteria set forth at the beginning of this chapter. The reservoir was operated to supply local irrigation demands and to enhance the salmon runs below the dam. In addition, consideration was given to development of water for export and to flood control.

Geology

Fiddlers damsite is located in an area of moderate relief with rounded hills rising 500 to 600 feet above the floor of a V-shaped valley. Middle Fork Cottonwood Creek is actively down-cutting and leaves terraces and moderately steep-walled cliffs along both sides of the stream channel.

The four main phases of the geologic study consisted of (1) geologic mapping, (2) diamond core drilling in the dam foundation, (3) exploration by auger holes, test pits, and trenches in the possible borrow areas, and (4) laboratory testing of construction materials. Four diamond drill core holes were drilled along the axis of the dam. About 100 power auger holes were drilled in several possible impervious borrow areas and 15 trenches were dug with a backhoe in three of these areas.

Damsite Geology. The predominant rock types at the damsite are mudstone, sandstone, and conglomerate. Plate 9, "Fiddlers Dam and Reservoir on Middle Fork Cottonwood Creek", shows a profile of the damsite and the geologic structure of the foundation.

No major faults were found at the damsite. There are some minor faults and shears in the mudstone but these would not cause foundation problems. Many of the shears are filled with calcite or healed over. Water tests performed on both abutments indicate that moderate grouting would be required to fill the fissures in the abutments and under the channel.

Reservoir Geology. The predominant rock type in the reservoir is mudstone with interbedded sandstone and siltstone. Leakage from the reservoir should be slight because of the impermeable nature of the rock.

Landslides, other than small ones in the weathered topsoil, should not be a problem in the reservoir. Likewise there should be very little reservoir silting.

Construction Materials. Of the several possible impervious material borrow areas studied, borrow area 1 on Plate 9, about 3 miles from the damsite, would produce the most suitable material. This area, which is part of the Tehama formation, contains more than 16,000,000 cubic yards.

The nearest large source of pervious material consists of dredger tailings located near the confluence of the North and Middle Forks of Cottonwood Creek about 9 miles downstream from the damsite, shown as borrow area 2 on Plate 9. These tailings were also considered for the Hulen Dam.

Two types of rock, sandstone and conglomerate, were studied for possible use as riprap. The sources of both are shown as borrow area 3 on Plate 9. Three areas containing conglomerate material totaling more than 300,000 cubic yards lie east and north of the damsite. Quarry sites for sandstone or conglomerate for riprap are available within 2 miles of the damsite.

Designs and Costs

A preliminary design and cost estimate was completed for a dam forming a reservoir with a storage capacity of 170,000 acre-feet. The dam, with crest elevation at 1,022 feet, USGS datum, would be 260 feet high and would have a crest width of 40 feet. It would consist of a homogeneous earthfill embankment with a pervious chimney drain and a layer of riprap on both faces. It would have side slopes of 3.5 to 1.0 on the upstream face and 2.5 to 1.0 on the downstream face. The total embankment would contain about 7,700,000 cubic yards.

The spillway, which would be constructed in a topographic saddle about eight-tenths of a mile northerly from the dam, was designed to pass the probable maximum flood inflow of 85,000 second-feet with a maximum spillway discharge of 73,000 second-feet. It would consist of an uncontrolled ogee weir with a crest length of 200 feet and a concrete-lined chute about 700 feet long. The entire spillway would be founded on mudstone.

The outlet works would consist of an intake structure, a 6-foot-diameter steel pipe inside of the 17-foot-diameter diversion tunnel, and an energy dissipating and control valve.

The project would require acquisition of about 6,000 acres of land for the reservoir and for recreational development. The estimated cost of these lands, based on recent comparable land sales in the area, would be $220,000.

Total capital costs of the dam, reservoir, and appurtenances were estimated to be $29,400,000, including engineering, contingencies, and interest during construction. Capitalized costs of these features, including present worth of operation, maintenance, and general expense, would be $30,100,000. The average annual equivalent cost is $1,400,000.

Costs of facilities required to transport water from Fiddlers Reservoir to the irrigation service area would be slightly greater than those required to deliver the water from Hulen since an additional 4 miles of canal and flume would be required to bring the water from Middle Fork Cottonwood Creek around and over the North Fork to the service area. The capitalized cost of the total delivery system would be about $1,350,000. The corresponding average annual equivalent cost is $63,000.

Costs of recreation facilities necessary to fulfill the predicted recreation demands were estimated at $2,100 per recreation unit. Operation, maintenance, and replacement of these facilities were estimated at 30 cents per visitor day. Total capitalized costs of recreation facilities, including present worth of operation and maintenance, are estimated to be $380,000. The average annual equivalent cost would be $18,000.

Fishery enhancement costs are made up of the cost of acquiring rights-of-way and the cost of planting fingerling salmon to initiate the spawning run. The capital cost of rights-of-way was estimated to be $230,000 and the cost of fingerling stocking was estimated at $60,000 each year for four years following project completion. The estimated total capitalized cost of fishery enhancement is $450,000. The corresponding average annual equivalent cost is $21,000. It was assumed that operation and maintenance of the spawning area would be handled by the Department of Fish and Game at no cost to the project.

The Fiddlers Reservoir area presently provides habitat for deer and quail. If a reservoir were constructed, adjacent areas would have to be improved to provide for the loss of this habitat. Sufficient deer habitat could be provided by the purchase and development of 320 acres of land west of and adjacent to the reservoir project lands and the improvement of an additional 440 acres of project lands near the reservoir. Installation of three quail guzzlers at strategic locations would mitigate the loss of quail habitat.

The capitalized cost of land purchase and improvement for wildlife preservation is estimated to be $130,000. The average annual equivalent cost is $6,000.

A summary of Fiddlers Project costs is presented in Table 27.

TABLE 27

SUMMARY OF FIDDLERS PROJECT COSTS
(170,000 Acre-Feet of Storage)

Item	Capitalized Costs	Average Annual Equivalent Costs
Dam, Reservoir, and Appurtenances	$30,100,000	$1,400,000
Irrigation Distribution Facilities	1,350,000	63,000
Recreation Facilities	380,000	18,000
Rights-of-Way and Initial Stocking for Fishery Enhancement	450,000	21,000
Wildlife Preservation	130,000	6,000
Total Project Costs	32,410,000	1,508,000

Project Accomplishments

The Fiddlers Project would accomplish the following project purposes: (1) local irrigation, (2) fishery enhancement, (3) recreation, (4) flood control, and (5) conservation for export. The benefits that could be derived from this project are presented in the following paragraphs.

Local irrigation benefits having a capitalized value of $4,020,000 would accrue to the project as a result of water supplied to the Gas Point Road subservice area. The average annual equivalent benefit would be $187,000.

Ten miles of Middle Fork Cottonwood Creek and the entire main stem of Cottonwood Creek (19 miles) would be improved for salmon spawning by water stored and released from Fiddlers Reservoir on a fisheries enhancement schedule. It is estimated that the adult salmon populations in the 29 miles of stream below the dam could be increased by 30,000 fish annually under project conditions. The capitalized benefit resulting from these fish would be about $6,450,000. The average annual equivalent benefit would be $300,000.

Reservoir-associated recreation would result from the 2,100 acres of water surface area and from the land developed for recreation use around the reservoir. It was estimated that 10,000 visitor days of recreation use would occur annually at the beginning of project operation and that this use would increase to 100,000 visitor days annually by the end of the 50-year period of analysis. The capitalized benefit from this use would be $1,270,000. The average annual equivalent benefit would be $59,000.

Water storage capacity at Fiddlers Reservoir would produce flood protection along the main stem of Cottonwood Creek in the vicinity of Cottonwood. Some measure of flood control would also be provided in areas along the Sacramento River downstream from the confluence with Cottonwood Creek. Benefits along Cottonwood Creek were estimated at $20,000 annually. Benefits to downstream areas were estimated to be about $85,000 annually. The total annual flood control benefit of $105,000 would have a capitalized value of $2,250,000.

Water stored in Fiddlers Reservoir during periods of surplus and released during periods of need for export to areas downstream from the local area would produce a firm yield of about 37,000 acre-feet per year at the Sacramento-San Joaquin Delta. The capitalized benefit from this water is $8,600,000. The average annual equivalent benefit would be $400,000.

A summary of the Fiddlers Project benefits is presented in Table 28.

TABLE 28

SUMMARY OF FIDDLERS PROJECT BENEFITS
(170,000 Acre-Feet of Storage)

Project Purpose	Capitalized Benefits	Average Annual Equivalent Benefits
Local Irrigation	$ 4,020,000	$ 187,000
Fishery Enhancement	6,450,000	300,000
Recreation	1,270,000	59,000
Flood Control	2,250,000	105,000
Conservation for Export	8,600,000	400,000
Total Project Benefits	22,590,000	1,051,000

Economic Justification

The present worth of project benefits throughout the 50-year period of economic analysis (1970-2020) was estimated to be $22,590,000. The total capitalized cost of the project, including present worth of future expenditures for additions and for operation and maintenance, was estimated to be $32,410,000. The resulting comparison of benefits and costs indicate that the Fiddlers Project is not economically justified under present economic conditions, having a benefit-cost ratio of only 0.7 to 1.0.

Rosewood Project

Rosewood Project in Tehama County would consist of a dam, reservoir, and appurtenances on the Dry Fork of South Fork Cottonwood Creek; recreation facilities around the reservoir; and 23 miles of improved stream channel for fishery enhancement.

Rosewood damsite is located on Dry Fork about 8 miles upstream from the junction with the South Fork Cottonwood Creek. The drainage area above the damsite contains about 127 square miles. This area produces much less runoff per square mile than any of the other Cottonwood Creek tributaries. Estimated average annual runoff for 1921-22 through 1940-41 was only 58,600 acre-feet, whereas an approximately equal drainage area above Dippingvat damsite on South Fork Cottonwood Creek produced an average annual runoff of 102,200 acre-feet for the same period.

Water stored in a reservoir at this site could be used to increase the total spawning salmon populations in Dry Fork and South Fork below the confluence with Dry Fork by about 9,500 fish annually, and would increase the annual adult salmon catch by about 28,500 fish. The reservoir could also provide a measure of flood control along Cottonwood Creek and along the Sacramento River. In addition, the project would provide an area which could be developed for water-associated recreation activities and it would increase the Delta export yield. It could also provide a water supply for agricultural use in the local area.

The water supply for Rosewood Reservoir could be supplemented by diversion of the flow of Cold Fork into Dry Fork. This could be accomplished by a diversion dam on Cold Fork in Section 17, Township 27N, Range 7W, MDB&M, and a canal leading from the reservoir along Weemasoul Road into Weemasoul Creek, a stream tributary to Rosewood Reservoir. The estimated average annual streamflow of Cold Fork for 1921-22 through 1940-41 is 29,900 acre-feet.

A preliminary cost estimate of the diversion structure required on Cold Fork indicates that the capital cost would be about $550,000. The average annual equivalent cost would be about $26,000.

A preliminary analysis was made of the Rosewood Project including the Cold Fork Diversion. This analysis showed that the addition of this diversion would produce benefits which were slightly less than the additional costs. Consequently, no further study was made of the Cold Fork Diversion. However, future studies of a Rosewood Project should include the possible addition of a diversion from Cold Fork.

Local agricultural requirements for the Evergreen Road subservice area shown on Plate 3 could be supplied with water conserved in a reservoir at the Rosewood site and conveyed to the service area in a system of canals and flumes at about elevation 700 feet, USGS datum. However, the terrain traversed by the conveyance facility is very rough, and preliminary estimates indicated that the cost of providing water from this source would be greater than the cost of ground water. Therefore, local irrigation was not considered as a project purpose in the final project analysis.

Reservoir Sizing

Project costs and benefits were estimated for a range of reservoir sizes. These sizes varied from a small reservoir capable of supplying only local water demands, to a large reservoir limited only by water supply and including all possible project purposes. When comparable costs and benefits were studied to determine the size that would yield maximum net benefits, it was revealed that project costs were in excess of benefits for all reservoir sizes. There is little variance in the benefit-cost ratio for any reservoir size. A project which includes a reservoir of 155,000 acre-foot capacity is presented herein for illustrative purposes only.

Project Operation

Project water yields were determined by operation studies completed under operation criteria set forth at the beginning of this chapter. The reservoir was operated to provide for maximum salmon enhancement after it was determined that the local irrigation demand could be more economically served from ground water. In addition, consideration was given to development of water for export and to flood control.

Geology

The area around Rosewood damsite and reservoir has moderate to low relief with gently rolling hills rising 200 to 400 feet above the broad, flat creek beds. The streams are actively down-cutting, leaving terraces and steep-walled cliffs along both sides of the stream channels.

Damsite. Foundation material at the proposed damsite consists of semiconsolidated beds of silty sand, sandy silt, and clay, with interbedded lenses of fine gravel and sand, all of the Tehama formation of Pliocene age.

Unconsolidated sediments consisting of sand and gravel occur in the channel section and similar material occurs as terraces above the channel.

Eighty-seven shallow power auger holes were drilled across the valley along and near the axis of the proposed dam to determine depth of overburden and physical characteristics of the Tehama formation and the terrace sediments. Three core holes were drilled in the channel section to check the semiconsolidated Tehama formation. Other field and laboratory tests were completed to aid in determining the porosity and density of the foundation materials.

The right abutment is part of the Tehama formation and consists of sandy silt and clay with some lenses of clayey gravel. The gravel lenses are believed to be discontinuous and should not present a seepage problem. No faults, shears, or landslides were observed.

Stream alluvium composed of sand and gravel layers, having a thickness of from 0 to 20 feet and an average thickness of about 10 feet, overlies the Tehama formation in the entire stream channel. There is no evidence of faults or shears in the channel section.

The left abutment rises sharply from the stream channel for a vertical distance of about 60 feet and then slopes gradually to the top of the abutment about 200 feet above streambed. The foundation material consists of sandy silts and clays similar to the right abutment. One steep ravine which would be partially covered by the upstream portion of the dam embankment, could be a troublesome landslide area if a dam is constructed. This particular area would require further study before a final design could be selected. There is no evidence of faults in this abutment.

Reservoir. The rock groups which lie within the reservoir area are mudstone, shale, and conglomerate of the Chico formation and the semiconsolidated sediments of the Tehama formation. Generally, there should be little seepage from the reservoir through these rock types. Also silting of the reservoir should be negligible.

Construction Materials. Thirty-seven power auger holes were drilled in areas possibly suitable for impervious and pervious borrow. Laboratory tests were completed on several samples taken from these test holes. Details regarding the extent of exploration and testing is available in the Department's unpublished office geology report.

Over 6,000,000 cubic yards of suitable impervious material are available within 1 mile of the proposed damsite. The borrow area is located upstream from the damsite and is designated Area 1 on Plate 10, "Rosewood Dam and Reservoir on Dry Creek".

Stream gravels in South Fork Cottonwood Creek, $3\frac{1}{2}$ miles southeast of the damsite, provide the nearest source of pervious material. This borrow area, shown as Area 2 on Plate 10, could provide more than 1,000,000 cubic yards of suitable material.

Sufficient quantities of material suitable for riprap may be obtained from the lower Cretaceous sandstone exposed in the hills approximately 10 miles upstream from the damsite. This area is shown as Area 3 on Plate 10.

Designs and Costs

A preliminary design and cost estimate was completed for a dam providing a reservoir with a storage capacity of about 155,000 acre-feet, and a water surface area of about 2,500 acres. The dam would consist of a homogeneous earthfill dam, 160 feet high, with a crest width of 30 feet, crest elevation of 785 feet, USGS datum, and side slopes of 3.5 to 1 on the lower portion and 3.0 to 1 on the upper portion of the upstream face and 2.5 to 1.0 on the downstream face. The embankment would contain about 5,700,000 cubic yards of fill.

The spillway, which would be constructed in a topographic saddle on the right abutment of the damsite, was designed to pass the probable maximum flood inflow of 37,500 second-feet with a spillway discharge of about 20,000 second-feet. It would consist of a concrete-lined approach channel, a concrete ogee weir, and a concrete-lined chute about 700 feet long. Surcharge over the spillway crest would be about 15 feet under probable maximum flood conditions.

The outlet works would consist of an intake tower and a 48-inch steel pipe inside of an 8-foot-diameter cut-and-cover conduit located on the right abutment of the dam. The cut-and-cover conduit would be used for diversion of the streamflow during construction of the dam.

The project would require acquisition of about 3,000 acres of land for the reservoir and for recreational development. The estimated cost of these lands, based on comparable land sales in the area, is $300,000. It was assumed that the reservoir area below normal pool elevation would be partially cleared and would cost about $100 per acre. Approximately 9 miles of State Highway 36 would have to be relocated. A route around the northern edge of the reservoir was selected. The cost of highway construction was estimated at $200,000 per mile.

Total capital cost of the dam, reservoir, and appurtenances was estimated to be $18,200,000, including engineering, contingencies, and interest during construction. Capitalized costs of these features, including present worth of operation, maintenance, and general expense, would be about $18,700,000. The average annual equivalent cost is $871,000.

Costs of recreation facilities necessary to fulfill the predicted recreation demands were estimated at $2,100 for each picnic unit and $3,000 for each camping unit. Costs of attendant recreation facilities such as boat launching ramps and swimming beaches were estimated separately. Operation, maintenance, and replacement of these facilities was estimated at 30¢ per visitor-day. Total capitalized costs of recreation facilities including present worth of operation and maintenance, were estimated to be about $2,000,000. The average annual equivalent cost would be about $93,000.

Fishery enhancement costs are made up of the cost of acquiring rights-of-way and the cost of initial stocking with fingerling salmon to begin the spawning run. The capital cost of right-of-way was estimated to be $206,000 and the cost of fingerling stocking was estimated at $20,000 each year for four years following project completion. The estimated total capitalized cost of fishery enhancement is $280,000. The corresponding average annual equivalent cost is $13,000. It was assumed that operation and maintenance of the spawning area would be handled by the Department of Fish and Game at no cost to the project.

The area that would be inundated by Rosewood reservoir presently provides habitat for some deer and many quail. If a reservoir were constructed, adjacent areas would have to be improved to provide for the loss of this habitat. Sufficient land for deer habitat could be provided by development of about 840 acres of land above the reservoir. Quail habitat could be provided by purchase and development of 80 acres of land downstream from the damsite.

The capitalized cost of land acquisition and improvements for wildlife preservation is estimated to be $150,000. The average annual equivalent cost is $7,000.

Table 29 presents a summary of Rosewood Project costs.

TABLE 29

SUMMARY OF ROSEWOOD PROJECT COSTS
(155,000 Acre-feet of Storage)

	Capitalized Cost	Average Annual Equivalent Costs
Dam, Reservoir, and Appurtenances	$18,700,000	$871,000
Recreation Facilities	2,000,000	93,000
Rights-of-Way and Initial Stocking for Fishery Enhancement	280,000	13,000
Wildlife Preservation	150,000	7,000
Total Project Costs	21,130,000	984,000

Project Accomplishments

The Rosewood Project would accomplish the following project purposes: (1) fishery enhancement, (2) recreation, (3) flood control, and (4) conservation for export.

About 7 miles of the Dry Fork of South Fork Cottonwood Creek below the Rosewood damsite, 8 miles of South Fork Cottonwood Creek, and about 8 miles of the main stem of Cottonwood Creek would be improved for salmon spawning by water stored and released from Rosewood Reservoir. It is estimated that the spawning run in this 23 miles of stream could be increased by 9,500 fish under project conditions. This would provide about 22,400 commercially caught and 6,100 sport-caught salmon annually. The capitalized benefit of these fish would be about $2,390,000 for the

50-year period of analysis. The average annual equivalent benefit would be $111,000.

Reservoir recreation would result from the 2,500 acres of reservoir water surface and from the land developed for camping and picnicking around the reservoir. The Rosewood Reservoir site has the best potential for recreation development of any reservoir in the Cottonwood Creek drainage basin. It was estimated that 100,000 visitor-days of recreation use would occur annually at the beginning of project operation and that this would increase to about 600,000 visitor-days annually by the end of the 50-year period of analysis. The present worth value of this benefit would be $6,100,000 and the average annual equivalent benefit would be $258,000.

Reservoir storage at Rosewood Reservoir would provide some flood protection along the main stem of Cottonwood Creek in the vicinity of Cottonwood. Some measure of flood control would also be provided in areas along the Sacramento River downstream from the confluence with Cottonwood Creek. Benefits in downstream areas would be about $75,000 annually. For the purpose of this study it was assumed that Rosewood Reservoir would prevent damages equal to those prevented by the other reservoirs in Cottonwood Creek basin. An annual benefit for the local area of $20,000 was used. The estimated flood control benefit would therefore be $95,000 annually. The capitalized benefit would be $2,040,000.

Water could be stored in Rosewood Reservoir during periods of surplus and released during periods of need for export to areas downstream from the local area. The firm yield of the Sacramento-San Joaquin Delta would be increased by about 23,000 acre-feet per year by the Rosewood Project. The estimated annual benefit of this yield is $250,000. The present worth value of this benefit is $5,370,000.

A summary of the Rosewood Project benefits is presented in Table 30.

TABLE 30

SUMMARY OF ROSEWOOD PROJECT BENEFITS
(155,000 Acre-Feet of Storage)

Project Purposes	Capitalized Benefits	Average Annual Equivalent Benefits
Fishery Enhancement	$ 2,390,000	$111,000
Recreation	6,100,000	285,000
Flood Control	2,040,000	95,000
Conservation for Export	5,370,000	250,000
Total Project Benefits	16,900,000	741,000

Economic Justification

The present worth of project benefits throughout the 50-year period of economic analysis (1970-2020) was estimated to be $16,900,000. The total capitalized cost of the project, including present worth of future expenditures for additions and for operation and maintenance, was estimated to be $21,130,000. The resulting comparison of benefits and costs shows that the benefit-cost ratio is 0.8 to 1.0 and that the project is therefore not economically justified under present economic conditions.

Best Development for Cottonwood Creek Basin

Only two of the four projects considered in the Cottonwood Creek basin were found to be economically justified. These two projects, Hulen on the North Fork and Dippingvat on the South Fork would, however, satisfy the local agricultural water requirement, provide a tremendous fishery enhancement in the main stem and South Fork of Cottonwood Creek, develop water-associated recreation, provide some flood protection in both local and remote areas, and provide a substantial new yield to the Sacramento-San Joaquin Delta.

The costs of constructing both projects at once would be essentially the same as the costs of constructing them as separate projects. Undoubtedly some savings in administration and operation would result from constructing the projects as a unit but this small savings was not estimated in this study.

Benefits from the combined projects would also be essentially the same as the total of the two separate projects. However, there would be a slight overlap of the stream channel improved for salmon spawning in the 8 miles of Cottonwood Creek below the confluence with the South Fork. There also might be some reduction in the estimated recreation benefits if both projects are constructed. It is felt, however, that at this stage of study the change in benefits is not within the limits of accuracy for estimating benefits and that the summation of the benefits of the two projects would be sufficient for benefit-cost comparison.

The total cost of the combined project would be $18,660,000 when all project costs are reduced to a present worth basis. On the same time basis the total combined project benefits are $40,570,000. Equivalent average annual costs and benefits are $869,000 and $1,887,000 respectively. The benefit-cost ratio for the combined project is 2.2 to 1.0.

For best development of the Cottonwood Creek Basin both Hulen and Dippingvat Projects should be constructed. At some later date, it may be possible that additional water storage facilities could economically be developed at the Fiddlers and Rosewood damsites. Periodic re-analysis of these sites should be made to evaluate this possibility.

Plans for Development of Cow and Bear Creek Basins

The Cow and Bear Creek Basins contain about 551 square miles of the Upper Sacramento River Basin drainage area. Cow Creek, with a drainage area of 427 square miles, is bounded on the north by the Pit River Basin and on the south by Bear Creek. Principal streams include Little Cow, South Cow, and Cow Creeks. Tributary streams include Oak Run, Clover, Basin Hollow, and Old Cow Creeks. Cow Creek enters the Sacramento River about 21 miles below Shasta Dam.

Bear Creek, with a drainage area of 124 square miles, is bounded by Cow Creek on the north and Battle Creek on the south, and joins the Sacramento River about 23 miles below Shasta Dam.

At higher elevations both basins consist of high ridges and steep valleys which broaden as they emerge from the foothills at the Sacramento River valley floor. Heavy stands of conifers exist at the higher elevations, but tree cover at lower elevations consists mainly of oak and other deciduous growth.

The following projects were considered in the preliminary plans for development of Cow and Bear Creeks.

1. Millville Project, consisting of a major storage reservoir on South Cow Creek, about 2 miles above the confluence with Old Cow Creek, a diversion from Old Cow Creek about 1 mile northerly from Millville damsite in Section 9, T31N, R2W, MDB&M, and a possible diversion from Bear Creek about 4 miles southeast of Millville damsite in Section 25, T31N, R2W, MDB&M.

2. Bella Vista Project consisting of a large storage reservoir on Little Cow Creek, about 1-1/2 miles south of the town of Bella Vista, a possible diversion from Oak Run Creek, in Section 25, T33N, R2W, MDB&M, about 11 miles northeast of Bella Vista damsite, and a possible diversion from Clover Creek, in Section 29, T33N, R1W, MDB&M, about 2 miles east of the diversion from Oak Run Creek.

Millville Project

The Millville Project consists of a dam and reservoir on South Cow Creek, and reservoir recreation, fishery enhancement, and wildlife preservation facilities. The damsite is in Shasta County in Section 17, Township 21 North, Range 2 West, MDB&M. This is about 2 miles upstream from the confluence with Old Cow Creek and about 19 miles east of Redding.

The drainage area of South Cow Creek tributary to Millville Reservoir contains 79 square miles. The estimated average annual runoff at the damsite for 1921-22 through 1940-41 is 71,900 acre-feet.

Project Analysis

The following project purposes were considered in planning for the Millville Project: local irrigation water supply, fishery enhancement, recreation, flood control, and conservation for export.

Preliminary studies showed that local flood protection at Millville Reservoir would be very minor due to the limited amount of flood damages that occur along South Cow and Cow Creeks. The only historical flood damage data available on Cow Creek is a damage estimate made by the U. S. Corps of Engineers following the 1955 flood. An estimate of the average annual flood damage expected without flood protection was made using this damage data, flood frequency studies, and the estimated nondamaging channel capacity of Cow Creek near Millville. The estimate shows that the expected average annual damages are only $14,000. These damages could be only partially prevented by Millville Reservoir. Therefore only incidental local flood control benefits would be provided by the surcharge reservoir storage.

The Cow Creek service area was subdivided into three subservice areas, Stillwater Plains, Cow Creek Bottoms, and Millville Plains. These areas are shown on Plate 4. The areas which generally comprise the Stillwater Plains and Cow Creek Bottoms subservice areas were considered by the U. S. Bureau of Reclamation to be served by pumping from the Sacramento River. However, it was found that these areas could not be economically served from that source.

Studies show that the ground water basin which underlies the Cow Creek service area is capable of supplying the estimated maximum annual demand of 48,000 acre-feet at an average cost of about $6 per acre-foot.

A preliminary estimate of the cost of storing and distributing water to the Stillwater Plains subservice area would be about $10 per acre-foot. This cost includes storage at Millville Reservoir and pumping from Cow Creek to the service area. Since ground water could be supplied for only $6 it was concluded that there would be no demand for surface water supplies in this area.

The Cow Creek Bottoms subservice area is rapidly developing into a suburban residential area. Much of the present water supply for both agricultural and domestic uses is being pumped from ground water. It was concluded that there would be no demand for surface water supplies in this area since ground water could be developed more economically. The potential for ground water development in the Cow Creek service area is discussed in Chapter 5.

Further studies showed that fishery enhancement, recreation, flood control in remote areas along the Sacramento River, and conservation for export could be included as project purposes.

Early plans for the Millville Project include the diversion of the flow of either or both Old Cow and Bear Creeks into Millville Reservoir.

The best plan for diverting Old Cow Creek would consist of a 145-foot-high Old Cow Creek Diversion Dam capable of diverting the entire surplus flow of Old Cow Creek into a canal leading to Millville Reservoir. The cost of the dam and canal was estimated to be about $6,000,000. The estimated maximum-impaired average annual streamflow of Old Cow Creek at the diversion point is about 57,000 acre-feet. The Millville Project was analyzed using the additional costs and benefits added by this diversion and it was found that costs were greatly in excess of benefits. Therefore, the Old Cow Creek Diversion was not included in further analysis of the Millville Project.

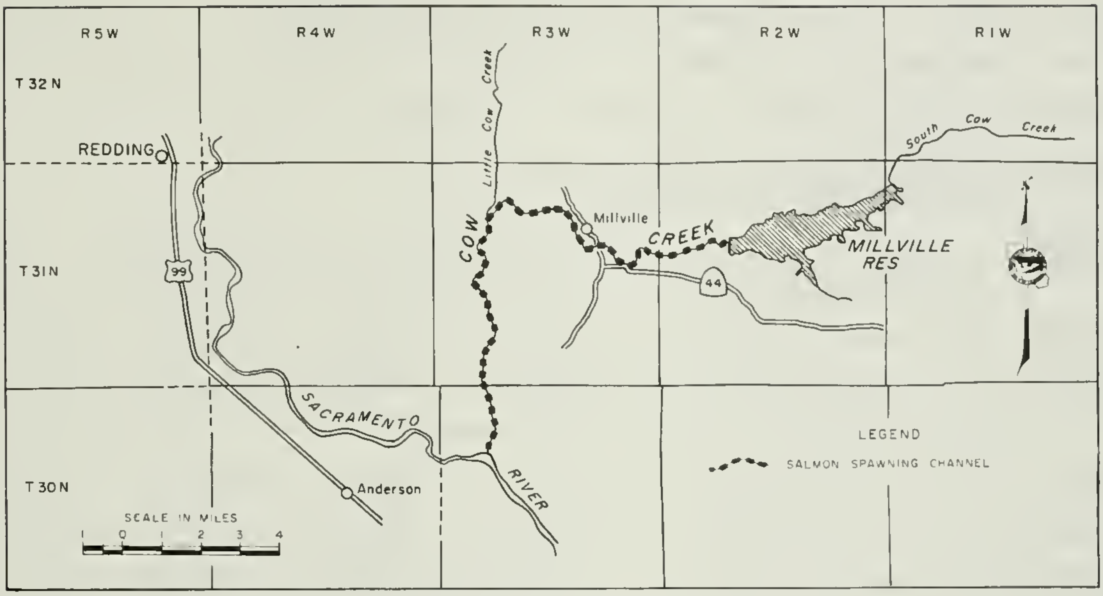
The most economical means of diverting flows of Bear Creek would be to construct a 140-foot-high Bear Creek Diversion Dam to divert the flow of Bear Creek into a canal leading to Millville Reservoir. The cost of the dam, its appurtenant structures and the canal was estimated to be about $2,650,000. The estimated maximum-impaired average annual runoff is 53,000 acre-feet. The Millville Project was analyzed using the additional costs and benefits added by the diversion. This analysis showed that the diversion costs greatly exceeded the additional project benefits. Therefore, the Bear Creek Diversion was not included as a feature of the Millville Project.

Reservoir Sizing. Project costs and benefits were compared for several sizes of Millville Reservoir. These sizes varied from a small reservoir which would supply only local needs to larger sizes required for multiple-purpose use. Various combinations of project purposes were studied in conjunction with the various sizes to determine the reservoir size which would provide maximum net project benefits. Final sizing and project planning studies indicated that a multiple-purpose Millville Reservoir with storage capacity of 74,000 acre-feet at normal pool elevation of 729 feet would provide maximum net project benefits. This project is discussed in the following sections.

General Features. The Millville Project as proposed would consist of the following project features: (1) dam and appurtenant structures, (2) reservoir, (3) stream improvement for salmon spawning, and (4) recreation facilities. General project features are shown in Figure 7.

FIGURE 7

MILLVILLE PROJECT



General Project Features
(All elevations are USGS datum)

Dam

Location	$NE\frac{1}{4}$, Sec, 17, T31N, R2W, MDB&M
Type	Zoned Earthfill
Height Above Streambed, in Feet	149
Crest Elevation, in Feet	749
Volume of Fill, in Cubic Yards	1,810,000

Reservoir

Drainage Area, in Square Miles	79
Water Surface Elevation at Normal Pool, in Feet	729
Storage Capacity, in Acre-Feet	74,000
Water Surface Area, in Acres	1,400

Spillway

Type	Chute with ungated ogee weir
Weir Crest Elevation, in Feet	729
Design Capacity, in Second-Feet	20,000

Outlet Works

Type	60-foot steel pipe encased in concrete

Project Accomplishments

Local Irrigation Yield, in Acre-Feet Per Year	0
Salmon Enhancement, in Numbers of Increased Annual Catch	29,000
Yield to Sacramento-San Joaquin Delta, in Acre-Feet Per Year . . .	21,000

Project Operation. Project water yields were determined by operation studies completed under operation criteria set forth at the beginning of this chapter. The reservoir was operated to provide the maximum salmon enhancement and to develop water for export from the Delta. A summary of the monthly operation study is presented in Table 31.

Geology

The topography along South Cow Creek in the vicinity of the dam and reservoir site varies from steep and overhanging to areas that are nearly flat. Rock at the damsite consists of three major geologic units. A basalt cap, formed by volcanic flows, overlies most of the area; underlying the basalt are various sedimentary and volcanic strata, the oldest of which is a welded tuff; consolidated sandstone, shale, and conglomerate of the Chico formation crops out or underlies the site at low elevations. Plate 11, "Millville Dam and Reservoir on South Cow Creek" shows geologic conditions at the site.

The Bureau of Reclamation has done some exploration at a damsite about one-quarter mile downstream from the site being considered in this study. Their work consisted of drilling and water testing five core holes, geologic mapping of the site, and a limited materials exploration program. Foundation exploration during the current investigation was limited to drilling nine auger holes to determine the depth of weathering of the sandstone and shale and to delineate the limits of the Tertiary sediments.

The lower portion of the right abutment is composed of sandstone, shale, and conglomerate of the Chico formation. Consolidated gravels, a tuff breccia layer, and partially consolidated post-Tuscan gravels compose the upper portion. There is evidence of a landslide on this abutment between elevation 670 and 750. The depth appears to be shallow, possibly 10 to 20 feet, and should not cause a structural problem in the dam foundation.

The channel section is generally composed of layers of stream gravels laid down over the Cretaceous rocks. In many places the rocks are washed clean but in other places the gravel layers are up to 10 feet thick.

TABLE 31

SUMMARY OF MONTHLY OPERATION
STUDIES OF MILLVILLE RESERVOIR
75,000 Acre-Feet of Storage

(In acre-feet)

Runoff Year	Storage on October 1	Inflow 1/	Water Releases and Losses: Fishery Enhancement	Evaporation	Spill	Total
1921-22	9,800	70,900	43,000	2,900	0	36,100
22-23	34,800	51,900	43,000	3,400	0	46,400
23-24	40,300	11,400	21,500 2/	2,800	0	24,300
24-25	27,400	40,000	43,000	2,500	0	45,500
1925-26	21,900	36,700	43,000	2,200	0	45,200
26-27	13,400	83,100	43,000	3,700	0	46,700
27-28	49,800	68,700	43,000	4,100	9,600	56,700
28-29	61,800	15,900	43,000	3,200	0	46,200
29-30	31,500	70,100	43,000	3,900	0	46,900
1930-31	54,700	12,300	21,500 2/	3,300	0	24,800
31-32	42,200	39,700	43,000	3,200	0	46,200
32-33	35,700	16,000	21,500 2/	2,800	0	45,400
33-34	27,400	35,200	43,000	2,400	0	45,400
34-35	17,200	57,500	43,000	2,700	0	45,700
1935-36	29,000	61,100	43,000	3,400	0	46,400
36-37	43,700	33,900	43,000	3,100	0	46,100
37-38	31,500	190,800	43,000	4,100	108,400	155,500
38-39	66,800	19,800	43,000	3,500	0	46,500
39-40	40,100	119,500	43,000	4,100	50,600	97,700
1940-41	61,900	144,000	43,000	4,200	94,800	142,000
Average	37,000	58,900		3,300		

1/ Estimated historical flow adjusted to allow for estimated ultimate development of the watershed above Millville Reservoir.

2/ Deficiency of 50 percent in releases in 1924, 1931, and 1933.

NOTE: Storage at normal pool is 74,000 acre-feet, at minimum pool 4,000 acre-feet. Storage on October 1 plus inflow minus water releases and losses equals storage on following October 1. Minimum storage for this operation study was 6,200 acre-feet on January 1, 1935. Release for fishery enhancement during May, June, July, and August was assumed to be sufficient to satisfy prior downstream water rights.

The rock which forms the left abutment is similar to that of the right abutment except that a welded tuff unit is present. There are no landslides on this abutment and probably very little preparation would be required to ready this abutment for dam construction.

The principal rock types within the reservoir are clay shales and alluvium. There would be no leakage through the shales; however, near the damsite, gravels and volcanic materials lie over the Cretaceous rocks. For water surface elevations above 720 feet, USGS, leakage would probably occur through both abutments and through the gravels which extend under the basalt-capped ridge east of the right abutment. Further subsurface exploration would be required to determine the magnitude of leakage. Should it be found that leakage would be excessive, the area could be blanketed with impervious material to retard water loss.

Both the U. S. Bureau of Reclamation and the Department of Water Resources have made investigations for borrow materials in the vicinity of Millville damsite. The Bureau, in 1945, located and sampled materials within the reservoir area and downstream from the damsite. The Department, during this investigation, has sampled and tested materials about 2 miles downstream from the proposed damsite. Location of possible construction material borrow areas are shown on the materials location map on Plate 11.

Adequate quantities of suitable impervious materials are available in borrow area 1 in the reservoir or from borrow area 2 downstream from the damsite.

About 750,000 cubic yards of pervious material are available in area 5 in the Cow Creek stream channel downstream from the town of Millville.

Unlimited quantities of basalt for riprap are available from quarry areas 3 and 4 located south of the damsite.

Project Designs and Costs

The designs and costs of the Millville Project are presented in the following paragraphs under the headings of dam and appurtenant structures, reservoir, stream management for fishery enhancement, preservation of wildlife, and recreation.

Dam and Appurtenant Structures. A zoned earthfill dam consisting of an impervious section with an interior rock drain and rock on the upstream face was selected for Millville damsite. This type of dam was chosen to make the best economic use of available construction materials while assuring adequate safety in the dam structure.

The dam would be 149 feet high, with a crest width of 30 feet and a crest length of about 1,450 feet. The crest would be at elevation 749 feet USGS datum. Plate 11 presents the plan, profile, and maximum section of Millville Dam.

The Embankment section also shown on Plate 11 was chosen to make maximum use of the impervious material. Zone 1 would contain clayey silt alluvium from borrow area 1 as shown on the construction materials map. Zone 2 consists of silty sands from borrow area 2 downstream from the damsite. The total embankment volume would be about 1,810,000 cubic yards.

A vertical chimney drain would be placed between Zones 1 and 2. Drain material would be obtained from stream gravel deposits below the damsite.

Stability against rapid drawdown would be provided by placing a rolled rock zone on the upstream face of the embankment. The rock material would be obtained by quarrying the adjacent basalt cap material. The weathered material would be placed next to the impervious Zone 2 material while the fresh-quarried rock would be used to form the outer shell. Selected material from the quarrying operation would be used to blanket the downstream slope of the embankment as a protection against erosion.

An average depth of stripping of 10 feet was assumed to be adequate under the entire dam structure. Foundation grouting quantities were based on two rows of 40-foot holes at 10-foot centers. Grout take was assumed to be about one sack per foot of hole. Geologic studies indicate relatively firm rock conditions below elevation 740 feet.

The Spillway would be excavated through the left abutment. Excavation would be through the welded tuff and gravel unit which would be susceptible to scour at high water velocities, so lining of the spillway would be required. The spillway was designed to pass the probable maximum flood inflow of 29,600 second-feet with a maximum spillway discharge of 20,000 second-feet. This flow would produce a maximum surcharge of 20 feet above the spillway lip.

The spillway would consist of (1) a 60-foot-wide approach channel with a 50-foot-long paved approach apron, (2) a control structure consisting of an ungated, 20-foot-high ogee weir founded on firm rock, and (3) a 60-foot-wide, concrete-lined chute section, about 650 feet long, terminating in a flip bucket energy dissipator.

The Outlet Works conduit would be located in the left abutment and would be constructed by cut-and-cover methods. Normal streamflow would be diverted through this conduit during construction of the dam.

The outlet works would consist of an intake tower located in the embankment with the inlet placed at elevation 650 feet and a 5-foot-diameter outlet pipe about 600 feet long passing under the embankment. Access to the control valve would be from the downstream end. Releases of up to 400 second-feet could be made through the outlet works. A 12-inch bypass would provide for emergency releases for fish.

Reservoir. About 3,000 acres of land would have to be acquired for the reservoir area and for areas suitable for recreation development. Of this amount, 1,100 acres within the reservoir area consisting of pasture and scattered oak trees would have to be partially cleared.

The South Cow Creek road would be located around the north side of the reservoir. Total length of the new road would be between 5 and 6 miles.

Table 32 includes a summary of the costs of Millville Dam, reservoir, and appurtenances.

TABLE 32

SUMMARY OF COSTS OF MILLVILLE DAM, RESERVOIR, AND APPURTENANCES

Item	Construction Cost	Engineering, Administration, Contingencies, and Interest During Construction	Total Capital Costs
Dam and Appurtenances			
Embankment	$2,260,000		
Spillway	530,000		
Outlet Works	400,000		
Subtotal	3,190,000	1,280,000	4,470,000
Reservoir			
Land Acquisition and Clearing	395,000		
Construction Facilities and Relocation of Roads	475,000		
Subtotal	870,000	350,000	1,220,000
Total	4,060,000	1,630,000	5,690,000

Stream Management for Fishery Enhancement. Studies conducted during this investigation by the Department of Fish and Game indicate that South Cow Creek below Millville damsite could be improved for salmon spawning with water released from reservoir storage. These studies also indicate that the main stem of Cow Creek below Palo Cedro could not be improved by additional water because essentially all suitable spawning gravel in this reach is presently being used. In order to properly manage the stream channel and improve some areas for maximum spawning activity, it would be necessary to acquire rights to manage South Cow Creek from Millville damsite to the confluence of the main stem of Cow Creek. The area required would be about 130 acres and would cost about $40,000. It was estimated that the present average spawning run in this reach of stream is about 750 fish. With improved flows provided by the proposed project, the spawning run could be increased by about 10,000 fish. The stream should be stocked with fingerling salmon at the rate of 200 fingerlings per adult spawner each year for 4 years following project construction to initiate the spawning run. This would cost about $20,000 per year.

The total estimated initial cost of improving the spawning in South Cow Creek would be $115,000. The average annual equivalent cost would be $5,400.

Preservation of Wildlife. Department of Fish and Game studies showed that development of the Millville Project would cause considerable loss of quail habitat. Deer losses would be negligible. Replacement of quail habitat could be provided by diversion of a small amount of water from the stream above the reservoir to 140 acres of land at the east end of the reservoir. Total present worth value of wildlife preservation costs would be $19,000. The average annual equivalent costs would be $900.

Recreation. Estimates of the recreation facilities needed at the Millville Project to meet projected recreation demands were made to determine if the site could be developed to meet the demand and to estimate costs of the recreation facilities. Estimated demand would require installation of about 17 recreation units during the first decade of project operation. These recreation units were designed for day use only. The number of recreation units required to meet the future demand was estimated on the basis of recreation use projections.

The costs of the recreation facilities were based on state park experiences and are estimated to be $2,100 for each recreation unit. This unit cost would include water supply, sanitary facilities, and interior recreation roads. Costs of other recreation facilities such as boat launching areas and swimming beaches were estimated separately.

Costs of operation, maintenance, and replacement of the recreation facilities were estimated from costs of similar recreation areas. This cost was found to be about 30¢ per visitor day.

Total present worth costs of installation of recreation facilities and operation, maintenance, and replacement during the 50-year period of analysis is $350,000. The average annual equivalent cost is $16,300.

Summary of Project Costs. A summary of the estimated project costs during the 50-year period of analysis is presented in Table 33. The capital cost of the project is estimated to be about $5,986,000. The present worth of the total expenditures over the 50-year period is estimated to be $6,530,000. The average annual equivalent cost would be $304,000.

TABLE 33

SUMMARY OF MILLVILLE PROJECT COSTS

Project Feature	Present Worth			Average Annual Equivalent Cost
	Capital Cost	Operations, Maintenance, Replacement, and General Expense	Total	
Dam, Reservoir, and Appurtenances	$5,690,000	$356,000	$6,046,000	$281,400
Access Rights and Stream Improvement for Salmon Spawning	115,000	0	115,000	5,400
Recreation Facilities	175,000*	175,000	350,000	16,300
Preservation of Wildlife	6,000	13,000	19,000	900
Total	5,986,000		6,530,000	304,000

* Includes present worth value of future expenditures.

Project Accomplishments and Benefits

Both the local and statewide economy would benefit from the Millville Project as proposed herein. Construction of Millville Reservoir with a storage capacity of 74,000 acre-feet would provide for fishery enhancement, recreation, flood control, and conservation of water for export. The accomplishments and benefits from each of these project purposes are discussed in this section.

Fishery Enhancement. The assured streamflow provided by Millville Project would make sufficient gravel available in South Cow Creek for an additional 10,000 salmon spawners. This increase would produce an increase in the commercial salmon catch of about 23,000, and an increase in the sport salmon catch of about 6,000. Figure 8 shows the flow in South Cow Creek during the spawning season for project conditions compared to the median impaired flow for 1921-22 through 1940-41. Minimum recorded monthly flows are also shown. Department of Fish and Game studies indicate that spawning in the main stem of Cow Creek below Palo Cedro would not be increased by additional water because essentially all suitable spawning gravel in this reach is presently being used. However, additional flow in this reach of the stream would not harm the present salmon run.

Benefits from increased production of salmon produced by the increased spawning activity would have a capitalized value of $2,380,000. This is equivalent to an average annual benefit of $111,000. A detailed description of salmon potential and possible production is presented in Appendix B.

Recreation. Millville Reservoir with a normal water surface elevation of 729 feet, USGS datum, would provide a good setting for water-associated recreation. Boating, picnicking, reservoir fishing, and swimming would be provided at Millville Reservoir. With adequate facilities provided for the predicted demand, it is estimated that there would be about 10,000 visitor-days of use annually at the beginning of project operation. This number would increase to about 70,000 visitor-days annually by the year 2020.

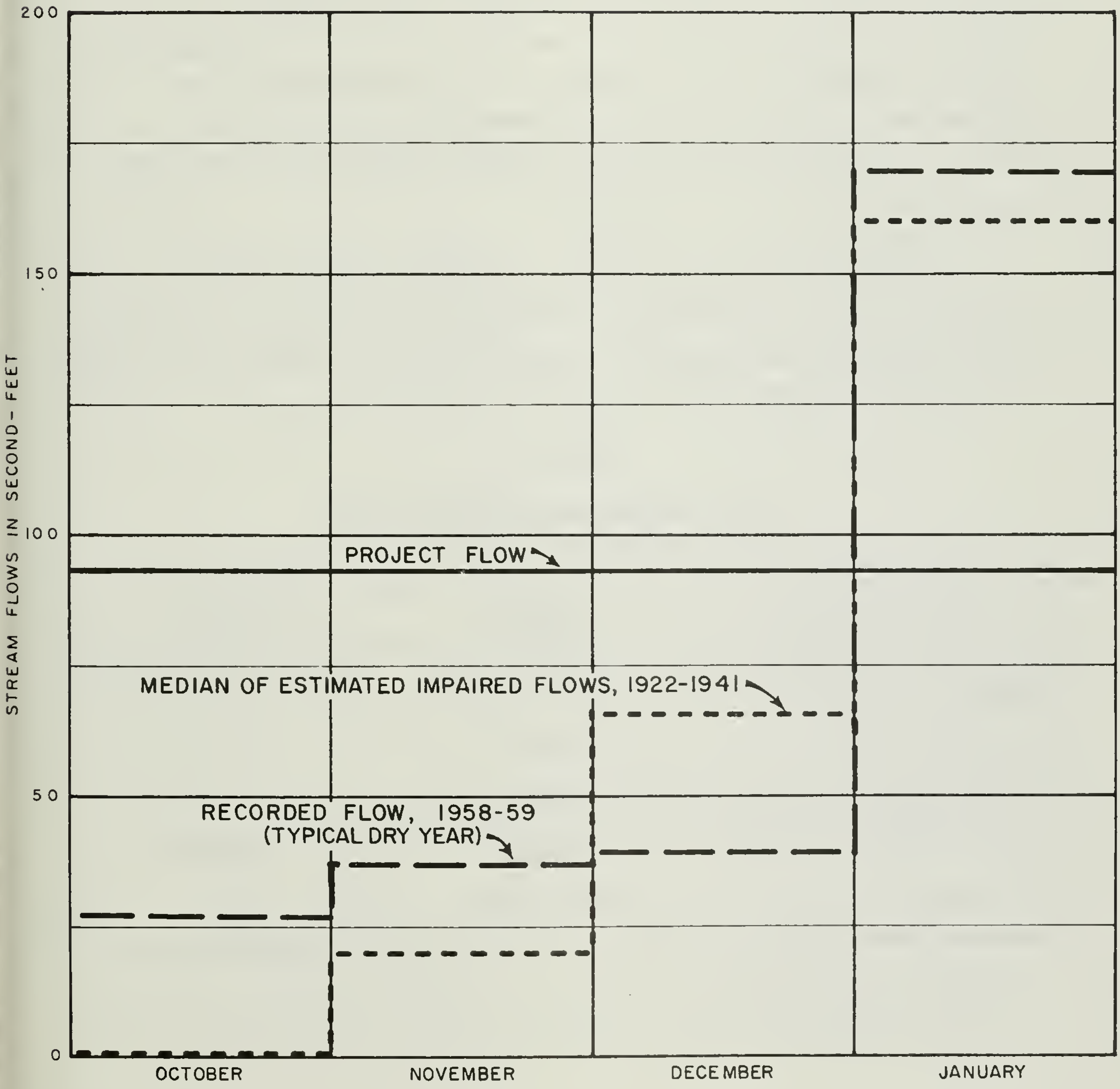
Total recreation benefits from this project have an estimated capitalized value of about $1,040,000. The average annual equivalent benefit would be $48,000.

Flood Control. Under present conditions, flood water of the Cow Creek drainage system causes very little damage. There is some bank erosion and agricultural damage at times of exceptionally high streamflow. Preliminary flood damage studies indicate that there would be no demand for flood control in the Cow Creek Flood plain downstream from Millville Reservoir.

Since Millville Reservoir would be operated to supply fishery enhancement water during the summer and fall months, it would generally be drawn down to its lowest storage each year at the beginning of the flood season. Consequently flood damages in the lower reaches of the Sacramento

FIGURE 8

COMPARISON OF AVERAGE MONTHLY STREAM FLOWS IN SOUTH COW CREEK BELOW MILLVILLE DAM DURING THE SALMON SPAWNING SEASON



River below the confluence with Cow Creek would be reduced by this project. As stated earlier, an annual flood control benefit of 50¢ per acre-foot of active storage was assigned to each tributary reservoir for flood reduction in the Sacramento Valley between Red Bluff and Colusa. This remote benefit would total about $35,000 annually. The capitalized value of this amount would be $750,000.

Conservation for Export. Since Millville Reservoir would be operated to provide for fishery enhancement, a nonconsumptive use, water which previously would have reached the Delta during periods of spill could now be exported to areas of need. It is estimated that about 21,000 acre-feet per year of new yield would be developed by this project.

The capitalized value of this yield is $4,890,000. The equivalent average annual value is $228,000.

Summary of Project Benefits. A summary of the estimated project benefits of the Millville Project is presented in Table 34. The present worth value of the total benefits is $9,060,000; the average annual equivalent value is $422,000.

TABLE 34

SUMMARY OF MILLVILLE PROJECT BENEFITS

Project Purpose	Present Worth of Total Benefits	Average Annual Equivalent Benefit
Fishery Enhancement	$2,380,000	$111,000
Recreation	1,040,000	48,000
Flood Control	750,000	35,000
Conservation for Export	4,890,000	228,000
Total	9,060,000	422,000

Economic Justification

The present worth value of the project benefits throughout the 50-year period of economic analysis (1970-2020) was estimated to be $9,060,000. The total capitalized cost of the project, based on 1963 price levels and including the present worth value of future expenditures for additions and for operation and maintenance, was estimated to be $6,530,000. The resulting comparison of benefits and costs indicate that the project is economically justified by a ratio of 1.4 to 1.0.

Cost Allocation

A preliminary allocation of project costs was made to determine the proportion of the costs that should be charged to each of the various project purposes. A summary of the results of the allocation are presented in Table 35.

The allocation shows that the annual cost of providing a new yield of 21,000 acre-feet annually at the Delta would be about $122,000. Since it was assumed that the demand for additional water in the Delta will not occur until 1980, water would be delivered only during the last 40 years of the period of project analysis. Based on this assumption, the cost per acre-foot of water delivered would be about $9.30.

Bella Vista Project

The Bella Vista Project would consist of a dam and reservoir on Little Cow Creek, recreation facilities around the reservoir, fishery enhancement stream improvement on 4-1/2 miles of Little Cow Creek, and wildlife preservation facilities. The damsite is in Shasta County about 4 miles upstream from the confluence of Little Cow with South Cow Creek. The drainage area of Little Cow Creek tributary to Bella Vista Reservoir is about 123 square miles. The estimated maximum impaired average annual runoff at the damsite for the study period 1921-22 through 1940-41 is 99,200 acre-feet.

Water stored in a reservoir at this site could be used to improve the salmon spawning areas in Little Cow Creek below the damsite, provide an irrigation supply for the Cow Creek bottoms subservice area, provide a measure of flood control along the Sacramento River downstream from the

TABLE 35

PRELIMINARY ECONOMIC COST ALLOCATION FOR THE MILLVILLE PROJECT
(Based on average annual equivalent values in dollars)

	Fishery Enhancement	Recreation	Flood Control	Conservation for Export	Total
Benefits	$111,000	$49,000	$35,000	$228,000	$423,000
Alternative Costs	270,000	1/	1/	131,000	
Total Justifiable Costs 2/	111,000	49,000	35,000	131,000	326,000
Separable Costs 3/	19,000	16,000	0	17,000	52,000
Remaining Benefits 4/	92,000	33,000	35,000	114,000	274,000
Percentage Distribution of Remaining Benefits	33.6%	12.0%	12.8%	41.6%	100.0%
Total Project Cost					304,000
Total Separable Cost					52,000
Total Remaining Joint Costs					252,000
Allocated Remaining Joint Costs 5/	85,000	30,000	32,000	105,000	252,000
Separable Costs	19,000	16,000	0	17,000	52,000
Total Allocated Cost	104,000	46,000	32,000	122,000	304,000

1/ Assumed to be in excess of benefits.
2/ The justifiable cost is the smaller of the two values, benefits and alternative costs.
3/ Separable costs are the difference between the total project cost, and the cost with a given purpose excluded.
4/ Remaining benefits represent the difference between total justifiable costs and the separable costs.
5/ Remaining joint costs are allocated in accordance with the percentage distribution of remaining benefits.

confluence with Cow Creek, provide an area which could be developed for water-associated recreation activities, and increase the Delta export yield.

Studies were made to determine if each of the above purposes were justified for inclusion in the project analysis. Results indicated that each purpose except local irrigation would be justified. Local irrigation would not be justified since ground water could be developed at less cost.

Reservoir Sizing

Benefits and costs for all proposed project purposes were estimated for reservoirs with various storage capacities. The project costs and benefits were compared at various sizes and for various combinations of project purposes. From this study it was determined that no project size was economically justified. Therefore, the project that is presented in the following sections is for illustrative purposes only.

Project Operation

Project water yields were determined by operation studies under operation criteria set forth at the beginning of this chapter. The reservoir was operated to provide for maximum salmon enhancement after it was determined that local irrigation demands could be more economically served from ground water. In addition, consideration was given to the development of water for export to the Delta.

The water supply of Bella Vista Reservoir could be supplemented by diversion from Clover Creek and Oak Run Creek. Location of the possible diversion sites are shown on Plate 3. Estimates of the amount of water available for diversion were made and used to determine the additional project benefits that would accrue. Costs of the diversions were also estimated. Preliminary study of the Bella Vista Project with and without the diversions showed that the project would not be economically justified.

Geology

Bella Vista damsite is located in a wide valley bounded on the east and west by broad, dissected plateaus which make up part of Stillwater Plains. The wide valley was formed by downcutting of the meandering stream channel.

Damsite. Foundation material at the proposed damsite consists of semiconsolidated clay, silt, sand, and gravel of the Tuscan-Tehama sediments which outcrop in horizontal beds on both abutments and extend beneath the channel. At the top of the abutment, the Tuscan-Tehama sediments are capped by approximately 20 feet of andesitic agglomerate. The channel section contains alluvium approximately 10 feet deep consisting of unconsolidated clay, silt, sand, and gravel, with isolated patches of Tuscan-Tehama sediments exposed in the present stream channel. No subsurface exploration was done at the damsite.

Reservoir. The entire reservoir area is underlain by the Tuscan-Tehama sediments. Light to moderate leakage may be expected to occur through gravel layers in the abutment unless special treatment is provided. Leakage from the reservoir would probably result in a higher water table downstream from and adjacent to the reservoir. Further study would be required to accurately estimate the quantity of leakage from a Bella Vista Reservoir. Silting in the reservoir should be negligible and landslides should not pose a problem.

Construction Materials. Some subsurface exploration of possible borrow materials was carried out during this investigation. A 41-foot deep core hole and eight auger holes were drilled at possible borrow area sites.

Studies indicate that sufficient quantities of semipervious and impervious material consisting of silty sand to clayey gravel alluvium are located in the reservoir area. Locations of these materials are shown as Area 1 on Plate 12, "Bella Vista Dam and Reservoir on Little Cow Creek". Stream gravel in Cow and Dry Creeks, within 3 miles of the proposed damsite, should provide sufficient pervious material. Adequate material for riprap or rockfill is available from a basalt flow, located approximately

4 miles east of the proposed damsite and shown as Area 3 on Plate 12. Generally, the construction materials, with the exception of quarried rock for riprap, can be removed by common excavation.

Designs and Costs

A preliminary design and cost estimate was completed for a reservoir with a storage capacity of 150,000 acre-feet. The dam would have a crest elevation of 617 feet, would be 130 feet high, and would have a crest width of 30 feet. It would consist of a homogeneous earthfill embankment with side slopes of 3.5 to 1 on the upstream face and 2.5 to 1 on the downstream face, and would contain about 4,500,000 cubic yards of fill. A typical cross section of the dam is shown on Plate 12.

An ungated spillway would be constructed across the left abutment of the damsite and would discharge into a ravine leading back to Little Cow Creek about one-half mile below the damsite. The spillway was designed to pass a probable maximum flood inflow of 46,000 second-feet with a spillway discharge of about 30,000 second-feet. This would require a maximum surcharge of 12 feet above the spillway lip. The spillway would consist of a 200-foot wide approach channel concrete-lined for the last 50 feet, an ungated concrete overflow weir 15 feet high and a concrete-lined chute about 400 feet long, terminating in a stilling basin. The water would then return to Little Cow Creek through the ravine.

The outlet works would be located in the left abutment and would be used for both diversion of the stream during construction and for controlled release of water from the reservoir following construction. The outlet works would consist of a reinforced concrete intake structure, a 60-inch-diameter steel pipe enclosed in a 9-foot, horseshoe-shaped concrete conduit, and the necessary control and energy dissipating valves.

Costs of acquiring the 4,000 acres of land necessary for the reservoir and recreation lands were estimated from recent comparable land sales in the area. The acquisition cost was estimated to be $1,300,000. It was assumed that the reservoir area below normal pool elevation (1,500 acres) could be partially cleared at a unit cost of about $100 per acre. Relocation of 12 miles of U. S. Highway 299 and three bridges between Redding and Burney would be required around the south side of the reservoir. A unit cost of highway construction of $215,000 per mile was used to estimate relocation costs.

The initial cost of the dam, reservoir, and appurtenances is estimated to be $18,400,000, including engineering, contingencies, and interest during construction. The capitalized cost of these features including present worth of operation, maintenance, and general expense would be about $18,900,000. The average annual equivalent cost is $880,000.

The cost of fishery enhancement is made up of the cost of acquiring rights-of-way and the cost of planting fingerling salmon to initiate the spawning run. The capital cost of right-of-way is estimated to be $26,000 and the cost of stocking fingerling salmon is $10,000 each year for four years following project completion. The total capitalized cost of fishery enhancement is $63,000; the average annual equivalent value is $2,900. It was assumed that operation and maintenance of this spawning area would be handled by the Department of Fish and Game at no cost to the project.

The cost of recreation facilities was estimated on the basis of $2,100 per recreation unit. Costs of operation, maintenance, and replacement of these facilities were estimated to be 30¢ per visitor-day. It was estimated that about 100 recreation units should be installed during the first decade of operation. A total of 483 recreation units would be installed during the 50-year period of economic analysis. Total capitalized cost of constructing recreation facilities, including the present worth of operation and maintenance, is estimated to be about $1,250,000. The average annual equivalent cost would be about $58,300.

The area that would be inundated by Bella Vista Reservoir presently provides habitat for many quail. If the reservoir were constructed, about 140 acres of land on Little Cow Creek above the reservoir site could be improved to provide for loss of quail habitat. The land considered for this improvement by the Department of Fish and Game is within the proposed reservoir take line. To maintain optimum quail habitat, a diversion structure in the stream above the reservoir and irrigation distribution facilities should be provided to supply water to the lands used for quail habitat.

The capitalized cost of initial land improvement, including present worth of operation and maintenance, is estimated to be $17,000. The equivalent average annual cost would be about $800.

Table 36 presents a summary of Bella Vista Project costs.

TABLE 36

SUMMARY OF BELLA VISTA PROJECT COSTS

Project Feature	Present Worth of Costs	Equivalent Average Annual Costs
Dam, Reservoir, and Appurtenances	$18,900,000	$880,000
Fishery Enhancement	63,000	2,900
Recreation Facilities	1,250,000	58,300
Wildlife Preservation	17,000	800
Total	20,230,000	942,000

Project Accomplishments

Bella Vista Project would include the following purposes: (1) fishery enhancement, (2) recreation, (3) flood control, and (4) conservation for export. The benefits that would be derived from this project are presented in the following paragraphs.

The portion of Little Cow Creek below Bella Vista damsite would be improved for salmon spawning by water stored and released from Bella Vista Reservoir. It is estimated that the spawning run in the 4-1/2 miles of stream below the dam could be increased by 5,000 fish under project conditions. This would provide an annual increase in the ocean commercial catch of about 12,900 salmon. The sport catch would be increased by about 2,100 salmon annually. The capitalized benefit from this increased salmon production would be about $1,190,000. The average annual equivalent value is $55,000.

Reservoir recreation would result from the 3,700 acres of water surface area, and from the recreation lands surrounding the reservoir that would be suitable for development of picnic facilities. Bella Vista Reservoir site has the best potential for recreation development of any reservoir in the Cow Creek Drainage Basin. The damsite is located only about 8 miles northeast of Redding with good access from State Route 44. It was estimated that 55,000 visitor days of recreation use would occur annually at the beginning of the project operation and that this use would increase to about 480,000 visitor days by the end of the 50-year period of analysis. The present worth value of this benefit would be $5,180,000 and the average annual equivalent value is $241,000.

Reservoir storage at Bella Vista Reservoir would provide some flood prevention along Little Cow Creek below the dam and along the main stem of Cow Creek below Palo Cedro. Preliminary study showed, however, that past damages were so small that the purpose of flood prevention in the local area could not be economically justified in Bella Vista Project. Some measure of flood control would be provided in some areas along the Sacramento River downstream from the confluence with Cow Creek. Benefits in downstream areas were estimated by methods described earlier and would total about $71,000 annually. The capitalized benefit would be $1,500,000.

Water could be stored in Bella Vista Reservoir during periods of surplus and released during periods of need for export to areas downstream from the local area. The firm yield of the Sacramento-San Joaquin Delta would be increased by about 34,000 acre-feet annually if Bella Vista Reservoir were operated as proposed herein. The present worth value of export benefits is $7,620,000. The equivalent average annual benefit is $355,000.

A summary of Bella Vista Project benefits is presented in Table 37.

TABLE 37

SUMMARY OF BELLA VISTA PROJECT BENEFITS
(150,000 acre-feet storage)

Project Purpose	Present Worth of Total Benefits	Equivalent Average Annual Benefit
Fishery Enhancement	$ 1,190,000	$ 55,000
Recreation	5,180,000	241,000
Flood Control	1,500,000	71,000
Conservation for Export	7,620,000	355,000
Total	15,490,000	722,000

Economic Justification

The present worth value of project benefits throughout the 50-year period of economic analysis (1970-2020) was estimated to be $15,490,000. The total capitalized cost of the project, based on 1963 price levels and including the present worth of future expenditures for additions and for operation and maintenance, was estimated to be $20,230,000. The resulting comparison of benefits and costs shows that the benefit-cost ratio is 0.8 to 1.0 and that, therefore, the project is not economically justified under present economic conditions.

Best Development of Water Resources in Cow and Bear Creek Basins

Studies of the potential for surface water development in the Cow and Bear Creek Basins indicate that there is a large undeveloped supply of surface water available. The studies also indicate that the demand for services from surface water storage projects would be limited and that local water supplies for agricultural and domestic use could best be supplied from ground water. Because of the limited demand for project services, full basin development would not be economically justified at this time.

The only surface water storage project economically justified is the Millville Project. The project, as proposed, does not include diversions from either Old Cow or Bear Creeks. If the demand for water continues to increase, diversion of water into and regulation by Millville Reservoir may become necessary and economical at some time in the future.

The Millville Project as proposed herein would be a multiple-purpose project which includes the purposes of fishery enhancement, recreation, flood control, and conservation for export. Considering the present stage of local area development and present economic conditions, this project is believed to be the proper development for the Cow Creek Basin at this time. It provides a nucleus around which future surface water developments could be staged as demands for conservation of water increase and economic conditions change.

Plans for Development of Thomes Creek Basin

Thomes Creek Basin consists of a 300-square-mile drainage area on the west side of the Sacramento River valley. The basin is bounded on the north by Cottonwood and Elder Creek Basins, on the west by the Eel River, and on the south by Stony Creek. Thomes Creek joins the Sacramento River about 15 miles downstream from Red Bluff.

Precipitation, which falls as rain and snow in the higher elevations of the Thomes Creek watershed, produces a large annual runoff which could be stored in a reservoir at Paskenta damsite. Even though the snowpack at high elevations tends to prolong the surface runoff into the early summer months, there is need for conservation of high winter runoff for use during the low streamflow periods. This could be accomplished by storage at the Paskenta site near the town of Paskenta.

Only cursory study of the potential for ground water development in the Thomes Creek area was completed during this investigation. However, extensive ground water investigations completed by the U. S. Bureau of Reclamation have indicated that only a nominal potential for ground water development exists within the Thomes Creek irrigation water service area boundaries.

Paskenta Reservoir is the only water storage site considered for development in the Thomes Creek Basin.

Paskenta Project

The Paskenta Project consists of a dam and reservoir on Thomes Creek, an irrigation distribution system, and recreation, fishery enhancement, and wildlife preservation facilities. The damsite is in Tehama County about 2-1/2 miles upstream from the town of Paskenta in Section 6, T23N, R6W, MDB&M.

The drainage area tributary to the reservoir contains about 185 square miles and produces an average runoff of about 180,000 acre-feet annually. The lowest runoff of record was 33,000 acre-feet in 1923-24, the highest runoff was 446,000 acre-feet in 1937-38. Present and future impairments to streamflow upstream from the site were studied. These studies revealed that future upstream impairments would be negligible.

Water stored in a reservoir at this site could be used for local irrigation, improvement of the salmon spawning areas in Thomes Creek, recreation, and export to the Delta. Operation of the reservoir for flood control could also provide a measure of flood control along Thomes Creek and the Sacramento River.

A feasibility study of the Paskenta Project as a local project to be developed by the Tehama County Flood Control and Water Conservation District was made by Clair A. Hill and Associates, Civil Engineers, in June 1961. It was concluded in that report that a multiple-purpose project including a reservoir with a capacity of 65,000 acre-feet would provide water for irrigation, fishery enhancement, and recreation and that the project benefit-cost ratio would be 1.28 to 1.00.

In that report no consideration was given to flood control as a primary function of the project because it was assumed that future diversion to Newville (Glenn) Reservoir would effect complete control of Thomes Creek runoff. However, it has not yet been decided when or if the Newville (Glenn) project will be built.

The plans presented in this bulletin are based on the assumption that Paskenta would be the only water development project on Thomes Creek and that it would not depend on any imports from the North Coast. However, the project as presented herein would be fully compatible with future developments in the North Coast.

<u>Project Analysis</u>

Preliminary study of the Paskenta Project indicated that there would be a demand for services from the following project purposes: local irrigation, fishery enhancement, recreation, flood control, and conservation for export. Studies indicated that each of the above purposes should be included in the project analysis since there is a demonstrated demand for each function and, in addition, the specific costs of each purpose were less than the estimated benefits.

Reservoir Sizing. Project costs and benefits were compared for several reservoir sizes varying from a small reservoir capable of supplying only local needs to the larger sizes required for multiple-purpose use. Several combinations of project purposes were studied in conjunction with the various sizes to determine the most economical size. These studies indicated that a multiple-purpose Paskenta Reservoir with storage capacity of 105,000 acre-feet at normal pool elevation of 987 feet would provide maximum net benefits.

General Features. The Paskenta Project as proposed would consist of the following project features: (1) dam and appurtenant structures, (2) reservoir, (3) stream improvement for salmon spawning, (4) irrigation distribution system, and (5) recreation facilities. General project features are shown in Figure 9.

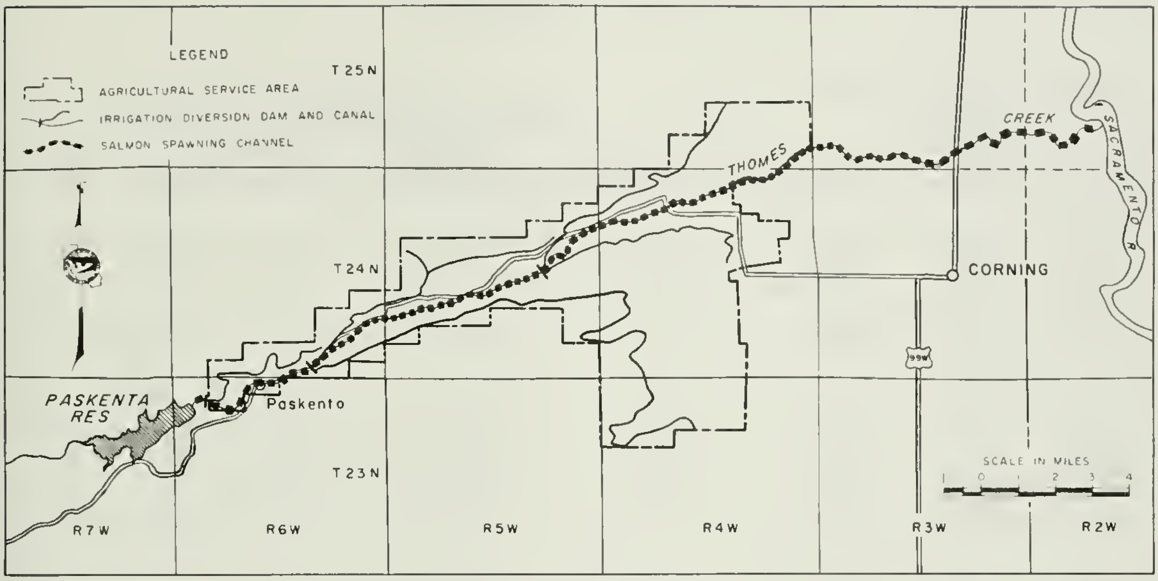
Project Operation. Project water yields were determined by operation studies completed under operation criteria set forth at the beginning of this chapter. The reservoir was operated to supply the maximum requirements for local irrigation, and to provide for maximum salmon enhancement. In addition, consideration was given to development of water for export and for flood protection. An annual summary of the monthly operation study is presented as Table 38.

Geology

Paskenta damsite was formed by down cutting of Thomes Creek through relatively soft rock beds sandwiched between two resistant conglomerate and sandstone beds. The foundation rock occurs in stratified beds having very steep cross-channel dips of 70 to 80 degrees. The greater portion of the damsite is a massive or thickly bedded fine to medium-grained sandstone. This sandstone is over 1,100 feet thick and extends from above the crest of the proposed dam on the left abutment across the channel. This unit includes

FIGURE 9

PASKENTA PROJECT



General Project Features
(All elevations are USGS datum)

Dam

Location . . . . SE$\frac{1}{4}$, Sec. 6, T23N, R6W, MDB&M
Type . . . . Zoned Earthfill
Height Above Streambed, in Feet 212
Crest Elevation, in Feet 1,002
Volume of Fill, in Cubic Yards . . . . 3,470,000 including dike

Reservoir

Drainage Area, in Square Miles 185
Water Surface Elevation at Normal Pool, in Feet 987
Storage Capacity, in Acre-Feet 105,000
Water Surface Area, in Acres 1,600

Spillway

Type . . . . Chute with gated weir, two 50' x 30' radial gates
Weir Crest Elevation, in Feet 957
Design Capacity, in Second-Feet 80,000

Outlet Works

Type . . . . 36-inch steel pipe encased in concrete

Project Accomplishments

Local Irrigation Yield, in Acre-Feet Per Year 63,000
Salmon Enhancement, in Numbers of Increased Annual Catch 20,000
Yield to the Sacramento-San Joaquin Delta, in Acre-Feet Per Year . 34,000

TABLE 38

SUMMARY OF MONTHLY OPERATION STUDIES
OF PASKENTA RESERVOIR
(In 1,000 acre-feet)

Runoff Year	Storage on Oct. 1	Inflow 1/	Water Releases and Losses: Local Irrigation	Fishery Enhancement	Evaporation	Spill	Total
1921-22	10.2	193.2	63.0	28.0	4.1	49.3	144.4
22-23	59.0	145.5	63.0	28.0	4 3	49.3	144.6
23-24	59.9	32.5	31.5 2/	14.0 2/	3.6	0	49.1
24-25	43.3	284.0	63.0	28.0	4.4	166.1	261.5
1925-26	65.8	144.4	63.0	28.0	4.1	64.2	159.3
26-27	50.9	337.1	63.0	28.0	4.3	228.1	323.4
27-28	64.6	256.7	63.0	28.0	4.4	165.6	261.0
28-29	60.3	55.4	63.0	28.0	3.2	0	94.2
29-30	21.5	142.2	63.0	28.0	4.0	16.9	111.9
1930-31	51.8	53.7	31.5 2/	14.0 2/	3.8	0	49.3
31-32	56.2	113.2	63.0	28.0	4.3	15.2	110.5
32-33	58.9	88.3	63.0	28.0	3.9	0	94.9
33-34	52.3	74.4	31.5 2/	14.0 2/	4.4	0	49.9
34-35	76.8	154.0	63.0	28.0	4.4	77.2	172.6
1935-36	58.2	190.0	63.0	28.0	4.3	95.6	190.9
36-37	57.3	112.2	63.0	28.0	4.3	12.5	107.8
37-38	61.7	446.2	63.0	28.0	4.5	341.4	436.9
38-39	71.0	64.7	63.0	28.0	3.9	0	94.9
39-40	40.8	285.1	63.0	28.0	4.3	172.4	267.7
1940-41	58.2	431.8	63.0	28.0	4.5	320.9	410.9
Average	53.9	180.2			4.2		

1/ Recorded flows at the stream gaging station "Thomes Creek at Paskenta."

2/ Deficiency of 50 percent in releases during 1924, 1931, and 1934.

NOTE: Storage at normal pool is 105,000 acre-feet, at minimum pool 5,000 acre-feet. Storage on October 1 plus inflow minus releases and losses equals storage on following October 1. Minimum storage for this operation study is 10,100 acre-feet on December 1, 1929. It was assumed that irrigation return flow and fishery enhancement releases would satisfy any prior downstream water rights.

a few mudstone and conglomerate interbeds. The remainder of the damsite is underlain by a thick mudstone unit extending from the sandstone at the base of the right abutment to above the proposed crest on the right abutment. This rock is firm and moderately hard on a freshly exposed surface, but slakes rapidly when exposed to air.

Several minor faults and shears are apparent in the damsite area. The largest fault, a high angle strike-slip fault, occurs in the channel section but is largely obscured by stream gravels. Actual displacement along the fault is not known since movement has been nearly parallel with the bedding, and no offsetting of beds has occurred. This fault does not appear to be a serious defect of the foundation.

In 1946 the U. S. Bureau of Reclamation drilled eight exploration holes having a total footage of 612 feet. Three holes were drilled in each abutment, one hole in the channel near the downstream toe of the dam, and one in a topographic saddle north of the damsite. No subsurface foundation exploration was conducted at the damsite during the current investigation.

Water pressure testing conducted during the previous subsurface explorations indicate that the rock is fairly tight. It is anticipated that only a small to moderate amount of grout will be required to seal the abutments.

Rock types in the reservoir area are predominantly mudstone and sandstone. The reservoir will not be subject to leakage, and slides will not be a problem since these rocks are not deeply weathered. Minor silting is expected in the upper portion of the reservoir where Thomes Creek discharges from its canyon and enters the reservoir. This will not seriously impair the usable storage capacity of the reservoir.

A borrow materials investigation program was conducted by the department during this investigation. Sixty-two auger holes were drilled and soil tests were conducted on samples taken from 30 of the holes.

Impervious materials occur in the terraced areas along Thomes Creek upstream from the damsite. This material is slopewash which consists of weathered and transported mudstone, sandstone, and conglomerate. The material varies from clayey silt to silty clay and is occasionally gravelly due to weathered conglomerate contributing to the slopewash. It is estimated that a sufficient supply of this material is available. However, the Tehama formation, located 2 miles east of the damsite, would also provide suitable material for impervious fill.

The proposed borrow areas for pervious material are located in the channel both upstream and downstream from the site and are shown on Plate 13, "Paskenta Dam and Reservoir on Thomes Creek". Due to larger rock sizes and greater uniformity, the downstream deposits are probably the most suitable for use as pervious material. These borrow locations are shown as area 5 on Plate 13. Oversize cobbles and boulders would have to be removed before this material could be placed as pervious fill.

Test blasting and core drilling was performed by the Department of Water Resources in a possible quarry area at the west end of Williams Butte in 1959. A diamond core hole drilled in this material indicated that the material below depth of 20 to 30 feet would be adequate for rock-fill or riprap.

Project Designs and Costs

The designs and costs of the Paskenta Project are presented in the following paragraphs under the headings of dam and appurtenant structures, reservoir, irrigation distribution system, stream management for fishery enhancement, preservation of wildlife, and recreation.

Dam and Appurtenant Structures. A zoned earthfill dam was selected for Paskenta Dam in order to take maximum advantage of available construction material. A typical cross section of the dam showing the various embankment materials is shown on Plate 13. The impervious material, which comprises Zones 1 and 2 of the dam embankment, would be obtained from borrow areas 1 and 2.

A chimney drain would be located well inside the downstream limit of Zone 1 to provide positive seepage control. Drain material would be excavated from area 5 shown on Plate 13.

A pervious rolled rock zone would be placed at the upstream edge of the fill to prevent failure of the embankment during rapid drawdown from the reservoir. The material for this zone would be obtained by quarrying conglomerate material from borrow areas 3 and 4.

The Spillway would be excavated through the left abutment. Excavation would be through soft shale and fairly firm sandstone that strike nearly parallel to the channel. A gated spillway was selected as the most economical design based on comparative cost estimates. The spillway was designed to pass the probable maximum flood inflow of 83,000 second-feet with a maximum spillway discharge of 80,000 second-feet and a water surface elevation 9 feet above normal pool. As a check of safety of the dam against overtopping in the event of failure of the gate operating mechanism, the maximum flood of record at Paskenta gaging station (23,700 second-feet) was routed over the top of the spillway gates. On the basis of this study, the height of the dam was increased by 6 feet to provide 15 feet of surcharge elevation above the top of the gates.

The Spillway would consist of (1) an approach channel with a 100-foot-long paved approach apron; (2) a control structure consisting of a 7.5-foot-high concrete overflow weir founded on firm rock, and two counterweighted radial gates, each 50 feet long by 30 feet high; and (3) a 100-foot-wide, concrete-lined chute section, about 800 feet long, which would terminate with a flip bucket to dissipate the energy of the water before it enters the stream section downstream from the dam.

The gates normally would be operated by electrically powered hoists, but, in addition a float chamber would be provided to insure automatic opening of the gates without any external source of power.

The Outlet Works would be located along the base of the right abutment and would be utilized for diversion of the stream during construction of the embankment. They would consist of an intake structure capable of releasing water from both upper and lower elevations of the reservoir, two 36-inch hydraulically operated slide gates for control of releases, a 36-inch welded steel pipe encased in concrete, and an energy dissipating valve at the downstream end.

The outlet works was designed to discharge 150 second-feet with a gross head of 80 feet.

Reservoir. About 3,000 acres of land must be acquired for the reservoir and for contiguous areas suitable for recreation development. Of this amount, 1,600 acres in the reservoir area generally consisting of brush and range land with scattered oak trees would have to be partially cleared.

About 2 miles of existing county road would require relocation, and 2 miles of access road to the dam would have to be constructed. There are no utilities located in the reservoir area which require relocation.

Table 39 includes a summary of the costs of Paskenta Dam, Reservoir, and Appurtenances.

Irrigation Distribution System. The Thomes Creek service area shown on Plate 4 and in Figure 9 could be served by water stored and released from Paskenta Reservoir. A canal leading directly from the main dam and four canals leading from two diversion structures downstream from the dam would supply the entire service area by gravity flow.

The canal leading from the main dam would be about 6 miles long and would have a maximum capacity of about 10 second-feet. Water would be released directly from Paskenta Dam at about elevation 800 feet. The canal would generally follow the topographic contour and would provide water for about 800 acres of land north of Thomes Creek adjacent to the town of Paskenta.

A small diversion dam across Thomes Creek about 4 miles downstream from the dam would be required to divert water into two canals at about elevation 700 feet. One canal would transport water to about 3,800 acres of land lying north of Thomes Creek in the vicinity of Flournoy. The canal would be about 10 miles long, with a flume across McCarty Creek, and would have a maximum capacity at the headworks of about 45 second-feet.

The second canal would transport water to about 1,000 acres of land on the south side of Thomes Creek upstream from Flournoy, and would continue through Squaw Hollow along Corning Road to serve two areas adjacent to the Corning Canal service area having a total area of about 3,500 acres. The first area, which lies along Glenn Road, contains about 1,500 acres, and the second area, lying along Tapscott Road, contains about 2,000 acres. The canal would be about 22 miles long and would have a maximum capacity at the headworks of about 70 second-feet. This capacity would be reduced progressively as water is used along the canal route.

Another small diversion dam in Thomes Creek would be required about 12 miles downstream from Paskenta Dam at about elevation 500 feet. Water from this dam would be diverted into two canals, one on each side of the stream.

TABLE 39

SUMMARY OF COSTS OF PASKENTA
DAM, RESERVOIR, AND APPURTENANCES

Item	Construction Cost	Engineering, Administration, Contingencies, And Interest During Construction	Total Capital Cost
Dam and Appurtenances			
Embankment	$4,300,000		
Spillway	2,000,000		
Outlet Works	240,000		
Saddle Dam	110,000		
Subtotal	6,650,000	2,500,000	9,150,000
Reservoir			
Land Acquisition and Clearing	390,000		
Construction Facilities and Relocation of Roads	340,000		
Subtotal	730,000	270,000	1,000,000
TOTAL	7,380,000	2,770,000	10,150,000

The north canal would transport water to about 4,200 acres of land surrounding Henleyville. It would be about 8 miles long and would have a maximum capacity of about 65 second-feet.

The south canal would transport water to about 2,500 acres of land bounded by Thomes Creek, the 500-foot topographic contour, and the Corning Canal service area. It would be about 7 miles long and would have a maximum capacity of about 40 second-feet.

Both diversion structures on Thomes Creek would be provided with fish passage facilities for upstream migrating adult salmon. Also, all main canals would be equipped with suitable fish screens to prevent loss of downstream migrating juvenile salmon.

The estimated construction cost of the 53 miles of canals and diversion structures, including 20 percent for engineering and contingencies but not including rights-of-way costs, would be $817,000. Annual operation and maintenance costs were estimated to be about $8,200. The total capitalized cost of construction, operation, and maintenance would be $990,000. The average annual equivalent cost would be $46,000.

Stream Management for Fishery Enhancement. Studies were conducted by the Department of Fish and Game at the request of the Tehama County Flood Control and Water Conservation District to be used for their feasibility study of the Paskenta Project. These studies indicate that nearly all of Thomes Creek below the damsite could be improved for salmon spawning with water released from reservoir storage. In order to properly manage the stream channel and improve some areas for maximum spawning activity, it would be necessary to acquire rights to manage about 30 miles of Thomes Creek below the damsite. The acquired area would consist of about 960 acres at a cost of about $200,000. With improved flows provided by the proposed project, the present spawning run could be increased by about 6,500 fish. The stream should be stocked with fingerling salmon at a rate of 200 fingerlings per adult spawner each year for 4 years following project construction, to initiate the spawning run. This would cost about $13,000 per year.

Following acquisition and initial improvement of the stream channel the maintenance required could be carried out by the regional headquarters of the Department of Fish and Game. Therefore, no annual cost was assigned to the project for operation and maintenance of spawning gravels.

The total estimated initial cost of increasing the spawning run in the 30-mile reach of Thomes Creek would be $240,000. The average annual equivalent cost would be $11,000.

Preservation of Wildlife. Department of Fish and Game wildlife studies conducted during the Tehama County Investigation showed that development of the Paskenta Project would cause loss of habitat for many deer which use the reservoir area. Their estimates indicate that purchase, control, and improvement of about 200 acres of land within the project boundary and 500 acres outside the boundary above maximum reservoir pool elevation would be required to compensate for the deer range lost by inundation.

A detailed description of the land and improvements required is presented in Appendix B. Initial development costs are estimated to be $38,000. Annual maintenance of the deer range and quail habitat is estimated to be $1,300. Total present worth value of wildlife preservation costs would be about $70,000. The average annual equivalent costs would be $3,300.

Recreation. Estimates of the recreation facilities needed at the Paskenta Project to meet the projected recreation demand were made to determine if the site could be developed to meet the demand and to estimate costs of the recreation facilities. Estimated demand would require installation of about 29 camp units and 24 picnic units during the first decade of project operation. The number of recreation units required to meet the future demand was estimated on the basis of recreation use projections.

The cost of the recreation facilities based on state park experiences is estimated to be $3,000 for each camp unit and $2,100 for each picnic unit. These unit costs would include water supply, sanitary facilities, and interior recreation roads. Costs of other recreation facilities such as boat launching areas and swimming beaches were estimated separately.

Costs of operation, maintenance, and replacement of the recreation facilities were estimated from costs experienced at similar recreation areas. This cost was found to be about 30¢ per visitor-day.

Total present worth cost of installation of recreation facilities and operation, maintenance, and replacement during the 50-year period of analysis is $810,000. The average annual equivalent cost is $37,700.

Summary of Project Costs. A summary of estimated project costs during the 50-year period of analysis is presented in Table 40. The capital

TABLE 40

SUMMARY OF PASKENTA PROJECT COSTS

Project Feature	Present Worth: Capital Cost	Present Worth: Operation, Maintenance, Replacement, and General Expense	Present Worth: Total	Average Annual Equivalent Cost
Dam, Reservoir, and Appurtenances	$10,150,000	$480,000	$10,630,000	$495,000
Irrigation Canals	820,000	170,000	990,000	46,000
Access Rights and Stream Improvement for Salmon Spawning	240,000	0	240,000	11,000
Recreation Facilities	450,000*	360,000	810,000	37,700
Preservation of Wildlife	40,000	30,000	70,000	3,300
TOTAL	11,700,000		12,740,000	593,000

* Includes present worth value of future facilities.

cost of the project is estimated to be about $11,700,000. Present worth of the total expenditures over the 50-year period is estimated to be $12,740,000. The average annual equivalent cost would be $593,000.

Project Accomplishments and Benefits

Paskenta Project as proposed herein would provide benefits to both the local and statewide economy. The accomplishments and benefits from each project purpose for a reservoir with a storage capacity of 105,000 acre-feet are discussed in this section.

Local Irrigation Supply. The Thomes Creek service area as shown on Plate 4 contains about 26,000 acres of land classified as irrigable. Of this area, 19,000 acres could be irrigated under maximum development, but only about 16,000 acres having a maximum water requirement of 52,000 acre-feet per year would be served by this project.

The proposed project could provide a firm annual yield of 63,000 acre-feet at the reservoir on an irrigation schedule. This would be sufficient to meet maximum project demands and allow 11,000 acre-feet per year for loss in transit to the service areas.

Benefits from supplying water to the service area were calculated by the procedure described at the beginning of this chapter. Table 7 in Chapter 2 shows projected land use by decades for the total project period. Table 10 shows projected water requirements over the project analysis period. Benefits based on the land use projections were calculated to have a capitalized value of about $8,550,000. This is equivalent to an average annual benefit of $398,000.

Fishery Enhancement. The assured streamflow provided by the Paskenta Project would make sufficient gravel available in Thomes Creek for an estimated 6,500 salmon spawners. A firm water supply of about 28,000 acre-feet would be made available on a demand schedule developed by fisheries biologists of the Department of Fish and Game. Figure 10 shows the flow in Thomes Creek during the spawning season under project conditions, as compared to the median impaired flow for 1922 through 1941. Recorded monthly flows for a typical dry year are also shown.

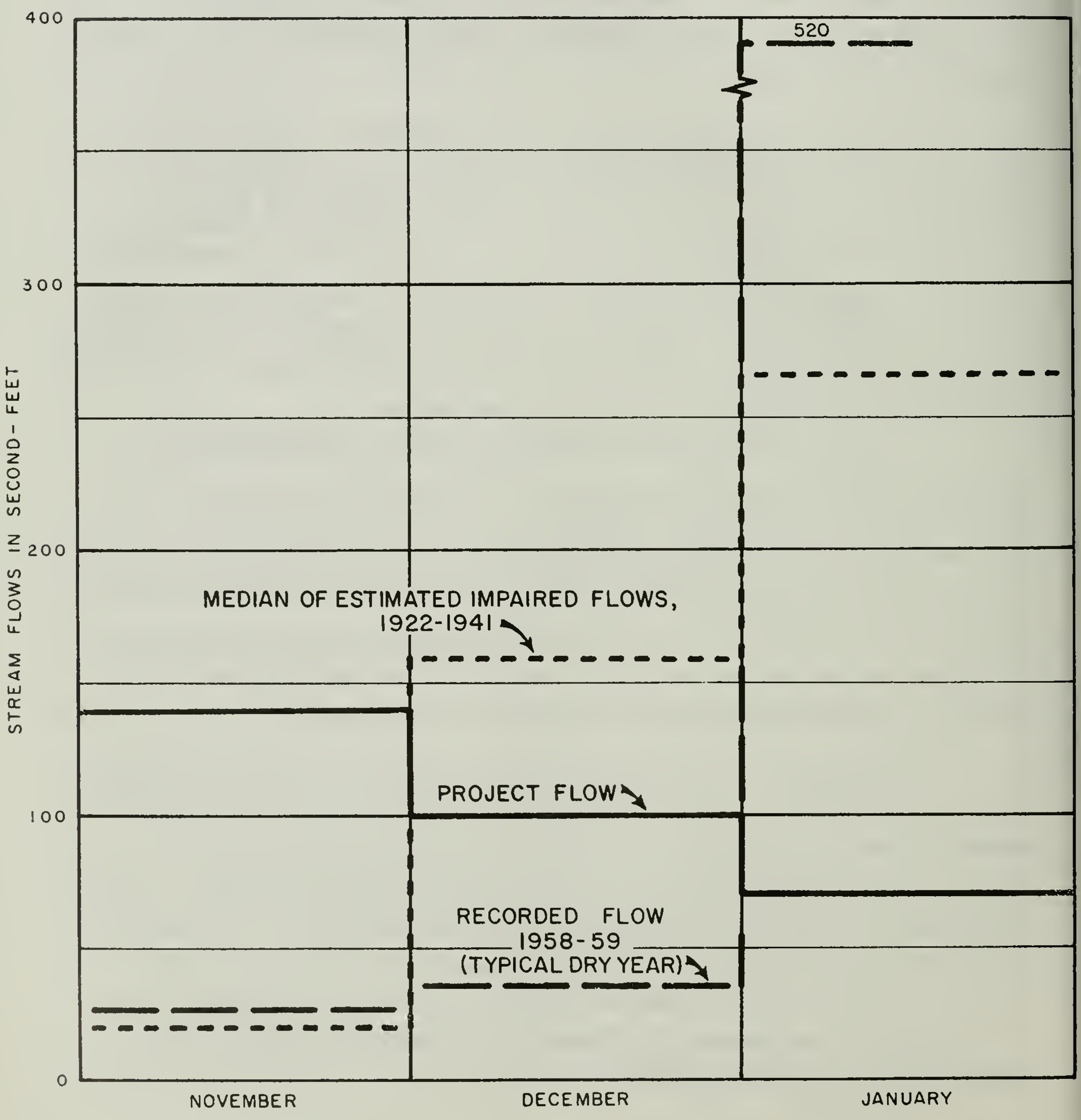
During an average year the 6,500 spawners would produce an increased commercial catch of about 16,000 salmon and an increased sport catch of about 4,000 salmon, and would provide 6,500 adult spawners to complete the spawning cycle. Benefits from the increased catch would have a capitalized value of $1,640,000. The average annual equivalent benefit would be about $76,000. The method used to compute these benefits was presented earlier in this chapter. A detailed description of the salmon potential and possible production is presented in Appendix B.

Recreation. Water-associated recreation in the form of camping, boating, picnicking, reservoir fishing, and swimming would be provided at Paskenta Reservoir. With adequate facilities provided for the predicted demand, it is estimated that there would be about 20,000 recreation visitor-days of use annually at the beginning of project operation. This number would increase to about 180,000 visitor-days annually by the year 2020.

Total recreation benefits for this project were estimated to have a capitalized value of about $2,200,000. The equivalent average annual benefit would be about $103,000.

FIGURE 10

COMPARISON OF AVERAGE MONTHLY STREAM FLOWS IN THOMES CREEK BELOW PASKENTA DAM DURING THE SALMON SPAWNING SEASON



Flood Control. Agricultural lands along Thomes Creek and downstream from the Paskenta damsite suffer flood damage at frequent intervals. Damages come mainly from inundation of farm land and from streambank erosion. There is occasionally some damage to public facilities such as roads and bridges.

Since Paskenta Reservoir would be operated to supply irrigation and fishery enhancement water during the summer and fall months, there would generally be at least 40,000 acre-feet of reservoir storage available on December 1 to impound flood waters.

Benefits from prevention of local flood damages were estimated by comparing them with benefits from Hulen Reservoir on Cottonwood Creek. This benefit at Paskenta Reservoir was estimated to be $25,000 annually. The capitalized value of this amount would be $540,000.

Earlier in this chapter it was stated that an annual flood control benefit of 50¢ per acre-foot of active storage was assigned to each tributary reservoir for flood reduction in the Sacramento Valley between Red Bluff and Colusa. This remote benefit to Paskenta Reservoir would total about $50,000 annually. The capitalized value of this amount would be $1,070,000.

Total capitalized value of flood control benefits would be $1,610,000. The average annual equivalent value is $75,000.

Conservation for Export. Since Paskenta Reservoir would store surplus water during flood years, and since the reservoir would be operated to provide water for fishery enhancement, some water which would have reached the Delta during periods of spill would now be conserved and released during periods of need to increase the yield of the Sacramento-San Joaquin Delta. It is estimated that this increased yield would be about 34,000 acre-feet annually. The capitalized value of the benefit from this water is about $7,850,000. The average annual equivalent benefit is $365,000.

Summary of Project Benefits. A summary of the estimated project benefits during the 50-year period of analysis is presented in Table 41. Present worth value of the total benefits which would accrue over the

50-year period is estimated to be $21,850,000. The average annual equivalent benefit would be $1,017,000.

TABLE 41

SUMMARY OF PASKENTA PROJECT BENEFITS

Project Purpose	Present Worth of Total Benefits	Average Annual Equivalent Benefit
Local Irrigation	$8,550,000	$ 398,000
Fishery Enhancement	1,640,000	76,000
Recreation	2,200,000	103,000
Flood Control	1,610,000	75,000
Conservation of Export	7,850,000	365,000
Total	21,850,000	1,017,000

Economic Justification

The present worth value of the project benefits was estimated to be $21,850,000. The total capitalized cost of the project, based on 1963 price levels and including the present worth value of future expenditures for additions and for operation and maintenance, was estimated to be $12,740,000. The resulting benefit-cost ratio, 1.7 to 1.0, indicates that the project is economically justified.

Cost Allocation

A preliminary allocation of project costs was made to compare the cost of producing local irrigation water, fishery enhancement, and export yields of this project, with costs of producing the same purposes from other projects. The results show that the project could supply 52,000 acre-feet of local yield at an annual cost of $287,000. The annual cost per acre-foot at canal-side would be about $5.60 or about $18.40 per acre.

Improved flow in Thomes Creek below Paskenta Dam would produce a combined increased annual salmon commercial and sport catch of about 20,000 fish. The annual cost allocated to these fish is $74,000, or about $4.00 per fish caught.

The allocation also shows that the annual cost of providing a new yield of 34,000 acre-feet annually at the Delta would be about $138,000. Assuming that the demand for additional Delta water will not occur until 1980 and that water would therefore be delivered only during the last 40 years of the 50-year project analysis period, the cost per acre-foot of water delivered would be about $6.50. Table 42 presents a summary of the preliminary cost allocation.

Best Development of Water Resources in Thomes Creek Basin

Studies of the potential for surface water development in the Thomes Creek drainage basin show that there is a large undeveloped supply of surface water available. This water supply could best be developed by a reservoir at the Paskenta site. New water yield developed would satisfy the irrigation water demand in the local area, provide fishery enhancement in Thomes Creek, and provide supplemental water supply to the Sacramento-San Joaquin Delta. The reservoir would also provide some flood control and a good setting for water-associated recreation activities.

Paskenta Reservoir, as discussed herein, could ultimately become a part of the large Glenn Reservoir Complex, an authorized feature of the State Water Project, which is being considered as the reregulatory unit for future North Coastal imports from the Middle Fork Eel River and from the Trinity River system. In this huge storage facility, Paskenta Reservoir would be one of three storage units. Water imported into the Sacramento Basin would flow into Paskenta Reservoir from the north and would flow from the reservoir via a channel on the south connecting the other storage units.

If Paskenta Reservoir were constructed before the Glenn Complex, it could be easily integrated into the system provided the water surface elevation is greater than 950 feet, USGS datum. The project proposed herein would have a normal water surface elevation at 987 feet. Therefore, the reservoir could be included in the system without increasing the height of the dam or otherwise changing the structure.

Considering both local and state-wide interests, it appears that the Paskenta Project proposed herein is economically justified and if constructed in the near future would satisfy local needs for irrigation water, provide some flood control, increase salmon populations in the Sacramento

TABLE 42

PRELIMINARY ECONOMIC COST ALLOCATION FOR THE PASKENTA PROJECT
(Based on average annual equivalent values in dollars)

	Local Irrigation	Fishery Enhancement	Recreation	Flood Control	Conservation for Export	Total
Benefits	$398,000	$76,000	$103,000	$75,000	$365,000	$1,017,000
Alternative Costs	410,000	250,000	1/	1/	212,000	---
Total Justifiable Costs 2/	398,000	76,000	103,000	75,000	212,000	864,000
Separable Costs 3/	150,000	25,000	38,000	0	46,000	259,000
Remaining Benefits 4/	248,000	51,000	65,000	75,000	166,000	605,000
Percentage Distribution of Remaining Benefits	41.0%	8.4%	10.8%	12.4%	27.4%	100.0%
Total Project Cost						593,000
Total Separable Cost						259,000
Total Remaining Joint Costs						334,000
Allocated Remaining Joint Costs 5/	137,000	28,000	36,000	41,000	92,000	334,000
Separable Costs	150,000	25,000	38,000	0	46,000	259,000
Total Allocated Costs	287,000	53,000	74,000	41,000	138,000	593,000

1/ Assumed to be in excess of benefits.
2/ The justifiable cost is the smaller of the two values, benefits and alternative costs.
3/ Separable costs are the difference between the total project cost and the cost with a given purpose excluded.
4/ Remaining benefits represent the difference between total justifiable costs and the separable costs.
5/ Remaining joint costs are allocated in accordance with the percentage distribution of remaining benefits.

River Basin, and develop a substantial new water yield to the Delta. The Glenn Complex could then be constructed at any future time without significantly changing the original project operation or accomplishments.

Best Tributary Stream Development for the Upper Sacramento River Basin

Each of the major tributary stream basins in the Upper Sacramento River Basin Investigation area have been studied, and proposals for proper development of the individual stream basins have been made. The next step in planning is to formulate a water resources development program for the entire basin using the proposed projects in each individual stream basin. In a properly formulated program, each individual project included must be economically justified and must have been compared with possible alternative means of accomplishing the project purposes. The Hulen, Dippingvat, Millville, and Paskenta Projects have met these criteria and therefore can be included in the Upper Sacramento River Basin water resources development program.

These four projects, and the ground water development projects discussed in detail in the next chapter, should be initiated as the nucleus of the total water resources development for the Upper Sacramento River Basin. The program would conform with the California Water Plan and present plans of the federal government and local water development agencies.

Local needs for agricultural water could be met from this combination of surface and ground water developments. Some flood protection would be provided in the local area, and in the Sacramento Valley between Red Bluff and Colusa.

The proposed development outlined herein would also help to fill the needs of the State of California for increased salmon populations both in the ocean and in the rivers and streams. It would develop water-associated recreational areas, and it would conserve surplus waters of the Sacramento River for use in areas of deficiency. Table 43 is a summary of program accomplishments which primarily have statewide benefits but would, in addition, benefit the local area.

TABLE 43

ACCOMPLISHMENTS OF THE UPPER SACRAMENTO RIVER BASIN WATER RESOURCES DEVELOPMENT PROGRAM

Project	Annual Increase In Total Salmon Populations	Visitor Days of Recreation Provided Over 50-year Period	Supplemental Annual Yield to Sacramento-San Joaquin Delta in Acre-feet
Hulen	84,000	7,100,000	34,000
Dippingvat	170,000	1,810,000	22,000
Millville	39,000	1,850,000	21,000
Paskenta	26,000	3,870,000	34,000
Total for Program	319,000	14,630,000	111,000

Table 44 presents a summary of the unit costs, computed by dividing the allocated cost by the units of the specific accomplishment, and the project benefit-cost ratios.

TABLE 44

SUMMARY OF UNIT COSTS OF STATEWIDE PROGRAM ACCOMPLISHMENTS

Project	Salmon Production (in dollars per salmon)	Recreation (in dollars per visitor day)	New Delta Yield (in dollars per acre-foot)	Benefit-Cost Ratio
Hulen	1.67	0.34	5.30	2.2
Dippingvat	1.34	0.40	6.30	2.1
Millville	2.42	0.55	9.30	1.4
Paskenta	3.00	0.38	6.50	1.7
Weighted Average for Program	1.69	0.38	6.60	1.9

The probable sequence of project development of Upper Sacramento River tributary reservoirs would be (1) Hulen, (2) Dippingvat, (3) Paskenta, and (4) Millville. Local interest, local demands for project services, and project financing would also play an important role in determining the proper sequence of development.

Each of the projects listed above would have statewide benefits which are substantially larger than their allocated costs, and each would produce substantial new yields for export, while at the same time enriching the local economy. It may therefore be in the best interest of the State of California to participate in the development of these projects.

CHAPTER V. GROUND WATER DEVELOPMENT

In addition to planning for surface water development projects within the Upper Sacramento River Basin area, the possibility of supplying future water requirements from ground water was also considered during this investigation. The areas studied in detail included the Thomes Creek, Cottonwood Creek, and Cow Creek service areas described earlier. An appraisal of the ground water development potential of the Thomes Creek service area indicated that little opportunity exists in that area for development of sufficient quantities to serve agricultural water demands. Similar studies conducted in the Cottonwood and Cow Creek service areas indicate that adequate supplies for agricultural development are available.

The Cottonwood and Cow Creek service areas lie wholly within the boundaries of the Redding ground water basin which has previously been studied by the Department as a part of the "Shasta County Investigation", Bulletin No. 22. The ground water development potential of the Redding ground water basin is therefore discussed in general terms, and the Cottonwood and Cow Creek service areas are discussed in detail in this chapter.

Scope of Ground Water Investigation

The ground water investigation consisted of reviewing and updating previous studies of the Redding ground water basin, and collecting additional water level measurements and other well data specifically pertaining to the Cottonwood and Cow Creek service areas. Study was concentrated in these areas since they comprise the lands which have the greatest need for a near-future water supply that cannot readily be obtained from other sources.

Redding Ground Water Basin

The Redding ground water basin contains most of the usable ground water in the Upper Sacramento River area. The boundaries of this basin were defined in Chapter II of this report.

Geology

Important fresh-water-bearing geologic formations recognized in the Redding ground water basin include alluvial deposits of Recent age, the Red Bluff formation of Pleistocene age, and the Tehama and Tuscan formations of Upper Pliocene age. The Tehama and Tuscan formations comprise the principal water-bearing deposits in the basin. The thickness of these formations varies from a feather-edge along the west and north boundaries to as much as 3,000 feet along U. S. Highway 99, 6 miles south of Cottonwood. These fresh water-bearing sediments are underlain by salt-water-bearing or nonwater-bearing rocks of the Chico formation of Cretaceous age.

Ground Water Measurements

A few measurements of ground water levels in wells were made by the Bureau of Reclamation in 1947 and 1948. From 1955 through 1958, the Department of Water Resources conducted a comprehensive investigation of the water resources of Shasta County. During this investigation an extensive program of well measuring was made in the Redding ground water basin. From 1958 through 1963, periodic measurements at representative wells have continued. Hydrographs of several of these wells in the Cottonwood and Cow Creek service areas are shown on Plate 14, "Ground Water Development Potential in the Cottonwood and Cow Creek Service Areas". In spite of substantially increased use of ground water since 1956, there has been no significant lowering of the water table, thus pointing out that the ground water reservoir is not presently being overdrawn in either of these areas.

Potential for Development

Most of the lands within the ground water basin have a medium to high potential for ground water development. Present data indicate that properly constructed and developed wells should yield sufficient quantities of ground water for agricultural and domestic purposes almost anywhere in the Cottonwood and Cow Creek service areas. However, since the Tehama and Tuscan formations, from which most of the pumped water is produced, are only moderately permeable, fairly deep wells and pump lifts of up to 160 feet are often required to produce irrigation yields.

The potential for ground water development in the Cottonwood and Cow Creek service areas is shown on Plate 14.

Storage Capacity

Ground water storage capacity is computed as the product of the specific yield and the total volume of material in the depth zone considered. Specific yield refers to the ratio of the volume of water that a unit of saturated soil will yield by gravity to the total volume, and is expressed as a percentage. Specific yield is determined by the physical characteristics of the materials found in the basin. The following tabulation, taken from estimates published in State Water Resources Board Bulletin No. 1, lists specific yield percentages for various classifications of materials found in the Redding ground water basin.

SPECIFIC YIELDS

Type of Materials	Specific Yield, in Percent
Gravel	25
Sand, including sand and gravel	20
Fine sand, tight sand, sandstone, and related deposits	10
Clay and gravel, cemented gravel and related deposits	5
Clay, silt, sandy clay, and related fine-grained deposits	3

In order to indicate the magnitude of ground water in storage, an estimate was made of the storage capacity directly beneath the proposed service areas. The storage capacity was computed by utilizing existing well logs and the above specific yield values to develop a composite specific yield for each depth interval between 0 and 300 feet. This value was then multiplied by the total volume of material in each depth zone. A summation of these storage capacities represents the total capacity within each area being considered. Storage capacities for the various service areas are listed in the following sections of the report.

Recharge

The Redding ground water basin is recharged primarily from precipitation which percolates into the underlying strata. Most of the recharge enters at the higher elevations and gradually moves through the underground formations into the ground water reservoir in the valley. Some water also enters the valley ground water reservoir from surface streams flowing through the area. Irrigated lands also contribute by deep percolation of applied water to the ground water basin. Total recharge to the basin has been, and appears to continue to be, more than adequate to supply the water required to replenish the amounts of ground water being extracted. Only a small seasonal variation in ground water levels has been observed, and accretions to the Sacramento River are known to occur from ground water.

Increases in use of ground water in the basin would induce additional subsurface inflow to these areas. As the water levels are lowered by increased use, a steeper hydraulic gradient will be created. This will tend to cause additional water to flow into the ground water basin. Lowering of ground water levels by increased pumping would also reduce the amount of ground water accretions to the Sacramento River and thus further increase the available ground water supply. Deep percolation of future imports of water from the Trinity River used in the Happy Valley and Bella Vista Water Districts will provide additional recharge to the ground water basin.

It is estimated that ground water replenishment from the above natural and irrigation sources will be sufficient to support the ultimate irrigation requirements for the Cow Creek and Cottonwood service areas without causing excessive lowering of ground water elevations.

Cottonwood Service Area

The Cottonwood service area and its three subareas, Gas Point, Evergreen, and Bowman Road, have been previously described in Chapter II and are shown on Plate 3. Because of its relatively small areal extent the Cottonwood service area is discussed herein as a single unit. However, tables showing yields of wells and ground water storage capacity present a breakdown by subareas.

The area underlying the Cottonwood service area is composed of Continental and Marine sediments which range in age from Recent to Cretaceous. Marine sediments of the Chico formation bound the ground water basin on the west, dip steeply to the east, and comprise the base of the ground water reservoir throughout the area. These sediments consist of a thick succession of sandstones and shales which are either impervious, or contain saline waters of unusable quality. The Continental sediments comprise thr ground water reservoir and consist of a heterogeneous mass of clays, silts, sands, gravels, or mixtures. The units of Continental sediments include stream channel and associated terrace deposits, and the Red Bluff and Tehama formations.

Ground water beneath the Cottonwood service area is either unconfined or semiconfined. Most domestic wells obtain water from unconfined zones in either the alluvium or terrace deposits, or the upper strata of the Tehama formation, while irrigation wells usually tap the deeper zones of the Tehama formation. Although some wells in the Cottonwood service area show semiconfined characteristics, the ground water reservoir is generally considered to be unconfined within the depth zones studied. Therefore, fluctuations in water levels are considered to be representative of changes in ground water storage.

Infiltration of precipitation provides the major source of recharge to the Cottonwood service area. Consequently, ground water levels are almost always highest in the spring after the winter rains and lowest in the fall after the pumping season.

The average amount of precipitation available for recharge was estimated by subtracting the estimated evapotranspiration of native vegetation and the surface runoff from the total amount of precipitation. The total recharge from this source was estimated to be on the order of 50,000 to 150,000 acre-feet annually.

Streamflow percolation in the upper reaches also provides a source of recharge. However, lack of data precludes an estimate of recharge from this source.

Only minor seasonal or long-term changes in ground water levels have been noted in the Cottonwood service area. Consequently, it can be concluded that the summation of inflows to the ground water reservoir and outflows are approximately equal. Therefore, as more ground water is utilized within the service area, more subsurface inflow will be induced or subsurface outflow will be reduced.

Data on the depth, yield, and specific capacity of wells in the Cottonwood service area are presented in Table 45. Most of these data were obtained from pump efficiency tests made by the Pacific Gas and Electric Company.

Waters contained in the ground water reservoir which underlies the Cottonwood service area are of good to excellent quality. These waters are generally of the calcium-magnesium bicarbonate type and are well suited for most beneficial uses. There appears to be little difference in quality between the shallow and deeper ground water bodies. However, the Chico formation which underlies the ground water reservoir contains saline waters unfit for any beneficial purpose. Thus, caution must be exercised that wells drilled near the western border of the service area should not penetrate these sediments. No known wells are currently subject to this hazard.

Most of the Cottonwood service area is underlain by several hundred feet of water-bearing materials. Even though these materials are mostly fine grained and have relatively low specific yields, the large volume of materials provides considerable storage capacity. Available well logs provided sufficient information to allow a determination of the average specific yield of each increment of depth between 0 and 300 feet below the ground surface. Ground water storage capacity was then computed for each depth interval by multiplying the average specific yield by the interval in feet and the areal extent in acres.

TABLE 45

IRRIGATION WELL DATA
COTTONWOOD SERVICE AREA

Subarea	Number of Active Wells	Depth, in Feet			Yield, in Gallons Per Minute			Specific Capacity, gpm/ft. of Drawdown	
		Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
Gas Point	12	720	240	450	1,500	540	1,060	30	9
Evergreen	5	370	180	280	900	70	510	130	1.5
Bowman Rd.	5	500	110	270	740	130	340	150	5

TABLE 46

ESTIMATED AVERAGE SPECIFIC YIELD AND
GROUND WATER STORAGE CAPACITY,
COTTONWOOD SERVICE AREA

Depth Interval, in Feet	Specific Yield, in Percent			Ground Water Storage Capacity, in Acre-Feet			
	Gas Point Subarea	Evergreen Subarea	Bowman Rd. Subarea	Gas Point Subarea	Evergreen Subarea	Bowman Rd. Subarea	Service Area Total
50-100	5.9	3.8	3.9	24,000	9,000	7,000	40,000
100-200	6.5	5.4	4.7	52,000	26,000	18,000	96,000
200-300	7.1	3.8	5.6	57,000	18,000	21,000	96,000
TOTAL				133,000	53,000	46,000	232,000

The storage capacity of the first 300 feet underlying the Cottonwood service area is summarized by subareas in Table 46.

Cow Creek Service Area

The Cow Creek service area and its three subareas, Stillwater Plains, Cow Creek Bottoms, and Millville Plains, has previously been described in Chapter II and is shown on Plate 3. A detailed discussion of this service area is presented below by subareas.

Stillwater Plains Subarea

Ground water in the Stillwater Plains subarea is stored in unconfined and semiconfined aquifers of the Tehama and Tuscan formations. These two formations grade into each other in a broad transitional zone along the north-south axis of the basin.

Most ground water development has occurred south of the Redding Municipal Airport. However, good irrigation wells have been drilled to the north, and the Enterprise Public Utility District recently completed an excellent municipal well in the northwest portion of the Stillwater Plains subarea.

Wells in this subarea produce up to 1,600 gallons per minute and often yield over 100 gallons per minute per foot of drawdown. The major water-producing zones consist of coarse gravels and interbedded clay layers which make up the upper and intermediate zones of the Tehama and Tuscan formations. These zones approach a combined thickness of 600 feet. Depths to water in irrigation wells range from about 70 feet along the southern boundary to over 100 feet in the north. Annual fluctuations throughout the area average about 3 feet. In general, irrigation wells in the southern portion have higher yields than those in the north.

Recharge to the ground water reservoir which underlies Stillwater Plains comes from infiltration of rainfall, deep percolation of stream and applied water on the plains, and subsurface inflow from the adjacent Anderson Cottonwood Irrigation District on the west, the dissected uplands on the north, and the Cow Creek Bottoms to the east.

Total recharge from these sources is greater than the estimated present and future pumping requirements. Consequently, subsurface outflow, which presently occurs along the southern boundary of the area, will continue under future conditions.

Cow Creek Bottoms Subarea

Ground water in the Cow Creek Bottoms subarea is stored in the gravels and sands of the Tuscan and interfingering Tehama formations. Alluvial deposits located near the ground surface are unimportant as a source of ground water as they are generally above the ground water table.

Wells in the Cow Creek Bottoms subarea derive their water from the moderately to highly permeable volcanic gravels of the Tehama-Tuscan formations similar to those found under the Stillwater Plains.

Present ground water development is fairly well distributed throughout the subarea. About 20 irrigation wells are located within or adjacent to the area, and at least 12 of these were active during the 1962 and 1963 seasons. Gross ground water pumpage probable does not exceed 1,000 acre-feet annually, since many of the wells are used only to supplement surface supplies during periods of inadequate streamflow.

Irrigation wells range from 130 to 250 feet in depth and average about 200 feet. These wells yield up to 1,000 gallons per minute and average about 550 gallons per minute. Domestic wells in the area average less than 100 feet in depth.

Pump efficiency tests show specific capacities ranging from 3 to 102 gallons per minute per foot of drawdown, but the average is around 30. Adjacent wells often have a wide range of specific capacities. This is believed to be due primarily to irregular distribution of the gravel deposits throughout the ground water reservoir, although some differences are also due to differences in depth, diameter, well construction methods, location of perforations, and degree of sanding or caving of the wells.

Depth to ground water in irrigation wells ranges from 9 feet near Oak Run Creek to 49 feet at the western boundary just south of Highway 44. South of Palo Cedro, along Cow Creek, the depths average about 20 feet. Annual fluctuations average less than 3 feet. An analysis was made of ground water levels in irrigation wells for the period 1955 to 1962. Individual seasons show a rise or lowering due to the variation in the amount of available recharge, but there has been no significant change during this time interval.

The ground water reservoir which underlies Cow Creek Bottoms is recharged by subsurface inflow from the north and east, by infiltration of rainfall, and by deep percolation of applied surface water on the northern and western portions of the subarea. Subsurface inflow from the Millville Plains and/or upward leakage from partially confined Tuscan aquifers appears probable. Unused ground water is discharged as influent seepage to Cow Creek and probably to the Sacramento River.

Millville Plains Subarea

Information regarding the ground water reservoir which underlies the Millville Plains subarea is limited to an irrigation well log and depth-to-water measurements on only one well.

Ground water beneath the Millville Plains is believed to be stored in Tuscan deposits comparable in occurrence and yield characteristics to those under the adjacent Cow Creek Bottoms to the west. These deposits may be coarser and contain better aquifers than those of the Tuscan formation. Recharge is from upland sources to the east as well as infiltration of rainfall on the plains.

The only well for which pumping data are available, 30N/3W-4M1, is 164 feet deep, and yields 40 gallons per minute. However, it is believed that properly constructed deeper wells will have characteristics approaching those found in the southern parts of the Stillwater Plains and Cow Creek Bottoms subareas.

Existing Irrigation Wells

Irrigation wells located within the Cow Creek service area generally range in depth between 100 and 500 feet. Data on the depth, yield, and specific capacity of wells in the Cow Creek service area are presented in Table 47. Most of these data were obtained from pump efficiency tests made by the Pacific Gas and Electric Company.

TABLE 47

IRRIGATION WELL DATA
COW CREEK SERVICE AREA

Subareas	Number of Active Wells	Depth, in Feet			Yield, in Gallons per Minute			Specific Capacity gpm/ft. of Drawdown	
		Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.
Stillwater Plains	17	510	200	320	1,600	200	1,000	130	6
Cow Creek Bottoms	13	240	130	180	1,070	35	550	100	1
Millville Plains	2[a]	--	--	--	--	--	--	--	--

(a) Data is available for only one well. Its depth is 164 feet, yields 40 gallons per minute and has a specific capacity of 5 gallons per minute per foot of drawdown.

Storage Capacity

Most of the Cow Creek service area is underlain by several hundred feet of water-bearing materials. The amount of ground water in storage within these materials is estimated as the product of average specific yield, the area in acres, and an average saturated depth interval. The average saturated depth intervals for the Cow Creek Bottoms and Millville Plains subareas are taken as the average depth of irrigation wells minus the unsaturated interval above the water table. However, for the Stillwater Plains, ground water storage is estimated for the upper water-bearing zone only, the base of which is defined by a volcanic mudflow. Estimated specific yield and estimated storage capacity for the three subareas of the Cow Creek service area are shown in Table 48.

TABLE 48

ESTIMATED AVERAGE SPECIFIC YIELD AND
GROUND WATER STORAGE CAPACITY,
COW CREEK SERVICE AREA

Subarea	Stillwater Plains	Cow Creek Bottoms	Millville Plains
Acres	14,500	8,700	6,700
Thickness of saturated sediments, in feet	280	150	84
Composite specific yield, in percent	10	5.8	5.0
Storage capacity, in acre-feet	400,000	75,000	28,000

Cost of Producing Ground Water

Cost estimates were made to determine the total cost of pumping ground water for numerous installations of varying capacities and pumping lifts. Well construction costs, pump costs, replacements, operation costs, and all miscellaneous costs were included. Total costs were estimated to range from 3 dollars per acre-foot for 50 feet of pumping depth, to 10 dollars per acre-foot for 300 feet of pumping depth. Average long-term costs are not expected to exceed 6 dollars per acre-foot.

CHAPTER VI. CONCLUSIONS AND RECOMMENDATIONS

The Upper Sacramento River Basin has a bountiful supply of water which, if properly developed, could meet the ultimate water needs of the Upper Sacramento River Basin. Plans for water control and development in this basin have been pursued on an intermittent basis since the turn of the century. Throughout this period these plans have changed in accordance with technological developments and the needs of the population. The conclusions reached as the result of this intensive study show that emphasis should be placed on development of tributary streams in the Upper Sacramento River Basin rather than the main stream of the river.

The present economy of the area is based primarily on the lumbering and forests products industry, agriculture, and recreation. It is generally agreed that continued growth of the economy will depend largely on expansion of recreation, including fishing, hunting, and tourism, and on increased agricultural production. Orderly development of the water resources of the area will assure this local expansion and, at the same time, provide statewide benefits in the form of additional water-associated recreation areas, flood protection in the Sacramento Valley, enhancement of the salmon runs in the Sacramento River, and conservation of water for export to areas of need.

Although small water conservation and flood protection projects have been undertaken by local agencies and individuals for many years, construction of Shasta Dam by the U. S. Bureau of Reclamation in the 1940's brought the first large water conservation reservoir to the Upper Sacramento River stream system. This reservoir, along with several smaller ones on the larger rivers and tributaries, has done much to bring the Sacramento River under control. However, irrigable lands within the Upper Sacramento River Basin remain without enough water, and flooding continues to occur throughout much of the Sacramento Valley.

The Upper Sacramento River Basin, with an average annual runoff of more than 2 million acre-feet, has an available water supply that is second only to the North Coastal area. Consequently, a major objective of this investigation was to develop plans for the orderly control and utilization of this water.

Three distinct water development possibilities are considered and evaluated in this report. These are:

1. A large reservoir on the Sacramento River at the Iron Canyon, or alternative, site.

2. A series of tributary reservoirs on Cottonwood, Cow, and Thomes Creeks.

3. Development of the extensive ground water reservoir which underlies much of the investigational area.

Detailed discussion of Iron Canyon Reservoir is contained in Chapter III; tributary reservoir development projects are presented in Chapter IV; and ground water development possibilities are presented in Chapter V.

Conclusions

Iron Canyon Project

Due to the need for flood protection in the lower Sacramento Valley, the ever increasing demands for electrical power production, and the demand for additional water supplies, studies of an Iron Canyon Project or alternatives have been made periodically over the past 60 years. Throughout this period three major problems have stood in the way of its construction. These are: (1) opposition by Tehama and Shasta County landowners to inundation of valuable agricultural lands, suburban homes, and urban areas within the reservoir area; (2) questionable engineering feasibility of constructing a large dam at any of the several available damsites because of poor foundation conditions; and (3) concern that a dam at the Iron Canyon or alternative site would adversely affect the extensive salmon and steelhead runs of the Sacramento River.

The Iron Canyon Project presented in this report would consist of the following general features: Iron Canyon Dam, Reservoir, and Powerplant; Iron Canyon Afterbay Dam and Reservoir; fish hatchery facilities below the afterbay dam; and fish conveyance and passage facilities from the afterbay dam to Iron Canyon Reservoir. This project was formulated in an attempt to resolve the above problems insofar as possible. As the result of several years of studies, the following conclusions are made regarding the Iron Canyon Project:

1. The normal water surface elevation of Iron Canyon Reservoir should not exceed an elevation of 401 feet to avoid

inundation of urban lands in the vicinity of Anderson and Cottonwood. At this elevation, the reservoir storage capacity would be 1 million acre-feet.

2. The Iron Canyon Project would: provide a measure of flood protection to more than 100,000 acres of lands along the east side of the Sacramento River between Red Bluff and Colusa; produce 153,000 kilowatts of dependable hydroelectric power capacity; produce an average water-associated recreational use of about 1 million visitor-days annually; and develop about 130,000 acre-feet of new yield available for export from the Sacramento-San Joaquin River Delta.
3. Because of adverse foundation conditions, extensive geologic explorations were made to determine whether a safe dam could be built. A board of consultants, hired to assist in evaluation of the study, concluded that a safe dam could be properly designed and constructed. Consequently, the design established after review by the board was used in formulating the Iron Canyon Project.
4. Fish passage facilities capable of handling 50 percent of the maximum adult upstream migrating salmon and steelhead runs would provide access to available spawning gravels above the reservoir. Facilities for safe passage of downstream migrating juvenile salmon and steelhead could be designed, provided these fish would collect at the dam so that they could be removed from the reservoir.
5. There may be a strong tendency of young fish spawned in the river above Iron Canyon Reservoir to become "residual" in the reservoir, rather than to go to the ocean. This conclusion was reached as the result of a downstream migrant study conducted by the Department of Fish and Game at Shasta Reservoir.
6. Spawning gravels inundated by Iron Canyon Reservoir could be fully mitigated by a fish hatchery capable of handling about 50 percent of the maximum fall salmon run.
7. Increased water temperatures below the Iron Canyon Project would pose a serious problem to the salmon and steelhead runs of the Sacramento River. However, the dam and powerplant probably could be designed to allow the release of

water from a lower level and reduce or eliminate the temperature problems. A final determination could be reached only by making a new temperature study. These conclusions were reached as the result of water temperature prediction studies made by a consulting engineer.

8. The Iron Canyon Project is not economically justified at the present time because of: (1) the high costs of the dam, spillway, and diversion tunnel; (2) the tremendous costs of land acquisition and road and utility relocations; and (3) the extensive fish hatchery and fish passage facilities needed to protect the salmon and steelhead resources of the Sacramento River. The ratio of project benefits to project costs is 0.73 to 1.

Tributary Stream Development

Development of water storage and conservation facilities on tributary streams was considered in planning for full utilization of the water resources of the Upper Sacramento River Basin. Both the immediate project area and the State as a whole would benefit from reservoir projects on the tributary streams. Direct benefits within the project area would be derived by increasing irrigation water supplies and by reduced flood damages. Recreation development and enhancement of the fishery would draw people and money into the project area, thereby providing large local secondary benefits that are not evaluated in the project analyses. Tributary reservoir projects would also contribute primary statewide benefits in the form of recreation, fishery enhancement, flood control, and increased water yield at the Sacramento-San Joaquin Delta.

Preliminary planning studies showed that no additional reservoir storage or diversion projects in the Battle, Paynes, or Clear Creek Basins are economically justified under present economic conditions. However, similar studies showed that four reservoir storage projects in the Cottonwood Creek Basin, two in the Cow Creek Basin, and one in the Thomes Creek Basins warrant detailed economic studies.

As a result of these intensive studies on these streams, the following conclusions are made:

1. The Hulen Project on North Fork Cottonwood Creek, with a reservoir storage of 136,000 acre-feet, would annually provide a firm yield of 20,000 acre-feet for local irrigation in the Gas Point Road subservice area, an increased statewide salmon catch of about 63,000 fish, environment for 270,000 visitor days of recreation use by year 2020, flood control benefits of about $85,000, and an increase in the Delta yield of about 34,000 acre-feet. The project is economically justified and has a benefit-cost ratio of 2.2 to 1.0.
2. An alternative Hulen Project with a reservoir storage of 132,000 acre-feet, but which does not include the purpose of local irrigation, is also economically justified, and has a benefit-cost ratio of 2.1 to 1.0.
3. The Dippingvat Project on South Fork Cottonwood Creek, with a reservoir storage of 71,000 acre-feet, would annually provide an increased statewide salmon catch of about 127,000 fish, environment for 70,000 recreation visitor days by year 2020, flood control benefits of about $53,000, and an increase in the Delta yield of about 22,000 acre-feet. The project is economically justified and has a benefit-cost ratio of 2.1 to 1.0.
4. The Fiddlers Project on the Middle Fork Cottonwood Creek, and the Rosewood Project on Dry Fork Cottonwood Creek, are not economically justified under present economic conditions.
5. The Millville Project on South Cow Creek, with a reservoir storage of 74,000 acre-feet, would annually provide an increase in the statewide salmon catch of about 29,000 fish, environment for 70,000 recreation visitor-days by year 2020, flood control benefits of about $35,000, and an increase in the Delta yield of about 21,000 acre-feet. The project is economically justified and has a benefit-cost ratio of 1.4 to 1.0.
6. The Bella Vista Project on Little Cow Creek is not economically justified under present economic conditions.

7. The Paskenta Project on Thomes Creek, with a reservoir storage of 105,000 acre-feet, would annually provide a firm yield of 52,000 acre-feet for local irrigation, an increase in the statewide salmon catch of about 20,000 fish, environment for 180,000 recreation visitor days by year 2020, flood control benefits of about $75,000, and an increase in the Delta yield of about 34,000 acre-feet. The project is economically justified and the benefit-cost ratio is 1.7 to 1.0.
8. Paskenta Project could be easily incorporated into the Glen Reservoir Complex, which is being considered as a storage and regulatory unit for future North Coastal projects.

Ground Water Development

The Redding ground water basin which lies under both the Cottonwood and Cow Creek Service Areas has medium to high potential for ground water development. The following conclusions are based on ground water studies conducted in these service areas.

1. In the Cottonwood Creek Service Area, the Gas Point Road subarea could be adequately and economically served by pumping from ground water or from surface water storage in Hulen Reservoir. An adequate ground water supply is available to satisfy the demand for agricultural water in both the Bowman Road and Evergreen Road subareas.
2. An adequate ground water supply could be developed to meet the agricultural water demands in the Cow Creek Service Area.

Total Basin Development

Proper initial development of the water resources of the Upper Sacramento River Basin could best be accomplished by construction of Hulen and Dippingvat Projects on Cottonwood Creek, Millville Project on Cow Creek, Paskenta Project on Thomes Creek, and by ground water development in the Cottonwood and Cow Creek Service Areas.

These projects appear to provide an excellent opportunity for the State and the local agencies to participate jointly in the coordinated development of the basin. They are also generally compatible with future state and federal plans to import water into the Sacramento River Basin.

Recommendations

It is recommended that:

1. This bulletin be used as an overall guide in the development of the water resources of Shasta and Tehama Counties, and further that the plans presented herein be reviewed periodically by local water development agencies in these counties to reflect changing needs for irrigation, recreation, fisheries enhancement, and flood control.
2. Further consideration of a reservoir at the Iron Canyon or alternative site on the main stream be deferred until such time as further needs for water, power, and flood control make such a project economically justified.
3. The Hulen and Dippingvat Projects on Cottonwood Creek, the Millville Project on Cow Creek, and the Paskenta Project on Thomes Creek, comprising the best initial means of developing the water resources of the Upper Sacramento Basin, be studied at the feasibility level according to the priority of need in the development of California's water resources, and that these reservoirs be evaluated to determine their suitability for financial participation by the State under Section 12880(f) of the Davis-Grunsky Act, or for authorization by the State as additional features of the State Water Resources Development System.

APPENDIX A

THE RECREATION POTENTIALS OF THE

TENTATIVE WATER PROJECTS OF THE

UPPER SACRAMENTO RIVER BASIN INVESTIGATION

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF PARKS AND RECREATION
DIVISION OF BEACHES AND PARKS
RECREATION CONTRACT SERVICES UNIT

UPPER SACRAMENTO RIVER BASIN INVESTIGATION

THE RECREATION POTENTIALS OF THE TENTATIVE WATER PROJECTS OF THE UPPER SACRAMENTO RIVER BASIN INVESTIGATION DEPARTMENT OF WATER RESOURCES

Prepared Under Supervision of

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OFFICE REPORT

MARCH 1964

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CHAPTER I. INTRODUCTION

The Upper Sacramento River Basin Investigation includes within its scope the consideration of all the beneficial uses of the sub-basins' water resources. This multipurpose water utilization concept includes analyses of each reservoir project for the purposes of flood control, irrigation, electric power generation, domestic water supply, fish and wildlife enhancement, and water-associated recreation.

The eight reservoir projects considered in this report are located within the 2,600 square mile drainage area of this investigation, in the northern end of the Central Valley. The two counties, Shasta and Tehama, in which these projects are envisioned, are presently favored with many water-associated recreation areas within a short travel distance of local population centers. In most circumstances these existing water-associated recreation areas are underdeveloped and, with further development, could accommodate a considerable increase of recreation use. Tehama and Shasta Counties depend on the recreation industry as a major source of their income. These counties are interested in expanding their economic growth by attracting more recreationists. Since the population predictions for these counties are small in comparison with other counties, any large future increase of recreation income must originate from outside these counties. To stimulate this non-local use, recreation facilities at water projects will have to offer high quality access and facilities to attract overnight users.

Seven of the proposed projects studied are located on tributaries to the Sacramento River (Figure 1). They are: Hulen Reservoir on the North Fork of Cottonwood Creek, Fiddlers Reservoir on the Middle Fork of

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
UPPER SACRAMENTO RIVER BASIN INVESTIGATION

POSSIBLE PLANS FOR DEVELOPMENT

Cottonwood Creek, Rosewood Reservoir on Dry Creek (a tributary to the South Fork of Cottonwood Creek), Dippingvat Reservoir on the South Fork of Cottonwood Creek, Bella Vista Reservoir on Little Cow Creek, Millville Reservoir on South Fork of Cow Creek, and Paskenta Reservoir on Thomes Creek. Each of these reservoirs was studied separately and in combination with other tentative Upper Sacramento River Basin tributary projects.

An additional plan to develop the Upper Sacramento River Basin proposes a major impoundment behind a dam constructed across the Sacramento River at Iron Canyon. This 27,000 surface acre project was studied as a single basin project and in combination with single tributary developments.

Authority and Planning History

The evaluation of the recreation potential of tentative water developments is authorized by Section 345 of the State Water Code which requires the consideration of water-associated recreation when evaluating a State Water Project. In 1958, the Department of Water Resources established a Recreation Services Unit to do the recreation evaluation for water projects. The department maintained this staff until July 1, 1963, the effective date of Resources Agency Order No. 7 which transferred the recreation planning functions to the Department of Parks and Recreation, Division of Beaches and Parks. Since 1958, recreation planning on the Upper Sacramento River Basin Investigation has been progressing in line with the program needs. With transfer of the water project recreation evaluation function to Division of Beaches and Parks, this work has been accomplished as partial fulfillment of Agreement Number 252781 between the Departments of Parks and Recreation and Water Resources.

Purpose and Scope

The purpose of this report is to summarize a copious amount of recreation project information that is on file in the Department of Water Resources and to present the potential recreation benefits for eight tentative Upper Sacramento River Basin reservoirs. Seven of these reservoirs are on streams tributary to the Sacramento River and one is on the Sacramento River. The scope of these studies varies from field reconnaissance and preliminary estimate of user demand to a level of study that includes estimates of recreation demand, shoreline land available for development, type and number of facilities that should be developed, cost of the facilities, and operation and maintenance costs.

CHAPTER II. AREA DESCRIPTIONS

Physiography

The climate of the Upper Sacramento River Basin was described by Sunset Magazine's staff based upon 40 years of records. The mean July (mid-recreation season) air temperature was approximately 82°F. The annual maximum recorded temperature was 115°F; the minimum recorded temperature 17°F. The average length of the vegetative growth season was 274 days (last killing frost in spring to first killing frost in fall), with an average annual precipitation of 23.10 inches. The possibility of having sunshine in mid-summer recreation season is more than 95 percent. Considering all the above-mentioned climate factors, water contact recreation should be popular if surface water temperatures are at least 65° to 70°F.

The proposed tributary reservoir developments in the northern Upper Sacramento Valley are located between altitudes of 400 feet to 1,500 feet above mean sea level. They are in low rolling foothill areas which have many gullies cut by late fall and early spring intermittent heavy runoff.

To make reasonable judgments as to size and type of recreation use in a proposed project area if the project were operating under present day conditions, and to estimate future demand for outdoor recreation at each proposed project, basic recreation information had to be compiled.

Population

According to the Census of 1960, Shasta and Tehama Counties had approximately 80,000 residents. The Department of Water Resources estimates that by 1980 there will be 142,000 people and, by 2010, 354,000 (Graph I).

These residents would use the Upper Sacramento River Basin water projects, but the amount of day use at each project would be fairly small because of competition between projects. It is assumed that the two counties will enhance their future recreation industry by encouraging participation by non-local recreationists. Therefore, population expansion prediction factors for the entire State of California were considered to estimate the number of non-local users who would utilize the recreation developments at the proposed water projects (Graph II).

Typical Upper Sacramento River Basin Topography

Per Capita Use-utilization of Outdoor Recreation

Historic evidence (1940-1960) derived from State Parks, National Parks, and National Forest recreation use reports revealed an increasing trend in per capita use utilization of out-of-door recreation areas. This increased use is due in part of rising disposable incomes, increasing amounts of leisure time, and increasing mobility. The historic trend of per capita use was projected into the future at the same rate as the historic rate of increase. This trend is presented in Graph III.

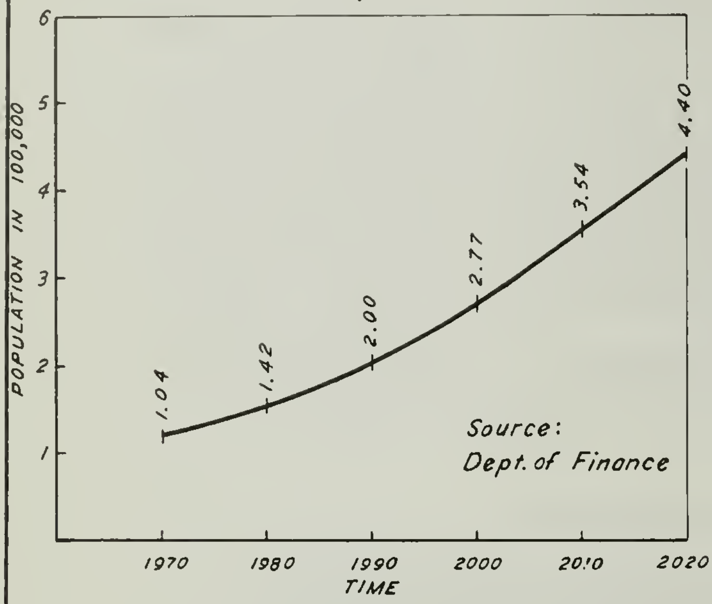
Origin of Recreation Users and Typical Reservoirs

Existing reservoirs, similar to project reservoirs, were sought out and studied, to estimate the type of recreation use which may occur at a tentative project and the origin of the users. The information gained from studying four typical reservoirs was applied to estimate the recreation use of the proposed project reservoirs. These study reservoirs chosen were Shasta, Folsom, Millerton and East Park.

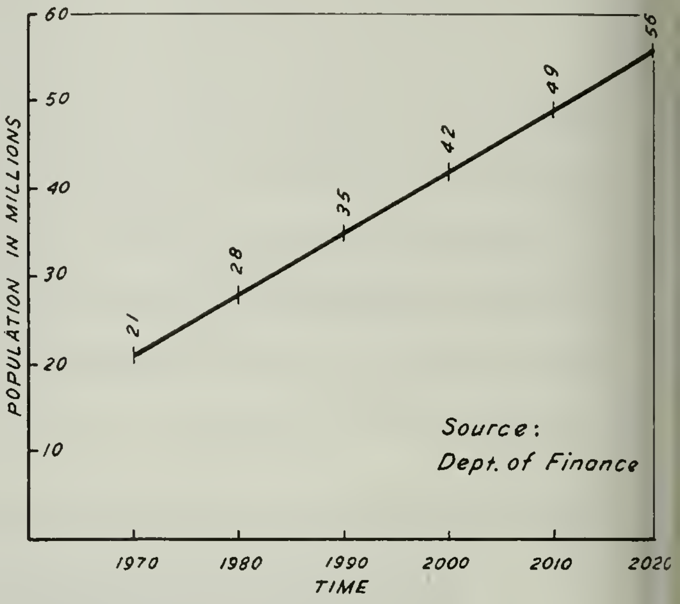
Folsom and Millerton Reservoirs historic use data were utilized to draw conclusions concerning probable local area recreation use. The 1958 and 1959 local resident (residence of day-users assumed to come from within a 35-mile radius of project) annual recreation use was determined to be

GRAPHS

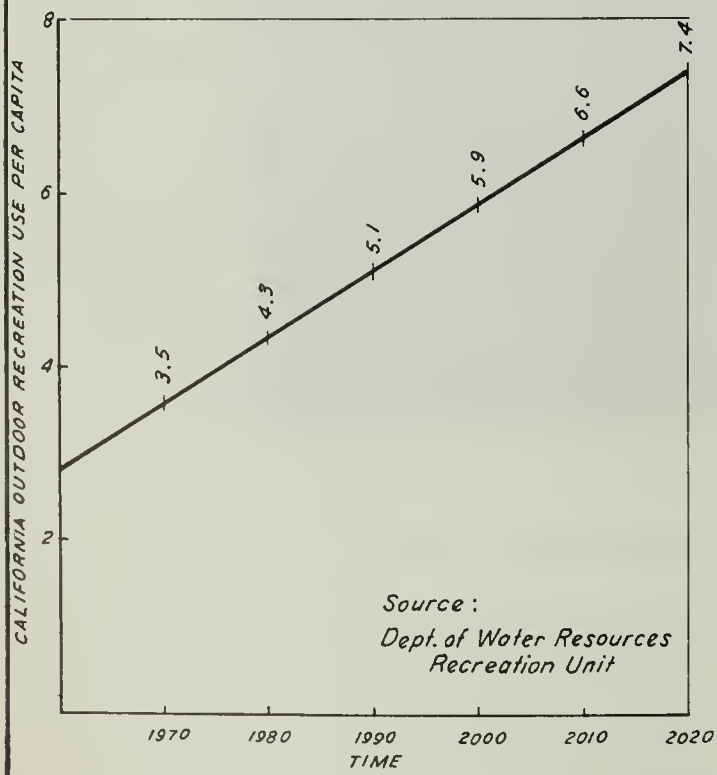
I
LOCAL POPULATION
(TEHAMA AND SHASTA COUNTY)
(100,000)



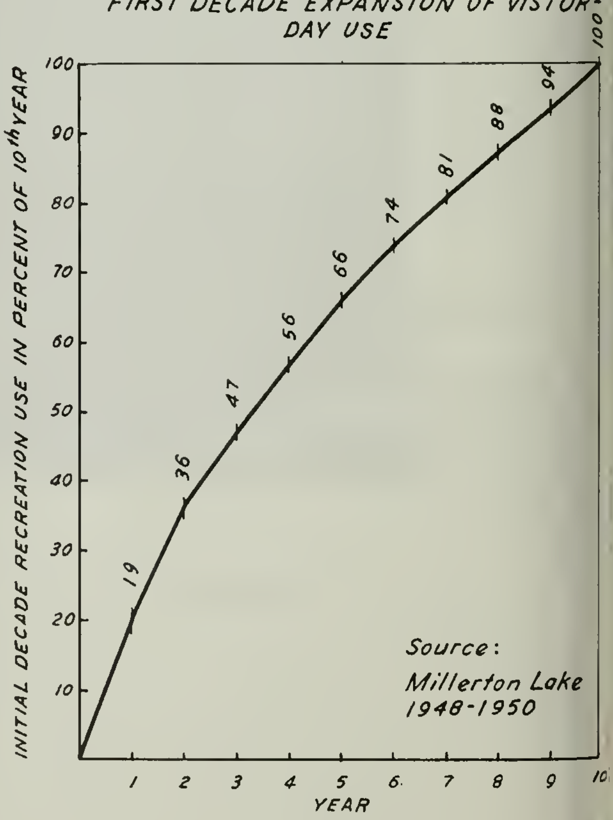
II
STATE POPULATION



III
OUTDOOR RECREATION USE PER CAPITA



IV
FIRST DECADE EXPANSION OF VISTOR-DAY USE



approximately 2.5 visits per capita. This annual rate of use was applied to 35 mile radius zones of influence around each of the tentative reservoirs and adjusted for competition from existing water projects as well as ones scheduled for construction. Studies conducted at Shasta Reservoir (Shasta County) and East Park Reservoir (Colusa County) were utilized in the derivation of the user origins and the types of use that may be expected at the Upper Sacramento River Basin projects.

Expected origin of users was determined from perusal of visitor records maintained by owners, and a county recreation survey, see Tables I and II. The types of recreation use encountered at East Park Reservoir were assumed to be representative of the types of recreation use to be expected at the proposed tributary reservoirs, while Shasta, Millerton, and Folsom Reservoirs were chosen to provide information to be applied to recreation use predictions at the Iron Canyon project.

Table I

Origin of Visitors, East Park Reservoir
1960

County Origin	Percent of Sample	County Origin	Percent of Sample
Colusa	59.6	Mariposa	.4
Contra Costa	6.6	Mendocino	.3
Sacramento	4.9	San Joaquin	.3
Alameda	4.5	Lake	.2
Sutter	3.9	Los Angeles	.2
Yuba	3.6	Merced	.2
Yolo	3.5	Placer	.2
Solano	2.6	Tehama	.2
Glenn	1.5	Kern	.1
Napa	1.9	Monterey	.1
Butte	1.0	Plumas	.1
San Mateo	1.0	Santa Barbara	.1
San Francisco	.9	Shasta	.1
Santa Clara	.6	Tulare	.1
Marin	.5	Out of State	.4
Sonoma	.5		

Source - D.W.R.
Sample Size - 4741 Visitors
April - September 1960

TABLE II

ORIGIN OF VISITORS, SHASTA RESERVOIR
1958

Region of Origin	Percent of Sample
In-state-local	36.2
In-state non-local	
San Francisco	29.7
Los Angeles	13.3
Sacramento	5.7
Eureka	3.0
Fresno	.4
San Diego	.4
Out-of-state	7.1
No answer	4.2

Source - Shasta County
Sample Size - 505 partie
August 30 - 1958

Present Recreation Use of Project Areas

In the project areas of the Upper Sacramento River Basin Investigation, the majority of recreation uses are oriented around fish and wildlife activities. The tributary projects are located on lands which are primarily in private ownership, where management for grazing and other agricultural uses necessitates the limiting of general public access for fishing and hunting. The future recreation use of these areas will probably not increase significantly as long as agricultural development is dominant; also, the present and future recreation use without the attractive power of water surfaces is assumed to be negligible.

The Iron Canyon project would inundate a part of the Sacramento River which is intensively used for recreation purposes and it has the potential for future increases in recreation use. To establish the level of present and historic use, Department of Fish and Game and U. S. Fish and Wildlife Service studies and data were analyzed. The present level of use was established and projected into the future. The methods used in this work will be discussed in the Recreation Analysis Chapter of this report.

CHAPTER III. RECREATION ANALYSIS

Methodology

Each reservoir site was given a field reconnaissance by aerial observation and ground survey. The purpose of these initial field studies was to determine the potential of the land to support water-associated recreation at each site, and the approximate water elevation that could best be developed for water-associated recreation.

When the initial field study indicated that a project had a recreation development potential, a user demand study was made. The water projects of the Upper Sacramento River Basin Investigation were found to have varying degrees of recreation potential. Therefore, the expected demand for the project's potential recreation resource was studied by comparing various similar existing reservoirs. The studies of similar reservoirs were made to discover basic recreation information such as origin of recreationists, types and proportions of water-associated activities, and the recreation user needs that existing areas are not supplying.

The predicted recreation visitor-day demand for each of the tentative reservoirs was determined by calculating the origin and number of visitors from distance zones and their populations at comparable existing reservoirs. The determined rate of visitors use per capita of these zones was then applied to the present and predicted future populations of corresponding zones around the tentative reservoirs. Evaluations of historic records of recreation use in relation to population growth have indicated an increasing trend in per capita outdoor recreation activity. Assuming that these trends will continue, the rate of increased outdoor use was applied to the predicted per capita use which would originate from each established population expected to recreate at the studied reservoirs. The total level of use expected at each project is the summation of all predicted visitor-days from each of the project population zones during the particular time period. The total decade use was estimated by assuming that use would increase at a constant rate during each decade so that the average annual use during each decade would be equivalent to the average of the use at the beginning and end of that decade. The average annual use for the decade would be the arithmetic mean of the total decade use.

Competitive Recreation

Competition from existing and future projects had to be taken into account when determining the potential demand for recreation at any one or combination of new water projects. Many opportunities to participate in water-associated recreation are to be found in the counties of Shasta, Trinity, Lassen, Glenn and Tehama. An example is the area which is proposed for inclusion in the Whiskeytown-Shasta-Trinity National Recreation Area. This recreation area, which would be operated by the U. S. Forest Service and the National Park Service, would include three large reservoirs with appropriate recreation developments designed to permit public enjoyment of a total water surface of 49,000 surface acres and 550 miles of shoreline. Projects considered in the Sacramento River Basin Investigation would add another 30,000 surface acres to this total. The day user recreation demand at each studied reservoir was adjusted by considering a 35-mile average distance from the reservoir as the zone of influence of a particular reservoir for day users. When a zone overlapped the influence area of another reservoir, the recreation demand was apportioned to establish the estimate for visitor-day use at each reservoir.

The Iron Canyon Project would have a larger water surface than any of the other tentative projects studied in the Upper Sacramento River Basin Investigation. This project would compete for recreation visitor days with the existing projects such as Shasta, Trinity, Whiskeytown, Lake Almanor, Lake Britton, and Black Butte Reservoirs. After considering the relative merits of the existing and potential water bodies, it was assumed that Iron Canyon Reservoir would draw approximately 30 percent of the total recreation day use potential demand of residents of the area within 35 miles of the project and that none of the tributary projects would significantly reduce visitation at the Iron Canyon Project.

Cost of Facilities to Support Recreation Use

To receive the predicted visitor-day use at proposed project reservoirs, recreation developments such as access facilities, water supply, sanitary facilities, camp and picnic units would have to be provided. Capital costs of these facilities and the operation, maintenance and replacement costs during the repayment period of the project are part of the multipurpose project costs. To estimate these costs, guides for average recreation facility costs were developed from cost records obtained from the Division of Beaches and Parks. These guides are used for preparing preliminary cost estimates and are revised at frequent intervals. Camping units at the Iron Canyon Project were estimated at $3,000 per unit and picnic units at $2,750. The tributary reservoirs were planned as county or local district developments with less pretentious facilities. Therefore, the picnic unit cost was estimated at $2,100. These camp and picnic unit costs include a table, access to a stove, cleared and leveled space, parking area, and a prorata share of internal circulatory roads, sanitary facilities, water supply, power supply, trails, barriers, signs, and a check station. Other costs such as primary access roads, boat launching ramps, etc., were estimated separately for each project in consultation with a landscape architect.

Tributary Reservoirs

Each of the reservoirs being considered in the studies of the Upper Sacramento River Basin tributaries could accommodate more or less similar forms of recreation activities such as warm-water fishing, swimming, boating, picknicking, camping, and water skiing.

The population of the basin is generally concentrated along the main highways paralleling the Sacramento River. The reservoir sites are located on side roads 10 to 20 miles from the present population concentrations.

The reservoirs have normal pool elevations between 600 feet and 1,200 feet. This results in a little variation in climate and vegetative cover between reservoir sites.

Although there is variation in the topgraphy, the features of the terrain may be generalized by stating that all the reservoirs are in a similar foothill area between the Sacramento Valley floor and the major mountain formations.

All the reservoirs will impound bodies of water with sufficient surface area to attract recreational users.

The tributary (to the Sacramento River) reservoir sites are so located that they will satisfy the needs of a great many people who are seeking outdoor water-associated recreation and who will make use of the best available location within a limited travel distance.

According to studies by the California Public Outdoor Recreation Plan Committee, as published in Part I of the California Public Outdoor Recreation Plan (1960), the average one-way distance for one-day round trips by automobile -- for outdoor recreation -- is 35 miles. In central valley foothill reservoirs, where the primary attraction is the body of water behind the dam, it has been found that the majority of users reside within 35 miles of the reservoir. The California Public Outdoor Recreation Plan Committee found this to be true at Folsom Reservoir. The Department of Water Resources Recreation Unit studies at East Park Reservoir found that 60 percent of the users reside in the county where the reservoir is located (Table I). A similar situation was found when user origin was studied at other central valley reservoirs.

From the results of these studies, it follows that the demand for the day-use, water-associated type of recreation that will be provided by the Upper Sacramento Basin tributary reservoirs may be estimated if the population within a 35-mile radius of the reservoir is known. Recreation use and needs should be expected to change in proportion to changes in the population of the surrounding area.

Shasta County Best Available Resource

The reservoirs presented in Table III will probably share the role of being the best available resource to satisfy the demand by Shasta County residents for water-associated outdoor reservoir type recreation. The following table contains estimates of the percentage of the demand for day-use reservoir recreation areas that each reservoir may be expected to fulfill.

TABLE III

SUPPLY OF DAY-USE, BEST AVAILABLE RESOURCE
RESERVOIR RECREATION FOR SHASTA COUNTY RESIDENTS

Trinity-Lewiston Reservoirs	8 percent
Whiskeytown Reservoir	28 percent
Shasta Lake and Keswick Reservoir	3[illegible] percent
Bella Vista 1/	17 percent
Millville Reservoir 1/	5 percent
Hulen Reservoir 1/	7 percent
Fiddlers Reservoir 1/ 2/	2 percent

1/ Reservoirs on streams tributary to the Sacramento River considered by the Upper Sacramento River Basin Investigation.
2/ Fiddlers will also answer some of the Tehama County demand.

East of the Sacramento River, the investigation proposes to develop the Cow Creek drainages. Bella Vista Reservoir would be created by a 140-foot dam located on Little Cow Creek in Section 20, T32N, R3W (Figure 2). At a maximum water surface elevation of 614 feet, MSL, a 4450 surface acre pool would store 200,000 acre-feet of water. The predicted annual drawdown as a multipurpose project is 18 feet or a drawdown to a 3370 surface acre reservoir. The Bella Vista project would be located within 8 miles of the City of Redding via the high-speed U. S. Highway 299. The predicted population growth of the Redding area should result in residential development near the reservoir. The indicated large water surface area, the tentative operations schedule, and the shoreline topography are conducive to water-associated recreation use.

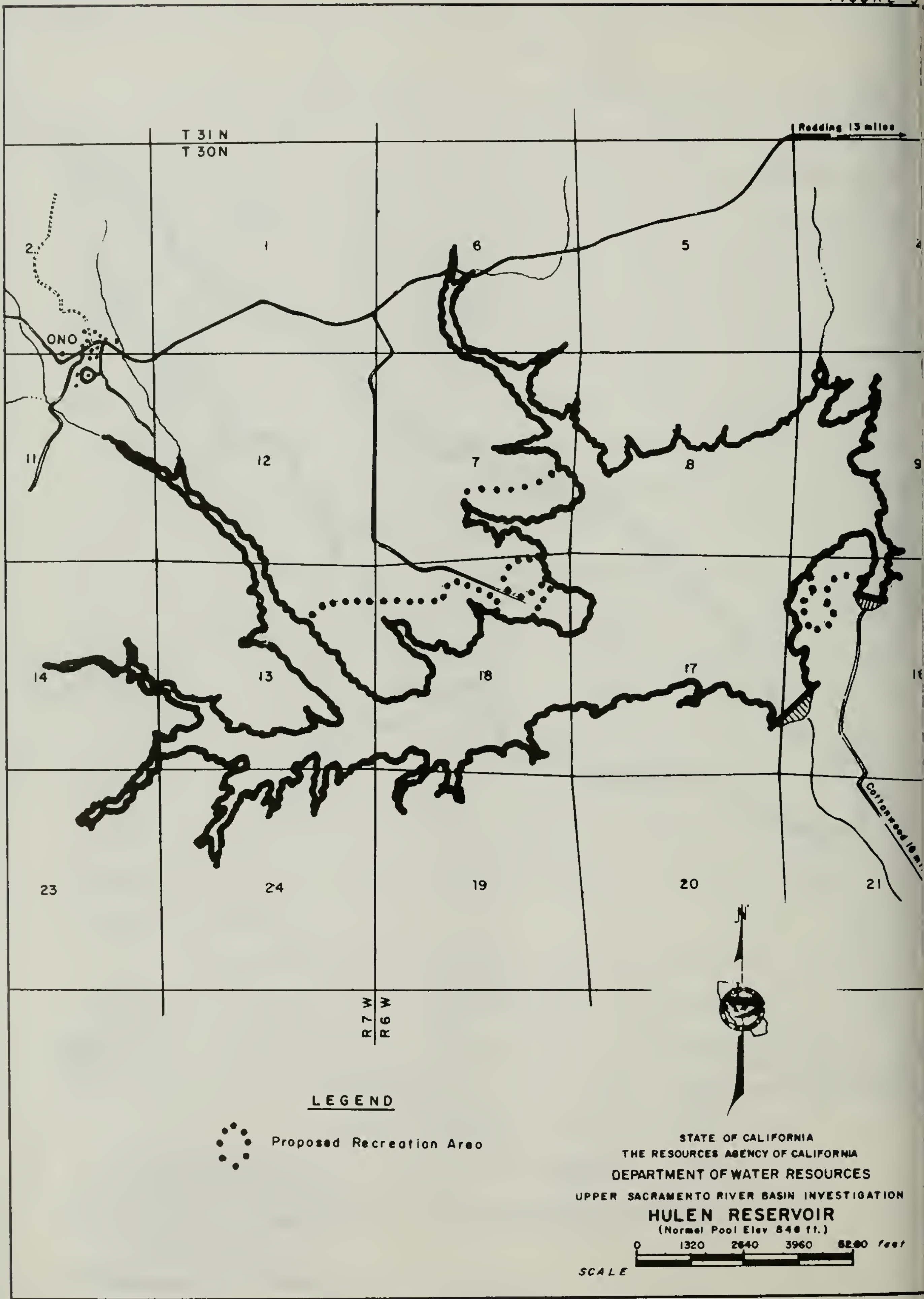
27
28
29
33
34
35
St. H'w'y 299
2
32
31
4
3
11
T33N
T32N
5
10
6
9
8
15
7
16
17
22
R4W
R3W
12
18
21
8 miles to Redding
20
13
Bella Vista
19
N
LEGEND
Proposed Recreation Area
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
UPPER SACRAMENTO RIVER BASIN INVESTIGATION
BELLA VISTA RESERVOIR
(Normal Pool Elev. 614 ft.)
0 1000 2000 3000 4000 feet
SCALE

Millville reservoir project is approximately nine air miles southeast of the Bella Vista project. This reservoir would have about 1,580 surface acres at a maximum pool elevation of 743 MSL. The 168-foot dam would be located on the South Fork of Cow Creek in Section 17, T31N, R2W, (Figure 4). The reservoir would store 95,000 acre-feet. Annual operations indicate an average drawdown of 24 feet which would decrease the maximum pool to a surface area of 1,270 surface acres. Millville project would serve the same recreation users that the Bella Vista would, but Millville project has more difficult access than Bella Vista and has a smaller pool surface because of the basin size and the annual average operation is less conducive to water-associated recreation.

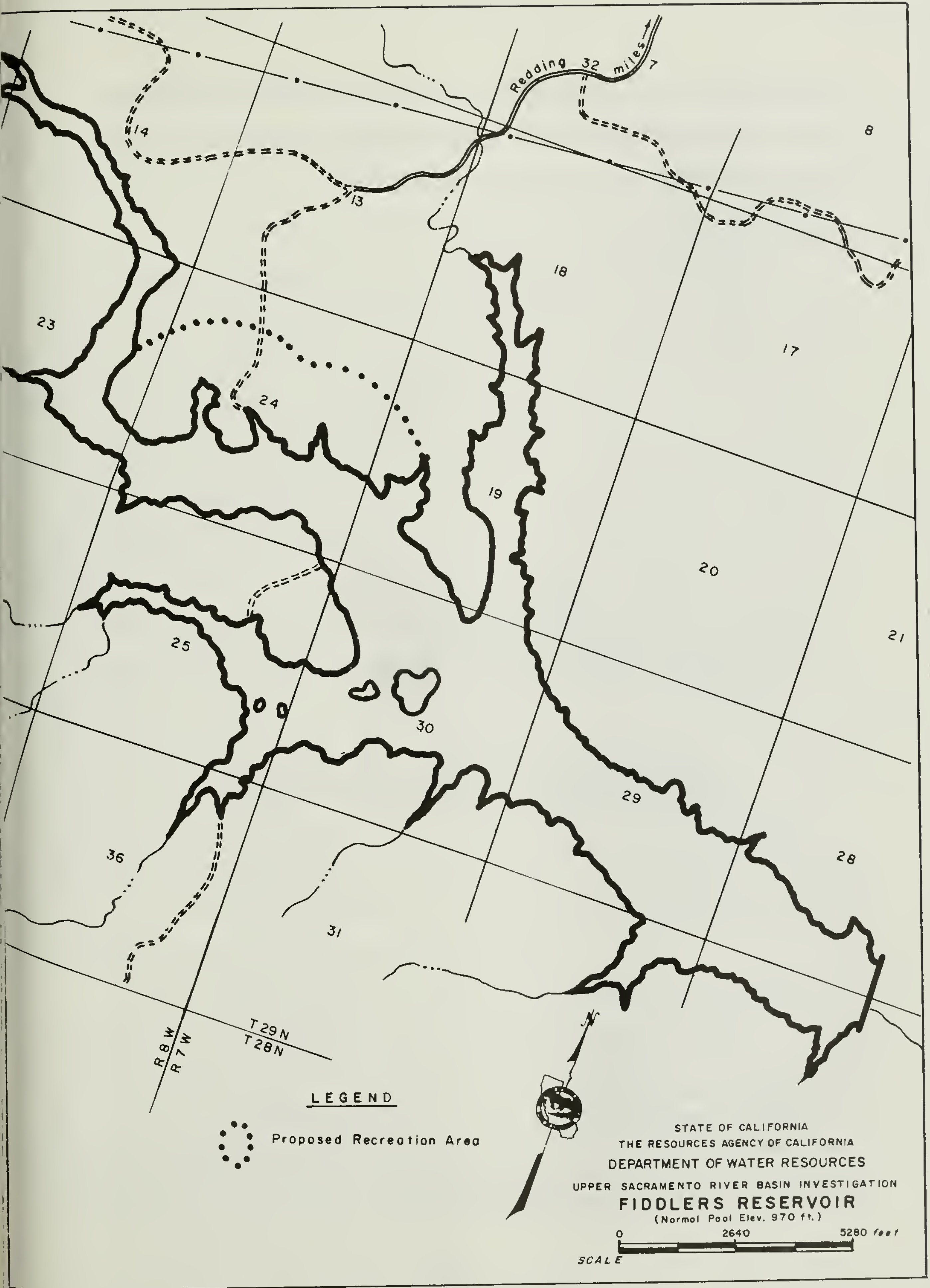
On the west side of the Sacramento River the investigation envisions that the Cottonwood Creek drainage would be developed. The Hulen project would be located on the North Fork of Cottonwood Creek. This reservoir was studied at two water elevations, 793 feet MSL and 848 feet MSL. Both project sizes have dams located in Section 16, T30N, R6W MDB&M. (Figure 5). The 94,000 acre-foot reservoir at 848 feet MSL operating at an average drawdown of 18 feet, was found to be the most desirable for recreation purposes due to the larger water surface which would allow separation of water-associated uses, and would have a longer shoreline of suitable topography for recreation facility development.

Approximately 9 miles southwest of the Hulen project is a tentative development on the North Fork of Cottonwood Creek. Fiddlers reservoir was studied at a maximum elevation of 970 feet MSL. A 237-foot dam located in Section 23 and 33, T28N, R7W (Figure 6), would create a 1500 surface acre maximum pool. Average annual drawdown is estimated as 35 feet, which would decrease the pool surface to 1120 acres. The general topography of the reservoir area is very steep, therefore limiting the development of recreation


2
3
4
9
10
11
12
14
15
16
17
21
22
23
T31N R2W
MDB&M
St. H'w'y 44
12 miles to Redding
LEGEND
Proposed Recreation Area
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
UPPER SACRAMENTO RIVER BASIN INVESTIGATION
MILLVILLE RESERVOIR
(Normal Pool Elev. 743 ft.)
0 1250 2500 3750 5000 feet
SCALE



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
UPPER SACRAMENTO RIVER BASIN INVESTIGATION
HULEN RESERVOIR
(Normal Pool Elev 848 ft.)


Redding 32 miles
7
8
14
13
18
23
17
24
19
20
21
25
30
29
36
28
31
R8W
R7W
T29N
T28N
LEGEND
Proposed Recreation Area
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
UPPER SACRAMENTO RIVER BASIN INVESTIGATION
FIDDLERS RESERVOIR
(Normal Pool Elev. 970 ft.)
0
2640
5280 feet
SCALE

use facilities. This reservoir is the least accessible of the tributary projects from the standpoint of quality of present roads and distance to present and probable future population centers.

Tehama County Best Available Resource

The reservoirs studied in the Upper Sacramento River Basin Investigation in Tehama County would satisfy most of the recreation demand of west Tehama County residents for day-use water-associated reservoir recreation. Lake Almanor, Bucks Lake, and Oroville Reservoir, are within 35 miles of the lightly populated eastern portion of Tehama County, therefore dominating the local light recreation demand of this area. The following paragraphs are concerned with the reservoirs that will serve Tehama County residents as the best available resource supplying water-associated recreation. The following table contains estimates of the percentage of the total demand by Tehama County residents for day-use reservoir recreation areas at each reservoir.

TABLE IV

SUPPLY OF DAY-USE, BEST AVAILABLE RESOURCE RESERVOIR RECREATION FOR TEHAMA COUNTY RESIDENTS

RESERVOIR	PERCENT
Fiddlers Reservoir	4 percent
Rosewood Reservoir	33 percent
Dippingvat Reservoir	6 percent
Paskenta Reservoir	22 percent
Black Butte Reservoir 1/ 2/	30 percent
Lake Almanor, Bucks Lake, and Oroville Reservoir 2/	5 percent

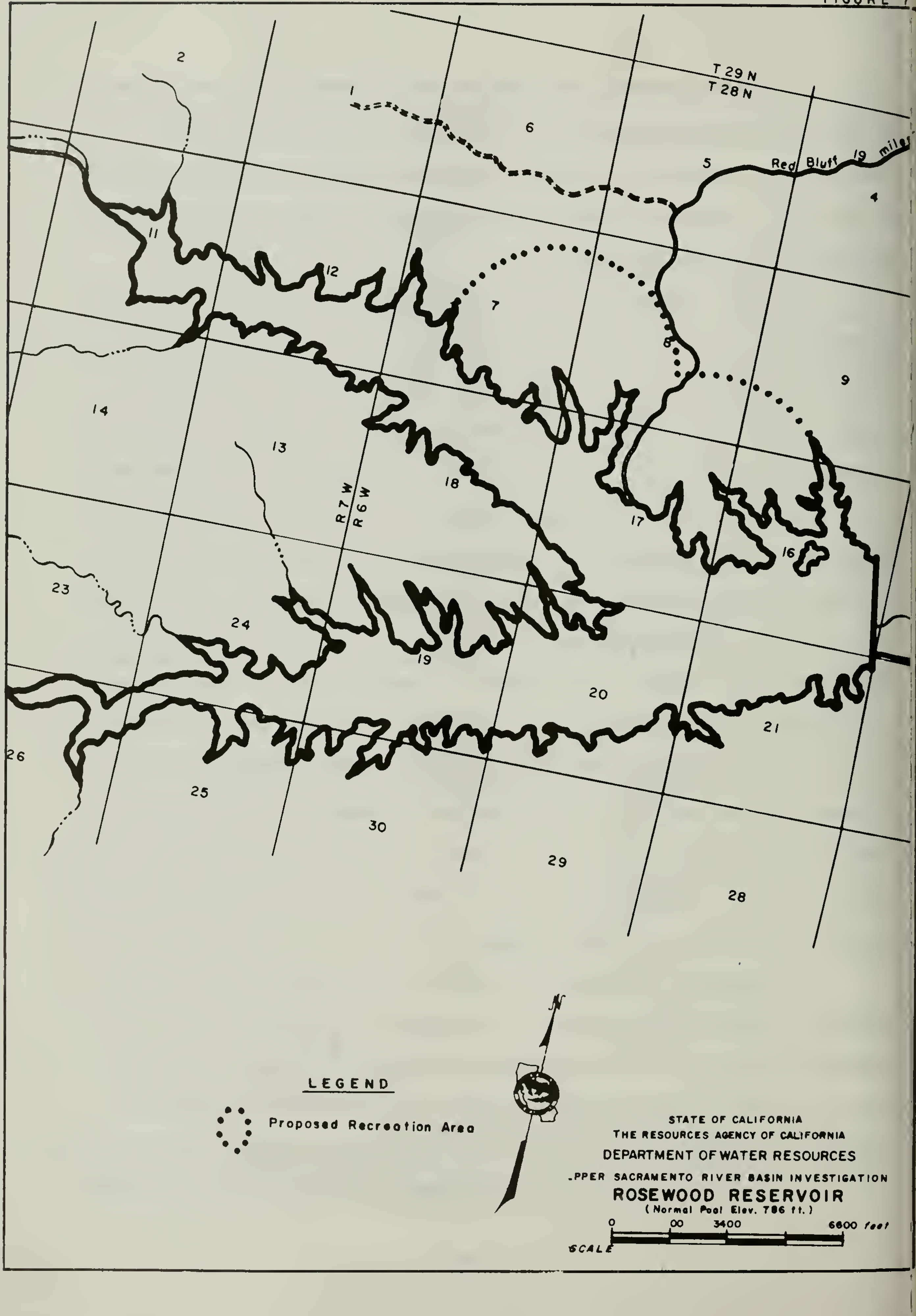
1/ Corps of Engineers Reservoir, built in 1963 on Stony Creek in Glenn County
2/ Competitive local recreation reservoirs.

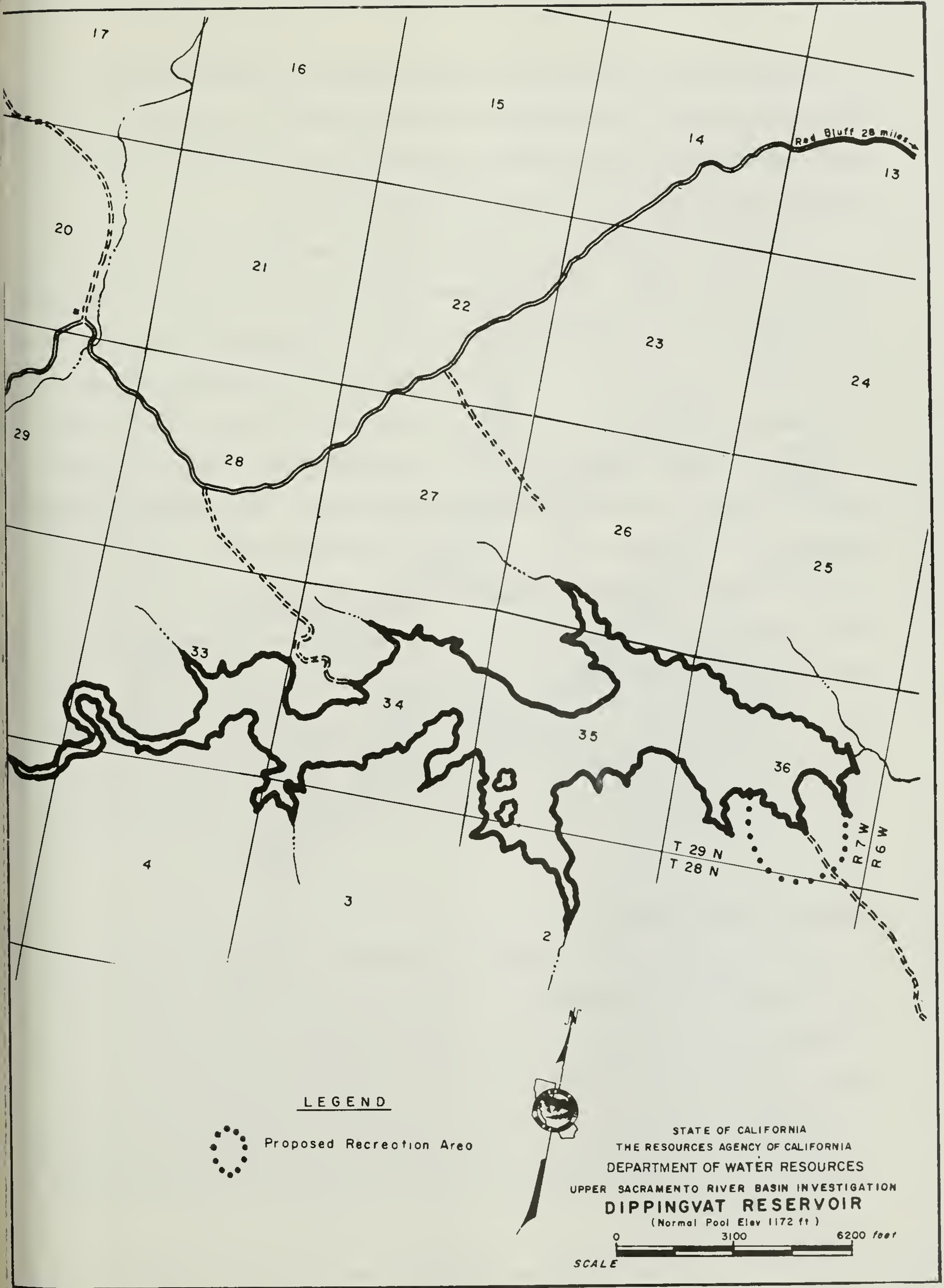
Fiddlers Reservoir, on the Shasta-Tehama County line, was discussed in the previous section describing Shasta County recreational demand. This reservoir will probably share part of the role of being an available resource to satisfy the demand by Tehama County residents for near-by outdoor, water-associated, reservoir recreation.

Rosewood Reservoir project would be located on Dry and Salt Creeks, tributaries to the South Fork of Cottonwood Creek. The 190-foot high dam would be located in Section 16, T28N, R6W, MDB&M (Figure 7). The Rosewood project would have a maximum surface area of 3,020 acres at a water surface elevation of 786 feet MSL. Operation studies indicate an average drawdown of 24 feet to a surface area of 2,320 acres. The general terrain along the shoreline is steep and limits to one area the shore lands available for recreation facility development. The best topography for initial development is located to the northwest of the reservoir overlooking Dry Creek Valley. This hill area is covered with scattered oak trees; however, the local practice of tree removal for livestock range improvement indicates that the trees might not be present by the time the reservoir is constructed. The Rosewood project is about 20 miles west of Red Bluff, and may be reached by a relatively poor quality state highway which is not included in the State Freeway or Expressway System. For the residents of Red Bluff, Rosewood would be the most convenient reservoir for day-use and should support good use.

Approximately eight miles south of the Rosewood project is the Dippingvat project on the South Fork of Cottonwood Creek (Figure 8). Dippingvat Reservoir would be created by a 217-foot high dam in Section 36, T27N, R7W, MDB&M. This reservoir would have a 1,005 surface acre lake at a maximum pool elevation of 1,172 feet MSL. The average drawdown would be 28 feet to a pool surface area of 780 acres. Dippingvat project is located in an area

FIGURE 7


T 29 N
T 28 N
Red Bluff 19 miles
R 7 W
R 6 W
LEGEND
Proposed Recreation Area
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
.PPER SACRAMENTO RIVER BASIN INVESTIGATION
ROSEWOOD RESERVOIR
(Normal Pool Elev. 786 ft.)
0
3400
6600 feet
SCALE

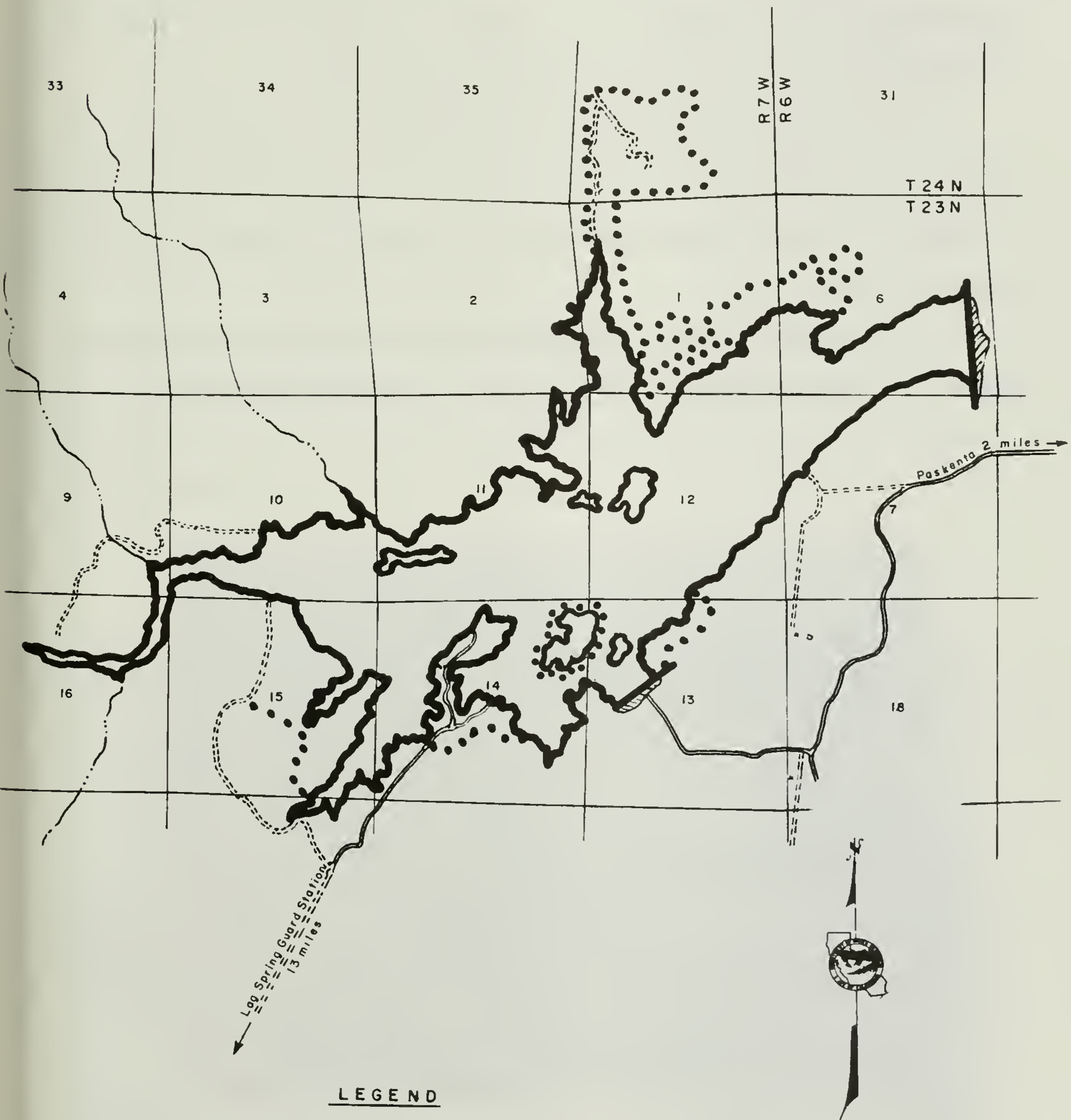

17
16
15
14
Red Bluff 28 miles
13
20
21
22
23
24
29
28
27
26
25
33
34
35
36
T 29 N
T 28 N
R 7 W
R 6 W
4
3
2
N
LEGEND
Proposed Recreation Area
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
UPPER SACRAMENTO RIVER BASIN INVESTIGATION
DIPPINGVAT RESERVOIR
(Normal Pool Elev 1172 ft)
0
3100
6200 feet
SCALE

of very steep terrain with limited access. Analyzed by present day land development standards, this project has a low potential for recreation use. Future demands for recreation waters and land may well negate these present standards and increase the desirability of this project.

The Paskenta project has had extensive feasibility exploration by the State investigations as well as investigations for approval of Davis-Grunsky grant by the Tehama County Flood Control and Water Conservation District. The Upper Sacramento River Basin Investigation recreation analysis was accomplished for a reservoir with a capacity of 137,000 acre-feet. To impound this water, a 250-foot high dam would be constructed across Thomes Creek in Section 6, T23N, R6W, MDB&M (Figure 9), and a saddle-dam in Section 13. These dams would create a reservoir with a maximum surface area of 1,940 acres (surface elevation of 1,006 feet MSL. The average operations drawdown of 27 feet would reduce the surface area to 1,450 acres. Paskenta project is well suited for water-associated recreation in reference to the topography and attractive scenic environment. The majority of the initial recreation use will probably originate from Orland and Corning approximately 25 miles east. Future population growth of Glenn and Tehama Counties would result in increased use of reservoir recreation areas.

Sacramento River Reservoir

One site on the main stem of the Sacramento River has been studied in this investigation to determine if it is a feasible site for the development of a large multipurpose reservoir. This site is located 4.5 miles northeast of Red Bluff. The dam (Iron Canyon) would consist of an earthfill dam approximately 170 feet in height across the main river channel (crest elevation 420 feet above sea level). The primary purposes of this project would be conservation yield,



LEGEND

Proposed Recreation Area

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
UPPER SACRAMENTO RIVER BASIN INVESTIGATION

PASKENTA RESERVOIR
(Normal Pool Elev. 1006 ft.)

SCALE 0 — 3700 — 7400 feet

hydroelectric power generation, flood control, and recreation. Iron Canyon Dam would impound a reservoir of approximately 27,000 surface acres at normal pool. Tentative operation schedules call for an average annual 40 foot draw-down to average pool of 10,000 surface acres. At normal pool, the north to south length of the reservoir is approximately 21 miles.

The annual operation schedule would provide a maximum pool late in the spring and a minimum pool in the late fall. Recreation facilities would be located on slopes approaching the maximum acceptable standards, and in the minimum pool area.

The potential water-associated recreation areas lie at an average elevation of 450 feet above sea level. These areas generally consist of

Iron Canyon Damsite and the Bald Hill Recreation Area (left side).

gently sloping foothills with outcroppings of igneous rocks. The upper reaches of the project are characterized by the flood plain valleys of the Cottonwood and Cow Creek drainages. At normal pool, 400 feet above sea level, considerable areas of flat land in the upper reaches of the reservoir would be inundated. With a 40-foot drawdown, these areas would be exposed as large mud flats.

The climate of the project area is typically hot and dry in the summer, and cool in the winter, with abundant rainfall. Spring and late fall are especially pleasant seasons. The hot summer season would be very conducive to water-associated activities, if facilities are built close to the water.

Blue oak, valley oak, and annual grasses comprise the major vegetative cover of the project area. The landscape is further enhanced by interesting outcroppings of igneous rocks. Shallow soil is evident in many of the short grass areas.

Potential Recreation Area

Iron Canyon Analysis

The recreation studies of the Iron Canyon project are more detailed than the studies of the tributary reservoirs. Iron Canyon studies delineated lands which should be used for present and future recreation development purposes and the benefits that could be expected to accrue.

The calculation of gross dollar benefits entailed four steps. The first step required the estimating of recreational use by type of use and place-of-residence of the users. These estimates covered the 50 year project repayment period. The second step involved field studies to determine if there was enough land adjacent to the reservoir to satisfy the predicted use. The third step consisted of the preparation of a recreation land use plan in order to calculate the recreational development costs; and the fourth step involved the determination of a value for a visitor-day. This value was determined by the Economists of the Department of Water Resources from data relating to place-of-residence of recreation visitors.

Method of estimating recreational use was discussed in the General Methodology section of a previous chapter. Table V and VII present the estimated recreational use that Iron Canyon Reservoir project would receive if developed by 1970.

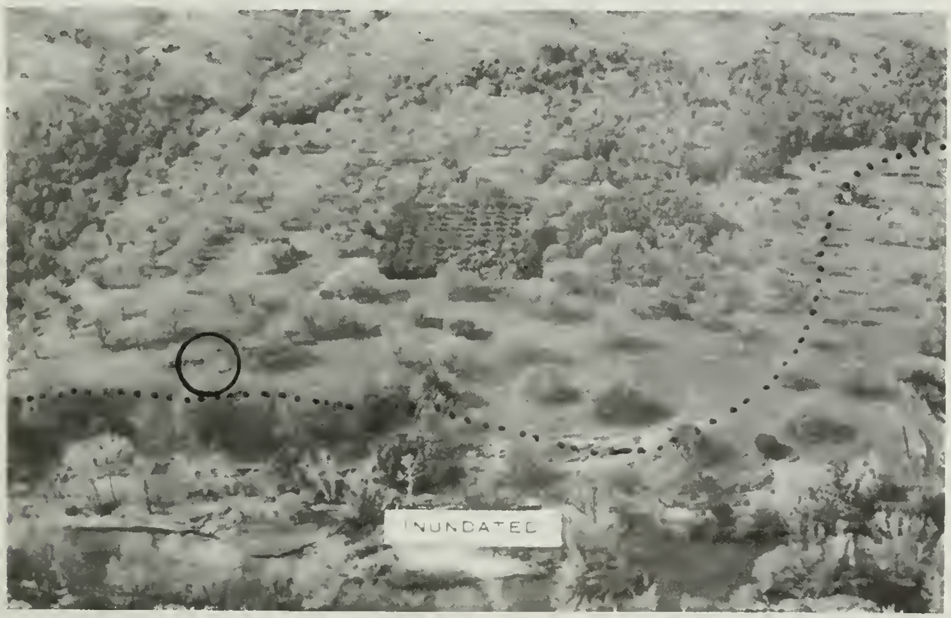
In 1958 Shasta County made a survey of recreationists at Shasta Lake. The county determined the counties of origin from the persons interviewed. The results (presented previously in Table II) were compiled and grouped into general areas of origin which included both state regions and miscellaneous out-of-state areas. The proportion of local to non-local use was 38 to 62 percent. These figures are calculated by including out-of-state use and were utilized for sizing day-use and overnight facilities at Iron Canyon Reservoir. Out-of-state users are deducted for calculation of benefits, making the proportion of local to non-local use by California residents 40.8 percent and 59.2 percent. However, facilities must be provided for use by nonresidents, and assumes that user origin at Iron Canyon will be similar to that of Shasta Reservoir.

Proposed Recreation Areas

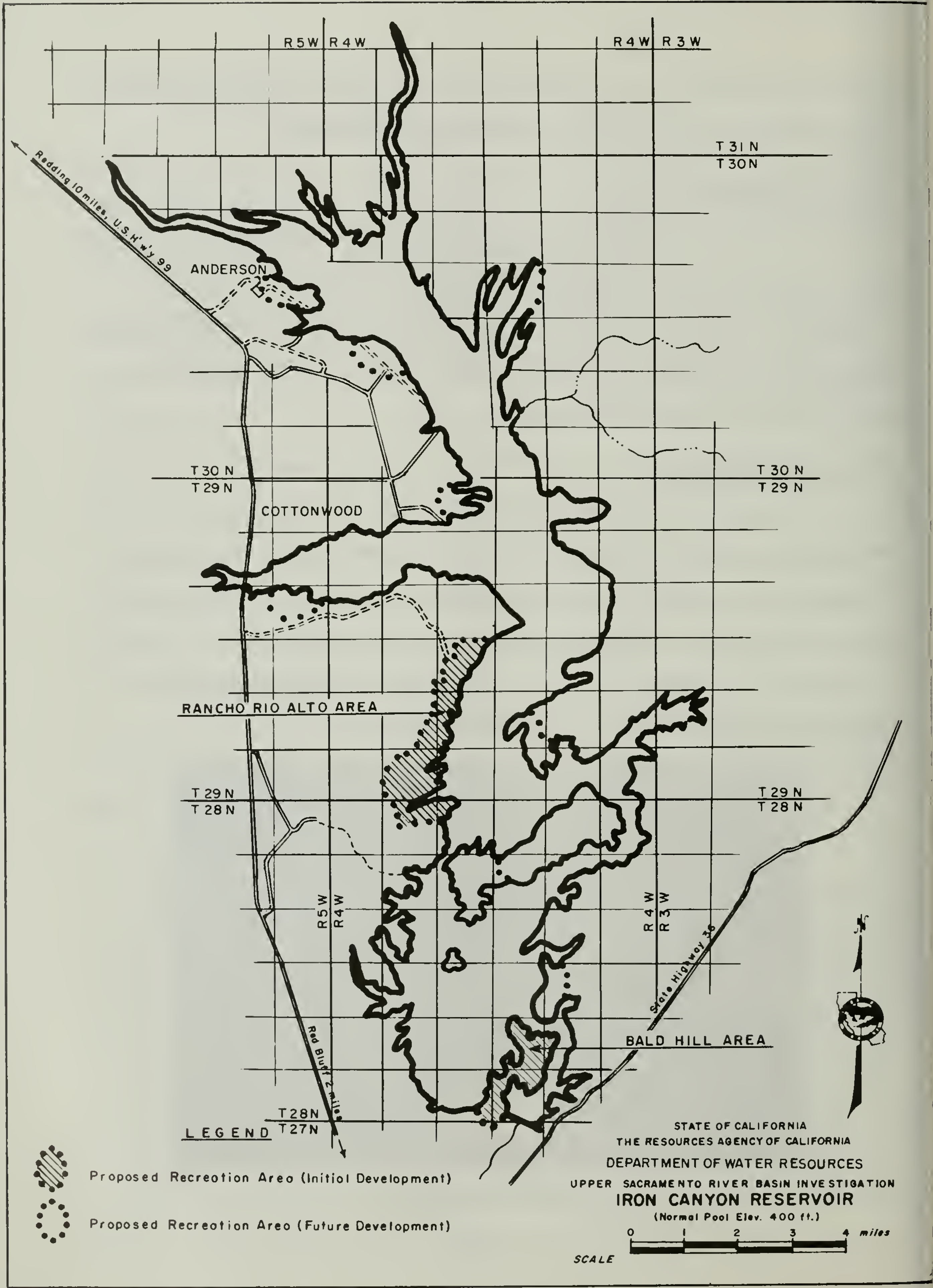
Figure 10 delineates the general project lands suitable for recreation development that should be set aside for initial and future use of the public. Two areas, Rancho Rio Alto and Bald Hill, are considered best for initial development. The seven additional areas shown should be preserved for future development.

Archaeological Survey

Aerial and ground reconnaissance surveys of the potential Iron Canyon Reservoir site indicate the area may have valuable archaeological remains. One group of aboriginal midden accumulations and house pits was located in an area being considered for recreation development. More of these sites will probably be found when qualified archaeologists survey the entire reservoir site prior to inundation.



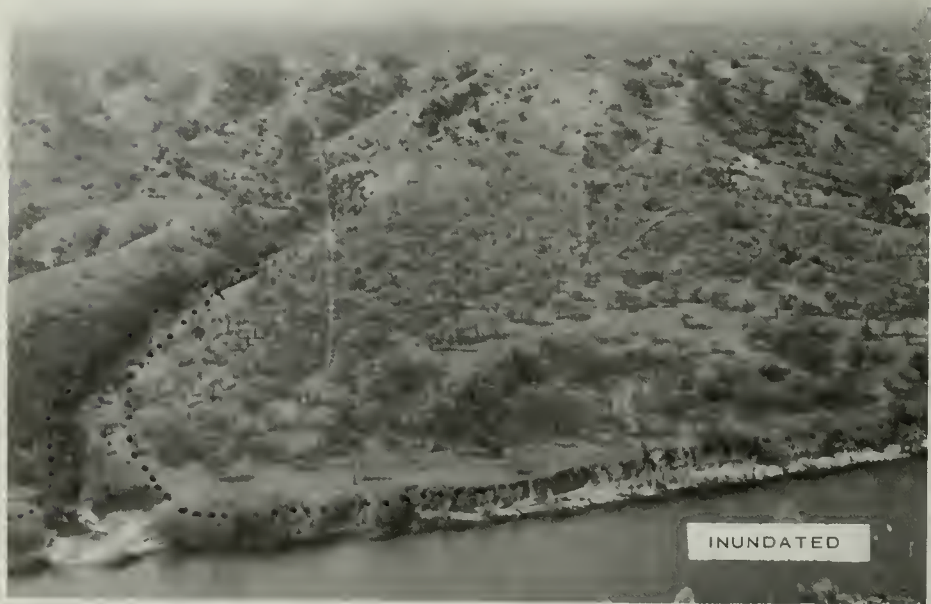
Indian "House Pit"


R5W R4W
R4W R3W
T31N
T30N
Redding 10 miles, U.S. H'w'y 99
ANDERSON
T30N
T29N
COTTONWOOD
RANCHO RIO ALTO AREA
T29N
T28N
R5W
R4W
R4W
R3W
State Highway 36
Red Bluff 2 miles
BALD HILL AREA
T28N
T27N
LEGEND
Proposed Recreation Area (Initial Development)
Proposed Recreation Area (Future Development)
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
UPPER SACRAMENTO RIVER BASIN INVESTIGATION
IRON CANYON RESERVOIR
(Normal Pool Elev. 400 ft.)
0 1 2 3 4 miles
SCALE

Rancho Rio Alto Area

Rancho Rio Alto - North End

Rancho Rio Alto - Center Area



Rancho Rio Alto - South End

Estimated Recreation Visitor-Days Use

To determine the net visitor-day recreation benefits attributable to the water project, studies were made of the present and the future recreation use with and without the project. The estimated present use was projected into the future for the repayment period of the project. Total use without the project was deducted from the gross project recreation use. The resulting use was the net visitor-day use attributed to the project. The Department of Fish and Game and the U. S. Fish and Wildlife Service furnished use data which were utilized to establish present visitor-day use of the Sacramento River in the area to be inundated by Iron Canyon. The net recreation use which can be accredited to the project is presented in Tables V and VII.

TABLE V

Iron Canyon Recreation
Gross and Net Visitor-days Use by Decades
(nearest 1,000's)
Visitor-Days

Decade	(With Project) Iron Canyon Project	(Without Project) River	Net Increase of Use
1970-80	2,862,000	1,455,000	1,407,000 1/
1980-90	5,783,000	2,088,000	3,695,000
1990-00	9,257,000	2,839,000	6,418,000
2000-10	13,821,000	3,703,000	10,118,000
2010-20	19,553,000	4,765,000	14,788,000
TOTALS	51,276,000	14,850,000	36,426,000

1/ The 1970-80 period of man-day use shows a small net increase of use for the decade. This fact seems reasonable because of the replacement of an established well-known recreation area by a new recreation environment.

NOTE: The fish and wildlife detriments of the Iron Canyon Project are far more significant than the losses of visitor-days within the project area. The anadromous fish that propagate within and above the Iron Canyon project annually supports a multi-million dollar downstream sport and commercial fishery.

CHAPTER IV.

EVALUATION OF ALTERNATE RESERVOIR ELEVATIONS

Each tributary reservoir has been evaluated on the basis of a pre-determined set of conditions that applied to a particular proposal. These conditions included the following items:

1. Damsite location.
2. Maximum water surface elevation.
3. Average water surface elevation during summer months.
4. Minimum water surface elevation.

Water surface area, exposed shore, and drawdown were derived from available area, capacity, and elevation data. With this information, each reservoir proposal was oriented to the following items:

1. The involved landscape above and below the water lines.
2. Location in relation to local population.
3. Access between population centers and the reservoir shore.
4. Location in relation to other water-associated recreation attractions.

Water project investigation involves the comparison of the merits of several alternative beneficial water developments and uses. A reduction or increase in the size of a reservoir usually results from a change in the relative importance of one of the project purposes (e.g., loss of part of a service area). Such a change produces results that influence the other project purposes (e.g., price of new water, more water available for remaining uses, new surface area of reservoir). In connection with the preceding concepts, it is sometimes necessary to evaluate the recreation attributes of alternative reservoir sizes and operations.

A lower level reservoir may fill and spill more frequently (also, the period during which the spilling occurs may extend into the summer season) and thus partially counteracting the adverse characteristics associated with fluctuating reservoirs. This more favorable operation may offset the smaller water area and smaller shoreline. Under other circumstances the lack of carry-over can result in drawdowns during dry cycles that virtually eliminate recreation use of the reservoir for the duration of a dry cycle. Such operation schedules also reduce the incentive to develop access and facilities for use during years of favorable water conditions.

The evaluation of different reservoir sizes should be made in view of proposed reservoir operations. In the Upper Sacramento tributaries, alternate reservoir elevations have been considered without reference to the alternate reservoir operation involved. The reconnaissance of the tributary reservoir sites indicated that minor alterations of reservoir storage capacities would not in themselves critically affect recreation development and use.

The following table evaluates alternate reservoir water elevations on the Upper Sacramento River tributaries. It is assumed that other reservoir operation characteristics will change in proportion to the change in reservoir storage. The evaluations are based on the estimated changes in usable shoreline.

TABLE VI

ALTERNATE SIZE RESERVOIR RECREATION
COST AND USE PREDICTION FACTORS

Reservoir	Normal Water Surface Elevation U.S.G.S. Datum	Storage Capacity in Acre-feet	Water Surface Acres at Normal Pool	Factor
Hulen	828	62,500	1,350	1.00
	793	25,000	770	.75
Bella Vista	614	200,000	4,500	1.00
	586	100,000	2,750	.63
Millville	743	97,000	1,580	1.00
	710	50,000	1,160	.86
Fiddlers	970	114,000	1,550	1.00
	1,015	200,000	2,450	1.26
Rosewood	786	200,000	3,000	1.00
	744	100,000	1,900	.80
Dippingvat	1,172	74,000	1,000	1.00
	1,130	40,000	680	.82
Paskenta	1,006	135,000	1,940	1.00
	950	55,000	1,060	.74

CHAPTER V. SUMMARY AND CONCLUSIONS

All of the eight reservoirs in the Upper Sacramento River Basin Investigation studied by the Northern Branch Recreation Contract Services Unit have some degree of recreational use potential (Table VII). These studies also indicated that none of these reservoirs has enough recreation demand to justify the project on recreation as the sole project purpose. The low predictions summarized in Table VII are partially due to the fact thah the local population is small and will continue to be small. Also, the competition for user-days and capital investment for facilities will be extreme because of the large established reservoirs within a short distance of the envisioned projects.

The physiography is similar for all of the reservoir sites in the Upper Sacramento River Basin. The topography is composed of generally rolling foothills and steep stream cut canyons at the altitude of 400 to 1,500 feet above sea level. The recreation season climate is hot and arid which tends to promote water contact sports. The typical vegetative cover is sparse, composed in part of deciduous oaks, digger pines, several brush species, and annual grasses.

Present recreation use centers around hunting and angling. The tributary reservoir sites are mostly privately owned and restricted to owner recreation use. Present public recreation use is found along the Sacramento River in the areas which would be inundated by Iron Canyon Reservoir. The importance of this section of the river in the production of anadromous species of fish is reflected in the harvest by recreationists and commercial fishermen in other parts of the state, and the local fishing for these species.

TABLE VII

SUMMARY OF THE COST AND
RECREATION USES DEMAND PREDICTIONS
OF THE

UPPER SACRAMENTO RIVER BASIN INVESTIGATION

Decade	Without Iron Canyon Project 1/							With Iron Canyon Project and One of the Below							Iron Canyon Project 2/
	Hulen (Elevation 828 ft.)	Bella Vista (Elevation 614 ft.)	Millville (Elevation 743 ft.)	Fiddlers (Elevation 970 ft.)	Rosewood (Elevation 786 ft.)	Dippingvat (Elevation 1,172 ft.)	Paskenta (Elevation 1,006 ft.)	Hulen (Elevation 828 ft.)	Bella Vista (Elevation 614 ft.)	Millville (Elevation 743 ft.)	Fiddlers (Elevation 970 ft.)	Rosewood (Elevation 786 ft.)	Dippingvat (Elevation 1,172 ft.)	Paskenta (Elevation 1,006 ft.)	Iron Canyon (Elevation 400 ft.)
1970 - 1980															
1980 level	46,000	101,000	18,000	15,000	108,000	15,000	40,000	23,000	69,000	15,000	10,000	82,000	9,000	39,000	433,000
Total Visitor Days	307,000	670,000	120,000	100,000	720,000	100,000	267,000	153,000	460,000	100,000	67,000	547,000	60,000	260,000	1,407,000
Total Cost	$ 277,000	461,000	145,000	120,000	743,000	133,000	333,000	168,000	385,000	132,000	193,000	580,000	107,000	329,000	5,034,000
1980 - 1990															
1990 level	73,000	160,000	28,000	24,000	171,000	24,000	63,000	36,000	110,000	24,000	16,000	130,000	15,000	62,000	723,000
Total Visitor Days	595,000	1,305,000	230,000	195,000	1,395,000	195,000	515,000	295,000	895,000	195,000	130,000	1,060,000	120,000	505,000	3,695,000
Total Cost	$ 285,000	538,000	132,000	110,000	721,000	119,000	300,000	159,000	409,000	118,000	140,000	557,000	87,000	297,000	3,954,000
1990 - 2000															
2000 level	116,000	250,000	44,000	45,000	281,000	40,000	93,000	57,000	173,000	38,000	30,000	214,000	24,000	91,000	1,128,000
Total Visitor Days	945,000	2,050,000	360,000	345,000	2,260,000	320,000	780,000	465,000	1,415,000	310,000	230,000	1,720,000	195,000	765,000	6,418,000
Total Cost	$ 431,000	844,000	149,000	155,000	1,141,000	135,000	363,000	193,000	381,000	120,000	104,000	868,000	82,000	354,000	6,492,000
2000 - 2010															
2010 level	165,000	356,000	63,000	66,000	421,000	60,000	135,000	81,000	245,000	54,000	44,000	320,000	36,000	133,000	1,636,000
Total Visitor Days	1,405,000	3,030,000	535,000	555,000	3,510,000	500,000	1,140,000	690,000	2,090,000	460,000	370,000	2,670,000	300,000	1,120,000	10,118,000
Total Cost	$ 543,000	1,170,000	207,000	221,000	1,636,000	198,000	521,000	266,000	808,000	178,000	146,000	1,244,000	121,000	505,000	8,590,000
2010 - 2020															
2020 level	225,000	483,000	85,000	94,000	610,000	80,000	182,000	110,000	333,000	73,000	62,000	464,000	49,000	178,000	2,275,000
Total Visitor Days	1,950,000	4,195,000	740,000	800,000	5,155,000	700,000	1,585,000	955,000	2,890,000	635,000	530,000	3,920,000	425,000	1,555,000	14,788,000
Total Cost	$ 733,000	1,567,000	276,000	309,000	2,331,000	258,000	661,000	360,000	1,081,000	237,000	203,000	1,733,000	156,000	653,000	11,916,000
TOTALS															
Visitor Days for Five Decades	5,202,000	11,250,000	1,985,000	1,995,000	13,040,000	1,815,000	4,287,000	2,558,000	7,750,000	1,700,000	1,327,000	9,917,000	1,100,000	4,205,000	36,426,000
Cost for Five Decades	$2,269,000	4,580,000	909,000	915,000	6,572,000	843,000	2,178,000	1,146,000	3,264,000	785,000	786,000	4,982,000	553,000	2,138,000	35,986,000

1/ Considering each of the tributary reservoirs as if it were the only reservoir to be developed within the drainage area. Existing reservoirs (Shasta, Almanor, etc.) and those reservoirs in development stage (Black Butte, Whiskeytown, etc.) are considered as competing reservoirs.

2/ The size and location of Iron Canyon Project is such that the development or nondevelopment of the tributary projects will have no sizeable effect on estimated recreation use of Iron Canyon.

TABLE VII A

PREDICTED FACILITY DEVELOPMENT
WITHOUT IRON CANYON OR OTHER TRIBUTARY LOCAL PROJECTS

Reservoir and decade	Camp units developed ($3,000 ea.)	Picnic units developed ($2,100 ea.)	Capital cost camp and picnic units	Capital costs above units	Operation, maintenance and replacements	Total cost decade
Hulen Reservoir						
1970 - 1980	None	46	88,000	99,000	90,000	277,000
1980 - 1990	"	27	57,000	54,000	174,000	285,000
1990 - 2000	"	43	90,000	65,000	276,000	431,000
2000 - 2010	"	49	103,000	30,000	410,000	543,000
2010 - 2020	"	60	126,000	38,000	569,000	733,000
Bella Vista Reservoir						
1970 - 1980	None	101	212,000	54,000	195,000	461,000
1980 - 1990	"	59	123,000	34,000	381,000	538,000
1990 - 2000	"	90	189,000	57,000	598,000	844,000
2000 - 2010	"	106	223,000	63,000	884,000	1,170,000
2010 - 2020	"	127	267,000	76,000	1,224,000	1,567,000
Millville Reservoir						
1970 - 1980	None	18	38,000	72,000	35,000	145,000
1980 - 1990	"	10	21,000	44,000	67,000	132,000
1990 - 2000	"	16	34,000	10,000	105,000	149,000
2000 - 2010	"	19	40,000	11,000	156,000	207,000
2010 - 2020	"	22	46,000	14,000	216,000	276,000
Fiddlers Reservoir						
1970 - 1980	None	15	32,000	59,000	29,000	120,000
1980 - 1990	"	9	19,000	34,000	57,000	110,000
1990 - 2000	"	21	44,000	10,000	101,000	155,000
2000 - 2010	"	21	44,000	15,000	162,000	221,000
2010 - 2020	"	28	59,000	17,000	233,000	309,000
Rosewood Reservoir						
1970 - 1980	90	72	493,000	40,000	210,000	743,000
1980 - 1990	52	42	250,000	64,000	407,000	721,000
1990 - 2000	92	73	410,000	71,000	660,000	1,141,000
2000 - 2010	116	93	520,000	92,000	1,024,000	1,636,000
2010 - 2020	159	127	744,000	82,000	1,505,000	2,331,000
Dippingvat Reservoir						
1970 - 1980	None	15	32,000	72,000	29,000	133,000
1980 - 1990	"	9	19,000	43,000	57,000	119,000
1990 - 2000	"	16	34,000	8,000	93,000	135,000
2000 - 2010	"	20	42,000	10,000	146,000	198,000
2010 - 2020	"	20	42,000	12,000	204,000	258,000
Paskenta Reservoir						
1970 - 1980	32	27	153,000	102,000	78,000	333,000
1980 - 1990	20	15	92,000	58,000	150,000	300,000
1990 - 2000	25	20	117,000	18,000	228,000	363,000
2000 - 2010	28	21	128,000	61,000	332,000	521,000
2010 - 2020	40	31	185,000	14,000	462,000	661,000

TABLE VII B

PREDICTED FACILITY DEVELOPMENT
WITH IRON CANYON PROJECT AND ONE OF THE LOCAL PROJECTS

Reservoir and decade	Camp units developed ($3,000 ea.)	Picnic units developed ($2,100 ea.)	Capital cost camp and picnic units	Capital costs above units	Operation, maintenance and replacements	Total cost decade
Hulen Reservoir						
1970 - 1980	None	23	48,000	75,000	45,000	168,000
1980 - 1990	"	13	27,000	46,000	86,000	159,000
1990 - 2000	"	21	44,000	13,000	136,000	193,000
2000 - 2010	"	24	50,000	15,000	201,000	266,000
2010 - 2020	"	29	61,000	20,000	279,000	360,000
Bella Vista Reservoir						
1970 - 1980	None	69	145,000	106,000	134,000	385,000
1980 - 1990	"	41	86,000	62,000	261,000	409,000
1990 - 2000	"	63	132,000	36,000	413,000	581,000
2000 - 2010	"	72	151,000	47,000	610,000	808,000
2010 - 2020	"	88	185,000	53,000	843,000	1,081,000
Millville Reservoir						
1970 - 1980	None	15	32,000	71,000	29,000	132,000
1980 - 1990	"	9	19,000	42,000	57,000	118,000
1990 - 2000	"	14	29,000	1,000	90,000	120,000
2000 - 2010	"	16	34,000	10,000	134,000	178,000
2010 - 2020	"	19	40,000	12,000	185,000	237,000
Fiddlers Reservoir						
1970 - 1980	None	10	21,000	152,000	20,000	193,000
1980 - 1990	"	6	13,000	89,000	38,000	140,000
1990 - 2000	"	14	29,000	8,000	67,000	104,000
2000 - 2010	"	14	29,000	9,000	108,000	146,000
2010 - 2020	"	18	38,000	10,000	155,000	203,000
Rosewood Reservoir						
1970 - 1980	68	55	320,000	100,000	160,000	580,000
1980 - 1990	40	32	187,000	61,000	309,000	557,000
1990 - 2000	70	56	328,000	38,000	502,000	868,000
2000 - 2010	90	70	417,000	28,000	779,000	1,224,000
2010 - 2020	120	96	562,000	28,000	1,143,000	1,733,000
Dippingvat Reservoir						
1970 - 1980	None	9	19,000	70,000	18,000	107,000
1980 - 1990	"	6	13,000	39,000	35,000	87,000
1990 - 2000	"	9	19,000	6,000	57,000	82,000
2000 - 2010	"	12	25,000	8,000	88,000	121,000
2010 - 2020	"	13	27,000	5,000	124,000	156,000
Paskenta Reservoir						
1970 - 1980	32	26	151,000	102,000	76,000	329,000
1980 - 1990	20	15	92,000	58,000	147,000	297,000
1990 - 2000	23	20	111,000	20,000	223,000	354,000
2000 - 2010	35	28	164,000	14,000	327,000	505,000
2010 - 2020	38	30	174,000	25,000	454,000	653,000
Iron Canyon Reservoir	($3,000 ea.)	($2,750 ea.)				
1970 - 1980	475	150	2,113,000	1,607,000	1,314,000	5,034,000
1980 - 1990	300	125	1,244,000	32,000	2,678,000	3,954,000
1990 - 2000	425	150	1,687,000	519,000	4,286,000	6,492,000
2000 - 2010	550	175	2,131,000	57,000	6,402,000	8,590,000
2010 - 2020	700	250	2,788,000	78,000	9,050,000	11,916,000
TOTAL	2,450	850	9,963,000	2,293,000	23,730,000	35,986,000

APPENDIX B

PRELIMINARY FISH AND WILDLIFE

RECOMMENDATIONS

State of California **The Resources Agncy**

Memorandum

To : Honorable William E. Warne, Director
Department of Water Resources
P. O. Box 388
Sacramento, California 95802

Date: November 9, 1964

From : Department of Fish and Game

Subject: WP-State of California, Department of Water Resources - Upper Sacramento River Basin Investigation - Preliminary Fish and Wildlife Recommendations

The Upper Sacramento River Basin Investigation has been completed. The conclusions of the study are presently being prepared for presentation in DWR Bulletin No. 150. The fish and wildlife phase of this investigation, carried on under contract by the Fish and Game Contract Services Section, has had as one of its purposes the determination of facilities required and the management recommendations necessary for the preservation and possible enhancement of the fish and wildlife resources of the area.

We are supplying you, in this memorandum, with certain data on existing salmon runs that would be influenced by the Iron Canyon Project and facilities that would be required to compensate for probable salmon losses under a particular set of assumed conditions, so that you may complete Bulletin No. 150 on schedule. Included also are estimates of probable wildlife losses in connection with both the tributary development and Iron Canyon Reservoir, and estimates of measures required for adequate compensation for these losses and their costs.

While it is anticipated that the Iron Canyon Project would pose serious problems in regards to main river salmon spawning, the opposite is expected from upstream tributary development. The results of preliminary studies indicate that Cow and Cottonwood Creek could be enhanced considerably for salmon spawning by water storage projects providing water releases of a suitable temperature and quality.

Please keep in mind that the data herein that concern probable salmon losses and required artificial propagation facilities are based on a number of broad assumptions that are not presently substantiated by facts. These assumptions are: (1) that both adult and juvenile salmon and steelhead can be transported successfully around Iron Canyon Dam;

(2) adult and juvenile salmon and steelhead can successfully negotiate the reservoir, both up- and downstream; (3) water of a suitable quality and temperature will be available for operation of an artificial propagation facility. The recommendations made in this memorandum are valid only if these assumed conditions are met.

If assumptions 1 and 2 cannot be met, all salmon and steelhead that spawn above the proposed Iron Canyon Dam would have to be artificially propagated to maintain existing runs. This would create a new problem, due to the unprecedented size of required artificial propagation facilities. Experience in designing and operating such an enormous plant is lacking.

Failure to meet assumption 3, regardless of any other conditions, would, in essence, result in the loss of the anadromous fish resources of the Upper Sacramento River. No feasible means of mitigation of adverse water temperatures, or compensation for the resource loss, is known.

FISH

The Iron Canyon Project will destroy approximately 126 acres of gravel out of an estimated total of 256 acres of spawning gravel in the Upper Sacramento River (Table 1). It is estimated the 126 acres of spawning gravel in the project area has been utilized by king salmon runs numbering as high as 153,000 fish. The king salmon spawning distribution in the Upper Sacramento River was determined for this study by both aerial and ground surveys (Tables 1-2-3).

The aerial survey (Table 1) showed the gross distribution of spawning gravel but failed to show the intensity of spawning. The spawning ground surveys (Table 2) showed the spawning intensity of some areas well, but during years of high water, good counts for all areas were difficult to obtain. In order to resolve the differences between the two survey methods, the spawning distributions, obtained in Table 1 and 2, were averaged in Table 3 to produce an adjusted distribution. It is felt that the adjusted king salmon spawning distribution is more representative than the distributions obtained by either of the other two methods taken individually.

Spawning ground surveys, although they produce only estimated numbers of salmon, give an indication of gross distribution of fish in the drainage (Table 4). It is possible to apply the distribution schedules from Tables 3 and 4 to runs not broken down by area and to then calculate the numbers of fish in the run that spawned in the project area. The estimated maximum number of king salmon utilizing the project area was determined in this manner (Table 5).

As mitigation for the loss of spawning gravels in the project area, the Iron Canyon facilities should include a hatchery large enough to hatch and rear the maximum number of eggs that could be produced by the displaced salmon. A spawning run of 153,000 king salmon would normally be composed of 61,000 (40%) females and 92,000 (60%) males (Table 6). A run of 61,000 female king salmon depositing an average of 6,500 eggs each would produce a total of 396,500,000 eggs (Table 7). The Iron Canyon Hatchery, based on these calculations, should be designed for a maximum capacity of 397,000,000 king salmon eggs.

The Iron Canyon Hatchery should be designed to handle the maximum run expected, but in order to make calculations for the annual operation cost, the figures should be based on the average number of female salmon to be handled. The average number of female salmon calculated to have spawned in the project area from 1950 to 1960 was 32,000 (Table 8). A run of 32,000 female king salmon could be expected to deposit an average of 208,000,000 eggs or roughly 52 percent of the maximum calculated number.

Plans for the comprehensive development of the Upper Sacramento River Basin call for reservoirs on the Cow and Cottonwood Creek drainages in addition to a main river project. Reservoirs under consideration on Cow Creek include the Bella Vista and Millville Projects. Cottonwood Creek development plans call for projects at the Hulen, Fiddlers, Rosewood, and Dippingvat sites.

Salmon presently spawn in the lower reaches of Cow and Cottonwood Creeks, but because of low fall streamflows, the runs are small. Storage projects on these streams, with cold water reserved for fall release, could materially enhance their salmon spawning potential. The proposed projects were studied under various release schedules to determine at what flow the greatest salmon spawning enhancement could be obtained. The results of the studies are presented in Tables 9 through 14.

WILDLIFE

Wildlife and fisheries studies have been conducted concurrently during the Upper Sacramento River Basin Investigation. A reconnaissance wildlife survey of the area was made to determine what detrimental effects the proposed projects would have on wildlife populations. Data gathered during these wildlife surveys are compiled in Table 15. Based on the wildlife surveys, Table 15 provides an estimate of the wildlife losses and mitigation expenditures needed for compensation. Wildlife losses and mitigation measures are estimated for each area based on acreages included in the table. The preliminary studies produced good reconnaissance estimates of the effect of proposed projects on wildlife; however, additional studies will be needed to refine these estimates and to evaluate the effects of service areas on wildlife if subject investigation is continued through the full feasibility level.

Director

SACRAMENTO RIVER KING SALMON SPAWNING DISTRIBUTION,
AS DETERMINED BY PHOTOGRAPHIC GRAVEL SURVEY, FALL 1960

Table 1

Stream section	Surface acres of river	Surface acres of utilized spawning gravel	As percent of total disturbed gravel	Utilized spawning area as percent of total river surface area	Number of river mile in section surveyed
Keswick Dam to upper end of Iron Canyon Reservoir	834	84	33%	10%	18
Area affected by project	2,227	126	49%	6%	41
Area below project	1,621	46	18%	3%	42
TOTAL	4,682	256	100%	19%	101 miles

SACRAMENTO RIVER KING SALMON SPAWNING DISTRIBUTION
AS DETERMINED BY FALL SPAWNING GROUND SURVEY

Table 2

Stream section	Distribution of salmon carcasses					
	1956	1957	1958	1959	1960	Averag
Keswick Dam to upper end of Iron Canyon Reservoir	67%	35%	39%	67%	65%	54%
Area affected by project	28%	52%	50%	31%	29%	38%
Area below project	5%	13%	11%	2%	6%	8%

ADJUSTED KING SALMON SPAWNING DISTRIBUTION
FOR UPPER SACRAMENTO RIVER

Table 3

Stream section	Aerial survey distribution	Salmon carcass distribution	Adjusted spawning distribution
Keswick Dam to upper end of Iron Canyon Reservoir	33%	54%	43%
Area affected by project	49%	38%	44%
Area below project	18%	8%	13%

DISTRIBUTION OF UPPER SACRAMENTO RIVER FALL KING SALMON RUN

Table 4

Spawning distribution	1956		1957		1958		1959		1960		Average
	Number	%	Number	%	Number	%	Number	%	Number	%	
Coleman Hatchery 1/	2,661	2	7,689	9	7,853	4	7,100	2	8,940	3	4%
Main River 2/	92,783	74	59,500	72	119,900	70	259,500	85	224,000	85	77%
Tributaries 2/	30,317	24	15,347	19	44,426	26	38,631	13	30,113	12	19%
TOTAL RUN	125,761		82,536		172,179		305,231		263,053		

1/ Actual number of salmon taken at Keswick trap.
2/ Estimates obtained from spawning ground survey carcass counts.

ESTIMATED MAXIMUM NUMBER OF FALL RUN KING SALMON UTILIZING PROJECT AREA

Table 5

Maximum run of king salmon in upper Sacramento River	Main river spawners 77% of total run	Project area spawners 44% of total main river run
451,000 1/	347,000	153,000

1/ Estimate obtained from 1953 spawning ground survey.

BREAKDOWN OF SPAWNING RUN

Table 6

Maximum number of spawners utilizing project area	Maximum number of female salmon 40% of total run	Maximum number of male salmon 60% of total run
153,000	61,000	92,000

SUGGESTED SIZING OF IRON CANYON HATCHERY

Table 7

Maximum number of female salmon	Average number of eggs/fish	Total number of eggs
61,000	6,500	396,500,000

PREDICTED AVERAGE OPERATION LEVEL

Table 8

Maximum number of female salmon	Average number of eggs/fish	Total number of eggs
$\bar{X}$ 32,000	6,500	208,000,000

TABLE 9

POTENTIAL ENHANCEMENT OF COW CREEK FOR
KING SALMON SPAWNING BY CONTROLLED RELEASES OF WATER
FROM BELLA VISTA AND MILLVILLE RESERVOIRS

Project	Fish release storage in acre-ft.	Stream section	Spawning release in cfs.	Number of stream miles	total spawning gravel in ft.²	No. ♀ KS accommodated 1/	No. ♂ KS accommodated 2/	Potential spawning run 3/	Potential comm. catch 4/	Potential sport catch 5/	Total potential production	Present average spawning run 6/	Computed present comm. catch	Computed present sport catch	Computed present total run	Increase in spawning run	Increase in commercial catch	Increase in sport catch	Total increased production
Bella Vista	50,000	Little Cow Creek	100	4.5	143,000	1,682	2,523	4,205	9,924	2,691	16,820	498	1,175	319	1,992	3,707	8,749	2,372	14,828
		Main Cow Creek									1,824	456	1,076	292	1,824				
	70,000	Little Cow Creek	150	4.5	167,000	1,965	2,948	4,913	11,595	3,144	19,652	498	1,175	319	1,992	4,415	10,420	2,825	17,660
		Main Cow Creek									1,824	456	1,076	292	1,824				
	90,000	Little Cow Creek	200	4.5	179,000	2,106	3,159	5,265	12,425	3,370	21,060	498	1,175	319	1,992	4,767	11,250	3,051	19,068
		Main Cow Creek									1,824	456	1,076	292	1,824				
Millville	30,000	South Cow Creek	60	9.0	198,000	2,329	3,494	5,823	13,742	3,727	23,292	752	1,775	481	3,008	5,071	11,967	3,246	20,284
		Main Cow Creek									1,824	456	1,076	292	1,824				
	50,000	South Cow Creek	100	9.0	387,000	4,553	6,830	11,383	26,864	7,285	45,532	752	1,775	481	3,008	10,631	25,089	6,804	42,524
		Main Cow Creek									1,824	456	1,076	292	1,824				
	70,000	South Cow Creek	150	9.0	504,000	5,929	8,894	14,823	34,982	9,487	59,292	752	1,775	481	3,008	14,071	33,207	9,006	56,284
		Main Cow Creek									1,824	456	1,076	292	1,824				
	90,000	South Cow Creek	200	9.0	621,000	7,306	10,959	18,265	43,105	11,690	73,060	752	1,775	481	3,008	17,513	41,330	11,209	70,052
		Main Cow Creek									1,824	456	1,076	292	1,824				

1/ Space factor computed at 85 square feet per spawning female.

2/ Number of male king salmon computed at 1.5 males per female.

3/ Potential spawning run computed as 25 percent of total run.

4/ Potential commercial catch computed as 59 percent of total run.

5/ Potential sport catch computed as 16 percent of total run.

6/ The annual Cow Creek fall-run king salmon spawning population has averaged 1,706 fish in the years from 1956-60. The distribution of the spawning fish in the drainage is not definitely known at this time so an arbitrary distribution was made based on the amount of spawning gravel available. At a projected flow of 150 cfs Little Cow Creek contained 29.2 percent, South Cow Creek contained 44.1 percent, and Main Cow Creek contained 26.7 percent of the available spawning gravel.

TABLE 10

POTENTIAL ENHANCEMENT OF MAIN COTTONWOOD CREEK FOR
KING SALMON SPAWNING BY CONTROLLED RELEASES OF WATER
FROM HULEN RESERVOIR

Fish release storage in acre-ft.	Stream section	Spawning release in cfs.	Natural flow in cfs.	Combined flow in cfs.	Number of stream miles	Total spawning gravel in ft.²	No. ♀ KS accommodated 1/	No. ♂ KS accommodated 2/	Potential spawning run 3/	Potential comm. catch 4/	Potential sport catch 5/	Total potential production	Present average spawning run 6/	Computed present comm. catch	Computed present sport catch	Computed present total run	Increase in spawning run	Increase in commercial catch	Increase in sport catch	Total increased production
20,000	Upper Cottonwood	100	20	120	11.5	378,250	4,450	6,676	11,126											
	Lower Cottonwood	100	50	150	7.8	152,100	1,789	2,684	4,473											
						530,350	6,239	9,360	15,599	36,814	9,983	62,396	1,054	2,487	675	4,216	14,545	34,327	9,308	58,180
30,000	Upper Cottonwood	150	20	170	11.5	470,500	5,535	8,303	13,838											
	Lower Cottonwood	150	50	200	7.8	179,400	2,111	3,167	5,278											
						649,900	7,646	11,470	19,116	45,114	12,234	76,464	1,054	2,487	675	4,216	18,062	42,627	11,559	72,248
40,000	Upper Cottonwood	200	20	220	11.5	565,500	6,654	9,981	16,635											
	Lower Cottonwood	200	50	250	7.8	214,500	2,524	3,786	6,310											
						780,000	9,178	13,767	22,945	54,150	14,685	91,780	1,054	2,487	675	4,216	21,891	51,663	14,010	87,564
50,000	Upper Cottonwood	250	20	270	11.5	660,500	7,771	11,657	19,428											
	Lower Cottonwood	250	50	300	7.8	237,900	2,799	4,199	6,998											
						898,400	10,570	15,856	26,426	62,365	16,913	105,704	1,054	2,487	675	4,216	25,372	59,878	16,238	101,488

1/ Space factor computed at 85 square feet per spawning female.

2/ Number of male king salmon computed at 1.5 males per female.

3/ Potential spawning run computed as 25 percent of total run.

4/ Potential commercial catch computed as 59 percent of total run.

5/ Potential sport catch computed as 16 percent of total run.

6/ Present run spawns in lower 4 to 6 miles of main stem. Fish counts for years 1956-60 ranged from 350 to 3,300 spawners.

TABLE 11

POTENTIAL ENHANCEMENT OF SOUTH FORK
AND MAIN COTTONWOOD CREEK FOR KING SALMON SPAWNING
BY CONTROLLED RELEASES OF WATER FROM DIPPINGVAT RESERVOIR

Fish release storage in acre-ft.	Stream section	Spawning release in cfs.	Natural flow in cfs.	Combined flow in cfs.	Number of stream miles	Total spawning gravel in ft.²	No. ♀ KS accommodated 1/	No. ♂ KS accommodated 2/	Potential spawning run 3/	Potential comm. catch 4/	Potential sport catch 5/	Total potential production	Present average spawning run 6/	Computed present comm. catch	Computed present sport catch	Computed present total run	Increase in spawning run	Increase in commercial catch	Increase in sport catch	Total increased production
20,000	South Fork Cottonwood	50	0	50	27.0	390,000	4,588	6,882	11,470											
	Lower Cottonwood	50	50	100	7.8	130,260	1,532	2,298	3,830											
						520,260	6,120	9,180	15,300	36,108	9,792	61,200	1,054	2,487	675	4,216	14,246	33,621	9,117	56,984
40,000	South Fork Cottonwood	100	0	100	27.0	970,000	11,412	17,118	28,530											
	Lower Cottonwood	100	50	150	7.8	152,100	1,789	2,684	4,473											
						1,122,100	13,201	19,802	33,003	77,887	21,122	132,012	1,054	2,487	675	4,216	31,949	75,400	20,447	127,796
60,000	South Fork Cottonwood	150	0	150	27.0	1,380,000	16,235	24,353	40,588											
	Lower Cottonwood	150	50	200	7.8	179,400	2,111	3,167	5,278											
						1,559,400	18,346	27,520	45,866	108,244	29,354	183,464	1,054	2,487	675	4,216	44,812	105,757	28,679	179,248

1/ Space factor computed at 85 square feet per spawning female.

2/ Number of male king salmon computed at 1.5 males per female.

3/ Potential spawning run computed as 25 percent of total run.

4/ Potential commercial catch computed as 59 percent of total run.

5/ Potential sport catch computed as 16 percent of total run.

6/ Present run spawns in lower 4 to 6 miles of main stem. Fish counts for years 1956-60 ranged from 350 to 3,300 spawners.

TABLE 12

POTENTIAL ENHANCEMENT OF COTTONWOOD CREEK
FOR KING SALMON SPAWNING BY CONTROLLED RELEASES OF WATER
FROM HULEN AND DIPPINGVAT RESERVOIRS

Fish release storage in acre-ft.	Stream section	Spawning release in cfs.	Natural flow in cfs.	Combined flow in cfs.	Number of stream miles	Total spawning gravel in ft.^{2}	No. ♀ KS accommodated 1/	No. ♂ KS accommodated 2/	Potential spawning run 3/	Potential spawning catch 4/	Potential comm. catch 5/	Total potential production	Present average spawning run 6/	Computed present comm. catch	Computed present sport catch	Computed present total run	Increase in spawning run	Increase in commercial catch	Increase in sport catch	Total increased production
20,000	Upper Cottonwood	100	20	120	11.5	378,250	4,450	6,676	11,125											
20,000	South Fork Cottonwood	50	0	50	27.0	390,000	4,588	6,882	11,470											
	Lower Cottonwood	150	50	200	7.8	179,400	2,111	3,167	5,278											
					46.3	947,650	11,149	16,725	27,874	65,783	17,839	111,496	1,054	2,487	675	4,216	26,820	63,296	17,164	107,280
30,000	Upper Cottonwood	150	20	170	11.5	470,500	5,535	8,303	13,838											
40,000	South Fork Cottonwood	100	0	100	27.0	970,000	11,412	17,118	28,530											
	Lower Cottonwood	250	50	300	7.8	237,900	2,799	4,199	6,998											
					46.3	1,678,400	19,746	29,620	49,366	116,504	31,594	197,464	1,054	2,487	675	4,216	48,312	114,017	30,919	193,248
40,000	Upper Cottonwood	200	20	220	11.5	565,500	6,653	9,980	16,633											
60,000	South Fork Cottonwood	150	0	150	27.0	1,380,000	16,235	24,353	40,588											
	Lower Cottonwood	350	50	400	7.8	241,800	2,845	4,268	7,113											
					46.3	2,187,300	25,733	38,601	64,334	151,828	41,174	257,336	1,054	2,487	675	4,216	63,280	149,341	40,500	253,120

1/ Space factor computed at 85 square feet per spawning female.

2/ Number of male king salmon computed at 1.5 males per female.

3/ Potential spawning run computed as 25 percent of total run.

4/ Potential commercial catch computed as 59 percent of total run.

5/ Potential sport catch computed as 16 percent of total run.

6/ Present run spawns in lower 4 to 6 miles of main stem. Fish counts for years 1956-60 ranged from 350 to 3,300 spawners.

TABLE 13

POTENTIAL ENHANCEMENT OF DRY CREEK, SOUTH FORK,
AND MAIN COTTONWOOD CREEK FOR KING SALMON SPAWNING
BY CONTROLLED RELEASES OF WATER FROM ROSEWOOD RESERVOIR

Fish release storage in acre-ft.	Stream section	Spawning release in cfs.	Natural flow in cfs.	Combined flow in cfs.	Number of stream miles	Total spawning gravel in ft.²	No. ♀ KS accommodated 1/	No. ♂ KS accommodated 2/	Potential spawning run 3/	Potential comm. catch 4/	Potential sport catch 5/	Total potential production	Present average spawning run 6/	Computed present comm. catch	Computed present sport catch	Computed present total run	Increase in spawning run	Increase in commercial catch	Increase in sport catch	Total increased production
20,000	Dry Creek	50	0	50	7.5	22,000	259	389	648											
	South Fork Cottonwood	50	0	50	7.0	56,000	659	989	1,648											
	Lower Cottonwood	50	50	100	7.8	130,260	1,532	2,298	3,830											
							2,450	3,676	6,126	14,457	3,921	24,504	1,054	2,487	675	4,216	5,072	11,970	3,246	20,288
30,000	Dry Creek	75	0	75	7.5	38,000	448	672	1,120											
	South Fork Cottonwood	75	0	75	7.0	98,000	1,153	1,730	2,883											
	Lower Cottonwood	75	50	125	7.8	140,400	1,652	2,478	4,130											
							3,253	4,880	8,133	19,194	5,205	32,532	1,054	2,487	675	4,216	7,079	16,707	4,530	28,316
45,000	Dry Creek	100	0	100	7.5	54,000	635	953	1,588											
	South Fork Cottonwood	100	0	100	7.0	140,000	1,648	2,472	4,120											
	Lower Cottonwood	100	50	150	7.8	152,100	1,789	2,684	4,473											
							4,072	6,109	10,181	24,027	6,516	40,724	1,054	2,487	675	4,216	9,127	21,540	5,841	36,508

1/ Space factor computed at 85 square feet per spawning female.

2/ Number of male king salmon computed at 1.5 males per female.

3/ Potential spawning run computed as 25 percent of total run.

4/ Potential commercial catch computed as 59 percent of total run.

5/ Potential sport catch computed as 16 percent of total run.

6/ Present run spawns in lower 4 to 6 miles of main stem. Fish counts for years 1956-60 ranged from 350 to 3,300 spawners.

TABLE 14

POTENTIAL ENHANCEMENT OF MIDDLE FORK AND
MAIN COTTONWOOD CREEK FOR KING SALMON SPAWNING BY
CONTROLLED RELEASES OF WATER FROM FIDDLERS RESERVOIR

Fish release storage in acre-ft.	Stream section	Spawning release in cfs.	Natural flow in cfs.	Combined flow in cfs.	Number of stream miles	Total spawning gravel in ft.²	No. ♀ KS accommodated 1/	No. ♂ KS accommodated 2/	Potential spawning run 3/	Potential comm. catch 4/	Potential sport catch 5/	Total potential production	Present average spawning run 6/	Computed present comm. catch	Computed present sport catch	Computed present total run	Increase in spawning run	Increase in commercial catch	Increase in sport catch	Total increased production
40,000	Middle Fork Cottonwood	100	0	100	10.3	275,000	3,235	4,853	8,088											
	Upper Cottonwood	100	20	120	11.5	378,250	4,450	6,676	11,126											
	Lower Cottonwood	100	50	150	7.8	152,100	1,789	2,684	4,473											
							9,474	14,213	23,687	55,901	15,160	94,748	1,054	2,487	675	4,216	22,633	53,414	14,485	90,532
60,000	Middle Fork Cottonwood	150	0	150	10.3	330,000	3,882	5,823	9,705											
	Upper Cottonwood	150	20	170	11.5	470,500	5,535	8,303	13,838											
	Lower Cottonwood	150	50	200	7.8	179,400	2,111	3,167	5,278											
							11,528	17,293	28,821	68,018	18,445	115,284	1,054	2,487	675	4,216	27,767	65,531	17,770	111,068
80,000	Middle Fork Cottonwood	200	0	200	10.3	385,000	4,529	6,794	11,323											
	Upper Cottonwood	200	20	220	11.5	564,500	6,635	9,953	16,588											
	Lower Cottonwood	200	50	250	7.8	214,500	2,524	3,786	6,310											
							13,688	20,533	34,224	80,769	21,903	136,896	1,054	2,487	675	4,216	33,170	80,769	21,228	132,680

1/ Space factor computed at 85 square feet per spawning female.

2/ Number of male king salmon computed at 1.5 males per female.

3/ Potential spawning run computed as 25 percent of total run.

4/ Potential commercial catch computed as 59 percent of total run.

5/ Potential sport catch computed as 16 percent of total run.

6/ Present run spawns in lower 4 to 6 miles of main stem. Fish counts for years 1956-60 ranged from 350 to 3,300 spawners.

TABLE 15

ESTIMATED WILDLIFE LOSSES AND MITIGATION EXPENDITURES FOR
UPPER SACRAMENTO RIVER DEVELOPMENT PROJECTS,
BASED ON PRELIMINARY WILDLIFE SURVEYS

Area 1/	Reservoir 2/ surface area (acres)	Significant wildlife losses				Acreage required for wildlife mitigation			Wildlife mitigation expenditures				
		Deer (days-of-use)	Quail	Waterfowl (days-of-use)	Pheasant	Deer and Quail 3/	Quail 4/	Waterfowl and Pheasants	Land 5/	Habitat 6/ improvement	Fencing 7/	Annual 8/ O.&M.	Habitat Manipulation 6/ at 10-year interval
Iron Canyon Reservoir	27,400	--	2,700	--	1,000	--	500	--	--	$16,000	$3,500	$2,000	--
Iron Canyon Afterbay	3,000	--	220	--	300	--	25	--	--	800	1,000	100	--
Butte Basin	--	--	--	10,000,000	15,000	--	--	1,200	$300,000	55,200	--	24,300	--
Hulen Reservoir	1,900	9,900	240	--	--	620	--	--	4,800 9/	21,120	4,500	2,640	$19,840
Fiddlers Reservoir	1,750	16,300	390	--	--	760	--	--	6,900 10/	17,200 12/	3,500	3,040	16,000
Rosewood Reservoir	2,700	30,800	990	--	--	900	--	--	11,200 11/	21,760	2,500	3,600	19,200
Dippingvat Reservoir	1,250	33,100	360	--	--	580	--	--	9,600 11/	14,400 13/	3,500	2,320	12,800
Bella Vista Reservoir	4,800	--	990	--	--	--	140	--	--	3,480	1,500	560	--
Millville Reservoir	1,400	--	1,040	--	--	--	140	--	--	4,480	2,000	560	--

1/ No evaluation of wildlife losses on service areas was made.
2/ Wildlife evaluations were made on these reservoir surface acreages.
3/ Acreage partially included within D.W.R. take line.
4/ Acreage included within D.W.R. take line, Snow '58, Sweeney '59; does not include water diversions.
5/ Prices taken from D.W.R. except Butte Basin which was $250/acre.
6/ Prices estimated at $32/acre, except Butte Basin which was $46/acre.
7/ Prices estimated at $1,000/mile.
8/ Prices estimated at $4/acre, except Butte Basin which was $20.25/acre.
9/ Assuming 160 acres outside D.W.R. take line.
10/ Assuming 230 acres outside D.W.R. take line.
11/ Assuming 320 acres outside D.W.R. take line.
12/ Includes installation of 3 guzzlers at $400 each.
13/ Includes installation of 4 guzzlers at $400 each.

APPENDIX C

BOARD OF CONSULTANTS' REPORT ON
IRON CANYON DAM

Following is the Board of Consultant's report on Iron Canyon Dam, dated May 11, 1961:

Mr. Alfred R. Golze',
Chief Engineer
Department of Water Resources

The Board of Consultants has reviewed the current status of investigations and studies for the Iron Canyon Dam during its meeting with your staff during May 9, 10, and 11, 1961. The Board's previous report was dated September 28, 1960. The present report answers specific questions presented in a memorandum dated May 8, 1961, prepared by John W. Keysor, and contains some additional comments and suggestions by the Board. The numbered paragraphs below follow the numbering of the memorandum questions.

(1) In our opinion, concrete structures for the spillway weir and power intake, as shown on Plates Nos. 1, 2, and 3, Plan 5, dated May 5, 1961, can be founded safely on a thickness of 50 feet or more of the Iron Canyon agglomerate. Indeed, further investigations and tests during final design may demonstrate that lesser thicknesses of the agglomerate will be adequate.

(2) We believe that the design criteria used in the development of Plan 5 are acceptable and adequate for this stage of the investigation and that no further exploration and testing are required at this time. Pending the further investigations that will precede final design, we suggest that foundation loadings on the agglomerate be limited to 12 tons per square foot.

(3) Differential deformations are affected as much by unequal loadings and structural rigidity as by the modulus of elasticity of the supporting materials. For the general type of structures contemplated by Plan 5, we believe that serious differential deformations will not result or lead to design difficulties.

(4) It is our opinion that the character of soft lenses in the Iron Canyon agglomerate indicated by investigations to date probably will not have detrimental effects on the support of concrete structures. However, uncemented materials at foundation level disclosed by excavation should be removed and more intensive exploration by closely-spaced holes should be accomplished before or during construction. We doubt that costly corrective measures will be required.

(5) The Board believes definitely that a full-height concrete dam of some type should not be considered infeasible and that, at some future investigational level, a hollow-type concrete structure in the river section incorporating spillway, power intake, powerhouse and river diversion, and with earth embankments on the two sides on the river section, should be investigated fully. However, Plan 5, with modifications suggested in later paragraphs, is believed adequate for the present objectives.

(6) We believe that the Iron Canyon agglomerate can be used for rolled fill. However, we recommend that cost of removal of oversize boulders during excavation for borrow be included in the estimates. A test fill should definitely be a part of the final design investigations.

(7) Underseepage through the Sacramento tuff and sand at Totten Dike can be controlled by relief walls, the location and spacing of which can be determined by piezometer observations under and downstream from the completed structure. Seepage through the Sacramento tuff and sand on the left abutment of the main dam presents more serious problems, and it is recommended that the abutment be moved upstream from the Plan 5 location to terminate against a wider part of the ridge. This move would increase significantly the seepage path for any water tending to escape the reservoir toward Grobey Gulch.

(8) We do not believe that artesian pressures within the Seven-Mile tuff and sand will create unsafe conditions or detrimental uplift provided adequate thicknesses of agglomerate and weight of structures or overburden are present to resist the uplift. Relief of artesian pressures by wells probably will be required. Piezometers should be installed early in the construction operations and the need for relief wells should be determined from piezometric observations. Relief of artesian pressures will not cause detrimental settlements because pressures in the Seven-Mile tuff and sand in any case will be greater than those now existing.

(9) We believe that Plan 5 is appropriate to the geology of the site except that the left abutment should be moved upstream as recommended in (7).

(10) We see no reason to depart from our previous opinion that the spillway channel should be fully lined and should terminate in a structure firmly seated in agglomerate.

(11) For the preconstruction stage of investigation for Iron Canyon Dam, we recommend:

> (a) Additional drilling along the selected axis and at specific structures, including alternative locations if required. This drilling has the purposes of delineating more specifically the depths and characteristics of the formations and of permitting water pressure testing and field permeability determinations. Samples for physical testing of foundation formations should be recovered from selected drill locations.

(b) Construction of test fills to determine feasible construction and control procedures and to secure samples for physical testing of impervious and pervious embankment fill materials.

(c) Model studies of hydraulic structures.

(d) If it develops that large shafts or tunnels will be included in the design, test adits should be excavated in the materials involved.

We recognize the limited objectives of the present investigation and believe that Plan 5 comes close to meeting these objectives. We suggest, however, that a more efficient and economical design may result from eliminating one of the deep cuts on the sides of the river and combining the intake and spillway structures. This combination should and can make provisions for future expansion of the intake and power facilities. The combined structure will represent a simplification which may, in final design, lead to selection of a river-section concrete structure with side earth embankments. If the concrete structure is so located and designed that heights and loads transverse to the river are approximately uniform, the thickness of agglomerate beneath the structure required to minimize differential deformations will be decreased. This implies moving the structure upstream with the accompanying advantages of higher agglomerate in the abutments, but downstream pressure relief and erosion protection problems may be aggravated.

It is our understanding that the present study has the objective of coordinating existing information, determining physical feasibility and safety, and providing estimates of approximate costs. Our report is directed only toward these objectives. We believe that, with the suggested modifications, Plan 5 meets these objectives and that cost estimates based thereon will be conservative. Foreseeable changes in final design will most likely lead to economies.

We commend your staff on the quality of the geological and engineering investigations that have made possible the conclusions presented herein.

Roger Rhoades
Consulting Geologist

B. E. Torpen
Consulting Engineer

Philip C. Rutledge
Consulting Engineer

APPENDIX D

PREDICTED WATER TEMPERATURES IN
IRON CANYON RESERVOIR AND AFTERBAY

PREDICTED WATER TEMPERATURES IN IRON CANYON RESERVOIR AND AFTERBAY

Jerome M. Raphael
Consulting Civil Engineer

Summary

A study has been made of the temperature of the water leaving Iron Canyon Reservoir and Iron Canyon Afterbay, using the general geometry of the project, the hydrology of an average water year, and the meteorological records of a typical year. This study shows that during the month of July, water entering the Iron Canyon Reservoir will be heated a maximum of 20° F. in the reservoir, and an additional 4° F. in the afterbay. The maximum temperatures are predicted to be 69° F. for the reservoir and 72.5° F. for the afterbay. Water will be heated slightly after it leaves the afterbay and proceeds down the Sacramento River, but data are not available at present to make a prediction of the amount of this heating.

Iron Canyon Reservoir

The water that flows into the Iron Canyon Reservoir has two principal sources: Shasta Dam, and the Trinity Project of the U. S. Bureau of Reclamation's Central Valley Project. Water from these two sources joins in the Keswick Reservoir, and flows down the Sacramento River to the headwaters of the Iron Canyon Reservoir. From the reservoir, the water flows either over a spillway during a high water year directly to the Sacramento River, or through penstocks to a powerplant and afterbay before rejoining the river. Plate 3 shows the general geography of the area of this study. It can be seen that there are a number of minor inflows to the system, but these are considered to be insignificant as far as affecting the final temperature of the water.

Iron Canyon Dam and Reservoir

The general layout of Iron Canyon Dam and the details of the powerplant are shown on Plate 5. By examining Plate 5, it can be seen that water leaving the reservoir, whether over the spillway or through the penstocks, is controlled by the wide approach channel with a floor at elevation 310. Since the maximum reservoir elevation is at elevation 401, it can be seen that this is quite a shallow reservoir, generally. As a matter of fact, dividing the volume at maximum capacity by the corresponding surface area given on the area/capacity curve gives an average depth of only 37 feet. The essential shallowness of this reservoir is at first glance rather difficult to grasp, since the hydraulic height of the dam is over 150 feet, but the area/capacity curve shows that less than 4 percent of the reservoir volume lies below elevation 310, the elevation of the approach channel.

Iron Canyon Afterbay

The general disposition of the Iron Canyon Afterbay that re-regulates the flow from the Iron Canyon Powerplant is shown on Plate 3. The area/capacity curve shown on Figure 1 gives the essential geometric characteristics of this body of water. It can be seen that this is also a very shallow body, averaging a depth of 13 feet at its maximum capacity of 54,000 acre-feet to an average depth of 10 feet at minimum permissible storage of 27,000 acre-feet. The hydrograph of the afterbay is given on Figure 2.

Hydrology

The general hydrology of the Iron Canyon Reservoir was taken from the Department of Water Resources Operation Study No. 12-2, using 1935-36 as an average water year. This study, the essential parts of which are given on Table 1, below, gives only monthly totals or averages. Since daily rates were desired for the temperature computations, these had to be computed as average daily flows from the total monthly flow, and naturally resulted in a smoother variation of flow than the peaked

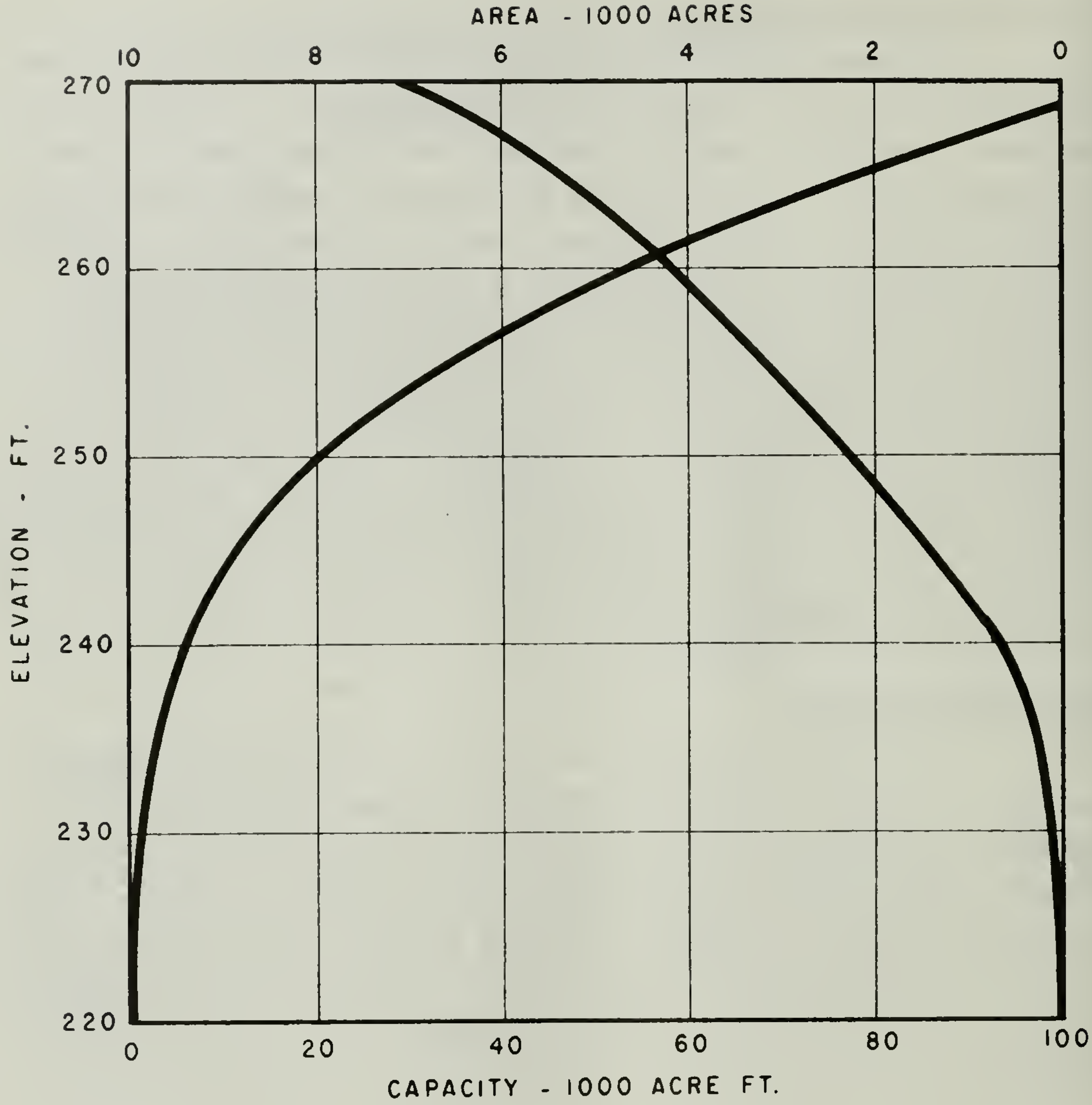


FIG. I

IRON CANYON AFTERBAY
AREA AND CAPACITY CURVES

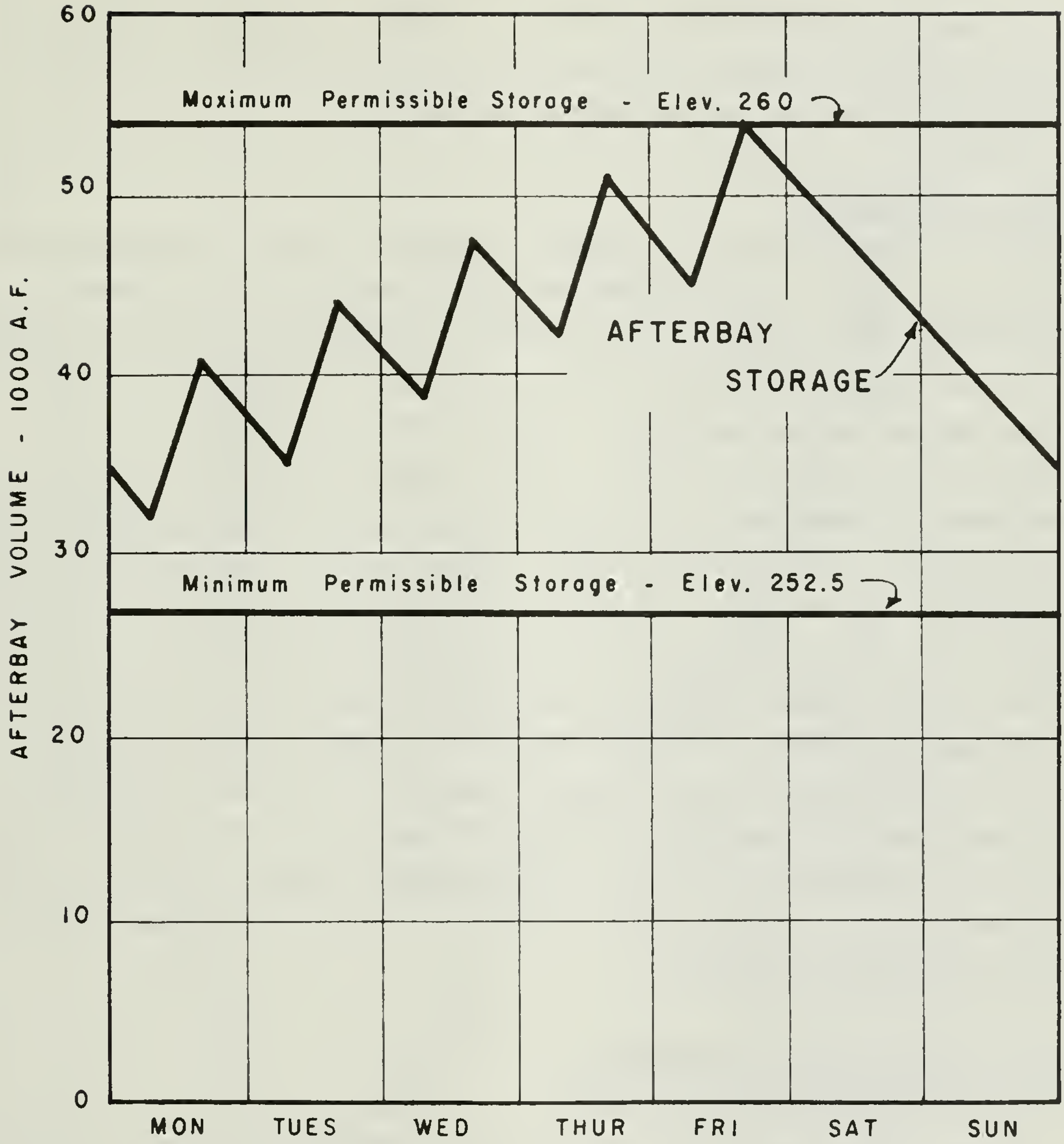


FIG. 2

IRON CANYON AFTERBAY
STORAGE HYDROGRAPH

flow that is characteristic of nature. However, considering the degree of regulation afforded by Shasta Dam, the Trinity system, and Keswick Dam, this is not too unrealistic an assumption.

Inflow Temperature

Since the Trinity Project has yet to reach its full operating condition, there are no temperature records available for a normal operating year. However, as a start, it was suggested that it be assumed that the normal temperature cycle at Keswick due primarily to outflow from Shasta Dam and Powerplant remains essentially unchanged by the addition of the Trinity outflow. Water temperatures in the penstocks at Keswick Powerplant are recorded as part of the normal operating records of the plant, and averaged daily. Fourteen years of records were available from 1950 to 1963. All of these data, with the exception of one year where the temperature was recorded the same each day for the entire year, were averaged to produce the thermal record given in Figure 3. Although there must be a slight amount of thermal energy added to the water between Keswick Dam and the headwaters of Iron Canyon Reservoir, it was considered that with the large volume of flow and the short distance, the temperature should not change appreciably. Thus, the temperatures given on Figure 3 were considered to be the inflow temperatures for Iron Canyon Reservoir.

Basic Heat Transfer Relationships

The mathematical prediction of temperature in rivers and reservoirs is based on the heat budget, which means accounting for all heat originally contained in a body of water, and all heat that flows into and out of the body during a particular interval. Two general methods of computation are available. The first method can be used with bodies of water such as shallow lakes or flowing streams in which the water is so stirred by wind or current that temperatures are uniform. The second method is suitable for deeper lakes having a well-defined temperature gradient, and is generally applied to the prediction of temperature in large storage reservoirs.

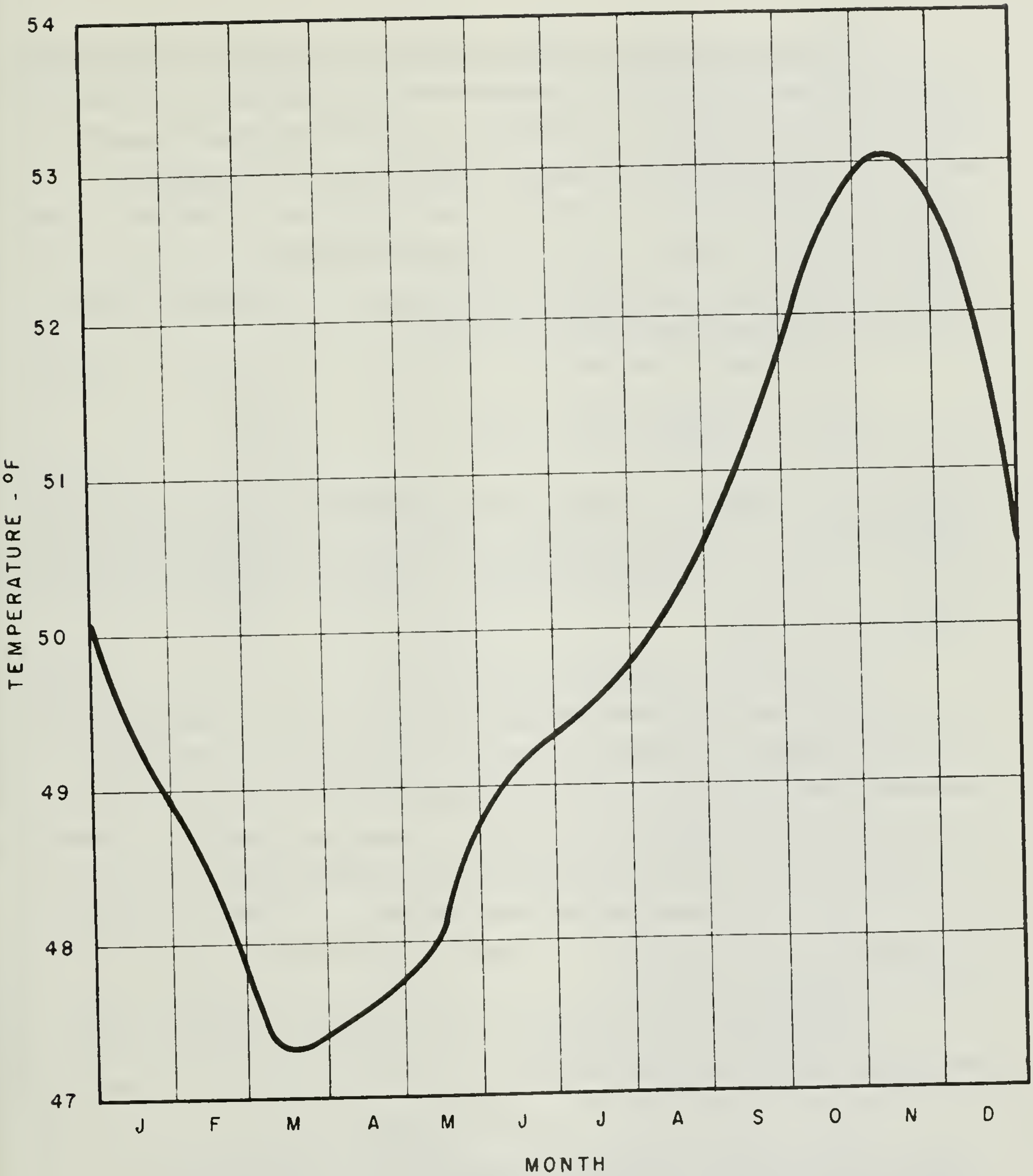


FIG. 3

KESWICK POWERPLANT
TEMPERATURE OF WATER IN PENSTOCKS

In the first method, assuming that the lake is at uniform temperature at any instant of time Θ_o, the lake may be visualized as a vessel containing a mass of water m_w at temperature t_w into which flows a mass of water m_i at temperature t_i and out of which flows m_o at temperature t_w. A vast quantity of heat is transferred across the surface of the lake. The total surface heat transfer per unit of time acting on the entire surface area A of the lake is the product Q_tA where Q_t is the quantity of heat transferred at the surface in Btu ft^{-2} hr^{-1}.

The change in temperature of the water can be computed from

$$\Delta t_w = \frac{1}{V_l} \quad \frac{Q_tA\Theta}{62.5} + V_i \; (t_i - t_w) \qquad (1)$$

where V_l is the volume of the lake in acre-feet; V_i is the volume of inflow in acre-feet; A is the surface area in acres; and all temperatures are in degrees fahrenheit. The energy budget for the body of water can be expressed in the following form

$$Q_t = Q_s - Q_r - Q_b - Q_h - Q_e + Q_v \qquad (2)$$

in which Q_t is the increase in energy stored in the body of water; Q_s is the solar radiation incident to the water surface; Q_r is the reflected short-wave radiation; Q_b is the back radiation, or the net energy lost by the body of water through the exchange of long-wave radiation between the body of water and the atmosphere; Q_h is the energy conducted from the body of water to the atmosphere as sensible heat; Q_e is the energy used for evaporation; and Q_v is the net energy advected into the body of water by rain, all in Btu ft^{-2} hr^{-1}.

Solar radiation is primarily a function of the solar altitude. The solar altitude can be found from

$$\sin \alpha = \sin \phi \sin \delta + \cos \phi \cos \delta \cos h \qquad (3)$$

in which α is the solar altitude in degrees; ϕ is the latitude of the site in degrees; δ is the declination of the sun in degrees; and h is the hour angle of the sun, positive before noon, negative after noon. A portion of this incoming solar radiation is reflected from the water surface in varying amounts depending on the solar altitude and amount of cloud cover. The combined function ($Q_s - Q_r$) is presented as a graph giving the insolation as a function of solar altitude.

The effect of cloud cover in reducing insolation can be determined from

$$Q_i = (1 - 0.0071\ C^2)\ (Q_s - Q_r) \qquad (4)$$

in which Q_i is the net short-wave insolation including effect of cloud cover, in Btu ft^{-2} hr^{-1}; and C is the cloud cover, expressed as tenths of sky covered.

The interchange of the long-wave radiation from the water to the sky, and from the atmosphere to the water is termed effective back radiation. This depends on the temperature of the atmosphere and of the water surface, the emissivity and the reflectivity of the water surface, and to some extent on vapor pressure and cloud cover. This can be computed from

$$Q_b = 0.970\ \sigma\ (T_w^{\ 4} - \beta\ T_a^{\ 4}) \qquad (5)$$

in which Q_b is the effective back radiation, Btu ft^{-2} hr^{-1}; σ is the Stefan-Boltzmann radiation constant; T_w is the absolute temperature of the water surface; T_a is the absolute temperature of the atmosphere; and β is a radiation factor which is a function of the cloud cover and the vapor pressure.

The loss of heat due to the water evaporated at the surface can be found from

$$Q_e = 16\ U\ (e_w - e_a) \qquad (6)$$

where Q_e is expressed in Btu ft^{-2} hr^{-1}; U is in knots as usually recorded in weather records; e_w is the vapor pressure of saturated air at the temperature of the water surface, and e_a is the observed vapor pressure of the air, both in inches of mercury.

Sensible heat is conducted to or from the body of water by the air whenever a temperature difference exists between air and water. This can be found from

$$Q_h = 0.00543\ U\ P\ (t_a - t_w) \qquad (7)$$

in which Q_h is the heat conducted from air to water, Btu ft^{-2} hr^{-1}; U is the wind velocity, in knots; P is the atmospheric pressure, in inches of mercury; and t_a and t_w are the air and water temperature respectively, in degrees Fahrenheit.

In extending these basic relationships to deep reservoirs with a well defined temperature gradient, one additional heat transfer mechanism might be considered, the convection and conduction of heat from layer to layer. In the typical case, the deep reservoir might be visualized as being made up of a number of distinct horizontal bodies of water at different uniform temperatures lying on top of one another. As long as no water movement takes place, these will lie in a stable array, as determined by their relative densities. When water is withdrawn from the reservoir, say from a conduit located some distance below the surface, water primarily from the layer at the level of the conduit will flow out through it, together with minor amounts from layers above and below the conduit, as determined by the laws of hydrodynamics. Water leaving any layer must be replaced by water from a higher and warmer layer, and this movement accounts for the convective transfer of heat, the characteristic equation for which is the second term of Equation (1). For all practical purposes, conduction, or the slow drift of heat from a warmer to a cooler layer, may be neglected, as the amount involved is a minute fraction of that transferred by convection. It can be assumed that water entering the reservoir will dive down beneath any warmer layers of water and mix with the layer of water at or just below the temperature of the inflowing water.

The final problem for a deep reservoir is to account for the quantity of heat transferred at the surface. The basic heat relationships have already been described for the shallow lake at uniform temperature. At the surface, it can be assumed that although a distinct and sharp temperature gradient may exist during the hours of sunshine, during the night when heat flows out of the surface layer, local convection currents will tend to transfer cooled surface waters downward and warmer subsurface waters upward, resulting in a surface layer of finite thickness at uniform temperature.

General Scheme of Temperature Analysis

The essential hydraulic characteristics of the outflow from the Iron Canyon Reservoir for 1936 are shown schematically on Figure 4. This shows that the water surface ranged from elevation 363 to 389, giving a depth range in the approach channel of 50 to 76 feet. It is conceded that it is entirely possible that the depth of the reservoir is sufficient to set up temperature gradients. However, the size and position of the floor of the approach channel result in flow into the penstocks from all elements of the water in the approach channel in rather equal proportions, and it is considered that the temperature of the water leaving the reservoir through the penstocks will be the average temperature of the water in the approach channel. Once this assumption is made, it is more efficient to consider the lake as at uniform temperature and determine the effluent temperature directly, than to break up the lake into horizontal layers. and recombine them to find the effluent temperature. The essentially shallow nature of the reservoir together with the short retention time of the water strengthens this assumption of water essentially at a uniform temperature that varies with time.

A daily interval was chosen for analyzing the temperature of the reservoir, and the analysis was carried out from April 1 when normally most stratified reservoirs are at uniform temperature, to the end of the calendar year. However, for detailed study of the temperature in the afterbay, with large weekly variations in volume and short inflow period, three-hour time intervals were used in the analysis.

Climatological Data

The validity of the temperature analysis is increased by the use of detailed climatological records typical of the area under study. Fortunately such a detailed record was available in the Local Climatological

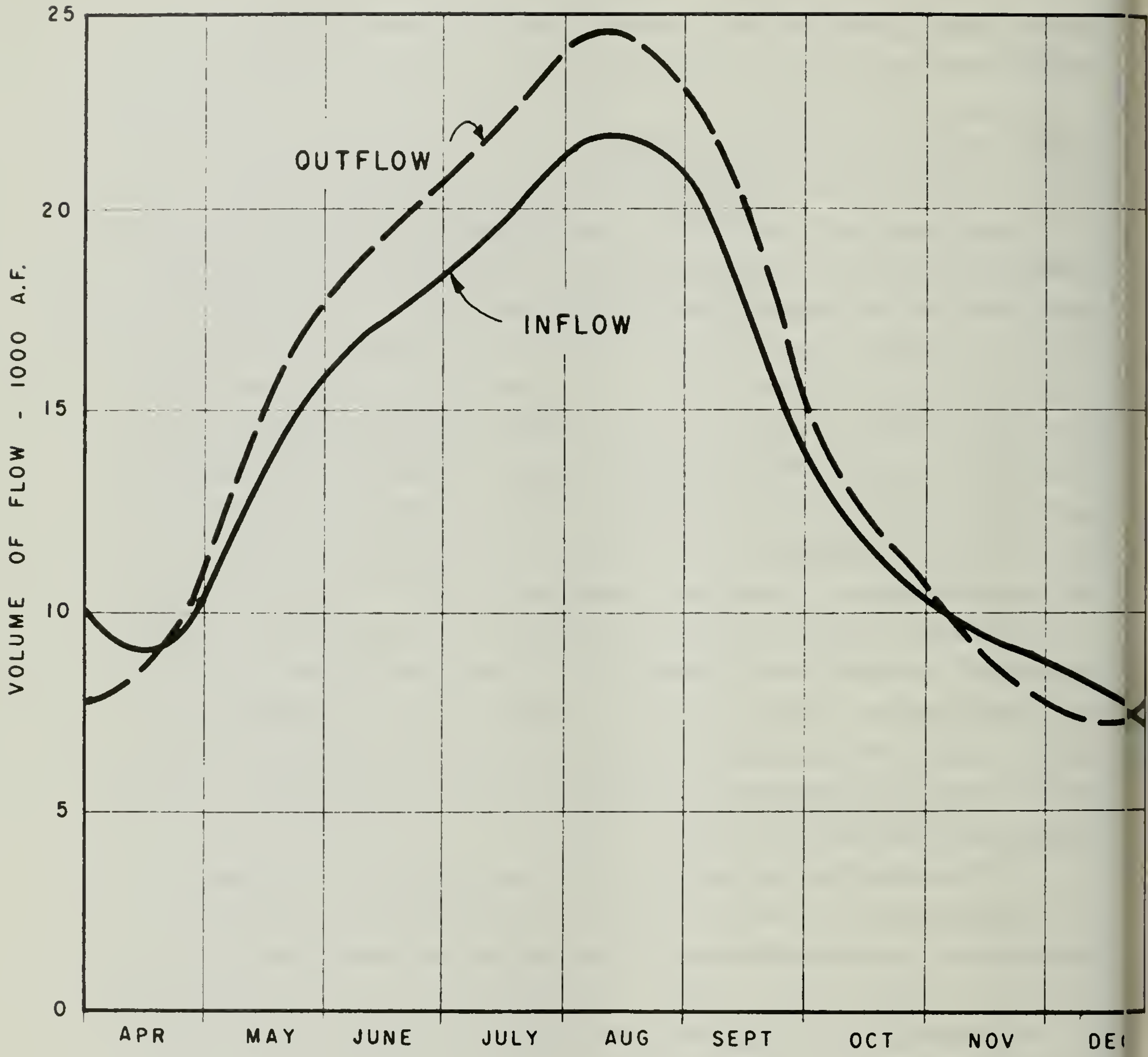


FIG. 4

IRON CANYON RESERVOIR
INFLOW AND OUTFLOW HYDROGRAPHS

Data Supplement of the U. S. Weather Bureau for Bidwell Field at Red Bluff, California, in the middle of the area under study. The year 1961 was chosen as representative and used in the analysis. Radiation data were taken from Table 1 of "Water Temperatures in Shallow Reservoirs with Particular Reference to Oroville Dam", by J. M. Raphael, October, 1960.

Reservoir Temperature

The temperatures predicted for the Iron Canyon Reservoir are shown on Figure 5, together with the air temperature and the temperature of the inflow to the reservoir. The average daily air temperature shows the usual jagged, irregular characteristics riding on top of the seasonal variation. The inflow temperatures are very smooth, reflecting the large bodies of water in the Shasta and Trinity systems, with withdrawal at great depth in these reservoirs. The water temperature in the Iron Canyon Reservoir shows some variation reflecting short-time variations in air temperature, but the heating effect of up to 20° F. over the inflow temperatures is the most important characteristic of the computed temperature. The maximum water temperature of 69° F. is attained in late June, when high air temperatures are coupled with less than peak inflow volume, and fairly high reservoir volume.

In general, it must be concluded that the Iron Canyon Reservoir and Powerplant form an ideal water heater. Relatively cold water entering this shallow reservoir in the summer is heated at the surface by interchange of radiation and heat from the atmosphere. This same warm surface is at once withdrawn by the penstocks at their high location, coupled with the skimming effect of the approach channel. It might be conjectured that if the intakes for the penstocks could be lowered to a position quite near the bottom of the reservoir, then the cold inflowing water might flow through the reservoir under the relatively warmer surface waters, with minimal mixing, and on out through the penstocks. Such a conjecture might well be tested with a new temperature study.

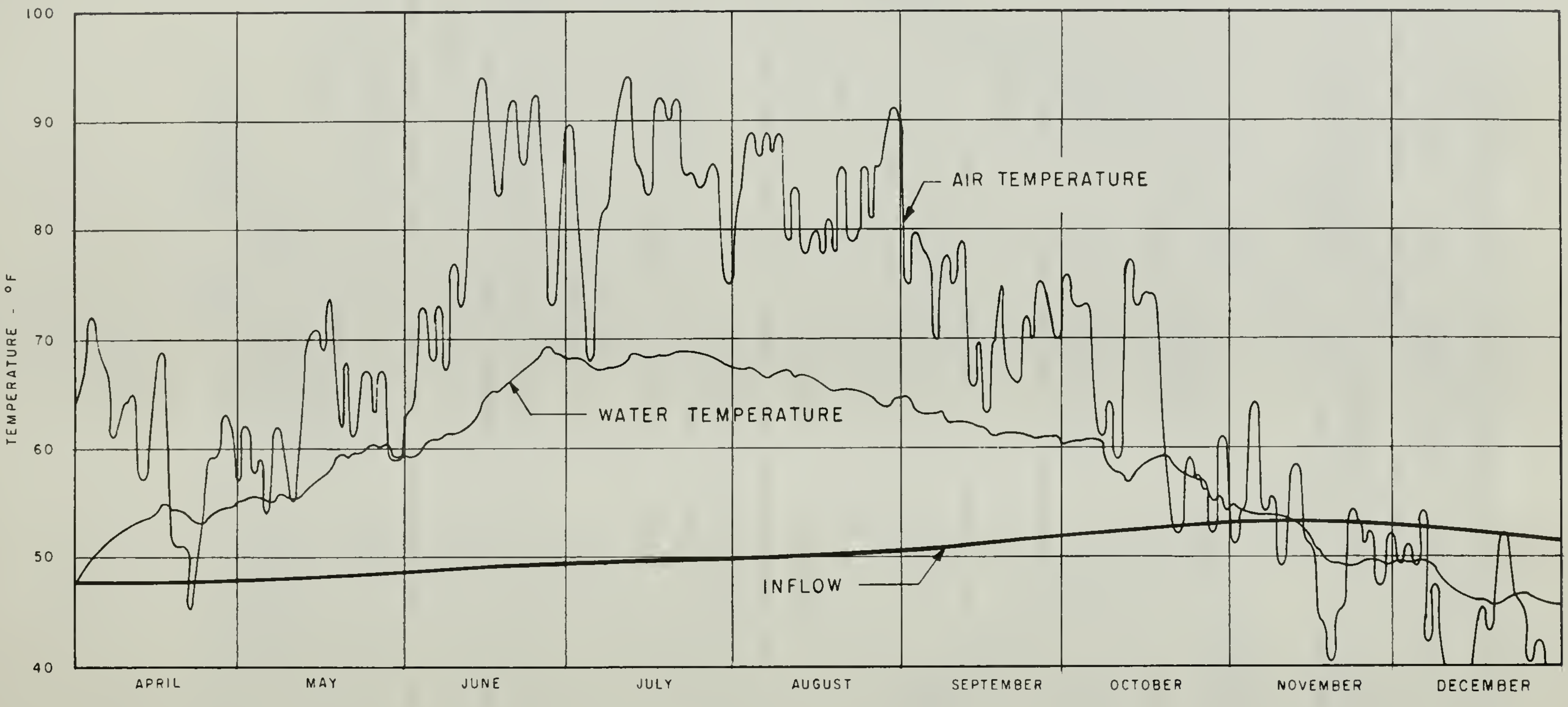


FIG. 5

IRON CANYON RESERVOIR
PREDICTED TEMPERATURES

Afterbay Temperatures

A study was made for the heating of the water in the afterbay for mid-July, the month of highest average temperatures of the water leaving the reservoir. Results of this study are shown on Figure 6, for a typical operating week. At the top of the figure the air temperature is shown as a dotted curve, reaching maximum temperatures of 110° F. At the bottom, the sawtooth diagram shows how the volume of the reservoir increases each day when the powerplant is operating, only to decrease again when the plant ceases generating. There is a general upward trend until the weekend, when the volume decreases steadily to the minimum of Monday morning. The five short dashes near the center of the figure represent the duration of inflow by their length, and the temperature of the inflowing water by their position on the temperature scale. The slightly wavy line shows the predicted temperature of the water leaving the afterbay. As can be seen, the afterbay temperature is affected by two opposing influences. The cold inflowing water tends to cool it, and almost simultaneously, the warming air temperature tends to warm it. It can be seen that the water is warmed about an additional 4° F. in the afterbay, after it leaves the reservoir, to a maximum of 72° F. Although similar studies were not conducted for the other summer months, it is estimated that the temperature of water in the afterbay will increase an average of 3° F. in June and August, 2° F. in May and September, and 1° F. in October.

It is estimated that the chief cause of the high temperature rise in the Iron Canyon Reservoir is the relative shallowness of the reservoir coupled with withdrawal of the water near the surface. If the intakes for the penstocks could be lowered, it is quite likely that the cold inflowing water might dive beneath the warmer surface waters, and flow out through the penstocks without mixing. This might well be the object of a new temperature study, using a stratified reservoir.

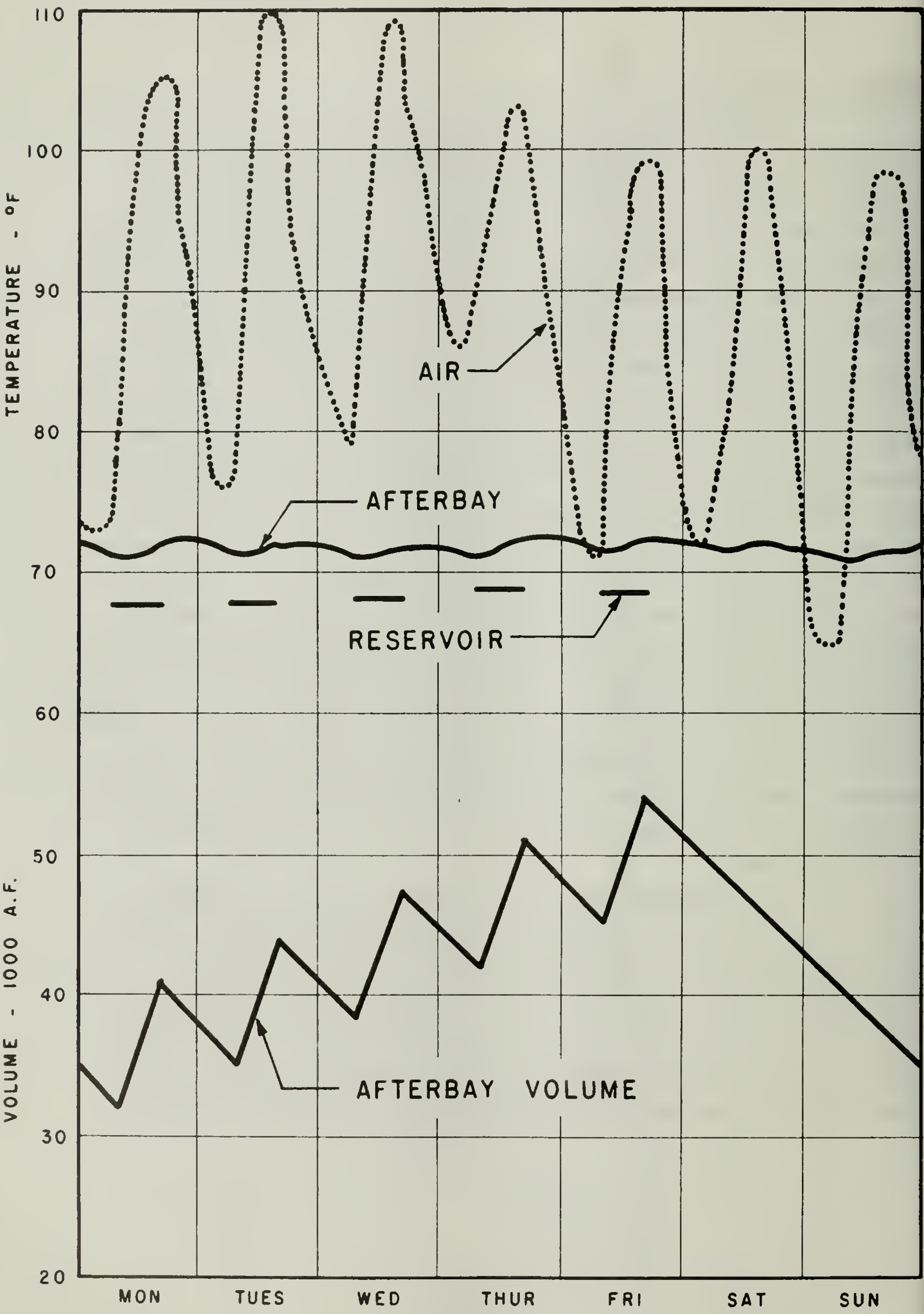


FIG. 6

IRON CANYON AFTERBAY
PREDICTED TEMPERATURES

Reliability

It is natural to question how reliable are the predictions of temperature made by the above study. In 1962, a similar study was completed of the temperature rise of the Columbia River as it flowed downstream 92 miles through three damsites. In making this study, six separate bodies of water were considered, feeding each other in turn. At the end of this stretch of water, the computed temperature of the water was compared with the temperature recorded in the penstocks of the final powerplant. It was shown that the computed temperatures were everywhere within the zone of reliability of the observed outflow temperatures, and it was concluded that the method for predicting river temperatures could be relied on for studying comparative effects of various schemes of operation for rivers and reservoirs.

Table 1 - Hydrology of Iron Canyon Reservoir

Month	Total Monthly Inflow M A-F	Total Monthly Outflow M A-F	End of Month Storage M A-F	End of Month Area MA	End of Month Elevation Feet
March	316	224	692	21.2	389.0
April	310	328	670	20.5	387.7
May	502	558	604	18.8	384.3
June	551	621	523	16.7	379.8
July	668	745	433	14.3	373.8
August	650	720	354	12.3	368.0
September	412	450	310	11.1	364.3
October	320	334	292	10.8	363.0
November	268	232	328	11.6	366.0
December	221	239	310	10.8	364.3

M A-F: 1,000 acre-feet
MA: 1,000 acres

APPENDIX E

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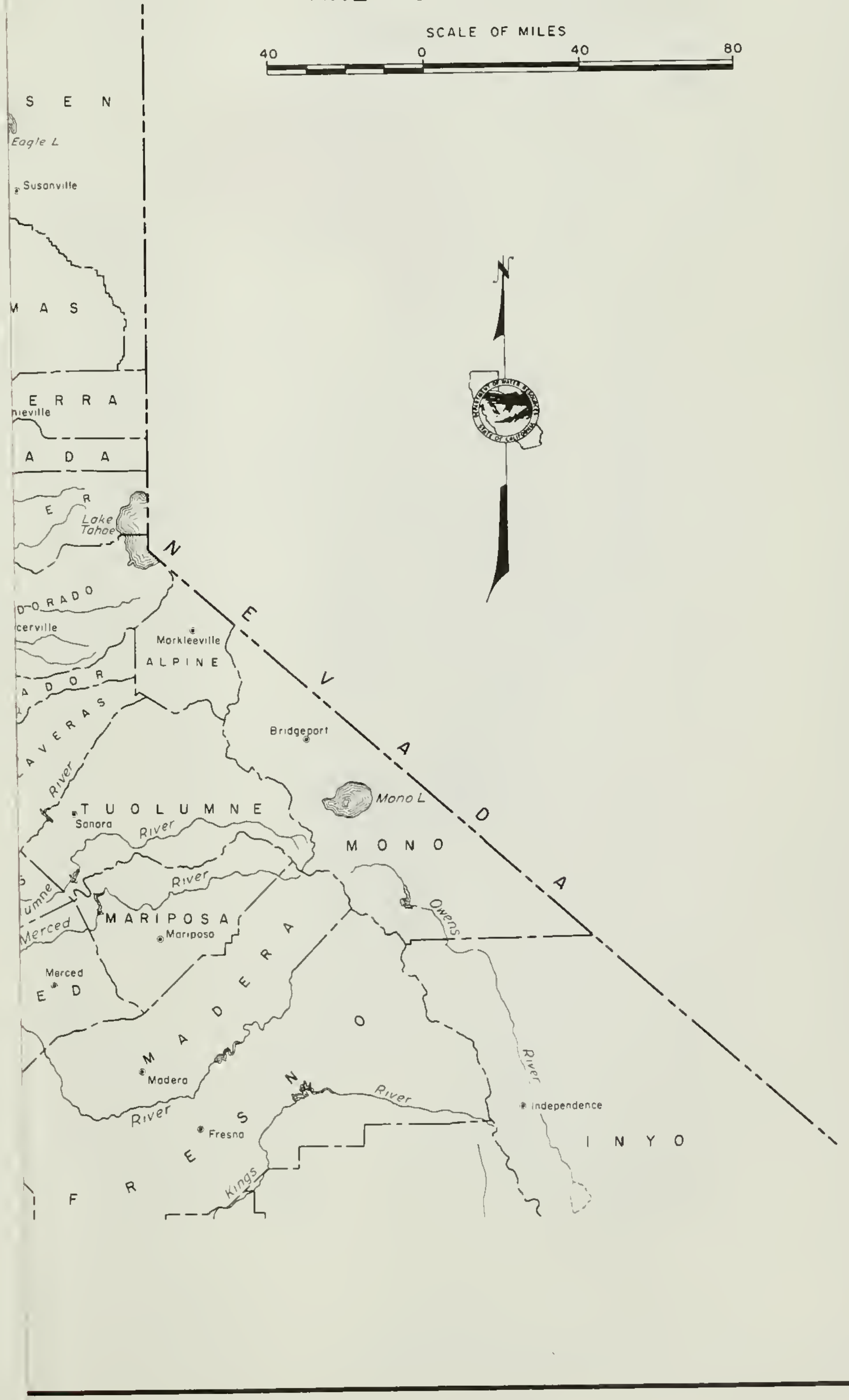
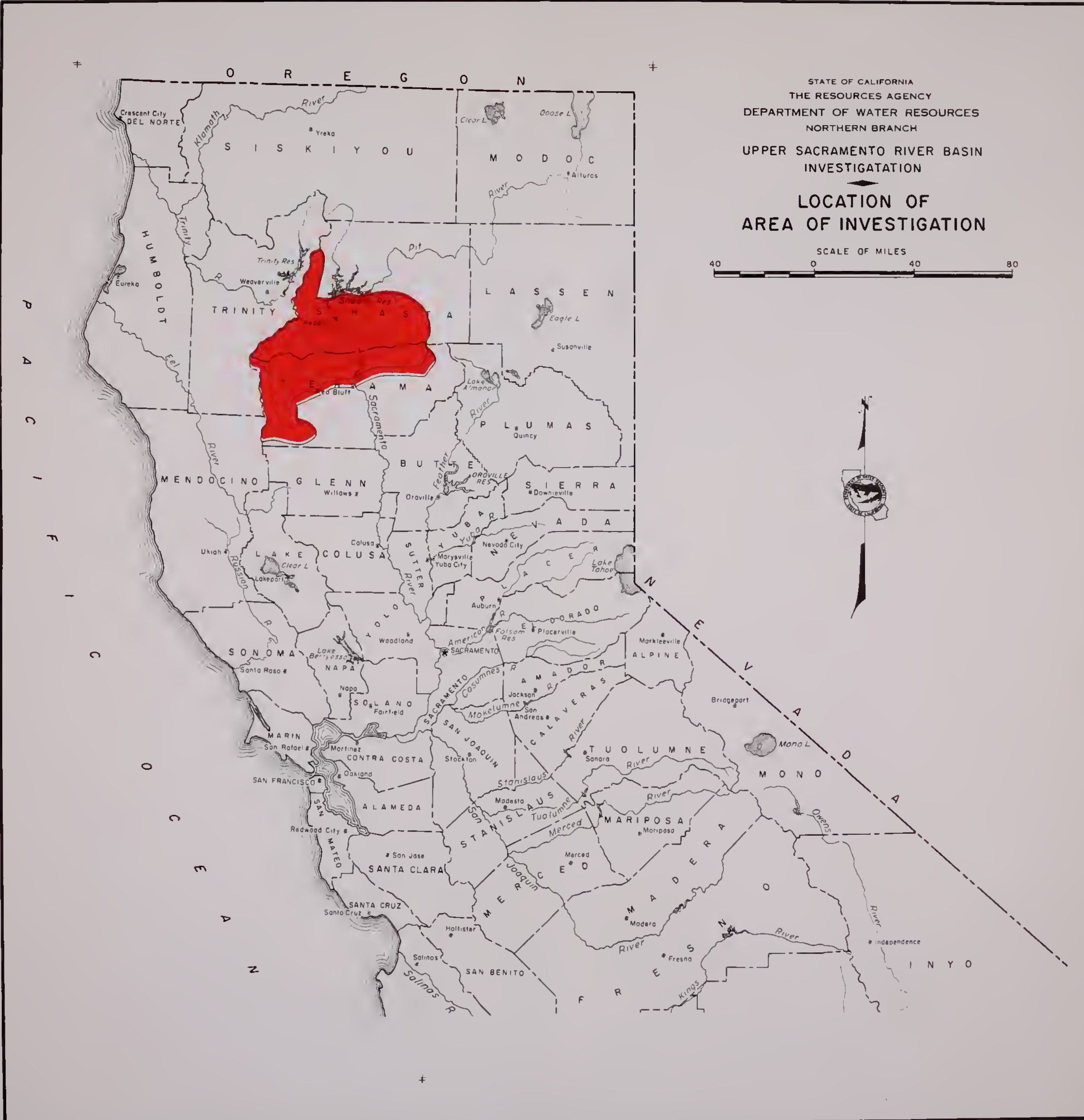
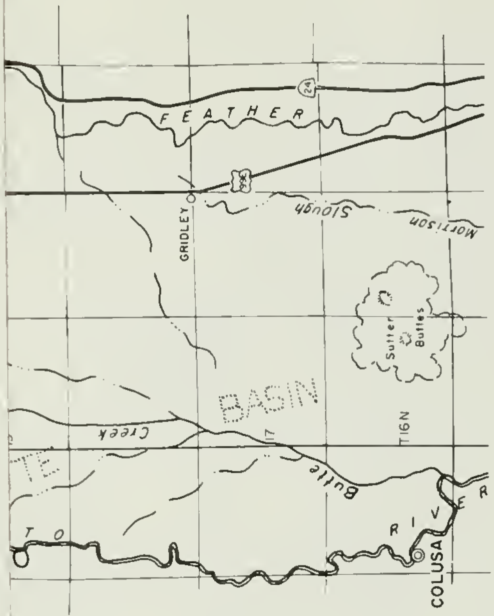
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH

UPPER SACRAMENTO RIVER BASIN
INVESTIGATATION

LOCATION OF AREA OF INVESTIGATION




STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER BASIN INVESTIGATATION
LOCATION OF AREA OF INVESTIGATION
SCALE OF MILES
40 0 40 80
OREGON
NEVADA
PACIFIC OCEAN
DEL NORTE
Crescent City
SISKIYOU
Yreka
MODOC
Alturas
Clear L
Goose L
Klamath River
HUMBOLDT
Eureka
TRINITY
Weaverville
Trinity Res
SHASTA
Shasta Res
Pit
LASSEN
Eagle L
Susanville
TEHAMA
Red Bluff
Lake Almanor
PLUMAS
Quincy
MENDOCINO
Ukiah
GLENN
Willows
BUTTE
Oroville
Oroville Res
SIERRA
Downieville
NEVADA
Nevada City
YUBA
Marysville
Yuba City
SUTTER
COLUSA
Colusa
LAKE
Clear L
Lakeport
PLACER
Auburn
Lake Tahoe
EL DORADO
Placerville
Folsom Res
American R
SACRAMENTO
YOLO
Woodland
SONOMA
Santa Rosa
NAPA
Napa
Lake Berryessa
SOLANO
Fairfield
MARIN
San Rafael
Martinez
CONTRA COSTA
SAN FRANCISCO
Oakland
ALAMEDA
SAN MATEO
Redwood City
SANTA CLARA
San Jose
SANTA CRUZ
Santa Cruz
Hollister
SAN BENITO
Salinas
Salinas R
ALPINE
Markleeville
AMADOR
Jackson
Cosumnes R
Mokelumne R
CALAVERAS
San Andreas
SAN JOAQUIN
Stockton
TUOLUMNE
Sonora
Stanislaus R
STANISLAUS
Modesto
Tuolumne R
MARIPOSA
Mariposa
Merced R
MERCED
Merced
MADERA
Madera
MONO
Mono L
Bridgeport
FRESNO
Fresno
Kings R
INYO
Independence
Owens River
Eel
Russian
Feather
Sacramento



LEGEND

LINES OF EQUAL MEAN ANNUAL PRECIPITATION IN INCHES (50 Year mean, 1905-06 Through 1954-55)

PRECIPITATION STATION

ACTIVE STREAM GAGING STATION

INACTIVE STREAM GAGING STATION

POINT OF ESTIMATED RUNOFF

BOUNDARY OF AREA OF INVESTIGATION

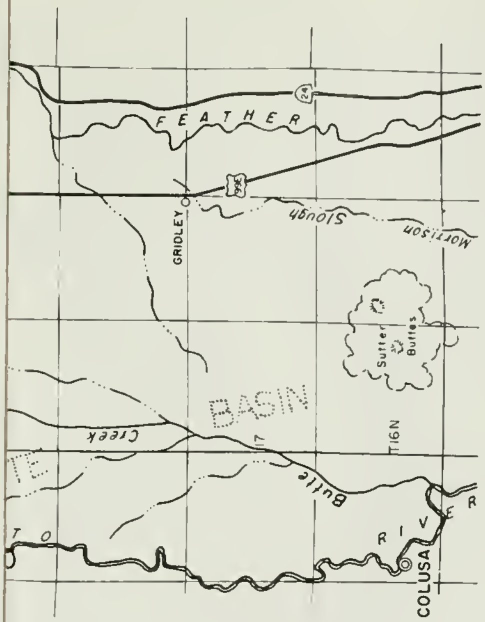
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER BASIN INVESTIGATION

LINES OF EQUAL MEAN ANNUAL PRECIPITATION

SCALE OF MILES
4 0 4 8

PLATE 2


LEGEND
LINES OF EQUAL MEAN ANNUAL PRECIPITATION IN INCHES (50 Year mean, 1905-06 Through 1954-55)
PRECIPITATION STATION
ACTIVE STREAM GAGING STATION
INACTIVE STREAM GAGING STATION
POINT OF ESTIMATED RUNOFF
BOUNDARY OF AREA OF INVESTIGATION
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER BASIN INVESTIGATION
LINES OF EQUAL MEAN ANNUAL PRECIPITATION
SCALE OF MILES
OREGON
NEVADA
REDDING
RED BLUFF
COTTONWOOD
CHICO
OROVILLE
COLUSA
SHASTA RES.
KESWICK RES.
WHISKEYTOWN RES.
TRINITY RES.
LEWISTON RES.
SACRAMENTO RIVER
FEATHER
BUTTE BASIN



D

CONSIDERED FOR DEVELOPMENT

OF INVESTIGATION

JRAL SERVICE AREAS

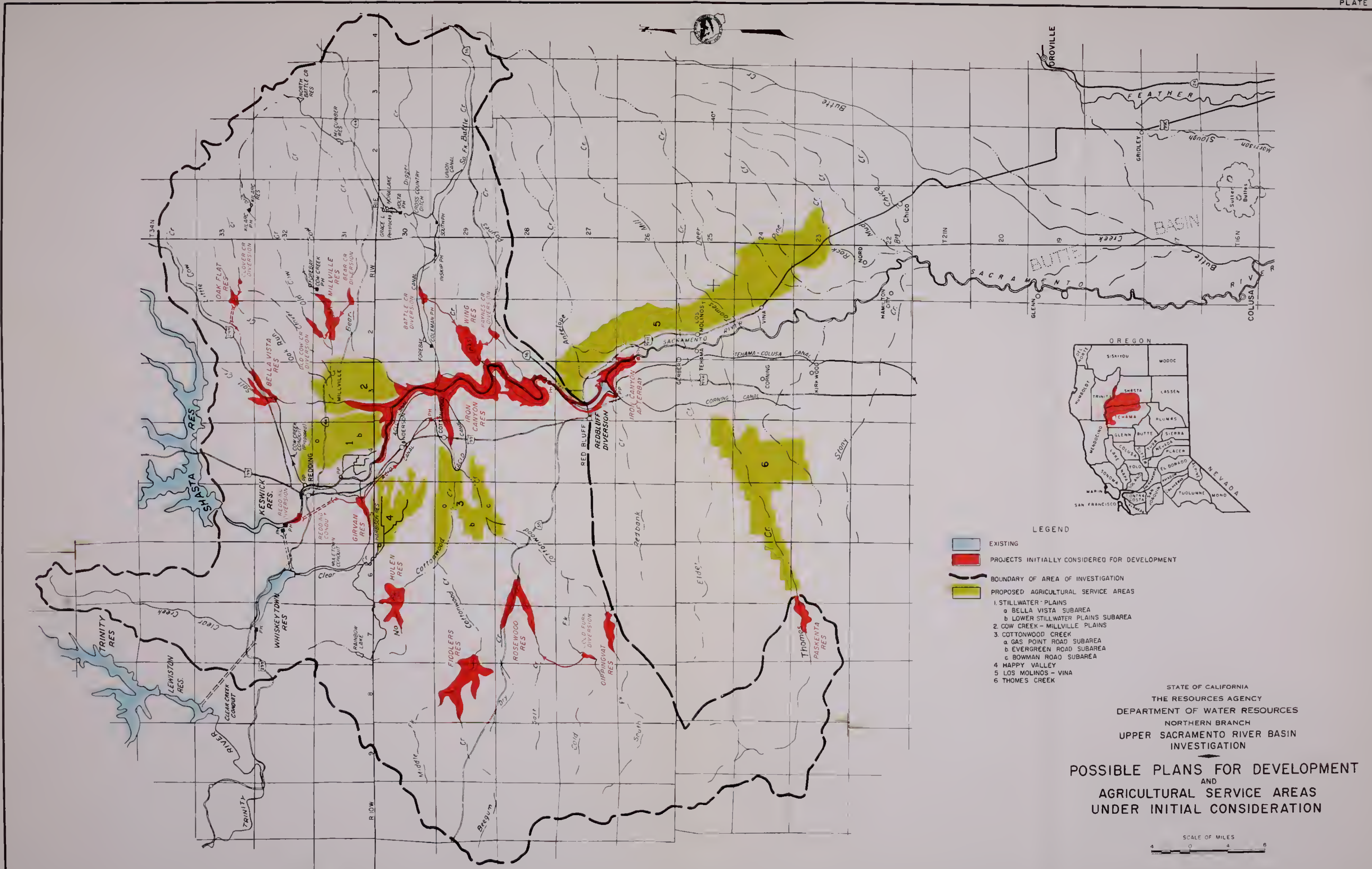
S
SUBAREA
TER PLAINS SUBAREA
VILLE PLAINS
EK
O SUBAREA
OAD SUBAREA
SUBAREA

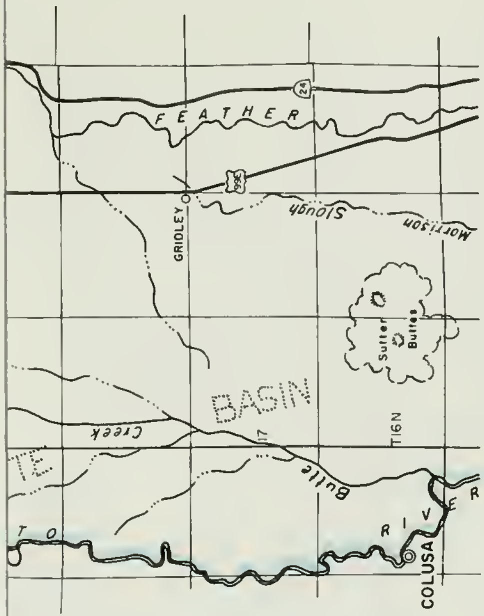
INA

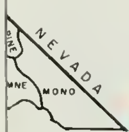
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER BASIN
INVESTIGATION

POSSIBLE PLANS FOR DEVELOPMENT AND AGRICULTURAL SERVICE AREAS UNDER INITIAL CONSIDERATION

SCALE OF MILES
4 0 4 8


LEGEND
EXISTING
PROJECTS INITIALLY CONSIDERED FOR DEVELOPMENT
BOUNDARY OF AREA OF INVESTIGATION
PROPOSED AGRICULTURAL SERVICE AREAS
1. STILLWATER - PLAINS
a BELLA VISTA SUBAREA
b LOWER STILLWATER PLAINS SUBAREA
2. COW CREEK - MILLVILLE PLAINS
3. COTTONWOOD CREEK
a GAS POINT ROAD SUBAREA
b EVERGREEN ROAD SUBAREA
c BOWMAN ROAD SUBAREA
4 HAPPY VALLEY
5 LOS MOLINOS - VINA
6 THOMES CREEK
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER BASIN INVESTIGATION
POSSIBLE PLANS FOR DEVELOPMENT AND AGRICULTURAL SERVICE AREAS UNDER INITIAL CONSIDERATION
SCALE OF MILES
4 0 4 8
SHASTA RES
KESWICK RES.
WHISKEYTOWN RES
TRINITY RES
LEWISTON RES.
REDDING
RED BLUFF
REDBLUFF DIVERSION
IRON CANYON RES
FIDDLERS RES
ROSEWOOD RES
HULEN RES
PASKENTA RES
OROVILLE
CHICO
CORNING
COLUSA
GRIDLEY
SACRAMENTO RIVER
FEATHER
BUTTE BASIN
OREGON
NEVADA





LEGEND

EXISTING OR AUTHORIZED FACILITIES

PROJECTS PROPOSEO FOR INITIAL DEVELOPMENT

STREAM CHANNELS PROPOSED FOR FISHERY ENHANCEMENT

PROPOSEO AGRICULTURAL SERVICE AREAS

AREAS TO BE SERVEO FROM SURFACE WATER DEVELOPMENT
1. COTTONWOOD CREEK-GAS POINT ROAD SUB AREA
2 THOMES CREEK

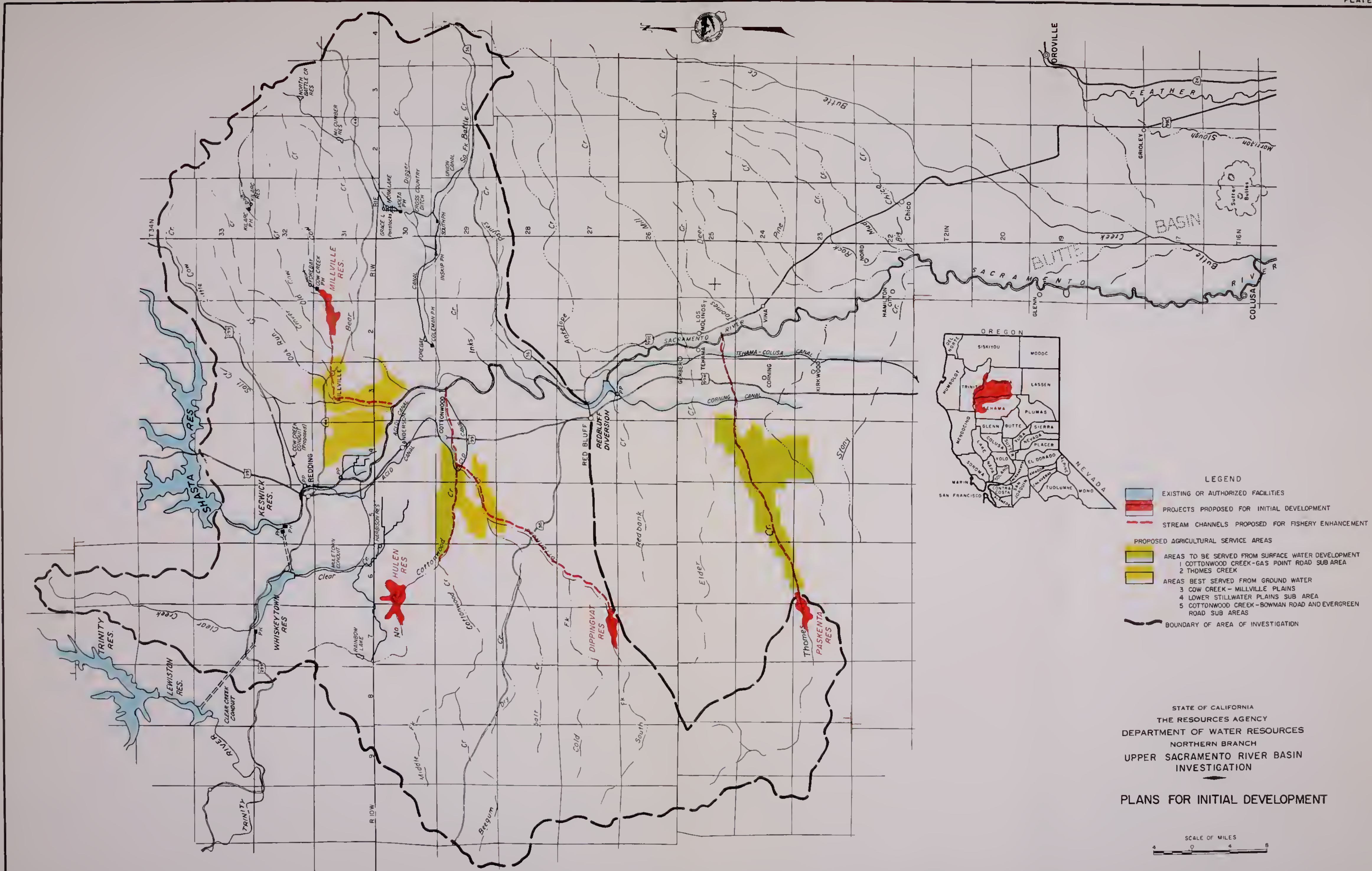
AREAS BEST SERVEO FROM GROUND WATER
3 COW CREEK - MILLVILLE PLAINS
4 LOWER STILLWATER PLAINS SUB AREA
5. COTTONWOOD CREEK-BOWMAN ROAD AND EVERGREEN ROAD SUB AREAS

BOUNDARY OF AREA OF INVESTIGATION

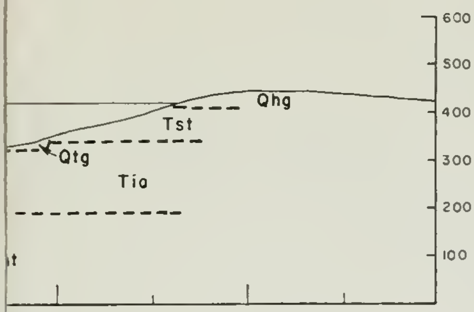
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER BASIN
INVESTIGATION

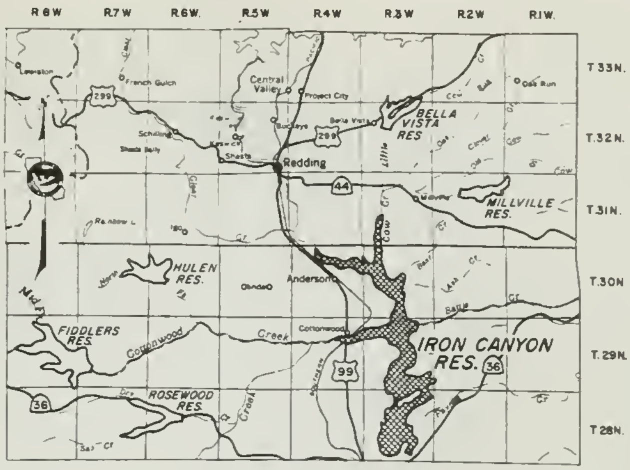
PLANS FOR INITIAL DEVELOPMENT

SCALE OF MILES
4 0 4 8



LEGEND
EXISTING OR AUTHORIZED FACILITIES
PROJECTS PROPOSED FOR INITIAL DEVELOPMENT
STREAM CHANNELS PROPOSED FOR FISHERY ENHANCEMENT
PROPOSED AGRICULTURAL SERVICE AREAS
AREAS TO BE SERVED FROM SURFACE WATER DEVELOPMENT
1 COTTONWOOD CREEK-GAS POINT ROAD SUB AREA
2 THOMES CREEK
AREAS BEST SERVED FROM GROUND WATER
3 COW CREEK - MILLVILLE PLAINS
4 LOWER STILLWATER PLAINS SUB AREA
5 COTTONWOOD CREEK-BOWMAN ROAD AND EVERGREEN ROAD SUB AREAS
BOUNDARY OF AREA OF INVESTIGATION
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER BASIN INVESTIGATION
PLANS FOR INITIAL DEVELOPMENT
SCALE OF MILES
MILLVILLE RES.
HULEN RES
DIPPINGVAT RES
PASKENTA RES
SHASTA RES.
KESWICK RES.
WHISKEYTOWN RES
TRINITY RES.
LEWISTON RES.
REDDING
RED BLUFF
REDBLUFF DIVERSION
CORNING
TEHAMA
LOS MOLINOS
GERBER
KIRKWOOD
VINA
HAMILTON CITY
CHICO
GLENN
COLUSA
OROVILLE
GRIDLEY
SACRAMENTO RIVER
FEATHER
BUTTE BASIN
TEHAMA-COLUSA CANAL
CORNING CANAL
ANDERSON CANAL
COW CREEK CONDUIT (Proposed)
CLEAR CREEK CONDUIT
OREGON
NEVADA

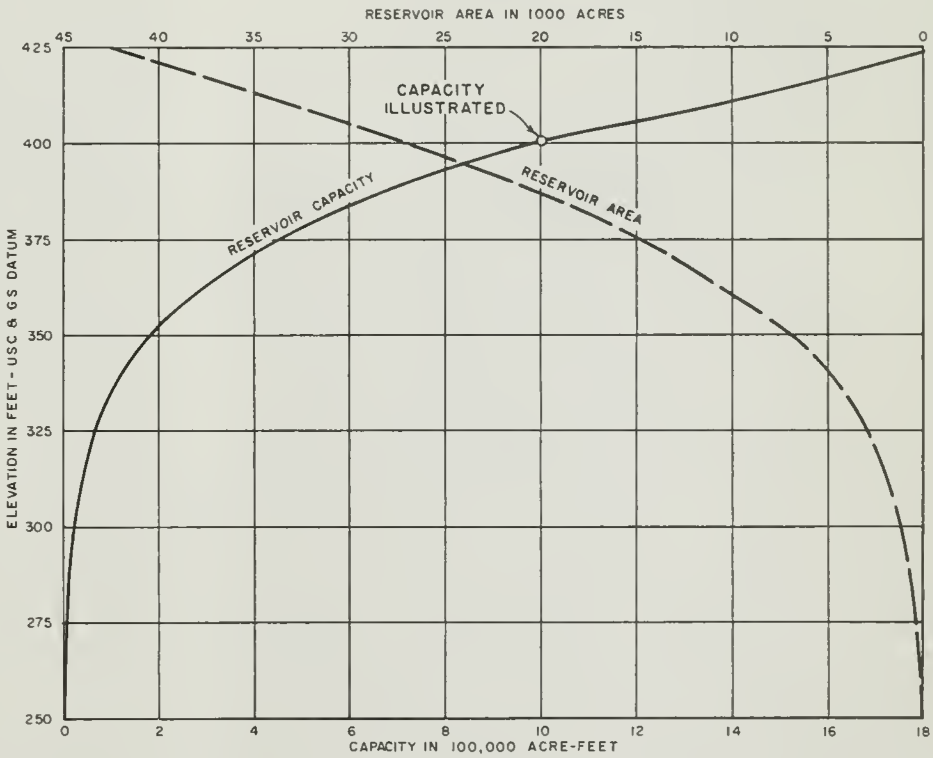




LOCATION MAP

SCALE OF MILES

0 8 16



AREA-CAPACITY-CURVES

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

UPPER SACRAMENTO RIVER BASIN INVESTIGATION

IRON CANYON DAM

PRELIMINARY DESIGN

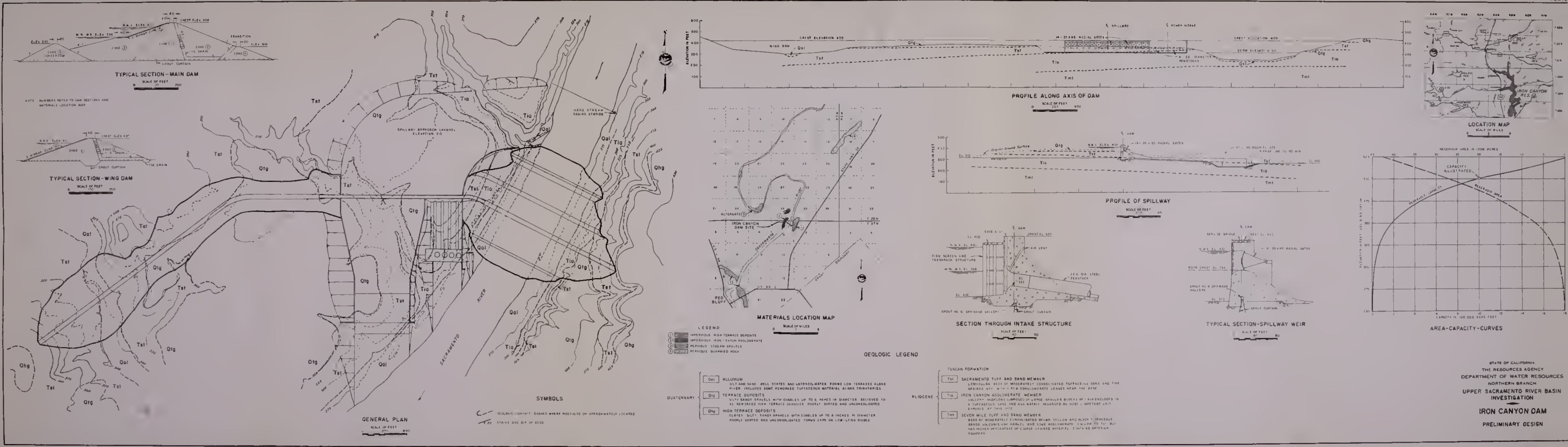
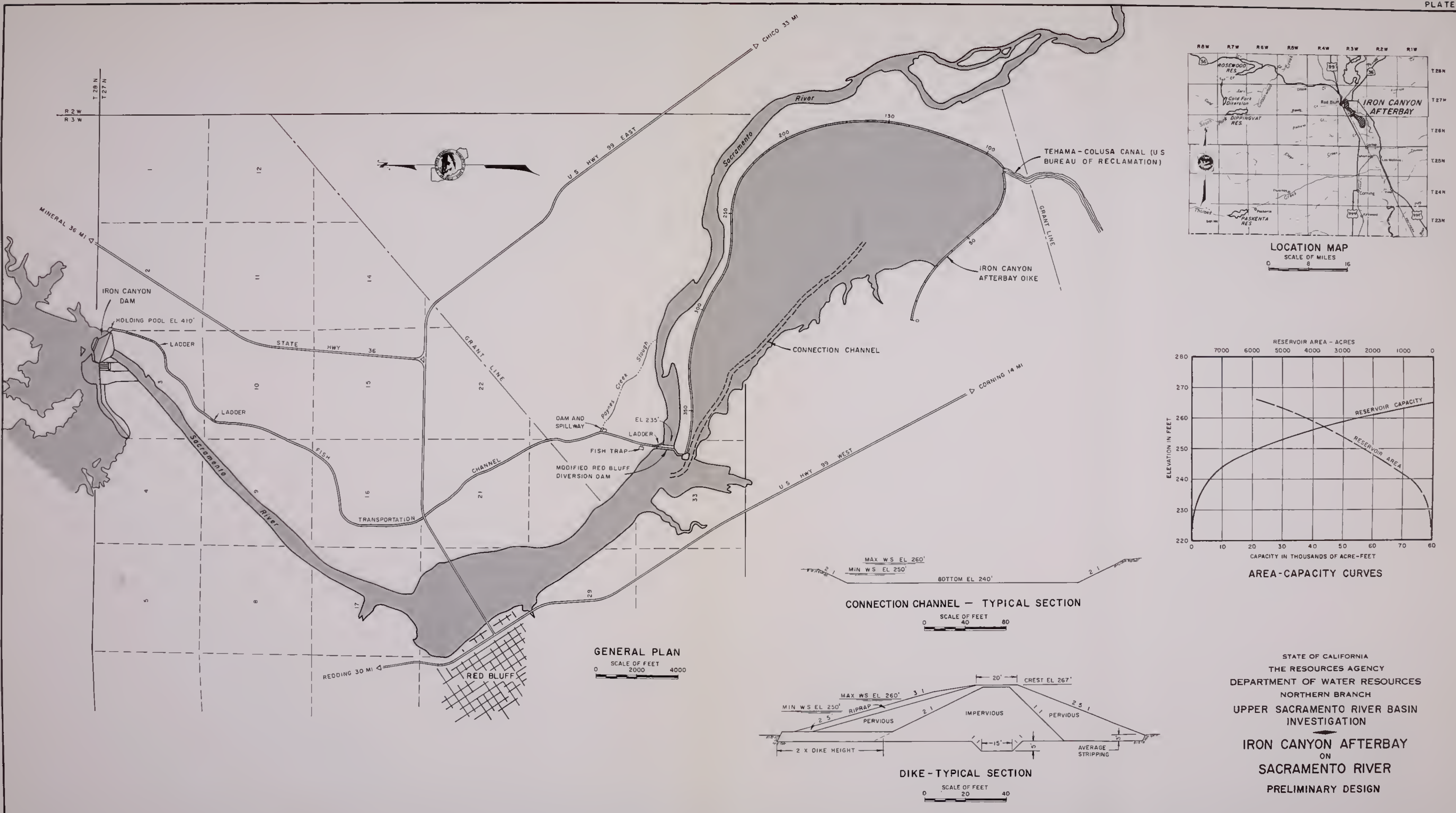
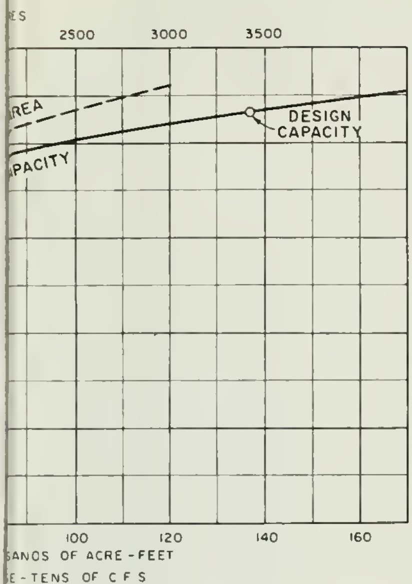
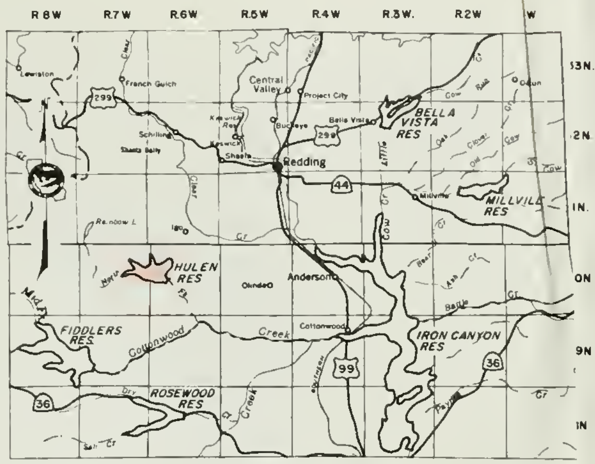


PLATE
TYPICAL SECTION-MAIN DAM
TYPICAL SECTION-WING DAM
GENERAL PLAN
SACRAMENTO RIVER
SYMBOLS
PROFILE ALONG AXIS OF DAM
MATERIALS LOCATION MAP
IRON CANYON DAM SITE
RED BLUFF
LEGEND
IMPERVIOUS HIGH TERRACE DEPOSITS
IMPERVIOUS IRON CANYON AGGLOMERATE
PERVIOUS STREAM GRAVELS
PERVIOUS QUARRIED ROCK
PROFILE OF SPILLWAY
SECTION THROUGH INTAKE STRUCTURE
TYPICAL SECTION-SPILLWAY WEIR
LOCATION MAP
IRON CANYON RES.
AREA-CAPACITY-CURVES
GEOLOGIC LEGEND
QUATERNARY
Qal ALLUVIUM
SILT AND SAND WELL SORTED AND UNCONSOLIDATED FORMS LOW TERRACES ALONG RIVER INCLUDES SOME REWORKED TUFFACEOUS MATERIAL ALONG TRIBUTARIES
Qtg TERRACE DEPOSITS
Qhg HIGH TERRACE DEPOSITS
PLIOCENE
TUSCAN FORMATION
Tst SACRAMENTO TUFF AND SAND MEMBER
Tia IRON CANYON AGGLOMERATE MEMBER
Tmt SEVEN MILE TUFF AND SAND MEMBER
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER BASIN INVESTIGATION
IRON CANYON DAM
PRELIMINARY DESIGN


GENERAL PLAN
SCALE OF FEET
0 2000 4000
IRON CANYON DAM
HOLDING POOL EL 410'
LADDER
LADDER
STATE HWY 36
MINERAL 36 MI
U S HWY 99 EAST
CHICO 33 MI
U S HWY 99 WEST
CORNING 14 MI
REDDING 30 MI
RED BLUFF
Sacramento River
GRANT LINE
FISH TRANSPORTATION CHANNEL
DAM AND SPILLWAY
Paynes Creek Slough
EL 235'
LADDER
FISH TRAP
MODIFIED RED BLUFF DIVERSION DAM
CONNECTION CHANNEL
IRON CANYON AFTERBAY DIKE
TEHAMA-COLUSA CANAL (U S BUREAU OF RECLAMATION)
R 2 W
R 3 W
T 28 N
T 27 N
LOCATION MAP
SCALE OF MILES
0 8 16
IRON CANYON AFTERBAY
ROSEWOOD RES
DIPPINGVAT RES
PASKENTA RES
Red Bluff
Corning
AREA-CAPACITY CURVES
RESERVOIR AREA - ACRES
7000 6000 5000 4000 3000 2000 1000 0
ELEVATION IN FEET
220 230 240 250 260 270 280
CAPACITY IN THOUSANDS OF ACRE-FEET
0 10 20 30 40 50 60 70 60
RESERVOIR CAPACITY
RESERVOIR AREA
CONNECTION CHANNEL — TYPICAL SECTION
MAX W S EL 260'
MIN W S EL 250'
BOTTOM EL 240'
2:1
SCALE OF FEET
0 40 80
DIKE-TYPICAL SECTION
20'
CREST EL 267'
MAX WS EL 260'
MIN W S EL 250'
RIPRAP
PERVIOUS
IMPERVIOUS
PERVIOUS
3:1
2.5:1
2:1
1:1
2.5:1
15'
5'
2 X DIKE HEIGHT
AVERAGE STRIPPING
SCALE OF FEET
0 20 40
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER BASIN INVESTIGATION
IRON CANYON AFTERBAY
ON
SACRAMENTO RIVER
PRELIMINARY DESIGN



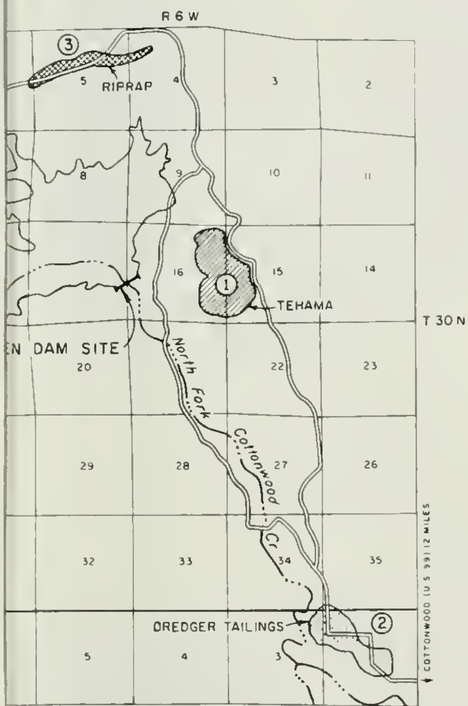
CHARGE CURVES



LOCATION MAP

SCALE OF MILES

0 8 16



MATERIALS LOCATION MAP

SCALE OF MILES

0 1 2

LEGEND

1. SOURCE OF IMPERVIOUS MATERIAL
2. SOURCE OF PERVIOUS MATERIAL
3. SOURCE OF RIPRAP

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

UPPER SACRAMENTO RIVER BASIN
INVESTIGATION

HULEN DAM AND RESERVOIR
ON
NORTH FORK COTTONWOOD CREEK

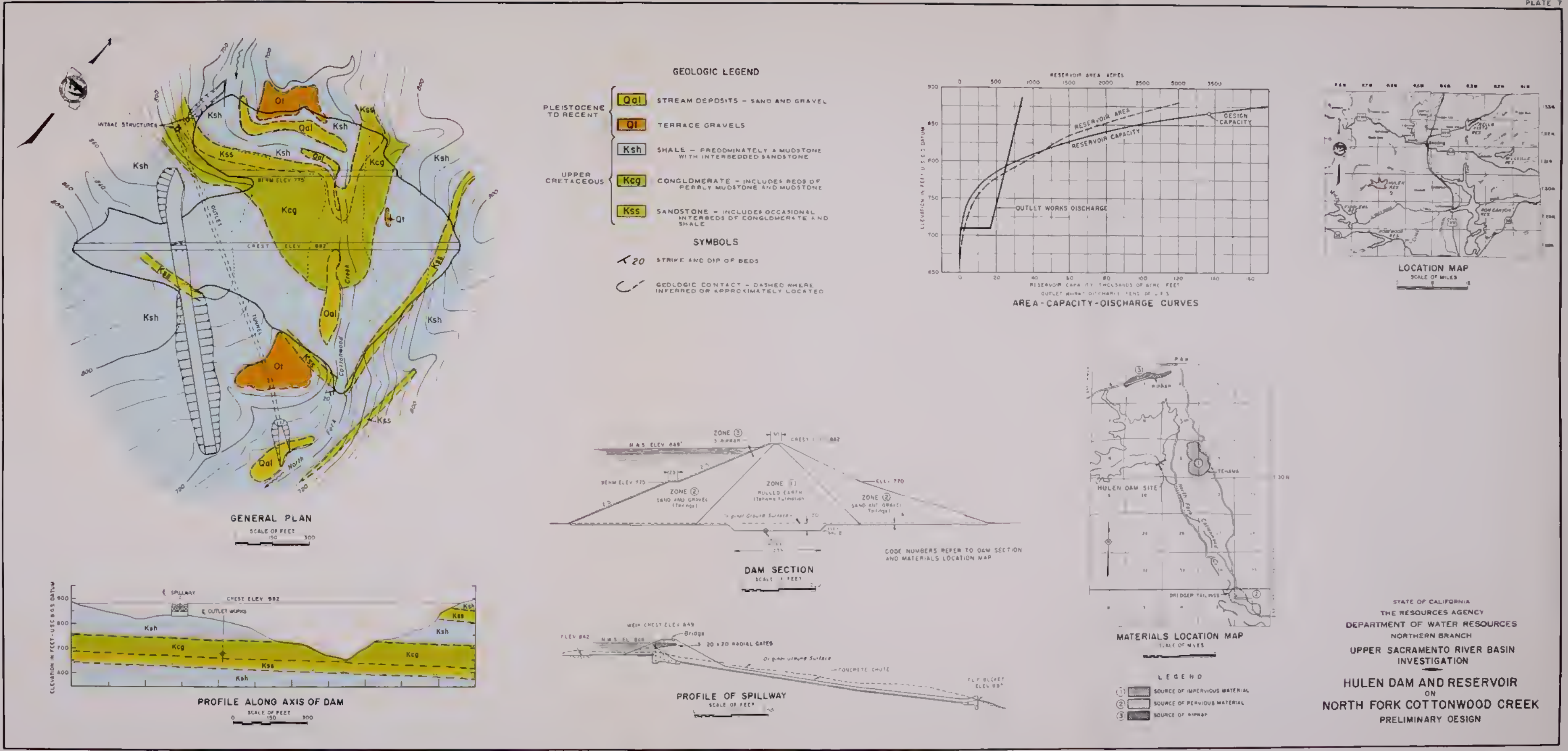
PRELIMINARY DESIGN

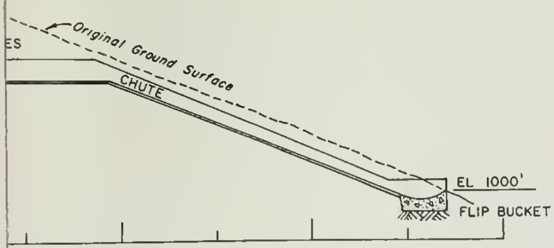
INDEX OF PRECIPITATION STATIONS AND STREAM GAGING STATIONS

Map Reference Number	Station
	PRECIPITATION STATIONS
1	Anderson - Gilman Ranch
	Bull Mountain Lookout
	Bengum
	Bengum 2 SW
	Churn Creek
6	Coleman Fish Hatchery
	Corning - Houghton Ranch
	Dales
	Darrah Springs Fish Hatchery
10	Ferguson Ranch
11	Fleurnoy
12	Forward Mill
13	French Gulch
14	Harrison Gulch Ranger Station
15	Igo
16	Los Molinos 3N
17	Macumber
18	Millville
19	Mineral
20	Ono
21	Paskenta Ranger Station
	Paynes Creek
	Red Bluff (U.S. Weather Bureau at Airport)
	Redding Fire Station No. 2
	Rosewood
26	Saddle Camp Ranger Station
27	Shasta
28	Shasta Dam
29	Volta Powerhouse
	STREAM GAGING STATIONS
	Shasta Lake near Redding
	Sacramento River at Keswick
	Sacramento River near Redding
	Sacramento River at Balls Ferry
	Sacramento River at Jellys Ferry
	Sacramento River at and near Red Bluff
36	Sacramento River at Redbank Creek
	Clear Creek at French Gulch
	Clear Creek near Igo
39	North Fork Cottonwood Creek at Ono
40	North Fork Cottonwood Creek near Igo
41	Middle Fork Cottonwood Creek near Ono
	Dry Fork of South Fork Cottonwood Creek near Cottonwood
43	South Fork Cottonwood Creek near Cottonwood
44	Cottonwood Creek near Cottonwood
45	Redbank Creek near Red Bluff
46	Elder Creek at Gerber
	Elder Creek near Henleyville
48	Elder Creek near Paskenta
49	Thomes Creek at Paskenta
50	Little Cow Creek near Ingot
51	Salt Creek near Bella Vista
	Oak Run Creek near Oak Run
	Clover Creek near Oak Run
54	Old Cow Creek at Kilarc Diversion
	South Cow Creek at Wagoner Canyon
56	South Cow Creek near Millville
57	Cow Creek near Millville
58	Bear Creek near Millville
59	South Fork Battle Creek near Mineral
60	Battle Creek near Cottonwood
61	Paynes Creek near Red Bluff
62	Antelope Creek near Red Bluff
63	Mill Creek near Los Molinos
64	Deer Creek near Vina

Note: Precipitation stations shown are those having generally ten or more years of record. Stream gaging stations shown are those used in hydrologic studies for the investigation.

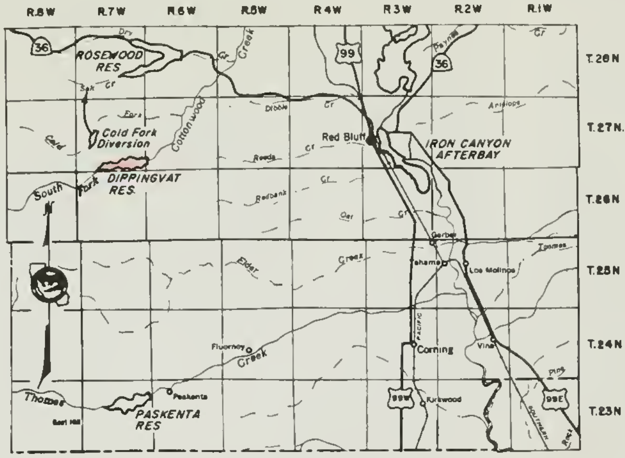
PLATE 7





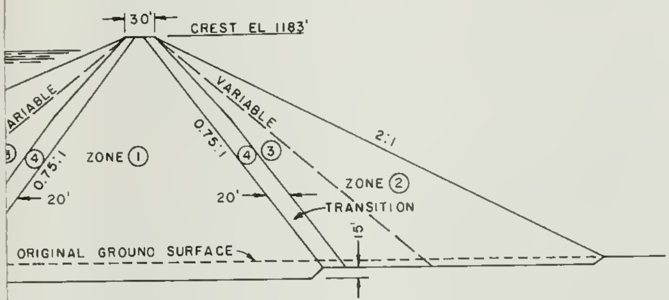
F SPILLWAY

F FEET
0 200



LOCATION MAP

SCALE OF MILES
0 8 16



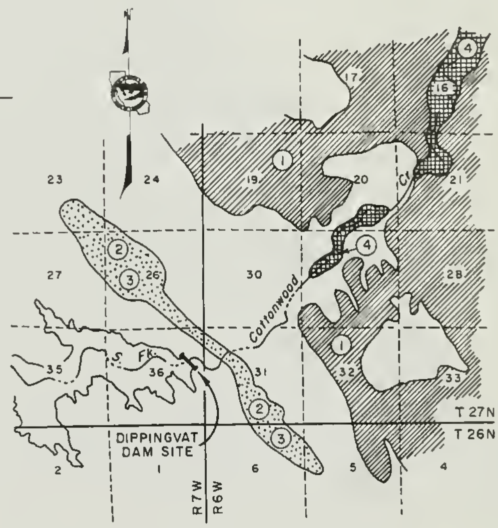
MUM DAM SECTION

SCALE OF FEET
100 200

NOTE CODE NUMBERS REFER TO DAM SECTION AND MATERIALS LOCATION MAP

LEGEND

① IMPERVIOUS - ROLLED EARTH
② QUARRIED ROCK - DUMPED
③ QUARRIED ROCK - ROLLED
④ TRANSITION - STREAM GRAVELS



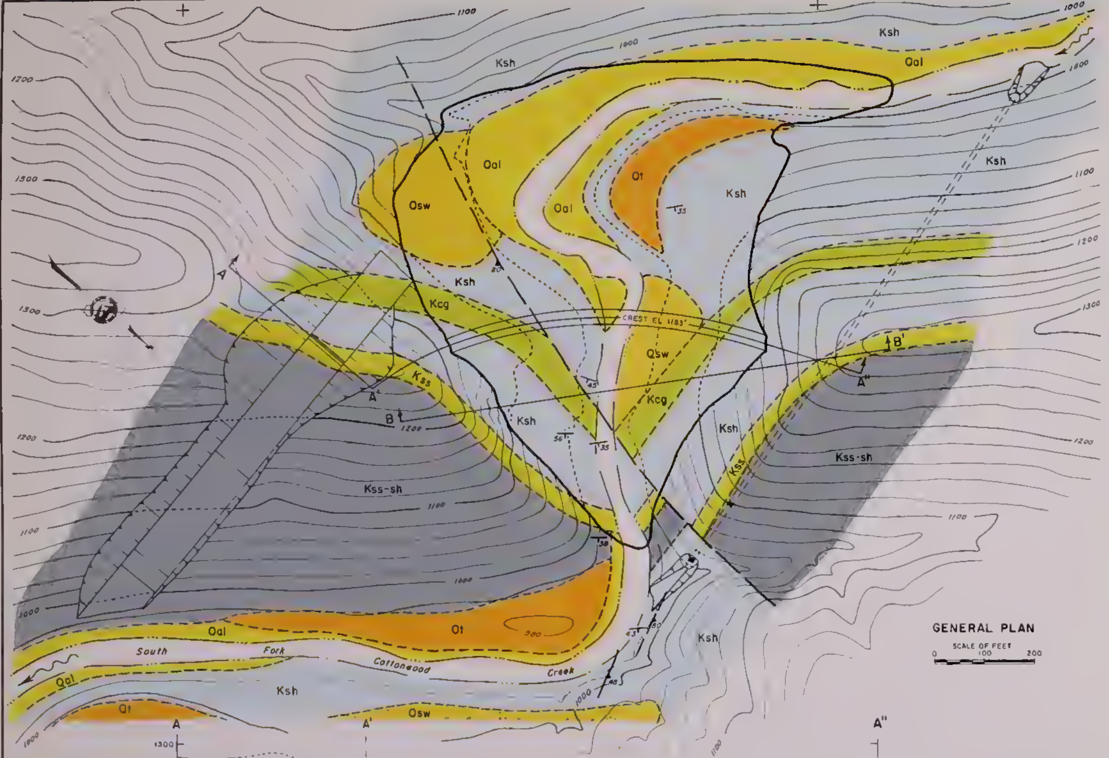
MATERIALS LOCATION MAP

SCALE OF MILES
0 1 2

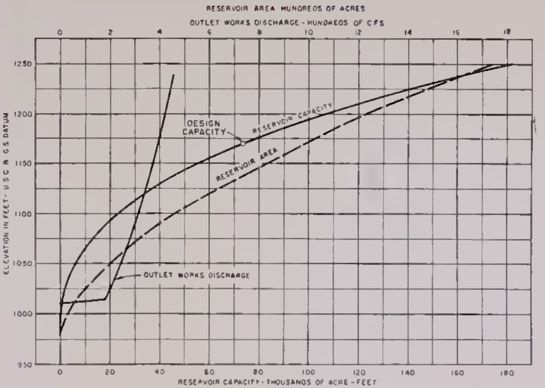
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER BASIN INVESTIGATION

DIPPINGVAT DAM AND RESERVOIR ON SOUTH FORK COTTONWOOD CREEK

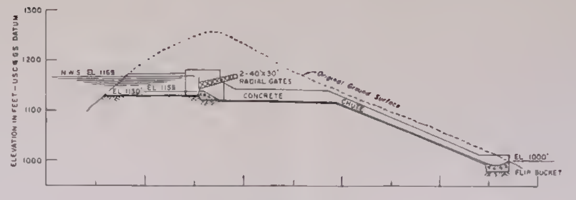
PRELIMINARY DESIGN



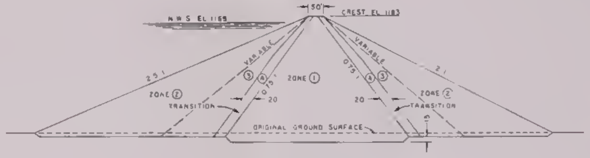
GENERAL PLAN
SCALE OF FEET
0 100 200



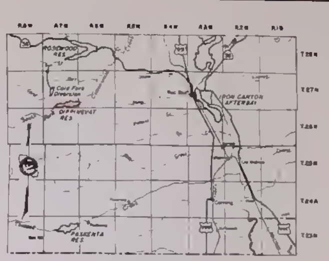
AREA-CAPACITY-DISCHARGE CURVES



PROFILE OF SPILLWAY
SCALE OF FEET
0 100 200



MAXIMUM DAM SECTION
SCALE OF FEET
0 100 200



LOCATION MAP
SCALE OF MILES
0 5 15

NOTE: CODE NUMBERS REFER TO DAM SECTION AND MATERIALS LOCATION MAP

LEGEND
1 IMPERVIOUS - ROLLED EARTH
2 QUARRIED ROCK - DUMPED
3 QUARRIED ROCK - ROLLED
4 TRANSITION - STREAM GRAVELS

MATERIALS LOCATION MAP
SCALE OF MILES

GEOLOGIC LEGEND

PLEISTOCENE TO RECENT

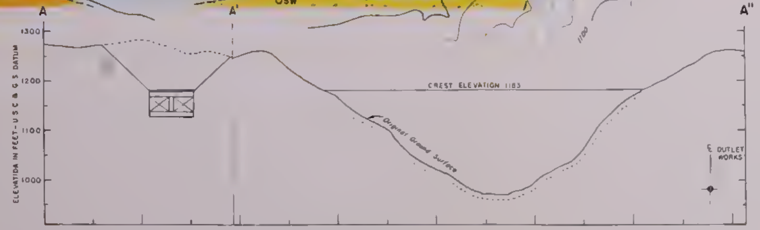
- Qal — STREAM CHANNEL DEPOSITS: UNCONSOLIDATED SAND AND GRAVEL
- Qsw — SLOPEWASH: ACCUMULATION OF CLAYEY MATERIAL AND ROCK FRAGMENTS
- Qt — TERRACE DEPOSITS: UNCONSOLIDATED SILT WITH SAND AND GRAVEL

UPPER CRETACEOUS

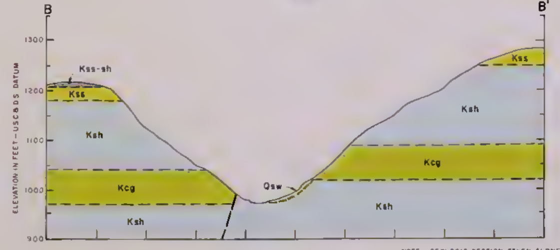
- Ksh — SHALE: GENERALLY A MUDSTONE WITH THIN INTERBEDS OF SANDSTONE
- Kss — SANDSTONE: INCLUDES A FEW THIN INTERBEDS OF SANDY SHALE AND MUDSTONE
- Kcg — CONGLOMERATE: THICK MASSIVE BEDS OF WELL CEMENTED PEBBLE CONGLOMERATE
- Kss-sh — SANDSTONE AND SHALE: OCCURRING IN THIN ALTERNATING BEDS

SYMBOLS

- 35 — STRIKE AND DIP OF BEDS
- GEOLOGIC CONTACT - DASHED WHERE INFERRED OR APPROXIMATELY LOCATED
- 80 — FAULT WITH ANGLE OF DIP
- B B' — GEOLOGIC SECTION LINE



SECTION A-A'-A''
SCALE OF FEET
0 100 200



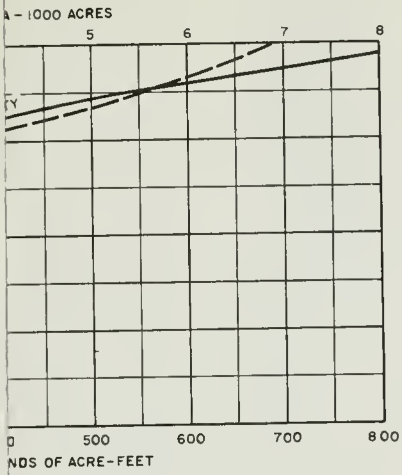
SECTION B-B'
SCALE OF FEET
0 100 200

NOTE: GEOLOGIC SECTION TAKEN ALONG STRIKE OF BEDS. BEDS DIP DOWNSTREAM AT ANGLES OF 35° TO 40°

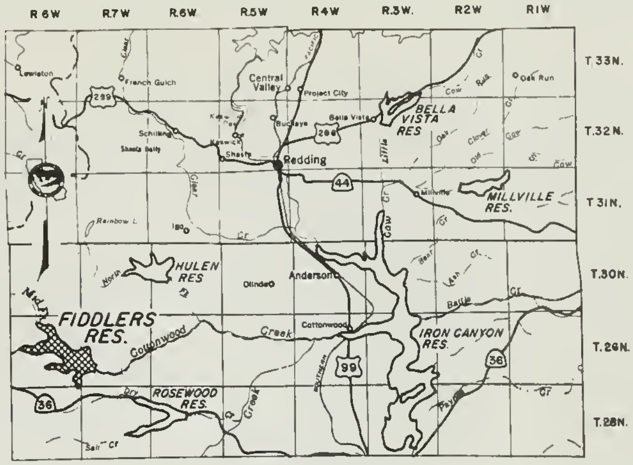
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER BASIN INVESTIGATION

DIPPINGVAT DAM AND RESERVOIR
ON
SOUTH FORK COTTONWOOD CREEK

PRELIMINARY DESIGN



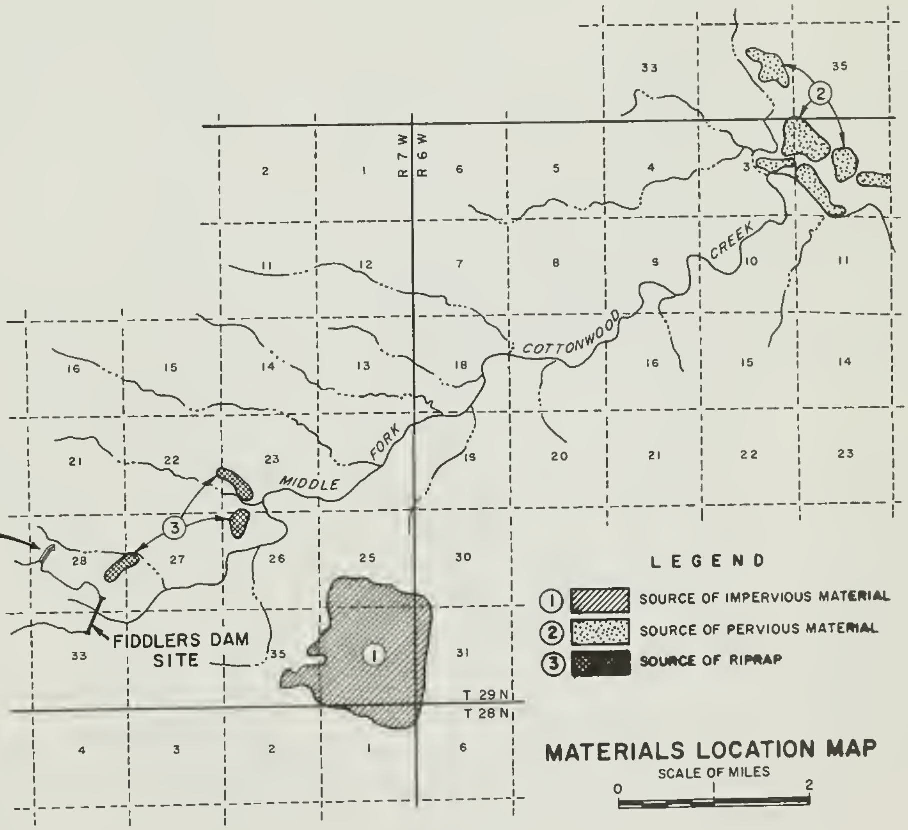
TY - CURVES



LOCATION MAP

SCALE OF MILES

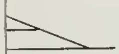
0 8 16



MATERIALS LOCATION MAP

SCALE OF MILES

0 2

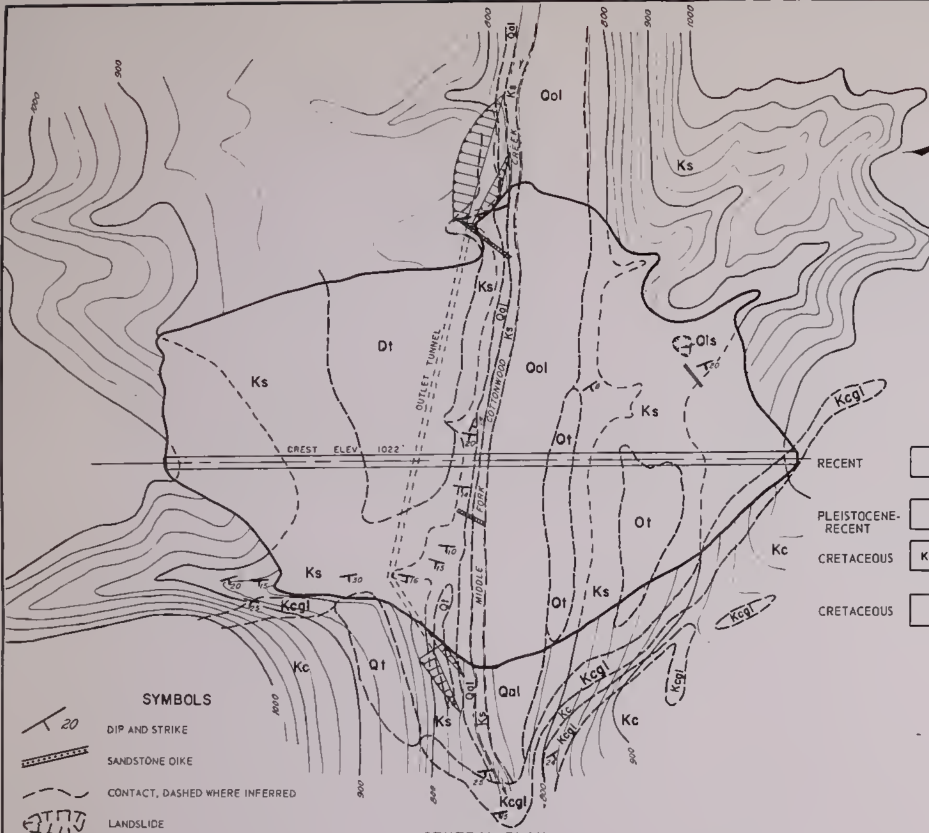


STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH

UPPER SACRAMENTO RIVER BASIN INVESTIGATION

FIDDLERS DAM AND RESERVOIR
ON
MIDDLE FORK COTTONWOOD CREEK

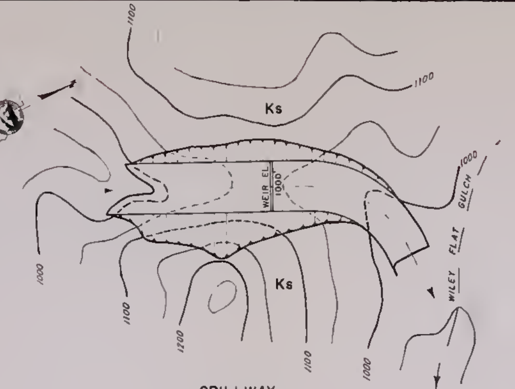
PRELIMINARY DESIGN



GENERAL PLAN
SCALE OF FEET
0 200 400

SYMBOLS

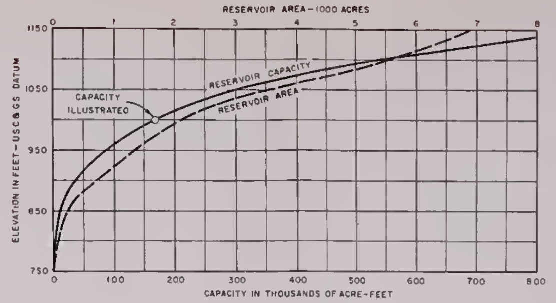
- DIP AND STRIKE
- SANDSTONE DIKE
- CONTACT, DASHED WHERE INFERRED
- LANDSLIDE
- FAULT, DASHED WHERE INFERRED



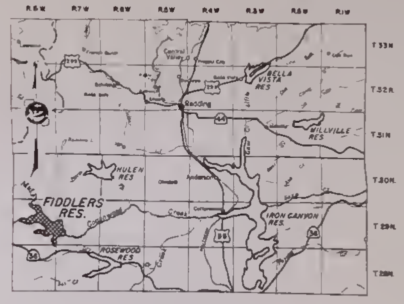
SPILLWAY
SCALE OF FEET
0 200 400

GEOLOGIC LEGEND

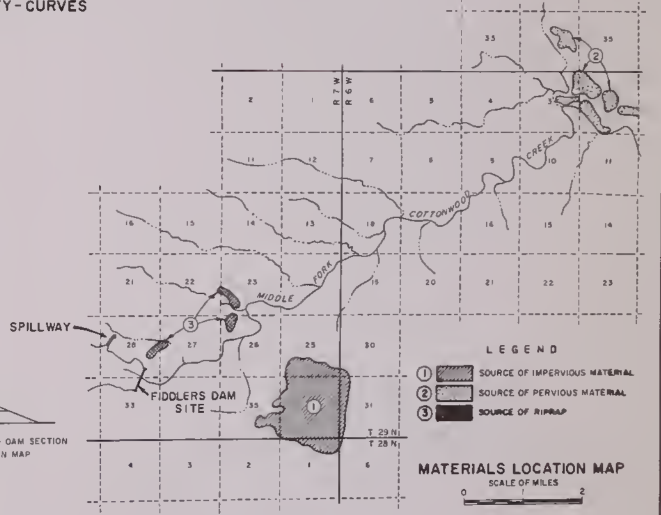
RECENT	Qal	ALLUVIUM UNDIFFERENTIATED CHANNEL FILL AND FLOOD-PLAIN DEPOSITS UNCONSOLIDATED SAND AND GRAVEL BARS WITH LENSES OF SILT AND CLAY
PLEISTOCENE-RECENT	Qt	TERRACE DEPOSITS SMALL GRAVEL TO BOULDERS IN A MATRIX OF SILT AND CLAY WITH SOME SAND. GENERALLY COVERED BY SLOPEWASH
CRETACEOUS	Ks & Kc	SHASTA-CHICO SERIES DARK GRAY TO BLACK MARINE MUDSTONE WITH INTERBEDDED SANDSTONE AND SILTSTONE. CHICO GROUP LIES TO THE EAST OF THE BASAL CONGLOMERATE
CRETACEOUS	Kcgl	BASAL CONGLOMERATE PEBBLE TO BOULDER SIZE MATERIAL IN A MATRIX OF SAND, BONDED BY CARBONATE CEMENT. GENERALLY GRAY-BROWN COLOR. BASAL MEMBER OF CHICO GROUP



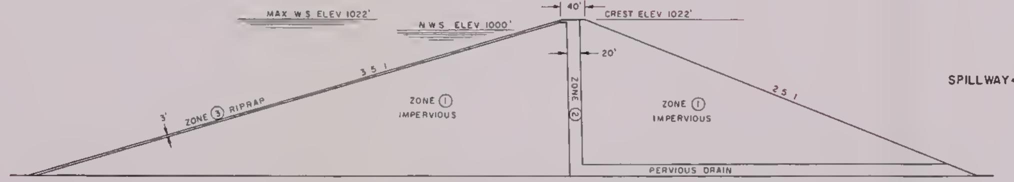
AREA-CAPACITY-CURVES



LOCATION MAP
SCALE OF MILES
0 8 16

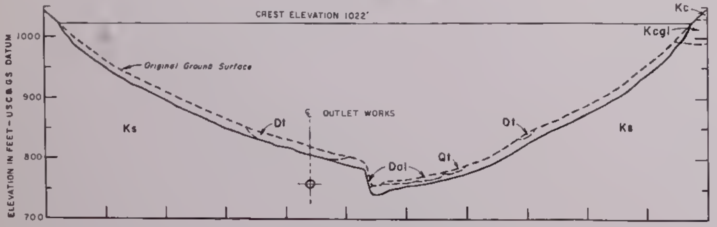


MATERIALS LOCATION MAP
SCALE OF MILES
0 1 2

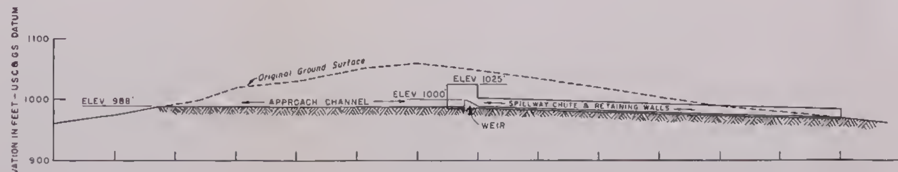


NOTE: CODE NUMBERS REFER TO DAM SECTION AND MATERIALS LOCATION MAP

MAXIMUM DAM SECTION
SCALE OF FEET
0 100 200



PROFILE ALONG AXIS OF DAM
LOOKING UPSTREAM
SCALE OF FEET
0 200 400



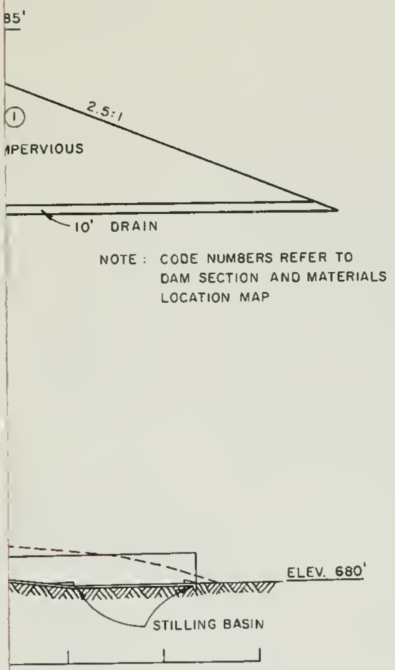
PROFILE OF SPILLWAY
SCALE OF FEET
0 100 200

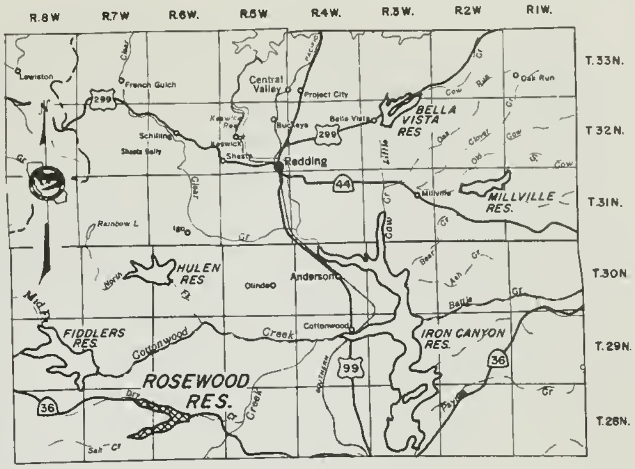
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH

UPPER SACRAMENTO RIVER BASIN INVESTIGATION

FIDDLERS DAM AND RESERVOIR ON MIDDLE FORK COTTONWOOD CREEK

PRELIMINARY DESIGN

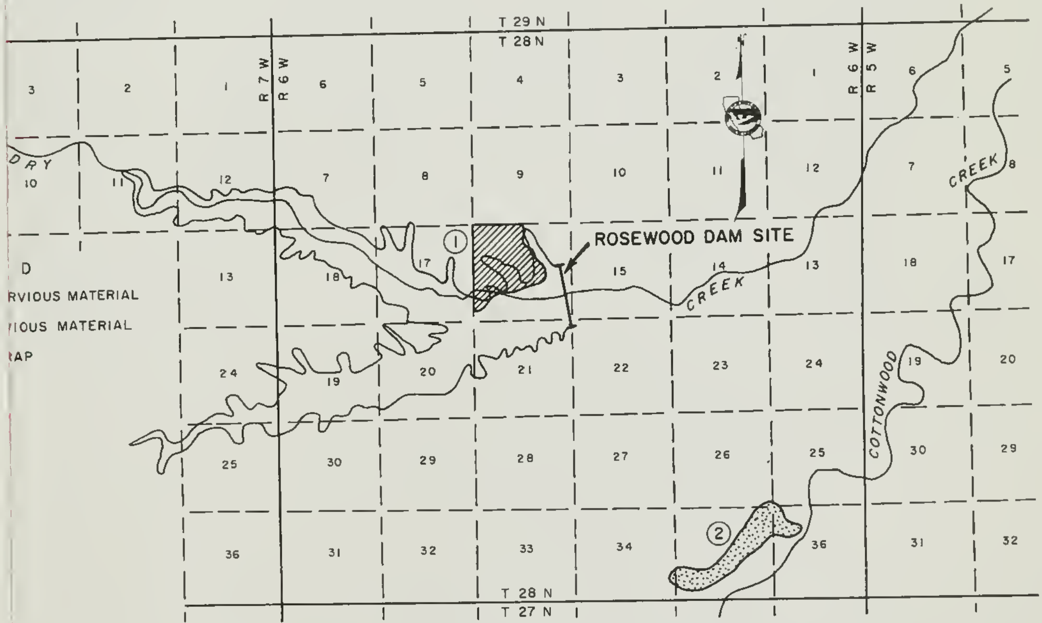




LOCATION MAP

SCALE OF MILES

0 8 16



MATERIALS LOCATION MAP

SCALE OF MILES

0 2

STATE OF CALIFORNIA

THE RESOURCES AGENCY

DEPARTMENT OF WATER RESOURCES

NORTHERN BRANCH

UPPER SACRAMENTO RIVER BASIN INVESTIGATION

ROSEWOOD DAM AND RESERVOIR ON DRY CREEK

PRELIMINARY DESIGN

GENERAL PLAN

SCALE OF FEET 0 300 600

GEOLOGIC LEGEND

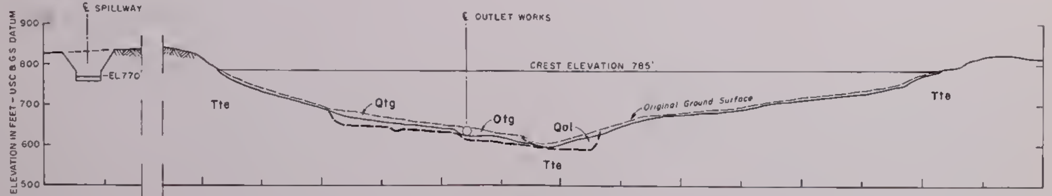
RECENT — Qal — STREAM CHANNEL DEPOSITS
SAND AND GRAVEL WITH LENSES OF SILT AND CLAY

PLEISTOCENE-RECENT — Qtg — TERRACE DEPOSITS
SMALL GRAVEL AND BOULDERS IN A YELLOWISH MATRIX OF SAND AND SILT WITH MINOR AMOUNTS OF CLAY

UPPER PLIOCENE — Tte — TEHAMA FORMATION (INCLUDING THE NOMLAKI TUFF MEMBER)
SEMICONSOLIDATED SILTY SAND, SANDY SILT AND CLAY WITH INTERBEDDED LENSES OF SAND AND FINE GRAVEL, GENERALLY PALE TO REDDISH BUFF IN COLOR

SYMBOL

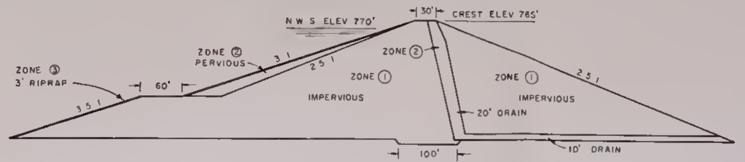
GEOLOGIC CONTACT, DASHED WHERE INDEFINITE OR INFERRED



PROFILE ALONG AXIS OF DAM

LOOKING UPSTREAM

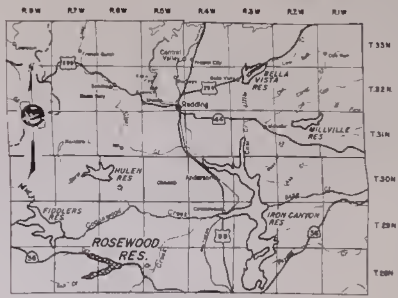
SCALE OF FEET 0 300 600



MAXIMUM DAM SECTION

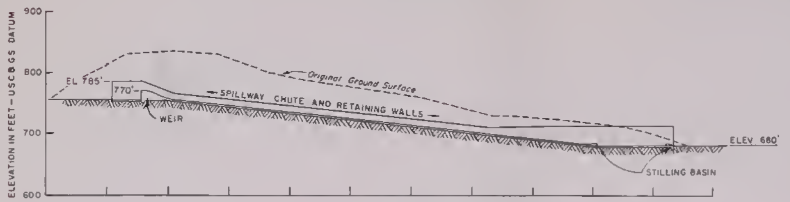
SCALE OF FEET 0 100 200

NOTE: CODE NUMBERS REFER TO DAM SECTION AND MATERIALS LOCATION MAP



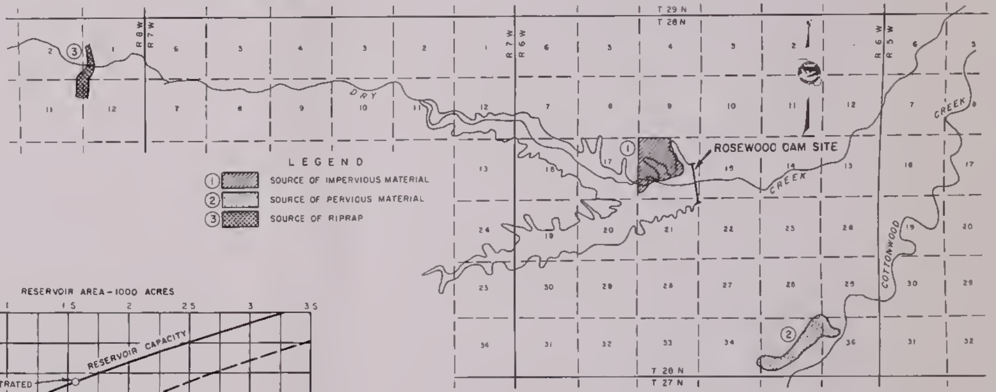
LOCATION MAP

SCALE OF MILES 0 8 16



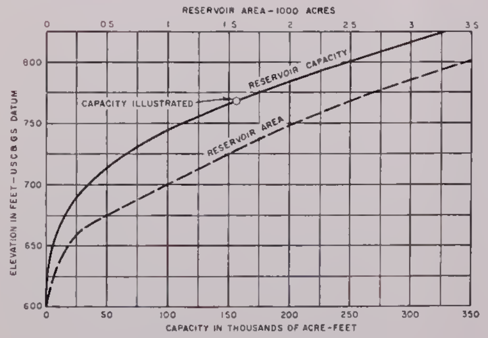
PROFILE OF SPILLWAY

SCALE OF FEET 0 100 200



MATERIALS LOCATION MAP

SCALE OF MILES 0 1 2

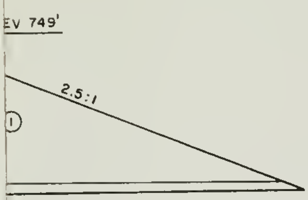


AREA-CAPACITY-CURVES

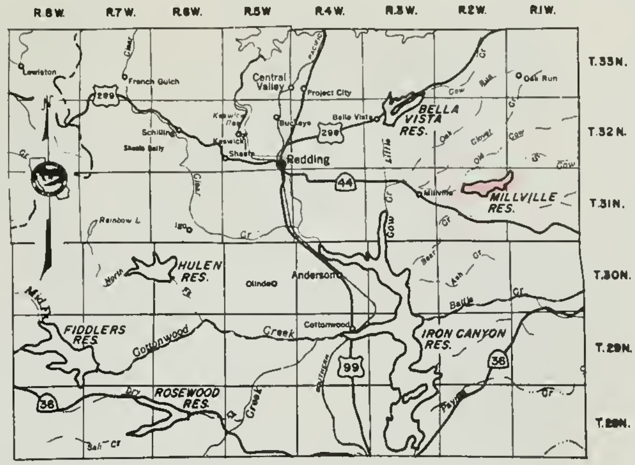
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH

UPPER SACRAMENTO RIVER BASIN INVESTIGATION

ROSEWOOD DAM AND RESERVOIR
ON
DRY CREEK
PRELIMINARY DESIGN

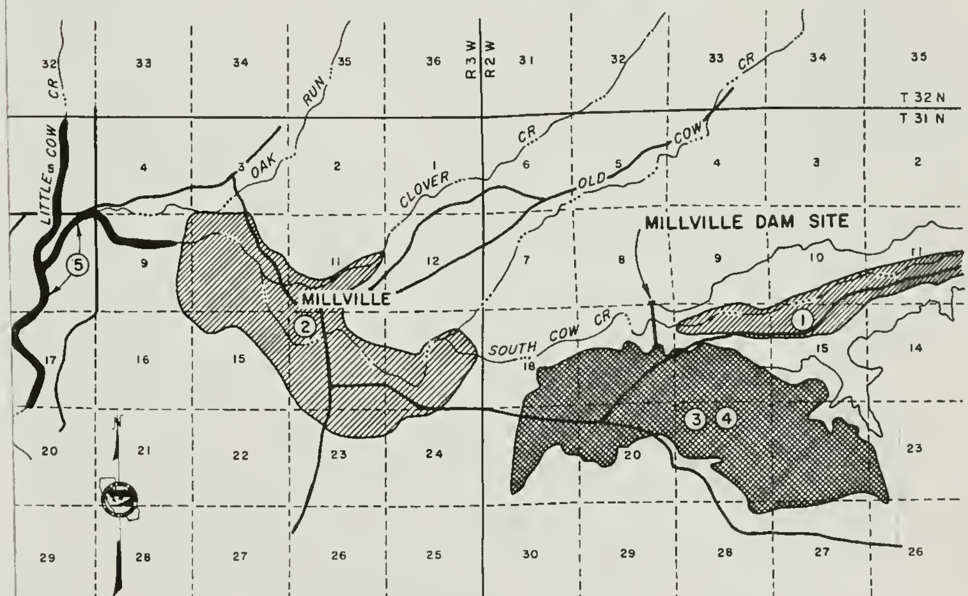


NOTE: CODE NUMBERS REFER TO DAM SECTION AND MATERIALS LOCATION MAP



LOCATION MAP

SCALE OF MILES
0 8 16



MATERIALS LOCATION MAP

SCALE OF MILES
0 1 2

LEGEND

SOURCE OF IMPERVIOUS MATERIAL
1. CLAY-GRAVEL ALLUVIUM
2. SILT-SAND-CLAY ALLUVIUM

SOURCE OF QUARRIED ROCK
3. FRESH BASALT
4. WEATHERED BASALT

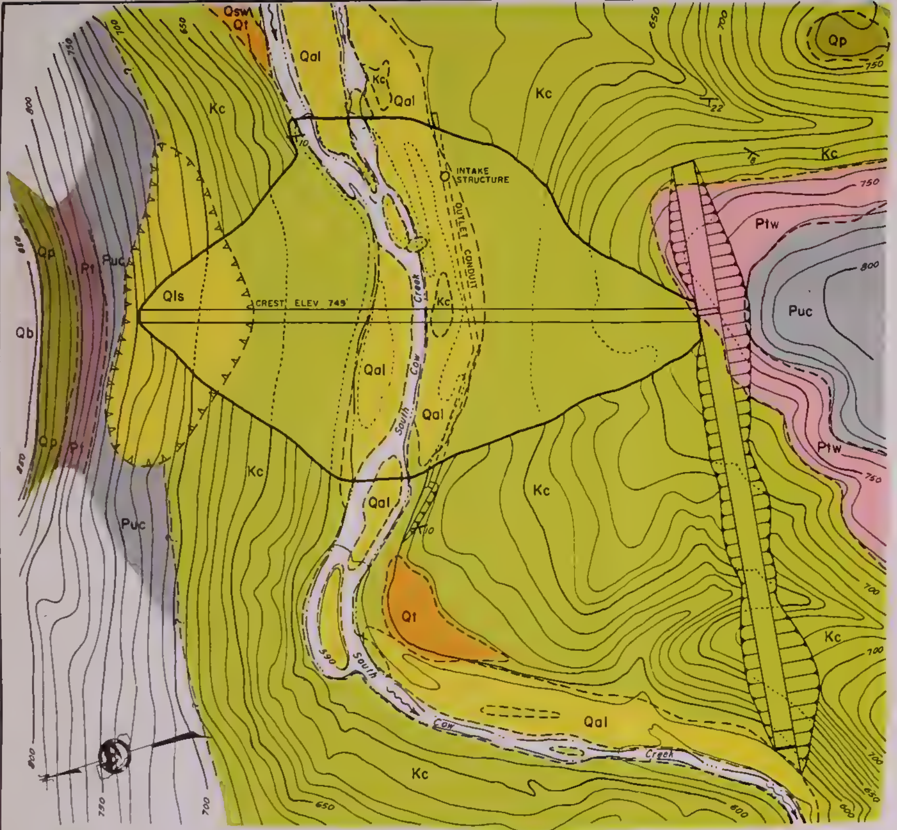
SOURCE OF PERVIOUS MATERIAL
5. STREAM GRAVELS

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

UPPER SACRAMENTO RIVER BASIN INVESTIGATION

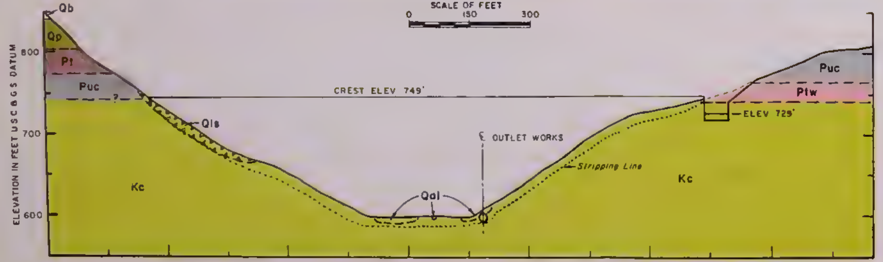
MILLVILLE DAM AND RESERVOIR ON SOUTH COW CREEK

PRELIMINARY DESIGN



GENERAL PLAN

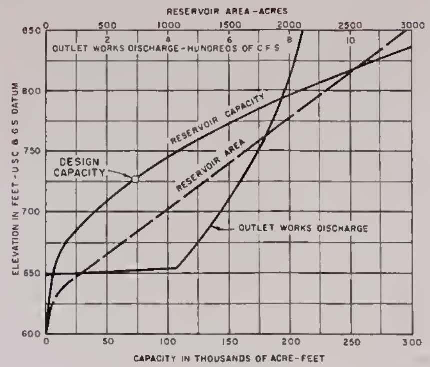
SCALE OF FEET 0 150 300



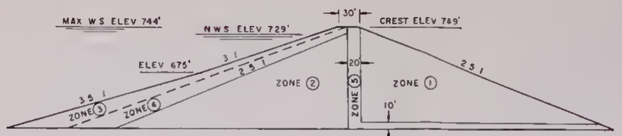
PROFILE ALONG AXIS OF DAM

LOOKING UPSTREAM

SCALE OF FEET 0 150 300



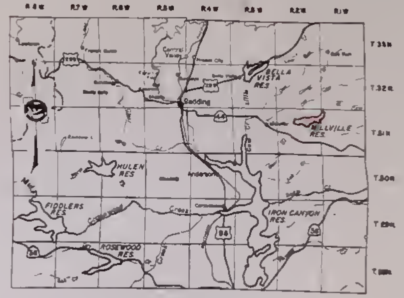
AREA-CAPACITY-DISCHARGE CURVES



MAXIMUM DAM SECTION

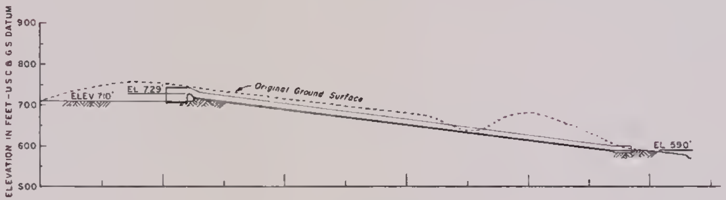
SCALE OF FEET 0 100 200

NOTE CODE NUMBERS REFER TO DAM SECTION AND MATERIALS LOCATION MAP



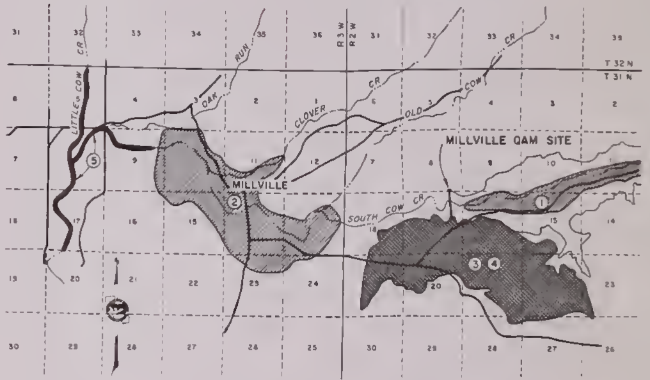
LOCATION MAP

SCALE OF MILES 0 8 16



PROFILE OF SPILLWAY

SCALE OF FEET 0 150 300



MATERIALS LOCATION MAP

SCALE OF MILES 0 1 2

LEGEND

SOURCE OF IMPERVIOUS MATERIAL
(1) CLAY - GRAVEL ALLUVIUM
(2) SILT - SAND - CLAY ALLUVIUM

SOURCE OF QUARRIED ROCK
(3) FRESH BASALT
(4) WEATHERED BASALT

SOURCE OF PERVIOUS MATERIAL
(5) STREAM GRAVELS

GEOLOGIC LEGEND

PLEISTOCENE TO RECENT

- Qal — STREAM CHANNEL ALLUVIUM — THIN DEPOSITS OF SAND AND GRAVEL
- Qsw, Qt — SLOPEWASH AND TERRACE DEPOSITS — CLAY AND GRAVELLY CLAY
- Qls — LANDSLIDE OR HILLSLUMP
- Qb — BASALT
- Qp — POST TUSCAN GRAVEL — PARTIALLY CONSOLIDATED SILTY TO CLAYEY GRAVEL

UPPER PLIOCENE

- Pt — TUSCAN FORMATION — CONSISTS MAINLY OF TUFF BRECCIA
- Puc — TUSCAN-TEHAMA FORMATION — COMPACT LAYERS OF SAND AND GRAVEL
- Ptw — WELDED TUFF UNIT — INCLUDES A CHANNEL FILL OF CLAY, SAND AND GRAVEL WITH WELDED TUFF BLOCKS AND A THIN LAYER OF NONWELDED TUFF NEAR BOTTOM OF UNIT

CRETACEOUS

- Kc — CHICO FORMATION — INCLUDES SANDSTONE, SHALE AND CONGLOMERATE

SYMBOLS

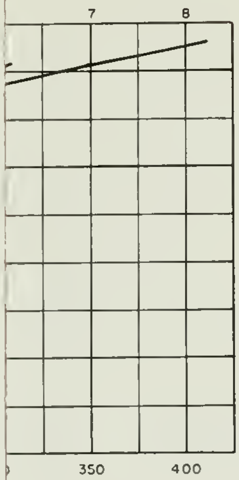
- 20 — STRIKE AND DIP OF BEDS
- GEOLOGIC CONTACT - DASHED WHERE INFERRED OR APPROXIMATELY LOCATED

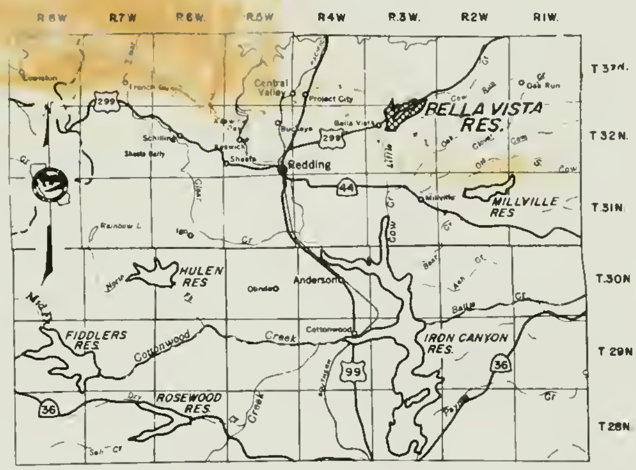
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH

UPPER SACRAMENTO RIVER BASIN INVESTIGATION

MILLVILLE DAM AND RESERVOIR ON SOUTH COW CREEK

PRELIMINARY DESIGN

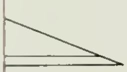




LOCATION MAP

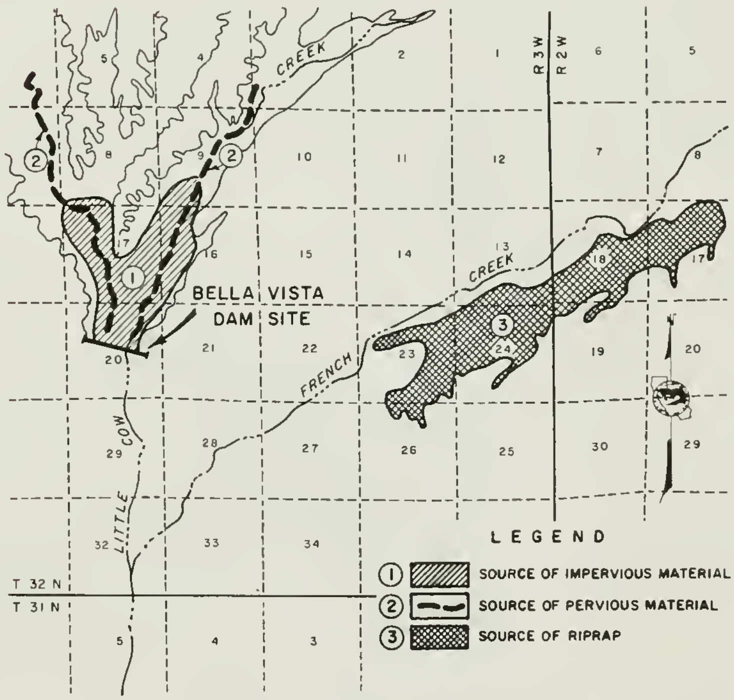
SCALE OF MILES

0 8 16



10'

NUMBERS REFER TO
SECTION AND MATERIALS
ION MAP



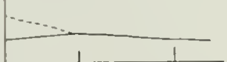
LEGEND

(1)	SOURCE OF IMPERVIOUS MATERIAL
(2)	SOURCE OF PERVIOUS MATERIAL
(3)	SOURCE OF RIPRAP

MATERIALS LOCATION MAP

SCALE OF MILES

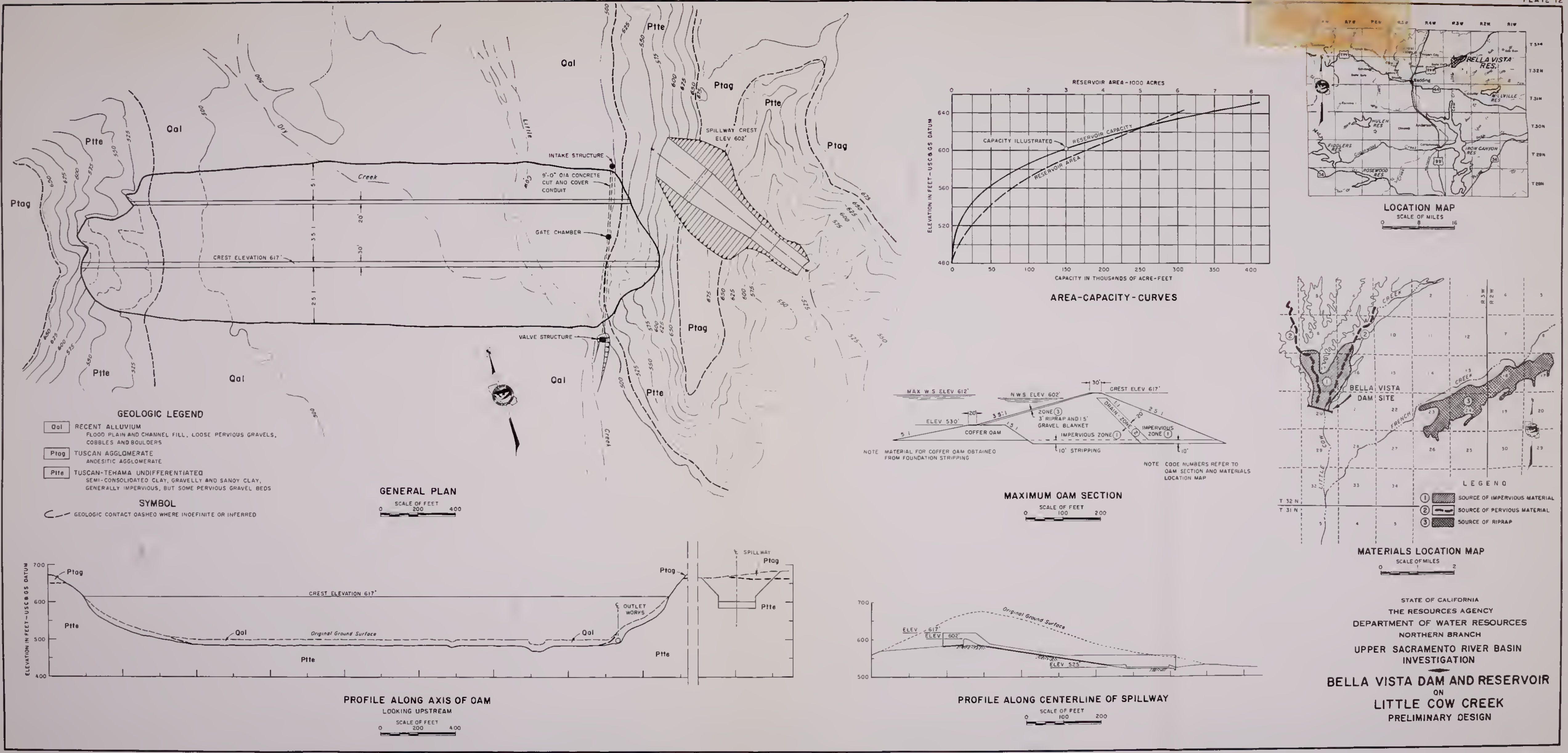
0 1 2

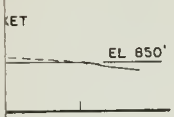


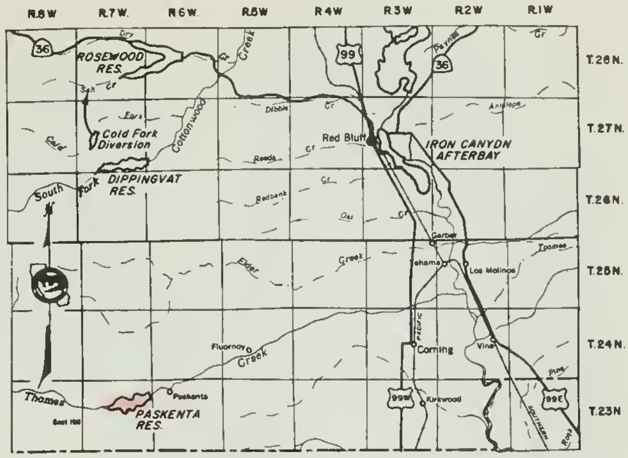
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH

UPPER SACRAMENTO RIVER BASIN
INVESTIGATION

BELLA VISTA DAM AND RESERVOIR
ON
LITTLE COW CREEK
PRELIMINARY DESIGN


GEOLOGIC LEGEND
Qal RECENT ALLUVIUM
FLOOD PLAIN AND CHANNEL FILL, LOOSE PERVIOUS GRAVELS, COBBLES AND BOULDERS
Ptag TUSCAN AGGLOMERATE
ANDESITIC AGGLOMERATE
Ptte TUSCAN-TEHAMA UNDIFFERENTIATED
SEMI-CONSOLIDATED CLAY, GRAVELLY AND SANDY CLAY, GENERALLY IMPERVIOUS, BUT SOME PERVIOUS GRAVEL BEDS
SYMBOL
GEOLOGIC CONTACT DASHED WHERE INDEFINITE OR INFERRED
INTAKE STRUCTURE
9'-0" DIA CONCRETE CUT AND COVER CONDUIT
GATE CHAMBER
VALVE STRUCTURE
CREST ELEVATION 617'
SPILLWAY CREST ELEV 602'
Little Cow Creek
GENERAL PLAN
SCALE OF FEET
0 200 400
RESERVOIR AREA-1000 ACRES
ELEVATION IN FEET-USC&GS DATUM
CAPACITY ILLUSTRATED
RESERVOIR CAPACITY
RESERVOIR AREA
CAPACITY IN THOUSANDS OF ACRE-FEET
AREA-CAPACITY-CURVES
LOCATION MAP
SCALE OF MILES
0 8 16
BELLA VISTA RES.
MILLVILLE RES
HULEN RES
IRON CANYON RES
FIDDLERS RES
ROSEWOOD RES
Redding
MAX W S ELEV 612'
N W S ELEV 602'
CREST ELEV 617'
ELEV 530'
COFFER DAM
ZONE 3 3' RIPRAP AND 1.5' GRAVEL BLANKET
DRAIN ZONE 2
IMPERVIOUS ZONE 1
10' STRIPPING
NOTE MATERIAL FOR COFFER DAM OBTAINED FROM FOUNDATION STRIPPING
NOTE CODE NUMBERS REFER TO DAM SECTION AND MATERIALS LOCATION MAP
MAXIMUM DAM SECTION
SCALE OF FEET
0 100 200
BELLA VISTA DAM SITE
LITTLE COW CREEK
FRENCH CREEK
LEGEND
1 SOURCE OF IMPERVIOUS MATERIAL
2 SOURCE OF PERVIOUS MATERIAL
3 SOURCE OF RIPRAP
MATERIALS LOCATION MAP
SCALE OF MILES
0 1 2
CREST ELEVATION 617'
Original Ground Surface
OUTLET WORKS
SPILLWAY
PROFILE ALONG AXIS OF DAM
LOOKING UPSTREAM
SCALE OF FEET
0 200 400
ELEV 617'
ELEV 602'
ELEV 525'
Original Ground Surface
PROFILE ALONG CENTERLINE OF SPILLWAY
SCALE OF FEET
0 100 200
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER BASIN INVESTIGATION
BELLA VISTA DAM AND RESERVOIR
ON
LITTLE COW CREEK
PRELIMINARY DESIGN





LOCATION MAP

SCALE OF MILES

0 8 16

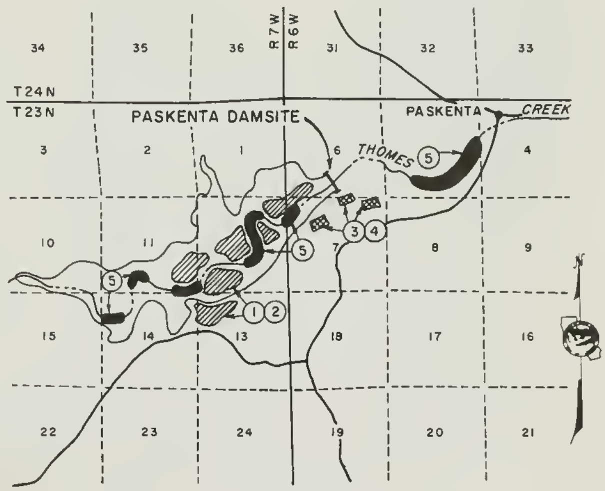
LEGEND

SOURCE OF IMPERVIOUS MATERIAL
(1) CLAY-SILT SLOPEWASH
(2) UNDERLYING TERRACE DEPOSITS

SOURCE OF QUARRIED ROCK
(3) WEATHERED CONGLOMERATE
(4) FRESH CONGLOMERATE

SOURCE OF PERVIOUS MATERIAL
(5) STREAM GRAVELS

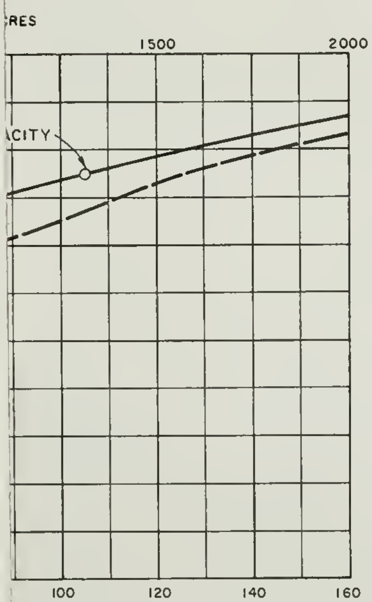
TION



MATERIALS LOCATION MAP

SCALE OF MILES

0 1 2



RGE CURVES

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

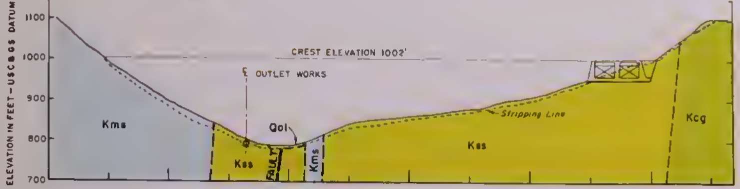
UPPER SACRAMENTO RIVER BASIN INVESTIGATION

PASKENTA DAM AND RESERVOIR ON THOMES CREEK

PRELIMINARY DESIGN

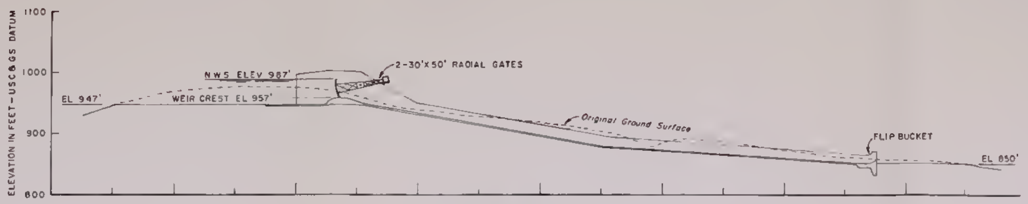
GENERAL PLAN

SCALE OF FEET 0 150 300



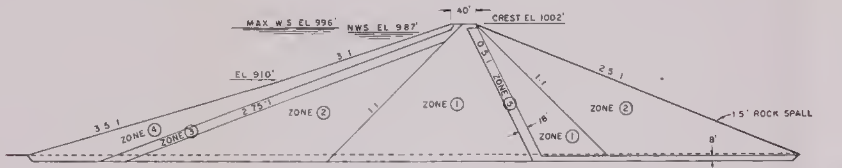
PROFILE ALONG AXIS OF DAM
LOOKING UPSTREAM

SCALE OF FEET 0 150 300



PROFILE OF SPILLWAY

SCALE OF FEET 0 100 200



MAXIMUM DAM SECTION

SCALE OF FEET 0 100 200

NOTE: CODE NUMBERS REFER TO DAM SECTION AND MATERIALS LOCATION MAP

GEOLOGIC LEGEND

PLEISTOCENE TO RECENT

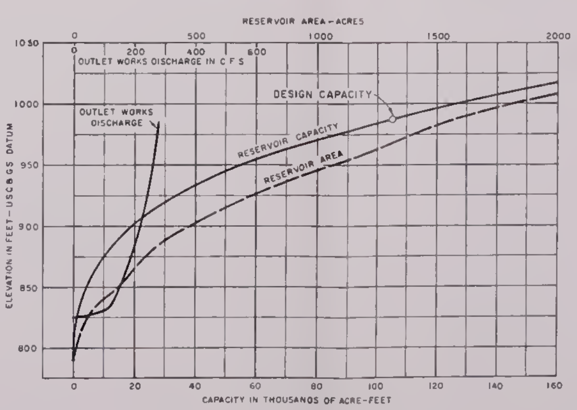
- **Qal** STREAM CHANNEL DEPOSITS
  UNCONSOLIDATED SAND AND GRAVEL

UPPER JURASSIC TO LOWER CRETACEOUS

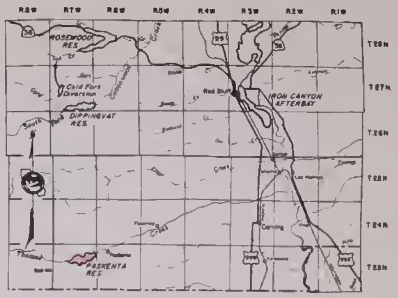
- **Kms** MUDSTONE
  INCLUDES A FEW THIN SANDSTONE BEDS
- **Kss** SANDSTONE
  INCLUDES OCCASIONAL THIN INTERBEDS OF MUDSTONE AND CONGLOMERATE
- **Kcg** CONGLOMERATE
  GENERALLY IN THICK MASSIVE BEDS WITH OCCASIONAL INTERBEDS OF MUDSTONE

SYMBOLS

- 75 STRIKE AND DIP OF BEDS
- GEOLOGIC CONTACT - DASHED WHERE INFERRED OR APPROXIMATELY LOCATED
- FAULT - DASHED WHERE INFERRED OR APPROXIMATELY LOCATED; DOTTED WHERE CONCEALED
- LANDSLIDE



AREA-CAPACITY-DISCHARGE CURVES

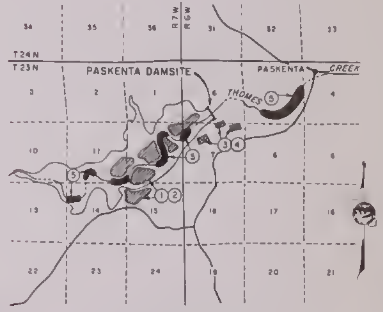


LOCATION MAP

SCALE OF MILES 0 8 16

LEGEND

- SOURCE OF IMPERVIOUS MATERIAL
  - (1) CLAY-SILT SLOPEWASH
  - (2) UNDERLYING TERRACE DEPOSITS
- SOURCE OF QUARRIED ROCK
  - (3) WEATHERED CONGLOMERATE
  - (4) FRESH CONGLOMERATE
- SOURCE OF PERVIOUS MATERIAL
  - (5) STREAM GRAVELS



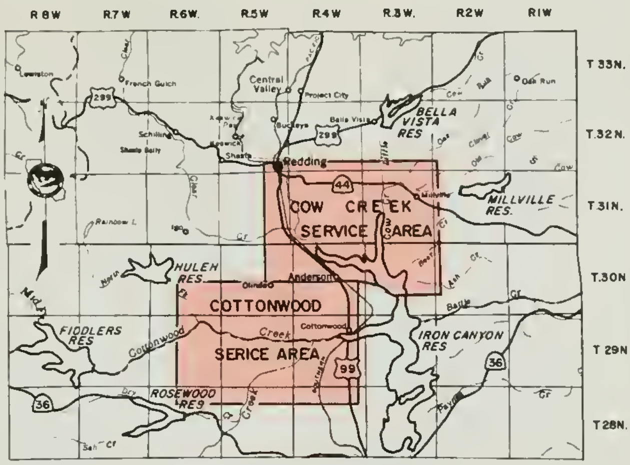
MATERIALS LOCATION MAP

SCALE OF MILES 0 2

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

UPPER SACRAMENTO RIVER BASIN INVESTIGATION

PASKENTA DAM AND RESERVOIR
ON
THOMES CREEK
PRELIMINARY DESIGN



LOCATION MAP

SCALE OF MILES

0 8 16

LEGEND

(green)	"A" ZONE:	BEST AREAS FOR DEVELOPMENT OF GROUND WATER. PROPERLY CONSTRUCTED WELLS SHOULD YIELD SUFFICIENT WATER FOR IRRIGATION
(yellow)	"B" ZONE:	GOOD AREAS FOR DEVELOPMENT OF GROUND WATER. PROPERLY CONSTRUCTED WELLS SHOULD YIELD SUFFICIENT WATER FOR MOST IRRIGATION. YIELDS GENERALLY WILL BE SOMEWHAT LESS THAN IN "A" ZONES.
(orange)	"C" ZONE:	FAIR AREAS FOR DEVELOPMENT OF GROUND WATER. PROPERLY CONSTRUCTED WELLS MAY YIELD SUFFICIENT WATER FOR LIMITED IRRIGATION. YIELDS SHOULD BE SUFFICIENT FOR DOMESTIC AND STOCKWATERING PURPOSES, BUT GENERALLY WILL BE SUBSTANTIALLY LESS THAN "A" OR "B" ZONES.
(pink)	"D" ZONE:	POOR AREAS FOR DEVELOPMENT OF GROUND WATER. PROPERLY CONSTRUCTED WELLS MAY YIELD SUFFICIENT WATER FOR DOMESTIC USE OR STOCKWATERING. THE POSSIBILITY OF DRY HOLES IS MUCH GREATER IN "D" ZONES THAN IN OTHER ZONES.
———		SERVICE AREA BOUNDARY
- - - -		SUBAREA BOUNDARY

STATE OF CALIFORNIA

THE RESOURCES AGENCY

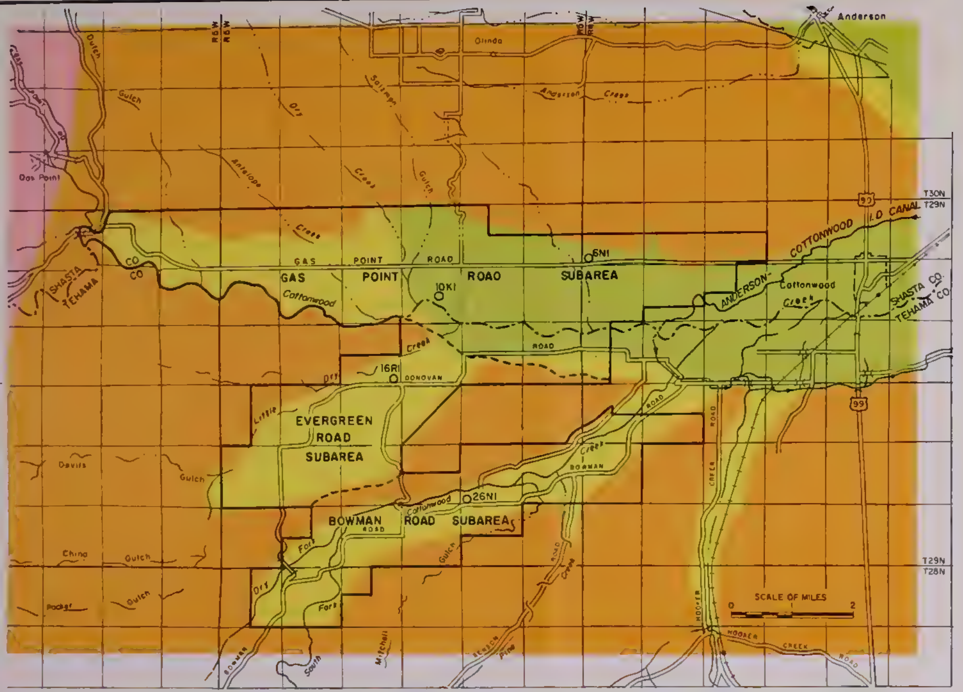
DEPARTMENT OF WATER RESOURCES

NORTHERN BRANCH

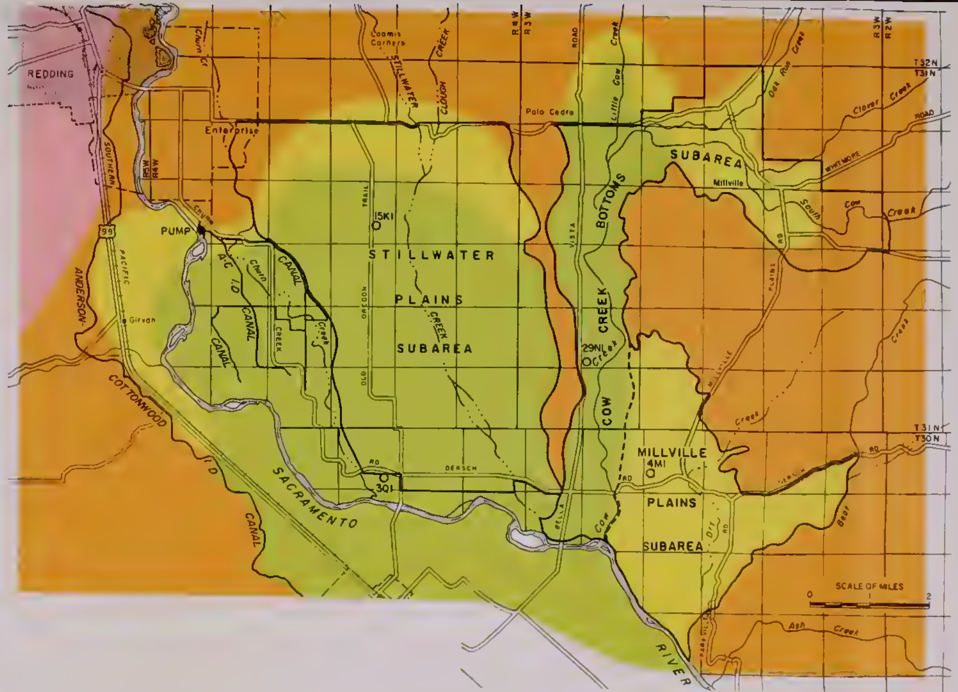
UPPER SACRAMENTO RIVER BASIN INVESTIGATION

GROUND WATER DEVELOPMENT POTENTIAL IN THE COTTONWOOD AND COW CREEK SERVICE AREAS

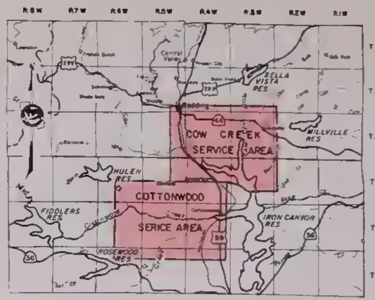
1964



COTTONWOOD SERVICE AREA



COW CREEK SERVICE AREA



LOCATION MAP

SCALE OF MILES

LEGEND

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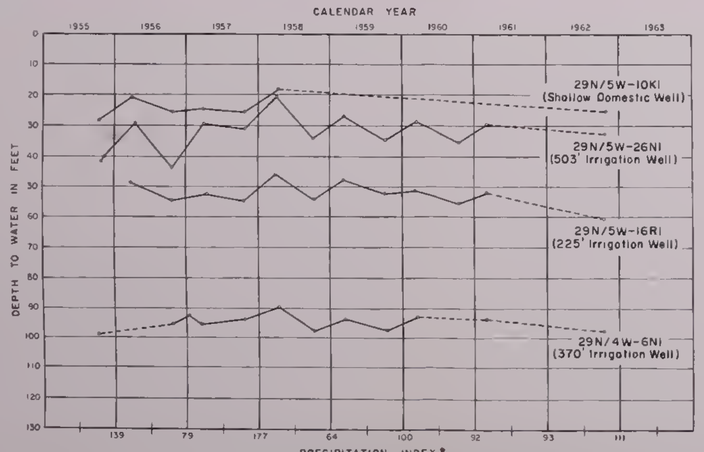
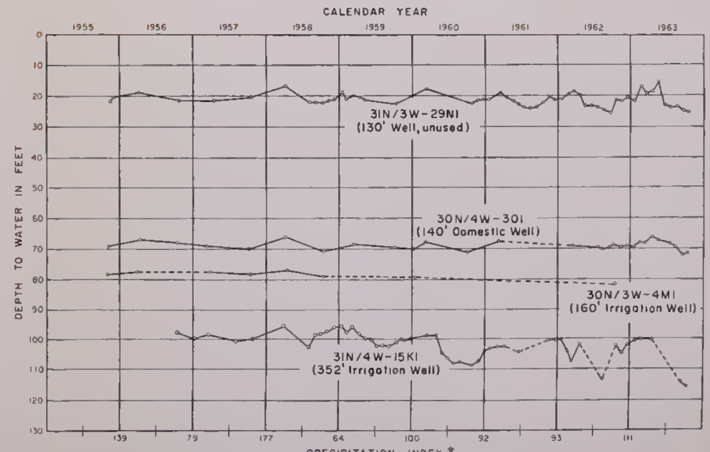
- SERVICE AREA BOUNDARY
- SUBAREA BOUNDARY



WELL HYDROGRAPHS–COTTONWOOD SERVICE AREA

* Seasonal Precipitation (July through June) Times 100 Divided by Average Annual Precipitation (Based on Records at Redding Fire Station No 2)



WELL HYDROGRAPHS–COW CREEK SERVICE AREA

STATE OF CALIFORNIA
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NORTHERN BRANCH

UPPER SACRAMENTO RIVER BASIN INVESTIGATION

GROUND WATER DEVELOPMENT POTENTIAL IN THE COTTONWOOD AND COW CREEK SERVICE AREAS

1964

Call Number:

381809
~~Calif. Dept. of Water~~
Resources.
Bulletin.

TC824
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no.150
c.2