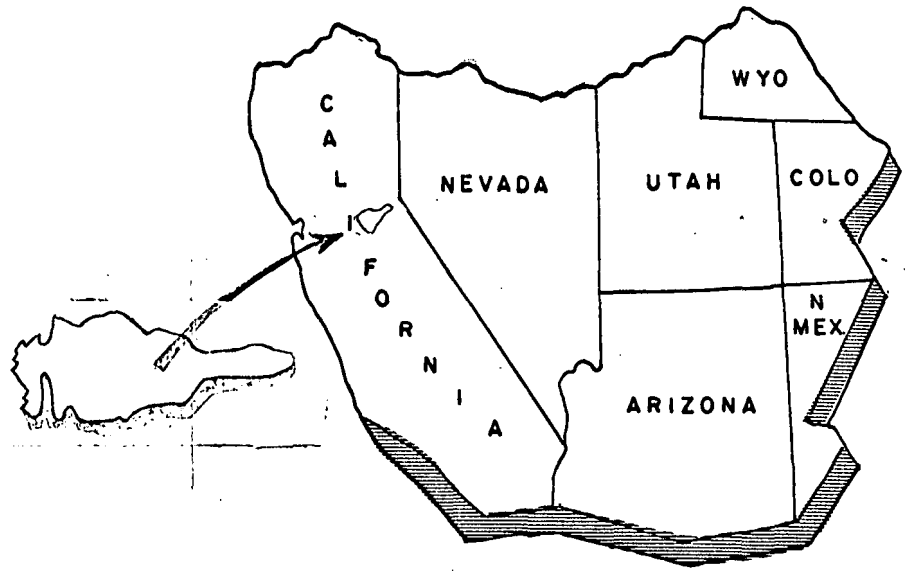
TUOLUMNE RIVER BASIN
STANISLAUS RIVER BASIN
CALIFORNIA

SONORA-KEYSTONE UNIT CENTRAL VALLEY PROJECT

WATER QUALITY CONTROL STUDY



ENVIRONMENTAL PROTECTION AGENCY

DECEMBER 1970

WATER QUALITY CONTROL STUDY
SONORA-KEYSTONE UNIT
CENTRAL VALLEY PROJECT
TUOLUMNE COUNTY, CALIFORNIA

ABSTRACT

The proposed Sonora-Keystone Unit of the Central Valley Project will provide an annual water supply of 30,000 acre-feet for agricultural and municipal uses. If population growth occurs as projected, existing water quality will be degraded. Enrichment of the project reservoirs will support the growth of algae and other aquatic plants which will interfere with recreational use. Multi-level outlets will be necessary to allow the withdrawal of the best available quality of water for beneficial uses including protection of downstream fisheries. With provision of such outlets, the proposed reservoir releases will be of adequate quality and quantity to maintain downstream beneficial uses and storage for flow regulation will not be required.

ENVIRONMENTAL PROTECTION AGENCY

DECEMBER 1970

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I. INTRODUCTION

AUTHORITY

The water quality control study of the Sonora-Keystone Unit of the Central Valley Project which is described in this report was made in accordance with the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.) and Executive Order 11507, February 4, 1970.

PURPOSE AND SCOPE

The purpose of this report is to describe (1) the need for and value of reservoir storage for streamflow regulation for water quality control and (2) the potential impact of the project on water quality. The study is limited to those tributary streams of the Stanislaus and Tuolumne Rivers that are affected by the project, (North Fork Tuolumne River, South Fork Stanislaus River, and Sullivan Creek). The study period of 1970 to 2020 is considered in this report. Facilities were provided in this study on a schedule to meet increasing needs up to a 50-year design horizon, with necessary replacements, maintenance, and operation of facilities projected for a 100-year economic life.

ACKNOWLEDGEMENTS

The following Federal, State, and local agencies have provided valuable assistance in the preparation of this report:

California Regional Water Quality Control Board, Central Valley Region, Sacramento, California

Tuolumne County Planning Commission
Sonora, California

U. S. Bureau of Outdoor Recreation
San Francisco, California

U. S. Bureau of Reclamation, Region 2
Sacramento, California

U. S. Bureau of Sport Fisheries and Wildlife
Sacramento, California

U. S. Forest Service, Stanislaus National Forest
Sonora, California

II. SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

FINDINGS

1. The first stage project of the Sonora-Keystone Unit would develop runoff in the Stanislaus and Tuolumne River Basins to provide an annual water supply of 30,000 acre-feet. This supply would be used in a gross service area of 150,000 acres situated on a ridge between the deep canyons of the Stanislaus and Tuolumne River systems. In addition, 20,700 acre-feet would be used annually for fishery releases.

2. Including summer residents, the present (1970) population of the study area is estimated at approximately 21,000 persons and is concentrated in the vicinity of Sonora, Twain Harte, Mi-Wuk Village, and Tuolumne.

3. The area's economy depends upon recreation, agriculture, mineral production, and lumbering. Recreation is an important activity, with the Stanislaus National Forest, Yosemite National Park, Dodge Ridge ski area, and historic mining towns such as Columbia providing the major attractions. Recreation homes and cabins also bring numerous visitors into the area.

4. The existing major source of water for the study area is the Tuolumne Canal System. It diverts water from the South Fork Stanislaus River at Lyons Reservoir to supply local requirements and to generate hydroelectric power.

5. No significant ground water basins exist within the study area, and additional development will be limited to individual efforts.

6. Surface waters of the Stanislaus and Tuolumne Rivers are generally of excellent mineral quality and are well suited for all beneficial uses.

7. Waste discharge requirements established by the California Regional Water Quality Control Board, Central Valley Region attempt to eliminate direct surface discharges to the streams of the area, whenever possible.

8. The population of the study area is projected to increase from approximately 21,000 in 1970 to 54,730 by the year 2020. Annual recreational use will exceed 1.4 million recreation days.

9. Annual water requirements for municipal and industrial use, irrigation, and fishery releases will increase from 31,700 acre-feet in 1970 to 50,700 acre-feet by the year 2020.

CONCLUSIONS

1. Anticipated use of the study area will result in greatly increased waste loads that will overload the present disposal to land systems. Additional controls such as restrictions on land use, advanced waste treatment, and/or collection and export of wastes will be necessary to minimize water quality degradation.

2. Browne's Meadow and New Phoenix Reservoirs will stratify. Multi-level outlets will be needed in order to obtain the best available quality of water for downstream releases as well as for diversion for municipal use.

3. Projected nitrogen and phosphorus concentrations in waters of Lyons, New Phoenix, and Browne's Meadow Reservoirs will support undesirable algal and aquatic growths which will reduce the quantity and the quality of recreational use at the reservoirs.

4. Assuming adequate waste treatment (85 percent BOD removal) is provided, and multi-level outlets are installed, storage for flow regulation for water quality control will not be required in project reservoirs.

5. The project will affect water quality in the Sacramento-San Joaquin Delta. It will be necessary to operate the reservoirs in conjunction with all other units of the Central Valley Project in a manner which will avoid violation of Federal/State water quality standards established for the delta.

RECOMMENDATIONS

1. The U. S. Bureau of Reclamation should work with Federal, State, and local agencies to insure that land use restrictions and waste collection and treatment facilities required to minimize water quality degradation will be provided.

2. Multi-level outlets should be installed in Browne's Meadow and New Phoenix Reservoirs to permit withdrawals from various depths in order to obtain the best quality water available for downstream releases, as well as diversions for municipal, industrial, and agricultural use.

3. In accordance with Executive Order 11507, this project should be operated in conjunction with all other units of the Central Valley Project in a manner which will prevent violation of Federal/State water quality standards established for the Sacramento-San Joaquin delta.

4. Contract specifications for the various facilities should include provisions necessary to protect water quality during construction.

5. Since water quality in and downstream of the proposed reservoirs is dependent on the operation schedule of the reservoirs, the Federal Water Quality Administration should be apprised of all revisions in the operation schedules of project reservoirs so that the Bureau of Reclamation can be advised on questions concerning water quality.

III. PROJECT DESCRIPTION

The Sonora-Keystone Unit of the Central Valley Project would develop water resources of the Stanislaus and Tuolumne River Basins for use in Tuolumne County, California. Project plans call for construction in stages. The proposed first stage project, which is evaluated in this report, would provide for construction of Browne's Meadow Reservoir with a capacity of 60,000 acre-feet on the North Fork Tuolumne River, and the enlargement of Phoenix Reservoir to a capacity of 30,000 acre-feet on Sullivans Creek. These project reservoirs when operated in conjunction with existing Lyons Reservoir (capacity 5,500 acre-feet) on the South Fork of the Stanislaus River, would provide the gross service area of 150,000 acres in the vicinity of Sonora, California with a total annual water supply of 30,000 acre-feet. Of this total, 16,000 acre-feet would be for agricultural purposes and 14,000 acre-feet for municipal and industrial requirements. An additional 20,700 acre-feet would be provided annually for fishery releases. The first stage project would also include construction of Browne's-Lyons Conduit, Mi-Wuk Pumping Plant, and about 40 miles of new pipelines to serve municipal, industrial and agricultural requirements (see figure 1 at back of report).

The first stage facilities could be incorporated into an expanded or second stage project which would provide an additional 16,000 acre-feet of water per year to meet the projected water requirements of the service area for the year 2020. This second-stage would be required approximately 25 years after completion of the first stage and as presently proposed would consist of Bell Meadows Reservoir (capacity 12,000 acre-feet), Pine Valley Reservoir (capacity 2,600 acre-feet) and an enlarged Lyons Reservoir. The second stage features are not evaluated in this report.

The Sonora-Keystone Service area has been divided into three subareas (see figure 1). Service for the Mi-Wuk Subarea will be provided by pumping from the Browne's-Lyons Conduit which heads at Browne's Reservoir. The Tuolumne Ditch Subarea will be served from the existing Tuolumne Ditch which heads at existing Lyons Reservoir. The Sonora Subarea will be served from conveyance and distribution facilities that will head at New Phoenix Reservoir.

IV. STUDY AREA DESCRIPTION

LOCATION AND BOUNDARIES

The study area is located within Tuolumne County, which is situated on the western slopes of the Sierra Nevada directly east of San Francisco, California. Prinicipal communities within the study area include Sonora, Twain Harte, Tuolumne, Mi-Wuk Village, and Long Barn. The study area also includes major portions of the Stanislaus National Forest. The area is bordered on the north and west by the Stanislaus River and its South Fork, and on the east and the south by the Tuolumne River and its North Fork. Thus, the study area is situated on a ridge between the deep canyons of the Stanislaus and Tuolumne River systems.

GEOGRAPHY AND GEOLOGY

Most of the 1,456,000 acres in Tuolumne County are within either the Stanislaus National Forest or Yosemite National Park. Elevations range from less than 400 feet in the foothills to over 13,000 feet at the crest of the Sierra Nevada. The topography ranges from gentle and moderately rolling foothills to rugged slopes. Vegetative cover in the rolling foothills consists of open grasslands, brush, oak trees, and native and improved grasses. Vegetative cover changes to extensive tracts or merchantable timber as the elevations increase.

Geologic features of the area are characteristic of the Sierra Nevada which has been described as an immense, tilted fault block. The area can be divided into two major geologic provinces, (1) a low elevation or foothill belt largely composed of metamorphic rocks, and (2) the High Sierra, principally composed of granitic rocks. The soils found in Tuolumne County can be divided into two broad categories. The first is recent alluvial soils which are suitable for croplands. The second category is the upland soils which are limited primarily to drylands or irrigated pasture and deciduous orchards.

CLIMATE

Because of the wide range in elevation, precipitation and temperature vary greatly throughout the area. The average monthly distribution of precipitation at selected points in and near Tuolumne County is shown in table 1. The elevation

at Knight's Ferry, Sonora, and Pinecrest is 320, 1825, and 5350 feet respectively. Practically all of the precipitation occurs during the months of October through April, and the annual precipitation increases as the elevation increases.

TABLE 1

AVERAGE MONTHLY DISTRIBUTION OF PRECIPITATION AT KNIGHT'S FERRY, SONORA, AND PINECREST [1]

Month	Precipitation in Inches		
	Knight's Ferry	Sonora	Pinecrest
October	0.8	1.5	2.9
November	1.4	3.0	4.3
December	3.2	5.2	7.9
January	3.7	6.3	7.5
February	3.2	5.6	7.6
March	2.9	5.4	6.1
April	1.5	2.6	4.6
May	0.6	1.2	2.2
June	0.1	0.3	0.9
July	0.0	0.0	0.1
August	0.0	0.0	0.0
September	0.3	0.2	0.6
Totals	17.7	31.3	44.7

The foothill areas typically experience hot, dry summers and mild winters. Above 5,000 feet the winter is long, usually severe, and accompanied by heavy snowfall. The varied climate causes a wide range in the length of the growing season, which varies from 135 days in the upper areas to 255 days in the lower elevations.

PRINCIPAL COMMUNITIES

The gold rush days brought a large influx of "fortune seekers" into the area in the early 1850's, and many of the old mining towns that sprang up along the Mother Lode are still in existence. Sonora, the only incorporated city and the county seat, had a 1960 population of 2,725, and the Sonora census division had a total population of 7,913. In recent years, the population in

the area of Twain Harte, Pinecrest, Mi-Wuk Village, Long Barn, and Strawberry has increased rapidly due to the establishment of summer homes and cabins in the area. The 1960 population of the Twain Harte-Tuolumne census division was 4,910. The 1960 census showed a combined population of 1,581 in the remainder of the county; thus, the total population of the county was 14,404 at the time of the 1960 census [2]. By 1968, the total county population was estimated to have increased to 20,400 [3].

V. ECONOMY

PRESENT

The Sonora-Keystone study area is located within Tuolumne County and includes the major economic centers of the county. Therefore, economic conditions in the study area are similar to those of Tuolumne County.

Total employment in Tuolumne County in 1967 was 3291 with the breakdown by industry as shown in table 2. Employment in the manufacturing industry is primarily in the field of lumber and wood products. Production approached 192 million board feet in 1966. Agriculture is also of economic importance to the area with more than a tenth of county land being in farms [3].

Recreation constitutes an important economic activity of Tuolumne County and the Sonora-Keystone study area. The Stanislaus National Forest, Yosemite National Park, Dodge Ridge ski area, and historic mining towns such as Columbia are major attractions to recreationists. Development of recreation homes and cabins in areas near Twain Harte, Mi-Wuk Village, Tuolumne, Long Barn, Pinecrest, and Strawberry has increased rapidly in recent years. In 1967 the Summit Ranger District of the Stanislaus National Forest had an annual use of 1,752,000 visitor-days (12-hour aggregate use). Recreation activities include camping, picnicking, hiking, winter sports, boating, and swimming.

TABLE 2

TUOLUMNE COUNTY EMPLOYMENT [3]
1967

Industry	Employment
Manufacturing	932
Retail and Wholesale Trade	876
Services	681
Contract Construction	319
Transportation & Public Utilities	264
Finance, Insurance, Real Estate	119
Other	100
Total	3,291

FUTURE

Estimates of future population within the study area were made by the U. S. Bureau of Reclamation. These projections are shown in table 3.

TABLE 3

ESTIMATED POPULATIONS-SONORA-KEYSTONE UNIT
(Including Summer Recreation Resident Population)

Year	Sub-Areas			Total
	Mi-Wuk	Tuolumne Ditch	Sonora	
1970	2350	9060	9810	21,220
1980	3080	11880	12750	27,710
1990	3830	14610	15820	34,260
2000	4580	17530	18990	41,100
2010	5300	20460	22160	47,920
2020	6040	23370	25320	54,730

The economic importance of recreation to the area is expected to increase as development of recreation facilities attracts additional visitors to the area. Preliminary estimates by the U. S. Bureau of Outdoor Recreation indicate that recreational use at Lyons, New Phoenix, and Browne's Meadow Reservoirs will exceed 1.4 million general recreation-days during the summer recreation season.

Development of recreation homes and cabins will play an important part in future economic activity. Projections of summer resident recreation populations were made by the U. S. Bureau of Reclamation and are shown in table 4.

TABLE 4

PROJECTED RESIDENT RECREATION POPULATION
YEAR 2020

Month	Mi-Wuk Subarea	Tuolumne Ditch Subarea
October	2440	3380
November	0	0
December	0	0
January	0	0
February	0	0
March	0	0
April	0	0
May	2440	3380
June	4200	7450
July	7200	11800
August	6800	11300
September	4200	7100

VI. WATER RESOURCES OF THE STUDY AREA

SURFACE WATER

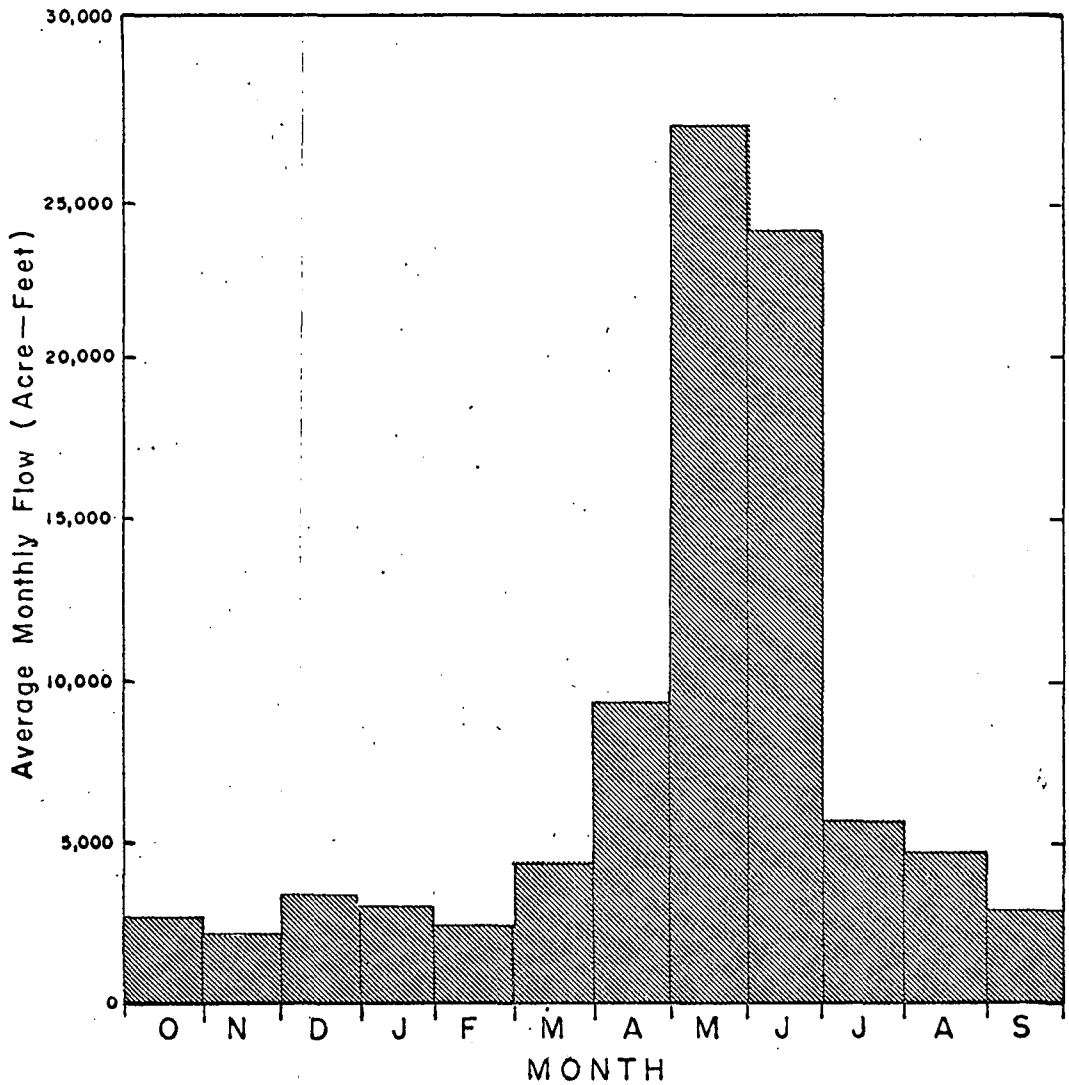
Runoff in the Stanislaus and Tuolumne River Basins is derived primarily from melting snow. Therefore, peak flows generally occur in the spring and early summer months, and low flows occur in the late summer months. Average monthly discharges for the South Fork of the Stanislaus River at Strawberry and the North Fork of the Tuolumne River near Tuolumne are shown in figure 2 and figure 3, respectively.

Annual runoff also varies considerably due to large fluctuations in annual precipitation which falls in the form of snow on the upper mountains. Estimates of natural runoff at selected stations in the vicinity of the study area have been made by the California Department of Water Resources [1]. Some of these estimates of average annual natural runoff and drainage areas are shown in table 5.

TABLE 5

ESTIMATED AVERAGE ANNUAL NATURAL RUNOFF
AT SELECTED STATIONS [1]
(1920-1955)

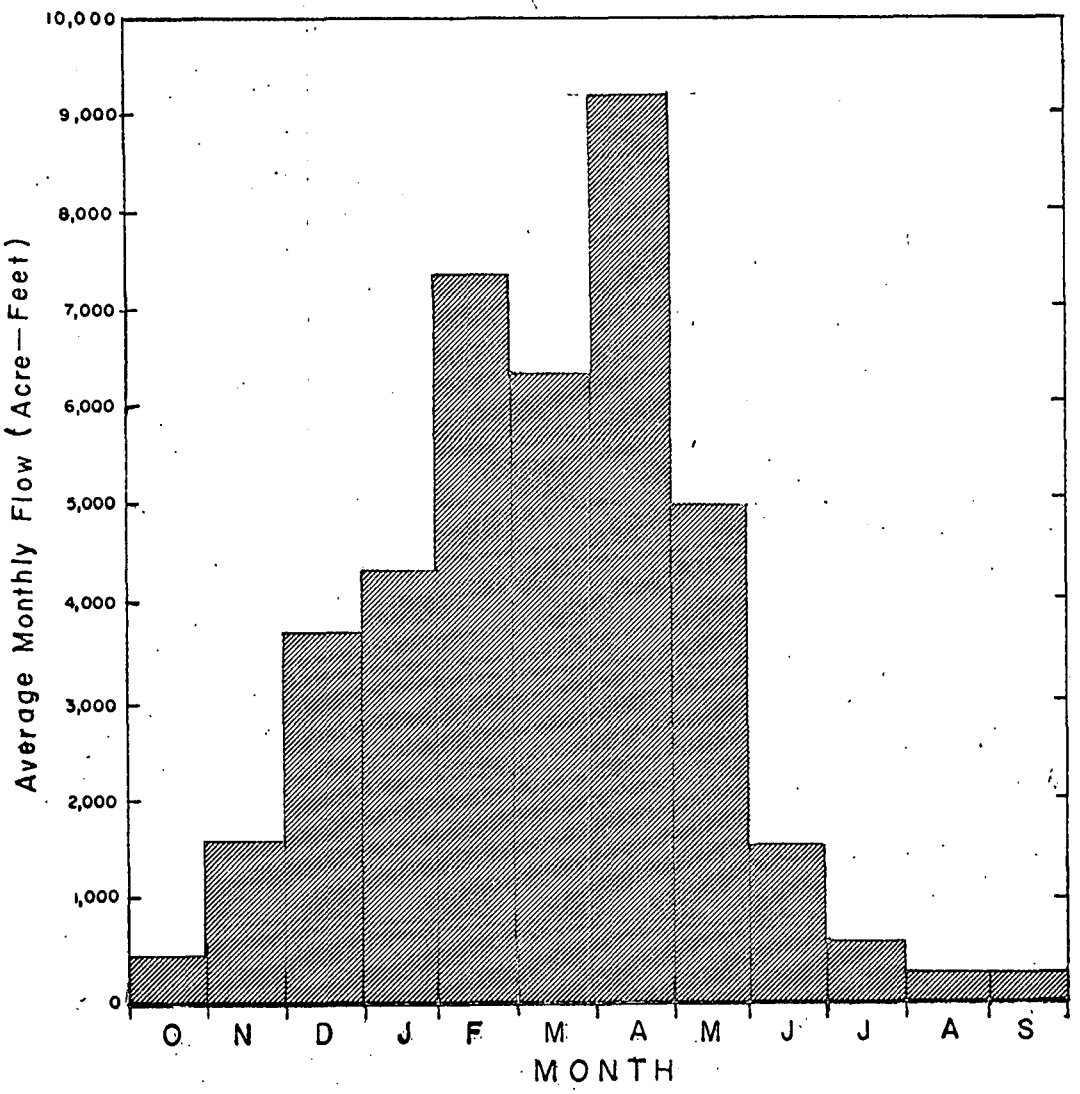
Station	Drainage Area in Square Miles	Runoff 1000's AF
South Fork Stanislaus River at Strawberry	49	85
South Fork Stanislaus River near Long Barn	67	105
Stanislaus River near Knight's Ferry	972	1,067
North Fork Tuolumne River at Browne's Meadow Dam Site	-	21
Tuolumne River near Hetch Hetchy	462	723
Tuolumne River above La Grange Dam	1,540	1,724



SONORA KEYSTONE STUDY

AVERAGE MONTHLY FLOW
SOUTH FORK, STANISLAUS RIVER
AT STRAWBERRY, CALIF.

Figure 2



SONORA KEYSTONE STUDY

AVERAGE MONTHLY FLOW
NORTH FORK, TUOLUMNE RIVER
NEAR TUOLUMNE, CALIF.

Figure 3

Flow of the Stanislaus River is regulated by reservoirs, conduits, and power facilities of the Pacific Gas and Electric Company as well as by Melones Reservoir, operated by the Oakdale and South San Joaquin Irrigation Districts. Melones Reservoir is presently being enlarged by the U. S. Army Corps of Engineers. Flow of the Tuolumne River is regulated by major storage reservoirs (Hetch Hetchy, Lake Eleanor, and Cherry Lake) and diversion facilities of the City and County of San Francisco as well as by Don Pedro Reservoir which is operated by the Modesto and Turlock Irrigation Districts. Don Pedro Reservoir is presently being enlarged.

GROUND-WATER

No significant ground-water basins exist within the study area. Ground-water use is limited to individual and small local withdrawals. The wells have a limited capacity and many provide insufficient supplies during late fall months of water deficient years. Additional development will be limited to individual efforts.

QUALITY OF SURFACE AND GROUND-WATER

The surface waters of the Tuolumne and Stanislaus Rivers are of excellent mineral quality in the study area and are generally suited for all uses. The waters are characterized by a low content of total dissolved solids, chloride, boron, and by a low percentage of sodium. The waters are within the limits of a Class I irrigation water (suitable for most crops under any condition of soil and climate) and the U. S. Public Health Service Drinking Water Standards for raw water supplies.

Ground-water in the study area is generally of satisfactory quality for irrigation uses. However, the ground-water from some wells has been found to exceed the U. S. Public Health Service Drinking Water Standards for arsenic, iron, and manganese [1].

Mineral analyses of surface and ground-water in the Upper Stanislaus and Tuolumne basins are shown in table 6. Monthly samples are taken by Department of Water Resources from the Tuolumne River below Don Pedro Reservoir and from the Stanislaus River at Tullock Reservoir. Records from this sampling program indicate that both rivers consistently are of excellent quality.

TABLE 6

MINERAL ANALYSIS OF REPRESENTATIVE WATERS OF THE STANISLAUS AND TUOLUMNE RIVER BASINS [1]

Sample Point	Sample Date	Conductance at 25°C (EC x 10^6)	Percent sodium	Mineral constituents, in parts per million: Boron (B)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate and bicarbonate (HCO_3/CO_3)	Chloride (Cl)	Sulfate (SO_4)	Nitrate (NO_3)	Total dissolved solids
Surface water in Stanislaus River Basin												
South Fork Stanislaus at Lyons Reservoir	6/15/59	25	33	.10	2.1	0.2	1.7	10	1.0	0.6	0.6	21
South Fork Stanislaus at Italian Bar	5/14/59	22	30	.17	2.6	0.1	1.7	12	0.3	1.0	0.4	21
Surface water in Tuolumne River Basin												
Hunter Creek near Tuolumne	6/16/59	108	17	.07	14	1.4	4.2	56	2.5	1.0	0.6	73
North Fork Tuolumne River near Tuolumne	6/16/59	78	27	.07	8.2	1.3	4.6	42	1.0	0.6	0.8	65
North Fork Tuolumne River near Long Barn	6/15/59	69	25	.10	7.2	1.2	4.0	38	1.5	0.0	0.9	64
Clavey River near Tuolumne	6/16/59	36	27	.10	3.3	017	2.1	16	1.0	0.8	0.7	29
Tuolumne River at Lumsden	6/16/59	17	28	.10	1.9	0.4	1.2	8	1.0	0.6	0.6	13
Ground-water from wells in both river basins												
AVERAGE OF TEN SAMPLES		501	14	.11	45	28	18	259	12	30	9.0	---

VII. WATER USES

PRESENT

Development of water resources within the Tuolumne and Stanislaus River Basins has been primarily confined to projects that supply water to areas outside of the study area. The Modesto and Turlock Irrigation Districts constructed Don Pedro Reservoir in 1923 to obtain a water supply for the lower Tuolumne River Basin. They are presently constructing New Don Pedro Reservoir to enlarge this supply and to generate hydroelectric power. The City and County of San Francisco developed Hetch Hetchy, Lake Eleanor, and Cherry Lake Reservoirs to supply municipal and industrial water to the San Francisco Peninsula. Oakdale and South San Joaquin Irrigation Districts constructed Melones Reservoir on the Stanislaus River in 1926, and the Tri-Dam Project in 1957. New Melones Reservoir is presently being constructed by the U. S. Army Corps of Engineers.

At the present time, the greater part of the study area receives its water supply from the Tuolumne Canal System, owned and operated by the Pacific Gas and Electric Company. Water is diverted from the South Fork Stanislaus River downstream from the existing Lyons Reservoir and into Tuolumne Ditch. Water is withdrawn from Tuolumne Ditch to supply local water requirements and for generation of hydroelectric power in the Phoenix power house, from which it is allowed to flow into a tributary of Sullivan Creek and eventually into Phoenix Reservoir.

Present water deliveries within Tuolumne County Water District No. 2, which includes the Sonora-Keystone study area, average about 9,000 acre-feet annually. Urban, suburban, rural, domestic, and recreational developments require about 28 percent of this total; irrigated crops require the remaining 72 percent.

FUTURE

In the future, water resources of the study area will continue to be used extensively for irrigation, fish propagation, municipal supplies, and recreation. Recreation will continue as an important economic activity of the area and, therefore, non-consumptive recreational uses of water will be particularly significant. Projections of future water requirements for municipal and industrial use, irrigation, and fish propagation within the Sonora-Keystone Unit were made by the U. S. Bureau of Reclamation and are shown in table 7.

TABLE 7

WATER REQUIREMENTS
SONORA-KEYSTONE UNIT
(Acre-Feet/Year)

Year	M&I	Irrigation	Fishery Releases a/	Total
1970	5,300	5,700	20,700	31,700
1975	6,140	9,240	20,700	36,080
1980	6,980	12,770	20,700	40,450
1990	8,660	16,300	20,700	45,660
2000	10,340	16,300	20,700	47,340
2010	12,020	16,300	20,700	49,020
2020	13,700	16,300	20,700	50,700

a/ Includes 5,400 acre-feet for South Fork Stanislaus River and 15,300 acre-feet to North Fork Tuolumne River.

The U. S. Fish and Wildlife Service has projected fishing use of the project reservoirs, as well as the South Fork Stanislaus River and North Fork Tuolumne River. The angler use resulting from project conditions and proposed management and development measures is shown in table 8. New Phoenix Reservoir would support an expanded warm water fishery. Browne's Meadow Reservoir, Lyons Reservoir, North Fork Tuolumne River, and South Fork Stanislaus River would support trout fisheries.

TABLE 8

PROJECTED FISHERY USE
SONORA-KEYSTONE UNIT[4]
(Angler-days)

Location	1971	2020
Browne's Meadow Reservoir	50,000	150,000
Lyons Reservoir	27,500	37,500
New Phoenix Reservoir	31,100	89,600
North Fork Tuolumne River	22,000	38,000
South Fork Stanislaus River	9,200	23,600

Recreational use of the project reservoirs will constitute an important use of water in the study area. This use, excluding fishery use, was projected by the U. S. Bureau of Outdoor Recreation (table 9). The projection is based upon the assumption that domestic and recreational waste loads will receive treatment that will remove 80 percent of the nitrogen and 90 percent of the phosphorus.

TABLE 9

RECREATION USE
SONORA-KEYSTONE UNIT [5]
(Recreation-days)

Reservoir	Project Year		
	1	25	50
New Phoenix Reservoir	104,000	420,000	500,000
Browne's Meadow Reservoir	275,000	676,000	768,000
Lyons Reservoir	88,000	178,000	200,000

VIII. WATER QUALITY CRITERIA

Protection of existing and proposed beneficial uses of the area's water resources requires the maintenance of certain levels of water quality.

In order to protect the trout fishery, it is necessary to maintain a dissolved oxygen concentration of 7 mg/l and temperatures below 70 degrees Fahrenheit. Since New Phoenix Reservoir will support a warm water fishery, an expanded fishery will be developed. Warm water game fish are tolerant to temperatures above the mid-seventies and dissolved oxygen levels near 5 mg/l.

Recreational use of the streams and reservoirs will require that water quality criteria provide water conditions which are aesthetically acceptable to the recreationist. Recreational use of project reservoirs will be partially dependent upon the acceptability of such physical parameters as temperature, clarity, color, odor, and the absence of nuisance growths of algae and other aquatic vegetation. In addition, water must be essentially free toxic substances and pathogenic organisms which are dangerous to public health.

Nutrient criteria are needed which when enforced, will restrict aquatic growth to a level comparable with natural lakes of generally pleasing character. Hutchinson has cited phosphorus levels of 0.01-0.03 mg/l PO_4-phosphorus as typical of clean lakes [6]. From a study of lakes in Wisconsin, Lackey and Sewyer have recommended 0.015 mg/l PO_4-phosphorus and 0.30 mg/l inorganic nitrogen as maximum levels to be present at the time of spring overturn if nuisance growths of algae are to be avoided [7]. The FWQA has suggested a water quality of 0.02 mg/l total phosphorus for Lake Sebasticook, Maine [8]. The Lake Erie Enforcement Conference Technical Committee has recommended water quality objectives of 0.015-0.025 mg/l total PO_4-phosphorus and 0.30 mg/l total inorganic nitrogen for Lake Erie [9]. Sylvester has suggested that undesirable algal crops and taste and odor problems were accompanied by combinations of nitrate plus ammonia nitrogen levels and combined tannin and lignin levels when each rose above 0.50 mg/l [10].

IX. WATER QUALITY CONTROL NEEDS

PRESENT

To provide the protection needed to maintain water quality compatible with beneficial uses, the California Regional Water Quality Control Board, Central Valley Region, has established waste discharge requirements in the area. A current objective of the board is to eliminate direct surface discharges to streams.

At the present time, waste loads in the study area are primarily attributable to municipal, recreational, and agricultural development. Industrial development is limited, and the waste load from this source is correspondingly small. The present (1967) study area population is approximately 20,000 persons. Sonora and Jamestown provide primary treatment and discharge to Woods Creek; the town of Tuolumne provides primary treatment prior to discharge to the North Fork of the Tuolumne River. Long Barn, Mi-Wuk Village, and other communities discharge wastes to land by means of leaching fields or hillside sprinkling after treatment by septic tanks.

Twain Harte, a favorite location for recreation homes, has an estimated winter population of 2,000 and a summer population of 3,500. Waste water from Twain Harte receives primary treatment and is discharged on land by means of hillside sprinklers. Hydraulic overloading during the summer months results in a direct discharge to Sullivan Creek. Waste loads from recreational development upstream of the study area at Pinecrest and the Dodge Ridge ski area are discharged to land which drains to the South Fork Stanislaus River and North Fork Tuolumne River.

FUTURE

Anticipated development in the study area will result in greatly increased waste loads. Municipal and industrial, agricultural and recreational waste loads will all increase. Projected nitrogen and phosphorus waste loads for various stream basins prior to any treatment are shown in table 10.

TABLE 10

AVERAGE ANNUAL NITROGEN AND PHOSPHORUS WASTE LOADS a/
(1000's Lbs.)

Basin	1970		1995		2020	
	N	P	N	P	N	P
S. F. Stanislaus	127	32	400	100	628	157
N. F. Tuolumne	166	30	494	123	776	187
Sullivans Creek	87	22	197	50	231	58
Woods Creek	123	31	208	52	278	69

a/ Includes municipal, industrial, agricultural and recreational loads without treatment

The waste treatment methods currently used in the area will not be capable of adequately treating these projected waste loads. A concise description of the problem is provided in a statement by the California Regional Water Quality Control Board, Central Valley Region:

> Topography, geology and soil conditions usually encountered in the foothill and mountainous areas generally are not conducive to the exclusion of any appreciable volumes of liquid wastes. Intensive development usually leads to the ultimate failure of the disposal system with accompanying deterioration of surface and ground water quality. This is especially true where raw or partially treated wastes are involved. The shallow soils in these areas soon become saturated and direct and indirect run-off occurs in ever increasing volumes. Downstream water users are generally unaware of the inherent dangers, believing themselves protected by a no discharge policy or ordinance. Of special note are discharges from winter sports areas. When the ground is frozen, the discharges may pass directly to surface streams. Rains and spring melt saturate the soil so that thawed wastes are conveyed directly into the adjacent ground waters which discharge rapidly to surface streams. A policy of waste exclusion is ineffectual at best and may be unreasonable under such conditions. [11]

Studies by Foster and others [12] on nutrient removals by hillside spraying provide quantitative data on the limitations of land disposal systems. Under favorable loading and weather conditions,

phosphate removals varied from 76 percent to 93 percent and total nitrogen removal from 54 percent to 68 percent. During unfavorable winter weather conditions, phosphate and total nitrogen removals were reduced to 27 and 26 percent respectively.

Waste water renovation efficiencies by spraying onto forested land was also studied by Parizek et al. [13]. Results varied with soil depth and application rates. Percentage removals ranged from 38.0 to 86.0 for nitrate N, 25.0 to 86.0 for organic nitrogen as N, and 60.5 to 99.2 for phosphorus, as soil depth varied from forest floor to twelve inches, and application rate varied from one to two inches per week.

In view of the increased waste loads projected and the limitations of disposal systems presently in use, maintenance of water quality at a level compatible with present and future beneficial uses will require provision of additional controls. These controls could take the form of restrictions on land use, advanced waste treatment, and/or collection and export of wastes.

Due to the presence of scattered waste loads which are not amenable to central collection, such as those associated with recreation and recreation homes, it is estimated that even with the above-mentioned controls or protective measures, it will be very difficult or economically impractical to obtain a nutrient removal efficiency greater than 80 percent nitrogen and 90 percent phosphorus. Advanced waste treatment or a waste export system serving the major population centers will be necessary to achieve this overall efficiency.

X. PROJECTED WATER QUALITY

WATER QUALITY IN THE RESERVOIRS

Concentrations of nitrogen and phosphorus in the project reservoirs were calculated assuming various levels of treatment efficiency. Table 11 shows the projected concentrations in the year 2020 with the highest level of treatment assumed feasible being provided, i.e., 30 percent nitrogen removal and 90 percent phosphorus removal.

TABLE 11

PROJECTED NITROGEN AND PHOSPHORUS CONCENTRATIONS
YEAR 2020
(mg/l)

	Lyons Reservoir		New Phoenix Reservoir		Browne's Meadow Reservoir	
	N	P	N	P	N	P
October	1.51	0.19	1.08	0.14	1.26	0.16
November	0.92	0.12	1.08	0.14	1.26	0.16
December	0.43	0.06	1.04	0.13	1.28	0.16
January	0.35	0.05	0.98	0.13	1.34	0.16
February	0.30	0.04	0.93	0.12	1.40	0.17
March	0.26	0.04	0.89	0.12	1.42	0.17
April	0.36	0.05	0.86	0.12	1.37	0.17
May	0.40	0.05	0.82	0.11	1.24	0.16
June	0.42	0.05	0.78	0.11	1.14	0.14
July	0.70	0.08	0.82	0.11	1.14	0.14
August	1.12	0.14	0.92	0.12	1.19	0.14
September	1.53	0.19	1.04	0.14	1.26	0.16

The projections consider that a portion of the nutrients entering the reservoirs from the various waste sources will be removed from solution and not be available to support the growth of algae and other aquatic plants. Nutrients are incorporated in plant biomass which is in turn removed from the euphotic zone by such phenomena as sedimentation and transport associated with hydro-mechanical mixing. The percentage of the nutrients that will be retained in an unavailable form will depend upon such factors as nutrient load, volumne of euphotic zone, extent of biological activity, reservoir detention time, and the level from which withdrawals are made. [14]

Nutrient retention in Lyons Reservoir will be comparatively low due to the relatively short average detention time. Average annual nutrient retention is estimated at 10 percent. Due to the longer detention time and the assumption that multi-level outlets will be provided in New Phoenix and Browne's Meadow Reservoirs, the nutrient retention is estimated at 30 and 50 percent respectively.

Even with the retention phenomenon and the assumption of high level of waste treatment, nutrient concentrations projected for the year 2020 will support the growth of algae and other aquatic plants at a level which will interfere with recreational use of the project reservoirs. Algal blooms will result in conditions that will be aesthetically objectionable to recreationists. Growth of rooted aquatic plants will reduce the surface area of the reservoirs and interfere with recreation and fishing activities.

Excessive growth of aquatic plants will increase the organic load present in the water. Using the nutrient levels predicted for 2020, algal yield for each project reservoir was estimated assuming stratification would occur and a dry weight algal cell nitrogen content of 7 percent. This percentage was chosen as representative of the range found by several investigators. [15, 16, 17]. Estimates of the BOD of dead algae [15, 17, 18] used in conjunction with predictions of algal yield indicate that oxygen levels in the lower depths of the project reservoirs may be seriously depressed in summer months during periods of algae die-off. Depressed oxygen levels would affect the fishery in the reservoirs and, if provisions for reaeration or selective withdrawal are not made, would affect the fishery and waste assimilative capacity of the streams below Lyons and Browne's Meadow Reservoirs.

WATER QUALITY DOWNSTREAM OF THE STUDY AREA

Water quality in New Melones Reservoir on the Stanislaus River and New Don Pedro Reservoir on the Tuolumne River will be affected by the Sonora-Keystone Project. The Sonora-Keystone Project will provide 30,000 acre-feet of water for additional agricultural and municipal development. As a result of the additional development, increased waste loads will be generated within the study area. A large majority of the increased load will be tributary to New Don Pedro Reservoir and will result in an increase in the concentration of total dissolved solids. Nutrient trapping in the project reservoirs will reduce the net nutrient load to both New Melones and New Don Pedro Reservoirs. The above mentioned water quality changes would be off-setting, and the net benefits or detriments resulting from such changes would be relatively small when compared with the benefits computed for the project reservoirs.

Ultimately any development in the Central Valley will have an affect on the water quality in the Sacramento-San Joaquin Delta. Water Quality Standards for the Delta as required by the Water Quality Control Act of 1965 (P.L. 89-234) have been adopted by the State and approved by the Secretary of the Interior. The U. S. Bureau of Reclamation will therefore operate the Central Valley Project in such a manner as to maintain these delta water quality standards.

The maintenance of these standards will be dependent in part upon the maintenance of an adequate outflow from the delta for the purpose of conveying conservative wastes out of the Sacramento-San Joaquin River Basins and for repelling the incursion of sea water. The maintenance of this delta outlfow during the critical summer months is dependent upon the integrated operation of all units of the Central Valley Project (CVP) and the State Water Project.

Because the Sonora-Keystone Unit is only one of many units in the CVP and since the operation of the CVP is complex, it is not yet possible to directly relate the required delta outflow in a direct manner to the annual yield to be developed by the Sonora-Keystone Unit. Although the degradation resulting from consumptive use of the water developed in the Sonora-Keystone Unit may be small and not identifiable in the delta, the operation of the entire CVP, including all existing and future units, should recognize and avoid depletion of delta outflow below the level necessary to maintain water quality at least equal to the standards which have been and will be established by the State and Federal Governments.

FLOW REGULATION REQUIREMENTS

Minimum flow requirements immediately downstream of project reservoirs, compatible with conservation and development of fish life, were determined by the U. S. Fish and Wildlife Service and appear in table 12.

Projected waste loads to the South Fork Stanislaus River downstream of Lyons Reservoir and the North Fork Tuolumne River downstream of Browne's Meadow Reservoir are limited to scattered recreational use and natural runoff. The major waste loads in the study area will be discharged above the project reservoirs and Woods Creek.

TABLE 12

FISHERY RELEASES
SONORA-KEYSTONE UNIT

Stream	: April 16 to Oct. 15	: Oct. 15 to April 15
South Fork Stanislaus River below Lyons Reservoir	10 cfs	5 cfs
North Fork of Tuolumne River below Browne's Meadow Reservoir	28 cfs	14 cfs

Fishery releases from Browne's Meadow and Lyons Reservoir will be sufficient to assimilate the projected waste loads and maintain the dissolved oxygen concentration of 7 mg/l necessary to protect the fish resources. Therefore, storage for flow regulation for water quality control will not be required in Browne's Meadow or Lyons Reservoirs. This conclusion is based on the assumptions that (1) adequate treatment providing 85 percent BOD removal will be obtained, and (2) reservoir releases will contain a minimum dissolved oxygen content of approximately 7 mg/l. It is important to note that in view of projected reservoir water quality as discussed previously, assumption (2) is most likely valid only if provisions are made for reaeration or selective withdrawal of reservoir releases.

Sullivan Creek, downstream from Phoenix Reservoir, is intermittent and has no fish resource; therefore, releases for fish maintenance flows will not be made from New Phoenix Reservoir. Due to the lack of beneficial use and the present requirement of the California Regional Water Quality Control Board, Central Valley Region prohibiting direct discharge to surface waters, storage for flow regulation for water quality control will not be required in New Phoenix Reservoir.

MULTI-LEVEL OUTLETS

Browne's Meadow and New Phoenix Reservoirs will have maximum water depths of approximately 200 and 100 feet respectively. Physical and climatic conditions will cause both reservoirs to stratify. Algae die-off may deplete or seriously depress oxygen levels in the hypolimnion of both reservoirs. Multi-level outlets would permit withdrawals from various depths in order to obtain the best quality water available for downstream fishery releases as well as diversions for municipal, industrial, and agricultural use.

An adequate multi-level outlet structure is costly, and these costs must be related to the beneficial effects on downstream water use. It is, however, extremely difficult to foresee and predict with a high degree of accuracy over a long period of time the water quality conditions which may develop at specified levels of a reservoir. The useful life of a reservoir is normally very long and conversion of a single level outlet after the reservoir is constructed is quite costly. In many existing reservoirs adverse water quality conditions have developed which were not anticipated prior to construction. The risks and subsequent costs incurred with single-level outlets are considered greater than the insurance cost of including the multi-level outlet in the initial construction. For these reasons, it is recommended that multi-level outlets be constructed in New Phoenix and Browne's Meadow Reservoirs.

EFFECT OF PROJECT CONSTRUCTION

The construction agency must take adequate measures to protect the quality of both ground and surface waters during construction of the project. Provisions should be included in contract specifications so that contractors will be cognizant of requirements to protect water quality in the work area. Silt detention basins should be constructed at all work areas to eliminate excessively turbid water leaching from earth work from entering surface waters. In equipment maintenance areas, special precautions should be taken to contain spilled fuels, lubrication products and wash water. Waste water disposal systems from construction camps and all other construction activities affecting water quality should comply with requirements of local and state water quality control authorities. Performance specifications should be submitted to the Federal Water Quality Administration by the construction agency for review and comment during the preparation of project plans and specifications in compliance with E. O. 11507.

EFFECT OF WATER QUALITY ON RECREATION

Water quality plays an important part in the consumer behavior of the average recreationist. As water quality varies, public acceptance (expressed as recreation use) also varies. The variety of public reaction to water quality suggests a relationship between certain physical parameters, such as temperature, clarity, color, etc., and the intensity of recreation use. Many parameters influencing the recreationist are actually wrought by chemical and/or biological mechanisms. The turbidity and/or slimes and odors produced by algal populations are prime examples.

A rule curve was developed to relate recreational use intensity to the extent of enrichment of the project reservoirs. This curve,

shown on figure 4, attempts to relate conditions known to exist in eutrophic lakes with the anticipated public reaction, assuming alternative recreation areas exist.

The affect of water quality on the amount of recreational use may be approximated by employing the rule curve. In addition to affecting the amount of recreation use, the water quality of the reservoir water will influence the value of the remaining recreation use. The U. S. Bureau of Outdoor Recreation has indicated that the value of a recreation day will vary from $1.10 to $0.95 at New Phoenix Reservoir and from $1.14 to $1.08 at Lyons Reservoir as the water quality deteriorates from satisfactory to undesirable for recreational use. The corresponding value at Browne's Meadow Reservoir will vary from $1.20 to $0.95. [5]

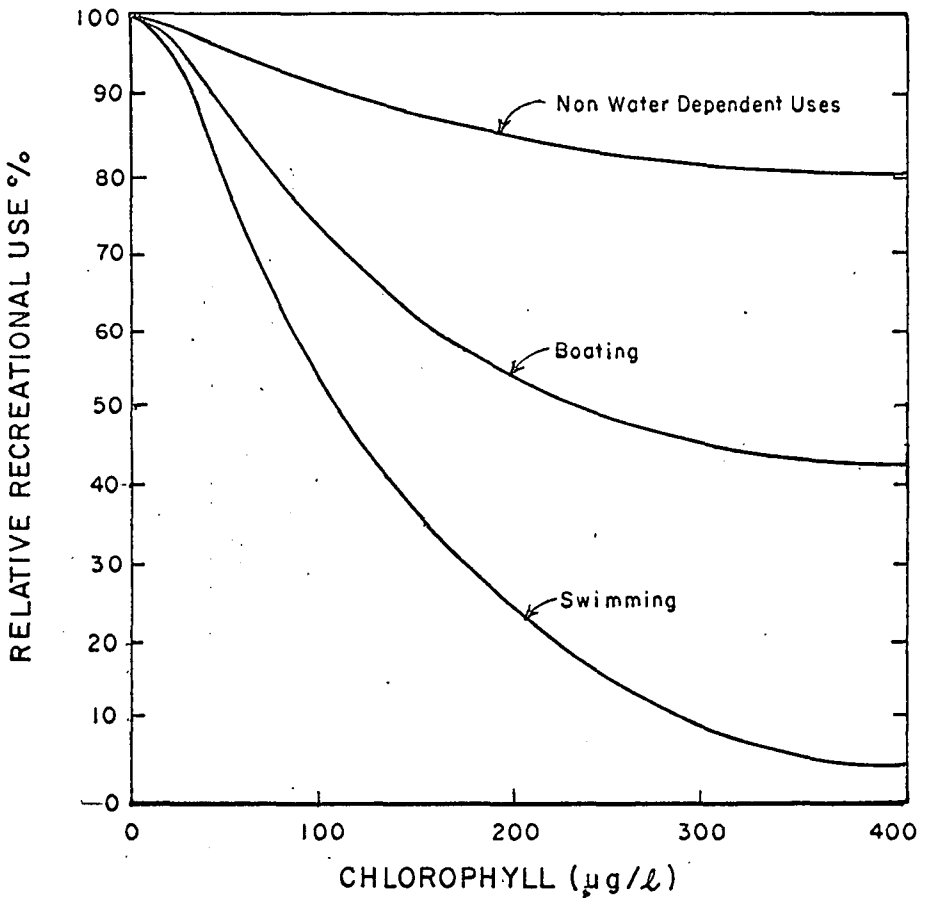
The relationship between recreation use and the projected water quality expressed as chlorophyll (figure 4) was used to determine the probable recreational use that will result at the project reservoirs when the influence of water quality is considered. The resulting use appears in table 13. This use is based upon the assumption that domestic and recreational wastes will receive advanced treatment that will remove 80 percent of the nitrogen and 90 percent of the phosphorus.

TABLE 13
RECREATION USE a/[5]

Project Year	New Phoenix Reservoir Use a/	Browne's Meadow Reservoir Use	Lyons Reservoir Use
1	104,000	275,000	88,000
25	420,000	676,000	178,000
30	500,000	722,000	200,000
35	500,000	768,000	200,000
50	500,000	768,000	200,000
100	500,000	768,000	200,000

a/ Use expressed in recreation days

Even with consideration of water quality, it was found that eventually the demand for recreation at the project reservoirs will exceed the capacity determined by the U. S. Bureau of Outdoor Recreation. The recreation capacities of New Phoenix, Lyons, and Browne's Meadow Reservoirs are 500,000, 200,000 and 768,000 recreation days, respectively. New Phoenix and Lyons reservoirs will reach capacity use in project year 30 and Browne's Meadow in project year 35. It is estimated that if water quality were not a consideration, capacity use of recreational facilities at the three project reservoirs would be reached in project year 25.



NOTE:

1. Above curves compare water dependent recreational use (swimming and boating) and non water dependent uses (camping, sight-seeing etc.) to levels of eutrophication in the project reservoirs expressed here in terms of chlorophyll. These curves are meant to apply during the period of June through September of any year. Water quality benefits or detriments may be estimated from adjustments of projected recreational use using the curves.
2. Chlorophyll (a) concentrations refer to near surface algal crops. Ratios of chlorophyll to biologically available nutrients in the near surface region are assumed as 1:1 for phosphorus and 1:10 for nitrogen by weight.

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WATER QUALITY & RECREATIONAL USE

Figure 4.

XI. REFERENCES

1. CALIFORNIA DEPARTMENT OF WATER RESOURCES. 1962 Bulletin No. 95, Tuolumne County Water District - No. 2, Investigation.

2. U. S. DEPARTMENT OF COMMERCE. United States Census of Population 1960.

3. STATE OF CALIFORNIA. 1968. California Statistical Abstract.

4. U. S. BUREAU OF SPORT FISHERIES AND WILDLIFE. 1967. Memorandum Report to Bureau of Reclamation on Sonora-Keystone Unit, First Stage, Central Valley Project, California.

5. U. S. BUREAU OF OUTDOOR RECREATION. 1970. A Study of the Recreation Aspects of the Proposed Sonora-Keystone Unit, Central Valley Project, Tuolumne County, California.

6. HUTCHINSON, G. E. 1957. Treatise On Limnology, Vol. 1: Geography, Physics and Chemistry. John Wiley.

7. LACKEY, J. B. AND C. N. SAWYER. 1945. Plankton Productivity of Certain Southeastern Wisconsin Lakes as Related to Fertilization. I. Survey. Sewage Works Journal, 17(3), 573-585 pp.

8. FEDERAL WATER POLLUTION CONTROL ADMINISTRATION. 1966. Fertilization and Algae in Lake Sebasticook, Maine.

9. FWPCA REPORT OF THE LAKE ERIE ENFORCEMENT CONFERENCE TECHNICAL COMMITTEE, George L. Harlow, Chairman, Approved by Conferees, June 1, 1967.

10. SYLVESTER, R. O. AND R. W. SEABLOOM. 1965. Influence of Site Characteristics on Quality of Impounded Water. Journal American Water Works Association. Vol. 57, No. 12.

11. CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD, CENTRAL VALLEY REGION. Water Quality Management in Mountainous Areas.

12. FOSTER, H. B. AND P. C. WARD, AND A. PRUCHA. 1965. Nutrient Removal by Effluent Spraying. Journal of Sanitary Engineering, December 1965.

13. PARIZK, R. R., L. T. KARDOS, W. E. SOPPER, E. A. MYERS, D. E. DAVIS, M. A. FARRELL, AND J. B. NESBITT. 1967. Waste Water Renovation and Conservation.

14. MACKENTHUN, K. M. AND W. M. INGRAM. 1967. Biological Associated Problems in Freshwater Environments.

15. JEWELL, WILLIAM J. AND PERRY L. McCARTY. 1968. Aerobic Decomposition of Algae and Nutrient Regeneration. Technical Report No. 91, FWPCA Grant WP-1037. June 1968.

16. FEDERAL WATER POLLUTION CONTROL ADMINISTRATION. 1968. Water Quality Criteria. Report of the National Technical Advisary Committee to the Secretary of the Interior, April 1, 1968.

17. VARMA, MAN M. AND FRANCIS DI GIANO. 1968. Kinetics of Oxygen Uptake by Dead Algae. Journal Water Pollution Control Federation, April 1968.

18. MILOJEVIC, MILOJE. 1967. Contribution of Steam Sterilized Algae to BOD. Journal Water Pollution Control Federation, July 1967.

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