566

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

INVESTIGATION OF TURBID RELEASES FROM TRINITY RESERVOIR--TRINITY RIVER DIVISION CENTRAL VALLEY PROJECT, CALIFORNIA

Report No. Hyd-566

Hydraulics Branch
DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

August 1, 1966

CONTENTS

	Page
Abstract	iii
The Problem	1
Conclusions	1
Acknowledgments	1
Introduction	2
Problem Analysis	3
Field Sampling and Measurements	3
Laboratory Analyses	4
Summary of Results	5
	Table
Field Sampling Locations	1
Field Sampling Results	2
Results of Laboratory Analyses	3
	Figure
Location Map	1
Water Temperatures and Turbidity in Trinity and Whiskeytown Reservoirs	2

ABSTRACT

Visual observations, field measurements, and laboratory analyses indicated that turbid releases from Trinity Reservoir were caused by withdrawal from a turbid density current which probably originated during the December 1964 flood. Very fine particles of clay were suspended in the cool lower layers of Trinity and Whiskeytown Reservoirs. The particles were identified by petrographic examination as primarily montmorillonite and kaolinite with a size considerably less than one micron. The turbidity disappeared as the reservoir cooled to a nearly uniform temperature during the winter season of 1965-66. Additional sampling in the fall of 1966 is recommended to determine if the turbidity reappears with a renewal of temperature stratification.

DESCRIPTORS-- *reservoirs/ *density currents/ hydraulics/ *water quality/ *stratification/ *turbidity/ research and development/ flood/ temperature/ suspended sediments/ clay minerals/ kaolin/ montmorillonites/ silts/ water analysis
IDENTIFIERS-- stratified flow/ thermal stratification/ Central Valley Proj, Calif/ California/ Trinity Dam, Calif/ Whiskeytown Dam, Calif/ selective level releases

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Office of Chief Engineer
Division of Research
Hydraulics Branch
Denver, Colorado
August 1, 1966

Report No. Hyd-566
Author: D. L. King
Coordinated by: W. M. Borland
Checked by: T. J. Rhone
Reviewed by: W. E. Wagner
Submitted by: H. M. Martin

INVESTIGATION OF TURBID RELEASES FROM TRINITY RESERVOIR--TRINITY RIVER DIVISION CENTRAL VALLEY PROJECT, CALIFORNIA

THE PROBLEM

Following the December 1964 flood, releases made from Trinity Reservoir were turbid and roily which adversely affected the water quality for fish propagation and downstream users. The Chief Engineer was asked for recommendations and advice on research and investigation of the problem and possible corrective measures.

CONCLUSIONS

1. Field and laboratory measurements showed a conformity between the temperature stratification and degree of turbidity in both Trinity and Whiskeytown Reservoirs, Figure 2. When the temperature stratification disappeared, the turbidity reduced to zero.

2. The reservoir water was of generally good quality but contained suspended clay materials far less than 1 micron (0.0001 cm) in size.

3. The suspended material from Trinity Reservoir consisted primarily of clay minerals: kaolinite, montmorillonite, and illite.

4. Samples from Whiskeytown Reservoir were similar to the Trinity samples. Silt content was higher but the particle sizes were smaller.

ACKNOWLEDGMENTS

The Hydrology Branch, Division of Project Investigations, and the Chemical Engineering and Hydraulics Branches, Division of Research, cooperated in this investigation. Consultations were also held with the Division of Irrigation Operations and the Division of Engineering Geology. Laboratory chemical analyses were supervised by

P. R. Tramutt and petrographic examinations were performed under the supervision of W. Y. Holland. E. A. Jenne, Water Resources Division, U.S. Geological Survey, aided the investigation by pressure filtering one of the samples for X-ray examination. W. M. Borland represented the Hydrology Branch and acted as coordinator of the investigation.

INTRODUCTION

Trinity Dam is the principal feature of the Trinity River Division of the Central Valley Project. Trinity Reservoir, located in northern California near Redding, Figure 1, has a storage capacity of 2-1/2 million acre-feet. Releases from Trinity Reservoir pass into Lewiston Reservoir behind Lewiston Dam about 6 miles downstream from Trinity Dam. Flows are diverted from Lewiston Reservoir through Clear Creek Tunnel and Powerplant into Whiskeytown Reservoir.

The geologic formation on the right side of Trinity Reservoir consists of decomposed gravels, shales, and tuffaceous sediments that could be carried by runoff into the reservoir. There are also one or two landslide areas around the lake. An area on the right side of the reservoir had recently been burnt over by a forest fire. Turbidity was observed at the surface of Trinity Reservoir immediately after the December 1964 flood and was apparently distributed throughout the lake. The suspended material probably settled into the lower portion of the reservoir during normal summer stratification, thus providing the source of the turbid releases. The Regional Director in October 1965 expressed concern over the possible effects of the continued turbid releases on downstream water users.

The suspended material might have originated in the main channel or tributaries upstream from the reservoir during the flood or might have been caused by torrential rains with heavy runoff or landslides in the reservoir area.

Water samples were obtained from Trinity Reservoir and several points as far downstream as Whiskeytown Reservoir for limited chemical analyses. Turbidity and temperature data obtained during sampling aided in defining the stratification and in tracing the density current through the reservoir system. Well-defined stratification was observed in October and December 1965; by March 23, 1966, the stratification was very weak.

Color photographs showed that the turbid releases were greenish-yellow; the discolored water carried through Whiskeytown Reservoir and was discharged into Clear Creek at Whiskeytown Dam. It was also reported that discharge from Spring Creek Powerplant, downstream from Whiskeytown, was turbid and greenish-yellow in color.

The turbidity problem apparently extended through the system; therefore, water samples and temperature and turbidity data were taken at several points in the system. Primary attention was given to Trinity Reservoir, where the problem originated, and Whiskeytown Reservoir near the downstream end of the system.

The intake structure at Trinity Dam allows withdrawal from the reservoir at one level only. Modifications to the structure to permit selective withdrawal could not be economically justified. The volume of flocculants required to coagulate and settle suspended material in a reservoir of this size was also impractical. Therefore, there appeared to be no practicable solution to this problem. However, as indicated by the data of March 23, 1966, a density current is no longer present. Either the turbidity was diffused throughout the reservoir during temperature destratification in the spring, or releases from the reservoir consumed the dense lower layer. The former premise appears more likely. The problem could reappear, however, which lends importance to the design of multiple outlets for reservoirs.

PROBLEM ANALYSIS

Field Sampling and Measurements

Table 1 lists the locations from which water quality samples were obtained for laboratory analysis. Temperature and turbidity profiles were also obtained at each location. Initial sampling at several points in the system was accomplished on October 27, 28, and 29, 1965. Additional samples were obtained in Trinity Reservoir, Whiskeytown Reservoir, and in the Trinity River below Lewiston Dam on December 1 and 2, 1965. These samples were sent to Denver for analysis. On March 23, 1966, several samples were taken from Trinity Reservoir, and two of these were analyzed in the Denver Laboratory.

Temperature, turbidity, and dissolved oxygen measurements are listed in Table 2 and variations in temperature and turbidity are shown graphically in Figure 2. Turbidity values were determined in the Region 2 laboratory at Sacramento using both a Hach Colorimeter and a Jackson Candle. The Jackson Candle data, expressed as Jackson Candle Units (J. C. U.) are presented in Table 2 and Figure 2.

Figure 2 clearly indicates the presence of stratification in Trinity and Whiskeytown Reservoirs in October and December 1965. In both reservoirs, the cooler layer occupied the greatest portion of the depth. In general, the turbid region corresponded to the cool layer of the temperature stratification. Figure 2B also shows that the largest concentration of the turbidity was on the main arm of Trinity Reservoir. The figure also shows that the temperature stratification and turbidity were present in Whiskeytown Reservoir, as had been indicated earlier by visual observations. On March 23, 1966, the temperature stratification in Trinity Reservoir was quite weak, but the water temperature was cooler than observed in October and December. The absence of well-defined stratification may account for the zero turbidity observed on this date. The suspended material may have diffused through the reservoir, thus reducing the concentration to a negligible quantity.

Laboratory Analyses

The results of analyses performed by the Chemical Engineering Branch in Denver are summarized in Table 3. Although all the December samples listed in Table 2 were available, only the five from the upstream and downstream limits of the system were chosen for analysis. Two of the March samples were submitted; one was used for chemical analysis and the other was pressure-filtered for petrographic examination.

The December samples, A1 and A4 near the bottom of Trinity Reservoir, remained colloidal even after centrifuging. The samples remained turbid after 10 days and no improvement was gained from the addition of a flocculating agent.

Residues from Samples A4 and D1 in Trinity Reservoir were examined by microscope and X-ray diffraction in the Petrographic Laboratory. The results were generally similar for each of the samples, which were believed to adequately represent the material suspended in Trinity and Whiskeytown Reservoirs. The material consisted primarily of clay minerals: kaolinite, montmorillonite, and illite. The montmorillonite predominated in Sample A4 and the kaolinite was most abundant in D1. The clay particle size was too small to be measured by light microscope and the broadening of the X-ray diffraction lines suggested an average particle size of much less than 1 micron. A few fibers and silt grains were also present which may have been introduced as atmospheric dust. The silt particles in the samples ranged up to 40 microns in diameter and could not have remained in suspension for a long period. The silt consisted of angular quartz, feldspar, mica, chlorite, amphiboles, and other unidentified minerals.

Sample E1 from Whiskeytown Reservoir was also examined and found to be similar to the Trinity samples. The silt content was higher and the silt particle size (1 to 5 microns) was smaller than in the Trinity samples. The particles were primarily angular with many platy (micaceous) and prismatic forms corresponding to micas, chlorites, and amphiboles. Quartz and feldspar, with a few cottonlike fibers and shreds of wood or plant material, were also present. The clay minerals were mainly kaolinite with some montmorillonite.

The March samples, A2 and A3 from Trinity Reservoir, were submitted for laboratory analysis. The chemical analysis of Sample A2 is shown in Table 3. The sample was generally similar to the December samples, with the important exception that suspended sediment was essentially absent. Sample A3 was pressure filtered and the very thin, buff-colored coating on a nitrocellulose filter disk was examined in the Petrographic Laboratory. Results of X-ray diffraction were inconclusive because of the very small sample size, but it seemed likely that montmorillonite and possibly mica-clay were present.

SUMMARY OF RESULTS

Visual observations, field measurements, and laboratory analyses clearly indicated the presence of a turbid density current in the reservoirs of the Trinity River Division. The turbidity was the result of very fine suspended clay particles in the cool lower layer of the temperature stratified reservoirs. The suspended material probably entered Trinity Reservoir during the flood of December 1964. Sampling in March 1966 showed that the stratification had weakened during winter cooling and that the turbidity was no longer present. The absence of turbidity may be directly related to the condition of uniform temperature in the reservoir. The turbidity may have diffused to a negligible concentration as the temperature stratification weakened. Additional sampling at intervals is recommended to determine if the turbidity again becomes prevalent as the strength of the temperature stratification increases.

Table 1

FIELD SAMPLING LOCATIONS

Site code	Location
A	Trinity Reservoir, 1,000 feet above dam
B	Trinity Reservoir, 6 miles above dam on main arm of river
C	Trinity Reservoir, 4 miles above dam on main arm of river
D	Trinity Reservoir, 4 miles above dam on Stuart Fork
E	Whiskeytown Reservoir, 1,000 feet above dam
F	Lewiston Reservoir at Trinity power outlet
G	Tailrace of Clear Creek Powerplant
H	Fish ladder below Lewiston Dam

Table 2

FIELD SAMPLING RESULTS

October 27, 28, and 29, 1965					December 1 and 2, 1965					March 23, 1966				
Sample No.	Depth ft	Turbidity J.C.U.	Temp. °F	D. O. ppm	Sample No.	Depth ft	Turbidity J.C.U.	Temp. °F	D. O. ppm	Sample No.	Depth ft	Turbidity J.C.U.	Temp. °F	D. O. ppm
A 1	369	30	46	4.0	A 1	370	40	45.	3.8	A 1	382	0	43.1	7.4
2	350	30	46	4.0	2	350	30	45	--	2	375	0	43.1	--
3	325	15	46	--	3	325	15	45	--	3	350	0	43.1	--
4	300	8	46	5.4	4	300	9	45	6.2	4	325	0	43.1	--
5	275	7	46	--	5	275	5	45	--	5	300	0	43.1	7.6
6	250	5	46	--	6	250	4	45	--	6	275	0	43.1	--
7	225	5	46.	--	7	225	4	45	--	7	250	0	43.1	--
8	200	4	46.5	6.4	8	200	3	45	7.0	8	225	0	43.3	--
9	175	4	47	--	9	175	3	45.5	--	9	200	0	43.4	7.6
10	150	1	47	--	10	150	2	46	--	10	175	0	43.4	--
11	125	0	48	--	11	125	0	46.5	--	11	150	0	43.4	--
12	100	0	50	6.2	12	100	0	49	6.2	12	125	0	43.6	--
13	75	0	53	--	13	75	0	50.5	--	13	100	0	43.8	7.8
14	50	0	61	--	14	50	0	50.5	--	14	75	0	44.2	--
15	25	0	61	7.4	15	25	0	51	--	15	50	0	44.3	--
16	0	0	61	7.2	16	0	0	51	7.6	16	25	0	44.5	--
B 1	289	--	--	--	C 1	358	45	45	4.0	17	0	0	45.4	7.8
2	260	4	47	--	2	325	20	45	--	C 1	330	0	42.9	8.6
3	225	--	--	--	3	300	15	45.5	5.6	2	300	0	42.9	7.8
4	175	2	47.5	--	4	275	10	46	--	3	250	0	42.9	--
5	100	--	51	--	5	250	5	46	--	4	200	0	43.1	8.0
6	50	2	61	--	6	225	5	46	--	5	150	0	43.5	--
7	0	--	61	--	7	200	3	46	6.4	6	100	0	43.8	7.6
C 1	350	30	47	--	8	175	3	46.5	--	7	50	0	44.5	--
2	325	15	48	--	9	150	2	46.5	--	8	0	0	46.4	8.2
3	300	10	49	--	10	125	0	46.5	--	D 1	300	0	43.1	7.6
4	275	8	49	--	11	100	0	47	6.2	2	250	0	43.1	--
5	225	0	--	--	12	75	0	51	--	3	200	0	43.3	7.8
6	150	0	--	--	13	50	0	51	--	4	150	0	43.4	--
7	0	0	62	--	14	25	0	51	--	5	100	0	43.6	7.6
D 1	267	8	47	--	15	0	0	53	7.4	6	50	0	44.3	--
2	230	8	47	--	D 1	273	15	46	5.0	7	0	0	46.8	8.4
3	150	3	48	--	2	250	10	46	--	--	--	--	--	--
E 1	160	7	52	--	3	225	9	46	--	--	--	--	--	--
2	135	6	52	--	4	200	9	46.5	7.0	--	--	--	--	--
3	110	5	52	--	5	175	3	46.5	--	--	--	--	--	--
4	80	5	53	--	6	150	3	48	--	--	--	--	--	--
5	50	5	53	--	7	125	0	48	--	--	--	--	--	--
6	30	4	59	--	8	100	0	49.5	6.0	--	--	--	--	--
7	15	4	59	--	9	75	0	51	--	--	--	--	--	--
F 1	3	6	46	7.0	10	50	0	52	--	--	--	--	--	--
G 1	3	7	47	--	11	25	0	52	--	--	--	--	--	--
H 1	3	7	48	8.0	12	0	0	52.5	7.8	--	--	--	--	--
--	--	--	--	--	E 1	168	15	48.5	9.0	--	--	--	--	--
--	--	--	--	--	2	150	15	48.5	--	--	--	--	--	--
--	--	--	--	--	3	125	10	49.5	--	--	--	--	--	--
--	--	--	--	--	4	100	10	50.5	7.8	--	--	--	--	--
--	--	--	--	--	5	75	8	51	--	--	--	--	--	--
--	--	--	--	--	6	50	5	51	--	--	--	--	--	--
--	--	--	--	--	7	25	5	51.5	--	--	--	--	--	--
--	--	--	--	--	8	0	5	51.5	9.6	--	--	--	--	--
--	--	--	--	--	F 1	3	10	44.5	7.4	--	--	--	--	--
--	--	--	--	--	H 1	3	10	43	10.0	--	--	--	--	--

Table 3

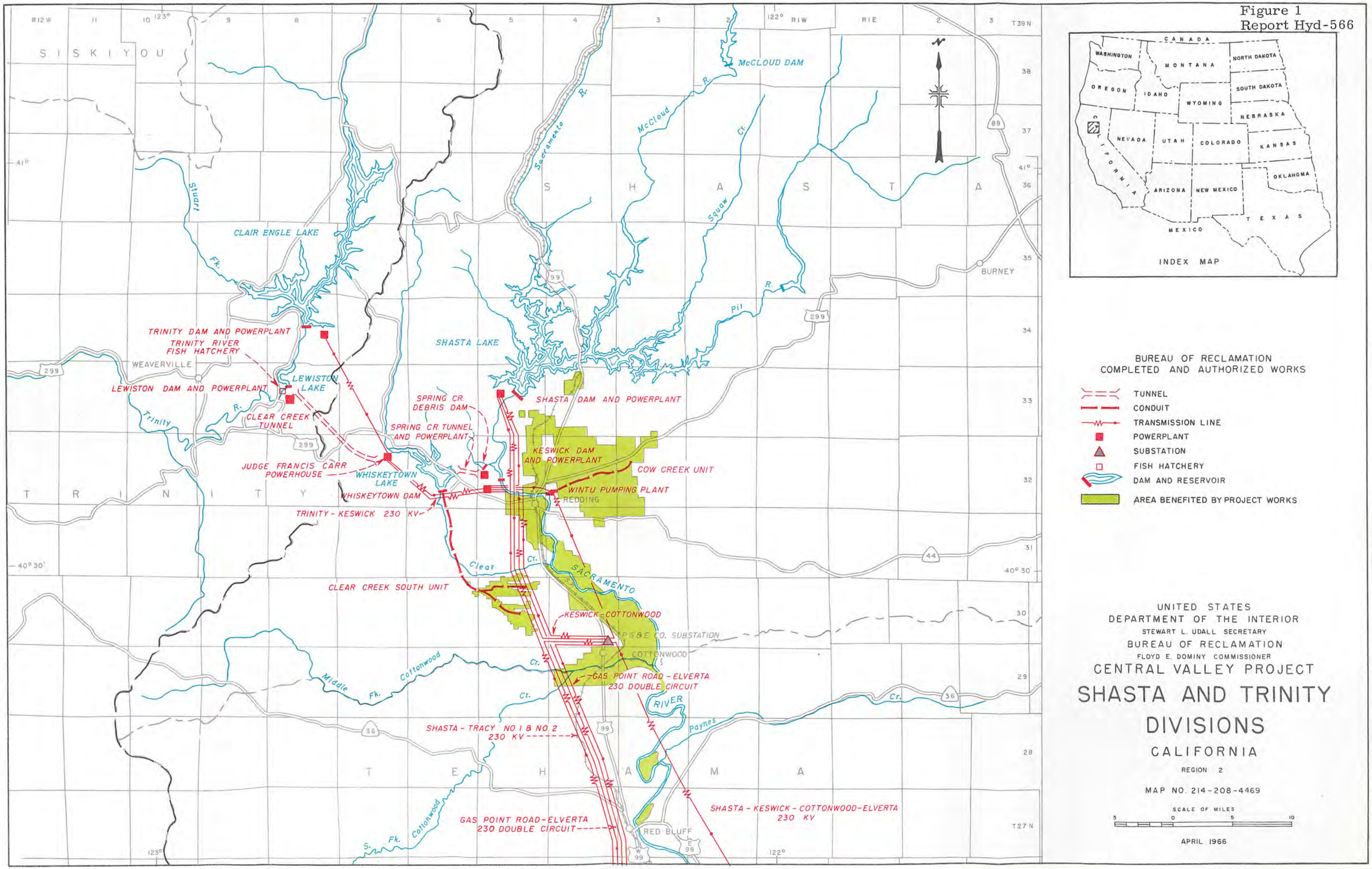
RESULTS OF LABORATORY ANALYSES

December 1 and 2, 1965					March 23, 1966				
Sample No.	pH	Ec x 10^6 @ 25° C	TDS ppm	Sediment ppm	Sample No.	pH	Ec x 10^6 @ 25° C	TDS ppm	Sediment ppm
A1	7.9	96	82	15.0	A2**	7.3	103	100	--
A4	7.6	94	60	9.1*	--	--	--	--	--
C1	7.6	94	72	30.6	--	--	--	--	--
D1	7.7	91	52	32.0*	--	--	--	--	--
E1	7.6	87	52	13.1*	--	--	--	--	--

*Sediment residues examined by Petrographic Laboratory

**Also: Ca - 6.6 ppm, Mg - 7.0 ppm, Na - 3.7 ppm, K - 0.8 ppm, CO_3 - 0.0 ppm, HCO_3 - 52 ppm, SO_4 - 3.4 ppm, Cl - 2.8 ppm

Figure 1
Report Hyd-566



GPO 972-437

FACTUAL DATA ON THE

SHASTA AND TRINITY RIVER DIVISIONS

SHASTA DIVISION

SHASTA DAM AND SHASTA LAKE on the Sacramento River head a drainage area of 6,600 square miles and store a maximum of 4,552,000 acre-feet of water. Floods are controlled and surplus winter runoff is stored for many uses including irrigation in the Sacramento Valley, maintenance of navigation flows in the Sacramento River, conservation of fish life in the Sacramento River, protection of the Sacramento-San Joaquin Delta from intrusion of saline ocean water, transfer of water to Mendota Pool via Delta-Mendota Canal in exchange for San Joaquin River water diverted by Friant Dam, provision of water for municipal and industrial as well as irrigation use in the Contra Costa and other areas, and generation of hydroelectric energy. The dam is a curved concrete gravity type structure, with a height of 602 feet and a crest length of 3,460 feet.

SHASTA POWERPLANT is located just below Shasta Dam. Water from the dam is released through five 15-foot diameter penstocks leading to the five main generating units and two station service units. The total nameplate capacity of these units, including the two station service units of 2,000 kilowatts each, is 379,000 kilowatts.

KESWICK DAM AND POWERPLANT are located on the Sacramento River nine miles downstream from Shasta Dam. The dam creates an afterbay for Shasta Lake and Trinity River Division and smooths out the uneven water releases from the powerplants. The dam also has migratory fish trapping facilities operating in conjunction with the Coleman Fish Hatchery on Battle Creek 25 miles downstream. Keswick Dam is a concrete gravity type structure 159 feet high with a crest length of 1,046 feet. The powerplant has three generating units with a total nameplate capacity of 75,000 kilowatts.

TRINITY RIVER DIVISION

The Trinity River Division was authorized by the Congress in 1955 and completed in 1964. Above Lewiston Dam, Trinity River drains 720 square miles of high-water-producing, mountainous country. Surplus water from the Trinity River Basin is stored, regulated, and diverted through a system of four dams and reservoirs, 4 powerplants, 3 tunnels, and 1 siphon into the Sacramento River for use in water deficient areas of the Central Valley Basin. Additional power generating capacity is also provided for northern and central California and for transmission to Tracy Pumping Plant. In addition, Trinity River Division improves recreational opportunities and increases minimum flows in the Trinity River.

Trinity River water is stored in Clair Engle Lake behind Trinity Dam. Releases from this reservoir are utilized by a 100,000 kilowatt powerplant and reregulated in Lewiston Lake seven miles downstream. Lewiston Dam regulates flows to meet the downstream requirements of the Trinity River Basin, including those of the Trinity River fishery. Water not needed in the Trinity River Basin is diverted by Lewiston Dam through the Clear Creek Tunnel to the 134,000 kilowatt Judge Francis Carr Powerhouse and then into Whiskeytown Lake behind Whiskeytown Dam on Clear Creek, a tributary of the Sacramento River. From Whiskeytown Lake the water from Trinity River, and surplus flows from Clear Creek, will flow through the Spring Creek Tunnel to the 150,000 kilowatt Spring Creek Powerplant and discharge into existing Keswick Reservoir on the Sacramento River. Above Keswick Dam, Trinity River water is combined with the Sacramento River water to provide irrigation service to lands in Shasta County, to meet the ultimate requirements of the Sacramento Canals, and to help supply water to lands in the Delta-Mendota Canal service area, the San Luis Unit, and other areas of the Central Valley Project.

TRINITY DAM AND CLAIR ENGLE LAKE on the Trinity River head a drainage area of over 700 square miles and store a maximum of 2,448,000 acre-feet of water. Flows are regulated and surplus water is stored for irrigation. The dam is an earthfill structure 537 feet high with a crest length of 2600 feet.

TRINITY POWERPLANT at Trinity Dam has 2 generators with an installed nameplate capacity of 100,000 kilowatts.

LEWISTON DAM AND POWERPLANT, about seven miles downstream from Trinity Dam, create an afterbay to Trinity Powerplant and a diversion dam for diverting water by means of Clear Creek Tunnel to Whiskeytown Lake. Lewiston Dam, an earthfill structure 91 feet high and 754 feet long, has a reservoir capacity of 14,600 acre-feet. Lewiston Powerplant, using releases for the support of fish life and other downstream purposes in the Trinity River, has one station service unit with an installed nameplate capacity of 350 kilowatts.

TRINITY RIVER FISH HATCHERY - The Trinity River is one of California's most famous fishing streams. To maintain the salmon and the steelhead fisheries below Lewiston Dam, 150 cubic feet per second are released from Lewiston Dam between January and the end of September of each year. Releases are increased to 200 c.f.s. during the months of October and December and to 250 c.f.s. during November. The higher releases in the fall facilitate natural spawning. The Trinity River Fish Hatchery, with a capacity of about 40,000,000 eggs, is located immediately downstream from Lewiston Dam and compensates for upstream spawning area rendered inaccessible and unusable by the dams.

CLEAR CREEK TUNNEL, 17½ feet in diameter and 10.8 miles long, enables transfer of water from Lewiston Dam to the Judge Francis Carr Powerhouse and Whiskeytown Lake.

JUDGE FRANCIS CARR POWERHOUSE, located on Clear Creek, has two generators with a total installed nameplate capacity of 134,000 kilowatts.

WHISKEYTOWN DAM AND LAKE are located on Clear Creek. The dam provides regulation for Trinity River flows discharged from the Judge Francis Carr Powerhouse and regulates the runoff from the Clear Creek drainage area. The dam is an earthfill structure 282 feet high, with a crest length of 2,250 feet, and creates a reservoir with a capacity of 241,000 acre-feet.

SPRING CREEK TUNNEL AND POWERPLANT. The tunnel diverts water from Whiskeytown Lake on Clear Creek, a tributary of the Sacramento River, to the Spring Creek Powerplant. The tunnel is 18½ feet in diameter and about 3 miles in length, including the 17-foot

SPRING CREEK DEBRIS DAM AND RESERVOIR. The dam is an earthfill structure 194 feet high, located on Spring Creek above the powerplant tailrace. The reservoir, with a capacity of 5,800 acre-feet, controls debris which would otherwise enter the powerplant tailrace, and provides important fishery benefits by controlling contaminated runoff resulting from old mine tailings on Spring Creek.

COW CREEK UNIT, located in Shasta County, was authorized as a part of the Trinity River Division in 1955. The unit features will consist of Wintu Pumping Plant, maximum capacity of 93 cubic feet per second at the main conveyance, and a pressure system with branching pressure distribution lines. Each year about 23,900 acre-feet of water will be lifted 294 feet from the Sacramento River by the Wintu Pumping Plant into the 8-mile long Bella Vista Conduit. This supplemental supply, in combination with local ground water, will serve about 6,800 acres of irrigable land east of Redding.

CLEAR CREEK SOUTH UNIT, located in Shasta County, was authorized as a part of the Trinity River Division. The major feature will be the 11.7 mile long Muletown Conduit which will transport about 15,000 acre-feet of water from Whiskeytown Lake to serve about 4,600 acres of irrigable land and 550 acres of municipal and industrial land, west of Anderson.

POWER

THE TRANSMISSION SYSTEM consists of switchyards, high voltage lines, and substations for delivery of power to project pumps and for wholesale disposal of excess power. The backbone of the system consists of three 230-kilovolt circuits from Shasta Powerplant to Tracy Pumping Plant with a 230-kilovolt connection between Folsom Powerplant and Elverta Switchyard. Recent Trinity additions include a 230-kilovolt double circuit from Trinity Division Powerplants to Elverta and a 230-kilovolt single circuit from Elverta to Tracy.

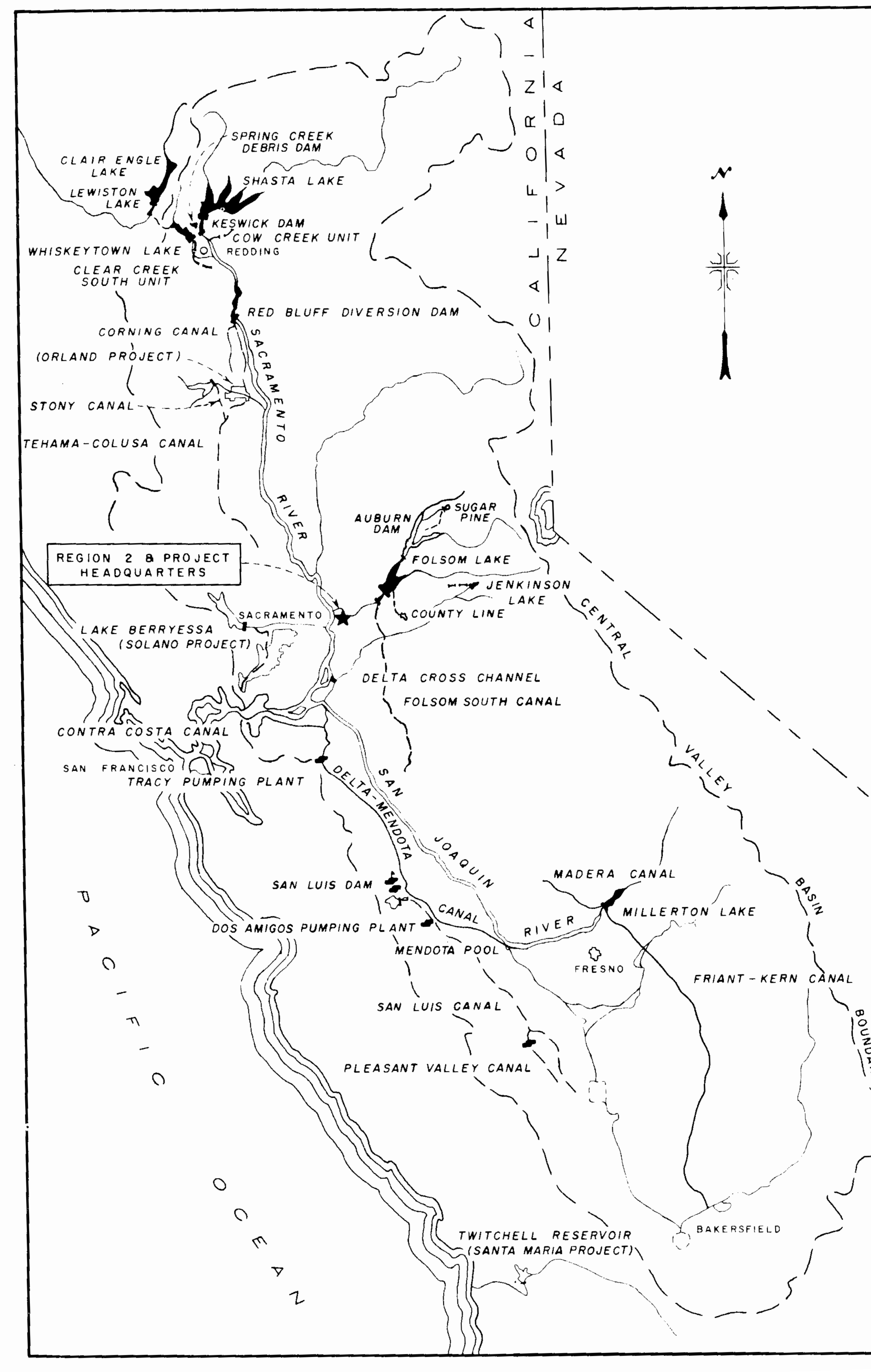
OTHER PROJECT FEATURES

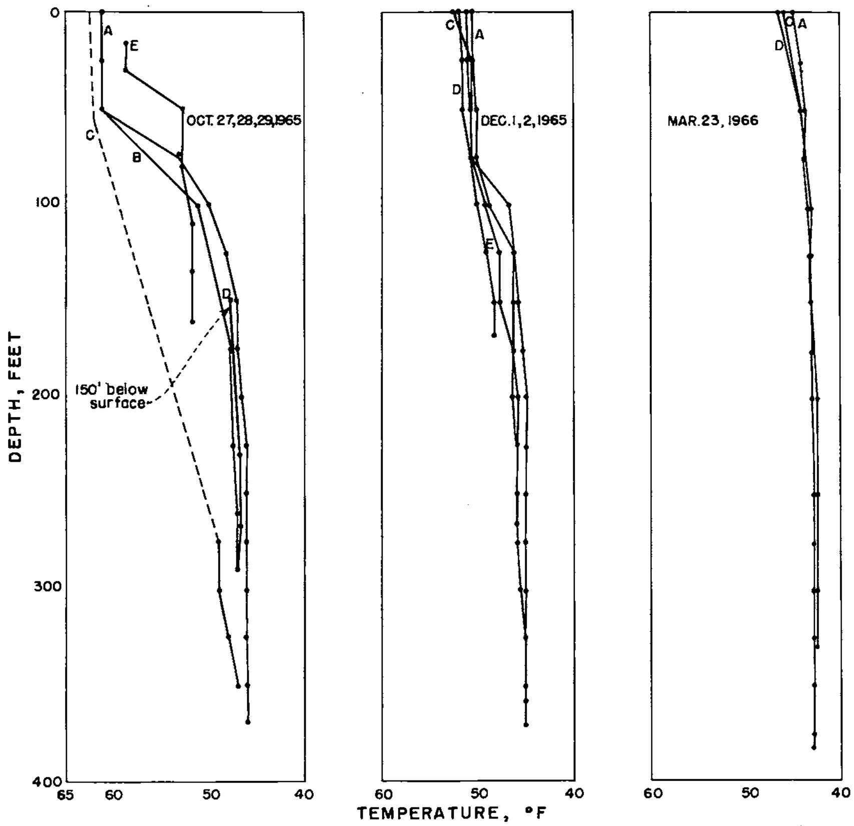
In addition to the Shasta and Trinity River Divisions, the Central Valley Project includes a number of other divisions and units. These are the Sacramento Canals Unit, operating and under construction; the Folsom Unit with operating Folsom and Nimbus Dams and Powerplants; the authorized Auburn-Folsom South Unit with the Auburn Dam and Folsom South Canal; Delta Division with the Delta Cross Channel which carries Sacramento River water across the river delta area, the Tracy Pumping Plant which lifts the water 197 feet into the Delta-Mendota Canal and the Contra Costa Canal system; the Friant Division with Friant Dam on the San Joaquin River, and Friant-Kern and Madera Canals which distribute San Joaquin River water from Friant Dam to agricultural areas to the north and south; and the San Luis Unit, a joint federal-state project, under construction.

Central Valley Project	No. 214-208-3329
Central Valley Project, North Half	No. 214-208-4174
Central Valley Project, South Half	No. 214-208-4175
Central Valley Project, Delta Division	No. 214-208-4177
Central Valley Project, San Luis Unit	No. 214-208-4178

Address all inquiries regarding additional information concerning this project to:

REGIONAL DIRECTOR, REGION 2
BUREAU OF RECLAMATION
P.O. BOX 2511,
SACRAMENTO, CALIFORNIA 95811

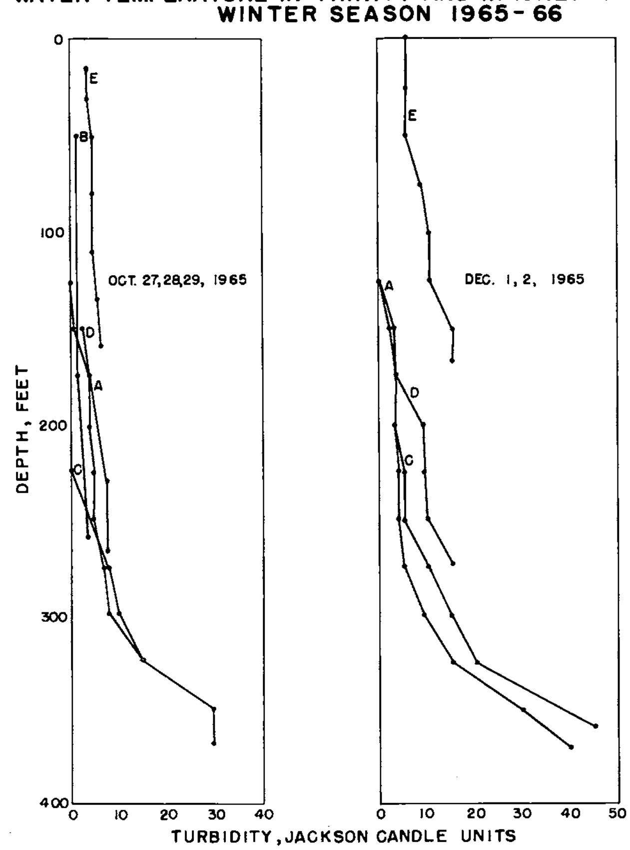




A. WATER TEMPERATURE IN TRINITY AND WHISKEYTOWN RESERVOIRS WINTER SEASON 1965-66

NOTES

Site A - Trinity Reservoir, 1000' upstream from dam
Site B - Trinity Reservoir, 6 miles above dam on main arm of river.
Site C - Trinity Reservoir, 4 miles above dam on main arm of river.
Site D - Trinity Reservoir, 4 miles above dam on Stuart Fork.
Site E - Whiskeytown Lake, 1000' above dam.



B. TURBIDITY IN TRINITY AND WHISKEYTOWN RESERVOIRS WINTER SEASON 1965-66

ON MARCH 23, 1966, TURBIDITY WAS ZERO AT SITES A, C, AND D.

INVESTIGATION OF TURBID RELEASES FROM TRINITY RESERVOIR

7-1750
(10-64)

CONVERSION FACTORS--BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, January 1964) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given on pages 10-11 of the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg; that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Table 1

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
	LENGTH	
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
	0.3048 (exactly)*	Meters
	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
	1.609344 (exactly)	Kilometers
	AREA	
Square inches	6.4516 (exactly)	Square centimeters
Square feet	929.03 (exactly)*	Square centimeters
	0.092903 (exactly)	Square meters
Square yards	0.836127	Square meters
Acres	0.40469*	Hectares
	4,046.9*	Square meters
	0.0040469*	Square kilometers
Square miles	2.58999	Square kilometers
	VOLUME	
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
	CAPACITY	
Fluid ounces (U.S.)	29.5737	Cubic centimeters
	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
	0.473166	Liters
Quarts (U.S.)	9,463.58	Cubic centimeters
	0.946358	Liters
Gallons (U.S.)	3,785.43*	Cubic centimeters
	3.78543	Cubic decimeters
	3.78533	Liters
	0.00378543*	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	764.55*	Liters
Acre-feet	1,233.5*	Cubic meters
	1,233,500*	Liters

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
MASS		
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
FORCE/AREA		
Pounds per square inch	0.070307	Kilograms per square centimeter
	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
	47.8803	Newtons per square meter
MASS/VOLUME (DENSITY)		
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
MASS/CAPACITY		
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
BENDING MOMENT OR TORQUE		
Inch-pounds	0.011521	Meter-kilograms
	1.12985×10^6	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	1.35582×10^7	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
VELOCITY		
Feet per second	30.48 (exactly)	Centimeters per second
	0.3048 (exactly)*	Meters per second
Feet per year	0.965873×10^{-6}*	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
	0.44704 (exactly)	Meters per second
ACCELERATION*		
Feet per second^2	0.3048*	Meters per second^2
FLOW		
Cubic feet per second (second-feet)	0.028317*	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
FORCE*		
Pounds	0.453592*	Kilograms
	4.4482*	Newtons
	4.4482×10^{-5}*	Dynes
WORK AND ENERGY*		
British thermal units (Btu)	0.252*	Kilogram calories
	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	1.35582*	Joules
POWER		
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
HEAT TRANSFER		
Btu in./hr ft^2 deg F (k, thermal conductivity)	1.442	Milliwatts/cm deg C
	0.1240	Kg cal/hr m deg C
Btu ft/hr ft^2 deg F	1.4880*	Kg cal m/hr m^2 deg C
Btu/hr ft^2 deg F (C, thermal conductance)	0.568	Milliwatts/cm^2 deg C
	4.882	Kg cal/hr m^2 deg C
Deg F hr ft^2/Btu (R, thermal resistance)	1.761	Deg C cm^2/milliwatt
Btu/lb deg F (c, heat capacity)	4.1868	J/g deg C
Btu/lb deg F	1.000*	Cal/gram deg C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
	0.09290*	M^2/hr
WATER VAPOR TRANSMISSION		
Grains/hr ft^2 (water vapor transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	304.8*	Liters per square meter per day
Pound-seconds per square foot (viscosity)	4.8824*	Kilogram second per square meter
Square feet per second (viscosity)	0.02903* (exactly)	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	35.3147*	Millicuries per cubic meter
Milliamps per square foot	10.7639*	Milliamps per square meter
Gallons per square yard	4.527219*	Liters per square meter
Pounds per inch	0.17858*	Kilograms per centimeter

GPO 845-237

ABSTRACT

Visual observations, field measurements, and laboratory analyses indicated that turbid releases from Trinity Reservoir were caused by withdrawal from a turbid density current which probably originated during the December 1964 flood. Very fine particles of clay were suspended in the cool lower layers of Trinity and Whiskeytown Reservoirs. The particles were identified by petrographic examination as primarily montmorillonite and kaolinite with a size considerably less than one micron. The turbidity disappeared as the reservoir cooled to a nearly uniform temperature during the winter season of 1965-66. Additional sampling in the fall of 1966 is recommended to determine if the turbidity reappears with a renewal of temperature stratification.

ABSTRACT

Visual observations, field measurements, and laboratory analyses indicated that turbid releases from Trinity Reservoir were caused by withdrawal from a turbid density current which probably originated during the December 1964 flood. Very fine particles of clay were suspended in the cool lower layers of Trinity and Whiskeytown Reservoirs. The particles were identified by petrographic examination as primarily montmorillonite and kaolinite with a size considerably less than one micron. The turbidity disappeared as the reservoir cooled to a nearly uniform temperature during the winter season of 1965-66. Additional sampling in the fall of 1966 is recommended to determine if the turbidity reappears with a renewal of temperature stratification.

ABSTRACT

Visual observations, field measurements, and laboratory analyses indicated that turbid releases from Trinity Reservoir were caused by withdrawal from a turbid density current which probably originated during the December 1964 flood. Very fine particles of clay were suspended in the cool lower layers of Trinity and Whiskeytown Reservoirs. The particles were identified by petrographic examination as primarily montmorillonite and kaolinite with a size considerably less than one micron. The turbidity disappeared as the reservoir cooled to a nearly uniform temperature during the winter season of 1965-66. Additional sampling in the fall of 1966 is recommended to determine if the turbidity reappears with a renewal of temperature stratification.

ABSTRACT

Visual observations, field measurements, and laboratory analyses indicated that turbid releases from Trinity Reservoir were caused by withdrawal from a turbid density current which probably originated during the December 1964 flood. Very fine particles of clay were suspended in the cool lower layers of Trinity and Whiskeytown Reservoirs. The particles were identified by petrographic examination as primarily montmorillonite and kaolinite with a size considerably less than one micron. The turbidity disappeared as the reservoir cooled to a nearly uniform temperature during the winter season of 1965-66. Additional sampling in the fall of 1966 is recommended to determine if the turbidity reappears with a renewal of temperature stratification.

Hyd-566
King, D L
INVESTIGATION OF TURBID RELEASES FROM TRINITY RESERVOIR--TRINITY RIVER DIVISION--CENTRAL VALLEY PROJECT, CALIFORNIA. USBR Lab Rept Hyd-566, Hyd Br, August 1966. Bureau of Reclamation, Denver, 5 p, 2 fig, 5 tab

DESCRIPTORS-- *reservoirs/ *density currents/ hydraulics/ *water quality/ *stratification/ *turbidity/ research and development/ flood/ temperature/ suspended sediments/ clay minerals/ kaolin/ montmorillonites/ silts/ water analysis
IDENTIFIERS-- stratified flow/ thermal stratification/ Central Valley Proj, Calif/ California/ Trinity Dam, Calif/ Whiskeytown Dam, Calif/ selective level releases

Hyd-566
King, D L
INVESTIGATION OF TURBID RELEASES FROM TRINITY RESERVOIR--TRINITY RIVER DIVISION--CENTRAL VALLEY PROJECT, CALIFORNIA. USBR Lab Rept Hyd-566, Hyd Br, August 1966. Bureau of Reclamation, Denver, 5 p, 2 fig, 5 tab

DESCRIPTORS-- *reservoirs/ *density currents/ hydraulics/ *water quality/ *stratification/ *turbidity/ research and development/ flood/ temperature/ suspended sediments/ clay minerals/ kaolin/ montmorillonites/ silts/ water analysis
IDENTIFIERS-- stratified flow/ thermal stratification/ Central Valley Proj, Calif/ California/ Trinity Dam, Calif/ Whiskeytown Dam, Calif/ selective level releases

Hyd-566
King, D L
INVESTIGATION OF TURBID RELEASES FROM TRINITY RESERVOIR--TRINITY RIVER DIVISION--CENTRAL VALLEY PROJECT, CALIFORNIA. USBR Lab Rept Hyd-566, Hyd Br, August 1966. Bureau of Reclamation, Denver, 5 p, 2 fig, 5 tab

DESCRIPTORS-- *reservoirs/ *density currents/ hydraulics/ *water quality/ *stratification/ *turbidity/ research and development/ flood/ temperature/ suspended sediments/ clay minerals/ kaolin/ montmorillonites/ silts/ water analysis
IDENTIFIERS-- stratified flow/ thermal stratification/ Central Valley Proj, Calif/ California/ Trinity Dam, Calif/ Whiskeytown Dam, Calif/ selective level releases

Hyd-566
King, D L
INVESTIGATION OF TURBID RELEASES FROM TRINITY RESERVOIR--TRINITY RIVER DIVISION--CENTRAL VALLEY PROJECT, CALIFORNIA. USBR Lab Rept Hyd-566, Hyd Br, August 1966. Bureau of Reclamation, Denver, 5 p, 2 fig, 5 tab

DESCRIPTORS-- *reservoirs/ *density currents/ hydraulics/ *water quality/ *stratification/ *turbidity/ research and development/ flood/ temperature/ suspended sediments/ clay minerals/ kaolin/ montmorillonites/ silts/ water analysis
IDENTIFIERS-- stratified flow/ thermal stratification/ Central Valley Proj, Calif/ California/ Trinity Dam, Calif/ Whiskeytown Dam, Calif/ selective level releases