U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

REPORT

ON

CALAVERAS LAKE

BEXAR COUNTY

TEXAS

EPA REGION VI

WORKING PAPER No. 638

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON

and

ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

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REPORT
ON
CALAVERAS LAKE
BEXAR COUNTY
TEXAS
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WITH THE COOPERATION OF THE
TEXAS WATER QUALITY BOARD
AND THE
TEXAS NATIONAL GUARD
FEBRUARY, 1977

CONTENTS

FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Texas Water Quality Board for professional involvement, to the Texas National Guard for conducting the tributary sampling phase of the Survey, and to those Texas wastewater treatment plant operators who voluntarily provided effluent samples.

Hugh C. Yantis, Jr., Executive Director of the Texas Water Quality Board, and John B. Latchford, Jr., Director, and the staff of the Field Operations Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Thomas Bishop, the Adjutant General of Texas, and Project Officer Colonel William L. Seals, who directed the volunteer efforts of the Texas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

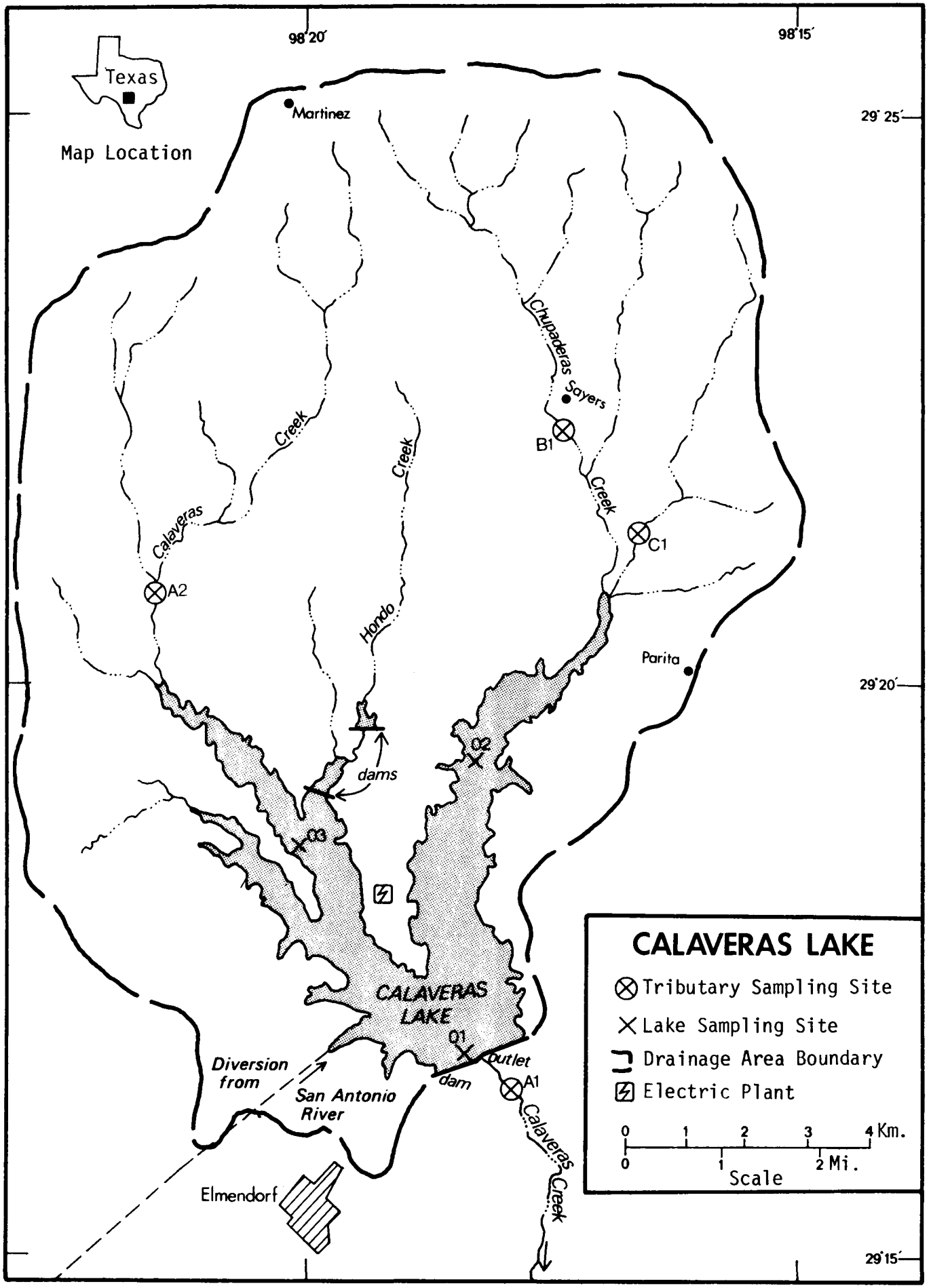
NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

State of Texas

NAME	COUNTY
Amistad	Val Verde
Bastrop	Bastrop
Belton	Bell, Coryell
Braunig	Bexar
Brownwood	Brown
Buchanan	Burnet, Llano
Caddo	Harrison, Marion, TX; Caddo Parish, LA
Calaveras	Bexar
Canyon	Comal
Colorado City	Mitchell
Corpus Christi	Jim Wells, Live Oak, San Patricio
Diversion	Archer, Baylor
Eagle Mountain	Tarrant, Wise
Fort Phantom Hill	Jones
Houston	Harris
Kemp	Baylor
Lake O'The Pines	Camp, Marion, Morris, Upshur
Lavon	Collin
Lewisville (Garza-Little Elm)	Denton
Livingston	Polk, San Jacinto, Trinity, Walker

Lyndon B. Johnson	Burnet, Llano
Medina	Bandera, Medina
Meredith	Hutchinson, Moore, Potter
O. C. Fisher (San Angelo)	Tom Green
Palestine	Anderson, Cherokee, Henderson, Smith
Possum Kingdom	Palo Pinto, Stephens, Young
Sam Rayburn	Angelina, Jasper Nacogdoches, Sabine, San Augustine
Somerville	Burleson, Lee, Washington
E. V. Spence	Coke
Stamford	Haskell
Stillhouse Hollow	Bell
Tawakoni	Hunt, Rains, Van Zandt
Texoma	Cooke, Grayson TX; Bryan, Johnston, Love, Marshall, OK
Travis	Burnet, Travis
Trinidad	Henderson
Twin Buttes	Tom Green
White River	Crosby
Whitney	Bosque, Hill
Wright Patman (Texarkana)	Bowie, Cass


98°20'
98°15'
29°25'
29°20'
29°15'
Texas
Map Location
Martinez
Chupaderas Creek
Sayers
B1
C1
Calaveras Creek
A2
Hondo Creek
Parita
dams
Q2
Q3
Q1
CALAVERAS LAKE
Diversion from San Antonio River
dam
outlet
A1
Calaveras Creek
Elmendorf
CALAVERAS LAKE
Tributary Sampling Site
Lake Sampling Site
Drainage Area Boundary
Electric Plant
0 1 2 3 4 Km.
0 1 2 Mi.
Scale

CALAVERAS LAKE

STORET NO. 4808

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Calaveras Lake is eutrophic; i.e., well supplied with nutrients and quite productive. Whether nutrient enrichment is beneficial or deleterious depends on the actual or potential effect on the uses of the lake. In this regard, the Texas Water quality Board has indicated that there is little or no known impairment of the designated beneficial uses of this lake.

Calaveras Lake ranked fourteenth in overall trophic quality when the 39 Texas reservoirs sampled in 1974 were compared using a combination of six water quality parameters*. Twenty-one of the reservoirs had less median total phosphorus, two had less and five had the same median dissolved orthophosphorus, none of the others had less but one had the same median inorganic nitrogen, 34 reservoirs had less mean chlorophyll a, and 20 had greater mean Secchi disc transparency.

Survey limnologists noted emergent macrophytes along the shoreline at station 1 in August and at stations 2 and 3 in November.

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* See Appendix A.

B. Rate-Limiting Nutrient:

The algal assay results are not considered representative of conditions in the lake at the time the samples were collected due to a significant change in nutrient concentrations during shipment of the samples from the field to the laboratory.

The lake data indicate nitrogen limitation at all sampling times.

C. Nutrient Controllability:

1. Point sources--No point sources were known to discharge to the Calaveras Lake drainage basin during the sampling year. However, the phosphorus load in the diversion from the San Antonio River accounts for almost the entire load to the lake, and it is likely that the wastewater treatment facilities at San Antonio contribute to the enrichment of Calaveras Lake. It is reported that in water year 1975 (10/01/74-09/30/75) the San Antonio Salado Creek and Rilling Road plants discharged 21,993,126 m^3 (60,255 m^3/day) and 114,393,860 m^3 (313,408 m^3/day) of sewage effluent, respectively, to the San Antonio River at points 12.1 and 24.9 km upstream from the point of diversion to Calaveras Lake (Anonymous, 1976).

The present phosphorus loading of 0.76 g/m^2/year is over six times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 15). Improvement of the present trophic condition is dependent upon the reduction of the load in the San Antonio River. Minimization of point-source phosphorus could result in persistent phosphorus limitation of primary productivity in the lake.

2. Non-point sources--The apparent non-point-source phosphorus contribution accounted for all of the total phosphorus load during the sampling year. Calaveras Creek contributed 1.4%, Chupaderas Creek contributed 0.6%, Unnamed Stream C-1 contributed 0.4%, and the San Antonio River diversion contributed an estimated 92.2%. The ungaged minor tributaries and immediate drainage contributed an estimated 3.1%. However, as noted above, much of the load in the diversion from the San Antonio River is contributed by upstream point sources rather than non-point sources.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 13.96 kilometers^2.
2. Mean depth: 5.5 meters.
3. Maximum depth: >9.1 meters.
4. Volume: 76.780 x 10^6 m^3.
5. Mean hydraulic retention time: 20 years (based on outflow).

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)†††	Mean flow (m^3/sec)†††
Calaveras Creek	32.9	0.040
Chupaderas Creek	20.7	0.030
Unnamed Stream C-1	6.7	0.010
San Antonio River diversion	-	0.183*
Minor tributaries & immediate drainage -	100.3	0.150
Totals	160.6	0.413

2. Outlet -

Generating plant diversion	-	0.122
Calaveras Creek	174.6**	0.000 (intermittent flow)
Total	174.6	0.122***

C. Precipitation****:

1. Year of sampling: 94.0 centimeters.
2. Mean annual: 70.0 centimeters.

† Table of metric conversions--Appendix B.
†† Latchford, 1974.
††† For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
* Yost, 1976.
** Includes area of lake.
*** Outflow adjusted to equal sum of inflows minus evaporation; see page 11.
**** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Calaveras Lake was sampled four times in 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at three stations on the lake (see map, page vi). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first and last visits, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 9.4 meters at station 1, 4.3 meters at station 2, and 4.9 meters at station 3.

The sampling results are presented in full in Appendix D and are summarized in the following table (the August nutrient samples were not properly preserved and were not analyzed).

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR CALAVERAS LAKE
STORET CODE 4808

PARAMETER	1ST SAMPLING (3/13/74) 3 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (5/23/74) 3 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (8/16/74) 3 SITES RANGE	MEAN	MEDIAN
TEMP (C)	15.2 - 23.7	21.0	21.0	25.5 - 30.7	28.3	28.5	28.6 - 32.9	30.2	29.9
DISS OXY (MG/L)	3.2 - 8.6	7.5	8.2	2.0 - 8.0	4.8	5.0	3.2 - 7.8	6.0	6.5
CNDCTVY (MCROMO)	440. - 510.	487.	488.	561. - 620.	590.	585.	629. - 696.	648.	631.
PH (STAND UNITS)	7.7 - 8.6	8.3	8.4	7.6 - 8.5	8.1	8.0	8.0 - 9.0	8.7	8.9
TOT ALK (MG/L)	125. - 129.	127.	127.	117. - 130.	125.	125.	****** - **********		
TOT P (MG/L)	0.024 - 0.043	0.034	0.032	0.030 - 0.055	0.036	0.033	****** - **********		
ORTHO P (MG/L)	0.005 - 0.017	0.009	0.006	0.003 - 0.010	0.006	0.005	****** - **********		
NO2+NO3 (MG/L)	0.020 - 0.120	0.045	0.040	0.020 - 0.070	0.032	0.020	****** - **********		
AMMONIA (MG/L)	0.020 - 0.090	0.036	0.030	0.020 - 0.080	0.034	0.030	****** - **********		
KJEL N (MG/L)	0.600 - 0.900	0.790	0.800	0.600 - 0.800	0.718	0.700	****** - **********		
INORG N (MG/L)	0.040 - 0.210	0.081	0.070	0.040 - 0.150	0.065	0.050	****** - **********		
TOTAL N (MG/L)	0.630 - 1.020	0.835	0.840	0.620 - 0.870	0.750	0.720	****** - **********		
CHLRPYL A (UG/L)	12.1 - 13.8	13.0	13.0	13.1 - 55.4	32.5	28.9	12.4 - 28.0	22.1	26.0
SECCHI (METERS)	0.6 - 1.2	0.9	0.9	0.9 - 1.2	1.1	1.1	0.9 - 1.2	1.1	1.1

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR CALAVERAS LAKE
STORET CODE 4808

4TH SAMPLING (11/ 5/74)

PARAMETER	3 SITES RANGE	MEAN	MEDIAN
TEMP (C)	23.8 - 27.1	25.1	24.8
DISS OXY (MG/L)	6.8 - 8.0	7.6	7.6
CNDCTVY (MCROMO)	528. - 562.	540.	538.
PH (STAND UNITS)	8.2 - 8.6	8.4	8.4
TOT ALK (MG/L)	114. - 127.	121.	121.
TOT P (MG/L)	0.057 - 0.164	0.078	0.067
ORTHO P (MG/L)	0.009 - 0.055	0.021	0.017
NO2+NO3 (MG/L)	0.020 - 0.040	0.029	0.030
AMMONIA (MG/L)	0.004 - 0.060	0.035	0.035
KJEL N (MG/L)	0.400 - 1.000	0.710	0.700
INORG N (MG/L)	0.034 - 0.100	0.064	0.070
TOTAL N (MG/L)	0.420 - 1.020	0.739	0.740
CHLRPYL A (UG/L)	15.3 - 27.5	22.4	24.5
SECCHI (METERS)	0.7 - 1.2	0.8	0.7

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/13/74	1. Merismopedia sp.	3,032
	2. Chroomonas sp.	2,592
	3. Dactylococcopsis sp.	2,298
	4. Nitzschia sp.	1,467
	5. Cryptomonas sp.	1,320
	Other genera	9,488
	Total	20,197
05/23/74	1. Dactylococcopsis sp.	3,190
	2. Nitzschia sp.	1,202
	3. Merismopedia sp.	1,110
	4. Anabaenopsis sp.	833
	5. Melosira sp.	832
	Other genera	6,288
	Total	13,455
08/16/74	1. Oscillatoria sp.	2,950
	2. Lyngbya sp.	2,397
	3. Raphidiopsis sp.	1,696
	4. Merismopedia sp.	1,217
	5. Anabaenopsis sp.	1,107
	Other genera	7,192
	Total	16,559
11/05/74	1. Oscillatoria sp.	7,756
	2. Dactylococcopsis sp.	3,283
	3. Centric diatoms	938
	4. Raphidiopsis sp.	649
	5. Pennate diatoms	577
	Other genera	2,202
	Total	15,405

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
03/13/74	1	12.1
	2	13.8
	3	13.0
05/23/74	1	13.1
	2	28.9
	3	55.4
08/16/74	1	26.0
	2	28.0
	3	12.4
11/05/74	1	27.5
	2	24.5
	3	15.3

C. Limiting Nutrient Study:

The algal assay results are not considered representative of conditions in the lake at the time the samples were taken (03/13/74 and 11/05/74) due to significant changes in nutrient concentrations during shipment of the samples from the field to the laboratory.

The lake data indicate nitrogen limitation. The mean inorganic nitrogen to orthophosphorus ratios were 11 to 1 or less at all sampling times, and nitrogen limitation would be expected.

Nitrogen limitation, as indicated by the algal assay or by in-lake nitrogen to phosphorus ratios, does not necessarily mean

that the trophic condition of the lake can be improved by controlling nitrogen inputs. In many cases, the apparent condition of nitrogen-limitation results from excessive phosphorus input from point sources and is often accompanied by a corresponding increase in primary production. In such cases, the reversal of the enriched condition depends upon phosphorus control, not nitrogen control.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Texas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the high runoff months of April and May when two samples were collected at one of the sites. Sampling was begun in September, 1974, and was completed in July, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Texas District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

The water level of the lake is maintained by pumping water from the San Antonio River. Diversions to the lake during the sampling year amounted to 5,785,068 m^3 (0.183 m^3/sec). Water is taken from the lake and used in the cooling towers of an electric plant. Withdrawal of up to 45,639,130 m^3 per year is authorized (Anonymous, 1976; Yost, 1976).

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and the mean annual flows.

Nutrient loads for the diversion from the San Antonio River were calculated using the mean nutrient concentrations measured at the U.S.G.S. water-quality sampling station (08181800 - 518 meters downstream from the pumping station) and the mean annual flow (Anonymous, 1976). Nutrient

loads in the diversion to the electric plant were calculated using the mean nutrient concentrations measured at lake sampling station 3 and the estimated annual flow.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the mean concentrations in Chupaderas Creek at station B-1 and the mean annual ZZ flow.

A. Waste Sources:

1. Known municipal - None in immediate drainage.

2. Known industrial - None.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Calaveras Creek	145	1.4
Chupaderas Creek	65	0.6
Unnamed Stream C-1	40	0.4
San Antonio River diversion	9,730	92.2
b. Minor tributaries & immediate drainage (non-point load) -	325	3.1
c. Known municipal STP's - None	-	-
d. Septic tanks - None	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	245	2.3
Total	10,550	100.0

2. Outputs -

Lake outlet - Generating plant diversion	175	
Calaveras Creek	-	(intermittent flow)
Total	175	

3. Net annual P accumulation - 10,375 kg.

* See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Calaveras Creek	1,535	2.8
Chupaderas Creek	1,155	2.1
Unnamed Stream C-1	410	0.7
San Antonio River diversion	31,520	56.8
b. Minor tributaries & immediate drainage (non-point load) -	5,765	10.4
c. Known municipal STP's - None	-	-
d. Septic tanks - None	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	15,070	27.2
Total	55,455	100.0

2. Outputs -

Lake outlet -	Generating plant diversion	3,245
	Calaveras Creek	- (intermittent flow)
	Total	3,245

3. Net annual N accumulation - 52,210 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
Calaveras Creek	4	47
Chupaderas Creek	3	56
Unnamed Stream C-1	6	61

* See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.76	0.74	4.0	3.7

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Calaveras Lake:	
"Dangerous" (eutrophic loading)	0.12
"Permissible" (oligotrophic loading)	0.06

V. LITERATURE REVIEWED

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Latchford, John B., Jr., 1974. Personal communication (lake morphometry). TX Water Qual. Bd., Austin.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

Yost, I. D., 1976. Personal communication (diversions to and from Calaveras Lake). U.S. Geol. Surv., Austin.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	4809	CANYON RESERVOIR	445
2	4823	LAKE MEREDITH	441
3	4813	EAGLE MOUNTAIN LAKE	430
4	4816	KEMP LAKE	423
5	4801	AMISTAD LAKE	402
6	4805	BROWNWOOD LAKE	394
7	4802	BASTROP LAKE	393
8	4838	WHITE RIVER RESERVOIR	390
9	4825	POSSUM KINGDOM RESERVOIR	387
10	4835	TRAVIS LAKE	384
11	4803	BELTON RESERVOIR	384
12	4831	STILLHOUSE HOLLOW RESERV	372
13	4812	DIVERSION LAKE	372
14	4808	CALAVERAS LAKE	362
15	4839	WHITNEY LAKE	357
16	4822	MEDINA LAKE	342
17	4827	SAM RAYBURN RESERVOIR	322
18	4828	E V SPENCE RESERVOIR	321
19	4837	TWIN BUTTES RESERVOIR	311
20	4810	LAKE COLORADO CITY	310
21	4824	PALESTINE LAKE	302
22	4818	LAKE OF THE PINES	298
23	4807	CADDO LAKE	297
24	4814	FT PHANTOM HILL LAKE	296
25	4806	LAKE BUCHANAN	261
26	4830	STAMFORD LAKE	259
27	4819	LAVON RESERVOIR	258
28	4832	TAWAKONI LAKE	253

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
29	4821	LYNDON B JOHNSON LAKE	238
30	4834	TEXOMA LAKE	217
31	4829	SOMERVILLE LAKE	208
32	4826	SAN ANGELO RESERVOIR	200
33	4833	TEXARKANA LAKE	176
34	4815	GARZA LITTLE ELM RESERVO	173
35	4836	TRINIDAD	169
36	4804	BRAUNIG LAKE	159
37	4811	CORPUS CRISTI LAKE	155
38	4817	HOUSTON LAKE	139
39	4820	LIVINGSTON LAKE	91

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4801	AMISTAD LAKE	95 (36)	5 (2)	100 (38)	100 (38)	39 (14)	63 (21)	402
4802	BASTROP LAKE	79 (30)	76 (28)	82 (31)	47 (18)	17 (0)	92 (34)	393
4803	BELTON RESERVOIR	92 (35)	26 (10)	97 (37)	68 (26)	17 (0)	84 (31)	384
4804	BRAUNIG LAKE	5 (2)	42 (16)	50 (19)	8 (3)	49 (17)	5 (2)	159
4805	BROWNWOOD LAKE	66 (25)	70 (26)	29 (11)	87 (33)	58 (22)	84 (31)	394
4806	LAKE BUCHANAN	47 (18)	21 (7)	74 (28)	63 (24)	17 (0)	39 (14)	261
4807	CADDO LAKE	26 (10)	91 (33)	42 (16)	32 (12)	76 (29)	30 (10)	297
4808	CALAVERAS LAKE	45 (17)	100 (38)	47 (18)	11 (4)	67 (25)	92 (34)	362
4809	CANYON RESERVOIR	99 (37)	8 (3)	95 (36)	97 (37)	49 (17)	97 (37)	445
4810	LAKE COLORADO CITY	39 (14)	76 (28)	26 (10)	42 (16)	88 (33)	39 (14)	310
4811	CORPUS CRISTI LAKE	8 (3)	47 (18)	18 (7)	13 (5)	61 (23)	8 (3)	155
4812	DIVERSION LAKE	68 (26)	83 (31)	32 (12)	29 (11)	97 (37)	63 (21)	372
4813	EAGLE MOUNTAIN LAKE	71 (27)	91 (33)	34 (13)	79 (30)	79 (30)	76 (28)	430
4814	FT PHANTOM HILL LAKE	24 (9)	66 (25)	21 (8)	74 (28)	95 (36)	16 (6)	296
4815	GARZA LITTLE ELM RESERVO	34 (13)	13 (5)	16 (6)	34 (13)	55 (21)	21 (7)	173
4816	KEMP LAKE	76 (29)	61 (22)	55 (21)	55 (21)	84 (32)	92 (34)	423
4817	HOUSTON LAKE	16 (6)	16 (6)	0 (0)	24 (9)	72 (27)	11 (4)	139
4818	LAKE OF THE PINES	54 (20)	76 (28)	66 (25)	39 (15)	17 (0)	46 (17)	298
4819	LAVON RESERVOIR	21 (8)	29 (11)	3 (1)	84 (32)	100 (38)	21 (7)	258
4820	LIVINGSTON LAKE	3 (1)	3 (1)	39 (15)	26 (10)	17 (0)	3 (1)	91
4821	LYNDON B JOHNSON LAKE	39 (14)	11 (4)	53 (20)	66 (25)	39 (14)	30 (10)	238
4822	MEDINA LAKE	99 (37)	0 (0)	89 (34)	37 (14)	17 (0)	100 (38)	342
4823	LAKE MEREDITH	82 (31)	91 (33)	71 (27)	95 (36)	39 (14)	63 (21)	441
4824	PALESTINE LAKE	54 (20)	32 (12)	63 (24)	53 (20)	49 (17)	51 (19)	302
4825	POSSUM KINGDOM RESERVOIR	74 (28)	91 (33)	84 (32)	58 (22)	17 (0)	63 (21)	387
4826	SAN ANGELO RESERVOIR	13 (5)	45 (17)	8 (3)	0 (0)	88 (33)	46 (17)	200
4827	SAM RAYBURN RESERVOIR	59 (22)	39 (15)	68 (26)	76 (29)	17 (0)	63 (21)	322
4828	E V SPENCE RESERVOIR	50 (19)	83 (31)	45 (17)	50 (19)	17 (0)	76 (28)	321

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4829	SOMERVILLE LAKE	29 (11)	55 (21)	24 (9)	3 (1)	67 (25)	30 (10)	208
4830	STAMFORD LAKE	18 (7)	97 (37)	5 (2)	18 (7)	82 (31)	39 (14)	259
4831	STILLHOUSE HOLLOW RESERV	88 (33)	37 (14)	87 (33)	92 (35)	17 (0)	51 (19)	372
4832	TAWAKONI LAKE	32 (12)	70 (26)	37 (14)	21 (8)	63 (24)	30 (10)	253
4833	TEXARKANA LAKE	11 (4)	51 (19)	13 (5)	16 (6)	72 (27)	13 (5)	176
4834	TEXOMA LAKE	39 (14)	34 (13)	61 (23)	45 (17)	17 (0)	21 (7)	217
4835	TRAVIS LAKE	88 (33)	21 (7)	92 (35)	82 (31)	17 (0)	84 (31)	384
4836	TRINIDAD	0 (0)	61 (22)	11 (4)	5 (2)	92 (35)	0 (0)	169
4837	TWIN BUTTES RESERVOIR	59 (22)	21 (7)	58 (22)	61 (23)	49 (17)	63 (21)	311
4838	WHITE RIVER RESERVOIR	84 (32)	61 (22)	76 (29)	89 (34)	17 (0)	63 (21)	390
4839	WHITNEY LAKE	63 (24)	51 (19)	79 (30)	71 (27)	17 (0)	76 (28)	357

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	4809	CANYON RESERVOIR	445
2	4823	LAKE MEREDITH	441
3	4813	EAGLE MOUNTAIN LAKE	430
4	4816	KEMP LAKE	423
5	4801	AMISTAD LAKE	402
6	4805	BROWNWOOD LAKE	394
7	4802	BASTROP LAKE	393
8	4838	WHITE RIVER RESERVOIR	390
9	4825	POSSUM KINGDOM RESERVOIR	387
10	4835	TRAVIS LAKE	384
11	4803	BELTON RESERVOIR	384
12	4831	STILLHOUSE HOLLOW RESERV	372
13	4812	DIVERSION LAKE	372
14	4808	CALAVERAS LAKE	362
15	4839	WHITNEY LAKE	357
16	4822	MEDINA LAKE	342
17	4827	SAM RAYBURN RESERVOIR	322
18	4828	E V SPENCE RESERVOIR	321
19	4837	TWIN BUTTES RESERVOIR	311
20	4810	LAKE COLORADO CITY	310
21	4824	PALESTINE LAKE	302
22	4818	LAKE OF THE PINES	298
23	4807	CADDO LAKE	297
24	4814	FT PHANTOM HILL LAKE	296
25	4806	LAKE BUCHANAN	261
26	4830	STAMFORD LAKE	259
27	4819	LAVON RESERVOIR	258
28	4832	TAWAKONI LAKE	253

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
29	4821	LYNDON B JOHNSON LAKE	238
30	4834	TEXOMA LAKE	217
31	4829	SOMERVILLE LAKE	208
32	4826	SAN ANGELO RESERVOIR	200
33	4833	TEXARKANA LAKE	176
34	4815	GARZA LITTLE ELM RESERVO	173
35	4836	TRINIDAD	169
36	4804	BRAUNIG LAKE	159
37	4811	CORPUS CRISTI LAKE	155
38	4817	HOUSTON LAKE	139
39	4820	LIVINGSTON LAKE	91

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR TEXAS 02/11/76

LAKE CODE 4808 CALAVERAS

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 174.6

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
4808A1	174.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4808A2	32.9	0.04	0.03	0.02	0.05	0.09	0.06	0.02	0.01	0.11	0.06	0.02	0.01	0.04
4808B1	20.7	0.03	0.02	0.01	0.03	0.06	0.04	0.01	0.01	0.07	0.04	0.01	0.01	0.03
4808C1	5.7	0.01	0.01	0.00	0.01	0.02	0.01	0.00	0.00	0.02	0.01	0.00	0.00	0.01
4808ZZ	114.2	0.13	0.11	0.05	0.15	0.31	0.21	0.06	0.04	0.40	0.22	0.06	0.02	0.15

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 174.6
SUM OF SUB-DRAINAGE AREAS = 174.6
TOTAL FLOW IN = 2.72
TOTAL FLOW OUT = 0.02

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
4808A1	9	74	0.0	7	0.0				
	10	74	0.0	7	0.0				
	11	74	0.0	7	0.0				
	12	74	0.0	7	0.0				
	1	75	0.0	7	0.0				
	2	75	0.0	6	0.0				
	3	75	0.0	7	0.0				
	4	75	0.0	7	0.0	23	0.0		
	5	75	0.0	8	0.0	22	0.0		
	6	75	0.62	11	0.0				
	7	75	0.74	7	0.00				
	8	75	0.0	13	0.0				
4808A2	9	74	0.0	7	0.0				
	10	74	0.0	7	0.0				
	11	74	0.0	7	0.0				
	12	74	0.0	7	0.0				
	1	75	0.0	7	0.0				
	2	75	0.0	6	0.0				
	3	75	0.0	7	0.0				
	4	75	0.0	7	0.0	23	0.0		
	5	75	0.0	8	0.0	22	0.0		
	6	75	0.0	11	0.0				
	7	75	0.0	15	0.0				
	8	75	0.0	13	0.0				

TRIBUTARY FLOW INFORMATION FOR TEXAS 02/11/76

LAKE CODE 4808 CALAVARAS

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	AY	FLOW
4808H1	9	74	1.33	7	0.0				
	10	74	0.0	7	0.0				
	11	74	0.11	7	0.0				
	12	74	0.00	7	0.01				
	1	75	0.0	7	0.0				
	2	75	0.08	6	0.28				
	3	75	0.0	7	0.0				
	4	75	0.0	7	0.0	23	0.0		
	5	75	0.10	8	0.08				
	6	75	0.37	11	1.25				
	7	75	0.00	15	0.0				
	8	75	0.0	13	0.0				
4808C1	9	74	0.0	7	0.0				
	10	74	0.0	7	0.0				
	11	74	0.0	7	0.0				
	12	74	0.0	7	0.0				
	1	75	0.0	7	0.0				
	2	75	0.0	6	0.0				
	3	75	0.0	7	0.0				
	4	75	0.0	7	0.0	23	0.0		
	5	75	0.0	8	0.0	22	0.0		
	6	75	0.0	11	0.0				
	7	75	0.0	15	0.0				
	8	75	0.0	13	0.0				
4808Z2	9	74	1.19						
	10	74	0.59						
	11	74	1.30						
	12	74	1.08						
	1	75	1.13						
	2	75	6.46						
	3	75	1.36						
	4	75	0.74						
	5	75	3.14						
	6	75	1.76						
	7	75	0.91						
	8	75	0.40						

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/02/11

480801
29 16 44.0 098 18 21.0
CALAVERAS LAKE
48029 TEXAS

11EPALES
3

2111202
0034 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/03/13	14 20	0000	21.3		48	485	8.00	127	0.040	0.800	0.040	0.006
	14 20	0006	20.8	8.6		475	8.00	125	0.030	0.700	0.040	0.005
	14 20	0015	20.6	8.4		480	8.00	125	0.020	0.800	0.030	0.012
	14 20	0030	15.2	3.2		440	7.70	129	0.090	0.900	0.120	0.017
74/05/23	13 15	0000	29.5		48	595	8.45	123	0.040	0.800	0.050	0.007
	13 15	0005	28.5	8.0		591	8.35	122	0.020	0.700	0.020	0.005
	13 15	0015	27.4	5.2		585	8.05	125	0.020	0.600	0.020	0.003
	13 15	0020	26.9	2.0		576	7.60	128	0.030	0.600	0.020	0.004
	13 15	0031	25.5	2.0		561	7.60	128	0.030	0.600	0.020	0.005
74/08/16	10 15	0000	29.0	7.0	48	636	9.00					
	10 15	0005	28.8	6.6		631	9.00					
	10 15	0015	28.6	6.4		630	8.90					
	10 15	0020	28.6	6.2		630	8.90					
74/11/05	14 55	0000	25.1	8.0	48	539	8.46	117	0.004	0.500	0.030	0.017
	14 55	0005	24.4	7.8		538	8.41	116	0.050	0.500	0.030	0.019
	14 55	0015	24.8	7.4		538	8.31	117	0.050	0.400	0.030	0.033
	14 55	0030	24.8	7.4		538	8.23	118	0.060	0.600	0.040	0.055

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/03/13	14 20	0000	0.032	12.1	
	14 20	0006	0.024		
	14 20	0015	0.028		
	14 20	0030	0.032		
74/05/23	13 15	0000	0.031	13.1	
	13 15	0005	0.033		
	13 15	0015	0.030		
	13 15	0020	0.032		
	13 15	0031	0.031		
74/08/16	10 15	0000		26.0	
	10 15	0011			1.0
74/11/05	14 55	0000	0.057	27.5	
	14 55	0005	0.064		
	14 55	0015	0.068		
	14 55	0030	0.164		

STORET RETRIEVAL DATE 76/02/11

480802
29 19 19.0 098 18 15.0
CALAVERAS LAKE
48029 TEXAS

11EPALES
3

2111202
0018 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/03/13	14 50	0000	21.1		24	490	8.55	127	0.030	0.900	0.030	0.014
	14 50	0006	21.0	8.2		490	8.50	127	0.020	0.900	0.020	0.013
	14 50	0014	20.4	7.8		485	8.40	127	0.030	0.800	0.040	0.006
74/05/23	13 30	0000	29.1		42	583	8.50	117	0.030	0.800	0.020	0.004
	13 30	0005	28.2	8.0		577	8.45	124	0.020	0.700	0.020	0.005
	13 30	0014	27.2	5.4		575	8.20	124	0.020	0.700	0.020	0.006
74/08/16	09 55	0000	30.0	7.8	36	629	9.00					
	09 55	0005	30.0	7.6		629	8.90					
	09 55	0014	29.9	7.0		630	8.90					
74/11/05	15 10	0000	24.1	8.0	26	535	8.53	114	0.020	0.400	0.020K	0.015
	15 10	0005	24.1	6.8		530	8.48	127	0.020K	1.000	0.020K	0.016
	15 10	0010	23.8	7.0		528	8.36	124	0.030	1.000	0.020K	0.020

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/03/13	14 50	0000	0.043	13.8	
	14 50	0006	0.038		
	14 50	0014	0.041		
74/05/23	13 30	0000	0.037	28.9	
	13 30	0005	0.039		
	13 30	0014	0.037		
74/08/16	09 55	0000		28.0	
74/11/05	15 10	0000	0.066	24.5	
	15 10	0005	0.097		
	15 10	0010	0.077		

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/02/11

480803
29 18 37.0 098 20 04.0
CALAVERAS LAKE
48029 TEXAS

11EPALES
3

211202
0015 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/03/13	15 30	0000	23.7		36	510	8.60	126	0.040	0.800	0.060	0.006
	15 30	0006	22.9	8.6		509	8.60	126	0.030	0.700	0.040	0.006
	15 30	0011	22.8	8.0		505	8.60	126	0.030	0.600	0.030	0.006
74/05/23	13 45	0000	30.7		36	618	8.00	127	0.030	0.800	0.020	0.006
	13 45	0005	29.6	4.8		614	7.90	127	0.050	0.800	0.070	0.010
	13 45	0016	28.6	3.2		620	7.75	130	0.080	0.800	0.070	0.007
74/08/16	10 40	0000	32.9	3.2	42	696	8.00					
	10 40	0005	32.6	4.0		689	8.20					
	10 40	0010	32.0	3.8		684	8.20					
74/11/05	15 30	0000	27.1	7.8	26	562	8.53	126	0.030	0.900	0.040	0.009
	15 30	0005	26.6	7.4		551	8.56	126	0.040	0.800	0.040	0.011
	15 30	0010	25.8	8.0		543	8.39	126	0.050	1.000	0.020	0.017

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/03/13	15 30	0000	0.032	13.0	
	15 30	0006	0.034		
	15 30	0011	0.033		
74/05/23	13 45	0000	0.055	55.4	
	13 45	0005	0.033		
	13 45	0016	0.042		
74/08/16	10 40	0000		12.4	
	10 40	0009			1.0
74/11/05	15 30	0000	0.059	15.3	
	15 30	0005	0.061		
	15 30	0010	0.068		

APPENDIX E

TRIBUTARY DATA

STORET RETRIEVAL DATE 76/03/10

48088A1
29 16 25.0 098 17 55.0 4
CALAVARAS CREEK
48017 7.- ELMENDORF
U/CALAVARAS LAKE
SEC RD 1518 BRDG .6 MI NE OF JCT US 181
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/09/07	11 05		0.016	0.600	0.015	0.005	0.035
74/10/07	09 45		0.024	0.550	0.035	0.020	0.060
74/11/07	10 45		0.016	0.800	0.030	0.010	0.040
74/12/07	15 05		0.024	1.300	0.024	0.005K	0.020
75/01/07	10 30		0.024	0.800	0.032	0.005	0.030
75/02/06	11 00		0.005	0.800	0.024	0.008	0.020

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/03/10

4805A2
29 20 40.0 098 21 30.0 4
CALAVARAS CREEK
48 7.5 ELMENDORF
T/CALAVARAS LAKE
FOSTER RD BRDG 1.7 MI S OF SULP SPRS RD
11EPALES 21112H4
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/09/07	10 35		0.216	0.900	0.020	0.025	0.080
74/12/07	14 40		0.296	0.700	0.016	0.030	0.100
75/01/07	11 00		0.008	0.600	0.024	0.005K	0.020
75/02/06	10 40		0.352	1.100	0.048	0.048	0.100
75/03/07	12 00		0.135	0.900	0.070	0.005	0.020
75/05/22	11 20		0.065	1.100	0.045	0.025	0.140
75/06/11	10 45		0.250	1.150	0.095	0.115	0.280
75/07/15	12 05		0.350	1.600	0.065	0.025	0.170

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/03/10

480881
29 22 08.0 098 17 20.0 4
CHUPADERAS CREEK
48 7.5 ELMENDORF
T/CALAVARAS LAKE
STUART RD BRDG .3 MI S OF JCT US 87
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/09/07	10 05		0.312	1.000	0.165	0.015	0.040
74/10/07	09 10		0.448	0.400	0.045	0.005K	0.020
74/11/07	10 20		0.088	0.600	0.035	0.015	0.030
74/12/07	14 20		0.232	1.700	0.168	0.015	0.030
75/01/07	10 10		0.104	0.800	0.040	0.005K	0.010
75/02/06	10 15		0.448	1.000	0.048	0.152	0.210
75/03/07	11 40		0.005	0.950	0.030	0.010	0.060
75/04/07	09 25		0.170	0.900	0.165	0.005K	0.040
75/04/23	10 20		0.125	0.650	0.110	0.010	0.030
75/05/08	10 40		0.610	1.350	0.260	0.015	0.020
75/05/22	11 00		0.700	0.800	0.200	0.020	0.050
75/06/11	10 30		0.100	1.100	0.065	0.100	0.300
75/07/15	11 45		0.560	0.700	0.105	0.005	0.060

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/03/10

480dC1
29 21 20.0 098 16 38.0 4
UNNAMED STREAM
48 7.5 ELMENDORF
T/CALAVARAS LAKE
COOKSEY RD BRDG 1.3 MI S OF JCT US 87
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/02/06	10	00	0.152	0.600	0.048	0.024	0.070
75/05/22	10	10	0.280	1.500	0.325	0.032	0.090
75/06/11	10	15	0.130	1.250	0.090	0.105	0.230