DATA ON DYE DISPERSION IN A REACH OF THE SACRAMENTO RIVER NEAR RED BLUFF, CALIFORNIA

OPEN-FILE REPORT

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division
Menlo Park, California, 1970
Prepared in cooperation with the
CALIFORNIA WATER RESOURCES CONTROL BOARD

Balding — DATA ON DYE DISPERSION IN THE SACRAMENTO RIVER NEAR RED BLUFF, CALIFORNIA

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By

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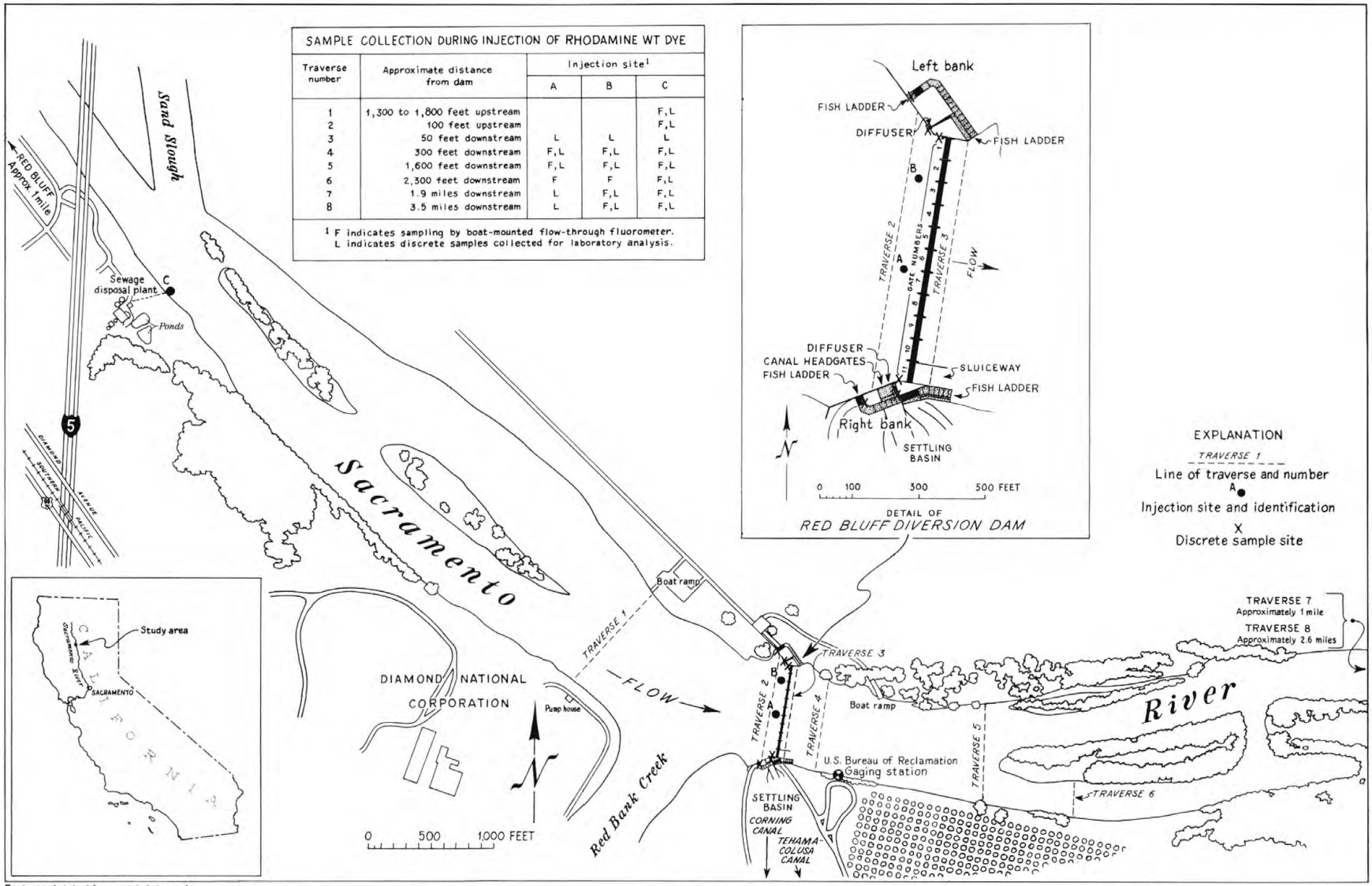
ILLUSTRATION

APPENDIXES

SAMPLE COLLECTION DURING INJECTION OF RHODAMINE WT DYE

Traverse number	Approximate distance from dam	Injection site[1]		
		A	B	C
1	1,300 to 1,800 feet upstream			F,L
2	100 feet upstream			F,L
3	50 feet downstream	L	L	L
4	300 feet downstream	F,L	F,L	F,L
5	1,600 feet downstream	F,L	F,L	F,L
6	2,300 feet downstream	F	F	F,L
7	1.9 miles downstream	L	F,L	F,L
8	3.5 miles downstream	L	F,L	F,L

[1] F indicates sampling by boat-mounted flow-through fluorometer.
L indicates discrete samples collected for laboratory analysis.



Base map sketched from aerial photographs supplied by U.S. Bureau of Reclamation

FIGURE 1.—Map of dye-dispersion study area in the vicinity of Red Bluff diversion dam, Sacramento River, California, October 1969.

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INTRODUCTION

Late in October 1969, the U.S. Geological Survey, in cooperation with the California Water Resources Control Board, obtained data on the dispersion of injected dye in a reach of the Sacramento River near Red Bluff, Calif. The study area was in the vicinity of the Red Bluff diversion dam, immediately downstream from the mouth of Red Bank Creek (fig. 1).

The U.S. Bureau of Reclamation is presently constructing the Tehama-Colusa Canal. The canal will receive water from the reservoir behind the diversion dam and the first 3.5 miles of the canal will be used as an artificial spawning channel. As many as 60 million king salmon fingerlings a year are expected to hatch in the spawning channel. Sewage and industrial effluents enter the Sacramento River upstream from the headgates to the canal. The poorly dispersed and diluted effluents discharged into the river may have damaging effects on eggs and fingerlings in the artificial spawning channel.

According to a study made by David R. Minard of the Federal Water Pollution Control Administration (written commun., May 2, 1969), a 1 percent solution of the upstream industrial effluent from a low-grade papermill increased the growth of the bacterium Pseudomonas and caused 100-percent fatalities by suffocation among the salmon fingerlings.

Purpose and Scope

The purpose of this study was to define the lateral limits of dispersion of waste water discharged into the Sacramento River in the vicinity of the Red Bluff diversion dam. The information was obtained to assist other agencies in their evaluation of proposed sites for waste discharge with respect to the Tehama-Colusa Canal intake. The scope of the work included injecting fluorescent dye (rhodamine WT) to simulate waste discharges at the sewage plant outfall about 1.1 miles upstream from the dam, and at two points on the floor of the reservoir about 60 feet upstream from the dam (fig. 1). The last two points were selected to simulate waste discharges by a proposed waste-water distribution system for Diamond National Corp. The concentration of dye in the water was monitored downstream from the injection sites. Monitoring was done by using a combination of boat-and shore-mounted flow-through fluorometers with recorders and by collection of discrete samples for subsequent laboratory analysis.

Prior to the start of field operations, a decision was made in conference with personnel of the Central Valley Regional Water Quality Control Board, to omit dye injection at the existing outfall of the Diamond National Corp. Injection at this site would have duplicated work done in March 1969 by Mr. Minard of the Federal Water Pollution Control Administration.

Acknowledgments

Personnel of the Diamond National Corp. and various city, state, and federal agencies were most helpful in making arrangements for the work. The generous assistance of David R. Minard of the Federal Water Pollution Control Administration, Paul Jepperson of the Central Valley Regional Water Quality Control Board, Curtis Sweitzer of the U.S. Bureau of Reclamation, and Marvin Kennedy of the city of Red Bluff is gratefully acknowledged. Particular thanks is given to John T. Limerinos of the Geological Survey for his considerable input of time and experience in planning and performing the work.

This report was prepared by the Geological Survey, Water Resources Division, in cooperation with the California Water Resources Control Board as part of the water resources studies in the Central Valley of California. The work was done in October 1969 under the general supervision of R. Stanley Lord, district chief in charge of water resources investigations in California, and under the immediate supervision of Willard W. Dean, chief of the Sacramento subdistrict office.

FIELD OPERATIONS

On October 27, 1969, personnel from the Geological Survey along with Mr. Minard, Mr. Jepperson, and Mr. Sweitzer met at the diversion dam with Sven Johnson of the U.S. Bureau of Sport Fisheries and Wildlife and Richard J. Hansen of the California Department of Fish and Game.

The physical operations and goals of the project were discussed. The three dye injection sites above the dam were confirmed along with discrete sampling sites and boat traverses upstream and downstream from the dam (fig. 1). Mr. Hansen requested that some additional samples be obtained 2 to 4 miles downstream from the dam (traverses 7 and 8) in a natural spawning area of the river.

The openings of the bottom release gates of the diversion dam were left unchanged throughout the study. The gate openings were:

gate	1	- 1.0 foot
gates	2-5	- closed
gates	6-10	- 0.5 foot each
gate	11	- 2.8 feet

There was no diversion of water into the Tehama-Colusa Canal.

Discharge data were collected at the Geological Survey gaging station on the Sacramento River above Bend Bridge, near Red Bluff, about 14 miles upstream from the dam on October 28, 29, and 30, 1969. The rated discharges were 8,480, 8,460, and 8,440 cfs (cubic feet per second). Flow in Red Bank Creek was very low and assumed to be negligible.

The dye was injected at three sites (fig. 1), one each day. Lateral traverses were made using a boat-mounted flow-through fluorometer. Discrete samples also were taken in conjunction with the fluorometer and at fixed stations such as the fish ladders, diffusers, and at gates one and eleven at the dam. A flow-through fluorometer was set up at the right-bank fish ladder during the final dye injection at site C.

October 28, 1969

The first dye injection began at 9:30 a.m. at site A (fig. 1), 60 feet upstream from the diversion dam opposite the pier between gates 6 and 7. Dye was injected at a rate of 24 ml/min (milliliters per minute) or 14×10^{-6} cfs for approximately 7.5 hours with the injection hose resting on the bottom of the reservoir. Samples were collected at downstream traverses. The dye plume was easily seen on the downstream side of gate 6 and downstream on the left side of the island. Results of fluorometric analysis are in appendix A. Appendix B contains graphs of the results of traverses with boat-mounted fluorometer.

October 29, 1969

The second dye injection began at 8:55 a.m. at site B (fig. 1), 60 feet upstream from the diversion dam opposite the pier between gates 2 and 3, at a rate of 22 ml/min or 13×10^{-6} cfs for approximately 7 hours. The injection hose was resting on the bottom of the reservoir. Samples were collected at downstream sites and discrete samples were obtained on the upstream side of the dam at both diffusers and fish ladders and at gates 1 and 11. The dye passed through gate 1 and continued downstream on the left side of the channel.

October 29 and 30, 1969

The third dye injection began at 10:00 p.m. on October 29 at the waste-water effluent pipe of the Red Bluff sewage plant, 1.1 miles upstream from the dam (site C, fig. 1). Dye was injected at 29 ml/min (17×10^{-6} cfs) for approximately 15 hours. The injection was started in the evening to insure stabilization of the dye plume throughout the study reach. It took 2 hours and 25 minutes for the leading edge of the dye cloud to reach the flow-through fluorometer installed at the right-bank fish ladder approximately 5,800 feet downstream, indicating an approximate mean velocity of 0.67 foot per second.

Samples were collected at the same sites as during the dye injection on October 29 with the addition of traverses 1 and 2, and the flow-through fluorometer at the right-bank fish ladder. At the Red Bluff sewage plant, the average effluent discharge rate for October 30 was 1.34 million gallons per day or 2.08 cfs.

GENERAL DISCUSSION

Sampling of Traverses

The use of a boat-mounted flow-through fluorometer allowed an instantaneous definition of the lateral position of the dye cloud, and also determination of concentration of dye in the traverses (fig. 1, appendixes). The intake for the boat-mounted fluorometer was 1.5 to 2.0 feet below the water surface. Discrete samples collected from the boat were taken at the surface for comparative purposes only. In each traverse, samples of the dye plume were collected: (1) At the lateral edges, (2) at the peak concentration, and (3) at intermediate points. At each sampling point, the horizontal distance was measured using a transit on the shore and a stadia rod on the boat.

There are in some instances large differences between the concentrations obtained by field (flow-through fluorometer) and laboratory (discrete samples) analyses. The differences probably are due to minor changes in the position of the boat between the time that the fluorometer was read and the sample collected. While sampling near the edge of the dye plume, any lateral change of boat position would tend to cause disparate results between field and laboratory analyses.

Samples numbered 1278 and 1279 in traverse number 1 of injection C (appendix A) were surface and bottom samples taken at the same point. Results of analysis are nearly identical for the two samples, demonstrating that vertical mixing was nearly complete and that the point of sample collection in the vertical plane was not critical at the sampling site. Similar results were obtained with samples 1288 and 1289.

Discrete Sampling at the Dam

Analysis of discrete samples collected at the diffusers, fish ladders, and gates 1 and 11 show considerable fluctuation in concentration of dye. Fluctuations probably are due to minor lateral movement of the dye plume. Samples number 1222, 1223, and 1224 of dye injection B (appendix A) probably are not representative. They were collected prior to the dye injection and should have represented background fluorescence only. The water samples probably were contaminated.

Fluorometer at the Fish Ladder

The flow-through fluorometer installation in the right-bank fish ladder was used only during the dye injection at point C on October 29 and 30. The intake for the fluorometer was about 2 feet below the water surface. Lateral movement of the dye plume is the probable cause of the fluctuations in concentrations obtained at this site, (appendix B).

Calibration of Fluorometers

The boat-mounted fluorometer was the same instrument that Mr. Minard used in March 1969. His instrument was calibrated on the assumption that the concentration of the factory supplied 20 percent solution of rhodamine WT, was $1{,}000 \times 10^6$ micrograms per liter instead of 200 micrograms per liter; the specific gravity of the dye was not considered. The second flow-through fluorometer and the fluorometer used in the laboratory to analyze the discrete samples were calibrated on the same assumption for the sake of continuity.

The discrete sample fluorometer and second flow-through fluorometer were calibrated in the laboratory using procedures recommended by J. F. Wilson (1968, p. 20-26)1/ and information supplied by Mr. F. A. Kilpatrick (written commun., Sept. 29, 1969). The second flow-through fluorometer was calibrated using Wilson's second method (Wilson, 1968, p. 26).

SUMMARY

After injection of dye at site A, the dye cloud remained in midstream at traverse 4, shifted toward the left bank at traverse 5, and was dispersed fairly evenly across the channel at traverses 7 and 8.

The dye cloud from injection B passed through gate 1 and continued on down the left bank through traverses 4 and 5 and had started to disperse toward the right bank at traverses 7 and 8.

Injection of dye at site C resulted in a dye cloud that stayed near the right bank through the entire reach. Dye was present at the canal headgates, the fish ladder, diffuser, and gates 7 through 11 near the right-bank end of the dam.

Lateral dispersion of dye from the three injection sites is valid only under the conditions existing during the fieldwork October 28-30, 1969. The flow pattern at the dam will be different if the discharge changes in the Sacramento River or Red Bank Creek, if the gate settings at the dam are changed, and particularly when there is a large diversion to the Tehama-Colusa Canal.

1. Wilson, J. F., Jr., 1968, Fluorometric procedures for dye tracing: U.S. Geol. Survey Techniques of Water Resources Inv., Book 3, Chap. A12, 31 p.

APPENDIX A.--Results of fluorometric analysis

Sample site	Sample number	Time (Pacific std. time)	Position of sample, in feet, from right bank 1/	Concentration of dye, in micrograms per liter	
				Field	Laboratory
Dye injected at site A, 0930 to 1700, October 28, 1969					
Traverse 3	1373	1243	Gate 5		4.4
	1374	1245	6		14.5
	1375	1245	7		1.7
	1376	1245	8		.5
	1377	1246	9		.1
	1378	1246	10		.0
	1379	1247	11		.1
	1380	1247	11		.0
Traverse 4	1366	1215	403	15.4	0.2
	1367	1223	478	27.0	25.0
	1368	1227	543	.5	.0
	1369	1230	673	.2	.0
	1370	1234	528	2.3	3.7
	1371	1237	386	.6	1.1
	1372	1240	383	.9	.8
Traverse 5	1381	1420	653	2.2	2.0
	1382	1422	723		.9
	1383	1427	693	15.3	14.5
	1384	1429	707	9.3	10.8
	1385	1431	678	13.7	11.5
Traverse 6	The flow-through fluorometer did not show any indication of dye at this section.				
Traverse 7	1386	1500	30		1.5
	1387				1.9
	1388				2.5
	1389				2.7
	1390				2.9
	1391				2.7
	1392				2.7
	1393				2.2
	1394				Lost
Traverse 7	1395				3.0
	1396				2.9
	1397				2.7
	1398				2.5
	1399				2.2
	1400				2.5
	1401	1507	469		2.5
	1402				.0
Traverse 8	1404	1525	482		2.4
	1405				2.2
	1406				2.2
	1407		241		2.0
	1408				1.8
	1409				1.5
	1410		120		1.4
	1411		96		.7
	1412		0		.4
Dye injected at site B, 0855 to 1600, October 29, 1969					
Traverse 3	1329	1153	1		4.4
	1330	1154	3		.4
	1331	1155	5		.2
	1332	1157	6		.0
	1333	1158	8		.7
Traverse 4	1320	1122	647	0.4	1.8
	1321	1125	637	.3	.7
	1322	1128	791	5.6	5.9
	1323	1132	803	5.0	4.4
	1324	1138	735	14.2	15.4
	1325	1140	729	13.3	15.5
	1326	1145	672	3.9	11.2
	1327	1147	704	5.8	11.2
	1328	1150	757	1.8	10.1
Traverse 5	1334	1223	715	1.4	1.3
	1335	1226	743	4.5	6.4
	1336	1227	754		11.5
	1337	1233	757	8.5	10.6
	1338	1235	747	6.8	8.8
	1339	1237	737	2.8	3.1
	1340	1240	724	.8	1.2
	1341	1242	803		10.8
	1342	1244			.0
Traverse 6	The flow-through fluorometer did not show any indication of dye at this section.				

Sample site	Sample number	Time (Pacific std. time)	Postion of sample, in feet, from right bank 1/	Concentration of dye, in micrograms per liter	
				Field	Laboratory
Dye injected at site B--Continued					
Traverse 7	1343	1303	Gate 470	4.6	5.6
	1344		450	4.5	Lost
	1345	1305	400	3.8	4.6
	1346	1307	330	2.7	3.7
	1347	1308	250	1.4	1.8
	1348	1310	170	1.0	1.5
	1349	1311	100	.2	.0
	1350	1312	20	.1	.0
Traverse 8	1351	1322	480	2.1	2.7
	1352	1323	390	2.2	2.9
	1353	1324	320	1.6	2.4
	1354	1327	240	1.2	1.8
	1355	1328	160	.6	.8
	1356	1329	100	.2	.4
	1358	1331	20	.2	.2
Upstream side of gate No. 1	1225	0850			5.3
	1232	0955			4.5
	1238	1055			5.1
	1245	1210			1.4
Left bank diffuser	1226	0850			3.2
	1233	0955			17.5
	1239	1055			.6
	1246	1210			1.1
Left bank fish ladder	1227	0850			1.4
	1234	0955			25.0
	1240	1055			.9
	1247	1210			Lost
Upstream side of gate No. 11	1222	0755			4.9
	1228	0920			.9
	1235	1040			.9
	1241	1115			1.3
	1248	1215			.4
Right bank diffuser	1223	0755			39.0
	1229	0920			.4
	1236	1040			.7
	1243	1115			1.3
	1249	1215			.6
Right bank fish ladder	1224	0755			2.9
	1230	0920			1.1
	1237	1040			1.6
	1244	1115			.7
	1250	1215			.4
Dye injected at site C, 2200, October 29 to 1300, October 30, 1969					
Traverse 1	1272	0930	871	0.0	0.0
	1273	0937	236	.3	.0
	1274	0941	215	1.0	.5
	1275	0944	134	5.1	5.4
	1276	0947	61	6.6	7.5
	1277	0949	39	7.4	8.7
	1278	0955	a13	8.0	9.3
	1279	0958	b13	7.9	9.3
	1281	1002	0	7.9	9.3
Traverse 2	1280	1052	293	0.1	0.2
	1282	1055	235	1.1	.7
	1283	1057	193	2.1	1.6
	1284	1100	169	2.7	3.2
	1285	1102	125	5.4	4.2
	1286	1103	79	3.7	3.6
	1287	1105	35	7.2	8.4
	1288	1110	b0	7.4	8.4
	1289	1110	a0	7.5	8.7
	1290	1113	115	3.6	3.7
	1291	1116	60	7.4	6.6
	1292	1117	80	5.5	6.7
Traverse 3	1293	1240	7		0.0
	1294	1241	8		.1
	1295	1242	9		.3
	1296	1243	10		1.0
	1304	1307	11		2.9
Traverse 4	1297	1248	13	4.5	5.5
	1298	1249	0		5.9
	1299	1251	118	3.0	6.5

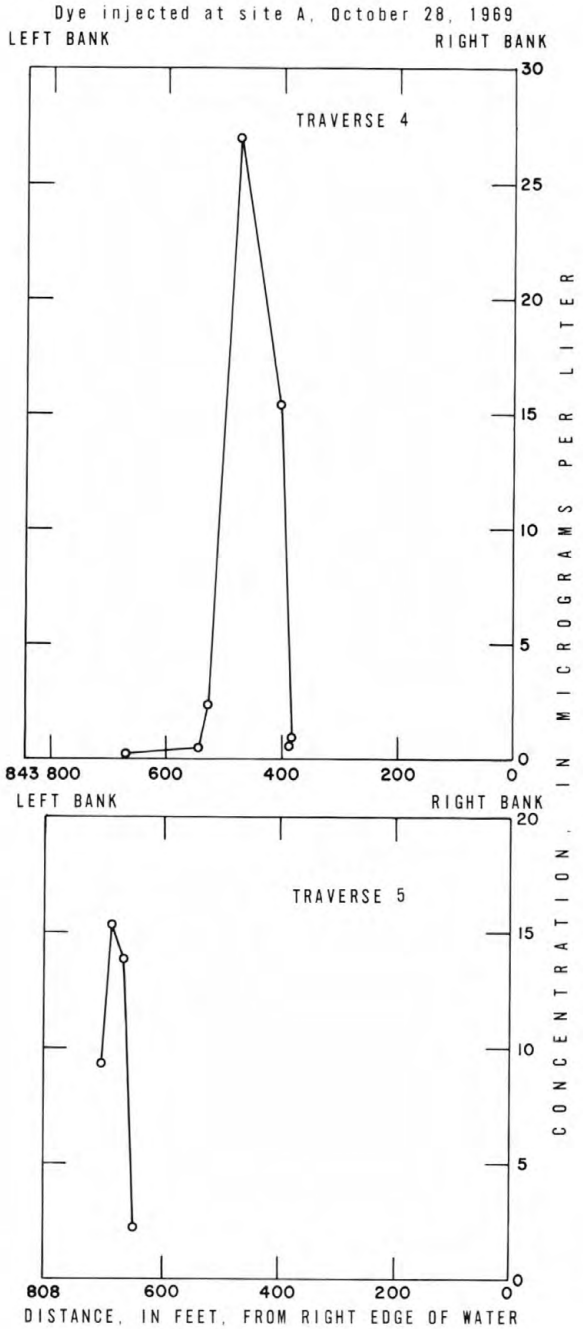
See footnotes at end of table.

APPENDIX A.--Continued

Sample site	Sample number	Time (Pacific std. time)	Position of sample, in feet, from right bank 1/	Concentration of dye, in micrograms per liter		Sample site	Sample number	Time (Pacific std. time)	Position of sample, in feet, from right bank 1/	Concentration of dye, in micrograms per liter	
				Field	Laboratory					Field	Laboratory
Dye injected at site C--Continued						Dye injected at site C--Continued					
Traverse 4	1300	1253	Gate 198	1.0	1.2	Right bank	1253	0900			9.0
	1301	1256	208	1.0	1.1	fish ladder	1257	1000			8.8
	1302	1258	276	.2	.4		1260	1100			9.1
	1303	1302	346	.0	.0		1264	1200			8.6
							1267	1300			8.6
Traverse 5	1311	1356	656	0.0	0.0		1270	1400			9.0
	1312	1358	638	.8	.7						
	1313	1359	613	1.7	1.5	Flow-through		2100		0.0	
	1314	1400	585	2.8	3.5	fluorometer		2400		.0	
	1315	1402	545	3.3	3.8	in right-		0025		trace	
						bank fish		0045		.4	
Traverse 6	1305	1313	0	5.2	6.0	ladder		0100		1.0	
	1306	1324	15	4.8	5.5			0115		2.4	
	1307	1327	45	4.6	5.7			0130		3.1	
	1308	1328	85	4.1	4.6			0145		4.0	
	1309	1330	145	3.5	4.2						
	1310	1331	169	3.3	4.6			0200		4.8	
								0215		4.8	
Traverse 7	1316	1412	10	3.6	4.2			0230		5.2	
	1317	1413	80	2.3	2.9			0245		5.5	
	1318	1414	170	1.8	2.2			0300		5.3	
	1319	1415	250	.8	1.1			0315		5.5	
	1441	1416	250	1.0	.9			0330		5.3	
	1442	1417	370	.4	.6			0345		5.5	
	1443	1417	420	.3	.3						
	1444	1418	470	.1	.4			0400		5.3	
								0415		5.5	
Traverse 8	1445	1426	470	0.4	1.0			0430		5.5	
	1446	1428	360	.5	1.1			0445		5.8	
	1447	1428	320	.8	1.7			0500		6.2	
	1448	1430	240	1.1	1.9			0515		5.9	
	1449	1430	190	1.4	2.7			0530		6.5	
	1450	1431	160	1.8	3.4			0545		6.4	
	1451	1433	120	2.6	3.2						
	1452	1435	80	2.8	3.4			0600		6.0	
	1453	1435	50	3.2	4.6			0615		6.2	
	1454	1436	20	3.2	4.2			0630		6.6	
								0645		7.2	
Upstream	1202	0830			7.0			0700		7.3	
side of gate	1205	0930			3.2			0715		6.8	
No. 1	1208	1030			4.0			0730		7.0	
	1211	1130			1.9			0745		7.0	
	1214	1230			1.9						
	1217	1330			1.3			0800		6.6	
	1220	1430			1.3			0815		6.8	
								0830		7.2	
Left bank	1203	0830			1.1			0900		7.2	
diffuser	1206	0930			4.6			0915		7.5	
	1210	1030			1.6			0930		7.9	
	1212	1130			.5			0945		7.7	
	1215	1230			1.6						
	1218	1330			.6			1000		8.4	
	1221	1430			.6			1015		8.5	
								1030		7.7	
Left bank	1204	0830			1.2			1045		8.0	
fish ladder	1207	0930			7.9			1100		8.2	
	1209	1030			3.2			1115		8.4	
	1213	1130			2.3			1130		8.0	
	1216	1230			1.4			1145		7.5	
	1219	1330			1.3						
	1413	1430			.9			1200		7.9	
								1215		8.0	
Upstream	1251	0900			16.0			1230		7.2	
side of gate	1254	1000			8.7			1245		6.5	
No. 11	1258	1100			8.1			1300		5.7	
	1261	1200			7.4			1315		5.5	
	1265	1300			6.8			1330		6.2	
	1268	1400			7.8			1345		5.3	
								1400		6.8	
Right bank	1252	0900			13.0			1412		7.0	
diffuser	1256	1000			9.2						
	1259	1100			8.1						
	1263	1200			8.1						
	1266	1300			7.8						
	1269	1400			8.1						

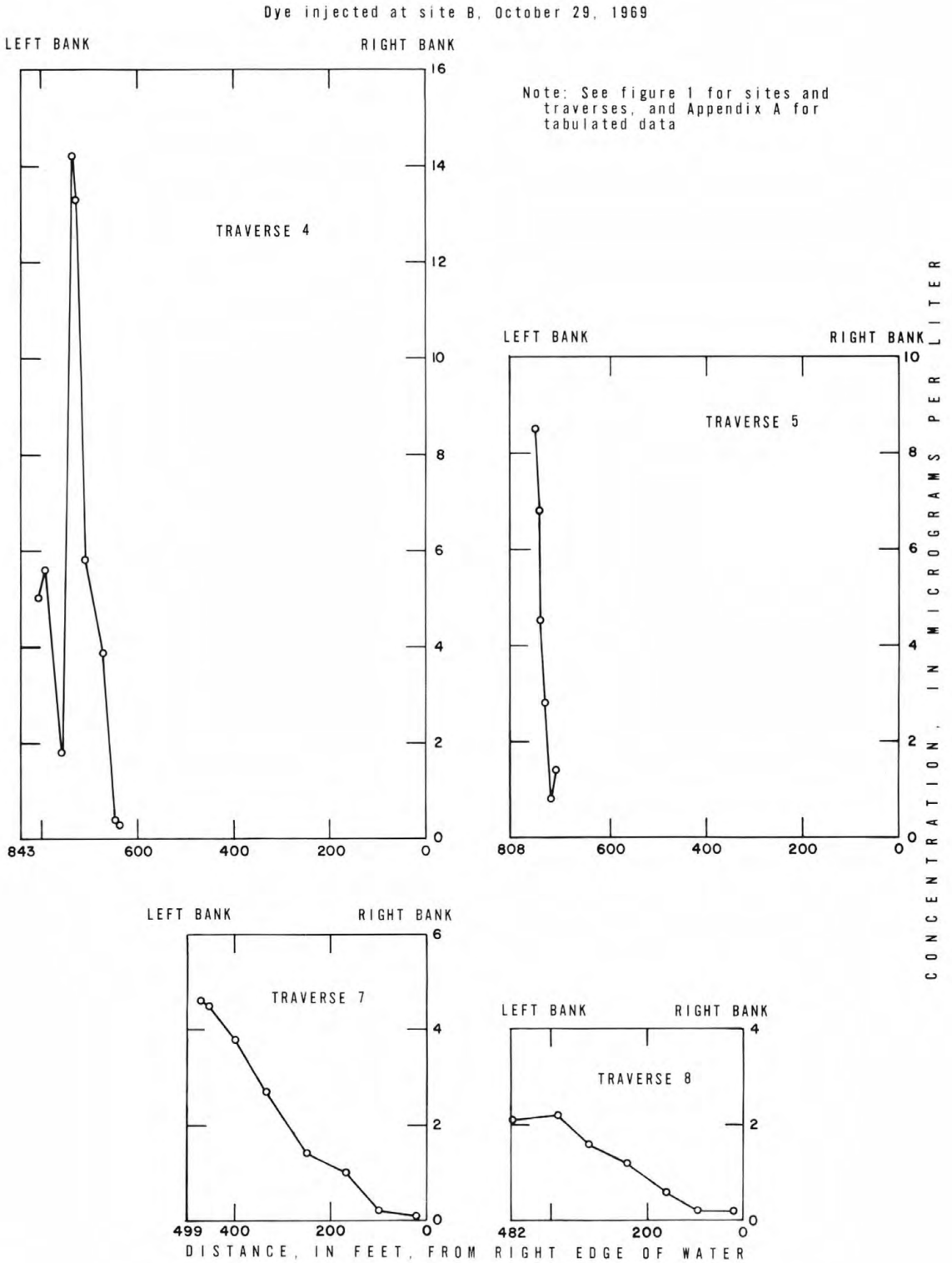
1. Position given opposite gates for traverse 3.
a. Surface.
b. Bottom.

APPENDIX B.--Graphs of selected fluorometric traverses

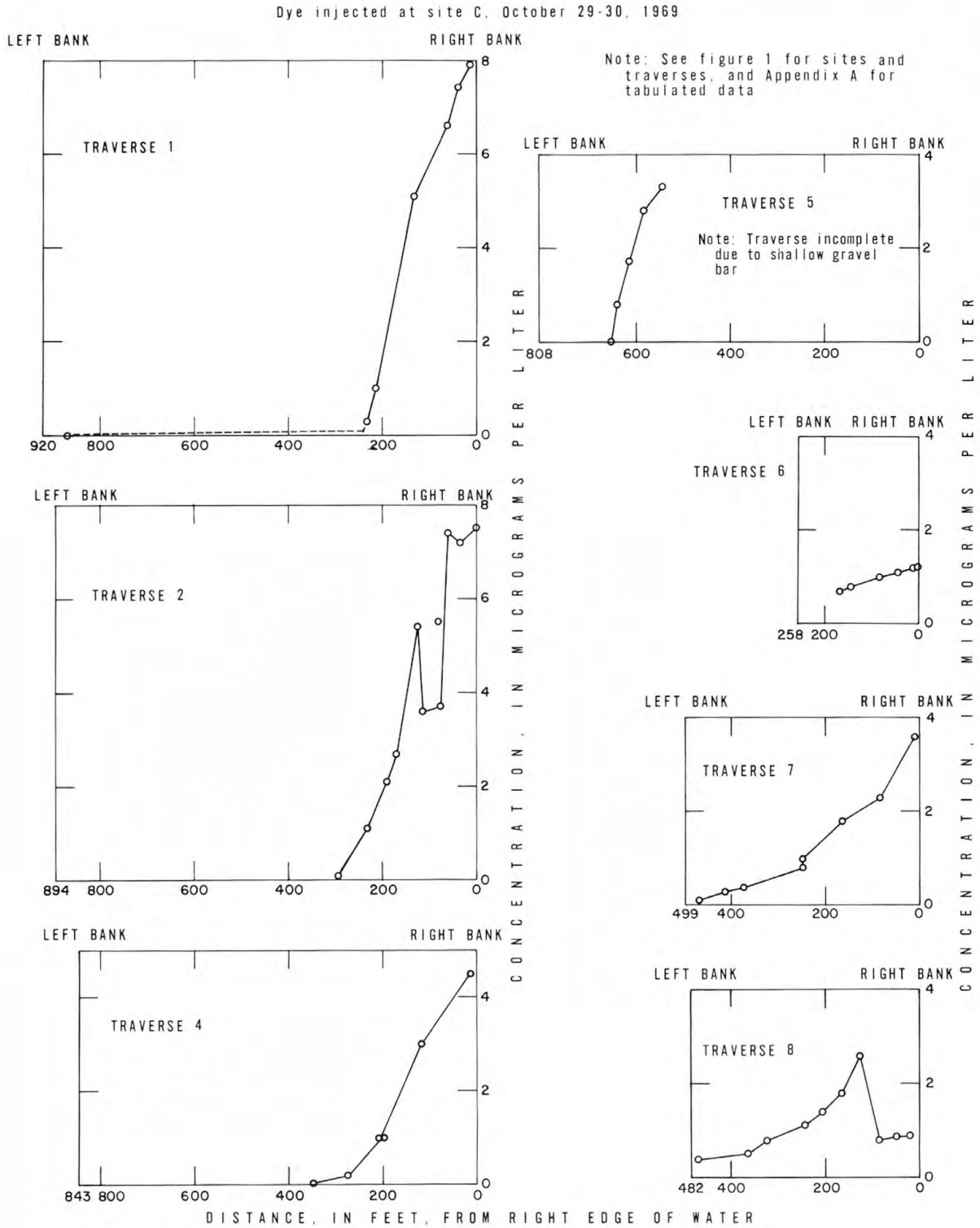


Note: See figure 1 for sites and traverses, and Appendix A for tabulated data

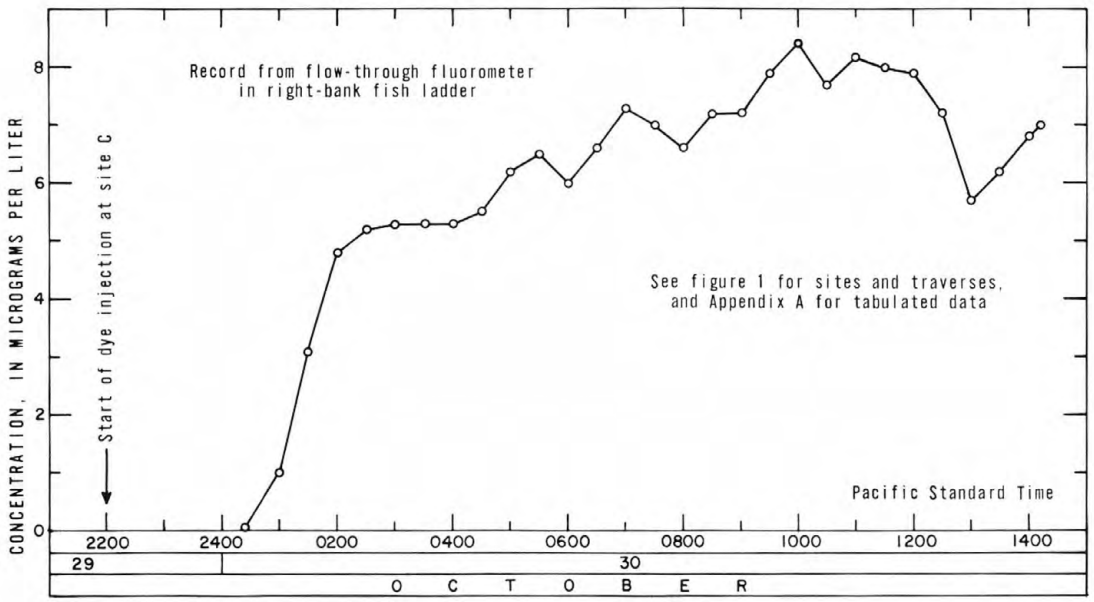
APPENDIX B.--Continued



APPENDIX B.--Continued



APPENDIX B.--Continued

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