TEXAS WATER DEVELOPMENT BOARD

REPORT 90

QUANTITY AND QUALITY OF LOW FLOW IN SABINE AND OLD RIVERS NEAR ORANGE, TEXAS SEPTEMBER 12-15, 1967

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> Prepared by the U.S. Geological Survey in cooperation with the Texas Water Development Board and the Sabine River Authority of Texas

> > January 1969

TABLE OF CONTENTS

Page

INTRODUCTION	1
DESCRIPTION OF STUDY AREA	1
METHODS OF INVESTIGATION	3
Water-Level Measurements	3
Streamflow Measurements	3
Water-Quality Measurements	3
ANALYSIS OF DATA	3
Water-Stage Records and Observations	3
Streamflow Distribution	3
Water-Quality Variations	5
Sabine River-Mile +22.6 to Mile +10.9	7
Sabine River-Mile +10.9 to Mile +5.6	14
Old River-Mile T +10.5 to Mile T +4.8	14
Old River-Mile T +4.8 to Mile T 0.0	14
Sabine River–Mile +5.6 to Mile -1.6	14
Big Bayou—Mile T +5.5 to Mile T 0.0	16
Inflow From Tributaries	16
SUMMARY OF CONCLUSIONS	16
REFERENCES	17

TABLES

1.	Summary of Discharge Measurements, Sabine River Basin Near Orange, Texas	4
2.	Chemical Analyses of Water From Streams in the Sabine River Basin Near Orange, Texas	9

TABLE OF CONTENTS (Cont'd.)

Page

FIGURES

1. Map Showing Locations of Streamflow and Chemical-Quality Data-Collection Sites	2
 Diagrams Showing Summary of Stage and Flow Data for the Tide-Affected Reaches of the Sabine and Old Rivers 	5
3. Diagram Showing the Tide-Affected Reaches of the Sabine and Old Rivers	6
4. Profiles of Weighted-Average Chloride in the Sabine and Old Rivers	7
 Sections Showing Variations of Dissolved Solids, Chloride, and Dissolved Oxygen at Three Sites in the Sabine and Old Rivers Upstream From the Advance of Sea Water 	8
 Sections Showing Variations of Dissolved Solids, Chloride, and Dissolved Oxygen at Three Sites in the Sea-Water Affected Reaches of the Sabine and Old Rivers 	15

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INTRODUCTION

The U.S. Geological Survey's stream-gaging and chemical-quality station, Sabine River near Ruliff. Texas, is the lowermost site on the Sabine River for which daily streamflow and water-quality records are available. Downstream from this station, the Old River anabranch of the Sabine River diverts part of the flow into Louisiana, where two large privately owned canal companies pump water for rice irrigation. Similarly, the Sabine River Authority of Texas diverts water from the mainstem Sabine River for industrial and irrigation uses. The Sabine and Old Rivers rejoin in the tidal reach upstream from Orange, Texas. Because the lower reach of the Sabine River is tidal, sea water from the Gulf of Mexico periodically intrudes through Sabine Lake into both the Sabine and Old Rivers. Although several private firms have collected some water-quality information on the tidal reach of the Sabine River (Forrest and Cotton, 1966, p. 5), the effects of tide on water quality and the extent of salt-water intrusion have not been defined adequately. Moreover, neither the quantity of water that flows from the mainstem into Old River nor the quantity or quality of tributary inflow downstream from the station near Ruliff is known. Therefore, in April 1966, the U.S. Geological Survey, in cooperation with the Sabine River Authority of Texas and the Texas Water Development Board, began a series of investigations of the quantity and quality of flow in streams of the Sabine River basin between the Ruliff gaging station and Orange. Purposes of the investigations were: (1) to determine the distribution of flow in the mainstem and anabranches of the Sabine River in the study area; (2) to devise a method whereby the distribution of flow can be estimated from discharge records of the gaging station Sabine River near Ruliff; (3) to define the effects of tide on quality of the water; and (4) to determine the quality and quantity of tributary inflow.

The results of investigations made on April 12, 1966, and during the period October 31 to November 4, 1966, when flow at the Ruliff station was about 1,680 cfs (cubic feet per second) and 500 cfs, respectively, have been described by Rawson, Reddy, and Smith (1967).

A third investigation, the results of which are described herein, was made during the low-flow period September 12-15, 1967, to supplement the earlier investigations.

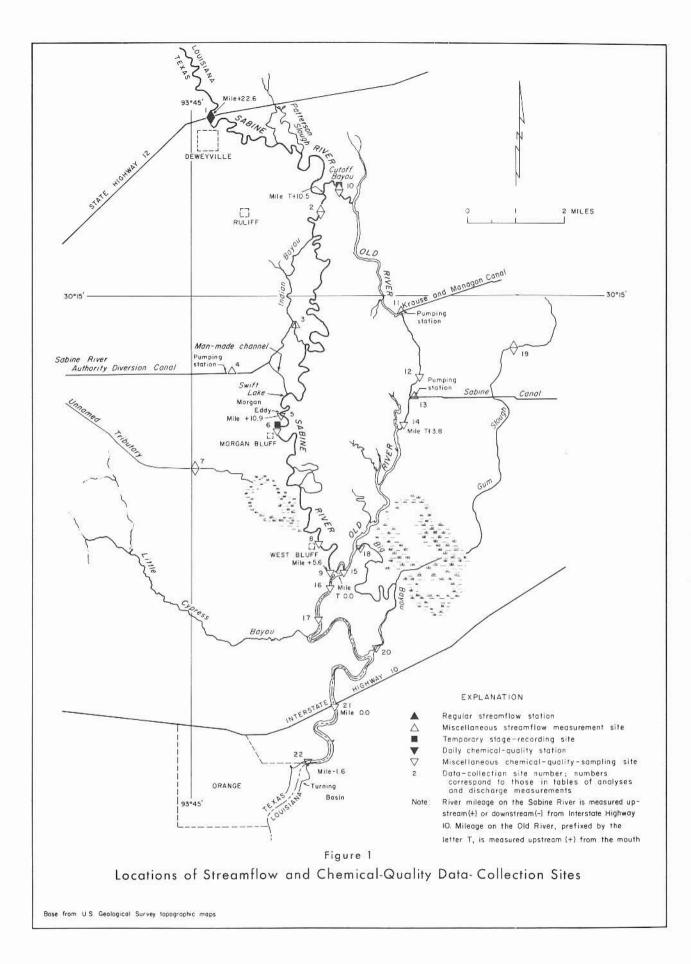
DESCRIPTION OF STUDY AREA

The area studied extends from the stream-gaging station Sabine River near Ruliff to the head of the ship-turning basin near Orange (Figure 1). Although flow in the mainstem and anabranches of the Sabine was restricted to their channels during this study, the streams overflow frequently. Therefore, much of the area, which ranges from about 15 feet above mean sea level to sea level, is poorly drained swampland. The area is covered by a profuse growth of pine, cypress, and other large trees.

About 5 miles downstream from the station near Ruliff, the Sabine River branches and part of the flow enters Old River through Cutoff Bayou. The Old River anabranch extends gulfward for about 11 miles in Louisiana and then rejoins the mainstem. Periodically, two privately owned companies in Louisiana divert part of the flow from Old River for rice irrigation.

Downstream from the divergence of Indian Bayou, the channel of the Sabine River is blocked by a sandbar Figure 3. Consequently, during low-flow periods, all of the mainstem flow below Cutoff Bayou divergence enters the Indian Bayou anabranch. Periodically, the Sabine River Authority diverts part of this flow for irrigation and industrial use. During previous investigations, part of the flow from Indian Bayou was returned to the mainstem Sabine River through a man-made channel at Swift Lake. However, during this investigation, the man-made channel was completely blocked by a sand dam. Although the lower reach of Indian Bayou was partly blocked by a sandbag dam, some flow passed over the dam and returned to the mainstem.

Downstream from Indian Bayou, the channel of the Sabine River meanders in a series of almost complete loops across the flood plain; Old River is much



straighter. Although channel widths differed from site to site, they generally increased in the downstream direction. The channel of the Sabine River near Ruliff was about 145 feet wide, whereas at Interstate Highway 10, it was more than 500 feet wide. The width of the Old River channel increased from about 35 feet in the upper reach to about 175 feet near the mouth. Similarly, depths generally increased in the downstream direction. The maximum depth of water observed in the Sabine River near Ruliff was about 3 feet, but depths of more than 30 feet were noted at Interstate Highway 10. Although the downstream increase in depth was usually gradual, the depth of the Sabine River near the mouth of the Old River increased abruptly from about 10 feet (site 9) to more than 20 feet (site 16). No such abrupt change in depth of the Old River was noted.

In Figure 1 and in the following discussion, river mileage on the mainstem Sabine River (including Indian Bayou) is measured upstream and downstream from Interstate Highway 10, which is designated as mile 0.0. Upstream mileage is designated as positive (+); downstream mileage is designated as negative (-). Mileage on other streams (including Old River) is measured upstream from the mouths, each of which is designated as mile T 0.0.

METHODS OF INVESTIGATION

Water-Level Measurements

Two temporary water-stage recorders were installed to measure the fluctuations of water levels caused by the tide and the diversion of water by the Sabine River Authority and two Louisiana pumping plants (Figure 1). One of these instruments continuously recorded the water-level fluctuations in the Sabine River at Morgan Bluff (site 6). The other recorder was installed in Cutoff Bayou (site 10) to determine if the reach was affected by tide and if the distribution of flow between the Sabine and Old Rivers was affected by operation of pumping plants. During some periods, the recorder in Cutoff Bayou was inoperative. However, the stage record was supplemented by frequent visual observations of water levels.

Streamflow Measurements

To determine the distribution of flow between the Sabine River and the Old River anabranch, discharge was measured repeatedly in Cutoff Bayou (site 10) and once in the Sabine River downstream from the divergence of Old River (site 2). Flow passing the station near Ruliff (site 1) during these measurements was determined from gaging-station records. Also, discharge was measured in all diversion canals, and all accessible tributaries were inspected for flow.

Water-Quality Measurements

Because the specific conductance of a water is related to the number and types of ions in solution, field measurements of specific conductance can be used to detect variations in the salinity of a stream. Therefore, conductance was measured at many sites in the mainstem and anabranches of the Sabine River to detect longitudinal, transversal, and vertical variations of salinity. At most of these sites, specific conductance, temperature, pH, and dissolved oxygen were measured at the surface and bottom in one or more verticals. When vertical variations were detected, the water-quality measurements were made at several intermediate depths. If no change in conductance occurred, a single sample for laboratory analysis was collected. If a sharp change occurred, samples for laboratory analysis were collected from the surface, bottom, and intermediate depths. Also, samples were collected from each flowing tributary located during the study. In the laboratory, the specific conductance and chloride content of each sample were determined and were used to select a number of samples for more complete chemical analysis. The relation of conductance to the concentrations of chloride and dissolved solids in these samples was used to calculate the chloride and dissolved-solids content of water at other points where conductance was measured.

ANALYSIS OF DATA

Water-Stage Records and Observations

Locations at which temporary water-stage recorders were installed are shown in Figure 1; variations of river stage at these sites and records of pumping plant operations are shown graphically in Figure 2. Records of stage for the Sabine River at Morgan Bluff (site 6), supplemented by field observations at upriver sites, indicate that the stage and thus the flow of the Sabine River were affected by tide as far upstream as the partial dam on Indian Bayou (Figure 3). Similarly, field observations and records of stage for Cutoff Bayou (Figure 2, site 10) indicate that the stage and flow throughout Old River were affected by tide (Figure 3).

Streamflow Distribution

Locations where discharge was measured are shown in Figure 1; results of discharge measurements are given in Table 1. During the investigation, flow in the Sabine River near Ruliff receded fairly uniformly from about 315 cfs to about 300 cfs and averaged about 305 cfs. However, the distribution of flow between the Sabine and Old Rivers varied because of the effects of tide and pumping. The discharges measured in Cutoff Bayou (site 10) ranged from 159 cfs to 195 cfs. Because Cutoff Bayou was tidal, the discharge was not directly

SITE	DATE (1967)	STREAM	LOCATION	RIVER		E, IN CUBIC FEET PER NABRANCH TRIBUTARY	SECOND DIVERSION
1	Sept. 12	Sabine River	Lat 30°18'13'', long 93°44'37'', at gaging station, Sabine River near Ruliff, Texas	+22.6	314		
1	Sept. 14	do	do	do	298		
2	Sept. 13	Sabine River	Lat 30°16'30'', long 93°42'21'', 0.5 mile downstream from Cutoff Bayou	+17.3	a109		
3	do	Indian Bayou	Lat 30°14'30'', long 93°42'52'', 500 feet downstream from Sabine River Authority's diversion canal, 2.5 miles south- southeast of Ruliff, Texas	+13.9	a,b 54		
3	do	do	do	do	a,b 24		
14	do	Sabine River Authority's diversion canal	Lat 30°13'42", long 93°44'13", about 1.4 miles upstream from Swift Lake				120
7	Sept. 14	Unnamed tribu- tary to Sabine River	Lat 30°11'53'', long 93°45'00'', at Old Texas State Highway 87	T+1.4		0.2	
10	Sept. 13	Cutoff Bayou (Old River)	Lat 30°16'51'', long 93°41'57'', 0.8 mile downstream from Sabine River	T+9.8		a,b 185	
10	Sept. 14	do	do	do		a,b 170	
10	do	do	do	do		a,b 175	
10	do	do	do	do		a,b 159	
10	Sept. 15	do	do	do		ь 195	
11	Sept. 14	Krause and Managon Canal Co.'s canal	Lat 30°14'44", long 93°40'35", 3.9 miles southeast of Ruliff, Texas				45
13	do	Sabine Canal Co.'s canal	Lat 30°13'10", long 93°40'13", 5.3 miles southeast of Ruliff, Texas				80
19	do	Gum Slough	Lat 30°14'03'', long 98°38'21'', at Louisiana State Highway 109	T+6.7		2	

Table 1.--Summary of Discharge Measurements, Sabine River Basin Near Orange, Texas

a. Probably affected by pumping.b. Affected by tide.

- 4 -

related to stage (Figure 2). Consequently, the range of measured discharges does not necessarily represent the range that actually occurred. Nevertheless, the discharge measurements indicate that the portion of flow that entered Old River through Cutoff Bayou varied considerably.

Although the effect of pumping-station operations on the stage of Cutoff Bayou was masked by the effect of tide, much of the variation in the distribution of flow between the Sabine and Old Rivers resulted from pumping. For example, during periods when the Sabine River Authority's pumping plant was operating, the amount of water stored in Indian Bayou and thus the amount of water that flowed over the partial dam (site 3) and returned to the mainstem Sabine River decreased. However, lowering the stage by pumping caused the gradient into Indian Bayou to increase. In response to this increased gradient, the proportion of upriver inflow to Indian Bayou increased.

During previous investigations when flow at the Ruliff station was about 1,680 cfs and 500 cfs, about

half the flow entered the Indian Bayou anabranch. Therefore, Rawson, Reddy, and Smith (1967, p. 21) concluded that during other periods when streamflow conditions were similar, the daily inflow that enters the mainstem Sabine River through Indian Bayou could be estimated by subtracting the amount of water diverted by the Sabine River Authority from 50 percent of the mean daily discharge of the Sabine River near Ruliff. However, the construction of dams in Indian Bayou and in the man-made channel that connects Indian Bayou to the mainstem and changes in pumping-station operations have altered flow conditions. Under these altered conditions, the streamflow records of the Sabine River near Ruliff cannot be used to estimate accurately the downstream distribution of flow.

Water-Quality Variations

Locations of chemical-quality sampling sites are shown in Figure 1; results of chemical analyses are given in Table 2. Profiles of the weighted-average chloride concentrations for the Sabine and Old Rivers are shown

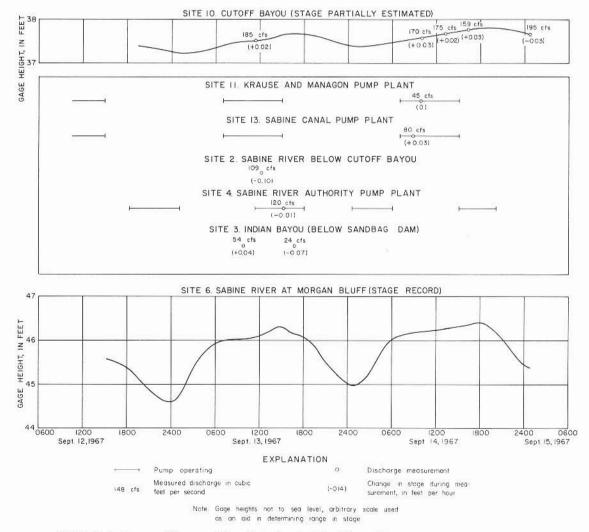
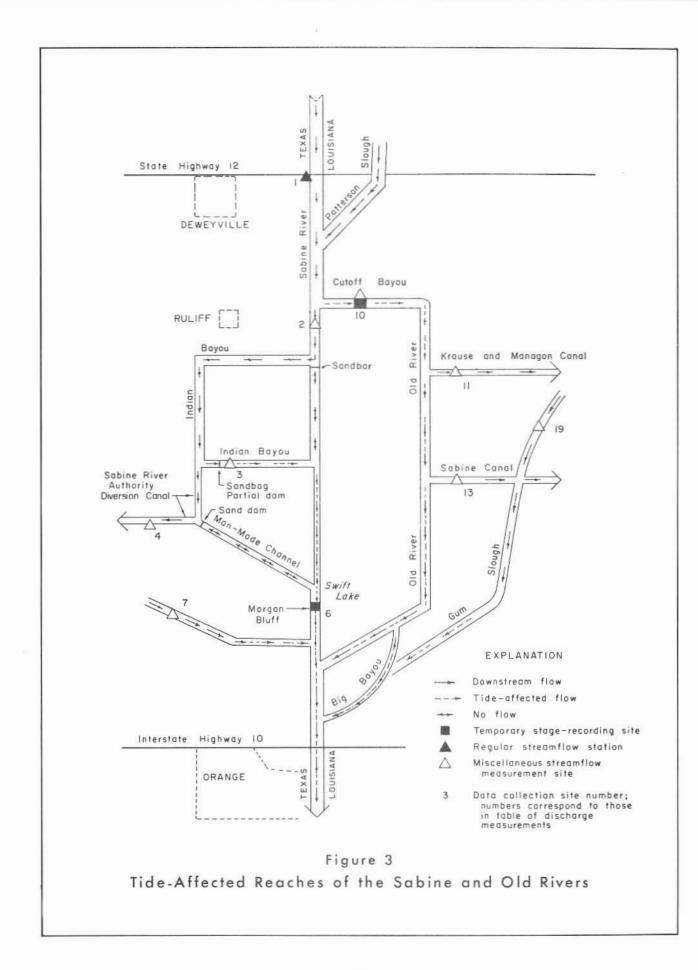


Figure 2.-Summary of Stage and Flow Data for the Tide-Affected Reaches of the Sabine and Old Rivers



- 6 -

in Figure 4. Because samples were not collected from all sampling sites at the same tidal phase, the chloride profiles do not represent conditions that actually existed at any given time. Instead, the profiles show the average chloride concentration of water in each cross section at the time of sampling and the approximate extent of salt-water intrusion. In the following discussion the chloride profiles were used to subdivide the study area into six reaches.

Sabine River-Mile +22.6 to Mile +10.9

Data in Figure 4 and Table 2 show that the weighted-average chloride content of water in this 11.7-mile reach of the Sabine River increased from 21 ppm (parts per million) at site 1 (mile +22.6) to 60 ppm at site 5 (mile +10.9). Water at sites 1 and 2 was fresh and well mixed—the water contained 90 ppm dissolved solids and 21 ppm chloride at the surface, bottom, and intermediate depths (Figure 5). Although water at site 5 was fresh, the dissolved-mineral content was minimum at the surface and gradually increased with depth. Water at the surface contained 115 ppm dissolved solids and 37 ppm chloride, whereas water at the bottom contained 190 to 278 ppm dissolved solids and 75 to 129 ppm

chloride. No tributary inflow was noted in this reach; thus, the downstream increase of dissolved minerals and the corresponding increase of dissolved minerals with increase in depth are attributed to the upstream intrusion of sea water.

Water throughout the upper part of the reach was well aerated; however, the dissolved-oxygen content decreased somewhat in the lower part of the reach. At site 1, water at the surface, bottom, and intermediate depths contained 6.7 ppm dissolved oxygen (86 percent of saturation). At site 5, water at the surface contained 5.7 to 6.3 ppm dissolved oxygen (72 to 80 percent of saturation), whereas water at the bottom contained 4.7 to 5.2 ppm (59 to 67 percent of saturation). Among the more significant factors that affect the dissolved-oxygen content of any stream are the amounts and nature of organic material present, the temperature and dissolvedmineral content of the water, bacterial activity, photosynthesis, and aeration from exposure to the atmosphere. Aeration is influenced greatly by the dissolved-oxygen deficiency; the character of the streambed; and the depth, volume, and velocity of flow. The downstream decrease of dissolved oxygen between sites 1 and 5 probably resulted from a combination of several of these factors. Because dissolved oxygen at

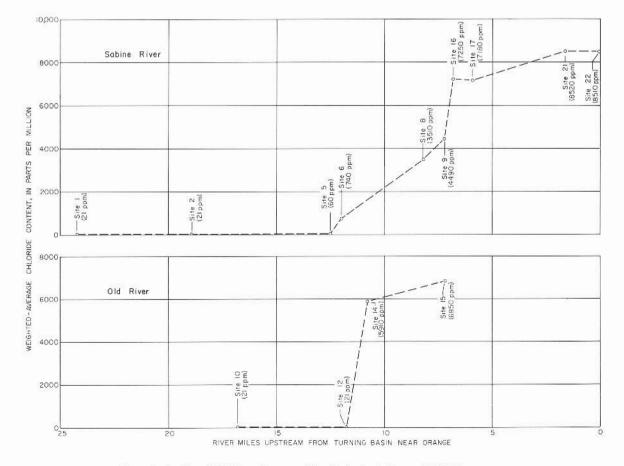
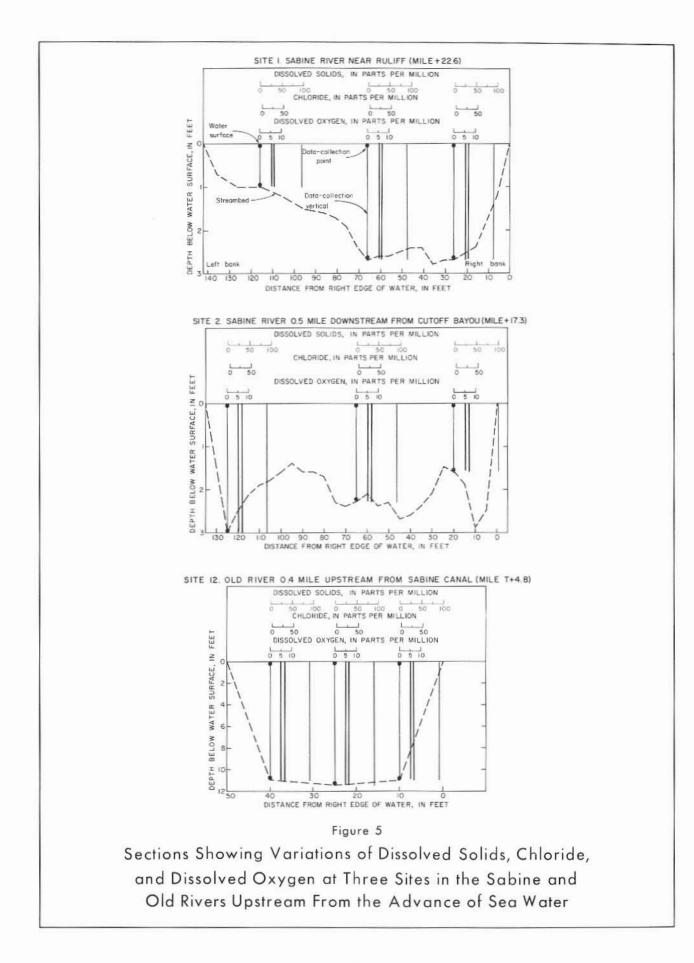


Figure 4 .- Profiles of Weighted-Average Chloride in the Sabine and Old Rivers



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	Sulfate (SO4)		RIVER NEAN HULLIFF		6.4		DOWNSTREAM FROM				MORGAN EDDY	20			AT MORGAN BLUFF	1.1		128	11	SE	8.8	WEST BLUFF	1111
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point	Depth below water surface	(feet)		0.6	2.7	0.1.0		0 1.6	0 2.3	0 3.0		o v n	0 5 11 5	0 9 2 9		0	0 10	10 12	20	n			0 N .0 N 0
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Table 2.--Chemical Analyses of Water From Streams in the Sabine River Basin Near Orange, Texas

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(Results in parts per million except as indicated)

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Table 2.--Chemical Analyses of Water From Streams in the Sabine River Basin Near Orange, Texas-Continued

- 11 -

	Density (gm/m1 at 20 ^a	- 1		111	111	1.002	1.006	1.011		0.	1.004				1	11	11	1	1.0	; ;	1.010
	hlt	d Lab		**-		0.04		00		5					-			-	ė	_	
		Field			-1-1-1		7.1			6.9	-				_	0.1	-	-	0.7	-	0.0
Spective	Conductance Cmiterondese at 25° (C)	Lab		111		10.50	18900	260		5510 8970	140		421		i			1	16900		25500
20.0	Conducts Chicago at 25°	Field		10000 11000 20000	25000 25000 26000		18000	25000		5300 8500	14000				17000	20000	24000		17000	22000	24000
-		ate					1920			858									1710		
Hardness	Cal- Cal- Cium, Mag-	sium s					1990			902									1770		
Dit-	solved solids (calcu-	lated)	q	5860 6500 12500	15600 16200 16200	5220 5850	11300	16200		3080 5130 7720	8460		220		9930	15600	15600	000001	12500	13500	15600
Dissolved	(DO) Percent	tion	+4.3)Continued	81 75 21	***	81 78	30	44	+5.4)	80 68 45	39				2% C	4		-	200	11	44
Diss	20 20	bpm	4.3)-	6.2 5.8	ų ų ų	6.2	01.02		e T +	000 F	2.9	+6.7)		(2.0+)	8. D	n 10	e e je	3	3.9	8	99
	NI- Lrate (NO-)	2	(Mile +						H (Mil			H		(Mile T							
	(C1)			a3240 a3600 a6950	a8660 a9000 a9000	#2900 3240	6260 a8660	0006	BIG BAYOU 200 YARDS DOWNSTRRAM FROM UPPER MOUTH (Mile T	1680 2850 a4300	4680	SLOUGH AT LOUISIANA STATE HIGHWAY 109 (Mile	102		a 5520	a8660	a8660	100021	5520 a6950	a7500	a8660 8660
	Sulfate (SO4)		SOUTHERN PACIFIC RAILROAD CROSSING				851		M FROM U	380		TE HIGHW		BIG BAYOU 300 YARDS UPSTREAM FROM LOWER MOUTH					196		
		(HCO ₃)	IFIC RA				81		WNSTREA	54		ANA STA		TREAM F					\$1.		
	Po- tas- sium	(K)	GRN PAC				126		ARDS DO	58		LOUISI.		SQU SQU					601		
	Sodium (Na)		AT SOUTH				3430		OU 200 Y	1560		LOUGH AT		0 300 YAI					3020		
	Mag- ne-	(Mg)	RIVER				396		BIG BAY	177		GUM S1		IG BAYO					0022		
	Cal- cium		SABINE				144		E 18.	70		SITE 19.		20.					131		
	Silica (SiO ₂)		re 17.				8.3		SITE	12		ŝ		SITE					n x		
J.L		°.	SITE	28.0 28.0 28.0	28. u 28. u	28.0	28.5	29.0		27.5	28.5		28.0		29.0	28.5	28 . 5 28 . 5	OB	28.5	28.5	28.5
Water	temperature	ж. •		82 82 82	888	8 8	6.8	9 9 9 9 9 9	1	825 82 82 82 82 82 82 82 82 82 82 82 82 82	83		82		84	5.8	53	2 0	2.2	83	833
point	Depth below water-	(feet)		0010	10	00	s cl	15		0 01 1	ŝ				0 %	3 00	13	01	2 64	'n	10
Sumpling point	Distance from right edge of water	(feet)		100	100	200	200	000		200	20				100	100	100	10.4	175	175	175
	Hour			1127 1129 1131	1135	1139	1143	1147	1	1050	1056		1100		1205	1209	1211		1217	1219	1221
	Date (1967)			Sept.15 do do	3 8 8 8	9 9 9	e e	9 69 69		Sept.15 do do	op		Sept.15		Sept.15	do	ob ob	3 -	8 8	qo	do do

Table 2.--Chemical Analysis of Water From Streams in the Subine River Basin Near Orange. Texas-Continued

· 12 ·

	pH Density	at 20°	Field Lab		1.007	1.008	1.009		-		7.2 1.012		800-1	1.5	1.54		110-1		1.007	0101	1.010	1.007	1,009	1.010	1.010	7.1 1.010	-	1.008	1.009	1 010	1.011
Specific	conductance (micromhos	at 25° C)	Field Lab Fie		19700	22500	24200	26700	27400	28500	28700	18300	22800	25800	26800	27600	28000		19900	25600	26200	20000	23900	25900	26600	28300	20900	23500	24600	25800	28100
554	1		-		1	ţ	;	1	;	ł	3100	ţ		DRC 7	ł	1	1		-							2970			-		
Hardness	Cal-	Sag-	stum		;	;	ţ	1	1	1	3190	ł			1	f	1									3060					
	solved	solids (calcu-	lated)		11800	13700	14800	16500	17100	17600	17900	10700	15000	15800	16500	17000	1/300		11900	15600	16000	11900	15300	15700	16300	17100	12500	14200	15000	16600	17200
Dissolved	(DO)	Percent	tion		70	23	10		÷	÷ •		70	16	- 19	-	÷ •	4	(9)	64	ų =	+	64	81	:"	n	• •	64	61	= "		0
DISN	•	-	_	(0)	5.1	1.7		0	ņ	ų,		5.1	CN 4		5	ņ		(Mile -1.6)	4.7		Ð.+	4.7	÷ 3	~		0.0	4.7	1.4	aç e	1	c
	_	(NO2)		(Mile 0.0)							5.2															5.5					
	÷	(C1)			6550	7640	8230	9210	9500	0616	0866	5960	1690	8810	9210	0490	0806	NEAR ORANGE	6600	8660	8910	6600	8510	8760	0906	9680	6940	7890	0150	9260	9590
	Sulfate	(204)		SABINE RIVER AT INTERSTATE HIGHWAY 10	1	1	: :	1	-	ł	1340	:			1	1	:	TURNING BASIN								1290					
	81- car-		(HCO3)	INTERST	;	1	: :	1	ţ	1	113	1	16	21	1	1	:									113				-	
	-0d	s1um	-	VER AT	1	1	1	1	ł		204	1	167	1	ł	1	;	AT HEAD OF								196					
	Sodium	(Na)		ABINE RI	1	-	1	1	1	1	5470	1	4610		ł	1	:	RIVER AT 1								5390					
	Mag-	S1um	(Mg)	21.	1	;		1	ŀ	; ;	640	I			ł	1		SABINE R								613					
	Cal-	(Ca)		SITE	ł	1		1	1	11	225	I	103	3 1	1	1	1	22.								217					
	Silica	(Si0 ₂)			E	I		1	Ę	1	5.5	l	1 10	31	Ľ	1		SITE								4.9					
r	21	-	р ,							28.0	29.0				28.5				29.0	28.5	28.5	29.0		- A.		28.5	29.0	28.5	28-01	28.5	28.5
Water	tenperature		A		84	20 0		83	83	5 8 8	84	84		83	6.83	200	20		48 43	83	83	** 0	200	83	20	83	84	503	200	200	58
point	Depth helow miter	Surface	(leet)		0	•	e e e	18	23	82	85	0	+ x	13	18	2 0	*0		0.5	10	15	0.1	10	15	50	30	0	- C	15	20	25
зŤ		12	(leet)		200	200	200	200	200	200	200	300	200	300	300	2002	000		100	100	100	200	200	200	200	200	300	300	200	300	300
	Hour	-	-		1345	1347	1321	1353	1355	1350	1011	1403	1402	1409	1411	5161	CTLT		1435	1439	1441	1443	1447	1449	1451	1455	1457	1459	1001	1505	1507
	Date				Sept.15	ę,	8 8	8.8	op	0 e	3 8	ę.	8 8	3.8	op ,	99			Sept.15	ę	qo	ę.	2 Q	op	op -	8 8	op	op	00	9	op e

Table 2.-Chemical Analyses of Water From Streams in the Sabine River Basin Near Orange, Texus-Continued

- 13 -

different sites was measured at different times of the day, differences in photosynthetic activity and water temperature probably caused some variation in the observed concentrations of dissolved oxygen. More important, as the water moves downstream through the profuse vegetation, it picks up natural organic debris, the oxidation of which utilizes dissolved oxygen. Moreover, according to Forrest and Cotton (1966, p. 12-13), the dissolved-oxygen content of water in the lower reaches of the Sabine River is being depleted by pollution. The tidal intrusion of this polluted water upstream would result in depletion of dissolved oxygen at upstream sites. Furthermore, because the stream gradient decreases and the channel widens in the downstream direction, velocity and turbulence decrease; thus, the rate of aeration decreases. The velocity and rate of aeration periodically are decreased still further by the rising tide.

Sabine River-Mile +10.9 to Mile +5.6

The chloride profile (Figure 4) shows that the weighted-average chloride content of water in this reach increased from 60 ppm at site 5 (mile +10.9) to about 4,500 ppm at site 9 (mile +5.6). Although water at site 5 was fresh, Figure 6 shows that salt water advanced as far upstream as site 6 (mile +10.4). At site 6, mixing was poor and considerable horizontal stratification of fresh and salt water occurred. Water from the surface to a depth of about 6 feet contained 245 ppm dissolved solids and 106 ppm chloride; water below a depth of 15 feet contained more than 7,800 ppm dissolved solids and 4,300 ppm chloride. The dissolved-oxygen content of the water also varied greatly with increase in depth. Water at the surface contained 6.1 to 6.2 ppm dissolved oxygen; below a depth of 15 feet, the water contained 0.5 ppm. Although the decrease of dissolved oxygen roughly coincided with the increase in salinity, the increase in salinity was responsible for only a small part of the decrease in dissolved oxygen. The solubility of oxygen in water decreases as the salinity increases; however, the amount of oxygen dissolved by sea water in equilibrium with air is about 80 percent of that dissolved by fresh water. At site 6, water at the surface was 76 to 77 percent saturated with dissolved oxygen; below a depth of 15 feet, the water was only 7 percent saturated. These data indicate that much of the dissolved-oxygen deficit resulted from the oxidation of organic material. Although the source of the organic material was not ascertained, the fact that water which was deficient in dissolved oxygen was also the more saline water indicates that the organic material was from downstream sources.

Although erosion of the salt-water wedge by fresh-water currents and turbulence caused some mixing at downstream sites, the salinity and dissolved-oxygen gradient at site 9 (mile +5.6) near the mouth of Old River remained large. Water at the surface contained

2,840 to 2,970 ppm dissolved solids, 1,560 to 1,630 ppm chloride, and 5.5 to 6.2 ppm dissolved oxygen. Bottom water contained 15,600 ppm dissolved solids, 8,660 ppm chloride, and 0.2 to 0.3 ppm dissolved oxygen.

Old River-Mile T +10.5 to Mile T +4.8

Water in the upper 5.7-mile reach of the Old River was fresh, well aerated, and similar in chemical character to water in the upstream reach of the mainstem Sabine River (Figure 5). Water at sites 10 (mile T +9.8) and 12 (mile T +4.8) contained 90 ppm dissolved solids, 21 ppm chloride, and 6.4 to 7.1 ppm dissolved oxygen.

Old River-Mile T +4.8 to Mile T 0.0

Figure 4 shows that the weighted-average chloride content in this reach increased from 21 ppm at site 12 (mile T +4.8) to more than 6,800 ppm at site 15 (mile T +0.2). Salt water was detected as far upstream as site 14 (mile T +3.8). At this site, mixing was poor and the interface between waters with different salinities and concentrations of dissolved oxygen was fairly sharp (Figure 6). Water at the surface contained 1,500 ppm dissolved solids, 800 ppm chloride, and 6.2 ppm dissolved oxygen (78 percent of saturation). Below a depth of 7 feet, the water contained more than 15,500 ppm dissolved solids, 8,600 ppm chloride, and 0.5 ppm dissolved oxygen (7 percent of saturation).

At site 15, near the mouth of Old River, the dissolved-solids and chloride concentrations of water at the surface were 2,650 ppm and 1,460 ppm, respectively. The salinity gradient from surface to bottom remained large-water at the bottom contained 16,200 to 17,200 ppm dissolved solids and 9,000 to 9,590 ppm chloride. The dissolved-oxygen content also varied greatly with depth. The upper 2 feet of water contained 6.2 ppm dissolved oxygen (79 to 81 percent of saturation); below a depth of 7 feet, the dissolved oxygen decreased abruptly to 0.3 ppm (4 percent of saturation).

Sabine River-Mile +5.6 to Mile -1.6

The weighted-average chloride concentration of water in this 7.2-mile reach increased from about 4,500 ppm at site 9 (mile +5.6) to more than 8,500 ppm at site 22 (mile -1.6). Much of the increase occurred in the upper 0.4 mile of this reach (Figure 4). At site 16 (mile +5.2), for example, the average chloride content of the water was more than 7,200 ppm. In the 0.4-mile reach between sites 9 and 16, depths of water increase abruptly in the downstream direction—from about 10 feet at site 9 to more than 20 feet at site 16 (Table 2). This abrupt increase in depth is a natural barrier to the upstream advance of salt water (Rawson, Reddy, and Smith, 1967, p. 20). Nevertheless, some salt water

spilled over the barrier and advanced farther upstream in the mainstem Sabine River. However, the quantity was considerably less than that which advanced into Old River where no such abrupt change in depth occurred (Figure 4).

Although mixing of fresh and salt water generally increased downstream from site 16, complete mixing was not attained. At site 22, the lowermost site in the study area, water at the surface contained 11,900 to 12,500 ppm dissolved solids and 6,600 to 6,940 ppm chloride, whereas water at the bottom contained 16,000 to 17,500 ppm dissolved solids and 8,910 to 9,690 ppm chloride. The dissolved-oxygen content of the water decreased from 4.7 ppm at the surface to 0 ppm below depths of 20 feet.

Big Bayou-Mile T +5.5 to Mile T 0.0

About 0.7 mile upstream from its mouth, Old River branches and part of the flow enters Big Bayou (Figure 1). Big Bayou flows for about 5.5 miles in Louisiana and then joins the Sabine River. The weightedaverage chloride content of water in Big Bayou increased from 2,770 ppm at site 18 (mile T +5.4) to 7,830 ppm at site 20 (mile T +0.2). Mixing of the water increased in the downstream direction, but complete homogeneity was not attained. At site 20, for example, water at the surface contained 9,930 ppm dissolved solids, 5,520 ppm chloride, and 3.8 to 3.9 ppm dissolved oxygen; water at the bottom contained 15,600 ppm dissolved solids, 8,660 ppm chloride, and 0.3 ppm dissolved oxygen.

Inflow From Tributaries

Measured tributary inflow to the study reach totaled only about 2.2 cfs–0.2 cfs from an unnamed tributary (site 7) and 2 cfs from Gum Slough (site 19). Water in the unnamed tributary contained 184 ppm dissolved solids and 80 ppm chloride; water in Gum Slough contained 220 ppm dissolved solids and 102 ppm chloride.

SUMMARY OF CONCLUSIONS

During the period September 12-15, 1967, measured tributary inflow to the Sabine and Old Rivers between the stream-gaging station Sabine River near Ruliff and the ship-turning basin near Orange totaled about 2.2 cfs. Streamflow of the Sabine River at the station near Ruliff averaged about 305 cfs and receded fairly uniformly from about 315 cfs on September 12 to about 300 cfs on September 15. Downstream from the Ruliff Station, the distribution of flow between the Sabine River and Old River anabranch varied considerably in response to changes in stage produced by tidal fluctuations and pumping. Therefore, under the conditions that existed during the study, no accurate method can be devised for estimating the distribution of flow between the Sabine and Old Rivers.

Previous investigations (Rawson, Reddy, and Smith, 1967, p. 21) indicated that during low-flow periods the daily inflow that enters the mainstem Sabine River through Indian Bayou could be estimated from streamflow records of the upstream station Sabine River near Ruliff. However, because of changes in channel conditions produced by the construction of dams in Indian Bayou, use of streamflow records of the Sabine River near Ruliff for estimating the daily inflow at downstream sites is no longer possible.

Because the lower reach of the Sabine River is tidal, sea water from the Gulf of Mexico periodically intrudes through Sabine Lake into both the Sabine and Old Rivers. During this investigation, water in the 11.7-mile reach of the Sabine River between the Ruliff station and Morgan Eddy and the upper 5.7-mile reach of the Old River was fresh and well aerated. Water throughout much of these reaches contained less than 100 ppm dissolved solids and 25 ppm chloride and more than 6.0 ppm dissolved oxygen. Farther seaward, the intrusion of sea water resulted in a large increase in the concentrations of dissolved solids and chloride in both the Sabine and Old Rivers. Although mixing of fresh water with sea water increased seaward, complete homogeneity was not attained. At the head of the ship-turning basin near Orange, the lowermost site in the study area, water at the surface contained 11,900 to 12,500 ppm dissolved solids and 6,600 to 6,940 ppm chloride, whereas water at the bottom contained 16,000 to 17,500 ppm dissolved solids and 8,910 to 9,690 ppm chloride. The dissolved-oxygen content of the water at this site decreased from 4.7 ppm at the surface to 0 ppm below depths of 20 feet.

Dissolved-oxygen concentrations in the reach affected by salt-water intrusion generally decreased greatly with depth. Although the decrease of dissolved oxygen coincided roughly with the increase in salinity, only a small part of the dissolved-oxygen deficit resulted from the increase in salinity. Much of the deficit probably resulted from the oxidation of organic pollutants pushed upstream by the periodic rise of the tide. Forrest and Cotton, 1966, Water quality study: Sabine River Authority of Texas duplicated rept. 22 p.

Rawson, Jack, Reddy, D. R., and Smith, R. E., 1967, Low-flow studies, Sabine and Old Rivers near Orange, Texas, quantity and quality, April 12, October 31 -November 4, 1966: Texas Water Devel. Board Rept. 66, 23 p.