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REPORT 26

BASE-FLOW STUDIES BIG ELKHART AND LITTLE ELKHART CREEKS TRINITY RIVER BASIN, TEXAS

Quantity and Quality, September 15-16, 1965

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By

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Prepared by the U.S. Geological Survey
in cooperation with the
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TABLE OF CONTENTS

TABLES

TABLE OF CONTENTS (Cont'd.)

FIGURES

BASE-FLOW STUDIES

BIG ELKHART AND LITTLE ELKHART CREEKS

TRINITY RIVER BASIN, TEXAS

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INTRODUCTION

These base-flow studies were made by the U.S. Geological Survey under the 1966 cooperative agreement with the Texas Water Development Board that provided for the investigation of the water resources of Texas.

The object of the studies was to determine the quantity and quality of the streamflow of Big Elkhart and Little Elkhart Creeks at the time of the investigation. Among the factors evaluated were: any apparent interchange of surface and ground water in the base flow; and the suitability of the streamflow for domestic, municipal, irrigation, and industrial uses, respectively. For purposes of this report, base flow was defined as that part of the precipitation that had percolated into the ground and was discharged to the stream. River miles were measured in an upstream direction, zero being assigned to the mouth of each creek.

One reach on each of the creeks was selected for study. The Big Elkhart reach extended from the creek mouth, at the Trinity River, to a county highway bridge, which was 26.0 river miles upstream and 3.5 miles northwest of Grapeland (Figure 5). The Little Elkhart reach extended from the creek mouth to the old Grapeland-Crockett highway bridge, 17.5 river miles upstream and 4.3 miles south of Grapeland (Figure 5). The mouth of Little Elkhart Creek is at mile 1.3 on Big Elkhart Creek.

Conditions for determining gains or losses of streamflow were favorable during the report period (September 15-16, 1965). It was preceded by about 14 days without rainfall, and by less-than-average rainfall from May to September. Weather conditions during the study varied from cloudy and cool to clear and hot. Conditions were good for high evapotranspiration. According to measurements of flow at sites 8 and 19 (Figure 5) on each day of the investigation, the streamflow remained essentially constant.

In both creeks, the streambeds are composed principally of sand that has been blown and washed in from the adjacent hills. The stream channels are characterized by long pools formed chiefly by sand bars, and by some mud and silty clay bars. The channels are cut in flat bottomed valleys throughout most of the reaches. On the flood plains, patches of land with dense growths of deciduous trees and bushes intersperse open areas that support only small grasses and bushes. Little farming is done on the flood plains of either creek.

Background information available for this work was limited. No base-flow investigations of the reaches had been made prior to 1965, except for a few measurements of water discharge made and a few water samples collected at site 7 (mile 11.7) during 1962-64.

Data on the quantity and quality of base flows are used in the selection of reservoir sites for information on the amount of base flow and probable quality of impounded water and on channel gains or losses, which could affect storage in potential reservoirs. Data in this report are pertinent to the reservoir to be built on Little Elkhart Creek under State of Texas Permit No. 2165 issued June 22, 1965, to the Houston County Water Control and Improvement District No. 1. The dam will be near mile 7 on Little Elkhart Creek, will impound 19,500 acre-feet for water supply, and will inundate the creek channel to mile 14, approximately, when water reaches spillway crest at elevation 260 feet.

RELATION OF GEOLOGY TO BASE FLOW

The Big Elkhart and Little Elkhart Creeks flow across the outcrop areas of four geologic formations--the Sparta Sand, Weches Greensand, Queen City Sand, and alluvium (Figure 5). These geologic units, which consist generally of sandy and shaly beds, contribute various amounts of water to the streams and sustain their flow.

The Sparta Sand, disconformably overlying the Weches Greensand, has a maximum thickness of about 300 feet and consists of sand, sandy shale, and shale. The lower part of the Sparta is predominantly medium sand, generally unconsolidated and massively bedded. The sand grades upward into finer thin-bedded sand and sandy shale. The uppermost part of the Sparta commonly consists of lignitic chocolate-colored shale and thin-bedded silty sand. The Sparta Sand, the principal source of ground water in Houston County, supplying wells with capacities ranging from less than 100 gpm (gallons per minute) to more than 1,000 gpm, yields the largest amounts of base flow to the streams.

The Weches Greensand, disconformably overlying the Queen City Sand, consists of as much as 100 feet of glauconitic fossiliferous marl, sand, sandstone, shale, and limestone, plus iron concretions and thin lenticular beds of iron-cemented sandstone. Locally, the lower contact of the Weches is difficult to determine because its sediments have a color similar to those in the upper part of the Queen City Sand. The Weches, not known to yield water to wells in Houston County, was not found to contribute much base flow to the streams in the study area.

The Queen City Sand consists chiefly of cross-bedded, fine to medium sand interbedded with sandy and lignitic shale and has a maximum thickness of about 300 feet. The sand generally ranges from gray to tan in color, but where overlain by the Weches the sand generally is red because of iron leached from the overlying formation. The Queen City Sand, which yields less than 500 gpm of water to wells in the northwestern half of Houston County, seemed to be contributing a small amount of base flow to the streams during this investigation.

The alluvium consists chiefly of silt, sand, and gravel and has an estimated maximum thickness of about 50 feet near the channel of the Trinity River. The alluvium generally yields water to the streams except possibly near the more deeply incised Trinity River, where the streams may lose water to the alluvium.

BASE FLOW AS RELATED TO CHEMISTRY AND GEOLOGY OF THE STUDY AREA

Streamflow was measured and water samples for chemical analyses were taken at 12 sites in the study area; all except site 11 were on Big Elkhart and Little Elkhart Creeks. Site 11 was on Caney Creek, a major tributary of the Little Elkhart Creek headwaters. A 100-ml (milliliter) sample of water for determination of ferrous iron and a 100-ml sample for determination of total iron also were collected at these sites. Each of these water samples was vacuum filtered through a 0.80 micron plastic-membrane filter at the site of collection to eliminate any iron present in suspended sediment. To fix the ferrous ions and thus prevent their being oxidized to the ferric state, 4 ml of 0.2 percent bipyridine solution was added immediately to the ferrous iron sample. Although streamflow and specific conductance were determined at eight additional sites (4, 5, 6, 13, 14, 15, 16, and 17) on the tributaries to Big Elkhart and Little Elkhart Creeks in order to disclose any highly mineralized inflow, none was found. A sample for chemical analysis was collected at sites 2 and 6, respectively. The results of the streamflow measurements are given in Table 1, and chemical analyses are shown in Table 2. These data, which are shown graphically on Figure 1 for Big Elkhart Creek and on Figure 2 for Little Elkhart Creek, show changes in chemical quality and in amount of flow throughout the two reaches. Results of analyses are shown graphically on Figure 3 for Big Elkhart and Little Elkhart Creeks, and for some tributaries. The total height of each vertical bar in Figure 3 is proportional to the total concentration of anions (negatively charged constituents) or cations (positively charged constituents) expressed in equivalents per million. Each bar is divided into segments to show the concentration of cations and anions that make up the total. Shown on Figure 4 is the ferrous and ferric iron concentration at each site, as well as the manganese concentration at sites 1 and 10.

Streamflow in Big Elkhart Creek was clear at site 1, but turbid at site 2 and downstream. Little Elkhart Creek streamflow was clear throughout the reach.

The streamflow on Big Elkhart Creek increased from 3.44 cfs (cubic feet per second) at site 1 (mile 26.0) to 6.34 cfs at site 9 (mile 1.3) near the mouth of Little Elkhart Creek. A loss is indicated in the reach from the confluence of the two creeks to the mouth of Big Elkhart Creek, for the combined flow of the creeks at their confluence was 10.18 cfs and the flow of Big Elkhart Creek near its mouth was 8.91 cfs. The Little Elkhart Creek streamflow increased from 0.52 cfs at mile 17.5 to 3.84 cfs near its mouth. Tributaries heading in the Sparta Sand updip from the main streams contributed the major part of the streamflow. No diversion was found on either stream.

At mile 22.0 (site 3) the streamflow was 4.38 cfs, and the water contained 169 ppm (parts per million) dissolved solids--a reduction of 29 ppm from site 2, but an increase of about 150 percent from site 1. As shown in Figure 3, each constituent increased from site 1 to site 3; however, chloride had the largest increase (about 350 percent). Because of the increased concentration of chloride and sodium, these became the principal constituents of the water. Calcium and magnesium, present in approximately equal amounts, together constituted about 30 percent more than the bicarbonate plus sulfate ion concentration. As evidenced by the change in composition of the water between sites 1 and 3, the mineralized inflow in the reach had a lower ratio of sodium to chloride than the other water of the stream. This low sodium chloride ratio is typical of salt water produced with oil in many oil fields (Leonard and Ward, 1962), and indicates that oil-field brine is the cause of the sudden increase in concentration of dissolved constituents in the stream. Total iron concentration increased from 0.33 ppm at site 1 to 0.39 ppm at site 3.

The stream channel at site 1 cuts across the Weches Greensand (Figure 5), but the bed of the stream is made up of sediments from the surrounding hills of Sparta Sand. Because the Weches is relatively impermeable, ground-water effluent from the overlying Sparta Sand issues along the contact of the two formations and contributes to the streamflow. The channel cuts into the Queen City Sand within a mile downstream from site 1. The Queen City Sand is fairly permeable and probably contributes streamflow between sites 1 and 3.

In any stream, the chemical constituents and amount of water are potentially controlled by the geologic formations traversed by the stream and its tributaries; this subject is discussed in the following report sections on "Big Elkhart Creek" and "Little Elkhart Creek." The mileage points at which measurements were made in this investigation are used to indicate the successive divisions within each reach.

Characteristics of Big Elkhart Creek

Reach from Mile 26.0 to Mile 22.0

The field investigation of Big Elkhart Creek was begun upstream from Grapeland oil field on September 15, 1965. In the 4 miles studied, streamflow increased from 3.44 cfs to 4.38 cfs; and the dissolved-solids content increased from 67 ppm to 169 ppm (150 percent), probably due to brine inflow from the oil field (Figure 5).

At mile 26.0 (site 1) the streamflow was 3.44 cfs and the water contained 67 ppm (parts per million) dissolved solids. According to a chemical analysis of the water, in Table 3 and Figure 3, the principal dissolved constituents were bicarbonate, chloride, and sodium plus potassium. Magnesium and calcium were present in approximately equal amounts that, together, were approximately equal to the bicarbonate ions. The chemical analysis indicates the water at site 1 is typical ground-water effluent (from Sparta Sand) in this area.

Although the streamflow was not measured at mile 24.4 (site 2), a water sample was taken and preliminary analysis showed a major change in the chemical composition of the water. The dissolved solids increased from 67 ppm at site 1 to 198 ppm (200 percent increase) at site 2. Although evapotranspiration was taking some of the flow in the reach, the rate of loss did not exceed the rate of gain, which was primarily from the Queen City Sand.

Reach From Mile 22.0 to Mile 11.7

Between mile 22.0 (site 3) and mile 11.7 (site 7) the streamflow increased from 4.38 cfs to 5.87 cfs, and the dissolved solids increased from 169 ppm to 194 ppm.

Estimates of streamflow, field conductivity measurements at two sites (4 and 5), and an analysis of the water in Murchison Branch (site 6): all indicate that the Sparta Sand was contributing water of approximately the same type as that at site 1. The water at sites 3 and 7 was similar in chemical composition, except for a 25 ppm increase in dissolved solids at site 3. The reason for this increase is not known; however, one possible explanation is that brine inflow from the oil field had been reduced for a short period. Therefore, a slug of less concentrated water moved downstream and, at the time of the investigation, was at site 3. This explanation is partially substantiated by the fact that the analyses at sites 8 and 9 showed approximately the same amount of constituents as those at sites 2 and 7. Total iron concentration increased from 0.39 ppm to 0.42 ppm in the reach.

The stream cuts across the Queen City Sand throughout this reach. Because the Queen City Sand yields less streamflow than the Sparta Sand, a reduction was expected in the rate of gain in discharge within this reach as compared to that in the previous reach; however, a large unnamed tributary joins the creek at mile 15.0 (Figure 5). A large area north of Big Elkhart Creek is drained by this tributary, whose stream channel cuts through the Sparta and the Queen City Sands. This stream was not checked during the study, but is known to have perennial flow. The addition of flow from this tributary may have counteracted evapotranspiration and caused the rate of increase in flow to remain approximately the same as that in the reach from mile 26.0 to mile 22.0 (Figure 1).

Reach from Mile 11.7 to Mile 5.2

Between mile 11.7 (site 7) and mile 5.2 (site 8) the streamflow increased from 5.87 cfs to 6.00 cfs, and the dissolved solids increased only 10 ppm to 204 ppm.

An analysis of the streamflow at site 8 indicated the water was similar to that at site 7 (Table 2). Total iron concentration increased from 0.42 ppm to 0.44 ppm.

The stream channel cuts across the Queen City Sand throughout the reach. As shown in Figure 1, the rate of gain in streamflow was less in this reach than in the two previously discussed. The Queen City Sand probably did not contribute to the streamflow at the rate the Sparta Sand did via tributaries in the upper reaches.

Reach from Mile 5.2 to Mile 1.3

Between mile 5.2 (site 8) and mile 1.3 (site 9) the streamflow increased from 6.00 cfs to 6.34 cfs, and the dissolved-solids concentration remained almost the same.

According to a chemical analysis of the streamflow at site 9, the water was approximately the same type as at site 7 (Figure 3).

Total iron concentration decreased from 0.44 ppm at site 8 to 0.40 ppm at site 9. This was the first decrease in total iron (Figure 1); however, the indicated decrease was within the accuracy limits of the analysis. The ferrous ions may have been oxidizing and settling out, thereby reducing the total iron content.

In this reach the stream channel is cut into the alluvium. The alluvium is fairly permeable and under appropriate water-table conditions could easily contribute the gain of 0.34 cfs in the reach.

Reach from Mile 1.3 to Mouth

Between mile 1.3 (site 9) and the mouth of Big Elkhart Creek (near site 21) the streamflow increased from 6.34 cfs to 8.91 cfs, and the dissolved solids decreased from 203 ppm to 143 ppm. Total iron concentration increased from 0.40 ppm to 0.49 ppm. The major tributary, Little Elkhart Creek, joins Big Elkhart Creek immediately downstream from site 9 (see following discussion on the Little Elkhart Creek reach). This tributary contributed 3.84 cfs of streamflow that contained only 53 ppm dissolved solids (Figure 3).

The addition of Little Elkhart Creek water lowered the dissolved-solids concentration of Big Elkhart Creek streamflow. In Table 2 and Figure 3, sodium plus potassium and chloride are shown to be the principal dissolved constituents in this reach of Big Elkhart Creek. The calcium concentration is about twice that of magnesium, and together their ions are approximately equal to those of the bicarbonate and sulfate.

The total flow of Big Elkhart Creek below the mouth of Little Elkhart Creek was indicated (Figure 5) to be 10.18 cfs (6.34 + 3.84 cfs). A streamflow measurement near the mouth of Big Elkhart Creek indicated a decrease of 1.27 cfs. Throughout the 1-mile reach, the stream channel is in the alluvium, which usually contributes water to streamflow. However, the ground-water table in sloping toward the channel of the Trinity River, which is more deeply incised than that of Big Elkhart Creek, may be below the creek channel. Under these conditions, the creek would lose water to the alluvium.

Characteristics of Little Elkhart Creek

Reach from Mile 17.5 to Mile 14.7

On September 16, 1965, the studies were resumed at site 10. This site was at the upstream end of the reach investigated on Little Elkhart Creek. Streamflow increased from 0.52 cfs at mile 17.5 (site 10) to 1.78 cfs at mile 14.7 (site 12). Dissolved solids decreased from 76 ppm to 54 ppm. The addition of water from Caney Creek caused the changes in both flow and chemical content.

The graphic presentation of the chemical analysis of streamflow at site 10 shows that the principal dissolved constituents were sodium plus potassium, bicarbonate, and chloride. (See Table 2.) Magnesium and calcium were present in approximately equivalent amounts and together were approximately equivalent to the bicarbonate. Total iron concentration was 1.4 ppm.

During this investigation, Little Elkhart Creek had less flow than Caney Creek (Table 1). The water of Caney Creek, however, with a total iron content of 0.39 ppm, and that of Little Elkhart Creek contained about the same relative proportion of most of the other dissolved constituents (Figure 3). The combination of these two creeks resulted in the generally improved quality of the water at site 12, even though the total iron content measured here was 0.66 ppm.

Graphically illustrated in Figure 2 is the fact that the reach from Caney Creek to site 12 is a losing one. The stream has cut into the Sparta Sand in this reach, and is probably receiving ground-water effluent; but the demands of evaporation and evapotranspiration seem to exceed the supply of effluent thus contributed.

Reach from Mile 14.7 to Mile 10.0

Between mile 14.7 (site 12) and mile 10.0 (site 18) the streamflow increased from 1.78 cfs to 4.11 cfs. Hays Branch, with 1.84 cfs, was the major contributor. Dissolved solids decreased only 7 ppm to 47 ppm in this reach.

Specific conductance of the water at site 18 and at five sites (13, 14, 15, 16, and 17) on tributaries indicated that the chemical content of the streamflow had not changed much from site 12 (Table 2). Total iron content decreased from 0.66 ppm at site 12 to 0.61 ppm at site 18.

The channel at site 12 is in the Sparta Sand, and about 1½ miles downstream cuts into the Weches Greensand. Numerous small springs at the contact were noted in this reach. After the contribution of Hays Branch inflow, the reach gains only slightly (Figure 2). Actually, the sum of streamflow at sites 12-17 exceeds that measured at site 18, for by the time the amount of tributary inflow entering the main stream travels to site 18, the supply diminishes through evapotranspiration.

Reach from Mile 10.0 to Mile 6.8

Between mile 10.0 (site 18) and mile 6.8 (site 19) the streamflow decreased from 4.11 cfs to 4.01 cfs. The dissolved-solids concentration remained almost constant. Total iron concentration decreased 0.04 ppm to 0.57 ppm.

Specific conductance of the streamflow at site 19 indicated the dissolved-solids concentration would be about the same as that at site 20; therefore, only a preliminary analysis was run (Table 2).

The channel in this reach is cut into the Weches Greensand. Because the Weches is relatively impermeable, the slight loss in streamflow may be attributed to evapotranspiration. A proposed reservoir upstream from site 19 will overlie, for the most part, the Weches Greensand and should, therefore, be fairly tight.

Reach from Mile 6.8 to Mouth

Between mile 6.8 (site 19) and the mouth of Little Elkhart Creek (near site 20) the streamflow decreased from 4.01 cfs to 3.84 cfs. Dissolved solids increased 4 ppm to 53 ppm. Total iron concentration increased 0.05 ppm to 0.62 ppm.

Figure 3 shows the chemical character of streamflow at site 20 was almost identical to that at site 12.

The channel in this reach cuts across the Weches Greensand and Queen City Sand for about half the distance to the mouth, then across alluvium for the remaining distance. The reach was a losing reach (Figure 2). This loss probably was due to the water table in the alluvium being below the stream channel because of the more deeply cut Trinity River and/or to evapotranspiration.

RELATION OF WATER QUALITY TO USE

Water quality is an important factor in selecting municipal water sources, in successful irrigation, and in the location of industrial plants. In order to evaluate the water quality in terms of principal types of uses, the major chemical characteristics of the water from Big Elkhart and Little Elkhart Creeks at low flow were determined. Because the chemical-quality data discussed in this report were obtained from water samples collected during a period when the streamflow was sustained by effluent ground water (ground water is usually more concentrated than surface runoff), the data probably represent the maximum concentration of dissolved solids likely to occur in either creek and its tributaries. Flood runoff, of course, should have much lower concentrations. The following discussion relates the quality of the streamflow of the study area to domestic and municipal use, to irrigation, and to industrial use.

Domestic and Municipal Use

The standards generally quoted in evaluating the quality and safety of water supplies for domestic and municipal use are those of the U.S. Public Health Service (1962, p. 7). According to these standards, the maximum limits for dissolved solids, sulfate, and chloride are 500 ppm, 250 ppm, and 250 ppm, respectively. Concentrations in both creeks were below these limits. The standards also state that the acceptable upper limits for iron and manganese is 0.3 ppm and 0.05 ppm, respectively. The analyses of waters from both creeks show concentrations of total iron to be above the limit throughout both reaches (Figures 1 and 2). According to two analyses (Table 2), manganese also is present in both creeks in excess of the limit. The relatively high concentration of iron and manganese noted at the low flows during this investigation probably would not be significant in the total content of a reservoir. Both substances are easily removed by conventional treatment processes.

Irrigation

The U.S. Salinity Laboratory Staff (1954, p. 69) established standards for determining the suitability of water for irrigation. In these standards, the three following characteristics appear to be most important in determining the quality of irrigation water: total concentration of soluble salts (salinity hazard); relative proportion of sodium to other cations (sodium hazard); and concentration of boron or other elements that may be toxic. Therefore, Big Elkhart Creek streamflow, which can be classified as medium in salinity hazard and as low in sodium hazard, can be used satisfactorily for irrigation if a moderate amount of leaching occurs. The water in Little Elkhart Creek, which can be classified as low in salinity hazard and low in sodium hazard, is excellent for irrigation for almost all soils. Analyses indicate that the water in each creek is sufficiently free of boron to be used for irrigating boron-sensitive crops.

Industrial Use

The quality requirements of water for industrial purposes vary widely from place to place. For some purposes, such as cooling, water of almost any quality can be used; but in some manufacturing processes and in high-pressure steam boilers, water approaching the quality of distilled water may be necessary. The water-quality requirements for many types of industry and processes (listed in Table 3) can be met by waters from Big Elkhart and Little Elkhart Creeks.

SUMMARY AND CONCLUSIONS

The base-flow investigations on Big Elkhart and Little Elkhart Creeks indicate no large gain or loss of base flow in either channel. The major contributor of flow was found to be the Sparta Sand. Less flow was contributed by the Queen City Sand and even less by the Weches Greensand; so, at times, a net loss occurred within short reaches because of evapotranspiration. A relatively sharp decrease in flow occurred in the alluvium near the mouth of Big Elkhart Creek.

A proposed reservoir, located on Little Elkhart Creek between mile 7 and mile 14, will overlie, for the most part, the Weches Greensand; because the Weches is relatively impermeable, the reservoir should be fairly tight. A base inflow to the reservoir of about 4 cfs was indicated.

The chemical analyses indicate water in both creeks can be used for domestic, municipal, irrigation, and industrial purposes with a minimum of treatment. The relatively high concentration of iron and manganese at low flow probably will not be significant in the total content of a reservoir insofar as water for domestic and municipal uses is concerned. The water samples collected during this investigation were from effluent ground water. Flood runoff should have lower concentrations and, unless polluted by mankind, would improve the water quality.

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Table 1.--Summary of discharge measuring sites, Big Elkhart and Little Elkhart Creeks and tributaries, September 15-16, 1965

Site No.	Date	Stream	Location	River Miles a/	Water Temp. (°F)	Discharge in cfs Main Stream	Tributary	Remarks
	Sept.							
b/ 1	15	Big Elkhart Creek	Lat 31°31'49", long 95°31'01", at bridge on county road, 3.5 miles northwest of Grapeland.	26.0	76	3.44		Stream is flowing across Weches Greensand here, but upstream streambeds are mainly in Sparta Sand.
c/ 2	15	do	Lat 31°30'58", long 95°32'08", at bridge on Farm Road 1272, 3.7 miles northwest of Grapeland.	24.4	81	(d)		Channel in Queen City Sand.
b/ 3	15	do	Lat 31°29'22", long 95°33'27", at bridge on county road, 4.5 miles west of Grapeland.	22.0	79	4.38		Stream is flowing through Queen City Sand. Hills are of Weches Greensand capped by Sparta Sand.
4	15	Unnamed tributary to Big Elkhart Creek	Lat 31°29'40", long 95°34'00", at bridge on county road, 4.8 miles west of Grapeland.	T .6	80		e/0.22	Streambed cut into Sparta Sand
5	15	do	Lat 31°29'49", long 95°34'42", at bridge on county road, 5.8 miles west of Grapeland.	T 1.0	80		e/ .75	Do.
c/ 6	15	Murchison Branch, tributary to Big Elkhart Creek	Lat 31°27'47", long 95°36'21", at culvert on Farm Road 227, 7.6 miles southwest of Grapeland.	T 3.0	84		e/ .07	
b/ 7	15	Big Elkhart Creek	Lat 31°27'53", long 95°39'36", at bridge on Farm Road 227, 11 miles west of Grapeland.	11.7	80	5.87		Stream is flowing across Queen City Sand.
b/ 8	15	do	Lat 31°24'36", long 95°39'22", on Farm Road 2544, 11.7 miles southwest of Grapeland.	5.2	80	6.00		Do.
b/ 9	15	do	Lat 31°22'43", long 95°39'55", 200 ft upstream from Little Elkhart Creek, 13.2 miles southwest of Grapeland.	1.3	82	6.34		Stream is flowing across alluvium.
b/10	16	Little Elkhart Creek	Lat 31°25'52", long 95°29'36", at bridge on old Grapeland-Crockett highway, 4.3 miles south of Grapeland.	17.5	78	.52		Stream is flowing across a wide expanse of Sparta Sand.
b/11	16	Caney Creek, tributary to Little Elkhart Creek	Lat 31°25'54", long 95°30'08", at bridge on county road, 4.3 miles south of Grapeland.	T .4	77		1.65	Stream is flowing across Sparta Sand and is the major tributary to headwaters of Little Elkhart Creek.
b/12	16	Little Elkhart Creek	Lat 31°25'22", long 95°31'46", 350 ft upstream from Hays Branch, 6 miles southwest of Grapeland.	14.7	79	1.78		Stream is flowing across the basal part of the Sparta Sand.
13	16	Hays Branch, tributary to Little Elkhart Creek	Lat 31°25'25", long 95°31'48", 50 ft upstream from mouth, 6.0 miles southwest of Grapeland.	T 0	80		1.84	Do.
14	16	Unnamed tributary to Little Elkhart Creek	Lat 31°25'38", long 95°32'18", 5.9 miles southwest of Grapeland	T .4	86		e/ .05	Do.
15	16	do	Lat 31°26'52", long 95°32'53", at bridge on county road, 5.0 miles southwest of Grapeland.	T 1.9	78		e/ .14	
16	16	do	Lat 31°26'08", long 95°33'39", at bridge on county road, 6.2 miles southwest of Grapeland	T 1.6	84		.35	
17	16	do	Lat 31°25'37", long 95°34'27", at bridge on county road, 7.2 miles southwest of Grapeland.	T 1.1	80		.88	
18	16	Little Elkhart Creek	Lat 31°24'48", long 95°35'01", 8.2 miles southwest of Grapeland.	10.0	84	4.11		Stream is flowing across Weches Greensand, but upstream streambeds are predominantly in the Sparta Sand.
b/ 19	16	do	Lat 31°23'58", long 95°36'53", at bridge on Farm Road 229, 10.3 miles southwest of Grapeland.	6.8	83	4.01		Stream is flowing across Weches Greensand near the contact of the Weches and Sparta.
b/20	15	do	Lat 31°22'41", long 95°39'56", 150 ft upstream from mouth, 13.4 miles southwest of Grapeland.	0	81	3.84		Stream is flowing across alluvium.
b/21	16	Big Elkhart Creek	Lat 31°22'18", long 95°40'27", 1/4 mile upstream from mouth, 14.1 miles southwest of Grapeland.	.3	82	8.91		Stream is flowing across Trinity River flood plain silt deposits, which are underlain by the Queen City Sand.

a River miles measured above mouth of stream; "T" indicates the site is above the mouth of a tributary.
b Quality of water sample, ferrous iron sample, and total iron sample collected
c Quality of water sample collected
d Not measured
e Estimated

Table 2.--Chemical analyses of streamflow, Big Elkhart and Little Elkhart Creeks and tributaries, September 15-16, 1965

(Analytical results in parts per million except as indicated)

Site No.	Stream	Date 1965	Discharge (cfs)	Silica (SiO_2)	Iron (Fe) (Total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated) Parts per million	Dissolved solids (calculated) Tons per day	Hardness as $CaCO_3$ Calcium, Magnesium	Hardness as $CaCO_3$ Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
1	Big Elkhart Creek	Sept. 15	3.14	17	0.33	4.2	1.8	12		20	4.6	16	0.1	1.0	--	a 67	0.62	18	2	1.2	99	6.2
2	do.	do.	--	--	--	--	--	--		18	--	97	--	--	--	b 198	--	42	27	--	372	6.2
3	do.	do.	4.38	17	.39	8.2	4.5	43		22	12	72	.1	.5	--	169	2.00	39	21	3.0	293	6.3
4	Unnamed tributary	do.	c .22	--	--	--	--	--		--	--	--	--	--	--	b 45	.03	--	--	--	56	--
5	do.	do.	c .75	--	--	--	--	--		--	--	--	--	--	--	b 47	.09	--	--	--	58	--
6	Murchison Branch	do.	c .07	28	--	4.8	1.9	7.6	1.5	22	6.4	6.9	.1	4.5	--	73	.01	20	2	.7	90	6.2
7	Big Elkhart Creek	do.	5.87	16	.42	11	4.0	52		28	4.8	91	.1	.5	--	194	3.07	44	21	3.4	370	6.4
8	do.	do.	6.00	--	.44	--	--	--		30	--	95	--	--	--	b 204	3.30	48	23	--	386	7.0
9	do.	do.	6.34	16	.40	12	4.9	53		32	9.2	91	.1	.5	0.04	203	3.47	50	24	3.3	384	6.7
10	Little Elkhart Creek	Sept. 16	.52	21	1.4	6.5	2.6	11		32	4.4	13	.1	.5	--	d 76	.11	27	1	.9	106	6.2
11	Caney Creek	do.	1.65	15	.39	3.0	1.1	4.6	2.3	16	3.8	5.2	.1	1.8	--	45	.04	12	0	.6	56	6.4
12	Little Elkhart Creek	do.	1.78	17	.66	3.8	1.6	6.0	2.3	20	4.4	7.4	.1	1.2	--	54	.26	16	0	.7	69	6.2
13	Hays Branch	do.	1.84	--	--	--	--	--		--	--	--	--	--	--	b 42	.21	--	--	--	52	--
14	Unnamed tributary	do.	c .05	--	--	--	--	--		--	--	--	--	--	--	b 42	.01	--	--	--	52	--
15	do.	do.	c .14	--	--	--	--	--		--	--	--	--	--	--	b 55	.02	--	--	--	70	--
16	do.	do.	.35	--	--	--	--	--		--	--	--	--	--	--	b 57	.05	--	--	--	73	--
17	do.	do.	.88	--	--	--	--	--		--	--	--	--	--	--	b 41	.10	--	--	--	50	--
18	Little Elkhart Creek	do.	4.11	--	.61	--	--	--		18	--	5.8	--	--	--	b 47	.52	13	0	--	60	6.3
19	do.	do.	4.01	--	.57	--	--	--		20	--	5.7	--	--	--	b 49	.53	14	0	--	63	6.3
20	do.	Sept. 15	3.84	18	.62	3.8	1.6	5.2	2.3	19	4.8	6.0	.1	1.8	.04	53	.55	16	1	.6	68	6.2
21	Big Elkhart Creek	Sept. 16	8.91	17	.49	9.8	3.3	34		30	7.6	56	.1	.5	--	143	3.44	38	13	2.4	261	6.4

a Manganese (Mn) 0.09 ppm
b Calculated from specific conductance
c Estimated
d Manganese (Mn) 0.16 ppm

Table 3.--Water-quality tolerances for industrial applications[1]

(Allowable limits in parts per million except as indicated)

Industry	Turbidity	Color	Color + O_2 consumed	D.C. (ml/l)	Odor	Hardness	Alkalinity (as $CaCO_3$)	pH	Total solids	Ca	Fe	Mn	Fe + Mn	Al_2O_3	SiO_2	Cu	F	CO_3	HCO_3	OH	$CaSO_4$	Na_2SO_4 to Na_2SO_3 ratio	General[2]
Air conditioning[3]	--	--	--	--	--	--	--	--	--	--	0.5	0.5	0.5	--	--		--	--	--	--	--	--	A, B
Baking	10	10	--	--	--	(4)	--	--	--	--	.2	.2	.2	--	--		--	--	--	--	--	--	C
Boiler feed:																							
0-150 psi	20	80	100	2	--	75	--	8.0+	3,000-1,000	--	--	--	--	5	40		--	200	50	50	--	1 to 1	--
150-250 psi	10	40	50	.2	--	40	--	8.5+	2,500-500	--	--	--	--	.5	20		--	100	30	40	--	2 to 1	--
250 psi and up	5	5	10	0	--	8	--	9.0+	1,500-100	--	--	--	--	.05	5		--	40	5	30	--	3 to 1	--
Brewing: [5]																							
Light	10	--	--	--	Low	--	75	6.5-7.0	500	100-200	.1	.1	.1	--	--		1	--	--	--	100-200	--	C, D
Dark	10	--	--	--	Low	--	150	7.0→	1,000	200-500	.1	.1	.1	--	--		1	--	--	--	200-500	--	C, D
Canning:																							
Legumes	10	--	--	--	Low	25-75	--	--	--	--	.2	.2	.2	--	--		--	--	--	--	--	--	C
General	10	--	--	--	Low	--	--	--	--	--	.2	.2	.2	--	--		1	--	--	--	--	--	C
Carbonated beverages[6]	2	10	10	--	0	250	50	--	850	--	.2	.2	.3	--	--		.2	--	--	--	--	--	C
Confectionary	--	--	--	--	Low	--	--	(7)	100	--	.2	.2	.2	--	--		--	--	--	--	--	--	--
Cooling[8]	50	--	--	--	--	50	--	--	--	--	.5	.5	.5	--	--		--	--	--	--	--	--	A, B
Food, general	10	--	--	--	Low	--	--	--	--	--	.2	.2	.2	--	--		--	--	--	--	--	--	C
Ice (raw water)[9]	1-5	5	--	--	--	--	30-50	--	300	--	.2	.2	.2	--	10		--	--	--	--	--	--	C
Laundering	--	--	--	--	--	50	--	--	--	--	.2	.2	.2	--	--		--	--	--	--	--	--	--
Plastics, clear, undercolored	2	2	--	--	--	--	--	--	200	--	.02	.02	.02	--	--		--	--	--	--	--	--	--
Paper and pulp: [10]																							
Groundwood	50	20	--	--	--	180	--	--	--	--	1.0	.5	1.0	--	--		--	--	--	--	--	--	A
Kraft pulp	25	15	--	--	--	100	--	--	300	--	.2	.1	.2	--	--		--	--	--	--	--	--	--
Soda and sulfite	15	10	--	--	--	100	--	--	200	--	.1	.05	.1	--	--		--	--	--	--	--	--	--
Light paper, HL-Grade	5	5	--	--	--	50	--	--	200	--	.1	.05	.1	--	--		--	--	--	--	--	--	B
Rayon (viscose) pulp:																							
Production	5	5	--	--	--	8	50	--	100	--	.05	.03	.05	<8.0	<25	<5	--	--	--	--	--	--	--
Manufacture	.3	--	--	--	--	55	--	7.8-8.3	--	--	.0	.0	.0	--	--		--	--	--	--	--	--	--
Tanning[11]	20	10-100	--	--	--	50-135	135	8.0	--	--	.2	.2	.2	--	--		--	--	--	--	--	--	--
Textiles:																							
General	5	20	--	--	--	20	--	--	--	--	.25	.25	--	--	--		--	--	--	--	--	--	--
Dyeing[12]	5	5-20	--	--	--	20	--	--	--	--	.25	.25	.25	--	--		--	--	--	--	--	--	--
Wool scouring[13]	--	70	--	--	--	20	--	--	--	--	1.0	1.0	1.0	--	--		--	--	--	--	--	--	--
Cotton bandage[13]	5	5	--	--	Low	20	--	--	--	--	.2	.2	.2	--	--		--	--	--	--	--	--	--

1/ American Water Works Association, 1950.
2/ A--No corrosiveness; B--No slime formation; C--Conformance to Federal drinking water standards necessary; D--NaCl, 275 ppm.
3/ Waters with algae and hydrogen sulfide odors are most unsuitable for air conditioning.
4/ Some hardness desirable.
5/ Water for distilling must meet the same general requirements as for brewing (gin and spirits mashing water of light-beer quality; whiskey mashing water of dark-beer quality).
6/ Clear, odorless, sterile water for syrup and carbonization. Water consistent in character. Most high quality filtered municipal water not satisfactory for beverages.
7/ Hard candy requires pH of 7.0 or greater, as low value favors inversion of sucrose, causing sticky product.
8/ Control of corrosiveness is necessary as is also control of organisms, such as sulfur and iron bacteria, which tend to form slimes.
9/ $Ca(HCO_3)_2$ particularly troublesome. $Mg(HCO_3)_2$ tends to greenish color. CO_2 assists to prevent cracking. Sulfates and chlorides of Ca, Mg, Na should each be less than 300 ppm (white butts).
10/ Uniformity of composition and temperature desirable. Iron objectionable as cellulose adsorbs iron from dilute solution. Manganese very objectionable, clogs pipelines and is oxidized to permanganates by chlorine, causing reddish color.
11/ Excessive iron, manganese or turbidity creates spots and discoloration in tanning of hides and leather goods.
12/ Constant composition; residual alumina 0.5 ppm.
13/ Calcium, magnesium, iron, manganese, suspended matter, and soluble organic matter may be objectionable.

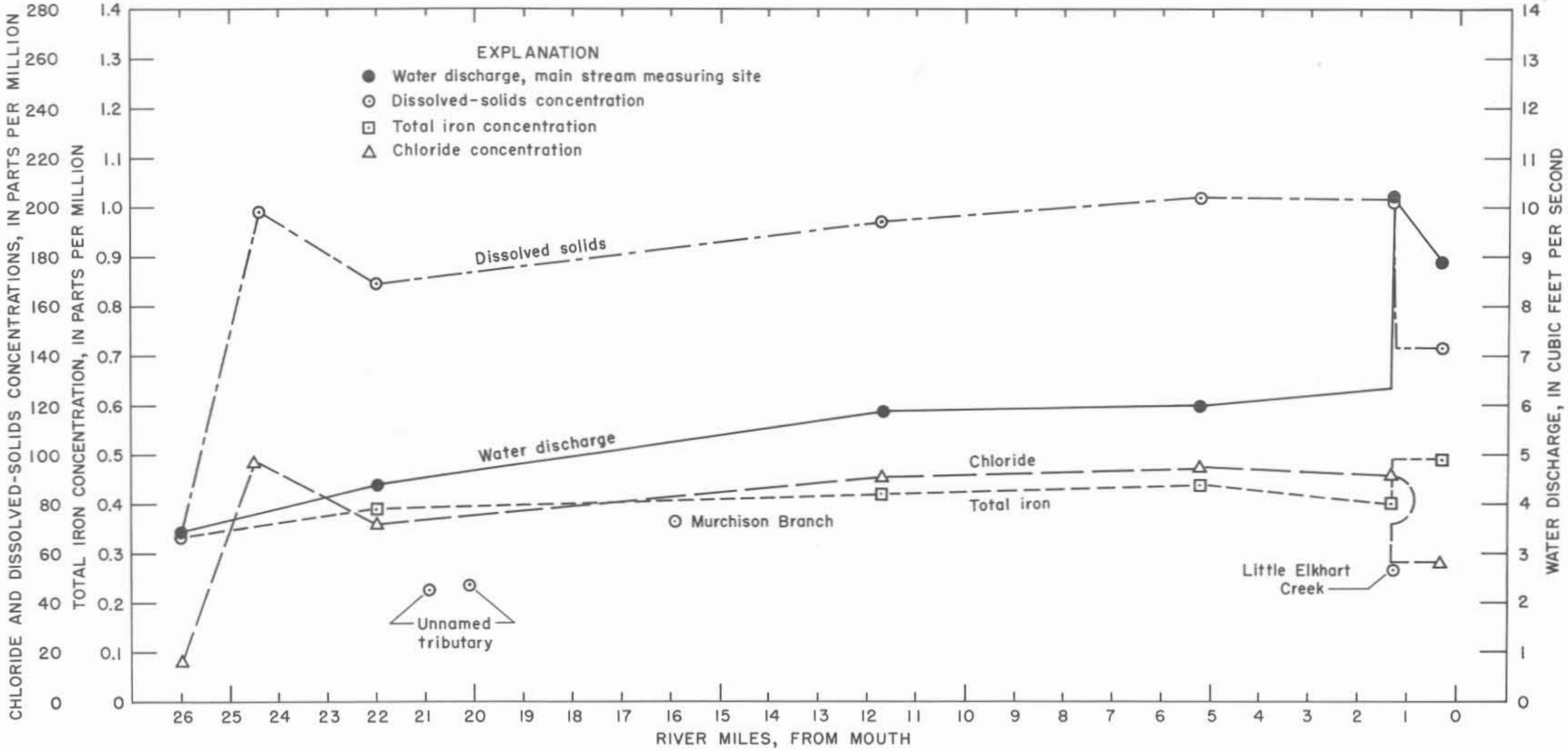

Figure 1

Profiles of Total Iron, Chloride, and Dissolved - Solids Concentrations, and of Water Discharge, Big Elkhart Creek, September 15-16, 1965

U.S. Geological Survey in cooperation with the Texas Water Development Board

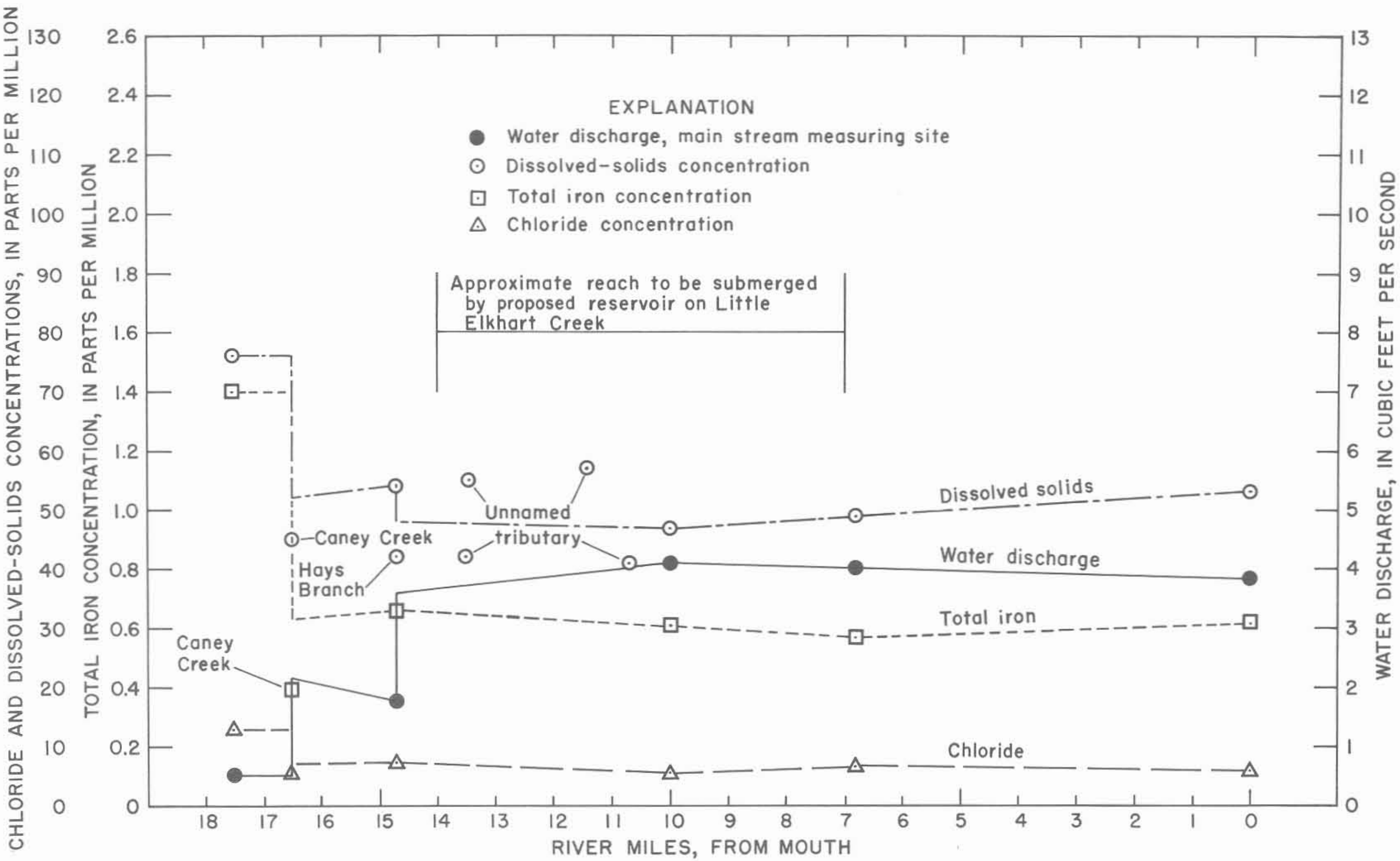

Figure 2

Profiles of Total Iron, Chloride, and Dissolved - Solids Concentrations, and of Water Discharge, Little Elkhart Creek, September 15 - 16, 1965

U.S. Geological Survey in cooperation with the Texas Water Development Board

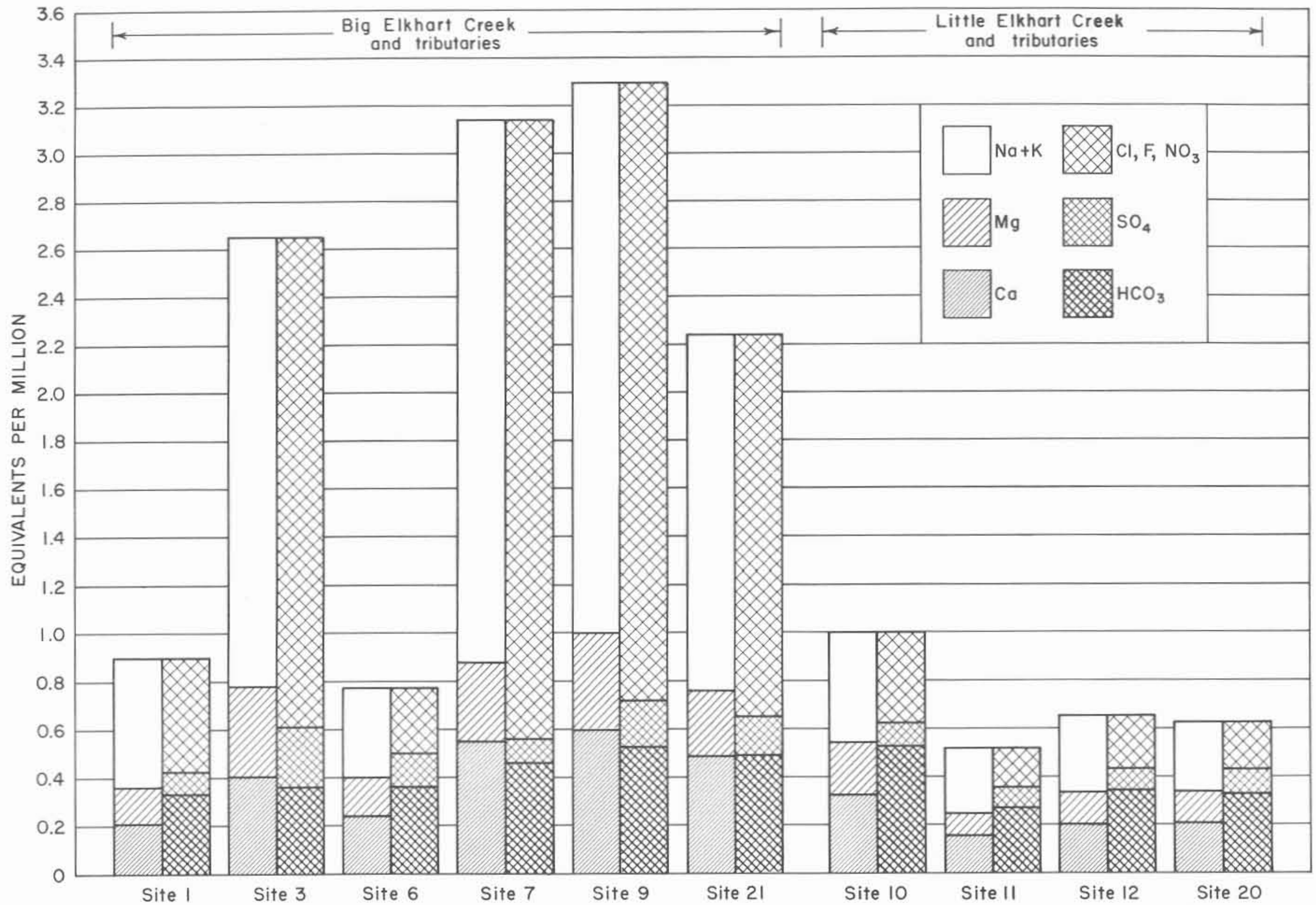

Figure 3

Graph of Chemical Analyses of Streamflow of Big Elkhart and Little Elkhart Creeks and Tributaries, September 15-16, 1965

U.S. Geological Survey in cooperation with the Texas Water Development Board

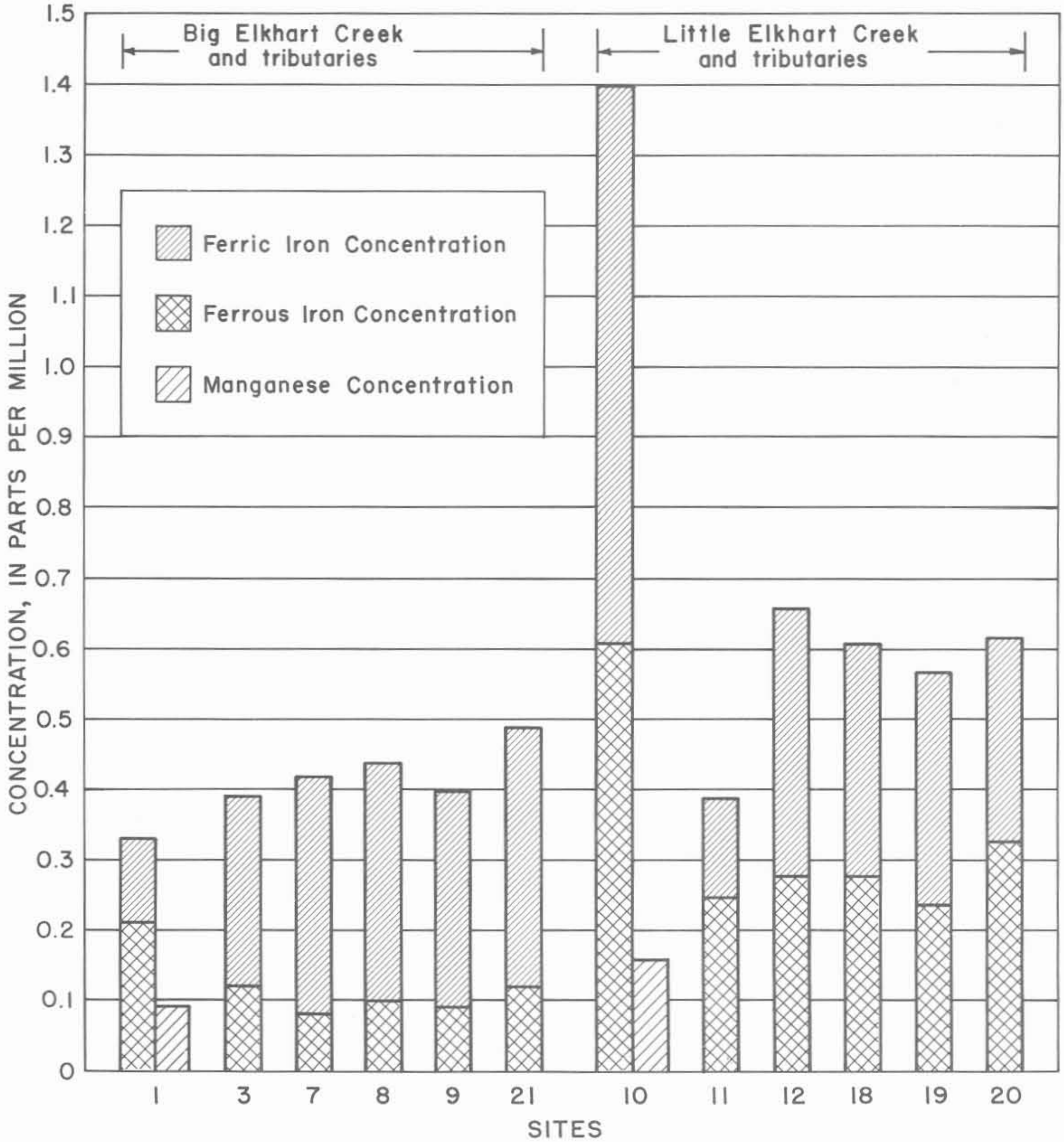

Figure 4

Graph of Iron and Manganese Concentrations at Sites on Big Elkhart and Little Elkhart Creeks and Tributaries, September 15-16, 1965

U.S. Geological Survey in cooperation with the Texas Water Development Board

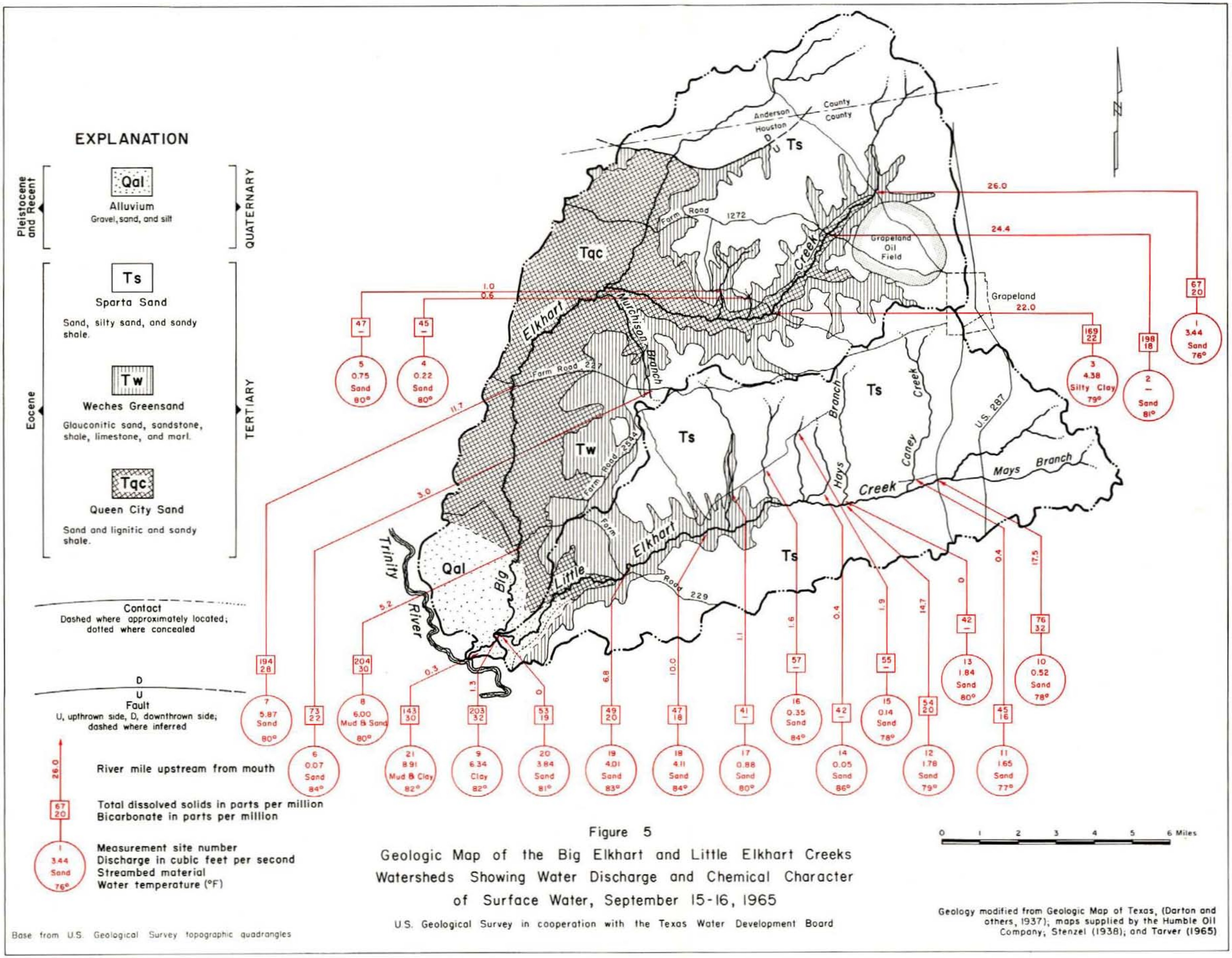

Figure 5

Geologic Map of the Big Elkhart and Little Elkhart Creeks Watersheds Showing Water Discharge and Chemical Character of Surface Water, September 15-16, 1965

U.S. Geological Survey in cooperation with the Texas Water Development Board