TEXAS WATER COMMISSION

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BASE-FLOW STUDIES

LLANO RIVER, TEXAS

Quantity and Quality

By

Pat H. Holland and H. B. Mendieta
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INTRODUCTION

This investigation was made under the provisions of the 1962 cooperative agreement between the Texas Water Commission and the U.S. Geological Survey, Water Resources Division, for the investigation of the water resources of Texas.

The purpose of the investigation was to determine the quality of water and the interchange of surface and ground waters in the Llano River below the town of Junction during January 1962 when evaporation and transpiration were not significant, and to compare the results with those of investigations made in 1918, 1925, and 1952. The reach studied extends 83.5 miles from Junction, Kimble County, to Llano, Llano County (Plate 1).

There had been no runoff-producing rains for 66 days prior to this investigation. Continuous streamflow records at the gaging stations Llano River near Junction and Llano River at Llano show that the flow during this investigation, January 17-24, was declining slowly and the flow of the river and its tributaries was being sustained only by ground-water accretions to the stream system.

Supporting data not given in the text, tables, and figures are available in the files of the U.S. Geological Survey, Austin, Texas.

GENERAL GEOLOGY OF THE LLANO RIVER WATERSHED

The Llano River watershed is transected about midway by the dividing line between the Edwards Plateau and Central Texas sections of the Great Plains province. An irregular and prominent faulted zone of rocks of early Paleozoic age forms a bench which is the boundary between the two sections. To the east of the escarpment is the Llano Basin, about 25 miles wide and 50 miles in length, whose floor is about 600 feet below the bench formed by the Paleozoic rocks and 1,000 feet below the frayed escarpment that marks the present edge of the Edwards Plateau.

The rocks in the watershed range in age from Early Cretaceous in the upper reaches to Pennsylvanian, Ordovician, and Cambrian in the middle reaches to Precambrian in the lower parts. Figure 1 is a generalized geologic map showing the outcrop of rocks of Cretaceous, Paleozoic, and Precambrian age.

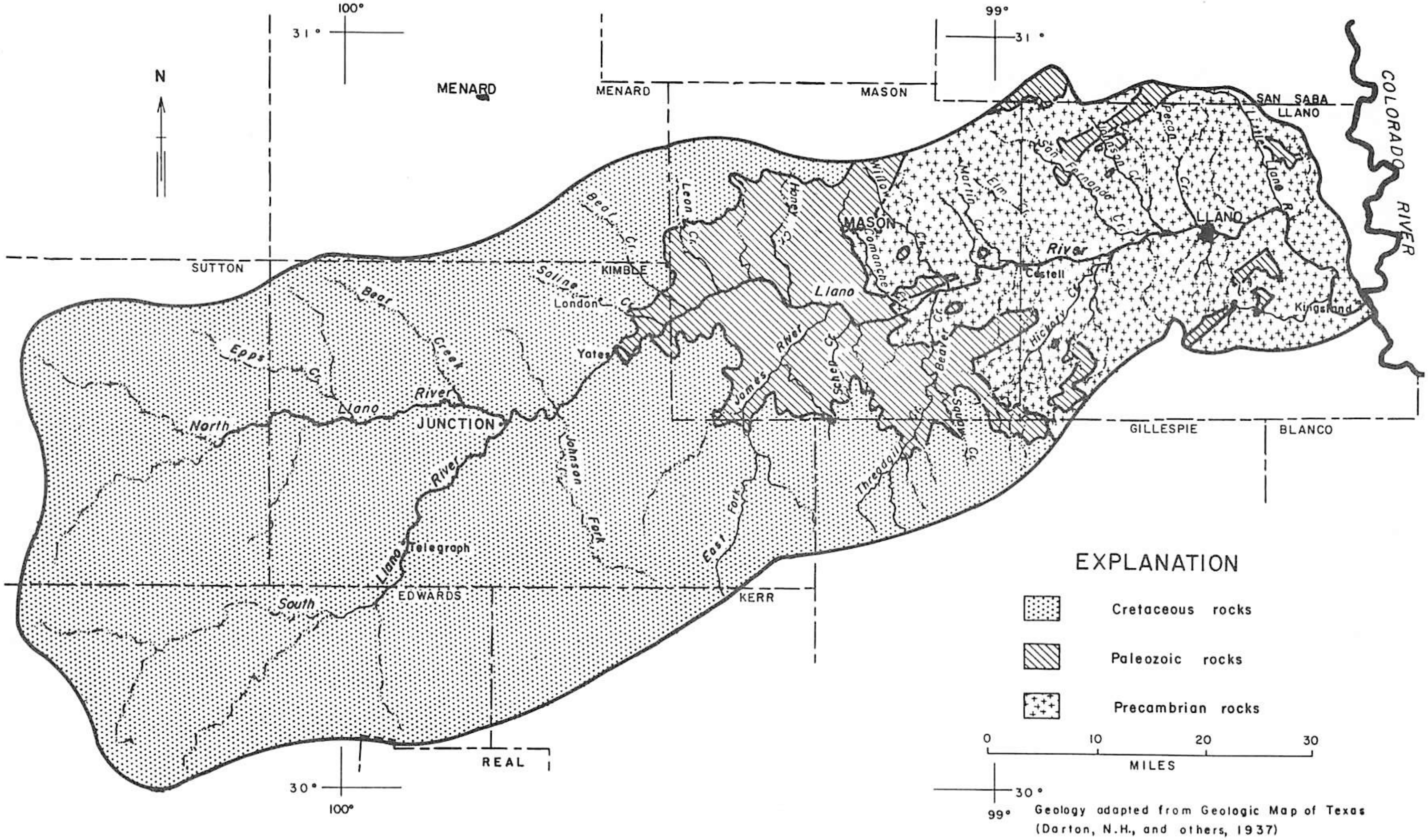

Figure 1

Generalized Geologic Map of the Llano River Watershed

U.S. Geological Survey in cooperation with the Texas Water Commission

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The North and South Llano Rivers head in an upland plateau which is capped with the Georgetown Limestone of the Washita Group. Wide draws in this plateau develop downstream into gully-like heads of dissecting stream valleys that cut into the Fredericksburg Group, whose most prominent formation is the Edwards Limestone. The Georgetown, Edwards, and Comanche Peak Limestones are usually considered as a single hydrologic unit and are referred to as the Edwards and associated limestones.

Individual limestone beds in the Edwards are massive and usually highly fractured and jointed. Solution channels in interconnected joints and fissures honeycomb the formation, resulting in a high relative porosity capable of absorbing and storing large quantities of water. The base flow at the confluence of the North and South Llano Rivers is practically all derived from springs and seeps at the base of the Edwards and associated limestones. In the 84-mile reach below the confluence of the North and South Llano Rivers, 74 miles had tributary inflow that was either all or partly derived from the Edwards and associated limestones.

As the stream valleys become deeper, the lowermost of the Cretaceous rocks, those of the Trinity Group, are exposed. The outcrop of the Trinity Group widens below the confluence of the North and South Llano Rivers, extends northward in a broad belt toward London, and then narrows to a thin belt along the escarpment surrounding the bench formed by rocks of Paleozoic age. The Trinity is composed of sandstone and limestone that probably store and release small amounts of water. The headwaters of most of the tributaries crossing the rocks of the Trinity Group are underlain by Edwards and associated limestones. The flow measurements and the sampling of this study were not of sufficient detail to delineate the proportion of the flow contributed by each formation.

Small areas of Pennsylvanian rocks are adjacent to faulted zones near the Kimble-Mason County line and southwest of the town of Mason. These are remnants of the Canyon Group of the Upper Pennsylvanian and the Marble Falls Limestone of the Lower and Middle Pennsylvanian.

Paleozoic rocks that form the bench surrounding the Llano Basin are principally of the Ellenburger Group of Early Ordovician age and members of the Riley and Wilberns Formation of Late Cambrian age. The outcrop of the Ellenburger Group covers generally the outer or western edge of the surrounding plateau. The group consists of the Tanyard, Gorman, and Honeycut Formations in ascending order. The rocks of this group are mostly limestone and dolomite.

The Riley Formation has been divided into three members: the Hickory Sandstone Member, the Cap Mountain Limestone Member, and the Lion Mountain Sandstone Member. All three crop out in Mason County, and the Hickory also crops out along the fault lines surrounding the Llano Basin. George (1947) states that the Hickory is the main water-bearing unit in the region of the Llano uplift.

The rocks of the lower part of the Llano Basin are chiefly Precambrian in age. The basin was once an area of uplift but the uplifted area was eroded to an almost level surface and Cretaceous limestone was deposited. After another episode of uplift, erosion removed the overlying limestone and part of the underlying Precambrian rocks. The rolling floor of the basin is composed of gneiss, schistose granite, and schist; large knobs of granite rise 400 to 600 feet above the general level of the basin. According to George (1947), the Precambrian rocks yield small quantities of water to many farm and ranch wells in Mason County. This low-flow study was not of sufficient detail to determine the amount of flow from these rocks.

DISCUSSION OF FLOW DATA

At the time of this investigation of Llano River system, from the towns of Junction to Llano, derived most of its base flow from springs on the two forks above Junction and from tributary inflow in the reach. The combined flow of the South and North Llano Rivers from Junction and above amounted to 129 cfs (cubic feet per second) on January 17, 1962. This is 69 percent of the flow at Llano. The combined tributary inflow, below Junction, during the period of study was 53 cfs, or 28 percent of the flow at Llano. The sectional gains and losses in the river, channel, excluding inflow from tributaries, amounted to gains of 38.6 cfs and losses of 32.6 cfs. The data indicate that the river reach has sufficient ground-water inflow, possibly from gravel deposits in the river channel and flood plain, to make up all losses in the reach (see Table 1). During the summer months, May through September, this may not be true as evaporation and transpiration would be much greater than that experienced during this investigation.

Two of the three previous investigations, those of 1918 and 1925, bear out the above findings (Tables 2 and 3). In both of these studies the sectional losses and gains in the channel are about equal and the increase in flow at Llano over that at Junction is about equal to the tributary inflow (Figure 2). The September 3-4, 1952, investigation was made during an extreme drought when the reach was producing little or no base flow below the mouth of Johnson Fork. The accumulated flow of 18.8 cfs at that point was lost in the 55-mile reach to evaporation, transpiration, and other channel losses (Table 4). This is not an excessive natural loss for evapotranspiration during a hot and dry period at this time of the year.

During the 1962 investigation the flow of the Llano River was wholly from ground-water sources, and no surface runoff from rainfall was encountered at any time. No precipitation of consequence fell during the period and the weather, although cold, was favorable for this type of study. During January the flow of the Llano River was declining slowly. At the gaging station near Junction the daily flow dropped from 131 to 120 cfs during the month. At Llano the daily flow varied from a high of 193 to a low of 170 cfs during January.

At Junction where the North and South Llano Rivers meet, the river channels are cut down into the wide and extensive beds of alluvium and no doubt a considerable amount of water is stored in and transmitted through these beds. The North Llano River showed a decrease in surface flow from 29 to 16.3 cfs in the 3.5 miles between the gaging station and the measuring section about 0.5 mile above its confluence with the South Llano River. This apparent loss of flow no doubt is only temporary and the water soon comes to the surface at the first rock outcrop in the channel downstream. The measured surface discharge of 98.0 cfs on the South Llano just above the confluence is probably somewhat less than the true flow due to underflow through the alluvium. Therefore, in making assumptions and conclusions in this report the discharge of 129 cfs at site 4, mile 6.3, was used as the true contributions of both forks from above Junction. It was considered that the total flow had been forced to the surface by the rock streambed at and below the regular gaging station 4 miles below the confluence.

In the 25 miles from Junction to the falls 3 miles above Saline Creek, the river channel has many long, deep pools lined with large trees at the edge of the water. These pools are connected by either gravel bars or by steep rock riffles with some small falls.

From river mile 25 to mile 40 the channel is of rock, very wide, with shallow pools and steep rock riffles. The terrain in this reach is very rough, and satisfactory measuring sections on the river are difficult to locate.

From Farm to Market Road 1871 to the Mason-Llano County line (river miles 40 to 66) the channel is mostly gravel and sand with many outcrops of rock. The riffles and rapids are both serrated rock and large gravel and boulders. A few long, deep pools were found, some lined with large trees. The lower end of this reach is in granite (Precambrian rocks) and some granite sand begins showing in the streambed, particularly in the many tributaries.

The riverbed in the reach from Castell to Llano (river miles 66 to 83) is mostly rock with shallow coverings of sand and gravel here and there. Two small reservoirs are located in the lower end of this reach. The city of Llano uses water from the river for municipal supply and was pumping 0.5 cfs during the investigation period.

A number of irrigation projects are located on the Llano River from Junction to Llano and on its tributaries both in the reach and above Junction. Permits and Certified Filings covering large acreages are recorded by the Texas Water Commission in the Llano watershed. During this investigation several irrigation pumps were observed in the reach but none were in operation. It is believed that no significant amounts of water were diverted for irrigation at any time during this study. During the growing season, in periods of deficient rainfall, a large part of the base flow of this stream can be diverted by irrigation pumps.

CHEMICAL QUALITY OF BASE FLOW

Water samples from 31 sites were collected for chemical analyses during the 1962 low-flow investigation in the Llano River watershed. The dissolved-solids and chloride concentrations, and the water discharge are shown on Figure 3 as a profile for the reach of the stream under investigation. Measured tributary inflow is also shown with the dissolved-solids concentration of the inflow at the junction of the tributary with the Llano River. More complete chemical analyses are given in Table 5.

Analyses of a sample collected at mile 3.1, the first sampling point of the Llano River below the junction of the North and South Forks, one from mile 81.1, the Llano River near the end of the study reach, and analyses of 4 samples from intervening tributaries are presented graphically on Figure 4. The total height of each vertical bar is proportional to the total concentration of anions (negatively charged constituents) or cations (positively charged constituents) expressed in equivalents per million. The bar is divided into segments to show the individual cations and anions.

At low flow the waters of the Llano River watershed are saturated with calcium and magnesium bicarbonates, which are dissolved from the limestone and dolomite that crop out over much of the area. The low flow also contains sodium chloride, which increases the solubility of calcium and magnesium.

The low flow of the North and South Forks of the Llano River is derived from springs and seeps in the Edwards Limestone. At mile 3.1, immediately below the junction of the two forks, calcium, magnesium, and bicarbonate were the major constituents of the water, and concentrations of sodium, chloride, and sulfate were low.

This type of water is characteristic of drainage from the outcrops of Edwards and associated limestones. The outcrops of the Trinity Group yield water whose chemical composition is similar to that of the Edwards water. Because tributary inflow both upstream and downstream from the Trinity outcrop is derived from the Edwards and associated limestones, the small quantity of inflow from the Trinity Group has an indistinguishable effect on the chemical quality of the Llano River.

Some headwaters of tributaries in the lower Llano River watershed are underlain by limestone rocks of Paleozoic age which also yield a calcium-magnesium-bicarbonate type of water. Thus, the tributaries in the entire reach of the investigation do not change the type of water in the Llano River.

All the tributary inflow was more mineralized than the water of the Llano River, and caused concentrations of magnesium, sodium, sulfate, and chloride in the main stem to increase slightly throughout the reach investigated. However, the dissolved-solids content decreased from 259 to 225 ppm (parts per million) in the 79-mile reach below mile 3.1, because of reduction of calcium and bicarbonate concentrations. This reduction must be due to precipitation of calcium carbonate, as the weighted-average concentration of calcium in tributary inflow was about the same as the concentrations at the upstream site on the main stem, and the weighted-average concentration of bicarbonate in tributary inflow was slightly greater than the concentration in the main stem. Calculations indicate that calcium carbonate was being deposited along the streambed at a rate of about 20 tons per day. Deposition occurs because the loss of dissolved carbon dioxide from the water decreases the solubility of calcium bicarbonate.

The analyses of the samples collected on the main stem during this investigation were very similar to the analyses of 6 samples collected at low flows during 1948, 1949, and 1960 from the Llano River at Llano. The dissolved-solids concentrations for the 6 earlier samples ranged from 184 to 224 ppm for low flows that ranged from 86 to 233 cfs.

RELATION OF QUALITY OF WATER TO USE

Water quality is an important factor is selecting municipal water sources, in sucessful irrigation, and in the location of industrial plants. Though the scope of this study did not require detailed water analyses, the major chemical characteristics of the Llano River water at low flow were determined. A comparison of these analyses with commonly used water-quality criteria showed that the water was good for all three uses.

Standards published by the U.S. Public Health Service (1962) list limits of concentrations of dissolved constituents which should not be exceeded for potable water used on interstate common carriers. These standards, which are generally accepted as a basis for determining the suitability of a water for domestic or municipal use, require that chloride or sulfate concentrations not exceed 250 ppm and that total dissolved solids not exceed 500 ppm.

All the samples collected within the reach of the Llano River investigated had less than 250 ppm chloride or sulfate, and the water would undoubtedly be of better quality during higher flows.

The dissolved-solids concentrations of all the samples collected on the main stem were about 250 ppm (Figure 3). Tributary inflow generally contained less than 350 ppm dissolved solids. The small flow of Saline Creek with a dissolved-solids concentration of 571 ppm was the only water that exceeded the limit set for public supply. The hardness of the samples of water ranged from 188 to 394 ppm which classes the water as very hard. The water of the low flows and possibly higher flows should be softened for domestic or municipal use.

According to the U.S. Salinity Laboratory Staff (1954), the characteristics of an irrigation water that appear most important in determining its use include: (1) total concentration of soluble salts; and (2) relative proportion of sodium to other cations. Under the Salinity Staff standards, which were established for arid areas, water of the Llano River would be classified as low-salinity and low-sodium, and would be excellent for irrigation.

The highest dissolved-solids concentrations in a stream are normally found during periods of low flow, when all the flow in the stream is effluent ground water from seeps and springs. Ground water usually contains more dissolved solids than surface runoff as ground water remains in contact with the rocks and soils for much longer periods. The chemical quality of the Llano River in the reach under investigation therefore was probably at or near the maximum range of concentrations of dissolved solids. During periods of flood runoff the dilution effect will further lower the dissolved-solids concentrations.

SUMMARY AND CONCLUSIONS

During this investigation the Llano River system, from Junction to Llano (83.5 miles), derived 69 percent of its accumulated base flow from springs that originate in the watershed above Junction. These springs and most of the tributary inflow below Junction emit from the base of the Edwards and associated limestones. Tributary inflow in the reach amounts to 53 cfs and sectional gains and losses amount to 38.6 cfs and 32.6 cfs, respectively. The data indicate that the river reach receives enough ground-water effluent possibly from alluvial deposits on the river channel and flood plain, directly to the channel, to make up all losses from the channel. These findings are generally in agreement with the results of investigations made in 1918 and 1925. However, the results of the September 1952 investigation do not agree with the 1962 findings. The 1952 study was made during an extreme drought when tributary inflow and ground-water effluent directly to the stream were near zero, and in September when evaporation and transpiration losses were high. At that time all of the 18.8 cfs of initial flow was lost or used in a 55-mile reach below Junction.

Chemical analyses of 31 water samples collected during the investigation show the dissolved-solids concentrations ranged from 225 to 571 ppm. The highest dissolved-solids concentrations on the main stem was 259 ppm at a point 3.1 miles below the confluence of the North and South Llano Rivers. The analyses indicate that the base flow of the Llano River meets the limits set by the U.S. Public Health Service Drinking Water Standards. The low dissolved-solids concentrations and the low percent sodium of the Llano River water make it an excellent irrigation water under the U.S. Salinity Laboratory Staff standards for irrigation water.

REFERENCES

George, W. O., 1947, Ground-water conditions in the vicinity of Mason, Mason County, Texas: U.S. Geol. Survey open-file rept.

U.S. Public Health Service, 1962, Drinking water standards, 1962: U.S. Public Health Service Pub. 956, 61 p.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agriculture Handb. 60, 160 p.

Table 1.--Summary of discharge measurements, January 1962

Site No.	Date 1962	Stream	Location	River mile	Water temp. (°F)	Discharge in cfs Main stream	Discharge in cfs Tributary	Remarks
	Jan.							
1	17	South Llano River	0.2 mi above confluence with North Llano River	0	48	98.0		Loose gravel streambed
--	17	North Llano River	At gaging station (8-1485) near Junction and 4 mi above confluence with South Llano River		--		29.0	Recording gage record
2	17	North Llano River	0.6 mi above confluence with South Llano River	a/.2	51		16.3	Loose gravel streambed
3	17	Llano River	At flood gage - Llano River near Junction	3.1	49	127		Firm gravel streambed
--	17	Llano River	At gaging station (8-1500) near Junction	4.0		123		Recording gage record
4	17	Llano River	600 ft below falls on Roy Nelson Ranch	6.3	48	129		Firm gravel streambed
5	17	Johnson Fork	400 ft below County road crossing	a/8.4	46		14.5	Firm gravel streambed
6	17	Gentry Creek	At U. S. Highway 377 - 1.5 mi above mouth	a/9.1	46		b/.3	Loose gravel streambed
7	18	Llano River	1.7 mi below Johnson Fork	10.1	46	148		Loose gravel streambed
8	18	Llano River	About 3 mi above Sycamore Creek	12.0	49	142		Rock and gravel streambed
9	18	Sycamore Creek	At mouth	a/15.1	50		b/.3	Gravel streambed
10	18	Unnamed Creek	At mouth	a/15.7	50		b/.05	Rock streambed
11	18	Llano River	About 1 mi below Sycamore Creek	15.8	50	144		Smooth rock streambed
12	18	Llano River	About ½ mi above Red Creek	18.5	51	148		Firm gravel streambed
13	18	Red Creek	At mouth	a/19.2	51		b/.02	Rock streambed
14	18	Llano River	2.8 mi below Red Creek	22.0	51	149		Firm gravel streambed
15	19	Unnamed Creek	At mouth	a/25.0	47		b/.05	Gravel streambed

Table 1.--Summary of discharge measurements, January 1962--Continued

Site No.	Date 1962	Stream	Location	River mile	Water temp. (°F)	Discharge in cfs Main stream	Discharge in cfs Tributary	Remarks
	Jan.							
16	19	Llano River	1.8 mi above Saline Creek	25.1	46	152		Rock and gravel streambed
17	19	Saline Creek	At mouth	a/26.9	50		b/0.2	Rock streambed
18	19	Salt Creek Spring	1½ mi above mouth of Salt Creek	a/28.5	50		b/ .01	Flows from rock crevice
19	19	Bear Creek	2½ mi above mouth	a/28.6	51		.4	Rock streambed
20	19	Llano River	About 1 mi below Leon Creek	33.6	46	145		Rock streambed
21	20	Big Bluff Creek	At mouth	a/35.5	45		b/2.0	Rock streambed
22	20	Llano River	At Farm Road 1871	40.0	42	157		Gravel streambed
23	20	Honey Creek	About ½ mi above mouth	a/41.0	51		3.04	Gravel streambed
24	20	Mill Creek	At mouth	a/41.2	45		2.0	Gravel streambed
25	21	James River	About ¼ mi above mouth	a/44.4	48		6.07	Gravel streambed
26	21	Llano River	About ¼ mi below James River	44.6	45	164		Loose gravel streambed
27	21	Unnamed Creek	About ½ mi above mouth	a/45.2	45		.2	Probably flow from artesian wells
27A	21	Artesian Well	About 1½ mi above mouth of unnamed Creek	a/46.2			.2	Well flows into small stock tank that overflows into creek
28	21	Schep Creek	About 4 mi above mouth	a/47.7	46		.1	Rock streambed
29	21	Panther Creek	About 1 mi above mouth	a/47.9	46		.2	Gravel streambed
30	22	Llano River	About 2 mi above Comanche Creek	50.0	45	156		Gravel and rock streambed
31	22	Comanche Creek	About 2½ mi above mouth	a/52.4	44		b/4.0	Sand streambed
32	22	Beaver Creek	At mouth	a/55.0	40		b/6.0	Rock streambed
33	22	Llano River	500 ft below Beaver Creek	55.1	46	165		Firm gravel streambed
34	22	Willow Creek	About ½ mi above mouth	a/57.2	40		3.5	Sand streambed
35	23	Stone Creek	At mouth	a/60.8			0	Sand streambed

Table 1.--Summary of discharge measurements, January 1962--Continued

Site No.	Date 1962	Stream	Location	River mile	Water temp. (°F)	Discharge in cfs: Main stream	Discharge in cfs: Tributary	Remarks
	Jan.							
36	23	Llano River	About $\frac{1}{4}$ mi below Stone Creek	60.9	40	176		Sand and gravel streambed
37	23	Herman Creek	At mouth	a/61.6	40		1.0	Sand streambed
38	23	Martin Creek	At mouth	a/64.1			0	Sand streambed
39	23	Keyser Creek	At mouth	a/65.2			0	Sand streambed
40	23	Bear Spring Branch	At mouth	a/66.5			0	Sand streambed
41	23	Llano River	About $1\frac{1}{2}$ mi below Castell	67.4	40	175		Sand and gravel streambed
42	23	Elm Creek	At mouth	a/67.6	40		.2	Sand streambed
43	23	Rhodes Creek	At mouth	a/68.5	40		.02	Sand streambed
44	23	Lie Festa Creek	At mouth	a/69.5	40		0	Sand streambed
45	23	Hickory Creek	At Farm Road 152	a/73.9	41		3.0	Sand streambed
46	24	Llano River	About $\frac{1}{2}$ mi below Hickory Creek	74.3	40	175		Gravel on rock streambed
47	23	Six Mile Creek	At Farm Road 152	a/77.2	40		.3	Sand streambed
48	24	San Fernando Creek	At State Highway 29	a/77.7	40		b/5.0	Sand streambed
49	24	Johnson Creek	At State Highway 29	a/79.8	40		1.0	Sand streambed
50	24	Llano River	800 ft below Upper Llano City Dam	81.1	40	185		Gravel streambed
51	24	Pecan Creek	At State Highway 29	a/82.0			0	Sand streambed
52	23	Flag Creek	At Farm Road 152	a/82.8			0	Sand streambed
--	24	Llano City pumps	--	--			c/-.5	City water supply
53	24	Llano River	600 ft below gaging station (8-1515) at Llano	83.5	42	188		Sand streambed

a/ River miles on Llano River at mouth of tributary.
b/ Discharge estimated.
c/ City of Llano diverting 0.5 cfs.

Table 2.--Summary of discharge measurements, March and April 1918

Date 1918	Stream	Location	River mile	Discharge in cfs: Main stream	Discharge in cfs: Tributary	Discharge in cfs: Diversion
Apr.						
1	South Llano River	Just above North Llano River	0	29.2		
1	North Llano River	At mouth	0		1.8	
1	Llano River	3 mi below Junction - gaging station	3	42.6		
2	Neal Pump	3/4 mi above Johnson Fork	6.2			a/0.5
2	Westervelt Pump	1/2 mi above Johnson Fork	6.5			a/ .8
2	Johnson Fork	At mouth - 7.0 mi below Junction	b/7.0		7.5	
2	Llano River	Just below Johnson Fork	7.0	47.9		
2	J. W. White Pump	At Damtown	19.5			1.8
2	Llano River	Due south of London - at Damtown	20	42.5		
2	Llano River	3 mi SE of Streeter	35	40.2		
3	James River	At mouth	b/43		.5	
3	Llano River	Just below James River	43	42.3		
3	Comanche Creek	At mouth	b/51		0	
3	Llano River	1/2 mi above Beaver Creek	54	37.4		
3	Beaver Creek	At mouth	b/54.5		.5	
3	Willow Creek	At mouth	b/55.5		0	
3	Llano River	At Castell	64	45.3		
3	Hickory Creek	At mouth	b/72.5		0	
3	Llano River	9 mi above Llano	73.5	50.8		
Mar.						
31	Llano River	3/4 mi above Llano Dam	82	56.4		
31	Llano River	1/4 mi below Llano Dam (temporary gage)	83	65.7		

Table 2.--Summary of discharge measurements, March and April 1918--Continued

Date 1918	Stream	Location	River mile	Discharge in cfs		
				Main stream	Tribu-tary	Diver-sion
Apr.						
1	Little Llano River	At mouth	b/90.5		0	
1	Llano River	Just above Miller Creek near Lone Grove	92	65.7		
1	Miller Creek	At mouth	b/92		.1	
1	Honey Creek	At mouth	b/102		0	
1	Llano River	At mouth near Kingsland	106	58.8		

a/ Discharge estimated.
b/ River miles on Llano River at mouth of tributary.

Table 3.--Summary of discharge measurements, February 1925

Date 1925	Stream	Location	River mile	Discharge in cfs Main stream	Tributary	Remarks
Feb. 14	Llano River	At junction of North and South Forks	0	97.7		Gravel beds
14	Llano River	1,000 ft below the junction	.2	101		
14	Llano River	3 mi below the junction - gaging station	3.0	101		
15	Johnson Fork	6.8 mi below the junction	a/6.8		12.2	Seepage through gravel
15	Llano River	6.8 mi below the junction	6.8	111		
15	Llano River	At Yates-London road crossing	15.0	107		
16	Bluff Creek	Southeast of Streeter	a/35.5		.7	
16	Llano River	1½ mi below Bluff Creek	37.0	114		Rock channel
16	James River	Near mouth - 9 mi SE of Mason	a/43.6		3.8	
17	Llano River	0.4 mi below James River	44.0	114		
17	Llano River	3/4 mi above Beaver Creek	54.2	118		Gravel channel
17	Beaver Creek	About 0.3 mi above mouth	a/55.0		.7	
18	Llano River	At Castell-Mason road crossing	64.9	118		Gravel channel
18	Llano River	At Castell - gaging station	69.7	122		Gravel channel
19	Llano River	About 8 mi above Llano	74.7	114		
19	Llano River	3/4 mi above Llano	82.3	119		
20	Llano River	Just below dam at Llano	83.0	118		Sand and rock channel
20	Little Llano River	At mouth	a/90.0		b/1.1	
20	Llano River	3 mi below Little Llano River	93.0	116		Sand channel
20	Miller Creek	At mouth	a/93.2		b/ .1	
21	Llano River	At old Llano-Kingsland road	94.2	121		Sand channel
21	Llano River	At Llano-Kingsland road	98.7	120		
21	Llano River	At Kingsland - just above mouth	105	122		Sand channel

a/ River miles on Llano River at mouth of tributary.
b/ Discharge estimated.

Table 4.--Summary of discharge measurements, September 1952

Date 1952	Stream	Location	River mile	Discharge in cfs Main stream	Tributary
Sept.					
3	Llano River	Near Junction - gaging station	0	16.8	
3	Johnson Fork	At road 3.3 mi east of Junction	a/4		2.03
3	Llano River	At road 2.3 mi SE of Teacup	10	15.8	
4	Llano River	At Ranch Road 385, 3.8 mi NE of Teacup	16	13.6	
3	Llano River	At road crossing 10 mi SW of Mason	35	5.67	
3	James River	10 mi S of Mason, ½ mi above mouth	a/38		0
3	Llano River	At road crossing 8.5 mi S of Mason	39	2.57	
4	Llano River	At U. S. Highway 87, 0.5 mi S of Hedwig	47	.73	
4	Llano River	At road crossing at Castell	59	.01	
4	Llano River	At road crossing 13.9 mi W of Llano	64	0	
4	Llano River	At road crossing 1.6 mi W of Llano	76	0	
4	Llano River	At Llano - gaging station	79	0	

a/ River miles on Llano River at mouth of tributary.

Table 5.--Chemical analyses of streams in the Llano River watershed

Results in parts per million, except as indicated

Site No.	Date of collection	Discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids (calculated): Parts per million	Dissolved solids (calculated): Tons per acre-foot	Dissolved solids (calculated): Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25° C)	pH
1	Jan. 17, 1962----------	98.0	--	--	--	--		252	--	14	--	240	0.33	63.5	216	10	--	--	432	7.4
2	do.------------------	16.3	--	--	--	--		244	--	24	--	270	.37	11.9	222	22	--	--	482	7.5
3	do.------------------	127	11	60	18	11		252	12	18	5.2	259	.35	88.8	224	17	10	0.3	450	7.6
4	do.------------------	129	--	--	--	--		248	--	18	--	249	.34	86.7	216	13	--	--	447	7.5
5	do.------------------	14.5	--	--	--	--		276	--	20	--	267	.36	10.5	234	8	--	--	481	7.6
7	Jan. 18, 1962----------	148	--	--	--	--		248	--	18	--	247	.34	98.7	214	11	--	--	444	7.6
8	do.------------------	142	--	--	--	--		252	--	19	--	247	.34	94.7	216	10	--	--	444	7.6
11	do.------------------	144	--	--	--	--		232	--	20	--	239	.33	92.9	202	12	--	--	429	7.4
12	do.------------------	148	--	--	--	--		216	--	19	--	226	.31	90.3	188	11	--	--	406	7.4
14	do.------------------	149	--	--	--	--		232	--	20	--	240	.33	96.6	204	14	--	--	431	7.4
16	Jan. 19, 1962----------	152	--	--	--	--		236	--	20	--	230	.31	94.4	196	3	--	--	414	7.4
17	do.------------------	a .2	2.2	58	44	87		199	124	158	.0	571	.78	.31	326	162	37	2.1	1,020	7.6
18	do.------------------	a .01	--	--	--	--		448	--	30	--	438	.60	.01	394	27	--	--	787	7.3
19	do.------------------	.4	15	56	52	38		332	70	64	.0	458	.62	.49	354	82	19	.9	779	7.7
20	do.------------------	145	--	--	--	--		204	--	20	--	231	.31	90.4	196	29	--	--	416	7.4
21	Jan. 20, 1962----------	a2.0	--	--	--	--		284	--	36	--	314	.43	1.70	252	20	--	--	565	7.6
22	do.------------------	157	--	--	--	--		224	--	20	--	234	.32	99.2	198	14	--	--	420	7.4
23	do.------------------	3.04	--	--	--	--		284	--	21	--	286	.39	2.35	254	22	--	--	514	7.5
25	Jan. 21, 1962----------	6.07	3.0	39	44	16		309	20	28	.5	302	.41	4.95	278	26	11	.4	563	7.8
26	do.------------------	164	--	--	--	--		216	--	19	--	231	.31	101	196	19	--	--	415	7.5
30	Jan. 22, 1962----------	156	--	--	--	--		230	--	21	--	244	.33	103	207	18	--	--	439	7.6
31	do.------------------	a4.0	--	--	--	--		213	--	69	--	359	.49	3.88	216	42	--	--	645	7.8
32	do.------------------	a6.0	--	--	--	--		255	--	60	--	348	.47	5.64	248	39	--	--	625	7.8
33	do.------------------	165	--	--	--	--		219	--	22	--	240	.33	107	199	20	--	--	431	7.6
34	do.------------------	3.5	--	--	--	--		201	--	70	--	337	.46	3.18	190	26	--	--	606	7.7
36	Jan. 23, 1962----------	176	--	--	--	--		226	--	23	--	245	.33	116	204	19	--	--	440	7.7
41	do.------------------	175	--	--	--	--		216	--	23	--	239	.33	113	198	21	--	--	429	7.7
46	Jan. 24, 1962----------	175	--	--	--	--		210	--	26	--	239	.33	113	193	21	--	--	430	7.6
48	do.------------------	a5.0	6.7	43	35	43		267	36	63	.0	358	.49	4.83	252	32	27	1.2	656	7.8
50	do.------------------	185	6.7	40	22	14		204	16	24	2.6	255	.31	112	190	23	13	.4	421	7.6
53	Apr. 28, 1948----------	b233	11	33	17	14		177	9.5	19	.8	192	.26	121	152	7	17	.5	353	--
53	July 27, 1948----------	b216	14	40	16	9.3		182	11	16	3.5	200	.27	117	166	16	11	.3	355	--
53	Sept. 21, 1948---------	88	18	37	14	8.5		176	8.2	10	1.8	184	.25	43.7	150	6	11	.3	311	--
53	Nov. 21, 1948----------	86	8.2	38	21	3.6		191	9.6	16	.0	190	.26	44.1	181	25	4	.1	362	--
53	Feb. 8, 1949-----------	108	6.2	40	22	12		213	13	19	.8	218	.30	63.6	190	16	12	.4	401	--
53	May 19, 1960-----------	114	9.0	35	22	19		197	16	29	.0	227	.31	69.9	178	16	19	.6	417	7.7
53	Jan. 24, 1962----------	188	--	--	--	--		204	--	24	--	225	.31	--	188	21	--	--	417	7.6

a Estimated.
b Mean daily discharge.

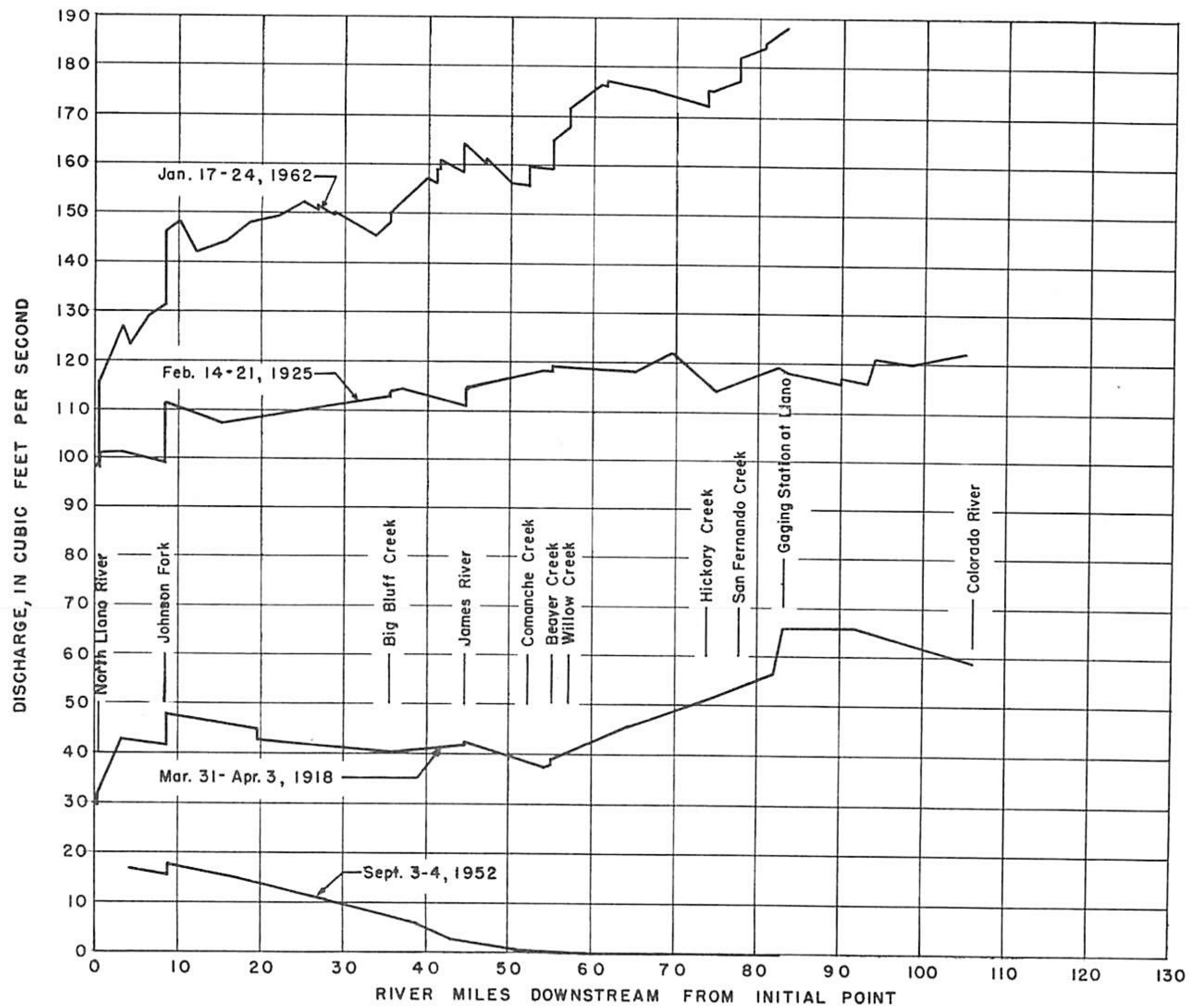

Figure 2

Discharge Profiles of the Llano River

U.S. Geological Survey in cooperation with the Texas Water Commission

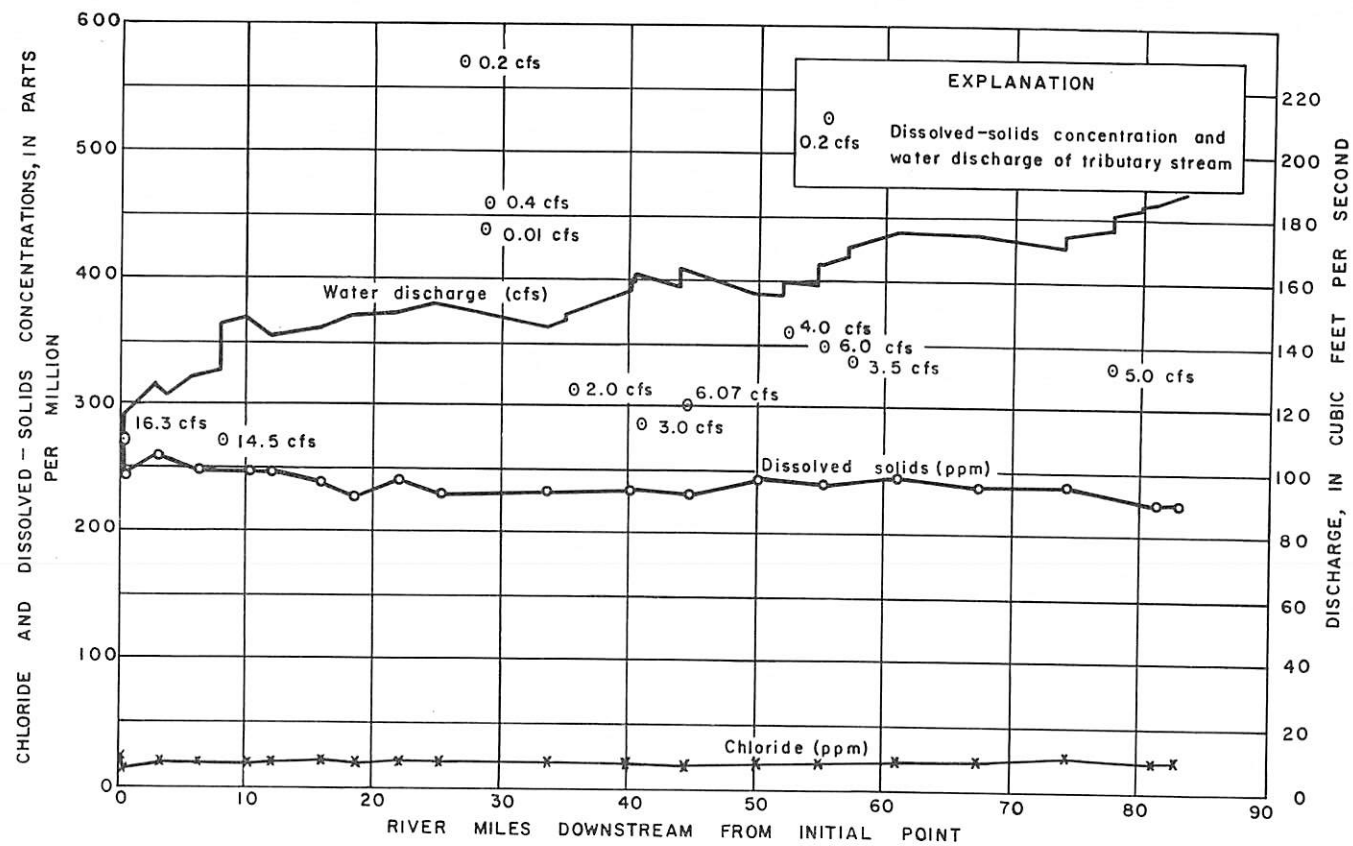

Figure 3

Profile of Chloride and Dissolved-Solids Concentrations and Water Discharge, Llano River, January 17-24, 1962, with Dissolved-Solids Concentration and Discharge of Tributary Streams

U.S. Geological Survey in cooperation with the Texas Water Commission

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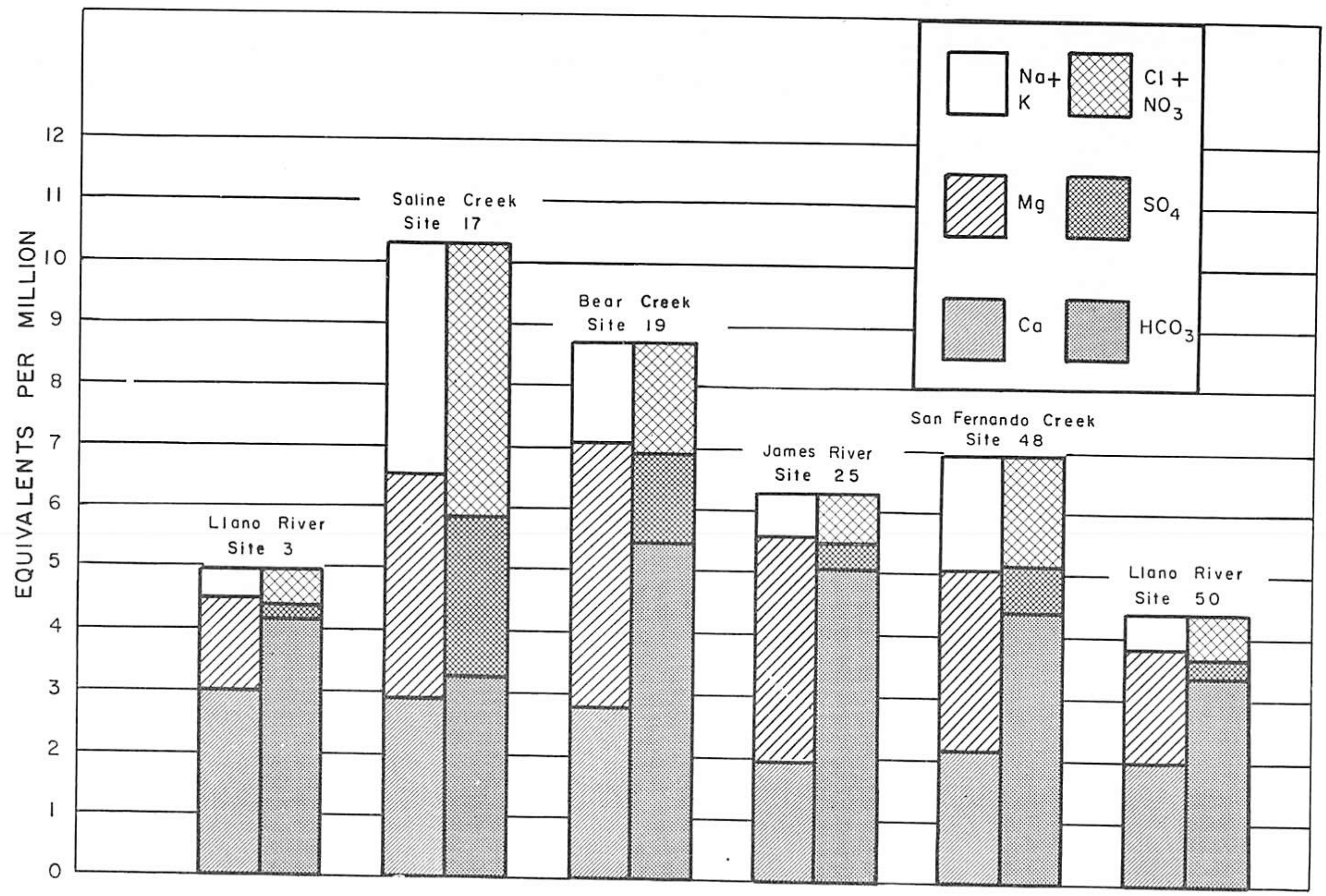

Figure 4

Chemical Analyses of Waters of the Llano River Watershed

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