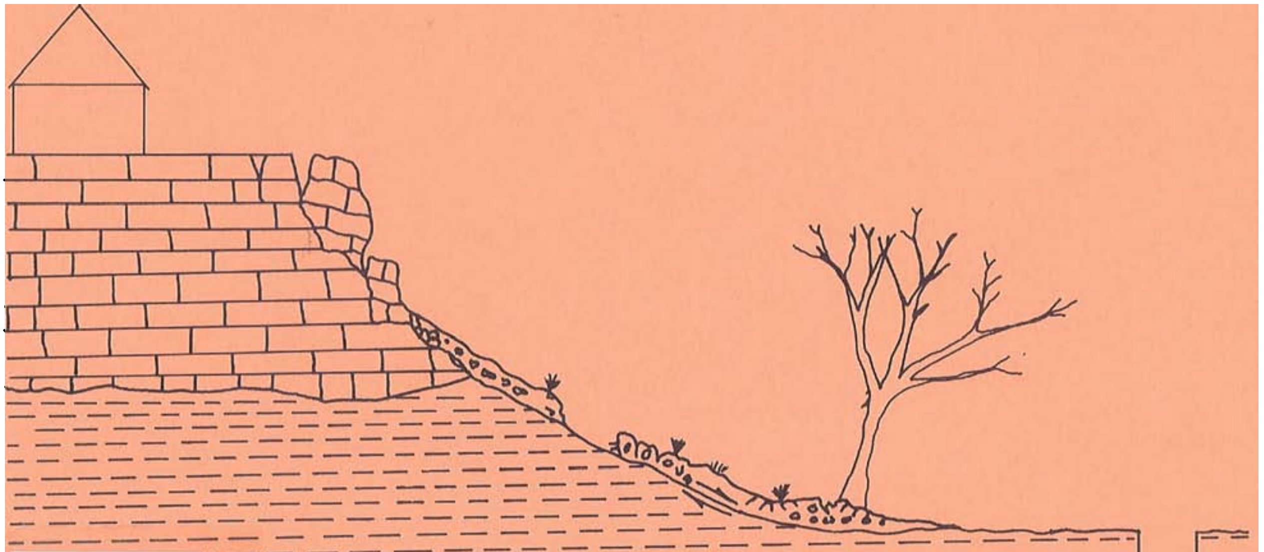
URBAN FLOODING AND SLOPE STABILITY IN AUSTIN, TEXAS

AUSTIN GEOLOGICAL SOCIETY FIELD-TRIP GUIDEBOOK



FIELD-TRIP LEADERS

VICTOR R. BAKER, E. L. GARNER, L. JAN TURK, AND KEITH YOUNG

Austin Geological Society

Field-Trip Guidebook

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URBAN FLOODING AND SLOPE STABILITY

AUSTIN, TEXAS

Leaders

Victor R. Baker, E. L. Garner,
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Contributors

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Field-trip mileages begin with Stop 1, where participants are expected to meet.

Mileage	Interval	
0.0	0.0	STOP 1: North access road to U.S. 183 on east side of Missouri Pacific railroad.
		The purpose of this stop is to obtain a view of upper Shoal Creek prior to urbanization. Shoal Creek from here downstream to Anderson Ln. (fig. 1) was like this before urbanization. The next six stops are to study the history of Shoal Creek--past, present, and future.
		The headwaters of Shoal Creek are north of Stop 1 and to the left (west) of the Balcones Research Center. A few small springs feed Shoal Creek at the headwaters, but most of the water evaporates upstream from Stop 1.
		The tree line represents the main fault of the Balcones Fault System in this area. To the west of Stop 1 is a valley, which more or less parallels U.S. 183 up and over the scarp. The water from this drainage, which includes much more area than the headwaters of Shoal Creek, comes through the flats to the northwest and joins Shoal Creek. This is the primary source of flow during floods.
.3	.3	Turn left on Shoal Creek Blvd.

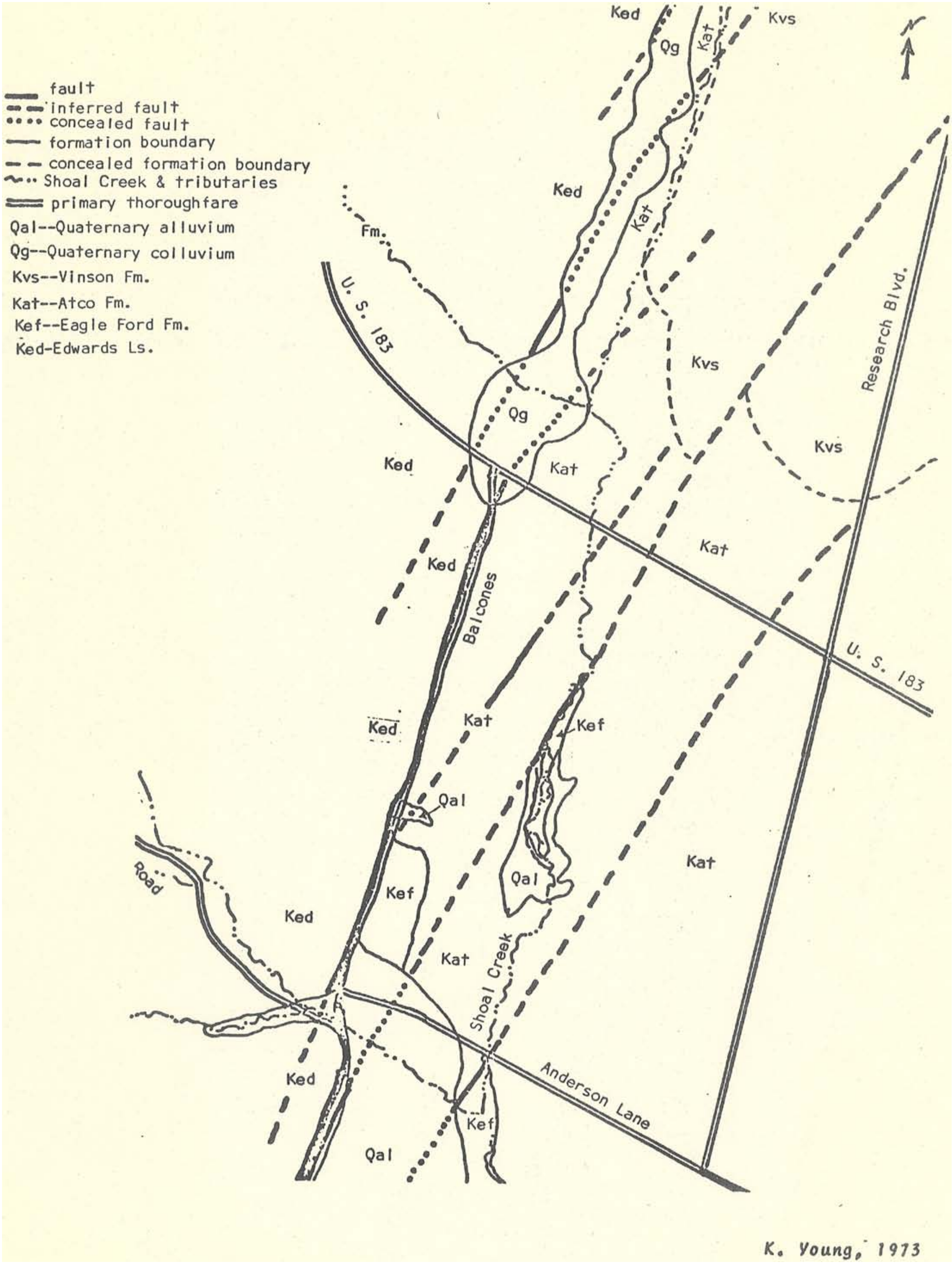


Figure 1 MAP OF SHOAL CREEK FROM SPICEWOOD SPRINGS ROAD TO U. S. 183 (for Stops 1 and 2)

Mileage	Interval	
0.5	0.2	STOP 2: Shoal Creek and Shoal Creek Blvd. The channelization of Shoal Creek is emphasized at this stop. The channel has been excavated from here all the way to Northwest Park. Evidence for one of the faults shown on figure 1 are vertical beds in the Atco Formation just east of the Barn.
.7	.2	One of the many open storm drains in this part of Austin. They not only increase flood runoff, but are dangerous to small children. The reason storm drains are open in this part of the city is the cost of blasting; closed storm drains require a deeper excavation than open storm drains. This one is floored by the Atco Formation.
1.2	.5	Cross Steck Ave.; driving on Atco Formation.
1.6	.4	Cross Anderson Ln.; still on Atco Formation.
1.8	.2	STOP 3: Spicewood Springs Rd. and Shoal Creek. At this locality, a tributary flowing more or less parallel to Spicewood Springs Rd. enters Shoal Creek. Just upstream from this site, a motorcyclist was drowned in the flood of June 1972, when 8 inches of rain fell in a small area at the head of this small tributary in an hour. The large hole in the stream bed just below the bridge was produced by the flood as it carved the soft Eagle Ford marls out of the bottom of the channel. The bridge across Shoal Creek is much too small for the newly excavated channel, and water will back up behind the bridge during a flood. The Eagle Ford-Austin (Atco Formation) boundary is exposed near the top of the channel of Shoal Creek at this locality. The telephone pole to the south is leaning because the creep of the soil on the Austin Chalk. The stone pillar by the apartments is leaning in the opposite direction as the result of erosion and undercutting during the heavy rains of June 1972. Return to Shoal Creek Blvd. and turn left (south).
2.5	.7	Turn left on Greenlawn.
2.8	.3	Turn right on Daugherty.
2.9	.1	Turn right on Albata.

Mileage	Interval	
3.2	0.3	STOP 4: Northwest Park. At the southwest corner of Northwest Park, Shoal Creek is not excavated or widened and trees and brush retard the flow of water. The flow is confined to a narrower channel, and water spreads farther out on the floodplain than it does upstream. All of the widening and straightening of the channel upstream merely funnels the water more rapidly to this particular locality, where it slows down and begins to spread. The boundary between the Eagle Ford and the Austin Chalk is exposed in the bank of Shoal Creek at this locality. Return to Shoal Creel Blvd. via Albata, Daugherty, and Greenlawn, retracing the route on Shoal Creek Blvd.
4.6	1.4	STOP 5: Shoal Creek Blvd. and Shoal Creek. Although the channel is deeper at this point, the meandering of Shoal Creek requires the retaining wall at the bend in the channel downstream from the bridge. A fault with Buda Limestone on the upthrown and downstream side serves as a temporary base level. The fault is about 150 yards upstream from the bridge at White Rock Dr.
5.1	.5	STOP 6: Shoal Creek at Hunt Terrace. In this reach of Shoal Creek, there is no artificial channel; the natural channel is narrow; the water flows more slowly than upstream; and there is flooding, even with discharges of less than a 10-year recurrence interval, because the development upstream has increased flood runoff, which will be increased even more with additional upstream development.
5.6	.5	White Rock Dr.: A fault 150 yards upstream from this bridge exposes Buda Limestone that serves as a temporary base level.
6.1	.5	Northland Dr. and Shoal Creek: The channel of Shoal Creek is narrowed at this bridge by fill for the abutments so that the span would be shorter. This fill and the narrowing of the channel backs floodwater upstream onto the shallow banks.

Mileage	Interval	
6.9	0.8	Hancock Dr. and Shoal Creek: The bridge at Hancock Dr. is frequently underwater because the bridge cannot accommodate the volume of water that comes downstream during some floods. Originally designed for the 10-year flood, the bridge is flooded frequently now because upstream development has resulted in greatly increased flood runoff.
7.5	.6	45th St.: Below 45th St., the channel of Shoal Creek is naturally deep. Floods are not a problem here, except on the west bank in the Ridgelea area, where houses were built too close to the channel.
8.3	.8	Turn right on 30th St.; travelling on the Del Rio Formation.
8.4	.1	Turn right into the parking lot of the Jefferson Building.

STOP 7:

The Jefferson Building and the adjacent building are near the top of the Del Rio. Buda Limestone was exposed in the top of the excavations and it is about 70 feet to the Georgetown Limestone. The Shoal Creek Hospital is on Eagle Ford fill, which in turn rests on the Del Rio Formation. There is also about 70 feet of Del Rio between this site and the underlying Georgetown Limestone. There is a fault between the site of Stop 7 and the hospital (fig. 2).

Another fault is just east of the east bank of Shoal Creek, but west of the Shoal Creek Medical Tower. Consequently, the Shoal Creek Medical Tower and the new Seton Hospital are on the Eagle Ford Formation. It is only about 15 feet to the Buda Limestone, so the building sites were excavated to the limestone.

The Del Rio Claystone can be seen in the outcrop at this stop, and its effect can be observed on the east side of the parking lot of the Jefferson Building.

Turn right on 38th St. as you leave.

8.5	.1	Turn left on Jefferson Ave.; take it easy through the stoplights; we will wait at the next stop.
8.6	.1	Continue on Jefferson across 35th St.
9.1	.5	Turn left on West 29th St.
9.4	.3	Turn right on Wooldridge Ave.
9.5	.1	Continue left on Wooldridge.

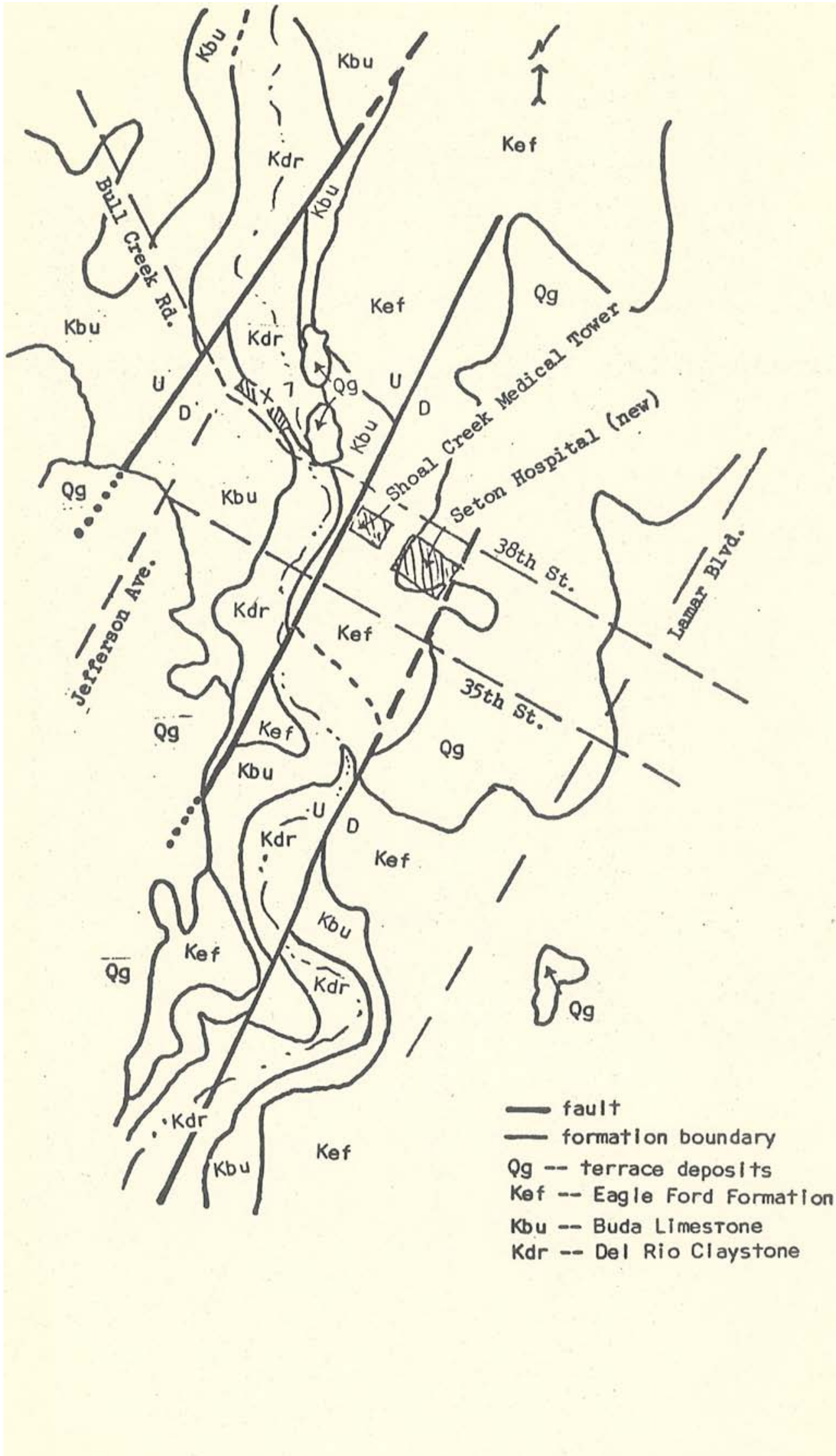


Figure 2 AREA OF SHOAL CREEK MEDICAL PARK

Mileage	Interval	
9.7	0.2	Turn left on Claire.
10.0	.3	Turn right on Shoal Creek Blvd.
10.1	.1	STOP 8: Wooten Park.

Like many small drainage basins in Texas, Shoal Creek lacks the gaging-station records that permit standard hydrologic flood-frequency analysis, but a highly approximate solution to this problem was obtained by environmental geology students at the University of Texas. Data on highwater marks at various cross sections (fig. 3) along Shoal Creek were obtained from local residents, from records of the National Weather Service, from historical records of the Austin-Travis collection of the Austin Public Library, and from bridge-design specifications of the Austin City Engineering Department.

Standard hydraulic-calculation procedures yielded data (table 1) that could be plotted as a partial-duration series (fig. 4). Extrapolation of the data suggests that every year, there is a 1-percent probability of a flood of 20,000 cubic feet per second.

Some of the results of upstream development can be seen here. The many cobbles of Buda Limestone and Eagle Ford flaggy beds were washed to this site on the streambed during construction of the Shoal Creek Medical Tower and the Shoal Creek Hospital.

Because of upstream channelization and urbanization, flood runoff has increased until Shoal Creek is downcutting along this reach in Wooten and Pease Parks. In the last 10 to 15 years, the streambed has been lowered from 1.5 to 3 feet.

Mileage	Interval	
10.15	.05	Turn right on Lamar Blvd.
10.4	.25	Crossing 24th St.; continue on Lamar; driving on Del Rio Formation.
11.3	.9	Turn right on 12th St.
11.4	.1	Turn right on Castle Hill.

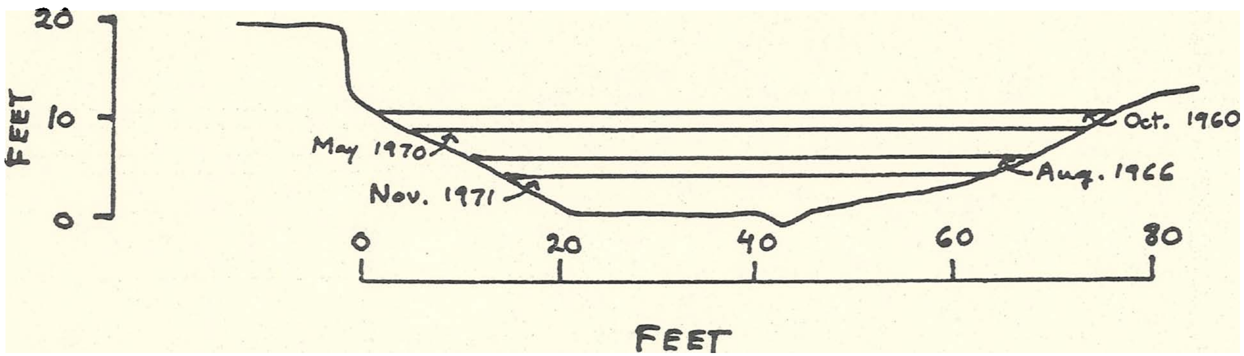


FIGURE 3.-Shoal Creek 30 feet upstream of 12th street bridge

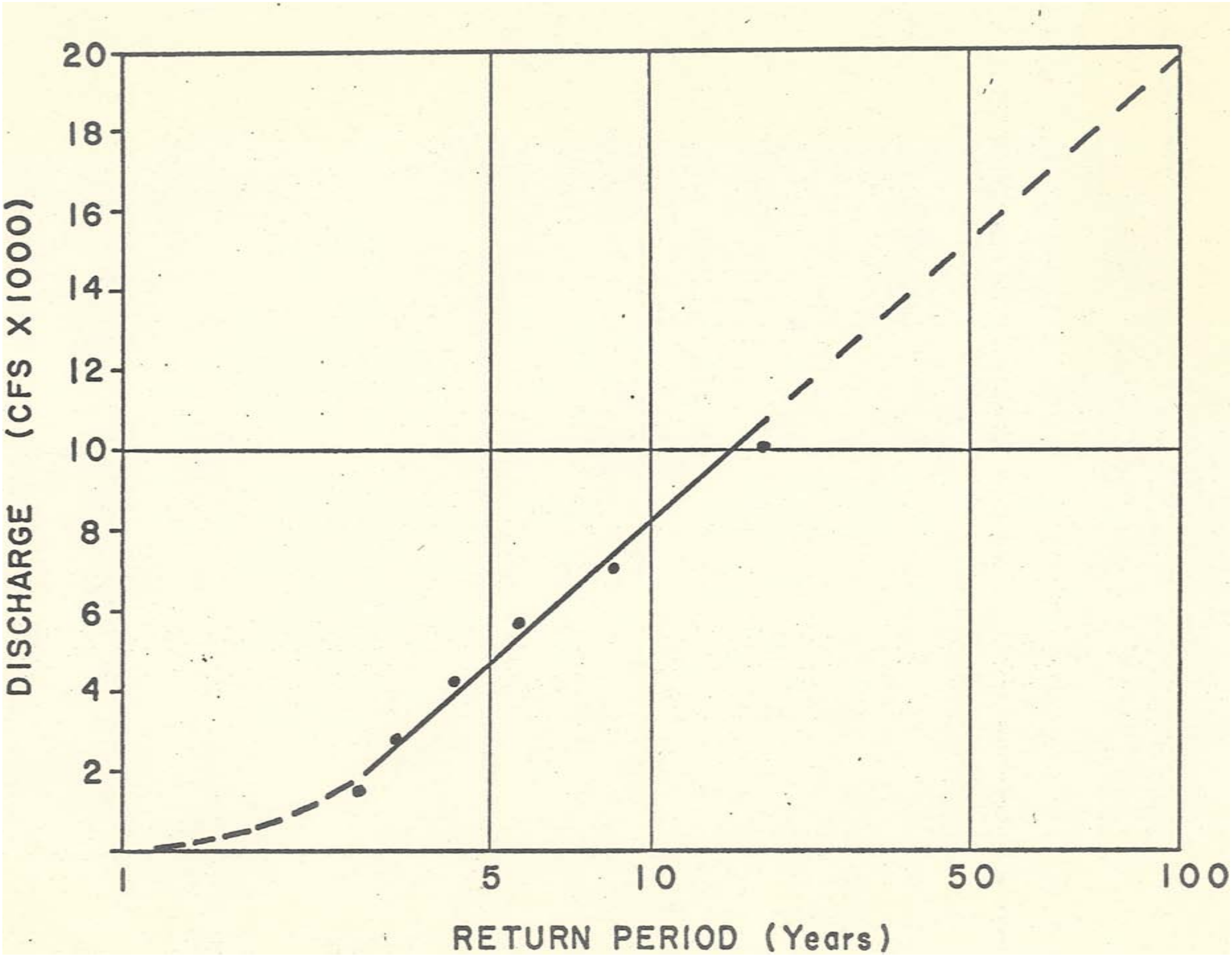


Figure 4

Partial-duration series for data in Table 1

TABLE 1

Historical Flood Data for Shoal Creek
at 12th St. Bridge

Rank	Discharge[1] cfs	Date	Return period[2]
1	10,000[3]	Oct. 1957	17
2	7,000[3]	June 1964	8.5
3	5,600	Oct. 1960	5.6
4	4,200	May 1970	4.2
5	2,500	Aug. 1966	3.4
6	1,300	Nov. 1971	2.8

[1] Approximate calculation using Manning equation with n = 0.034 and channel-bottom slope.

[2] Partial-duration series for discharges greater than 1,300 cfs (Dalrymple, 1960); $RP = \frac{\text{years of record} + 1}{\text{rank}} = \frac{17}{\text{rank}}$.

[3] Estimated from data obtained at other cross sections.

Mileage	Interval	
11.5	0.1	STOP 9: Del Rio along Enfield.
		The brick apartments are 15 to 20 years old. Three types of foundation movement are apparent: (1) Natural down-slope creep on the steep slope, which has pulled one section of the building away from another and has tilted the retaining wall in front of the buildings; (2) differential settlement of the building foundations, steps, curbs, and retaining walls, owing to the low bearing capacity and plasticity of the Del Rio; and (3) cracking of the concrete and asphalt pavement caused by shrinking and swelling of the weathered claystone.
		The site is near the Buda-Del Rio boundary. Seasonal changes in the moisture content of the clay affect the rate of movement. The loading of such hillslopes with buildings contributes to increased shear stresses along the near-surface zone of plastic deformation that characterizes the Del Rio hillslopes.
11.6	.1	Turn right on Enfield.
11.7	.1	Turn right on Lamar.
12.4	.7	Turn right on west First St.
13.1	.7	STOP 10: Proposed site of new Austin High School, if it ever gets out of the courts.
		This site has been flooded by the Colorado River about six times in the last century. Although defined by engineers as part of the 100-year flood plain, this site has been under water on an average of about once every 20 years. Figure 5 shows the extent of the 1869, 1935, and 1938 floods.
13.7	.6	Turn left for Lamar Blvd. access.
14.0	.3	Turn right on Butler and left on Josephine.
14.2	.2	STOP 11: Barton Springs Rd. near Lamar (fig. 6).
		The contact between the resistant Buda Limestone and the underlying Del Rio Claystone is exposed behind the gas station. In this part of Austin, the Del Rio forms a moderate slope beneath the hills capped by Buda Limestone. The clay readily fails by landslides and slow creep. Blocks of the brittle Buda Limestone form from tension induced by plastic deformation of the clay. Many such blocks can be seen along Barton Springs Rd. to the west.

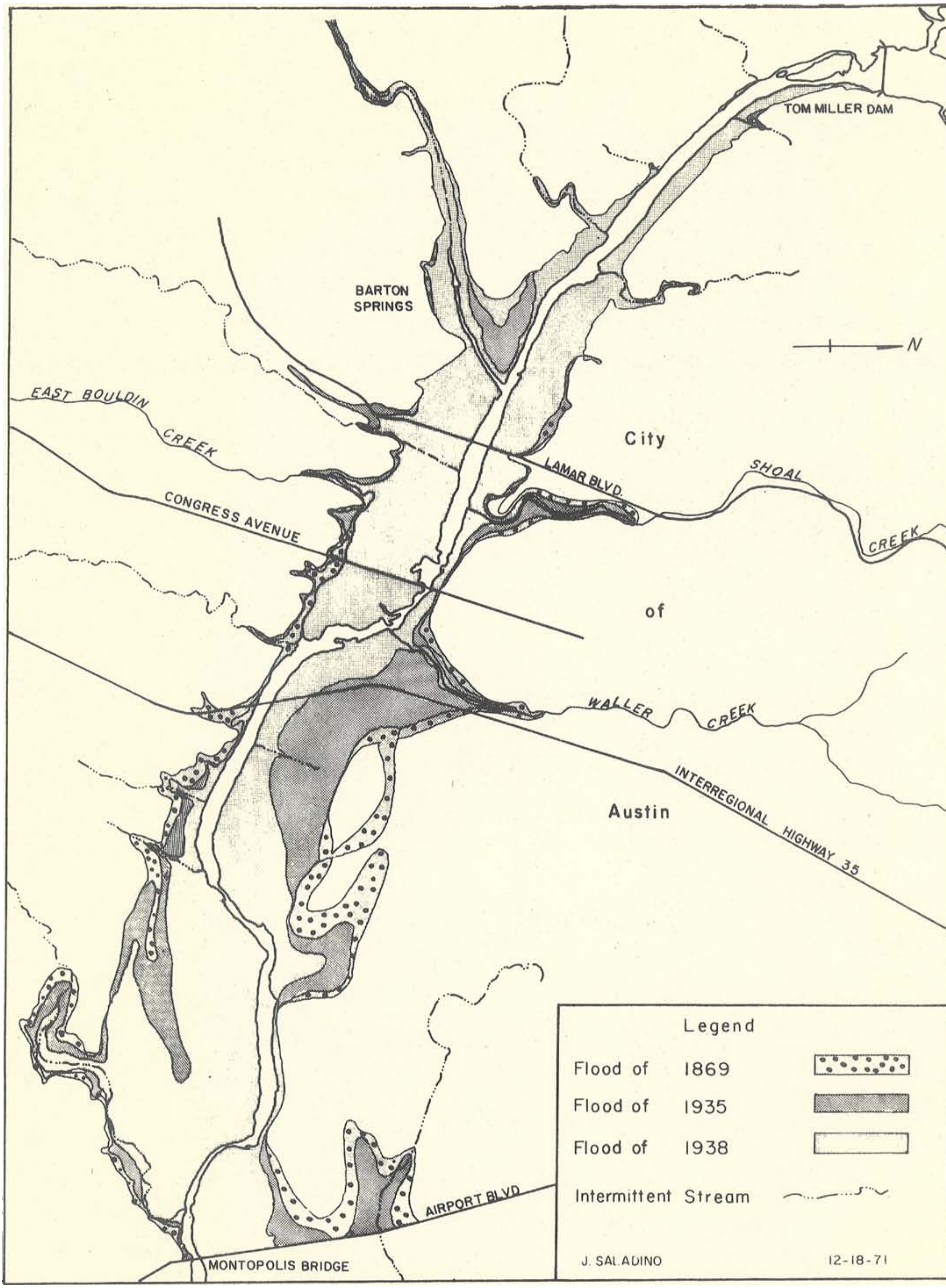
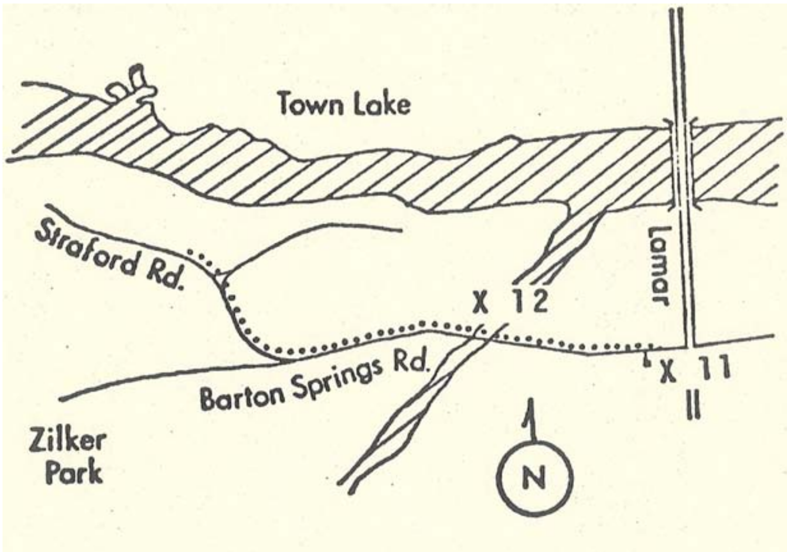


FIGURE 5.-Flood levels of Colorado River at Austin, Texas



Localities for stops 11 and 12

Figure 6

Mileage	Interval	
		Several sheet or slab slides in the colluvium mantling the hillslope can be seen at this site. These slides all appeared following the rains of January and February, 1973, after support had been removed from the base of the hillslope by construction of the gas station.
		Figure 7 shows a larger such landslide that occurred during the construction of a storm sewer in a small drainage just north of Barton Springs Rd. The colluvium, consisting of angular limestone rubble in a plastic clayey matrix, overlies a nearly impervious surface of Del Rio Clay. Runoff enters cracks and fissures of the calving Buda Limestone and flows along the permeability boundary formed at the clay-colluvium contact. This results in a great reduction of cohesion, which will lead to landslides if triggered by the removal of support at the base of the slope.
		Turn right on Barton Springs Rd.
14.9	0.7	Turn right on Zilker Park road.
15.0	.1	STOP 12 (fig. 6): Zilker Park at Shoal Creek.
		The southeast abutment and footing for this bridge is founded in Del Rio. Note the cracking and settling of the concrete structure. A small slump recently removed the fence and part of the west shoulder of Robert E. Lee Rd. Slide material and the toe of the slump are still visible. To replace the right-of-way lost in the slide, the city cut the toe of the Del Rio slope on the east side of the road. Note the heavy cribbing and French drain installed by the city.
15.6	.6	Continue around Zilker Park road. The collapsed area on the right is the site of the old Zilker Park sanitary landfill, which extends to the west of Mopac Blvd.
15.7	.1	Turn left on Stratford Dr.
15.8	.1	Turn left on Barton Springs Rd.
16.2	.4	Turn right on Robert E. Lee Rd.
16.4	.2	STOP 13: Barton Springs baseball diamonds. Walk to Barton Creek.

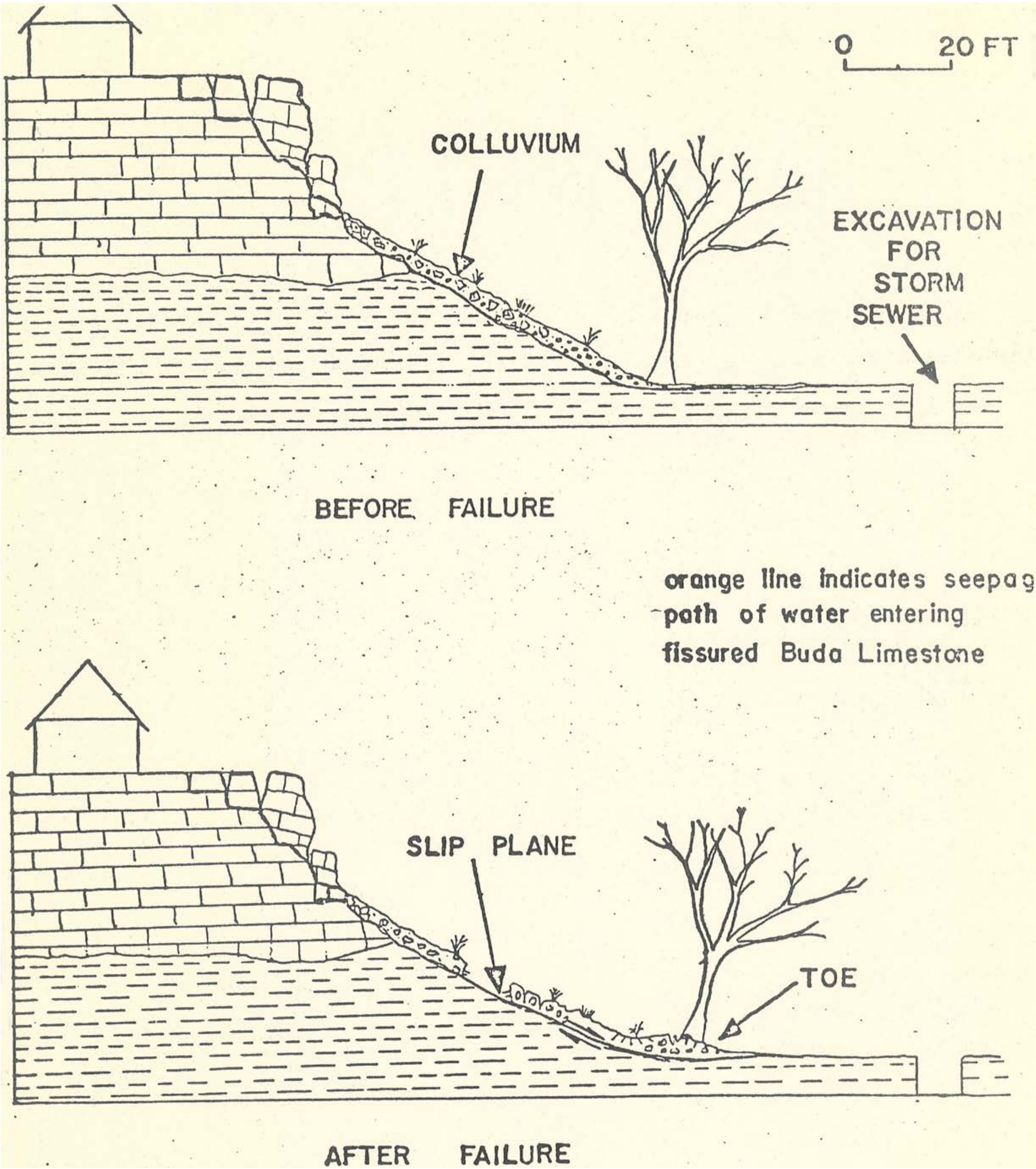


Figure 7 SHEET SLIDE IN DEL RIO SLOPE MANTLED WITH COLLUVIUM BARTON SPRINGS ROAD

Mileage   Interval

Barton Creek, with a drainage area of 125 square miles, is typical of the small drainage basins along the Balcones front of the Edwards Plateau. Unlike Shoal Creek, it has largely escaped urban development and retains an aesthetic appeal because of its deep entrenchment of 500 to 800 feet below the general topographic surface. New access roads, such as the proposed Mopac Expressway, will probably stimulate demand for urbanization along the lower part of the drainage.

Such a change in land use must contend with serious problems of potential flooding. These problems characterize all flood plain development in the future megalopolis that planners predict for the region extending from Dallas to San Antonio. The major population centers of the region are all located on rivers or streams where intense flooding has occurred.

The Balcones front of the Edwards Plateau coincides with what may be the most catastrophic precipitation regime in the conterminous United States. The most intense point rainfall for a 24-hour period recorded in the United States was measured at Thrall in Williamson County, where 38.2 inches fell in the storm of September 9-10, 1921.

Rainfall of exceptional intensity may occur when a tropical storm moves inland from the Gulf, and its warm, moisture-laden air is cooled by the increase in altitude at the Balcones Escarpment. One result of the precipitation pattern along the Balcones front is that the peak discharges for floods of large recurrence intervals (e.g., the 10-year and 30-year floods) exceed those recorded elsewhere in the United States for watersheds of equivalent area (Hoyt and Langbein, 1955, p. 296; Leopold and others, 1964, p. 66). Some recent major floods occurred in September 1952, on the Pedernales River, and in May 1972, on Comal Creek and the Guadalupe River.

High topographic relief and relatively unvegetated slopes promote rapid runoff during infrequently high rainfall on the Barton Creek watershed. The flood of 1935 completely filled the valley at this site, submerging Barton Springs swimming pool. The 100-year flood, modified to reflect near-future urbanization, may be as great as 72,500 cubic feet per second.

Mileage	Interval	
		In contrast to such catastrophic events, the more frequent low flows are greatly diminished by losses into the fractured, permeable Balcones Fault Zone. During dry periods, the end point of the streamflow migrates upstream until it reaches the Mount Bonnel Fault, the western perimeter of this zone. The water that disappears is presumably discharged less than 3 miles away at Barton Springs.

References:

Dalrymple, Tate, 1960, Flood-frequency analyses: U.S. Geol. Survey Water-Supply Paper 1534-A, 80 p.

Hoyt, W. G., and W. B. Langbein, 1955, Floods: Princeton Univ. Press, Princeton, 469 p.

Leopold, L. B., M. G. Wolman, and J. P. Miller, 1964, Fluvial processes in geomorphology: San Francisco, Freeman, 604 p.

To the east of this stop, there is slumping in the Del Rio Claystone. This style of slumping is discussed more fully under Stops 11 and 14. Notice that urban development is beginning on this unstable slope.

Mileage	Interval	
		Turn right on Robert E. Lee Rd.
17.0	0.7	Turn right on Rabb Rd.
17.7	.7	Continue south on Rae Dell.
18.0	.3	Continue on Rae Dell.
18.2	.2	Turn left on Barton Skyway.
18.25	.05	STOP 14 (fig. 8): Westhill Dr.

This stop illustrates many of the construction problems associated with the Del Rio Clay. Two large slumps occur on the east side of the street. The southern slump (fig. 9) exhibits very active slip planes. Plane 2 has moved approximately 1 foot since September 1972. Fresh slickensided surfaces can be observed at the minor scarps on the surface of this slump. The present movement of the slump mass across Westhill Dr. has taken place since April 1972, when the toe of the slide was graded to the curb by the city of Austin.

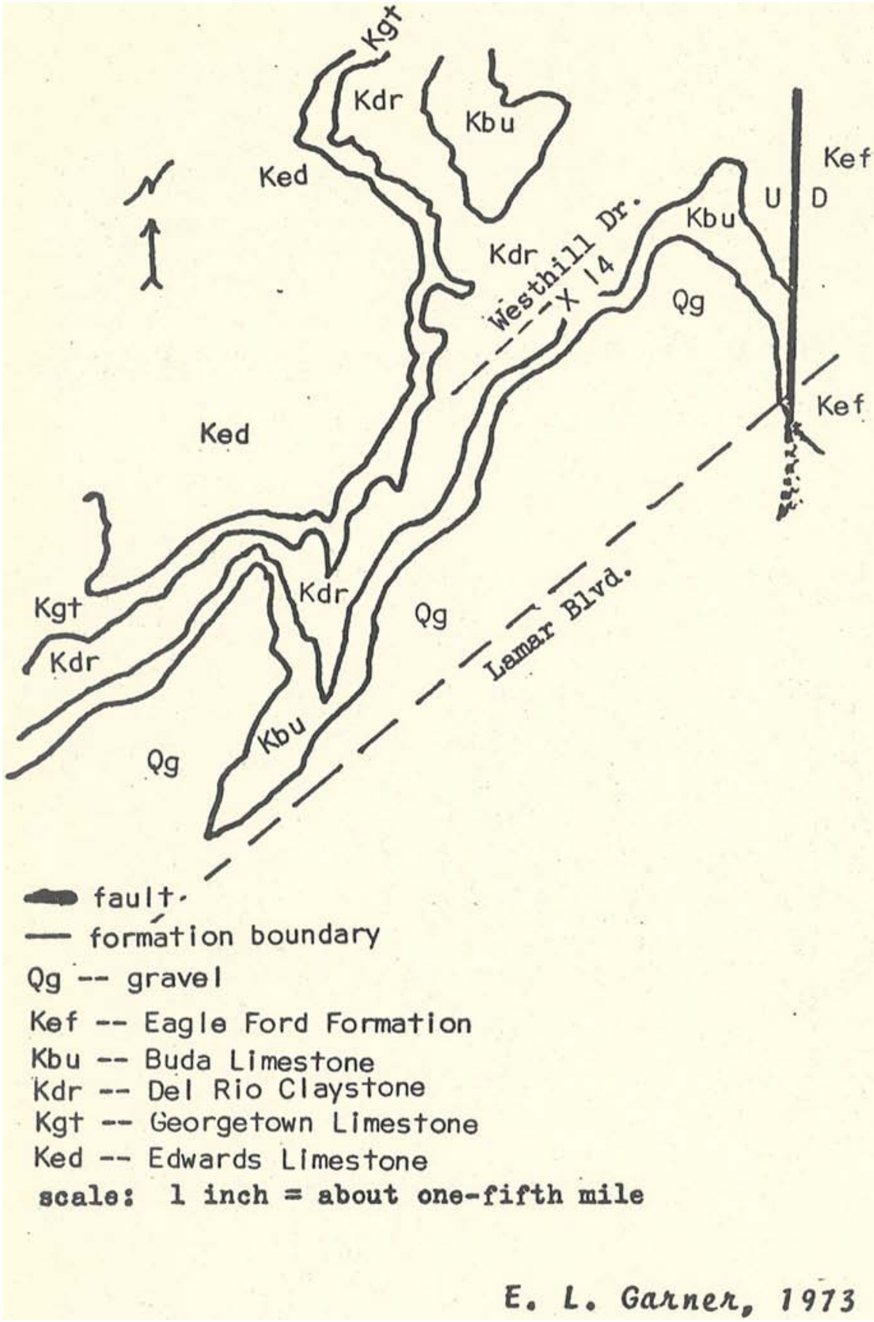


Figure 8

WESTHILL DRIVE AREA

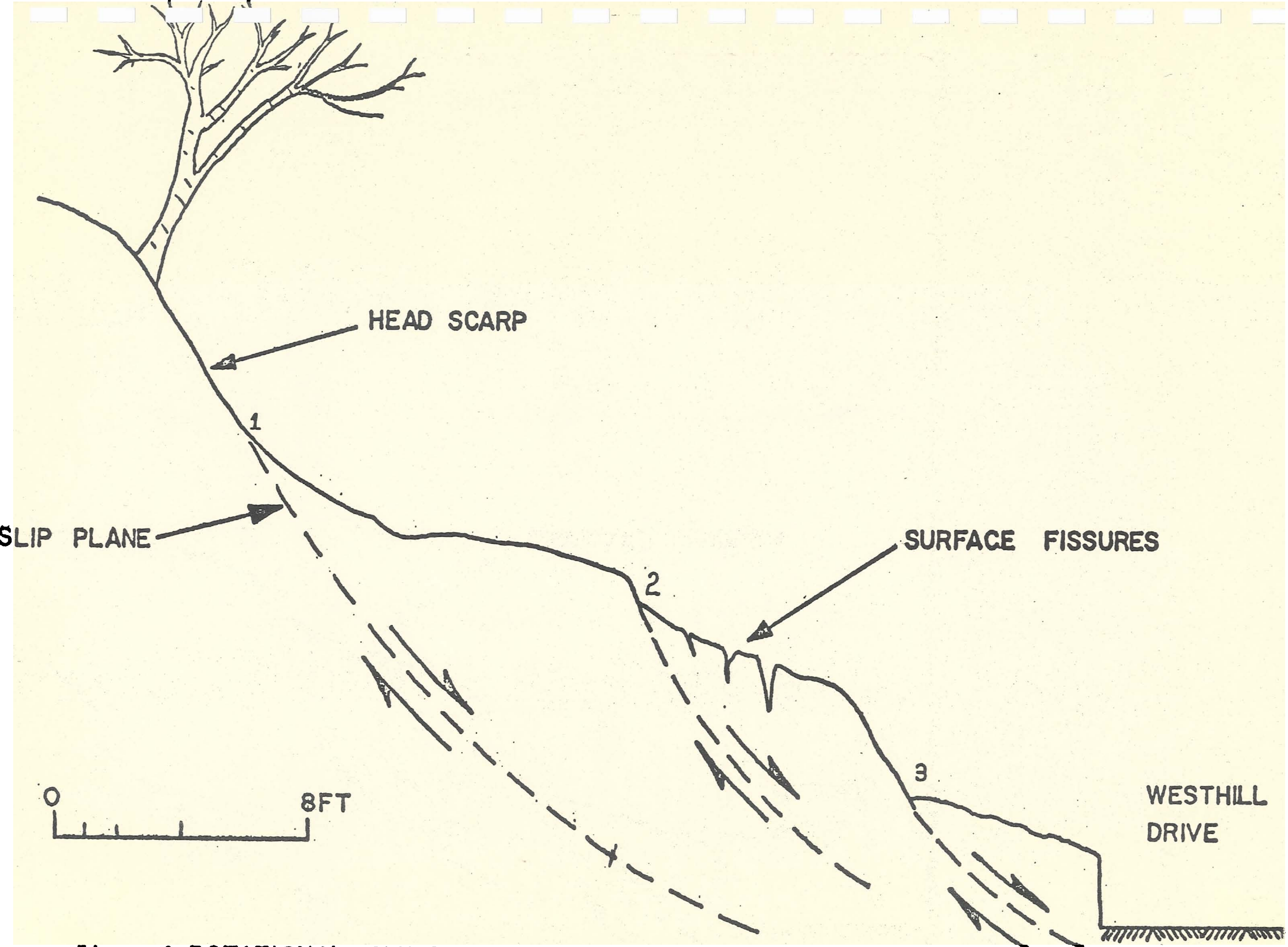


Figure 9 ROTATIONAL SLUMPING IN DEL RIO CLAY
WESTHILL DRIVE

Mileage	Interval	
		The next slide to the north is not as active, but displays a very steep head scarp. Construction of the dwelling above this scarp began in January 1973. Footings were laid within 1 foot of the head scarp, and part of the head scarp has been covered with concrete to retard erosion.
		Driveways and walkways on the east side of Westhill Dr. show cracking and settling caused by the slow creep of the Del Rio. Tension cracks and pressure ridges occur on Westhill Dr. itself, along the steep section of road that passes below the Del Rio-Buda contact.
		Rates of movement in these near-surface creep zones are affected by moisture and temperature changes. Below an upper zone of seasonal creep, movement probably results from plastic deformation of the clay along a shattered shear zone rather than along distinct shear surfaces as in the landslides. Problems could probably be minimized by placing 12-24 inches of well-graded subbase beneath rigid pavement.
		Figures 10-12 show a comparison of the Del Rio and Sprinkle Clays with other clays.
18.4	0.15	Turn left on Lamar.
19.2	.8	Turn right on Oltorf.
19.4	.2	Crossing West Bouldin Creek; on Atco Formation.
20.1	.7	Crossing south First St.; on Vinson Formation.
20.5	.4	Crossing Congress Ave.; a few tens of yards east of Congress, a fault exposes the Vinson Formation on the west and the Dessau Formation on the east.
20.9	.4	The apartments on the left have some units on the unstable nontronite clays associated with the St. Edwards pyroclastic-explosion cone.
21.2	.3	Crossing fault from Dessau Chalk to Pflugerville Chalk.
21.3	.1	Crossing Interstate 35.
21.7	.4	Intersection of Oltorf and Parker Ln.; turn left. This is approximately the fault contact of the Pflugerville Chalk (uppermost Austin) and Sprinkle Claystone (lower Taylor).

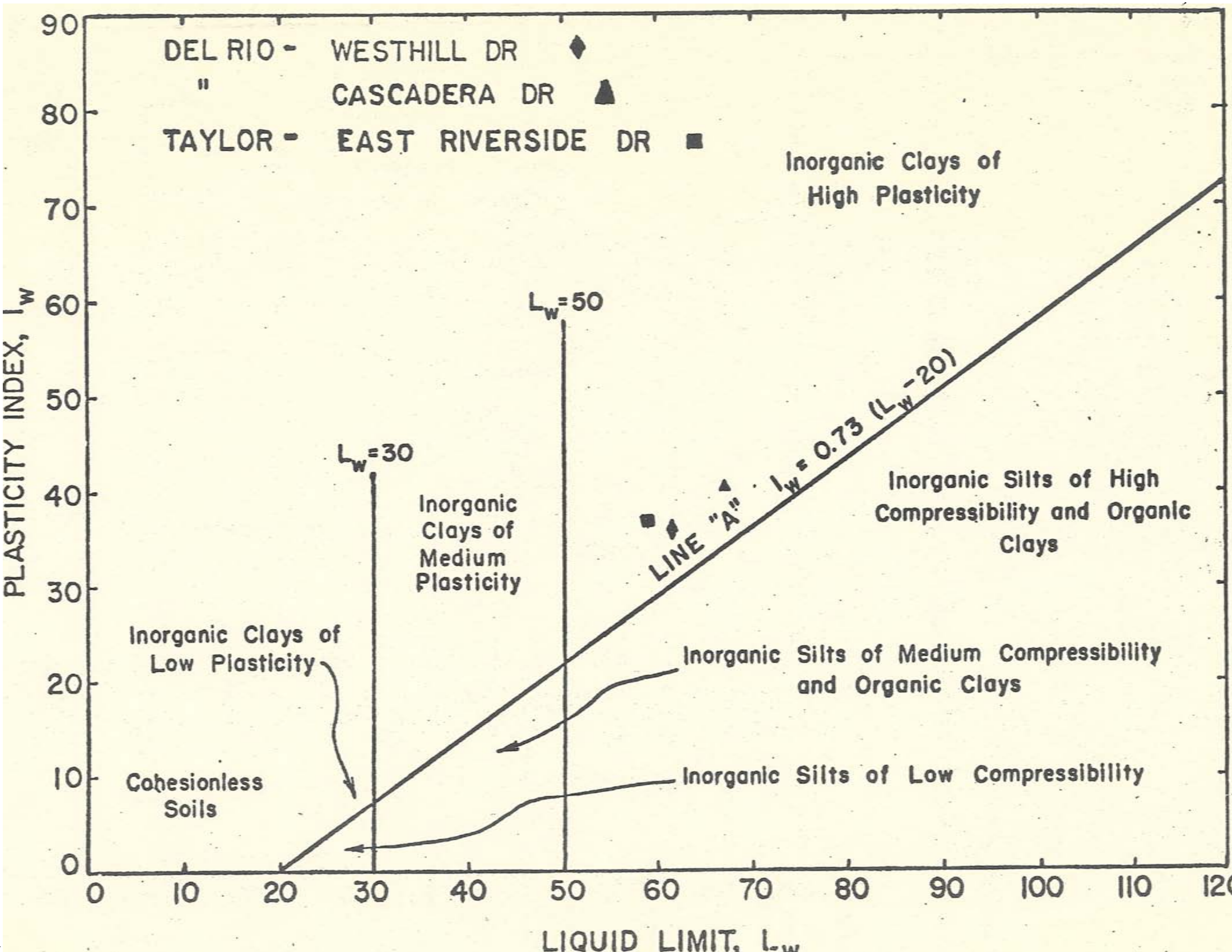


Figure 10 **PLASTICITY CHART**

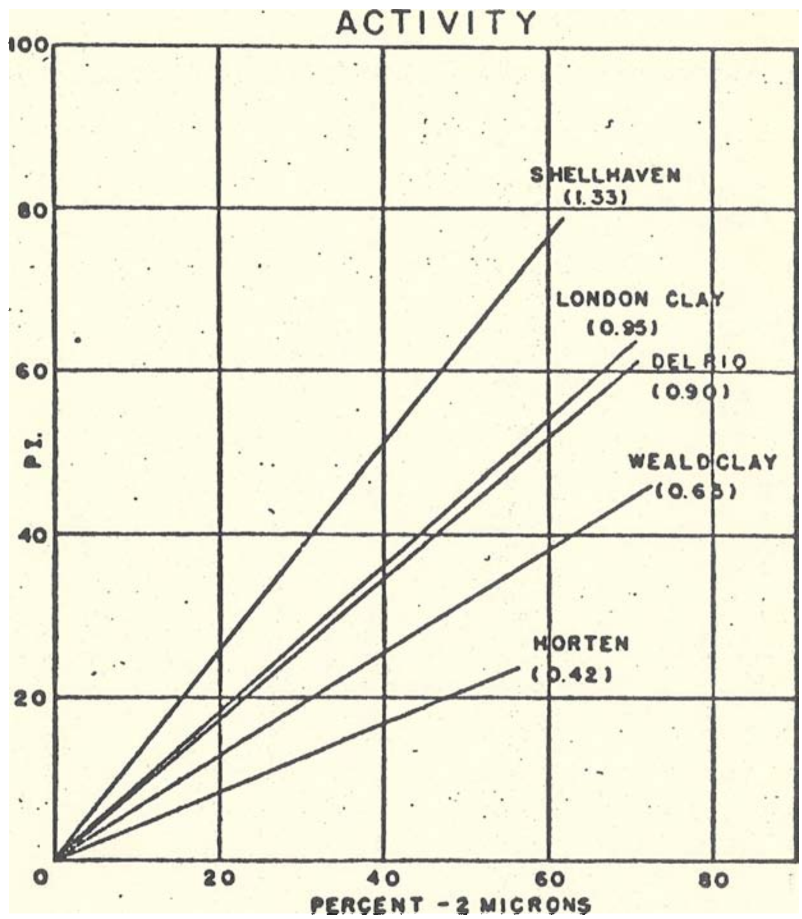


Figure 11 RELATION BETWEEN PLASTICITY INDEX AND CLAY FRACTION FOR THE DEL RIO CLAY AND OTHERS AFTER SKEMPTON EXCEPT FOR DEL RIO VALUES

From Harpster, 1956, U. T. thesis

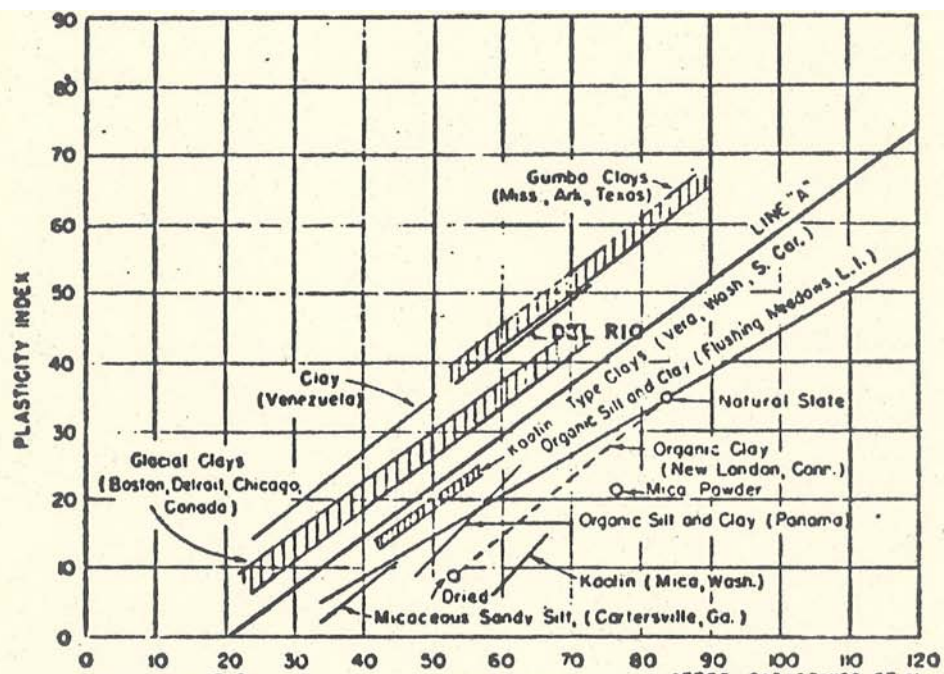


Figure 12

RELATION BETWEEN LIQUID LIMIT AND PLASTICITY INDEX FOR TYPICAL SOILS

From Harpster, 1956, U. T. thesis

Mileage	Interval	
22.1	0.4	Four-way stop at Woodland and Parker Ln.
22.5	.4	Turn left into Stop-&-Go before reaching Riverside Dr.
		STOP 15:
		The flood plain of the Colorado River to the northeast, now so densely populated with apartment houses, was under water in 1869 and 1935; and most of it was under water in 1938 (fig. 13).
22.8	.3	Turn right on Royal Crest. The retaining wall west of and behind the Safeway store failed in the fall of 1971. Note that there are no weep holes.
22.9	.1	Stone retaining walls are supposed to hold back the unstable Sprinkle Clay.
23.1	.2	Turn right on Woodland Ave.
23.2	.1	STOP 16 (fig. 14): Woodland Ave.
		In this area, the terrain above the base of the line of junipers is on caliche or on gravels associated with a terrace. The rock below the junipers is Sprinkle Claystone. In this area, foundation pads of caliche and river loam are laid down under the slabs for apartments and residences. Some pads are only 1.5 feet thick, but others are about 4 feet thick. Notice that the retaining walls are morticed and are not free. The construction methods are unacceptable for this type of construction. Because there are less resistant formations overlying the Taylor, these slopes are not as steep as where the Del Rio Clay is overlain by the Buda Limestone.
23.4	.2	Turn left on Willow Creek Dr.
23.6	.2	Turn right on Riverside Dr.
23.95	.35	Turn left on Pleasant Valley Rd.
24.3	.35	The apartments on the left are on the part of the Colorado River flood plain that was under water to a depth of 12 feet or more in 1935.
25.2	.9	Longhorn Dam.
25.8	.6	Turn right on Fifth St.
26.0	.2	Turn left on Tillery St.

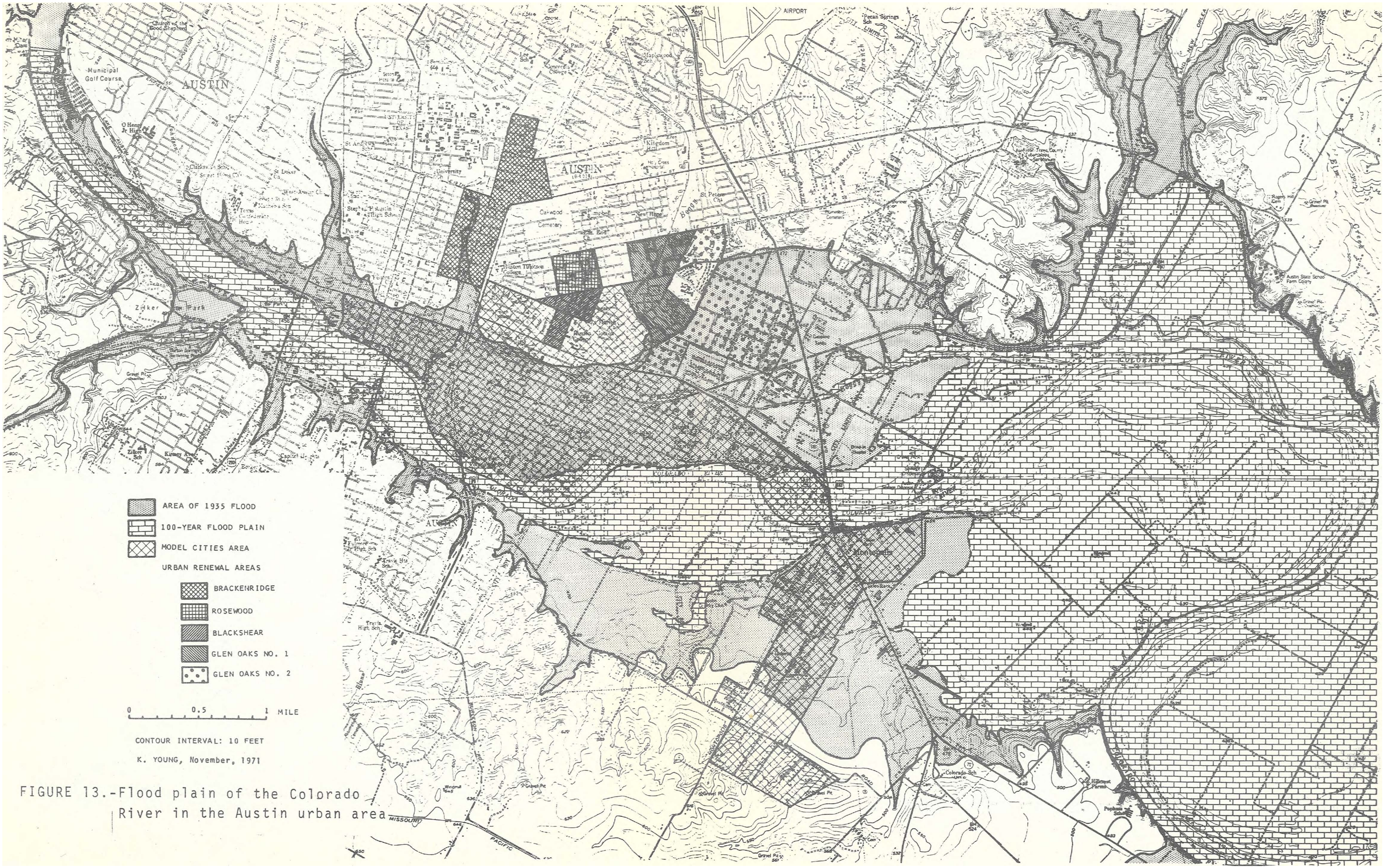


FIGURE 13.-Flood plain of the Colorado River in the Austin urban area

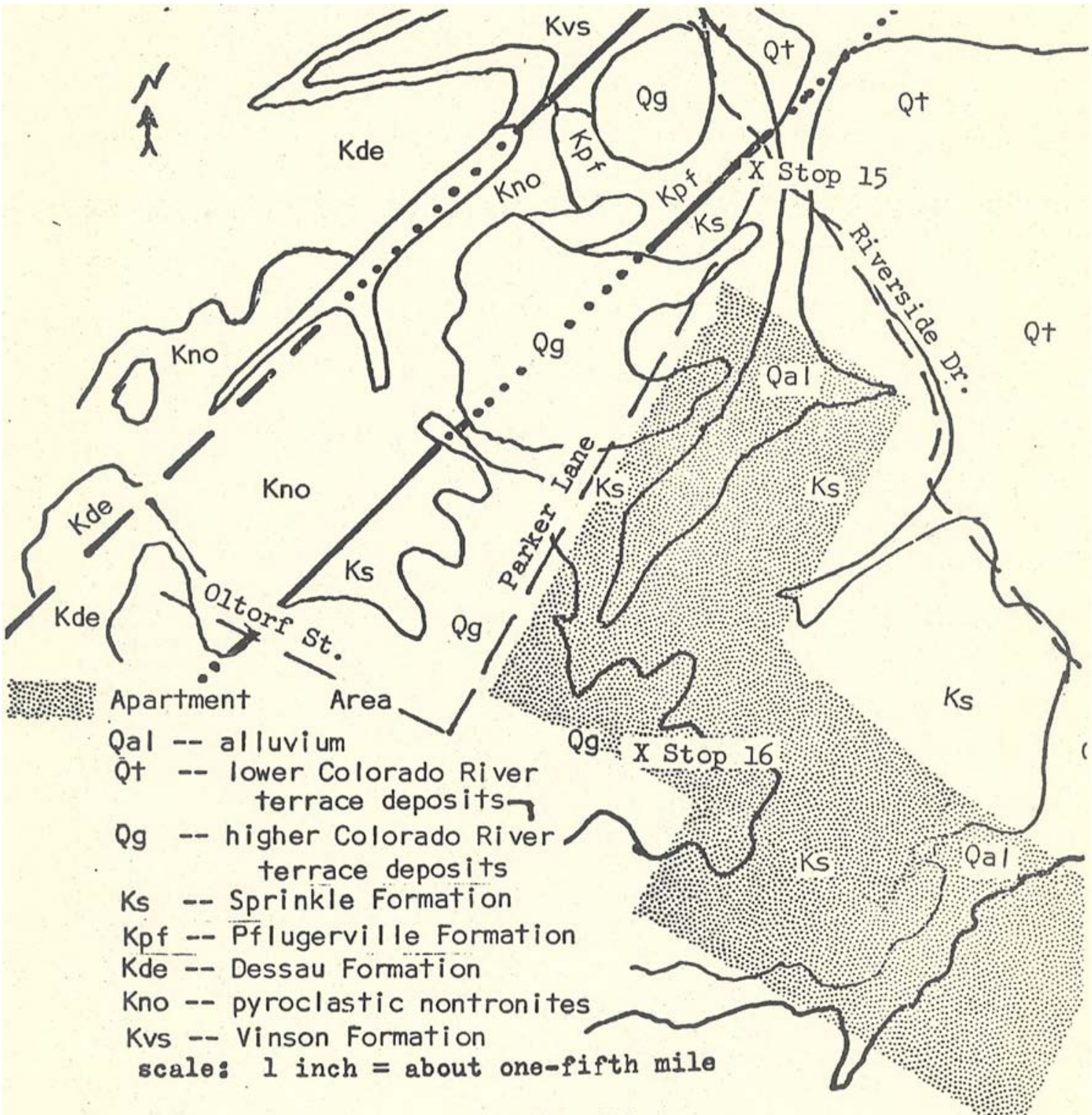
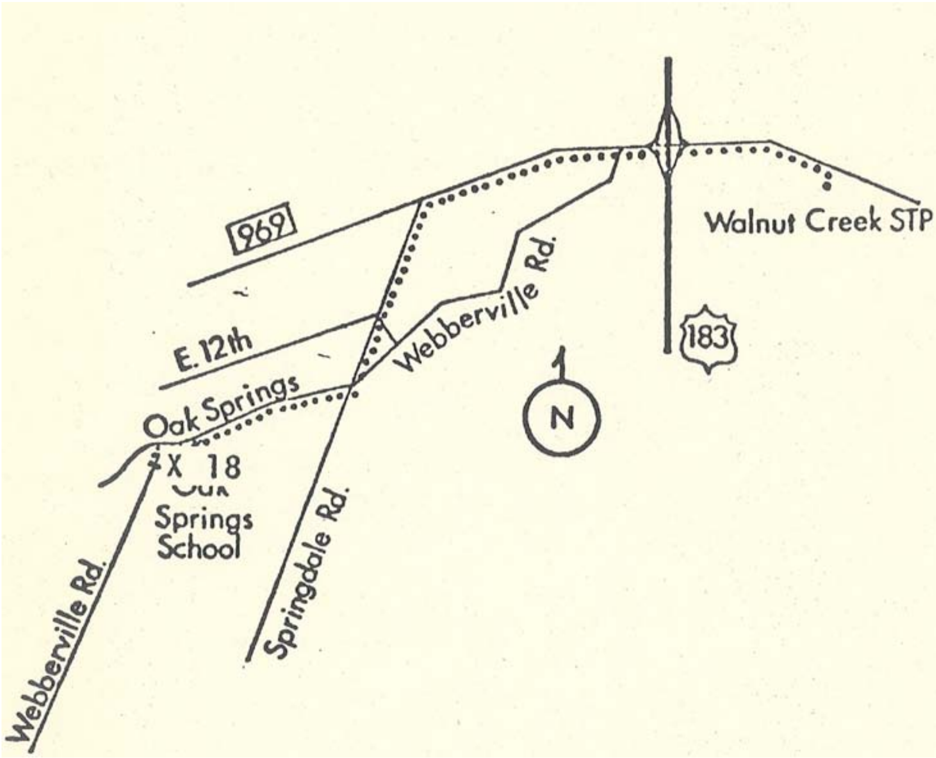


Figure 14

PARKER LANE AREA

K. Young, 1973

Mileage	Interval	
26.5	0.5	Cross Boggy Creek and turn left on Lyons St.
26.7	.2	STOP 17: St. Joseph's Elementary School. The main buildings were constructed on pillars to avoid the periodic floods from Boggy Creek. These floods have grown increasingly more severe with urban development on the headwaters of Boggy Creek above Manor Rd. and in the vicinity of Delwood Shopping Center. The floors of the main buildings are also above all but the most severe of the floods of the Colorado River.
27.0	.3	Turn right on Webberville Rd.
27.6	.6	STOP 18: Oak Springs Elementary School. Pull into the parking lot (figs. 15 and 16). Across the street are the buildings of the East Washington Urban-Housing Project. The higher buildings are on gravels of a Colorado River terrace, ahd the lower buildings are on Sprinkle (lower Taylor) Claystone. The apartment buildings on gravel suffer little damage. Many of the buildings on unstable Sprinkle Claystone have been repaired and even partly rebuilt. This is an excellent example of using "standard" construction plans without regard for the geology.
27.7	.1	Turn right on Oak Springs Rd. The margin of the flood-waters of the 1935 flood followed Oak Springs Rd. very closely in this vicinity.
28.2	.5	Cross Airport Blvd. From here to beyond Springdale Rd., the Sprinkle Claystone squeezes out from under the over-lying terrace gravels much as toothpaste from a tube. The hummocky surface at the foot of the terrace is the result of flowage of Sprinkle Clay.
28.6	.4	Turn left on Springdale Rd.
28.75	.15	Continue to left on Springdale Rd.
29.5	.75	Caution light at Webberville Rd. (east 19th St.). The light does mean caution. Continue on Springdale Rd.



969
Walnut Creek STP
Webberville Rd.
183
E. 12th
Webberville Rd.
Oak Springs
N
X 18
Oak
Springs
School
Springdale Rd.
Webberville Rd.

Figure 15

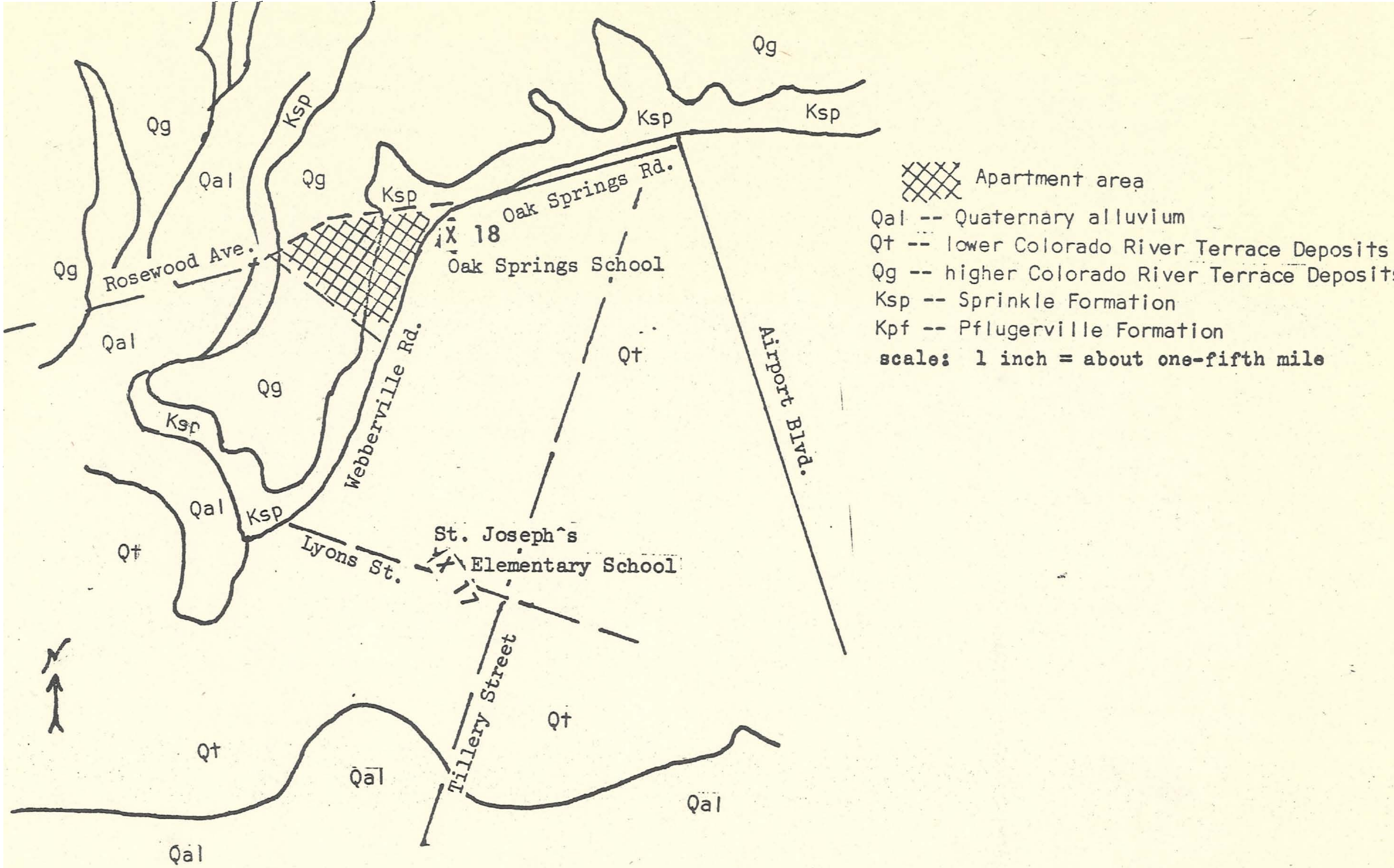


Figure 16

OAK SPRINGS SCHOOL AREA

K. Young, 1973

Mileage	Interval	
31.2	1.7	Turn left to

STOP 19: Springdale Rd. just south of Little Walnut Creek.

Freshly exposed Sprinkle Claystone can be observed at this locality. It is easily eroded. The zigzagging fence and tilted telephone and power poles testify to creep. This area was bared in 1968 and again in the fall of 1972. *Exogyra ponderosa* and other fossils can be collected here.

The clays of the Taylor and Navarro groups behave in a way that is similar to the Del Rio. They are susceptible to creep, settlement, shrink-swell, and are probably more erodible than the Del Rio. The gypsum deposits are rather recent, and are deposited by water seeping from the weathered material. The calcium is from the marl, and the sulfate is from the oxidation of iron sulfide.

Before you leave, drive south on the street to the east to the first intersection. There you will see extensive flow in overly-steepened Sprinkle Claystone slopes.

This is the last stop. It has been pleasure; drive carefully.