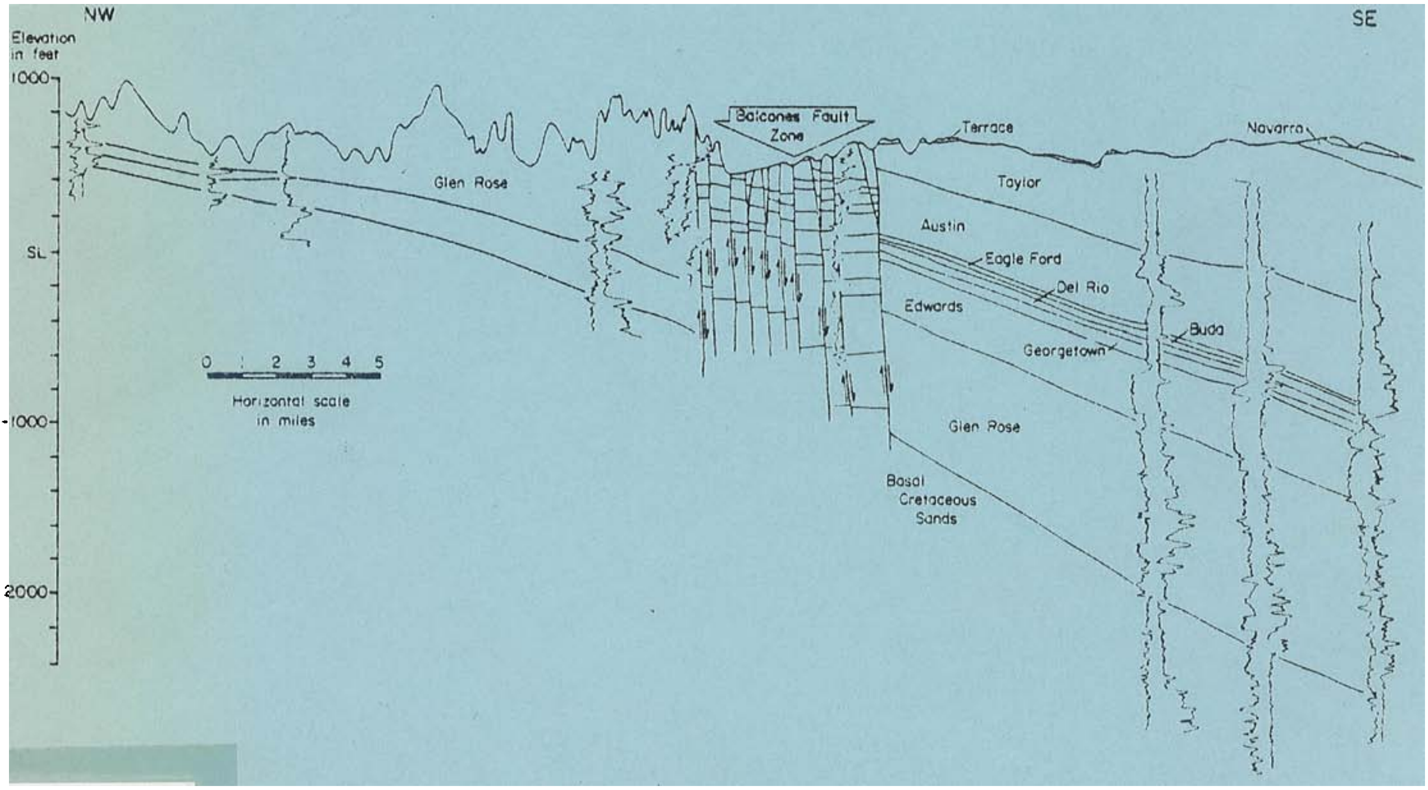
URBAN HYDROLOGY AND OTHER ENVIRONMENTAL ASPECTS OF THE AUSTIN AREA



Austin Geological Society Field-Trip Guidebook

December 8, 1979

L. E. Garner and C. M. Woodruff, Jr.
Co-leaders

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AUSTIN GEOLOGICAL SOCIETY
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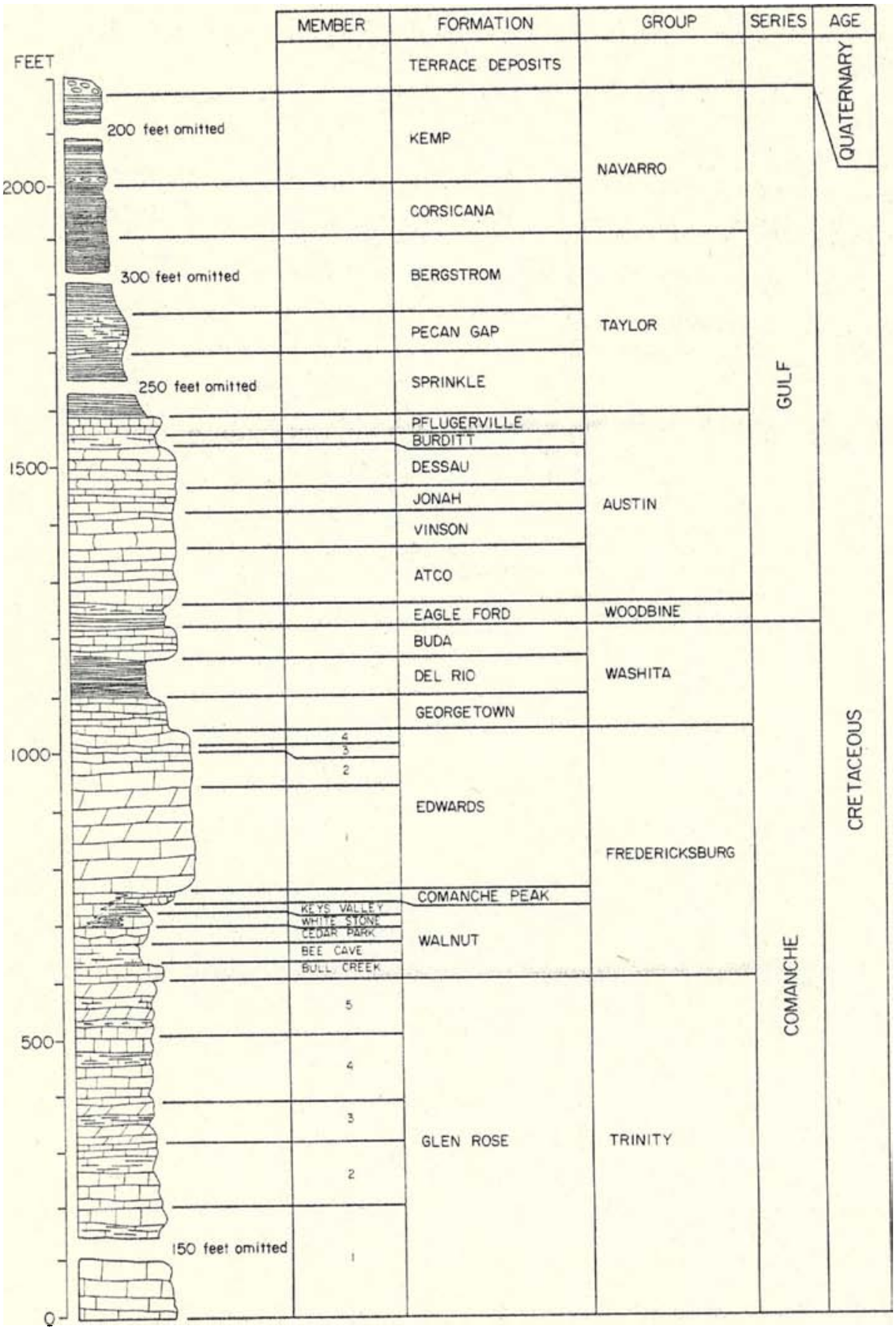

Frontispiece: Stratigraphic section in the Austin area (from: Garner and Young, 1976).

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ILLUSTRATIONS

INTRODUCTION

This field trip is intended to be a survey of selected creeks in the Austin area. We will stop along Shoal Creek, Waller Creek, Barton Creek, Cherry Creek, and unnamed drainage courses in the East Riverside apartment complex area (fig. 1).

It is our purpose to demonstrate both the problems and potentials associated with water courses in the urban and suburban environment. Simply stated, streams in cities (as elsewhere) are conveyance systems for water, sediment, and dissolved materials. Streams are also aesthetic resources owing to their terrain attributes and their habitat value. There are, however, many instances in which natural balances are upset by intensive human activities. Too, people may inadvertently get in the way of ongoing natural processes simply because they were unaware of these processes or of potentially adverse consequences. Understanding the interactions between people and their hydrologic environment in cities entails our appreciating how a stream reacts to its geologic and climatic setting in an undisturbed condition. Given these baseline conditions, revealed by drainage nets and watershed configurations and by historical discharge rates for various magnitudes of rainfall, we can chart some of the responses of a stream to urbanization.

Marked changes occur in the hydrologic regimes of streams as a result of urban development (Leopold, 1968, 1973). These changes include modification of both low flow and flood discharge, and an array of secondary effects such as bank erosion, sedimentation, landsliding (mass wasting),and declines in water quality--all of which affect the health, safety, and aesthetic

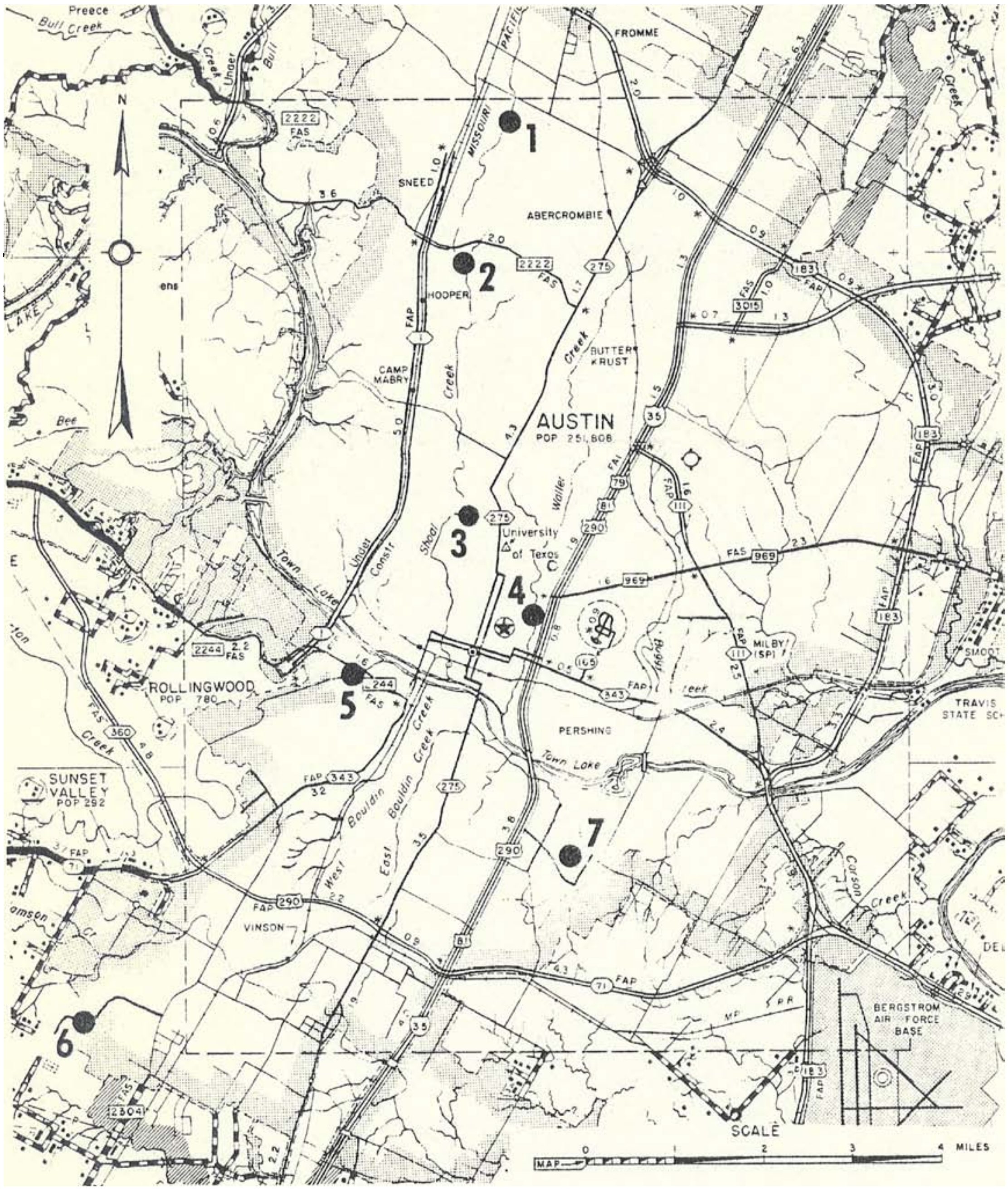

Figure 1. Index map showing field trip stops.

characteristics of the urban environment. Of particular note in the Austin area is the danger of flooding. This problem is especially acute here because of the local climatic setting; the area near the Balcones Escarpment has been cited (Hoyt and Langbein, 1955) as the locus of largest flood-producing storms in the conterminous United States.

The modification of hydrologic regimes in cities is the result of large areas being covered by impervious surfaces such as pavement and roofs. The more impervious cover on a watershed, the more extreme will be the streams' responses to various weather conditions. That is, most small urban streams have both anomalously high discharge for a given rainfall event and little or no discharge during dry periods. Streams of this sort that are either dry or subject to flash floods are termed "flashy".

The amount of pavement and "flashy" streams are related in the following way. Because impervious surfaces cover much of the ground surface in urban areas, thus preventing infiltration of rainwater into soil or substrate, a larger area of the drainage basin contributes to overland flow. Also, because of more efficient drainage from the uplands afforded by gutters, streets, and storm drains, runoff occurs more rapidly than would have occurred given the same amount of rainfall before urbanization. Figure 2 illustrates how a stream draining a nonurbanized basin responds to rainfall of a given magnitude as compared to the same basin after urbanization. When rain falls on an unaltered watershed, on the other hand, the soil must be wetted before a significant amount of surface runoff can occur. In addition, natural vegetation cover tends to retard runoff and decreases the rate of

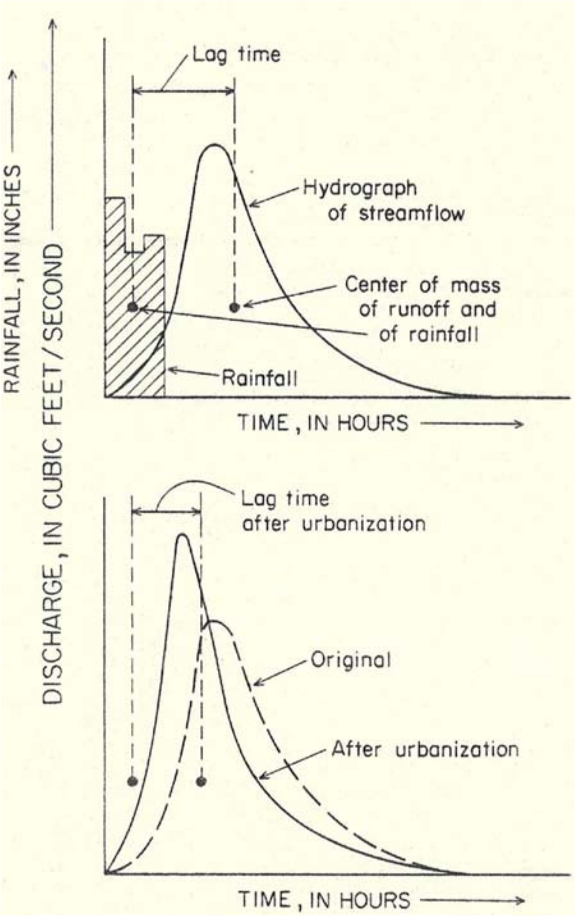

Figure 2. Comparison of runoff responses to a given amount of rainfall by a hypothetical drainage basin before and after urbanization.

water flow into the channel after a rain. Hence, there is a lag period between the bulk of precipitation and the bulk of runoff; in most instances, rainfall has stopped before much runoff begins.

In short, in an urban environment, more water is discharged as streamflow, and this greater discharge occurs more rapidly, resulting in higher peak flows than in nonurban settings of the same size. Conversely, because more of the local water budget is expended as rapid runoff immediately after rains, there is less recharge and storage in local ground-water systems that would otherwise sustain base flow of streams. Hence, many urban streams cease flowing during dry weather. Associated with increased peak flow are (1) flooding of areas that were previously above flood levels and (2) increased bank erosion and channel scour; these processes endanger both private property and public facilities (roads and bridges). Decreased base flow causes insufficient dilution of pollutants derived from street runoff and results in an overall decline in water quality.

Several methods have been employed to alleviate these urban hydrologic problems. However, in the Austin area drainage basins many of these "cures" have led to new problems. A stream is commonly in a state of delicate balance in terms of normal discharge, expected peak flow, sediment load, stream gradient, channel cross-section, and stream bank characteristics. When any one of these attributes is altered, there are commonly adjustments of all the others until a balance is reestablished. Thus, interactions of this kind demand that a watershed be considered as a functional system consisting of interdependent parts rather than an array of isolated (or loosely connected) local conditions. Disturbances in stream systems are often propagated both upstream and downstream as the system adjusts to maintain an equilibrium. Yet these responses by streams to alterations are not commonly recognized by those unfamiliar with geologic processes. As a result, certain facets of the urban hydrologic setting have been "mitigated" at the expense of others. For example, flooding may be alleviated at one locality by straightening the stream channel, but this commonly exacerbates other problems such as bank stability, or it merely transfers (and increases) flooding downstream.

The first three stops illustrate the progressive (downstream) effects of human interferences with the natural hydrologic setting of Shoal Creek. The fourth stop, along Waller Creek, illustrates a laudable attempt at wise use of an urban watercourse, but this attempt has been impeded by the recurrence of stream processes that should have been expected and allowed for in designing the parkland there. Stop 5 is at the mouth of Barton Creek where we will see the effects of stream processes on slope stability. There, we will also discuss the diverse relations between aquifer recharge, spring discharge, and water quality and quantity in this relatively large and important watershed. The next group of stops (all denoted as "Stop 6") includes several views of recent subdivision development and the associated responses of Cherry Creek in South Austin. Stop 7 views the flood-prone area along Colorado River as well as the potential impact of flooding from small side streams in the East Riverside apartment area. In all instances problems are caused by human interference with a natural system without recognizing the dynamics of and interconnection within the fluvial environment.

STOP 1

Shoal Creek at Foster Lane

Shoal Creek drains an elongate basin of 13.06 mi^2. Its headwaters are in the Hill Country in northwest Austin, but most of its drainage basin lies on the east side of the Balcones Escarpment. Much of the basin is developed for either urban use (commercial and light industrial) or as suburban tracts. In order to alleviate the flood runoff problems caused by urbanization, many segments of the stream network have been "improved" as is seen at Stop 1.

At this locality the Shoal Creek watershed increases by about 42 percent where the channelized main trunk ditch flows into the concrete tributary culvert that parallels Foster Lane (fig. 3). In the past, there have been large (albeit periodic) contributions of water and sediment by this tributary of Shoal Creek, as indicated by the alluvial fan mapped where the stream debouches from the Hill Country across the main fault-line scarp. So, in order to contain the runoff from these naturally flashy streams (with additional high levels of runoff due to urbanization) both the main and tributary channels have been straightened, widened, and deepened.

Immediately upstream along the main course of Shoal Creek, a fault juxtaposes Eagle Ford Clay against Austin Chalk. Downstream from the fault contact, the Eagle Ford is being rapidly eroded to reestablish the natural stream gradient that was erased by construction of the "improved" channel. This process poses two problems. First, it threatens property along the channelized reaches by undermining and decreasing the stability of the highly plastic (weak) clay deposit; downstream from this locality, slump blocks occasionally fall into the channel and constrict the cross-

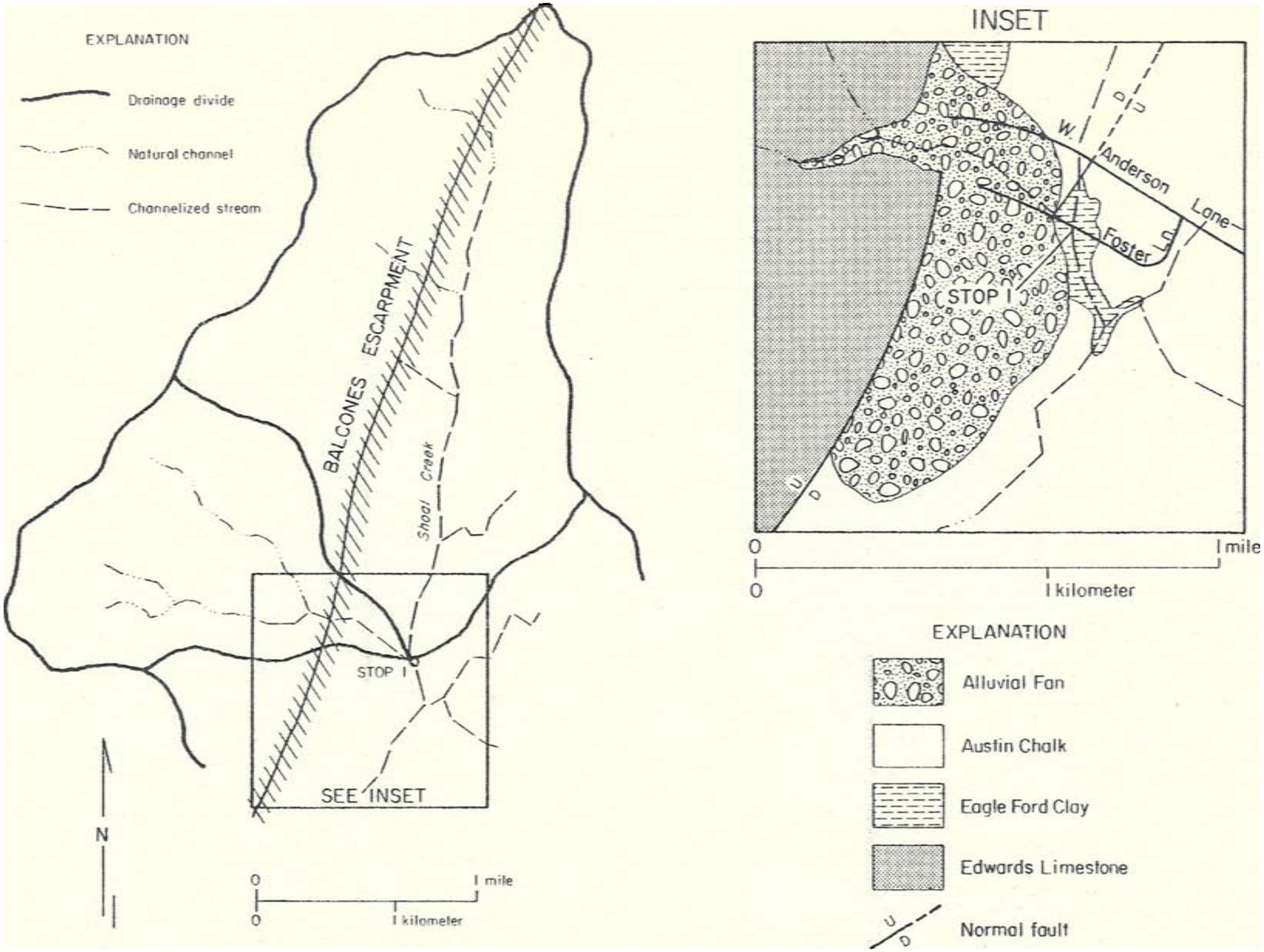

Figure 3. Map showing Stop 1 in relation to the Shoal Creek drainage basin, with inset showing local geologic substrate (for stratigraphic position of geologic units <u>see</u> Frontspiece).

sectional area of the ditch. Second, erosion of both stream bank and channel furnishes increased sediment--including dislodged blocks of Austin Chalk--and this bedload tends to choke the channel and decrease the efficiency of the stream as a storm-water conveyance system. In other words, channel improvements at this locality contribute to processes that tend to negate the channel improvements. Worse yet, some problems are merely transferred to downstream locations, as is seen at Stop 2.

STOP 2

Shoal Creek at Northland Drive

The channel of Shoal Creek has been left in a natural condition through this reach. Note the meandering channel and the vegetation growing along the stream banks. Despite their scenic attributes, these unmodified channels do not discharge flood waters very efficiently. The increased runoff resulting from urban development is further abetted by periodic high discharge rates channelled from the "improved" reaches upstream from Northwest Park (fig. 4). Thus, large volumes of water are quickly routed to these downstream reaches that are not adapted to accommodate such large floods. The bedload cobbles and boulders of Austin Chalk and Buda Limestone attest the velocity and sediment-transporting capacity of periodic streamflow at this locality.

Further compounding the flooding problems here is the constriction of the channel cross-sectional area at the Northland Drive bridge. The cross-sectional area under the bridge is about 300 ft^2, compared to a channel area of 731 ft^2 at Stop 1. Thus, while the catchment area for Shoal Creek increased by 62 percent, the size of the channel has <u>decreased</u>

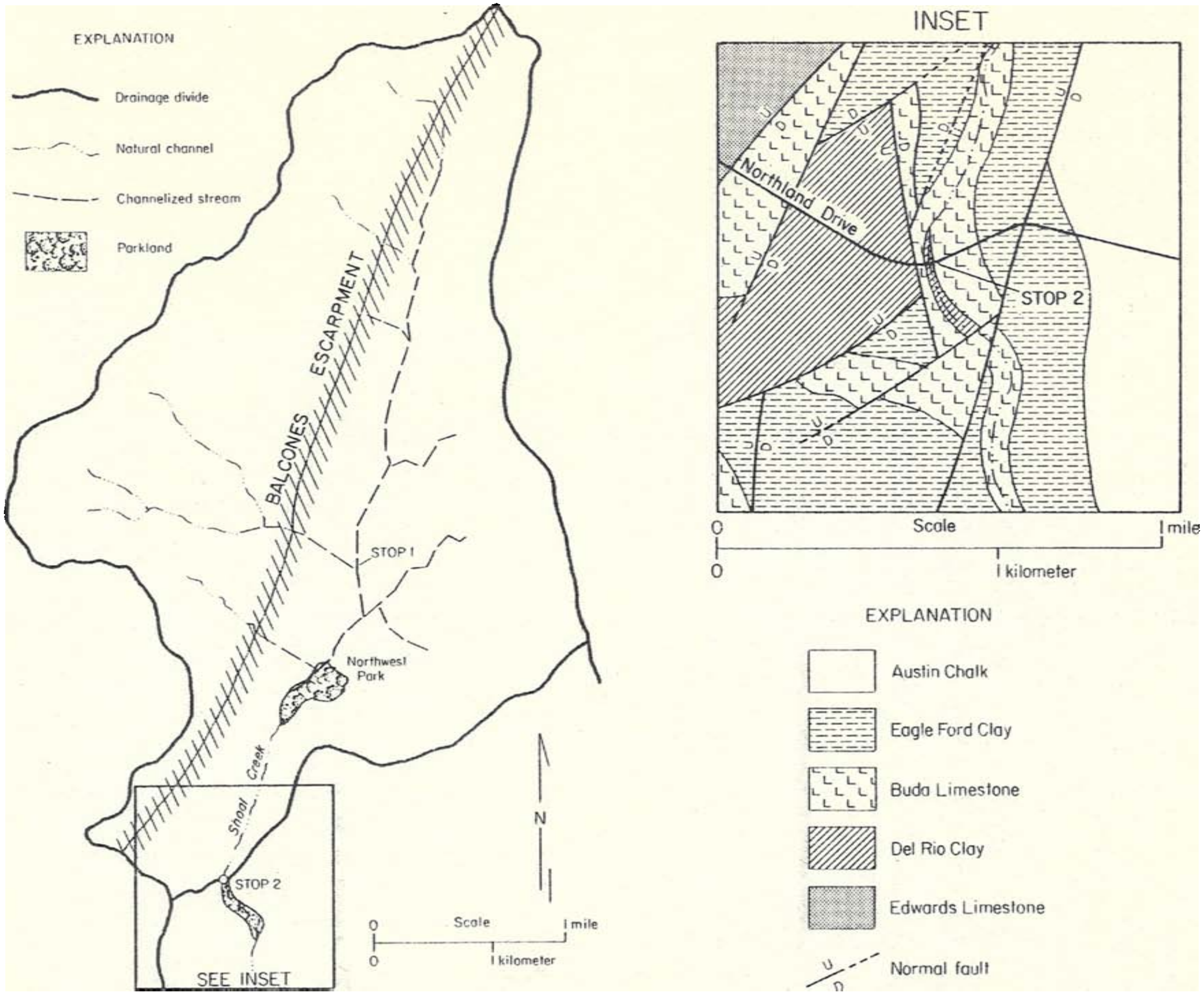

Figure 4. Map showing Stop 2 in relation to the Shoal Creek drainage basin, with inset showing local geologic substrate.

by over 50 percent. The bridge was designed to span a smaller channel--probably as a money-saving measure. However, with increased development upstream, the bridge is subject to overflow by flooding with increasing frequency.

Besides increased flooding at this locality, another problem (that is in part due to increased magnitude and frequency of flood discharge) is mass wasting (landsliding) of the stream banks. As shown in figure 4, Buda Limestone is underlain here by Del Rio Clay. Slumping is clearly evident on the western bank of Shoal Creek. Conditions of slope instability are exacerbated by erosion of toes of slopes, by repeated saturation of slopes, and by overloading of the tops of slopes. All these conditions occur at this locality and at many other places along Shoal Creek.

Downstream from Northland Drive, there are considerable stream reaches bounded by a park and greenbelt system, including hike and bike trails. This is a good use for such a dynamic setting. It lessens the impacts on private property due to flooding or mass wasting, and it also affords inhabitants a scenic greenbelt within the city.

STOP 3

Shoal Creek at Wooten Park

Wooten Park is part of the system of greenbelts established along creek bottoms in Austin. As pointed out, this is a prudent use of areas subject to ongoing processes; development of greenbelts along creeks should mediate the necessity of channelization. However, once the process of channelization has begun, effects are transmitted downstream, and this almost always requires channelization of downstream reaches. Moreover,

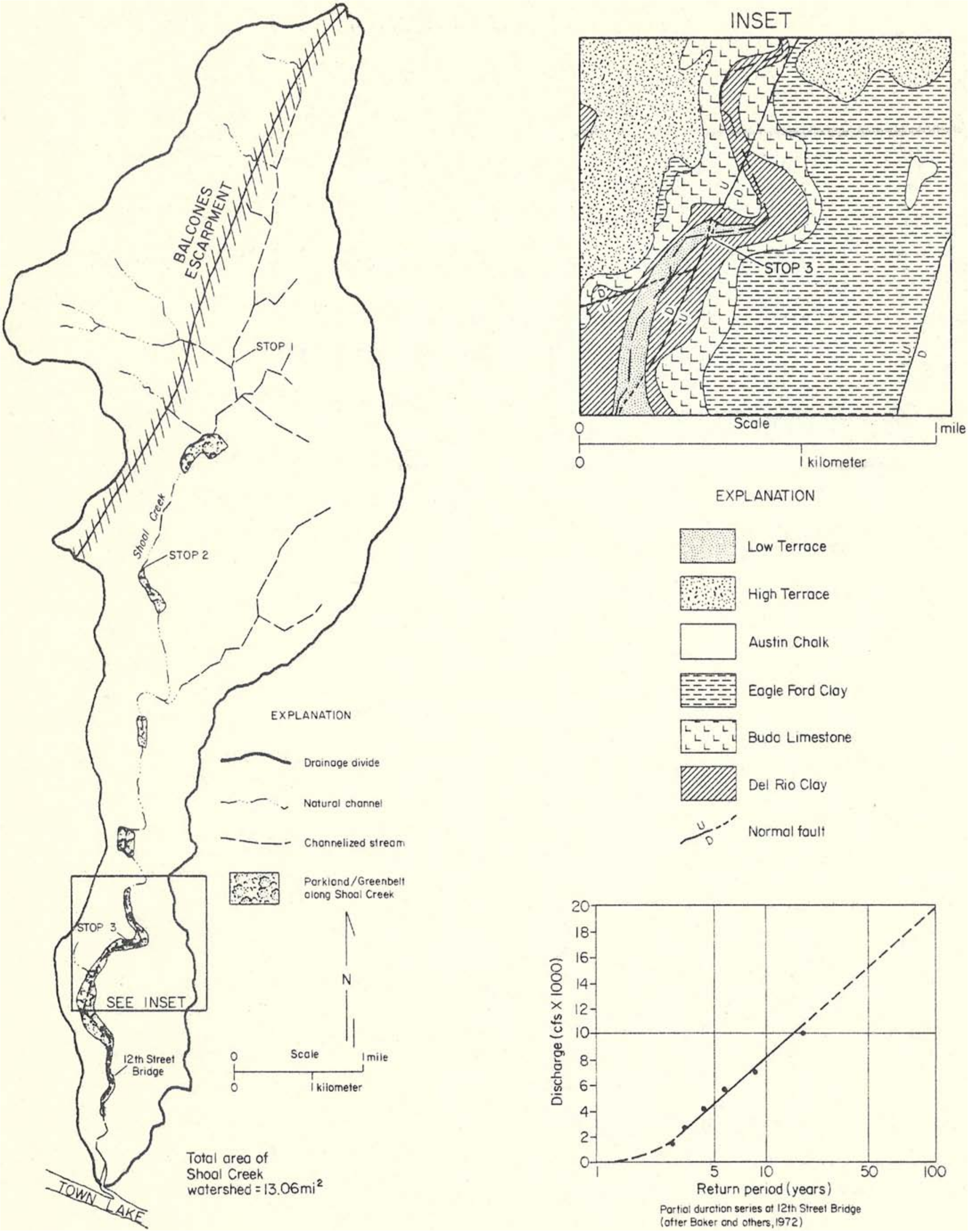

Figure 5. Map showing Stop 3 in relation to the Shoal Creek drainage basin, with insets showing local geologic substrate and flood frequency.

the concrete channel here also prevents bank erosion which otherwise might affect Lamar Boulevard. Thus, Shoal Creek is channelized in Wooten Park, despite the fact that in parkland there is aesthetic value in retention of unmodified stream reaches. Channelization has produced local steep stream gradients and this has been propagated downstream by means of the stream incising into the channel bottom. At Wooten Park, Shoal Creek has incised as much as 3 ft since the concrete channel was first emplaced, as indicated by the periodic repair to the base of the concrete revetment. As expected, there has also been progressively greater discharge of water and sediment in response to upstream channelization and subsequent erosion; evidence of this is found in historical flood reports (Baker and others, 1973) and in the presence of coarse-grained channel lag deposits supplied from upstream. The response of Shoal Creek to the emplacement of a low-water crossing may be seen a few hundred yards upstream from this stop where the hike and bike trail crosses the creek. The damming effect of that low-water crossing has resulted in upstream deposition of very coarse sediment (boulders), while immediately downstream there is incision that threatens to undermine the structure.

Shoal Creek does not have an extensive discharge (gage) record (*see* Slade and others, 1979), but Baker and others (1973) computed approximate probabilities of floods based on historical records (*see* figure 5). These data indicate that the "100-year flood" for Shoal Creek at the 12th Street Bridge (below Wooten Park) should have a discharge of about 20,000 cfs. Notably, the 1960 flood, in which discharge was only 5,000 cfs, reached a height of about 12 ft above the stream bed at the 12th Street Bridge.

There, the cross-sectional area of the channel is about 1550 ft^2, while the channel cross-section at Wooten Park is only about 500 ft^2. It is evident that there is a continued threat from flooding at this locality, and this is the main reason for channel "improvements" in this park/greenbelt area.

STOP 4

Waller Creek at Symphony Square and Waterloo Park

Waller Creek drains a watershed of 5.45 mi^2 including most of downtown Austin, the State Capitol complex, and The University of Texas at Austin campus. Because of this intensive development, Waller Creek is an ideal natural laboratory for studying the effects of urbanization on hydrologic regimes. The basin contains two U.S. Geological Survey stream gaging stations, both of which have recorded streamflow since 1954. Moreover, a study has been conducted demonstrating the interactions between urban development and storm runoff (see Espey and others, 1966). There is, then, a considerable amount of published data that documents the recurrent (and, in fact, the progressive worsening) flood problems along Waller Creek.

In response to flooding, there have been ongoing efforts to establish a system of parks along Waller Creek similar to those along Shoal Creek. Symphony Square and Waterloo Park are two links in a park complex that will soon extend north to Eastwood Park beyond The University of Texas campus. The apparent model for this creekside park is the famous "Riverwalk" in San Antonio, where commercial establishments and a public park coexist along the tree-lined, downtown reaches of the San Antonio

River. Unfortunately, the Riverwalk and Waterloo Park do not occupy similar geomorphic settings, and thus, they are not subject to similar processes. The San Antonio Riverwalk is adjacent to a constant-level lake created by damming a meander loop of the river. This area, then, is part of an artificially altered and controlled environment. It is not subject to significant fluctuation in discharge or in water levels such as occur in an unaltered stream. Neither is there a periodic inflow of trash and other debris characteristic of most urban streams. Waller Creek, on the other hand, is a stream typical of urban areas. It is characterized by extreme fluctuations of discharge; it conveys copious quantities of debris; and during periods of low flow it shows evidence of pollution. In short, Waller Creek has not been "tamed" in the same manner that the San Antonio River has. Instead, it is an active urban stream that conveys water, sediment, solutes, and debris from throughout its watershed to its mouth.

Waterloo Park and Symphony Square have not been designed with these processes in mind. Consequently, the walkways and footbridges are subject to damaging torrents of flood water as well as the aftermath of muddy sidewalks, debris-strewn stream banks, and malodorous stagnant pools during periods of low flow. Many of the walkways have actually been placed <u>within the channel</u> of Waller Creek. That is, in many areas the sidewalks are not on the floodplains but are within the areas inundated by bankfull discharge. As pointed out by Leopold (1974) the recurrence rate of bankfull discharge in most rivers is about 2 events per year.

The problems with constructing these walkways at such proximity to the creek would have been obvious if the past history of discharge in Waller Creek had been considered. Recent flood data span only 19 years, and historical records document prior floods of considerably greater magnitudes. As shown in figure 6, the peak recorded discharge at 23rd Street was more than 4,000 cfs with a gage height of 9 ft. Espey and others (1966) also documented the tendency toward progressively more severe flood runoff problems owing to urbanization (fig. 6).

Waterloo Park and Symphony Square are examples of good intentions gone awry. Parks are usually excellent ways of using urban watercourses, and if hydrologic factors had been considered in planning Waterloo Park, most of its flood runoff problems might have been avoided. As it happened, continuing maintenance is the price paid for failure to recognize the dynamics of urban streams.

As we return to our cars, note the "permeable pavement" that makes up the parking lots near Symphony Square. This kind of pavement is good for the urban environment (though probably bad for the ankles of women or cowboys, who wear high heels); the open tiles allow some infiltration of rainwater into soil and substrate, thus retarding some of the rapid runoff into Waller Creek.

STOP 5

Barton Springs Road at Barton Creek

The southeast abutment and footing for the bridge at this stop (fig. 7) is founded in the Del Rio Clay. This locality has long been noted for the continued slumping of the incompetent clay. The head of the slope is repeatedly loaded by city maintenance crews in an effort to keep Robert E. Lee Road repaired and the toe of the slope is repeatedly removed by the currents of Barton Creek.

The reason we inspect this stop today is not to discuss the slumping

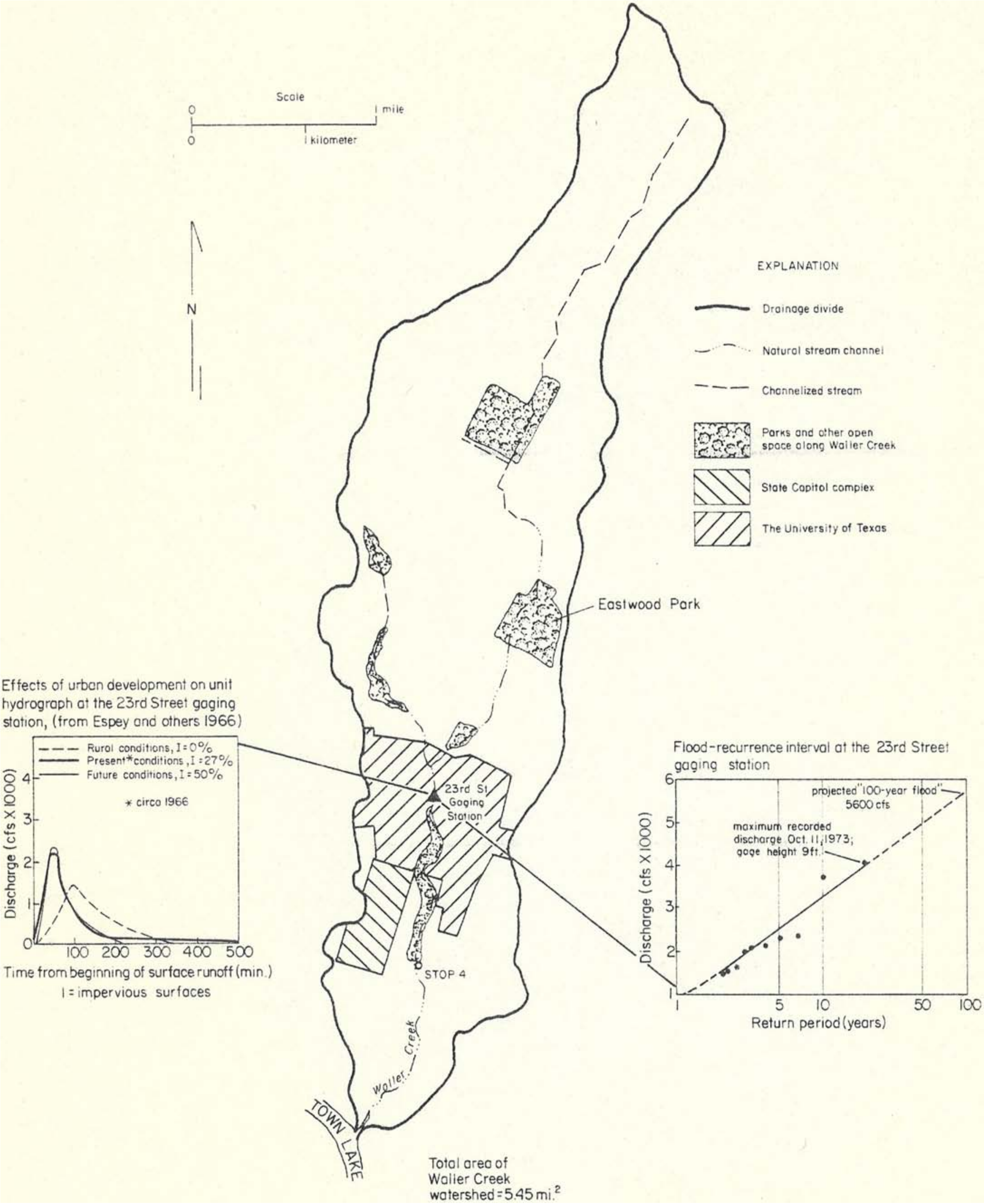

Figure 6. Map showing Stop 4 in relation to the Waller Creek drainage basin, with insets showing the response of the creek to urbanization.

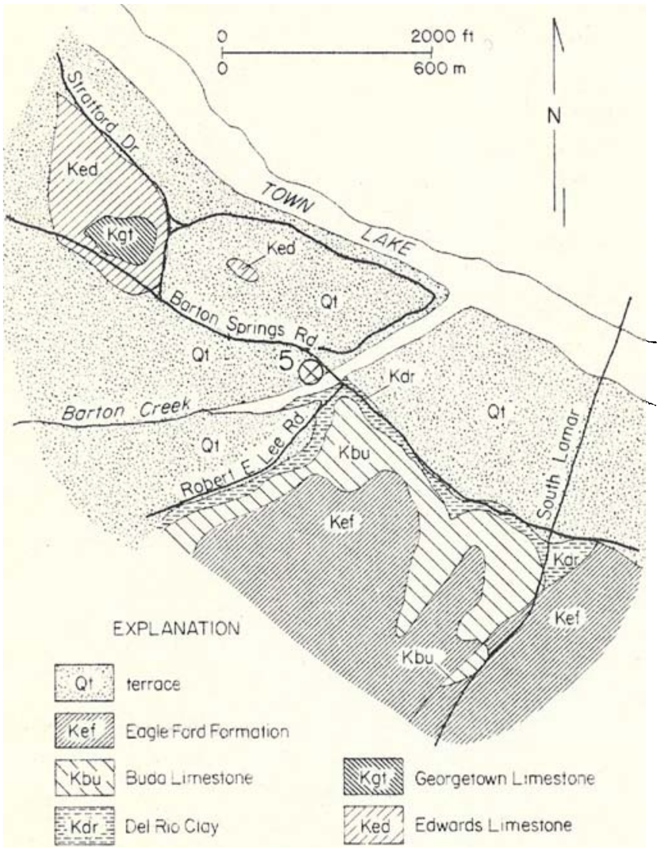

Figure 7. Map showing geologic setting of Stop 5.

characteristics of the Del Rio Clay. Our main purpose is to observe an indirect result of the combined action of continuing mass wasting and stream processes. The protrusion of the slump toe into Barton Creek has started to alter the flow pattern of the stream so that the stream is eroding the west bank just upstream from the bridge. The undercutting is being caused by the deflected currents and increased current velocity caused by the slump toe. The end effect of this process could be the complete undercutting of the bridge abutment. If high-density development is permitted in the Barton Creek watershed, the increase in runoff and flooding could accelerate the process at this locality. A consideration of watershed characteristics and effects of residential development in the Barton Creek drainage basin affords a perspective on processes affecting the lower reaches of the creek as well as Barton Springs.

Barton Creek drains a watershed of 125 mi^2; it rises in the Hill Country ranch lands of Hays County and in southwestern Travis County. Until recently, there have been few intensive urban pressures on Barton Creek because its incised valley has prevented easy and inexpensive road access for residential development. Now, however, accelerated population growth and increasing land values have changed the economic situation, so that many of the lower parts of the Barton Creek watershed are or soon will be developed. Hence, many of the same processes and responses observed in other urban creeks may eventually occur along Barton Creek as well. Potential problems include increasingly frequent floods and worsened water quality of base flow. Also there are aesthetic problems of trash and other debris that may wash into the stream and ultimately into the park premises near Barton Springs.

A potentially more serious problem associated with the suburban development of the Barton Creek watershed is the impact on water quality in the Edwards aquifer, and hence, on the water quality of Barton Springs. A recent thesis (St. Clair, 1979) has addressed this issue, as do other ongoing consulting studies. St. Clair, however, limited the areal extent of her study mainly to the Rollingwood area; her findings indicate that septic tanks in her study area (which is underlain by the Edwards Limestone) have had generally minimal impact on Barton Springs. But, given the current data base, geologists cannot say with certainty exactly where the recharge areas are that feed the Edwards aquifer. St. Clair (1979, p. 82) presented geochemical evidence indicating that most recharge to Barton Springs comes from Barton Creek during high discharge periods, whereas, during periods of low flow there is a mixture of recharging waters from Barton Creek and Colorado River. However, her data also indicate that ground water in the Rollingwood area originates from sources other than Barton Creek. These uncertainties point up the need for integrated hydrologic studies of the various creeks that cross the Edwards Limestone in the area southwest of Austin (fig. 8).

Most aquifer recharge probably occurs along stream bottoms within the Edwards terrane, but there is probably some further infiltration that occurs across the uplands underlain by the Edwards. Too, the upper reaches of these watersheds--upstream from the Edwards terrane--are important for maintaining the quality of waters eventually recharged, because the runoff from these areas provides base flow that ultimately crosses the recharge zones. Because of these geologic and geometrical controls, the various watersheds may be subdivided into three zones in order of their importance to the recharge process. Zone 1 lies within channel reaches of streams where they transect the Edwards Limestone.

Figure 8. Simplified geologic map showing drainage basins for Barton Creek, Williamson Creek, Slaughter Creek, Bear Creek, and Onion Creek, all of which probably provide recharge to the Edwards Aquifer in the Austin area.

Zone 2 includes all the upland areas underlain by the Edwards Limestone within the Balcones Fault Zone. Zone 3 includes all the Hill Country areas upstream from the faulted Edwards terrane. These upstream reaches are underlain mainly by the Glen Rose Limestone, but also to a minor extent by erosional remnants of the Walnut Formation and the Edwards Limestone where they cap isolated hills.

The specific role that each of these areas plays in the quality and quantity of water recharged into the Edwards aquifer may be ascertained by a systematic program of mapping and monitoring. A data base is needed that will integrate surface water hydrology and ground water responses to various climate regimes. Some of these data are now being collected by scientists at the U.S. Geological Survey. However, it takes years of data collection and analysis to predict consequences of specific scenarios reliably, and meanwhile city planners must make decisions on the basis of the best possible information. During our lunch break here at Zilker Park we will hear from Raymond Slade of the U.S. Geological Survey, who will discuss ongoing studies of creeks in the Austin Area. Also, Robin Moats will explain how planners for the City of Austin take into account watershed development and its effect on the urban environment.

STOP 6

General Statement--Cherry Creek Area

The Cherry Creek Subdivision provides an example of the impacts of residential development on stream processes. Development of this subdivision has been rapid, most of the houses having been built during the last seven years. At the present time we can see completed residential areas to the east and an area under construction on the hillside to the west. As noted on zoning signs along Westgate Boulevard, there will be commercial development along that street, so we may expect continued and increasing "flashy" conditions along Cherry Creek. The problems related to suburban development of the Cherry Creek watershed include flooding, erosion, bank instability, and sedimentation. These problems arise largely because development was superimposed onto a stream system that was adjusted to an entirely different hydrologic regime. Because of this, a balance has been upset, and the stream has responded to the stresses thus imposed by either eroding or depositing material to reestablish an equilibrium. J. Hoover Mackin (the late Farish Professor of Geology at The University of Texas) summarized the response of many streams to either natural or human-imposed stresses as obeying Le Chatelier's Principle. This principle (which is derived from chemical theory and experiment) dictates that a system in a state of equilibrium respond to stresses in such a way as to absorb the effect of the imposed stresses. In a geomorphic context, use of this principle presumes a stream to be in harmony with its environment--with the ambient climate, terrain, and bedrock conditions. If a local imbalance occurs in sediment supply such that the stream is deprived of sediment through a given reach, the stream will respond to this stress by eroding its bank and channel in a downstream direction to reestablish a balance with respect to stream discharge and channel geometry. If base level of a stream is lowered, the stream will generally erode in an upstream direction. If, on the other hand, base level is raised, sediment deposition will occur in an upstream direction.

If too much sediment is introduced at a point, deposition of sediment will commonly occur in a downstream direction. These responses take time, and there are secondary and other subsequent long-term impacts owing to these effects. But the fact remains that the responses are predictable. The failure to recognize the responses of streams to imbalances imposed by human activities was aptly summarized by Mackin (1948, p. 508): "It is certain that the long-term response of streams to the operations of the present generation of engineers will provide much employment for future generations of engineers and lawyers."

6-A--Cherry Creek at Berkeley Avenue

The parts of the Cherry Creek Subdivision seen on this trip are located in one of the many fault complexes which occur within the Balcones fault zone. A 1 mi^2-area within this complex includes fault-bound exposures of Austin Chalk, Eagle Ford Clay, Buda Limestone, Del Rio Clay, Georgetown Limestone, and Edwards Limestone.

The feature of interest at Stop 6A is a channelized segment of Cherry Creek. The bridge spans a fault contact between the Buda Limestone and the Del Rio Clay; on the southwest side of the bridge, the ditch is cut into hard Buda Limestone, whereas to the north of the bridge the ditch is cut into the erodible Del Rio Clay (fig. 9). Property owners are concerned about erosion, as indicated by the sign on the fence next to the bridge at this stop. Thus, in order to retard erosion, the streambed has been filled with limestone rubble by city maintenance crews; however, the process has merely been transferred downstream; as was seen at Stop 1 on Shoal Creek. Note the erosional notch at the contact between the limestone rubble and the underlying clay.

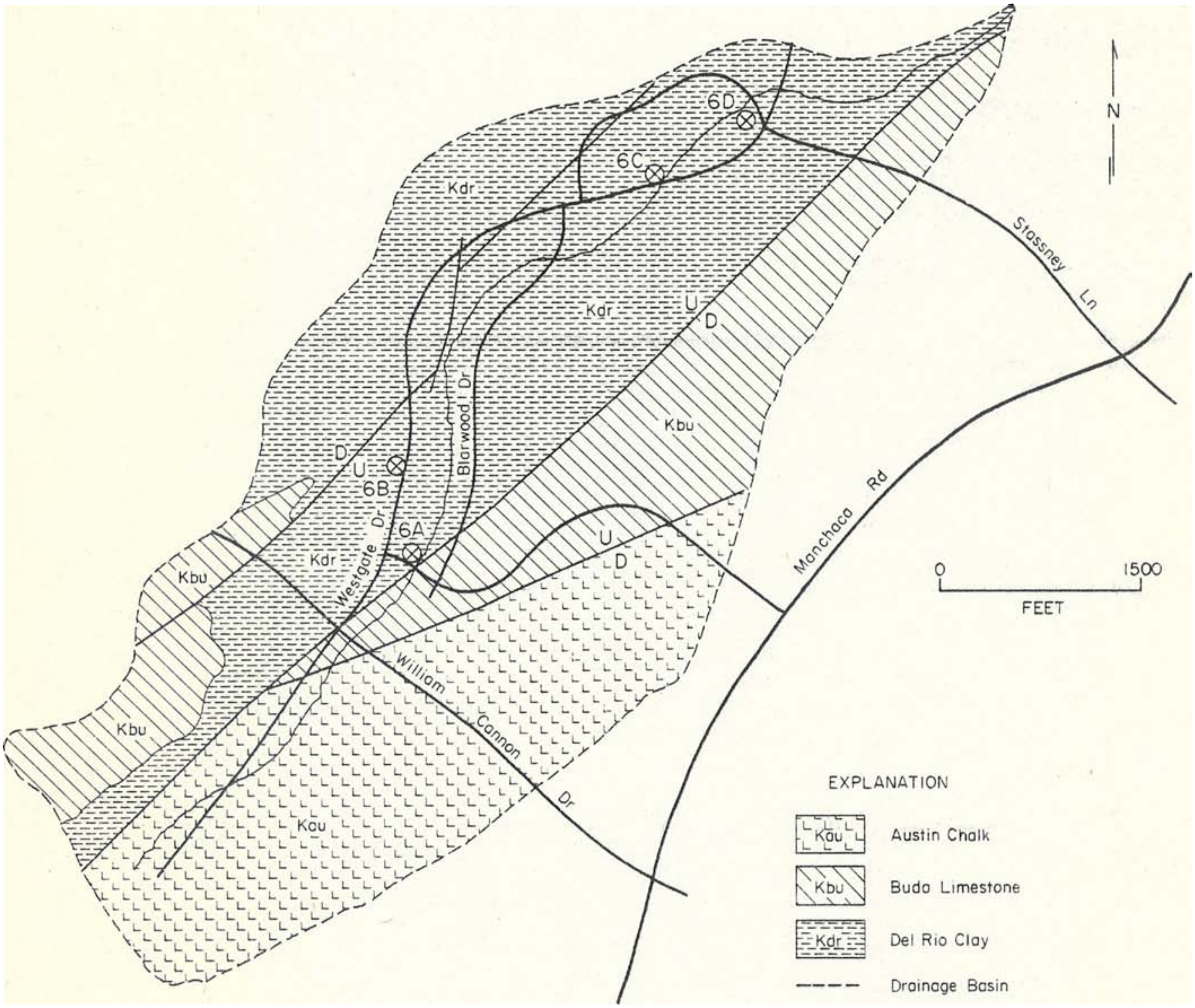

Figure 9. Geologic map of the Cherry Creek drainage basin (a sub-basin of Williamson Creek) with locations of Stops 6A, 6B, and 6C (Stop 6D will not be made on this trip).

The net effect of adding new material in the upstream area is to provide very coarse sediment to the downstream area. Higher discharge rates caused by suburban development have sharply increased the erosion and transportation abilities of the headwater reaches of Cherry Creek, so that limestone boulders are easily moved during frequent floods. At subsequent stops within this area we will observe the effects of transport of limestone blocks down the stream course. Sediment deposited in the downstream area restricts the stream channel and increases the flood hazard.

6-B--Drainage Culvert at Westgate Boulevard

At this locality a culvert has been constructed beneath Westgate Boulevard in order to collect runoff from the hillslope to the west. That hillslope consists of a small, ill-defined drainage basin underlain mainly by Del Rio Clay with Buda Limestone capping the hill. The culvert allows runoff from this hill to be transmitted to Cherry Creek via a storm sewer and a short ditch.

The drainage collection point at this locality was originally a small, concrete-lined basin. However, the basin was emplaced at a lower topographic level than that occupied by the undisturbed, intermittent stream. Hence, in order to reestablish an equilibrium profile, rapid erosion proceeded upstream from the culvert. Within two years the gully has been enlarged more than 60 feet by headward erosion of soil formed on the Del Rio Clay. Debris and eroded soil are also beginning to clog the culvert beneath the street and the downstream drainageway to the east.

If present conditions are not rectified, erosional debris will eventually plug the storm sewer and deposition will occur in the gully west of Westgate Boulevard. Hence, the erosion begun by emplacement of the culvert is self-limiting. Ultimately, however, slope wash will flow directly across Westgate Boulevard, burying the street in sediment and posing a flood hazard to the dwellings on the east side of the street. Increased development of the hill slope will further increase the amount of runoff and potential flooding. These problems could have been predicted and allowed for in the street design if the stream system had been recognized as having a naturally established profile that reflects adjustments to climate, bedrock, and local terrain conditions. Engineering design must allow for these processes whenever a stream course is modified.

6-C--Cherry Creek at the intersection of Westgate and Coatbridge

At this locality, Cherry Creek is a channelized ditch designed to transmit efficiently the periodic floods that are partly a result of residential development across the watershed. However, there are two problems here that tend to negate the flood-prevention channelization design. These are the right-angle turns imposed on the channel, and the constricted culverts beneath Westgate Boulevard. Furthermore, we can see further examples of the ongoing processes of stream adjustment because of the upsetting of erosional and depositional balances.

One major problem in the design of this channelized reach is the series of nearly right-angle turns imposed on the creek to conform to the location of Westgate Boulevard. Furthermore, Cherry Creek is routed beneath the road via a series of culverts that trend diagonally to the road. The culverts are of smaller cross-sectional area than the local channelized stream reach, and the effective cross section that can accommodate flood flow is further constricted because of the angle at which the drainage course crosses the road. The combination of unwieldy angles in the channel and restricted cross-sectional areas of the culverts almost ensures a flood problem here. During periods of high discharge, Cherry Creek will tend to avoid the right-angle turns and flow out of its channel and directly across Westgate Boulevard.

Natural processes dictate that streams be in disequilibrium with right-angle bends, hence these abrupt turns are seldom seen in nature. When streams are modified, engineers and landscape architects would be well advised to heed this dictum and to avoid imposing this kind of geometry on a channelized stream.

Deposition of coarse detritus in the culverts further decreases the cross-sectional areas and further abets flood problems. This deposition occurs because of the constricted channel where it enters the culvert and because of sediment supply afforded by rip rap emplaced upstream for the purpose of erosion abatement.

On the downstream side of the culvert is another right-angle bend in the creek, and there, erosion is a problem. This erosion exacerbates slope instability, and a concrete apron has been emplaced to lessen this effect. Erosion, however, is undermining this concrete structure. This erosion occurs both because of the abrupt bend in the artificial channel and because of a local sediment deficiency owing to deposition immediately upstream at the head of the culvert. Erosion at this locality again demonstrates how a stream obeys Le Chatelier's Principle in reacting to absorb the effects of stresses.

STOP 7

East Riverside Apartment Complex Area

Several environmental geologic problems occur in the vicinity of East Riverside Drive as a result of intensive commercial and apartment development without regard for various natural constraints. As in other areas, the natural constraints tend to compound one another; in this instance there is a convergence of flood hazards both from the Colorado River and from local tributaries. Too, unstable slopes and expansive clays in the area pose many problems, particularly with construction and maintenance of buildings and roads. We mention these construction difficulties only in passing, since the main purpose of this trip is to view examples of problems related to urban hydrology. However, the claystone and marl that underlie this area (fig. 10) are very erodible, creating a terrain characterized by steep slopes and numerous small, intermittent water courses. These terrain conditions plus the impermeable substrate and soil ensure high runoff rates even in a natural unaltered setting. As already noted, urban development results in increased runoff for a given rainfall event, so that this kind of terrain is particularly susceptible to flooding from locally derived runoff.

Combined with the flood potential that results from normal development on a steeply sloping clay terrane is a classic blunder in street design. The natural drainage courses were largely ignored (and commonly destroyed by being filled or blocked) in the process of road and apartment construction. Worse, the streets were commonly

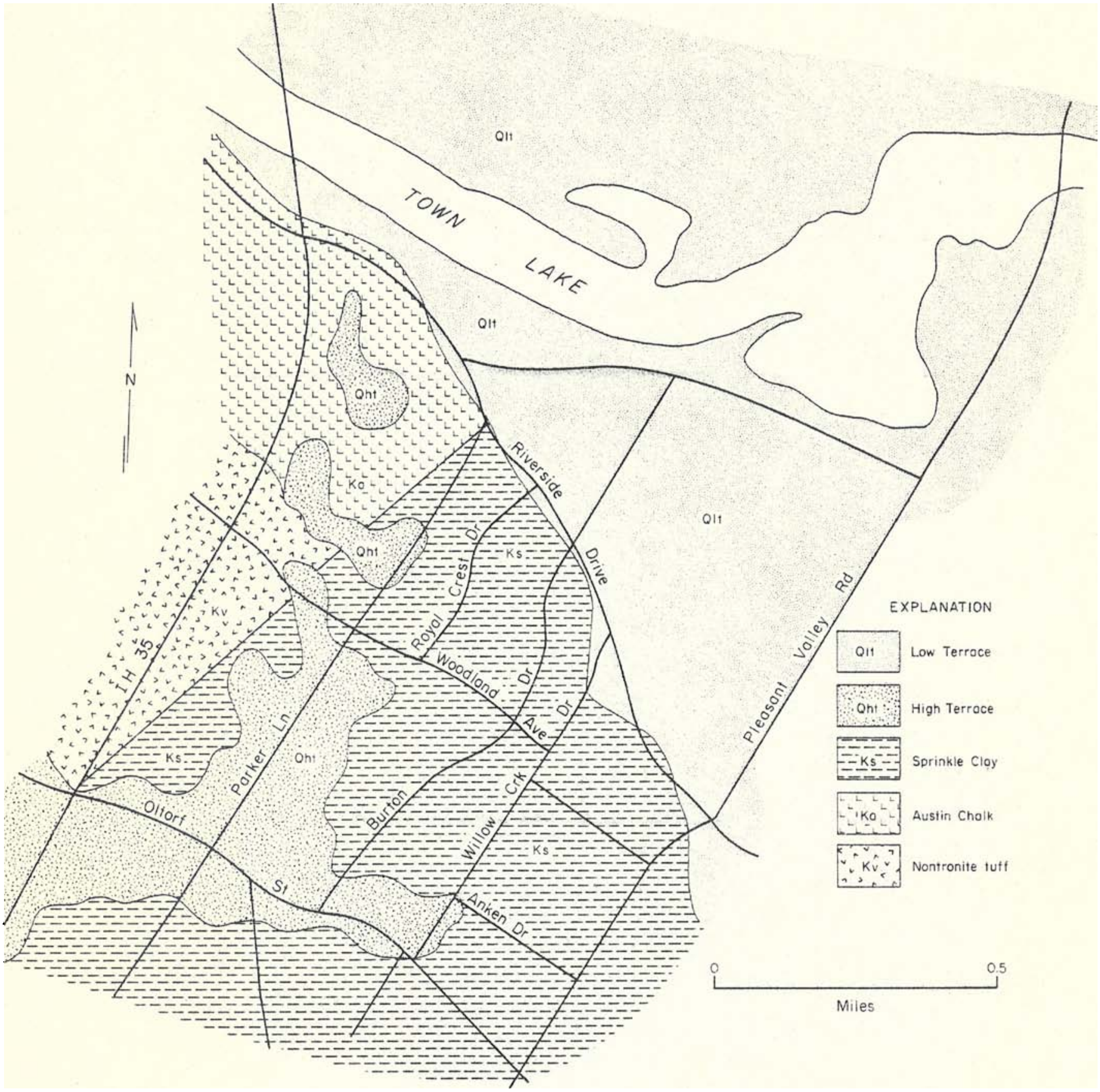

Figure 10. Geologic map of East Riverside apartment complex area.

constructed along the topographic lows that trend down the hillslopes (fig. 11). This means that streets were constructed within local drainage courses. Today, these streets--arteries to East Riverside Drive--coincide with intermittent streamcourses. The streets convey runoff from the impermeable pavement and clay terrane to the lowlands along the Colorado River. A flood hazard thus threatens not only motorists on these streets but also apartments and businesses occupying the flat (Colorado River) floodplain and terraces north of Riverside Drive. As development continues to spread across the Club Creek drainage basin (fig. 11), flooding in the lower reaches of these tributaries will be an increasing problem.

Flooding by the Colorado River along Town Lake is not generally considered a hazard in the Austin area because of the protection afforded by Mansfield Dam and other such structures upstream. Because this floodplain is declared officially "safe," development there is widespread. Austin High School occupies the geomorphic floodplain, as will the proposed Hyatt Hotel and the Austin American-Statesman building. However, a word of caution is needed; flood prevention provided by dams is not absolute. There are several sites where flooding might again occur along the Colorado River. A flood upstream from Mansfield Dam might exceed its flood-pool retention capacity. Furthermore, an intense localized storm might create a high magnitude flood below Mansfield Dam; this kind of event is what resulted in the devastating New Braunfels flood of 1972. In that instance a cloudburst dumped 16 inches of rainfall during a 2-hour period mainly within the 15 mi^2 watershed of Blieders Creek (Baker, 1975). The presence of the previously noted

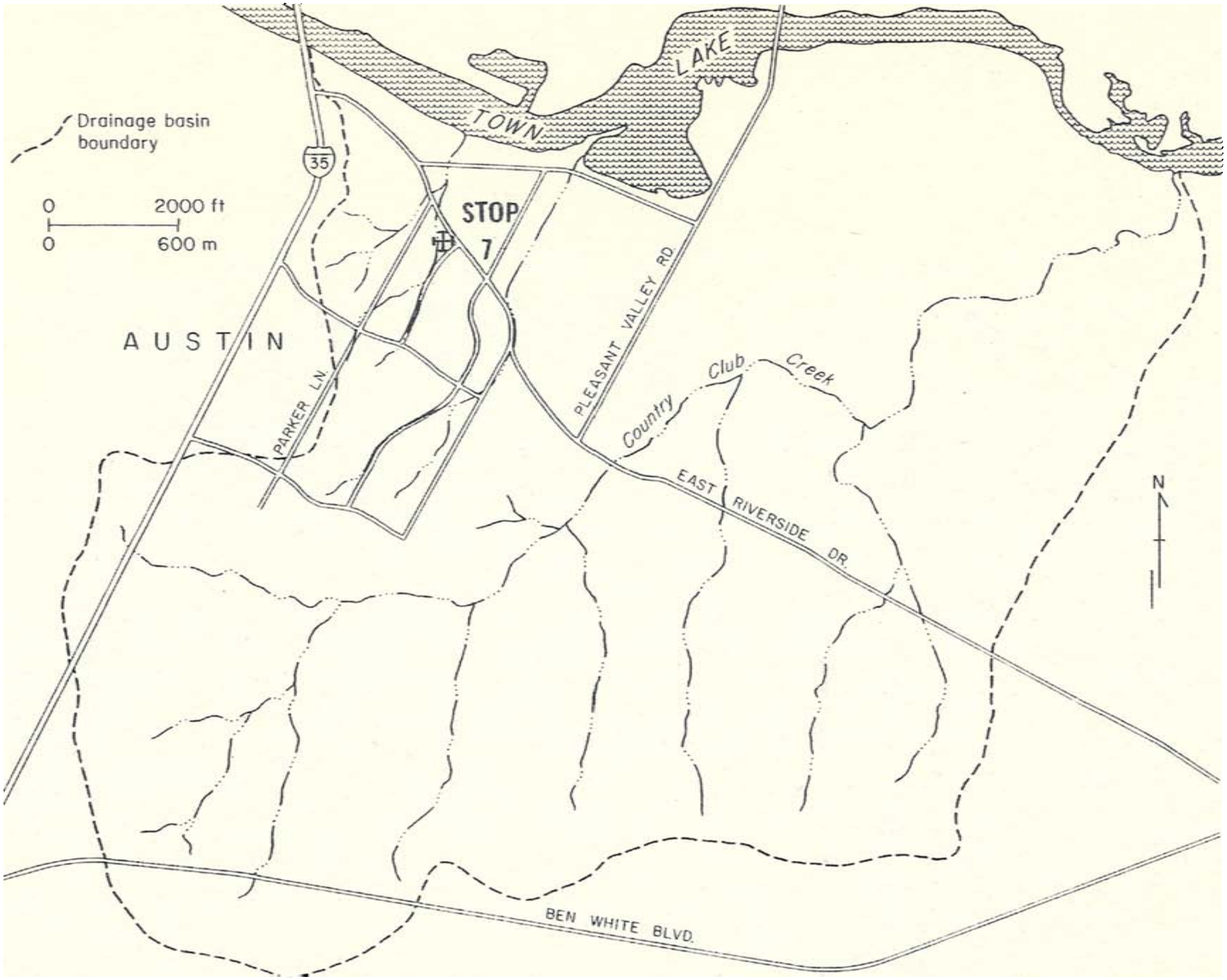

Figure 11. Location map for Stop 7 showing geometry of tributaries and of drainage basins in the East Riverside area.

"climatic hazard" along the Balcones Escarpment further adds to the menace of high-magnitude, low-frequency floods by the Colorado River in Austin. As pointed out by Leopold (1977), people need to be aware of the fact that flood prevention structures merely defer the flood events. Dams eliminate the low-magnitude, high-frequency (yearly) floods; they do not eliminate the long-term hazard resulting from extraordinary rainfall events.

In the East Riverside area, the geomorphic floodplain and terrace north of Riverside Drive is not included within the "100 year" floodplain designated by the U. S. Army Corps of Engineers. Yet this area was flooded by the Colorado River in 1869, 1935, and 1938 (fig. 12). Today, despite the upstream dams, the area still lies within the potential reach of infrequent, large-magnitude flood events, and it is faced with local flooding on an annual basis because of developments on the uplands constructed without regard to maintenance of adequate drainage systems.

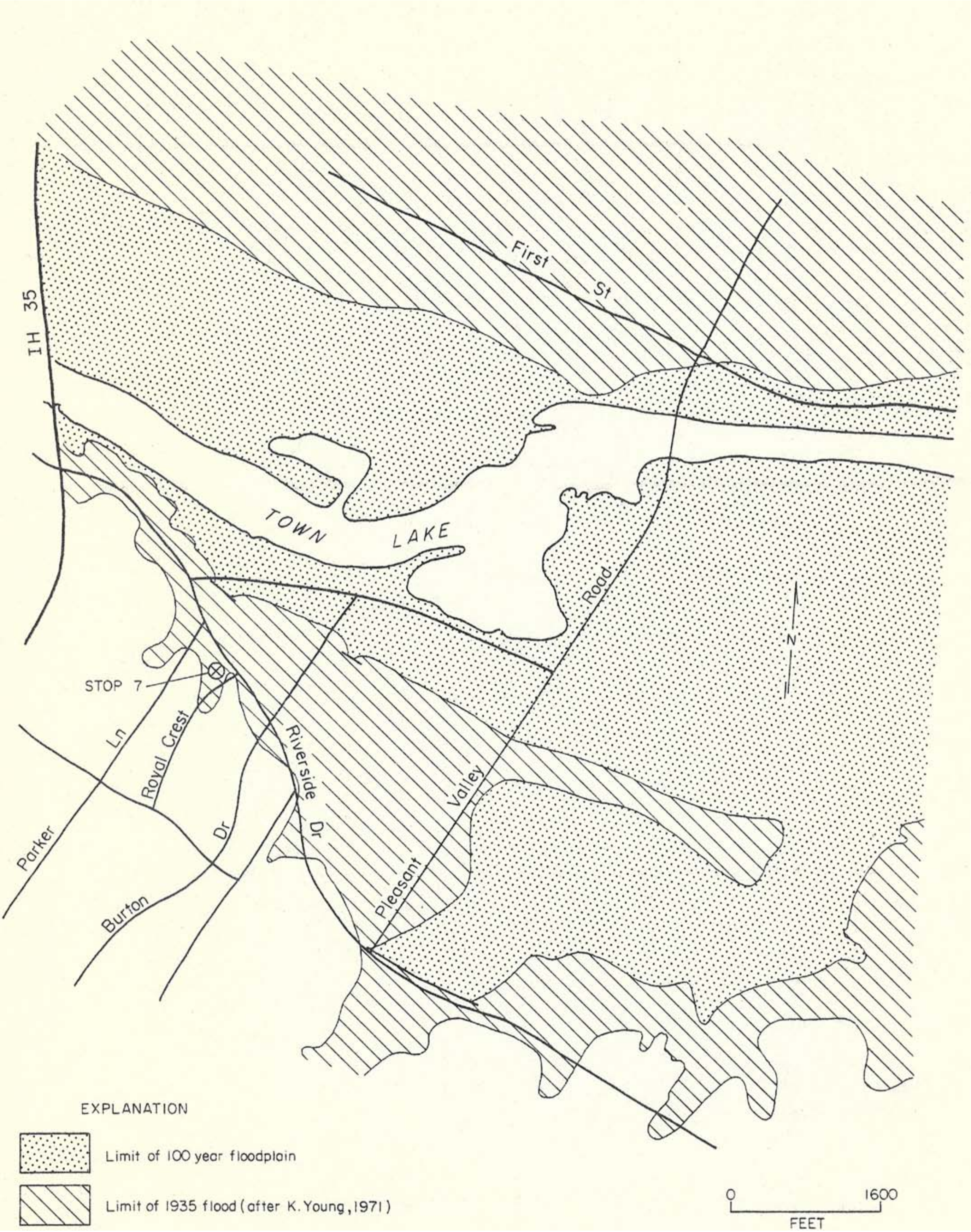

Figure 12. East Riverside area showing hazard zones for Colorado River flooding (modified from Baker, and others, 1973).

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APPENDIX

Road Log

mileage	
0	East Mall Circle, U.T. Campus next to Geology Building.
0.1	Turn left at San Jacinto.
0.2	Turn left at 24th; proceed to MOPAC.
1.8	Turn right onto MOPAC.
6.0	Cross Mt. Bonnell Fault; we have been traversing fault-bound mosaic of Del Rio Clay, Buda Limestone, and Eagle Ford Clay (*see* frontispiece); now we are on Edwards Limestone; note topographic escarpment along fault trace.
7.0	Turn right from Balcones Drive (MOPAC/under construction) onto Anderson Ln.
7.2	Turn right at Shoal Creek Blvd.
7.3	Turn left at Foster Ln.
7.4	STOP 1 After stop, turn around and return to Shoal Creek Blvd.
7.5	Turn left on Shoal Creek Blvd.; proceed to Northland Dr.
9.5	STOP 2 After stop, continue south on Shoal Creek Blvd.
11.6	Turn left at 38th St.; note Seiders Spring Park, part of the city's park/greenbelt system along creeks.
11.9	Turn right at Lamar Blvd.; proceed to Wooten Park.
12.9	Turn right on (unnamed) park cutoff to Gaston Ave.
12.9	STOP 3 After stop, proceed straight on park cutoff.
13.0	Turn right onto Lamar.
14.0	Turn left onto 15th St.
15.0	Turn right onto Red River St.
15.3	STOP 4 After stop, continue south on Red River.

15.8	Turn right onto East 6th St.
16.9	Turn left onto Lamar; proceed across Town Lake.
17.6	Turn right on Barton Springs Rd.; note unstable slope behind Exxon Station; Del Rio Clay periodically slumps creating a landslide of blocky Buda Limestone.
18.4	Turn left into Zilker Park and immediately turn left again into first parking area; proceed to northeast extremity of parking lot.
18.6	STOP 5 (Lunch) After stop, return to Barton Springs Rd.
18.9	Turn left on Barton Springs Rd.
19.4	Barton Springs Rd. becomes access road to MOPAC; note terrain and vegetation changes; we have crossed from Quaternary terrace deposits onto the Edwards Limestone.
19.8	Turn right onto Bee Cave Rd.; for the next 2 miles we will cross a mosaic of faults that mainly juxtapose various units of the Edwards Limestone.
22.0	Cross Mt. Bonnell Fault; here the Edwards Limestone is displaced downward against the Glen Rose Limestone (a stratigraphic displacement of approximately 700 ft); in other words, the equivalent stratum that we are traversing on the northwest (Glen Rose) side of the fault would be about 700 ft below ground immediately across the Mt. Bonnell Fault to the southeast.
23.6	Turn left onto Loop 360.
25.1	Cross Mt. Bonnell Fault again; this time from Glen Rose back to Edwards.
26.0 to 27.6	Note terrain to right; Barton Creek parallels Loop 360 at a distance of about 1,000 to 2,000 ft.
27.6	Cross Barton Creek.; note U.S. Geological Survey gage station housed on bridge.
28.3	Turn right onto U.S. 290/State Hwy. 71.
29.1	We are traversing a karstic (sinkhole) plain formed in the Edwards Limestone; note Tony Burger Athletic Field on left; it is constructed within large sink and thus has drainage problems.

29.8 Turn left on Brodie Ln.; here we cross a very gentle drainage divide between Barton Creek and Williamson Creek; local sinkholes indicate prevalence of subsurface infiltration rather than surface runoff in this area.

31.3 Turn left onto Wm. Cannon Dr.

32.1 Cross hillcrest that marks edge of Cherry Creek drainage basin (a sub-basin of Williamson Creek).

32.3 Turn left onto Westgate Blvd.

32.5 Turn right on Berkeley Ave.

32.5 STOP 6A
After stop return to Westgate Blvd.

32.6 Turn right at Westgate Blvd.

32.7 STOP 6B
After stop, proceed north on Westgate.

33.4 STOP 6C
After stop, proceed straight ahead on Westgate.

33.6 Turn right on Stassney Ln.

34.9 to
35.3 Minor detour; remain on Stassney Ln.

35.7 Turn left onto South 1st St.

36.0 Cross Williamson Creek; note Austin chalk in stream bed.

36.1 Cross Williamson Creek.
36.3 Cross Williamson Creek; note incised terrain ahead and houses on floodplain to our right on south side of creek.

37.2 Cross Ben White Blvd.

39.7 Turn right on Barton Springs Rd.

39.8 Turn right on Riverside Dr.; proceed east across IH-35.

41.6 Turn right on Royal Crest Dr.

41.7 STOP 7
After stop, proceed straight on Royal Crest.

41.9 Turn left at Woodland Ave.

42.1 Turn left onto Burton Dr.; note density of apartments to the right.

42.5	Turn left on Riverside Dr.
43.2	Turn left on IH-35.
45.0	Take 15th St. exit.
45.1	Turn left onto 15th St.
45.5	Turn right at Trinity St.
45.8	Intersect San Jacinto; proceed straight at Santa Rita, No. 1, the first discovery oil well on University lands (discovery made in Reagan County, Texas, May 28, 1923).
46.2	Left into East Mall Circle.
46.3	END OF TRIP