PHYSICAL ENVIRONMENT OF CAMP MABRY, AUSTIN, TEXAS

by

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prepared for

Texas Army National Guard

Funding provided by the Adjutant General's Department of Texas

under Letter of Agreement Number TX93-ED3-02 ENV244-D3

Bureau of Economic Geology

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Austin, Texas 78713-7508

June 1994

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INTRODUCTION

This report describes the physical attributes of Camp Mabry, in Austin, Texas, headquarters of Texas Army National Guard training. This is one of five reports completed on training sites; complementary reports describe training sites at Camp Bowie, Camp Swift, Fort Wolters, and King Ranch. The purpose of these five reports is to provide the natural physical data generally reported in an Environmental Assessment (EA) in conformity with the Environmental Protection Act and to present data applicable to an environmental training manual. The data are presented in text and maps; the maps show spatial layers that can be useful when a Geographic Information System (GIS) is later developed for training site management. Most of the data are collected from available sources in state and federal government reports and files.

PHYSICAL SETTING

Introduction

Camp Mabry is unique compared to other training facilities because it operates in a heavily populated urban area of northwest Austin (fig. 1). City streets generally bound the property. The rear boundaries of residential properties along Balcones Drive on the west and an exit road of the Missouri Pacific (MoPac) expressway on the east form the property limits oriented north-south. Other boundaries are 45th Street on the north and 35th Street on the south, oriented east-west. The adjacent properties are residential, except for the Austin State School and the Camp Ray Hubbard facility of the Texas Department of Transportation, which surround the southeast corner of Camp Mabry.

The area of Camp Mabry comprises 376 acres, of which 200 acres is available for training activities (Texas Adjutant General's office, personal communication, 1994). The site has

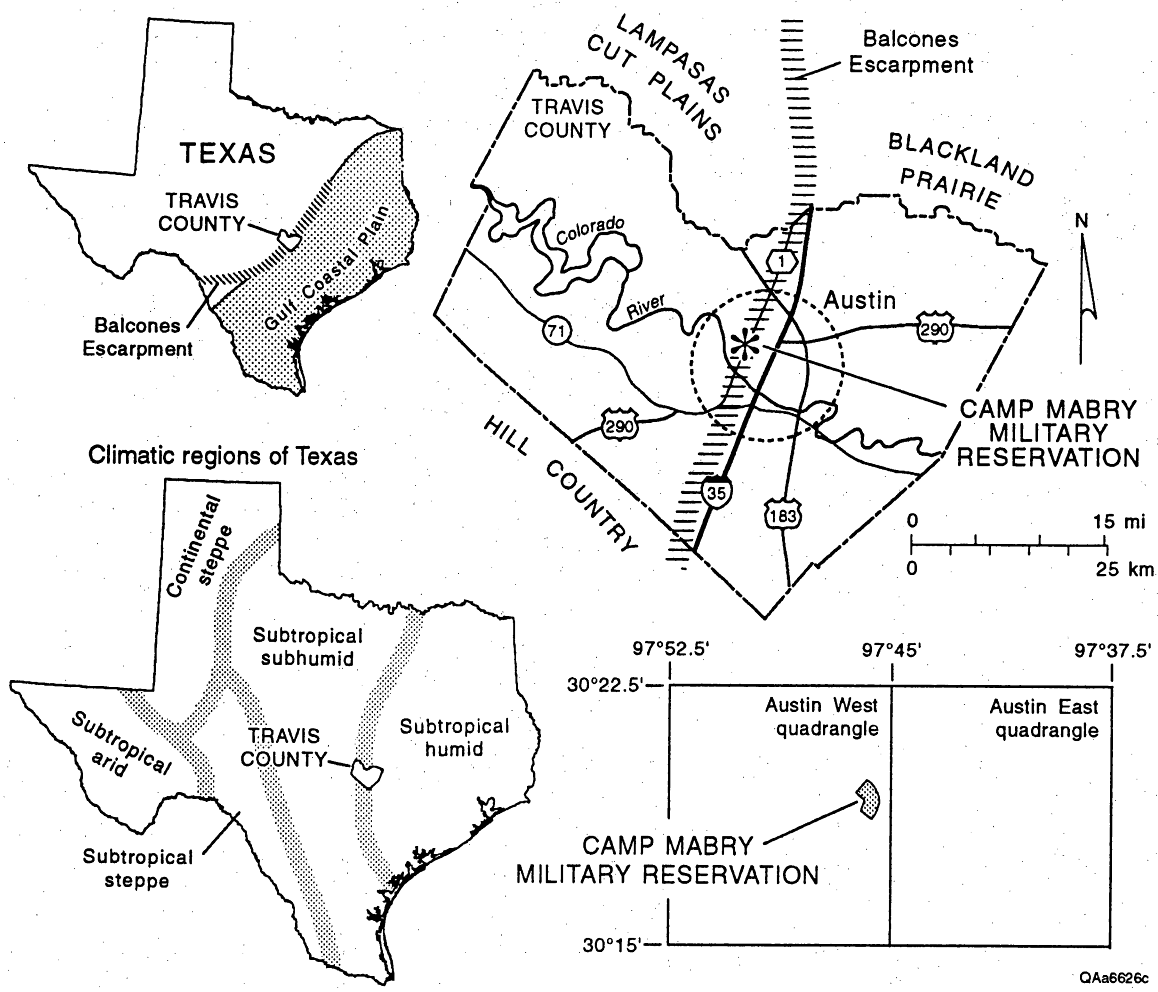

Figure 1. Index map of Travis County, Texas, showing major highways, ecological/physiographic provinces, and location of Camp Mabry. Insets show physiographic elements, climatic regions (after Larkin and Bomar, 1983), and 7.5-minute quadrangles containing the study area.

numerous buildings, including housing for 39 officers and 400 enlisted personnel, offices, maintenance facilities, storage, and indoor training.

Little natural area remains on site; most of the camp area has been cleared at least once, as is readily seen on an aerial photograph (pl. 1). More than 60 percent of the area is both landscaped and regularly mowed. Old and modern fills modify the natural slopes. Natural areas are riparian strips along streams flowing across the camp in the northwest third and southwest corner of the property. In the northwest third of the property, a heavy second growth of large trees occupies east-sloping hillsides. In landscaped areas, large live oak trees remain common on the site and have grown unnaturally large from access to constant water supply and applied fertilizers.

Climate

The climate in Austin is subtropical, subhumid (table 1). Austin experiences large ranges in temperature. Average high temperatures are 91.6°F in June, 95.4°F in July, and 95.3°F in August (fig. 2). The hottest day in Austin was July 6, 1954, when the temperature reached 109°F; this occurred during a severe drought. In 1963 the temperature exceeded or equaled 100°F for 40 days; the average is 12 days. The most severe winter in Austin was 1939–40 and produced 44 days of temperatures at or below 32°F. In the same year there were 14 consecutive days of freezing. The coldest recorded temperature in Austin was –2° in 1949.

Winds at Camp Mabry are recorded at Robert Mueller Airport in Austin (fig. 3, app. A). Southerly and southeasterly winds dominate the weather from March through August. Southerly and northerly winds are nearly equally represented from September until February. Winds exceeding 21 m.p.h. are more common from northers than from other storm fronts.

The average annual rainfall in Austin is about 32 inches (fig. 4, app. B). The smallest annual rainfall was 11.4 inches in 1954; the greatest annual rainfall was 52.3 inches in 1992. The wettest months are generally May and September, and the driest months are January and July.

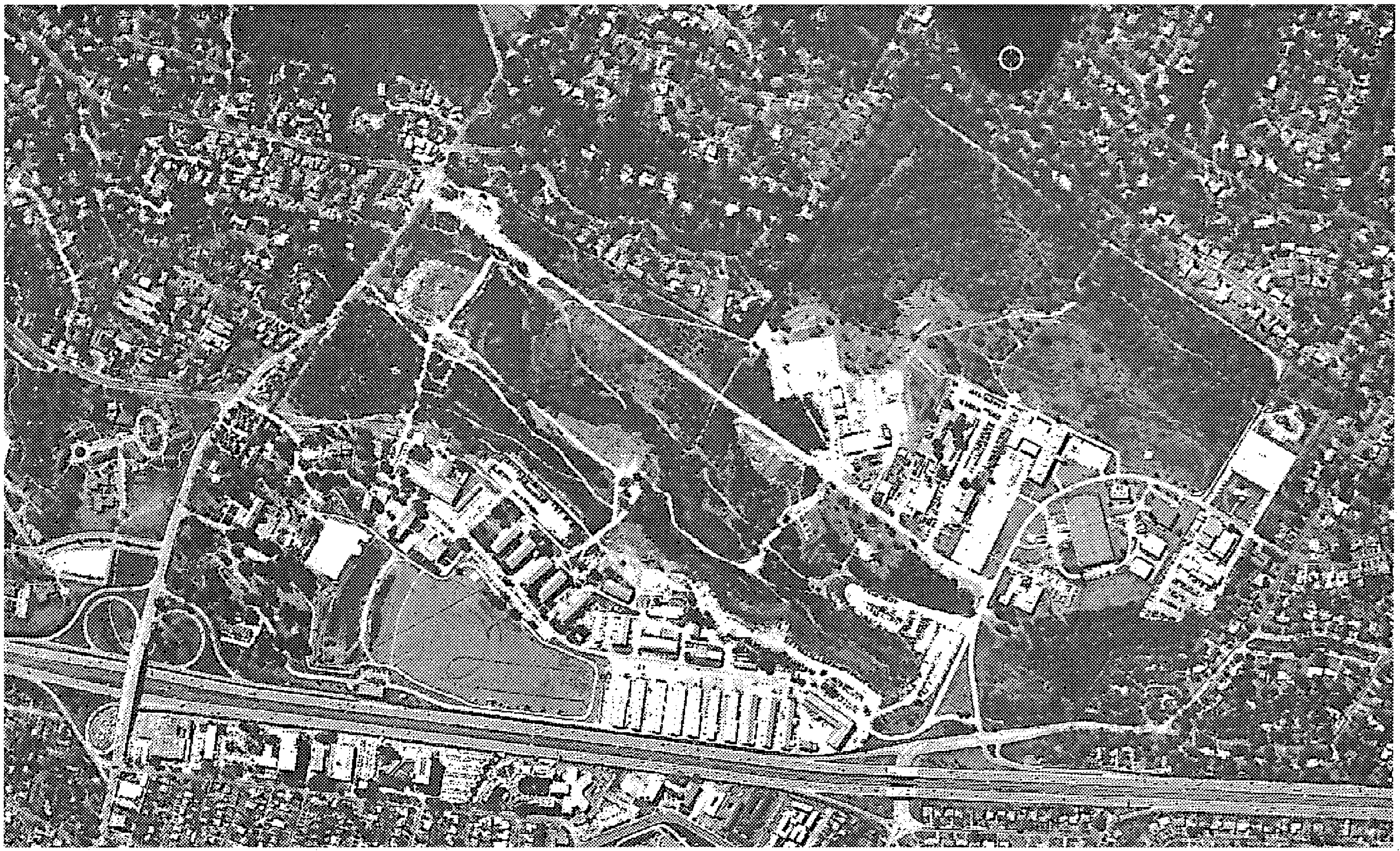

Plate 1. Aerial photograph of Camp Mabry. Concentrations of tall trees are most prominent on the northwestern property line boundary and in the easternmost drainage.

Table 1. Climatic statistics for Camp Mabry area, Texas.

Month	Average amount of sunshine (percent of possible amount)[1]	Average monthly temperatures (°F)[2]		Average number of freezes[3]	Average number of days ≥100 °F[4]	Average monthly precipitation (inches)[5]	Average monthly gross lake surface evaporation rate (inches)[6]	Average relative humidity (percent)[7]				Average wind direction and speed (mph)[8]	Average number of cold fronts[9]	Average number of days with various sky conditions[10]		
		Low	High					6 a.m.	12 p.m.	6 p.m.	12 a.m.			Clear	Partly cloudy	Cloudy
January	48	38.8	59.4	9	0	1.60	2.4	79	61	58	73	S 10	6	9	6	16
February	52	42.2	64.1	5	0	2.49	2.6									
March	55	49.3	71.7	1	0	1.68	3.6									
April	53	58.3	79.0	0	0	3.11	4.3	83	58	54	76	SSE 11	8	8	7	15
May	57	65.1	84.7	0	0	4.19	5.3									
June	70	71.5	91.6	0	1	3.06	7.0									
July	76	73.9	95.4	0	4	1.89	9.0	87	50	46	74	S 8	2	11	14	6
August	75	73.7	95.3	0	6	2.24	9.0									
September	67	69.1	89.3	0	<1	3.60	7.0									
October	66	58.7	80.8	0	0	3.38	5.7	83	54	53	75	S 8	5	13	9	9
November	57	48.1	69.2	1	0	2.20	3.9									
December	51	41.4	62.8	5	0	2.06	2.9									

Average annual low temperature[2]	57.5°F	Coldest observed temperature[11]	-2°F (January 31, 1949)
Average annual high temperature[2]	78.6°F	Hottest observed temperature[11]	109°F (July 26, 1954)
Average annual temperature[2]	68.5°F		
Average annual precipitation[5]	31.5 inches		
Average annual gross lake surface evaporation rate[6]	63.0 inches		

Notes:

[1] Average amount of sunshine at Robert Mueller Municipal Airport in Austin, Texas, 1942–1980, from U.S. Department of Commerce data summarized in Bomar (1983, table F-7).

[2] Average temperatures at Robert Mueller Municipal Airport in Austin, Texas, 1951–1980, from Bomar (1983, tables B-5 and B-7). Average monthly low temperature is average of daily minimum temperatures for the month; average monthly high temperature is average of daily maximum temperatures for the month. Average annual low temperature is average of monthly lows for the year; average annual high temperature is average of monthly highs for the year; average annual temperature is average of annual low and high temperatures. Original data from National Weather Service and Cooperative Observer Network.

[3] Average number of freezes per month at Robert Mueller Municipal Airport in Austin, Texas, 1951–1980, from Bomar (1983, table B-2).

[4] Average number of days per month with temperature 100°F or greater, at Robert Mueller Municipal Airport in Austin, Texas, 1951–1980, from Bomar (1983, table B-9).

[5] Average precipitation at Robert Mueller Municipal Airport in Austin, Texas, 1951–1980, from Bomar (1983, table C-2). Data from Cooperative Observer Network of the National Weather Service.

[6] Gross lake surface evaporation rates in Austin area, 1951–1980, estimated from contour maps in Larkin and Bomar (1983, p. 51–56). Data from Texas Department of Water Resources Surface Water Data Unit.

[7] Average relative humidity at Robert Mueller Municipal Airport in Austin, Texas, 1962–1980, from U.S. Department of Commerce data summarized in Bomar (1983, table F-4).

[8] Average wind speed and direction at Robert Mueller Municipal Airport in Austin, Texas, for approximately 20-year period ending in 1980, from U.S. Department of Commerce data summarized in Bomar (1983, table F-2).

[9] Average number of cold fronts passing Robert Mueller Municipal Airport in Austin, Texas, 1961–1970, from Illinois State Water Survey data summarized in Bomar (1983, table F-5).

[10] Average number of days with various sky conditions at Robert Mueller Municipal Airport in Austin, Texas, 1942–1980, from U.S. Department of Commerce data summarized in Bomar (1983, table F-6).

[11] Information from Bomar (1983, table B-6).

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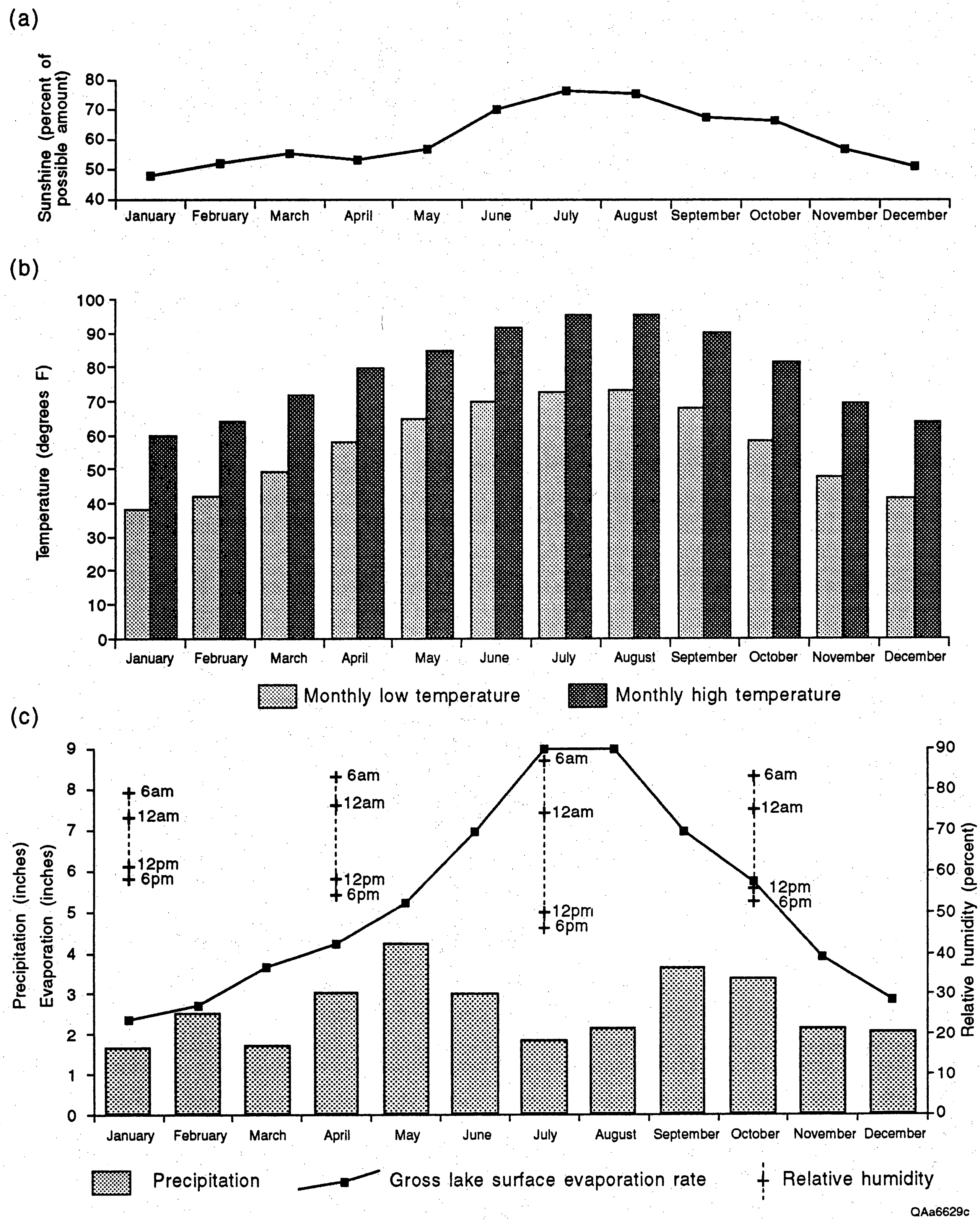

Figure 2. Climatic trends in the Camp Mabry area, Austin, Texas: (a) average amount of sunshine (1942–1980); (b) average monthly low and high temperatures (1951–1980); and (c) average monthly precipitation (1951–1980), average gross lake-surface evaporation rate (1950–1979), and average relative humidity (at 6 a.m., 12 p.m., 6 p.m., and 12 a.m., 1962–1980; see table 1 for data and sources).

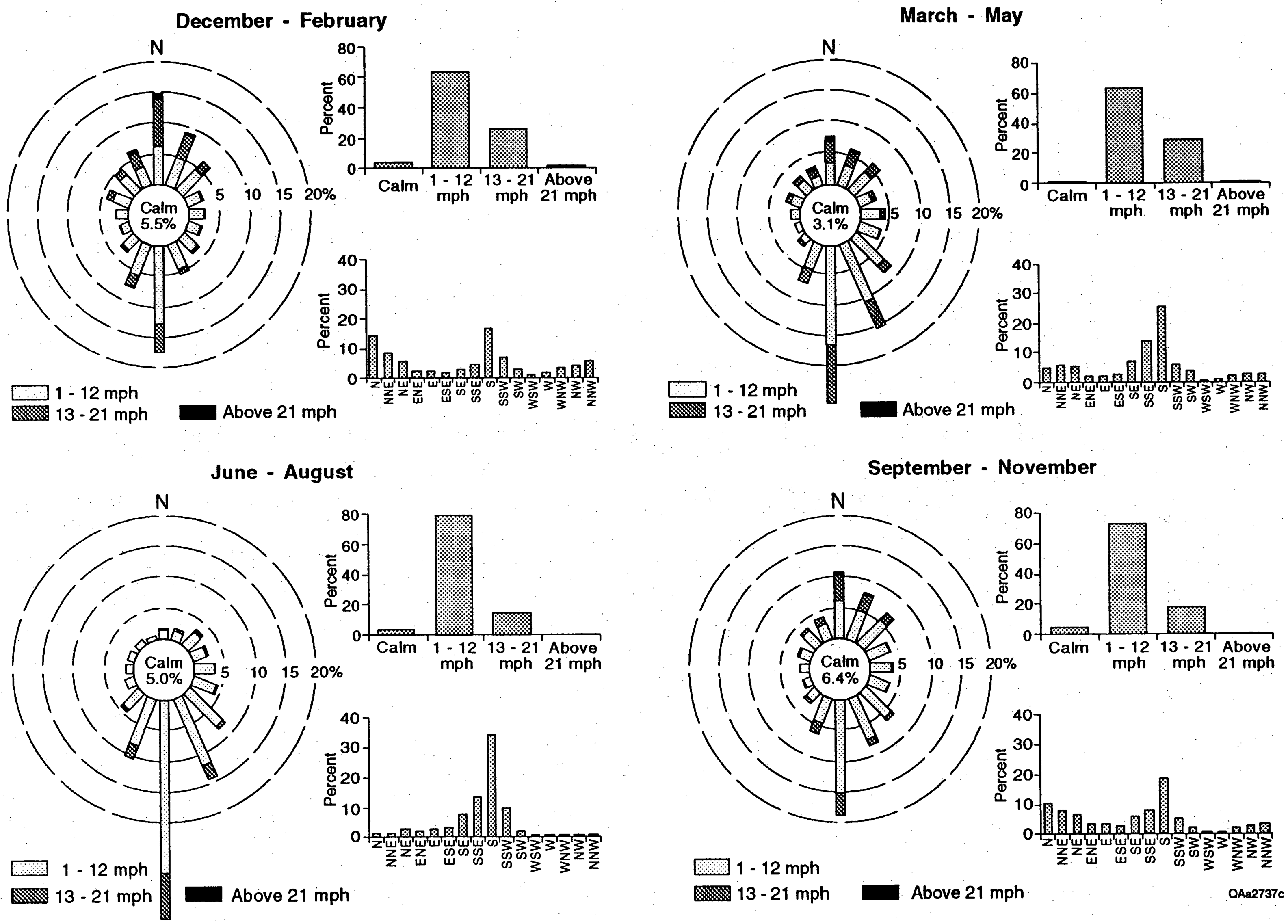

Figure 3. Graphs of average wind direction and speed at Robert Mueller Airport in Austin, 1961–1980. Arms of wind roses point in the direction from which the wind blows: for example, in the plot for December–February, the darkly shaded area on the arm pointing due south indicates that approximately 5 percent of the time the wind blew from the south at speeds between 13 and 21 m.p.h. Data for these diagrams are given in appendix A; modified from plots presented in Larkin and Bomar (1983, p. 67–68 and 78–81). Bar diagrams beside each circular diagram indicate percentage of all winds by ranges of speed and direction. Wind speeds of 13 m.p.h. and greater are capable of raising dust.

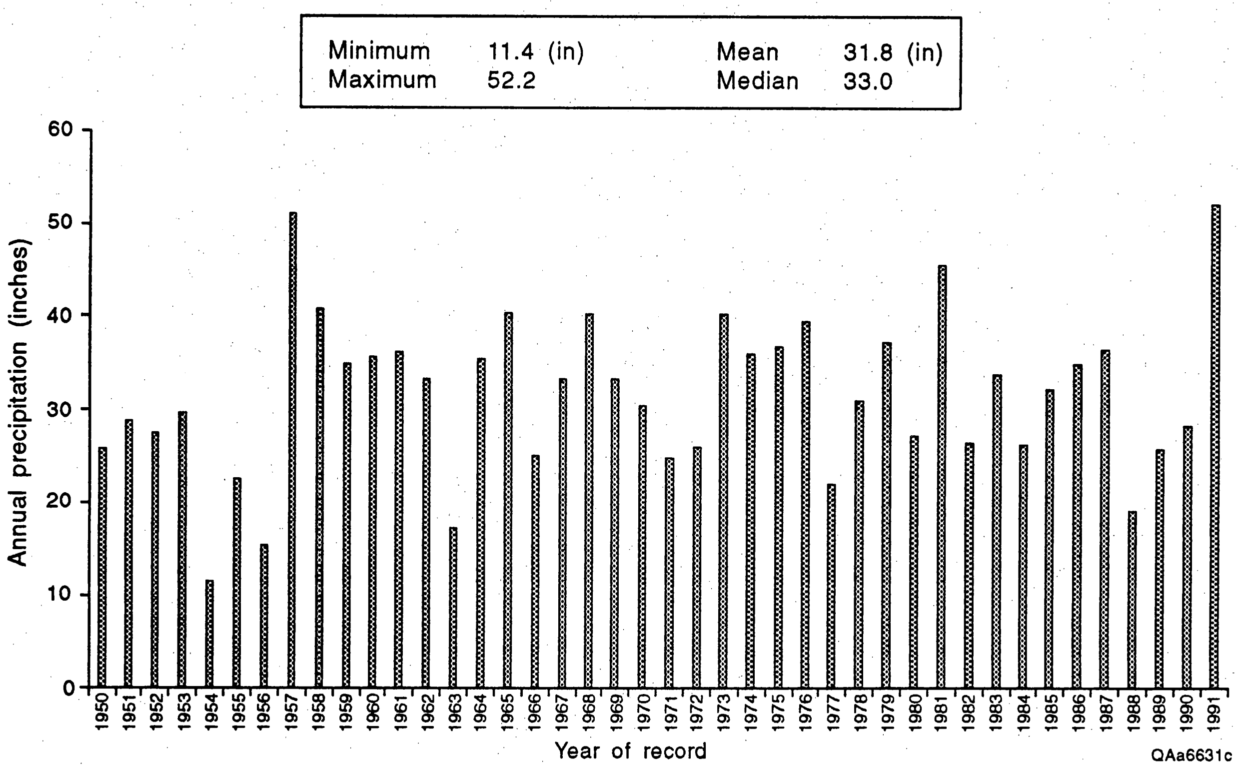

Figure 4. Bar chart of annual precipitation recorded at Robert Mueller Airport in Austin 1950–1991, with summary statistics; see appendix for data and source. Average annual precipitation in Austin for 1950–1991 was 31.8 inches (compare with 31.5 inches for 1951–1980, listed in table 1).

Austin and Camp Mabry are subject to intense rains because of the orographic effect of the Balcones Escarpment. Thunderheads (cumulonimbus clouds) may become relatively stationary above the escarpment, allowing many inches of rainfall on a small area in a short time. An illustrative event occurred on Memorial Day, 1981, when nearly 11 inches of rain fell in 4 hours, principally on the saturated Shoal Creek drainage basin, and caused flooding that took 13 lives. The same vicinity can also have excessively long dry spells, as exemplified by 65 days without rain in 1993.

Terrain

The intersection of the Upper Coastal Plain, the Blackland Prairie, with the Edwards Plateau nearly bisects the city of Austin. Typical of the Coastal Plain are the low rolling hills east of Interstate 35. The Edwards Plateau is locally typified by the terrain along U.S. Highway 183 between Texas Highway 360, Capital of Texas Highway, and the city of Leander. At the junction of the Coastal Plain and the Edwards Plateau is a dissected slope called the Balcones Escarpment; its relationship to faults is described later. The Camp Mabry terrain is part of the dissected fault escarpment similar to many areas of the Texas "Hill Country," but the relief is considerably less.

Just west of Camp Mabry, Mount Bonnell is one of the highest locations in Austin, at an elevation of 785 ft. Below Mount Bonnell, the elevation of the dammed Colorado River (Lake Austin) is slightly less than 500 ft. The USGS Austin West 7.5-minute topographic quadrangle, mapped in 1954, shows the highest point on Camp Mabry to be slightly above 700 ft (fig. 5). The high point is located in the northwestern property block. The lowest point is approximately 530 ft, where an intermittent stream exits the training site at 35th Street. Relief on the training site is about 170 ft. The terrain is rolling to hilly in the western part where the major faults are more frequent. Steepest slopes (> 20 percent) occur in the west-side valley walls of the easternmost drainage basin. A relatively flat area (<2 percent slope) occurs on the

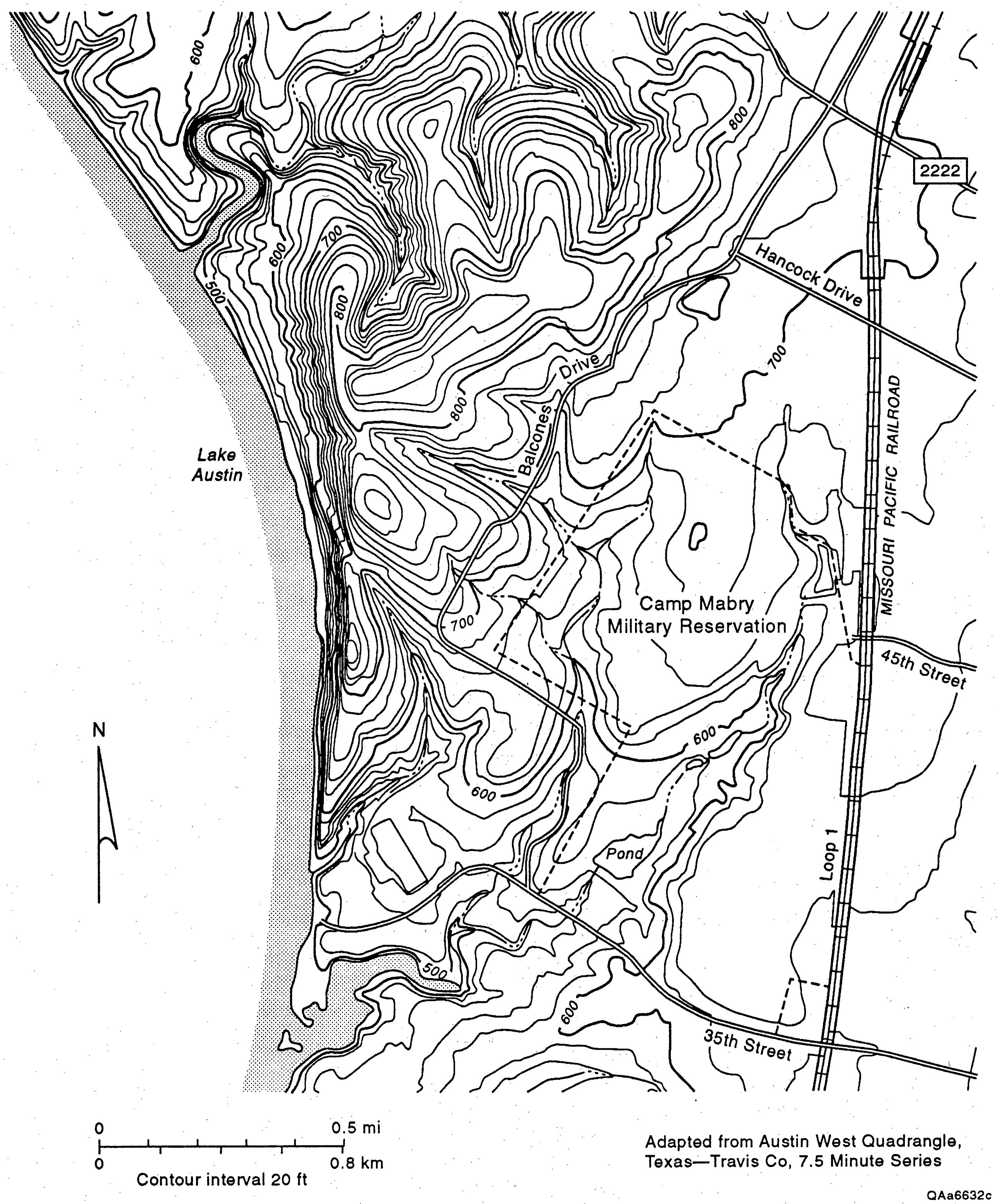

Figure 5. Terrain of the Camp Mabry vicinity, extracted for the Austin West, Texas, 7.5-minute topographic quadrangle, U.S. Geological Survey (1954). The contour interval is 20 ft. The property boundaries of the Camp Mabry Military Reservation National Guard are shown by the fine dash-dot lines.

parade ground/athletic field nearly encircled by the 640-ft contour near Texas Loop 1 (MoPac expressway). Intersecting faults bound this flat area. The USGS topographic quadrangle, constructed from 1954 photogrammetry, does not account for numerous fills and grading put in place by the Texas Army National Guard to level ground for construction of buildings and parking areas.

Surface Hydrology

The principal drainage at the Camp Mabry training site is an unnamed southwestward-flowing intermittent stream (fig. 6). Its uppermost drainage heads above Highland Park School near the intersection of Northland Road and Balcones Drive. The narrow southwestward-flowing drainage basin comprises slightly more than 1 mi^2. The drainage divide on the west is relatively high; much of it lies above 800 ft, including Mount Barker. On the other hand, the easternmost basin divide is comparatively low, about 650 ft. The westernmost divide isolates Dry Creek basin, and the easternmost divide separates Shoal Creek drainage, one of the flashiest, floodprone streams in Austin. Three check dams on Camp Mabry create ponds; the southernmost pond is the largest and permanently contains water. Below the pond, this principal drainage flows into an estuary of Lake Austin near Laguna Gloria Art Museum.

The principal drainage has a western tributary that joins the main drainage at the small Lake Austin estuary near Laguna Gloria and is an ephemeral valley. This valley or draw orients parallel to the west boundaries of Camp Mabry and flows north to south from just inside the west boundary to just outside the west boundary at 35th Street. This valley collects water flowing off the upthrown block of the Mount Bonnell Fault scarp, which forms a very high western divide, including Mount Barker. It is a small drainage basin of about 0.7 mi^2.

No stream gauges have measured discharges from the two streams. The spill points where the streams discharge from Camp Mabry on 35th Street are above the 100-year floodplain of the Colorado River.

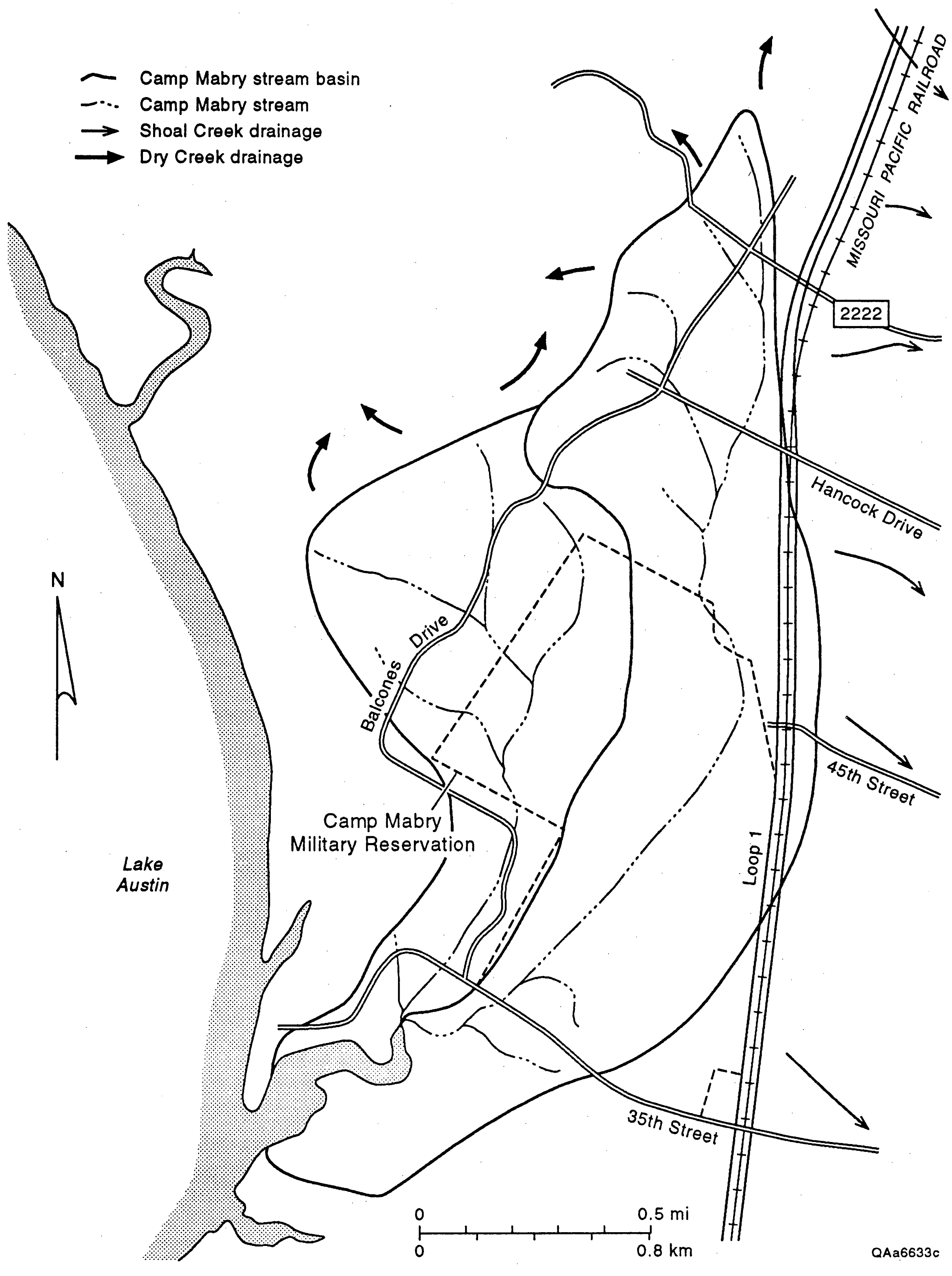

Figure 6. Stream basins and streams that drain Camp Mabry. Topography is from the U.S. Geological Survey Austin West quadrangle. All streams related to Camp Mabry are intermittent. Also shown are streams that flow from the divides to Dry Creek on the west and Shoal Creek on the east.

AREAL GEOLOGY

Camp Mabry is located in a complex down-dropped block of the Balcones Fault Zone. The surface stratigraphy is difficult to map because (1) most of the area has been landscaped and planted at one time or another, (2) numerous faults checkerboard the training site (as mapped by Rodda and others, 1970), and (3) Camp Mabry slopes are generally slight and soil covered, leaving few outcrops of bare rock, except in the principal stream.

Stratigraphy

Six formations crop out in the fault blocks located on Camp Mabry (fig. 7). The formations are, oldest to youngest, the upper member of the Edwards Limestone (member 4), the Georgetown Formation, the Del Rio Clay, the Buda Formation, the Eagle Ford Group, and the Atco Formation of the Austin Group.

Informal member 4 of the Edwards Formation is 40 ft thick and consists mostly of gray to tan, micritic, thin- to thick-bedded limestone, dolomitic limestone, and dolomite. This formation crops out along 35th Street in the two stream valleys west of the Adjutant General's Headquarters (fig. 7). There is no sharp contact with the overlying formation. This member of the Edwards Formation is relatively resistant to weathering, solution, and erosion. The upper beds contain fossil oysters where exposed in the creek south of 35th Street.

The Georgetown Formation is the next youngest unit. It crops out in the three southwest-flowing stream valleys that cross 35th Street. Thin interbeds of gray to tan, nodular-weathering, hard, fine-grained limestone, marly limestone and marl contain abundant fossil shells. The formation supports vegetation typical of limestone terrane: live oaks and especially abundant juniper. Natural slopes are stable. The formation is difficult to excavate, commonly requiring blasting. For construction, the unit forms a stable foundation, but its low infiltration capacity is poor for septic tanks.

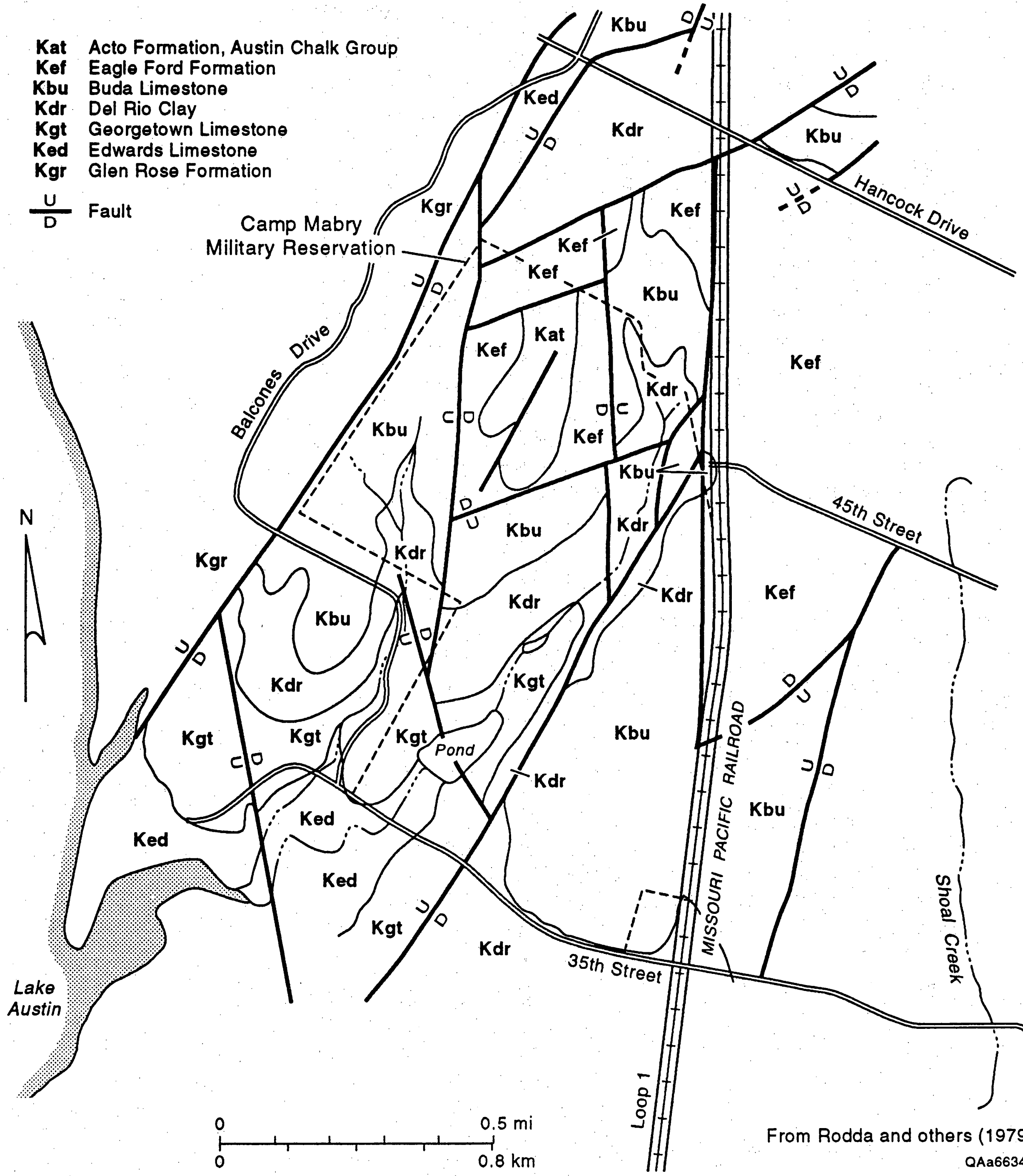

Figure 7. Areal geology of the Camp Mabry vicinity, from Rodda and others (1979). Faults are shown by the bold lines carrying the U (upthrown block) and D (downthrown block) symbols. On Camp Mabry, the outcropping formations, oldest to youngest, are Edwards, Ked; Georgetown, Kgt; Del Rio, Kdg; Buda, Kbu; Eagle Ford, Kef; and Atco (Austin), Kat.

The Del Rio Clay overlies the Georgetown Formation and is well represented on Camp Mabry (fig. 7). The clays underlie valley slopes along both the southward-flowing streams. Dark gray to light brown, gypsiferous, pyritic clays comprise these strata. One rarely sees the clays in outcrop because the unstable strata rapidly slump and slide upon exposure. The clays develop gentle to moderate slopes, where not capped by the overlying Buda Limestone. Del Rio clays have a high plasticity index and low bearing capacity and high shrink-swell properties. The unit has low infiltration capacity and behaves as an aquiclude, sometimes perching water beneath limestones. Large blocks of the overlying, jointed limestone can become dangerously unstable, detach, and slide downslope.

The Buda Limestone, which overlies the Del Rio Clay, is the principal subcrop below the athletic field/parade ground and the surrounding buildings. This limestone formation also underlies most of western Camp Mabry. Gray to tan, hard, fine-grained, glauconitic limestone frequently contains shell fragments and is generally strongly jointed. The lower part is somewhat less resistant than the upper part and weathers into nodular structures. In outcrop fresh surfaces are yellowish to pink. Live oak, juniper, and elm commonly grow on this formation. The Buda Limestone commonly forms steep, clifflike faces where the underlying Del Rio clays are not exposed. The bearing capacity also depends on its separation from the Del Rio; as limestone thickness decreases, bearing strength decreases. Infiltration capacity is low, and there is generally inadequate absorption of septic-tank effluent.

The next higher formation is the Eagle Ford Formation; it underlies much of northwestern Camp Mabry (fig. 7). The upper part is dark gray clay; the middle part consists of thin interbeds of sandy and flaggy limestone, chalk, clay, and bentonite; and the lower part is mostly dark gray calcareous clay. The formation generally forms grassy, low-relief areas with few native trees. Low to moderate slope stability decreases with increased moisture content. The bearing capacity of this formation is generally low, and local areas have high shrink-swell properties. Low to moderate infiltration capacities permit moderately successful installations of septic tanks.

The youngest formation cropping out on Camp Mabry is the Atco Formation of the Austin Chalk Group. The Atco Formation is a crops out in a small area occupying the highest elevations of Camp Mabry on the curve of the road south of the residential part of the camp. Gray to white, thin- to thick-bedded, massive to slightly nodular, fine-grained limestone, marly limestone, and chalk comprise the lithologic types. High slope stability reflects the need to use heavy equipment to rip or excavate this formation. Bearing capacity is high, and septic-tank effluents are moderately well absorbed, mainly related to density of fractures.

Structural Geology

Camp Mabry is located east of and adjacent to the escarpment that identifies the Balcones Fault Zone. The Balcones Fault Zone is the major fault system in Central Texas between Del Rio and Waco. It is composed of a series of down-to-the-coast en echelon faults. The fault system has controlled settlement patterns and much Texas history, because numerous perennial springs in its escarpment supply local potable water.

The Mount Bonnell Fault is immediately west of the Camp Mabry northwest property line and is the major fault of the Balcones Fault Zone in the Austin vicinity (fig. 7). Near Camp Mabry the Mount Bonnell Fault separates the high-relief terrain including Mount Bonnell and Mount Barker from the moderate-relief terrain of Camp Mabry. The same fault separates older rock units including the Glen Rose and basal Edwards Formations from a younger rock sequence including uppermost Edwards to Austin Formations on Camp Mabry (fig. 7).

Camp Mabry is situated on the eastern down-dropped fault block of the Mount Bonnell Fault. In this block, Garner and Young (1976) mapped three other down-to-the-east faults that trend almost due north and transect the training site (fig. 7). The easternmost of these faults trends parallel to the MoPac railroad and nearly lies on the Camp Mabry east property boundary. Blocks between the three faults are cut in a checkerboard pattern by three complementary faults that strike slightly north of east. Several other minor normal faults are also present. None of the faults on Camp Mabry has been active for a long geologic time, but they determine the local distribution of bedrock and soils present. Relative movements of the faults have produced a synclinal fold in this fault block.

The Balcones Fault System is more than 5 million years old and of Miocene age, according to Garner and Young (1976). No post-Miocene fault movement has been documented. The significance of the faults is the manner in which they juxtapose different rock units, and therefore soils, against one another. One side of a fault may pose engineering properties different from those of the adjacent fault block. Also, they produce stratigraphic control for the movement of ground water, as well as defining solution passages for caves transporting ground water.

SOILS

Camp Mabry soils reflect the calcareous bedrocks that dominate the vicinity and are represented by the Tarrant-Brackett-Denton soil association (Godfrey and others, 1973). This association includes shallow, stony to gravelly clay soils, shallow loamy soils, and deep-cracking clay soils.

The principal soils units are Austin, Brackett, and Volente, with minor representation by Tarrant soils (Werchan and others, 1974). All the mapped soils have three-letter symbols in which U (fig. 8) indicates urban soils; the connotation is strongest where U is a prefix. The distribution of the soils is shown in figure 8.

Austin soils underlie about 60 percent of Camp Mabry. The Austin soils are moderately deep, well-drained, silty clay soils underlain by fractured chalk. Most of these soils occur in moderately rolling to gently sloping terrain. The Austin soils developed under a prairie grass vegetation with varied height. They do not form rich topsoils in many regions, although Austin soils are locally plowed and farmed for cotton. The soils provide difficult construction sites because high shrink-swell properties are ubiquitous. Low permeability adds to problems in

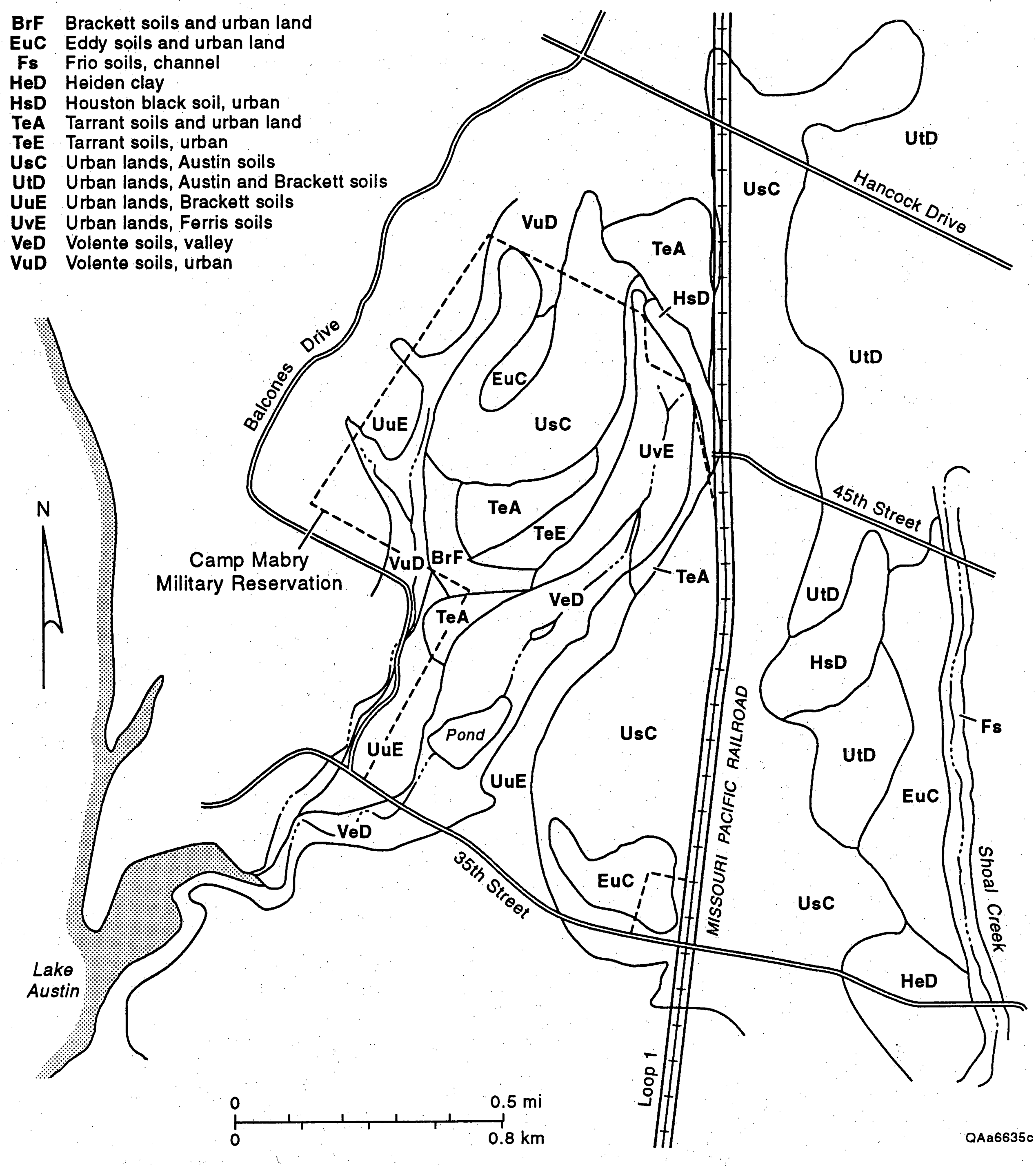

Figure 8. Soils in the Camp Mabry vicinity. Note that most of the soils have an urban modifier for their map symbol, reflective of the urban location of Camp Mabry.

septic fields and for irrigation, as does moderate corrosivity to metals. During very dry weather cycles, extremely deep cracking also causes problems.

The Brackett soils appear most commonly where valley walls flatten onto a shoulderlike terrain. The Brackett soils are stony clays commonly underlain by limestones and marls; they occupy large areas of undulating to steep topography on relatively steep slopes. The surface layer is commonly a gravelly clay loam that fines rapidly downward where mature. They make poor topsoils because of excessive rock content, but that same rock content is useful for natural construction materials. Trafficability is moderately good in rolling terrain. This soil also has high shrink-swell potential and low permeability that make for poor performance by septic-tank filter fields and by irrigation on level terrains.

Volente soils are most prominent in the principal drainages for Camp Mabry and in the valley immediately west of the property line, along the Mount Bonnell Fault much of the way. The Volente series consists of deep well-drained soils that develop on slope alluvium. The upper layer is generally a dark brown, grayish, silty clay loam. The total soil package (solem) is relatively thick, up to 6 ft. Volente soils are moderately permeable and maintain high moisture contents. High shrink-swell properties accompanied by low permeability and slow infiltration negatively affect use of septic tanks.

There are only two small patches of Tarrant soils that occur on the divide between the two western drainages of Camp Mabry. Tarrant soils are thin, well-drained stony clay loams overlying limestone. They occupy nearly level to gently sloping ridges; slopes are frequently complex. The upper soil does not exceed 8 inches in thickness; the underlying subsoil is little more than 1 ft thick, and it contains abundant rock fragments. Because Tarrant soils contain abundant rock fragments, often more than 50 percent by volume, and grade rapidly into shallow bedrock, their capability to support large engineering projects is commonly limited.

The Eddy soil forms over chalk, and one small patch of the Eddy gravelly loam occurs on the high knoll in the northwest third of the camp. The Eddy soil represents less than 5 percent of Camp Mabry soil series.

Although the relatively strong expansive soil properties will limit uses of these above soils, they are generally stable when undisturbed. Camp Mabry is fortunate in having only a small strip of Houston black clay in the northeast corner of the site (fig. 8). Houston black clay is a vertisol, strongly plastic and unstable on even modest slopes. Houston black clay and the similar Heiden clay and vertisol are common just east of the training site in Shoal Creek drainage where that soil forms on the Del Rio Clay. Within Shoal Creek bottomland the Frio loam is present in a very narrow strip alongside the channel (fig. 8).

GROUND-WATER HYDROLOGY

In Travis County and the Camp Mabry vicinity, the strata dip gently southeast, with some exceptions caused by the major faults of the Balcones Fault Zone. Faults, fractures, and the topography control ground-water storage and movement. Ground water flows generally southeast or toward the Colorado River.

Hydrostratigraphic Units

The oldest and deepest productive hydrostratigraphic units in Travis County are the lower, middle, and upper Trinity aquifers. The lower Trinity aquifer comprises members of the Travis Peak Formation. The Hosston Sand is the aquifer member and produces potable water west of Camp Mabry. The Hammett Shale is the aquiclude member capping the Hosston Sand. The lower Trinity aquifer is not produced below Camp Mabry because of structural complexity. East of the training site, Lower Trinity waters are too saline to be potable (Brune and Duffin, 1983).

The middle Trinity aquifer includes the Cow Creek Limestone and Hensell Sand members of the Travis Peak Formation and the lower member of the Glen Rose Formation. The Hensell Sand carries most of the water; this middle Trinity aquifer also becomes saline west of Camp Mabry. The upper member of the Glen Rose Formation and the overlying Paluxy Formation compose the upper Trinity aquifer, as classified by the Texas Water Development Board, but this aquifer is not produced from beneath Camp Mabry. The upper Trinity aquifer lies about 250 ft below the Edwards aquifer and could provide potable water. It does not become saline except at the county line between Travis and Bastrop and Caldwell Counties.

The Edwards and associated limestones aquifer is a major Texas aquifer that is best known as the water supply for San Antonio. That water supply comes from a southern Edwards limestone aquifer controlled by river basins of the Nueces, San Antonio, and Guadalupe Rivers. A ground-water divide at Kyle, Texas, separates the southern Edwards limestone aquifer from the northern Edwards limestone aquifer, in which ground-water flow depends on the configuration of the Colorado River basin.

It is the northern Edwards aquifer that is the principal aquifer underlying Camp Mabry. Here the Edwards aquifer behaves as an artesian system. It overlies the Walnut Formation, in which limestones, marls, and clays behave as a barrier to ground-water flow, and on top of the Edwards unit the Del Rio Clay acts as a cap, a tight aquiclude.

In Travis County, minor aquifers include (1) the Austin Chalk, especially the upper and lower fractured members, which is capped by the tight clays of the Taylor and Navarro Groups, (2) the reworked nontronite beds of the Pilot Knob volcanic dome, and (3) scattered Quaternary alluvial aquifers associated with older floodplains and terraces of the Colorado River system. Only the Austin Chalk aquifer provides ground water within a 2-mi radius of Camp Mabry.

Edwards and Associated Limestones Aquifer

The source of water in the Edwards and associated limestones aquifer is direct infiltration from precipitation onto the outcrop and infiltration from streams crossing the outcrops and especially at intersections of the streams with faults of the Balcones Fault Zone. As the Edwards and associated limestones aquifer is dominated by fractures, especially where enlarged by solution and evidenced by local sinkholes, the aquifer responds rapidly to infiltration. This response is evident in figure 9, in which high and low water levels in an Edwards well near Camp Mabry correspond directly to the high and low annual rainfalls.

Much of the time this aquifer is saturated, especially in the Balcones Fault Zone. Springs commonly issue from Edwards outcrops in areas where the topography is lower than aquifer water levels, particularly where the plumbing is enhanced by faults. Brune and Duffin (1983, their figure 20) provide a beautiful illustration showing the excellent correlation of monthly precipitation with springflow from Barton Springs for the years 1917–1976. This correlation emphasizes the rapid transport of infiltrated ground water following heavy or light precipitation. The varying heads of the confined aquifer reflect the efficiencies of infiltration and transport of ground water.

Relatively small amounts of ground water are withdrawn from wells penetrating the Edwards and associated limestones aquifer. Most ground water flows from springs, eventually recharging the local streams and the dammed Colorado River lakes. According to calculations by Guyton (1958), the annual discharge for the Edwards and associated limestones aquifer between Kyle and Austin would approximate 40,000 acre-ft, of which less than 1,000 acre-ft is ground-water pumpage. For Travis County, ground-water pumpage ranged from 1740 to 930 acre-ft between 1955 and 1976 (Brune and Duffin, 1983). No actively pumping well has been identified near Camp Mabry.

Edwards water levels range from 450 to 550 ft above mean sea level (fig. 10) in the vicinity of Camp Mabry, where the Edwards potentiometric surface slopes south from the drainage basins of Shoal and Waller Creeks. Water depth varies about 60 ft over 40 yr and is clearly responsive to drought and wet cycles (Brune and Duffin, 1983, their figure 19). In southern Travis County, the Edwards potentiometric surface (Brune and Duffin, 1983; Senger and Kreitler, 1984) slopes northeast toward the Colorado River within drainage basins including Onion, Bear, Slaughter, Williamson, and Barton Creeks.

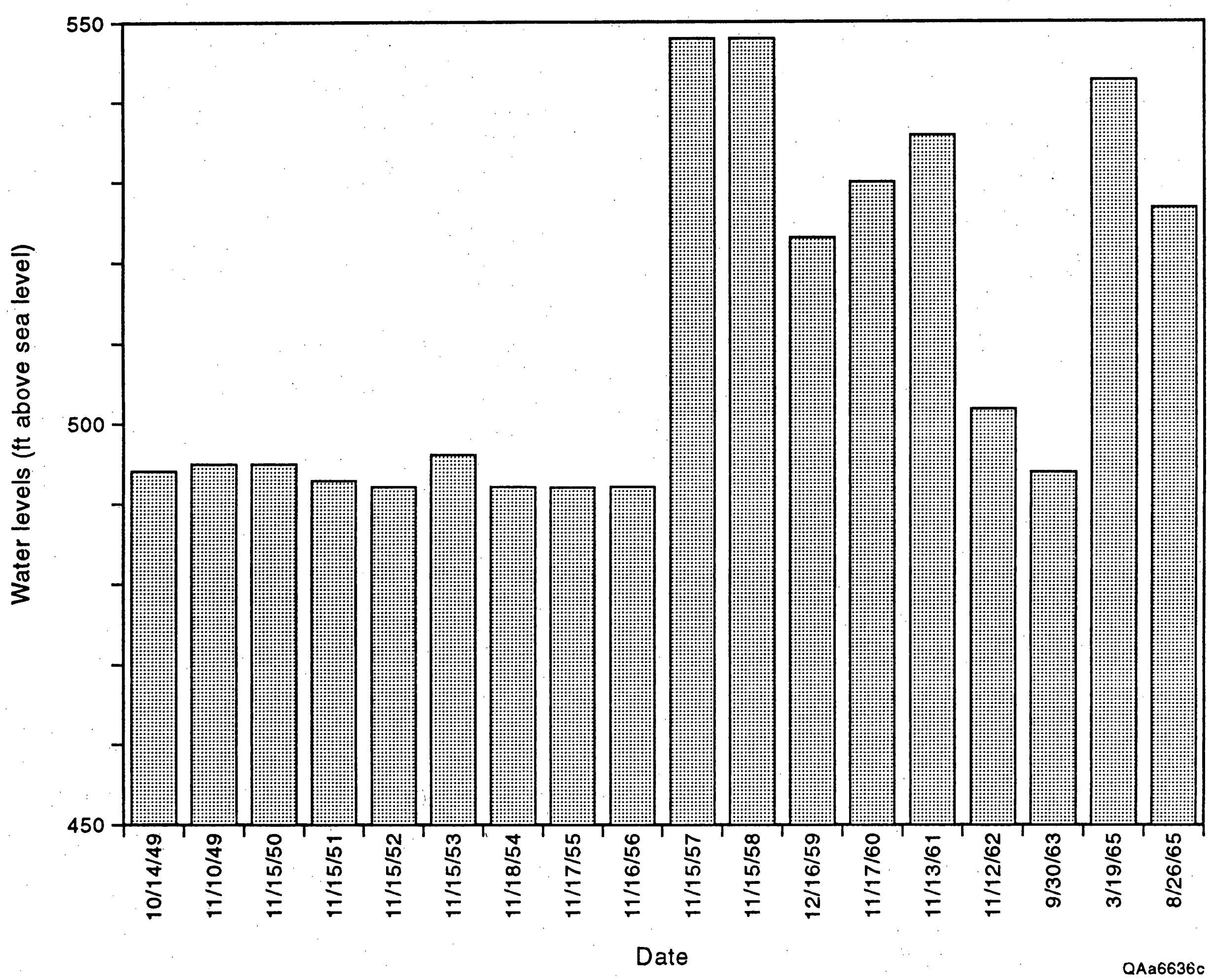

Figure 9. Water levels in an Edwards Limestone aquifer well adjacent to Camp Mabry (1949–1965). Although the sampling has temporal irregularity, the end of the drought in 1956 is apparent with a rapid recovery of water level.

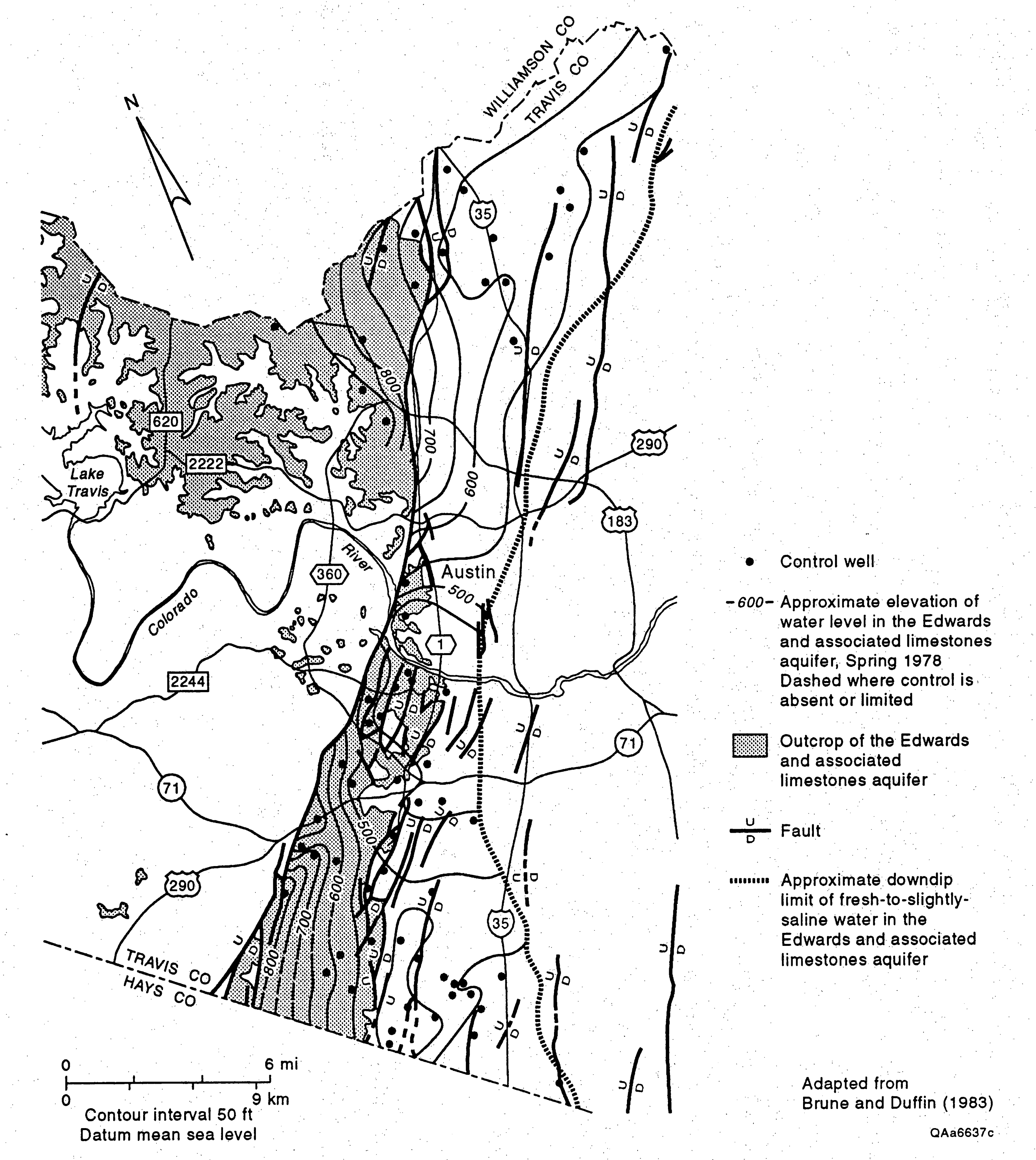

Figure 10. Approximate altitude of water levels in wells completed in the Edwards and associated limestones aquifer, spring 1978, from Brune and Duffin (1983, their fig. 21).

Water Quality

Ground water in the Edwards and associated limestones aquifer of Travis County is predominantly calcium bicarbonate composition, locally calcium magnesium bicarbonate. To the east and coincident with decreasing permeability, the ground-water composition is sodium sulfate and ultimately sodium chloride. The water has consistently moderate to high hardness. The area of greater chemical concentrations and hardness is named locally the "bad water zone."

The range of chemical compositions of ground water in five representative Edwards wells, monitored by the Texas Water Development Board nearby Camp Mabry, is shown in table 2. The Edwards ground water is a calcium carbonate type water low in magnesium. One well displays high hardness and large total dissolved solids (TDS), reflecting high concentrations of sulfate and chloride along with sodium. The other wells have no exceptional concentrations and display moderate hardness and total dissolved solids. Regressive functions comparing TDS to depth and chemical constituents (fig. 11) indicate that TDS is unresponsive to depth but responsive to most chemical components except bicarbonate. Chemical analyses indicate no pollution signatures.

Austin Chalk Aquifer

Producible ground water commonly occurs in the upper weathered zone of the Austin Chalk and often in the hard upper and lower chalk members that are strongly fractured. Although ground water also saturates the Austin marls and clays, it is not producible. Austin ground water generally occurs under water table conditions, and producing wells containing the unconfined ground water in chalk are shallow, less than 40 ft. Ground-water flow is largely controlled by topography and reflects fracture intensities and orientations. Water levels in Austin wells respond rapidly to local rainfall, as shown in figure 12. Austin Chalk discharge is principally spring flow into local creeks.

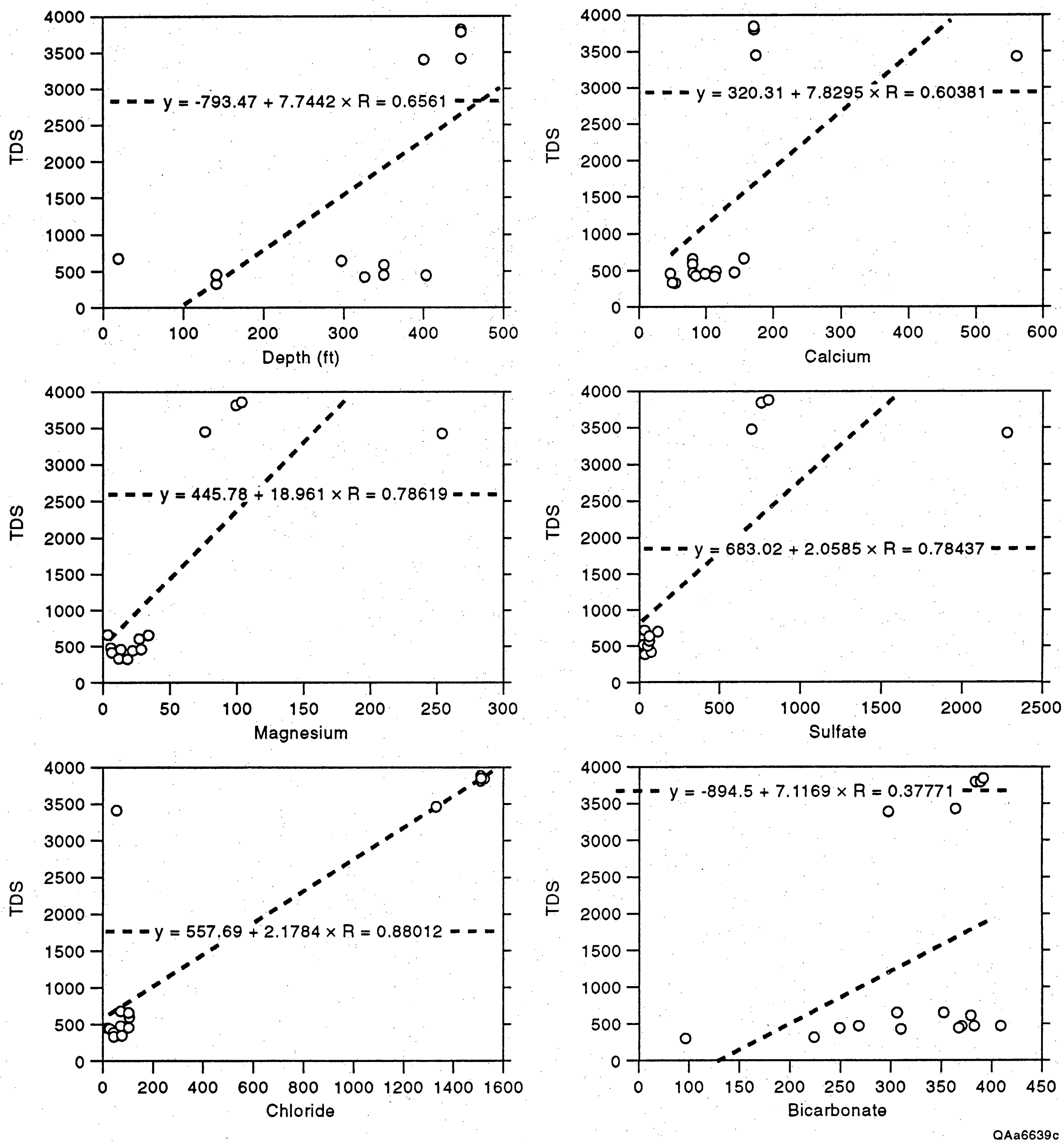

Figure 11. Relation of total dissolved solids in the Edwards and associated limestones aquifer with depth and anion-cation analyses from water wells nearby Camp Mabry.

Table 2. Anion/cation analyses of three Austin Chalk aquifer and five Edwards Limestone aquifer water wells nearest to Camp Mabry. Data are from well files of the Texas Water Development Board Ground Water Data System.

	Austin (3)			Edwards (5)		
	Maximum	Mean	Minimum	Maximum	Mean	Minimum
Temperature		24			22	
pH		7.3		7.7	7.4	6.9
Silica		28		35	19	11
Calcium	100	74	25	35	19	11
Magnesium	10	6	3	255	88	8
Sodium	22	19	15	1,090	190	83
Bicarbonate	342	262	49	392	361	267
Sulfate	350	98	<4	2,270	698	54
Chloride	58	31	11	1,540	911	28
TDS	388	292	148	3,875	2,747	427
Hardness	316	218	77	2,446	836	272

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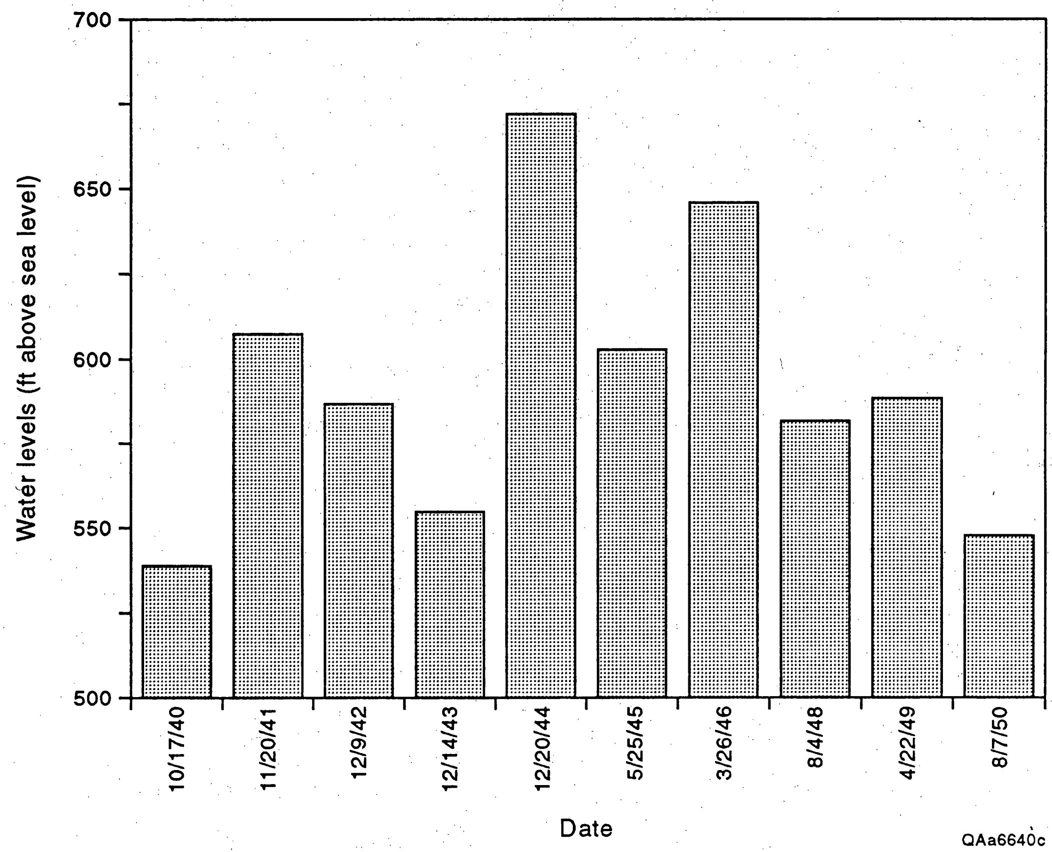

Figure 12. Water levels, 1940–1950, in a water well in the unconfined Austin aquifer adjacent to Camp Mabry. The fluctuations are suspect because of rapid response to local precipitation.

As shown by Brune and Duffin (1986, their figure 19) water levels remain relatively constant through time, only 22 ft of water level change in 19 yr. Austin Chalk wells have small, inconsistent yields and have been used mainly for domestic and livestock needs.

Water Quality

The ground water in the Austin Chalk is a calcium bicarbonate type; it is usually fresh, neutral, and hard. Chemical compositions of the ground water in three representative wells in the vicinity of Camp Mabry, as monitored by the Texas Water Development Board, are shown in table 1. These wells produce excellent potable water. Magnesium is a relatively unimportant component in these calcium bicarbonate waters. Sulfate appears to be the primary component responsible for the greater TDS and increased hardness in certain Austin wells. No signature of pollution is apparent in these chemical data.

ENVIRONMENTAL ISSUES

Camp Mabry is quite different from nearly all other Texas Army National Guard training sites in that the site is entirely enclosed within the large urban area of the City of Austin and surrounding incorporated communities. Much of Camp Mabry is landscaped in conformity with other residential and institutional areas of the city. For that reason, some of the environmental issues associated with Camp Mabry relate to urban runoff during heavy rainfall. Amounts of impervious cover and fertilizer and pesticide loading become important elements, as all Camp Mabry drainage flows into Lake Austin on the Colorado River (fig. 5). Experiments at Camp Mabry in composting and xeric landscaping with low water demand could be relevant to other rural training sites that have no urban elements, if mitigation and/or repair of vegetative cover were to be required.

Wind erosion is not a problem, as a result of the extensive cover by planted grasses, shrubs, and trees as well as minimal disturbances of natural vegetation. Stream erosion is unlikely except in an extreme flood event because the principal natural drainages have gentle slopes and heavy to moderate vegetative cover. All of Camp Mabry sits above the 100-yr floodplain, according to flood insurance maps of FEMA (1981).

Camp Mabry is different from other training sites in that a large proportion of troop training takes place indoors. Vehicle maintenance and shop work, similar to many urban commercial ventures, need environmental oversight for the appropriate disposition of solvents, oil, grease, and metals to prevent their entering the natural environment. Techniques may be developed here with wide application throughout the Texas Army National Guard program. Camp Mabry may have interesting recycling opportunities with so many paper exercises and business requirements at this major command center for the Texas Army National Guard.

No significant natural economic resources other than ground water occur on or below Camp Mabry that should be protected from private-sector development. An example of this issue in the City of Austin is local gravel and sand that comprises mineable alluvial terraces, many of which have been lost to the future community as a result of residential development and urban cover.

Currently there is no environmental monitoring at Camp Mabry. Monitoring of water chemistry in the intermittent streams that transect the training site is probably warranted. Samples should be collected at the entry point and spill point of the stream on the wane of major flows, one in May and one in October. It would be wise to test for most potential pollutants from upstream sources as well as Camp Mabry sources. These data would probably show that no pollutants are coming from the training site, a valuable reference in case of environmental litigation or pressure to limit this base's activities.

ACKNOWLEDGMENTS

Funding for this work was provided by the Adjutant General's Department of Texas under Letter of Agreement Number TX93-ED3-02 ENV244-D3. James Resner, Conservation Scientist, called attention to various important features at Camp Mabry. Jay A. Raney reviewed the manuscript. Amanda Masterson edited the report, and Susan Lloyd completed the word processing. Kerza A. Prewitt, William C. Bergquist, and Joel L. Lardon prepared the illustrations under the supervision of Richard L. Dillon. Pasteup was by Margaret L. Evans.

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Appendix A. Average wind direction and speed at Robert Mueller Municipal Airport in Austin, Texas, 1961–1980.

DECEMBER - FEBRUARY

(Calm 5.5 percent of time; average direction and speed in January: S 10 mph [1])

DIRECTION	Estimated percentage [2] 1 - 12 mph	13 - 21 mph	Above 21 mph	Cumulative Percentage
N	5.9	7.7	1.3	14.9
NNE	4.9	4.1	0.3	9.3
NE	4.6	1.6	0.0	6.2
ENE	2.4	0.3	0.0	2.7
E	2.6	0.1	0.0	2.7
ESE	2.0	0.2	0.0	2.2
SE	3.1	0.3	0.0	3.4
SSE	4.5	0.8	0.0	5.3
S	13.2	4.5	0.0	17.7
SSW	5.3	2.3	0.1	7.7
SW	2.4	0.6	0.0	3.0
WSW	1.5	0.1	0.0	1.6
W	2.1	0.1	0.0	2.2
WNW	2.9	1.1	0.0	4.0
NW	3.3	1.3	0.2	4.8
NNW	3.1	2.6	0.7	6.4
Totals	63.8	27.7	2.6	94.1

MARCH - MAY

(Calm 3.1 percent of time; average direction and speed in April: SSE 11 mph [1])

DIRECTION	Estimated percentage [2] 1 - 12 mph	13 - 21 mph	Above 21 mph	Cumulative Percentage
N	3.5	3.5	0.7	7.7
NNE	3.4	2.6	0.1	6.2
NE	3.8	1.8	0.0	5.6
ENE	2.2	0.5	0.0	2.7
E	3.2	0.4	0.0	3.6
ESE	3.1	0.3	0.0	3.4
SE	6.0	1.5	0.0	7.5
SSE	9.8	4.7	0.0	14.5
S	15.8	10.1	0.0	25.9
SSW	4.2	2.3	0.0	6.5
SW	1.6	0.4	0.0	2.0
WSW	0.9	0.0	0.0	0.9
W	1.3	0.1	0.0	1.4
WNW	1.7	0.5	0.1	2.4
NW	1.9	1.0	0.2	3.1
NNW	1.3	1.2	0.3	2.9
	63.7	31.1	1.4	96.3

JUNE - AUGUST

(Calm 5.0 percent of time; average direction and speed in July: S 8 mph [1])

DIRECTION	Estimated percentage [2] 1 - 12 mph	13 - 21 mph	Above 21 mph	Cumulative Percentage
N	1.4	0.4	0.0	1.8
NNE	1.6	0.3	0.0	1.9
NE	2.7	0.5	0.0	3.2
ENE	2.4	0.3	0.0	2.7
E	3.3	0.2	0.0	3.5
ESE	3.8	0.3	0.0	4.1
SE	7.7	0.7	0.0	8.4
SSE	11.9	2.5	0.0	14.4
S	28.0	7.3	0.0	35.3
SSW	8.1	2.3	0.0	10.4
SW	3.6	0.4	0.0	4.0
WSW	1.5	0.0	0.0	1.5
W	1.1	0.0	0.0	1.1
WNW	1.0	0.0	0.0	1.0
NW	1.1	0.0	0.0	1.1
NNW	0.7	0.0	0.0	0.7
Totals	79.7	15.4	0.0	95.1

SEPTEMBER - NOVEMBER

(Calm 6.4 percent of time; average direction and speed in October: S 8 mph [1])

DIRECTION	Estimated percentage [2] 1 - 12 mph	13 - 21 mph	Above 21 mph	Cumulative Percentage
N	6.3	4.5	0.3	11.1
NNE	5.1	2.8	0.3	8.2
NE	5.5	1.6	0.0	7.1
ENE	3.5	0.3	0.0	3.8
E	3.7	0.2	0.0	3.9
ESE	3.5	0.1	0.0	3.6
SE	6.1	0.4	0.0	6.5
SSE	7.3	1.0	0.0	8.3
S	15.4	3.7	0.0	19.1
SSW	4.6	1.6	0.0	6.2
SW	2.1	0.4	0.0	2.5
WSW	1.3	0.1	0.0	1.4
W	1.6	0.1	0.0	1.7
WNW	2.3	0.2	0.0	2.5
NW	3.2	0.4	0.0	3.6
NNW	2.8	1.2	0.0	4.0
	74.1	18.7	0.7	93.5

Notes:

(1) Average wind direction and speed for approximately 20-year period ending in 1980, reported in Bomar (1983, table F-2);

(2) Percentage of winds blowing from each of 16 principal directions within ranges of speed indicated, estimated from graphic plots in Larkin and Bomar (1983, p. 67-68, and 78-81), based on original U.S. Department of Commerce dataset of measurements made at 3-hr intervals at 12 a.m. (midnight), 3 a.m., 6 a.m., 9 a.m., 12 p.m. (noon), 3 p.m., 6 p.m., and 9 p.m.

Appendix B. Annual precipitation recorded at Robert Mueller Municipal Airport in Austin, 1950–1991.

Year	Precipitation (in)	Year	Precipitation (in)
1950	25.8	1971	24.9
1951	29.0	1972	26.1
1952	27.7	1973	40.4
1953	29.7	1974	36.2
1954	11.4	1975	36.8
1955	22.5	1976	39.6
1956	15.4	1977	22.1
1957	51.3	1978	31.0
1958	41.0	1979	37.5
1959	35.0	1980	27.4
1960	35.8	1981	45.7
1961	36.4	1982	26.6
1962	33.5	1983	34.0
1963	17.3	1984	26.3
1964	35.5	1985	32.5
1965	40.6	1986	35.0
1966	25.2	1987	36.6
1967	33.5	1988	19.2
1968	40.4	1989	25.9
1969	33.6	1990	28.4
1970	30.6	1991	52.2
Minimum	11.4	Mean	31.8
Maximum	52.2	Median	33.0

Original data from National Weather Service, obtained through the Texas Natural Resources Information System.