Ground-Water and Surface-Water Hydrology of Camp Barkeley, Taylor County, Texas

Final Report

R. Stephen Fisher, Principal Investigator
Robert E. Mace
Erika Boghici

assisted by
Conrad A. Kuharic and Martina Blüm

prepared for

Adjutant General's Department of Texas
Texas Army National Guard
James F. Resner II
and
The Nature Conservancy of Texas
Contract No. Texas THCB-95-1-05-01
T. James Fries, Project Manager

Bureau of Economic Geology
Noel Tyler, Director
The University of Texas at Austin
Austin, Texas 78713-8924

May 31, 1996

CONTENTS

Figures

EXECUTIVE SUMMARY

Ground-water and surface-water investigations were conducted on Camp Barkeley, Taylor County, Texas, to provide the Texas Army National Guard with information needed to preserve environmental quality and resources while planning and conducting training and preparedness activities. Spatial information such as surface geology, watersheds, elevation data, floodplains, well locations, and water levels were converted to digital files and submitted to the Texas Army National Guard Geographic Information System office at Camp Mabry, Austin, Texas, for future use in managing the training facility. Similar investigations were conducted on Camps Bowie, Mabry, Maxey, and Swift, and Fort Wolters. Results of those studies are presented separately.

Previous reports and public data files were examined to obtain background information on the camp and surrounding area. These data guided our more focused studies on the training facility. Ground-water studies included locating existing wells on and near the camp; installing new wells as needed for ground-water characterization; testing and sampling selected wells; determining ground-water levels, chemical compositions, and aquifer hydraulic properties; and developing a conceptual model of ground-water flow. Surface-water studies delineated watersheds and mapped floodplains.

Alluvium along streams and the Antlers Formation are the principal aquifers in the Camp Barkeley area. Approximately 42 percent of all wells listed by the Texas Water Development Board (TWDB) in Taylor County produce from alluvium. Depths to water in existing wells vary both within and between formations, suggesting that the ground-water system is not well integrated. Ground-water compositions recorded in TWDB files show most samples to be fresh waters. A conceptual ground-water flow model resulting from this study indicates that local recharge most likely occurs through interconnected vertical fractures. Much of the water that infiltrates on topographically high parts of Camp Barkeley probably discharges at the edges of the mesas, with only minor discharge, if any, to deeper aquifers.

The training facility resides in the Clear Fork River Basin. No significant permanent streams exist on the camp. Surface runoff flows to various first-order tributaries and creeks and ultimately to Lake Fort Phantom Hill, Clear Fork Brazos River, and the Brazos River. No significant 100-yr floodplains exist on Camp Barkeley; however, severe rainfalls can produce heavy sheetflow and runoff that can quickly but temporarily fill arroyos and cause severe erosion.

INTRODUCTION

This report summarizes ground-water and surface-water studies at Camp Barkeley, Taylor County, Texas, conducted by the Bureau of Economic Geology (BEG) for the Texas Army National Guard. This work was part of a larger study of Texas Army National Guard training facilities that included Camp Bowie (Brown County), Camp Mabry (Travis County), Camp Maxey (Lamar County), Camp Swift (Bastrop County), and Fort Wolters (Parker County). These investigations, in conjunction with aquatic and biological surveys conducted by the Texas Parks and Wildlife Department, provide information needed by the Texas Army National Guard to plan training and preparedness activities in a way that will protect and enhance environmental resources without compromising training needs and national security readiness. Reports of similar investigations on the other training facilities are presented separately.

This report presents results of ground-water and surface-water analyses and describes how we prepared data files for Geographic Information System (GIS) coverages of the camp and surrounding area. The ground-water analyses contain information regarding hydrostratigraphy, camp and perimeter well surveys, monitor well drilling, well testing, aquifer properties, ground-water levels, ground-water chemistry, and a conceptual ground-water flow model. The surface-water analyses contain information regarding streams and drainage basins on and near the camp, watershed delineations, stream-flow duration, flood frequency, and floodplain analysis. The GIS data preparation section contains descriptions of the original data sets, how they were obtained, and how they were processed to obtain GIS coverages for the camp.

Regional Setting

Camp Barkeley is located in Taylor County southwest of Abilene (fig. 1). The geomorphology of the camp is dominated by the Callahan Divide, a dissected Cretaceous upland that rises above the Permian rolling hills. Elevations on the reservation range from 1,940 to 2,400 ft. The northern part of the camp has a relatively flat topography underlain by Permian red beds. To the south, steep slopes rise up to a Cretaceous tableland remnant with elevations as high as 2,400 ft. This upland area is dissected by a northwest-trending valley incised into the Permian red beds to an elevation of 2,100 ft. The camp lies within the Brazos River drainage area.

The general soils map of Taylor County (Connor, 1976) shows the Sagerton-Rowena-Rotan association as mostly deep, noncalcareous to calcareous clay loams with about 33 percent minor soils, such as Clairemont, Gageby, Mangum, Shep, and Tobosa soils in the northern part of

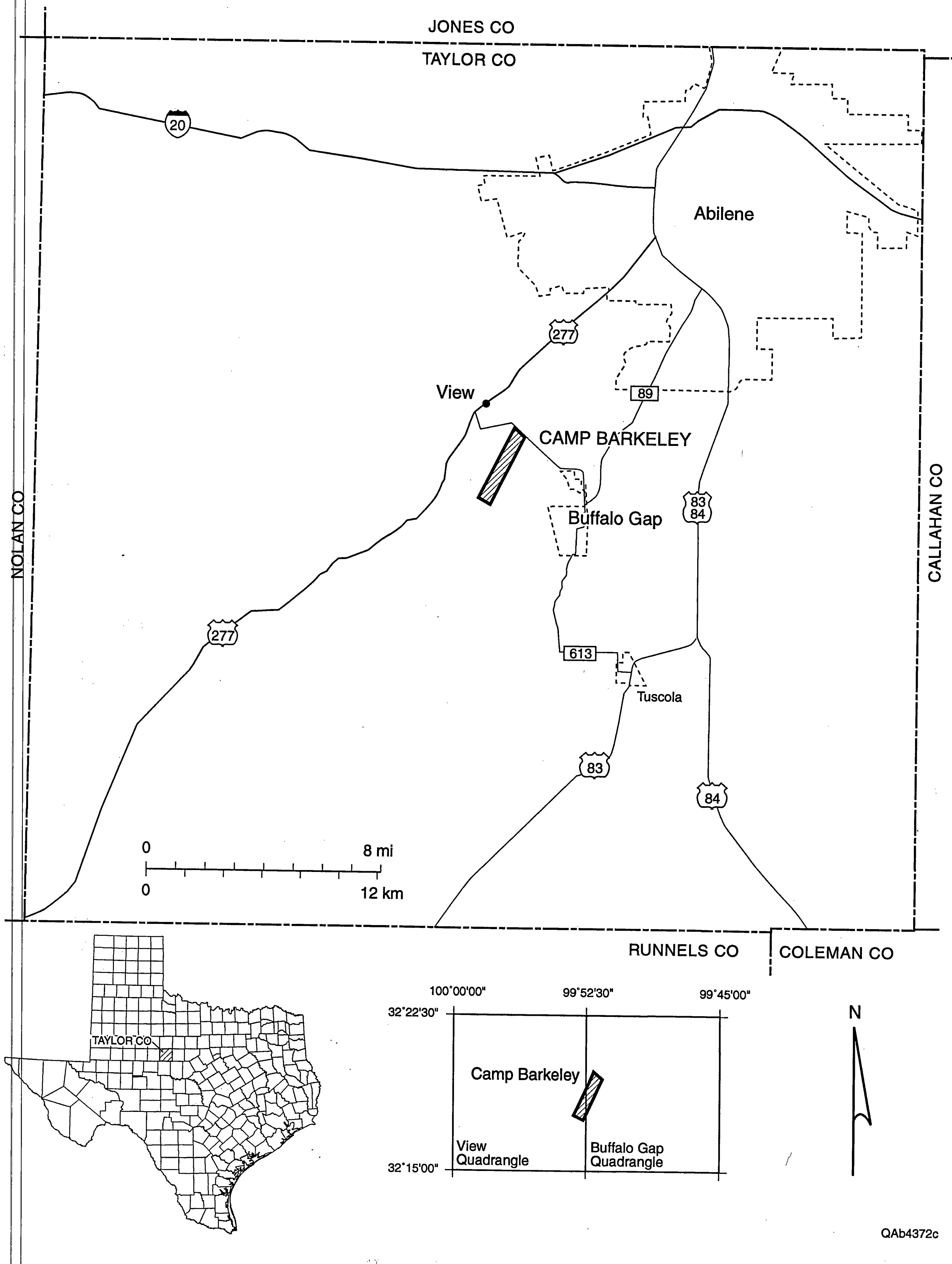


Figure 1. Index map showing location of Camp Barkeley and major highways and towns.

the camp. The Tarrant-Tobosa association extends farther south on the camp, having very shallow to deep, calcareous, cobbly clays and clays. Minor soils, such as Quanah, Kavett, Valera, Rioconcho, Speck, and Mereta, make up 42 percent of this association.

The following descriptions are summarized from the Soil Survey of Taylor County (Connor, 1976). Sagerton soils, occurring mainly on uplands having convex surfaces, contain an upper layer of reddish-brown clay loam underlain by a clay layer that is reddish-brown in the upper part and red in the lower part. These layers are underlain by a clay loam that is pink in the upper part and red beneath. Rowena and Rotan soils exist on upland, concave surfaces. The upper layer of the Rowena soil is a dark grayish-brown clay loam. This layer is underlain by clay whose color changes downward from dark grayish-brown to dark brown followed by a reddish-yellow clay layer. The Rotan soils have a surface layer of dark brown clay loam, followed downward by dark grayish-brown clay loam turning dark brown in the lower part of the layer. These grayish-brown to brown upper layers are underlain by a layer of reddish-yellow clay loam.

Tarrant soils, found on undulating to steep slopes, have a dark grayish-brown cobbly clay surface layer underlain by a dark grayish-brown very cobbly clay. These soils are underlain by limestone. The nearly level to gently sloping Tobosa soils have a dark brown clay layer at the surface, followed downward by brown clay and pink silty clay layers.

Taylor County lies within the mesquite-grassland vegetation region represented by open stands of mesquite within grassland (Tharp, 1939). Tharp (1939) describes buffalo, various gramma, purple triple-awn, and foxtail grasses in combination with other bunch grasses on the Permian red beds.

Taylor County lies within the subtropical, subhumid climatic region (Larkin and Bomar, 1983). The average yearly wind directions measured at the weather station in Abilene are from the south to south-southeast, varying between 11 and 14 mph (Bomar, 1983). However, strong northerly cold fronts are accompanied by strong gusty winds raging mostly between September and March.

The following temperature and precipitation records are compiled by Bomar (1983) for Abilene. The mean annual high temperature is 76.3°F, with highest temperatures in July and August. The mean annual low temperature is 52.6°F. Temperatures can be extreme—as low as –9°F on January 4, 1947, and as high as 111°F on August 3, 1943. Precipitation averages 23.3 inches annually, mostly falling between April and October.

Average monthly gross lake-evaporation rates are highest in July and August and lowest in January (Larkin and Bomar, 1983). The gross lake-evaporation rate averages 75 inches annually in Taylor County.

Geology and Hydrostratigraphy

Formations of the Permian and Cretaceous systems crop out on Camp Barkeley (fig. 2). The lower elevations of the camp consist of the Vale and Choza Formations, and the uplands consist of Cretaceous rocks including the Antlers Formation capped by the Fredericksburg Group. The Vale Formation, the lower part of which crops out in the northern and southern areas of the camp, consists mostly of red shales with thin and scattered lenticular sandstones in the lower part and many thin interbedded dolomite and shale stringers in the upper part. This formation is easily identified near the camp by its deep red color. The Antlers Formation, Trinity Group, consists of light-colored sandstone in the upper part, silty sandstone in the middle part, and light-colored sandstone with some conglomerate in the lower part. On the camp, the Trinity Group forms the lower slopes of the mesas. The Fredericksburg Group, consisting of the Walnut Formation, the Comanche Peak Limestone, and the Edwards Limestone, is undifferentiated on geologic maps of the area. The Walnut Formation is a marly yellow clay that locally grades into shaly limestone. The Comanche Peak Limestone consists of gray, nodular, marly limestone. The Edwards Limestone is a cream to gray, crystalline limestone with abundant chert nodules. The Fredericksburg Group caps the mesas on the camp. The Vale Formation underlies the northern mesa, and the Choza Formation underlies the southern mesa. The composition of the Choza Formation is very similar to the composition of the Vale Formation in the Camp Barkeley area.

The recognized principal aquifers in Taylor County are the alluvial deposits bordering rivers and streams and the Antlers Formation (Taylor, 1978). About 42 percent of the wells listed with the Texas Water Development Board (TWDB) are completed in alluvium, and most are located along Jim Ned Creek. Wells northwest of Camp Barkeley are completed in alluvium of Elm Creek. About 18 percent of the wells listed with the TWDB are completed in the Antlers Formation. These wells are completed in Cretaceous outliers that are erosional remnants of the once-continuous Cretaceous formations.

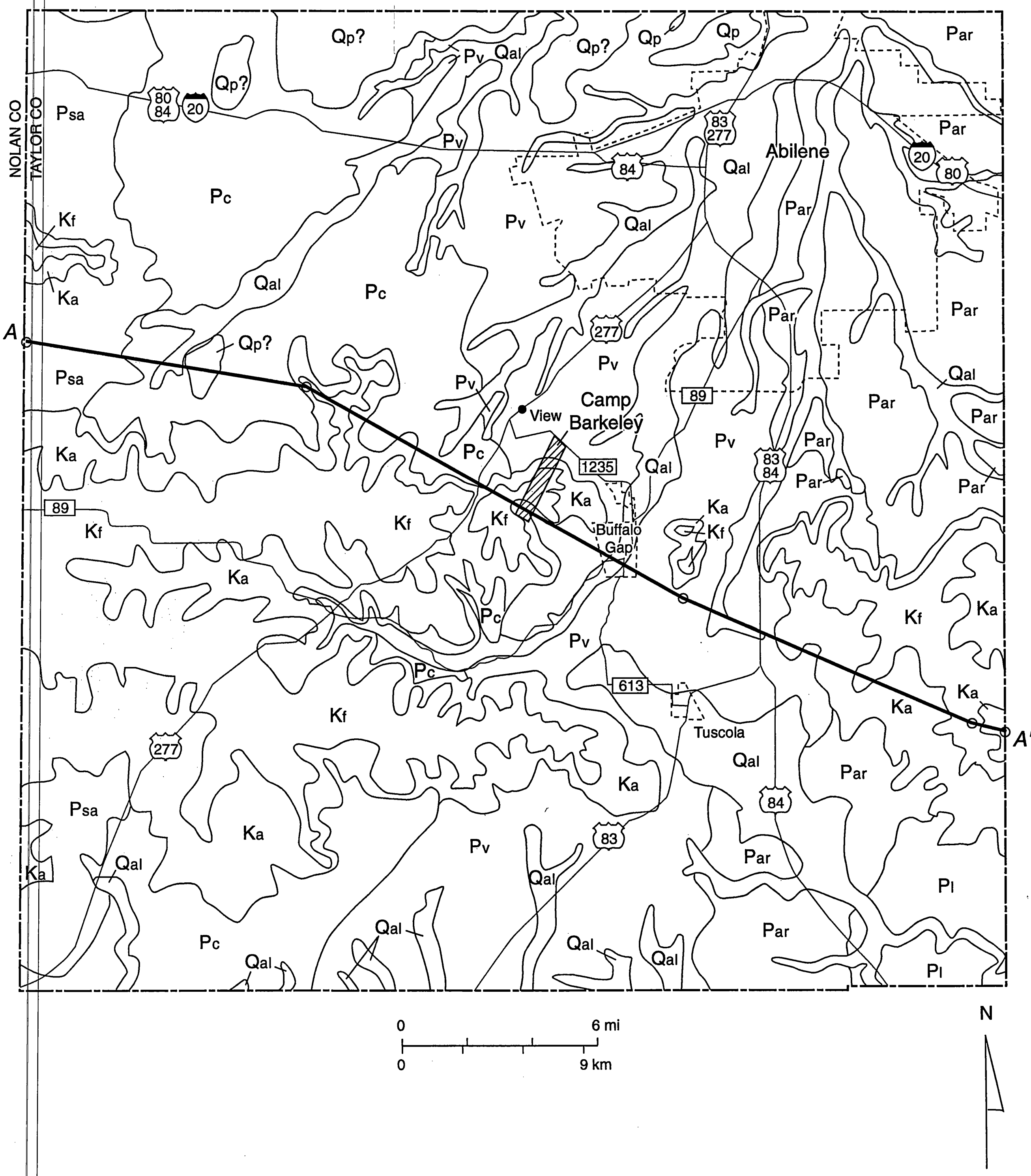
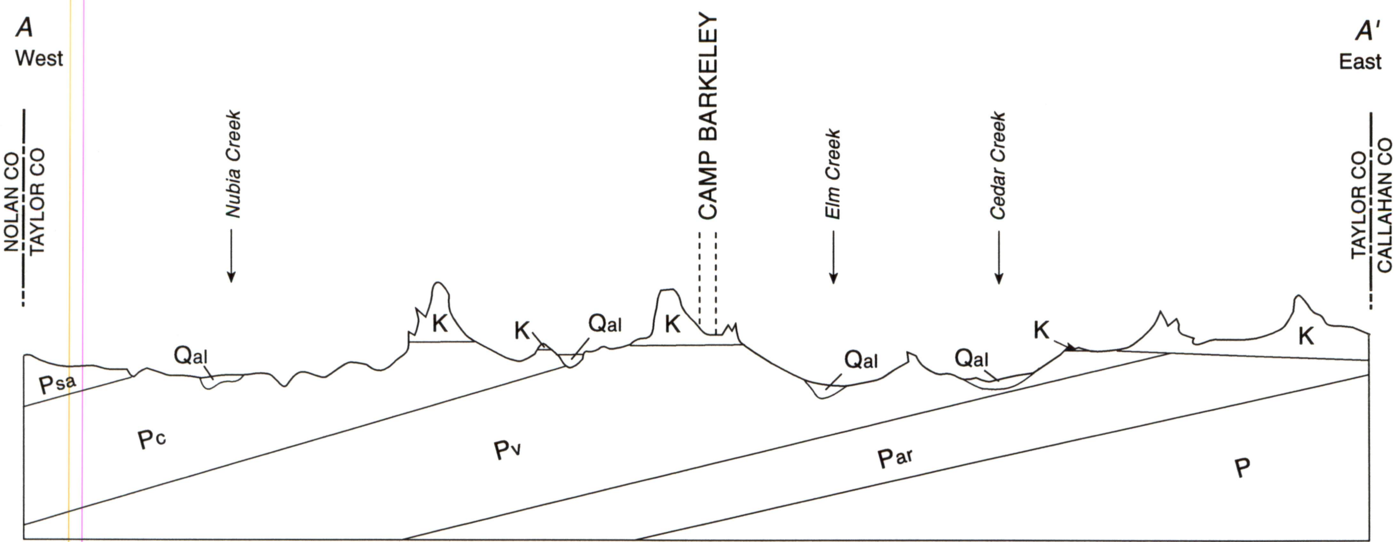


Figure 2. (a) Generalized geologic map, Taylor County.



QUATERNARY	RECENT	Qal	Alluvium	
	PLEISTOCENE	Qp	undivided	
			Seymour	
CRETACEOUS (K)	COMANCHE	Kf	Edwards Limestone	Fredericksburg Group
			Comanche Peak Limestone	
			Walnut	
		Ka	Antlers Formation	Trinity Group
PERMIAN (P)	LEONARD	Psa	San Angelo Formation	Pease River Group
		Pc	Choza Formation	Clear Fork Group
		Pv	Vale Formation	
		Par	Arroyo Formation	
		Pl	Lueders Formation	Wichita Group

QAb4414(b)c

Figure 2. (b) Schematic cross section and stratigraphic column, Taylor County.

METHODS

Ground-Water Analysis

Well Inventory

We visited Camp Barkeley to locate wells on and near the camp. For wells on the camp, detailed measurements and descriptions were made of well location, type, depth, water level, diameter, and casing construction. Camp personnel were interviewed concerning known or potential well locations. We drove on all camp roads to search for evidence of wells, inventoried wells near the camp, and measured water level and well depth if possible. These data were important for generating water-level maps in the vicinity of the camp.

Monitor Well Installation

The installation of monitor wells at Camp Barkeley included (1) selecting and staking appropriate hydrogeologic sites for well locations, (2) arranging access to the well sites and a source of water, (3) drilling the well, (4) developing the well, (5) installing casing, and (6) developing the cased well. Drilling sites were chosen to best investigate the hydrogeology of the camp and still be accessible to a drill rig. Before staking the well sites, we contacted camp commanders to ensure that the locations would not interfere with camp activities and were not located near any known buried utilities. We coordinated our drilling with the camps to ensure that our activities would not interfere with training schedules.

We drilled the monitor wells with a Central Mine Equipment 75 drilling rig. Depending on the geology, we used hollow stem augering, solid stem boring, rotary/wet coring or a combination thereof to install the wells. Most wells were installed using hollow stem augering. A few wells required solid stem boring or rotary/wet coring owing to the presence of hard rock. The drilling mud we used for solid stem boring and rotary/wet coring was biodegradable Super Mud. Where possible, we collected core and cuttings for inspection at our facilities.

After a well was drilled, we augered or flushed the cuttings from the hole and purged the well with a bailer, usually removing one to two wellbore volumes of water. Well completion consisted of installing 2-inch well screen and pipe, placing a sandpack around the screen, placing a bentonite seal above the sandpack, grouting to a few feet below land surface, installing a well guard, and cementing the guard in place with a well pad. We installed either 10- or 20-ft-long

0.010-inch slotted screen in the wells. The sandpack consisted of 20/40 sand and straddled the screen. We installed locking above-ground well guards on each of the wells. Once the well was completed and the cement had dried, we developed the well again with a bailer or an electrical submersible pump.

Well Testing

We conducted a pumping test and a bail test in two wells near the camp. The pumping test was performed at a private well that had a pump to supply water for domestic use. The well was allowed to rest unpumped until water levels stabilized. When the pump was started, water levels were measured with an electronic water-level meter inserted through a vent hole at the wellhead. We measured pump discharge rate using a 12-gal carboy and a stopwatch. Once water-level drawdown reached a quasi-steady state, the pump was turned off and water-level recovery was measured. Drawdown and recovery data were input into a spreadsheet and transmissivity was interpreted using the Theis type curve and Theis recovery method (Theis, 1935) and the Jacob straight-line method (Cooper and Jacob, 1946).

We conducted a bail test at another private well that supplied water for cattle. The well was allowed to rest unpumped until water levels stabilized. When the pump was started, water levels were measured with an electronic water-level meter through the top of the well to verify that only well storage was being removed. Once the water-level reached the level of the pump, the pump was turned off and water-level recovery was measured. Recovery data were input into a spreadsheet and interpreted for transmissivity using the Cooper and others (1967) curve-matching method.

Surface-Water Analysis

Watershed Delineation

Watersheds were delineated for Camp Barkeley using the hydrologic functions of ArcInfo Grid (ESRI, 1993). This method takes digital elevation data and determines flow directions and points of flow accumulation along hypsography. For each stream link between different order streams, the program determines subwatersheds, or drainage areas, corresponding to that stream link (Maidment, 1995).

Floodplain Analysis

Floodplain analysis involves determining the area adjacent to a river or stream that will flood for a specified return period (for example, a 100-yr flood). The standard procedure is to determine the 100-yr flood at key points on the stream and use backwater computation to determine stages upstream (Linsley and others, 1982, p. 452). If available, the 100-yr flood is usually determined from stream-gauge record. However, this data is usually lacking, and regional frequency methods or loss rate and unit hydrograph applied to the 100-yr rainfall can be used (Linsley and others, 1982, p. 452). Because most of the camps lack stream-gauge records, we used the loss rate and unit hydrograph method to estimate the 100-yr floodplain.

Our floodplain analysis consisted of (1) designing 100-yr 24-h synthetic storms, (2) determining the 100-yr flood hydrographs at strategic points in the watersheds, (3) assessing 100-yr flooding surfaces, and (4) mapping the 100-yr floodplains on 1:24,000 USGS topographic maps.

To design the 100-yr 24-h synthetic storms, we first used maps published by the U.S. Weather Bureau (Herschfield, 1961, as shown in Chow, 1964, p. 9–56) to determine the 100-yr 24-h rainfall for each camp and fort. We then used these rainfall rates with the SCS Type II distribution (Bedient and Huber, 1988) to generate the storms.

To determine the 100-yr flood hydrographs, we used HEC-1 (Hydrologic Engineering Center, 1981) with SCS unit hydrographs (Soil Conservation Service, 1957) and Muskingum routing (McCarthy, 1938). Input to HEC-1 included: subbasin drainage area, runoff curve numbers, basin lag, routing storage coefficient, and routing weight factor. Runoff curve numbers, used to define the unit hydrographs, are a function of soil type, vegetation, land use, antecedent moisture, and the hydrologic properties of the catchment surface. Basin lag, also called catchment lag, is the elapsed time, or response time, between rainfall and runoff occurrence and is partly a function of hydraulic length, catchment gradient, drainage density, and drainage patterns. The routing storage coefficient, or time constant, is a function of the channel reach length and the speed of the flood wave. The routing weight factor is a function of the flow and channel characteristics that affect the dispersion of the flood wave downstream.

We delineated detailed subwatersheds and determined subwatershed drainage area with ArcInfo (ESRI, 1993). We calculated weighted curve numbers in ArcInfo for each subwatershed using STATSGO (Soil Conservation Service, 1991) digital hydrologic soil data and land-use data assuming moderate antecedent moisture conditions (I_a = 0.25 inch). Because the majority of the watersheds were ungauged, we estimated the basin lag, t_p, using (Linsley and others, 1982, p. 224):

$$t_p = C_t\left(\frac{LL_c}{\sqrt{s}}\right)^n, \quad (1)$$

where C_t is a constant that varies between 1.8 and 2.2 for units of miles (Snyder, 1938), L is the distance from discharge point to the upstream watershed divide, L_c is the stream length, n is 0.35 for valley drainage areas (Linsley and others, 1982, p. 225), and s is the channel gradient. For this study, we chose a mean C_t value of 2.0. We assigned the routing storage coefficient as 0.20, a typical value for most natural streams (Linsley and others, 1982, p. 219). We measured L, L_c, and s from USGS 1:24,000 topo sheets. We estimated the routing traveltime constant, K, using (Linsley and others, 1982, p. 465–541):

$$K = \frac{bL\sqrt{A}}{\sqrt{s}}, \quad (2)$$

where A is the drainage area and b is a constant between 0.04 and 0.08 for L in miles and A in square miles. For this study, we chose a mean b value of 0.06. With the above data input into HEC-1, we modeled 100-yr flood hydrographs for subwatersheds on or just outside the camps and fort. We recorded peak flows for these 100-yr flood hydrographs for assessing flooding depths.

We used HEC-RAS (Hydrologic Engineering Center, 1995) to estimate 100-yr flooding surfaces at the locations where we determined the flood hydrographs. Input to HEC-RAS included: topographic cross sections at hydrograph locations, stream lengths between cross sections, Manning's n values, discharge rates, and stream-flow boundary conditions. We measured topographic cross sections from USGS 1:24,000 topo sheets perpendicular to the stream path. Using a map roll gauge, we measured stream lengths between cross sections from the topo sheets. We assumed Manning's n values to be 0.06 on the banks (Hydrologic Engineering Center, 1995) and 0.05 in and near the stream channel. HEC-1 supplied the peak 100-yr discharge rates for each hydrograph location. We assigned the stream-flow boundary condition at the output end of the model as a critical depth boundary. In all simulations, we assumed subcritical flow. After inputting the above information, HEC-RAS determined the flood surface at each of the chosen locations.

We mapped the 100-yr floodplains by transcribing the 100-yr flood surfaces estimated by HEC-RAS onto USGS 1:24,000 topo sheets and interpolating between and extrapolating from hydrograph locations. Once mapped, we digitized the floodplains in ArcInfo geographic information system (GIS) and printed maps.

GIS Data Preparation

An effort was made to import spatial hydrologic and hydrogeologic information into a GIS. Where possible, data bases with spatial coordinates were uploaded into the GIS, and interpreted data such as contour maps were digitized and attributed. The information was placed into ArcInfo GIS so data coverages could be overlaid and compared with each other. Care was taken to ensure proper projections were used when transferring information from digital files downloaded from State computers or when digitizing from USGS topographic sheets. Well postings and hydrologic and hydrogeologic analysis were done on virgin USGS topographic sheets to facilitate data automation and to ensure the best possible data transfer.

A data dictionary was prepared for the Camp Barkeley coverages to ensure that subsequent users will be informed as to method of data automation and the accuracy of the information. All GIS data files were delivered to the Adjutant General's Office of the Texas Army National Guard at Camp Mabry for inclusion in their GIS program.

GROUND-WATER HYDROLOGY

Well Inventory

We found three wells or abandoned well sites on Camp Barkeley during this study (fig. 3). The only water well found was a hand-dug well in the southern part of the camp. This well (CBK-B001) is 16.9 ft deep, has a diameter of 3 ft, and holds no water though the walls appeared damp when surveyed in September 1995. The well crown consists of cement with native stone casing to 1 ft below land surface. The rest of the well is open completion with what appears to be 6 ft of clay and sand and 6 ft of colluvium. A few feet of rock are near the bottom of the hole. This well has apparently collapsed because its reported depth in the TWDB files (well 30-42-401) was 65 ft in 1971. The water table at this well is approximately 32 ft below land surface (measured in 1971).

The other two wells (CBK-B002 and CBK-B003) are old oil wells that have been filled, per the report by Captain Decker, facility manager. We found no wells at these sites, confirming that the wells have been destroyed. Captain Decker also mentioned that a new oil well may soon be drilled on the southwestern tip of the camp.

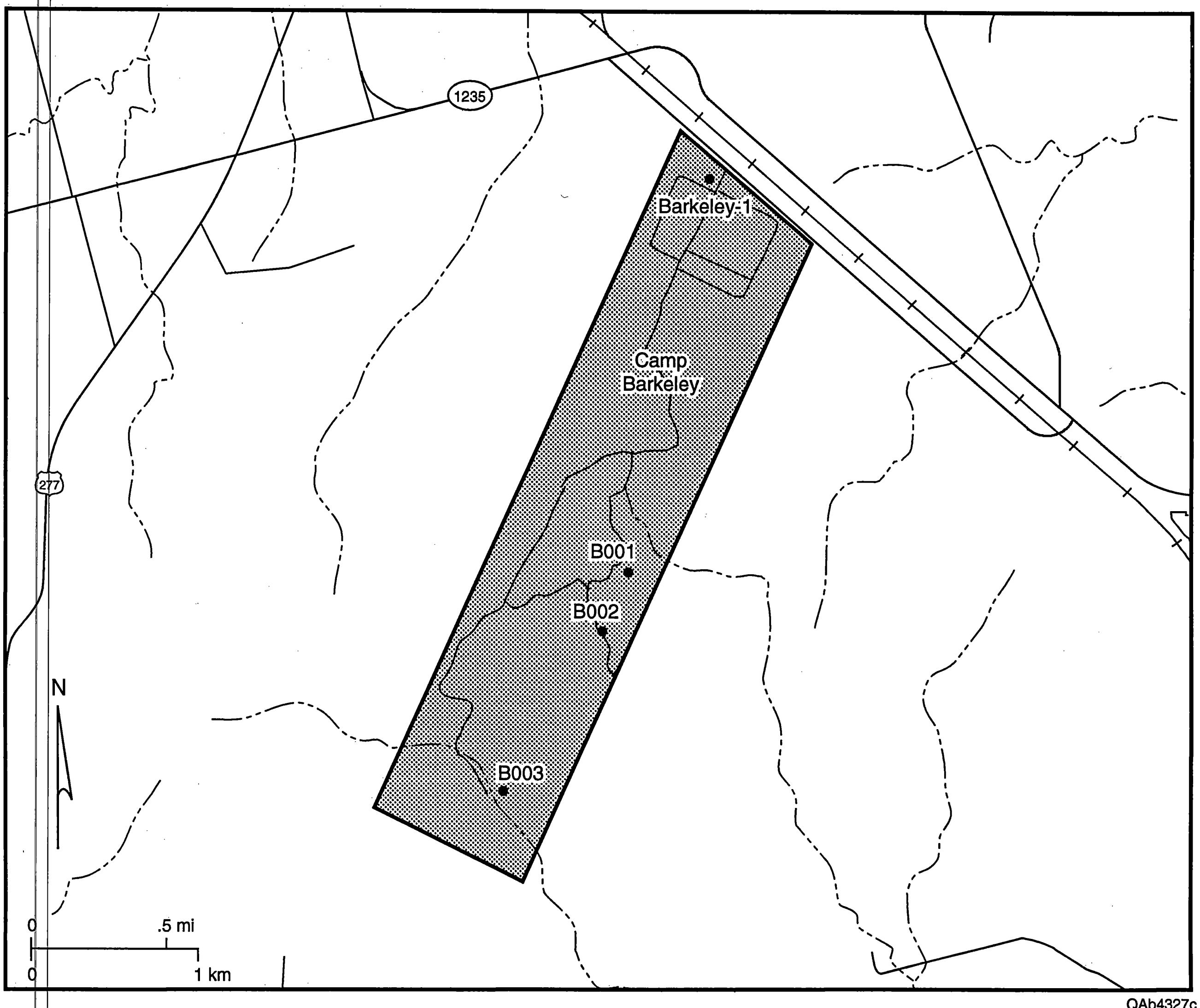


Figure 3. Well locations on Camp Barkeley.

We located 64 wells around Camp Barkeley (fig. 4; app. 1). Water-level measurements were obtained from eight wells and were estimated by owners for another nine wells. Well depths for 26 wells ranged from about 15 to 268 ft, with 16 wells between 15 and 50 ft, 2 between 80 and 90 ft, 3 between 120 and 150 ft, and the remainder between 180 and 268 ft. Depth to water was measured or estimated to be less than 20 ft for seven wells, at 25 ft for three wells, between 60 and 95 ft for three wells, and at 235.9 ft for one well.

Well depths and locations are strongly controlled by geology and historical population patterns. Many wells are present southeast of Camp Barkeley, but all are shallow. No local sewage treatment facility is available, and the residents all use septic systems. The shallow water is reported to be contaminated with colliform bacteria. Land north of the camp is underlain by shales of the Permian Vale and Choza Formations. Low-lying areas hold either permanent or intermittent ponds having areas of lush vegetation, suggesting little infiltration. Very few wells are drilled in this area, and most that exist there appear to be completed in alluvium near creeks. Several wells were found and measured that produce from Cretaceous formations west of the camp. East of the camp are springs that probably issue from the base of the Cretaceous section where flow is impeded by Permian shales.

Monitoring Well Construction

The BEG drilled two wells at Camp Barkeley, and we also incorporated data from two nearby wells into our studies. One of the existing wells is completed in the Antlers Formation and the other is completed in the colluvium along the mesa perimeter. We drilled our wells in the Vale Formation near the camp entrance (fig. 3) because there are no nearby wells in the Vale Formation and because little is known about this formation in Taylor County. BARKELEY-1 is 53.5 ft deep, and BARKELEY-2 is 93.2 ft deep. Detailed well schematics are included in appendix 2.

Hydraulic Properties

No previously reported pumping tests are reported for wells in the Antlers, Vale, or Choza Formations or in the Fredericksburg Group in Taylor County. The only reported aquifer tests are specific capacity tests in the Choza Formation and well yields in the other formations. Taylor (1978) reported three specific capacity tests with calculated specific capacities of 0.9, 3.2, and 6.8 gallons per minute per ft (gpm/ft). These values correspond to transmissivities of 170, 610, and 1,300 ft^2/day (method of Thomasson and others, 1960).

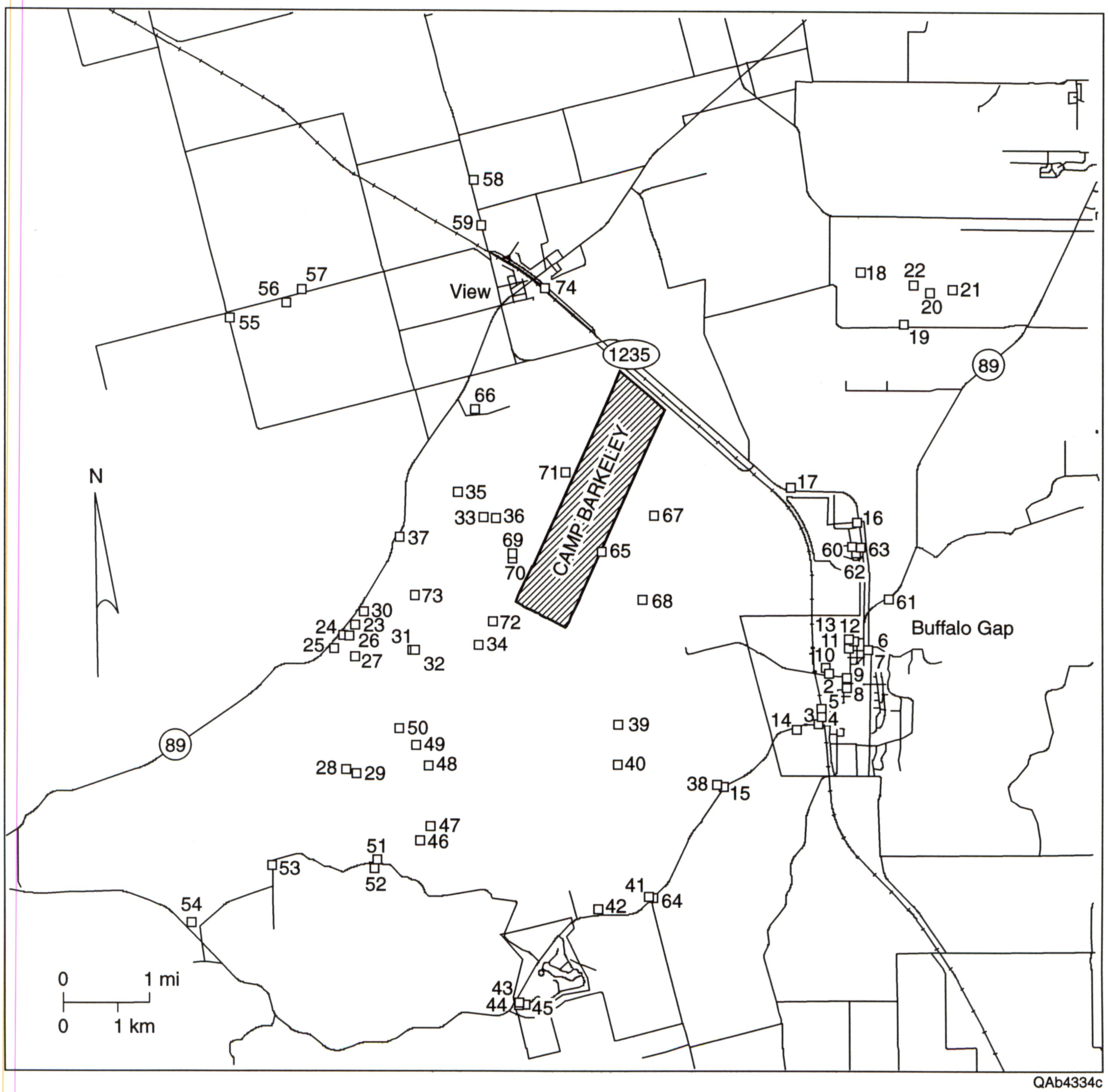


Figure 4. Well locations around Camp Barkeley.

Well yield tests represent the amount of pumping a well can sustain; however, these tests do not quantify aquifer permeability and are biased by user requirements and pump size. Nevertheless, well yields do offer information on the relative productivity of aquifers. Well yields in the formations of interest are not high, with most values under 60 gallons per minute (gpm) (fig. 5). The Antlers Formation has most well yields below 40 gpm (fig. 3a), and the Choza Formation has the highest well yields with values as high as 150 gpm (fig. 3b). The few well yield tests in the Fredericksburg Group and the Vale Formation have values less than 30 gpm (fig. 3c and 3d). The Fredericksburg Group probably has higher transmissivities than the Permian formations because the Fredricksburg Group is locally fractured.

We conducted a pumping test at a well (S036) completed in the Antlers Formation west of the camp (fig. 4) and determined that transmissivity ranges from 46 to 140 ft^2/day depending on the method of analysis (fig. 6). A bail test we ran in a well (S071) completed in colluvium along the mesa perimeter west of the camp showed a transmissivity of 13.5 ft^2/day with a storativity of 10^{-5} (fig. 7).

Ground-Water Chemistry

Each of the water-yielding formations had water-quality assessments reported in the TWDB files (app. 3). Total dissolved solids (TDS) for the Antlers Formation ranged from 269 to 750 mg/L, with most values between 300 and 400 mg/L (fig. 8a). TDS for the Fredericksburg Group was similar, ranging from 250 to 574 mg/L with most values between 250 and 400 mg/L (fig. 8b). TDS in the Permian system were considerably higher, with values in the Choza Formation ranging from 368 to 5,136 mg/L and most values between 750 and 1,000 mg/L (fig. 5c). TWDB files report two values of TDS, 1,675 and 4,200 mg/L, in the Vale Formation (fig. 8c).

Waters from the Cretaceous formations (the Antlers Formation and the Fredericksburg Group) are predominantly calcium-bicarbonate in composition (figs. 9a and 10a, respectively). Waters from the Permian formations are more chemically diverse and not easily classified. There is no dominant type of water composition in the Choza Formation, with many samples having almost equal proportions of sodium, calcium, and magnesium (fig. 9b). The water composition of the Vale Formation and undifferentiated Permian system is similar to the water composition of the Choza Formation, though chlorine may be the dominant anion (fig. 10b).

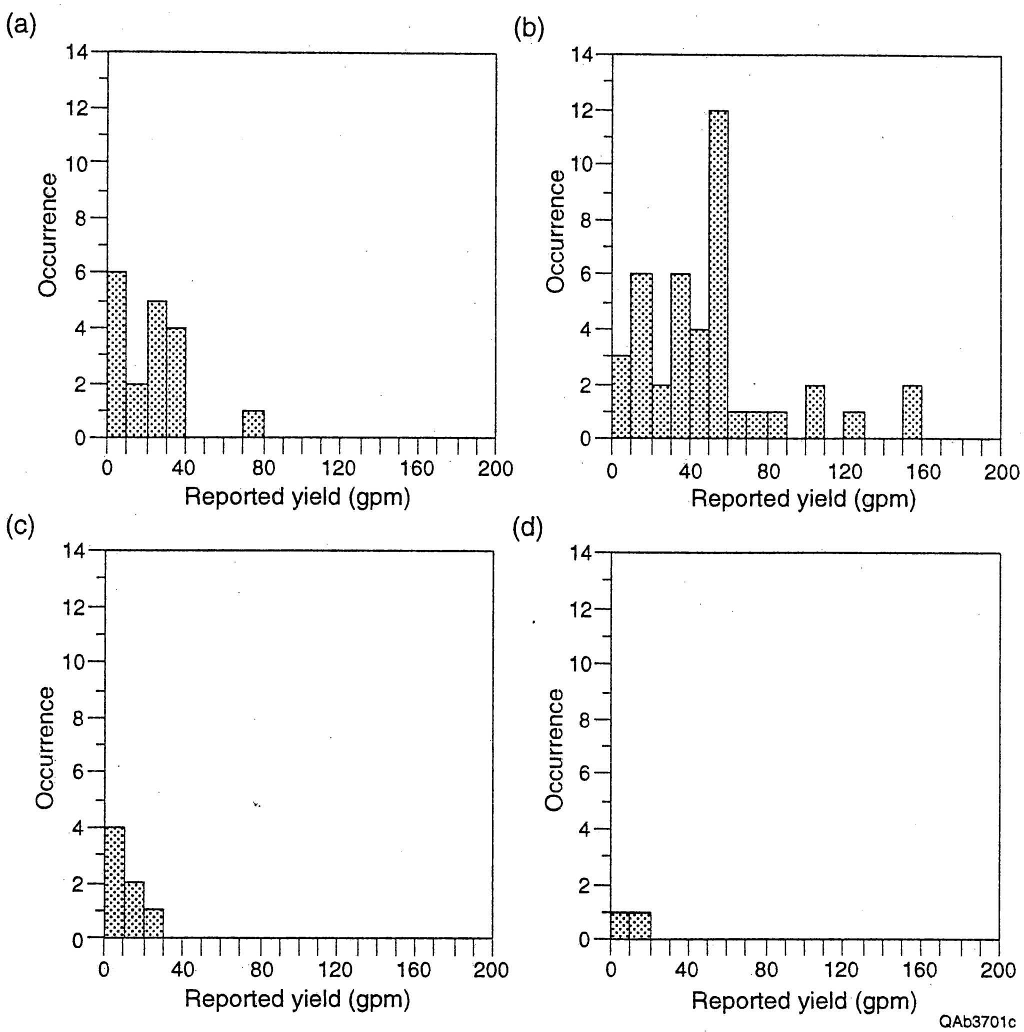


Figure 5. Well yields reported for the (a) Antlers Formation, (b) Choza Formation, (c) Fredericksburg Group, and (d) the Vale Formation in Taylor County.

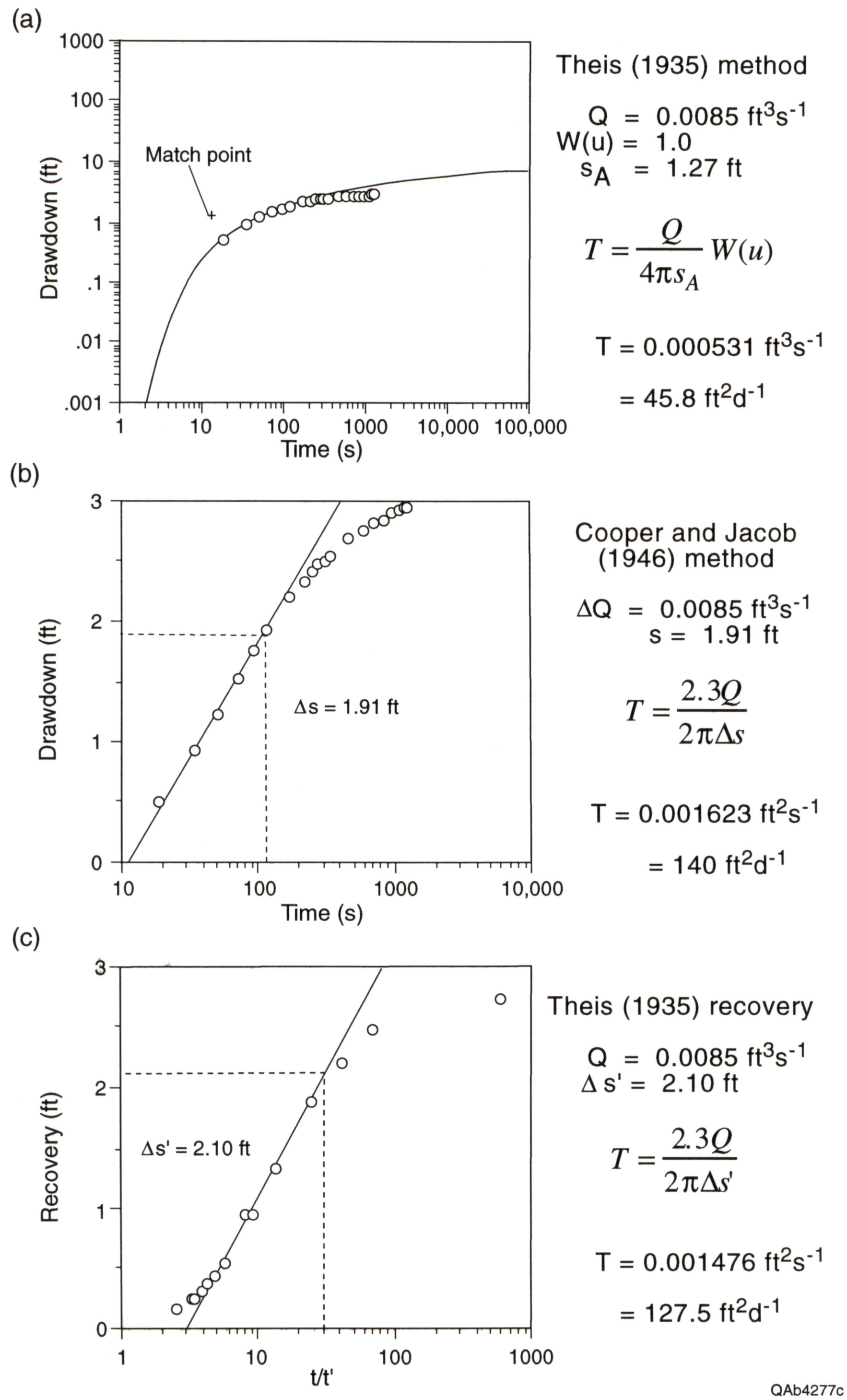


Figure 6. Interpretation of pumping test results at S036 near Camp Barkeley using (a) the Theis method, (b) the Jacobs method, and (c) Theis recovery.

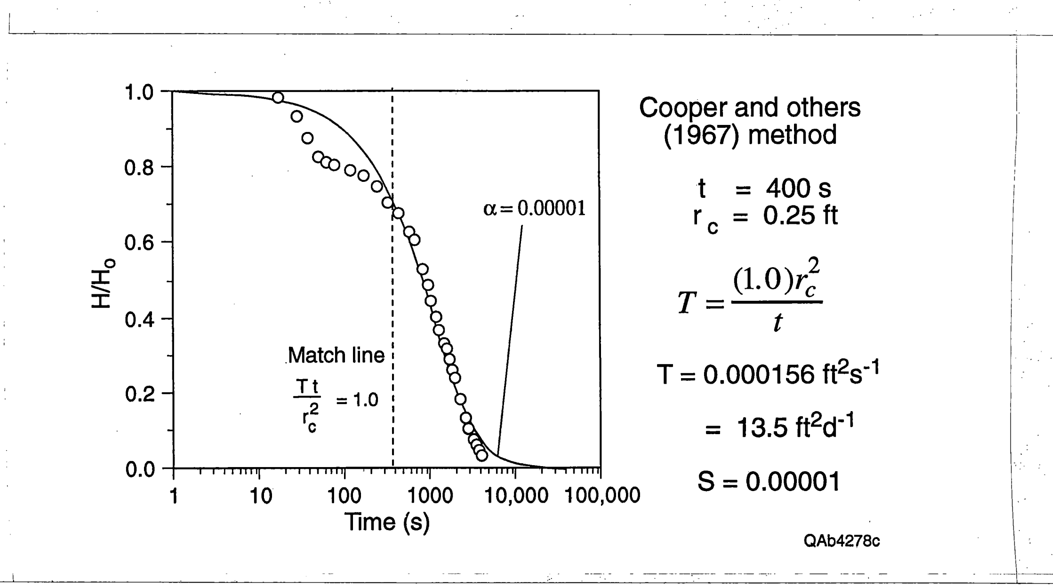


Figure 7. Interpretation of bail test results at S071 near Camp Barkeley using Cooper and others (1967) method.

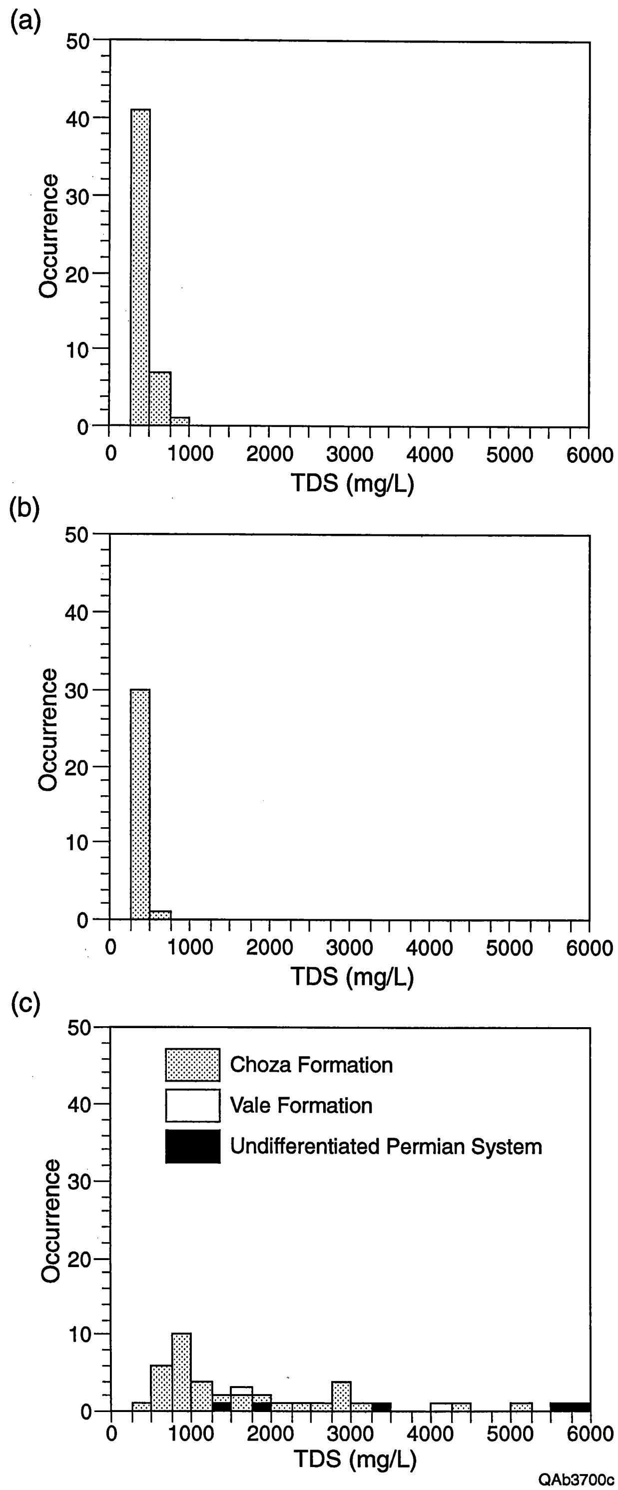


Figure 8. Histograms of total dissolved solids (TDS) in (a) the Antlers Formation, (b) the Fredericksburg Group, and (c) the Permian System in Taylor County.

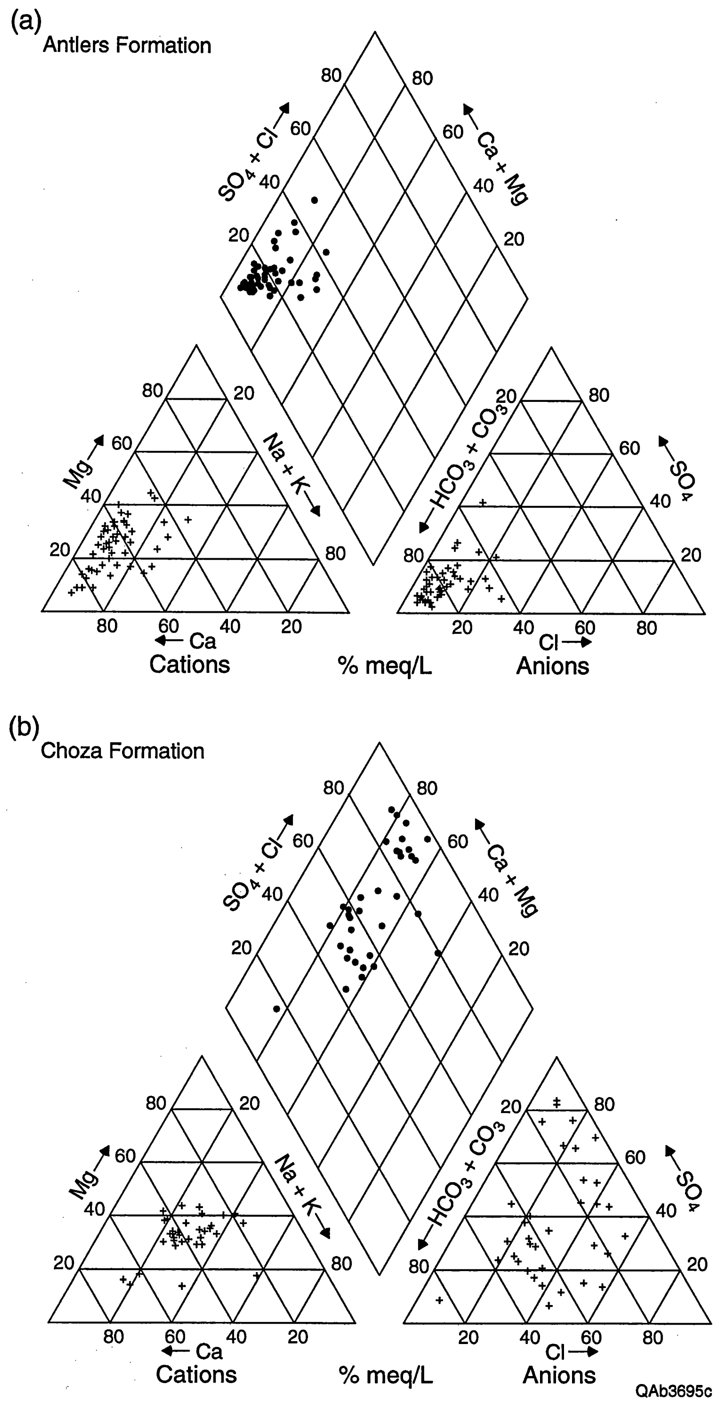


Figure 9. Trilinear diagram showing chemical composition of ground-water samples from the (a) Antlers and (b) Choza Formations in Taylor County.

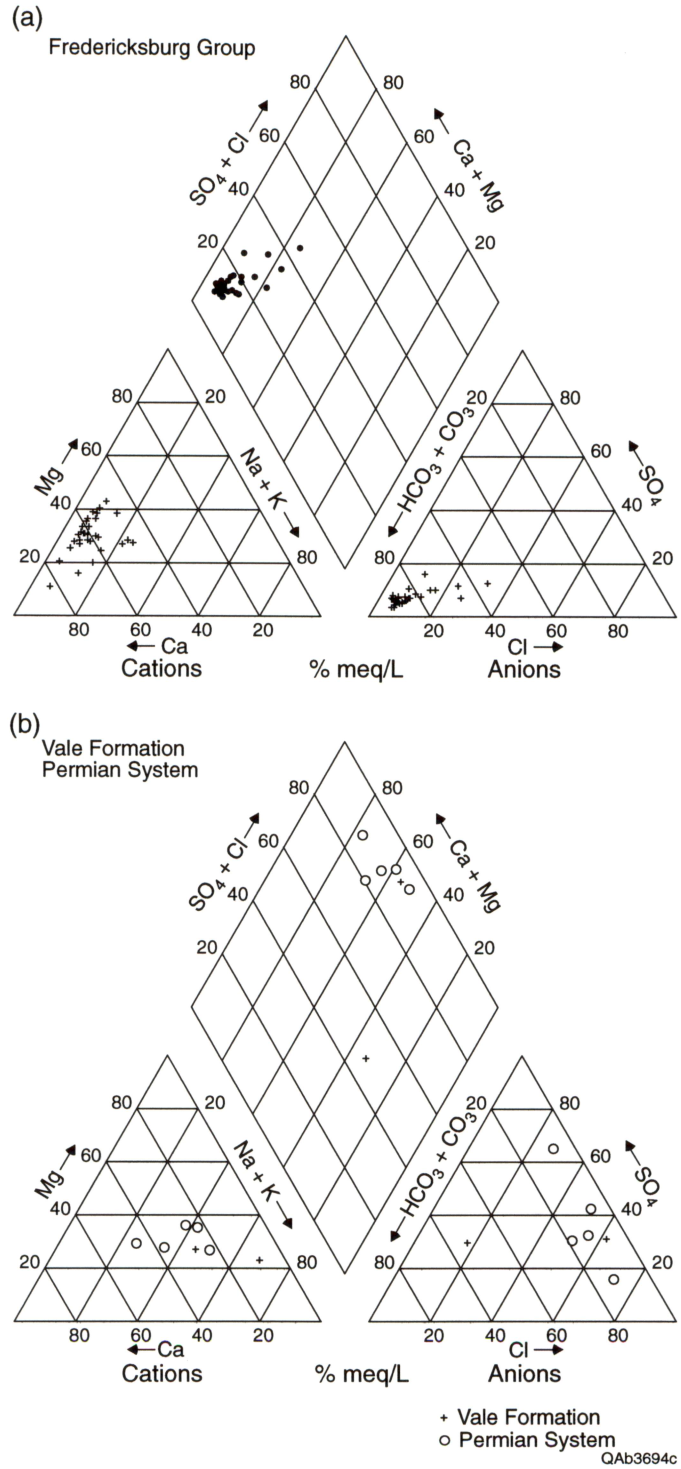


Figure 10. Trilinear diagram showing chemical composition of ground-water samples from (a) the Fredericksburg Group and (b) the Vale Formation and Permian System in Taylor County.

Water Levels

TWDB files had sufficient water-level data to construct long-term hydrographs for the Choza Formation (fig. 11a and 11b), alluvium (fig. 11c), and the Antlers Formation (fig. 11d). These hydrographs show similar patterns of water-level fluctuations that are likely due to long-term variations in recharge to the aquifers.

Depths to water vary from formation to formation and vary spatially within formations. Two wells in the Vale Formation were 124 and 58 ft deep with depth to water of 27 and 4.5 ft, respectively. Depth to water in the Cretaceous varied from 2 to 197 ft with well depths ranging from 15 to 294 ft. Wells measured in the Antlers Formation near Camp Barkeley had depths to water of 100 to 240 ft. A hand-dug well in the southern, low-lying part of Camp Barkeley (completed in alluvium/colluvium and the Vale or Choza Formation) had a water level 32 ft below land surface in 1971. The wells we drilled in the Vale Formation had no water in them, which indicates that the vadose, or unsaturated, zone beneath Camp Barkeley is greater than 93 ft deep.

Water levels show that ground water flows from centers of the Cretaceous mesas outward toward mesa edges (fig. 12). Water levels in the Vale Formation indicate that ground-water flow is directed from the mesa edges toward surface-water drainages to the north and east (fig. 12).

Conceptual Flow Model

The following conceptual flow model is based on the results of our camp surveys and published information about the Camp Barkeley area. Rainfall on the training facility percolates into the ground and recharges water-bearing units beneath Camp Barkeley. This recharge most likely occurs through preferential flow paths consisting of vertically interconnected fractures. The rainfall that percolates into the Fredericksburg Group that caps the camp mesas travels to the water table and moves laterally to discharge points on the perimeters of the mesas. Part of the water moves from the Fredericksburg Group into the underlying Antlers Formation and then discharges to the perimeter of the mesas. Minor amounts of water may also be transferred from the Antlers Formation into the underlying Permian strata. Some ground water might migrate from offsite into the camp through the Fredericksburg Group and the Antlers Formation from the west.

Water that exits the Fredericksburg Group and Antlers Formation either discharges through seeps and minor springs or moves into permeable colluvium created by the erosion of

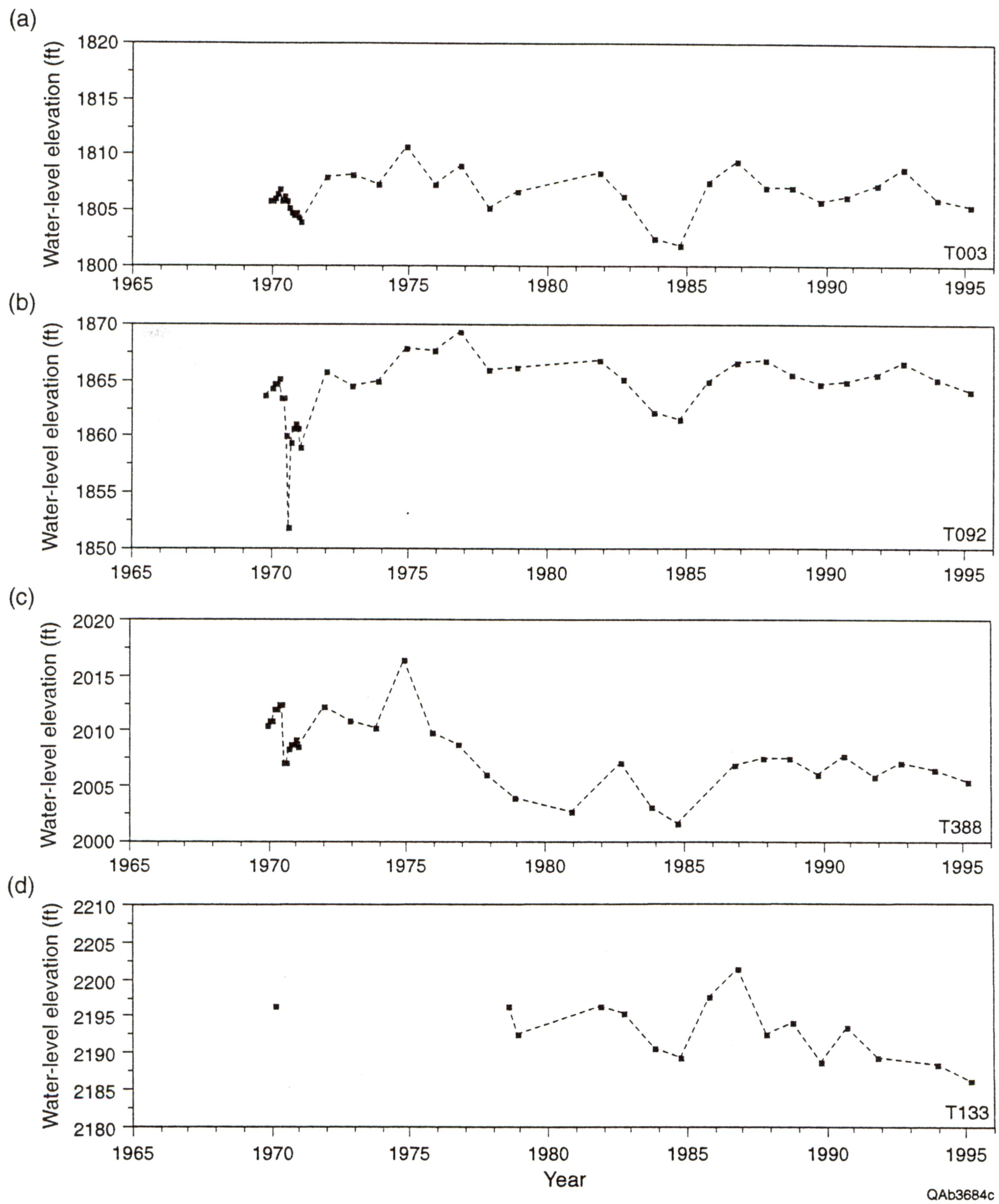


Figure 11. Water levels measured in the Choza Formation in wells (a) 29-32-913 and (b) 29-40-601, in the alluvium of Elm Creek in well (c) 30-50-118, and in the Antlers Formation in well (d) 29-48-601 for Taylor County.

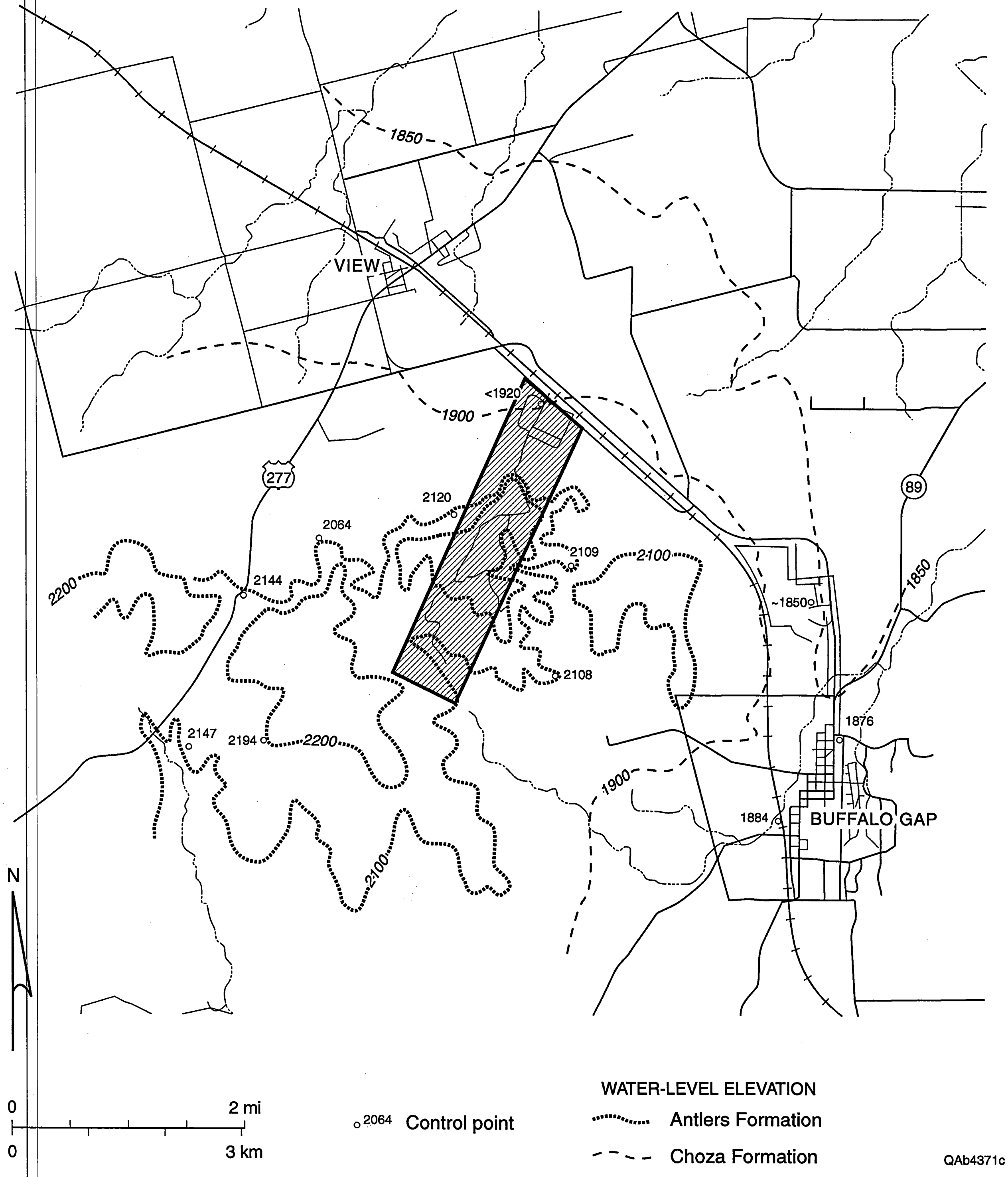


Figure 12. Potentiometric surface map of water levels in the Antlers and Vale Formations.

the mesa cliffs. A small part of the water moves into the Vale Formation where it is either lost by evapotranspiration or discharges into local topographic lows.

SURFACE-WATER HYDROLOGY

Principal Streams and Drainage Basins

Camp Barkeley resides in the Clear Fork River Basin (TDWR, 1984), which is part of the Brazos River Basin (zone 2) (TDWR, 1983). Surface water on the camp moves into first-order tributaries of the Elm Creek and Little Elm Creek drainage basin. Runoff in the south and northeast areas of the camp feeds into local intermittent creeks that connect into intermittent Elm Creek. Runoff on the northwest side of the camp feeds into local intermittent creeks that connect into intermittent Little Elm Creek (fig. 13). These creeks flow to the northeast, through Abilene, into Lake Fort Phantom Hill, into Clear Fork Brazos River, and into the Brazos River. Drainage is dentritic. Channel slopes are steeper where streams run from the mesas into the surrounding lowlands. Camp activities such as road construction have altered drainage on the camp. For example, the entrance road leading up the mesa has directed runoff along the sides of the road, which has led to erosion and has perhaps shortened the path of water into small streams.

Flow Duration and Flood Frequency

No stream gauges exist on Camp Barkeley; however, there are two gauges nearby on Elm Creek and Little Elm Creek that accept discharge from low-order creeks that drain the camp. Elm Creek and Little Elm Creek are intermittent streams with flows as high as 1,600 and 900 cubic feet per second (cfs), respectively (figs. 14a and 15a). Water is not flowing in Elm Creek 45 percent of the time, and no flow exists in Little Elm Creek 80 percent of the time (figs. 14b and 15b). Using a log Pearson Type III fit to the annual maxima series, there is a 50 percent chance of having an annual flood greater than 400 cfs in Elm Creek (fig. 14c) and a 50 percent chance of having an annual flood greater than 185 cfs in Little Elm Creek (fig. 15c).

Floodplain Analysis

Camp Barkeley does not contain substantial 100-yr floodplains. The only mappable floodplain, which barely extends from the streambed, is on the small stream in the southern part of the camp (fig. 13). Owing to the steep slopes near the mesa, rainfalls may cause substantial sheet flows and runoffs that can fill nearby arroyos and erode the landscape. Down the camp road up to the mesa, erosion due to runoff is evident. The 100-yr 24-h rainfall is 8.5 inches with a maximum

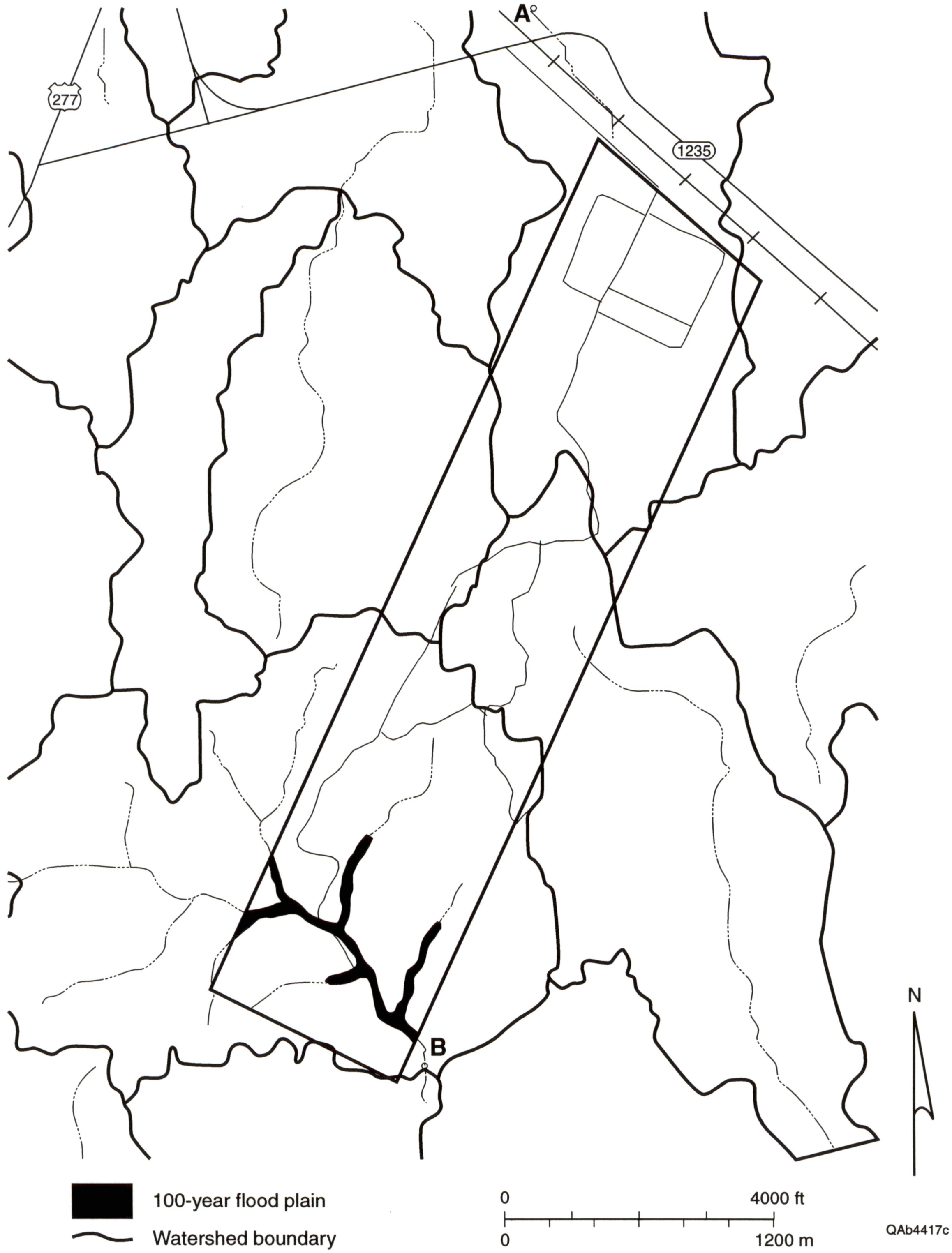


Figure 13. Watershed delineations and 100-yr floodplains for Camp Barkeley. Points A and B refer to flood hydrographs in figure 16.

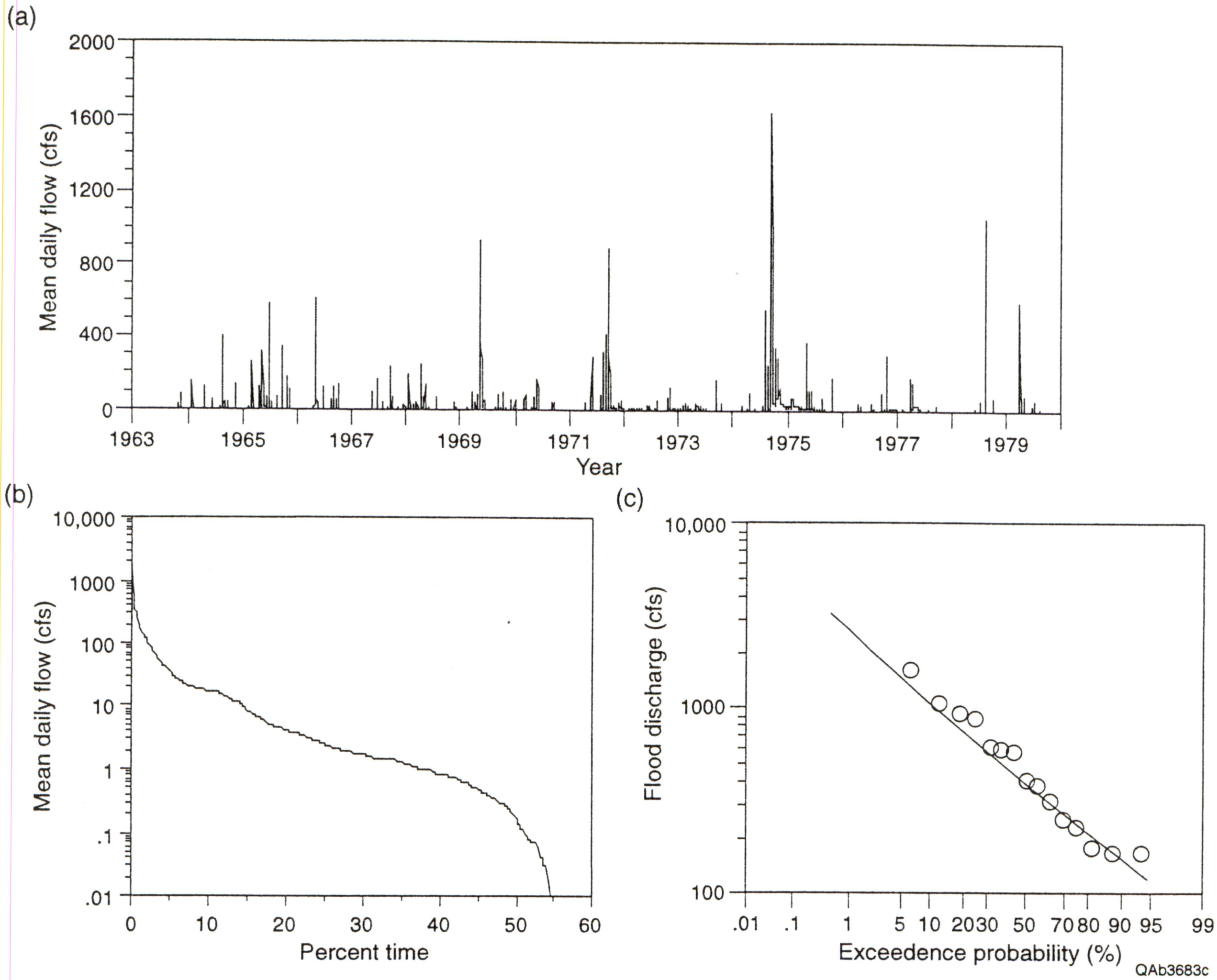


Figure 14. (a) Mean daily flow, (b) flow duration, and (c) flood frequency analysis with a log Pearson III fit for a stream gauge on Elm Creek near Abilene.

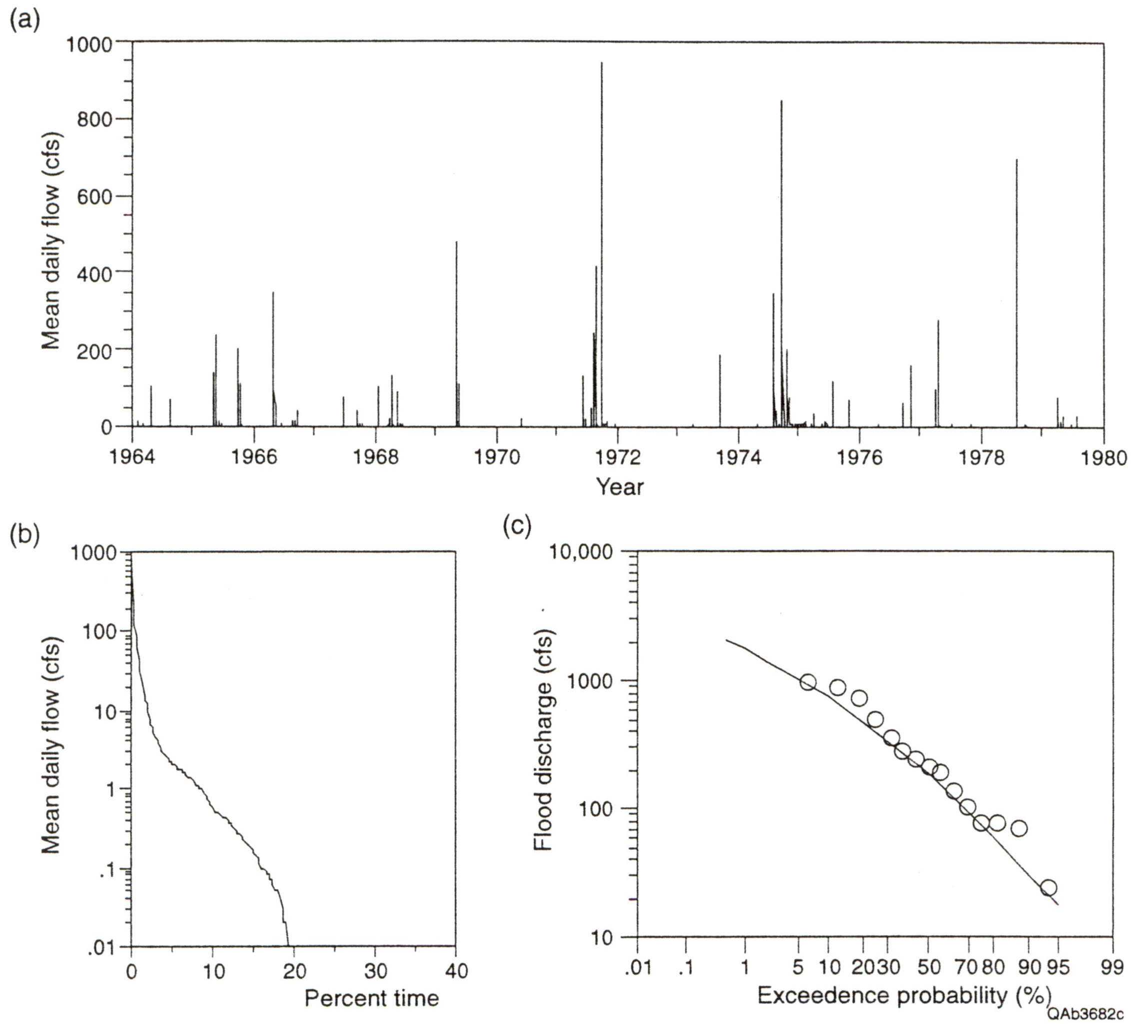


Figure 15. (a) Mean daily flow, (b) flow duration, and (c) flood frequency analysis with a log Pearson III fit for a stream gauge on Little Elm Creek near Abilene.

SCS Type II distributed rainfall intensity of 3.61 inches/h (fig. 16a). This 100-yr rainfall results in a maximum flow of 918 cfs in the northern stream (fig. 16b for point A in fig. 13) and 2,538 cfs in the southern stream (fig. 16c for point B in fig. 13).

GIS DATA PREPARATION

Several layers of data and information were automated for inclusion into a geographical information system (GIS). These layers include:

- Roads
- Watersheds
- Digital elevation map (DEM)
- Floodplains
- Soil maps
- Location of off-camp wells
- Location of on-camp wells
- Water-level maps

The data dictionary for these layers is included in appendix 4.

SUMMARY

Ground-water and surface-water investigations at Camp Barkeley were conducted to assist the Texas Army National Guard in planning and conducting training and readiness activities while preserving environmental quality and water resources. The training facility occupies an area of rolling hills and mesas, with approximately 460 ft of relief between high and low areas. Ground water in the Camp Barkeley area is produced from alluvial deposits bordering streams and rivers and the Antlers Formation (Trinity Group). One water well was found on the camp and 64 wells were located around the facility. The locations of existing wells are strongly controlled by geology and population centers; most existing wells are located southeast of the camp. Recharge on the camp is thought to occur primarily through interconnected vertical fractures on topographically high regions. Much of the local recharge discharges at the perimeters of mesas or into colluvium formed by erosional retreat of the mesa cliff.

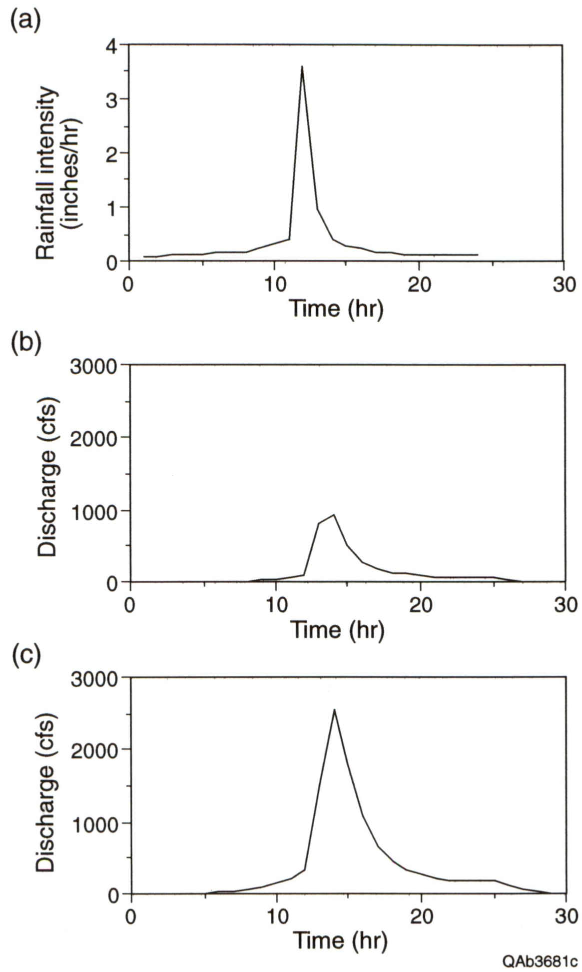


Figure 16. Flood hydrograph analysis for Camp Barkeley including (a) 100-yr 24-h SCS Type II distributed rainfall intensity and 100-yr flood hydrographs near the camp boundary for (b) the northern stream (point A, fig. 13) and (c) the southern stream (point B, fig. 13).

Surface runoff on Camp Barkeley flows to arroyos, intermittent streams, or tributaries that ultimately discharge to Lake Fort Phantom Hill, Clear Fork Brazos River, or the Brazos River. Surface runoff after heavy storms can be intense, rapidly filling arroyos and streambeds and causing heavy erosion. However, 100-yr floodplains are essentially confined to stream channels because of the high relief of the camp grounds and the fact that there are no permanent streams on the grounds.

Spills or contaminants on topographically high parts of the camp, particularly over fracture zones, are the greatest threat to ground-water quality. Surface contamination or debris that can be swept into streambeds and arroyos during intense rainstorms are the most likely threats to the quality of surface water.

ACKNOWLEDGMENTS

This work was funded by the Texas Army National Guard under interagency contract THCB-95-1-05-01. We thank Jim Fries of The Nature Conservancy of Texas, Project Manager, for helpful discussions and suggestions. Jim Resner, Paul Powell, and William Furr of the Texas Army National Guard Adjutant General's Office ensured access to the camp and to previous reports. Captain William Decker greatly assisted this study by providing access to Camp Barkeley and information regarding wells on the camp grounds. Bill Mullican, Jordan Foreman, William Doneghy, Bart Kelley, Andy Graham, and Sammy Jacobo assisted with drilling and documenting monitor wells. Alan Dutton reviewed the draft report. Others contributing to this report were Nancy Cottington, Patrice A. Porter, Jana S. Robinson, Scott Schulz, and Tari Weaver, graphics; Jeannette Miether, editing; Alison Boyd, proofreading; and Susan Lloyd, pasteup and word processing.

REFERENCES

Bedient, P. B., and Huber, W. C., 1988, Hydrology and floodplain analysis: Reading, Massachusetts, Addison-Wesley Publishing Company, 630 p.

Bomar, G. W., 1983, Texas weather: Austin, Texas, University of Texas Press, 265 p.

Chow, V. T., 1964, Handbook of applied hydrology, a compendium of water-resources technology: New York, McGraw-Hill Book Company, variously paginated.

Connor, N. R., 1976, Soil survey of Taylor County: U.S. Government Printing Office, U.S. Department of Agriculture and Soil Conservation Service, 66 p.

Cooper, H. H., and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well field history: American Geophysical Union Transactions, v. 27, p. 526–534.

Cooper, H. H., Bredehoeft, J. D., and Papadopulos, I. S., 1967, Response of a finite-diameter well to an instantaneous charge of water: Water Resources Research, v. 3, p. 263–269.

ESRI, 1993, Cell-based modelling with Grid: ArcInfo user's guide: Redmond, California, Environmental Systems Research Institute, variously paginated.

Herschfield, D. M., 1961, Rainfall frequency atlas of the United States, for durations from 30 minutes to 24 hours and return periods from 1 to 100 years: U.S. Weather Bureau, Technical Report 40, variously paginated.

Hydrologic Engineering Center, 1981, HEC-1 flood hydrograph package, user's manual and programmer's manual (updated 1988): Davis, California, U.S. Army Corp of Engineers, variously paginated.

Hydrologic Engineering Center, 1995, HEC-RAS river analysis system: Davis, California, U.S. Army Corp of Engineers, variously paginated.

Larkin, T. J., and Bomar, G. W.,1983, Climatic atlas of Texas: Texas Department of Water Resources, 151 p.

Linsley, R. K., Jr., Kohler, M. A., and Paulhus, J. L. H., 1982, Hydrology for engineers: New York, McGraw-Hill Book Company, 508 p.

Maidment, D. R., 1995, Hydrologic data sets and tools for their interpretation: Palm Springs, California, GIS and Hydrology Workshop, 15th annual ESRI User Conference, variously paginated.

McCarthy, G. T., 1938, The unit hydrograph and flood routing: U.S. Army Corps of Engineers, conference of the North Atlantic Division, unpublished paper, unpaginated.

Snyder, F. F., 1938, Synthetic unit hydrographs: Transaction of the American Geophysical Union, v. 19, pt. 1, p. 447–454.

Soil Conservation Service, 1957, Use of storm and watershed characteristics in synthetic hydrograph analysis and application: Washington, D.C., U.S. Department of Agriculture, variously paginated.

Soil Conservation Service, 1991, State soil geographic data base (STATSGO): Washington, D.C., U.S. Department of Agriculture, miscellaneous publication no. 1492, variously paginated.

Taylor, H. D., 1978, Occurrence, quantity, and quality of ground water in Taylor County, Texas: Texas Department of Water Resources Report 224, 126 p.

TDWR, 1983, Water for Texas, planning for the future: Texas Department of Water Resources, Austin, Texas, 39 p.

TDWR, 1984, Water for Texas, technical appendix: Texas Department of Water Resources, Austin, Texas, variously paginated.

Tharp, B. C., 1939, The vegetation of Texas: Houston, The Anson Jones Press, The Texas Academy of Science, 74 p.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage: Transactions of the American Geophysical Union, v. 16, p. 519–524.

Thomasson, H. J., Olmstead, F. H., LeRoux, E. R., 1960, Geology, water resources, and usable ground-water storage capacity of part of Solano County, California: U.S. Geological Survey Water Supply Paper 1464, 693 p.

Appendix 1

Well Inventory Data Base

Appendix 1. Well inventory data base.

Well no.	Depth (ft)	Water level (ft BTOC)	Casing height (ft)	Diameter (inches)	Casing material	Well use	Land-surface elevation (ft)	Water level (ft BLS)
S001	-	-	-	30	concrete	-	-	-
S002	-	-	-	-	-	-	-	-
S003	40	-	-	-	-	-	-	-
S004	35	19.5	3.75	120	concrete	municipal	1898	15.75
S005	30	-	-	-	-	municipal	-	-
S006	48	~14	-	12	steel	municipal	1890	14 est.
S007	48	~14	-	12	steel	municipal	1890	14 est.
S008	-	-	-	-	-	-	-	-
S009	-	-	-	6	PVC	yard and pool	-	-
S010	32	~13	-	8	PVC	yard	1902	13 est.
S011	40	~25	-	8	iron pipe	yard	1902	25 est.
S012	-	-	-	-	-	-	-	-
S013	-	-	-	-	-	-	-	-
S014	-	-	-	-	-	-	-	-
S015	-	-	-	-	-	-	-	-
S016	-	-	-	-	-	-	-	-
S017	-	-	-	-	-	-	-	-
S018	-	-	-	-	-	-	-	-
S019	-	-	-	-	-	-	-	-
S020	-	-	-	-	-	-	-	-
S021	-	-	-	-	-	-	-	-
S022	-	-	-	-	-	-	-	-
S023	268	95.64	0.82	6	PVC	domestic	2205	94.82
S024	138	-	-	6	PVC	domestic	-	-
S025	~120	-	-	6	PVC	domestic	-	-
S026	-	-	-	-	-	-	-	-
S027	81.6	63.73	0.67	6	galvanized pipe	unused	2202	63.06
S028	~50	~45	-	60	stone	domestic	-	-
S029	~20	~10	-	6	PVC	yard & garden	-	-
S030	90	~45	-	-	-	-	-	-
S031	150	-	-	6	steel	-	-	-
S032	184	91.06	8.46	4	stovepipe	-	2310	82.60
S033	>180	-	-	-	-	-	-	-
S034	200	-	-	6	PVC	unused	-	-
S035	~240	237.23	1.33	5	PVC	-	2305	235.90

Appendix 1. Well inventory data base.

Well no.	Depth (ft)	Water level (ft BTOC)	Casing height (ft)	Diameter (inches)	Casing material	Well use	Land-surface elevation (ft)	Water level (ft BLS)
S036	265	236.81	0.5	6	steel	domestic	2360	-
S037	23.7	18.25	1.91	36	stone	unused	2150	16.34
S038	-	-	-	-	-	-	-	-
S039	~15	-	-	60	concrete	domestic	-	-
S040	40	-	-	6	PVC	-	-	-
S041	40	25 est.	-	8	iron pipe	irrigation	-	25 est.
S042	-	-	-	-	-	-	-	-
S043	33.08	1.75	-0.95	6	PVC	unused	1995	2.70
S044	-	2.32	-0.95	6	PVC	unused	1995	3.27
S045	-	-	-	6	PVC	unused	1995	-
S046	-	-	-	-	-	-	-	-
S047	-	-	-	-	-	-	-	-
S048	-	-	-	-	-	-	-	-
S049	-	-	-	-	-	-	-	-
S050	-	-	-	-	-	-	-	-
S051	-	-	-	-	-	-	-	-
S052	-	-	-	-	-	-	-	-
S053	-	-	-	-	-	-	-	-
S054	-	-	-	-	-	-	-	-
S055	-	-	-	-	-	-	-	-
S056	-	-	-	-	-	-	-	-
S057	-	-	-	-	-	-	-	-
S058	-	-	-	-	-	-	-	-
S059	-	-	-	-	-	-	-	-
S060	-	-	-	-	-	-	-	-
S061	40	-	-	6	-	unused	-	-
S062	-	-	-	6	-	stock and yard	-	-
S063	-	-	-	6	-	stock and yard	-	-
S064	30	25 est.	-	-	brick	unused	-	-
S065	190*	99.4	2.17	6	steel	stock	2305	
S066	-	-	-	-	-	-	-	
S067	-	173.74	0.58	4	steel	aband	2280	
S068	-	-	-	-	-	-	-	
S069	-	-	-	6	steel	stock	-	
S070	-	-	-	-	-	aband	-	

Appendix 1. Well inventory data base.

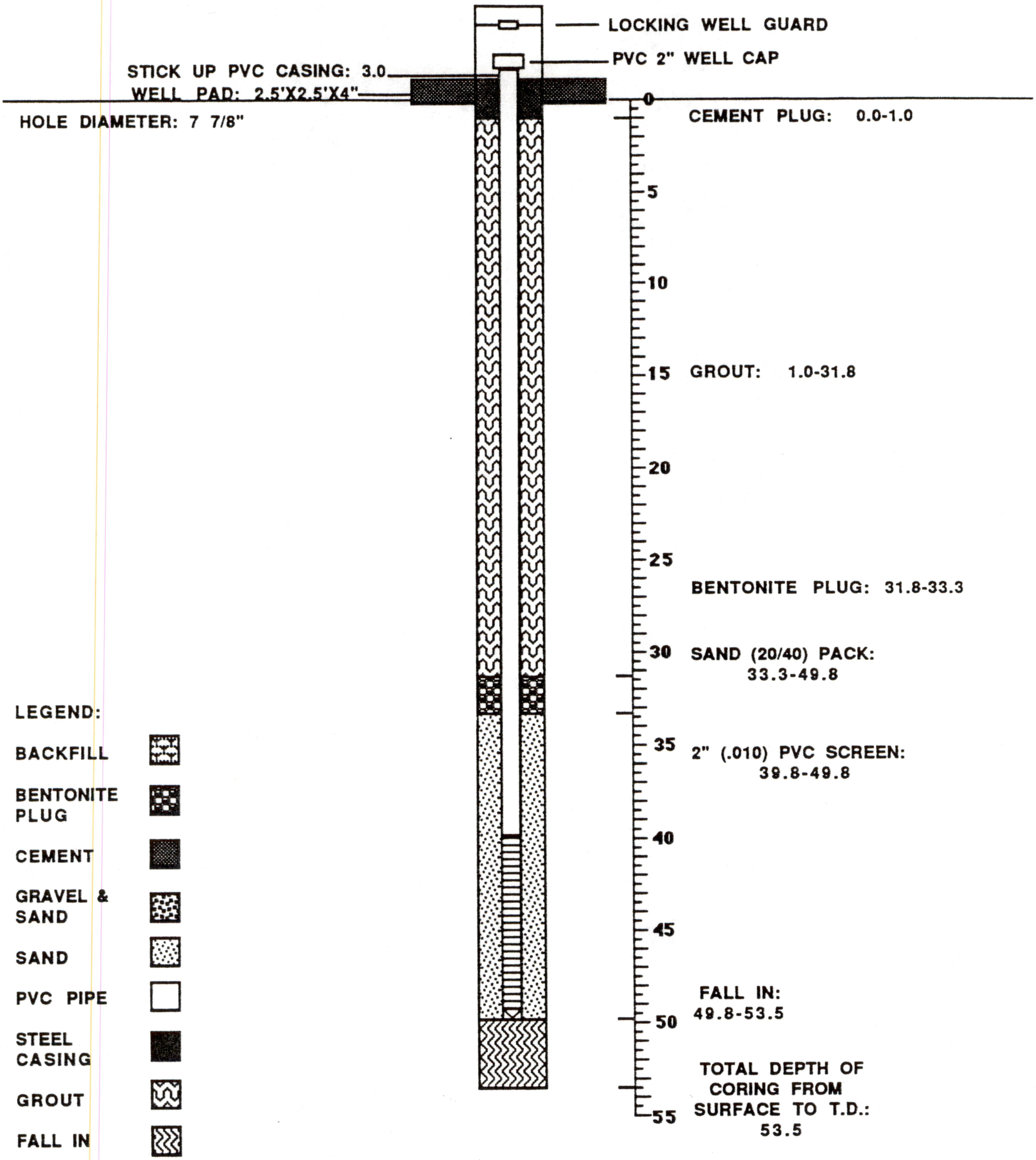
Well no.	Depth (ft)	Water level (ft BTOC)	Casing height (ft)	Diameter (inches)	Casing material	Well use	Land-surface elevation (ft)	Water level (ft BLS)
S071	-	19.87	0	6	stove pipe	stock	-	
S072	-	-	-	-	-	-	-	
S073	-	-	-	-	-	-	-	
S074	-	-	-	-	-	-	-	

All depths are reported by the owners except:
* from TWDB files
~ indicates owner-supplied information
BTOC: below top of casing
BLS: below land surface

Appendix 2

Detailed Well Schematics and Drilling Reports for Monitor Wells

WATER MONITOR SCHEMATIC
CAMP BARKELEY #1
DRILL DATE: 12/3/95
NATIONAL GUARD PROJECT



Send original copy by certified mail to: TNRCC, P.O. Box 13087, Austin, TX 78711-3087 — *Please use black ink.*

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

State of Texas WELL REPORT

Texas Water Well Drillers Advisory Council
P.O. Box 13087
Austin, Texas 78711-3087
512-239-0530

Camp Barkeley #1

1) OWNER Texas National Guard (Name) **ADDRESS** P.O. Box 5218 (Street or RFD) Austin (City) Tx (State) 78763 (Zip)

2) ADDRESS OF WELL: County Taylor — Camp Barkeley Buffalo Gap (Street, RFD or other) Buffalo Gap (City) Texas (State) 79508 (Zip) **GRID #** 30-41-5

3) TYPE OF WORK (Check): ☒ New Well ☐ Deepening ☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☒ Monitor ☐ Environmental Soil Boring ☐ Domestic ☐ Industrial ☐ Irrigation ☐ Injection ☐ Public Supply ☐ De-watering ☒ Testwell
If Public Supply well, were plans submitted to the TNRCC? ☐ Yes ☐ No

5) 32° 19' 39" / 99° 52' 2" — N

6) WELL LOG: Date Drilling: Started 12/3 19 95 — Completed 12/3 19 95

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
7 7/8	Surface	53.5

7) DRILLING METHOD (Check): ☐ Driven ☐ Air Rotary ☐ Mud Rotary ☒ Bored ☐ Air Hammer ☐ Cable Tool ☐ Jetted ☒ Other Augared

From (ft.)	To (ft.)	Description and color of formation material
0.0	3.5	Brown top soil with caliche
3.5	53.5	Red clay spotted with green intervals

(Use reverse side if necessary)

8) Borehole Completion (Check): ☐ Open Hole ☒ Straight Wall ☐ Underreamed ☐ Gravel Packed ☐ Other
If Gravel Packed give interval . . . from ____ ft. to ____ ft.

CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2"	N	PVC Schedule 40 riser	3.0 Above Surface	39.8	
2"	N	PVC Schedule 40 screen	39.8	49.8	.010

9) CEMENTING DATA: [Rule 338.44(1)]
Cemented from 4" Above Surface ft. to 1.0 ft. No. of Sacks Used 3.5
____ ft. to ____ ft. No. of Sacks Used ____
Method used Hand Poured
Cemented by Drill Crew
Distance to septic system field lines or other concentrated contamination N/A ft.
Method of verification of above distance N/A

10) SURFACE COMPLETION
☒ Specified Surface Slab Installed [Rule 338.44 (2) (A)]
☒ Specified Steel Sleeve Installed [Rule 338.44 (3)(A)]
☐ Pitless Adapter Used [Rule 338.44 (3)(b)]
☐ Approved Alternative Procedure Used [Rule 338.71]

11) WATER LEVEL:
Static level ____ ft. below land surface Date ____
Artesian flow ____ gpm. Date ____

12) PACKERS: Type Depth

13) TYPE PUMP: ☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder ☐ Other ____
Depth to pump bowls, cylinder, jet, etc., ____ ft.

14) WELL TESTS: Type test: ☐ Pump ☐ Bailer ☐ Jetted
Yield: ____ gpm with ____ ft. drawdown after ____ hrs.

15) WATER QUALITY: Did you knowingly penetrate any strata which contained undesirable constituents?
☐ Yes ☐ No
Type of water? ____ Depth of strata ____
Was a chemical analysis made? ☐ Yes ☐ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 15 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME University of Texas/Bureau of Economic Geology (Type or Print) **WELL DRILLER'S LICENSE NO.** 3187-M

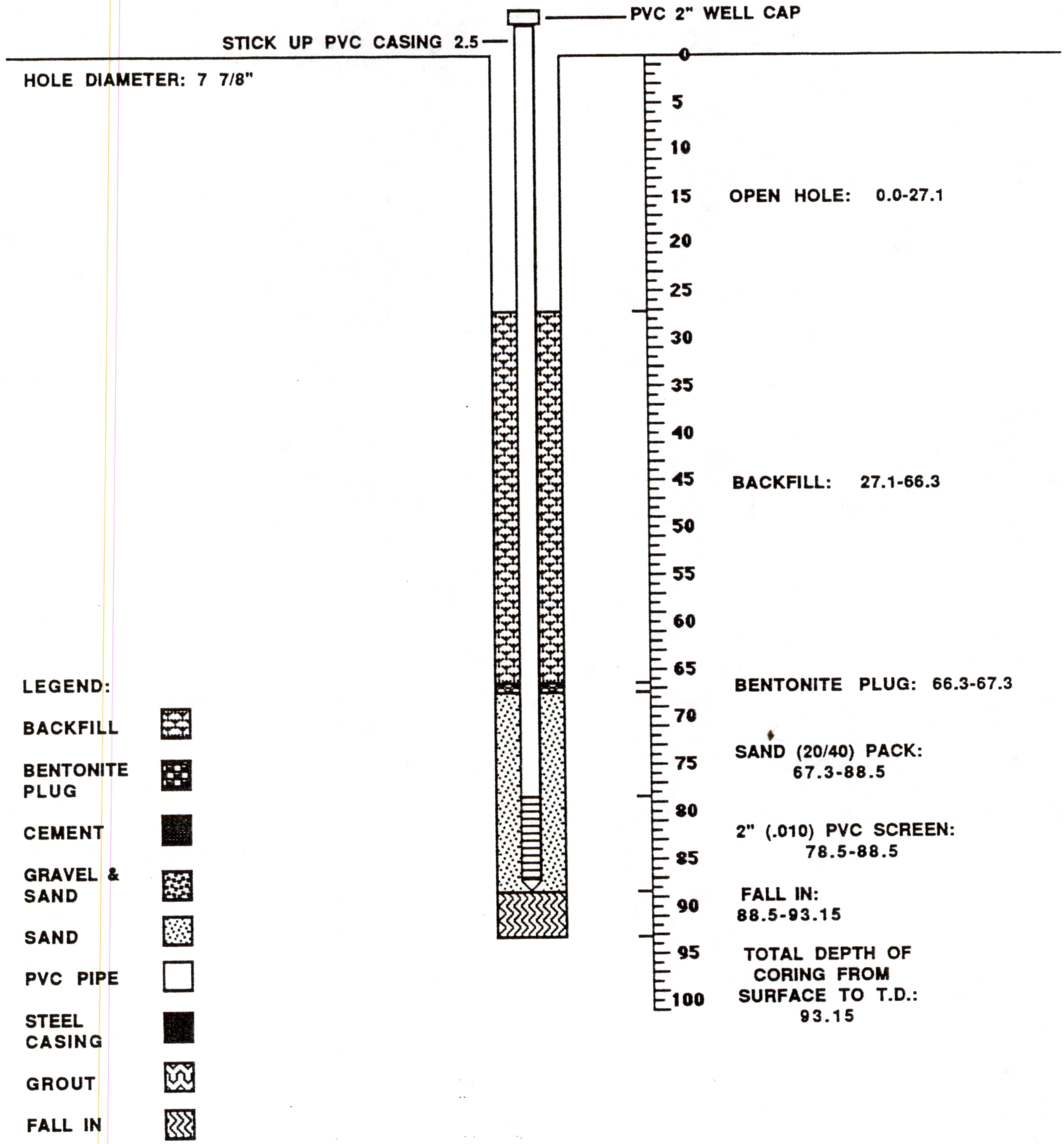
ADDRESS P.O. Box X University Station (Street or RFD) Austin (City) Texas (State) 78701 (Zip)

(Signed) James Doss (Licensed Well Driller) **(Signed)** Jordan Forman (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

TNRCC-0199 (Rev. 11-01-94) TNRCC COPY

WATER MONITOR SCHEMATIC
CAMP BARKELEY #2
DRILL DATE: 2/14/95
NATIONAL GUARD PROJECT



Send original copy by certified mail to: TNRCC, P.O. Box 13087, Austin, TX 78711-3087 — *Please use black ink.*

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

State of Texas WELL REPORT

Texas Water Well Drillers Advisory Council
P.O. Box 13087
Austin, Texas 78711-3087
512-239-0530

Camp Barkeley #2

1) OWNER Texas National Guard (Name) **ADDRESS** P.O. Box 5218 (Street or RFD) Austin (City) Tx (State) 78763 (Zip)

2) ADDRESS OF WELL: County Taylor — Camp Barkeley Buffalo Gap (Street, RFD or other) Buffalo Gap (City) Texas (State) 79508 (Zip) **GRID #** 30-41-5

3) TYPE OF WORK (Check): ☒ New Well ☐ Deepening ☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check): ☒ Monitor ☐ Environmental Soil Boring ☐ Domestic ☐ Industrial ☐ Irrigation ☐ Injection ☐ Public Supply ☐ De-watering ☒ Testwell
If Public Supply well, were plans submitted to the TNRCC? ☐ Yes ☐ No

5) 32° 19' 39" / 99° 52' 2" — N

6) WELL LOG: Date Drilling: Started 2/13 19 96 Completed 2/14 19 96

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
7 7/8	Surface	93.15

7) DRILLING METHOD (Check): ☐ Driven ☐ Air Rotary ☐ Mud Rotary ☒ Bored ☐ Air Hammer ☐ Cable Tool ☐ Jetted ☒ Other Augared

From (ft.)	To (ft.)	Description and color of formation material
0.0	3.4	Brown soil with caliche
3.4	8.4	Brown sandy soil
8.4	13.4	Light red sandy clay
13.4	91.0	Red clay spotted with green intervals
91.0	93.2	Very hard grey rock

(Use reverse side if necessary)

8) Borehole Completion (Check): ☐ Open Hole ☒ Straight Wall ☐ Underreamed ☐ Gravel Packed ☐ Other
If Gravel Packed give interval . . . from ____ ft. to ____ ft.

CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2"	N	PVC Schedule 40 riser	2.5' Above Surface	78.5	
2"	N	PVC Schedule 40 screen	78.5	88.5	.010

9) CEMENTING DATA: [Rule 338.44(1)]
Cemented from ____ ft. to ____ ft. No. of Sacks Used ____
____ ft. to ____ ft. No. of Sacks Used ____
Method used N/A
Cemented by ____
Distance to septic system field lines or other concentrated contamination N/A ft.
Method of verification of above distance N/A

10) SURFACE COMPLETION N/A
☐ Specified Surface Slab Installed [Rule 338.44 (2) (A)]
☐ Specified Steel Sleeve Installed [Rule 338.44 (3)(A)]
☐ Pitless Adapter Used [Rule 338.44 (3)(b)]
☐ Approved Alternative Procedure Used [Rule 338.71]

11) WATER LEVEL:
Static level ____ ft. below land surface Date ____
Artesian flow ____ gpm. Date ____

12) PACKERS: Type Depth

13) TYPE PUMP: ☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder ☐ Other
Depth to pump bowls, cylinder, jet, etc., ____ ft.

14) WELL TESTS: Type test: ☐ Pump ☐ Bailer ☐ Jetted
Yield: ____ gpm with ____ ft. drawdown after ____ hrs.

15) WATER QUALITY: Did you knowingly penetrate any strata which contained undesirable constituents?
☐ Yes ☐ No
Type of water? ____ Depth of strata ____
Was a chemical analysis made? ☐ Yes ☐ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 15 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME University of Texas/Bureau of Economic Geology (Type or Print) **WELL DRILLER'S LICENSE NO.** 3187-M

ADDRESS P.O. Box X University Station (Street or RFD) Austin (City) Texas (State) 78701 (Zip)

(Signed) ____ James Doss (Licensed Well Driller) (Signed) ____ Jordan Forman (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

Appendix 3

Taylor County Water Chemistry Data

Appendix 3. Taylor County water chemistry data.

State well number	YR	Temp (C°)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Sr (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	Cl (mg/L)	F (mg/L)	NO_3 (mg/L)	pH	TDS (mg/L)	Total alk (mg/L)	Total hardness (mg/L)	Spec. cond. (mW)
Antlers Formation:																		
2948403	1993	21	16	87	33	58	2.2	0.48	334.4	53	67	0.81	34.66	7.2	516	274	353	904
2948406	1969	18	11	67	22	19	-	-	273	18	21	0.6	28	7.6	320	224	256	592
2948601	1982	23	11	100	21	14	-	-	371	44	8	0.3	0.9	8.1	381	304	336	730
2948602	1970	20	10	69	44	22	4	-	383	59	20	0.5	0.4	7.6	417	314	353	790
2948605	1970	18	11	67	41	27	-	-	368	66	23	0.6	0.4	7.6	416	302	339	790
2948705	1978	21	10	57	34	55	-	-	328	103	17	1.1	0.4	8	438	269	283	800
2955602	1970	17	16	88	14	23	-	-	305	39	20	0.5	6.5	7.3	356	250	277	648
2955603	1970	18	11	102	11	9	-	-	282	22	20	0.3	39	7.4	352	231	302	640
2955604	1970	12	7	78	14	7	-	-	276	23	8	0.3	0.4	7.7	273	226	252	507
2956101	1969	21	11	79	20	7	-	-	314	16	10	0.5	3.5	7.6	301	257	274	568
2956104	1970	18	10	71	25	15	1	-	307	20	23	0.7	4.8	7.5	321	252	280	604
2956202	1969	20	12	67	18	11	-	-	275	10	13	0.6	10.5	7.9	277	225	242	510
2956206	1993	19	16	70	19	20	1.9	0.28	274.6	16	19	0.61	13.86	7.4	311	225	53	552
2956207	1970	18	15	62	18	11	-	-	260	6	17	0.5	12	7.8	269	213	232	500
2956301	1970	20	11	89	23	17	-	-	333	34	27	0.5	10.5	7.7	375	273	316	700
2956303	1970	20	10	110	45	22	-	-	382	112	53	1.2	1.5	7.6	542	313	458	1036
2956304	1970	19	8	67	31	40	-	-	338	68	28	1.2	0.4	7.7	409	277	294	765
2956502	1982	19	12	100	5	8	-	-	299	17	9	0.2	13	7.8	311	245	272	576
2956503	1970	16	11	74	25	9	-	-	328	15	10	0.5	5.5	8.2	311	269	286	580
2956601	1970	18	10	74	27	14	-	-	340	31	11	0.6	0.4	7.6	335	279	298	632
2956901	1970	18	12	98	28	25	-	-	406	52	13	0.5	1.8	7.5	429	333	360	816
2956902	1970	-	11	84	27	12	-	-	350	36	12	0.5	0.4	7.5	354	287	322	664
2964301	1970	10	18	99	29	11	-	-	375	28	14	0.7	34	7.8	418	307	366	770
3041401	1970	19	11	112	38	14	-	-	393	110	21	0.6	0.4	7.4	500	322	435	930
3041701	1970	18	11	90	20	15	-	-	334	44	15	0.3	0.4	7.7	359	274	308	670
3041703	1970	19	17	119	8	14	-	-	314	44	35	0.3	11	7.7	402	257	333	740
3041802	1970	21	13	142	10	24	1	-	340	24	96	0.3	0.4	7.7	477	279	394	924
3043602	1993	18	16	108	16	18	1.7	0.5	375.9	28	18	0.37	0.49	7.1	391	308	335	584
3043703	1970	19	10	96	16	35	-	-	336	50	30	0.3	14	7.9	416	275	307	770
3043803	1970	12	19	118	22	66	-	-	433	50	96	0.6	0.4	7.7	584	355	386	1078
3049102	1970	18	8	95	38	14	-	-	447	17	21	2.4	0.4	7.4	415	366	394	822
3049401	1970	21	10	101	36	20	-	-	438	36	31	0.5	6.5	7.4	456	359	398	876
3049402	1970	19	11	85	24	7	-	-	357	21	7	0.5	0.4	7.5	331	293	313	620

Appendix 3. (cont.)

State well number	YR	Temp (C°)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Sr (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	Cl (mg/L)	F (mg/L)	NO_3 (mg/L)	pH	TDS (mg/L)	Total alk (mg/L)	Total hardness (mg/L)	Spec. cond. (mW)
Antlers Formation (cont.):																		
3049601	1970	13	17	123	22	23	1	-	418	46	38	0.6	0.4	7.8	476	343	396	882
3049602	1970	15	20	115	25	34	-	-	451	42	29	0.7	0.4	7.4	487	370	388	900
3049603	1970	17	18	135	38	77	-	-	439	128	95	1	42.5	7.5	750	360	495	1395
3049605	1970	18	16	148	30	30	-	-	337	216	26	1	18	7.7	650	276	492	1155
3049901	1970	13	15	123	18	61	-	-	472	78	38	1	0.4	7.6	566	387	382	1043
3050801	1970	27	19	87	21	12	2	-	317	55	5	1.2	0.4	7.7	358	260	303	628
3051201	1970	19	13	185	12	17	-	-	388	39	58	0.3	143	7.4	658	318	510	1148
3051203	1970	14	12	105	10	12	-	-	348	16	17	0.4	0.4	7.3	343	285	304	632
3051204	1970	19	10	76	23	6	-	-	294	43	4	0.7	3	7.7	310	241	285	576
3051205	1970	18	13	95	21	9	-	-	342	36	11	0.4	12	7.7	365	280	325	665
3051301	1970	18	11	72	32	7	-	-	357	12	10	0.8	0.4	7.3	320	293	312	612
3051302	1970	18	12	85	20	12	-	-	351	15	13	0.3	0.4	7.4	330	288	296	616
3051501	1970	18	12	106	13	17	-	-	340	30	21	0.5	10	7.6	376	279	320	680
3051502	1993	21	13	123	14	29	2.6	0.59	316	43	46	0.36	65.08	7.2	492	259	365	640
3051601	1993	21	14	96	12	11	1.8	0.5	310	11	17	0.29	21.07	7.1	337	254	289	740
3051602	1970	21	14	93	12	10	-	-	325	12	19	0.2	0.4	7.5	320	266	282	588
Fredricksburg Group:																		
2947601	1969	19	16	99	35	59	-	-	318	58	109	0.7	41	7.2	574	261	391	1120
2947604	1982	23	12	94	13	19	-	-	304	26	24	0.6	28.8	8.1	366	249	289	679
2947902	1970	8	13	69	22	33	-	-	284	31	37	0.7	15	8	360	233	264	660
2947903	1970	14	11	64	18	13	-	-	256	14	16	0.6	9	7.8	271	210	233	498
2947904	1970	13	8	82	29	44	-	-	325	46	68	0.7	5.5	7.8	443	266	325	855
2947905	1970	6	8	64	16	9	-	-	256	11	13	0.6	3.5	7.8	250	210	226	465
2948701	1969	17	11	80	25	20	-	-	338	20	22	0.6	14	7.7	358	277	302	660
2948703	1970	13	9	75	26	11	-	-	326	20	13	0.7	6.5	7.8	321	267	296	604
2948704	1970	14	9	89	26	9	-	-	346	23	14	0.6	14	7.7	354	284	329	664
2948807	1970	15	8	70	33	12	-	-	348	24	19	0.6	0.4	7.7	338	285	312	645
2948808	1970	14	9	84	28	8	-	-	360	20	13	0.4	4.5	7.7	343	295	326	640
2956102	1970	9	10	68	19	12	-	-	279	14	15	0.6	5.5	7.8	281	229	247	522
2956103	1970	9	6	69	21	9	-	-	290	14	12	0.6	5.5	7.8	279	238	208	516
2956105	1970	12	8	67	27	11	-	-	299	20	21	0.7	8.5	7.7	310	245	277	576
2956106	1970	13	9	71	19	9	-	-	284	13	16	0.3	7	7.9	283	233	256	513

State well number	YR	Temp (C°)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Sr (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	Cl (mg/L)	F (mg/L)	NO_3 (mg/L)	pH	TDS (mg/L)	Total alk (mg/L)	Total hardness (mg/L)	Spec. cond. (mW)
Fredricksburg Group (cont.):																		
2956107	1970	13	5	75	19	7	-	-	300	17	9	0.5	2	7.7	282	246	267	525
2956108	1970	19	10	84	21	26	-	-	271	23	63	0.5	21	7.8	381	222	297	730
2956109	1970	13	15	96	30	21	-	-	381	28	37	0.5	17	7.4	431	312	364	800
2956110	1970	9	10	84	31	9	-	-	390	12	14	0.6	3.5	7.6	355	320	339	685
2956201	1969	19	13	72	22	12	-	-	312	12	13	0.6	4.5	7.6	302	256	269	564
2956204	1970	18	10	72	22	10	-	-	311	12	12	0.6	3.5	7.8	295	255	270	506
2956205	1970	18	9	85	37	11	-	-	415	20	15	0.5	2	7.9	383	340	367	735
2956208	1970	16	12	72	22	8	-	-	307	10	13	0.5	2	7.9	290	252	271	556
2956302	1970	13	12	65	32	22	-	-	345	23	23	0.6	0.4	8.1	347	283	292	655
2956504	1970	9	10	79	43	16	-	-	388	39	22	0.5	21	8.1	421	318	376	800
3049101	1970	14	12	83	36	14	-	-	344	59	27	0.5	0.4	7.3	401	282	355	765
3049403	1970	14	20	121	27	11	-	-	459	28	16	0.3	0.4	7.6	449	376	413	840
3049607	1970	-	2	85	16	24	-	-	298	32	34	0.3	0.4	7.5	340	244	279	675
3051208	1970	23	7	71	27	8	-	-	338	21	9	0.5	5	7.7	314	277	291	576
3051209	1970	19	7	97	8	8	-	-	310	22	8	0.2	0.4	7.7	303	254	275	560
3051303	1970	18	9	102	17	7	-	-	361	23	9	0.4	3.5	7.7	348	296	325	640
Choza Formation:																		
2932709	1968	-	29	137	177	404	-	-	440	830	475	2.8	77	7.7	2348	361	1070	4524
2932907	1969	21	16	220	89	155	3	-	204	780	162	0.9	24	7.5	1550	167	910	2856
2932909	1969	22	7	89	70	125	-	-	211	215	257	0.6	24	7.6	891	173	510	1823
2932912	1991	22	-	207	94	164	5.8	7.89	220.9	666	292	0.62	26	7.1	1572	181	912	2820
2940201	1970	22	12	375	181	391	5	-	304	1560	407	1.1	90	7.5	3171	249	1680	6048
2940202	1970	20	8	114	75	140	-	-	22	620	183	0.8	0.4	6.3	1152	18	590	2268
2940203	1970	18	29	135	78	74	-	-	410	222	163	1.2	30	7.4	933	336	660	1760
2940205	1970	19	-	373	187	336	-	-	306	1280	650	1	0.4	7	2977	251	1700	5814
2940301	1969	22	27	136	107	100	-	-	410	302	121	2.4	189	7.4	1185	336	780	2160
2940303	1969	22	16	58	36	27	-	-	342	30	18	0.9	14	7.6	368	280	293	700
2940312	1969	21	15	540	82	154	-	-	205	1570	126	0.9	39	7.4	2627	168	1700	4756
2940313	1970	21	20	112	44	61	2	-	284	241	51	0.8	43	7.6	714	233	462	1296
2940314	1991	23	-	89	49	41	6.4	4.3	308.8	152	67	0.8	38	7.3	599	253	428	985
2940315	1970	19	24	76	55	120	-	-	377	121	136	1.7	68	7.5	787	309	416	1458
2940319	1978	22	15	569	77	193	-	-	198	1669	120	0.6	32	8	2772	162	1738	5022

Appendix 3. (cont.)

State well number	YR	Temp (C°)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Sr (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	Cl (mg/L)	F (mg/L)	NO_3 (mg/L)	pH	TDS (mg/L)	Total alk (mg/L)	Total hardness (mg/L)	Spec. cond. (mW)
Choza Formation (cont.):																		
2940320	1970	20	18	91	45	82	-	-	346	138	94	0.7	15	7.2	653	284	413	1287
2940324	1991	21	-	136	62	90	4.9	4.1	356	300	117	0.59	49	7	939	292	599	1820
2940327	1970	21	22	160	75	97	3	-	326	257	165	0.7	176	7.5	1115	267	708	2052
2940328	1970	21	21	113	71	94	2	-	383	143	179	0.7	53	7.6	865	314	570	1694
2940330	1991	21	-	359	176	259	11	16.5	376	945	624	0.57	180	6.8	2756	308	1638	4060
2940501	1970	18	36	600	383	630	60	-	580	1390	1740	1	11	7.3	5136	478	3060	10416
2940502	1970	19	17	610	290	387	8	-	265	2600	437	1.1	14	7.5	4494	217	2720	8448
2940503	1970	22	18	425	186	283	5	-	303	1000	760	1	58	7.5	2884	248	1830	5658
2940601	1981	20	31	137	69	89	-	-	389	88	245	0.9	76	8.1	927	319	626	1790
2940605	1969	21	18	342	63	132	4	-	273	1020	74	1.3	10	7.2	1798	224	1110	3255
2940606	1969	19	27	98	84	114	-	-	470	133	194	1.7	40	7.6	922	385	590	1769
2940607	1969	21	28	72	79	137	-	-	421	101	198	3	94.	7.5	919	345	510	1755
2940609	1970	-	20	132	122	143	4	-	323	127	392	1	212	7.8	1311	265	830	2528
2940610	1991	21	-	100	73	134	6.6	16.2	326	120	292	1.17	-	6.7	903	267	568	1650
2940801	1969	18	18	82	42	95	-	-	334	111	66	0.7	134	7.5	712	274	377	1260
2940902	1970	21	21	75	43	85	-	-	310	36	164	1	31	7.5	608	254	367	1192
2940904	1970	24	17	92	47	67	-	-	348	129	104	1.1	2	7.6	630	285	423	1208
2956801	1969	27	17	158	27	136	-	-	411	243	139	1.6	18.	7.3	942	337	510	1749
3025712	1970	17	19	73	100	186	-	-	472	256	170	2.4	122	7.7	1160	387	590	2144
3057301	1970	29	34	174	83	510	5	-	442	463	690	2.4	65	7.7	2243	362	780	4340
Vale Formation:																		
3033506	1970	24	13	403	248	730	4	-	320	1080	1510	1.2	54	7.2	4200	262	2030	8517
3034401	1970	17	17	53	86	451	-	-	950	419	179	3	0.4	8.1	1675	780	489	3069
Undifferentiated Permian System:																		
3033402	1979	-	19	301	255	484	-	-	419.8	882	1137	1.2	0.1	7.7	3285	344	1800	6832
3033403	1979	-	23	443	405	885	-	-	439.3	1873	1745	0.9	1.3	7.8	5592	360	2771	11340
3033701	1979	-	22	190	87	185	9	-	279.5	326	426	0.5	106.7	7.8	1489	229	832	2961
3033703	1979	-	22	300	117	177	-	-	231.9	242	819	0.4	45.4	7.9	1836	190	1229	3900
3033704	1979	-	22	429	310	1042	-	-	375.9	2822	890	1.0	120.8	7.5	5821	308	2345	10920

Appendix 4

GIS Data Dictionary

GIS DATA DICTIONARY

Several layers of spatial hydrologic and hydrogeologic data were input to the Bureau of Economic Geology GIS system. Maps were digitized using a Calcomp digitizing table, under the ArcEdit module of GIS ArcInfo, on a Sparc500 Workstation. When possible, the data from the paper originals of the U.S. Geological Survey (USGS) 1:24,000-scale, 7.5-minute topographic maps were either transferred on Mylar or digitized during one session to minimize the distortions related to environmental factors. The digital data base, regardless of the original projection, will be delivered in the Universal Transverse Mercator (UTM) coordinate system, with the following parameters:

Ellipsoid: Clarke 1866
Horizontal Datum: NAD27
Units: meters
Zone 14

The digital data represent the following.

Digital Elevation Models (DEM) were acquired from MicroPath at 1:24,000 scale, where available (View, Buffalo Gap, Paris, Lake Bastrop, Elgin East, McDade, Graford East, Mineral Wells East, Mineral Wells West, and Whitt), or were created from digital elevation contours and streams using the Grid module of ArcInfo (Topogrid). The cell size for DEMs is 30 m, with a horizontal accuracy of ±3 m and a vertical accuracy of ±10 m. The DEMs were used to delineate watersheds of interest.

Watersheds represent polygon coverages encompassing the drainage areas. They were outlined from DEMs for Camp Swift, Camp Mabry, Camp Barkeley, and Fort Wolters or were defined from USGS topographic quads and then transferred to a digital format. Possible inaccuracy might be related to human error and imperfections of the digitizing equipment. Given the USGS-stated positional accuracy of ±40 ft for its 7.5-minute quads, and the inadvertent positional shifts that may have been introduced during the digitizing process, it can be estimated that the positional accuracy of most features will be approximately ±50 ft.

Floodplains are polygon coverages, digitized from USGS topographic quads, with the aforementioned accuracy estimate.

Well locations are point coverages, digitized from USGS topographic quadrangles; they include existing and recently drilled wells, with an internally assigned well name (number) as an item in the Point Attribute Table (PAT). They include wells on and around the camps.

Soil maps are generalized soil maps at 1:250,000 scale compiled by the U.S. Department of Agriculture Soil Conservation Service. They contain polygons describing groups of soil types and attached attribute tables with extensive sets of numerical values, including their hydrologic properties, which were used to specify the percentage of the map unit occupied by soils in each hydrologic group. The digital data were obtained from the Texas Natural Resources Information System (TNRIS) ftp site.

Water levels represent water-level contours, which, owing to scarcity of control points and the inherent interpolation problems of the software, were hand drawn and then digitized from Mylar overlays.

Cultural features include roads and generalized streams at 1:24,000 scale, at various extents around the camp. They were obtained from the TNRIS ftp site and are the latest version of Texas Department of Transportation (TxDOT) urban maps. These files were originally digitized from USGS 7.5-minute quadrangles. Updates are made periodically using TxDOT highway construction plans, aerial photographs, official city maps, and field inventory. These files contain most of the features found on 7.5-minute quads, except for items such as contour lines, fence lines, jeep trails, electrical transmission lines, oil and gas pipelines, and control data monuments.

The county map files are based on the following map projection system:

TEXAS STATEWIDE MAPPING SYSTEM (NAD27)

Projection: Lambert Conformal Conic

Ellipsoid: Clarke 1866

Datum: North American 1927

Longitude of Origin: 100 degrees west (-100)

Latitude of Origin: 31 degrees 10 minutes north

Standard Parallel #1: 27 degrees 25 minutes north latitude

Standard Parallel #2: 34 degrees 55 minutes north latitude

False Easting: 3,000,000 ft

False Northing: 3,000,000 ft

Unit of Measure: feet (international)

Positional Accuracy: These digital maps were created primarily for the purpose of producing county/urban published maps. Certain features, particularly railroads and streams, have been displaced in congested areas so as to insure map readability at county map scales.

Miscalculation of false northing and easting required reprojection of the DGN digital files, at the correct values (914,400 ft), in order to obtain the perfect overlay with several preexisting county and quadrangle files.

CAMP BARKELEY

Base maps: the USGS 7.5′ topographic quadrangles, View and Buffalo Gap, are in the State Plane coordinate system, North Central Zone (5351), datum NAD27, units in feet.

Coverage name	Coverage type	Initial projection	Final projection	Source	Accuracy	Description
Bkswellsutm	Point	State Plane North Central Zone	UTM	Digitized from USGS 7.5′ topographic quads	±40 ft RMS = 0.003	Location of off-camp wells
Bkcwellsutm	Point	State Plane North Central Zone	UTM	Digitized from USGS 7.5′ topographic quads	±40 ft RMS = 0.004	Location of on-camp wells
Arcamprdutm	Arc	Texas State Plane	UTM	TXDOT digital county files	±50 ft	Highways near the camp
Offcamprdutm	Arc	Texas State Plane	UTM	TXDOT digital county files	±50 ft	Highways and off-camp well locations
Oncamproads	Arc	Texas State Plane	UTM	Digitized from USGS 7.5′ topographic quads	±40 ft RMS = 0.003	Roads and trails in the camp
Streamsutm	Arc	UTM	UTM	Delineated from DEM	±40 ft	Streams and rivers delineated from DEM analysis; threshold = 5,000
Wshedutm	Polygon	UTM	UTM	Delineated from DEM	±40 ft	Watersheds corresponding to river segments
Boundutm	Polygon	State Plane North Central Zone	UTM	Texas Parks and Wildlife digital files	unknown	Camp boundary
Fplainutm	Polygon	State Plane North Central Zone	UTM	Digitized from USGS 7.5′ topographic quads	±40 ft RMS = 0.002	Floodplains
Fpstreamutm	Arc	State Plane North Central Zone	UTM	Digitized from USGS 7.5′ topographic quads	±40 ft RMS = 0.002	Stream orders and cross sections used for the HEC-RAS model
Quadutm	Polygon	UTM	UTM	TNRIS digital files	±100 ft	1:24,000-scale topographic quadrangles: View and Buffalo Gap
Soilsutm	Polygon	Texas State Plane	UTM	STATSGO digital database	unknown	1:250,000-scale distribution of soils in the watersheds
Wlevels	Arc	State Plane North Central Zone	UTM	Digitized from USGS 7.5′ topographic quads	±40 ft RMS = 0.002	Digitized water-level contour maps