GEOLOGY AND HYDROGEOLOGY OF NAVAL AIR STATION CHASE FIELD AND NAVAL AUXILIARY LANDING FIELD GOLIAD, BEE AND GOLIAD COUNTIES, TEXAS

By Grant L. Snyder

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95–4038

Prepared in cooperation with the
U.S. NAVY, NAVAL FACILITIES ENGINEERING COMMAND,
SOUTHERN DIVISION, CHARLESTON, SOUTH CAROLINA

Austin, Texas
1995

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
cubic foot per day (ft^3/d)	0.0003277	liter per second
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
foot per year (ft/yr)	0.3048	meter per year
foot squared per day (ft^2/d)	0.09290	meter squared per day
gallon per day (gal/d)	0.003785	cubic meter per day
gallon per minute (gal/min)	0.06309	liter per second
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
seconds per square foot (sec/ft^2)	10.764	seconds per square meter
square foot (ft^2)	0.09290	square meter
	Temperature	
degree Celsius (°C)	1.8×(°C+32)	degree Fahrenheit

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Geology and Hydrogeology of Naval Air Station Chase Field and Naval Auxiliary Landing Field Goliad, Bee and Goliad Counties, Texas

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Abstract

The geologic formations that crop out near Naval Air Station Chase Field and Naval Auxiliary Landing Field Goliad military bases consist of fluvial to fluvial-deltaic sediments of Tertiary and Quaternary age. These formations include the Fleming and Goliad Formations of Miocene age, Lissie Formation of Pleistocene age, fluvial terrace deposits of Pleistocene to Holocene age, and alluvium of Holocene age. The lithology of these formations consists of sand, sandstone, silt, and clay, with lesser amounts of gravel and caliche in the outcrops.

The freshwater aquifers underlying the study area are the unconfined Evangeline (water-table) aquifer, comprising the upper sandy parts of the Fleming Formation and Goliad Formation, and confined Fleming aquifers, comprising the thick sandstone beds of the Fleming Formation. Both military bases withdraw potable water from one of the confined aquifers. At Naval Air Station Chase Field, the transmissivity and storativity of the confined aquifer where the base withdraws its public water supply are 1,060 feet squared per day and $1.2x10^{-4}$, respectively, as computed from the results of a 74-hour constant-discharge aquifer test. Selected water-quality field measurements of specific conductance, pH, and temperature indicate that each of the three aquifers at Naval Air Station Chase Field are somewhat insulated from one another by the intervening confining units.

Large vertical hydraulic-head gradients are present between the unconfined Evangeline aquifer and confined Fleming aquifers at Naval Air Station Chase Field and Naval Auxiliary Landing Field Goliad. These gradients, together with the results of the aquifer test at Naval Air Station Chase Field and assumed characteristics of the confining units, indicate that downward flow of ground water probably occurs from the water-table aquifer to the underlying aquifers. The rate of downward flow between the two confined Fleming aquifers (from A-sand to B-sand) can be approximated using an estimate of vertical hydraulic conductivity of the intervening confining unit obtained from assumed storage characteristics and data from the aquifer test. Under the relatively high vertical hydraulic-head gradient induced by the aquifer test, ground-water movement from the A-sand aquifer to the B-sand aquifer could require about 490 years; and about 730 years under the natural gradient. Future increases in ground-water withdrawals from the B-sand aquifer might increase downward flow in the aquifer system of the study area.

INTRODUCTION

A reconnaissance investigation to delineate the subsurface geology and describe the hydrogeology at Naval Air Station (NAS) Chase Field and Naval Auxiliary Landing Field (NALF) Goliad (fig. 1) was conducted from April to November 1993, by the U.S. Geological Survey (USGS), in cooperation with the U.S. Navy, Naval Facilities Engineering Command. Data from this investigation supplement data collected in conjunction with the Naval Assessment and Control of Installation Pollutants (NACIP) program of the U.S. Navy and will aid in guiding any additional NACIP work concerning the deactivation of these military bases, which were officially closed in February 1993.

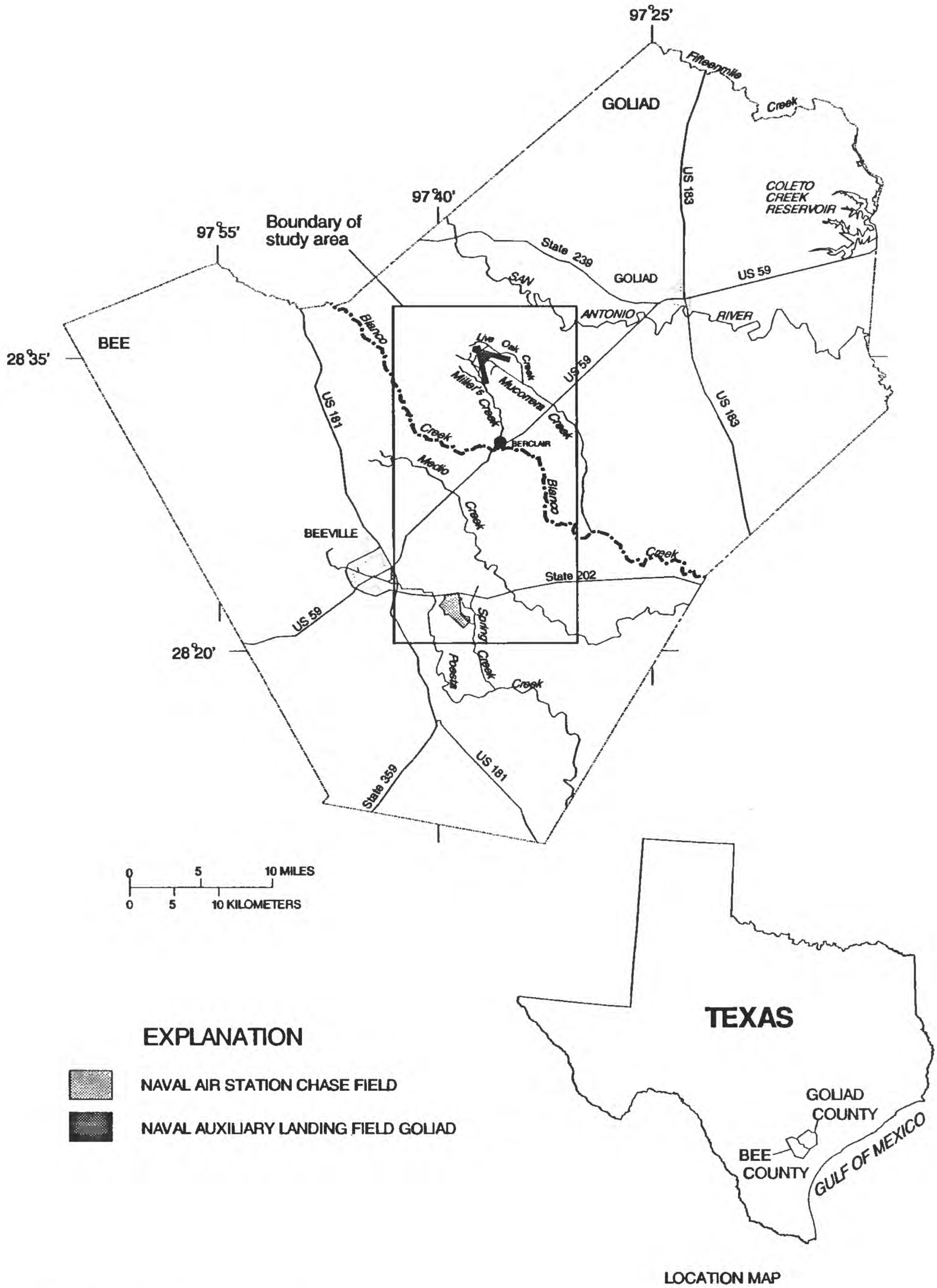

Figure 1. Location of the study area.

Geologic and hydrogeologic information that improves the understanding of flow in the shallow ground-water system is essential for selection and evaluation of actions involved with the transfer of custody of these properties and any future industrial development.

Purpose and Scope

This report describes the results of a reconnaissance investigation of the geology and hydrogeology of the surface and shallow subsurface at NAS Chase Field and NALF Goliad. The data in this report were obtained from test borings, monitor wells, water-supply wells, an aquifer test, a site investigation done by a previous contractor (Environmental and Safety Designs, Inc./Allen & Hoshell, 1993), and surface geologic investigations. The scope of the investigation was limited to defining the aquifers and the hydraulic interaction among the aquifers and confining units at both military bases.

Methods of Investigation

Available geologic information and previous studies done at NAS Chase Field and NALF Goliad and examination of the geologic formations that crop out in the study area were used as part of the investigation. Available data on the geology and hydrogeology of the study area, including drillers' and geophysical logs, were compiled and analyzed. A well inventory of all wells on both military bases and selected wells within the study area was done using Global Positioning System survey techniques. Water-level measurements were made at 27 monitor wells that had been constructed as part of a previous NACIP investigation at NAS Chase Field and NALF Goliad. Also, water-level measurements were made at the eight water-supply wells from both military bases and at selected wells surrounding NAS Chase Field. These water-level measurements were used to help define the conceptual hydrogeologic model of the study area. Specific conductance, pH, and temperature were measured at selected water-supply wells in the study area to aid in aquifer characterization. At NAS Chase Field, an aquifer test of the confined aquifer from which the public water supply is withdrawn was done to estimate aquifer properties and to obtain information about the hydraulic connection between the pumped aquifer and the two overlying aquifers.

Description of the Study Area

NAS Chase Field is in south-central Bee County and NALF Goliad is in western Goliad County (fig. 1). The study area is in south-central Texas in the western Gulf Coastal Plain physiographic province (Fenneman, 1938). The Gulf Coastal Plain, which slopes generally toward the Gulf of Mexico, consists of moderately hilly terrain in the northern part and nearly flat to gently rolling plains in the southern part (Ryder, 1988). The interstream surfaces are broad flats whose only relief is shallow basins caused by unequal drying and shrinkage of the calcareous clays (Fenneman, 1938). The shallow subsurface of the study area consists of fluvial to fluvial-deltaic sands and clays of Tertiary and Quaternary age. Surface altitudes in the study area range from about 100 ft above sea level in the southern part of the study area to about 350 ft above sea level in the northern part.

The major streams draining the study area are Poesta Creek in the southwestern part of the study area, Medio Creek and Blanco Creek in the center, and the San Antonio River in the northeastern part of the study area (fig. 1). NAS Chase Field is drained by a large excavated drainage ditch that empties into Spring Creek, a tributary of Poesta Creek. NALF Goliad is drained by Miller's Creek, Mucorrera Creek, and Live Oak Creek, which are upper tributaries of Blanco Creek.

Acknowledgments

Special thanks are extended to the officials of NAS Chase Field, the City of Beeville, the Texas Department of Criminal Justice, and the Texas Water Development Board who gave freely of their time and records. Particular thanks also are extended to David Fuehrer and Lisa Bennett of Environmental and Safety Designs, Inc./Allen & Hoshell (EnSafe/A&H) for their insights concerning data collection. Also, thanks are extended to the well drillers and landowners who granted access to their land, wells, and records.

GEOLOGY

The geologic formations that crop out near NAS Chase Field and NALF Goliad are sedimentary deposits of Tertiary and Quaternary age (fig. 2; table 1) consisting of the Fleming, Goliad, and Lissie Formations; fluvial terrace deposits; and alluvium. The Oakville Sandstone conformably underlies the Fleming

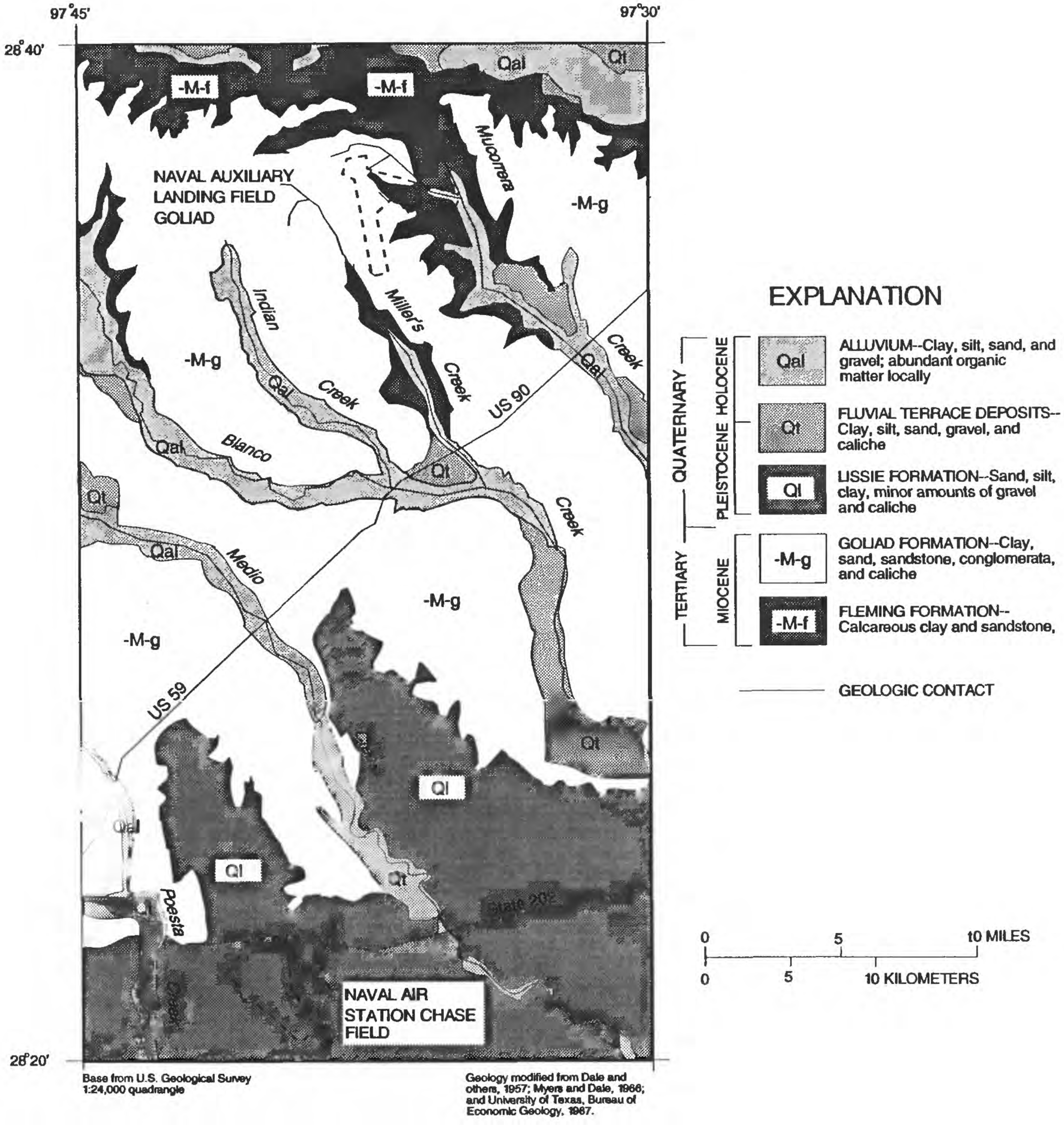

Figure 2. Surface geology near Naval Air Station Chase Field and Naval Auxiliary Landing Field Goliad.

Table 1. Summary of the lithology and hydrogeology of the geologic units near Naval Air Station Chase Field and Naval Auxiliary Landing Field Goliad, Texas

[Geology modified from Solis (1981); lithology modified from the University of Texas, Bureau of Economic Geology (1987). *, not in study area; +, subsurface only in study area]

System	Series	Stratigraphic unit	Thickness (feet)	Lithology	Hydrogeologic unit
Quaternary	Holocene	Alluvium	0–20	Clay, silt, sand, and gravel; abundant organic matter locally	Local alluvial aquifers
	Holocene / Pleistocene	Fluvial-terrace deposits	0–20	Clay, silt, sand, and gravel; concretions and massive accumulations of calcium carbonate (caliche) in zone of weathering	
	Pleistocene	Beaumont Formation *	*	Clay, silt, sand, and gravel; calcareous concretions and massive accumulations of calcium carbonate (caliche) and concretions of iron manganese oxide in zone of weathering	Chicot aquifer
		Lissie Formation	0–30	Sand, silt, clay, and minor amounts of gravel; locally contains calcareous concretions and massive accumulations of calcium carbonate (caliche) in zone of weathering	
Tertiary	Miocene	Goliad Formation	0–250	Clay, sand, sandstone, and conglomerate; locally contains calcareous concretions and massive accumulations of calcium carbonate (caliche) in zone of weathering	Evangeline aquifer
		Fleming Formation	650–800	Clay and sandstone; clay, calcareous; sandstone, medium grained, calcareous, thick bedded; some crossbedding	Burkeville confining system (Fleming aquifers) after Wesselman (1983)
		Oakville Sandstone +	300–500	Sandstone and clay; sandstone, medium grained, calcareous, thick bedded with minor amounts of gravel; clay, calcareous	Jasper aquifer
	Oligocene	Catahoula Formation +	350–600	Clay and sand; clay, bentonitic, noncalcareous except for calcareous concretions locally; sand, tuffaceous, crossbedded lenses	

Formation but does not crop out in the study area. The Beaumont Formation overlies the Lissie Formation, but does not crop out in the study area. The lithology of these formations consists of sand, sandstone, silt, and clay, with lesser amounts of gravel and caliche in the outcrops. These sediments were deposited in a fluvial to fluvial-deltaic setting. The formations in the study area generally dip to the southeast at a rate of approximately 20 to 40 ft/mi (Myers and Dale, 1966).

Tertiary System

The Tertiary system in the study area comprises the Fleming and Goliad Formations of Miocene age (table 1). The Fleming and Goliad Formations are composed of consolidated to unconsolidated sediments.

The oldest geologic unit that crops out in the study area is the Fleming Formation of Miocene age, whose uppermost beds crop out in the bottoms of creeks adjacent to NALF Goliad (fig. 2). The Fleming Formation includes all of the strata up to the base of the Goliad Formation (table 1). Dumble (1894) described the Fleming Formation of south Texas, originally the Lagarto Clay, as a calcareous clay with a little sand. In Bee and Goliad Counties, the Fleming Formation is composed predominately of non-marine, silty-to-sandy calcareous clays, and thick beds of sandstone deposited as fluvial, braided-to-meanderbelt facies; and interfluvial-interdeltaic floodbasin facies (Solis, 1981, p. 28). The sandstone beds consist of fine- to medium-grained, silica cemented quartz sand that could have an areal extent of several miles as observed in drillers' and geophysical logs of wells near NAS Chase Field and the city of Beeville. These sandstones terminate updip, downdip, and laterally by facies changes (Wesselman, 1983). The upper part of the Fleming Formation generally contains greater quantities of sand (40 to 60 percent) than the lower part (25 to 45 percent) (Solis, 1981, p. 27–29). Although the formation thickens downdip to the southeast, the section thins southwestward from about 800 ft at NALF Goliad to about 650 ft near NAS Chase Field (Dale and others, 1957, p. 10). Beneath NAS Chase Field, the top of the Fleming Formation is approximately 270 ft below the surface. Fossils in the Fleming Formation include reworked Cretaceous marine invertebrates and Miocene terrestrial vertebrates of *Protohippus* sp. (Sellards and others, 1932).

The Goliad Formation unconformably overlies the Fleming Formation and crops out in an irregular band across central Bee and Goliad Counties (fig. 2). The Goliad Formation, as described by the University of Texas, Bureau of Economic Geology (1987), consists of clay, sand, and sandstone, with chert conglomerates and caliche in the outcrop. Caliche is a surface deposit formed in semi-arid climates by the evaporation of calcium bicarbonate saturated ground water, leaving calcium carbonate precipitate in the interstices of the sand and gravel. Caliche occurs as a strongly cemented crust or succession of crusts in the unsaturated zone of soils (American Geological Institute, 1987, p. 95). These caliche deposits, which in some areas consist of more than 30 percent calcium carbonate, mantle broad areas along the outcrop of the Goliad and Lissie Formations, producing a well consolidated surface that is quite different from that of the loose sands exposed in northeastern parts of the State (Sellards and others, 1932, p. 755). The interbedded nature of the sands and clays in the Goliad Formation generally make correlation of individual beds over long distances difficult. However, at NAS Chase Field, several sandstone beds have an areal extent of at least 1 mi as observed in drillers' and geophysical logs of wells at the facility. At NAS Chase Field, the top of the Goliad Formation lies 20 to 30 ft below the surface with an average thickness of about 240 ft, as measured in gamma-ray borehole geophysical logs of the water-supply wells. At NALF Goliad, the Goliad Formation is approximately 50 ft thick and crops out over most of the interstream surfaces. Fossils include reworked fragments of terrestrial vertebrates and a few invertebrates from earlier formations of Miocene age.

Quaternary System

The Quaternary system in the study area comprises the Lissie Formation of Pleistocene age, fluvial terrace deposits of Pleistocene to Holocene age, and alluvium of Holocene age (table 1). The Lissie Formation, fluvial terrace deposits, and alluvium are all fluvial and stream terrace deposits composed mostly of clay, silt, sand, and gravel.

The University of Texas, Bureau of Economic Geology (1987) describes the Lissie Formation as consisting of thick beds of sand containing lens-shaped bodies of gravel, interbedded with silt and clay. As in the Goliad Formation, there are calcareous concretions and crusts of caliche that form in the unsaturated zone (table 1). Typically, the caliche in the outcrop makes differentiation of the Lissie Formation from the underlying Goliad Formation difficult. At NAS Chase Field, a consolidated crust of caliche is present in the subsurface at approximately the Goliad and Lissie Formations contact. This "hardpan" layer was encountered during the drilling of several monitor wells as reported by Environmental and Safety Designs, Inc./Allen & Hoshell (1993). The Lissie Formation unconformably overlies the Goliad Formation and is unconformably overlain by the Beaumont Formation. The Beaumont Formation has outcrops in southern Bee County, but none within the study area. The outcrop of the Lissie Formation is approximately 25 mi wide in Bee County, underlying all of NAS Chase Field and extending approximately 2 mi northwestward to a southwest-to-northeast trending contact with the Goliad Formation. At NAS Chase Field, the Lissie Formation is approximately 20 to 30 ft thick; however, it thickens rapidly southeastward to about 400 to 600 ft in the subsurface (Sellards and others, 1932, p. 783).

The fluvial terrace deposits of clay, silt, sand, gravel, and caliche are present along parts of Poesta Creek west of NAS Chase Field; on Medio Creek east of NAS Chase Field; on Blanco Creek south of NALF Goliad; on Mucorrera Creek southeast of NALF Goliad; and on the northeast corner of the study area (fig. 2). Terraces are produced by downcutting of the flood plains adjacent to each stream. The lithology of these terraces generally is similar to the underlying formations in the study area, but can be differentiated by topographic position.

Alluvial deposits are present in Poesta, Medio, Blanco, Miller's, and Mucorrera Creeks (fig. 2). These deposits can be differentiated from adjacent contacts with fluvial terrace deposits and other formations by their high organic content, lack of cementation and weathering, and topographic position.

HYDROGEOLOGY

The shallow hydrogeologic units within the study area are part of the Gulf Coast Aquifer System (Pettijohn, Busby, and Beckman, 1993), and include the Chicot aquifer, Evangeline aquifer, and the Burkeville confining system (table 1) (Baker, 1979). The fluvial terrace and other alluvial deposits that are present in the study area constitute minor aquifers when and where they are saturated.

The Chicot aquifer comprises the Lissie Formation and the overlying Beaumont Formation outside the study area (table 1). The Chicot aquifer and the Evangeline aquifer are hydraulically connected, but are differentiated on the basis of lithologic and hydraulic properties. The average hydraulic conductivity of the Chicot aquifer is about 10 times greater than that of the Evangeline aquifer (Wesselman, 1967; Ryder, 1988). The Chicot aquifer is the primary source of ground water for domestic and agricultural water users in southeastern Bee County and areas to the southeast. In the immediate vicinity of NAS Chase Field, the Chicot aquifer is virtually absent because the Lissie Formation is thin and usually unsaturated. Hence, the updip limit of the Chicot aquifer is approximately 2 mi to the southeast of NAS Chase Field.

The Evangeline aquifer (Jones and others, 1956, p. 205) comprises the upper sandy part of the Fleming Formation and all sediments of the Goliad Formation (table 1). The Evangeline aquifer is the principal source of ground water for most domestic and agricultural water users in Bee and Goliad Counties; however, the aquifer yields only small quantities of water (less than 100 gal/min). The Evangeline aquifer is unconfined throughout the study area. Regional ground-water movement is toward the southeast at a rate of approximately 10 ft/yr (Myers and Dale, 1966, p. 16). The local and intermediate ground-water-flow systems in the Evangeline aquifer are highly influenced by topography and streamflow. The water quality of the Evangeline aquifer in the study area is fresh to slightly saline (dissolved-solids concentrations less than 3,000 mg/L [milligrams per liter]) (Myers and Dale, 1966).

The Burkeville confining system (Wesselman, 1967, p. 18; Baker, 1979, p. 40) comprises the thickly bedded clays and sandstones from the top of the Oakville Sandstone to the upper sandy part of the Fleming Formation (table 1). Regionally, the Burkeville confining system is the confining unit separating the overlying Evangeline aquifer (upper Fleming Formation and Goliad Formation) and the underlying Jasper aquifer (Catahoula Formation and Oakville Sandstone). The Fleming Formation contains thick beds of sandstone, which are confined aquifers that Wesselman (1983) termed the Fleming aquifers. In Bee and Goliad Counties, these aquifers are used for public water supply by naval facilities and municipalities and for irrigation of crops. These aquifers yield moderate quantities of water to wells (up to approximately 1,000 gal/min). Ground-water movement within the Fleming aquifers is slow, downward, and generally toward the southeast (Ryder, 1988). This movement is indicated by a downward vertical hydraulic-head gradient within the Burkeville confining system and a gulfward hydraulic-head gradient within the regional aquifer system. Water quality of the Fleming aquifers in Bee and Goliad Counties tends to be fresh to slightly saline (Dale and others, 1957; Myers and Dale, 1966).

The local alluvial aquifers in the study area act as separate water-yielding units. These alluvial aquifers are variably saturated when in direct hydraulic connection with the Evangeline aquifer or streams, and are rarely used for public or domestic water supply. Myers and Dale (1966) report only a few small-diameter wells producing fresh to slightly saline water from fluvial-terrace or alluvial deposits. Within the study area, no wells are known to be completed in fluvial-terrace or alluvial deposits.

Hydrogeology Beneath Naval Air Station Chase Field

NAS Chase Field is centered on a topographic high that slopes southeastward at approximately 20 ft/mi. The soils that formed from weathered Lissie Formation sediments are fine sandy to clayey loams that allow for slow to very slow infiltration of precipitation (Guckian and others, 1981). These soils contribute to rapid runoff from rainfall to topographically low areas. Predevelopment surface drainage was to Poesta Creek on the west, Medio Creek on the east, and Spring Creek on the southeast (fig. 1). Currently (1995), runoff from NAS Chase Field is collected in an extensive drainage system and channeled into a large drainage ditch that was excavated between the southeastern boundary of the facility and Spring Creek.

The aquifers underlying NAS Chase Field include the Evangeline aquifer and two Fleming aquifers, which are used for public water supply. In this report, the unconfined Evangeline aquifer will be referred to as the water-table aquifer, the uppermost Fleming aquifer will be referred to as the A-sand aquifer, and the next lower aquifer will be referred to as the B-sand aquifer. The aquifers are separated from one another (and from underlying units) by thick, clayey confining units. Collectively, the aquifers and confining units will be referred to as the aquifer system (fig. 3).

The altitude of the water table at NAS Chase Field was determined from water-level data obtained from wells (figs. 4, 5; table 2 at end of report). A map showing measured water levels was prepared (fig. 5). However, the data are insufficient to indicate the direction of ground-water flow in the water-table aquifer. The depth to the water table ranges approximately from 0 to 30 ft below land surface, depending on topographic position.

In the conceptual model of the aquifer system (fig. 6), the water table coincides with land surface in Poesta Creek and is deepest on the crest of topographic highs. Heath (1983) reported that, in general, ground water in the shallowest part of the saturated zone moves from interstream areas toward streams, and the depth to water is greater along the divide between streams than it is beneath the flood plain. In effect, the water table usually is a subdued replica of the land surface. Therefore, under natural conditions, the shallowest ground water at NAS Chase Field probably moves toward Poesta Creek on the west side of the base and toward Medio Creek on the east side of the base. In this conceptual hydrogeologic model, shallow ground-water flow (local flow systems), the most rapid flow component, is down the hydraulic gradient toward topographically low areas (Toth, 1963). At greater depths in the water-table aquifer, the ground-water flow (intermediate flow systems) is probably from the topographically high areas downward and then toward Poesta and Medio Creeks. The deepest and probably slowest component of ground-water flow (regional flow systems) is in the lower part of the unconfined aquifer and in the confined aquifers generally moving toward the southeast. Ground-water flow within the confining units probably tends to move almost vertically because of the low hydraulic conductivity of the units (Hubbert, 1940).

The A-sand aquifer is a sandstone unit approximately 20 ft thick that extends throughout the NAS Chase Field area as indicated by drillers' and geophysical logs of wells (fig. 3). The B-sand aquifer is a sandstone unit approximately 80 ft thick that can be correlated to wells in Beeville (approximately 5 mi west). The A-sand aquifer and B-sand aquifer are separated by a thick clayey confining unit approximately 100 ft thick (fig. 3).

The water-table aquifer is penetrated by 1 non-potable water-supply well (WSW7, AW–79–43–202) near the southwestern boundary of the base and 22 monitoring wells at various locations that were constructed for a previous NACIP investigation. The A-sand aquifer is penetrated by two non-potable water-supply wells (WSW5, AW–79–43–310; and WSW6, AW–79–43–311) in the southern areas of NAS Chase Field. The B-sand aquifer is penetrated by three water-supply wells (WSW1A, AW–79–43–308; WSW2, AW–79–43–309; and WSW4, AW–79–35–908) that supply the public water system for NAS Chase Field (fig. 4).

Since 1943, NAS Chase Field has obtained water for public supply from the B-sand aquifer, pumping an average of 480,000 gal/d (Myers and Dale, 1966, p. 20). Since 1943, six wells have been completed in the B-sand aquifer; however, only three existed at any one time. The current (1995) operating water-supply wells, WSW1A, WSW2, and WSW4, are the second group of B-sand aquifer wells operating at NAS Chase Field (fig. 4). The three original wells have been destroyed and are not included in the inventory done for this

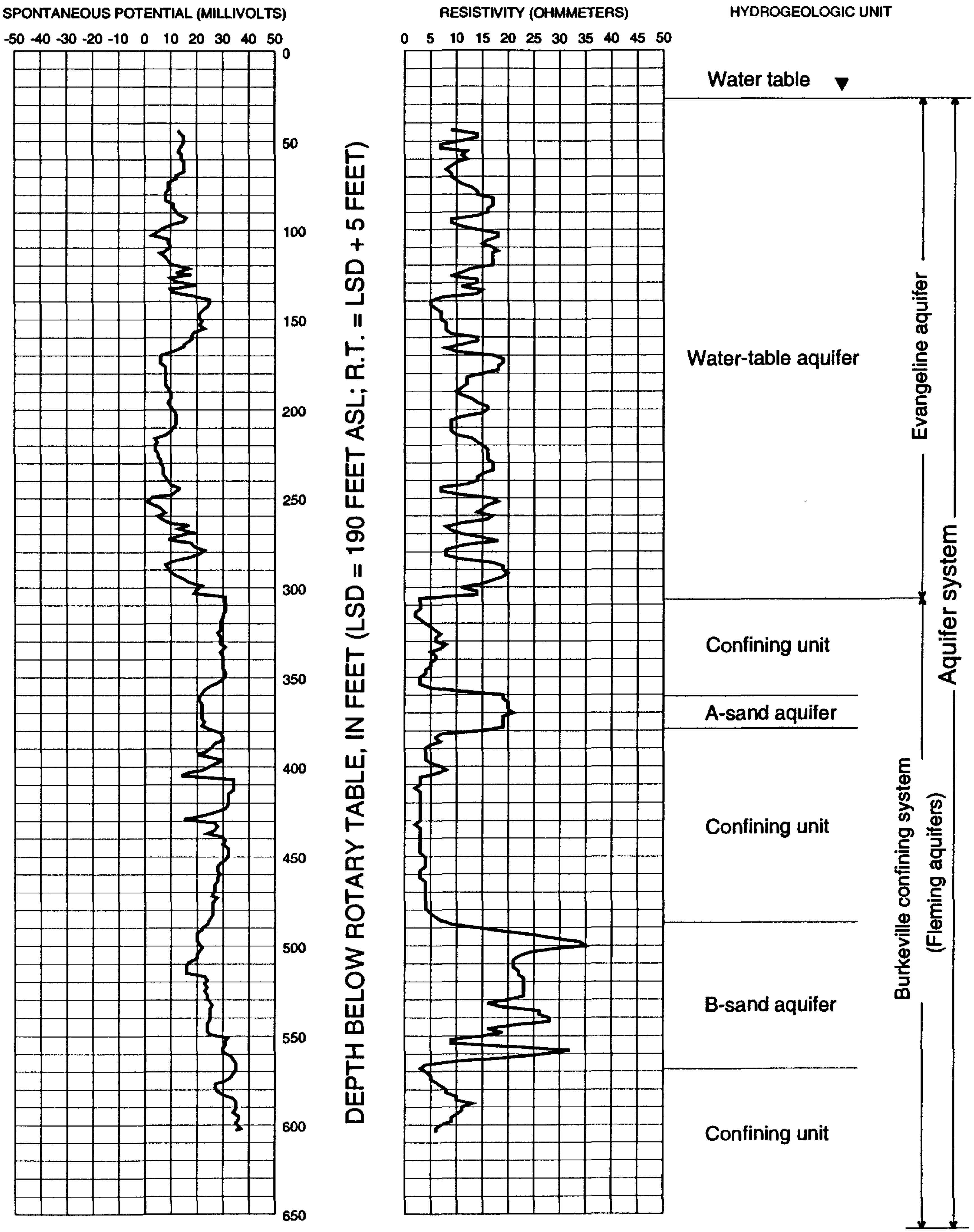

Figure 3. Borehole geophysical well log of water-supply well 1A (AW–79–43–308) showing typical hydrostratigraphy at Naval Air Station Chase Field, Texas.

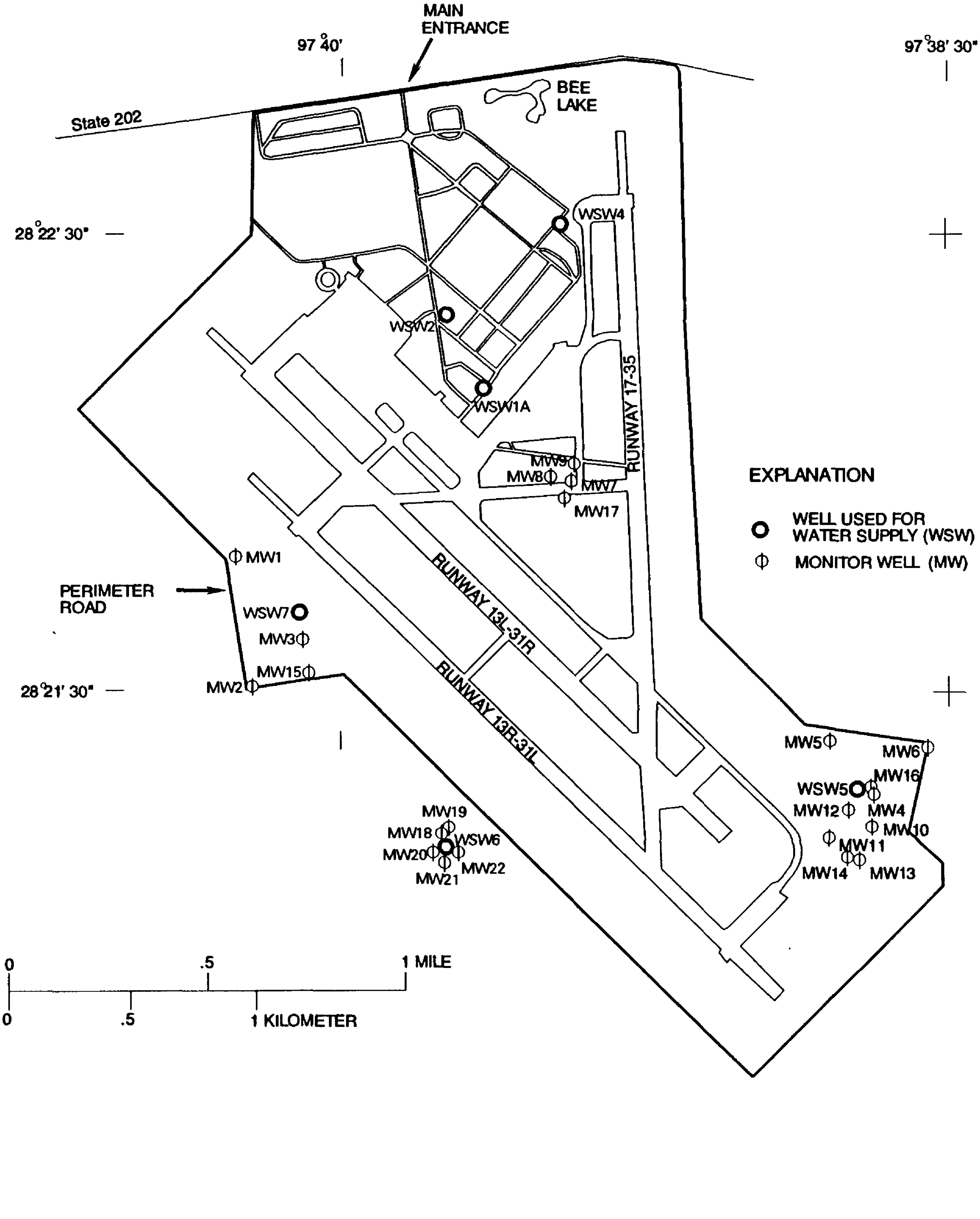

Figure 4. Location and type of wells at Naval Air Station Chase Field, Texas.

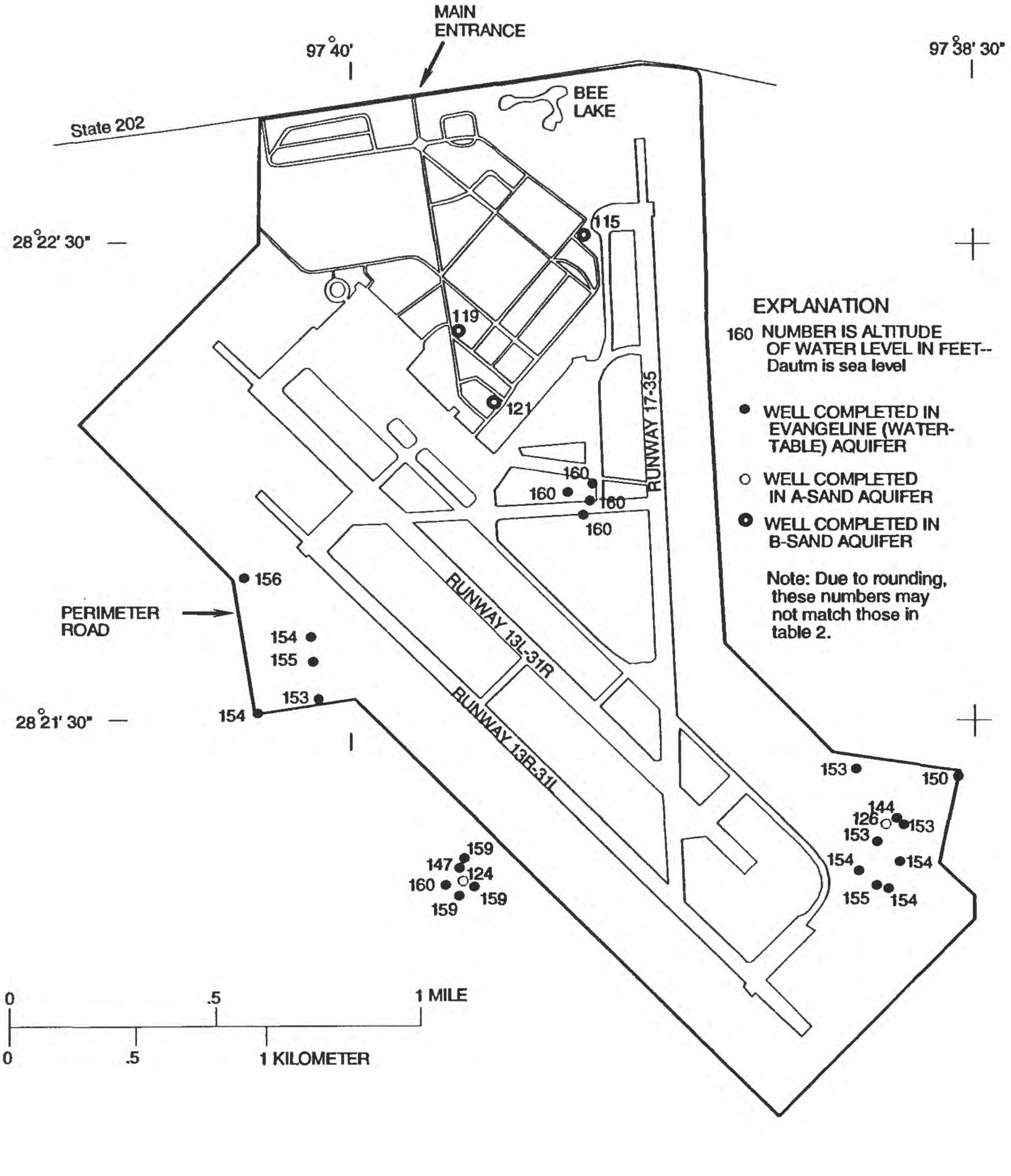

Figure 5. Water levels in wells completed in the Evangeline (water-table) aquifer, A-sand aquifer, and B-sand aquifer at Naval Air Station Chase Field, Texas, summer 1993.

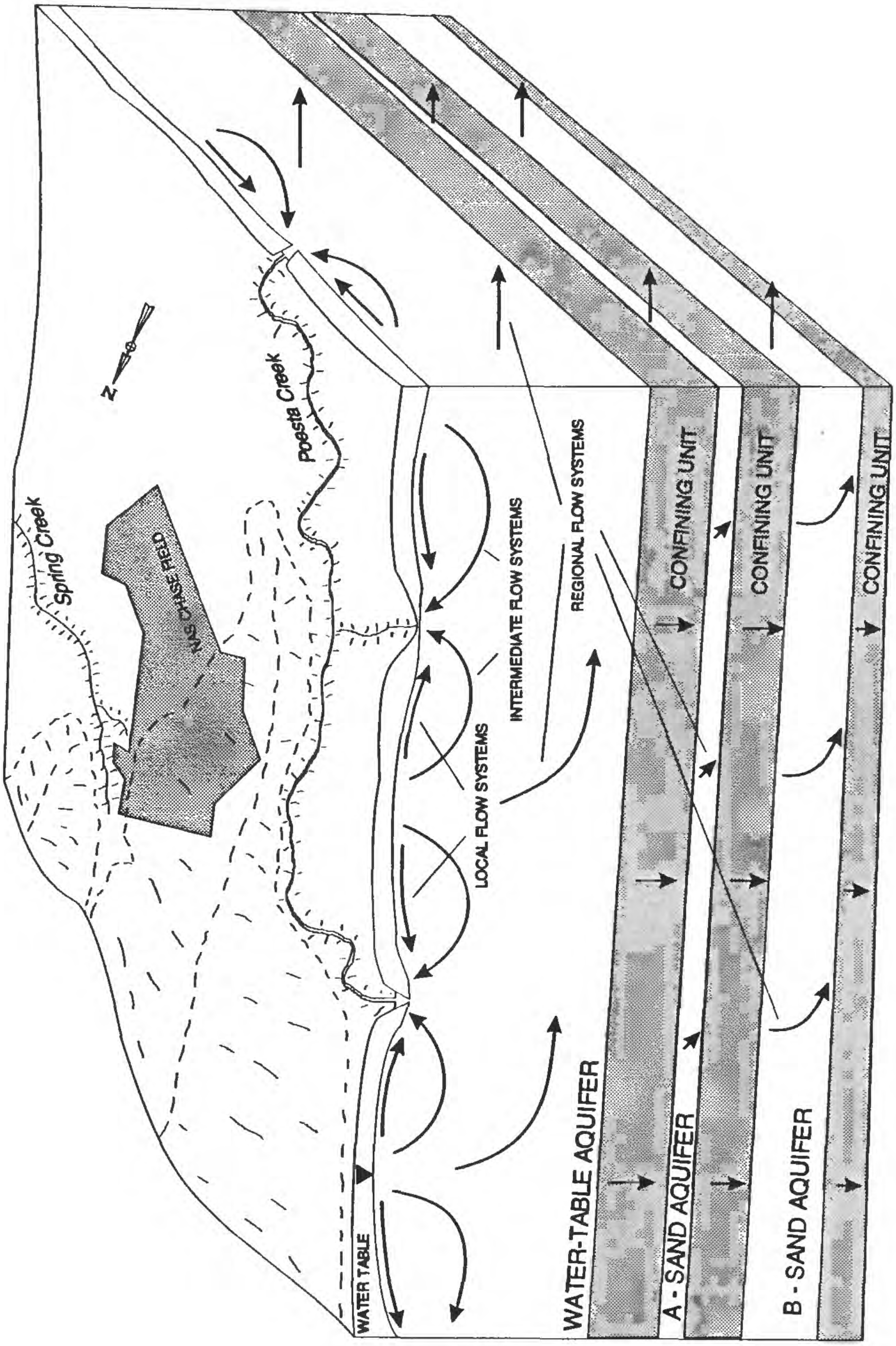

Figure 6. Conceptual hydrogeologic model of the aquifer system underlying Naval Air Station Chase Field, Texas.

investigation. The potentiometric surface of the B-sand aquifer is approximately 75 ft below land surface near the NAS Chase Field cantonment area. However, water levels are highly variable because the three wells are pumped on a rotating basis, thereby creating cones of depression in the potentiometric surface.

The hydraulic interaction among the aquifers and confining units was assessed by conducting an aquifer test. The aquifer test caused increased vertical hydraulic-head gradients from overlying and underlying units toward the pumped aquifer (the B-sand aquifer) as water was withdrawn at a constant rate. To document the increased downward gradient, heads were monitored in the B-sand aquifer, the A-sand aquifer, and the water-table aquifer during the test. These data were then used to compute properties of the B-sand aquifer characterizing its capacity to transmit and store water. These properties are termed transmissivity and storativity, respectively. In addition, the rate of leakage from the confining units during the test was computed.

The test involved pumping well WSW1A (AW–79–43–308) at a rate of 520 gal/min for 74 hours and 15 minutes. In the B-sand aquifer, observation wells were WSW2 (AW–79–43–309) at a radial distance of 996 ft from the pumped well and WSW4 (AW–79–35–908) at a radial distance of 2,264 ft; in the A-sand aquifer, wells WSW5 (AW–79–43–310) and WSW6 (AW–79–43–311) at radial distances of 7,450 ft and 6,060 ft, respectively; and in the water-table aquifer, all water-table monitor wells on NAS Chase Field. Changes in water levels due to pumping (drawdowns) in the B-sand aquifer were measured by datalogger/pressure transducers and steel tape; in the A-sand aquifer by automatic digital recorders and steel tape; and in the water-table aquifer by steel tape. Continuous water-level measurement began 8 days before the pump was turned on. No water-level trends that needed to be accounted for in the data analysis were detected.

The test data were analyzed using the Hantush (1960) modified method. This method takes into account water leaking from overlying and underlying confining units and, particularly, water coming from storage in the confining units. The method involved plotting on logarithmic paper the drawdown, s, in each of the two observation wells in the pumped aquifer against the time, t, since pumping began divided by the square of the distance of the respective observation well from the pumped well, r^2. The resulting set of two time-drawdown curves is overlain on and matched to the family of logarithmic type curves of the Hantush well function H(u, β) versus 1/u (Lohman, 1972, pl. 4). After the "best match" of data curves to type curves[1] is obtained and the values of the leakage parameter, β, associated with the matched type curves noted, a match point on the superimposed graphs is selected that yields values of s, t/r^2, H(u, β), and 1/u (fig. 7). With values of these parameters graphically determined, the transmissivity and storativity of the pumped aquifer and the rate of leakage from the confining units above and below the pumped aquifer during the test can be computed from the following equations:

$$T = \frac{Q}{4\pi s} H(u, \beta), \qquad (1)$$

where T = transmissivity of the aquifer, in feet squared per day;
Q = discharge of the pumped well, in cubic feet per day;
s = drawdown at the observation well, in feet; and
H(u, β) = Hantush (1960) well function (dimensionless).

$$S = \frac{4Ttu}{r^2}, \qquad (2)$$

where S = storativity of the aquifer (dimensionless);
t = time since pumping began, in days;
u = the variable of integration in the Hantush (1960) well function (dimensionless); and
r = radial distance from the pumped well to the observation well, in feet.

$$q_L = Q_{gpm}[1 - e^{nt}\operatorname{erfc}(\sqrt{nt})], \qquad (3)$$

where q_L = rate of leakage from confining units during aquifer test, in gallons per minute;
Q_{gpm} = discharge of the pumped well, in gallons per minute;
$n = 16\left(\frac{\beta}{r}\right)^2\left(\frac{T}{S}\right)$ in $days^{-1}$, where β = leakage parameter (dimensionless);
erfc (x) = complimentary error function of x (dimensionless); and

other parameters are as previously defined.

[1]A constraint of the curve-matching process is that the r values for the data curves representing each well fall on proportional β curves (Reed, 1980, p. 28; Tibbals and Grubb, 1982, p. 11); therefore, the ratio β/r should be approximately the same for each data curve that is matched, as shown in figure 7.

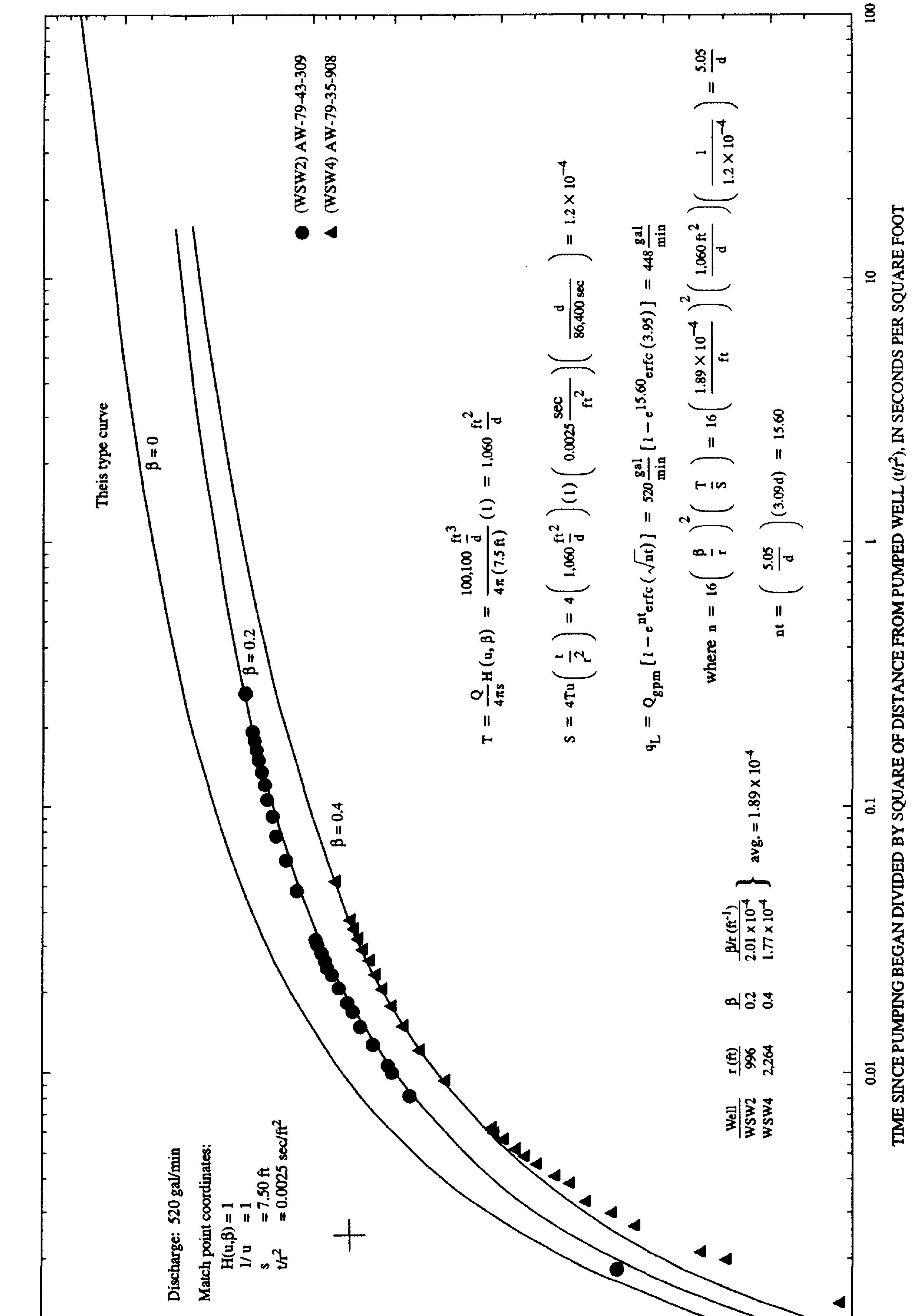

Figure 7. Relation of drawdown in observation wells to t/r^2 for the B-sand aquifer at Naval Air Station Chase Field, Texas.

Application of the above equations resulted in a computed transmissivity of 1,060 ft^2/d, a computed storativity of 1.2×10^{-4}, and a computed rate of leakage during the test of 448 gal/min. The transmissivity is small compared to values representing what Freeze and Cherry (1979, p. 60) term "good aquifers for water well exploitation" (greater than about 13,000 ft^2/d). The storativity is in the range typical of most confined aquifers (10^{-5} to 10^{-3}) (Lohman, 1972, p. 8). The rate of leakage indicates that the source for most of the 520-gal/min well discharge during the test (86 percent) was the confining units rather than the pumped aquifer. The pumpage was derived mainly from storage in the confining units rather than from leakage through the confining units from overlying or underlying aquifers. This is indicated by the fact that the time-drawdown curves shown in figure 7 had not "flattened out" by the end of the test—that is, drawdown had not stabilized but was continuing to increase, thus a steady-state condition had not been reached. Under continued pumping stress, leakage from overlying aquifers would not begin until a later time.

As an additional check on the physical plausibility of the match-determined leakage parameters (β values), the assumption was made that the specific storage of the clay in the confining units was 10^{-5}/ft so that vertical hydraulic conductivity of the confining units could be estimated (E.P. Weeks, U.S. Geological Survey, written commun., 1994). Assuming that one-half of the leakage is derived from the upper confining unit and applying the following equations modified from Hantush (1960, p. 3,716):

$$\lambda = 4\frac{\beta}{r}, \qquad (4)$$

and

$$\lambda = 2\sqrt{\frac{K'S'_s}{TS}}, \qquad (5)$$

where K' = vertical hydraulic conductivity of the upper and lower confining units, in feet per day;

S'_s = specific storage of the upper and lower confining units, in $feet^{-1}$; and

other parameters are as previously defined; vertical hydraulic conductivity is computed as:

$$K' = 4\left(\frac{\beta}{r}\right)^2 \frac{TS}{S'_s} = 1.8 \times 10^{-3} ft/d. \qquad (6)$$

This estimate seems plausible and falls within a range of published values for vertical hydraulic conductivity of clays (Todd, 1980, fig. 3.3).

The time at which some drawdown in the overlying A-sand aquifer might occur can be estimated from the relation:

$$t \le \frac{b'^2 S'_s}{10K'}, \qquad (7)$$

where b' = confining-unit thickness, in feet; and

other parameters are as previously defined (Hantush, 1960, p. 3,724).

By substituting a b' of 120 ft from geophysical logs and previously assumed values for S'_s and K', the relation indicates that no drawdown would occur in the A-sand aquifer for at least 8 days. This result is consistent with the fact that no drawdown was observed in the A-sand aquifer during the 74-hour aquifer test. If pumping were to be continued and the stress due to pumping was large enough to cause drawdown ultimately to reach the water-table aquifer, it would not happen until a much later time.

Large vertical hydraulic-head gradients are present in the aquifer system at NAS Chase Field. In 1993, under static conditions, a hydraulic-head difference of approximately 55 ft existed between the water-table aquifer and the B-sand aquifer. A hydraulic-head difference of approximately 30 ft exists across the 120 ft-thick confining unit between the A-sand aquifer and the B-sand aquifer (upper confining unit). These gradients indicate a potential for downward flow of ground water. By substituting the estimated K' and b' of the upper confining unit and the hydraulic-head difference across the upper confining unit into Darcy's Law, specific discharge can be computed:

$$v = \frac{Q}{A} = K'\left(\frac{dh}{b'}\right) = 4.5 \times 10^{-4} ft/d, \qquad (8)$$

where v = specific discharge, in feet per day

A = cross-sectional area of flow, in square feet;

dh = hydraulic-head difference across the upper confining unit, in feet; and

other parameters are as previously defined.

Using this vertical specific discharge, the computed travel time of ground water from the A-sand aquifer to the B-sand aquifer is long. Depending on the value of vertical hydraulic-head gradient (dh/b') used in the computation, estimated travel times from the A-sand aquifer to the B-sand aquifer could range from about 730 years under the natural gradient to about 490 years under the gradient at the conclusion of the aquifer test. Vertical rates of flow for the water-table aquifer and its lower confining unit could not be estimated from the analysis of this aquifer test.

The specific conductance, pH, and temperature of water from wells in the aquifer system were measured whenever possible during the study (table 3). The most variable constituent measured was specific conductance. The values varied widely and decreased with increasing depth. The specific conductance for the water-table aquifer was 2,670 μS/cm (microsiemens per centimeter at 25 °C), an average of 1,462 μS/cm for the A-sand aquifer, and an average of 1,129 μS/cm for the B-sand aquifer. The differing values of specific conductance indicate that these three aquifers are somewhat insulated from one another by the intervening confining units.

Hydrogeology Beneath Naval Auxiliary Landing Field Goliad

NALF Goliad is in western Goliad County approximately 6 mi north of Berclair, Tex. (fig. 1). The topography is typical of areas where the erosion of Goliad Formation outcrops have resulted in the formation of ridges, valleys, and cuestas. The topographic relief is 100 ft or more in the immediate area of the airfield. In this area, the soils that form from Goliad Formation sediments are sandy, clayey loams to calcareous loams. These soils allow for moderate to good infiltration and drainage (U.S. Department of Agriculture, Soil Conservation Service, 1975). The area is drained by Miller's Creek to the southwest, Mucorrera Creek to the east, and Live Oak Creek to the north.

The Goliad Formation is approximately 50 ft thick in the NALF Goliad area. Therefore, the water-table aquifer is a thin hydrogeologic unit (approximately 35 ft thick) compared to the water-table aquifer at NAS Chase Field, where a greater thickness of the Goliad Formation is present. Currently (1995), NALF Goliad uses two wells for water supply (fig. 8) that are completed in Fleming aquifers. Because of the lack of adequate data from driller's or geophysical logs, it is not known if the aquifers and confining units at NALF Goliad correlate with those at NAS Chase Field. WSW1 (KP–79–28–102) is used for potable water, and WSW2 (KP–79–28–101) is used for firefighting and maintaining a small recreational pond. As part of a site assessment conducted by Environmental and Safety Designs, Inc./Allen & Hoshell (1993), five monitor wells (fig. 8; table 2) were constructed in the water-table aquifer near the base cantonment area. Water-level data obtained from the monitor wells (fig. 9) indicates that the water table ranges from 0 to 15 ft below land surface. Because few wells with completion information are available for monitoring, data are insufficient to indicate the direction of ground-water flow at NALF Goliad. However, it is reasonable to assume that the configuration of the water table is a subdued replica of the land surface, and that ground-water flow in the local, intermediate, and regional flow systems generally is probably similar to that previously described at NAS Chase Field.

A steep vertical hydraulic-head gradient, similar to that at NAS Chase Field, is present between the water-table aquifer and the confined Fleming aquifers, as determined by water-level measurements in wells at NALF Goliad. A vertical hydraulic-head difference of approximately 80 ft was measured across the units between the water-table aquifer and confined Fleming aquifers. This gradient indicates the potential for downward ground-water flow from the water-table aquifer to confined Fleming aquifers. The rate of vertical flow (if any) is unknown because data from which to estimate vertical hydraulic conductivity do not exist for the confining units beneath NALF Goliad. Aquifer tests were not conducted at NALF Goliad.

SUMMARY AND CONCLUSIONS

The geologic formations near NAS Chase Field and NALF Goliad consist of fluvial to fluvial-deltaic sediments of Tertiary and Quaternary age. The lithology of these formations consists of sand, sandstone, silt, and clay, with lesser amounts of gravel, and caliche in the outcrops. The freshwater aquifers underlying the study area are the unconfined Evangeline aquifer, comprising the upper sandy part of the Fleming Formation and the Goliad Formation; and two confined Fleming aquifers, comprising the thick sandstone beds of the Fleming Formation.

A constant-discharge aquifer test was done on the Fleming (B-sand) aquifer from which NAS Chase Field withdraws water for public water supply. This aquifer test was done to determine the hydraulic properties of transmissivity and storativity for the B-sand

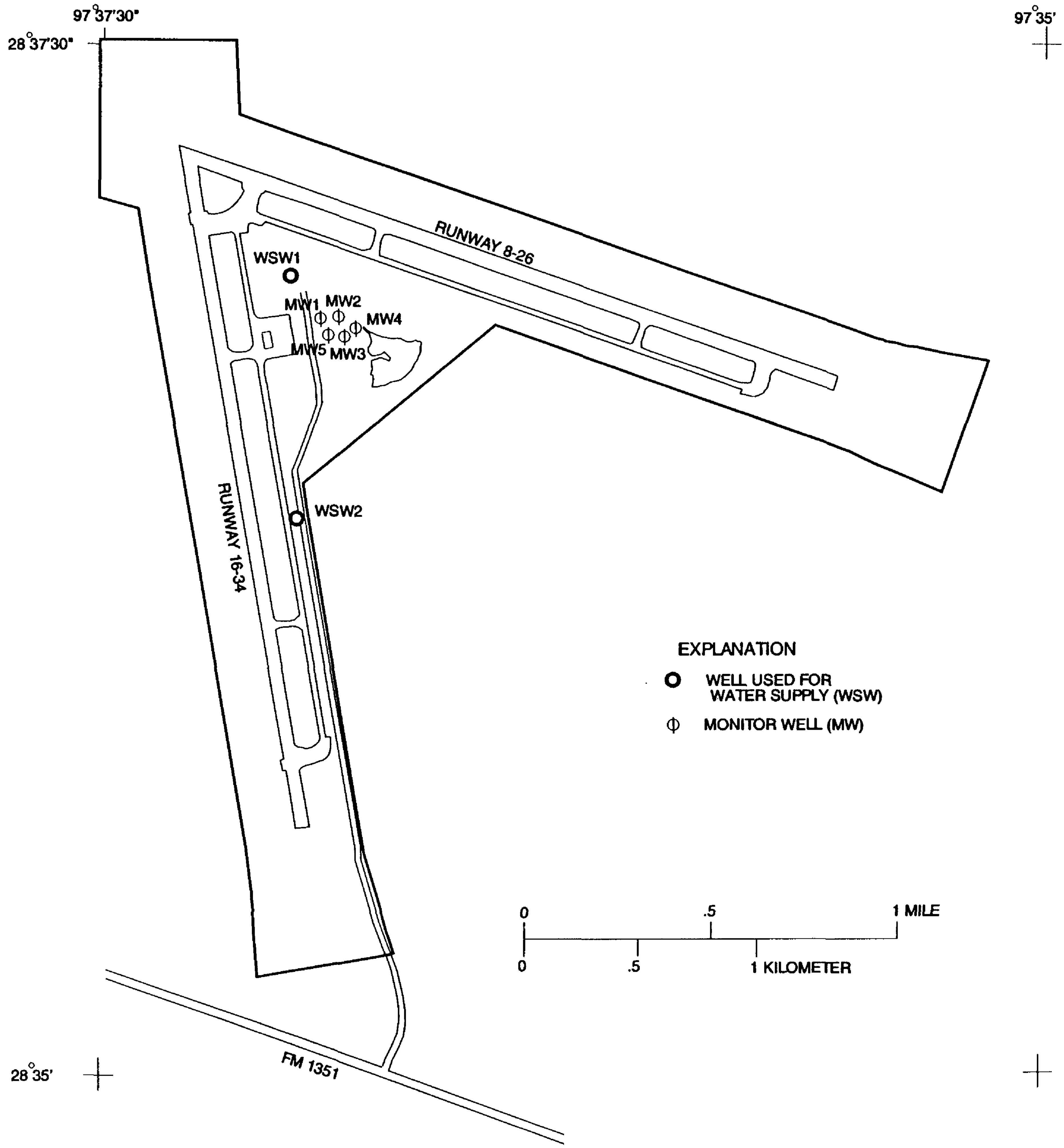

Figure 8. Location and type of wells at Naval Auxiliary Landing Field Goliad, Texas.

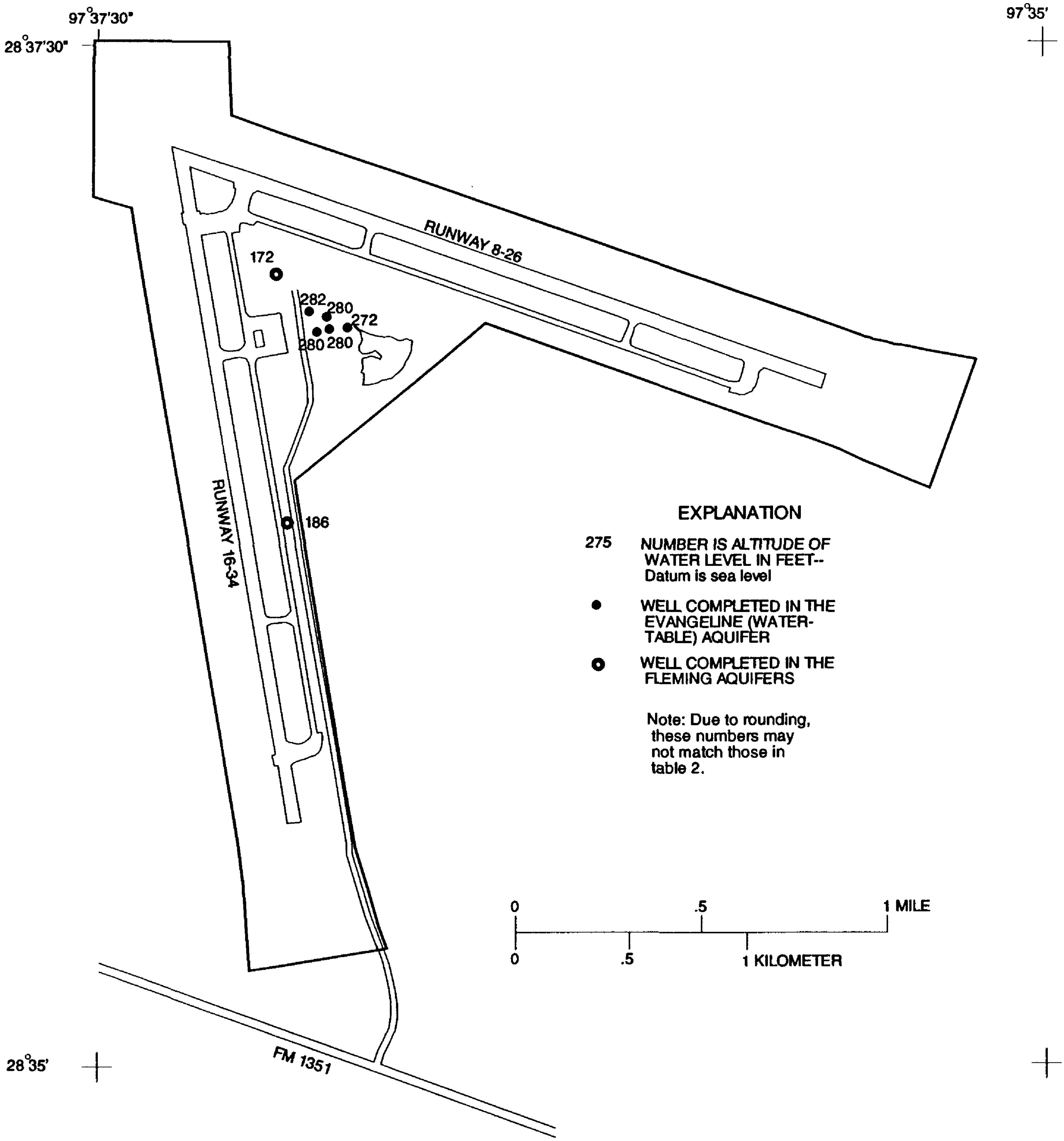

Figure 9. Water levels in wells completed in the Evangeline (water-table) aquifer and Fleming aquifers at Naval Auxiliary Landing Field Goliad, Texas, summer 1993.

Table 3. Selected water-quality constituents of wells sampled near Naval Air Station Chase Field, Texas

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; NAS, Naval Air Station]

State well number	Hydrogeologic unit	Specific conductance (µS/cm)	pH	Temperature (°C)	Remarks
AW–79–34–901	Jasper aquifer	2,600	7.6	34.0	City of Beeville well 5
AW–79–34–902	Unnamed Fleming aquifer, stratigraphically lower than aquifers at NAS Chase Field	2,100	7.1	27.4	City of Beeville well 4
AW–79–34–903	Jasper aquifer	2,710	7.6	34.3	City of Beeville well 7
AW–79–43–202	Evangeline (water-table) aquifer	2,670	7.3	23.7	NAS Chase Field water-supply well 7
AW–79–43–308	Fleming B-sand aquifer	1,123	7.2	27.3	NAS Chase Field water-supply well 1A
AW–79–43–309	Fleming B-sand aquifer	1,135	7.3	27.0	NAS Chase Field water-supply well 2
AW–79–43–310	Fleming A-sand aquifer	1,760	7.2	27.3	NAS Chase Field water-supply well 5
AW–79–43–311	Fleming A-sand aquifer	1,165	7.2	27.5	NAS Chase Field water-supply well 6

aquifer; and to obtain information about the hydraulic connection between the B-sand aquifer, the overlying A-sand aquifer, and the unconfined Evangeline (water-table) aquifer. The aquifer test was analyzed using the Hantush modified method. Values for transmissivity of 1,060 ft^2/d and storativity of $1.2X10^{-4}$ were computed for the B-sand aquifer. The computed rate of leakage from the adjacent confining units to the B-sand aquifer during the test was 448 gal/min, which is 86 percent of the well discharge. The aquifer-test data indicated that most of the water discharged from the pumped well was derived from storage in the confining units. The 74-hour aquifer test did not last long enough for drawdown to reach the A-sand aquifer. Data and assumed specific storage of the confining units indicated that the test would have had to last at least 8 days for drawdown to reach the A-sand aquifer. Thus, the test did not last long enough to allow leakage from the A-sand aquifer to commence and did not demonstrate definitively that a hydraulic connection exists between the B-sand aquifer and the overlying aquifers.

Large vertical hydraulic-head gradients are present between the water-table aquifer and the Fleming aquifers at NAS Chase Field and NALF Goliad. In 1993, under static conditions, the vertical hydraulic-head difference between the water-table aquifer and the lowest confined aquifer in the system studied measured approximately 55 ft at NAS Chase Field and approximately 80 ft at NALF Goliad. Analysis of the data of the aquifer test at NAS Chase Field indicates that the confining unit(s) immediately above and (or) below the B-sand aquifer leak water under a gradient. Based on the natural gradients, the results of the aquifer test, and assumed characteristics of the confining units, it is concluded that ground-water movement downward probably occurs in the hydrogeologic units of the freshwater aquifer system of the study area. However, the rate of downward flow as estimated from the data and assumptions indicate a long travel time from the A-sand aquifer to the B-sand aquifer—probably from about 490 to about 730 years, depending on the vertical hydraulic-head gradient. Vertical flow velocities for the water-table aquifer and its lower confining unit could not be estimated from the analysis of this aquifer test. At NALF Goliad, no aquifer testing was done. Thus, no data for vertical hydraulic conductivity exist from which to estimate flows within the aquifer system at NALF Goliad. The rate of downward flow in a ground-water system can increase as the downward vertical gradient increases. Accordingly, future increases in ground-water withdrawals from the B-sand aquifer could decrease head in the B-sand aquifer, increase the downward vertical gradient, and result in increased downward flow in the aquifer system of the study area.

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Table 2. Records of wells inventoried at Naval Air Station Chase Field and Naval Auxiliary Landing Field Goliad, Texas

[Source of depth data: D, driller; O, owner; R, other reported; S, U.S. Geological Survey. Casing material: S, steel; --, data not available; P, PVC (polyvinylchloride). Water-yielding unit: Oakville, Oakville Sandstone; Fleming, Fleming Formation (A- or B-sand aquifer where shown; Goliad, Goliad Formation. Primary use of site: W, withdrawal; U, unused; O, observation. Altitude of land surface and of water level: Datum is sea level. Primary use of water: P, public water supply; S, stock; I, irrigation; H, domestic; J, industrial; U, unused; R, recreation. Remarks: NAS, Naval Air Station; NALF, Naval Auxiliary Landing Field. ft, feet; in., inches; TAMU AES, Texas A&M University Agricultural Experimental Station; --, data not available; NAVFACENGCOM, Naval Facilities Engineering Command]

State well number	Owner	Date well constructed	Depth of well (ft)	Source of depth data	Diameter of casing (in.)	Casing material	Water-yielding unit	Altitude of land surface (ft)	Altitude of water level (ft)	Date water level measured	Primary use of site	Primary use of water	Remarks
AW-79-34-901	City of Beeville	03-28-47	1,526	D	11.75 6.63	S S	Oakville	213	111.00	12-92	W	P	Well 5
AW-79-34-902	City of Beeville	02-10-45	623	D	12.75 8.63	S S	Fleming	213	141.20	12-92	W	P	Well 4
AW-79-34-903	City of Beeville	07-04-58	1,550	D	14 12.75	S S	Oakville	210	110.90	12-92	W	P	Well 7
AW-79-35-106	TAMU AES Farm	--	147	O	4.5	S	Goliad	290	197.96	06-23-93	W	S	Well 2
AW-79-35-107	TAMU AES Farm	01-18-84	432	D	14	S	Goliad	278	194.21	06-22-93	W	I	Well 3
AW-79-35-501	TAMU AES Farm	--	148	R	8	S	Goliad	255	204.29	06-22-93	W	I,H	Well 1
AW-79-35-702	City of Beeville	05-21-54	1,600	D	14 12.75	S S	Oakville	204	121.61	01-26-93	W	P	Well 6
AW-79-35-706	City of Beeville	04-03-65	1,580.66	D	14 12.75 8.63	S S S	Oakville	220	123.80	12-92	W	P	Well 8
AW-79-35-805	AEO Motors	--	153	S	--	--	Goliad	177	144.25	06-23-93	U	J	
AW-79-35-908	NAVFACENGCOM	_	599	D	16.00 8.00	S S	Fleming B	188.94	114.89	08-11-93	W	P	NAS Chase Field water-supply well 4
AW-79-35-909	Martha Welder	08-27-74	310	D	4	P	Fleming	185	118.00	08-28-74	W	S	
AW-79-35-910	Damian Welder	01-06-64	505	O	4.5	S	Fleming	175	124.12	06-23-93	W	H	
AW-79-35-911	Damian Welder	--	500	O	6	S	Fleming	179	125.31	06-25-93	W	S	Old oil well; plugged back and reperforated near 500 ft
AW-79-43-202	NAVFACENGCOM	1987	83.4	S	8.75	S	Goliad	175.49	154.32	08-19-93	W	P	NAS Chase Field water-supply well 7
AW-79-43-203	NAVFACENGCOM	01-21-92	55	D	2	P	Goliad	178.23	155.81	08-19-93	O	U	NAS Chase Field monitor well 1

Table 2. Records of wells inventoried at Naval Air Station Chase Field and Naval Auxiliary Landing Field Goliad, Texas—Continued

State well number	Owner	Date well con-structed	Depth of well (ft)	Source of depth data	Diame-ter of casing (in.)	Casing ma-terial	Water-yielding unit	Alti-tude of land surface (ft)	Alti-tude of water level (ft)	Date water level mea-sured	Pri-mary use of site	Pri-mary use of water	Remarks
AW–79–43–204	NAVFACENGCOM	01–21–92	55	D	2	P	Goliad	174.88	153.57	08–19–93	O	U	NAS Chase Field monitor well 2
AW–79–43–205	NAVFACENGCOM	01–22–92	45	D	2	P	Goliad	174.59	155.29	08–19–93	O	U	NAS Chase Field monitor well 3
AW–79–43–206	NAVFACENGCOM	07–27–93	130	D	2	P	Goliad	174.30	153.29	08–19–93	O	U	NAS Chase Field monitor well 15
AW–79–43–208	Raymond Welder, Jr.	--	68	S	4.5	S	Goliad	185	150.48	07–22–93	W	S	Windmill lift
AW–79–43–308	NAVFACENGCOM	02–27–68	577	D	16 8	S S	Fleming B	193.57	120.56	09–07–93	W	P	NAS Chase Field water-supply well 1A
AW–79–43–309	NAVFACENGCOM	10–31–73	555	D	16	S	Fleming B	192.48	119.47	09–07–93	W	P	NAS Chase Field water-supply well 2
AW–79–43–310	NAVFACENGCOM	01–12–71	345	D	4	P	Fleming A	170.48	126.31	08–11–93	W	P	NAS Chase Field water-supply well 5
AW–79–43–311	NAVFACENGCOM	01–14–71	403	D	4	P	Fleming A	171.37	124.29	08–11–93	W	P	NAS Chase Field water-supply well 6
AW–79–43–312	NAVFACENGCOM	01–16–92	43.5	D	2	P	Goliad	169.37	153.19	08–19–93	O	U	NAS Chase Field monitor well 4
AW–79–43–313	NAVFACENGCOM	01–16–92	47	D	2	P	Goliad	168.98	152.72	08–19–93	O	U	NAS Chase Field monitor well 5
AW–79–43–314	NAVFACENGCOM	01–15–92	39.5	D	2	P	Goliad	166.24	149.57	08–19–93	O	U	NAS Chase Field monitor well 6
AW–79–43–315	NAVFACENGCOM	02–12–92	66.5	D	2	P	Goliad	189.81	160.10	08–19–93	O	U	NAS Chase Field monitor well 7
AW–79–43–316	NAVFACENGCOM	02–20–92	72	D	2	P	Goliad	189.27	160.25	08–19–93	O	U	NAS Chase Field monitor well 8
AW–79–43–317	NAVFACENGCOM	02–20–92	68.5	D	2	P	Goliad	187.47	160.32	08–19–93	O	U	NAS Chase Field monitor well 9
AW–79–43–318	NAVFACENGCOM	01–29–92	39.8	D	2	P	Goliad	167.28	153.59	08–19–93	O	U	NAS Chase Field monitor well 10

Table 2. Records of wells inventoried at Naval Air Station Chase Field and Naval Auxiliary Landing Field Goliad, Texas—Continued

State well number	Owner	Date well constructed	Depth of well (ft)	Source of depth data	Diameter of casing (in.)	Casing material	Water-yielding unit	Altitude of land surface (ft)	Altitude of water level (ft)	Date water level measured	Primary use of site	Primary use of water	Remarks
AW–79–43–319	NAVFACENGCOM	01–10–92	44.1	D	2	P	Goliad	170.22	153.54	08–19–93	O	U	NAS Chase Field monitor well 11
AW–79–43–320	NAVFACENGCOM	01–30–92	45	D	2	P	Goliad	167.69	153.37	08–19–93	O	U	NAS Chase Field monitor well 12
AW–79–43–321	NAVFACENGCOM	01–09–92	45	D	2	P	Goliad	170.82	154.39	08–19–93	O	U	NAS Chase Field monitor well 13
AW–79–43–322	NAVFACENGCOM	01–08–92	45	D	2	P	Goliad	171.25	154.66	08–19–93	O	U	NAS Chase Field monitor well 14
AW–79–43–323	NAVFACENGCOM	07–21–93	132	D	2	P	Goliad	170.19	144.45	08–19–93	O	U	NAS Chase Field monitor well 16
AW–79–43–324	NAVFACENGCOM	07–20–93	53	D	2	P	Goliad	190.47	159.94	08–19–93	O	U	NAS Chase Field monitor well 17
AW–79–43–325	NAVFACENGCOM	08–04–93	136	D	--	P	Goliad	170.72	147.19	08–19–93	O	U	NAS Chase Field monitor well 18
AW–79–43–326	NAVFACENGCOM	08–05–93	40	D	2	P	Goliad	170.96	158.62	08–19–93	O	U	NAS Chase Field monitor well 19
AW–79–43–327	NAVFACENGCOM	08–06–93	38	D	2	P	Goliad	170.14	160.21	08–19–93	O	U	NAS Chase Field monitor well 20
AW–79–43–328	NAVFACENGCOM	08–06–93	31	D	2	P	Goliad	169.72	158.87	08–19–93	O	U	NAS Chase Field monitor well 21
AW–79–43–329	NAVFACENGCOM	08–06–93	31	D	2	P	Goliad	170.15	158.69	08–19–93	O	U	NAS Chase Field monitor well 22
AW–79–43–331	John C. Breidenbach	01–17–74	319	D	4	P	Fleming	161	116.00	01–17–74	W	H	Well 2, Quonset hut well
AW–79–43–332	John C. Breidenbach	--	80	S	4.5	S	Goliad	156	139.60	06–23–93	W	H	Well 1
AW–79–43–333	Raymond Welder, Jr.	--	--	S	--	--	Fleming	173	--	--	W	S	Runway construction well
KP–79–28–101	NAVFACENGCOM	1967	250	O	7	S	Fleming	298	186.37	08–09–93	W	R	NALF Goliad water-supply well 2

Table 2. Records of wells inventoried at Naval Air Station Chase Field and Naval Auxiliary Landing Field Goliad, Texas—Continued

State well number	Owner	Date well constructed	Depth of well (ft)	Source of depth data	Diameter of casing (in.)	Casing material	Water-yielding unit	Altitude of land surface (ft)	Altitude of water level (ft)	Date water level measured	Primary use of site	Primary use of water	Remarks
KP–79–28–102	NAVFACENGCOM	06–09–69	670	O	10.34	S	Fleming	304	172.20	08–09–93	W	P	NALF Goliad water-supply well 1
KP–79–28–103	NAVFACENGCOM	11–19–91	42.5	D	2	P	Goliad	299.66	281.96	11–19–91	O	U	NALF Goliad monitor well 1
KP–79–28–104	NAVFACENGCOM	11–22–91	44	D	2	P	Goliad	297.24	279.58	11–22–91	O	U	NALF Goliad monitor well 2
KP–79–28–105	NAVFACENGCOM	11–23–91	40	D	2	P	Goliad	293.63	279.82	11–23–91	O	U	NALF Goliad monitor well 3
KP–79–28–106	NAVFACENGCOM	11–23–91	42	D	2	P	Goliad	296.58	280.26	11–23–91	O	U	NALF Goliad monitor well 5
KP–79–28–107	NAVFACENGCOM	11–25–91	35	D	2	P	Goliad	289.16	271.56	11–25–91	O	U	NALF Goliad monitor well 4