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Geohydrologic Summary for Herbicide Orange Sites at Eglin AFB Fl and the Naval Construction Battalion Center, Gulfport MS

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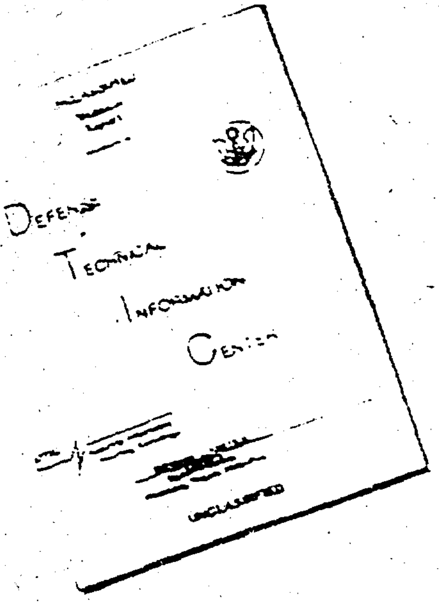

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The geohydrologic conditions at Eglin Air Force Base (EAFB), Florida, and the Naval Construction Battalion Center (NCBC) at Gulfport, Mississippi, have been evaluated to assess the potential impacts on the groundwater resulting from the contamination of surficial soils by storage and handling of military herbicides. The results from this evaluation are used to determine the likelihood of herbicide residues being transported in the shallow groundwater. A trace contaminant of one of the herbicides, 2,3,7,8-tetrachlorodibenzo-p-dioxin, is the constituent of greatest concern. A monitoring program is proposed for each of the military sites.

Both sites are situated in the Gulf of Mexico Coastal Plain. The subsurface sediments are composed of quartz sand, clay, gravel, and silt. The permeable sands from aquifers, and the impermeable clays form aquicludes or confining beds. Horizontal permeabilities are much higher than vertical permeabilities. The water in the shallow aquifer at each site is soft and relatively unmineralized because of relatively insoluble quartz (continued

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sand and high recharge from rainfall. Low pH and high iron concentrations are caused by the low buffering capacity of the aquifer materials.

The monitoring systems proposed at each site will have one well upgradient and several wells downgradient. A monitoring plan for nearby surface waters is also recommended. The wells will sample the shallow groundwater flow system.

The possibility of dioxin contaminants migrating to deeper zones is extremely remote at either site. However, deeper monitoring wells should be considered if significant dioxin concentrations are found in the shallow groundwater system. The monitoring program will generate data that can be used to evaluate potential migration of contaminants.

SUMMARY

The geohydrologic conditions at Eglin Air Force Base (EAFB), Florida, and the Naval Construction Battalion Center (NCBC) at Gulfport, Mississippi, have been evaluated to assess the potential impacts on the groundwater resulting from the contamination of surficial soils by storage and handling of military herbicides. The results from this evaluation are used to determine the likelihood of herbicide residues being transported in the shallow groundwater. A trace contaminant of one of the herbicides, 2,3,7,8-tetrachlorodibenzo-p-dioxin, is the constituent of greatest concern. A monitoring program is proposed for each of the military sites.

Both sites are situated in the Gulf of Mexico Coastal Plain. The subsurface sediments are composed of quartz sand, clay, gravel, and silt. The permeable sands form aquifers, and the impermeable clays form aquicludes or confining beds. Horizontal permeabilities are much higher than vertical permeabilities. The water in the shallow aquifer at each site is soft and relatively unmineralized because of insoluble quartz sand and high recharge from rainfall. Low pH and high iron concentrations are caused by the low buffering capacity of the aquifer materials.

The monitoring systems proposed at each site will have one well upgradient and several wells downgradient. A monitoring plan for nearby surface waters is also recommended. The wells will provide the opportunity to sample the shallow groundwater flow system.

The possibility of dioxin contaminants migrating to deeper zones is extremely remote at either site. However, deeper monitoring wells should be considered if significant dioxin concentrations are found in the shallow groundwater system. The monitoring program will generate data that can be used to evaluate potential migration of contaminants.

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PREFACE

All reports were prepared for the Air Force Engineering and Services Center, Engineering and Services Laboratory, Tyndall AFB Florida, under Job Order Number (JON) 1900 2067. The principal contractor, EG&G Idaho Inc., is a captive contractor of the Department of Energy, Idaho National Engineering Laboratory.

This report is one of four reports encompassing the Air Force Soil Sampling and Analysis Program. The goal of this program was to define the horizontal and vertical extent of Herbicide Orange derived 2,3,7,8-tetrachlorodibenzo-p-dioxin at the three primary herbicide sites. In addition, an initial groundwater evaluation was prepared for the sites at the Naval Construction Battalion Center, Gulfport, Mississippi and Eglin Air Force Base, Florida.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service. At NTIS it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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SECTION I
INTRODUCTION

A. OBJECTIVE

The purpose of this investigation is to use existing data to describe the hydrogeological conditions at Eglin Air Force Base and the Naval Battalion Center sites and then use this information to develop groundwater monitoring programs to detect 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and Herbicide Orange in the groundwater. The geohydrological data obtained from the field program can be used to evaluate potential contaminant movements and assess potential environmental impacts. The well-drilling and monitoring results will help determine the need for additional monitoring or cleanup activities at each site.

B. BACKGROUND

The areas discussed in this report include the south-central portion of Eglin Air Force Base (EAFB), in Okaloosa County, between the cities of Fort Walton Beach and Niceville in the western part of the Florida Panhandle (Figure 1) and the Naval Construction Battalion Center (NCBC), located within the city limits of Gulfport, Mississippi, in the extreme southeastern portion of the state in Harrison County (Figure 2).

1. Regional Geologic Setting

EAFB and NCBC are situated in the Gulf of Mexico Coastal Plain, which consists of unconsolidated sands, gravels, limestones, silts, and clays of Cretaceous to Recent Age. The coastal plain covers Louisiana, Mississippi, Florida, and the southern parts of Alabama, Georgia, and South Carolina. The rocks of the coastal plain are younger than the Appalachian Mountain complex and thicken in a southward direction.

According to Howe (Reference 1), "The Gulf Coast region of the United States is the landward side of the most active geosyncline in North America." "The northern border of the Gulf of Mexico," Howe continues,

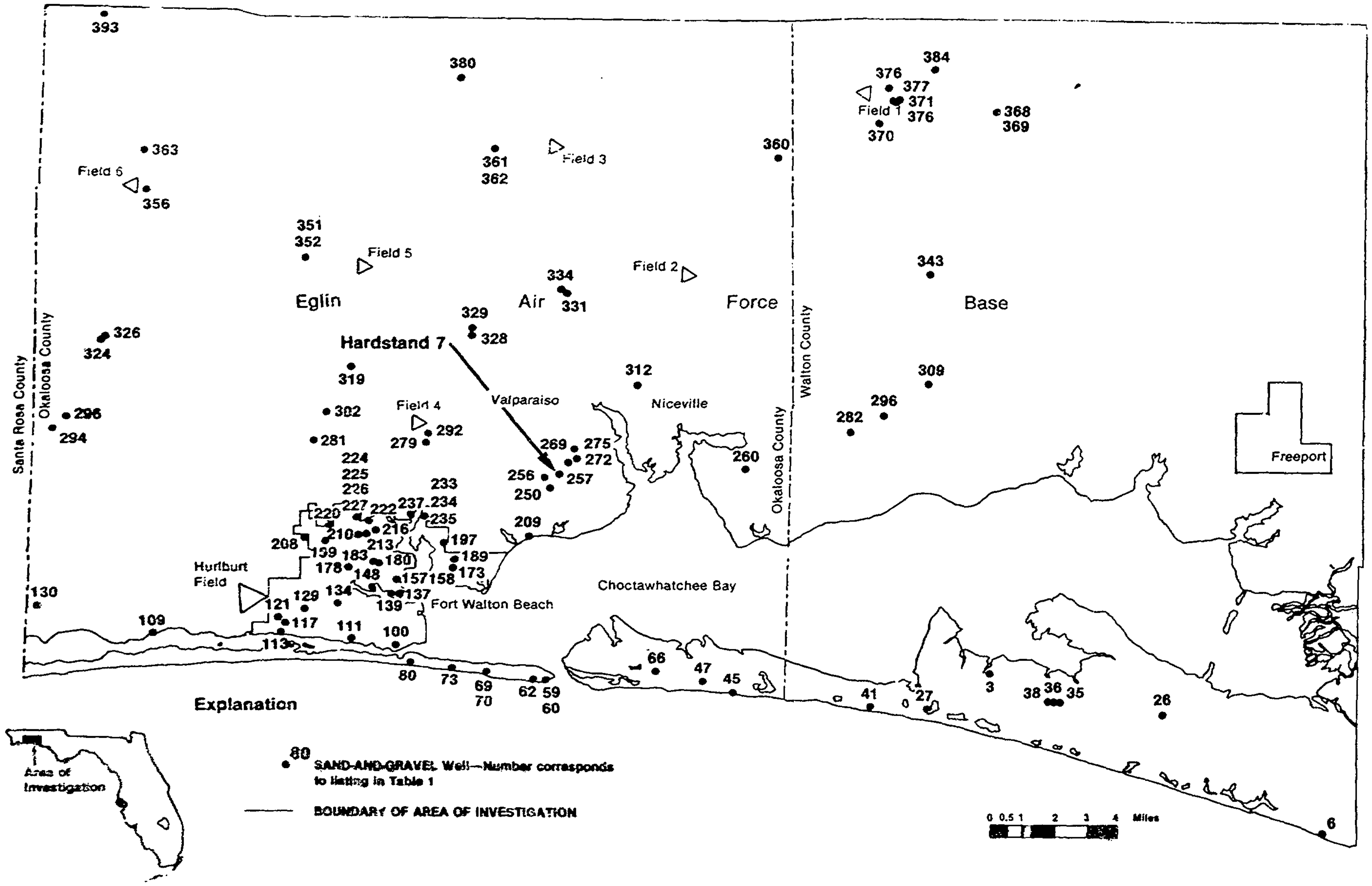


Figure 1. Area of Investigation and Locations of Selected Sand-and-Gravel Wells and Hardstand 7, Southern Okaloosa and Walton Counties, Florida (Reference 2).

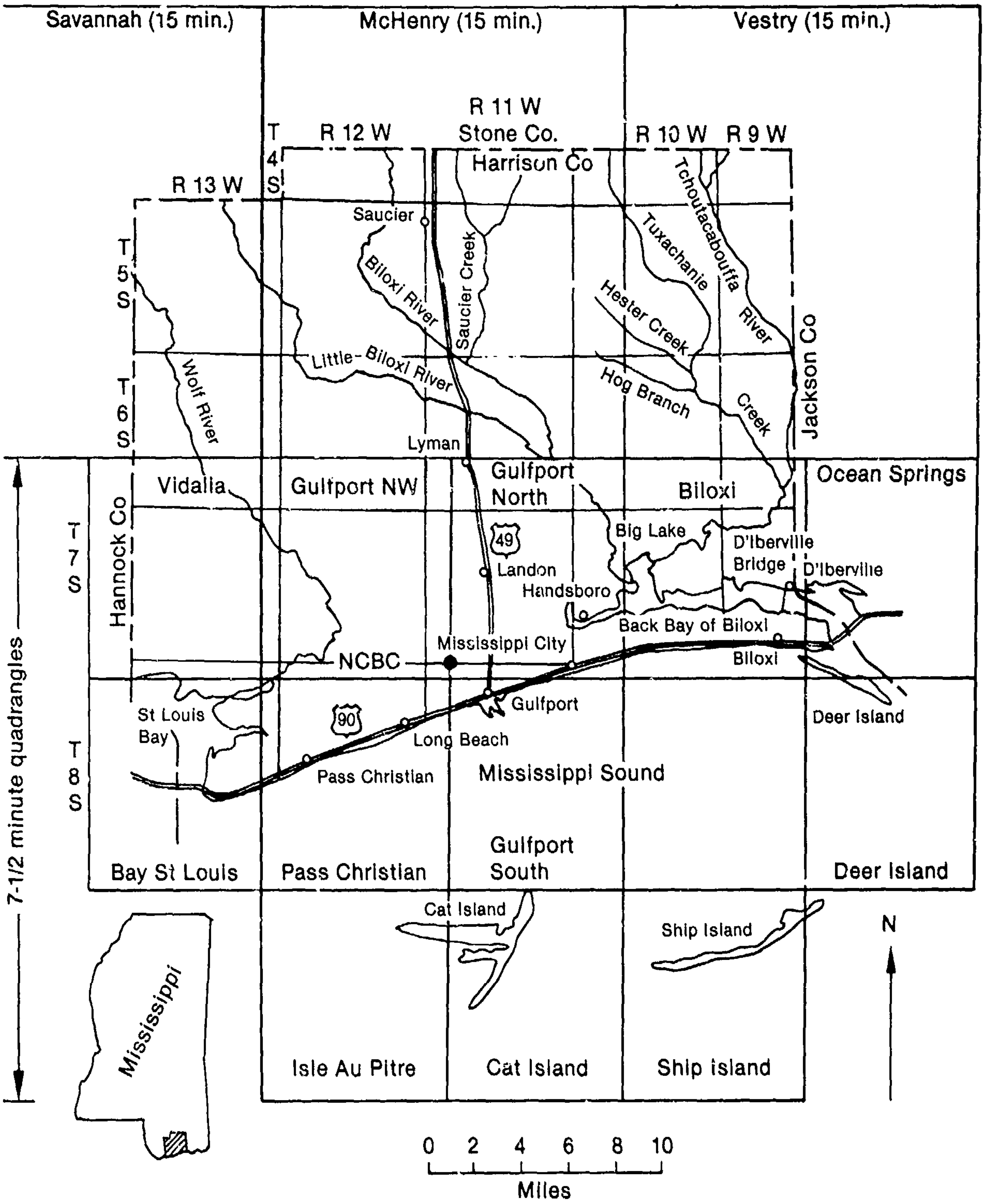


Figure 2. Location Map and Topographic Quadrangles, Harrison County, Mississippi (Reference 3).

> drains the earth's second largest degradation tract. These sediments have been concentrated along a narrow zone paralleling the present shore, and, since the beginning of the Eocene, have accumulated to a thickness which probably exceeds 30,000 feet. . . . The conclusion appears inescapable that the region of the present coastline has been depressed under the weight of these deposits to almost three times the present maximum depth of the Gulf of Mexico. The major axis of the Gulf Coast geosyncline approximately parallels the Louisiana coastline, but a transverse structure, normally referred to as the Mississippi Embayment, extends inland up the valley of the Mississippi. The formations which make up the landward side of the geosyncline are all wedge-shaped, thickening rapidly from the outcrop gulfward.

EAFB and NCBC lie on the north flank of the Gulf Coast geosyncline and east flank of the Mississippi Embayment. This results in the southwestward dip, characteristic of all formations in the area at least as far down as the base of the Cretaceous deposits.

The subsurface geology of EAFB has more in common with that of NCBC than it does with the geology of peninsula Florida to the east. Only two peninsula Florida units are present at EAFB. EAFB and NCBC have geologic similarities that will be described in more detail.

2. Previous Investigations

a. Western Florida Panhandle

Early studies provided a general view of the geology, hydrology, and surface features of the western Florida panhandle. Marsh (Reference 4) completed the first detailed investigation of the geology of the western Florida panhandle. Some of his work included parts of EAFB. Barraclough and Marsh (Reference 5) described the geologic and hydrologic units in the area from the Choctawhatchee River to Mobile Bay, including most of EAFB. They identified a series of aquifers and aquicludes down to the base of the freshwater. Their report provides documentation of a decline of almost 100 feet in the Floridan aquifer at Fort Walton Beach, Florida, from 1936 to 1960. The report depicts the spatial variations in water quality within the Floridan aquifer.

The aquifers and aquitards of the westernmost portion of the Florida Panhandle were identified and named by Musgrove et al. (Reference 6). A water resources study by Musgrove et al. (Reference 7) covered part of EAFB. Hydrologic data of the area are given in Reference 8. Reference 9 discusses the relation of the Bucatunna Clay Member to geology and groundwater of western Florida. Pascale (Reference 10) prepared a report on the water resources of Walton County, Florida.

The water resources of Okaloosa county were compiled by Foster and Pascale (Reference 11) and by Trapp et al. (Reference 12). These reports explain why water levels had declined so drastically in some areas, provide information on other sources of water, and provide water management alternatives. A detailed hydrologic investigation was completed by Barr et al. (Reference 13) in 1981. This report evaluated various water management techniques for meeting the future water needs of the area and developed a mathematical model of the groundwater system. The shallow stratigraphy of Okaloosa County and vicinity was prepared by Clark and Schmidt (Reference 14). Reference 2 presents the hydrology of the sand-and-gravel aquifer in southern Okaloosa and Walton Counties.

b. Southeastern Mississippi

The first detailed study of the Gulf Coastal area in Mississippi was prepared by Brown et al. (Reference 15). This report describes the geology and groundwater resources of the area and provides information concerning the decline in yields of artesian wells and estimated future groundwater supplies. Newcome, Shattles, and Humphreys

(Reference 3) published a report on water for the growing needs of Harrison County. Their evaluation indicated little use of surface water resources, but showed that groundwater withdrawals had resulted in average water-level declines of 1 foot per year. They described freshwater aquifers to a depth of 1/2 mile. Shows (Reference 16) reported on the water resources of Mississippi. He described the various geologic formations and aquifers, outlined the quality of groundwater, evaluated surface water resources, and discussed future water development. Reference 17, a report on sources for water supplies in Mississippi, is a guide to the availability of freshwater in the state, including surface and groundwater. Maps of each aquifer show the areal extent, outcrop areas, thickness and elevation, permeability, and water quality.

C. SCOPE

This report provides hydrogeologic characterization and monitoring plans for two sites used to store and handle herbicides used by the Defense Department. Of greatest concern is the presence of small amounts of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) found as an impurity in Herbicide Orange. Herbicide Orange consisted of a 50:50 mixture of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). The 2,4,5-T contained the TCDD impurities. During previous and ongoing soil sampling programs, TCDD was found in concentrations ranging up to about 1000 ppb in the site soils.

SECTION II

GEOHYDROLOGIC ENVIRONMENT OF EGLIN AFB

EAFB is located in the southern portion of Okaloosa, Walton, and Santa Rosa Counties in the western Florida Panhandle. To the north, the area is near the boundary of the Alabama-Florida state line; and to the south, the base is bounded by the Gulf of Mexico. The principal city is Fort Walton Beach, Florida.

EAFB covers approximately 750 square miles, one of the largest land areas of any military facility in the United States. The land is relatively flat to gently rolling terrain. The drainage is southward or westward, and streams flow into Choctawhatchee or East Bay. Most of EAFB is in the Western Highlands, and the portion near the Gulf of Mexico and the bay is in the Coastal Lowlands. The Western Highlands are divided into sandhills and four other physiographic divisions (Reference 12). Most of EAFB is included in the sandhills. The sandhills are generally 50 feet or more above sea level and have a low drainage density because much of the rainfall infiltrates into the highly permeable sands. The streams that drain these hills have high base flow and occupy deep, narrow ravines. These narrow ravines have formed by headward erosion of seeps or water table springs. The heads of these streams are called "steepheads" because of their steep walls and semicircular shape.

A. CLIMATE

At EAFB, the climate is humid and semitropical. Summers are warm, with temperatures averaging about 80°F; winds from the gulf usually make most nights comfortably cool. Winters are mild, averaging about 54°F, with occasional frost from November through February. The average annual temperature at nearby Pensacola is 68°F. The temperature extremes at Pensacola have ranged from a high of 103°F to a low of 7°F. On the average, about 275 frost-free days occur annually. Winter temperatures can be about 10°F higher along the coast than in the northern portion of EAFB.

The average annual rainfall at the National Weather Service station at Niceville, Florida (near the center of EAFB), is 64.1 inches, as shown in Figure 3. From 1941 to 1979, the highest annual rainfall was 95 inches in 1975, and the lowest was 31 inches in 1954. Rainfall is the source of all fresh groundwater at EAFB.

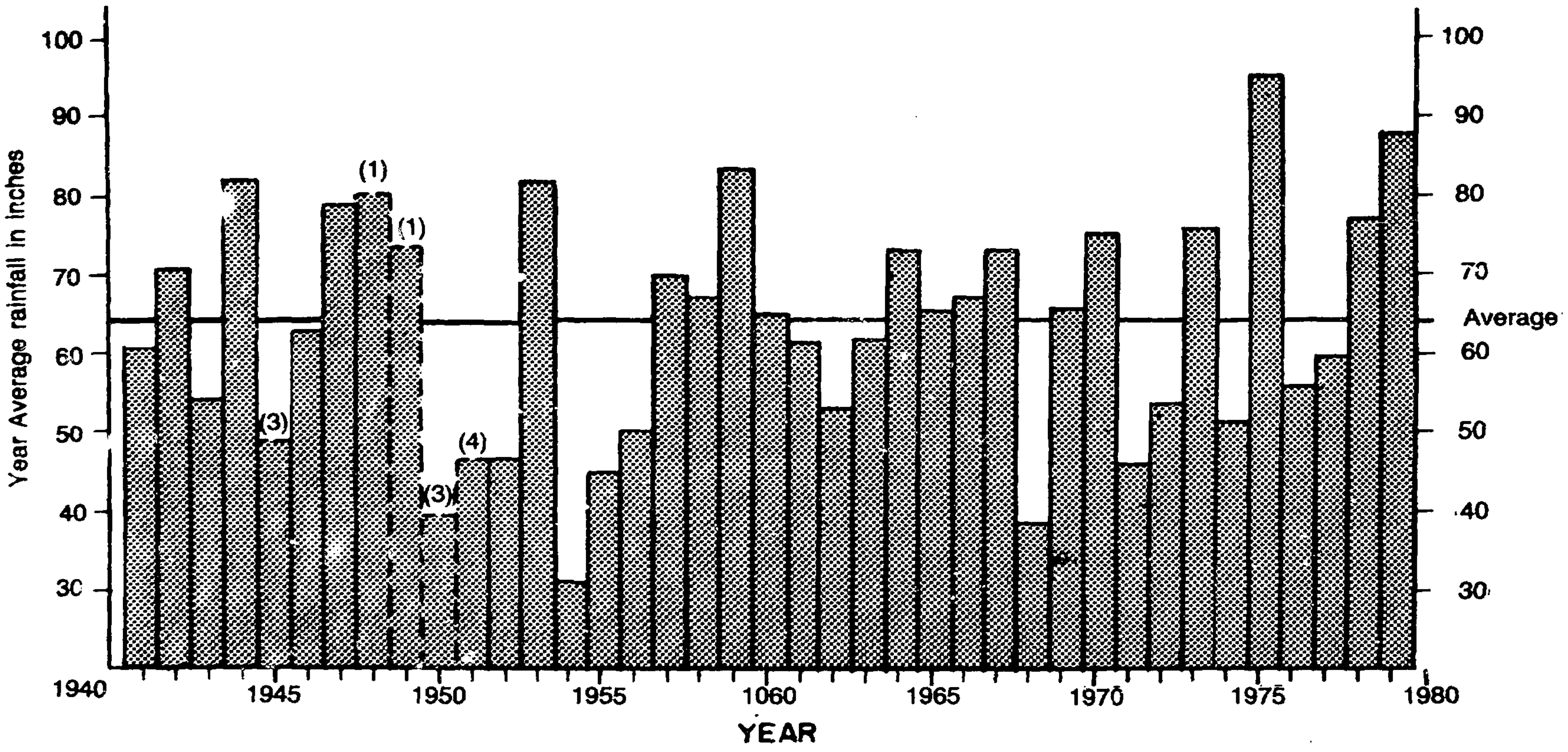
The pattern of seasonal distribution is the same over EAFB. The wettest periods occur in early spring and in summer; and the driest, in October and November. The monthly average rainfall ranges from 3.5 inches in October to 8.8 inches in July. However, the amount of rainfall can vary for the same month in different years. During July, the precipitation has ranged from less than 3 inches to more than 23 inches. Intense storms may either be a result of convective type of weather systems or from hurricanes.

B. GEOLOGY

A thick sequence of sand, gravel, and clay extends from the surface to as much as 800 feet deep at EAFB. Below this sequence, marine limestones, clay beds, and shale beds are found. EAFB is on the extreme eastern flank of the Gulf of Mexico Sedimentary Basin. Many of the formations dip to the southwest as a result of this feature.

The geological formations at EAFB are given in Table 1. From the surface downward, the formations start with the Pleistocene terrace deposits and Citronelle Formation (10 to 200 feet thick). Below is the Lower Member of the Pensacola Clay (50 to 500 feet thick). Next are the Bruce Creek limestone, the Tampa Formation, and the Chickasawhay Limestone (100 to 540 feet thick). Beneath these limestones is the Bucatunna Clay Member of the Byram Formation (40 to 120 feet thick). The Ocala Group lies below the Bucatunna followed by the Lisbon equivalent, the Tallahatta Formation, and the Hatchetigbee Formation. The Ocala Group, Lisbon equivalent, and the Tallahatta Formation are 300 to 1500 feet thick.

The formations discussed above are described in detail in several publications listed in Section I. Formations from the land surface



Note: Numbers in parenthesis represent number of months missing.

Figure 3. Yearly Rainfall Distribution at Niceville, Florida (Reference 13).

TABLE 1. GEOLOGIC UNITS IN SOUTHERN OKALOOSA AND WALTON COUNTIES AND THEIR HYDROGEOLOGIC EQUIVALENTS.

Epoch	Stage	Formation	Thickness (ft)	Lithologic Description	Hydrogeologic Unit	Hydrologic Characteristics
Recent to Pliocene		Pliocene Recent Sands	50-250	Unconsolidated, white to light gray fine to medium quartz sand. Accessories include heavy minerals and phosphate.	Sand-and-Gravel Aquifer	Water mainly unconfined. In Fort Walton Beach, includes surficial unconfined unit and lower leaky artesian unit. Yields range from less than 20 gal/min in coastal lowlands of Walton County to 1000 gal/min in uplands of western Okaloosa County. Tapped by shallow wells for domestic supply a few larger capacity wells for irrigation. Currently not used by municipal systems for public consumption.
		Citronelle Formation	50-250	Predominantly non-marine quartz sands with thin stringers of clay or gravel discontinuous over short distances.		
		Miocene Coarse Clastics	50-200	Found only along the western portion of Okaloosa County, the Miocene coarse clastics are comprised of poorly consolidated sand, gravel, clay and shell beds.		
Upper Miocene	Chocta-whatchee	Intracoastal	0-360	Lithologically, the Intracoastal is made up of a poorly consolidated, sandy, clayey, microfossiliferous limestone.	Pensacola Clay Confining Bed	Restricts vertical movement of water because of thickness and comparatively low permeability. In the area of investigation grades laterally from dense clay and sandy clay in western part to clayey, silty sand in the eastern part. Not a source of water.
Upper to Middle Miocene	Alum Bluff	Alum Bluff Group (Northern Portion Only)	0-300	The Alum Bluff occurs as a mixture of sands, clays and shell beds in relatively well sorted thin beds. The matrix material is commonly clay or carbonate cement.		
		Pensacola Clay	0-190	In the western half of the study area, the Pensacola Clay interfingers with the Intercoastal Formation and Alum Bluff Group. The Pensacola is predominantly a bluish gray to olive gray, dense, silty clay.		

TABLE 1. GEOLOGIC UNITS IN SOUTHERN OKALOOSA AND WALTON COUNTIES AND THEIR HYDROGEOLOGIC EQUIVALENTS (CONCLUDED).

Epoch	Stage	Formation	Thickness (ft)	Lithologic Description	Hydrogeologic Unit	Hydrologic Characteristics
Lower Miocene	Tampa	Bruce Creek Limestone	20-220	Light gray to white in appearance, the Bruce Creek is moderately indurated, granular, and occurs as a clastic limestone. Accessories include a sand fraction which increases north and east.	Upper Limestone of the Floridan Aquifer	Principal source of water in area of investigation. Yields large quantities of fresh water under confined conditions. Yields range from 250 gal/min to over 1000 gal/min. Sustained yields are generally lowest immediately adjacent to the coast in Okaloosa County. Individual zones vary greatly in permeability and vertical hydraulic connection. Contains over 250 ppm chlorides in parts of southeastern Walton and southwestern Okaloosa counties.
		Tampa Stage Limestones	30-140	Lithologically, similar to Chickasawhay Limestones but slightly less dolomitic. Silt and clay content increase towards the top of the formation.		
Upper Oligocene	Vicksburg	Chickasawhay	30-260	Primarily a tan sucrosic dolomite but may also occur as a cream to buff fossiliferous limestone.		
Middle to Lower Oligocene		Bucatunna Clay-Member Byram Formation	0-130	The Bucatunna is a medium to dusky, yellowish-brown calcareous clay. Accessories include up to 10 percent quartz sand and up to 1 percent phosphate. The top contact of the Bucatunna Clay is sharp and well defined from the overlying limestone.	Bucatunna Clay Confining Bed	Where present, restricts vertical movement of water between overlying and underlying hydrogeologic units. Generally present in coastal Walton and Okaloosa counties but absent in northern parts of area.
Upper Eocene	Jackson	Ocala Group Limestones	165-600	A white to light gray, chalky, fossiliferous relatively pure calcium carbonate limestone. Occasionally the limestone is interlayered with thin streaks of light brown to tan dolomite layers.	Lower Limestone of the Floridan Aquifer	Comprises a separate hydrogeologic unit in coastal Walton and Okaloosa counties. In other parts, cannot be hydrologically distinguished from upper limestone aquifer.
Middle Eocene	Claiborne	Lisbon/ Tallahatta Formations	345-500 170-300	Massive shaly to chalky limestones, often dark gray to brownish gray to cream in color. Thin shaly beds predominate in the more calcareous portions.	Claiborne Confining Unit	Predominantly impermeable strata. Comprises the base of the groundwater flow system.

to the top of the Hatchetigbee Formation include almost all of the beds containing freshwater in the area and a few containing saltwater (Table 1).

C. AQUIFERS AND AQUICLUDES

The geologic formations have been grouped into six geohydrologic units based on lithology and permeability. From the land surface downward, they are the sand-and-gravel aquifer, the Pensacola Clay (aquitard), the upper limestone of the Floridan aquifer, the Bucatunna Clay (aquitard), the lower limestone of the Floridan aquifer, and the underlying shales and clays (aquitard) (Figure 4). The three aquifers contain the available freshwater in the area, and the aquitards greatly retard the vertical movement of water between aquifers. These geohydrologic units were first identified by Musgrove et al. (Reference 6) and were extended into Okaloosa and Walton Counties by Barraclough and Marsh (Reference 5) (Figure 5).

1. Sand-and-Gravel Aquifer

The sand-and-gravel aquifer consists predominantly of quartz sand, ranging from white to light brown. The grains range from very fine to very coarse. The sand grades laterally into lenses of gravel. Clay and sandy clay are found in the aquifer.

The sand-and-gravel aquifer materials were deposited in an environment similar to that of the present Mississippi River delta. This is indicated by the rapid changes in lithology over short distances, the absence of fossils, and the abundance of sand and gravel. The sediments were probably deposited by a network of braided streams across the surface of the delta. In this environment, clay was deposited in quiet pools or abandoned channels while gravel was being laid down by swiftly flowing streams nearby.

In places, the sand-and-gravel aquifer has a high average porosity and permeability and is an excellent reservoir for groundwater.

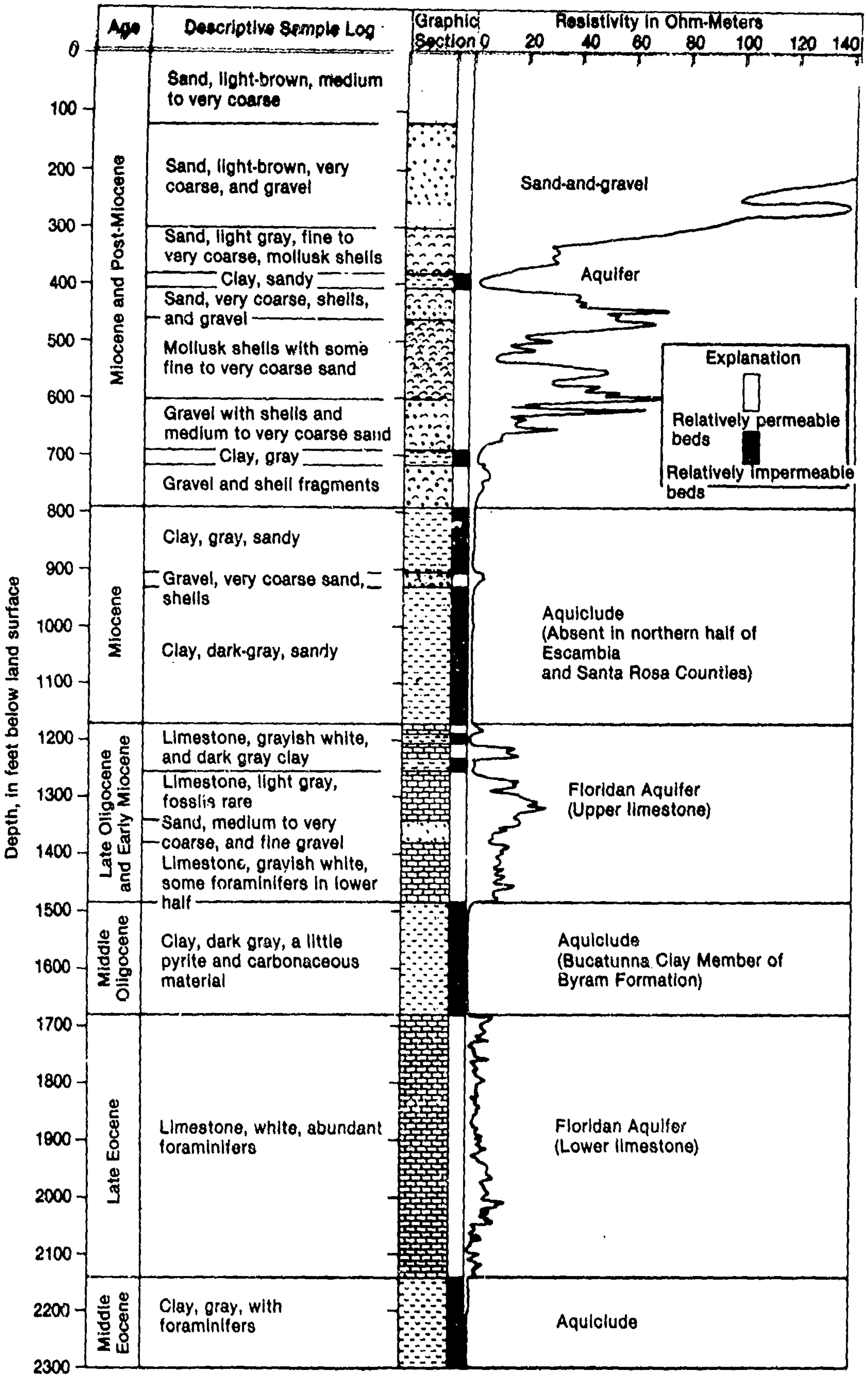


Figure 4. Hydrogeologic Sequence in Western Florida (Reference 5).

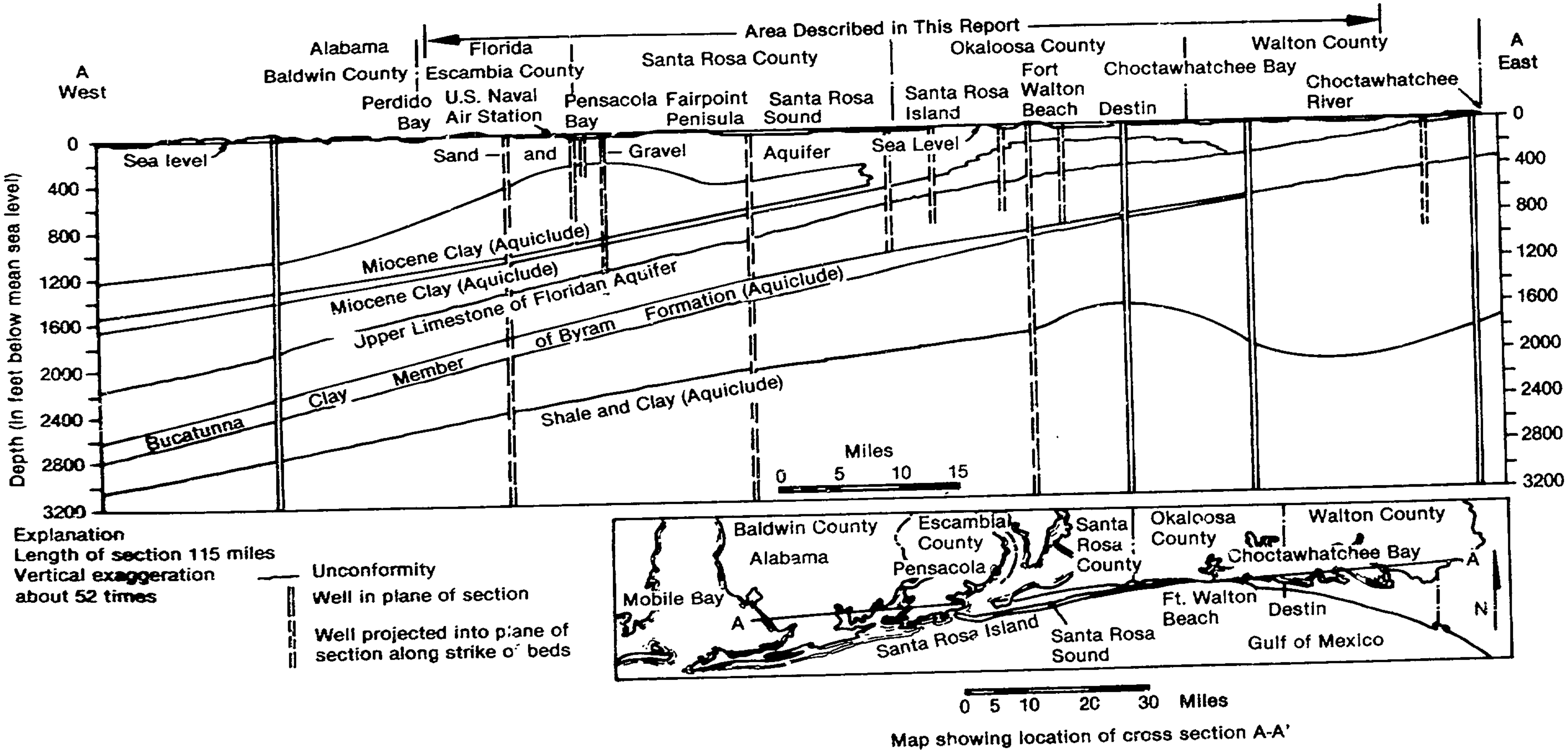


Figure 5. Geologic Cross Section A-A' along the Gulf Coast of Western Florida (Reference 5).

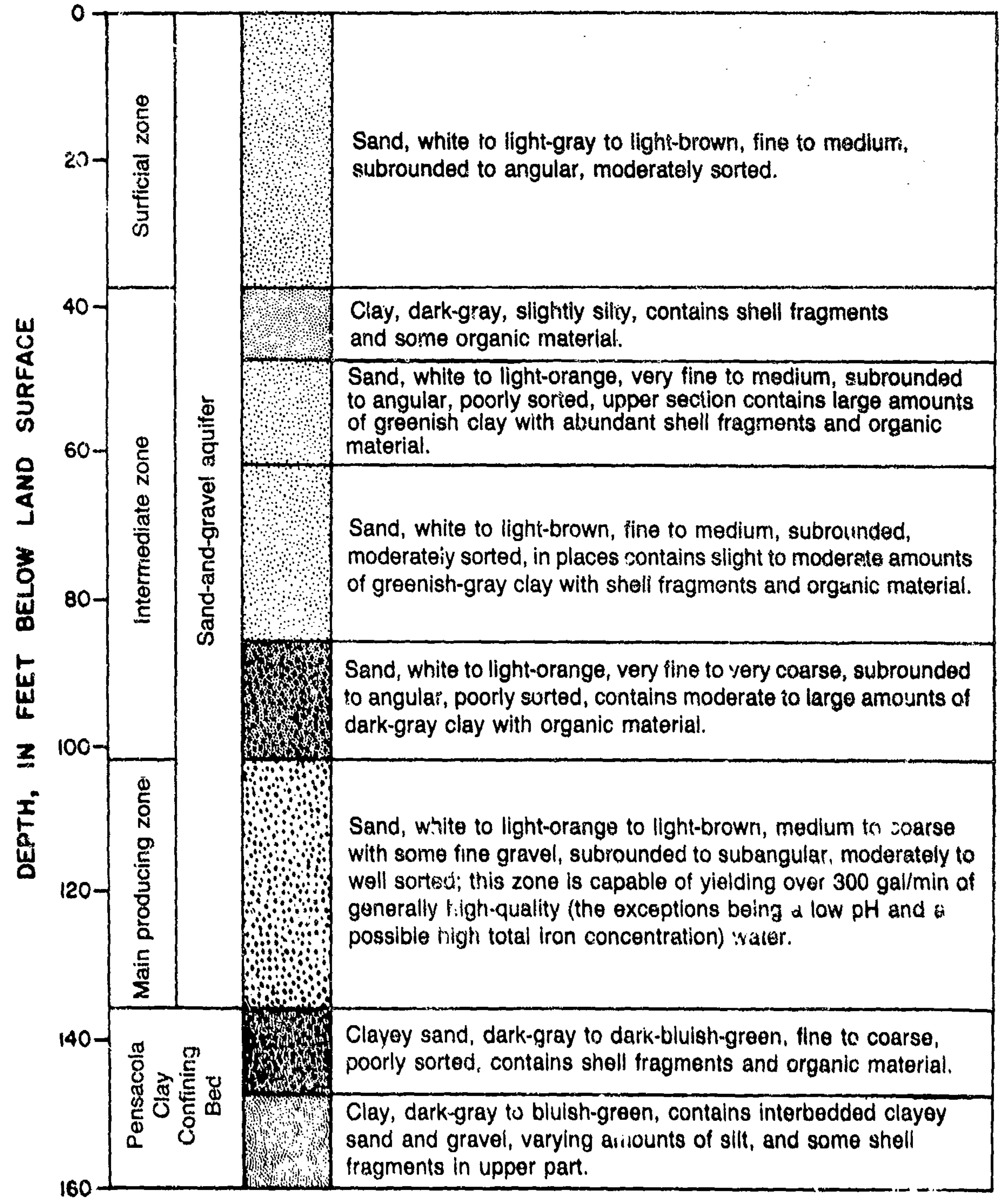
The aquifer consists principally of relatively insoluble quartz grains, which accounts for the remarkably low mineral content and softness of the water. Groundwater in the sand-and-gravel aquifer is derived almost entirely from rain falling in the area (Reference 7).

In the EAFB area, the sand-and-gravel aquifer has been divided into three hydrologic zones (Reference 13) based on differences in lithology and hydraulic properties. The zones are (1) a surficial water table zone, (2) an intermediate zone of relatively low permeability, and (3) a main producing zone (Figure 6). The surficial unit contains fine-to-medium, moderately well-sorted sand. The intermediate unit consists of silty clay, poorly sorted fine to medium sand, and fine-to-very coarse, poorly sorted clayey sand. The lower unit of medium-to-coarse sand with some gravel is the main producing zone of the aquifer. Some wells yield over 300 gallons per minute (gpm) of good quality water. One or two of these zones may be absent where the aquifer is thin.

Water in the sand-and-gravel aquifer is unconfined. In places, the intermediate zone confines the water in the main producing zone, and the water is under slight artesian pressure. Some perched lakes and water tables occur where the surficial sands are underlain at shallow depths by clays and silts that restrict the downward movement of water to the regional water table (Reference 13).

The sand-and-gravel aquifer in Southern Okaloosa County is made up of sediments that range in age from late Miocene to Recent (about 10 million years ago to the present). Its thickness at EAFB ranges from about 10 to more than 200 feet. Figure 7 shows the thickness of the aquifer.

The permeability of the zones varies from place to place because of the variability of the sediments. The grain sizes of the sediments increase to the west, and the clay content generally decreases. The sand-and-gravel aquifer is anisotropic and heterogeneous.



Sand, white to light-gray to light-brown, fine to medium, subrounded to angular, moderately sorted.

Clay, dark-gray, slightly silty, contains shell fragments and some organic material.

Sand, white to light-orange, very fine to medium, subrounded to angular, poorly sorted, upper section contains large amounts of greenish clay with abundant shell fragments and organic material.

Sand, white to light-brown, fine to medium, subrounded, moderately sorted, in places contains slight to moderate amounts of greenish-gray clay with shell fragments and organic material.

Sand, white to light-orange, very fine to very coarse, subrounded to angular, poorly sorted, contains moderate to large amounts of dark-gray clay with organic material.

Sand, white to light-orange to light-brown, medium to coarse with some fine gravel, subrounded to subangular, moderately to well sorted; this zone is capable of yielding over 300 gal/min of generally high-quality (the exceptions being a low pH and a possible high total iron concentration) water.

Clayey sand, dark-gray to dark-bluish-green, fine to coarse, poorly sorted, contains shell fragments and organic material.

Clay, dark-gray to bluish-green, contains interbedded clayey sand and gravel, varying amounts of silt, and some shell fragments in upper part.

Figure 6. Generalized Stratigraphic Description of the Sand-and-Gravel Aquifer and the Uppermost Part of the Underlying Pensacola Clay Confining Bed, Fort Walton Beach Area (Reference 2).

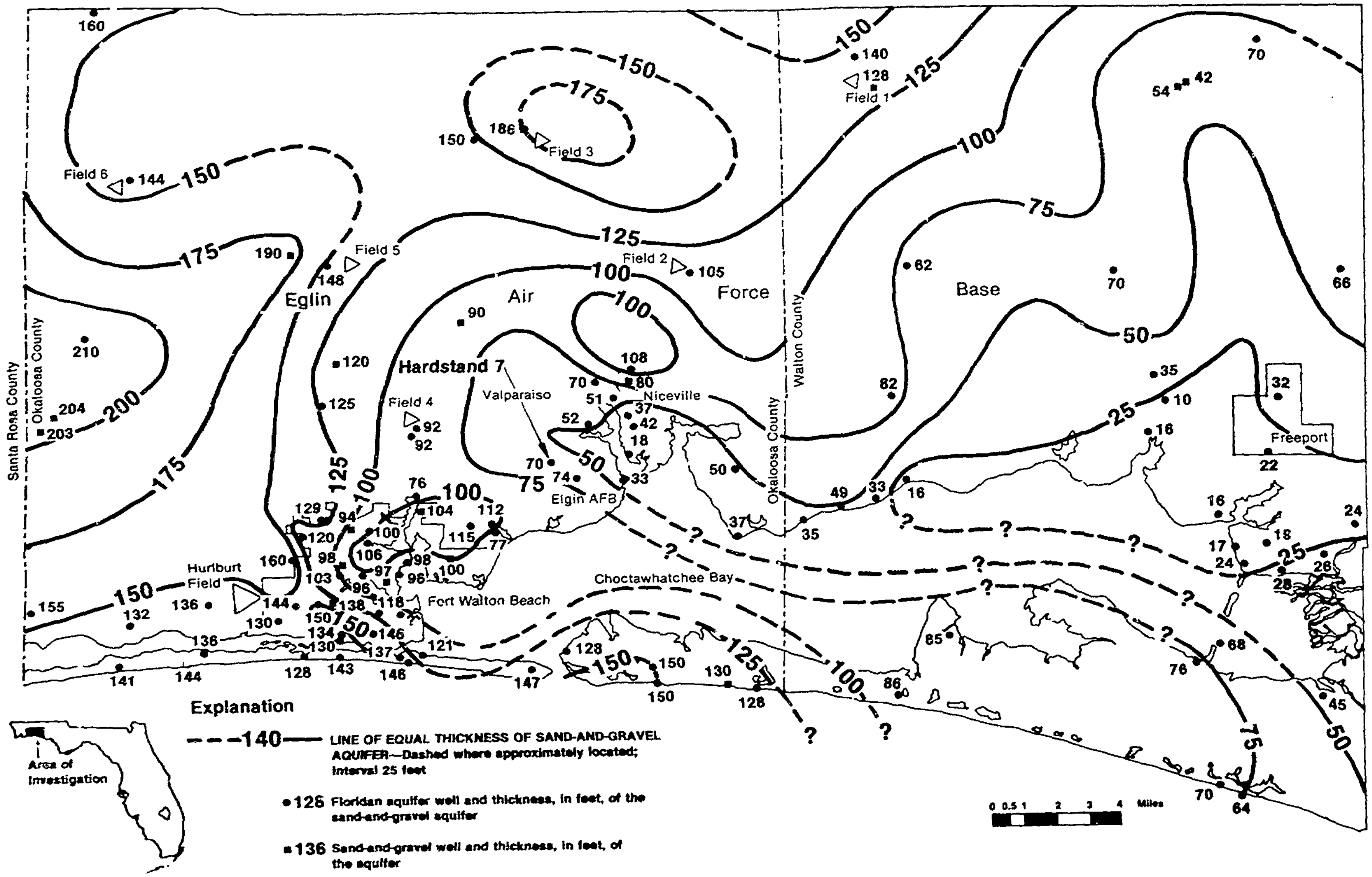


Figure 7. Thickness of the Sand-and-Gravel Aquifer (Reference 2).

Using pump tests, Hayes and Barr (Reference 2) defined the hydraulic properties of the main producing zone of the sand-and-gravel aquifer in seven areas in and near Fort Walton Beach in 1983. The wells tested were screened for 20 or 40 feet and pumped at 50 to 382 gpm. The resulting transmissivities ranged from 700 to 6200 ft^2/day and averaged about 2500 ft^2/day. The hydraulic conductivity ranges from about 20 to 300 ft/day and averages about 80 ft/day. The high values reflect the highly permeable nature of the sand-and-gravel aquifer materials.

Hayes and Barr concluded that wells located in the aquifer to the north and northwest of Fort Walton Beach could produce from 500 to more than 1000 gpm. Where the sand-and-gravel aquifer is less than 50 feet thick and is composed of fine-to-medium sand, yields of 25 to 100 gpm may be expected.

The generalized potentiometric surface of the main producing zone of the sand-and-gravel aquifer is shown in Figure 8. The contours show that water in the main producing zone generally moves from north to south and discharges toward the Gulf of Mexico and Choctawhatchee Bay.

Data on groundwater recharge to the sand-and-gravel aquifer are not readily available. A range of 15 to 20 inches per year provides a rough estimate.

2. Pensacola Clay (Aquiclude)

Relatively impermeable sediments underlie the sand-and-gravel aquifer in most of southern Okaloosa County. Marsh (Reference 13) named all sediments below the sand-and-gravel aquifer to the marine limestones, the Pensacola Clay. The Pensacola Clay is composed of a highly impermeable sequence of clay, sandy clay, silty clay, clayey sand, and clayey limestone. This bed restricts movement of water between the sand-and-gravel aquifer and the upper limestone of the Floridan aquifer (Reference 5). The Pensacola Clay also restricts saltwater from

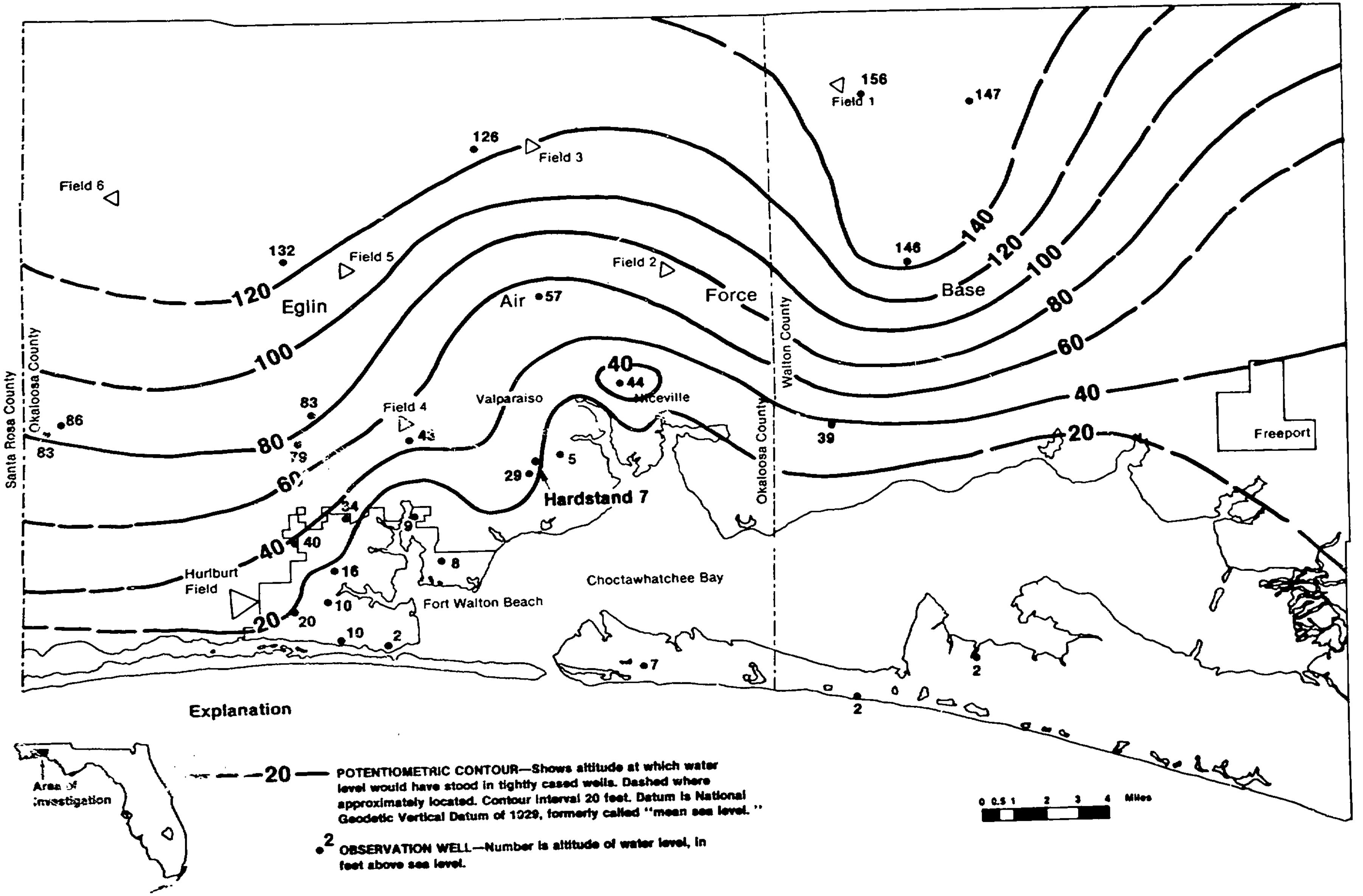


Figure 8. Generalized Potentiometric Surface of the Main Producing Zone of the Sand-and-Gravel Aquifer (Reference 2).

Choctawhatchee Bay and the Gulf of Mexico from moving into the upper limestone of the Floridan aquifer.

At EAFB, the altitude of the top of the Pensacola Clay ranges from about 140 feet above sea level to 140 feet below sea level, as shown in Figure 9. Generally, the top of the Pensacola Clay dips about 17 feet per mile to the southwest.

Figure 10 shows the thickness of the Pensacola Clay. The bed ranges from less than 50 feet thick to almost 500 feet thick. The thickness of the bed increases to the west.

The age of the Pensacola Clay was given as Late Miocene (Reference 5). This would result in an approximate age of 10 to 15 million years.

3. Upper Limestone of the Floridan Aquifer

The upper limestone of the Floridan aquifer (Figure 4) constitutes the principal aquifer for most water uses at EAFB and the surrounding area. It consists of an extensive sequence of interbedded limestones and dolomites. The aquifer includes the Bruce Creek limestone, the Tampa Formation, and the Chickasawhay limestone.

The upper limestone is composed of light gray to brown dolomitic limestone and some dolomite that has a distinctive spongy texture. It contains abundant shell fragments of clams, snails, and microscopic animals. In much of the area, the upper limestone contains layers of green and brown clay. The presence of clay in the upper limestone reduces both the permeability and the effective porosity of the aquifer. The reduced permeability due to clay deposits may provide an explanation for the substantial decline of water in the upper limestone (Reference 5).

The upper limestone of the Floridan aquifer is recharged directly by rain where the limestone lies at the surface of the ground. The upper

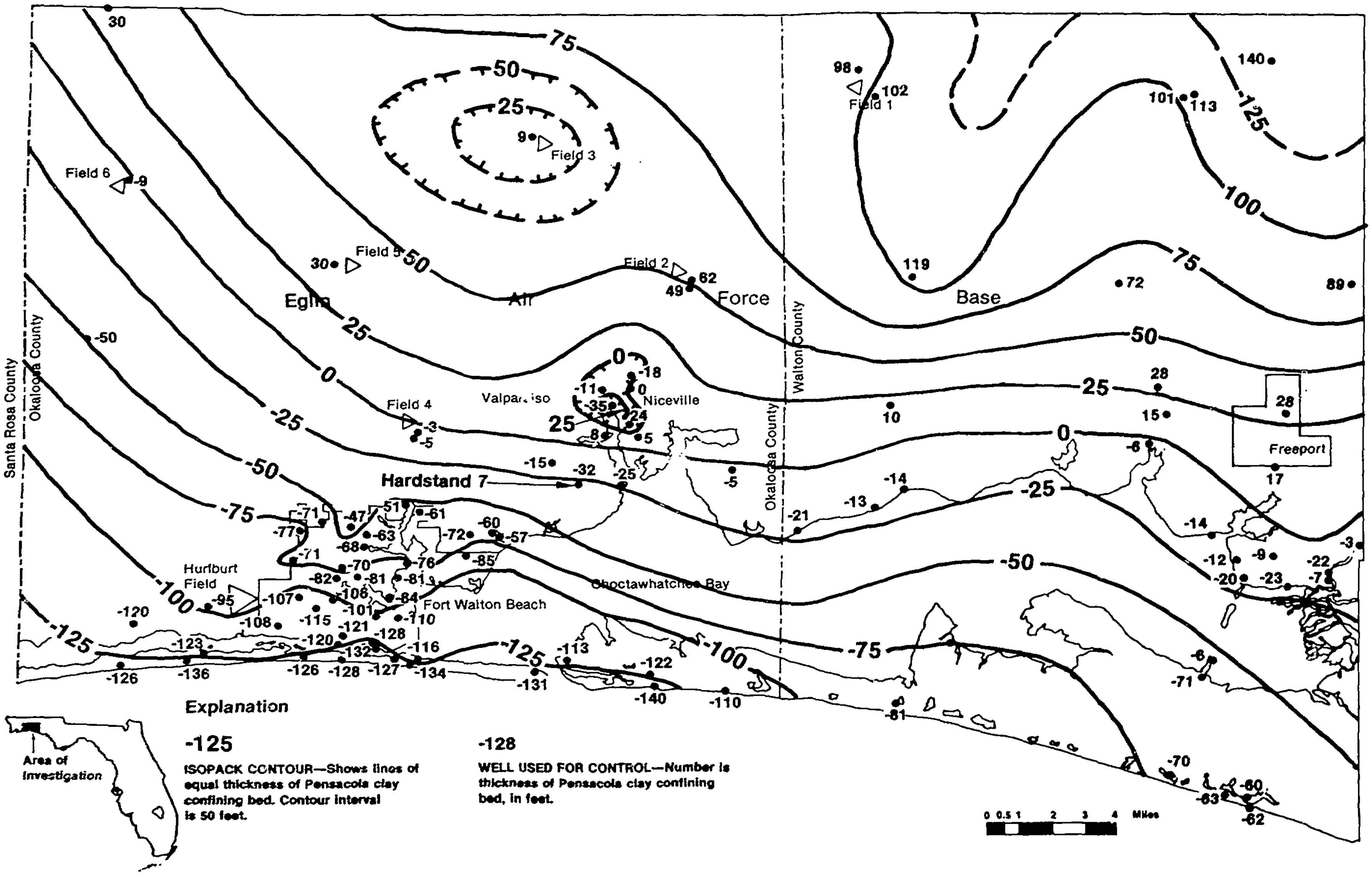


Figure 9. Map Showing Altitude of the Top of the Pensacola Clay Confining Bed (Reference 13).

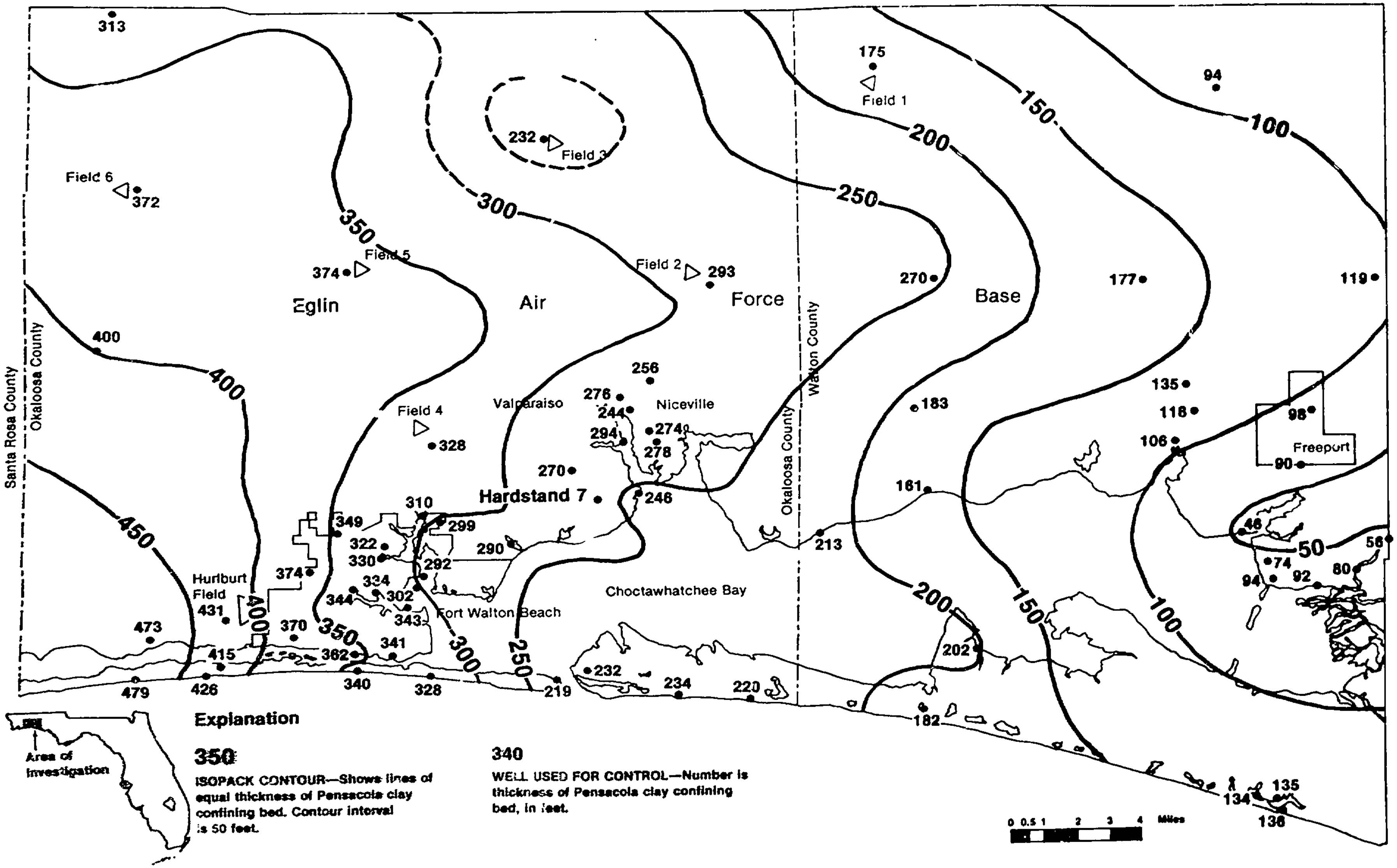


Figure 10. Map Showing Thickness of the Pensacola Clay Confining Bed (Reference 13).

limestone is recharged by percolation from the sand-and-gravel aquifer where the sand-and-gravel aquifer overlies it. Water is discharged from the Floridan aquifer by seepage of water into the gulf, pumping from wells, and upward leakage.

Figure 11 shows the altitude of the top of the upper limestone of the Floridan aquifer. The surface ranges from 50 feet above sea level in the east to more than 600 feet below sea level near the Okaloosa and Santa Rosa county line. The top of the aquifer has an average apparent dip of about 20 feet/mile from east to west.

4. Bucatunna Clay (Aquiclude)

The upper limestone of the Floridan aquifer is separated from the lower limestone by the Bucatunna Clay Member of the Byram Formation (Reference 9). The clay bed is uniform in thickness and regionally extensive. The Bucatunna underlies westernmost Florida and parts of Alabama, Mississippi, and Louisiana. The Bucatunna is more than 200 feet thick in Santa Rosa County and pinches out in southern Walton County.

The Bucatunna consists of soft gray silty-to-sandy clay. It contains a variety of fossils. The bed dips south-southwest at about 25 feet/mile.

The Bucatunna Clay serves as an effective confining bed to retard migration of water from the lower limestone upward to the upper limestone of the Floridan aquifer. The major producing wells at EAFB have not increased in salinity.

5. Lower Limestone of the Floridan Aquifer

The lower limestone of the Floridan aquifer is more variable in thickness than the upper limestone. The lower limestone is as much as 1500 feet thick in Walton County and less than 300 feet thick at Mobile Bay. It is one of the few formations that thins downdip (to the west).

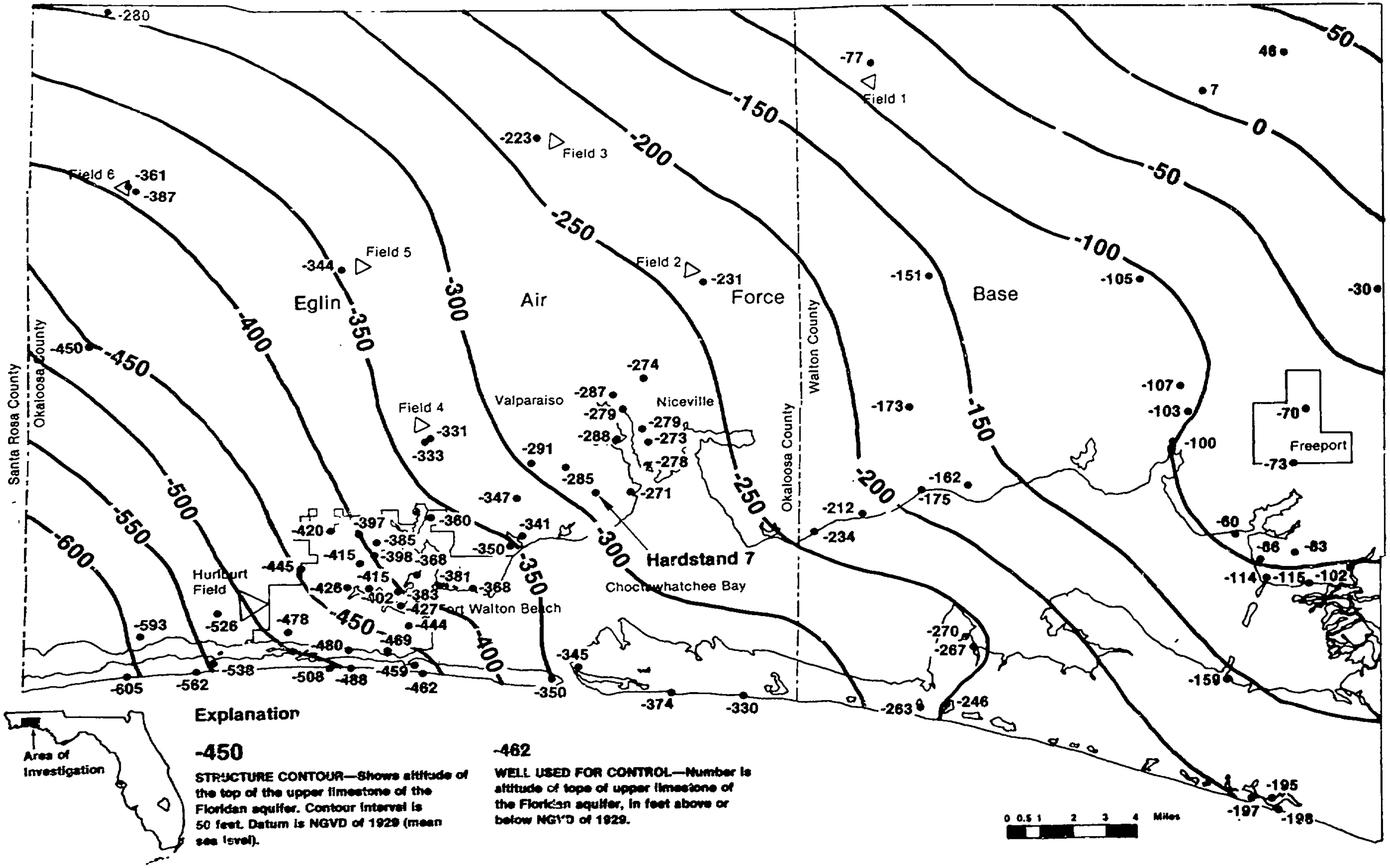


Figure 11. Map Showing Altitude of the Top of the Upper Limestone of the Floridan Aquifer (Reference 13).

The lower limestone is white to grayish cream and is soft and chalky. It contains a variety of corals, clams, and other shells. Some lenses of gray shale, siltstone, and clay are found in the lower limestone.

6. Clay and Shale (Aquiclude)

Beneath the lower limestone of the Floridan aquifer, dense beds of clay and shale are found. These beds are of low permeability and generally define the base of the freshwater. Little water would migrate through these clays and shales. They are of Middle Eocene Age (about 50 million years old).

D. WATER LEVEL DECLINES

Limited quantities of water have been withdrawn through wells from the sand-and-gravel aquifer. The aquifer furnishes water for domestic uses and a few larger supplies. Because of the limited use of water, changes in the water level are generally caused by seasonal fluctuations.

Greatly increased use of water from the upper limestone of the Floridan aquifer has caused drastic water level declines in the area around Fort Walton Beach. Barraclough and Marsh (Reference 5) identified a decline of 95 feet between 1936 and 1957. The decline has continued as pumpage has increased. In southern Okaloosa County, about 1.5 million gallons of water per day (mgd) were pumped from the upper limestone in 1940. By 1978, this amount had increased to 15 mgd. Barr, Maristany, and Kwader (Reference 13) expect this pumpage to increase to about 22 mgd by the year 2000 (Figure 12).

The lower limestone of the Floridan aquifer is not penetrated by wells near EAFB. This aquifer contains saltwater to the west and freshwater to the east. The potentiometric surface in the lower limestone is probably similar to the potentiometric surface in the upper limestone prior to the substantial declines.

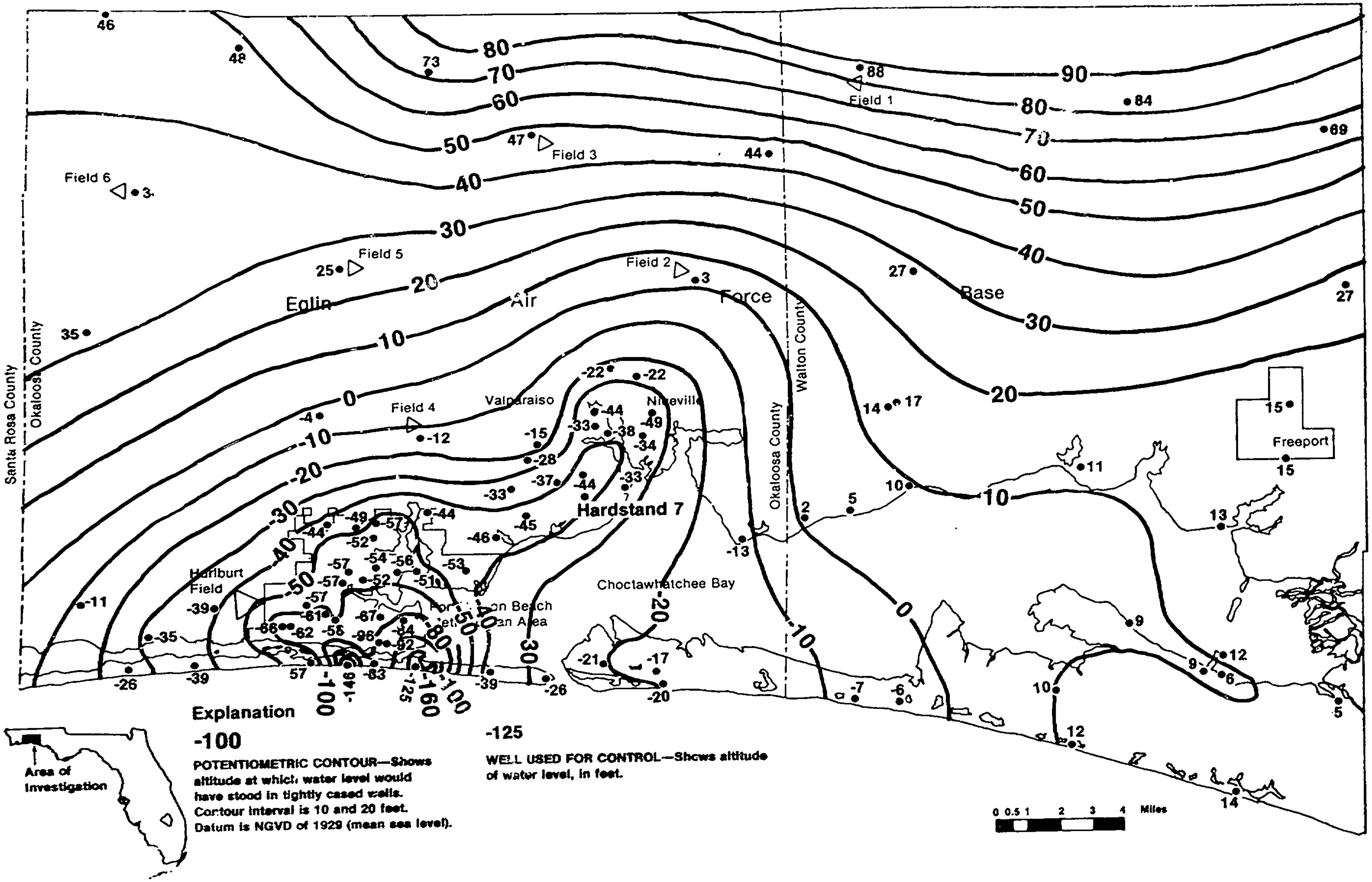


Figure 12. Map Showing the Potentiometric Surface of the Upper Limestone of the Floridan Aquifer in July 1978 (Reference 13).

E. ALTERNATIVE SOURCES OF WATER

The water level declines in the upper limestone are expected to continue with growth and development of southern Okaloosa County. This decline may eventually cause saltwater to move into the upper limestone from the lower limestone or directly from the Gulf of Mexico. Some water management techniques may be needed to reduce the water level declines in the upper limestone. Several possible scenarios for management include: (1) developing a well field in the upper limestone north of Fort Walton Beach, (2) developing a well field in the sand-and-gravel aquifer, (3) using the area's extensive surface-water supply, (4) recharging the upper limestone by allowing water from the sand-and-gravel aquifer to flow down wells to the upper limestone, and (5) recharging the upper limestone with surface water. These possible changes in water management may produce significant changes in the groundwater flow system and thus alter potential waste migration paths.

F. GEOHYDROLOGY OF HARDSTAND 7, EGLIN MAIN FIELD

Hardstand 7, an asphalt and concrete aircraft parking area, is located about 1500 feet west of the north-south runway and about 5600 feet north of the northwest-southeast runway on the main Eglin airdrome (Figure 13). Hardstand 7 is about 5-1/2 miles northeast of Fort Walton Beach. The elevation of Hardstand 7 is 65 feet above sea level. The surface soil is sandy, and precipitation infiltrates readily in most areas.

Hardstand 7 was used for herbicide storage and loading during spray testing from 1962 through 1970. Spillage during loading, spray nozzle cleaning or malfunction, and airplane prop wash were sources of herbicide to the nearby surfaces. The diesel oil herbicide base decreased soil permeability locally and increased runoff toward Hardstand Pond. The temporary use of a pit to collect surface runoff may have localized some downward herbicide movements.

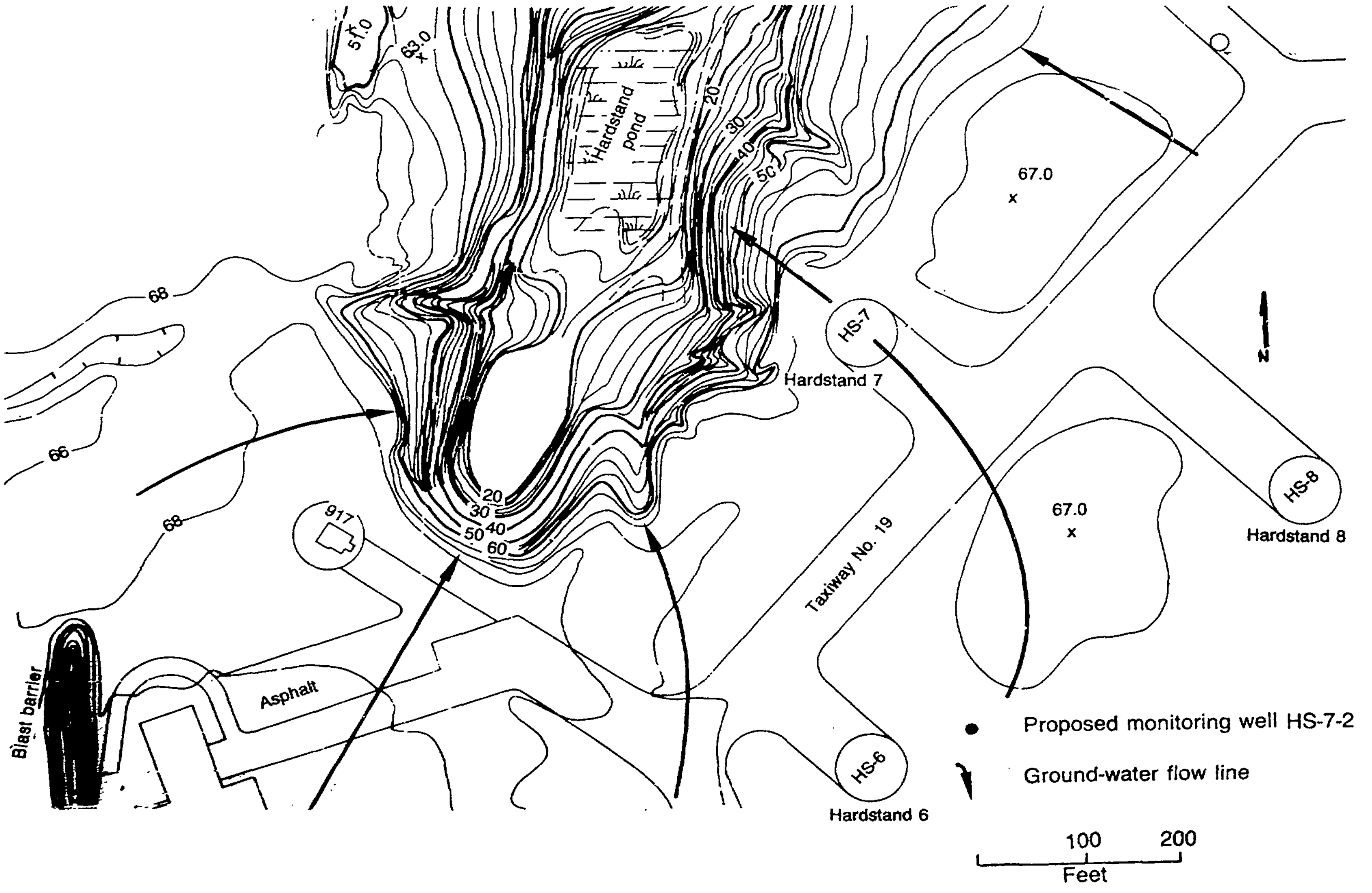


Figure 13. Hardstand 7, Hardstand Pond, Groundwater Flow Lines.

Hardstand 7 is located at the edge of a ravine that drops 50 feet over a 220-foot run to a small pond called Hardstand Pond. Hardstand Pond drains into a small stream that flows north and enters Beaver Pond, Tom's Pond, Tom's Bayou, and Choctawhatchee Bay. This ravine is a typical "steephead," formed by spring flow, with steep sides and a semicircular shape.

Water in the sand-and-gravel aquifer at Hardstand 7 is derived from local rainfall on the surrounding area and from lateral flow from the west-northwest. Information on nearby wells shows that well depths range from 68 to 86 feet, the yields range from 5 to 30 gpm, and the wells are all in the main producing zone of the sand-and-gravel aquifer. The nearest well that withdraws water from the sand-and-gravel aquifer is about 800 feet west of Hardstand 7. The well (Number 257) is 68 feet deep. There are several other shallow wells from 1500 to 2000 feet in a westerly direction. If the monitoring of groundwater in the Hardstand 7 area indicates herbicide contamination, it is recommended that the nearest water supply wells be sampled for contaminants.

Figure 4 gives the hydrogeologic sequence in western Florida. The sand-and-gravel aquifer at Hardstand 7 is about 80 feet thick. The saturated thickness of the aquifer is about 35 feet. The top of the Pensacola Clay is about 15 feet below sea level and is about 270 feet thick. The top of the upper limestone of the Floridan aquifer is about 285 feet below sea level and is about 465 feet thick.

The Bucatunna Clay is about 55 feet thick, and the top is about 750 feet below sea level. The top of the lower limestone of the Floridan aquifer, which is about 800 feet below sea level, is about 315 feet thick. The top of the shale and clay is about 1120 feet below sea level.

The water level in the sand-and-gravel aquifer at Hardstand 7 is about 20 feet above sea level and about 45 feet below the land surface.

The potentiometric surface (water level) in the upper limestone varied from 20 to 35 feet below sea level in 1978 (85 to 100 feet below the land surface). Computer projections suggest that the water level will decline about 1 foot per year (another 35 feet by 2020) if pumping increases as in the past (Reference 13).

The artesian pressure head (water level) in the lower limestone of the Floridan aquifer at Hardstand 7 may be around 40 to 50 feet above sea level (15 to 25 feet below the land surface). Further data are required to confirm this estimate.

The hydraulic head relationships between aquifers are necessary to evaluate potential contaminant migration. The hydraulic gradients are such that groundwater tends to flow downward from the sand-and-gravel aquifer to the upper limestone aquifer and upward from the lower limestone aquifer to the upper limestone aquifer. The low permeabilities of the Pensacola Clay and Bucatunna Clay aquicludes between the aquifers strongly retard this movement.

Based on available information, it is highly unlikely that any significant contamination from pollutants in the Hardstand 7 area could migrate through the Pensacola Clay and into the main drinking water supply, the upper limestone of the Floridan aquifer.

The differences in water levels in the sand-and-gravel aquifer and the upper limestone of about 50 feet in 1978 and a projected difference of about 90 feet in the future would indicate that water from the sand-and-gravel aquifer could move downward. Some water will eventually move through the Pensacola Clay. The low permeability, however, would prevent any significant migration of pollutants through the clay layer. The sorptive characteristics of the clay would provide additional attenuation of contaminants.

The average vertical hydraulic conductivity of the Pensacola Clay in southern Okaloosa County is about 1×10^{-5} ft/day with a range of

1×10^{-2} to 1×10^{-6} ft/day (Reference 13). The quantity of water that could move from the sand-and-gravel aquifer through the Pensacola Clay to the upper limestone of the Floridan aquifer at EAFB can be calculated. For current head differences of about 50 feet, about 0.006 gallon/year per square foot would move through the 270-foot-thick Pensacola Clay. For future head differences of 90 feet, about 0.009 gallon/year per square foot would move through the confining layer. The theoretical flow through an area of 100 by 100 feet would be about 90 gallons/year. It may take approximately 50,000 years for water to move from the sand-and-gravel aquifer to the Florida aquifer. This estimated quantity of water would be subjected to a high dilution factor as it mixes with water flowing in the underlying upper limestone.

G. MOVEMENT OF WATER IN THE SAND-AND-GRAVEL AQUIFER

Generally, groundwater flow in the main producing zone of the sand-and-gravel aquifer is southward at EAFB toward discharge into Choctawhatchee Bay and the Gulf of Mexico. The average gradient is about 10 feet/mile. The average aquifer porosity is 0.25, and the average hydraulic conductivity is 150 feet/day. The average linear velocity of this water would be about 1.1 feet/day or 400 feet/year. The generalized flow direction at the Hardstand 7 area would be eastward, toward discharge into Boggy Bayou and Choctawhatchee Bay.

However, Hardstand Pond, a local discharge area, probably influences groundwater flow in the upper portions of the sand-and-gravel aquifer. The resulting movement would be in a northwest direction for water in the Hardstand 7 area.

The directional change would be gradual as the groundwater moved toward discharge into Hardstand Pond (Figure 13). The average linear velocity of this groundwater would be about 0.7 foot/day (about 260 feet/year) in the immediate area around Hardstand 7 and Hardstand Pond. Velocity calculations were made using an estimated gradient of 3 feet in 1000 feet, hydraulic conductivity of 70 feet/day, and a porosity of 0.30. It would take about 1 year for solutes from the Hardstand 7 area to reach the Hardstand Pond. This estimate does not allow for any dispersion, sorption, or decay mechanisms that may slow solute movement. Actual hydrogeologic measurements at Hardstand 7 will allow more accurate velocity estimates.

H. WATER QUALITY IN THE SAND-AND-GRAVEL AQUIFER

Water from the sand-and-gravel aquifer is suitable for domestic, industrial, and irrigation use. The water meets the State and Federal requirements for public drinking water supplies; however, some chemical constituents or physical conditions of the water constitute isolated problems. The pH is as low as 4.5, and iron concentrations are as high as 4.3 mg/L. The concentration of hydrogen sulfide is sometimes high enough to give the water an odor and make it corrosive. Some water has a turbid appearance from colloidal clay. Some wells near saline water have higher values of chloride and other constituents (Reference 2).

Water in the sand-and-gravel aquifer is extraordinarily soft and relatively unmineralized. The dissolved-solids content of the water is generally less than 50 mg/L. The large amount of relatively insoluble quartz sand in the aquifer and high rainfall are some reasons for the low mineralization.

I. GROUNDWATER MONITORING

The objectives of the groundwater monitoring program are as follows:

1. To determine if the herbicide-contaminated soil is discharging contaminants to the surficial aquifer

2. To determine the concentrations of waste constituents

3. To provide hydrogeological data that can be used to evaluate corrective actions

4. To collect sedimentary samples during drilling for waste and hydrogeologic characteristic determinations

5. To determine flow direction and magnitude of the groundwater and potential contaminants

6. To obtain data from which contaminant movement predictions can be made.

It is recommended that the monitoring system consist of one upgradient background well and four downgradient wells, located to intercept potential contaminant pathways. The wells should be constructed to allow sampling at the water table of the sand-and-gravel aquifer. The most likely location to detect herbicide contaminants is the uppermost aquifer near Hardstand 7. The expected shallow local groundwater flow systems will allow the wells to monitor lateral or downgradient migration of pollutants as the groundwater moves toward surface discharge at Hardstand Pond.

The proposed well locations are noted in Figure 14. Upgradient well HS-7-1 should be located 200 feet northeast of the edge of Hardstand 6, 300 feet southwest of the edge of Hardstand 8, and 150 feet southeast of the edge of Taxiway 19. This location is a slight topographic high lying at about 66 feet above sea level. This is about [illegible]0 feet south-southeast of the center of Hardstand 7. The well is located upgradient from Hardstand 7 and should be a sufficient distance away that no herbicide contamination can be found. The well is located so that information on the groundwater gradient and background water quality can be obtained.

A deep boring should be made at the HS-7-1 monitoring location to determine the location of the various hydrogeologic units. The specific locations of the aquifers and aquicludes will determine groundwater flow and associated contaminant movements. The boring should penetrate the top of the Pensacola Clay, which is expected to be about 90 to 100 feet below the surface at this location. Split-spoon samples should be taken at 5-foot intervals and wherever there is a change in lithology, as determined

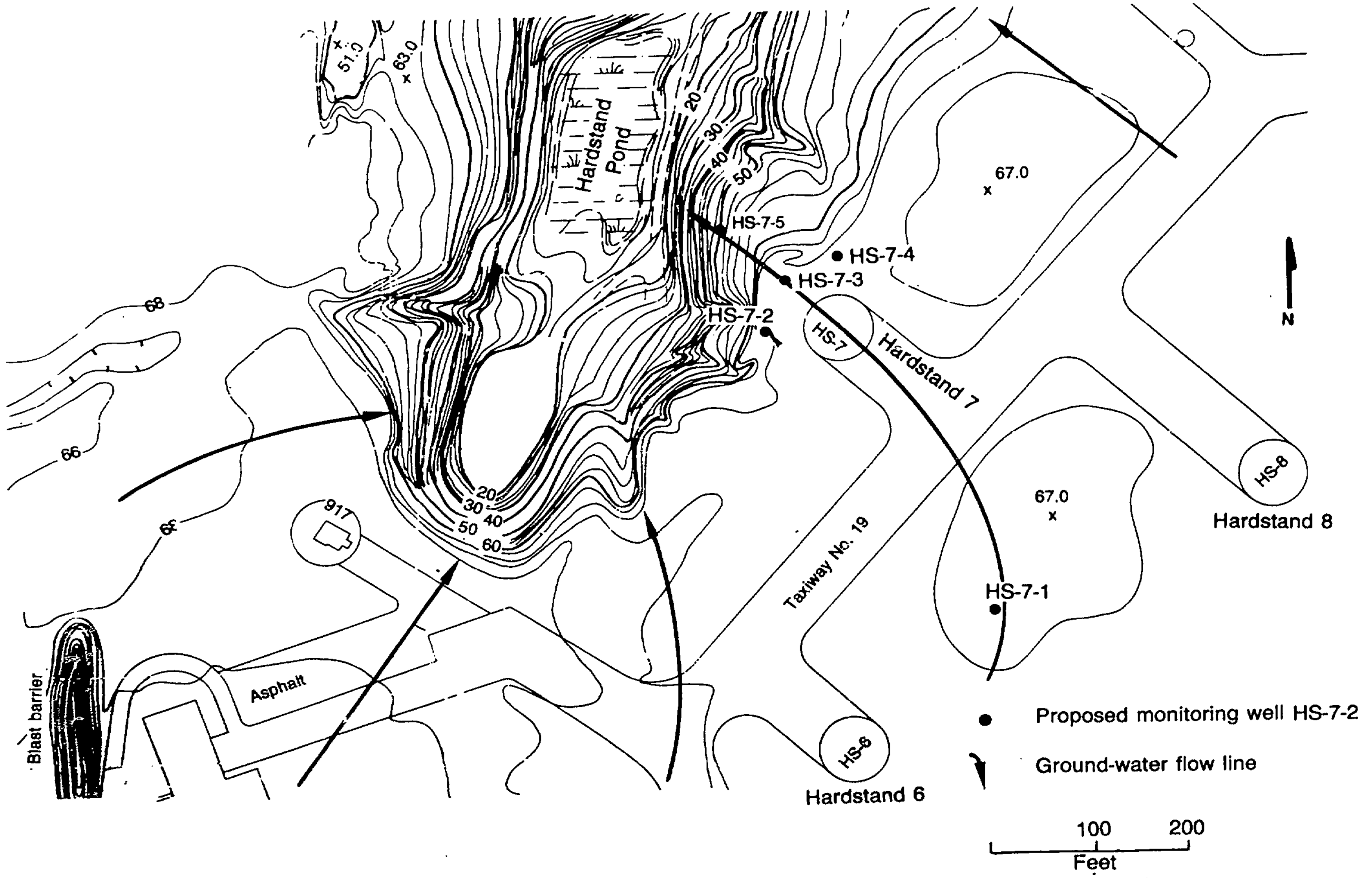


Figure 14. Hardstand 7, Hardstand Pond, Locations of Proposed Monitoring Wells.

by well cuttings. Three soil samples from each lithologic unit encountered should have grain size determinations made, including hydrometer analysis to determine clay content. Cumulative grain size curves should be prepared from the data. The Unified Soil Classification System should be used to describe the soils. Porosity measurements and three laboratory permeability tests of each saturated lithologic unit should be made. The laboratory tests will indicate the variability of the hydraulic properties of the soil and can be correlated with the more accurate field slug tests. The laboratory permeability tests will give vertical conductivity values that may be much lower than the field tests, which reflect the horizontal permeability. Porosity data are useful in determining the groundwater seepage velocity. The measurement of the total organic carbon (TOC) of representative samples should also be made to allow for evaluation of potential dioxin sorption mechanisms.

Well construction should consist of 2-inch inside diameter (ID) stainless steel casing with a 15-foot stainless steel well screen penetrating 10 feet below the water table. PVC well casing should not be used because of potential interference with organic analyses. The well casing should be cleaned before placement and kept isolated from potential contaminants at the surface. The lower portion of the borehole may require grouting before placement of the well screen and casing. The well screen should contain the appropriate slot size for the surrounding formation materials. Noncaving soil materials that allow an open hole to be maintained should allow the placement of a grout in the annular space between the well casing and hole. A high-density, slow-setting bentonite grout developed by the American Colloid Company is recommended. The grout will prevent potential channelization of contaminants from the surface to the aquifer. It is recommended that the well be developed, using a surge block, as well as purging with compressed air. Frequent conductivity measurements over several months could be used to determine whether the well has reached an equilibrium relationship with the formational water, thus,providing the required representative water quality samples.

Three downgradient monitoring wells are proposed to be located near Hardstand 7 in a circular pattern. Well HS-7-2 should be located 50 feet west of the west edge of Hardstand 7. This area, which shows nearby surface herbicide contamination, is near a pit formerly used to collect herbicides. The borings for Well HS-7-2 need only be deep enough to construct a water table well in the same manner as HS-7-1. Sampling should be made in a similar fashion, but portions of each split-spoon soil sample should be retained for potential dioxin and Herbicide Orange analysis.

Well HS-7-3 should be located 50 feet northwest of the northwest edge of Hardstand 7. This boring should be carried down into the Pensacola Clay and be sampled and instrumented in the same manner as the other borings. Portions of the split-spoon samples down to the depth of the well screen should be retained for potential dioxin and Herbicide Orange analysis. Grout should be tremied into the borehole up to the level of the bottom of the well screen. This should be done as the auger is removed to obtain a seal before the hole collapses. The data from Borings HS-7-1 and HS-7-3 should be used to construct a hydrogeological cross section along the expected groundwater flow path.

Well HS-7-4 should be located 50 feet north of the north edge of the concrete on Hardstand 7. The boring need only be deep enough to allow water table well construction similar to HS-7-2 and HS-7-3.

These three monitoring wells should determine if waste solutes are moving in the groundwater away from Hardstand 7. Their close proximity to the expected contaminant sources should enable any contaminant transport to be eventually detected. The three wells are at an elevation of about 64 feet above sea level.

Well HS-7-5 should be located about halfway between well HS-7-3 and Hardstand Pond. This location would be about 150 feet northwest of the northwest edge of the concrete on Hardstand 7. The elevation of this site is about 50 feet above sea level. This well boring should be drilled deep enough to construct a water-table well completed as the previous wells.

Hydraulic conductivity slug tests should be conducted on Wells HS-7-1, 2, 3, 4, and 5. Both rising and falling head tests should be run. A pressure transducer should be used to record head changes due to the high formation conductivity expected. The conductivity values obtained may be as much as one order of magnitude lower than actual bulk aquifer conductivity that would be determined by a large-scale pump test of the aquifer.

Some seeps or very small springs discharge water from the sand-and-gravel aquifer into Hardstand Pond. These seeps are 1 or 2 feet above the pond level. This is the first location where flowing groundwater might transport dioxins or associated compounds back into the surface environment.

The Hardstand Pond seeps next to Hardstand 7 should be monitored by angling a short 4- or 6-inch-diameter stainless steel pipe with about 3 feet of stainless steel well screen into the seep area. The well screen should be plugged at the bottom.

All wells should be provided with locking protective steel cases and and should be permanently identified. Well-completion reports that describe well-drilling methods and materials should be prepared. Specific depths and material intervals for each well should be documented. Well-development methods should be described.

J. DRILLING METHODS AND WELL CONSTRUCTION

It is recommended that a hollow-stem, continuous-flight auger be used to construct the well boreholes and to install well casings and screens. This equipment allows undisturbed soil samples to be taken at intervals as the drilling proceeds. Drilling fluid is not required, minimizing contamination problems. Split-spoon or Shelby tube samplers can be used with clear plexiglass tubes and sample catchers suitable for loose sands at NCBC. The clear tubes can be quickly sealed at both ends so that hydrogeologic properties can be determined at a later date, yet the core material is available for visual examinations. If clear tubes are used, they should be stored in a darkened area. A 6-inch-ID hollow stem will allow for the best placement of well-screen gravel packs and grouts. Four-inch hollow stems are often used, but placement of the filters and seals is more problematical. Grout seals should be placed from the bottom up using a tremie tube. All drilling equipment that enters the borehole or contacts such equipment should be steam-cleaned before use. Use of lubricants between drill stem sections should be restricted. Drilling equipment should be stored in clean areas and not be allowed to contact surface soils after cleaning.

Since organic analysis is of main concern and the groundwater is not excessively corrosive, the use of stainless steel for well construction is recommended due to lower cost and greater strength. The well casing and screen should be steam-cleaned before installation.

The well casing should extend from the land surface down to just above the water table. The outside of the casing should be grouted around the land surface to prevent any contaminants from moving down the outside of the casing. The well casing should be protected with a locking steel case at the surface. Each well should have a 15-foot screen, installed so that the top is about 5 feet above the normal water table. This would provide about 10 feet of screen below the water table. There should be sufficient permeability to withdraw a water sample through this sandy interval. The well can also sample a rising water table during periods of heavy rainfall. The rising water levels may carry more contaminants than the normal water level. The bottoms of each well should be sealed.

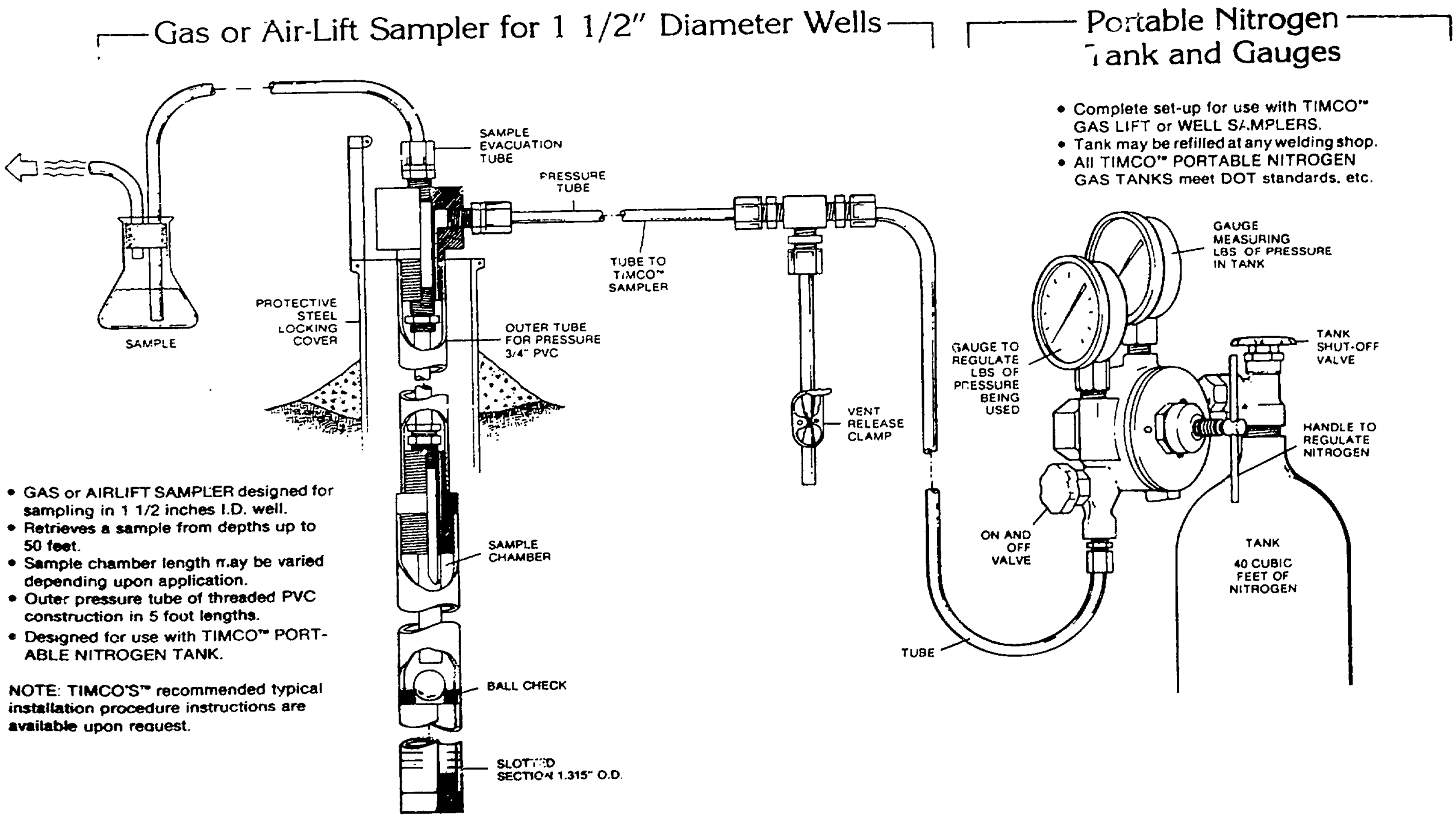
After the well casings are grouted in place, the top of the casing should be carefully surveyed to determine the location and the elevation. Accurate elevations of the measuring point on the well are needed for accurate measurements of the water table. The hydraulic gradient, which will be used to show the direction of groundwater flow and to calculate the groundwater velocity, can then be determined. Water levels should be measured before water is removed from the well for sampling.

If possible, installations should be developed so that the groundwater sampling equipment does not have to be installed and removed for each sampling. This greatly reduces the chance of introducing foreign material into the well. If equipment is put into the well, such as water-level measuring equipment, care should be taken to avoid cross-contamination.

To eliminate this concern, a dedicated gas or airlift sampler can be installed in each well. Figure 15 shows a typical installation. The sampler can be manufactured entirely out of Teflon®, if desired. The setup is installed in place and uses a nitrogen bottle to pressure up the installation. A check ball is used to allow water to enter. It seals when pressure is applied and the water in the sampler is forced to the surface, where it is collected. Alternately, a submersible pump or bailer could be used to sample the wells.

K. AQUIFER SAMPLING TECHNIQUES

Before sampling, the well should be purged by removing at least five borehole water volumes. The static water level should be measured before purging. Purging and water sample collection are best done using a positive-displacement submersible pump constructed from inert materials such as stainless steel and Teflon®. An alternative method is the use of a Teflon® or stainless steel bailer. Proper cleaning of sampling equipment is essential. If nondedicated sampling equipment is used, wells should be sampled in order of least contaminated to most contaminated. Conductivity, pH, and temperature should be measured in the field on unfiltered samples. All inorganic samples should be immediately filtered in the field and acidified when indicated. A field blank and duplicate should be included to provide a quality assurance/quality control check on analysis.



- GAS or AIRLIFT SAMPLER designed for sampling in 1 1/2 inches I.D. well.
- Retrieves a sample from depths up to 50 feet.
- Sample chamber length may be varied depending upon application.
- Outer pressure tube of threaded PVC construction in 5 foot lengths.
- Designed for use with TIMCO™ PORTABLE NITROGEN TANK.

NOTE: TIMCO'S™ recommended typical installation procedure instructions are available upon request.

- Complete set-up for use with TIMCO™ GAS LIFT or WELL SAMPLERS.
- Tank may be refilled at any welding shop.
- All TIMCO™ PORTABLE NITROGEN GAS TANKS meet DOT standards, etc.

Figure 15. TIMCO® Gas or Airlift Sampler for Small Diameter Wells.

L. VADOSE MONITORING

If soil or groundwater analysis results indicate significant downward movement of dioxin, monitoring of the vadose (unsaturated) soils above the water table should be implemented. Four to six pressure-vacuum porous-cup lysimeters placed in areas of concern would provide adequate monitoring of downward contaminant movement in the soils above the water table (see Figure 16). Inert materials such as Teflon® should be used for instrument construction wherever possible. Solvent cements and polyvinyl chloride should not be used. Depth of lysimeter placement should be guided by the known extent of dioxin contamination. Careful adherence to lysimeter installation procedures is necessary to ensure that the instrument functions as expected. The proper placement of silica flour around the ceramic cup of the lysimeter is of greatest concern. An inert gas should be used to purge the water sample to minimize potential equilibrium changes. The limited water sample size obtained from lysimeters limits the number of parameters available for analysis.

M. SAMPLING SCHEDULE AND PARAMETER LIST

It is recommended that five rounds of detailed analyses at quarterly intervals, followed by a program of reduced parameter scope and frequency, be instituted as follows:

1. Initial Five Rounds (Quarterly)

Conductivity

pH

Temperature

Water elevation (MSL) (0.01 ft accuracy)

Hardness (including calcium and magnesium analysis)

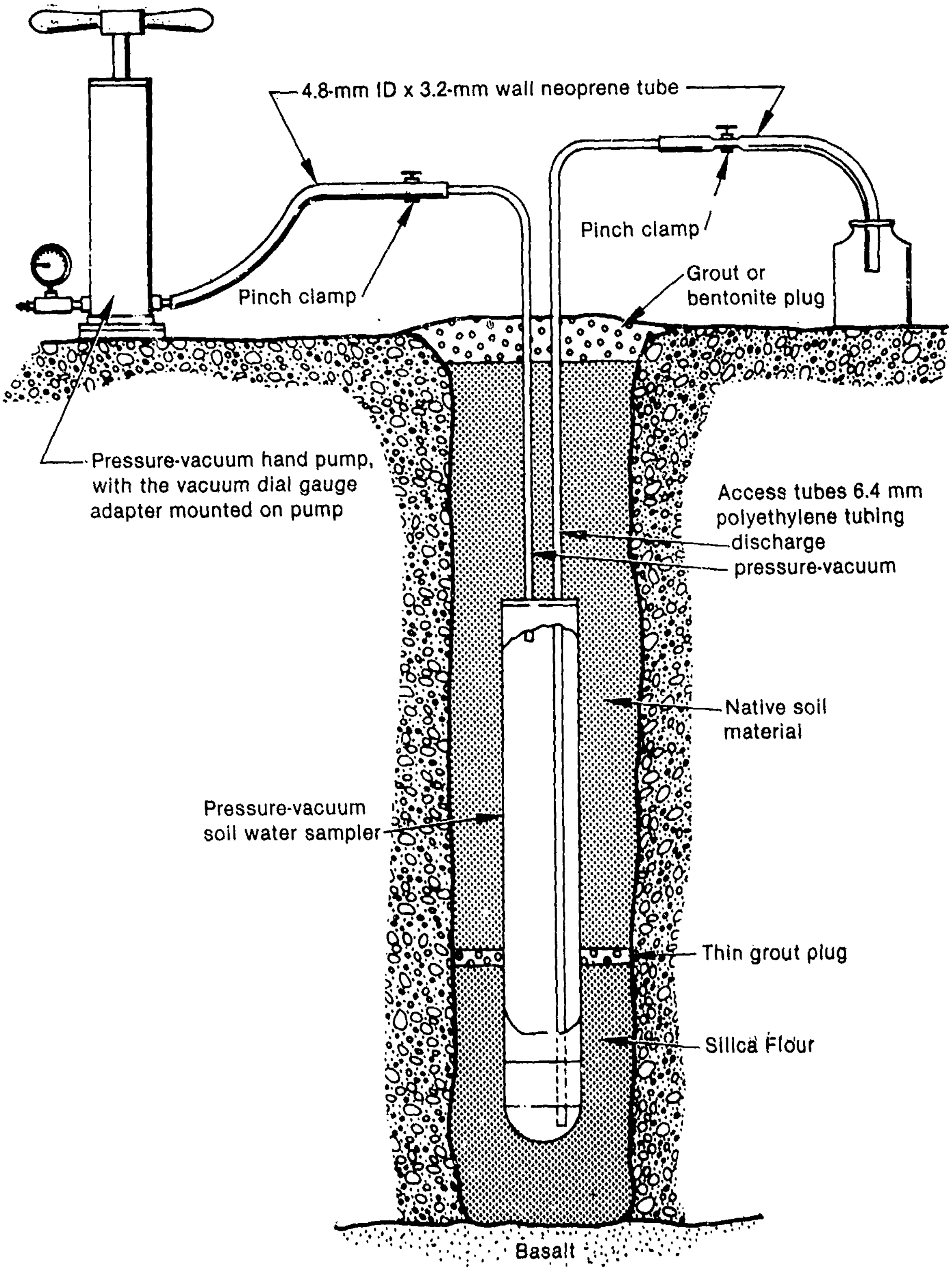


Figure 16. Porous Cup Sampler Installation (Reference 18).

Alkalinity

2,3,7,8-TCDD, 1.0 ppt detection limit

2,4,5-T

2,4-D

Complete gas chromatography/mass spectrometry (GC/MS) organic analysis including volatile, acid, and base neutral extractions. Specific herbicide compounds and their degradation products should be examined.

Chloride, sulfate, sulfide, nitrate, iron, manganese, copper, zinc, boron, arsenic, barium, cadmium, chromium, selenium, antimony, lead, mercury, silver, fluoride, potassium.

2. Long-Term Monitoring (Semiannual)

Conductivity

pH

Temperature

Water elevation (MSL)

Total organic carbon (TOC)

Total organic halogens (TOX)

2,3,7,8-TCDD, 1.0 ppt detection limit

2,4,5-T

2,4-D

Plus any other parameters identified from initial sampling round identified as being of environmental concern.

Diesel fuel component analysis may be a useful indicator of potential herbicide movements. Long-term monitoring could be supplemented with gas chromatography (GC) methods to detect low levels of these components. EPA Method 625 (Base/Neutral Extractables) or GC/flame ionization detector (FID), with use of a diesel fuel sample as a standard to allow quantification, are two suggested methods. Total organic halogen (TOX) and TOC are useful for detecting larger quantities of broad groups of organic compounds, and would need to be followed by the more sensitive and specific GC techniques, if positive results are found.

N. DIOXIN MIGRATION

Herbicides stored and tested at EAFB at Hardstand 7 included Herbicide Orange, Purple, Blue, White, and Orange II. Because of the much larger quantities stored and because of its TCDD impurities, Herbicide Orange is of greatest concern. Herbicide Orange contained equal amounts of 2,4,-D and 2,4,5-T. Diesel fuel was used as a vehicle for application during testing. The 2,4,5-T contained dioxin as a manufacturing impurity with an estimated range from less than 0.02 to 15 ppm in Herbicide Orange. Herbicide Blue, containing arsenic, and Herbicide White, containing picloram, were stored only a short time and are not thought to be significant contaminants. Orange II and Purple contained different esters of 2,4,5-T in its formulations.

Dioxin has a very low solubility in water. Choudhary, Keith, and Rappe (Reference 19) have determined solubility values ranging from 0.2 to 0.6 ppb. Dioxin's hydrophobic nature tends to prevent its movement with percolating water. Instead, it accumulates on the soil particles through various soil sorption mechanisms.

Attenuation is a term used to describe the effects of adsorption, ion exchange, and mineral precipitation on waste solutes such as TCDD when they are in solution. The clay and organic content of the soil through which the solute flows are important factors influencing sorption. Sorption, as expressed by a distribution coefficient (K_d), can be measured with batch experiments in the laboratory. Measurement of solute uptake as test solutions flow through columns of geologic materials is a more realistic way to represent the field conditions for K_d determination. Some of the core material derived from the drilling of monitoring wells could be used to measure K_d. The K_d can then be used to quantify the degree to which TCDD is attenuated as it moves through the aquifer materials. Literature values could be used for a first approximation.

The extent of the contamination of dioxin at EAFB is being determined by an extensive concurrent surface and subsurface sampling program of which the geohydrologic investigation is associated. This will help determine the possible attenuation of dioxin with time and the concentrations at depth.

Migration of dioxin away from Hardstand 7 area can occur by direct volatilization and on grains of sediment moving offsite by wind transport as well as by the hydrological mechanisms described below.

Direct surface runoff is another source of dioxin migration. Where the source material is at or near the surface, heavy precipitation can cause enough erosion so that some sedimentary material could be transported by water. Precipitation associated with hurricanes, where rainfalls of 6 to 12 inches may occur in a day, are an example. The high rainfall and the short drainage distances allow contaminants to reach receiving waters. This process tends to move less contaminants with time because the more easily moved material has been carried away. The sediments in Hardstand Pond were analyzed in a previous study (Reference 20), and no TCDD was found.

Herbicide contaminants moving from the surficial materials into the groundwater would be directed toward the Hardstand Pond where the water would discharge. TCDD's affinity for soil particles would probably prevent any TCDD from traveling that far. As discussed previously, the low permeability of the Pensacola Clay aquiclude would prevent contaminants from reaching the upper limestone of the Floridan aquifer.

SECTION III

GEOHYDROLOGIC ENVIRONMENT OF THE NAVAL CONSTRUCTION BATTALION CENTER

The Naval Construction Battalion Center (NCBC) is located within the city limits of Gulfport, Harrison County, Mississippi (Figure 2). The Gulf of Mexico is located less than 2 miles to the south.

NCBC covers about 2 square miles. The land is generally level with gently rolling terrain. Drainage occurs to the south toward the Gulf of Mexico. NCBC is in the Coastal Plain Meadows Region. The elevation of the NCBC ranges from about 25 to 35 feet above sea level.

The facility was used to store about 0.85 million gallons of herbicides, mostly Herbicide Orange, from 1968 to 1977. The storage site for herbicides at NCBC is about 1.5 miles north of the Gulf of Mexico.

A. CLIMATE

NCBC has a humid, semitropical climate. Summers are long and warm, and winters are short and mild. The average annual temperature at Gulfport is 68°F. Temperatures seldom exceed 100°F or fall below 25°F. On the average, about 270 frost-free days occur annually (Reference 3).

The average annual rainfall along the coast averages more than 60 inches. July is normally the wettest month; and October, the driest. Heavy showers can produce up to 12 inches of rain in a day. Floods can follow such rains, although much of the rainfall infiltrates into the ground over the area (Reference 3).

B. GEOLOGY

The gulf coastal area has been slowly subsiding for millions of years, forming a trough known as the Gulf Coast geosyncline. As the trough sunk, streams emptying into the Gulf of Mexico have kept the trough nearly full by depositing huge quantities of sand, gravel, and mud. These sand and gravel deposits make up the principal aquifers in the Gulfport area (Table 1). Limestones, sandstones, and shales are also present at great depths below Gulfport.

Beds of Miocene Age are about 3500 feet deep near Gulfport (Figure 17). They include the Pascagoula Formation, the Hattiesburg Formation, and the Catahoula Sandstone (Table 2). The beds have been collectively called the Miocene aquifer system. The Bucatunna Clay Member of the Byram Formation underlies the Miocene beds (Reference 17).

Above the Miocene rocks are beds of the Pliocene Series, which include the Citronelle Formation and Graham Ferry Formation.

Water-bearing beds of the Miocene and Pliocene Series are composed chiefly of clean quartz sand, are tan to light gray, and range in grain size from very fine to very coarse. Both the bed thickness and the grain size vary considerably within short distances, typical effects of deltaic and estuarine deposition. Many beds are more than 100 feet thick (Reference 3).

The strike of the beds is east-southeast. The dip of the base of the Miocene rocks is south-southwest at about 90 feet per mile near Gulfport. The dip of the sediments above an elevation of 1000 feet below sea level on the coast probably is about 30 feet per mile (Reference 3). The dip of the beds probably is less in the shallow zone because of normal seaward thickening of the section.

At Gulfport, the top 40 to 200 feet of sediment are composed of alluvial and terrace deposits, beach deposits, and the Citronelle

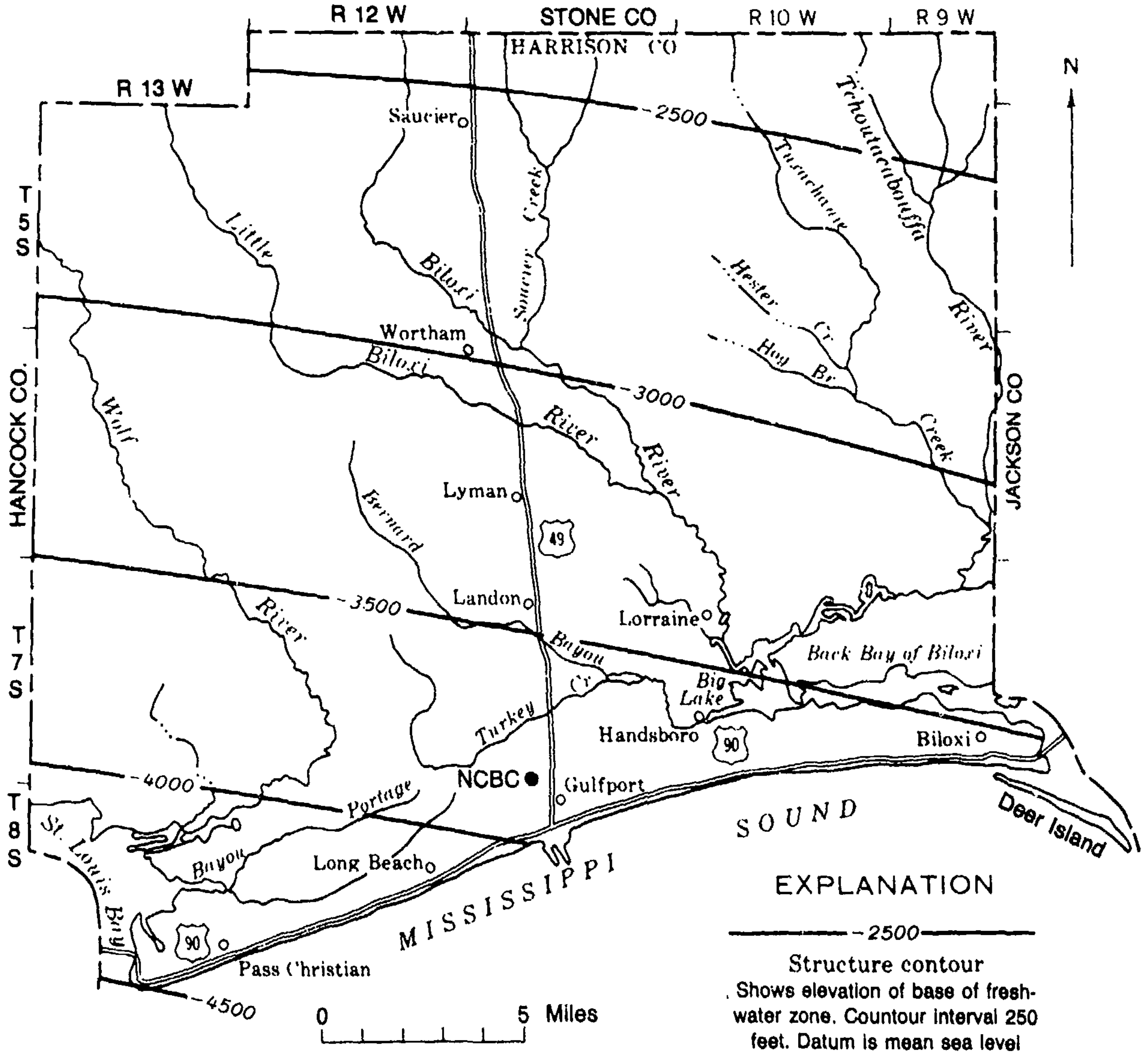


Figure 17. Elevation of the Base of the Miocene Rocks, Harrison County, Mississippi (Reference 3).

TABLE 2. GEOLOGIC UNITS AND MAJOR AQUIFERS IN MISSISSIPPI (REFERENCE 17).

Erathem	System	Series	Group	Geologic unit	Major aquifer	
Cenozoic	Quaternary	Holocene and Pleistocene		Undifferentiated alluvium and terrace deposits Mississippi River valley alluvial aquifer	Mississippi River valley alluvial aquifer	
		Pleistocene		Loess Terrace deposits, undifferentiated		
		Pliocene		Citronelle Formation	Citronelle aquifers	
				Graham Ferry Formation	Miocene aquifer system	
		Miocene		Pascagoula Formation		
				Hattiesburg Formation		
				Catahoula Sandstone		
		Oligocene	Vicksburg Group	Byram Formation		
				Bucatunna Clay Member		
				Middle Marl Member		
				Glendon Limestone Member	Oligocene aquifer system	
				Marianna Limestone		
				Mint Spring Marl Member		
				Forest Hill Sand		
		Eocene	Jackson Group	Yazoo Clay Moodys Branch Formation		
			Claiborne Group	Cockfield Formation	Cockfield aquifer	
				Cook Mountain Formation		
				Sparta Sand	Sparta aquifer system	
				Zilpha Clay		
				Winona Sand	Winona-Tallahatta aquifer	
				Tallahatta Formation		
				Neshoba Sand Member		
				Basic City Shale Member		
				Meridian Sand Member	Meridian-upper Wilcox aquifer	
				Hatchetigbee Formation		
		Paleocene	Wilcox Group	Tuscahoma Formation		
				Nanafalia Formation	Lower Wilcox aquifer	
				Fearn Springs Member		
			Midway Group	Naheola Formation		
				Porters Creek Clay Matthews Landing Marl Member Clayton Formation		
Mesozoic	Cretaceous	Upper Cretaceous	Selma Group	Prairie Bluff Chalk and Owl Creek Formation		
				Ripley Formation	Ripley aquifer	
				Demopolis Chalk		
				Coffee Sand	Coffee Sand aquifer	
				Mooreville Chalk Arcola Limestone Member		
				Eutaw Formation Tombigbee Sand Member McShan Formation	Eutaw-McShan aquifer	
			Tuscaloosa Group	Gordo Formation	Gordo aquifer	Tuscaloosa aquifer system
				Coker Formation	Coker aquifer	
		Lower Cretaceous		Undifferentiated		
Paleozoic	Pennsylvania Mississippian Devonian			Undifferentiated	Paleozoic aquifer system	

Formation. Some authors place the Citronelle Formation in the Pliocene and others place it in the Pleistocene.

C. AQUIFERS AND AQUICLUDES

Geologic units containing freshwater near Gulfport are of the Miocene or younger age. There are no thick, consistently traceable clay beds (aquicludes). The sand-and-gravel beds (aquifers) are irregular in thickness and extent. Some sandy zones, however, can be traced for reasonable distances. All rocks from the base of the Miocene to within 200 feet of the land surface are Miocene and Pliocene rocks (Table 3). The rocks from near the land surface to about 200 feet in depth are designated Citronelle Formation. On the surface are terrace, alluvial, and beach deposits. These deposits range from 10 to about 50 feet thick (Reference 3).

Aquifers at depths of more than 500 feet maintain sufficient artesian pressure to support flowing wells except where nearby pumping has lowered the head. The main recharge areas are several miles north of Gulfport. Recharge occurs by infiltration of rain that falls on sandy outcrops. The beds have high transmissivity in the horizontal direction and low transmissivity in the vertical direction (Reference 3).

Deep wells in the Gulfport area had water levels about 100 feet above sea level 100 years ago. Today, the water levels are at or below sea level. Saltwater intrusion as a result of the lowered groundwater levels, however, is not evident. In fact, freshwater occurs more than 12 miles offshore (south of Gulfport) (Reference 3).

Developed sand zones are generally permeable. For example, deep wells at Gulfport can be produced an average of 500 gpm with 25 to 70 feet of drawdown. Wells near Gulfport produce large quantities of water if they penetrate a thick section of medium-to-coarse sand and the well screen is developed properly. Table 4 gives the drillers' logs of three wells drilled on NCBC to illustrate the various sand and clay layers.

TABLE 3. STRATIGRAPHIC COLUMN AND WATER RESOURCES IN SOUTH MISSISSIPPI.

ERA	System	Series	Group	Stratigraphic Unit	Thickness (feet)	Water Resources
Cenozoic	Quaternary	Holocene		Alluvium	0-80	Not an important aquifer. A few large wells may be possible along some of the major streams in local areas. Salt water has intruded this aquifer adjacent to the Mississippi Sound.
		Pleistocene		Terrace Deposits	0-100	Some local wells tap this aquifer, but is not used over a very extensive area. Large quantities of water may be available in the southern part where a number of these deposits are developed in a staircase fashion. Salty water is present along the coast in some of these deposits.
				Citronelle	0-100	Supplies shallow domestic wells throughout most of the area. A few municipal wells are completed in this aquifer. Quality of water is fair. The water usually contains low dissolved solids and has a low pH.
	Tertiary	Pliocene		Graham Ferry	0-200	Main source of water supply for municipal and industrial wells in the vicinity of Pascagoula A number of wells in western Jackson and eastern Harrison Counties utilize this aquifer. Quality of water is generally good. Water is slightly alkaline and iron is seldom a problem in the wells at Pascagoula.
		Miocene		Pascagoula	0-1000	An important source of water supply for the municipal, industrial and domestic wells in Hancock, Harrison and Jackson Counties. The Pascagoula, Hattiesburg and the Catahoula are difficult to differentiate in the subsurface. Recent publications have placed all of the aquifers into "Miocene aquifers." Quality of water is good from this aquifer. Color is high in a number of wells adjacent to the Mississippi Sound. Hydrogen sulfide content may be a local problem.
				Hattiesburg	0-400	An important source of water supply for the municipal wells at Lucedale. This aquifer has the potential of supplying large volumes of water to wells in Pearl River, Stone and George Counties. Numerous domestic wells tap this aquifer in the central part of the area (southern Forrest, Greene, Perry, Pearl River, Stone and George Counties). The quality of water is generally good.
				Catahoula	500-900	An important source of water in the northern half of the area. The aquifer supplies numerous municipal, industrial, and domestic water supplies as far south as northern Pearl River, Stone and George Counties. The aquifer is fresh farther south but because of the depth and availability of shallower aquifers is not generally used. The quality of water is generally good.

TABLE 4. DRILLERS' LOGS OF THREE DEEP WELLS ON NCBC, MISSISSIPPI

U.S. Naval Depot 1

Harrison County 160
Altitude: 23.0 feet

Driller: Layne Central Company

	Thick (feet)	Depth (feet)
Recent and Pamlico deposits		
Topsoil	3	3
Pamlico sand		
Sand and gravel	13	16
Graham Ferry formation		
Clay	56	72
Sand, mucky	20	92
Clay	69	161
Clay, sandy	64	225
Sand, fine	11	236
Clay, sandy	23	259
Sand, fine	25	284
Clay, sandy	52	336
Clay, tough	186	522
Clay, sandy	85	607
Gumbo	46	653
Clay, sandy	13	666
Sand and thin strata of clay	19	685
Sand, mucky	25	710
Sand and thin strata of clay	26	736
Sand	18	754
Clay	16	770
Sand	6	776
Clay	4	780
Shale, sandy	90	870
Sand, fine	21	891
Sand	25	916
Pascagoula (?) formation		
Clay and shale	198	1114
Sand, fine	6	1120
Sand	16	1136
Sand and thin strata of shale	21	1157
Shale, gummy, and sand	16	1173
Sand	21	1194
Clay, tough	36	1230

TABLE 4. DRILLERS' LOGS OF THREE DEEP WELLS ON NCBC, MISSISSIPPI (CONTINUED)

U.S. Naval Depot 2

Harrison County 161
Altitude: 31.71 feet

Driller: Layne Central Company

	Thick (feet)	Depth (feet)
Recent deposits		
Topsoil	5	5
Pamlico sand		
Sand: contains magnetite, kyanite, staurolite zircon, tourmaline, rutile, epidote, leucoxene, pyrite, limonite, muscovite, and hornblende	20	20
Graham Ferry formation		
Clay, sandy	28	53
Sand	7	60
Clay	41	101
Sand, fine-grained muddy	13	114
Clay, tough	33	147
Muck, sandy	8	155
Clay, tough	15	170
Clay, sandy	31	250
Clay, tough	12	262
Clay, sandy	24	286
Clay	24	310
Sand, fine-grained blue; quartz, abundant, sericitized feldspar, plagioclase feldspar (albite-andesine), minor quantity of orthoclase; 15% of heavy minerals examined in this sample is serrated hornblende, magnetite, kyanite, siderite, zircon, epidote, leucoxene, pink garnet, staurolite, pyrite, rutile, muscovite, tourmaline	18	328
Clay, tough	94	422
Sand, quartz, abundant altered grains of sericite and chalcedony, less abundant microcline and orthoclase, minor sodic plagioclase; pyrite, magnetite, dyanite, epidote, zircon, staurolite, hornblende, tourmaline, rutile, pink garnet, ilmenite, and leucoxene	15	437
Gumbo	51	488

TABLE 4. DRILLERS' LOGS OF THREE DEEP WELLS ON NCBC, MISSISSIPPI (CONTINUED)

U.S. Naval Depot 2

Harrison County 161
Altitude: 31.71 feet Driller: Layne Central Company

	Thick (feet)	Depth (feet)
Sand, quartz, abundant microcline and orthoclase; minor sodic plagioclase; magnetite, epidote, kyanite, zircon, pyrite, pink garnet, staurolite, serrated hornblende, leucoxene, tourmaline, muscovite, and ilmenite	21	509
Clay, tough	23	532
Shale, sandy	14	546
Clay, tough	46	592
Shale, sandy	36	628
Clay, tough	7	635
Shale, sandy	20	655
Clay	23	678
Clay, sandy	9	687
Sand, fine-grained loose; quartz, microcline and orthoclase; more plagioclase which is oligoclase-andesine; magnetite, epidote, dyanite, zircon, pink garnet, pale and normal-colored hornblende, leucoxene tourmaline, rutile; pyrite in lower 25 feet	38	725
Sand and shale	48	773
Sand, fine; magnetite, epidote, kyanite, zircon, pink garnet, staurolite, serrated hornblende, leucoxene, pyrite, tourmaline, and rutile	12	785
Shale, sandy	15	800
Shale, gummy	12	812
Sand, fine water-bearing; quartz, microcline abundant, minor orthoclase, sanidine, and oligoclase-andesine; magnetite, zircon, epidote, kyanite, leucoxene, serrated hornblende, pyrite, tourmaline, staurolite, and pink garnet	38	850
Shale, gummy	60	910
Shale, sandy	34	944

TABLE 4. DRILLERS' LOGS OF THREE DEEP WELLS ON NCBC, MISSISSIPPI (CONTINUED)

U.S. Naval Depot 2

Harrison County 161
Altitude: 31.71 feet

Driller: Layne Central Company

	Thick (feet)	Depth (feet)
Pascagoula (?) formation		
Shale, gummy	218	1162
Sand, quartz, abundant microcline, minor orthoclase, little or no plagioclase; siderite, magnetite, pyrite, zircon, epidote, hornblende, kyanite, staurolite, leucoxene, tourmaline, muxcovite, biotite, green mica, rutile, pink garnet	16	1222
Shale, gummy	66	1288

U.S. Naval Depot 3

Harrison County 162
Altitude: 27.5 feet

Driller: Layne Central Company

	Thick (feet)	Depth (feet)
Recent and Pamlico deposits		
Sand	45	45
Graham Ferry formation		
Clay and thin strata of sand	45	90
Clay, sandy	152	242
Sand, fine	68	310
Sand	18	328
Clay, tough	128	456
Clay sandy	36	492
Clay	108	600
Sand, fine	38	638
Clay	16	654
Shale, sandy	18	672
Sand	88	760
Shale, sandy	47	807
Sand	33	840
Shale, sandy	15	855
Clay, sandy	33	888
Sand	45	933
Gumbo	49	982
Sand, fine-grained strata	38	1020

TABLE 4. DRILLERS' LOGS OF THREE DEEP WELLS ON NCBC, MISSISSIPPI (CONCLUDED)

U.S. Naval Depot 3

Harrison County 162
Altitude: 27.5 feet

Driller: Layne Central Company

	Thick (feet)	Depth (feet)
Pascagoula (?) formulation		
Gumbo	69	1089
Shale, hard	111	1200
Sand	8	1208
Clay, tough	17	1225
Shale, hard	34	1259
Sand	20	1279
Clay, tough	25	1304

The base of the freshwater zone in the Gulfport area is more than 2500 feet below sea level (Figure 18) (Reference 3). Test wells at Gulfport have penetrated the freshwater section at 2500 feet. The artesian pressure head at this depth is about 100 feet above sea level, with the permeable sand beds more than 100 feet thick (Reference 16).

Saltwater occurs naturally in deposits laid down in a deltaic or marine environment. The saltwater can be flushed and replaced by freshwater flowing through the materials.

The chloride content of water from wells near Gulfport does not show an increasing trend over the pumping record. When the freshwater levels are lowered by pumping, saltwater could intrude from the Gulf of Mexico or from beds containing brines that underlie the area. Data from the offshore islands suggest that the freshwater/saltwater interface is distant. Saltwater from long-trapped brines beneath the area seems the most logical derivation of the high chlorides below 2500 feet (Reference 15).

Groundwater recharge to the Citronelle aquifer was calculated (Reference 17) to be about 12 inches/year. Recharge to the overlying alluvial, terrace, and beach deposits is likely to be greater, with an estimated range of 15 to 20 inches/year.

D. WATER QUALITY

The water quality at Gulfport is generally very good for most purposes. The water is of a sodium bicarbonate type. In general, sodium, bicarbonate, and chloride increase with depth; and calcium, magnesium, and sulfate remain unchanged (Reference 3).

Most groundwaters near Gulfport are soft, containing less than 250 mg/L of dissolved solids. Iron in the groundwater is a problem in some areas near Gulfport. The pH ranges from 6.0 to 9.1. In general, the pH of the water increases with depth and toward the Gulf of Mexico (Reference 3).

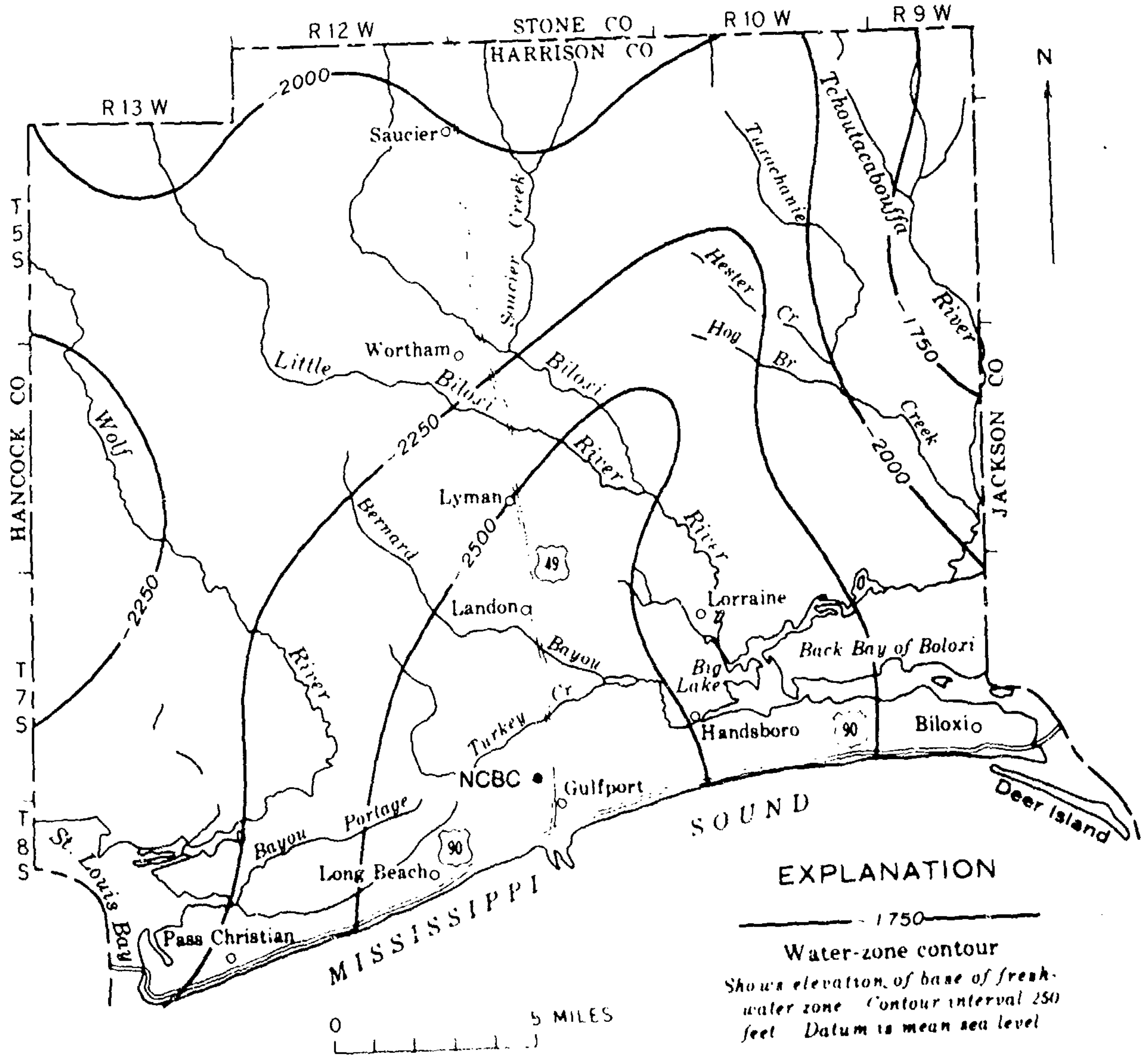


Figure 18. Configuration of the Base of the Freshwater Zone in Harrison County, Mississippi (Reference 3).

The temperature of the shallow groundwater (about 50 feet deep) near Gulfport is usually about 68°F. A significant geothermal gradient accounts for a 1°F increase in temperature for every 62 feet in depth (Reference 3). For example, water from a well 1500 feet deep would be expected to be about 92°F.

E. GEOHYDROLOGY OF NCBC--HERBICIDE STORAGE AREA

The Herbicide Storage Area (HSA) at NCBC covers about 15 acres. The HSA is located in the central portion of NCBC (Figure 19). The area is bounded by Goodier Avenue, Greenwood Avenue, Seventh Street, and Ninth Street. It is approximately 400 feet wide by 1500 feet long. The HSA is very flat. The average elevation of the land surface is 30 feet and ranges from 29 to 32 feet above sea level. The groundwater table is about 3 to 6 feet below the surface.

The HSA is drained by a system of shallow ditches, storm sewers, and culverts in the center of the area. The ditches, which are graded to the west, discharge into a canal in the northwest portion of NCBC.

The drainage culverts on the HSA are 15 to 24 inches in diameter, and the two outlet culverts under Goodier Avenue are 18 inches and 27 inches in diameter. The bottoms of the culverts are 26 and 27 feet above sea level. The culverts and ditches are 2 to 5 feet lower than the land surface. The bottom of the surface drainage system is just above the water table in the uppermost or shallow aquifer system. The shallow groundwater system will rise during rainy periods and discharge into the surface drains. This groundwater discharge could transport contaminants out of the HSA area through the drainage system.

The surface of the HSA was treated about 40 years ago with cement and compacted to make a layer of soil cement 5 to 14 inches thick. Where the soil cement is thin, cracks in the soil cement increase the potential for contaminant migration as surface water infiltrates.

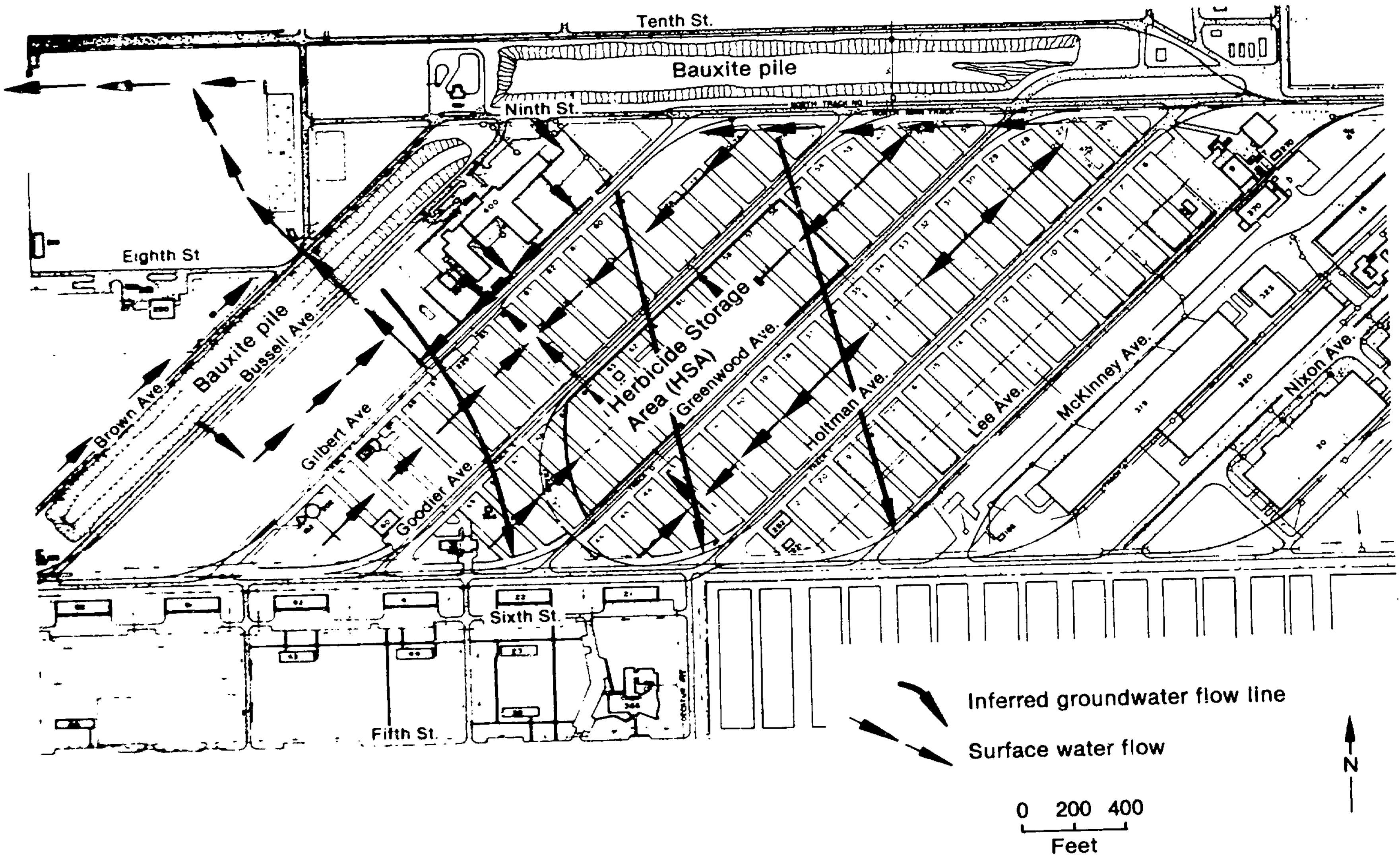


Figure 19. NCBC Herbicide Storage Area, and Inferred Shallow Groundwater Flow Lines.

1. Aquifers and Aquicludes

The near-surface deposits at NCBC are composed of deposits of quartz sands and gravels, clays, and silts. Organic material has been deposited locally. The near-surface deposits may be composed of alluvium, terrace deposits, and the Citronelle Formation (Reference 16 and Table 2).

The Miocene and Pliocene deposits furnish most of the water supply for the NCBC area. The thickness and extent of the various beds change with distance. The wells are drilled until a suitable aquifer material is located. A screen is set at the desired depth, and the well is developed. The producing zones are variable. For example, the five public supply wells on NCBC are screened to various depths ranging from 649 feet to 1196 feet, with 10- to 70-foot well screen intervals. In each well, other zones of sandy material could produce water (Table 4).

2. Surficial Aquifer

The permeable portion of the near-surface layers has been called the surficial aquifer. This aquifer is recharged by rain that falls in the nearby area. The rain percolates down to the shallow water table, found only a few feet below the surface, and then moves laterally toward a discharge area. The water moves more freely laterally than downward because of the presence of lenses of relatively impermeable clays and silts.

The most permeable portion of the surficial aquifer at the HSA is the sandy unit just below the soil layer. This sandy unit averages about 24 feet thick, as determined by 14 nearby shallow soil borings.

The hydraulic conductivity of the sand zones in the surficial aquifer is expected to be about 150 feet/day (Reference 17). This value compares well with average values for similar aquifer materials. Groundwater velocities in the surficial aquifer at the HSA are low because the hydraulic gradient is rather flat, probably about 3 or 4 feet/mile.

The porosity ranges from 0.20 to 0.[illegible]0. The average linear velocity ranges from about 0.3 to 0.6 feet/day or about 100 to 200 feet/year. The velocity of groundwater in the surficial aquifer would increase near areas of discharge because the hydraulic gradient would increase.

3. Movement of Water

The HSA and nearby area are a small topographic high, compared to the surrounding land. The elevation of the high ranges from about 25 feet to about 33 feet above sea level.

The flat area around the HSA is a recharge area where rainfall recharges the surficial aquifer. Groundwater moves away from the center of recharge in four directions, depending on the local conditions. The overall flow direction in all the aquifers at Gulfport is southward, toward the Gulf of Mexico.

During the late 1940s, NCBC was used to store national stockpile material. Bauxite is stored in two large hills. One hill is about 500 feet north of the HSA, and the other hill is about 900 feet northwest of the HSA (Figure 19).

These bauxite hills are likely to be causing the water in the surficial aquifer to rise above the surrounding flat areas. This buildup of water level would act as a barrier to flow northward or westward. Therefore, because of the small groundwater mounds under the bauxite hills and the slightly higher land to the east of the HSA, the flow direction of water in the surficial aquifer is likely to be to the south, or the south-southeast.

4. Geochemistry

Attenuation is a term used to describe the effects of adsorption, ion exchange, and mineral precipitation on waste solutes such as TCDD when they are in solution. The clay and organic content of the soil through which the solute flows are important factors influencing sorption. Sorption, as expressed by distribution coefficients (K_d), can be measured with batch experiments in the laboratory. Measurement of solute uptake as test solutions flow through columns of geologic materials is a more realistic way to represent the field conditions. Column studies are preferred for measuring K_d (distribution coefficient). Some of the core material derived from the drilling of monitoring wells could be used to measure K_d. The K_d can then be used to quantify the degree to which TCDD is attenuated as it moves through the aquifer materials. Literature values could be used for a first approximation.

F. GROUNDWATER MONITORING

The objectives of the groundwater monitoring program are as follows:

1. To determine if the HSA is discharging contaminants to the surficial aquifer
2. To determine the concentrations of waste constituents
3. To provide hydrogeological data that can be used to evaluate corrective actions
4. To collect sedimentary samples during drilling for waste and hydrogeologic characteristic determinations
5. To determine flow direction and magnitude of the groundwater and potential contaminants
6. To obtain data from which contaminant movement predictions can be made.

The proposed monitoring system consists of one upgradient or background well and seven downgradient wells. The well borings should be drilled through the first permeable zone of sand layers and into the underlying clay layer. The most likely location to detect pollutants will be the uppermost part of the surficial aquifer. The wells would monitor lateral or downgradient migration of herbicide residues as the groundwater moves southward from the HSA.

The upgradient monitoring well (MW 1) is located so that information on the hydraulic gradient and background water quality can be obtained. The well is located 50 feet southeast of Gilbert Avenue, 360 feet northwest of Goodier Avenue, and 290 feet south of 9th Street (Figure 20). This location is a sufficient distance away from the HSA that contamination is avoided. It is not too close to any drainage ditches and is 320 feet south of the nearest bauxite hill.

The upgradient well boring should be drilled to penetrate the entire permeable sequence of the surficial aquifer and into the top of the first significant clay layer. The boring depth should be about 35 feet, but the clay layer may be deeper in this area. Core samples should be collected during drilling so that the geologic layers can be described. The elevation of the land surface at this well (MW 1) is 30 feet above sea level.

Seven potentially downgradient monitoring wells will be located around HSA (Figure 20). MW 2 should be located 10 feet northwest of Goodier Avenue, 790 feet north of 7th Street, 50 feet southwest of a northwest-southeast drainage ditch, and at the corner of storage area number 84. This location is on the northwest side of the HSA and just south of a drainage ditch that receives drainage from the HSA. MW 2 should be drilled to a depth of about 30 feet. The land surface elevation at this well is 30 feet above sea level.

MW 3 should be located 20 feet southeast of Greenwood Avenue, 190 feet north of 7th Street, and 120 feet northeast of Track Y. This well location is just south of the drum storage and is directly downgradient. MW 3 should be drilled to a depth of about 30 feet. The land surface elevation at this well is 32 feet above sea level.

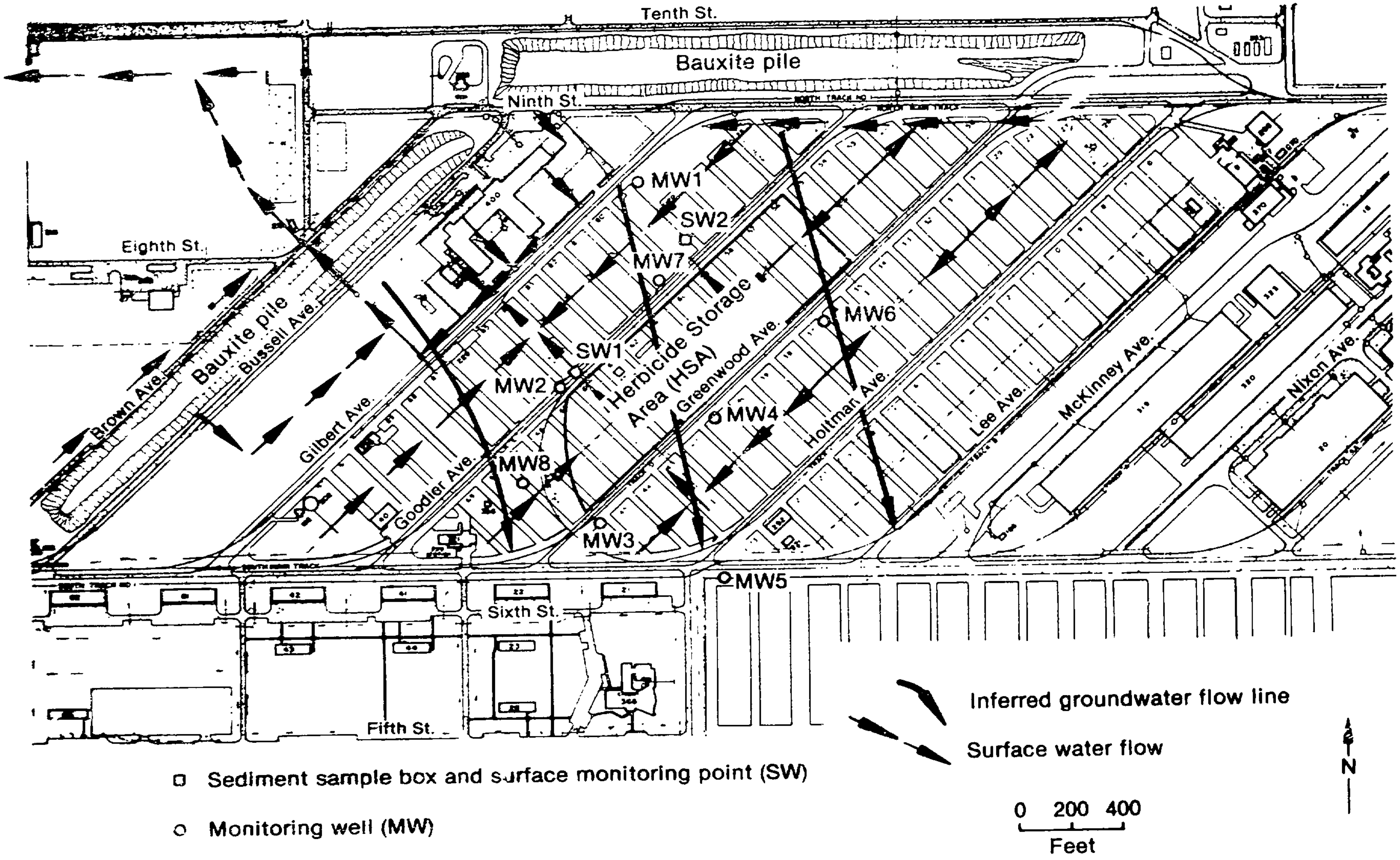


Figure 20. NCBC Herbicide Storage Area, Locations of Proposed Monitoring Wells.

MW 4 should be located 20 feet southeast of Greenwood Avenue, 600 feet north of 7th Street, and 710 feet northeast of Track Y. This well location is less than 100 feet from drum storage and downgradient from part of the HSA. The well should be drilled to a depth of about 30 feet. The land surface elevation of this well is 31 feet above sea level.

MW 5 should be located near the intersection of 7th Street and Decatur Avenue. This area is the nearest off-base land to the HSA. The well should be about 100 feet east of Decatur Avenue and about 20 feet south of 7th Street. The location in this grassy area can be moved or adjusted because of power lines, shrubs, trees, and fences, or for appearance.

MW 5 is an important monitoring well to determine if any waste products are moving offsite. The location is only about 550 feet southeast of some of the former drum storage at the HSA. Continuing monitoring at this site will answer questions about change of water quality with time in the surficial aquifer and about the transport of waste solutes offsite.

MW 5 should be drilled about 30 feet deep. Nearby soil boring logs indicate that the sandy zone is about 20 to 24 feet thick. A clay layer is found below the sand. The water level in MW 5 should be about 6 feet below the land surface. The elevation of this well is about 32 feet above sea level.

MW 6 should be located 20 feet southeast of Greenwood Avenue, 1030 feet north of 7th Street, and 1300 feet northeast of Track Y. MW 6 should be drilled to a depth of about 30 feet. The land surface elevation at this well is 32 feet above sea level.

MW 7 should be located 10 feet northwest of Goodier Avenue, 1260 feet north of 7th Street, and at the corner of storage area number 80. MW 7 should be drilled to a depth of about 30 feet. The land surface elevation at this well is 30 feet above sea level.

MW 8 should be located 200 feet southeast of Goodier Avenue, 230 feet northwest of Greenwood Avenue, 40 feet southwest of Track Y, and 330 feet north of 7th Street. MW 8 should be drilled to a depth of about 30 feet. The land surface elevation at this well is 30 feet above sea level.

The well design for the eight wells is based on a minimal amount of information on the surficial aquifer. Hydraulic gradients could differ from the inferred gradients postulated. Additional wells may be needed to further define groundwater movements or contaminant locations. Because of the shallow groundwater and unconsolidated materials, additional wells could be added at a moderate cost. The well locations could be changed slightly if they would interfere with current or future NCBC operations, power lines, driving routes, or future storage plans.

Well screens should be 10 feet long and set so that they intersect the water table. If an open hole remains below the anticipated depth of the well screen after the boring, then the boring should be grouted with bentonite up to the bottom of the well screen elevation.

The monitoring wells will determine if waste solutes are moving in the shallow groundwater away from the HSA. The sediment samples, taken during well boring, can be analyzed for TCDD, 2,4-D, and 2,4,5-T to determine if wastes have migrated to these well locations. Because the soils tend to sorb contaminants as they move past, these contaminants can be detected even though the groundwater concentration may be very low.

Stratigraphic information derived from sediment samples from the borings should be used to delineate aquifer properties. Undisturbed sediment samples taken during boring should be subjected to grain-size analysis including hydrometer analysis. At least three grain-size analyses for each soil type at the site should be made. The Unified Soil Classification System should be used to describe the soil types encountered. Several soil samples should be analyzed for total organic carbon (TOC). This parameter will be useful in evaluating the potential of the soils to attenuate the contaminants. Dioxins are tightly bound to soils, and the strength of binding has been related to the organic matter content of the soils. Dioxins generally do not move in groundwater supplies, but some evidence exists of vertical movement in soils that are low in organic matter. Some of the sand layers at NCBC would be very low in organic matter. Selected soil samples may be analyzed for TCDD, 2,4-D, and 2,4,5-T, as described earlier. Three undisturbed samples from each major soil type should be tested for hydraulic conductivity in the laboratory. Although laboratory measurements will tend to give vertical conductivity values, they provide an indication of the soil heterogeneity and anisotropy, when compared to slug- or pump-test data. Laboratory values are usually one or more orders of magnitude less than field measurements.

The undisturbed soil samples should be taken every 5 feet during boring and whenever drill cuttings show a change in lithology. Samples should be stored in airtight containers and be archived for 1 year to allow for additional testing, if needed.

G. DRILLING METHODS

A hollow-stem, continuous-flight auger should be used to construct the well boreholes. This equipment allows undisturbed soil samples to be taken at intervals as the drilling proceeds. A 6-inch-ID hollow stem will allow for the best placement of well-screen gravel packs and grouts. Four-inch hollow stems are often used, but placement of the filters and seals is more problematical. Grout seals should be placed from the bottom up, using a tremie tube. All drilling equipment that enters the borehole or contacts such equipment should be steam cleaned before use. Use of lubricants between drill stem sections should be restricted. Drilling equipment should be stored in clean areas and not be allowed to contact surface soils after cleaning.

Auger drilling rigs generally are mobile and fast, and operate well in unconsolidated formations. Drilling fluid is not required, thus minimizing contamination problems. Split-spoon or Shelby tube samplers can be used with clear plexiglass tubes and sample catchers suitable for loose sands at NCBC. The clear tubes can be quickly sealed at both ends so that hydrogeologic properties can be determined at a later date, yet the core material is available for visual examinations.

Cross-contamination can be minimized, if specific sample collection and handling procedures are followed. These methods are described in detail in Reference 18.

H. INSTALLATION OF INSTRUMENTATION

The monitoring instruments should be installed while the hollow-stem auger is in the hole. A 2-inch casing and well screen can be installed inside the hollow stem.

The well casing and screen and all downhole sampling equipment should be made of stainless steel or polytetrafluoroethylene (PTFE), also known as Teflon®. Teflon® represents a nearly ideal well sampling material. It is inert to chemical attack, has poor sorptive properties, and has a low leach potential. Teflon® will not be attacked by low pH waters.

Since organic analysis is of main concern and the groundwater is not excessively corrosive, the use of stainless steel for well construction is recommended because of lower cost and greater strength. The well casing and screen should be steam cleaned before installation.

The well casing should extend from the land surface down to just above the water table. The outside of the casing should be grouted around the land surface to prevent any contaminants from moving down the outside of the casing. The well casing should be protected with a locking steel case at the surface. A 10-foot screen should be used in each well and installed about 2 feet above the normal water table. There should be sufficient permeability to withdraw a water sample through this sandy interval. The well can also sample a rising water table during heavy rainfall periods. The rising water levels may carry more contaminants than the normal water level. The bottom of each well casing should be sealed.

After the well casings are grouted in place, the top of the casing should be carefully surveyed to determine the location and the elevation. Accurate elevations of the measuring point on the well are needed for accurate measurements of the water table. The hydraulic gradient, which will be used to show the direction of groundwater flow and to calculate the groundwater velocity, can then be determined. Water levels should be measured before any water removal from the well.

If possible, installations should be developed so that the sampling equipment does not have to be installed and removed for each sampling. This greatly reduces the chance of introducing foreign material into the well. If equipment is put into the well, such as water-level measuring equipment, care should be taken to avoid cross-contamination.

To eliminate this concern, a dedicated gas or airlift sampler can be installed in each well. Figure 15 shows a typical installation. The sampler can be obtained entirely out of Teflon®, if desired. The setup is installed in place and uses a nitrogen bottle to pressure up the installation. A check ball is used to allow water to enter. It seals when pressure is applied and the water in the sampler is forced to the surface, where it is collected. The wells should be developed by alternately surging the well with a surge block and blowing out accumulated fines with compressed air. Frequent conductivity and pH measurements should be used to document that a stabilized condition has been achieved. After well development, slug tests should be made at each well to determine hydraulic conductivity. Both rising and falling head tests, using a displacement block and pressure transducer, should be performed.

I. AQUIFER SAMPLING TECHNIQUES

Before sampling, the well should be purged by removing at least five borehole water volumes. The static water level should be measured before purging. Purging and water sample collection are best done using the dedicated sampling device or a positive displacement submersible pump constructed from inert materials such as stainless steel and Teflon®. An alternative method is the use of a Teflon® or stainless steel bailer. Proper cleaning of sampling equipment is essential. If nondedicated sampling equipment is used, wells should be sampled in order of least contaminated to most contaminated. Conductivity, pH, and temperature should be measured in the field on unfiltered samples. All inorganic samples should be immediately filtered in the field and acidified when indicated. A field blank and duplicate should be included to provide a quality assurance/quality control check on analysis.

J. VADOSE MONITORING

If soil analysis results indicate significant downward movement of dioxin, it is recommended that monitoring of the vadose (unsaturated) soils above the water table be implemented. Four to six pressure-vacuum porous-cup lysimeters placed in areas of concern would provide adequate monitoring of downward contaminant movement in the soils above the water table (see Figure 16). Inert materials such as Teflon® should be used for instrument construction wherever possible. Solvent cements and polyvinyl chloride should not be used. Depth of lysimeter placement should be guided by the known extent of dioxin contamination. Careful adherence to lysimeter installation procedures is necessary to ensure that the instrument functions as expected. The proper placement of silica flour around the ceramic cup of the lysimeter is of greatest concern. An inert gas should be used to purge the water sample to minimize potential equilibrium changes. The limited water sample size obtained from lysimeters limits the number of parameters available for analysis.

K. SURFACE WATER AND SEDIMENT MONITORING

The monitoring program should include water and sediment samples collected in the surface water drainage ditches near culverts. Two ditches and culverts drain the HSA to the northwest. Culverts are under Goodier Avenue. Samples should be collected in the drainage ditch near the culvert on the northwest side of Goodier Avenue. Water samples would be collected in the ditch, at the soil sample collection box. Soil samples should be collected in a soil sample box that would be designed to trap and store sediments being removed from the HSA during periods of high rainfall. The open box would be placed with the top edge flush with the existing drainage bottom. The accumulated sediments would be removed periodically for analysis. These locations will help determine if waste products are currently moving offsite in water or sediments. The sampling locations are noted in Figure 20. The recommended surface water and soil sampling program should be coordinated with any ongoing sampling activities.

L. SAMPLING SCHEDULE AND PARAMETER LIST

Five rounds of detailed groundwater, surface water, and surface sediment analyses at quarterly intervals should be followed by a program of reduced parameter scope and frequency and instituted as follows:

1. Initial Five Rounds (Quarterly)

   Conductivity

   pH

   Temperature

   Water elevation (MSL) (0.01 ft accuracy)

Hardness (including calcium and magnesium analysis)

Alkalinity

2,3,7,8-TCDD, 1.0 ppt detection limit

2,4,5-T

2,4-D

Complete GC/MS organic analysis including volatile, acid, and base neutral extractions. Specific herbicide compounds and their degradation products should be examined.

Chloride, sulfate, sulfide, nitrate, iron, manganese, copper, zinc, boron, arsenic, barium, cadmium, chromium, selenium, antimony, lead, mercury, silver, fluoride, potassium.

2. Long-Term Monitoring (Semiannual)

Conductivity

pH

Temperature

Water elevation (MSL)

Total organic carbon (TOC)

Total organic halogens (TOX)

2, 3, 7, 8-TCDD, 1.0 ppt detection limit

2, 4, 5-T

2, 4-D

Plus any other parameters identified from initial sampling round to be of environmental concern.

Diesel fuel component analysis may be a useful indicator of potential herbicide movements. Long-term monitoring could be supplemented with gas chromatography methods to detect low levels of these components. EPA Method 625 (Base/Neutral Extractables) or gas chromatrography/flame ionization detector, with use of a diesel fuel sample as a standard to allow quantification, are two suggested methods. TOX and TOC are useful for detecting larger quantities of broad groups of organic compounds, and would need to be followed by the more sensitive and specific GC techniques, if positive results are found.

M. DIOXIN MIGRATION

Herbicides stored at NCBC at the HSA included Herbicide Orange, Blue, White, and Orange II. Herbicides Blue and White were stored for a short time in the late 1960s. Herbicide Orange and Orange II were stored until 1977. Herbicide Orange contained equal amounts of 2,4,-D and 2,4,5-T. Diesel fuel was used as a vehicle for application. The 2,4,5-T contained dioxin as a manufacturing impurity, which is estimated to have ranged from less than 0.02 to 15 ppm in Herbicide Orange. Herbicide Blue, containing arsenic, and Herbicide White, containing picloram, were stored only a short time and are not thought to be significant contaminants. Orange II contained a different ester of 2,4,5-T in its formulation.

Dioxin has a very low solubility in water. Choudhary, Keith, and Rappe (Reference 19) have determined solubility values ranging from 0.2 to 0.6 ppb. Dioxin's hydrophobic nature tends to prevent its movement with percolating water. Instead, it accumulates on the soil particles through various soil sorption mechanisms.

It has been reported that some of the drums rusted and some leakage occurred. Monitoring of near-surface sedimentary material has indicated contamination of herbicide residues at the HSA. The primary contaminant of concern is TCDD. Soil samples on the HSA indicate dioxin at concentrations of 1 to 300 parts per billion (ppb). Sediment samples in the drainage ditches contained dioxin at a concentration of a few ppb.

An extensive concurrent surface and subsurface sampling program (of which the geohydrologic investigation is associated) will determine the extent of dioxin contamination. This program will help determine the possible attenuation of dioxin with time and the concentrations at depth.

Migration of dioxin away from the HSA can occur by direct volatilization and on grains of sediment moving offsite by wind transport, as well as the hydrological mechanisms described below.

Direct surface runoff of dioxin-contaminated soil is another source of dioxin migration. Where source material is at or near the surface, heavy precipitation can cause enough erosion so that some sedimentary material could be transported by water to the drainage ditches centered in the HSA. Precipitation associated with hurricanes where rainfalls of 6 to 12 inches may occur in a day are an example. The high rainfall and the short distances to drainage ditches within the contaminated area allow direct access of contaminants to the ditches and then to the receiving waters. This process tends to move fewer contaminants with time because the more easily moved material has been carried away. The sediments in the ditches show low levels of dioxin contamination.

Most of the rain falling on the HSA would percolate into the permeable sandy zones or move laterally along the soil cement until it encounters a crack and then moves downward. Although dioxin is not readily soluble in water, downward percolating waters could transport a small amount dissolved in the water. Some of the rainfall that has infiltrated into the surface sediments would travel short distances and be discharged to the ditches nearby. The proposed sampling of water and sediment in the two ditches that drain the HSA to the west would allow evaluation of contaminant movements due to these mechanisms.

Some of the rainfall that percolates into the permeable surficial sediments will move down to the surficial aquifer. Then, groundwater movement in the surficial aquifer is primarily lateral. The direction of local groundwater movement in the surficial aquifer is from topographically high areas to areas of discharge such as ditches and canals. The general direction of movement in the surficial aquifer is toward the Gulf of Mexico. Some of the near-surface sandy beds contain mostly quartz with little clay, silt, or organic material and have permeabilities associated with medium-to-coarse sand. Because quartz sand would not strongly sorb the dioxin, some dioxin would probably be transported in this medium. At the HSA, this mechanism has the highest potential to transport contaminants over a period of years. The proposed monitoring system should help determine if this occurs. The monitoring well (MW 5) located at the edge of NCBC and down the inferred hydraulic gradient from the HSA in the surficial aquifer should identify any contaminants transported. No use is made of water from the surficial aquifer at NCBC. Little use of the surficial aquifer to the south of NCBC has been identified. Some use of the water for lawn and garden irrigation may occur. The nearest small irrigation well may be about 1/2 mile from the HSA. A well survey of the area south of NCBC should be made if any potential wells tapping the surficial aquifer need to be identified.

Contaminant migration from the surficial aquifer downward to underlying aquifers is possible. Most of the permeable beds in the geologic environment at Gulfport are hydraulically connected to some degree. Clay beds pinch out, grade into sandy layers, thin, or become more permeable with distance. Water from different aquifers or zones can migrate upward or downward, depending on different hydraulic heads.

Deeper aquifers along the gulf coast contain sufficient artesian pressure to flow at the surface, except where withdrawals have lowered the head (Reference 3). Pressure in the aquifers is a result of confinement of water-saturated sand between overlying and underlying beds of relatively impermeable clay as the water flows southward down the dip from areas where it enters the ground.

The main recharge areas occur several miles north of the coast. Recharge of the aquifers occurs by infiltration of rain that falls on the outcrops, by percolation that moves through overlying sandy deposits, and by movement between aquifers. Water quality is similar for all aquifers. Individual sand beds are not continuous. The sand beds or lenses are sufficiently interconnected hydraulically to permit interflow but not to create a common pressure head in all aquifers. This is caused by a high transmissivity in a horizontal direction and a low transmissivity in a vertical direction (Reference 3).

The hydraulic heads of the aquifer beneath the surficial aquifer are not known. Little use is made of the water in sands at depths of around 50 feet to a few hundred feet below the surface at Gulfport. Most large-capacity wells at Gulfport withdraw water from a depth of 500 to 1200 feet. Therefore, the hydraulic head in the aquifers below about 100 feet are reported to be above the land surface. If this is so, then downward migration of dioxin is not possible. In addition, if water could eventually move through beds of fine-grained material, any dissolved dioxin would tend to be bound to the material. From the information at hand, downward migration of dioxin is considered to be a remote possibility. In addition, significant movement of dioxin down to the principal pumping zones in the Gulfport area is not considered to be possible under the hydraulic and geochemical conditions.

SECTION IV

SUMMARY AND CONCLUSIONS

The geology, hydrology, and water quality of EAFB and NCBC have been summarized to assess the potential impacts on the groundwater from handling, testing, and storing various herbicides. The summary provides an evaluation of the probability of herbicide residues being transported in the shallow groundwater system or into deep aquifers.

The sites in Florida and Mississippi are situated in the Coastal Plain. This region is part of the Gulf Coast geosyncline, the most active in North America, which has been depressed under the weight of sedimentary deposits carried from the north. Beds that outcrop to the east of EAFB are more than 30,000 feet deep beneath the Mississippi River. NCBC and EAFB lie on the north flank of the geosyncline, which gives a southwestward dip to the formations of about 20 feet per mile. The beds consist of sand, gravel, limestone, silt, and clay.

The area has a humid, semitropical climate. The average annual temperature is 68°F. The average annual rainfall exceeds 60 inches.

EAFB has six geohydrologic units, based on lithology and permeability. From the land surface downward, they are the sand-and-gravel aquifer, the Pensacola Clay (aquitard), the upper limestone of the Floridan aquifer, the Bucatunna Clay (aquitard), the lower limestone of the Floridan aquifer, and the underlying shales and clays (aquitard). The three aquifers contain the freshwater in the area, and the aquitards restrict the movement of water between aquifers.

The sand-and-gravel aquifer consists of quartz sand, gravel, and clay and sandy clay. The aquifer contains soft, unmineralized water. The aquifer has been divided in three zones: a surficial water table zone, an intermediate zone of low permeability, and a main producing zone. Groundwater moves from higher lands toward discharge into salty bays. The

Pensacola Clay separates the two aquifers by thick, relatively impermeable clays.

The upper limestone of the Floridan aquifer supplies almost all the water in the EAFB area. The water is usually under artesian pressure and is recharged from the northeast. Extensive pumping from the aquifer along the coastal area has caused declines of about 240 feet in about 30 years. Methods are described to manage the area's water resources to reduce this decline. No saltwater intrusion has occurred, although the water level is substantially below sea level along the coast.

The Bucatunna Clay separates the upper and lower limestones of the Floridan aquifer. Little use is made of water from the lower limestone because it is salty in the southern part and because of the depth. No freshwater exists at EAFB below the lower limestone of the Floridan aquifer.

At Hardstand 7, the area at EAFB where the herbicide was handled and tested, the saturated part of the sand-and-gravel aquifer is about 35 feet thick. The water table is about 45 feet below the surface. The water flow in the area is generally to the east; but, at Hardstand 7, the flow would be northwest toward discharge into Hardstand Pond.

A groundwater monitoring program is proposed to determine if herbicide residues are migrating in groundwater, to determine waste concentrations, to evaluate corrective actions, and to collect sedimentary samples for dioxin determinations. The monitoring system will have one well upgradient and four wells downgradient. A collection system near the seeps at Hardstand pond is proposed. Hollow-stem augering with drive core sampling is the proposed drilling method. A system to collect water samples and measure the water levels is proposed. This system will minimize cross-contamination and enable representative water samples to be collected. The suggested monitoring frequency is discussed. The data collected and interpreted would provide information needed to evaluate and predict potential contaminant movements within the groundwater system.

The hydrogeological system at EAFB limits potential contaminant movements to the uppermost aquifer materials. The hydrophobic nature of TCDD makes significant contamination of the groundwater unlikely.

NCBC has several geohydrologic units, based on lithology and permeability. From the land surface downward, they are beach, alluvial, and terrace deposits (part of which form the surficial aquifer); the Citronelle Formation; the Graham Ferry Formation, the Pascagoula Formation, the Hattiesburg Formation, and the Catahoula Sandstone. The beds from the Citronelle downward have been called the Pliocene and Miocene aquifer system. Beneath the Miocene rocks is the Bucatunna Clay Member of the Byram Formation. The beds of Miocene age are as deep as about 3500 feet near Gulfport. The beds consist of sand, clay, gravel, and silt. The grain size and bed thickness vary considerably within short distances.

The aquifers at moderate depths contain sufficient artesian pressure to flow at the surface, except where pumping has lowered the head. Recharge areas are several miles to the north. Recharge is from rainfall. The beds have high transmissivity horizontally and low transmissivity vertically. Water levels have dropped about 1 foot per year for the past 100 years. Saltwater encroachment as a result of the declining heads is not evident. The base of the freshwater zone at Gulfport is about 2500 feet below sea level. Groundwaters are soft, of good quality, and contain less than 250 mg/L of dissolved solids. The aquifer contains a large proportion of relatively insoluble quartz sand, which explains the low mineralization. The water is a sodium bicarbonate type.

At NCBC, the Herbicide Storage Area (HSA) covers about 15 acres. The elevation of the land surface is from 29 to 32 feet above sea level. Shallow ditches and culverts drain the HSA and flow offsite. The surface of the HSA was covered with soil cement about 40 years ago.

The near-surface deposits at the HSA are sedimentary sand, gravel, clay, and silt. The upper permeable part is the surficial aquifer, an unconfined (water table) aquifer. The water table is from 4 to 6 feet below the land surface. The hydraulic conductivity of clean, medium-to-coarse sands is about 150 feet per day. The groundwater velocity in the surficial aquifer at the HSA is estimated to be 100 to 200 feet per year. The flat area around the HSA is a recharge area. The overall flow direction is south to south-southeast.

A groundwater monitoring system is proposed to determine if herbicide residues are migrating in groundwater. The monitoring system will have one well upgradient and seven wells downgradient and surrounding the HSA. Water and sediment sampling is proposed for two drainage ditches that drain the HSA. A system to collect water samples and measure water levels is proposed. The system will minimize cross-contamination and allow representative samples to be collected. A suggested sampling frequency is discussed. The possibility of deeper waste migration of dioxins is very remote. The data collected and interpreted will provide information needed to evaluate and predict potential contaminant movements.

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