STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES
Tom Gardner, *Executive Director*

DIVISION OF RESOURCE MANAGEMENT
Jeremy A. Craft, *Director*

FLORIDA GEOLOGICAL SURVEY
Walter Schmidt, *State Geologist and Chief*

SPECIAL PUBLICATION NO. 31

ENVIRONMENTAL GEOLOGY AND HYDROGEOLOGY OF THE OCALA AREA, FLORIDA

By
Ed Lane and Ronald W. Hoenstine

Published for the

FLORIDA GEOLOGICAL SURVEY

Tallahassee
1991

TABLE 1

CONVERSION FACTORS AND ABBREVIATIONS

This conversion table is for the convenience of readers who may prefer to use metric units instead of the English units given in this report.

MULTIPLY	BY	TO OBTAIN
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
gallon (gal)	3.785	liter (L)
gallons (gal)	0.003785	cubic meter (m^3)
gallons per minute (gal/min)	0.06308	liter per second (L/s)
gallons per minute per foot [(gal/min) /ft]	0.207	liter per second per meter [(L/s) /m]
gallons per minute (gpm)	0.0022	cubic feet per second (cfs)
cubic feet per second (cfs)	449	gallons per minute (gpm)
pound avoirdupois (lb)	0.4536	kilogram (kg)
ton, short	0.9072	megagram (Mg)

Chemical concentrations and water temperatures are given in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (ug/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million.

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$(°F = 1.8\ (°C) + 32.$$

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

STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES
Tom Gardner, *Executive Director*

DIVISION OF RESOURCE MANAGEMENT
Jeremy A. Craft, *Director*

FLORIDA GEOLOGICAL SURVEY
Walter Schmidt, *State Geologist and Chief*

SPECIAL PUBLICATION NO. 31

ENVIRONMENTAL GEOLOGY AND HYDROGEOLOGY OF THE OCALA AREA, FLORIDA

By
Ed Lane and Ronald W. Hoenstine

Published for the

FLORIDA GEOLOGICAL SURVEY

Tallahassee
1991

DEPARTMENT
OF
NATURAL RESOURCES

LETTER OF TRANSMITTAL

FLORIDA GEOLOGICAL SURVEY
Tallahassee

June 1991

Governor Lawton Chiles, Chairman
Florida Department of Natural Resources
Tallahassee, Florida 32301

Dear Governor Chiles:

The Florida Geological Survey, Division of Resource Management, Department of Natural Resources, is publishing as Special Publication No. 31, *Environmental Geology and Hydrogeology of the Ocala Area, Florida,* prepared by staff geologists Ed Lane and Ronald W. Hoenstine. This report presents data on the geology and hydrology of the Ocala area, which is one of the fastest growing urban areas in Florida. This report is timely because of the growth rate, and the information will be of significant use to local, county, and state planners, as well as to the private sector. The data will assist these groups to develop and implement long range plans to effectively manage this growth.

Respectfully,

Walter Schmidt, Ph.D.
State Geologist and Chief
Florida Geological Survey

Printed for the

Florida Geological Survey

Tallahassee
1991

ISSN 0085-0640

CONTENTS

Page

Acknowledgements vii
Introduction and purpose 1
Location and transportation 1
Climate 1
Map Coverage 1
Well and locality numbering system 4
Previous investigations 4
Geology 4
  Geomorphology 4
  Geologic history 11
Water Resources 16
  The Hydrologic cycle 16
  Surface water 18
  Aquifers 23
    Floridian aquifer system 23
    Intermediate aquifer system 26
    Surficial aquifer system 26
Evolution of karst terrain 26
  Chemical weathering of carbonate rocks 26
  Karst in the Ocala area 29
Water quality 29
Potentiometric surface 37
Water usage 37
Mineral resources 46
  Limestone 46
  Sand 49
  Undifferentiated resources 49
Land Use 49
Environmental hazards associated with karst 60
Solid waste disposal 65
Summary 69
References 70

FIGURES

Figure 1 Location map 2
Figure 2 Transportation map for Marion County 3
Figure 3 Average monthly air temperature at Ocala 5
Figure 4 Monthly rainfall distribution for Ocala 6
Figure 5 Annual rainfall for Ocala 7
Figure 6 Topographic map coverage of Marion County 8
Figure 7 Locality and well numbering system 9
Figure 8 Geomorphology of Ocala and Marion County 10
Figure 9 Terraces and shorelines of Ocala and Marion County 12
Figure 10 Stratigraphic column 13
Figure 11 Cross section location map 14
Figure 12 Cross sections A-A′ and B-B′ 15
Figure 13 Hydrologic cycle 17
Figure 14 Surface water of Marion County 19

Figure 15 Generalized cross-section showing hydrogeological features common to the Ocala area 21
Figure 16 Porosity and permeability of granular material 22
Figure 17 Hydrostratigraphic correlation chart 24
Figure 18 Drainage well in bottom of a sinkhole 25
Figure 19 Evolution of karst landscape and underground drainage 27
Figure 20 Karst limestone surface exposed by a flood in Ocala in 1982 30
Figure 21 Solution pipes in Ocala limestone surface 31
Figure 22 Topographic map of the Ocala area 32
Figure 23 Sinkholes in City of Ocala 33
Figure 24 Sinkhole in City of Ocala 33
Figure 25 Sinkhole in City of Ocala 34
Figure 26 Sinkhole in City of Ocala 34
Figure 27 Location of Ocala Very Intensely Studied Area (VISA) 38
Figure 28 Potentiometric surface maps of the upper Floridan aquifer system 39-43
Figure 29 Change in potentiometric surface of the upper Floridan aquifer system from September 1987 to May 1988 44
Figure 30 Fresh ground and surface water withdrawals 45
Figure 31 Mineral resources map 47
Figure 32 Active limestone quarry near Ocala 48
Figure 33 General soil map of Ocala 50
Figure 34 Residential land use 53
Figure 35 Commercial land use 54
Figure 36 Industrial land use 55
Figure 37 Agricultural land use 56
Figure 38 Governmental land use 57
Figure 39 Institutional land use 58
Figure 40 Miscellaneous land use 59
Figure 41 Drainage basin of the Oklawaha River with drainage basins of Silver and Rainbow Springs 61
Figure 42 Limestone fracture zone enlarged by dissolution of Ocala Group limestone 62
Figure 43 Flood waters recharging Floridan aquifer system through sinkhole, 1982 63
Figure 44 Graphs showing relationships among rainfall, ground-water levels in the Floridan aquifer system and discharge of Silver Springs 64
Figure 45 Finished cell of the Marion County landfill, 1989 66
Figure 46 Newly opened cell at the Marion County landfill, 1989 67
Figure 47 Leachate holding tank at the Marion County landfill, 1989 67
Figure 48 Generalized cross section of new cells at the Marion County landfill, 1989 68

TABLES

Table 1 Conversion factors and abbreviations . . . . . inside front cover
Table 2 Water quality for Silver Springs for 1946 and 1972 20
Table 3 Specific parameters of a well used in DER's ground-water quality monitoring program at Ocala airport 35
Table 4 Screen analyses of sand samples 51

ACKNOWLEDGEMENTS

The authors wish to thank the following people and organizations who gave freely of their time and information. Their assistance provided a firm foundation for this study. Gary Maddox, Department of Environmental Regulation, who provided land use data and water quality data; Earl Blankenship, Solid Waste Administrator, Marion County Board of Commissioners, for information on the Marion County landfill; Philip Cosson, Planner, City of Ocala, for statistical data for Ocala; Dennis G. Thompson, Planning Director, Division of Planning, Marion County Board of Commissioners, for statistical data on Marion County; the Economic Development Council of Ocala for business and economic information; and G. C. Phelps, U.S. Geological Survey, for information on the aquifer systems in the Ocala area. In addition, the authors appreciate the efforts of Ken Campbell, Richard Johnson, Jim Jones, Ted Kiper, Jackie Lloyd, Frank Rupert, Walter Schmidt, Tom Scott, Steven Spencer, and Bill Yon in reviewing this report.

SPECIAL PUBLICATION NO. 31

ENVIRONMENTAL GEOLOGY AND HYDROGEOLOGY OF THE OCALA AREA, FLORIDA

By
Ed Lane, P.G. #141 and Ronald W. Hoenstine, P.G. #57

INTRODUCTION AND PURPOSE

Florida is experiencing phenomenal population growth. A significant part of this growth is occurring in the Ocala area, which is one of the fastest growing urban areas in the nation. Ocala, which had a 1987 population of 44,980, is projected to have an annual growth rate of 4.64 percent through 1995 (Thompson, 1988). Rapid urban growth places unusual stresses on the environment due to the demands of energy, construction, transportation, water supplies, and waste disposal. This report is designed to help local governments mitigate the impacts of society's pressures on the environment.

The principal objectives of this report are to interpret and summarize available cultural information and scientific data. By integrating cultural, climatological, geological, and hydrological data the report will illustrate the importance that geology plays in land-use planning for the Ocala urban area. Graphics are emphasized as a means of presenting data in a format that can be readily used by the public, scientists, planners, water managers, and public policy makers.

LOCATION AND TRANSPORTATION

The City of Ocala is located in north-central peninsular Florida, approximately in the center of Marion County (Figure 1). The air-mile circles on Figure 1 show that Ocala also lies about equidistant from both extremes of the state's extent, from Pensacola in the western panhandle to Miami near the southern tip of the peninsula.

This central location makes Ocala a natural hub of Marion County's transportation system (Figure 2). Several of the state's major roads pass near or through Ocala: Interstate 75, US 27, US 41, US 441, US 301, and State Highways 40 and 475. A beltway encircling Ocala utilizing existing and new roads is currently being considered. CSX Transportation (formerly the Seaboard Coast Line Railroad) has several routes that branch out of Ocala, eventually connecting to Gainesville, Jacksonville and points north, and south to Tampa, Orlando, and Miami. Several airlines have scheduled service to Ocala Municipal Airport.

CLIMATE

Ocala's location in north-central peninsular Florida is reflected in its humid, subtropical climate. Its annual average temperature is 71.1°F, varying from low averages of approximately 58°F in December and January to high averages of about 82°F during July and August (Figure 3).

Rainfall distribution for Ocala is shown in Figures 4 and 5. Summer is the "wet" season, caused by an increase in thunderstorm activity (Figure 4). Figure 5 shows substantial fluctuations above and below annual average rainfall, with the widest extremes for the period occurring within two years of each other, in 1982 and 1984. The high rainfall of 1982 was due mainly to a series of April thunderstorms that struck north central Florida from Marion County southward to Brevard County. Hail the size of golf balls covered the ground in many areas. On April 8, thunderstorms dropped up to 12 inches of rain over Marion County, and additional rains of April 9 produced storm totals up to 20 inches, causing flooding and 150 sinkholes, with heaviest damage in the Ocala area (NOAA, 1982). This incident is discussed in more detail in the Environmental Hazards section.

MAP COVERAGE

A total of 32 U.S. Geological Survey topographic maps are required to completely cover Marion County (Figure 6). These maps, which were used as base maps to plot field data, are 7½ minute quadrangles drawn at a scale of

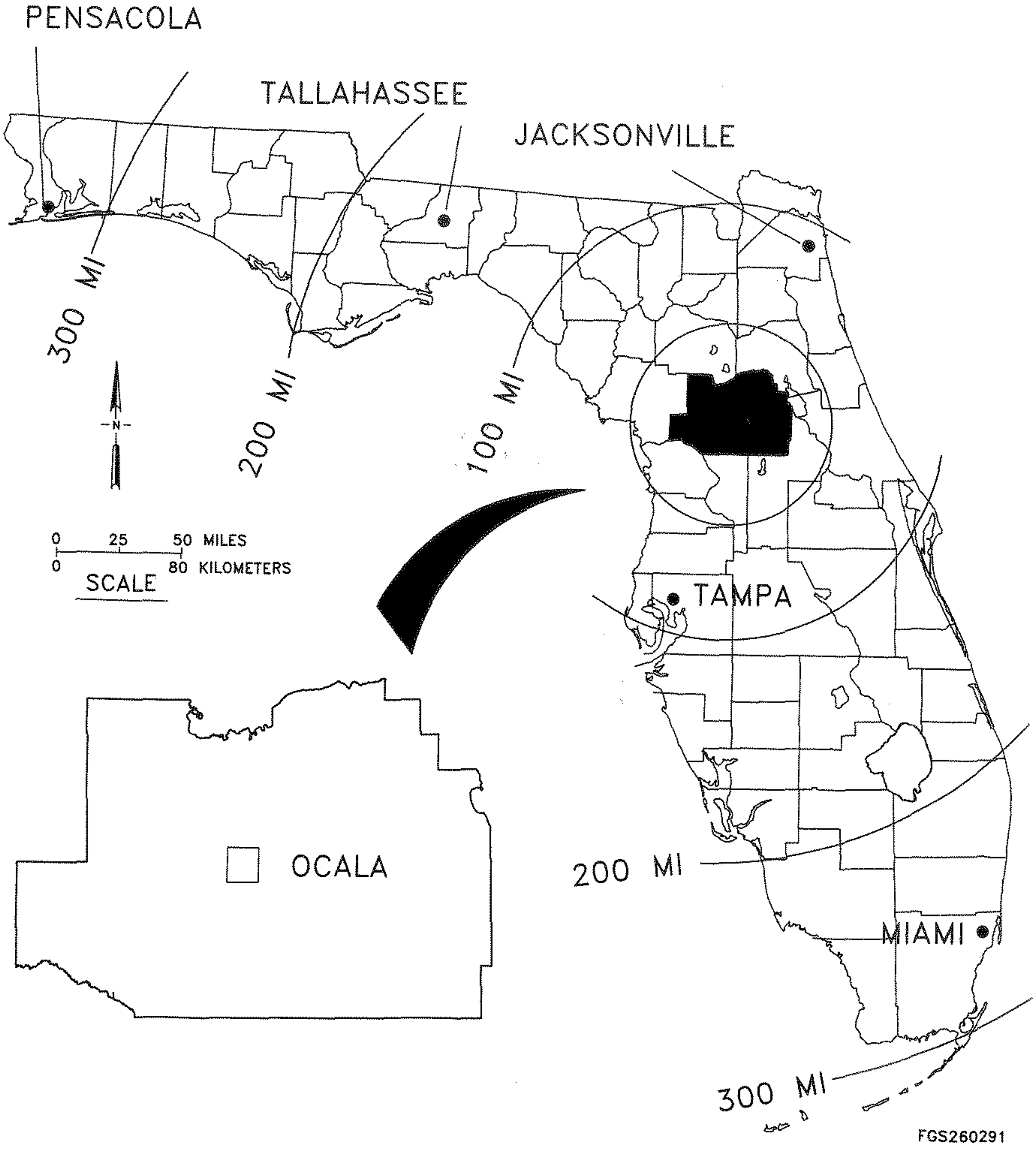


Figure 1. Location map for Marion County and the City of Ocala. Red circles indicate air-mile distances from Ocala.

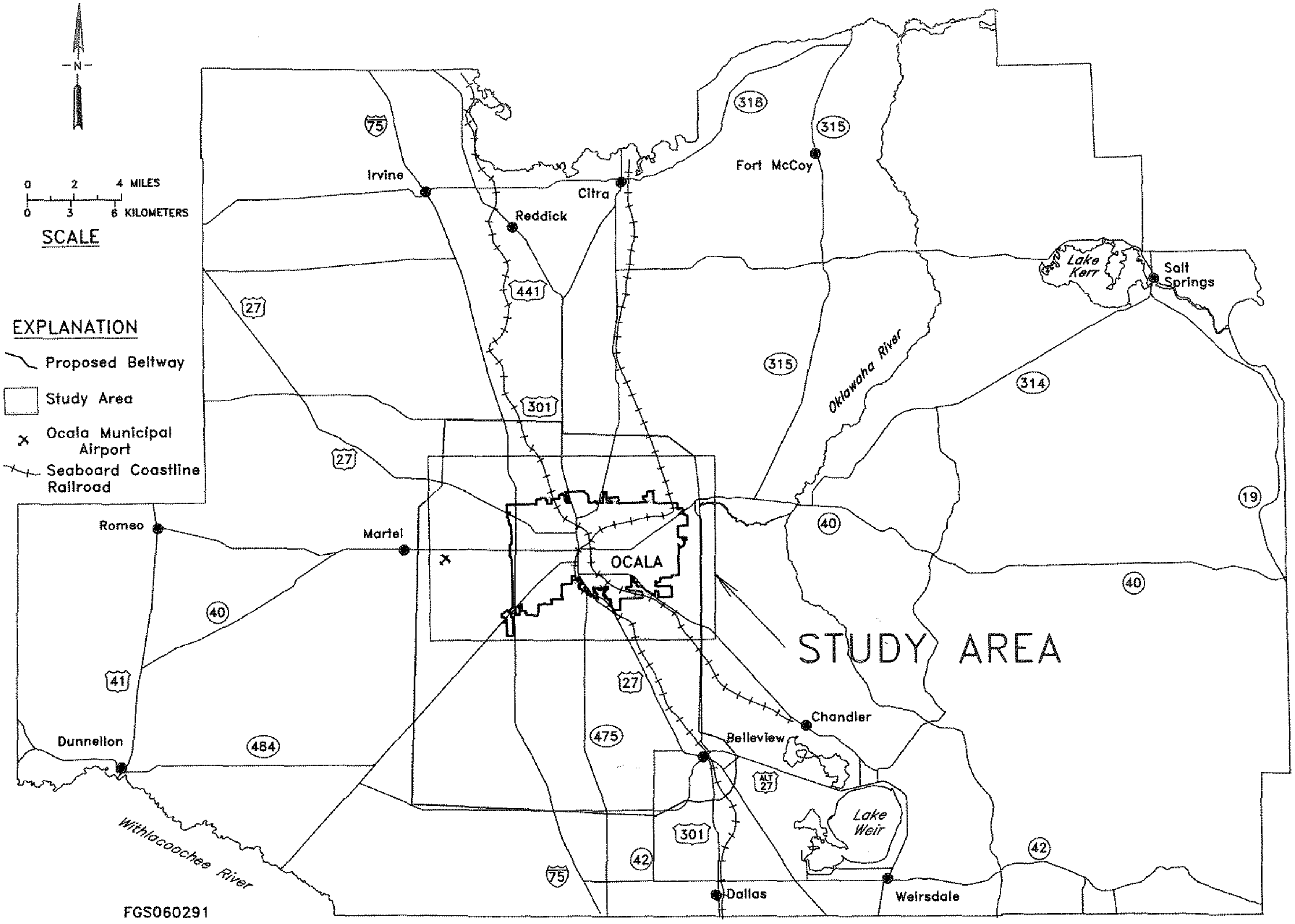


Figure 2. Transportation map for Marion County.

1:24,000. All of the maps have 10-foot land elevation contour intervals. Also, the other U.S. Geological Survey maps of the State of Florida, at scales of 1:100,000, 1:250,000, and 1:500,000 include Marion County. In addition, the Florida Department of Transportation general highway map for Marion County was used in plotting roads and location descriptions. Other maps of interest covering Marion County and Ocala include the Florida Geological Survey's Environmental Geology Series: Gainesville (Knapp, 1978), Orlando (Scott, 1978), Daytona Beach (Scott, 1979), and Tarpon Springs sheets (Deuerling and MacGill, 1981), all 1:250,000 scale. A mineral resources map of Marion County (Hoenstine et al., 1988) is reproduced herein as Figure 31, at reduced scale.

WELL AND LOCALITY NUMBERING SYSTEM

The well and locality numbering system used in this report is based on the location of the well or locality, and uses the rectangular system of section, township and range for identification (Figure 7). The number consists of five parts. These are: 1) prefix letters designating L for locality, W for well, and Mr for Marion County, 2) the township, 3) the range, 4) the section, and 5) the quarter/quarter location within the section.

The basic rectangle is the township, which is 6 miles on a side and encompasses 36 square miles. It is consecutively measured by tiers both north and south of the Florida Base Line, an east-west line that passes through Tallahassee, as Township north or south. This basic rectangle is also consecutively measured both east and west of the Principal Meridian, a north-south line that passes through Tallahassee, as Range East or West. In recording the township and range numbers, the T is left off the township numbers and the R is left off the range numbers (e.g., 17S, 23E). Each township is divided equally into 36 one-mile-square blocks called sections, and are numbered 1 through 36, as shown on Figure 7.

The sections are divided into quarters with the quarters labeled "a" through "d." In turn, each of these one-quarter sections is divided into quarters with these quarter/quarter squares labeled "a" through "d" in the same manner. The "a" through "d" designation may be carried to any extent needed.

The location of well W-1762 on Figure 7 would be in the center of the northwest quarter of the northwest quarter of Section 28, Township 17 South, Range 23 East, Marion County.

PREVIOUS INVESTIGATIONS

A number of previous studies have been published on the Ocala area. Many of these investigations have focused on water resources, including Anderson and Faulkner (1973), who conducted a study into the quantity and quality of the surface water in Marion County. Rosenau et al. (1977) addressed in general terms the hydrogeology of Silver Springs and its tributaries; Miller (1986) published a comprehensive study of the hydrogeology of the Floridan aquifer system; and Marella (1988) reported on water use and trends.

Other studies have been undertaken of a more general nature. Knapp (1978) presented the environmental geology of the city of Ocala and surrounding area in a map format. Hoenstine et al. (1988) published a map that addressed the mineral resources of Marion County. Thompson (1988) compiled statistical data on population, housing and transportation for Marion County. The Marion County Planning Department (1988) developed a future land use plan addressing major development, urban service, goals, objectives, and policies. The City of Ocala Planning Department and the Ocala-Marion County Metropolitan Planning Organization (1988) prepared a City of Ocala Statistical Profile, including data on census, utilities, traffic, and other cultural parameters.

GEOLOGY

GEOMORPHOLOGY

Marion County lies near the north edge of the central (mid-peninsular) physiographic zone of White (1970). This zone is characterized by a series of ridges and valleys trending approximately parallel to the Atlantic Coast. Within this area, these distinct ridges and valleys comprise geomorphic subdivisions which are generally named for nearby towns or geographic areas (Figure 8).

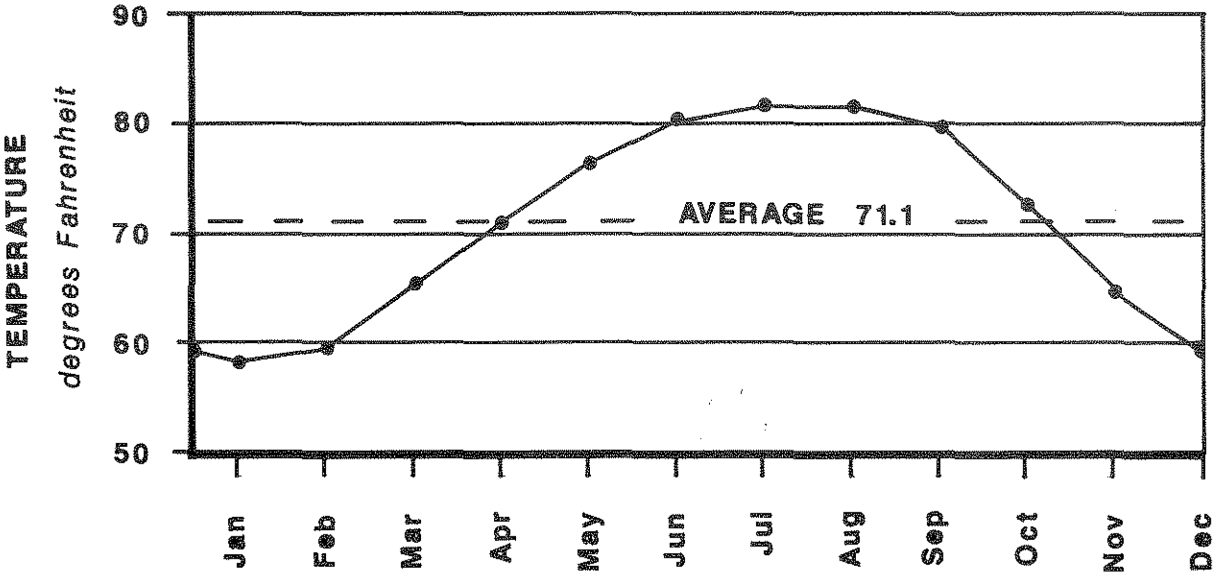


Figure 3. Average monthly air temperature at Ocala for period of record 1951-1986 (NOAA).

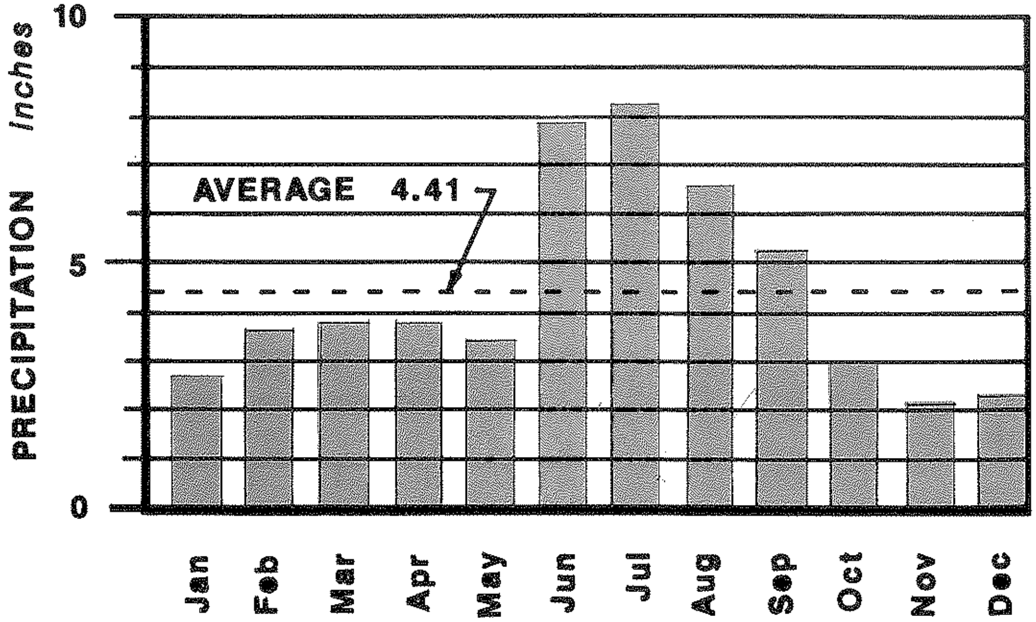


Figure 4. Average monthly rainfall for Ocala for period of record 1951-1986, showing distribution of summer "wet" season and winter "dry" season (NOAA).

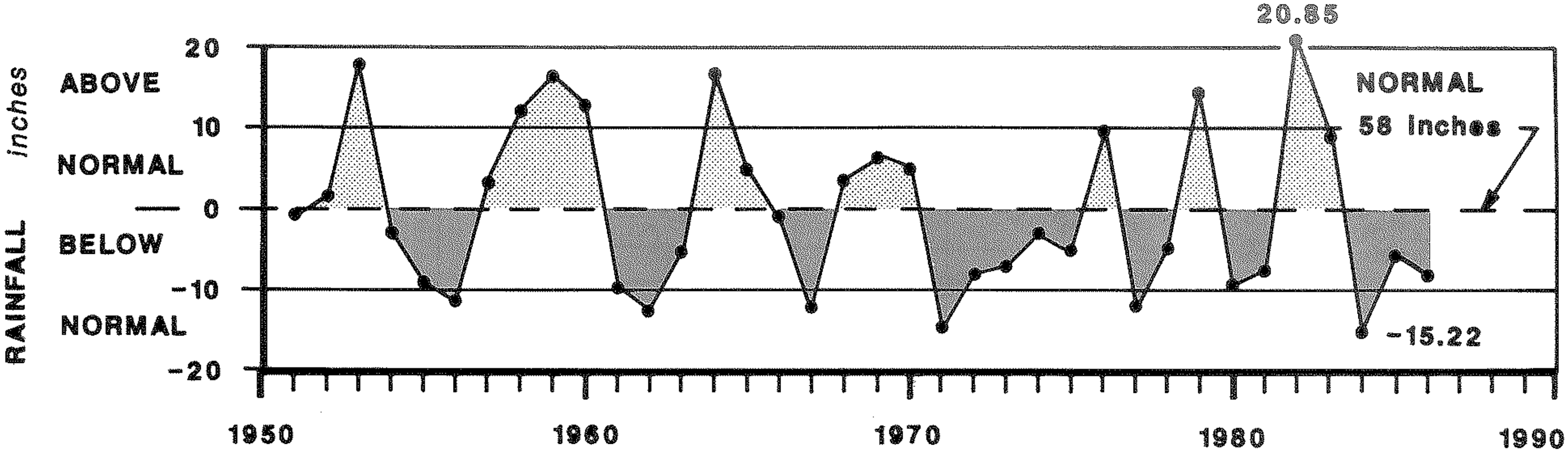
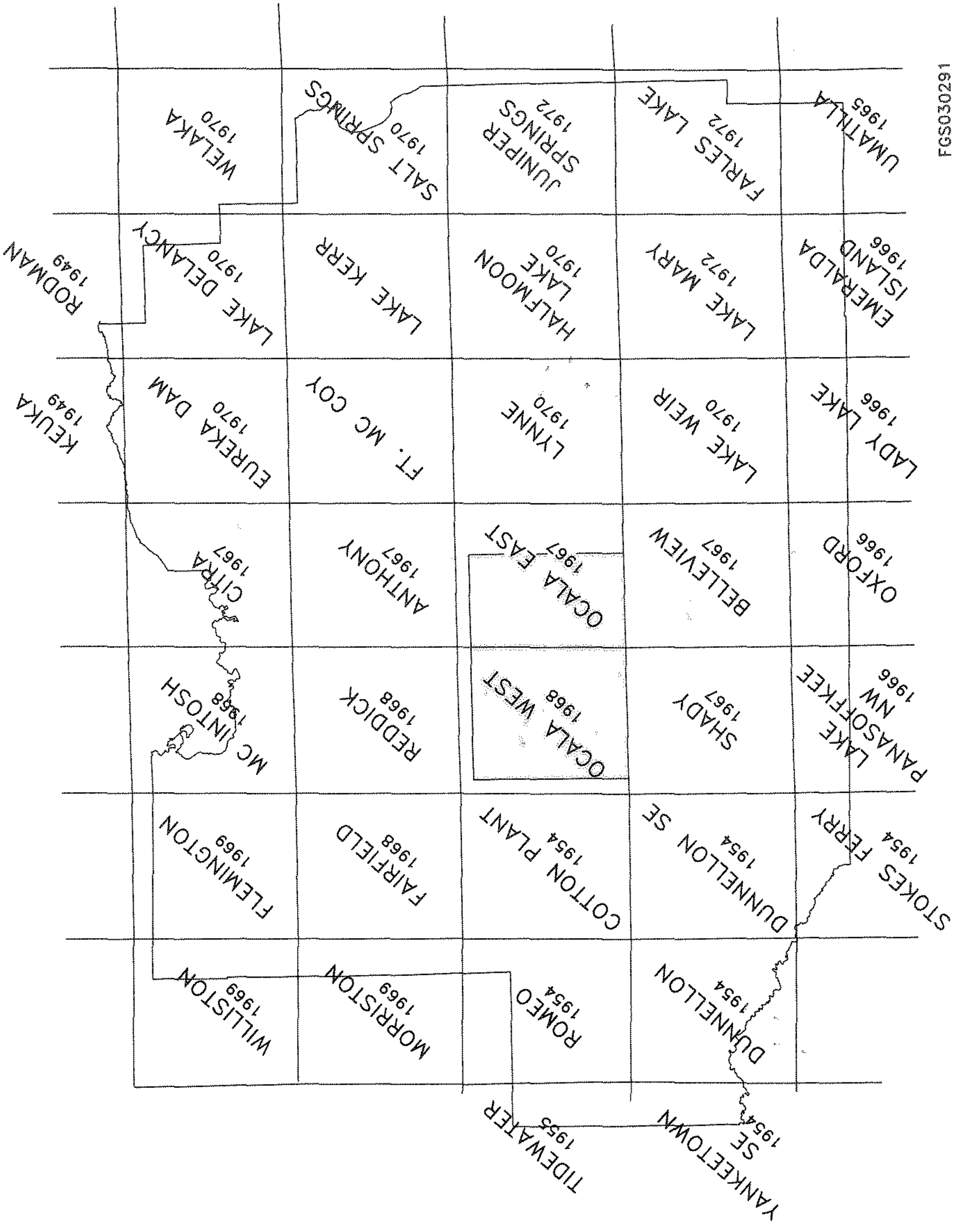


Figure 5. Annual rainfall at Ocala for period of record 1951-1986, showing deviation above and below normal amount (NOAA).



FGS030291

Figure 6. Topographic map coverage of Marion County, U.S. Geological Survey 7-1/2 minute quadrangles.

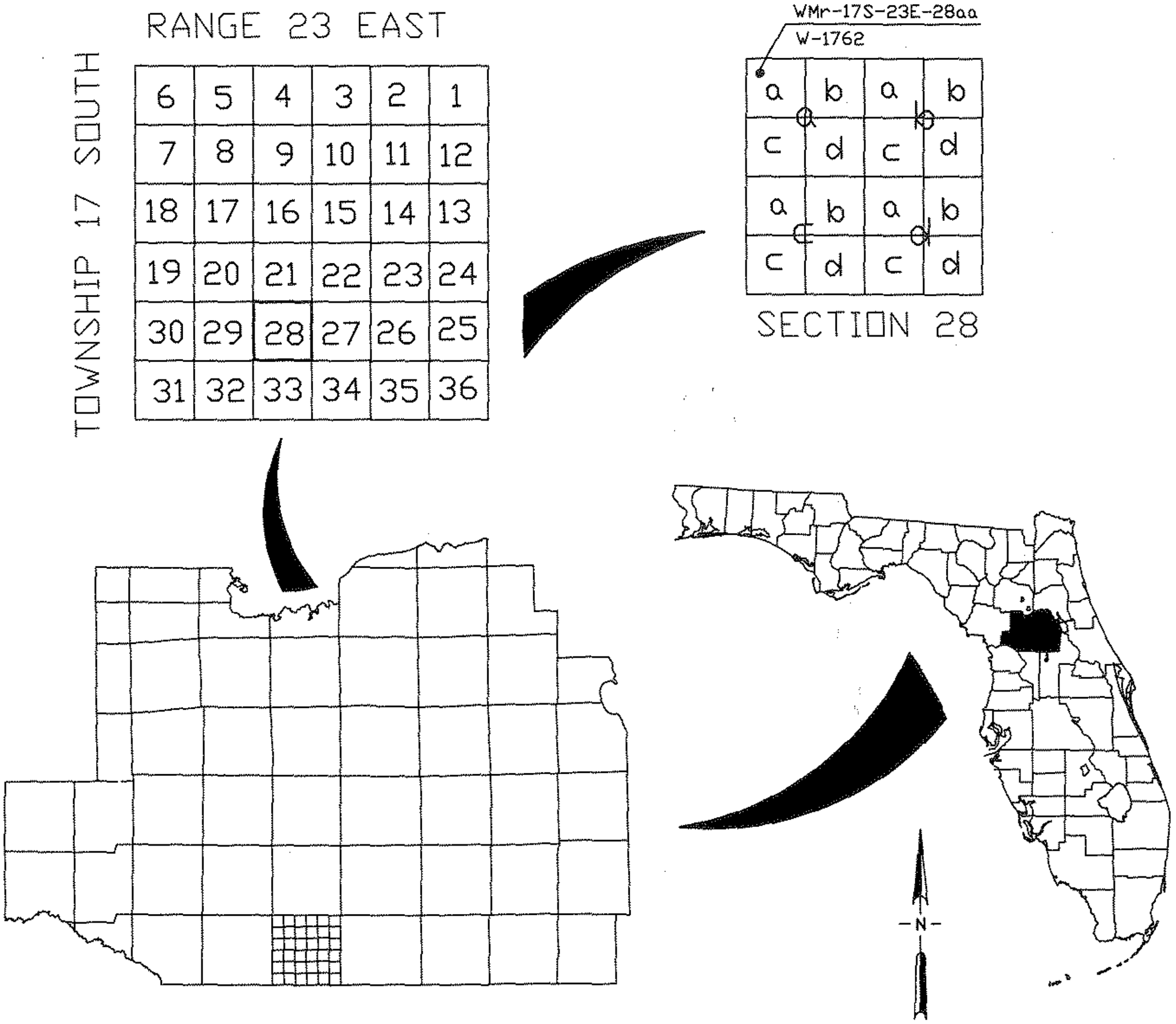


Figure 7. Locality and well numbering system.

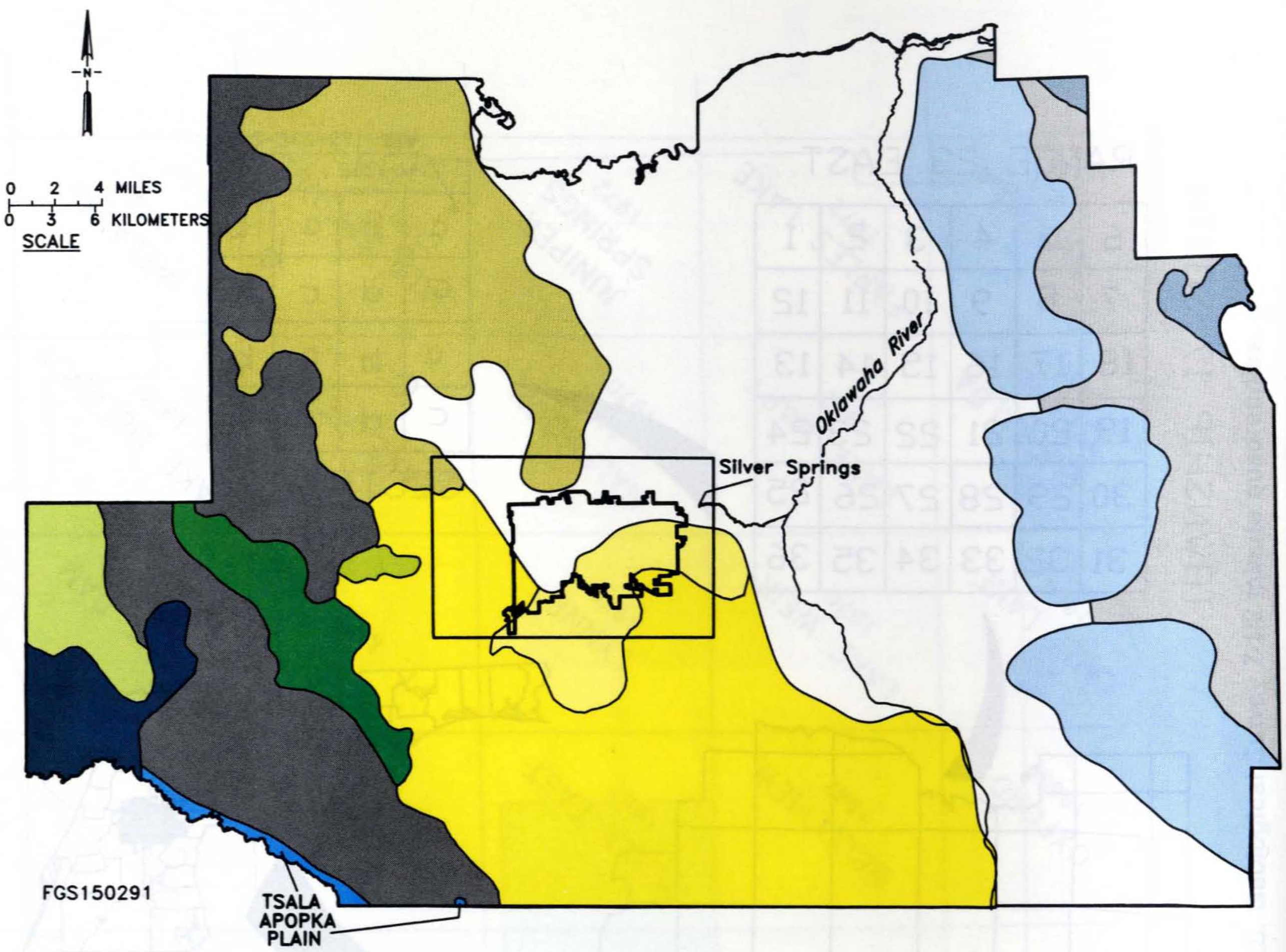


Figure 8. Geomorphology of Ocala and Marion County (modified after White, 1970).

Four of these geomorphic subdivisions are present within the Ocala area. From north to south these include portions of the Fairfield Hills, the Central Valley, the Sumter Upland and the Ocala Hills.

The extreme southern portion of the Fairfield Hills is present in the north-central part of the study area. Named for the community of Fairfield, this geomorphic feature forms an irregular 15 by 20 mile area in northwest Marion County and is underlain by surface and near-surface clayey sands and sandy clays of the Hawthorn Group. Within the Ocala area this feature has elevations ranging from 75 to 135 feet above mean sea level (MSL). White (1970) considers the Fairfield Hills to be remnants of a former upland surface.

The Central Valley occupies the northeastern, central, and a portion of the northwestern part of the study area. This geomorphic feature, which originates in Alachua County and extends through east-central Marion County and Lake County into Orange County, is underlain in the near-surface by sand with minor amounts of silt and clay. In contrast to the relatively high elevations associated with the Fairfield Hills, the Central Valley ranges in elevation from approximately 50 to 75 feet above MSL in the study area.

The Sumter Upland, located south of the Fairfield Hills and the Ocala Hills, occupies the western third and southeastern part of the study area. This feature is characterized by sand and clayey sand hills having elevations ranging from 70 to 150 feet above MSL. This region contains few lakes or ponds.

The Ocala Hills comprise an elevated area in the south-central and east-central part of the study area. Bounded on the north by the Central Valley and lying within the Sumter Upland, this feature is a nine-mile-long series of hills trending southwestward from Ocala. Composed primarily of clayey sand, these hills have elevations that range from about 75 to 100 feet above MSL. White (1970) postulated an origin similar to the Fairfield Hills.

Superimposed on the present day topography of Marion County are a series of relict marine terraces (Figure 9). Formed during the Pleistocene Epoch, they reflect higher sea level stands. Healy (1975) recognized three marine terraces based on elevation in this part of Marion County. From highest (oldest) to lowest (youngest) these include the Sunderland-Okefenokee Terrace (100 to 170 feet above MSL), the Wicomico Terrace (70 to 100 feet above MSL), and the Penholoway Terrace (42 to 70 feet above MSL).

The higher Sunderland-Okefenokee Terrace generally coincides with the Ocala Hills and Fairfield Hills. The Wicomico Terrace is associated with the Central Valley and lower elevations of the Sumter Upland. The Penholoway Terrace is located in the northeastern part of the study area in the lower elevations of the Central Valley. Healy (1975) recognizes the higher Coharie Terrace (170 to 215 feet above MSL) and two lower terraces — the Talbot Terrace (25 to 42 feet above MSL) and the Pamlico Terrace (8 to 25 feet above MSL) as being present in Marion County outside of the study area (Figure 9).

GEOLOGIC HISTORY

Located in north-central Florida, the study area is underlain by a thick sequence of Mesozoic and Cenozoic Era carbonate sedimentary rocks (limestone and dolomite) which are mantled by siliciclastic sediments composed of quartz sand, silt, clayey sand and sand. The carbonate sequence is in turn underlain by metamorphic basement rocks at a depth of approximately 4,200 feet below land surface. An oil test well drilled in 1926 by the Ocala Oil Corporation eight miles southwest of Ocala (Florida Geological Survey (FGS) W-18, section 10, Township 16S, Range 20E) encountered a quartzite mica schist at a depth of 4,100 feet below land surface.

Much of the stratigraphy (the sequence of layered rocks and their characteristics) of western Marion County has been influenced by the Ocala Platform. This structural feature, previously called the Ocala Uplift by Puri and Vernon (1964), was described by them as "...a gentle anticlinal flexure about 230-miles long and 70-miles wide exposed near the surface in west-central Florida." The influence of the Ocala Platform in Marion County causes the Ocala Group and Hawthorn Group sediments to occur at shallow depths in western Marion County relative to their greater depths in eastern Marion County. Figure 10 is a generalized stratigraphic column showing Middle Eocene and younger sediments present in the Ocala area.

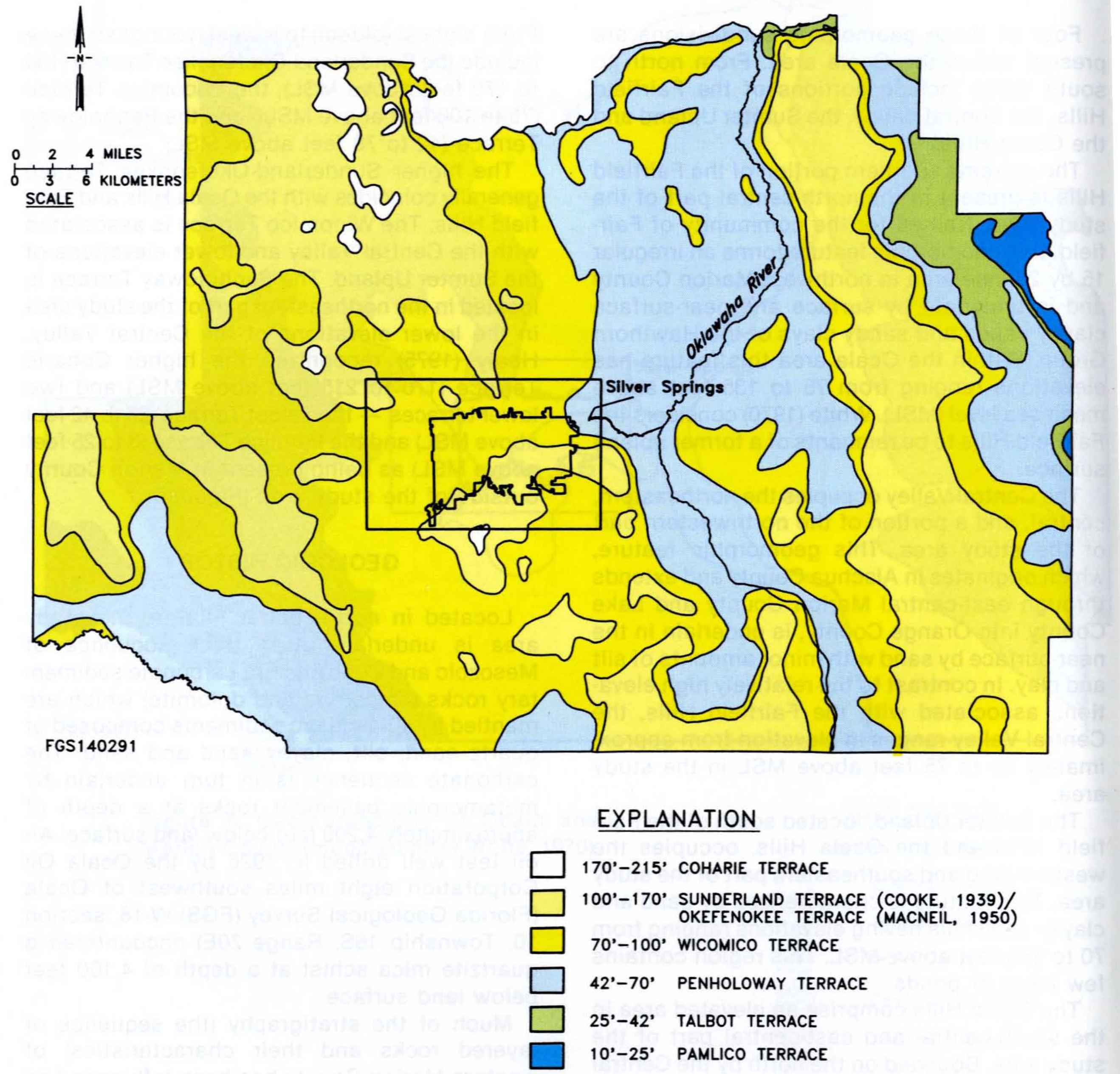


Figure 9. Terraces and shorelines of Ocala and Marion County (modified after Healy, 1975).

SYSTEM	SERIES	FORMATION
QUATERNARY	Holocene	Undifferentiated Sands and Clays
	Pleistocene	
		Cypresshead Formation
TERTIARY	Pliocene	
	Miocene	Hawthorn Group
	Oligocene	absent
	Eocene	Ocala Group
		Avon Park Formation

Figure 10. Stratigraphic column.

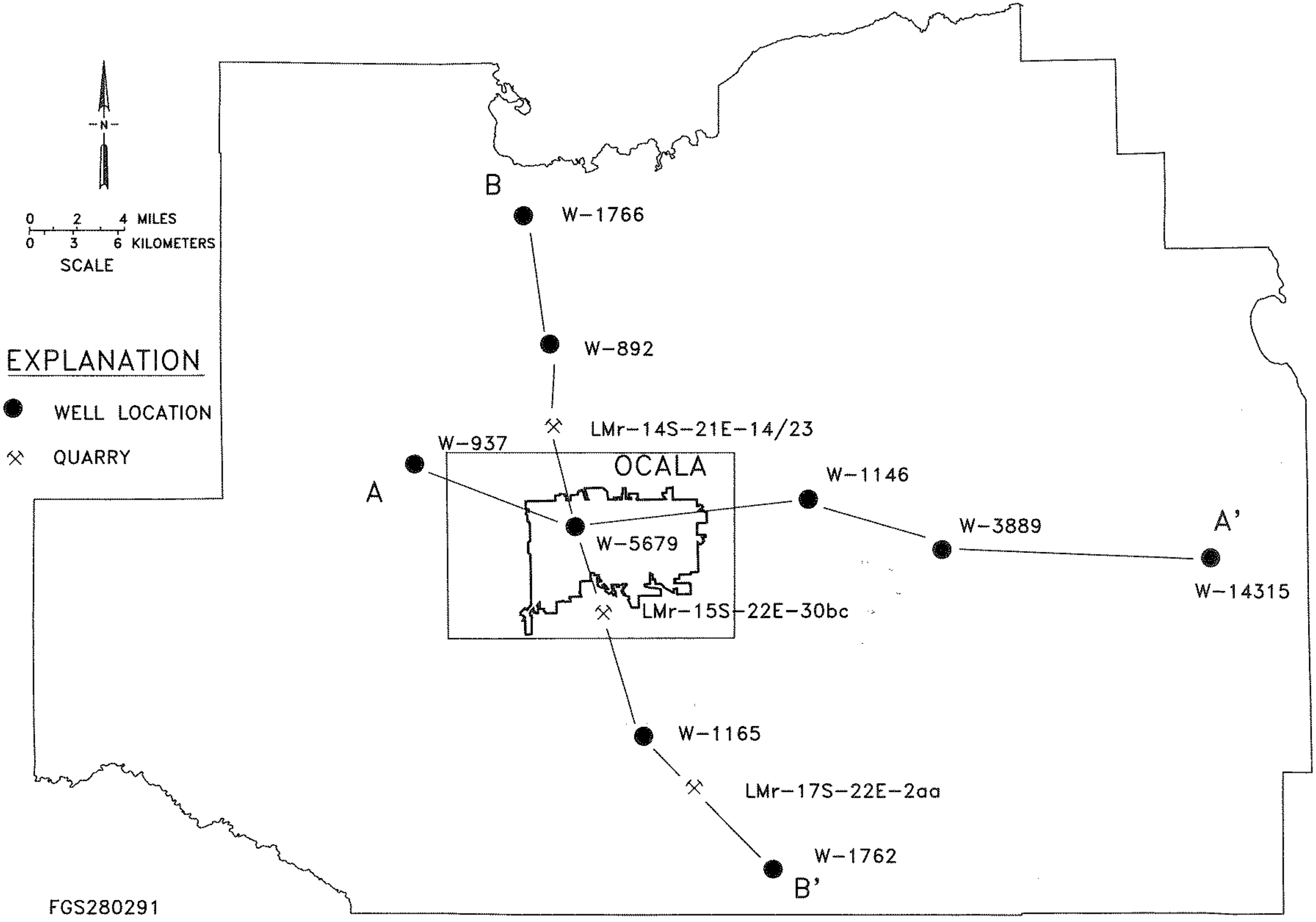


Figure 11. Cross section location map.

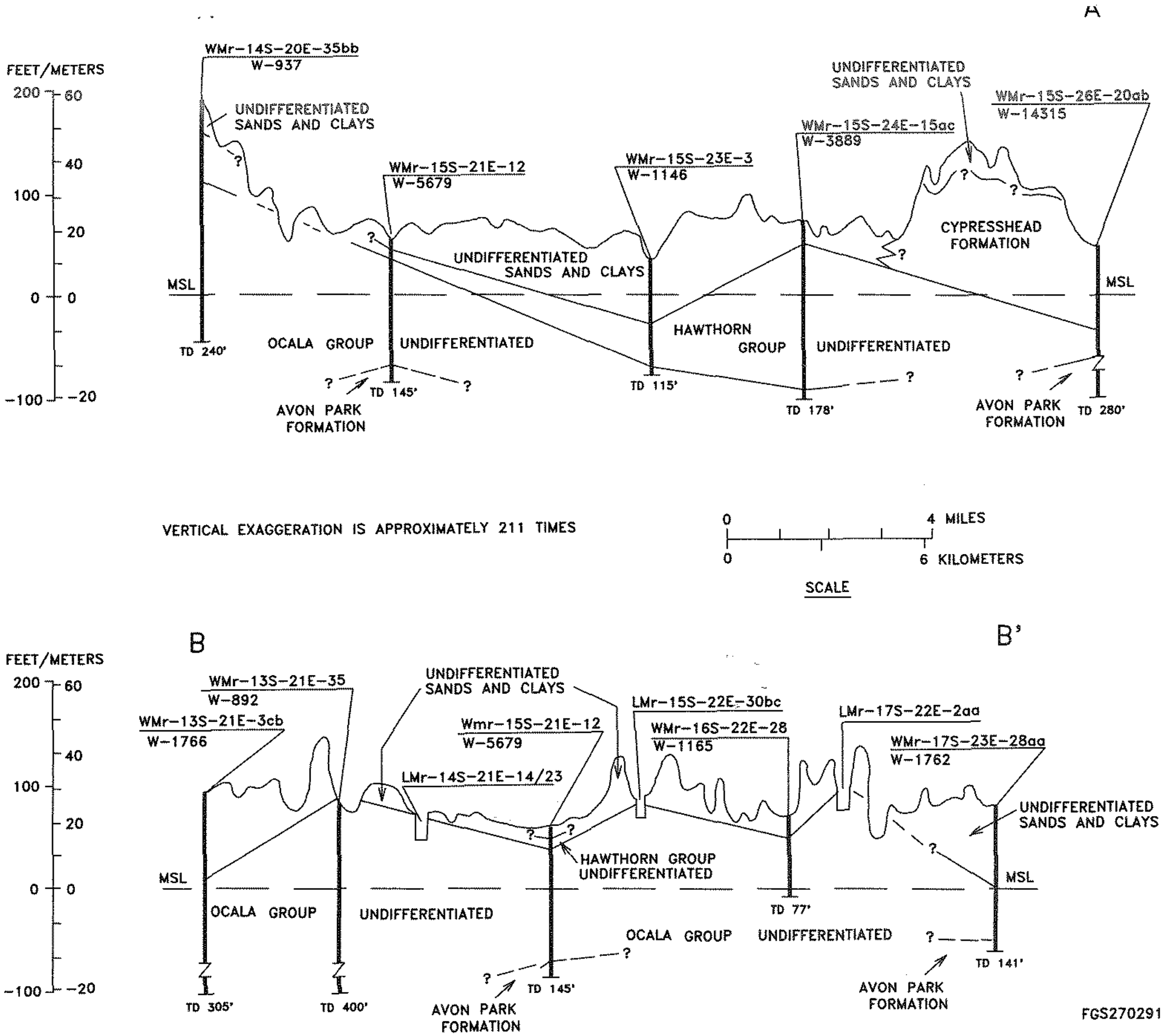


Figure 12. Cross sections A-A′ and B-B′.

The oldest rocks exposed in Florida are the Avon Park Formation. These rocks have no surface occurrences in the study area. They form part of the Floridan aquifer system in Marion County and underlie the Ocala Group limestones.

The oldest rocks exposed in the study area are the Ocala Group limestones. These rocks, referred to in this report as the "Ocala Group Undifferentiated," were deposited approximately 38 to 40 million years ago during the Eocene Epoch. Marine fossils associated with these sediments, including foraminifera, mollusks, bryozoans, and echinoids, are abundant and indicate that deposition took place in a shallow marine setting.

The Ocala Group limestone commonly occurs as a soft, white, fossiliferous limestone. The occurrence of the distinctive foraminifera genus *Lepidocyclina* is common to abundant and often used as a guide in identifying these sediments. Within the immediate Ocala area, it is variable in thickness ranging from less than 50 feet in FGS well W-1153 (section 30b, Township 15S, Range 23E) to a maximum observed thickness of approximately 190 feet in FGS well W-892 (Figures 11 and 12) (section 35, Township 13S, Range 21E). Some variations in thickness are a result of limestone removal through erosional karst processes, which are discussed in detail later in this report.

The Hawthorn Group overlies the Ocala Group limestone in the Ocala area. These sediments, consisting of interbedded phosphatic clay, sand, dolomite, and limestone, are undifferentiated in this report and are referred to in the cross sections as "Hawthorn Group Undifferentiated" (Figure 12). These diverse lithologic sediments were deposited during the Early and Middle Miocene Epoch.

Common to lithologies within the Hawthorn Group and an important lithologic guide to its identification is the presence of phosphate grains. This constituent, which may comprise greater than eight percent of the sediment sample, is generally disseminated throughout sandy clays and very fine to medium, clayey, quartz sands and carbonates. The unconformable boundary between the Hawthorn Group and the underlying Ocala Group is readily apparent. This distinctive lithologic boundary presents a sharp contrast between the common phosphatic sand present in the lower Hawthorn in the Ocala area and the richly fossiliferous, white to cream colored Ocala Group limestone.

The Hawthorn Group has an average thickness of approximately 20 to 30 feet throughout the study area. Exceptions to this occur due to the presence of a number of paleosinks in Ocala limestone in which Hawthorn Group and younger sediments have filled old, inactive sinkholes. One such occurrence is FGS W-3889 (section 15dd, Township 15S, Range 24E) which penetrated 144 feet of Hawthorn Group sediments over the Ocala Group.

The Cypresshead Formation is present over much of the eastern half of Marion County east of Ocala. This Pliocene-Pleistocene unit, which overlies the Hawthorn Group, has outcrops in the Ocala National Forest and in southeastern Marion County. Lithologically, it consists of an orange to white, very fine to coarse clayey sand and some gravel. Highly variable in thickness, the Cypresshead Formation may reach over 100 feet with even greater thicknesses encountered in paleosinks.

Sands, silts, clayey sands, and clays, referred to in this report and cross sections as "Undifferentiated Sands and Clays," form a surface veneer over most of the study area. In general, they overlie the Cypresshead Formation in eastern Marion County and the Hawthorn Group in the rest of the county. Exceptions occur in western Marion County where the Hawthorn Group and Cypresshead Formation are missing, in which case these sediments directly overlie the Ocala Group limestone. Typically, these Pleistocene and Holocene age sediments consist of sand with a clay matrix and occasional occurrences of quartz pebbles. Figure 12 illustrates the variable thickness of these sediments. Undifferentiated sediments within the study area are generally less than 10-feet thick.

WATER RESOURCES

THE HYDROLOGIC CYCLE

The hydrologic cycle describes the continuous movement and interaction of water in all its phases on, above, and below the earth's surface. Figure 13 shows the main phases of the hydrologic cycle in Florida.

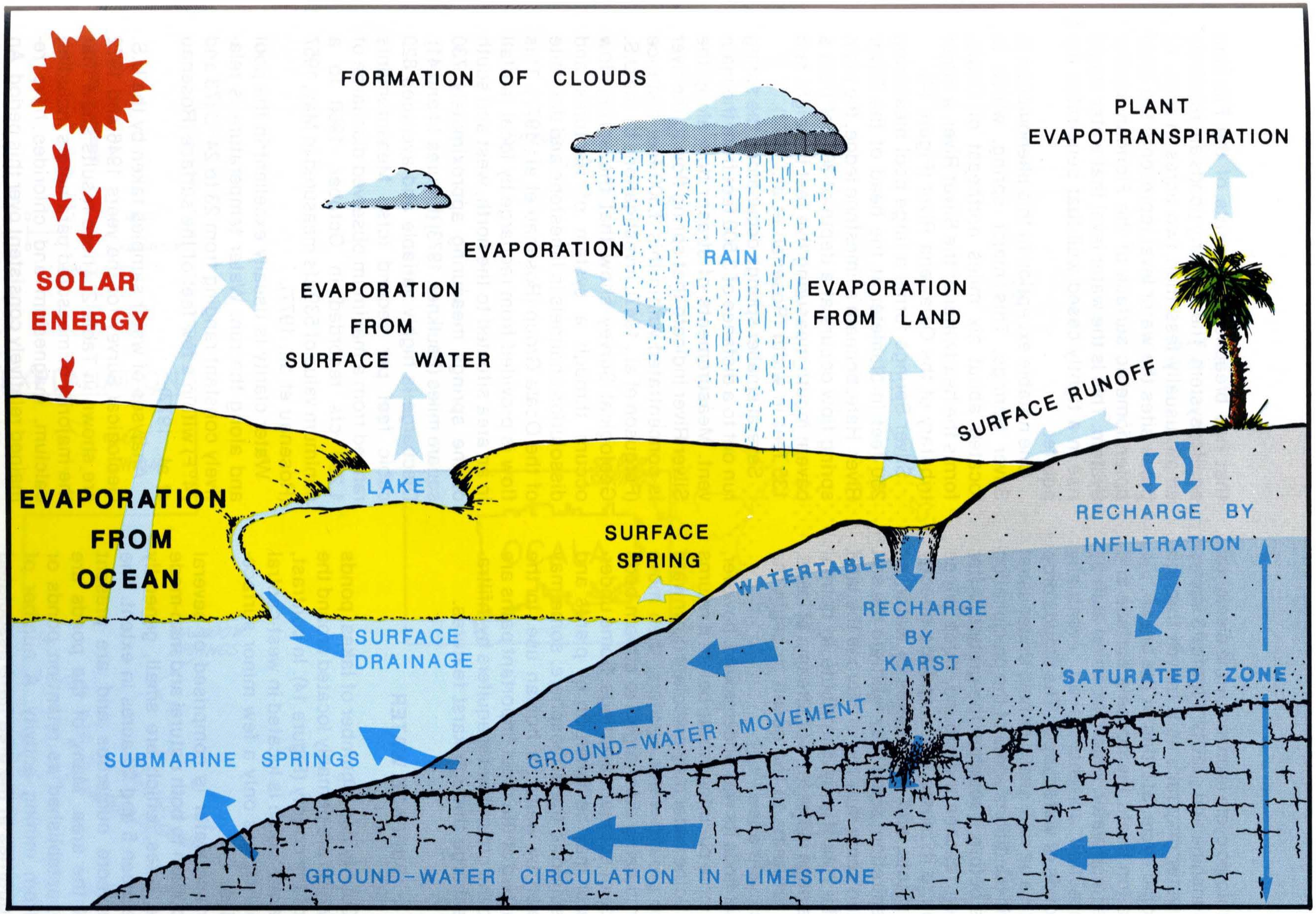


Figure 13. Hydrologic cycle, showing its main phases as they occur in Florida.

The hydrologic cycle is driven by the elemental forces of sunshine and gravity. Figure 13 shows the paths water may take as it moves through the hydrologic cycle. Starting at the ocean, the sun's radiation heats the ocean's surface and evaporates fresh water, which is carried aloft by rising convection currents of air, eventually forming clouds of water vapor. The clouds drop their moisture as rain, snow, or hail. Under usual atmospheric conditions some of the precipitation evaporates before it reaches the ground. After precipitation reaches the ground, three things can happen to it: some will evaporate directly from soil, plants, and free bodies of water, as evapotranspiration; some may infiltrate the soil or rocks; and some may run off across the land surface. The runoff may contribute to normal surface drainage in the form of streams or lakes, eventually returning to the ocean to begin the hydrologic cycle anew.

Water that finds its way underground, however, will have a more circuitous route before it returns to the sea. Some water may percolate downward to recharge ground-water aquifers, then move laterally until being discharged to stream beds or in surface or submarine springs. Some underground water may be taken up by plants and evapotranspired to the atmosphere; some may be withdrawn by wells for human use. In the Ocala area, two of the most important paths are recharge to the ground-water aquifers by infiltration and recharge through karst features.

SURFACE WATER

Marion County has a number of lakes, ponds and rivers which are primarily located around the perimeter of the county (Figure 14). In contrast, the Ocala area, which is located in west-central Marion County, has only a few minor surface-water bodies.

This surface water is comprised of several lakes, in addition to both natural and man-made ponds. The lakes, which are small, generally average between 5 and 20 acres in extent. The ponds are more numerous and are present throughout the area. Many of the ponds are man-made, established as retention ponds or resulting from mining activity. A number of limestone quarries in the area have associated water bodies formed as a result of excavation that has breached sediments of the Floridan aquifer system. These quarry ponds are relatively small, usually less than two acres in area. At these sites the water level represents the local potentiometric surface of the Floridan aquifer system. This is the water level that water would rise in a tightly cased well that penetrates the aquifer.

One notable exception to this phenomenon is Silver Springs. This major spring, which is located about six miles northeast of Ocala, forms the headwater of the Silver River, a major tributary of the Oklawaha River (Figure 14).

Silver Springs forms a large pool measuring 250 feet in diameter at the head of the Silver River. Here, beneath a limestone ledge, the main spring flow occurs at a depth of 30 feet from a cavern mouth measuring five feet in height and 135 feet in width (Rosenau et at., 1977).

Several smaller springs occur along the spring run out to a distance of 3,500 feet from the main vent. Measurements of stream flow along the Silver River indicate that spring flow to the river is concentrated within this 3,500 feet distance (Ferguson et al., 1947). Investigations by the U.S. Geological Survey show that the spring flow occurs through a system of fractures and dissolution channels in limestone and dolomite of the Ocala Group (Rosenau et al., 1977). This flow is provided from recharge by local rainfall in an area situated to the north, west and south of the springs measuring approximately 730 square miles (Faulkner, 1973) (Figures 14 and 41). Discharge is highly variable and averages 820 cubic feet per second (cfs). Measurements ranged from a maximum observed discharge of 1,290 cfs recorded in October, 1960 to a minimum value of 539 cfs measured in May, 1957 (Rosenau et al., 1977).

Water clarity is usually excellent in the pool and along the run. Water temperature is relatively constant ranging from 23 to 24°C (73 and 74°F) within a few feet of the surface (Rosenau et al., 1977).

Analyses of water samples taken by the U.S. Geological Survey for the years 1946 and 1972 are shown in Table 2. These results show that the majority of measured parameters including calcium, magnesium and chlorides have remained relatively consistent over this period. An exception to this is the nitrates (NO_3 as N) which

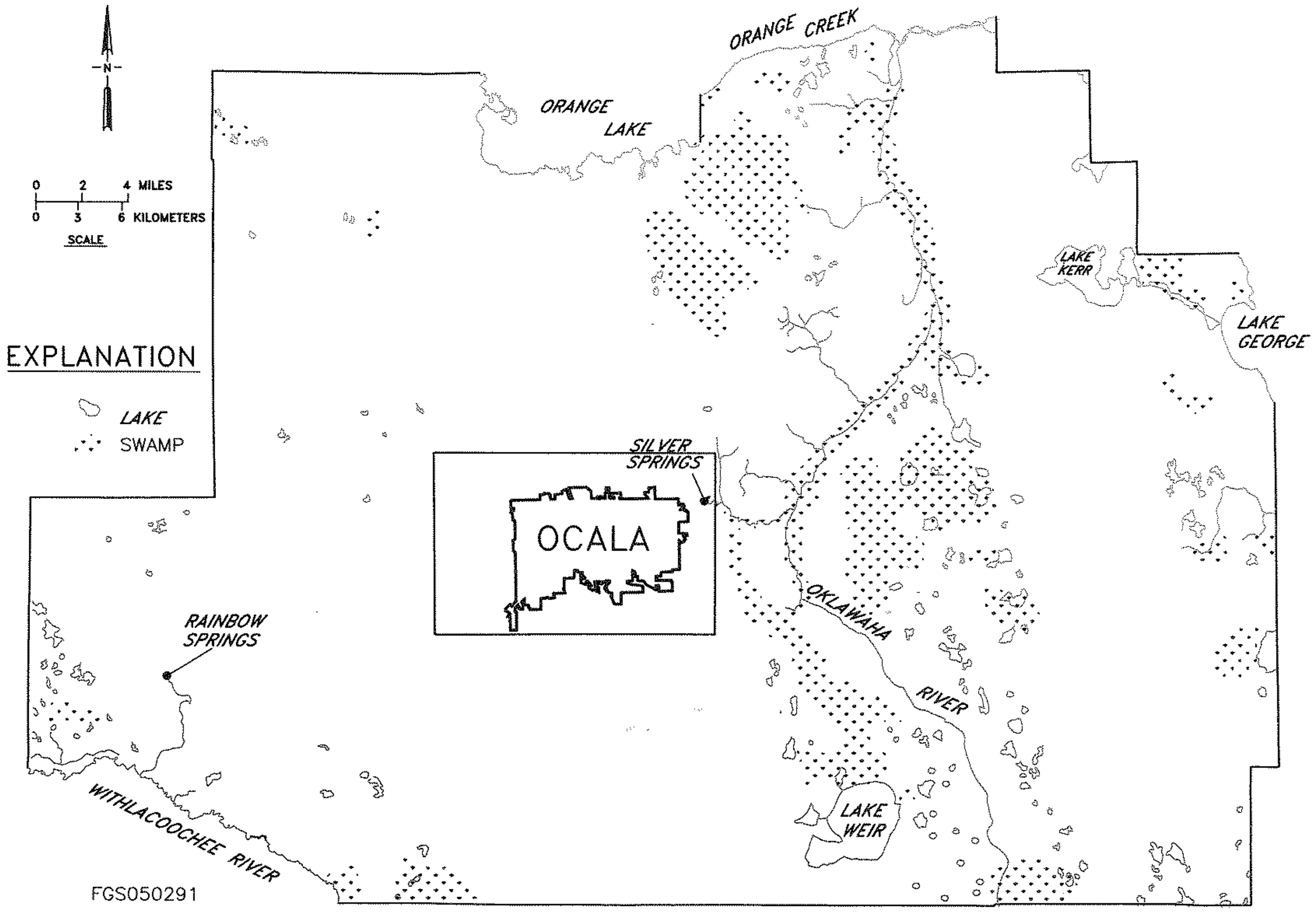


Figure 14. Surface water of Marion County.

Table 2. Water quality for Silver Springs for 1946 and 1972 (Rosenau et al., 1977). Units are in milligrams per liter unless otherwise noted.

Date of Collection	October 21 1946	September 16 1972
Nitrite (NO_2 as N)	——	0.00
Nitrate (NO_3 as N)	0.29	2.6
Calcium (Ca)	68	68
Magnesium (Mg)	9.6	9.3
Sodium (Na)	4.0	4.3
Potassium (K)	1.1	.2
Silica (SiO_2)	9.2	9.8
Bicarbonate (HCO_3)	200	200
Carbonate (CO_3)	0	0
Sulfate (SO_4)	34	39
Chloride (Cl)	7.8	8.0
Fluoride (F)	.1	0.2
Nitrate (CO_3)	1.3	——
Dissolved solids		
Calculated	——	242
Residue on evaporation at 180°C	237	246
Hardness as $CaCO_3$	210	210
Noncarbonate hardness as $CaCO_3$	——	42
Alkalinity as $CaCO_3$	——	170
Specific conductance (micromhos/cm at 25°)	401	420
pH (units)	7.8	8.1
Color (platinum cobalt units)	4	0
Temperature (°C)	——	23.5
Turbidity (JTU)	——	0
Biochemical oxygen demand (BOD, 5-day)	——	.1
Total organic carbon (TOC)	——	8.0
Organic nitrogen (N)	——	.37
Ammonium (NH_4 as N)	——	.03
Orthophosphate (PO_4 as P)	——	.14
Total phosphorus (P)	——	.14
Strontium (Sr)	——	500 ug/l
Arsenic (As)	——	0 ug/l
Cadmium (Cd)	——	0 ug/l
Chromium (Cr^6)	——	0 ug/l
Cobalt (CO)	——	0 ug/l
Copper (Cu)	——	0 ug/l
Lead (Pb)	——	2 ug/l

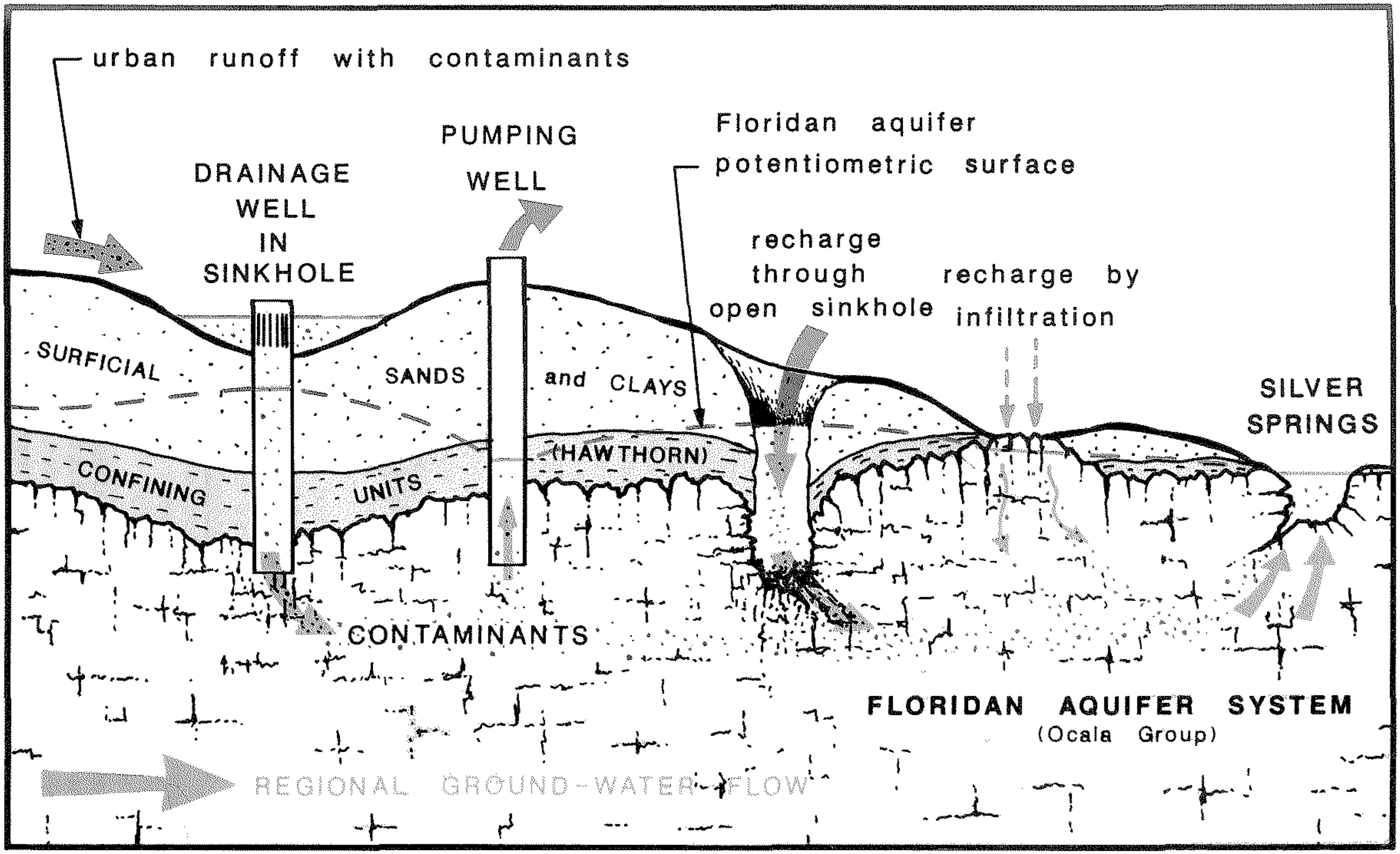


Figure 15. Generalized cross-section showing hydrogeological features common to the Ocala area. Recharge to the Floridan aquifer system can occur in several ways: (1) by infiltration from rain through thin, sandy soil or where limestone crops out at the surface; (2) through sinkholes that breach the confining units; or (3) by drainage wells. Drainage wells pose a threat to the aquifer due to contaminants in urban runoff. Discharge from the aquifer is by pumpage or at springs.

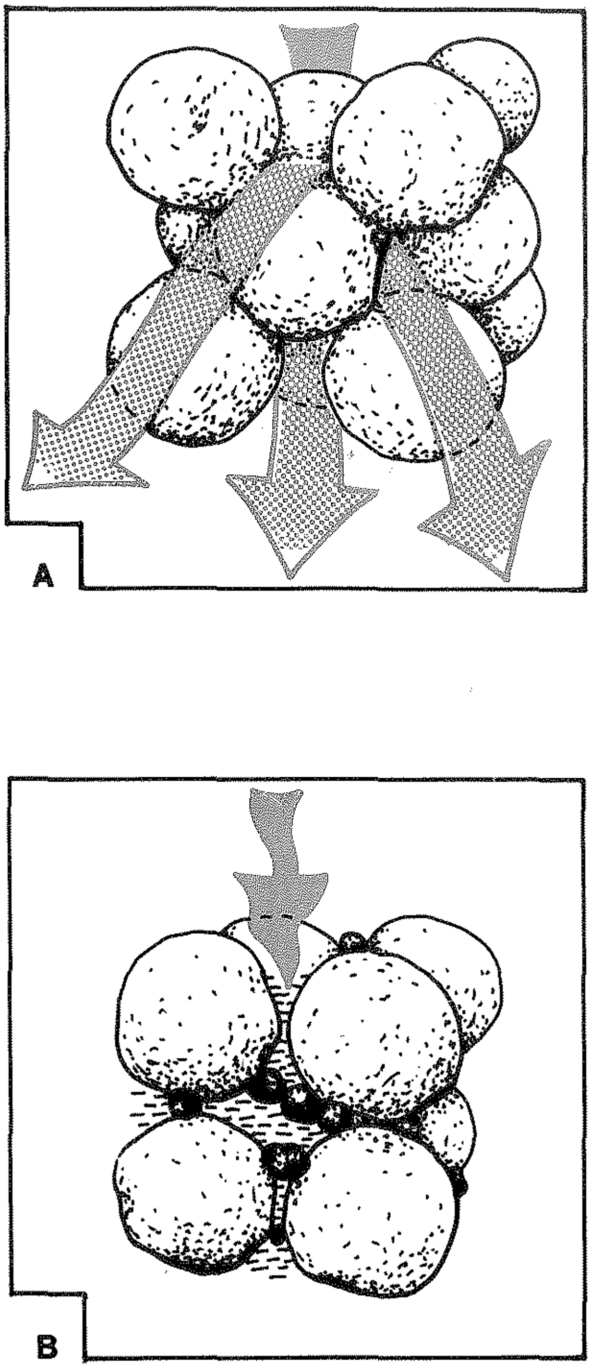


Figure 16. Porosity and permeability as shown by two examples of a well-sorted granular material, such as sand. In Figure A the porous and permeable sand is clean with open, interconnected voids that allow water to move freely. In Figure B the same well-sorted, porous sand is rendered impermeable to water flow due to the retarding effect of the interstitial material, such as clay (from Lane, 1986).

shows an increase. This may be attributed to the effects of intensive agriculture practices, such as fertilization and spraying, which are used within the Silver Springs drainage basin.

AQUIFERS

Figure 15 illustrates several hydrogeological features commonly encountered in Florida sediments and rocks. This figure particularly applies to the local conditions in the Ocala area.

All ground water occupies the open spaces, or pores, that occur in many of the rocks of the earth's crust. Aquifers are defined as units of rocks or sediments that yield water in sufficient quantities to be economically useful for society's activities.

Porosity and permeability are two fundamental characteristics of rocks or sediments that control the quantities of water that they can store, transmit, or release. Porosity and permeability are intimately related. A porous medium, such as clean sand or gravel, has voids which may contain water, as shown in Figure 16. Permeability is a measure of a porous medium's ability to allow fluids to move through its pores. By definition, then, permeability implies that a rock's pores are interconnected so fluids can move through them. A clean sand, therefore, is permeable; water can migrate through it (Figure 16a). Porous rocks are not always permeable, however. A similar, well-sorted sand may have its interstices filled with clay, small grains of organic matter, or some other fine-grained material, which effectively blocks the free passage of water (Figure 16b). In this case, the sand would be classified as impermeable (if only very small quantities of water could pass through it).

Limestone, though usually thought of as being "solid" rock, often has a granular texture and considerable porosity and permeability, either primary (developed when the limestone was deposited) or secondary (developed after deposition). Ground-water flow through granular and porous limestone is, therefore, similar to flow through sand. This is an important concept to keep in mind during the following discussions of aquifers and chemical weathering of limestone.

Floridan Aquifer System

The Floridan aquifer system is the principal source of water for the city of Ocala. Indeed, this aquifer is the principal artesian aquifer in Florida, Georgia, Alabama, and South Carolina (Miller, 1986). Figure 17 correlates the geologic formations that comprise the Floridan aquifer system, which includes the Ocala Group and the Avon Park Formation.

In general, the Ocala Group limestone forms the top of the Floridan aquifer system. This top occurs at or near land surface throughout the Ocala area, creating a matter of environmental concern. The industrial, commercial, and residential growth in Ocala brings associated environmental risks to the extremely fragile aquifer system. Because of the Floridan aquifer system's near-surface occurrence in a highly karstic area, the potential exists for significant contamination of this system from the flow of surface waters into the aquifer or from an accidental spill (Phelps, 1989). Porous surface sands and numerous sinkholes serve as excellent conduits for potential pollutants to enter the aquifer.

Recharge to the Floridan aquifer system in this area occurs in the form of rainfall and ground-water inflow from potentiometrically higher areas immediately to the north and south (Faulkner, 1973). In addition, recharge occurs via sinkholes, which are numerous throughout the area, some of which have drainage wells installed to control urban runoff (Figures 15 and 18). Ground-water discharge in and around Ocala occurs primarily from Silver and Rainbow Springs.

The water quality of the Floridan aquifer system is considered excellent for public and domestic consumption. The water is a hard, calcium bicarbonate type, commonly free of bacteriological contamination. The mineral content usually increases with depth (Faulkner, 1973).

Ocala's public water supply is currently obtained from a well field consisting of five wells located in the northeastern part of the city (section 10bb, Township 15S, Range 22E). These wells are 24 inches in diameter, have casing depths ranging from 86 feet to 140 feet below

HYDRO-STRATIGRAPHIC UNIT	GEOLOGIC UNIT	SERIES
SURFICIAL AQUIFER SYSTEM	UNDIFFERENTIATED TERRACE MARINE AND FLUVIAL DEPOSITS	POST-MIOCENE
INTERMEDIATE AQUIFER SYSTEM AND INTERMEDIATE CONFINING UNIT	HAWTHORN GROUP	MIOCENE
FLORIDAN AQUIFER SYSTEM	OCALA GROUP	EOCENE
	AVON PARK FORMATION	

FGS010291

Figure 17. Hydrostratigraphic correlation chart (Southeastern Geological Society, 1986).

Figure 18. City drainage well in bottom of a sinkhole connecting to the upper Floridan aquifer system. This type of well is used to control flooding by diverting urban runoff into the cavernous limestone aquifer. Florida Geological Survey photograph.

land surface, and are drilled to depths ranging from 190 feet to 266 feet below land surface. An older abandoned well field is located near the center of the city. Wells in this field now serve as monitoring wells.

In addition to the Floridan aquifer system, two other aquifer systems may be present. FGS well data suggests that a surficial aquifer system and an intermediate aquifer system may have sporadic occurrences in the Ocala area, as discussed below.

Intermediate Aquifer System

An intermediate aquifer system may be present in isolated pockets of relatively thick deposits of Hawthorn Group sediments. As cross section A-A' shows, Hawthorn Group thicknesses may be as great as 130 feet (W-3889, Figure 12). Presently, there are no data indicating that either the surficial or intermediate aquifer systems are being used as sources of water (Phelps, personal communication, 1989).

Surficial Aquifer System

When near-surface sand and clay lenses or beds are arranged so that the units can retain infiltrated water for a reasonable length of time, the sediments are included in a shallow aquifer system (Southeastern Geological Society, 1986). A surficial aquifer system may be present in areas having appreciable thicknesses (on the order of tens-of-feet) of undifferentiated sand and clay sediments.

EVOLUTION OF KARST TERRAIN

The evolution of any terrain into characteristic landforms involves weathering and erosional or accretionary processes: wind, water, frost heaving, slumping, or wave activity, to name a few. In most areas, the predominant weathering, erosional, and transporting agent is water, either falling, flowing across the land, or circulating through subsurface rocks.

Ocala lies in a karst terrain, an area characterized by undulating hill and swale topography, sinkholes, disappearing streams, springs, and caves. The two things necessary to create karst are abundant in the area: limestone in the shallow subsurface and slightly acidic waters to dissolve it.

CHEMICAL WEATHERING OF CARBONATE ROCKS

The creation of karst involves the development of underground drainage systems (Figures 19a, 19b, 19c, 19d). Most chemical erosion processes that create karst take place unnoticed, underground, and imperceptibly slowly. Over time, perhaps after thousands of years, evidence of these persistent processes will occur as the formation of a sinkhole, a spring, ground subsidence, an influx of muddy water in a well, or as some other karst phenomenon that may interfere with society's activities.

Chemical weathering is the main erosive process that forms karst terrain, in an evolutionary sequence shown in Figures 19a, 19b, 19c, 19d. As rain falls, some nitrogen and carbon dioxide gases dissolve into it, forming a weak acidic solution. When the water contacts decaying organic matter in the soil, it can become even more acidic. When the water contacts limestone, its corrosive attack begins. All rocks and minerals are soluble in water to some extent, but limestone is especially susceptible to dissolution by acidic water. Limestones, by nature, tend to be fractured, jointed, laminated, and to have units of differing texture, all characteristics which, from the standpoint of percolating ground water, are potential zones of weakness. These zones of weakness in the limestone are avenues of attack that, in time, the acidic waters will enlarge and extend. Given geologic time, conduits will form in the rock and allow water to flow relatively unimpeded for long distances.

During the chemical process of dissolving the limestone, the water takes into solution some of the minerals. The water containing the dissolved minerals moves to some point of discharge which may be a spring, a stream bed, the ocean or a well.

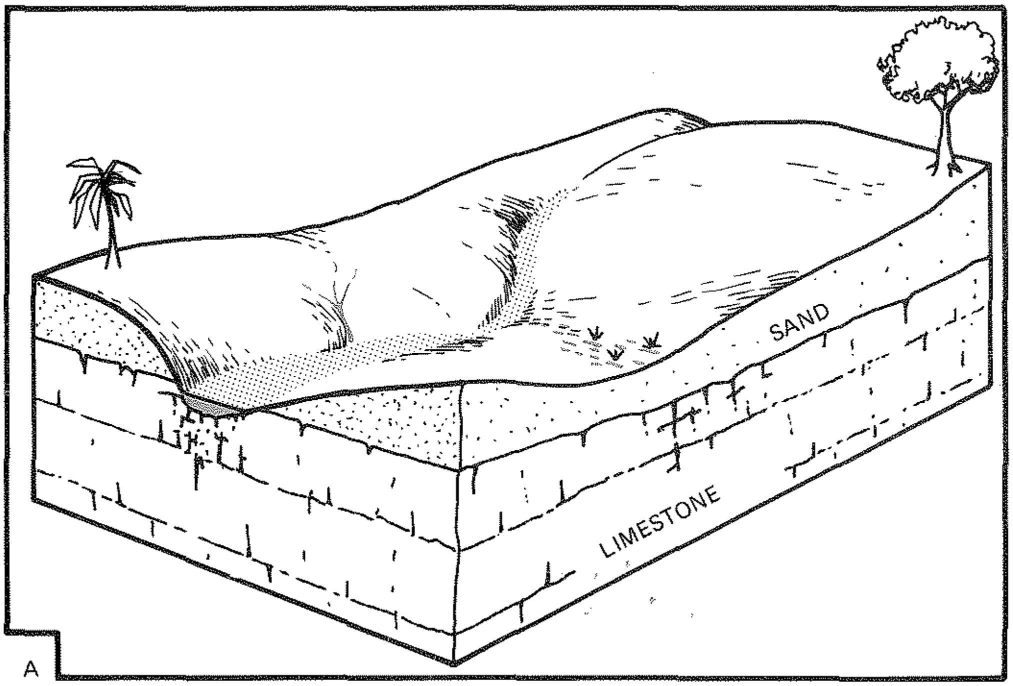


Figure 19a. Relatively young karst landscape showing underlying limestone beds and sandy overburden with normal, integrated surface drainage. Solution features are just beginning to develop in the limestone (after Lane, 1986).

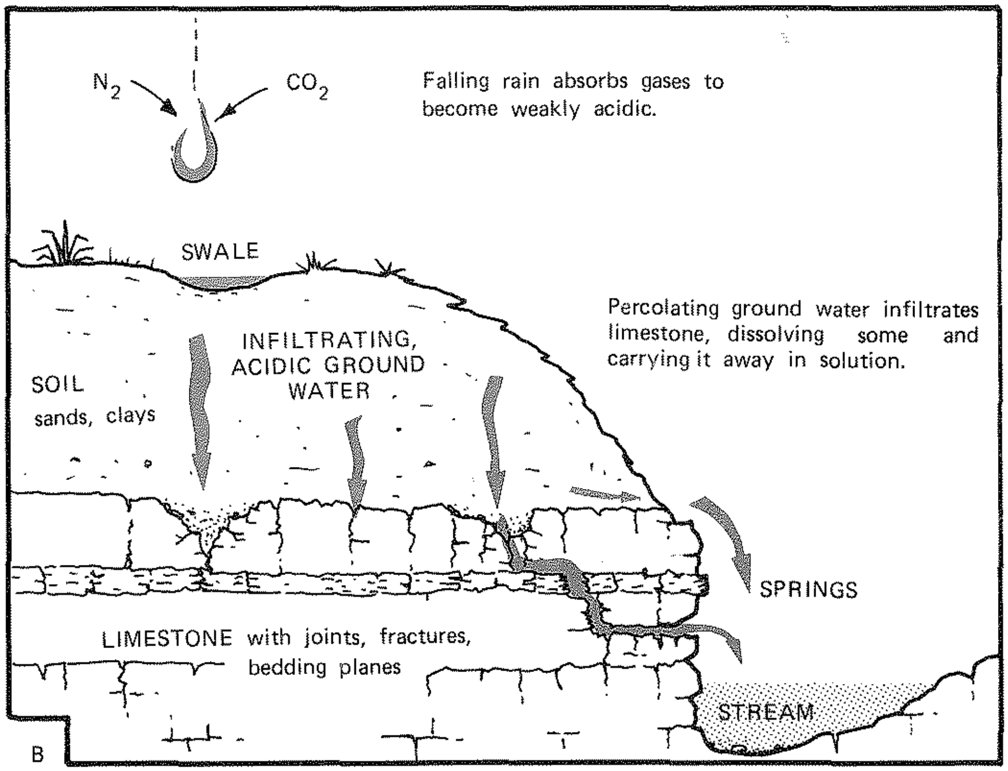


Figure 19b. Detail of Figure 19a showing early stages of karst formation. Limestone is relatively competent and uneroded. Chemical weathering is just beginning, with little internal circulation of water through the limestone. Swales, forming incipient sinkholes act to concentrate recharge (after Lane, 1986).

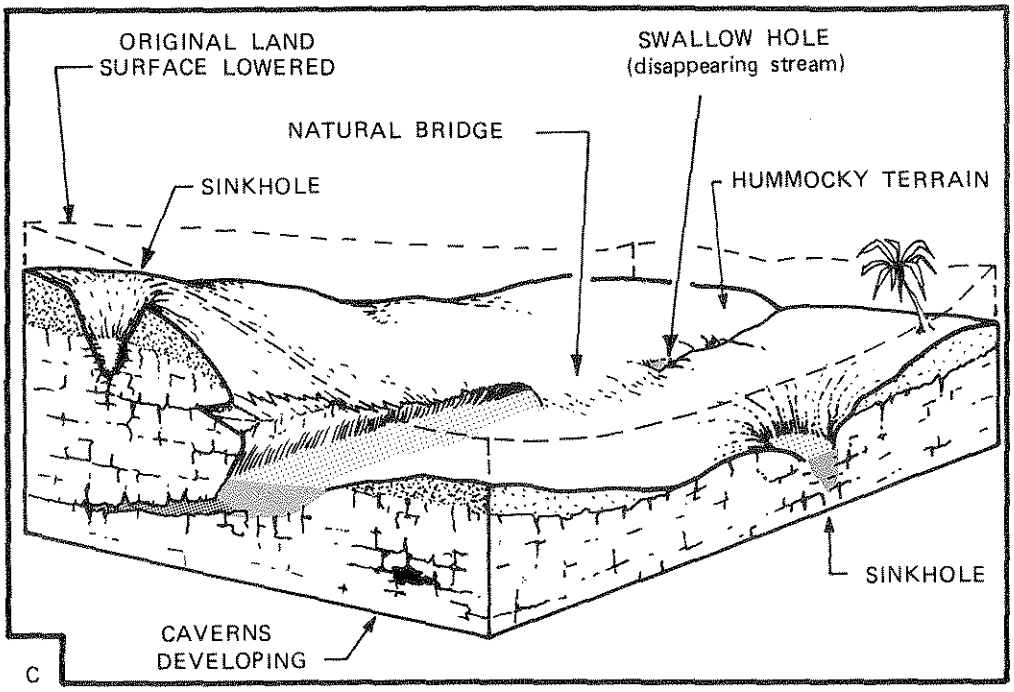


Figure 19c. Advanced karst landscape. Original surface has been lowered by solution and erosion. Only major streams flow in surface channels and they may cease to flow in dry seasons. Swales and sinkholes capture most of the surface water and shunt it to the underground drainage system. Cavernous zones are well-developed in the limestone (after Lane, 1986).

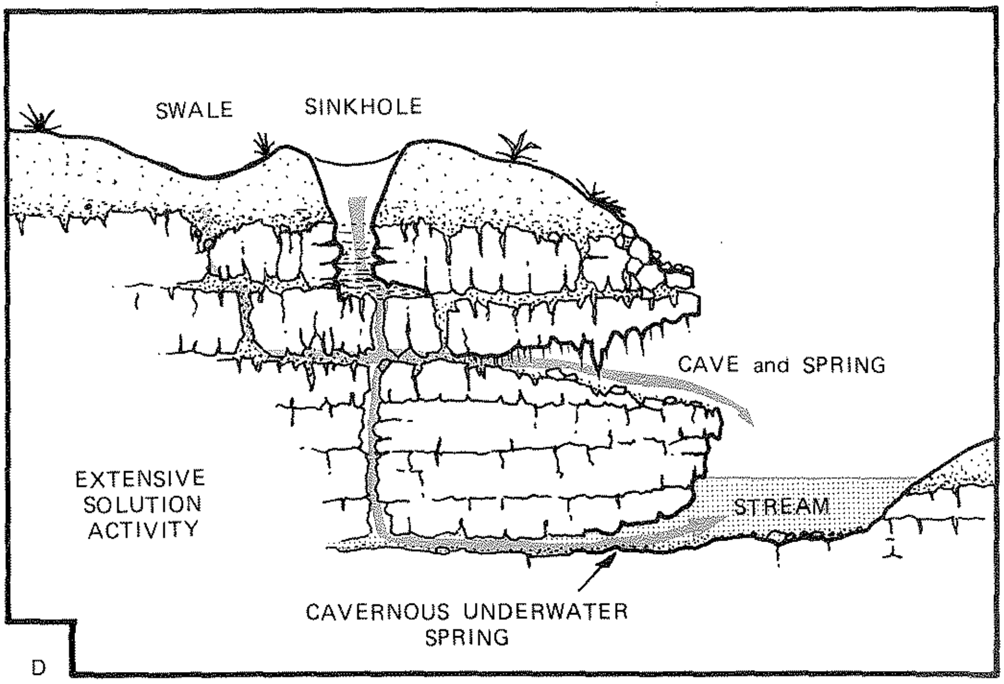


Figure 19d. Detail of Figure 19c showing advanced stage of karst formation. Limestone has well-developed interconnected passages that form an underground drainage system, which captures much or all of prior surface drainage. Overburden has collapsed into cavities forming swales or sinkholes. Caves may form. Land surface has been lowered due to loss of sand into the limestone's voids. Silver Spring is an example of a cavernous underwater spring (after Lane, 1986).

Removal of the rock, with the continuing formation or enlargement of cavities, can ultimately lead to the collapse of overlying rocks or sediments. If the collapse is sudden and complete, an open sinkhole will result, sometimes revealing the cavity in the rock (Figures 20 and 21). More often, though, debris or water covers the entrance to subterranean drainage. Partial subsidence of the overburden into cavities will form swales at the surface, producing hummocky, undulating topography. By this slow, persistent process of dissolution of limestone and subsequent collapse of overburden, the land is worn down to form a karst terrain.

At some point in this process of dissolution of underground rocks, any existing surface drainage system will begin to be transformed into a dry or disappearing stream system. Continuing dissolution of the limestone will create more swales and sinkholes, which will divert more of the surface water into the underground drainage. Eventually, all of the surface drainage may be diverted underground, leaving dry stream channels that flow only during floods, or disappearing streams that flow down swallow holes (sink holes in stream beds) and reappear at distant points to flow as springs or resurgent streams.

KARST IN THE OCALA AREA

There are a variety of karst features in the Ocala area. Figure 22 shows the extent to which the area's topography has been dissected by karst features. Silver Springs is a spectacular example of a cavernous spring, as shown in Figure 19d. It is the source of Silver River, and a major discharge point for water from the Floridan aquifer system, with flows ranging from 539 to 1,290 cubic feet per second (834,000,000 to 1,997,000,000 gallons per day) (Rosenau et al., 1977). These quantities of water can dissolve and carry away in solution as much as 541 tons of limestone per day (Lane, 1986), which gives some idea of the erosive capacity of karst processes.

Sinkholes are common features in the Ocala area (Figures 23, 24, 25, 26). Sinclair and Stewart (1985) classify the sinkholes that occur in the Ocala area as three types: solution, cover-collapse, and cover-subsidence. In their classification solution sinkholes occur in areas where limestone is exposed at land surface or is covered by thin soil and permeable sand. Under these conditions the land surface subsides gradually. The topographic expression of this type of sinkhole is usually a bowl-shaped depression that may have ponded water. The rolling, hill-and-swale topography of the Ocala area is typical. Cover-collapse sinkholes generally occur suddenly, in areas where limestone is near the surface. Sinkhole walls tend to be near-vertical, exposing limestone in the round solution pipes that lead to the underground drainage system (Figures 20 and 21). Cover-subsidence sinkholes occur where the overburden is relatively permeable and poorly cohesive, which characterizes much of the soil in the Ocala area. In areas of thick sand cover subsidence may be sudden or proceed slowly over many years, producing sinkholes only a few feet in diameter and depth.

WATER QUALITY

The Florida Department of Environmental Regulation (DER) monitors a number of water wells in Marion County which are part of the department's statewide ground-water quality monitoring network. This network is made up of wells placed in areas assumed to be unaffected by man at the present time.

One of these wells is located west of the city of Ocala, at the Ocala Airport (section 19b, Township 15S, Range 21E). This six-inch well is drilled to a depth of 90 feet below land surface into the upper Floridan aquifer system. Table 3 lists the specific parameters analyzed and their respective values for this well. All of the values are within established U.S. Environmental Protection Agency (EPA) units for potable water.

In addition to the ambient network wells, DER and the St. Johns River Water Management District (SJRWMD) are in the process of establishing a Very Intense Study Area (VISA) network within the city of Ocala. This VISA is located in the east-central part of the study area (Figure 27) and is one of five initial VISAs to be established in the water management district. In contrast to the ambient wells, which are strategically placed to monitor unaffected areas whose ground water is not associated with degradation due to pollution sources, the VISA wells are intended to monitor the impact of a potential or confirmed pollution source on local water quality (based on land-use activity).

Figure 20. Karst limestone surface exposed by a flash-flood in Ocala in 1982. Note vertical solution pipes. Florida Geological Survey photograph.

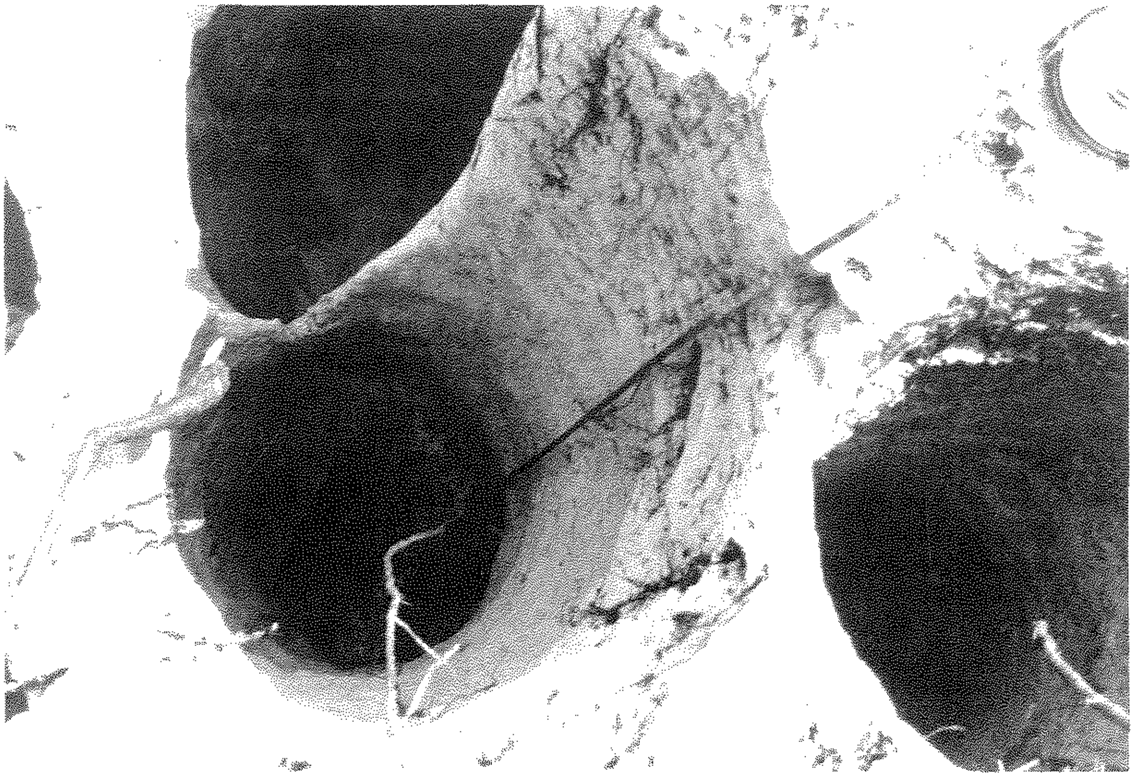


Figure 21. Close-up of solution pipes in Ocala limestone surface, in the same area as in Figure 20. Pipes are between one and two feet in diameter. Sinkholes and other karst surface expressions can appear when such pipes become unplugged of their sediment-fill. Florida Geological Survey photograph.

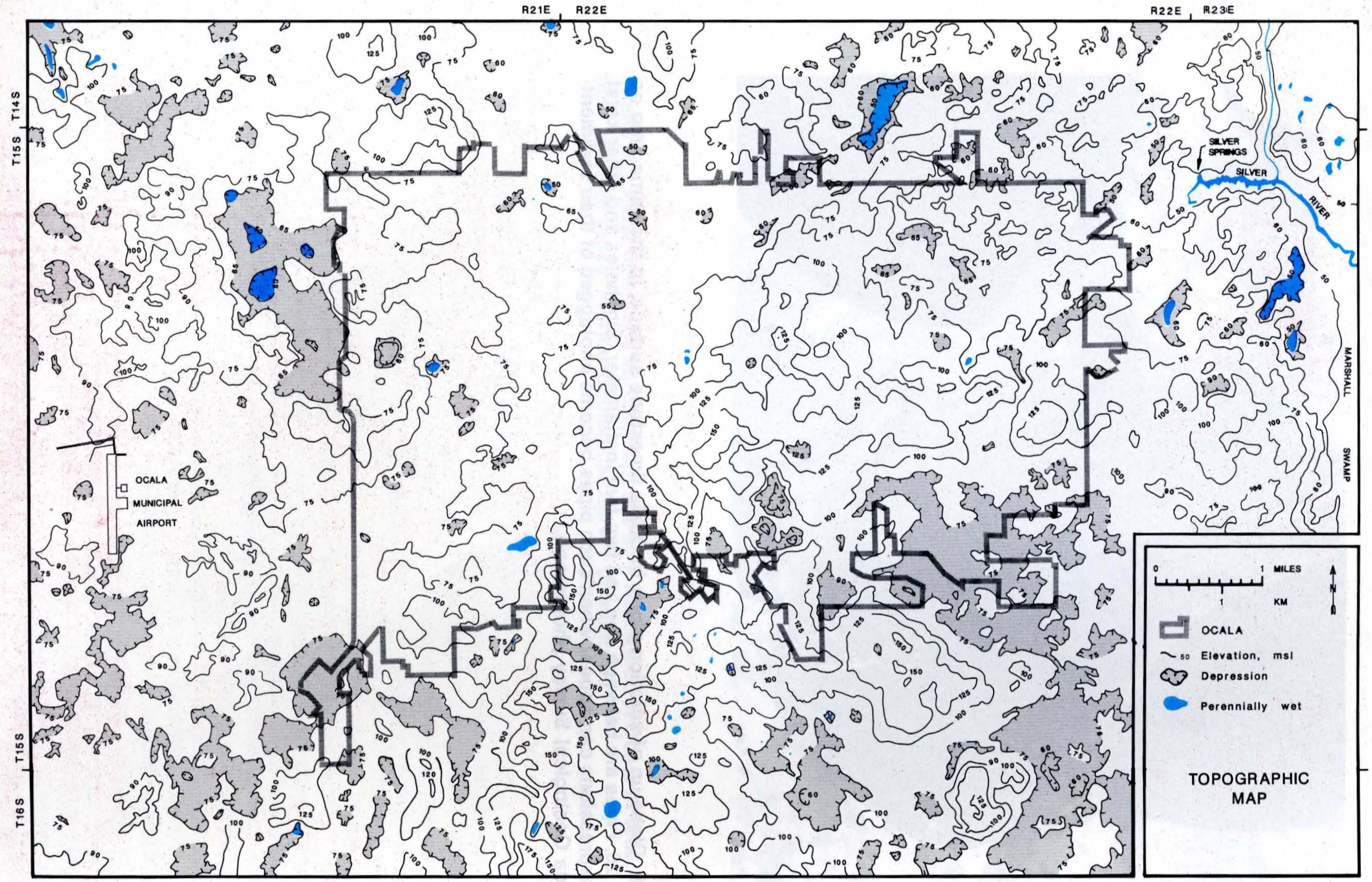


Figure 22. Topographic map of the Ocala study area showing larger karst features. Hundreds of smaller sinkholes and depressions do not show at this scale. Contour interval is 25 feet with selected intermediate contours.

Figure 23. Sinkholes in City of Ocala formed during the flood of April 1982. Florida Geological Survey photograph.

Figure 24. Sinkhole in City of Ocala formed during the flood of April 1982. Florida Geological Survey photograph.

Figure 25. Sinkhole in City of Ocala formed during the flood of April 1982. Florida Geological Survey photograph.

Figure 26. Sinkhole in City of Ocala formed during the flood of April 1982. Florida Geological Survey photograph.

Table 3. Water quality analysis of Ocala Airport Ground-Water quality monitor well (sec 19b, Township 15S, Range 21E) (Dept. of Environmental Regulation data, 1989)

PARAMETER	AVERAGE	UNITS*
1, 1, 1 Trichloroethane	1.0000	ug/l
1, 1, 2 Trichloroethane	1.0000	ug/l
1, 1 Dichloroethene	1.0000	ug/l
1, 1 Dichloroethane	1.0000	ug/l
1, 2 Dichloroethane	1.0000	ug/l
1, 2 Dichlorobenzene	1.0000	ug/l
1, 2 Dichloropropane	1.0000	ug/l
1, 3 Dichlorobenzene	1.0000	ug/l
1, 4 Dichlorobenzene	1.0000	ug/l
1122 Tetrachloroethane	1.0000	ug/l
Arsenic	0.0020	mg/l
Barium	0.0300	mg/l
Bicarbonate	108.0000	mg/l
Bromoform	1.0000	ug/l
Bromomethane	1.0000	ug/l
Bromodichloromethane	1.0000	ug/l
C1, 3 Dichloropropene	1.0000	ug/l
Cadmium	0.0020	mg/l
Calcium	38.3000	mg/l
Carbonate	0.1000	mg/l
Carbon Tetrachloride	1.0000	ug/l
Chloromethane	1.0000	ug/l
Chloride	3.4000	mg/l
Chloroethane	1.0000	ug/l
Chlorobenzene	1.0000	ug/l
Chloroform	1.0000	ug/l
Chromium	0.0120	mg/l
Conductivity	230.0000	umhos/cm
Copper	0.0130	mg/l
Dibromochloromethane	1.0000	ug/l
Dichlorodifluoromethane	1.0000	ug/l
Fluoride	0.0460	mg/l
Iron	0.0300	mg/l
Lead	0.0200	mg/l
Magnesium	1.7600	mg/l
Manganese	0.0050	mg/l
Mercury	0.0000	mg/l
Methylene Chloride	1.0000	ug/l
Nitrate	0.9240	mg/l
pH	7.4000	s.u.
Phosphate	0.0810	mg/l
Potassium	0.2100	mg/l
Selenium	0.0020	mg/l
Silver	0.0080	mg/l
Sodium	2.2000	mg/l

PARAMETER	AVERAGE	UNITS*
Sulfate	8.1400	mg/l
T1, 2 Dichloroethene	1.0000	ug/l
T1, 3 Dichloropropene	1.0000	ug/l
Total Dissolved Solids	157.0000	mg/l
Temperature	24.5000	degree C
Tetrachloroethene	1.0000	ug/l
Total Organic Carbon	13.7000	mg/l
Trichloroethene	1.0000	ug/l
Trichlorofluoromethane	1.0000	ug/l
Vinyl Chloride	1.0000	ug/l
Zinc	0.0200	mg/l
2, 4, 5-TP	0.0020	ug/l
2, 4-D	0.0050	ug/l
2 Chloroethyl Vinyl Ether	1.0000	ug/l
4, 4'-DDD	0.0100	ug/l
4, 4'-DDE	0.0040	ug/l
4, 4'-DDT	0.0100	ug/l
Aldrin	0.0040	ug/l
Benzene	1.0000	ug/l
Chlordane	0.0100	ug/l
Dieldrin	0.0020	ug/l
Endosulfan I	0.0100	ug/l
Endrin	0.0010	ug/l
Ethyl Benzene	1.0000	ug/l
Heptachlor	0.0030	ug/l
Heptachlor Expoxide	0.0800	ug/l
Laboratory pH	7.7700	s.u.
Methoxychlor	0.0100	ug/l
Mirex	0.0010	ug/l
Parathion	0.0100	ug/l
Sulfide	0.1000	mg/l
Toluene	1.0000	ug/l
Toxaphene	0.1000	ug/l
g-BHC	0.0000	ug/l
Gross PCB's	0.0100	ug/l

---

* ug/l = micrograms per liter
mg/l = milligrams per liter
s.u. = standard units
umhos/cm = micromhos per centimeter

The Ocala VISA is placed in an area designated as "mixed urban-light industrial" covering approximately three square miles. This VISA will have a number of wells installed to monitor the local area's water quality. Water quality from these wells will be compared to that of nearby wells in the ambient ground-water quality background network to determine if any degradation is occurring as a result of land-use activities within the VISA.

POTENTIOMETRIC SURFACE

Figures 28a-28e show the potentiometric surface of the upper Floridan aquifer system for the months of May and September for the years 1978, 1980, 1982, 1984, 1986, and 1988 (SJRWMD data). The potentiometric surface is a measurement used by hydrogeologists to show the elevation or altitude (expressed in feet above mean sea level) at which water level would stand in tightly cased wells that penetrate the aquifer.

These contoured data show that Ocala and surrounding areas have a potentiometric surface that varies in a narrow range from 40 to 47 feet above MSL. A maximum value of 47 feet above MSL was recorded in September 1982 and a minimum value of 40 feet above MSL was recorded in May of 1988. This may be attributed to increased consumption of ground water that SJRWMD records show occurred over this period of time.

The potentiometric surface appears to be relatively stable, having shown minimal variations over a period of time in which the City of Ocala has had significant growth. Figure 29 lends support to this observation as the change in potentiometric surface experienced variations from minus two feet to plus one foot in the period from September 1987 to May 1988, similar to seasonal fluctuations shown for prior years (Figures 28a, 28b, 28c, 28d, 28e). Approximately half of the study area experienced a slight rise in the potentiometric surface, while a large part of the rest of Marion County had no observed change.

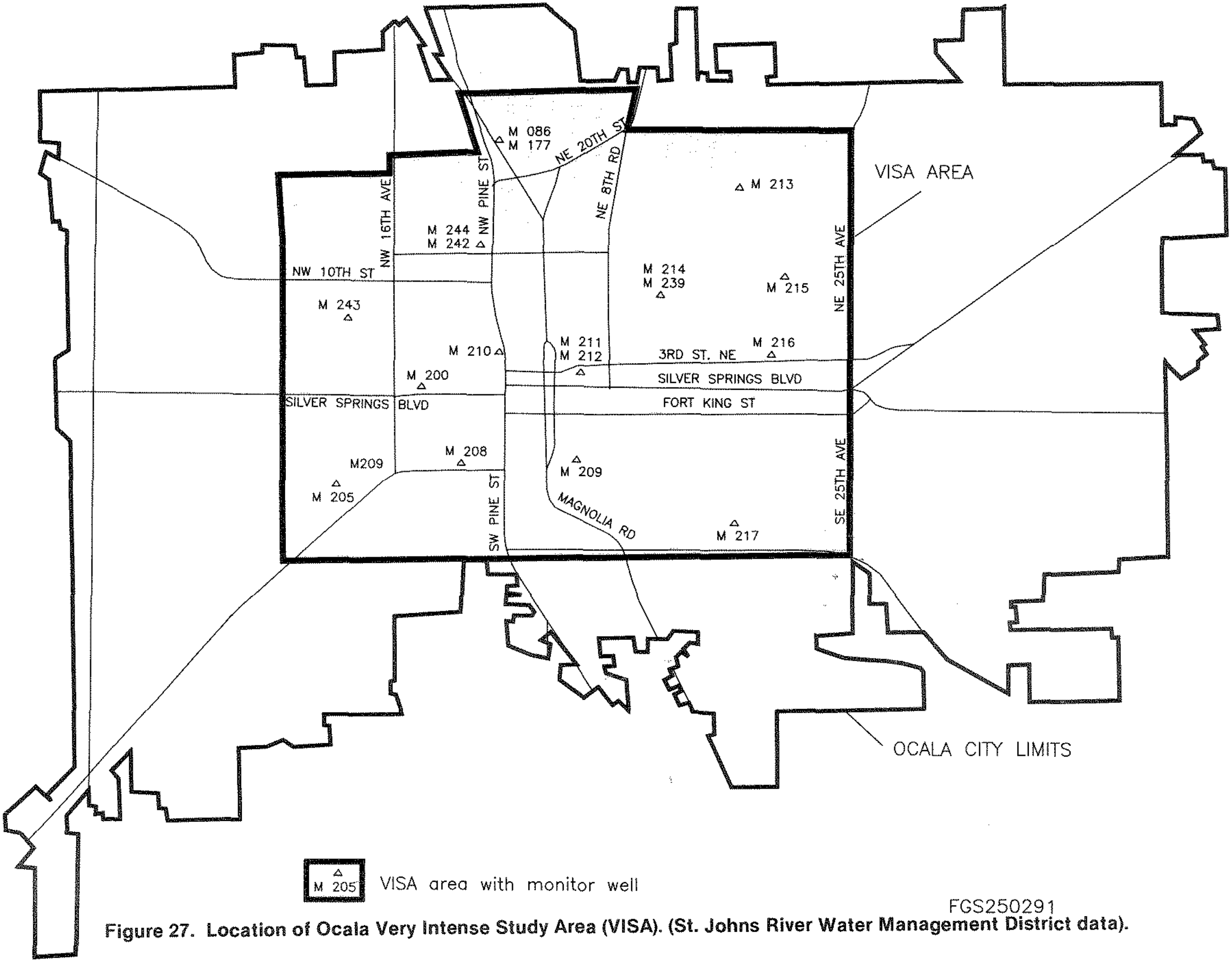
WATER USAGE

Figure 30 shows the various water usages from both ground and surface water withdrawals in the St. Johns River Water Management District for 1986 (the latest year for which data are available). These data clearly illustrate the importance of the Floridan aquifer system, as it was the source of more than 90 percent of the ground water withdrawn in the district in 1986.

The diagrams (Figure 30) show the dominance of the agricultural sector and to a lesser extent the public water supply as users of ground water. Together, these two categories accounted for 73 percent of the ground water withdrawn from the district in 1986.

The agricultural sector is the largest user of ground water in Marion County. Within this category irrigation accounts for the largest usage. The largest uses of water for irrigation are field corn followed by improved pastures, golf course turf grass and sod. In the county, water withdrawn for these purposes totaled 8.56 million gallons/day from ground water and 2.10 million gallons/day from surface water for the year 1986. This withdrawal has experienced fluctuations over time showing a 28 percent decline for the period 1975 to 1985 and a 22 percent increase from 1985 to 1986. It should be noted that agricultural water usage is extremely sensitive to weather conditions and shows the greatest seasonal variations in withdrawals.

The second largest user of ground water is the public water supply which accounts for 35 percent of the ground-water usage (Figure 30). The Floridan aquifer system supplies 100 percent of the City of Ocala's public water supply and supplies more than 95 percent of the entire district's public water (SJRWMD data). Specifically, the City of Ocala withdrew an average of 7.668 million gallons of water per day for this purpose. This amount is included in the 10.91 million gallons per day extracted from the Floridan aquifer system for all of Marion County in 1986. The public water supply usage in Marion County increased by 50 percent in the period from 1980 to 1985.



FGS250291

Figure 27. Location of Ocala Very Intense Study Area (VISA). (St. Johns River Water Management District data).

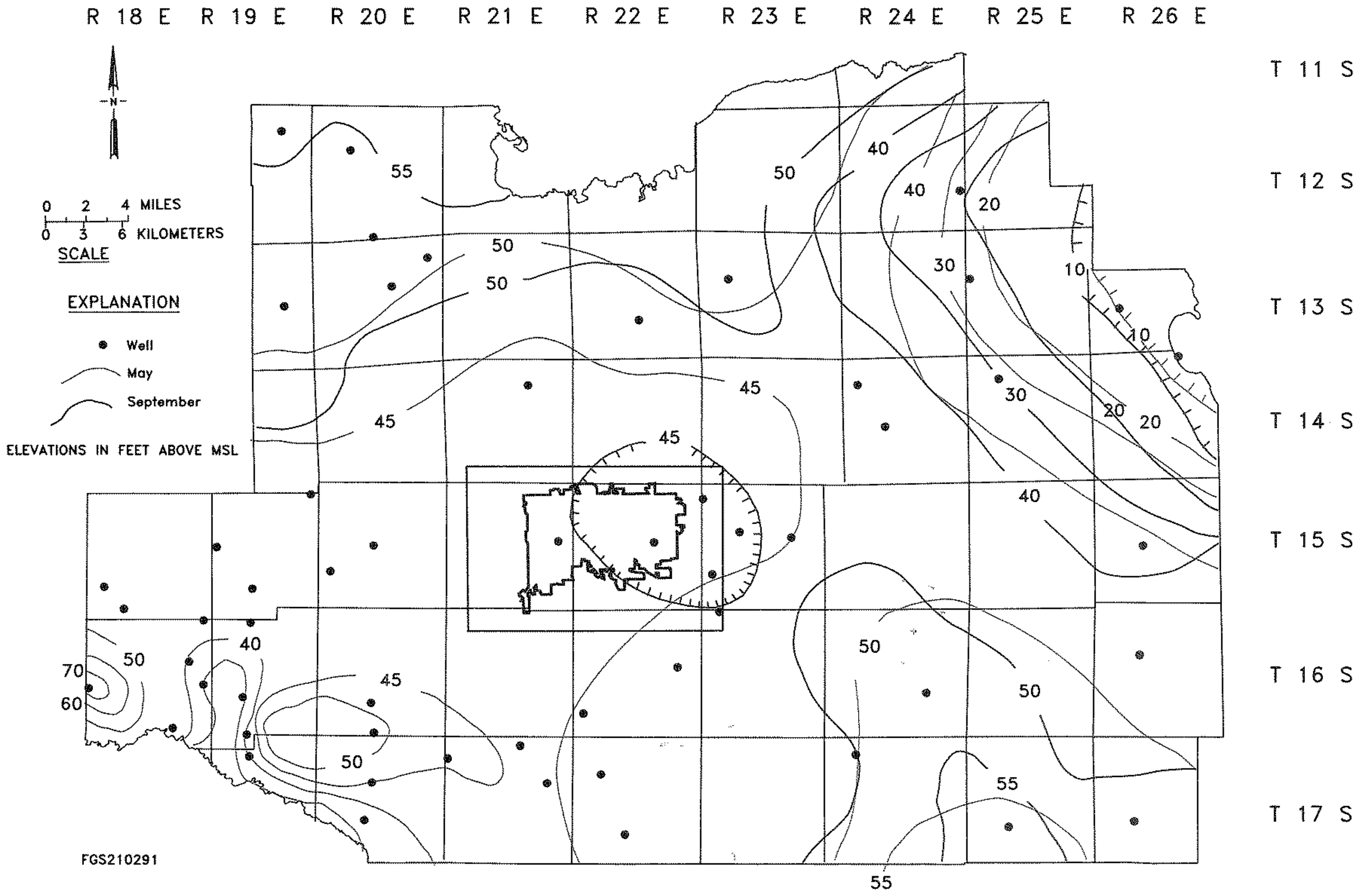


Figure 28a. Potentiometric surface of the upper Floridan aquifer system in Marion County, May 1978 and September 1978 (unpublished St. Johns River Water Management District data).

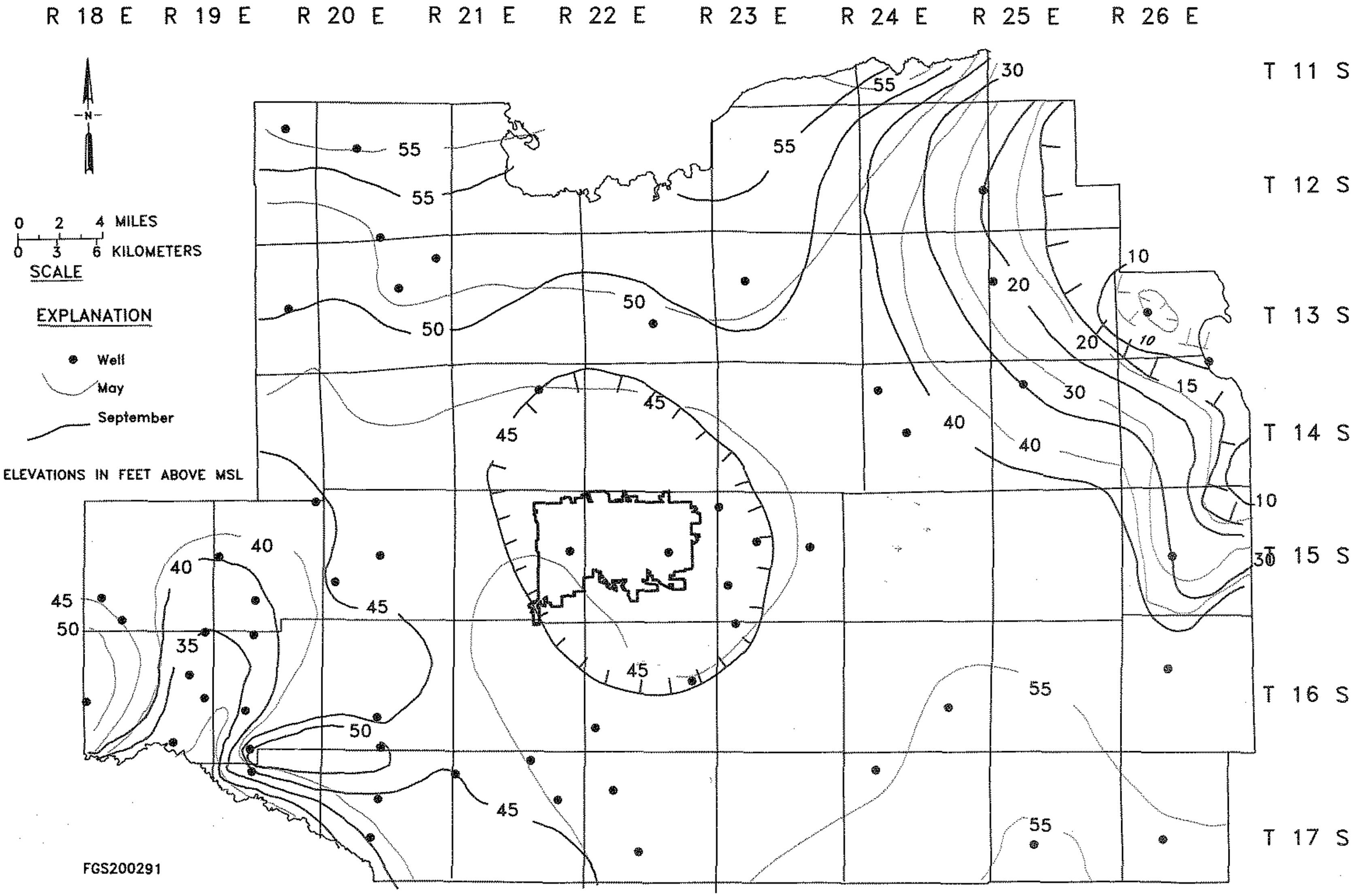


Figure 28b. Potentiometric surface of the upper Floridan aquifer system in Marion County, May 1980 and September 1980 (unpublished St. Johns River Water Management District data).

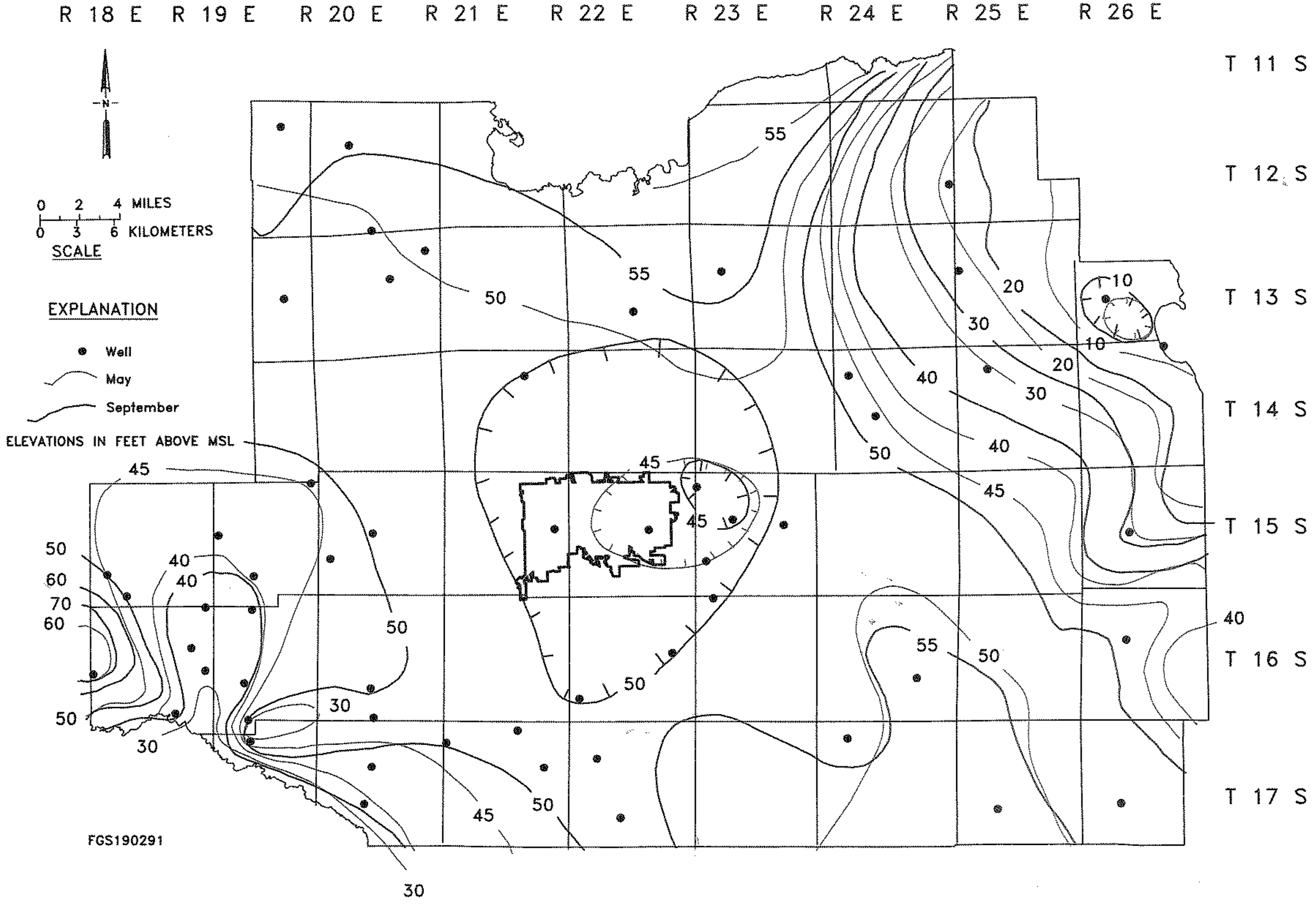


Figure 28c. Potentiometric surface of the upper Floridan aquifer system in Marion County, May 1982 and September 1982 (unpublished St. Johns River Water Management District data).

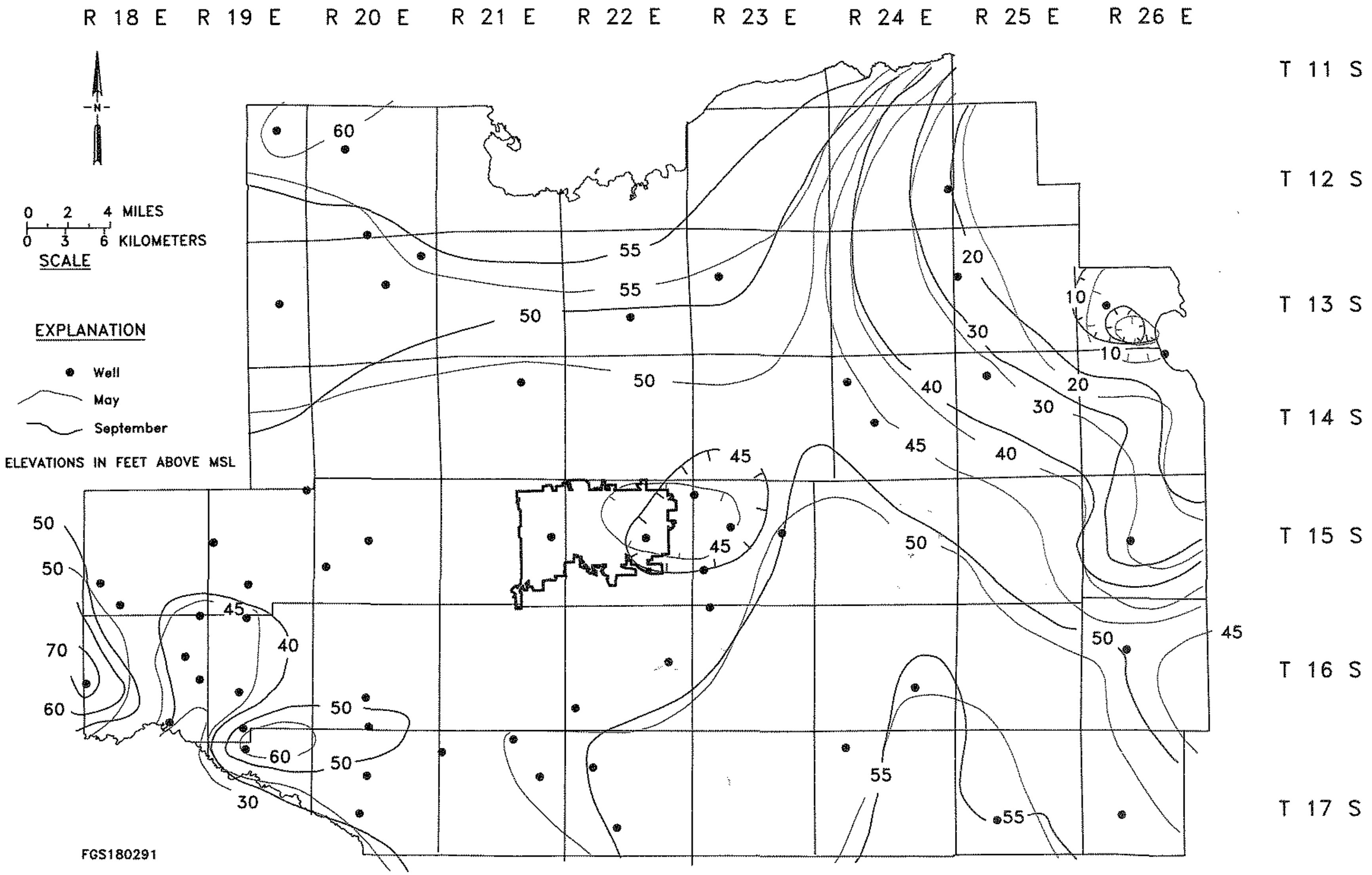


Figure 28d. Potentiometric surface of the upper Floridan aquifer system in Marion County, May 1984 and September 1984 (unpublished St. Johns River Water Management District data).

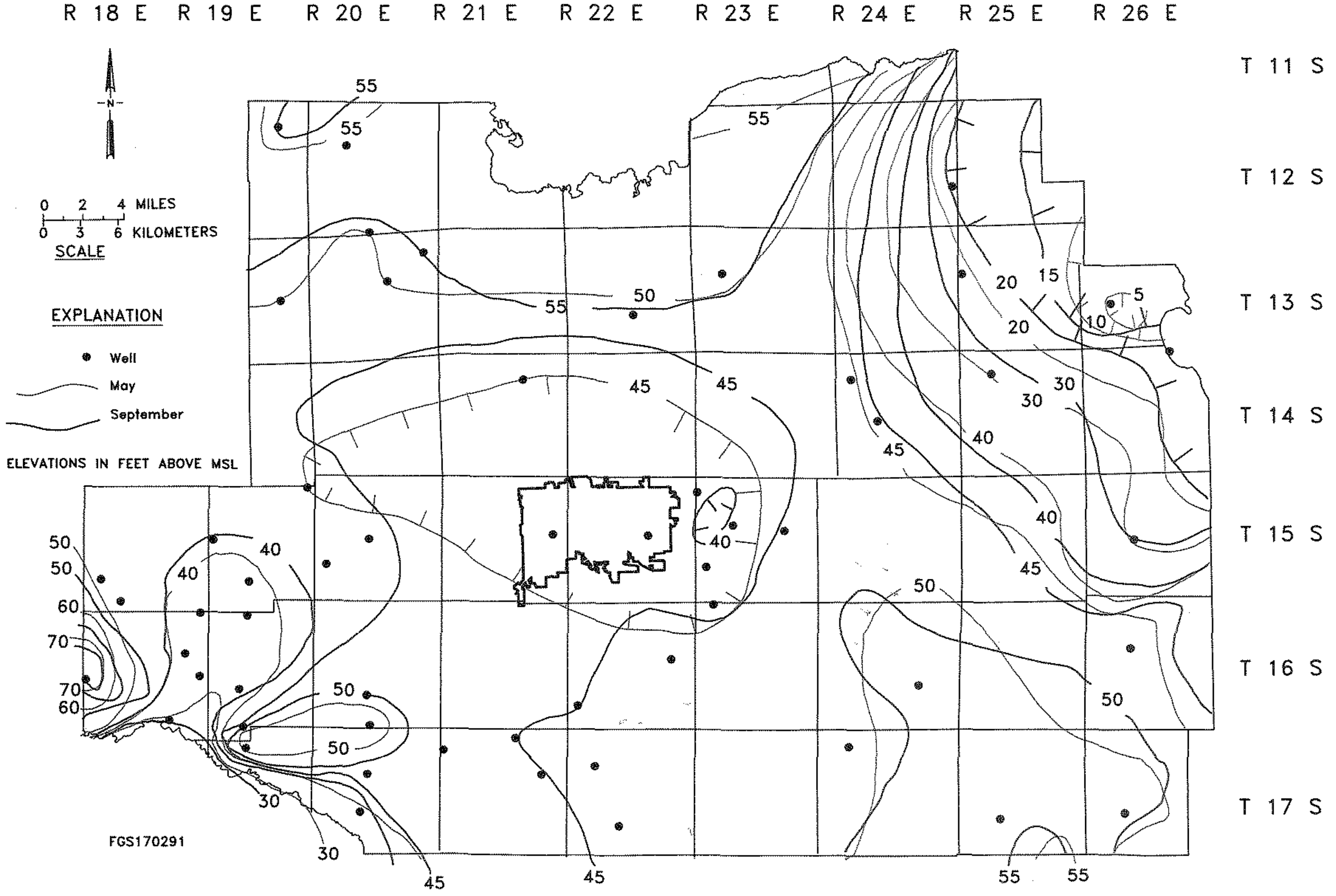


Figure 28e. Potentiometric surface of the upper Floridan aquifer system in Marion County, May 1986 and September 1986 (unpublished St. Johns River Water Management District data).

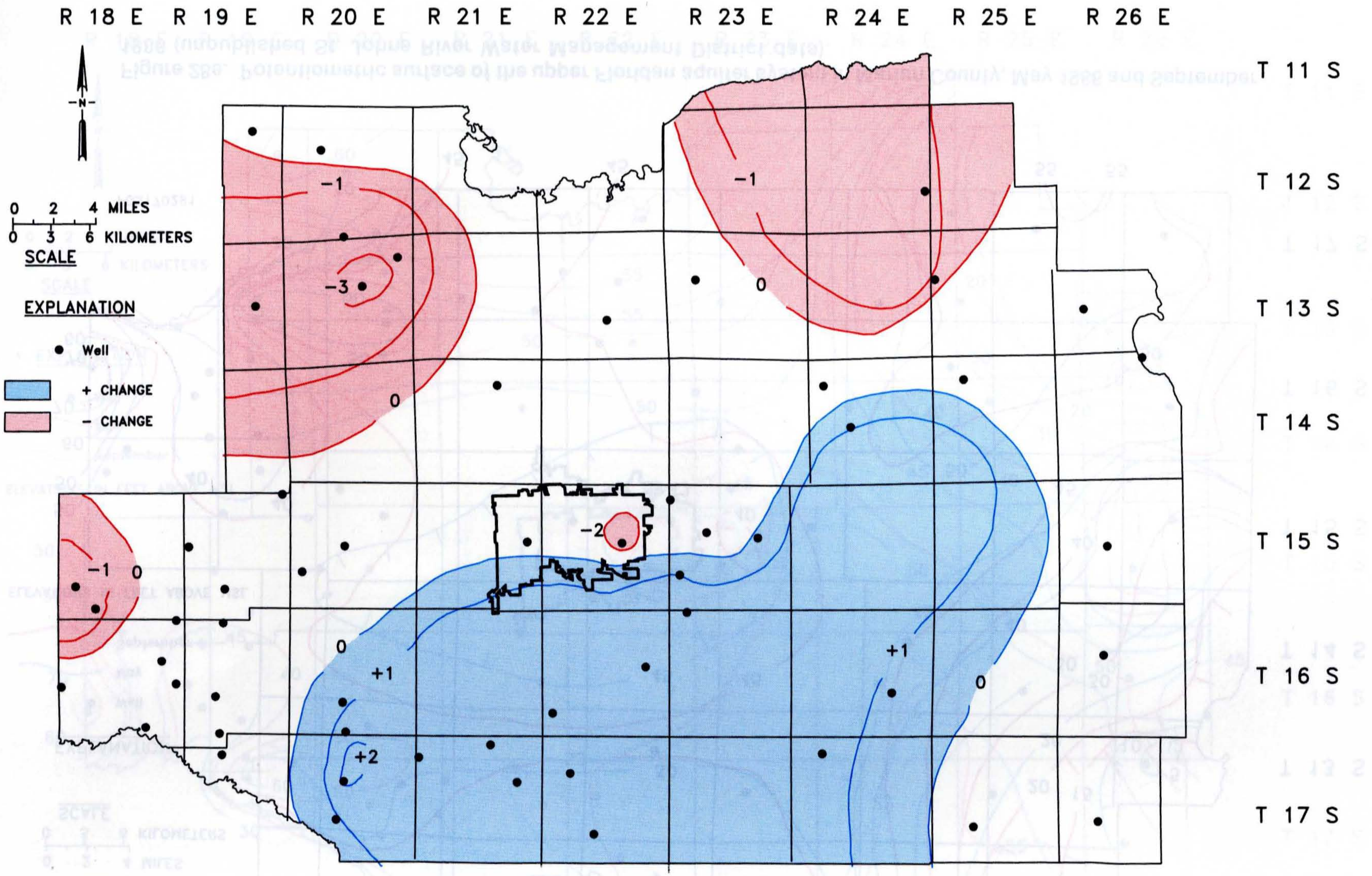


Figure 29. Change in the potentiometric surface of the upper Floridan aquifer system from September 1987 to May 1988 (unpublished St. Johns River Water Management District data).

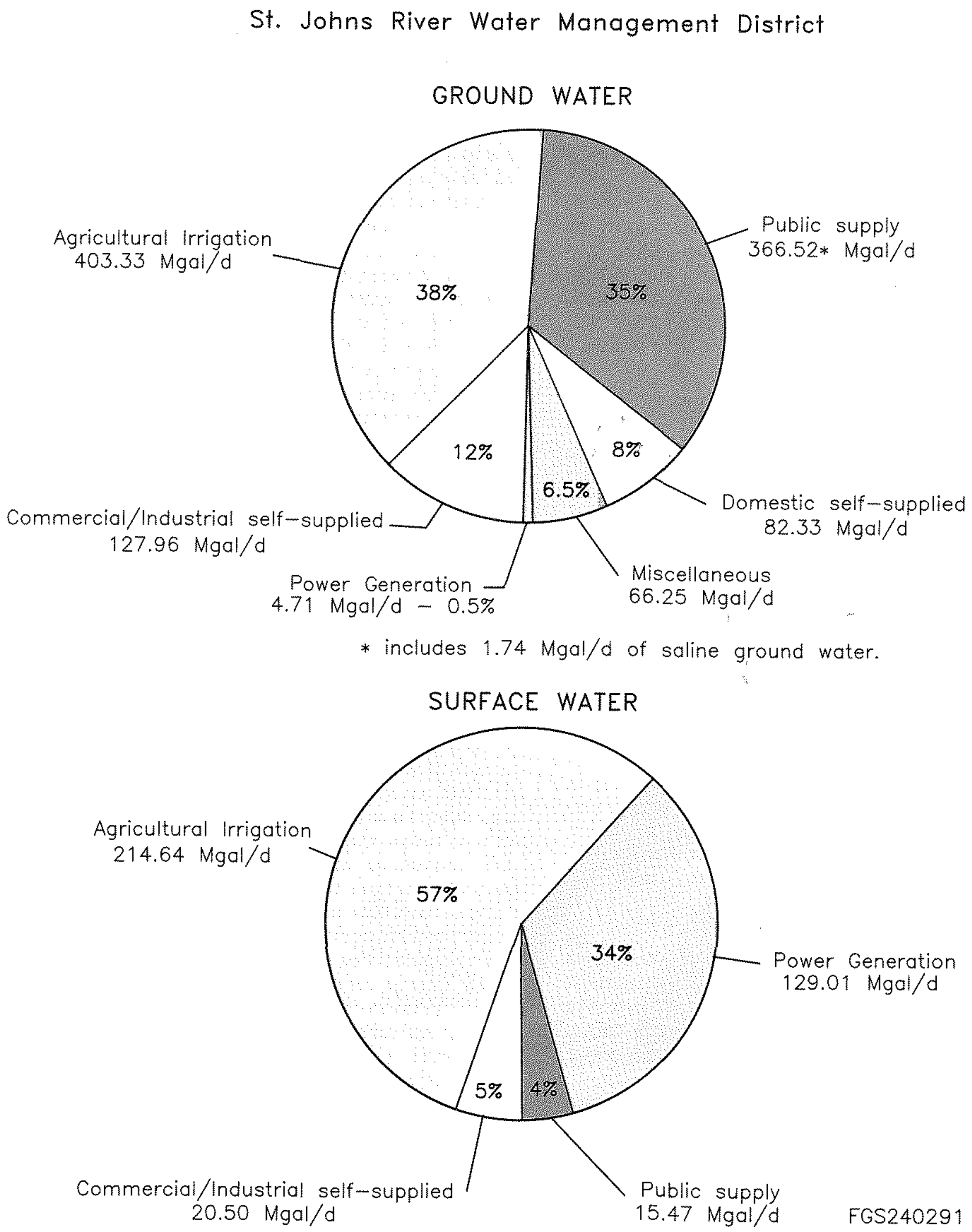


Figure 30. Fresh ground and surface water withdrawals by category, 1986, in the St. Johns River Water Management District (after Marella, 1988).

The commercial/industrial water use in Marion County (primarily in the study area) increased from 0.3 to 2.6 million gallons/day between 1975 and 1985. This amounts to a dramatic 780 percent increase, a strong indication of economic and population growth.

The total extraction of ground water from the underlying aquifer systems in Marion County for all uses amounted to 33.36 million gallons/day for 1986. This total fresh water use in the county, excluding thermoelectric power generation, increased by 37 percent in the period from 1975 to 1985 and eight percent from 1985 to 1986.

MINERAL RESOURCES

The following is a general discussion of the economic geology of the Ocala area. It is not intended to be a complete investigation leading to immediate industrial development because, in many cases, the data represent information on a single outcrop, pit or mine. However, where the data are favorable, they may indicate that certain areas might warrant further investigation and consideration in land-use planning. Figure 31 is a mineral resource map designed to present an overview of the major mineral commodities in and around Ocala (Hoenstine et al., 1988). Factors such as thickness of overburden as well as the quality and volume of the deposit will affect the mining of the mineral commodity at any specific site. The following is a discussion of the limestone, sand, and more general undifferentiated resources present in the area.

LIMESTONE

Limestone deposits of considerable economic value are present in Marion County. Figure 31 shows the distribution of the limestone deposits in Marion County. High calcium Ocala Group limestones lie at or near the surface throughout much of west-central Marion County.

The Ocala Group limestones have been mined in Marion County for many years as indicated by the numerous active and inactive quarries present throughout the county (Figure 31). As a point of interest, Marion County has one of the highest concentrations of limestone mines in the state. These mines are generally confined to the west-central part of the county. A number of inactive mines are present in the north-central portion of Ocala and one active mine is less than one mile north of the study area (Figure 32).

All companies mining limestone in the county employ the open pit method for extracting the rock. This method uses heavy equipment for the removal of vegetation and overburden prior to mining a new quarry. The amount of overburden can vary from a few inches to as much as 50 feet (Hoenstine et al., 1988). For example, areas in the southwestern part of Marion County have thick deposits of overburden which may have potential as a local source of fill. After clearing the area to be mined, shot holes are frequently drilled into the rock and the quarry face is shattered by blasting. The shattered rock is then loaded by dragline or front-end loader into trucks and transported to rock crushers for processing. This process involves size reduction and subsequent screening to obtain the various rock size fractions (Campbell, 1986).

The Ocala Group limestones are presently mined by a number of companies including Stavola Industries, Boutwell Construction, Monroe Mines, Ocala Bedrock, and Rainbow Marion Mines. This limestone is fairly soft and is removed using bulldozers and front-end loaders. The depth of mining is dependent on available equipment. Currently, some companies are mining limestone from a maximum depth of 65 feet below the water table by dragline. In many instances, this results in a total mined section of greater than 100-feet deep.

Limestone has a variety of uses, most of which are dependent on the specific deposit's physical properties or chemical composition. In Marion County, the primary use of the commodity is for roadbase material with minor amounts used for agricultural lime and the processing of glass sand.

Total production and resource estimates of limerock produced from the Ocala Group in the area are not available. However, the widespread occurrence and thickness of the Ocala Group limestone suggest that these deposits can be mined for many years.

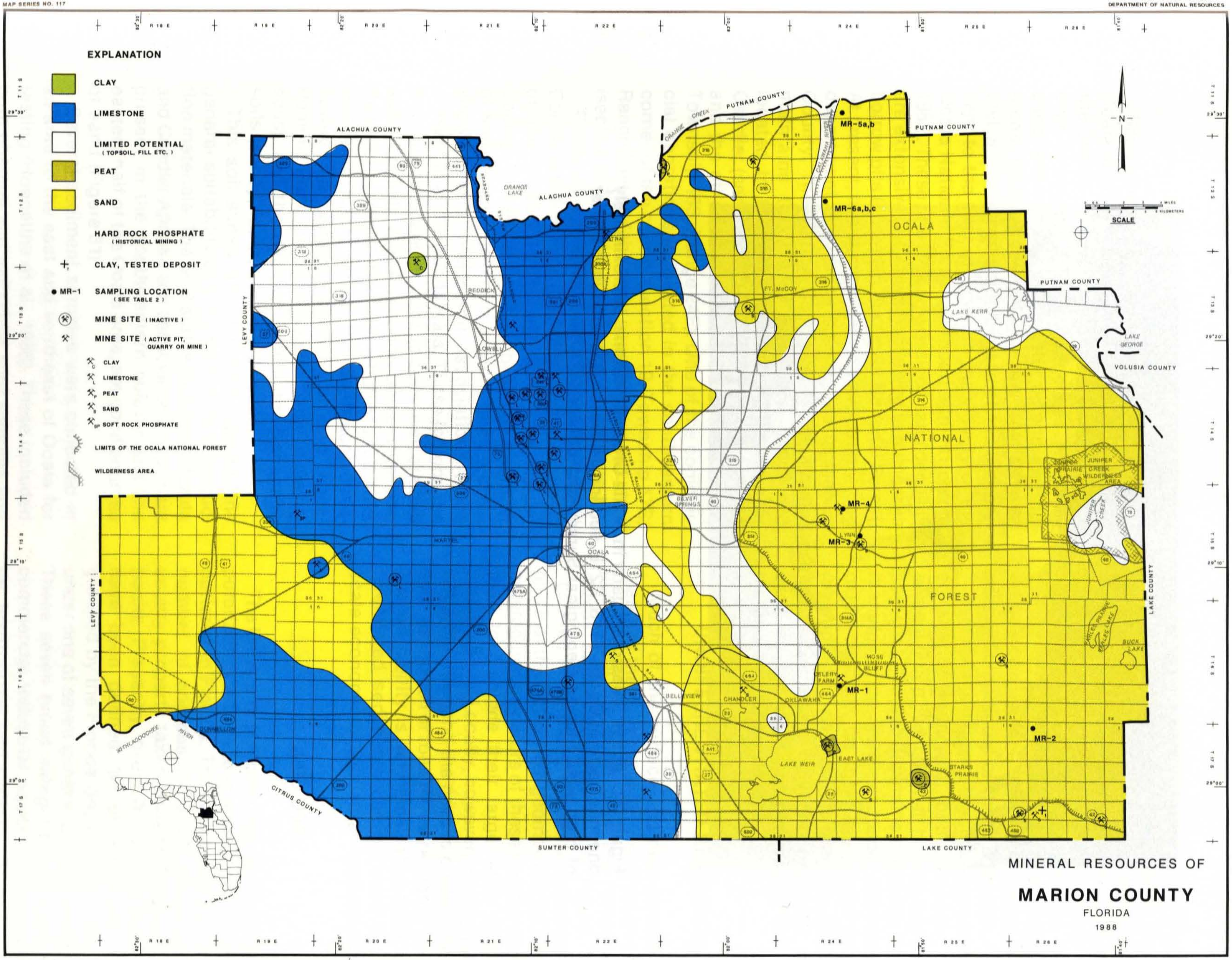


Figure 31. Mineral resources map of Marion County (Hoenstine et al., 1988).

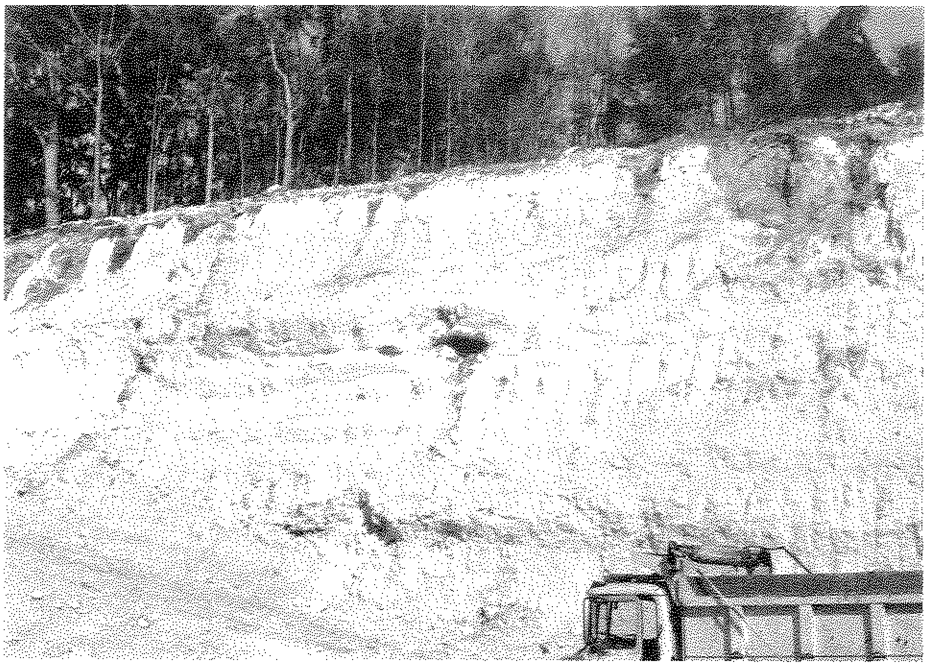


Figure 32. Active limestone quarry in Ocala Group limestone, approximately one mile north of Ocala, T14S, R21E, section 34. Note karst conduit in center of high wall. Florida Geological Survey photograph.

SAND

Sand covers much of the eastern third of the Ocala area. In the topographically low region of the Central Valley, sand forms a surface veneer over limestone. Thicker sequences of clayey sand and sandy clay cap the upland and hill areas. Thicknesses typically vary from 40 to 60 feet with a maximum thickness of 100 feet present to the east of Ocala in the vicinity of the Ocala National Forest (Cathcart and Patterson, 1983). These fine to coarse-grained sand deposits are extensive and can be observed in numerous borrow pits located in the Ocala National Forest. At present, two commercial and two county road department operations are located in Marion County. The Marion County Road Department maintains two clayey sand pits, which are located to the southeast of Ocala, one near Candler (section 26, Township 16S, Range 22E) and the other one at Celery Farm (section 27, Township 16S, Range 24E). One of the commercial operations is located in the southeastern corner of the county (section 19, Township 17S, Range 26E) and the other near the town of Lynne (section 3, Township 15S, Range 24E) (Figure 31).

Figure 33 is modified from a United States Soil Conservation Service (USSCS) map showing part of the USSCS (1979) soil survey of Marion County. This survey, which is based on a number of soil samples taken to a depth of 80 inches, shows several major soil associations to be present in and around Ocala. These include the Astatula and Candler-Apopka soils (well drained sandy soils), the Arredondo-Gainesville and Kendrick-Hague-Zuber and Bluff-Martel soils (sandy to loamy soils), the Sparr-Lochloosa-Tavares and Eureka-Paisley-Eaton and Lynee-Pomona-Pompano soils (sandy, loamy to clayey soils), and the Blichton-Flemington-Kanapaha soils (sandy, loamy and clayey soils).

This soil survey also provides data on the general suitability of soils for use as construction materials. The SCS states that the Astatula and Candler-Apopka soil associations, which are present in the southwestern quarter and the eastern half of the Ocala area, are good sources of sand (Figure 31).

Several sediment samples were collected in an area to the east and southeast of Ocala for testing (Hoenstine et al., 1988). These included both channel and individual spot samples and were taken from selected existing pits (Figure 31).

Laboratory procedures involved in analyzing the samples consisted of drying then quartering using a riffle type sample splitter. One quarter was then weighed and screened using a U.S. Standard Sieve Series. Data obtained are presented in Table 4 (Hoenstine et al., 1988). This information can be useful in assessing the economic potential of these deposits.

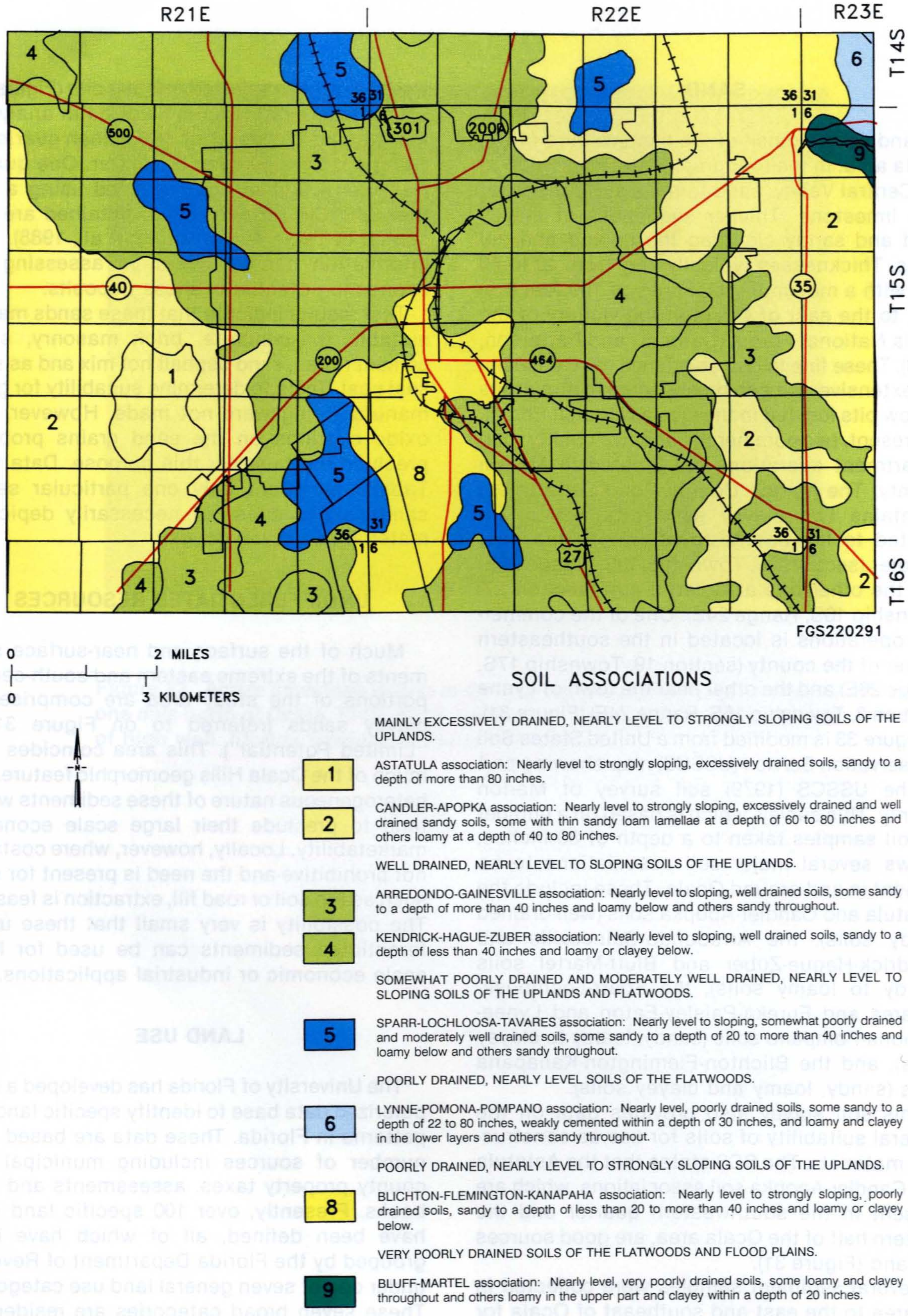
Test results indicate that these sands may be suitable for concrete, brick masonry, sand-cement riprap, sand-asphalt hot mix and as sand seal coat. Tests to determine suitability for glass manufacturing were not made. However, iron oxide coatings on the sand grains probably preclude their use for this purpose. Data from Table 3 represent only one particular set of samples and does not necessarily depict all material in a given deposit.

UNDIFFERENTIATED RESOURCES

Much of the surface and near-surface sediments of the extreme eastern and south-central portions of the study area are comprised of clayey sands (referred to on Figure 31 as "Limited Potential"). This area coincides with much of the Ocala Hills geomorphic feature. The heterogeneous nature of these sediments would tend to preclude their large scale economic marketability. Locally, however, where costs are not prohibitive and the need is present for uses such as top soil or road fill, extraction is feasible. The possibility is very small that these undifferentiated sediments can be used for large scale economic or industrial applications.

LAND USE

The University of Florida has developed a computerized data base to identify specific land use patterns in Florida. These data are based on a number of sources including municipal and county property taxes, assessments and platbooks. Presently, over 100 specific land uses have been defined, all of which have been grouped by the Florida Department of Revenue under one of seven general land use categories. These seven broad categories are residential, commercial, industrial, agricultural, governmental, institutional and miscellaneous.



SOIL ASSOCIATIONS

MAINLY EXCESSIVELY DRAINED, NEARLY LEVEL TO STRONGLY SLOPING SOILS OF THE UPLANDS.

1 ASTATULA association: Nearly level to strongly sloping, excessively drained soils, sandy to a depth of more than 80 inches.

2 CANDLER-APOPKA association: Nearly level to strongly sloping, excessively drained and well drained sandy soils, some with thin sandy loam lamellae at a depth of 60 to 80 inches and others loamy at a depth of 40 to 80 inches.

WELL DRAINED, NEARLY LEVEL TO SLOPING SOILS OF THE UPLANDS.

3 ARREDONDO-GAINESVILLE association: Nearly level to sloping, well drained soils, some sandy to a depth of more than 40 inches and loamy below and others sandy throughout.

4 KENDRICK-HAGUE-ZUBER association: Nearly level to sloping, well drained soils, sandy to a depth of less than 40 inches and loamy or clayey below.

SOMEWHAT POORLY DRAINED AND MODERATELY WELL DRAINED, NEARLY LEVEL TO SLOPING SOILS OF THE UPLANDS AND FLATWOODS.

5 SPARR-LOCHLOOSA-TAVARES association: Nearly level to sloping, somewhat poorly drained and moderately well drained soils, some sandy to a depth of 20 to more than 40 inches and loamy below and others sandy throughout.

POORLY DRAINED, NEARLY LEVEL SOILS OF THE FLATWOODS.

6 LYNNE-POMONA-POMPANO association: Nearly level, poorly drained soils, some sandy to a depth of 22 to 80 inches, weakly cemented within a depth of 30 inches, and loamy and clayey in the lower layers and others sandy throughout.

POORLY DRAINED, NEARLY LEVEL TO STRONGLY SLOPING SOILS OF THE UPLANDS.

8 BLICHTON-FLEMINGTON-KANAPAHA association: Nearly level to strongly sloping, poorly drained soils, sandy to a depth of less than 20 to more than 40 inches and loamy or clayey below.

VERY POORLY DRAINED SOILS OF THE FLATWOODS AND FLOOD PLAINS.

9 BLUFF-MARTEL association: Nearly level, very poorly drained soils, some loamy and clayey throughout and others loamy in the upper part and clayey within a depth of 20 inches.

Figure 33. General soil map of Ocala study area (after U.S. Soil Conservation Service Soil Survey of Marion County, 1979).

Table 4. Screen analyses of sand samples in Marion County, Florida (Hoenstine et al., 1988).

DEPOSITS			LABORATORY TEST DATA SCREEN ANALYSIS SIEVE NO. AND CUMULATIVE WEIGHT PERCENT RETAINED							
SAMPLE NO.	LOCATION (T,R,SEC.)	METHOD OF SAMPLING	4	8	16	30	50	100	200	*FINENESS MODULUS
MR-1	16S,24E,22ac	CHANNEL	-	1.070	11.22	44.560	73.580	94.540	97.560	3.23
MR-2	17S,26E,5ba	CHANNEL	-	0.030	1.520	10.480	28.960	79.460	94.770	2.15
MR-3	15S,24E,14da	CHANNEL	-	-	1.230	27.080	55.890	84.980	96.690	2.66
MR-4	15S,24E,3dc	SPOT	-	0.050	6.300	35.100	56.580	88.050	99.700	2.86
MR-5a	11S,24E,28bd	CHANNEL	-	3.090	12.700	35.570	58.220	90.850	97.990	2.98
MR-5b	11S,24E,28bd	CHANNEL	-	-	5.010	47.680	82.740	94.910	97.800	3.28
MR-6a	12S,24E,20ab	CHANNEL	-	2.080	14.680	42.520	39.080	82.030	94.900	2.95
MR-6b	12S,24E,20ab	CHANNEL	-	0.400	12.870	39.750	52.330	71.910	95.220	2.72
MR-6c	12S,24E,20ab	CHANNEL	-	0.220	3.760	12.030	27.150	76.150	95.540	2.15

*FINENESS MODULUS: A MEANS OF EVALUATING SAND AND GRAVEL DEPOSITS WHICH CONSISTS OF SIEVING SAMPLES THROUGH A STANDARDIZED SET OF SIEVES, ADDING THE CUMULATIVE WEIGHT PERCENTAGES OF THE INDIVIDUAL SCREENS, DIVIDING BY 100, AND COMPARING THE RESULTANT FINENESS MODULUS NUMBER TO VARIOUS SPECIFICATION REQUIREMENTS (BATES AND JACKSON, 1980).

Figures 34 through 40 are computer generated, color-coded illustrations that show either the number of parcels or the acreage within a section (640 acres) which are devoted to the stated land use. These numbers are based on percentages of the value in the section on the map which contains the greatest numerical sum (in parcels of acreage as indicated) of that specific land use. For example, the section in Marion County which has the greatest number of parcels for the residential land use, contains 1,000 parcels (Figure 34). This section is shown on the map in the same color as the 81 to 100 percent category. The other sections are shown in colors representing intervals from 1 to 100 percent, based on this 100 percent value of 1,000.

The residential category includes vacant residential, single family, mobile homes, condominiums and multi-family units. As Figure 34 shows, this category is well represented in the Ocala area with a number of the sections falling in the 81 to 100 percent category. The densest residential areas are located adjacent to the central part of the city. The lightest residential development occurs in northwest Ocala. As would be expected, Ocala, which is the largest city in Marion County, has the highest concentration of maximum residential values in the county. Residential housing units in Ocala totaled 18,871 units, 21.18 percent of the total in Marion County in 1988 (Thompson, 1988).

The proximity of the Ocala Group limestone to land surface in the western half of the study area is a cause for concern when planning residential development. The presence of a thin cover of undifferentiated sands and clays and Hawthorn Group sediments overlying limestone bedrock in this area is a situation conducive to the development of sinkholes and potential structural damage. In addition, the geology of this area permits easy access of potential contaminants to this limestone unit which is the upper part of the Floridan aquifer system. Extensive use of septic tanks and associated drain fields here has the potential for significant degradation of ground-water quality.

Similarly, the surficial aquifer system present in the thick deposits of Undifferentiated Sands and Clays in the eastern half of the study area could experience contamination by residential developments using drain fields and septic tanks. Additionally, the use of pesticides and fertilizers on residential lawns and gardens could degrade water quality of both the Floridan aquifer system in the western half of the study area and the surficial aquifer system in the eastern half.

The commercial land use classification includes vacant commercial property, department stores, supermarkets, regional and community shopping centers, professional services buildings, service stations, parking lots, restaurants, motels, golf courses, and tourist attractions. Except for the City of Ocala, this category is lightly represented throughout the county (Figure 35). The localized commercial activity recorded in Ocala is in part a consequence of the city's rapid development and the diversity of services associated with this growth.

Some commercial categories, such as service stations and large parking lots associated with malls and supermarkets, pose serious environmental threats to the fragile protection of the ground water offered by the thin soil cover over the limestone. Specifically, leaking or improperly installed underground fuel storage tanks could cause significant degradation of the limestone aquifer. This is of special concern in the central part of Ocala where the highest concentration of commercial activity occurs (Figure 35). Here, limestone is near to land surface and the associated ground water is highly susceptible to contamination. Also, runoff from improperly designed parking lots has the potential to infiltrate surrounding unpaved sediments which, in eastern and central Ocala, form a thin permeable cover over the Floridan aquifer system.

Ocala's industrial complex is similar to the commercial category in its diversity and concentration in the Ocala area (Figure 36). This activity includes light manufacturing, heavy equipment manufacturing, warehousing, canneries, and lumber yards. The area's large mobile home manufacturing plants are represented in this category.

The concentration of industrial activity in central and west-central Ocala poses risks similar to those of commercial activities. The proximity of the aquifer to land surface in this area and its susceptibility to contamination requires that effective procedures involving the usage and disposal of industrial chemicals must be implemented and strictly monitored.

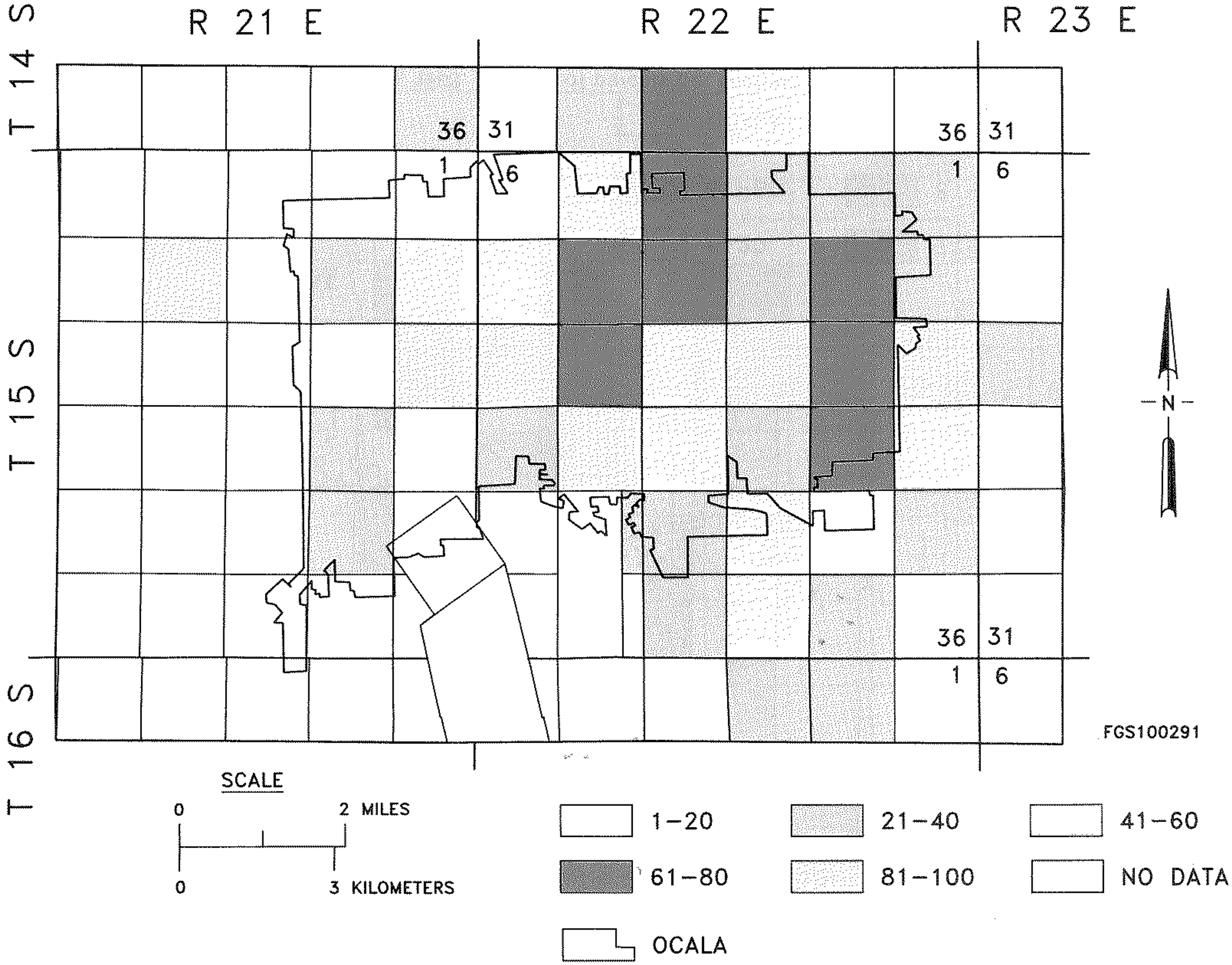


Figure 34. Residential land use, 1988. Number of parcels per section, 100% = 1,000 (from Hatchitt, 1989).

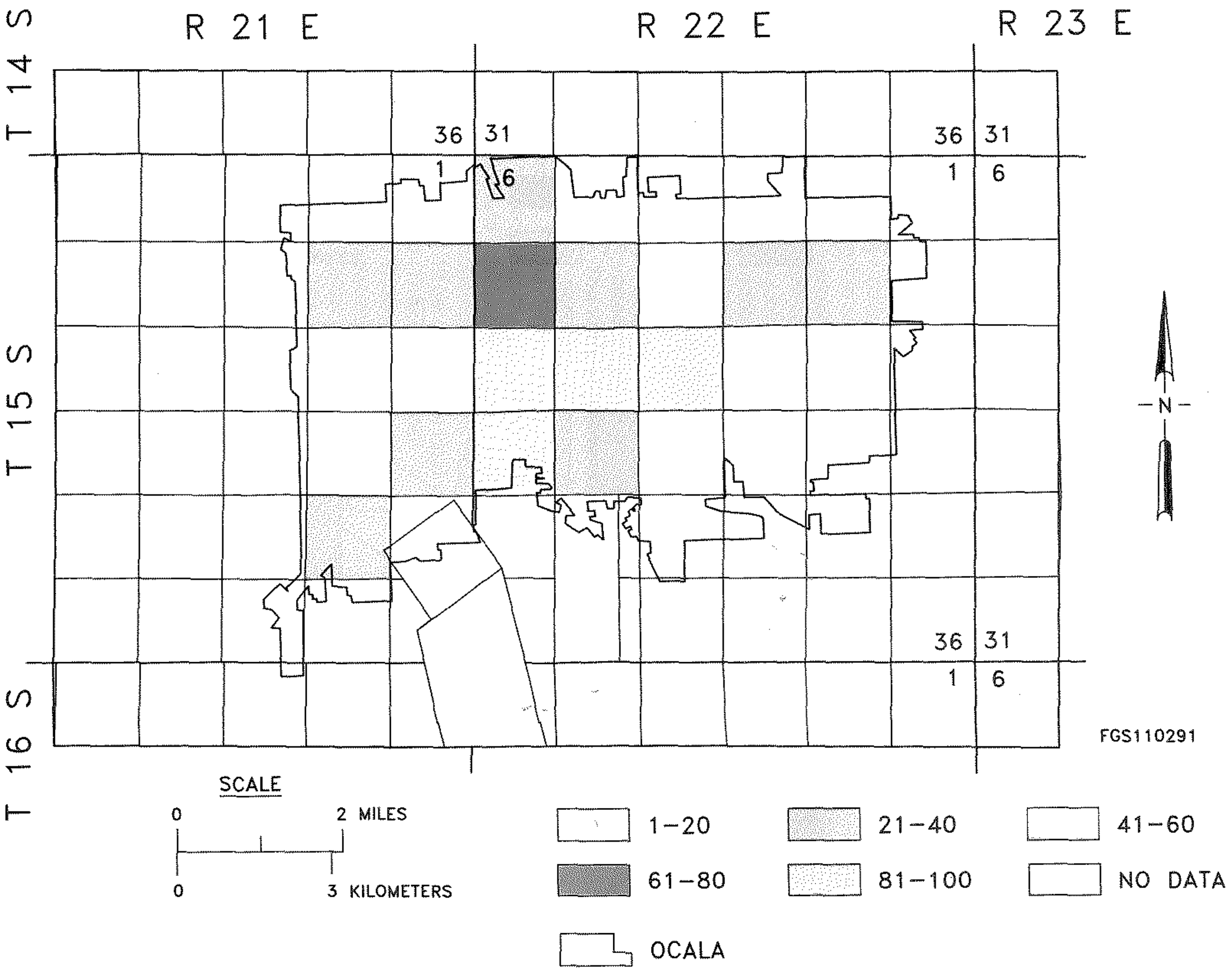


Figure 35. Commercial land use, 1988. Number of parcels per section, 100% = 200 (from Hatchitt, 1989).

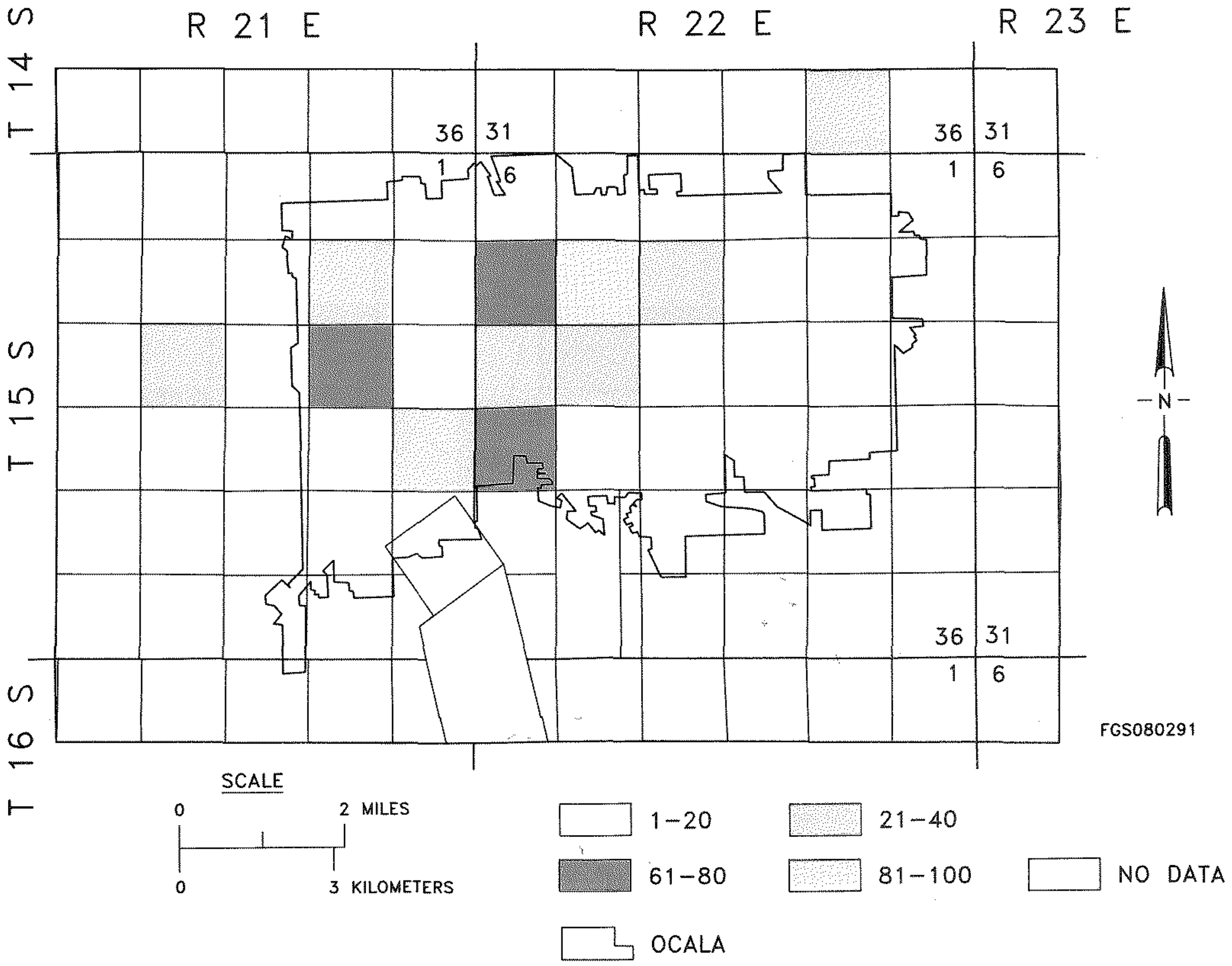


Figure 36. Industrial land use, 1988. Number of parcels per section, 100% = 100 (from Hatchitt, 1989).

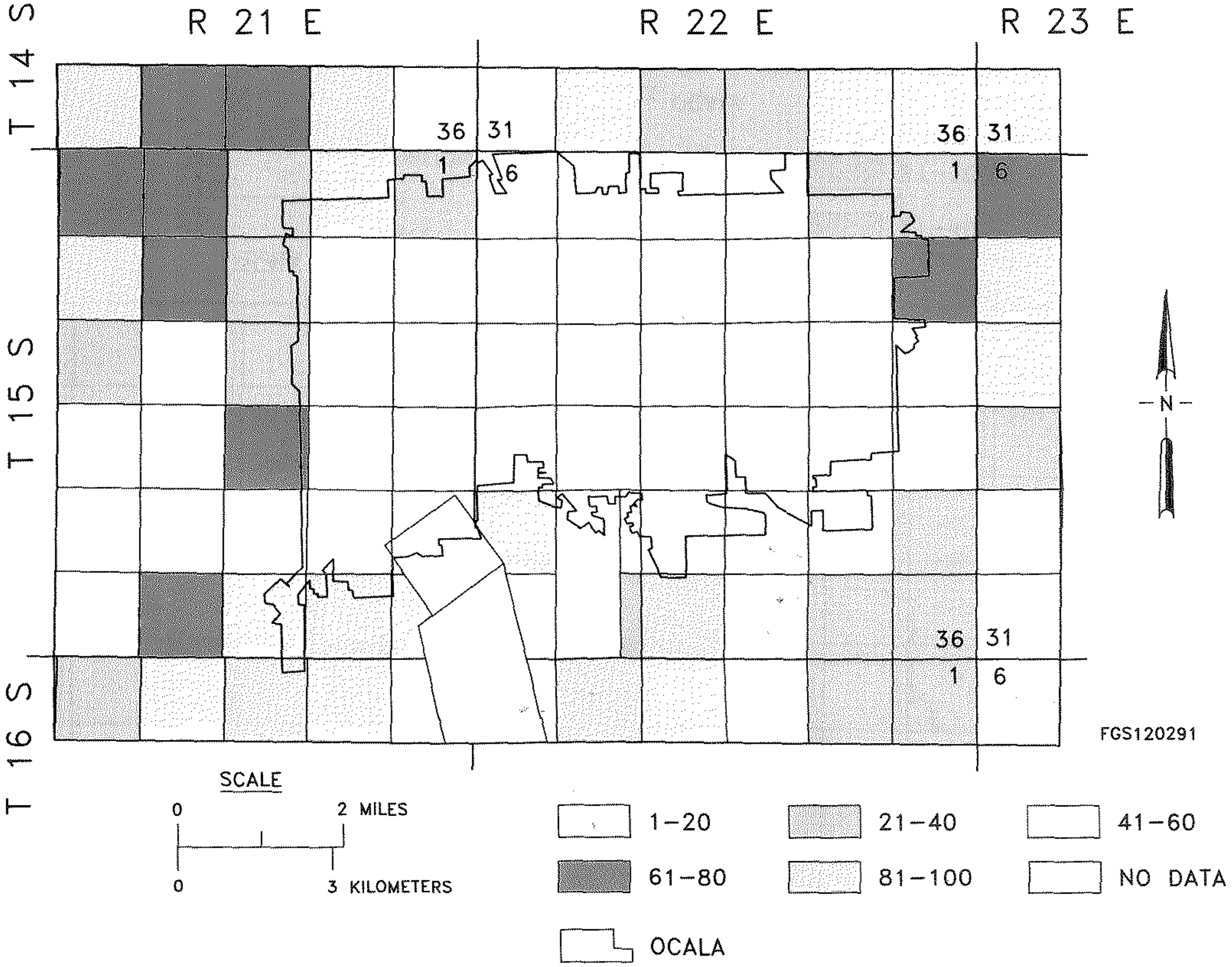


Figure 37. Agricultural land use, 1988. Number of parcels per section, 100% = 640 (from Hatchitt, 1989).

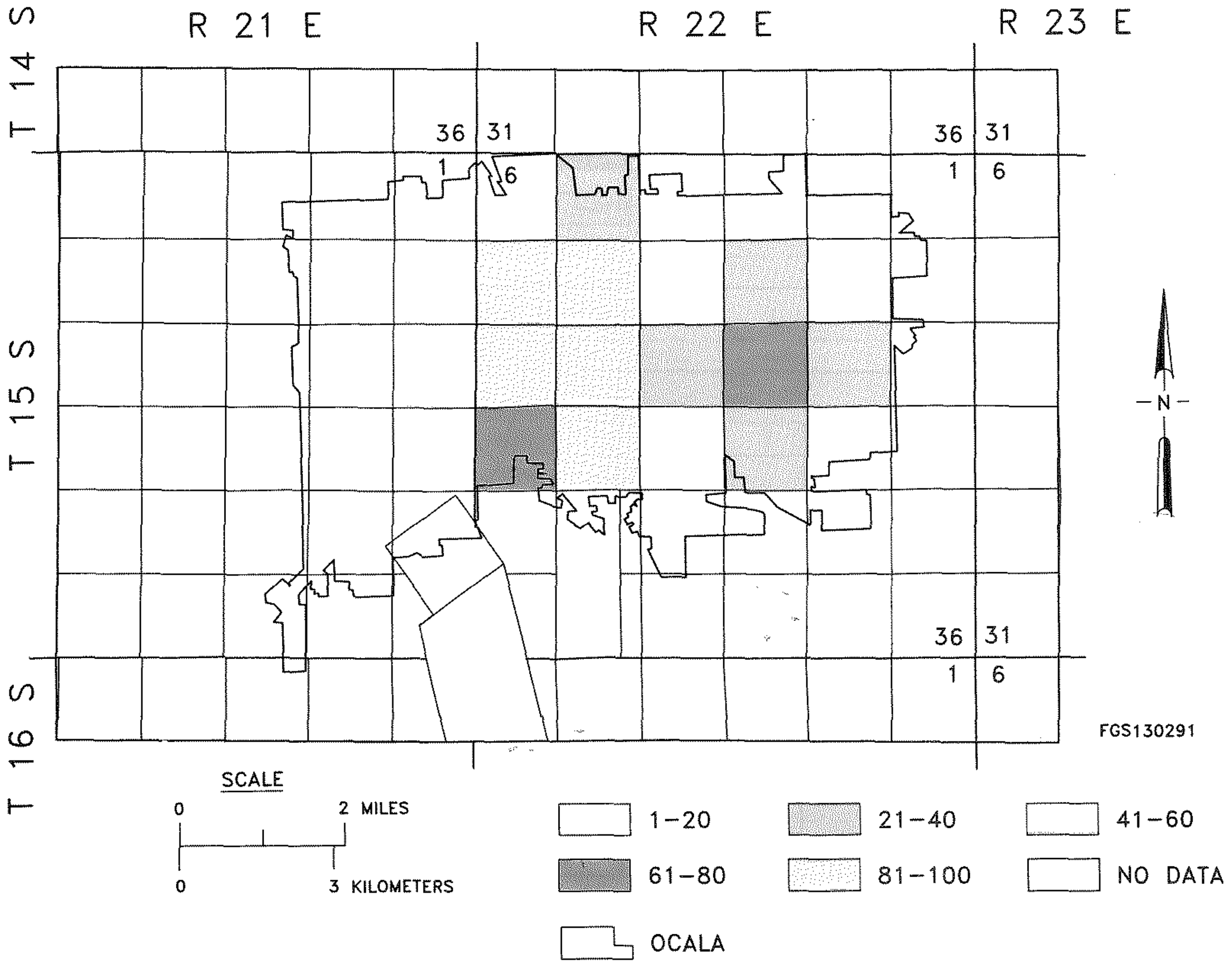


Figure 38. Governmental land use, 1988. Number of parcels per section, 100% = 20 (from Hatchitt, 1989).

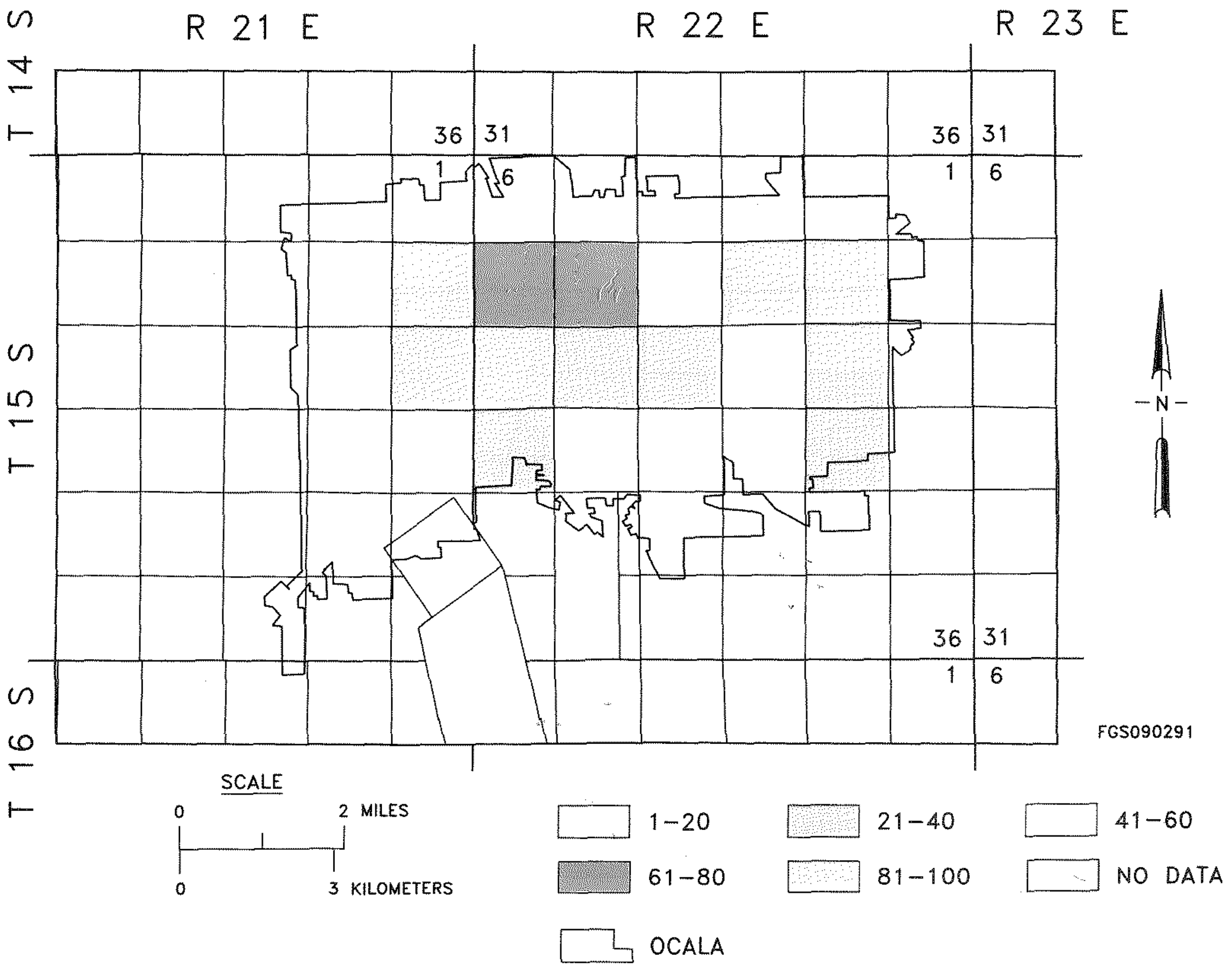


Figure 39. Institutional land use, 1988. Number of parcels per section, 100% = 20 (from Hatchitt, 1989).

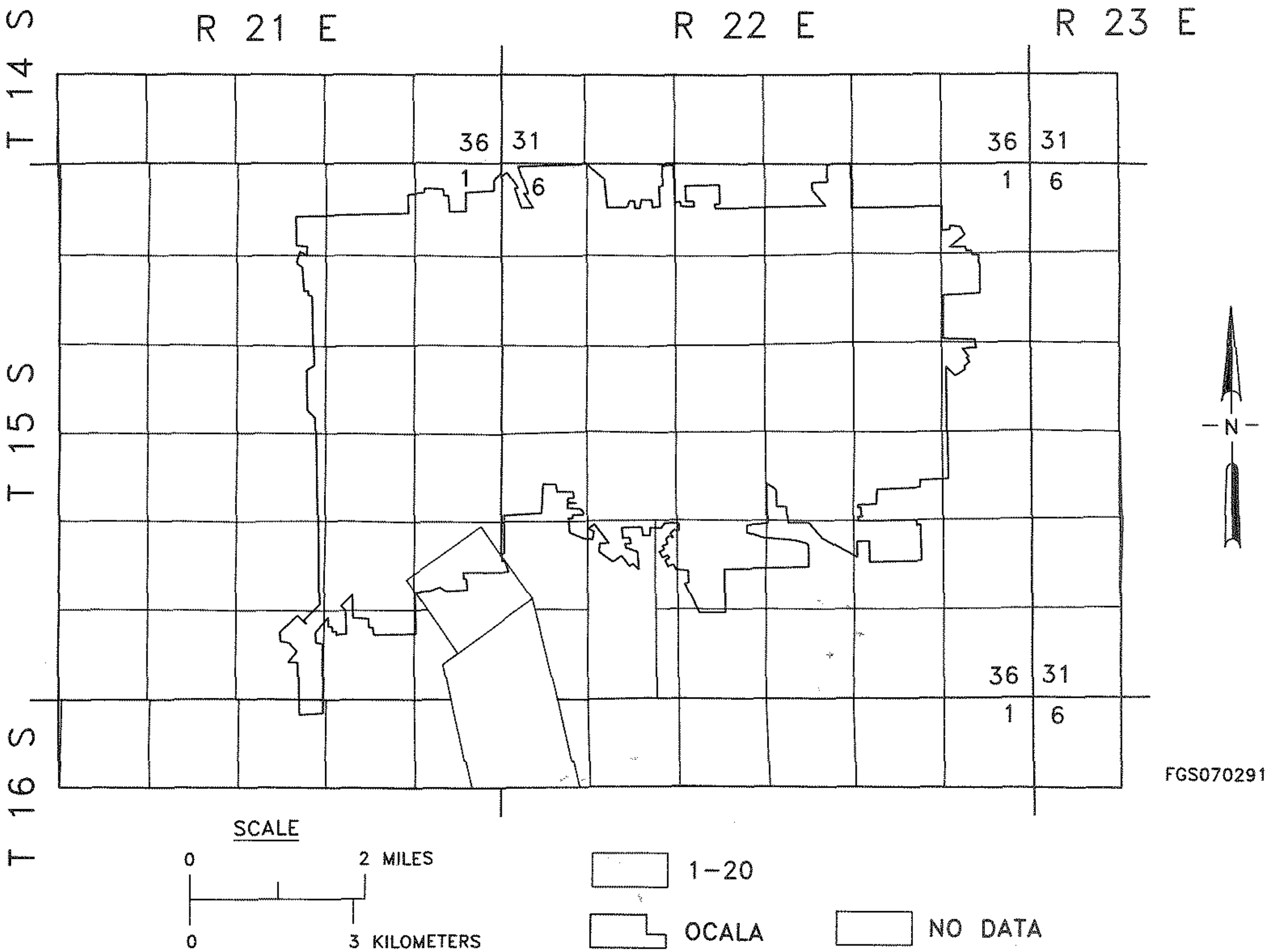


Figure 40. Miscellaneous land use, 1988. Number of parcels per section, 100% = 640 (from Hatchitt, 1989).

Agriculture is an extremely important component of Marion County's economy. In addition to vegetables, fruit, field crops, and ornamentals, Marion County is nationally recognized for its thoroughbred horse farms. Figure 37 shows that a significant percentage of the county is involved in agriculture. In contrast, the City of Ocala has a small amount of agricultural acreage. This may be reduced in the future as continued growth and development in the city and the county will doubtless expand in part at the expense of agriculture.

Large scale use of pesticides, herbicides, and fertilizers by the agricultural sector is an ever-present threat to Ocala's ground-water supply. Concentrations of agriculture in the northeastern part of the study area is of particular concern as the Floridan aquifer system occurs almost at land surface there, providing pollutants easy access to ground water.

As the county seat, Ocala has a number of city and county government activities. These activities are part of the governmental category which includes municipal government facilities (county and city), public colleges, hospitals and schools (Figure 38).

The institutional category is well represented in the Ocala area (Figure 39). It includes churches, private schools and colleges, private hospitals, clubs, convalescent homes and cultural organizations.

The miscellaneous category (Figure 40) is a general classification. It incorporates everything not covered by the above categories. These include such things as railroads, rivers, lakes, sewage disposal and rights-of-way of streets, roads, and ditches.

ENVIRONMENTAL HAZARDS ASSOCIATED WITH KARST

The karst terrain of the study area creates special conditions that are responsible for most of the area's environmental hazards, excluding such weather hazards as hurricanes. The prior discussion of the evolution of the local karst terrain pointed out the most important aspect of karst — its underground drainage system. Karst and its intimate relationship to the area's water resources dictates, to a large degree, the extent to which society's activities can stress the environment — and not create problems.

An adequate supply of fresh water is a keystone to a high standard of living, for public water supplies, for industrial demands, and for agricultural usage, such as irrigation farming. Because of karst there is very little surface water available; consequently, most of the area's water supplies are ground water from the Floridan aquifer system. Protection of the quality of the area's ground water must be of paramount concern in any planning, development, or regulatory context. Special conditions associated with karst hydrologic systems require special precautions and considerations.

The study area lies wholly within the drainage basin of Silver Springs. Faulkner (1973) analyzed regional surface and ground-water levels to determine the drainage basins of the Oklawaha River, and Rainbow and Silver Springs (Figure 41). Note that the springs' drainage basins lie partly within and partly outside the Oklawaha River's surface drainage basin divide, which was drawn along topographic highs. This anomalous situation is due to karst. The well developed underground drainage for the area provides rapid recharge to the shallow sand aquifers or to the limestone aquifer. Many of the sinkholes open directly into the limestone or they have permeable sediment fill which allows infiltration.

This situation illustrates the uncertainties in dealing with ground-water problems in karst terrain. Relative to the tiny pores in most sandy, unconsolidated sediments, the karstic porosity of the Floridan aquifer system's limestones are megascopic, as shown in Figures 20, 21, and 42. These cavernous openings in the limestone permit conduit flow to occur, analogous to flow in a system of open pipes. Countless sinkholes in the area provide direct, almost instantaneous, recharge to the aquifer. Recharge, in this context, refers to water from any source, along with entrained contaminants, that enter the Floridan aquifer system. The ability of these avenues of recharge to accept practically limitless quantities of surface water was dramatically demonstrated during the flooding of parts of Ocala as a result of torrential rains in April 1982, when nearly 12 inches of rain fell in one day (Figure 43).

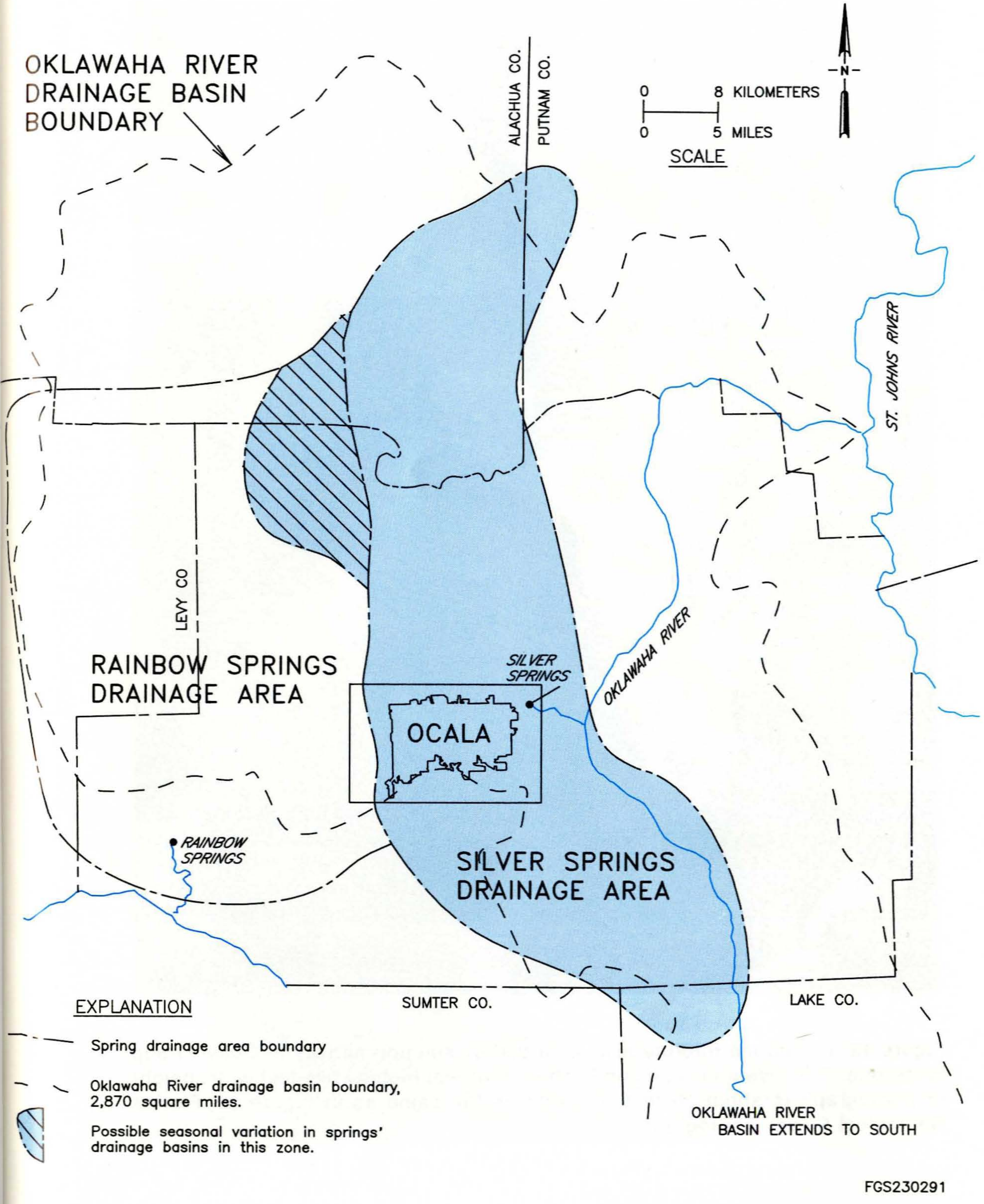


Figure 41. Drainage basin of the Oklawaha River with drainage basins of Silver and Rainbow Springs superimposed (modified after Faulkner, 1973).

Figure 42. Limestone fracture zone enlarged by solution activity in Ocala Group limestone. The cavernous opening is about four-feet high by two-feet wide; height of photograph is about 20 feet. Location is the same as in Figure 32. Florida Geological Survey photograph.

Figure 43. Flood waters recharging Floridan aquifer system through a sinkhole that opened up as a result of the April 1982 flood in Ocala. Ocala Group limestone is within two to three feet of surface here. Florida Geological Survey photograph.

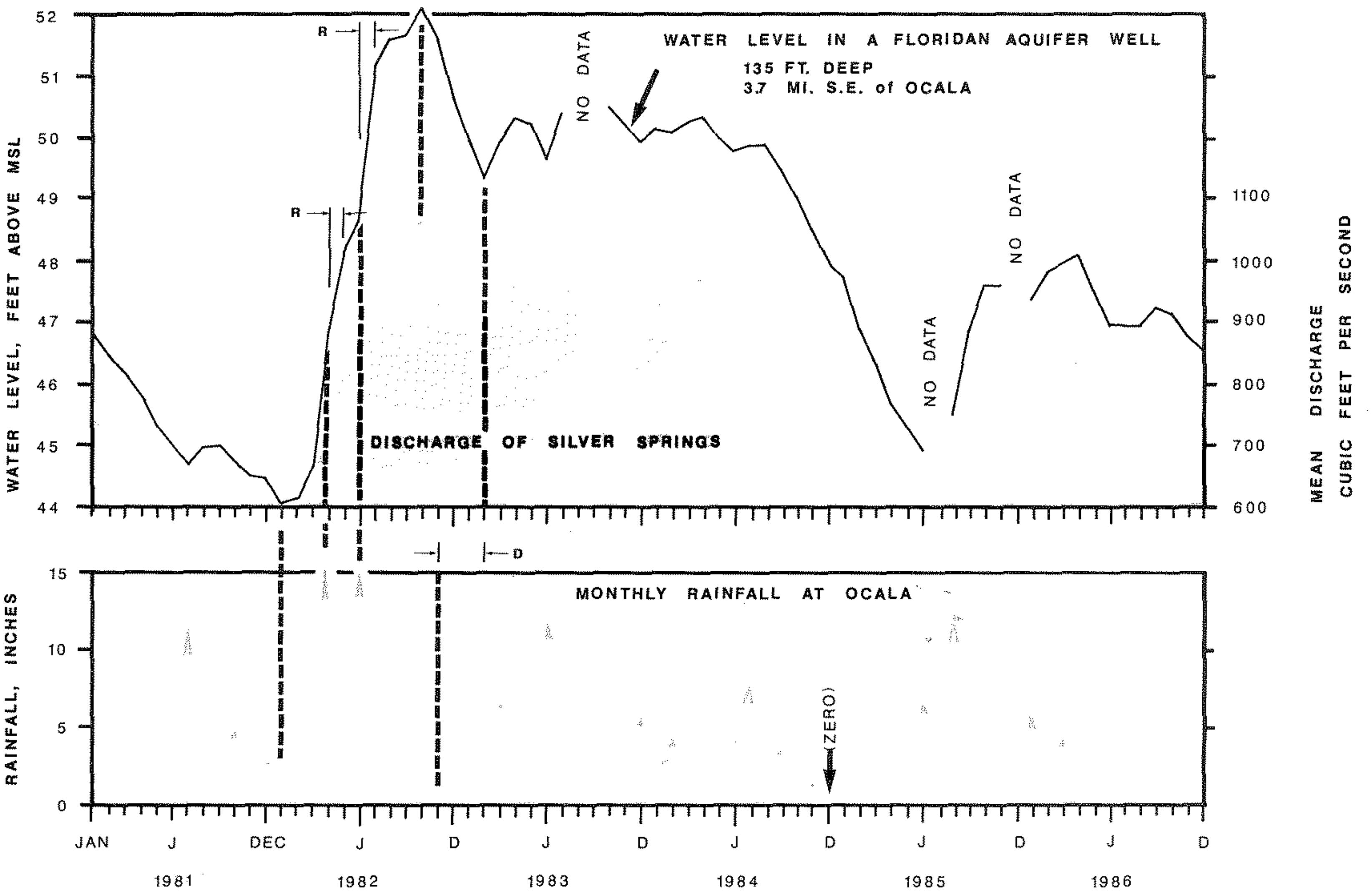


Figure 44. Graphs showing relationships among rainfall, ground-water levels in the Floridan aquifer system and discharge of Silver Springs. Note that all three graphs display very similar curves, which indicates a strong cause-effect relationship. Note the very short recharge lag-time (R) between major rainfall events and a rise in the water level in the Floridan aquifer system well, usually only a few days. The discharge lag-time (D) is longer and represents the delays due to the water's travel through recharge, storage within the aquifer, and eventual discharge at Silver Springs; this can vary from a few days to a few weeks. Data from U.S. Geological Survey, Water Resources Data, 1981-1986.

It is not difficult, therefore, to visualize how rapidly the cavernous porosity of the aquifer can transmit recharge through the system, from a point of entry, such as a sinkhole, to a point of discharge, such as a well or spring. Conduit flow would prevail in many cases, with transit times of only hours or days from point of entry to a point of discharge that could be several miles distant. Figure 44 illustrates the two most important characteristics of the Floridan aquifer system's response to hydrologic events in the Ocala area: (1) rapid recharge to the aquifer through karst features and thin soil cover over the limestone, and (2) rapid transit of water through the aquifer.

Up to a point, the natural workings of Ocala's hydrologic system can be considered favorable to society's activities. The area has plenty of rain, which can be easily recharged to the aquifer, providing large quantities of fresh water in storage, which can be easily tapped by wells. However, when society intrudes with some of its activities, which do not consider the workings of the karst hydrology, the results can be environmental problems. Examples of society's stresses to the karst environment are: large expanses of pavement and roofs, drainage wells for surface runoff, some types of agricultural and industrial practices, and landfills.

Paving and roofing remove large amounts of land that would otherwise be diffuse recharge areas, thereby concentrating runoff and recharge to smaller areas. As urbanization continues, this has the cumulative effect of concentrating sources of potential contaminants to the aquifer. The use of drainage wells to alleviate surface-water flooding problems also acts to concentrate potential contamination to the aquifer (Figure 18). In urban development plans there is a need to dedicate more green-belt open areas to offset the loss of recharge areas.

The over-application of fertilizers, pesticides, or the use of chemicals that are long-lived or non-biodegradable, and the over-application of irrigation water can create sources of contamination. New methods of irrigation, such as trickle delivery and root delivery, conserve large quantities of water while at the same time reducing the build-up of salts in the soil.

Urban growth inevitably brings construction and service industries, such as gas stations and merchandisers, or manufacturing plants. With very few exceptions in the past, most of these activities have been implicated as sources of pollution to surface or ground water. Before operating permits or business licenses are issued, permitting authorities should require an inventory of materials to be handled, processed or dispensed, as well as a plan that adequately addresses waste disposal practices at each location.

SOLID WASTE DISPOSAL

Past and current practices of open dumping and landfilling have been documented as sources of ground-water pollution in Florida's karst terrain (Hoenstine et al., 1987). Recent regulatory and engineering approaches are designed to prevent contaminants from leaving the landfills.

Managing solid waste is a monumental task that faces the nation. In many local areas it has become a critical task, demanding short-term solution. To avoid a garbage crisis in the near future it will be necessary to change the nation's attitude towards solid waste disposal, and to indulge in careful planning based on those changed attitudes. Instead of a "throw away" society we must become a "recycle and conserve" society.

Realize that the United States generates between 150–300 million tons of solid waste per year, about 4 to 8 pounds per person per day. Florida generates more than 13 million tons of solid waste per year, about 7 pounds per person per day. At the Marion County landfill, southeast of Ocala, the daily input varies from 600–650 tons per day — with peak inputs up to 1,000 tons per day (Earl Blankenship, Solid Waste Administrator, Marion County landfill, pers. comm., 1989). This means that, on the average, every person in Marion County generates from 6.5 to 10.9 pounds of solid waste per day. In recent years the disposal of these quantities of solid waste has resulted in a mountain, literally, being created southeast of Ocala; this truncated pyramidal mountain currently has a 10-acre footprint and rises 90 to 100 feet above the surrounding flat countryside (Figure 45). Three additional, similar mountains will rise nearby before the landfill reaches its planned capacity.

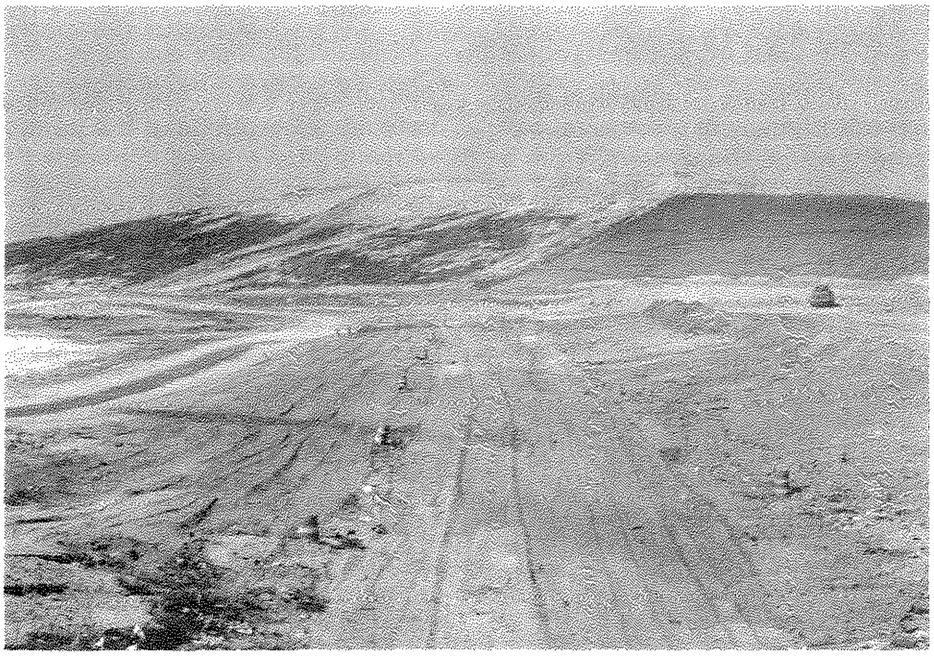


Figure 45. Finished cell of the Marion County landfill, view to north. Florida Geological Survey photograph, February 1989.

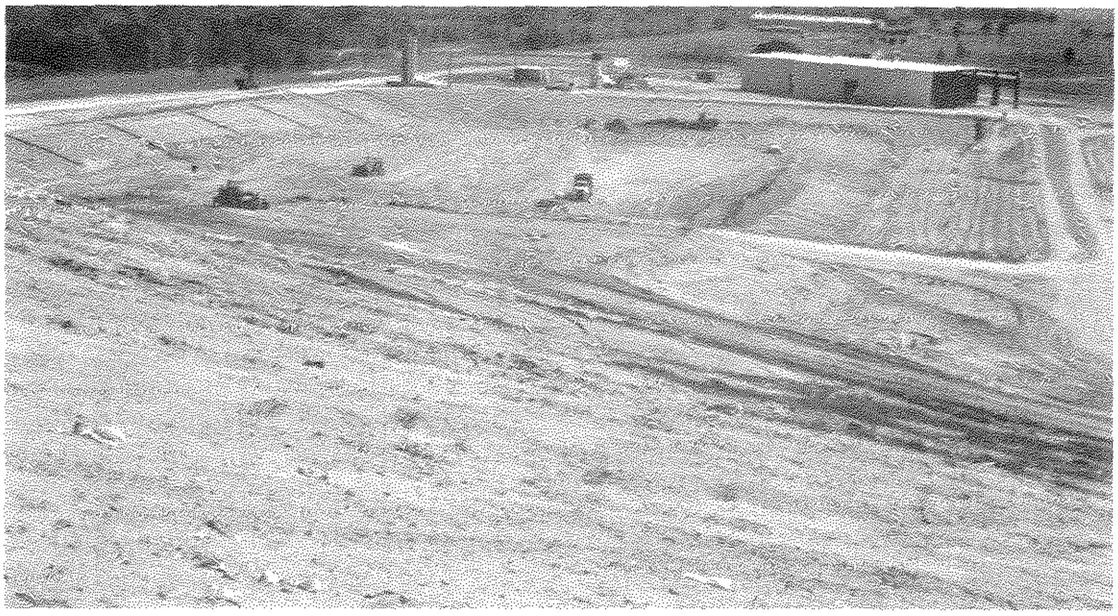


Figure 46. Newly opened cell at the Marion County landfill, showing plastic liner on left and background walls. The liner has been covered with sand on the other two walls for protection. Note the leachate collection pipes on the left and the 30,000 gallon holding tank in the left background. View to the south from the top of the recently finished, older cell, shown in Figure 45. Florida Geological Survey photograph, February 1989.

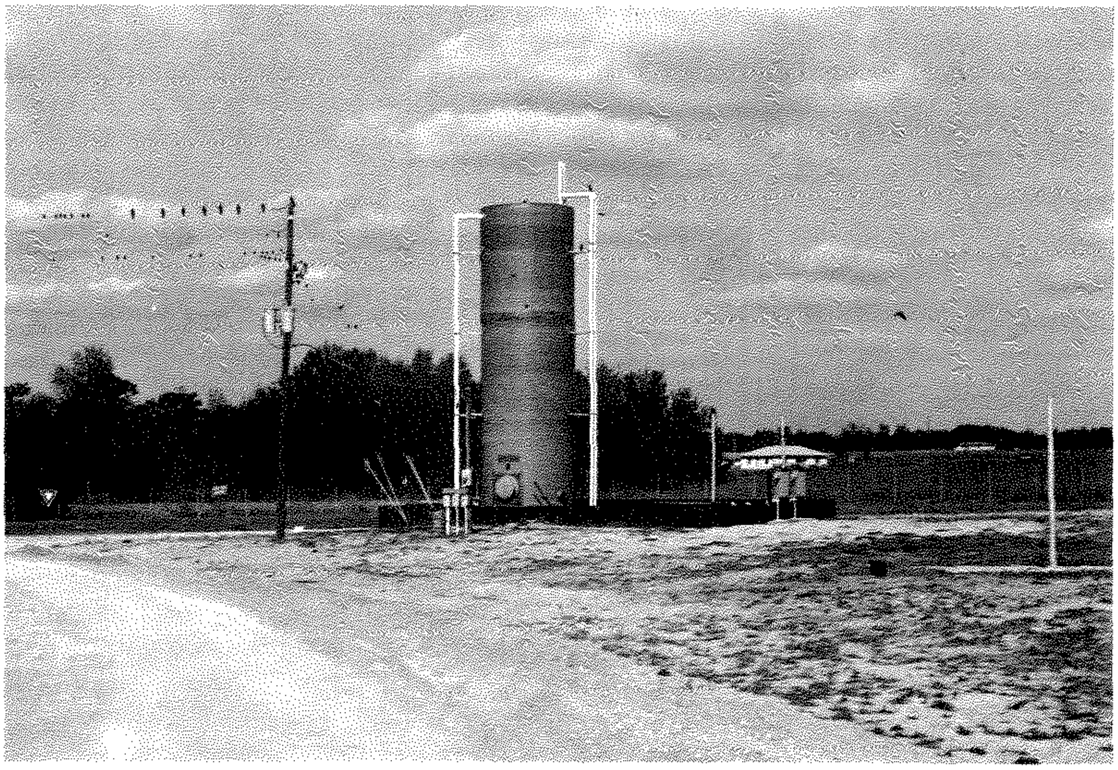


Figure 47. The 30,000 gallon leachate holding tank at the Marion County landfill, showing some of the pipes that connect to those shown in Figure 46. Florida Geological Survey photograph, February 1989.

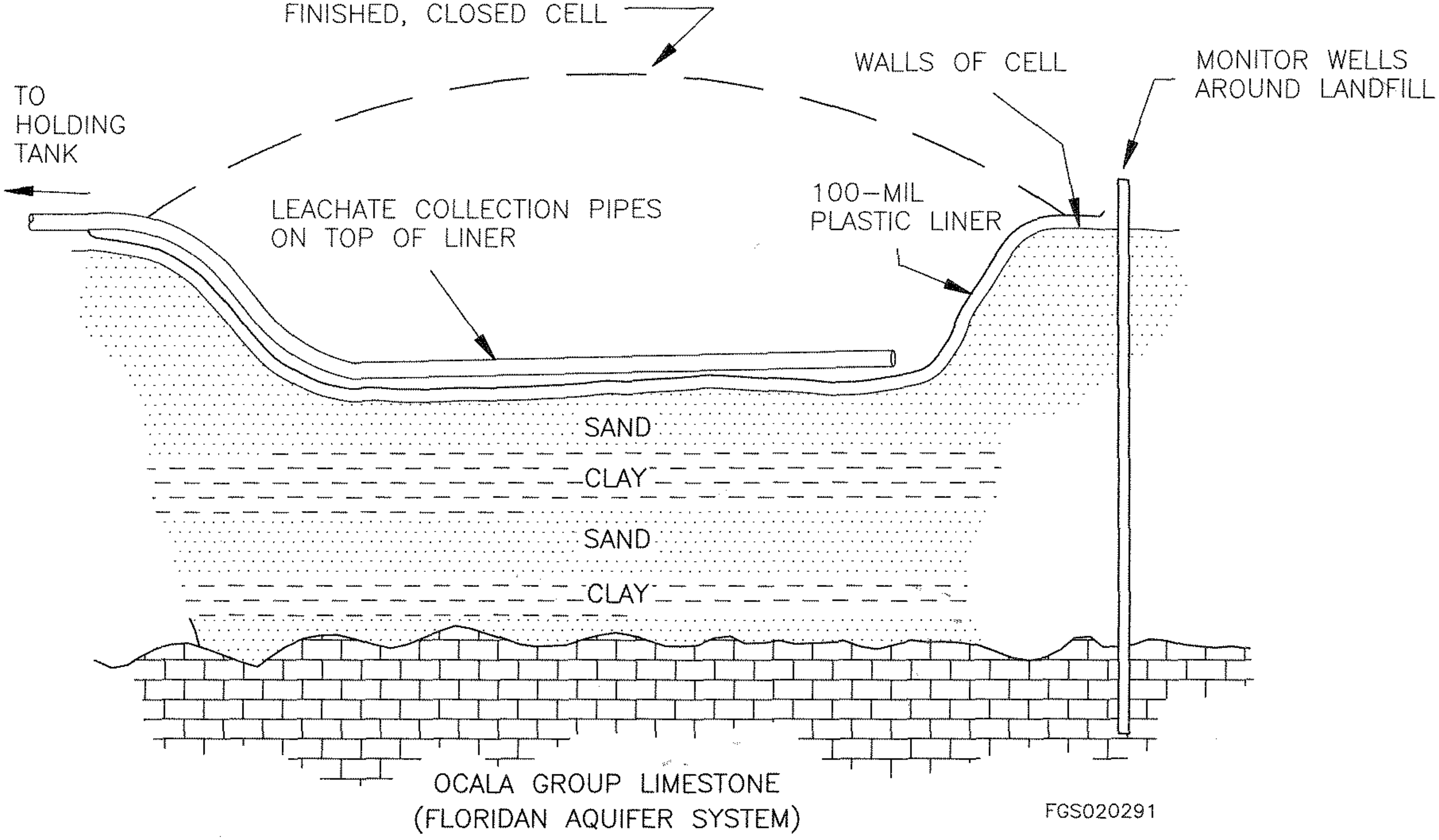


Figure 48. Generalized cross section of new cells at the Marion County landfill, 1989. Not to scale.

Some of the more obvious problems associated with the disposal of such huge quantities of solid waste are: large expenditures by local governments to operate landfills; landfills are very difficult to site in a safe environment; and the available good sites are becoming harder to find. One of the most important problems with solid waste disposal is the potential for contaminating ground and surface water by biological and chemical constituents that leach out after burial.

Federal and state regulatory agencies have mandated many requirements for operating landfills to protect the environment. Current policy towards landfill design is to build facilities that almost totally isolate the refuse from the environment. The first of the new cells at the Marion County landfill, which started operation in early 1989, incorporates much state-of-the-art technology to achieve this goal. Present and future cells have double linings of clay in the sub-floor, topped by a 100-mil-thick plastic liner that extends up the sides of the cell (Figure 46), forming what is, in effect, a liquid-proof container in which the solid waste is placed; water is excluded and leachate is contained. An extra measure of protection is provided by a leachate collection system, consisting of a series of suction pipes laid on top of the liner, and connected to a 30,000-gallon, fiberglass holding tank (Figure 47). Should it be necessary, collected leachate may be transported to an off-site waste-treatment facility. Figure 48 shows these design features in the new cells.

The older landfill, however, was begun before the present standards and technology were available for operating solid waste disposal facilities. The Florida Department of Environmental Regulation requires all landfill operations to maintain a system of ground-water monitoring wells around the facility, and to regularly sample and test the aquifers, in order to detect any contamination. As of the date of this report, no deterioration of ground-water quality has been detected.

SUMMARY

The data and information in this report establishes the intimate relationship among climate, geology, and hydrology of the Ocala area. There are demonstrated reasons for citizens, planners, and other governmental agencies to have concerns with regards to past, and future, industrial, agricultural, and urban development. Protection of Ocala's ground-water resources must be a top priority in planning, development, or regulatory context.

The carbonate rocks of the Floridan aquifer system occur at or near land surface in the study area. Their high degree of karstification provides easy, and rapid, access to the aquifer by rainwater and any entrained contaminants. Urbanization increases the types and amounts of contaminants to the aquifer, as well as concentrating runoff so that the natural filtering action of soil overburden is bypassed. Potential threats to ground-water quality due to urbanization include improperly installed septic tanks and drain fields, leaking storage tanks for petroleum or other chemicals, runoff from paved areas, drainage wells, and improper landfilling practices.

Agriculture is a major part of the area's economy. Wide-spread use of chemicals to increase yields poses a significant threat to the ground water. Indiscriminant and over-application of irrigation water increases the possibility of ground-water contamination.

REFERENCES

Anderson, W., and Faulkner, G. L., 1973, Quantity and quality of surface water in Marion County, Florida: prepared by the U.S. Geological Survey in cooperation with the Southwest Florida Water Management District and the Board of County Commissioners of Marion County, Florida, scale: 4 miles to 1 inch.

Campbell, K. M., 1986, Industrial minerals of Florida: Florida Geological Survey Information Circular 102, 94 p.

Cathcart, J. B., and Patterson, S. H., 1983 Mineral resource potential of the Farles Prairie and Buck Lake roadless areas, Marion County, Florida: U.S. Geological Survey Map Series MF-1519B.

City of Ocala Planning Department and the Ocala-Marion County Metropolitan Planning Organization, 1988, City of Ocala Statistical Profile, 75 p.

Deuerling, R. J., and MacGill, P. L., 1981, Environmental geology series, Tarpon Springs sheet: Florida Bureau of Geology Map Series 99, scale 1:250,000.

Faulkner, G. L., 1973, Geohydrology of the cross-Florida barge canal area with special reference to the Ocala vicinity: U.S. Geological Survey Water Resources Investigation 1-73, 117 p.

Ferguson, G. E., Lingham, G. W., Love, S. K. and Vernon, R. O., 1947, Springs of Florida: Florida Geological Survey Bulletin 31, 198 p.

Hatchitt, J., 1989, Florida summary mapping system (users guide), Armasi, Inc., 17 p.

Healy, H. G., 1975, Terraces and shorelines of Florida: Florida Bureau of Geology Map Series 71, scale 1:2,000,000.

Hoenstine, R. W., Lane, E., Rupert, F. R., Yon, J. W., Jr., and Spencer, S. M., 1988, Mineral Resources of Marion County, Florida: Florida Geological Survey Map Series 117, scale: 2 miles to 1 inch.

__________, Lane, E., Spencer, S. M., and O'Carroll, T., 1987, A Landfill site in a karst environment, Madison County, Florida — a case study, *in*: Proceedings of the 2nd Multidisciplinary Conference on Sinkholes and the Environmental Impacts of Karst, Beck, B. F., and Wilson, W. L., eds.: Florida Sinkhole Research Institute, University of Central Florida, Orlando, Florida, p. 253-258.

Knapp, M. S., 1978, Environmental geology series, Gainesville sheet: Florida Bureau of Geology Map Series 79, scale 1:250,000.

Lane, E., 1986, Karst In Florida: Florida Geological Survey Special Publication 29, 100 p.

Marella, R. L., 1988, Water withdrawals, use and trends in the St. Johns River Water Management District: St. Johns River Water Management District Technical Publication 88-7, 131 p.

Marion County Planning Department, 1988, Future land use element, Marion County Comprehensive Plan, March 1988 draft, 72 p.

Miller, J. A., 1986, Hydrogeologic framework of the Floridan aquifer system in Florida and in parts of Georgia, Alabama, and South Carolina: U.S. Geological Survey Professional Paper 1403-B, 91 p.

NOAA (National Oceanic and Atmospheric Administration), 1982, Storm Data, v. 24, no. 4, 46 p.

NOAA (National Oceanic and Atmospheric Administration), 1981-1986, Climatological Annual Summaries, Florida.

Phelps, G. C., 1989, Hydrogeology and effects of selected drainage wells and improved sinkholes on water quality in the upper Floridan aquifer, Silver Springs Basin, Marion County, Florida: *in* Water Resources Activities in Florida, U.S. Geological Survey Open File Report 89-227, p. 68.

Puri, H. S., and Vernon, R. O., 1964, Summary of the geology of Florida and a guidebook to the classic exposures: Florida Geological Survey Special Publication 5 (revised), 312 p.

Rosenau, J. C., Faulkner, G. L., Hendry, C. W., Jr., and Hull, R. W., 1977, Springs of Florida (revised): Florida Geological Survey Bulletin 31, 461 p.

Scott, T. M., 1978, Environmental geology series, Orlando sheet: Florida Bureau of Geology Map Series 85, scale 1:250,000.

__________, 1979, Environmental geology series, Daytona Beach sheet, Florida Bureau of Geology Map Series 93, scale 1:250,000.

Sinclair, W. C., and Stewart J. W., 1985, Sinkhole type, development and distribution in Florida: Florida Bureau of Geology Map Series 110, scale: 30 miles to 1 inch.

Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986: Florida Geological Survey Special Publication 28, 8 p.

Thompson, D., 1988, Marion County statistical overview: Marion County Department of Community Development, 63 p.

U.S. Geological Survey, 1981-1986, Water Resources Data, Florida - Surface Water Records and Groundwater Records, vol. 1, Northeast Florida.

United States Soil Conservation Service, 1979, Soil survey of Marion County area, Florida: U.S. Department of Agriculture Soil Conservation Service in cooperation with University of Florida, Institute of Food and Agricultural Sciences, 148 p.

White, W. A., 1970, The geomorphology of the Florida peninsula: Florida Bureau of Geology Bulletin 51, 164 p.

FLORIDA GEOLOGICAL SURVEY
903 W. TENNESSEE STREET
TALLAHASSEE, FLORIDA 32304-7700

Walter Schmidt, Chief
Peter M. Dobbins, Admin. Asst.
Jessie Hawkins, Custodian
Alice Jordan, Librarian
Sandie Ray, Admin. Secretary
Vanessa Allred, Library Asst.

GEOLOGICAL INVESTIGATIONS SECTION

Thomas M. Scott, Senior Geologist/Administrator
Jon Arthur, Petrologist
Paulette Bond, Geochemist
Dianne Brien, Research Asst.
Ken Campbell, Sedimentologist
Cindy Collier, Secretary
Mitch Covington, Biostratigrapher
Joel Duncan, Sed. Petrologist
Bob Fisher, Research Asst.
Rick Green, Research Asst.
Mark Groszos, Research Asst.
Kent Hartong, Research Asst.
Jim Jones, Cartographer
Clay Kelly, Research Asst.
Ted Kiper, Cartographer
Nancy LaPlace, Research Asst.
Milena Macesich, Research Asst.
Mel Martinez, Research Asst.
Ted Maul, Research Asst.
Robert Mince, Research Asst.
John Morrill, Driller
Larry Papetti, Research Asst.
Albert Phillips, Asst. Driller
Frank Rupert, Paleontologist
Frank Rush, Lab Tech.
Tom Seal, Research Asst.

MINERAL RESOURCE INVESTIGATIONS AND ENVIRONMENTAL GEOLOGY SECTION

Jacqueline M. Lloyd, Senior Geologist/Administrator
Ed Lane, Env. Geologist
Ron Hoenstine, Env. Geologist
Steve Spencer, Economic Geologist

OIL AND GAS SECTION

L. David Curry, Administrator
Brenda Brackin, Secretary
Robert Caughey, Dist. Coordinator
Joan Gruber, Secretary
Don Hargrove, Engineer
Scott Hoskins, Dist. Coordinator
Barbara McKamey, Secretary
Marycarol Reily, Geologist
Koren Taylor, Research Asst.
Charles H. Tootle, Pet. Engineer