GROUND-WATER QUALITY IN THE MIOCENE AND SURFICIAL AQUIFER SYSTEMS OF COASTAL GEORGIA

John C. Donahue

GEORGIA DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
WATER RESOURCES BRANCH
REGULATORY SUPPORT PROGRAM

ATLANTA
2005

CIRCULAR 12T

GROUND-WATER QUALITY IN THE MIOCENE AND SURFICIAL AQUIFER SYSTEMS OF COASTAL GEORGIA

John C. Donahue

The preparation of this report was funded in part through a grant from the U.S. Environmental Protection Agency under the provisions of Section 106 of the Federal Water Pollution Control Act of 1972, as amended.

GEORGIA DEPARTMENT OF NATURAL RESOURCES
NOEL HOLCOMB, COMMISSIONER

ENVIRONMENTAL PROTECTION DIVISION
CAROL A. COUCH, DIRECTOR

WATER RESOURCES BRANCH
NOLTON JOHNSON, BRANCH CHIEF

ATLANTA
2005

CIRCULAR 12T

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. INTRODUCTION

1.1 PURPOSE AND SCOPE

This report, covering the period February 2004 through August 2005, is the first in a series of summaries to examine potential ground-water impairment within specific areas of Georgia or involving specific types of wells. The previous nineteen summaries of the Circular 12 series dealt with the chemical quality of ground water Statewide.

These summaries are among the tools used by the Georgia Environmental Protection Division (EPD) to assess trends in the quality of the State's ground-water resources. EPD is the State organization with regulatory responsibility for maintaining and, where possible, improving ground-water quality and availability. EPD has implemented a comprehensive statewide ground-water management policy of anti-degradation (EPD, 1991; 1998). Five components comprise EPD's current ground-water quality assessment program:

1. The Georgia Ground-Water Monitoring Network. The Georgia Geologic Survey Branch (GGS) of EPD and its successor, the Regulatory Support Program of the Water Resources Branch, maintain this program. Early in calendar year 2004, a three-part monitoring program replaced the Statewide aquifer-specific monitoring network. The new program will examine ground-water: a) in the coastal area for influx of connate brines, sea water, or low-quality surface water; b) in the Piedmont and Blue Ridge for impacts from development and rural land use as well as to gain a more thorough understanding of the area's ambient ground water; and c) from small public water systems to spot check for intermittent contamination that might escape detection under item 2) below. The current report summarizes findings for part a) of the program, the Coastal Monitoring Project.

2. Sampling of public drinking water wells as part of the Safe Drinking Water Program, also of the Water Resources Branch. This program provides data on the quality of ground water that the residents of Georgia are using.

3. Special studies addressing specific water quality issues. A survey of nitrite/nitrate levels in shallow wells located throughout the State of Georgia (Shellenberger, et al., 1996; Stuart, et al., 1995), operation of a Pesticide Monitoring Network conducted jointly by the GGS and the Georgia Department of Agriculture (GDA) (Tolford, 1999; Glen, 2001), and the Domestic Well Water Testing Project conducted jointly by the GGS and the GDA (Overacre, 2004, Berry, 2005) are examples of these types of studies.

4. Ground-water sampling at environmental facilities such as municipal solid waste landfills, RCRA facilities, and sludge disposal facilities. The primary agencies responsible for monitoring these facilities are EPD's Land Protection, Watershed Protection, and Hazardous Waste Management Branches.

5. The wellhead protection program (WHP), which is designed to protect the area surrounding a municipal drinking water well from contaminants. The U.S. Environmental Protection Agency (EPA) approved Georgia's WHP Plan on September 30, 1992. The WHP Plan became a part of the Georgia Safe Drinking Water Rules, effective July 1, 1993. The protection of public water supply wells from contaminants is important not only for maintaining ground-water quality, but also for ensuring that public water supplies meet health standards.

1.2 COASTAL GROUND-WATER MONITORING NETWORK

The study area for the Coastal Monitoring Project involved the same thirteen coastal-area counties described in GGS Bulletin 113 (Figure 1-1) (Clarke et al., 1990). The area comprises the six waterfront counties (Bryan, Camden, Chatham, Glynn, Liberty, and Mc Intosh) along with seven nearby inland counties (Brantley, Bulloch, Charlton, Effingham, Long, Screven, and Wayne).

The current project sought to sample 90 to 100 wells evenly distributed throughout the study area. The aquifer systems targeted by the study consisted of the Surficial aquifer system and the Miocene aquifer system (upper and lower Brunswick aquifers) (Clarke et al., 1990). Waters from the sampled wells were field tested for pH, conductivity, temperature, and salinity. The sampled wells were also located using a global positioning system (GPS) receiver. Sample waters were analyzed for nitrate and pesticides, with analysis for total dissolved solids (TDS) added after the end of July 2004.

Assembling the candidate wells began in March 2004 and continued through much of the length of the project. Candidate wells came from a variety of sources. Nearly all the candidates in Bryan, Bulloch, Chatham, Effingham, Liberty, and Screven Counties originated from data bases and information compiled by Mr. Roy Rountree, then of the GGS, incident to updating the State list of irrigation well permittees. Elsewhere in the study area, well owner lists maintained for the Domestic Well Pesticide Sampling Project (Berry, 2005; Overacre, 2004) furnished many candidates, as did reviews of county health department files and visits with local fire officials. Yet more candidates came from reviews of files on industrial, public water system, and irrigation well permittees kept at EPD. An effort was made to include among the candidates down-gradient wells on or near golf courses and similar areas. (At one golf course, a misunderstanding led to irrigation pond water rather than irrigation well water being sampled. See Table A-2, station 127-3 in Glynn County.)

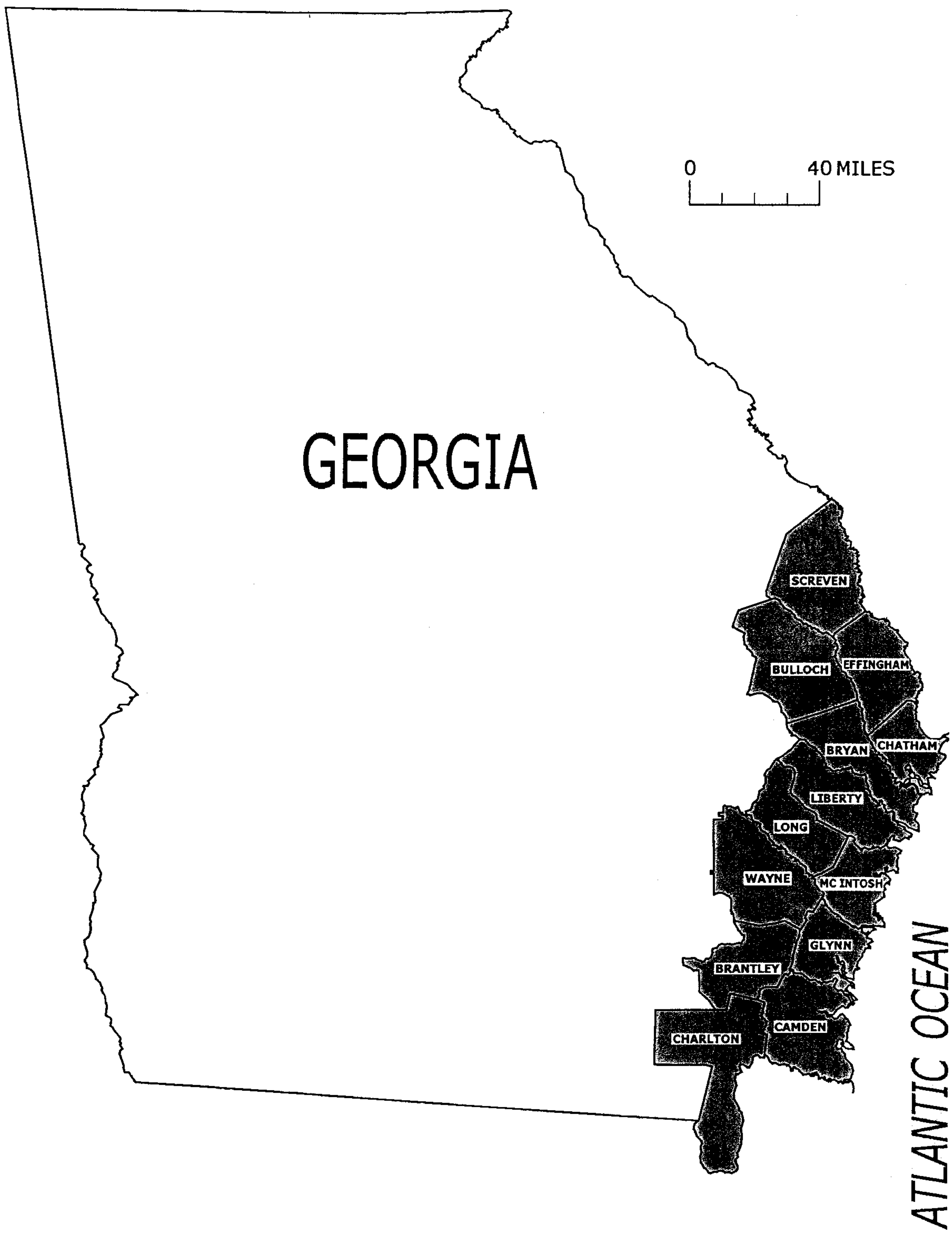

Figure 1-1. Map of Georgia, Showing the Counties Comprising the Study Area.

Sampling began in July 2004 and concluded in August 2005. One hundred and one wells were eventually sampled, of which 37 tapped the Miocene and 64 drew from the Surficial aquifers. Even distribution of the sampled wells could not always be maintained due to withdrawal of well owners from the study; to the presence of large areas with few or no wells (e.g. the Okefenokee Swamp); and to reassignment as Surficial of some wells reported as Miocene that did not penetrate sufficiently into the Miocene stratigraphic column to reach the Miocene aquifer system.

CHAPTER 2. HYDROGEOLOGIC FRAMEWORK

2.1 MIOCENE AQUIFER SYSTEM

The following discussion, except where noted, relies exclusively on the descriptions due to Clarke et al. (1990).

2.1.1 Lithology

The Miocene stratigraphic column in the coastal area of Georgia contains three sequences, each composed of a basal dense phosphatic dolomite or limestone layer, a middle clay layer, and an upper sandy layer. The sandy layer in each of the carbonate/clay/sand sequences is water bearing whereas the carbonate and clay layers are confining. The term applied to the lowest sequence is the Miocene C unit and to the middle sequence the Miocene B unit. The sandy layers of the two lower sequences are called the upper and lower Brunswick aquifers. The sandy layer in the uppermost sequence (Miocene A unit) is hydraulically connected with the Surficial aquifer and is part of that aquifer system.

2.1.2 Geophysical Markers

The phosphate material contains some uranium, which results in radioactivity markedly higher in the phosphatic carbonate layers than in neighboring layers. The radioactivity allows the lower portions of the confining layers, termed in descending order geophysical horizons A, B, and C, to be mapped radiometrically where suitable wells or boreholes are available.

2.1.3 Extent of the Aquifer System

The combined thickness of the B and C units is as little as about 33 feet in a test well at Fort Pulaski in Chatham County, but increases to over 320 feet in northern Brantley and southern Wayne Counties. The sandy part of the C unit is missing at the Fort Pulaski location and the sandy part of unit B is about 20 feet thick. The permeable portion of unit C is also missing in Bulloch County. Mark Hall (personal communication), former drilling crew supervisor at GGS, notes that the thickness of the permeable parts of the Miocene column remains attenuated southward into Liberty County. The maximum reported permeable thicknesses of units B and C are 150 feet and 70 feet, respectively.

Miocene strata cover the entire study area. These strata outcrop over most of Screven and Bulloch Counties, and in the western parts of Bryan, Long, Wayne, and Brantley Counties.

The above-mentioned geophysical horizons have been mapped from the St. Marys River at the southern edge of Camden County northward to a latitude of about 32 degrees, 30 minutes (a little north of well 103-3, Figure 2-1) and from the coast westward to 82 degrees west longitude (i.e., about as far west as well 49-2, Figure 2-2). The geophysical horizons remain unmapped north of 32 degrees, 30 minutes, and west of 82 degrees, an area including nearly all of Screven and Charlton Counties, the northern parts of Bulloch and Effingham Counties, as well as the western parts of Wayne and Brantley Counties.

2.1.4 Definition

For the purpose of this report, the Miocene aquifer system consists of the combined units B and C in areas away from those of Miocene outcrop. The aquifer system contains the upper and lower Brunswick aquifers as defined by Clarke et al. (1990) together with upper, lower, and intervening confining layers. Because of likely breaching in and near areas of Miocene outcrop, the Miocene A unit and water-bearing post-Miocene sediments are usually herein considered to be hydraulically connected with the Miocene aquifer system and therefore part of it.

Geophysical horizons A and C are taken to represent the upper and lower confining units, respectively, of the aquifer system. For wells in the area of Charlton County where geophysical horizons A and C are unmapped, well-bottom elevations were compared with Section A-A' on the Geologic Map of the State of Florida (2001) and with Section D-D' on Plate 4 of Clarke et al. (1990). Wells 49-8 and 49-10 seem to be deep enough to have penetrated the upper confining unit represented by geophysical horizon A. With the exception of well 251-6 in Screven County, wells situated in or near Miocene outcrop areas are considered Miocene because of the likelihood of breaches in the upper confining layer. Well 251-6 is near enough to post-Miocene outcrop and shallow enough that it almost certainly taps the Surficial aquifer. One of the difficulties encountered during the study was that some wells were reported to draw from the Miocene aquifer system because they were completed in the Miocene A unit, which is actually part of the Surficial aquifer system.

2.2 SURFICIAL AQUIFER SYSTEM

As with the Miocene aquifer system, the following discussion, except where noted, relies exclusively on the descriptions due to Clarke et al. (1990).

2.2.1 Lithology

That portion of the stratigraphic column in the coastal area of Georgia that hosts the Surficial aquifer system consists of the topmost Miocene phosphatic carbonate/clay/sand sequence together with post-Miocene sediments. The post-Miocene sediments consist of Pliocene phosphatic, micaceous, clayey sands; of Pleistocene arkosic sands and gravels with discontinuous clay beds; and of Holocene interbedded muds, sands, and gravels.

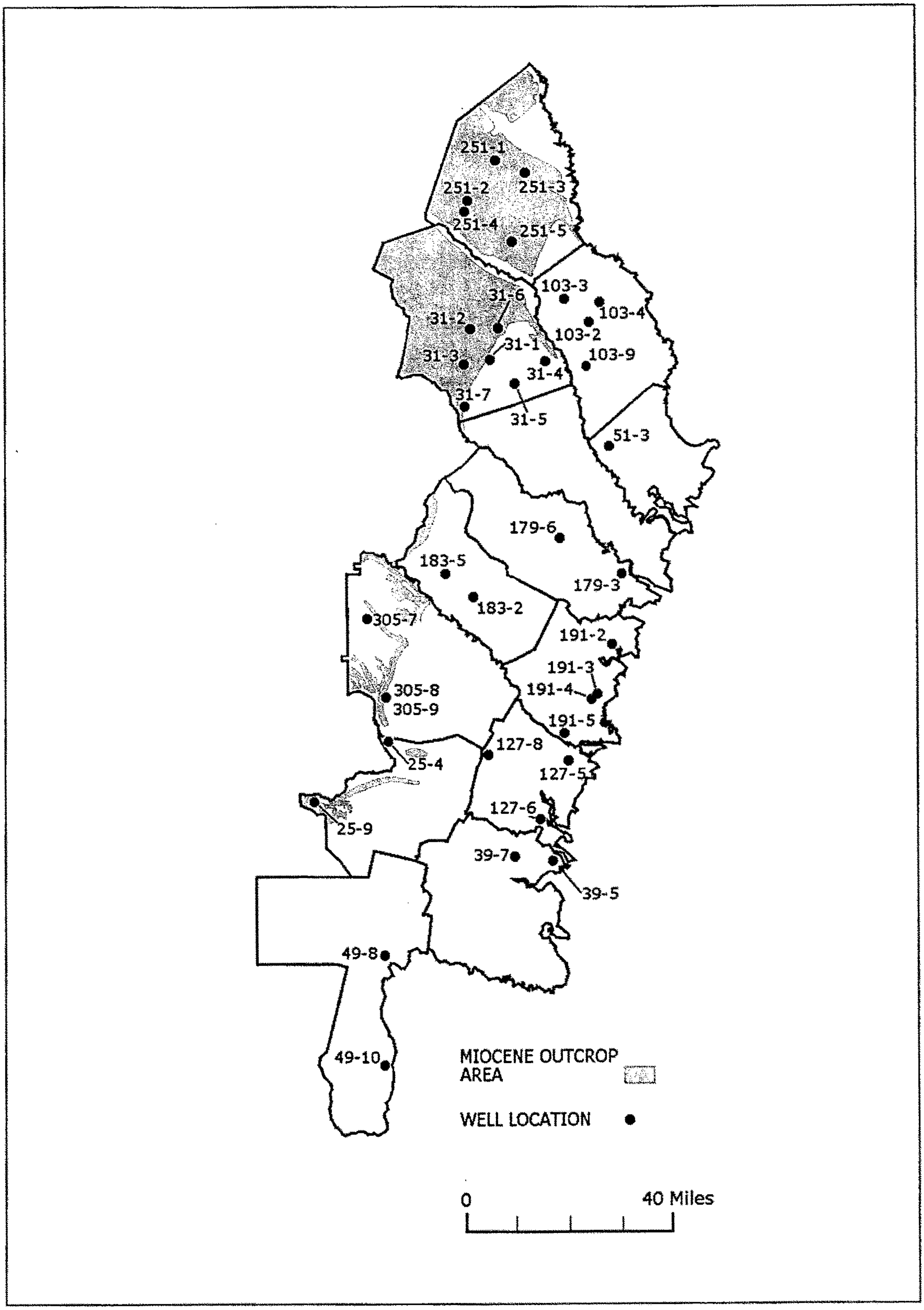

Figure 2-1. Map of Study Area, Showing Miocene Well Locations.

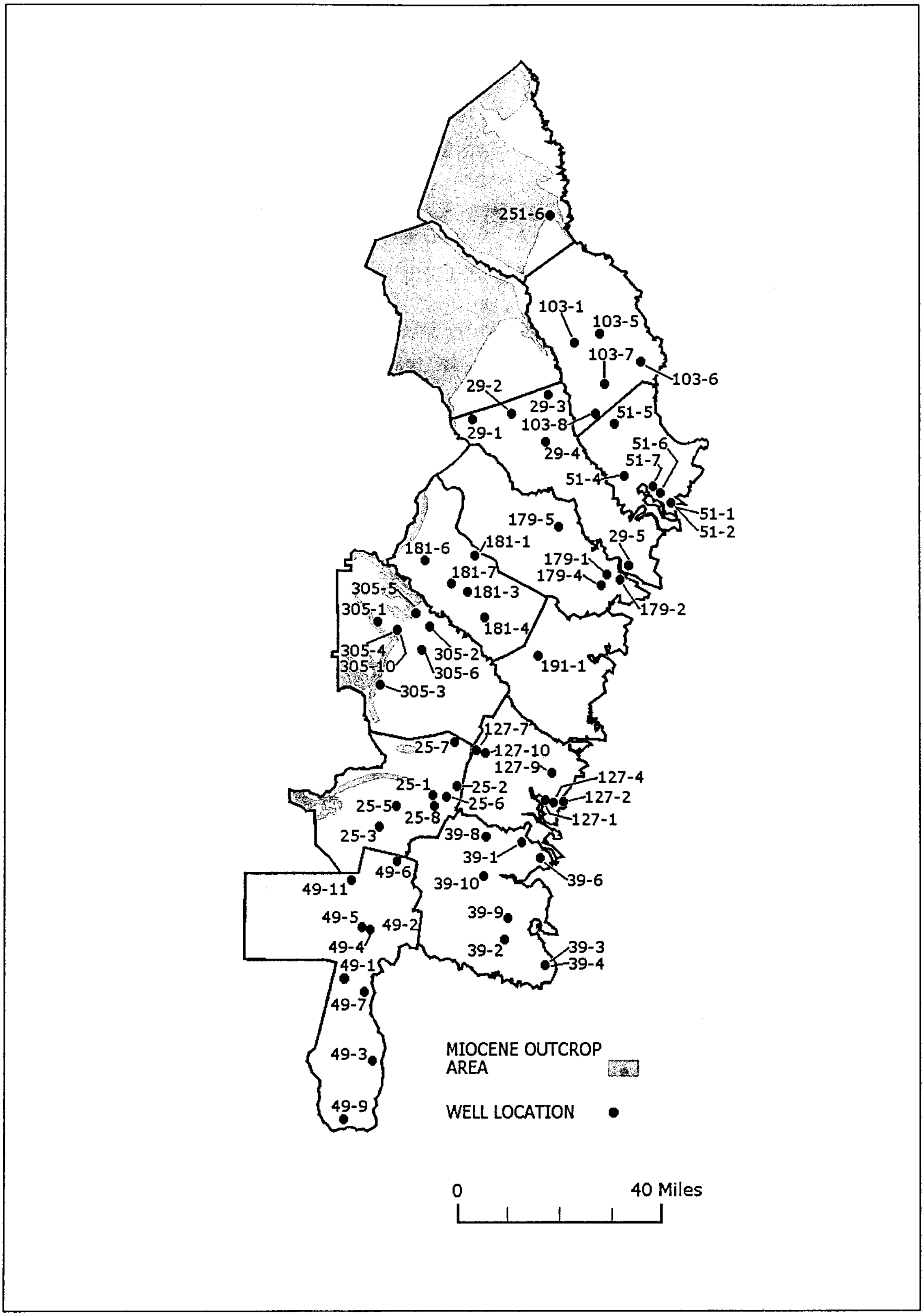

Figure 2-2. Map of Study Area, Showing Surficial Well Locations.

2.2.2 Extent of the Aquifer System

The post-Miocene unit is absent in most of Screven and Bulloch Counties and in small areas of Bryan, Long, Wayne, and Brantley Counties (Figures 2-1 and 2-2). The thickness of the combined Miocene unit A/post-Miocene unit varies from about 380 feet in northwestern Wayne County, to about 400 feet in central Glynn County, to about 180 feet in far southern Bulloch County, to about 80 feet in Chatham County. Despite bulges as described above in Bulloch County and elsewhere, the combined Miocene unit A/post-Miocene unit overall thins to the northwest. The permeable thickness varies, being about 65 feet at a test well site at Skidaway Island in eastern Chatham County (monitoring wells 51-1 and 51-2 are also located on Skidaway Island, Table A-3) and about 230 feet at a test well site at Gardi in eastern Wayne County.

2.2.3 Definition

For the purpose of this report, the Surficial aquifer system consists of the combined Miocene unit A and the post-Miocene unit in areas away from those of Miocene outcrop. Due to the potential for breaches in the confining layer at the base of Miocene unit A, areas in or near Miocene outcrop areas are considered part of the Miocene aquifer system. Owing to clay layers that can be locally thick and extensive, the Surficial aquifer system can in places contain a lower Surficial aquifer, which may be under artesian conditions, and an upper Surficial aquifer, which is unconfined. Elsewhere the aquifer system is unconfined or semi-confined.

CHAPTER 3. METHODS

3.1 FIELD METHODS

Conductivity, pH, salinity, and temperature were monitored in the field with a Horiba Model U-10 water quality meter. A Garmin Etrex Legend GPS receiver measured the latitude and longitude of the sampling station.

In most cases, wells had dedicated pumps, and plumbing downstream of the wellhead included spigots or other outlets. The outlet nearest the wellhead was typically used as the monitoring and collection point. The pump was turned on and the spigot was allowed to flow freely. Every three minutes the water quality meter's calibration cup was used to catch an aliquot of water for monitoring. Conductivity, pH, salinity, and temperature were then measured and recorded. Monitoring continued until these parameters stabilized, typically 12 to 15 minutes. The last recorded readings of pH, conductivity, and salinity are those reported (Table A-2).

In a few cases, the wells (such as water-level monitoring wells) lacked dedicated pumps. If the well was not flowing (two were), a polyethylene single check valve bailer was attached to a nylon string and lowered by hand into the well to obtain monitoring and sample water. Bailing continued until the field parameters stabilized or until the water column became severely depleted or disturbed and turbid (or until foul weather curtailed the effort). A new bailer and length of string were used for each well.

When the field parameters stabilized, a pesticide sample was collected in a 1 liter amber bottle, a nitrate sample was collected in a plastic 125 milliliter bottle, and a TDS sample was collected in a half-gallon (approx. 2 liter) plastic jug. At one station during each sampling trip, a field duplicate for pesticides and nitrate were collected, per instructions for EPA Method 525.2 and GDA Laboratories Division Document #P-407B.

When sampling was completed, the pesticide sample was spiked with 5 milliliters of 6-normal hydrochloric acid for purposes of preservation and preparing the sample water for analysis. The pesticide and nitrate sample bottles (including the field reagent blanks mentioned below) were then placed in doubled plastic bags. The bagged samples and the TDS jug were finally placed on ice in a cooler.

Field reagent blanks for pesticides and nitrate, previously prepared at the laboratory, accompanied filled sample bottles throughout the trip. At each sampling station these blanks would be exposed to atmosphere as a check against airborne contamination. At the last sampling station on the trip, the pesticide field reagent blank would receive a hydrochloric acid preservative spike.

3.2 LABORATORY METHODS

Pesticides, nitrate, and TDS were measured in the laboratory. The GDA laboratory at Tifton performed the nitrate and pesticide analyses. The EPD laboratory in Atlanta performed the TDS analyses.

EPA Method 525.2 can analyze for a variety of (organic) pesticides and semi-volatile organic compounds (Table A-1). The method extracts the analytes from acidified sample water using adsorbent-coated solid media. A solvent wash removes the analytes from the medium. Evaporating the wash liquid produces an analyte concentrate that can then be analyzed with a gas chromatograph/ mass spectrometer apparatus.

For determining nitrate concentrations, the study employed the method described in GDA Laboratories Division Document # P-407B (2004). The procedure uses ion chromatography to measure the analyte concentration. Ground-water samples need no preparation before analysis unless the samples contain particulates or have high dissolved solids contents. For such cases, the procedure calls for an added filtering step to remove particulates or an added dilution step to lower the dissolved solid concentration.

EPA Method 160.1 is used to measure TDS. The method consists of evaporating a filtered water sample to dryness at 180°C and weighing the residue.

CHAPTER 4. RESULTS

4.1 pH

The pHs of waters from Miocene wells ranged 4.05 to 9.67 and were predominantly basic, with waters from 31 of 37 stations being above 7.00. Four wells yielding waters with acidic pH were of shallower depths, 100' or less, although shallow well depth did not necessarily guarantee acidic water. Wells giving acidic water were all located in interior counties (Screven, Bulloch, Wayne) in or near outcrop areas.

The pH range for waters from Surficial wells extended from 4.03 to 9.28. The majority of tested waters were basic, with 38 out of 64 stations giving water with pHs above 7.00. Acidic pHs generally characterized waters from shallower wells, all but two of them 100' or less, although, again, shallow well depth did not necessarily guarantee acidic water.

4.2 CONDUCTIVITY AND SALINITY

The conductivities for waters from Miocene wells ranged from 44 uS/cm to 536 uS/cm. Conductivities for Surficial wells ranged from 16 uS/cm to 810 uS/cm. Charlton County contains the Miocene well and the Surficial well registering the highest conductivities for their respective aquifer systems as well as the three wells registering the highest conductivities overall.

Waters with lower conductivities, as a rule, come from shallower wells. However a shallow well depth by no means guarantees low-conductivity water. Surficial wells 39-10 (Camden County), 49-5 (Charlton County), and 51-2 (Chatham County) are examples of shallow wells with high-conductivity waters. Deeper wells almost always give waters with higher conductivities. Miocene well 51-3 in Chatham County is the only good exception: with a depth of 210 feet, it yielded water with a conductivity of 77 uS/cm, an amount expected for a well of half or less that depth.

Six counties show a greater incidence of higher conductivity well water than the rest of the study area: Chatham, McIntosh, Glynn, Camden, Brantley, and Charlton. As mentioned above, three Charlton County wells, two Surficial and one Miocene, registered the highest conductivities in this study.

The salinity measurement performed by the U-10 water quality meter is computed from the conductivity and the temperature of the sample. The meter's salinity measurement is keyed to the conductivity of seawater and, in the case of relatively fresh waters, assumes the sample water to be dilute seawater. The salinity value put out by the instrument is corrected for the sample temperature.

The salinity is expressed as a weight percent, that is, grams of sodium chloride per hundred grams of sample water (Stewart, 2005). As a derivative measurement of conductivity, salinity faithfully follows conductivity, but is of a coarser scale.

4.3 NITRATE

Two Miocene wells, both located in the outcrop area, yielded water with detectable nitrate (Table 4-1). One well, 31-1, a 100-foot deep well in Bulloch County, yielded water with a nitrate content in excess of the Primary Maximum Contaminant Level of 10 ppm as nitrogen. The well is a holdover from the earlier Georgia Ground-Water Network and has a history of producing water with excessive nitrate/nitrite. The other Miocene well, 251-2 in Screven County, is about 25 feet deep and yielded a sample slightly below the Primary Maximum Contaminant Level.

Eight Surficial wells had water with detectable nitrate, with concentrations ranging from 1.21 ppm as nitrogen to 6.13 ppm as nitrogen (Table 4-1). These wells were located in Effingham and Long Counties (two wells each) and in Wayne County (four wells). All of the Surficial wells were less than 100 feet deep and seven were 50 feet deep or less.

Settings for wells yielding water with detectable nitrate are tabulated below (Table 4-1). Densely built areas include towns or cities. Lightly built areas refer

Table 4-1. Settings of Wells Yielding Water with Detectable Nitrate.

Well No.	Aquifer	County	Nitrate, ppm N	Depth	Setting
31-1	Miocene	Bulloch	14.05	100'	Row crop field nearby, rural
103-1	Surficial	Effingham	1.64	20'	Lawn/garden, densely built
103-8	Surficial	Effingham	2.06	80'	Workshop area, lightly built
183-1	Surficial	Long	1.74	25'	Lawn/garden, lightly built
183-6	Surficial	Long	1.21	25'	Lawn/garden, rural
251-2	Miocene	Screven	9.98	25'	Cow pasture, rural
305-1	Surficial	Wayne	5.04	19'	Rural
305-3	Surficial	Wayne	1.40	42'	Lawn/garden, densely built
305-4	Surficial	Wayne	4.53	50'	Lawn/garden, chicken coop nearby, rural
305-8	Surficial	Wayne	6.13	35'	Lawn/garden, rural

to widely spaced subdivisions or to houses placed on acreages. Rural areas refer to regular farms or extensive woods. The lawn/garden designation refers to a well placed in the yard area of a house. The yard usually contains flower or vegetable gardens.

4.4 PESTICIDES

The study uncovered no well waters with detectable pesticides.

4.5 TOTAL DISSOLVED SOLIDS

TDS were not added to the testing repertoire until after the sampling campaign was underway. Some wells in Brantley, Camden, and Effingham Counties, therefore, lack TDS data.

For Miocene wells, the TDS concentrations ranged from 47 ppm to 760 ppm. For Surficial wells, the TDS concentrations ranged from not detected to 680 ppm.

The TDS concentration generally mirrors conductivity (and salinity), although some divergence can occur. One source of divergence is that the TDS concentration depends on the amount both ionic and non-ionic (such as silica, see Stewart, 2005) dissolved material, whereas, the conductivity (and salinity) depends exclusively on the amount of dissolved ionic material. Other sources of divergence include loss of chloride during drying and loss of dissolved gasses (Stewart, 2005).

CHAPTER 5. SUMMARY AND CONCLUSIONS

5.1 pH

Shallow wells, whether Miocene or Surficial, produced most of the acidic ground water encountered in this study. Depths are less than about 100 feet with many in the general 20-foot to 30-foot range. For Miocene wells, these are located in or adjacent to outcrop areas. However, a shallow well depth does not guarantee acidic water. Surficial wells 29-1 (Bryan County) and 49-3 (Charlton County) are good examples of very shallow wells (25 feet and 32 feet deep, respectively) that yield basic water. Deep wells, those deeper than about 100 feet, usually produce basic water. Surficial well 305-10 at 200 feet and Miocene well 305-7 at 430 feet, both in Wayne County, are exceptions.

5.2 CONDUCTIVITY AND SALINITY

Salinity is a measure derived from conductivity. Conductivities and salinities, as a rule, tend to be lower in shallower wells. However, shallow well depth does not guarantee low conductivity or salinity. Deeper wells tend to give water with higher conductivities. Again, large well depth does not necessarily assure high conductivity or salinity.

Six counties show a greater incidence of higher conductivity well water than the rest of the study area: Chatham, McIntosh, Glynn, Camden, Brantley, and Charlton. As mentioned above, two Charlton County wells, one Surficial and one Miocene, registered the highest conductivities in this study. The higher conductivities and salinities for Chatham, McIntosh, Glynn, and Camden Counties may reflect their position as oceanfront counties. Bryan and Liberty Counties are also oceanfront counties but showed no incidence of elevated conductivities and salinities.

Charlton and Brantley Counties are inland but border on the Okefenokee Swamp. The instances of elevated ground-water conductivity and salinity in these two counties may reflect the influence of the swamp on local ground-water hydrology.

The operating manual for the U-10 water quality meter cites a normal seawater salinity of 3.3%. Stewart (2005) gives a range of 3.46% to 3.48% for salinities in most ocean waters. The maximum salinity found in the current study is 0.03%.

Monitoring for salt-water intrusion in the future may utilize a denser network in the oceanfront area.

5.3 NITRATE

Nitrate occurrences are restricted to waters from shallow wells in the unconfined portions of the Miocene and Surficial aquifer systems. Septic system effluent from nearby houses, animal wastes in pastures and other enclosures, and fertilizers used on lawns, gardens, and row-crop fields can all furnish nitrate to ground water, particularly in the unconfined zone. Wells yielding water with detectable nitrate usually had lawns, gardens, active animal enclosures, row-crop fields, or houses nearby.

5.4 PESTICIDES

The study found no pesticides in any samples taken in the study area. The lack of pesticides may result from: a) non-use, as during winter; b) effective isolation of the Miocene and lower Surficial aquifers from the unconfined Surficial aquifer in the sampled areas; c) failure to migrate away from an area of use by way of water.

5.5 TOTAL DISSOLVED SOLIDS

TDS concentrations tend to follow conductivities and salinities, though not very strictly. The TDS measurement may include non-ionic soluble solids, which affect conductivity very little. Thus the TDS measurement on a sample can be high relative to the corresponding conductivity or salinity, which depends on soluble ionic materials.

5.6 GOLF COURSES AND SIMILAR AREAS

Wells 39-3 and 39-4, irrigation wells for an institutional lawn area, lie within the lawn area and are drilled into the deep Surficial aquifer (probably Miocene unit A) (Tables A-2 and A-3). Wells 51-4 and 127-10 are adjacent to golf courses, with 51-4 in the unconfined Surficial aquifer and 127-10 in the deep Surficial aquifer. Sample 127-3 consisted of (mistakenly sampled) golf course pond water. None of the samples from these water supplies contained detectable nitrate or pesticides.

The lack of nitrate and pesticides in the deep Surficial wells may reflect the effective isolation of the lower Surficial aquifer from the unconfined Surficial aquifer in the sampled areas. The lack of pesticides and nitrate in the unconfined Surficial well water and the pond water may result from their being sampled during winter, when these substances are little in use. The lack may also indicate that these substances are not moving away from the areas of application by way of water.

CHAPTER 6. LIST OF REFERENCES

Berry, M., 2005, Domestic Well Water Testing Project 2000-2004: Georgia Geologic Survey Project Report 55, 154 p.

Clarke, J.S., Hacke, C.M., and Peck, M.F., 1990, Geology and Ground-Water Resources of the Coastal Area of Georgia: Georgia Geologic Survey Bulletin 113, 116 p., 12 pl.

EPD, 1991, A Ground-Water Management Plan for Georgia: Georgia Geologic Survey Circular 11 (1991 edition).

EPD, 1998, A Ground-Water Management Plan for Georgia: Georgia Geologic Survey Circular 11 (1998 edition).

GDA Laboratories Division, 2004, Preparation and Analysis of Nitrate, Nitrate Nitrogen, Chloride and Sodium Chloride in Feed, Fertilizer, and Waters SOP: Document Number P-407B, Revision Number 1, 5 p.

Glen, J.C., 2001, Pesticide Monitoring Network 1989-2000: Georgia Geologic Survey Project Report 43, 58 p.

Overacre, L., 2004, Domestic Well Water Testing Project 2003: Georgia Geologic Survey Project Report 53, 65 p.

Shellenberger, D.L., Barget, R.G., Lineback, J.A., and Shapiro, E.A., 1996, Nitrate in Georgia's Ground Water: Georgia Geologic Survey Project Report 25, 12 p., 1 pl.

Stewart, R. H., 2005, Introduction to Physical Oceanography (online version): Texas A&M University, 17 Chapters; http://oceanworld.tamu.edu/ocng_textbook/contents.html

Stuart, M.A., Rich, F.J., and Bishop, G.A., 1995, Survey of Nitrate Contamination in Shallow Domestic Drinking Water Wells in the Inner Coastal Plain of Georgia: Ground Water, Vol. 33, No. 2, p. 284-290.

Tolford, B., 1999, Pesticide Monitoring Network 1998-1999: Georgia Geologic Survey Project Report 40, 60 p.

APPENDIX

Laboratory and Well Data

LABORATORY AND WELL DATA

The standard testing regimen for all samples collected for the Coastal Ground-Water Monitoring Project consisted of laboratory analyses for pesticides, nitrate, and total dissolved solids (TDS), and of field measurements of pH and conductivity.

USEPA has set forth a series of serially numbered laboratory analytical methods officially recognized as suitable for environmental purposes. The current study made use of two of these methods, Method 525.2 for pesticides and Method 160.1 for TDS. The nitrate analysis relied on a method routinely used by the GDA for testing drinking water, fertilizer, and animal feed described in GDA Laboratories Division Document P-407B (2004). The method is similar to EPA Method 300.1. The GDA lab reports pesticide concentrations only if pesticides are detected. Otherwise, the laboratory reports “no detection of pesticides”. Nitrate, if detected, is reported as milligrams per liter (parts per million) as nitrogen. The detection limits for pesticides ranged from 0.05 to 2.58 micrograms per liter (parts per billion) depending on the compound and the state of the analytical apparatus.

Table A-1 lists the various parameters tested in the laboratory. Table A-2 lists the values for both laboratory parameters and field parameters for each well. Table A-3 gives location and depth data for each well. These data include: latitude, longitude, well depth, surface elevation, well bottom elevation, and the approximate elevation, if available or applicable, of the geophysical A horizon near the top of the Miocene stratigraphic column.

For this appendix, the following abbreviations are used:

mg/L	= milligrams per liter (parts per million)
mgN/L	= milligrams per liter as nitrogen
ug/L	= micrograms per liter (parts per billion)
uS/cm	= microsiemens/centimeter
N/A	= not available
ND	= not detected
OA	= outcrop area
rp	= repeat sample
TDS	= total dissolved solids
su	= standard units
--	= not analyzed

Table A-1. Laboratory Parameters.

EPA Method 525.2 Pesticides

Pesticides that the GDA Tifton Laboratory can analyze using EPA Method 525.2.

Alachlor	Ethoprop
Ametryn	Fenamiphos 2
Atrazine	Fluridone
Bromacil	Hexachlorocyclohexane, alpha
Butylate	Hexazinone
Carboxin 2	Lindane
Chlordane components	Merphos 2
Chlorneb	Methoxychlor
Chlorpropham	Metolachlor
Chlorothalonil	Metribuzin
Chlorpyrifos	Mevinphos
Cyanazine	Norflurazon
Dacthal (DCPA)	cis-Permethrin
4,4'-DDE	trans-Permethrin
4,4'-DDT	Prometon
Diazinon 2	Prometryn
2,4-Dinitrotoluene	Pronamide
Disulfoton 2	Simazine
Disulfoton Sulfoxide 2	Stirofos
Disulfoton Sulfone	Tebuthiuron
Endosulfan I	Terbufos2
Endosulfan II	Toxaphene
Endosulfan Sulfate	Triademefon
EPTC	Trifluralin

GDA Document P-407B Analytes

Nitrate	

EPA Method 160.1 Analytes

Total Dissolved Solids (TDS)	

Table A-2. Ground-Water Analyses, Coastal Ground-Water Monitoring Project.

Well #	Aquifer	pH su	Date sampled	Conductivity uS/cm	Salinity %	525.2 pesticides ug/L	Nitrate mg/L	TDS mg/L
Brantley County								
25-1	Surficial	8.54	08/25/04	248	0.00	ND	ND	470
25-2	Surficial	7.86	07/28/04	285	0.01	ND	ND	N/A
25-3	Surficial	8.01	07/28/04	205	0.00	ND	ND	N/A
25-4	Miocene	8.28	07/28/04	214	0.00	ND	ND	N/A
25-5	Surficial	8.20	07/28/04	199	0.00	ND	ND	N/A
25-6	Surficial	7.50	05/11/05	299	0.01	ND	ND	270
25-7	Surficial	7.48	05/11/05	304	0.01	ND	ND	290
25-8	Surficial	4.72	05/11/05	59	0.00	ND	ND	70
25-9	Miocene	7.86	05/11/05	142	0.00	ND	ND	180
Bryan County								
29-1	Surficial	8.24	12/15/04	163	0.00	ND	ND	160
29-2	Surficial	5.45	12/15/04	27	0.00	ND	ND	28
29-3	Surficial	5.06	12/15/04	22	0.00	ND	ND	43
29-4	Surficial	6.15	12/15/04	62	0.00	ND	ND	98
29-5	Surficial	8.03	12/16/04	197	0.00	ND	ND	180
Bulloch County								
31-1	Miocene	4.78	09/15/04	109	0.00	ND	14.05	93
31-2	Miocene	8.62	09/15/04	147	0.00	ND	ND	150
31-3	Miocene	8.43	09/15/04	145	0.00	ND	ND	150
31-4	Miocene	7.86	09/15/04	150	0.00	ND	ND	170
31-5	Miocene	4.83	09/15/04	44	0.00	ND	ND	47
31-6	Miocene	8.00	03/30/05	137	0.00	ND	ND	160
31-7	Miocene	8.43	09/15/04	120	0.00	ND	ND	130
Camden County								
39-1	Surficial	7.90	07/29/04	309	0.01	NA	NA	NA
39-1rp	Surficial	7.66	10/14/04	306	0.01	ND	ND	290
39-2	Surficial	7.90	07/29/04	370	0.01	ND	ND	NA
39-3	Surficial	8.02	07/06/05	389	0.01	ND	ND	350
39-4	Surficial	7.80	07/06/05	340	0.01	ND	ND	340
39-5	Miocene	7.89	07/29/04	376	0.01	ND	ND	NA
39-6	Surficial	8.02	07/29/04	305	0.01	ND	ND	NA
39-7	Miocene	8.12	08/25/04	333	0.01	ND	ND	200

Table A-2 (Continued). Ground-Water Analyses, Coastal Ground-Water Monitoring Project.

Well #	Aquifer	pH su	Date sampled	Conductivity uS/cm	Salinity %	525.2 pesticides ug/L	Nitrate mg/L	TDS mg/L
Camden County (cont.)								
39-8	Surficial	9.28	08/25/04	239	0.01	ND	ND	420
39-9	Surficial	8.25	08/25/04	458	0.01	ND	ND	260
39-10	Surficial	7.83	08/26/04	407	0.01	ND	ND	23
Charlton County								
49-1	Surficial	7.51	03/16/05	398	0.01	ND	ND	370
49-2	Surficial	4.83	08/11/04	20	0.00	ND	ND	23
49-3	Surficial	7.54	08/11/04	156	0.00	ND	ND	120
49-4	Surficial	7.18	08/25/04	791	0.03	ND	ND	NA
49-4rp	Surficial	7.16	03/16/05	810	0.03	--	--	760
49-5	Surficial	7.26	08/11/04	704	0.03	ND	ND	680
49-6	Surficial	4.69	08/12/04	16	0.00	ND	ND	15
49-7	Surficial	7.31	04/20/05	407	0.01	ND	ND	360
49-8	Miocene	7.09	04/20/05	536	0.02	ND	ND	480
49-9	Surficial	7.54	05/12/05	226	0.00	ND	ND	190
49-10	Miocene	7.57	05/12/05	350	0.01	ND	ND	300
49-11	Surficial	4.59	05/12/05	25	0.00	ND	ND	40
Chatham County								
51-1	Surficial	5.88	03/31/05	22	0.00	--	ND	44
51-1rp	Surficial	5.77	06/02/05	21	0.00	ND	ND	40
51-2	Surficial	5.78	03/31/05	501	0.02	ND	ND	500
51-3	Miocene	9.67	03/09/05	77	0.00	ND	ND	110
51-4	Surficial	5.41	03/09/05	70	0.00	ND	ND	97
51-5	Surficial	7.25	03/09/05	400	0.01	ND	ND	390
51-6	Surficial	7.46	03/31/05	322	0.01	ND	ND	300
51-7	Surficial	7.66	03/31/05	192	0.00	ND	ND	180
Effingham County								
103-1	Surficial	5.00	07/15/04	52	0.00	ND	1.64	NA
103-2	Miocene	7.96	07/14/04	171	0.00	ND	ND	NA
103-3	Miocene	7.56	07/14/04	229	0.00	ND	ND	NA
103-4	Miocene	8.23	07/15/04	155	0.00	ND	ND	NA
103-5	Surficial	5.74	07/15/04	33	0.00	ND	ND	NA
103-6	Surficial	4.03	07/15/04	37	0.00	ND	ND	NA

Table A-2 (Continued). Ground-Water Analyses, Coastal Ground-Water Monitoring Project.

Well #	Aquifer	pH su	Date sampled	Conductivity uS/cm	Salinity %	525.2 pesticides ug/L	Nitrate mg/L	TDS mg/L
Effingham County (cont.)								
103-7	Surficial	4.03	07/14/04	18	0.00	ND	ND	NA
103-8	Surficial	5.35	12/16/04	62	0.00	ND	2.06	65
103-9	Miocene	8.01	07/14/04	168	0.00	ND	ND	NA
Glynn County								
127-1	Surficial	7.98	10/13/04	255	0.00	ND	ND	250
127-2	Surficial	6.88	10/13/04	381	0.01	ND	ND	360
127-3	POND	7.24	10/14/04	305	0.01	ND	ND	290
127-4	Surficial	7.55	10/13/04	322	0.01	ND	ND	300
127-5	Miocene	7.85	10/14/04	345	0.01	ND	ND	320
127-6	Miocene	7.64	12/02/04	333	0.01	ND	ND	330
127-7	Surficial	7.93	12/02/04	298	0.01	ND	ND	270
127-8	Miocene	7.73	12/02/04	346	0.01	ND	ND	320
127-9	Surficial	7.70	02/16/05	306	0.01	ND	ND	290
127-10	Surficial	7.92	02/17/05	298	0.01	ND	ND	270
Liberty County								
179-1	Surficial	7.91	11/10/04	241	0.00	ND	ND	250
179-2	Surficial	6.08	11/10/04	130	0.00	ND	ND	140
179-3	Miocene	7.93	11/10/04	216	0.00	ND	ND	210
179-4	Surficial	5.57	11/10/04	36	0.00	ND	ND	60
179-5	Surficial	5.69	11/10/04	125	0.00	ND	ND	120
179-6	Miocene	8.05	11/10/04	170	0.00	ND	ND	170
Long County								
183-1	Surficial	6.39	01/12/05	110	0.00	ND	1.74	99
183-2	Miocene	7.07	06/01/05	203	0.00	ND	ND	180
183-3	Surficial	7.91	01/26/05	228	0.00	ND	ND	210
183-3rp	Surficial	7.53	06/01/05	234	0.00	ND	ND	210
183-4	Surficial	7.38	01/12/05	202	0.00	ND	ND	200
183-5	Miocene	7.53	01/12/05	248	0.00	ND	ND	250
183-6	Surficial	4.98	01/12/05	27	0.00	ND	1.21	37
183-7	Surficial	7.87	01/13/05	181	0.00	ND	ND	180

Table A-2 (Continued). Ground-Water Analyses, Coastal Ground-Water Monitoring Project.

Well #	Aquifer	pH su	Date sampled	Conductivity uS/cm	Salinity %	525.2 pesticides ug/L	Nitrate mg/L	TDS mg/L
Mc Intosh County								
191-1	Surficial	7.19	12/01/04	231	0.00	ND	ND	200
191-2	Miocene	8.05	12/01/04	262	0.01	ND	ND	250
191-3	Miocene	8.43	12/01/04	309	0.01	ND	ND	300
191-4	Miocene	8.46	12/01/04	317	0.01	ND	ND	300
191-5	Miocene	8.12	08/11/05	294	0.01	ND	ND	290
Screven County								
251-1	Miocene	6.86	09/29/04	137	0.00	ND	ND	140
251-2	Miocene	6.24	09/29/04	174	0.00	ND	9.98	210
251-3	Miocene	7.60	09/29/04	132	0.00	ND	ND	140
251-4	Miocene	7.70	09/29/04	172	0.00	ND	ND	210
251-5	Miocene	7.54	09/29/04	157	0.00	ND	ND	160
251-6	Surficial	5.71	09/30/04	71	0.00	ND	ND	79
Wayne County								
305-1	Surficial	4.42	10/27/04	66	0.00	ND	5.04	52
305-2	Surficial	7.73	10/27/04	156	0.00	ND	ND	160
305-3	Surficial	4.49	10/28/04	32	0.00	ND	1.40	30
305-4	Surficial	6.05	10/27/04	77	0.00	ND	4.53	82
305-5	Surficial	7.86	10/27/04	141	0.00	ND	ND	170
305-6	Surficial	7.85	10/28/04	165	0.00	ND	ND	140
305-7	Miocene	6.97	10/28/04	148	0.00	ND	ND	180
305-8	Miocene	4.05	01/26/05	66	0.00	ND	6.13	ND
305-9	Miocene	7.95	01/26/05	137	0.00	ND	ND	160
305-10	Surficial	6.76	10/27/04	120	0.00	ND	ND	150

Table A-3. Well Depth and Location Data.

Well No.	Aquifer	Latitude	Longitude	Well Depth	Well Head Elevation	Well Bottom Elevation	Approx. Elevation, Horizon A
Brantley County							
25-1	Surficial	31°14' 07.0"	81°50' 51.8"	280'	71'	-209'	-270'
25-2	Surficial	31°13' 50.2"	81°46' 49.1"	240'	52'	-188'	-270'
25-3	Surficial	31°09' 39.4"	82°00' 40.6"	250'	55'	-195'	-240'
25-4	Miocene	31°21' 37.5"	82°00' 29.9"	300'	60'	-240'	OA
25-5	Surficial	31°11' 14.9"	81°59' 40.0"	260'	66'	-194'	-255'
25-6	Surficial	31°13' 39.3"	81°47' 22.9"	200' to 300'	50'	-150' to -250'	-250'
25-7	Surficial	31°20' 11.9"	81°46' 35.2"	220'	71'	-149'	-300'
25-8	Surficial	31°13' 24.0"	81°50' 35.2"	25'	69'	44'	-270'
25-9	Miocene	31°12' 03.5"	82°14' 03.5"	~100' (<200)	127'	-73' to 21'	OA
Bryan County							
29-1	Surficial	32°08' 43.6"	81°43' 01.6"	25'	106'	81'	-60'
29-2	Surficial	32°10' 01.7"	81°36' 41.4"	80'	98'	18'	-80'
29-3	Surficial	32°12' 39.7"	81°31' 34.3"	40' to 50'	71'	21' to 31'	-80'
29-4	Surficial	32°06' 42.0"	81°30' 01.7"	40'	78'	38'	-155'
29-5	Surficial	31°46' 01.4"	81°14' 43.7"	100'	10'	-90'	-220'
Bulloch County							
31-1	Miocene	32°19' 00.0"	81°40' 24.0"	100'	116'	16'	OA
31-2	Miocene	32°20' 27.3"	81°44' 24.7"	100'	167'	67'	OA
31-3	Miocene	32°16' 47.5"	81°43' 48.8"	300'	159'	-141'	OA
31-4	Miocene	32°19' 33.1"	81°33' 08.5"	140'	102'	-38'	OA
31-5	Miocene	32°14' 06.1"	81°36' 48.1"	80'	95'	15'	-60'
31-6	Miocene	32°23' 04.4"	81°40' 06.7"	<100'	162'	>62'	OA
31-7	Miocene	32°11' 42.0"	81°46' 49.6"	80'	120'	40'	-60'
Camden County							
39-1	Surficial	31°05' 28.2"	81°35' 00.9"	220'	23'	-197'	-320'
39-2	Surficial	30°49' 39.9"	81°40' 23.0"	240'	22'	-218'	-250'
39-3	Surficial	30°47' 39.7"	81°34' 17.9"	285'	30'	-255'	-300'
39-4	Surficial	30°47' 10.3"	81°34' 10.4"	290'	25'	-265'	-300'
39-5	Miocene	31°02' 27.4"	81°32' 24.7"	460'	6'	-454'	-300'
39-6	Surficial	31°02' 29.3"	81°32' 26.6"	180'	8'	-172'	-300'
39-7	Miocene	31°06' 09.3"	81°42' 36.7"	455'	20'	-435'	-240'

Table A-3 (Continued). Well Depth and Location Data.

Well No.	Aquifer	Latitude	Longitude	Well Depth	Well Head Elevation	Well Bottom Elevation	Approx. Elevation, Horizon A
Camden County (cont.)							
39-8	Surficial	31°06' 02.7"	81°42' 36.4"	195'	20'	-175'	-240'
39-9	Surficial	30°51' 23.3"	81°37' 58.8"	200'	12'	-188'	-240'
39-10	Surficial	30°57' 47.6"	81°41' 59.1"	65'	18'	-47'	-200'
Charlton County							
49-1	Surficial	30°44' 27.0"	82°07' 37.7"	300'	155'	-145'	N/A
49-2	Surficial	30°51' 05.1"	81°58' 26.3"	30'	68'	38'	-210'
49-3	Surficial	30°31' 58.0"	82°01' 48.0"	32'	40'	8'	N/A
49-4	Surficial	30°50' 14.0"	82°02' 21.5"	200'	76'	-124'	N/A
49-5	Surficial	30°51' 14.2"	82°03' 44.2"	80'	72'	-8'	N/A
49-6	Surficial	31°03' 03.9"	81°57' 21.8"	75'	83'	8'	N/A
49-7	Surficial	30°43' 19.2"	82°03'46.1"	85'	72'	-13'	N/A
49-8	Miocene	30°47' 24.4"	82°01' 41.8"	320'	65'	-255'	-200'
49-9	Surficial	30°23' 40.2"	82°07' 19.3"	120'	125'	5'	N/A
49-10	Miocene	30°31' 22.6"	82°02' 17.6"	300'	80'	-220'	N/A
49-11	Surficial	30°57' 57.2"	82°06' 51.5"	50' to 60'	126'	56' to 66'	N/A
Chatham County							
51-1	Surficial	31°56' 41.3"	81°02' 18.0"	61.3'	10.97'	-50.33'	-130'
51-2	Surficial	31°56' 41.3"	81°02' 18.0"	17.1'	11.00'	-6.1'	-130'
51-3	Miocene	32°07' 18.0"	81°15' 37.2"	210'	20'	-190'	-165'
51-4	Surficial	32°00' 18.2"	81°15' 18.0"	20' to 30'	15'	-5' to -15'	-175'
51-5	Surficial	32°06' 10.4"	81°12' 47.5"	32'	10'	-22'	-165'
51-6	Surficial	31°58' 55.9"	81°03' 55.4"	48'	12'	-36'	-140'
51-7	Surficial	32°00' 29.7"	81°04' 10.5"	70'	15'	-55'	-140'
Effingham County							
103-1	Surficial	32°20' 07.4"	81°23' 32.2"	20'	95'	75'	-30'
103-2	Miocene	32°25' 15.7"	81°22' 52.8"	60'	80'	20'	N/A
103-3	Miocene	32°14' 07.4"	81°19' 23.0"	80'	131'	51'	N/A
103-4	Miocene	32°26' 56.9"	81°21' 27.3"	80'	102'	22'	N/A
103-5	Surficial	32°22' 13.8"	81°18' 22.2"	30'	58'	28'	-60'
103-6	Surficial	32°14' 52.2"	81°13' 17.2"	80'	51'	-29'	-120'
103-7	Surficial	32°14' 07.4"	81°19' 23.0"	80'	80'	0'	-110'

Table A-3 (Continued). Well Depth and Location Data.

Well No.	Aquifer	Latitude	Longitude	Well Depth	Well Head Elevation	Well Bottom Elevation	Approx. Elevation, Horizon A
Effingham County (cont.)							
103-8	Surficial	32°09' 10.2"	81°19' 45.8"	80'	33'	-47'	-140'
103-9	Miocene	32°17' 45.6"	81°23' 49.7"	185'	75'	-110'	-55'
Glynn County							
127-1	Surficial	31°13' 28.2"	81°32' 06.0"	200'	25'	-175'	-330'
127-2	Surficial	31°12' 13.0"	81°22' 35.3"	55'	16'	-39'	-340'
127-3	POND	31°17' 02.3"	81°31' 01.7"	0'	23'	23'	-350'
127-4	Surficial	31°13' 15.3"	81°30' 12.6"	250'	15'	-235'	-350'
127-5	Miocene	31°16' 41.3"	81°28' 36.7"	560'	15'	-545'	-340'
127-6	Miocene	31°07' 59.9"	81°33' 36.5"	540'	13.5'	-526.5'	-320'
127-7	Surficial	31°17' 58.3"	81°41' 53.3"	280'	18'	-262'	-300'
127-8	Miocene	31°18' 13.2"	81°41' 24.7"	630'	17'	-613'	-305'
127-9	Surficial	31°16' 46.9"	81°31' 03.2"	250'	24'	-226'	-340'
127-10	Surficial	31°17' 36.3"	81°41' 25.5"	75'	20'	-55'	-300'
Liberty County							
179-1	Surficial	31°45' 26.5"	81°20' 48.3"	150'	34.4'	-115.6'	-240'
179-2	Surficial	31°45' 39.2"	81°17' 20.7"	60'	24'	-36'	-190'
179-3	Miocene	31°45' 39.2"	81°17' 20.7"	400'	24'	-376'	-190'
179-4	Surficial	31°44' 26.4"	81°19' 32.6"	150'	29.5'	-120.5'	-225'
179-5	Surficial	31°51' 23.7"	81°25' 28.5"	20'	21'	1'	-185'
179-6	Miocene	31°53' 41.7"	81°25' 30.5"	400'	16'	-384'	-180'
Long County							
183-1	Surficial	31°48' 18.4"	81°42' 11.6"	25'	89'	64'	-140
183-2	Miocene	31°43' 21.5"	81°43' 26.0"	400'	63'	-337'	-200'
183-3	Surficial	31°43' 21.2"	81°43' 26.2"	250'	63'	-187'	-200'
183-4	Surficial	31°38' 41.9"	81°40' 13.0"	140'	36'	-104'	-230'
183-5	Miocene	31°47' 48.9"	81°49' 47.1"	260'	78'	-182'	-155'
183-6	Surficial	31°48' 15.9"	81°52' 48.5"	25'	60'	35'	-145'
183-7	Surficial	31°44' 51.8"	81°47' 55.3"	170'	64'	-106'	-170'
Mc Intosh County							
191-1	Surficial	31°32' 25.4"	81°31' 33.7"	110'	20'	-90'	-240'

Table A-3 (Continued). Well Depth and Location Data.

Well No.	Aquifer	Latitude	Longitude	Well Depth	Well Head Elevation	Well Bottom Elevation	Approx. Elevation, Horizon A
Mc Intosh County (cont.)							
191-2	Miocene	31°34' 43.6"	81°19' 54.3"	450'	24.6'	-425.4'	-290'
191-3	Miocene	31°28' 23.2"	81°22' 42.6"	480'	22'	-458'	-300'
191-4	Miocene	31°28' 21.1"	81°22' 52.6"	428'	20'	-408'	-300'
191-5	Miocene	31°22' 58.5"	81°26' 04.3"	500'	25'	-475'	-355'
Screven County							
251-1	Miocene	32°48' 56.6"	81°40' 01.3"	100' to 200'	121'	-79' to 21'	OA
251-2	Miocene	32°43' 20.6"	81°44' 37.8"	25'	291'	266'	N/A
251-3	Miocene	32°45' 05.4"	81°35' 04.6"	60'	118'	58'	OA
251-4	Miocene	32°43' 43.5"	81°44'28.2"	140'	289'	149'	OA
251-5	Miocene	32°37' 31.6"	81°35' 59.7"	175'	191'	16'	OA
251-6	Surficial	32°41' 47.0"	81°28' 59.1"	30'	153'	123'	N/A
Wayne County							
305-1	Surficial	31°37' 20.9"	82°01' 10.9"	19'	135'	116'	-230'
305-2	Surficial	31°38' 33.9"	81°51' 25.8"	295'	99'	-196'	-240'
305-3	Surficial	31°28' 54.0"	82°01' 00.6"	42'	125'	83'	-250'
305-4	Surficial	31°37' 03.6"	82°00' 36.7"	50'	137'	87'	-230'
305-5	Surficial	31°39' 52.9"	81°55' 07.8"	220'	110'	-110'	-220'
305-6	Surficial	31°31' 55.7"	81°54' 02.5"	230'	90'	-140'	-250'
305-7	Miocene	31°41' 50.1"	82°04' 40.7"	430'	160'	-270'	N/A
305-8	Miocene	31°27' 52.2"	82°02' 00.5"	30' to 35'	122'	87' to 92'	OA
305-9	Miocene	31°27' 52.7"	82°02' 00.2"	280'	122'	-158'	OA
305-10	Surficial	31°37' 03.6"	82°00' 36.7"	200'	137'	-63'	-230'