AQUIFER PERFORMANCE TEST REPORT

Tybee Island Miocene (Upper Brunswick) Aquifer, Chatham County, Georgia

March 19-March 23, 1997

By

Bill Sharp, Sam Watson, and Rex Hodges

Department of Natural Resources
Environmental Protection Division
Georgia Geologic Survey

Project Report No. 33

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This report has not been reviewed for conformity with Georgia Geologic Survey editorial standards, stratigraphic nomenclature, and standards of professional practice.

DEPARTMENT OF NATURAL RESOURCES
Lonice C. Barrett, Commissioner
ENVIRONMENTAL PROTECTION DIVISION
Harold F. Reheis, Director
GEORGIA GEOLOGIC SURVEY
William H. McLemore, State Geologist

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ABSTRACT

As part of the Georgia Geologic Survey's "Evaluation of the Miocene Aquifers in the Coastal Area of Georgia Project", the Department of Geological Sciences at Clemson University conducted a pump test at the Georgia Geologic Survey's Tybee Island well cluster, located at the Tybee Island Sewage Treatment Plant, Chatham County, Georgia. A test of the Upper Brunswick aquifer at Tybee Island, was conducted from March 19 through March 23, 1997 using Tybee 2 as the pumping well, along with Tybee 4 and Tybee 3 as observation wells. The Lower Brunswick aquifer is not present at the Tybee Island test site. The observation well, Tybee 4, is located 48.3 feet away from Tybee 2 and is screened over the same hydrogeologic interval as the pumping well (Upper Brunswick aquifer). A storativity of 0.0001 and a transmissivity of 21,500 ft^2/day (2000 m^2/day) were calculated for the Upper Brunswick aquifer based on the pump test data. Transmissivity calculations were made using an average flow rate of 100.8 gpm to obtain values of 2000 m^2/day, with a storativity of 0.0001 and a skin factor of 213. Data from observation well Tybee 4 were not used in the calculations due to a non-Theis drawdown vs. time curve. The extremely quick pumping response and approach to equilibrium of the observation well are attributed to very high hydraulic conductivities in the vicinity of the test site. This apparent "direct connection" between wells may be due to the local geology consisting of a fractured carbonate, shell hash, or a gravelly channel deposit. The 8.8 meter (29 ft.) effective aquifer thickness of the Upper Brunswick at Tybee Island yields hydraulic conductivities of 741 ft/day (226 m/day). Tybee 1, drilled to the Lower

Floridan aquifer, is not screened but was left open at the bottom of the casing. Tybee 1 was not used in the pump test. Tybee 3, located approximately 14 ft away from the pumped well and screened in the surficial unconfined aquifer, was monitored to detect vertical leakage across the confining unit separating the Upper Brunswick Aquifer from the overlying unconfined aquifer. No water-level changes directly related to pumping were observed in Tybee 3, suggesting no pumping related leakage across the confining unit separating the Upper Brunswick aquifer and the surficial water table aquifer. Small drawdown and recovery perturbations superposed on the water level vs. time curves were observed for both the pumping well, Tybee 2 and the observation well, Tybee 4. These are believed to be caused by the nearby City of Tybee Island Water and Sewer Department water supply well, which pumps from the Upper Floridan aquifer. It is also believed that the extremely rapid response in well, Tybee 2 and Tybee 4 to pumping from the production well is most likely due to the wells being screened in the same hydrologic zone, suggesting an absence of a confining unit between the Upper Brunswick aquifer and the Upper Floridan aquifer in the vicinity of the test site.

ACKNOWLEDGMENTS

Funding for this project was provide through the Geologic Survey Branch of the Georgia Environmental Protection Division. Georgia Geologic Survey (William Steele and Earl Shapiro) oversaw well installation and coordinated logistical arrangements with Clemson University Geological Sciences Department Personnel to conduct the Tybee Island Miocene (Upper Brunswick) aquifer performance test. Welby Stayton of the United States Geological Survey (USGS) provided water level trend data and Roger McFarland, also of the USGS, provided tidal data. Electricity was provided by the City of Tybee Island Water and Sewer Department. George Reese, assistant supervisor of the Tybee Island Water and Sewer Department provided general assistance.

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INTRODUCTION

Purpose of the Tybee Island Miocene (Upper Brunswick) Aquifer Performance Test

Due to the hydrologic stress imposed on the Eocene to Oligocene age Upper Floridan aquifer, the principal water source of coastal Georgia, the Geologic Survey Branch of the Georgia Environmental Protection Division is investigating the Miocene (Upper and Lower Brunswick) aquifers as an alternative source of ground water for the region. The test on Tybee Island is to be one of seven Miocene aquifer tests to be conducted at selected sites in the coastal area of Georgia. Four of the seven test sites will be located in coastal counties, and three of the sites will be located inland where agricultural ground-water use is prevalent. The purpose of the Tybee Island pump test is to estimate the transmissivity and storativity of the Miocene (Upper Brunswick) aquifer at the test site. Eventually the hydrologic properties from each of the seven sites will be analyzed to determine if the Miocene (Upper and Lower Brunswick) aquifers are viable alternatives to the Upper Floridan aquifer for smaller-demand needs such as community water supply, golf courses, agricultural (lower demand or supplemental), small industries, and non-contact cooling water.

Site Conditions

Location

Tybee Island is located approximately 15 miles east of Savannah, Georgia. Figure 1 is a map of Georgia showing the location of the Tybee Island test site, the St. Marys test site and the Toombs County test site. The Tybee Island well cluster is located at the Tybee Island Sewage Treatment plant on Tybee Island, Chatham County, Georgia, as illustrated in figure 2. Locations of the Tybee Island Sewer Department's Upper Floridan production well and Fort Pulaski are also shown in Figure 2. Figure 3 is a map of the Tybee Island test site showing the relative locations of the pump well and the observation wells.

Hydrogeologic Setting

The Tybee Island well cluster is drilled into Coastal Plain sediments ranging in age from middle Eocene to Holocene. The Coastal Plain sediments in the study area consist of unconsolidated to semiconsolidated layers of sand and clay and semi-consolidated to very dense layers of limestone and dolomite (Clarke, et al., 1990). Strata underlying the site dips and thickens to the southeast. The thickness of the Coastal Plain sediments at the Tybee Island well cluster is approximately 3800 ft (1158 m), based on Hilton Head test well #1 which is located 20 miles to the northeast along regional strike. The hydrostratigraphy of the site consists of four aquifers. From deepest to shallowest, these are the Lower Floridan, the Upper Floridan, the Upper Brunswick and the surficial aquifer. The major hydrogeologic units, geophysical well logs, and screen depth intervals of wells are shown in Figure 4.

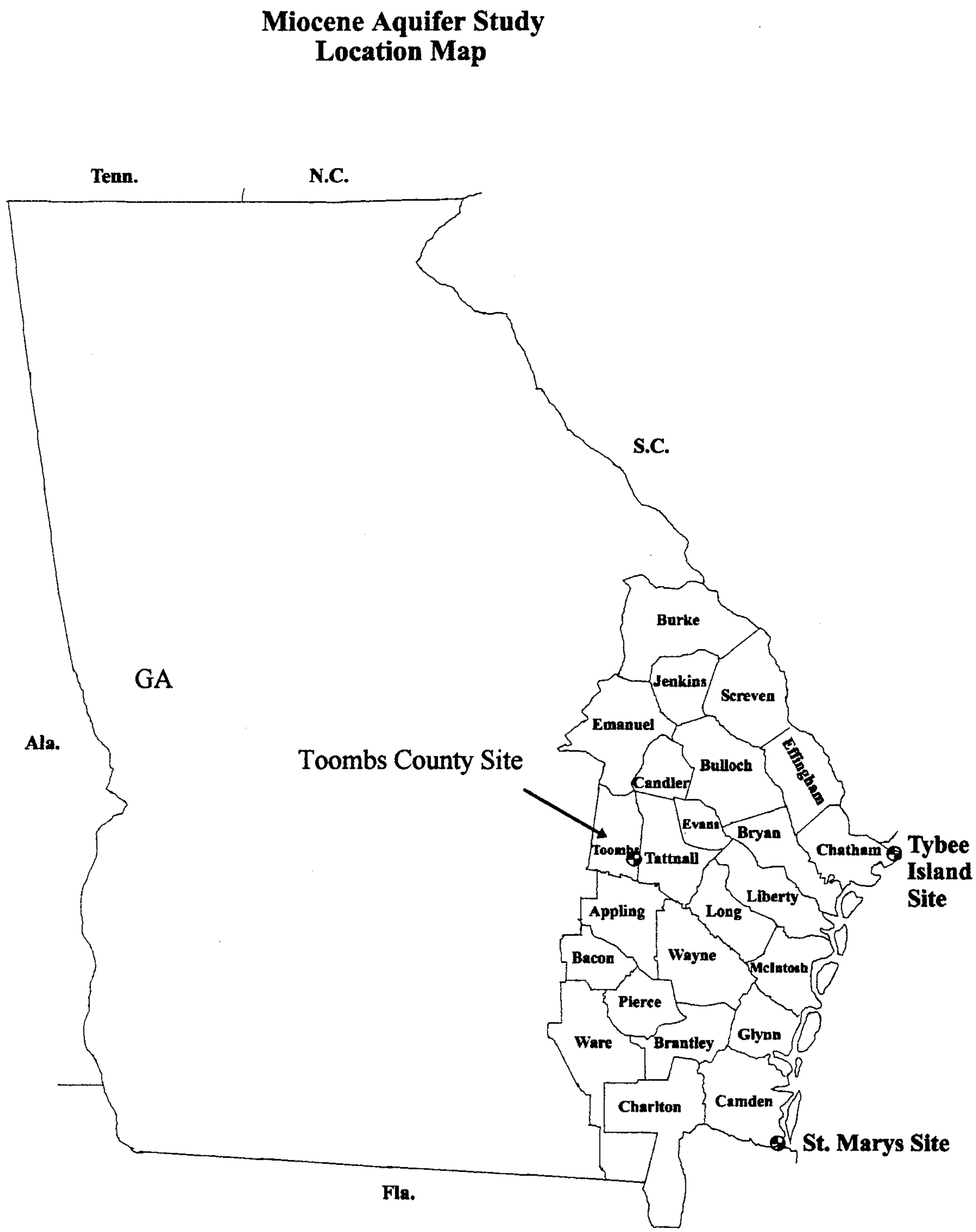


Figure 1: Map of Georgia showing the location of Tybee Island test site.

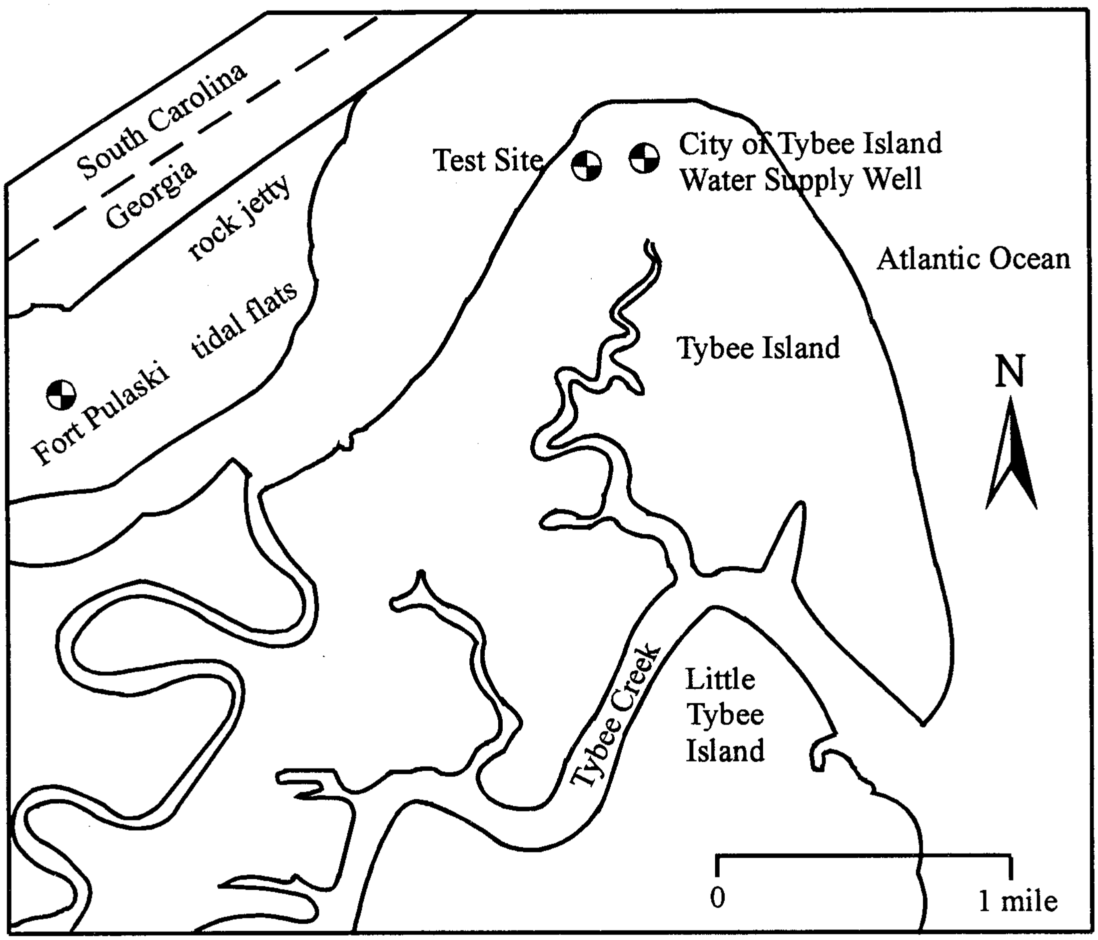


Figure 2: Map of Tybee Island showing location of test site, the City of Tybee Island water supply well and Fort Pulaski.

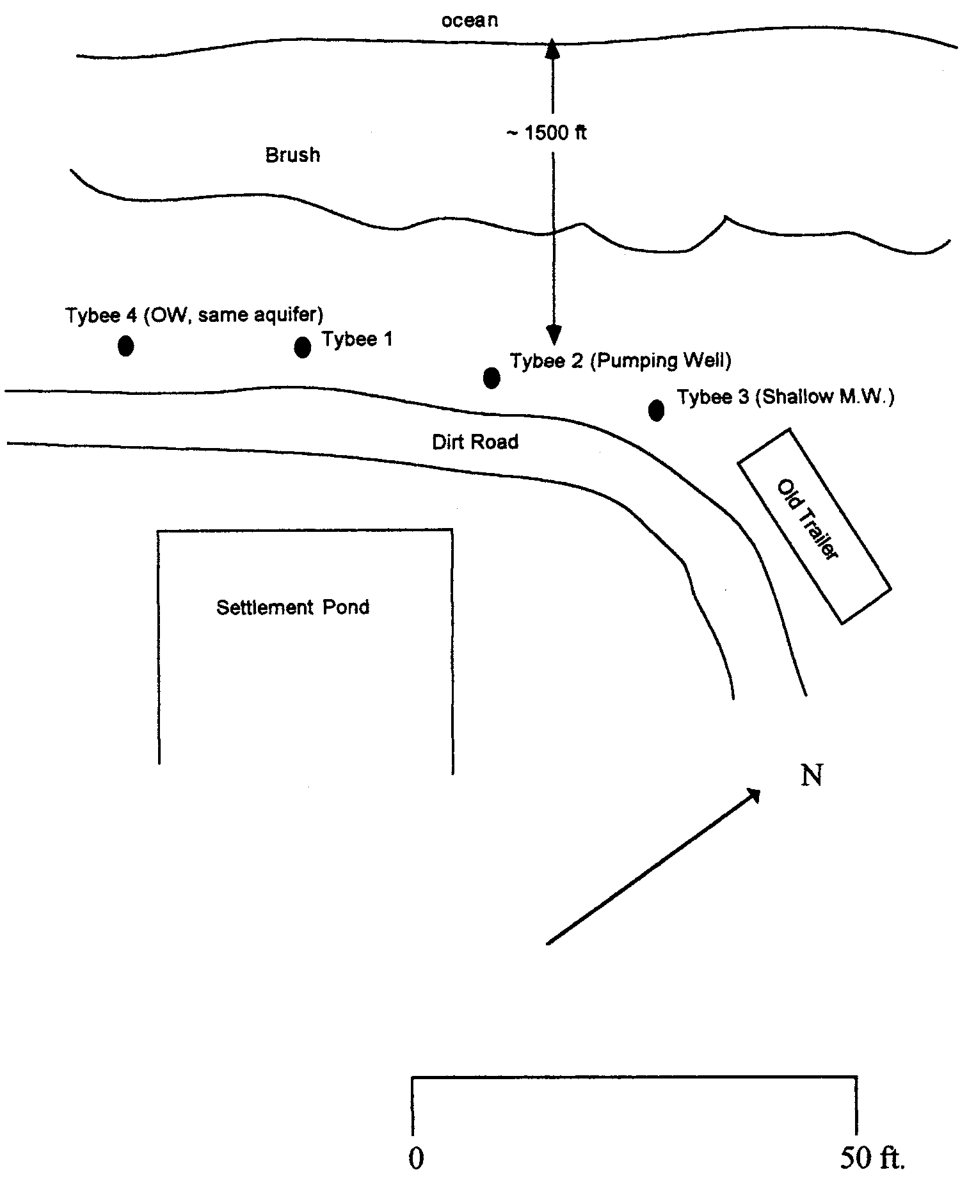
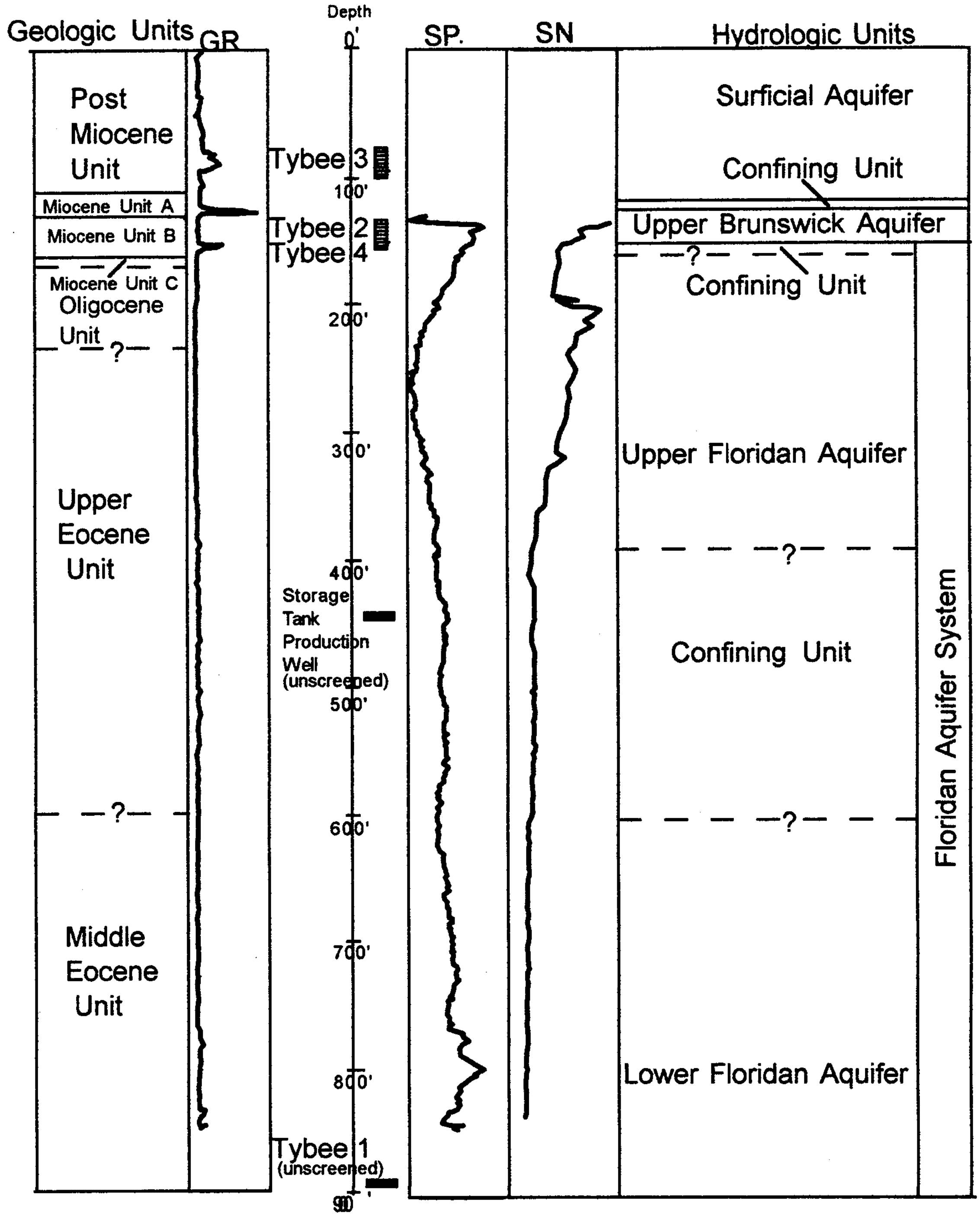


Figure 3: Map of test site showing relative locations of wells.



GR = gamma ray, SP = spontaneous potential, SN = short normal resistivity

= screened interval = open interval

Figure 4: Geophysical logs, geologic and hydrologic units, and depth of screen intervals at the Tybee Island test site.

Description of Wells Used for the Test

Tybee 2 was used as the pumping well and Tybee 4 served as the observation well for the test. Tybee 3 (screened in the unconfined, surficial aquifer) was also monitored to detect any potential leakage. The construction diagrams for each of the wells, including the Tybee Island Water/Sewer Department's Upper Floridan water supply well, are shown in Figures 5-8.

Site coordinates: 32 01'27" lat. 80 51'11" long.

Date of construction: 05/16/96

Ground elevation: 10 ft MSL

Screened hydrologic unit: Upp. Brun. aq.

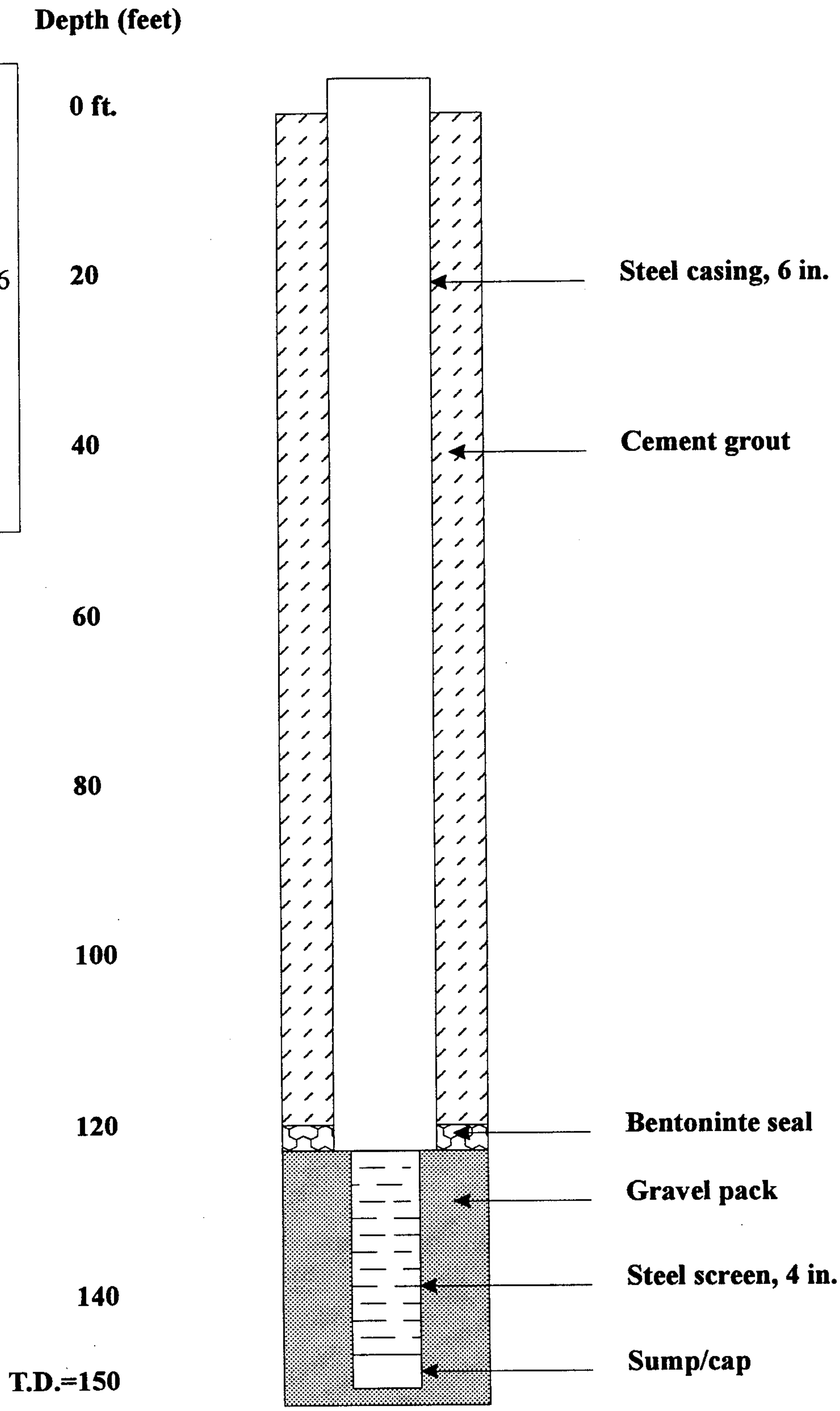


Figure 5: Well construction diagram for pump well Tybee 2

Site coordinates:
32 01'27" lat.
80 51'11" long.

Date of construction: 06/05/96

Ground elevation: 10 ft MSL

Screened hydrologic unit: Surficial aq.

Distance from pumping well: 13.6 ft.

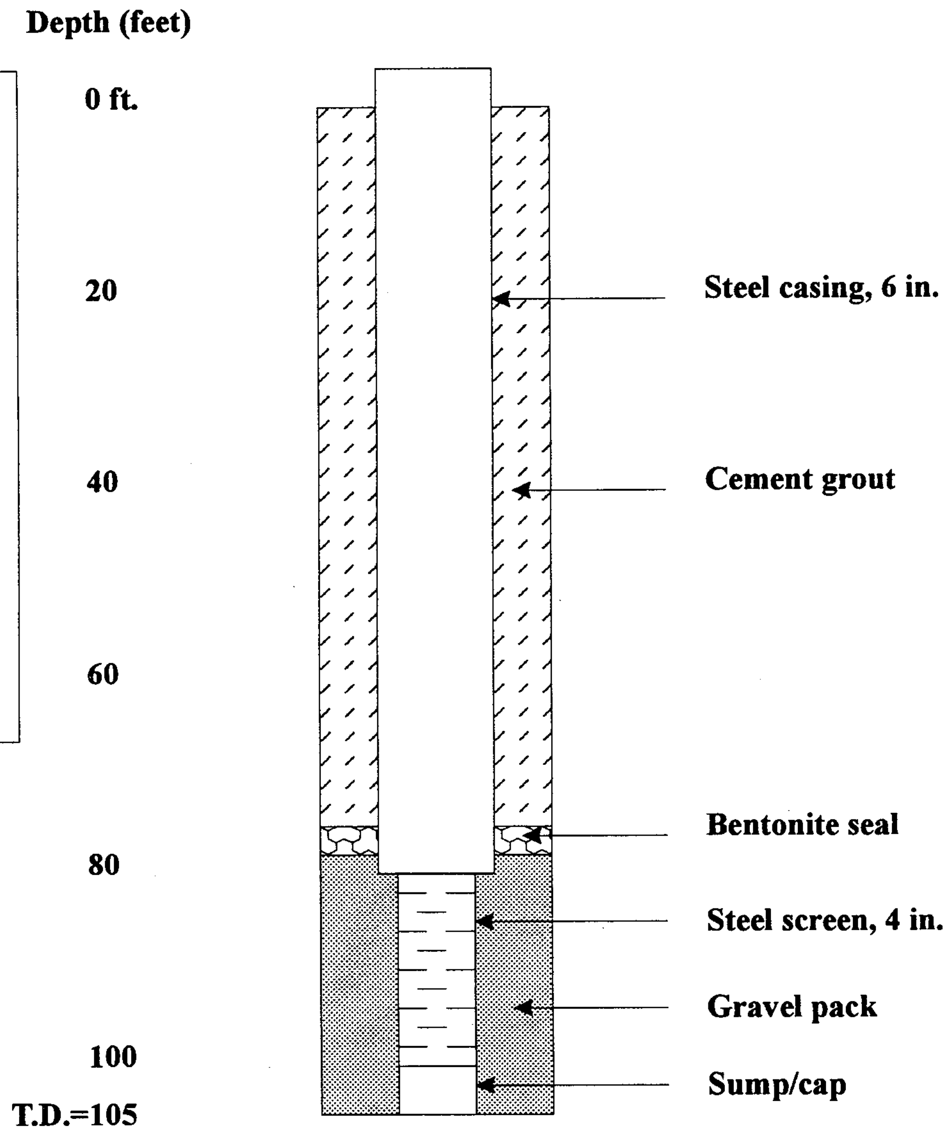


Figure 6: Well construction diagram for monitor well Tybee 3

Site coordinates:
32 01'27" lat.
80 51'11" long.

Date of construction: 06/96

Ground elevation: 10 ft MSL

Screened hydrologic unit: Upp. Brun. aq.

Distance from pumping well: 48.3 ft

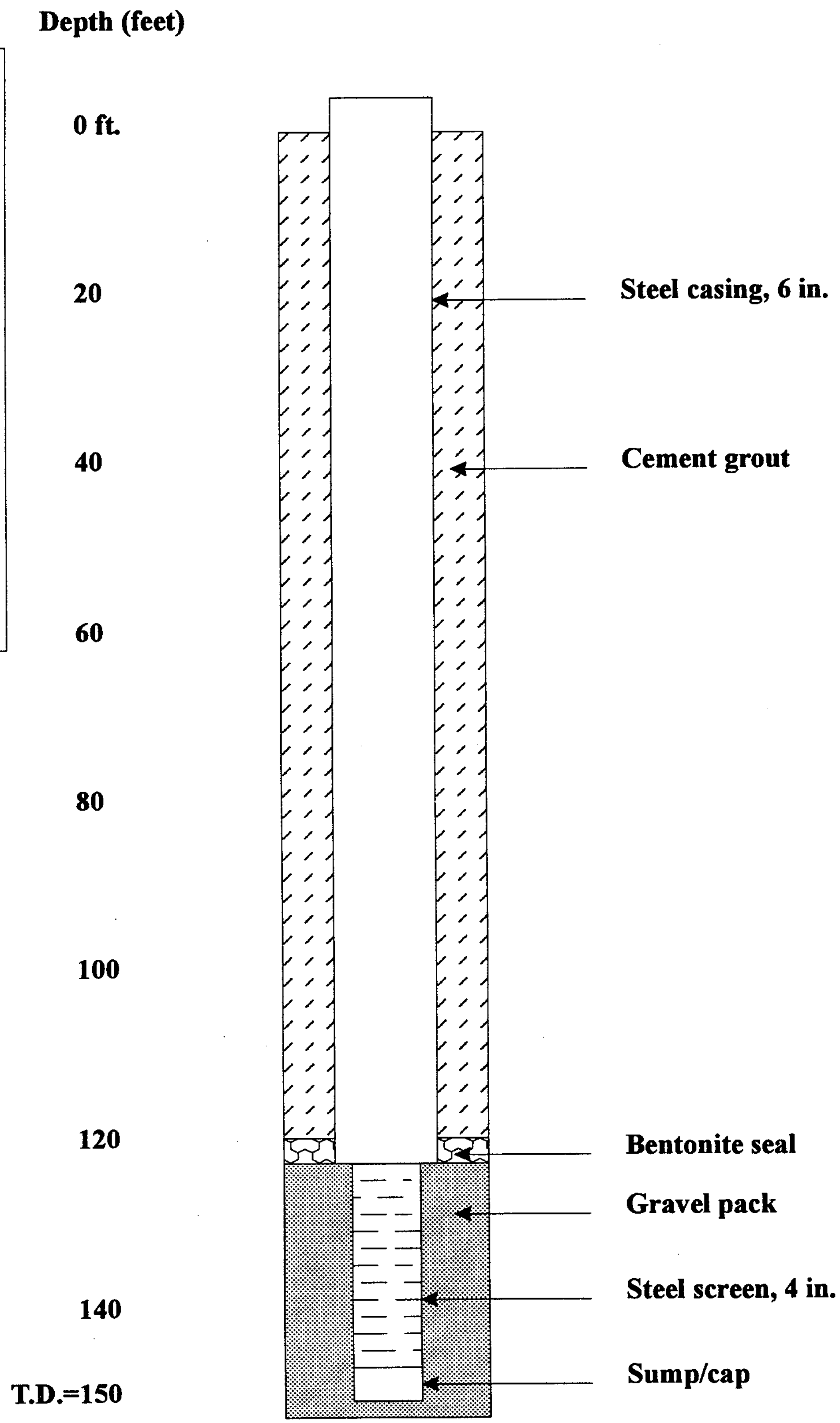
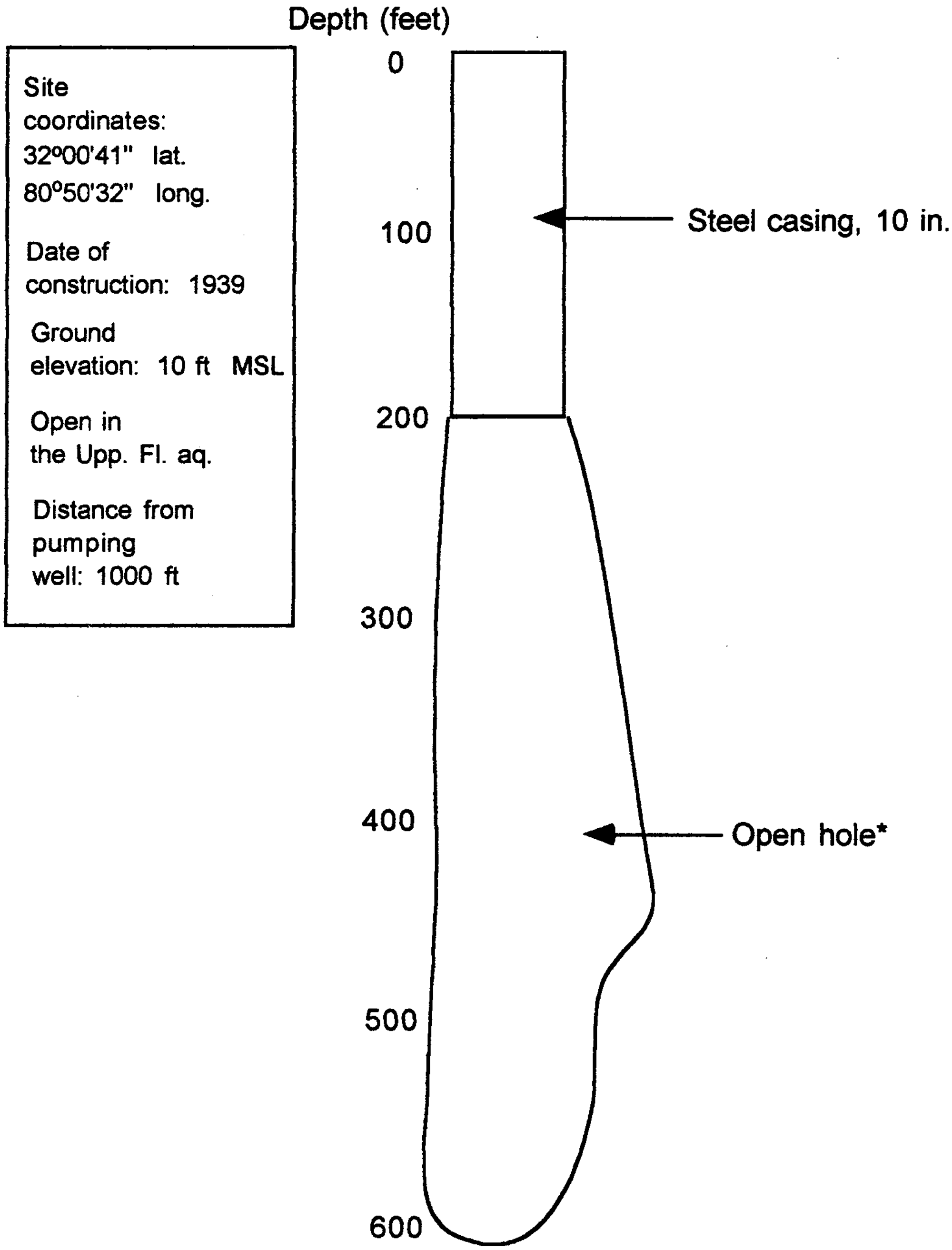


Figure 7: Well construction diagram for monitor well Tybee 4



*Due to no casing, most of this open hole interval has probably caved in, therefore most production will be from the top portion of the open hole interval (near Tybee 2 and Tybee 4).

Figure 8: Well construction diagram for the City of Tybee Island Water/Sewer Department's Upper Floridan water supply well.

METHODS

Test Logistics

A pump test is composed of three periods of data collection: background, pumping, and recovery. Background data are used to determine if the aquifer is in an equilibrium condition and the extent to which it is being affected by inconsistent external forces. Background data are also used to determine the barometric efficiency of the monitored aquifer so test data can be corrected for changes in atmospheric pressure. The aquifer is then pumped, creating a pressure drawdown cone extending radially from the pumping well. After pumping stops, the aquifer is allowed to recover to pre-test conditions.

The test took place from March 19 to March 23, 1997. The Upper Brunswick aquifer was pumped using Tybee 2 and monitored using Tybee 4. The unconfined aquifer was monitored in order to detect leakage, using Tybee 3. The test consisted of 9.04 hours of background data collection, 72.00 hours of pumping and 17.60 hours of recovery data collection.

Data Acquisition Methods

Water level readings are recorded as pressure changes in meters of water relative to an initial equilibrium static water level condition. For the duration of a pump test (background through recovery), quartz crystal transducers measure water level changes in the pumping well and observation wells. Relative water level changes are recorded automatically on the computer data acquisition system at operator-specified intervals ranging from 3 seconds to 5 minutes throughout the test. An additional transducer monitors and records changes in atmospheric pressure, which are used to correct for atmospheric induced changes in water levels in the test wells. The transducers are calibrated to a maximum of 0.005% of full scale (1.5 mm for a 45 psi transducer) for repeatability and hysteresis. The resolution of a 45 psi transducer is normally about 0.2 mm.

Pumping Well Data Acquisition Methods

The pumping well, Tybee 2, is screened over nearly the entire Upper Brunswick aquifer from -115 to -135 ft (-35.1 to -41.1 m) MSL (Figure 4). A 100 psi transducer was placed approximately 10 ft below a 5 HP pump which was lowered down the well for the test.

Observation Well Data Acquisition Methods

Observation well Tybee 4 was also screened in the Upper Brunswick aquifer from -115 to -135 ft (-35.1 to -41.2 m) MSL. The shallow surficial well, Tybee 3, was monitored to detect vertical leakage, if present, between the Upper Brunswick and the surficial aquifer units. The relative screen positions are shown in Figure 4. Pressure transducers (45 PSI) were placed below the water level surface in the wells to continuously monitor water level changes.

Analysis Methods

Atmospheric Pressure Corrections

The initial analysis step is to correct the raw pressure data from the wells for changes in atmospheric pressure. These variations can mask the small response of an aquifer in an observation well. Removal of atmospheric pressure-induced water level changes makes it easier to detect water level changes that result from pumping.

Barometric corrections are made by subtracting atmospheric pressure changes multiplied by the barometric efficiency (BE) of an aquifer from the corresponding water level measurements. The BE of an aquifer is the ratio of the change in hydraulic head in an aquifer (due to atmospheric changes) to the actual change in atmospheric pressure. A BE of 1 indicates that 100 percent of the atmospheric pressure changes have been transmitted to the aquifer. A BE of 0 would indicate that none of the atmospheric pressure changes have been transmitted to the aquifer. A typical BE for confined aquifers in the Coastal Plain of Georgia is about 0.6, ranging from 0.4 to 0.8.

Tidal Effects Corrections

The Tybee Island test site is located approximately 1500 feet from the Atlantic Ocean and the raw pressure data from the wells were strongly affected by the ocean tidal cycle. Therefore it is necessary to remove the changes in raw well pressure due to this tidal effect in order to detect well pressure changes responding solely to pumping. Tide data from the Fort Pulaski tidal station (located approximately 3 miles west of the test site, Figure 2) was used for corrections.

Tidal effect corrections are made by subtracting the change in tide (in terms of sea level), multiplied by the tide factor, from the barometric corrected well pressure. The tide factor is the ratio of the change in hydraulic head in an aquifer (due to the tidal movements in relation to sea level) to the actual change in tide in relation to sea level. A tide factor of 1 indicates that 100 percent of the changes in tides (in relation to sea level) have been transmitted to the aquifer. A tidal factor of 0 would indicate that 0 percent of tide factor of 1 indicates that 100 percent of the changes in tides (in relation to sea level) have been transmitted to the aquifer. A tidal factor of 0 would indicate that 0 percent of the changes in tides (in relation to sea level) have been transmitted to the aquifer. The sum of the barometric correction factors and tidal correction factors for each well is unity (1).

Well Analysis Methods

Data from an observation well, screened in the same aquifer as the pumping well, can be analyzed to calculate the storativity and transmissivity of the aquifer (see Test Logistics and Pumping Rates). Data from the pumping well are governed by three variables: the transmissivity and storativity of the aquifer, and the skin factor of the pumping well. If one of the three variables is known or can be estimated, the other two can be calculated. The skin factor of the pumping well is unknown and could be highly variable depending on well installation. The storativity of the aquifer is less sensitive than the transmissivity. It is estimated from analysis of observation well data (if available) or from average storativity values of similar aquifers. This storativity value is then used in the analysis of the pump well data. Variable rate curve matching of drawdown data yields a transmissivity value for the aquifer and a skin factor for the pumping well using the superposition of the Theis solution (1935) or Jacob straight-line method (Cooper and Jacob, 1946) for variable flow rates, modified for the skin factor analysis of Van Everdingen (1953) for confined aquifers with fully penetrating wells. For partial penetrating wells, data are analyzed using the Hantush (1961, 1964) solution for partial penetrating wells modified to account for the skin factor and multiple flow rate. The Hantush solution is used to calculate the transmissivity of the aquifer and the skin factor of the well, while correcting for vertical flow within the aquifer. Hydraulic conductivity is calculated by dividing the transmissivity by the effective aquifer thickness. Permeability can then be calculated by multiplying the hydraulic conductivity in m/sec by a factor of 104,000 to convert to darcys (at 20° C; Fetter, 1988).

RESULTS

Duration of the Test

The pump test, using pumping well Tybee 2 and observation well Tybee 4, took place over a five day span in the middle of March, 1997. The specific times for each phase of the test are shown in Table I.

Data	No. of hours	Time interval
Background Data	9.04 hours	(09:07 03/19/97 to 18:09 03/19/97)
Pump On	72.0 hours	(18:09 03/19/97 to 18:09 03/22/97)
Recovery (pump off)	17.6 hours	(18:09 03/22/97 to 11:45 03/23/97)
Total test	98.64 hours	(09:07 03/19/97 to 11:45 03/23/97)

Table I. Chart showing times for each phase of the test.

Data Acquisition Results

Pumping Rates

Drawdown in the pumping well was created by pumping water from well Tybee 2 using a 5 hp submersible pump. For the duration of the pumping phase of the test, the flow rate showed cyclic fluctuations of approximately .75 gpm in magnitude, as illustrated in Figure 9. Because the fluctuations followed a regular cyclic pattern and were small in magnitude, they did not interfere with the analysis. A time-weighted average flow rate was calculated to be 100.8 gpm. Flow rates during the test were automatically measured and recorded using an Omega digital flow meter.

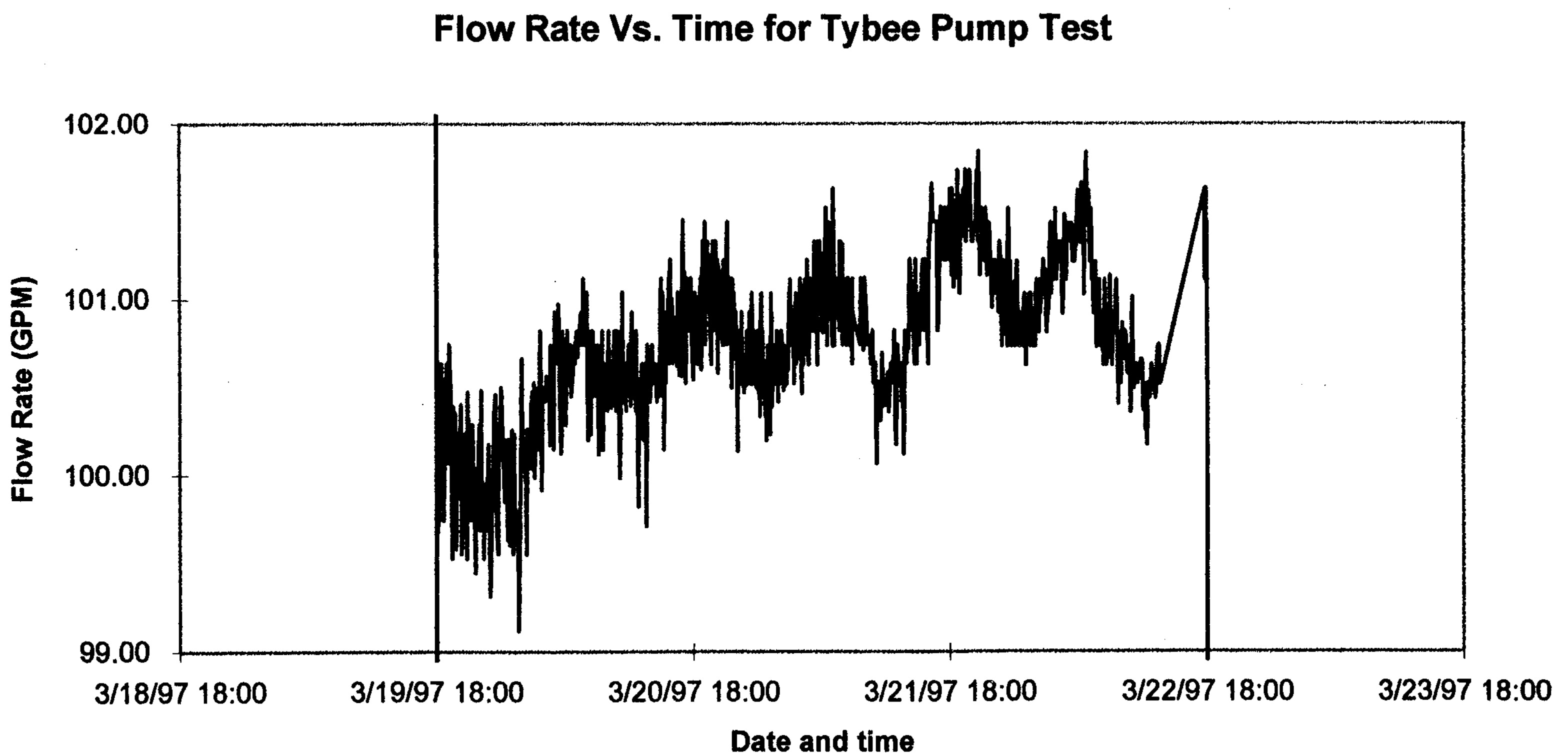


Figure 9: Graph showing flow rate vs. time over the duration of the test.

Water Level Readings

During the test, 2391 water level data points were recorded in the pumping and observation wells by the data aquisition system. Data points were recorded as frequently as every 3 seconds at times of rapidly changing water levels (i.e. at the beginning and end of the test), decreasing to every 5 minutes when water level changes were relatively small. Figure 10 shows plots of water level changes vs. time for the pumping well Tybee 2, including the ocean tide fluctuations, observed drawdown and recovery with barometric corrections only applied, and observed drawdown and recovery with both tidal corrections and barometric corrections applied. Figure 11 shows plots of water level vs. time (barometric and tidal corrected) for the pumping well Tybee 2 and the observation well Tybee 4.

Water Level Change During the Test

A maximum drawdown of about 9.8 meters (32.35 ft) was observed in Upper Brunswick pumping well Tybee 2 after approximately 71.9 hours of pumping. A maximum drawdown of approximately 1.4 meters (4.58 ft) was seen in observation well Tybee 4.

Observation well Tybee 4 showed non-typical immediate response to pumping which indicates an almost direct connection (fracture or zone of extremely high permeability) to the pumping well.

The surficial observation well Tybee 3 showed no observable changes in water level due to pumping as shown in Figure 12.

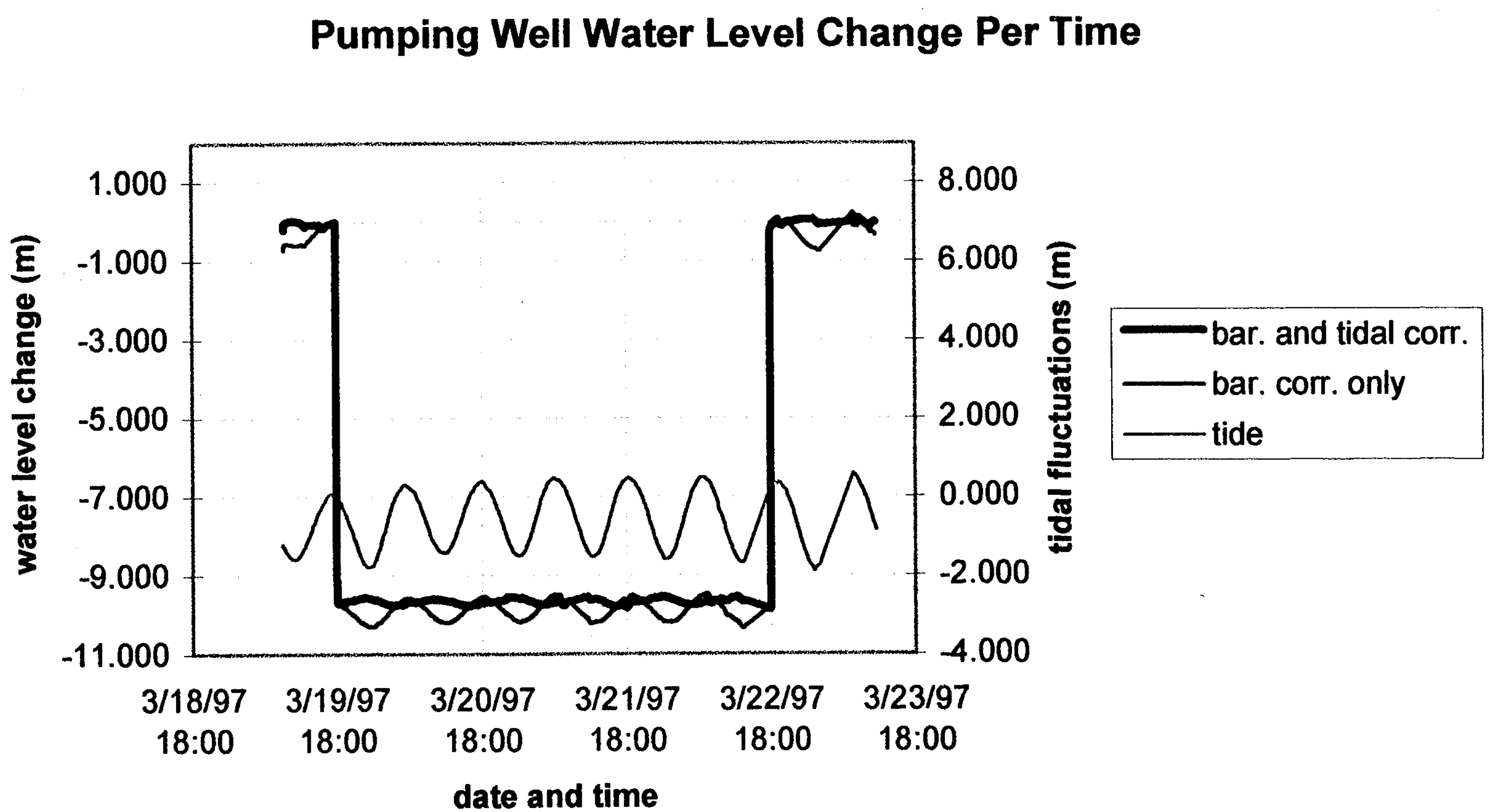


Figure 10: Change in water level vs. time for pumping well Tybee 2 showing tidal fluctuations, drawdown and recovery (barometric corrections only), and drawdown and recovery showing both barometric and tidal corrections.

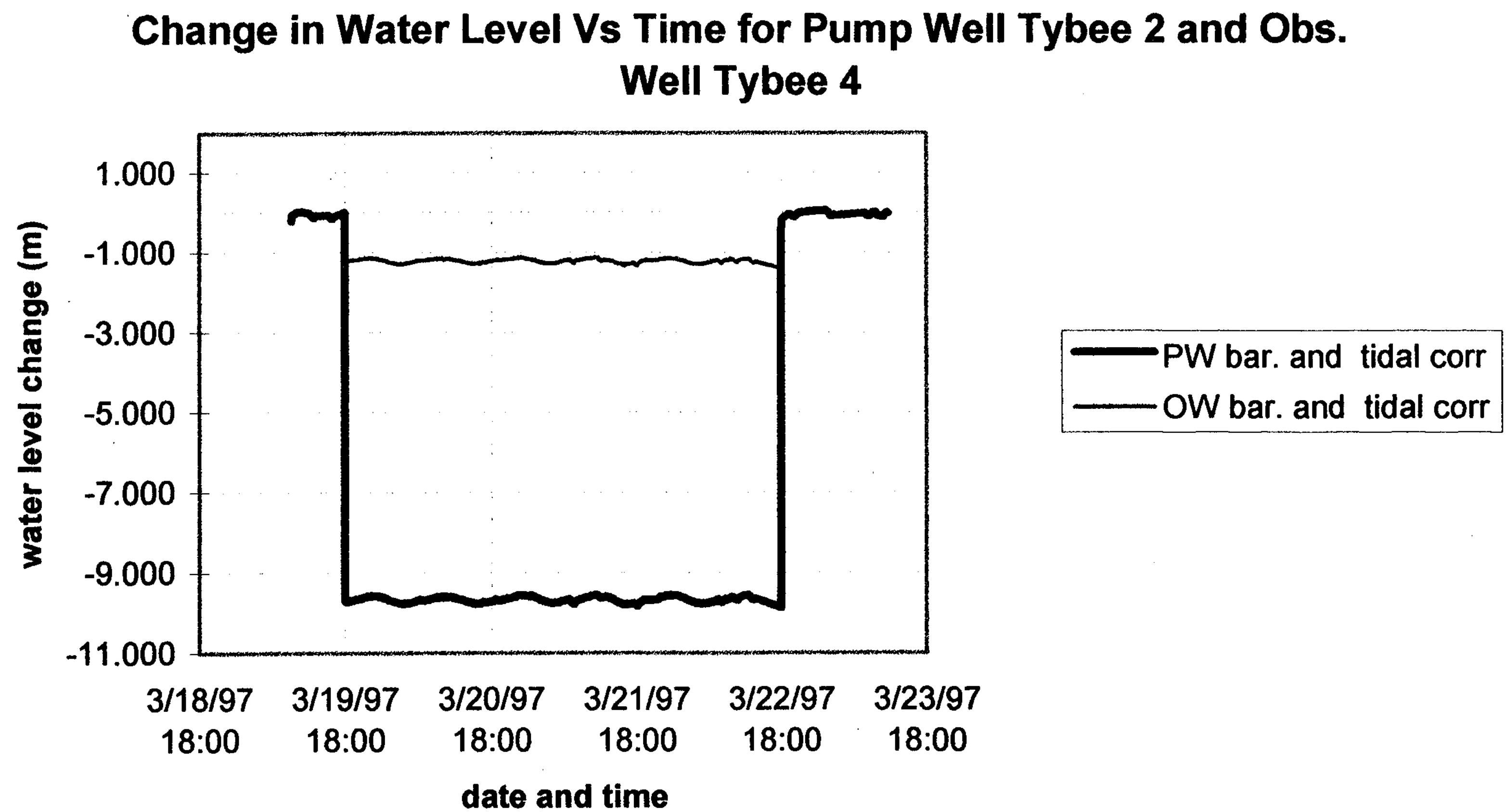


Figure 11: Change in water level vs. time for pumping well Tybee 2 and observation well Tybee 4 showing barometric and tidal corrected drawdown and recovery.

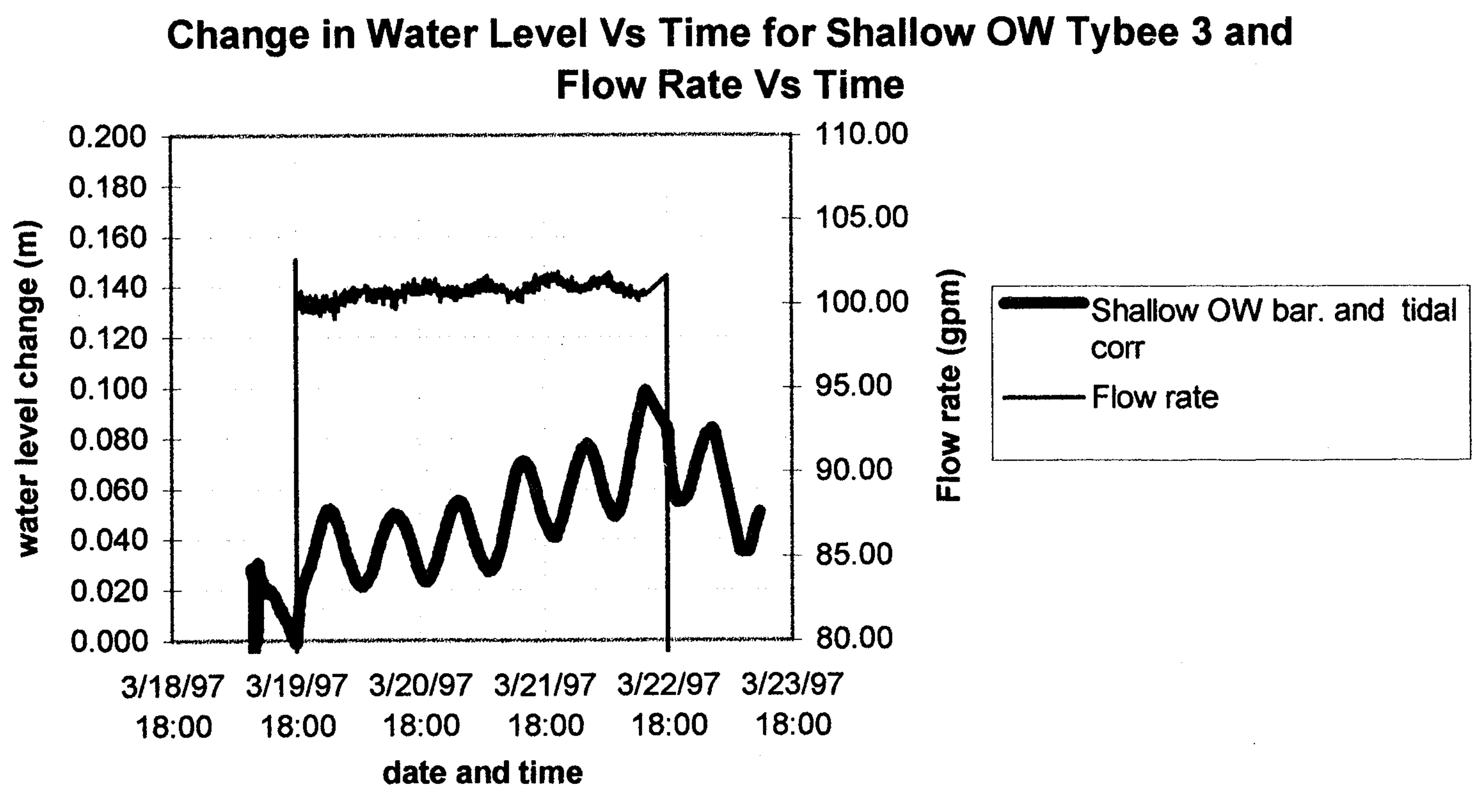


Figure 12: Change in water level vs. time for monitor well Tybee 3 and flow rate vs. time.

The cyclic water level fluctuation (18 to 20 cm for the pumping well and 14 to 16 cm for the observation well, Figure 10) not removed by barometric and ocean tide corrections is believed to be caused by the flow rate fluctuations approximately coinciding with the water level fluctuations as shown in Figure 13.

Static water levels, measured from the top of the casing of the pumping and observation wells, were taken on 03/19/97 prior to starting the test as illustrated in Table II.

Well	Screened zone	Depth of static WL pror to pumping	Max. depth of static WL due to pumping	Max.drawdown
Tybee 2	Upper Brunswick	38.4 ft (11.70 m)	70.75 ft (21.6 m)	32.35 ft (9.8 m)
Tybee 4	Upper Brunswick	37.6 ft (11.46 m)	42.2 ft (12.8 m)	4.58 ft (1.4 m)
Tybee 3	Surficial	13.5 ft (4.11 m)	13.2 ft (4.03.m)	-.26 ft (-.08 m)

Table II. Static water levels and maximum drawdown for test wells.

Data Analysis Results

Barometric Corrections

Water level pressure data from the pumping well and observation wells were corrected for atmospheric pressure changes using the following barometric efficiencies. The barometric efficiencies were calculated using the method described in a previous section (atmospheric pressure corrections). Table III shows calculated barometric efficiencies for the Upper Brunswick aquifer and the surficial aquifer.

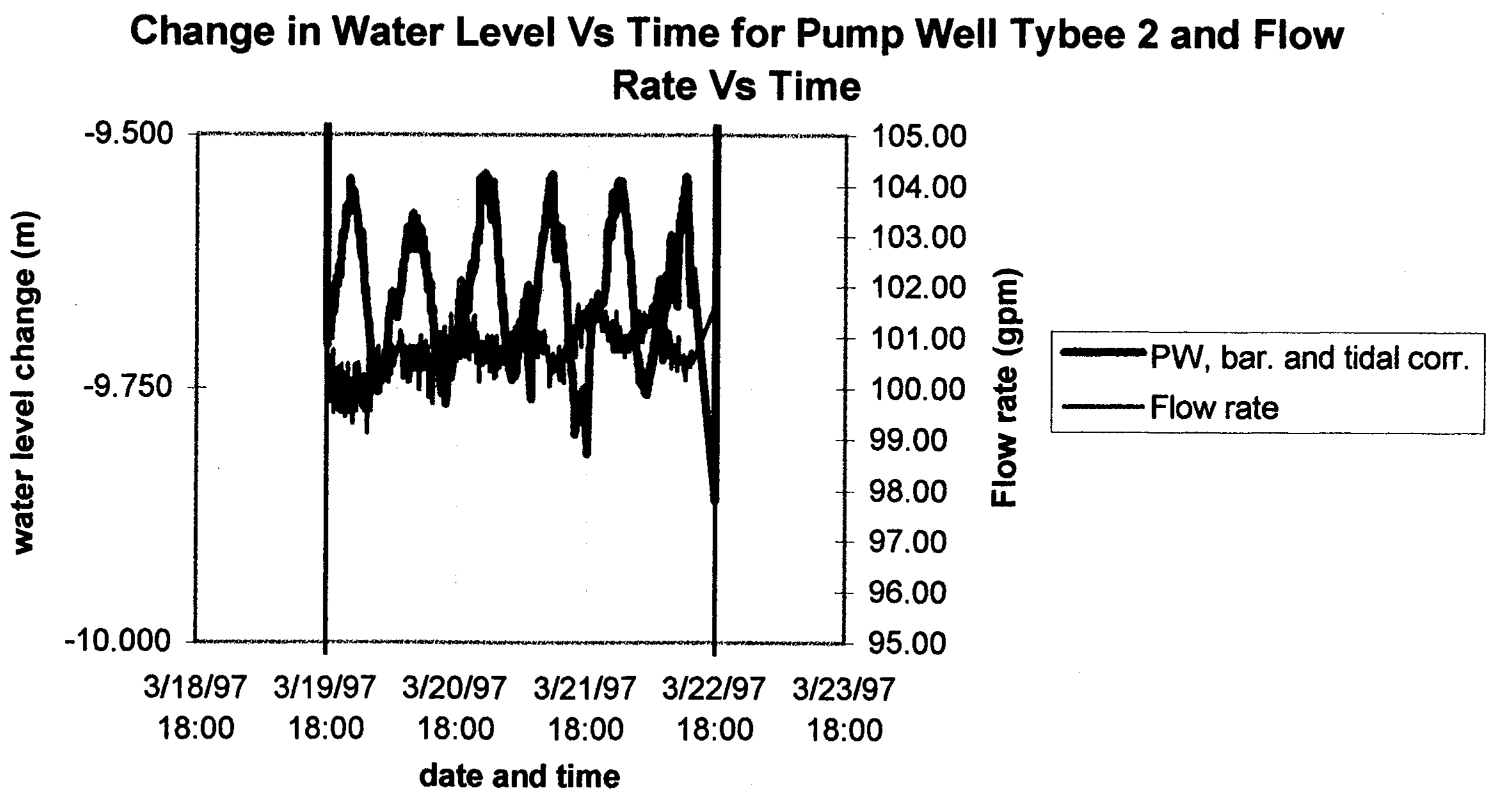


Figure 13: Change in water level vs. time for monitor well Tybee 3 and flow rate vs. time.

Tidal Corrections

Water level pressure data from the pumping well and observation wells were corrected for tidal effects using the following tidal effeciencies. The tidal efficiencies were calculated using the method described in a previous section (tidal effects correction). Table III shows calculated barometric efficiencies for the Upper Brunswick aquifer and the surficial aquifer.

Well	Tidal Efficiency	Barometric Efficiency
Tybee 2-Upper Brunswick	.400	.600
Tybee 4-Upper Brunswick	.400	.600
Tybee 3-Surficial	.005	.995

Table III. Calculated tidal efficiency and barometric efficiencies

Calculated Aquifer Properties

Data from observation well Tybee 4 was not used to calculate storativity for the Upper Brunswick aquifer because the drawdown curve could only be matched using unrealistic values for storativity (see Discussion). The storativity of the Upper Brunswick aquifer was estimated to be 0.0001. Pump well skin factor and transmissivity of the Upper Brunswick aquifer at the Tybee Island test site were calculated using data collected from the pumping well Tybee 2 during the 72 hour pump test. Figure 14 shows a Theis-Jacob curve match for measured and calculated drawdown vs. time. Early time data (from 1 to 1000 seconds) were not used in the curve match because of well bore storage effects . Calculated drawdown for the Upper Brunswick pumping well Tybee 2 was based on an average flow rate of 100.8 gpm, a well radius of 2 inches, and a storativity of 0.0001. Hydraulic conductivity and permeability calculations are based on

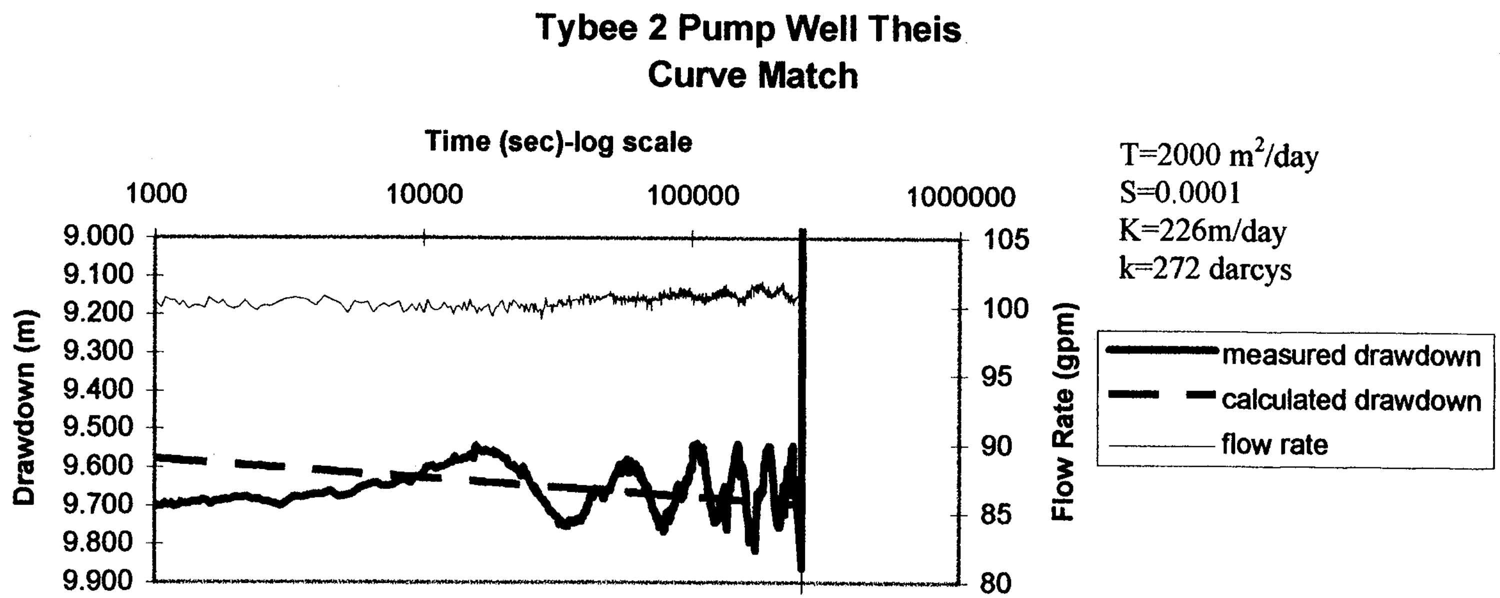


Figure 14: Theis-Jacob analysis (curve match) for pumping well Tybee 2 using a flow rate of 100.8 gpm.

the transmissivity and effective aquifer thickness of 29 ft (8.84 m) for the Upper Brunswick aquifer (Figure 4). Acceptable curve matches for the pumping well Tybee 2 data were also achieved using a range of storativity values from 0.0001 to 0.000001 as shown in Table IV. Changing the storativity in the curve match analysis did not affect the transmissivity because changes in storativity are compensated for in the skin factor.

Transmissivity	16100-26900 ft^2/day (1500-2500 m^2/day)
Hydraulic Conductivity	640-1070 ft/day (195-325 m/day)
Permeability	200-300 darcys

Table IV. Calculated parameters for Tybee 2 data using a range of storativity from 0.0001 to 0.000001.

Calculated Skin Factor

The skin factor is a variable that quantitatively describes the conductive properties of the well itself. A high skin factor would normally indicate a poorly developed well, whereas a skin factor of 0 normally indicates a perfectly developed well. A relatively high skin factor of 213 was calculated for the pumping well, Tybee 2. However, due to the apparent highly conductive properties of the “porous” media at the test site, this does not neccesarily indicate a poorly developed well. Additionally, if the estimated storativity of 0.0001 is high, the actual skin factor would be lower.

Specific Capacity

An average flow rate of 100.8 gpm created a 32.35 ft (9.8 m) drawdown after 24 hours in well Tybee 2 (Upper Brunswick). This equates to a specific capacity of 3.13 gpm/ft.

DISCUSSION

Analysis

The unusual response of the observation well, and the immediate drawdown and approach to equilibrium, suggests a direct connection between the observation well and the pumping well. One possibility for this "direct connection" is that the formation contains a bed of extremely permeable shell hash. Another possibility would be a well sorted coarse sand within the formation such as an ancient channel of the Savannah River. A less likely possibility (based on expected lithology) is that the pumping well and observation well are connected by a fractured carbonate.

An analysis using the Theis method follows, keeping in mind that a fractured aquifer with conduit-flow does not follow a typical Theis response.

A complete observation well analysis using the Theis curve matching method was not possible for Tybee 4. In order to produce a curve match for the observed drawdown in the observation well Tybee 4, an unrealistic storativity value of 10^{-23} was required. However, the transmissivity value in the observation well analysis agrees with that of the pumping well. Since a storativity value from the observation well analysis was not possible, the storativity used in the pumping well analysis had to be estimated. An acceptable curve match in the pumping well analysis could be achieved using many combinations of skin factors and storativity values, however storativity was varied only within reasonable ranges. A typical value for storativity for a confined aquifer is 0.0001. The best curve match for the pumping well was achieved using a storativity of 0.0001, a transmissivity of 2000 m^2/day, and a skin factor of 213. Acceptable matches were also achieved using transmissivities ranging from 1500 to 2500 m^2/day, storativities ranging from 0.0001 to 0.000001, and skin factors ranging from 157 to 269. This yielded permeabilities ranging from 200 to 340 darcys. Changing the storativity in the curve match analysis did not affect the transmissivity because changes in storativity are compensated for in the skin factor.

Ocean Effects

Due to the test site being close to the ocean (approximately 1500 ft.), the tides had a large effect on the observed water levels in the Upper Brunswick screened wells (Tybee 2 and Tybee 4). At high tide, the increased load due to the added water weight causes a corresponding and immediate increase in water level. After correcting water level data for ocean tidal fluctuation effects as well as barometric effects, the water level vs. time curves still show some small scale cyclic fluctuation (Figure 11). These fluctuations are interpreted as a response to a variable flow rate. Because the fluctuations are small in magnitude and follow a regular cyclic pattern, they do not interfere with analysis.

Leakage

No leakage was detected across the confining layer that separates the Upper Brunswick aquifer and the surficial aquifer at the Tybee Island test site. Figure 12 shows a 8 cm overall increase in water level for shallow observation well Tybee 3, over the duration of the pump test.

Small drawdown perturbations superposed on the water level vs. time curves were observed for Tybee 2 and Tybee 4 (Figure 15). This small scale cyclic drawdown and recovery effect was caused by pumping from the Upper Floridan aquifer using the City of Tybee Island Sewage Treatment Plant's water storage tank production well, open at depths of approximately 200 feet to 600 feet (Figure 4 and Figure 8). It is believed that the extremely rapid response of the Upper Brunswick Aquifer to pumping from the sewage department's production well is most likely due to both wells being screened in the same hydrologic zone, indicating the absense of a confining unit between the Upper Brunswick aquifer and the Upper Floridan aquifer in the vicinity of the test site. The sewage treatment plant's management helped to conduct an experiment which identified the storage tank pump as the cause of the drawdown perturbations in the test wells. About 5 times a day, for approximately 15 minutes, 800 gpm is pumped from the Upper Floridan Aquifer to refill the storage tank. The production well is located approximately 1000 feet southeast of the test site and pumps an average of approximately 46,000 gpd.

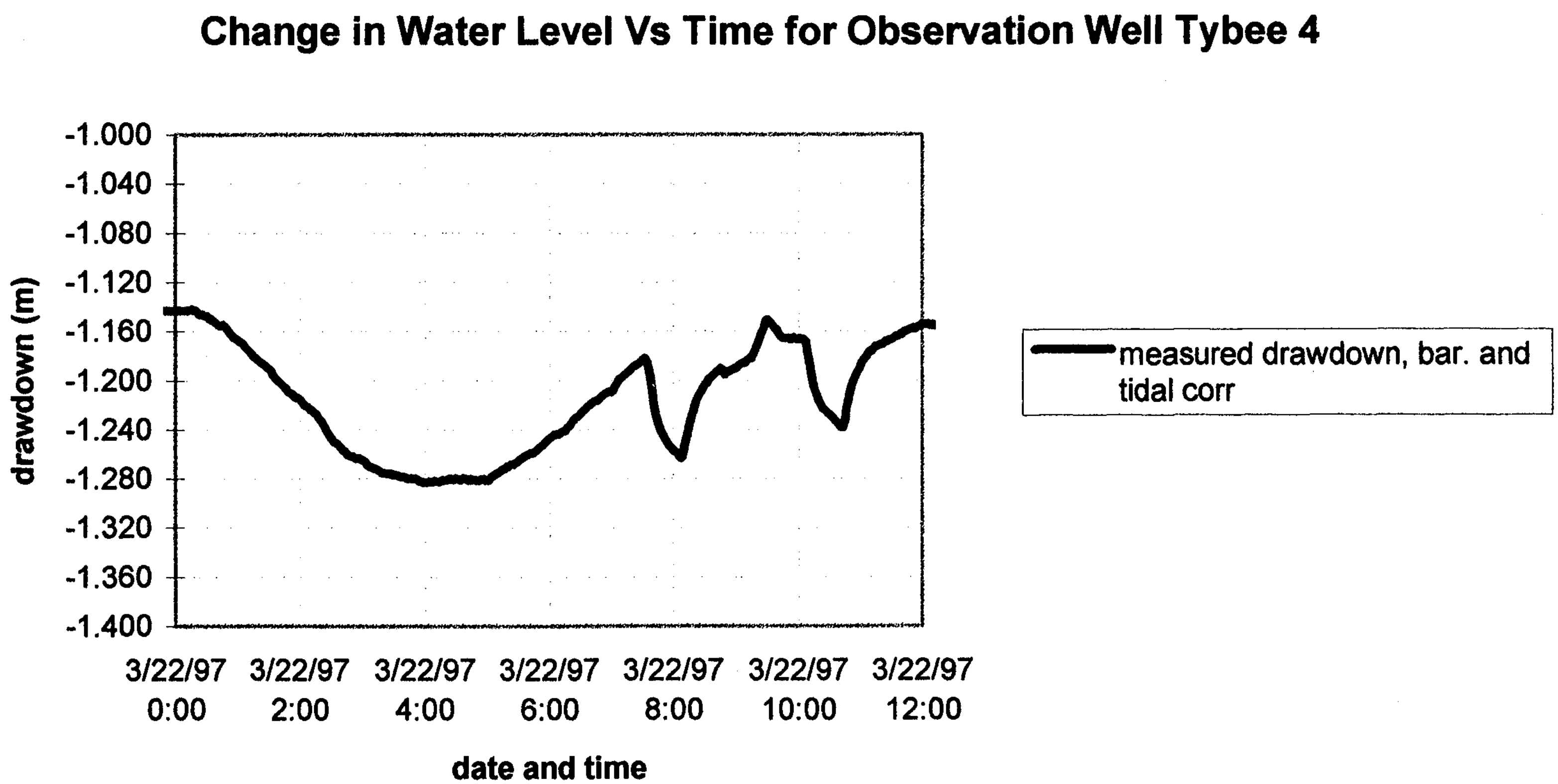


Figure 15: Water level vs. time for observation well Tybee 4, showing small superposed drawdown and recovery perturbations.

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