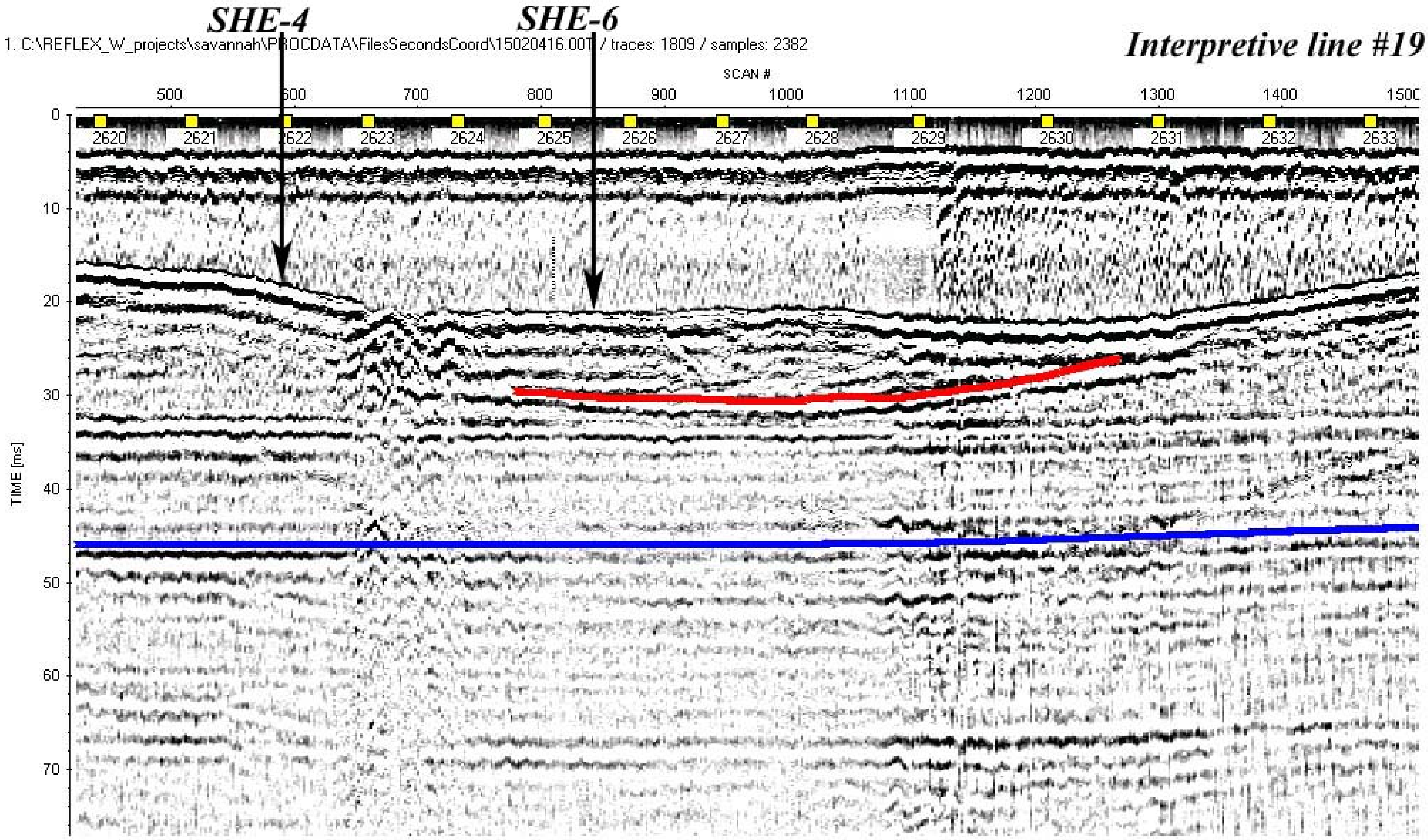
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SHE-6
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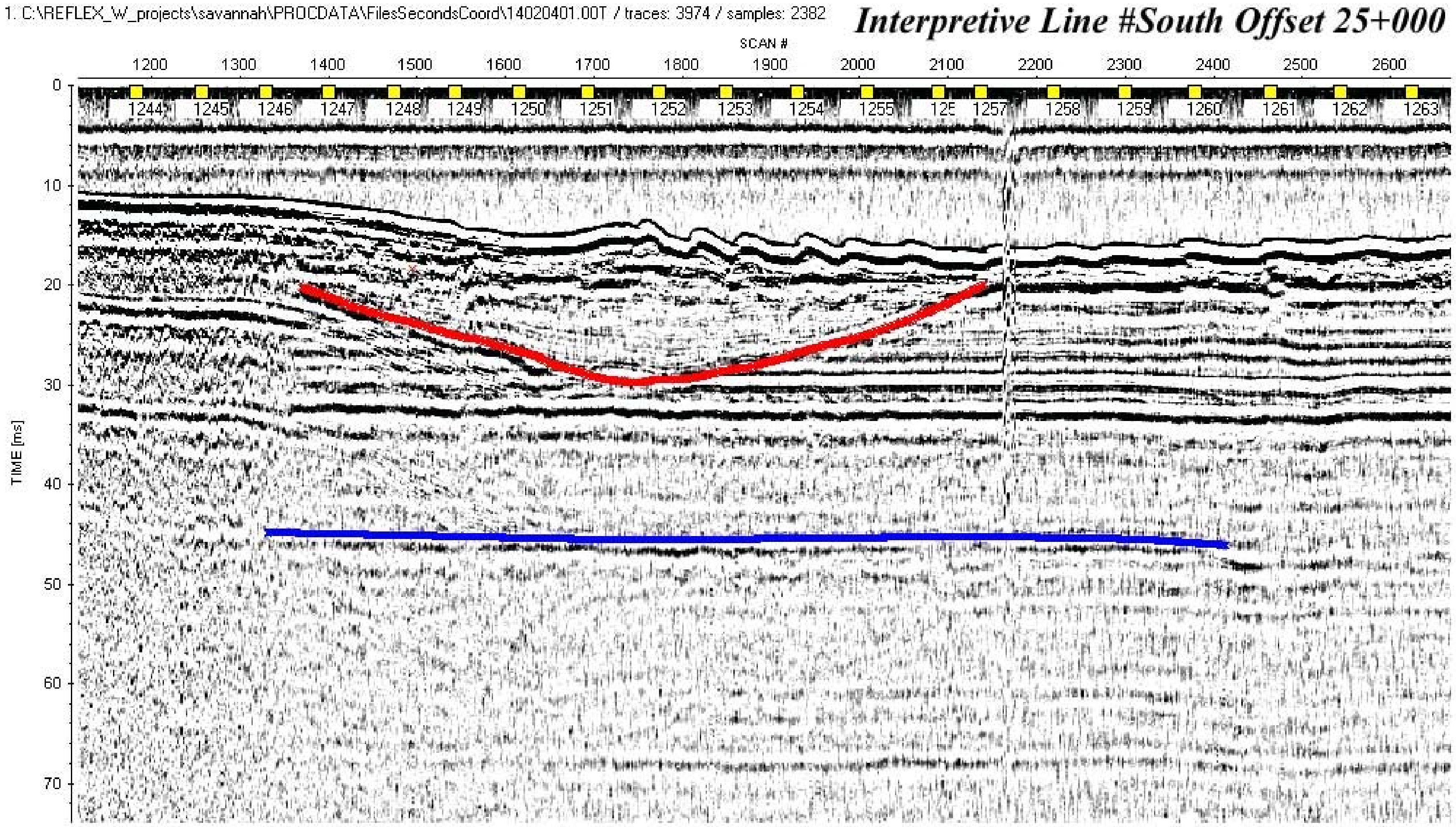
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2400
2500
2600
1244
1245
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1251
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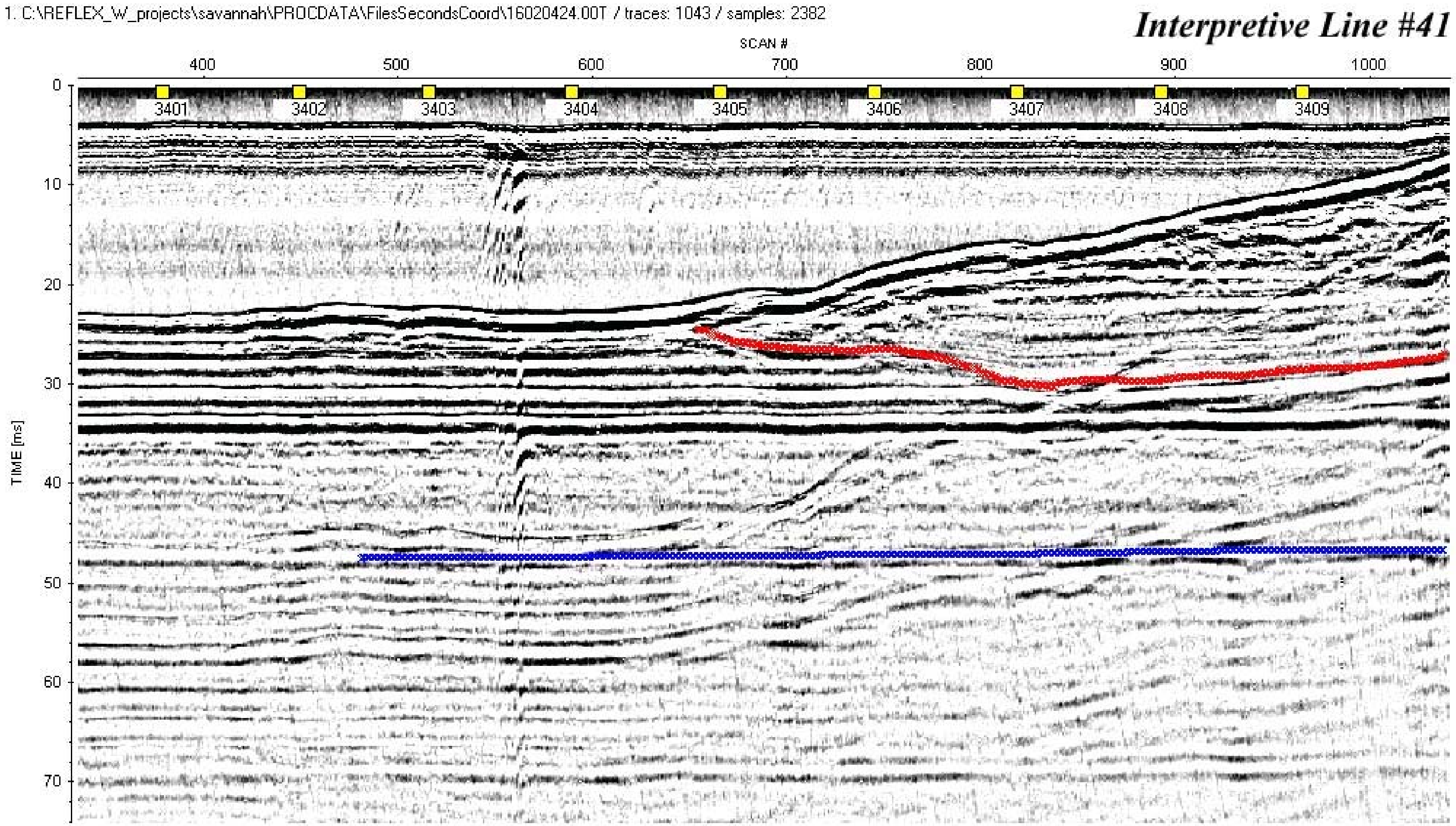
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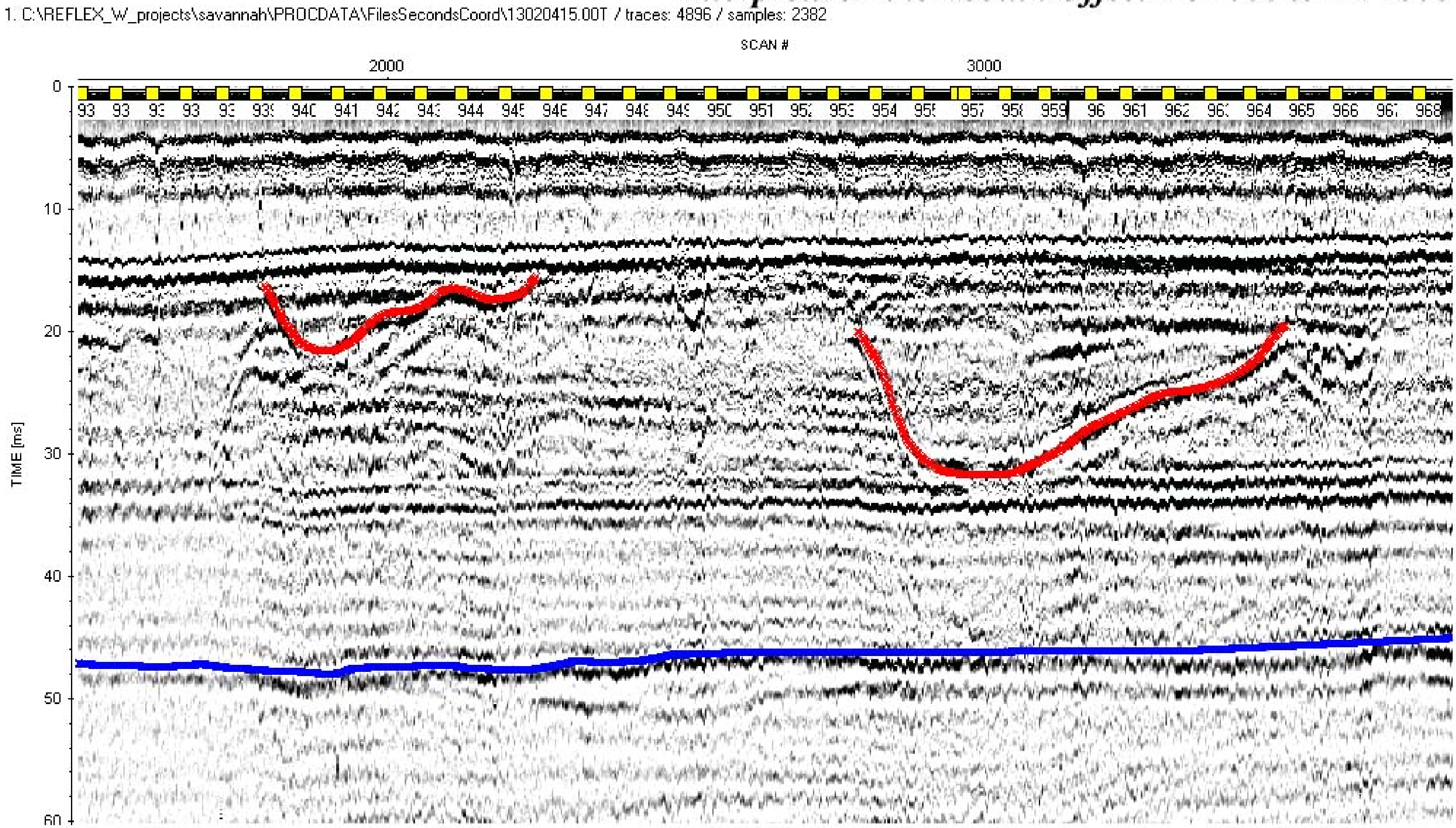


APPENDIX B

CDM Ground-Water Model Studies Technical Memorandum

United States Army Corps
of Engineers
Savannah District

Savannah Harbor Expansion Three-Dimensional Salt Water Intrusion Modeling

September 27, 2005

Technical Memorandum

Contents

List of Figures

Section 1
Introduction

1.1 Purpose and Scope

This technical memorandum documents the groundwater flow model developed to evaluate the potential impacts to the Upper Floridan aquifer by the proposed dredging of the Savannah Harbor channel. The work was completed under Contract No. DACW17-01-D-0013 - 3-Dimensional Salt Water Intrusion Modeling, Savannah Harbor Expansion Project.

1.2 Project Background

The Savannah Harbor Expansion (SHE) Project was conceived to deepen the Savannah Harbor and entrance channel to various depths below Mean Low Water (MLW) (ACOE, 2002). The 3-Dimensional Salt Water Intrusion Modeling Study was conducted as part of a series of investigations to determine if deepening of the Savannah Harbor channel has the potential to impact the water quality in Upper Floridan aquifer within the project area. The Floridan aquifer is the largest source of freshwater in the coastal area of Georgia and the potential for saltwater intrusion is a growing concern among the coastal communities and State and Federal agencies.

To evaluate regional groundwater management issues and the saltwater intrusion problem in coastal Georgia, the USGS has developed a regional MODFLOW model. The USGS groundwater model covers the entire 24-county coastal Georgia area, and extends north into Jasper County, South Carolina, and south into Nassau County, Florida. USGS's regional model does not have sufficient detail to effectively evaluate potential changes in groundwater heads, gradients, and migration of saline water due to dredging of the Savannah channel. Therefore, for this project a fully 3-dimensional, finite element groundwater flow and saltwater intrusion model with a higher level of discretization in the Savannah area was developed. The regional hydrogeologic structure, including model layering, aquifer properties and boundaries conditions of the SHE groundwater model were based on the USGS groundwater model. In the Savannah area detailed bathymetric and lithologic data were incorporated to refine the river channel geometry and the underlying hydrogeologic conditions.

1.3 Study Approach

The overall approach adopted by CDM for this study consisted of the following steps:

- **Data Review and Analysis**: CDM conducted a review of existing data and reports on aquifer studies and investigations for the proposed SHE Project, including the ACOE Savannah District's studies.

- **Development of Groundwater Flow and Saltwater Intrusion Model**: CDM developed a groundwater flow model with saltwater intrusion simulation capabilities based on the existing USGS groundwater model. A finite element modeling code with a flexible grid structure was used so that the SHE groundwater model would have a sufficient level of detail along the Savannah River to evaluate the relative impact of the proposed dredging program. The model was specifically developed to simulate intrusion of salt water from the Savannah River in the harbor area, with the focus on the stretch of the river channel where dredging is proposed.

- **Refinement of the model:** The refinement involved: increasing the discretization of the finite element grid along the Savannah River in the project area; improving the representation of the Miocene confining unit based on ACOE boring data; improving the channel and offshore bathymetry based on detailed ACOE survey data and data available from NOAA.

- **Model Calibration:** The SHE groundwater model's ability to represent both steady-state and transient groundwater head and flow conditions was tested. Additionally, the model's ability to simulate saline water migration through the Miocene unit as measured in SHE boreholes was tested.

- **Model Application.** Once the model was tested and was shown to be able to adequately reproduce observed groundwater heads, gradients, and chloride concentrations, it was applied to evaluate the potential impacts of the proposed dredging by simulating the rate of migration of saline water from the Savannah River into the underlying groundwater system under a variety of input parameter assumptions. Potential migration of seawater through the offshore portion of the navigation channel was simulated. Other chloride sources such as salt marshes and the migration of seawater through undredged areas were not included in the simulations.

Section 2
Model Development

2.1 Model Background

The numerical groundwater flow and transport model used to evaluate the potential impacts of the SHE project is based on the regional USGS groundwater model. This section provides an overview of the SHE groundwater model structure and input parameters derived from the USGS groundwater model. Detailed information on the USGS groundwater model will be available in a report to be published in 2005.

2.2 Modeling Codes

The modeling software utilized in this study includes DYNFLOW (single phase groundwater flow), DYNTRACK (solute transport) and DYNCFT (dual-phase, density dependent groundwater flow).

2.2.1 DYNFLOW

DYNFLOW is a fully three-dimensional, finite element groundwater flow model. This model has been developed over the past 25 years by CDM engineering staff, and is in general use for large scale basin modeling projects and site specific remedial design investigations. It has been applied to over 200 groundwater modeling studies in the United States. The DYNFLOW code has been reviewed and tested by the International Groundwater Modeling Center (IGWMC) (van der Heijde 1985). The code has been extensively tested and documented by CDM.

The governing equation for three-dimensional groundwater flow that is solved by DYNFLOW is:

$$S_s \frac{\partial \phi}{\partial t} = \frac{\partial}{\partial x_i} K_{ij} \frac{\partial \phi}{\partial x_j} ; i, j = 1,2,3$$

where the state variable φ represents the potentiometric head [L]; K_{ij} represents the hydraulic conductivity [LT^{-1}] tensor; S_s is the specific storativity (volume/volume/length), [L^{-1}]; x_j is a Cartesian coordinate and t is time.

DYNFLOW uses a grid built with a large number of tetrahedral elements. These elements are triangular in plan view, and give a wide flexibility in grid variation over the area of study. An identical grid is used for each level of the model, but the thickness of each model layer (the vertical distance between levels in the model) can vary at each point in the grid. In addition, 2-dimensional elements can be inserted into the basic 3-dimensional grid to simulate thin features such as faults. One-dimensional elements can be used to simulate the performance of wells which are perforated in several model layers.

2.2.2 DYNTRACK

The solute transport code used in this study is DYNTRACK. DYNTRACK uses the random-walk technique to solve the advection-dispersion equation. DYNTRACK has been developed over the past 15 years by CDM engineering staff. The partial differential equation describing transport of conservative solutes in a groundwater flow field is:

$$n_e \frac{\partial C}{\partial t} = \frac{\partial}{\partial x_i} n_e D_{ij} \frac{dC}{dx_j} - q_i \frac{dC}{dx_i} ; i, j = 1,2,3$$

where C is the concentration at any x_i location, n_e is the effective porosity, q_i is the specific discharge vector, and D_{ij} is the dispersion tensor. The first term on the right hand side of the equation represents the dispersive flux as embodied by Fick's Law; the second term represents the advective flux of solute mass.

DYNTRACK uses a Langrangian approach to approximate the solution of the partial differential equation of transport. This process uses a random walk method to track a statistically significant number of particles, wherein each particle is advected with the mean velocity within a grid element and then randomly dispersed according to specified dispersion parameters.

In DYNTRACK, a solute source can be represented as an instantaneous input of solute mass (represented by a fixed number of particles), as a continuous source on which particles are input at a constant rate, or as a specified concentration at a node. The concentration within a particular zone of interest is represented by the total number of particles that are present within the zone multiplied by their associated solute mass, divided by the volume of water within the zone. DYNTRACK has also been reviewed and tested by the IGWMC (van der Heijde 1985).

2.2.3 DYNCFT

To fully simulate variable density effects on groundwater flow, the coupled flow and transport model DYNCFT was used. DYNCFT combines the groundwater flow capabilities of DYNFLOW, with the contaminant transport capabilities of DYNTRACK. Coupling flow and transport computations allows the effect on groundwater flow of fluid density gradients associated with solute concentration gradients to be incorporated into model simulations (i.e., density-dependent flow). In DYNCFT the flow and transport computations are loosely coupled. At each time step, the flow computations are completed first, holding densities constant, then the transport computations are completed. The computed heads are then re-adjusted to account for the effects of the fluid density. The main transport-related application for the SHE groundwater model is the migration of saline water from the Savannah River.

2.3 Model Domain and Finite Element Grid

The domain or geographic extent of the SHE groundwater model is based on the USGS groundwater model. The extent of active cells within the USGS groundwater model was used as the basis in determining the domain of the SHE groundwater model. The SHE groundwater model domain has an area of approximately 42,250 square miles, and is discretized into 16,362 triangular elements defined by 8,257 nodes at the vertices of the triangles. **Figure 2-1** illustrates two typical finite elements and the associated terminology.

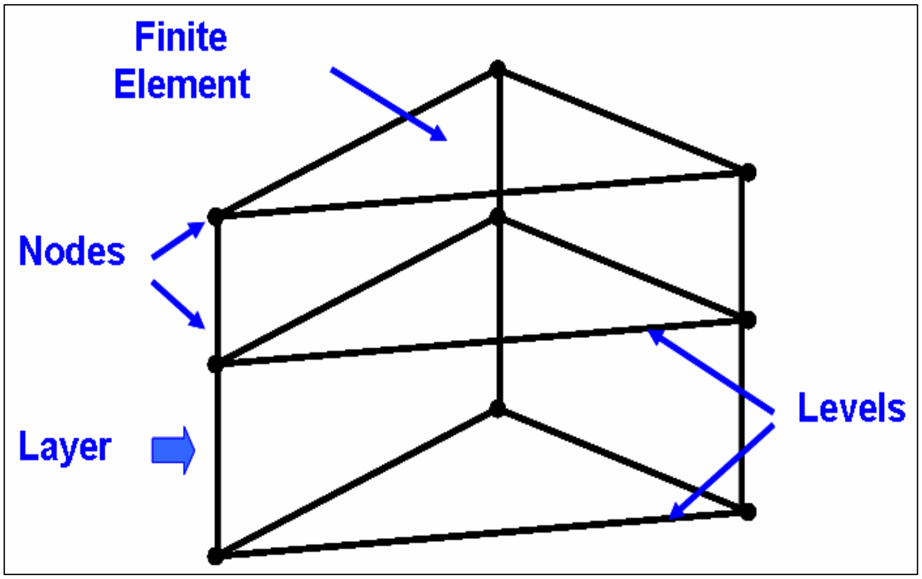


Figure 2-1: Typical Finite Element Structure and Terminology

Figure 2-2 shows the domain of the SHE groundwater model's finite-element grid. In order to represent the proposed dredging, discretization is finest in the area of the Savannah River. Within the river, node spacing is on the order of 125 feet. **Figure 2-3** shows a portion of the grid with detailed discretization near the city of Savannah. The node spacing increases outside of the Savannah River area. The typical inland node spacing is 4.5 to 5 miles. Offshore nodal spacing is approximately 10.5 to 11 miles.

2.4 Boundary Conditions

DYNFLOW accepts various types of boundary conditions on the groundwater flow system including:

- Specified head boundaries (where the piezometric head is known, such as at rivers, lakes, ocean, or other points of known head). These boundaries maintain the specified head, and adjust the flow into or out of the model to maintain that head.

- Specified flux boundaries (such as rainfall infiltration, well pumpage, and no-flow "streamline" boundaries). These boundaries specify the amount of water into or out of the model (including specifying no flow), and vary the head to maintain the specified flux.

- Rising water boundaries; these are hybrid boundaries (specified head or specified flux boundary) depending on the system status at any given time. Generally used at the ground surface to simulate streams, wetlands, and other areas of groundwater discharge. This boundary allows the head to rise to the land surface elevation, after which it acts as a fixed head, discharging water to the surface. Some of the river nodes were assigned rising water boundaries.

- Head-dependent flux (3rd type) boundaries including "River" and "General Head" boundary conditions. This boundary was not used in the model.

The boundary conditions assigned in the SHE groundwater model are based on the USGS groundwater model and modified as described below to fit the finite-element model structure. The types of groundwater flow boundary conditions used for the model are fixed heads and no flow boundary conditions. Fixed concentration boundary conditions are used for the seawater transport computations. **Figure 2-4** shows the location of the boundary condition nodes in the model. Both groundwater flow and transport boundary conditions are described in more detail below.

2.4.1 Savannah River Boundary Condition

A fixed head boundary condition was applied to nodes within the Savannah River at the top water level in the area of interest of the Savannah Harbor. Heads were assigned a value of zero to represent the long-term average water level in the river. Further upstream, the Savannah River nodes were assigned either fixed heads based on the estimated elevation of the water surface in the river or a rising node boundary to allow the surficial aquifer to discharge to the river. For the saline water migration simulations, the Savannah River nodes were assigned a constant chloride concentration. The chloride concentrations in the Savannah River were obtained from the surface water modeling conducted for the SHE by Tetra Tech (Tetra Tech, November, 2004). **Figure 2-5** illustrates the simulated mean salinity for the Savannah River for both dredging and no dredging conditions generated by the Tetra Tech surface water model. These salinity values represent simulated average annual concentrations of river water at the bottom of the river from preliminary surface water model simulations. Salinity was converted to chloride concentration by multiplying the salinity values by 0.37, a reasonable value for sea water (Harrey, 1969).

2.4.2 Ocean Boundary Condition

Offshore nodes located within the Atlantic Ocean (see **Figure 2-4**) were assigned an equivalent freshwater head at the top level (free water surface) of the model. The equivalent freshwater head is computed as shown below.

*Equivalent Freshwater Head = Depth of Seawater * Relative Seawater Density*

For example, if the depth of seawater at the ocean boundary node is 100 feet, the equivalent freshwater head is 100 * 0.025 = 2.5 feet. The relative density of seawater compared to freshwater was obtained from The Chemistry and Fertility of Sea Waters (Harvey, 1969). Only the migration of seawater through the navigation channel is simulated, the inland migration of seawater in other areas is not simulated, and therefore no concentration boundary condition is required. The east and southeast boundaries of the model (located in the ocean) are modeled as no flow boundaries consistent with the USGS groundwater model.

2.4.3 Southwest and Southern Boundaries

A fixed head boundary condition was assigned to nodes along the southwest boundary of the model (see **Figure 2-4**). The values assigned as fixed heads were interpolated onto the grid from computed values in the USGS groundwater model.

2.4.4 Northwest and Northeast Boundaries

The northwest and northeast boundaries of the model are no-flow boundaries consistent with USGS groundwater model.

2.4.5. Base of the Model

A no-flow boundary condition is assigned at the base of the model consistent with the USGS groundwater model.

2.4.6 Water Table

Consistent with the representation in the USGS groundwater model and using the assumption that pumping in the Upper Floridan aquifer is the driving force of the downward gradient, the water table is represented as fixed head values within the surficial aquifer unit throughout the model.

2.5 Model Layering and Stratigraphy

The conceptual layout out of the aquifer and confining units in the model is based on the USGS groundwater model. Table 2-1 lists the seven basic hydrogeologic units represented in the model.

Table 2-1
Hydrogeologic Units Represented in the Model

Regional Hydrogeologic Unit	Savannah Harbor Area Hydrogeologic Unit	Relative Depth
Surficial Aquifer	Surficial Aquifer	Shallow
Miocene Confining Units	Miocene Confining Units	↓
Miocene Aquifer	Not Present	
Upper Floridan Confining Unit	Upper Floridan Confining Unit	
Upper Floridan Aquifer	Upper Floridan Aquifer	
Lower Floridan Confining Unit	Lower Floridan Confining Unit	
Lower Floridan Aquifer	Lower Floridan Aquifer	Deep

Figures 2-6 through **2-10** show cross sections through the model layering showing the hydrogeologic units listed above. Thicknesses of the hydrogeologic units were interpolated from the USGS groundwater model. To provide sufficient vertical discretization to simulate chloride migration beneath the river, these seven

hydrogeologic units of the SHE groundwater model were divided into 12 levels and 11 layers as summarized in Table 2-2.

Table 2-2: Model Layering and Hydrogeologic Units

Layer	Regional Hydrogeologic Unit	Savannah Harbor Area Hydrogeologic Unit
11	Surficial Aquifer	
10	Miocene Confining	Miocene Confining
9	Miocene Confining	Miocene Confining
8	Miocene Confining	Miocene Confining
7	Miocene Aquifer	Not Present
6	Upper Floridan Confining	
5		
4	Upper Floridan Aquifer	Upper Floridan Aquifer
3		
2	Lower Floridan Confining	Lower Floridan Confining
1	Lower Floridan Aquifer	Lower Floridan Aquifer

Figures 2-11 through **2-17** illustrate the thickness of each of the seven hydrogeologic units for the entire model domain.

2.6 Aquifer Properties

Figures 2-11 through **2-17** illustrate the distribution of the major aquifer hydraulic properties. The aquifer properties were derived from the USGS groundwater model.

2.7 Groundwater Recharge

Groundwater recharge is not explicitly simulated. The fixed heads in the surficial aquifer generate groundwater flux either into, or out of the model depending on the simulated heads in the model levels below the surficial aquifer.

2.8 Groundwater Pumping

The groundwater pumping specified in the model was taken directly from data files developed by the USGS for the regional MODFLOW model. Groundwater pumping data are available in two formats - well specific and distributed. The well specific pumping data are based on individual well, or facility permits. Typically, well specific data are available for 1 MGD permits or larger, and in most cases the total permit capacity is known but not the individual well production. The distributed pumping data refer to the total groundwater pumping estimates for each of the 24 Georgia counties located within the model domain. For the historical simulation, groundwater pumping data were obtained from the USGS. Figure **2-18** illustrates the total groundwater pumping applied in the model for the historical period from 1900 to 2000. Note that for projection simulations, the 2000 pumping was projected to continue indefinitely into the future.

Well Specific Pumping

Within the Georgia counties, in many cases, the locations and pumping rates for specific wells are known. At these locations a pumping rate is specified at the horizontal location of the wells. The pumping is assigned vertically to the appropriate aquifer unit (e.g. Upper or Lower Floridan) based on information about the screened interval of each well. **Figure 2-19** shows the specified pumping well locations within the Upper and Lower Floridan aquifers.

Distributed Pumping

The difference in pumping volumes between the individual county total and the known permit specific pumping is distributed equally to the nodes that fall within that county. This approach is similar to the USGS's methodology. The distributed pumping is allocated to the appropriate aquifer unit according to the vertical distribution developed by the USGS for the regional model. **Figure 2-20** shows the allocation of county-based distributed pumping for the year 2000.

2.9 Model Calibration

2.9.1 Steady State Calibration

Model calibration is the process of making adjustments to model input parameters until the output from the model reasonably matches a set of measured data and the observed behavior of the ground water flow system. The USGS groundwater model is calibrated to steady-state year 2000 conditions, and input data sources are referenced in Sections 2-6 through 2-8. In steady-state calibrations, measured and model-computed heads (water levels) are compared, and the difference between the two, referred to as the residual, is calculated.

This modeling study was not designed to seek a fully calibrated model of the Savannah area aquifer system, but rather to test the plausible range of input parameters and their effect on results. Nevertheless, the model results were examined against data to test whether the SHE groundwater model adequately represents the observed conditions and is consistent with the USGS representation. To do this, the simulated steady-state heads for the year 2000 were compared to both the calibration targets used by the USGS and the actual simulated USGS groundwater model heads. **Figure 2-21** shows a comparison between the simulated SHE groundwater model heads and the measured groundwater heads in the Upper and Lower Floridan aquifers for the year 2000 by plotting the location and magnitude of water level residuals. The figure also shows the simulated head contours for the Upper Floridan aquifer. Typically, a calibration is considered adequate when there is no systematic head bias across the model, and the standard deviation of residuals should be within 10-15% of the total measured head gradient across the model domain.

Figure 2-21 shows that no single area of the model has systematically high or low simulated groundwater heads relative to the measured values. Additionally, the standard deviation of 11 feet is significantly lower than 10 percent of the total measured head gradient across the model which is 200 to 300 feet. Within the Savannah area alone the range of measured heads in the Floridan aquifer system is approximately 100 feet. Based on this assessment the SHE groundwater model is adequately calibrated to simulate steady conditions.

Figure 2-22 and **2-23** show a comparison between the simulated SHE groundwater model heads and the USGS groundwater model heads for the Upper and Lower Floridan aquifers. The figures illustrate that both models produce comparable results, which is as expected because the overall hydrogeologic structure, aquifer properties and applied hydraulic stresses are consistent.

2.9.2 Transient Testing

In addition to the steady-state calibration check, the SHE groundwater model's ability to reproduce both the historical temporal behavior of groundwater heads and the measured chloride levels in the Miocene confining unit below the Savannah River was tested. Measured groundwater head data is available for the model area from around the 1980s onward. However, to test the model's ability to reproduce the measured levels of chloride in the Miocene confining unit, a transient simulation starting with pre-development conditions (1900) was developed.

The transient testing was performed for the period of 1900 to 2000, using an annual time step. Surficial aquifer heads were kept constant from 1900 to 1960, and then changed every 10 years based on a linear interpolation between the 1900 and 2000 values. Pumping was varied every 5 to 10 years depending on the availability of data as shown in Figure 2-18. Chloride concentrations in the Savannah River were kept constant using the chloride distribution described in Section 2.4.1 Figures **2-24** through **26** illustrate the pre-development heads in the surficial, Upper and Lower Floridan aquifers respectively. Primary interest is in the heads simulated in the area of interest. No attempt was made to estimate changes to fixed head boundary conditions along the southern boundary, because they had no impact on results near Savannah.

The resulting simulated groundwater heads in selected wells in the Savannah area are shown Figures **2-27** and **2-28**. Although in most cases, data were available for only a limited period within the 100 years simulated these graphs show that the model can effectively reproduce the long-term behavior observed in the groundwater heads in the Upper Floridan aquifer. The model accurately simulated the heads, as well as the general trends in heads, even though annual variations in pumping could not be simulated due to a lack of data.

Figures **2-29** through **2-40** illustrate the measured (from pore water samples) and simulated chloride concentration profiles at the SHE boreholes along the Savannah River. Concentrations of chlorides at the bottom of the river were taken from the TetraTech surface water model. The simulated results represent the chloride concentrations resulting from the migration of saline water from the Savannah River over the 100 year transient simulation period. These figures illustrate that the aquifer properties from the USGS groundwater model generally result in an overall depth of penetration of saline water somewhat deeper than observed, and chloride concentrations higher than measured. The simulated depth of penetration and chloride concentrations is most sensitive to the vertical hydraulic conductivity of the

Miocene confining unit. Therefore, for the model application the calibrated value of the vertical hydraulic conductivity for the Miocene confining unit is considered to represent the mid-range of reasonable values, but is perhaps somewhat more transmissive than it actually is. In this sense, the model results represent a conservative (i.e. too rapid) penetration of salt water. Several additional comments are in order

- Note that in most cases, the assumption of the starting concentration taken from the Tetra Tech surface water model results appears to reasonably match the data (e.g. Figures 2-29, 2-30, 2-31, 2-35, and 2-38). In one case, it appears to be slightly too high (Figure 2-34). In some cases, it might be somewhat too low (e.g. 2-36).

- The model simulates the Miocene confining units as a homogeneous unit, in which the total vertical hydraulic conductivity is conservatively estimated at about $1.5x10^{-4}$ feet per day. In reality, the rate of penetration and concentration is greatly affected by local heterogeneities in the unit (including small sandy layers). Thus the pore sample data is quite variable, while model results are expected to show smooth curves of decreasing concentration. The intent was to accurately simulate (or slightly overestimate) the depth of penetration, and use as accurate as possible surface chloride concentrations, but not to try to simulate local heterogeneity. In this way, projection simulations at steady state, when the actual concentration curves will eventually smooth out, will be reasonably projected.

- A second set of simulations, using a lower vertical hydraulic conductivity, was also tested, which underestimated the rate of salt water penetration. The true system response lies somewhere in between the two simulations.

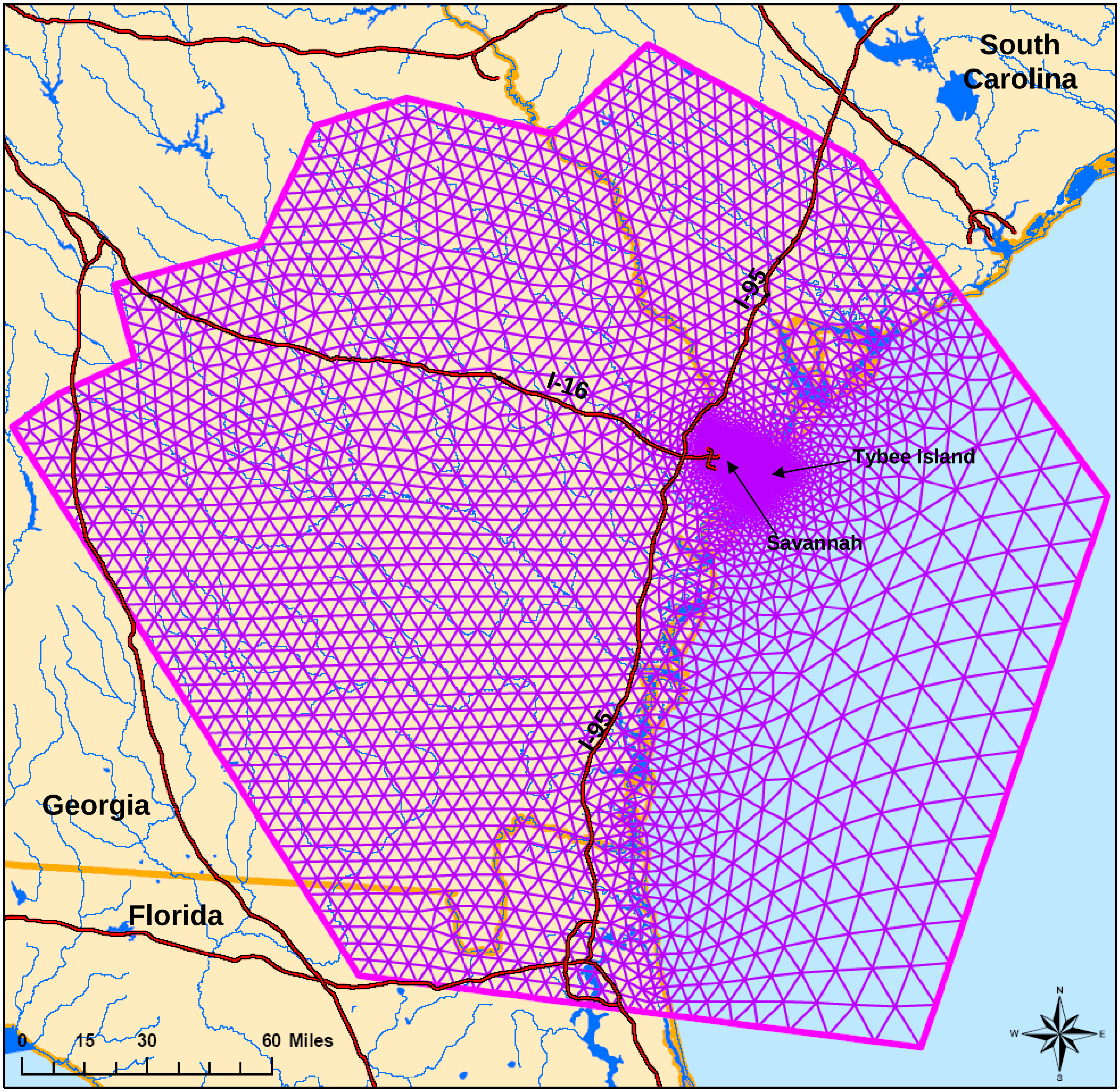


Figure 2-2
Model Domain and Finite Element Grid

Savannah Harbor Expansion
Groundwater Model Studies

Figure 2-3
Detailed View of Finite Element Grid in Savannah Area

Savannah Harbor Expansion
Groundwater Model Studies

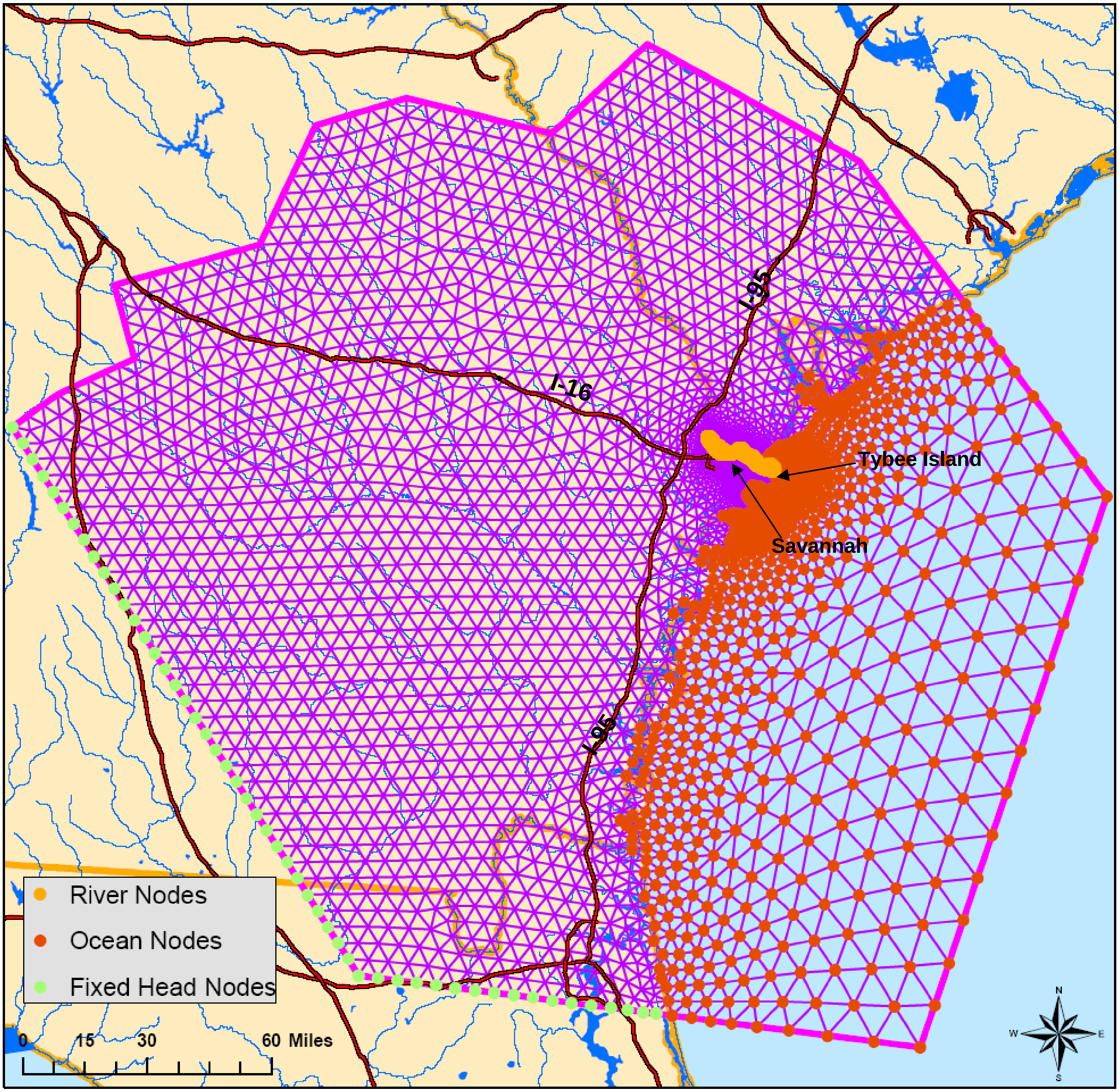


Figure 2-4
Boundary Condition Type and Location Map

Savannah Harbor Expansion
Groundwater Model Studies

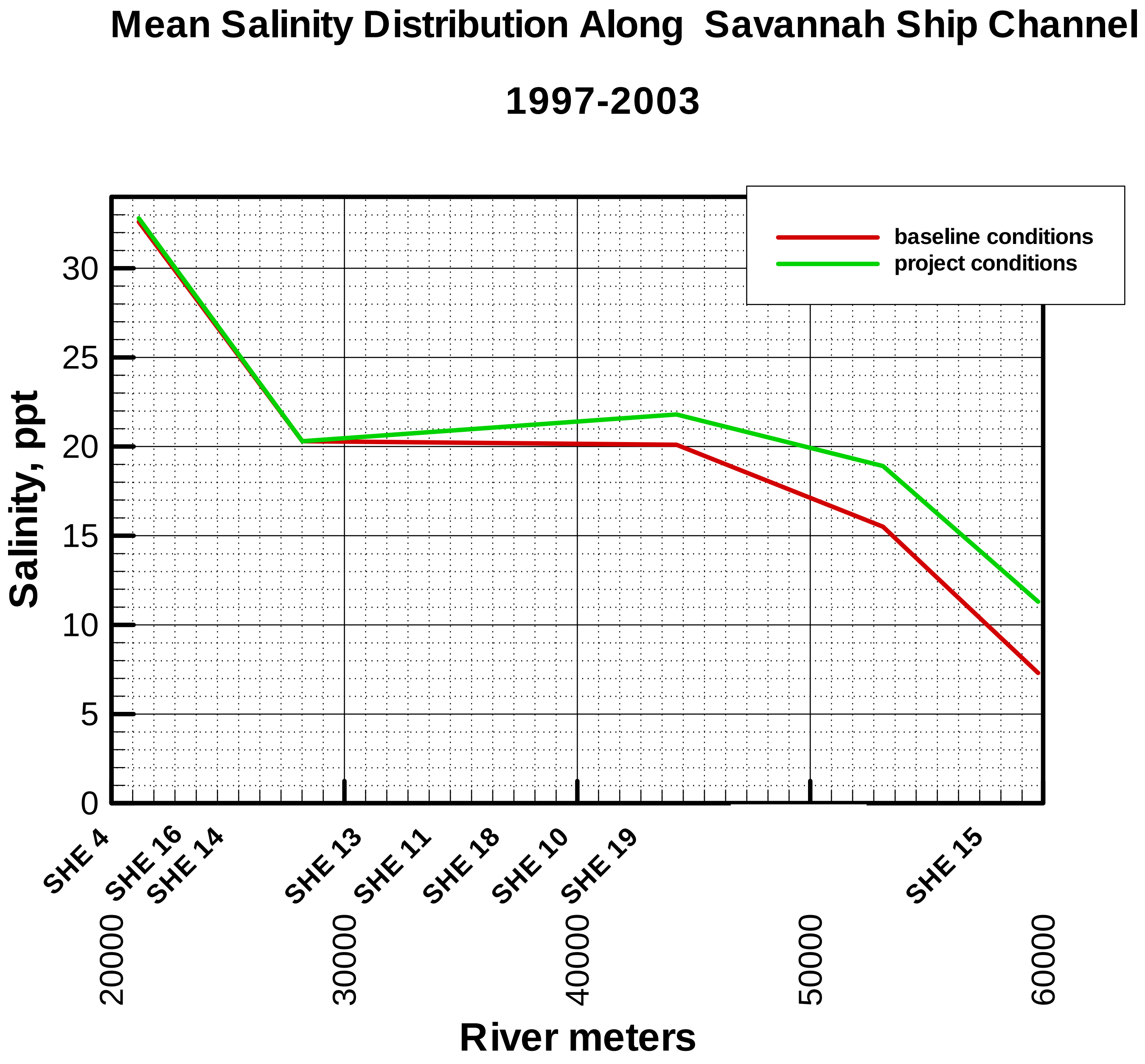
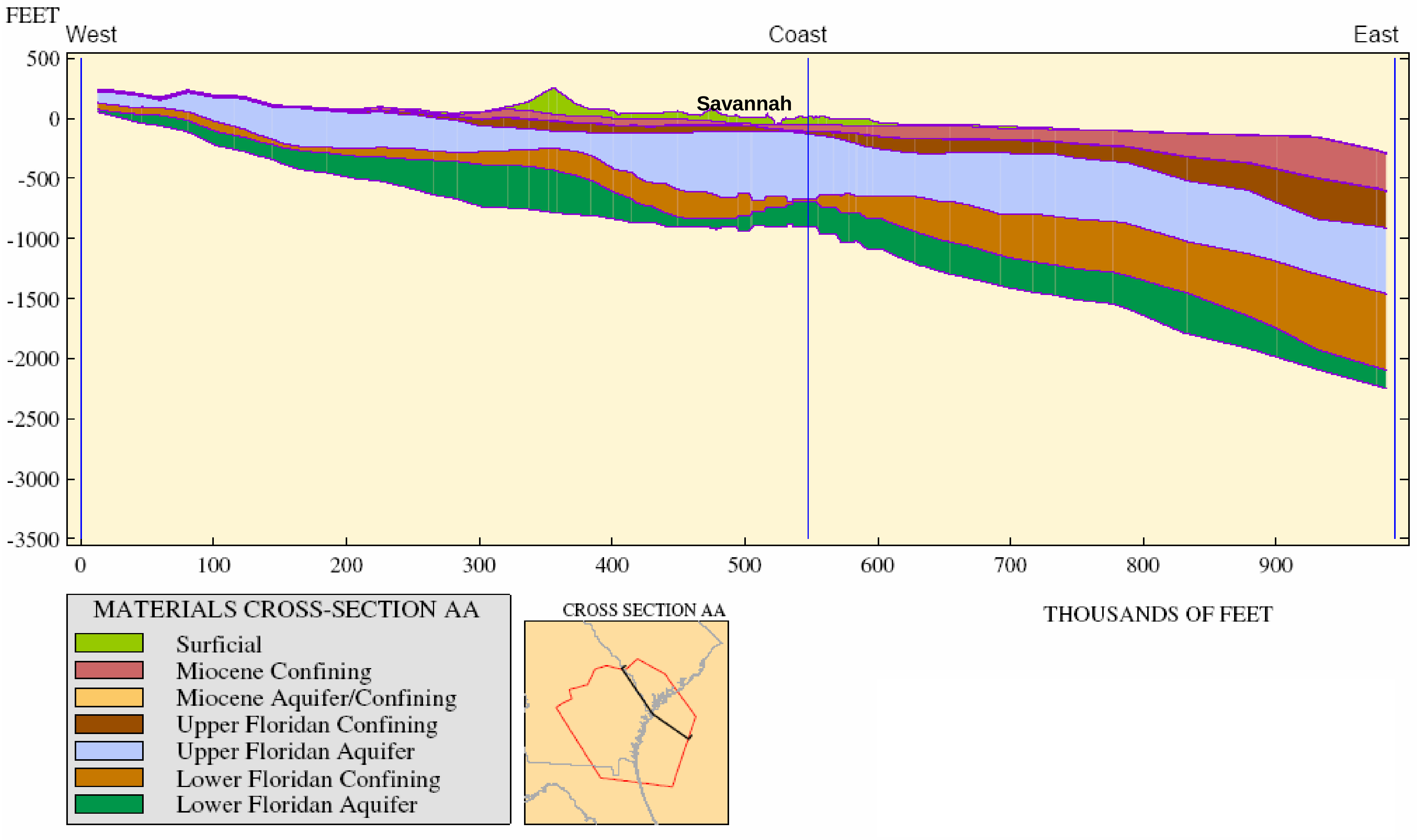


Figure 2-5
Savannah River Salinity Profile – Dredging and No Dredging

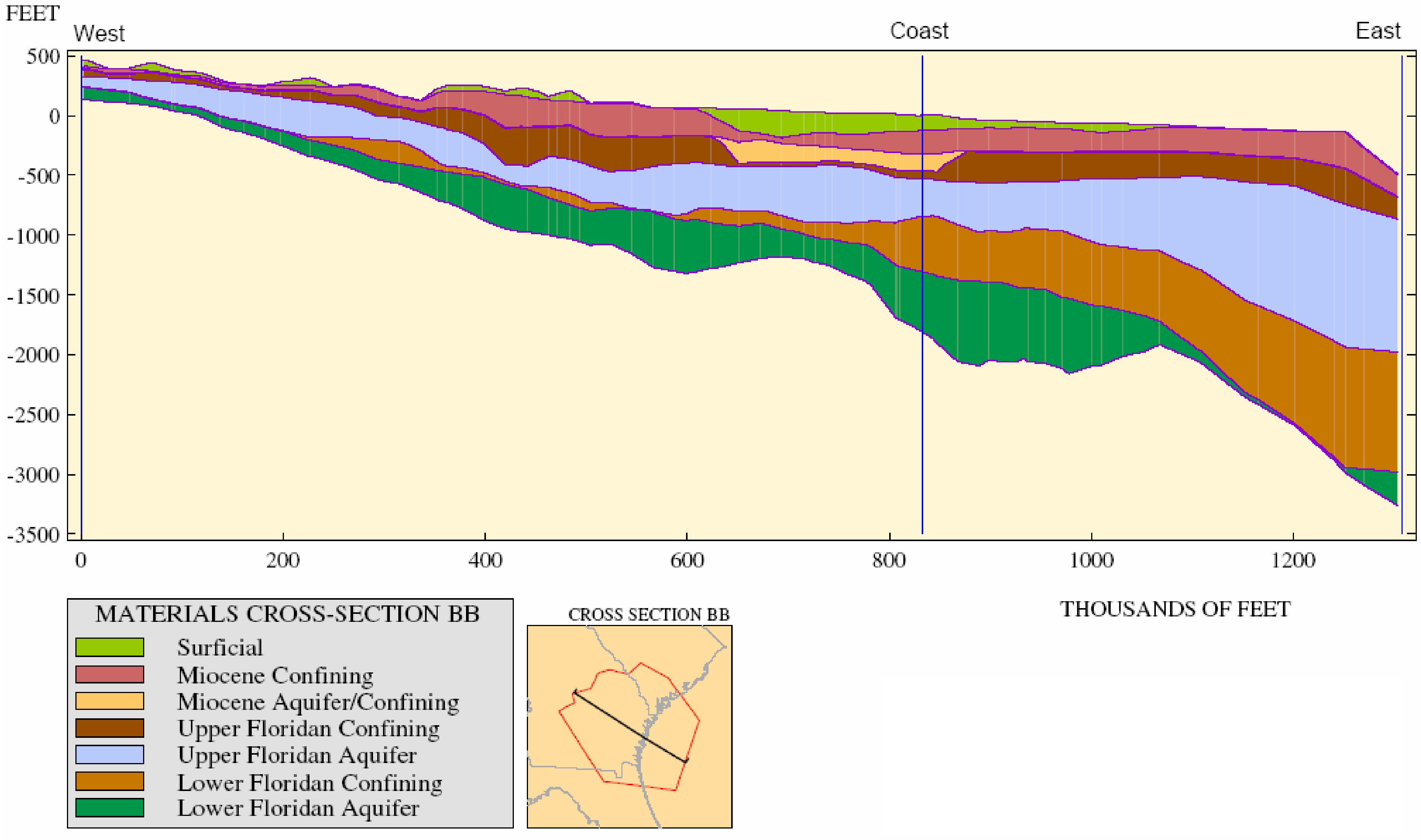


The Miocene Aquifer is not present in this cross-section which runs through Savannah.

Figure 2-6
Cross Section through Model
Normal to Coastline through Savannah Area

Savannah Harbor Expansion
Groundwater Model Studies

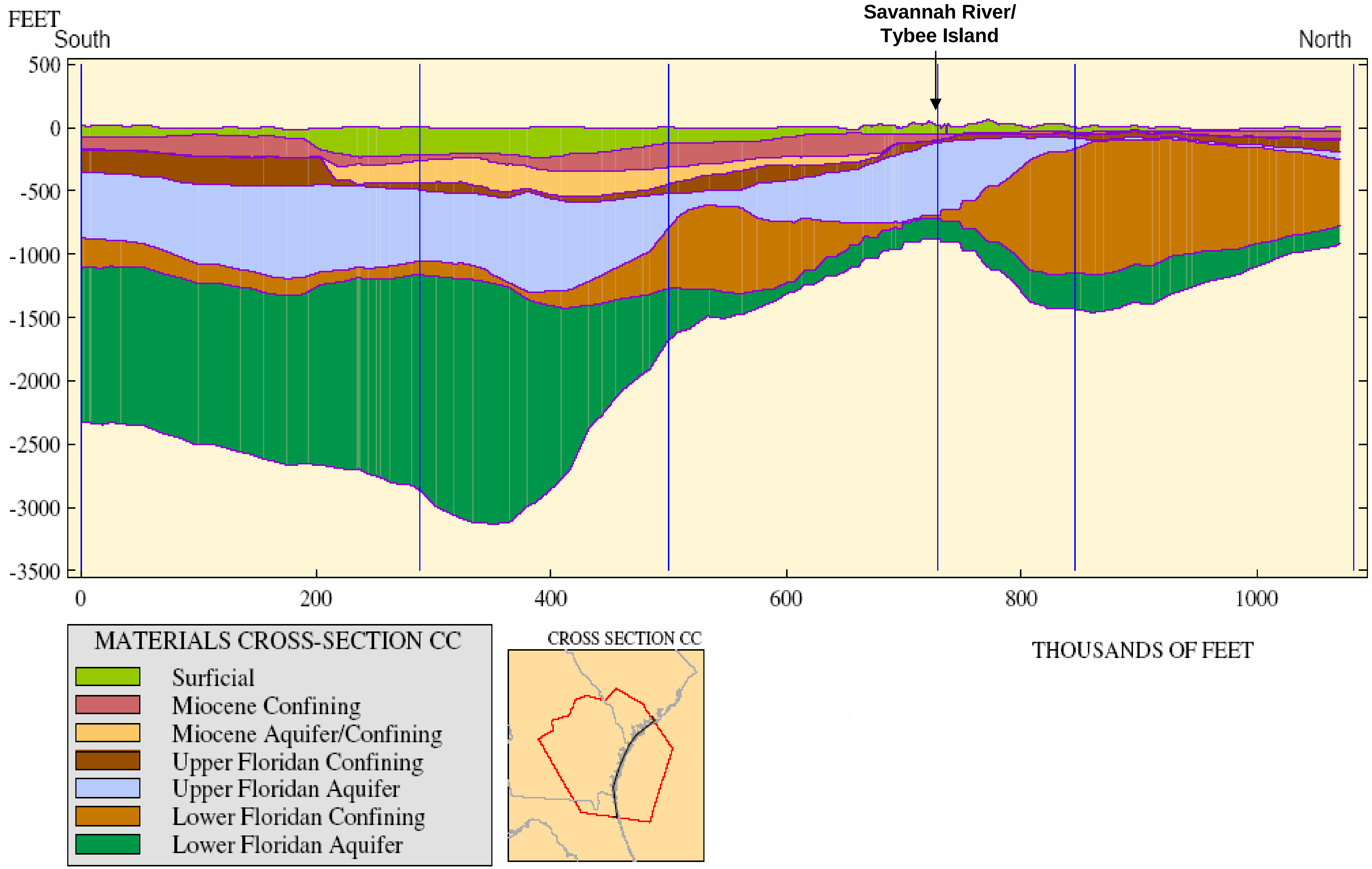
CDM



The Miocene Unit in this cross-section has aquifer properties in some areas and confining unit properties in others.

Figure 2-7
Cross Section through Model
Normal to Coastline through Center of Model

Savannah Harbor Expansion
Groundwater Model Studies



The Miocene Unit in this cross-section has aquifer properties in some areas and confining unit properties in others.

Figure 2-8
Cross Section Along Coastline

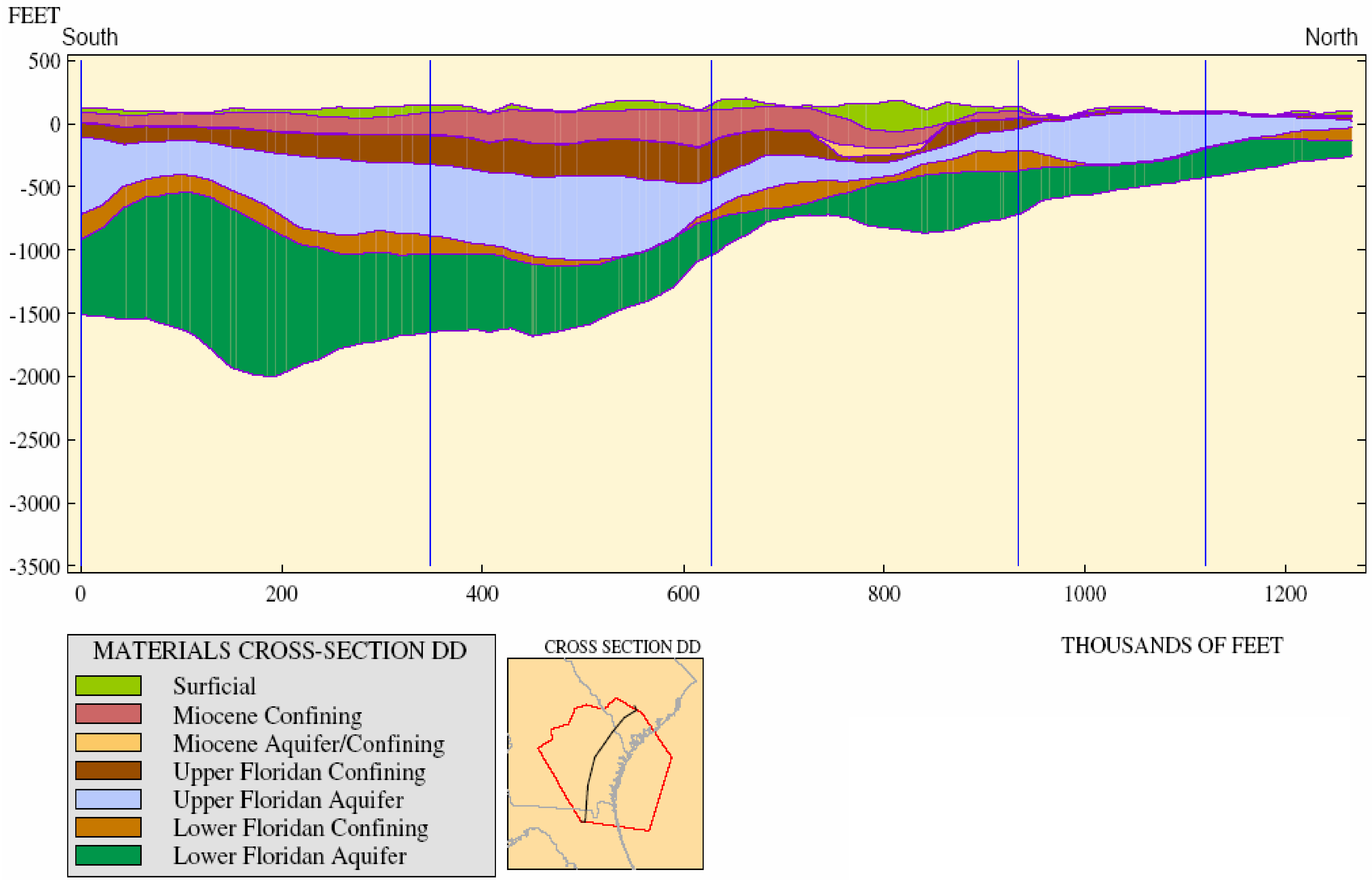
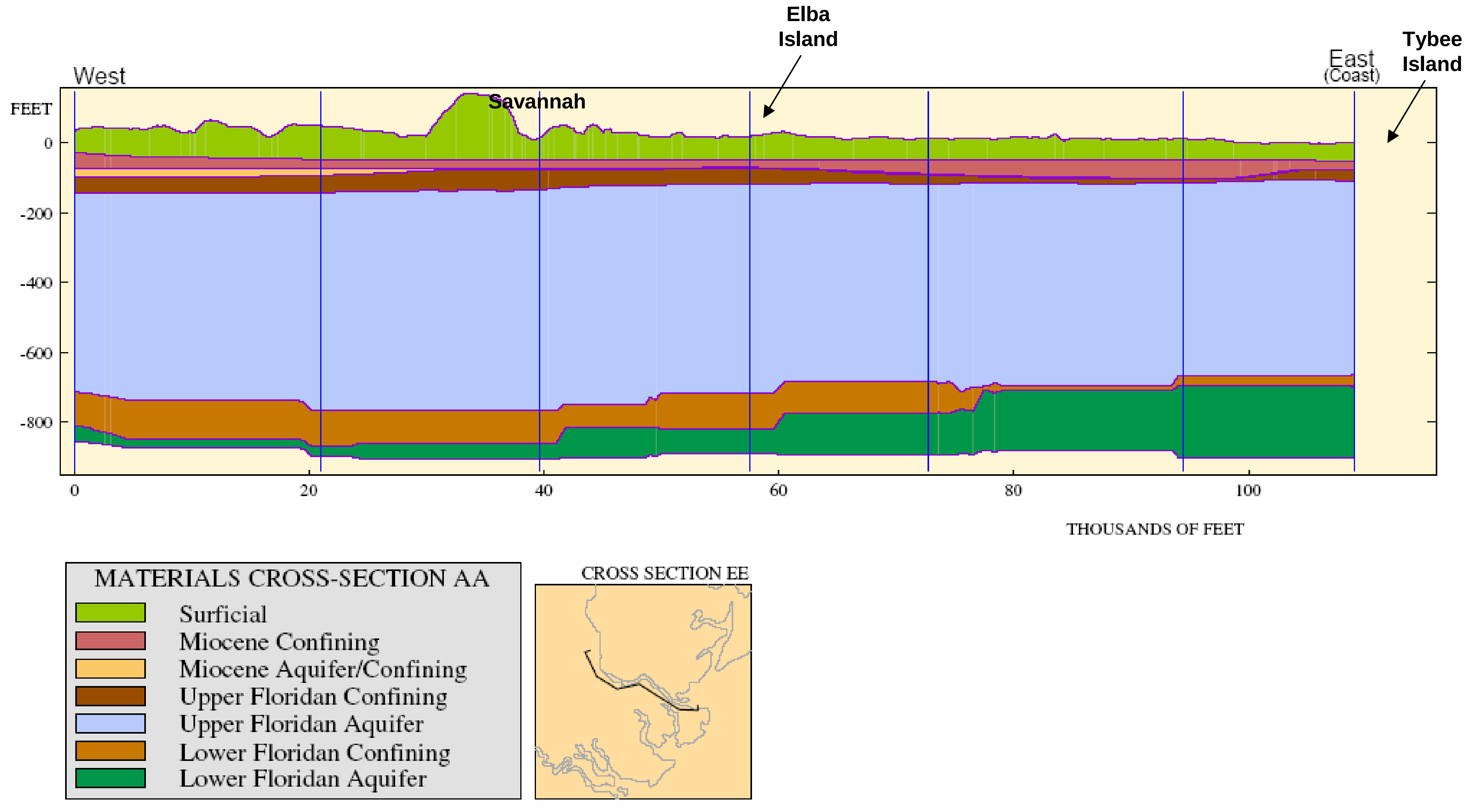


Figure 2-9
Cross Section Parallel to Coastline Inland of Savannah



In the Savannah area the Miocene Unit has confining unit properties; further upgradient the unit has aquifer properties.

Figure 2-10
Cross Section Along Savannah River in Project Area

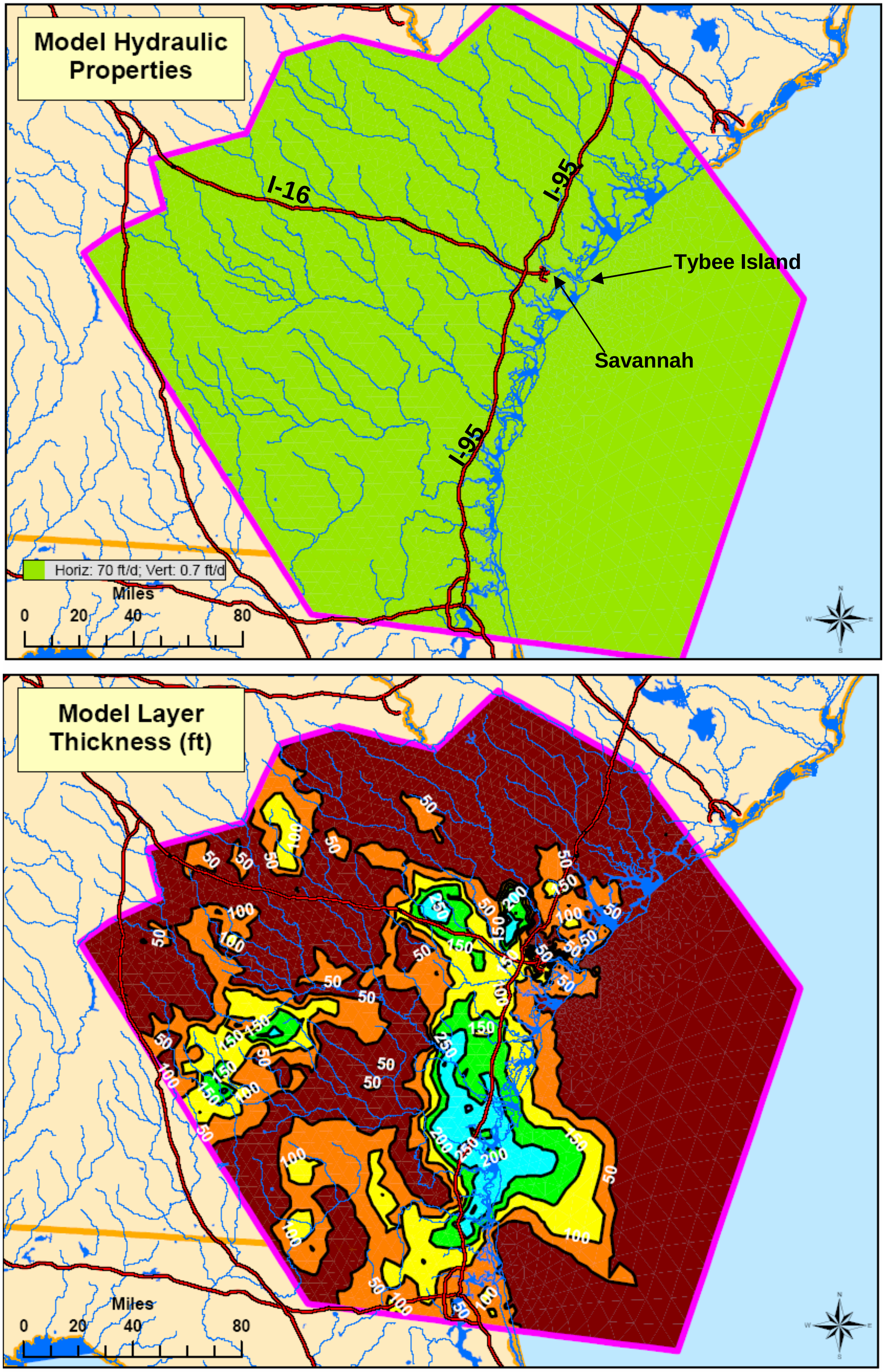


Figure 2-11
Hydraulic Properties and Thickness of Surficial Aquifer

CDM

Savannah Harbor Expansion
Groundwater Model Studies

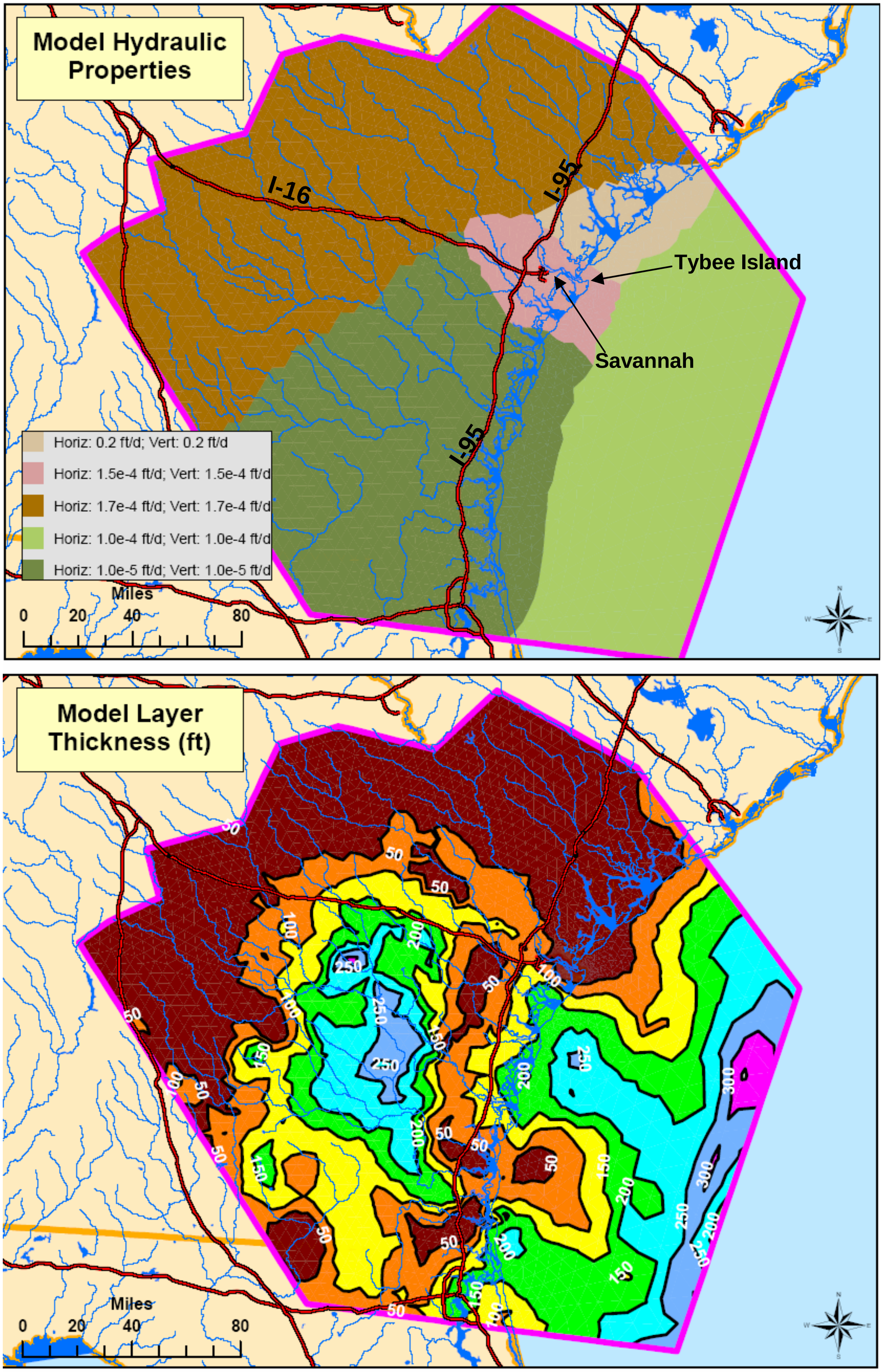


Figure 2-12
Hydraulic Properties and Thickness of Miocene Confining Unit

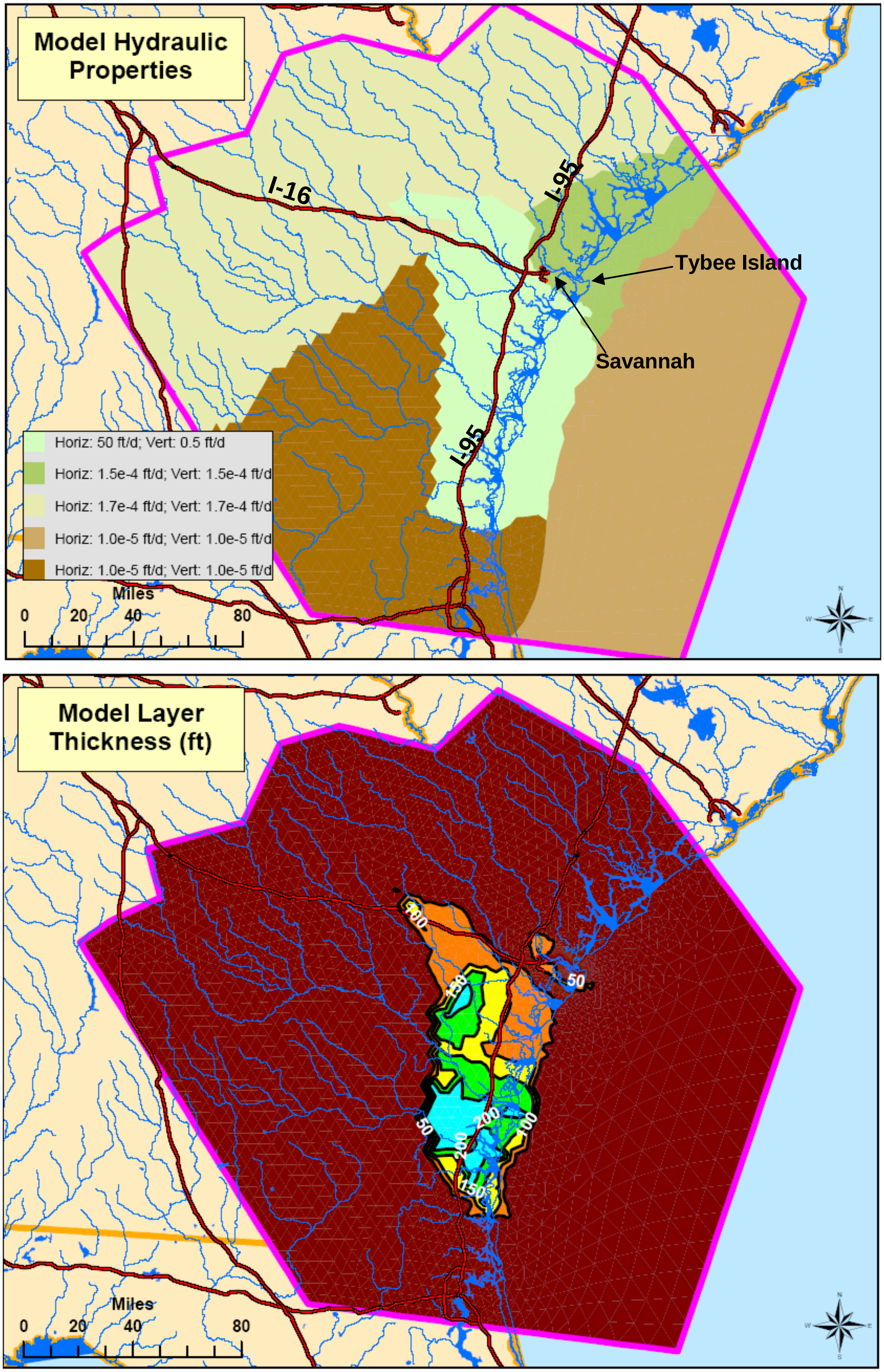


Figure 2-13
Hydraulic Properties and Thickness of Miocene Aquifer/Confining Units

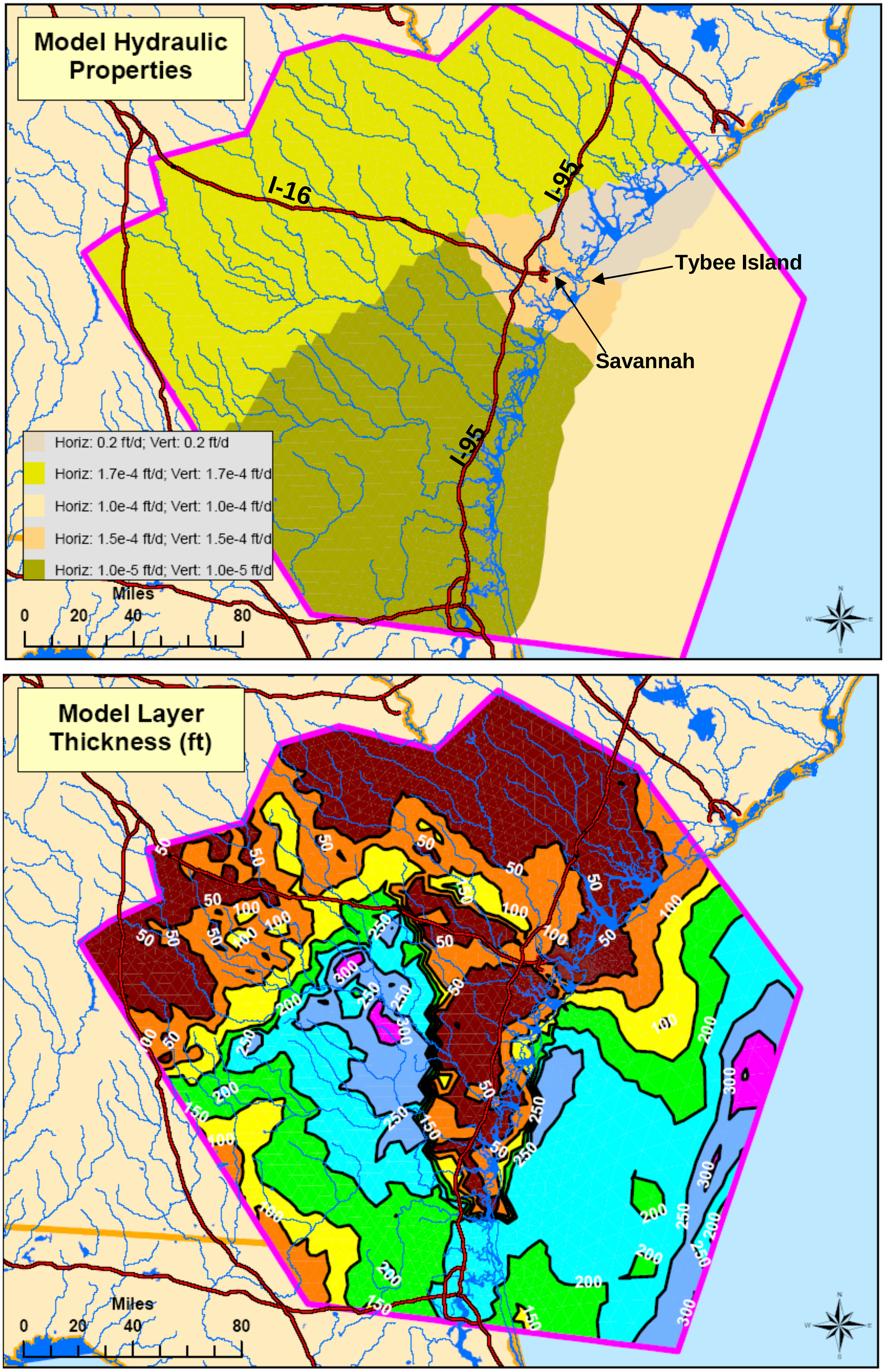


Figure 2-14
Hydraulic Properties and Thickness of Upper Floridan Confining Unit

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Groundwater Model Studies

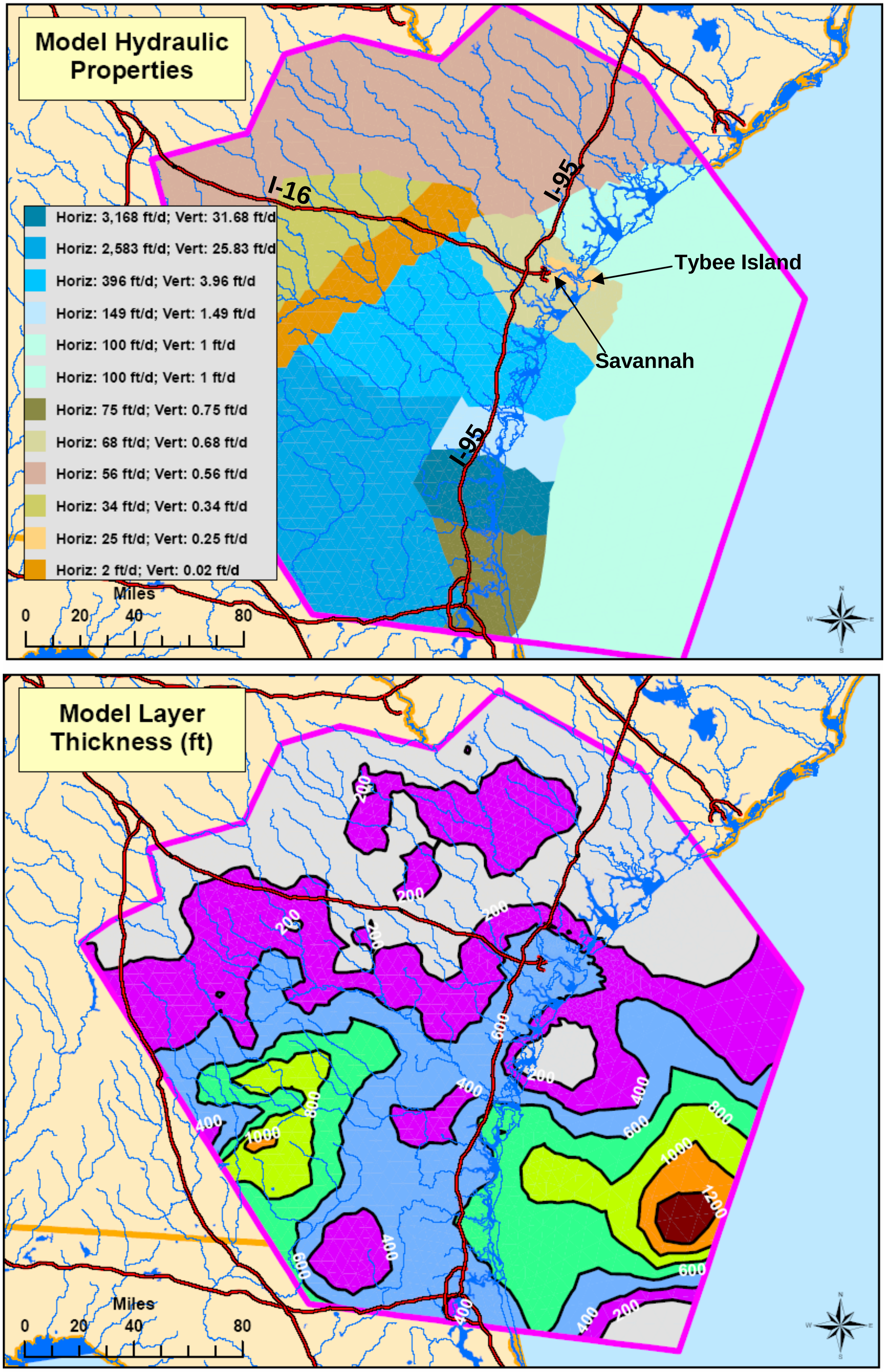

Figure 2-15
Hydraulic Properties and Thickness of Upper Floridan Aquifer

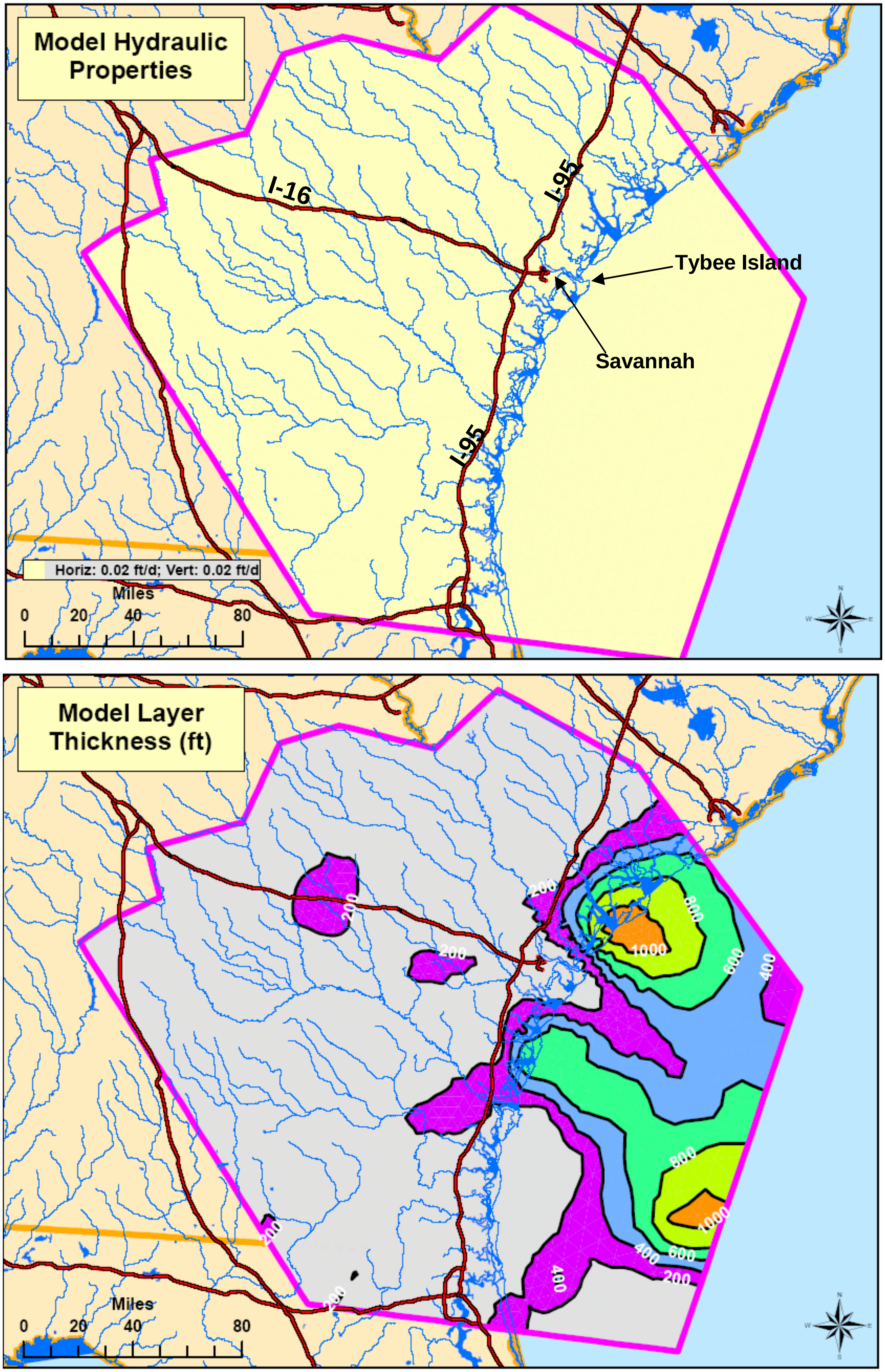

Figure 2-16
Hydraulic Properties and Thickness of Lower Floridan Confining Unit

CDM

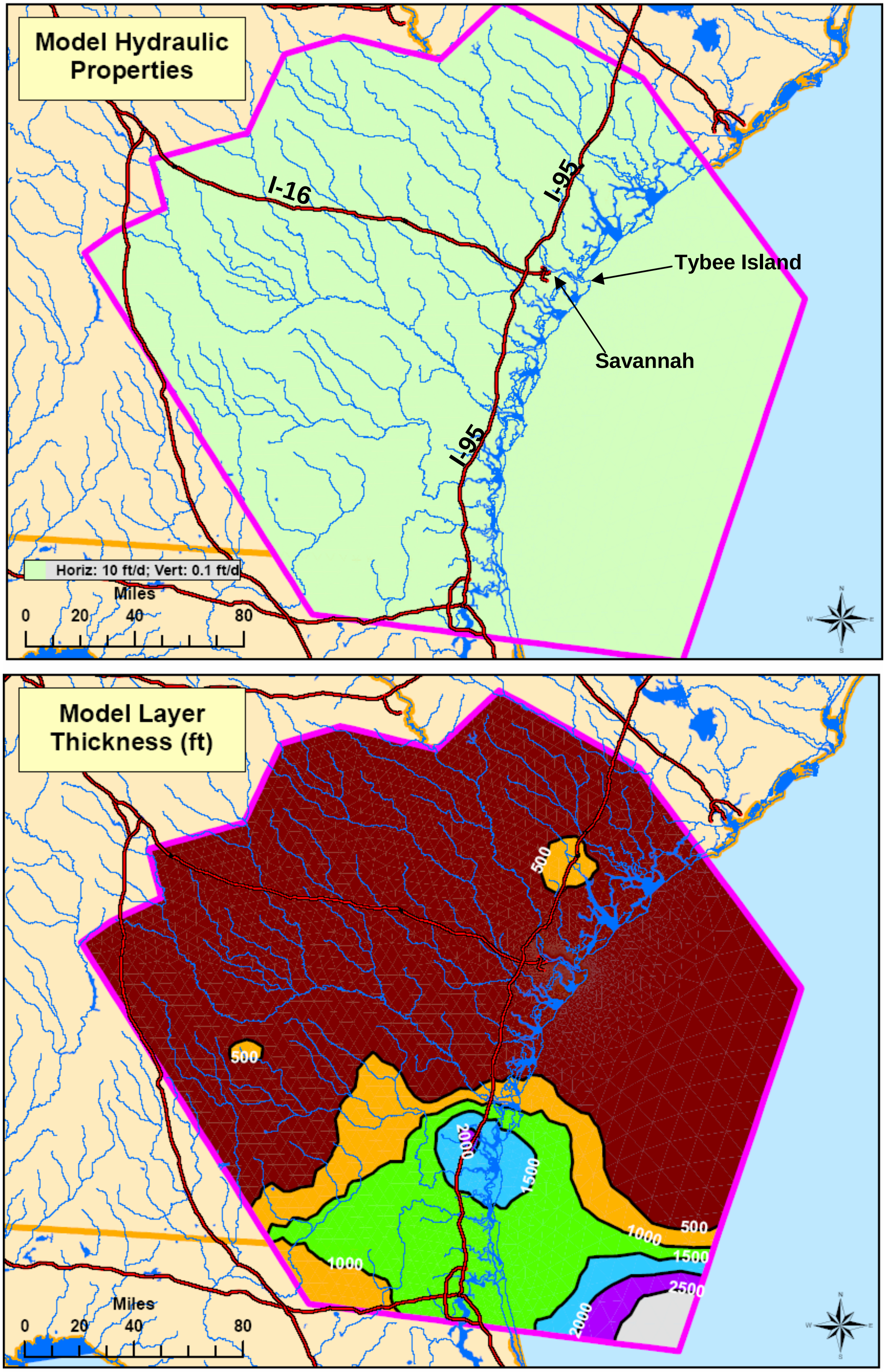

Figure 2-17
Hydraulic Properties and Thickness of Lower Floridan Aquifer

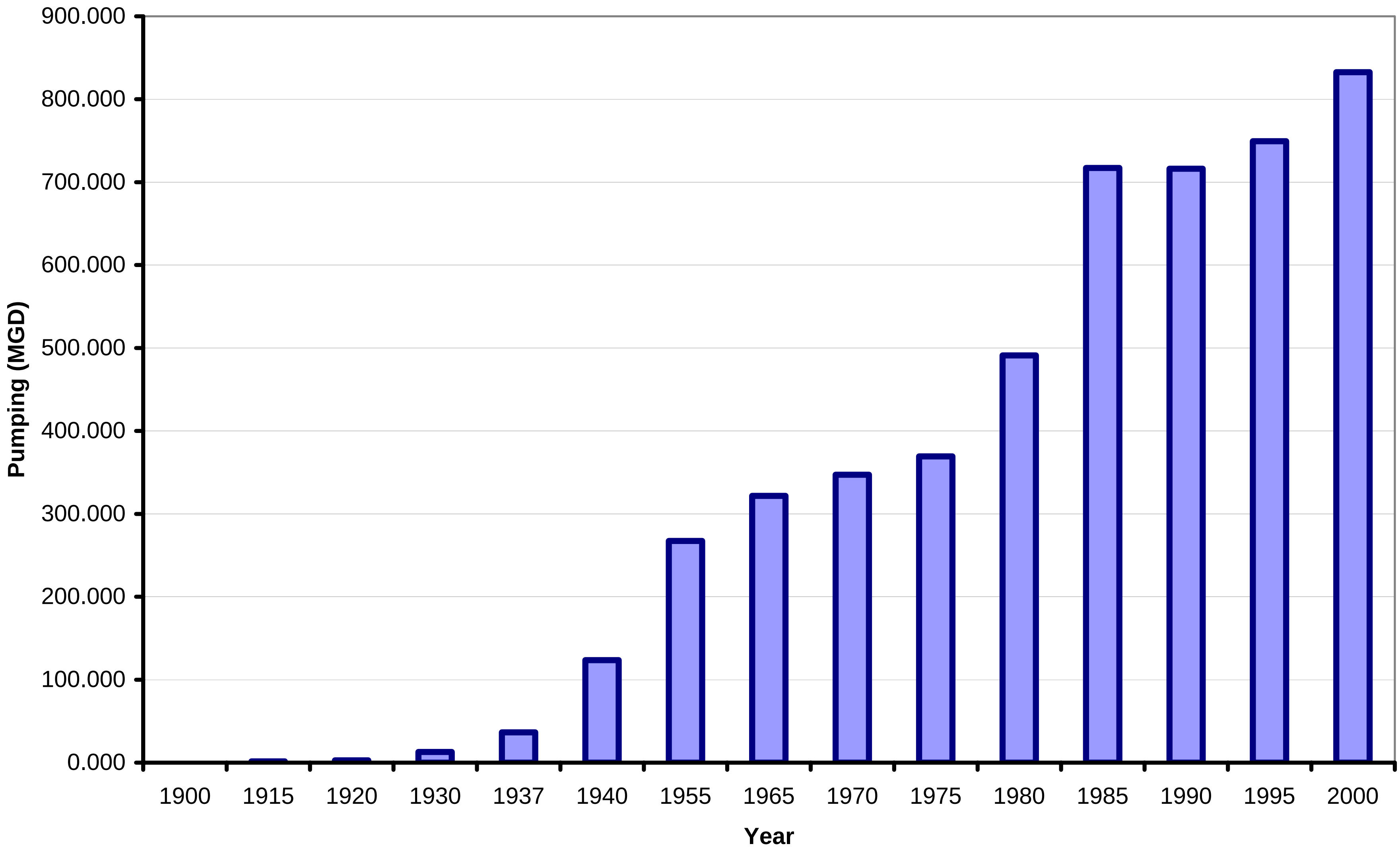

Figure 2-18
Applied Groundwater Pumping for Historical Simulation (1900 to 2000)

CDM

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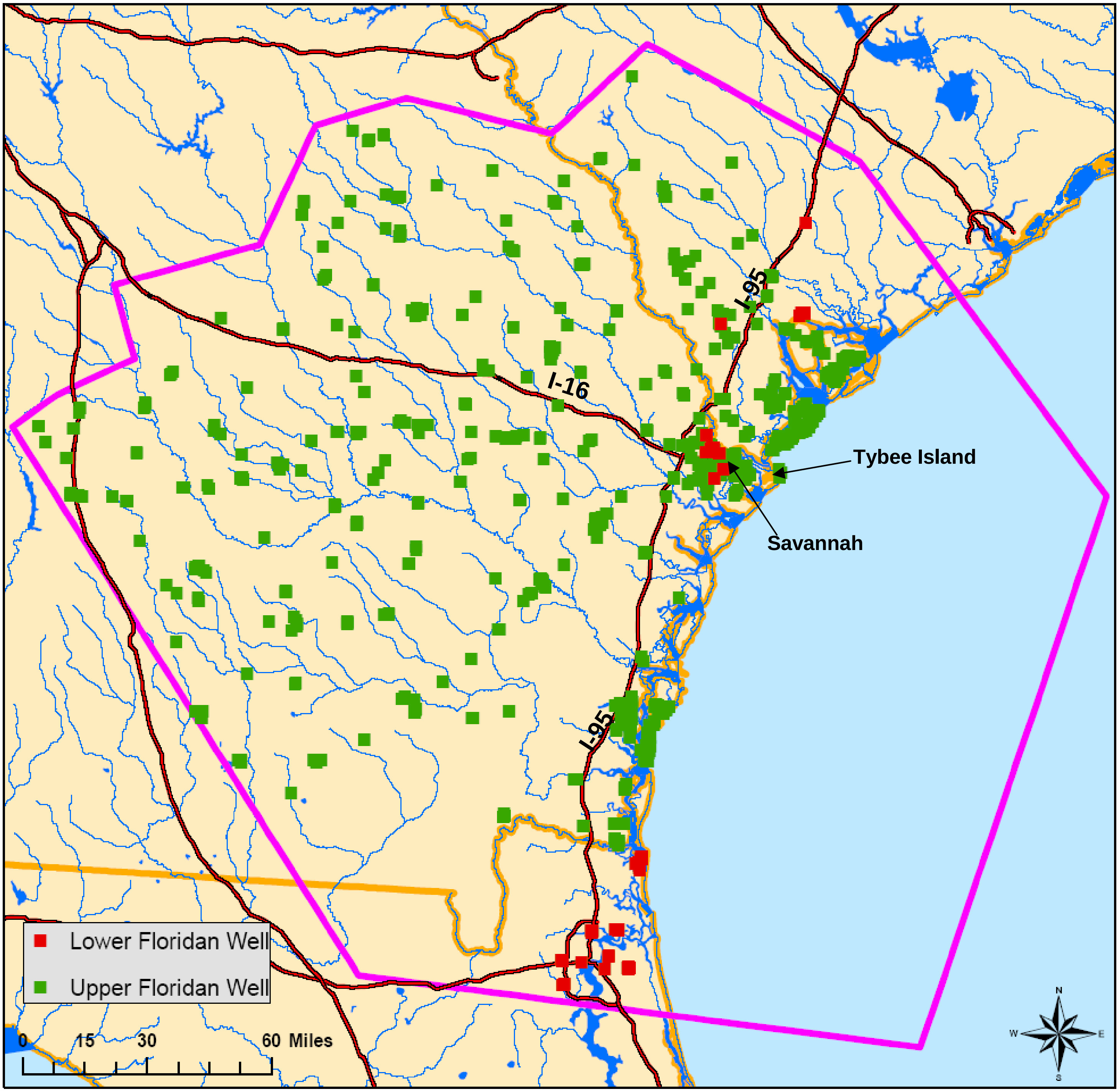

Figure 2-19
Well Pumping Locations for Year 2000

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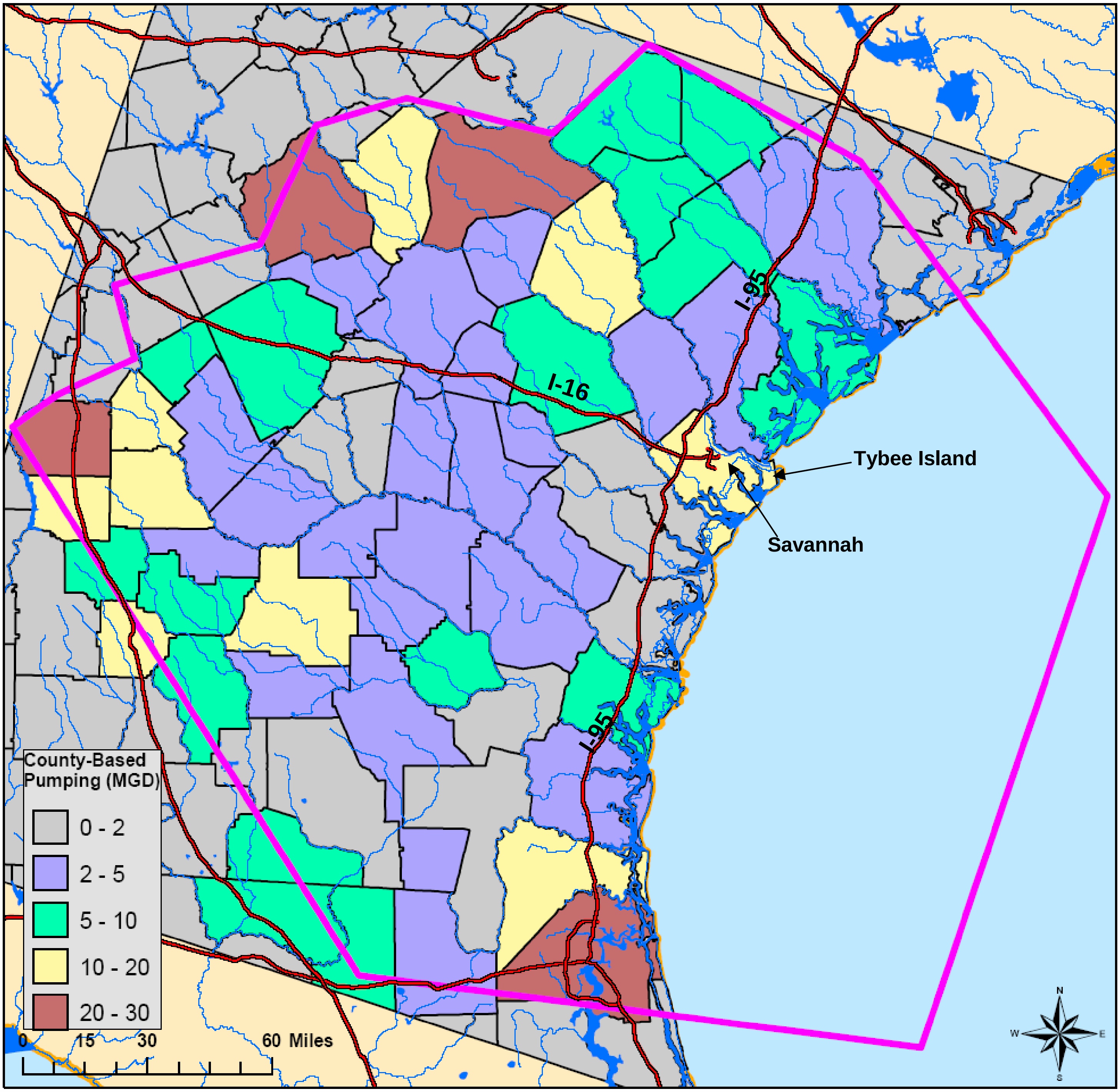

Figure 2-20
County-Based Pumping for Year 2000

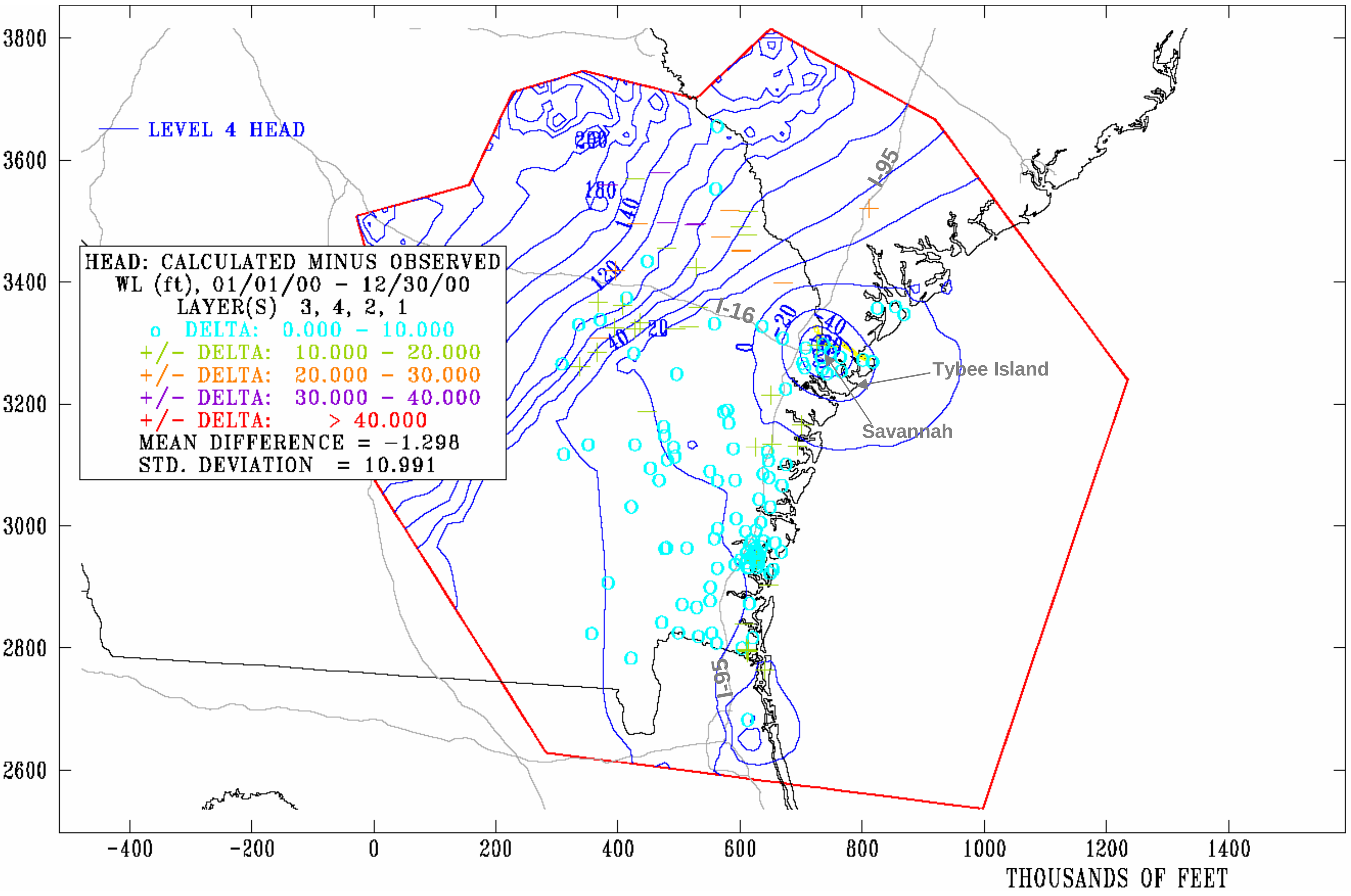

Figure 2-21
Steady State Calibration for Year 2000

CDM

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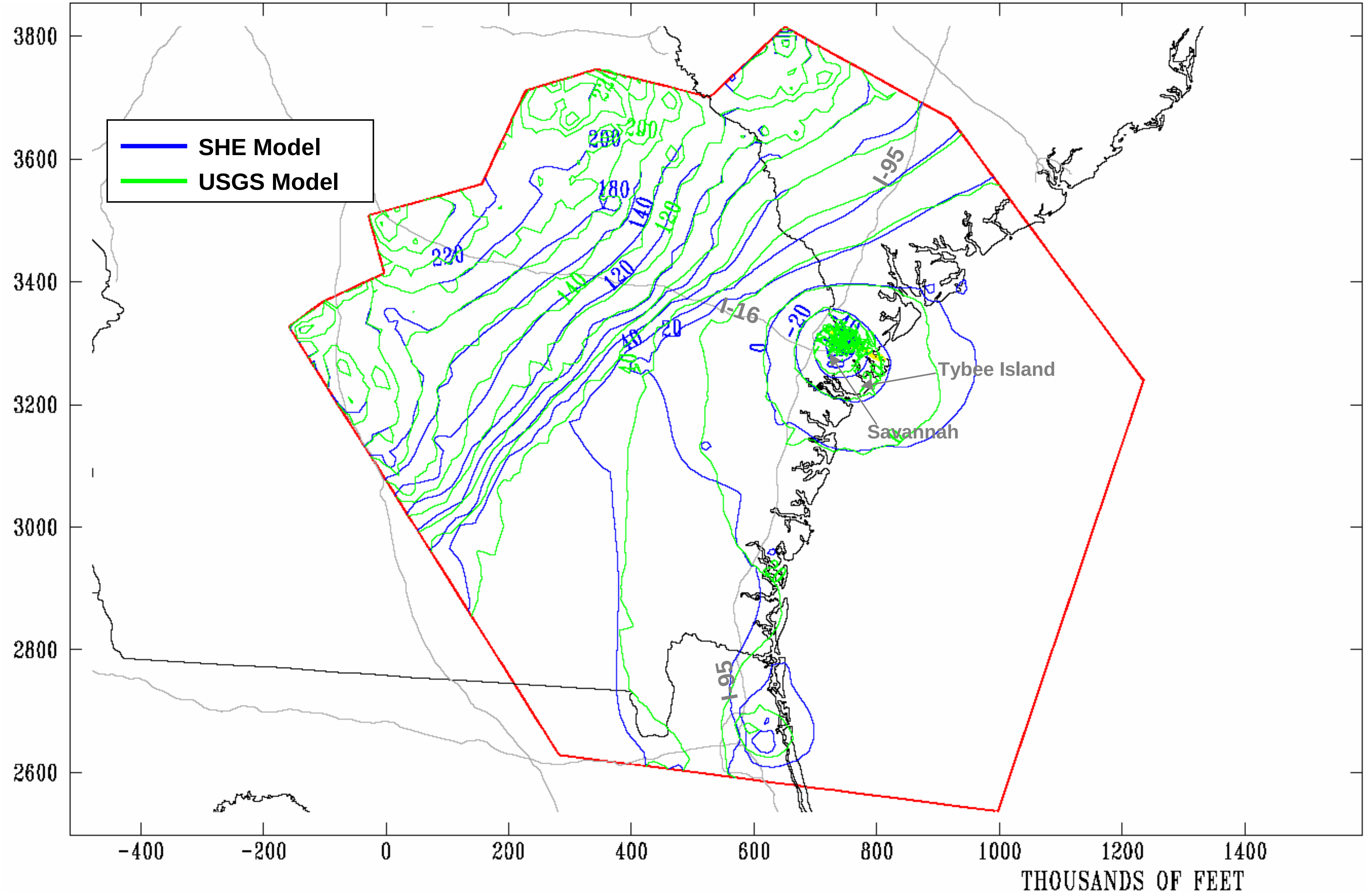

Figure 2-22
Comparison of SHE Model Results vs. USGS Model Results
In the Upper Floridan Aquifer for Year 2000

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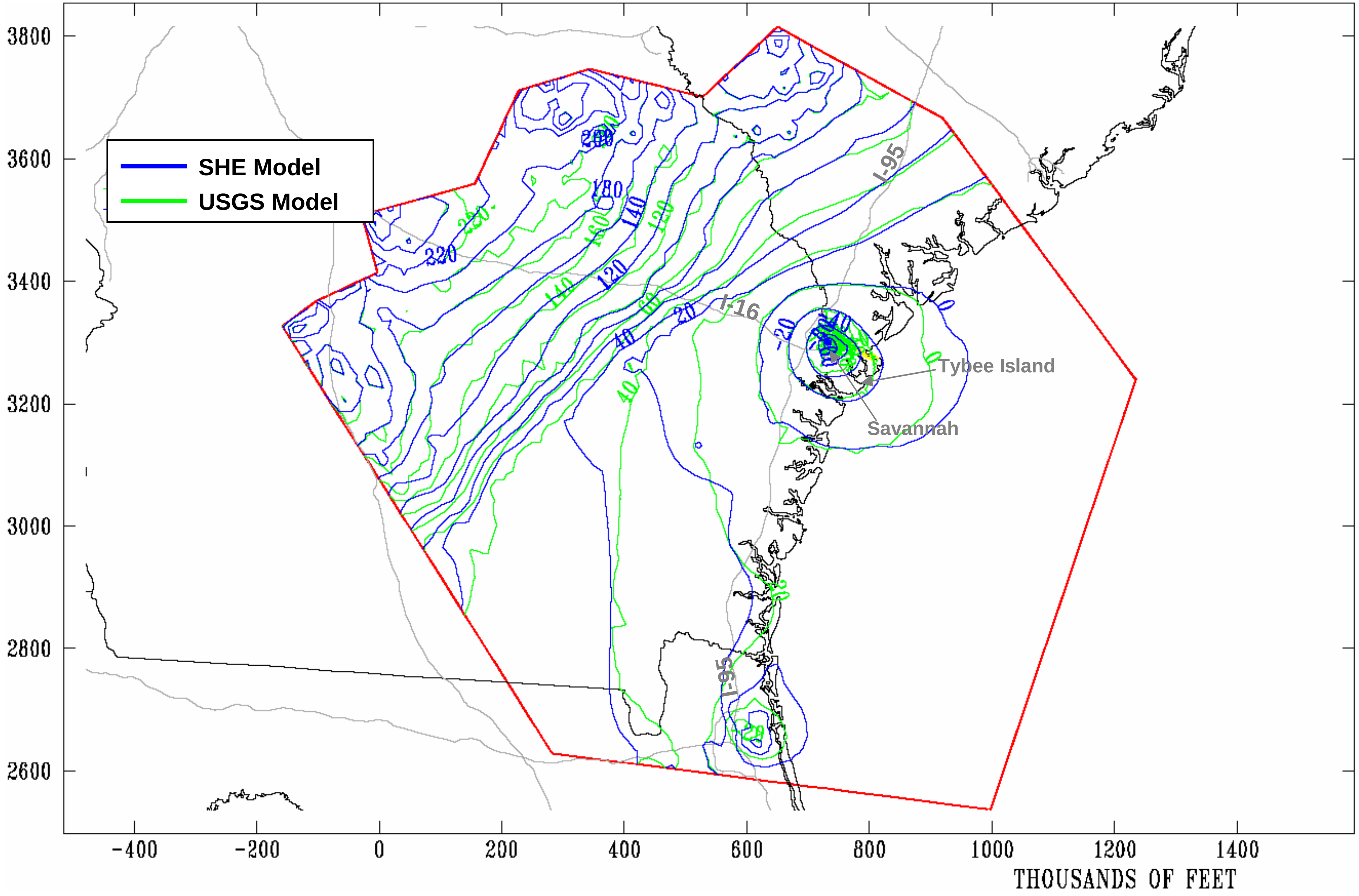

Figure 2-23
Comparison of SHE Model Results vs. USGS Model Results
In the Lower Floridan Aquifer for Year 2000

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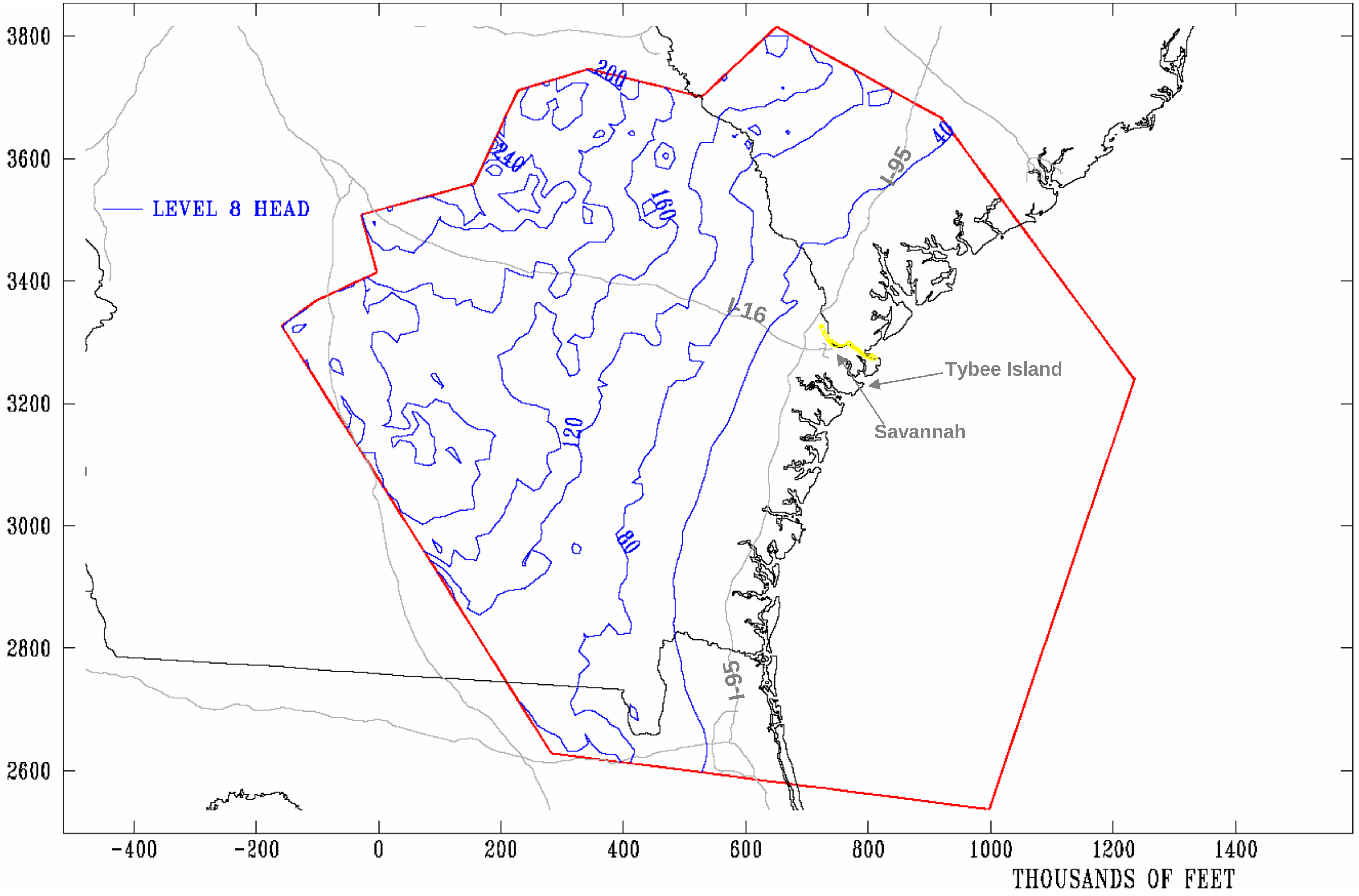

Figure 2-24
Simulated Surficial Aquifer Heads for Predevelopment Conditions

CDM

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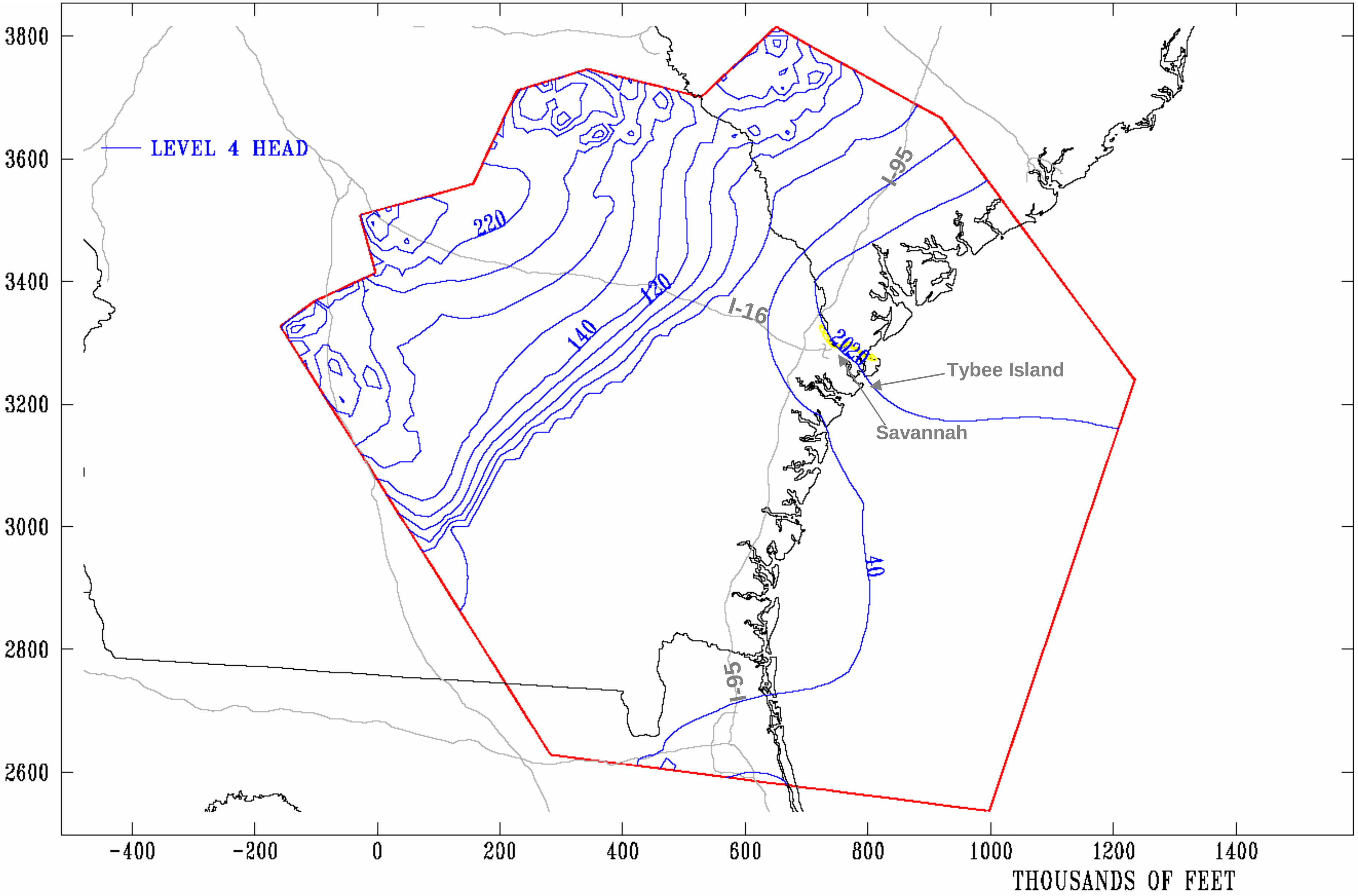

Figure 2-25
Simulated Upper Floridan Aquifer Heads for Predevelopment Conditions

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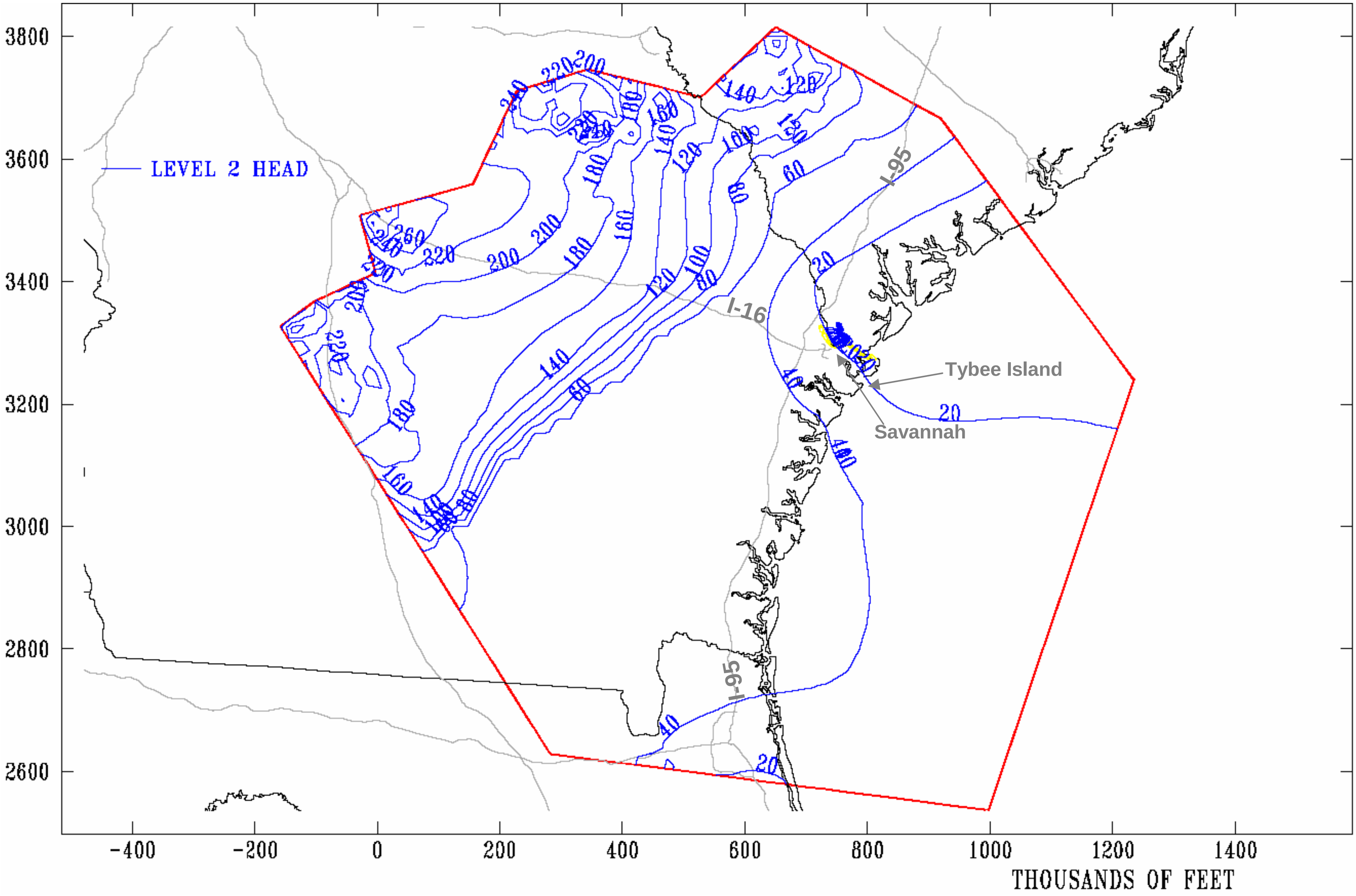

Figure 2-26
Simulated Lower Floridan Aquifer Heads for Predevelopment Conditions

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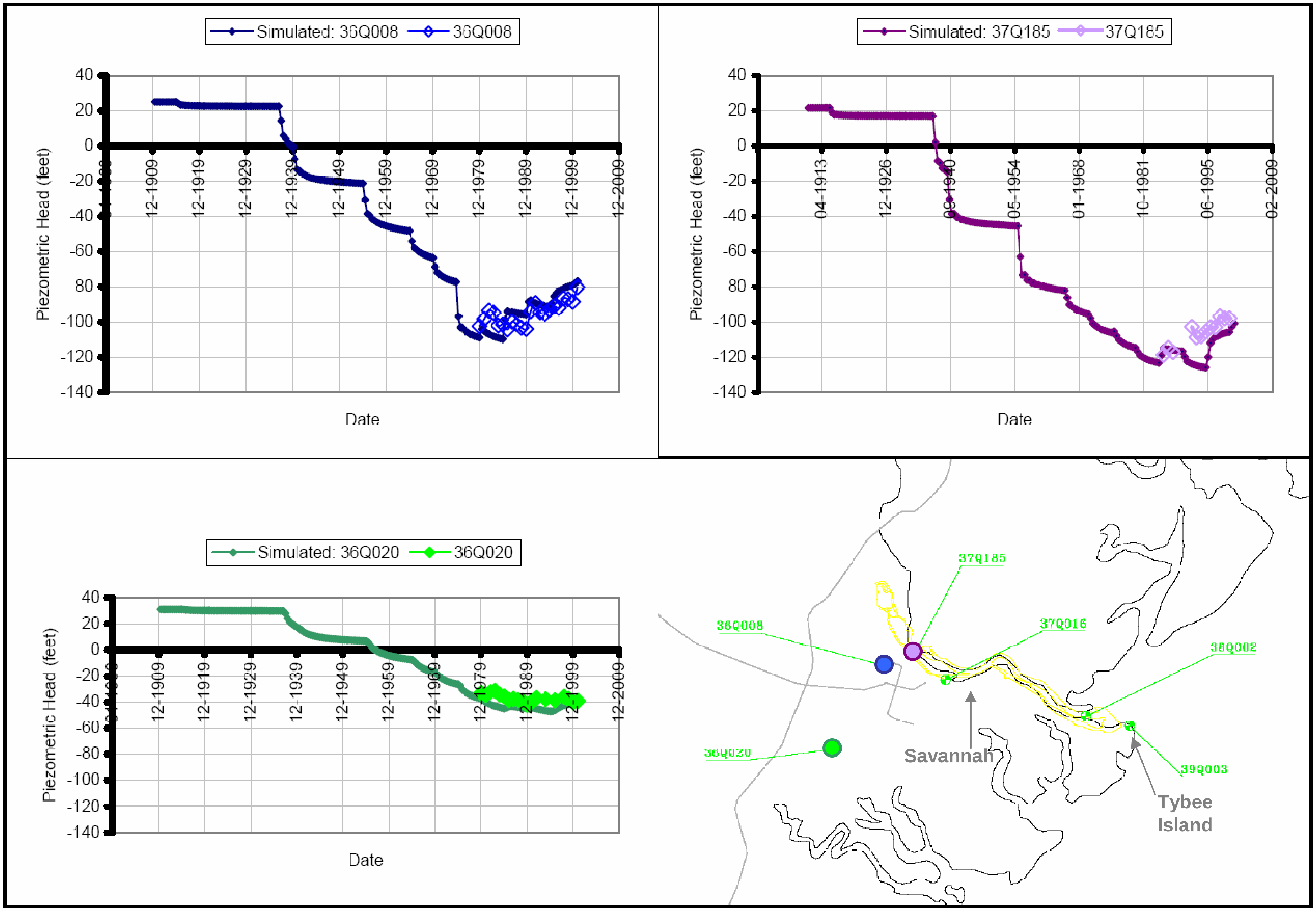

Figure 2-27
Comparison of Historical Simulated and Measured Heads in Upper Floridan Aquifer

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Groundwater Model Studies

CDM

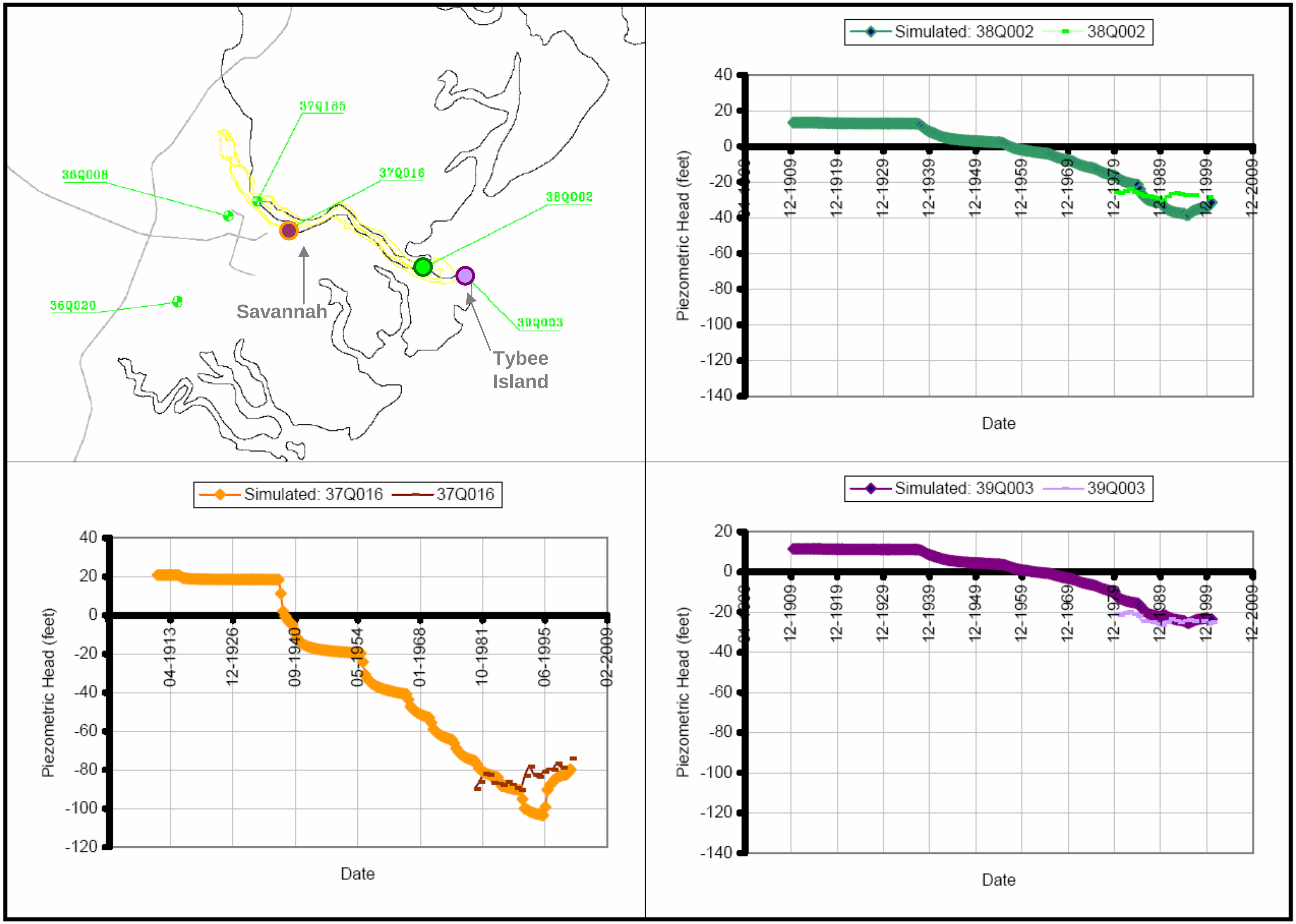

Figure 2-28
Comparison of Historical Simulated and Measured Heads in Upper Floridan Aquifer

Savannah Harbor Expansion
Groundwater Model Studies

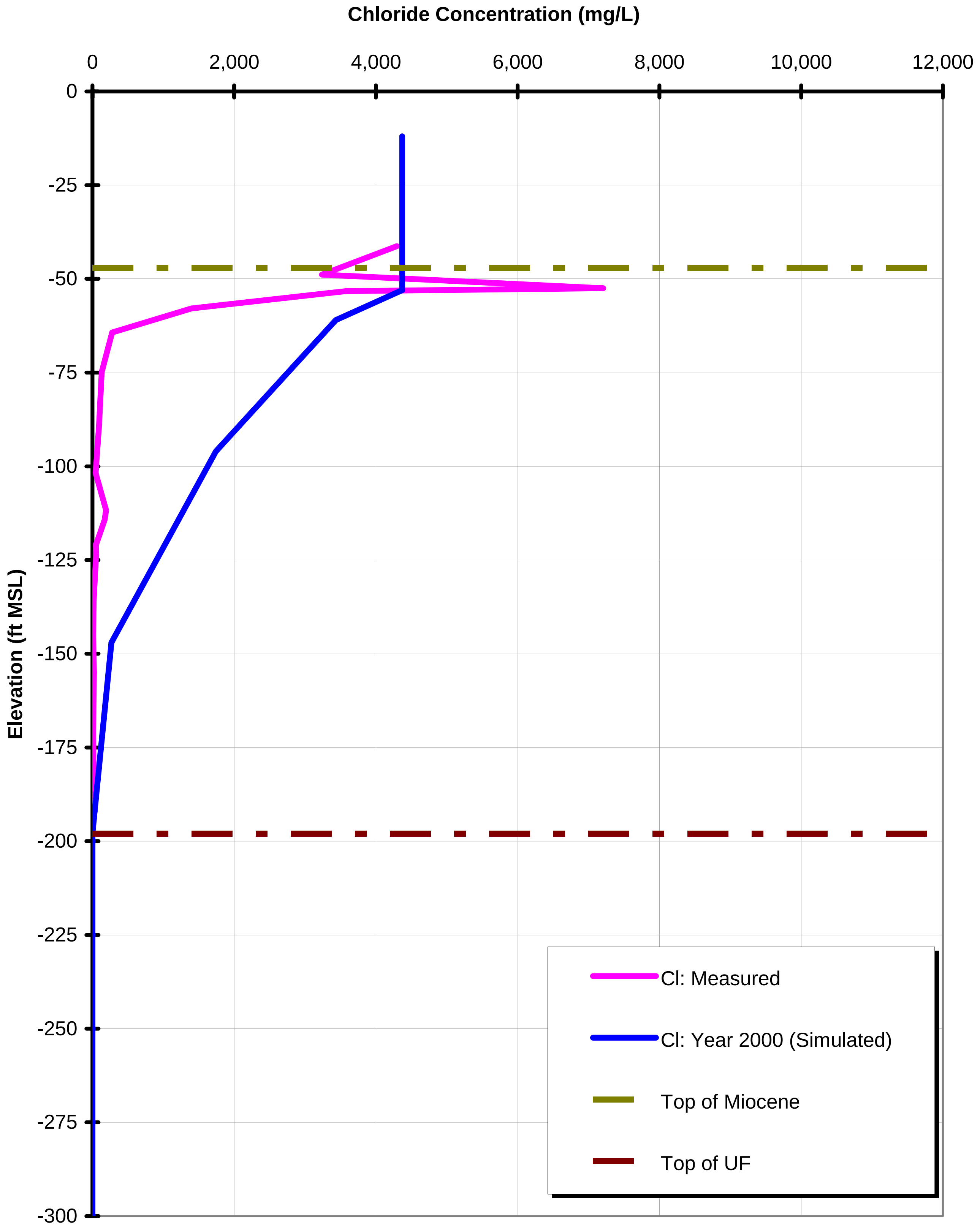

Figure 2-29
Measured and Simulated Chloride Measurements at SHE-15 Borehole

Savannah Harbor Expansion
Groundwater Model Studies

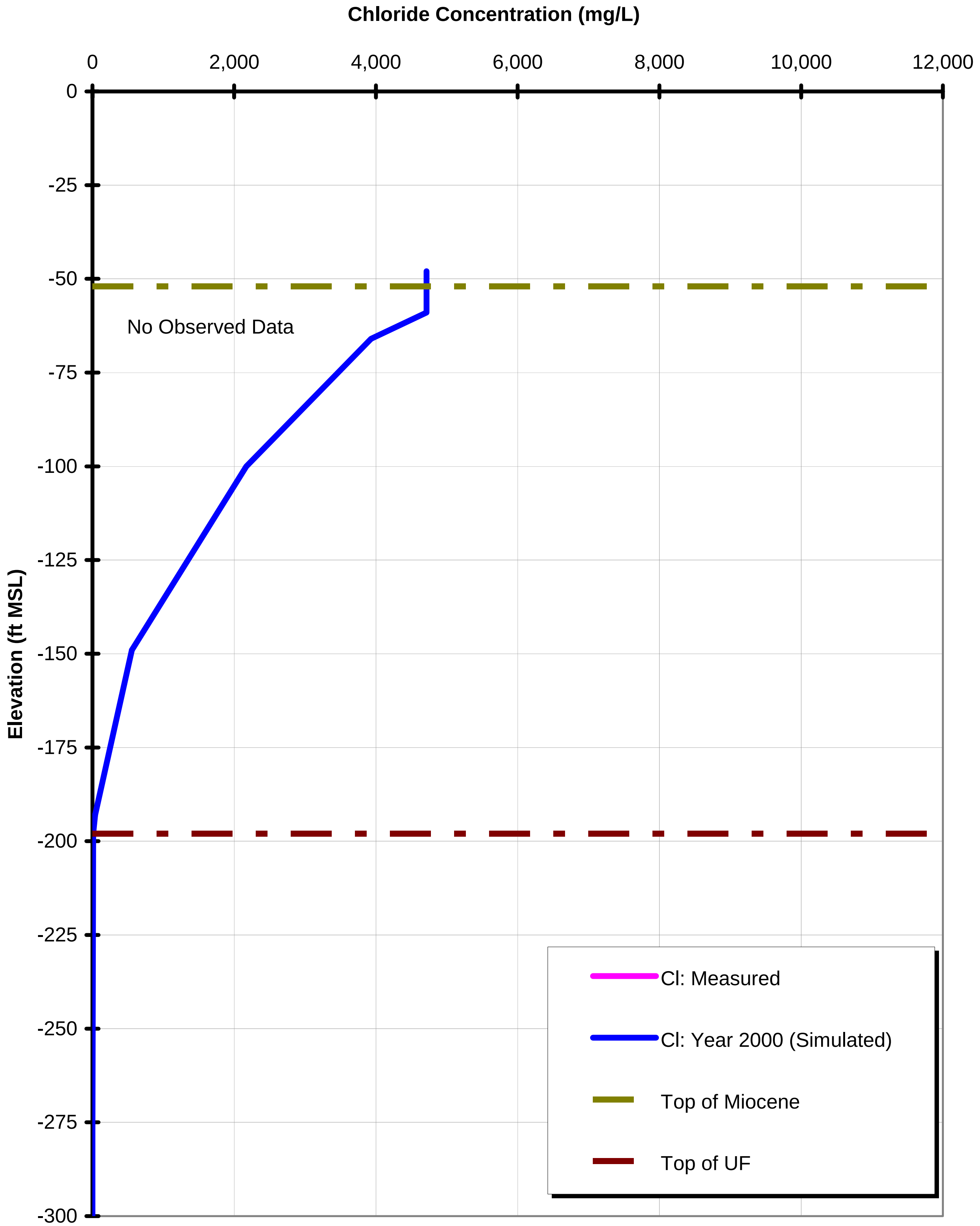

Figure 2-30
Measured and Simulated Chloride Measurements at SHE-5 Borehole

CDM

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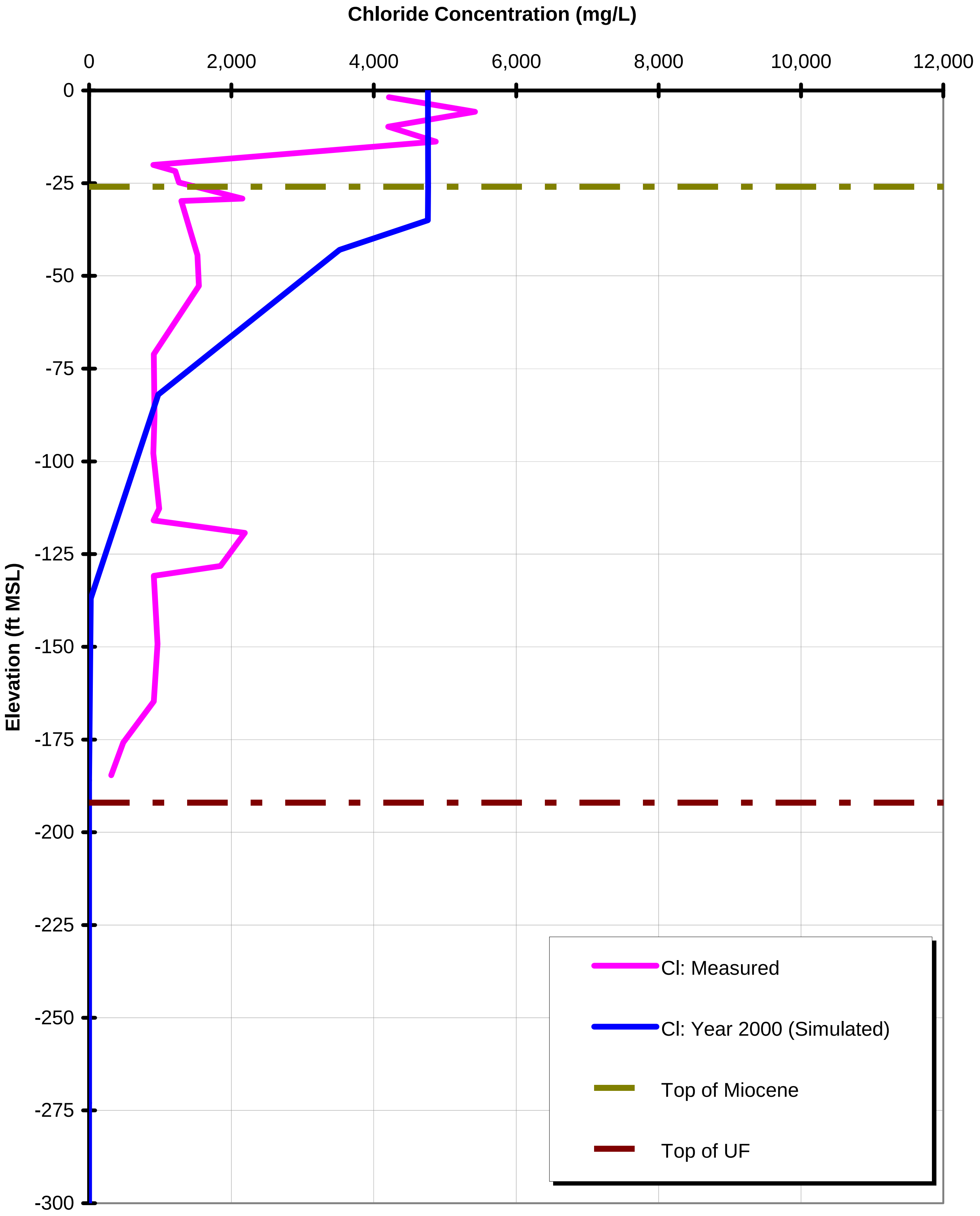

Figure 2-31
Measured and Simulated Chloride Measurements at SHE-9 Borehole

Savannah Harbor Expansion
Groundwater Model Studies

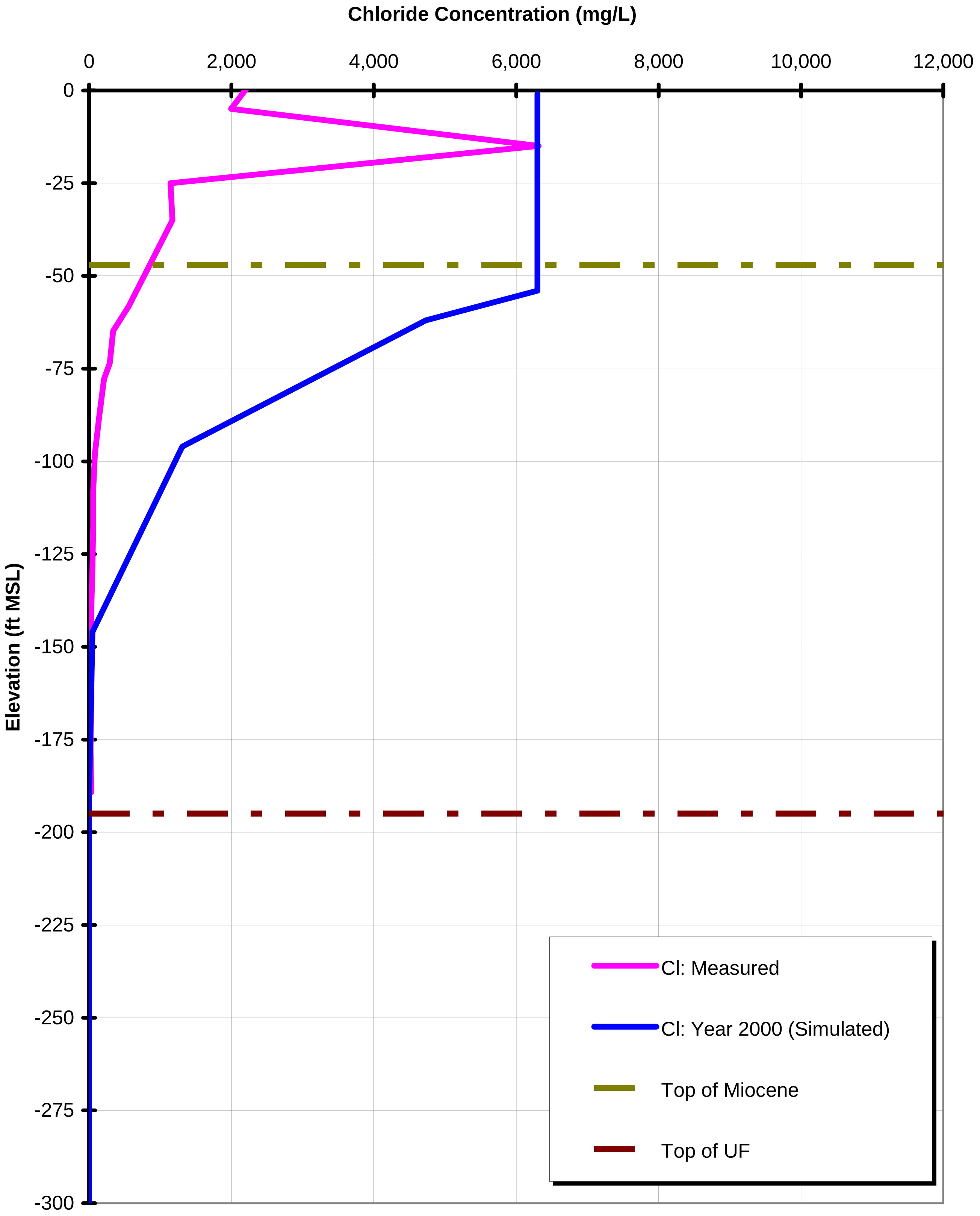

Figure 2-32
Measured and Simulated Chloride Measurements at SHE-19 Borehole

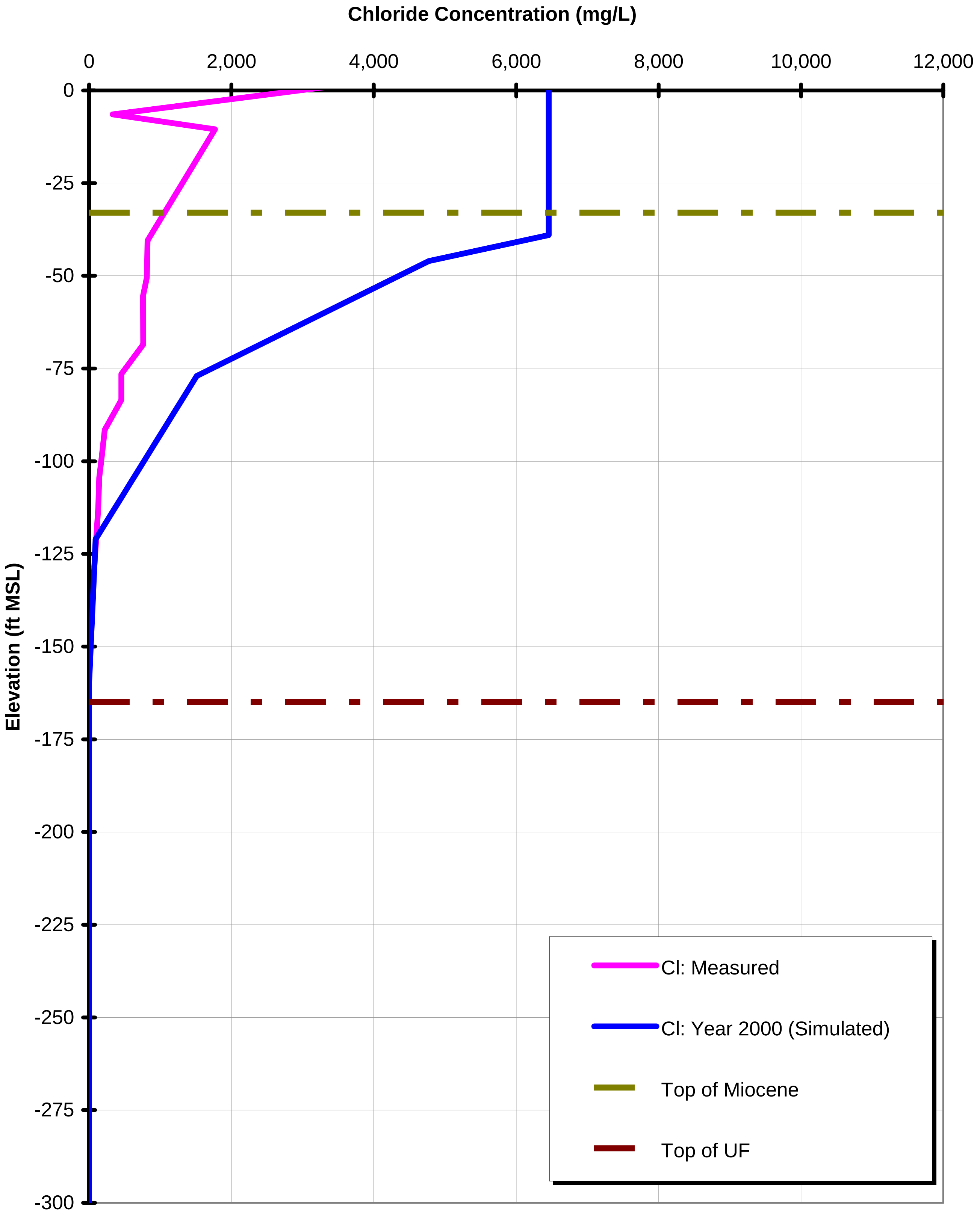

Figure 2-33
Measured and Simulated Chloride Measurements at SHE-10 Borehole

CDM

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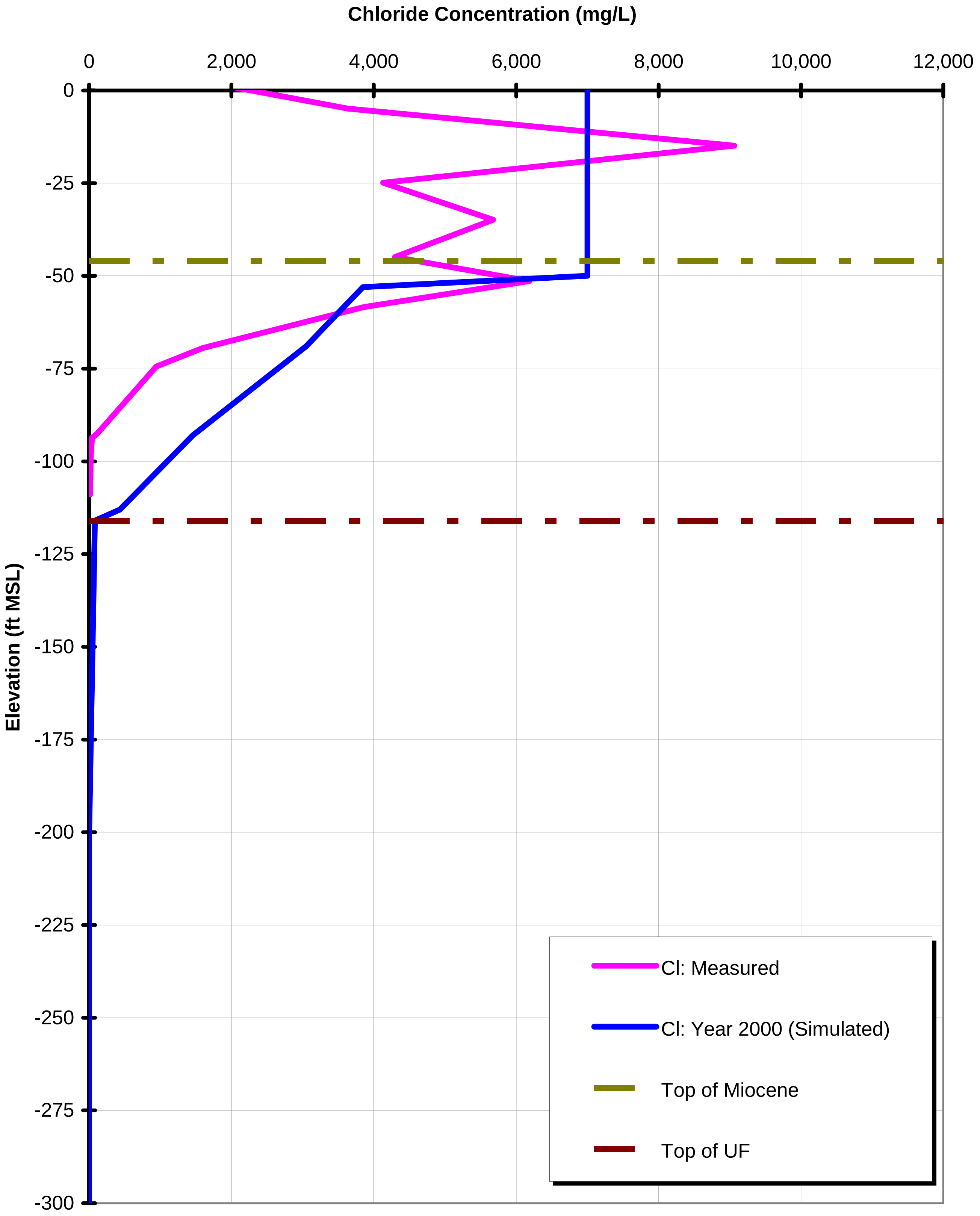

Figure 2-34
Measured and Simulated Chloride Measurements at SHE-18 Borehole

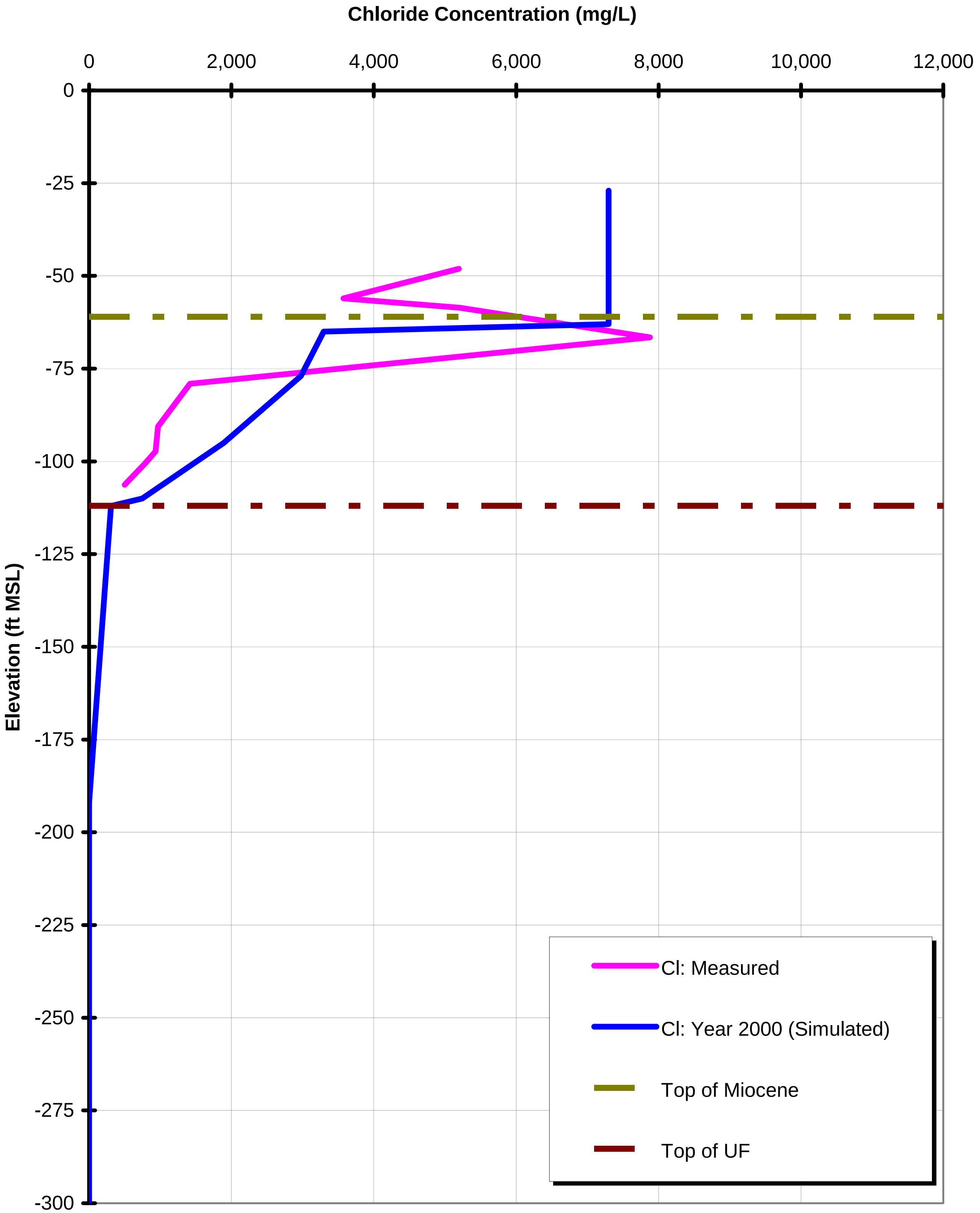

Figure 2-35
Measured and Simulated Chloride Measurements at SHE-11 Borehole

CDM

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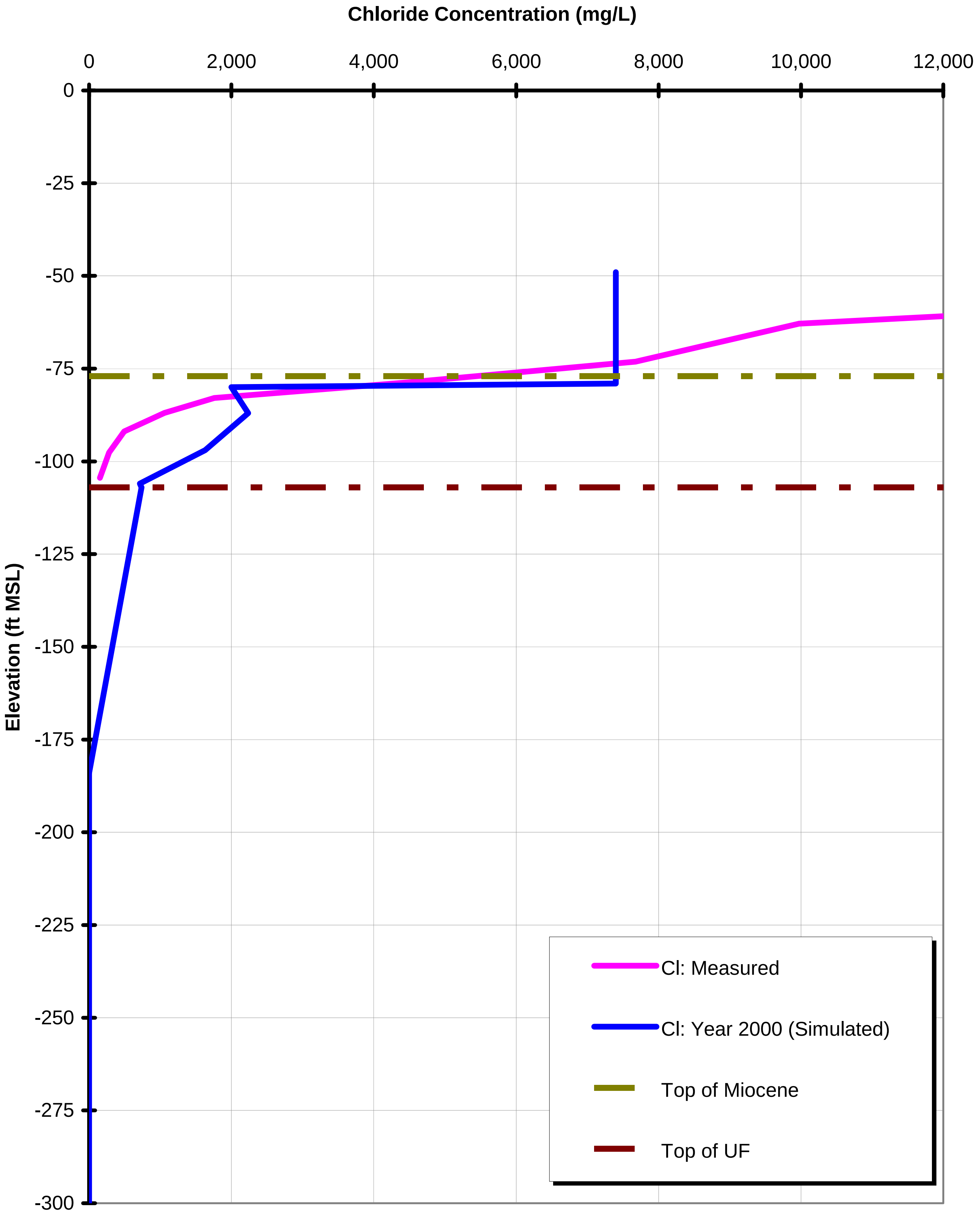

Figure 2-36
Measured and Simulated Chloride Measurements at SHE-13 Borehole

CDM

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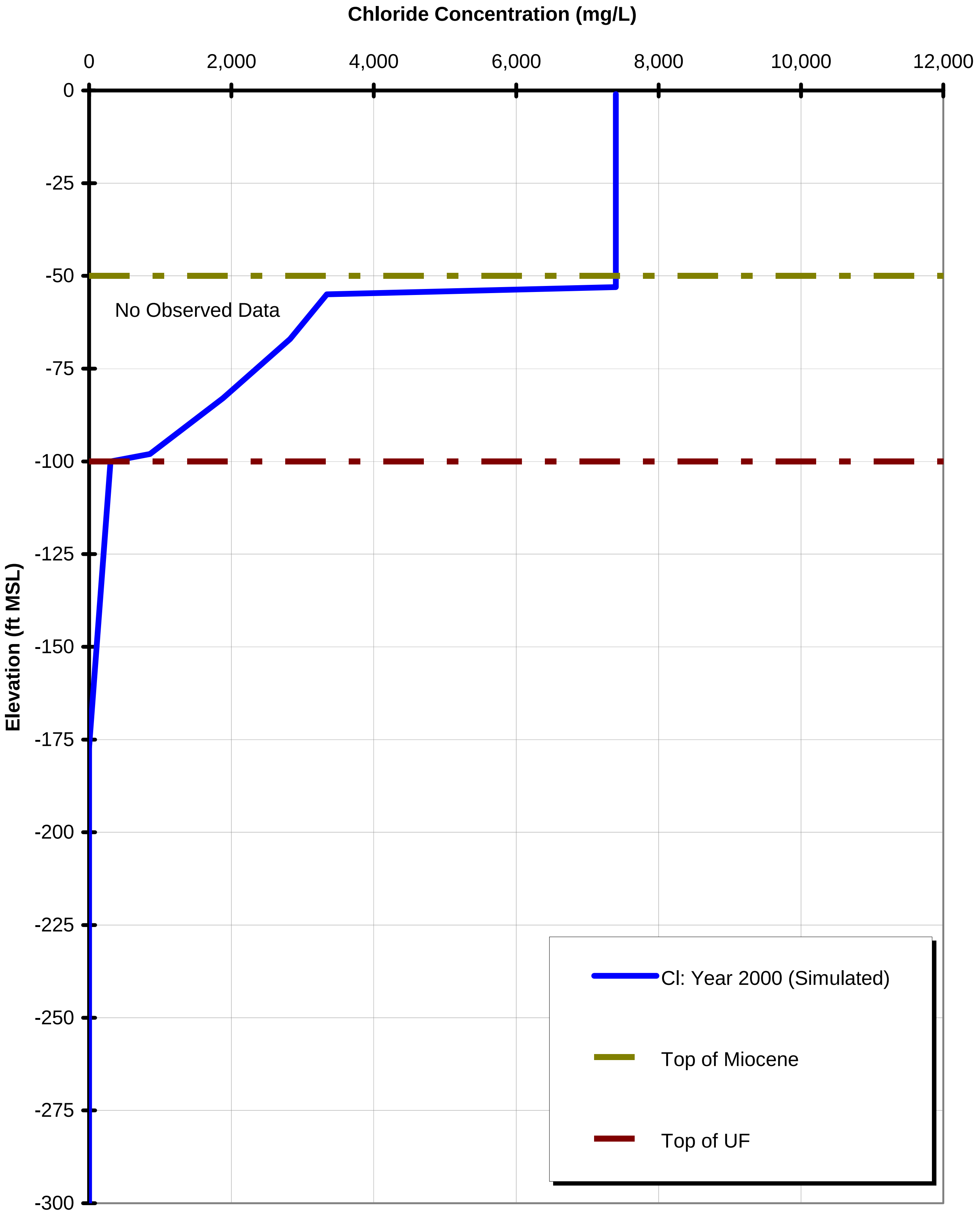

Figure 2-37
Measured and Simulated Chloride Measurements at SHE-2 Borehole

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Groundwater Model Studies

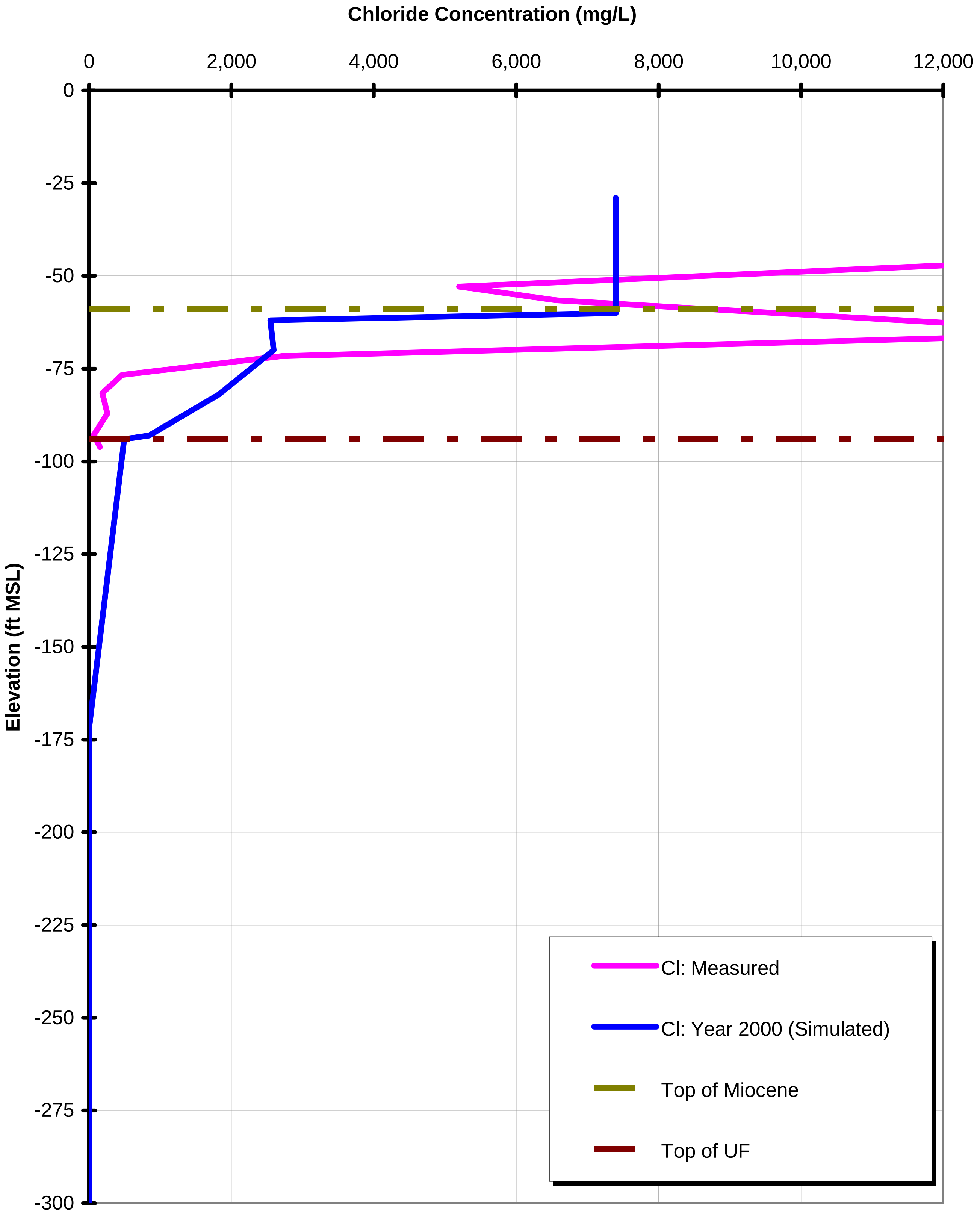

Figure 2-38
Measured and Simulated Chloride Measurements at SHE-14 Borehole

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Groundwater Model Studies

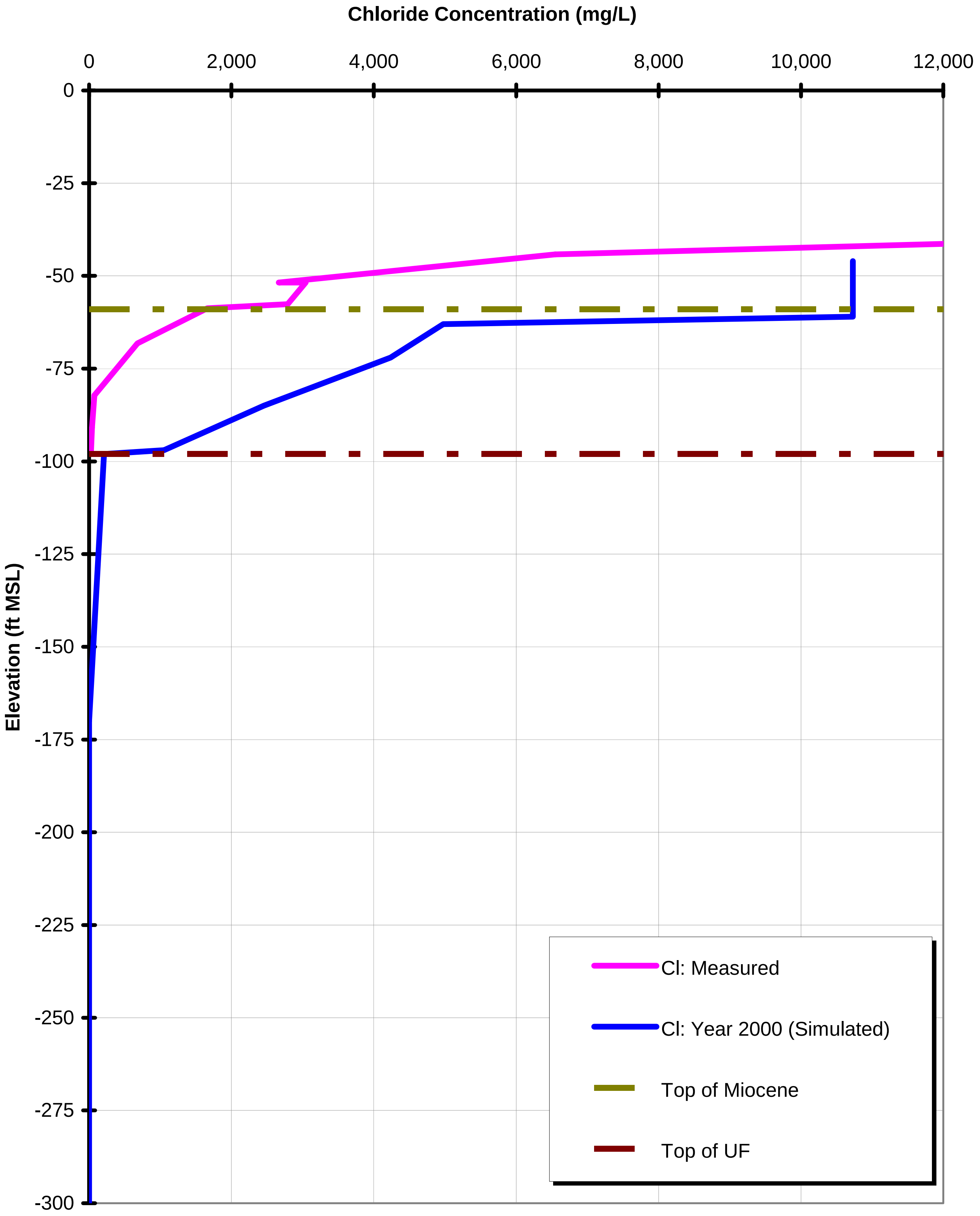

Figure 2-39
Measured and Simulated Chloride Measurements at SHE-17 Borehole

CDM

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Groundwater Model Studies

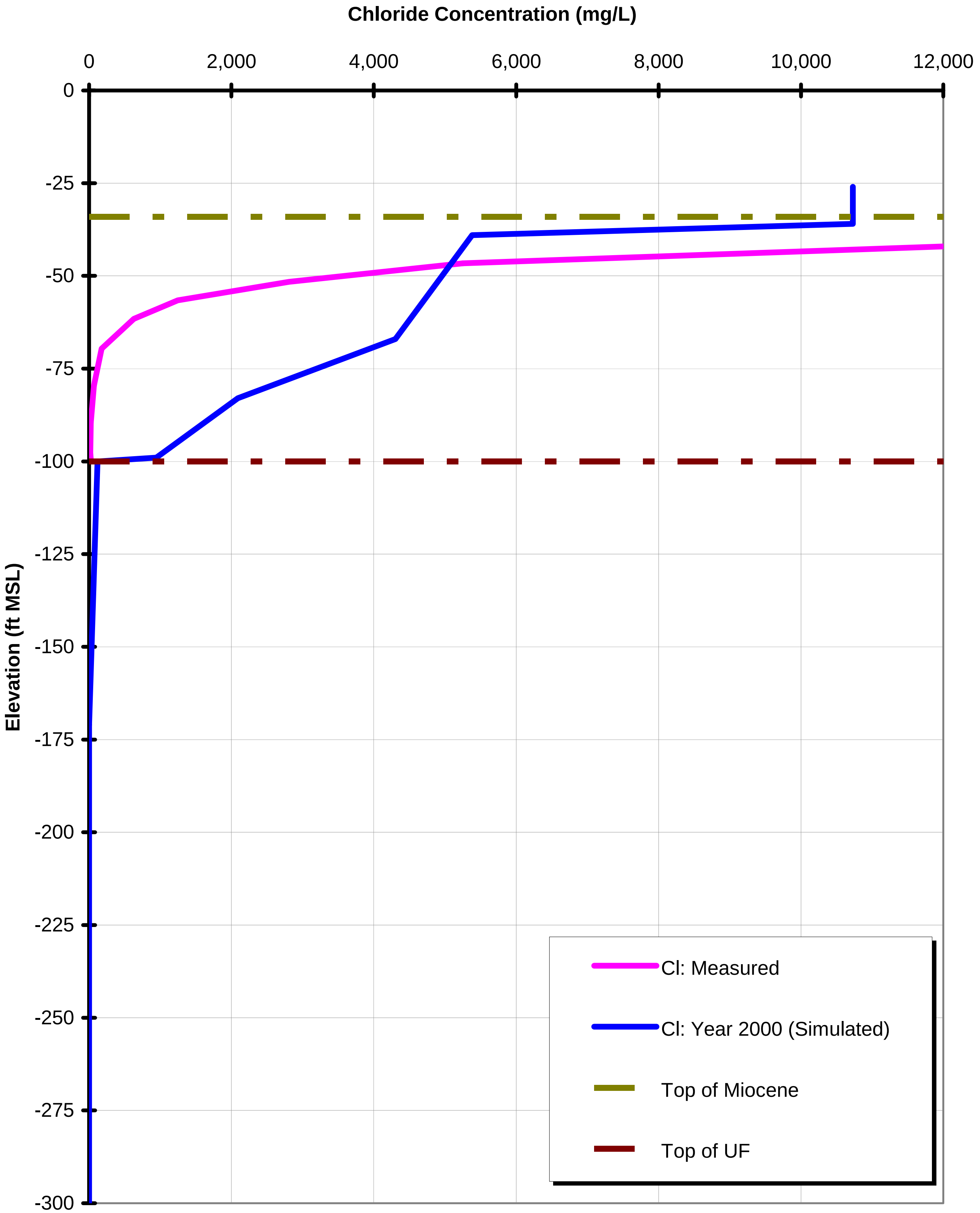

Figure 2-40
Measured and Simulated Chloride Measurements at SHE-16 Borehole

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Groundwater Model Studies

Section 3
Model Application

3.1 Methodology

The focus of the modeling study was to assess the impacts of dredging the Savannah River navigation channel on groundwater flow and saltwater migration into the Upper Floridan aquifer. The potential impacts of the proposed dredging program were evaluated in terms of the relative increase in simulated future chloride concentrations and the change in the rate of chloride penetration as a result of migration of saline water from the area of the navigation channel through Miocene confining unit into the Upper Floridan aquifer. Seawater intrusion from the Atlantic Ocean or nearby salt marshes was not simulated. Using this approach the impacts of dredging are more clearly documented and are not obscured by the impact that Savannah area pumping has in drawing water from all areas with overlying salt water.

The SHE groundwater model discussed in Section 2 was calibrated to a single set of aquifer parameters based on the calibrated USGS groundwater model. These parameters provide the overall 'best fit' in terms of the observed and simulated groundwater heads and gradients. In terms of the simulated chloride concentrations in the Miocene confining unit, the calibrated aquifer parameters generally result in an overall depth of penetration somewhat deeper than observed, and chloride concentrations higher than measured. Simulated migration through the Miocene confining unit is most sensitive to the vertical hydraulic conductivity assigned to the unit. Therefore, for the model application two different values of vertical hydraulic conductivity for the Miocene unit were used: the calibrated value, which represents the mid range of reasonable values, and a lower value. In this way, the true conditions are bounded by the two sets of results.

Table 3-1 illustrates the range of vertical hydraulic conductivity for the Miocene confining units in the area of interest utilized for the predictive simulations. On the low end of the range, a reduction in the vertical hydraulic conductivity by an order of magnitude results in simulated heads in the cone of depression in the Upper Floridan aquifer to be about 30 feet too low when compared to field data. However, the resulting chloride profiles at the SHE borehole locations using the lower value of Miocene vertical hydraulic conductivity were generally more consistent with the measured values. Using the calibrated value, the head distribution was accurate in the cone of depression, but the model somewhat overestimated the rate of penetration when compared to the pore water sample data.

CDM also evaluated increasing the vertical hydraulic conductivity of the Miocene unit approximately 5 fold. The groundwater flow results indicated that using a vertical hydraulic conductivity significantly higher than the calibrated value would result in simulated heads in the Upper Floridan aquifer being approximately 30 feet too high.

Table 3-1 Sensitivity Analysis Parameters

Sensitivity Parameters		Calibration Statistics		Upper Floridan Head at Well 37Q185	
Unit	Vertical Hydraulic Conductivity (feet/day)	Mean Difference (ft)	Standard Deviation (ft)	Simulated (feet, MSL)	Observed Mean Year 2000 (feet, MSL)
Miocene Confining Unit	Low-Value 1.50E-05	-5.5	12.4	-126.7	-96.8
	Mid-Value 1.50E-04	-1.121	10.86	-100.8	

The higher vertical hydraulic conductivity value also resulted in the simulated chlorides concentration significantly different than those measured in the SHE boreholes. Using a vertical hydraulic conductivity for Miocene higher than the calibrated value results in unrealistic Miocene and Upper Floridan chloride concentrations, and therefore for this analysis, the hydraulic conductivity values shown in Table 3-1 represent the appropriate range of expected conditions in the Miocene confining unit.

3.2 Predictive Simulations

To evaluate the potential impact of the dredging on flow and chloride concentrations in the Miocene, and eventually chloride levels in the Upper Floridan, simulations were run forward in time with a 1-year time-step for a period of 200 years. These predictive simulations used the following input parameters:

- Initial groundwater heads: The year 2000 steady-state groundwater levels were used as the starting condition for the simulation.

- Groundwater pumping: Groundwater pumping was kept constant at year 2000 levels. This provides a conservative assessment of future groundwater production in the area, since there is general consensus that pumping will not be allowed to increase in the future

- Chloride concentrations in the Miocene: The simulated 2000 distribution of chlorides in the Miocene Unit, as shown in **Figures 3-1** and **3-2** were used as the initial condition (**Figure 3-3** shows the location of the cross-sections). Note that these figures represent significant penetration of chlorides into the Miocene confining units as of "today", or the start of the projection simulation. These starting chlorides are generally an overestimate of chloride penetration, as discussed above, and therefore represent a conservative starting assumption.

- Savannah River salinity. As discussed in Section 2, the Savannah River nodes were assigned a constant chloride concentration. The chloride concentrations used for the dredging simulations are higher than the no dredging scenario and were obtained from the surface water modeling conducted for the SHE by Tetra Tech (Tetra Tech, November 2004). For the dredging scenario, the higher values were applied at the beginning of the simulation (year 2000).

- Miocene thickness and dredged depths. Data provided by the ACOE was used to determine the change in elevation of the top of the Miocene confining unit as a result of the dredging. For the groundwater modeling it was assumed that dredging would occur as described by the "6-foot" improvement option, plus an additional 3 feet of material which is simulated as removed, but is actually only disturbed as part of the dredging process. Dredging depths range from 55 to 59 feet below MLW, or elevations range from -58 to -62 feet MSL. These depths are considered the maximum depths that could occur.

- Transport parameters. Table 3-2 shows the transport parameters utilized in the simulations.

Table 3-2 Transport Modeling Parameters

Parameter	**Value**
Longitudinal Dispersivity	30 feet
Transverse Dispersivity	3 feet
Upper Floridan Vertical Dispersion Anisotropy	0.1 (dimensionless)
Effective Porosity	0.1 (dimensionless)
Retardation	1 = no retardation (dimensionless)

- Salt water density. The ratio of salt water density to fresh water density was varied linearly from 1.0 for zero chloride concentration to 1.013 for a chloride concentration of 10,000 mg/L.

3.3 Simulations Results

The simulations were evaluated using several sets of results as described below. For each set of results, two different values of vertical hydraulic conductivity of the Miocene (mid and low-values) are used to bracket the range of potential impacts.

- Vertical profiles of simulated chloride concentrations at the SHE borehole locations for the year 2200 for no dredging and dredging scenarios.

- Simulated time history of chloride concentrations beneath the dredged channel adjacent to the SHE borehole locations from the year 1990 to 2200 for no dredging and dredging scenarios.

- Simulated time history of chloride concentrations at selected Upper Floridan production wells from the year 1990 to 2200 for no dredging and dredging scenarios.

In addition to the three types of results described above, figures are presented showing simulated chloride plumes in the Upper Floridan aquifer and chloride concentrations in cross-sections through the Savannah River These concentration contour plots provide a broader, more qualitative view of the modeling results.

Vertical Profiles of Simulated Chloride Concentrations after 200 years

Using the boreholes shown location map shown in **Figure 3-4**, results in **Figures 3-5** through **3-16** illustrate the simulated chloride concentration as a function of depth through the Miocene confining unit *for the year 2200* for the no dredging and dredging scenarios and two different values of vertical hydraulic conductivity of the Miocene confining unit. The charts labeled "A" illustrate the results based on the calibrated (mid-range) hydraulic conductivity value for the Miocene unit which, based on the simulated chloride profiles. Charts labeled "B" illustrate the results with the lower hydraulic conductivity value. Several observations can be made based on these results.

- At all borehole locations, the chloride concentration at the top of the Miocene is higher for the dredging scenario. This increase in salinity is based on the Savannah River salinity modeling resulted provided by Tetra Tech. This is one of the primary reasons for slightly higher chloride concentrations in the Miocene and Upper Floridan after dredging.
- The figures illustrate the shift in concentration that will take place in the next 200 years as water with higher chloride concentrations migrates downward due to the vertical groundwater head gradients.
- For the dredging conditions, the increased chloride concentrations at the top of the Miocene results in higher concentrations at the bottom of the Miocene, and generally higher concentrations in the Upper Floridan.
- In terms of the impact study, the change in concentration in the Upper Floridan aquifer is of primary importance. The results show that the simulated chloride concentrations drop off significantly in the Upper Floridan aquifer due to the higher flow within the aquifer and the consequent dilution effect.
- The difference between the dredging and no dredging chloride concentrations in the Upper Floridan aquifer at the SHE borehole locations is generally small in all the profiles, suggesting that the dredging will not significantly alter the expected chloride concentration in the Upper Floridan, which is primarily a function of the downward groundwater gradient caused by pumping.

The difference between no dredging and dredging simulated chloride concentrations in the upper part of the Upper Floridan is more easily visualized in the time history plots shown in **Figures 3-17** through **3-28** discussed below.

Time-History of Simulated Chloride Concentrations

Figures 3-17 through **3-28** illustrate the simulated chloride concentrations as a function of time beneath the dredged channel adjacent to each of the SHE borehole locations for both the no dredging, and the dredging scenarios, using the range of hydraulic conductivity values for the Miocene confining unit. The concentrations shown are computed for the top 50 to 60 feet of the Upper Floridan aquifer. Similar to the previous figures, charts labeled "A" illustrate the results based on the mid-range hydraulic conductivity value for the Miocene unit and charts labeled "B" illustrate the results with the lower hydraulic conductivity value. It is expected that the actual behavior of the system will fall between the two sets of results.

Several conclusions can be drawn from these figures:

- All the figures represent expected concentrations directly beneath or adjacent to the river. These are the maximum concentrations to be expected, and they drop off as you move away from the river to the north or south.

- The concentrations shown are those only resulting from salt water coming through the Miocene confining units directly below the river channel. Concentration impacts from all other areas overlain by salt water are not simulated.

- In the upstream locations (represented by SHE-15 through SHE-10 - from river station 89+00 to 47+00) either breakthrough[1] into the Upper Floridan does not occur ("B" charts) or concentrations remain relatively low, typically not exceeding 100 to 200 mg/L as seen in the "A" charts. The Miocene Confining Unit is thicker at these upstream borehole locations than at the locations farther downstream. Under all conditions at these locations there is no appreciable increase in Upper Floridan chloride concentrations as a result of the dredging.

- For the mid hydraulic conductivity simulations ("A" charts) in locations further downstream, starting with SHE-18 (river station 31+00) simulated concentrations at SHE-13, SHE-2, and SHE-14 are significantly higher than locations further upstream. Concentrations at the top of Upper Floridan aquifer directly below the river after 200 years range from several hundred to greater than 1000 mg/L. For the low hydraulic conductivity simulation, concentrations are either significantly lower such as at SHE-18 and SHE-11, or breakthrough in the Upper Floridan is simulated to occur much later than the year 2200 – by as much as 100 years.

- Even after 200 years, the system is still in transition in most of the study area.

- In general, the dredging appears to have limited impact on the timing of breakthrough into the Upper Floridan aquifer. In the upper reaches since breakthrough is not simulated to occur during the 200 year simulation period, the dredging does not appear to speed up the occurrence of breakthrough. In the lower reaches, where the Miocene is thinner, in some cases the dredging does appear to speed up the occurrence of breakthrough by as much as 10 to 15 years

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[1] For this study, "breakthrough" is said to occur when the simulated chloride concentrations in the top 50 to 60 feet of the Upper Florida Aquifer initially exceeds 250 mg/L.

(Figure 3-22), however earlier breakthrough is not generally discernable in the majority of the locations (Figures 3-24, 3-25 and 3-26).

- As the system approaches steady state, the increased chloride concentration in the downward flux from Savannah River eventually results in slightly increased concentrations in the Upper Floridan aquifer (see Figures 3-24, 3-25 and 3-26).

Simulated chloride concentration time-histories are also generated for nearby Upper Floridan production wells shown on **Figure 3-29.** The simulated chloride concentrations are shown **Figures 3-30** through **3-48** for both the no dredging and the dredging scenarios utilized the mid and lower hydraulic conductivity values. These results illustrate that with the mid-value of hydraulic conductivity for the Miocene, chloride concentrations in Savannah area production wells could increase by 10 to 50 mg/L by the year 2200 as a result of downward migration from the river. Using the lower value of hydraulic conductivity, concentrations are effectively zero at most of the wells. For the mid-value of hydraulic conductivity for the Miocene, the difference between the dredging and no dredging in the simulated production well chloride concentrations ranges from negligible to less than 10 mg/L. **Figure 3-48** illustrates the simulated chloride concentrations in the Upper Floridan at the Tybee Island well. For the mid-value of hydraulic conductivity in the Miocene, breakthrough is simulated to occur in the next 20 to 30 years, with concentrations increasing steadily through the 200 year simulation period. However, the difference between no dredging and dredged appears to be imperceptible at this location. For the low-value hydraulic conductivity in the Miocene, breakthrough appears to be considerably further into the future, with practically no increase in simulated chloride concentrations over the 200 year period.

Simulated Chloride Concentrations Distributions

Figures 3-49 and **3-52** show plan view simulated chloride concentrations in the Upper Floridan aquifer for the years 2000, 2050, and 2200, with and without dredging. Note that, because of the flow direction caused by the heavy pumping in the area of downtown Savannah, chloride plumes tend to move parallel to the river. Thus, the concentration results discussed above are relevant only for concentrations directly below the river. Impacts north or south of the river disappear over a relatively short distance.

These figures illustrate how concentrations in the Upper Floridan vary spatially with time. Along the downstream reaches of the river, concentrations are significantly higher than those in the upstream areas. Nonetheless, for the mid value of hydraulic conductivity simulations in which breakthrough is simulated to occur, the difference between the dredging and no dredging scenarios is not significant.

3.4 Study Conclusions

- A fully 3-dimensional groundwater flow model with saltwater intrusion simulation capabilities was developed and applied to evaluate the relative impact of the proposed SHE dredging program.

- Depressed groundwater heads in the Upper Floridan aquifer due to Savannah area pumping induces downward flow from the river through the Miocene to Upper Floridan aquifer. These vertical head gradients are the dominant force in causing downward movement of salt water through the Miocene confining unit.

- An analysis of the downward volume of flow of saline water from the area of the Savannah River impacted by the dredging shows that the total volume of downward moving salt water is small. The model simulates downward flow from the area of river affected by dredging to be between 50 to 250 gallons per minute under existing conditions, depending on the hydraulic conductivity of the Miocene. With dredging, this value increases by between 2 to 7 gallons per minute – approximately 3 to 4 percent. When compared to total groundwater production in Chatham County, which is on the order of 70 to 80 million gallons per day (49,000 to 56,000 gpm), this is relatively insignificant.

- The 200 year projection simulations show salt water from the river potentially penetrating the Miocene and reaching the Upper Floridan aquifer. The simulated concentrations in the top of the Upper Floridan aquifer are very sensitive to the hydraulic conductivity of the Miocene, and ultimately the thickness of the Upper Floridan over which the concentrations are calculated. In this analysis, the concentrations were computed for the top 50 to 60 feet of the Upper Floridan aquifer only.

- In the upper reaches of the river near the center of the cone of depression, where the Miocene is thicker, localized concentrations in the Upper Floridan aquifer beneath the river are simulated to be approximately 0 mg/L for low-value hydraulic conductivity simulations and up to 100 mg/L for the mid-value hydraulic conductivity simulations after 200 years.

- Downstream, where the Miocene is relatively thin, chloride concentrations directly beneath the river approach 500 mg/L after 200 years in some areas for the low-value hydraulic conductivity simulations. For the mid-value hydraulic conductivity simulations, equilibrium is reached after approximately 100 years, with some concentrations as high as 1400 mg/L in some areas.

- The simulated maximum chloride concentrations in the top of the Upper Floridan aquifer for the dredging conditions appear to increase mainly due to increased river source concentration assigned at the bottom of the river. In the upstream reaches of the river, the differences due to the dredging are minor. Downstream, where higher river concentrations occur, the increase in concentrations in the Upper Floridan aquifer directly below the river due to dredging ranges from 10 to 200 mg/L. These differences are typically observed 50 or more years into the future.

- The increased salinity in the Savannah River and the reduced thickness of the Miocene confining unit due to dredging do not appear to significantly affect the timing of breakthrough of chlorides into the Upper Floridan aquifer. Model results and pore water sample results suggest that limited breakthrough of salt water into the Upper Floridan aquifer may occur very soon in the downstream area, but may not occur for decades further upstream.

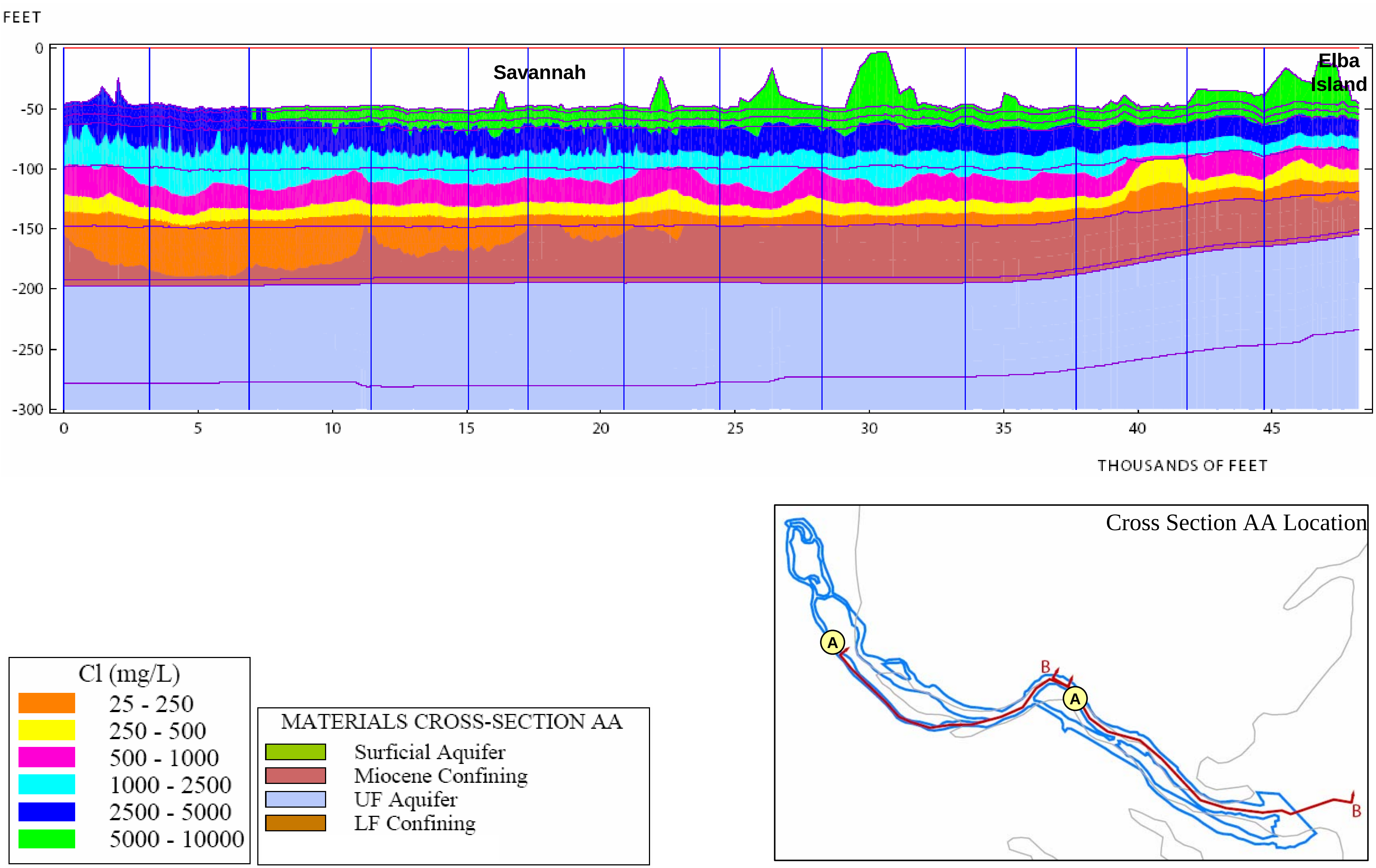


Figure 3-1
Cross Section Showing Concentrations Along Upstream Section of the Channel for 'Current' Conditions

Savannah Harbor Expansion
Groundwater Model Studies

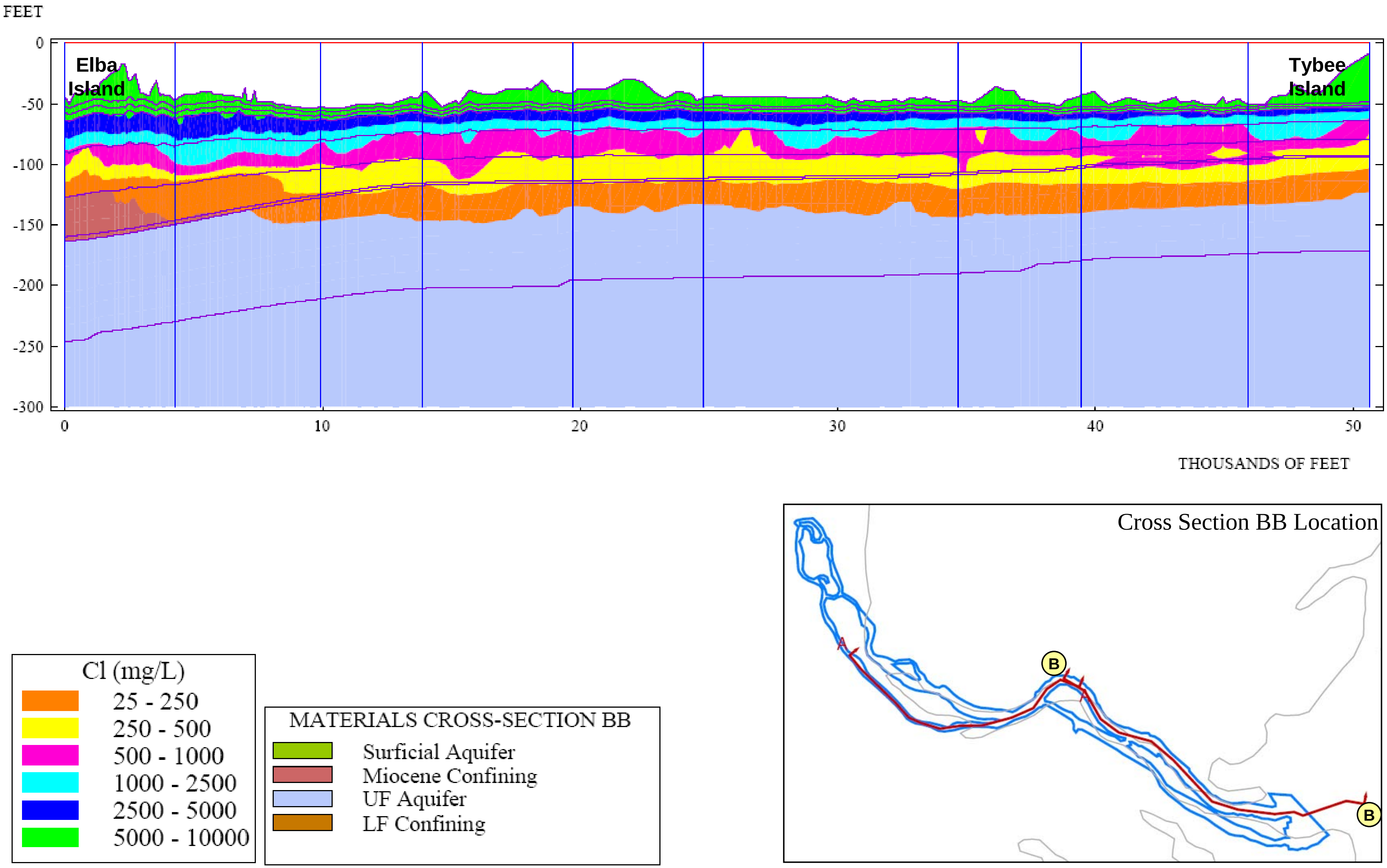


Figure 3-2
Cross Section Showing Concentrations Along Downstream Section of the Channel for 'Current' Conditions

Savannah Harbor Expansion
Groundwater Model Studies

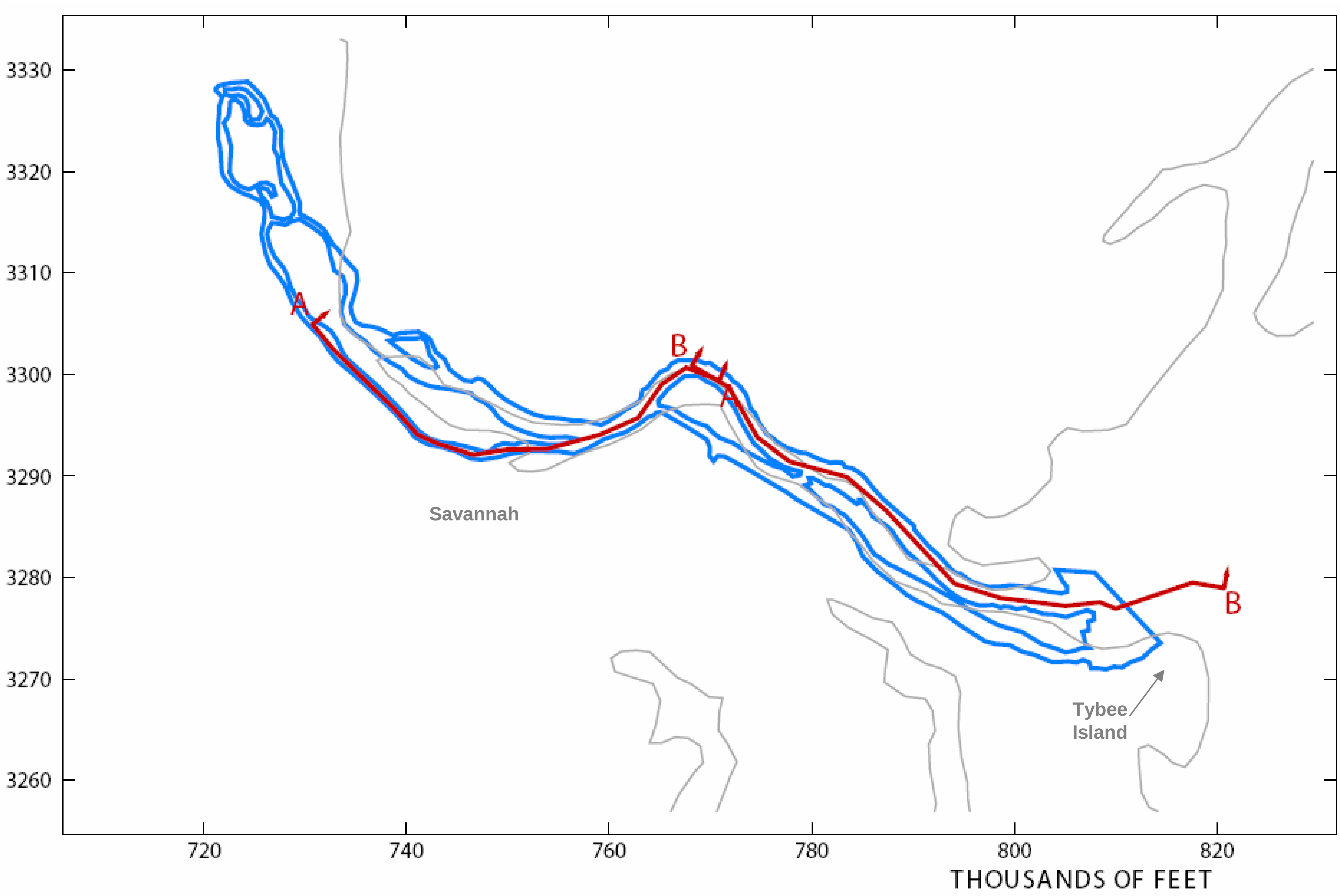
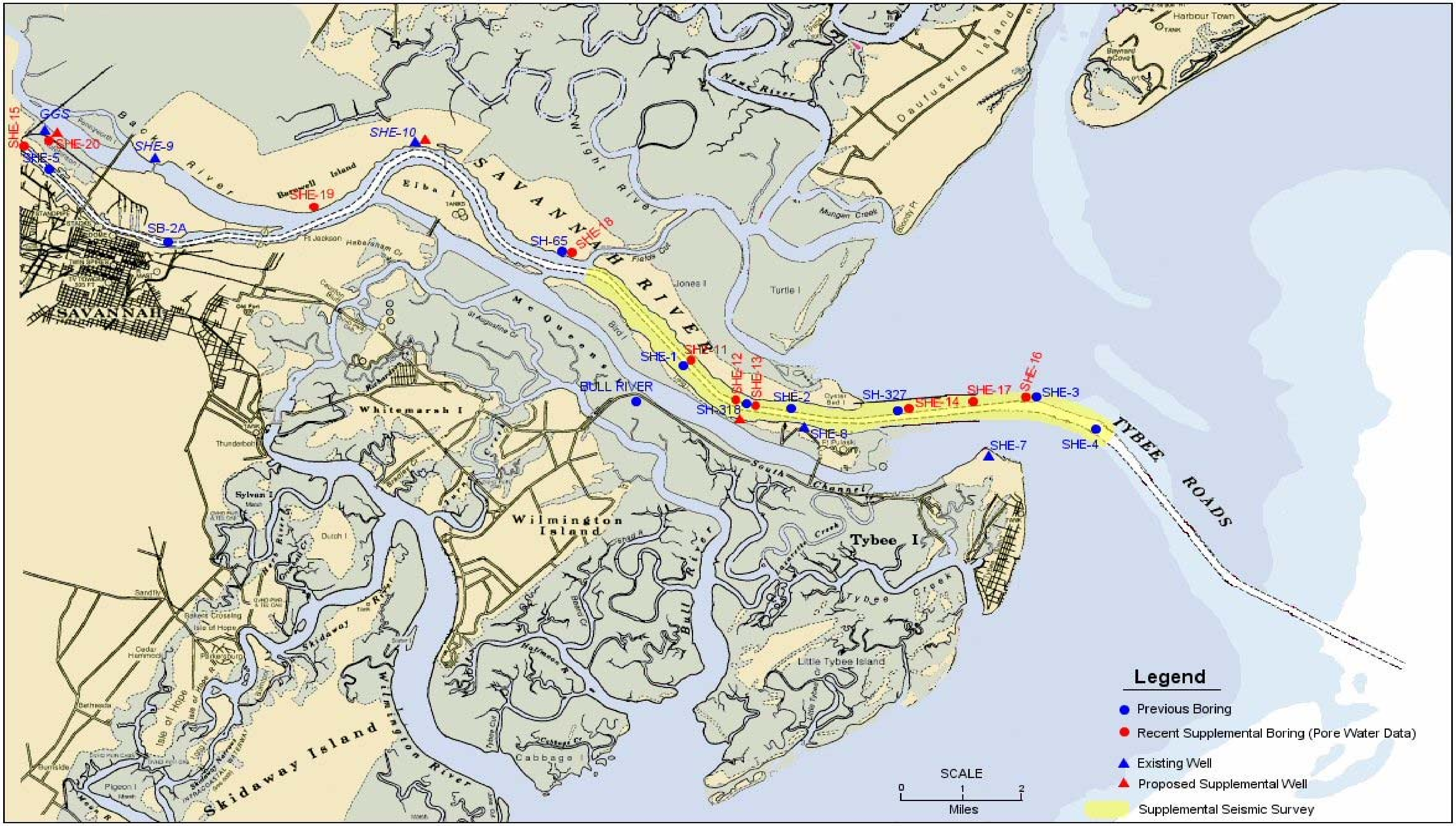


Figure 3-3
Cross Section Location Map

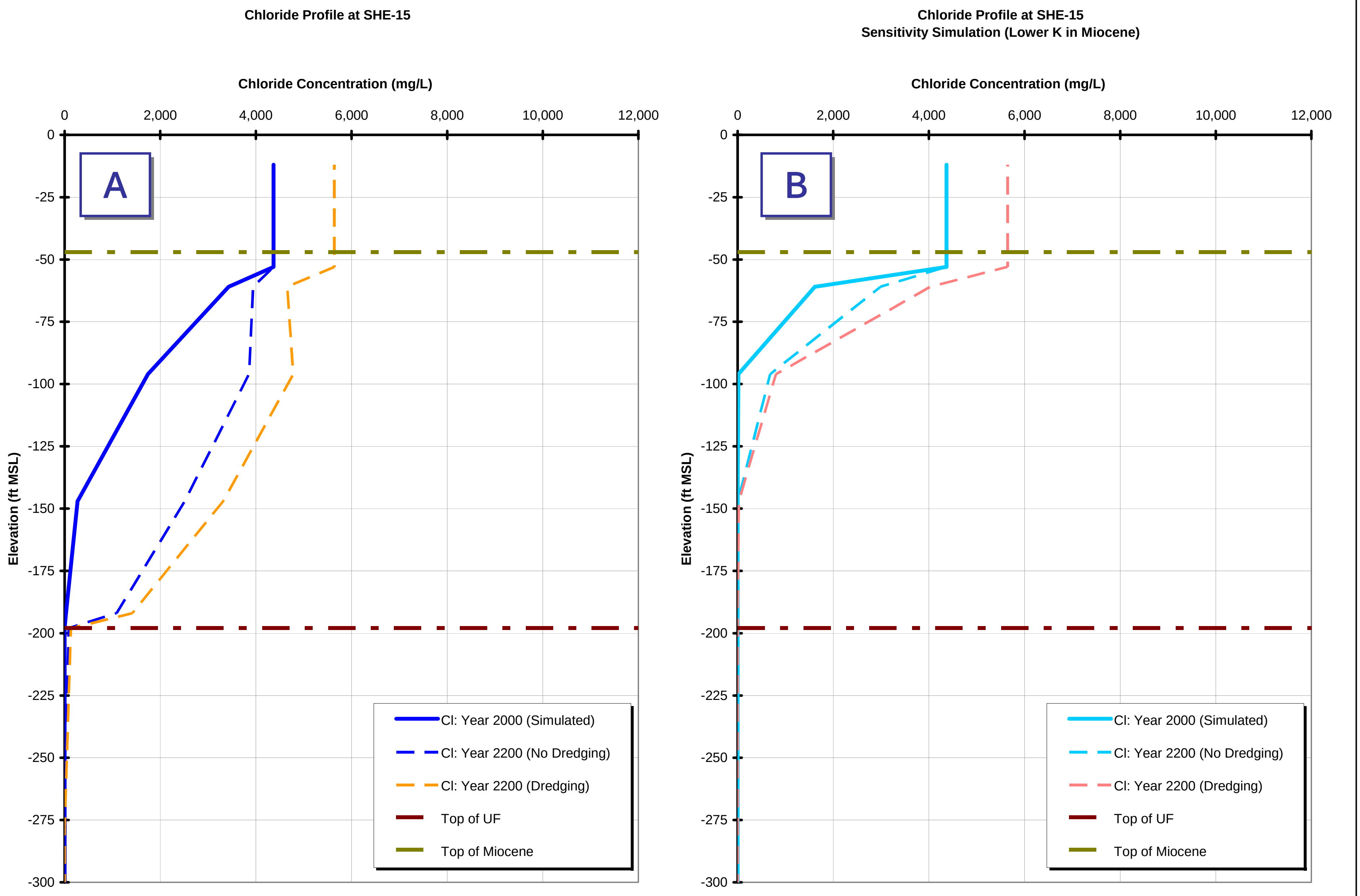
CDM

Savannah Harbor Expansion
Groundwater Model Studies



Source:
U.S. Army Corps of Engineers, Savannah District
Geology/Hydrogeology Section

Figure 3-4
Borehole Location Map



Chloride Profile at SHE-15

Chloride Profile at SHE-15
Sensitivity Simulation (Lower K in Miocene)

Figure 3-5
Comparison of Simulated Concentration Profiles at SHE-15 for No Dredging and Dredging

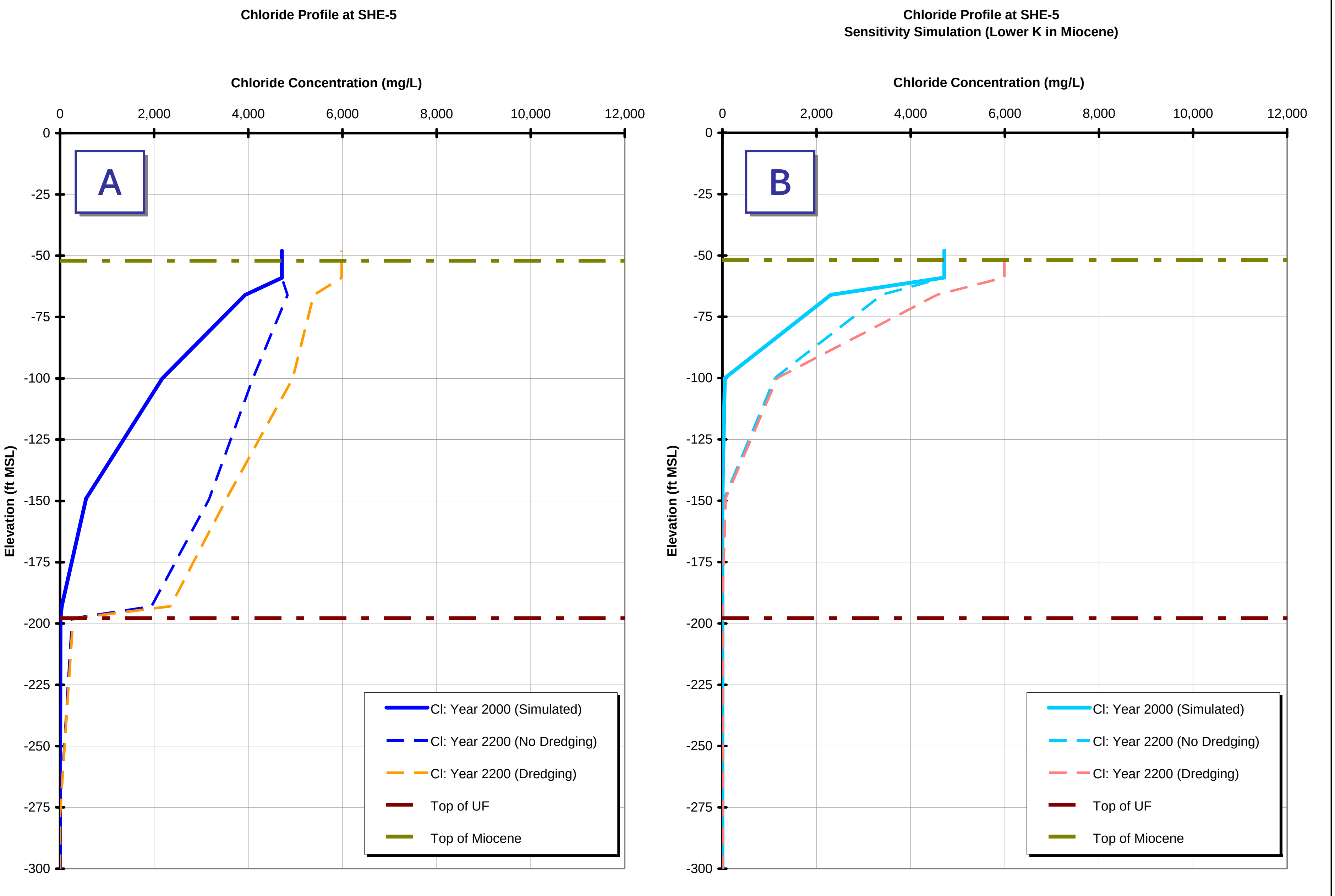


Figure 3-6
Comparison of Simulated Concentration Profiles at SHE-5 for No Dredging and Dredging

CDM

Savannah Harbor Expansion
Groundwater Model Studies

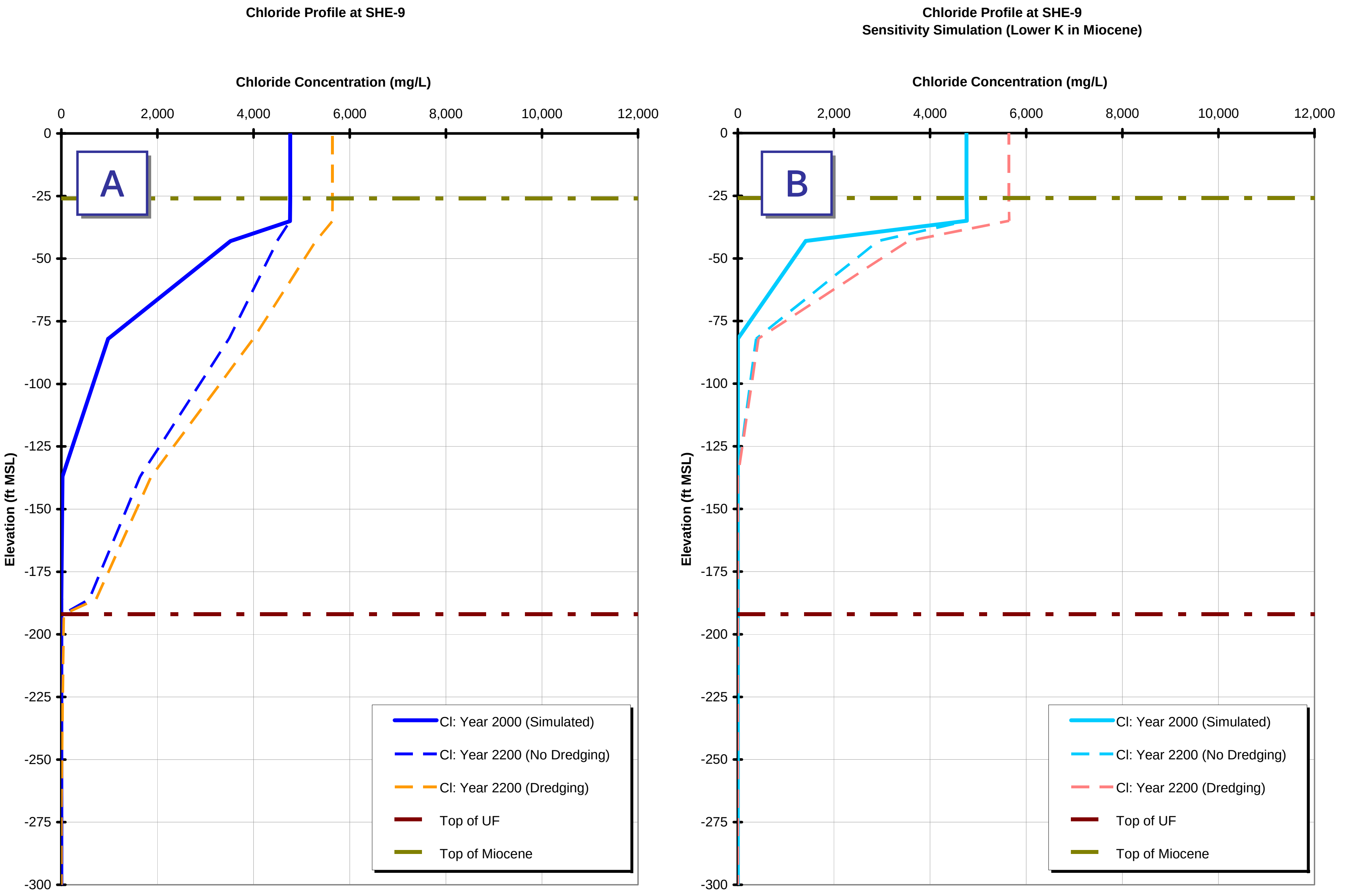


Figure 3-7
Comparison of Simulated Concentration Profiles at SHE-9 for No Dredging and Dredging

CDM

Savannah Harbor Expansion
Groundwater Model Studies

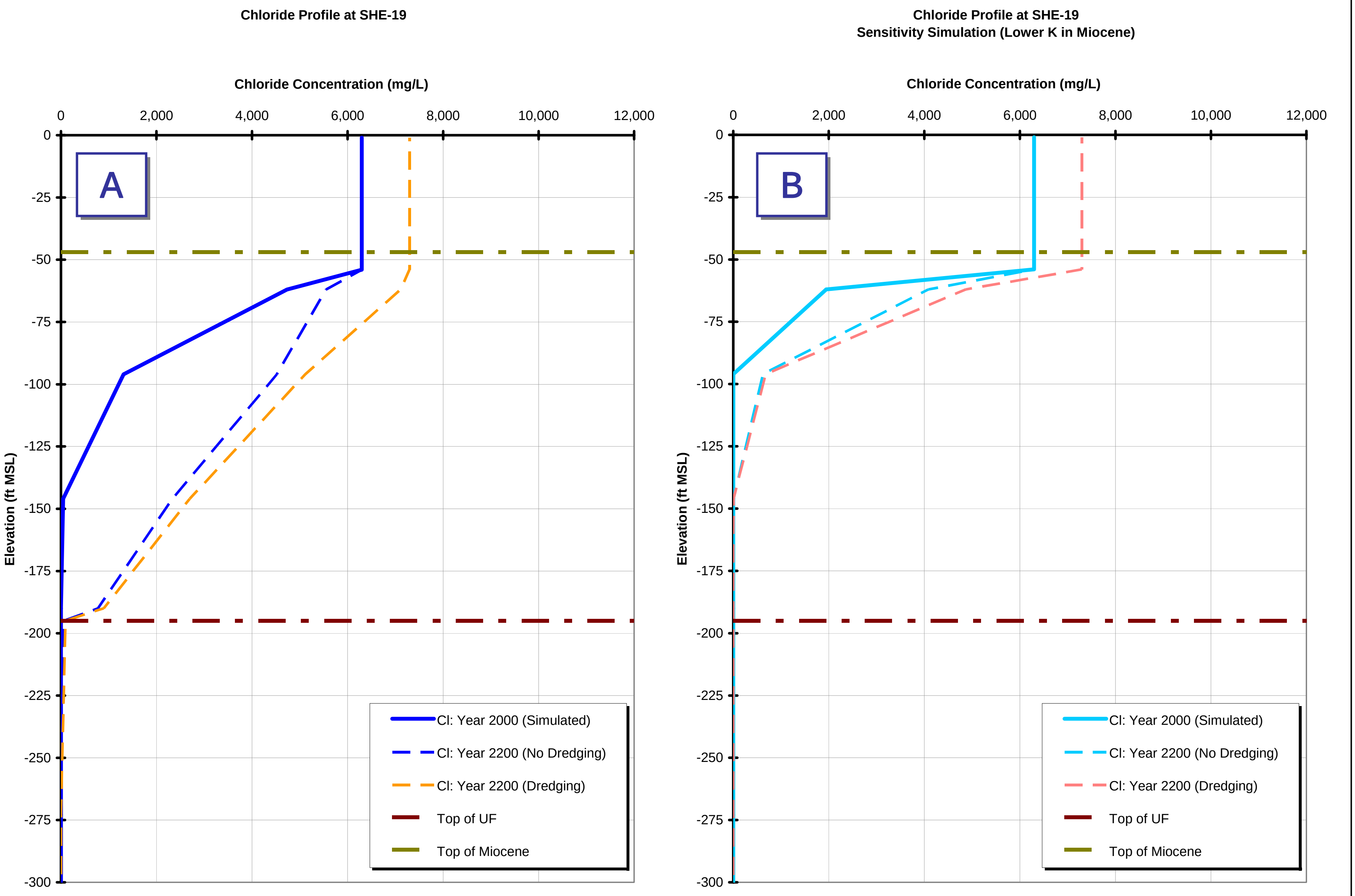


Figure 3-8
Comparison of Simulated Concentration Profiles at SHE-19 for No Dredging and Dredging

CDM

Savannah Harbor Expansion
Groundwater Model Studies

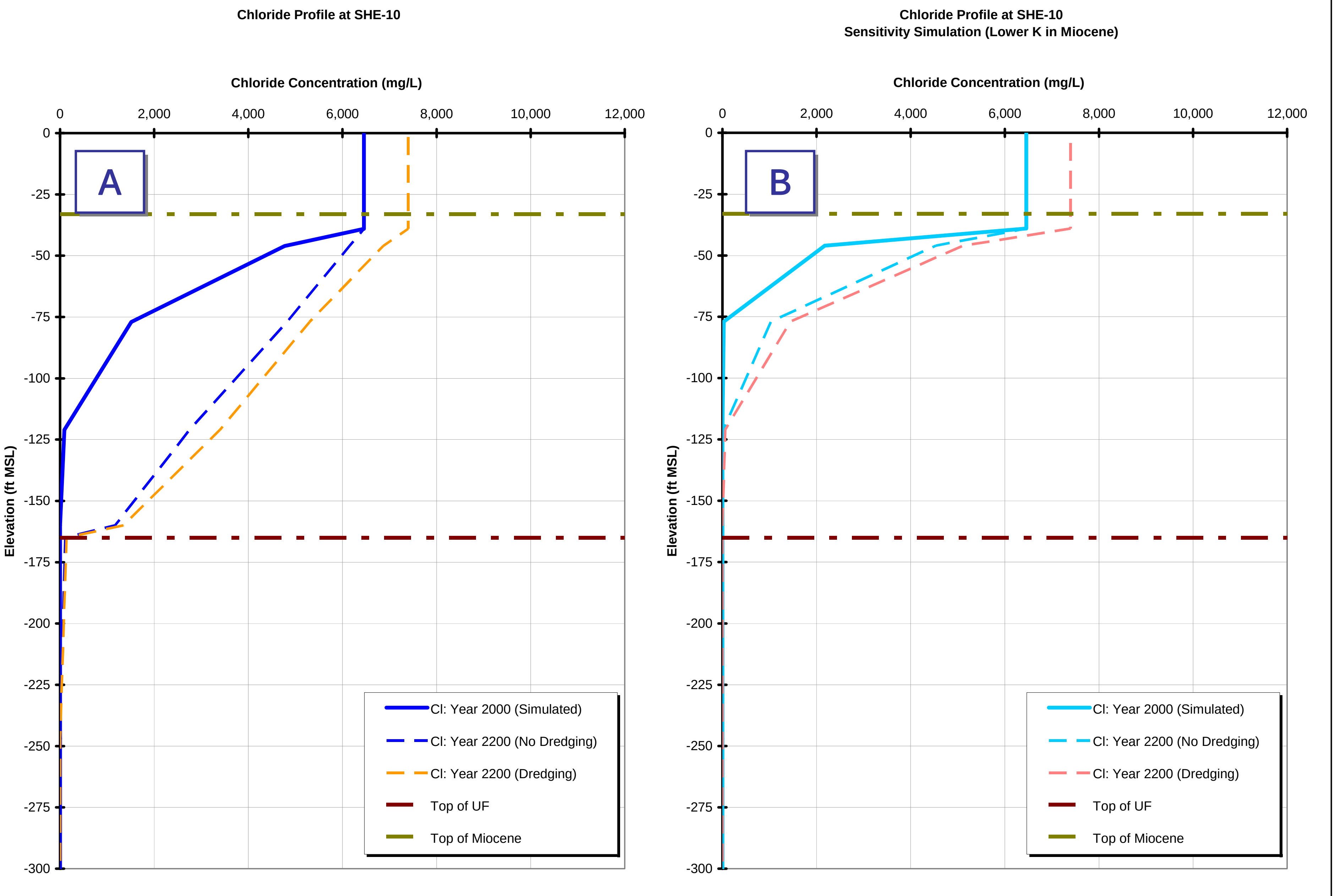


Figure 3-9
Comparison of Simulated Concentration Profiles at SHE-10 for No Dredging and Dredging

CDM

Savannah Harbor Expansion
Groundwater Model Studies

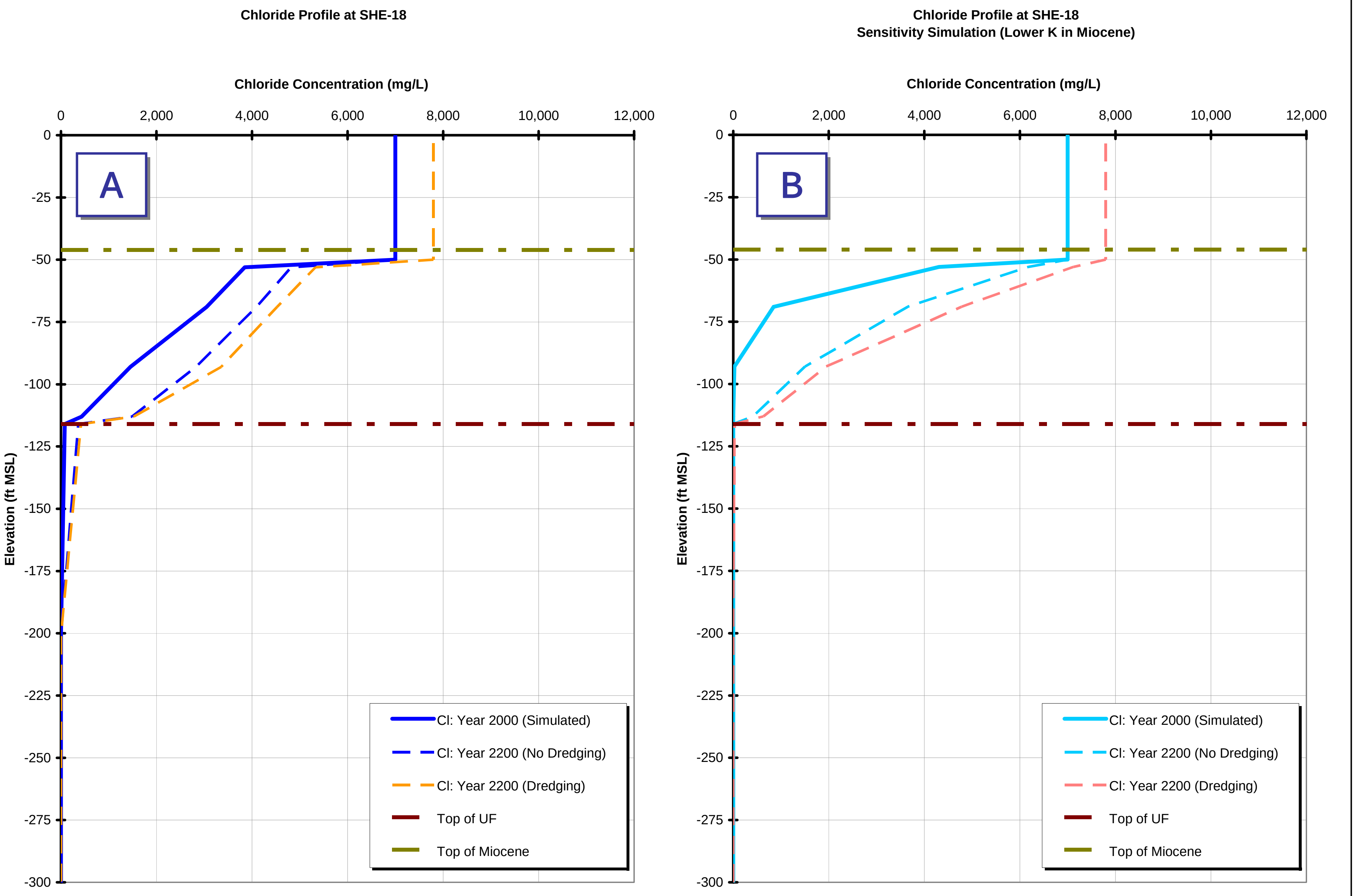


Figure 3-10
Comparison of Simulated Concentration Profiles at SHE-18 for No Dredging and Dredging

CDM

Savannah Harbor Expansion
Groundwater Model Studies

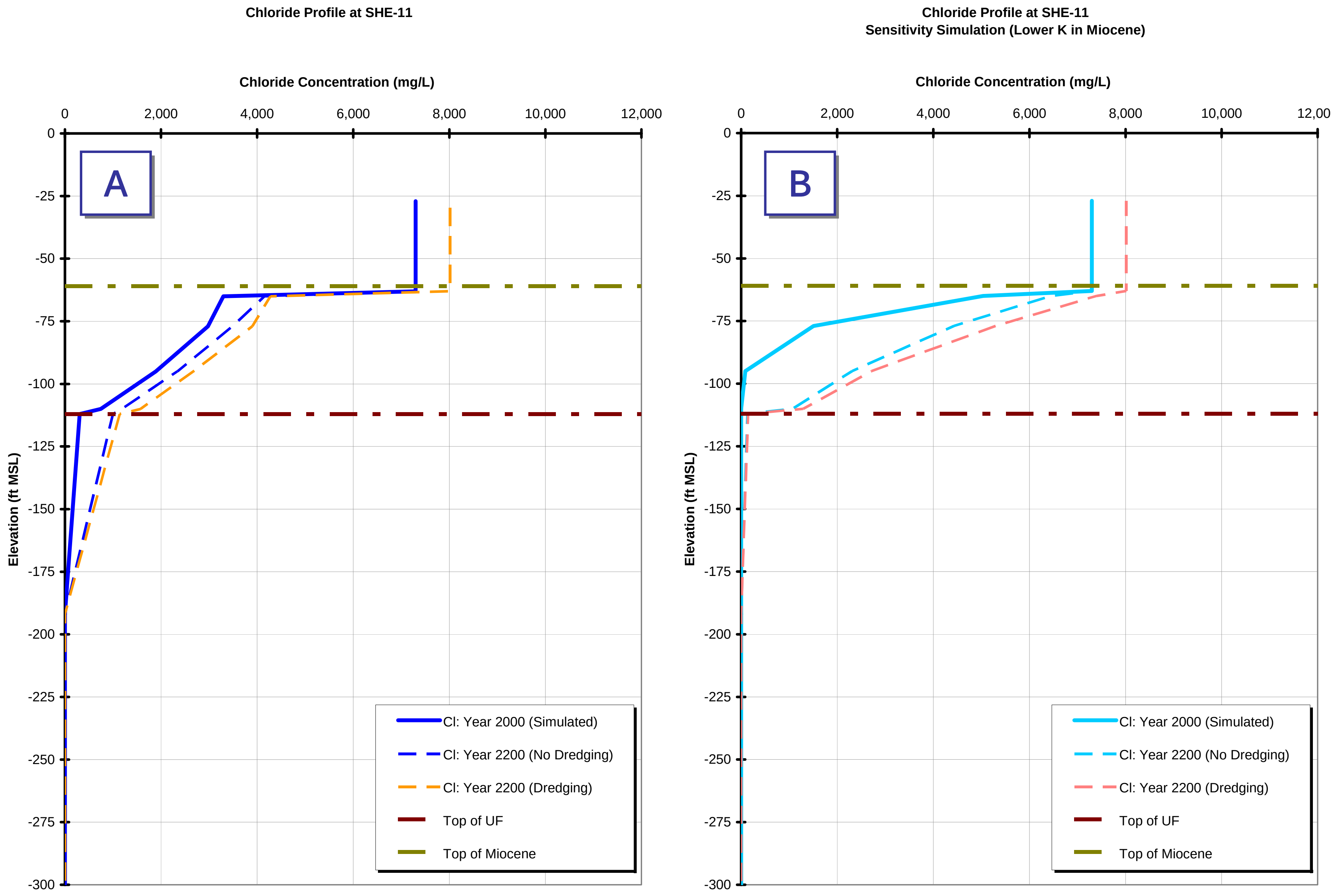


Figure 3-11
Comparison of Simulated Concentration Profiles at SHE-11 for No Dredging and Dredging

Savannah Harbor Expansion
Groundwater Model Studies

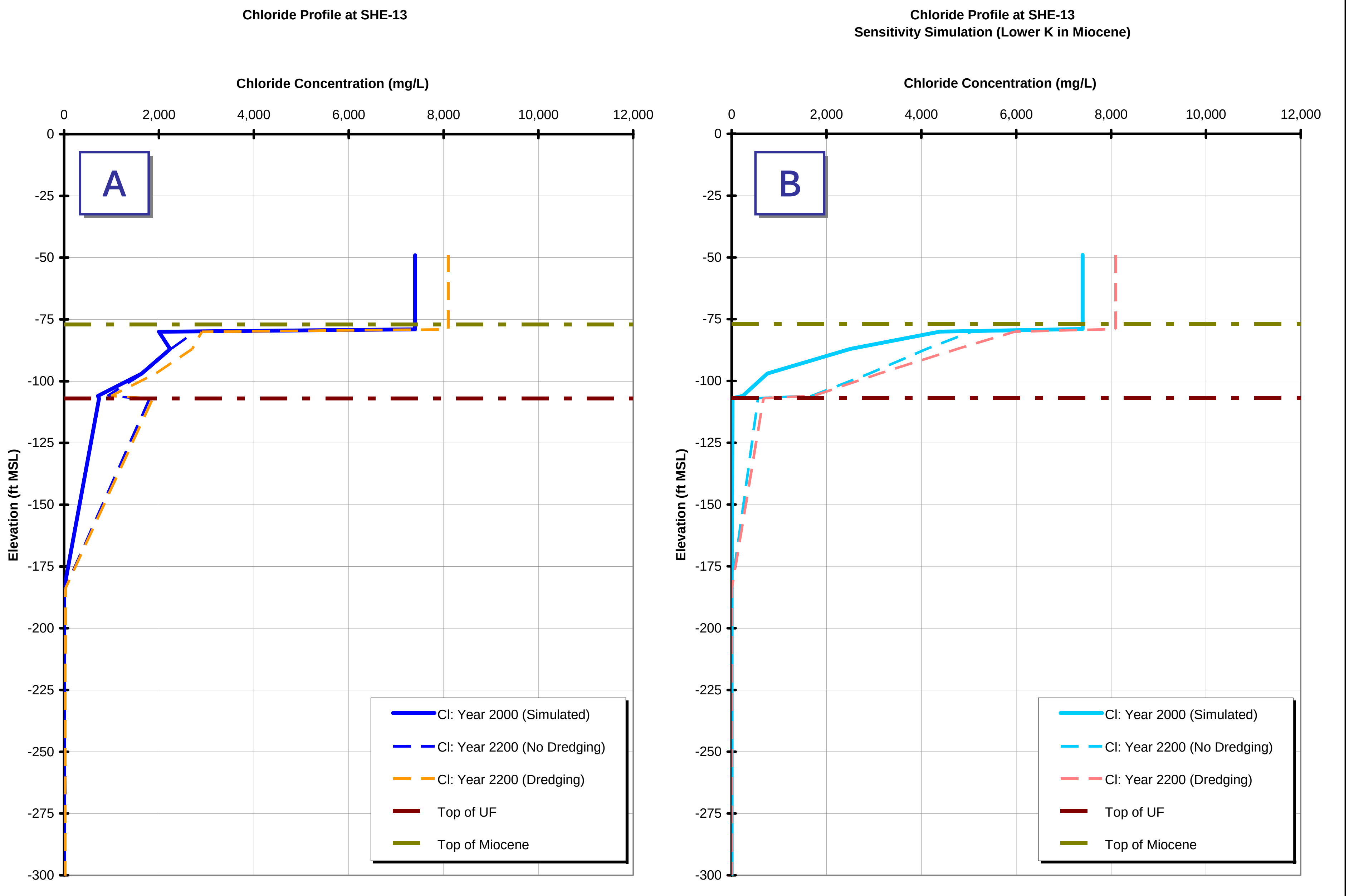


Figure 3-12

Comparison of Simulated Concentration Profiles at SHE-13 for No Dredging and Dredging

CDM

Savannah Harbor Expansion
Groundwater Model Studies

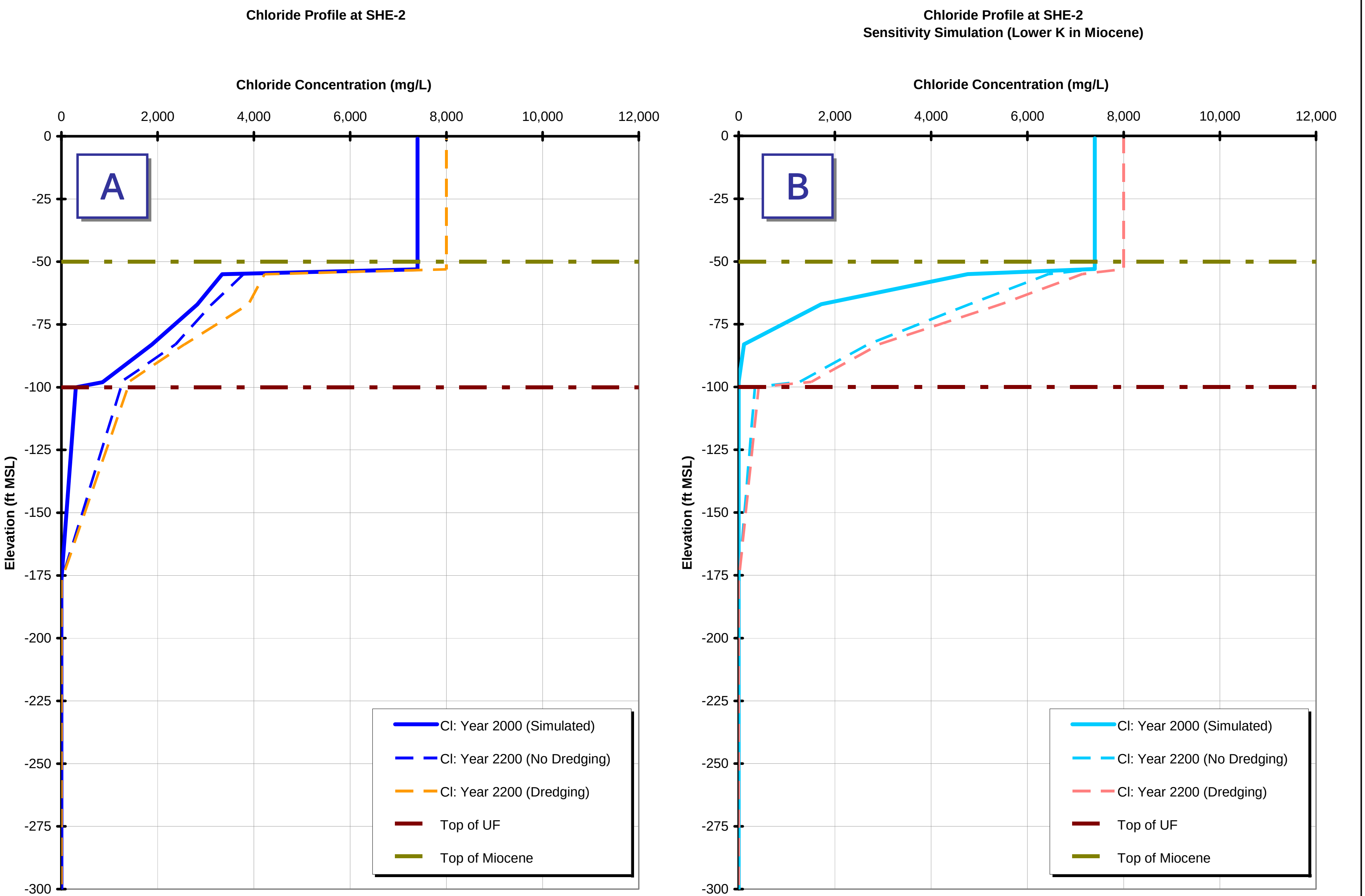


Figure 3-13
Comparison of Simulated Concentration Profiles at SHE-2 for No Dredging and Dredging

CDM

Savannah Harbor Expansion
Groundwater Model Studies

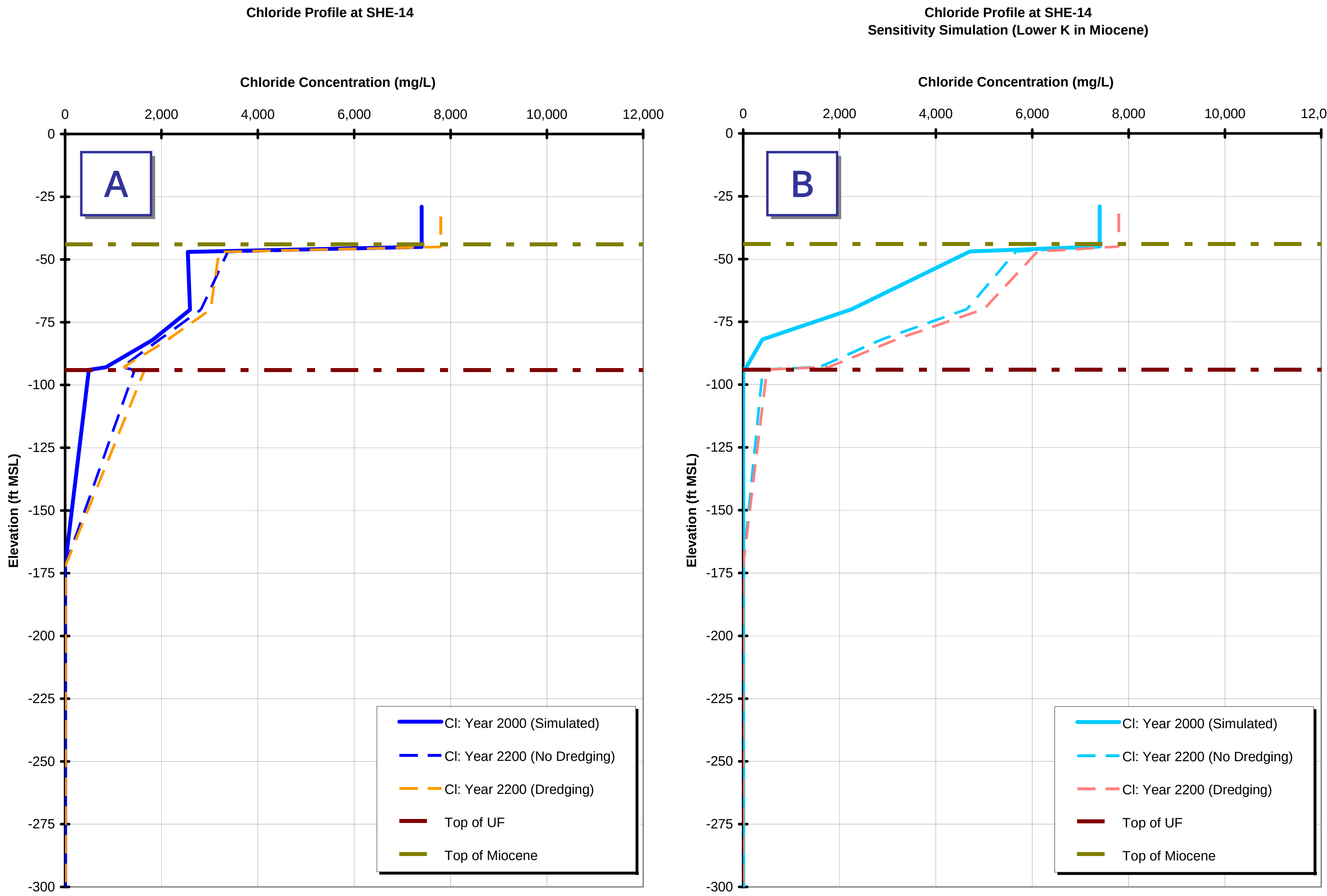


Figure 3-14
Comparison of Simulated Concentration Profiles at SHE-14 for No Dredging and Dredging

Savannah Harbor Expansion
Groundwater Model Studies

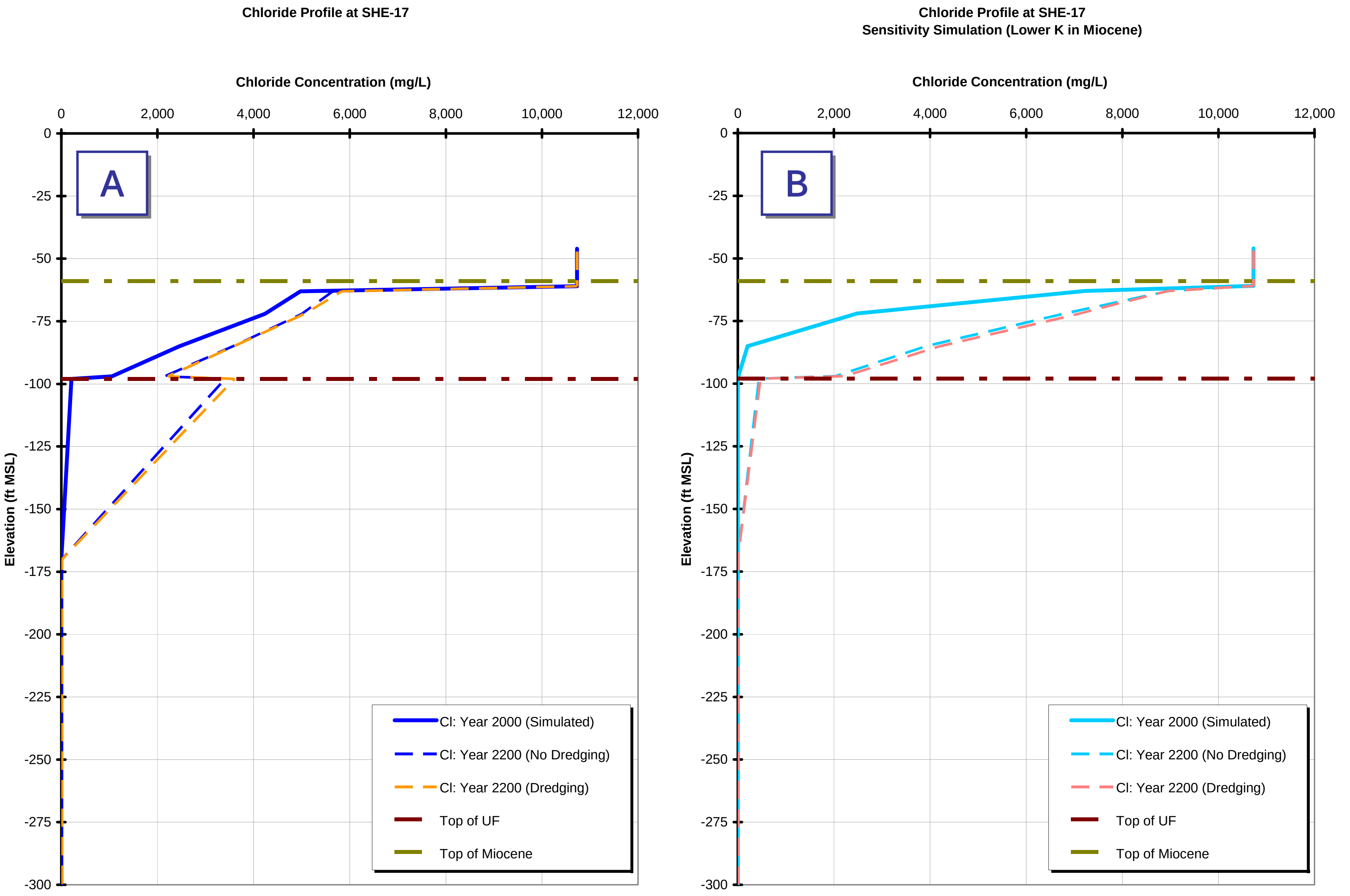


Figure 3-15
Comparison of Simulated Concentration Profiles at SHE-17 for No Dredging and Dredging

CDM

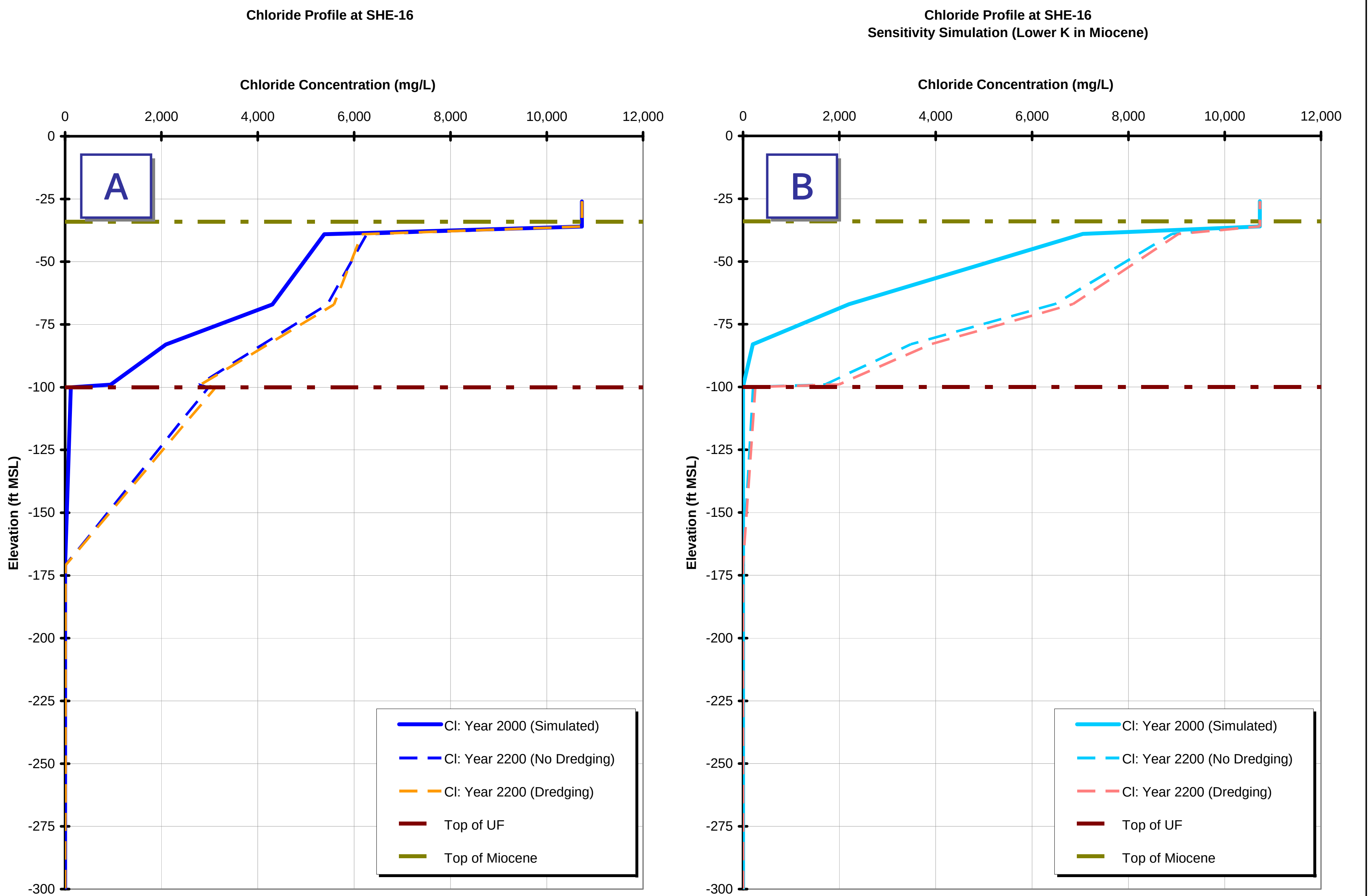
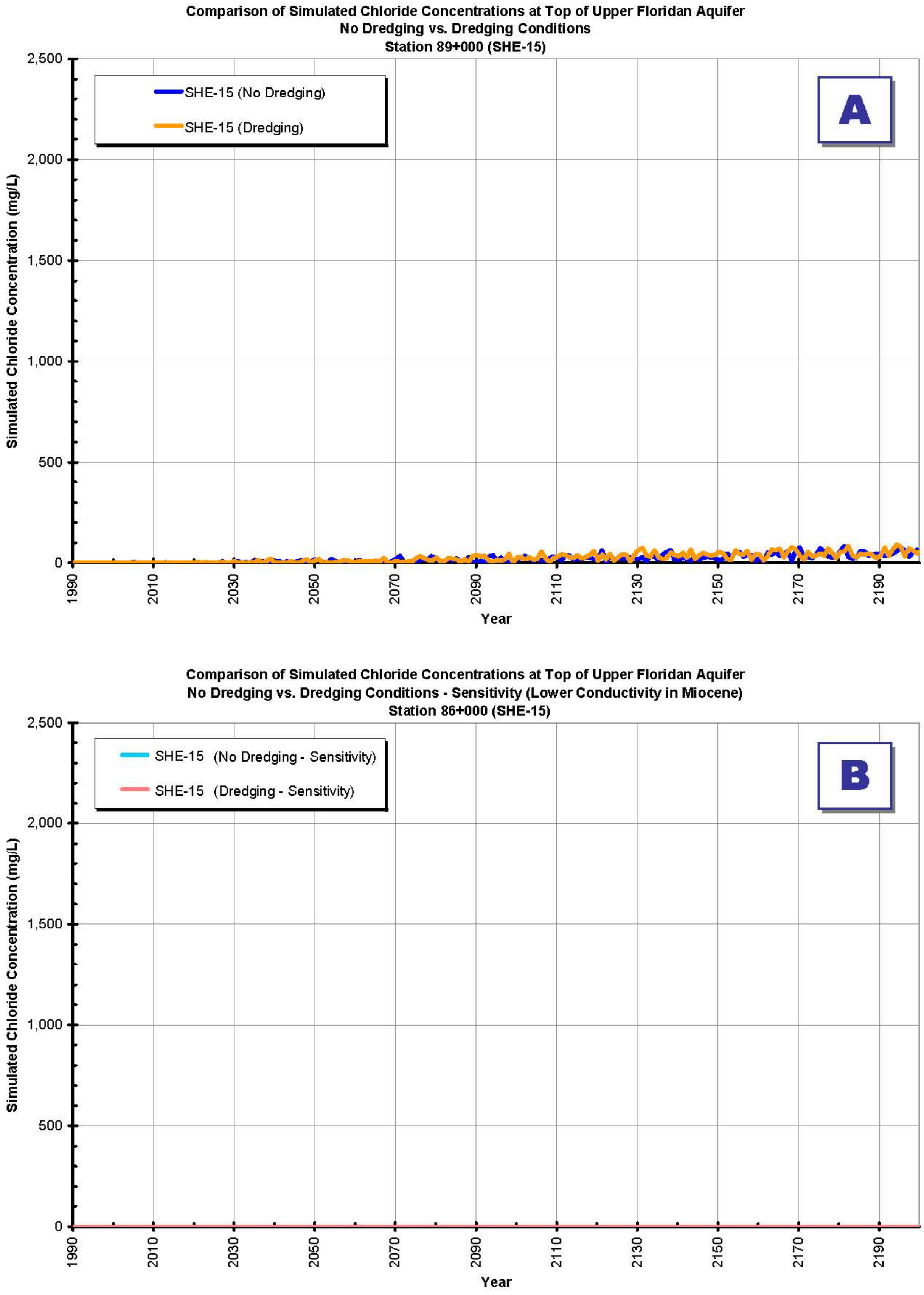


Figure 3-16
Comparison of Simulated Concentration Profiles at SHE-16 for No Dredging and Dredging

CDM

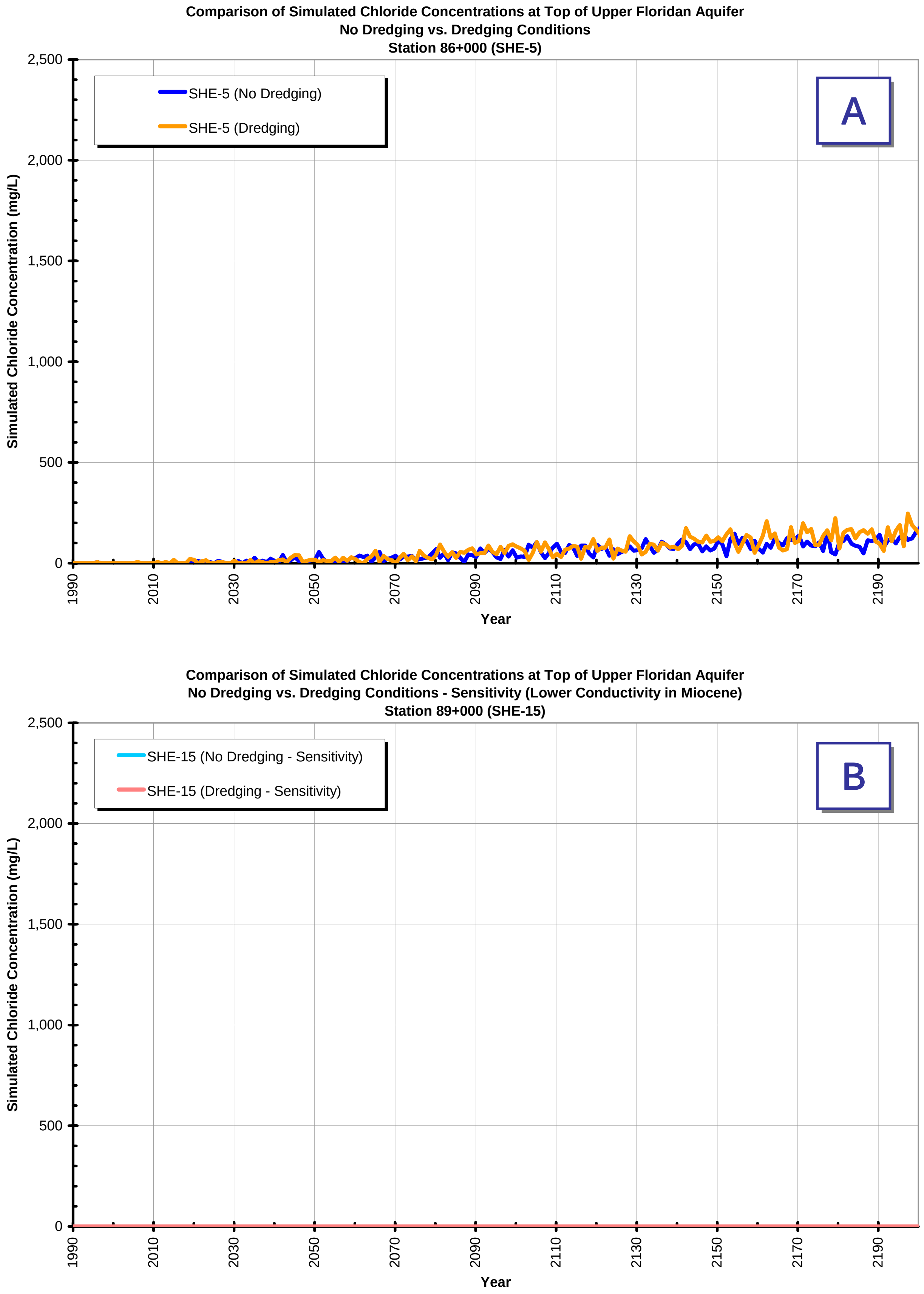
Savannah Harbor Expansion
Groundwater Model Studies



Comparison of Simulated Chloride Concentrations at Top of Upper Floridan Aquifer
No Dredging vs. Dredging Conditions
Station 89+000 (SHE-15)

Comparison of Simulated Chloride Concentrations at Top of Upper Floridan Aquifer
No Dredging vs. Dredging Conditions - Sensitivity (Lower Conductivity in Miocene)
Station 86+000 (SHE-15)

Figure 3-17
Comparison of Simulated Concentration Time Histories at SHE-15
for No Dredging and Dredging



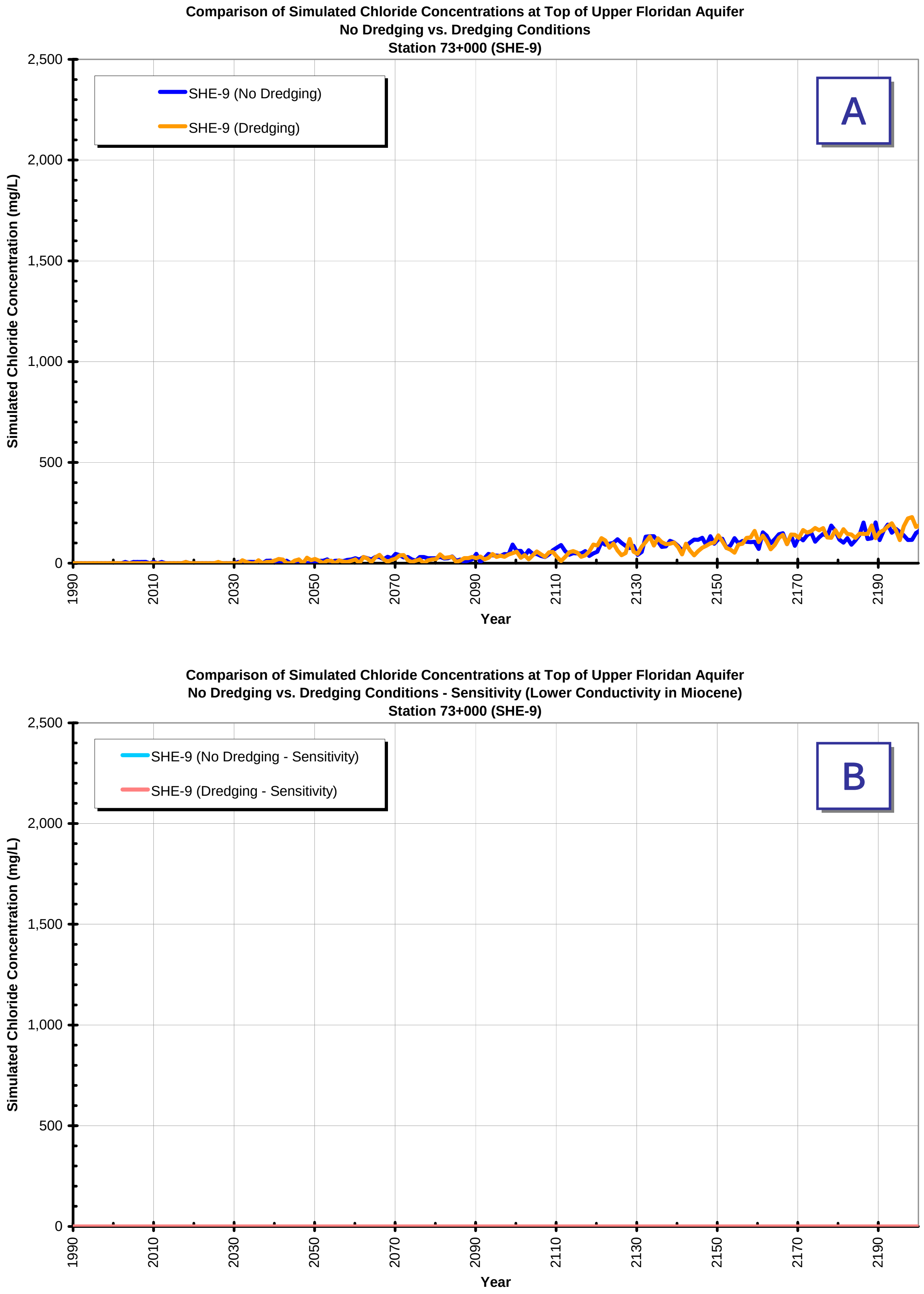
Comparison of Simulated Chloride Concentrations at Top of Upper Floridan Aquifer
No Dredging vs. Dredging Conditions
Station 86+000 (SHE-5)

Comparison of Simulated Chloride Concentrations at Top of Upper Floridan Aquifer
No Dredging vs. Dredging Conditions - Sensitivity (Lower Conductivity in Miocene)
Station 89+000 (SHE-15)

Figure 3-18
Comparison of Simulated Concentration Time Histories at SHE-5
for No Dredging and Dredging

CDM

Savannah Harbor Expansion
Groundwater Model Studies



Comparison of Simulated Chloride Concentrations at Top of Upper Floridan Aquifer
No Dredging vs. Dredging Conditions
Station 73+000 (SHE-9)

Comparison of Simulated Chloride Concentrations at Top of Upper Floridan Aquifer
No Dredging vs. Dredging Conditions - Sensitivity (Lower Conductivity in Miocene)
Station 73+000 (SHE-9)

Figure 3-19
Comparison of Simulated Concentration Time Histories at SHE-9
for No Dredging and Dredging

Savannah Harbor Expansion
Groundwater Model Studies

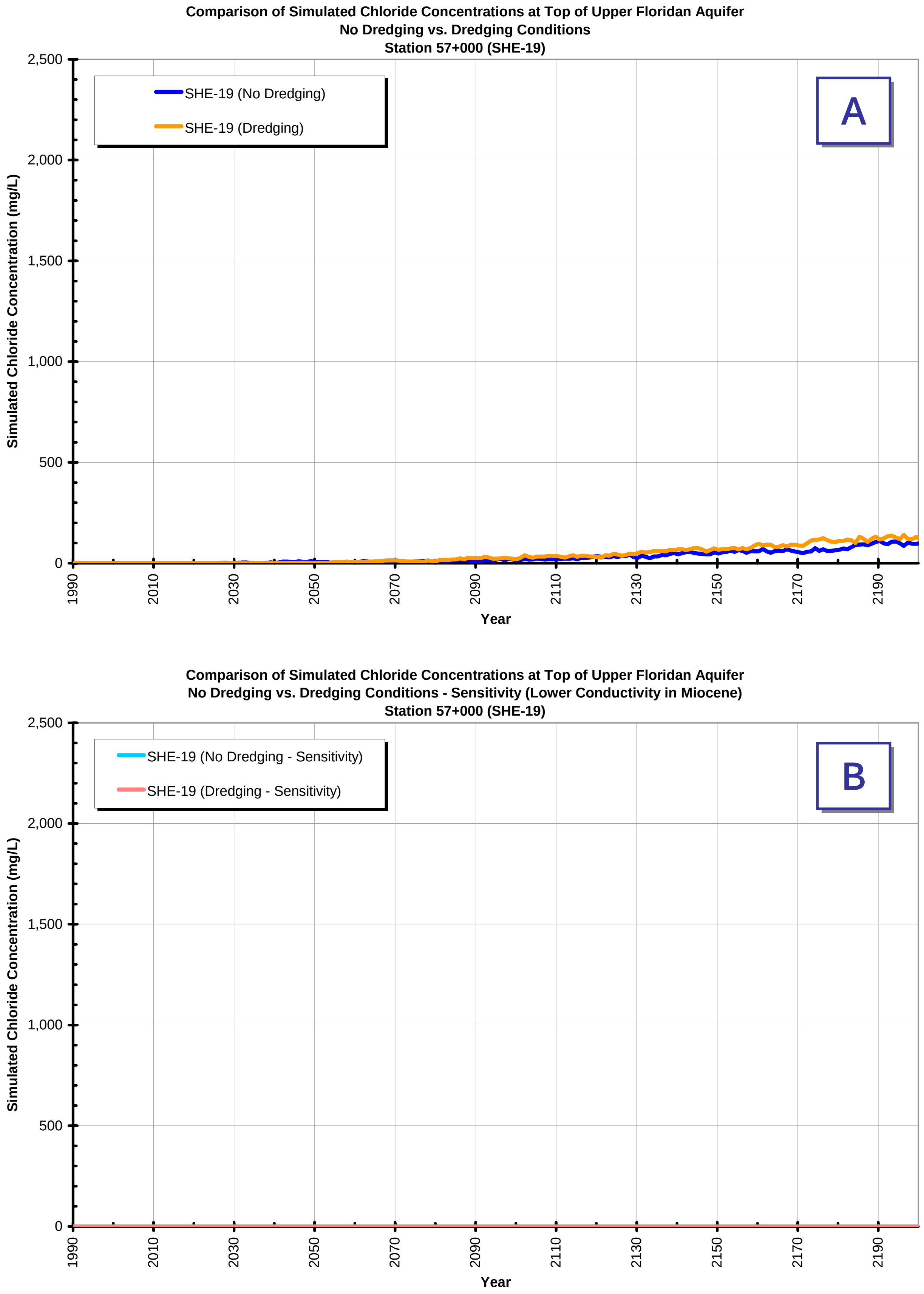
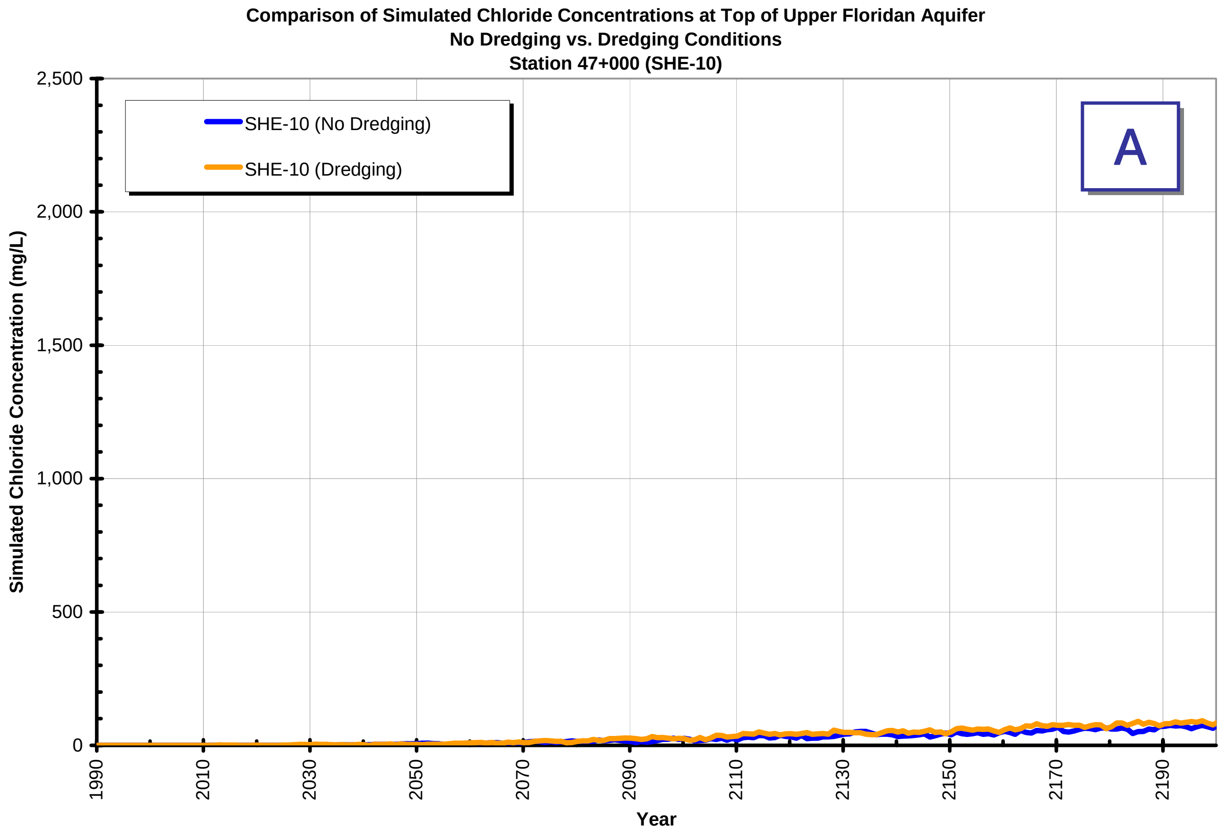


Figure 3-20
Comparison of Simulated Concentration Time Histories at SHE-19
for No Dredging and Dredging

CDM

Savannah Harbor Expansion
Groundwater Model Studies



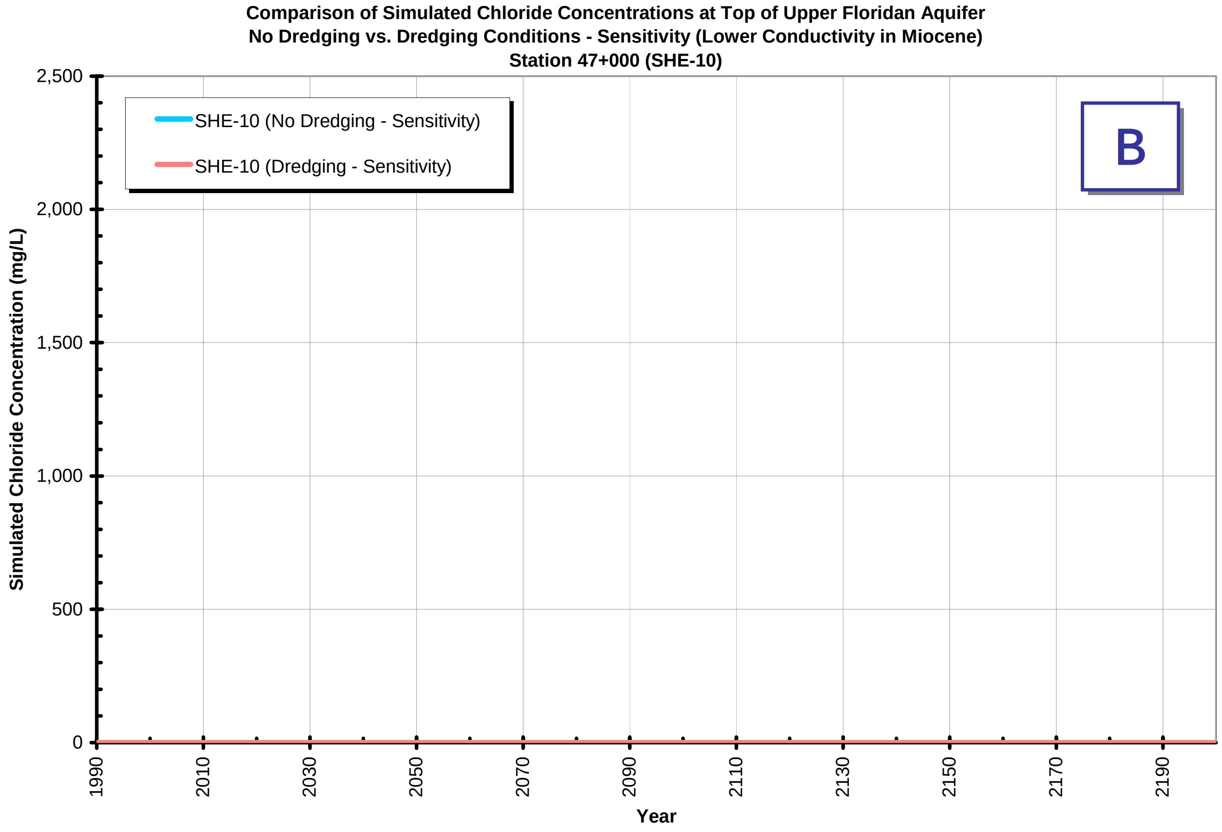


Figure 3-21
Comparison of Simulated Concentration Time Histories at SHE-10
for No Dredging and Dredging

Savannah Harbor Expansion
Groundwater Model Studies

CDM

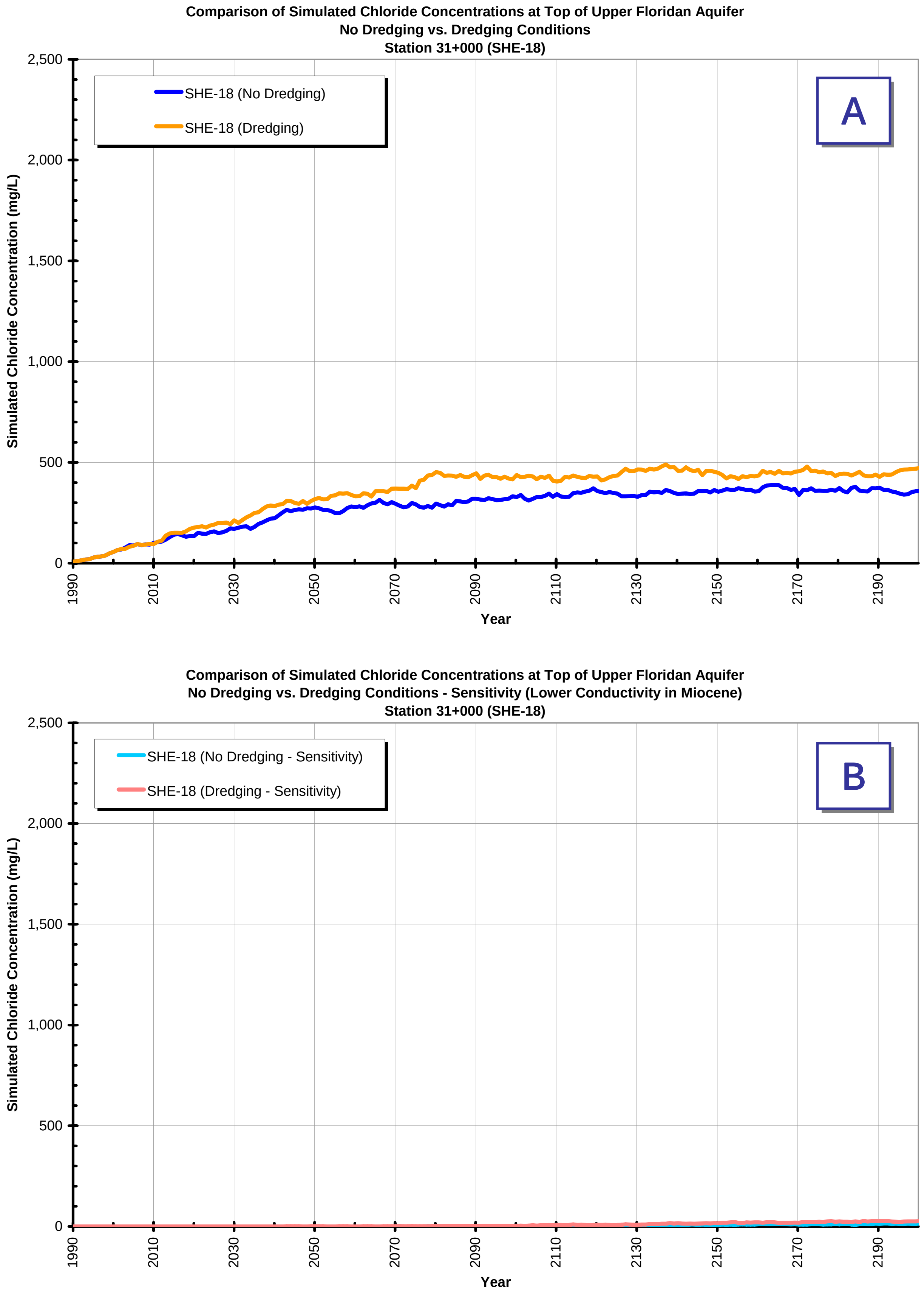


Figure 3-22
Comparison of Simulated Concentration Time Histories at SHE-18
for No Dredging and Dredging

CDM

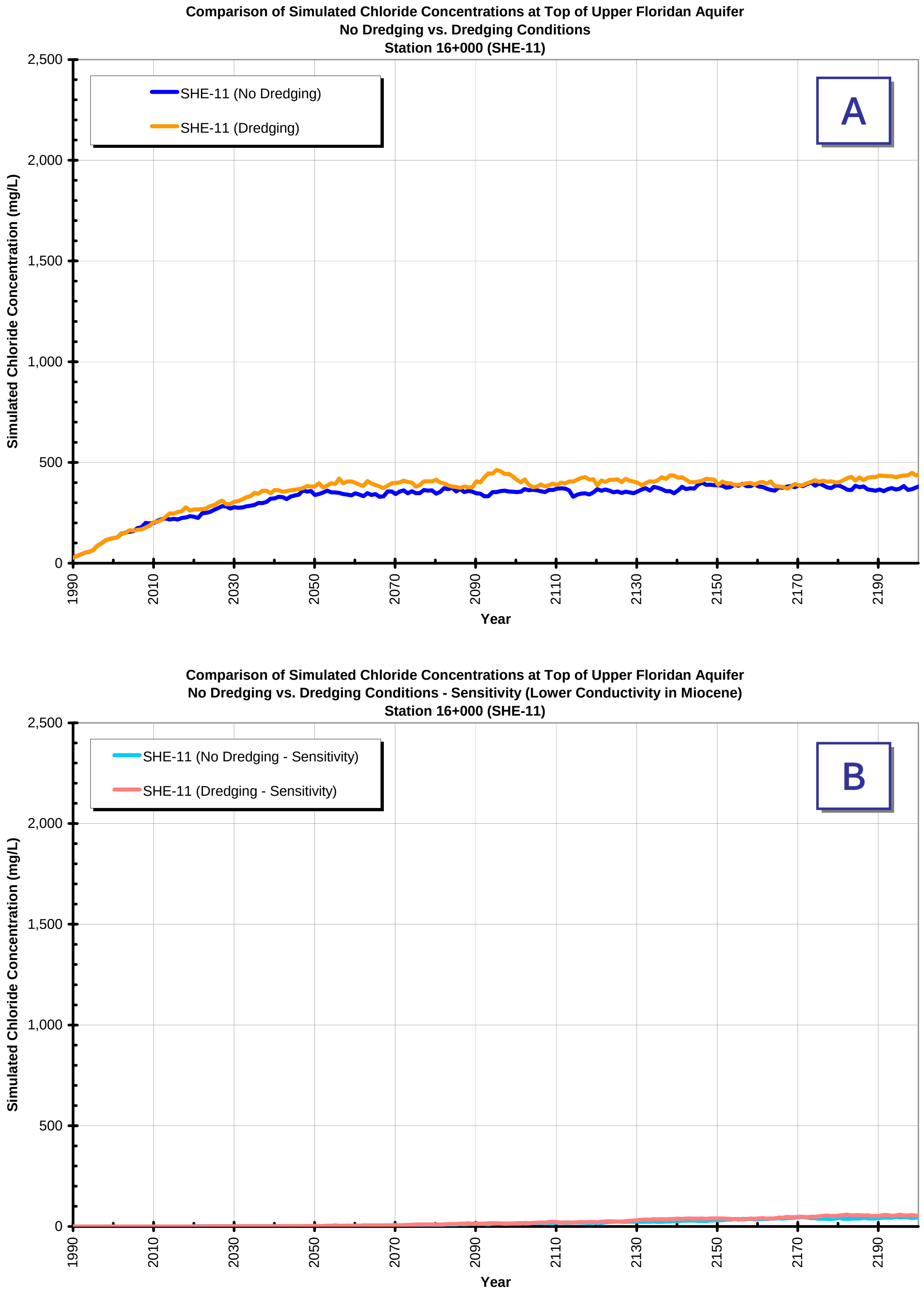


Figure 3-23
Comparison of Simulated Concentration Time Histories at SHE-11
for No Dredging and Dredging

Savannah Harbor Expansion
Groundwater Model Studies

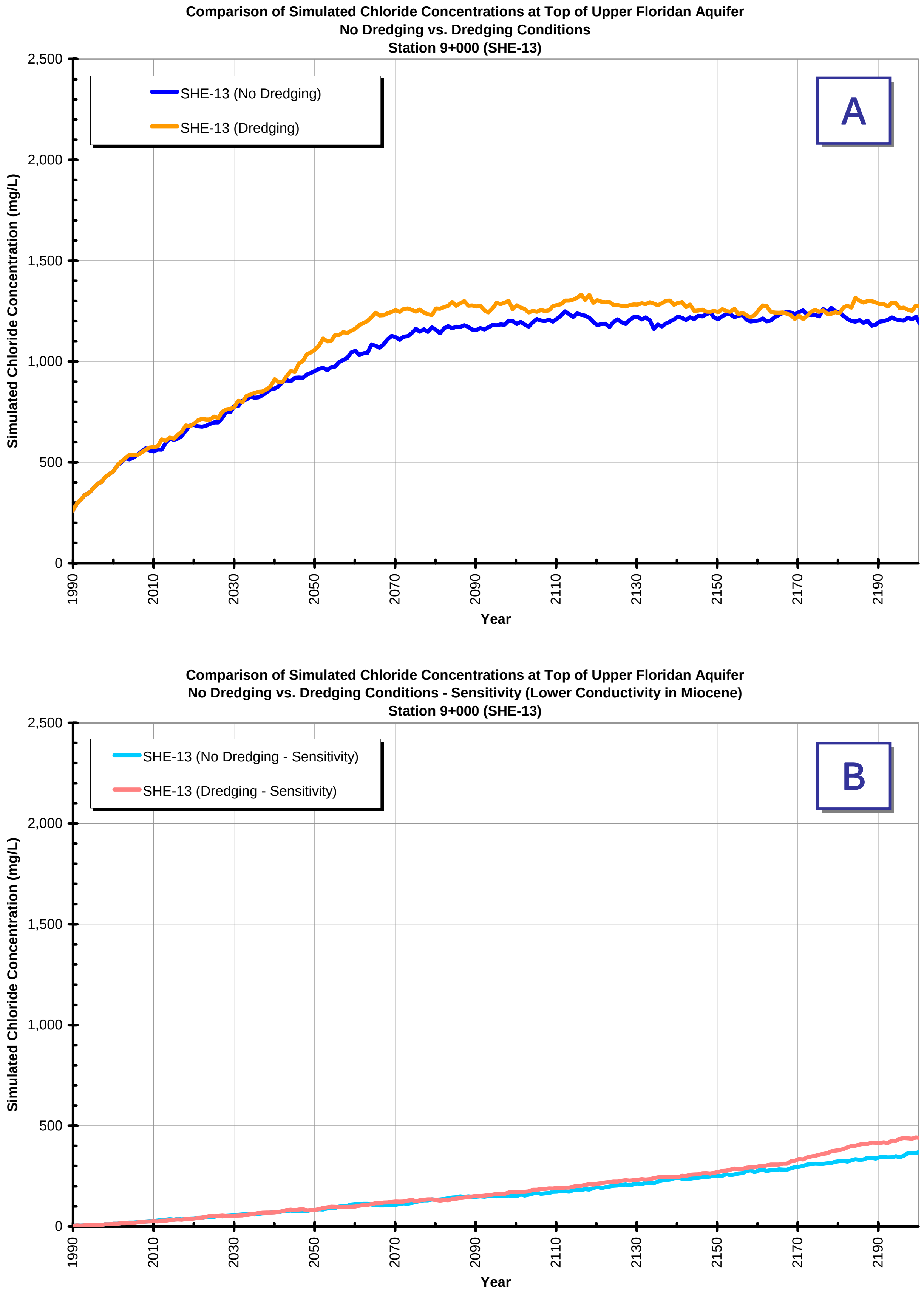
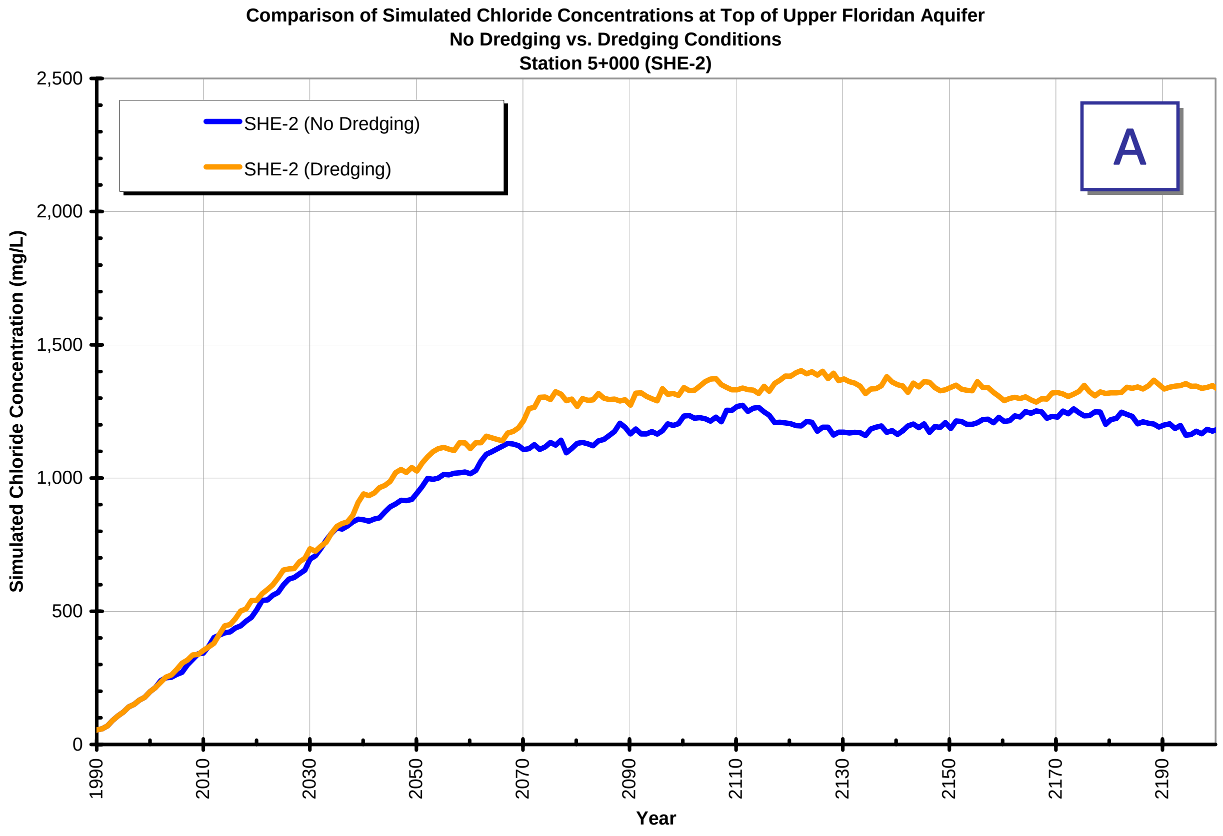


Figure 3-24
Comparison of Simulated Concentration Time Histories at SHE-13
for No Dredging and Dredging

Savannah Harbor Expansion
Groundwater Model Studies



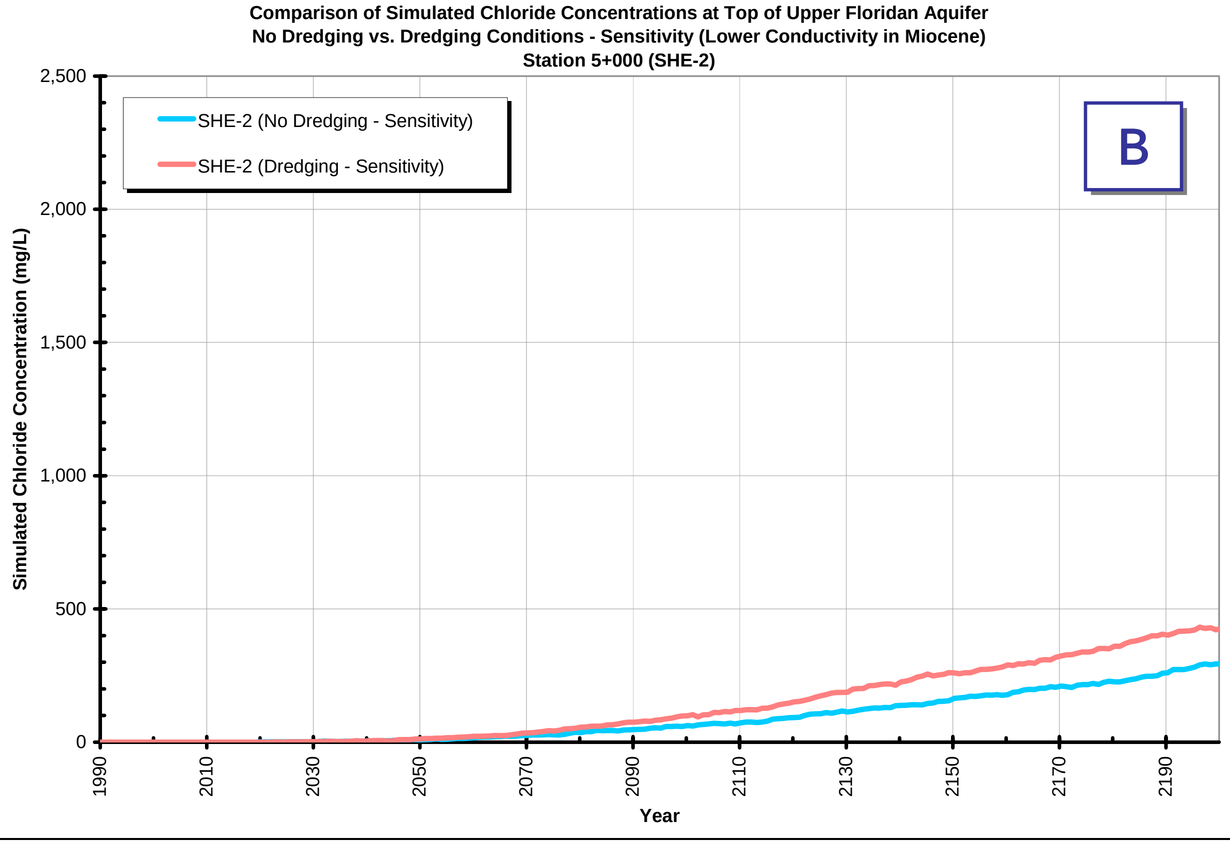


Figure 3-25
Comparison of Simulated Concentration Time Histories at SHE-2
for No Dredging and Dredging

CDM

Savannah Harbor Expansion
Groundwater Model Studies

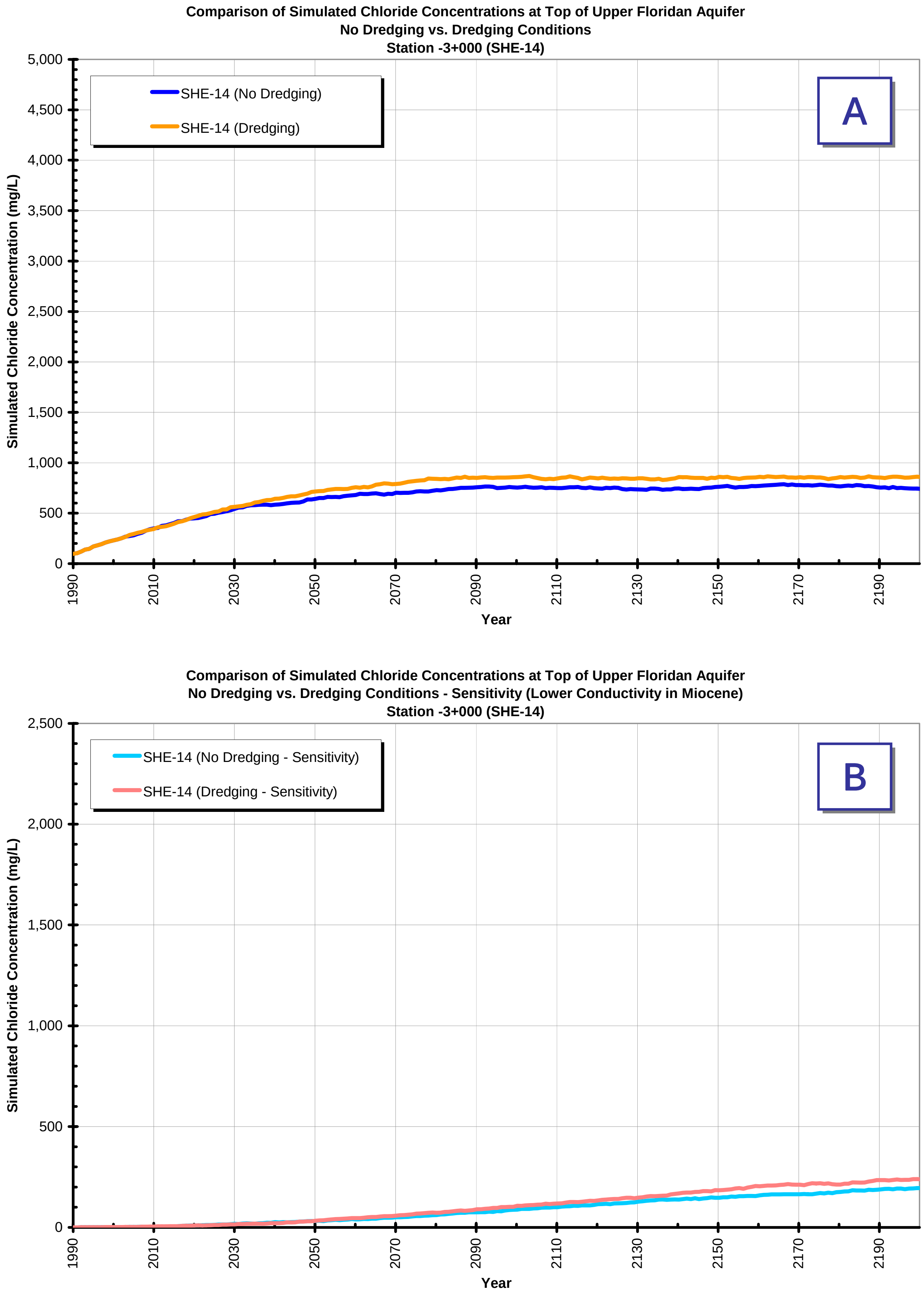
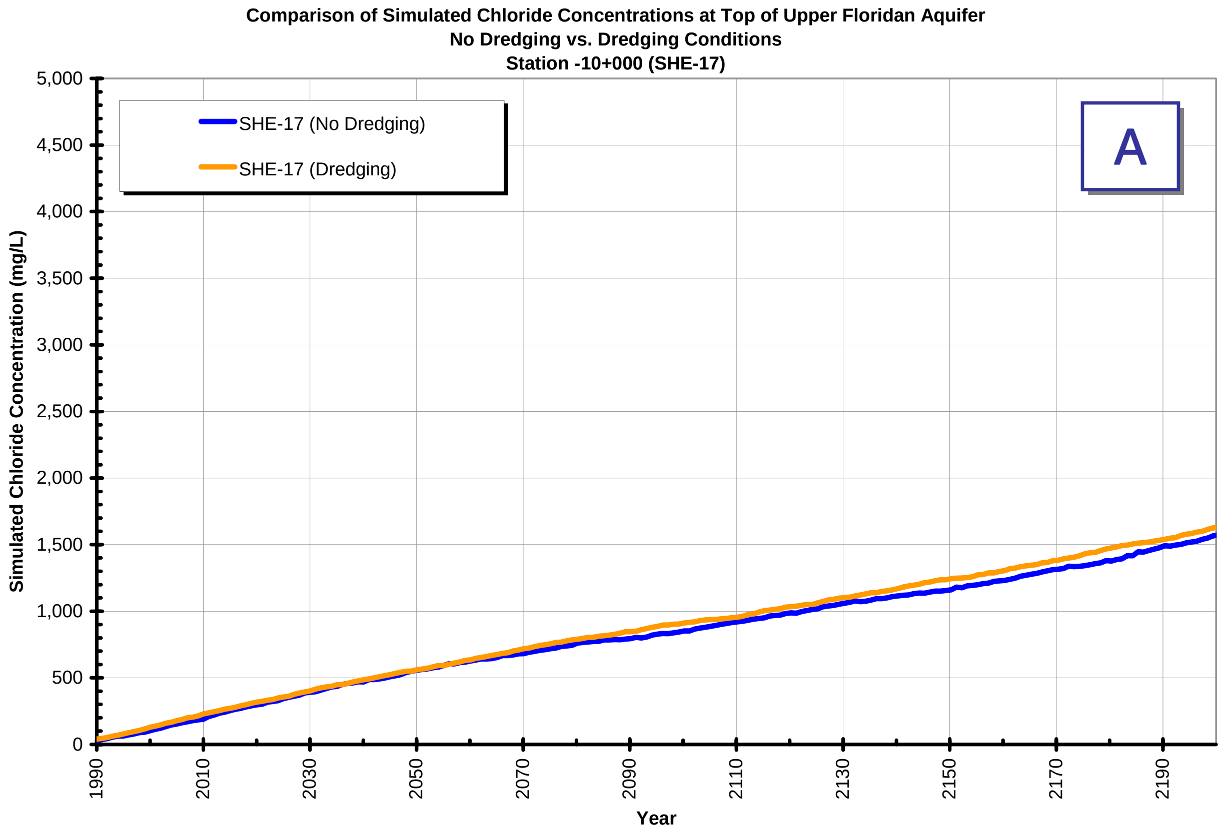


Figure 3-26
Comparison of Simulated Concentration Time Histories at SHE-14
for No Dredging and Dredging



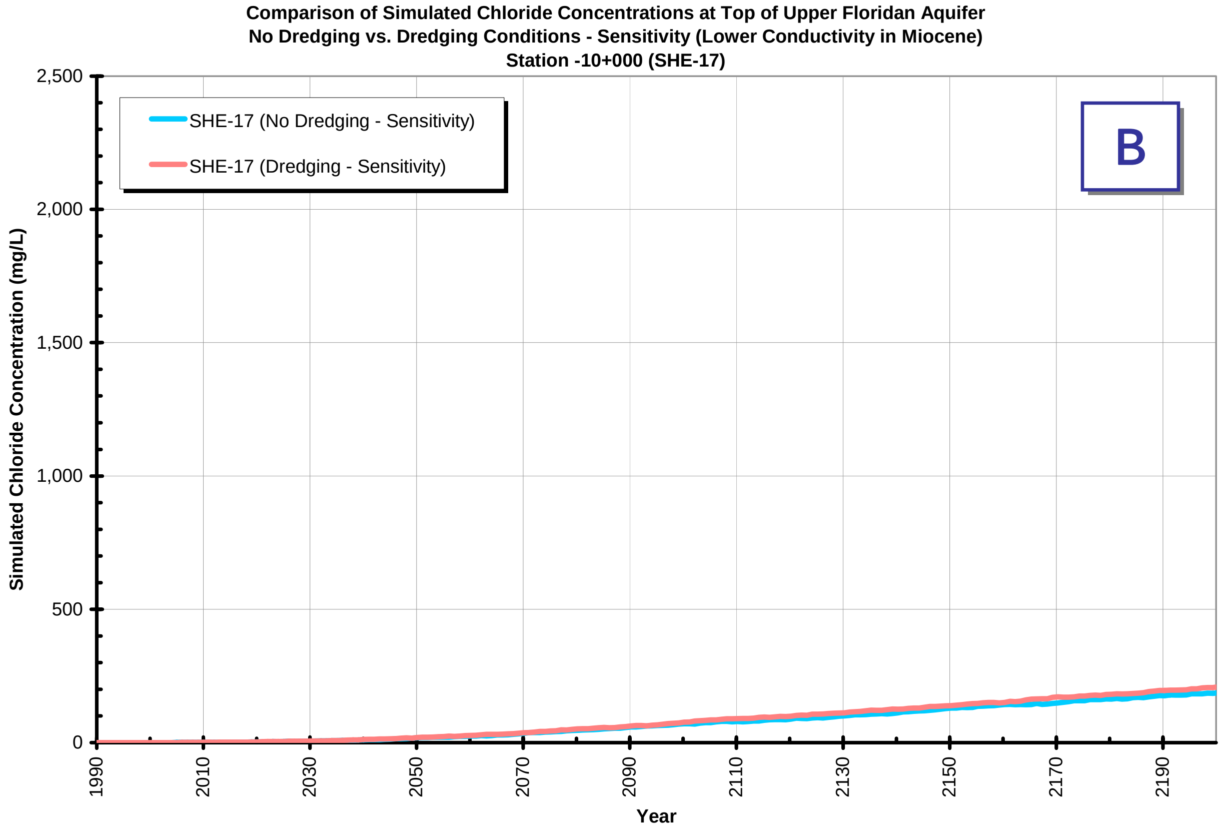


Figure 3-27
Comparison of Simulated Concentration Time Histories at SHE-17
for No Dredging and Dredging

Savannah Harbor Expansion
Groundwater Model Studies

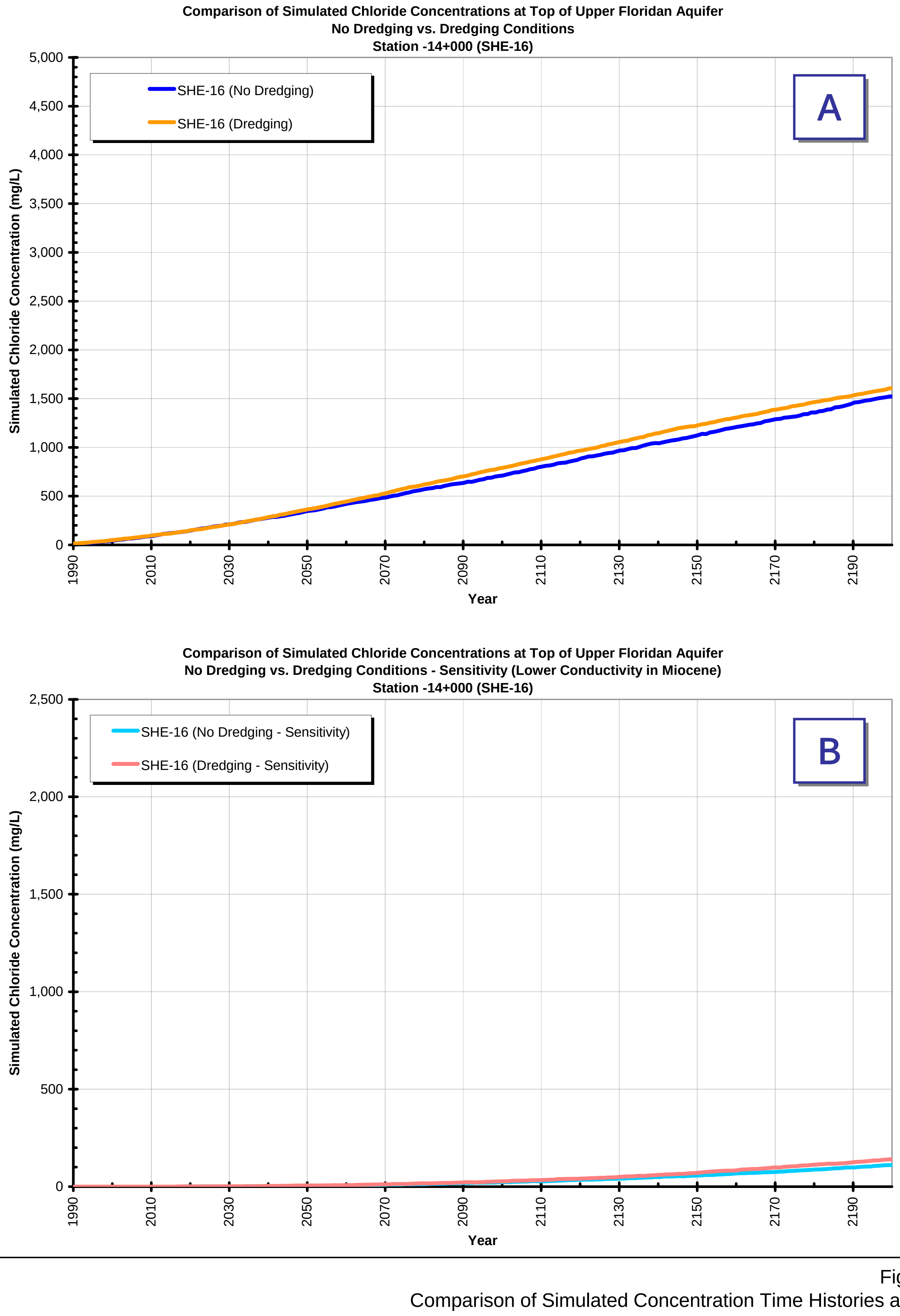
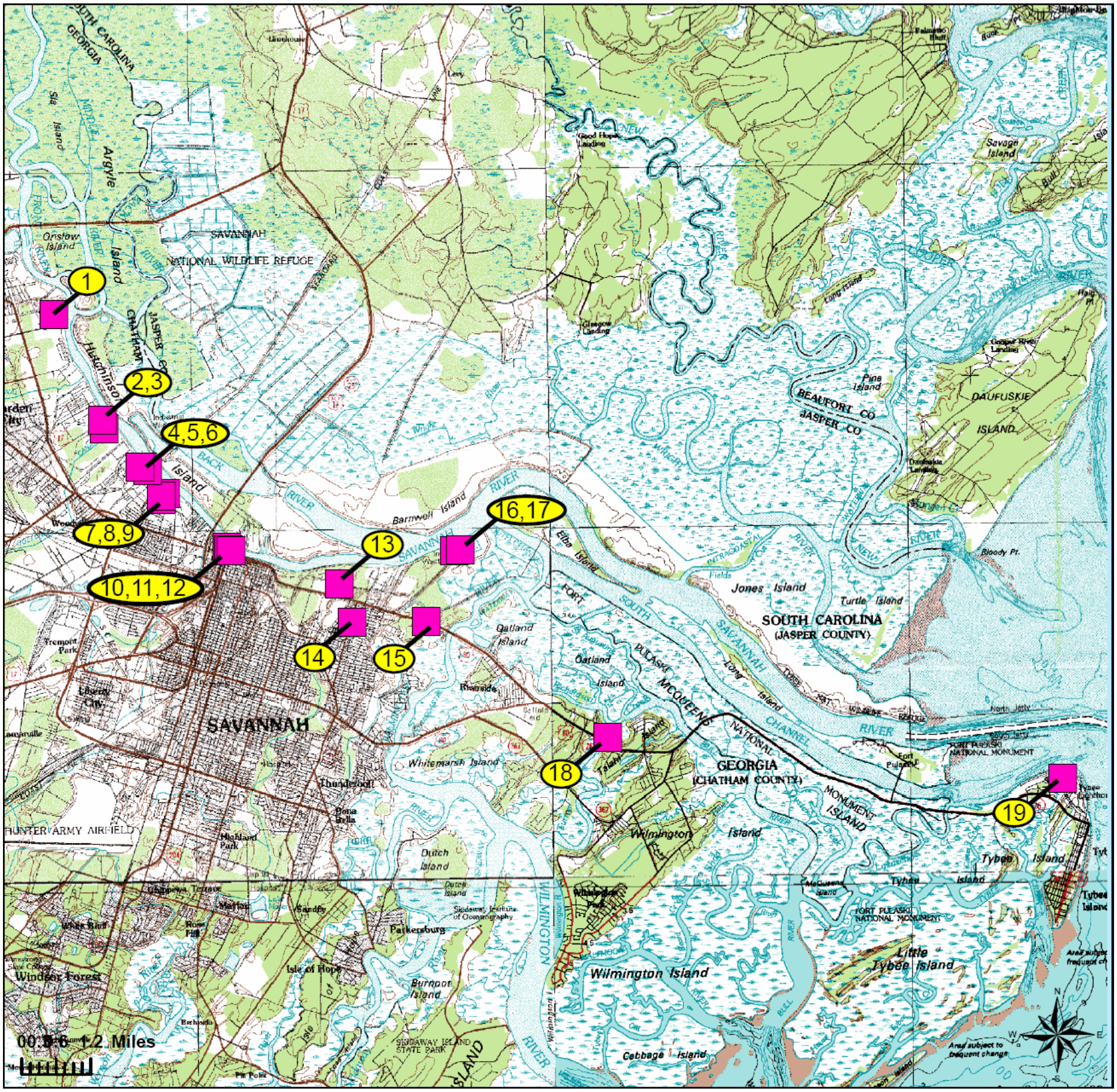


Figure 3-28
Comparison of Simulated Concentration Time Histories at SHE-16
for No Dredging and Dredging

Savannah Harbor Expansion
Groundwater Model Studies

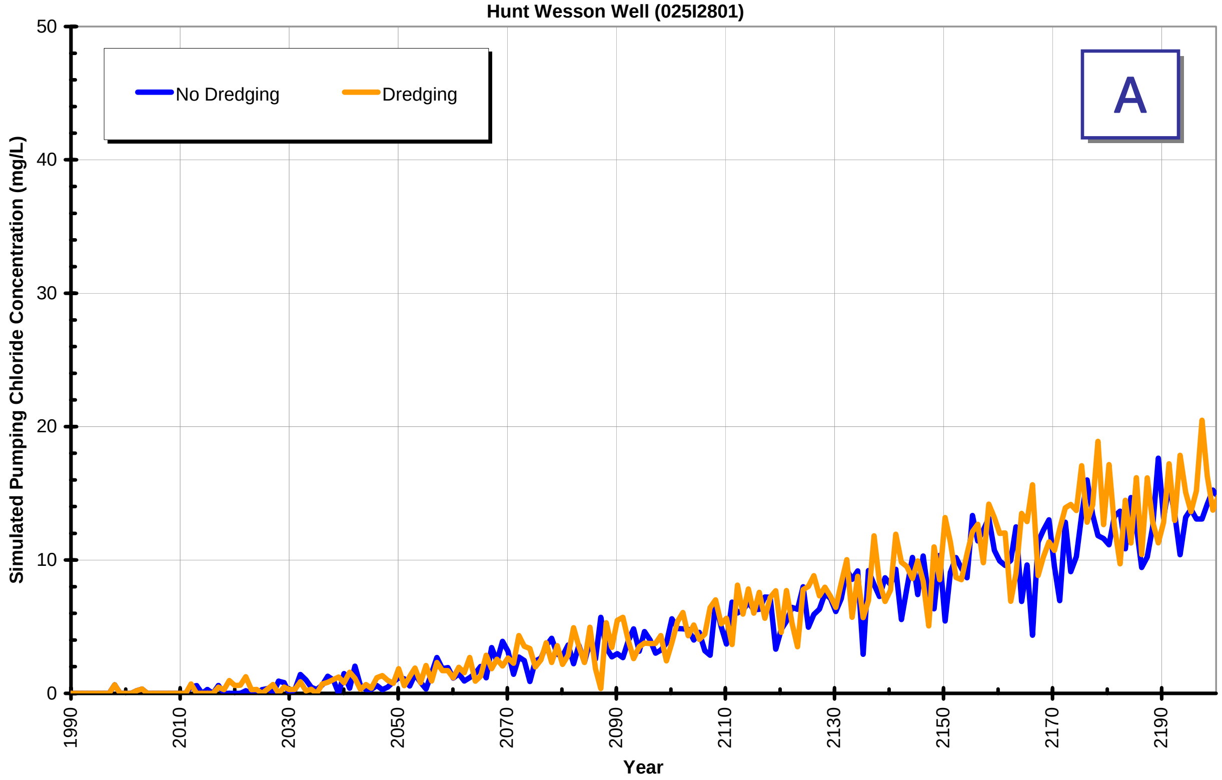


ID	Name	ID	Name
1	Savannah Sugar Refinery Well (025I2901)	10	SEPCO - Riverside Thermo Plant Well (025T0301)
2	GAF Corp. Well (025I3501)	11	SEPCO - Riverside Thermo Plant Well (025T0302)
3	Gold Bond Building Products Well (025I3301)	12	SEPCO - Riverside Thermo Plant Well (025T0303)
4	International Paper Well #1	13	Southern States Phosphate Well (025I3101)
5	International Paper Well #2	14	Savannah Main Well #11
6	International Paper Well #5	15	City of Garden City Well (025M0101)
7	Hunt Wesson Well (025I2801)	16	Kemira Well (025I3001)
8	Hunt Wesson Well (025I2802)	17	Kemira Well (025I3002)
9	Hunt Wesson Well (025I2803)	18	Whitemarsh Island Well #28
		19	Tybee Island Well (025M0602)

Figure 3-29
Location of Selected Pumping Wells

Savannah Harbor Expansion
Groundwater Model Studies

Comparison of Simulated Chloride Concentrations
No Dredging vs. Dredging Conditions
Hunt Wesson Well (025I2801)



Comparison of Simulated Chloride Concentrations
No Dredging vs. Dredging Conditions - Sensitivity (Lower Conductivity in Miocene)
Hunt Wesson Well (025I2801)

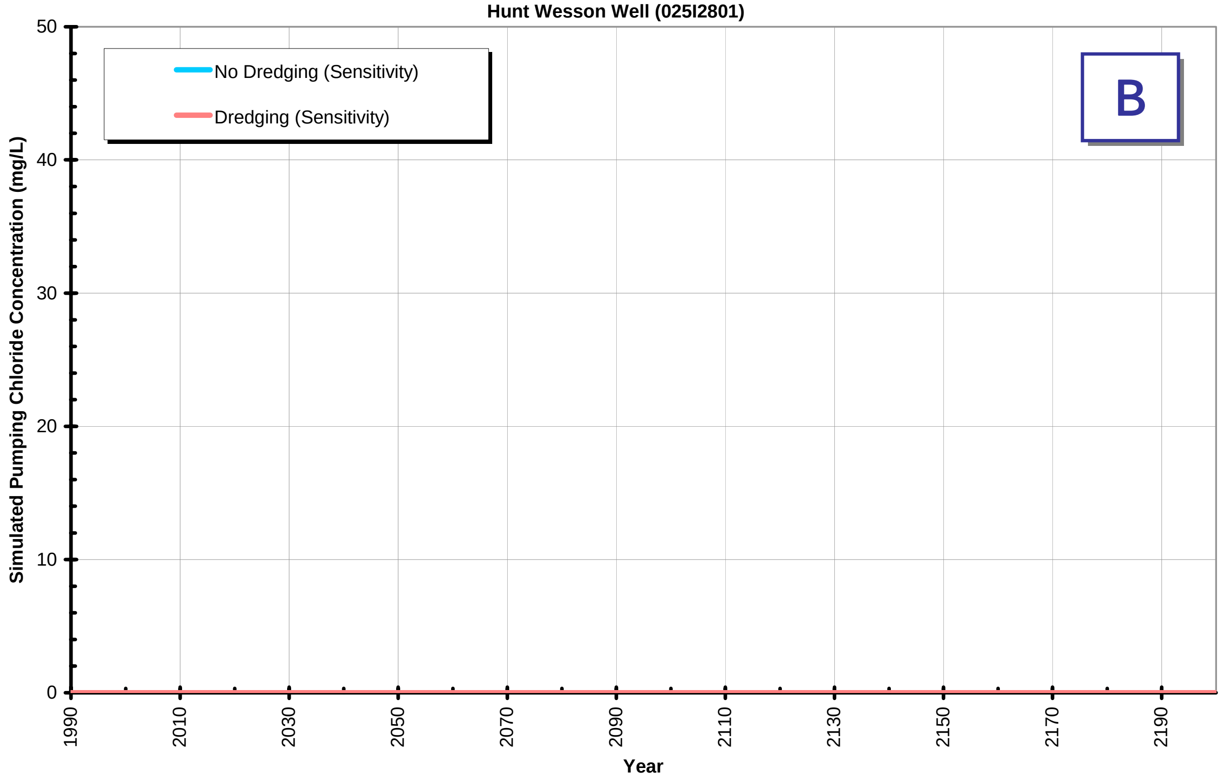


Figure 3-30
Pumping Well Concentrations for No Dredging and Dredging
At Hunt Wesson Well (025E2801)

Savannah Harbor Expansion
Groundwater Model Studies

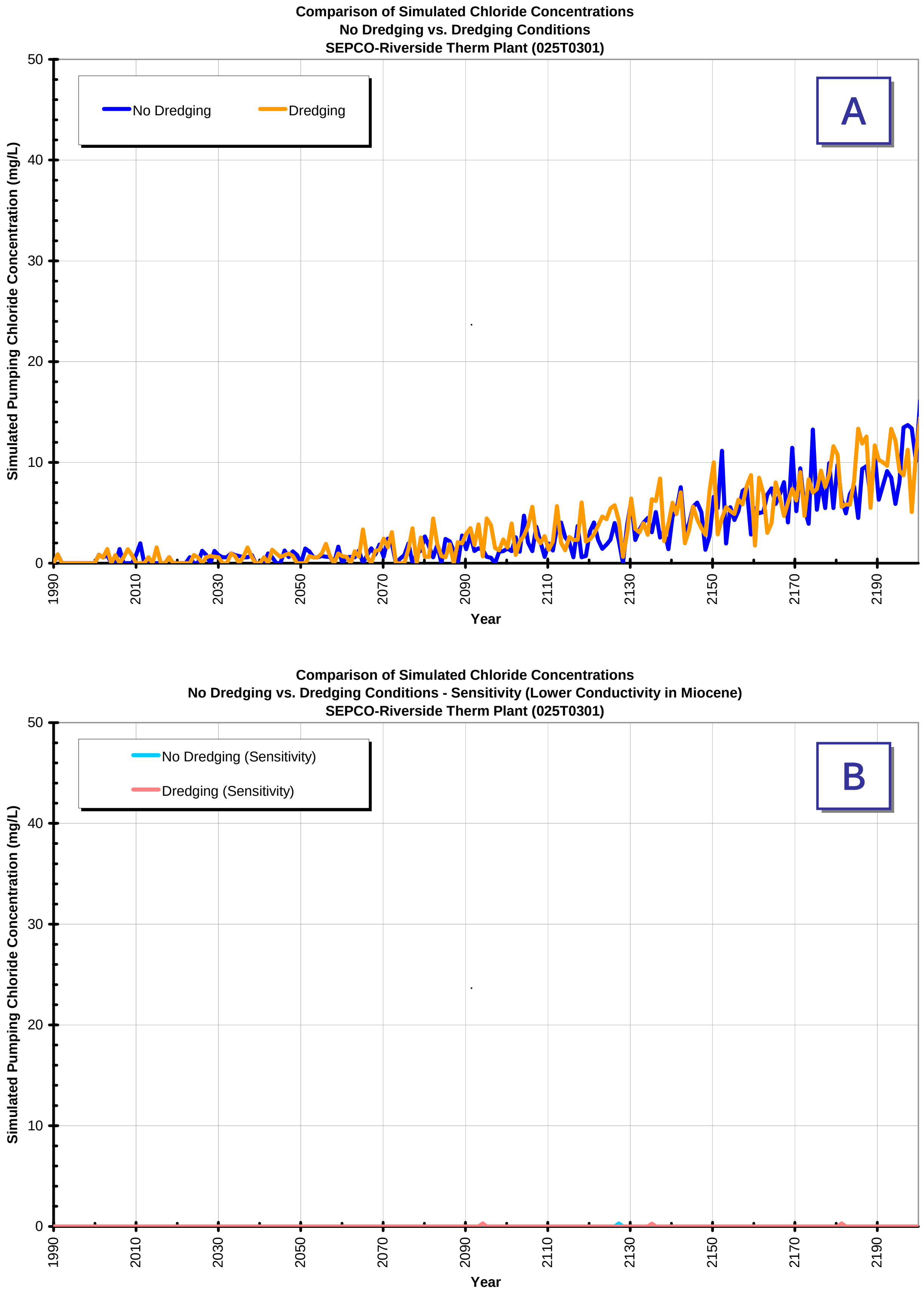
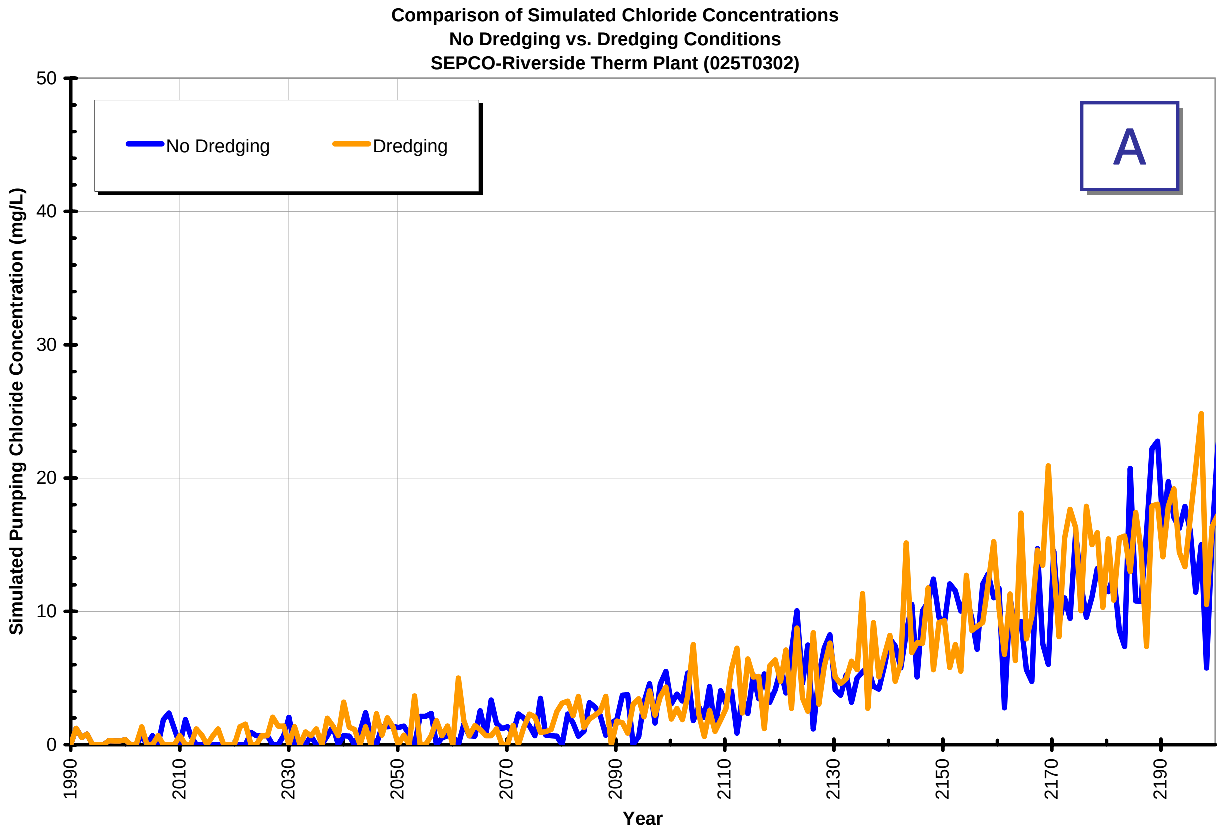


Figure 3-31
Pumping Well Concentrations for No Dredging and Dredging
At SEPCO-Riverside Therm. Plant (025T0301)

Savannah Harbor Expansion
Groundwater Model Studies



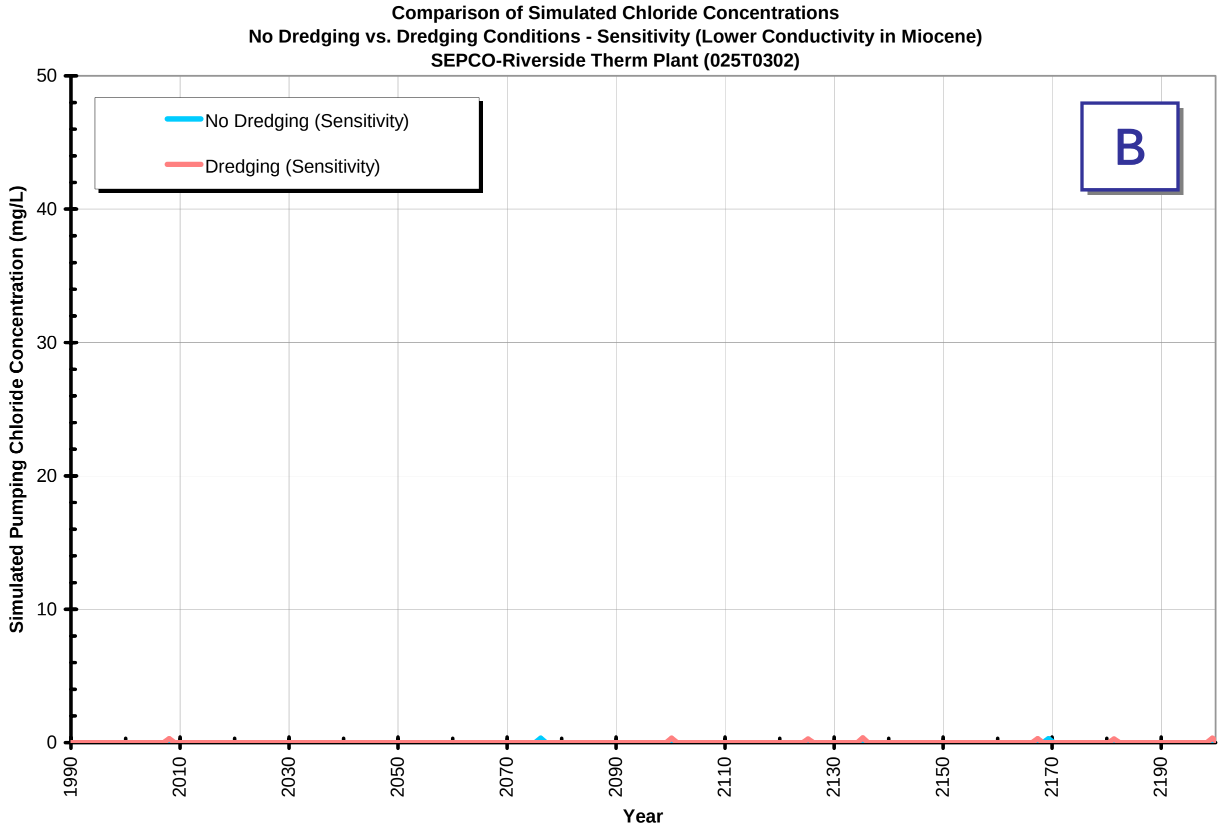


Figure 3-32
Pumping Well Concentrations for No Dredging and Dredging
At SEPCO-Riverside Therm. Plant (025T0302)

Savannah Harbor Expansion
Groundwater Model Studies

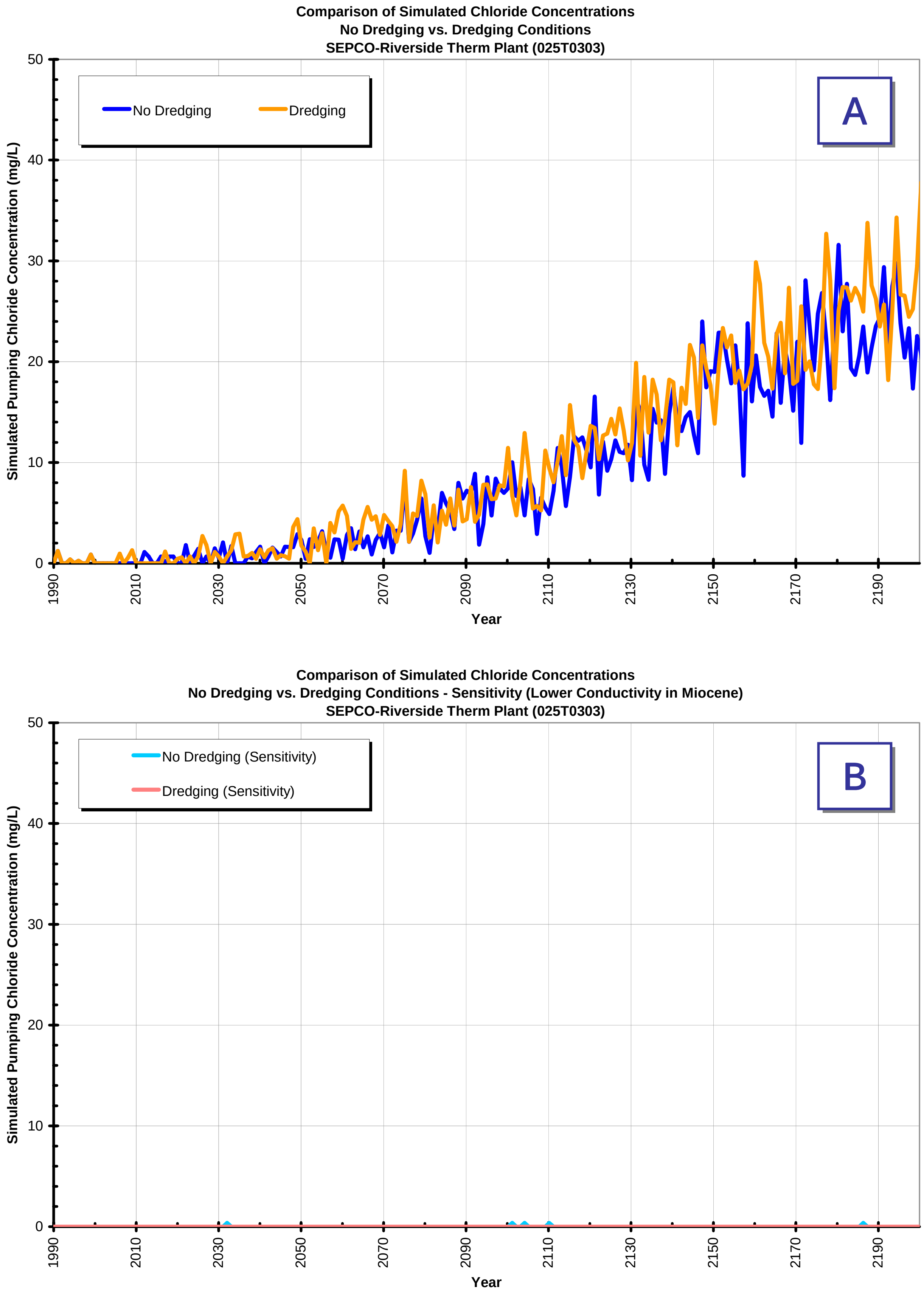


Figure 3-33
Pumping Well Concentrations for No Dredging and Dredging
At SEPCO-Riverside Therm. Plant (025T0303)

Savannah Harbor Expansion
Groundwater Model Studies

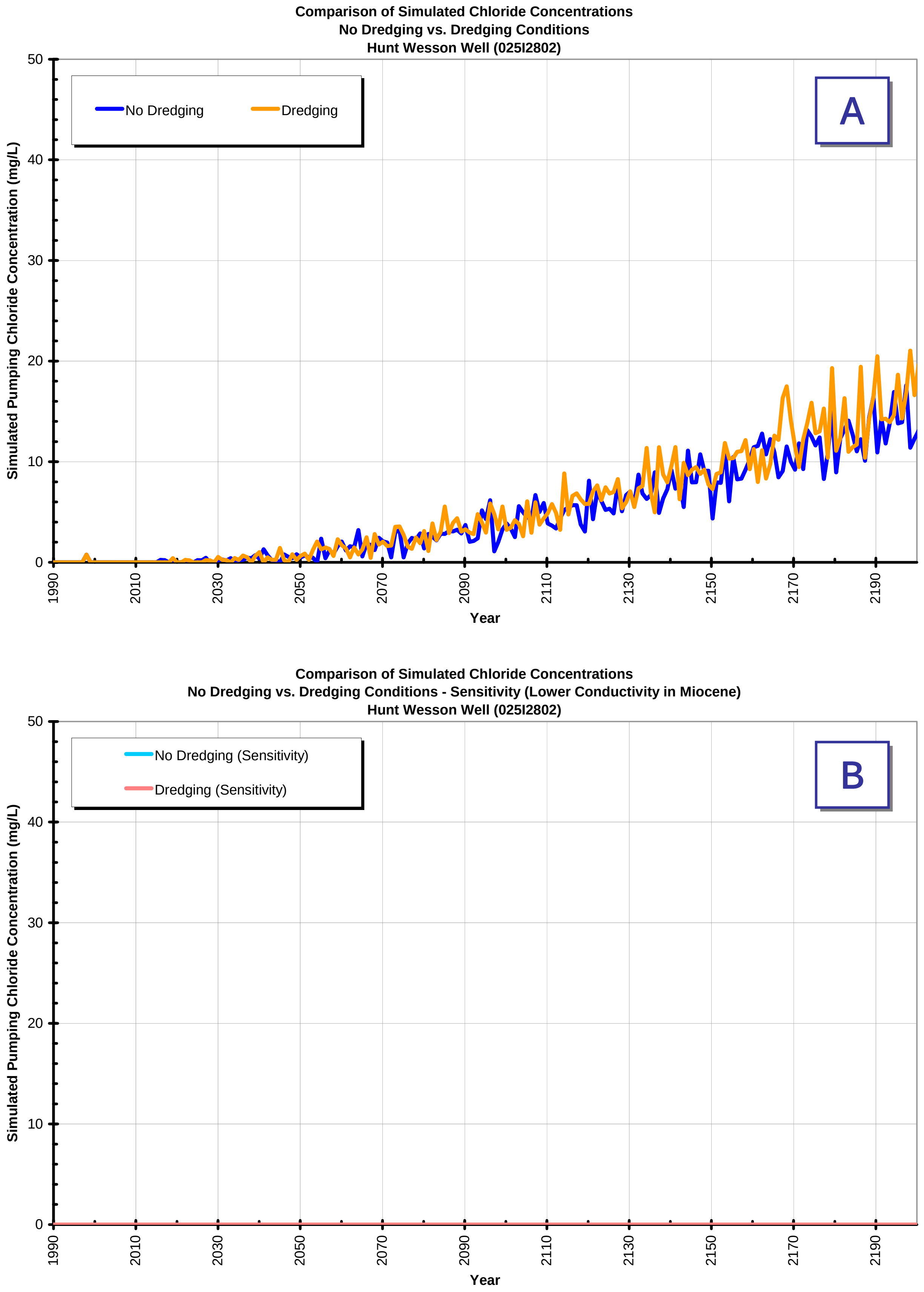


Figure 3-34
Pumping Well Concentrations for No Dredging and Dredging
At Hunt Wesson Well (028E2802)

Savannah Harbor Expansion
Groundwater Model Studies

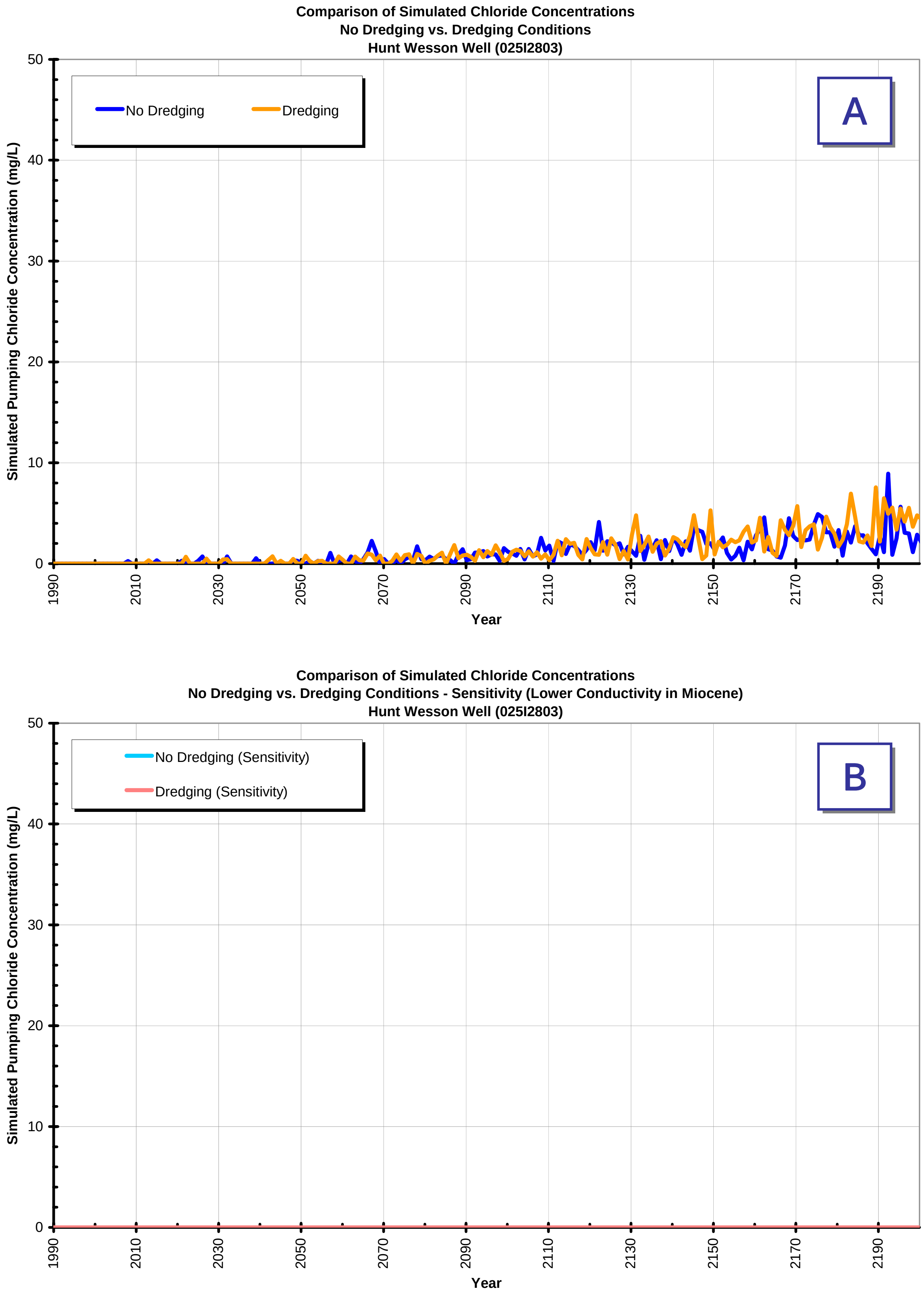
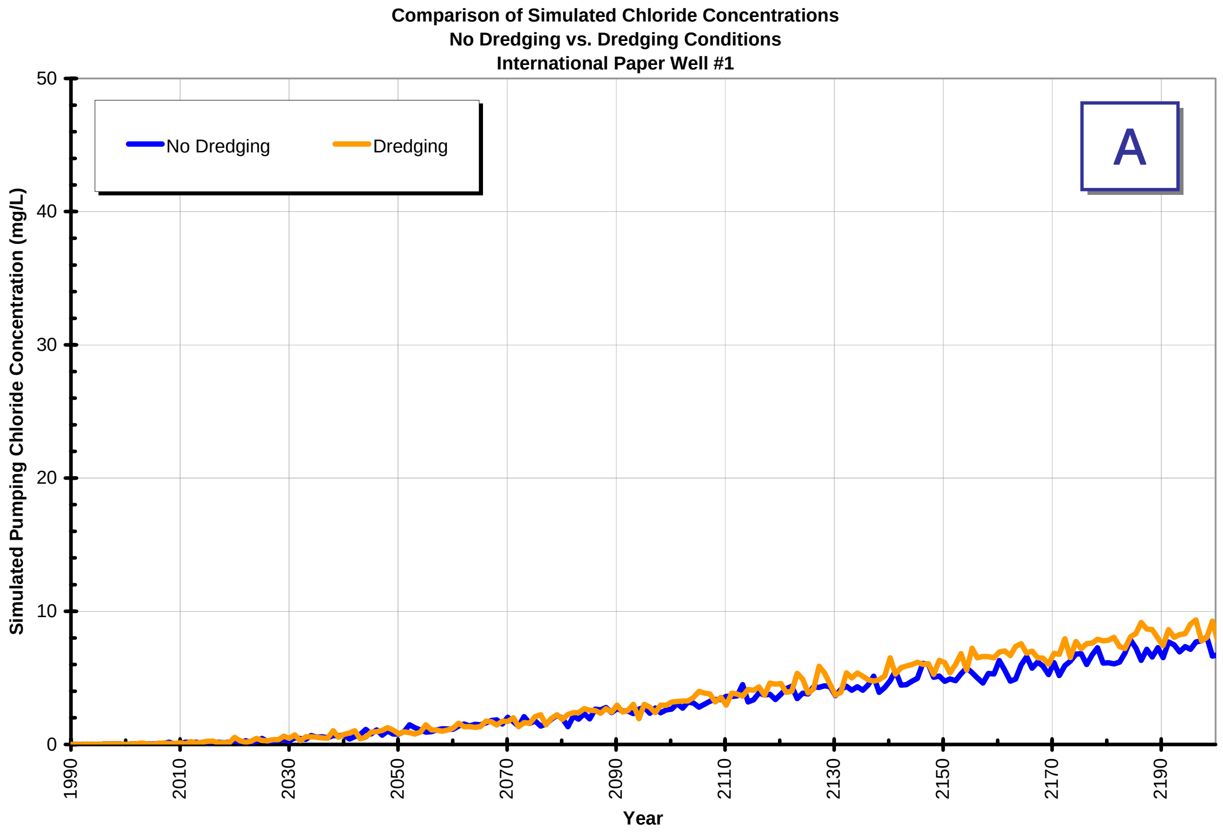


Figure 3-35
Pumping Well Concentrations for No Dredging and Dredging
At Hunt Wesson Well (025I2803)

Savannah Harbor Expansion
Groundwater Model Studies



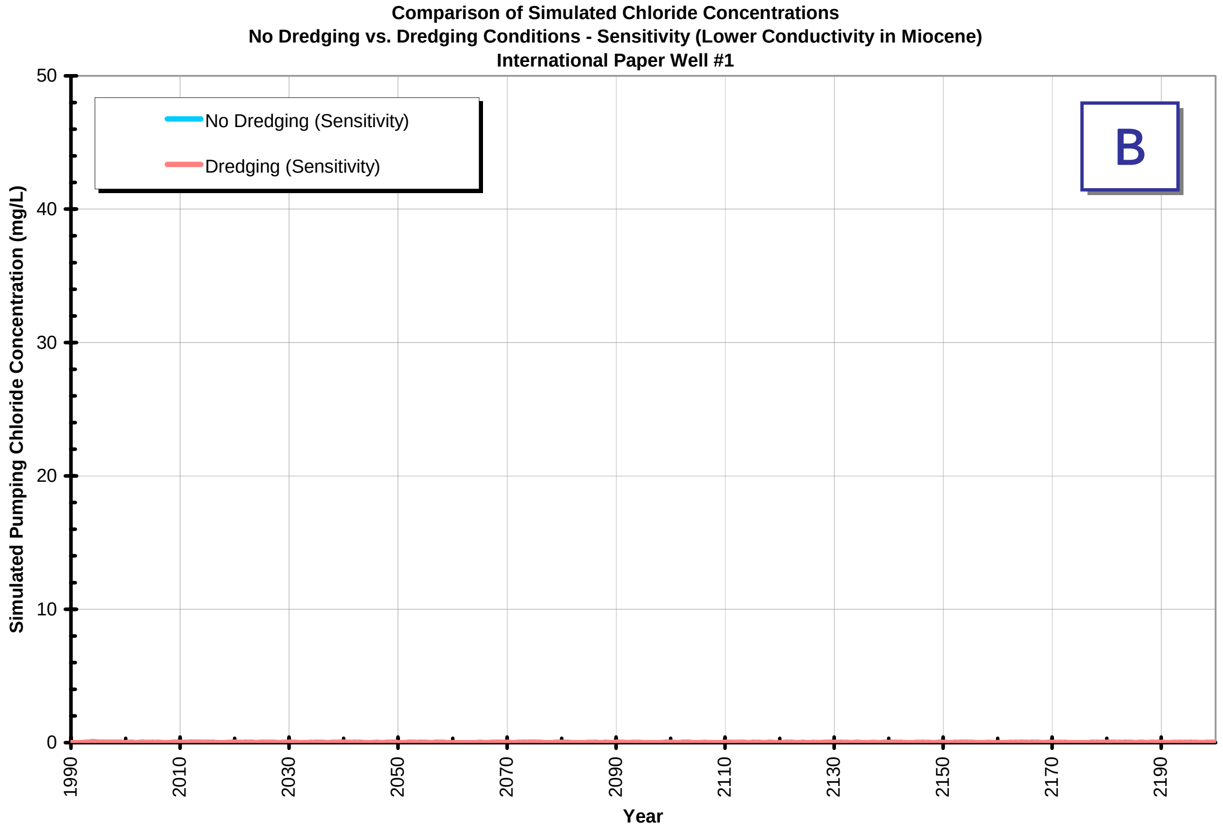


Figure 3-36
Pumping Well Concentrations for No Dredging and Dredging
At International Paper Well #1

Savannah Harbor Expansion
Groundwater Model Studies

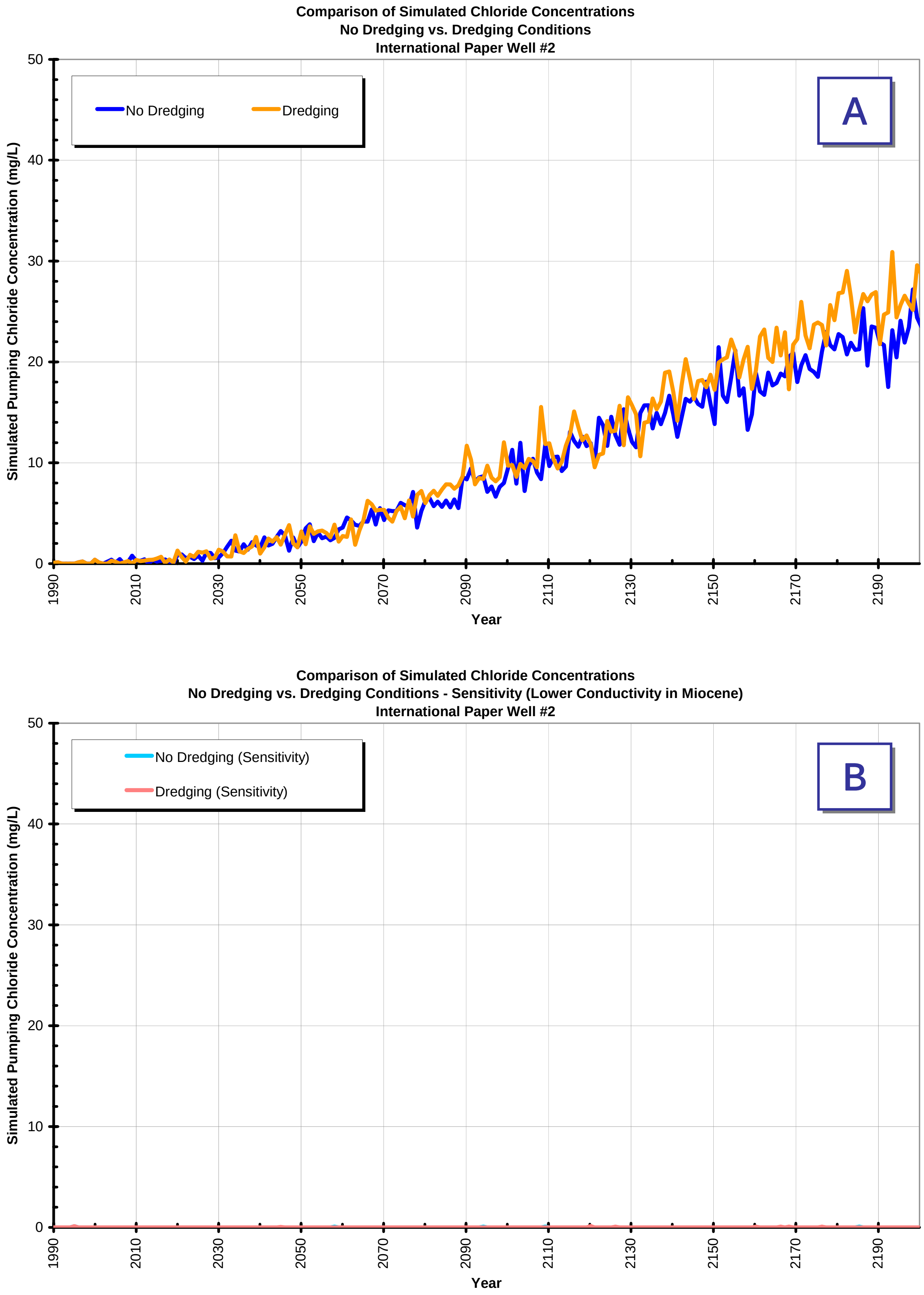
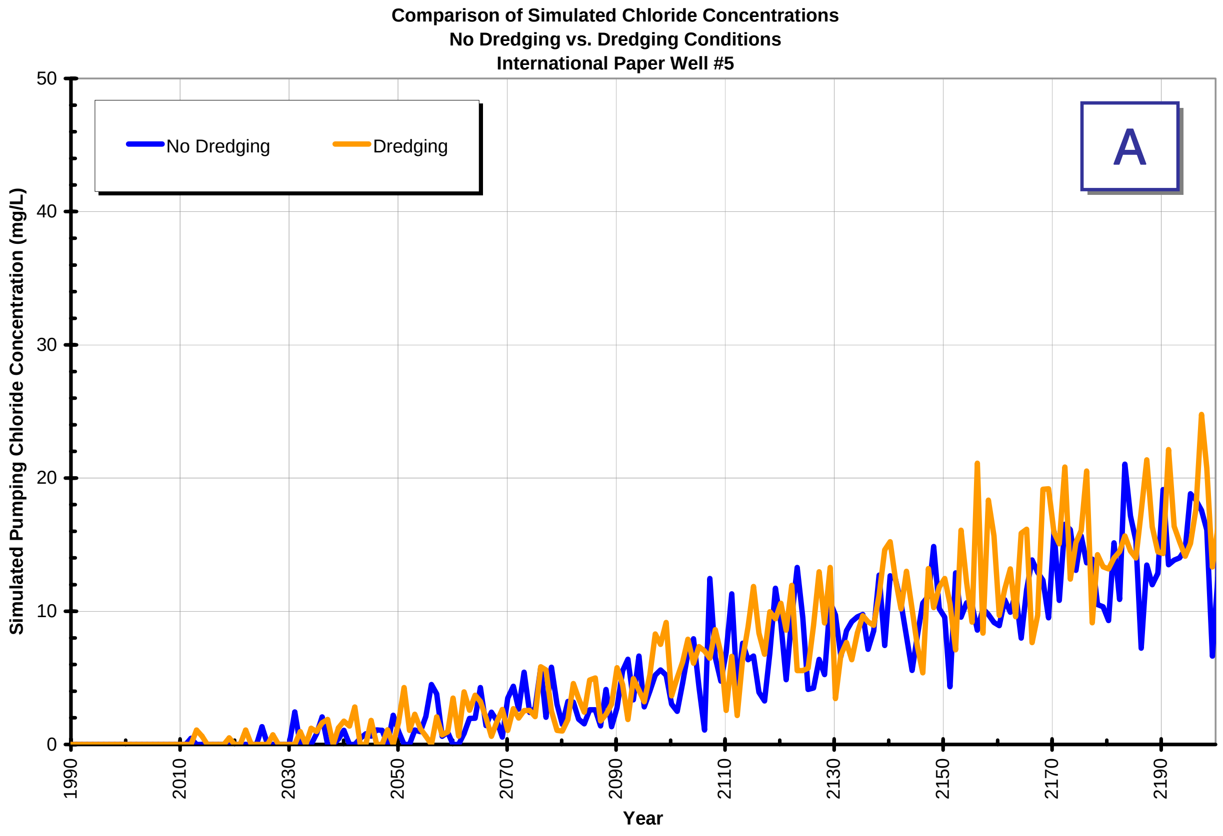


Figure 3-37
Pumping Well Concentrations for No Dredging and Dredging
At International Paper Well #2

Savannah Harbor Expansion
Groundwater Model Studies



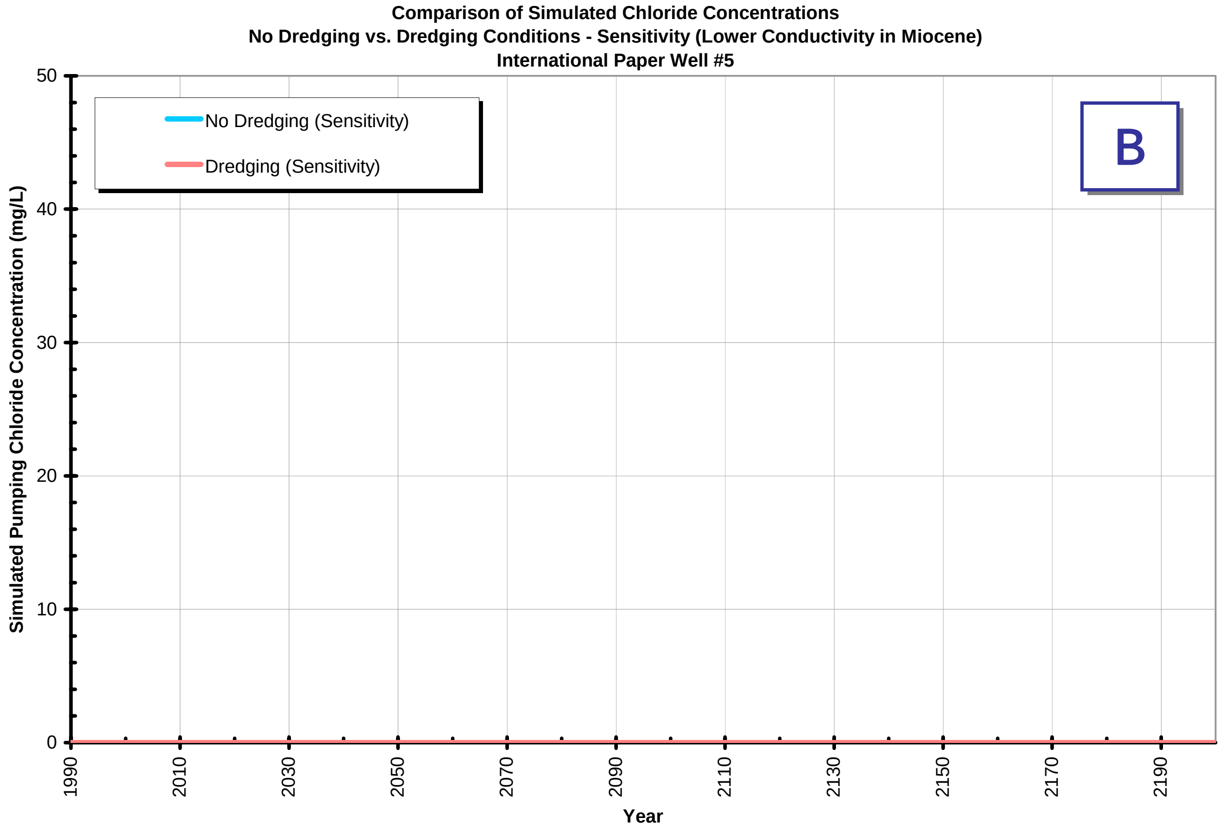
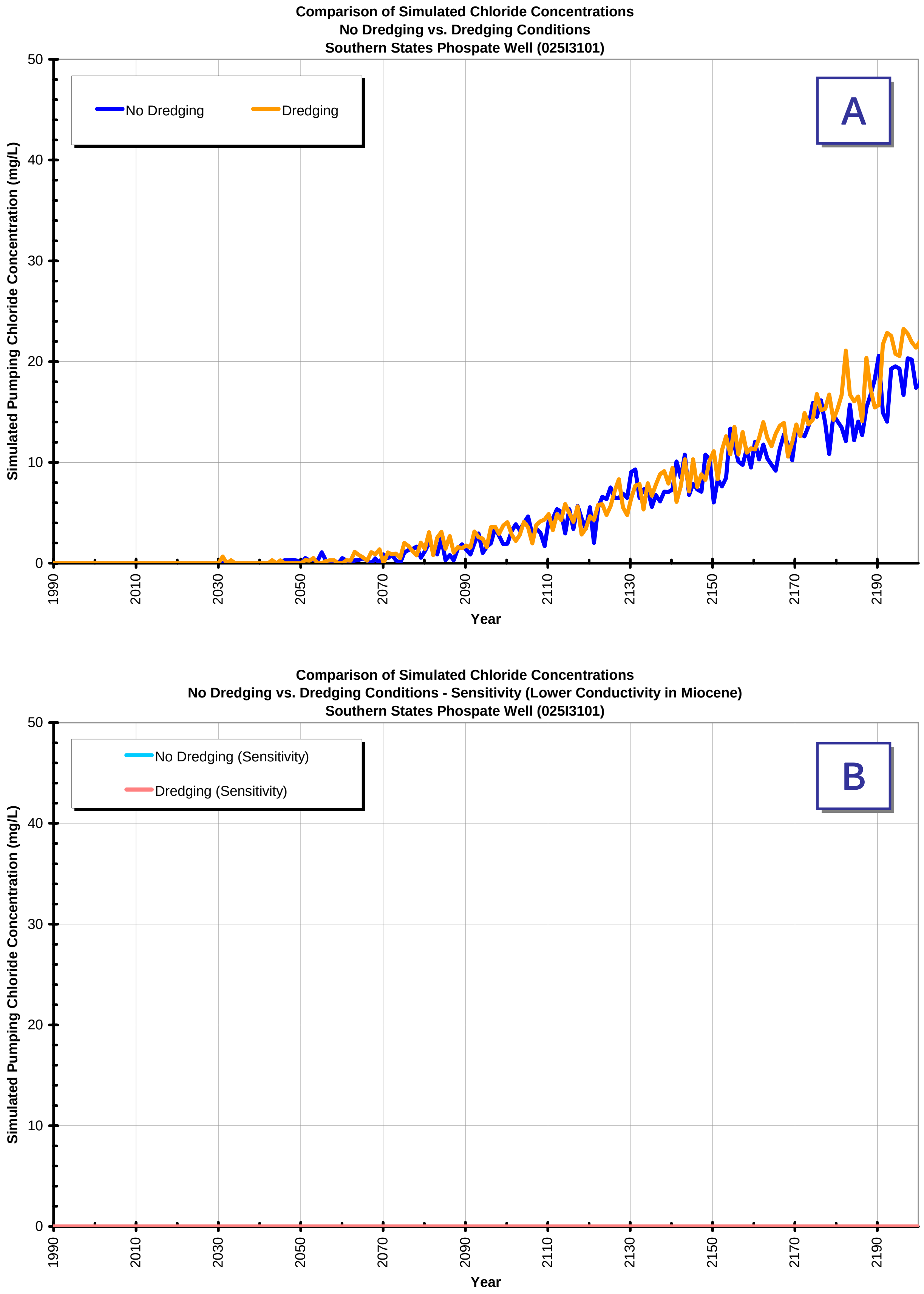


Figure 3-38
Pumping Well Concentrations for No Dredging and Dredging
At International Paper Well #5

Savannah Harbor Expansion
Groundwater Model Studies


Comparison of Simulated Chloride Concentrations
No Dredging vs. Dredging Conditions
Southern States Phospate Well (025I3101)

Comparison of Simulated Chloride Concentrations
No Dredging vs. Dredging Conditions - Sensitivity (Lower Conductivity in Miocene)
Southern States Phospate Well (025I3101)

Figure 3-39
Pumping Well Concentrations for No Dredging and Dredging
At Southern States Phosphate Well (025I3101)

Savannah Harbor Expansion
Groundwater Model Studies

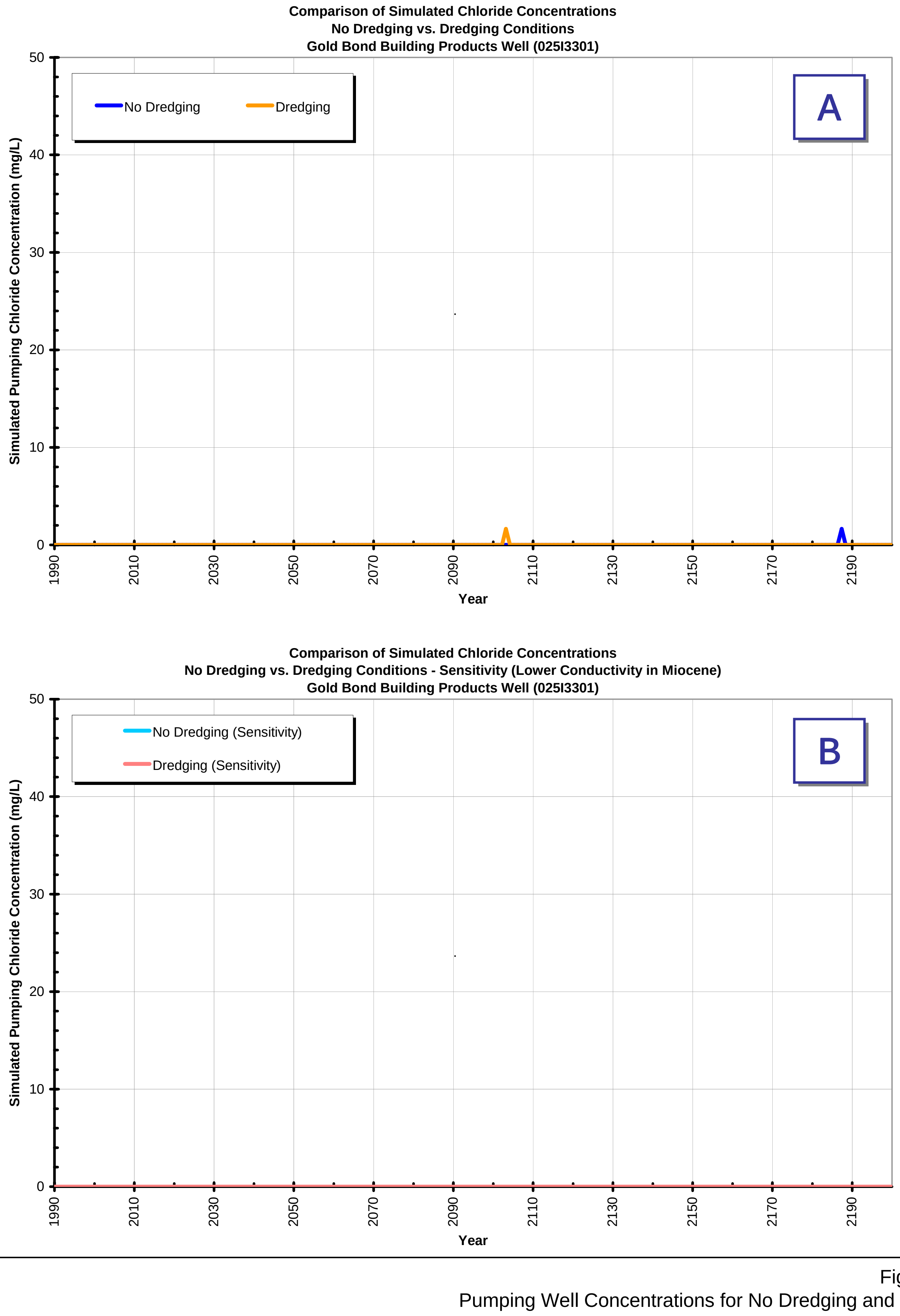


Figure 3-40
Pumping Well Concentrations for No Dredging and Dredging
At Gold Bond Building Products Well (025I3301)

Savannah Harbor Expansion
Groundwater Model Studies

CDM

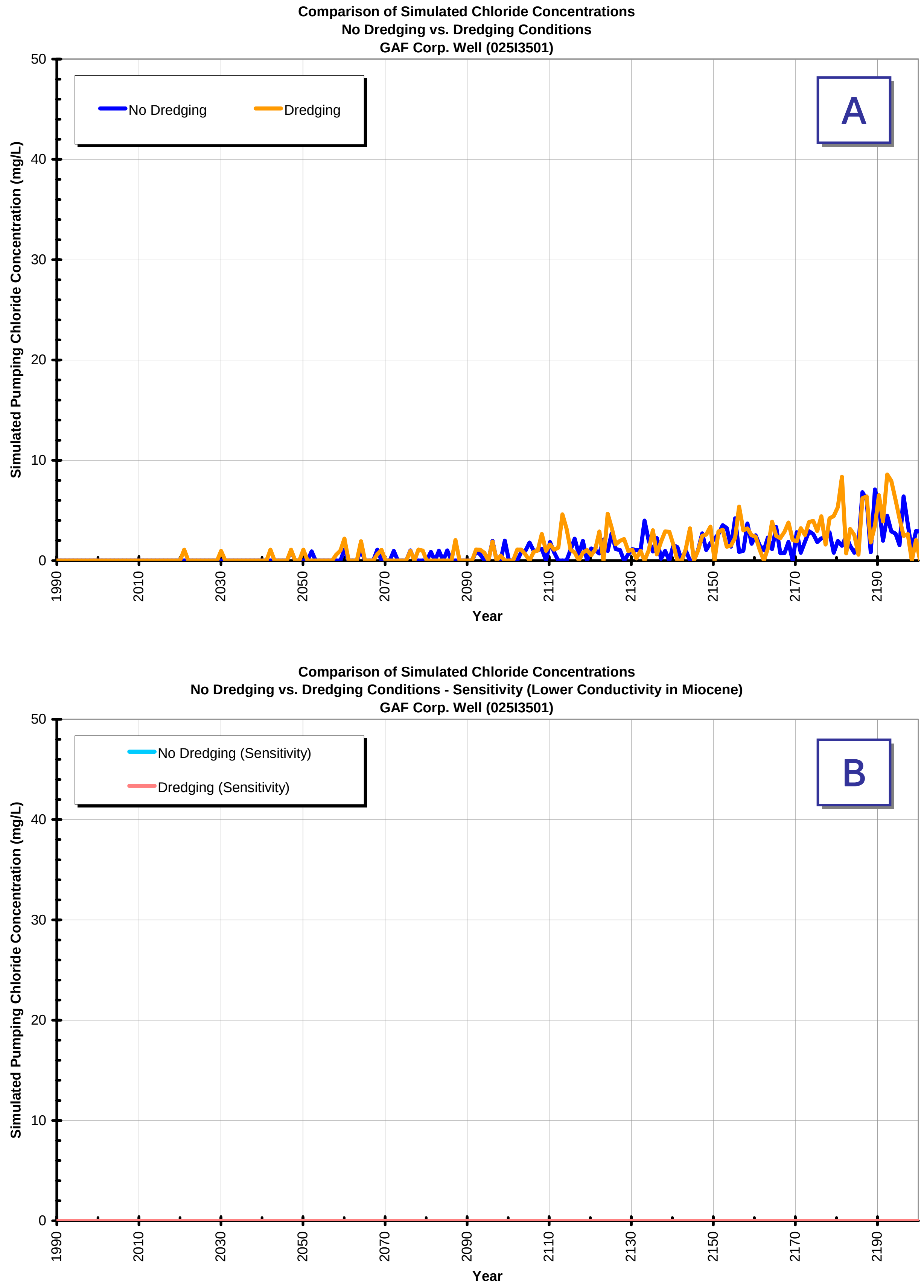
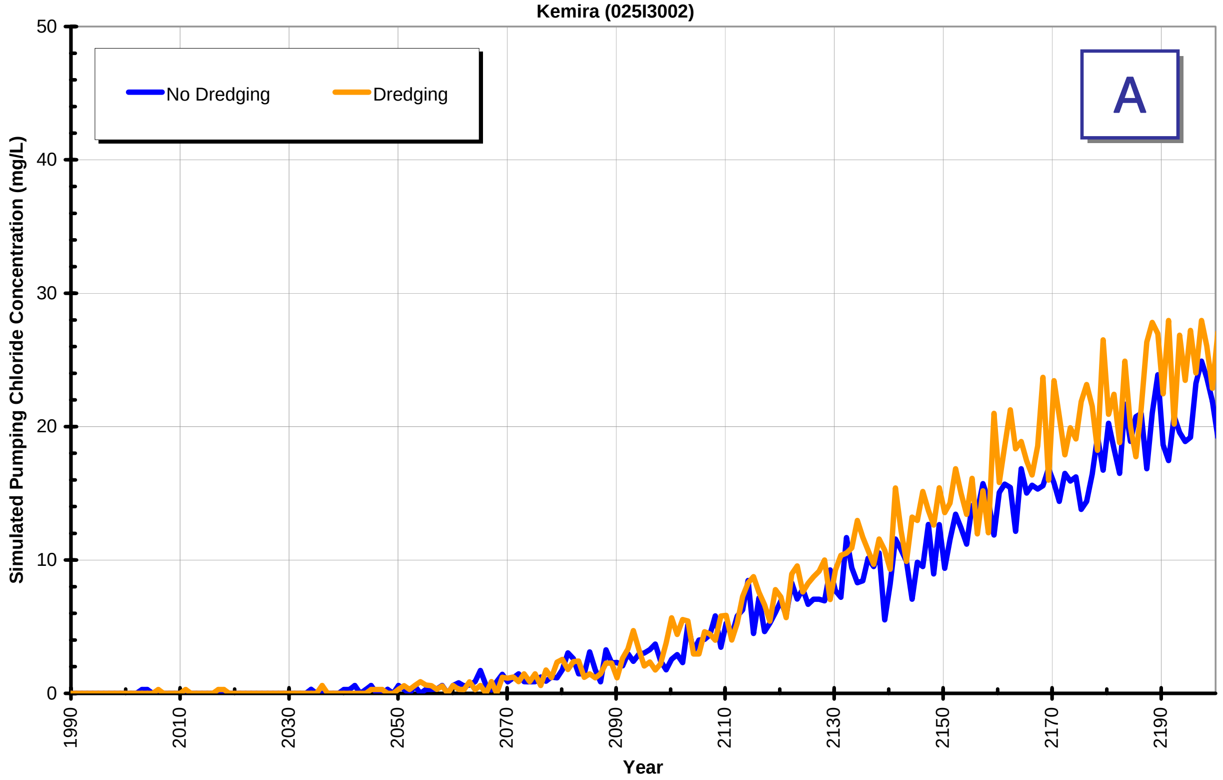


Figure 3-41
Pumping Well Concentrations for No Dredging and Dredging
At GAF Corp. Well (025I3501)

CDM

Savannah Harbor Expansion
Groundwater Model Studies

Comparison of Simulated Chloride Concentrations
No Dredging vs. Dredging Conditions
Kemira (025I3002)



Comparison of Simulated Chloride Concentrations
No Dredging vs. Dredging Conditions - Sensitivity (Lower Conductivity in Miocene)
Kemira (025I3002)

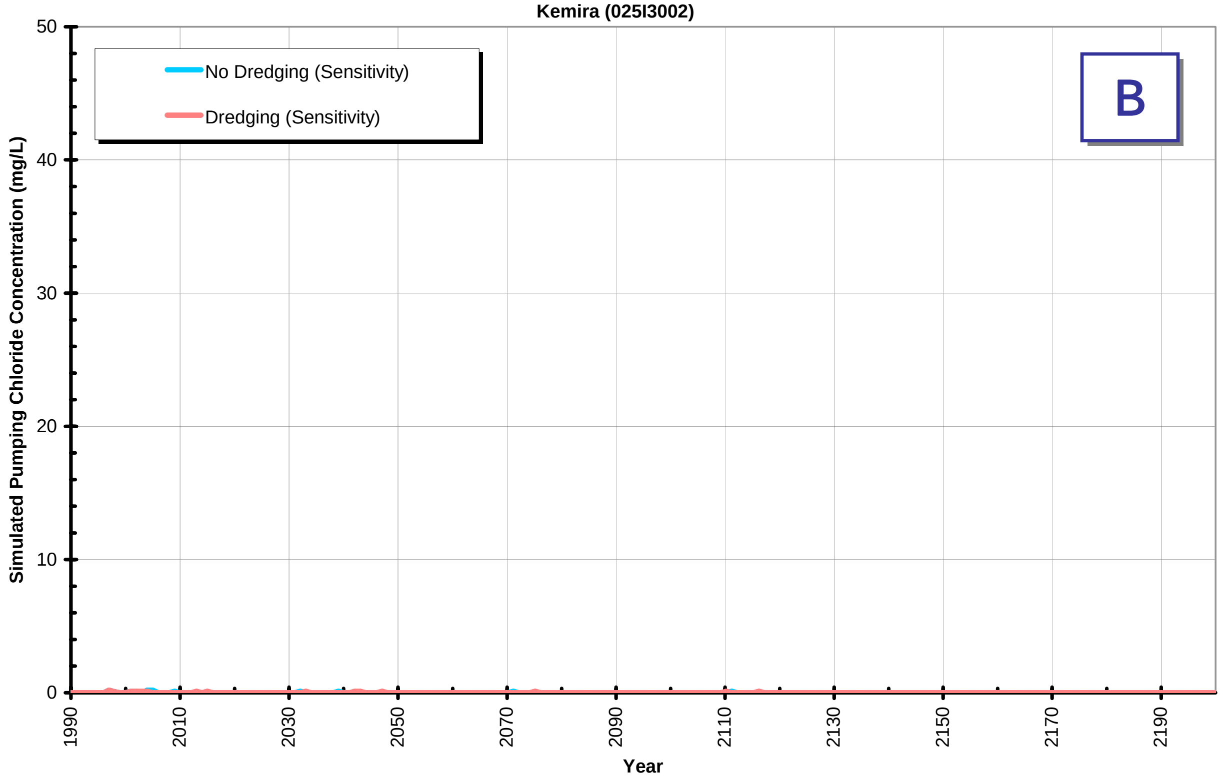
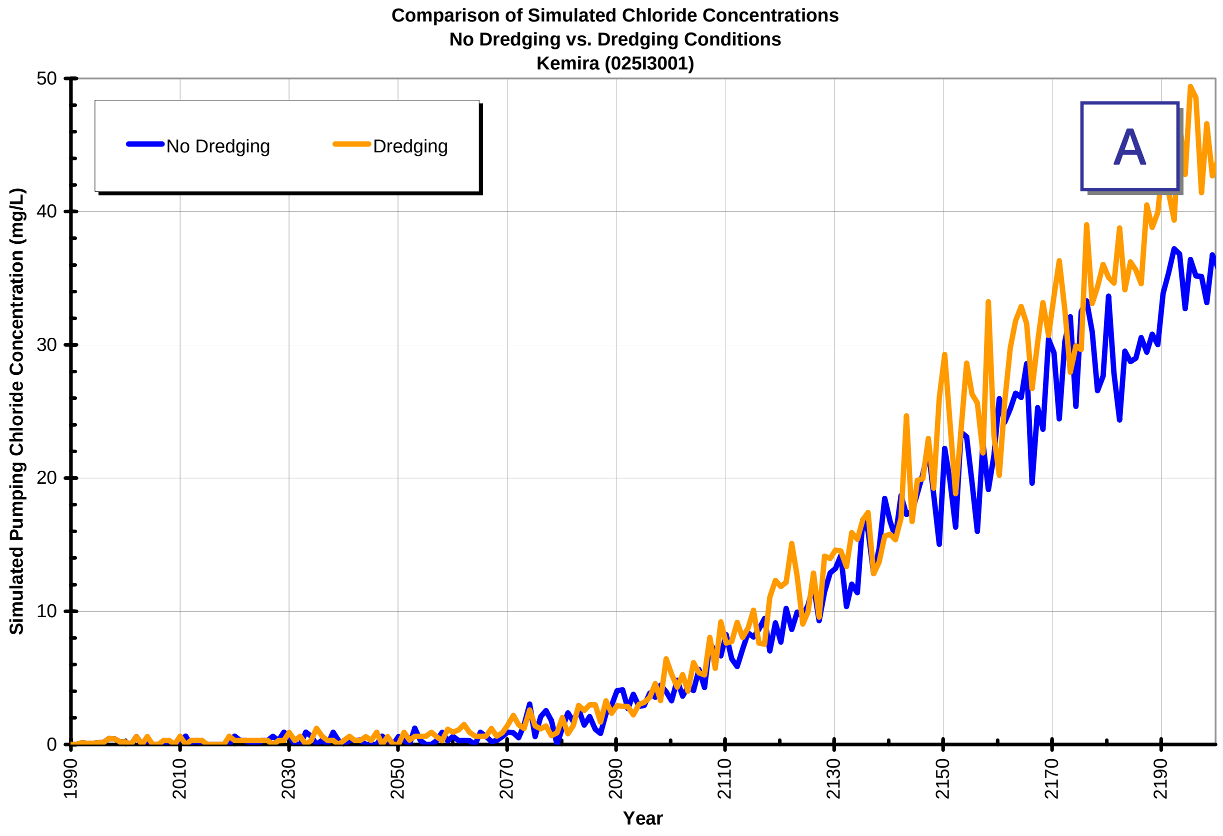


Figure 3-42
Pumping Well Concentrations for No Dredging and Dredging
At Kemira Well (025E3002)

Savannah Harbor Expansion
Groundwater Model Studies



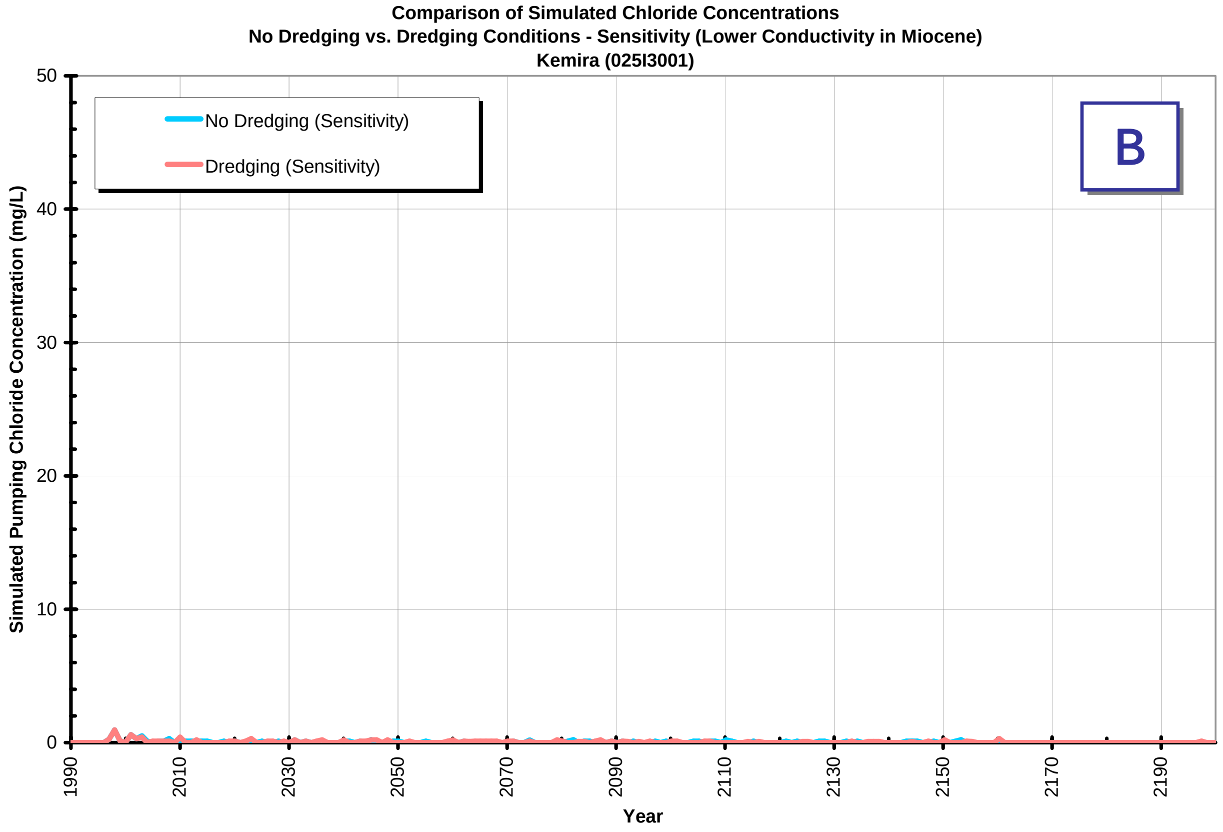


Figure 3-43
Pumping Well Concentrations for No Dredging and Dredging
At Kemira Well (025I3001)

CDM

Savannah Harbor Expansion
Groundwater Model Studies

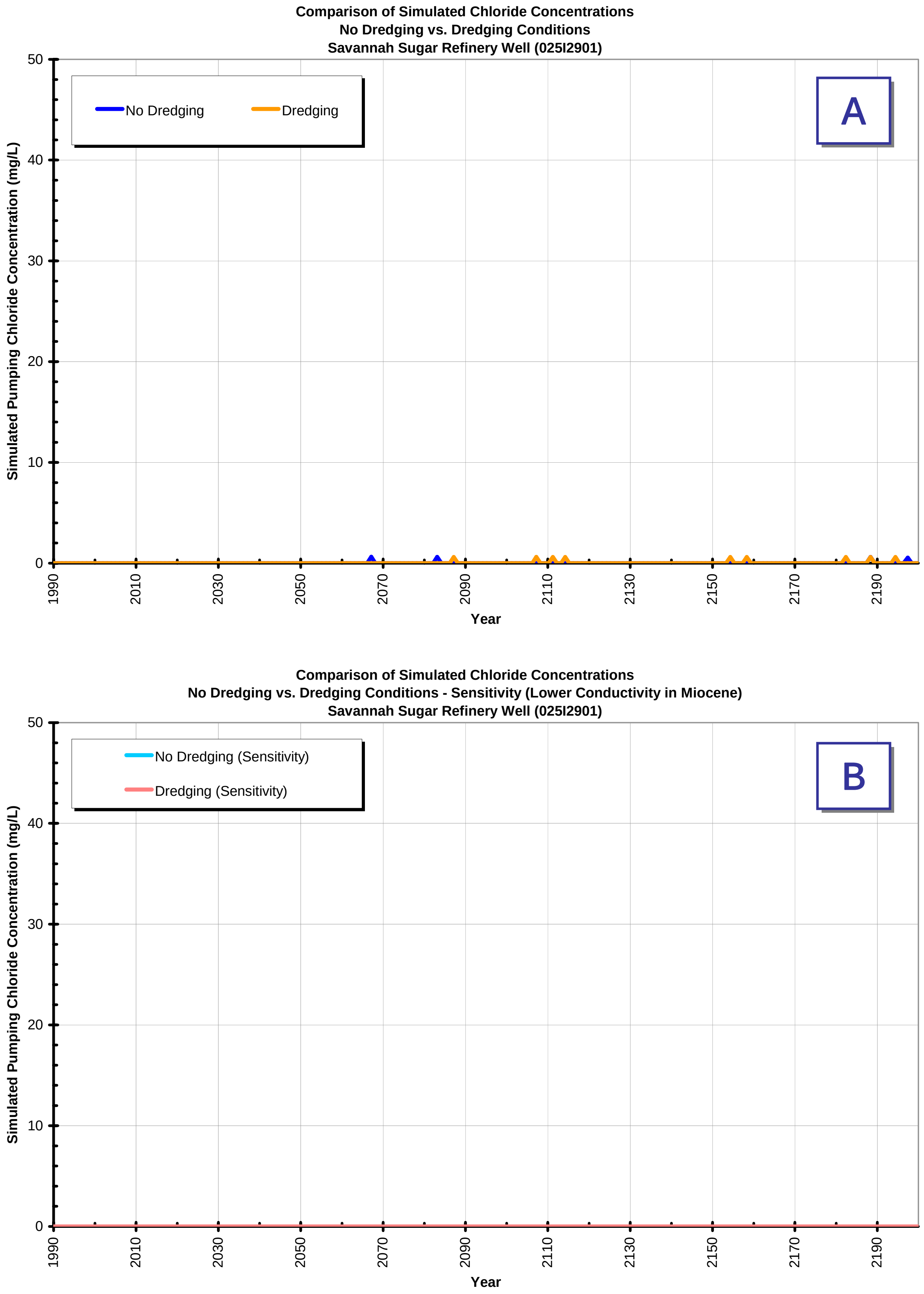


Figure 3-44
Pumping Well Concentrations for No Dredging and Dredging
At Savannah Sugar Refinery Well (025I2901)

Savannah Harbor Expansion
Groundwater Model Studies

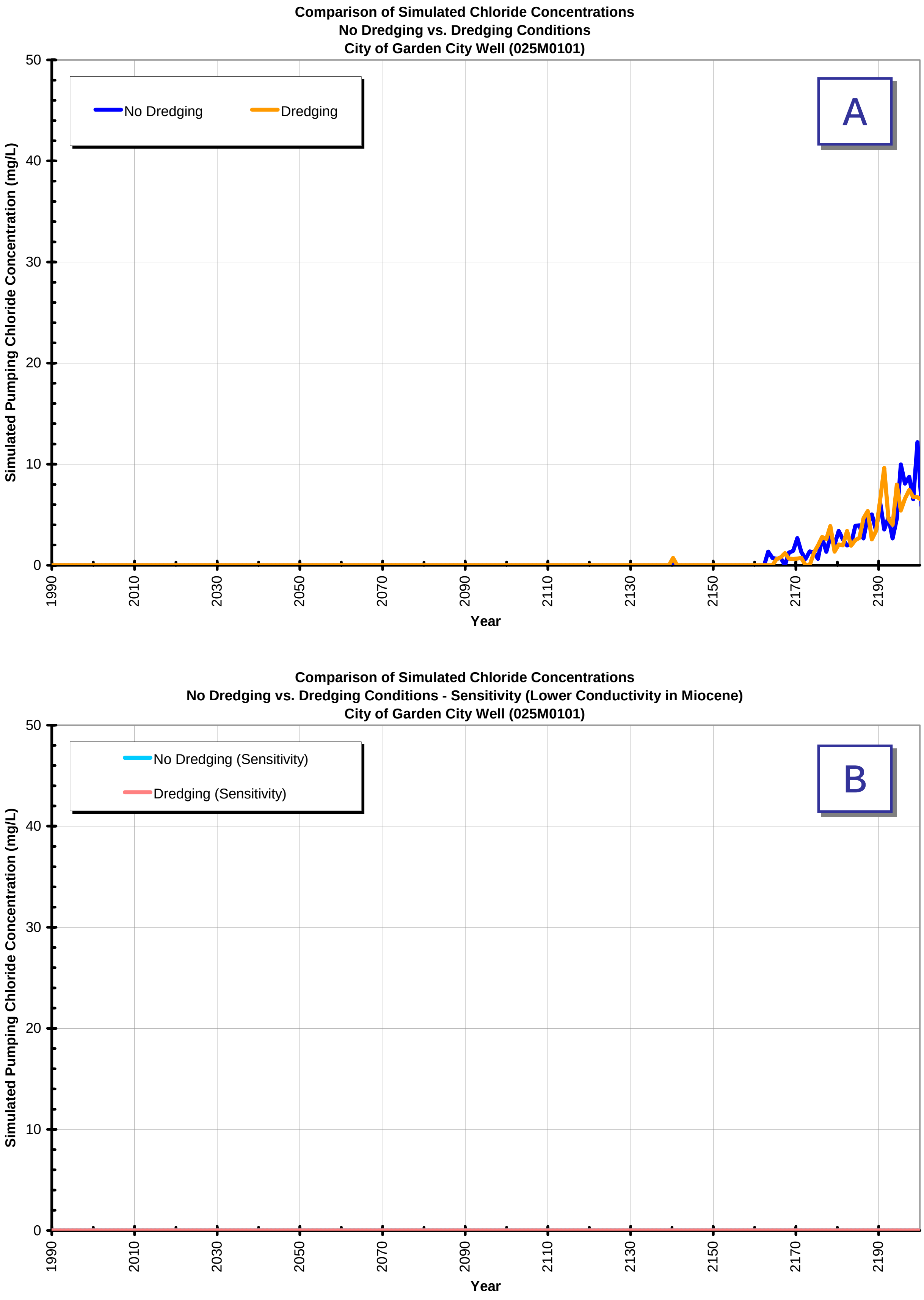
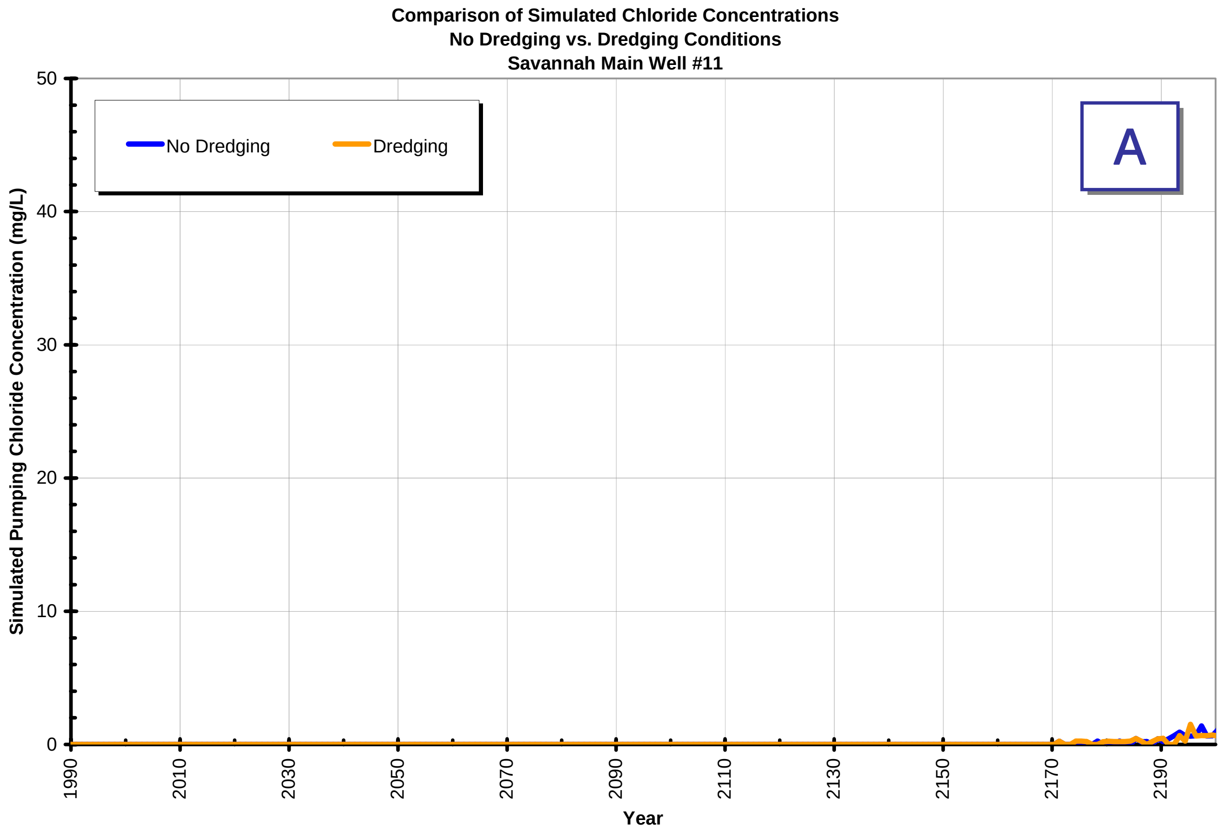


Figure 3-45
Pumping Well Concentrations for No Dredging and Dredging
At City of Garden City Well (025M0101)

Savannah Harbor Expansion
Groundwater Model Studies

CDM



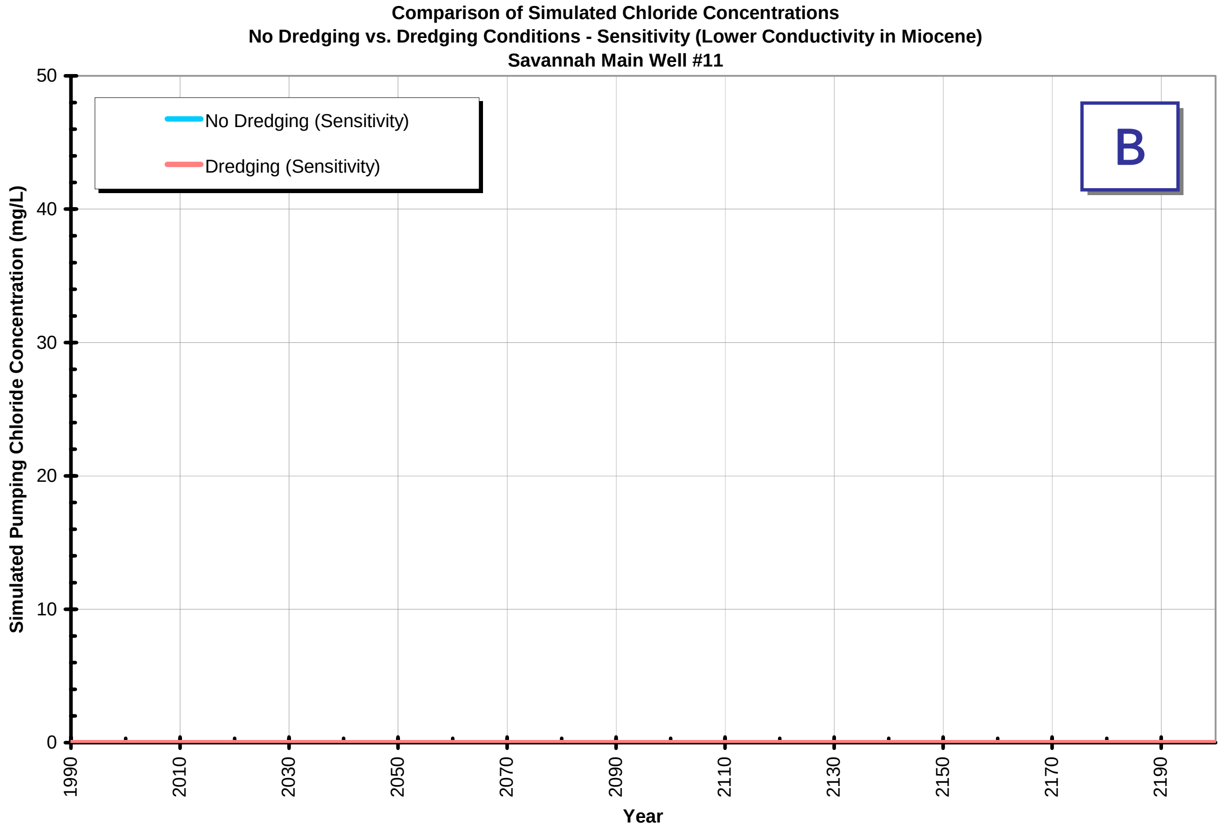
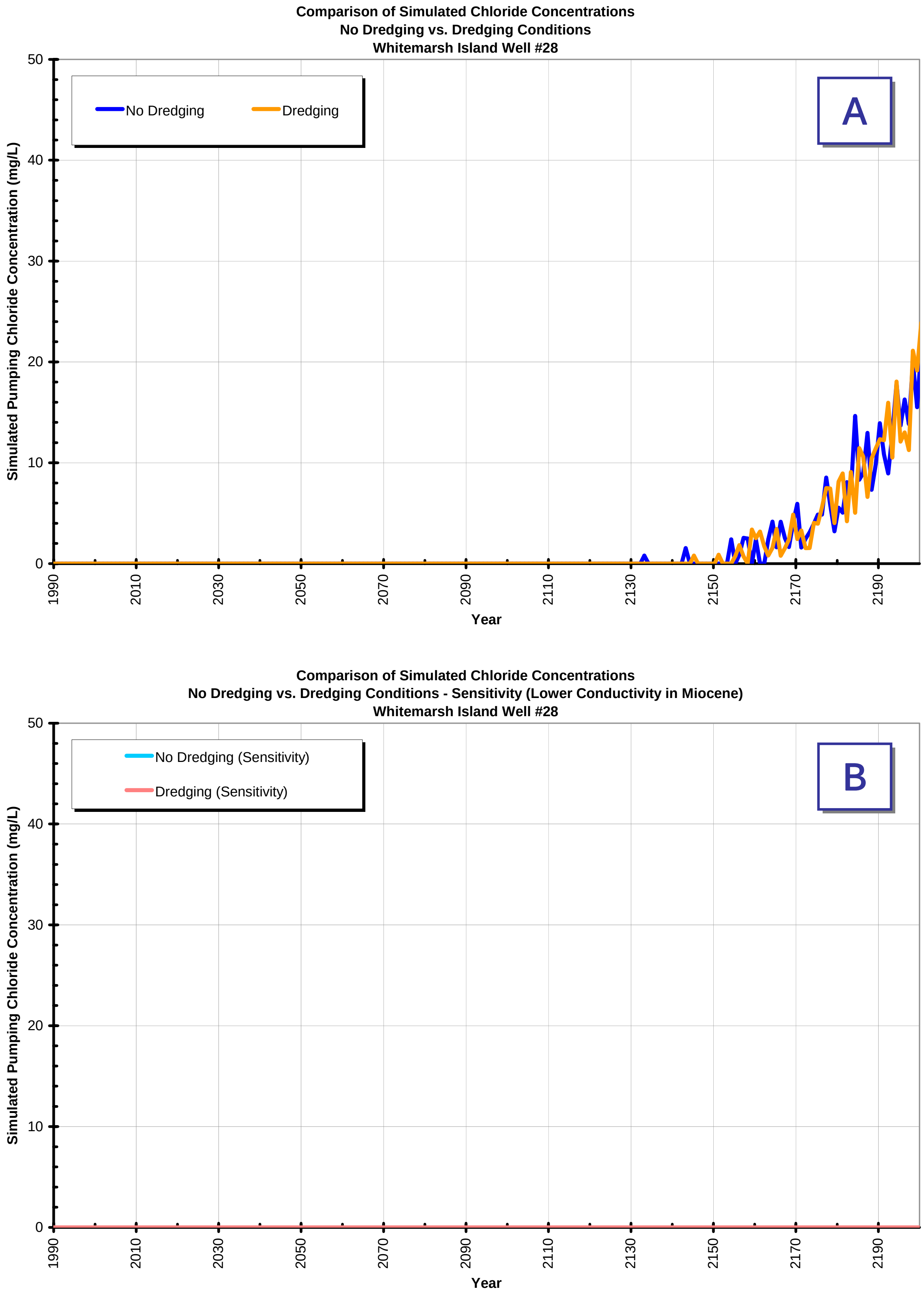


Figure 3-46
Pumping Well Concentrations for No Dredging and Dredging
At Savannah Main Well #11

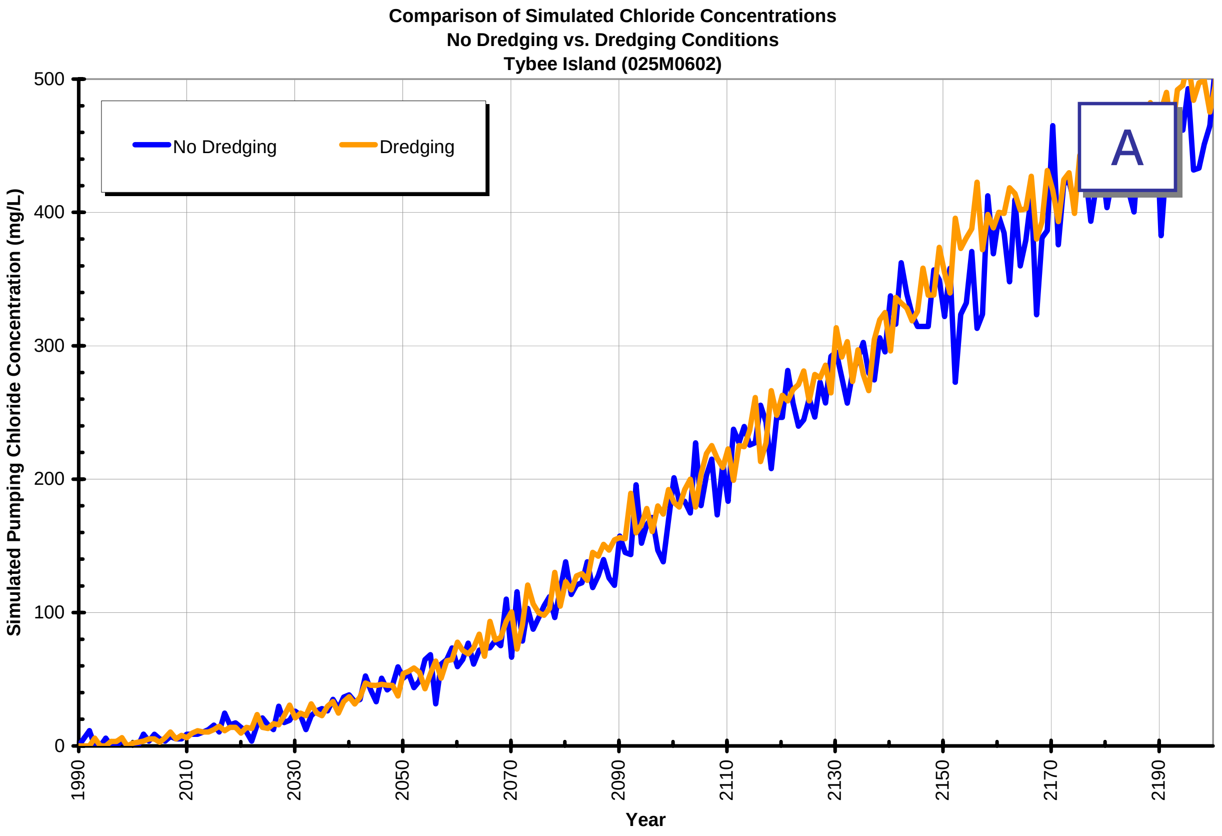
Savannah Harbor Expansion
Groundwater Model Studies


Comparison of Simulated Chloride Concentrations
No Dredging vs. Dredging Conditions
Whitemarsh Island Well #28

Comparison of Simulated Chloride Concentrations
No Dredging vs. Dredging Conditions - Sensitivity (Lower Conductivity in Miocene)
Whitemarsh Island Well #28

Figure 3-47
Pumping Well Concentrations for No Dredging and Dredging
At Whitemarsh Island Well #28

Savannah Harbor Expansion
Groundwater Model Studies



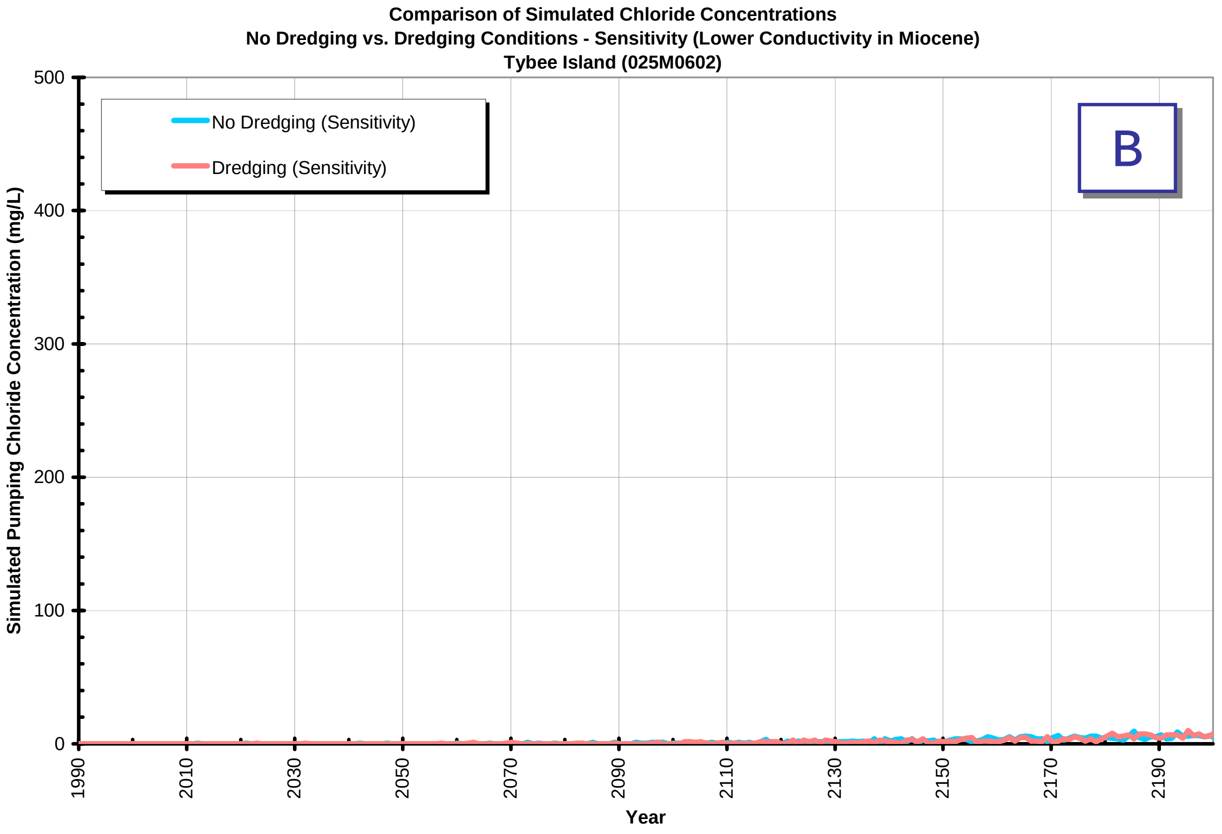


Figure 3-48
Pumping Well Concentrations for No Dredging and Dredging
At Tybee Island (025M0602)

CDM

Savannah Harbor Expansion
Groundwater Model Studies

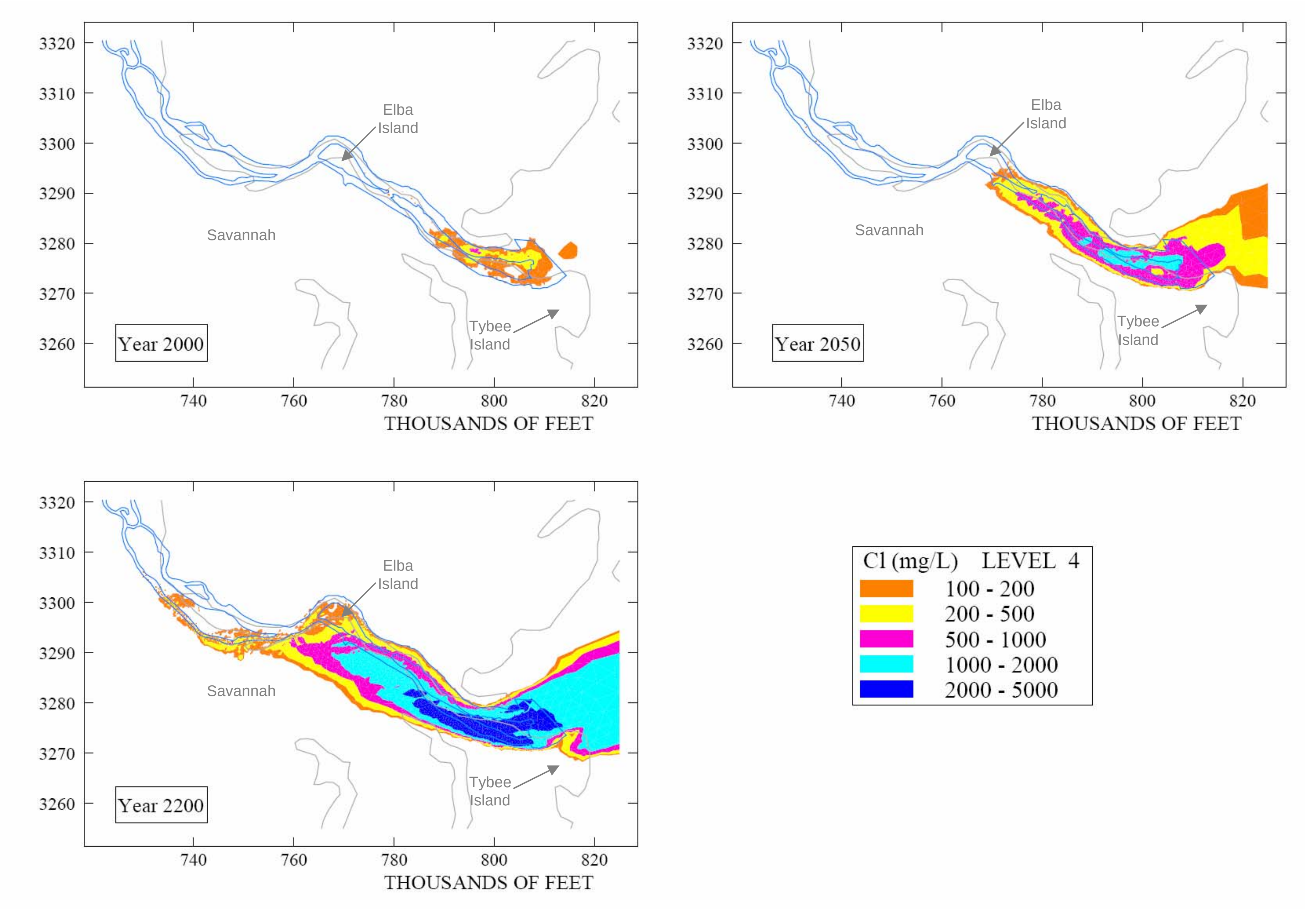


Figure 3-49
Plan View of Concentrations in the Upper Floridan – Year (2000, 2050 and 2200) No Dredging

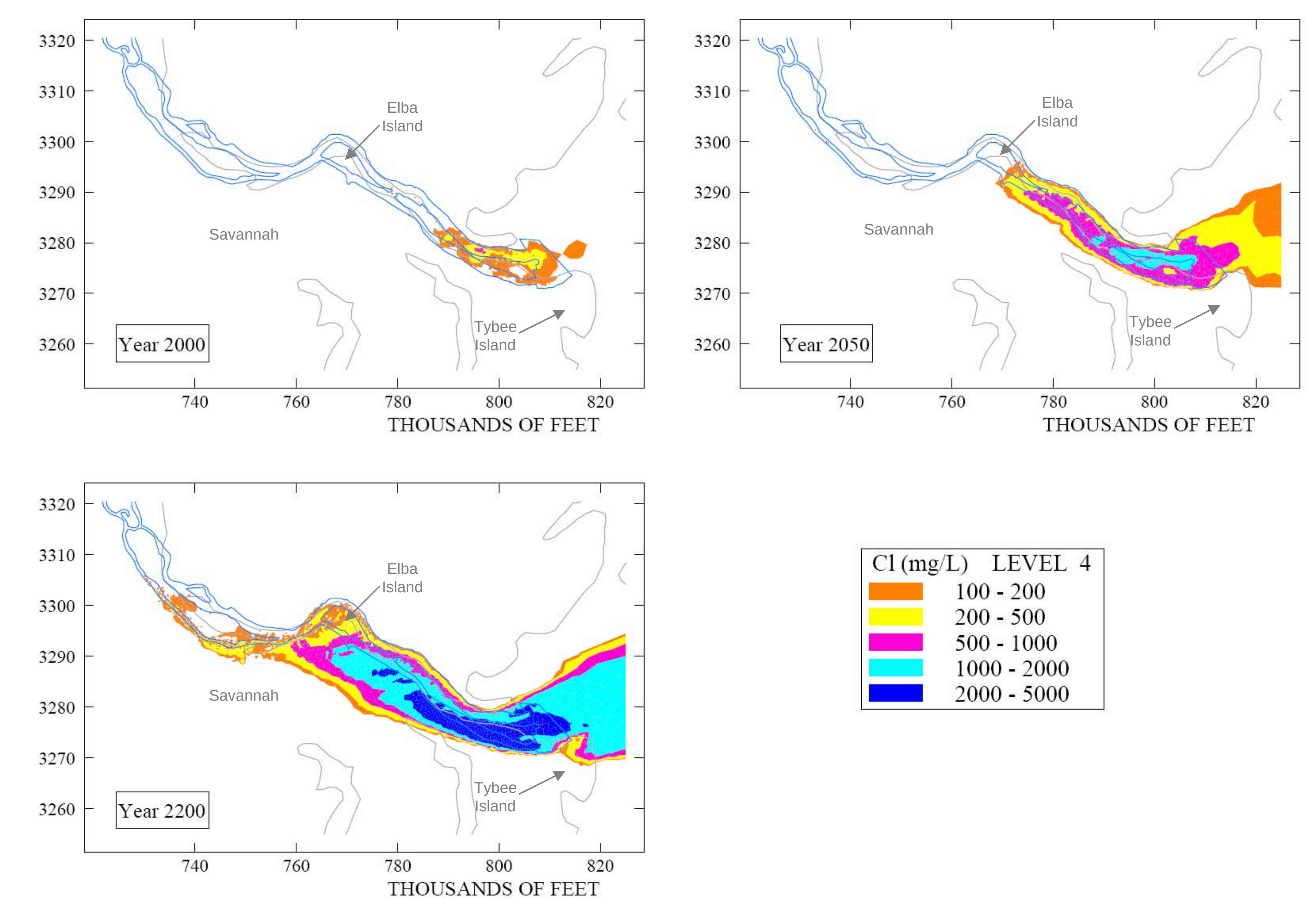


Figure 3-50
Plan View of Concentrations in the Upper Floridan – Year (2000, 2050 and 2200) Dredging

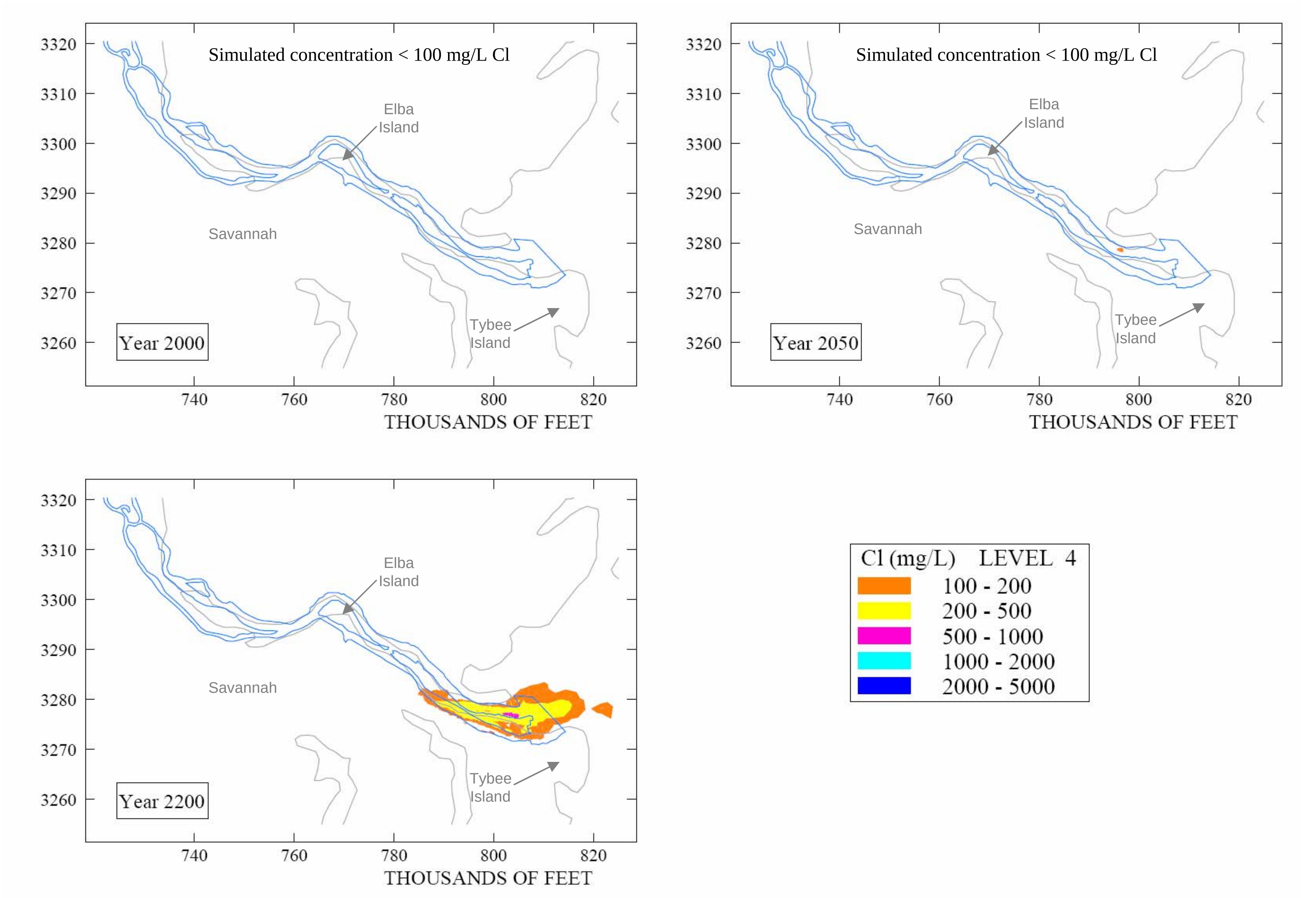


Figure 3-51
Plan View of Concentrations in the Upper Floridan – Year (2000, 2050 and 2200) No Dredging
Sensitivity Simulation – Lower Conductivity in Miocene

Savannah Harbor Expansion
Groundwater Model Studies

Savannah Harbor Expansion Groundwater Modeling Studies
Aquifer Performance Test Simulations

CDM conducted several simulations to evaluate the potential response in the Surficial Aquifer and Miocene Confining Unit to a long-term pumping test conducted with a well screened in the Upper Floridan Aquifer.

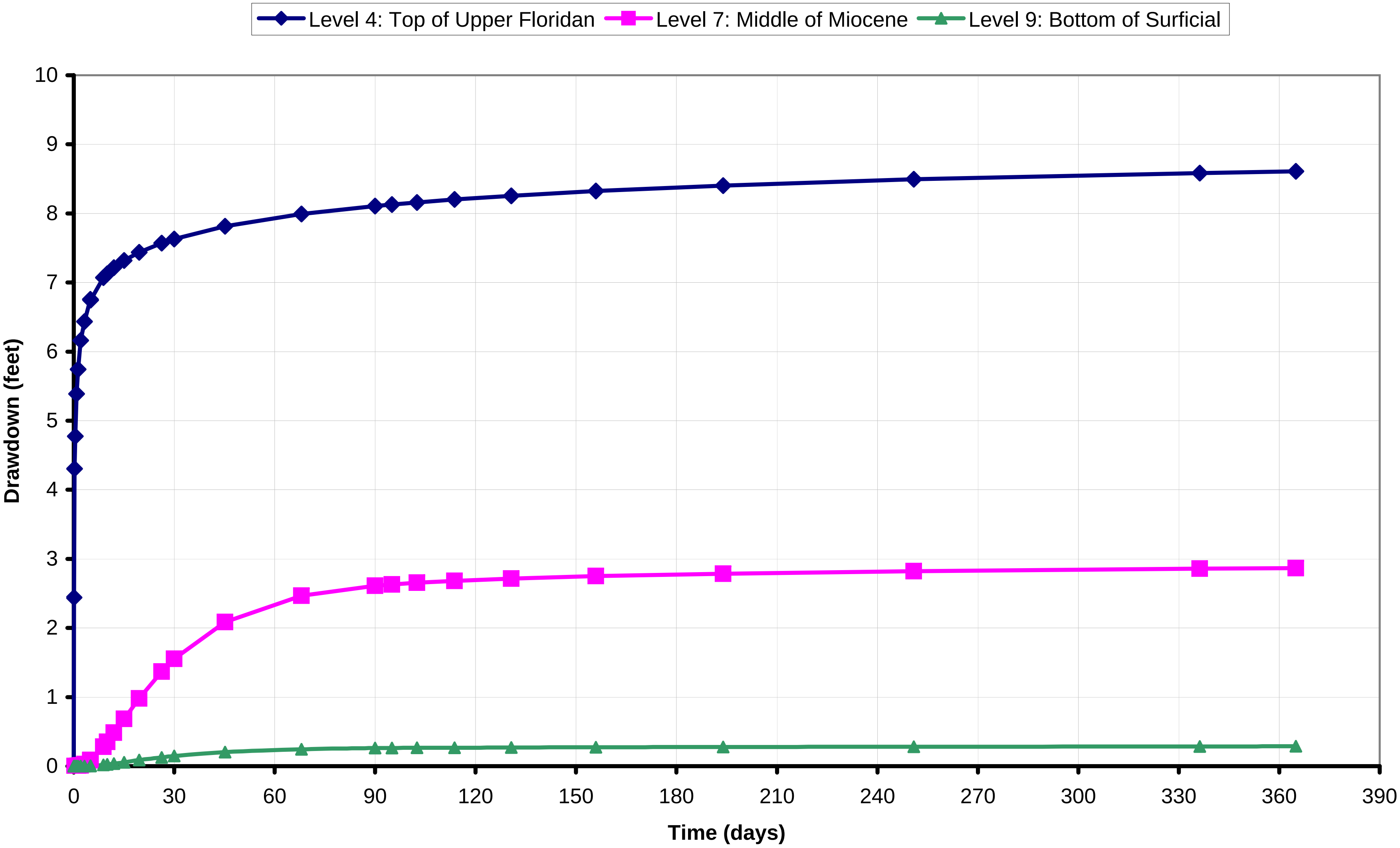
The pumping well used in the simulation was located on Tybee Island at the approximately location of the Tybee Island Test Well Cluster. Three different pumping rates (500, 1000 and 2000 gpm) were evaluated, and the simulations were run for a period of 1 year. The simulated response in observations wells at distances of 750, 1100 and 2400 feet was recorded.

At the lowest pumping rate simulated (500 gpm) the simulated drawdown in the Surficial Aquifer at the pumping well location was less than 0.5 feet after 1 year of pumping. At the observation point located 1100 feet from the pumping well the simulated response in the Surficial Aquifer was less than 0.25 feet, and in the Miocene Confining Unit the simulated response was less than 2 feet. At the observation point located 2400 feet away practically no response in the Surficial Aquifer or Miocene Confining Unit was noted.

At the highest pumping rate simulated (2000 gpm) the simulated drawdown at the pumping well location in the Surficial Aquifer was approximately 1 foot, and approximately 12 feet in the Miocene Confining Unit. At the observation point located 1100 feet from the pumping well the simulated drawdown in the Surficial Aquifer and Miocene Confining Unit was approximately 0.6 and 6 feet respectively.

Response time in the Surficial Aquifer and Miocene Confining Unit was relatively slow, with heads gradually decreasing over a period of 30 to 60 days. The slow response time and expected drawdowns of only a few inches would make it difficult to perform a pump test. The test would have to be at least two months in duration, and pump at least 1000 gpm over this period of time to develop sufficient data with which to assess the vertical hydraulic conductivity of the Miocene units.

Pump Test Simulation 1 - Simulated Piezometric Head at Pumping Well
Pumping Rate = 500 GPM



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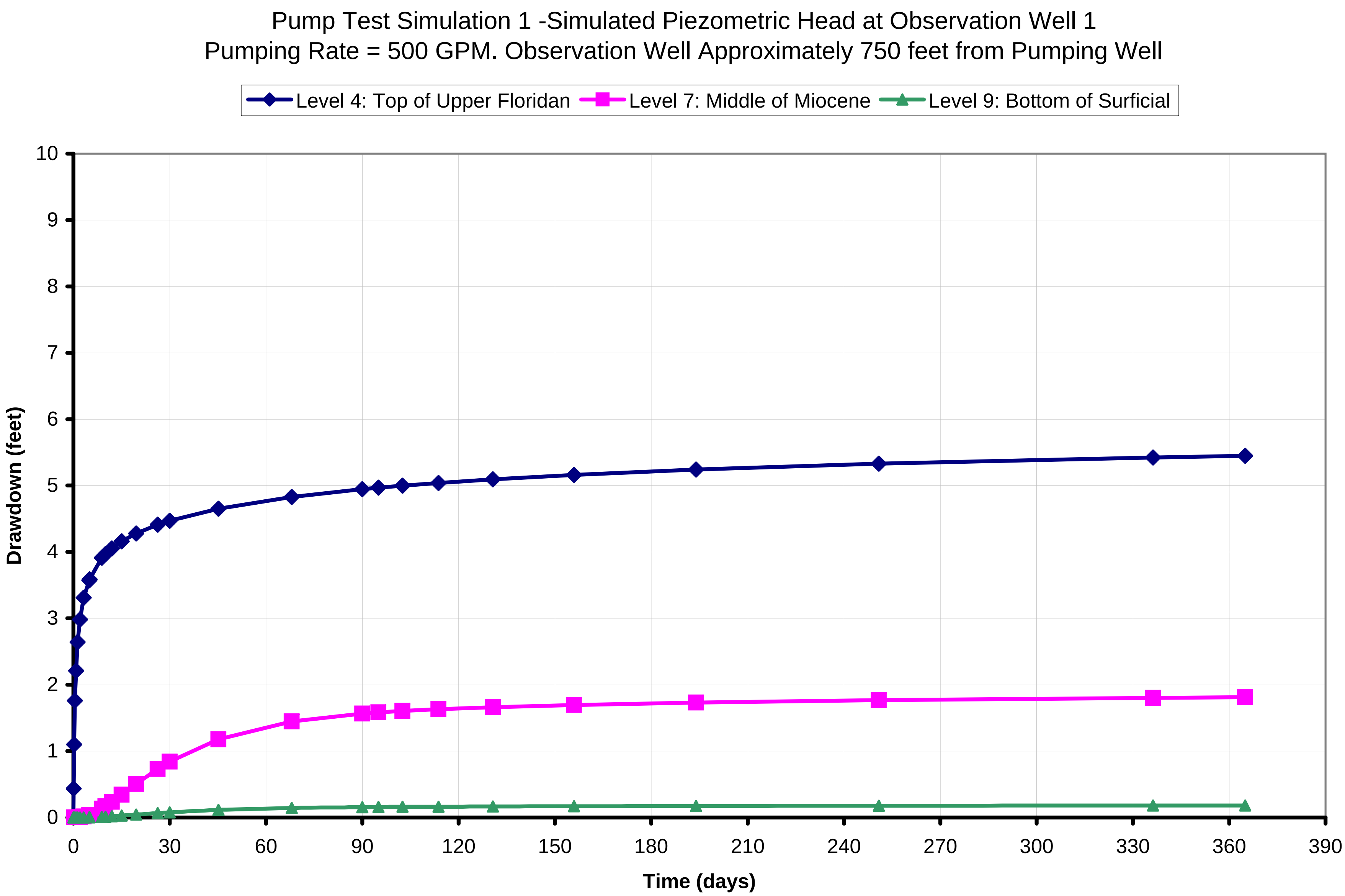
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies



Pump Test Simulation 1 -Simulated Piezometric Head at Observation Well 1
Pumping Rate = 500 GPM. Observation Well Approximately 750 feet from Pumping Well

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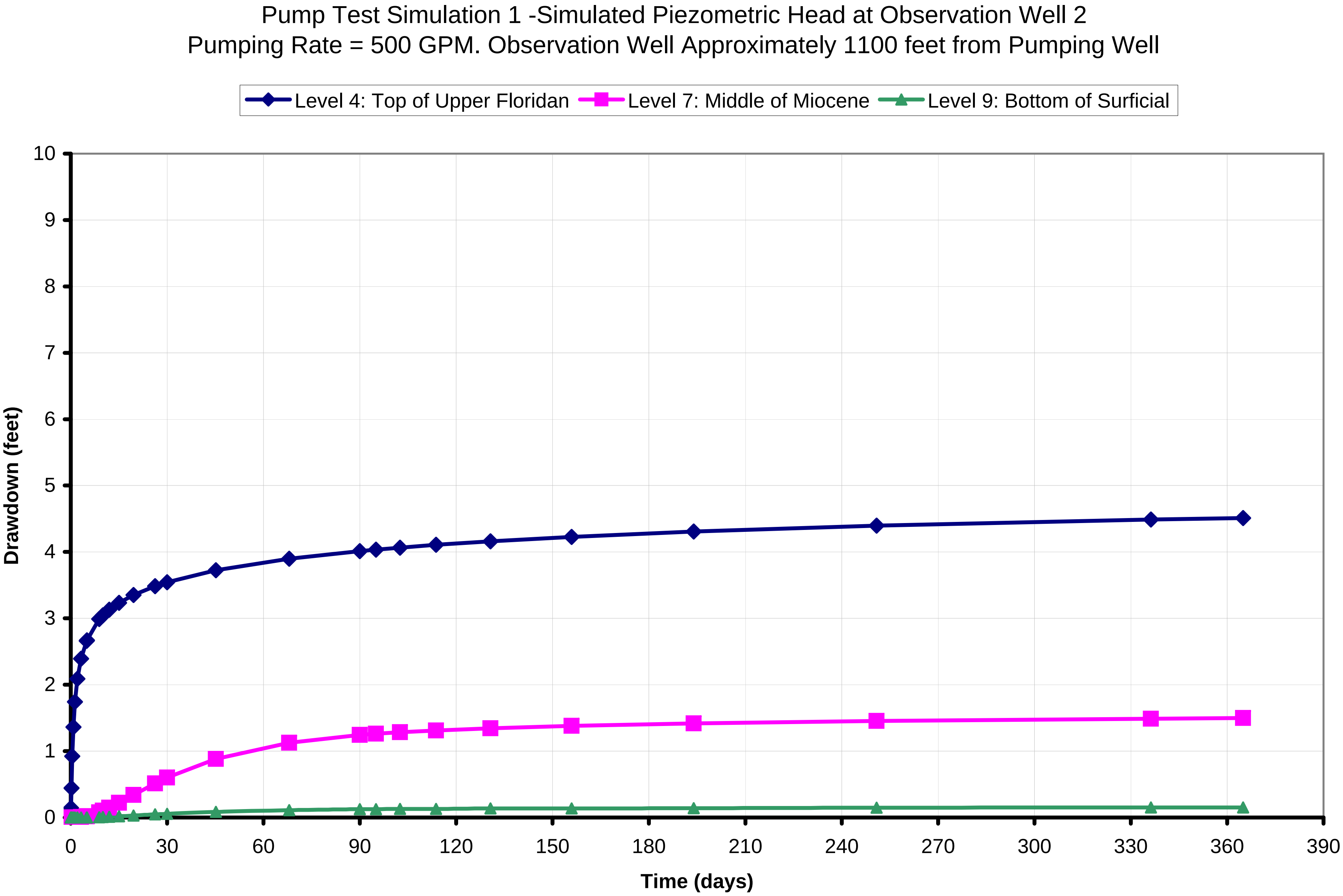
Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies



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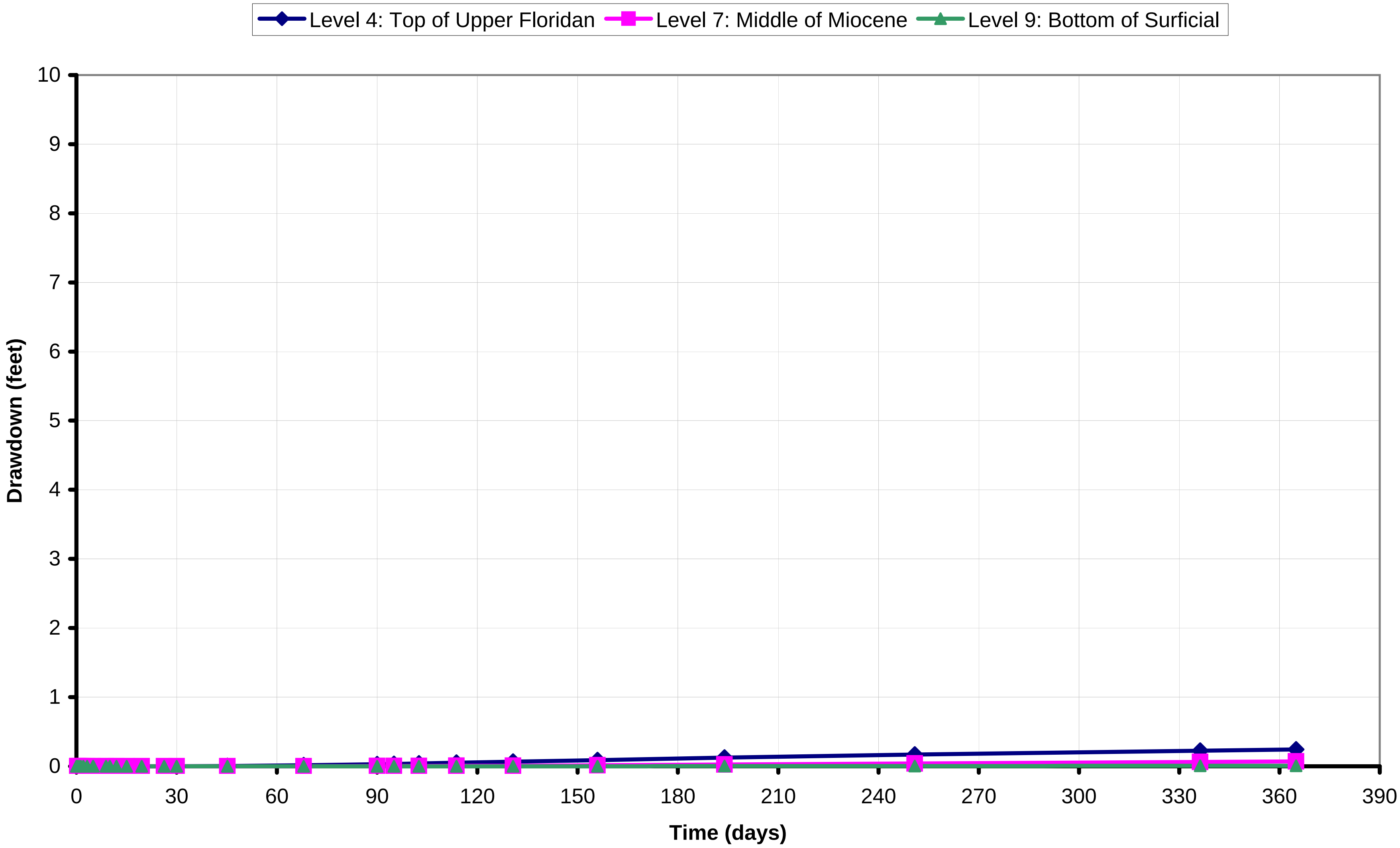
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

Pump Test Simulation 1 -Simulated Piezometric Head at Observation Well 3
Pumping Rate = 500 GPM. Observation Well Approximately 2400 feet from Pumping Well



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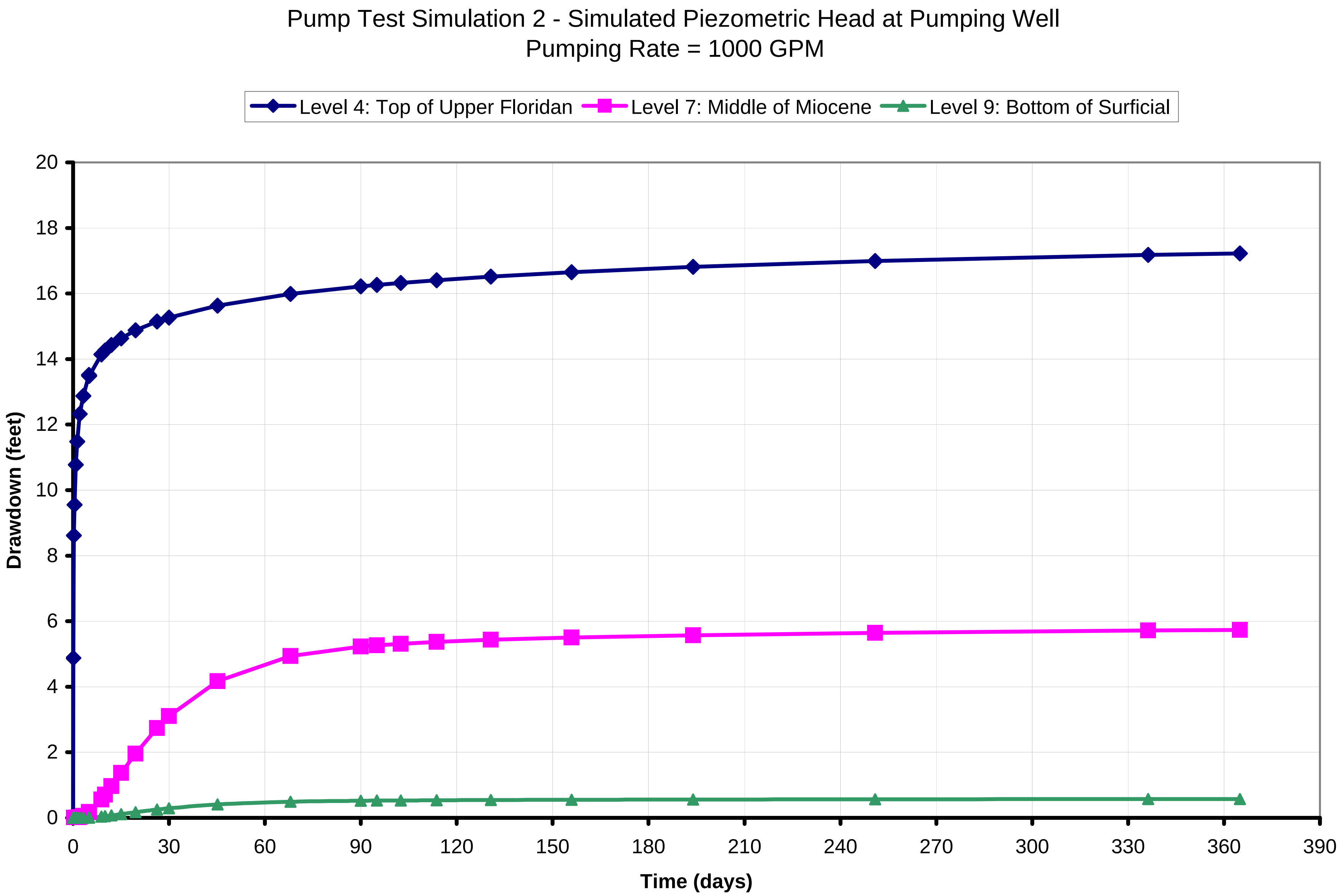
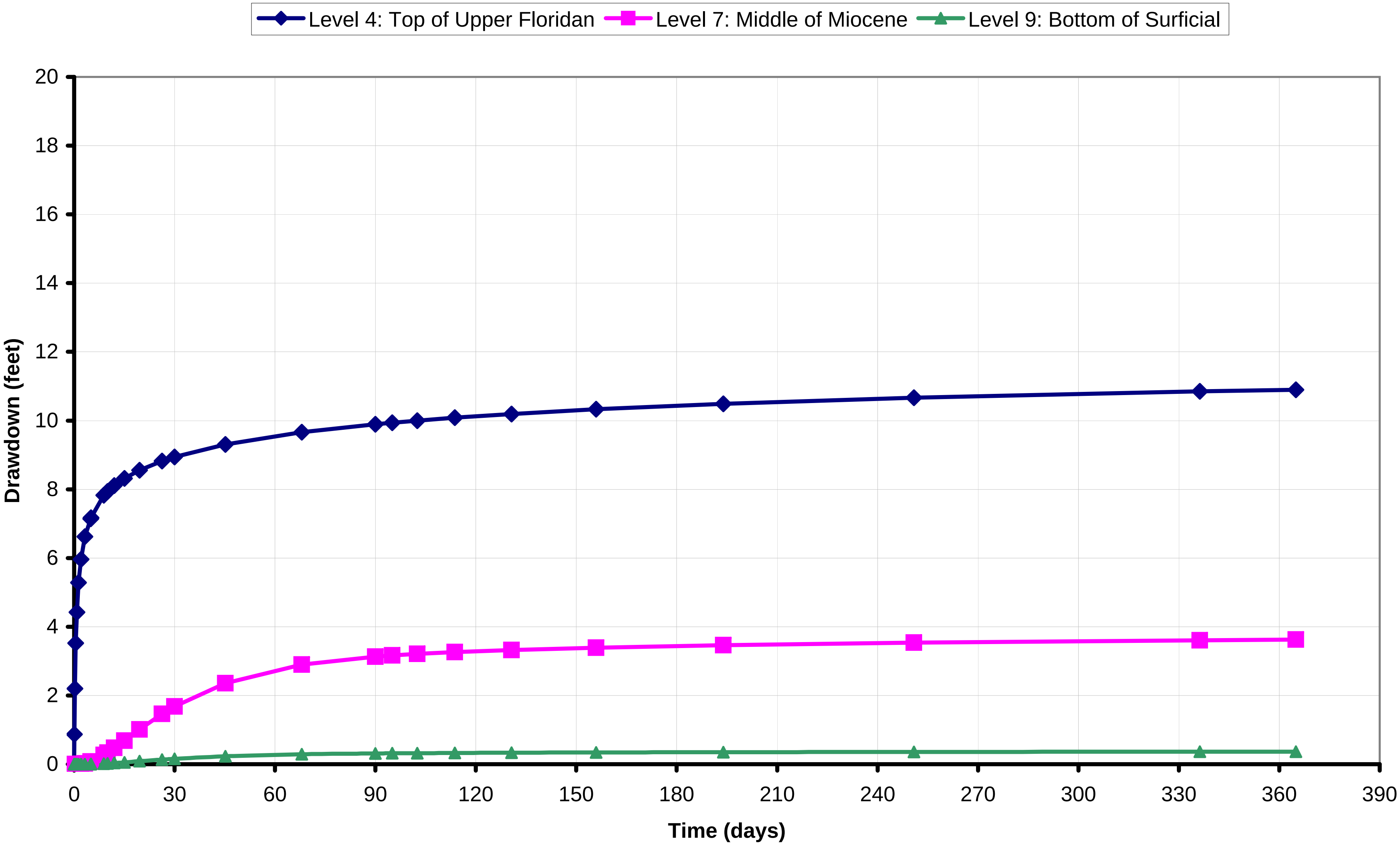
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies



Pump Test Simulation 2 - Simulated Piezometric Head at Pumping Well
Pumping Rate = 1000 GPM

Pump Test Simulation 2 -Simulated Piezometric Head at Observation Well 1
Pumping Rate = 1000 GPM. Observation Well Approximately 750 feet from Pumping Well



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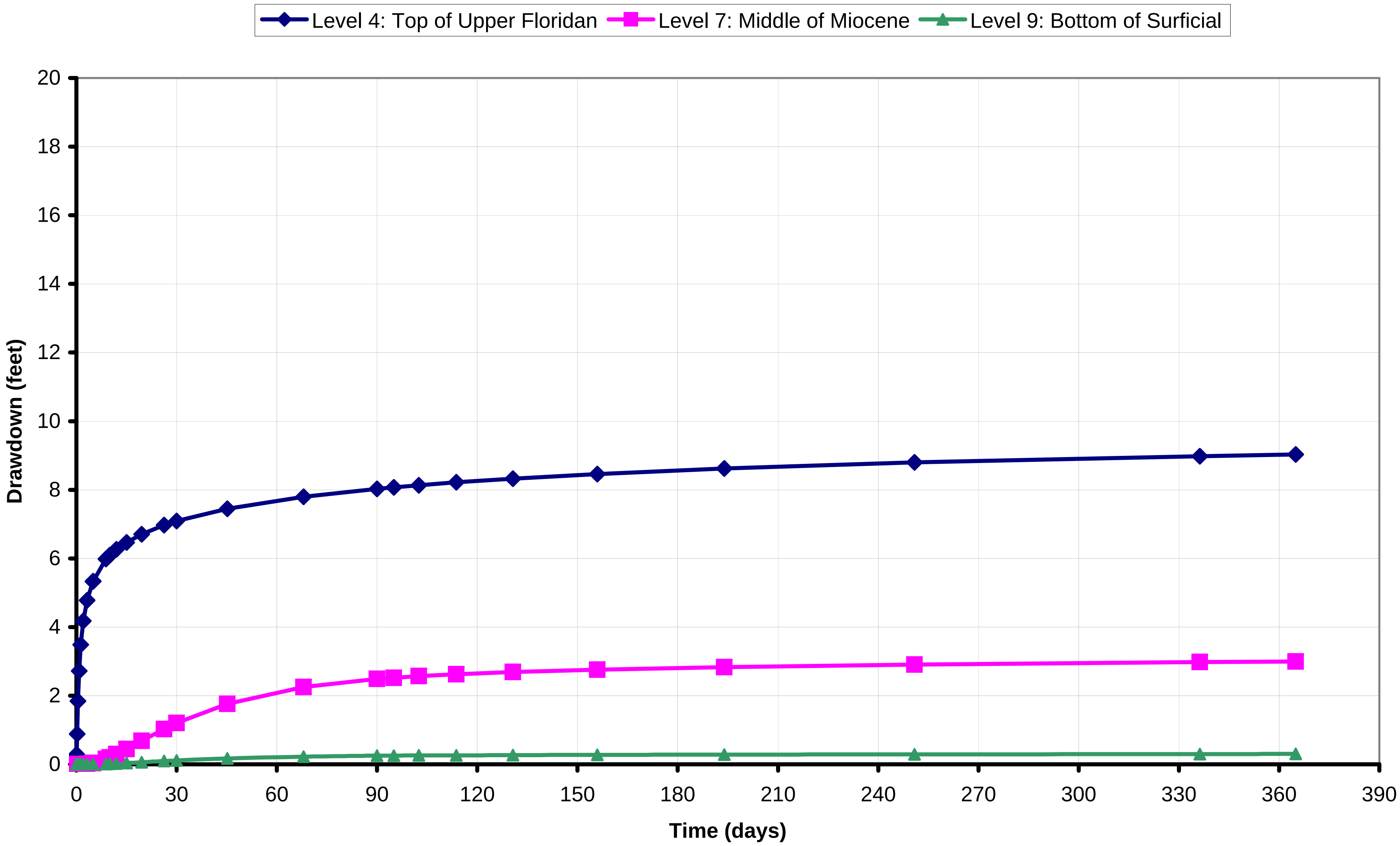
Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

Pump Test Simulation 2 -Simulated Piezometric Head at Observation Well 2
Pumping Rate = 1000 GPM. Observation Well Approximately 1100 feet from Pumping Well



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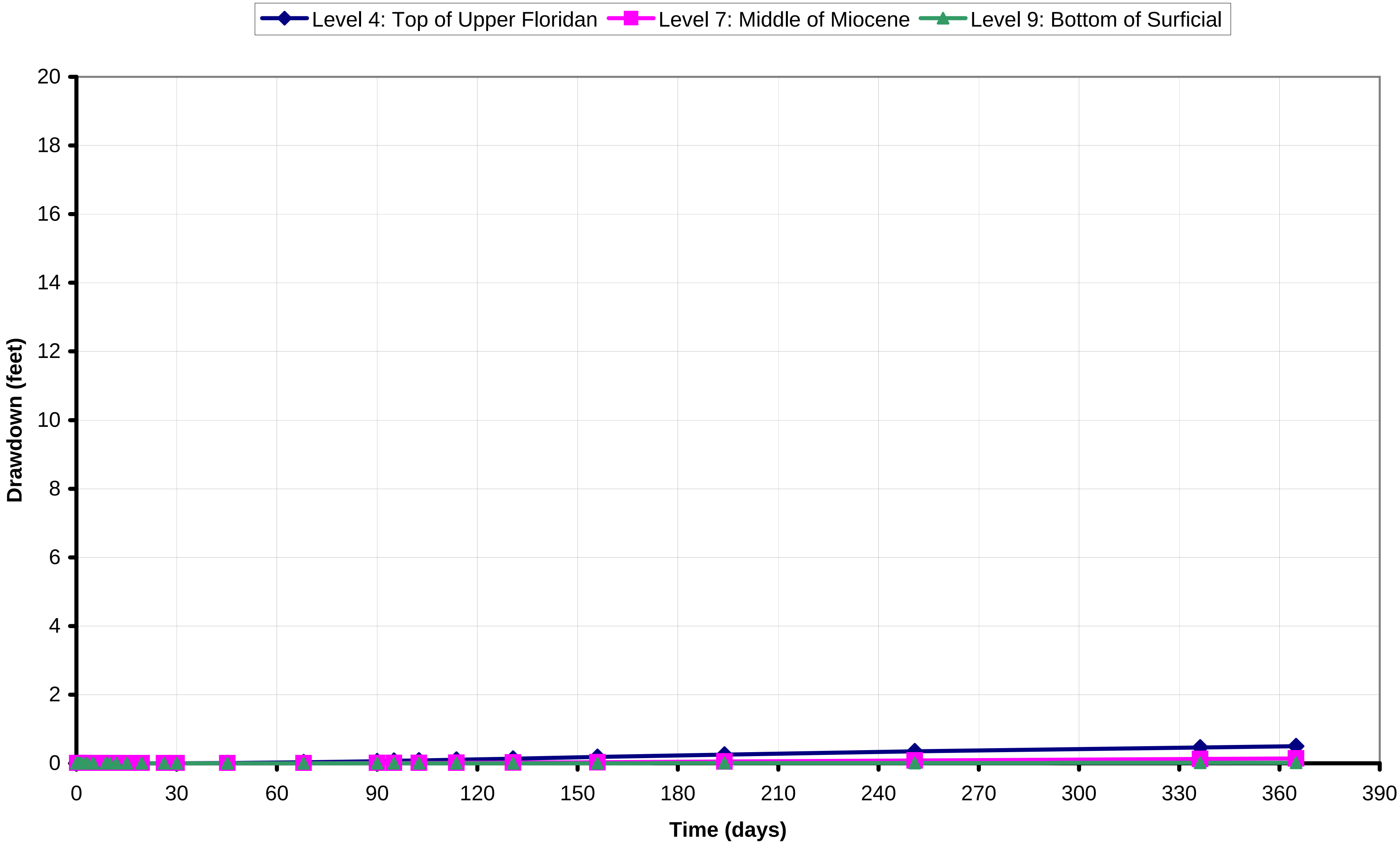
Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

Pump Test Simulation 2 -Simulated Piezometric Head at Observation Well 3
Pumping Rate = 1000 GPM. Observation Well Approximately 2400 feet from Pumping Well



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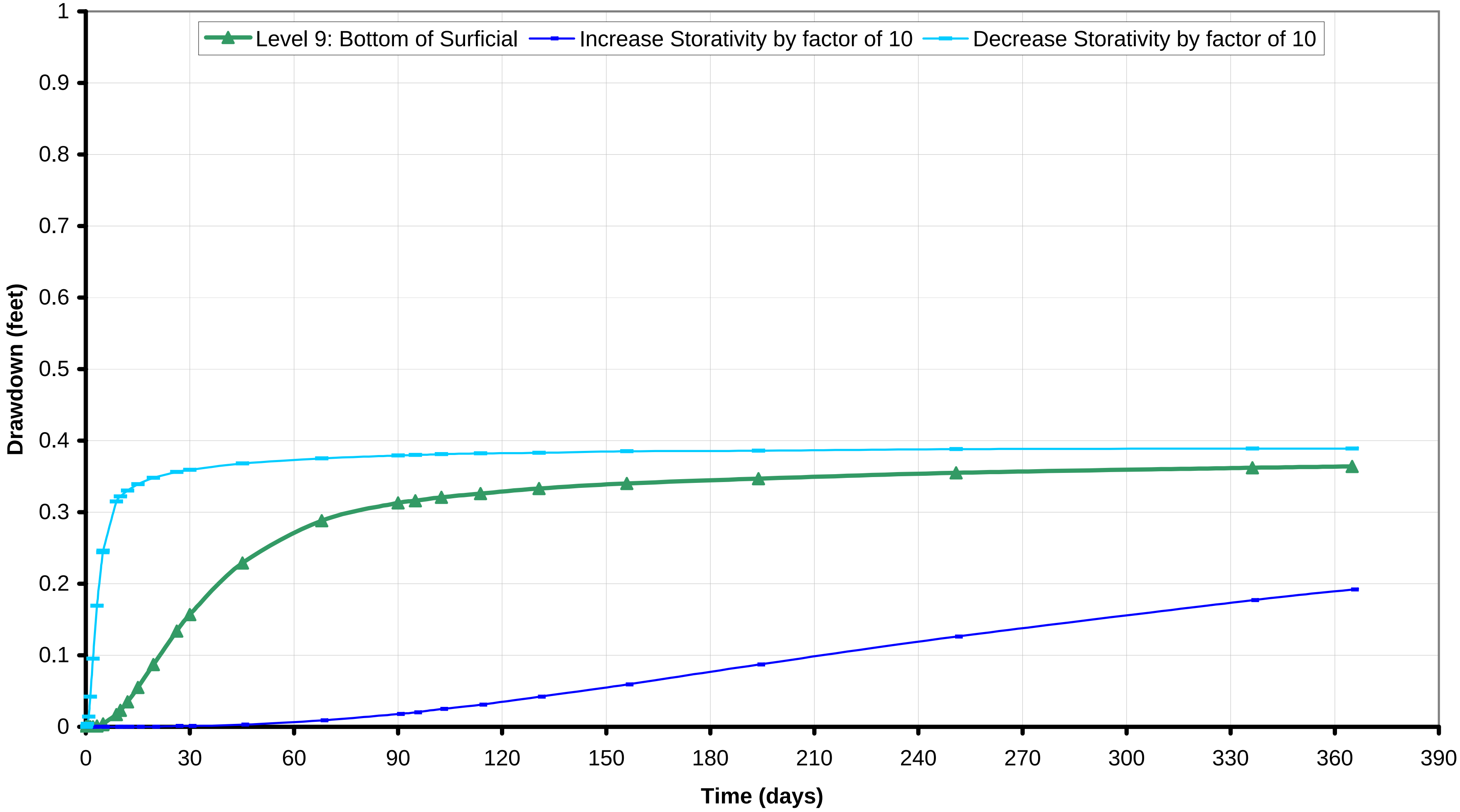
Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

Pump Test Simulation 2 and Sensivity Simulations
Simulated Piezometric Head at Observation Well 1 - Model Level 9 - Base of Surficial Aquifer
Pumping Rate = 1000 GPM. Observation Well Approximately 750 feet from Pumping Well



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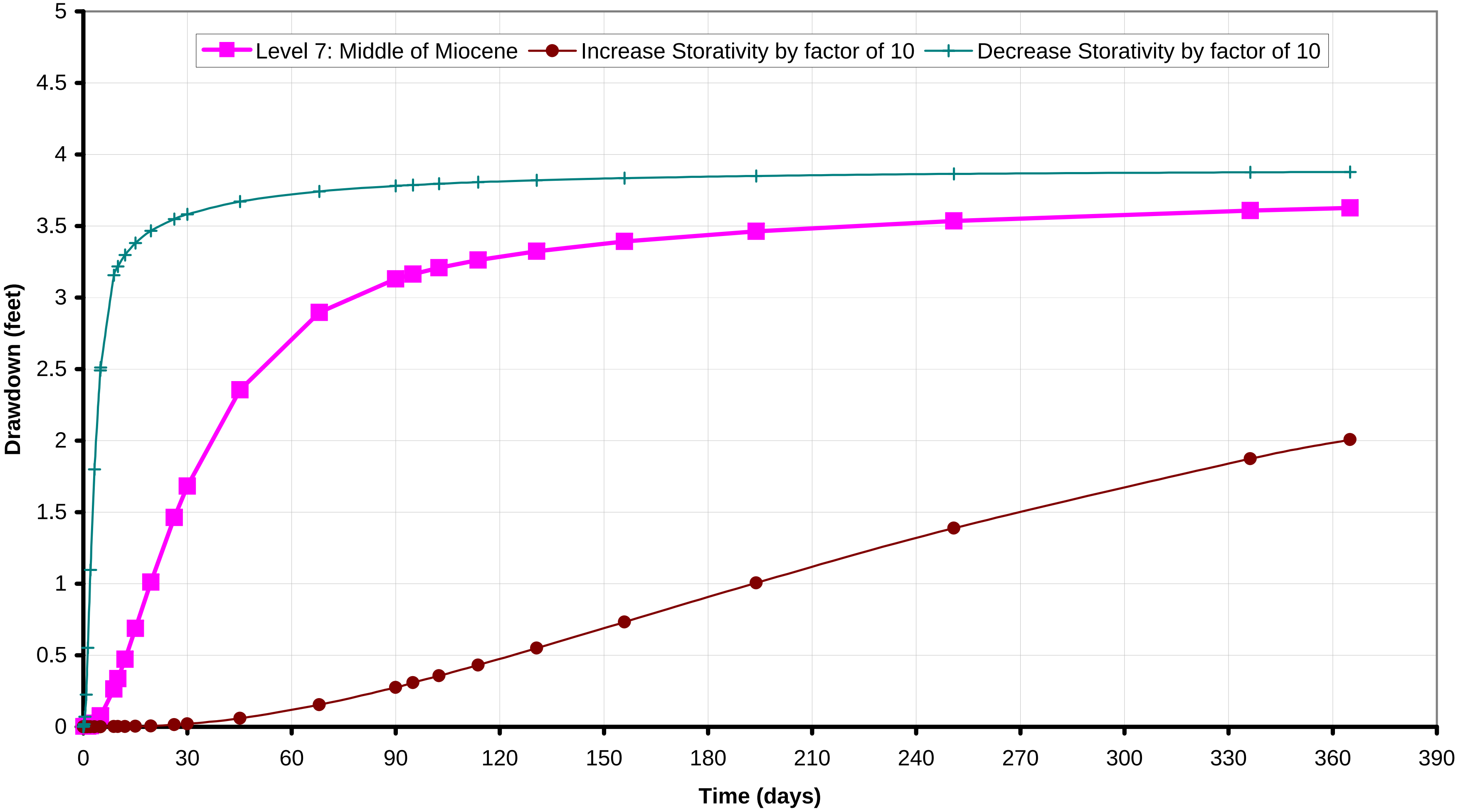
Pump Test Simulation 2 and Sensivity Simulations
Simulated Piezometric Head at Observation Well 1 - Model Level 7 - Middle of Miocene Confining
Pumping Rate = 1000 GPM. Observation Well Approximately 750 feet from Pumping Well



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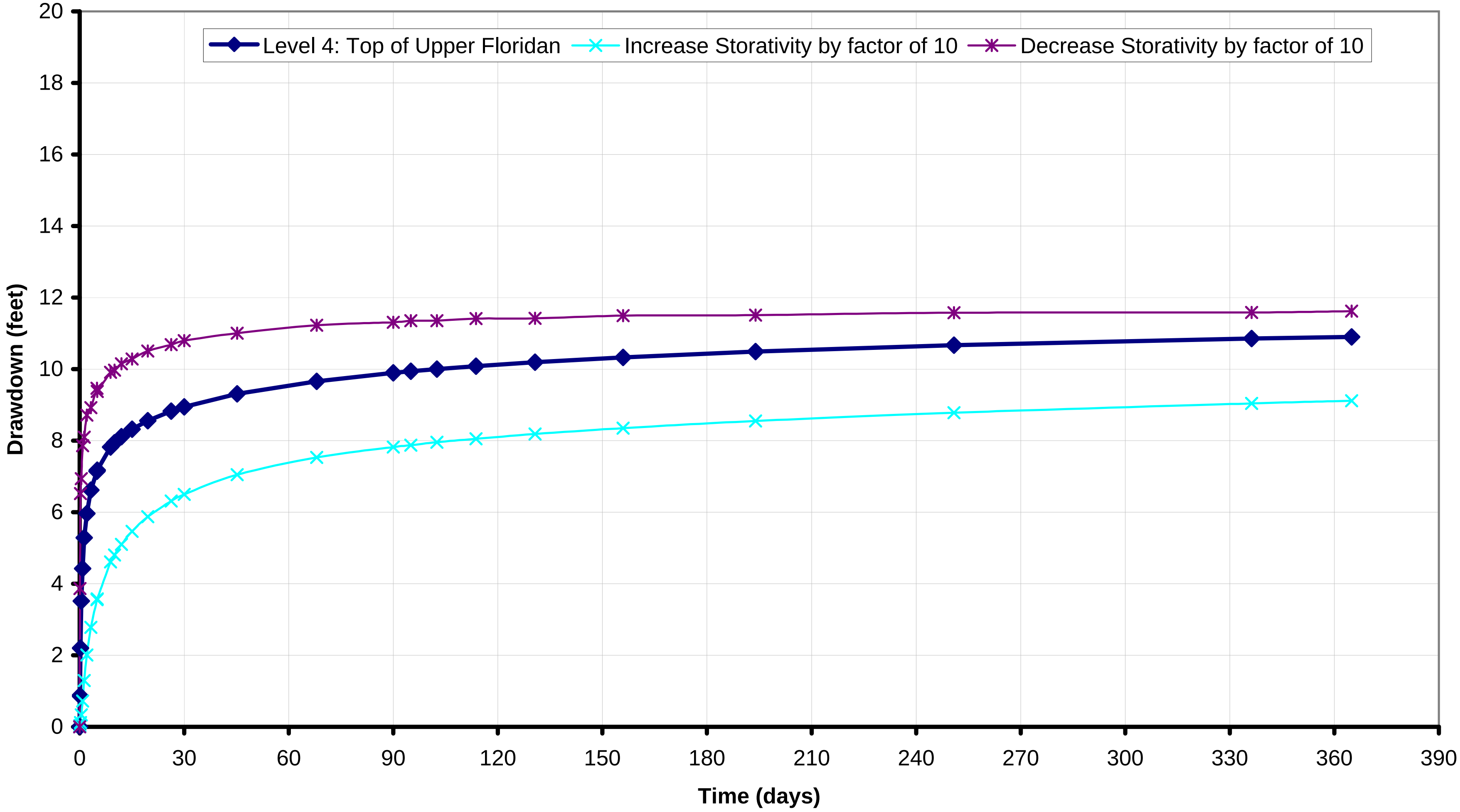
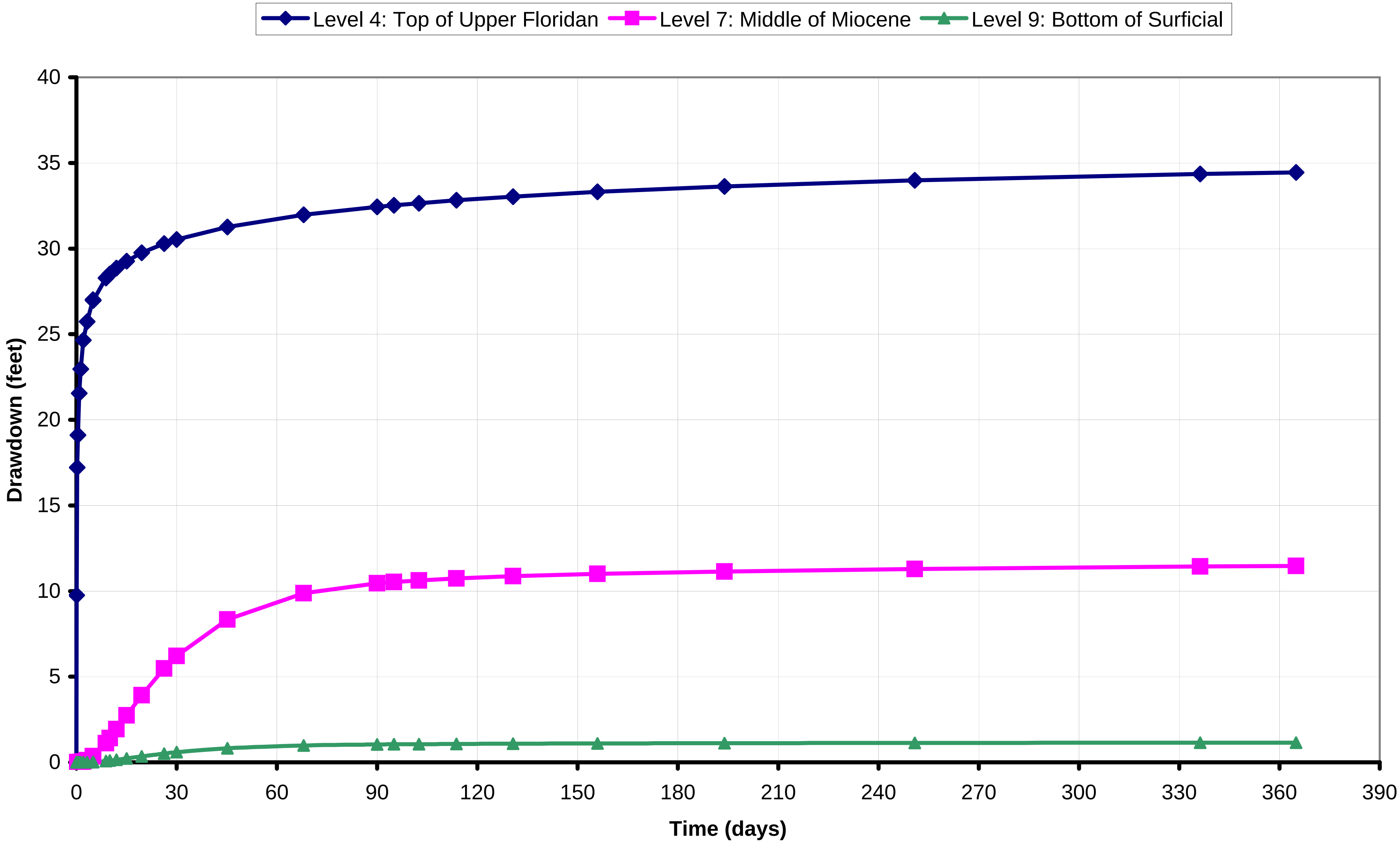
Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

Pump Test Simulation 2 and Sensivity Simulations
Simulated Piezometric Head at Observation Well 1 - Model Level 4 - Upper Floridan
Pumping Rate = 1000 GPM. Observation Well Approximately 750 feet from Pumping Well



Pump Test Simulation 3 - Simulated Piezometric Head at Pumping Well
Pumping Rate = 2000 GPM



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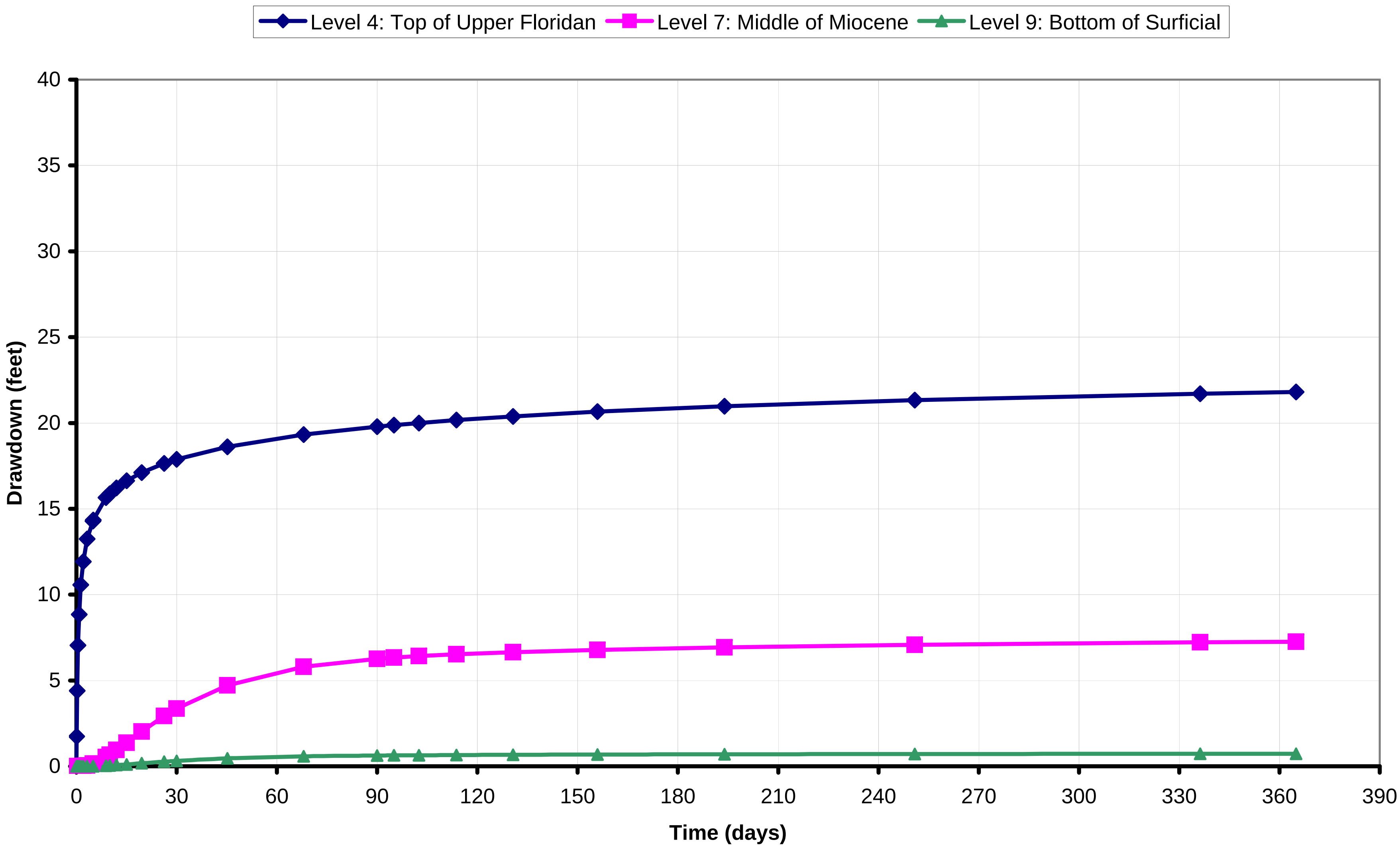
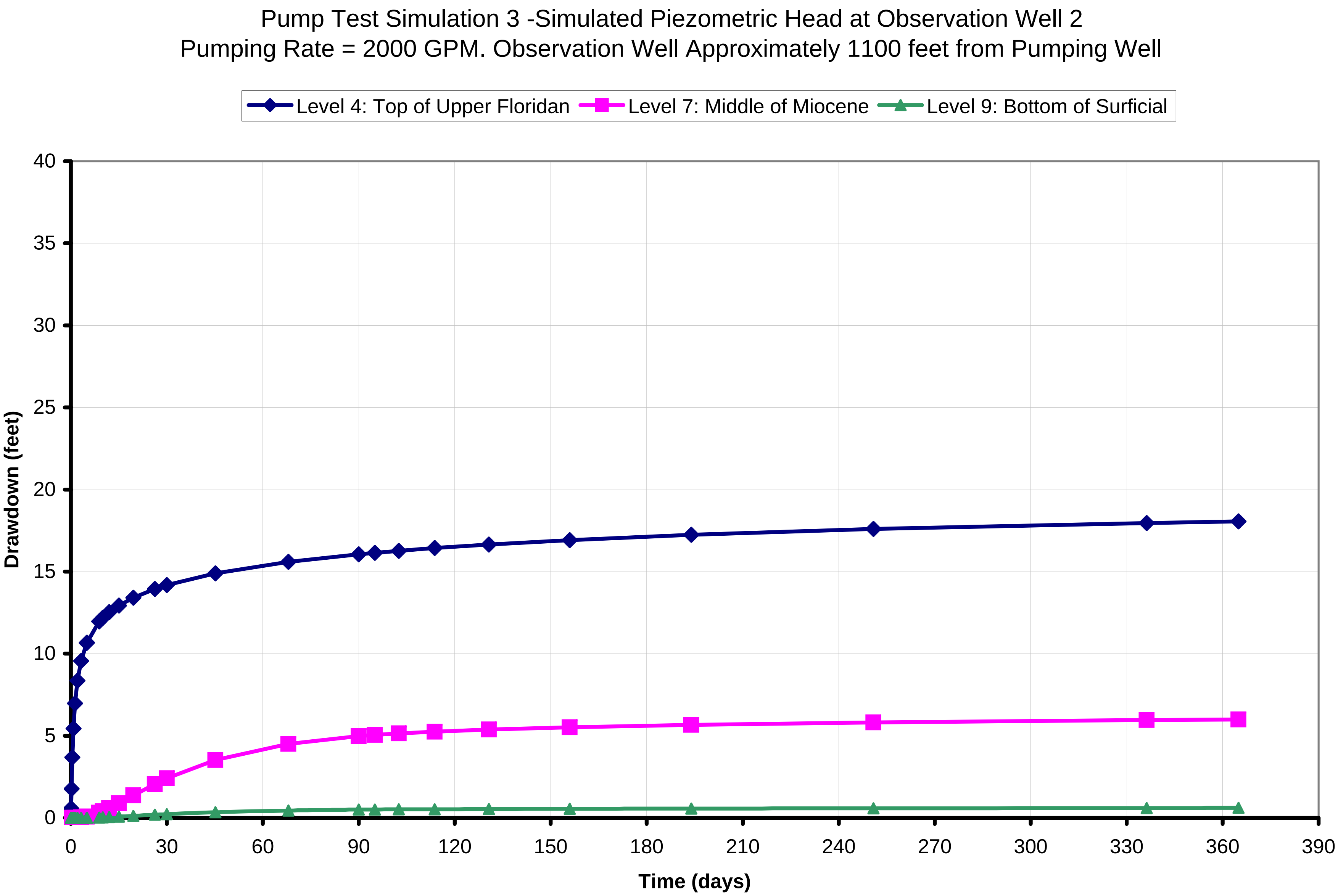
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

Pump Test Simulation 3 -Simulated Piezometric Head at Observation Well 1
Pumping Rate = 2000 GPM. Observation Well Approximately 750 feet from Pumping Well





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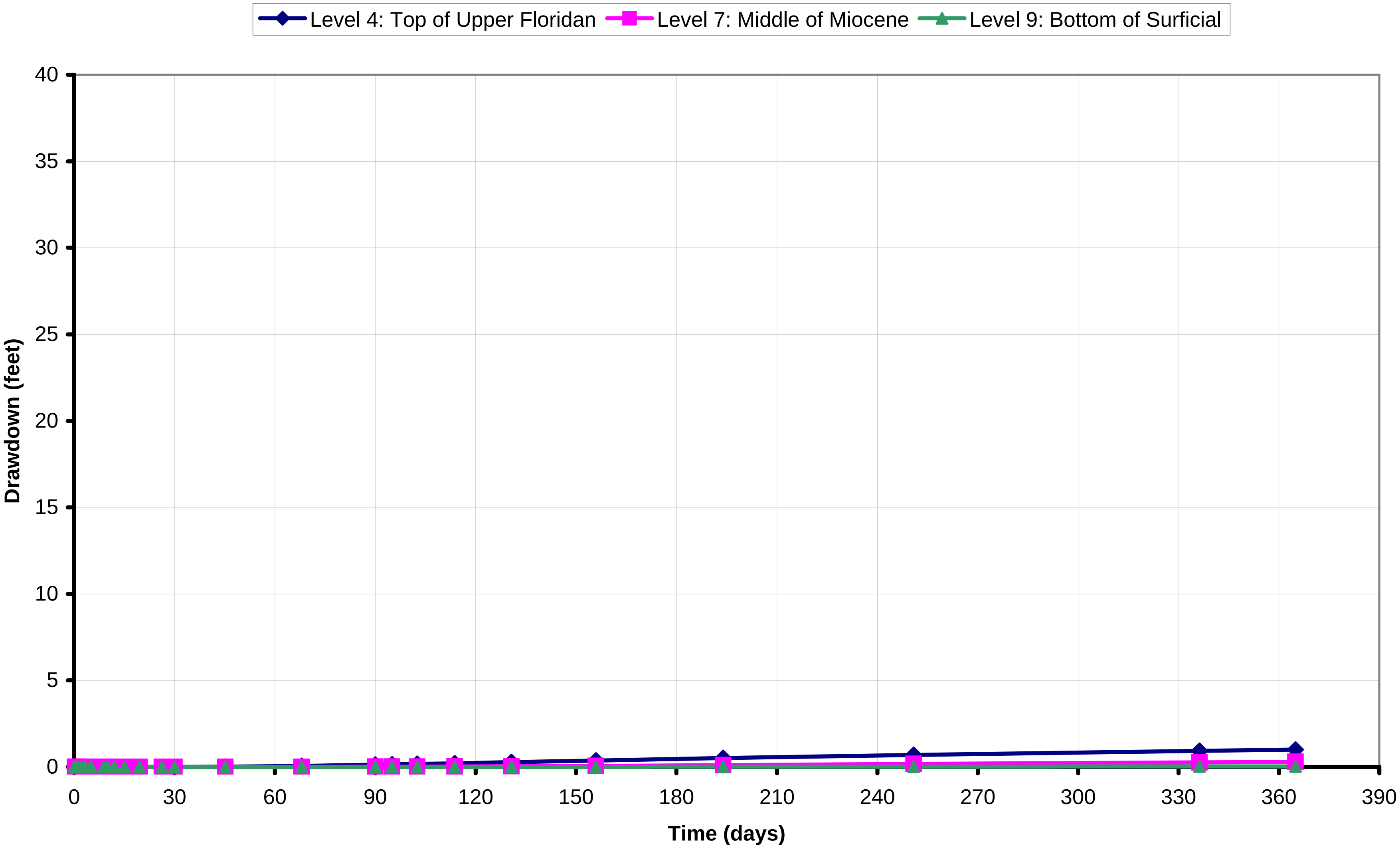
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

Pump Test Simulation 3 -Simulated Piezometric Head at Observation Well 3
Pumping Rate = 2000 GPM. Observation Well Approximately 2400 feet from Pumping Well



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Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

APPENDIX C

GIS ANALYSES

Geologic and Hydrogeologic GIS Analyses Performed as Part of the Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer

1. OVERVIEW

A geologic and hydrogeologic GIS was developed as part of the *Supplemental Studies* in order to enhance visualization and analysis of both historical and newly collected data. Ultimately, the resulting maps and products included in this report will be incorporated into the larger harbor-wide GIS. ArcGIS 9 was used as the framework for the GIS. Data was compiled and entered into a Microsoft Access 2000 database, which, in turn, was linked and integrated with the GIS as a geodatabase. ArcInfo Desktop version 9 with Spatial Analyst and 3-D Analyst extensions was used to process and analyze the data. ArcMap version 9, a two-dimensional visualization tool, was used to produce maps and figures.

The GIS served not only as a repository for organizing and viewing raw data, but also as a helpful tool for enhanced visualization and advanced analysis of the compiled data sources. The analyses completed provided a comprehensive view of the navigation channel to aid in visualizing major changes to the Savannah River through time. Detailed calculations are outlined below, and the model builder flow chart illustrating the calculation steps for all surfaces is included as Figure 1.

2. DATA SOURCES

2.1. GEOLOGIC DATA

As part of the objectives outlined in the supplemental studies, historical boring logs were compiled, digitized, and added to the GIS. Coordinates for each boring were converted to NAD83, Georgia State Plane Coordinate System, East Zone. The boring locations and corresponding digitized boring logs were plotted in the GIS to provide a clickable resource for quick reference. In addition, major formation elevations were identified for each boring log and entered into an integrated database, which served as the basis for creating various surfaces of the lithologic units underlying the navigation channel for both the ground-water model and GIS analyses. Over 400 boring logs and their interpretations were processed and mapped as part of this study.

The Savannah District compiled permeability and hydraulic conductivity, porewater, gamma, and soil conductivity data collected as part of the 1998 feasibility study as well as the data collected as part of the supplemental studies into a geodatabase that was integrated with the GIS. The tabular data was plotted according to location and elevation from which it was collected. In addition, where available, plotted data curves and lab reports including grain-size analyses and soil classifications were scanned, and the resulting image files were linked to the data location to allow quick access to the data source.

2.2. HYDROGEOLOGIC DATA

Drawdown data of the Upper Floridan aquifer (Peck et al., 1999) was obtained from the USGS and incorporated into the GIS. The potentiometric contours generated by the well data cover the cone of depression around Savannah and coastal Georgia, and limited areas of South Carolina and Florida. In order to illustrate a more complete view of the potentiometric heads in the Upper Floridan, SCDHEC data

(Ransom and White, 1998) was included in the potentiometric surface calculation as well.

2.3. SEISMIC DATA

As detailed in task 3, all seismic data collected as part of the supplemental studies was acquired in digital format to facilitate its inclusion in the GIS. OSI also provided all subbottom interpretation data in Microsoft Excel “pick files,” X, Y, Z formatted data that included coordinates and elevations of each reflector along each survey trackline. The data was loaded into the geodatabase and used to create detailed surfaces of not only the major lithologic contacts, but also of each major paleochannel as it intersected the navigation channel. Additionally, the tracklines were plotted and embedded with hyperlinks to image files of each interpreted cross section that included color-coded interpretations of each reflector.

2.4. HISTORICAL DREDGING RECORDS

Historical dredging records were incorporated into the GIS to assess the location and amount of confining material removed through time. Internal historical documents including annual surveys, congressional authorizations, status reports, exam studies, and design memoranda were reviewed for information regarding channel depth and geometry. The resulting authorized depths and widths were compiled into a spreadsheet with interpolated coordinates and incorporated into the GIS. Whenever available, digitized bottom survey data (1986 and 2003) and geometry design files superseded information gathered from congressional authorizations or other text-based sources.

3. BASE SURFACES

X, Y, Z data files containing locations and elevations of critical geologic contacts or features along the Savannah River were used to define raster surfaces. ESRI defines a raster as "a spatial data model that defines space as an array of equally sized cells arranged in rows and columns. Each cell contains an attribute value and location coordinates. Unlike a vector structure, which stores coordinates explicitly, raster coordinates are contained in the ordering of the matrix. Groups of cells that share the same value represent geographic features."

3.1. STUDY AREA

The study area domain for the GIS was defined using a combination of raster surfaces with a 20-foot cell size. The coverage areas were defined by annual surveys, seismic data, and geologic formation elevations interpreted from boring logs. Areas where data was present were defined as "true" and given a value of "1," and areas where all values were not 1 were reclassified as "0." The resulting domain was used in the calculation to trim subsequent raster surfaces. When any created raster is divided by the study area domain, values located outside the domain are divided by 0. The undefined value is then eliminated from the raster, resulting in a trimmed surface that matches the area of the study area domain.

3.2. ANNUAL SURVEYS

Three-D Analyst was used to process the X, Y, Z values from the 1986 and 2003 annual surveys and create 3-D topographic surfaces of the navigation channel and turning basins. Two rasters, one of the 1986 annual survey and one of the 2003 survey, were created. The 2003 annual survey did not cover Kings Island Turning Basin; for that reason, in order to create a complete bottom survey, 2004 exam study data from Kings Island Turning Basin was spliced with the 2003 annual survey data. The data was converted to a Triangular Irregular Network (TIN) surface model of the data points, where a TIN is a vector data structure used to store and display surface models. A TIN partitions geographic space using a set of irregularly spaced data points, each of which has an X, Y, and Z value. These points are connected by edges into a set of contiguous, non-overlapping triangles, creating a continuous surface that represents the terrain. The resulting surface model was then converted to a raster surface with a 20-foot cell size. The raster calculator within Spatial Analyst was then utilized to trim the raster surface to match that of the study area domain.

3.3. MIOCENE EXPOSURE TIME STEPS

Several surfaces were created to approximate the exposure of the Miocene in the bottom of the navigation channel through time. Historical surveys and documents were used to define depths along the channel through time. The depths and locations were combined into an X, Y, Z format in an effort to examine the historical evolution of the navigation channel. The X, Y, Z data was used to created a series of 3-D polygons in ArcScene representing the depth and width of a given stretch of the channel in time. The 3-D polygons were exported as 2-D tiffs with world files for each surface and year. The tiff was then displayed in ArcMap and georeferenced to correct for 3-D distortion. The tiff was then reclassified with exposed areas equal to “1” and all other values equal to “0.” The reclass values equal to “1” were then converted to a 2-D polygon. The resulting images were combined with the trimmed Pre-Dredging Miocene surface to represent areas where the Miocene confining unit was exposed in the bottom of the navigation channel (Figures 2 and 3).

3.4. MIOCENE (UNDISTURBED)

A surface was created to represent the top of the Miocene underlying the navigation channel before paleochannel incisions and erosional processes (including dredging activities) impacted the surface. “Natural” Miocene values were extracted from the boring log interpretations by using those values where the contact occurred at least ten feet below the elevation of the river bottom at the time of drilling. Ten feet was used in order eliminate including points where the contact was buried only by “fluff,” or recent deposits that collect in between maintenance dredging events. The data was also supplemented with several “estimated” values of the elevation of the contact in order to create a complete coverage for the Miocene surface. The estimated values were created by examining cross sections and interpreting reasonable values where boring data was sparse or absent.

The X, Y, Z data points determined from the process described above were converted to a TIN surface, and the resulting TIN surface was converted to a raster surface with a 20-foot cell size. The raster calculator was then utilized to trim the surface to match that of the study area domain.

Similarly, “All” Miocene values were extracted from boring log interpretations and used to create another intermediary raster. These two factor surfaces (“Natural” and “All”) were then mosaicked for maximum values, yielding the Undisturbed Miocene surface.

3.5. MIOCENE (PRE-DREDGING)

Two rasters were combined to create a raster surface representing the elevation of the top of the confining unit before dredging activities and minor natural erosional processes impacted the contact. Subbottom seismic data from the survey performed as part of the supplemental studies was used to create a trimmed raster surface of each of the eight major paleochannels identified between river stations +30+000 to –30+000. The X, Y, Z data was converted to TIN surfaces of each paleochannels, and the TINs were converted to raster surfaces. The resulting eight rasters were then “mosaicked” together to create one paleochannel raster (“Paleos_only”). The Undisturbed Miocene raster was mosaicked with the paleochannel raster using the “minimum” values mosaic method. The resulting raster values corresponded to the lowest elevation of the two surfaces and represented the erosion of the contact specifically by paleochannel incisions (“mio_undis_pal”).

3.6. MIOCENE (CURRENT)

A number of calculations were involved to create a refined surface representing the surface of the Miocene as it appears today. Boring log data, geophysical data, and bathymetry data were all combined to form a refined surface.

Two rasters were combined in order to create a raster representing the current approximate surface of the top of the Miocene confining unit. First, all boring logs that contained the elevation of the top of the Miocene, including those where the contact occurred within ten feet of the river bottom at the time of drilling, were combined with several “estimated” values as described above to create a raster surface of the top of the Miocene (“MioceneALL”). This surface was then mosaicked with mio_nat for minimum values. The X, Y, Z data was used to create a TIN surface and then converted to a raster surface with a 20-foot cell size, and the raster calculator was used to trim the raster to match the domain of the study area. The “MioceneALL” raster and the paleochannel raster were combined using the “minimum” values mosaic method to create a raster representing the approximate elevation of the top of the Miocene confining unit (“Mio_min_pal”).

An intermediary raster surface (“Mmp_as_neg”) was created in order to refine the elevation of the top of the Miocene confining unit as it appears underneath the navigation channel. The intermediary surface represented additional thickness of Miocene material removed that was not accounted for in the Mio_min_pal surface described above. The raster calculator was used to add the approximated Miocene surface to the Mmp_as_neg surface account for additional material removed by the most recent dredging event (2003 Annual Survey). The returned values represented the current elevation of the Miocene confining unit after the most recent dredging event (Figure 4).

3.7. MIOCENE (PROPOSED)

Three surfaces were used to create a surface representing the elevation of the Miocene confining unit after the proposed 6-foot improvement. First, a raster surface representing the proposed dredge depths was created. The study area domain was combined with polygons of the proposed depths by station number. The 3-D polygons were converted to a raster and then trimmed to match the domain of the study area (“pd_area”) using a reclass surface. The final surface (“prop_depth”) represented proposed depths within the navigation channel.

The Pre-Dredging Miocene surface was then multiplied by the pd_area surface to trim the proposed depth coverage to the navigation channel coverage area (Mio_ud_pda). Next, the Proposed Depth surface was subtracted from the undisturbed Miocene surface within the navigation channel ("pd_mio"). The returned values were then reclassified where negative values were equal to "1" and all other values were equal to "0." The reclass surface was then multiplied by the pd_mio surface, and the negative return values were added to the prop_depth surface, yielding a raster that represented the elevation of the top of the Miocene confining layer following the proposed dredging activities ("mio_prop").

3.8. LIMESTONE

Subbottom seismic data from both the 1997 and 2002 surveys and boring log data were combined to create a surface representing the elevation of the top of the Oligocene limestone (Upper Floridan aquifer). Cross section interpretations were used to create several "estimated" values where data was sparse or absent in order to provide complete coverage of the study area domain. The resulting X, Y, Z data were converted to a TIN surface, and the TIN surface was then converted to a raster surface with a 20-foot cell size. The raster calculator was utilized to trim the raster to match the domain of the study area.

4. CALCULATED THICKNESS SURFACES

4.1. MIOCENE REMOVED (PALEOCHANNELS)

The Undisturbed Miocene raster and the Pre-dredging Miocene raster were used to calculate the thickness of material removed within the paleochannels. The Pre-dredging Miocene surface was subtracted from the Undisturbed Miocene surface using the raster calculator. The resulting positive values represented the thickness of material (feet) removed by paleochannels incising the Miocene surface (Figure 5).

4.2. MIOCENE REMOVED (DREDGING)

The 2003 Annual Survey surface and the Pre-dredging Miocene surfaces were subtracted in order to calculate the thickness of Miocene removed due to dredging and natural erosional processes other than the paleochannel incisions (Figure 6). The returned negative values represented thickness of Miocene removed. A reclass surface of the returned raster was created to convert the values to a positive thickness where the raster value equaled “1” when the surface was less than zero and the raster value equaled “0” when the surface was greater than zero. The reclass surface was then multiplied by the original returned calculated surface, yielding a surface where negative values represented thickness of Miocene removed and zero values indicated no Miocene material had been removed.

4.3. MIOCENE REMOVED (DREDGING; PALEOCHANNELS)

The total thickness of feet of Miocene material removed was created by combining the data from Miocene removed by dredging and Miocene removed by paleochannels surface. First, using map algebra, the Miocene removed by dredging raster was multiplied by –1. Then, the Miocene removed by paleochannels raster was mosaicked with the Miocene removed by dredging raster for maximum values. The output surface represented total thickness of Miocene removed due to natural erosion in the paleochannel areas and dredging along the remainder of the course of the river (Figure 7).

4.4. PLEISTOCENE/RECENT MATERIAL THICKNESS (DEPTH TO MIOCENE)

The 2003 Annual Survey surface and the Current Miocene surface were used to identify where the Miocene unit is exposed in the bottom of the navigation channel and calculate the thickness of material remaining above the Miocene contact. The depth to Miocene was calculated by subtracting the Current Miocene surface from the 2003 Annual Survey surface. The resulting raster yielded no negative values; returned positive values represented current Pleistocene/Recent material remaining on top of the Miocene and zero values indicated that Miocene material had already been removed and is thus exposed in the bottom of the navigation channel (Figure 8).

4.5. NATURAL MIOCENE THICKNESS

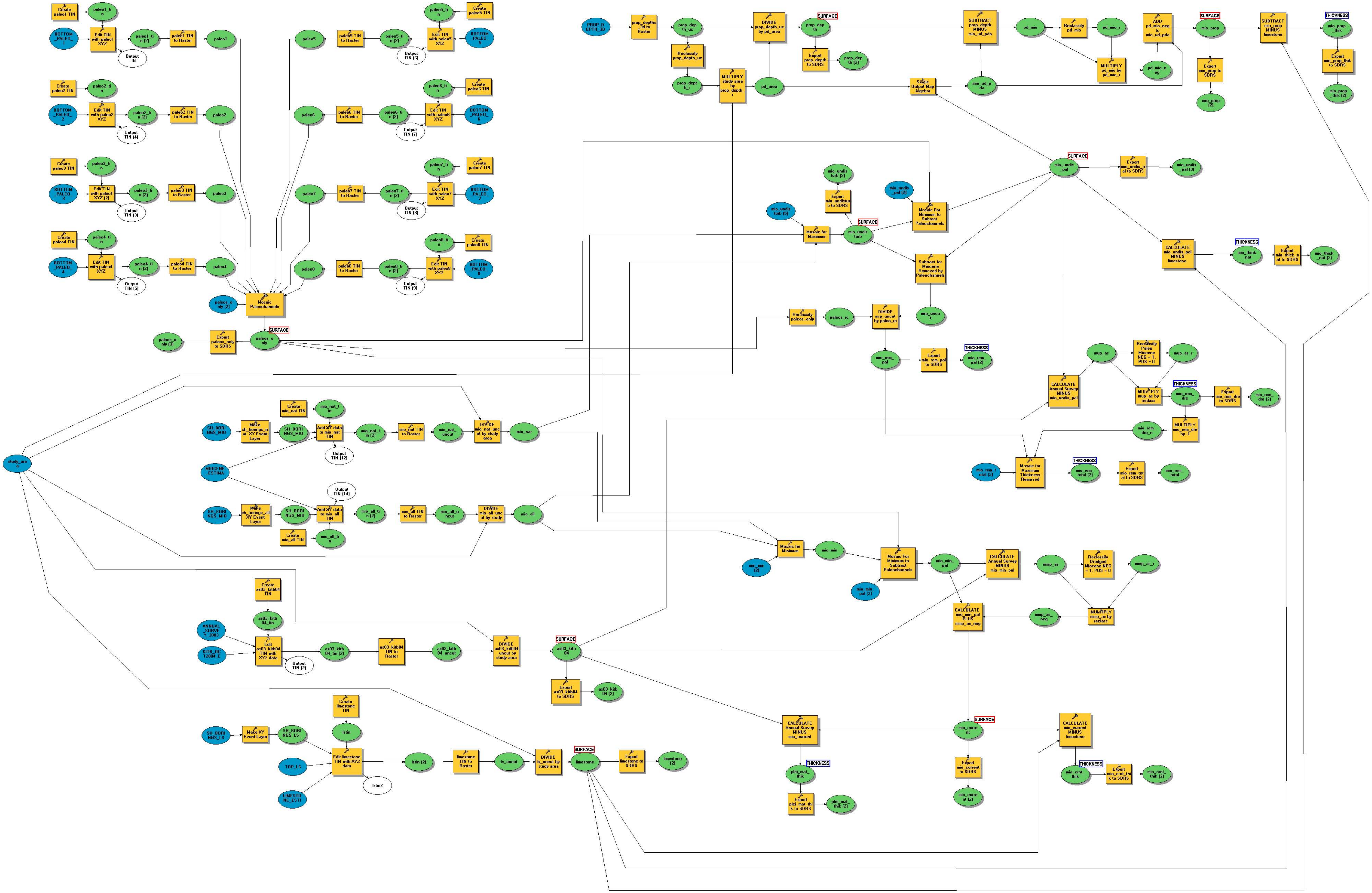
The Pre-dredging Miocene surface ("mio_undis_pal") and the Limestone surface were used to create a surface representing the thickness of the confining unit prior to modern dredging activities. Using the raster calculator, the Limestone surface was subtracted from the Pre-dredging Miocene surface, and all returned values represented the natural thickness (feet) of the Miocene confining unit ("mio_thik_nat").

4.6. CURRENT MIOCENE THICKNESS

The Limestone surface was subtracted from the Current Miocene surface in order to determine the thickness of the confining unit. The returned raster values indicated thickness of Miocene material in feet underlying the navigation channel (Figure 9).

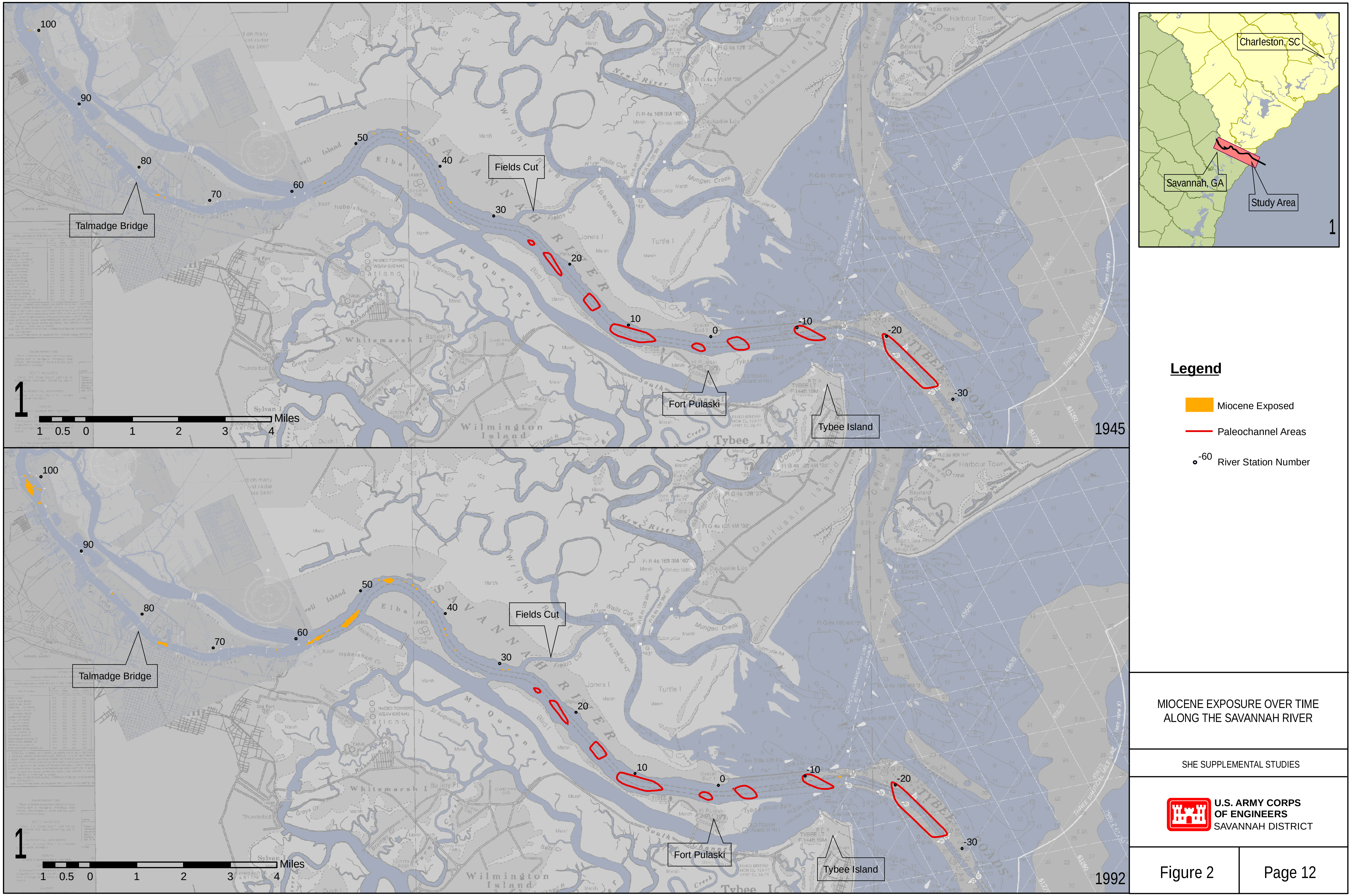
4.7. PROPOSED MIOCENE THICKNESS

Similar to the two Miocene thicknesses described above, a surface was created to represent the thickness of the Miocene following the proposed dredging activities. The raster calculator was used to subtract the Limestone surface from the proposed Miocene surface ("mio_prop"). The returned values represented a projected thickness of the confining unit after the proposed dredging (Figure 10).



GIS Analyses Performed as Part of the Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer

Figure 1

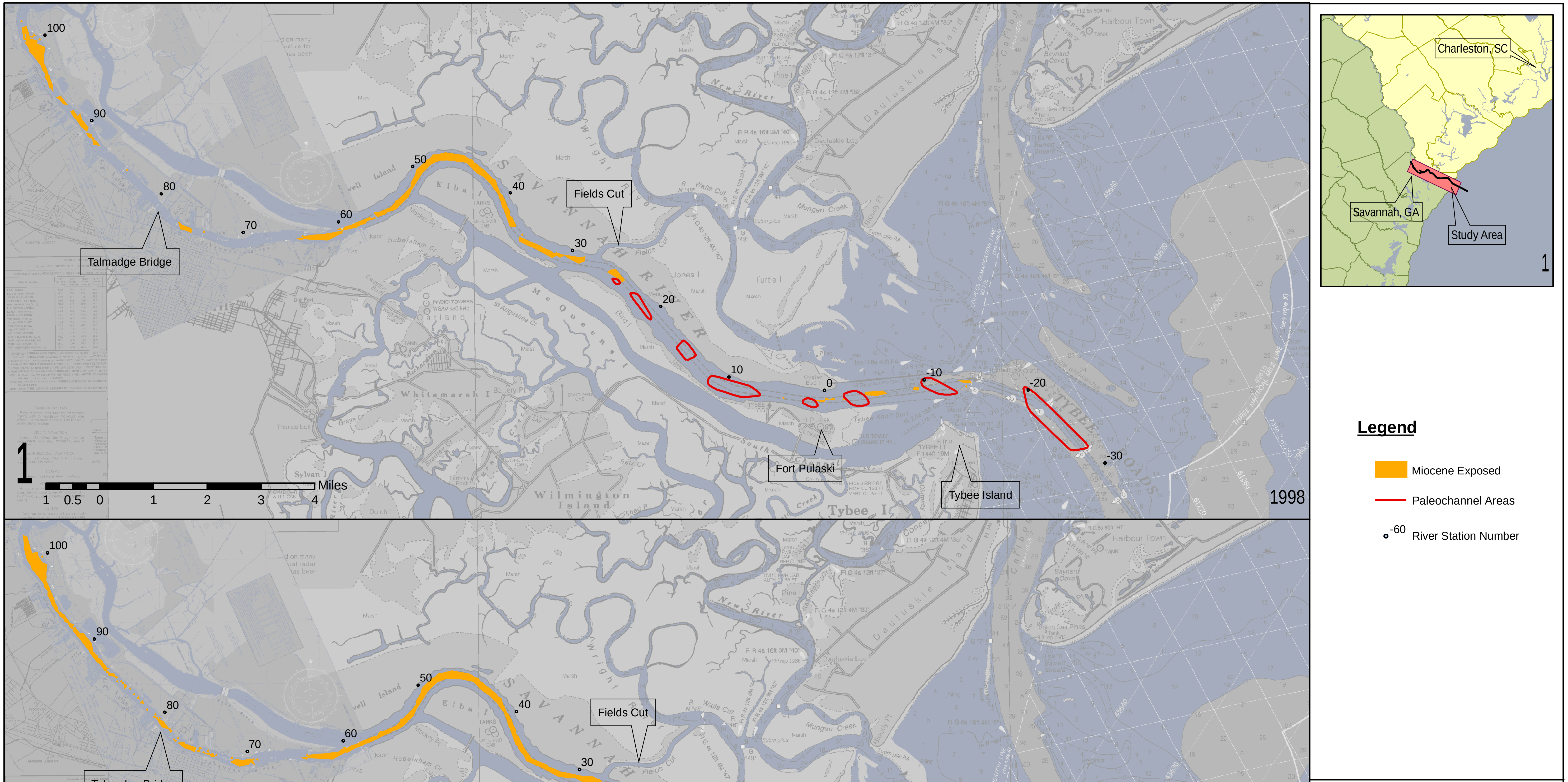


MIOCENE EXPOSURE OVER TIME
ALONG THE SAVANNAH RIVER

SHE SUPPLEMENTAL STUDIES

U.S. ARMY CORPS
OF ENGINEERS
SAVANNAH DISTRICT

Figure 2

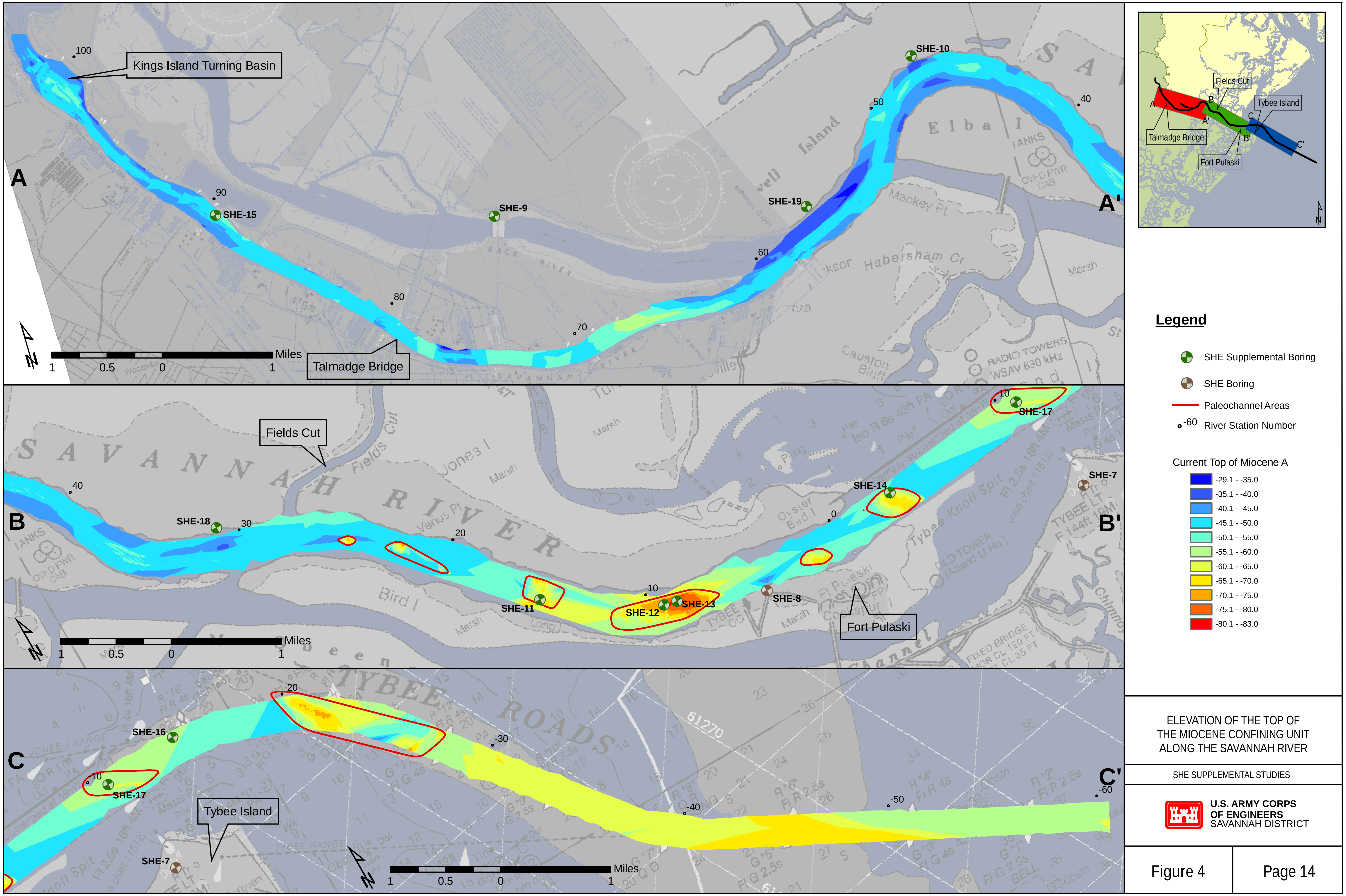


MIOCENE EXPOSURE OVER TIME
ALONG THE SAVANNAH RIVER

SHE SUPPLEMENTAL STUDIES

**U.S. ARMY CORPS
OF ENGINEERS**
SAVANNAH DISTRICT

Figure 3

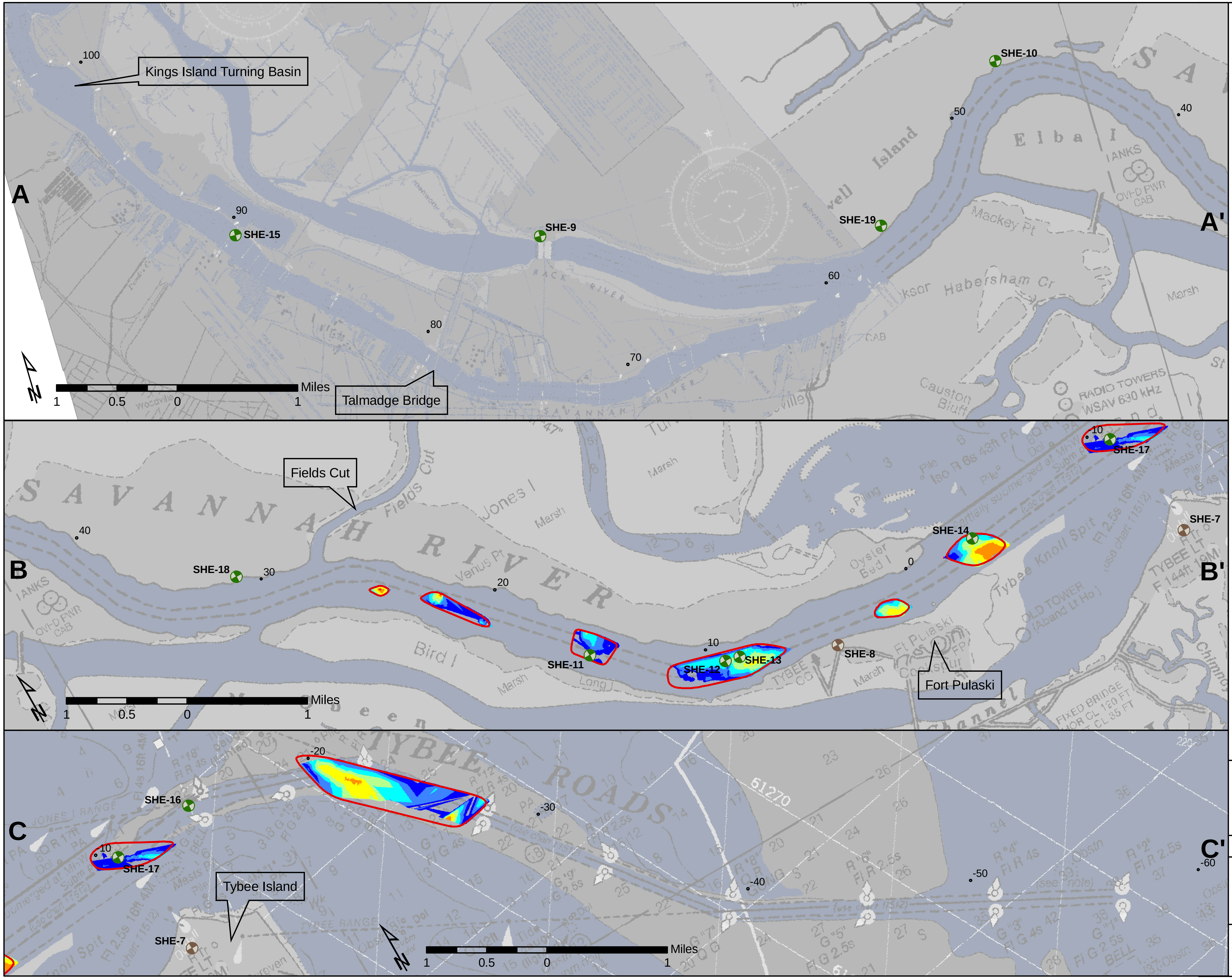


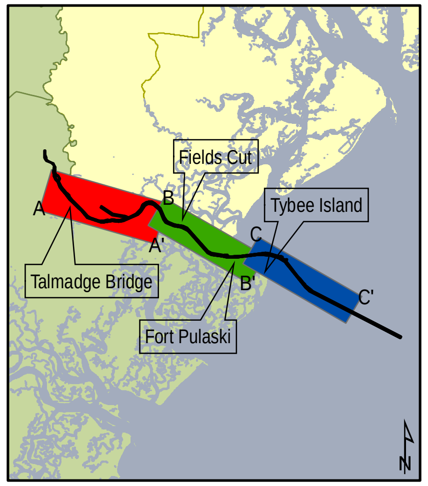
ELEVATION OF THE TOP OF
THE MIOCENE CONFINING UNIT
ALONG THE SAVANNAH RIVER

SHE SUPPLEMENTAL STUDIES

U.S. ARMY CORPS
OF ENGINEERS
SAVANNAH DISTRICT

Figure 4





Legend

- 🟢 SHE Supplemental Boring
- 🟤 SHE Boring
- 🟥 Paleochannel Areas
- -60 River Station Number

Miocene Removed by Paleochannels (ft)

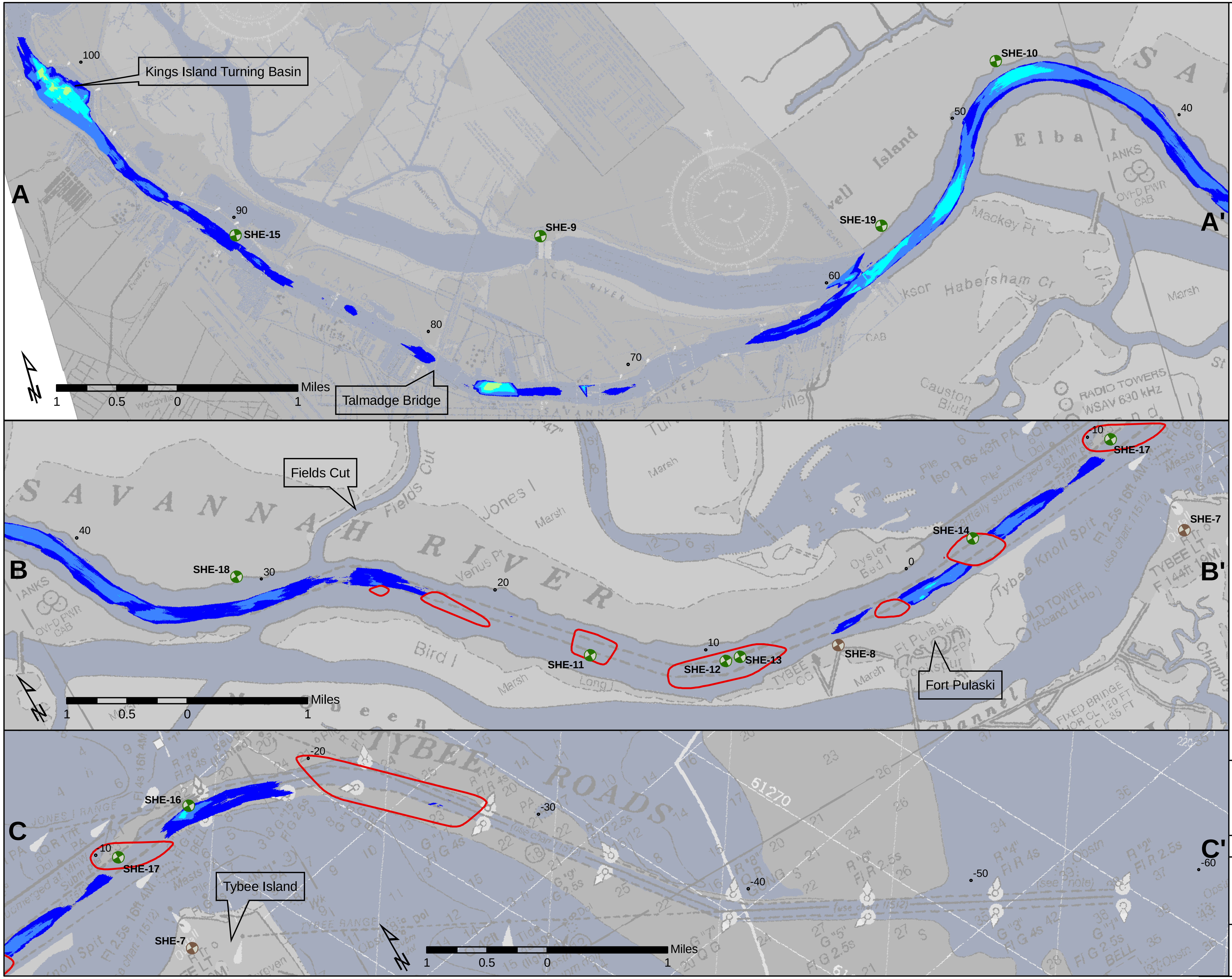
⬜	0.0
🟦	0.1 - 5.0
🟦	5.1 - 10.0
🟦	10.1 - 15.0
🟩	15.1 - 20.0
🟨	20.1 - 25.0
🟧	25.1 - 30.0
🟥	30.1 - 32.6

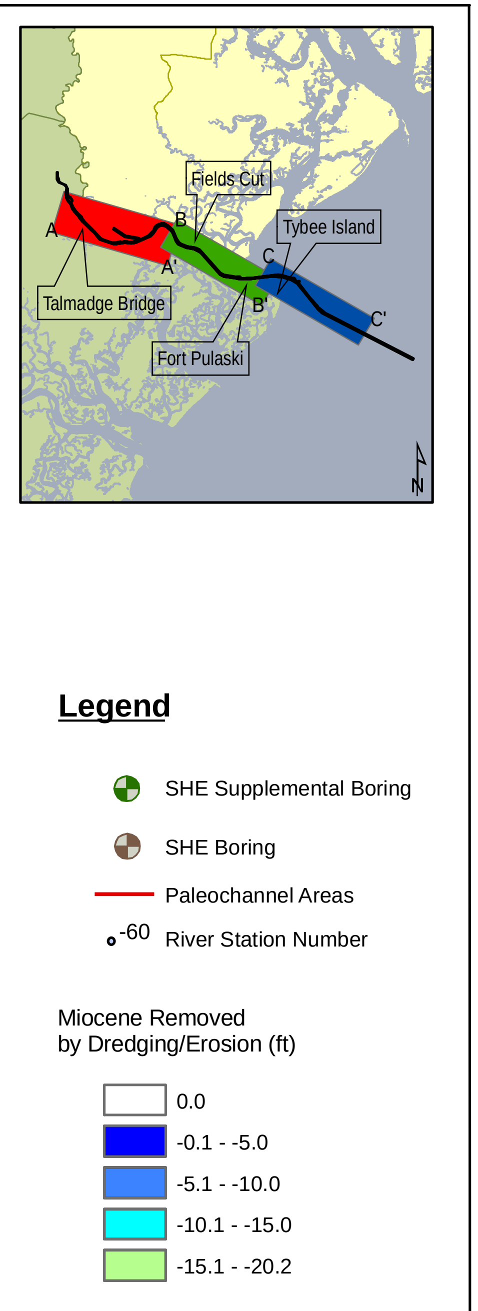
THICKNESS OF MIOCENE
REMOVED BY PALEOCHANNELS
ALONG THE SAVANNAH RIVER

SHE SUPPLEMENTAL STUDIES

U.S. ARMY CORPS
OF ENGINEERS
SAVANNAH DISTRICT

Figure 5



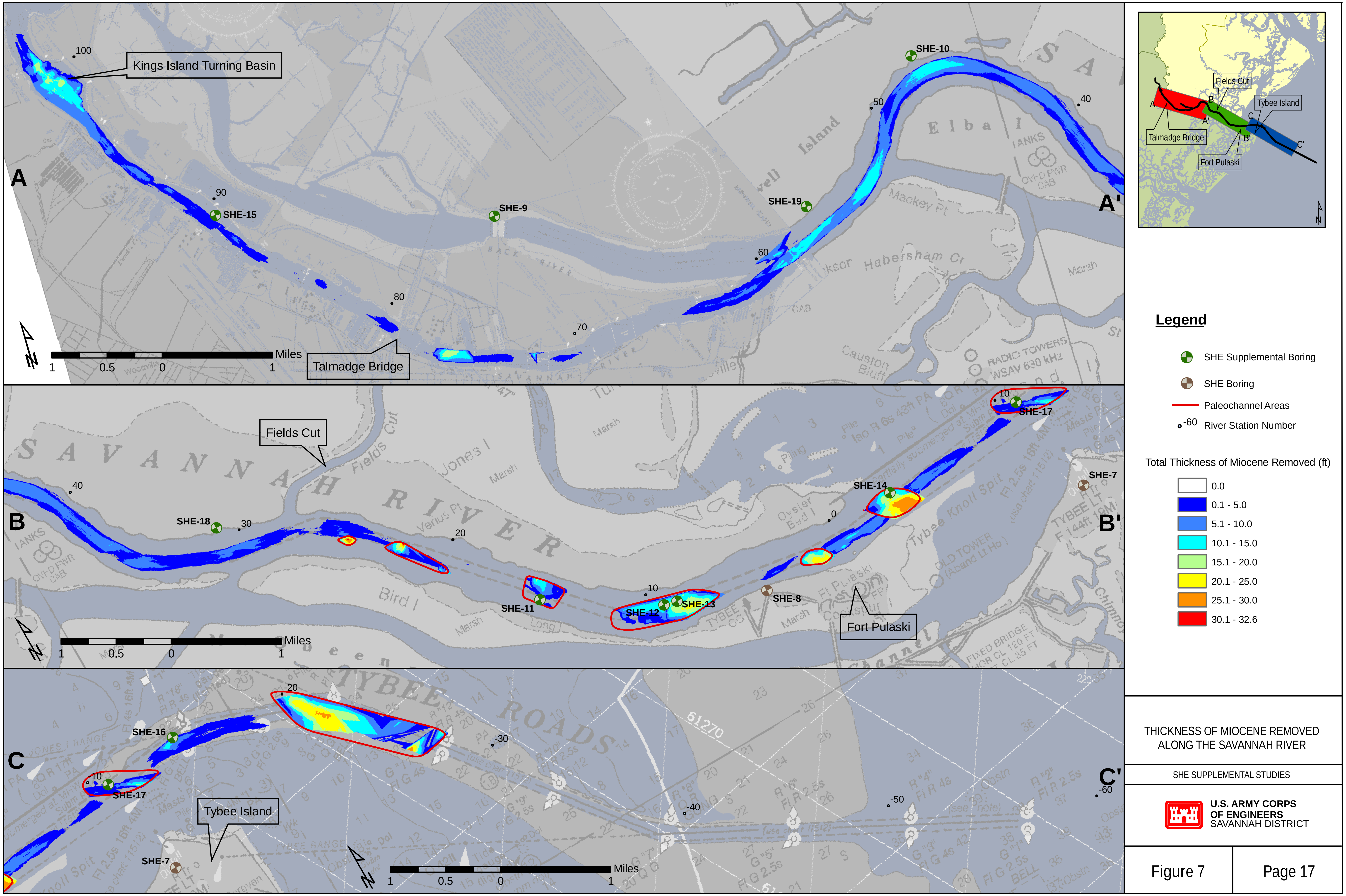


THICKNESS OF MIOCENE
REMOVED BY DREDGING/EROSION
ALONG THE SAVANNAH RIVER

SHE SUPPLEMENTAL STUDIES

U.S. ARMY CORPS
OF ENGINEERS
SAVANNAH DISTRICT

Figure 6

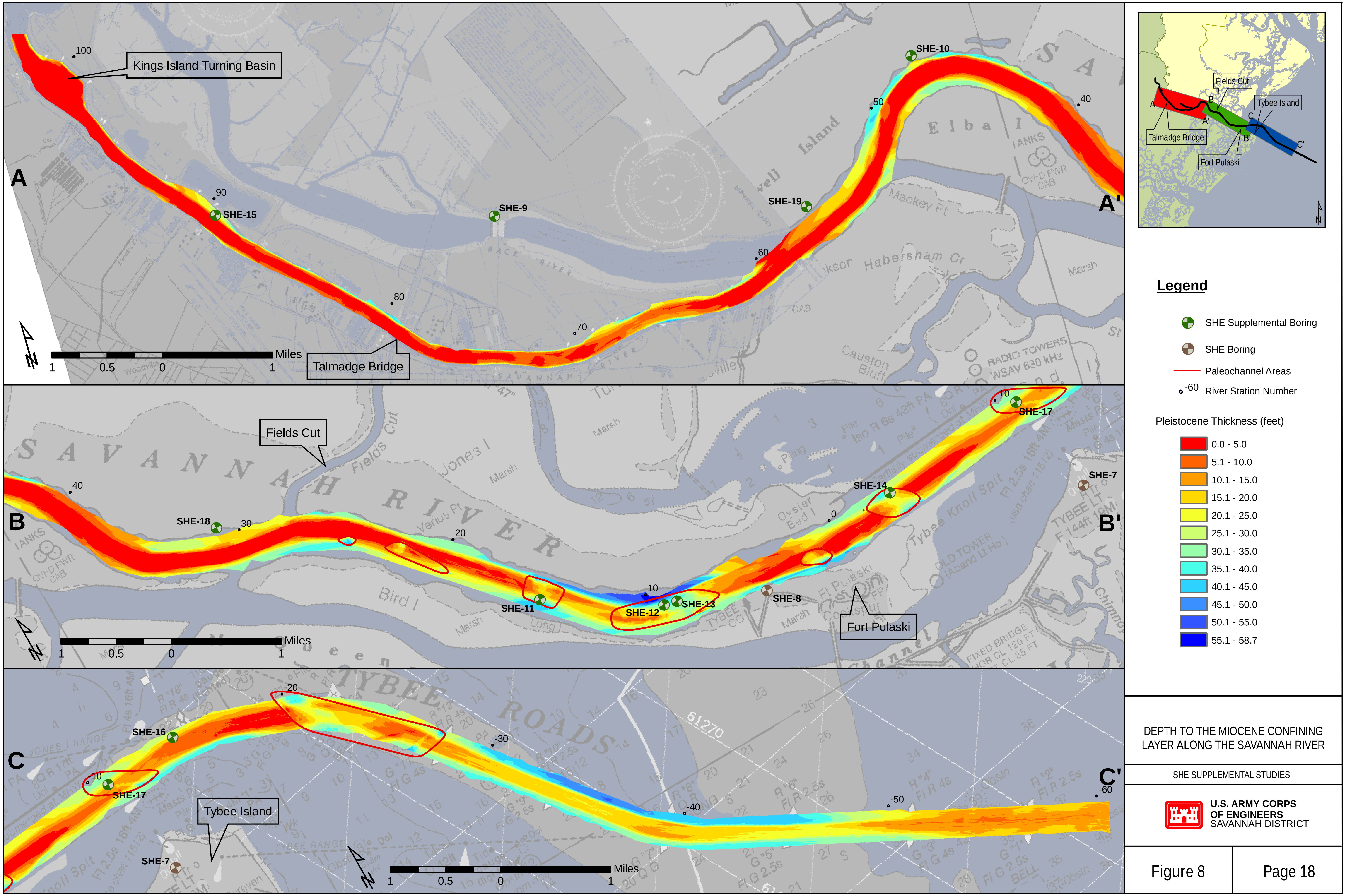


THICKNESS OF MIOCENE REMOVED
ALONG THE SAVANNAH RIVER

SHE SUPPLEMENTAL STUDIES

U.S. ARMY CORPS
OF ENGINEERS
SAVANNAH DISTRICT

Figure 7

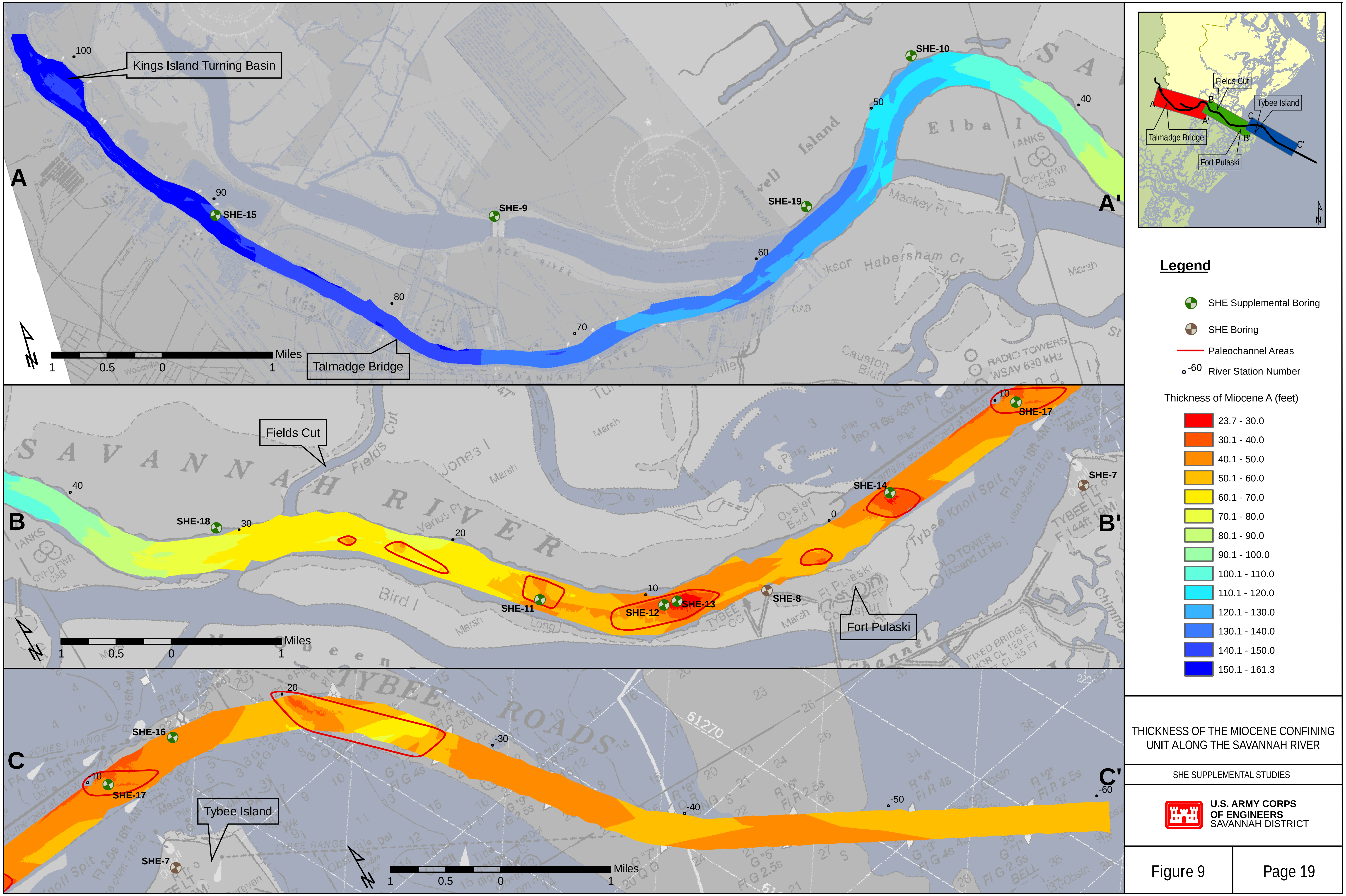


DEPTH TO THE MIOCENE CONFINING LAYER ALONG THE SAVANNAH RIVER

SHE SUPPLEMENTAL STUDIES

U.S. ARMY CORPS
OF ENGINEERS
SAVANNAH DISTRICT

Figure 8

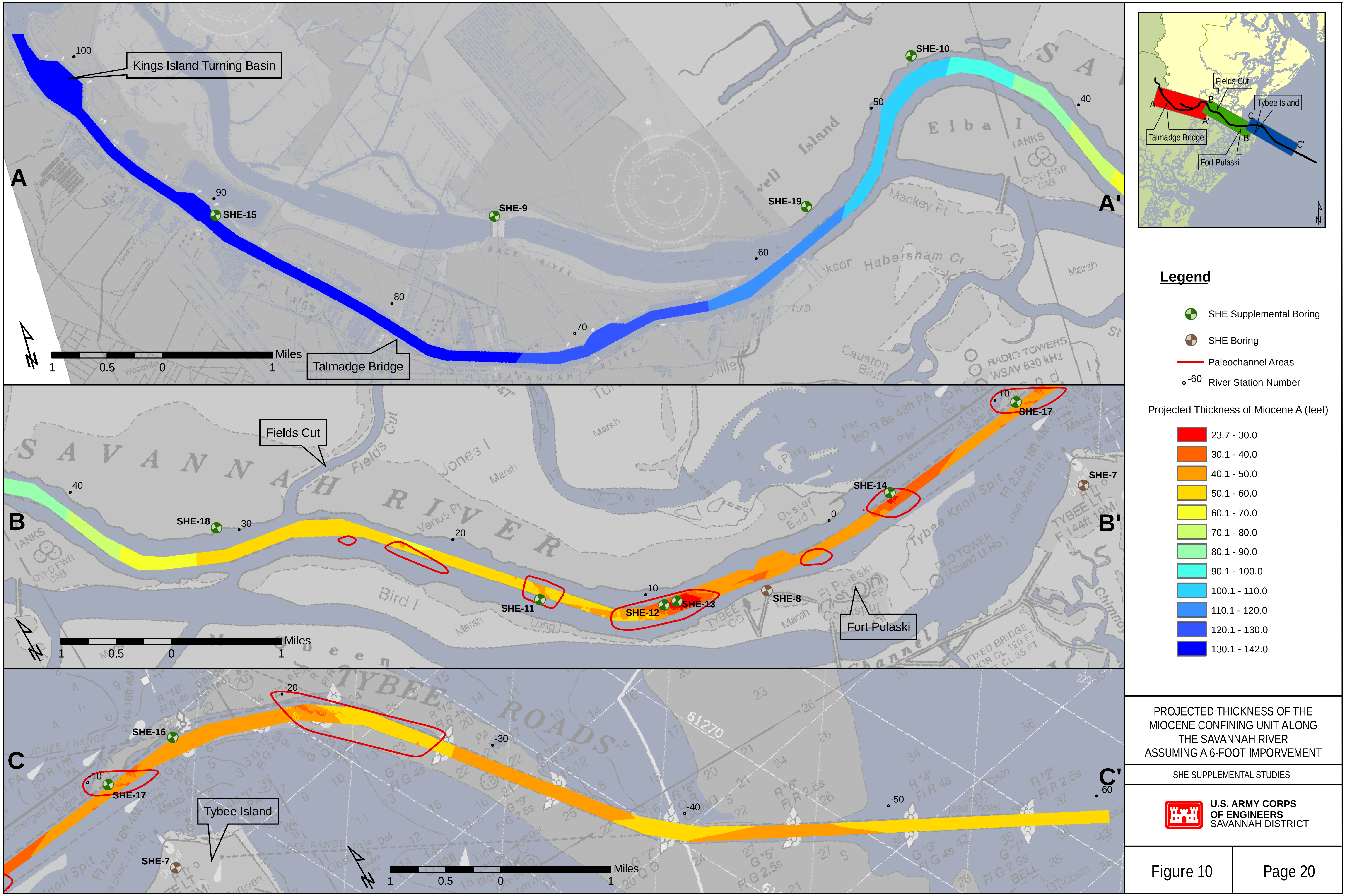


THICKNESS OF THE MIOCENE CONFINING UNIT ALONG THE SAVANNAH RIVER

SHE SUPPLEMENTAL STUDIES

U.S. ARMY CORPS
OF ENGINEERS
SAVANNAH DISTRICT

Figure 9



PROJECTED THICKNESS OF THE
MIOCENE CONFINING UNIT ALONG
THE SAVANNAH RIVER
ASSUMING A 6-FOOT IMPORVEMENT

SHE SUPPLEMENTAL STUDIES

U.S. ARMY CORPS
OF ENGINEERS
SAVANNAH DISTRICT

Figure 10

APPENDIX D

Boring Logs

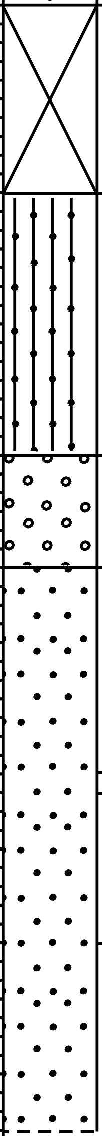
DRILLING LOG

DIVISION SOUTH ATLANTIC

INSTALLATION SAVANNAH, GA

SHEET 1 OF 8 SHEETS

1. PROJECT SAVANNAH HARBOR DEEPENING
2. LOCATION *(Coordinates or Station)* N-765318.998 E-992787.271 GA EAST
3. DRILLING AGENCY SAVANNAH DISTRICT
4. HOLE NO. *(As shown on drawing title and file number)* : SHE-9
5. NAME OF DRILLER P. ROUNTREE
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN >373.0'
8. DEPTH DRILLED INTO ROCK 10.0'
9. TOTAL DEPTH OF HOLE 373.0'
10. SIZE AND TYPE OF BIT HQ CORE BARREL
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* MLW
12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500
13. TOTAL NO. OF SOIL SAMPLES TAKEN : DISTURBED 0 : UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 18
15. GROUND WATER ELEVATION N/A
16. DATE HOLE : STARTED 15 Sept 2001 : COMPLETED 4 Oct 2001
17. ELEVATION TOP OF HOLE 15.2' MLW
18. TOTAL CORE RECOVERY FOR BORING 86 %
19. SIGNATURE OF INSPECTOR C. SMITH



ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
15.2	0		Wash.			NOTE: Change of scale to 1" = 5' at 10.0'. Elevation to top of casing = 16.2 MLW
5.2'	10		(SM) Tan to brown fine silty SAND, trace dark mineral grains, trace mica, wet.	Pull 1 Run=10.0 Rec=6.0		
	15					
-0.2'			(SW) Gray well graded SAND, little fines, little shell fragments up to 0.3 inches, trace fine to coarse gravel.			
-4.8'	20		(SP) Gray fine poorly graded SAND, little mica, little shell fragments up to 0.1 inches, trace dark mineral grains.	Pull 2 Run=5.3 Rec=1.0		
	25		Little fines, trace organic material. Laminated.	Pull 3 Run=10.0 Rec=1.0		
	30		Trace fine gravel.			
	35					

CONTINUED ON SHEET No. 2

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 16.2' MLW	Hole No. SHE-9
PROJECT SAVANNAH HARBOR DEEPENING	INSTALLATION SAVANNAH, GA	SHEET 2 OF 8 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L)
	35		SP (Continued).		P-1	0 1000 2000
				Pull 4 Run=6.5 Rec=1.5		
	40		Zone of medium subangular quartz sand.			
-25.6'			(SC) Tan to brown fine clayey SAND, trace dark mineral grains, trace fine gravel, trace mica.	Pull 5 Run=3.5 Rec=1.8	P-2	RECENT
-28.3'	45		(SM)-MIOCENE A-Green fine silty SAND, little fine mica, trace dark mineral grains.			MIOCENE A
	50			Pull 6 Run=10.0 Rec=1.5		
					P-3	
	55		Trace mica.			
				Pull 7 Run=10.0 Rec=7.0	P-4	
	60		Partings of fine quartz sand.			
			Tan to light olive green, increased fines.		P-5	
-49.1'	65		(ML) Light olive green low plasticity SILT, little fine sand, not cemented. Green, laminated, trace mica.		K-1	
-52.2'			(SM) Green fine silty SAND, little clay, trace mica, trace dark mineral grains. Light olive green to yellow, decreased clay content, rare horizons of gray fine quartz sand, laminated.	Pull 8 Run=10.0 Rec=10.0	P-6	
	70					
	75					

CONTINUED ON SHEET No. 3

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 16.2' MLW

Hole No. SHE-9

PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 3 OF 8 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L)
	75	SM (Continued).		P-7	0 1000 2000
				K-2	
		Green, sand partings every 0.3 feet.			
		Partings less common.			
	80		Pull 9 Run=10.0 Rec=10.0		
		Trace medium subangular sand.			
	85				
				P-8	
		Increased fines.			
-73.0'		(SC) Green fine clayey SAND, trace dark mineral grains, partings of fine sand.			
-73.7'	90	(SM) Green fine silty SAND, trace mica, trace dark mineral grains, laminated.	Pull 10 Run=10.0 Rec=10.0		
	95	Partings of fine sand occurring every 0.3 feet.			
				P-9 K-3	
	100		Pull 11 Run=10.0 Rec=10.0		
				P-10	
	105				
		Partings occur every 0.5 feet.			
				P-11	
		3" layer of fine quartz sand.			
		Decreased sand, partings frequent, laminated.	Pull 12 Run=10.0 Rec=10.0		
-93.6'	110	(ML) Green low plasticity SILT, some fine sand, not cemented, laminated, rare partings of fine sand.			
		0.2 foot thick horizon of fine sand.		P-12	
	115				

CONTINUED ON SHEET No. 4

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 16.2' MLW

Hole No. SHE-9

PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 4 OF 8 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L) 0 1000 2000
-99.1'	115	ML (Continued).			
		(SM) Green fine silty SAND, trace mica, trace dark mineral grains.	Pull 13 Run=6.7 Rec=6.7	K-4 P-13	
	120	Gradational color change from green to light olive green to cream. Cream colored horizons are indurated.			
		Dark olive green, finely laminated.	Pull 14 Run=3.3 Rec=3.3	P-14	
		Little mica, increased fines.			
	125	Trace mica.			
		Decreased fines, medium to fine sand. Partings of fine sand throughout.	Pull 15 Run=6.6 Rec=7.6	P-15 K-5	
	130	Trace shell fragments up to 0.01", laminae less pronounced, very stiff.			
-115.4'		(ML) Gray to dark gray indurated SILT, little fine sand, trace phosphatic grains, highly cemented.		P-16	
		Some fine sand with trace dark mineral grains, moderately cemented.	Pull 16 Run=2.4 Rec=2.0		
-117.5'		(SM) Olive green silty medium to fine SAND, little phosphatic grains, laminated.			
-118.0'	135	(ML) Gray to tan low plasticity SILT, trace fine sand, laminated, moderately cemented.	Pull 17 Run=9.6 Rec=2.2	P-17	
	140	Indurated.			
		Moderately to highly cemented, increased sand content.			MIOCENE A
-127.4'	145	(SM)-MIOCENE B-Dark olive green to black fine phosphatic SAND, trace fine gravel.		P-18 K-6 P-19	MIOCENE B
		Some silt.	Pull 18 Run=7.4 Rec=4.8		
-132.1'	150	(ML) Gray, low plasticity SILT, little fine sand with trace dark mineral grains, trace phosphatic grains, hard.			
			Pull 19 Run=3.6 Rec=0.0		
		(SM) Gray silty fine SAND, little dark mineral grains, trace phosphatic grains.			
-138.7'	155				

CONTINUED ON SHEET No. 5

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 16.2' MLW

Hole No. SHE-9

PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 5 OF 8 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L) 0 1000 2000
	155		SM (Continued).			
				Pull 20 Run=10.0 Rec=4.5		
	160					
			Olive green, no phosphatic grains.			
			Decreased fines.			
			Moderately cemented.		K-7 P-20	
	165		Medium to fine sand.			
				Pull 21 Run=8.5 Rec=1.3		
	170					
					P-21	
				Pull 22 Run=1.5 Rec=0.5		
	175		Fine sand, trace mica.			
			Partings of fine sand with trace dark mineral grains occurring every 0.3 feet, not cemented.			
				Pull 23 Run=10.0 Rec=10.0		
	180				K-8 P-22	
-165.2'			(SC) Green fine clayey SAND, some dark mineral grains, laminated.			
					P-23	
	185					
				Pull 24 Run=10.0 Rec=6.8		
	190				K-9 P-24	
			Little dark mineral grains.			
			Some dark mineral grains.		P-25	
	195					

CONTINUED ON SHEET No. 6

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 16.2' MLW	Hole No. SHE-9
PROJECT SAVANNAH HARBOR DEEPENING	INSTALLATION SAVANNAH, GA	SHEET 6 OF 8 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L) 0 1000 2000
	195		SC (Continued).			
-180.6'			(SM) Green fine silty SAND, some dark mineral grains, laminated. Occasional partings of fine sand with little dark mineral grains.	Pull 25 Run=6.8 Rec=7.6		
	200				P-26	
				Pull 26 Run=3.2 Rec=2.4	K-10	
	205				P-27	
-191.8'			(LS) Limestone, hard, slightly weathered, fine grained, gray to white, 15% dark phosphatic grains, HCl rxn.	Pull 27 Run=8.5 Rec=0.5		MIOCENE B LIMESTONE
	210					
			0.2' thick horizon of olive green high plasticity clay with trace fine quartz sand, trace phosphatic grains up to 0.25".	Pull 28 Run=1.5 Rec=0.2		
	215		0.2' thick horizon of olive green high plasticity clay with trace fine quartz sand, trace phosphatic grains up to 0.25".			
			Burrow infilled with olive green silty fine to medium quartz SAND, trace phosphatic grains up to 0.3", trace shell fragments up to 0.25".	Pull 29 Run=10.0 Rec=9.5		
	220				P-28	
			Moderately weathered, fossils present, moderately hard, burrow present at 220.6 infilled with silty, shelly sand same as above.			
			Slightly weathered.			
	225		Mottled red to green to gray, highly fossiliferous, very soft.			
			Cream with trace of green, vuggy, soft.			
			Horizons of mottled green to white to gray sandy material, very soft.			
			Cream, small vugs up to 0.1" fossiliferous, soft.	Pull 30 Run=10.0 Rec=10.5	P-29	
	230		Vuggy, vugs infilled with olive green silty material.			
			Vugs up to 0.25".			
			Very vuggy, highly fossiliferous, hard.			
	235					

CONTINUED ON SHEET No. 7

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 16.2' MLW	Hole No. SHE-9
PROJECT SAVANNAH HARBOR DEEPENING	INSTALLATION SAVANNAH, GA	SHEET 7 OF 8 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L) 0 1000 2000
	235		LS (Continued).			
			Highly weathered, no vugs, some sand sized shell fragments, very soft.			
			Cream, vuggy, very fossiliferous, hard.			
			Highly weathered, no vugs, some shell fragments up to 0.25".	Pull 31 Run=10.0 Rec=10.0	P-30	
	240		Cream to white, hard, moderately weathered, small vugs.			
			Soft, highly weathered. 0.5" diameter burrow infilled with olive green silty material.			
	245					
	250		Very soft.	Pull 32 Run=10.0 Rec=4.9		
	255		Hard, vugs up to 0.5 inches, highly fossiliferous.		P-31	
			Very soft, cream to tan, no vugs. 1" horizon of hard, vuggy, fosssiliferous material.			
			Moderately hard.	Pull 33 Run=10.0 Rec=9.3		
	260		Soft.			
	265		Moderately hard.		P-32	
			Soft.			
			Hard.			
			Soft.	Pull 34 Run=10.0 Rec=9.3		
	270					
-254.8'			Vuggy, hard, very fossiliferous.			
			Less vugs, moderately hard.			
	275					

CONTINUED ON SHEET No. 8

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 16.2' MLW

Hole No. SHE-9

PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 8 OF 8 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	275		LS (Continued).			
	280			Pull 35 Run=10.0 Rec=4.5		
-269.7'	285					NOTE: Change of scale to 1" = 20' at 290.0'.
						Core logging stopped at 284.9'. Hole was advanced using 4" rock bit with no sample collection to final depth.
	290					
	310					
	330					
	350					
	370					

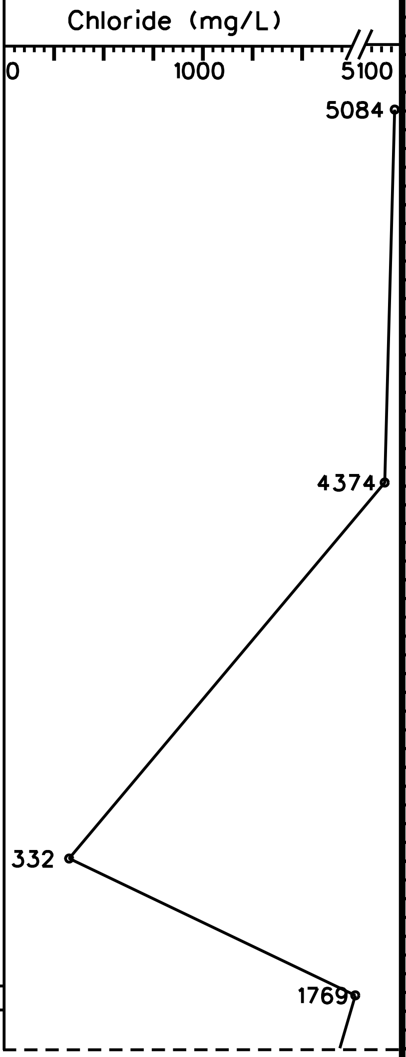
BOTTOM OF BORING AT 373.0'

Hole No. SHE-10

DRILLING LOG	DIVISION SOUTH ATLANTIC	INSTALLATION SAVANNAH, GA	SHEET 1 OF 7 SHEETS

1. PROJECT: SAVANNAH HARBOR DEEPENING
2. LOCATION *(Coordinates or Station)*: N-767200 E-1014100 GA EAST
3. DRILLING AGENCY: SAVANNAH DISTRICT
4. HOLE NO. *(As shown on drawing title and file number)*: SHE-10
5. NAME OF DRILLER: P. ROUNTREE
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: >243.0'
8. DEPTH DRILLED INTO ROCK: 10.0'
9. TOTAL DEPTH OF HOLE: 243.0
10. SIZE AND TYPE OF BIT: HQ CORE BARREL
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*: MLW
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing 1500
13. TOTAL NO. OF SOIL SAMPLES TAKEN: DISTURBED 0 : UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES: 12
15. GROUND WATER ELEVATION: N/A
16. DATE HOLE: STARTED 30 Jan 2002 : COMPLETED 15 Feb 2002
17. ELEVATION TOP OF HOLE: 23.5' MLW
18. TOTAL CORE RECOVERY FOR BORING: 74 %
19. SIGNATURE OF INSPECTOR: C. SMITH

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
23.5	0		Wash.			NOTE: Change of scale to 1"=5' at 10.0'.
	10					
11.5'			(SM) Gray to green fine silty SAND, trace dark mineral grains, trace mica, trace sand-sized shell fragments; mottled with gray to green low plasticity silt (dredge spoils).	Pull 1 Run=10.0 Rec=0.5		
	15					
	20					
	25			Pull 2 Run=10.9 Rec=1.0		
	30		(SW) Gray well graded SAND, trace fine gravel, trace fine dark mineral grains, trace sand-sized shell fragments, trace organic material.			
-8.4'			(MH) Gray to brown fat SILT, trace fine sand, trace fine gravel.	Pull 3 Run=10.0 Rec=2.2		
-9.0'			Seams of fine sand with little mica.		P-1	
			Organic material, soft, seams of lean silt and fine silty sand.			
	35					



CONTINUED ON SHEET No. 2

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 23.5' MLW

Hole No. SHE-10

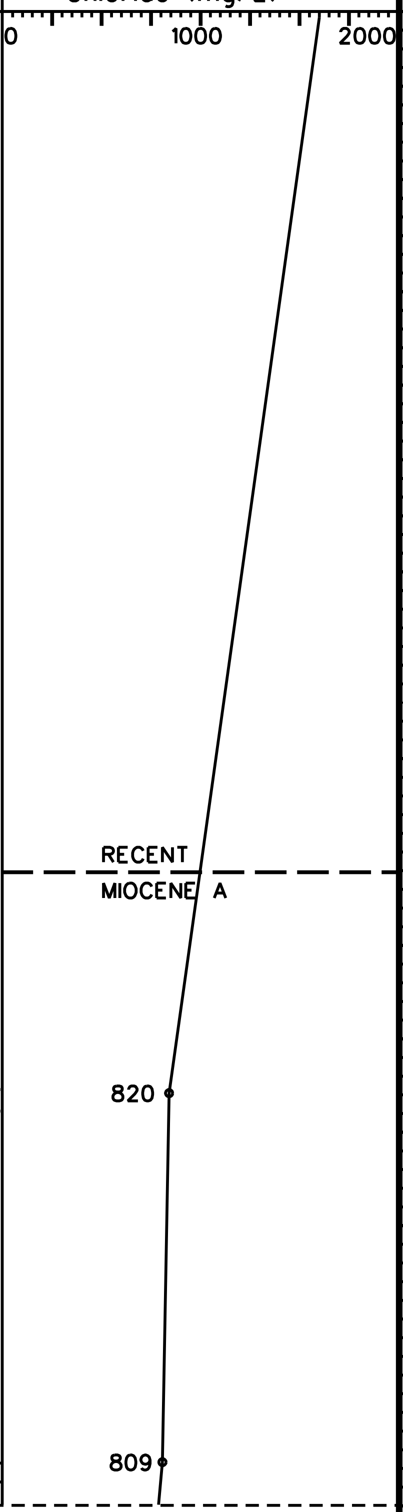
PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 2 OF 7 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT CORE RECOVERY e	SAMPLE NO. f
-11.6'	35	MH (Continued).		
		(SM) Light gray to gray coarse to medium silty SAND, trace dark mineral grains trace sand-sized shell fragments.		
	40			
	45		Pull 4 Run=5.0 Rec=2.5	
-23.8'		(SP) Tan to white coarse to medium poorly graded SAND, trace dark mineral grains trace sand-sized shell fragments.		
	50		Pull 5 Run=5.0 Rec=0.0	
	55			
			Pull 6 Run=10.0 Rec=1.5	
-34.5'		(SM) Green fine silty SAND, little dark mineral grains, trace organic material (Miocene A).		
	60			
			Pull 7 Run=1.5 Rec=1.5	P-2
		Yellow to green, increased silt content.		
-41.9'	65	(ML) Green low plasticity SILT, little fine sand, trace organic material, trace dark mineral grains, finely laminated, seams of fine sand occur every 0.2'.		
		Light olive green.	Pull 8 Run=8.5 Rec=3.2	
	70			
		Green, some sand.		P-3
	75	CONTINUED ON SHEET No. 3		

REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g



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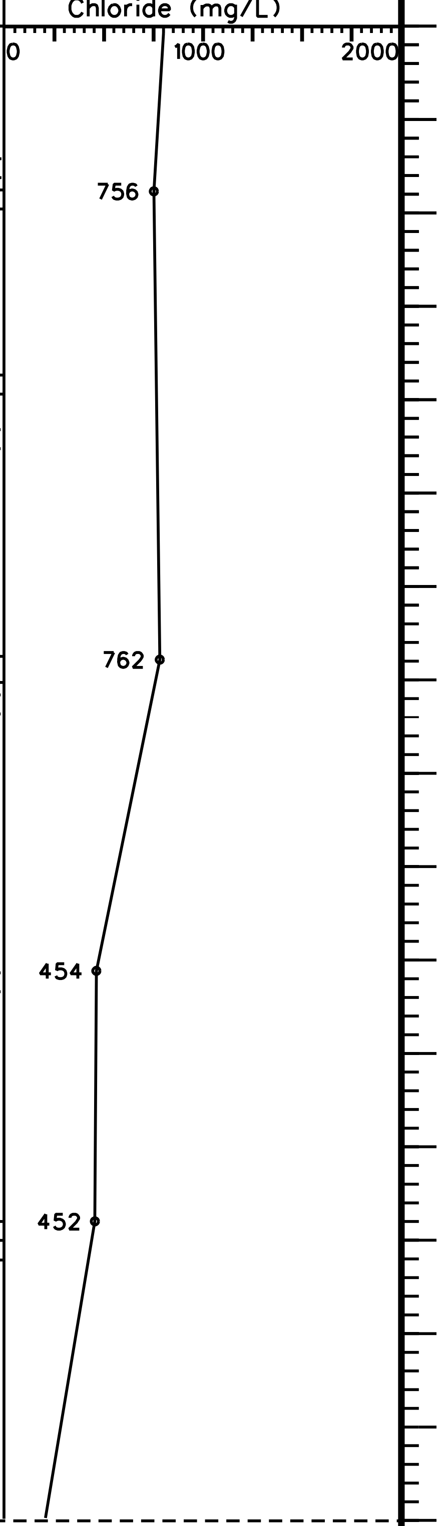
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE 23.5' MLW
Hole No. SHE-10
PROJECT SAVANNAH HARBOR DEEPENING
INSTALLATION SAVANNAH, GA
SHEET 3 OF 7 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f
	75	ML (Continued).		
-53.3'		(SM) Green fine silty SAND, little dark mineral grains, trace organic material, trace black, coarse, rounded phosphatic grains, partings of green low plasticity silt occur every 0.3'.	Pull 9 Run=10.0 Rec=7.0	K-1 P-4
-55.5'	80	(ML) Green low plasticity SILT, trace fine sand with little dark mineral grains, trace organic material, finely laminated with partings of fine sand occuring every 0.1'.		
		Light green, trace mica.		
		Sand partings less common.		
		Green, trace black, rounded phosphatic grains, blocky, no sand partings.	Pull 10 Run=4.0 Rec=8.5?	P-5 K-2
	85	No phosphatic grains.		
		Partings of fine sand.		
	90		Pull 11 Run=8.0 Rec=3.8	P-6 K-3
	95	Finely laminated, little fine sand, trace phosphatic grains.	Pull 12 Run=10.0 Rec=10.0	
		Partings rare, not laminated.		
	100			P-7
-77.4'		(SM) Green fine silty SAND, trace dark mineral grains, trace organic material, silt partings throughout.		
		Trace clay, trace phosphatic grains.		
-80.2'		(ML) Green low plasticity SILT, little fine sand, trace phosphatic grains, laminated.		
	105	Some fine sand, no phosphatic grains.		
		Trace fine sand.	Pull 13 Run=10.0 Rec=10.0	P-8 K-4
	110	Trace phosphatic grains.		
		Partings of fine sand common, no phosphatic grains.		
	115			

REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g



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DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 23.5' MLW

Hole No. SHE-10

PROJECT SAVANNAH HARBOR DEEPENING

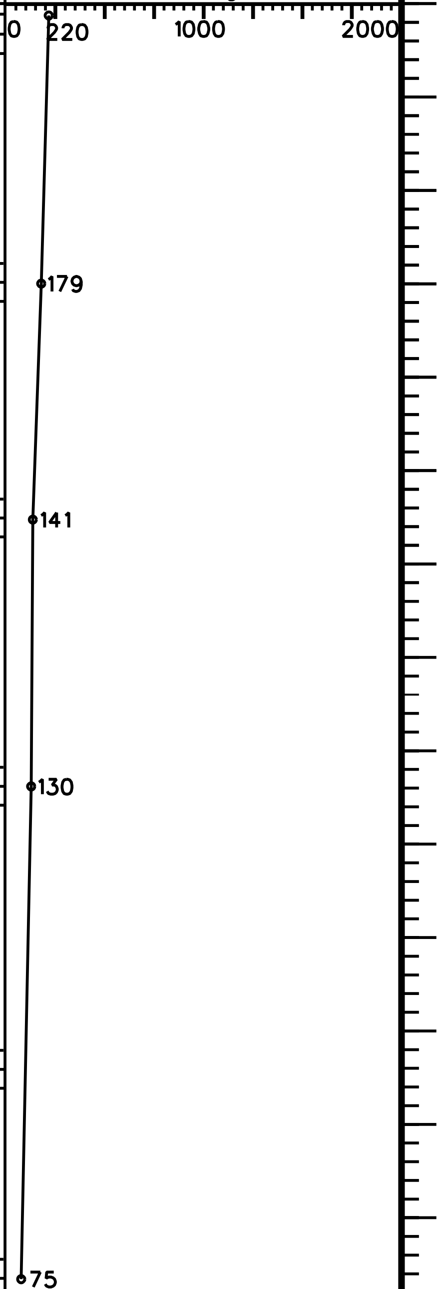
INSTALLATION SAVANNAH, GA

SHEET 4 OF 7 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f
	115	ML (Continued).		P-9 K-5
			Pull 14 Run-10.0 Rec-10.0	
	120			
				K-6 P-10
	125			
-103.5'		(SC) Green fine clayey SAND, some dark mineral grains.	Pull 15 Run-10.0 Rec-10.0	
				K-7 P-11
-106.6'	130	(CH) Green high plasticity CLAY, finely laminated partings of white calcareous material.		
	135	Trace organic material.		
				K-8 P-12
-114.1'		(SC) Green fine clayey SAND, trace organic material, laminated partings of fine sand.	Pull 16 Run-10.0 Rec-10.0	
-114.7'		(ML) Green low plasticity SILT, little fine sand, trace organic material, occasional partings of fine sand.		
-114.7'	140	Finely laminated with partings of white calcareous material, trace mica, trace dark mineral grains.		
-116.2'		(SP) Dark olive green fine poorly graded SAND, some dark mineral grains, trace organic material, trace rounded phosphatic grains.		
			Pull 17 Run-3.7 Rec-3.7	K-9 P-13
	145	(SM) Dark olive green fine phosphatic silty SAND, some dark mineral grains, trace organic material.		
		Trace fine phosphatic gravel, silt partings.		
-123.2'		(LS) Limestone, fine grained, cream to gray little dark mineral grains, trace fine gravel, very hard.	Pull 18 Run-3.0 Rec-0.6	
				K-10 P-14
	150	Occasional partings of olive green silt up to 1" thick.	Pull 19 Run-3.3 Rec-3.5	
	155			

REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g

Chloride (mg/L)



CONTINUED ON SHEET No. 5

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 23.5' MLW	**Hole No.** SHE-10
PROJECT SAVANNAH HARBOR DEEPENING	INSTALLATION SAVANNAH, GA	SHEET 5 OF 7 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L) 0 4000 8000
	155		Limestone (Continued).			
				Pull 20 Run=10.0 Rec=8.4		
	160				K-11 P-15	
					K-12 P-16	
	165			Pull 21 Run=10.0 Rec=10.0		MIOCENE A
-145.5'	170		(SM) Green fine silty SAND, little dark mineral grains, trace clay, hard.			MIOCENE B
			Cream to green, very hard, trace mica. Partings of green silt up to 0.1" thick.			
	175				P-17 K-13	
				Pull 22 Run=10.0 Rec=10.0		
	180		Burrow present, concentric inclusion.			
	185				K-14 P-18	
				Pull 23 Run=6.3 Rec=6.3		MIOCENE B
-165.8'	190		(LS) Limestone, very hard, cream to black, fossiliferous, vuggy with coarse to medium sand filling in voids.			LIMESTONE
			Cream, less vugs.	Pull 24 Run=3.7 Rec=2.0		
			Mottled with black phosphatic coloration, less fossils.			
			Little phosphatic fine gravel, voids are common and up to 1/8", silty sand filling in voids.	Pull 25 Run=1.4 Rec=1.4	P-19	
	195					

CONTINUED ON SHEET No. 6

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 23.5' MLW	Hole No. SHE-10
PROJECT SAVANNAH HARBOR DEEPENING	INSTALLATION SAVANNAH, GA	SHEET 6 OF 7 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	195		LS (Continued).			
			Cream to gray, phosphatic zoning common, very fossiliferous, no fine gravel.			
			Gray, vugs increase in size.			
			Dissolution cavities, fine gravel filling in voids.	Pull 26 Run=8.6 Rec=8.0		
	200		No fine gravel, vuggy.			
			Fine to medium grained, hard, voids are smaller, fossils are smaller and broken.			
	205					
				Pull 27 Run=10.0 Rec=10.0		
	210					
			Voids are up to 1/4" and common.			
	215					
				Pull 28 Run=10.0 Rec=8.2		
	220					
			Zones of grayish green silty material.			
			Cream, fossils are up to 1", vuggy.			
	225		Not vuggy, fine grained, no large fossils.			
			Vuggy with voids up to 1/2".			
				Pull 29 Run=10.0 Rec=9.1		
	230					
			Soft.			
			Hard.			
	235					

CONTINUED ON SHEET No. 7

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 23.5' MLW	Hole No. SHE-10
PROJECT SAVANNAH HARBOR DEEPENING	INSTALLATION SAVANNAH, GA	SHEET 7 OF 7 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	235		LS (Continued). Voids up to 1/4", fossils up to 1/2", soft. Voids less common, hard.	Pull 30 Run=10.0 Rec=9.5		
	240					
-219.5'						NOTE: Change of scale to 1"=30' at 250.0'.
	245					Core logging stopped at 243.0'. Hole advanced to 270' using 9 7/8" rock bit in order to set 6" SS casing. Hole further advanced using 5 7/8" rock bit to final depth of 370.0'.
	250					
	280					
	310					
	340					
-346.5'	370					

Sample	Top Depth	Chloride (mg/L)
10SP1	10.0	5086
10SP2	20.0	4374
10SP3	30.0	332
P-1	33.5	1769
P-2	63.8	820
P-3	73.9	810
P-4	79.4	756
P-5	84.3	NV
P-6	92.2	762
P-7	100.4	454
P-8	107.0	452
P-9	115.6	220
P-10	122.6	179
P-11	128.5	141
P-12	136.0	130
P-13	143.5	NV
P-14	152.5	76
P-15	161.5	NV
P-16	168.5	NV
P-17	174.0	NV
P-18	184.9	NV
P-19	193.0	NV

SP = Screen point sample

NV = No value reported

BOTTOM OF BORING AT 370.0'

275

Hole No. SHE-11

DRILLING LOG	DIVISION SOUTH ATLANTIC	INSTALLATION SAVANNAH, GA	SHEET 1 OF 3 SHEETS

1. PROJECT
SAVANNAH HARBOR DEEPENING

2. LOCATION *(Coordinates or Station)*
X-1038083.3, Y-747009.2 GA EAST

3. DRILLING AGENCY
SAVANNAH DISTRICT

4. HOLE NO. *(As shown on drawing title and file number)* : SHE-11

5. NAME OF DRILLER
D. HEWETT

6. DIRECTION OF HOLE
☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.

7. THICKNESS OF OVERBURDEN >140.0'

8. DEPTH DRILLED INTO ROCK 10.0'

9. TOTAL DEPTH OF HOLE 140.0'

10. SIZE AND TYPE OF BIT HQ CORE BARREL

11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
MLLW

12. MANUFACTURER'S DESIGNATION OF DRILL
Failing 1500 CD-3

13. TOTAL NO. OF SOIL SAMPLES TAKEN : DISTURBED 0 : UNDISTURBED 0

14. TOTAL NUMBER CORE BOXES 5

15. GROUND WATER ELEVATION N/A

16. DATE HOLE : STARTED 09 Dec 2003 : COMPLETED 12 Dec 2003

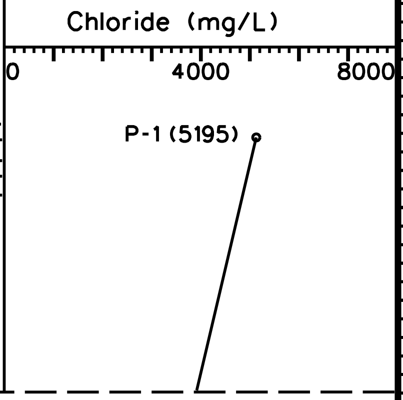
17. ELEVATION TOP OF HOLE 0.0' MLLW

18. TOTAL CORE RECOVERY FOR BORING 86 %

19. SIGNATURE OF INSPECTOR
C. SMITH, G. TAYLOR, M. McINTOSH

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT CORE RECOVERY e	BOX NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
0.0	0		Water. BOTTOM OF RIVER AT -32.8'			NOTE: Change of scale to 1" • 5' at 30.0'. Set 73' of 6" casing to a depth of -54.8'. Began using Super Gel-X freshwater drilling mud at -32.0". Grouted hole after completion of boring.
-32.8'			Wash.			
-47.8'			(SM) Gray to green fine silty SAND, trace dark mineral grains, firm to stiff.		P-1	
-48.9'			(CL) Gray to green low plasticity CLAY, trace fine quartz sand, stratified structure, firm to stiff.	Pull 1 Run•8.5 Rec•8.5	K-1	

Depth scale: 30, 35, 40, 45, 50, 55



CONTINUED ON SHEET •2

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 0.0' MLLW

Hole No. SHE-11

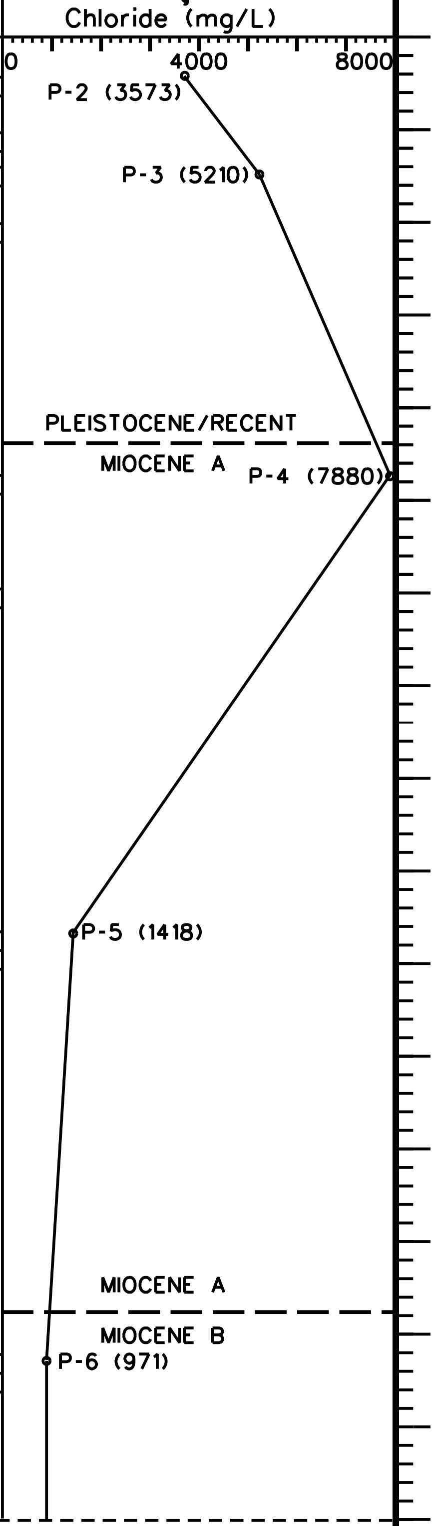
PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 2 OF 3 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	BOX NO. f
	55 60		CL (Continued).	Pull 2 Run=10.0 Rec=6.9	P-2 K-2 P-3 K-3
-65.3'	65		(SW) Gray well graded, well rounded SAND, loose, 10% gravel up to 0.5", 5% shell fragments up to 0.5".		
-65.8'	70		(SM)-MIOCENE A-Dark olive green phosphatic silty SAND, slightly indurated, trace shell fragments up to 0.5". No shell fragments, trace black phosphatic medium sand sized grains. Green.	Pull 3 Run=6.5 Rec=5.0	P-4 K-4
-70.6'			(SP) Dark olive green fine to medium phosphatic poorly graded SAND, trace fines, stiff.		
-72.8'	75 80		(SM) Dark olive green phosphatic silty SAND, trace black medium sand sized grains, 2% subangular dark mineral fine gravel, highly indurated. Green to gray, 5% black grains. Gray, coarse black grains, 5% quartz gravel up to 0.25". Gray to green, burrows up to 1" occurring every 0.4 to 0.5', increased fines. Green, not indurated, no burrows.	Pull 4 Run=3.0 Rec=1.2 Pull 5 Run=2.0 Rec=1.6 Pull 6 Run=11.0 Rec=7.5	P-5 K-5
-83.5'	85		(CL) Green low plasticity CLAY, 5% black medium sand sized phosphatic grains, 1% very fine quartz sand, indurated, hard, burrow at 102.0'. Not indurated, stiff.		
-89.3'	90 95		(SM)-MIOCENE B-Green fine silty SAND, trace black fine sand sized grains, slightly indurated.	Pull 7 Run=3.0 Rec=3.7 Pull 8 Run=10.0 Rec=10.2	P-6 K-6

REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g



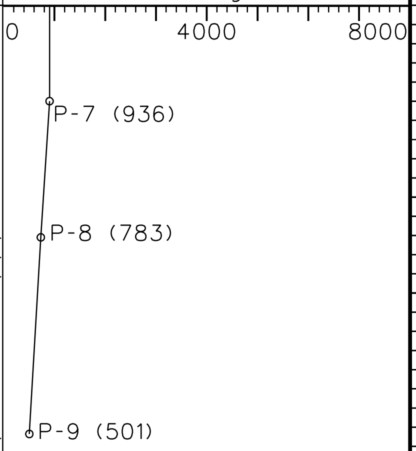
CONTINUED ON SHEET *3

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 0.0' MLLW	Hole No. SHE-11	
PROJECT SAVANNAH HARBOR DEEPENING	INSTALLATION SAVANNAH, GA		SHEET 3 OF 3 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	BOX NO. f
	95		SM (Continued).		
			Not indurated.	Pull 8 Run=10.0 Rec=10.2	P-7 K-7
	100				P-8 K-8
			Slightly indurated.		
	105			Pull 9 Run=9.5 Rec=9.7	P-9 K-9
	110			Pull 10 Run=2.0 Rec=2.1	
-111.8'			(LS) Limestone, highly weathered, very fine to fine grained, few vugs up to 0.25", black, fossiliferous, weak HCl rxn.	Pull 11 Run=1.5 Rec=1.3	
			Moderately weathered, less vugs, gray, strong HCl rxn.	Pull 12 Run=1.5 Rec=1.2	
	115		Slightly weathered, cream colored. 0.1" lens of slightly weathered, green to brown, moderate HCl rxn at 131.9'.	Pull 13 Run=2.0 Rec=2.3	
			Moderately weathered, gray to white, highly fossiliferous, strong HCl rxn.	Pull 14 Run=5.0 Rec=4.9	
	120				
-121.8'					

REMARKS
(Drilling time, water loss, depth of weathering, etc., if significant)
g

Chloride (mg/L)



MIOCENE B

LIMESTONE

Sample	Top Elev	Mud Cond. (mS/cm)
P-1	-48.3	4.45
P-2	-56.3	5.83
P-3	-58.8	6.14
P-4	-66.8	6.22
P-5	-79.3	5.98
P-6	-90.8	7.82
P-7	-97.5	7.93
P-8	-100.8	5.43
P-9	-106.5	6.50

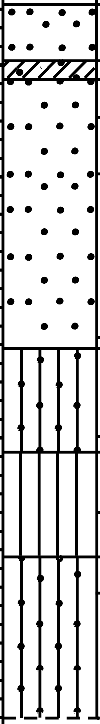
BOTTOM OF BORING AT -121.8'

125

Hole No. SHE-12

DRILLING LOG	DIVISION SOUTH ATLANTIC	INSTALLATION SAVANNAH, GA	SHEET 1 OF 2 SHEETS

1. PROJECT SAVANNAH HARBOR DEEPENING
2. LOCATION *(Coordinates or Station)* X-1043110.36, Y-743816.9 GA EAST
3. DRILLING AGENCY SAVANNAH DISTRICT
4. HOLE NO. *(As shown on drawing title and file number)* : SHE-12
5. NAME OF DRILLER D. HEWETT
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN >92.3'
8. DEPTH DRILLED INTO ROCK 0.0'
9. TOTAL DEPTH OF HOLE 92.3'
10. SIZE AND TYPE OF BIT 1⅜" I. D. SPLITSPOON
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* MLLW
12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500 CD-3
13. TOTAL NO. OF SOIL SAMPLES TAKEN : DISTURBED 20 : UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES NONE
15. GROUND WATER ELEVATION N/A
16. DATE HOLE : STARTED 16 DEC 2003 : COMPLETED 17 DEC 2003
17. ELEVATION TOP OF HOLE 0.0' MLLW
18. TOTAL CORE RECOVERY FOR BORING NONE %
19. SIGNATURE OF INSPECTOR C. SMITH, M. McINTOSH



ELEVATION (FT) 0.0 a	DEPTH (FT) b 0	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT MOISTURE CONTENT e	JAR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g	BLOWS/FT.
	45		Water. BOTTOM OF RIVER AT -45.9'			NOTE: Change of scale to 1" = 5' at 60.0'. Set 65' of casing to a depth of -46.9'. Began using Super Gel-X freshwater drilling mud at -45.9'. Grouted hole after completion of boring.	
-45.9			(SP) Tan fine poorly graded SAND, trace dark mineral grains, trace shell fragments up to 0.5", wet.		1	Switch to saltwater drilling mud.	44
-47.4			(SC) Dark gray medium to fine clayey SAND, trace dark mineral grains, moderate HCl rxn, moist.		2		54
-47.9	50		(SP) Dark gray fine poorly graded SAND, little dark mineral grains, trace shell fragments up to 0.25", not cemented, strong HCl rxn, wet.		3		43
			No shells, trace well rounded fine gravel, trace fines.		4		52
			No fine gravel, little fines.		5		60
			Lens of dark gray low plasticity clay, trace very fine quartz sand.		6		49
-55.1	55		(SM) Dark gray fine silty SAND, trace dark mineral grains, not cemented, partings of white fine calcareous material, stiff.		7		47
			No white partings, finely laminated.		8		47
-57.9			(ML) Gray to green low plasticity SILT, stiff, not cemented, blocky, strong HCl rxn, dry. Burrow and partings present filled with medium to fine sand, trace dark mineral grains, trace shell fragments up to 0.25".		9		41
	60				10		40
-60.6			No burrows, trace medium to fine sand, moist.		11		38
			(SM) Gray to green fine silty SAND, little dark mineral grains, strong HCl rxn, not cemented, moist.		12		49
	65		Partings of white calcareous material.		13		50

CONTINUED ON SHEET #2

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

BLOWS PER FOOT: NUMBER REQUIRED TO DRIVE 1⅜" I. D. SPLITSPOON W/140 LB. HAMMER FALLING 30".

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 0.0' MLLW

Hole No. SHE-12

PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 2 OF 2 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT MOISTURE CONTENT e	JAR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
-65.4	65		SM (Continued).		13	
			(SP) Gray, fine to medium poorly graded SAND, trace mica, trace dark mineral grains, trace shell fragments up to 1/16".		14	65
			Little shell fragments, little fines.		15	49
	70		(ML) Grayish green low plasticity SILT, trace very fine sand, no cementation, blocky, moderate HCl rxn, dry (MIOCENE A).		16	88
-71.0			Some fine sand, trace heavy mineral grains.		17	PALEOCHANNEL MIOCENE A 76
			Partings of fine quartz sand occurring every 0.3 inches. Orange colored partings at 90.8'.		18	
					19	76
-74.2					20	50/1.3
	75		BOTTOM OF BORING AT 74.2'			

Hole No. SHE-13

DRILLING LOG	DIVISION SOUTH ATLANTIC	INSTALLATION SAVANNAH, GA	SHEET 1 OF 2 SHEETS

1. PROJECT
SAVANNAH HARBOR DEEPENING

2. LOCATION *(Coordinates or Station)*
X-1043732, Y-743660 GA EAST

3. DRILLING AGENCY
SAVANNAH DISTRICT

4. HOLE NO. *(As shown on drawing title and file number)* : SHE-13

5. NAME OF DRILLER
D. HEWETT

6. DIRECTION OF HOLE
☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.

7. THICKNESS OF OVERBURDEN >125.5'

8. DEPTH DRILLED INTO ROCK 0.5'

9. TOTAL DEPTH OF HOLE 125.5'

10. SIZE AND TYPE OF BIT HQ CORE BARREL

11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
MLLW

12. MANUFACTURER'S DESIGNATION OF DRILL
Failing 1500 CD-3

13. TOTAL NO. OF SOIL SAMPLES TAKEN : DISTURBED 0 : UNDISTURBED 0

14. TOTAL NUMBER CORE BOXES 5

15. GROUND WATER ELEVATION N/A

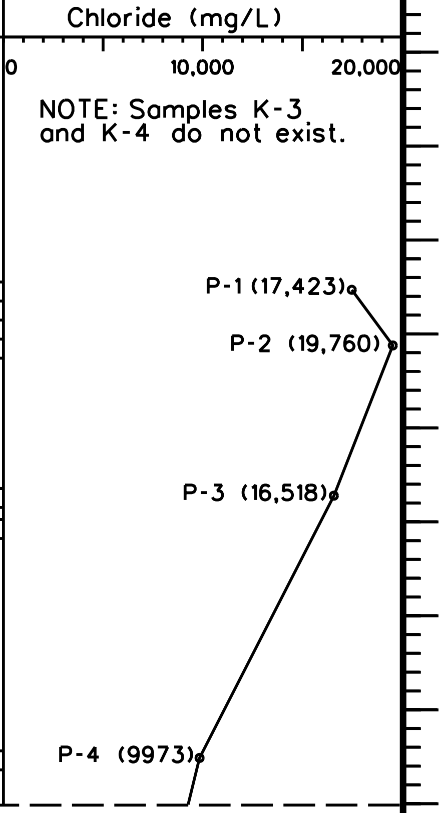
16. DATE HOLE : STARTED 12 Jan 2004 : COMPLETED 14 Jan 2004

17. ELEVATION TOP OF HOLE 0.0' MLLW

18. TOTAL CORE RECOVERY FOR BORING 80 %

19. SIGNATURE OF INSPECTOR
C. SMITH, G. TAYLOR, M. McINTOSH

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
0.0	0					
	40		Water.			NOTE: Change of scale to 1" = 5' at 60.0'. Set 73' of 6" casing to a depth of -54.6'. Began using Super Gel-X freshwater drilling mud @ -44.6'. Grouted hole after completion of boring.
			BOTTOM OF RIVER AT -44.6'			
-44.6'	45		(SC) Gray, fine clayey SAND, 3% shell fragments up to 1/4", 2% dark mineral grains, HCl rxn, wet, sulfur odor.	Pull 1 Run=10.0 Rec=4.5		NOTE: Samples K-3 and K-4 do not exist.
	50		(SM) Gray, medium to fine silty SAND, 10% shell fragments up to 1/8", 10% dark mineral grains, 1% micaceous material, HCl rxn, moist.			
-51.1'					P-1 K-1 P-2	
-54.6'	55		(SC) Gray, fine clayey SAND, 3% shell fragments up to 1/4", 2% dark mineral grains, HCl rxn, wet, sulfur odor.			
			Occasional interbedded clayey sand and laminated silt in layers from 1/2" to 2" thick.	Pull 2 Run=5.0 Rec=5.0	P-3 K-2	
			Greenish gray, clay layers thicker.			
-59.9'	60		(ML) Greenish gray low plasticity SILT, 2% very fine sand, not cemented, laminated, strong HCl rxn, dry.			
-62.6'			(SC) Gray fine clayey SAND, 3% shell fragments up to 1/8" inches, 1% dark mineral grains, weak HCl rxn, wet.	Pull 3 Run=5.5 Rec=3.0	P-4	
			Trace gravel up to 1", 1" calcareous shell fragment at 81.7'.			
-64.6'	65		(ML) Greenish gray low plasticity SILT, 2% very fine sand, not cemented, blocky, strong HCl rxn, dry.			



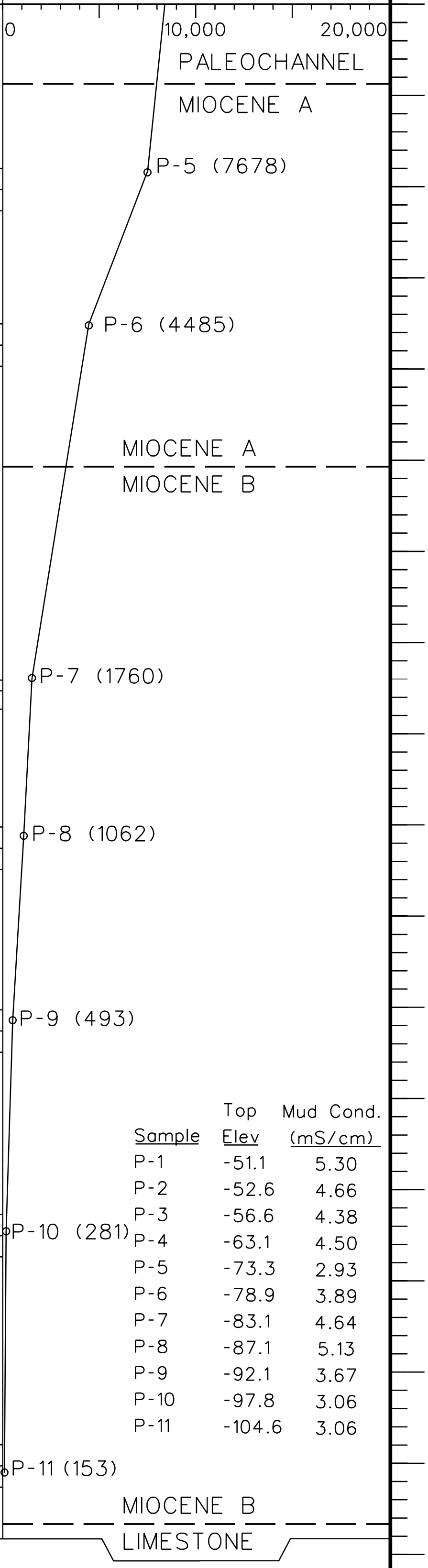
CONTINUED ON SHEET #2

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE 0.0' MLLW
Hole No. SHE-13

PROJECT SAVANNAH HARBOR DEEPENING
INSTALLATION SAVANNAH, GA
SHEET 2 OF 2 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L)
-65.6'	65		ML (Continued). (SC) Greenish gray fine clayey SAND, 10% dark mineral grains, strong HCl rxn, moist.			
-67.1'	70 75		(ML)-MIOCENE A-Green to gray low plasticity SILT, trace very fine sand, 1% dark mineral grains, laminated, moderate HCl rxn, very stiff to hard. Laminae up to 1/2" thick, partings of gray fine quartz sand with 10% dark mineral grains. Laminae up to 1/4" thick, sand partings less common. Increased clay content.	Pull 4 Run=12.0 Rec=9.0	P-5 K-5 P-6 K-6	
-77.6'	80		(SP)-MIOCENE B-Dark olive green phosphatic coarse poorly graded SAND, well rounded, trace pea gravel, no HCl rxn, stiff. Yellow green, trace dark mineral grains, no phosphatic grains, no pea gravel, very weak HCl rxn, hard.	Pull 5 Run=3.5 Rec=2.5		
-82.7'			(SM) Dark olive green phosphatic fine silty SAND, trace pea gravel up to 1/4", no HCl rxn, stiff.	Pull 6 Run=10.0 Rec=10.3		
-82.9'	85		(ML) Light olive green low plasticity SILT, 1% very fine sand, <1% dark mineral grains, no HCl rxn, stiff. Olive green.		P-7 K-7 P-8 K-8	
-90.3'	90		(SM) Tan, indurated fine silty SAND, sub-angular, trace dark mineral grains, HCl rxn, hard. Light olive green, not indurated, 5% very fine sand, no HCl rxn, very stiff.			
-91.6'	95 100		(SC) Light olive green fine clayey SAND, little dark phosphatic grains up to 1/4", trace dark mineral grains, trace shell fragments up to 1/4", no HCl rxn, very stiff.	Pull 7 Run=10.0 Rec=4.5	P-9 K-9 P-10 K-10	
-101.1'	105		(SM) Olive green fine silty SAND, little dark mineral grains, trace mica, no HCl rxn, stiff. Gradational darkening down to 125.0'. Lens of clayey sand.	Pull 8 Run=6.0 Rec=6.4	P-11 K-11	
-106.6'			(LS) Limestone, very soft, highly weathered, fine grained, white to dark gray, phosphatic grains filling in vugs.			
-107.1'			BOTTOM OF BORING AT -107.1'			



Sample	Top Elev	Mud Cond. (mS/cm)
P-1	-51.1	5.30
P-2	-52.6	4.66
P-3	-56.6	4.38
P-4	-63.1	4.50
P-5	-73.3	2.93
P-6	-78.9	3.89
P-7	-83.1	4.64
P-8	-87.1	5.13
P-9	-92.1	3.67
P-10	-97.8	3.06
P-11	-104.6	3.06

Hole No. SHE-14

DRILLING LOG

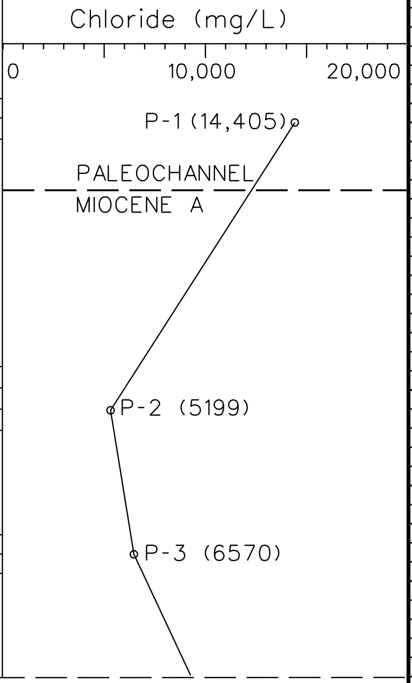
DIVISION SOUTH ATLANTIC

INSTALLATION SAVANNAH, GA

SHEET 1 OF 2 SHEETS

1. PROJECT SAVANNAH HARBOR DEEPENING
2. LOCATION *(Coordinates or Station)* X-1055157, Y-743062 GA EAST
3. DRILLING AGENCY SAVANNAH DISTRICT
4. HOLE NO. *(As shown on drawing title and file number)* SHE-14
5. NAME OF DRILLER D. HEWETT
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN >119.0'
8. DEPTH DRILLED INTO ROCK 0.5'
9. TOTAL DEPTH OF HOLE 119.0'
10. SIZE AND TYPE OF BIT HQ CORE BARREL
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* MLLW
12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500 CD-3
13. TOTAL NO. OF SOIL SAMPLES TAKEN DISTURBED 0 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 5
15. GROUND WATER ELEVATION N/A
16. DATE HOLE STARTED 21 Jan 2004 COMPLETED 24 Jan 2004
17. ELEVATION TOP OF HOLE 0.0' MLLW
18. TOTAL CORE RECOVERY FOR BORING 82 %
19. SIGNATURE OF INSPECTOR C. SMITH, G. TAYLOR, M. McINTOSH

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
			Water. BOTTOM OF RIVER AT -34.3'			
-34.3'	35 40		(SM) Tan to black, medium to coarse silty SAND, little oyster shells up to 0.1", trace fine gravel, trace fine dark mineral grains, not cemented, no HCl rxn, wet.	Pull 1 Run=10.0 Rec=2.0		NOTE: Change of scale to 1" = 5' at 30.0'. Set 68' of 6" casing to a depth of -49.3. Began using Super Gel-X freshwater drilling mud at -34.3'. Grouted hole after completion of boring.
-42.8' -43.3'			(SP) Tan fine to medium well rounded poorly graded SAND.			
-44.3'	45		(SW) White to black well rounded well graded SAND, 5% gravel up to 1", trace fines.		K-1 P-1	
			(ML) Greenish gray, stiff, medium plasticity SILT, trace very fine sand, finely laminated, moist.			
-47.1'	50		(SM)-MIOCENE A-Greenish gray fine quartz silty SAND, trace dark mineral grains, trace mica, weak HCl rxn, moist. Partings of gray very fine quartz sand, trace dark mineral grains, no HCl rxn, moist. Finely laminated. Laminated, trace dark mineral grains. Finely laminated.	Pull 2 Run=10.0 Rec=10.6	K-2 P-2	
	55		Decreased fines, wet, not laminated, no partings. Laminated, moist.	Pull 3 Run=10.0 Rec=5.9	K-3 P-3	
	60		CONTINUED ON SHEET #2			NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.



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DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 0.0' MLLW

Hole No. SHE-14

PROJECT SAVANNAH HARBOR DEEPENING

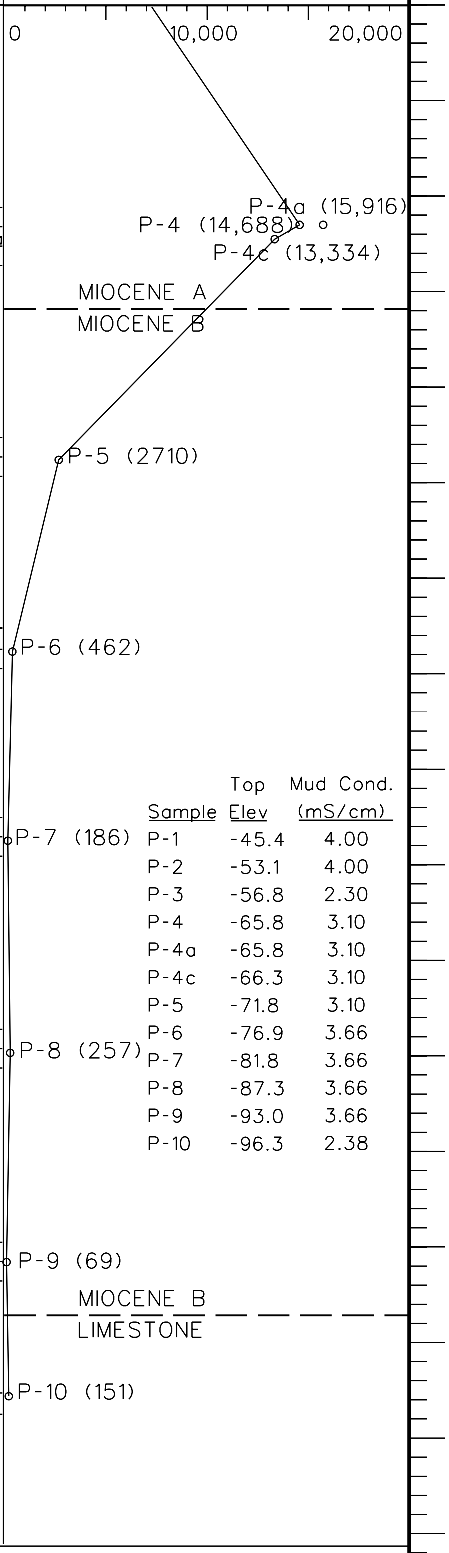
INSTALLATION SAVANNAH, GA

SHEET 2 OF 2 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f
	60	SM (Continued).		
-62.9'		(SW) Gray to green well graded SAND, little medium to fine dark mineral grains, trace shell fragments up to 0.01", trace fines, weak HCl rxn, soft, wet.		
-64.3'	65	(SP) Tan to black and dark olive green mottled fine poorly graded well rounded phosphatic SAND, trace coarse grains, trace shell fragments, no HCl rxn, wet.		K-4 P-4, P-4a P-4c
-67.9'		(SM)-MIOCENE B-Dark olive green fine phosphatic silty SAND, trace fine gravel, wet.	Pull 4 Run=10.0 Rec=10.0	
-69.8'	70	(SC) Light olive green fine clayey quartz SAND, trace dark mineral grains, blocky, very stiff, dry.		K-5 P-5
		Olive green.		
	75	Decreased clay content.		K-6 P-6
-77.4'		(SM) Olive green fine silty SAND, trace dark mineral grains, blocky, very stiff, dry.	Pull 5 Run=10.0 Rec=10.2	
	80			K-7 P-7
		Layers of olive green very stiff silt up to 1".		
	85	No silt layers.		
		Some dark mineral grains.	Pull 6 Run=10.0 Rec=10.2	K-8 P-8
		Decreased silt content, hard.		
	90	Finely laminated.		K-9 P-9
-93.5'		(SP) Dark olive green fine phosphatic SAND, some rounded dark mineral grains, little fines, very stiff, moist.		
-94.2'	95	(LS) Limestone, highly weathered, aphanitic black, HCl rxn, shattered.		
		Very soft, fine grained, white, little dark mineral grains, little shell fragments up to 0.25", strong HCl rxn.	Pull 7 Run=6.0 Rec=5.5	P-10
		Tan.		
-100.3'	100	BOTTOM OF BORING AT -100.3'		

REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g

Chloride (mg/L)



Sample	Top Elev	Mud Cond. (mS/cm)
P-1	-45.4	4.00
P-2	-53.1	4.00
P-3	-56.8	2.30
P-4	-65.8	3.10
P-4a	-65.8	3.10
P-4c	-66.3	3.10
P-5	-71.8	3.10
P-6	-76.9	3.66
P-7	-81.8	3.66
P-8	-87.3	3.66
P-9	-93.0	3.66
P-10	-96.3	2.38

Hole No. SHE-15

DRILLING LOG	DIVISION SOUTH ATLANTIC	INSTALLATION SAVANNAH, GA	SHEET 1 OF 5 SHEETS

1. PROJECT
SAVANNAH HARBOR DEEPENING

2. LOCATION *(Coordinates or Station)*
E-979959.61, N-769041.05 GA EAST

3. DRILLING AGENCY
SAVANNAH DISTRICT

4. HOLE NO. *(As shown on drawing title and file number)* : SHE-15

5. NAME OF DRILLER
D. HEWETT

6. DIRECTION OF HOLE
☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.

7. THICKNESS OF OVERBURDEN >224.5'

8. DEPTH DRILLED INTO ROCK 10.2'

9. TOTAL DEPTH OF HOLE 224.5'

10. SIZE AND TYPE OF BIT HQ CORE BARREL

11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
MLLW

12. MANUFACTURER'S DESIGNATION OF DRILL
Failing 1500

13. TOTAL NO. OF SOIL SAMPLES TAKEN : DISTURBED 0 : UNDISTURBED 0

14. TOTAL NUMBER CORE BOXES 14

15. GROUND WATER ELEVATION N/A

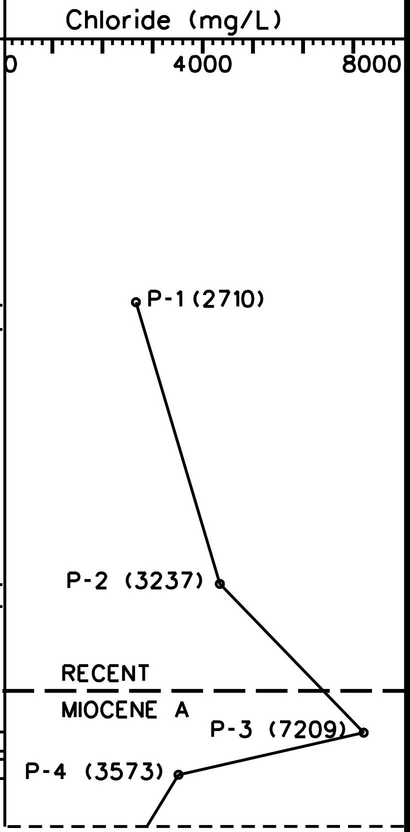
16. DATE HOLE : STARTED 13 APR 2004 : COMPLETED 16 APR 2004

17. ELEVATION TOP OF HOLE 0.0' MLLW

18. TOTAL CORE RECOVERY FOR BORING 83 %

19. SIGNATURE OF INSPECTOR
C. SMITH/M. McINTOSH

ELEVATION (FT) 0.0 a	DEPTH (FT) b 0	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
	30		Water.			NOTE: Change of scale to 1" = 5' at 30.0'. Set 71' of 6" casing to a depth of -37.6'. Began using Super Gel-X freshwater drilling mud at -34.3'. Grouted hole upon completion of boring.
-34.3'			BOTTOM OF RIVER AT -34.3'			
	35		(MH) Dark gray to black fat SILT, soft, wet.	Pull 1 Run=5.0 Rec=0.0		
			Brown to gray.			
	40			Pull 2 Run=5.0 Rec=2.0	P-1	
	45			Pull 3 Run=5.0 Rec=1.5		
-49.3'			(SP) Gray to brown medium to fine poorly graded SAND, trace black grains, soft, mottled with gray fat silt from above.		P-2	
	50					
-51.3'			(SW) Gray to brown well graded SAND, trace black grains, trace mica, trace fine gravel, soft.	Pull 4 Run=5.0 Rec=4.2		
-51.5'			(ML) Gray to green lean SILT, laminated, blocky texture, stiff (Miocene A).		P-3 P-4	
			Clayey, not laminated, soft.			
	55					



CONTINUED ON SHEET No. 2

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE
0.0' MLLW

Hole No. SHE-15

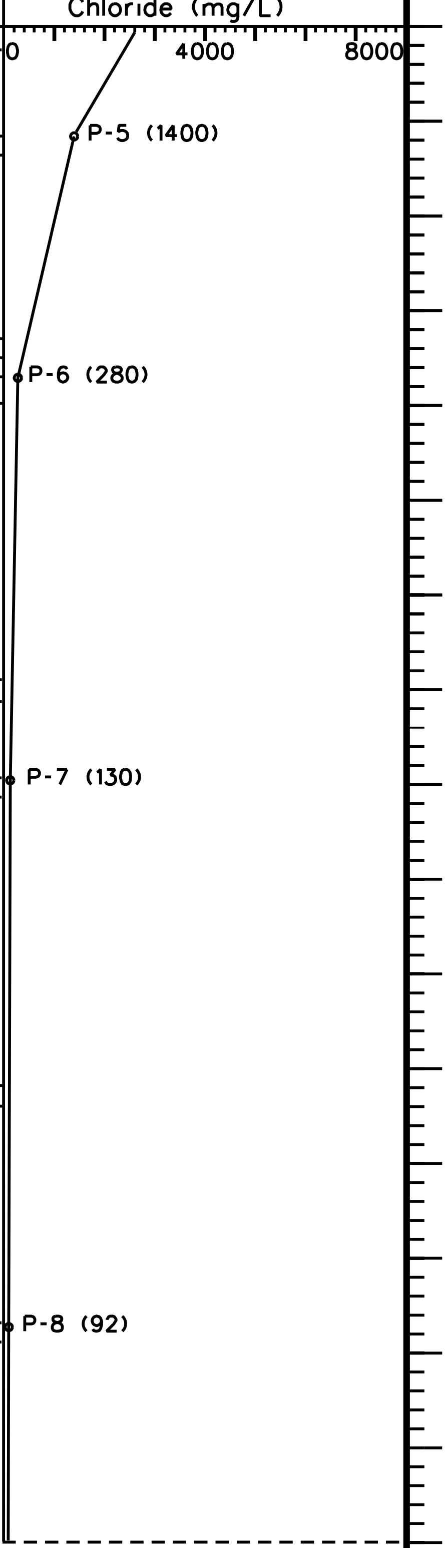
PROJECT
SAVANNAH HARBOR DEEPENING

INSTALLATION
SAVANNAH, GA

SHEET 2
OF 5 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f
	55	ML (Continued).		K-1
-55.6'		(SC) Green fine clayey sand, soft.	Pull 5 Run=5.0 Rec=5.0	P-5
-59.3'	60	(SM) Green to gray fine silty SAND, trace organic matter, laminated, firm to stiff.	Pull 6 Run=5.0 Rec=5.3	
		Gray, very stiff.		K-2
	65	Green, firm.		P-6
		Hard.	Pull 7 Run=10.0 Rec=10.0	
	70			K-3
		Occasional partings of gray fine sand.		
-74.3'	75	(ML) Green lean SILT, laminated, hard, partings of fine sand occur every ~0.5'.		P-7
-77.5'		(SM) Green fine silty SAND, laminated, firm to stiff.	Pull 8 Run=10.0 Rec=10.0	
	80	Very stiff to hard.		K-4
-83.7'	85	(ML) Greenish gray lean SILT, little organic matter, laminated, hard.		
		Clayey.		
		Trace clay.	Pull 9 Run=10.0 Rec=8.0	P-8
-89.5'	90	(SM) Green fine silty SAND, little organic matter, little mica, laminated, stiff.		
		Partings of gray fine sand.		
	95			

REMARKS
(Drilling time, water loss, depth of weathering, etc., if significant)
g



CONTINUED ON SHEET No. 3

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 0.0' MLLW

Hole No. SHE-15

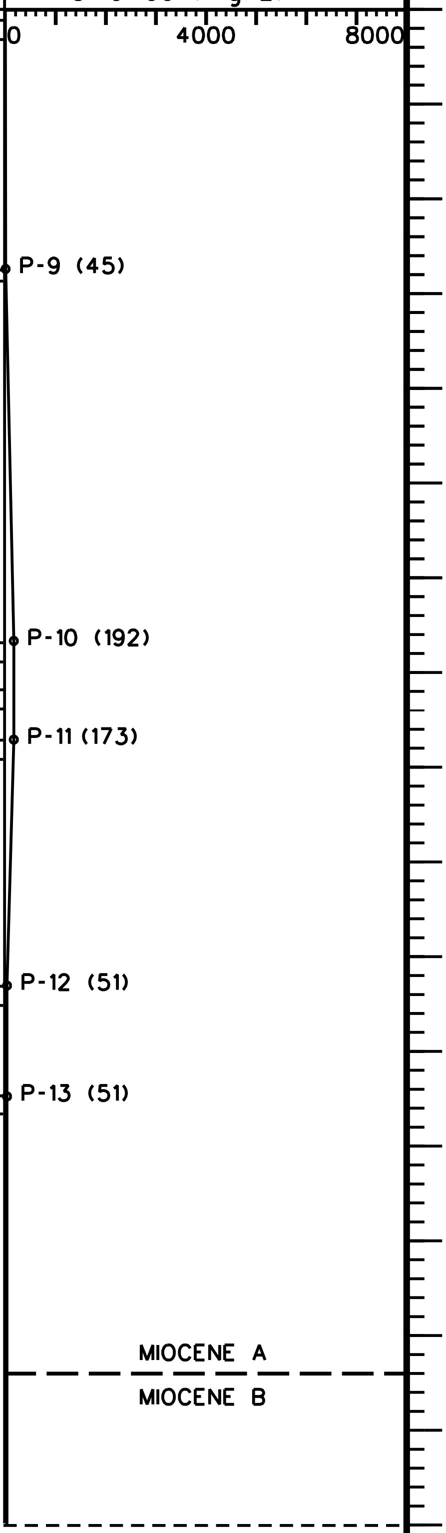
PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 3 OF 5 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f
	95	SM (Continued).		K-5
-97.3'	100	(SC) Gray fine clayey SAND, trace mica, trace organic matter, HCl rxn, firm.	Pull 10 Run=8.0 Rec=8.2	
-101.4'		(SM) Green fine silty SAND, little black grains, trace organic matter, HCl rxn, stiff. Clayey, weak HCl rxn, hard.		P-9
-103.1'	105	(ML) Green lean SILT, laminated, HCl rxn, hard.	Pull 11 Run=10.0 Rec=5.0	
-107.1'	110 115	(SM) Green fine silty SAND, trace organics, weak HCl rxn, hard.		P-10 K-6 P-11
-115.8'	120	(SC) Green fine clayey SAND, trace mica, finely laminated, weak HCl rxn, firm to stiff. Phosphatic, medium to fine. (SP) Tan fine poorly graded SAND, little dark grains, indurated.	Pull 12 Run=10.0 Rec=9.0	P-12
-122.1'		Partings of green clayey sand every 0.5'.	Pull 13 Run=2.0 Rec=2.0	
-123.6'		(SC) Tan to yellow fine clayey SAND, trace fine phosphatic grains, HCl rxn, stiff to hard. Green.	Pull 14 Run=1.0 Rec=1.0	P-13
-124.4'	125	(SP) Tan fine poorly graded SAND, trace dark grains, weak HCl rxn very stiff, partings of green clayey sand throughout. No partings, hard.	Pull 15 Run=2.0 Rec=0.5	
-127.3'		(SM) Brown to green fine silty SAND, laminated, firm.		
-128.5'	130	(SP) Gray medium to fine poorly graded SAND, some dark grains, soft to firm, 0.1' horizons of green lean clay occur every ~0.4'.	Pull 16 Run=9.0 Rec=6.8	
-131.0'		(CL) Green lean CLAY, finely laminated, stiff, partings of gray fine sand every ~0.5' (Miocene B). Tan colored parting. Tan colored parting.		
-134.1'	135	(SC) Grayish green fine clayey SAND, laminated, weak HCl rxn, stiff to hard.		

REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g



CONTINUED ON SHEET No. 4

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 0.0' MLLW	Hole No. SHE-15
PROJECT SAVANNAH HARBOR DEEPENING	INSTALLATION SAVANNAH, GA	SHEET 4 OF 5 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L)
	135	▨	SC (Continued).		K-7 P-14	0 4000 8000 P-14 (18)
		▨	Trace phosphatic grains, firm.			
		▨	Partings of tan lean clay occur throughout, very stiff.			
	140	▨	Partings every ~0.5'.	Pull 17 Run=10.0 Rec=9.5		
		▨	No partings, medium to fine sand, hard.			
	145	▨			K-8 P-15	P-15 (12)
		▨	Green, fine sand.			
		▨	Increased silt content.			
-150.5'	150	⁝	(SM) Green fine silty SAND, weak HCl rxn, hard.	Pull 18 Run=10.0 Rec=9.5		
-152.0'		▨	(SC) Green fine clayey SAND, laminated, weak HCl rxn, hard.			
-152.9'		⁝	(SM) Green fine silty SAND, trace mica, blocky, very stiff to hard.			
	155	⁝			P-16 K-9	P-16 (22)
	160	⁝		Pull 19 Run=6.0 Rec=6.0		
	165	⁝		Pull 20 Run=10.0 Rec=10.0		
	170	⁝			K-10 P-17	P-17 (11)
	175					

CONTINUED ON SHEET No. 5

DRILLING LOG (Cont Sheet)

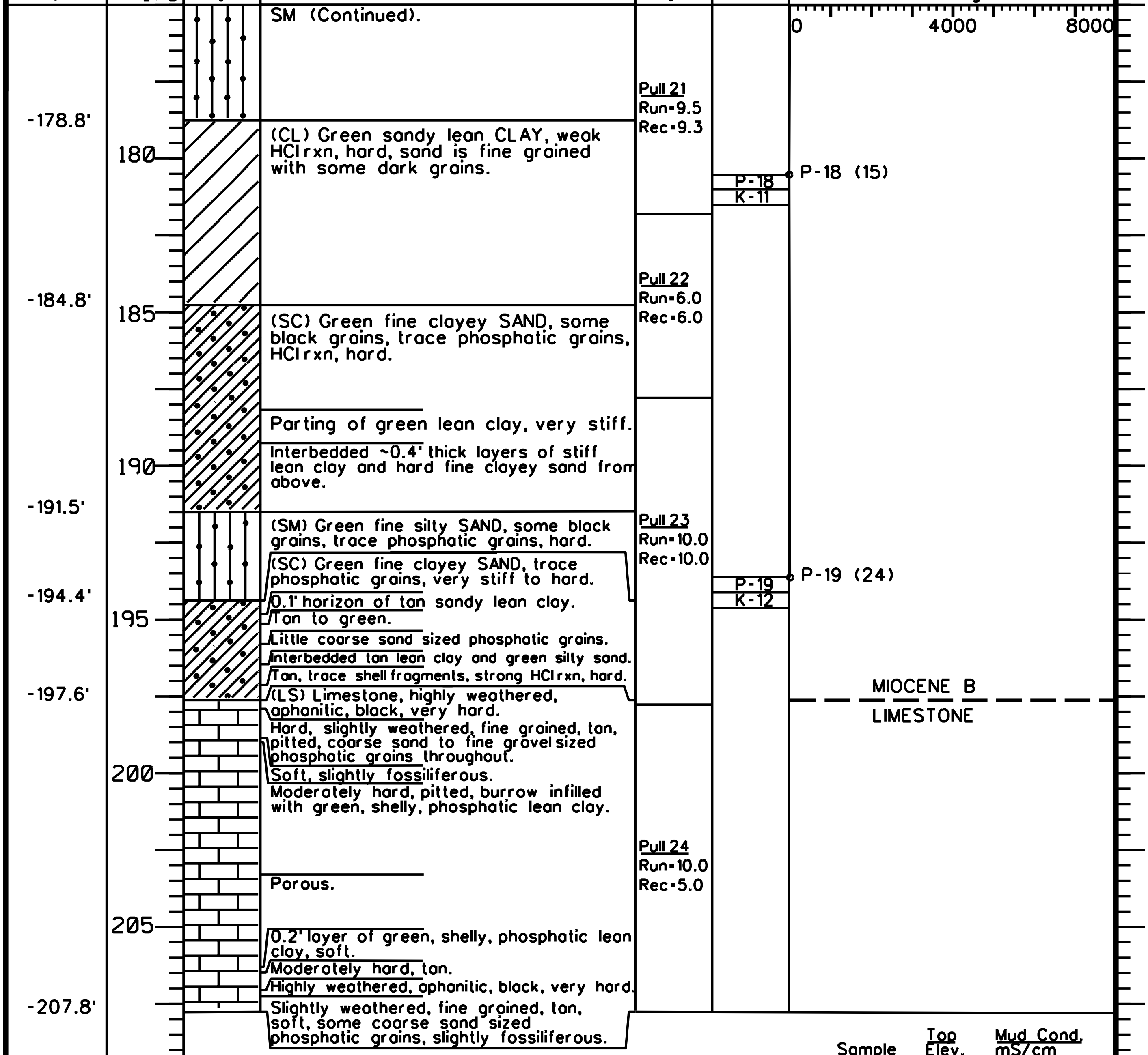
ELEVATION TOP OF HOLE 0.0' MLLW

Hole No. SHE-15

PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 5 OF 5 SHEETS



ELEVATION (FT) a	DEPTH (FT) b	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L)
	175	SM (Continued).	Pull 21 Run=9.5 Rec=9.3		
-178.8'	180	(CL) Green sandy lean CLAY, weak HCl rxn, hard, sand is fine grained with some dark grains.		P-18 K-11	P-18 (15)
-184.8'	185	(SC) Green fine clayey SAND, some black grains, trace phosphatic grains, HCl rxn, hard. Parting of green lean clay, very stiff. Interbedded ~0.4' thick layers of stiff lean clay and hard fine clayey sand from above.	Pull 22 Run=6.0 Rec=6.0		
-191.5'	190	(SM) Green fine silty SAND, some black grains, trace phosphatic grains, hard. (SC) Green fine clayey SAND, trace phosphatic grains, very stiff to hard.	Pull 23 Run=10.0 Rec=10.0	P-19 K-12	P-19 (24)
-194.4'	195	0.1' horizon of tan sandy lean clay. Tan to green. Little coarse sand sized phosphatic grains. Interbedded tan lean clay and green silty sand. Tan, trace shell fragments, strong HCl rxn, hard.			MIOCENE B
-197.6'		(LS) Limestone, highly weathered, aphanitic, black, very hard. Hard, slightly weathered, fine grained, tan, pitted, coarse sand to fine gravel sized phosphatic grains throughout.			LIMESTONE
	200	Soft, slightly fossiliferous. Moderately hard, pitted, burrow infilled with green, shelly, phosphatic lean clay. Porous.	Pull 24 Run=10.0 Rec=5.0		
	205	0.2' layer of green, shelly, phosphatic lean clay, soft. Moderately hard, tan. Highly weathered, aphanitic, black, very hard.			
-207.8'		Slightly weathered, fine grained, tan, soft, some coarse sand sized phosphatic grains, slightly fossiliferous.			
	210				
	215				

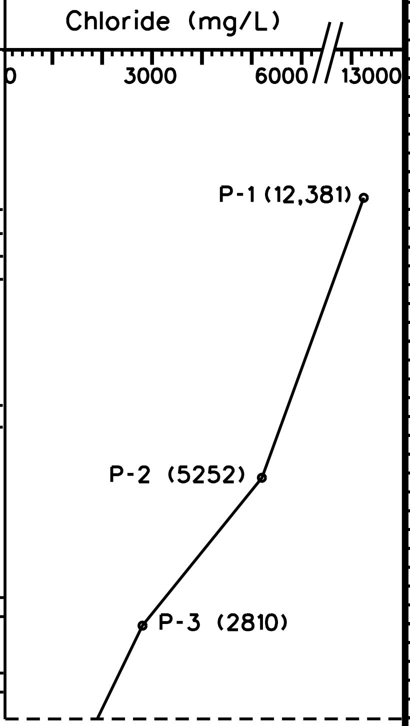
BOTTOM OF BORING AT -207.8'

Sample	Top Elev.	Mud Cond. mS/cm
P-1	-41.3	2.70
P-2	-48.9	2.66
P-3	-52.5	2.66
P-4	-53.3	3.28
P-5	-57.9	2.85
P-6	-64.3	2.15
P-7	-74.9	1.23
P-8	-89.2	1.07
P-9	-101.8	1.00
P-10	-111.7	1.00
P-11	-114.3	1.00
P-12	-120.8	1.00
P-12a	-120.8	1.00
P-13	-123.6	2.42
P-14	-135.8	2.43
P-15	-145.2	2.15
P-16	-155.0	1.36
P-17	-171.0	0.95
P-18	-180.5	1.01
P-19	-193.6	0.93

Hole No. SHE-16

DRILLING LOG	DIVISION SOUTH ATLANTIC	INSTALLATION SAVANNAH, GA	SHEET 1 OF 3 SHEETS

1. PROJECT SAVANNAH HARBOR DEEPENING
2. LOCATION *(Coordinates or Station)* E-1066369, N-744241 GA EAST
3. DRILLING AGENCY SAVANNAH DISTRICT
4. HOLE NO. *(As shown on drawing title and file number)* : SHE-16
5. NAME OF DRILLER D. HEWETT
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN >112.3'
8. DEPTH DRILLED INTO ROCK 13.5'
9. TOTAL DEPTH OF HOLE 112.3'
10. SIZE AND TYPE OF BIT HQ CORE BARREL
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* MLLW
12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500
13. TOTAL NO. OF SOIL SAMPLES TAKEN : DISTURBED 0 : UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 7
15. GROUND WATER ELEVATION N/A
16. DATE HOLE : STARTED 27 APR 2004 : COMPLETED 28 APR 2004
17. ELEVATION TOP OF HOLE 0.0' MLLW
18. TOTAL CORE RECOVERY FOR BORING 87 %
19. SIGNATURE OF INSPECTOR C. SMITH/M. McINTOSH

ELEVATION (FT) 0.0 a	DEPTH (FT) 0 b	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
	30 35		Water. BOTTOM OF RIVER AT -37.3'			NOTE: Change of scale to 1" = 5' at 30.0'. Set 63' of 6" casing to a depth of -43.8'. Began using Super Gel-X freshwater drilling mud at -37.3'. Grouted hole upon completion of boring.
-37.3'	40		(SC) Green fine shelly clayey SAND, trace rounded, coarse sand-sized phosphatic grains, strong HCl rxn, very stiff (Miocene A). Trace sand sized shell fragments.	Pull 1 Run=5.5 Rec=4.0	P-1 K-1	
-43.4'	45 50		(SM) green fine silty SAND, trace phosphatic grains, trace sand sized shell fragments, strong HCl rxn, stiff. Some phosphatic grains. Very stiff.	Pull 2 Run=5.0 Rec=5.0 Pull 3 Run=5.0 Rec=4.8	P-2 P-3	
-52.7'			(SC) Green fine clayey SAND, little phosphatic grains, strong HCl rxn, stiff. Phosphatic. 0.1' lens of shelly clayey sand.	Pull 4 Run=5.0 Rec=5.0	K-2	
-55.0'	55					

CONTINUED ON SHEET No. 2

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE
0.0' MLLW

Hole No. SHE-16

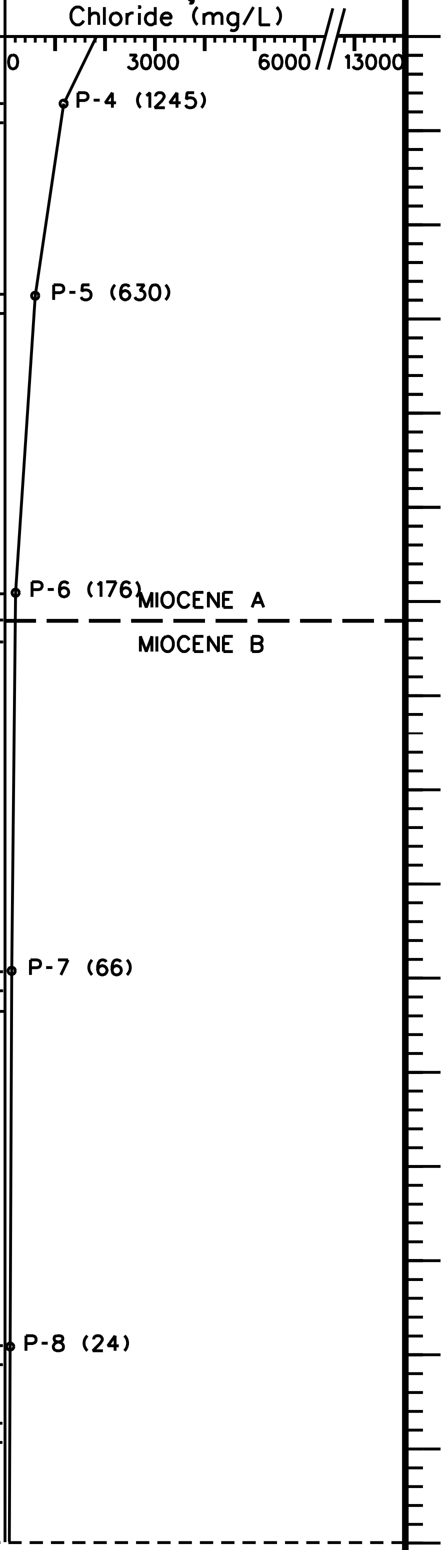
PROJECT
SAVANNAH HARBOR DEEPENING

INSTALLATION
SAVANNAH, GA

SHEET 2
OF 3 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f
	55	SC (Continued).		
-55.8'		Dark green to brown to black, highly phosphatic, very stiff.		P-4
-57.2'		(ML) Gray to tan lean SILT, hard, mottled with phosphatic clayey sand from above.		
		(SM) Green to black phosphatic fine silty SAND, hard.	Pull 5 Run=5.0 Rec=5.0	
		Very stiff.		
	60	Trace coarse sand sized rounded phosphatic grains.		
		Hard.		
		Some coarse sand sized rounded phosphatic grains.		P-5
		Soft, trace coarse sand sized rounded phosphatic grains.	Pull 6 Run=2.5 Rec=2.5	
		Very stiff.		
-64.9'	65	Trace shell fragments.		
		(ML) Tan lean SILT, trace fine sand is phosphatic, weak HCl rxn, indurated.	Pull 7 Run=3.5 Rec=1.7	
		0.1' diameter burrow infilled with green to black silty sand.		
	70		Pull 8 Run=8.0 Rec=8.0	P-6 K-3
		Green, hard. Partings of tan and black fine sand occurring ~1.0' (Miocene B).		
	75			
		Sand partings occurring every ~0.5'.		
	80	Sand partings throughout.		P-7
-80.5'		(SM) Green fine silty SAND, finely laminated, rare partings of lean silt, hard.	Pull 9 Run=10.0 Rec=10.0	K-4
	85			
-87.9'		(ML) Green lean SILT, trace fine sand is black, hard.		
-90.0'	90	(SM) Green fine silty SAND, finely laminated, rare partings of lean silt, hard.	Pull 10 Run=10.0 Rec=10.0	P-8 K-5
-94.4'		(ML) Green lean SILT, trace fine sand is black, hard.		
	95			

REMARKS
(Drilling time, water loss, depth of weathering, etc., if significant)
g



CONTINUED ON SHEET No. 3

DRILLING LOG (Cont Sheet)

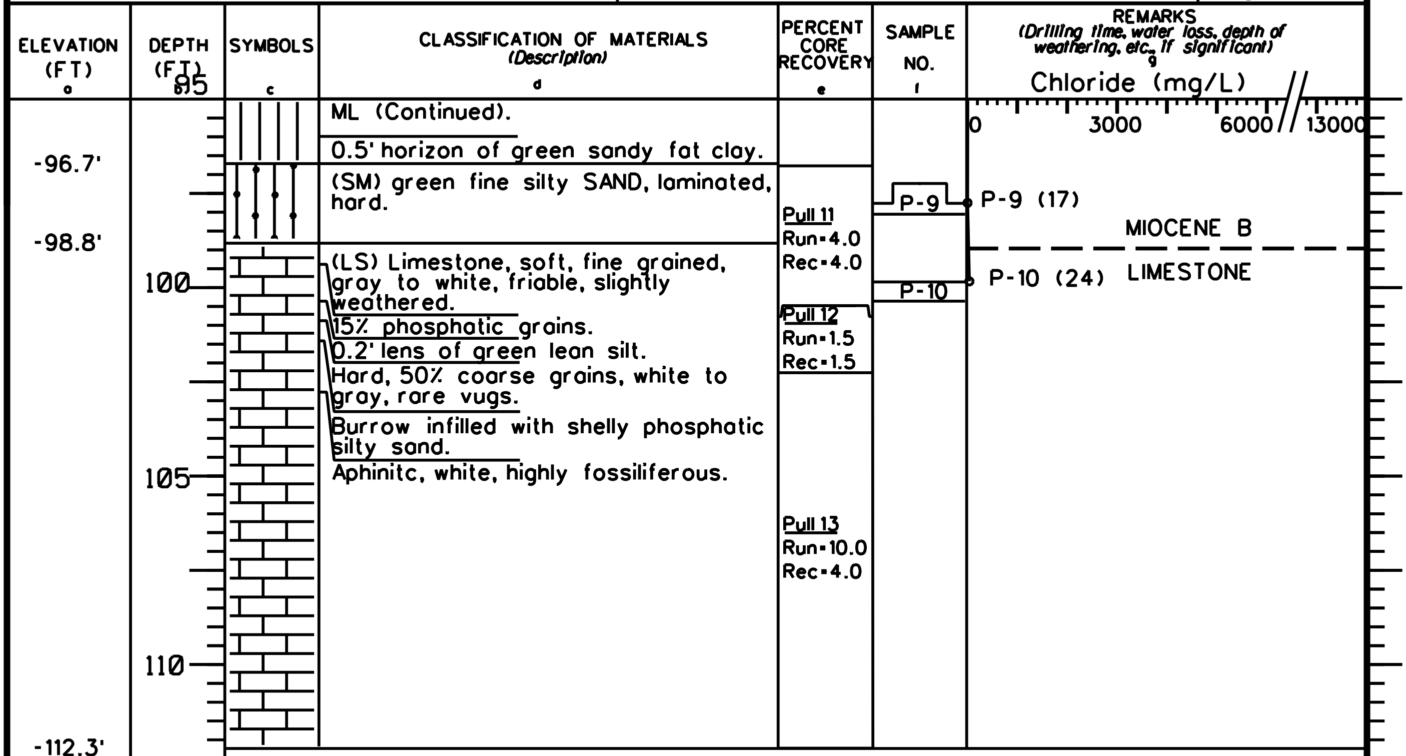
ELEVATION TOP OF HOLE 0.0' MLLW

Hole No. SHE-16

PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 3 OF 3 SHEETS



ML (Continued).

0.5' horizon of green sandy fat clay.

(SM) green fine silty SAND, laminated, hard.

(LS) Limestone, soft, fine grained, gray to white, friable, slightly weathered.

15% phosphatic grains.

0.2' lens of green lean silt.

Hard, 50% coarse grains, white to gray, rare vugs.

Burrow infilled with shelly phosphatic silty sand.

Aphinitc, white, highly fossiliferous.

Pull 11
Run=4.0
Rec=4.0

Pull 12
Run=1.5
Rec=1.5

Pull 13
Run=10.0
Rec=4.0

BOTTOM OF BORING AT -112.3

Sample	Top Elev.	Mud Cond. (mS/cm)
P-1	-42.0	1.98
P-2	-46.8	2.25
P-3	-51.8	2.25
P-4	-56.8	2.31
P-5	-61.8	1.20
P-6	-69.8	1.75
P-7	-79.8	1.77
P-8	-89.8	1.77
P-9	-97.8	0.72
P-10	-99.8	0.72

115
120
125
130
135

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Hole No. SHE-17

DRILLING LOG

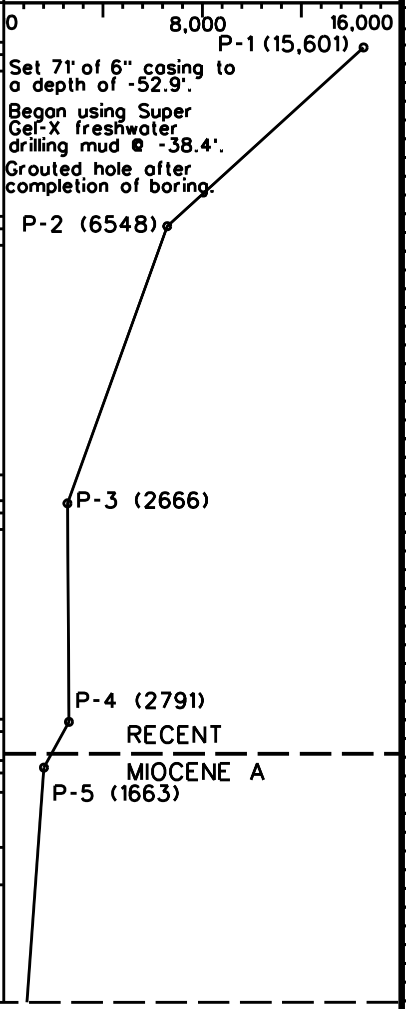
DIVISION SOUTH ATLANTIC

INSTALLATION SAVANNAH, GA

SHEET 1 OF 3 SHEETS

1. PROJECT SAVANNAH HARBOR DEEPENING
2. LOCATION *(Coordinates or Station)* X-1062567, Y-743811 GA EAST
3. DRILLING AGENCY SAVANNAH DISTRICT
4. HOLE NO. *(As shown on drawing title and file number)* : SHE-17
5. NAME OF DRILLER D. HEWETT
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN >128.0'
8. DEPTH DRILLED INTO ROCK 0.5'
9. TOTAL DEPTH OF HOLE 128.0'
10. SIZE AND TYPE OF BIT HQ CORE BARREL
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* MLLW
12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500 CD-3
13. TOTAL NO. OF SOIL SAMPLES TAKEN : DISTURBED 0 : UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 6
15. GROUND WATER ELEVATION N/A
16. DATE HOLE : STARTED 05 May 2004 : COMPLETED 06 May 2004
17. ELEVATION TOP OF HOLE 0.0' MLLW
18. TOTAL CORE RECOVERY FOR BORING 67 %
19. SIGNATURE OF INSPECTOR C. SMITH, M. McINTOSH

ELEVATION (FT) 0.0 a	DEPTH (FT) b 0	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
			Water. BOTTOM OF RIVER AT -38.4'			NOTE: Change of scale to 1" = 5' at 37.5'. Chloride (mg/L)
-38.4'	40		(MH) Gray, fat SILT, trace mica, trace sand sized shell fragments, stiff, partings of fine sand occur every ~1.0'.	Pull 1 Run=5.0 Rec=4.2	P-1 K-1	Set 71' of 6" casing to a depth of -52.9'. Began using Super Gel-X freshwater drilling mud @ -38.4'. Grouted hole after completion of boring.
	45		Sand partings every ~0.5', blocky texture.	Pull 2 Run=5.0 Rec=4.0	P-2 K-2	
			Partings of white calcareous material occur every ~1.0'.			
	50		Laminated.	Pull 3 Run=5.0 Rec=5.4	T-1 P-3 K-3	
-52.9' -53.4'			(SM) Gray, silty fine SAND, slightly calcareous, soft.			
	55		(MH) Gray fat SILT, partings of calcareous fine sand occur every ~1.0'.		P-4	RECENT
-58.4'	60		(SM)-MIOCENE A-Dark green to black silty fine phosphatic SAND, slightly calcareous, hard, phosphate grains range in size from fine to coarse.	Pull 4 Run=10.0 Rec=6.6	P-5 K-4 T-2	MIOCENE A
	65		Burrow present, infilled with tan silt.			



CONTINUED ON SHEET #2

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

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DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 0.0' MLLW

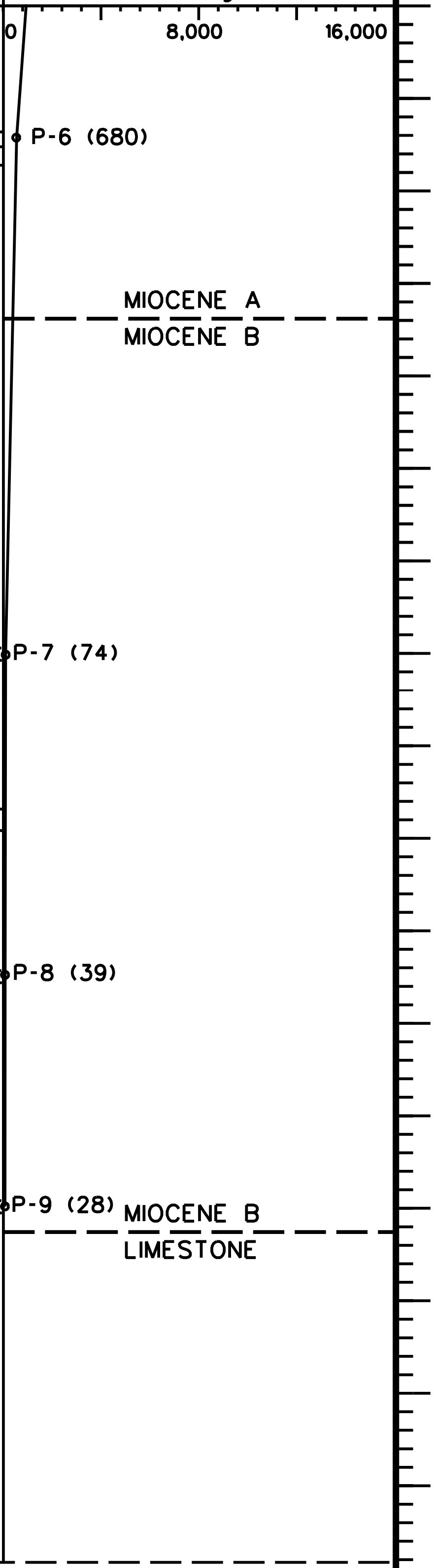
Hole No. SHE-17

PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 2 OF 3 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L)
	65		SM (Continued).			
				Pull 5 Run=10.0 Rec=7.2	P-6 K-5	P-6 (680)
	70					
-70.7'			(ML)-Cream lean SILT, trace very fine sand, slight HCl rxn, hard; mottled with dark olive green to black silty sand from above.			
			0.4' horizon of dark olive green silty sand.			MIOCENE A
-73.4'			Cream, stiff.			MIOCENE B
-74.3'	75		(SC)-MIOCENE B-Green fine clayey SAND, stiff.			
			(SM) Green fine silty SAND, stiff to very stiff.			
				Pull 6 Run=10.0 Rec=0.5		
	80					
			Partings of gray fine sand occur every ~0.1'.			
			Gray to tan, weak HCl rxn.		P-7	P-7 (74)
			Green, hard.			
	85					
				Pull 7 Run=9.5 Rec=9.5	K-6	
	90				P-8	P-8 (39)
			Burrow present, infilled with black silt.			
	95					
				Pull 8 Run=8.0 Rec=7.8	P-9	P-9 (28) MIOCENE B
-98.1'			(LS) Limestone, soft, moderately weathered, fine grained, gray to tan, slightly porous, some phosphatic grains.			LIMESTONE
			Trace phosphatic grains.			
	100		Vug infilled with green silty sand.			
			Gray to cream.			
			Some vugs, some fossils, hard.			
			Vuggy, fossiliferous.			
	105					



DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 0.0' MLLW	Hole No. SHE-17
PROJECT SAVANNAH HARBOR DEEPENING	INSTALLATION SAVANNAH, GA	SHEET 3 OF 3 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
	105		LS (Continued).			
				Pull 9 Run=10.0 Rec=3.2		
			Little vugs, slightly weathered, trace fossils.			
-109.9'	110		BOTTOM OF BORING AT -109.9'			

Sample	Top Elev	Mud Cond. (mS/cm)
P-1	-39.7	1.46
P-1a	-39.7	1.46
P-2	-44.4	1.55
P-3	-52.0	1.55
P-3a	-52.0	1.55
P-4	-57.8	2.30
P-5	-58.9	2.78
P-6	-68.4	4.54
P-7	-82.4	2.49
P-8	-91.1	2.49
P-9	-97.4	2.49

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Hole No. SHE-18

DRILLING LOG	DIVISION SOUTH ATLANTIC	INSTALLATION SAVANNAH, GA	SHEET 1 OF 5 SHEETS

1. PROJECT
SAVANNAH HARBOR DEEPENING

2. LOCATION *(Coordinates or Station)*
E-1026349.8, N-757753.3 GA EAST

3. DRILLING AGENCY
SAVANNAH DISTRICT

4. HOLE NO. *(As shown on drawing title and file number)* : SHE-18

5. NAME OF DRILLER
D. HEWETT

6. DIRECTION OF HOLE
☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.

7. THICKNESS OF OVERBURDEN >153.5'

8. DEPTH DRILLED INTO ROCK 12.0'

9. TOTAL DEPTH OF HOLE 153.5'

10. SIZE AND TYPE OF BIT HQ CORE BARREL

11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
MLLW

12. MANUFACTURER'S DESIGNATION OF DRILL
Failing 1500

13. TOTAL NO. OF SOIL SAMPLES TAKEN : DISTURBED 0 : UNDISTURBED 0

14. TOTAL NUMBER CORE BOXES 8

15. GROUND WATER ELEVATION N/A

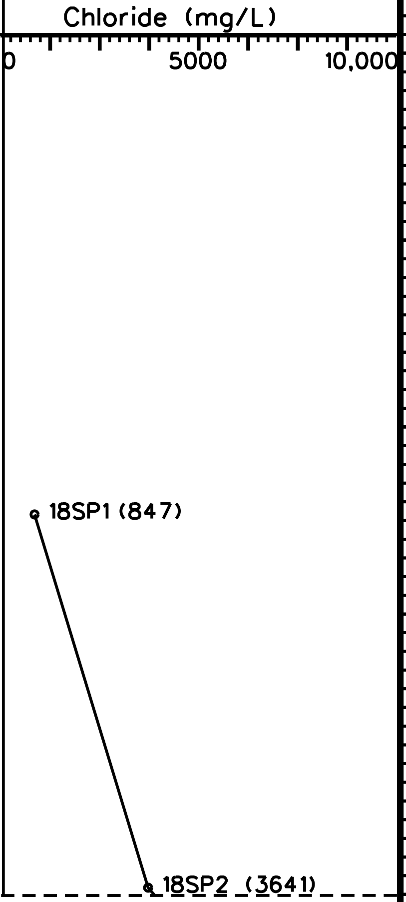
16. DATE HOLE : STARTED 22 JUN 2004 : COMPLETED 30 JUN 2004

17. ELEVATION TOP OF HOLE 27.0' MLLW

18. TOTAL CORE RECOVERY FOR BORING 56 %

19. SIGNATURE OF INSPECTOR
C. SMITH/M. McINTOSH

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
27.0	0					Began using Super Gel-X freshwater drilling mud at 7.0'. Grouted hole upon completion of boring.
	5					
20.0'			(SM) Tan to brown medium to fine silty SAND, trace roots, weak HCl rxn, stiff.			
16.7'	10		(SP) Tan coarse to medium poorly graded SAND, trace mica, soft. 0.1' lens of red to tan silty sand. Fine. Coarse to medium.	Pull 1 Run=5.0 Rec=2.1		
14.3'			(ML) Tan to red to brown sandy lean SILT, sand is fine grained, trace mica, soft. Little organic matter.			
	15			Pull 2 Run=10.0 Rec=5.6		
			(SP) Tan to orange coarse to medium poorly graded SAND, trace organic matter, trace fine gravel.			
7.4'	20		0.3' horizon of medium clayey sand. Fine. Coarse to medium. 0.1' lens of organic sandy clay. Fine.			
	25			Pull 3 Run=8.5 Rec=0.3		
-3.0'	30		CONTINUED ON SHEET No. 2			



NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 27.0' MLLW

Hole No. SHE-18

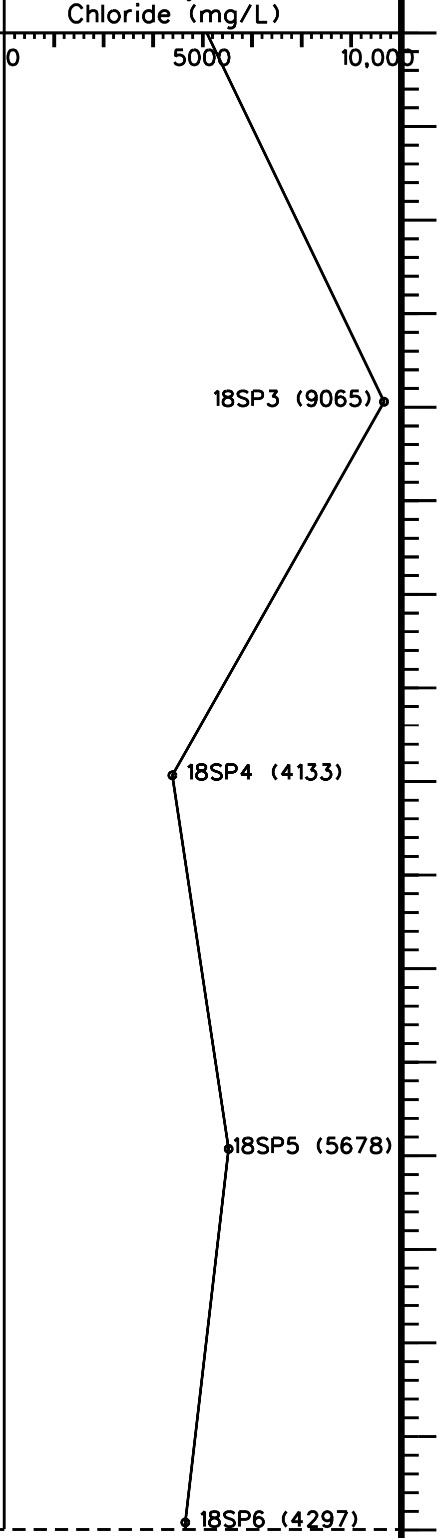
PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 2 OF 5 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT CORE RECOVERY e	SAMPLE NO. f
	30		(MH) Dark gray fat SILT, soft.	Pull 4 Run=4.0 Rec=0.3	
-5.5'	35		(SC) Brown to orange fine clayey SAND, firm.	Pull 5 Run=9.8 Rec=0.8	
-12.5'	40		(SM) Dark gray fine silty SAND, trace mica, firm.		
			Tan to brown.		
-17.5'	45		0.2' horizon of brown fat clay.		
	50		(MH) Gray clayey fat SILT, partings of brown fine poorly graded sand, stiff.	Pull 6 Run=9.2 Rec=1.9	
-25.3'			(SP) Tan fine poorly graded SAND, stiff.		
			Gray, medium to fine, trace mica.		
	55		Interbedded with black organic matter.		
			Tan, coarse.	Pull 7 Run=10.0 Rec=6.3	
	60		Coarse to medium.		
			0.3' horizon of silty sand.	Pull 8 Run=3.0 Rec=1.7	
	65		Gray, fine.		
	70				

REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g



CONTINUED ON SHEET No. 3

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 27.0' MLLW

Hole No. SHE-18

PROJECT SAVANNAH HARBOR DEEPENING

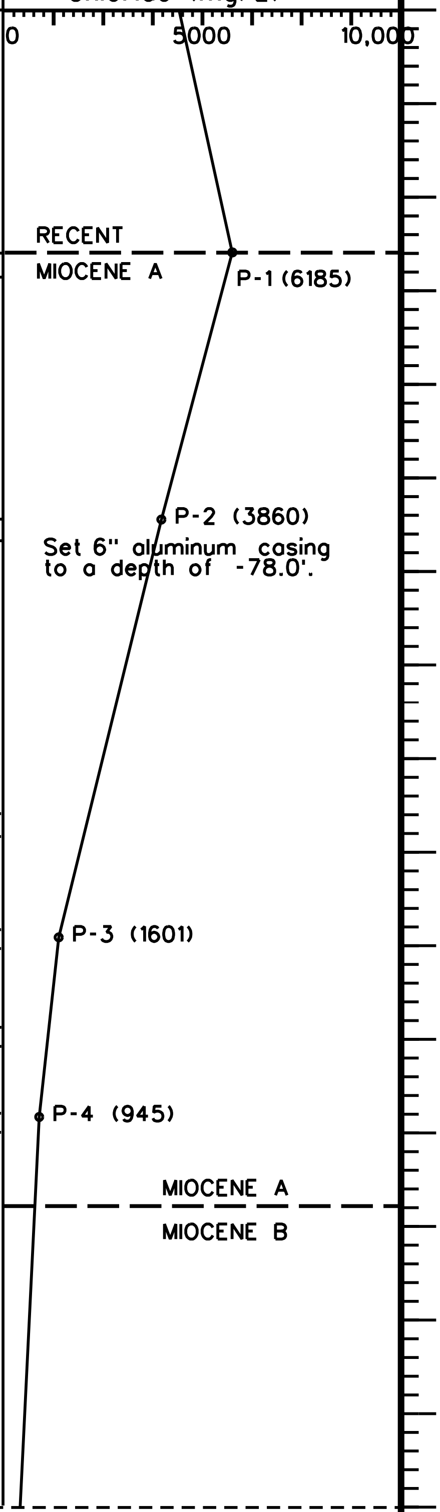
INSTALLATION SAVANNAH, GA

SHEET 3 OF 5 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f
	70 75		SP (Continued).	Pull 9 Run=7.0 Rec=7.0	
-49.4'			(ML) Green lean SILT, very stiff (Miocene A).	Pull 10 Run=10.0 Rec=7.9	P-1
-52.4'	80		(SM) Green fine silty SAND, very stiff. Green to black. Partings of tan lean silt.		
-56.8'	85		(ML) Green lean SILT, blocky, stiff.		P-2
-59.4'			(SM) Green fine silty SAND, stiff.	Pull 11 Run=10.0 Rec=10.0	
-61.2'	90		(ML) Dark green to black phosphatic lean SILT, laminated, very stiff.		K-1
-66.5'	95		(SM) Dark green to black phosphatic fine silty SAND, laminated, weak HCl rxn, petroleum odor, hard.	Pull 12 Run=7.2 Rec=6.5	P-3 K-2 P-4
-72.9'	100		Limestone, cream to gray, hard, slightly pitted, fine grained.	Pull 13 Run=0.6 Rec=0.8 Pull 14 Run=0.7 Rec=0.5	
-75.0'	105 110		(SM) Tan to light green fine silty SAND, lenses of silty clay, slightly indurated, hard (Miocene B).	Pull 15 Run=1.5 Rec=0.2 Pull 16 Run=9.2 Rec=0.3	

REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g

Chloride (mg/L)

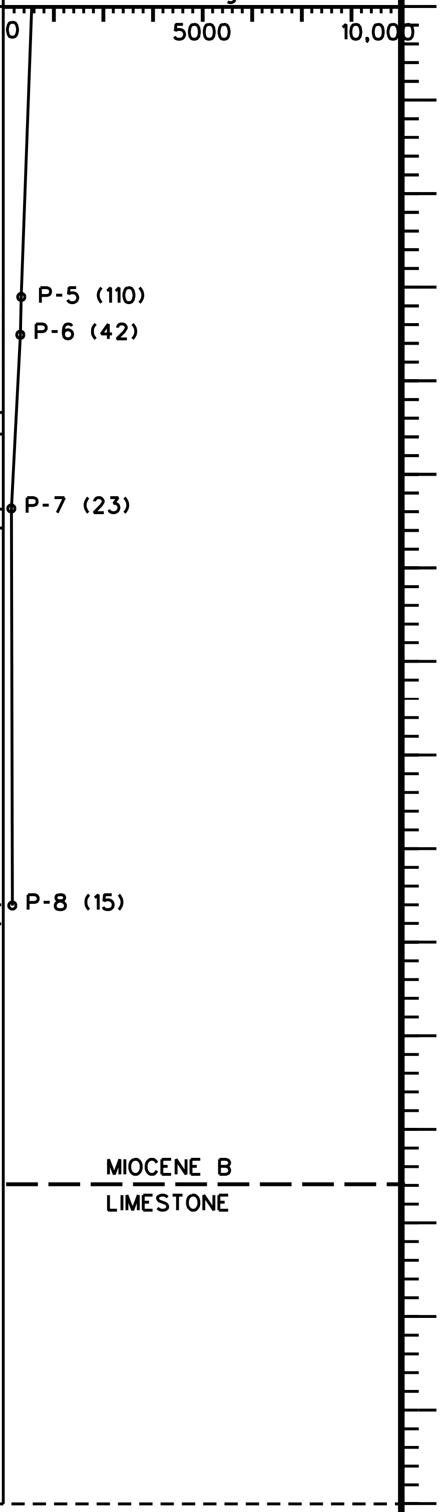


Set 6" aluminum casing to a depth of -78.0'.

CONTINUED ON SHEET No. 4

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 27.0' MLLW		Hole No. SHE-18
PROJECT SAVANNAH HARBOR DEEPENING	INSTALLATION SAVANNAH, GA		SHEET 4 OF 5 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L)
	110		SM (Continued).			0 5000 10,000
	115			Pull 17 Run=5.6 Rec=0.6		
					P-5	P-5 (110)
			Green with lenses of gray fine poorly graded sand, not indurated.		P-6	P-6 (42)
			No sand lenses.			
	120			Pull 18 Run=6.0 Rec=6.0	K-3	
					P-7	P-7 (23)
			Very hard.			
	125					
	130			Pull 19 Run=10.0 Rec=9.6		
					K-4 P-8	P-8 (15)
	135		Very stiff, 0.2' horizon of soft lean silt.			
				Pull 20 Run=7.0 Rec=7.8		
	140			Pull 21 Run=0.5 Rec=0.6		MIOCENE B
-114.5'			Limestone, phosphatic, dark gray to black, very hard, highly weathered, aphinitic.	Pull 22 Run=1.5 Rec=0.2		LIMESTONE
			Gray, fossiliferous, vuggy, fine grained, moderately hard.			
	145		0.1' lens of black phosphatic, very hard, aphinitic material.			
			Gray, slightly vuggy.			
	150					



CONTINUED ON SHEET No. 5

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE
27.0' MLLW

Hole No. SHE-18

PROJECT
SAVANNAH HARBOR DEEPENING

INSTALLATION
SAVANNAH, GA

SHEET 5
OF 5 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L) 0 5000 10,000
	150		Limestone (continued).	Pull 23 Run=10.0 Rec=4.5		
			Sandy, fossiliferous, vuggy, hard.			
-126.5'			BOTTOM OF BORING AT -153.5'			
	155					

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DRILLING LOG

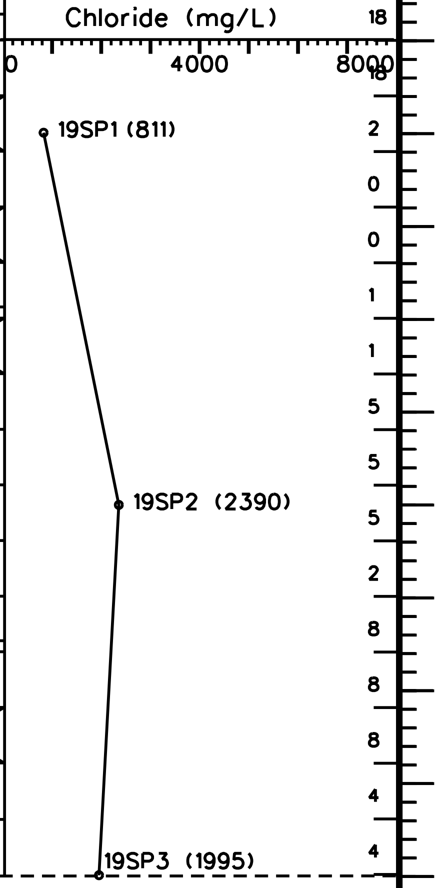
DIVISION: SOUTH ATLANTIC

INSTALLATION: SAVANNAH, GA

SHEET 1 OF 7 SHEETS

1. PROJECT: SAVANNAH HARBOR DEEPENING
2. LOCATION *(Coordinates or Station)*: E-1007278.7, N-761688.5 GA EAST
3. DRILLING AGENCY: SAVANNAH DISTRICT
4. HOLE NO. *(As shown on drawing title and file number)*: SHE-19
5. NAME OF DRILLER: D. HEWETT
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: >233.5'
8. DEPTH DRILLED INTO ROCK: 14.7'
9. TOTAL DEPTH OF HOLE: 233.5'
10. SIZE AND TYPE OF BIT: 1 3/8" SS, HQ CORE BARREL
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*: MLLW
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing 1500
13. TOTAL NO. OF SOIL SAMPLES TAKEN: DISTURBED: 52 UNDISTURBED: 0
14. TOTAL NUMBER CORE BOXES: 13
15. GROUND WATER ELEVATION: N/A
16. DATE HOLE: STARTED: 6 JUL 2004 COMPLETED: 27 JUL 2004
17. ELEVATION TOP OF HOLE: 21.0' MLLW
18. TOTAL CORE RECOVERY FOR BORING: 69 %
19. SIGNATURE OF INSPECTOR: C. SMITH/M. McINTOSH

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	PERCENT RECOVERY e	JAR/SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g	
21.0	0		(SC) Tan to brown medium to fine clayey SAND, trace organic matter, stiff.		1 2	Grouted hole upon completion of boring.	12
18.7'			(ML) Gray to brown lean SILT, little fine sand, very stiff. Sand is medium to fine, stiff.		3 4		28 14
16.5'	5		(SM) Gray fine silty SAND, stiff.		5 6		9
14.2'			(SP) Gray medium poorly graded SAND, medium.		7 8		18 18
11.3'	10		(MH) Gray fat SILT, trace fine gravel, very soft.		☒ 9 ☒ 10		2 0 0
6.3'	15		(SM) Tan to gray fine silty SAND, finely laminated, very loose.		11 ☒		1 1
5.3'			(SP) Tan to brown medium to fine poorly graded SAND, loose.		12		5
3.0'			(SM) Gray fine silty SAND, occasional lenses of gray fat silt up to 0.2', loose.		13		5
1.5'	20		(CH) Gray to black sandy fat CLAY, sand is fine, trace mica, soft. 0.3' horizon of gray fine clayey sand.		14 15 16 17		5 2 8
-2.7'	25		(SM) Gray fine silty SAND, loose.		18 ☒		8 8
-6.2'			(MH) Gray to black sandy fat SILT, sand is fine, soft.		19		4
-7.5'			(CL) Gray lean CLAY, finely laminated, sulfur odor, medium stiff.		20		4
	30						



CONTINUED ON SHEET No. 2

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

BLOWS PER FOOT: NUMBER REQUIRED TO DRIVE 1 3/8" ID SPLITSPOON W/ 140 LB. HAMMER FALLING 30".

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 21.0' MLLW

Hole No. SHE-19

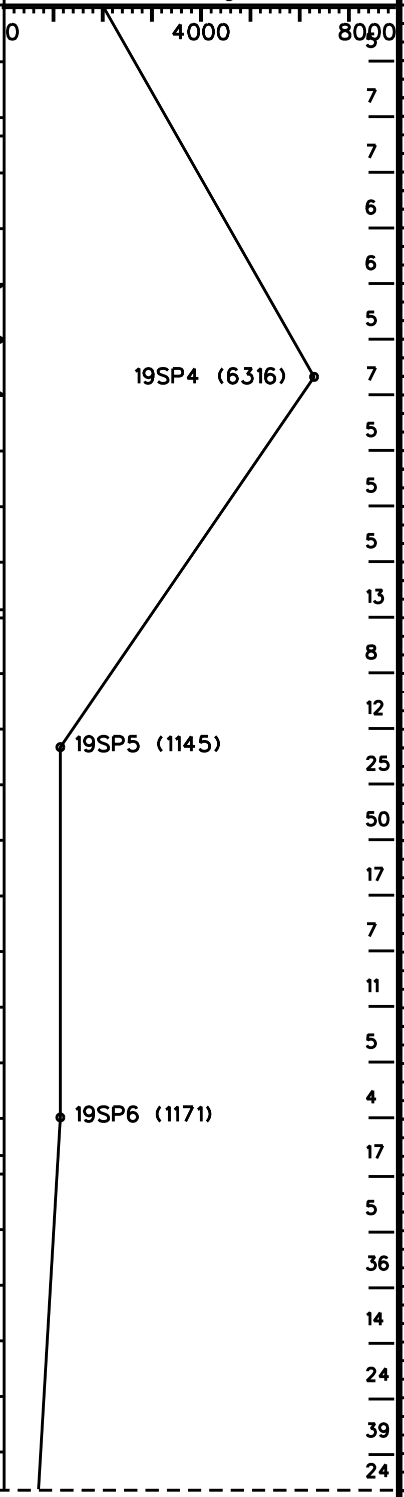
PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 2 OF 7 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	JAR/ SAMPLE NO. f
	30	CL (Continued). Little sand, trace organics. Trace sand.		21 22
-12.5'		(SC) Brown fine clayey SAND, trace mica, loose. Medium sand.		23 24
-13.5'	35	(SP) Brown coarse to medium poorly graded SAND, loose. Gray.		25 26 ☒
-18.0'	40	(CH) Gray fat CLAY, roots throughout, medium stiff. No organic matter, partings of fine sand occur every ~0.5'.		☒ 27 28 29
	45	0.2' seam of gray fine silty SAND, some mica, medium. Trace organic matter, partings of fine sand occur every ~0.3', stiff. Partings more common.		30 31 32 33
-28.7'	50	(SP) Gray medium to fine poorly graded SAND, medium. Fine, two 0.1' lenses of silty clay. Medium to fine, trace fine gravel.		34 35 36
-33.0'	55	(CH) Gray sandy fat CLAY, medium stiff. Trace sand, occurs in partings. Sand partings thorughout.		37 38 39 40
-40.0'	60	(SC) Gray medium to fine clayey SAND, medium.		41 42
-40.5'		(CH) Gray fat CLAY, organic matter throughout, partings of medium to fine sand occur every ~0.5', medium stiff. 0.4' horizon of gray medium poorly graded SAND, dense.		43 44
-43.5'	65	(SC) Gray medium clayey SAND, clay occurs as mottled with sand from above, medium. Trace fine gravel.		45 46
-46.5'		(SP) Gray medium to fine poorly graded SAND, trace fine gravel, dense.		47
-48.0'		(SM) Gray fine silty SAND, trace coarse gravel, medium.		48
	70			

REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g



CONTINUED ON SHEET No. 3

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 21.0' MLLW

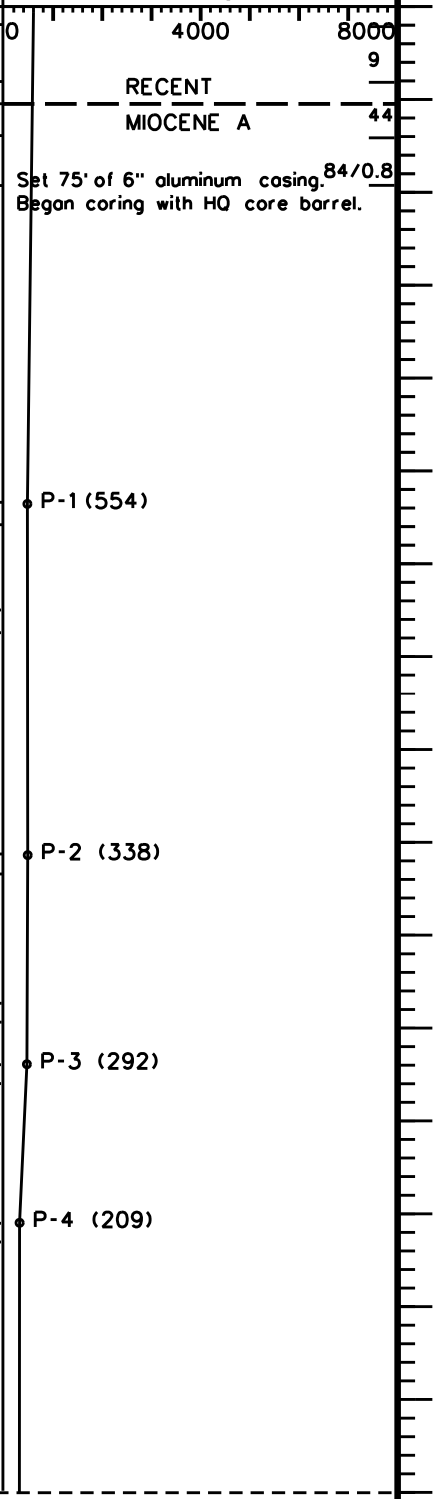
Hole No. SHE-19

PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 3 OF 7 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	JAR/ SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L)
	70		SM (Continued).			
-50.2'			(CH) Gray sandy fat CLAY, little shell fragments up to 0.25", medium stiff.		49	9
					50	RECENT
-51.6'			(SM) Grayish green fine silty SAND, little mica, trace white calcareous partings, dense (Miocene A).		51	MIOCENE A 44
					52	84/0.8
	75		Trace coarse gravel, very dense.			Set 75' of 6" aluminum casing. Began coring with HQ core barrel.
			No gravel.	Pull 1 Run=10.0 Rec=3.2		
	80					
					P-1	P-1 (554)
	85					
				Pull 2 Run=10.0 Rec=10.9	K-1	
	90					
					P-2	P-2 (338)
	95					
				Pull 3 Run=10.0 Rec=10.0	K-2	
			Finely laminated.		P-3	P-3 (292)
	100					
			Partings of fine sand occur every ~0.3'.		P-4	P-4 (209)
	105					
			(ML) Greenish yellow lean SILT, laminated, very stiff.	Pull 4 Run=10.0 Rec=10.5		
-87.7'			(SM) Green fine silty SAND, laminated, partings of fine sand occur every ~0.3', very stiff.			
-88.9'	110					



CONTINUED ON SHEET No. 4

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE: 21.0' MLLW

Hole No. SHE-19

PROJECT: SAVANNAH HARBOR DEEPENING

INSTALLATION: SAVANNAH, GA

SHEET 4 OF 7 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	JAR/ SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L)
	110		SM (Continued).			0 4000 8000
-91.2'			(ML) Cream to green lean SILT, very stiff.		P-5	P-5 (143)
-92.5'	115		(SC) Green fine clayey SAND, finely laminated, stiff.			
				Pull 5 Run=10.0 Rec=10.4	K-3	
	120					
				Pull 6 Run=0.4 Rec=0.4	P-6	P-6 (82)
			Partings of fine sand thoughout.			
	125					
				Pull 7 Run=9.6 Rec=9.6		
	130					
-111.4'			(CL) Green lean CLAY, partings of fine sand throughout, very stiff.		K-4 P-7	P-7 (58)
-112.5'	135		(SC) Green fine clayey SAND, finely laminated, very stiff.			
				Pull 8 Run=10.0 Rec=10.3		
-118.9'	140		(SM) Green fine silty SAND, finely laminated, very stiff.			MIOCENE B LIMESTONE
			Trace sand sized phosphatic grains.		K-5 P-8	P-8 (57)
	145			Pull 9 Run=10.0 Rec=10.5		
-126.2'			(SC) Green fine clayey SAND, finely laminated, stiff.			
			Decreased clay content.			
	150					

CONTINUED ON SHEET No. 5

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 21.0' MLLW

Hole No. SHE-19

PROJECT SAVANNAH HARBOR DEEPENING

INSTALLATION SAVANNAH, GA

SHEET 5 OF 7 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	JAR/ SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L) 0 4000 8000
	150	SC (Continued).			
				K-6 P-9	P-9 (47)
		Increased clay content.			
	155				
		0.9' vertical seam of gray fine sand.	Pull 10 Run=10.0 Rec=10.0		
-138.8'	160	(CL) Green lean CLAY, finely laminated, very stiff.			
				K-7 P-10	P-10 (NV)
		Sandy.			
	165				
			Pull 11 Run=10.0 Rec=7.5	K-8 P-11	P-11 (26)
-148.1'	170	(SM) Dark green to black medium to fine phosphatic silty SAND, firm.			
-152.5'		Limestone, moderately hard, fine grained, gray to black, phosphatic, some vugs.			
	175		Pull 12 Run=5.0 Rec=2.0		
		Soft, cream colored, sandy with lean silt intermixed in matrix, little phosphatic grains present.			
-157.5'		(ML) Gray to green sandy lean SILT, hard, partings of gray fine sand throughout, partially indurated.			
	180		Pull 13 Run=5.0 Rec=0.0		
			Pull 14 Run=0.5 Rec=2.0		
		Green.	Pull 15 Run=2.5 Rec=3.2	P-12	P-12 (35)
	185				MIOCENE A
-165.1'		(SM) Yellowish green fine silty SAND, sand is primarily dark mineral grains, very stiff (Miocene B).	Pull 16 Run=2.0 Rec=2.0		MIOCENE B
		Hard, partings of gray fine sand throughout.		P-13 K-9	P-13 (32)
	190				

CONTINUED ON SHEET No. 6

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 21.0' MLLW	Hole No. SHE-19
PROJECT SAVANNAH HARBOR DEEPENING	INSTALLATION SAVANNAH, GA	SHEET 6 OF 7 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	JAR/ SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g Chloride (mg/L) 0 4000 8000
	190		SM (Continued).	Pull 17 Run=5.0 Rec=5.0		
	195		Green, partings less common, increased clay content.			
			Sand partings throughout.	Pull 18 Run=10.0 Rec=10.0		
	200		Partings are rare.		K-10 P-14	P-14 (20)
	205			Pull 19 Run=10.0 Rec=0.3		
	210					
			Light green, decreased clay content.	Pull 20 Run=1.5 Rec=1.5	K-11 P-15	P-15 (30)
	215		Green with slight mottling of light green, very stiff, increased clay content.			
			Trace phosphatic grains.			
			Light green, mottled with cream lean silt and black phosphatic sand.	Pull 21 Run=8.5 Rec=8.2		MIOCENE B
-197.8'			Limestone, soft, fine grained, cream to black, black material is hard.			LIMESTONE
	220		Moderately hard, cream, fossiliferous, vuggy, phosphatic inclusion at 220'.			
			Soft, not fossiliferous, porous, aphinitic zones throughout.			
			Moderately hard, fine grained.	Pull 22 Run=2.0 Rec=2.3		
	225		Burrow infilled with sandy mixture of phosphatic grains and shell fragments.			
			Fossiliferous, vuggy.			
			Hard, tan to black, phosphatic.			
			Tan, not phosphatic.			
			Moderately hard to soft, sandy.			
			Soft.			
	230					

CONTINUED ON SHEET No. 7

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 21.0' MLLW	Hole No. SHE-19
PROJECT SAVANNAH HARBOR DEEPENING	INSTALLATION SAVANNAH, GA	SHEET 7 OF 7 SHEETS

ELEVATION (FT) a	DEPTH (FT) b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	PERCENT CORE RECOVERY e	JAR/ SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	230		Limestone (Continued).	Pull 23 Run=8.0 Rec=8.0		
-212.5'	235		BOTTOM OF BORING AT 233.5'			

Sample	Top Depth	Chloride (mg/L)
19SP1	10	811
19SP2	20	2390
19SP3	30	1995
19SP4	40	6316
19SP5	50	1145
19SP6	60	1171
P-1	83.3	554
P-2	89.8	338
P-3	98.5	292
P-4	102.8	209
P-5	112.9	143
P-6	123.0	82
P-7	133.0	58
P-8	142.6	57
P-9	153.1	47
P-10	162.9	NV
P-11	167.6	26
P-12	184.0	35
P-13	188.5	32
P-14	202.6	20
P-15	214.2	30

SP = Screen Point sample
NV = No Value reported

APPENDIX E

Soils Laboratory Analytical Results

CESAS-EN-GGe 1 August 2005

MEMORANDUM THRU

EN-GG
EN-G

FOR EN-GG (Card Smith)

SUBJECT: Savannah Harbor Expansion Permeability Study, Savannah, Georgia Requisition No. W33SJG40168635 and W33SJG41536745, Work Order No.'s 0330e & 0344e

1. Enclosed is our report of test results for the subject permeability study conducted throughout the year in 2004. The test results include flexible wall permeability data, grain-size distribution, Atterberg Limits, moisture content as-received, specific gravity, Unified Soil Classification, and triaxial testing.

2. The samples were received at various times throughout 2004, and were generally delivered in a foam padded box. Samples were typically wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss. Some of the final samples received were also placed into rigid plastic tubing and sealed for added protection. Overall, every effort was made to preserve the samples intact with minimal disturbance. Regardless of the received condition, some sample specimens required slight remolding in preparation of testing. Any specimen remolding was conducted with all efforts of preserving the as-received moist condition and density prior to engineering properties testing.

3. As the samples were received and prepared for permeability testing by ASTM D5084, some variations in the diameters of specimens required the utilization of various base and head platens. This was conducted in order to best match the diameters of the samples received. All permeability specimens were properly back-pressure saturated and verified to meet the required minimum B value of 95% prior to conducting permeation. The hydraulic conductivity was measured using a Mercury U-tube Manometer and the resultant values were reported at a target hydraulic gradient value of about 20. The reports are provided on EMU Form D5084-4.

4. Triaxial testing was also requested for a couple of samples. This was conducted using ASTM D4767 Consolidated Undrained Triaxial test with pore pressure measurements. The loading for specimens was selected at 0.5 and 1.0 tsf for each of two sample locations. Specimens were prepared by carefully trimming them from the as-received samples to an approximate diameter of 1.4 inches and height of 3 inches. Some sample specimens required slight remolding in preparation of testing, particularly for sample hole SHE-17 at depth 79.0 to 80.0 which classified as clayey sand.

5. The soil classification for the samples was reported from grain-size and Atterberg Limits results. When samples displayed characteristics of possible organics, oven-dried liquid limit testing was conducted in order to verify the classification description. When oven-dried liquid limit results were found to be less than 75% of the results from moist prepared liquid limit samples, then the soil was classified as an organic silt or organic clay. Some soil classification results were also visually identified when both the grain-size and Atterberg Limits tests were not performed. These sample classifications are identified as “Visual” within the reports. The reports are provided on ENG Form 2087.

6. If there are any questions or additional information is required, please contact me at (678) 354-0310.

Encl

MICHAEL P. WIELPUTZ, P.E.
Environmental & Materials Unit

CF: EN-ESF

SUMMARY OF MATERIAL PROPERTIES

PROJECT: Savannah Harbor Expansion Permeability Study, Savannah, GA
REQUISITION NO: W33SJG40168635 **WORK ORDER:** 330e

LAB Number	Hole No.	Sample No.	Depth		ASTM D422/D1140 Percent Passing		ASTM D4318 Atterberg Limits			ASTM D2216 MC%	ASTM D854 SpG	Dry Density (g/cc)	Void Ratio	Porosity	Hydraulic Gradient	Hydraulic Conductivity, $k_{20^\circ C}$ (cm/sec)	Color	ASTM D2487 Unified Soil Classification System
			start (ft)	end (ft)	No.4	No. 200	LL	PL	PI									
K6/205	SHE-11	K-1	48.5	49.0	100.0	87.7	84	24	60	75.7	2.68	0.817	2.250	0.692	22.4	4.79E-08	Olive Gray	Fat Clay (CH), with a little sand, a trace of mica and wood fragments.
K6/206	SHE-11	K-2	76.0	76.5	100.0	89.2	---	---	---	96.2	2.66	0.794	2.239	0.691	20.6	4.33E-08	Olive Gray	(Visual) Fat Clay (CH), with a little sand.
K6/207	SHE-11	K-3	78.5	79.0	100.0	95.2	---	---	---	65.5	2.70	0.725	2.672	0.728	21.7	5.40E-08	Olive Gray	(Visual) Fat Clay (CH), with a trace of sand.
K6/208	SHE-11	K-4	88.3	88.8	100.0	19.3	67	30	37	34.4	2.80	1.372	1.030	0.507	22.7	2.53E-07	Dark Olive Gray	Clayey Sand High LL (SC-H).
K6/209	SHE-11	K-5	97.8	98.3	100.0	59.3	76	39	37	38.0	2.74	1.338	1.030	0.507	23.8	6.44E-08	Pale Olive	Sandy Clayey Inorganic Silt High LL (MH).
K6/210	SHE-11	K-6	109.3	109.8	100.0	100.0	---	---	---	39.8	2.67	1.366	0.957	0.489	23.5	6.12E-08	Olive Gray	(Visual) Fat Clay (CH).
K6/211	SHE-11	K-7	117.0	117.5	100.0	20.6	---	---	---	38.2	2.65	1.205	1.186	0.543	22.7	9.48E-08	Dark Olive Gray	(Visual) Silty Sand (SM), with plastic fines.
K6/212	SHE-11	K-8	119.3	119.8	99.6	13.6	64	34	30	40.9	2.70	1.319	1.034	0.508	23.6	2.37E-07	Dark Olive Gray	Silty Sand (SM-H), with High LL plastic fines.
K6/213	SHE-11	K-9	125.0	125.5	100.0	48.1	144	71	73	72.3	2.65	0.880	1.963	0.663	23.1	3.92E-08	Dark Olive Gray	Silty Sand (SM-H), with High LL plastic fines.
K6/214	SHE-13	K-1	70.0	70.5	100.0	18.8	---	---	---	31.6	2.70	1.486	0.702	0.412	17.0	2.78E-06	Olive Gray	(Visual) Clayey Sand (SC).
K6/215	SHE-13	K-2	75.8	76.3	100.0	52.6	67	22	45	35.0	2.68	0.949	1.728	0.633	20.6	1.46E-07	Olive Gray	Sandy Fat Clay (CH).
K6/216	SHE-13	K-5	92.7	93.2	100.0	96.2	---	---	---	85.6	2.63	0.879	1.955	0.662	21.7	1.69E-07	Olive Gray	(Visual) Fat Clay (CH), with a trace of sand.
K6/217	SHE-13	K-6	98.3	98.8	100.0	98.3	---	---	---	75.4	2.70	0.838	2.206	0.688	21.0	9.92E-08	Olive Gray	(Visual) Fat Clay (CH), with a trace of sand.
K6/218	SHE-13	K-7	102.3	102.8	100.0	77.2	132	53	79	68.2	2.71	0.991	1.727	0.633	22.3	7.32E-08	Olive	Clayey Inorganic Silt High LL (MH), with some sand.
K6/219	SHE-13	K-8	106.5	107.0	100.0	65.7	---	---	---	62.1	2.68	0.974	1.693	0.629	22.2	8.81E-08	Olive Gray	(Visual) Clayey Inorganic Silt High LL (MH), with some sand.
K6/220	SHE-13	K-9	111.5	112.0	100.0	80.8	158	74	84	82.4	2.67	0.826	2.189	0.686	23.8	5.44E-08	Olive Gray	Clayey Inorganic Silt High LL (MH), with a little sand.
K6/221	SHE-13	K-10	117.2	117.7	100.0	89.0	---	---	---	92.8	2.66	0.727	2.516	0.716	23.1	4.88E-08	Olive Gray	(Visual) Clayey Inorganic Silt High LL (MH), with a little sand.
K6/222	SHE-13	K-11	124.0	124.5	100.0	38.5	151	67	84	49.5	2.69	1.037	1.577	0.612	22.9	1.32E-07	Dark Olive Gray	Silty Sand (SM-H), with High LL plastic fines.
K6/250	SHE-14	K-1	63.6	64.1	100.0	96.8	---	---	---	74.7	2.75	0.876	1.962	0.662	23.9	7.90E-08	Olive Gray	(Visual) Fat Clay (CH), with a trace of sand.
K6/251	SHE-14	K-2	70.6	71.2	100.0	89.2	130	38	92	76.3	2.72	0.970	1.827	0.646	23.1	7.39E-08	Olive Gray	Fat Clay (CH), with a little sand.
K6/252	SHE-14	K-3	75.0	75.5	100.0	97.9	---	---	---	76.7	2.77	0.955	1.859	0.650	22.0	1.58E-07	Olive Gray	(Visual) Fat Clay (CH), with a trace of sand.
K6/253	SHE-14	K-4	84.0	84.5	100.0	5.9	41	26	15	30.9	2.73	1.617	0.677	0.404	6.3	1.12E-04	Dark Olive Gray	Poorly Graded Silty Sand (SP-SM), with plastic fines.
K6/254	SHE-14	K-5	90.0	90.5	100.0	77.1	---	---	---	49.9	2.75	1.120	1.393	0.582	21.3	3.40E-08	Olive	(Visual) Clayey Inorganic Silt High LL (MH), with some sand.
K6/255	SHE-14	K-6	95.0	95.6	100.0	48.9	110	48	62	63.3	2.74	1.109	1.441	0.590	20.3	1.05E-07	Olive	Silty Sand (SM-H), with High LL plastic fines.
K6/256	SHE-14	K-7	100.0	100.5	100.0	60.0	156	59	97	72.0	2.71	0.984	1.731	0.634	21.9	5.69E-07	Olive Gray	Sandy Clayey Inorganic Silt High LL (MH).
K6/257	SHE-14	K-8	105.5	106.0	100.0	43.1	---	---	---	61.2	2.69	1.083	1.457	0.593	22.4	5.77E-08	Olive Gray	(Visual) Silty Sand (SM), with plastic fines.
K6/258	SHE-14	K-9	111.2	111.7	100.0	31.9	---	---	---	61.1	2.73	1.037	1.607	0.616	20.6	1.13E-07	Dark Olive Gray	(Visual) Silty Sand (SM), with plastic fines.
K6/259	SHE-15	K-1	71.7	72.3	100.0	80.8	186	73	113	105.0	2.64	0.717	2.469	0.712	23.4	1.48E-07	Dark Olive Gray	Clayey Inorganic Silt High LL (MH), with a little sand.
K6/260	SHE-15	K-2	80.0	80.5	100.0	72.2	---	---	---	65.5	2.66	0.964	1.745	0.636	22.7	4.74E-08	Dark Olive Gray	(Visual) Clayey Inorganic Silt High LL (MH), with some sand.
K6/261	SHE-15	K-3	89.0	89.6	100.0	72.6	108	34	74	79.6	2.71	0.890	2.043	0.671	22.4	1.46E-07	Dark Olive Gray	Fat Clay (CH), with some sand.

SUMMARY OF MATERIAL PROPERTIES

PROJECT: Savannah Harbor Expansion Permeability Study, Savannah, GA
REQUISITION NO: W33SJG40168635 **WORK ORDER:** 330e

LAB Number	Hole No.	Sample No.	Depth		ASTM D422/D1140 Percent Passing		ASTM D4318 Atterberg Limits			ASTM D2216 MC%	ASTM D854 SpG	Dry Density (g/cc)	Void Ratio	Porosity	Hydraulic Gradient	Hydraulic Conductivity, $k_{20^\circ C}$ (cm/sec)	Color	ASTM D2487 Unified Soil Classification System
			start (ft)	end (ft)	No.4	No. 200	LL	PL	PI									
K6/262	SHE-15	K-4	99.7	100.3	100.0	31.8	---	---	---	50.8	2.71	1.162	1.334	0.572	23.7	3.34E-07	Olive Gray with White sand lenses	(Visual) Clayey Sand (SC).
K6/263	SHE-15	K-5	112.0	112.6	100.0	94.7	144	59	85	74.8	2.58	0.906	1.836	0.647	22.6	2.44E-07	Olive Gray with White sand lenses	Clayey Organic Silt (OH), with a trace of sand.
K6/264	SHE-15	K-6	129.8	130.2	100.0	99.6				115.5	2.57	0.656	2.912	0.744	22.0	1.84E-08	Olive Gray	(Visual) Clayey Organic Silt (OH).
K6/265	SHE-15	K-7	152.0	152.5	100.0	31.6	94	35	59	42.0	2.66	1.301	1.045	0.511	20.3	6.55E-08	Olive Gray	Clayey Sand High LL (SC-H).
K6/266	SHE-15	K-8	161.4	161.9	100.0	18.1	66	35	31	30.6	2.66	1.500	0.764	0.433	21.4	5.74E-07	Olive Gray	Silty Sand (SM-H), with High LL plastic fines.
K6/267	SHE-15	K-9	172.0	172.5	100.0	54.7	---	---	---	60.5	2.64	1.033	1.543	0.607	22.1	6.64E-08	Olive Gray	(Visual) Sandy Inorganic Silt High LL (MH).
K6/268	SHE-15	K-10	187.7	188.2	100.0	40.5	137	55	82	54.9	2.69	1.112	1.414	0.586	22.5	4.96E-08	Olive Gray	Silty Sand (SM-H), with High LL plastic fines.
K6/269	SHE-15	K-11	198.0	198.5	100.0	49.9	---	---	---	59.6	2.70	1.030	1.571	0.611	22.1	6.33E-08	Olive Gray	(Visual) Silty Sand (SM).
K6/270	SHE-15	K-12	210.6	211.1	100.0	33.5	122	52	70	49.7	2.73	1.157	1.308	0.567	22.3	4.95E-07	Olive Gray	Silty Sand (SM-H), with High LL plastic fines.
K6/271	SHE-16	K-1	62.0	62.6	100.0	32.0	60	28	32	53.7	2.68	1.178	1.124	0.529	21.3	6.28E-07	Olive	Clayey Sand High LL (SC-H).
K6/272	SHE-16	K-2	73.0	73.5	100.0	16.4	---	---	---	37.5	2.68	1.351	0.884	0.469	22.4	7.09E-07	Olive	(Visual) Clayey Sand (SC).
K6/273	SHE-16	K-3	89.3	89.8	100.0	56.8	---	---	---	46.7	2.70	1.225	1.203	0.546	23.2	2.07E-08	Olive Gray	(Visual) Sandy Fat Clay (CH).
K6/274	SHE-16	K-4	99.3	99.8	100.0	44.0	110	41	69	51.0	2.72	1.239	1.222	0.550	23.1	7.26E-08	Olive Gray	Clayey Sand High LL (SC-H).
K6/275	SHE-16	K-5	111.0	111.5	100.0	46.5	99	44	55	49.7	2.71	1.150	1.376	0.579	19.0	2.98E-08	Dark Olive Gray	Silty Sand (SM-H), with High LL plastic fines.
K6/276	SHE-17	K-1	58.1	58.6	100.0	50.1	46	21	25	47.1	2.70	1.072	1.392	0.582	22.3	6.99E-08	Olive Gray & Dark Gray	Sandy Lean Clay (CL).
K6/277	SHE-17	K-2	62.8	63.4	100.0	59.6	---	---	---	44.4	2.69	1.083	1.366	0.577	20.5	6.38E-08	Olive Gray & Dark Gray	(Visual) Sandy Fat Clay (CH).
K6/282	SHE-17	T-1	69.1	70.1	100.0	73.0	87	30	57	60.5	2.71	---	---	---	---	---	Olive Gray & Dark Gray	Fat Clay (CH), with some sand.
K6/278	SHE-17	K-3	70.4	71.0	100.0	71.4	82	24	58	64.3	2.69	0.914	1.901	0.655	22.9	6.18E-08	Olive Gray & Dark Gray	Fat Clay (CH), with some sand.
K6/279	SHE-17	K-4	77.3	77.9	100.0	21.4	64	25	39	34.9	2.77	1.398	0.915	0.478	23.3	1.04E-06	Dark Olive Gray	Clayey Sand High LL (SC-H).
K6/283	SHE-17	T-2	79.0	80.0	100.0	22.0	62	23	39	36.3	2.79	---	---	---	---	---	Dark Olive Gray	Clayey Sand High LL (SC-H).
K6/280	SHE-17	K-5	86.9	87.4	100.0	11.8	---	---	---	33.3	2.81	1.419	0.995	0.499	22.6	2.29E-07	Dark Olive Gray	(Visual) Poorly Graded Silty Sand (SP-SM).
K6/281	SHE-17	K-6	104.8	105.2	100.0	54.6	106	46	60	42.9	2.71	1.290	1.089	0.521	20.8	4.87E-08	Olive	Sandy Clayey Inorganic Silt High LL (MH).
K6/284	SHE-18	K-1	91.5	92.2	100.0	97.9	328	108	220	179.7	2.52	0.454	4.454	0.817	22.8	2.12E-07	Dark Olive Gray	Clayey Organic Silt (OH), with a trace of sand.
K6/285	SHE-18	K-2	97.2	97.9	100.0	20.2	---	---	---	37.3	2.77	1.407	0.975	0.494	23.9	9.95E-08	Dark Olive Gray	(Visual) Silty Sand (SM).
K6/286	SHE-18	K-3	120.9	121.5	100.0	34.5	131	53	78	51.1	2.67	1.045	1.519	0.603	22.0	1.62E-07	Olive Gray	Silty Sand (SM-H), with High LL plastic fines.
K6/287	SHE-18	K-4	133.3	134.0	100.0	24.6	---	---	---	43.1	2.68	1.218	1.181	0.541	23.3	5.09E-08	Olive Gray	(Visual) Silty Sand (SM).
K6/288	SHE-19	K-1	86.2	87.0	100.0	51.4	72	31	41	43.9	2.72	1.362	0.992	0.498	22.4	3.27E-06	Olive Gray	Sandy Fat Clay (CH).
K6/289	SHE-19	K-2	96.7	97.5	100.0	95.6	156	63	93	85.1	2.71	1.081	1.493	0.599	23.5	2.61E-06	Olive Gray	Clayey Inorganic Silt High LL (MH), with a trace of sand.
K6/290	SHE-19	K-3	118.5	119.3	100.0	38.4	84	31	53	51.1	2.68	1.123	1.410	0.585	22.5	1.41E-07	Olive Gray	Clayey Sand High LL (SC-H).
K6/291	SHE-19	K-4	131.8	132.4	100.0	51.8	---	---	---	53.4	2.70	1.092	1.451	0.592	21.2	6.28E-08	Olive Gray	(Visual) Sandy Clayey Inorganic Silt High LL (MH).
K6/292	SHE-19	K-5	142.0	142.6	100.0	87.3	135	55	80	63.5	2.70	0.972	1.762	0.638	22.5	3.10E-08	Olive Gray	Clayey Inorganic Silt High LL (MH), with a little sand.

SUMMARY OF MATERIAL PROPERTIES

PROJECT: Savannah Harbor Expansion Permeability Study, Savannah, GA
REQUISITION NO: W33SJG40168635 **WORK ORDER:** 330e

LAB Number	Hole No.	Sample No.	Depth		ASTM D422/D1140 Percent Passing		ASTM D4318 Atterberg Limits			ASTM D2216 MC%	ASTM D854 SpG	Dry Density (g/cc)	Void Ratio	Porosity	Hydraulic Gradient	Hydraulic Conductivity, $k_{20°C}$ (cm/sec)	Color	ASTM D2487 Unified Soil Classification System
			start (ft)	end (ft)	No.4	No. 200	LL	PL	PI									
K6/293	SHE-19	K-6	152.5	153.1	100.0	91.5	---	---	---	81.7	2.69	0.880	2.037	0.671	23.1	2.58E-08	Olive Gray	(Visual) Clayey Inorganic Silt High LL (MH), with a trace of sand.
K6/294	SHE-19	K-7	162.3	162.9	100.0	99.7	250	83	167	124.7	2.59	0.618	3.191	0.761	24.3	1.18E-08	Olive Gray	Clayey Organic Silt (OH).
K6/295	SHE-19	K-8	167.1	167.6	100.0	70.3	---	---	---	155.7	2.55	0.512	3.903	0.796	22.2	3.15E-08	Olive Gray	(Visual) Clayey Organic Silt (OH), with some sand.
K6/296	SHE-19	K-9	188.8	189.3	100.0	31.1	69	37	32	28.5	2.68	1.497	0.755	0.430	21.9	9.60E-08	Olive	Silty Sand (SM-H), with High LL plastic fines.
K6/297	SHE-19	K-10	202.1	202.6	100.0	42.6	132	58	74	52.0	2.66	1.151	1.298	0.565	24.1	1.58E-08	Olive Gray	Silty Sand (SM-H), with High LL plastic fines.
K6/298	SHE-19	K-11	213.7	214.2	100.0	45.5	97	47	50	38.1	2.69	1.401	0.915	0.478	23.5	5.39E-08	Olive	Silty Sand (SM-H), with High LL plastic fines.

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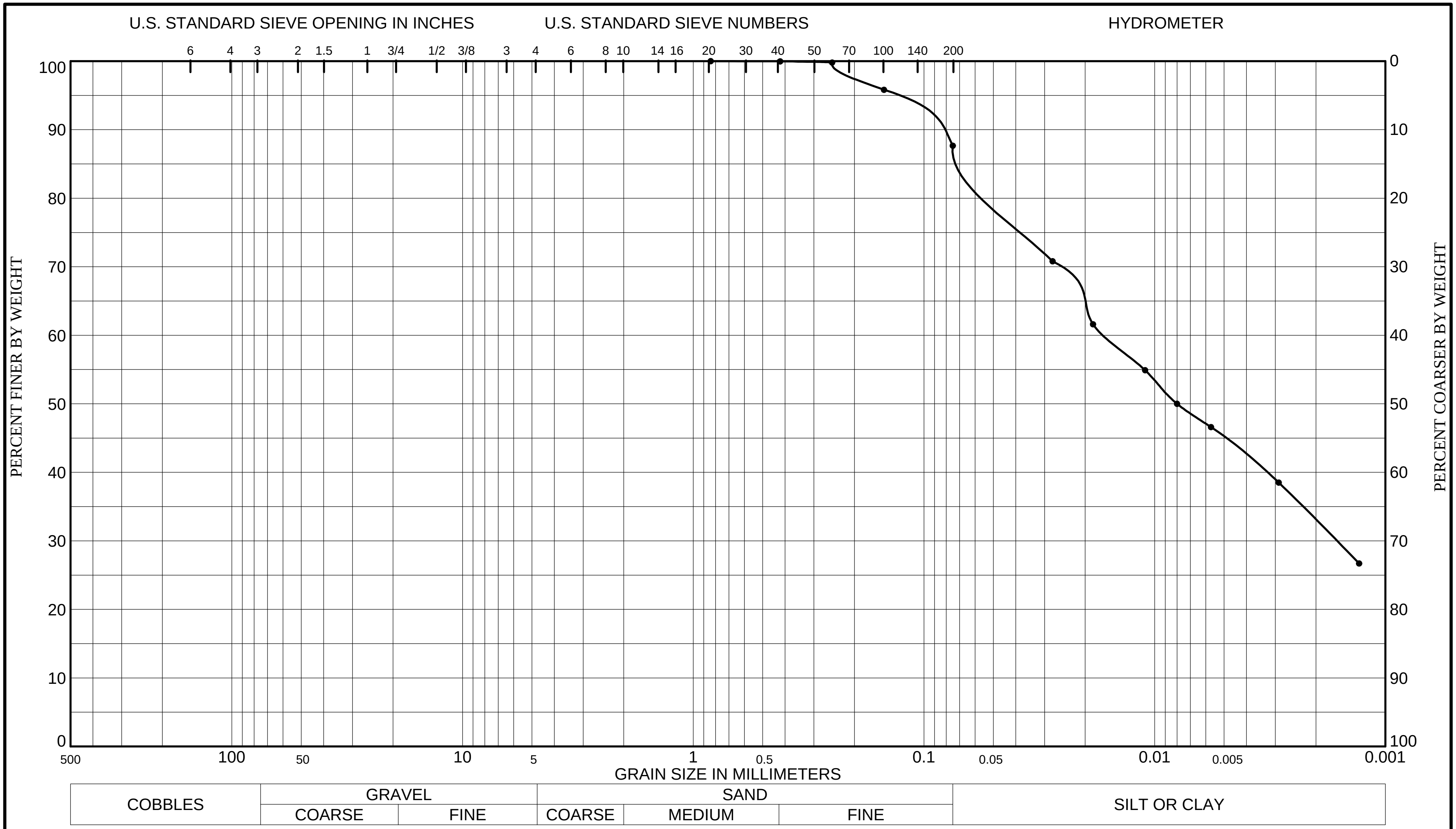
WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-1	48.5 to 49.0	Olive Gray, Fat Clay (CH), with a little sand, a trace of mica and wood fragments.	75.7	84	24	60

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/205

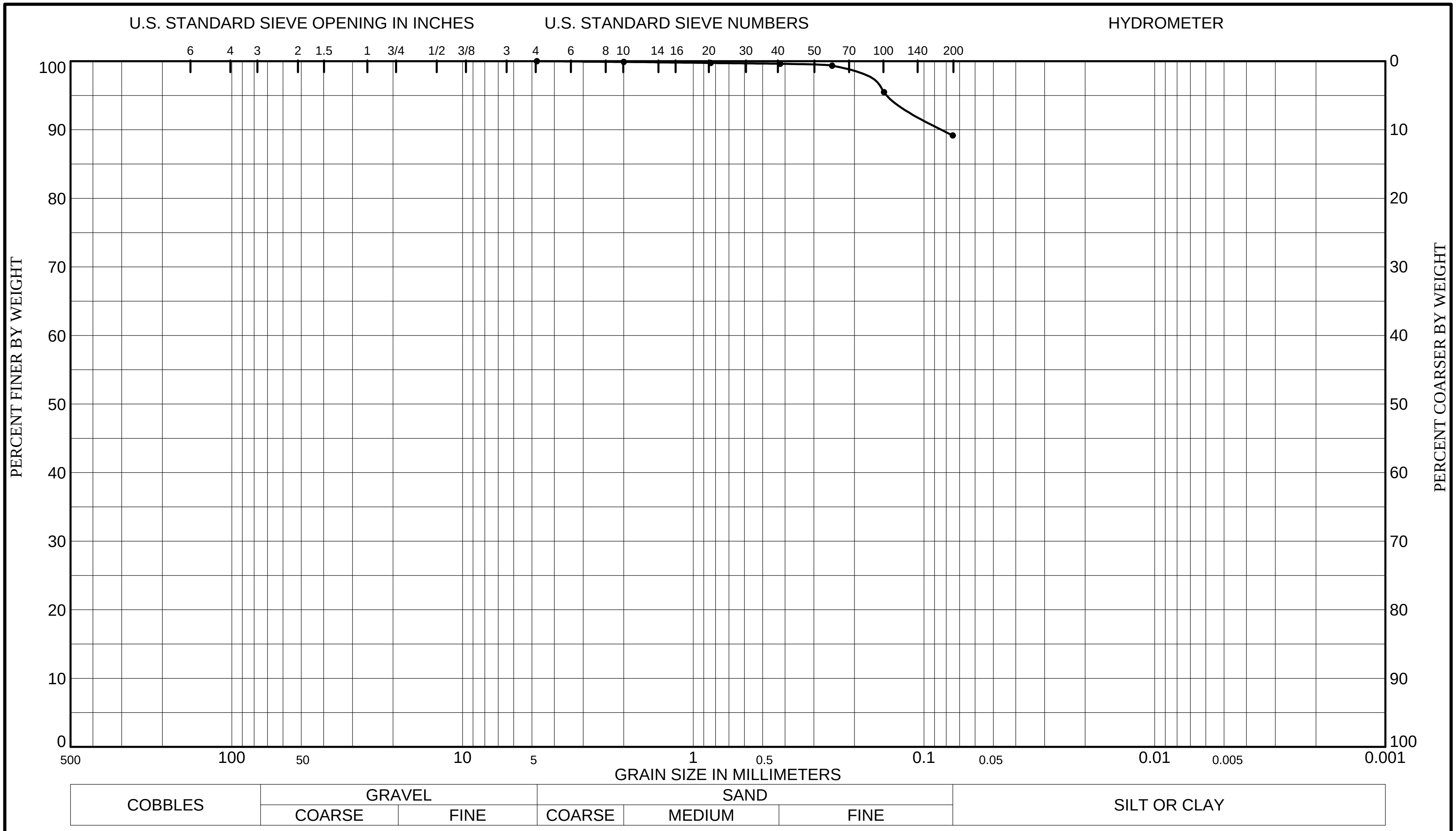
Boring No. SHE-11

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-2	76.0 to 76.5	Olive Gray, (Visual) Fat Clay (CH), with a little sand.	96.2			

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/206

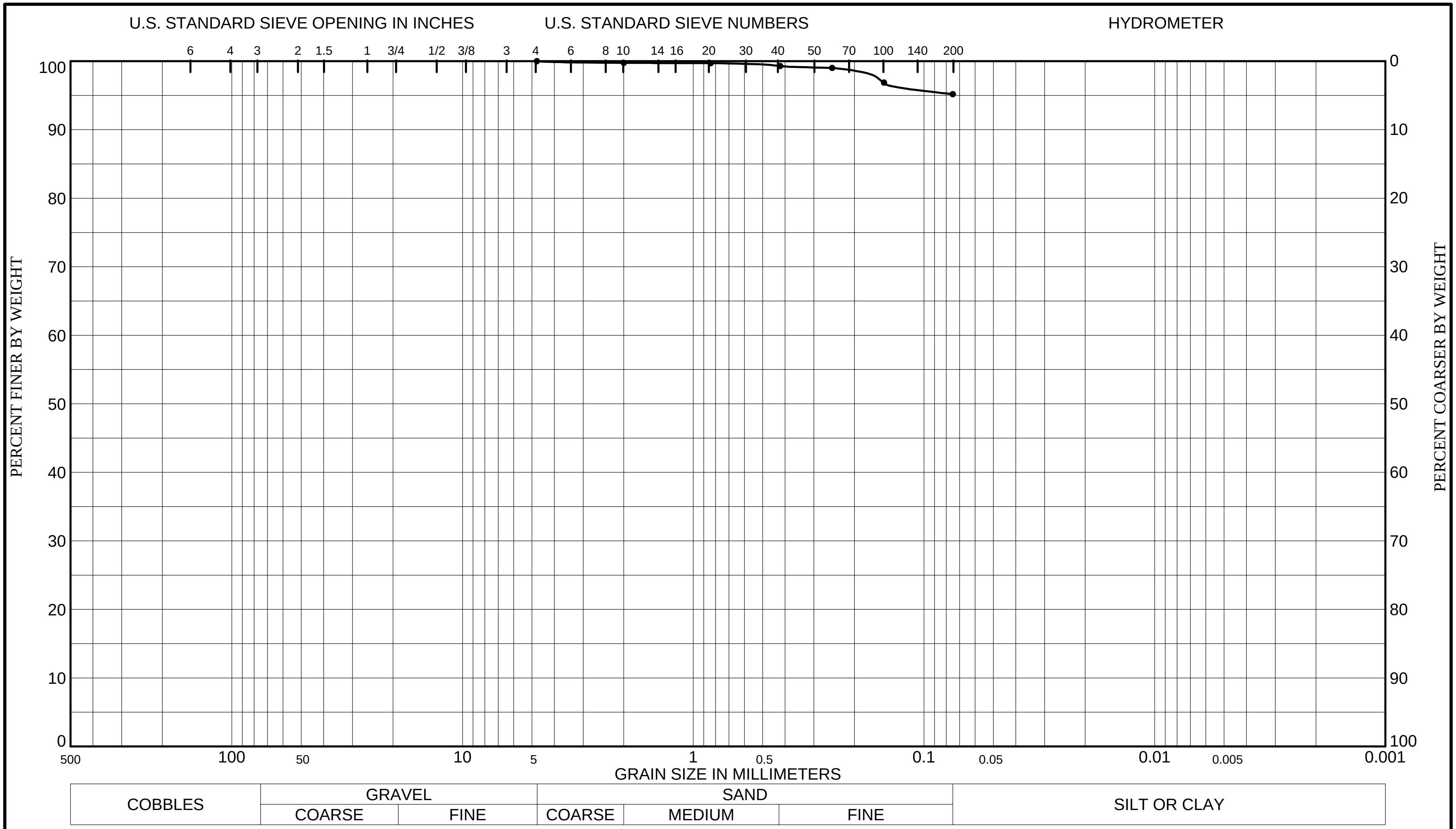
Boring No. SHE-11

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-3	78.5 to 79.0	Olive Gray, (Visual) Fat Clay (CH), with a trace of sand.	65.5			

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/207

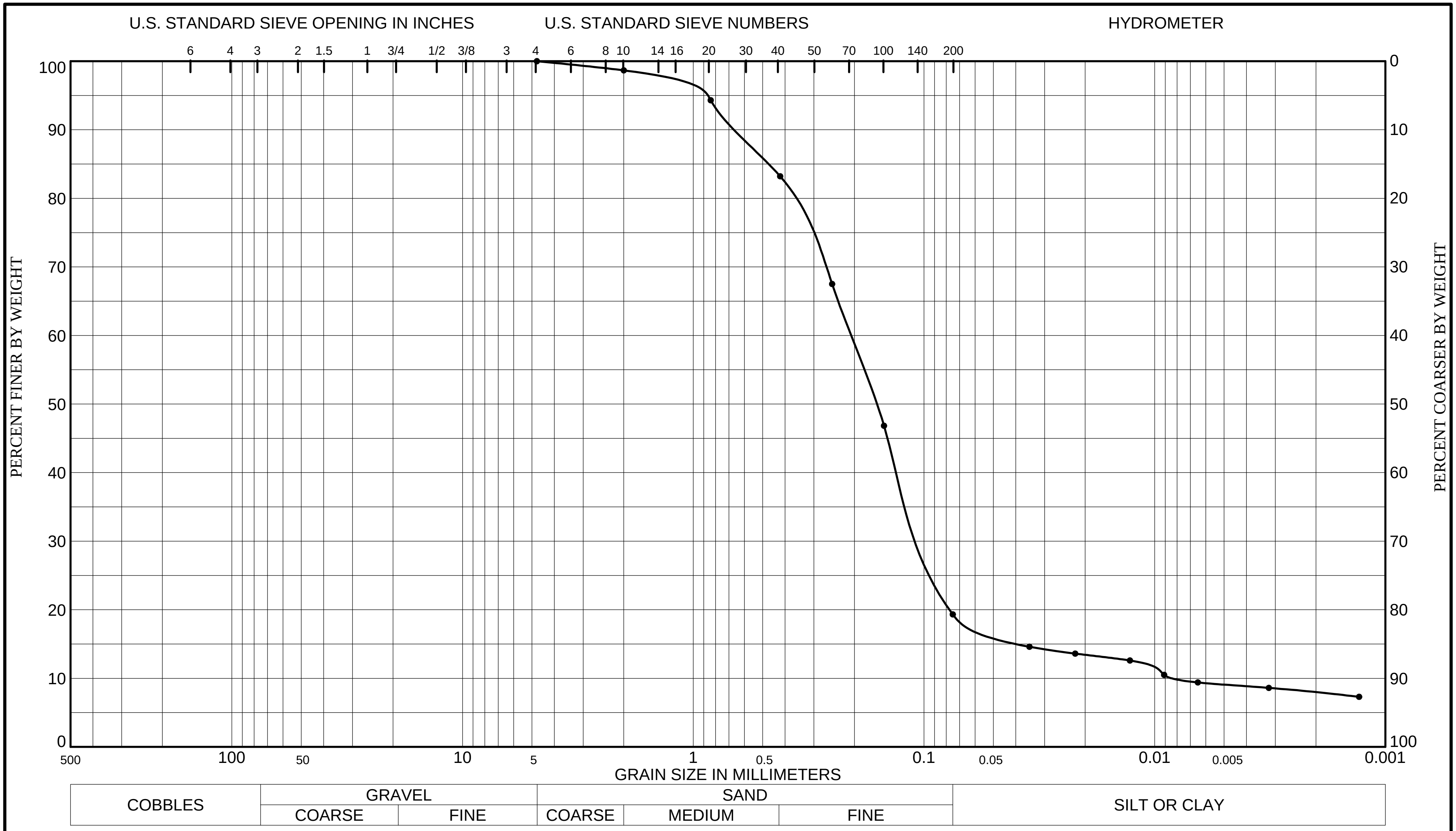
Boring No. SHE-11

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-4	88.3 to 88.8	Dark Olive Gray, Clayey Sand High LL (SC-H).	34.4	67	30	37

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/208

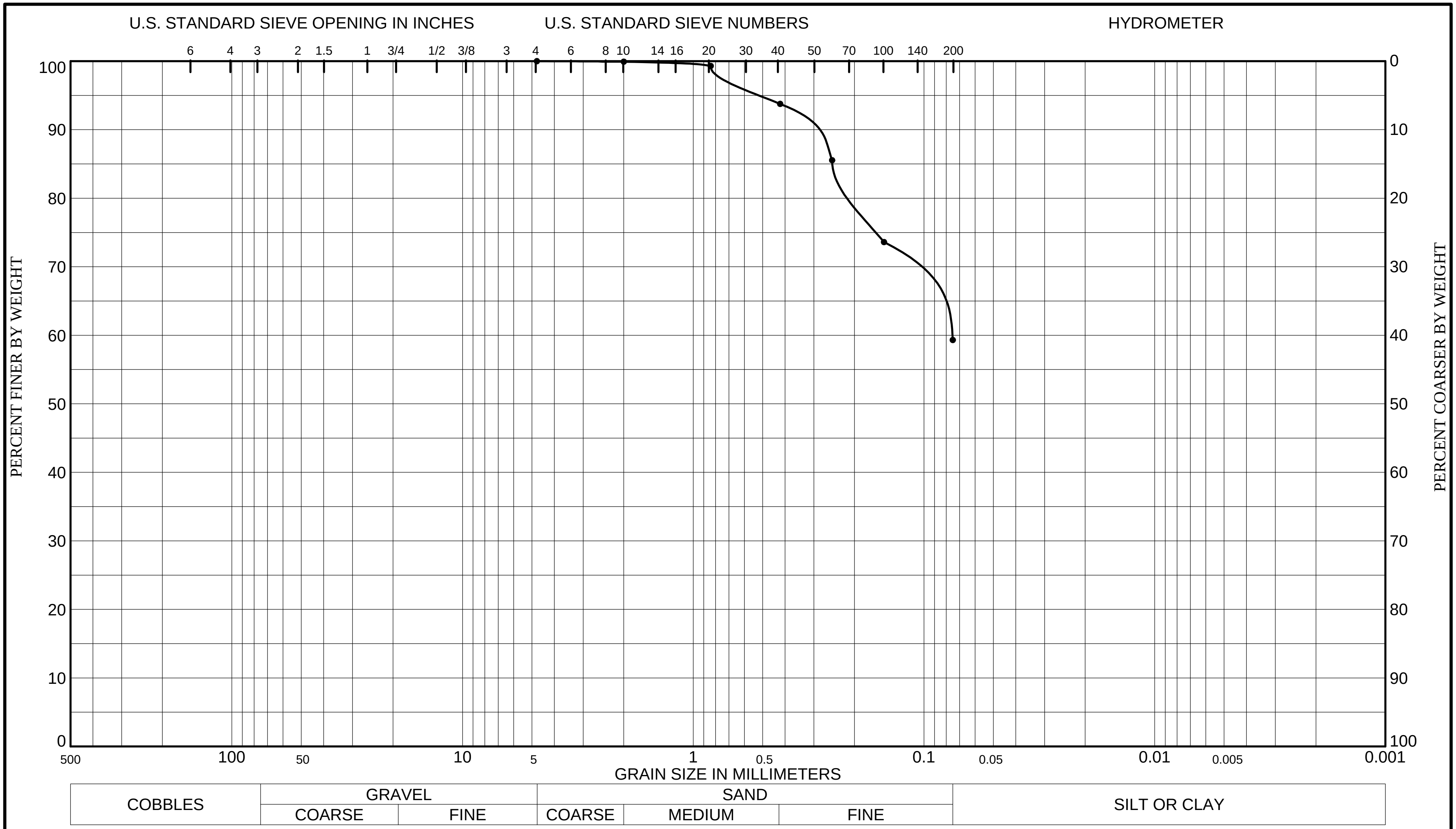
Boring No. SHE-11

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-5	97.8 to 98.3	Pale Olive, Sandy Clayey Inorganic Silt High LL (MH).	38.0	76	39	37

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/209

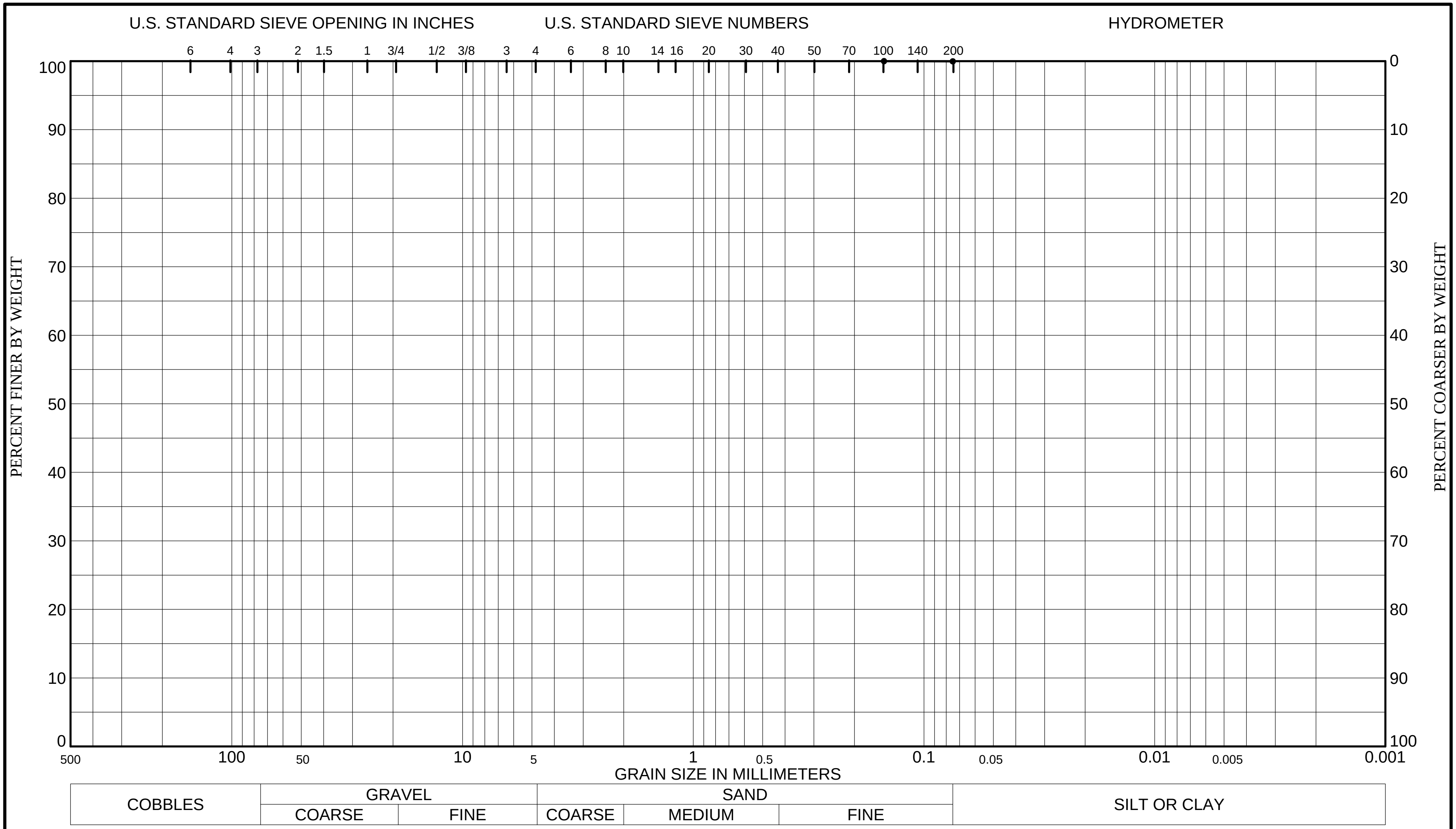
Boring No. SHE-11

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



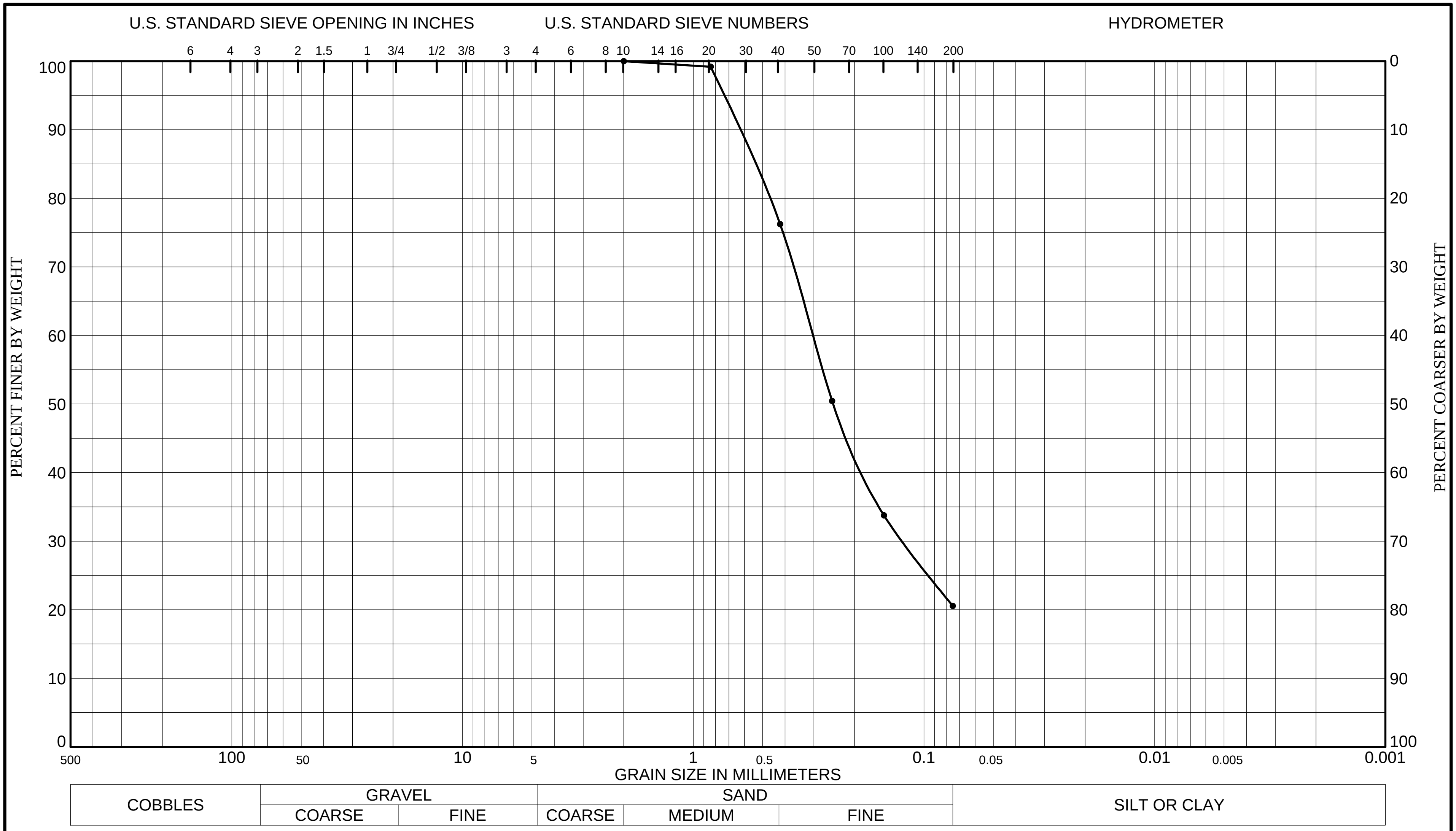
Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-6	109.3 to 109.8	Olive Gray, (Visual) Fat Clay (CH).	39.8			

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/210
Boring No. SHE-11
Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-7	117.0 to 117.5	Dark Olive Gray, (Visual) Silty Sand (SM), with plastic fines.	38.2			

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/211

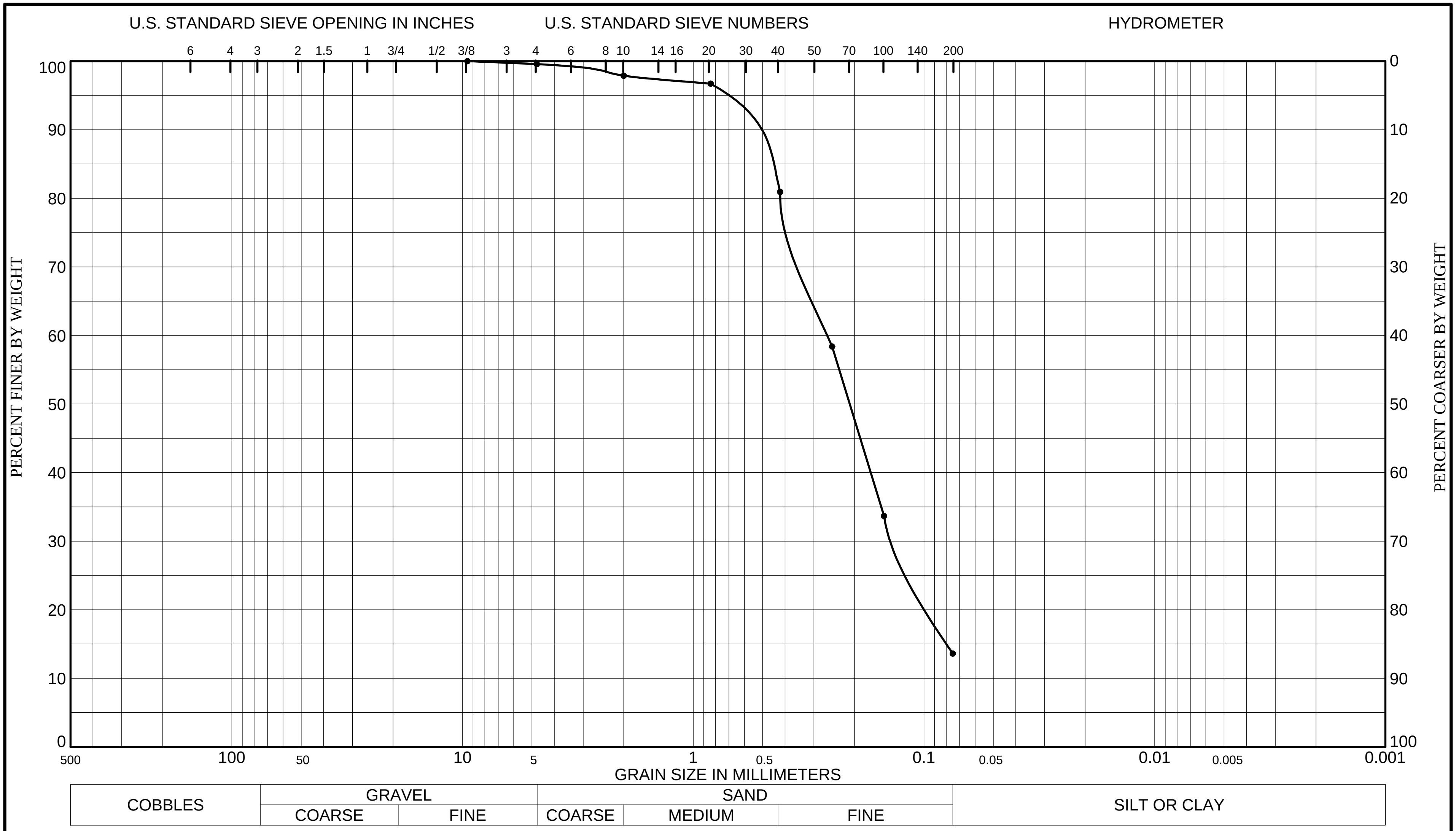
Boring No. SHE-11

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-8	119.3 to 119.8	Dark Olive Gray, Silty Sand (SM-H), with High LL plastic fines.	40.9	64	34	30

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/212

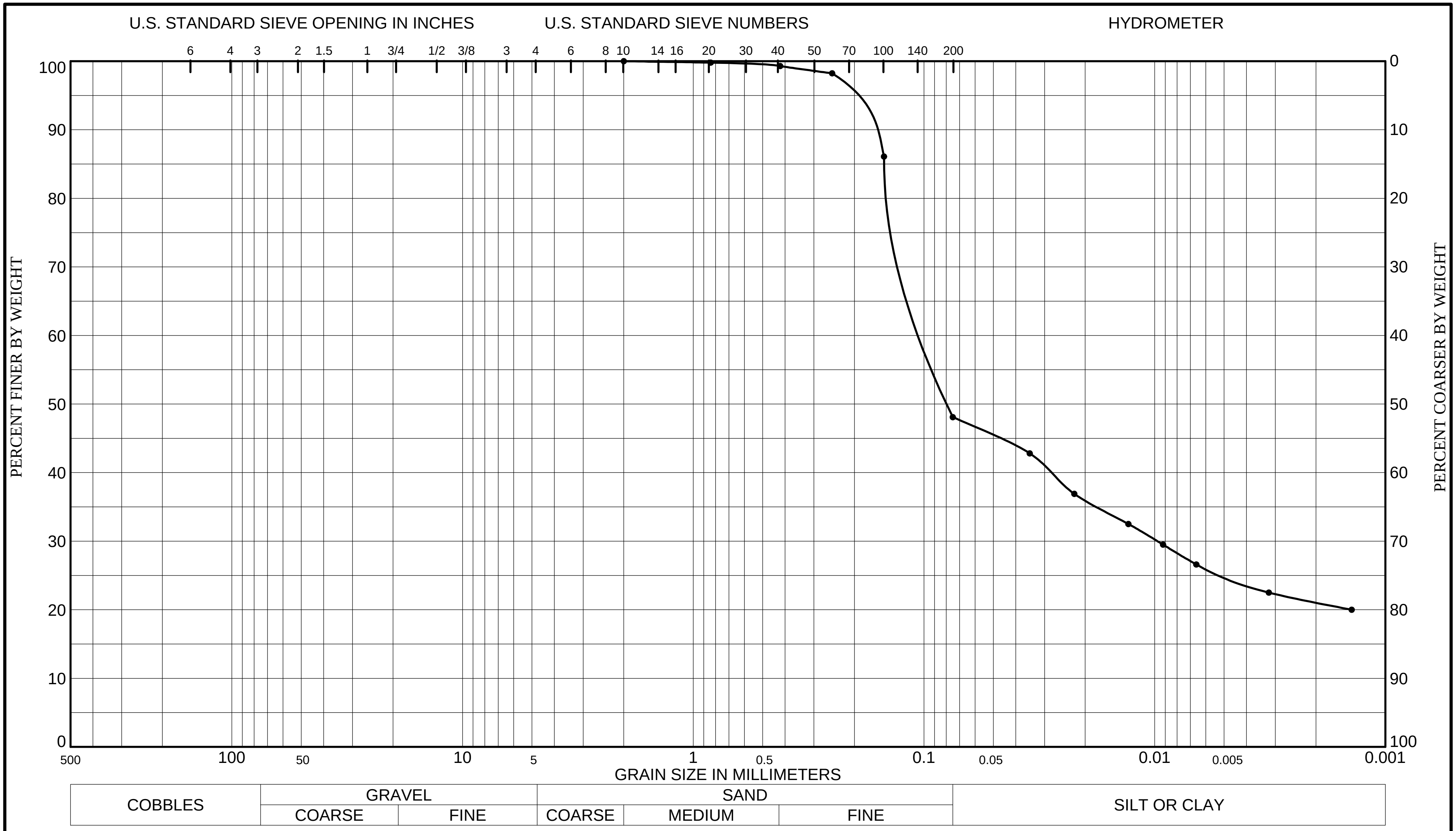
Boring No. SHE-11

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-9	125.0 to 125.5	Dark Olive Gray, Silty Sand (SM-H), with High LL plastic fines.	72.3	144	71	73

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/213

Boring No. SHE-11

Date 2/22/05

GRADATION CURVES

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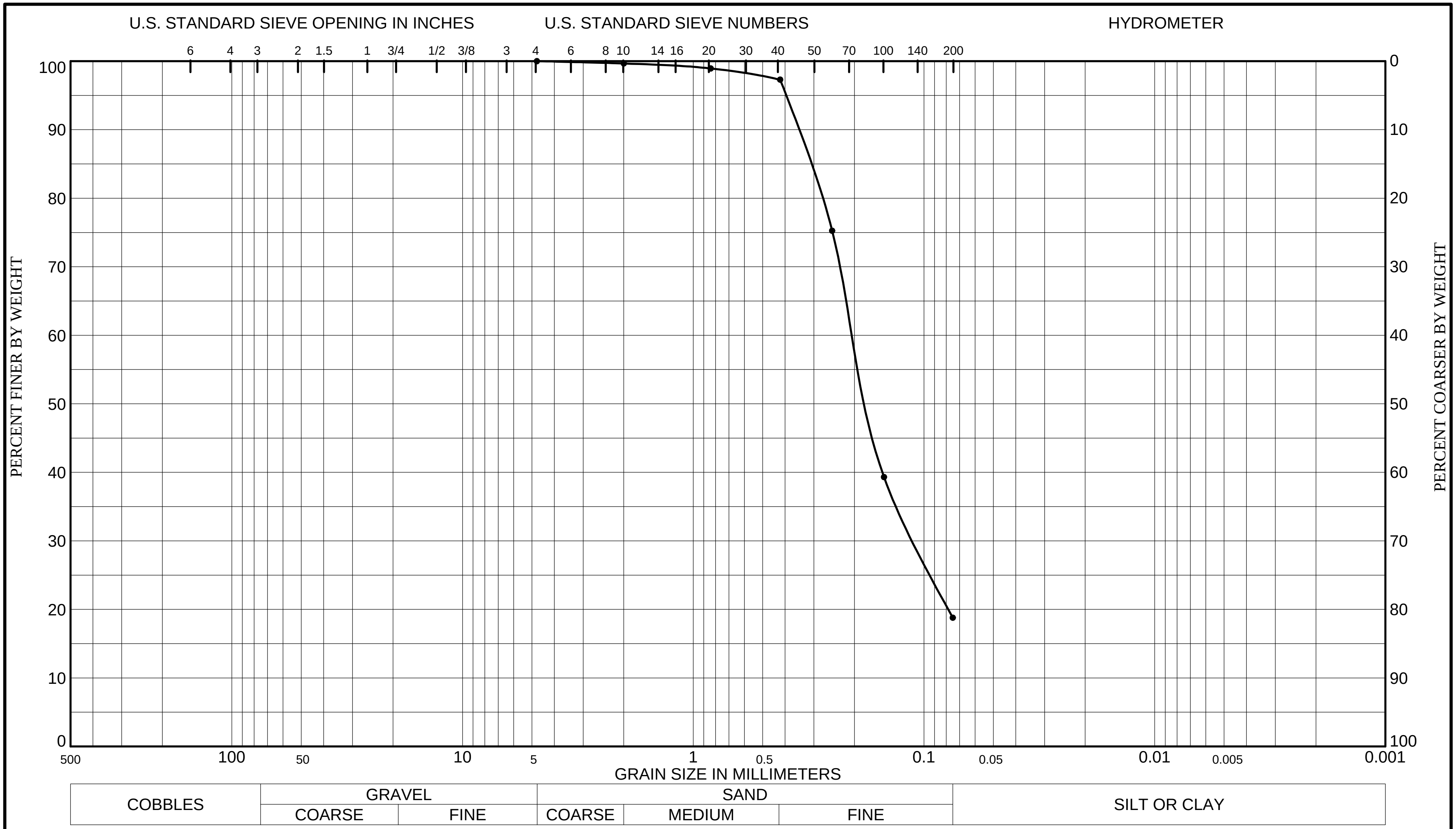
WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-1	70.0 to 70.5	Olive Gray, (Visual) Clayey Sand (SC).	31.6			

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/214

Boring No. SHE-13

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
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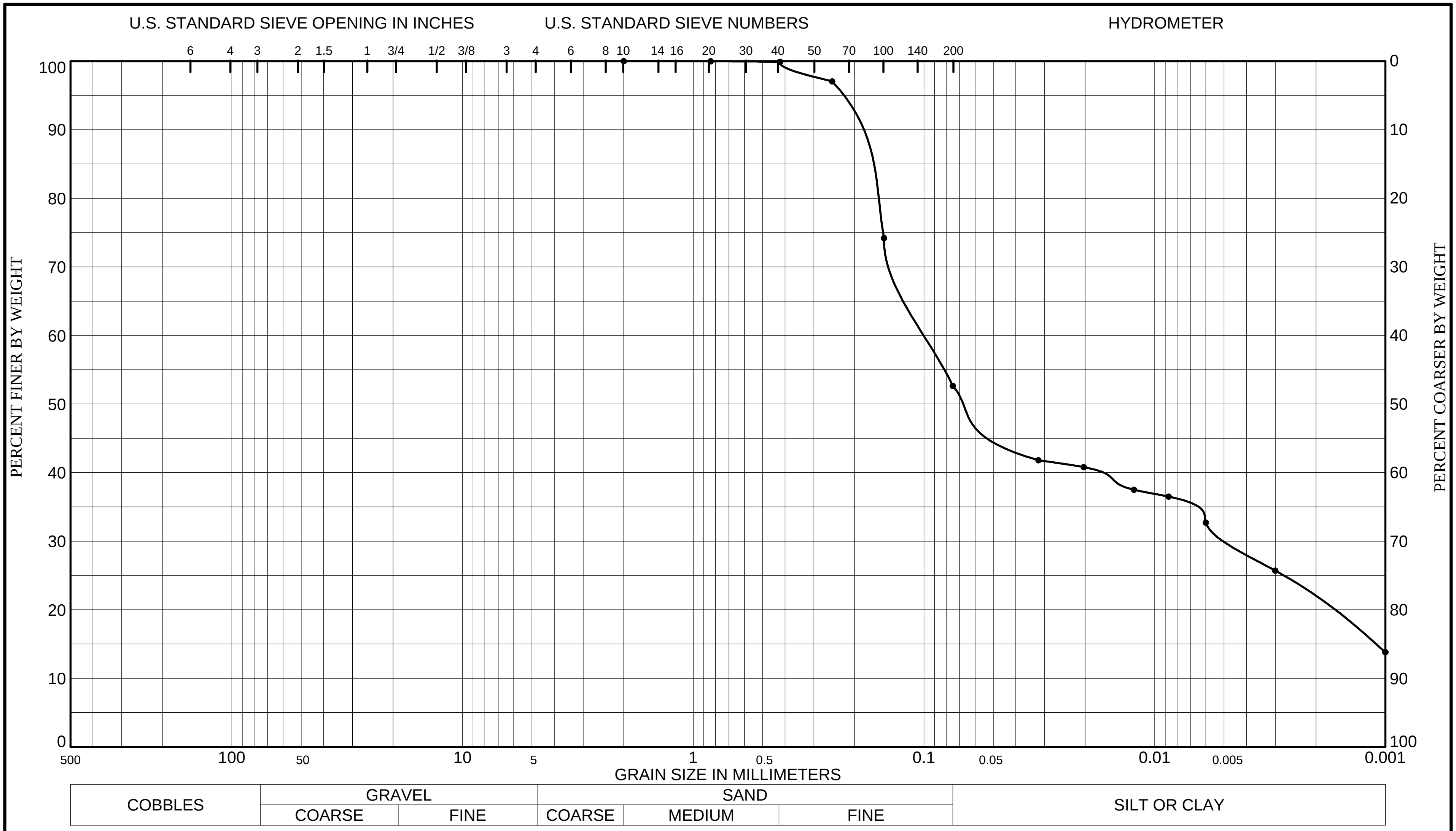
WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-2	75.8 to 76.3	Olive Gray, Sandy Fat Clay (CH).	35.0	67	22	45

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/215

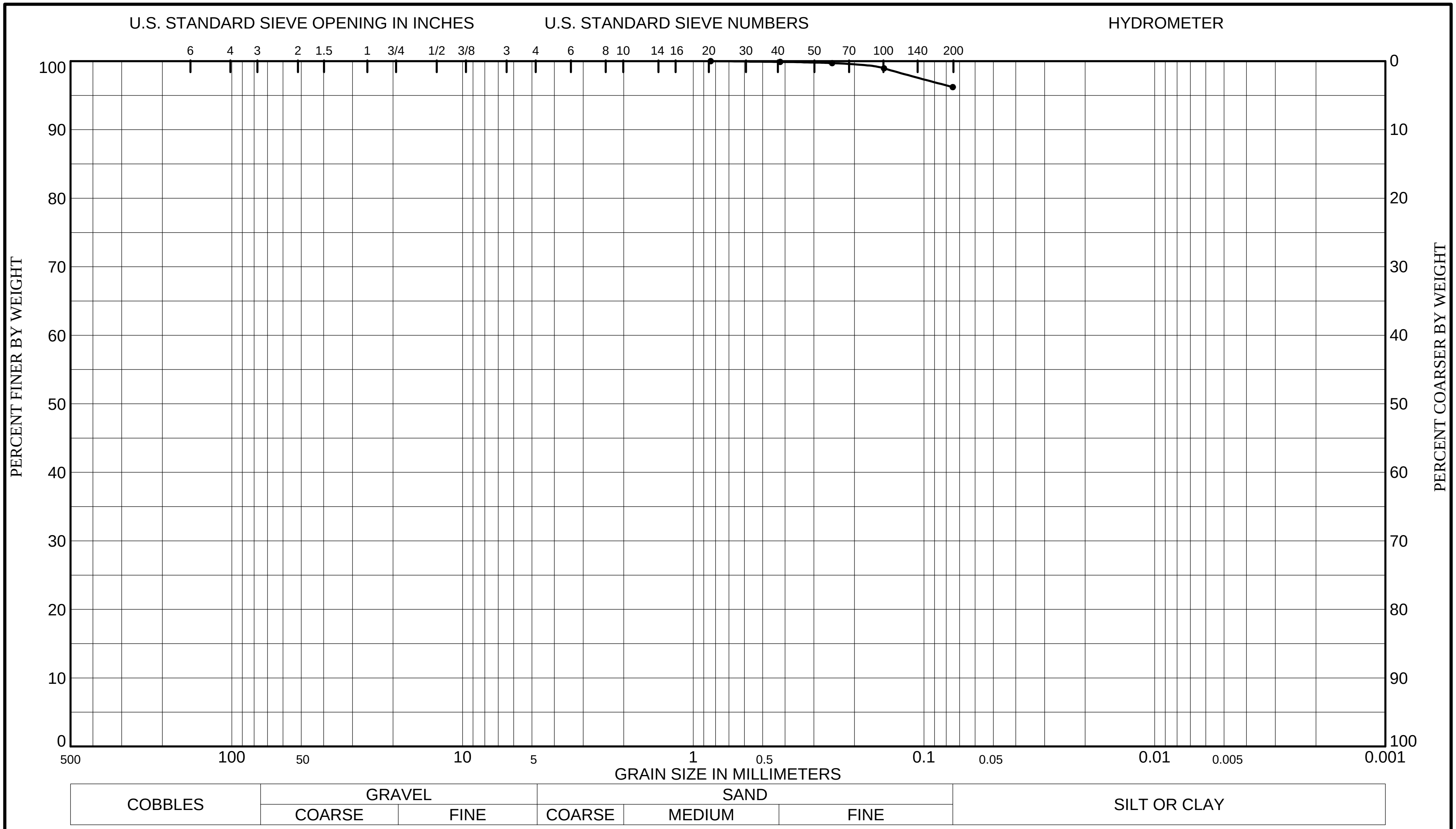
Boring No. SHE-13

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-5	92.7 to 93.2	Olive Gray, (Visual) Fat Clay (CH), with a trace of sand.	85.6			

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/216

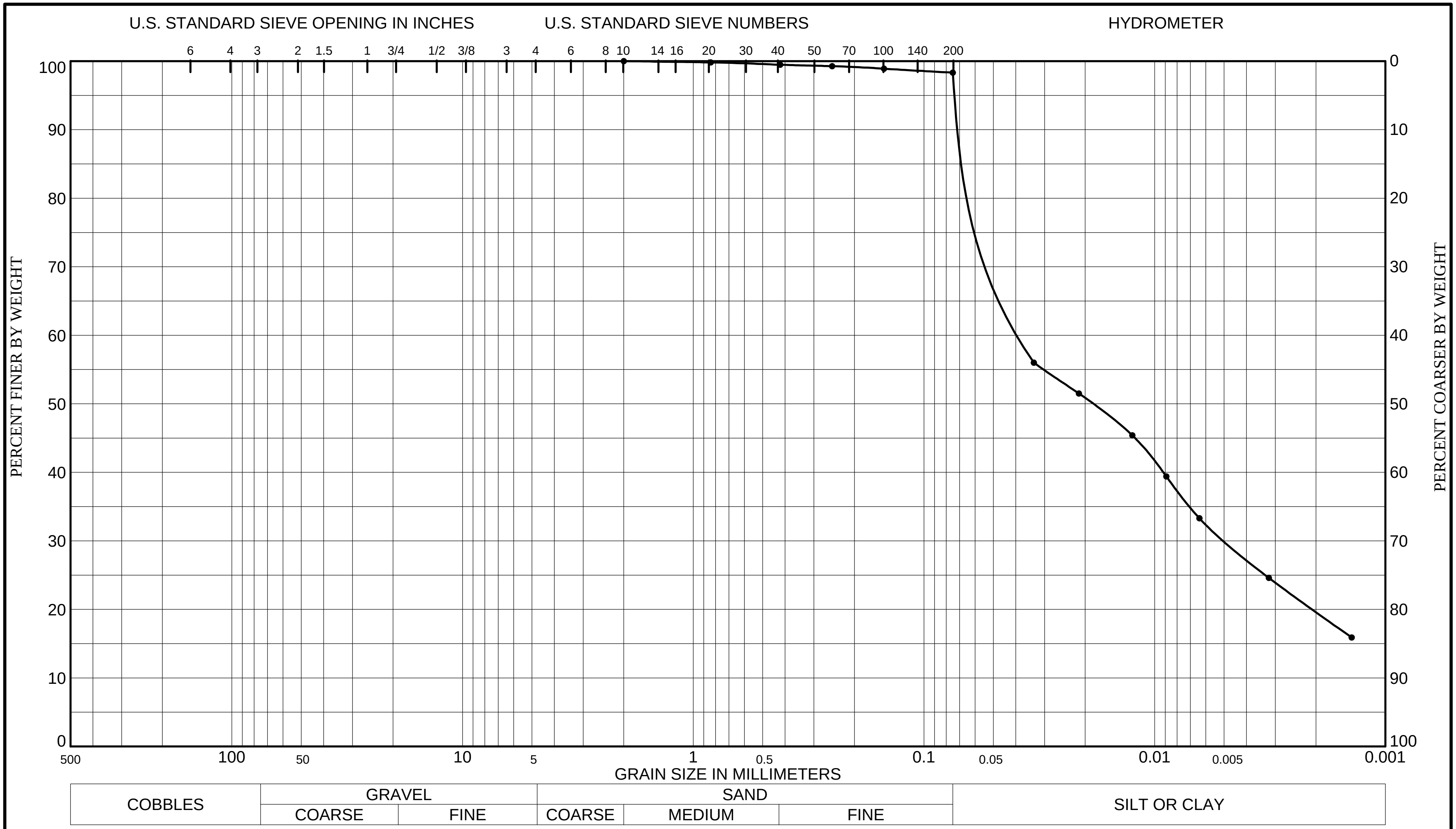
Boring No. SHE-13

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-6	98.3 to 98.8	Olive Gray, (Visual) Fat Clay (CH), with a trace of sand.	75.4			

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/217

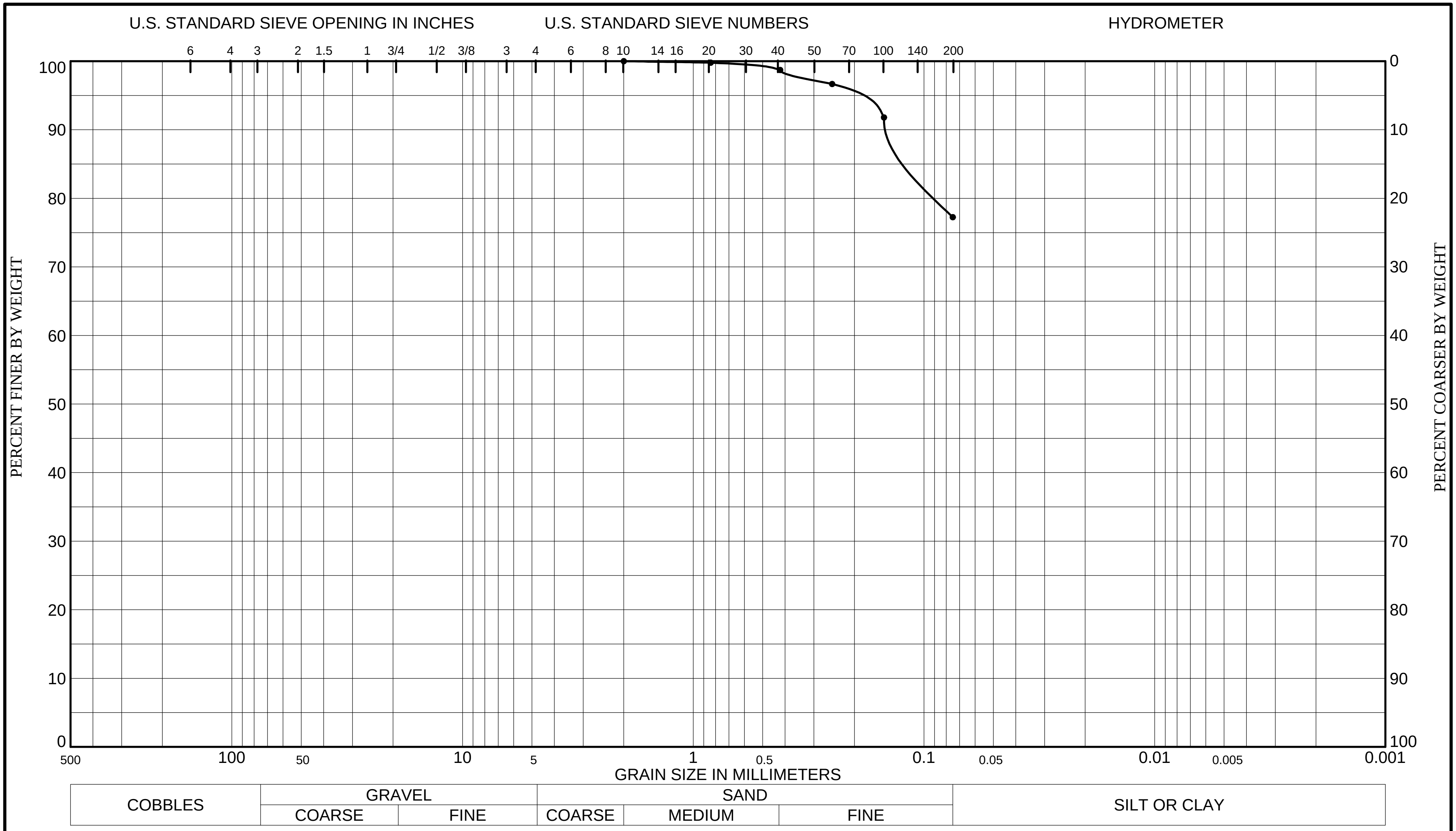
Boring No. SHE-13

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-7	102.3 to 102.8	Olive, Clayey Inorganic Silt High LL (MH), with some sand.	68.2	132	53	79

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/218

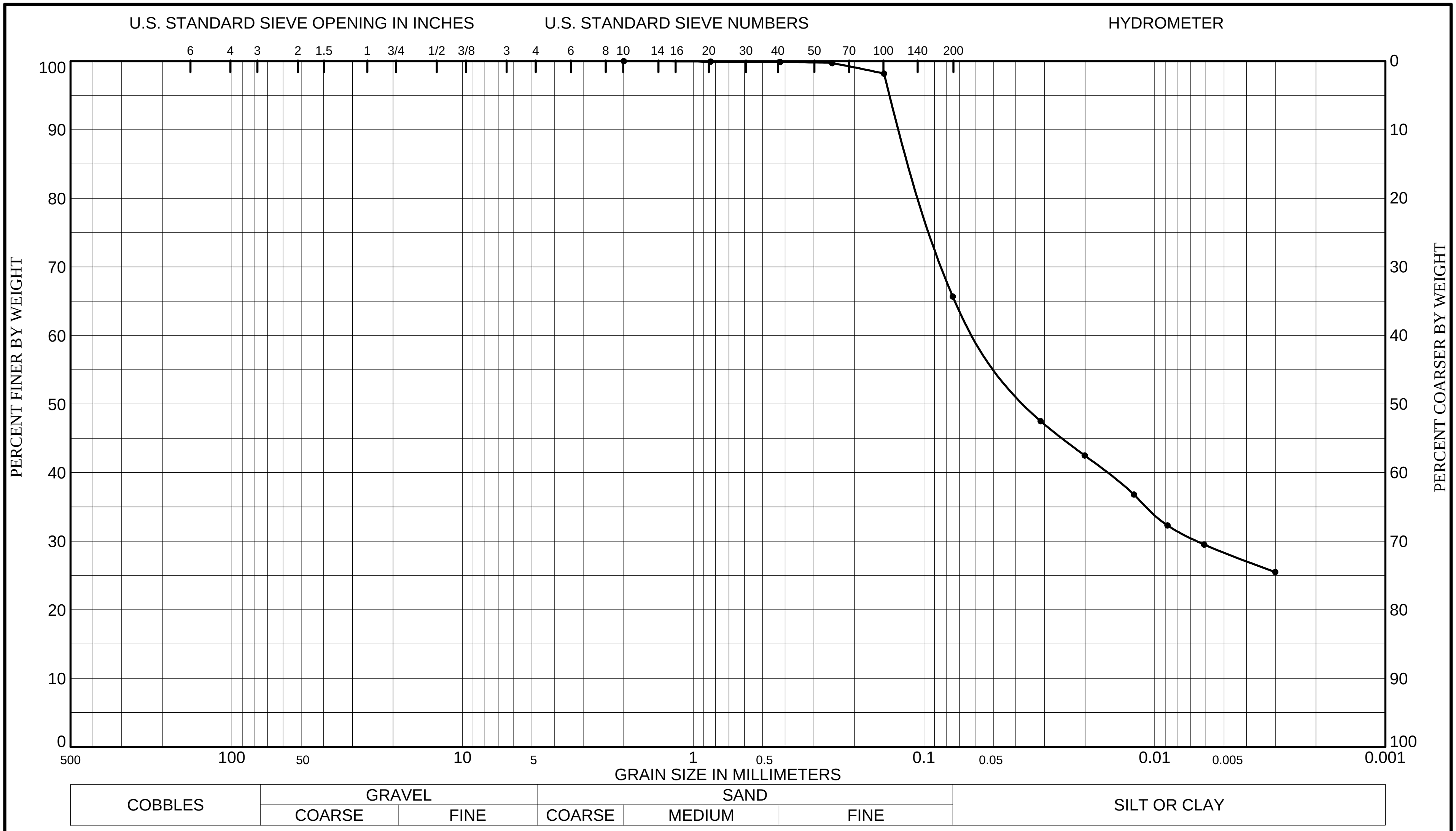
Boring No. SHE-13

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-8	106.5 to 107.0	Olive Gray, (Visual) Clayey Inorganic Silt High LL (MH), with	62.1			
		some sand.				

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/219

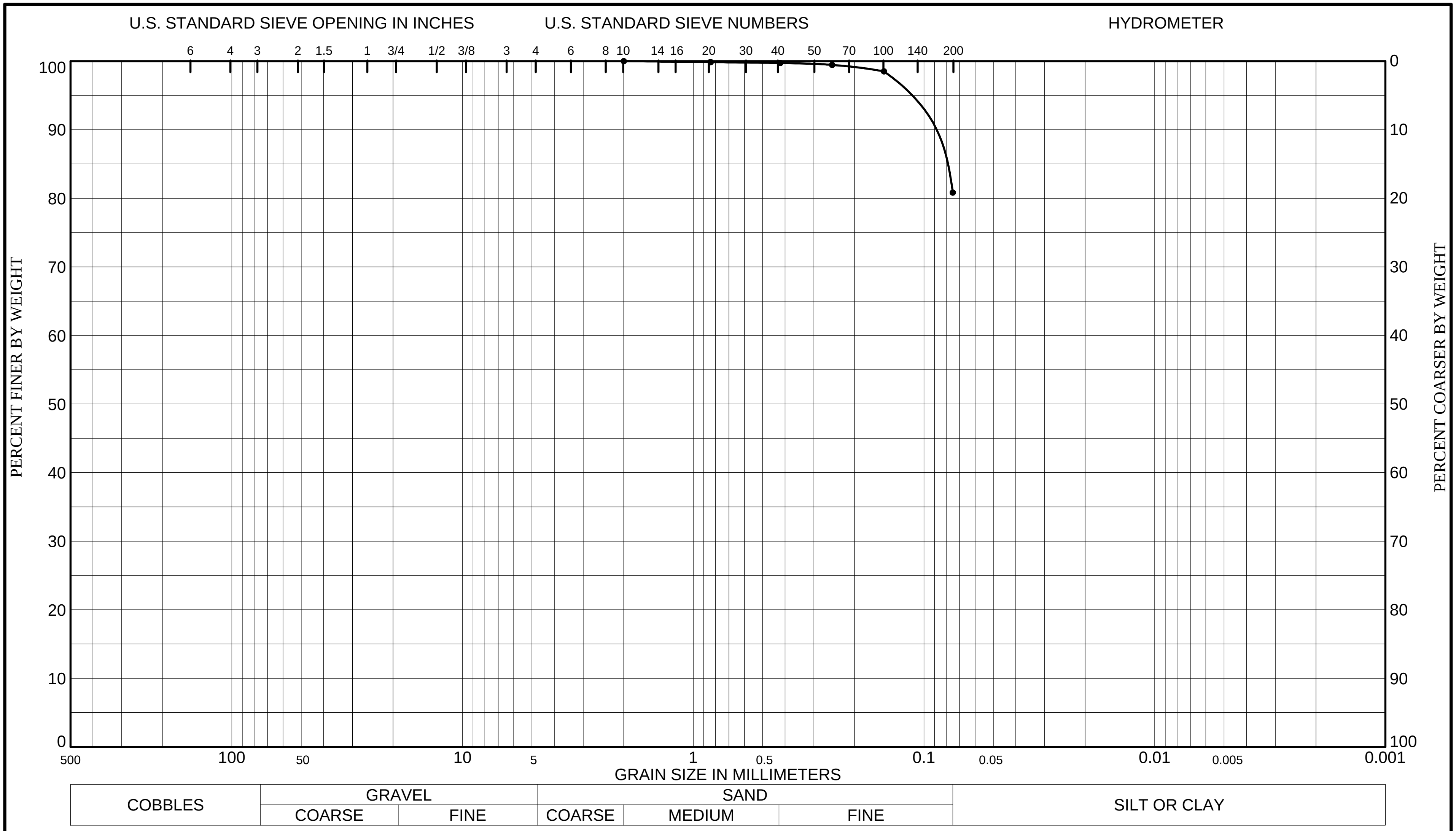
Boring No. SHE-13

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-9	111.5 to 112.0	Olive Gray, Clayey Inorganic Silt High LL (MH), with a little sand.	82.4	158	74	84

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/220

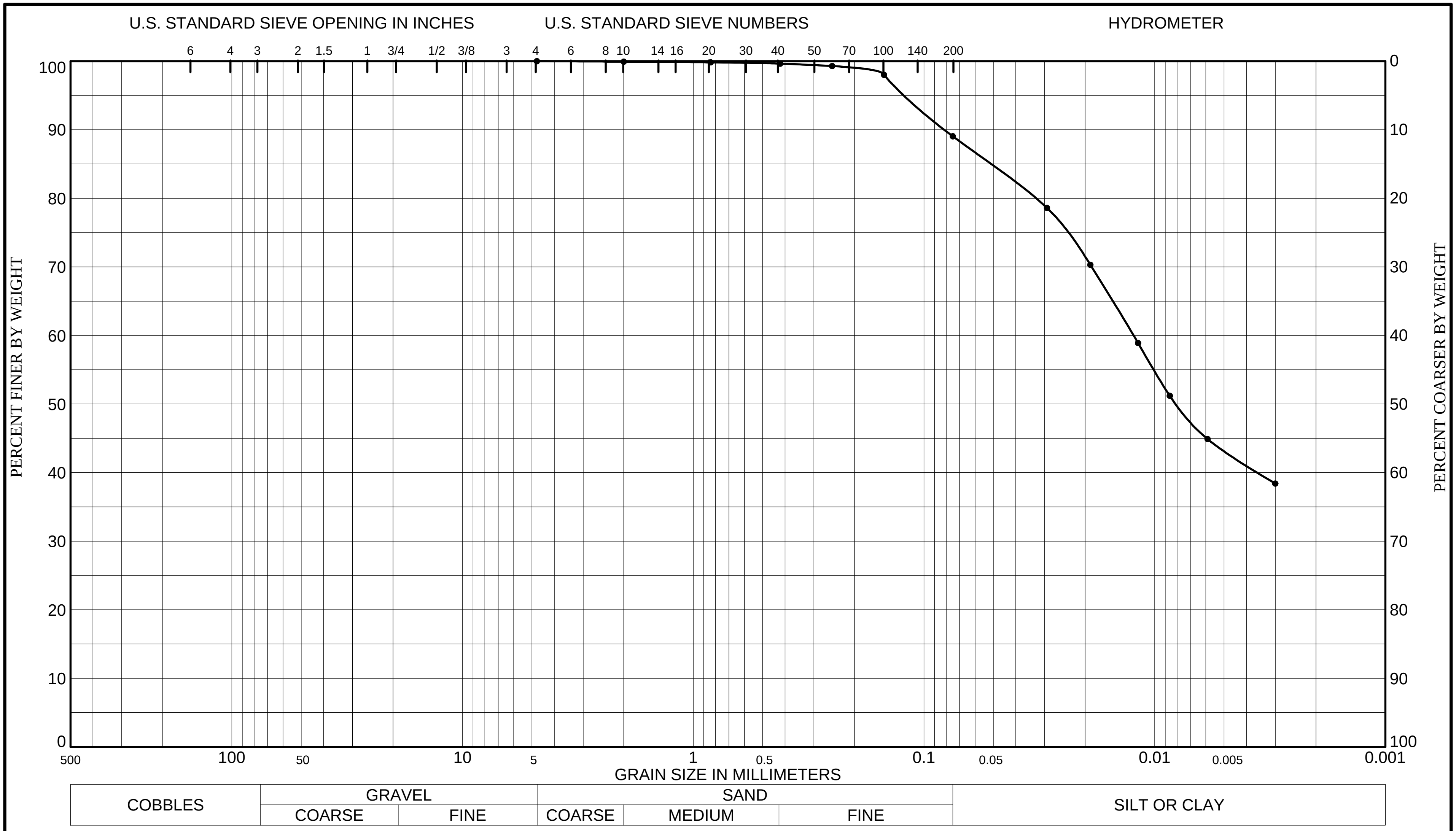
Boring No. SHE-13

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-10	117.2 to 117.7	Olive Gray, (Visual) Clayey Inorganic Silt High LL (MH), with a little sand.	92.8			

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/221

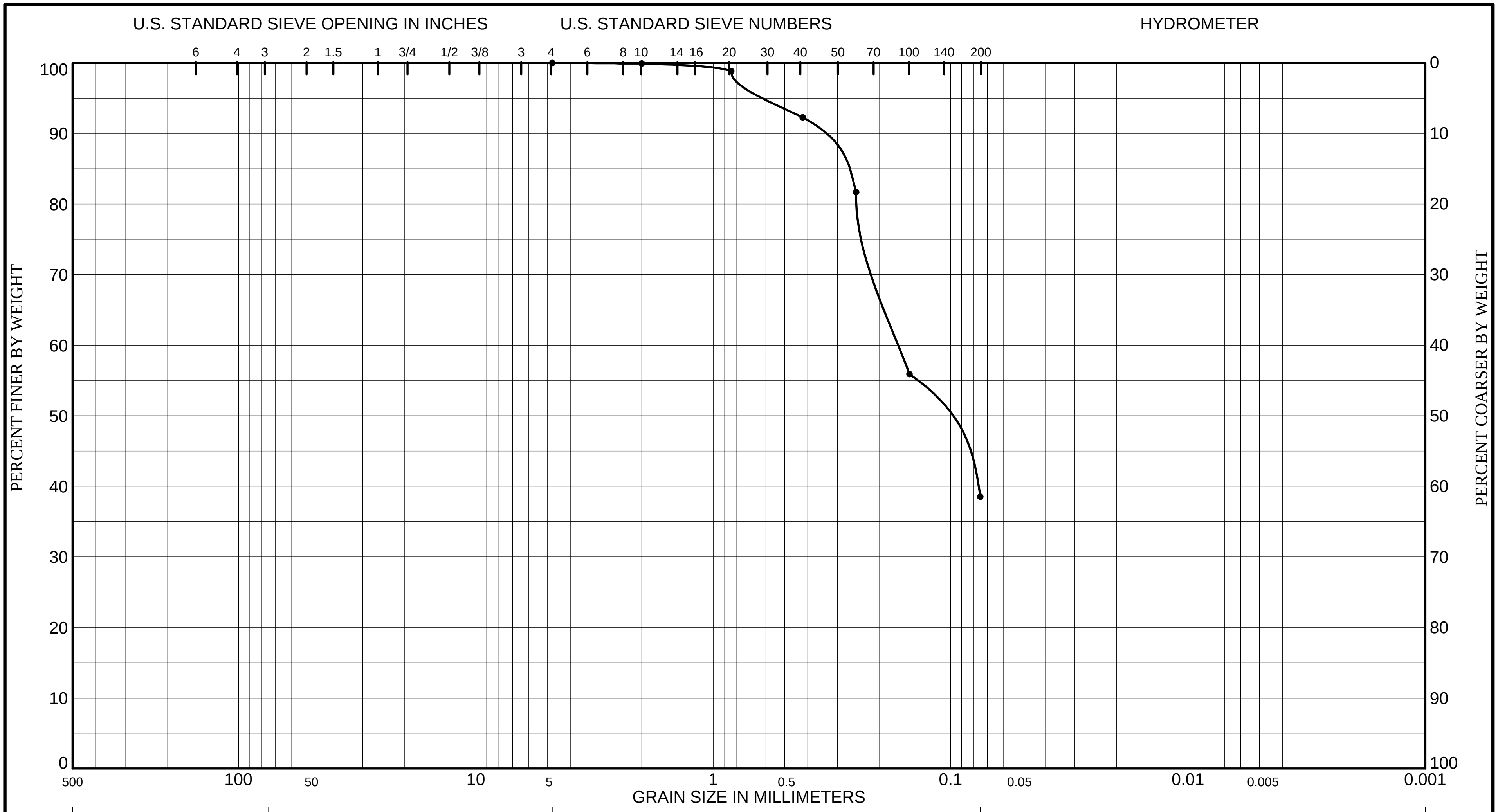
Boring No. SHE-13

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-11	124.0 to 124.5	Dark Olive Gray, Silty Sand (SM-H), with High LL plastic fines.	49.5	151	67	84

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

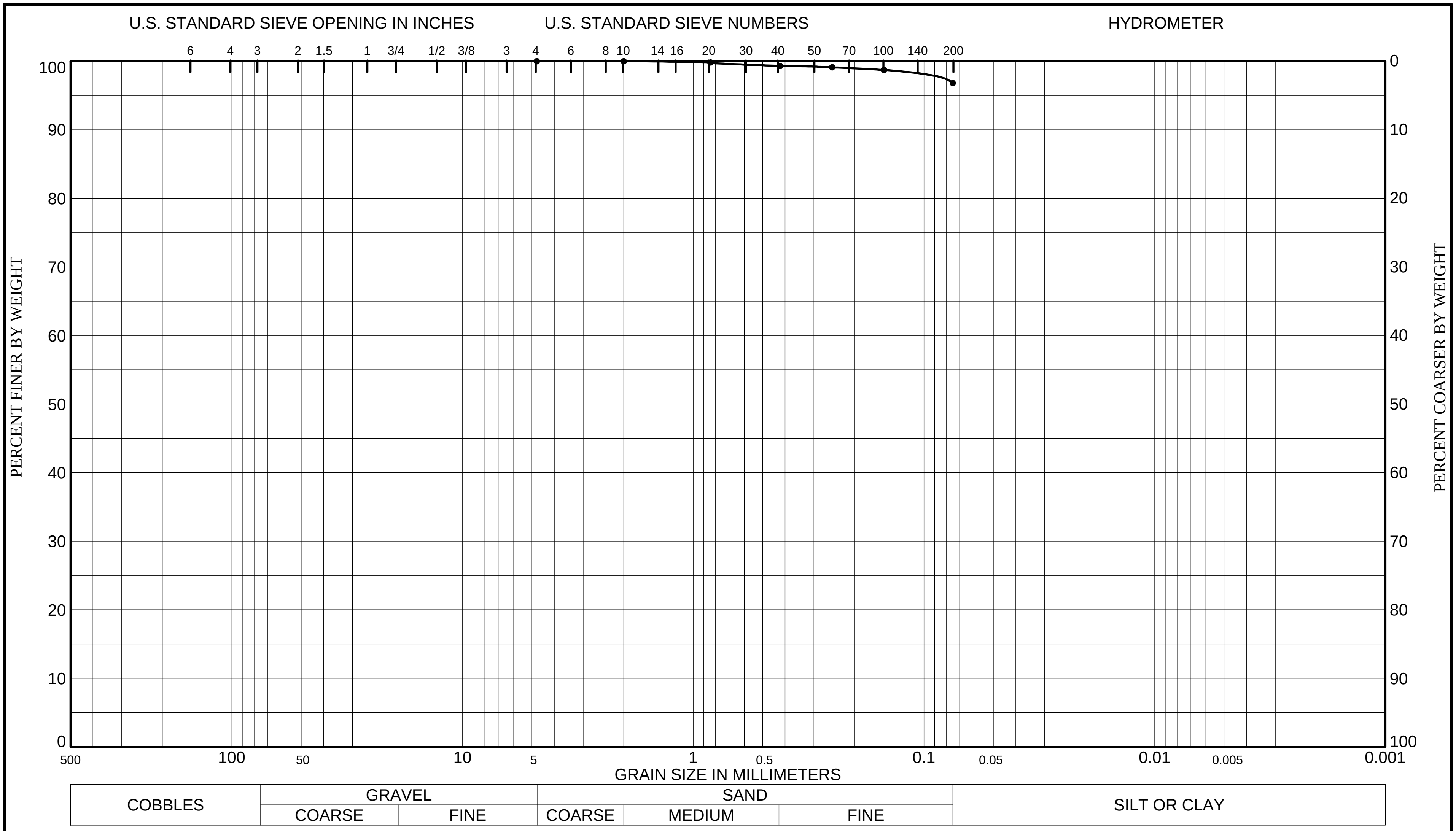
Lab No. K6/222

Boring No. SHE-13

Date 2/22/05

GRADATION CURVES

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-1	63.6 to 64.1	Olive Gray, (Visual) Fat Clay (CH), with a trace of sand.	74.7			

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/250

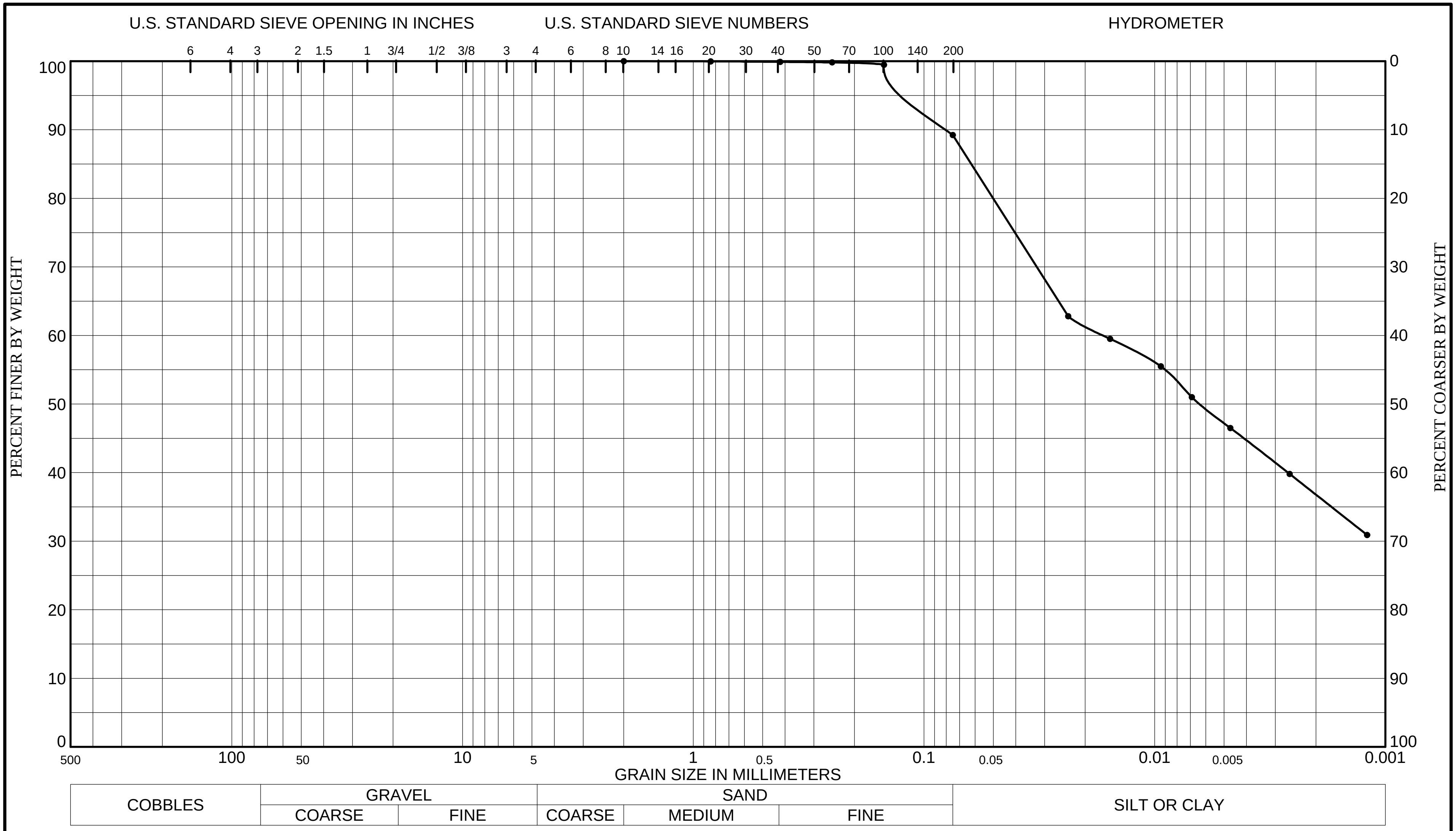
Boring No. SHE-14

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-2	70.6 to 71.2	Olive Gray, Fat Clay (CH), with a little sand.	76.3	130	38	92

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/251

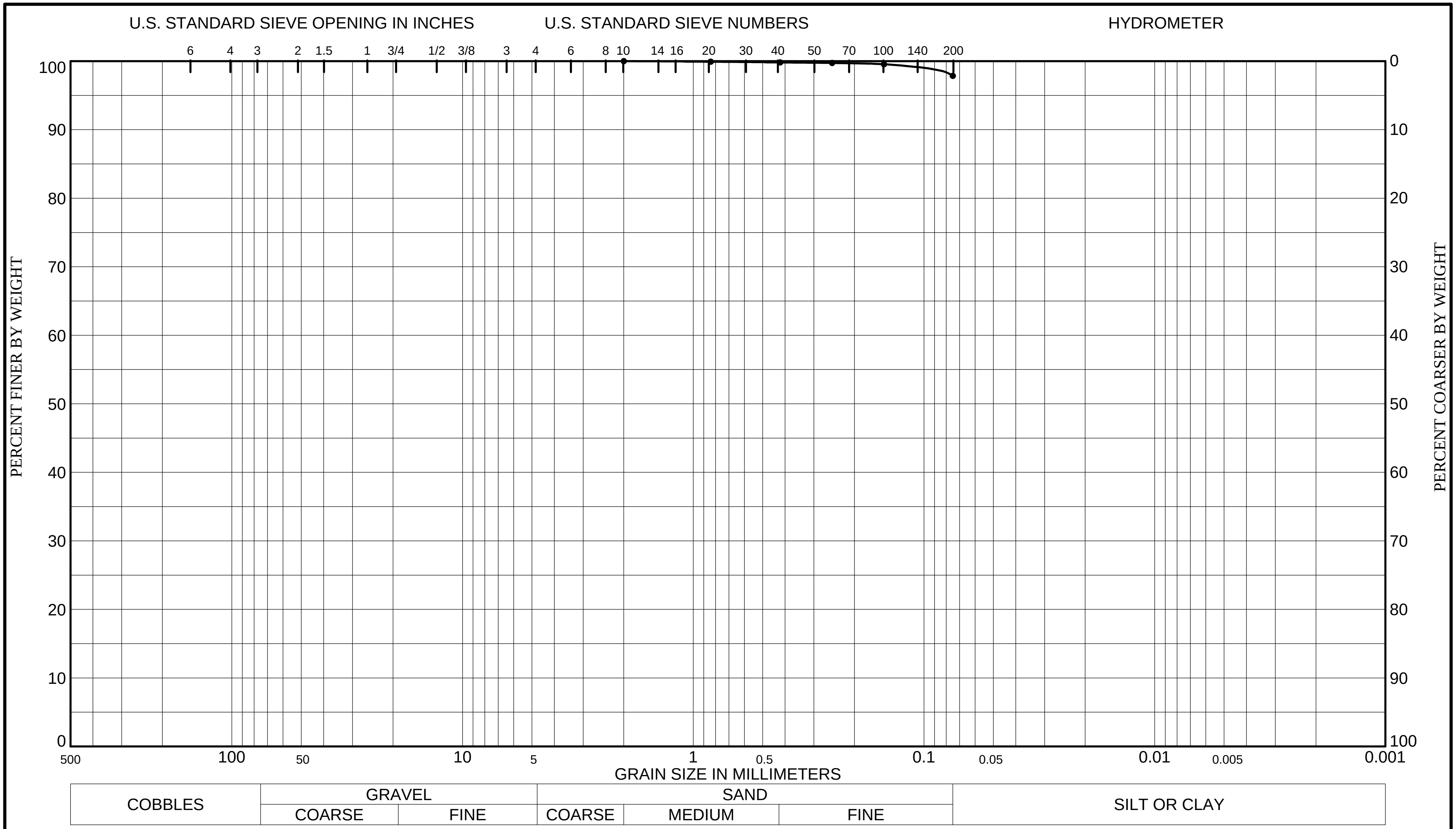
Boring No. SHE-14

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-3	75.0 to 75.5	Olive Gray, (Visual) Fat Clay (CH), with a trace of sand.	76.7			

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/252

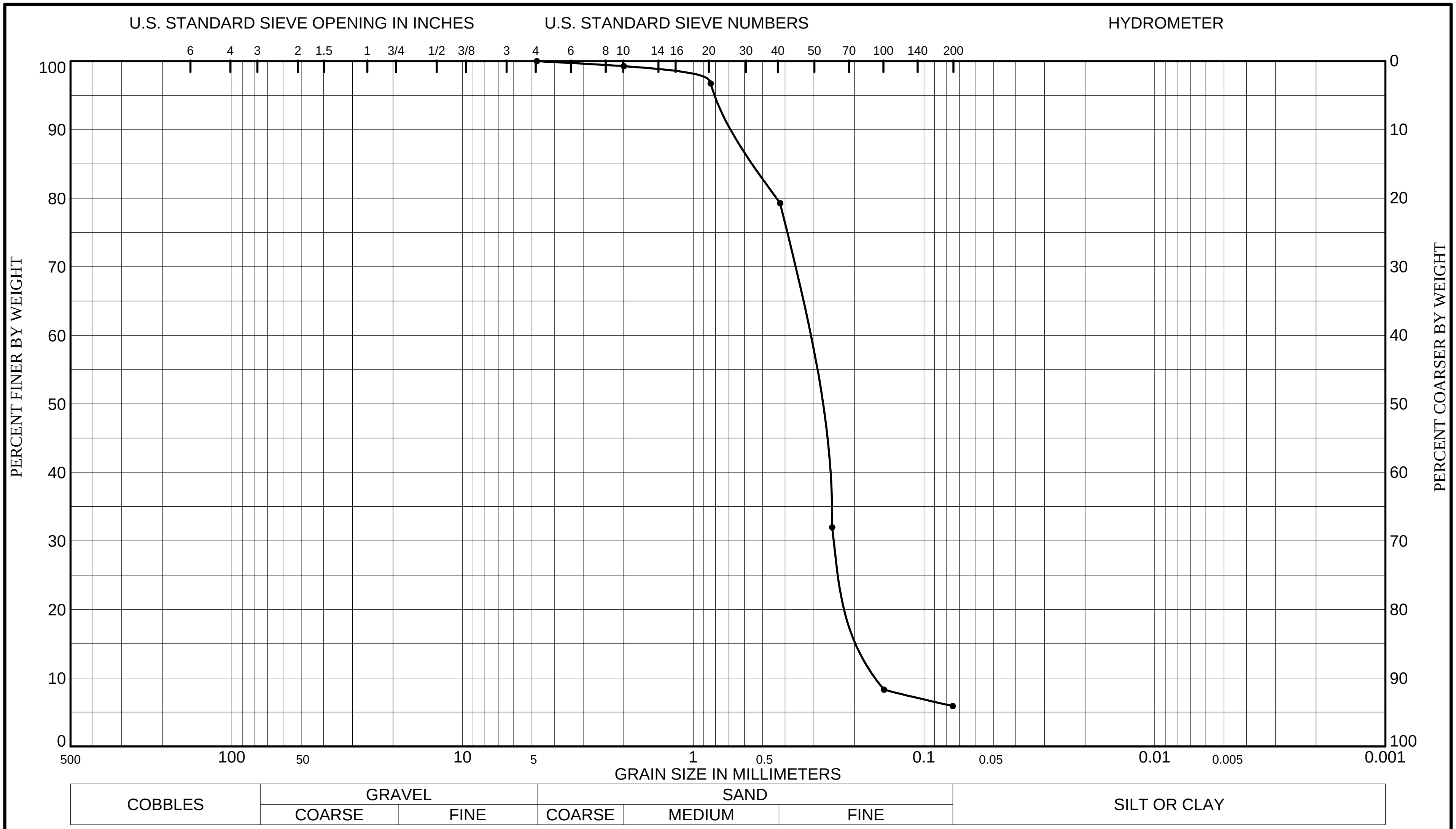
Boring No. SHE-14

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-4	84.0 to 84.5	Dark Olive Gray, Poorly Graded Silty Sand (SP-SM), with plastic fines.	30.9	41	26	15

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/253

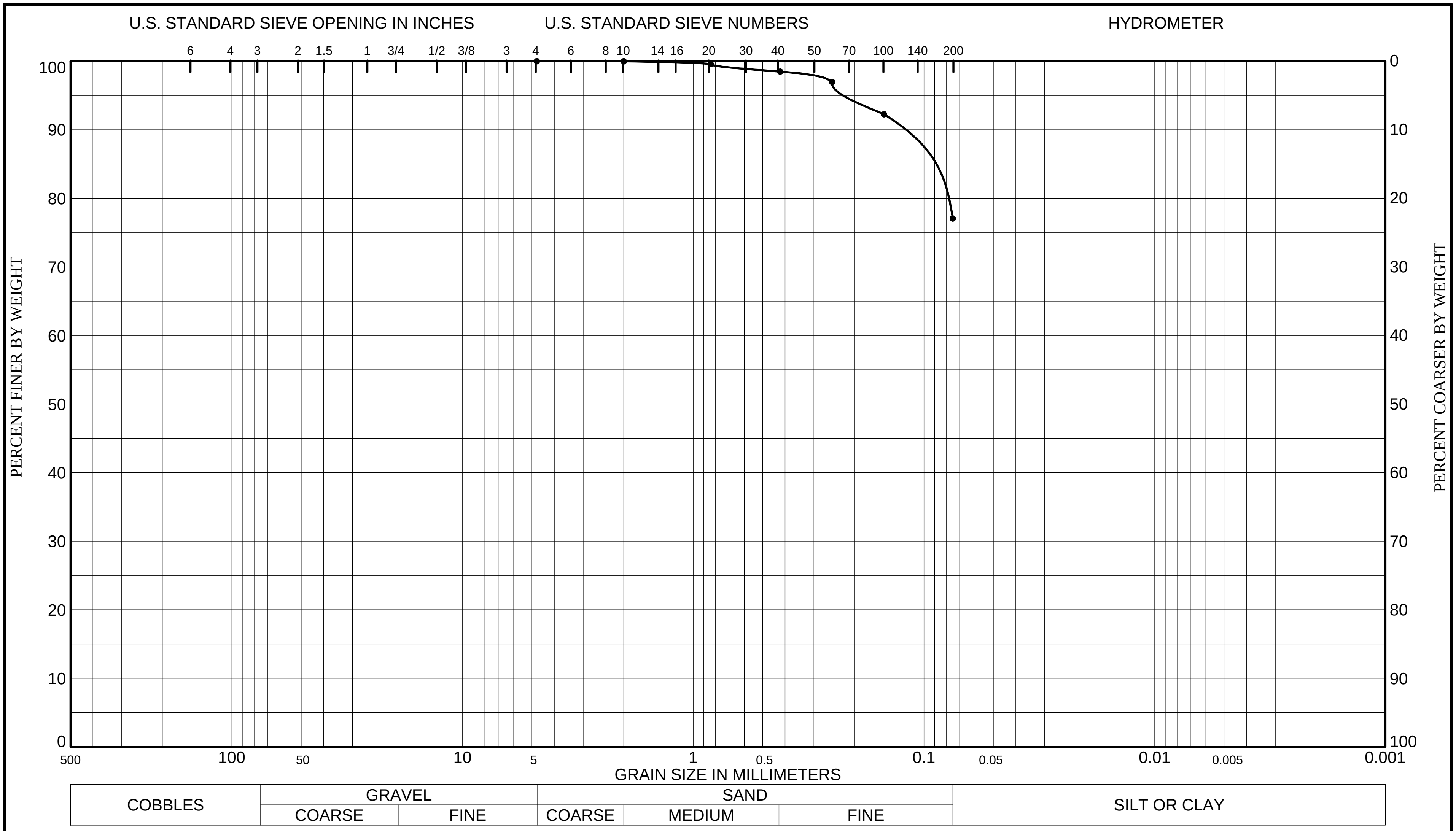
Boring No. SHE-14

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-5	90.0 to 90.5	Olive, (Visual) Clayey Inorganic Silt High LL (MH), with some sand.	49.9			

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/254

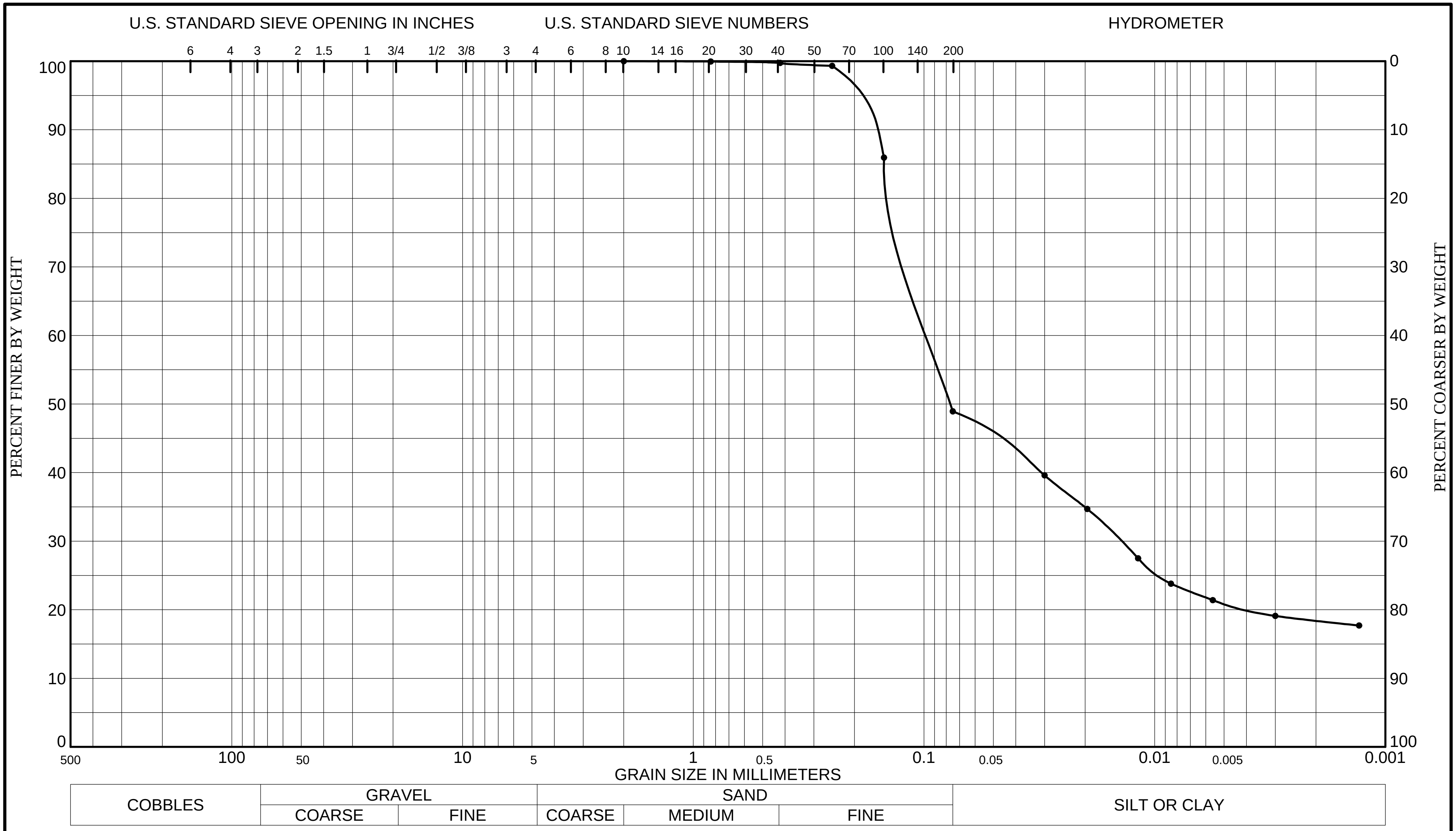
Boring No. SHE-14

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-6	95.0 to 95.6	Olive, Silty Sand (SM-H), with High LL plastic fines.	63.3	110	48	62

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/255

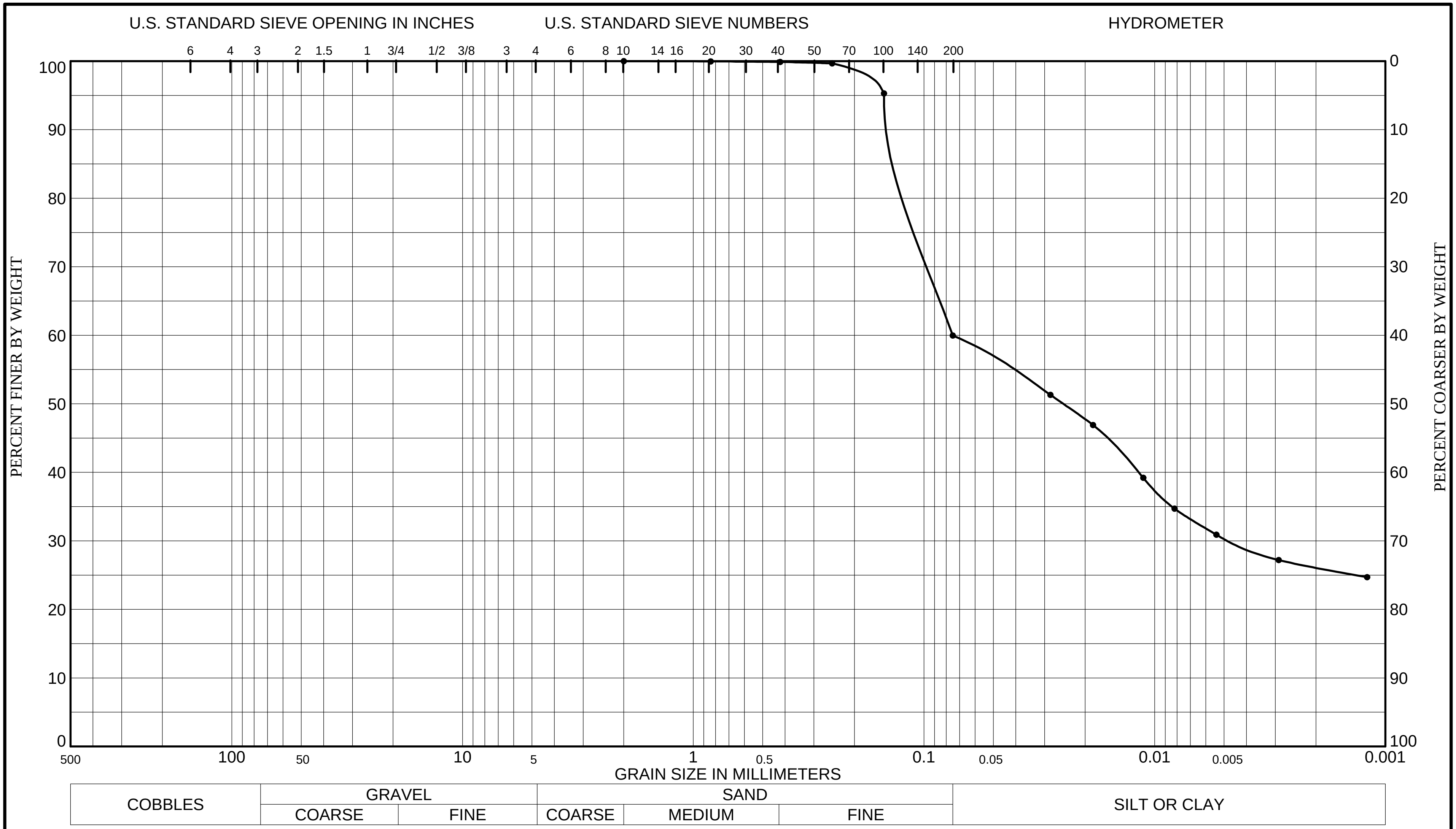
Boring No. SHE-14

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-7	100.0 to 100.5	Olive Gray, Sandy Clayey Inorganic Silt High LL (MH).	72.0	156	59	97

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/256

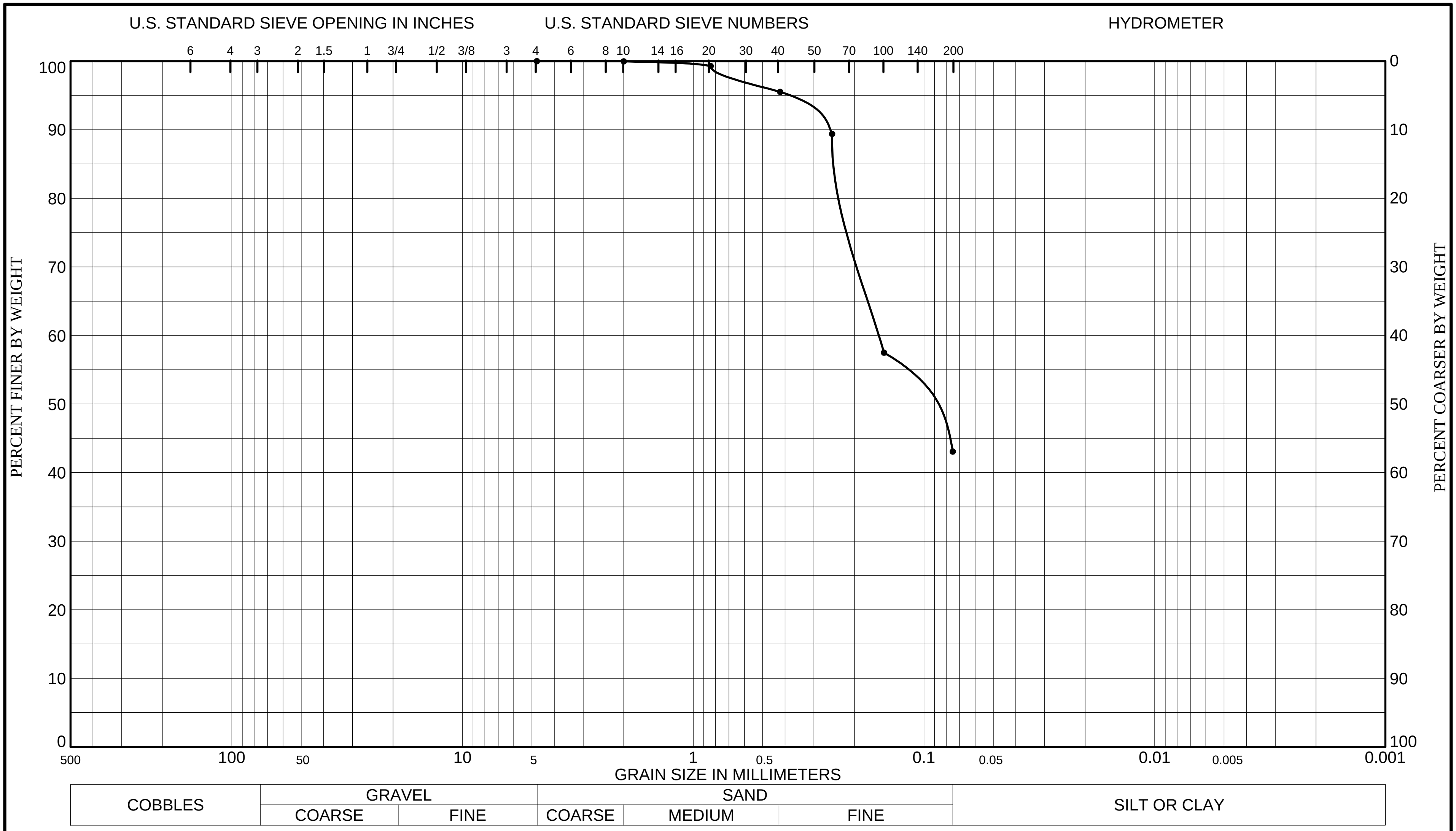
Boring No. SHE-14

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-8	105.5 to 106.0	Olive Gray, (Visual) Silty Sand (SM), with plastic fines.	61.2			

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/257

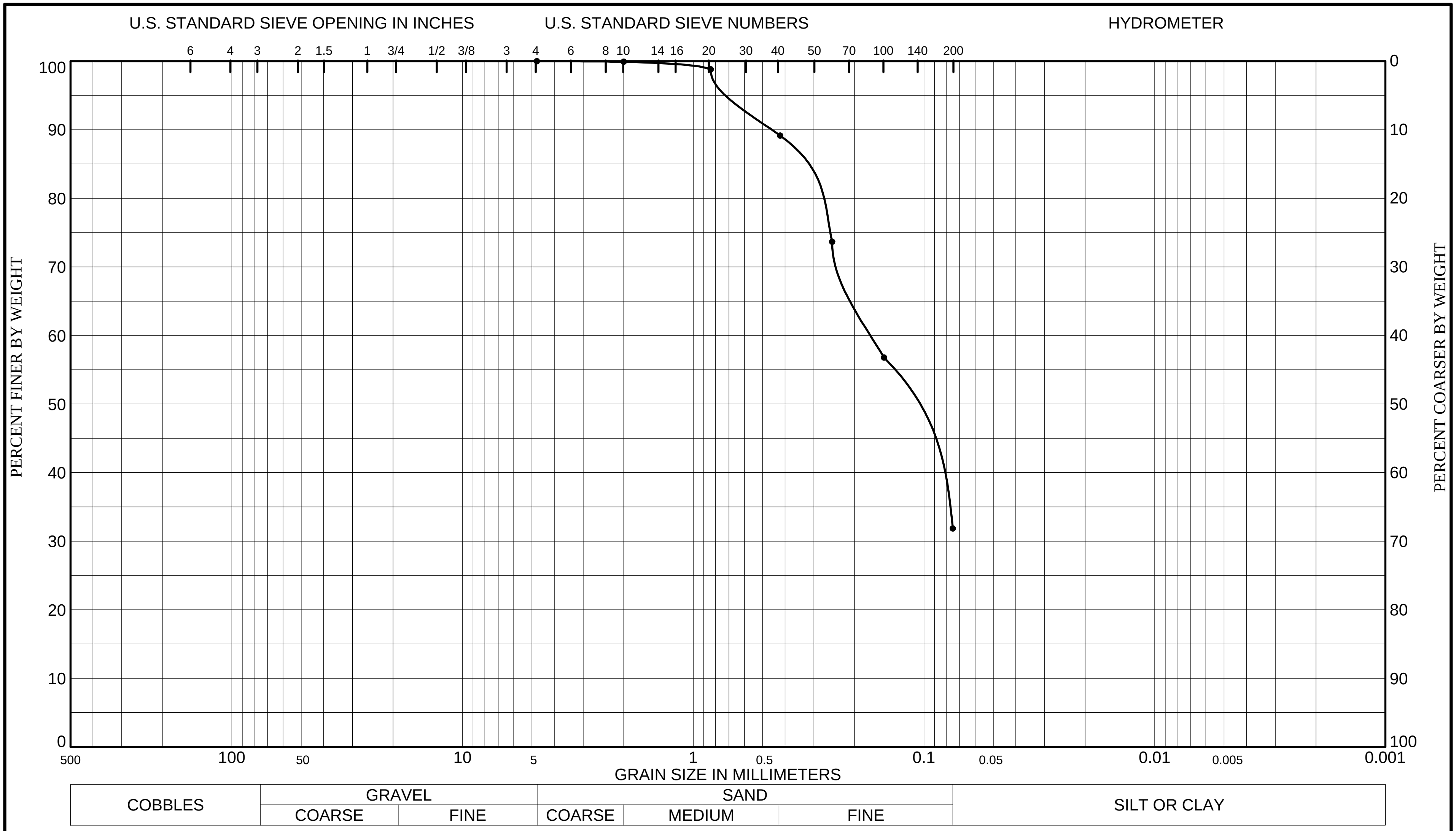
Boring No. SHE-14

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-9	111.2 to 111.7	Dark Olive Gray, (Visual) Silty Sand (SM), with plastic fines.	61.1			

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/258

Boring No. SHE-14

Date 2/22/05

GRADATION CURVES

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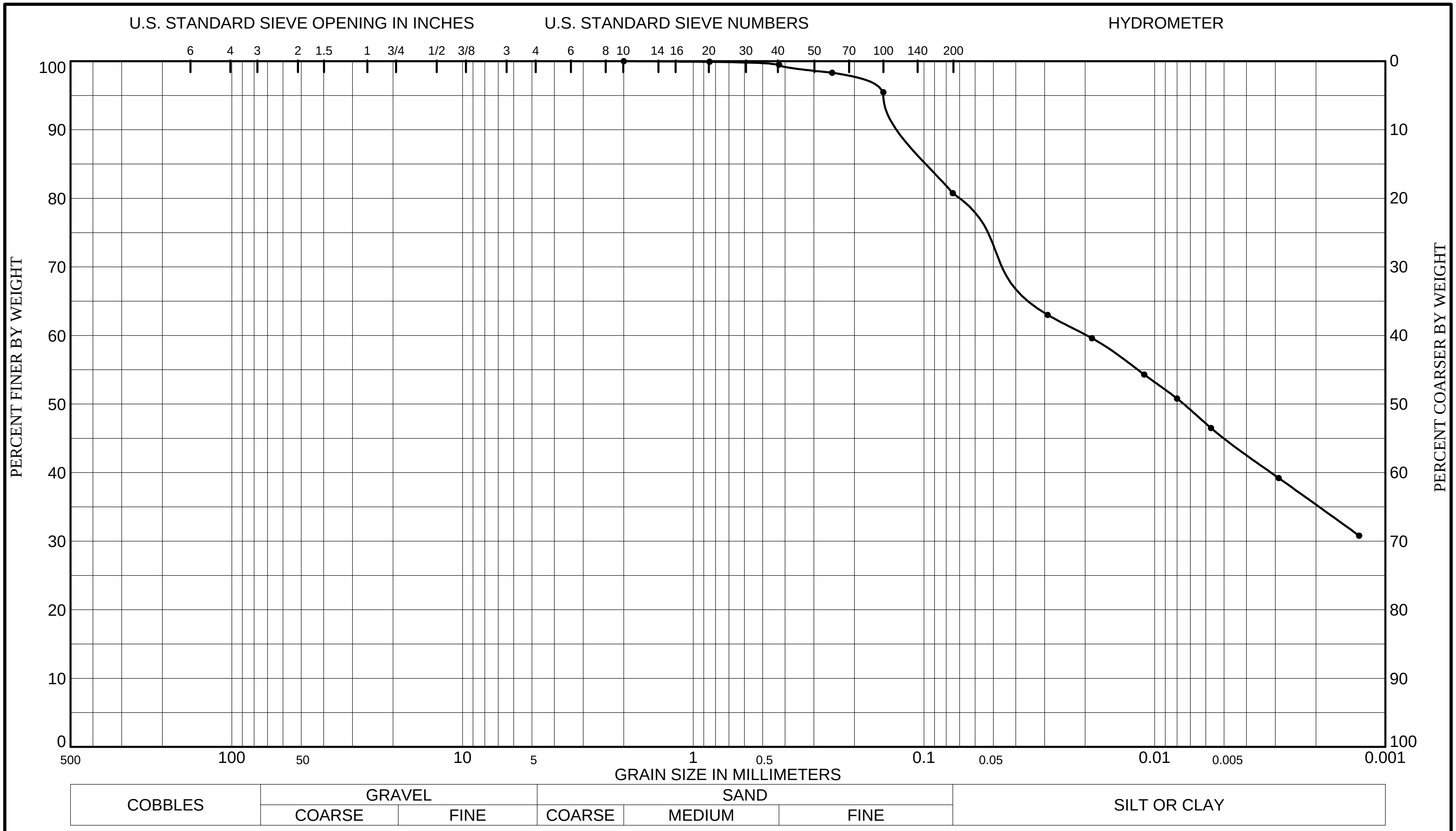
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-1	71.7 to 72.3	Dark Olive Gray, Clayey Inorganic Silt High LL (MH), with a little sand.	105.0	186	73	113

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/259

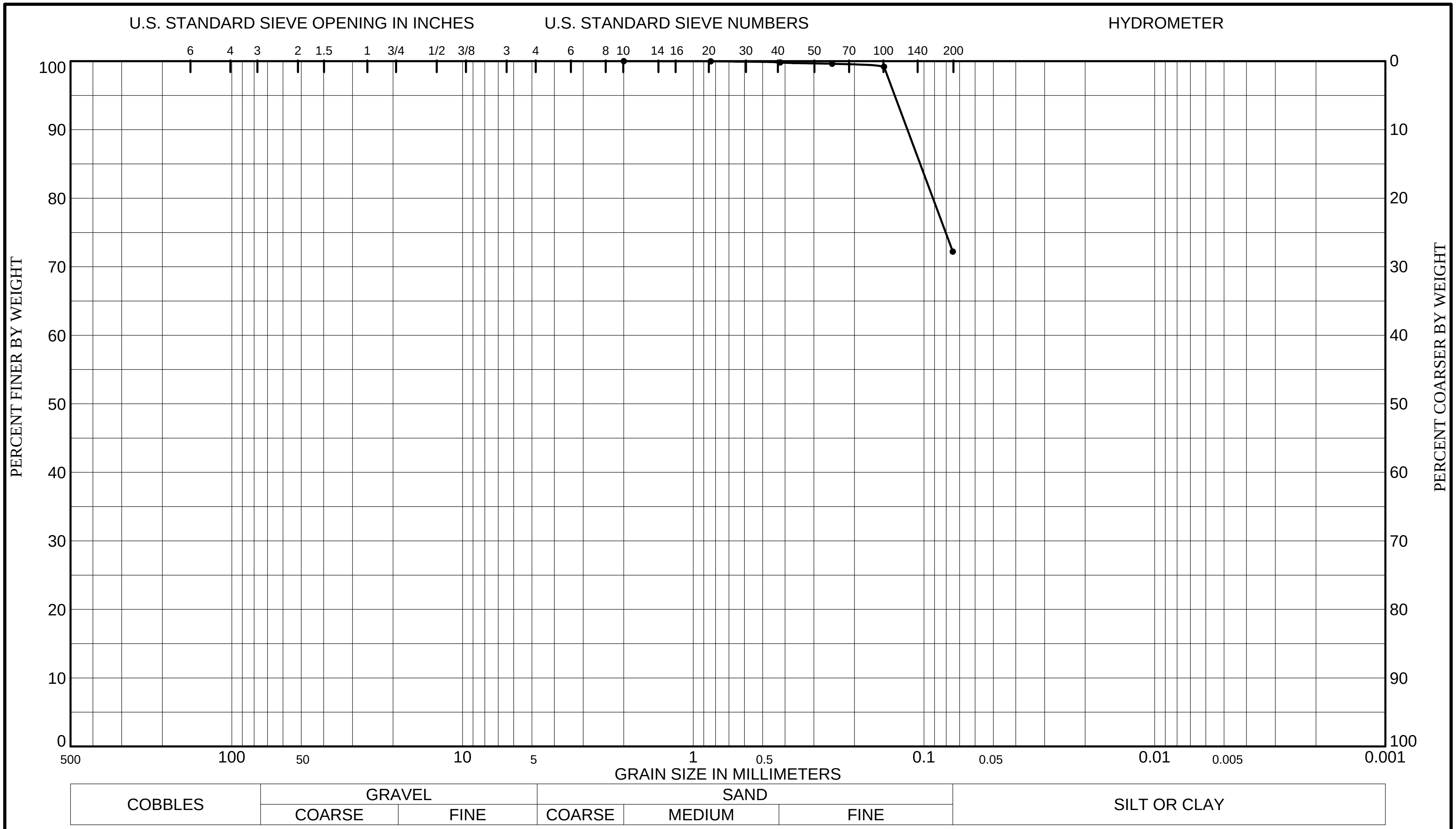
Boring No. SHE-15

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-2	80.0 to 80.5	Dark Olive Gray, (Visual) Clayey Inorganic Silt High LL (MH),	65.5			
		with some sand.				

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/260

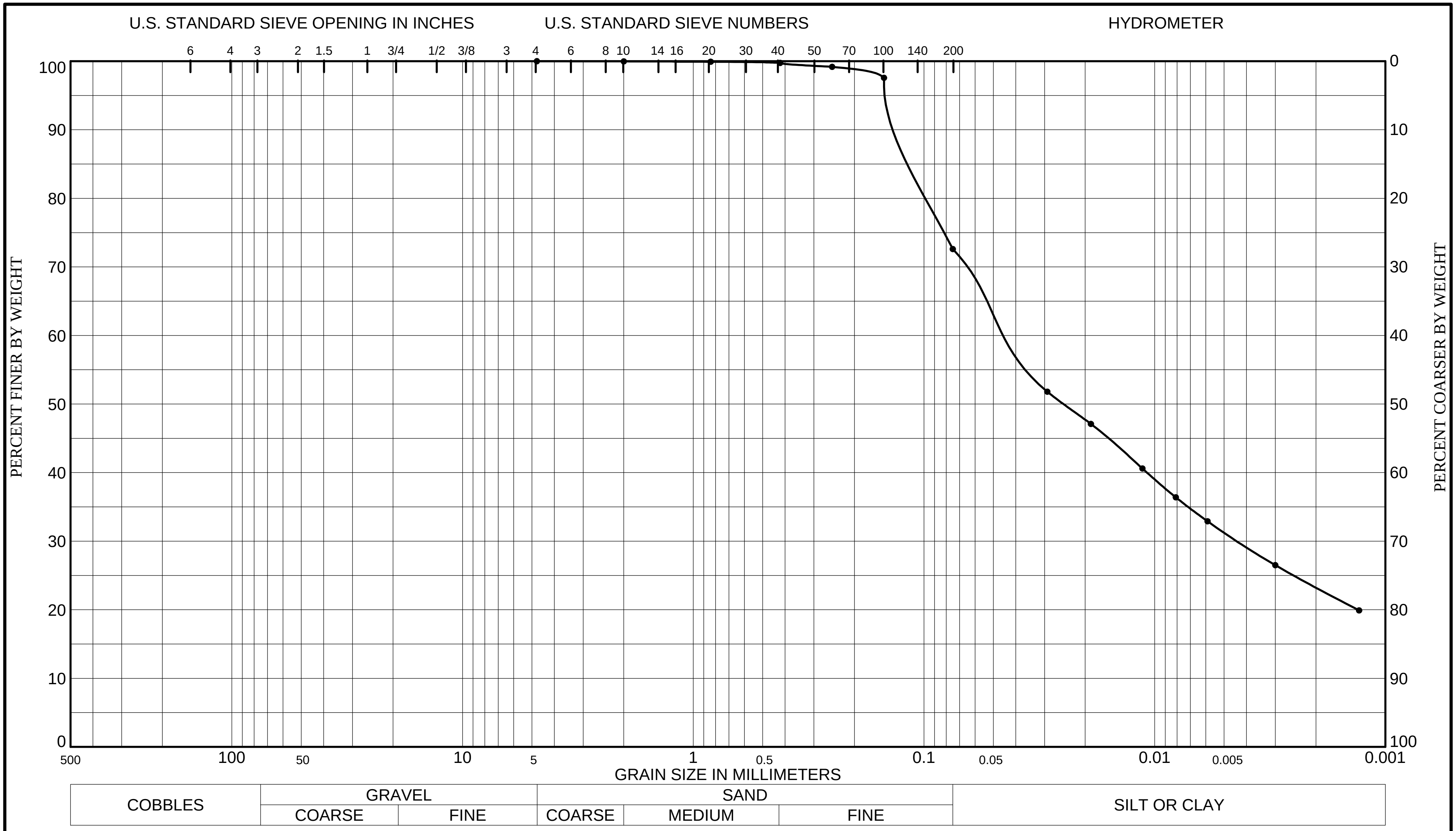
Boring No. SHE-15

Date 2/22/05

GRADATION CURVES

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



Sample No.	Depth (ft)	Classification	Nat w%	LL	PL	PI
K-3	89.0 to 89.6	Dark Olive Gray, Fat Clay (CH), with some sand.	79.6	108	34	74

Project Savannah Harbor

Savannah Harbor Expansion, Savannah, GA

Lab No. K6/261

Boring No. SHE-15

Date 2/22/05

GRADATION CURVES