Vanceboro Quarry Site

Hydrogeologic Characterization and
Predictive Modeling Analysis
Proposed Limestone Aggregate Quarry near
Wilmar, Beaufort County, North Carolina

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1.0 Introduction

Martin Marietta Aggregates, Inc. (MMA) is evaluating the feasibility of operating a limestone aggregate quarry in southern Beaufort County near the border with Craven County, North Carolina (Figure 1-1). MMA has completed wetlands evaluations, exploratory drilling to map the depth and quality of the limestone ore, and has secured a long-term lease for the quarry property. MMA proposes to operate an approximately 650-acre open-pit mine that will be excavated to a depth of approximately 120 feet below land surface. Successful mining of this type requires depressurization and dewatering of the limestone. Prior to pursuing mining permits, MMA contracted Groundwater Management Associates, Inc. (GMA) to perform a detailed hydrogeologic evaluation of the property. The focus of GMA's evaluation was to determine the volume of water to be withdrawn, and to define the size and magnitude of the drawdown resulting from groundwater withdrawals needed to support operation of the open-pit mine. A secondary focus was to evaluate the potential for part of the dewatering withdrawals to be made available for public use by public water systems. This document presents GMA's findings.

2.0 Scope of work

GMA's scope of work involved the following major tasks:

I) Research into the regional hydrogeologic setting of the property. GMA gathered regional hydrostratigraphic data from available publications, reviewed on-line data from the North Carolina Division of Water Resources (NCDWR), and reviewed data provided by the Potash Corporation of Saskatchewan (PCS Phosphate) from their phosphate mine facility located near Aurora, NC.

II) Permitting and construction of a production well and a monitoring well. GMA assisted MMA in acquiring a well construction permit from the North Carolina Division of Water Quality. In addition, GMA assisted with acquiring a Central Coastal Plain Capacity Use Area Permit from the NCDWR to allow for conducting a high-volume pumping test. Upon receipt of permits, GMA constructed a production well and a monitoring well so that detailed aquifer testing could be performed.

III) Aquifer testing. GMA performed a constant-rate aquifer pumping test for a period of 24 hours, during which GMA collected water levels and measured the pumping rate of the production well. The intent of the testing was to characterize the hydraulic properties of the aquifer.

IV) Groundwater flow modeling using Visual Modflow. GMA integrated data on the hydrostratigraphy and aquifer properties to develop a three-dimensional model of the regional- and local-scale groundwater flow systems. The model was calibrated and numerous simulations were performed to estimate the volume of water that must be withdrawn to allow for open-pit mining. The model also simulated the size and magnitude of the area of drawdown that would result from the mine dewatering.

V) Preparing a report of findings of the studies.

3.0 Regional Hydrogeologic Setting

The property (Figure 1-1) lies within the Coastal Plain Physiographic Province of North Carolina (NCGS, 1985). The Coastal Plain is a broad, relatively flat region comprising the eastern third of the State. Local topography is very flat, with local relief of only about 20 feet between upland plateau areas and tributaries (Figure 3-1). Maximum relief between the property and the Pamlico River is approximately 40 feet. The land surface largely owes its origin to a number of sea level advances and retreats that occurred throughout the Pleistocene Epoch (<1.8 million years ago). These sea level fluctuations created broad and generally flat terraces that slope gently to the east. Streams and rivers have incised these terraces to create the current topographic character of the area.

The Coastal Plain Province is underlain by marine, estuarine, and terrestrial sediments (up to 10,000 feet thick at Cape Hatteras) that were deposited over the past 200 million years. The property is underlain by approximately 1700 feet of Jurassic to Recent aged sediments and sedimentary rocks that were deposited on top of pre-Mesozoic aged (>250 million years) volcanic basement rocks (Lawrence and Hoffman, 1993).

The Mesozoic-aged sediments beneath the property are dominantly clastic in nature, and include sequences of silt and clay interbedded with sand and gravel zones with minor amounts of shell. These sediments are associated with deltaic and marginal marine depositional environments that predominated at the time along the eastern margin of North America from about 145 to 65 million years ago. These sediments have been hydrostratigraphically subdivided into four principal aquifers of the Cretaceous Aquifer System (CAS). The CAS includes (from deep to shallow) the Lower Cape Fear Aquifer, the Upper Cape Fear Aquifer, the Black Creek Aquifer, and the Peedee Aquifer. The CAS is extensively used as a source of water supply in the central portion of the Coastal Plain. However, in the vicinity of the property, the CAS is not extensively used because of the proximity of the freshwater-saltwater interface and the significant depth (>300 feet) to these deposits.

Overlying the CAS is a sequence of Cenozoic-aged (<65 million years) sediments of dominantly marine origin. These include significant beds of sands, shelly clays and fossiliferous sandy limestones. These sediments have been hydrostratigraphically subdivided into five aquifers, including (from deep to shallow): the Beaufort Aquifer, the Castle Hayne Aquifer, the Pungo River Aquifer, the Yorktown Aquifer, and the Surficial Aquifer. Many of these aquifers contain fresh water and are important sources for local and regional water supplies. Table 3-1 lists the principal aquifers that occur beneath the property and describe the characteristics of these aquifers.

Table 3-1: Regional Aquifer Framework, Beaufort County

Aquifer	Formations and Ages	Character and Use in Beaufort County
Surficial/Yorktown	Surficial Sediments (Pleistocene to Recent) Yorktown Formation (Pliocene)	This aquifer occurs as a veneer (up to 70 feet thick) of sandy to clayey sediments, locally fossiliferous with shells, bone, and teeth. The aquifer covers the entire County, except in areas where deeply incised streams and rivers cut into underlying units. Clays within the unit tend to serve as confining layers and restrict recharge to underlying aquifers. The aquifer is not currently used as a significant groundwater source. It may be used sporadically for irrigation and private residential water supply.
Pungo River Aquifer	Pungo River Formation (Miocene)	This fine-grained unit is composed of interbedded phosphatic clays, diatomaceous clays, phosphatic limestones, silty claystones, coquinas, calcareous clays, and phosphatic sands. It is not a major water-producing aquifer, but can supply usable quantities of water to some local wells. Phosphate from this formation is obtained by open-pit mining at PCS Phosphate.
Castle Hayne Aquifer System	Castle Hayne Formation (Eocene)	The Castle Hayne Formation is a sandy limestone and is characteristically highly fossiliferous (molluscan mold to bryozoan/echinoid skeletal). The aquifer typically has a hard cap rock of well-indurated limestone. The upper limestone unit has very high permeability. Middle to lower sections of the unit may be less indurated and have higher sand and clay contents.
	Beaufort Formation (Paleocene)	The Beaufort Formation includes fine- to medium-grained glauconitic sand with admixtures of shell fragments, gray clay, and local lenses of skeletal limestone. In Beaufort County, the Castle Hayne and Beaufort Formations do not appear to be separated by a recognizable confining layer, and are, herein, grouped as a single aquifer system. The aquifer is a major source of water supply to wells operated by Beaufort County and the City of Washington. In the vicinity of the PCS Phosphate Mine, the aquifer is very prolific and can support individual well withdrawals of more than 2500 gallons per minute.

Table 3-1: (Continued) Regional Aquifer Framework, Beaufort County

Aquifer	Formations and Ages	Character and Use in Beaufort County
Peedee Aquifer	Peedee Formation (Upper Cretaceous)	The Peedee Formation is composed of dark greenish-gray sand (glauconitic and argillaceous), fossiliferous marine clays, and calcareous sandstone. Due to its shallow occurrence, low yield potential, and lateral heterogeneity, the Peedee Aquifer has not been extensively utilized for industrial or public water-supply systems in the County.
Black Creek Aquifer	Black Creek Group [Tar Heel, Bladen, and Donoho Creek Formations]. (Upper Cretaceous)	The Black Creek Group is comprised of complexly interbedded sands, sandstones, and clays that were deposited in a deltaic to prodelta marginal marine environment. Black clays, lignite, and pyrite are common in the upper confining layer. Prolific sand sequences produce substantial quantities of water from the aquifer. These sand beds are often locally divided within the aquifer by thick interbeds of clay. These imbedded clays can locally act as confining layers within the aquifer. Saltwater intrusion can be a problem in this unit in Beaufort County.
Upper Cape Fear Aquifer	Cape Fear Formation (Upper Cretaceous)	The Upper Cape Fear Aquifer comprises permeable zones in the upper part of the Cape Fear Formation. The Upper Cape Fear Aquifer may also include some of the Middendorf Formation. The aquifer is comprised of marginal marine interbedded fine to coarse sands, gravels, and clays. The aquifer is not extensively used due to the aquifer depth and brackish water quality. In addition, Fluoride concentrations are often elevated in the Upper Cape Fear Aquifer.
Lower Cape Fear Aquifer	Cape Fear Formation (Upper Cretaceous)	The Lower Cape Fear aquifer is comprised of permeable sands and sandstone layers of the lower section of the Cape Fear Formation. These sediments are distinguished from the overlying younger sand units of the Cape Fear Formation based upon hydraulic head and water quality. The aquifer is unused in Beaufort County due to the depth of the aquifer and its brackish water quality.

Table 3-1: (Continued) Regional Aquifer Framework, Beaufort County

Aquifer	Formations and Ages	Character and Use in Beaufort County
Bedrock Aquifer	Basement Rocks (Pre-Mesozoic)	The Bedrock Aquifer is poorly understood and is unutilized as a groundwater resource in Beaufort County. Its lack of use is primarily due to the tremendous depth across most of the County, along with the availability of shallower, high-yielding, good-quality aquifers that overly the bedrock. Groundwater in the Bedrock Aquifer flows through fractures in the generally massive, impermeable rock matrix. Wells of the Piedmont of North Carolina commonly tap the Bedrock Aquifer for private residential, and industrial use. Seldom is bedrock used for large-scale public water supply.

The Castle Hayne Aquifer is the most extensively used aquifer in the area. The largest user of the Castle Hayne Aquifer is the Potash Corporation of Saskatchewan (PCS Phosphate), which operates a phosphate mine near Aurora, approximately 10 miles east of the proposed MMA mine (Figure 1-1). PCS Phosphate currently withdraws approximately 60 million gallons of water per day from the Castle Hayne Aquifer. This withdrawal has developed a regional cone of depression that extends approximately 3 miles west of the proposed MMA mine. Because MMA intends to mine limestone from the Castle Hayne Aquifer, dewatering operations must integrate the effects of the PCS Phosphate cone of depression on the area of drawdown that will result from groundwater withdrawals at the MMA mine.

4.0 Site Exploration and Well Construction

GMA obtained a permit from the North Carolina Division of Water Quality to construct a water-supply well (MMA1) on the property (Appendix I). The water-supply well was intended to provide data on the depth and thickness of the Upper Castle Hayne Aquifer. In addition, the production well served as a test well for determining the hydraulic characteristics of the Castle Hayne Aquifer on the property. The production well was also intended to be available as a future point of withdrawal to aid with mine depressurization/dewatering. Well construction and exploration involved the following procedures:

- Drilling a pilot hole to 150 feet depth using mud rotary drilling techniques
- Obtaining Natural Gamma, SP, and Resistivity geophysical logs of the pilot hole
- Installing an 8-inch diameter steel production well to 106 feet depth, including 50-slot stainless steel screen placed from 66 to 106 feet depth. The well was equipped with a water level drop tube to allow for accurate monitoring of water levels in the well.
- Developing the well until the water produced was sand-free and low turbidity
- The production well was equipped with a temporary locking aboveground well cover.

Following completion of the production well, GMA directed the well drilling contractor to install an observation well (OW1) 75 feet away from the production well. The observation well was constructed of 4-inch diameter PVC casing installed to 66 feet depth. The observation well was then advanced as an open hole well to a depth of 106 feet. The observation well remained open without collapse or excessive sand production, demonstrating that open-hole well construction is viable and may be appropriate for future production wells on the property. Figure 4-1 presents the drilling and geophysical logs of the production well installed on the property. Figure 4-2 is an as-built drawing of the production well. Appendix I includes copies of well construction records for the production well and observation well.

5.0 Regional Monitoring Well Data Collection and Pre-Pumping Conditions

Prior to conducting on-site aquifer tests, GMA contacted PCS Phosphate to obtain data on the regional groundwater-monitoring network operated by PCS Phosphate. PCS Phosphate provided coordinates, elevations, and well construction details for four (S-28, S-29, S-30, S-31) nearby monitoring wells (Figure 3-1). GMA was also given permission to open the four PCS Phosphate regional monitoring wells and measure water levels in these wells. Water level data collected by GMA are summarized in Table 5-1.

Table 5-1: Groundwater Level Data from Regional Monitoring Wells

Well	Well Depth (ft)	TOC Elevation	DTW (ft) 7/31/07	GW Elev. (ft) 7/31/07	DTW (ft) 8/6/07	GW Elev. (ft) 8/6/07
MMA1	106	38.9*	18.92	19.98	19.14	19.76
S-28	239	38.93	32.00	6.93	32.06	6.78
S-29	155.8	37.32	23.18	14.14	23.10	14.22
S-30	84.5	40.45	10.88	29.57	11.25	29.20
S-31	217.6	39.51	19.47	20.04	19.39	20.12

MMA1 is the 8-inch diameter production well installed at the Martin Marietta Aggregates site.
TOC – Top of Casing of the well
DTW – Depth to Water
GW Elev. – Groundwater Elevation above Mean Sea Level
* Assumed elevation based upon topographic maps

Figure 5-1 illustrates the potentiometric surface of the Castle Hayne Aquifer on August 6, 2007. The potentiometric surface exhibited an average hydraulic gradient of 0.0008 ft/ft toward the east-southeast. The potentiometric surface slope is consistent with the pumping influence from depressurization at the PCS Phosphate mine near Aurora.

6.0 Aquifer Testing

Predictive modeling of groundwater flow systems requires an accurate understanding of the hydraulic properties of the aquifers being modeled. Carefully performed aquifer tests can provide data necessary for determining these aquifer properties.

6.1 Field Testing and Data Collection

On August 6, 2007, GMA performed a constant-rate pumping test at MMA1. The test involved pumping the well at a rate of 524 gpm for a period of 24-hours. GMA personnel were on site throughout the pumping period to monitor the pumping rate and make adjustments, as necessary, to maintain a constant withdrawal. Flow from the well was measured using a 6" x 5" orifice weir. GMA deployed pressure transducers/data loggers and used electronic water level meters to accurately measure water levels in the pumping well (MMA1) and the on-site observation well (OW1) throughout the pumping test. In addition, GMA collected water levels at the PCS Phosphate monitoring wells at the end of the pumping period to determine drawdown affects at those locations. No significant drawdown influence was observed at the PCS Phosphate wells. Wells S-30 and S-31 exhibited water level declines of 0.08 and 0.05 feet, respectively. The small declines in water levels at these wells are not definitive evidence of drawdown that can be attributed to withdrawal from PW1. After 24-hours of pumping, GMA shut off the pump and recorded recovering water levels in the pumped well and the observation well for a period of 2 hours.

Pre-pumping water level data collected at the site and from the PCS Phosphate wells demonstrate that water levels were relatively stable prior to the start of the pumping test. Therefore, GMA did not correct the drawdown data for regional water level changes. Appendix II includes all field data collected from the aquifer testing.

6.2 Aquifer Test Data Analysis

Since the 1930's, hydrologists have developed a variety of methods for evaluating the hydraulic properties of aquifers. These various methods are based upon derivations of, and modifications to, the Theis equation (1935). The Theis equation allows for determination of the aquifer transmissivity and storage coefficient for a fully confined aquifer that is homogeneous, isotropic, and of infinite aerial extent. Advancements in aquifer test data analyses have led to methods that can determine hydraulic properties of aquifers that do not meet the ideal assumptions of the Theis method. Understanding the regional hydrogeologic setting and hydrostratigraphy of aquifer systems is essential to selecting the appropriate methodology(ies) for aquifer test data analyses. A standard approach is to first perform analyses using the Theis non-equilibrium reverse type curve method. This method involves graphing drawdown versus time values from an observation well on a logarithmic graph and matching with a type curve. If the water level data match well with the type curve, then a match point is selected on the graph, and calculations of transmissivity and storage coefficient are made. Appendix II includes the results of the Theis analysis for the observation well data.

GMA recognized that the drawdown data from the observation well deviated from the Theis type curve after about one hour of pumping. The observation well exhibited less drawdown in the well than would be predicted by the Theis equation for a fully confined aquifer. This "flattening" of the drawdown curve is indicative of a leaky aquifer condition where a portion of the water produced by the pumped well is derived from leakance across the confining layer(s) for the aquifer. GMA interprets the leakance to be a result of vertical flow of water from the Surficial/Yorktown Aquifer downward into the underlying Castle Hayne Aquifer. To more accurately characterize the aquifer properties in this "leaky aquifer" setting, GMA used the Hantush-Jacob (1955) method. The Hantush-Jacob method provides values of transmissivity and storage coefficient, and it also provides data on the degree of leakance of the aquifer. These are fundamental details that are important for successful predictive modeling. To supplement and confirm our estimations derived from the Theis and Hantush-Jacob methods, GMA analyzed the pumping well drawdown data using a simplification of the Theis method developed by Cooper and Jacob (1946). The Cooper-Jacob method can provide a reliable estimate of transmissivity of an aquifer, but it does not provide a reliable storage coefficient for data from a pumped well because it cannot account for the effects of well loss in a pumped well. We also analyzed the recovering water level data from the pumped well and the observation well using the Theis residual drawdown/recovery method (1935). Results of all aquifer test analyses are included in Appendix II.

All methods applied resulted in hydraulic property estimates were similar. Table 6-2 presents a summary of the aquifer test results from each method.

Table 6-2: Hydraulic Properties of the Upper Castle Hayne Aquifer from Aquifer Testing

	Observation Well		**Pumped Well**	
Method	Transmissivity (ft^2/day)	Storage Coefficient	Transmissivity (ft^2/day)	Storage Coefficient
Theis	4843	0.000209	NA	NA
Cooper-Jacob	4963	0.000204	5140	NA
Hantush-Jacob	5031	0.000203	NA	NA
Theis Recovery	5062	S/S' = 2.39	5155	S/S' = 2.33
Averages	*4975*	*0.000205*	*5148*	*NA*

NA = Not Applicable

Based upon the close agreement of estimates of transmissivity and storage coefficient for the aquifer test analyses, GMA used an average transmissivity of 5000 ft^2/day and average storage coefficient of 2×10^{-4} as representative for the Upper Castle Hayne Aquifer investigated at the site. Considering that aquifer testing was performed for the 40-feet-thick limestone of the Upper Castle Hayne Aquifer, GMA used an average hydraulic conductivity of 125 ft/day and specific storage of 5.1×10^{-6} as characteristic properties of the upper limestone unit to be modeled. Also, GMA utilized information on leakance from the Hantush-Jacob method to estimate the vertical hydraulic conductivity of the confining layer overlying the Castle Hayne Aquifer to be 0.0035 ft/day.

7.0 Hydrogeologic Framework Analysis

GMA collected regional and local data on hydrostratigraphy, including reviewing publications from the United States Geological Survey, the North Carolina Division of Water Resources, Master of Science Theses by Geologists from East Carolina University, data provided by PCS Phosphate, as well as on-site drilling results. These data were used to develop a framework of data on the depths, hydraulic properties, and head pressures of aquifers that could be affected by the mining operation. The framework analysis included all aquifers and confining layers occurring from the land surface downward to the confining layer of the Peedee Aquifer at a depth of about 400 feet beneath the property.

GMA mapped the elevation of the top of each aquifer and confining layer for an area of approximately 1800 square miles surrounding the proposed MMA mine. This mapping effort provided the framework of layers to be integrated into the regional groundwater flow model as discussed in Section 8.

8.0 Predictive Modeling

GMA has constructed a 3-dimensional groundwater flow model, utilizing the program Visual MODFLOW, to simulate the dewatering of the proposed quarry. Visual MODFLOW is a graphical user interface for programming MODFLOW 2000, a modular, 3-dimensional, finite-difference, groundwater flow model developed by the United States Geological Survey (USGS) (Harbaugh and others, 2000).

The purpose of this portion of the report is to:

1) Review the model design and input parameters
2) Describe the calibration techniques employed and,
3) Present a synopsis of pertinent simulations.

We do not attempt in this report to provide a full-scale presentation of the model and all of its implications. Our goal is to provide information that can be utilized by Martin Marietta Aggregates to make informed decisions regarding the future development of the proposed quarry site.

8.1 Previous Studies

Several MODFLOW models have been completed for this region of the North Carolina Coastal Plain. Sherwani (1973) performed the first significant modeling of the depressionization associated with phosphate mining at Aurora, based on data collected from the Joint Study (1971). Giese and others (1997) constructed a 3-dimensional MODFLOW model of the North Carolina Coastal Plain as part of the USGS Regional Aquifer-Systems Analysis (RASA) Program. Their model incorporates the calibration and simulation of flow for all regional aquifers in the North Carolina Coastal Plain. Their model also simulated the cone of depression in the Castle Hayne Aquifer associated with the 1980 PCS Phosphate withdrawals. Hargis (1982) performed predictive modeling of the Aurora mine for different pumping centers and pumping rates.

Reynolds (1992) also performed predictive modeling of the PCS Phosphate withdrawals, as part of an East Carolina University Master of Science Thesis in Geology, under the direction of Dr. Richard Spruill. Reynolds' MODFLOW model was used to predict the effects of increased pumping and to estimate the pumping rates required for the future mine advance to the northeast (Reynolds, 1992). GMA reviewed input parameters and results of previous models to assist in developing a model of the proposed quarry for Martin Marietta Aggregates. Table 8-1 lists various model properties reported in prior model reports as they pertain to GMA's model for the proposed quarry. Layers one through ten in this table refer to aquifers and confining layers that characterize the area near the PCS Phosphate mine.

Table 8-1: Aquifer Properties from Previous Models

Model Layer	Aquifer/Confining Layer Name	Hydraulic Conductivity
Layer One	Surficial Aquifer	From Reynolds = Hydraulic Conductivity of Surficial Aquifer is 50 to 80 ft/day dependant on location; Not listed in Giese; NCDWR = 12.5 ft/day Average Hydraulic Conductivity from Nine Surficial Aquifer Wells
Layer Two	Confining Layer Above the Yorktown Aquifer	Vertical Hydraulic Conductivity from Giese = 0.002 to 0.00087ft/day Vertical Hydraulic Conductivity from Reynolds = Combined Yorktown and Pungo River and Upper Castle Aquifer Confining Layer = 0.015 to 0.00015 ft/day
Layer Three	Yorktown Aquifer/ Pungo River Confining Layer & Aquifer	Giese Transmissivity ranges <500 to 1000+ ft^2/day Based on thickness of <100 feet
Layer Four	Confining Layer Above the Upper Castle Hayne Aquifer	Vertical Hydraulic Conductivity from Giese = 0.015 to 0.00015 ft/day Vertical Hydraulic Conductivity from GMA Test = 0.0035 ft/day
Layer Five	Upper Castle Hayne Aquifer	Hydraulic Conductivity = 125 ft/day GMA test Hydraulic Conductivity = 162 ft/day nearby NCDWR test Reynolds quotes 200 ft/day for Upper Castle Hayne Aquifer Giese and Reynolds lump Upper and Lower CHAq
Layer Six	Less Permeable Zone in the Upper Castle Hayne Aquifer	Hydraulic Conductivity known to be significantly less than the more permeable zone of Upper Castle Hayne Aquifer by GMA. Giese and Reynolds lump Upper and Lower CHAq
Layer Seven	Confining Layer Above the Lower Castle Hayne Aquifer	Not reported in Giese or Reynolds; equivalent to Confining Layer above the Upper Castle Hayne Aquifer.
Layer Eight	Lower Castle Hayne Aquifer	Less Permeable than the Upper Castle Hayne as a whole. Giese and Reynolds lump Upper and Lower
Layer Nine	Beaufort Confining Layer/Aquifer	Least permeable section in Castle Hayne Aquifer System 30 to 100 ft/day from Giese
Layer Ten	Confining Layer Above the Peedee Aquifer	Vertical Hydraulic Conductivity from Giese = 0.0075

Reynolds = Reynolds, 1992
Giese = Giese and others, 1997
NCDWR = Groundwater Management Section of the North Carolina Division of Water Resources

8.2 Model Description

GMA has constructed a 10-layer groundwater model that represents the post-Cretaceous aquifers and confining layers underlying the region of the proposed quarry. The majority area represented by the model is in Craven and Beaufort Counties, while the model area also includes portions of Hyde, Pamlico, and Pitt Counties. The model represents an area that is 200,000 by 250,000 feet or approximately 1,800 square miles (Figure 8-1). The model area was chosen to encompass the area of the cone of depression associated with the withdrawals at PCS phosphate, and the potential area that could be affected by withdrawals at the proposed quarry. Figure 8-2 illustrates the model grid. GMA has designed a model grid that is more closely spaced in the areas near the proposed quarry. The cell dimensions are 500 by 500 feet in this tighter portion of the grid.

The ten model layers, which represent the major aquifers and confining layers, are shown in Table 8-2. The base of the model corresponds with the top of the Peedee Aquifer, which is also the top of the Cretaceous Aquifer System (CAS).

Table 8-2: Model Layers

Model layer	Aquifer/Confining Layer
Layer 1	Surficial Aquifer
Layer 2	Confining Layer Above the Yorktown Aquifer
Layer 3	Yorktown Aquifer
Layer 4	Confining Layer Above the Castle Hayne Aquifer
Layer 5	High Permeability Zone in the Upper Castle Hayne Aquifer
Layer 6	Low Permeability Zone in the Upper Castle Hayne Aquifer
Layer 7	Confining Layer Above the Lower Castle Hayne Aquifer
Layer 8	Lower Castle Hayne Aquifer
Layer 9	Beaufort Confining Layer and Aquifer
Layer 10	Confining Layer Above the Peedee Aquifer

GMA developed a 3-dimensional framework for each of the model layers based on previous model reports, published USGS reports, and published data from the PCS Phosphate mine (Giese and others, 1997; Joint Study Report, 1971; Reynolds, 1992; and Leggette, Brashears, and Graham, 1991). GMA also utilized information available online at the North Carolina Division of Water Resources' website (NCDWR) (http://www.ncwater.org/Data_and_Modeling/Ground_Water_Databases/).

The elevation of the land surface was imported into the model framework from USGS digital elevations available online (http://data.geocomm.com/dem/). Figure 8-3 illustrates the land surface elevations utilized in the model framework.

Elevation maps for the top of each model layer were constructed by contouring interpreted data utilizing the Golden Software program, Surfer, and these surfaces were imported in Visual MODFLOW. Figure 8-4 is a cross-sectional view depicting the orientation and thickness of the 10 model layers. Figures 8-5 through 8-12 illustrate the elevations of the nine model layer surfaces (not including the land surface) relative to mean sea level.

8.3 Model Properties

The two most important hydraulic properties that must be assigned to each cell in the model are hydraulic conductivity and storage coefficient. GMA has assigned to each model layer at least one value for hydraulic conductivity and one value for storage coefficient. Hydraulic conductivity is a measure of an aquifer's ability to transmit water. It is a measure of the volume of water transmitted through a unit width of the aquifer under a hydraulic gradient of one. It is equal to the transmissivity of an aquifer divided by the aquifer thickness (Heath, 1983).

As presented in section 6.0, GMA performed aquifer testing at the proposed quarry site and derived the transmissivity of the Upper Castle Hayne Aquifer through the analysis of aquifer test data. The transmissivity of the zone tested by GMA in the Upper Castle Hayne Aquifer is 5000 ft^2/day, and this transmissivity equates to an average hydraulic conductivity of 125 ft/day, based on an interpreted aquifer thickness of 40 feet.

The hydraulic conductivity values for the other aquifers and for other areas of the Castle Hayne Aquifer were not tested by GMA, but were compiled from the literature, previous model studies, and the DWR's online groundwater database. The calibrated values of hydraulic conductivity utilized for each layer are illustrated in Figures 8-13 through 8-22. These values were modified during steady-state calibration within a reasonable range for each initial hydraulic conductivity value. The value of hydraulic conductivity of the Upper Castle Hayne Aquifer (Layer 5) was reduced during the transient calibration. !

Storage coefficient is another important model property that must be assigned to each cell. GMA has assigned each model layer one value for storage coefficient for all cells within that layer. Storage coefficient is a measurement of the volume of water that is released from, or taken into, storage per foot of hydraulic head change per unit surface area of aquifer multiplied by the aquifer thickness. ? Specific storage is equal to storage coefficient divided by aquifer thickness. Visual MODFLOW requires that each cell be assigned a value of specific storage. GMA utilized our best estimate of specific storage derived from the analysis of aquifer-test data from the testing performed at the proposed quarry site. The specific storage values of other model layers were derived from the literature, previous model studies, and the DWR's online groundwater database. Storage coefficient primarily affects transient simulations, and is therefore calibrated during the transient calibration. Consequently, GMA made minor adjustments to specific storage values during the transient calibration process. Table 8-3 lists the calibrated storage coefficient utilized for each model layer.

Table 8-3: Calibrated Specific Storage Values Utilized For Each Model Layer

Model layer	Aquifer/Confining Layer	Specific Storage	Average Storage Coefficient	thickness
Layer 1	Surficial Aquifer	0.02	0.2	10
Layer 2	Confining Layer Above the Yorktown Aquifer	0.0005	0.0075	
Layer 3	Yorktown Aquifer	5×10^{-7}	0.00001	
Layer 4	Confining Layer Above the Castle Hayne Aquifer	0.0005	0.0075	15
Layer 5	High Permeability Zone in the Upper Castle Hayne Aquifer	5×10^{-8}	0.000001	20
Layer 6	Low Permeability Zone in the Upper Castle Hayne Aquifer	5×10^{-7}	0.00001	20
Layer 7	Confining Layer Above the Lower Castle Hayne Aquifer	0.0005	0.0075	15
Layer 8	Lower Castle Hayne Aquifer	5×10^{-7}	0.00001	
Layer 9	Beaufort Confining Layer and Aquifer	5×10^{-7}	0.00001	
Layer 10	Confining Layer Above the Peedee Aquifer	0.0005	0.0075	

A value of specific yield must also be assigned to each model layer and is important during dewatering simulations of the proposed quarry. Specific yield is a measurement of the amount of water that a unit volume of saturated permeable rock will yield when drained by gravity. GMA utilized a specific yield of 0.2 feet/day for the Surficial Aquifer and the Castle Hayne Aquifer layers.

8.4 Model Boundaries

Recharge to the Surficial Aquifer is a major boundary in the model. A recharge rate of 1 inch per year was assigned to the Surficial Aquifer. This rate is consistent with previous models in this region (Giese and others, 1997; Reynolds, 1992). GMA did not vary the recharge rate during model calibration.

Two other major boundaries are utilized in the model. One boundary type, the General Head Boundary, is utilized to represent the continuation of an aquifer beyond the model area. General head boundaries are assigned by defining a hydraulic head and a conductance. The general head boundary will remove or add water to adjacent cells with lower hydraulic head, based on an assigned hydraulic head, and a threshold conductance, expressed in feet^2/day. The flow to adjacent cells is not allowed to exceed the conductance of the general head boundary. Visual MODFLOW has a default formula that calculates the conductance of a general head boundary based on the distance to the hydraulic boundary to be represented, and on the average hydraulic conductivity of the aquifer in which the boundary occurs. General head boundaries were utilized for the eastern limits of the model area to represent the continuation of each aquifer layer. The more deeply buried aquifers that extend beyond the western limit of the model area were also assigned general head boundaries at the western limit of the model. These general head boundaries were adjusted during the steady-state calibration.

Constant head boundaries were utilized in the Surficial Aquifer to represent large water bodies, such as the Pamlico River, where the hydraulic head is relatively constant and provides a consistent source of water. MODFLOW will continue to add or take water from cells adjacent to a constant head boundary based on the assigned hydraulic head. Constant head boundaries are not limited by a conductance value.

8.5 Steady-State Calibration

The initial hydraulic properties and boundary conditions were assigned to the model and steady-state model runs were utilized to simulate background conditions in the modeled area. GMA performed a steady-state calibration for the model that is based on the reported 2006 water levels in the Castle Hayne Aquifer, which includes the cone of depression associated with the PCS Phosphate withdrawals. This water level information was taken from PCS Phosphate's recent reporting based on their sentinel well network (PCS, 2007). Withdrawals from the PCS Phosphate mine were simulated through a series of model wells in the Upper Castle Hayne Aquifer layer. These modeled withdrawal rates were based on the average 2006 daily withdrawal of 60 MGD that was reported to the NCDWR at http://www.ncwater.org/Permits_and_Registration/.

GMA assigned head observation wells in the model to represent monitoring wells in the PCS sentinel well network. Each observation well is assigned a water level that represents an actual water level measured in 2006 in a monitoring well completed in the Castle Hayne Aquifer. GMA assigned eight pumping wells in the model to represent the reported 2006 withdrawals at the PCS Phosphate mine. Boundary conditions and hydraulic conductivities of the aquifers and confining units were adjusted until there was good agreement between observed water levels and those calculated by the model at head observation wells. Figure 8-23 shows a calibration graph for the steady-state calibration that compares the observed water levels with those calculated by the model for the 11 head observation wells that represent monitoring wells in the PCS sentinel network. An additional head observation well was added to Layer 1, the Surficial Aquifer, to aid in model calibration. The simulation of the cone of depression in the steady-state calibration is shown in Figure 8-24. The depth, shape, and extent of the cone of depression compares favorably with observed water level maps from 2006 PCS report.

8.6 Transient Calibration

GMA performed a transient calibration utilizing information obtained from the pumping test at the proposed quarry site. The goal of the transient calibration was to obtain a calculated drawdown response in the simulated pumping well that closely matches the drawdown observed in the actual pumping test performed at the proposed quarry location. GMA adjusted the storage coefficient of the Castle Hayne Aquifer to achieve agreement between the aquifer test data from the proposed quarry and calculated drawdown from the simulated pumping test. It was necessary to reduce the value of hydraulic conductivity of the Upper Castle Hayne Aquifer during the transient calibration, in order to achieve the drawdown observed during the pumping test at the proposed quarry.

Figure 8-25 is a transient calibration graph that illustrates the simulation of the pumping test at the proposed quarry location. MODFLOW does not account for well efficiency loses. Screen-and-gravel packed wells, such as the well that was tested at the proposed quarry location, typically have well efficiencies of 70 to 80%, and drawdown in the aquifer at the radius of the well is less than inside the well. GMA set a goal of achieving 75% of the observed drawdown in the transient calibration to account for efficiency losses.

8.7 Dewatering Simulations

GMA has performed numerous simulations of potential dewatering operations for the proposed quarry. GMA modified the model framework to represent the quarry operation, after the steady state and transient calibrations were completed. This was accomplished by assigning an elevation of 50 feet below mean sea level (MSL) for the quarry footprint, or an average of 20 feet into the limestone of the Upper Castle Hayne Aquifer. All layers above the Upper Castle Hayne Aquifer were eliminated within the quarry footprint. Dewatering simulations utilized a series of wells both outside the quarry footprint and within the quarry footprint, simulating what is essentially a sump pump. Wells outside the quarry footprint simulate proposed wells that have the potential to be utilized as public water supply wells.

Several dewatering simulations were attempted by GMA utilizing a variety of well locations. Figure 8-26 shows the simulated wells that were utilized in the majority of the quarry dewatering simulations. Five wells are located outside the quarry footprint, they are completed in the entire thickness of the Upper Castle Hayne Aquifer, and they are labeled wells West, West 2, MMA1, East, and South. Well names reflect their location relative to the quarry footprint. Well MMA1 is at the location of the well constructed and tested by GMA at the proposed quarry site, and it is located north of the quarry footprint. Three wells (DW1, DW2, and Center) are located within the quarry footprint. These wells represent withdrawals that could be accomplished through a quarry sump pump system. Table 8-4 lists the pumping rates utilized for each simulated well that resulted in dewatering of the quarry footprint.

Table 8-4: Pumping Rates for Simulated Castle Hayne Aquifer Dewatering Wells

Well Identification	Well Location	Pumping Rate (gpm)	Millions of Gallons Per Day
West	West of Quarry Footprint	750	1.080
West 2	West of Quarry Footprint	750	1.080
MMA1	North of Quarry Footprint	600	0.864
South	South of Quarry Footprint	1000	1.440
East	East of Quarry Footprint	1200	1.728
Center	Centered Within Quarry Footprint	2000	2.880
DW1	Within Quarry Footprint	750	1.080
DW2	Within Quarry Footprint	750	1.080
	Total	**7,800 gpm**	**11.2 MGD**

Dewatering the quarry footprint results in a cone of depression within the Upper Castle Hayne Aquifer that interacts with the cone of depression associated with the PCS Phosphate withdrawals. Figure 8-27 shows the resultant water levels in the Upper Castle Hayne Aquifer during dewatering of the quarry footprint and simultaneous depressurization pumping at PCS Phosphate. The cone of depression created by quarry dewatering has intersected the PCS Phosphate cone, however it is a much smaller than the PCS Phosphate cone. Figure 8-28 shows a more detailed view of the water levels in the Upper Castle Hayne Aquifer in the area of the cone of depression associated with the proposed quarry.

Figure 8-29 illustrates the amount of drawdown associated with the quarry dewatering for the calibrated model. The drawdown values in this figure represent the amount of drawdown in the quarry area due solely to the pumping necessary for dewatering the quarry footprint. This amount of drawdown does include drawdown induced by PCS Phosphate mine withdrawals, as the starting point for this model simulation included the background water levels from the steady-state calibration. Note that locations of nearby fish farms have been annotated on this figure and they are outside the 5 feet drawdown contour. Figure 8-30 is a cross-section view of the simulated quarry dewatering for the calibrated model.

Calibrated model simulations indicate that, if hydraulic conductivity is 70 ft/day for the Upper Castle Hayne Aquifer, the total pumping rate from perimeter and sump wells must be 11.2 MGD to dewater the quarry. In the calibrated base dewatering simulation, the 20-foot drawdown contour extends approximately 2 miles from the center of the simulated dewatered quarry, the 10-foot drawdown contour extends approximately 3.1 miles from the center of the quarry, and the 5-foot drawdown contour extends approximately 4.4 miles from the center of the quarry. No significant drawdown was predicted in the Lower Castle Hayne Aquifer during any of the dewatering simulations (Figure 8-31).

Any model is limited by the quality of the data that supports it. This model has the benefit of representing an area that is well studied, however as with any model there is a fair amount of uncertainty in the hydraulic properties of the aquifers and confining units at the site. GMA has prepared Table 8-5 to provide potential pumping rates necessary for dewatering the quarry footprint within the probable range of hydraulic properties at the site.

Table 8-5: Model Simulations

Dewatering Simulation	Hydraulic Conductivity of the Upper Castle Hayne Aquifer	Transmissivity of Layer 5 (High Permeability Zone of the Upper Castle Hayne Aquifer)	Specific Storage of the Upper Castle Hayne Aquifer	Withdrawal Necessary for Quarry Dewatering
Base Calibrated Model	70 ft/day	3150 ft^2/day	5.00E-08	11.2 MGD
Increased Hydraulic Conductivity	100 ft/day	4675 ft^2/day	5.00E-08	13.3 MGD
Higher Hydraulic Conductivity	125 ft/day	5800 ft^2/day	5.00E-08	15.9 MGD
Increased Specific Storage	70 ft/day	3150 ft^2/day	1.00E-07	11.2 MGD
Increased Specific Storage	70 ft/day	3150 ft^2/day	5.00E-07	11.2 MGD
Increased Specific Storage	70 ft/day	3150 ft^2/day	5.00E-07	11.8 MGD

?

If the hydraulic conductivity of the Upper Castle Hayne Aquifer is 125 ft/day, model simulations indicate that the total pumping rate would need to be 15.9 MGD to dewater the quarry. This simulation that utilizes the higher conductivity of 125 ft/day is referred to as the 'higher conductivity simulation'. Table 8-6 lists the pumping rates utilized for each simulated well that resulted in dewatering of the quarry footprint in the higher conductivity simulation.

Table 8-6: Pumping Rates for Simulated Castle Hayne Aquifer Dewatering Wells for the Higher Hydraulic Conductivity Simulation

Well Identification	Well Location	Pumping Rate (gpm)	Millions of Gallons Per Day
West	West of Quarry Footprint	1000	1.440
West 2	West of Quarry Footprint	1250	1.800
MMA1	North of Quarry Footprint	1000	1.440
South	South of Quarry Footprint	1200	1.728
East	East of Quarry Footprint	1800	2.592
Center	Centered Within Quarry Footprint	2000	2.880
DW1	Within Quarry Footprint	1400	2.016
DW2	Within Quarry Footprint	1400	2.016
	Total	**11,050 gpm**	**15.9 MGD**

Figure 8-32 shows the resultant water levels in the Upper Castle Hayne Aquifer during dewatering of the quarry footprint in the higher hydraulic conductivity simulation. The cone of depression created by quarry dewatering in the higher conductivity simulation is very similar to the cone of depression resultant from quarry dewatering at the calibrated hydraulic conductivity of 70 ft/day. The resultant cone of depression in the higher conductivity simulation also intersects the PCS Phosphate cone, and this cone of depression still much smaller than the PCS Phosphate cone. Figure 8-33 shows a more detailed view of the water levels in the Upper Castle Hayne Aquifer in the area of the cone of depression associated with the proposed quarry in the higher conductivity simulation.

Figure 8-34 illustrates the amount of drawdown associated with the quarry dewatering for the higher conductivity simulation. Again, the drawdown values in this figure represent the amount of drawdown in the quarry area due solely to the pumping necessary for dewatering the quarry footprint. The locations of nearby fish farms have also been annotated on this figure. Note that the northern fish farm, One Fish, Two Fish, LLC., is now inside the 5 feet drawdown contour within the Upper Castle Hayne Aquifer. There should be no drawdown in the Lower Castle Hayne Aquifer, the aquifer that supplies the fish farm at this location.

The higher conductivity simulation indicates that, if hydraulic conductivity is 125 ft/day for the Upper Castle Hayne Aquifer, the total pumping rate from perimeter and sump wells must be 15.9 MGD to dewater the quarry. In the higher conductivity simulation, the 20-foot drawdown contour extends approximately 2.3 miles from the center of the simulated dewatered quarry, the 10-foot drawdown contour extends approximately 3.9 miles from the center of the quarry, and the 5-foot drawdown contour extends approximately 5.7 miles from the center of the quarry.

The total pumping rate for quarry dewatering could range from 11.2 to 15.9 MGD depending on the actual values of hydraulic properties of the aquifer

8.8 Model Limitations

The model is limited first by the quantity and quality of the input data. The hydraulic conductivity and storage coefficient of the Upper Castle Hayne Aquifer at the proposed quarry site are known through the analysis of recently collected aquifer test data. GMA has utilized hydraulic property values at other locations in the model and for other aquifers that were either obtained from the literature, or were based on GMA's experience with the hydrogeology of this region. GMA assumed some model input values that were not available from the literature for other data that were not available. The model does not accurately predict the amount of drawdown that occurs in the Surficial Aquifer away from the quarry, because the calibration of the model was focused on the Upper Castle Hayne Aquifer.

The calibrated hydraulic conductivity and storage coefficient of the Upper Castle Hayne Aquifer were lower than those estimated from the aquifer test data by GMA. For this reason, GMA has modeled a range of horizontal conductivity values due to the uncertainty of these values. Although there is uncertainty in the model predictions, GMA contends that this model provides a reasonable estimate of the amount of pumping that is necessary to dewater the quarry, and it reasonably predicts the regional drawdown effects created by the dewatering.

9.0 Conclusions and Recommendations

GMA has completed a hydrogeologic characterization and predictive modeling of a limestone aggregate quarry planned by Martin Marietta Aggregates. The quarry would entail mining an area of approximately 650 acres to a depth of approximately 120 feet below land surface. Open-pit mining of this type requires dewatering of the subsurface to extract the ore. GMA's study focused on determining the volume of water required for dewatering and predicting the size and magnitude of the cone of depression that would result from groundwater withdrawals at the mine. Based upon our studies, GMA concludes the following:

- The proposed quarry lies within the Central Coastal Plain Capacity Use Area, wherein the North Carolina Division of Water Resources administers a water withdrawal permitting program to manage groundwater withdrawals.
- The PCS Phosphate mine near Aurora involves a large-volume withdrawal (at least 60 million gallons per day) from the Castle Hayne Aquifer that has created a regional cone of depression that extends to and beyond the proposed Martin Marietta Aggregates quarry site. Permitting of groundwater withdrawals necessary for dewatering the quarry requires a detailed understanding of the interactions between the PCS Phosphate cone of depression and the cone of depression that will result from the MMA quarry.
- GMA performed direct field testing of the hydraulic properties of the Castle Hayne Aquifer at the proposed MMA quarry, and we utilized the results of this direct testing in constructing a complex 3-dimensional groundwater flow model using Visual Modflow.
- Modeling simulations predict that withdrawals of 11.2 to 15.9 million gallons per day will be required to effectively dewater the approximately 650-acre quarry. These simulations are based upon a reasonable range of aquifer property values to approximate the water level responses to withdrawals at the mine.
- Drawdown effects of more than 5 feet associated with groundwater withdrawals at the quarry would be limited to a radius of about 6 miles surrounding the quarry. Because of the remote location of the quarry and the expanse of timberland owned by Weyerhaeuser around the quarry site, there are a very limited number of developed properties with wells that could be affected by the quarry withdrawals. GMA reviewed aerial photographs of the area, and we believe that the closest residential properties to the quarry site exist along Maul Swamp Road, about 2.3 miles west-southwest of the proposed quarry. Based upon the high-permeability dewatering simulation, 20 feet of drawdown would be projected to occur at 2.3 miles from the quarry. Other developed properties exist approximately 3 miles to the east and northeast of the proposed quarry. South, southwest, and west of the quarry property, the closest developed properties appear to be 5 to 6 miles away.
- GMA recommends that MMA perform an evaluation of the location and well construction details for all wells within a 6-mile radius of the quarry. We anticipate that most wells within this area would withdraw from the Lower Castle Hayne Aquifer because the Upper Castle Hayne has elevated iron concentrations. Because the model predicts minimal drawdown in the Lower Castle Hayne Aquifer, it is likely that well users within the 6-mile radius search area would not be adversely affected by dewatering operations of the proposed quarry. However, if Upper Castle Hayne Aquifer wells are identified within the 6-mile radius, Martin Marietta Aggregates should consider the potential for drawdown influence on such wells and determine if the influences would adversely impact the wells.
- Catfish farm operations located north and southeast of the quarry property lie close to the area where drawdown of about 5 feet is projected in the Upper Castle Hayne Aquifer. However,

these catfish farming operations have wells that withdraw from the Lower Castle Hayne Aquifer. Therefore, GMA does not expect that the proposed MMA quarry will significantly impact the well systems operated by these catfish farming operations.

Based upon the results of this study, and assuming that MMA plans to proceed with mining operations at the site, GMA makes the following recommendations:

- Contact the North Carolina Division of Water Resources and provide the results of this study for their consideration. It may be appropriate to meet with representatives of the NCDWR to determine permitting requirements for dewatering withdrawals.
- Contact regional water service providers to begin dialogue about the availability of water from the mine dewatering operations.
- Continue dialogue with PCS Phosphate regarding the planned mine dewatering so that a cooperative management approach can be taken with regard to Castle Hayne Aquifer withdrawals in the region.
- Proceed with evaluations of water discharge options and permitting of wastewater discharge from the proposed mining operation.
- Complete a well survey of all properties within a 6-mile radius of the proposed quarry to determine the location of any wells and the well construction details of these wells. Depending on the location of wells identified, MMA may want to consider mitigation strategies for any anticipated impacts on nearby wells.
- Gather supplemental data on groundwater withdrawal responses during initial mining operations. As a part of this data collection effort, GMA recommends that MMA install a sentinel well network to assist with monitoring of the drawdown effects of the mine dewatering and to answer regulatory concerns that are likely to arise in the withdrawal permitting process. The new data should be integrated into the model to develop refinements in simulations of groundwater withdrawal effects on the regional aquifer system.

10.0 Report Certification

This hydrogeologic characterization and predictive modeling report was prepared by Groundwater Management Associates, Inc., a professional corporation licensed to practice geology and engineering in North Carolina.

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Senior Hydrogeologist

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Principal Hydrogeologist

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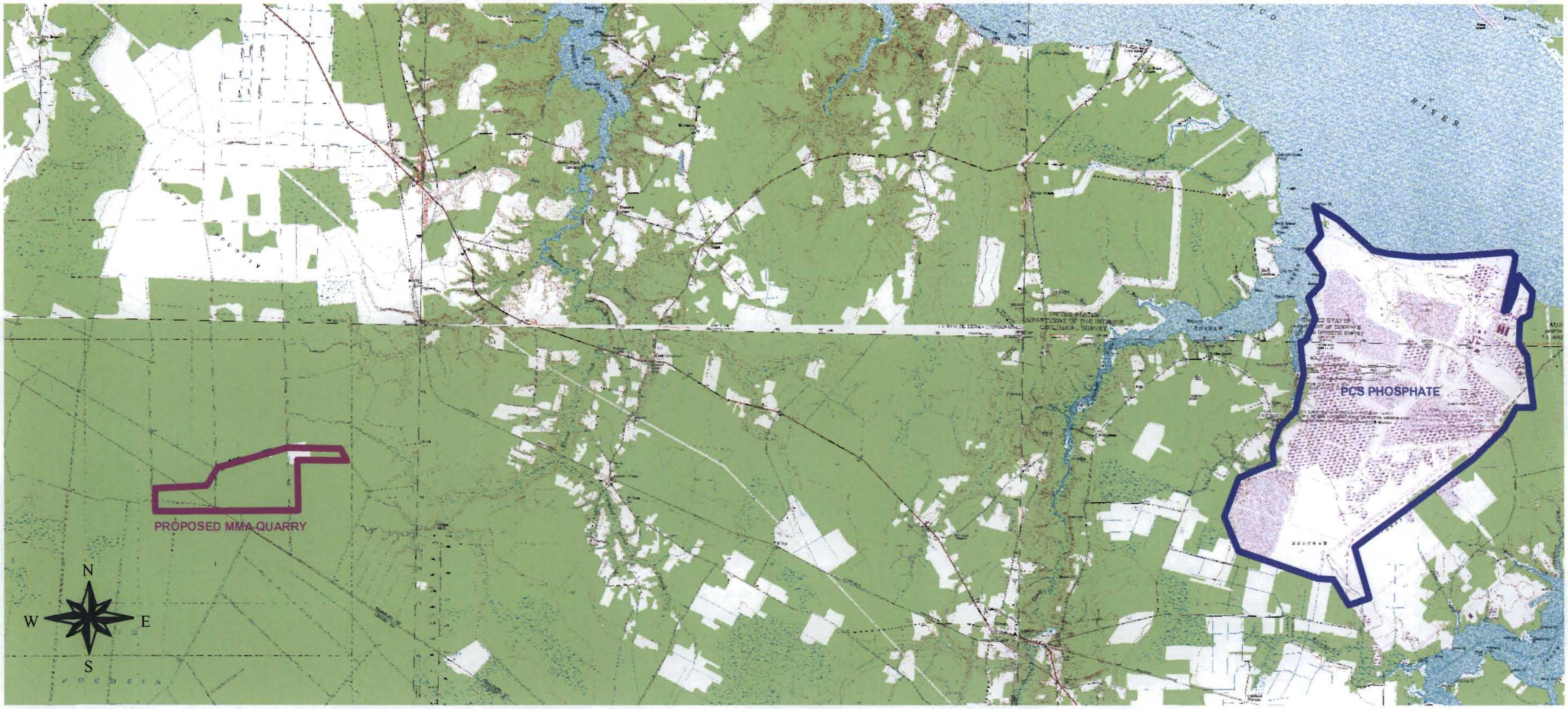
Figures

LOCATIONS OF THE PROPOSED MMA QUARRY AND THE PCS PHOSPHATE MINE



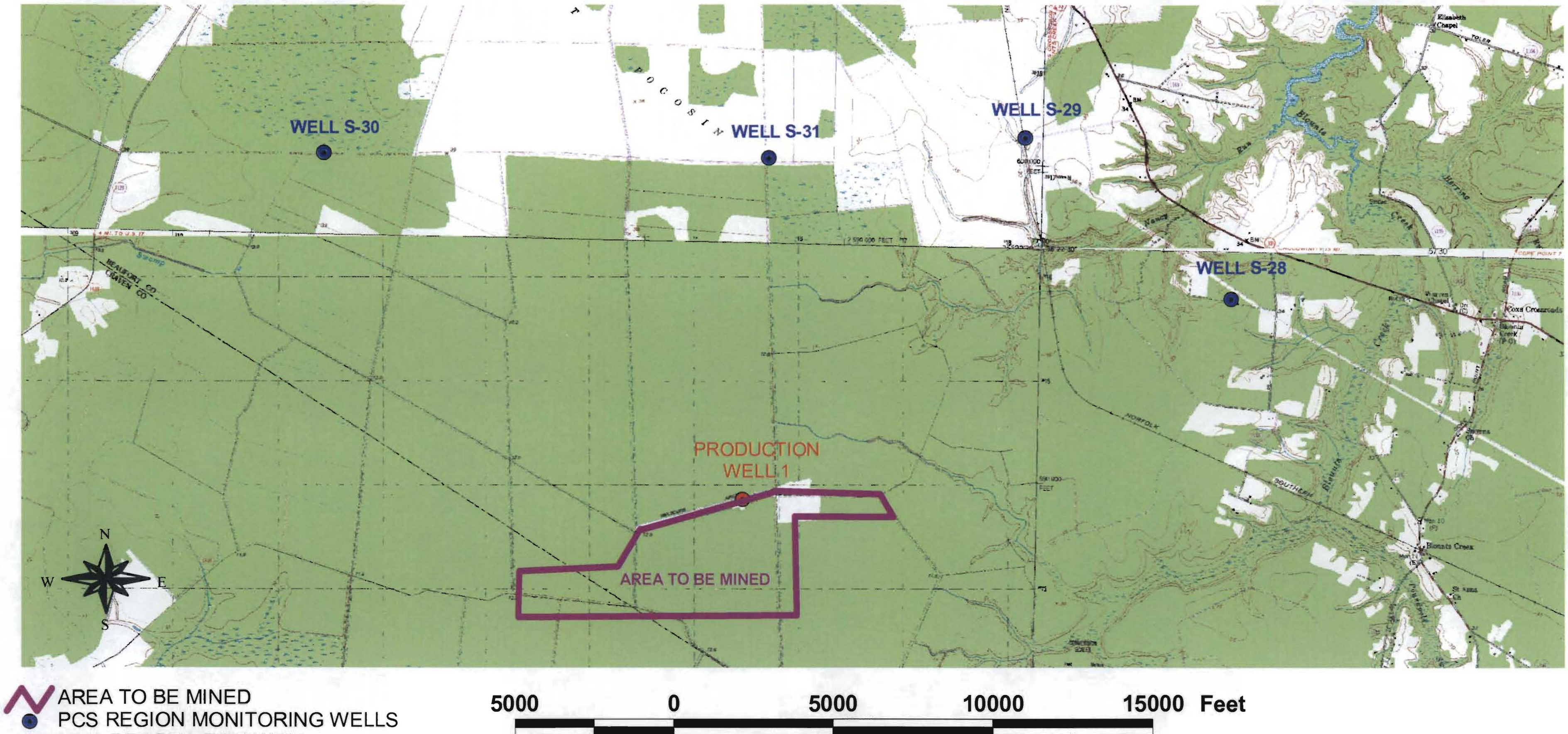
MMA AREA TO BE MINED

PCS PHOSPHATE

10000 0 10000 20000 30000 Feet

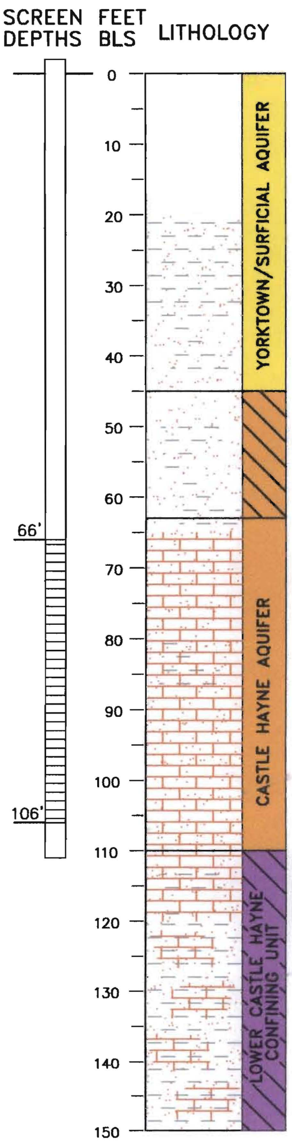
MARTIN MARIETTA (VANCEBORO SITE) WILMAR, BEAUFORT COUNTY, NC	ERNUL/EDWARD/BLOUNTS BAY/HACKNEY/BATH/AURORA QUADRANGLES NORTH CAROLINA - BEAUFORT COUNTY 7.5 MINUTE SERIES (TOPOGRAPHIC) CONTOUR INTERVAL=2 METERS MAP DATED 1983	FIGURE 1-1
GMA	GROUNDWATER MANAGEMENT ASSOCIATES, INC. 4300 SAPPHIRE COURT, SUITE 100 GREENVILLE, NORTH CAROLINA 27834	2/14/2008 PROJECT 62902

TOPOGRAPHIC MAP SHOWING LOCATION OF THE PROPOSED MMA QUARRY AND THE PCS PHOSPHATE SENTINEL WELL NETWORK



MARTIN MARIETTA (VANCEBORO SITE) WILMAR, BEAUFORT COUNTY, NC	ERNUL/EDWARD/BLOUNTS BAY/HACKNEY QUADRANGLES NORTH CAROLINA - BEAUFORT COUNTY 7.5 MINUTE SERIES (TOPOGRAPHIC) CONTOUR INTERVAL=2 METERS MAP DATED 1983	FIGURE 3-1
GMA	GROUNDWATER MANAGEMENT ASSOCIATES, INC. 4300 SAPPHIRE COURT, SUITE 100 GREENVILLE, NORTH CAROLINA 27834	2/14/2008 PROJECT 62902

MARTIN MARIETTA – VANCEBORO
PRODUCTION WELL 1 (PW1)



DESCRIPTION

0–20ft.
GMA not present.

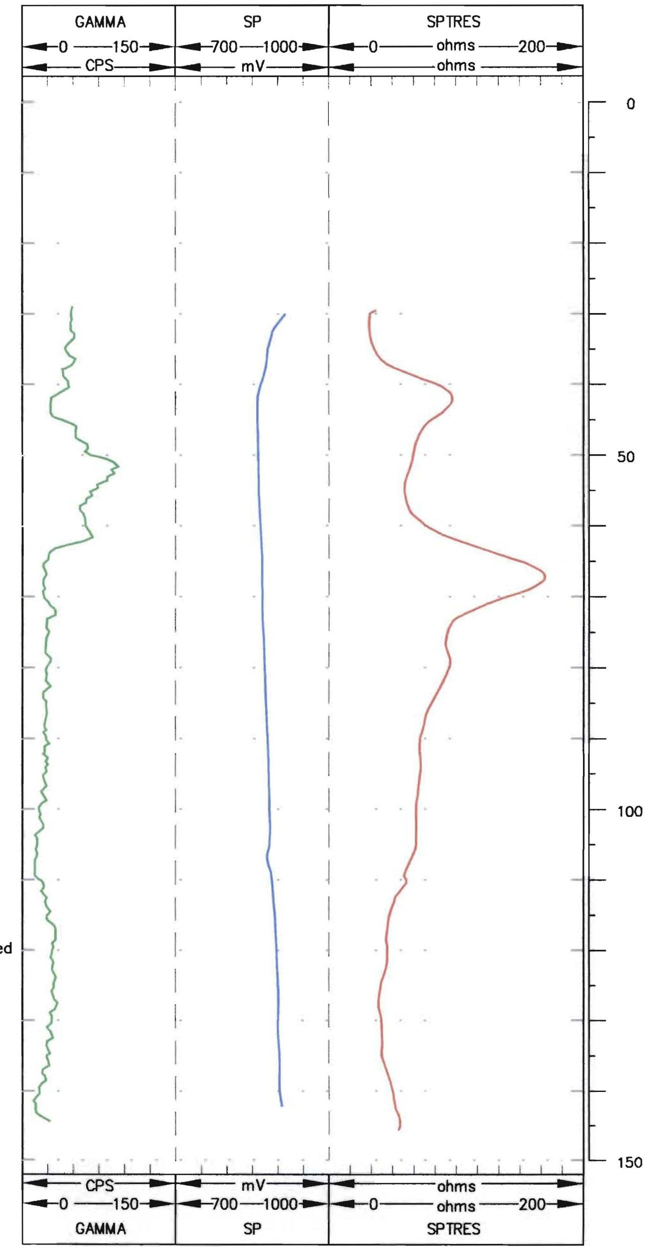
20–30ft.
Dark gray fine sandy silt with abundant organic material. Sand is salt and pepper colored.

30–40ft.
Dark gray clayey fine Sand with minor organic material.

40–66ft.
Light gray fine to medium quartz Sand. Less organic material. Becomes clayey fine to medium Sand at 50ft. BLS.

66–110ft.
Light gray fine sandy Limestone. Some minor loose quartz Sand and heavy minerals. Becoming slightly softer near bottom of section.

110ft.+
Light gray to gray clayey fine sandy Limestone Section seems to be intermittent hard zones of sandy Limestone and soft zones of clayey fine Sand. Becomes softer at depth with increased Clay content.



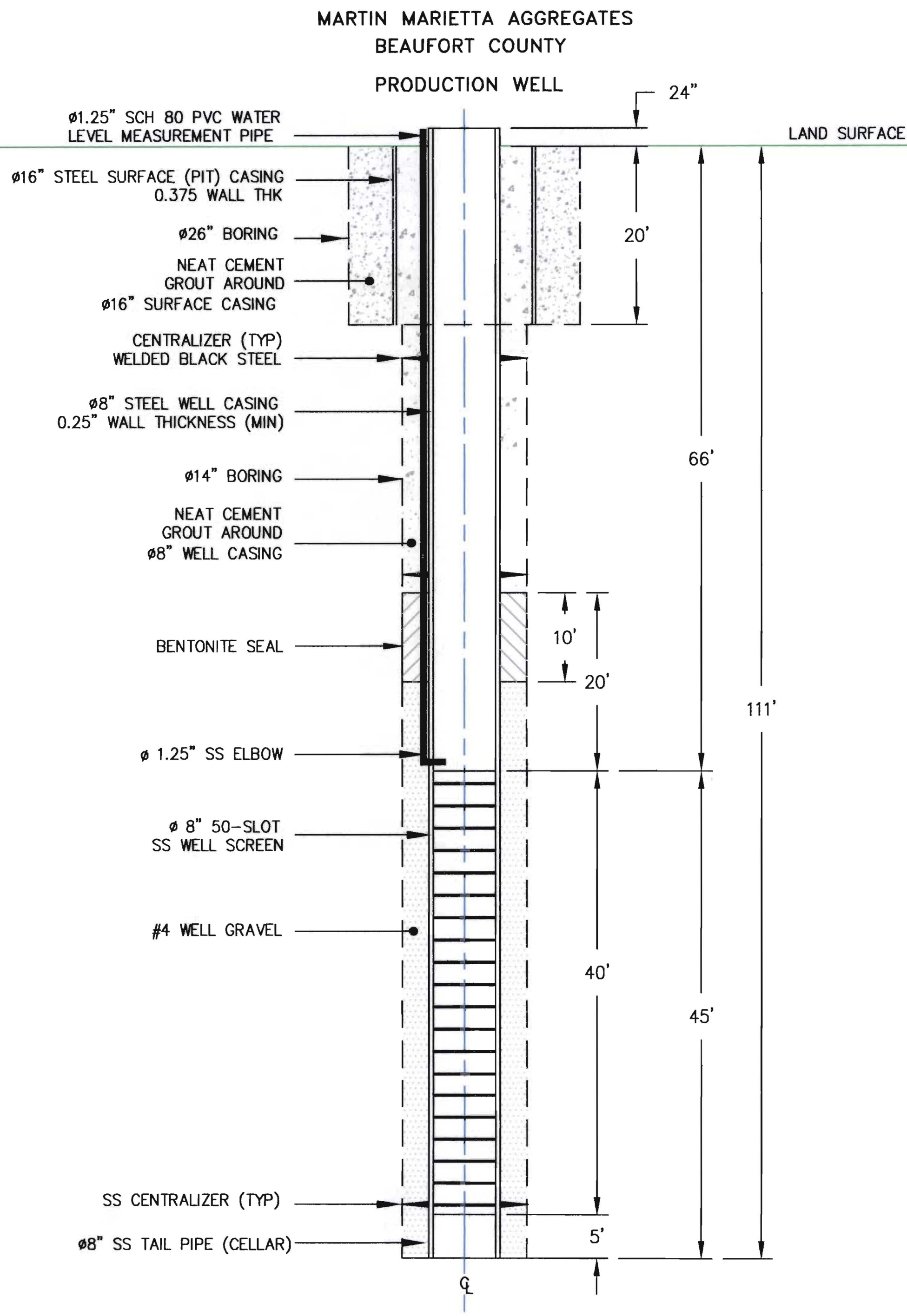
LEGEND

WELL COORDINATES
N35° 21' 10.5"
W77° 01' 51.6"

CASTLE HAYNE CONFINING UNIT

GMA

File: GJR\GMA\62902 GEO-LOG	DRILLING AND GEOPHYSICAL LOGS OF PRODUCTION WELL MMA1	Date: 2/14/2008
Project No. 62902	MARTIN MARIETTA AGGREGATES, WILMAR, BEAUFORT CO., NC	Figure 4-1



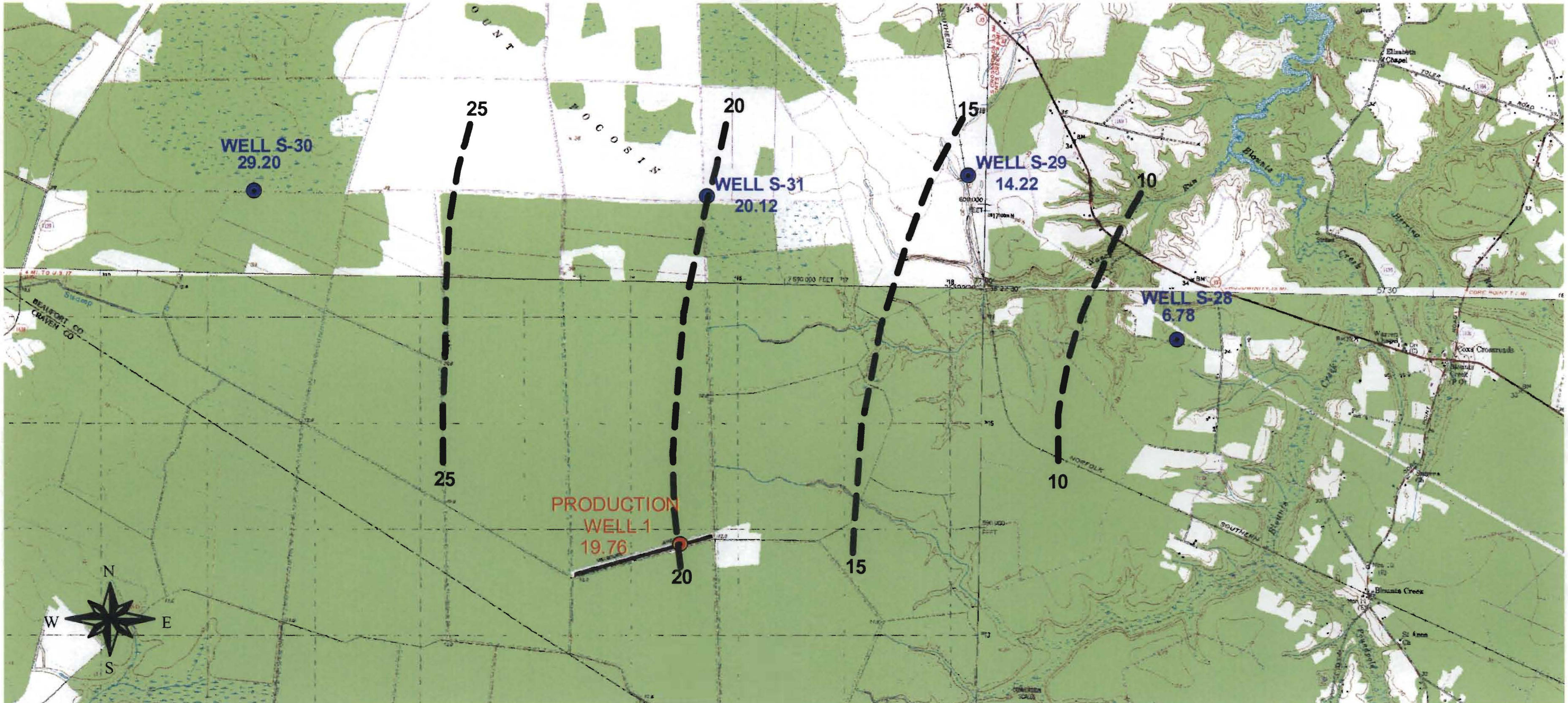
LEGEND

WELL COORDINATES
N35° 21' 09.9"
W77° 01' 51.4"

GMA
Groundwater Management Associates, Inc.

File: GJR\GMA\62902 PROD WELL	AS-BUILT DRAWING OF PRODUCTION WELL MMA1	Date: 2/14/2008
Project No. 62902	MARTIN MARIETTA AGGREGATES, BEAUFORT COUNTY, NC	Figure 4-2

POTENTIOMETRIC SURFACE OF THE UPPER CASTLE HAYNE AQUIFER ON AUGUST 6, 2007



CONTOUR
PCS REGION MONITORING WELLS
MMA PRODUCTION WELL
ELEVATION IN FEET MEAN SEA LEVEL (MSL)

5000 0 5000 10000 15000 Feet

MARTIN MARIETTA (VANCEBORO SITE) WILMAR, BEAUFORT COUNTY, NC	ERNUL/EDWARD/BLOUNTS BAY/HACKNEY QUADRANGLES NORTH CAROLINA - BEAUFORT COUNTY 7.5 MINUTE SERIES (TOPOGRAPHIC) CONTOUR INTERVAL=2 METERS MAP DATED 1983	FIGURE 5-1
GMA	GROUNDWATER MANAGEMENT ASSOCIATES, INC. 4300 SAPPHIRE COURT, SUITE 100 GREENVILLE, NORTH CAROLINA 27834	2/14/2008 PROJECT 62902

Figure 8-1: Model Area

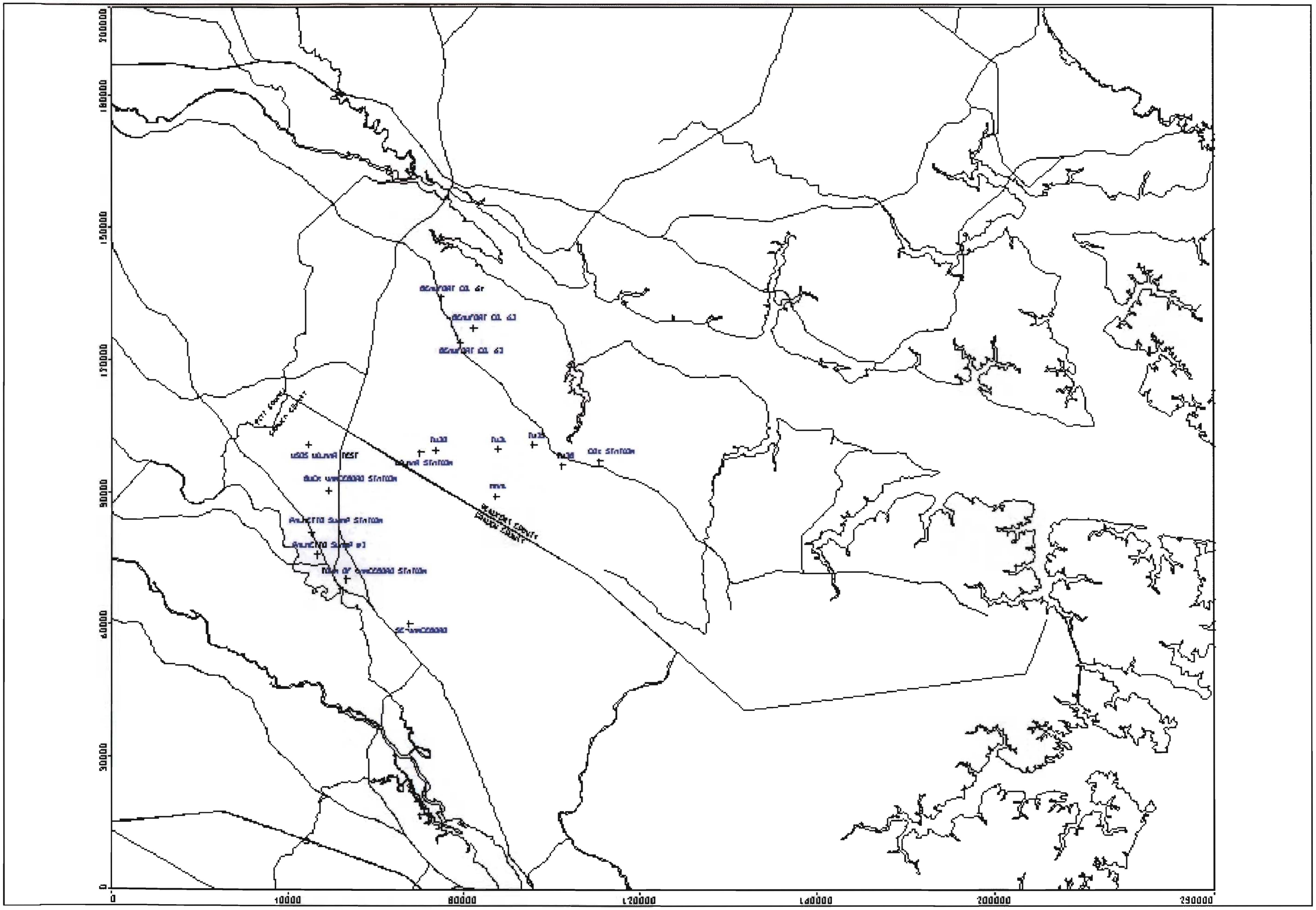


Figure 8-2: Model Grid

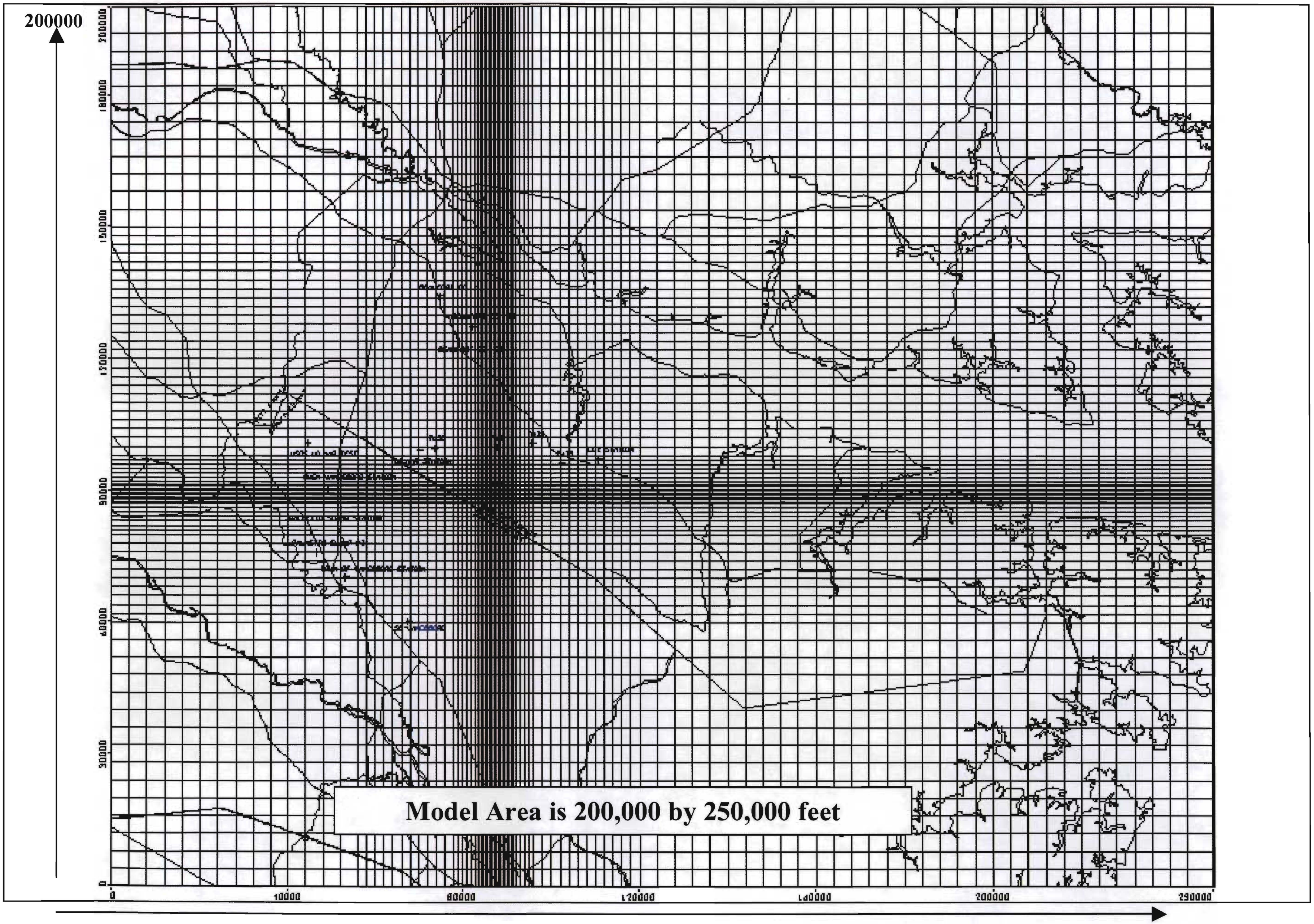


Figure 8-3: USGS Elevation Model Utilized For Land Surface Elevations

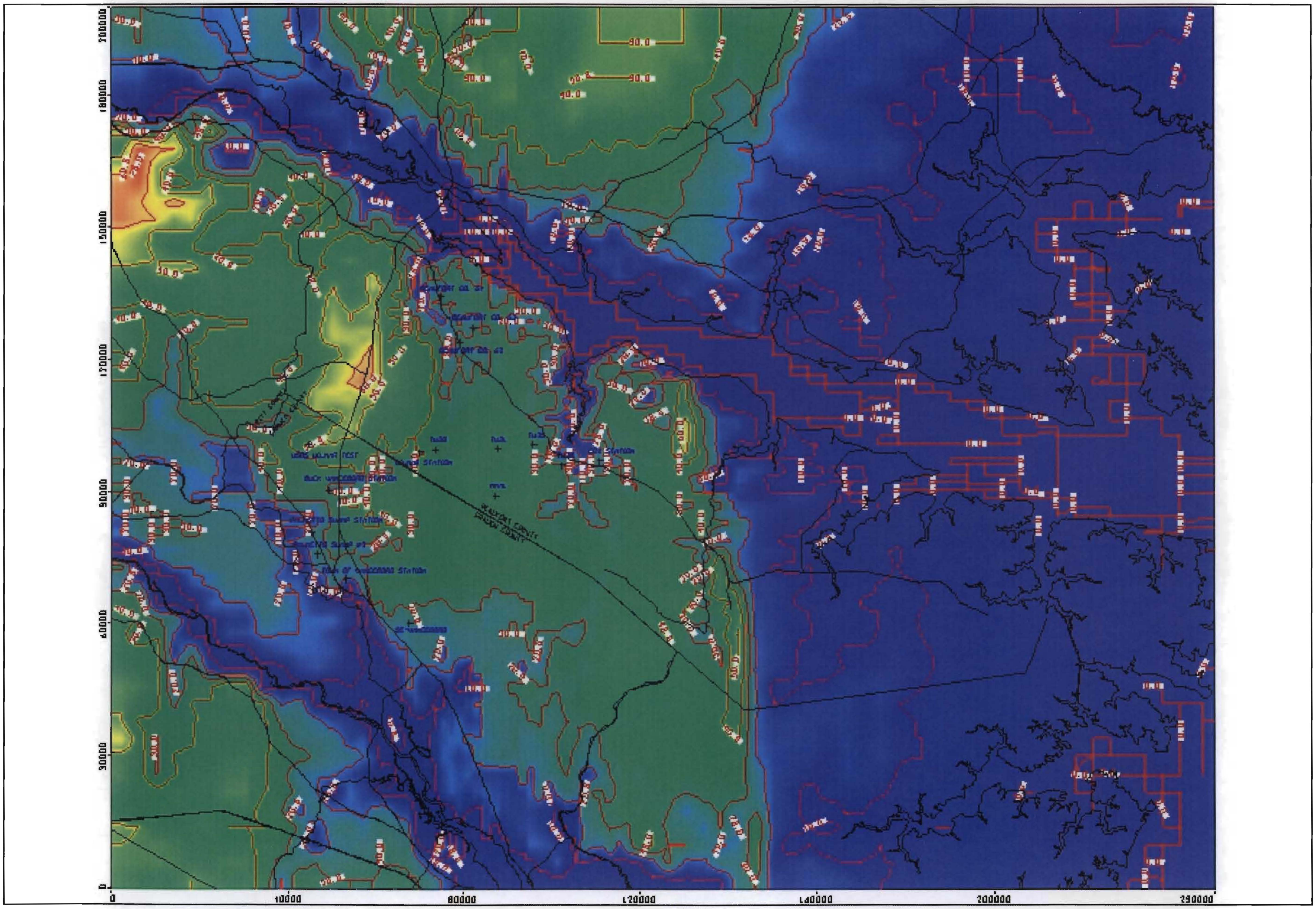
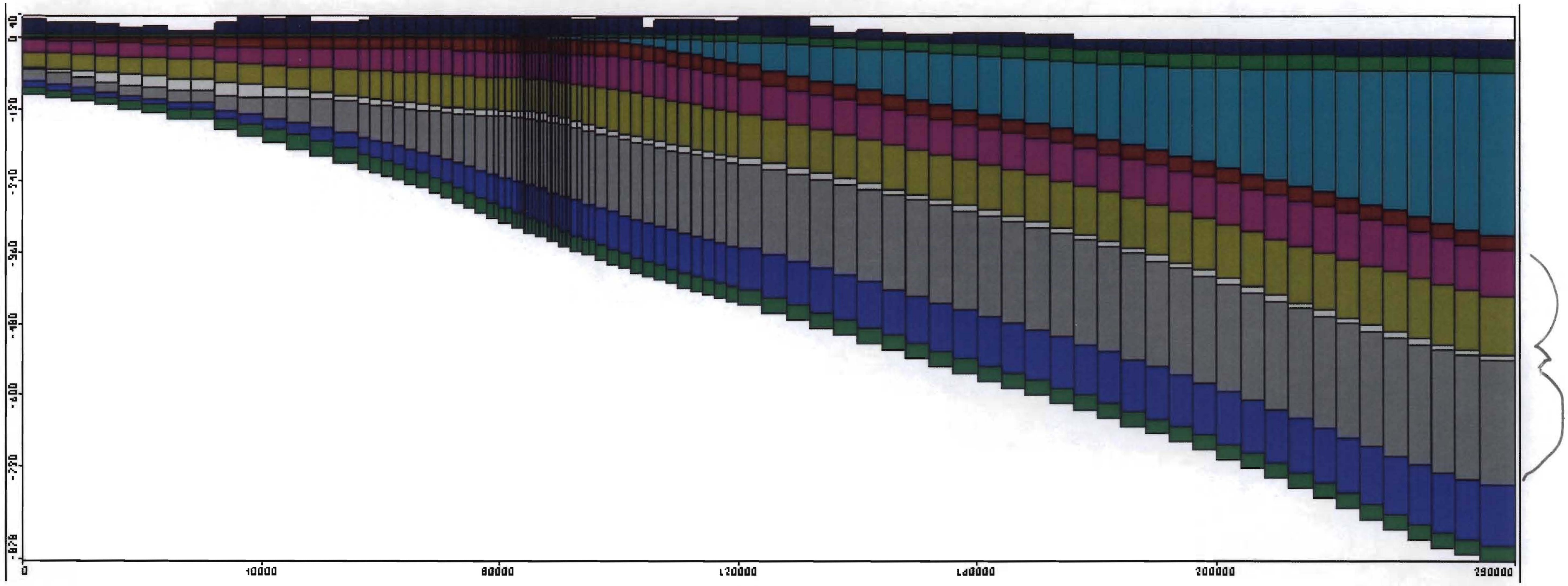


Figure 8-4: Model Layers



Layer 1 : Surficial AQ

Layer 2 : CL Above Yorktown AQ

Layer 3 : Yorktown Aquifer

Layer 4 : CL Above Castle Hayne AQ

Layer 5 : Upper Castle Hayne AQ (high permeability zone)

Layer 6 : Upper Castle Hayne AQ (low permeability zone)

Layer 7 : CL Above Lower Castle Hayne AQ

Layer 8 : Lower Castle Hayne AQ

Layer 9 : Beaufort CL and AQ

Layer 10 : Peedee CL

AQ = Aquifer CL = Confining Layer

Figure 8-5: Elevation Of The Top Of The Confining Layer Above The Yorktown Aquifer

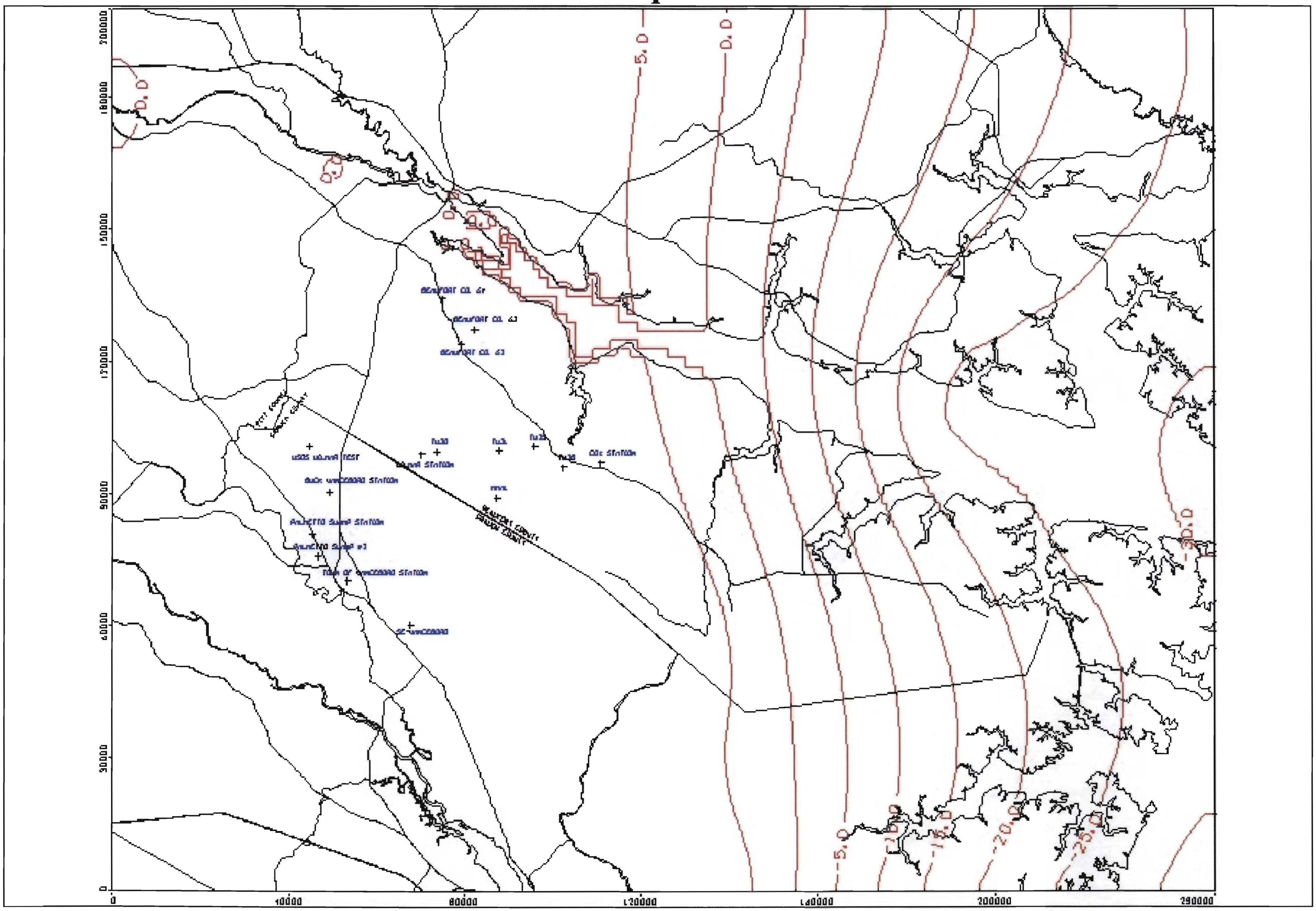


Figure 8-6: Elevation Of The Top Of The Yorktown Aquifer

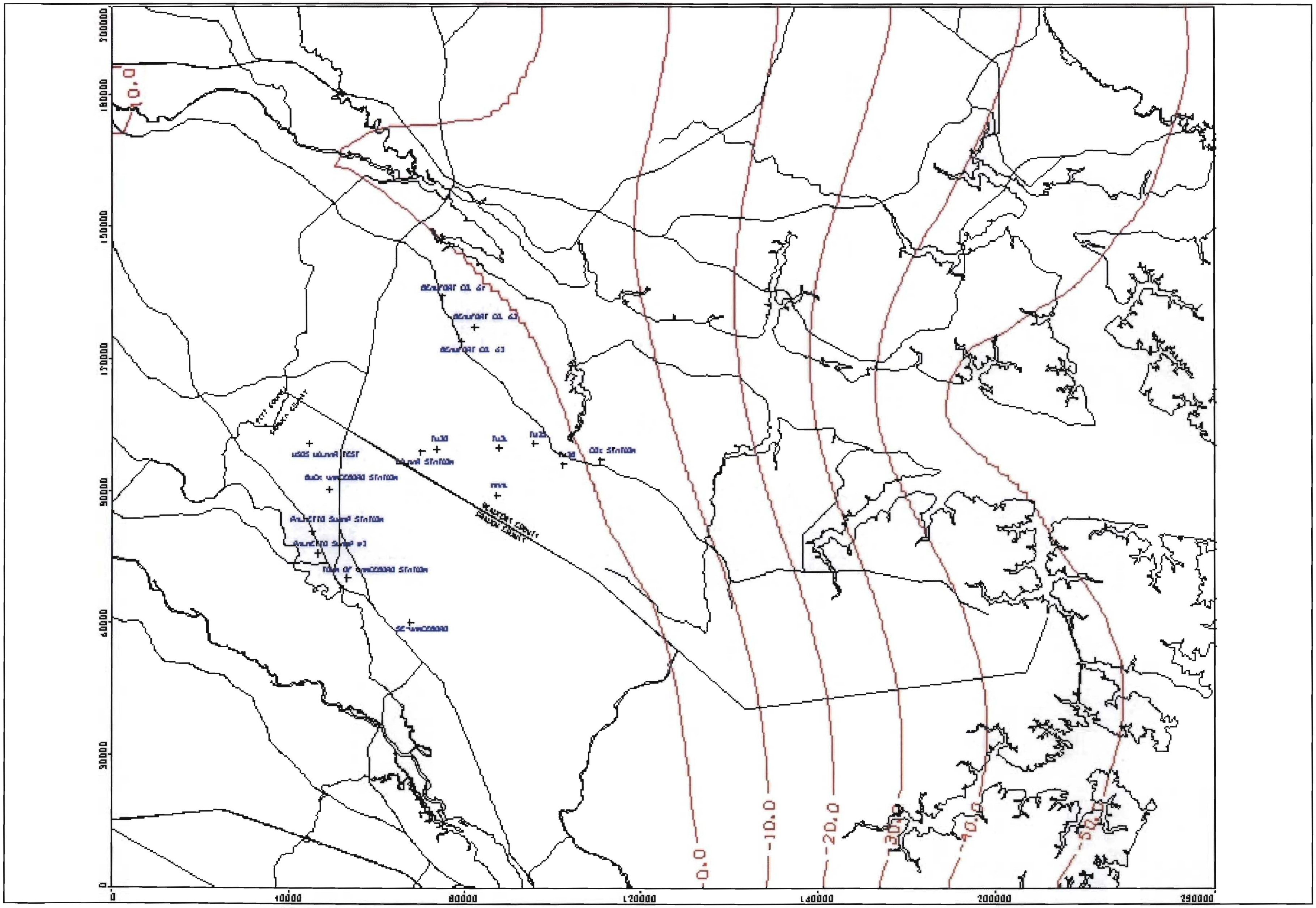


Figure 8-7: Elevation Of The Top Of The Confining Layer Above The Upper Castle Hayne Aquifer

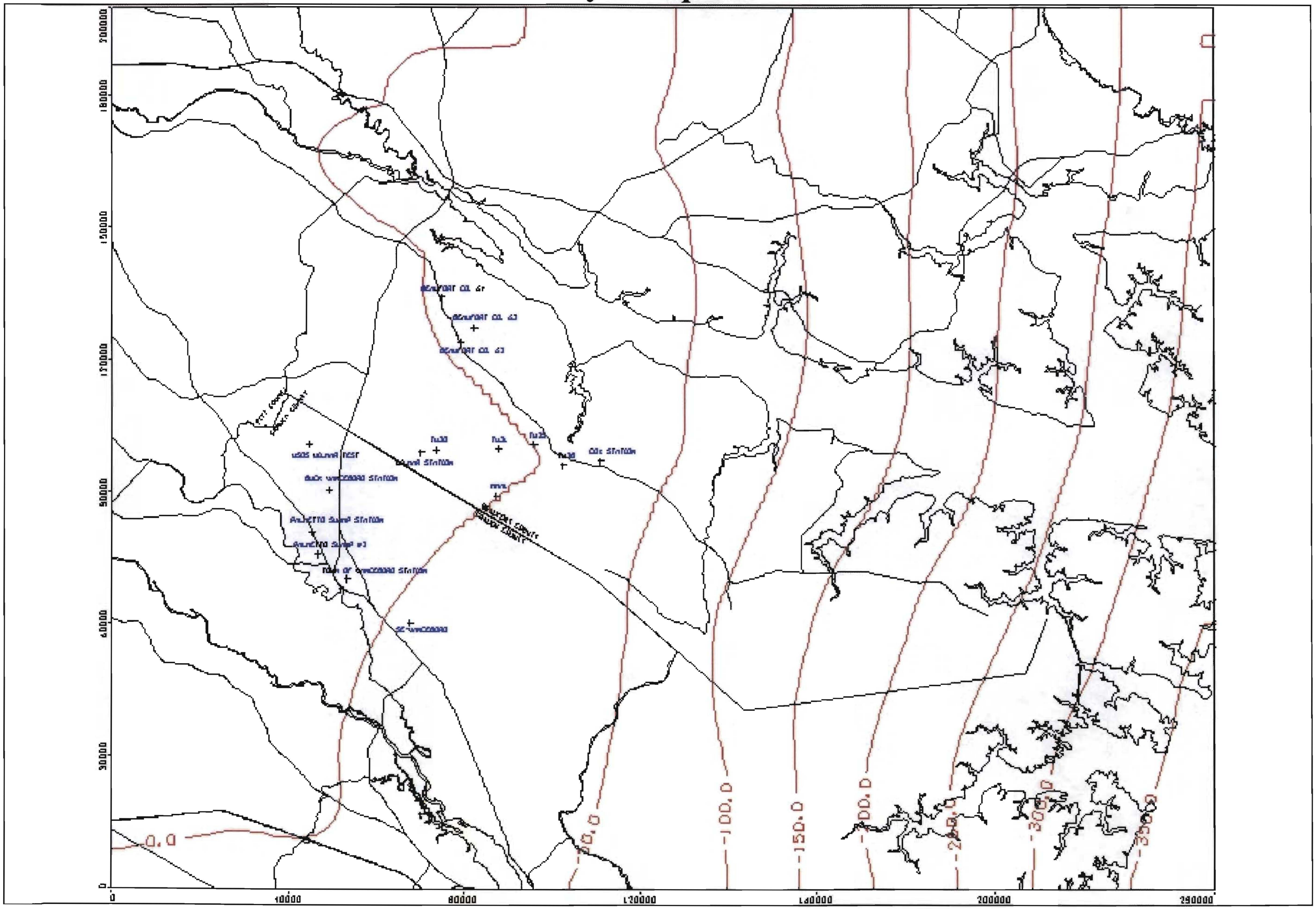


Figure 8-8: Elevation Of The Top Of The Upper Castle Hayne Aquifer

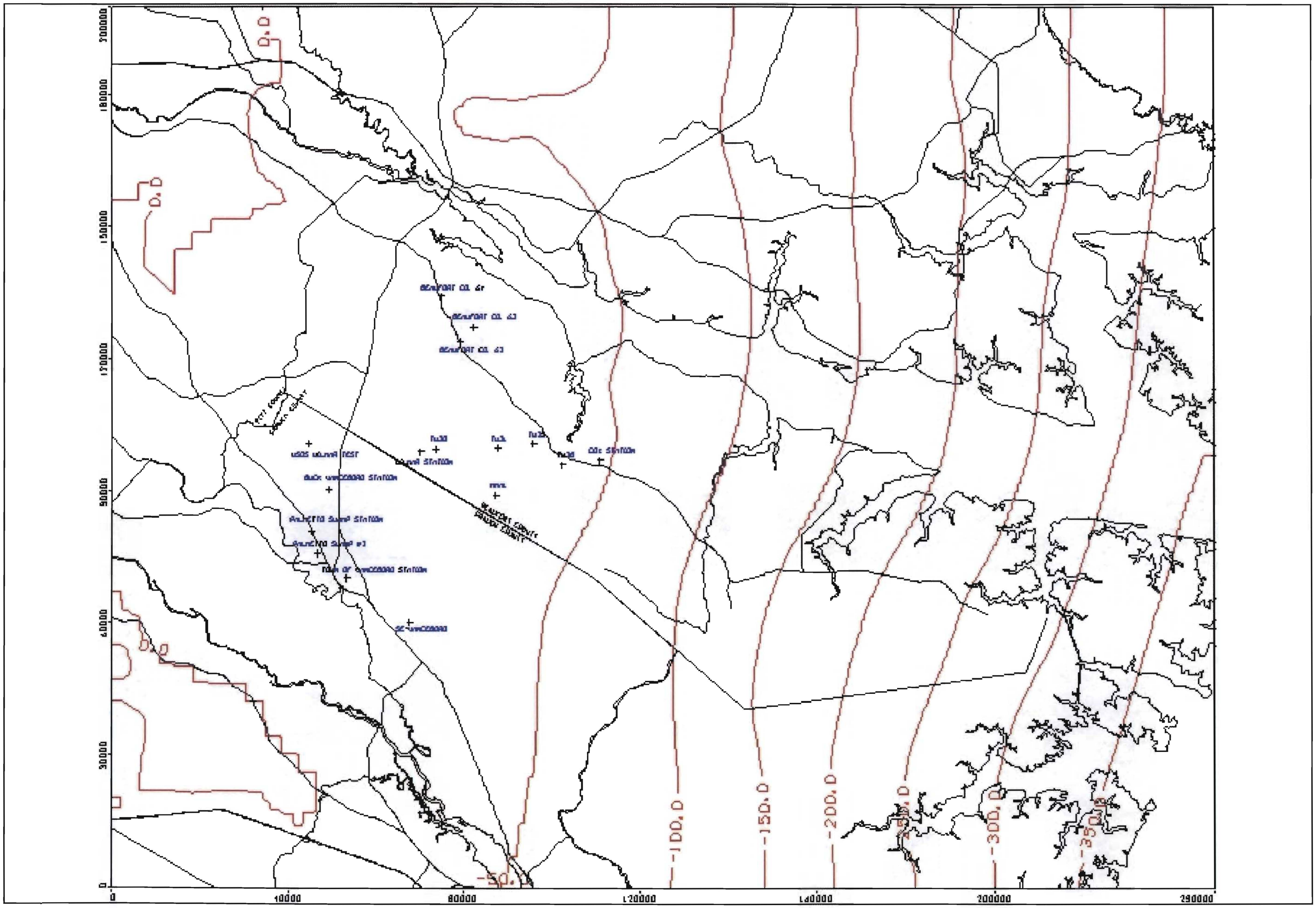


Figure 8-9: Elevation Of The Top Of The Confining Layer Above The Lower Castle Hayne Aquifer

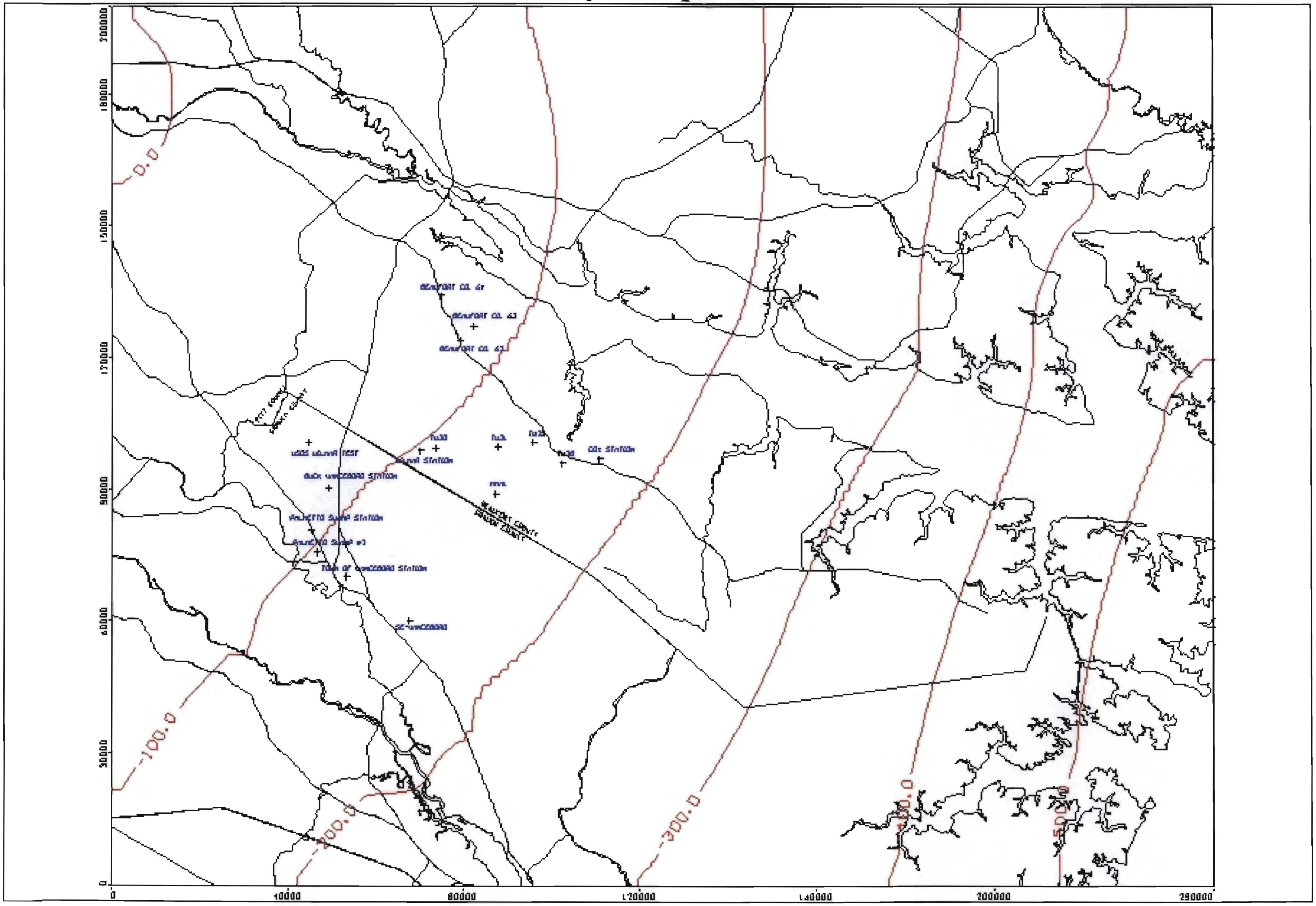


Figure 8-10: Elevation Of The Top Of The Lower Castle Hayne Aquifer

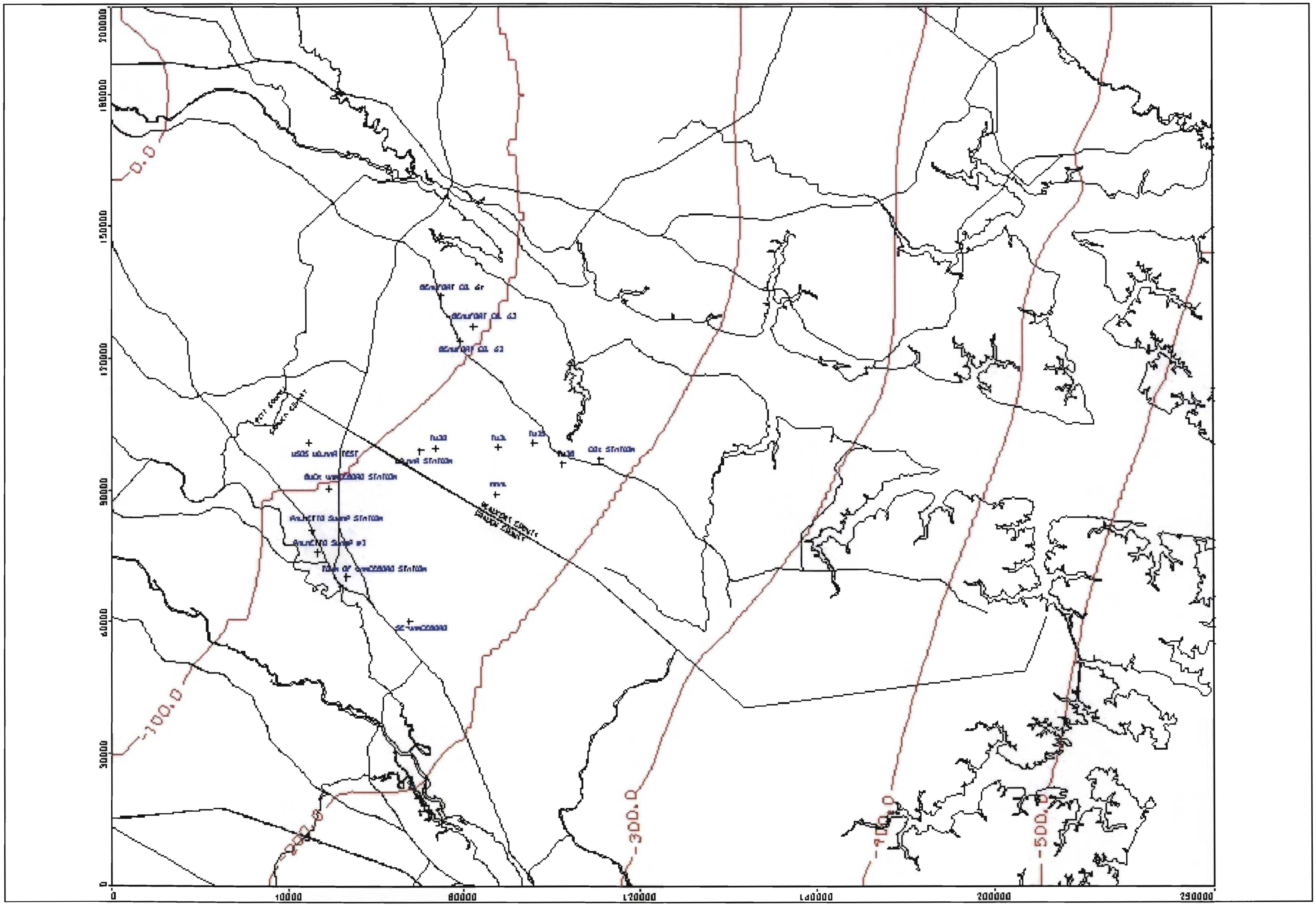


Figure 8-11: Elevation Of The Top Of The Confining Layer Above The Beaufort Aquifer

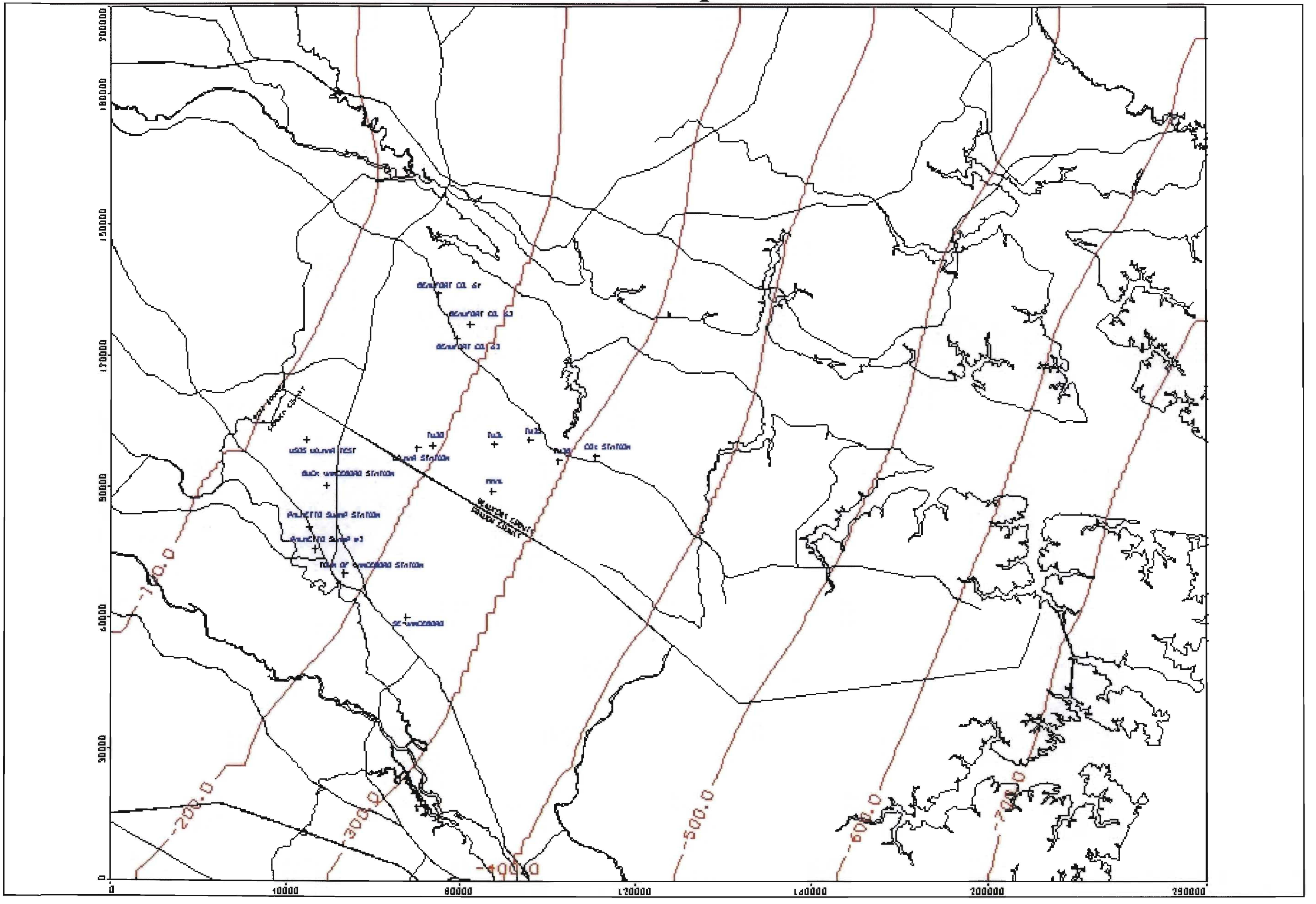


Figure 8-12: Elevation Of The Top Of The Confining Layer Above The Peedee Aquifer

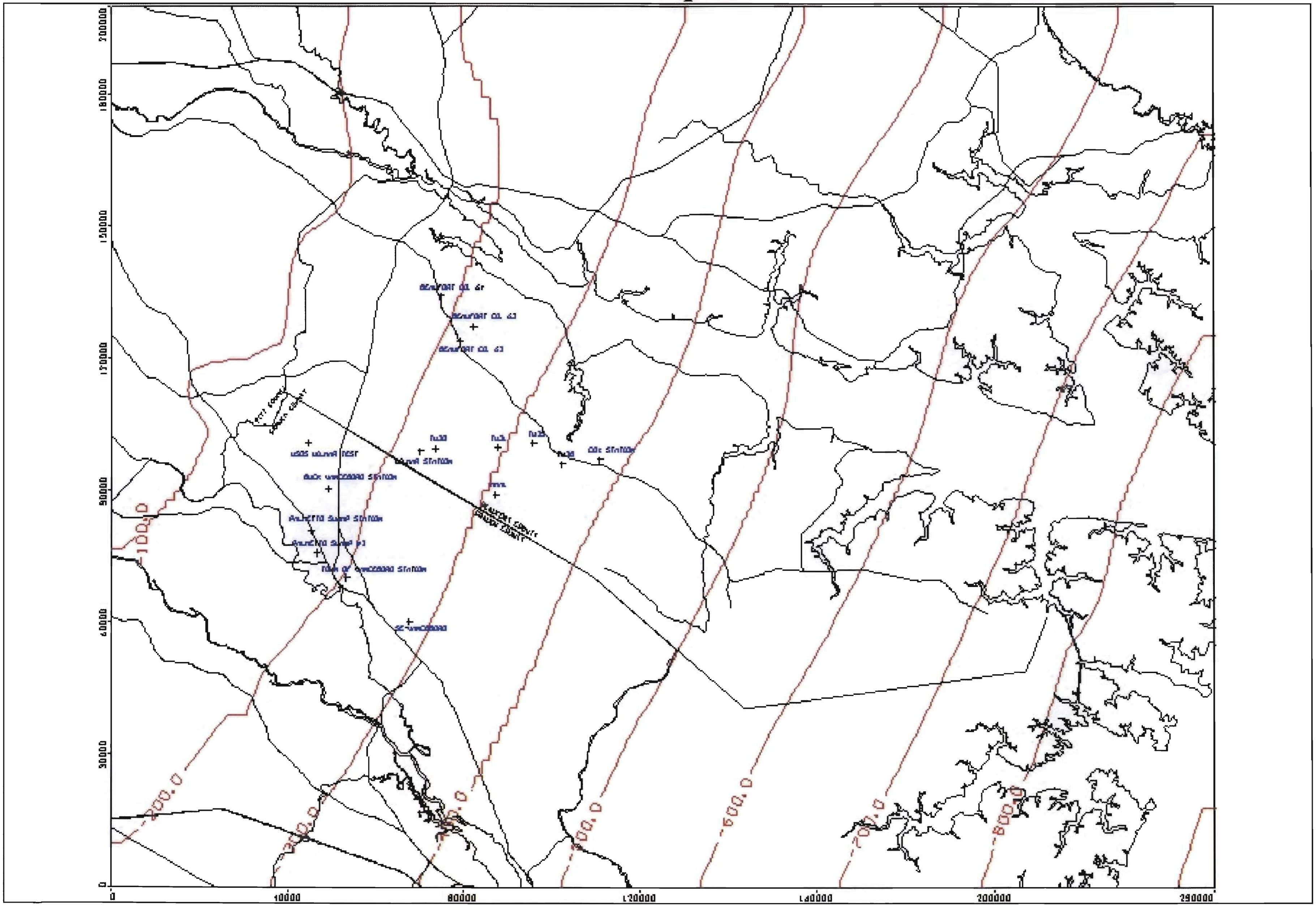
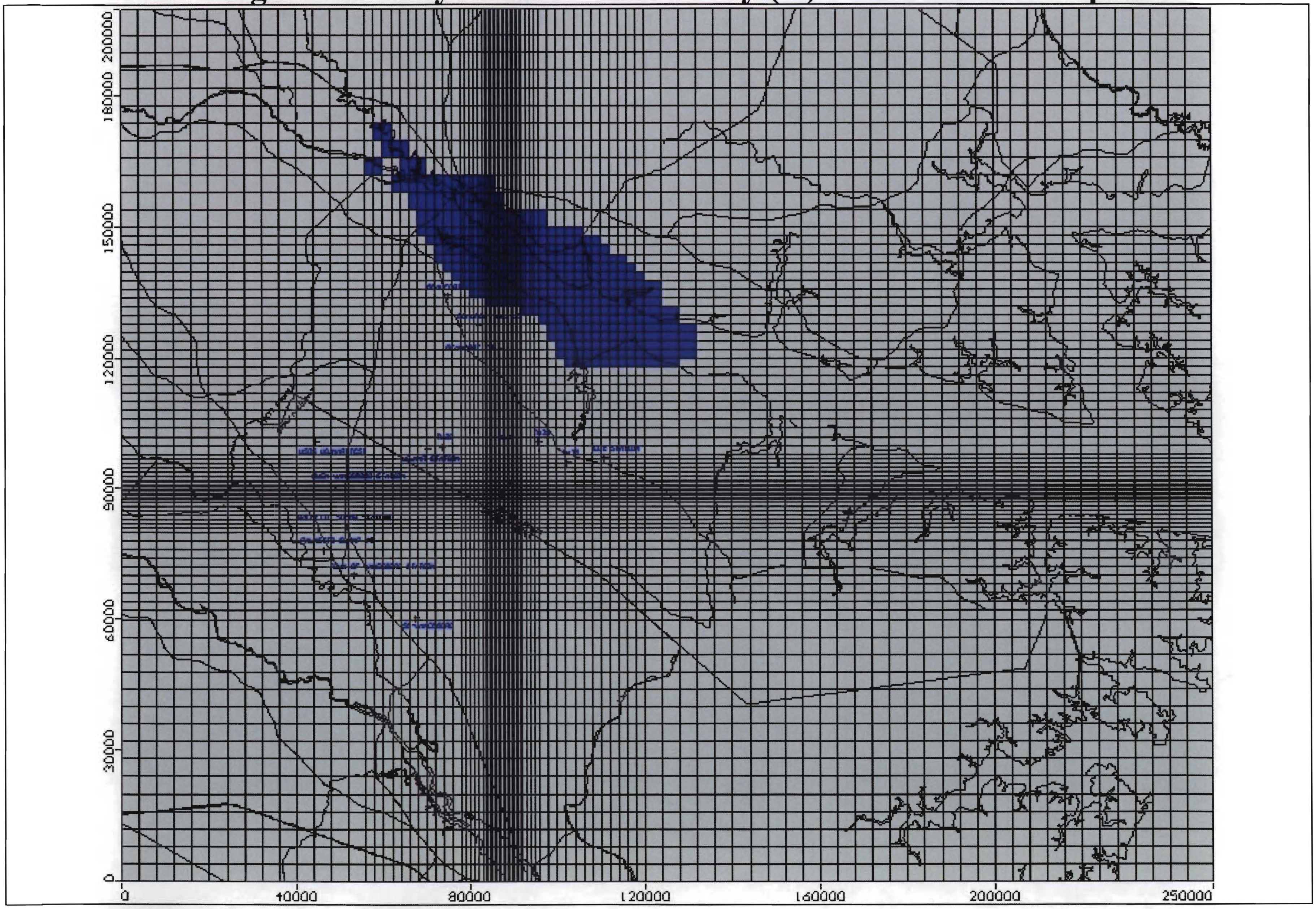


Figure 8-13: Hydraulic Conductivity (K) of the Surficial Aquifer



K = 50 ft/day

K = 60 ft/day

Figure 8-14: Hydraulic Conductivity (K) of the Yorktown Confining Layer

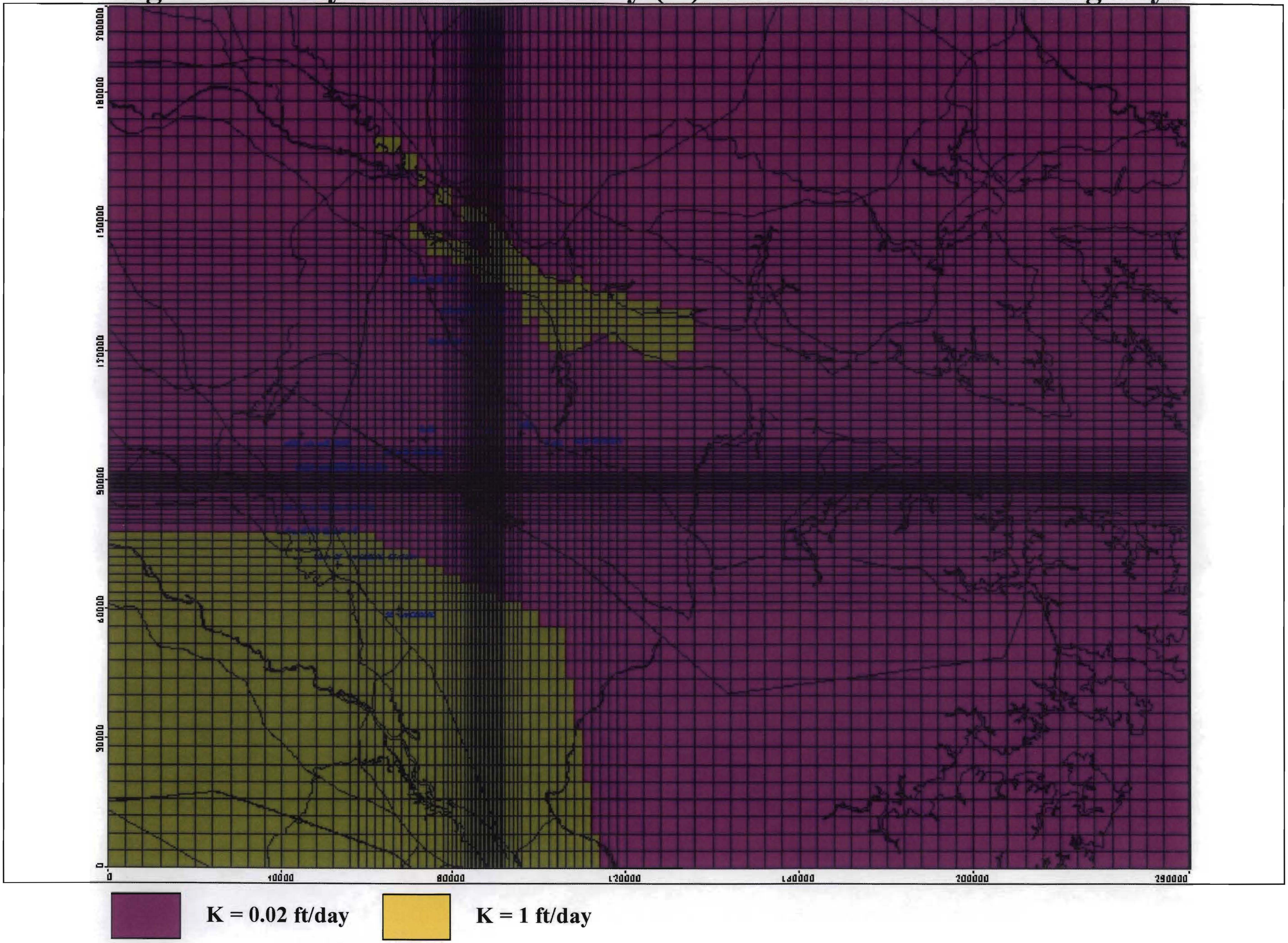


Figure 8-15: Hydraulic Conductivity (K) of the Yorktown Aquifer

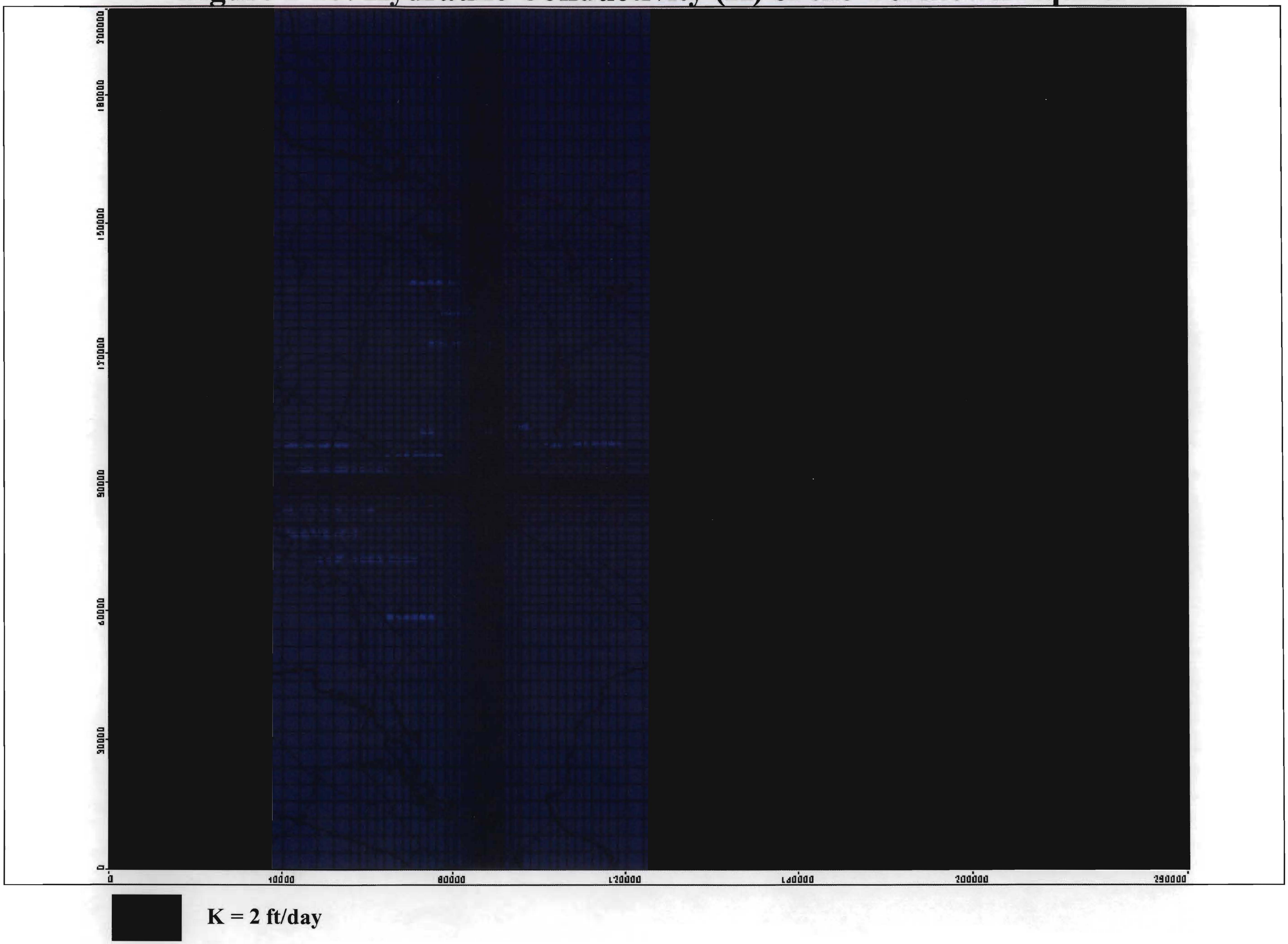
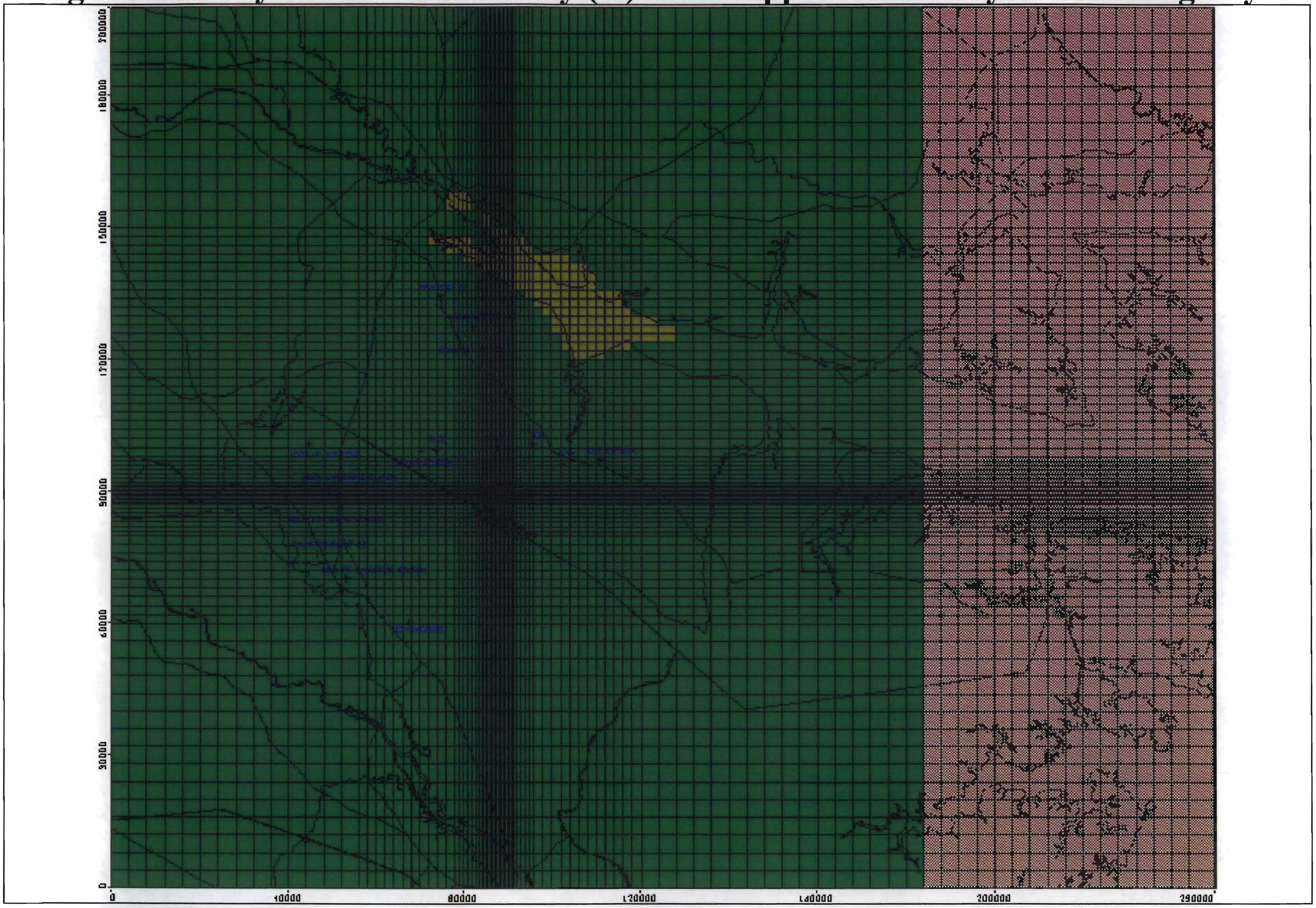


Figure 8-16: Hydraulic Conductivity (K) of the Upper Castle Hayne Confining Layer

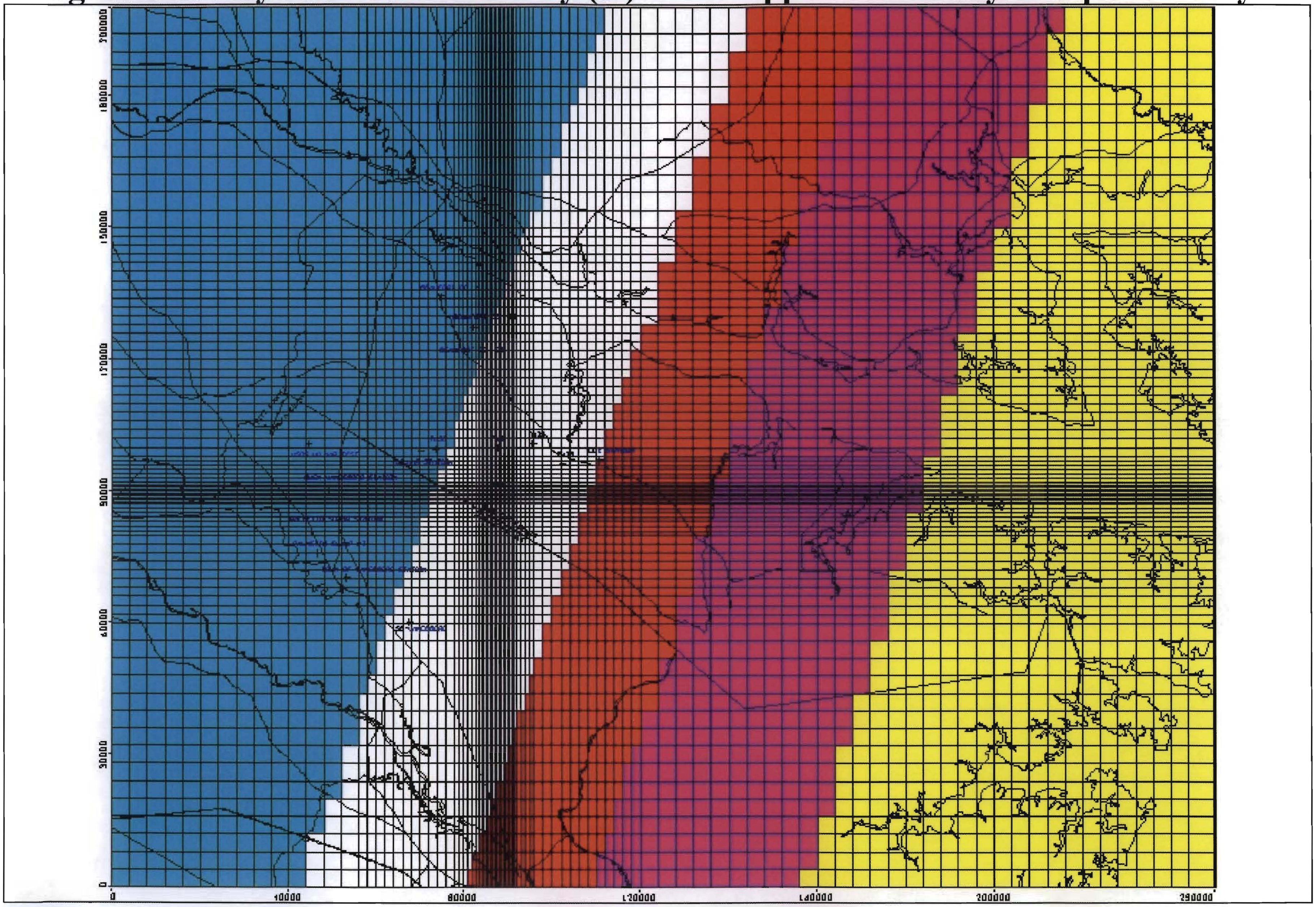


K = 1 e-6 ft/day

K = 1 ft/day

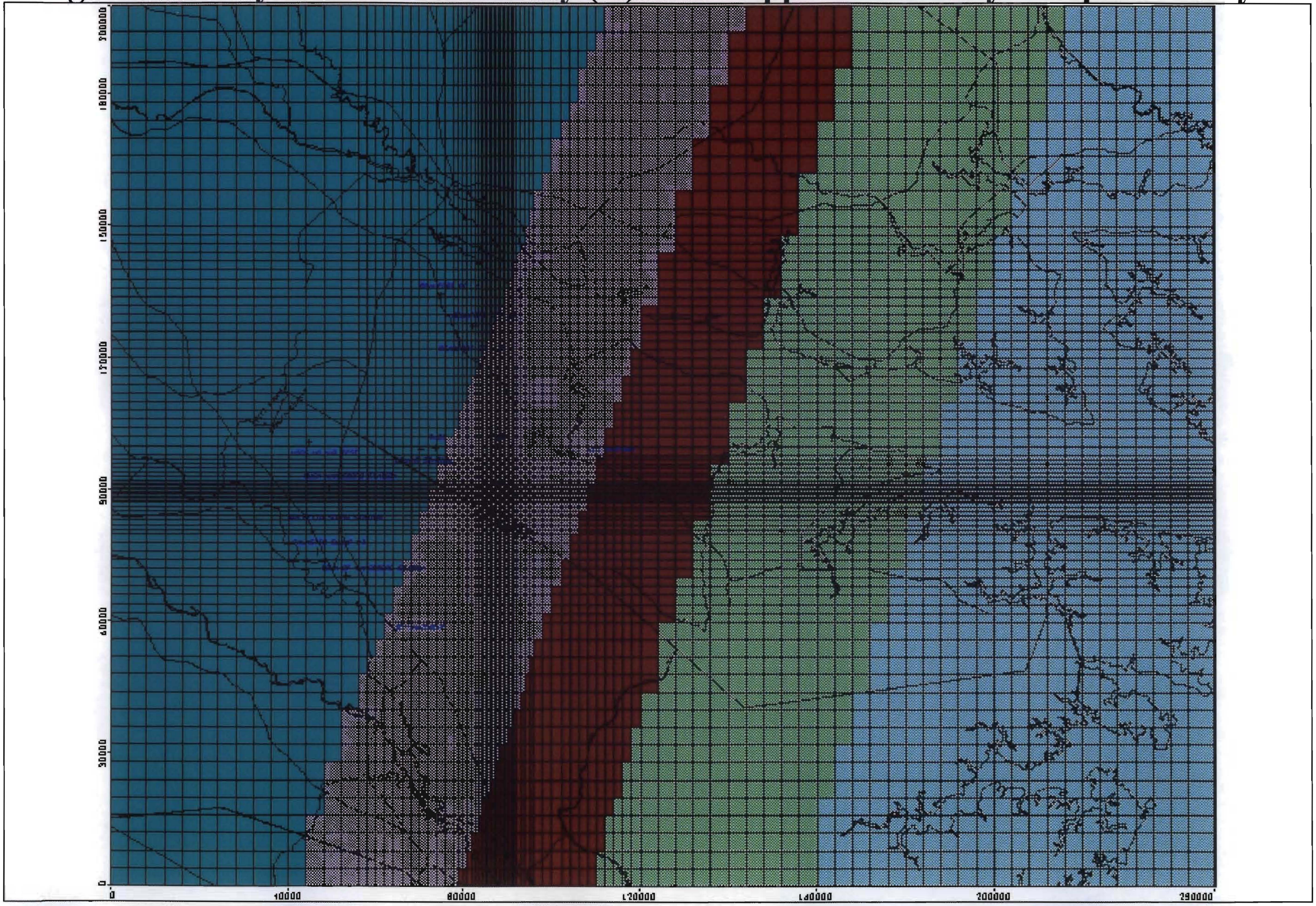
K = 5 e-7 ft/day

Figure 8-17: Hydraulic Conductivity (K) of the Upper Castle Hayne Aquifer – Layer 5



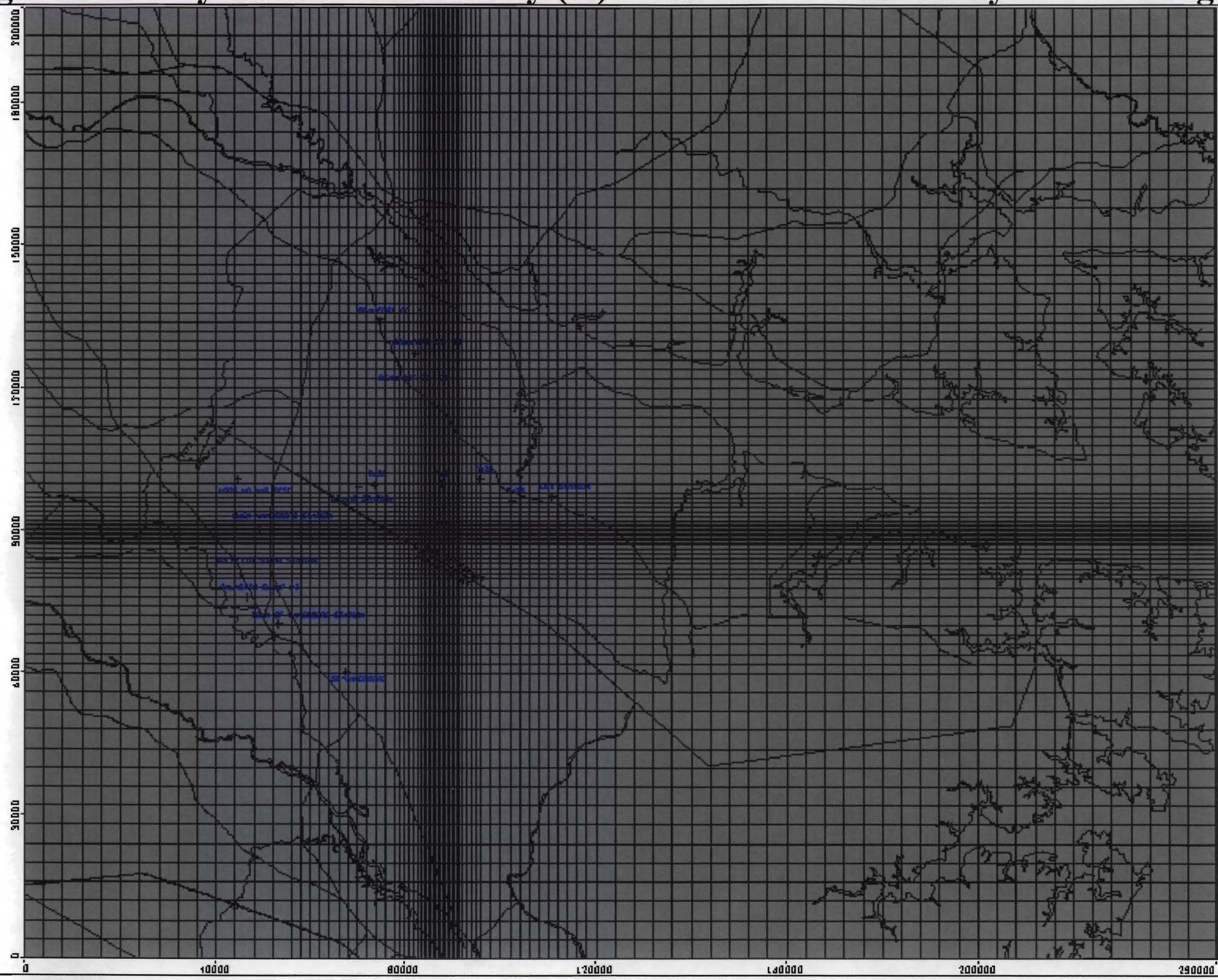
K = 80 ft/day | K = 70 ft/day | K = 180 ft/day | K = 260 ft/day | K = 320 ft/day

Figure 8-18: Hydraulic Conductivity (K) of the Upper Castle Hayne Aquifer – Layer 6



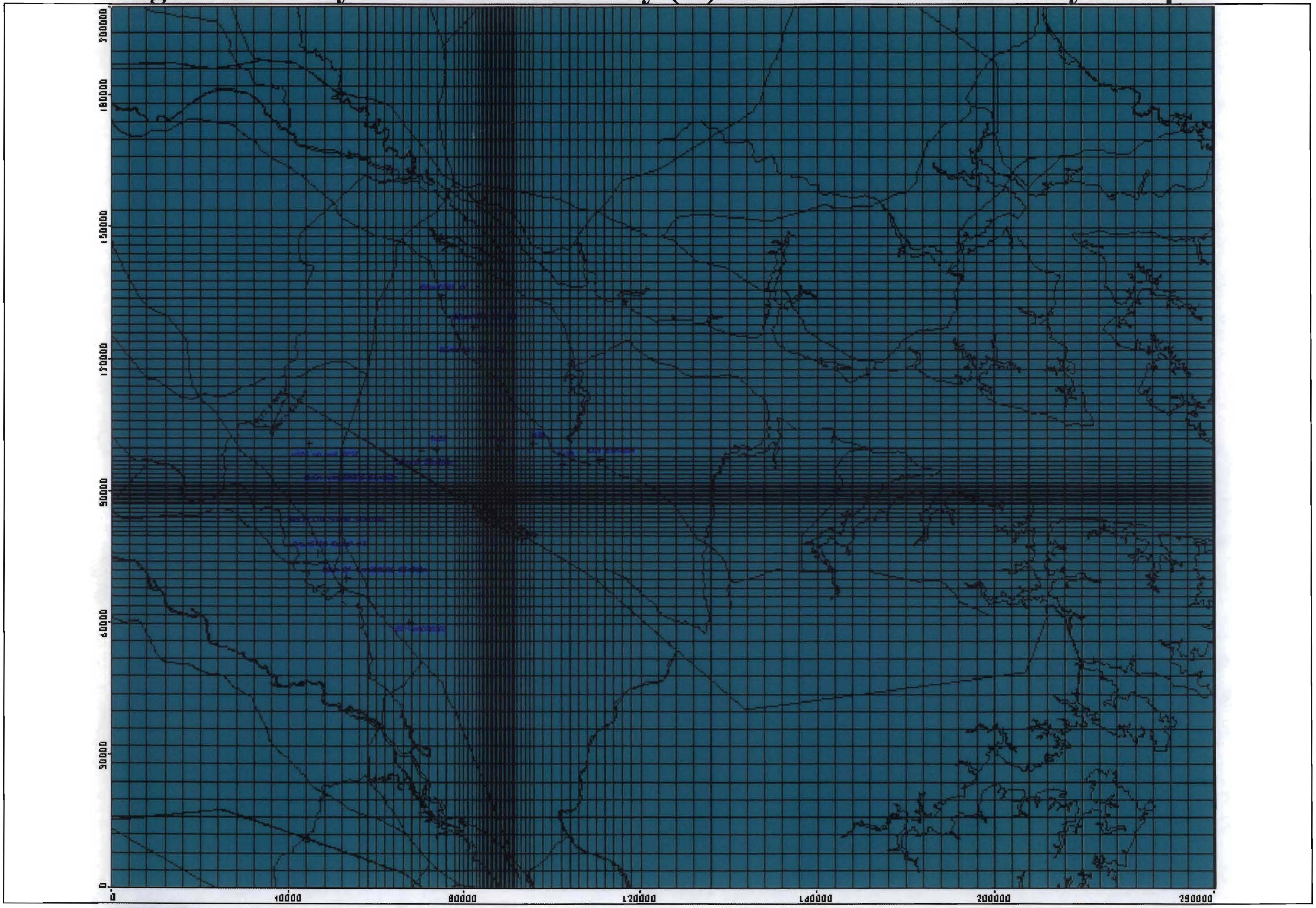
K = 2 ft/day	K = 3 ft/day	K = 8 ft/day	K = 10 ft/day	K = 15 ft/day
2.5%	4%	4%	4%	5%

Figure 8-19: Hydraulic Conductivity (K) of the Lower Castle Hayne Confining Layer



K = 0.001 ft/day

Figure 8-20: Hydraulic Conductivity (K) of the Lower Castle Hayne Aquifer



K = 2 ft/day

Figure 8-21: Hydraulic Conductivity (K) of the Beaufort Confining Layer and Aquifer

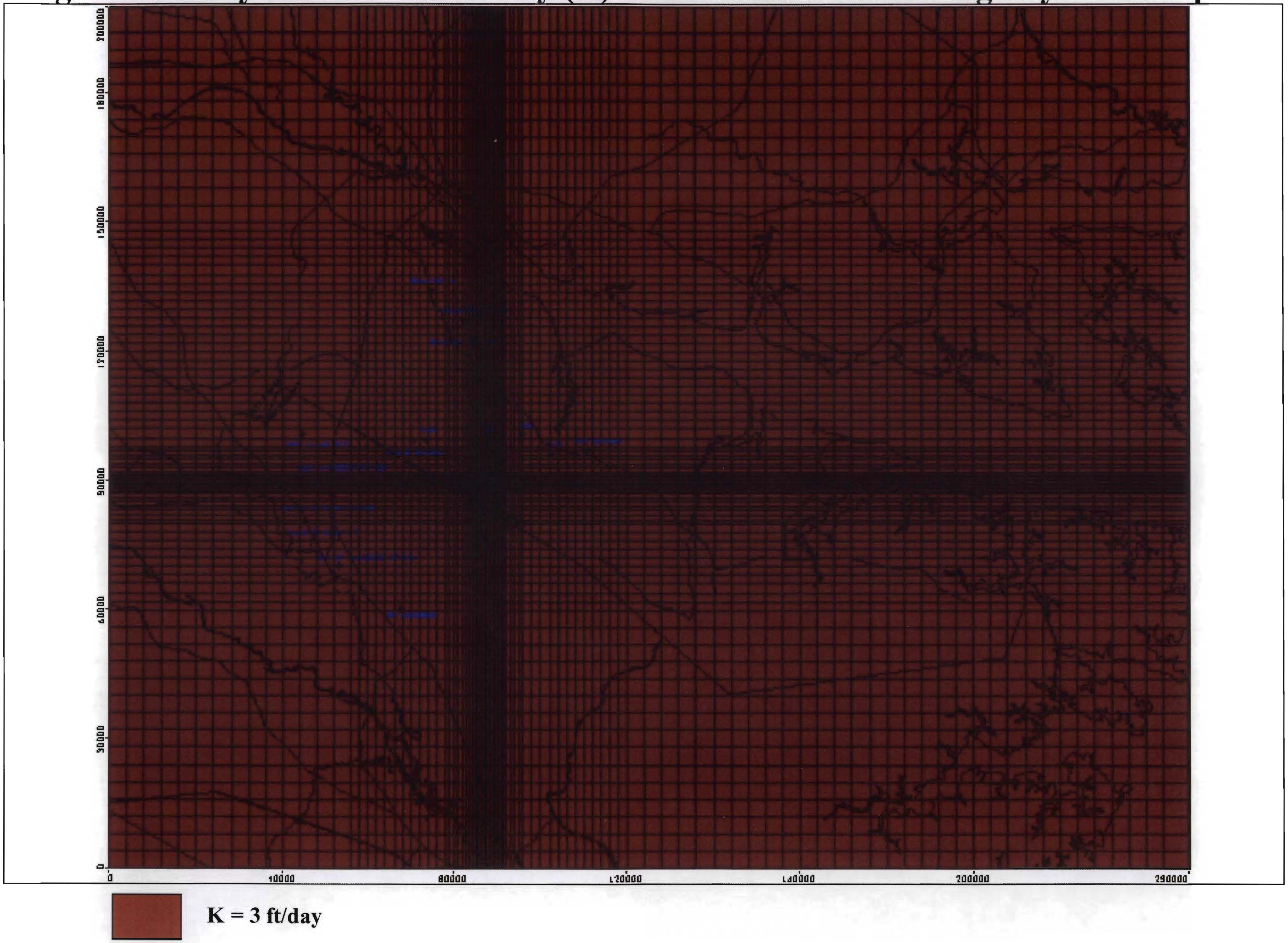
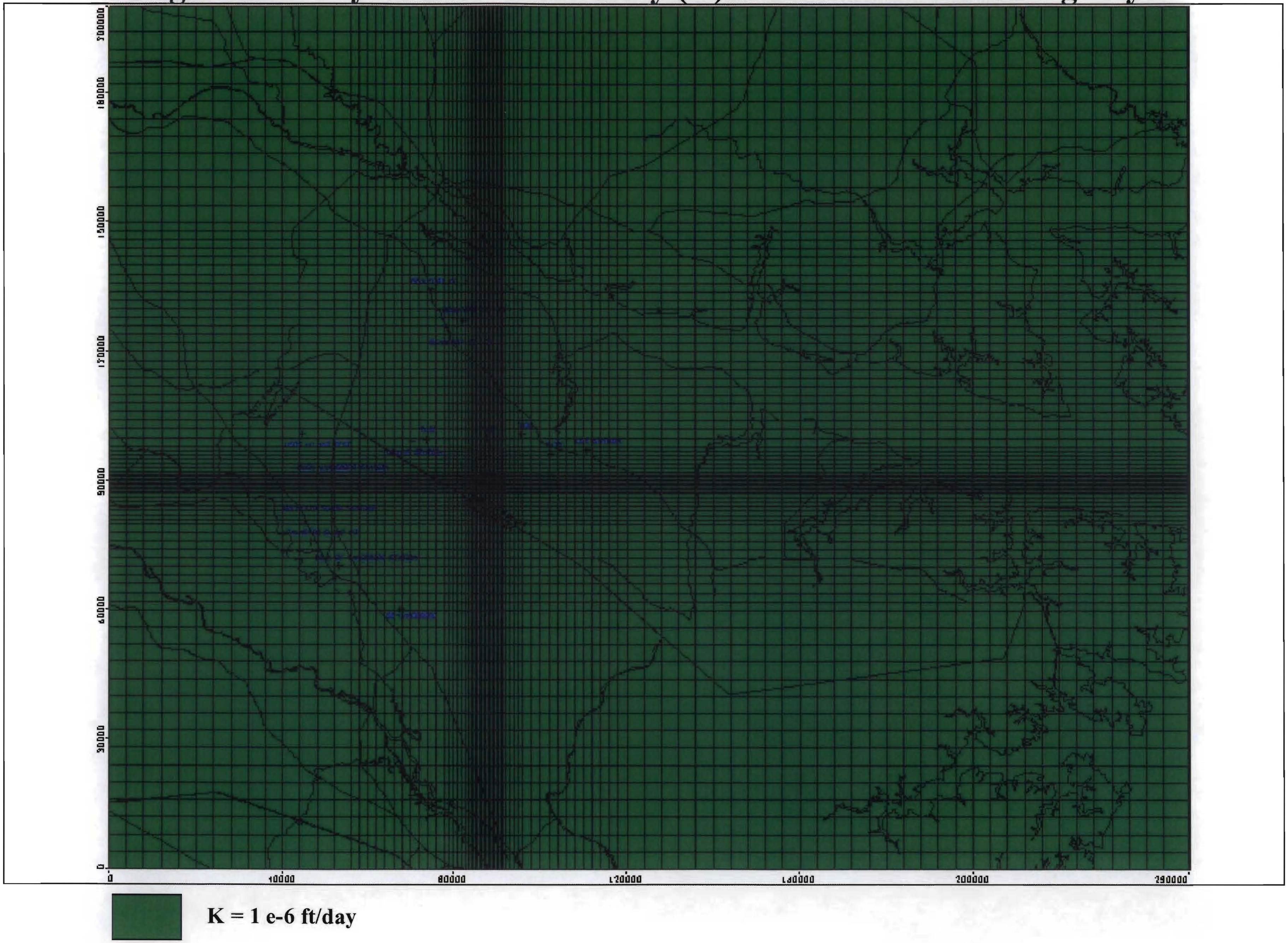


Figure 8-22: Hydraulic Conductivity (K) of the Peedee Confining Layer



K = 1 e-6 ft/day

Figure 8-23: Steady-State Calibration Graph

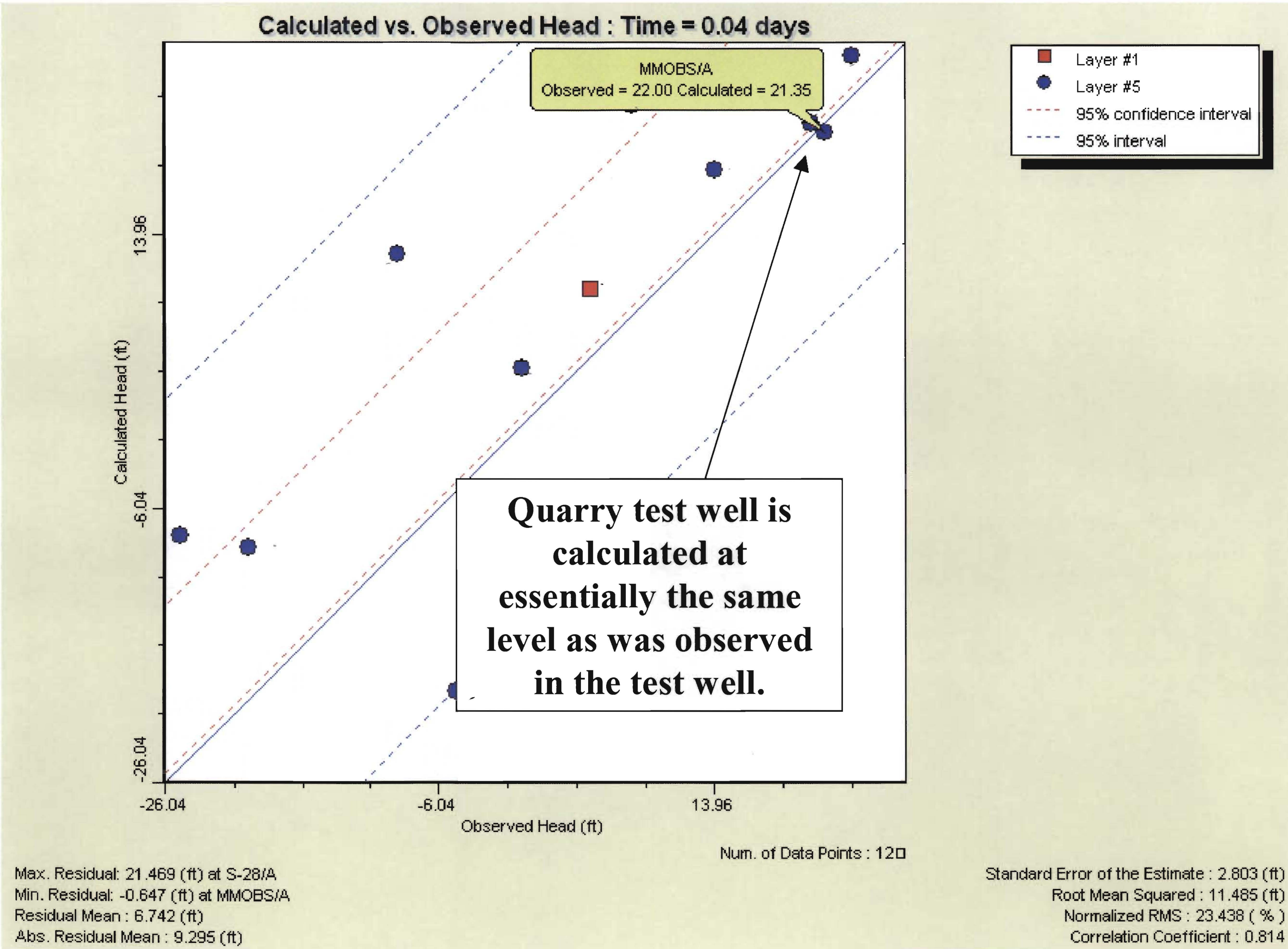


Figure 8-24: Simulated 2006 PCS Cone in the Upper Castle Hayne Aquifer

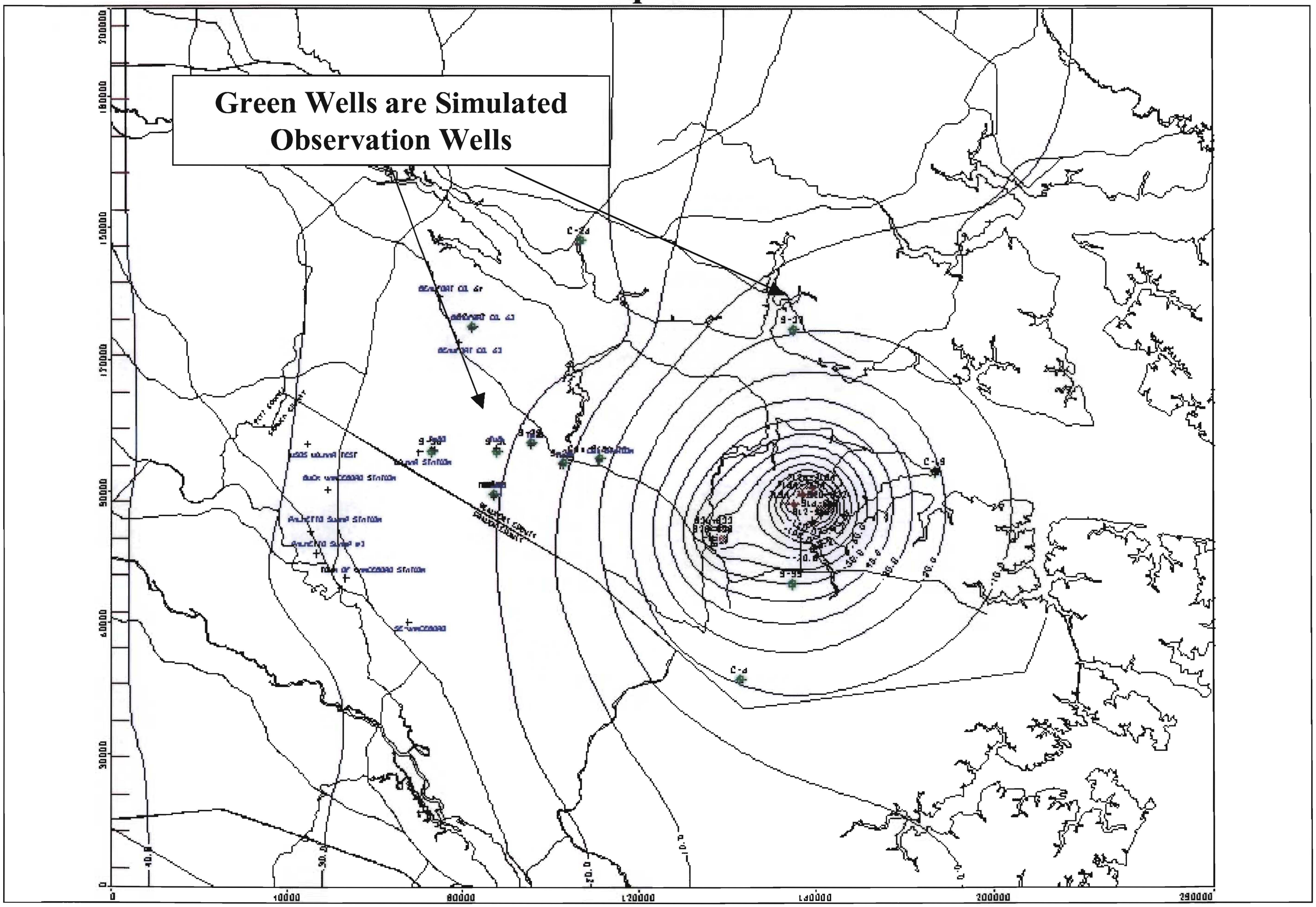


Figure 8-25: Transient Calibration Graph

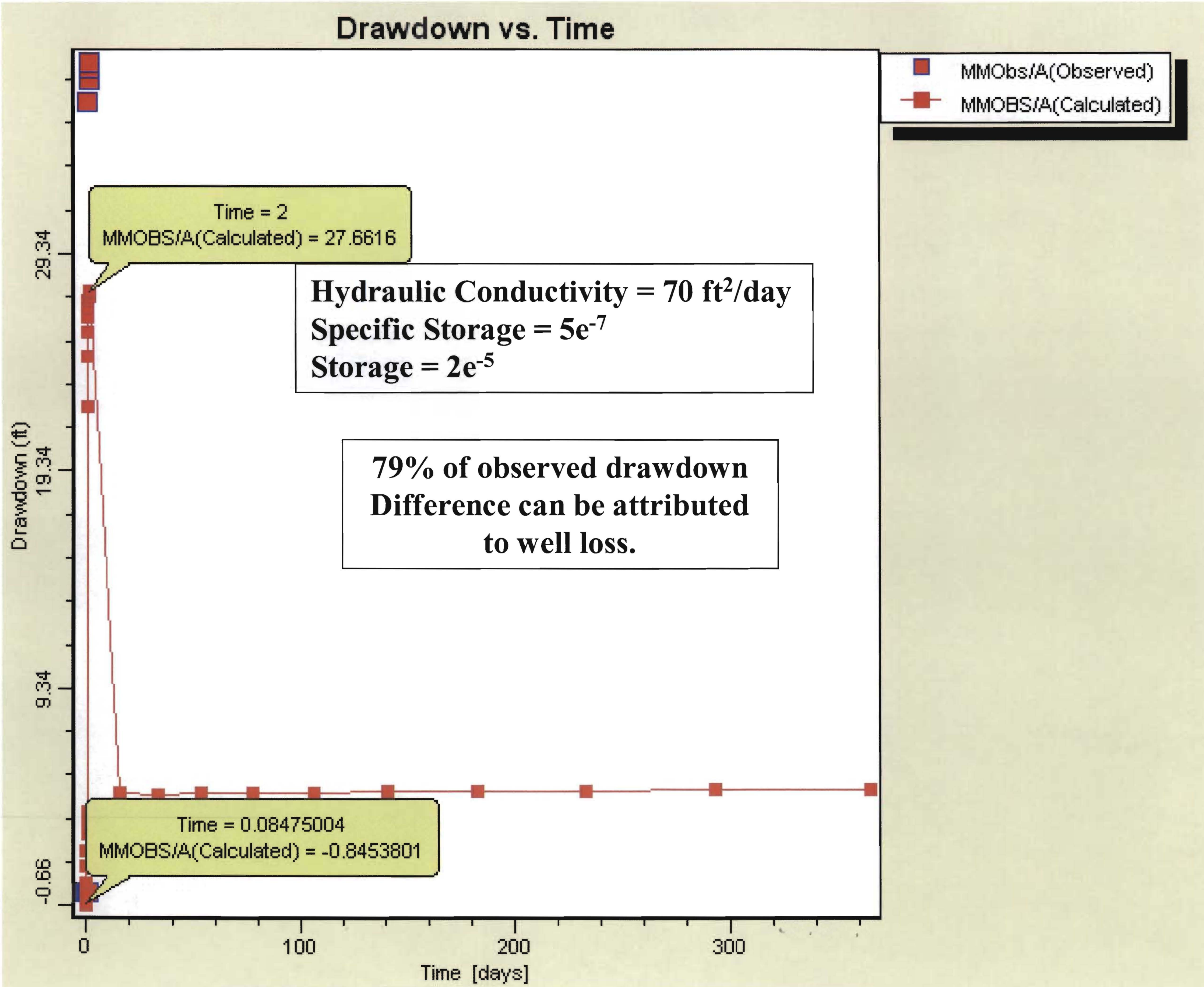


Figure 8-26: Simulated Dewatering Wells

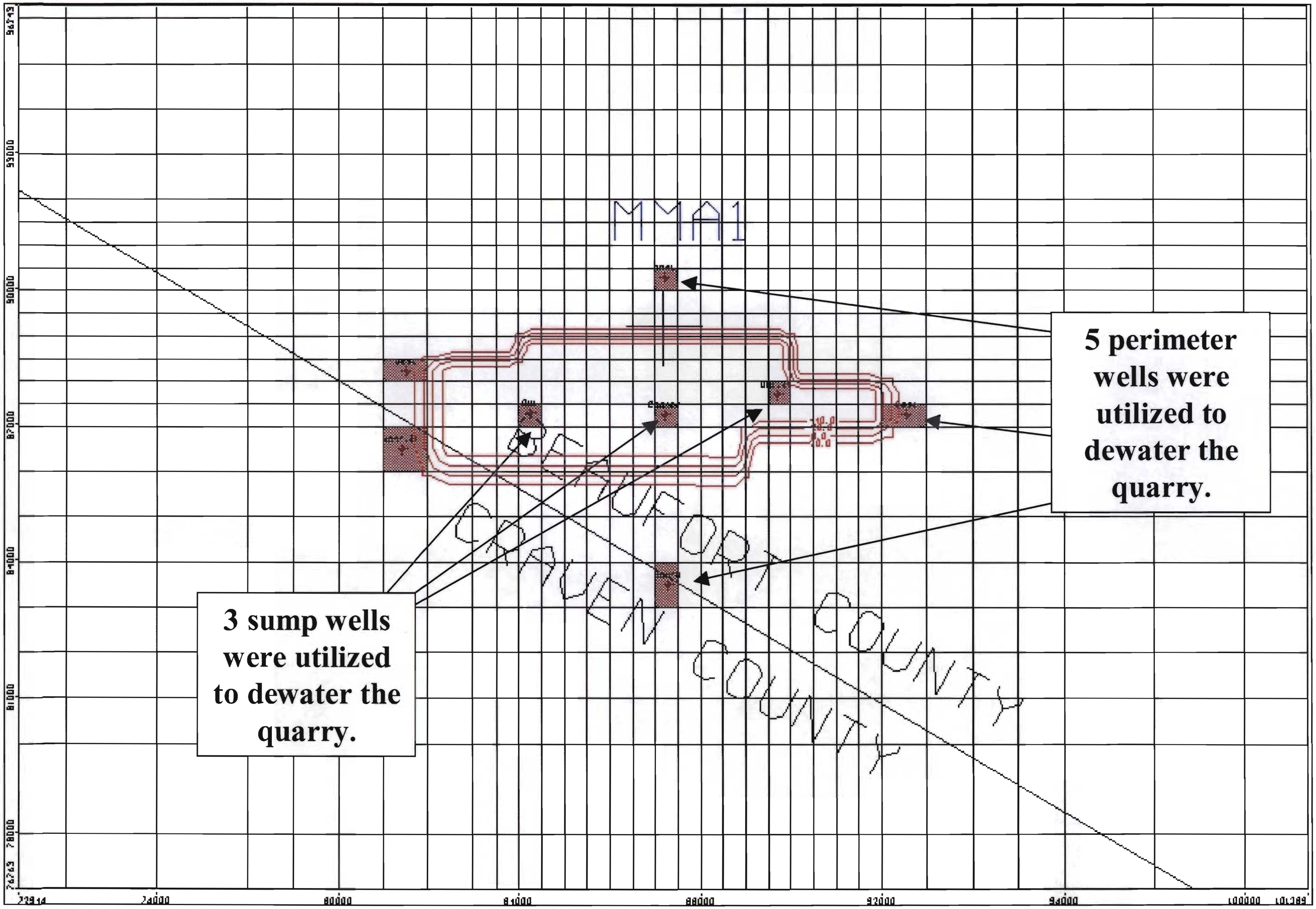


Figure 8-27: Water Levels in the Upper Castle Hayne Aquifer with Proposed Quarry Dewatered

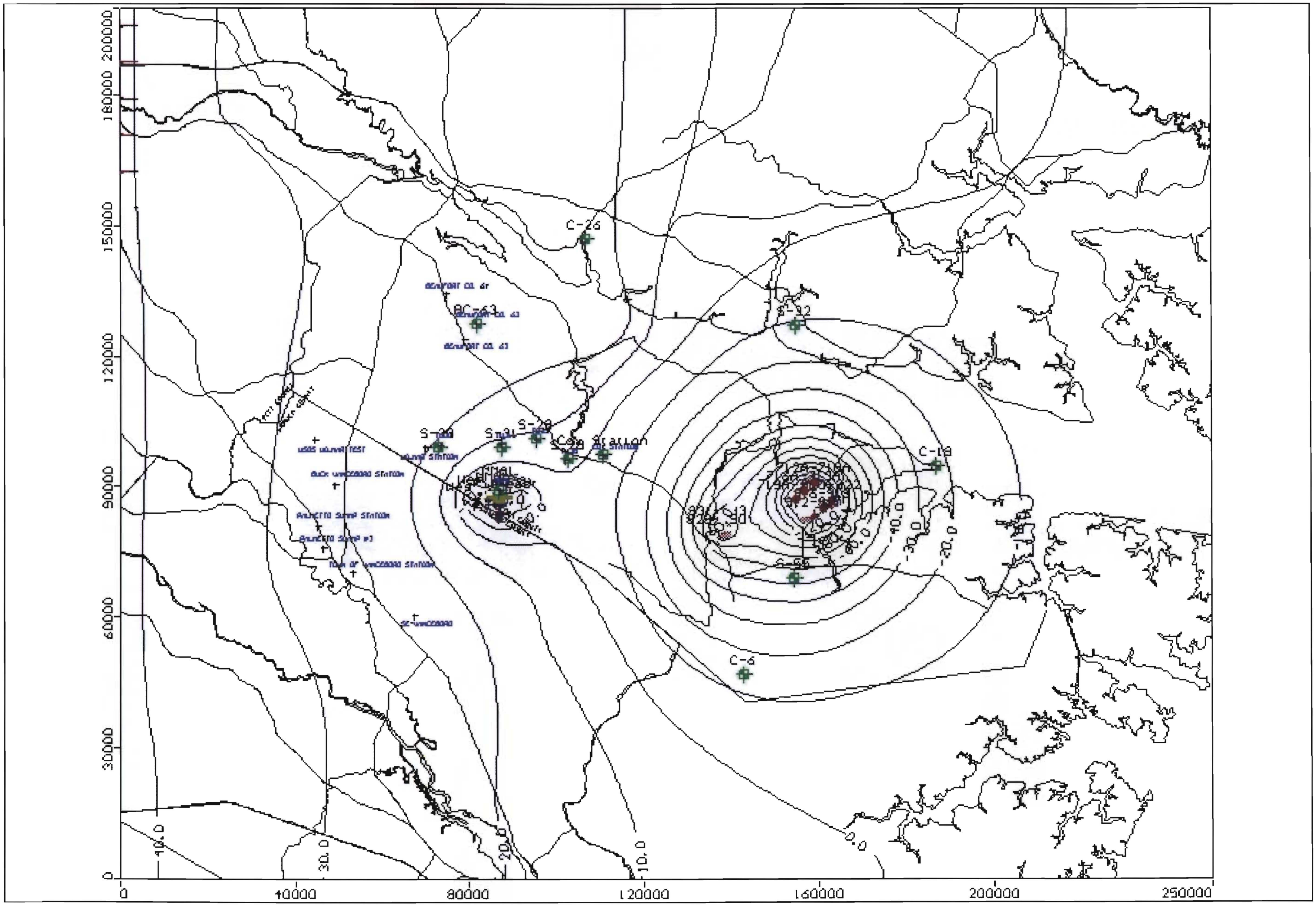


Figure 8-28: Close-up of Water Levels in the Upper Castle Hayne Aquifer with the Proposed Quarry Dewatered

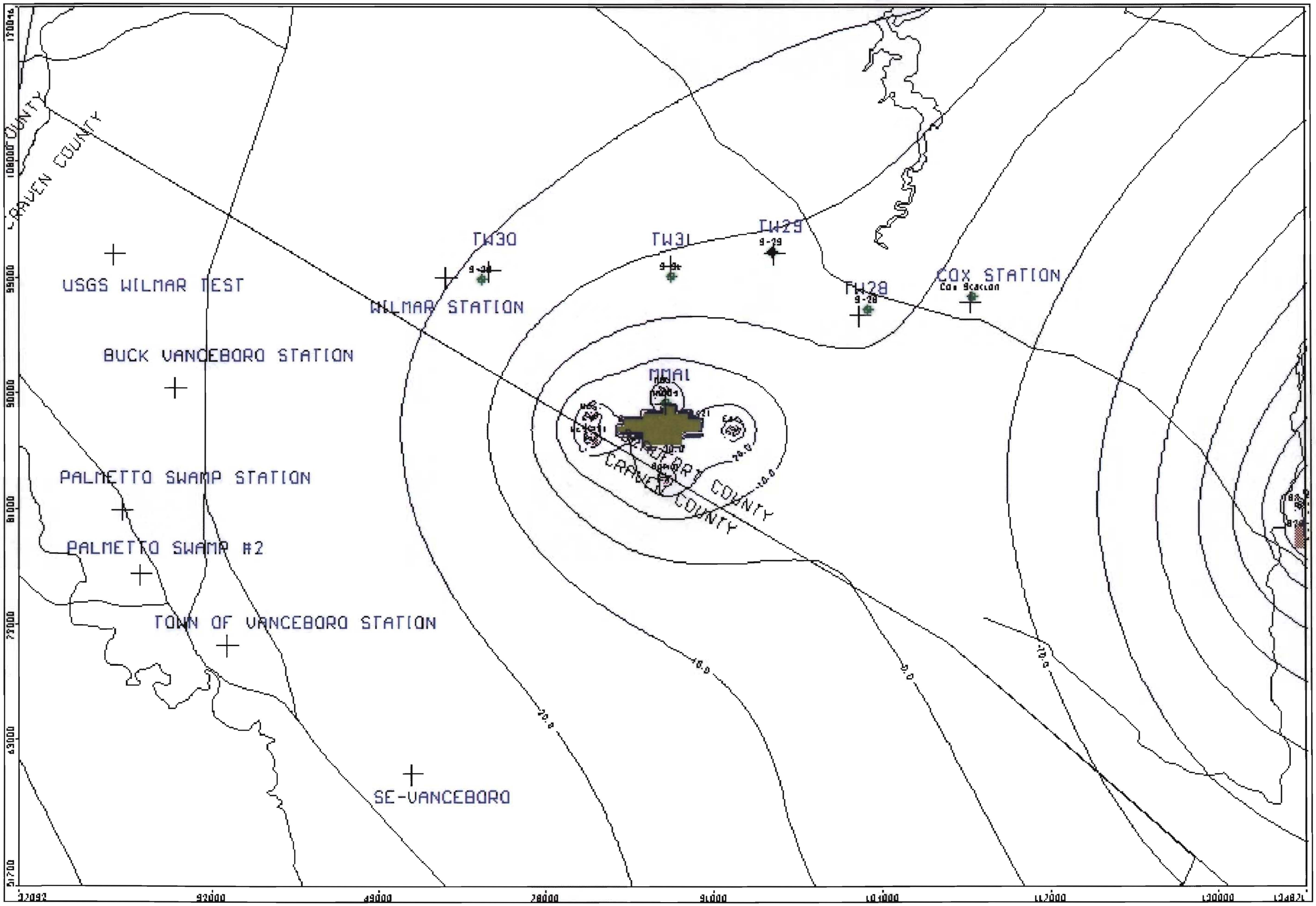


Figure 8-29: Drawdown in the Upper Castle Hayne Aquifer with Proposed Quarry Dewatered

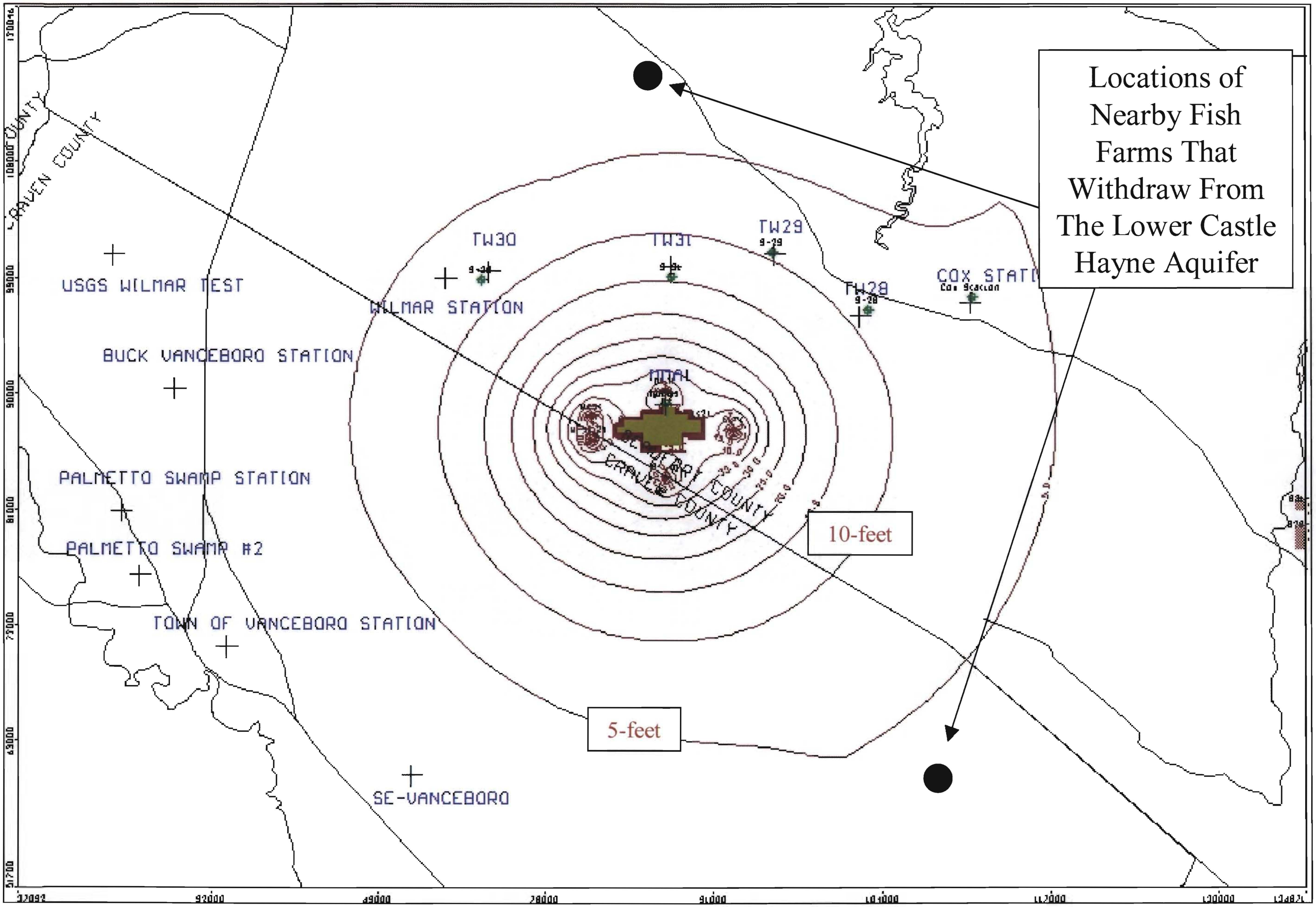


Figure 8-30: Cross Section of Proposed Mine Dewatering

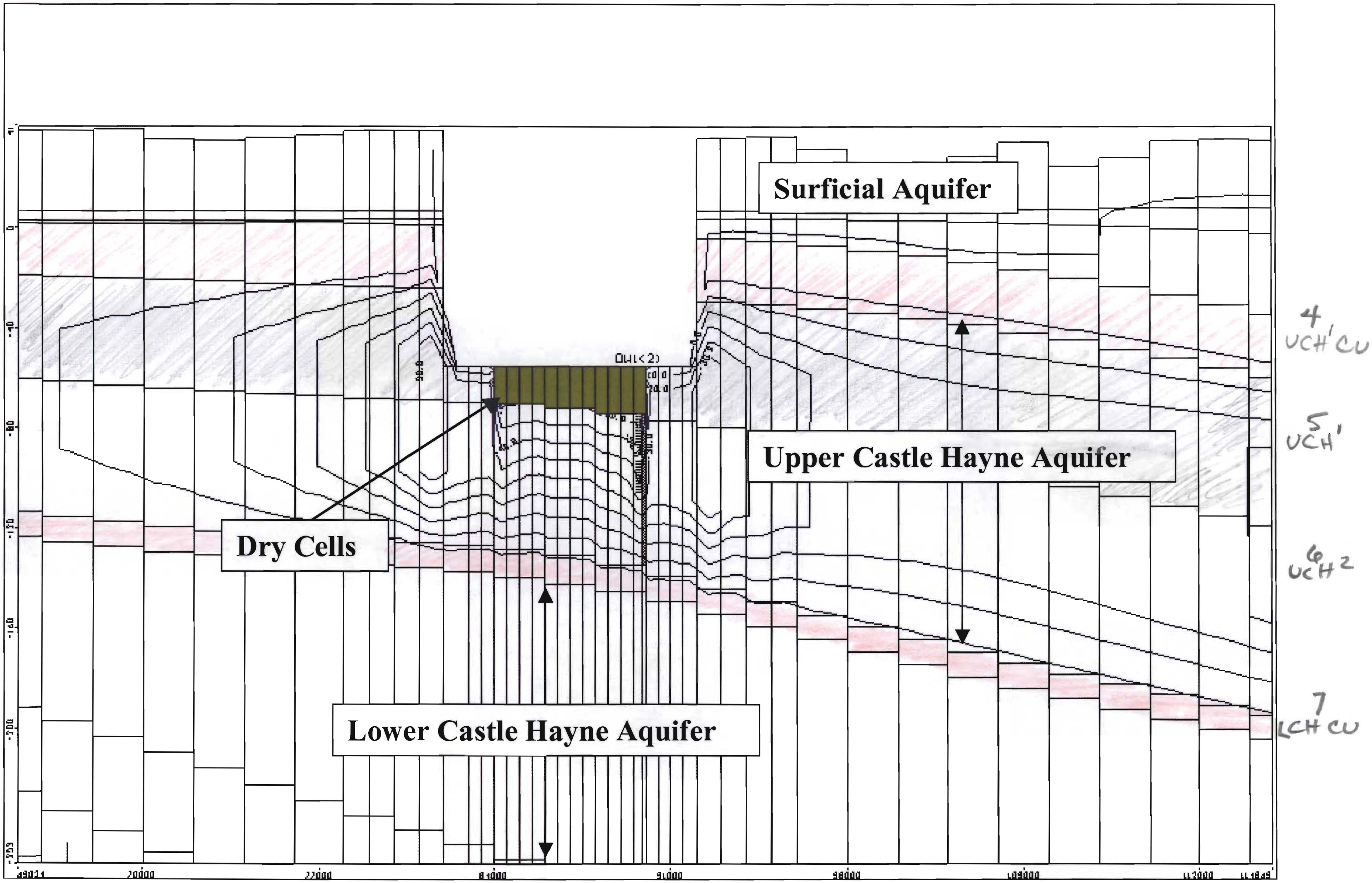


Figure 8-31: Less Than One Foot of Drawdown in the Lower Castle Hayne Aquifer During Proposed Mine Dewatering

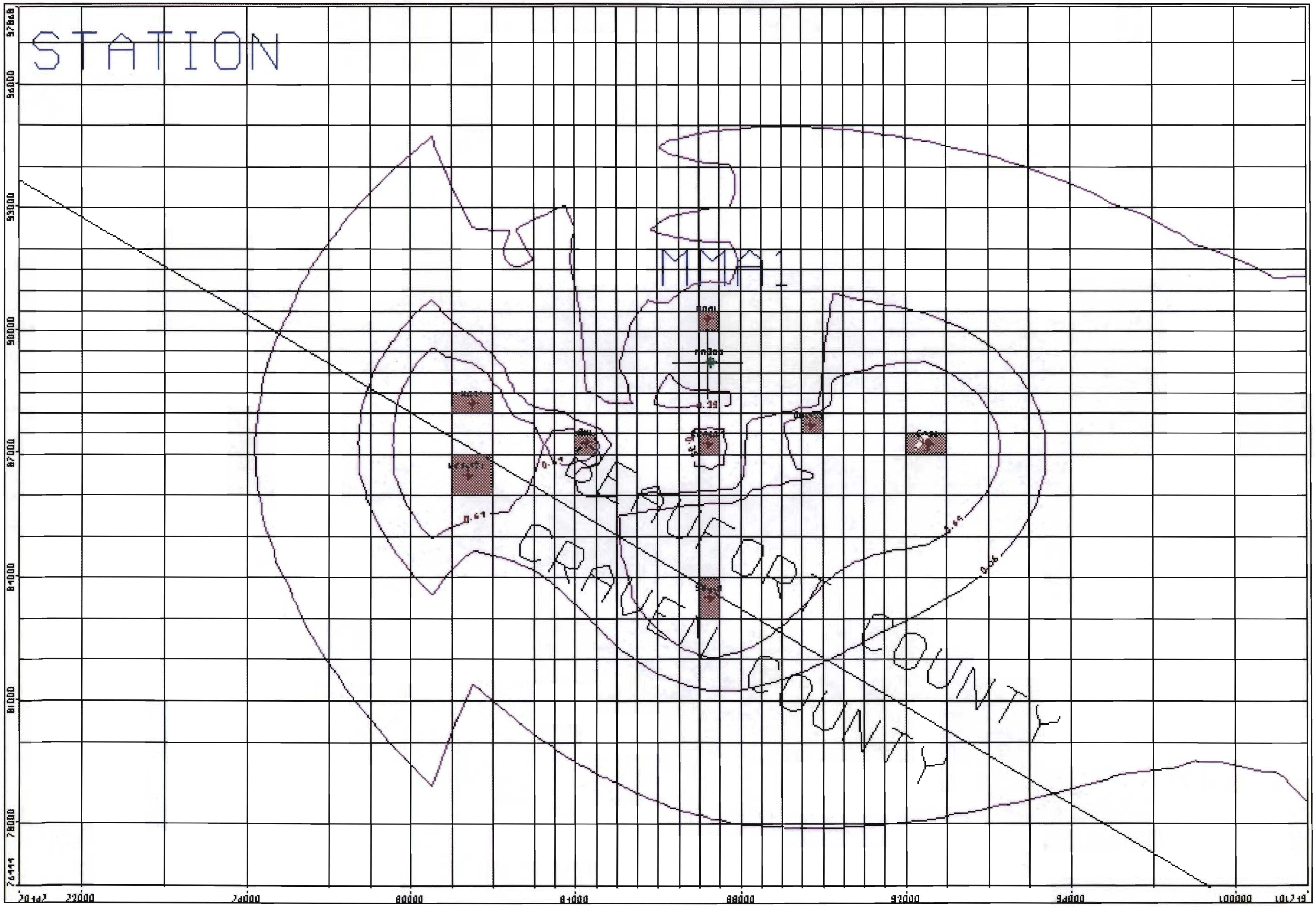


Figure 8-32: Water Levels in the Upper Castle Hayne Aquifer with Proposed Quarry Dewatered for the Higher Conductivity Simulation

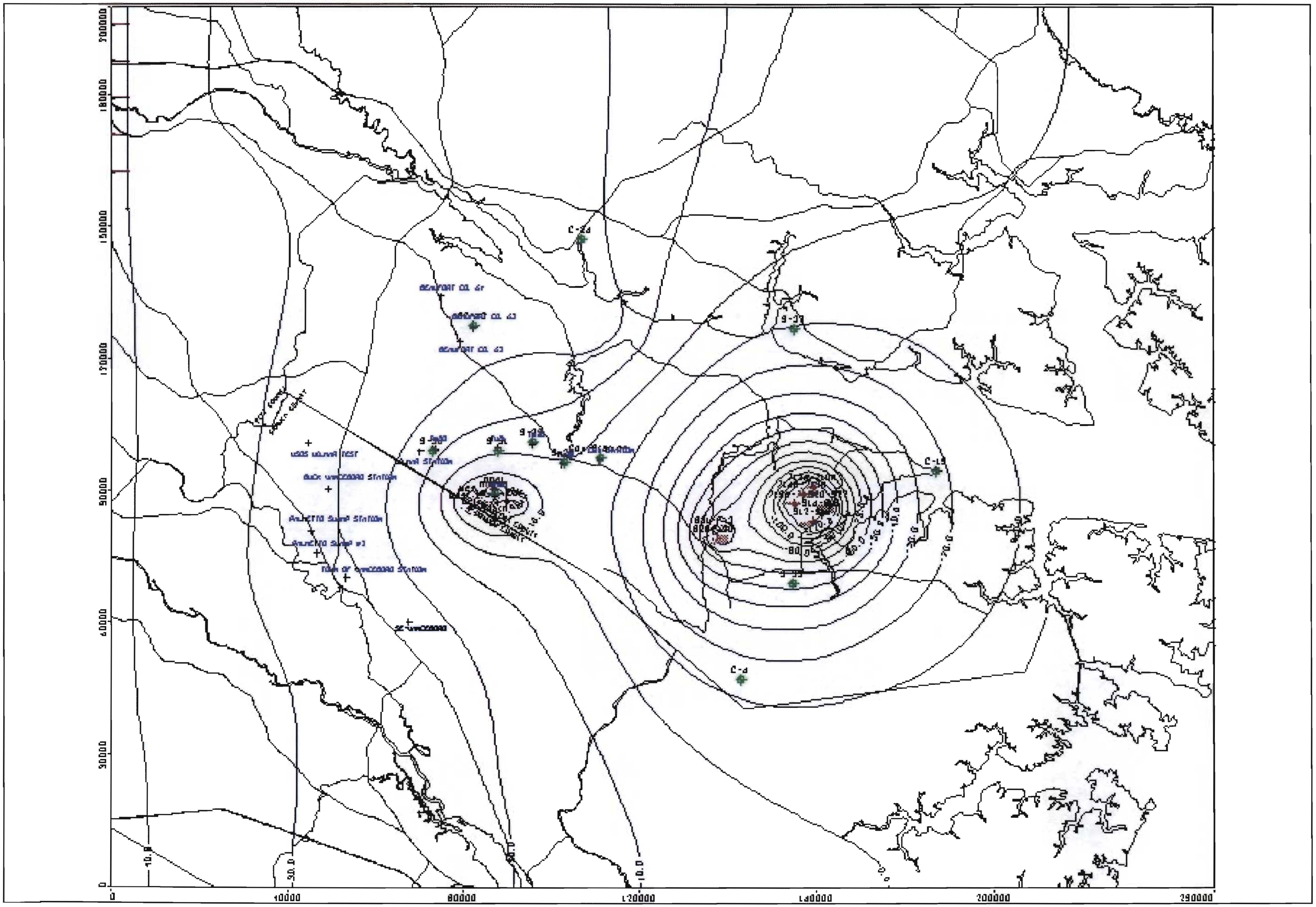


Figure 8-33:Close-up of Water Levels in the Upper Castle Hayne Aquifer with Proposed Quarry Dewatered for the Higher Conductivity Simulation

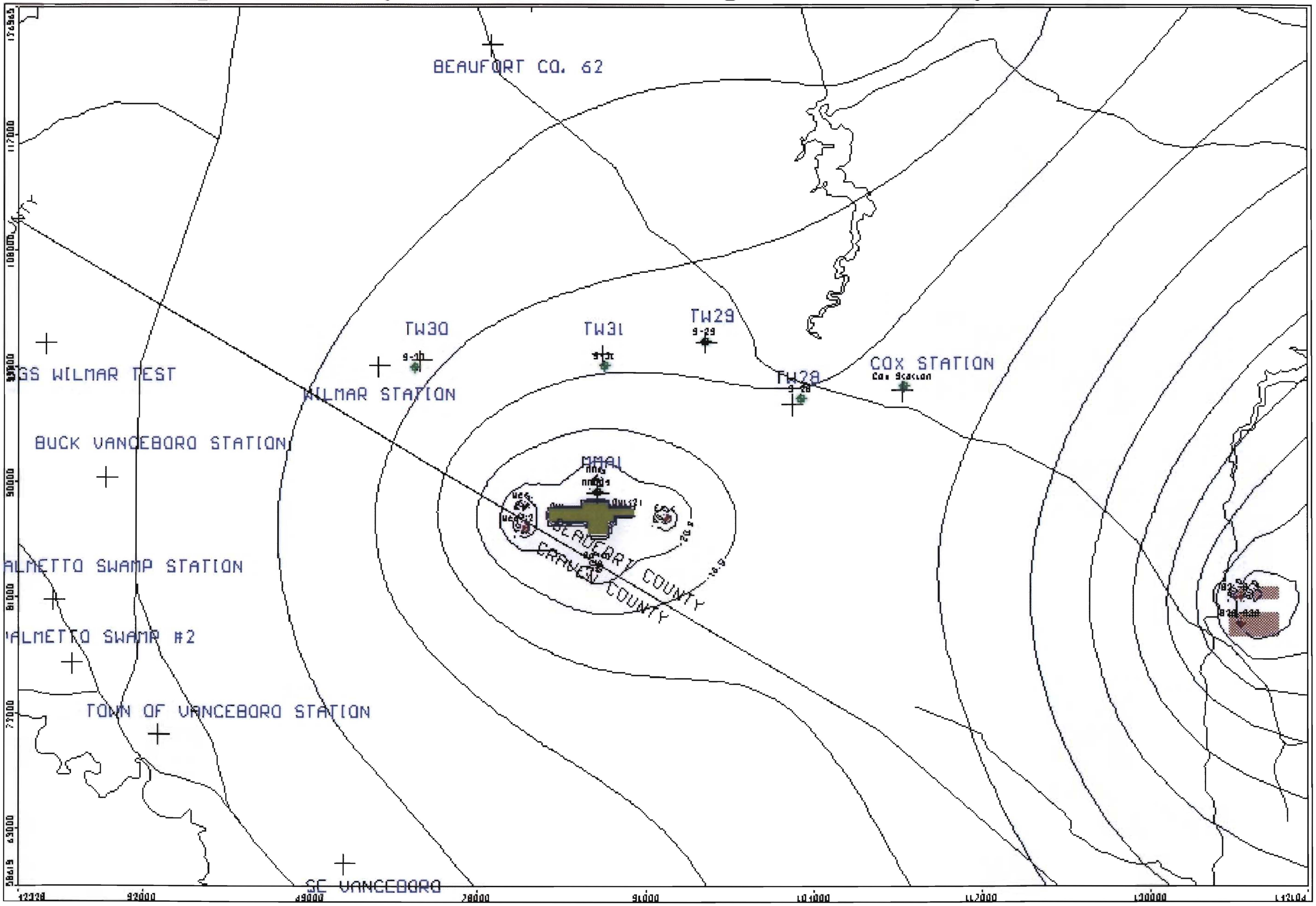
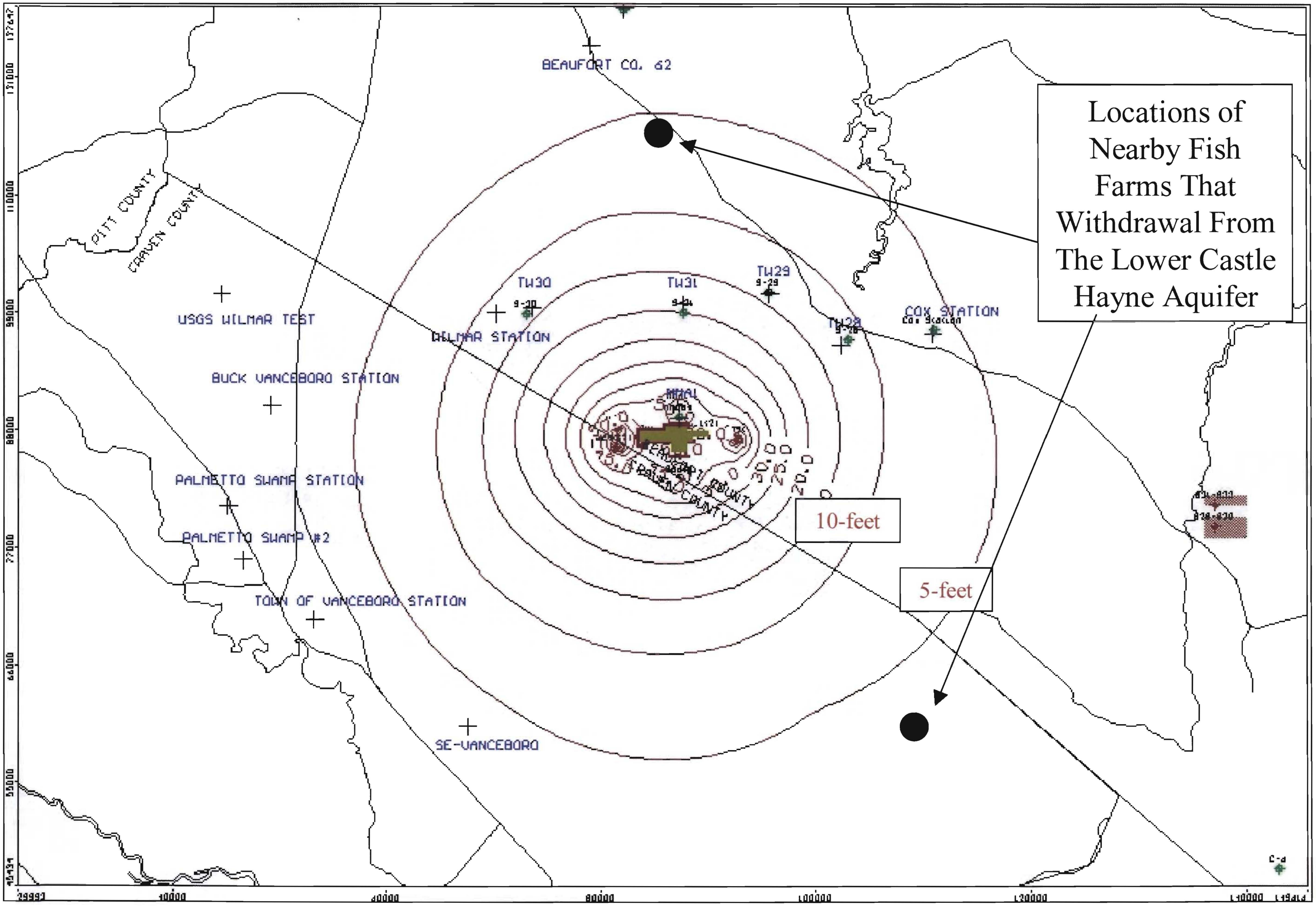


Figure 8-34: Drawdown in the Upper Castle Hayne Aquifer with Proposed Quarry Dewatered for the Higher Conductivity Simulation



Appendix I

Well Permit and Well Construction Records

Michael F. Easley, Governor

William G. Ross Jr., Secretary
North Carolina Department of Environment and Natural Resources

Coleen H. Sullins, Director
Division of Water Quality

DIVISION OF WATER QUALITY
Aquifer Protection Section

June 8, 2007

Mr. Horace Wilson
Martin Marietta Aggregates, Inc.
2710 Wycliff Road, Suite 104
Raleigh, North Carolina 27607

SUBJECT: Well Construction Permit No. WS0700877
Martin Marietta Aggregates, Inc., Industrial Supply/Mine Depressurization
Old Welbourn Air Strip, Welbourn Road, near Nancy Branch Road
Beaufort County, North Carolina

Dear Mr. Wilson:

In accordance with your application received June 7, 2007, we are forwarding herewith Well Construction Permit No. WS070087 dated June 8, 2007 issued to Martin Marietta Aggregates, Inc., for the construction of one (1) water supply well located at the old Welbourn Air Strip, Welbourn Road, near Nancy Branch Road in Beaufort County, North Carolina.

This Permit will be effective from the date of its issuance until December 8, 2007, and shall be subject to the conditions and limitations as specified therein.

If any parts, requirements, or limitations contained in this Permit are unacceptable to you, you have the right to an adjudicatory hearing before a hearing officer upon written demand to the Director within 30 days following receipt of this Permit, identifying the specified issues to be contended. Unless such demand is made, this Permit shall be final and binding.

Groundwater information collected in the coastal plain counties indicates declining groundwater levels in the Cretaceous Aquifer System. In an effort to protect and conserve the groundwater resources, the Division encourages water users to develop and implement a water conservation and management plan.

A Well Construction Record (GW-1) must be filled out by the driller and submitted to Environment & Natural Resources, Aquifer Protection Section, 1617 Mail Service Center, Raleigh, NC 27699-1636, within 30 days upon completion of the well construction.

If additional information or clarification is required, please contact me at (252) 948-3939.

Sincerely,

David May
Aquifer Protection Regional Supervisor
Washington Regional Office

cc: James Holley, GMA, Inc. (2025-E Eastgate Dr., Greenville, NC 27858)
Magette Well and Pump Co. (2342 US 13 South, Ahoskie, NC 27910)
Weyerhaeuser Company, (Attn: Land Use Manager, PO Box 1391, New Bern, NC 28569)
Aquifer Protection Central Files
DWR
WaRO

NORTH CAROLINA
ENVIRONMENTAL MANAGEMENT COMMISSION
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
PERMIT FOR THE CONSTRUCTION OF A WELL OR WELL SYSTEM

In accordance with the provisions of Article 7, Chapter 87, North Carolina General Statutes, and other applicable Laws, Rules and Regulations,

PERMISSION IS HEREBY GRANTED TO

Mr. Horace Wilson

FOR THE CONSTRUCTION OF one (1) industrial supply/mine depressurization well located in the Tertiary System. The well site location is at the old Welbourn Air Strip, Welbourn Road, near Nancy Branch Road in Beaufort County, North Carolina, in accordance with the application dated June 5, 2007, and in conformity with the specifications and supporting data, all of which are filed with the Department of Environment and Natural Resources and are considered a part of this permit.

This Permit is for well construction only, and does not waive any provisions or requirements of the Water Use Act of 1967, or any other applicable laws or regulations. Construction of a well under this Permit shall be in compliance with the North Carolina Well Construction Regulations and Standards, and any other laws and regulations pertaining to well construction.

This Permit will be effective from the date of its issuance until December 8, 2007, and shall be subject to other specified conditions, limitations, or exceptions as follows:

1. Notification shall be given to David May or Allen Clark, 943 Washington Square Mall, Washington, North Carolina 27889, telephone: (252) 948-3939 or (252) 948-3847, at least 24 hours prior to the start of construction.

2. All data including water levels, water analysis, pumping test(s) and other types of logs and data shall be submitted to the Department.

3. Any supply well, the use of which has been discontinued, shall be properly abandoned in accordance with NCAC 2C .0113 of the North Carolina Well Construction Standards, and a well abandonment report filed with the Department.

4. The proposed well is located within the Capacity Use Area as defined by Title 15A North Carolina Administrative Code, Subchapter 2E.0501 (Capacity Use Area Water Withdrawal). Section 2E.0502(b) Withdrawal Permits generally states: No person shall withdraw or utilize surface water or groundwater, or both in excess of 100,000 gallons per day without first obtaining a permit. To obtain information regarding a Water Use

Permit, please call the Division of Water Resources at (919) 733-4064.

5. Notification shall be given to David May or Allen Clark, 943 Washington Square Mall, Washington, North Carolina 27889, telephone (252) 948-3939, or (252) 948-3847 upon completion of the well construction.

6. In view of the proposed capacity use area, you should contact the Division of Water Resources at (919) 733-4064, for information concerning water conservation and management plans, relative to groundwater use.

Permit issued this the eighth day of June 2007.

NORTH CAROLINA ENVIRONMENTAL MANAGEMENT COMMISSION

David May

David May, Aquifer Protection Regional Supervisor
Division of Water Quality
By Authority of the
Environmental Management Commission

PERMIT NO. WS0700877

NON RESIDENTIAL WELL CONSTRUCTION RECORD

North Carolina Department of Environment and Natural Resources- Division of Water Quality

WELL CONTRACTOR CERTIFICATION # 2300

1. WELL CONTRACTOR:

Samuel L Wiggins
Well Contractor (Individual) Name

Magette Well & Pump Co., Inc.
Well Contractor Company Name

STREET ADDRESS 2342 US 13 South

Ahoskle NC 27910
City or Town State Zip Code

(252-)- 332-2265
Area code- Phone number

2. WELL INFORMATION:

SITE WELL ID #(if applicable) Martin Marietta Aggregates

STATE WELL PERMIT#(if applicable) ______

DWQ or OTHER PERMIT #(if applicable) WS0700877

WELL USE (Check Applicable Box) Monitoring ☐ Municipal/Public ☐ Industrial/Commercial ☐ Agricultural ☐ Recovery ☐ Injection ☐ Irrigation☐ Other ☐ (list use) Test Well

DATE DRILLED 7/2007

TIME COMPLETED 2:30 AM ☐ PM ☒

3. WELL LOCATION:

CITY: Wilmar COUNTY Beaufort

Old Welbom Road near Nancy Branch Road
(Street Name, Numbers, Community, Subdivision, Lot No., Parcel, Zip Code)

TOPOGRAPHIC / LAND SETTING:

☐Slope ☐Valley ☒Flat ☐Ridge ☐ Other ______
(check appropriate box)

LATITUDE 35d 21'10.5"

LONGITUDE 77 01'51.6"

May be in degrees, minutes, seconds or in a decimal format

Latitude/longitude source: ☒GPS ☐Topographic map

(location of well must be shown on a USGS topo map and attached to this form if not using GPS)

4. FACILITY- is the name of the business where the well is located.

FACILITY ID #(if applicable) ______

NAME OF FACILITY Martin Marietta Aggregates

STREET ADDRESS ______

City or Town State Zip Code

CONTACT PERSON ______

MAILING ADDRESS ______

City or Town State Zip Code

( )-
Area code - Phone number

5. WELL DETAILS:

a. **TOTAL DEPTH:** 106

b. **DOES WELL REPLACE EXISTING WELL?** YES ☐ NO ☒

c. **WATER LEVEL** Below Top of Casing: 19 FT.
(Use "+" if Above Top of Casing)

d. **TOP OF CASING IS** 3 FT. Above Land Surface*
*Top of casing terminated at/or below land surface may require a variance in accordance with 15A NCAC 2C .0118.

e. **YIELD (gpm):** 100 **METHOD OF TEST** Pump test

f. **DISINFECTION: Type** HTH **Amount** 1 pounds

g. **WATER ZONES** (depth):

From 66 To 106 From ___ To ___
From ___ To ___ From ___ To ___
From ___ To ___ From ___ To ___

6. CASING:

Depth	Diameter	Thickness/ Weight	Material
From +1 To 20 Ft.	10"	SDR21	PVC
From +3 To 66 Ft.	4"	SDR 21	PVCl
From ___ To ___ Ft.			

7. GROUT:

Depth	Material	Method
From 0 To 66 Ft.	neat cement	pumped
From ___ To ___ Ft.		
From ___ To ___ Ft.		

8. SCREEN:

Depth	Diameter	Slot Size	Material
From ___ To ___ Ft.	in.	in.	open hole
From ___ To ___ Ft.	in.	in.	
From ___ To ___ Ft.	in.	in.	

9. SAND/GRAVEL PACK:

Depth	Size	Material
From ___ To ___ Ft.		
From ___ To ___ Ft.		
From ___ To ___ Ft.		

10. DRILLING LOG

From To	Formation Description
0 - 2	top soil
2 - 25	fine grey sand
25 - 40	clay and sand
40 - 66	sand some clay
66 -85	limestone in and out of consolidated
85 - 95	SOFTER LIMESTONE
95 - 118	harder limestone
118 - 130	softer with some sand and clay

11. REMARKS:

I DO HEREBY CERTIFY THAT THIS WELL WAS CONSTRUCTED IN ACCORDANCE WITH 15A NCAC 2C, WELL CONSTRUCTION STANDARDS, AND THAT A COPY OF THIS RECORD HAS BEEN PROVIDED TO THE WELL OWNER.

SIGNATURE OF CERTIFIED WELL CONTRACTOR DATE

PRINTED NAME OF PERSON CONSTRUCTING THE WELL

Submit the original to the Division of Water Quality within 30 days. Attn: Information Mgt., 1617 Mail Service Center – Raleigh, NC 27699-1617 Phone No. (919) 733-7015 ext 568.

NON RESIDENTIAL WELL CONSTRUCTION RECORD

North Carolina Department of Environment and Natural Resources- Division of Water Quality

WELL CONTRACTOR CERTIFICATION # 2300

1. WELL CONTRACTOR:

Samuel L Wiggins
Well Contractor (Individual) Name

Magette Well & Pump Co., Inc.
Well Contractor Company Name

STREET ADDRESS 2342 US 13 South

Ahoskie NC 27910
City or Town State Zip Code

(252-)- 332-2265
Area code- Phone number

2. WELL INFORMATION:

SITE WELL ID #(if applicable) Martin Marietta Aggregates

STATE WELL PERMIT#(if applicable)

DWQ or OTHER PERMIT #(if applicable) WS0700677

WELL USE (Check Applicable Box) Monitoring ☐ Municipal/Public ☐ Industrial/Commercial ☐ Agricultural ☐ Recovery ☐ Injection ☐ Irrigation☐ Other ☐ (list use) Test Well

DATE DRILLED 6/2007

TIME COMPLETED 4:30 AM ☐ PM ☒

3. WELL LOCATION:

CITY: Wilmar COUNTY Beaufort

Old Welborn Road near Nancy Branch Road
(Street Name, Numbers, Community, Subdivision, Lot No., Parcel, Zip Code)

TOPOGRAPHIC / LAND SETTING:
☐Slope ☐Valley ☒Flat ☐Ridge ☐ Other
(check appropriate box)

LATITUDE 35d 21'10.5"

LONGITUDE 77 01' 51.6"

May be in degrees, minutes, seconds or in a decimal format

Latitude/longitude source: ☒GPS ☐Topographic map
(location of well must be shown on a USGS topo map and attached to this form if not using GPS)

4. FACILITY- is the name of the business where the well is located.

FACILITY ID #(if applicable)

NAME OF FACILITY Martin Marietta Aggregates

STREET ADDRESS

City or Town State Zip Code

CONTACT PERSON

MAILING ADDRESS

City or Town State Zip Code

( )-
Area code - Phone number

5. WELL DETAILS:

a. TOTAL DEPTH: 111

b. DOES WELL REPLACE EXISTING WELL? YES ☐ NO ☒

c. WATER LEVEL Below Top of Casing: 19 FT.
(Use "+" if Above Top of Casing)

d. TOP OF CASING IS 2 FT. Above Land Surface*
*Top of casing terminated at/or below land surface may require a variance in accordance with 15A NCAC 2C .0118.

e. YIELD (gpm): 600 METHOD OF TEST Pump test

f. DISINFECTION: Type HTH Amount 3 pounds

g. WATER ZONES (depth):

From 66	To 106	From	To
From	To	From	To
From	To	From	To

6. CASING:

Depth		Diameter	Thickness/ Weight	Material
From +1	To 20 Ft.	18"	.375	steel
From +2	To 66 Ft.	8"	.280	steel
From 106	To 111 Ft.	8"	SCH 10	stainless

7. GROUT:

Depth		Material	Method
From 0	To 20 Ft.	neat cement	pumped
From 20	To 46 Ft.	neat cement	pumped
From	To Ft.		

8. SCREEN:

Depth		Diameter	Slot Size	Material
From 66	To 106 Ft.	8" in.	.050 in.	stainless
From	To Ft.	in.	in.	
From	To Ft.	in.	in.	

9. SAND/GRAVEL PACK:

Depth		Size	Material
From 46	To 111 Ft.	4	SOUTHERN PRODUCTS
From	To Ft.		
From	To Ft.		

10. DRILLING LOG

From To	Formation Description
0 - 2	top soil
2 - 25	fine grey sand
25 - 40	clay and sand
40 - 66	sand some clay
66 -85	limestone in and out of consolidated
85 - 95	SOFTER LIMESTONE
95 - 118	harder limestone
118 - 130	softer with some sand and clay

11. REMARKS:

I DO HEREBY CERTIFY THAT THIS WELL WAS CONSTRUCTED IN ACCORDANCE WITH 15A NCAC 2C, WELL CONSTRUCTION STANDARDS, AND THAT A COPY OF THIS RECORD HAS BEEN PROVIDED TO THE WELL OWNER.

SIGNATURE OF CERTIFIED WELL CONTRACTOR DATE

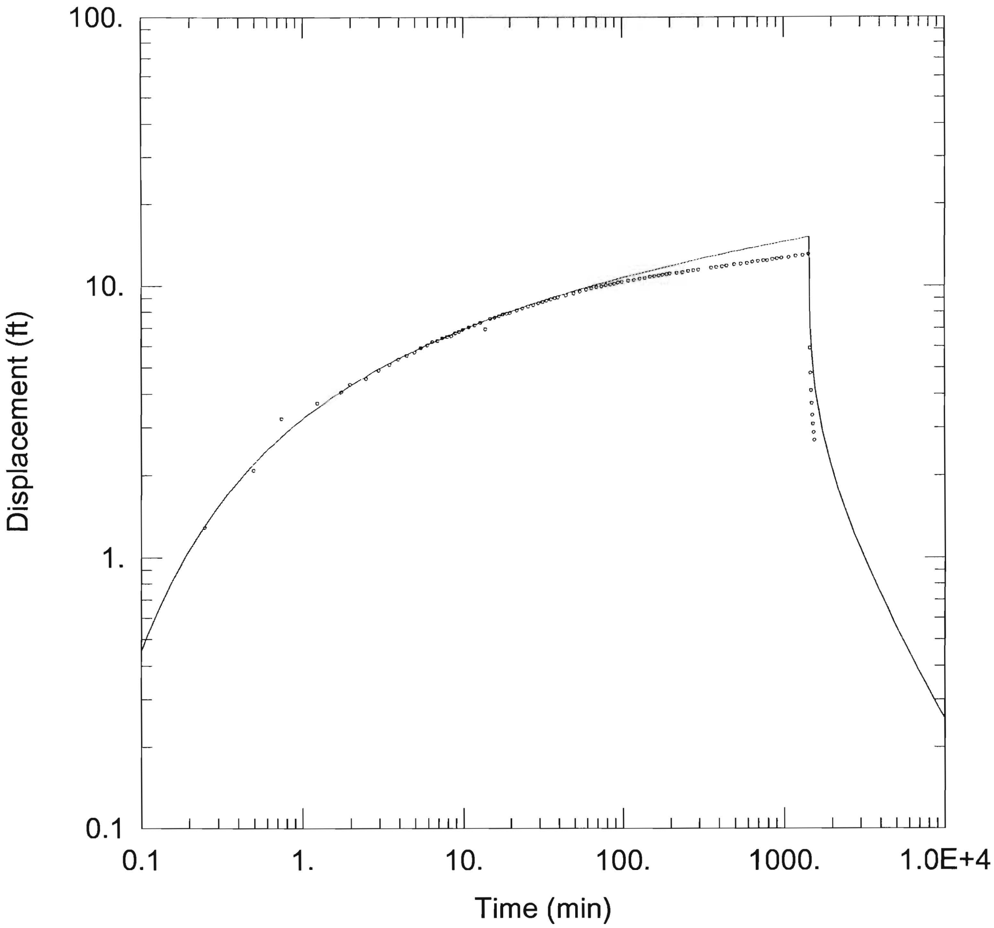
PRINTED NAME OF PERSON CONSTRUCTING THE WELL

Submit the original to the Division of Water Quality within 30 days. Attn: Information Mgt., 1617 Mail Service Center – Raleigh, NC 27699-1617 Phone No. (919) 733-7015 ext 568.

Form GW-1b
Rev. 7/05

Appendix II

Aquifer Test Data and Analyses



MARTIN MARIETTA AGGREGATES - VANCEBORO

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Date: 02/11/08 Time: 17:04:57

PROJECT INFORMATION

Company: GMA
Client: Martin Marietta Aggregates
Project: 62902
Location: Vanceboro
Test Well: PW
Test Date: 8/6/07

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW 1	0	0.333

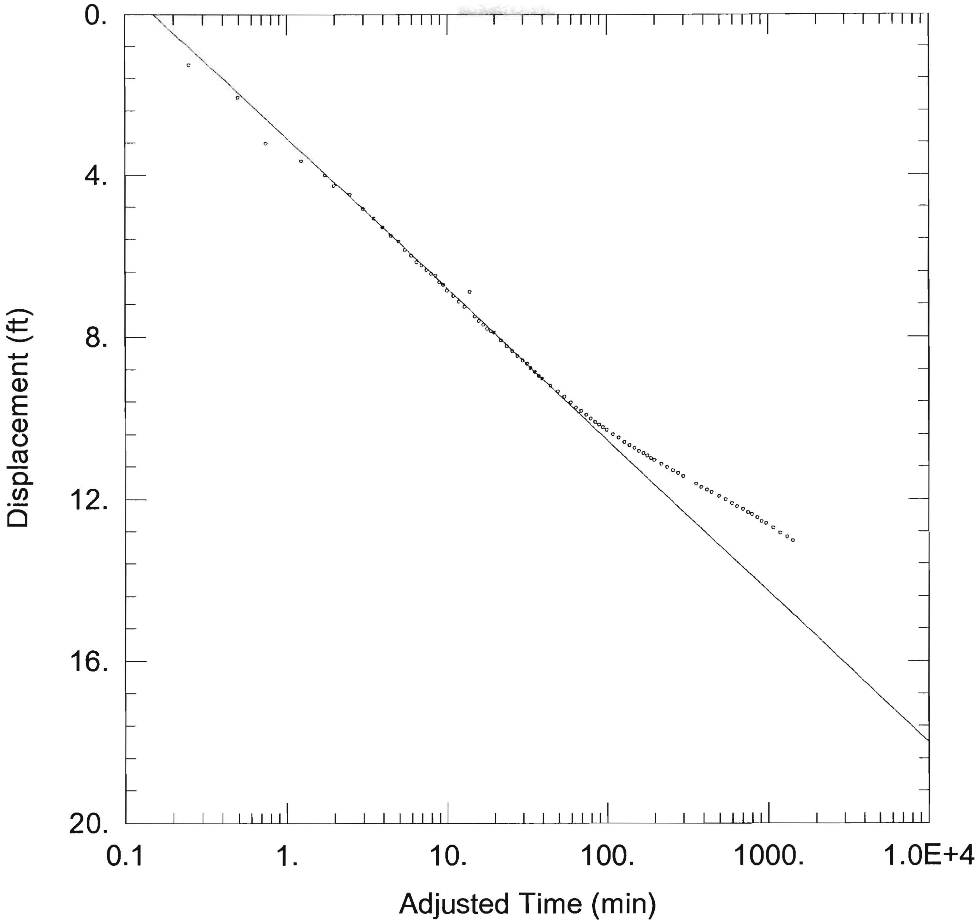
Observation Wells

Well Name	X (ft)	Y (ft)
OW 1	0	75.5

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 4842.7 ft^2/day
S = 0.0002094
Kz/Kr = 1.
b = 40. ft



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PROJECT INFORMATION

Company: GMA
Client: Martin Marietta Aggregates
Project: 62902
Location: Vanceboro
Test Well: PW
Test Date: 8/6/07

AQUIFER DATA

Saturated Thickness: 40. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW 1	0	0.333

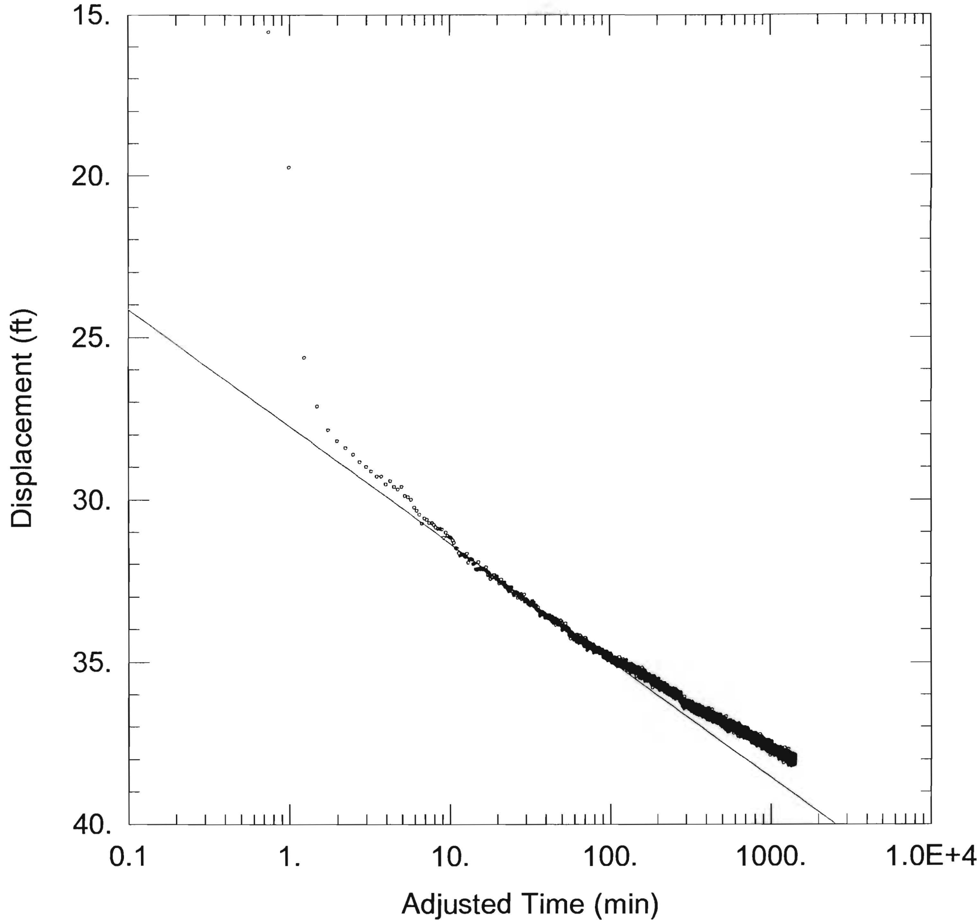
Observation Wells

Well Name	X (ft)	Y (ft)
◦ OW 1	0	75.5

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 4963. ft^2/day S = 0.0002041



MARTIN MARIETTA AGGREGATES - VANCEBORO

Data Set: Z:\...\PW Ptest CJ.aqt
Date: 02/11/08 Time: 17:05:08

PROJECT INFORMATION

Company: GMA
Client: Martin Marietta Aggregates
Project: 62902
Location: Vanceboro
Test Well: PW
Test Date: 8/6/07

AQUIFER DATA

Saturated Thickness: 40. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW 1	0	0

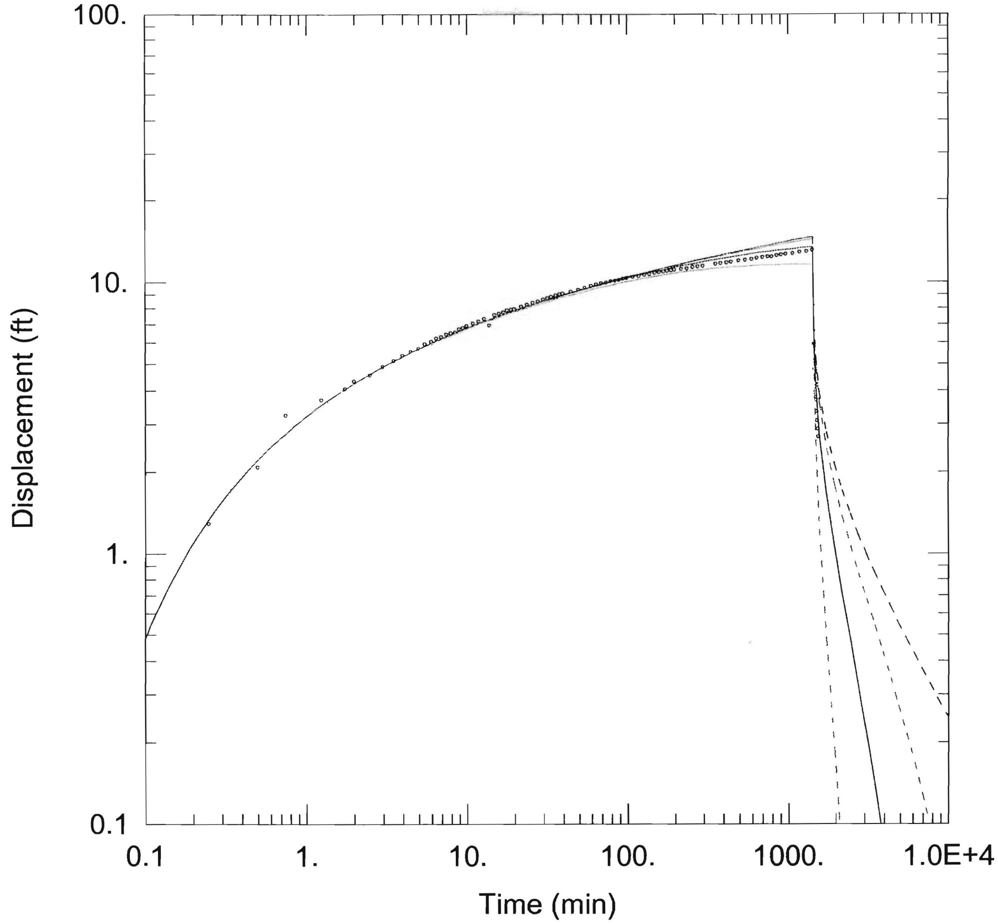
Observation Wells

Well Name	X (ft)	Y (ft)
PW 1	0	0.333

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 5140. ft^2/day S = 1.394E-6



MARTIN MARIETTA AGGREGATES - VANCEBORO

Data Set: Z:\...\OW Ptest HJ.aqt
Date: 02/11/08 Time: 17:04:49

PROJECT INFORMATION

Company: GMA
Client: Martin Marietta Aggregates
Project: 62902
Location: Vanceboro
Test Well: PW
Test Date: 8/6/07

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW 1	0	0.333

Observation Wells

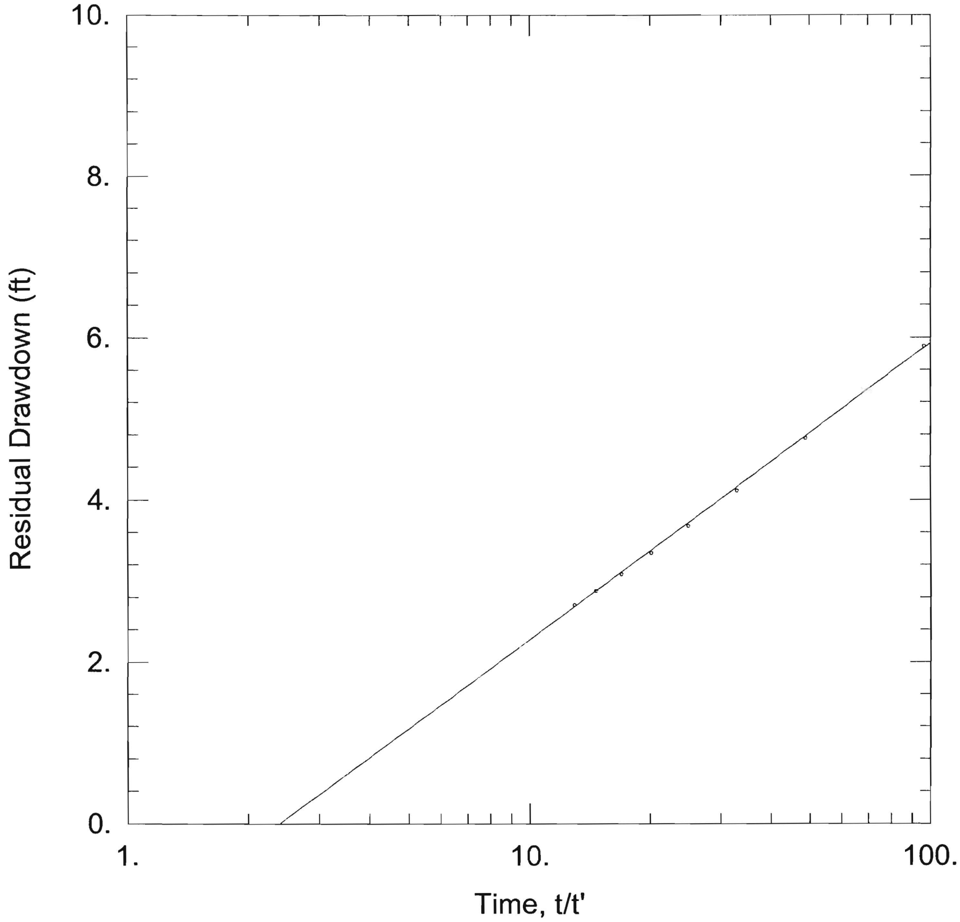
Well Name	X (ft)	Y (ft)
◦ OW 1	0	75.5

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush-Jacob

T = 5031.1 ft^2/day
r/B = 0.01498
b = 40. ft

S = 0.0002028
Kz/Kr = 1.



MARTIN MARIETTA AGGREGATES - VANCEBORO

Data Set: Z:\...\OW Ptest Rec.aqt
Date: 02/13/08 Time: 09:15:56

PROJECT INFORMATION

Company: GMA
Client: Martin Marietta Aggregates
Project: 62902
Location: Vanceboro
Test Well: PW
Test Date: 8/6/07

AQUIFER DATA

Saturated Thickness: 40. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW 1	0	0.333

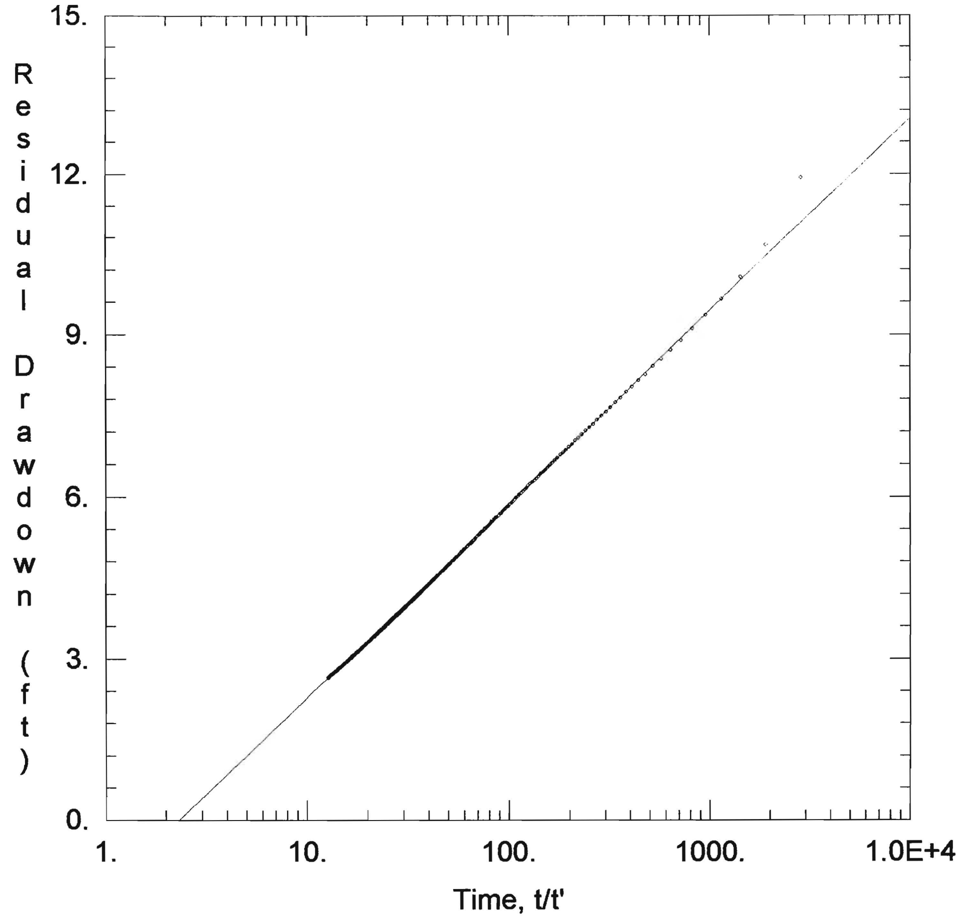
Observation Wells

Well Name	X (ft)	Y (ft)
OW 1	0	75.5

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 5062.1 ft^2/day S/S' = 2.389



MARTIN MARIETTA AGGREGATES - VANCEBORO

Data Set: Z:\...\PW Ptest Rec.aqt
Date: 02/11/08 Time: 17:05:29

PROJECT INFORMATION

Company: GMA
Client: Martin Marietta Aggregates
Project: 62902
Location: Vanceboro
Test Well: PW
Test Date: 8/6/07

AQUIFER DATA

Saturated Thickness: 40. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW 1	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
PW 1	0	0.333

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 5155.2 ft^2/day S/S' = 2.332

Project Name: M. Marietta		Project Location: Proposed Mine Near Vanceboro	
Pumping Test Monitoring Log Form		Well # PW	Static Level: 20.06 ft
Date	8/6/2007	Start Time	3:00 PM
Time (min)	**Water Level (ft)**	**Drawdown (ft)**	**Comments**
15sec			
30sec			
45sec			
1min			
1min15sec			
1min30sec			Adjusting Q to 524 gpm, probably started
1min45sec			at ~ 450 gpm
2min			
2min30sec			
3min			
3min30sec			
4min			
4min30sec	49.84	29.78	
5min	50.00	29.94	Adjust up to 524 gpm
5min30sec			
6min	50.55	30.49	524 gpm
6min30sec	50.68	30.62	
7min	50.82	30.76	
7min30sec	50.90	30.84	
8min	51.00	30.94	
8min30sec	51.13	31.07	
9min	51.20	31.14	
9min30sec	51.24	31.18	Adjust up to 524 gpm
10min	51.33	31.27	
11min	51.71	31.65	
12min	51.90	31.84	
13min	52.01	31.95	
14min	52.12	32.06	524 gpm steady
15min	52.20	32.14	
16min	52.35	32.29	524 gpm steady
17min	52.42	32.36	
18min	52.45	32.39	
19min	52.55	32.49	
20min	52.62	32.56	
22min	52.77	32.71	
24min	52.90	32.84	
26min	53.03	32.97	
28min	53.10	33.04	
30min	53.23	33.17	

Project Name: M. Marietta		Project Location: Proposed Mine Near Vanceboro	
Pumping Test Monitoring Log Form			Well # PW Static Level: 20.06 ft
Date	8/6/2007	Start Time	
Time (min)	Water Level (ft)	Drawdown (ft)	Comments
32min	53.33	33.27	524 gpm
34min	53.44	33.38	Slight adjust up to 524 gpm
36min	53.55	33.49	
38min	53.64	33.58	
40min	53.69	33.63	524 gpm steady
45min	53.90	33.84	
50min	54.05	33.99	
55min	54.17	34.11	Slight adjust up to 524 gpm
1hr	54.35	34.29	
1hr1min	54.54	34.48	
1hr11min	54.60	34.54	
1hr15min	54.62	34.56	
1hr20min	54.74	34.68	524 gpm
1hr25min	54.83	34.77	
1hr30min	54.90	34.84	
1hr35min	54.94	34.88	524 gpm
1hr40min	54.99	34.93	
1hr50min	55.12	35.06	
2hr	55.19	35.13	524 gpm
2hr10min	55.27	35.21	
2hr20min	55.35	35.29	
2hr30min	55.47	35.41	
2hr40.5min	55.48	35.42	
2hr50min	55.60	35.54	524 gpm
3hr	55.67	35.61	524 gpm steady
3hr10min	55.75	35.69	
3hr20min	55.78	35.72	
3hr40min	55.87	35.81	Slight adjust up to 524 gpm
4hr	56.04	35.98	
4hr20min	56.14	36.08	
4hr40min	56.22	36.16	Slight adjust up to 524 gpm
5hr	56.43	36.37	
6hr	56.64	36.58	
6hr30min	56.74	36.68	
7hr	56.76	36.70	524 gpm steady
7hr30min	56.84	36.78	524 gpm steady
8hr20min	56.98	36.92	524 gpm steady
9hr10min	57.07	37.01	

Project Name: M. Marietta		Project Location: Proposed Mine Near Vanceboro	
Pumping Test Monitoring Log Form		Well # PW	Static Level: 20.06 ft
Date	8/6/2007	Start Time	
Time (min)	Water Level (ft)	Drawdown (ft)	Comments
10hr	57.18	37.12	524 gpm
10hr50min	57.27	37.21	
11hr45min	57.37	37.31	524 gpm
12hr35min	57.42	37.36	524 gpm
13hr20min	57.53	37.47	
14hr20min	57.59	37.53	524 gpm
15hr20min	57.68	37.62	524 gpm
16hr20min	57.77	37.71	
18hr	57.87	37.81	
20hr	58.01	37.95	524 gpm
22hr	58.15	38.09	
24hr	58.18	38.12	524 gpm

Notes:

GMA Project #: 62902	
Measuring Point Description:	Top of 1.25-inch drop tube.
MP Height above Land Surface:	
Pump Intake Depth: 66 feet	
Well Pipe ID: 8-inch casing	
Target Q: 524 gpm	
Flow Meter Description:	6" x 5" Orifice Weir
Pumping Equipment Contractor:	Magette Well and Pump
Person Recoring Data:	Jay Holley

Project Name: M. Marietta		Project Location: Proposed Mine Near Vanceboro	
Pumping Test Monitoring Log Form		Well # OW	Static Level: 19.32 ft
Date	8/6/2007	Start Time	3:00 PM
Time (min)	Water Level (ft)	Drawdown (ft)	Comments
15sec	20.60	1.28	
30sec	21.40	2.08	
45sec	22.55	3.23	
1min15sec	23.00	3.68	
1min45sec	23.35	4.03	
2min	23.62	4.30	
2min30sec	23.84	4.52	
3min	24.18	4.86	
3min30sec	24.42	5.10	
4min	24.65	5.33	
4min30sec	24.85	5.53	
5min	25.00	5.68	
5min30sec	25.20	5.88	
6min	25.35	6.03	
6min30sec	25.50	6.18	
7min	25.58	6.26	
7min30sec	25.70	6.38	
8min	25.79	6.47	
8min30sec	25.84	6.52	
9min	25.99	6.67	
9min30sec	26.06	6.74	
10min	26.20	6.88	
11min	26.33	7.01	
12min	26.47	7.15	
13min	26.60	7.28	
14min	26.23	6.91	
15min	26.84	7.52	
16min	26.94	7.62	
17min	27.04	7.72	
18min	27.14	7.82	
19min	27.20	7.88	
20min	27.24	7.92	
22min	27.43	8.11	
24min	27.57	8.25	
26min	27.70	8.38	
28min	27.80	8.48	
30min	27.92	8.60	

Project Name: M. Marietta		Project Location: Proposed Mine Near Vanceboro	
Pumping Test Monitoring Log Form		Well # OW	Static Level: 19.32 ft
Date	8/6/2007	Start Time	3:00 PM
Time (min)	Water Level (ft)	Drawdown (ft)	Comments
32min	28.00	8.68	
34min	28.10	8.78	
36min	28.20	8.88	
38min	28.29	8.97	
40min	28.36	9.04	
45min	28.53	9.21	
50min	28.68	9.36	
55min	28.81	9.49	
1hr	28.95	9.63	
1hr1min	29.07	9.75	
1hr11min	29.16	9.84	
1hr15min	29.25	9.93	
1hr20min	29.34	10.02	
1hr25min	29.42	10.10	
1hr30min	29.48	10.16	
1hr35min	29.55	10.23	
1hr40min	29.61	10.29	
1hr50min	29.72	10.40	
2hr	29.81	10.49	
2hr10min	29.91	10.59	
2hr20min	30.00	10.68	
2hr30min	30.06	10.74	
2hr40.5min	30.14	10.82	
2hr50min	30.19	10.87	
3hr	30.25	10.93	
3hr10min	30.31	10.99	
3hr20min	30.36	11.04	
3hr40min	30.45	11.13	
4hr	30.54	11.22	
4hr20min	30.61	11.29	
4hr40min	30.68	11.36	
5hr	30.76	11.44	
6hr	30.95	11.63	
6hr30min	31.02	11.70	
7hr	31.09	11.77	
7hr30min	31.16	11.84	
8hr20min	31.25	11.93	
9hr10min	31.33	12.01	

Project Name: M. Marietta		Project Location: Proposed Mine Near Vanceboro	
Pumping Test Monitoring Log Form		Well # OW	Static Level: 19.32 ft
Date	8/6/2007	Start Time	3:00 PM
Time (min)	Water Level (ft)	Drawdown (ft)	Comments
10hr	31.42	12.10	
10hr50min	31.51	12.19	
11hr46min	31.57	12.25	
12hr37min	31.64	12.32	
13hr21min	31.70	12.38	
14hr21min	31.78	12.46	
15hr21min	31.87	12.55	
16hr21min	31.92	12.60	
18hr	32.03	12.71	
20hr	32.15	12.83	
22hr	32.25	12.93	
24hr	32.35	13.03	

Notes:

GMA Project #: 62902	
Measuring Point Description:	Top of casing.
MP Height above Land Surface:	
Pump Intake Depth: 66 feet	
Well Pipe ID: 4-inch casing	
Target Q: NA	
Flow Meter Description:	NA
Pumping Equipment Contractor: Magette Well and Pump	
Person Recoring Data:	Jay Holley