Geosyntec Consultants of NC, P.C.
NC License No.: C-3500 and C-295

APPENDIX H

Numerical Groundwater Modeling Report

Geosyntec Consultants of NC, P.C.
NC License No.: C-3500 and C-295

NUMERICAL MODELING

Chemours Fayetteville Works

Prepared for

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LIST OF ABBREVIATIONS

CAP	Corrective Action Plan
CFRW	Cape Fear River Watch
CO	Consent Order
EVS	Environmental Visualization System
ft	feet
ft bgs	feet below ground surface
ft/day	feet per day
GPM	gallons per minute
K	hydraulic conductivity
HPT	hydraulic profiling tool
LiDAR	Light Detection and Ranging
MSL	mean sea level
NCDEQ	North Carolina Department of Environmental Quality
NRMS	Normalized Root Mean Square
P_c	capillary pressure
PFAS	per- and polyfluoroalkyl substances
RMS	Root Mean Square
S_r	residual wetting phase saturation
S_s	specific storage
S_w	wetting phase saturation
USGS	United States Geological Survey
WWTP	wastewater treatment plant
α	Brooks-Corey-Burdine constitutive fitted parameter, alpha
δ	Brooks-Corey-Burdine constitutive fitted parameter, delta
λ	Brooks-Corey-Burdine constitutive fitted parameter, lambda
θ	unsaturated-flow porosity, theta

EXECUTIVE SUMMARY

This numerical modeling report was prepared by Geosyntec Consultants of NC, P.C. (Geosyntec) for The Chemours Company FC, LLC (Chemours) to assess groundwater flow at the Chemours Fayetteville Works facility (Site) using numerical modelng, pursuant to Paragraph 16 of the February 25, 2019 Consent Order (CO) among Chemours, the North Carolina Department of Environmental Quality (NCDEQ) and Cape Fear River Watch (CFRW). Paragraph 16 requires Chemours to submit a Corrective Action Plan (CAP) for the Site by 31 December 2019.

The objective of the numerical modeling program is to develop a model for use in the design and costing assessment of the various proposed groundwater remedies for the Site. In addition, the model will aid in assessing the effectiveness of each remedy. Based on the requirements of the modeling, the finite element code FEFLOW was chosen for the project. The model is intended to be hydraulic only, to aid in assessment of pumping and recharge reduction approaches. The model is not intended (in its current formulation) to simulate contaminant fate and transport. The modeling was conducted in accordance with NC guidance and the NCDEQ's 2007 Groundwater Modeling Policy (NCDEQ, 2007). Initial model parameters were chosen based on the available field data and published literature values where field data were not available. Calibration was performed using a sequenced trial and adjustment approach.

The calibrated model developed had a Normalized Root Mean Square (NRMS) error of 12.5% which is considered satisfactory based on the scale of the model and its intended end use in costing and preliminary design focusing on hydraulics only (as opposed to contaminant fate and transport). The majority of the error in the calibrated model occurs in the Perched Zone and will have limited effect of the ability of the model to predict capture of groundwater discharge to the surface water bodies. The steep topography, presence of a perched water bearing region, and lack of laterally extensive hydrostratagraphic units in many regions of the model domain makes this a challenging scenario to model, in both development and calibration stages.

Twenty simulations were conducted using the calibrated model to aid in the evaluation of the appropriate groundwater remedy of the CAP. Table 7 presents a description of the six key simulations examined in the model study area. All simulations consisted of groundwater extraction in some cases coupled with a barrier wall along the Cape Fear River. In general, to avoid capture of large volumes of water from the Cape Fear River, a barrier wall was required. Groundwater extraction minimization simulations of the location and extraction rates of the pumping wells (in combination with the barrier wall) indicated that a well spacing of 200 feet with extraction rates between 20 and 35 GPM

provided capture of groundwater discharge to the Cape Fear River without excessive capture of Cape Fear River water.

Based on the results of the numerical modeling program, groundwater remedy development would be supported by reducing uncertainty regarding:

- Interactions between the Surficial Aquifer and the Black Creek Aquifer along the bluffs; and
- Distribution of groundwater flows into surface water drainage features including onsite groundwater seeps, Willis Creek and Old Outfall 002.

A combination of additional simulations and targeted field investigations (aquifer testing) to address these uncertainties is recommended before final remedy design.

1. INTRODUCTION

1.1 Purpose of the Report

This numerical modeling report was prepared by Geosyntec Consultants of NC, P.C. (Geosyntec) for The Chemours Company FC, LLC (Chemours) to assess groundwater flow at the Chemours Fayetteville Works facility (Site) using numerical modelng, pursuant to Paragraph 16 of the February 25, 2019 Consent Order (CO) among Chemours, the North Carolina Department of Environmental Quality (NCDEQ) and Cape Fear River Watch (CFRW). Paragraph 16 requires Chemours to submit a Corrective Action Plan (CAP) for the Site by 31 December 2019. This CAP describes how groundwater will be remediated at Site with a primary focus on reducing Site associated per and polyfluoroalkyl substances (PFAS) from reaching the Cape Fear River.

This document focuses on the development, calibration and implementation of the numerical groundwater model to support remedy evaluation, selection and design at the Site.

1.2 Approach

The model was developed in accordance with the guidelines described in the NCDEQ 2007 Groundwater Modeling Policy (NCDEQ, 2007) to help support potential future discussions with the NCDEQ about modeling results and interpretations and decisions based on modeling effort.

To meet this requirement, the report was prepared based on the following structure:

- **Introduction** (this section);
- **General Setting** (Section 2) – describes the Site and surrounding areas, and geomorphological Site setting;
- **Conceptual Model** (Section 2.2) – describes the geology and hydrogeology of the Site, and Site-specific hydrologic and hydraulic boundaries;
- **Computer Model** (Section 4) – describes the model selection process, the capabilities of the selected model;
- **Groundwater Model Construction** (Section 5) – describes the model mesh development, hydraulic parameters of hydrostratigraphic units, groundwater model boundary conditions based on available Site-specific data, and selected model calibration targets;
- **Calibration** (Section 6) – discusses the residual and sensitivity analysis results of the model calibration process;

- **Predictive Simulations** (Section 7) – discusses the results of the predictive simulation suite performed to assess different groundwater extraction remedial strategies;

- **Summary and Conclusions** (Section 8) – discusses model assumption and limitations, and recommendations for potential future modeling efforts;

- **References** (Section 9).

2. GENERAL SETTING

2.1 Site Description and Surroundings

The Site is located within a 2,177-acre property at 22828 NC Highway 87, approximately 20 miles southeast of the city of Fayetteville along the Bladen-Cumberland county line in North Carolina. Figure 1 presents an overview of the Site location. Figure 2 presents a regional topographic map and Figure 3 presents a higher resolution topographic map of the Site.

The Site is bounded by NC Highway 87 to the west, Cape Fear River to the east, and on the north and south by forested areas, farmland and private residences. Zoning maps indicate that the surrounding areas are zoned as residential, agricultural, conservation, industrial or commercial.

The manufacturing area of the Site covers approximately 312 acres (Figure 3). Chemours also operates a wastewater treatment plant (WWTP) at the Site. The remaining areas are grassy areas, forests and wetlands.

2.2 Geomorphologic Site Setting

The Site is located on the Coastal Plain. In North Carolina, the Coastal Plain Physiographic Province extends from the present Atlantic Ocean inland to the Fall Line, an erosional contact boundary with the Piedmont Province. The Fall Line is approximately 40 miles northwest of the Site.

Most of the Site sits on a rather flat-lying area at typical elevations ranging from 125 feet above mean sea level (ft MSL) to 150 ft above MSL (Figure 3). The topography mildly slopes from the western boundary towards the north, east and south. The slope then steepens quite abruptly in these directions, resulting from incisions carved by surface water courses including:

- Towards the north, coinciding with the course of Willis Creek where the topography decreases to elevations ranging between 35 ft above MSL and 70 ft above MSL;

- Towards the east, coinciding with the course of the Cape Fear River where the elevation drops sharply to approximately 35 ft above MSL, forming a bluff face between the Site and the River;

- Towards the south, coinciding with the course of Georgia Branch Creek where the topography decreases to elevations ranging between 35 ft above MSL and 110 ft above MSL.

A topographic incision also coincides with the Old Outfall 002, sloping more mildly in the southern portion of the Site.

Willis Creek and Georgia Branch Creek are tributaries to the Cape Fear River. Willis Creek flows in an easterly direction and was observed to have flow rates around 2,900 gallons per minute (GPM) in dry weather and around 6,500 GPM following rainfall. Georgia Branch Creek, which is offsite for its entire course, is flowing in a southeasterly direction and was observed to have flow rates between 2,400 and 2,600 GPM in both wet and dry weather. Georgia Branch Creek runs northwest-southeast beside Highway 87 before turning east towards the Cape Fear River to the south of the Site. The median flow rate in the Cape Fear River is in the order of 750,000 GPM.

3. CONCEPTUAL MODEL

3.1 Aquifer System Framework

3.1.1 General

Multiple aquifer units occur underneath the Site, which are summarized in Table 1 (from youngest to oldest) while their typical positions in the vertical profile are illustrated in Figure 4.

Table 1: Site Aquifer System

Unit	Description	Classification	Typical K-values*
Floodplain Deposits	Predominantly fine-grained deposits. Closely associated with the Cape Fear River course, typically 10 to 15 ft in thickness.	Aquitard (where fine-grained), local aquifer (where more sandy)	0.1 ft/day to 1 ft/day

Unit	Description	Classification	Typical K-values*
Perched Zone	Predominantly loose silty sand, brown to reddish brown. Relatively thin in the eastern portion of the Site to a depth of about 20 ft below ground surface (bgs). In the western portion, an inferred erosional feature has likely resulted in the unit being thicker.	Unconfined perched groundwater body of local extent, porous medium	2 ft/day to 5 ft/day
Perched Clay	Predominantly stiff clay with minor silts, dark grey. Also spatially limited. Pinching out to the north. To the east and south, outcrops along the bluff face. To the west, terminates and becomes absent, presumably eroded by the erosional feature.	Aquitard of local extent, porous medium	< 1ft/day
Surficial Aquifer	Predominantly fine to medium-grained sand, white to light brown. Mostly continuous layer across Site area, typically 20 ft to 40 ft thick with a mild dip to the south. In the western portion, the absence of Perched Clay does not enable to differentiate the contact with the lithology representing the Perched Zone.	Unconfined aquifer, porous medium	2 ft/day to 5 ft/day
Black Creek Confining Unit	Predominantly organic-rich clay, hard, dark grey to black. Regionally extensive layer, 20 ft to 40 ft thick with a mild dip to the south.	Aquitard of regional extent, porous medium	<1 ft/day
Black Creek Aquifer	Predominantly dense medium-grained sand, dark grey. Regionally extensive layer, typically 20 ft to 40 ft thick. Thins out in the Cape Fear River vicinity (up to less than 5 ft), likely due to erosion and emplacement of recent Floodplain Deposits.	Confined aquifer of regional extent, porous medium	5 ft/day to 80 ft/day
Cape Fear Confining Unit	Predominantly clay, hard. Regionally extensive layer.	Aquitard of regional extent, porous medium	<1 ft/day

Notes to Table: *Sourced from the On and Offsite Assessment Report (Geosyntec, 2019) and the Additional Site Investigation Report (Parsons, 2018). Aquifer values derived from aquifer testing (i.e. slug test and pumping test), aquitard values derived from grain-sized analysis.

In the western portion of the Site (Figure 4), an erosional feature (i.e. paleochannel) is indicated to occur. The erosional feature is interpreted to have completely eroded the Perched Clay, enabling direct hydraulic connection between the Perched Zone and the Surficial Aquifer. In parts (northwest), the erosional feature is also interpreted to have incised into the top of the Black Creek Aquifer.

3.1.2 EVS Model

A three-dimensional (3D) hydrostratigraphic model of the Site was constructed using CTech's Earth Volumetric Studio (EVS) software (https://www.ctech.com/products/earth-volumetric-studio/). The EVS model was developed to interpolate the hydrostratigraphic model, along the horizontal and vertical directions, and develop the model mesh for the numerical groundwater model.

A review of the available borehole logs, hydraulic profiling tool (HPT) logs and geological mapping observations indicated that the horizontal and vertical distribution of available data varied throughout the Site; with a dense distribution in some areas (e.g., onsite observations of the Perched Zone) and sparse in others (e.g., western portion of the Site, south of Old Outfall 002, and onsite observations below the Perched Clay). The EVS model was therefore constructed using an iterative process, by generating and incorporating control points which were guided by the cross-sections from the On and Offsite Assessment Report (Geosyntec, 2019), field observations and professional judgement.

A review of the available borehole logs also suggested that the hydrostratigraphic units within the Site vicinity are not continuous and not hierarchically layered (i.e., not "pancake" layered), especially in units above the Black Creek Aquifer. The "indicator kriging" method was therefore utilized to develop the EVS model. This approach involved computing the probability for each hydrostratigraphic unit at every cell within the model domain, and then assigning the unit with the highest probability to the cell.

Using this approach, the EVS model was constructed using the kriging interpolation method. Model input parameters were selected based on a review of the overall data distribution, visual comparisons of results with various input parameters, overall interpolating computing time and software limitations. A total of 98 boring locations, 28 HPT locations, 42 geological mapping observations, and 36 control points were incorporated to the EVS model.

The top of the model (i.e., ground surface) was determined based on the Light Detection and Ranging (LiDAR) data from NC Dept. of Public Safety published on 18 October 2015. The streambeds of the Willis Creek and Old Outfall 002 were further refined based on surveyed data. The bottom of the model was set to -20 ft MSL, which is below the

Black Creek Aquifer and intersects the Cape Fear Confining Unit. However, the bottom of the model does not represent the bottom of the Cape Fear Confining Unit.

An overview of the EVS model is presented in Figure 5. Visuals from the EVS model are also provided in Appendix A, which includes an the EVS model boundary, aerial view of the input data, and model outputs in aerial views, 3D views and cross-sectional views along selected portions of the Site.

3.2 Groundwater Flow System

The groundwater flow system in the Perched Zone, Surficial Aquifer and Black Creek Aquifer and their relative interactions are briefly described in the following sections. Further description is available in the On and Offsite Assessment Report (Geosyntec, 2019).

3.2.1 Perched Zone

Groundwater levels in the Perched Zone are distributed according to a mound-like shape. Higher groundwater levels are indicated in the northeast of the manufacturing area, typically over 140 ft above MSL. Lower groundwater levels, at the edge of the mound, are less than 120 ft above MSL, coinciding with the edge of the Perched Clay or the bluff.

Groundwater from the Perched Zone is anticipated to be a manifestation of surface infiltration due to its localized nature i.e. not in connection with regional flow.

Groundwater flow in the Perched Zone is likely to be radial i.e. outward from the top of the mound. Groundwater from the Perched Zone discharges along the bluff, above the contact between the Perched Zone and the Perched Clay. Groundwater from the Perched Zone is also anticipated to recharge the Surficial Aquifer, either via leakage through the Perched Clay or else via the erosional feature i.e. where the Perched Zone is directly connected to the Surficial Aquifer.

3.2.2 Surficial Aquifer

Groundwater levels in the Surficial Aquifer range from above 115 ft above MSL in the western area of the Site to about 90 ft above MSL in the northern and eastern areas. Groundwater in this aquifer unit is indicated to predominantly flow in a northeasterly and easterly direction, towards Willis Creek and the Cape Fear River, respectively. Groundwater from the Surficial Aquifer also discharges near the toe of the bluff, above the contact with the Black Creek confining unit. Discharge from the Surficial Aquifer into the Old Outfall 002 is also likely where it cuts across this unit.

Groundwater in the Surficial Aquifer is recharged by the regional flow and leakage from the above units.

3.2.3 Black Creek Aquifer

In the eastern part of the Site, groundwater levels in the Black Creek Aquifer range from 90 ft above MSL near the top of the bluff to about 35 ft above MSL near the Cape Fear River. There is limited information in the western part of the Site. Groundwater flow in the Black Creek Aquifer is predominantly in an easterly direction, towards the river although localized flow towards Willis Creek is anticipated where the creek is incised into this aquifer. While the Cape Fear River acts as a groundwater discharge zone for the Black Creek Aquifer, the steep gradient along the bluff (0.03 to 0.04 ft/ft) combined with the thin section of the aquifer (up to less than 5 ft) likely indicates resistance to flow.

3.3 Boundaries, Sources and Sinks

The dominant hydrologic boundary is the Cape Fear River, which acts as the regional groundwater discharge zone for the Black Creek Aquifer. The tributaries to the Cape Fear River are also indicated to act as more localized hydrologic boundaries, with groundwater from the Site variably interacting with these surface water bodies.

The bluff above the Cape Fear River acts as a seepage face. The steep slope results in groundwater discharge above the interface between the two shallow aquifer units (i.e. Perched Zone and Surficial Aquifer) and their underlying aquitard. The Cape Fear Confining Unit is considered to form the base of the Site aquifer system, providing a hydraulic barrier to the deeper hydrostratigraphic units (not included in the geologic or numerical models).

The main source of water in the Perched Zone is indicated to be derived from Site infiltration (both rainfall, stormwater recharge and infiltration from previously unlined sediment ponds and ditches). The source of water in the Surficial Aquifer and the Black Creek Aquifer are leakage from the shallower units and throughflow from the regional aquifer system.

Responses from rainfall were assessed by comparing rainfall events against changes in groundwater levels. Initial results from selected wells across the three aquifer units indicated an increase in groundwater level following a 0.08-inch rain event after a lag time typically ranging between 1.5 and 2 days.

3.4 Water Budget

Over the long term, the rate of water inflow to the Site is equal to the rate of water outflow from the Site. Water enters the groundwater system from regional flow, Site rainfall, stormwater recharge and infiltration from previously unlined sediment ponds and previously ditches. Water leaves the system through discharge primarily to the Cape Fear River via direct discharge and onsite groundwater seeps, and to a lesser extent discharge to Willis Creek, Georgia Branch Creek, and Old Outfall 002. No water balance was developed for the Site during the EVS model development stage. One of the intended outcomes of the numerical model is to provide an initial water budget estimate in order to inform future work.

4. COMPUTER MODEL

4.1 Model Selection

The model is required to simulate variably saturated flow behaviors at the Site. The steep topography surrounding the Site is challenging to simulate, and therefore a finite element model was deemed to be more appropriate than a finite difference model. Various commercially available finite element models were assessed based on their ability to meet the study objectives and their maturity and acceptance in the scientific and regulatory communities. FEFLOW (DHI-WASY) was the most suitable numerical model based on those criteria.

4.2 Model Description

FEFLOW is a 3D finite element groundwater model widely recognized in industry, research and government and considered to be an industry standard for finite element groundwater modeling. The code uses the Richards' equation, the conservation of mass, and nonlinear relationships between capillary pressure (P_c) and wetting phase saturation (S_w) and between S_w and hydraulic conductivity (K) to solve for hydraulic heads. FEFLOW simulates 3D transient groundwater flow in unsaturated and variably saturated, confined and unconfined heterogeneous systems, and models the dynamic interaction with injection/extraction wells, recharge and surface water systems. This study used FEFLOW version 7.2 for the numerical groundwater flow model simulations. All groundwater models were simulated and post-processed within the built-in FEFLOW graphical user interface.

5. GROUNDWATER FLOW MODEL CONSTRUCTION

5.1 Model Mesh

The EVS geologic model described in Section 3.1.2 of this report was translated into a series of shape files representing each of the seven hydrostratigraphic units. The numerical model mesh was developed using the contact points for the seven hydrostratigraphic units, ground surface elevation from the LiDAR remote sensing dataset and field measurements along Willis Creek and the Old Outfall 002. This data were assembled and meshed within FEFLOW using the triangle mesh generation algorithm. The model mesh contained 1,878,129 elements and 372,054 nodes. The model varies in thickness from about 170 ft on top of the bluff to 55 ft at the base of bluff near the Cape Fear River.

5.2 Hydraulic Parameters

Initial model parameters were chosen based on the available field data (Geosyntec, 2019). Where ranges in data existed, mid-points of the ranges were chosen as the initial set of parameters. Hydraulic conductivity ranges for each hydrostratigraphic unit were presented in Table 1.

Hydraulic conductivity, specific storage (S_s), unsaturated-flow porosity (θ), residual wetting phase saturation (S_r), and Brooks-Corey-Burdine P_c-S_w-K constitutive parameters (alpha (α), lambda (λ), delta (δ)) are the main hydraulic parameters in the model. The distribution and assignment of these parameters is based on the conceptual model hydrostratigraphy. Hydraulic parameter distribution in the model was uniform across individual hydrostratigraphic units. The parameter values for each hydrostratigraphic unit were determined during the flow model calibration process (Section 6) and presented in Table 2.

Table 2: Calibrated Model Hydraulic Parameters For Each Hydrostratigraphic Unit

Hydrostratigraphic Unit	K (ft/day)	S_s (m^{-1})	θ	S_r (-)	α (m^{-1})	λ (-)	δ (-)
Floodplain Deposits	1.4	1.0×10^{-8}	0.32	0.2	0.5	0.15	25
Perched Zone	2.6	1.0×10^{-3}	0.3	0.1	11.5	0.56	7.3
Perched Clay	0.0014	1.0×10^{-8}	0.5	0.2	0.5	0.15	25
Surficial Aquifer	72	1.0×10^{-3}	0.33	0.1	11.5	0.56	7.3
Black Creek Confining Unit	0.43	1.0×10^{-8}	0.55	0.2	0.5	0.15	25
Black Creek Aquifer	144	5.1×10^{-5}	0.34	0.1	11.5	0.56	7.3
Cape Fear Confining Unit	1.1	1.0×10^{-8}	0.28	0.2	0.5	0.15	25

The hydraulic conductivities of the Surficial Aquifer and Black Creek Aquifer are greater than the original estimates presented in Table 1 (see calibration section for additional details). The estimates presented in Table 1 were based primarily on grain size distributions. The calibrated hydraulic conductivity of the Surficial Aquifer is in agreement with the aquifer test (72.3 ft/d) performed by Parsons (Parsons, 2018) and the ratio of hydraulic conductivities of the Surficial and Black Creek Aquifers is in agreement with the differences in geologic description based on the borehole logs (fine vs. medium grained sand).

S_r and the Brooks-Corey-Burdine (α, λ, δ) constitutive parameters for each hydrostratigraphic unit were selected based on the soil textural class and the estimated model parameters reviewed from Madi et al. (2018), Matlan et al. (2014), and Shao and

Irannejad (1999). These parameter assignments were simplified for the model by separating the hydrostratigraphic units as either aquifers or aquitards (see Table 1), after performing the first set of flow model calibration runs where each hydrostratigraphic unit was assigned distinct parameter sets. Aquifer units were assigned S_r and Brooks-Corey-Burdine constitutive parameters representative of sands; aquitard units were assigned S_r and Brooks-Corey-Burdine constitutive parameters representative of sandy clay, silty clay, and clay soil types.

5.3 Flow Model Boundary Conditions

The numerical model extent is a subset of the EVS model extent. The lack of available data on a regional scale required the model to be site-scale focused. Focusing on the Site enabled a detailed examination and quantitation of the steep topography and steep vertical gradients. The numerical model extent was closely tied to the boundary conditions chosen for the model:

Top Boundary: Established as the ground surface, taken from a combination of LiDAR data and topographic surveys performed along Willis Creek and the Outfall. Boundary conditions on the top boundary were either constant flux (to simulate rainfall recharge) or constant head equal to elevation (with a no inward flow constraint) to simulate seepage faces on the bluffs. Initial rainfall recharge values were selected with reference to the annual precipitation and evapotranspiration estimates for the Mid-Atlantic Coastal Plain (United States Geological Survey (USGS), 2005).

Bottom Boundary: Chosen as flat at an elevation of -20 ft above MSL which is located within the Upper Cape Fear confining unit. A no-flow hydraulic condition was applied to the entire bottom boundary of the model.

Northern Boundary: Willis Creek forms a hydraulic boundary north of the model domain. The creek is treated as a spatially-varying constant hydraulic head boundary from the northwest model corner to the outflow to the Cape Fear River located at the northeast model corner. The uppermost active nodes in the mesh along the Willis Creek boundary were linearly interpolated, from west to east along the creek, from a hydraulic head equal to the ground surface elevation at the westmost part of Willis Creek to a hydraulic head equal to the constant hydraulic head boundary value of the Cape Fear River. Application of this constant head condition to only the upper nodes in the mesh forces all groundwater flowing towards the boundary to discharge into the creek (as all nodes below the upper nodes were assigned a no-flow condition).

Eastern Boundary: The Cape Fear River forms a hydraulic boundary east of the model domain. The river is treated as a constant hydraulic head boundary in the uppermost active nodes with an elevation representative of a daily median water elevation in the river, as measured at the W.O. Huske Dam (United States Geological Survey (USGS) 2105500). The river wraps partially around the northeast and southeast corners of the model. Application of this constant head condition to only the uppermost nodes in the mesh forces all groundwater flowing towards the boundary to discharge into the river.

Southern Boundary: The model domain southern extent was chosen to represent a flow line from the western boundary to the eastern boundary. This selection was based on the available measured hydraulic head data and professional judgement (Geosyntec, 2019). A no flow condition was applied to the southern boundary.

Western Boundary: The western model boundary is not bounded by any clearly defined hydraulic features and may be a flow divide beneath a topographic high. This boundary was chosen as parallel to the Cape Fear River as limited hydraulic information was available to make a more refined choice. This boundary is located more than a quarter mile from the manufacturing area of the Site. Spatially-varying constant hydraulic head boundary conditions were applied linearly ranging from 125 ft (in the shallower portion of the domain) or 122 ft (in the deeper portion of the domain) at the southern end of the boundary to the elevation of Willis Creek at the northern end of the boundary.

5.4 Selection of Calibration Targets

The steady state flow model calibration targets were water level measurements taken at 77 of the 147 monitoring wells synoptically surveyed on October 15, 2019, screened in the Perched Zone, Surficial Aquifer, and Black Creek Aquifer units (Geosyntec, 2019). Of these 77 monitoring wells, 33 wells were located in the Perched Zone (Figure 6), 23 wells were located in the Surficial Aquifer (Figure 7), and 21 wells were located in the Black Creek Aquifer (Figure 8). The focus of this modeling study was on flow behaviors in the Black Creek Aquifer, and to a lesser extent the flow behaviors in the Surficial Aquifer and Perched Zone. Computed nodal hydraulic heads at the approximate reference well screen midpoint elevations in the FEFLOW model domain were compared to the field measured hydraulic heads at these 77 wells. FEFLOW calculates hydraulic heads at individual nodes rather than nodal intervals, therefore only monitoring well locations which had field measured hydraulic heads greater or equal to their respective well screen midpoints were included in the calibration analysis.

Seventy of the 147 wells from the October 15, 2019 synoptic water level survey were excluded from the calibration analysis based on one or more of the following criteria:

- Wells located offsite (20 monitoring wells);
- Wells located outside of the model domain (3 monitoring wells);

- Wells screened within the Floodplain Deposits hydrostratigraphic unit (6 monitoring wells);
- Wells where the hydraulic head groundwater elevation measurement was lower than the elevation of the well screen midpoint (19 monitoring wells);
- Wells where water levels were not measured in this synoptic water level survey (10 monitoring wells);
- Wells where the well construction details were not available to estimate an approximate well screen midpoint elevation (MW-7S); or
- Wells where the hydraulic head measured was considered anomalous/inconsistent and was either not used in the groundwater elevation contour development (pre-calibration) or removed from calibration analysis based on professional judgement and review (11 monitoring wells). For example, a high density of wells exists to the immediate southwest of the plant in the vicinity of the top of Old Outfall 002. Three of these eleven wells were retained for the calibration, with MW-31, MW-33, MW-34, MW-35, MW-36, PZ-29, PZ-32, and PZ-34 excluded from the calibration analysis.

6. CALIBRATION

6.1 Residual Analysis

The groundwater flow model was calibrated using a staged approach starting with the initial hydraulic parameter set described in Section 5.2 and the boundary conditions described in Section 5.3. Calibration testing was performed by trial and adjustment, evaluating the modeled hydraulic heads against the water level data described in Section 5.4. The final calibrated hydraulic parameters are presented in Table 3. Groundwater recharge due to rainfall was determined to result in a best fit when 70% of rainfall recharge (total precipitation multiplied by non-evapotranspiration fraction) was allowed to infiltrate to the Perched Zone. Localized anthropogenic stormwater recharge (in addition to rainfall recharge) and historical infiltration from previously unlined sedimentation basins was also included distributed across the footprint of the plant at a scoping level infiltration rate estimate of 80,000 GPD.

The final calibration statistics of the calibrated groundwater flow model are presented in Table 3. A graphical comparison of the model computed hydraulic heads versus the measured hydraulic heads from the October 2019 water level synoptic survey are presented in Figure 9.

Table 3: Final Calibrated Groundwater Flow Model Statistics

Hydro-stratigraphic Unit	Number of Well Observations	Mean Hydraulic Head Residual (ft)	Minimum Hydraulic Head Residual (ft)	Maximum Hydraulic Head Residual (ft)	RMS Error (ft)	NRMS Error (%)
Perched Zone	33	-1.33	-9.91	7.86	4.59	25.2%
Surficial Aquifer	23	-2.93	-12.62	4.84	5.47	6.2%
Black Creek Aquifer	21	2.52	-4.37	10.57	5.43	6.2%

Notes: RMS – Root Mean Square. NRMS – Normalized Root Mean Square. Residuals are calculated as the difference between computed hydraulic heads from the groundwater flow model and the measured hydraulic heads from the October 2019 synoptic water level survey (Geosyntec, 2019).

Assessing a model calibration based on statistics derived from residuals is driven by the end requirements of the model, its predictive use, and the quantity of quality data available during the calibration process. The end use of the current model is to assist in the design and costing of potential hydraulic approaches to managing flow into the Cape Fear River. This end use allows for a greater level of uncertainty than a detailed contaminant fate and transport modeling program used to inform risk. Overall, a Normalized Root Mean Square (NRMS) error of less than 10% is considered acceptable for the intended end use of this model. The calibration achieves this for the Surficial and Black Creek Aquifers individually and also for the overall model when not separated into individual hydrostratigraphic units. The calibration does not achieve this for the Perched Zone, and additional calibration efforts may be required.

Computed hydraulic head contours and hydraulic head residuals are presented in Figures 6 to 8, for the Perched Zone, Surficial Aquifer, and Black Creek Aquifer, respectively. Overall, the model computed hydraulic heads provide a reasonable fit to the October 2019 synoptic survey water level data in the Surficial Aquifer and Black Creek Aquifer units.

Outlier hydraulic heads (greatest residuals) can be grouped into three types:

- Overestimates of hydraulic head in the Black Creek Aquifer in the vicinity of the Cape Fear River (PW-10R, PIW-4D, PIW-9D, SMW-12).

- Underestimates of the hydraulic heads along the mid to bottom of the bluff slopes in the Surficial Aquifer (MW-9S, PIW-5S, PW-03, SMW-09).

- Overestimates of the hydraulic head along the Cape Fear River bluffs in the Perched Zone (MW-23, MW-30).

There is likely a correlation between the tendency of the model to overpredict hydraulic heads in the Black Creek Aquifer and underpredict hydraulic heads in the Surficial Aquifer in similar geographical locations. It is likely that there is better hydraulic communication across the Black Creek Confining Unit in the vicinity of the Cape Fear River than is present in the model. Adjustments to the hydraulic conductivity of the Black Creek Confining Unit resulted in poorer fits elsewhere in the model and no geologic evidence is present in the borehole logs to indicate a localized phenomenon. The higher hydraulic heads in the Black Creek Aquifer in the model result in larger gradients and conservative overestimates of discharge to the Cape Fear River so additional, unsupported localized parameter modifications were not attempted.

6.2 Seeps and Discharges

The model calibration process also included comparison of predicted seepage rates from the Willis Creek and Cape Fear River bluffs as well as discharges to the Old Outfall 002 and the Cape Fear River. Results of this secondary calibration assessment are presented in Table 4.

Table 4: Calibration to Seeps and Discharges

Seep/Discharge Target	Measured/Estimated[1]	Modeled
Willis Creek Bluff Seeps	> 50 GPM	102 GPM
Cape Fear River Bluff Seeps	280 GPM	34 GPM
Old Outfall 002 Flow	500 – 750 GPM	1,202 GPM[2]

Notes: [1]Data taken from CAP or Investigation Report. [2]This estimate includes discharge in the vicinity of the Cape Fear River that likely is directly discharged to the river and as such is an overestimate of the actual flow in the Old Outfall 002.

6.3 Sensitivity Analysis

Following model calibration, a sensitivity analysis was performed to key variables modified during the calibration process or chosen based on literature values:

- Recharge due to rainfall;
- Perched Zone Hydraulic Conductivity;
- Surficial Aquifer Hydraulic Conductivity;
- Black Creek Aquifer Hydraulic Conductivity;

- Perched Clay Hydraulic Conductivity;
- Western Boundary Condition Hydraulic Head Distribution.

The sensitivity of the model calibration to each variable is assessed qualitatively and quantitatively (where possible) in Table 5.

Table 5: Calibrated Model Sensitivity to Model Boundary Conditions and Hydraulic Parameters

Sensitivity Variable	Change	Sensitivity	NRMS Error
Calibrated Model	N/A	N/A	12.5%
Rainfall Recharge	+/- 20%	Low	13.6%/12.7%
Perched Zone K	+/- 50%	Low	11.6%/13.3%
Surficial K	+/- 20%	Low	12.7%/12.8%
Black Creek K	+/- 20%	Low	12.4%/12.7%
Perched Clay K	Across three orders of magnitude	High	31.7% at reference hydraulic conductivity. Sensitivity limited to Perched Zone.
Western Boundary Condition	Change in spatial distribution of hydraulic heads and absolute values of hydraulic heads	Moderate	Wide range depending on changes. Sensitivity limited to Surficial and Black Creek, limited sensitivity in Perched Zone.

The higher calibration assessment statistics (poorer fit) of the model in the Perched Zone are primarily due to the small range of observed hydraulic heads in the system (as compared to the Surficial and Black Creek Aquifers). The distribution of hydraulic heads in the Perched Zone is likely dependent on the actual locations of anthropogenic recharge which have been spatially variable over time. The model used a uniform spatially distributed recharge (in addition to rainfall recharge) to replicate the general mounding observed at the Site. This approach captured the overall behavior but does not capture the detailed spatial variability to a high degree of certainty.

7. PREDICTIVE SIMULATIONS

The predictive simulations were designed to investigate the effectiveness of extraction gallery well field distribution as a mechanism to capture the groundwater discharging to the Cape Fear River. The modeling conducted was comprised of the following:

- Extraction Wells Scenario with no Barrier Wall at the Base of the Bluff;
- Extraction Wells Scenario and Barrier Wall at the Base of the Bluff; and
- Extraction Wells Scenario and Barrier Wall Adjacent to the Plant.

A summary of the simulations conducted are presented in Table 6. For each scenario a base case was established, and sensitivity analyses were completed to assess and minimize the simulated degree of groundwater capture needed to reduce discharge to the Cape Fear River.

Table 6: Summary of Prediction Scenarios

Scenario Type	Scenario Description	Number of Extraction Wells
Extraction Wells Scenario with no Barrier Wall at the Base of the Bluff	Well Spacing at 50 ft and a uniform pumping rate of 30 GPM	164
	Well Spacing at 50 ft and a spatially variable pumping rate between 20 to 40 GPM	
	Well Spacing at 50 ft and a spatially variables pumping rate between 20 to 40 GPM, adjusted hydraulic conductivity within the Surficial and Black Creek Aquifers as sensitivity analysis	
Extraction Wells Scenario and Barrier Wall at the Base of the Bluff	Well Spacing at 200 ft spacing with a uniform pumping rate at 20 GPM	41
	Well Spacing at 200 ft spacing with a spatially variable pumping rate between 20 to 30 GPM	
	Well Spacing at 200 ft spacing with a spatially variable pumping rate between 20 to 30 GPM, adjusted extraction location towards the bluff as sensitivity analysis	
	Well Spacing at 200 ft spacing with a spatially variable pumping rate between 20 to 30 GPM, adjusted hydraulic conductivity within the Surficial and Black Creek Aquifers as sensitivity analysis	
	Well Spacing at 250 ft spacing with a uniform pumping rate at 30 GPM	31
	Well Spacing at 250 ft spacing with a spatially variable pumping rate between 20 to 30 GPM	

Scenario Type	Scenario Description	Number of Extraction Wells
	Well Spacing at 250 ft spacing with a spatially variable pumping rate between 20 to 30 GPM, adjusted extraction location towards the bluff as sensitivity analysis	
	Well Spacing at 250 ft spacing with a spatially variable pumping rate between 20 to 30 GPM, adjusted hydraulic conductivity within the Surficial and Black Creek Aquifers as sensitivity analysis	
Extraction Wells Scenario and Barrier Wall Adjacent to the Plant	Extraction wells west of the plant area. Well spacing of 200 ft with a uniform pumping rate of 40 GPM	49
	Extraction wells east of the plant area. Well spacing of 200 ft with a uniform pumping rate of 40 GPM	51
	Extraction wells west of the plant area. Well spacing of 250 ft with a uniform pumping rate of 40 GPM	36
	Extraction wells east of the plant area. Well spacing of 250 ft with a uniform pumping rate of 40 GPM	38

The following assumptions were made for the predictive model runs:

- Model parameters were taken from the model consistent with the model discussed in Section 5.0;
- The model was run for a forecast period of 1 year; and
- Initial conditions were taken from the final head of the model consistent with the model discussed in Section 5.0.

A summary of the predictive simulation results is presented in Table 7.

Table 7: Summary of Prediction Scenarios Results

Scenario Type	Scenario Description	Number of Extraction Wells	Black Creek Groundwater Discharge Rate into the Cape Fear River – Before Simulated Pumping (GPM)	Black Creek Groundwater Capture Flow into the Cape Fear River – By Simulated Pumping (GPM)
Extraction Wells Scenario with no Barrier Wall at the Base of the Bluff	Well Spacing at 50 ft and a uniform pumping rate of 30 GPM	164	1151	3522
	Well Spacing at 50 ft and a spatially variables pumping rate between 20 to 40 GPM		1151	3772
	Well Spacing at 50 ft and a spatially variables pumping rate between 20 to 40 GPM, adjusted hydraulic conductivity as sensitivity analysis		1445	3862
Extraction Wells Scenario and Barrier Wall at the Base of the Bluff	Well Spacing at 200 ft spacing with a uniform pumping rate at 20 GPM	41	1551	1389
	Well Spacing at 200 ft spacing with a spatially variable pumping rate between 20 to 30 GPM		1551	1421
	Well Spacing at 200 ft spacing with a spatially variable pumping rate between 20 to 30 GPM, adjusted extraction location towards the bluff as sensitivity analysis		1551	1459

Scenario Type	Scenario Description	Number of Extraction Wells	Black Creek Groundwater Discharge Rate into the Cape Fear River – Before Simulated Pumping (GPM)	Black Creek Groundwater Capture Flow into the Cape Fear River – By Simulated Pumping (GPM)
	Well Spacing at 200 ft spacing with a spatially variable pumping rate between 20 to 30 GPM, adjusted hydraulic conductivity as sensitivity analysis		1551	1532
	Well Spacing at 250 ft spacing with a uniform pumping rate at 30 GPM	31	1551	1419
	Well Spacing at 250 ft spacing with a spatially variable pumping rate between 20 to 30 GPM		1551	1322
	Well Spacing at 250 ft spacing with a spatially variable pumping rate between 20 to 30 GPM, adjusted extraction location towards the bluff as sensitivity analysis		1551	1337
	Well Spacing at 250 ft spacing with a spatially variable pumping rate between 20 to 30 GPM, adjusted hydraulic conductivity as sensitivity analysis		1551	1446
Extraction Wells Scenario and Barrier Wall Adjacent to the Plant	Extraction wells east of the plant area. Well spacing of 200 ft with a uniform pumping rate of 40 GPM	49	1551	1021
	Extraction wells west of the plant area. Well spacing of 200 ft with a uniform pumping rate of 40 GPM	51	1551	822

Scenario Type	Scenario Description	Number of Extraction Wells	Black Creek Groundwater Discharge Rate into the Cape Fear River – Before Simulated Pumping (GPM)	Black Creek Groundwater Capture Flow into the Cape Fear River – By Simulated Pumping (GPM)
	Extraction wells east of the plant area. Well spacing of 250 ft with a uniform pumping rate of 40 GPM	36	1551	824
	Extraction wells west of the plant area. Well spacing of 250 ft with a uniform pumping rate of 40 GPM	38	1551	719

7.1 Extraction Wells Scenario with no Barrier Wall

The initial model assumed an extraction well spacing of 5 feet apart along the base of the bluff between Willis Creek and the Old Outfall 002. These pumping scenarios indicated dewatering would occur along sections of the aquifer at the base of the bluff, resulting in significant capture of water from the Cape Fear River. Additional model runs were completed with the aim of reducing the capture of Cape Fear River water while providing capture of groundwater discharge. The minimal pumping scenario, based on the model runs completed, recommended the extraction gallery wells spacing of 50 feet apart.

7.2 Extraction Wells Scenario and Barrier Wall

The initial model assumed an extraction well spacing of 200 to 250 feet apart along the base of the bluff between Willis Creek and the Old Outfall 002. In addition to the extraction well gallery a low permeability barrier wall was placed between Cape Fear River and the extraction wells. A uniform pumping rate of 30 GPM was applied along the extraction galley of 41 wells. This extraction rate resulted in a groundwater depression along the base of the bluff between the extraction wells and the barrier wall. Additional model runs were completed to refine the extraction rate and spacing within the extraction gallery. The minimal pumping scenario, based on the model runs completed, recommended the extraction gallery wells to have a well spacing of 200 feet, and a variable pumping rate along the extraction gallery wellfield between 20 to 35 GPM. This scenario results in a minimum of excess produced water while still providing capture of discharging groundwater and minimal to no flow from the Cape Fear River to the extraction gallery.

In addition to the groundwater extraction minimization analyses for the remedial design simulations sensitivity analysis was also completed by increasing the hydraulic conductivities of hydrostratigraphic units to emphasize the flow interactions between the aquifer units and adjusted the recharge rate. The results indicated that the model is moderately sensitivity to the changes in hydraulic conductivity and is not sensitivity to the changes in recharge for the Black Creek Aquifer.

7.3 Extraction Wells Scenario and Barrier Wall Adjacent to the Plant

The initial model assumed an extraction well spacing of 200 to 250 feet apart west and/or east of the plant. Similar to the scenario of pumping along the Cape Fear River, this scenario resulted in dewatering of the aquifer along section at the base of the bluff, resulting in significant capture of water from the Cape Fear River. Model runs were completed with the goal of reducing the capture of water from the Cape Fear River and reducing the dewatering of the aquifers. The minimal pumping scenario, based on the model runs completed, recommended the extraction gallery wells spacing be less than 200 feet apart if extraction wells are placed above the bluff adjacent to the plant and required pumping rates to be above 40 GPM. The groundwater extraction minimization process indicated that greater volumes of extraction are required to provide the required hydraulic control at the base of the bluff as compared to other scenarios.

8. LIMITATIONS AND RECOMMENDATIONS

8.1 Model Assumptions and Limitations

The hydrogeologic conditions that control the movement of groundwater in the subsurface are complex and, as such, assumptions and simplifications must be made during the construction of the numerical model that are used to simulated groundwater flow. The following assumptions were made in the design of the Chemours Fayetteville Works groundwater flow model and should be considered when assessing any model predictions in the future:

- The model domain was limited to the spatial extent where hydrogeological data was available;
- Boundary conditions are aligned with geological and hydraulic boundaries identified within the EVS model;
- Changes to geology derived via the EVS model and Site data during the calibration process were avoided where possible; and

- The model was calibrated to an average steady-state condition based on data from October 2019.

- The modeling conducted for the Site was challenging from both design (three dimensional, spatially variable hydrostratigraphy, unsaturated, and steep topography driving steep hydraulic gradients) and calibration (day-long simulation times, significant hours to make changes to the complex model between calibration runs) standpoints. There are some identified regions of error in the predictions that are likely tied to uncertainties in the conceptual site model, and these could impact on the design of groundwater remedies for the Site. The process of site investigation – modeling – design is best undertaken in an iterative manner, with feedback from each step incorporated into the following steps.

8.2 Summary and Recommendations

The calibrated FEFLOW model meets the requirements of the NCDEQ's 2007 Groundwater Modeling Policy (NCDEQ, 2007) and supports remedy evaluation, selection and design at the Site. The calibrated model is deemed sufficiently accurate for the modeling goals of this work however new data should be incorporated into both the conceptual and numerical models when it becomes available.

Numerical modeling is an effective technique for identifying areas of uncertainty in conceptual models and source-pathway-receptor models. Based on the results of the numerical modeling program, groundwater remedy development would be supported by reducing uncertainty regarding:

- Interactions between the Surficial Aquifer and the Black Creek Aquifer along the bluffs; and

- Distribution of groundwater flows into surface water drainage features including onsite groundwater seeps, Willis Creek and Old Outfall 002.

A combination of additional simulations and targeted field investigations (aquifer testing) to address these uncertainties is recommended before final remedy design.

9. REFERENCES

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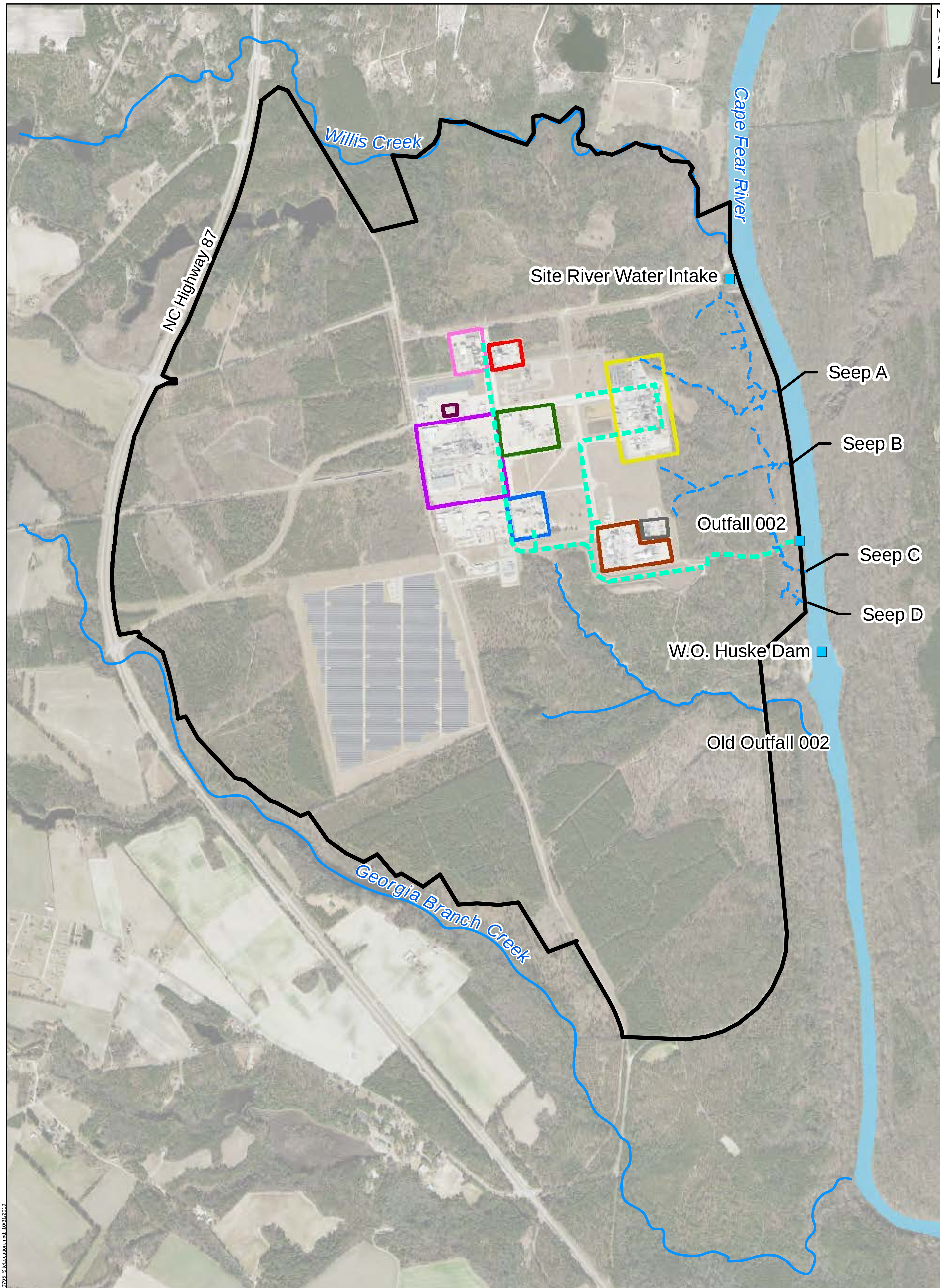
FIGURES



Legend

- Site Features
- Site Boundary
- Nearby Tributary
- Observed Seep (Natural Drainage)
- Site Drainage Network

Areas at Site

- Chemours Monomers IXM
- Chemours Polymer Processing Aid Area
- DuPont Polyvinyl Fluoride Leased Area
- Former DuPont PMDF Area
- Kuraray SentryGlas® Leased Area
- Kuraray Trosifol® Leased Area
- Wastewater Treatment Plant
- Power - Filtered and Demineralized Water Production
- Kuraray Laboratory

2,000 1,000 0 2,000 Feet

Notes:
1. The outline of the Cape Fear River shown on this figure is approximate (River outline based on compilation of open data sources from ArcGIS online service and North Carolina Department of Environmental Quality Online GIS - Major Hydro shapefile).
2. Basemap sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Site Location Map

Chemours Fayetteville Works, North Carolina

Geosyntec consultants

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Figure 1

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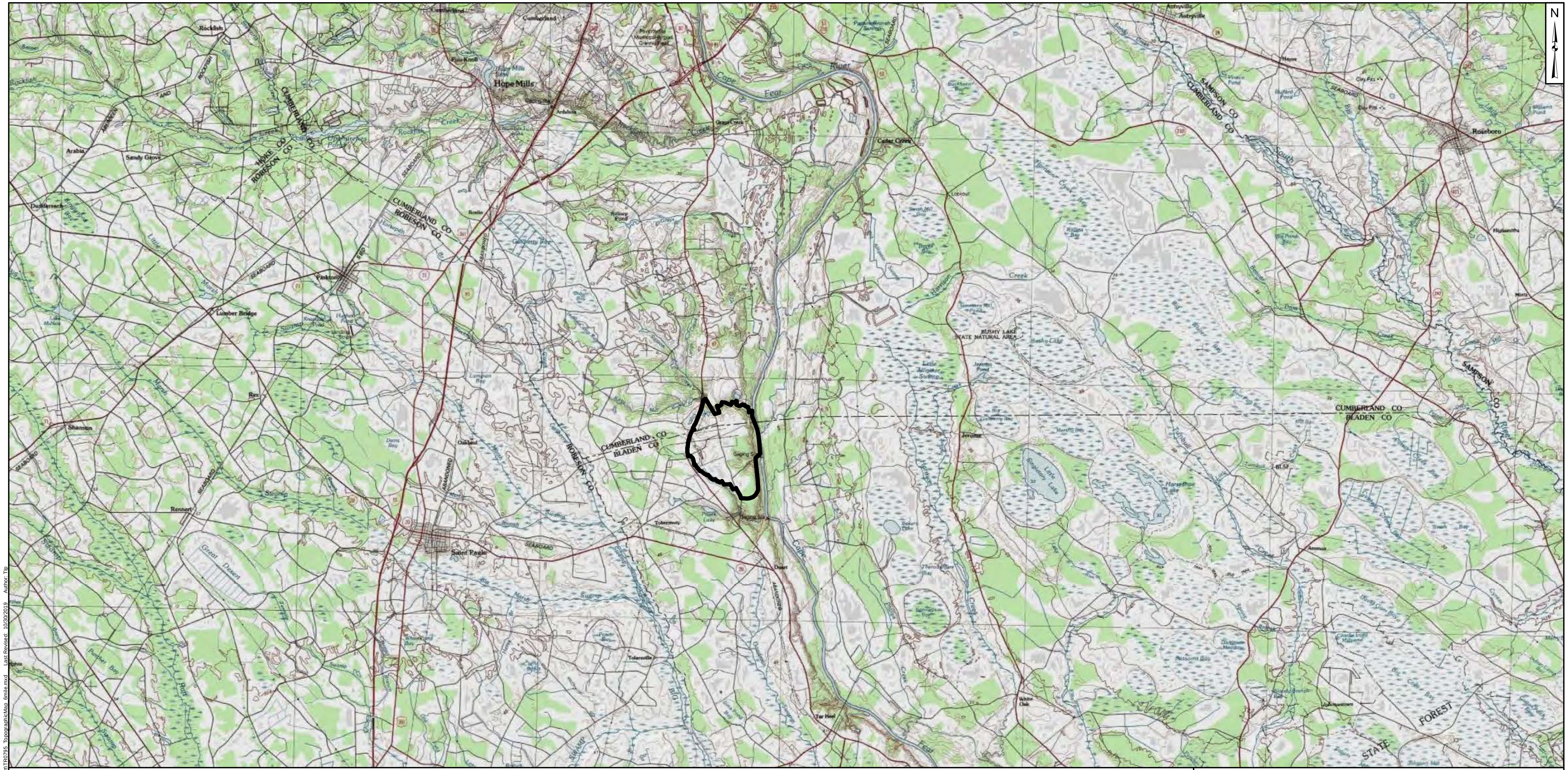

Legend

Site Boundary

Notes:
1. For topographic map symbols, please refer to this document: https://pubs.usgs.gov/gip/TopographicMapSymbols/topomapsymbols.pdf
2. Basemap source: © 2013 National Geographic Society, i-cubed

2 1 0 2 Miles

Regional Topographic Map

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Figure

2

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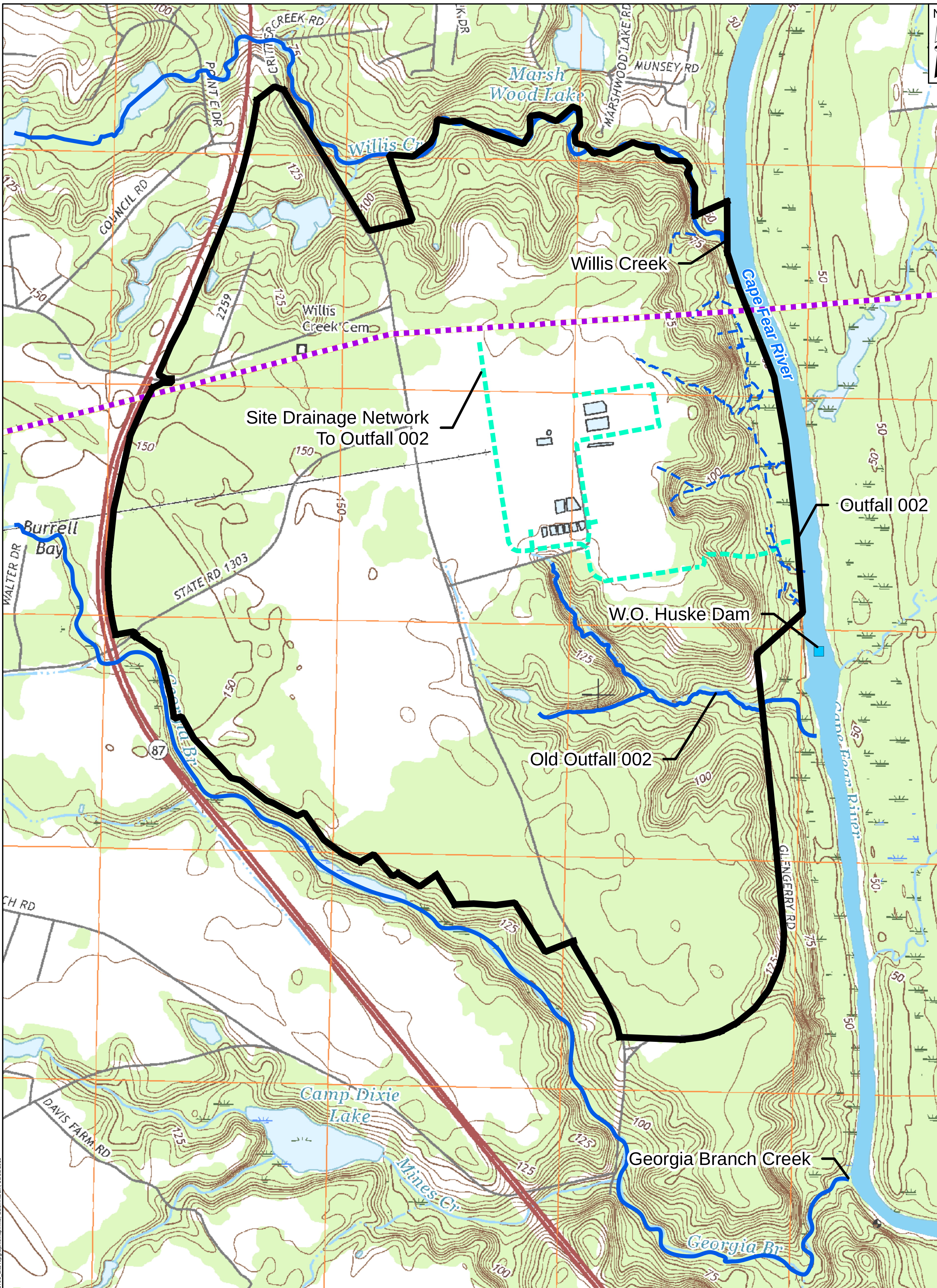
Projection: NAD 1983 StatePlane North Carolina FIPS 3200 Feet; Units in Foot US



Legend

Site Features	Observed Seep (Natural Drainage)
Site Boundary	Nearby Tributary
County Boundary	Site Drainage Network

Notes:
Basemap sources: Esri, Garmin, USGS, NPS (World Terrain Reference); Esri, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community (World Hillshade)

2,000 1,000 0 2,000 Feet

Site Topographic Map

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Figure 3

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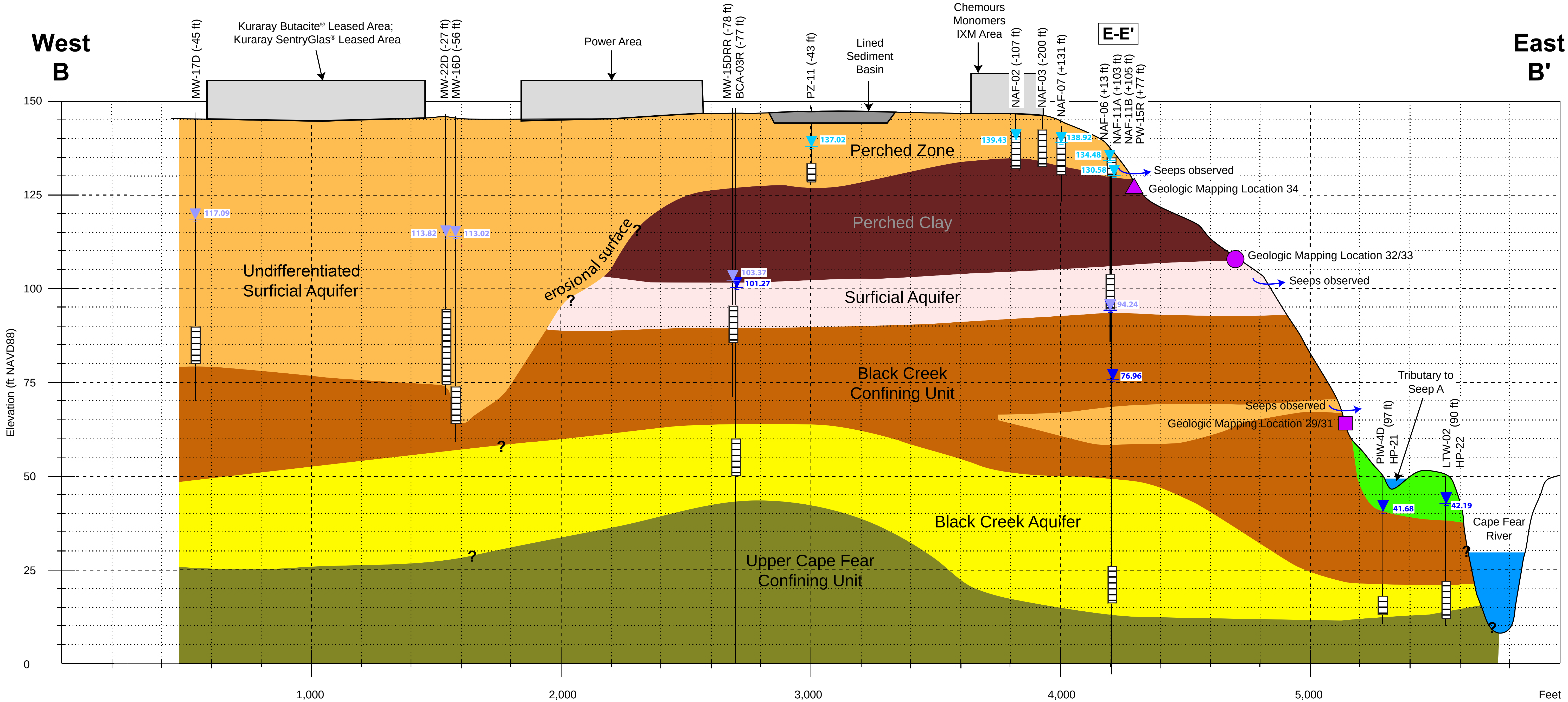


Legend

- Clay
- Silty or Sandy Clay with Organics
- Micaceous Clay
- Predominantly Fine to Medium-grained Sand
- Floodplain Deposits
- Fine to Medium-grained Sand with Variable Silt Content
- Fine to Medium Sand

MW-17D (100 ft) — Offset Distance +/- north/south of line; Location Name; Well Screen

110.98 Perched Zone Groundwater Elevation

102.94 Surficial Aquifer Groundwater Elevation

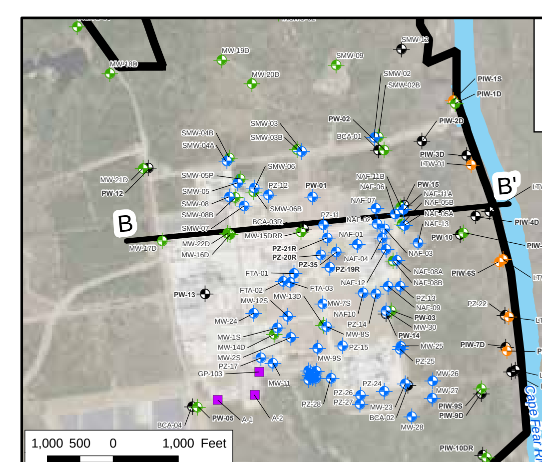
64.55 Black Creek Aquifer Groundwater Elevation

Geological Mapping Location

E-E' Corresponds to Section

Notes

ft NAVD88 - feet in 1988 North American Vertical Datum
Vertical Exaggeration = 15x
1. Lithology between borings is interpolated and estimated.
2. Groundwater elevations calculated from measured depth to water on 15 October 2019.
3. Cape Fear River water level indicated is median value for 15 October 2019 measured at the W.O. Huske Dam (USGS 2105500). Data obtained from National Water Information System (URL: https://waterdata.usgs.gov/nwis/inventory/?site_no=02105769, date accessed: 2019-09-24).
4. Geological Mapping Locations from Figure 6-1. Approximate mapping elevations listed in Table 6-1.
5. Seeps observed reported in Seeps and Creeks Investigation Report (Geosyntec, 2019)



Typical Site Cross-Section

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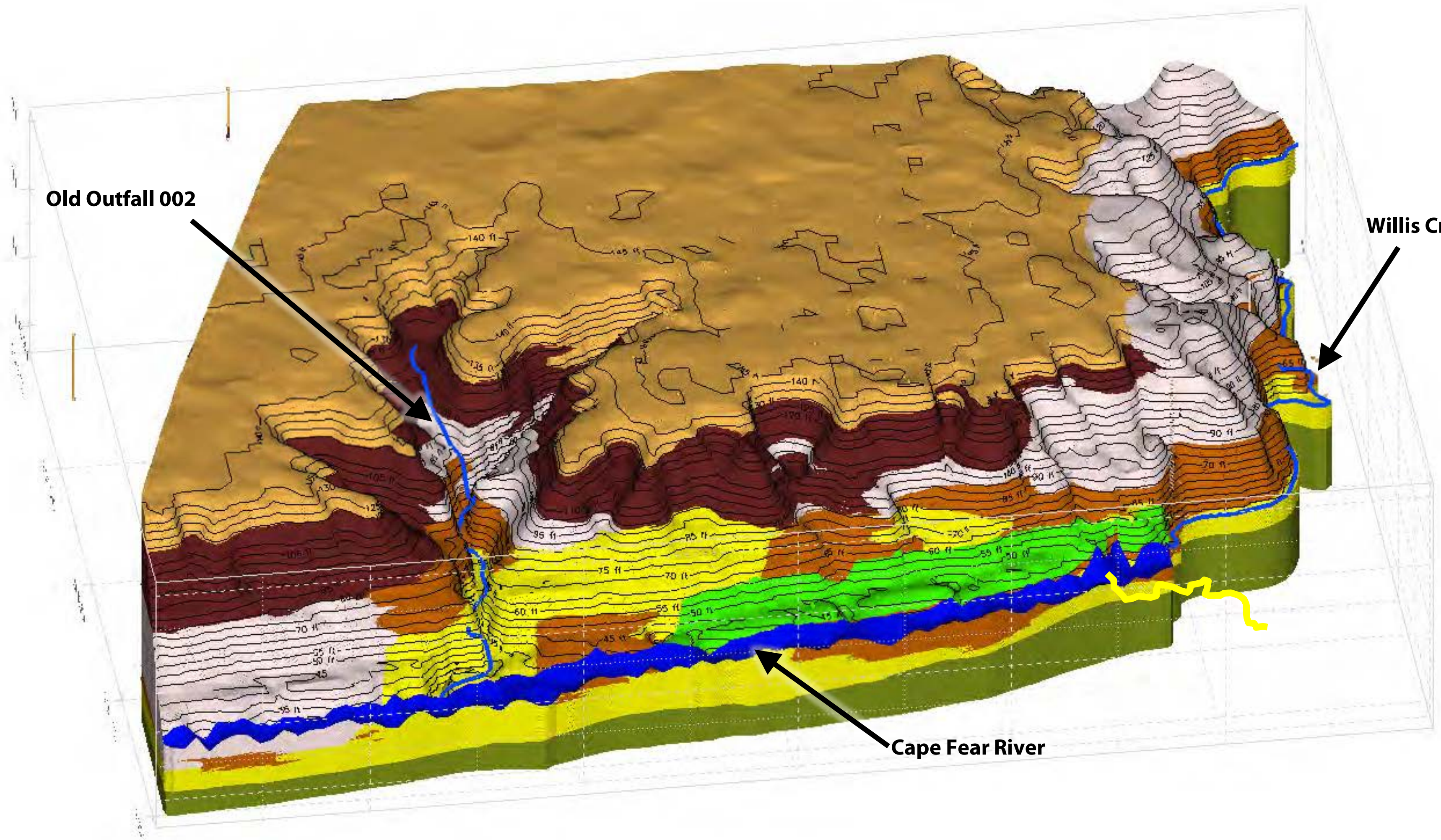
Figure 4



Units

- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]
- Water Features
- Elevation Contour Line (every 5-ft)

Note

1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.

Overview of EVS Model

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Figure 5

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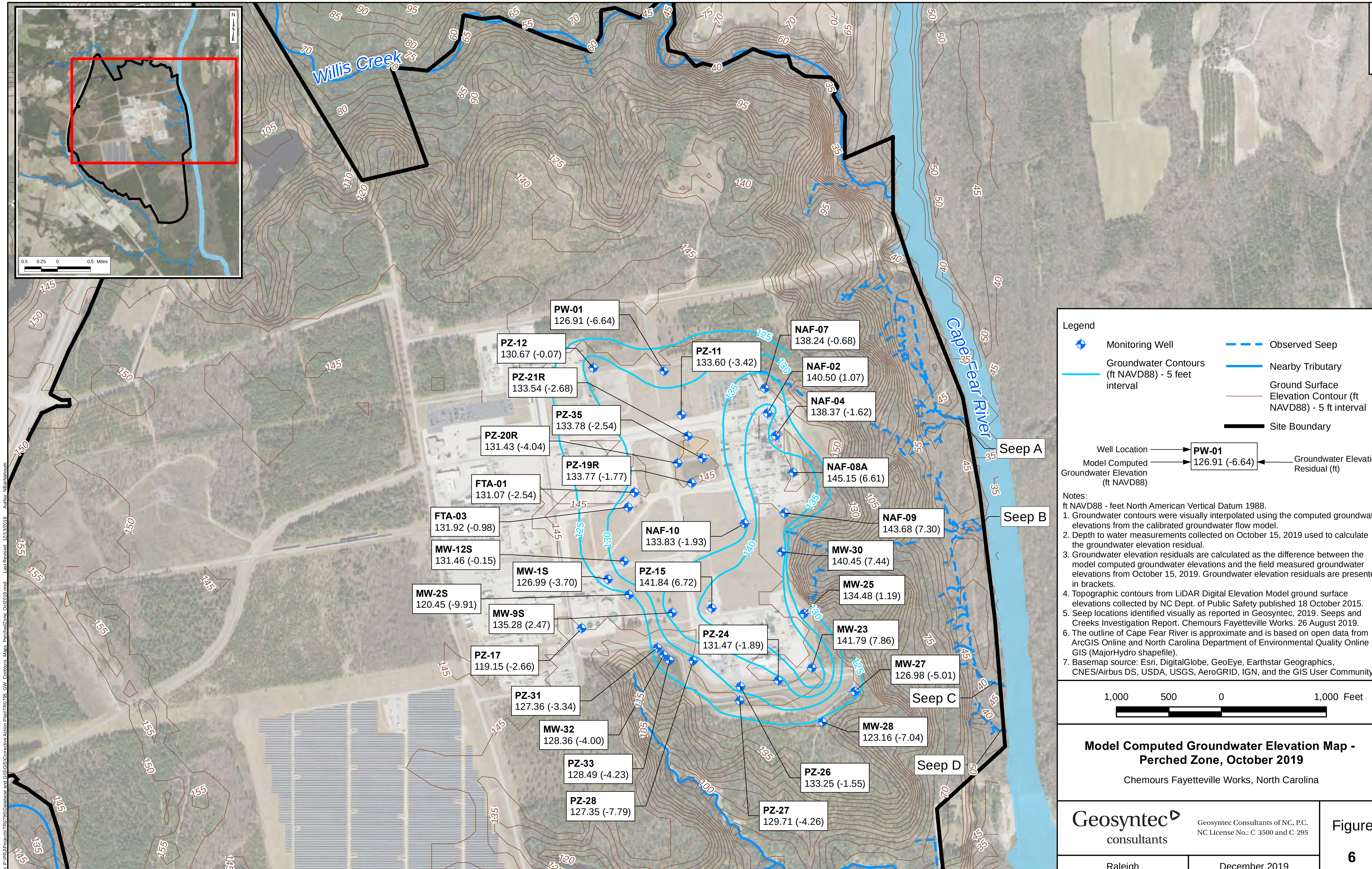

Notes:
ft NAVD88 - feet North American Vertical Datum 1988.
1. Groundwater contours were visually interpolated using the computed groundwater elevations from the calibrated groundwater flow model.
2. Depth to water measurements collected on October 15, 2019 used to calculate the groundwater elevation residual.
3. Groundwater elevation residuals are calculated as the difference between the model computed groundwater elevations and the field measured groundwater elevations from October 15, 2019. Groundwater elevation residuals are presented in brackets.
4. Topographic contours from LiDAR Digital Elevation Model ground surface elevations collected by NC Dept. of Public Safety published 18 October 2015.
5. Seep locations identified visually as reported in Geosyntec, 2019. Seeps and Creeks Investigation Report. Chemours Fayetteville Works. 26 August 2019.
6. The outline of Cape Fear River is approximate and is based on open data from ArcGIS Online and North Carolina Department of Environmental Quality Online GIS (MajorHydro shapefile).
7. Basemap source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Model Computed Groundwater Elevation Map - Perched Zone, October 2019

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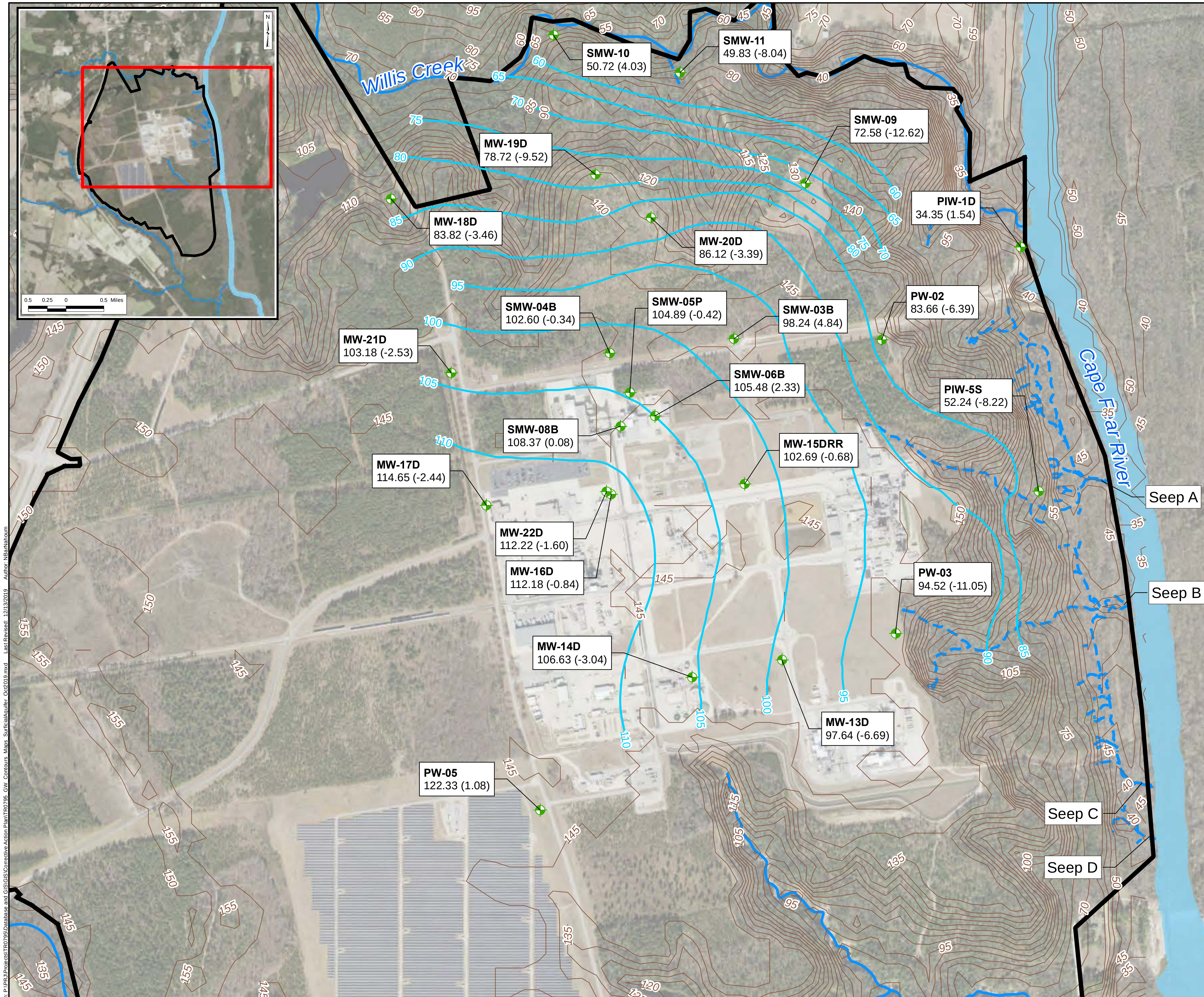
Figure 6

Projection: NAD 1983 StatePlane North Carolina FIPS 3200 Feet; Units in Foot US



Legend

- Monitoring Well
- Groundwater Contours (ft NAVD88) - 5 feet interval
- Observed Seep
- Nearby Tributary
- Ground Surface Elevation Contour (ft NAVD88) - 5 ft interval
- Site Boundary

Well Location → PW-03
Model Computed Groundwater Elevation (ft NAVD88) → 94.52 (-11.05) ← Groundwater Elevation Residual (ft)

Notes:
ft NAVD88 - feet North American Vertical Datum 1988.
1. Groundwater contours were visually interpolated using the computed groundwater elevations from the calibrated groundwater flow model.
2. Depth to water measurements collected on October 15, 2019 used to calculate the groundwater elevation residual.
3. Groundwater elevation residuals are calculated as the difference between the model computed groundwater elevations and the field measured groundwater elevations from October 15, 2019. Groundwater elevation residuals are presented in brackets.
4. Topographic contours from LiDAR Digital Elevation Model ground surface elevations collected by NC Dept. of Public Safety published 18 October 2015.
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6. The outline of Cape Fear River is approximate and is based on open data from ArcGIS Online and North Carolina Department of Environmental Quality Online GIS (MajorHydro shapefile).
7. Basemap source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

1,000 500 0 1,000 Feet

Model Computed Groundwater Elevation Map - Surficial Aquifer, October 2019

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Figure 7

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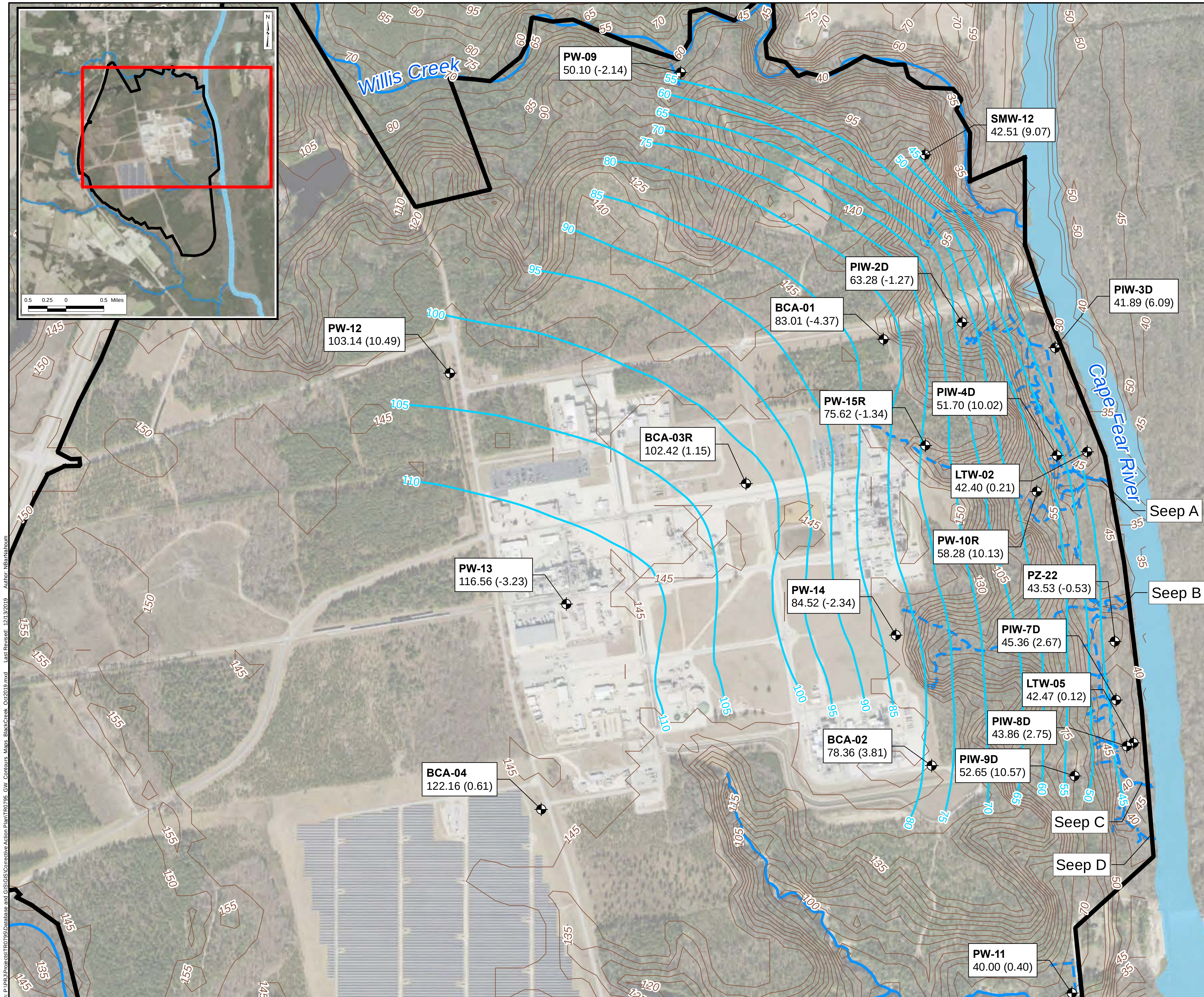
Projection: NAD 1983 StatePlane North Carolina FIPS 3200 Feet; Units in Foot US



Legend

- Monitoring Well
- Groundwater Contours (ft NAVD88) - 5 feet interval
- Observed Seep
- Nearby Tributary
- Ground Surface Elevation Contour (ft NAVD88) - 5 ft interval
- Site Boundary

Well Location → PZ-22
Model Computed Groundwater Elevation (ft NAVD88) → 43.53 (-0.53) ← Groundwater Elevation Residual (ft)

Notes:
ft NAVD88 - feet North American Vertical Datum 1988.
1. Groundwater contours were visually interpolated using the computed groundwater elevations from the calibrated groundwater flow model.
2. Depth to water measurements collected on October 15, 2019 used to calculate the groundwater elevation residual.
3. Groundwater elevation residuals are calculated as the difference between the model computed groundwater elevations and the field measured groundwater elevations from October 15, 2019. Groundwater elevation residuals are presented in brackets.
4. Topographic contours from LiDAR Digital Elevation Model ground surface elevations collected by NC Dept. of Public Safety published 18 October 2015.
5. Seep locations identified visually as reported in Geosyntec, 2019. Seeps and Creeks Investigation Report. Chemours Fayetteville Works. 26 August 2019.
6. The outline of Cape Fear River is approximate and is based on open data from ArcGIS Online and North Carolina Department of Environmental Quality Online GIS (MajorHydro shapefile).
7. Basemap source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

1,000 500 0 1,000 Feet

Model Computed Groundwater Elevation Map - Black Creek Aquifer, October 2019

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Figure 8

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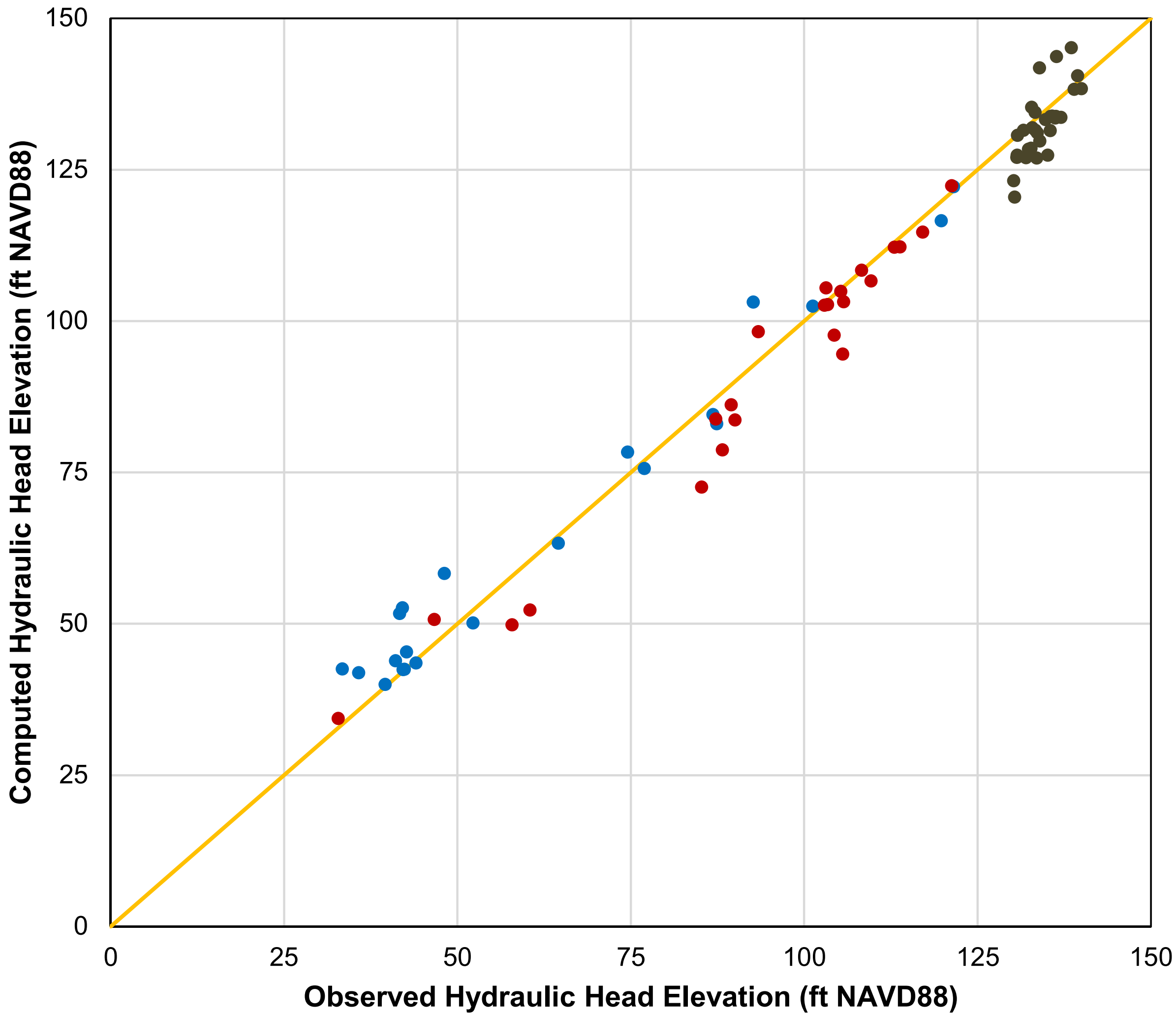
Path: P:\PRJ\Projects\TR0795\Database and GIS\GIS\Corrective Action Plan\TR0795_GW_Contours_Maps_BlackCreek_Oct2019.mxd Last Revised: 12/13/2019 Author: NBartholomew

Projection: NAD 1983 StatePlane North Carolina FIPS 3200 Feet; Units in Foot US



Legend

- Black Creek Aquifer
- Surficial Aquifer
- Perched Zone

Notes

NAVD88 - North American Vertical Datum of 1988

1. Observed hydraulic head elevations were obtained from a synoptic water level survey conducted on October 15, 2019.
2. Computed hydraulic head elevations were obtained from the calibrated steady state groundwater flow model.
3. Orange line represents the ideal calibration scenario where observed and computed hydraulic heads are equal.

Comparison of Observed and Computed Hydraulic Head Elevations

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Figure 9

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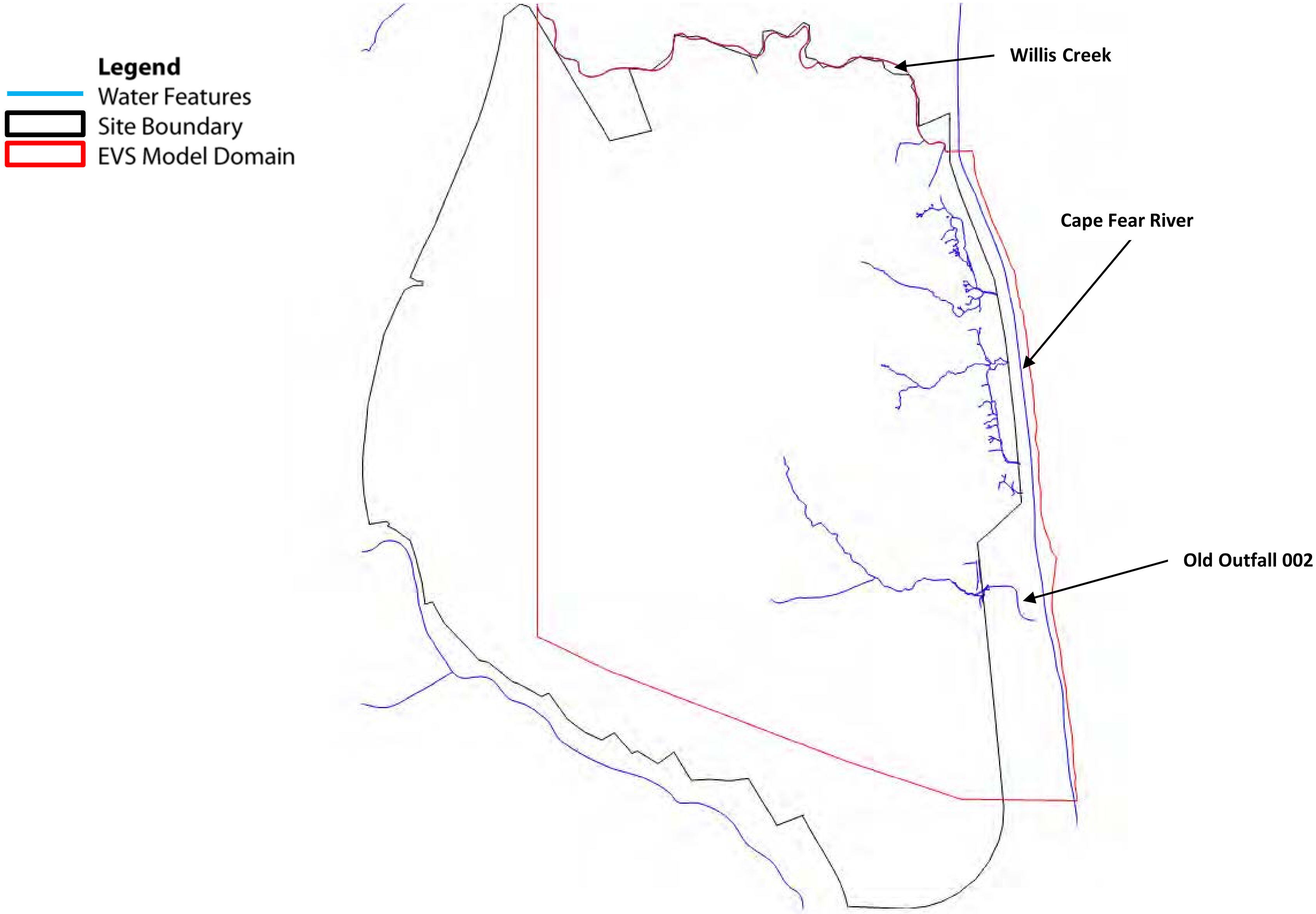
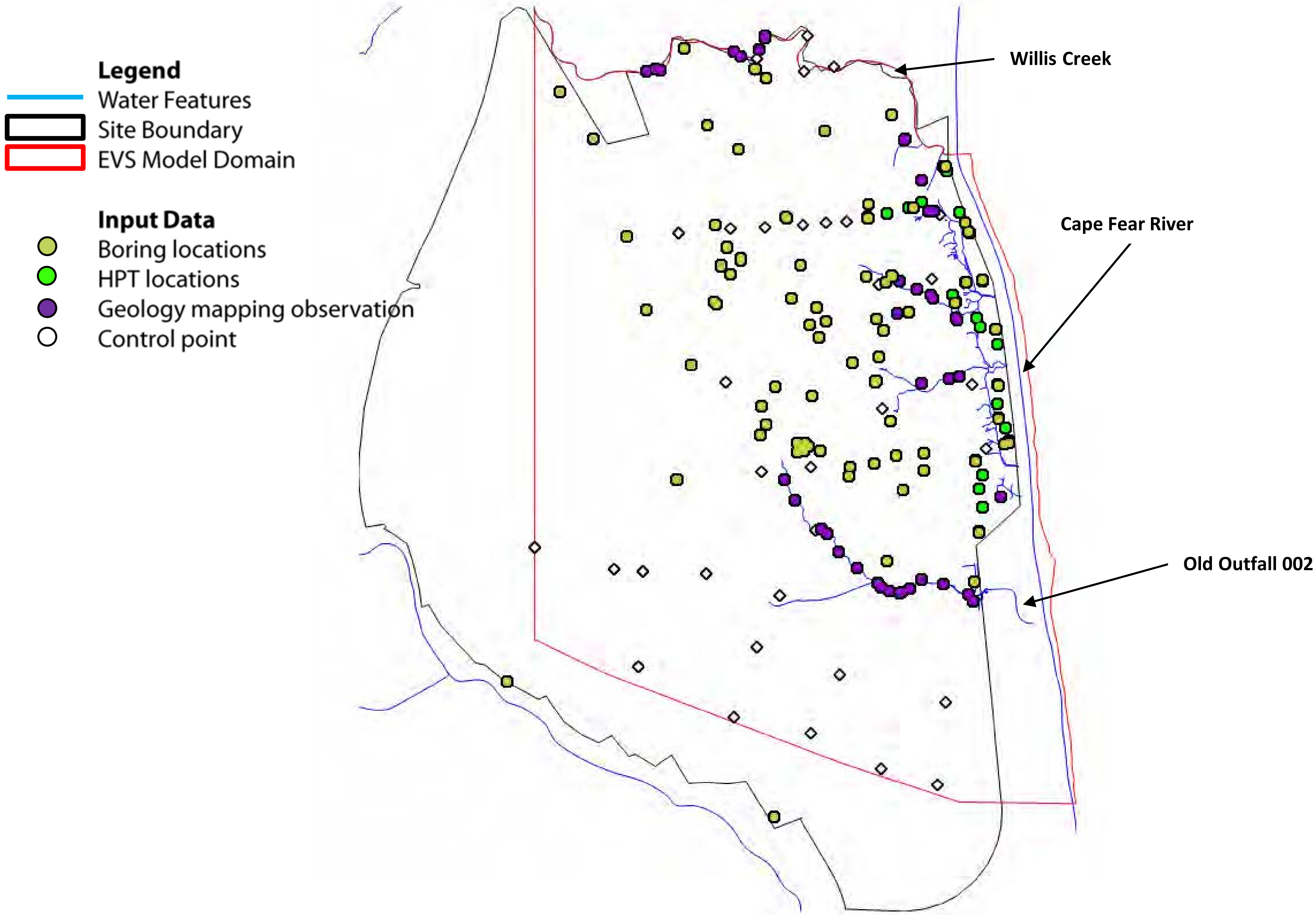
APPENDIX A
EXTRACTS FROM EVS MODEL

EVS Model Domain

Geosyntec consultants

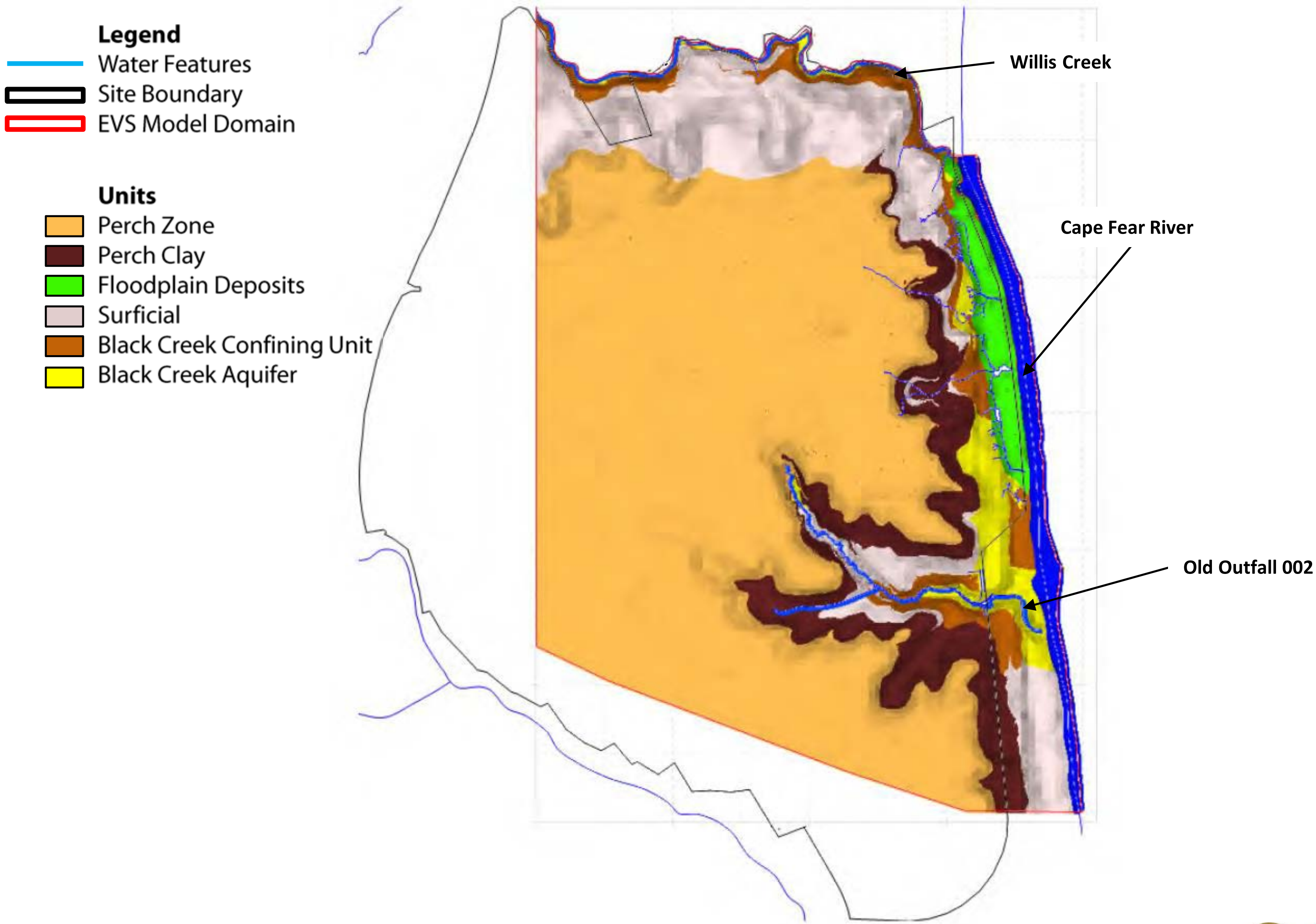


Input Data for EVS Model



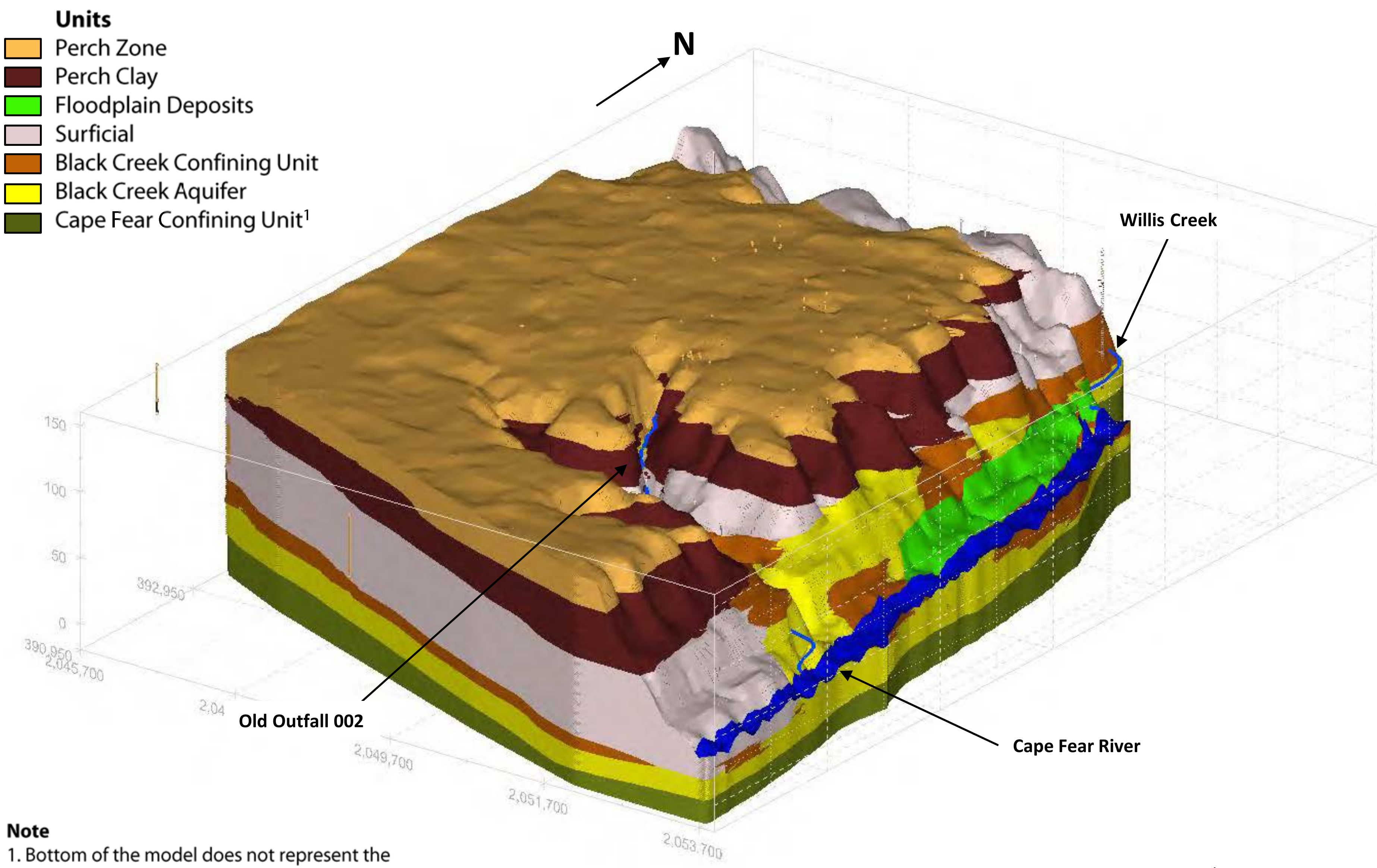
EVS Model Output – Plan View

Geosyntec consultants



EVS Model Output – 3D View (Facing Northwest)

Geosyntec consultants



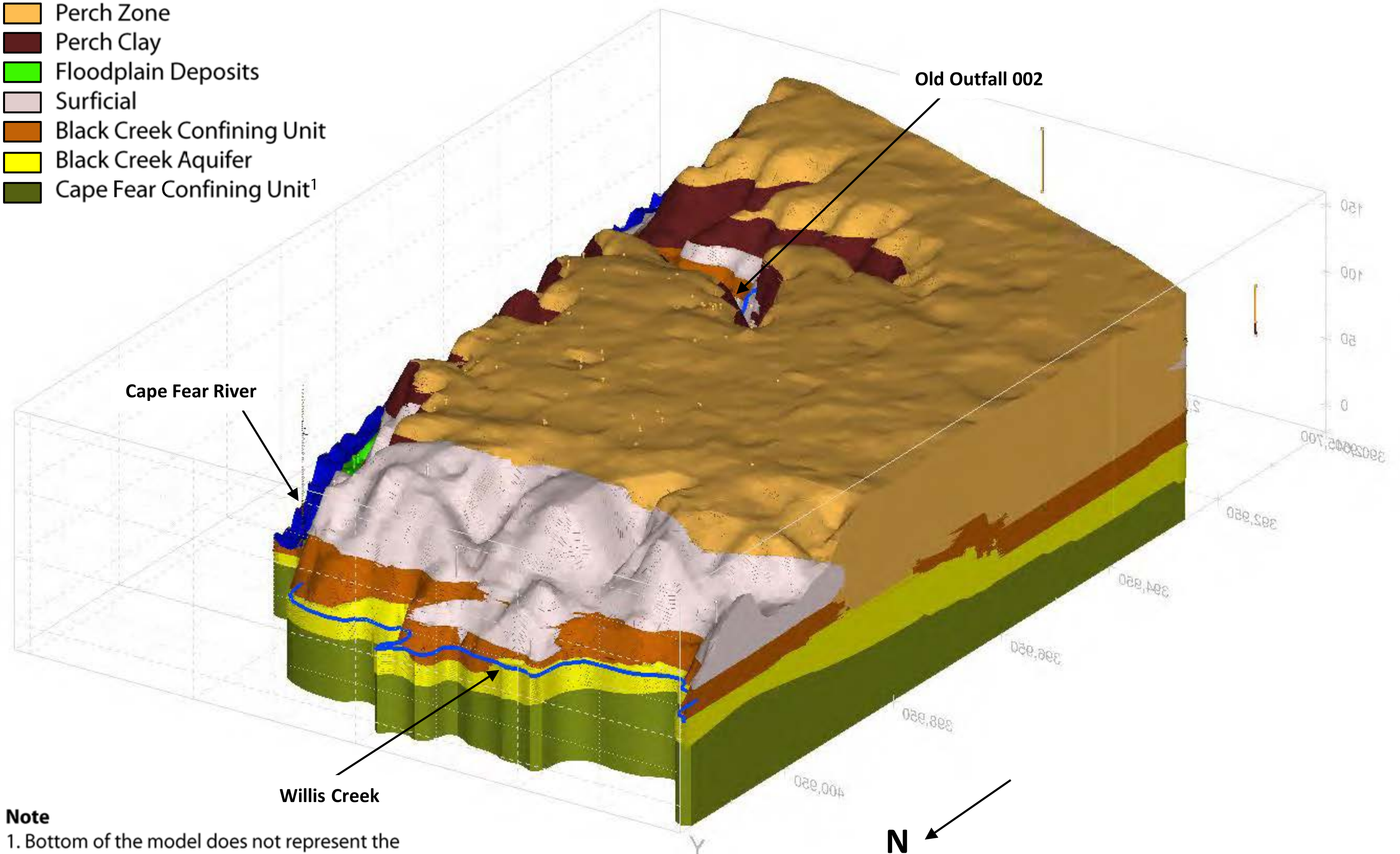
Note
1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.

Vertical Exaggeration = 15x

EVS Model Output – 3D View (Facing Southeast)

Geosyntec consultants

Units
- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]



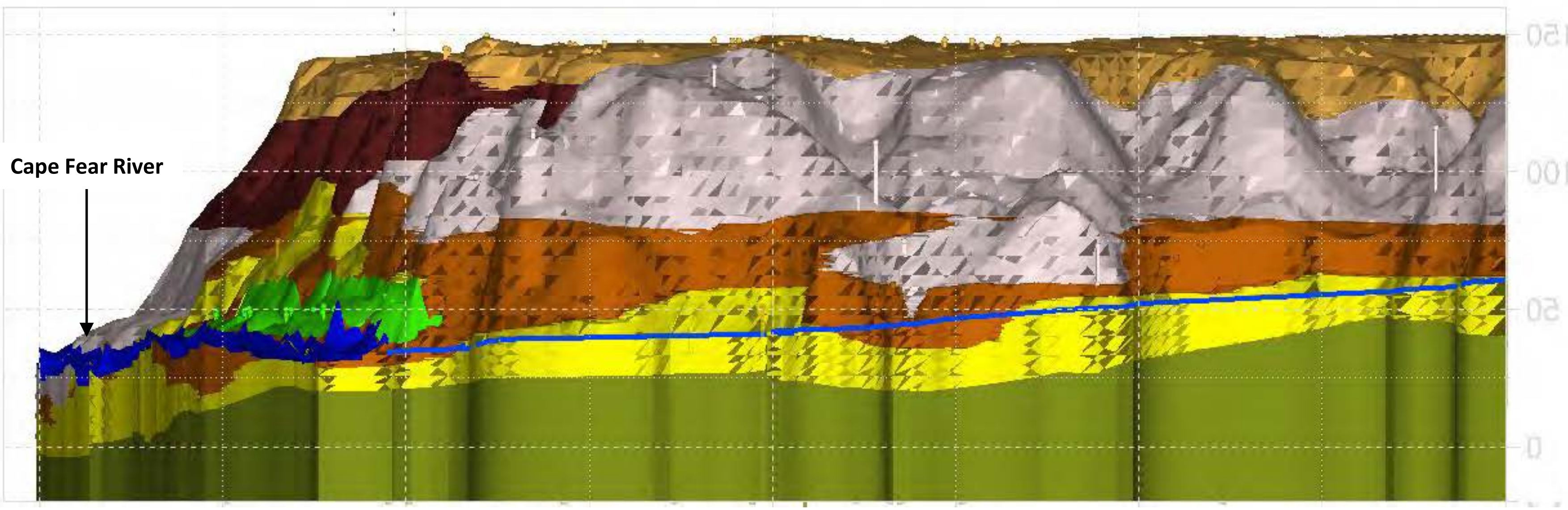
Note
1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.

Vertical Exaggeration = 15x

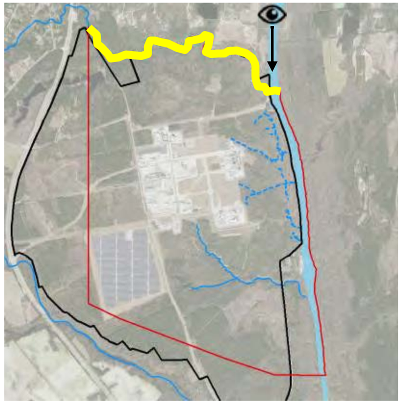
EVS Model Output – 3D View (North Boundary)

Geosyntec consultants

East **West**



Units
- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]



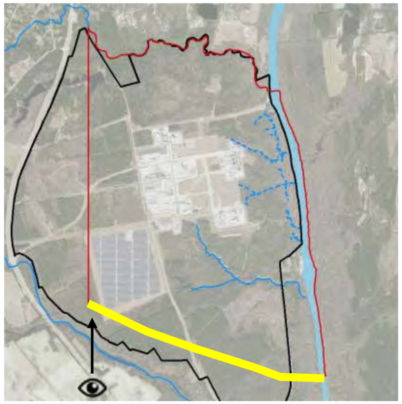
Note

1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.

Vertical Exaggeration = 15x

EVS Model Output – 3D View (South Boundary)

Geosyntec consultants



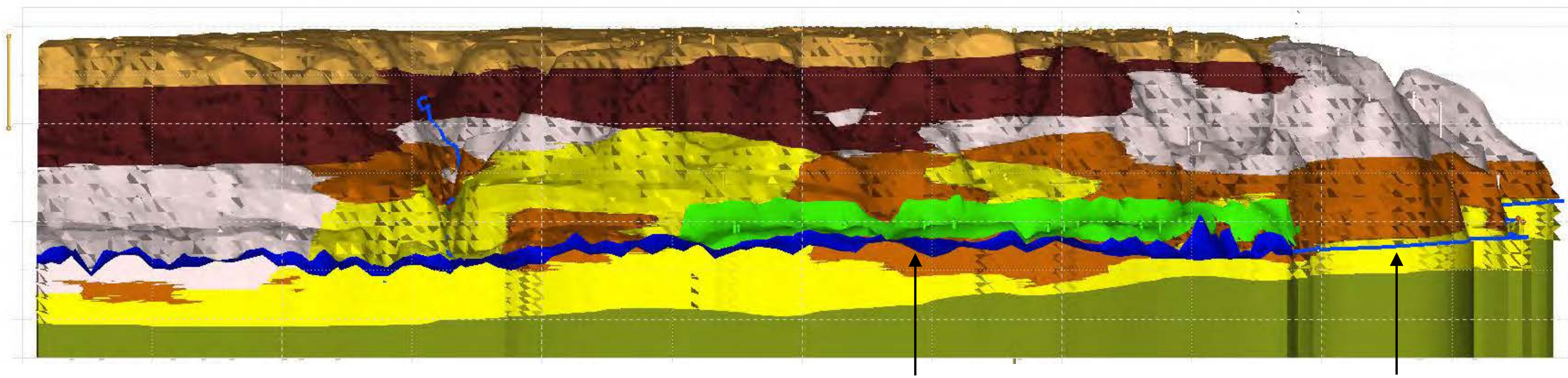
Note
1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.

Vertical Exaggeration = 15x

Units
- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]

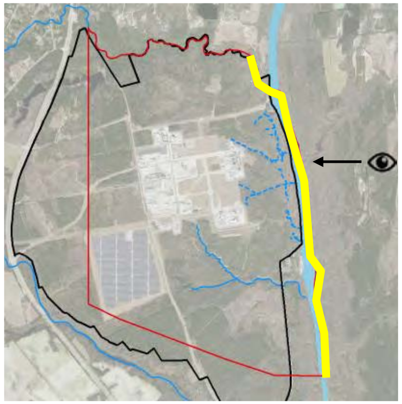
EVS Model Output – 3D View (East Boundary)

Geosyntec consultants



Vertical Exaggeration = 15x

Units
- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]

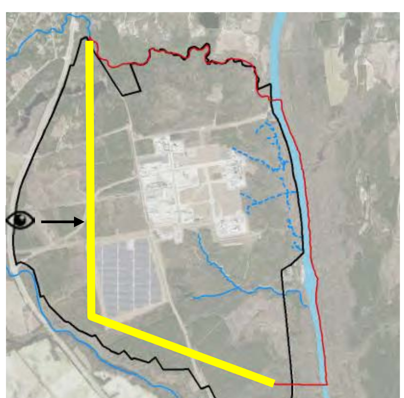


Note
1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.

EVS Model Output – 3D View (West Boundary)

Units

- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]

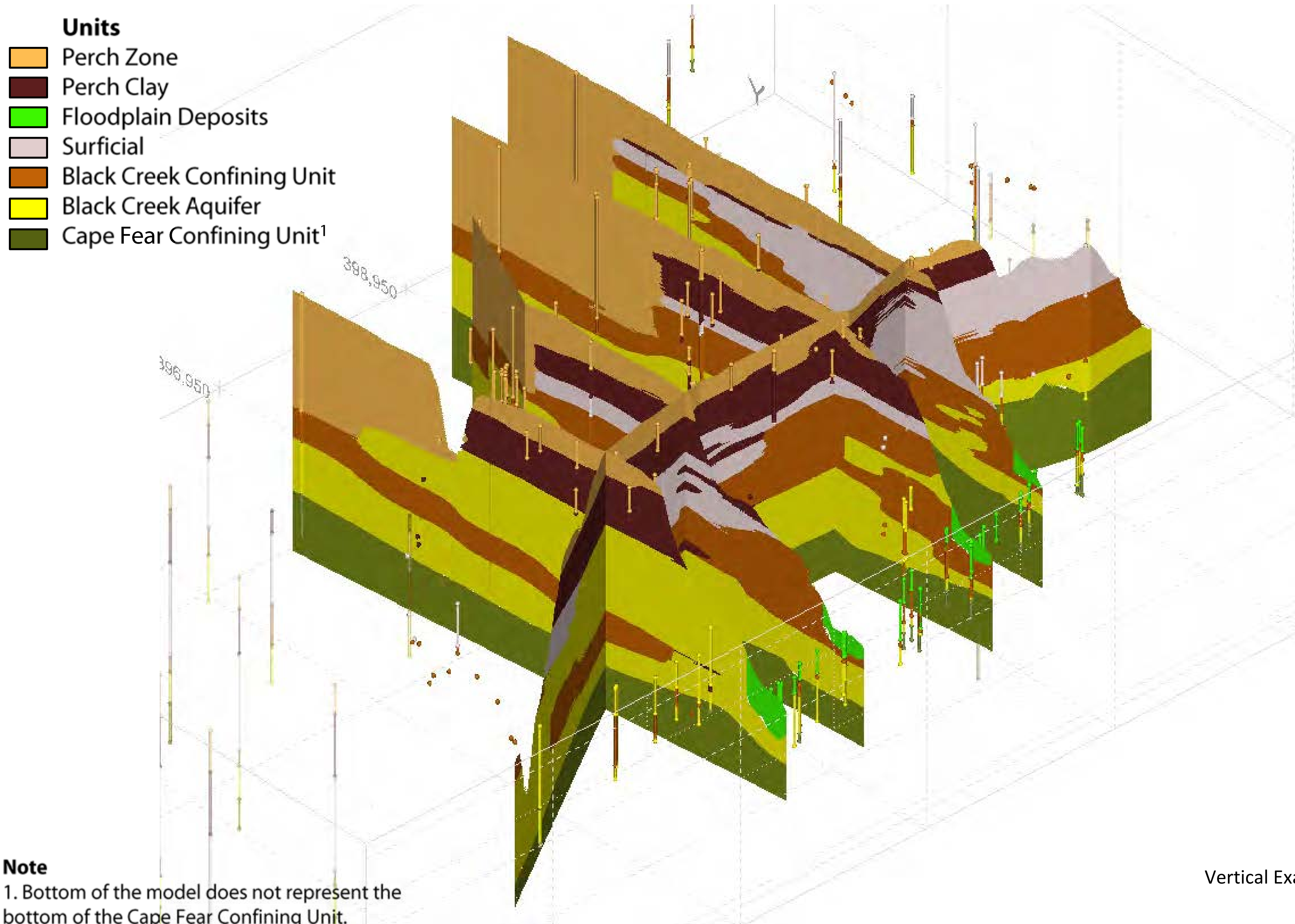


Note
1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.

Vertical Exaggeration = 15x

EVS Model Output – Cross-Sections in 3D View

Geosyntec consultants

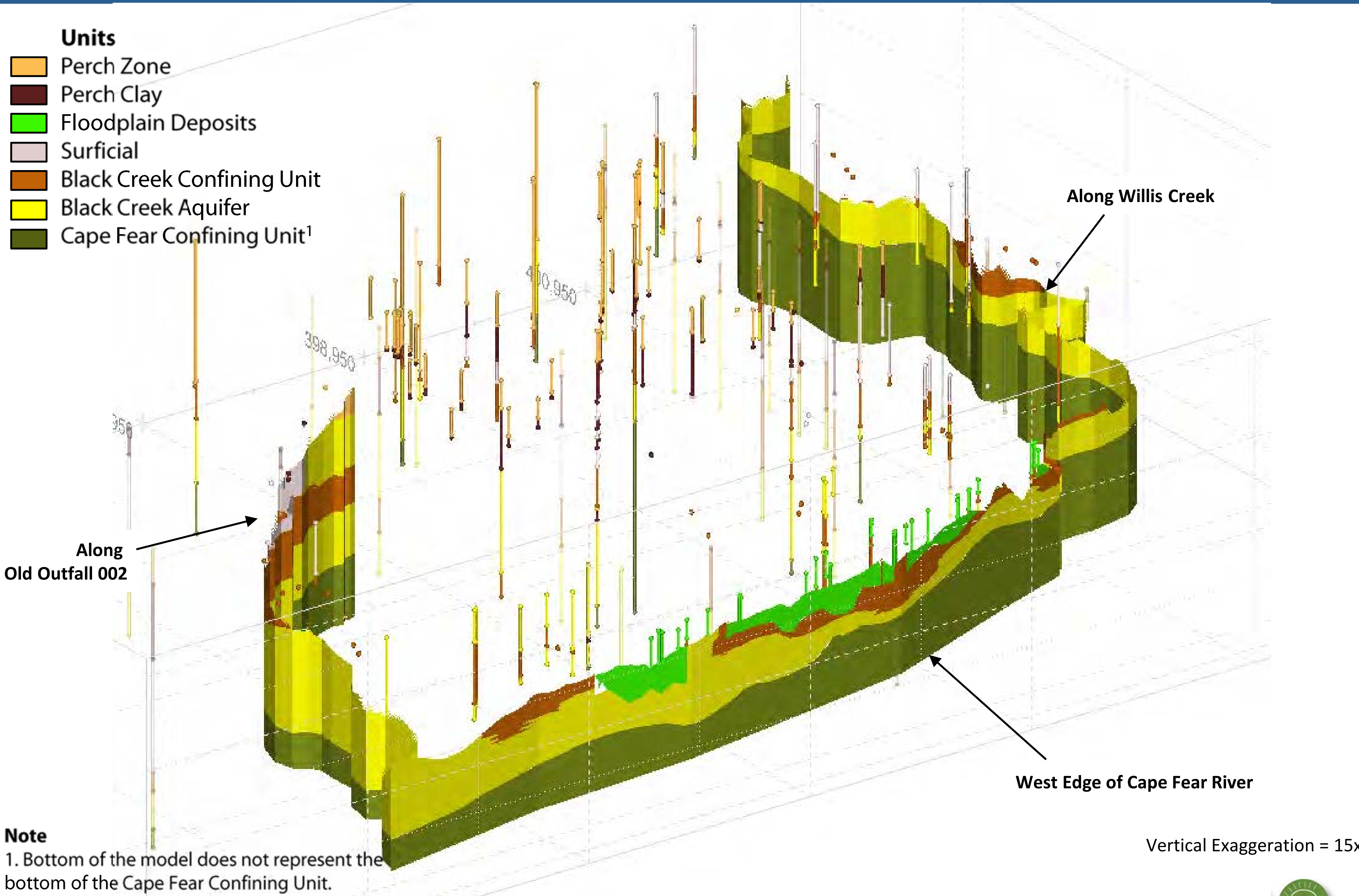


Note
1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.

Vertical Exaggeration = 15x

EVS Model Output – Cross-Sections in 3D View

Geosyntec consultants



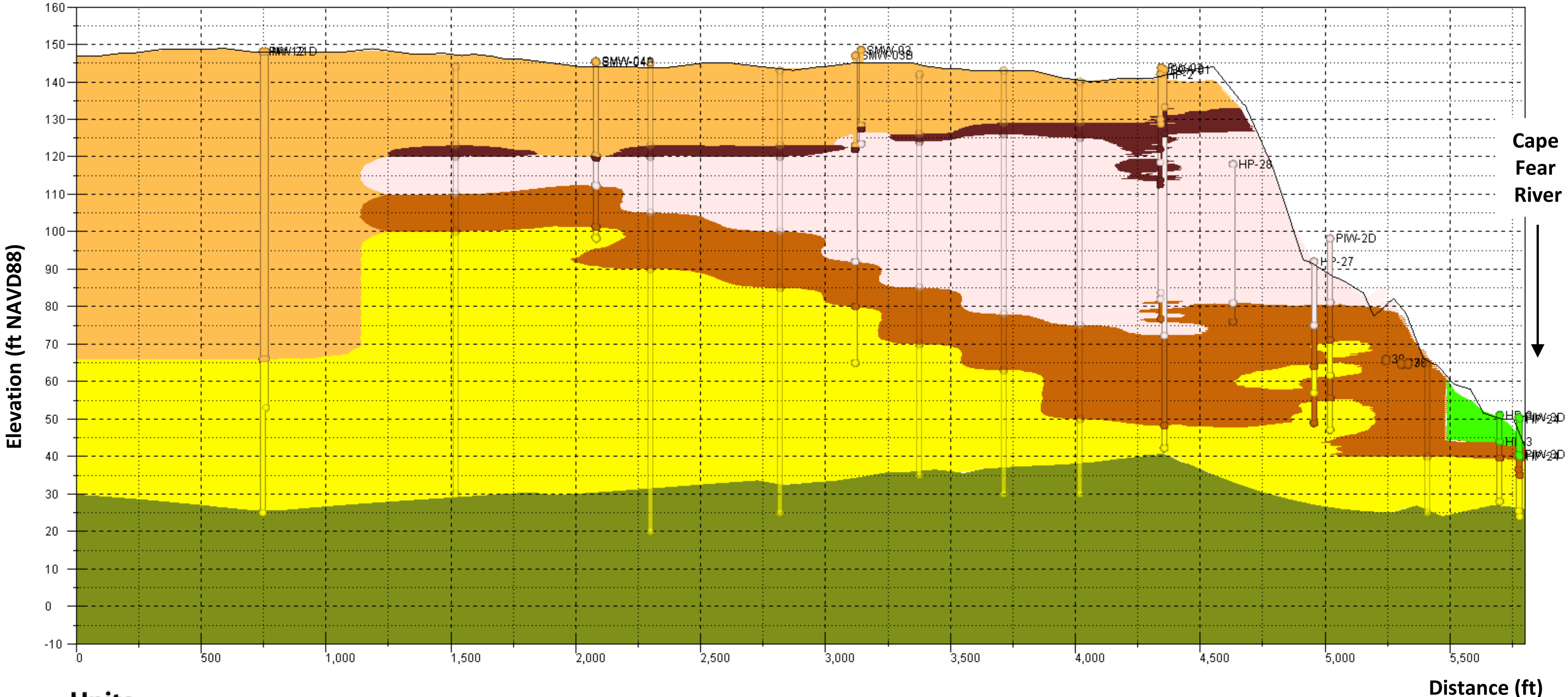
Note

1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.

EVS Model Output – Cross-Section A-A’

Geosyntec consultants

A (West) A’ (East)



Units

- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]

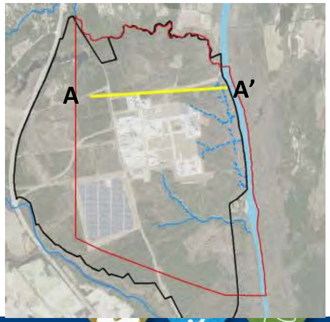
Locations

Boring or HPT location

Geology mapping observation point (elevation obtained from LiDAR data)

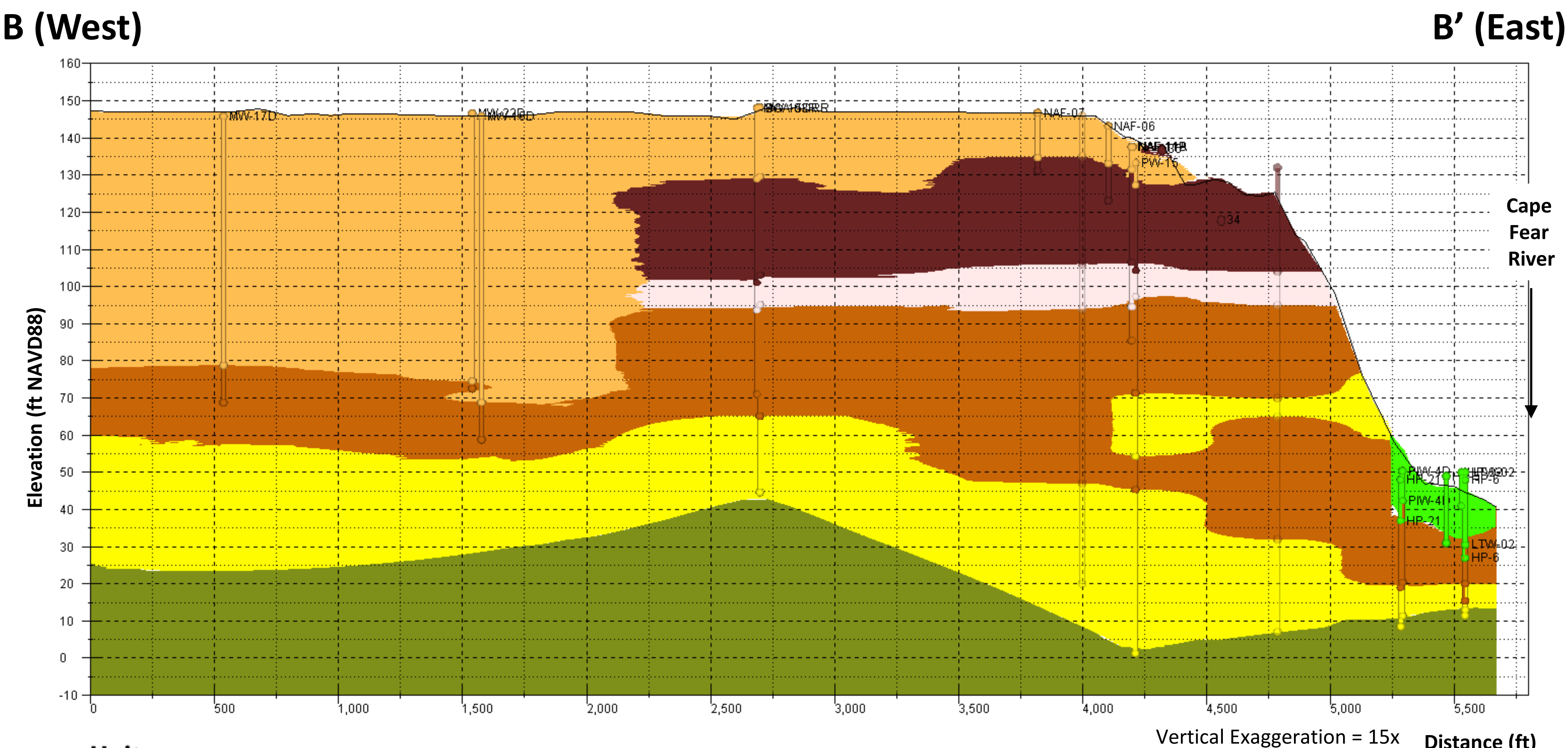
Note

1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.



EVS Model Output – Cross-Section B-B’

Geosyntec consultants



Units

- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]

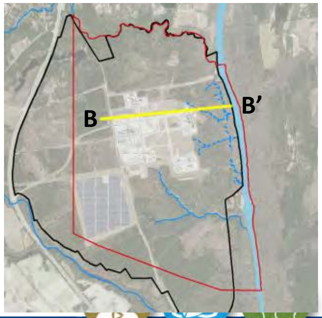
Locations

Boring or HPT location

Geology mapping observation point (elevation obtained from LiDAR data)

Note

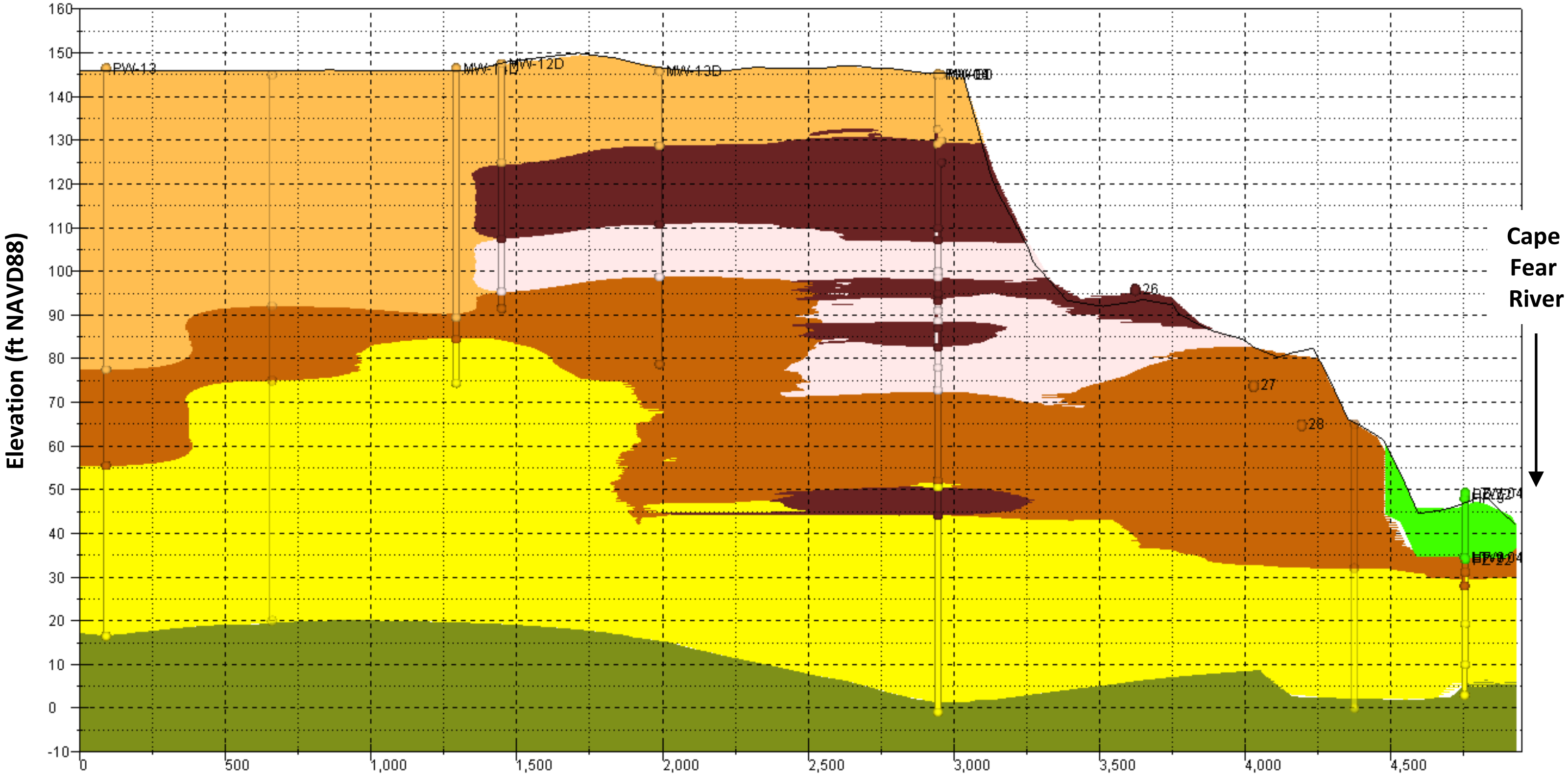
1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.



EVS Model Output – Cross-Section C-C’

Geosyntec consultants

C (West) **C’ (East)**



Vertical Exaggeration = 15x **Distance (ft)**

Units

- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]

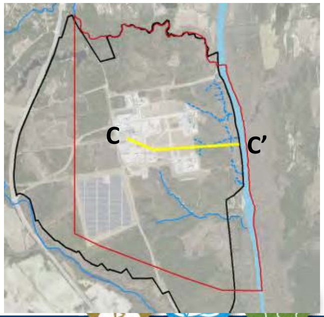
Locations

Boring or HPT location

Geology mapping observation point (elevation obtained from LiDAR data)

Note

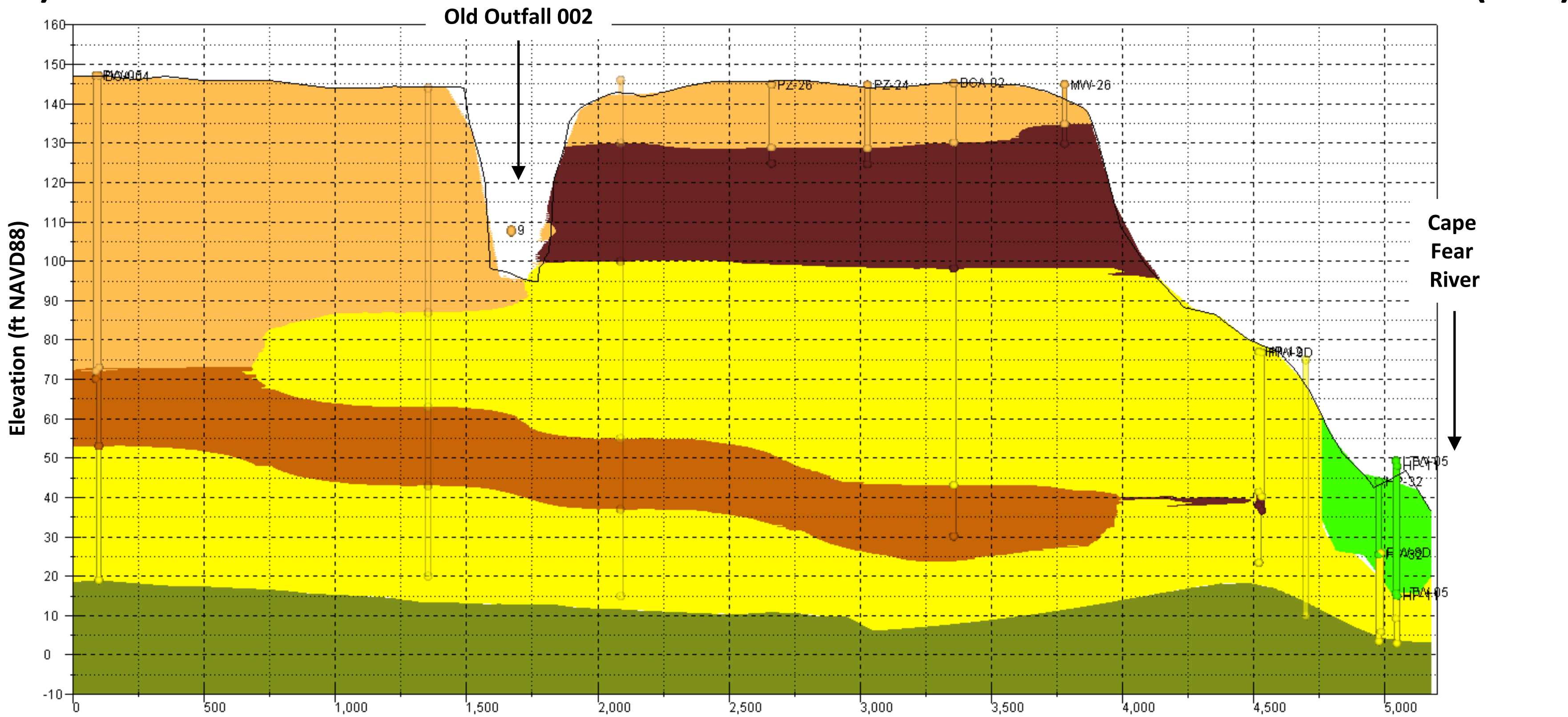
1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.



EVS Model Output – Cross-Section D-D’

Geosyntec consultants

D (West) D’ (East)

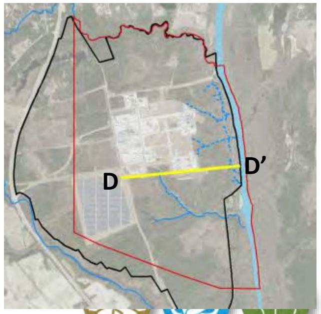


Vertical Exaggeration = 15x Distance (ft)

Units
- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]

Locations
- Boring or HPT location
- Geology mapping observation point (elevation obtained from LiDAR data)

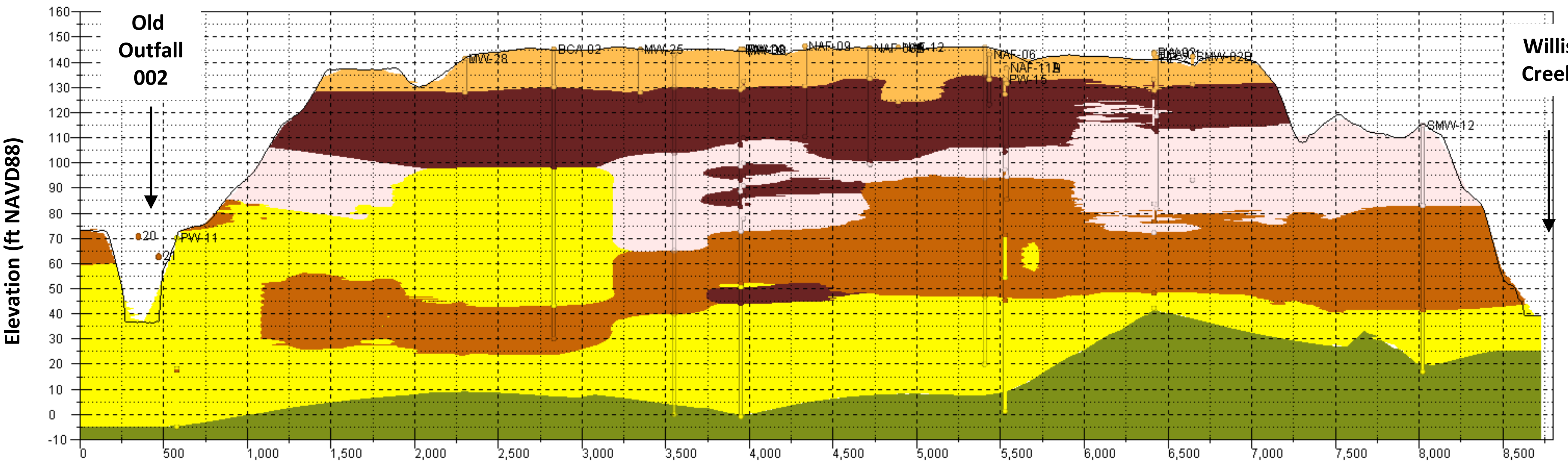
Note
1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.



EVS Model Output – Cross-Section E-E’

Geosyntec consultants

E (South) **E’ (North)**



Vertical Exaggeration = 15x

Vertical Exaggeration = 15x

Units

- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]

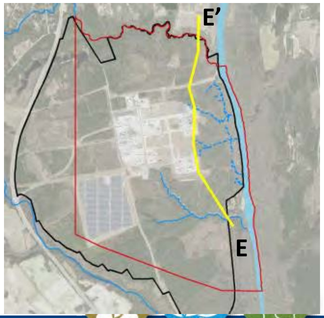
Locations

Boring or HPT location

Geology mapping observation point (elevation obtained from LiDAR data)

Note

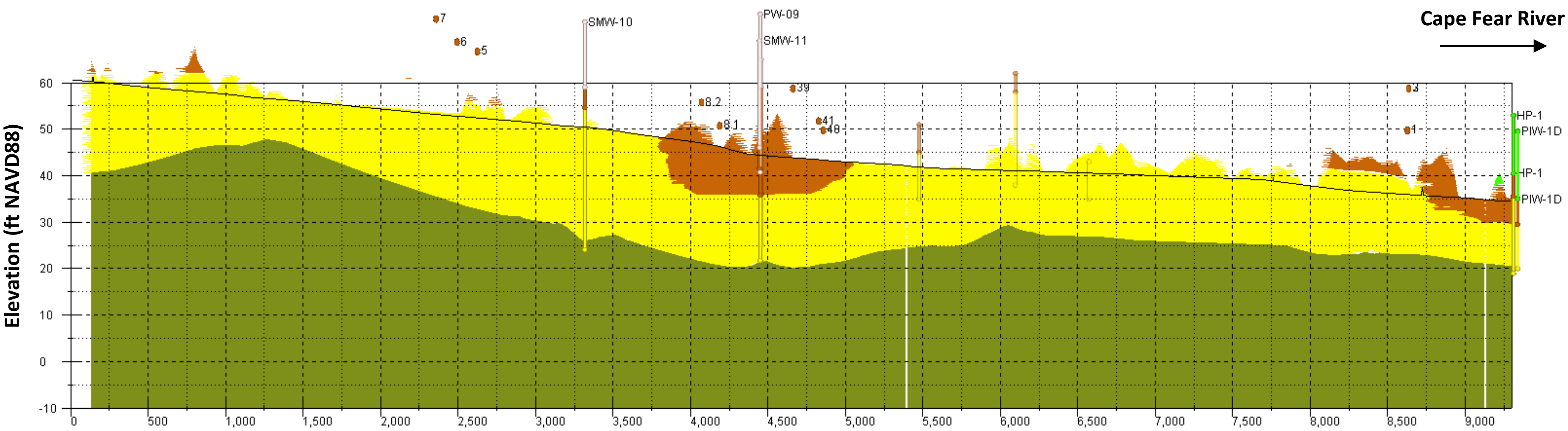
1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.



EVS Model Output – Cross-Section Along Willis Creek

Geosyntec consultants

1 (West) **1’ (East)**



Vertical Exaggeration = 15x

Distance (ft)

Vertical Exaggeration = 15x

Units

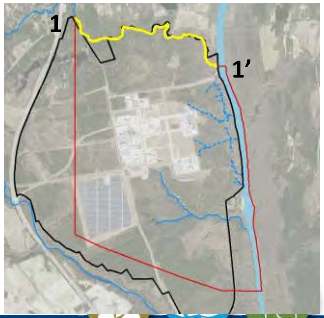
- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]

Locations

- Boring or HPT location
- Geology mapping observation point (elevation obtained from LiDAR data)

Note

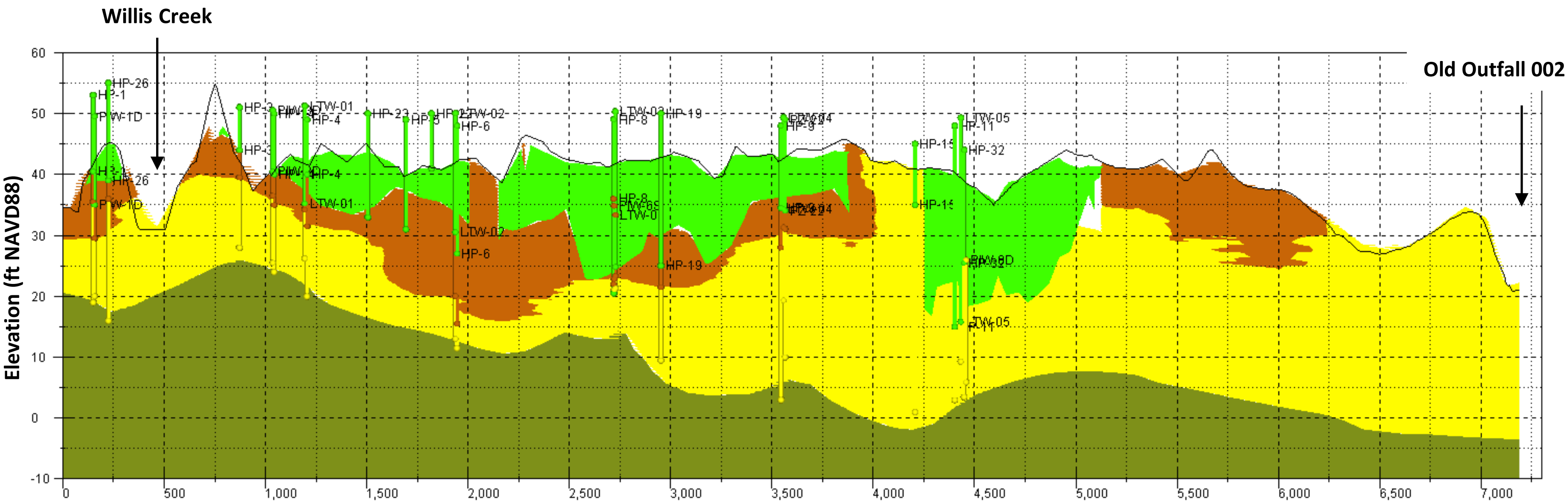
1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.



EVS Model Output – Cross-Section Along Cape Fear River

Geosyntec consultants

2 (North) **2' (South)**

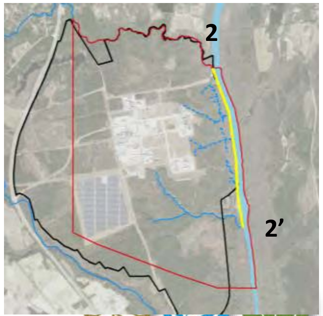


Vertical Exaggeration = 15x

Units
- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]

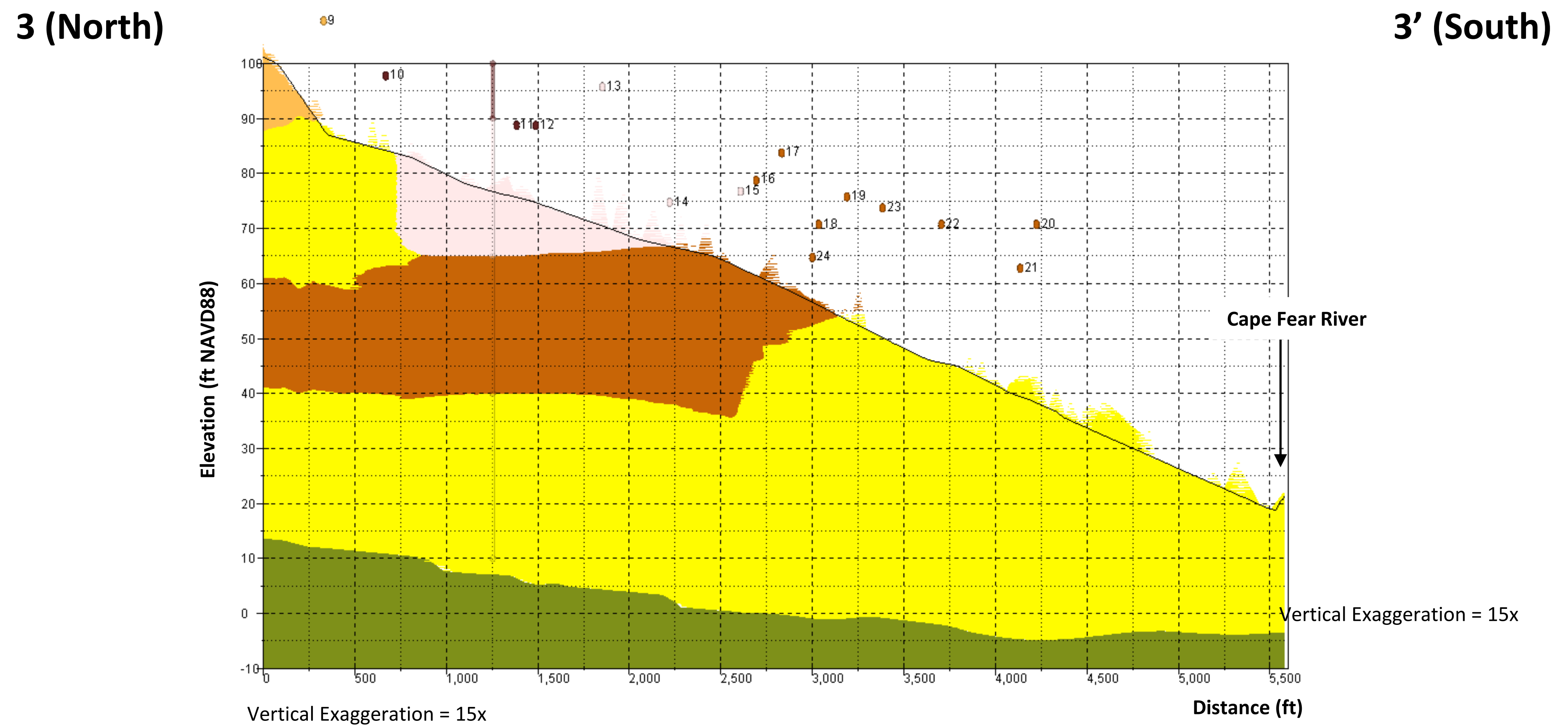
Locations
- Boring or HPT location
- Geology mapping observation point (elevation obtained from LiDAR data)

Note
1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.



EVS Model Output – Cross-Section Along Old Outfall 002

Geosyntec consultants



Units

- Perch Zone
- Perch Clay
- Floodplain Deposits
- Surficial
- Black Creek Confining Unit
- Black Creek Aquifer
- Cape Fear Confining Unit[1]

Locations

Boring or HPT location

Geology mapping observation point (elevation obtained from LiDAR data)

Note

1. Bottom of the model does not represent the bottom of the Cape Fear Confining Unit.