Appendix O

Findings of Cultural Resources Investigation at the Wilmington Site

Refer to Appendix B for additional regulatory correspondence related to this investigation.

ENVIRONMENTAL SERVICES, INC.
524 S. NEW HOPE ROAD
RALEIGH, NORTH CAROLINA 27610
919-212-1760 • FAX 919-212-1707
www.environmentalservicesinc.com

11 March 2008

Peter Sandbeck
Deputy State Historic Preservation Officer
North Carolina State Historic Preservation Office
4617 Mail Service Center
Raleigh, NC 27699-4617

Re: Potential GE Expansion, New Hanover County, North Carolina (ER 07-2157)
Archaeological Report

Dear Peter:

Enclosed are two copies of the archaeological survey report and two copies of the associated site forms for the archaeological investigation of the potential GE Expansion in New Hanover County, North Carolina, for your review. As a result of the investigation, two archaeological sites were recorded, one of which is recommended eligible for listing in the *National Register of Historic Places*.

If you have any questions or comments, please feel free to call me at (919) 212-1760.

Sincerely,

ENVIRONMENTAL SERVICES, INC.

Scott Seibel, RPA
Assistant Vice President

Encl.: Report (2)
Site Forms (4)

AN INTENSIVE CULTURAL RESOURCE INVESTIGATION: POTENTIAL GE EXPANSION NEW HANOVER COUNTY, NORTH CAROLINA

By:
Terri Russ, RPA
and
Matt Postlewaite

For:
RTI International

ESI Report of Investigations No. 1126

ER 07-155

March 2008

Environmental Services, Inc.
524 S. New Hope Road
Raleigh, NC 27610

MANAGEMENT SUMMARY

This report presents the findings of an intensive cultural resources investigation of the potential GE Expansion in New Hanover County, North Carolina. This investigation was conducted by Environmental Services, Inc., (ESI) of Raleigh, North Carolina, for RTI International to comply with Section 106 of the *National Historic Preservation Act* (NHPA 1966, as amended). All fieldwork was designed to comply with guidelines established by the Office of the Secretary of the Interior of the United States. The State Historic Preservation Office (SHPO) tracking number for this project is ER 07-2157.

Background research was conducted at a variety of institutions, including the Office of State Archaeology, the New Hanover County Public Library, and the Survey and Planning Branch of the SHPO. Field investigations focused on the identification and assessment of the significance of cultural resources occurring within the study area and consisted of pedestrian investigation, shovel testing, and test unit excavation. Areas of clear visibility, including eroded or exposed ground surfaces and unpaved roads within the study area, were inspected for historic structures, artifacts, and other signs of prehistoric or historic cultural activity. All shovel tests (n=305) were approximately 30 centimeters in diameter and dug to sterile subsoil; no shovel testing was conducted outside the study area. Field investigations occurred in October and November 2007 and were conducted by Terri Russ and Matt Postlewaite. Scott Seibel served as Principal Investigator.

As a result of the investigation, two new archaeological sites were recorded (31NH800** and 31NH801). **Table A** presents a summary of the documented archaeological site located within the study area.

Table A: Summary of Site Data

Site Number	Cultural Affiliation	Site Type	Recommendations
31NH800**	Historic-Late 18th-20th centuries	Domestic	Not Eligible- No Further Work
31NH801	Prehistoric-Middle Woodland	Short term habitation	National Register Eligible- Preservation by Avoidance

Site 31NH800**, an historic artifact scatter, does not have the potential to yield new information pertaining to the history of this area and is recommended not eligible for listing in the National Register. It is therefore recommended that no further work be conducted at this site and that development in this area be allowed to proceed as planned without concerns for impacts to significant cultural resources.

Site 31NH801, a Middle Woodland short-term occupation, is recommended eligible for the National Register. The site appears to retain intact subsurface deposits and has the potential to yield new information concerning Middle Woodland occupations in the southern Coastal Plain region. Current design plans call for no modifications to be made to the existing road that runs along the western boundary of site 31NH801. As such, there will be no adverse effects to the site by the proposed project. However, if design plans are modified to include impacts within the

site boundaries, coordination with the SHPO to determine if the impacts will be adverse and to design a plan to mitigate any adverse effects will be necessary.

ESI recommends that the potential GE Expansion, as currently planned, be allowed to proceed without concern for impacts to significant cultural resources. If the project boundaries are modified outside of the current study area, coordination with the SHPO to determine if additional cultural resource investigations are required will be necessary.

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1. INTRODUCTION

This report presents the findings of an intensive cultural resources investigation of the potential GE Expansion northwest of Wilmington, New Hanover County, North Carolina. This investigation was conducted by Environmental Services, Inc., (ESI) of Raleigh, North Carolina, for RTI International as a representative of General Electric Corporation (GE) to comply with Section 106 of the *National Historic Preservation Act* (NHPA 1966, as amended). All fieldwork was designed to comply with guidelines established by the Office of the Secretary of the Interior of the United States. The State Historic Preservation Office (SHPO) tracking number for this project is ER 07-2157.

The goal of the assessment was to identify and assess the significance of cultural resources that might occur within the study area. The term "cultural resources" as used herein is meant to refer to sites or objects that are archaeological, architectural, and/or historical in nature. "Significant" cultural resources are those meeting the criteria of eligibility for listing in the *National Register of Historic Places* (National Register), as defined in 36 CFR 60.4 and in consultation with the SHPO. Section 106 of NHPA requires that the effect of a project on significant cultural resources be taken into account on all projects involving federal funding and/or permitting. The guidelines for fulfilling the provisions of Section 106 are contained in the implementing regulations 36 CFR 800. The following report was prepared in accordance with federal and state guidelines.

The potential GE Expansion is located approximately 5 miles north of Wilmington, New Hanover County, North Carolina (**Figure 1.1**). The study area is bounded on the east by US 133/Castle Hayne Road and on the west by the Northeast Cape Fear River and is located approximately two miles south of the Pender County line. The 265-acre study area consists of the main facility (202 acres) and two proposed road corridors (63 acres).

Background research was conducted at a variety of institutions, including the Office of State Archaeology (OSA) and the Survey and Planning Branch of the SHPO. Field survey methods employed during the investigation consisted of pedestrian inspection and shovel testing. Pedestrian inspection focused on areas with good surface visibility including eroded uplands, unpaved roads, and stream cut banks. Vegetated areas were also inspected in an attempt to locate architectural features and abandoned cemeteries. Shovel tests were typically excavated at 30-meter intervals for site discovery and 15-meter intervals for site investigation. No shovel tests were excavated in wetlands or on slopes greater than 15 percent. Field investigations occurred in October and November 2007 and were conducted by Terri Russ and Matt Postlewaite. Scott Seibel served as Principal Investigator.

2. ENVIRONMENTAL BACKGROUND

Physiography and Geology

The study area is located in the Coastal Plains physiographic province. The landscape consists of level to gently sloping uplands, marshes, and flood plains (USDA 1977:1). Underlying geology is composed glauconitic, locally fossiliferous, and calcareous sand, clayey sand, and clay (NCGS 1991). Elevations within the study area range from a low of 5 feet above mean sea level (amsl) along the Northeast Cape Fear River in the southwest portion property to a high of 30 feet amsl in the central east portion of the property.

Hydrology

The study area lies within the Cape Fear River drainage basin. All water on the property drains directly into the Northeast Cape Fear River or along unnamed tributaries into Prince George Creek, a tributary of the Northeast Cape Fear River. A human-modified effluent channel flows through the southwestern portion of the study area and drains into the Northeast Cape Fear River.

Soils

Soil development is dependent upon biotic and abiotic factors that include past geologic activities, nature of parent material, environmental and human influences, plant and animal activity, age of sediments, climate, and topographic position. A general soil association contains one or more mapping units occupying a unique natural landscape position. Map units (soil series) are named for the major soil or soils within the unit, but may have minor inclusions of other soils.

A general soil association contains one or more mapping units occupying a unique natural landscape position. The study area occurs within three soil associations: Dorovan-Johnston, Kureb-Baymeade-Rimini, and Wrightsboro-Onslow-Kenansville. Dorovan-Johnston soils are very poorly drained, while Kureb-Baymede-Rimini soils are excessively drained to well drained. Wrightsboro-Onslow-Kenansville soils are somewhat poorly drained to well drained. The map units (soil series) are named for the major soil or soils within the unit, but may have minor inclusions of other soils. Soil mapping of New Hanover County shows thirteen soil units within the study area (USDA 1977). This is described in **Table 2.1** and shown in **Figure 2.1**.

Table 2.1: Study Area Soils

New Hanover County				
Name	**Code**	**Slope**	**Drainage**	**Landform**
Baymeade fine sand	Be	1-6%	Excessively	Flats and low ridges of uplands
Borrow Pit	Bp	---		
Dorovan soils	Do	---	Very poorly	Tidal and stream flood plains
Kenansville fine sand	Ke	0-3%	Well	Broad, smooth flats on uplands

Table 2.1: Study area Soils (continued)

New Hanover County				
Name	**Code**	**Slope**	**Drainage**	**Landform**
Leon sand	Le	---	Poorly	Smooth flats and stream terraces
Lynchburg fine sandy loam	Ls	---	Poorly	Flat or depression areas of uplands
Murville fine sand	Mu	---	Very poorly	Level soils on flats or in slight depressions on uplands
Onslow loamy fine sand	On	---	Moderately well	Broad, smooth flats on uplands
Pantego loam	Pn	---	Very poorly	Broad, smooth flats and light depressions on uplands
Woodington fine sandy loam	Wo	---	Poorly	Broad, smooth flats on uplands
Wrightsboro fine sandy loam	Wr	0-2%	Moderately well	Broad, smooth flats on uplands

Flora and Fauna

Vegetative Communities

Four terrestrial communities were identified within the study area. Dominant floral components associated with these terrestrial areas are discussed in each community description. The plant community names have been adopted and modified from the NHP classification system (Schafale and Weakley 1990). A description of each community follows.

Coastal Plain Small Stream Swamp

The Coastal Plain small stream swamp community is typically found adjacent to smaller streams that have relatively small watershed areas. Typical trees found in Coastal Plain small stream swamps include bald cypress, swamp tupelo, red maple, and green ash. Shrub species may consist of Virginia willow, tag alder, and buttonbush. Herbaceous species are typically sparse in Coastal Plain small stream swamps with occasional cattail (*Typha* spp.) and lizard's tail being relatively common.

Mixed Hardwood Forest

Mixed hardwood forest is a common plant community in the study area. This community type can consist of both upland areas and wetland areas. Typical tree species encountered in mixed hardwood forest includes, but is not limited to, red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), water oak (*Quercus nigra*), laurel oak (*Q. laurifolia*), southern red oak (*Q. falcata*), white oak (*Q. alba*), American sycamore (*Platanus occidentalis*), American beech (*Fagus grandifolia*), flowering dogwood (*Cornus florida*), green ash (*Fraxinus pennsylvanica*), and American elm (*Ulmus americana*). Shrub species may include wax myrtle (*Myrica cerifera*), American holly (*Ilex opaca*), tag alder (*Alnus serrulata*), and elderberry (*Sambucus canadensis*). Groundcover may be densely covered or very sparse. Typical species

include Japanese honeysuckle (*Lonicera japonica*), yellow jessamine (*Gelsemium sempervirens*), giant cane (*Arundinaria gigantea*), and bracken fern (*Pteridium aquilinum*).

Mixed Pine/Hardwood Forest

This plant community may have a mixture of the same species listed for the mixed hardwood forest with an additional component of native pine trees. These pines typically consist of loblolly pine (*Pinus taeda*), longleaf pine (*P. palustris*), and pond pine (*P. serotina*). Many of these mixed pine/hardwood forests have been subject to silviculture practices.

Pine Plantation

Pine plantations are characterized by having greater than 50 percent of tree cover dominated by pines. While some occur as natural even-aged stands as a result of succession from abandoned farms, most are the result of systematic plantings by silvicultural interests. Loblolly pine (*Pinus taeda*) dominates both planted and natural stands, but the latter contains increasing numbers of invading hardwoods from surrounding pine-mixed hardwood stands.

Wildlife

The following descriptions are summarized from Martof et al. (1980), Menhenick (1991), Hamel (1992), Rohde et al. (1994), and Palmer and Braswell (1995).

Terrestrial

Mammals expected to occur in and around the study area include raccoon (*Procyon lotor*), marsh rabbit (*Sylvilagus palustris*), white-tailed deer (*Odocoileus virginanus*), river otter (*Lutra canadensis*), beaver (*Castor canadensis*), nutria (*Myocastor coypus*), black bear *(Ursus americanus*), and Virginia opossum (*Didelphis virginiana*).

Reptile species expected include, but are not limited to, black racer (*Coluber constrictor*), eastern box turtle (*Terrapene carolina*), green anole (*Anolis carolinensis),* rough green snake (*Opheodrys aestivus*), ground skink (*Scincella lateralis*), and rat snake (*Elaphe obsoleta*).

Terrestrial or aboreal amphibians expected to occur in and around the study area include such species as southern leopard frog (*Rana utricularia*) and spring peeper (*Pseudacris crucifer*).

Avian species expected include great blue heron (*Ardea herodias*), red-shouldered hawk (*Buteo lineatus*), and belted kingfisher (*Ceryle alcyon*). Other species expected to occur in and around the study area include such species as mallard (*Anas platyrhynchos*), wood duck (*Aix sponsa*), American black duck (*Anas rubripes*), ruddy duck (*Oxyura jamaicensis*), snowy egret (*Egretta thula*), great egret (*Ardea alba*), blue jay (*Cyanocitta cristata*), American crow (*Corvus brachyrhynchos*), common yellowthroat (*Geothlypis trichas*), and various warblers (*Dendroica* spp.).

Aquatic

The following species are expected to occur in and around the study area: green frog (*Rana clamitans*), bull frog (*Rana catesbeiana*), American alligator (*Alligator mississippiensis*), snapping turtle (*Chelydra serpentina*), slider (*Pseudemys scripta*), mud turtle (*Kinosternon subrubrum*), banded water snake (*Nerodia fasciata*), brown water snake (*Nerodia taxispilota*), and cottonmouth (*Agkistrodon piscivorus*).

Freshwater fish species expected to occur in the water bodies proposed for crossing are the yellow perch (*Perca flavescens*), white perch (*Morone americana*), largemouth bass *(Micropterus salmoides),* chain pickerel *(Esox niger*), and various sunfish (*Lepomis* spp.). Other species that are not of recreational interest, but may be encountered in surrounding streams, include swamp darter (*Etheostoma fusiforme*), flier (*Centrarchus macropterus*), American eel (*Anguilla rostrata*), eastern mosquitofish (*Gambusia holbrooki*), tadpole madtom (*Noturus gyrinus*), yellow bullhead (*Ictalurus natalis*), and creek chubsucker (*Erimyzon oblongus*).

Land Use

Much of the study area is current or former pine plantation, with several large areas of disturbance resulting from borrow activities (**Figure 2.2**). There are currently no known industrial or agricultural uses of this land, though historically plantations were located in the vicinity of the study area.

3. CULTURAL BACKGROUND

Prehistoric Background

Pre-Clovis Period (??? – 10,000 BC)

Claims of pre-10,000 BC (C-14) human occupations in the New World have been met with considerable skepticism in the past. However, there is slowly increasing evidence of human populations in the Americas prior to the Clovis peoples. A number of sites in both North and South America apparently contain pre-Clovis evidence. The Meadowcroft Rock Shelter in Pennsylvania contains a reportedly pre-Clovis occupation (Adovasio et al. 1990), as does the Cactus Hill site in Virginia, where quartzite tools were recovered stratigraphically below a Clovis level (McAvoy 1997). Monte Verde is perhaps the most famous of the possible pre-Clovis sites in South America, with an average reported C-14 date of 12,500 BP (Dillehay 1997).

It is hypothesized that pre-Clovis populations in the Americas were relatively small and therefore their sites have low archaeological visibility. Additionally, a large problem with documenting pre-Clovis occupation of the Americas is that large areas once open to occupation are now under many meters of ocean. In the end, it is also believed that these peoples were quickly overrun or absorbed by Clovis people (Fiedel 1999; Morrow and Morrow 1999:225).

Paleoindian Period (10,000 – 8,000 BC)

At present, the earliest well-documented evidence for human occupations in the southeastern United States dates to the Paleoindian Period. During the Early Holocene (10,000 – 6,000 BC), which includes the Paleoindian Period, the Southeast underwent a transition from a patchy boreal forest with open areas of savannah favorable to large game to a more homogeneous oak-hickory forest, a transition basically complete by 8,000 BC (Watts et al. 1996; Delcourt and Delcourt 1985, 1987). Seasonal fluctuations in temperature, which were relatively small during the late Pleistocene when compared to present day, became more extreme as the Holocene onset (Delcourt and Delcourt 1985, 1987). Surface water was likely somewhat more scarce in this environment as compared to modern conditions. The topographic environment during the Early Holocene of the southern portion of North America, including the Southeast, was characterized by wide and deep valleys and broad plains (Schuldenrein 1996:3). During the terminal Pleistocene, sea levels were on average 70 meters below present day levels. Massive return of water to the oceans from retreating ice sheets caused sea levels to rebound to within a few meters of present levels by ca. 7,000 BC (Delcourt and Delcourt 1985, 1987).

Due to massive reworking of the landscape during the Early and Mid-Holocene, a vast percentage of Paleoindian archaeological sites have been either severely eroded or totally destroyed or are deeply buried under large amounts of Holocene sediments (Schuldenrein 1996:3). As such, our knowledge of the Paleoindian Period in the Southeast is quite limited. Sites containing Paleoindian artifacts are located in a variety of inland ecological and topographic settings. A lack of coastal Paleoindian sites may be due in part to rising sea levels which rendered coastal Paleoindian, if such existed, basically unreachable.

Anderson and colleagues (1990) have divided the Paleoindian tradition of the Southeast into three subperiods based on diagnostic stone point types, since fluted and other lanceolate projectile points and thumbnail endscrapers tend to be the only indisputable indicators of Paleoindian activity. The Early Paleoindian (ca. 10,000 – 9,000 BC) is characterized by Clovis points; the Middle Paleoindian (ca. 9,000 – 8,500 BC) is characterized by points such as Cumberland, Suwannee, Simpson, and Clovis-like variants; and the Late Paleoindian (ca. 8,500 – 8,000 BC) is characterized by Dalton, Hardaway, and Hardaway-Dalton. Archaeological evidence from Florida suggests that bone pins, stone knives, lithic scrapers, and atlatls were also used by Paleoindian hunters.

Current theory holds that these early people likely maintained a generalized hunting and gathering technology that enabled them to utilize a diverse range of micro-environments (Carbone 1983; Anderson et al. 1990). It is well documented that Paleoindian populations coexisted with Pleistocene megafauna such as mammoth, mastodon, giant ground sloth, and bison, although the extent to which southeastern Paleoindian peoples exploited these now extinct species is unclear. The emergence of Dalton projectile points during the Late Paleoindian may indicate an emphasis on hunting smaller game such as deer (Goodyear 1982). In general, few data are available for this early period, but it is suspected that settlements were small and briefly occupied, and that material possessions were light and portable. Paleoindian assemblages consist of heavily curated tools of high-grade lithic materials. Several researchers have suggested that high quality stone quarries were a primary factor influencing Paleoindian settlement, with free-roaming groups "loosely tethered" to a primary stone source (Dunbar and Waller 1983; Goodyear et al. 1989; Anderson et al. 1990).

No in situ archaeological remains of these earliest inhabitants have been found in the Coastal Plain, or elsewhere in North Carolina. Evidence does exist, however, in the form of isolated examples of fluted points recovered as surface finds. Some attempts have been made to compile distributions of these early tools across the state. The first effort was made some 30 years ago by Perkinson (1971, 1973), who recorded 16 projectile points within the Coastal Plain. A second study occurred more recently at a larger regional level by Anderson, who has attempted to elicit interaction data from the known distribution of Paleoindian projectile points (1990a, 1990b, 1995). Based on these investigations, site location and attribute data have been recorded for some 400 fluted points found throughout North Carolina. Given the gradual rise and fluctuation in sea level since Paleoindian times, however, it is probable that much if not all stratified evidence of this period is now under many feet of water.

<u>Archaic Period (8000 - 1000 BC)</u>

The environment of the Archaic period was characterized by warmer climatic conditions and higher sea levels that resulted in the emergence of mixed hardwood forest communities, particularly mesic oak-hickory forests (Smith 1986). The widespread extinction of Pleistocene megafauna species accompanied the environmental changes that marked the onset of the Holocene. At the same time, Archaic period Indians focused their subsistence strategies on the procurement of smaller game, fish, wild plant foods, and in some areas, shellfish. There seems to have been a significant increase in population during the Archaic, and groups began to develop regional habitat-specific adaptations and material assemblages (Smith 1986:10;

Steponaitis 1986:370-371). Over time, populations became increasingly sedentary, and a variety of site types evolved, including base camps or villages, short-term bivouacs, procurement camps, and cemeteries.

On the basis of distinct artifact (mostly lithic) assemblages, archaeologists have divided the Archaic period into three sub-periods, Early, Middle, and Late. These artifact assemblages, however, are based on excavations conducted in the North Carolina Piedmont. While the diagnostic projectile points recognized in the Piedmont are found in the Coastal Plain (Phelps 1983:22), differences in the distribution and relative abundance of point types are noted in the Coastal Plain (Daniel and Davis 1996; Ward and Davis 1999:75). Further work is needed to better determine the cultural sequence of the Archaic period in the Coastal Plain.

Early Archaic (8000 - 6000 BC)

The environmental conditions of the Early Holocene persisted into the Early Archaic Period. Sea levels continued to rise at an appreciable rate as glacial conditions hastened their retreat, apparently reaching levels within only a few meters of modern levels by 7,000 BC (Delcourt and Delcourt 1985, 1987). Additionally, oak-hickory forests still dominated the landscape. The Eastern Woodlands experienced a trend of desiccation during the Early Holocene (Schuldenrein 1996:23). Early to Mid-Holocene dryness appears to have been more pronounced in places such as Florida and the Georgia Coastal Plain than in the Carolinas (Watts et al. 1996:31).

There seems to be strong continuity between Early Archaic and previous Paleoindian lifeways in that the earliest Archaic populations exhibit settlement and subsistence practices similar to those of their Paleoindian predecessors. With the emergence of more numerous and diversified ecological settings during the Early Archaic, regional specialization increased and promoted greater interregional variation. Early Holocene populations are generally viewed as composed of small, nomadic bands that followed seasonal rounds on the basis of resource abundance, therefore occupying disparate geographic resource extraction locales throughout the year (Smith 1986:16-18). Familiarity with a specific region probably resulted in seasonal reuse of the same resource locale. Settlement during the Early Archaic is often held to be primarily logistical, with the use of winter base camps (Anderson and Hanson 1988; Cable 1992).

Three models have been developed in attempts to explain Early Archaic settlement patterning in the Southeast: Effective Temperature/Technological Organization (Claggett and Cable 1982); Wallace Reservoir (O'Steen 1983); and Band/Macroband (Anderson and Hanson 1988). Similarities are greater than differences between the three models, which all interpret Early Archaic lifeways as adaptations to factors such as environmental conditions and resource allocation. These models likely cannot be applied to the Southeast as a whole, but instead to different ways of life practiced by spatially and temporally spaced peoples. Within the Carolinas, however, there is some debate about the nature of Early Archaic settlement. While some researchers suggest that individual bands moved seasonally between the Piedmont and Coastal Plain along major drainages (Anderson and Hanson 1988), others have proposed that group movement was not confined to drainages and was more variable across the Piedmont and upper Coastal Plain (Daniel 1998).

Artifacts of the Late Paleoindian/Early Archaic represent a transitional period in terms of the stone tool assemblage, with projectile point shape shifting from lanceolate forms to notched varieties. Diagnostic points from the Coastal Plain are duplicates of Piedmont styles (Ward and Davis 1999:72). Early Archaic components are generally distinguished through the presence of distinct projectile point types, specifically the Palmer Corner Notched and Kirk Corner Notched points, with St. Albans, Le Croy, and Kanawah bifurcate based points occurring in lesser amounts (Coe 1964). Based on the degree of observable tool wear, it seems that Early Archaic tools underwent extensive modification and reuse, characteristic of a high degree of curation (Amick and Carr 1996:43). After projectile points had outlived their utility as viable spear points, they were frequently reworked into smaller tools such as drills, end scrapers, burins, and spokeshaves (Smith 1986:10). Early Archaic technologies also included several unifacial tool types represented by a variety of end and side scrapers. Some of these unifacial tools are fairly distinctive and share technological similarities with Paleoindian assemblages (Coe 1964; Daniel 1998). Although plant processing tools such as nutting stones, manos, metates, and cobbles have also been recovered from Early Archaic contexts within South Carolina and Georgia, ground stone artifacts from Early Archaic contexts are rare in North Carolina (Anderson and Schuldenrein 1983; Goodyear et al. 1979:103-104; Daniel 1998).

Middle Archaic (6000 - 3000 BC)

The Middle Archaic Period occurred during the Mid-Holocene, a time period during which the post-glacial environment of the southeast began to stabilize, eventually reaching nearly modern conditions (Schuldenrein 1996:3). The major climatic event of the Middle Archaic is the Altithermal (also known as the Hypsithermal and the Climatic Optimum), a warming and drying trend that occurred from ca. 6,000 – 3,000 BC that affected not just the Southeast, but the continent as a whole. Pollen records from the southeastern coastal plain and Florida evidence a replacement of the Early Holocene coastal plain oak and herb forest by pine and swamp forests during the Mid-Holocene (Watts et al. 1996:29), though this event was staggered across the region. Data concerning changes in vegetation communities in the Piedmont are lacking, but changes likely consisted of an increase in the hardwood diversity of the forests.

Middle Archaic cultures continued to exploit upland terrestrial resources, but gradually added the procurement of interior riverine resources to their subsistence schedule. Some groups were also exploiting the abundant aquatic resources of the Atlantic coastal estuaries (Russo 1992). The shift to the use of aquatic resources (both riverine and coastal) is generally attributed to climatic change and sea level rise associated with the warmer temperatures of the Middle Holocene Hypsithermal episode (Smith 1986:22), which is seen by many as the major event affecting human adaptation to environmental stress (Schuldenrein 1996:26). There may also have been a concomitant decline in upland resource yields due to the lack of rain (Smith 1986:22).

The Middle Archaic has been cited frequently by archaeologists as "a time of major technological innovations having significant socioeconomic impact" (Smith 1986:18). At that time, there was an increase in the kinds and numbers of ground stone tools in use, e.g., atlatl weights, axes, pendants, and pestles (Coe 1964; Griffin 1967). The proliferation of grinding tools may signal a rise in the importance of plant foods, although the recovery of botanical remains dating to the Middle Archaic is limited. Compared to the Early Archaic, during the

Middle Archaic the scale of land use decreased, use of local raw materials increased, technology became more expedient, and residential mobility increased (Amick and Carr 1996:53). These changes are attributed by some to possible increases in population densities (Sassaman et al. 1988).

The primary indicator of Middle Archaic activities in the Coastal Plain is a series of square and contracting stemmed points, including Stanly Stemmed, Morrow Mountain, Guilford Stemmed, and Halifax Side-Notched (Ward and Davis 1999). Halifax Side-Notched points were identified at the Gaston site on the Roanoke River, and were located stratigraphically above Guilford deposits (Coe 1964). While Halifax points are relatively common in the northern Coastal Plain, they are rarely found in the Piedmont (Coe 1964; Phelps 1983:23). Each of these stemmed point types is associated with a regional Middle Archaic phase. Besides morphological changes in projectile point types over time, additions to and changes in the artifact inventory of the Middle Archaic period are also evident. For instance, the finely crafted unifacial tools that were part of Early Archaic assemblages were supplanted by informal flake tools (Coe 1964). Simplification is seen as the major trend in lithic technology during this time, with tools being produced on more of an ad hoc basis, with a concomitant decrease in quality (Blanton and Sassaman 1989). This form of lithic technology is thought to reflect a subsistence regime based upon foraging and high residential mobility. Most Middle Archaic sites in North Carolina appear to represent temporary encampments and occur without any apparent preference for particular environmental or topographic locales (Ward and Davis 1999:63).

Late Archaic (3000 - 1000 BC)

By the beginning of the Late Archaic, climatic regimes across the Southeast had become essentially modern, signifying the onset of the Late Holocene. Along the coast, the previously rising Atlantic waters stabilized and relatively modern shoreline configurations were formed. As shorelines stabilized during the transition from the Mid- to Late Holocene, wetlands appear to have increased substantially, allowing for new and expanded subsistence strategies (Watts et al. 1996:37).

Compared to elsewhere in the Southeast, relatively little is known about the Late Archaic in North Carolina and even less in the Coastal Plain. Greater regionalism becomes apparent in Late Archaic adaptations, with increased sedentism and a focus on riverine and coastal resources notable in most areas of the Southeast (Smith 1986; Steponaitis 1986). A generalized hunting-gathering and fishing subsistence strategy was employed, although a few plants such as gourd, squash, sunflower, and chenopodium were cultivated in some areas of the Southeast (Steponaitis 1986:373). While Coastal Plain sites exhibit some of the characteristics noted for the Late Archaic (e.g., stone vessels), other elements such as dense middens and artifacts acquired through long-distance exchange are absent (Steponaitis 1986:372-378). There seems to have been a significant increase in population during the Archaic, and groups began to develop regional habitat-specific adaptations (cultures) and material assemblages (Smith 1986:10). Over time, populations became increasingly sedentary, and a variety of site types evolved, including base camps or villages, short-term bivouacs, procurement camps, and cemeteries.

In general, Late Archaic components are much more prevalent throughout the Southeast than are earlier Archaic and Paleoindian components. Sites dating to the Late Archaic are found in a wide assortment of ecological settings, and significant occupations of floodplains first occurred during this time. Entrenched mobility can be used to describe Late Archaic settlement and subsistence patterning, whereby a series of sites is systematically reoccupied (Graham and Roberts 1986). It can be viewed as a response to decreased mobility in areas with high population densities, and may be an outgrowth of the increasing specialization and decreased mobility of Middle Archaic groups (Amick and Carr 1996). The Late Archaic experienced a move from highly expedient tool making to an increased degree of curation. Increased investment in the curation of long use-life tools such as bifaces and the logistical procurement of raw materials are seen as responses to decreased availability of lithic raw materials.

Evidence for increased regionalism, which is common throughout the Southeast, occurs in the Coastal Plain with the appearance of the earliest ceramics between 2500 and 2000 BC (Phelps 1983:26-27). These ceramics are a fiber-tempered ware that appears predominantly in the southern portion of the Coastal Plain (i.e., below the Neuse River). This pottery is undecorated and is referred to as Stallings Plain (South 1976:28-29); its occurrence in the northern Coastal Plain is rare (Phelps 1983:26). The earliest known ceramic type in the northern Coastal Plain is Marcey Creek, which is tempered with steatite (Ward and Davis 1999:199). A style referred to as Croaker Landing has been recovered from the Davenport site (31BR28) in Bertie County and is likely contemporaneous with Marcey Creek. It is tempered with steatite and clay and was found with small, stemmed spear points (Egloff 1985). A regional division in material culture traits becomes more marked in the Coastal Plain during post-Archaic times.

Savannah River points are the main typological marker of the Late Archaic (Ward and Davis 1999:64), although smaller stemmed and side notched varieties also occurred. Artifacts common during this period included ground stone axes, celts, adzes, pestles, atlatl weights, and beads; lithic projectile points, cruciform drills, scrapers, and knives; and grinding slabs and fire cracked rock (Coe 1964:119). Small containers or bowls carved from soapstone (steatite) were widely distributed throughout much of the interior Southeast during this time (Sassaman 1993). In addition, artifacts made of exotic materials such as copper or whelk/conch shell are found in sites at great distances from their source(s) of origin, implying widespread exchange networks.

<u>Woodland Period (1000 BC - AD 1000)</u>

With trends toward increased population and greater settlement stability established during the Late Archaic, the emergence of small river valley "villages" has been noted throughout the Southeast during the Woodland period (Smith 1986; Steponaitis 1986). Also occurring at this time was a stronger commitment toward horticulture, although hunting, fishing, and gathering remained the primary means of subsistence. Maize may have been first cultivated in areas of the Southeast sometime between AD 200 and 400, but its use in the Coastal Plain was somewhat limited until around AD 1000, although even then "maize agriculture was not particularly important" (Coe 1964:51; Ward 1983:73; Scarry 1993). Earthen and stone mounds containing human burials and other material evidence suggestive of mortuary/ceremonial behavior were constructed over much of the southern Coastal Plain during the Woodland period, but none is known for the project vicinity.

Building on the trends that emerged during the Late Archaic, the Woodland period is characterized by the first widespread use of ceramic pots and the presence of horticulture (Smith 1986; Steponaitis 1986). Accordingly, the beginning of the Woodland period in the Coastal Plain is placed around 1000 B.C. and continues to about A.D. 1650 (Phelps 1983:17). By convention the period is divided into three subperiods: Early Woodland, Middle Woodland, and Late Woodland. These divisions, in turn, are associated with various phases that are marked archaeologically by changes in ceramic sequences. Spatial divisions in the Woodland Period in the Coastal Plain can be made as well, roughly comprising the northern and southern halves of the state. The northern region extends from the Neuse River basin to the Virginia state line and roughly encompasses the area occupied by Algonquian and Iroquois speaking groups at the time of European colonization (Ward and Davis 1999:194). The Iroquois (Tuscaroras) occupied the interior coastal plain, while the Algonquian lived in the eastern tidewater. The southern region extends from the Neuse River basin to the South Carolina state line. During the contact period, this area was inhabited by Siouan speaking peoples (Ward and Davis 1999:194).

Early and Middle Woodland (1000 BC – AD 1000)

Sand tempered pottery with cord marking appeared across the coastal region during the Early Woodland. In the southern region, this ceramic tradition is referred to as New River. While some believe that Deep Creek in the northern region and New River represent the same type (Phelps 1983), others see them as two separate, but related, traditions (Herbert and Mathis 1996). Interestingly, it appears that New River traditions were influential in Thom's Creek, Deptford, and Mossy Oak traditions in South Carolina and Georgia rather that the other way around (Trinkley 1989:80). As with the Early Woodland in the northern region, little is know about settlement patterning and subsistence (Phelps 1983:32; Ward and Davis 1999:199). It is suggested that settlement patterns and subsistence strategies during this period resemble those of the preceding Late Archaic, but this has not been proven through archaeological excavation.

A secondary ceramic type thought to be a transitional type between the Early and Middle Woodland is Hamp's Landing (Hargrove 1993:20). This ceramic contains crushed limestone marl temper and is typically cordmarked, fabric impresses, simple-stamped, and thong-marked (Ward and Davis 1999:202). Some believe that this type is related to the grog tempered Hanover of the Middle Woodland, stating that the size, shape, and density of the temper is more important than the type (Jones, Espenshade, and Kennedy 1997:101).

Two ceramic traditions mark the Middle Woodland Cape Fear Phase in the southern region: Hanover and Cape Fear. Hanover ceramics are grog tempered and typically exhibit cord and fabric marking and smoothed surface treatments (Herbert and Mathis 1996:147; South 1976:16). Ceramics of the Cape Fear tradition are sand tempered like the Mount Pleasant series of the northern region. Surface treatment of Cape Fear mirrors Hanover (Herbert and Mathis 1996:149).

Settlement during the Cape Fear Phase focused on stream and river banks, estuarine shorelines, and the edges of inland swamps and pocosins (Ward and Davis 1999:205). Although subsistence data is severely lacking except for the consumption of shellfish, it is believed that the Cape Fear

Phase followed a pattern of widespread resource utilization, with a focus on estuarine environments (Loftfield 1987).

Excavations at the Broad Reach site (31CR218) in Carteret County have produced possible evidence of Middle Woodland structures (Mathis 1997). Oval and circular post hole features have been found in association with Hanover pottery and suggest the presence of structures approximately 15 feet in diameter, possible semi-permanent shelters. Burials found at Broad Reach and site 31CR223 show that different burial practices existed during the Cape Fear Phase. At Broad Reach, a burial containing two flexed individuals was found, while a mass cremation containing at least 10 individuals was excavated at 31CR223 (Mathis 1993, 1997).

While sand burial mounds found in the Southern Coastal Plain have been considered part of the Cape Fear Phase, some believe them to represent an unnamed Late Woodland phenomenon extending though the Coastal Plains of South Carolina and Georgia (Ward and Davis 1999:210; Trinkley 1989:83). These mounds, that typically measure 25 to 50 feet in diameter and approximately 3 feet in height, contain secondary burials and cremations representing from 10 to 0ver 300 individuals (Phelps 1983; Holmes 1883; MacCord 1966; South 1966; Ward and Davis 1999:206-7). Grave goods recovered from these mounds include chlorite schist and steatite platform pipes similar to Hopewell designs and sand tempered ceramics with fabric-impressing and burnishing, a trait not found in Cape Fear ceramics (MacCord 1966).

Late Woodland-Contact Periods (AD 1000-1700)

The White Oak Phase represents the Late Woodland in the Southern Coastal Plain. Although it exhibits differences from the Colington Phase of the Northern Coast that will be discussed below, many more similarities exist. Both Phases had similar house designs, village size, and internal organization, as well as a mixed subsistence economy relying strongly on shellfish and other marine resources. Shell-tempered pottery was a major trait of both Phases, and evidence exists that Algonquian languages were spoken as far south as Onslow County. Not only do both exhibit very similar burial styles, skeletal remains from White Oak Phase interments are very similar to Algonquian skeletons from the Colington Phase. Data suggest that Algonquian culture spread as far south as the Onslow and Pender county lines (Ward and Davis 1999:222; Loftfield 1990; Ward 1982).

White Oak pottery (also referred to as Oak Island) is shell-tempered, a major similarity to Colington, though typical surface treatments are somewhat different. White Oak ceramics are often fabric-impressed, smoothed, plain, cordmarked, simple-stamped, and net impressed, just like Colington ceramics. However, White Oak ceramics are never incised as Colington ceramics are, but are sometimes burnished, which is rarely found on Colington pottery (Loftfield 1976:157-163; South 1976; Ward and Davis 1999:217).

There are still numerous issues surrounding the identification of White Oak pottery (Herbert 1997:17-18; Herbert and Mathis 1996:151). Misidentification is a significant issue, with White Oak possibly being confused with Hamp's Landing, which dates to the Early and Middle Woodland and is limestone/marl tempered. Also, some of the surface treatments, including

simple stamping, cord marking, and net impressing, are believed to be much more common in the Early and/or Middle Woodland periods.

A major trait of the White Oak phase is secondary burial in large ossuaries. Ossuaries excavated in Onslow County have contained up to and possibly in excess of 150 individuals (Loftfield 1990:119; Ward 1982:5). Excavations at Broad Reach have revealed smaller group burials containing less than 10 individuals each, some containing distinct, articulated bundles and others containing mixed, disarticulated remains (Mathis 1993:4-5). Variance in burial patterning between and even within ossuaries is thought to reflect differences in social standing of the interred individuals, both in relation to grave goods and the condition of the bones (Mathis 1993:5-7).

Around the Cape Fear River, however, it appears that a somewhat different cultural tradition was present. Excavation at the Cold Morning site (31NH28) in New Hanover County revealed a small ossuary containing the disarticulated remains of 15 individuals in association with White Oak pottery. The burial style is in contrast with the large ossuaries found in Onslow County. Additionally, analysis of the skeletal remains found strong similarity with Siouan peoples from the Piedmont (Coe et al. 1982:88). Incising of over one quarter of the sherds recovered is also a surface treatment not found anywhere else in the southern region; it is, however, found in the northern region (Ward and Davis 1999:223).

Historic Background

European explorers first investigated the North Carolina coast in the early sixteenth century. Giovanni da Verrazano, an Italian explorer, reached the mouth of the Cape Fear River in 1524. Sailing northward, Verrazano sailed into Onslow Bay and then continued along the Outer Banks, mistaking Pamlico and Albemarle sounds for the Pacific Ocean (Powell 1989:30).

Two years later, a Spanish fleet under the command of Lucas Vasques de Ayllon sailed up the eastern coast of Carolina, stopping for a time near Cape Fear. A contingent of ships continued north, possibly reaching Chesapeake Bay (Powell 1989:31). By the late 1550s, it was not uncommon for Spanish ships to be wrecked by storms along the Outer Banks (Powell 1989:32). In 1566, an expedition under Domingo Fernandez passed to the north of Roanoke Island and made landfall on the Currituck Peninsula, where the party erected a large wooden cross and conducted a brief exploration of the area (Powell 1989:32).

English exploration in the area began in earnest the 1580s. On March 25, 1584, Queen Elizabeth granted Walter Raleigh a charter to explore and colonize unknown lands (Powell 1989:38). One month later, a small expedition, organized by Raleigh and led by Philip Amadas and Arthur Barlowe, left Plymouth, England, for America. In July, Amadas and Barlowe reached the Carolina coast and claimed the land in the name of Queen Elizabeth.

The following year, Raleigh organized an attempt to establish a colony on Roanoke Island. At the end of July 1585, a fleet commanded by Sir Richard Grenville and Ralph Lane reached Roanoke Island where Lane set about constructing a fort. A detachment from this expedition followed the Roanoke and Chowan rivers into the interior of the mainland (Powell 1989:40-42).

Two years later, a civil settlement was established at Roanoke Island under the governorship of John White (Powell 1989:44), however, international politics kept supplies from reaching the colony. By the time English ships again called at Roanoke Island in 1590, the colonists had disappeared, and repeated attempts to find the colonists failed. After the failure of the "Lost Colony," English colonial efforts concentrated on the Chesapeake area. In 1607, Jamestown was settled on the James River in Virginia.

Soon after the settlement of Jamestown, the colonists began exploring the surrounding areas. Virginians referred to the Albemarle region as "South Virginia" or the "Southern Plantations," and many of the earliest settlers in the area came from the Virginia settlements (Watson 1982:2; Anthony and Ash 1980:7).

By the early 1660s, some attempts had been made to colonize the area at the mouth of the Cape Fear River. In 1660, a group from New England purchased land and began exploring the area. At about the same time, a group from Barbados took an interest in establishing a colony in the vicinity. In 1664, the Barbados group established a colony of about six hundred people along the banks of the Cape Fear River, but the settlement was abandoned within three years (Sharpe 1958:323-324; Lee 1971:5).

In 1663, Charles II granted Carolina to eight Lords Proprietors. Albemarle County was established in 1664 and four years later was divided into four precincts. Twenty-eight years later, in 1696, as settlers moved south to the Pamlico and Cape Fear Rivers, Bath County was established. In 1705, Bath was subdivided into the precincts of Beaufort, Hyde, and Craven.

During the early eighteenth century, the populations of Bath County continued to grow. In 1706, John Lawson, the surveyor general of the Carolina province, laid out a town on a bluff overlooking the Pamlico River; two years later that town was incorporated as Bath. In 1710, Baron Christoph von Graffenried, at the head of a group of Swiss and German settlers, established the town of New Bern at the confluence of the Neuse and Trent rivers (Powell 1989:70-73). During the early 1710s, settlers began establishing homes in present-day Onslow County (Onslow County Historical Association 1983:2), and a decade later, permanent settlers began living along the banks of the Cape Fear River and its tributaries (Lee 1971:7).

As a result of the growing population, New Hanover County was created in 1729 from parts of Craven Precinct (Sharpe 1954:327). In turn, New Hanover was partitioned for the creation of Onslow and Bladen counties in 1735, Duplin County in 1750, and Brunswick County in 1764 (Lee 1971:10).

Since the late 1600s, the Cape Fear River had been established as a port of entry for the Carolina colony. In 1726, the town of Brunswick was founded on the west bank of the river to act as a mercantile center (Lee 1971:12). By the early 1730s, the land at the juncture of the Northeast and Cape Fear Rivers, 15 miles upstream from Brunswick, was being settled, and was soon formed into a new town named Newtown or Newton (Sharpe 1954:326; Lee 1971:12). In 1740, Newtown was incorporated as Wilmington. With the establishment of Wilmington, Brunswick began a slow decline and was finally abandoned after the Revolutionary War (Powell 1989:84).

Throughout the eighteenth century, most of the residents of the Coastal Plain relied on agriculture for their livelihoods. The fertile soils in the area lent themselves to the cultivation of a wide array of produce including wheat, corn, rice, indigo, and tobacco (Powell 1989:132-134). Tobacco played an important role as a cash crop in the colonial economy. In addition, many people raised hogs and other livestock. The emergence of the cash crop economy in the eighteenth century led to the development of large plantations throughout the Cape Fear region. The current study area is located within or adjacent to the lands of some former plantations, including Rose Hill, Castle Haynes, The Hermitage, Point Pleasant, Rocky Run, and Rock Hill. These plantations are discussed in greater detail in the project specific history below.

The production of naval stores was a major industry in the Coastal Plain during the colonial era. Because of the vast forests of pine that blanketed the region, the early inhabitants were able to extract the tar, pitch, and turpentine that were so essential in the naval stores industry. At its height, the naval stores industry in the Cape Fear region was producing nearly one-third of all the turpentine in the world (Sharpe 1954:312). Not surprisingly, more naval stores were shipped to England from New Hanover than from any other area in the British Empire (Lee 1971:16). The abundant forests also gave rise to a lumber industry, with mills established throughout the Coastal Plain. The mills produced barrel components, planks, and shingles (Powell 1989:137).

After the Battle of Guilford Courthouse in 1781, Lord Cornwallis, the British commander, led his troops into Wilmington, where he remained for almost three weeks, during which time he decided to march north to Virginia. As the British army moved north along the Duplin Road and through the coastal plain, it terrorized the local populace by burning homes and appropriating personal property (Rankin 1959:62; Powell 1989:206). British troops evacuated Wilmington permanently on November 18, 1781; one month after Cornwallis surrendered at Yorktown, Virginia.

During the Antebellum period, Wilmington remained one of the most important shipping centers in the state. Though trade had suffered in the years after the American Revolution, by the 1820s Wilmington had undergone an economic revival. In 1830, the Port of Wilmington handled more freight tonnage than the Port of Richmond (Sharpe 1954:311). Because the economy of the region depended on the Cape Fear River, several projects were undertaken to improve the river through dredging and the construction of jetties (Lee 1971:37). In 1840, the Wilmington and Weldon Railroad, which connected Wilmington to the Roanoke River area and Virginia, was completed (Lee 1971:38-39).

The Civil War had a direct impact on Wilmington and New Hanover County. In April 1861, Union naval forces began a blockade of Southern ports. The Confederacy responded by utilizing blockade-runners. Wilmington, because of its port facilities, rail connections, and up-river location, quickly became a major blockade-running center (Sharpe 1954:311; Lee 1971:61). The mouth of the Cape Fear River was protected by Fort Fisher, a large earthwork fort that was constructed in 1861-62 (Lee 1971:65).

By August 1864, most of the supplies for the Army of Northern Virginia came through Wilmington (Lee 1971:69). Because of the importance of Wilmington as an entrepôt for supplies for the Confederacy, the city became one of the chief targets of Union strategists. In

December 1864, a Union armada bombarded Fort Fisher, and troops were landed, but the fort proved difficult to capture (Lee 1971:71; Powell 1989:376). A second assault on the fort was launched in January 1865. After three days of naval bombardment, Fort Fisher fell to Union troops. With the fall of Fisher, the Confederacy's last open port lay defenseless. By February, Wilmington surrendered to the Federal forces. After the fall of Fort Fisher and Wilmington, Confederate forces attempted to stall the Union advance to Goldsboro by constructing earthworks on the northern bank of the Northeast Cape Fear River. These earthworks guarded the Duplin Road, modern US 117, which led north from New Hanover County. However, the Confederate efforts to contain the Union advance proved to be too little too late, as Goldsboro was taken in March and the Confederacy collapsed in April 1865.

The end of hostilities in April 1865 brought many changes to the region. Foremost among them was the abolition of the slave system. In its place, a system of tenant farming and sharecropping was installed (Powell 1989:416). The large plantations that had characterized Antebellum agriculture in the Coastal Plain were broken up into smaller farms, so that by 1880, while the number of farms had more than doubled from pre-war numbers, the average acreage of each farm fell by more than 50 percent (Powell 1989:417).

In 1873, a movement to create a new county out of the agricultural section of New Hanover was begun. The movement arose from conflicts between the inhabitants of the rural areas of the county and the urban center at Wilmington that was overrun with carpetbaggers (Sharpe 1965:1523). Despite Republican opposition, Pender County was created by an act of the state legislature in 1875.

Aside from the dramatic agricultural and social changes wrought by Reconstruction, the era also marked a period of increased modernization. During the 1870s, textile mills began to appear in Wilmington (Lee 1971:88). By the 1880s, Wilmington was once again prospering as a seaport. The naval stores trade, though slowly dying, still accounted for much of the cargo passing through Wilmington. Cotton began to be a more important commodity in Wilmington's shipping economy (Sharpe 1954:312; Lee 1971:87). Also, the fertilizer and wood preservation industries began to be established in the region (Sharpe 1954:312).

As the twentieth century dawned, the Coastal Plain remained a largely agricultural area. Though cotton remained an important crop, many farmers began to diversify their crops. Tobacco, which had been grown in the region since the first settlement, began to take on a new importance. For example, by the middle of the twentieth century, tobacco had become the chief crop of Pender County (Sharpe 1965:1520). Other extractive industries supplemented the region's agrarian economy. Though the naval stores industry had, by the twentieth century, become an anachronism, the abundance of forested land continued to support an extensive lumber industry (Lee 1971:87).

The proliferation of the automobile in the early twentieth century caused the state to take over the maintenance and construction of roads. In 1921, the establishment of "The Good Roads System" led to the hard paving of many of the roads in the Coastal Plain. As other roads were built or improved, transportation became easier. Another result of state control of roads was the gradual decline of both the steamship and railroad industries in eastern North Carolina.

The start of World War II proved to be a boom period for Wilmington and New Hanover County. A large shipyard boom strengthened the local economy and drew people into the area. From 1940 to 1954, the number of industries in New Hanover County jumped from 90 to 128, and the workforce nearly tripled (Sharpe 1958:314).

Project Specific History

As noted above, the study area is adjacent to several colonial and antebellum plantations. Specifically, Rose Hill plantation is located on the Wilmington Site, approximately 700 meters south of the western road corridor. Other nearby plantations included Castle Haynes, The Hermitage, Rocky Run, Point Pleasant, and Rock Hill. The following presents a brief summary of the history of Rose Hill and nearby plantations.

Rose Hill was located on the east bank of the Northeast Cape Fear River, about six miles north of Wilmington. This land was originally part of a grant made to William Gray in 1736. Gray was prominent in the establishment of Wilmington and acted as the deputy surveyor of New Hanover County (Angley 1988:1).

After Gray's death in 1742, the land was conveyed to Captain William Lithgow. When Lithgow died, the land was transferred to his daughter and son-in-law who sold it to Richard Quince, a prominent merchant and planter, in 1767 (Angley 1988:2-3). In 1769, Quince sold 2,805 acres to Lewis Henry DeRossett who probably built the first substantial dwelling at Rose Hill. During the Revolutionary War, DeRossett, a loyalist, was forced to sell his property to Parker Quince, Richard's son (Angley 1988:4-5).

From 1779 until 1842, Rose Hill remained in the Quince family. By the 1840s, Rose Hill was considered an "inferior" rice plantation (Angley 1988:11). In 1842, the property was transferred to James F. McRae. By the end of the nineteenth century, the lands were being advertised for sale in 50-acre parcels. During the 1920s the property was owned by the Gore Estate Corporation, and the land is currently owned by GE Corporation (Angley 1988:12-15).

Castle Haynes was located on the north of Prince George Creek. It was established on 1,000 acres in 1731 by Captain Roger Haynes. Captain Haynes married Margaret Marsden, the daughter of Reverend Richard Marsden, who had established The Hermitage on 1,000 acres to the east of what is now US 117. Reverend Marsden died in 1742, bequeathing The Hermitage to Margaret. Captain Haynes died in 1743, thus leaving Margaret with Castle Haynes (Waddell 1909:53-54).

One of the Haynes' daughters married John Burgwin; the couple took ownership of The Hermitage. Their other daughter married General Hugh Waddell, and they took over Castle Haynes. The Castle Haynes plantation house, which resembled a castle, burned in 1801, and The Hermitage burned in 1881 (Waddell 1909:53-54).

Point Pleasant Plantation was located north of Rose Hill. It was established by Colonel James Innes. Colonel Innes came to Carolina in 1735 and served in various military expeditions. He

was a member of the governor's council from 1750 to 1759. When he died childless in 1759, he left his estate for the education of the poor (Waddell 1909:54).

Rock Hill was a plantation located between Rose Hill to the north and Sans Souci to the south. It was the residence of John Davis, who was also the owner of the Mulberry Plantation on the Northwest Cape Fear. Rocky Run was located roughly between Rose Hill to the west and The Hermitage to the west. Owners included Maurice Jones and his son-in-law Dr. Nathanial Hill (Waddell 1909:51).

State Agency-Controlled Information Withheld per 10 CFR 2.390

4. PREVIOUS INVESTIGATIONS

Previous Archaeological Investigations

Seven hundred and ninety-nine archaeological sites have been recorded to date in New Hanover County. There are fifteen terrestrial archaeological sites (31NH455, 467, 468, 471, 472, 477, 478, 482, 486, 493, 554, and 31NH689-692) and one ship wreck (0031NER) recorded within [redacted] of the study area.

The 1990 survey of the Military Ocean Terminal at Sunny Point resulted in the recording of 101 archaeological sites (Drucker et al. 1990). During that survey, twenty-seven Civil War earthworks were recorded, and it was recommended that the boundaries of the Fort Fisher State Historic Site be expanded to include the newly identified earthworks.

Excavations at site 31NH142, the Hamp's Landing Site, resulted in the identification of a previously undefined prehistoric ceramic ware type, now known as Hamp's Landing (Hargrove 1993). Hamp's Landing ceramics are characterized by the limestone temper and are believed to date to the Early Woodland period.

Two large-scale surveys were conducted prior to the construction of the Wilmington Bypass. A 1994 survey identified eight previously unrecorded sites and revisited five previously recorded sites (Klein et al. 1994). Of the thirteen sites, eleven contained prehistoric components and two contained historic components. The eleven prehistoric sites contribute to an archaeological district that was recommended eligible for listing in the National Register. Six archaeological sites (31NH707-712) were recorded during a 1997 survey of portions of the Wilmington Bypass corridor (Barse 1997). Only site 31NH707, a Woodland period occupation site, was recommended as eligible for listing in the National Register.

ESI performed an intensive cultural resources investigation of the Eastern North Carolina Natural Gas Project in 2003. This project spanned many counties, including New Hanover County. Two sites were revisited during the process of this investigation, though only one of the sites (31NH481) was found. Site 31NH481 is a limited activity, Woodland site (Di Gregorio et al. 2003). Neither of these previously recorded sites was recommended eligible for listing on the National Register.

In June 2007, ESI conducted a survey of the Sutton Steam Plant property in order to relocate 31NH500**, also known as the Pocomoke Community. This site was originally recorded in 1978, and a preliminary site report of the site was written by Mark Wilde-Ramsing in 1992. ESI identified two areas with the remains of domestic structures, including brick foundations and depressions. Historic artifacts such as brick, metal, glass, and pearlware were collected on the surface and in shovel tests (Postlewaite and Seibel 2007). A small cemetery reported by Wilde-Ramsing was not relocated during the investigation.

Project Specific Previous Investigations

State Agency-Controlled Information Withheld per 10 CFR 2.390

There are ten previously recorded archaeological sites (31NH404-407, 454, 455, 460, 465, 472, and 474; **Figure 4.1**) within [redacted] of the potential GE Expansion. These sites were identified during a survey conducted by the New Hanover County Comprehensive Employment Training Act Survey (C.E.T.A.) Project between 1977 and 1978 (Wilde-Ramsing 1978). All sites were identified by pedestrian inspection. A survey of the proposed Wilmington Bypass corridor (Klein et al. 1994) relocated sites 31NH460, 31NH472, and 31NH474, but did not assess them for National Register eligibility.

Artifacts collected at sites 31NH404 and 405 consisted of Woodland prehistoric ceramics. Site 31NH406/406** yielded Woodland prehistoric ceramics as well as historic artifacts. Site 31NH407 yielded Woodland ceramics as well as one Yadkin and one Badin projectile point, which are associated with Early Woodland cultures. Site 31NH454 yielded prehistoric lithic artifacts. Site 31NH460 yielded Middle Archaic-Middle Woodland artifacts (Klein, et al. 1994).

State Agency-Controlled Information Withheld per 10 CFR 2.390

Located approximately [redacted] southeast of the study area is site 31NH529** (the Quince Cemetery). It was identified as a nineteenth century cemetery, possibly associated with the Rose Hill Plantation, which once stood nearby. Artifacts from the cemetery site included brick and historic ceramics.

In addition to the previously recorded terrestrial archaeological sites, a single underwater site (Site 0031NER) was noted. Originally recorded in 1987, site 0031NER represents the "Rose Hill Wreck," a Colonial period merchant vessel sunken adjacent to the historic river landing of the Rose Hill plantation (Underwater Archaeological Unit 1987, 1988, 1997).

5. RESEARCH DESIGN AND METHODOLOGY

The goals of the investigation were to locate all cultural resources within the study area and to assess their eligibility for listing, if possible, in the National Register. Work towards these goals took place in two stages, background research and field investigations.

Background Research

Background research was conducted at the OSA, the New Hanover Public Library, and the Survey and Planning Branch of the SHPO and included a search of the North Carolina Archaeological Site Files and the study of historic maps of New Hanover County.

Field Survey Research Design

It is important to focus on locations that are conducive to human settlement when planning and conducting a cultural resource investigation. Factors that are usually constant in locating prehistoric archaeological sites include well-drained soils, proximity to and availability of a water source, relative elevation and slope, and hardwood vegetation. Often these factors are found in predictable combinations. Due to changes in the modern environment brought about by human activity, native biotic communities are often not present. Regional soil maps and detailed topographic maps generally serve as the best tools for identifying areas considered advantageous for human settlement and resource exploitation. When modeling for archaeological site location, archaeologists work under the assumption that the tendency for human activities to occur in locations that afford ready access to desired or important resources is sufficiently patterned and consistent to be predictable (Mathis 1979:10-11), though what is considered important by people can vary considerably between spatially and temporally separated cultures.

Field Methodology

Field methods employed by ESI during the intensive survey included a pedestrian investigation combined with shovel testing and the excavation of a limited number of test units. Pedestrian inspection focused on exposed surfaces such as unpaved road, eroded bluff banks, and other areas of clear surface visibility in an attempt to locate surface artifact scatters or above ground structural remains. Shovel tests were excavated at 30-meter intervals across the areas of well drained soils, with closer intervals (15 meters or less) for archaeological site investigations. Shovel testing occurred across the entire study area, excluding wetlands, areas of standing water, disturbed areas, and areas with slope greater than 15 percent.

Fieldwork during this project was separated into five areas (Area A, B, C, D, and E; see **Figure 5.1**). Both Areas A and B were subjected to full coverage shovel testing due to the presence of well drained soils and low surface visibility. Areas C and D, two proposed road corridors, were investigated with a combination of shovel testing and pedestrian inspection. Shovel testing was limited to well-drained, undisturbed soils in these areas. Pedestrian inspection focused on unpaved roads and borrow pit areas. Area E was comprised entirely of poorly drained and disturbed soils and was subjected to pedestrian inspection only

All shovel tests excavated measured approximately 30 centimeter in diameter and were excavated to a depth of 75 centimeters or subsoil, whichever was encountered first. All excavated sediments were screened through 6.35 millimeters (1/4 inch) steel mesh mounted upon portable shaker stands. Pertinent field data, including test locations, stratigraphy, environmental setting, topography, etc. were recorded for each shovel test in field notebooks carried by each shovel test crew. Crews backfilled each shovel test and marked the location with surveyor's flagging tape. Each test location was marked on a topographic field map of the study area.

Three 1-x-1 meter test units were excavated at site 31NH801 to evaluate its National Register eligibility. Each unit was excavated in arbitrary 10-centimeter levels within natural strata. All units were excavated to sterile subsoil, and soil color and texture, and notes on the stratigraphic relationship of any artifacts or cultural features were recorded. Soils were described using standardized measures such as Munsell Soil Color Charts

Laboratory Methodology

All field notes, forms, maps, and recovered artifacts were transported to the ESI laboratory in Raleigh, North Carolina. During fieldwork, a catalog system was employed to ensure that provenience data was recorded for each recovered artifact. In the laboratory, all artifacts were brushed clean of surface dirt, washed, and allowed to air dry. No artifact required stabilization or conservation.

Cultural materials were quantified, analyzed, and rebagged according to site number and provenience. Artifacts were analyzed according to material type and function, when possible. Prehistoric artifacts included ceramics, lithic tools, and debitage. The historic artifacts collected included mainly pottery and glass, though architectural materials such as nails were also recovered.

Prehistoric Artifacts

All prehistoric ceramic sherds recovered during the investigation were brushed clean of surface dirt, washed, and allowed to air dry. Whenever refitted sherds were noted in the assemblage, they were mended and counted as one item during analysis. Each sherd was examined to identify attributes and included standard descriptive categories such as paste, surface treatment, decoration, interior and exterior color, size, sherd thickness, and vessel portion. In addition, rim sherds were coded as to lip form, orientation, thickness, and other stylistic or potentially diagnostic attributes. An attempt was made to describe attributes for all sherds; however, badly eroded sherds and diminutive sherds (sherds measuring less than 10 millimeters in size) often could not be clearly classified. A general code of “Indeterminate” was utilized to describe an unidentifiable attributes during the analysis.

Ceramic analysis generally focused on identifying particular ceramic attributes diagnostic of particular temporal or cultural traditions. When possible, sherds were classified according to published pottery types for the region, although precautions were taken not to force sherds into existing ceramic classifications. Those sherds not easily recognized were assigned a descriptive

name based on surface treatment and temper (e.g. plain sand tempered). Diagnostic ceramics were used to identify cultural affiliation(s) and to determine relative dates for site activities.

During the analysis, all prehistoric lithic artifacts were counted, identified as to material type, and examined under magnification (10-60x) as needed. To determine their relative position on the reduction continuum, flakes were measured along their long axis and were further categorized on the basis of observable surface cortex. Primary flakes (PF) exhibit cortex over 100 percent of their outer surface, while secondary flakes (SF) possess cortex over less than 100 percent of their outer surface. Flakes that lacked cortex on the outer surface were classified as tertiary flakes (TF). Shatter are defined as angular fragments of stone that have been clearly modified, but lack a clear bulb of percussion.

A detailed morphological analysis was undertaken of each core, biface, and tool, during which the mode of modification (bifacial, unifacial) as well as the production stage was determined and recorded. Metric information such as maximum length (ML), maximum width (MW), and maximum thickness (MT) was also recorded and is given in that order (ML x MW x MT). All metric information was measured with a SkillTech caliper (maximum instrumental error = 0.5 mm).

Bifacial tools and points were analyzed according to a modified four part staging scheme based on morphological characteristics that identifies different stages within a single or multiple lithic reduction strategy modified from (Goode n.d. [in Johnson 1995 and Black et al. 1997]). In this scheme, Stages 1 and 2 of bifacial reduction are the beginning and intermediary manufacturing stages that can be identified according to characteristics such as edge sinuosity, degree of shaping, and presence/absence of cortex. A Stage 1 biface represents an edged biface, while a Stage 2 biface can be considered thinned biface. A Stage 3 biface can be considered a preform, while Stage 4 is the final manufacturing stage evidenced by final shaping and thinning of the biface. Stage 5 represents resharpening and/or remodification of the tool.

Stone Type Descriptions

As part of the lithic analysis, the raw materials used in making stone tools were identified. Three broad classes of stone were identified in the assemblages: aphyric rhyolite, porphyritic rhyolite, and quartz. Such general petrographic identifications typically satisfy the needs of archaeological classification, since the criteria for geoarchaeological analyses are usually less exacting than those used in geological analysis (Oliver 1995:105).

Descriptions used in referring to the lithic artifacts recovered are discussed below:

> *Aphyric (Flow-banded) Rhyolite*: This stone is a fine-grained type that is uniformly dark gray in color with light-colored bands (Coe 1964; Novick 1978; Oliver 1995; Daniel and Butler 1991, 1994). The fine lines characteristic of flow banding are most often revealed after the stone has been exposed and weathering has occurred.
>
> *Porphyritic Rhyolite*: Porphyritic rhyolite is dark gray to black with scattered white crystalline phenocrysts that distinguish it from flow-banded rhyolite. Phenocrysts refer to

crystalline structures that vary in size and morphology within fine-grained igneous rocks. Porphyritic rhyolite does not attain the same degree of obvious weathering, as does flow-banded rhyolite.

Quartz: Quartz is a form of silica that can occur in a variety of colors; material recovered during the survey was white. Because quartz does not always fracture in the same predictable manner as rhyolite and chert, quartz flakes demonstrating a bulb of percussion and platform are sometimes difficult to recognize.

Historic Artifacts

Historic artifacts were classified using Orser's (1988) functional typology (**Table 5.1**). Orser's typology provides a means for interpreting the relative importance of specific artifact classes at the site. Within this system, historic artifacts were analyzed according to material type and function, when possible. One additional category, *6. Unknown*, was added to the functional typology to better capture unidentified artifacts. Vessel morphology (i.e. bowl, plate, etc.) as well as the type of fragment (basal/footing, neck, rim/lip, body, etc.) were noted whenever possible for glass and ceramics. If necessary, specific references for bottle glass, nails, and other miscellaneous items were consulted (cf. Ellis 1997; Israel 1993; Tremont Nail Company n.d.). An attempt was made to classify all historic ceramics according to published pottery types (i.e. whiteware, pearlware, stoneware, etc.). Those sherds not easily recognized were assigned a descriptive name based on surface treatment and paste. Diagnostic ceramic types and maker's marks, when present, were used to determine relative dates for site activities.

Table 5.1: Functional Typology (modified from Orser 1988)

1. Foodways
   a. Procurement – Ammunition, fishhooks, fishing weights, etc.
   b. Preparation – Baking pans, cooking vessels, large knives, etc.
   c. Service – Fine earthenware, flatware, tableware, etc.
   d. Storage – Coarse earthenware, stoneware, glass bottles, canning jars, bottle stoppers, etc.
   e. Remains – Floral, faunal

2. Clothing
   a. Fasteners – Buttons, eyelets, snaps, hooks, eyes, etc.
   b. Manufacture – Needles, pins, scissors, thimbles, etc.
   c. Other – Shoe leather, metal shoe shanks, clothes hangers, etc.

3. Household/Structural
   a. Architectural/Construction – Nails, flat glass, spikes, mortar, bricks, slate, etc.
   b. Hardware – Hinges, tacks, nuts, bolts, staples, hooks, brackets, etc.
   c. Furnishings/Accessories – Stove parts, furniture pieces, lamp parts, fasteners, etc.

4. Personal
   a. Medicinal – Medicine bottles, droppers, etc.
   b. Cosmetic – Hairbrushes, hair combs, jars, etc.

Table 5.1: Functional Typology (continued)

c. Recreational – Smoking pipes, toys, musical instruments, souvenirs, etc.
d. Monetary – Coins, etc.
e. Decorative – Jewelry, hairpins, hatpins, spectacles, etc.
f. Other – Pocketknives, fountain pens, pencils, ink wells, etc.

5. Labor
a. Agricultural – Barbed wire, horse shoes, harness buckles, hoes, plow blades, scythe blades, etc.
b. Industrial – Tools, etc.

6. Unknown

Curation

The results of laboratory analysis were tabulated in the site descriptions. All field documents including notes, forms, and maps as well as the artifacts recovered during the survey were labeled and packed for permanent curation according to the OSA Archaeological Curation Standards and Guidelines. Presently, project materials are being temporarily housed at the ESI laboratory in Raleigh, North Carolina. Following project completion, all artifacts will be transported to the OSA curatorial facility for permanent storage.

Site Descriptions

Site descriptions contain a variety of information generally based on fields included on North Carolina Archaeological Site Forms, much of it presented in a succinct bullet format. Categories in the bullet format include: Site size; topography; elevation; environmental setting; soil type; nearest water; surface visibility; field procedures; cultural affiliation; and site function. Each site description also includes a detailed description of the work conducted at the site and the type of materials, etc. encountered. Also given are a listing of the artifacts recovered from the site separated by component and context and recommendations for the site (no further work, avoidance, testing, etc.).

When reporting the number of shovel tests excavated at site under the field procedures heading, all shovel tests used to both test the integrity of subsurface deposits and to delineate the boundaries of a site are included. For example, if a shovel test contains cultural material, but two tests on either side of the positive test do not contain cultural material, they are included in the shovel test count as they were used to delineate the boundary of the site.

Site Definitions and Evaluations

Archaeological sites are defined as discrete and potentially interpretable loci of cultural material (Plog et al. 1978). For the present study, an archaeological site is defined as a concentration of three or more artifacts (older than 50 years) within 30 meters of each other that appear to

represent either short or long-term activity. Isolated finds are defined as one to two artifacts recovered with no additional cultural material recovered from either the ground surface or from other shovel tests within 30 meters. With the exception of diagnostic projectile points or ceramic sherds, isolated finds yield less than the minimum data sufficient to forward statements concerning prehistoric land use and/or temporal affiliation.

National Register Eligibility Criteria

In order for a site, building, etc. to be considered a significant historic property, it must meet one or more of four specific criteria established in 36 CFR Part 60, National Register, and 36 CFR Part 800, Protection of Historic Properties. The evaluation of a prehistoric or historic archaeological site for inclusion on the National Register rests largely on its research potential, that is, its ability to contribute important information through preservation and/or additional study (Criterion D).

The National Register criteria for evaluation are stated as follows:

> *The quality of significance in American history, architecture, archaeology, engineering, and culture is present in districts, sites, buildings, structures, and objects that possess integrity of location, design, setting, materials, workmanship, feeling, and association, and;*
>
> *Criterion A: Properties that are associated with events that have made a significant contribution to broad patterns of our history;*
>
> *Criterion B: Properties that are associated with the lives of persons significant in our past;*
>
> *Criterion C: Properties that embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; and*
>
> *Criterion D: Properties that have yielded, or may be likely to yield, important information in prehistory or history.*

Archaeological Sites

While many archaeological sites are recommended as eligible to the NRHP under Criterion D, this is somewhat ill-defined. In order to clarify the issue of site importance, the following attribute evaluations add a measure of specificity that can be used in assessing site significance and National Register eligibility:

- Site Integrity – Does the site contain intact cultural deposits or is it disturbed?;

- Preservation – Does the site contain material suited to in-depth analysis and/or absolute dating such as preserved features, botanical and/or faunal remains, or human skeletal remains?;
- Uniqueness – Is the information contained in the site redundant in comparison to that available from similar sites, or do the remains provide a unique or insightful perspective on research concerns of regional importance?
- Relevance to Current and Future Research – Would additional work at this site contribute to our knowledge of the past? Would preservation of the site protect valuable information for future studies? While this category is partly a summary of the above considerations, it also recognizes that a site may provide valuable information regardless of its integrity, preservation, or uniqueness.

Nomenclature

Archaeological sites in North Carolina are most often discussed and recorded using the standardized nomenclature provided by the OSA. In order to maintain consistency, the following functional site designations utilized by the OSA are used in the site descriptions below:

Prehistoric:	Limited Activity	Long Term Habitation
	Lithic Workshop	Mound/Habitation Site
	Lithic Quarry	Mound (Isolated)
	Isolated Artifact Find	Human Skeletal Remains
	Short Term Habitation	Fish Weir
	Shell Midden	Other
	Prehistoric Cemetery/Ossuary	
Historic:	Domestic	Cemetery
	Agricultural	Dump (Waste Disposal)
	Commercial	Entertainment
	Transportation	Industrial
	Military	Unmarked Cemetery
	Religious	Other
	Governmental	

Although the designation “Other” is often placed on a site form when the nature of an historic artifact scatter cannot be determined, this report uses the term “Historic Artifact Scatter” to designate these site types.

6. RESULTS OF INVESTIGATIONS

The goal of the investigations at the 265-acre potential GE Expansion was to identify and assess the significance of cultural resources that might occur within the study area. As a result of this investigation, a total of 305 shovel tests and three 1-x-1 meter test units were excavated, and two archaeological sites (31NH800** and 31NH801) were recorded (**Figure 6.1**).

31NH800**

State Agency-Controlled Information Withheld per 10 CFR 2.390

Site Size: 450 m^2
Topography: Upland flat
Elevation: 20 feet amsl
Environmental Setting: Forested
Soil Type: Kenansville fine sand, 0 to 3 percent slope.
Nearest Water: [redacted] north
Surface Visibility: 20%
Field Procedure: Pedestrian inspection and shovel testing (n=19)
Cultural Affiliation: Late 18th-20th centuries
Site Function: Domestic

Site Description: Shovel testing of a forested upland flat within Area A revealed a subsurface scatter of historic artifacts (**Figure 6.2**). Shovel testing at 15-meter intervals yielded a total of 13 artifacts from six shovel tests (ST 11-3, D1, D3, D5, D11, and D14; see **Figure 6.3**). Artifacts were generally recovered from the top 25 centimeters below ground surface (bgs) within the plow zone, and included brick, glass, metal, and historic ceramics (**Table 6.1)**. Pedestrian inspection of an unpaved road bounding the site did not record any structural remains or additional cultural material.

Table 6.1: Artifact Summary from site 31NH800**

State Agency-Controlled Information
State of North Carolina

Withheld per 10 CFR 2.390

Soils in the shovel tests consisted of 10 to 30 centimeters of gray to dark gray sand (plowzone) over 10 to 40 centimeters of brown to strong brown sand. A third layer consisted of 30 to 60 centimeters of yellow to yellow brown sand. A few shovel tests encountered strong brown sandy clay at 40 centimeters bgs.

Recommendations: Based on the accepted temporal range for historic ceramics recovered from site 31NH800**, the site appears to date from the late eighteenth to early twentieth centuries. The site was located in a forested area that exhibited signs of silvicultural and other ground-disturbing activities. The lack of structural remains and low subsurface artifact density suggests that this site represents a short term occupation and does not have the potential to yield significant new information pertaining to the history of the area. Site 31NH800** is recommended not eligible for listing in the National Register. No further work is recommended for this location.

31NH801

Site Size: 3,600 m^2
Topography: Bluff
Elevation: 25 feet amsl
Environmental Setting: Forested
Soil Type: Baymeade fine sand, 1 to 6 percent slope.
Nearest Water: [redacted] north of an effluent channel
Surface Visibility: 20%
Field Procedure: Pedestrian inspection, shovel testing (n=17), test unit excavation (n=3)
Cultural Affiliation: Middle Woodland
Site Function: Short term habitation

State Agency-Controlled Information Withheld per 10 CFR 2.390

Site Description: This site is located within Area C (see **Figure 5.1**) along a forested bluff (**Figure 6.4**) overlooking a wetland area, likely an extinct channel of the Cape Fear River. Shovel testing along a 30-meter corridor east of an existing unpaved road (the centerline for a proposed road corridor) yielded six prehistoric artifacts including ceramics and lithic materials from ST 12-5, excavated on northern edge of the bluff (**Figure 6.5**).

State Agency-Controlled Information Withheld per 10 CFR 2.390

[redacted], sixteen additional shovel tests were excavated at 15-meter intervals along cardinal directions in order to delineate the site's boundaries. Nine of these shovel tests yielded a total of 96 additional prehistoric artifacts, including grog and fine sand tempered ceramics, lithic debitage, animal bone fragments, and charcoal (**Table 6.2**). The ceramics were consistent with Hanover and Cape Fear wares, both associated with the Middle Woodland Period (300 BC – AD 800).

State Agency-Controlled Information Withheld per 10 CFR 2.390

A possible cultural feature was bisected by one of the shovel tests ([redacted]). The feature, a possible pit, originated at a depth of 20 centimeters and measured approximately 17 centimeters in diameter. The roughly basin shaped stain extended approximately 30 centimeters in depth. Materials recovered from the shovel test included numerous charcoal fragments, burnt animal bone, and quartz debitage; however, as the feature was not identified until the completion of the shovel test excavation, these cultural materials could not be clearly associated with the feature.

Based on the artifact density, depth of recovery, and presence of a possible cultural feature, three formal test excavation units (TUs), each measuring 1-x-1 meters in size, were excavated in order to determine the archaeological integrity of the site within the proposed road corridor and Area of Potential Effects (APE), and to assist with determination of National Register eligibility. The

State Agency-Controlled Information Withheld per 10 CFR 2.390

first test unit (TU 1) was placed in the area of greatest artifact density as indicated by the preliminary shovel testing. The second test unit (TU 2) was placed adjacent to ST [redacted], which appeared to bisect a cultural feature (Feature 1). The final unit, TU 3, was placed southwest of TU 1, closer to the bluff edge and well within the APE

Table 6.2: Artifacts Recovered During Shovel Testing at 31NH801.

State Agency-Controlled Information
State of North Carolina

Withheld per 10 CFR 2.390

Soils in the test units were similar to those from surrounding shovel tests and consisted of approximately 10 to 15 centimeters of gray to grayish brown sand (Strat I) over 30 to 45 centimeters of yellowish brown sand (Strat II). Strat III consisted of pale yellow compact sand (**Figure 6.6, top**). The majority of artifacts were recovered from Strat II of the test units and shovel tests. **Table 6.3** shows the artifacts recovered from test unit excavations.

Table 6.3: Artifacts Recovered During Test Unit Excavation at 31NH801

State Agency-Controlled Information
State of North Carolina

Withheld per 10 CFR 2.390

State Agency-Controlled Information Withheld per 10 CFR 2.390

Two cultural features were recorded during the excavation of TU2 (**Figure 6.6, bottom**). Feature 1, bisected during the excavation of shovel test [redacted] [redacted] be a small pit feature. Feature 2 was a small post hole located adjacent to Feature 1. Both features were exposed during the excavation of TU2, Level 2 (14-24 centimeters below datum), mapped and photographed in plan view, and bisected, excavated, and recorded using standard accepted methodologies outlined in **Chapter 5.** Soils from the features were excavated and screened discretely.

Feature 1, bisected along its east-west axis, yielded one ceramic sherd and one piece of lithic debitage, in addition to a large amount of charcoal. The feature was fairly diffuse, with several concentrations of burnt wood and charcoal. The profile of the excavated feature revealed a generally insloping, basin-shaped feature with diffuse boundaries. The ceramic sherd recovered from Feature 1 was a sand tempered, incised ceramic sherd likely associated with the Middle Woodland Cape Fear series (ca. 300 BC – AD 1000).

Feature 2 was less diffuse in its initial plan view; however, in profile the feature edges were rather amorphous. The shape of the feature in profile was generally consistent with that of a prehistoric posthole; however, no artifacts were recovered from this feature.

<u>Summary:</u> Site 31NH801 is located on a high forested bluff, bordered by an unpaved road and wetland to the west, a disturbed borrow pit area to the north, and a human-modified effluent channel to the south. The bluff overlooks a wetland area west of the unpaved road, which appears to represent a remnant of an extinct paleochannel of the Northeast Cape Fear River. The eastern boundary of the site was not fully delineated, as the study area was limited to a 200-foot wide corridor extending 100 feet on either side of the centerline of the unpaved road cutting through the western edge of the bluff.

A total of 17 shovel tests and three 1-x-1 meter test units were excavated at the site in order to recover information regarding site size, cultural occupation, subsurface integrity, and National Register eligibility. As a result of the investigation, a total of 73 prehistoric lithics and 76 prehistoric ceramic sherds were recovered. Other cultural materials collected included bone (n=6) and charcoal (approximately 274 pieces). Diagnostic cultural materials recovered during the investigation included Middle Woodland Cape Fear and Hanover ceramics. The majority of artifacts were recovered from an apparently intact stratigraphic level (Strat II), ranging in thickness from 20 to 45 centimeters. The bluff does not appear to have been subjected to significant subsurface disturbance; however, the surrounding areas show evidence of heavy earth moving activities (road construction along the western edge of the bluff, borrow pit activity to the north, and the excavation of the effluent channel to the south).

<u>Recommendations</u>: Based on the results of this investigation, Site 31NH801 is recommended eligible for the National Register under Criterion D. The site's overall artifact density and presence of charcoal, faunal remains, and temporally diagnostic ceramics suggest that the site may represent a short term Middle Woodland habitation. Coastal Plain Middle Woodland sites containing evidence of faunal remains other than aquatic resources are quite rare in the region. The site appears to have good potential to retain such intact subsurface deposits.

Site 31NH801 will be avoided by construction activities. Current design plans call for no modifications to be made to the existing road that runs along the western boundary of the site. As such, there will be no adverse effects to the site by the proposed project. However, if design plans are modified to include impacts within the site boundaries, coordination with the SHPO to determine if the impacts will be adverse and to design a plan to mitigate any adverse effects will be necessary.

7. SUMMARY AND RECOMMENDATIONS

Environmental Services, Inc., of Raleigh, North Carolina, conducted this intensive cultural resource investigation of the potential GE Expansion in Wilmington, New Hanover County, North Carolina during October and November 2007 for RTI International (a representative of GE) to comply with Section 106 of the NHPA. As a result, 305 shovel tests and three 1-x-1 meter test units were excavated and over 450 prehistoric and historic artifacts were recovered. Two new archaeological sites (31NH800** and 31NH801) were recorded during this investigation. **Table 7.1** presents a summary of the documented archaeological sites within the study area.

Table 7.1: Summary of Site Data

Site Number	Cultural Affiliation	Site Type	Recommendations
31NH800**	Historic-Late 18^{th}-20^{th} centuries	Domestic	Not Eligible-No Further Work
31NH801	Prehistoric-Middle Woodland	Short term habitation	National Register Eligible-Preservation by Avoidance

Recommendations

Due to the lack of structural remains or subsurface integrity, site 31NH800** is recommended not eligible for listing in the National Register. No further work is recommended for this site. Site 31NH801, a prehistoric Middle Woodland habitation, appears to have the potential to contain intact subsurface deposits. The site is recommended eligible for listing in the National Register, and preservation by avoidance is recommended.

Current design plans call for no modifications to be made to the existing road that runs along the western boundary of site 31NH801. As such, there will be no adverse effects to the site by the proposed project. However, if design plans are modified to include impacts within the site boundaries, coordination with the SHPO to determine if the impacts will be adverse and to design a plan to mitigate any adverse effects will be necessary.

ESI recommends that the potential GE Expansion, as currently planned, be allowed to proceed without concern for impacts to significant cultural resources. If the project boundaries are modified outside of the current study area, coordination with the SHPO to determine if additional cultural resource investigations are required will be necessary.

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Appendix A: Artifact Tables

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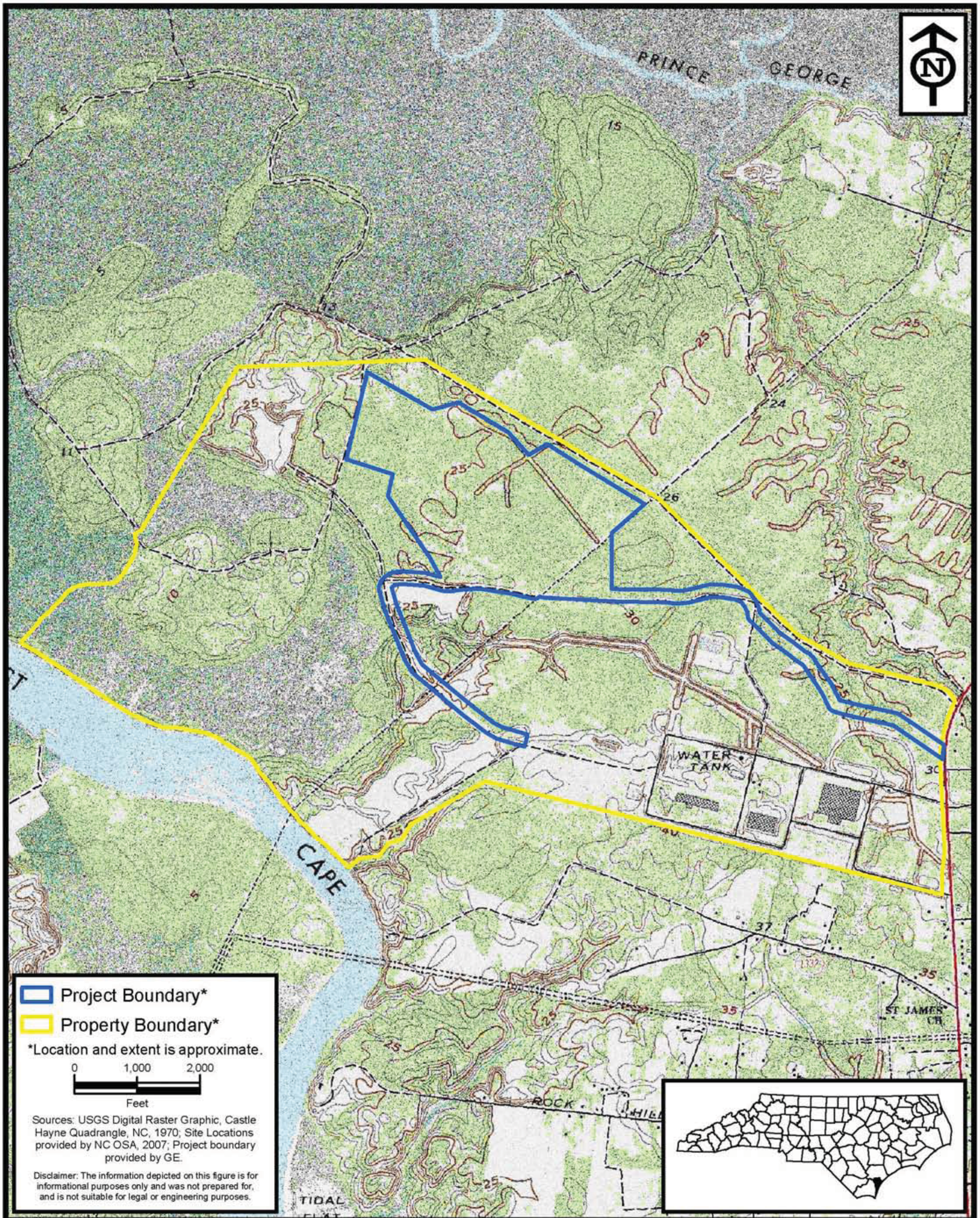

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Project Location
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New Hanover County, North Carolina

Project:	ER07155.00
Date:	Oct 07
Drwn/Chkd:	ESL/SS
Figure:	1.1

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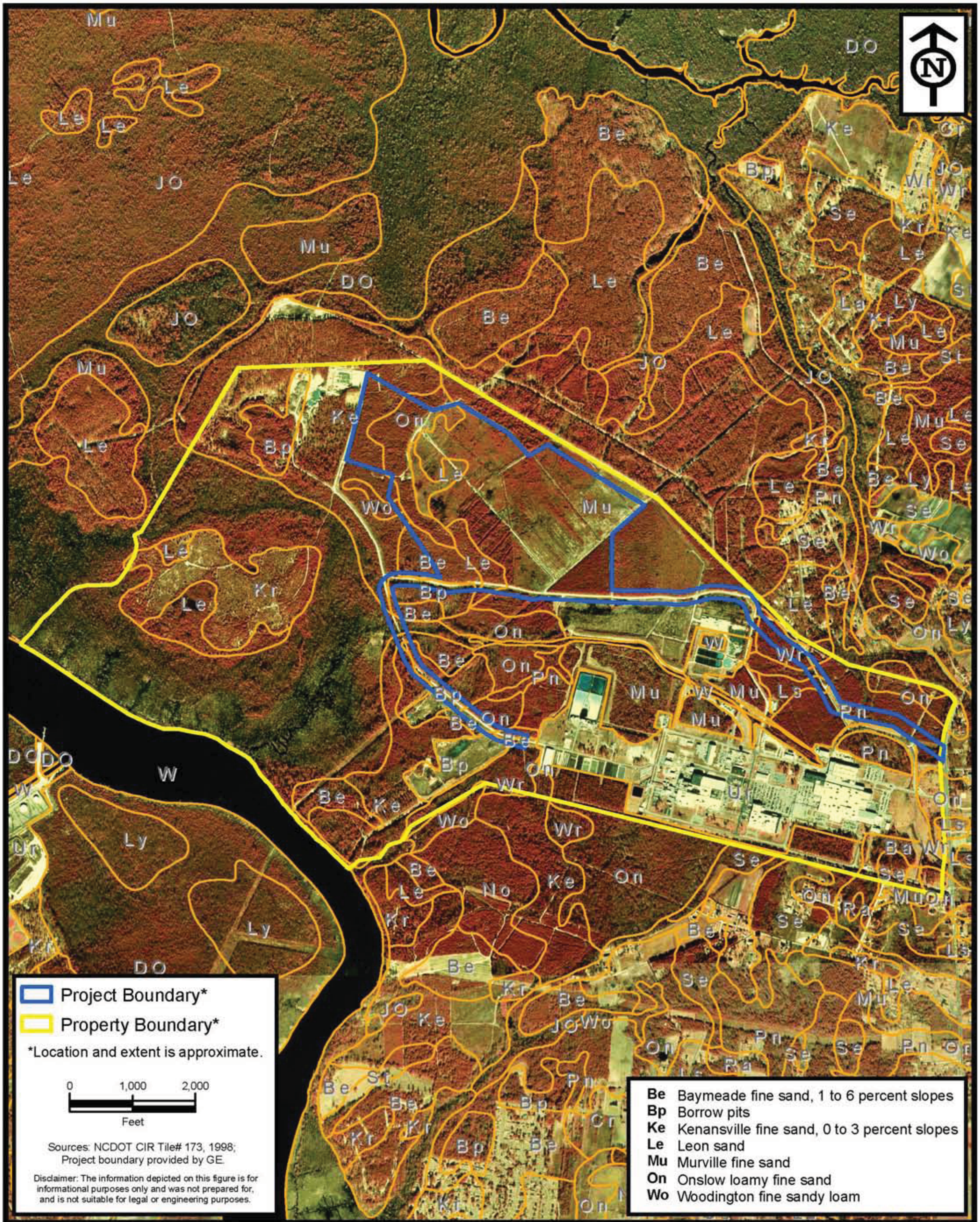

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Project Soils

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General view of vegetation within project area

General view of young pine plantation within project area

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Photos-Project Area Vegetation

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Figure:	2.2

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Figure:	**4.1**

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Figure:	**5.1**

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Site Locations
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Project:	ER07155.00
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Figure:	**6.1**

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View of site 31NH800**, facing east

View of site 31NH800** from dirt road, facing west

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Photos-Site 31NH800**

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New Hanover County, North Carolina

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Figure:	**6.2**

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Site Plan-31NH800**

Proposed GLE Facility

New Hanover County, North Carolina

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Figure:	**6.3**

iew of site 31NH801, facing south

iew of site 31NH801 from dirt road, facing east

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Photos-Site 31NH801

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Figure:	6.4

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Site Plan-31NH801
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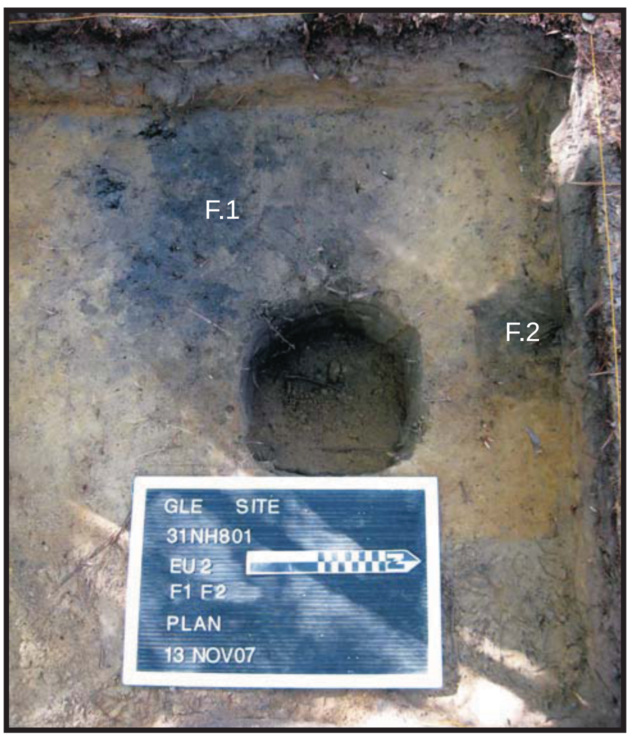
Figure:	6.

Typical soil profile for 31NH801



Features 1 and 2, E 2

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Photos-Site 31NH801

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Figure:	6.6

Appendix P

Numerical Modeling of Groundwater Flow and Contaminant Transport in the Principal Aquifer at the Wilmington Site

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Appendix P

Numerical Modeling of Groundwater Flow and Contaminant Transport in the Principal Aquifer at the Wilmington Site

P.1 Introduction

This document describes the development and application of a model to simulate groundwater flow and contaminant transport in the Principal Aquifer at the Wilmington Site. This document is derived from an appendix to the *2000-2001 Comprehensive Report of Organic Compounds in Groundwater* (RTI, 2002) and subsequent model calibration work conducted in 2004 (see **Section P.4**). Simulations for the analysis of the Proposed GLE Facility were performed using average recharge and water levels based on September 2003 data.

The primary goal of the modeling effort was to evaluate the effectiveness of the existing pumping-well network at containing the trichloroethylene (TCE) plumes in the active manufacturing central–eastern areas of the Wilmington Site. Specific additional objectives of the modeling effort included the following:

- Refine the conceptual model describing the Site hydrogeology and the transport of groundwater contaminants
- Develop and calibrate a quantitative, numerical groundwater flow model for the area that is consistent with the Site conceptual model
- Evaluate alternative groundwater-pumping scenarios
- Develop and calibrate a model to simulate the transport of TCE in groundwater
- Use the calibrated numerical flow model and transport models to simulate groundwater flow conditions at the Site and to predict future plume-migration patterns under alternative groundwater-pumping scenarios.

P.2 Conceptual Model

This section describes the conceptual model (i.e., the current qualitative understanding of the geology and hydrogeology of the Site and region and its relationship to the groundwater contamination). The conceptual model is the basis for the development of the quantitative flow and transport models.

P.2.1 Location and Topography

The Wilmington Site is located in northwest New Hanover County in the North Carolina Coastal Plain. Elevations in this region generally range between 0 and 50 feet (ft; 15 meters [m]) above mean sea level (msl). Based on review of the topographic map (**Figure P-1)** and other knowledge of the Site and region, the following features constitute major hydrogeologic boundaries for the groundwater-flow system: the Northeast Cape Fear River, streams (e.g., Ness Creek and Prince George Creek), the low-lying swampy areas, and the on-site effluent channel.

P.2.2 Hydrogeologic Units

The hydrogeologic units of interest in the Site area include the Surficial Aquifer, the semiconfining layer, and the Principal Aquifer.

P.2.2.1 Surficial Aquifer

The Surficial Aquifer includes undifferentiated, highly stratified deposits generally between 20 and 50 ft (6 and 15 m) msl. These sediments typically include terraced and barrier beach deposits, fossil sand dunes, and stream channel deposits. The sediment texture varies from medium to fine-grained sands to silts and clays. This aquifer is recharged directly by rainfall, and the water table is generally near the land surface (approximately from 0 to 10 ft [0 to 3 m] below ground). Discharge from the aquifer is into streams, drainage canals, and the low-lying swampy areas surrounding most of the upland areas. In addition, the Surficial Aquifer recharges groundwater into the underlying Principal Aquifer in some areas.

P.2.2.2 Semiconfining Layer

Relatively less-permeable silty and clayey deposits underlie most of the Surficial Aquifer and form the semiconfining layer. The semiconfining layer is a heterogeneous, interbedded unit that is not present in all areas. The semiconfining layer appears to be absent to the west and northwest of the Site. For example, a Site investigation indicated that there is no semiconfining layer in the Northwestern Site Sector (RTI, 1998).

P.2.2.3 Principal Aquifer

The Principal Aquifer lies below the Surficial Aquifer and the semiconfining layer. The Principal Aquifer consists of the upper zones of the Peedee Formation, a Cretaceous-age deposit that includes greenish-gray to dark-gray silt and sand interbedded with semi-consolidated calcareous sandstone and limestone. The upper portion of the Principal Aquifer is generally the most permeable and contains more sand than the lower zones. The unit dips to the southeast (see **Figure 3.4-9**); the Principal Aquifer coincides with the "Sandstone Aquifer" as labeled in this figure.

According to Bain (1970), there is a regional geologic contact that divides the portion of New Hanover County where the Wilmington Site is located (see **Figure 3.4-10**). To the east of this contact, the Principal Aquifer corresponds to the more permeable, upper sandy portion of the Peedee Formation, identified as "Sandstone Aquifer" on the cross section shown in **Figure 3.3-22**. To the west of this geologic contact, the upper Peedee Formation unit pinches out, and the sediment has an increasing silt and clay component and a lower permeability. The semiconfining layer also disappears to the west of this contact, causing the Principal and Surficial aquifers to essentially become the same hydrogeologic unit with similar properties. Because there is no semiconfining unit, the Principal Aquifer to the west and northwest of the geologic contact is a water-table (unconfined) aquifer rather than a confined aquifer. Although much of the area west of this contact at the Site has not been investigated thoroughly, the pattern has been confirmed for the northwest Site area, where the semiconfining unit is absent and the conductivities are relatively lower than in the eastern Site area (RTI, 1998).

P.2.3 Principal Aquifer Groundwater Flow

Because the focus of the modeling effort is on the Principal Aquifer, Surficial Aquifer groundwater flow patterns will not be discussed here.

Figure 3.4-10 shows Principal Aquifer water levels collected throughout the Wilmington Site in 2007. As this figure indicates, groundwater flows from upland areas toward the surrounding hydrogeologic boundaries, including streams, the Northeast Cape Fear River, and the low-lying swampy area that surrounds much of the region. The primary input of groundwater to the Principal Aquifer system is recharge from leakage through the overlying semiconfining layer and from direct seepage of rainwater in areas where the semiconfining layer is absent (e.g., west and northwest of the geologic contact in **Figure**

3.3-22). In general, groundwater enters the system through recharge and flows outward toward the hydrogeologic boundaries.

Principal Aquifer water elevations in the area have fluctuated over a range of approximately 10 to 15 ft (3 to 4.5 m) from 1999 through 2007 (**Figure 3.4-11**). Even though the water levels have varied over this range, the resulting groundwater flow patterns have generally been similar throughout this period, as is evident in comparing the water-level contours in **Figures P-2** (relatively high water levels), **P-3** (relatively moderate water levels), **and P-4** (relatively low water levels) from November 1998, October 1999, and September 2000, respectively. The water-level contours in **Figures P-2 through P-4** were generated automatically using a kriging interpolation method; therefore, in some areas, the patterns are somewhat inconsistent with those shown in **Figure 3.4-10**, which was produced manually using hydrogeologic insight (e.g., in the vicinity of the effluent channel). Nevertheless, the contour patterns in the figures are similar, thus demonstrating the general consistency of water-level patterns over time.

P.2.4 Hydrogeologic Parameters

This section describes general information about hydrogeologic parameters that were developed from site-specific data and analyses, as well as through literature research. The approach for estimating the specific model parameter values for the model is presented below in **Sections P.3.3, P.3.4, P.4.3, and P.4.5.**

Estimates for hydraulic conductivity were developed using existing knowledge of the Wilmington Site, including slug tests, grain-size analyses, and pumping tests. Site-wide hydraulic conductivity measurements are shown in **Figure 3.4-12**.

Hydraulic conductivity results from the Wilmington Site indicate that there is a general increasing trend in hydraulic conductivity from the west to east across the Site. For example, slug-test data generated in the Northwestern Site Sector of the Wilmington Site indicate geometric-mean hydraulic-conductivity values of 3 ft/day (0.9 m/day) (RTI, 1998, 1999a). In contrast, pumping tests in pumping well WW-9A in the Eastern Site Sector indicate a hydraulic conductivity in the 40 ft/day (12 m/day) range (RTI, 1996). The average of hydraulic conductivity measurements for the waste treatment (WT) site area (also in located in the Eastern Site Sector, but west of well WW-9A) fall between the ranges measured for the Northwestern and the Eastern Site sectors of the Wilmington Site, with a geometric mean of 16.8 ft/day (5.1 m/day) (RTI, 1999b). This observation agrees with the assessment by Bain (1970) that there is a regional geologic contact dividing the portion of New Hanover County where the Wilmington Site is located, as shown in **Figure 3.3-22**. To the east of this contact, the Principal Aquifer corresponds to the more permeable, upper sandy portion of the Peedee Formation, identified as the “Sandstone Aquifer” on the cross section shown in **Figure 3.4-9**. The conductivity to the east is correspondingly in the upper range of measured values for the Site. To the west of this geologic contact, the older strata of the Peedee Formation outcrop, and these strata have an increasing silt and clay component, and thus, have lower hydraulic conductivities than the upper sandy portion of the Peedee Formation.

The flow modeling includes only steady-state simulations and does not have a temporal component; therefore, aquifer storage properties are not required.

P.2.5 Hydrogeologic Boundaries

The principal hydrogeologic boundaries for the system are recharge, discharge to streams, discharge to the low-lying swampy area, and discharge to the Northeast Cape Fear River. In addition, groundwater flows into and out of an effluent channel crossing the Site. Each of these boundaries is described below.

P.2.5.1 Recharge

Recharge to the Principal Aquifer from the Surficial Aquifer depends on the hydraulic gradient between these aquifers and the thickness and vertical hydraulic conductivity of the semiconfining layer. Because the semiconfining layer is a highly heterogeneous, interbedded geologic unit, the amount of leakage through this layer can vary greatly in different areas. For any given conductivity and thickness of the semiconfining layer, recharge to the Principal Aquifer would increase with the hydraulic head difference between the Surficial and Principal Aquifers. Accordingly, the recharge rate can be estimated using the following form of Darcy's law:

$$\text{Recharge Rate} = K_v\,(h_{surf} - h_{princ})/L_{sl}$$

where K_v is the vertical hydraulic conductivity of the semiconfining layer, h_{surf} is the head in the Surficial Aquifer, h_{princ} is the head in the Principal Aquifer, and L_{sl} is the semiconfining layer thickness. An exception to this expression applies if the groundwater level in the Principal Aquifer were below the bottom of the semiconfining layer (e.g., in the immediate vicinity of pumping wells). In this case, h_{princ} should be the bottom of the semiconfining layer rather than the head in the Principal Aquifer (representing a seepage-face boundary where the Principal Aquifer is dewatered).

Figure P-5 shows the difference in the groundwater elevation between the Surficial and Principal aquifers based on data collected on September 12, 2000 (as described above, the bottom of the semiconfining layer is used where the aquifer is dewatered around some of the pumping wells). The Surficial Aquifer water levels are generally higher than the Principal Aquifer levels, with the difference varying between 2 and 18 ft (.6 to 5.4 m). The greatest differences are in the vicinity of the pumping wells, which have lowered the water levels in the Principal Aquifer. Combining the head difference in **Figure P-5** with the estimated thickness of the semiconfining layer (**Figure P-6**) and using an estimated vertical hydraulic conductivity of the semiconfining layer of 0.001 ft/day, the recharge to the Principal Aquifer is estimated to range approximately from 1 to 29 inches (2.5 to 74 centimeters [cm]) per year for the September 2000 time period (**Figure P-7**).

Small head differences between the Principal and Surficial aquifers could indicate relatively effective communication between these units (or even the absence of the semiconfining layer), where head gradients readily dissipate between the aquifers. In such areas, the above estimates of recharge would likely be inaccurate, because a greater volume of groundwater would be able to flow between the aquifers without a large head differential. One example is the Northwestern Site Sector where the semiconfining layer is absent. A calibrated, three-dimensional modeling of the Northwester Site Sector (RTI, 1999a) suggested a recharge rate of 11.6 inches (29.5 cm) per year, which is about 23% of the annual average rainfall in the Wilmington area of 50 inches (127 cm) per year.

The recharge values developed using the above methodology were applied as initial estimates for the modeling; however, considering the uncertainty of recharge estimates in the Principal Aquifer system, the recharge was varied using an automated flow-model calibration procedure (described in **Section P.3.4**) that minimizes the differences between measured and simulated groundwater elevations. The recharge parameter varied during the model calibration was the conductivity of the Semiconfining Layer.

P.2.5.2 Groundwater/Surface-Water Interaction

At higher elevations in the region, groundwater in the Principal Aquifer does not typically interact significantly with most surface-water features (e.g., streams) because the stream beds are separated from the aquifer by the less-permeable semiconfining layer. However, at lower elevations, surface water has often incised through the semiconfining layer and is in direct connection with the Principal Aquifer;

therefore, the Principal Aquifer groundwater elevations typically are influenced by surface water only at lower elevations.

Due to historical dredging of the original streambed, the effluent channel is the only known exception to this pattern. Much of the original dredged depth of the effluent channel streambed has been filled in with relatively more permeable sandy, alluvial sediments, and the semiconfining layer is thin or absent along much of the dredged length of the effluent channel. Therefore, groundwater can flow more readily between the Principal Aquifer and the effluent channel in the dredged areas. Upstream of the WT area, the effluent channel water level is generally higher than the groundwater elevations, thus indicating a losing stream (surface water seeps into the Principal Aquifer). Downstream of the WT area, the groundwater level is generally higher than the effluent channel water level, thus indicating a gaining stream (Principal Aquifer groundwater discharges into the effluent channel).

The low-lying swampy area surrounding much of the region constitutes an additional major hydrogeologic boundary. Very strong upward vertical gradients in the swampy area (on the order of 0.15 in the Northwestern Site Sector) indicate that this area is a major groundwater-discharge boundary (RTI, 1998).

P.2.5.3 Groundwater Pumping

A system of active pumping wells is maintained across the facility (shown in **Figure 3.4-10**) to provide water for plant processes and to prevent off-site migration of groundwater contamination. The total volume pumped from each well is currently measured twice monthly. The total volume data were time-averaged by dividing the total volume by the total time between measurements. The pumping rates remain within fairly consistent ranges, although maintenance activities or periods of variable water demand can lead to pumping-rate adjustments. Also, the pumping rates are modified occasionally to adjust the control of the contaminant plumes.

P.3 Flow-Model Development and Results

This section describes the development of the groundwater flow model, including the code, the finite-difference grid, input parameters, and boundary conditions.

P.3.1 Code Description

The flow model code, MODFLOW-2000, is a three-dimensional, block-centered, finite-difference numerical model that was developed by the U.S. Geological Survey (USGS; Harbaugh et al., 2000; McDonald and Harbaugh, 1988). MODFLOW-2000 can solve for steady-state and transient conditions. Simulation output includes water balances and heads for each time step and layer. MODFLOW-2000 can handle multiple boundary conditions, including specified head, specified flux, and various mixed-type boundaries. The model can also simulate multiple hydraulic sources and sinks, including recharge, rivers, drains, lakes, pumping wells, injection wells, and evapotranspiration.

P.3.2 Finite-Difference Grid

The model domain includes the Site area of concern and extends outside of this area to include the relevant regional hydrogeologic boundaries for the Principal Aquifer (**Figure P-8**). The boundaries include the low-lying swampy area to the northwest and southwest, the Northeast Cape Fear River to the west, and Prince George Creek to the northwest. The eastern lateral edge of the model is estimated to be perpendicular to the groundwater flow in this area. Because groundwater does not flow perpendicular to flow paths, this eastern edge of the model is established as a no-flow boundary for the flow system.

The spacing of the finite-difference rows and columns is shown in **Figure P-9**. Relatively fine grid spacing is often required for accurate transport modeling; therefore, the established grid spacing is 100 ft (30.5 m) in the area encompassing measured groundwater impacts at the Wilmington Site. In order to decrease computer memory and processing requirements, the grid spacing was increased outside of this area. A coarser grid is adequate in these regions because the contaminant plumes do not extend to these areas, making transport modeling unnecessary. With the spacing described above, the finite-difference grid contains 124 columns and 81 rows, giving a total of 10,044 finite-difference cells.

The design of the model top elevation depends on the location within the model domain. To the east of the geologic contact, the model top corresponds to the top surface of the Principal Aquifer (the bottom of the semiconfining layer). This unit generally dips to the southeast. To the west of the geologic contact, the top of the model corresponds to the land surface because the semiconfining unit is absent in this area and the aquifer is a water-table aquifer. Note that for a simulated water-table aquifer, the top surface is typically the land surface, even though the water level is usually below this level and is determined as part of the simulation. In contrast, for a simulated confined aquifer, the top surface represents the actual top of the aquifer.

Within the Wilmington Site, the model top surface was estimated by interpolating data from well and boring logs across the Site. Outside of the Wilmington Site and to the west of the geologic contact, the top of the model was set to the ground surface elevation based on USGS digital elevation model (DEM) data, which provide surface elevations across the region. Outside of the Wilmington Site and to the east of the geologic contact, the top of the model dips to the east following information from Bain (1970), as shown in **Figure P-10**. **Figure P-11** shows the final model top elevation distribution.

The model includes one layer. To the east of the geologic contact, this layer corresponds to the more permeable and more sandy section of the Principal Aquifer. In this region, this model layer extends 35 ft (11 m) below the top of the Principal Aquifer, which is the typical thickness of the aquifer estimated by Bain (1970). The bottom surface of the layer was derived by subtracting 35 ft (11 m) from Bain's estimated top-of-aquifer surface (**Figure P-10**). To the west of the geologic contact, Bain's surface was extrapolated through the model domain, giving the final bottom elevation distribution shown in **Figure P-12**.

P.3.3 Input Parameters and Boundary Conditions

As discussed in **Section P.2.3**, groundwater generally flows from upland recharge areas outward into discharge areas, including the swampy area, the Northeast Cape Fear River, and streams. This section discusses the model treatment of each of these discharge features and the additional boundaries within the flow-model domain (shown in **Figure P-8**). **Table P-1** summarizes specific values associated with these boundary conditions and includes a brief description of the basis for the values. The remainder of this section describes the estimation of input parameters and boundary conditions in more detail.

P.3.3.1 Hydraulic Conductivity

The model hydraulic conductivity distribution is based on a series of "pilot points" shown in **Figure P-13**. The hydraulic conductivity distribution is determined by interpolating (using a kriging algorithm) between conductivity values at each of these points. **Figure P-13** also shows the calibrated hydraulic conductivity field and the associated values of the conductivity at each of the pilot points. The resulting distribution varies continuously across the domain rather than being constant within areal parameter zones. The conductivity values at the pilot points were adjusted during calibration using the automated calibration procedure described below in **Section P.3.4**. Note that no measurements were performed at the off-site pilot-point locations shown in **Figure P-13**; nevertheless, the model-estimated conductivity

distribution compares well with the measured conductivities at the Site, as is evident when comparing **Figure P-13** with **Figure 3.4-12**.

P.3.3.2 Recharge

Recharge is represented through a recharge boundary in MODFLOW, which delivers a specified flux of groundwater to the top of the model. This recharge boundary extends throughout the model domain. Within the primary area of concern for the model, an initial estimate of the recharge was developed in **Section P.2.5.1**. Outside of this primary area of interest, the recharge was estimated as being constant within a series of recharge zones shown in **Figures P-14, P-15, and P-16**. These figures also show the calibrated recharge distribution resulting from the automated calibration procedure described below in **Section P.3.4**. The zonal recharge values and the semiconfining unit hydraulic conductivity (used to calculate the recharge within the primary area of interest) were adjusted automatically by the calibration routine.

P.3.3.3 Stream Drain Boundaries

As discussed in **Section P.2.5.2**, groundwater from the Principal Aquifer typically discharges to streams only at lower elevations, where the streams have incised through the semiconfining layer. At upper elevations, the semiconfining layer prevents significant interaction between streams and the Principal Aquifer. In this situation, streams can be represented in MODFLOW as drain boundaries. A drain boundary only allows groundwater to leave the system through discharge to the boundary. The rate of flux out of the system through a drain depends on the specified elevation of the drain and the surrounding groundwater piezometric head. If the piezometric head falls below the drain elevation, the boundary becomes inactive, and groundwater does not enter (or leave) the groundwater system through the drain. Likewise, the flux of water leaving the groundwater system increases as the piezometric head increases relative to the drain elevation. Drain elevations were set based on the estimated average elevation of water in the stream beds, which was derived through review of the topographic map and Site observation.

The flux of groundwater out of a drain boundary is also controlled by a conductance parameter, which is linearly proportional to the flux. For the drain boundaries, the conductance was set to a high enough value to allow nearly the maximum amount of flow out of the system. With a high conductance value, the drains are essentially specified head boundaries with the important difference that they only allow flow out of the groundwater system and are inactive if the piezometric head is below the drain elevation.

As **Figure P-8** shows, drain boundaries are specified for three streams to the south and southwest of the Wilmington Site, one stream to the north, and a portion of Prince George Creek along the northern model boundary.

P.3.3.4 Effluent Channel River Boundary

The effluent channel is modeled as a river boundary. This boundary is similar to a drain boundary, as described in **Section P.3.3.3**; however, groundwater can either enter or exit the flow system through river boundaries. If the hydraulic head in the aquifer is greater than the river boundary elevation, groundwater discharges into the river. If the head in the aquifer is less than the river elevation, water from the river recharges the aquifer. This treatment of the effluent channel is based on the interpretation that the effluent channel is a losing stream in its upper reaches and a gaining stream in its lower reaches (as described in **Section P.2.5.2**). The conductance of the effluent channel was varied along its length based on the interpretation that dredging led to caused variable degrees of communication with the Principal Aquifer. In addition, the effluent channel intersects the Principal Aquifer downstream where the conductance values are greatest. The conductance varies from 0.1 ft/day (0.03 m/day) at the channel's eastern edge to 100 ft/day (30.5 m/day) at its western edge. (Note that these values are expressed as the hydraulic

conductivity times the boundary width divided by the boundary thickness. This value is then multiplied by the finite-difference cell length to yield the actual boundary-conductance value.) The elevation of the effluent channel drain boundary was set based on both the topographic map and water elevations measured at effluent-channel stream gauges.

P.3.3.5 Specified-Head Boundary

Specified-head boundaries are used to describe the swampy area, the Northeast Cape Fear River, and much of Prince George Creek, which surround the model domain to the west, south, and much of the north, as shown in **Figure P-8**. The elevation of this boundary was estimated to be 3 ft (0.9 m) msl based on the topographic contour map.

P.3.3.6 No-Flow Boundary

The eastern lateral edge of the model is estimated to be perpendicular to the groundwater flow in this area. Groundwater does not flow perpendicular to flow paths; therefore, this eastern edge of the model is established as a no-flow boundary for the flow system. Also, the bottom of the model was set as a no-flow boundary because there is no evidence of significant interaction between the modeled groundwater flow system and groundwater flow deeper than the lower model boundary.

P.3.3.7 Pumping Wells

The pumping wells were modeled as specified flux boundaries. The pumping rates were estimated from site-specific data, as described in **Section P.2.5.3**.

P.3.4 Flow-Model Calibration

Minimization of the error between the simulated and measured results was achieved using an automated calibration procedure implemented using PEST, a nonlinear parameter estimation software. This method automatically adjusts the calibration parameters until a numerical error criterion (the root mean squared) is minimized. In addition to PEST, calibration curves (x-y plots of the simulated versus the measured heads) and alternative quantitative error criteria were reviewed.

P.3.4.1 Calibration Data Sets

The goal of model calibration is to minimize the differences between measured and simulated values. For the flow model, simulated groundwater elevations were compared with elevations measured during three time periods: November 1998 (**Figure P-2**), October 1999 (**Figure P-3**), and September 2000 (**Figure P-4**). These datasets each included groundwater elevations from all of the active monitoring wells at the Site. In addition, these datasets represent conditions at relatively low, high, and medium groundwater elevations, as described in **Section P.2.3**.

P.3.4.2 Automated Calibration Procedure

The PEST automated calibration procedure was set up to estimate values for the following parameters:

- The hydraulic conductivity at each pilot point location (**Figure P-13**)
- Recharge within the constant-value recharge zones (**Sections P.2.5.1 and P.3.3.2** and **Figures P-14, P-15, and P-16**)
- The semiconfining layer hydraulic conductivity within the Site area (**Sections P.2.5.1 and P.3.3.2**).

PEST allows automated calibration and incorporates powerful techniques of regularization. Regularization provides stability to the parameter-estimation process. Regularization involves additional "regularization observations" that constrain and control the direction of the parameter-estimation process. The following regularization constraints were included in the GE/GNF model calibration:

- The differences in hydraulic conductivity between adjacent pilot points were minimized. This constraint allowed the conductivity field to vary smoothly and only to deviate from homogeneity to the extent necessary to calibrate the model. (Note that adjacency between pilot points was determined by constructing a triangulated irregular network [TIN] between the points).
- The differences between adjacent recharge-zone values were minimized. Similar to the hydraulic conductivity, this constraint caused the recharge distribution only to deviate from homogeneity to the extent necessary to calibrate the model.

P.3.4.3 Calibration Error Criteria

Several quantitative error criteria are available, including: (1) mean error (ME), (2) mean absolute error (MAE), (3) root mean squared error (RMS), (4) RMS divided by the range of measured head values, (5) maximum residual, and (6) minimum residual.

The ME is the arithmetic average of the residuals (a residual value is the measured head subtracted from the simulated head at a particular point):

$$ME = \frac{\sum_{1}^{n} h_{meas} - h_{model}}{n}$$

where h_{meas} is a measured head value, h_{model} is the simulated head value, and n is the total number of measurements. The MAE is the mean of the absolute value of the residuals:

$$MAE = \frac{\sum_{1}^{n} \left| h_{meas} - h_{model} \right|}{n}$$

The RMS is calculated by squaring the residuals, taking an average of the squared residuals, and then taking the square root of the result:

$$RMS = \sqrt{\frac{\sum_{1}^{n} \left(h_{meas} - h_{model} \right)^2}{n}}$$

The RMS divided by the range is calculated by dividing the RMS by the overall range of measured head values (the minimum measured head subtracted from the maximum measured head).

P.3.4.4 Flow Calibration Results

Table P-2 provides the quantitative calibration results, including the residual values, ME, MAE, and RMS. All of these values indicate that the modeled heads are very close on average to the measured values, thereby providing an effective calibration to measured results. **Figure P-17** shows a graph of the

modeled versus the measured heads. The plotted values in this figure follow a linear pattern, and there is no clustering of data in particular regions above or below the x=y line, indicating that there is no systematic bias in the calibration results. This figure includes the results of a linear regression of the calibration curve. The slope of the regression line (0.9958) is very close to the ideal result of 1.0. Also, the coefficient of determination, or R^2 error (0.9786), is close to the ideal result of 1.0. The simulated head distributions for the November 1998, October 1999, and September 2000 in **Figures P-18, P-19, and P-20**, respectively, compare well with the contours produced from measurement data shown in **Figures P-2, P-3, and P-4**. (Note that **Figure P-20** shows the head distribution throughout the model domain.) These results collectively indicate that the groundwater flow model accurately represents groundwater flow conditions at the Site.

P.4 Model Calibration Update

The model calibration was updated in 2004 to represent the effects of a new pumping well (RW-4) installed in January 2002 after the initial model development was completed. All of the model setup and parameters were consistent with the previously developed model except for the recharge. The model was calibrated to three sets of groundwater elevation data: one set of data from a time before RW-4 was installed (January 2002) and two sets of data collected after RW-4 became operational (September 2003 and April 2004). These data span a representative range of pumping and groundwater-level conditions for the Site. Results of the calibration are summarized in **Figure P-21** and indicate good agreement between measurements and simulation results. Simulations for the analysis of the Proposed GLE Facility were performed using the modeled recharge condition more representative of average recharge and water levels based on September 2003 data.

Tables

Table P-1. Summary of Flow Model Parameters

Parameter	Value	Basis
Porosity	0.3	Typical value for fine to medium sands.
Recharge	See **Figures P-14, P-15, and P-16**	See **Sections P.2.5.1 and P.3.3.2**
Horizontal Hydraulic Conductivity	See **Figure P-13**	See **Sections P.2.4.1 and P.3.3.1**
Stream Drain Boundary Elevations	Variable	Topographic Map
Stream Drain Boundary Conductance	100 ft/day[a] (30.5m/day)	Large enough for the drains to act as specified head boundaries. (Expressed as the conductivity * boundary width/boundary thickness. This value is then multiplied by the finite-difference cell length.)
Effluent Channel River Boundary Elevation	Variable	Measured stream gauge elevations; topographic map
Effluent Channel River Boundary Conductance	0.1–100 ft/day[a] (30.5m/day) Between 574 and 957 ft^2/day (175 and 292 m/day)	An increasing trend from east to west, assuming increasing communication with the aquifer (due to the dredged depth and the channel elevation). Calibration to adjust the influence of the effluent channel on flow patterns (**Section P.3.3.4**)
Elevations of Hydrogeologic Units	Variable	Site boring and well logs; Bain (1970); Topographic map; Geologic interpretation
Swampy-Area Constant Head Elevation	3 ft (0.9 m)	Topographic map

[a] Expressed as the conductivity multiplied by the boundary width/boundary thickness. This value is then multiplied by the finite-difference cell length to yield the actual conductance value.

Table P-2. Calibration Statistics and Measured and Model Heads

Name	Date Measured	Measured Head (ft)	Model Head (ft)	Residual (ft)
BL-1B	11/20/1998	18.32	18.87	-0.55
BL-2B	11/20/1998	18.3	19.41	-1.11
BW-1B	11/20/1998	14.49	16.00	-1.51
BW-2B	11/20/1998	11.78	12.59	-0.81
BW-3C	11/20/1998	5.46	5.85	-0.39
BW-4B	11/20/1998	5.01	5.56	-0.55
BW-5B	11/20/1998	4.94	6.00	-1.06
BW-6B	11/20/1998	5.22	4.98	0.24
BW-7B	11/20/1998	6.69	7.59	-0.90
BW-8B	11/20/1998	12.23	12.29	-0.06
BW-9B	11/20/1998	7.57	8.51	-0.94
CW-1B	11/20/1998	19.95	19.13	0.82
CW-1C	11/20/1998	19.97	19.16	0.81
CW-2B	11/20/1998	26.73	25.34	1.39
CW-3B	11/20/1998	27.91	27.82	0.09
CW-4B	11/20/1998	20.33	20.16	0.17
CW-4C	11/20/1998	18.11	20.27	-2.16
CW-5B	11/20/1998	14.22	14.85	-0.63
CW-6B	11/20/1998	15.05	16.15	-1.10
CW-7B	11/20/1998	4.15	4.32	-0.17
CW-7D	11/20/1998	2.43	4.25	-1.82
CW-8B	11/20/1998	4.39	6.35	-1.96
CW-9B	11/20/1998	11.95	10.79	1.16
DW-1B	11/20/1998	8.24	7.89	0.35
DW-2B	11/20/1998	7.91	7.82	0.09
DW-3B	11/20/1998	6.98	9.18	-2.20
DW-4B	11/20/1998	7.69	9.47	-1.78
DW-5B	11/20/1998	11.48	11.75	-0.27
DW-6B	11/20/1998	12.62	12.09	0.53
DW-7B	11/20/1998	11.37	11.59	-0.22
FW-2B	11/20/1998	22.16	20.89	1.27
FX-1B	11/20/1998	23.1	23.81	-0.71
FX-2B	11/20/1998	22.53	22.87	-0.34
FX-3B	11/20/1998	21.87	21.78	0.09
LF-1B	11/20/1998	12.1	13.23	-1.13
LF-2B	11/20/1998	16.76	18.52	-1.76
LF-2C	11/20/1998	20.76	18.57	2.19
LF-3B	11/20/1998	18.16	18.50	-0.34
LF-3C	11/20/1998	18.07	18.56	-0.49
LF-4B	11/20/1998	17.53	18.84	-1.31
MW-1B	11/20/1998	8.93	9.14	-0.21
MW-2B	11/20/1998	21.07	19.83	1.24
MW-3B	11/20/1998	28.22	28.35	-0.13
MW-3C	11/20/1998	28.2	28.31	-0.11
MW-4B	11/20/1998	28.36	28.37	-0.01
MW-4C	11/20/1998	28.45	28.30	0.15
MW-5B	11/20/1998	23.11	23.35	-0.24
MW-5C	11/20/1998	23.16	23.39	-0.23
OB-1	11/20/1998	18.8	17.63	1.17
OB-10	11/20/1998	7.77	11.09	-3.32

Name	Date Measured	Measured Head (ft)	Model Head (ft)	Residual (ft)
OB-2	11/20/1998	12.99	13.57	-0.58
OB-4	11/20/1998	18.73	23.97	-5.24
OB-6	11/20/1998	5.14	6.17	-1.03
OB-7	11/20/1998	14.97	15.39	-0.42
OB-8	11/20/1998	17.74	16.47	1.27
OB-9	11/20/1998	17.71	16.36	1.35
OW-1B	11/20/1998	6.36	5.57	0.79
OW-2B	11/20/1998	7.03	5.70	1.33
OW-4B	11/20/1998	5.76	5.88	-0.12
PW-10B	11/20/1998	5.33	4.97	0.36
PW-11B	11/20/1998	6.72	5.09	1.63
PW-11D	11/20/1998	6.63	5.15	1.48
PW-12B	11/20/1998	7.03	6.80	0.23
PW-13B	11/20/1998	5.97	5.77	0.20
PW-14B	11/20/1998	5.09	5.27	-0.18
PW-15B	11/20/1998	5.61	3.34	2.27
PW-16B	11/20/1998	5.99	6.26	-0.27
PW-1B	11/20/1998	5.85	6.52	-0.67
PW-1C	11/20/1998	5.77	6.54	-0.77
PW-1D	11/20/1998	4.98	6.55	-1.57
PW-2C	11/20/1998	9.57	9.74	-0.17
PW-2D	11/20/1998	9.15	9.81	-0.66
PW-3C	11/20/1998	11.25	11.36	-0.11
PW-4C	11/20/1998	14.24	13.86	0.38
PW-5C	11/20/1998	20.42	19.54	0.88
PW-6C	11/20/1998	22.16	21.14	1.02
PW-7C	11/20/1998	22.56	21.31	1.25
PW-7D	11/20/1998	22.39	21.31	1.08
PW-8C	11/20/1998	21.81	22.03	-0.22
PW-9B	11/20/1998	8.13	7.96	0.17
BL-1B	10/6/1999	23.51	23.71	-0.20
BL-2B	10/6/1999	24.26	24.24	0.02
BW-1B	10/6/1999	18.17	17.76	0.41
BW-2B	10/6/1999	15.88	15.48	0.40
BW-3C	10/6/1999	9.46	8.90	0.56
BW-4B	10/6/1999	8.36	8.57	-0.21
BW-5B	10/6/1999	8.94	8.92	0.02
BW-6B	10/6/1999	9.29	8.58	0.71
BW-7B	10/6/1999	10.39	10.85	-0.46
BW-8B	10/6/1999	16.31	15.76	0.55
BW-9B	10/6/1999	11.91	11.64	0.27
CAF-16C	10/6/1999	21.77	21.93	-0.16
CAF-17C	10/6/1999	20.84	20.71	0.13
CW-1B	10/6/1999	24.23	23.10	1.13
CW-1C	10/6/1999	24.27	23.16	1.11
CW-2B	10/6/1999	31.61	31.64	-0.03
CW-3B	10/6/1999	33.94	34.10	-0.16
CW-4B	10/6/1999	24.71	24.60	0.12
CW-4C	10/6/1999	24.89	24.77	0.12
CW-5B	10/6/1999	16.5	15.08	1.42

Name	Date Measured	Measured Head (ft)	Model Head (ft)	Residual (ft)
CW-6B	10/6/1999	19.05	18.37	0.68
CW-7B	10/6/1999	7.44	7.90	-0.46
CW-7D	10/6/1999	7.69	7.85	-0.16
CW-8B	10/6/1999	8.91	9.19	-0.28
CW-9B	10/6/1999	17.57	14.75	2.82
DW-1B	10/6/1999	11.76	12.04	-0.28
DW-2B	10/6/1999	11.11	11.76	-0.65
DW-3B	10/6/1999	12.26	12.97	-0.71
DW-4B	10/6/1999	13.48	13.34	0.14
DW-5B	10/6/1999	16.22	15.96	0.26
DW-6B	10/6/1999	18.3	17.14	1.16
DW-7B	10/6/1999	16.18	15.71	0.47
FW-2B	10/6/1999	28.2	27.00	1.20
FX-1B	10/6/1999	28.58	29.41	-0.83
FX-2B	10/6/1999	27.72	28.22	-0.50
FX-3B	10/6/1999	27.02	27.01	0.01
LF-1B	10/6/1999	17.14	17.70	-0.56
LF-2B	10/6/1999	21.48	22.56	-1.08
LF-2C	10/6/1999	23.7	22.60	1.10
LF-3B	10/6/1999	20.69	21.98	-1.29
LF-3C	10/6/1999	21.03	22.06	-1.03
LF-4B	10/6/1999	22.4	22.12	0.28
MW-1B	10/6/1999	13.55	12.38	1.17
MW-2B	10/6/1999	25.78	24.50	1.28
MW-3B	10/6/1999	33.95	34.57	-0.62
MW-3C	10/6/1999	33.93	34.53	-0.60
MW-4B	10/6/1999	34.32	34.77	-0.45
MW-4C	10/6/1999	34.38	34.71	-0.33
MW-5B	10/6/1999	28.68	28.70	-0.02
MW-5C	10/6/1999	28.64	28.74	-0.10
OB-10	10/6/1999	12.59	14.99	-2.40
OB-2	10/6/1999	16.7	17.59	-0.89
OB-4	10/6/1999	31.86	28.15	3.71
OB-5	10/6/1999	19.34	18.86	0.48
OB-6	10/6/1999	10.82	6.94	3.88
OB-7	10/6/1999	20.54	19.77	0.77
OB-8	10/6/1999	20.39	20.04	0.35
OB-9	10/6/1999	16.98	18.71	-1.73
OCW-1C	10/6/1999	9.18	8.93	0.25
OCW-2C	10/6/1999	8.54	8.18	0.36
OCW-3C	10/6/1999	7.39	6.81	0.58
OCW-5D	10/6/1999	15.1	14.59	0.51
OW-2B	10/6/1999	9.06	9.51	-0.45
OW-3B	10/6/1999	9.25	9.41	-0.16
OW-4B	10/6/1999	9.55	9.48	0.07
PW-10B	10/6/1999	8.42	9.14	-0.72
PW-11B	10/6/1999	8.66	9.17	-0.51
PW-11D	10/6/1999	8.7	9.23	-0.53
PW-12B	10/6/1999	10.33	10.61	-0.28
PW-13B	10/6/1999	9.17	9.62	-0.45

Name	Date Measured	Measured Head (ft)	Model Head (ft)	Residual (ft)
PW-14B	10/6/1999	7.27	9.20	-1.93
PW-15B	10/6/1999	9	8.66	0.34
PW-16B	10/6/1999	8.98	9.71	-0.73
PW-1B	10/6/1999	8.98	9.68	-0.70
PW-1C	10/6/1999	8.76	9.68	-0.92
PW-1D	10/6/1999	8.53	9.68	-1.15
PW-2C	10/6/1999	13.88	13.57	0.31
PW-2D	10/6/1999	13.92	13.65	0.27
PW-3C	10/6/1999	16.41	15.34	1.07
PW-4C	10/6/1999	21.27	18.44	2.83
PW-5C	10/6/1999	25.2	25.07	0.13
PW-6C	10/6/1999	26.4	27.20	-0.80
PW-7C	10/6/1999	27.48	27.71	-0.23
PW-7D	10/6/1999	27.58	27.71	-0.13
PW-8C	10/6/1999	27.95	28.37	-0.42
PW-9B	10/6/1999	11.71	11.75	-0.04
WT-13B	10/6/1999	17.48	15.67	1.81
WT-14B	10/6/1999	16.82	15.11	1.71
WT-15B	10/6/1999	17.44	16.26	1.18
WT-16B	10/6/1999	15.54	14.49	1.05
WT-17B	10/6/1999	18.05	16.65	1.40
WT-7B	10/6/1999	21.84	21.49	0.35
WT-7C	10/6/1999	21.85	21.48	0.37
BL-1B	9/12/2000	18.82	20.41	-1.59
BL-2B	9/12/2000	17.98	20.85	-2.87
BW-1B	9/12/2000	16.75	17.29	-0.54
BW-2B	9/12/2000	14.15	14.76	-0.61
BW-3C	9/12/2000	8.7	8.35	0.35
BW-4B	9/12/2000	9.68	7.90	1.78
BW-5B	9/12/2000	7.96	8.32	-0.36
BW-6B	9/12/2000	8.7	7.70	1.00
BW-7B	9/12/2000	9.86	10.10	-0.24
BW-8B	9/12/2000	14.15	14.52	-0.37
BW-9B	9/12/2000	11.69	10.99	0.70
CAF-16	9/12/2000	20.37	20.49	-0.12
CAF-17	9/12/2000	19.28	19.35	-0.07
CW-1B	9/12/2000	21.4	21.11	0.29
CW-1C	9/12/2000	21.41	21.13	0.28
CW-2B	9/12/2000	27.57	27.14	0.43
CW-3B	9/12/2000	28.16	28.47	-0.31
CW-4B	9/12/2000	22.32	22.41	-0.09
CW-4C	9/12/2000	22.41	22.54	-0.13
CW-5B	9/12/2000	15.73	15.00	0.73
CW-6B	9/12/2000	17.22	17.75	-0.53
CW-7B	9/12/2000	7.49	6.59	0.90
CW-7D	9/12/2000	6.68	6.51	0.17
CW-8B	9/12/2000	8.46	8.72	-0.26
CW-9B	9/12/2000	15.24	13.12	2.12
DW-1B	9/12/2000	11	10.88	0.12
DW-2B	9/12/2000	11.07	10.31	0.76

Name	Date Measured	Measured Head (ft)	Model Head (ft)	Residual (ft)
DW-3B	9/12/2000	13.78	10.03	3.75
DW-4B	9/12/2000	13.62	11.09	2.53
DW-5B	9/12/2000	13.86	14.28	-0.42
DW-6B	9/12/2000	13.29	15.11	-1.82
DW-7B	9/12/2000	13.78	14.08	-0.30
FW-2B	9/12/2000	26.5	24.45	2.05
FX-1B	9/12/2000	24.97	25.44	-0.47
FX-2B	9/12/2000	23.82	24.43	-0.61
FX-3B	9/12/2000	23.16	23.47	-0.31
LF-1B	9/12/2000	16.15	17.10	-0.95
LF-2B	9/12/2000	20.6	21.37	-0.77
LF-2C	9/12/2000	23.4	21.40	2.00
LF-3B	9/12/2000	20.17	20.67	-0.50
LF-3C	9/12/2000	20.36	20.74	-0.38
LF-4B	9/12/2000	20.47	20.72	-0.25
MW-2B	9/12/2000	21.57	21.48	0.09
MW-3B	9/12/2000	29.11	28.60	0.51
MW-3C	9/12/2000	29.11	28.57	0.54
MW-4B	9/12/2000	28.57	28.84	-0.27
MW-4C	9/12/2000	28.67	28.81	-0.14
MW-5B	9/12/2000	25.2	25.25	-0.05
MW-5C	9/12/2000	24.93	25.27	-0.34
OB-1	9/12/2000	20.43	20.00	0.43
OB-10	9/12/2000	12.94	14.56	-1.62
OB-2	9/12/2000	13.59	14.35	-0.76
OB-5	9/12/2000	17.48	17.63	-0.15
OB-6	9/12/2000	4.64	6.48	-1.84
OB-8	9/12/2000	20.29	20.21	0.08
OB-9	9/12/2000	20.16	19.97	0.19
OCW-1C	9/12/2000	8.43	8.47	-0.04
OCW-2C	9/12/2000	7.77	7.77	0.00
OCW-3C	9/12/2000	6.68	6.50	0.18
OCW-5D	9/12/2000	13.64	13.69	-0.05
OW-2B	9/12/2000	8.78	8.89	-0.11
OW-3B	9/12/2000	8.59	8.97	-0.38
OW-4B	9/12/2000	8.81	9.06	-0.25
PW-10B	9/12/2000	7.65	8.65	-1.00
PW-11B	9/12/2000	7.75	8.65	-0.90
PW-11D	9/12/2000	7.62	8.72	-1.10
PW-12B	9/12/2000	9.63	9.57	0.06
PW-13B	9/12/2000	9.08	9.21	-0.13
PW-14B	9/12/2000	7.31	8.47	-1.16
PW-15B	9/12/2000	6.81	8.61	-1.80
PW-16B	9/12/2000	8.93	9.25	-0.32
PW-1B	9/12/2000	8.65	9.20	-0.55
PW-1C	9/12/2000	8.76	9.20	-0.44
PW-1D	9/12/2000	7.8	9.20	-1.40
PW-2C	9/12/2000	13.77	11.77	2.00
PW-2D	9/12/2000	13.7	11.85	1.86
PW-3C	9/12/2000	13.62	13.81	-0.19

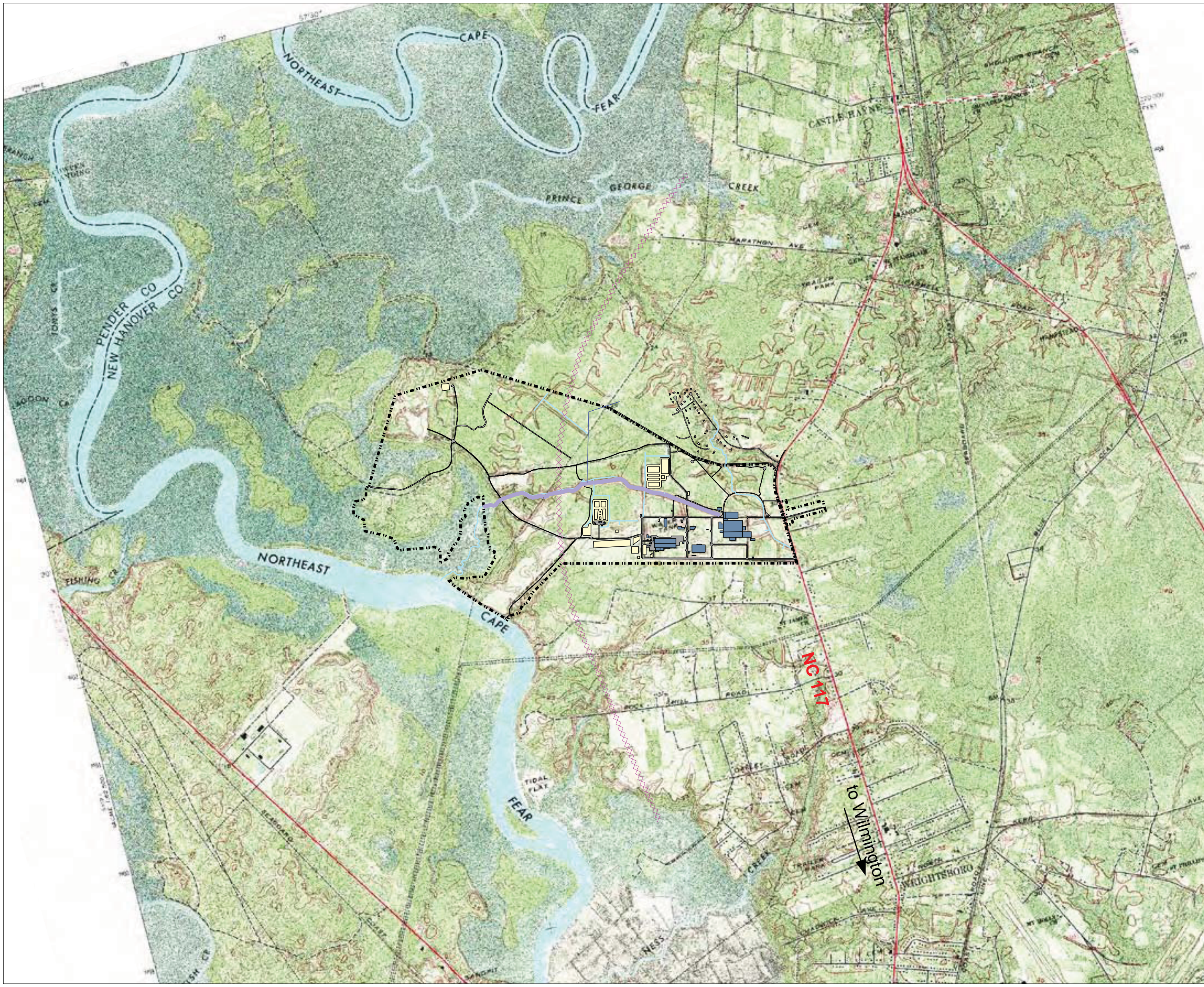
Name	Date Measured	Measured Head (ft)	Model Head (ft)	Residual (ft)
PW-4C	9/12/2000	15.75	17.19	-1.44
PW-5C	9/12/2000	23.37	23.82	-0.45
PW-6C	9/12/2000	25.2	25.84	-0.64
PW-7C	9/12/2000	26.06	25.54	0.52
PW-7D	9/12/2000	25.91	25.54	0.37
PW-8C	9/12/2000	25.44	25.62	-0.18
PW-9B	9/12/2000	11.45	10.32	1.13
WT-13B	9/12/2000	16.32	15.57	0.75
WT-14B	9/12/2000	15.81	15.02	0.79
WT-15B	9/12/2000	16.41	16.03	0.38
WT-16B	9/12/2000	14.58	14.18	0.40
WT-17B	9/12/2000	16.74	16.40	0.34
WT-20B	9/12/2000	14.46	14.13	0.33
WT-21B	9/12/2000	14.7	14.19	0.51
WT-22B	9/12/2000	16.58	14.36	2.22
WT-7B	9/12/2000	19.81	20.18	-0.37
WT-7C	9/12/2000	19.81	20.18	-0.37

Overall Statistics

Mean Error	**0.00**
Maximum Error	**3.88**
Minimum Error	**-5.24**
Mean Absolute Error	**0.77**
Sum of Squares	**311.39**
RMS	**1.08**
RMS/Range	**0.03**

Figures

Figure P-1
Location of GE/GNF Plant Site and Hydrogeologic Features and Boundaries
Wilmington Site



EXPLANATION

- Approximate western extent of the semi-confining layer and the more permeable, upper sandy portion of the Peedee Formation, after Bain (1970)
- Low-lying swampy area
- GE/GNF effluent channel
- Surface water
- GE/GNF Property Boundary

Plant North

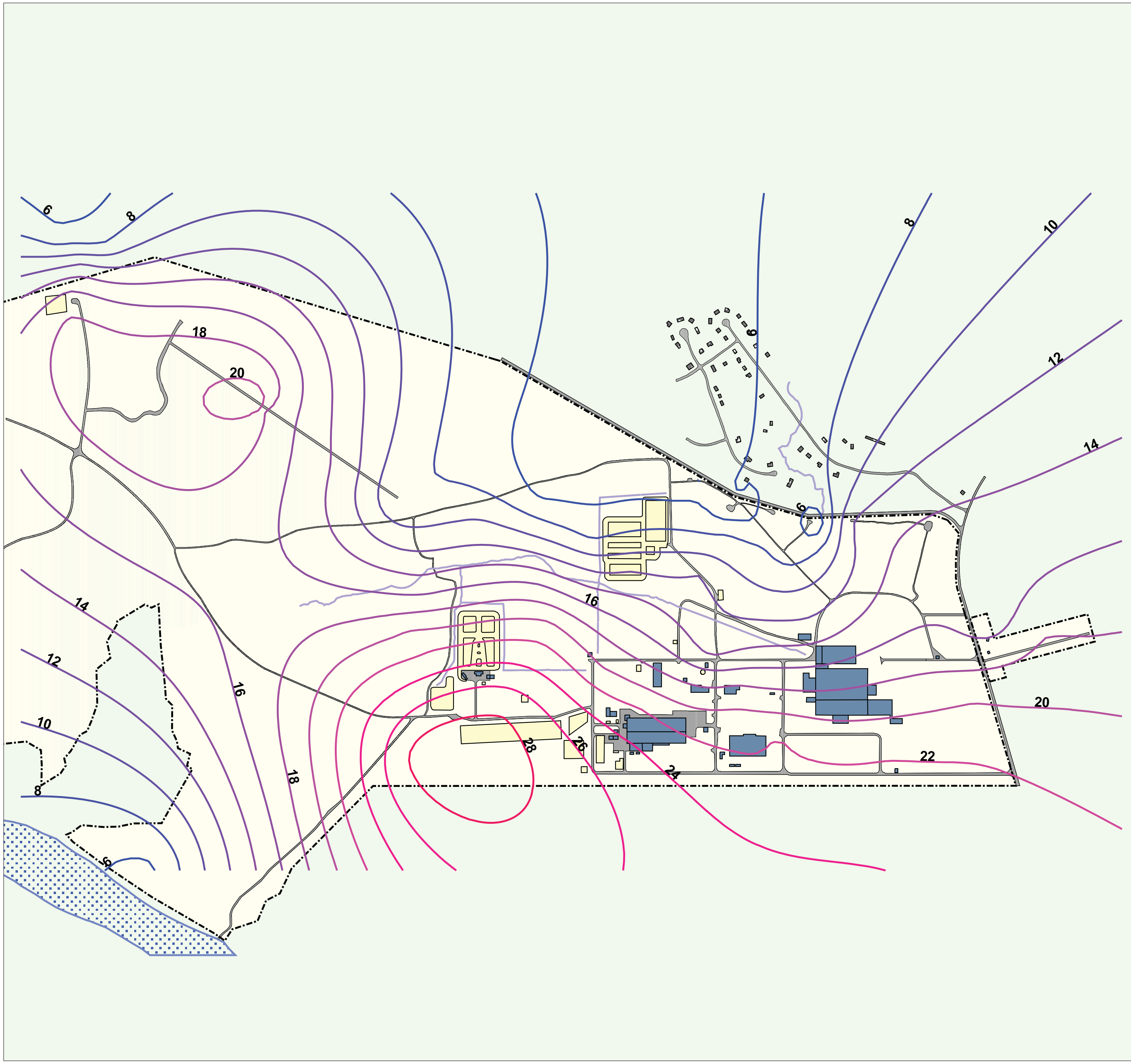
0 3000 Feet

Date: 1/22/02

Map No.: 7810003013a

Figure P-2
Principal Aquifer Groundwater Levels (Nov 1998)

Wilmington Site



Explanation

Groundwater elevation (ft MSL) (variable color)

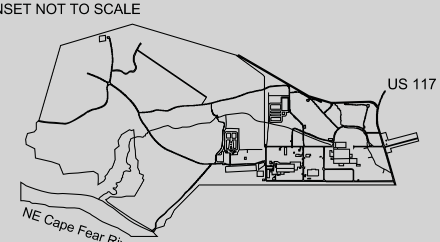
Road
Onsite building
Onsite facility
GE Property
Surface water

Note: Contours were derived through an automatic interpolation procedure (kriging) based on measured elevations.

Plant North

0 1800 Feet

INSET NOT TO SCALE



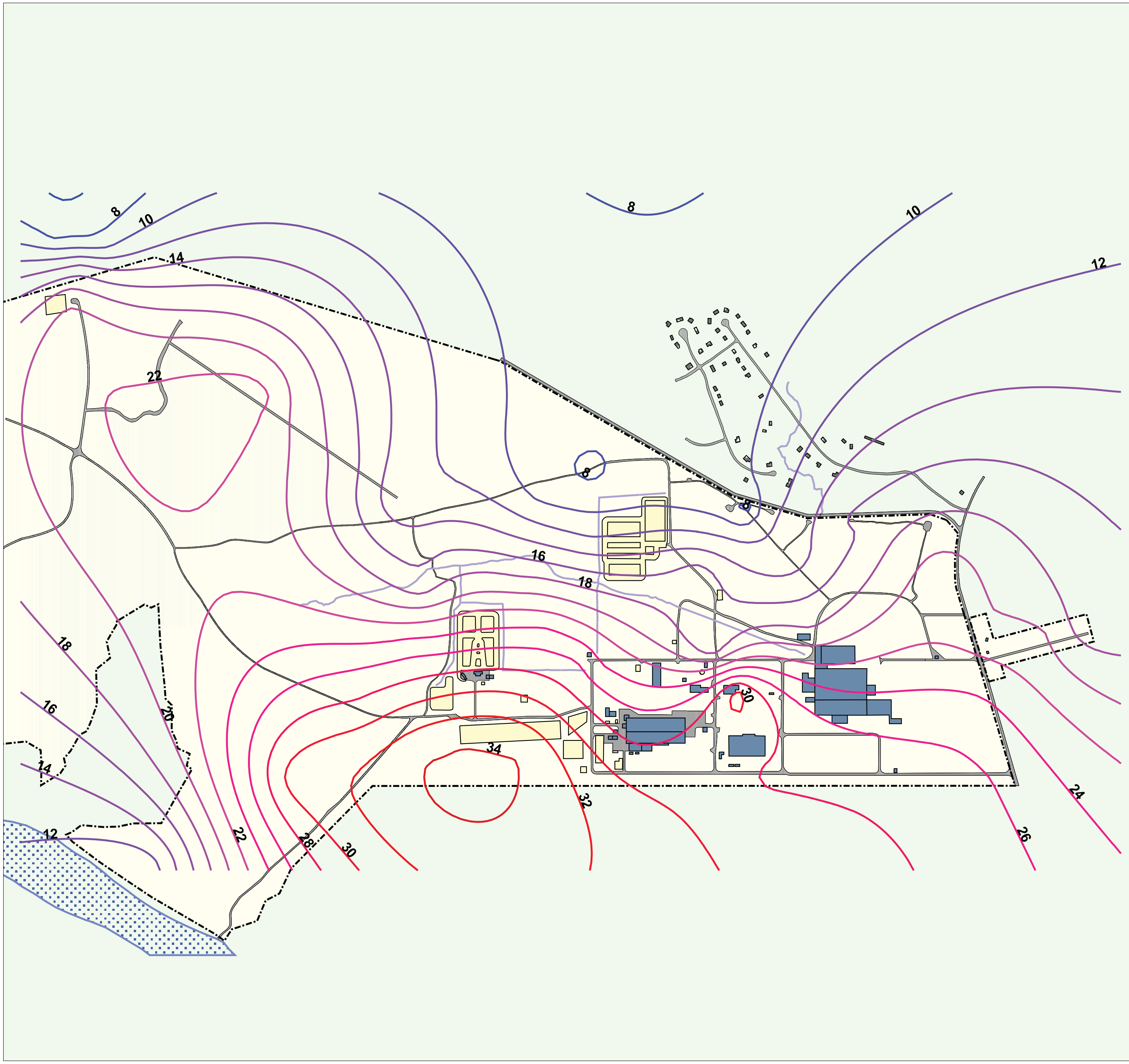
GE - Wilmington, NC Site

Date: 9/9/02

Map No.: 7810003013e

Figure P-3
Principal Aquifer Groundwater Levels (Oct 1999)

Wilmington Site



Explanation

- Groundwater elevation (ft MSL) (variable color)
- Road
- Onsite building
- Onsite facility
- GE Property
- Surface water

Note: Contours were derived through an automatic interpolation procedure (kriging) based on measured elevations.

Plant North

0 1800 Feet

Date: 9/10/02

Map No.: 7810003013d

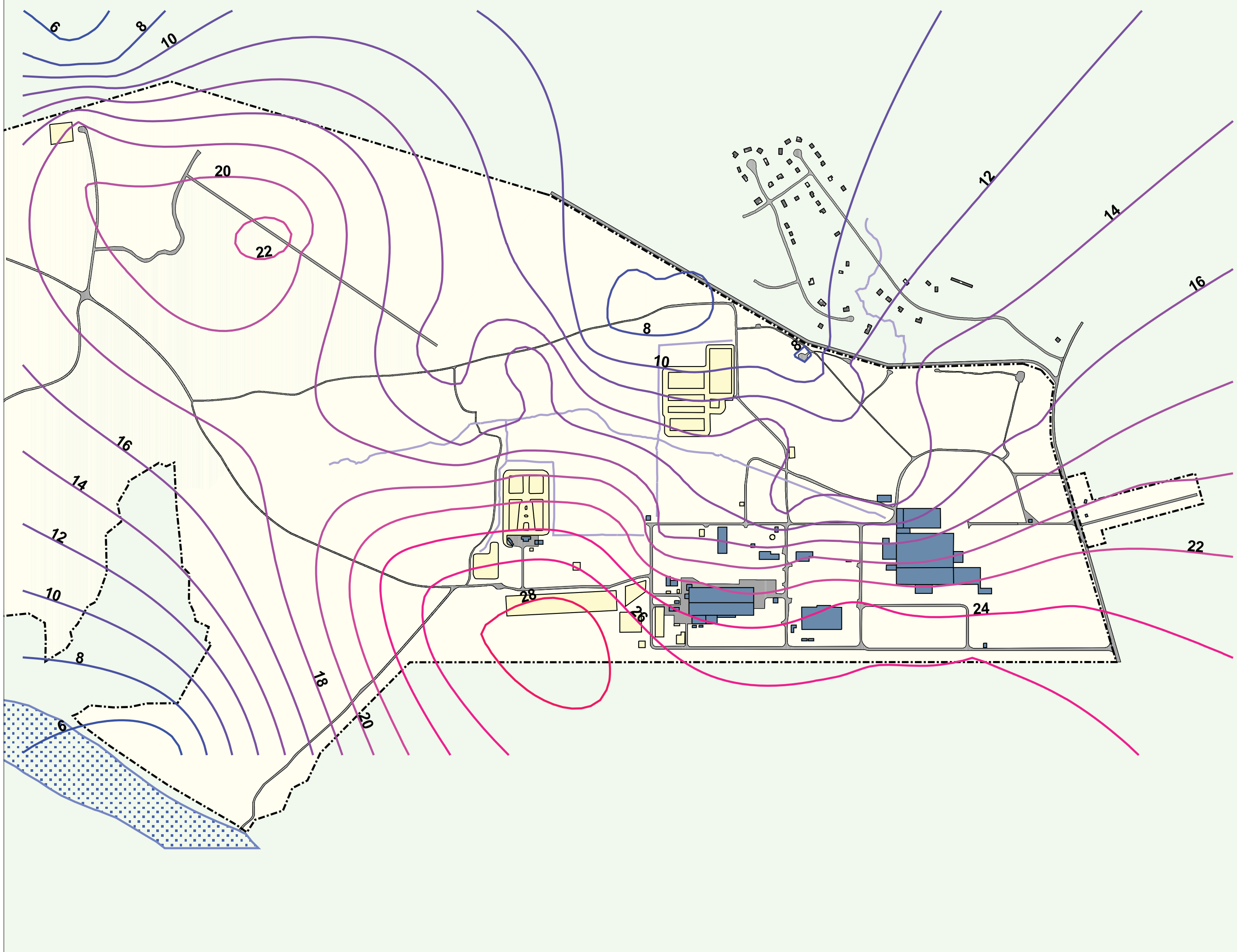


Figure P-4
Principal Aquifer Groundwater Levels (Sep 2000)

Wilmington Site

Explanation

Groundwater elevation (ft MSL) (variable color)

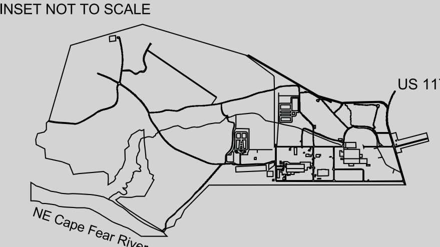
Road
Onsite building
Onsite facility
GE Property
Surface water

Note: Contours were derived through an automatic interpolation procedure (kriging) based on measured elevations.

Plant North

0 1800 Feet

INSET NOT TO SCALE

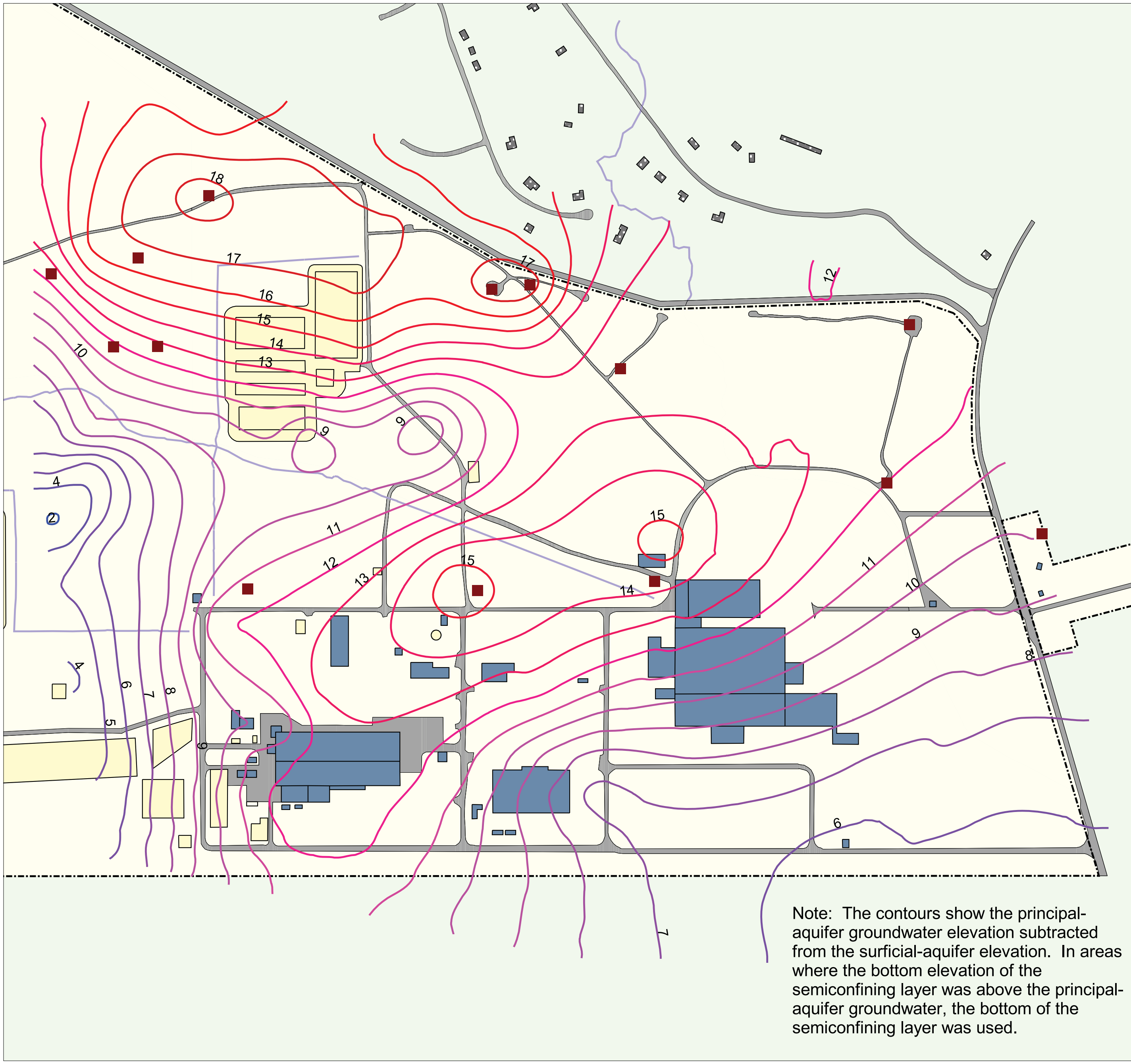


GE - Wilmington, NC Site

Date: 9/9/02 | Map No.: 7810003013c

Figure P-5
Piezometric Head Difference Between the Surficial and Principal Aquifers (9/12/00)

Wilmington Site



Note: The contours show the principal-aquifer groundwater elevation subtracted from the surficial-aquifer elevation. In areas where the bottom elevation of the semiconfining layer was above the principal-aquifer groundwater, the bottom of the semiconfining layer was used.

Explanation

Groundwater elevation difference between the surficial and the principal aquifers measured on 9/12/00 (feet msl)

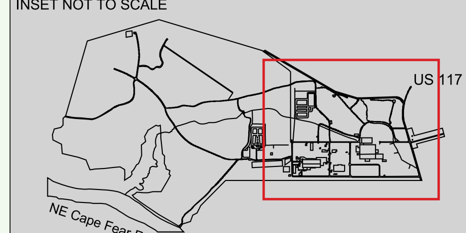
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

Pumping well

Road
Onsite building
Onsite facility
GE Property
Surface water

Plant North

0 850 Feet



GE/GNF - Wilmington, NC Site

Date: 9/9/02 | Map No.: 7810003013g

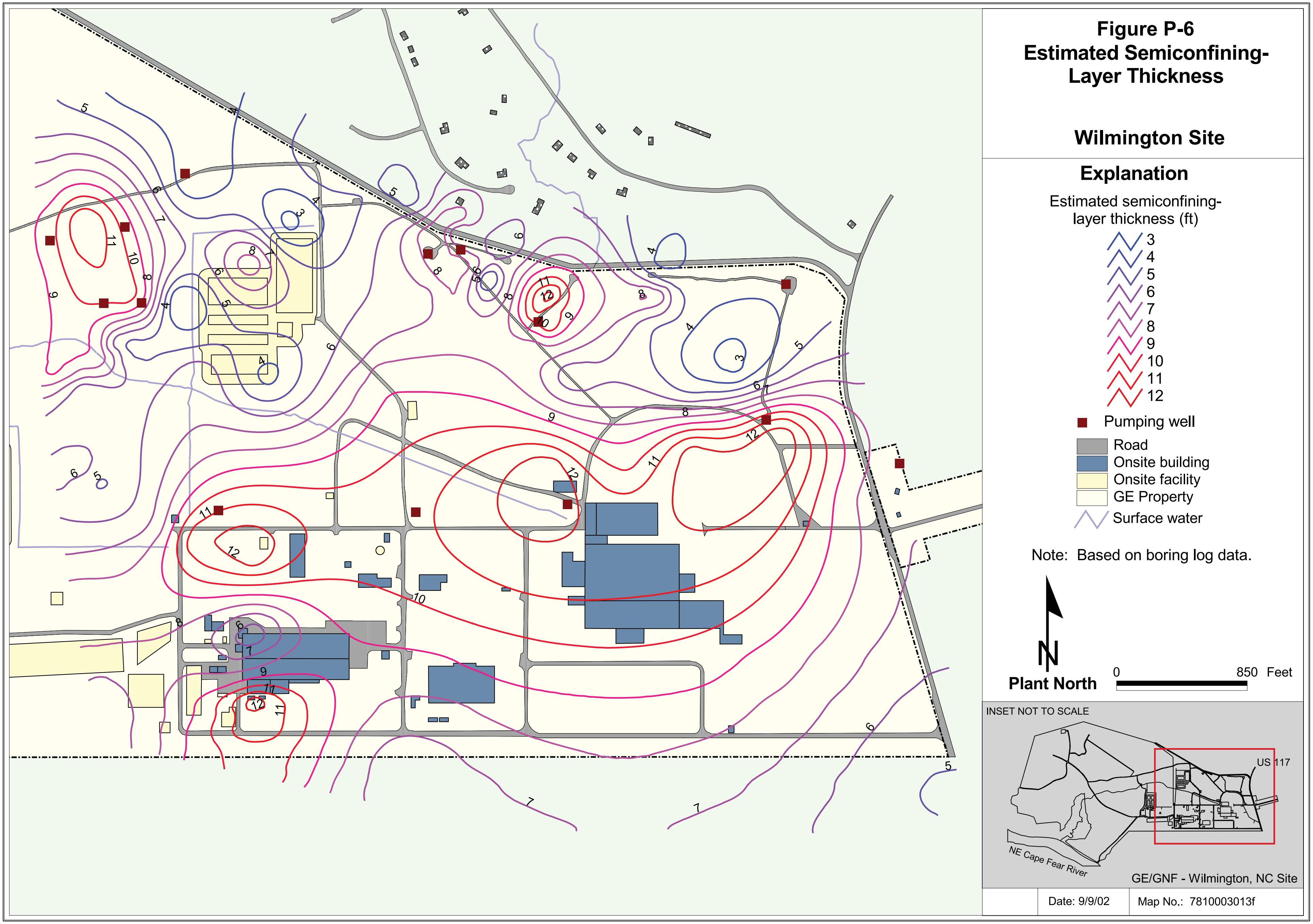


Figure P-6
Estimated Semiconfining-Layer Thickness
Wilmington Site
Explanation
Estimated semiconfining-layer thickness (ft)
3
4
5
6
7
8
9
10
11
12
Pumping well
Road
Onsite building
Onsite facility
GE Property
Surface water
Note: Based on boring log data.
Plant North
0
850 Feet
INSET NOT TO SCALE
US 117
NE Cape Fear River
GE/GNF - Wilmington, NC Site
Date: 9/9/02
Map No.: 7810003013f

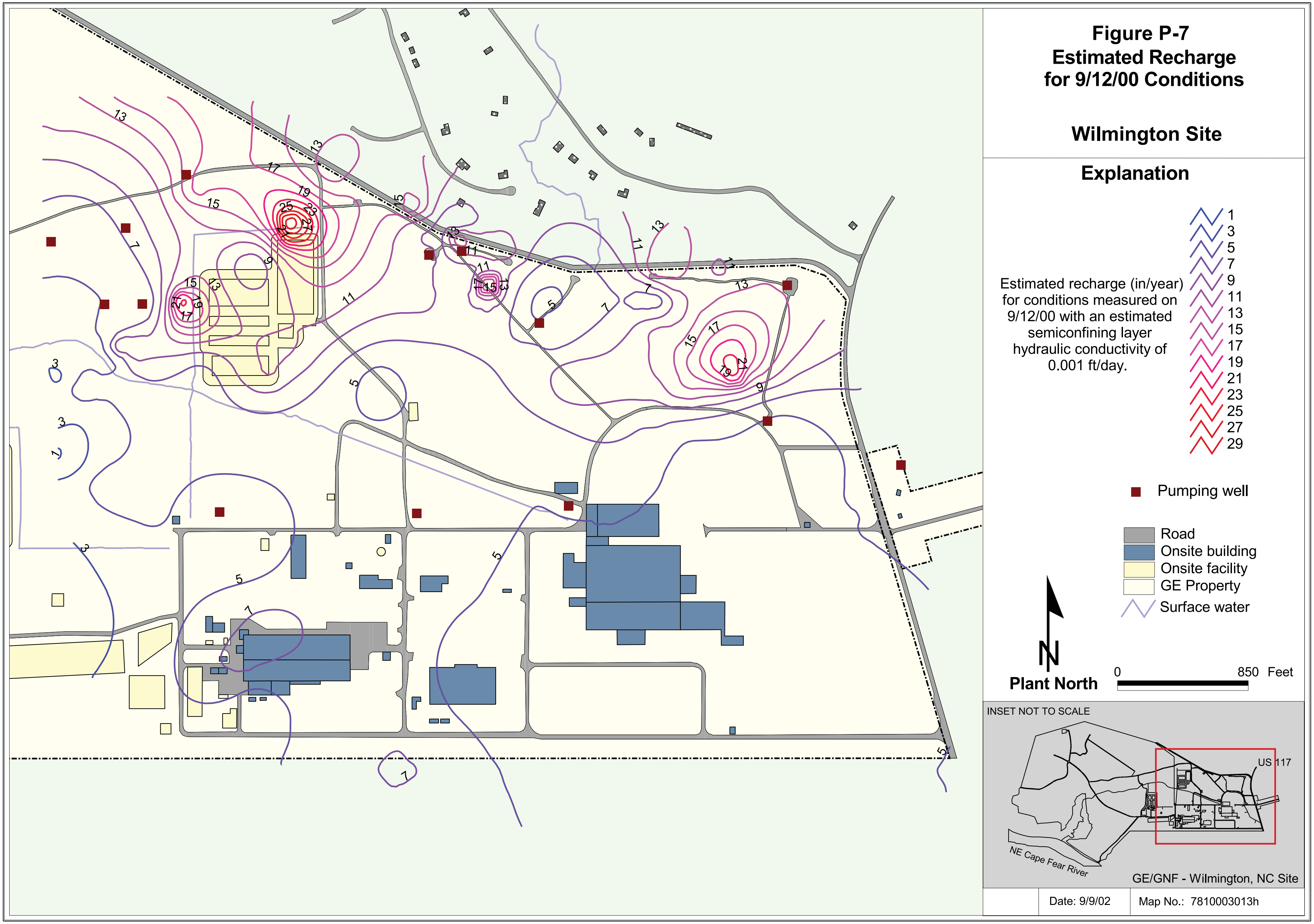
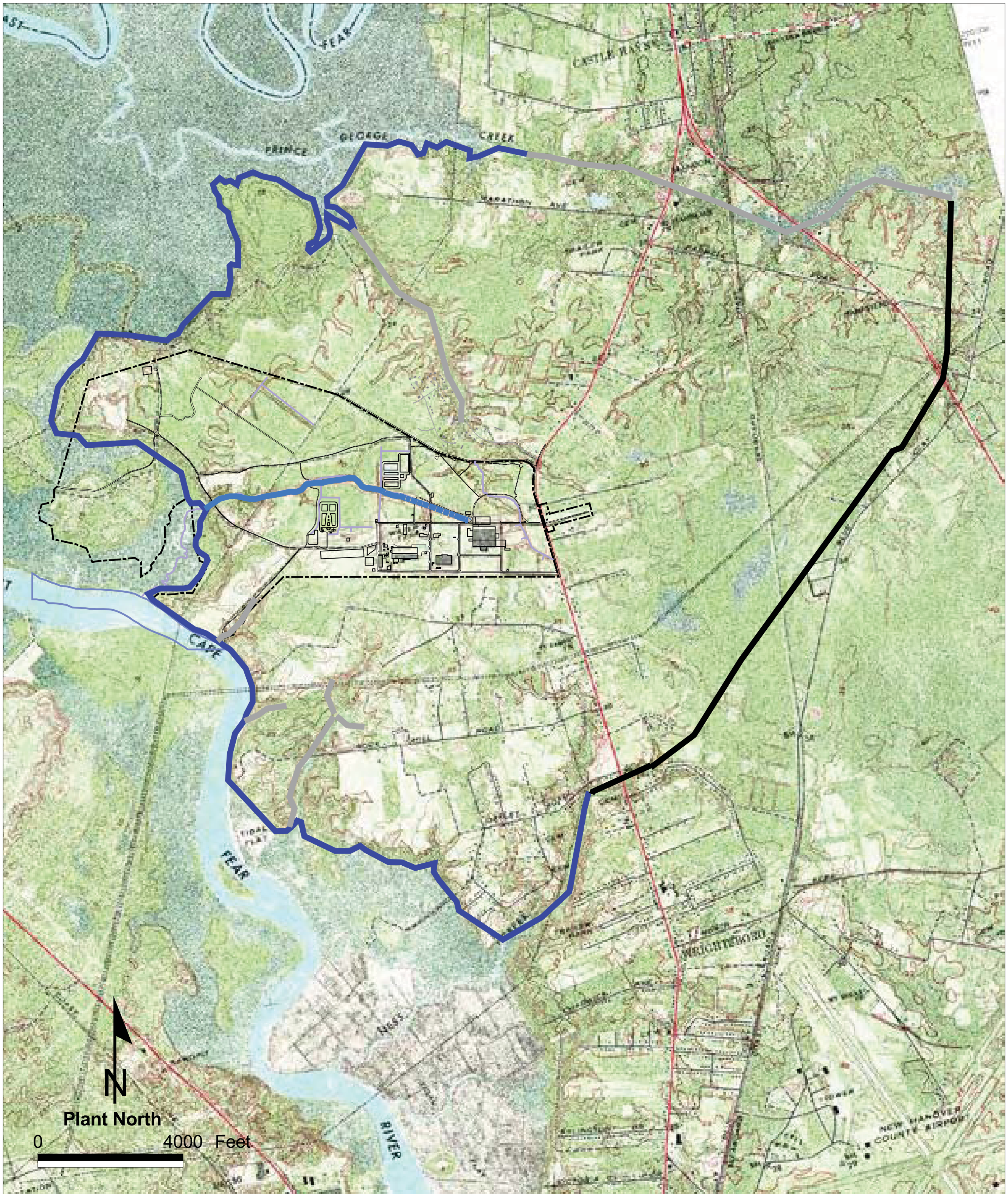
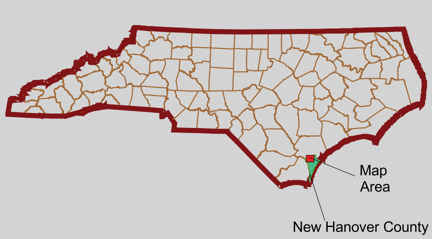


Figure P-7
Estimated Recharge
for 9/12/00 Conditions
Wilmington Site
Explanation
Estimated recharge (in/year) for conditions measured on 9/12/00 with an estimated semiconfining layer hydraulic conductivity of 0.001 ft/day.
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
Pumping well
Road
Onsite building
Onsite facility
GE Property
Surface water
Plant North
0
850 Feet
INSET NOT TO SCALE
US 117
NE Cape Fear River
GE/GNF - Wilmington, NC Site
Date: 9/9/02
Map No.: 7810003013h



State of North Carolina

INSET NOT TO SCALE



Date: 1/26/02 | Map No.: 7810003006b

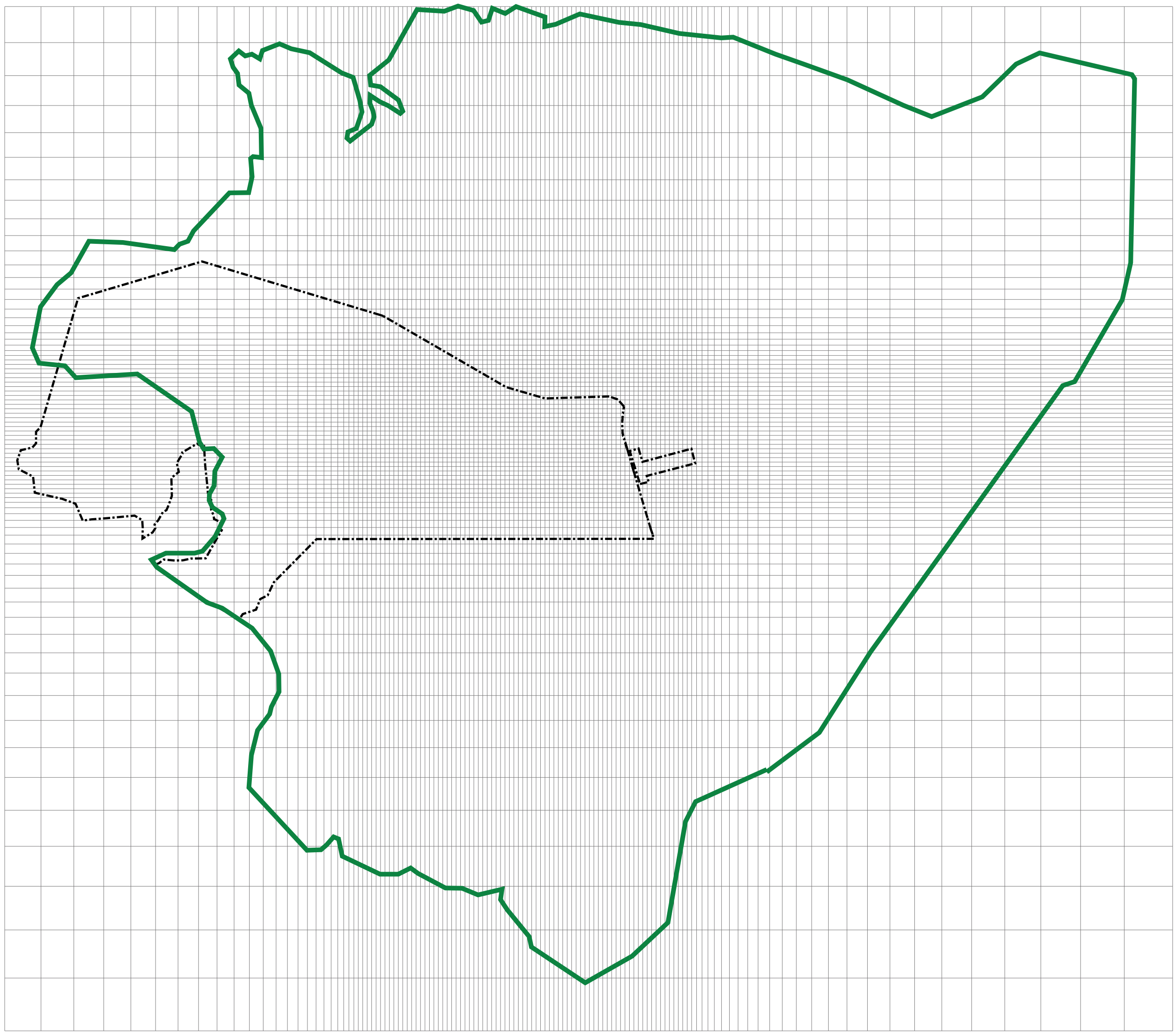
Explanation

- River boundary
- No flow boundary
- Drain boundary
- Constant head boundary
- GE/GNF property boundary
- Low-lying swampy area

Figure P-8

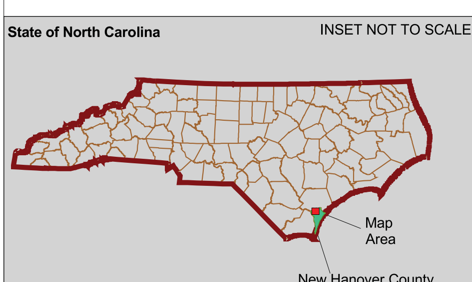
Model Domain and Boundaries

Wilmington Site



Plant North

0 4000 Feet



Date: 1/23/02

Map No.: 7810003006I

Explanation

Finite-difference grid

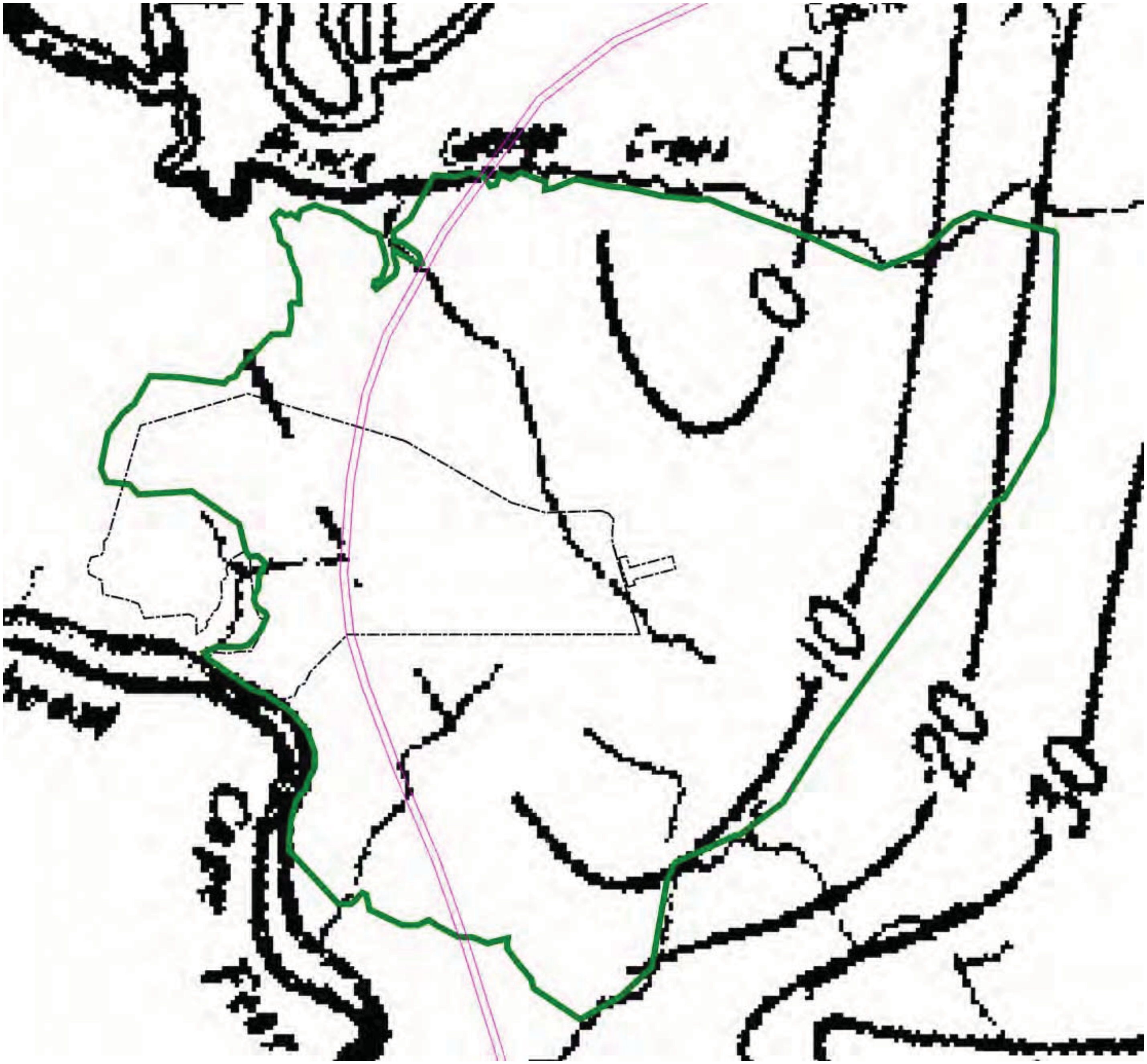
Model domain

GE/GNF property boundary

Figure P-9

Model Finite-Difference Grid

Wilmington Site



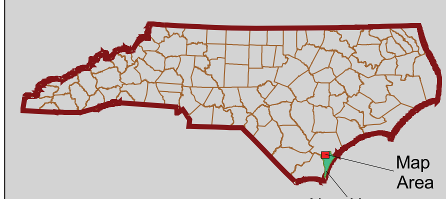


Figure P-10
Top of Aquifer as Shown by Bain (1970)

Wilmington Site

Explanation

Contours shown are the upper surface of the sandstone aquifer as presented by Bain (1970). The units are feet.

Approximate western extent of the semi-confining unit.

Model extent

GE/GNF property boundary

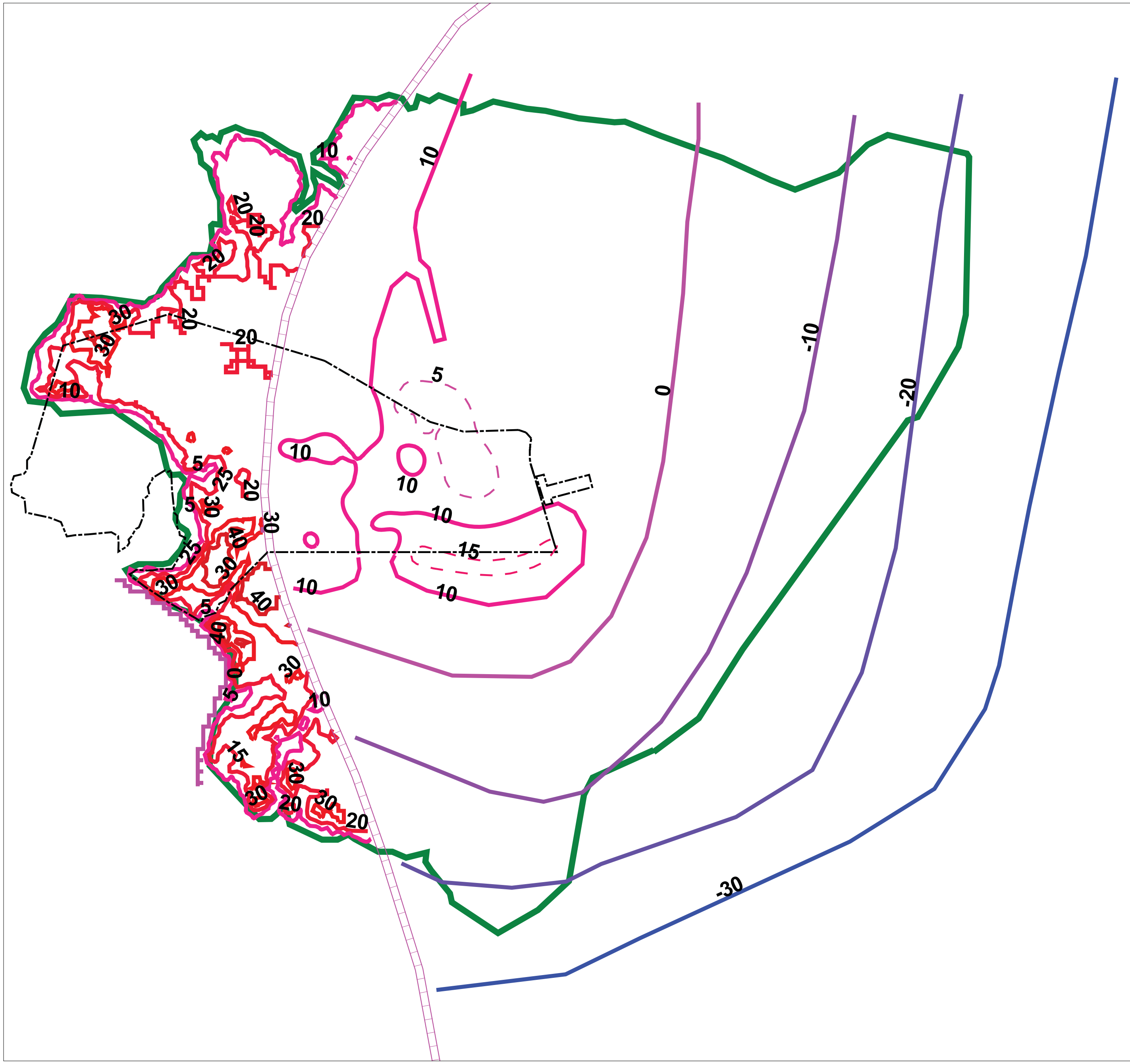
N
Plant North

0 4000 Feet

Date: 8/28/01 | Map No.: 7810003006c

Figure P-11
Top of Model Aquifer

Wilmington Site



Explanation

Contours shown are the upper surface of the simulated aquifer.
The units are feet msl.

Approximate western extent of the semi-confining layer.

Model extent

GE/GNF property boundary

Plant North

0 4000 Feet

State of North Carolina

Map Area

New Hanover County

INSET NOT TO SCALE

Date: 8/28/01 | Map No.: 7810003006d

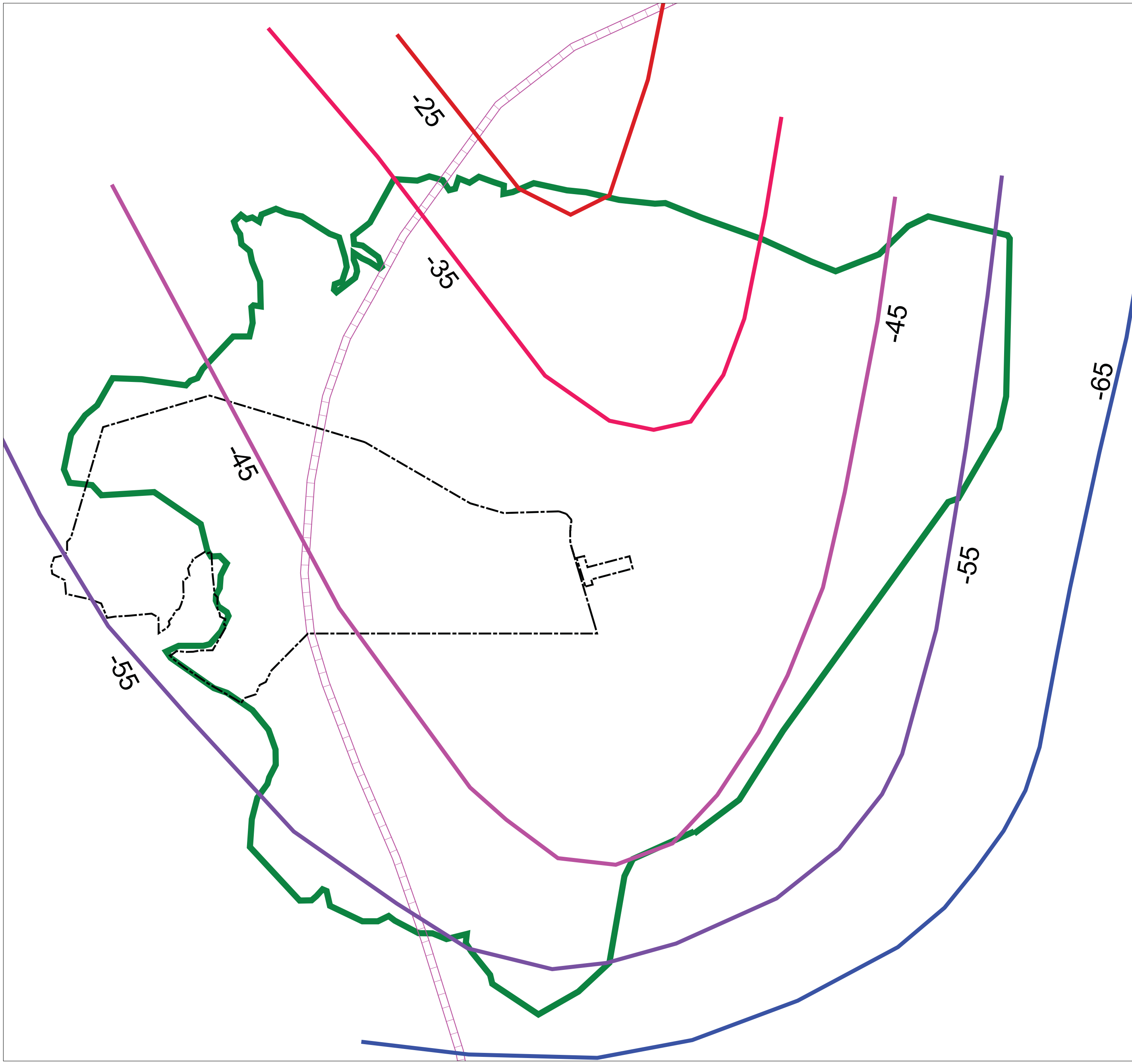


Figure P-12
Bottom of Model Aquifer

Wilmington Site

Explanation

Contours shown are the lower surface of the simulated aquifer. The units are feet.

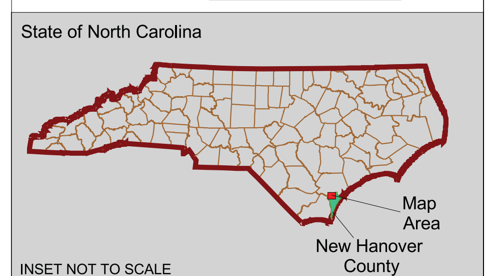
Approximate western extent of the semi-confining layer.

Model extent

GE/GNF property boundary

Plant North

0 4000 Feet

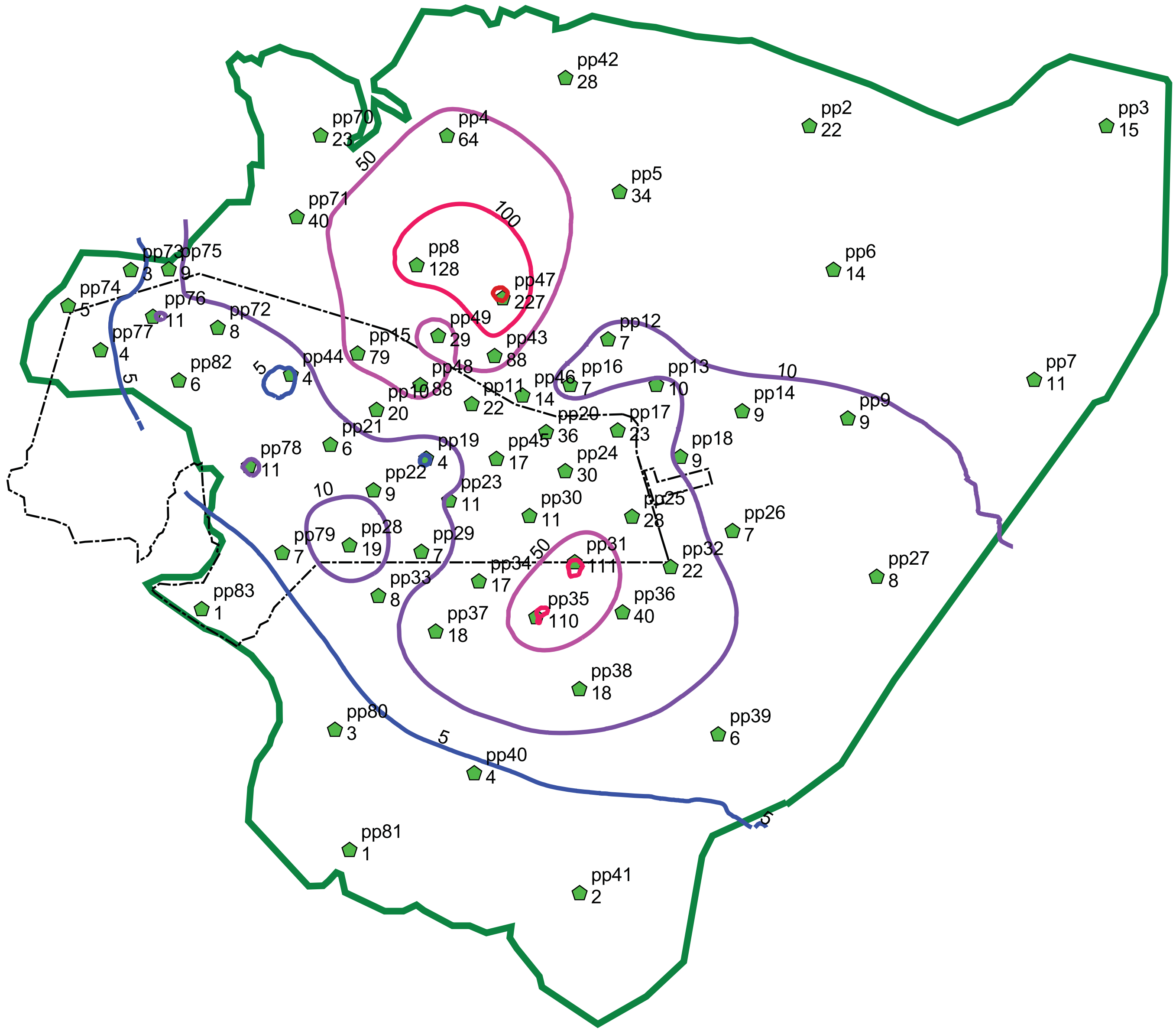


Date: 8/28/01

Map No.: 7810003006e

Figure P-13
Model Hydraulic Conductivity Distribution and Pilot Points

Wilmington Site



Explanation

Hydraulic conductiivity contours (ft/day)

- 5
- 10
- 50
- 100
- 200

Pilot point used to estimate the hydraulic conductivity field (labels beside pilot points are the id and estimated conductivity ([ft/day])

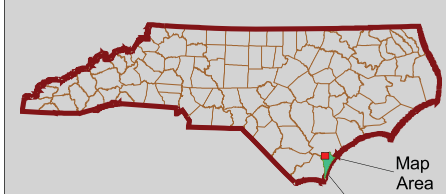
GE/GNF property boundary

Model extent

Note: Conductivity values next to the pilot points are computer generated. The only hydraulic conductivity measurements available were made within the site property (see Figure B-8).

Plant North

0 3600 Feet



Date: 9/9/02 | Map No.: 7810003006f

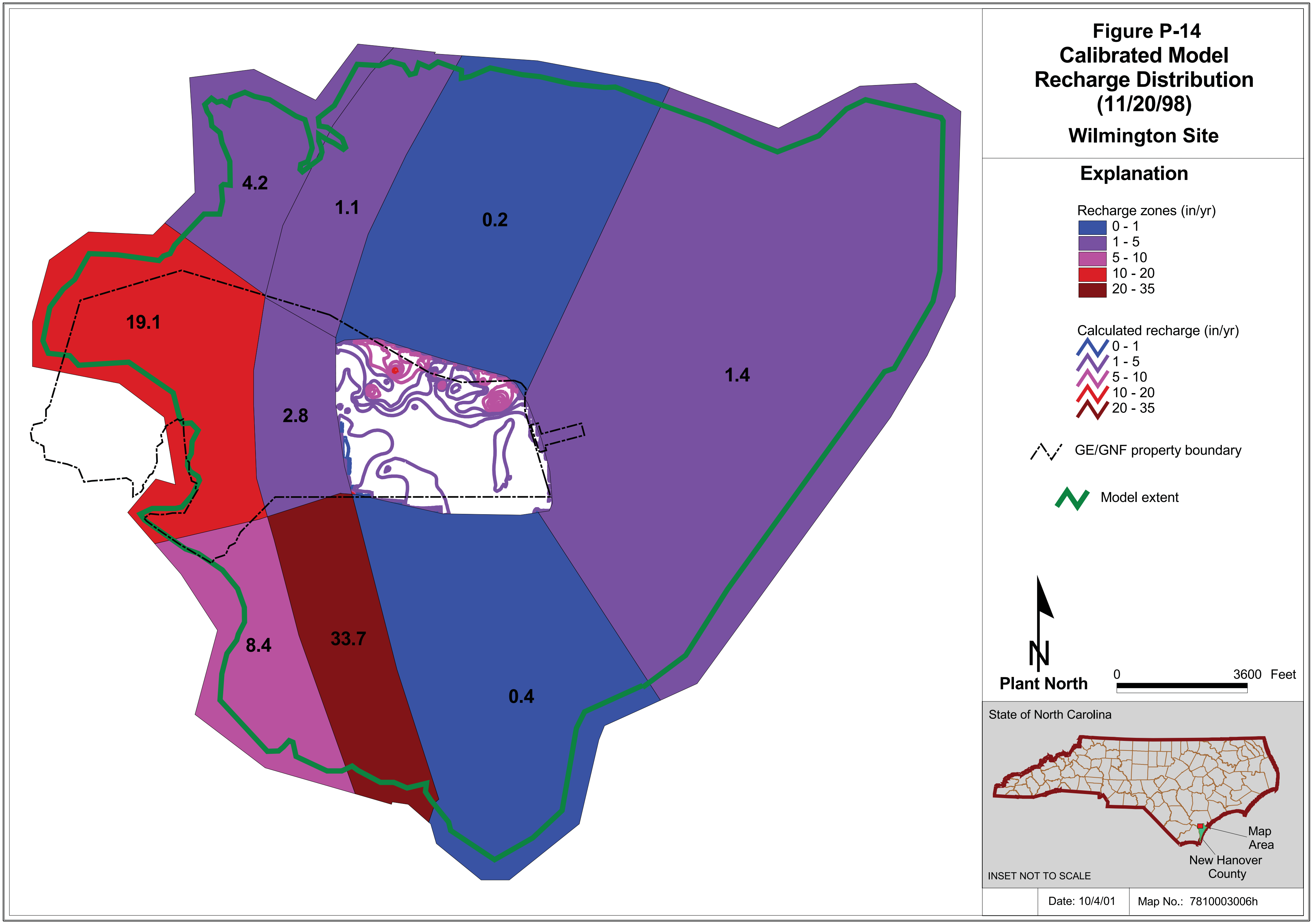


Figure P-14
Calibrated Model
Recharge Distribution
(11/20/98)
Wilmington Site
Explanation
Recharge zones (in/yr)
0 - 1
1 - 5
5 - 10
10 - 20
20 - 35
Calculated recharge (in/yr)
0 - 1
1 - 5
5 - 10
10 - 20
20 - 35
GE/GNF property boundary
Model extent
N
Plant North
0
3600 Feet
State of North Carolina
Map Area
New Hanover County
INSET NOT TO SCALE
Date: 10/4/01
Map No.: 7810003006h
4.2
1.1
0.2
1.4
19.1
2.8
8.4
33.7
0.4

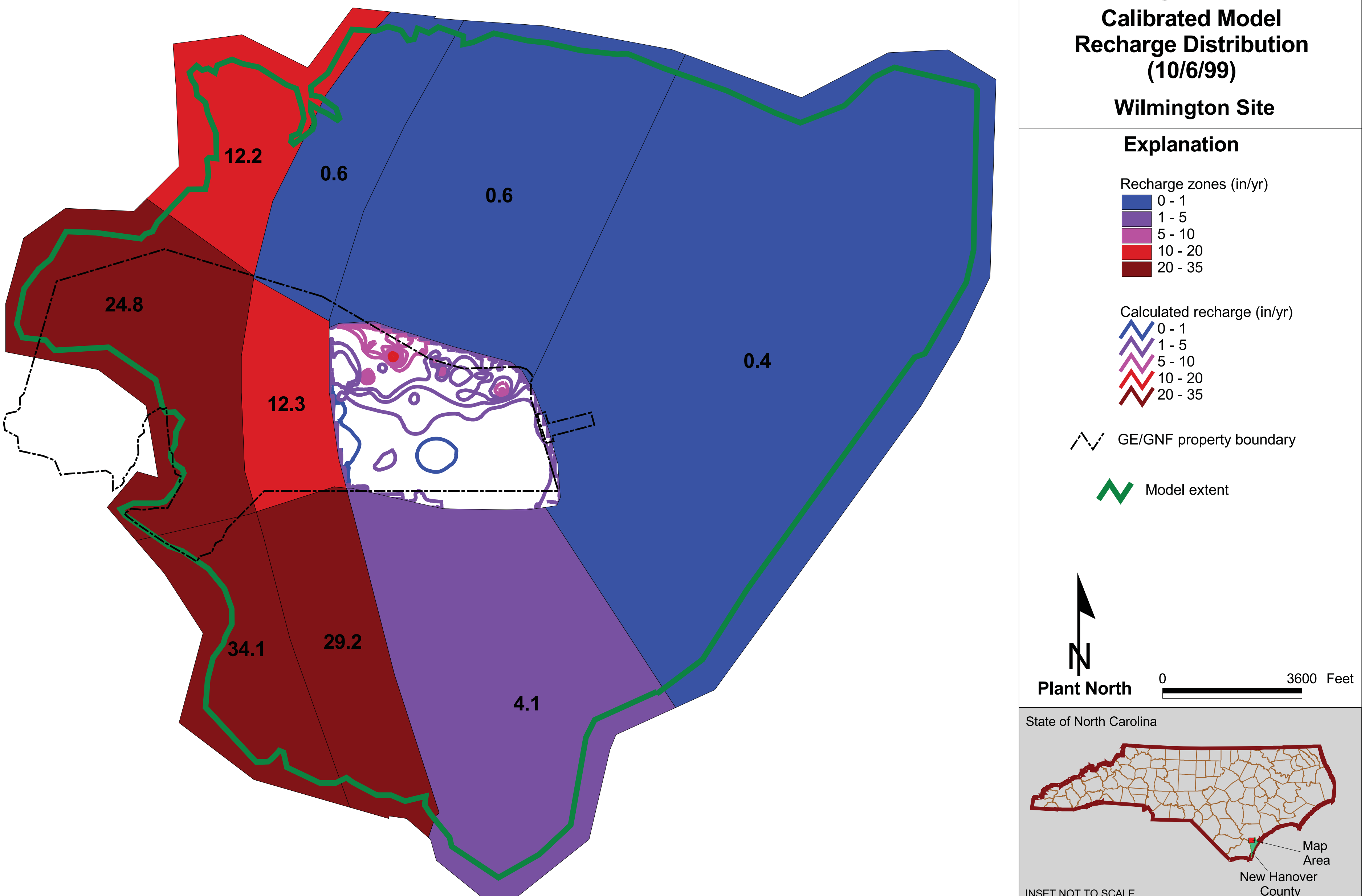


Figure P-15
Calibrated Model Recharge Distribution (10/6/99)
Wilmington Site

Date: 10/4/01

Map No.: 7810003006g

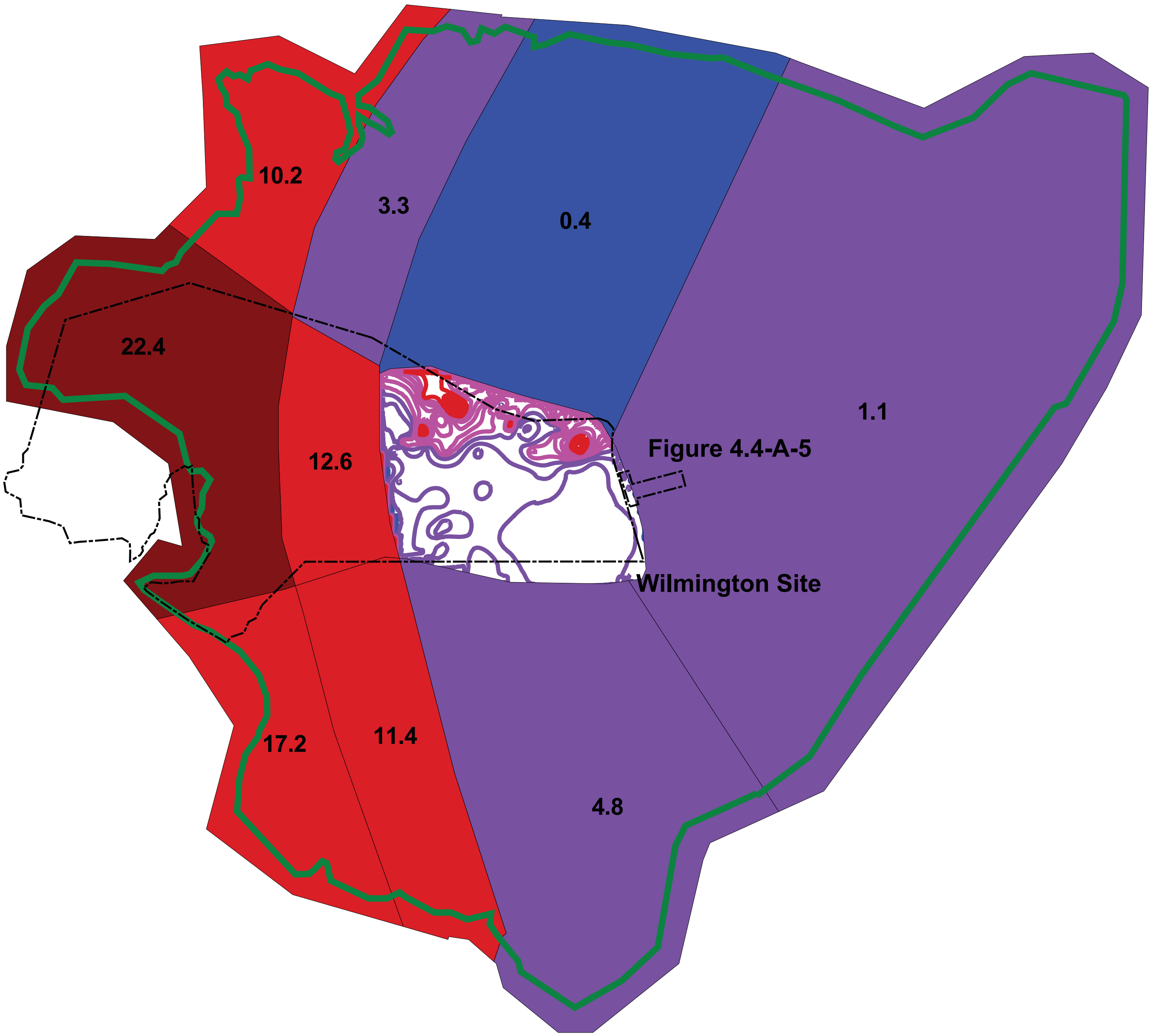


Figure P-16
Calibrated Model Recharge Distribution (9/12/00)
Wilmington Site

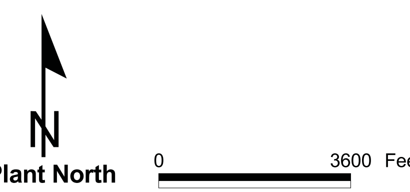
Explanation

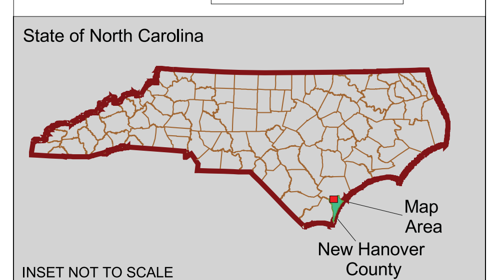
Recharge zones (in/yr)
- 0 - 1
- 1 - 5
- 5 - 10
- 10 - 20
- 20 - 35

Calculated recharge (in/yr)
- 0 - 1
- 1 - 5
- 5 - 10
- 10 - 20
- 20 - 35

GE/GNF property boundary

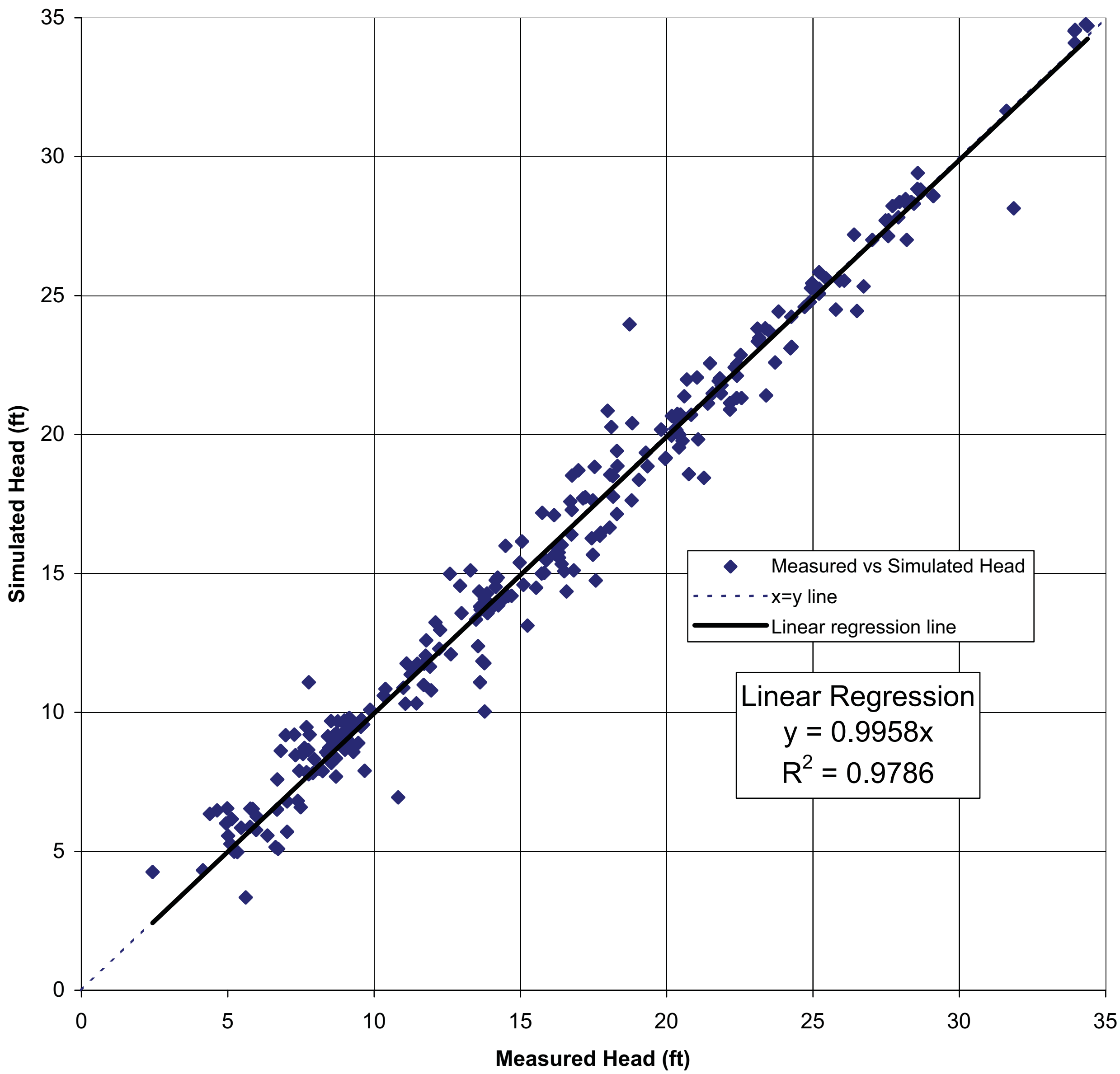
Model extent





Date: 10/4/01 | Map No.: 7810003006i

Figure P-17 Measured versus Simulated Heads



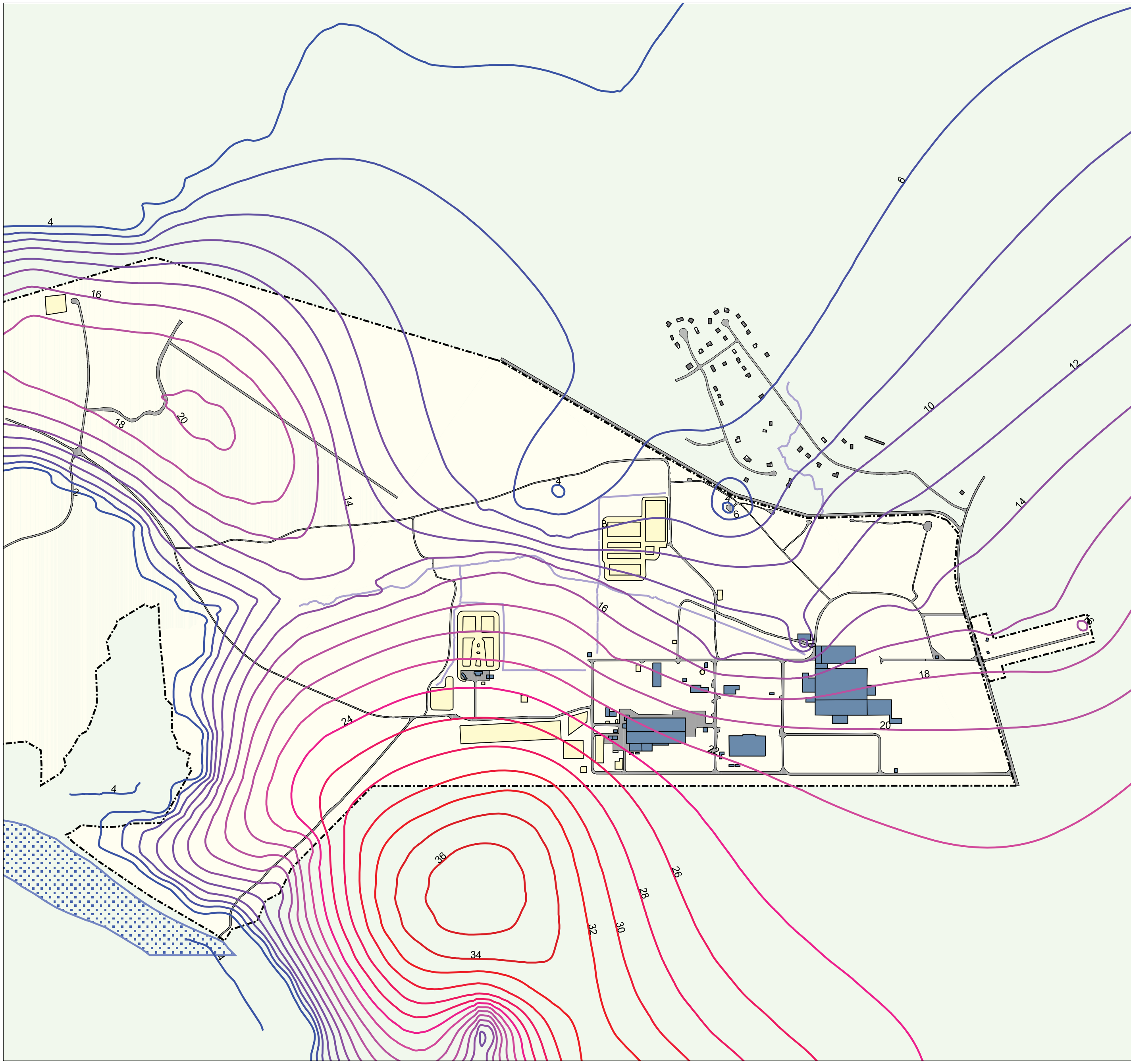


Figure P-18
Calibrated Groundwater Elevations – Site Area
Nov 1998

Wilmington Site

Explanation

Groundwater elevation contour (ft msl) (variable color)

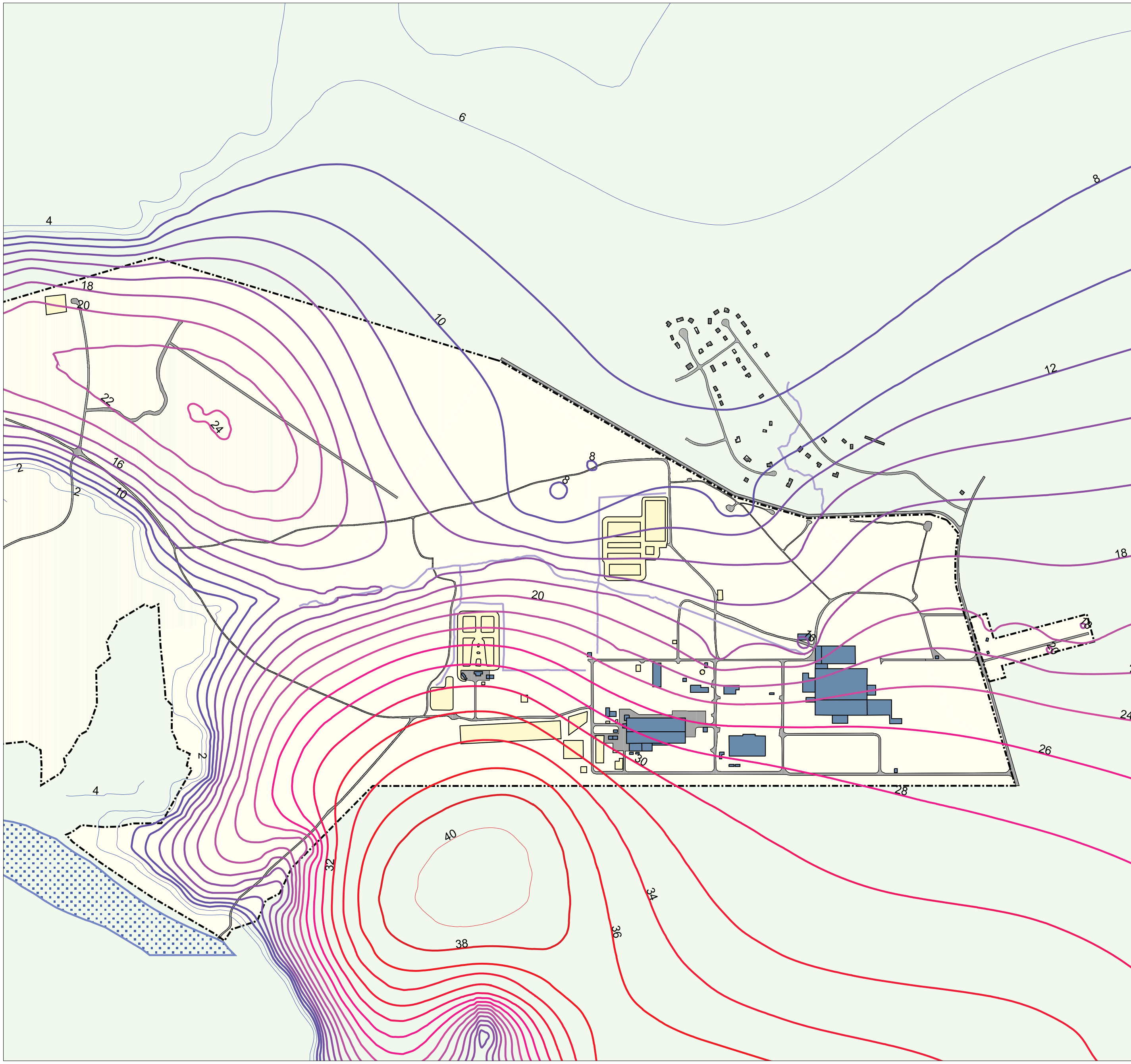
- Road
- Onsite building
- Onsite facility
- GE Property
- Surface water

GE - Wilmington, NC Site

Date: 9/4/02 | Map No.: 7810003013I

Figure P-19
Calibrated Groundwater Elevations – Site Area
Oct 1999

Wilmington Site



Explanation

Groundwater elevation contour (ft msl) (variable color)

Road
Onsite building
Onsite facility
GE Property
Surface water

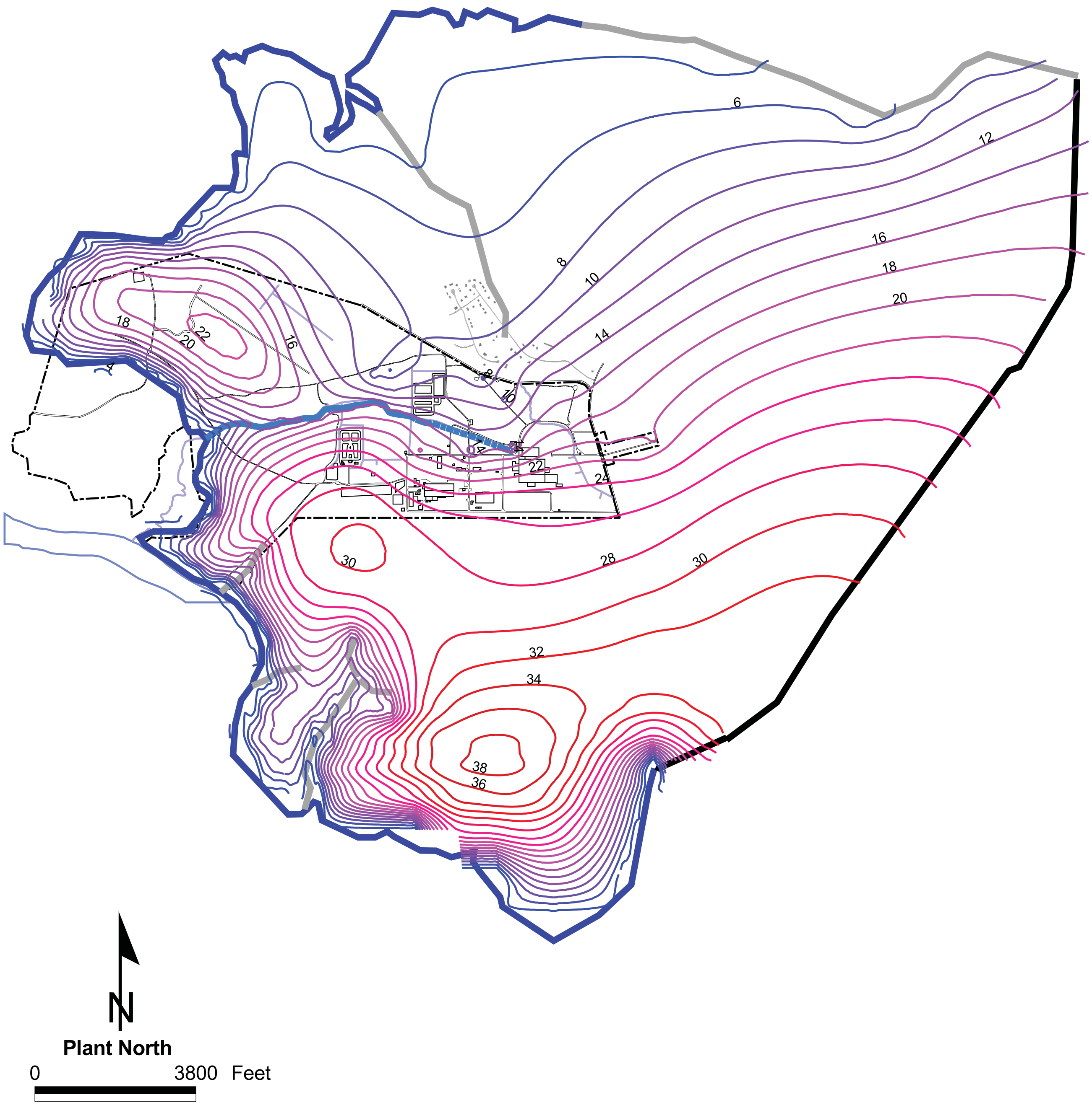
Plant North

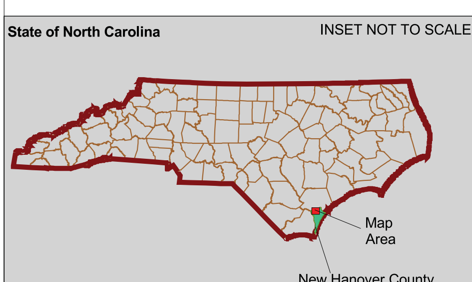
0 1800 Feet

INSET NOT TO SCALE

GE - Wilmington, NC Site

Date: 10/4/01 | Map No.: 7810003013m





Date: 10/4/01

Map No.: 7810003013k

Explanation

Groundwater elevation contour (ft msl) (variable color)

River boundary

No flow boundary

Drain boundary

Constant head boundary

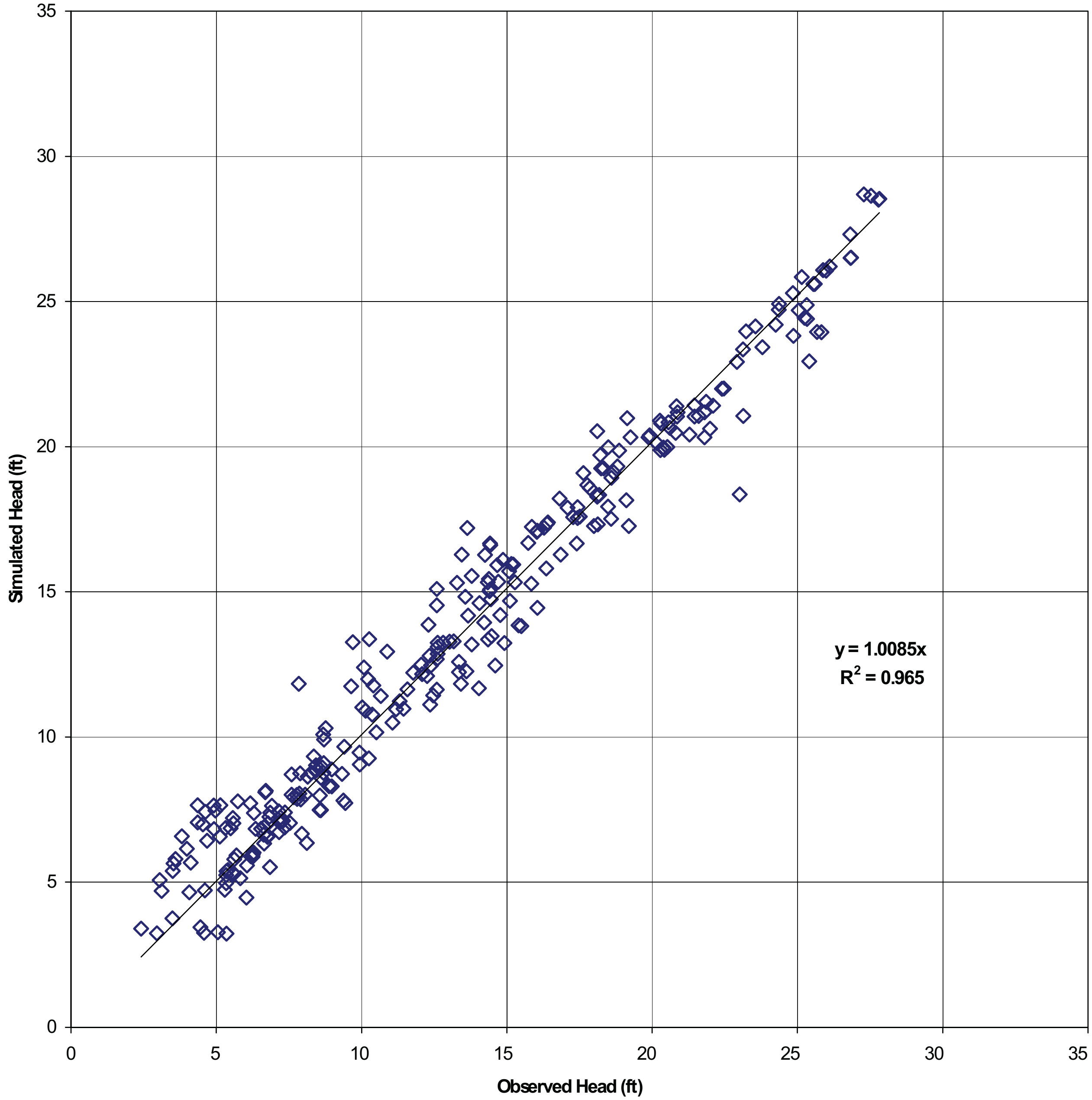
GE/GNF property boundary

Figure P-20

Calibrated Groundwater Elevations – Full Domain Sep 2000

Wilmington Site

Figure P-21 Model 2004 Update – Calibration Curve



Appendix Q

Air Emissions from Proposed GLE Facility: Construction Sources

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Appendix Q

Air Emissions from Proposed GLE Facility: Construction Sources

Q.1 Fugitive Dust

Construction of facilities the scale of the Proposed GLE Facility commonly produces fugitive dust emissions that potentially could have a temporary impact on air quality in the vicinity of the construction project. The fugitive dust emissions from the Proposed GLE Facility construction site were estimated. The estimates were derived following standard practices for applying fugitive dust emission factors developed for regulatory agencies to estimate PM emissions from construction activities when the area and duration for a construction project are known (WRAP, 2004). The key assumptions used for the estimates are summarized in **Table Q-1**, and the estimated fugitive dust emissions are presented in **Table Q-2**. Actual fugitive dust emissions levels from construction of the Proposed GLE Facility are expected to be lower than the values that were estimated using the general emissions factors. Fugitive dust emissions at the GLE construction site (i.e., GLE Facility site) are expected to be naturally mitigated by the high annual precipitation for the area in which the Proposed GLE Facility would be located (see **Section 3.6.2.2** of this Report, *Precipitation [Climate]*). In addition, regular use of water spray trucks and other fugitive dust-suppression practices that are planned to be used during construction (see **Section 5.6** of this Report, *Air Quality [Mitigation Measures]*) would further mitigate fugitive dust emissions at the GLE construction site.

Q.2 Off-Road Construction Equipment

The air emissions resulting from operation of the off-road construction equipment at the GLE construction site were estimated. The key assumptions used for the estimates are summarized in **Table Q-1**. Equipment-specific emissions factors were developed for the assumed equipment mixes using the U.S. Environmental Protection Agency's (EPA's) NONROAD emission factor model (U.S. EPA, 2004a). The estimated air emissions are presented in **Table Q-2**.

Q.3 Motor Vehicles

The motor vehicle traffic impacts projected to occur during the construction of the Proposed GLE Facility are discussed in **Section 4.2.2.1** of this Report (*Site Preparation and Construction [Proposed Action]*). Based on the motor vehicle trip estimates for the Proposed GLE Facility construction phase presented in **Section 4.2.2.1**, the air emissions resulting from these motor vehicle trips were estimated. The key assumptions used for the estimates are summarized in **Table Q-1**. Applicable emissions factors selected from existing factors developed using EPA's MOBILE vehicle emission factor model were used to predict the motor vehicle emissions associated with the Proposed GLE Facility construction phase. The estimated air emissions are presented in **Table Q-2**. Because motor vehicles are mobile sources, the emission estimates do not represent the emissions to the atmosphere from any one location (e.g., the GLE construction site or any other given point). Instead, the estimated emissions represent the incremental increase in air emissions to the atmosphere from all automobiles and trucks traveling along the same roadway routes that would be used by the automobiles and trucks traveling to and from the GLE construction site.

Table Q-1. Key Assumptions Used for Proposed GLE Facility Construction Air Emissions Estimates

Air Emission Source	Assumption Parameter	Assumption Value
General assumptions	Construction period	3 years
	Total number of construction days per year	260 days/year
	Hours per construction day	10 hours/day
	Total number of construction workers	300 to 500 workers during initial 3 years of construction, with total daily number varying depending on the construction activities
	Operating day schedule	Project site access road construction: Month 1 Project site preparation: Month 2 through Month 6 Buildings and general construction: Month 7 through Month 36
	Average number of on-site workers per construction day	375 workers[a]
Fugitive dust sources	Emission factors	Access road construction and project site preparation: 0.42 ton/acre/month Buildings and general construction activities: 0.11 ton/acre/month
Off-road construction equipment	Off-road equipment mix for site preparation and road construction	4 Dozers 4 Loaders 2 Graders 2 Compactors/rollers 1 Excavator 1 Water truck 1 Paver (on-site part time)
	Off-road equipment on-site during buildings and general construction	1 Crane 4 Tractors/loaders 4 Forklifts 4 Aerial lifts 2 Air compressors
	Emission factors	Equipment-specific factors for equipment mix using EPA's NONROAD emission factor model
Motor vehicles (automobiles, SUV, pickup trucks)	Average number of construction worker vehicle trips per work day	375 trips
	Average number of visitor vehicle trips per work day	20 trips
	Average vehicle miles traveled per trip	10 miles
	Emission factors	NC DAQ factors developed using EPA's MOBILE6 vehicle emission factor model

(continued)

Table Q-1. Key Assumptions Used for Proposed GLE Facility Construction Air Emissions Estimates (continued)

Air Emission Source	Assumption Parameter	Assumption Value
Motor vehicles (heavy-duty, diesel haul trucks and tractor trailers)	Average number of truck shipments to or from Proposed GLE Facility per day	30 Local trucks, including dump trucks, concrete trucks, waste hauling trucks, and other trucks from local construction material suppliers. 5 Long-haul trucks from equipment and material suppliers[c]
	Average vehicle miles traveled per trip per day	Local trucks = 20 miles[b] Long-haul trucks = 520 miles[c]
	Emission factors	NC DAQ factors developed using EPA's MOBILE6 vehicle emission factor model

[a] Basis for assumption is average of construction worker employment estimates for the initial 3 years of construction.

[b] Basis for assumption is each local trip consists of two 10-mile segments.

[c] Long- haul trucks are considered to be tractor–trailer trucks that travel to and from facilities outside of the Wilmington area, such as the facilities listed in **Table 4.2-2** and other facilities nationwide, depending on the type of material shipped.

Table Q-2. Estimated Air Emissions for Proposed GLE Facility – Construction Sources[a]

Air Emission Source	Average Daily Construction Air Emissions Resulting from On-site Construction Activities				
	CO	NO_x	SO_2	VOC	PM
Fugitive dust					1,500 lb/day
Off-road construction equipment	188 lb/day	45 lb/day	0.2 lb/day	8 lb/day	30 lb/day
Air Emission Source	**Annual Construction Air Emissions Resulting from On-site Construction Activities**				
	CO	**NO_x**	**SO_2**	**VOC**	**PM**
Fugitive dust					194 ton/yr
Off-road construction equipment	41 ton/yr	5 ton/yr	< 0.1 ton/yr	0.8 ton/yr	4 ton/yr
Motor Vehicles	**Average Daily Off-site Motor Vehicle Air Emissions Resulting from Construction Traffic to and from Proposed GLE Facility**				
	CO	**NO_x**	**SO_2**	**VOC**	**PM**
Automobiles	66 lb/day	11 lb/day	0.1 lb/day	12 lb/day	1 lb/day
Heavy-duty diesel trucks	36 lb/day	43 lb/day	0.2 lb/day	2 lb/day	5 lb/day

[a] Estimates based on assumptions presented in **Table Q-1**.

Appendix R

Air Emissions Dispersion Modeling for Construction Phase of Proposed GLE Facility Using AERMOD Model

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Appendix R

Air Emissions Dispersion Modeling from Construction Phase of Proposed GLE Facility Using AERMOD Model

R.1 Construction Air Emissions Dispersion Modeling

Air emissions dispersion modeling was performed to predict ambient air concentrations from the on-site air emissions released during the Proposed GLE Facility construction phase. The U.S Environmental Protection Agency's (EPA's) **A**MS/**E**PA **R**egulatory **Mod**el (AERMOD) was used for the modeling. This computer model uses steady-state Gaussian plume air dispersion algorithms to estimate air pollutant concentrations and deposition values at receptor sites up to a distance of 31 miles (50 kilometers [km]) from the air emissions source (U.S. EPA, 2006a). The AERMOD was used to estimate concentrations and deposition values of particulate matter (PM) with aerodynamic diameters less than 10 μm (PM_{10}) at receptors due to construction activity. The AERMOD can be used to model both wet and dry PM_{10} depletion from a plume. Dry deposition is removal of pollutants from the air due to gravitational settling; wet deposition occurs when precipitation removes pollutants from the air and deposits them on the ground. The AERMOD area depletion algorithm was selected for the dispersion modeling because it is an optimized method for calculating dry PM removal from the plume when modeling area sources (U.S. EPA, 2006b).

The AERMOD was also used to estimate concentrations of gaseous carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and volatile organic compounds (VOCs) at the Wilmington Site fenceline due to off-road construction equipment and other motor vehicles operating at the GLE construction site (i.e., GLE Facility site) and along the proposed North access road. Plume depletion was not included in the calculations involving gaseous air emissions.

R.2 AERMOD Site-Specific Input Data

Application of AERMOD to a given emission source scenario requires the input of Site-specific surface and upper air meteorological data (e.g., wind speeds and directions). The model also requires input values for Site-specific factors related to the air emission dispersion characteristics of the landscape surrounding the emission source. These parameters are surface-roughness length, albedo, and Bowen ratio. Surface-roughness length relates to the height of obstacles on the land surface around the emission source affecting the wind flow and is expressed as the height at which the mean horizontal wind speed is zero. Albedo is the fraction of incoming solar radiation that is reflected by the land surface around the emission source. The Bowen ratio is an indicator of surface moisture in the land surface around the emission source and is expressed as the ratio of sensible heat flux to latent heat flux. The values used for these AERMOD input parameters vary by the type of landscape (e.g., urban, deciduous forest, coniferous forest, swamp, cultivated land, grassland, water) and the season of the year.

The normal variability of weather conditions in the vicinity of the Proposed GLE Facility was represented using a 5-year period of surface meteorological data from the National Climatic Data Center's Integrated Surface Hourly Data (ISHD) collected at the Wilmington International Airport station (Station 13748). This airport weather station is approximately 4.5 miles (7.2 km) from the Proposed GLE Facility location and is considered to be representative of the local meteorological conditions at the GLE construction site. Upper air meteorological data are not collected at the Wilmington International Airport station; therefore, upper air data collected at the Charleston International Airport station (Station 13880), about 150 miles (241 km) southwest of the Wilmington Site, were used for the required AERMOD inputs. This station was chosen over other stations in the region where upper air data are collected because of its general

proximity and similar site conditions to those at the Wilmington International Airport. The metrological data used for modeling were for the years 1992 through 1996 because this time period was the most recent data available for which surface and upper air data from the two weather stations coincided. **Figure R-1** shows the wind rose based on data used for dispersion modeling of air emissions from the GLE construction site. The collected surface and upper air meteorological data were integrated into the appropriate combined surface and profile meteorological input files using the AERMOD's Meteorological Preprocessor (AERMET).

The *AERMET User's Guide* specifies seasonal values for surface roughness length, albedo, and Bowen ratio by land-cover type and season (U.S. EPA, 2004c). To select the appropriate parameter values to use for modeling the GLE construction site, four distinct land sectors in a 1.86-miles (3-km) radius around the GLE construction site were identified based on a general qualitative judgment of the extent of existing land development and the amount of open water within the circle formed by the selected radius. For each sector, the land-cover types and area percentages of those types within in the sector were obtained from the 2001 National Land Cover Dataset (NLCD) (USGS, 2003). Because land-cover type affects the atmospheric dispersion properties, individual surface-roughness length, albedo, and Bowen ratio values were selected for each of the four sectors around the GLE construction site. The land-cover categories used for the NLCD do not correspond directly to EPA's land-cover category descriptions used for AERMET; therefore, professional judgment was used to cross-reference the NLCD categories with the AERMET categories. Each parameter was considered individually because land cover affects each of these parameters differently. Separate seasonal parameter values were determined for each sector. These values were calculated as the average of the applicable seasonal value listed in the *AERMET User's Guide* for the land-cover category (cross-matched to the corresponding NLCD land-cover categories identified for the sector) weighted by the area of coverage in the sector. **Table R-1** presents the land-cover area weighted average surface roughness length, albedo, and Bowen ratio values developed for the GLE construction site and used as input for the AERMET modeling. Because Wilmington, NC, has a much higher than average annual rainfall (approximately 57 inches/year [1448 mm/year]) than the average for most of the country (approximately 31 inches/year [787 mm/year]) (NOAA, 2002, 2004), wet condition values were used for the Bowen ratio.

R.3 AERMOD Model Emission Source Assumptions

The GLE construction site is assumed to have the same boundaries as the Proposed GLE Facility (see **Figure R-2**). The AERMOD was run using a unitized emission rate (1 g/sec) to obtain the unitized concentration and deposition rates for each receptor location. Then, the corresponding unitized concentration and deposition rate values were multiplied by site-specific air pollutant emission factors to obtain predicted concentration and deposition values at each receptor location. The site-specific emission factors were based on the assumptions and emissions estimates for construction-related fugitive dust and vehicle emissions described in **Section 4.6.2.1.1** of this Report (*Site Preparation and Construction Air Emissions Sources*).

The GLE construction site was modeled as an area source with uniform emissions because the entire 100 acres (40.5 hectares [ha]) for the Proposed GLE Facility is expected to be cleared and graded as part of the initial site preparation. Off-road construction equipment was assumed to move over the entire GLE construction site. Construction motor vehicle traffic was assumed to use the proposed North access road to access the GLE construction site from N.C. Highway 133 (NC 133, also known as Castle Hayne Road). The access road was assumed to be unpaved during the site preparation stage of construction and later paved for the general construction stages. Assumptions made for the dispersion modeling were consistent with the emission estimate assumptions presented in **Table R-1**.

Fugitive dust emissions produced by wind erosion of the open spaces on the cleared GLE construction site were assumed to be of minor significance and not included in the AERMOD dispersion modeling for several reasons. First, based on a review of wind speed and precipitation data for the GLE construction site (**Section 3.6.2.2**) and EPA's AP-42 emission factors for wind-blown dust (U.S. EPA, 2006a), it was concluded that the potential for significant amounts of fugitive dust emissions at the GLE construction site due to wind erosion is small on an annual basis. Second, significant portions the GLE construction site would likely only be fully exposed to the wind for a relatively short periods of time during the overall construction phase before the construction of the building foundations and hard surfacing of the open storage and parking areas begins. Third, the large number of days per year with precipitation that is expected to occur at the GLE construction site would reduce the number of potential days for wind erosion to occur. Finally, the trees surrounding the GLE construction site and bordering the proposed North access road would serve as a wind break along portions of the exposed soil areas, further reducing the potential for wind blown dust from the site.

Emissions from the GLE construction site were assumed to occur only during daylight construction hours; therefore, AERMOD was set up with an assumed 10-hour daily work schedule (6 a.m. to 4 p.m.) from Monday through Friday. Short-term emission rates were calculated using the highest stage-specific emission rate for each source. This method produces the most conservative, short-term emission estimates. Annual emission values calculated weighting by the number of months for each stage of construction. The first year is expected to have the highest overall annual emissions and can be considered conservative for long-term average dispersion results. Twenty-four hour emission rates were estimated to be the same as those from the construction period having the highest emission rate for each source, and thus were considered conservative. The emission levels of PM_{10} due to road construction, clearing, grading of the site, and construction traffic were calculated assuming that a standard dust-suppression work practice is implemented of watering the GLE construction site and unpaved access road twice per day to keep particulate emissions to a minimum.

PM_{10} emission factors were used for the AERMOD dispersion modeling of the Proposed GLE Facility construction activities. Using EPA precedent (U.S. EPA, 1999), PM_{10} emissions were assumed to be distributed so that 60% had aerodynamic diameters between 10 μm and 2.5 μm, and 40% had aerodynamic diameters less than 2.5 μm ($PM_{2.5}$).

Wet and dry PM depositions were considered separately for 24-hour deposition flux values because 24-hour values must be added for each day at each receptor. The wet deposition values were zero for most time periods because wet deposition occurs only during precipitation events. Also, the maximum values for wet deposition are 2 to 3 orders of magnitude less than the maximum values for dry deposition.

Dispersion of the air emissions from the motor vehicles (e.g., worker automobiles, trucks) on the proposed North access road was also included in the AERMOD modeling of the Proposed GLE Facility construction air quality impacts. **Appendix Q** describes the assumptions made for emission calculations.

The AERMOD-predicted concentration at any given receptor location is the sum of the impacts from all on-site sources operating during the modeled Proposed GLE Facility construction phase. For example, the annual average PM concentration at a receptor location is the sum of the modeled annual average location-specific concentration due to GLE construction site emissions and the proposed North access road emissions. The same calculation procedure was be made for annual average PM deposition rates. Twenty-four hour PM concentrations and deposition rates were summed for the construction-day scenario on which the combination of construction activities were judged to be the highest total daily PM emission rate during the initial 3-year construction period.

R.4 AERMOD Receptor Grid Layout

Two sets of receptor grids were created in the AMS EPA Regulatory Model (AERMOD) at both on-site and off-site receptor locations around the Proposed GLE Facility for the purpose of assessing ground-level ambient concentrations from air emissions release during construction of the Facility. The first grid is a standard polar receptor grid created along 16 radials (i.e., 22.5-degree radials) originating from a point within the Proposed GLE Facility footprint and continuing outward to an endpoint distance of 31 miles (50 kilometers). Receptors were placed at the following distances (meters) along these radials: 350, 400, 500, 600, 700, 800, 900, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, 5000, 5500, 6000, 6500, 7000, 7500, 8000, 8500, 9000, 9500, 10000, 11000, 12000, 13000, 14000, 15000, 16000, 17000, 18000, 19000, 20000, 25000, 30000, 35000, 40000, 45000, and 50000. A second site-specific receptor grid was created along the entire perimeter length of the Wilmington Site property boundary (i.e., fenceline). These receptors were placed every 7.5 degrees. **Figure R-2** shows the relative receptor locations for polar and fenceline grids used for the AERMOD dispersion modeling of the Proposed GLE Facility construction activities. Dispersion of the particulate matter (PM) emissions generated during construction was modeled using both receptor grids. Dispersion of motor vehicle gaseous emissions was modeled using only the fenceline receptor grid.

R.5 AERMOD Modeling Results

The AERMOD model predicted maximum ambient air concentrations at the Wilmington Site property boundary (i.e., fenceline) due to air emissions from the Proposed GLE Facility on-site construction activities are presented in **Table R-2**. The maximum concentration at the fenceline represents the highest potential exposure location to the general public due to air emission sources associated with the Proposed GLE Facility construction activities. This is because these air emission sources would be on-site, ground-level sources (e.g., motor vehicle engine exhaust), and air concentrations from ground-level emission sources decrease with distance from the source location. General public access onto the Wilmington Site is and will continue to be restricted, thus preventing general public exposure to concentrations greater than the maximum concentration at the fenceline.

The Proposed GLE Facility would be located in a region for which the air quality is in attainment with all National Ambient Air Quality Standards (i.e., NAAQS) (see **Section 3.6.3.1).** Compliance with ambient air quality standards is determined by long-term ambient air quality monitoring at predetermined monitoring station locations using methods and analysis procedures established by the regulatory agencies. These ambient standards are not intended to be used for direct assessment of localized air quality impacts from individual, temporary emission sources such as construction projects. However, comparison of the predicted AERMOD concentrations with ambient air quality standards as presented in **Table R-2** provides an order-of-magnitude measure of the potential incremental contribution to ambient pollutant levels in the vicinity of emissions of the Proposed GLE Facility produced by the on-site construction activities.

The PM_{10} concentrations predicted by the AERMOD modeling of the Proposed GLE Facility construction activities include the contributions of fugitive dust and the PM_{10} vehicle emissions. **Figure R-3** shows isopleths of annual average concentration of PM_{10} due to construction activities. The maximum off-site annual average concentration of PM_{10} due to construction activities is predicted by the AERMOD model to be 3.5 $\mu g/m^3$ and occurs at the fenceline to the northeast (45-degree radial) of the GLE construction site. The maximum on-site annual average concentration of PM_{10} is predicted to be 12.3 $\mu g/m^3$. This predicted fenceline maximum PM_{10} concentration is one order-of-magnitude lower than the ambient air quality standard of 50 $\mu g/m^3$. The maximum off-site 24-hour average concentration value for PM_{10} is predicted to be 114 $\mu g/m^3$, which would occur at the fenceline to the northeast (52.5-degree radial), which

is less than the ambient air quality standard of 150 μg/m^3. The maximum predicted on-site value is 191 μg/m^3.

The quantity of PM that would be deposited on the ground and other surfaces in the vicinity of the GLE construction site were predicted using the AERMOD wet and dry deposition algorithms. **Figures R-4 through R-6** show that the AERMOD predicted annual dry, wet, and total deposition rates around the GLE construction site due to the construction activities would be very small. The total maximum annual deposition flux of PM_{10} predicted at the property fenceline is 0.3 g/m^2/year, which occurs to the northeast (37.5-degree radial) from the center of the source. The on-site predicted maximum annual deposition flux is 0.7 g/m^2/year. The maximum predicted 24-hour dry deposition flux at the property fenceline is 0.02 g/m^2/day, which occurs to the northeast (52-degree radial). Onsite, the maximum dry deposition flux value is 0.02 g/m^2/day.

Table R-2 also presents the maximum ambient air concentrations at the Wilmington Site property boundary (i.e., fenceline) predicted by the AERMOD modeling for gaseous air emissions from the Proposed GLE Facility on-site construction activities (i.e., carbon monoxide, nitrogen dioxide, volatile organic compounds, and sulfur dioxide exhausted from off-road construction equipment and other motor vehicles traveling on-site). All of the predicted concentrations are multiple orders of magnitude lower than the level of the ambient air quality standard used for comparison.

Table R-1. AERMOD Site-Specific Input Parameter Values Used for Proposed GLE Facility Construction Ambient Air Dispersion Modeling

Proposed GLE Facility Sector Orientation[a] and Land Cover Percentages[b]	Season	AERMET Input Parameter Values[c]		
		Surface Roughness Length (meters)	Albedo	Wet Bowen Ratio
Sector 1 - East of site 6% Developed land 10% Cultivated land/pasture 31% Forest 36% Woody wetlands <1% Open water 16% Other	Winter	0.62	0.41	0.47
	Spring	0.68	0.14	0.23
	Summer	0.72	0.15	0.24
	Fall	0.67	0.16	0.31
Sector 2 – Southeast of site 19% Developed land 16% Cultivated land/pasture 31% Forest 17% Woody wetlands <1% Open water 16% Other	Winter	0.56	0.45	0.47
	Spring	0.62	0.14	0.28
	Summer	0.67	0.16	0.33
	Fall	0.60	0.16	0.42
Sector 3 – Southwest of site 4% Developed land 1% Cultivated land/pasture 19% Forest 53% Woody wetlands 15% Open water 8% Other	Winter	0.62	0.32	0.44
	Spring	0.67	0.13	0.16
	Summer	0.68	0.13	0.16
	Fall	0.67	0.15	0.20
Sector 4 – Northwest and North of site <1% Developed land 1% Cultivated land/pasture 18% Forest 75% Woody wetlands 1% Open water 4% Other	Winter	0.73	0.32	0.47
	Spring	0.80	0.12	0.15
	Summer	0.80	0.14	0.14
	Fall	0.79	0.15	0.16

[a] Sector orientation in AERMOD set up as Sector 1 (15° to 75°), Sector 2 (75° to 180°), Sector 3 (180° to 255°), and Sector 4 (255° to 15°) where 0 degrees is North.

[b] Approximate sector land cover percentages within 3 kilometer-radius around Proposed GLE Facility identified using 2001 National Land Cover Dataset (NLCD).

[c] Value listed is proportional average by land cover percentage in sector of the applicable *AERMET User's Guide* land cover category seasonal values cross-matched to the corresponding NLCD land cover categories identified for the sector.

Table R-2. AERMOD Predicted Maximum Fenceline Air Pollutant Concentrations Due to Proposed GLE Facility Onsite Construction Activities

Air Pollutant	Averaging Time	AERMOD predicted maximum fenceline concentration ($\mu g/m^3$)	Comparable Ambient Air Quality Standard level[a,b] ($\mu g/m^3$)
Carbon monoxide (CO)	Annual average	0.6	No ambient standard
	8-hour	34	10,000
	1-hour	158	40,000
Nitrogen dioxide (NO_2)	Annual average	0.1	100
Particulate matter (PM_{10})	Annual average	3.5	50
	24-hour	114	150
Sulfur dioxide (SO_2)	Annual average	0.0007	78
	24-hour	0.01	364
	3-hour	0.04	1,300
Volatile organic compounds (VOC)	Annual average	0.08	No ambient standard [d]

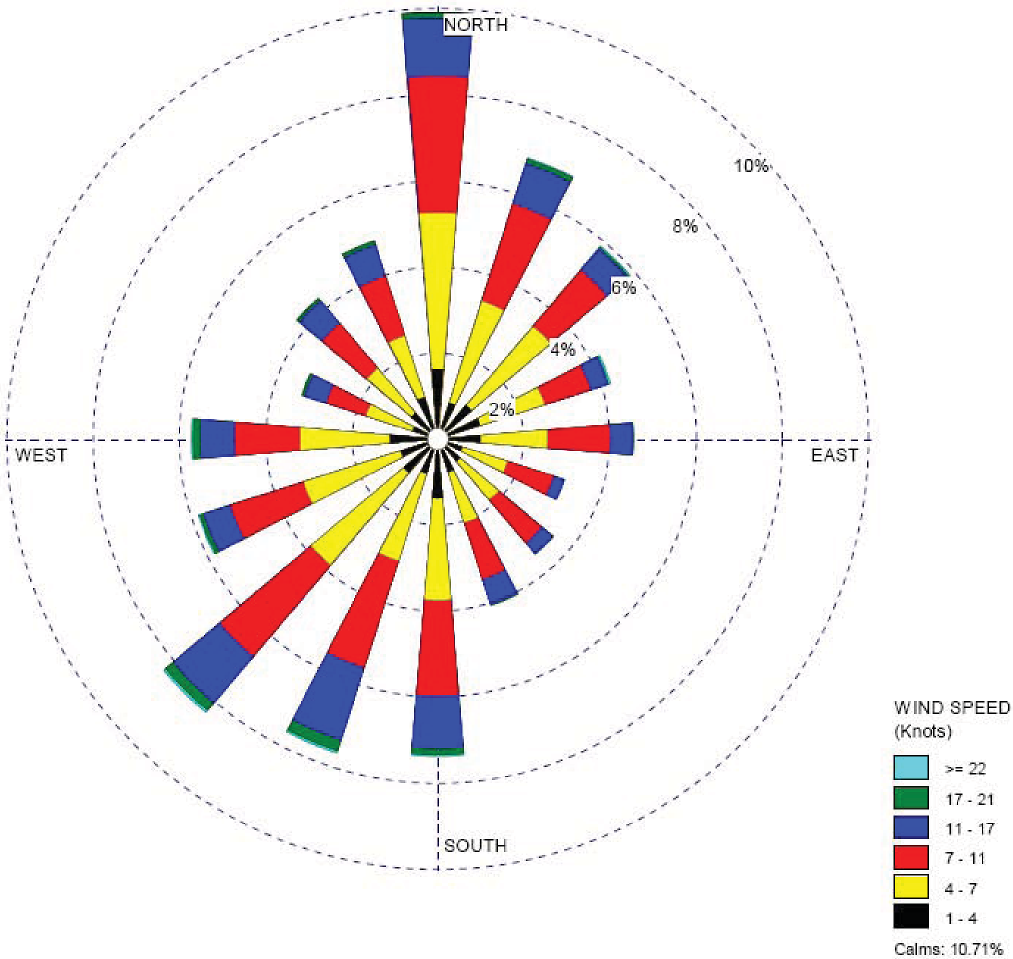
[a] Compliance with ambient air quality standards is determined by long term ambient air quality monitoring at predetermined monitoring station locations using methods and analysis procedures established by the regulatory agencies. These ambient standards are not intended to be used for direct assessment of localized ambient air pollutant concentrations from temporary emission sources such as those construction projects. The comparison of the predicted AERMOD concentrations with ambient air quality standards presented in this table is intended to provide an order-of-magnitude measure of the potential incremental contribution to ambient pollutant levels in the vicinity of emissions of the Proposed GLE Facility produced by on-site construction activities.

[b] Standards listed are the federal National Ambient Air Quality Standards (NAAQS), which the State of North Carolina has adopted as state standards with the exception of the annual average standard for PM. The federal annual average NAQQS has been revoked but the level is still maintained as a North Carolina state standard.

[c] No federal or State annual average air quality standard for this pollutant.

[d] No air quality standards are established specifically for VOCs. VOC is a precursor pollutant involve in the atmospheric photochemical formation of ozone for which ambient air quality standards have been established.

WIND ROSE PLOT:	DISPLAY:
Station #13748 - WILMINGTON/NEW HANOVER COUNTY, NC	**Wind Speed** **Direction (blowing from)**



COMMENTS:	DATA PERIOD:		
Source of Data: DS-3505.	**1992-1996** **Jan 1 - Dec 31** **00:00 - 23:00**		
	CALM WINDS: **10.71%**	TOTAL COUNT: **42911 hrs.**	
	AVG. WIND SPEED: **7.13 Knots**	DATE: **1/2/2008**	PROJECT NO.:

WRPLOT View - Lakes Environmental Software

Figure R-1. Wind rose for Wilmington International Airport based on 1992 through 1996 meteorological data used in construction dispersion modeling.

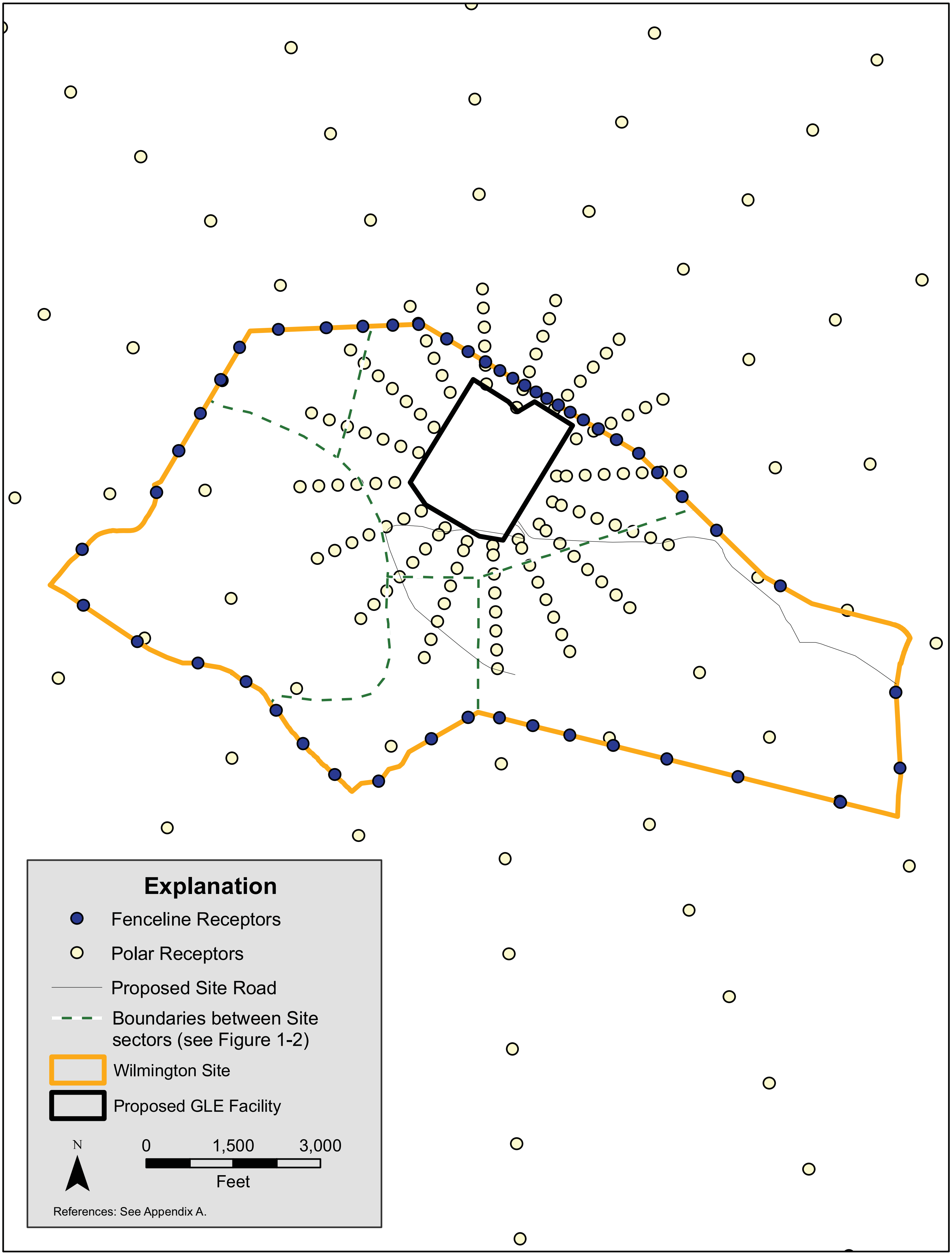


Figure R-2. Receptor grid patterns used for AERMOD modeling of the air emissions due to construction activities.

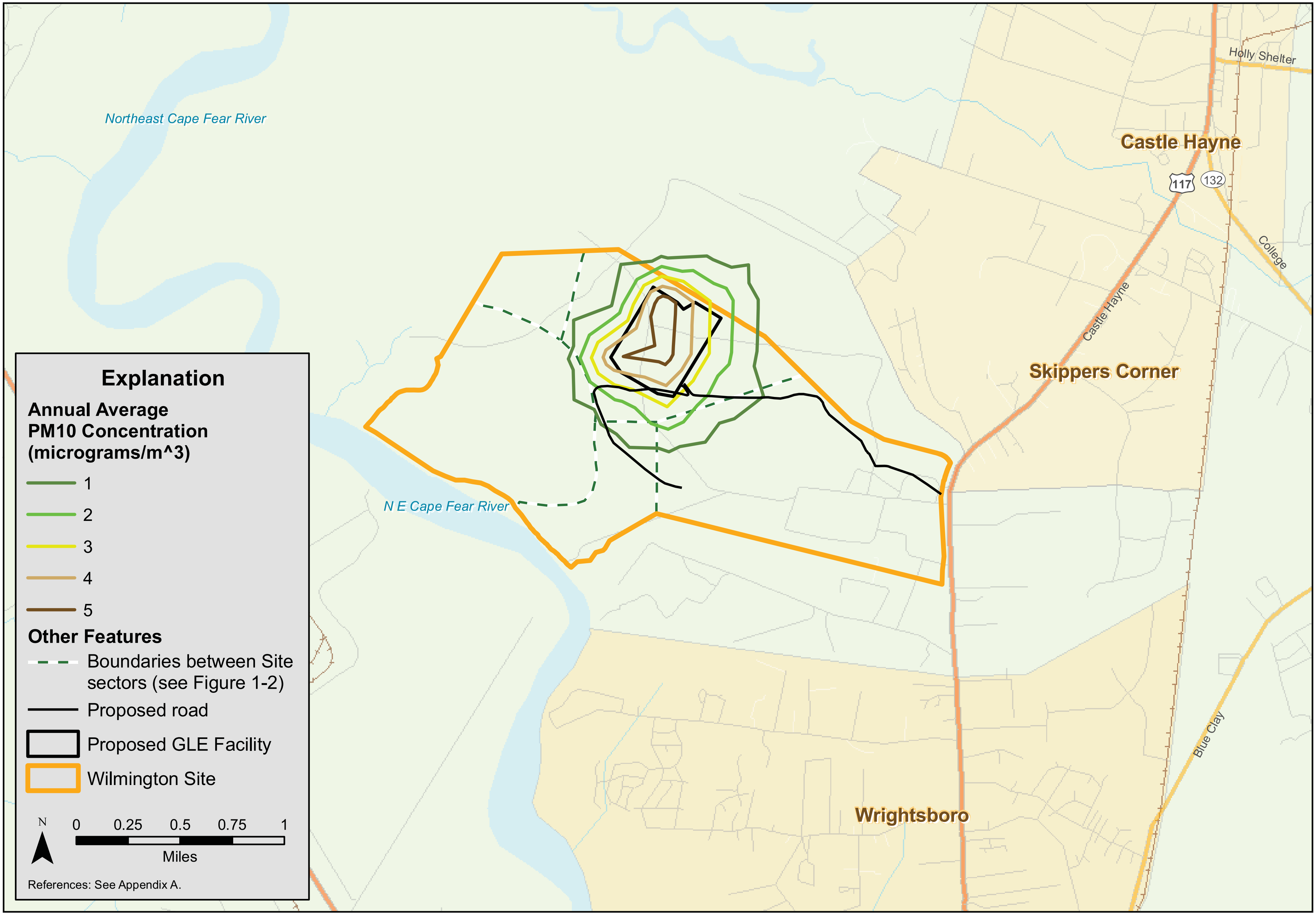


Figure R-3. Annual average concentration isopleths for PM_{10} due to construction activities.

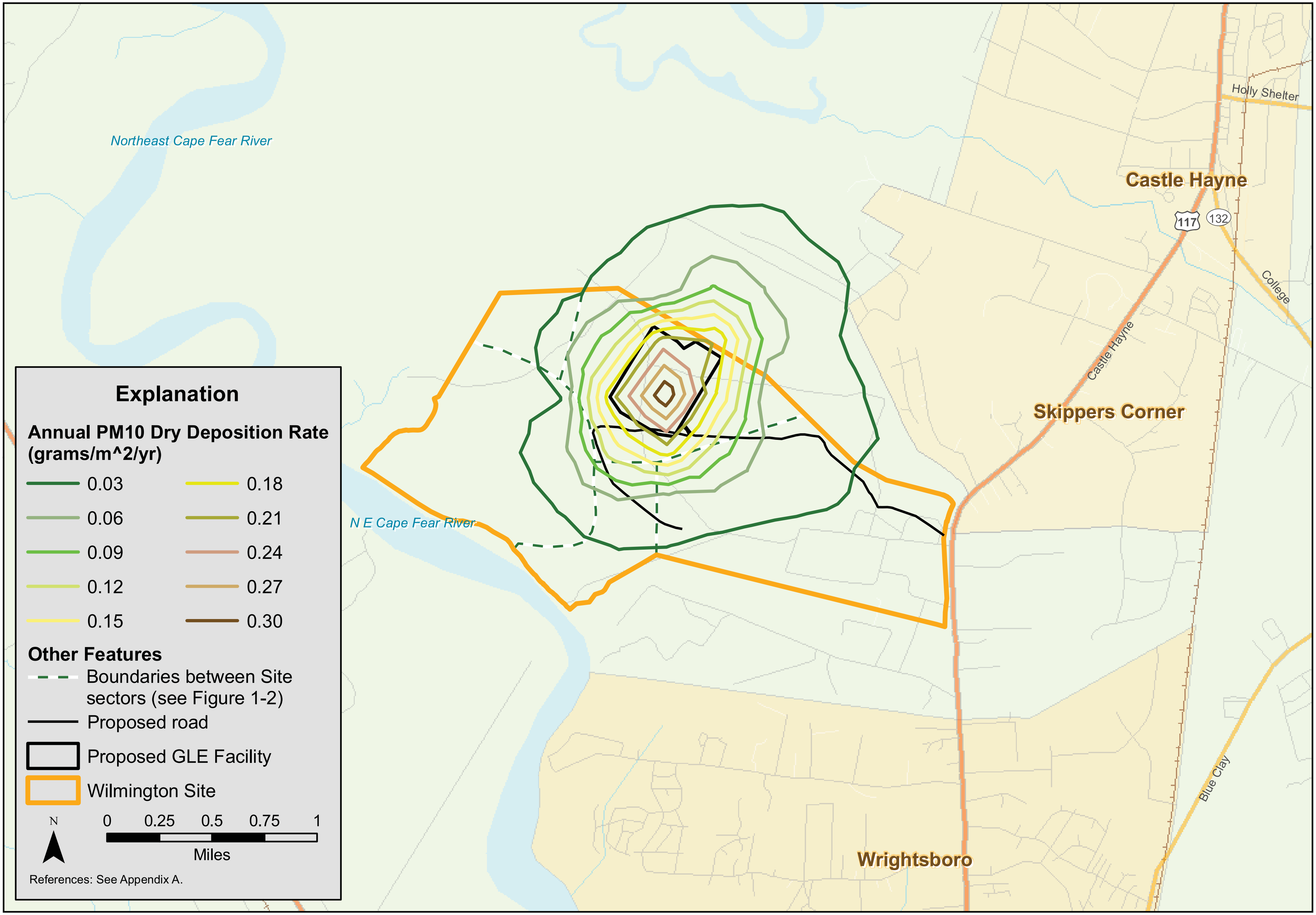


Figure R-4. Annual dry deposition rate isopleths for PM_{10} due to construction activities.

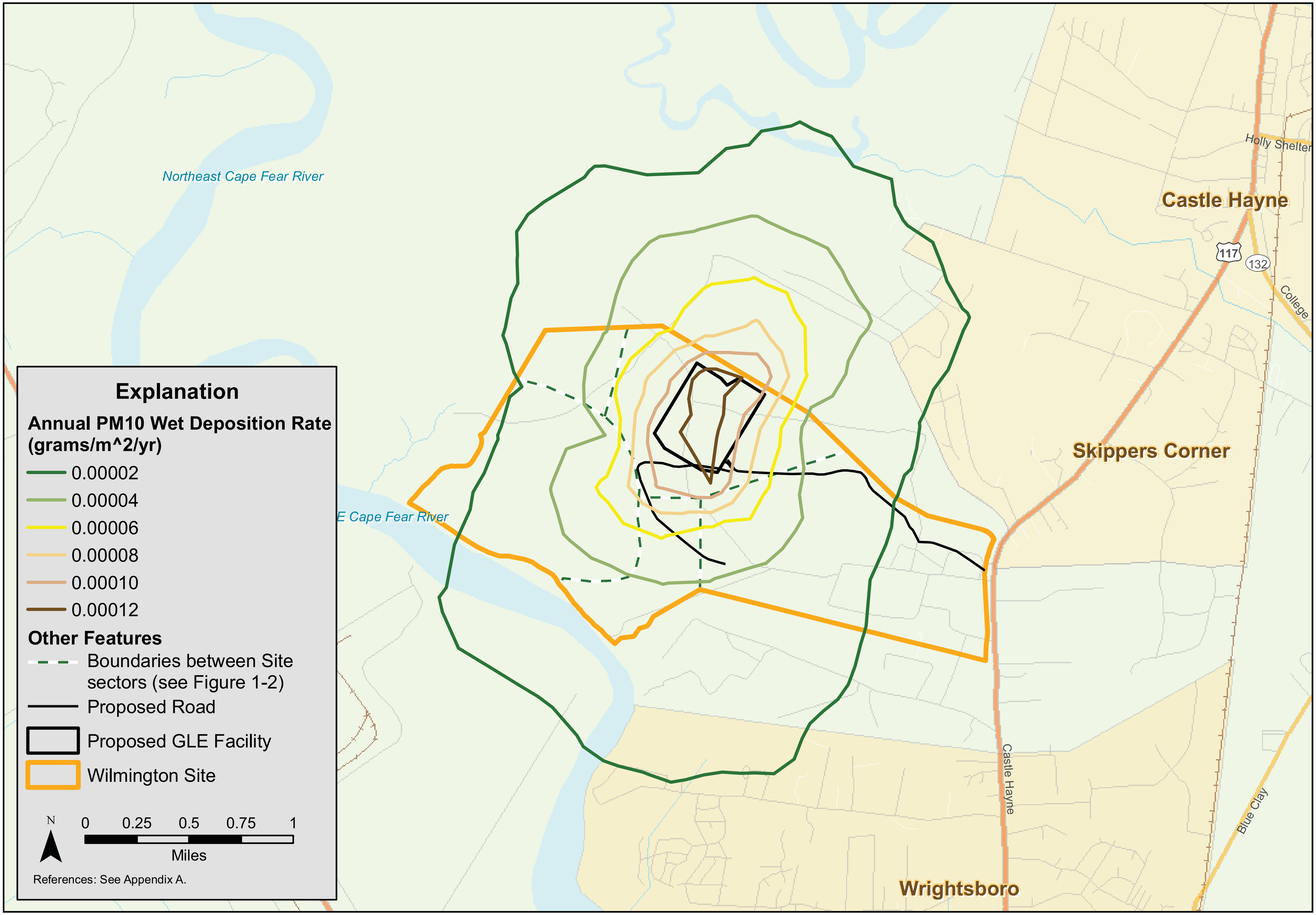


Figure R-5. Annual wet deposition rate isopleths for PM_{10} due to construction activities.

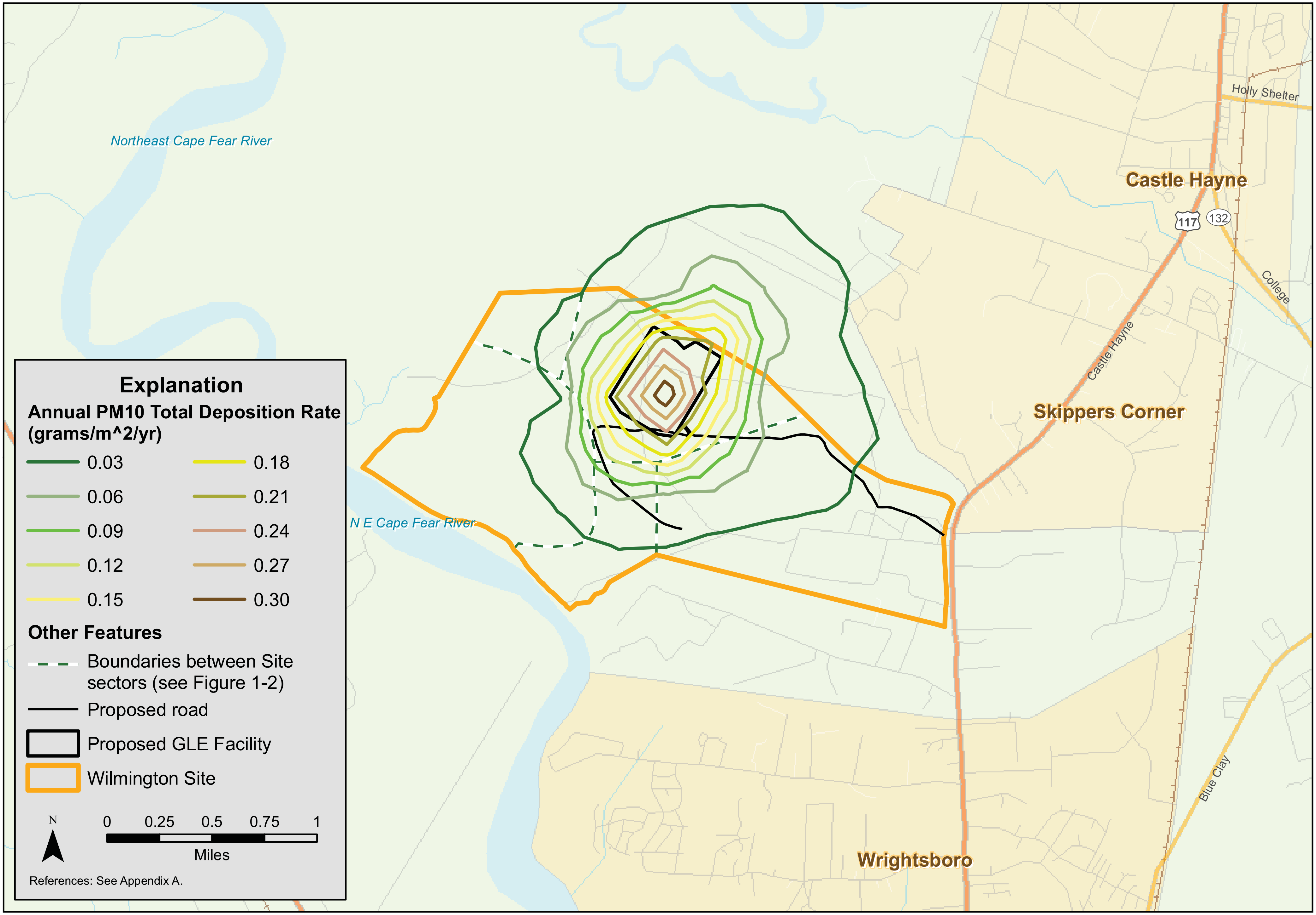


Figure R-6. Annual total deposition rate isopleths for PM_{10} due to construction activities.

Appendix S

Air Emissions Dispersion Modeling for Operation of the Proposed GLE Facility Using XOQDOQ Model

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Appendix S

Air Emissions Dispersion Modeling for Operation of the Proposed GLE Facility Using XOQDOQ Model

S.1 Operation Air Quality Impacts

Air emissions dispersion modeling was performed using the XOQDOQ model in NRCDose (version 2.3.9) to estimate the normalized concentration (Chi[χ]/Q) and/or relative deposition rate (D/Q) of uranium particle air emissions from the Proposed GLE Facility during normal operations at selected receptor locations (RSICC, 2007).The XOQDOQ model assumes that air emissions released into the atmosphere follow a Gaussian (normal) distribution around the plume centerline. Results may be calculated to a distance of 50 miles (80 kilometers [km]) from the source considering radioactive decay and depletion of the plume. The model assumes that the plume follows a straight-line trajectory between the source and all receptors (i.e., no plume meander); this approach produces conservative estimates. The XOQDOQ model also can calculate χ/Q and D/Q at user-defined locations.

S.2 XOQDOQ Meteorological Data

The XOQDOQ model requires joint frequency distributions for wind speed and direction by stability class. To generate these model input distributions, meteorological data were used for the years 1988 through 1992, collected at the Wilmington International Airport station (WebMET.com, 2002). These data were gathered in Met144 format and transformed to CD144 format using the U.S. Environmental Protection Agency's (EPA's) MET144 program. This data transformation was necessary to make them compatible with EPA's Stability Array (STAR) program, which generates the joint frequency distributions. The most recent data that could be found in the correct format for use with the STAR program were for calendar year 1992.

S.3 XOQDOQ Emission Source Model Assumptions

The main GLE operations building is planned to be vented through an emissions control system that discharges to the atmosphere through a single roof stack. The Fuel Manufacturing Operation (FMO) facility has multiple roof vents. In addition, separate FMO sources with stacks are located away from the main FMO building. Each source stack with the potential to emit uranium isotopes was included in XOQDOQ model as an individual source with an individual emission rate. The stacks were then grouped by geographic position into three stack groups to allow stacks that are in close proximity to each other to have their emissions contribution directly added at each receptor. The total contributions of each stack group were then spatially summed using geographic information systems (GIS) tools.

Figure S-1 shows the approximate location of the three stack groups used for the XOQDOQ modeling of the Proposed GLE Facility and FMO. Stack Group A represents the Proposed GLE Facility sources and is the location of the main GLE operations building's single stack. For the modeling analysis, Stack Group A is positioned approximately 1.1 miles (1.7 km) from the FMO building. Stack Group C represents the main FMO building roof stacks and other nearby separate sources with stacks within approximately 400 feet (ft; 122 meters [m]) of the main building. Stack Group B represents the two FMO sources with stacks that are too far away from the main building to be included in Stack Group C. Stack Group B is located between the main GLE operations building and the main FMO building approximately 0.7 mi (1.1 km) away from the Stack Group A and approximately 0.4 mi (0.6 km) away from Stack Group C. **Table S-1** lists the stack and vent gas-stream physical characteristics for the stacks in each stack group used for XOQDOQ dispersion modeling. All of the stacks are assumed to have a round cross section.

The total uranium and uranium isotopes (uranium-234 [^{234}U], uranium-235 [^{235}U], uranium-236 [^{236}U], and uranium-238 [^{238}U]) emission rates used for the XOQDOQ dispersion modeling were developed based on stack monitoring data for the existing FMO operations. The total uranium and uranium isotope emission rates used for each FMO stack are listed in **Table S-2**. The SILEX (Separation of Isotopes by Laser Excitation) laser process is a new technology for which air emissions monitoring data presently are not available. To model the stack air emissions from the main GLE operations building, total uranium and individual uranium isotope emission rates for Stack Group A were selected through a review of the FMO stack monitoring data; the modeling source term was based on data from one of the various FMO stacks judged to be most similar to sources expected for Proposed GLE Facility operations. The selected emission rate is considered to be a conservative assumption (i.e., the uranium and uranium isotope emission rates used for the XOQDOQ dispersion modeling are higher than the actual emissions expected from Proposed GLE Facility operations).

S.4 XOQDOQ Receptor Grid Layout

The XOQDOQ model uses a receptor grid for a standard set of receptor locations spaced along 16 radial directions beginning at 0.25 miles (0.4 km) and continuing to a distance of 50 miles (80 km) from the emission source. To this standard receptor grid, additional receptor locations for schools and hospitals in the vicinity of the Proposed GLE Facility were added to the model. Receptor locations were also added at points along the Wilmington Site fenceline to assess the highest off-site χ/Q and D/Q values.

S.5 XOQDOQ Modeling Results

The XOQDOQ modeling results were examined in two different ways to asses the air quality impact of the Proposed GLE Facility operations. First, the air emissions from the Proposed GLE Facility (Stack Group A) were examined for χ/Q and D/Q values at selected locations, as required by NUREG-1748, *Environmental Review Guidance for Licensing Actions Associated with NMSS (Nuclear Material Safety and Safeguards) Programs* (NRC, 2003). Second, the cumulative air quality impact due to air emissions from both the Proposed GLE Facility (Stack Group A) and the existing FMO (Stack Groups B and C) were evaluated. Only the χ/Q values predicted by the XOQDOQ model without decay and without depletion were considered further for several reasons. Assuming no decay or depletion occurs during the dispersion of the plume provides the most conservative (i.e., highest) concentration values. Secondly, the uranium isotopes that would be released have an extremely long half-life compared to the plume transport time or even the lifetime of the Proposed GLE Facility. Also, default values that are used in the XOQDOQ model for decay and depletion result in only slightly lower values, but represent isotopes of other elements with very short decay times compared to the uranium isotopes.

The predicted unitized concentrations (χ/Q) and relative depositions (D/Q) from Proposed GLE Facility air emissions for selected receptor locations are presented in **Table S-3**. The highest on-site χ/Q value is 1.3E-06 sec/m^3 and is predicted to occur at.0.25 miles (402 m) to the northeast of the main GLE operations building stack location. The highest off-site χ/Q occurs at the Wilmington Site fenceline at 0.3 miles (0.5 km) to the northeast with a value of 1.3E-06 sec/m^3. The nearest resident is located at 0.9 miles (1.5 km) to the east-southeast and has a χ/Q value of 2.7E-07 sec/m^3. Each of the specified schools and hospitals are significantly farther away than these locations, ranging from 3.4 miles (5.4 km) away to 29.8 miles (48 km) away. χ/Q values for the schools and hospitals are approximately one to two orders of magnitude lower than that for the nearest resident. **Tables S-4 through S-7** list the χ/Q and D/Q values predicted by the XOQDOQ model for all sectors to a distance of 50 miles (80 km).

Cumulative impacts of air emissions from both the Proposed GLE Facility and existing FMO were calculated by multiplying the χ/Q and D/Q values predicted by the XOQDOQ model for each stack by that stack's emission rates in Ci/sec listed in **Table S-2**. Because the stack groups were far enough away

from each other that they could not be considered to be collocated, the predicted concentration and deposition values for each stack group were spatially summed together using GIS software. The predicted cumulative annual average ambient concentrations of uranium isotopes emitted from the Proposed GLE Facility and the existing FMO facility are presented in **Table 4.6-5**. The predicted cumulative annual average deposition rates of uranium isotopes emitted from Proposed GLE Facility and the existing FMO facility are presented in **Table 4.6-6**.

Figures S-2 and S-3 show the predicted cumulative annual average ambient concentrations and deposition rates of uranium isotopes for the combination of Stack Groups A, B, and C. Most of the contribution for this maximum off-site point of impact is from the currently operating FMO stacks. The maximum off-site annual average concentration of uranium isotopes from the combined stacks is 8.4E-13 $\mu Ci/m^3$ and occurs 1.2 miles (2 km) to the south-southeast of the proposed GLE stack, or 0.1 mi (0.2 km) from the south fenceline near the FMO facility. Nearby, the point of maximum off-site deposition occurs with a value of 4.1E-07 $\mu Ci/m^2$/year, which is at a distance of 1.2 miles (1.9 km) to the south-southeast of the proposed GLE stack, or 158 feet (42 m) south of the fenceline near the operating FMO facility. Neither of these points occurs directly at a residence.

The maximally exposed existing residence has an annual average concentration of uranium isotopes from the combined stacks of 7.6E-13 $\mu Ci/m^3$ and is at a distance of 1.4 mi (2.2 km) from the main GLE building operations stack, or 0.2 miles (0.3 km) south of the fenceline near the operating FMO building. The combined deposition rate at this residence is 2.1E-07 $\mu Ci/m^2$/year. The nearest residence to the proposed GLE stack is 0.9 mi (1.5 km) to the ESE of the stack, or about 0.03 mi (50 m) from the fenceline of the Wilmington Site. The combined annual average concentration at this residence is 5.8E-13 $\mu Ci/m^3$, while the combined deposition rate is 1.5E-07 $\mu Ci/m^2$/year.

S.6 Operation Air Quality Impacts

The laser uranium-enrichment technology that would be used for the Proposed GLE Facility would not emit carbon monoxide, nitrogen oxides, sulfur dioxide, or volatile organic compounds. There is a potential for small gaseous releases associated with operation of the process that could contain uranium isotopes, hydrogen fluoride, and particulate uranyl fluoride. Any such gaseous releases would be contained within the main GLE operations building and routed to a high-efficiency, multi-stage emissions control system. The public health and ecological impacts associated with exposure to the cumulative ambient air uranium isotope concentrations predicted by XOQDOQ model for the Proposed GLE Facility with the existing FMO are discussed respectively in **Section 4.12**, *Public and Occupational Health*, and **Section 4.5**, *Ecological Resources Impacts*.

The operation of the Proposed GLE Facility would also result in small amounts of nonradioactive air emissions consisting of CO, NO_x, PM, VOCs, and SO_2 from the intermittent operation of auxiliary diesel electric generators and miscellaneous sources. The incremental air quality impacts from the operation of these sources at the Proposed GLE Facility are predicted to be SMALL and would not substantially change the ambient air quality in the vicinity of the Proposed GLE Facility.

Tables

Table S-1. Stack/Vent Characteristics Used for Proposed GLE Facility Operation Ambient Air Dispersion Modeling

Stack Group	Facility Stack ID#	Stack		Vented Gas Stream		
		Diameter m (in)	Release Height m (ft)	Velocity m/sec (ft/sec)	Flow Rate m^3/sec (ft^3/min)	Temperature
GLE Stack Group A	1	1.20 (47)	15.24 (50.0)	12.30 (40.4)	13.90 (29,452)	Ambient
FMO Stack Group B	5	0.25 (10)	3 (9.8)	11.50(37.7)	0.58 (1,235)	Ambient
	29	0.51 (20)	7 (23.0)	18.56 (60.9)	3.76 (7,970)	Ambient
FMO Stack Group C	1	1.12 (44)	20 (65.6)	14.43(47.3)	14.16 (30,000)	Ambient
	2	1.07 (42)	17 (55.8)	5.89 (19.3)	5.26 (11,155)	Ambient
	3	0.81 (32)	17 (55.8)	10.08(33.1)	5.23 (11,081)	Ambient
	4	0.30 (12)	17(55.8)	4.59 (15.1)	0.34 (710)	Ambient
	6	0.91 (36)	21(68.9)	9.65 (31.7)	6.34 (13,424)	Ambient
	7	0.64 (25)	18 (59.1)	15.21(49.9)	4.82 (10,204)	Ambient
	8	0.61 (24)	16 (52.5)	5.66 (18.6)	1.65 (3,501)	Ambient
	9	0.46 (18)	16.(52.5)	10.41 (34.2)	1.71 (3,621)	Ambient
	10	1.52 (60)	20 (65.6)	7.26 (23.8)	13.24 (28,064)	Ambient
	11	1.52 (60)	20 (65.6)	7.26 (23.8)	13.24 (28,064)	Ambient
	12	0.81 (32)	18 (59.1)	3.00 (9.8)	1.55 (3,294)	Ambient
	13	0.56 (22)	16 (52.5)	15.99 (52.5)	3.92 (8,311)	Ambient
	14	0.76 (30)	16 (52.5)	6.27 (20.6)	2.86(6,059)	Ambient
	15	0.56 (22)	17 (55.8)	15.28 (50.1)	3.75 (7,942)	Ambient
	16	0.46(18)	13 (42.7)	13.50 (44.3)	2.22(4,710)	(a)
	17	0.61 (24)	16 (52.5)	9.14 (30.0)	2.67 (5,652)	Ambient
	18	0.56 (22)	16 (52.5)	0.80 (2.6)	0.20 (417)	Ambient
	19	0.76 (30)	15 (49.2)	12.31 (40.4)	5.62 (11,898)	Ambient
	20	0.76 (30)	15 (49.2)	10.92 (35.8)	4.98 (10,553)	Ambient
	21	0.76 (30)	20 (65.6)	15.56 (51.0)	7.10 (15,038)	Ambient
	31	0.51 (20)	17 (55.8)	10.89 (35.7)	2.21 (4,677)	Ambient
	32	0.76 (30)	15 (49.2)	4.98 (16.3)	2.27 (4,808)	Ambient
	33	1.22 (48)	19 (62.3)	12.13 (36.8)	14.16 (30,000)	Ambient
	34	0.30 (12)	13 (42.7)	19.40 (63.6)	1.42 (3,000)	Ambient

[a] Vent gas stream is from waste incinerator. Gas stream temperature assumed to be 100°F (37.8°C).

Table S-2. Total Uranium and Uranium Isotope Emission Rates Used for Proposed GLE Facility Operation Ambient Air Dispersion Modeling

Stack Group	Facility Stack ID#	Uranium Isotope Emission Rate				
		Total U	^{234}U	^{235}U	^{236}U	^{238}U
		Ci/sec	Ci/sec	Ci/sec	Ci/sec	Ci/sec
GLE Stack Group A	1	1.47E-13	1.25E-13	4.88E-15	5.49E-17	1.77E-14
FMO Stack Group B	5	8.88E-16	7.52E-16	2.93E-17	3.30E-19	1.07E-16
	29	4.50E-15	3.81E-15	1.49E-16	1.68E-18	5.42E-16
FMO Stack Group C	1	1.47E-13	1.25E-13	4.88E-15	5.49E-17	1.77E-14
	2	9.89E-15	8.37E-15	3.27E-16	3.68E-18	1.19E-15
	3	1.58E-14	1.33E-14	5.23E-16	5.90E-18	1.90E-15
	4	2.85E-16	2.42E-16	9.42E-18	1.06E-19	3.42E-17
	6	2.19E-14	1.85E-14	7.23E-16	8.15E-18	2.63E-15
	7	1.65E-14	1.40E-14	5.45E-16	6.15E-18	1.99E-15
	8	2.70E-15	2.28E-15	8.91E-17	1.01E-18	3.23E-16
	9	2.76E-15	2.33E-15	9.10E-17	1.03E-18	3.33E-16
	10	9.39E-14	7.93E-14	3.10E-15	3.49E-17	1.13E-14
	11	5.30E-14	4.47E-14	1.75E-15	1.97E-17	6.34E-15
	12	2.63E-15	2.23E-15	8.69E-17	9.80E-19	3.16E-16
	13	4.66E-14	3.93E-14	1.53E-15	1.73E-17	5.58E-15
	14	2.51E-15	2.12E-15	8.28E-17	9.32E-19	3.01E-16
	15	6.94E-15	5.87E-15	2.30E-16	2.59E-18	8.34E-16
	16	4.44E-14	3.76E-14	1.46E-15	1.78E-17	5.34E-15
	17	3.87E-15	3.27E-15	1.28E-16	1.44E-18	4.66E-16
	18	3.84E-15	3.23E-15	1.27E-16	1.43E-18	4.60E-16
	19	1.14E-15	9.67E-16	3.77E-17	4.25E-19	1.37E-16
	20	7.07E-15	5.99E-15	2.34E-16	2.64E-18	8.50E-16
	21	1.46E-14	1.24E-14	4.85E-16	5.45E-18	1.76E-15
	31	3.03E-14	2.56E-14	1.00E-15	1.13E-17	3.65E-15
	32	3.52E-15	2.98E-15	1.16E-16	1.31E-18	4.22E-16
	33	1.67E-13	1.41E-13	5.52E-15	6.22E-17	2.00E-14
	34	9.01E-15	7.61E-15	2.98E-16	3.36E-18	1.08E-15

Table S-3. Predicted Unitized Concentration (Chi/Q) and Relative Deposition (D/Q) for Selected Receptors from Proposed GLE Facility Operation Air Emissions

Receptor Location	Direction From Proposed GLE Facility	Distance From Proposed GLE Facility	Chi/Q sec/m^3	D/Q 1/m^2
Highest on-site impact	NE	0.25 mi (0.4 km)	1.3E-06	1.9E-08
Highest off-site impact (fenceline)	NE	0.3 mi (0.5 km)	1.3E-06	1.6E-08
Nearest resident[a]	ESE	0.9 mi (1.5 km)	2.7E-07	1.3E-09
Writesboro Elementary School	SSE	3.4 mi (5.4 km)	2.1E-07	1.8E-10
Emma B. Trask Middle School	ESE	4.7 mi (7.5 km)	9E-08	9.9E-11
Emsley A. Laney High School	SE	5.2 mi (0.4 km)	9.6E-08	9.3E-11
New Hanover Regional Medical Center	S	9.0 mi (14.5 km)	1.9E-07	1.1E-10
Pender Memorial Hospital	N	14.9 mi (24.0 km)	6.9E-08	4.4E-11
Brunswick Community Hospital[a]	SW	29.8 mi (48.0 km)	2.0E-08	1.3E-11

[a] Not specified in model as a discrete receptor. Value calculated using geographic information systems (i.e., GIS) spatial averaging techniques.

Table S-4. Predicted Unitized Concentration (Chi/Q) for Receptors Close to the Proposed GLE Facility (< 5 miles)

NO DECAY, UNDEPLETED
ANNUAL AVERAGE CHI/Q (SEC/METER CUBED) DISTANCE IN MILES FROM THE SITE

SECTOR	.250	.500	.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
S	1.206E-06	9.578E-07	8.763E-07	8.957E-07	8.545E-07	7.513E-07	6.493E-07	5.630E-07	4.925E-07	4.351E-07	3.880E-07
SSW	1.082E-06	8.107E-07	6.245E-07	5.345E-07	4.216E-07	3.411E-07	2.819E-07	2.377E-07	2.040E-07	1.777E-07	1.568E-07
SW	9.261E-07	7.319E-07	5.948E-07	5.358E-07	4.486E-07	3.735E-07	3.137E-07	2.672E-07	2.310E-07	2.023E-07	1.792E-07
WSW	6.122E-07	4.990E-07	4.484E-07	4.457E-07	4.133E-07	3.595E-07	3.090E-07	2.671E-07	2.332E-07	2.057E-07	1.832E-07
W	7.466E-07	5.516E-07	5.176E-07	5.562E-07	5.584E-07	5.012E-07	4.378E-07	3.821E-07	3.357E-07	2.975E-07	2.659E-07
WNW	5.178E-07	3.550E-07	3.300E-07	3.571E-07	3.622E-07	3.266E-07	2.861E-07	2.501E-07	2.200E-07	1.952E-07	1.746E-07
NW	6.104E-07	4.200E-07	3.758E-07	3.915E-07	3.844E-07	3.429E-07	2.988E-07	2.604E-07	2.286E-07	2.025E-07	1.809E-07
NNW	6.656E-07	4.648E-07	3.917E-07	3.816E-07	3.515E-07	3.057E-07	2.630E-07	2.274E-07	1.986E-07	1.752E-07	1.561E-07
N	9.495E-07	7.537E-07	6.626E-07	6.477E-07	5.920E-07	5.121E-07	4.391E-07	3.789E-07	3.304E-07	2.913E-07	2.593E-07
NNE	1.091E-06	8.064E-07	6.561E-07	6.080E-07	5.304E-07	4.506E-07	3.828E-07	3.286E-07	2.855E-07	2.510E-07	2.231E-07
NE	1.328E-06	9.797E-07	7.858E-07	7.065E-07	5.927E-07	4.943E-07	4.156E-07	3.544E-07	3.065E-07	2.686E-07	2.380E-07
ENE	1.057E-06	7.642E-07	6.407E-07	5.921E-07	5.076E-07	4.265E-07	3.599E-07	3.075E-07	2.664E-07	2.337E-07	2.072E-07
E	1.031E-06	7.092E-07	5.869E-07	5.444E-07	4.710E-07	3.979E-07	3.368E-07	2.884E-07	2.501E-07	2.196E-07	1.949E-07
ESE	5.752E-07	3.837E-07	2.991E-07	2.696E-07	2.292E-07	1.924E-07	1.624E-07	1.388E-07	1.202E-07	1.054E-07	9.349E-08
SE	5.880E-07	4.190E-07	3.378E-07	3.110E-07	2.690E-07	2.273E-07	1.924E-07	1.647E-07	1.428E-07	1.254E-07	1.113E-07
SSE	5.946E-07	4.303E-07	3.777E-07	3.794E-07	3.583E-07	3.141E-07	2.711E-07	2.349E-07	2.054E-07	1.814E-07	1.617E-07

Table S-5. Predicted Unitized Concentration (Chi/Q) for Receptors Far from the Proposed GLE Facility (5 mi – 50 miles)

NO DECAY, UNDEPLETED
ANNUAL AVERAGE CHI/Q (SEC/METER CUBED) DISTANCE IN MILES FROM THE SITE

SECTOR	5.000	7.500	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000
S	3.492E-07	2.273E-07	1.649E-07	1.034E-07	7.372E-08	5.654E-08	4.545E-08	3.776E-08	3.214E-08	2.786E-08	2.452E-08
SSW	1.399E-07	8.874E-08	6.353E-08	3.929E-08	2.782E-08	2.123E-08	1.701E-08	1.409E-08	1.196E-08	1.035E-08	9.092E-09
SW	1.603E-07	1.026E-07	7.379E-08	4.583E-08	3.254E-08	2.489E-08	1.996E-08	1.656E-08	1.407E-08	1.219E-08	1.072E-08
WSW	1.646E-07	1.068E-07	7.728E-08	4.834E-08	3.445E-08	2.641E-08	2.122E-08	1.762E-08	1.500E-08	1.300E-08	1.144E-08
W	2.397E-07	1.569E-07	1.141E-07	7.178E-08	5.129E-08	3.939E-08	3.169E-08	2.634E-08	2.243E-08	1.946E-08	1.713E-08
WNW	1.575E-07	1.032E-07	7.505E-08	4.720E-08	3.373E-08	2.591E-08	2.084E-08	1.733E-08	1.476E-08	1.280E-08	1.127E-08
NW	1.630E-07	1.065E-07	7.733E-08	4.855E-08	3.467E-08	2.661E-08	2.140E-08	1.779E-08	1.515E-08	1.314E-08	1.157E-08
NNW	1.404E-07	9.109E-08	6.595E-08	4.128E-08	2.944E-08	2.258E-08	1.815E-08	1.508E-08	1.283E-08	1.113E-08	9.792E-09
N	2.330E-07	1.509E-07	1.092E-07	6.825E-08	4.860E-08	3.724E-08	2.991E-08	2.483E-08	2.113E-08	1.831E-08	1.611E-08
NNE	2.001E-07	1.290E-07	9.305E-08	5.795E-08	4.117E-08	3.149E-08	2.527E-08	2.096E-08	1.782E-08	1.543E-08	1.357E-08
NE	2.131E-07	1.366E-07	9.822E-08	6.099E-08	4.328E-08	3.308E-08	2.653E-08	2.200E-08	1.870E-08	1.619E-08	1.424E-08
ENE	1.857E-07	1.194E-07	8.601E-08	5.356E-08	3.808E-08	2.915E-08	2.340E-08	1.942E-08	1.652E-08	1.431E-08	1.259E-08
E	1.747E-07	1.125E-07	8.108E-08	5.051E-08	3.593E-08	2.751E-08	2.209E-08	1.834E-08	1.560E-08	1.352E-08	1.189E-08
ESE	8.377E-08	5.388E-08	3.885E-08	2.422E-08	1.724E-08	1.321E-08	1.061E-08	8.813E-09	7.498E-09	6.500E-09	5.719E-09
SE	9.979E-08	6.432E-08	4.643E-08	2.898E-08	2.063E-08	1.580E-08	1.269E-08	1.054E-08	8.961E-09	7.767E-09	6.832E-09
SSE	1.455E-07	9.468E-08	6.868E-08	4.307E-08	3.073E-08	2.358E-08	1.895E-08	1.575E-08	1.340E-08	1.162E-08	1.023E-08

Table S-6. Predicted Relative Deposition (D/Q) for Receptors Close to the Proposed GLE Facility (< 5 miles)

********************* RELATIVE DEPOSITION PER UNIT AREA (M**-2) AT FIXED POINTS BY DOWNWIND SECTORS *********************

DIRECTION FROM SITE	DISTANCES IN MILES .25	.50	.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
S	1.774E-08	8.869E-09	4.880E-09	2.922E-09	1.477E-09	9.027E-10	6.148E-10	4.514E-10	3.512E-10	2.865E-10	2.430E-10
SSW	1.509E-08	8.005E-09	4.442E-09	2.652E-09	1.341E-09	8.169E-10	5.538E-10	4.041E-10	3.119E-10	2.520E-10	2.116E-10
SW	1.317E-08	6.787E-09	3.748E-09	2.239E-09	1.131E-09	6.897E-10	4.686E-10	3.432E-10	2.662E-10	2.165E-10	1.830E-10
WSW	9.222E-09	4.491E-09	2.458E-09	1.470E-09	7.415E-10	4.532E-10	3.088E-10	2.270E-10	1.769E-10	1.447E-10	1.230E-10
W	1.183E-08	5.532E-09	3.011E-09	1.804E-09	9.101E-10	5.569E-10	3.794E-10	2.784E-10	2.160E-10	1.755E-10	1.480E-10
WNW	9.125E-09	3.727E-09	1.969E-09	1.172E-09	5.858E-10	3.582E-10	2.443E-10	1.794E-10	1.393E-10	1.132E-10	9.539E-11
NW	1.069E-08	4.339E-09	2.286E-09	1.360E-09	6.783E-10	4.145E-10	2.826E-10	2.077E-10	1.614E-10	1.314E-10	1.109E-10
NNW	1.113E-08	4.770E-09	2.544E-09	1.515E-09	7.583E-10	4.632E-10	3.155E-10	2.315E-10	1.796E-10	1.460E-10	1.231E-10
N	1.405E-08	6.952E-09	3.815E-09	2.280E-09	1.150E-09	7.026E-10	4.784E-10	3.514E-10	2.737E-10	2.238E-10	1.902E-10
NNE	1.514E-08	8.147E-09	4.526E-09	2.699E-09	1.363E-09	8.295E-10	5.621E-10	4.104E-10	3.173E-10	2.570E-10	2.165E-10
NE	1.895E-08	9.444E-09	5.177E-09	3.084E-09	1.552E-09	9.457E-10	6.430E-10	4.720E-10	3.676E-10	3.005E-10	2.557E-10
ENE	1.696E-08	6.918E-09	3.648E-09	2.167E-09	1.081E-09	6.615E-10	4.531E-10	3.360E-10	2.650E-10	2.200E-10	1.901E-10
E	1.718E-08	7.134E-09	3.774E-09	2.242E-09	1.118E-09	6.828E-10	4.660E-10	3.434E-10	2.684E-10	2.202E-10	1.877E-10
ESE	9.228E-09	4.045E-09	2.167E-09	1.291E-09	6.467E-10	3.949E-10	2.687E-10	1.970E-10	1.526E-10	1.237E-10	1.041E-10
SE	8.568E-09	4.088E-09	2.228E-09	1.331E-09	6.703E-10	4.095E-10	2.788E-10	2.046E-10	1.591E-10	1.297E-10	1.098E-10
SSE	9.038E-09	4.324E-09	2.360E-09	1.411E-09	7.118E-10	4.350E-10	2.960E-10	2.169E-10	1.682E-10	1.365E-10	1.151E-10

Table S-7. Predicted Relative Deposition (D/Q) for Receptors Far from the Proposed GLE Facility (5 mi – 50 miles)

********************* RELATIVE DEPOSITION PER UNIT AREA (M**-2) AT FIXED POINTS BY DOWNWIND SECTORS *********************

DIRECTION FROM SITE	5.00	7.50	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00
	DISTANCES IN MILES										
S	2.136E-10	1.318E-10	9.392E-11	5.516E-11	3.544E-11	2.411E-11	1.746E-11	1.323E-11	1.039E-11	8.413E-12	6.972E-12
SSW	1.843E-10	1.100E-10	7.699E-11	4.444E-11	2.836E-11	1.923E-11	1.387E-11	1.047E-11	8.182E-12	6.595E-12	5.434E-12
SW	1.604E-10	9.810E-11	6.955E-11	4.064E-11	2.605E-11	1.768E-11	1.276E-11	9.642E-12	7.539E-12	6.081E-12	5.015E-12
WSW	1.084E-10	6.744E-11	4.826E-11	2.847E-11	1.832E-11	1.247E-11	9.031E-12	6.844E-12	5.368E-12	4.345E-12	3.597E-12
W	1.292E-10	7.759E-11	5.450E-11	3.170E-11	2.042E-11	1.400E-11	1.022E-11	7.812E-12	6.175E-12	5.036E-12	4.200E-12
WNW	8.302E-11	4.931E-11	3.446E-11	2.005E-11	1.304E-11	9.035E-12	6.665E-12	5.147E-12	4.095E-12	3.364E-12	2.821E-12
NW	9.673E-11	5.788E-11	4.062E-11	2.373E-11	1.544E-11	1.069E-11	7.877E-12	6.073E-12	4.824E-12	3.955E-12	3.310E-12
NNW	1.073E-10	6.412E-11	4.495E-11	2.618E-11	1.696E-11	1.169E-11	8.575E-12	6.578E-12	5.204E-12	4.248E-12	3.540E-12
N	1.677E-10	1.045E-10	7.487E-11	4.416E-11	2.839E-11	1.928E-11	1.393E-11	1.053E-11	8.244E-12	6.660E-12	5.504E-12
NNE	1.893E-10	1.146E-10	8.085E-11	4.696E-11	2.998E-11	2.029E-11	1.462E-11	1.102E-11	8.610E-12	6.939E-12	5.722E-12
NE	2.258E-10	1.414E-10	1.016E-10	6.004E-11	3.858E-11	2.616E-11	1.885E-11	1.422E-11	1.109E-11	8.931E-12	7.352E-12
ENE	1.699E-10	1.108E-10	8.132E-11	4.913E-11	3.196E-11	2.184E-11	1.584E-11	1.201E-11	9.405E-12	7.604E-12	6.279E-12
E	1.655E-10	1.031E-10	7.392E-11	4.387E-11	2.850E-11	1.957E-11	1.427E-11	1.089E-11	8.564E-12	6.955E-12	5.766E-12
ESE	9.052E-11	5.367E-11	3.746E-11	2.172E-11	1.405E-11	9.683E-12	7.096E-12	5.437E-12	4.295E-12	3.500E-12	2.910E-12
SE	9.637E-11	5.905E-11	4.193E-11	2.459E-11	1.583E-11	1.079E-11	7.828E-12	5.938E-12	4.657E-12	3.769E-12	3.116E-12
SSE	1.005E-10	6.046E-11	4.250E-11	2.472E-11	1.590E-11	1.087E-11	7.908E-12	6.025E-12	4.745E-12	3.856E-12	3.204E-12

Figures

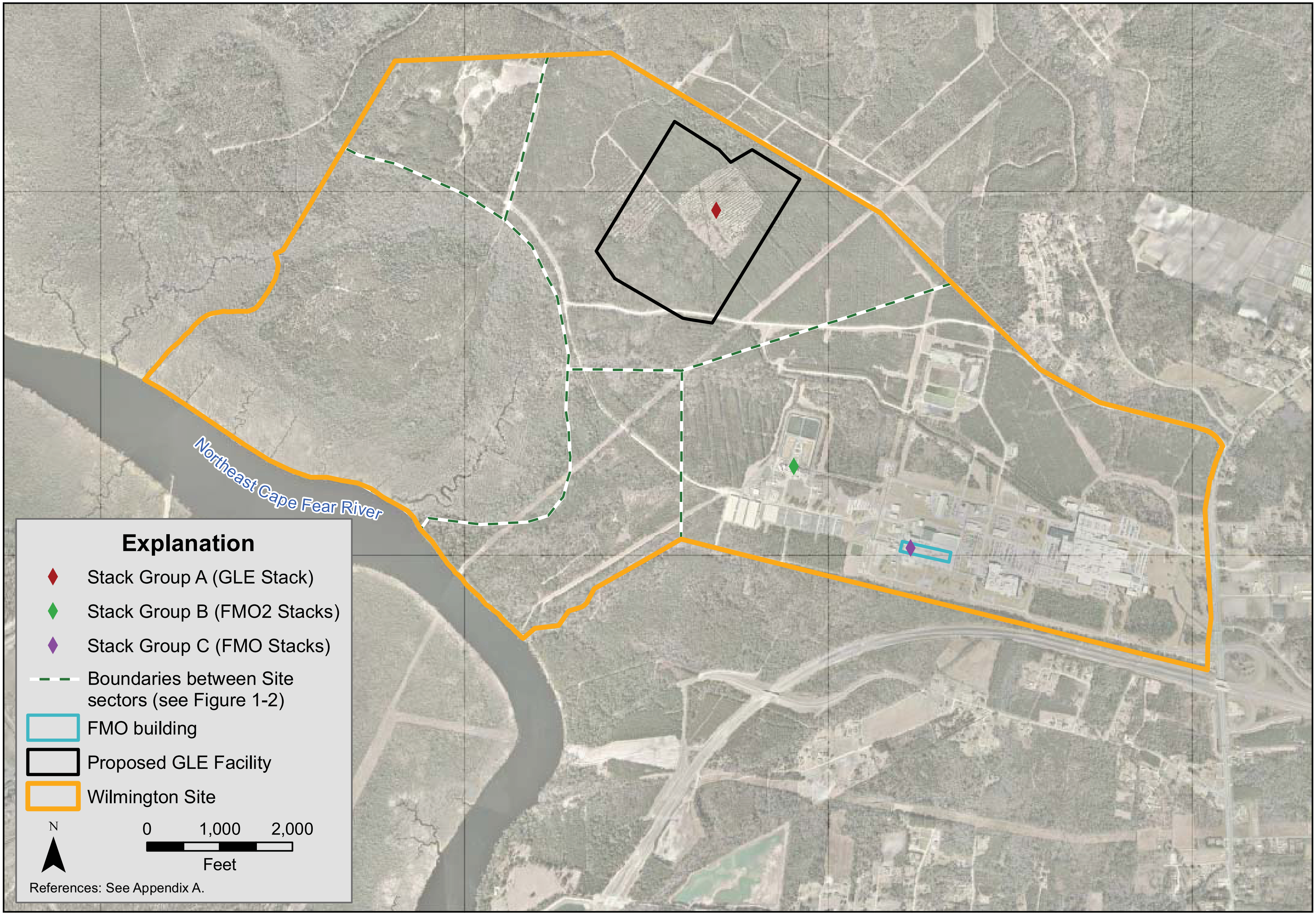

Figure S-1. Approximate relative location of stack groups used in XOQDOQ modeling.

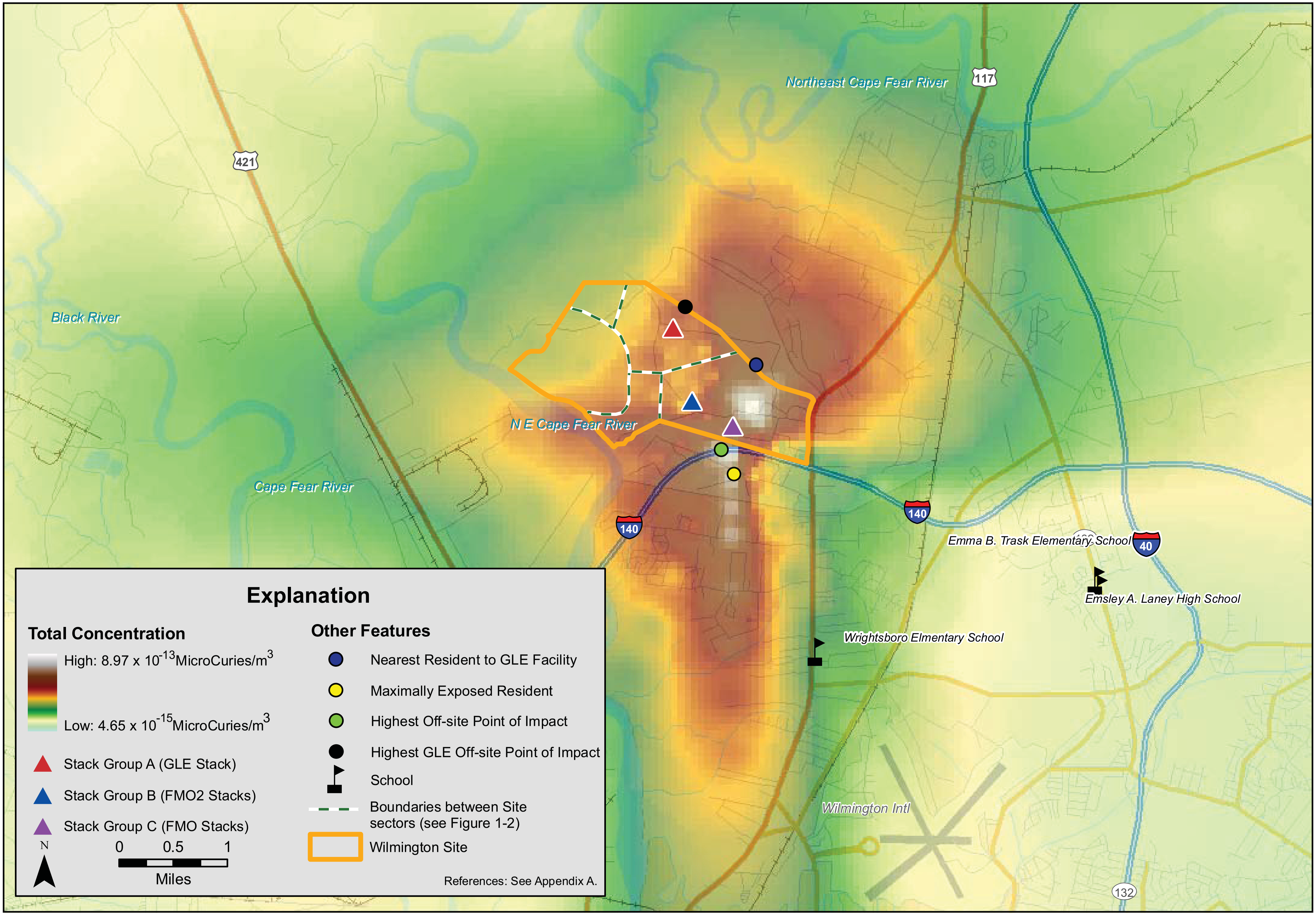

Figure S-2. Annual average concentration of radioisotopes from all stacks at the Wilmington Site.

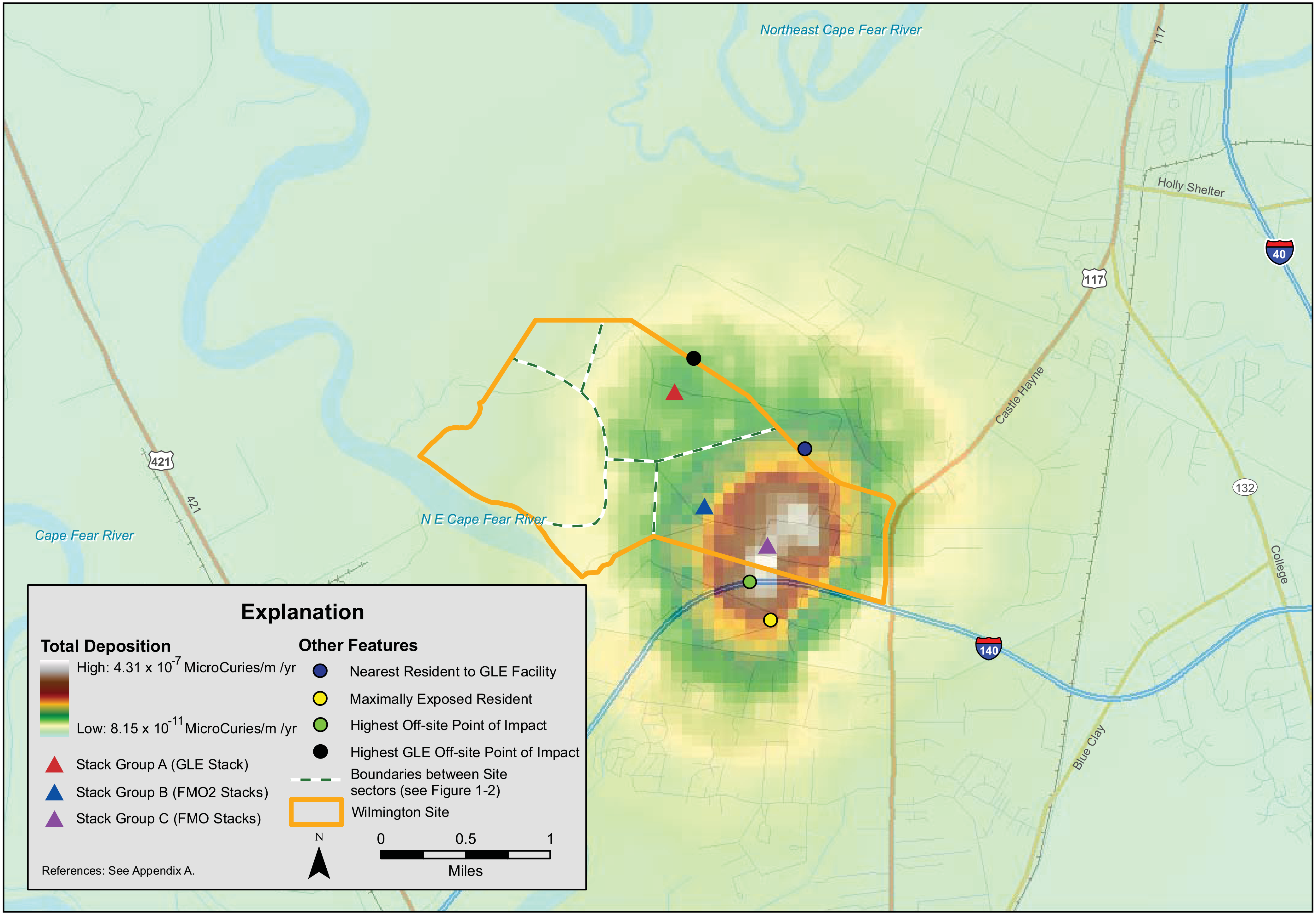

Figure S-3. Annual deposition rate of radioisotopes from all stacks at the Wilmington Site.

Appendix T

Facility-Specific Data Input and Assumptions Required for the Cadna/A® Noise Model

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Appendix T

Facility-Specific Data Input and Assumptions Required for the Cadna/A® Noise Model

T.1 Geometry Elements

- Topography: Acquired for New Hanover County. The site was slightly modified to represent the flat terrain where the Proposed GLE Facility would be located.
- Existing Buildings: Determined from aerial photos and observations during site visit.
- Future Buildings (used only in study of Facility Operations): Acquired from proposed site plan.

T.2 Road Construction Noise Sources

- Dozers: 4 per day
- Graders: 2 per day
- Loader: 4 per day
- Rollers: 2 per day
- Excavator: 1 per day
- Water Truck: 1 per day

These sources were positioned on the plan for the North Road portion of the GLE Study Area, which includes a proposed new road segment, and defined as a moving source with a speed of 1 mile per hour to represent road-building operations. The source levels for the construction equipment (built circa 1995) were based on sound levels measured from construction equipment outfitted with standard muffler and noise-control devices (no special noise control was considered). The source level for the water truck was based on the sound levels obtained from the Federal Highway Administration Traffic Noise Model® (FHWA TNM®) program (Federal Highway Administration, 1998). The operating hours of these sources were defined between 7 a.m. and 6 p.m.

T.3 Site Preparation Noise Sources

- Dozers: 4 per day
- Graders: 2 per day
- Loader: 4 per day
- Rollers: 2 per day
- Excavator: 1 per day
- Water truck: 1 per day
- Passenger vehicles: 375 per day
- Hauling vehicles: 35 per day

The heavy construction sources were positioned around the GLE Study Area in static locations to represent the average locations where this equipment may be during GLE Facility site preparation operations. The vehicles (i.e., hauling trucks and passenger vehicles) were located in the model along the

line of the new road segment in the North Road portion of the GLE Study Area. The source levels for the construction equipment were based on sound levels measured from construction equipment (built circa 1995) outfitted with standard muffler and noise-control devices (no special noise control was considered). The source levels for the water truck, hauling trucks, and passenger vehicles were based on the sound levels obtained from FHWA TNM program (Federal Highway Administration, 1998). The operating hours of these sources were defined between 7 a.m. and 6 p.m.

T.4 Facility Operations Noise Sources

- Passenger vehicles: 375 per day
- Hauling vehicles: 6 per day
- Cylinder hauling vehicles dedicated to Proposed GLE Facility: 4 per day
- Hauling vehicles using the western connector to existing facility: 2 per day
- Air handling units: 4
- Scrubber exhaust[a]: 1
- Cooling tower: 2
- Heat pumps: 2 per service building (6 total)
- Pump/lift station (25 horsepower [hp]): 2
- Electrical substation (60,000 kilovolt-amperes [kVA]): 1

The hauling vehicles and passenger vehicles were located in the model along the line of the new road segment. The hauling vehicles dedicated to the Facility were located to the southwest of the Facility for moving cylinders. The hauling vehicles using the existing south road that will connect the Proposed GLE Facility to the existing Wilmington Site facilities were located along this access road. The source levels for the hauling trucks and passenger vehicles were based on the sound levels obtained from FHWA TNM program (Federal Highway Administration, 1998). The operating hours of the passenger vehicle sources were defined to be spread evenly over a 24-hour period. The operating hours of all the hauling vehicles sources were defined with 90% of traffic occurring during daytime hours and 10% occurring during evening hours.

The air handling units, scrubber exhaust[a], and cooling towers are located on the rooftop of the proposed GLE operations building. Heat pumps are located on each of the service buildings. The two pump/lift stations and electrical substation are positioned to the southeast of the Proposed GLE Facility, near the vehicular entrance. All of this equipment is modeled as operating for 24 hours per day. The source levels of the pumps were estimated based on the horsepower of the pump motor (Hoover and Keith, 1996). The sound levels of the transformer were based on this being an outdoor, forced-air-cooled, immersed oil transformer of standard design with a capacity of 60,000 kVA (Ver and Anderson, 1977; National Electrical Manufacturers Association, 2000).

[a] Although scrubber exhaust noise was considered in this impacts assessment, the scrubber subsequently was removed from the Proposed GLE Facility design. Therefore, this is a conservative assessment of noise impacts from the operations phase of the Proposed Action.

Appendix U

Private Benefits and Costs of Proposed GLE Facility

GLE Proprietary Information

Withhold from Public Disclosure per 10 CFR 2.390

Revision 0

December 2008