*Introduction*

This analysis is of hurricane storm surge flooding potential focuses on Brunswick, New Hanover and Pender counties (the region) in the Southeast coastal corner of North Carolina. Exhibit 12 details the hurricanes that have made landfall in North Carolina since 1857. In summary, North Carolina has been stuck by 48 hurricanes since 1857. These storms included twelve Category 1, eight Category 2, eighteen Category 3, eight Category 4 and two Category 5 classified tropical cyclones. According to the State Climate Office of North Carolina...

> "North Carolina has a long and notorious history of destruction by hurricanes. Ever since the first expeditions to Roanoke Island in 1586, hurricanes are recorded to have caused tremendous damage to the state. Reliable classification of the intensity of tropical cyclones began in 1886. Since that time, there have been 951 tropical cyclones that have been recorded in the Atlantic Ocean and the Gulf of Mexico. Approximately 166 or 17.5% of those tropical cyclones passed within 300 miles of North Carolina. The coast of North Carolina can expect to receive a tropical storm or a hurricane once every four years, while a tropical cyclone affects the state every 1.3 years."

The region has a very diverse mix of agriculture, suburban, urban and recreational land use. This analysis uses both state and national geospatial data sets and ESRI software to conduct an analysis of slow moving hurricane coastal surge potential. The investigation is focused on categorizing affected land cover and population for Category 1 and 2, Category 3 and Category 4 and Category 5 slow moving hurricanes. In addition, potential shelters are identified and capacity calculated.

As this is a regional overview, all maps depicting the spatial relationships of storm surge, population shelters and land cover are provided at a 1:500,000 scale using NAD 1983 State Plane North Carolina FIPS 3200 for projection and Datum North American 1983 for elevation.

Please be aware that all data can be used for more specific local areas of interest. The data can also be applied to further questions such as evacuation routes, storm surge mitigation and disaster planning.

This data provides the basic examination of location, population and land cover that can be affected slow moving hurricanes and provides the base for further detailed analysis.

*Regional Geography – Elevation, Population and Elevation*

The elevation of the region ranges from sea level to 90 meters above sea level. The elevation profile of the region is shown in Exhibit 3. Of note is the very high percentage of land that is 0 to seven meters in elevation reflecting the coastal nature of the region.

| *ELEVATION (METERS)* | *PERCENT OF TOTAL* |
|---|---|
| 0 - 3 | 18.26% |
| 3 - 7 | 19.28% |
| 7 - 10 | 15.56% |
| 10 - 14 | 19.34% |
| 14 - 17 | 13.81% |
| 17 - 20 | 11.18% |
| 20 - 23 | 2.19% |
| 23 - 90 | 0.37% |

The region has the following characteristics for land cover. Land cover for the region is graphically shown in Exhibit 1. In summary 8.5% of total land cover or 187 square kilometers are classified as developed (open, low medium and high intensity). 72% of the land cover can be grouped into non-developed (water, forest, wetlands, shrub, etc.).

| *LAND COVER TYPE* | *PERCENT* | *SQUARE KILOMETERS* |
|---|---|---|
| Open Water | 3.97% | 87.64 |
| Developed- Open Space | 4.35% | 96.00 |
| Developed- Low Intensity | 3.21% | 70.84 |
| Developed- Medium Intensity | 0.77% | 16.91 |
| Developed- High Intensity | 0.18% | 3.97 |
| Barren Land (Rock/Sand/Clay) | 0.54% | 11.93 |
| Deciduous Forest | 0.83% | 18.23 |
| Evergreen Forest | 25.95% | 572.48 |

| | | |
|---|---|---|
| Mixed Forest | 1.65% | 36.44 |
| Shrub/Scrub | 4.15% | 91.62 |
| Grassland/Herbaceous | 10.01% | 220.84 |
| Pasture/Hay | 0.42% | 9.29 |
| Cultivated Crops | 8.86% | 195.54 |
| Woody Wetlands | 31.45% | 693.75 |
| Emergent Herbaceous Wetlands | 3.65% | 80.52 |
| Total | 100.00% | 2206.00 |

Using the TIGER 2000 census blocks, the region has a total population of 276,545 persons in 115,443 households. Exhibit 2 classifies the distribution and location of the region's population.

*Land Cover Strom Surge Analysis*

The following table shows the land cover affected by the three categories of storm surge. Exhibits 5, 6 and 7 illustrate the progression of surge by storm category and land cover affected. In summary, 38 Square kilometers or 20% of the total of developed land cover (open, low medium and high intensity) could be affected by category 4 and 5 storm. For a category 1 and 2 storms, 4.73 square kilometers or 2.5% of total developed would be affected by surge. For a category 3 storm, 20.14 square kilometers or 10% of the total developed land cover could be inundated by storm surge. For the purposes of this effort all developed land was symbolized in a similar manner.

| | ***CATEGORY 1 AND 2*** | | ***CATEGORY 3*** | | ***CATEGORY 4 AND 5*** | |
|---|---|---|---|---|---|---|
| ***LAND COVER AFFECTED*** | ***PERCENT*** | ***SQUARE KILOMETERS*** | ***PERCENT*** | ***SQUARE KILOMETERS*** | ***PERCENT*** | ***SQUARE KILOMETERS*** |
| Open Water | 10.57% | 7.01 | 8.03% | 18.45 | 5.97% | 20.91 |
| Developed- Open Space | 2.58% | 1.71 | 3.39% | 7.80 | 4.72% | 16.52 |
| Developed- Low Intensity | 3.26% | 2.16 | 3.82% | 8.79 | 4.68% | 16.39 |
| Developed- Medium Intensity | 1.12% | 0.74 | 1.29% | 2.96 | 1.23% | 4.32 |
| Developed- High Intensity | 0.18% | 0.12 | 0.26% | 0.59 | 0.24% | 0.83 |
| Barren Land (Rock/Sand/Clay) | 3.81% | 2.53 | 3.13% | 7.20 | 2.49% | 8.72 |
| Deciduous Forest | 0.32% | 0.21 | 0.53% | 1.21 | 0.88% | 3.08 |
| Evergreen Forest | 5.15% | 3.42 | 7.90% | 18.15 | 12.08% | 42.33 |

| | CATEGORY 1 AND 2 | | CATEGORY 3 | | CATEGORY 4 AND 5 | |
|---|---|---|---|---|---|---|
| LAND COVER AFFECTED | PERCENT | SQUARE KILOMETERS | PERCENT | SQUARE KILOMETERS | PERCENT | SQUARE KILOMETERS |
| Mixed Forest | 0.57% | 0.38 | 0.88% | 2.02 | 1.44% | 5.03 |
| Shrub/Scrub | 0.97% | 0.64 | 1.29% | 2.96 | 2.01% | 7.04 |
| Grassland/Herbaceous | 3.02% | 2.00 | 3.87% | 8.90 | 5.29% | 18.52 |
| Pasture/Hay | 0.11% | 0.07 | 0.19% | 0.43 | 0.26% | 0.92 |
| Cultivated Crops | 0.80% | 0.53 | 1.42% | 3.25 | 2.54% | 8.90 |
| Woody Wetlands | 34.36% | 22.79 | 39.25% | 90.22 | 37.71% | 132.11 |
| Emergent Herbaceous Wetlands | 33.18% | 22.01 | 24.77% | 56.93 | 18.48% | 64.73 |
| TOTAL | | 66.33 | | 229.87 | | 350.35 |

*Population Storm Surge Analysis of Population*

The following table summarizes the households and population affected by the three categories of storm surge. Exhibits 8, 9 and 10 show the progression of surge by storm category and persons affected by census block.

| | CATEGORY 1 AND 2 | CATEGORY 3 | CATEGORY 4 AND 5 |
|---|---|---|---|
| Total Persons Affected | 28,656 | 44,868 | 68,587 |
| Total Households Affected | 12,617 | 19,519 | 29,484 |

*Shelter Capacity and Locations*

Exhibit 11 details shelter capacity and location. In summary, there are 61 shelters available with a total capacity of approximately 20,000 people.

*Analysis Methods*

A combination of vector and raster data were used in this analysis and the high level steps are described below.

1. All vector and raster data were masked to reflect the three county area.

2. National Elevation Data (NED) were merged to create a regional hillshade relief used to provide an overlay foundation.

4. Census blocks data were symbolized to reflect population density.

5. Land cover types affected by storm surge were extracted by storm category masks.

6. Population affected by storm surge determined and selected by location (block centroid in flood area).

7. Any shelter in any storm surge site was removed by location.

8. All calculations of percentages, areas, totals were performed on feature and raster attribute tables.

*Analysis Exhibits*

The following table depicts the geospatial relationship exhibits or maps produced by this analysis.

| ***Map*** | ***Exhibit No.*** |
|---|---|
| Total Regional Land Cover | Exhibit 1 |
| Total Regional Population | Exhibit 2 |
| Regional Elevation Profile | Exhibit 3 |
| Storm Surge by Storm Category | Exhibit 4 |
| Land Cover affected by Category 1 and 2 Storms | Exhibit 5 |
| Land Cover affected by Category 3 Storm | Exhibit 6 |
| Land Cover affected by Category 4 and 5 Storms | Exhibit 7 |
| Population affected by Category 1 and 2 Storms | Exhibit 8 |
| Population affected by Category 3 Storm | Exhibit 9 |
| Population affected by Category 4 and 5 Storms | Exhibit 10 |
| Shelter Locations and Capacity | Exhibit 11 |
| Historical Hurricane Landfalls in North Carolina | Exhibit 12 |

*Conclusions*

This high level analysis illustrates the key following facts when regional geography is combined with the geospatial relationships of population, land cover, shelters and storm surge that should be of concern to disaster planning and mitigation.

1. Even for a Category 1 and 2 storms there is not enough shelter capacity available in the region. Capacity is short by 8,000 persons and woefully short for Category 3, 4 and 5 storms.

2. Category 3, 4 and 5 storms can affect 10% to 20% of developed land cover due to the coastal location of developed land.

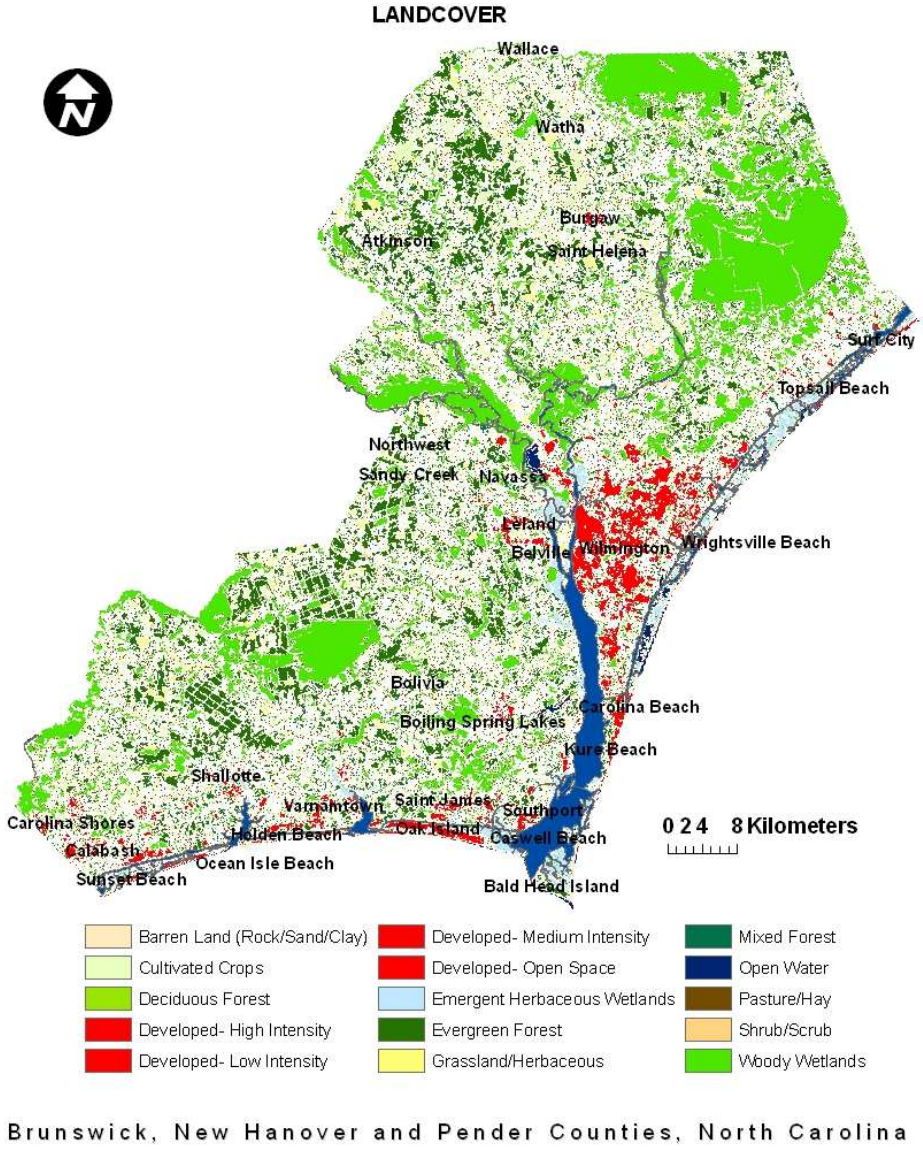
3. Only 2.5% of developed land cover yet 10% of the population can be affected by Category 1 and 2 storm surge.

4. 16% of the population can be affected by Category 3 storm surge.

5. 25% of the population can be affected by Category 4 and 5 storm surge.

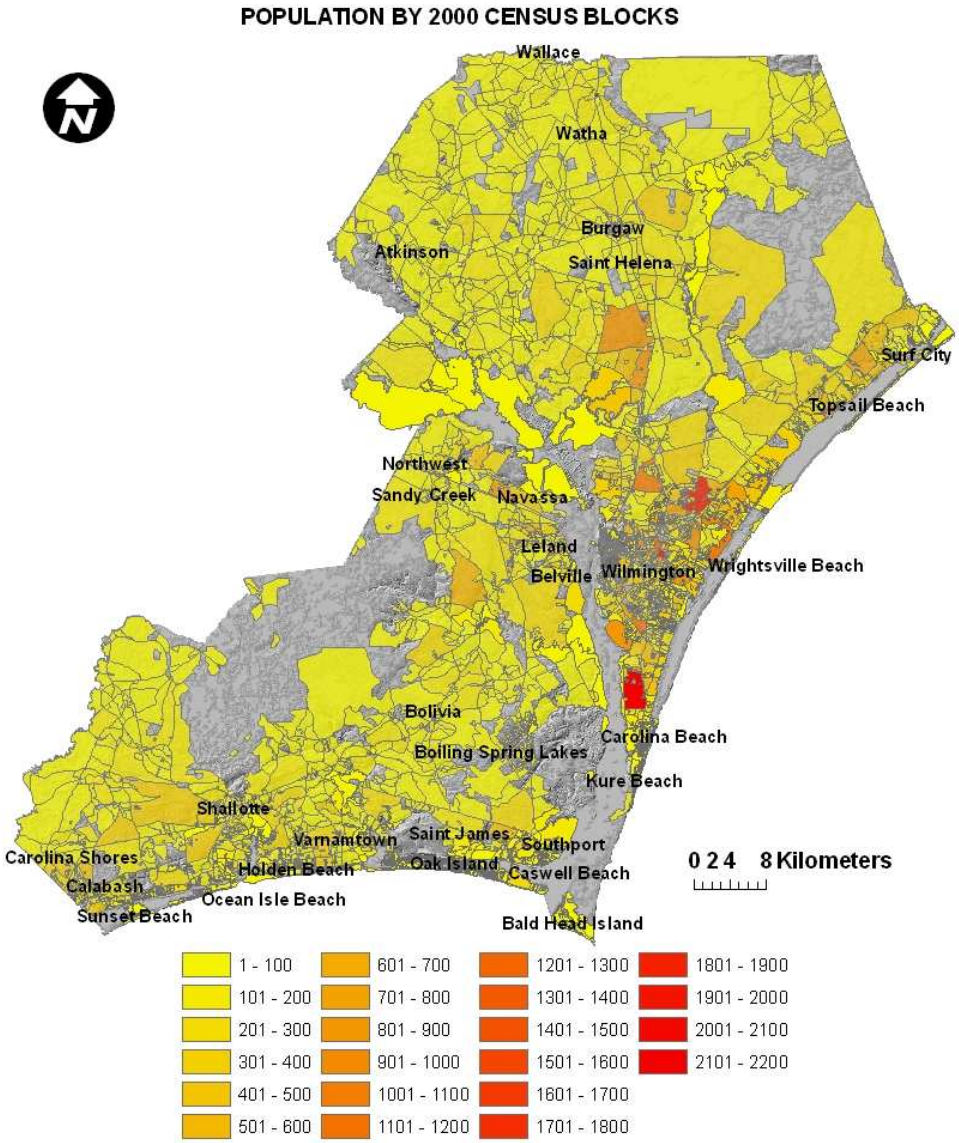
6. 28 of the 48 hurricanes that have hit the North Carolina coast since 1857 have been Category 3 or higher.

## EXHIBIT 1 – Regional Characteristics Land Cover of the Region



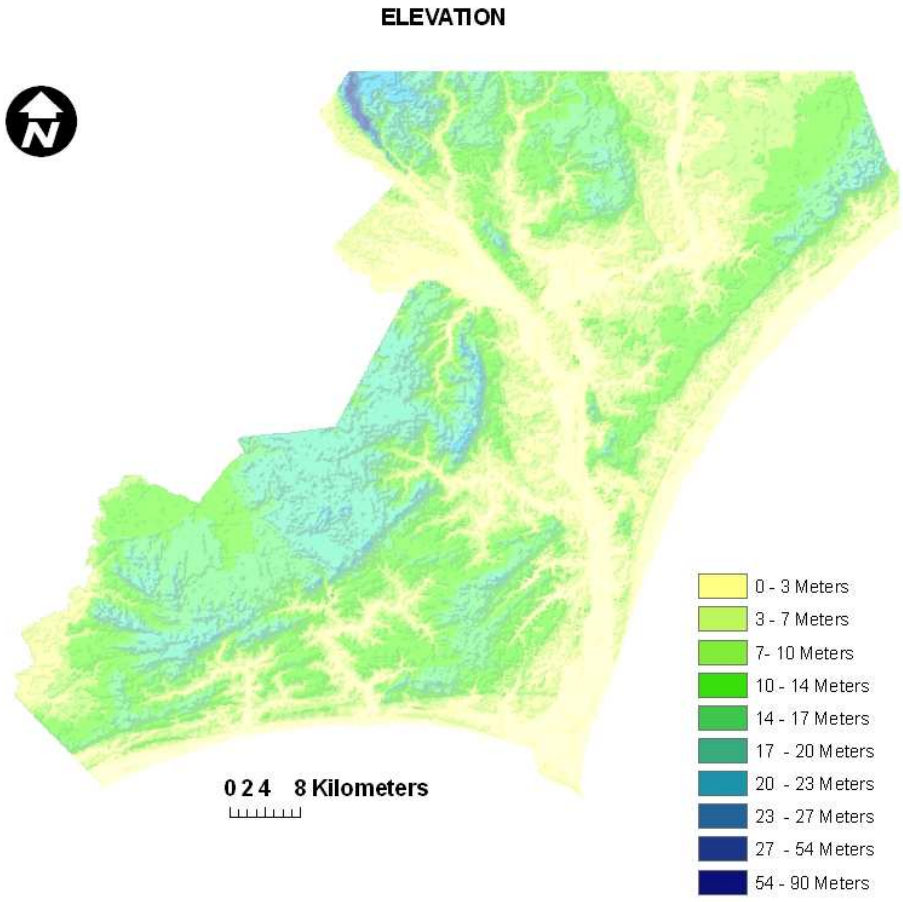

Brunswick, New Hanover and Pender Counties, North Carolina

## EXHIBIT 2 – Regional Characteristics Population of the Region



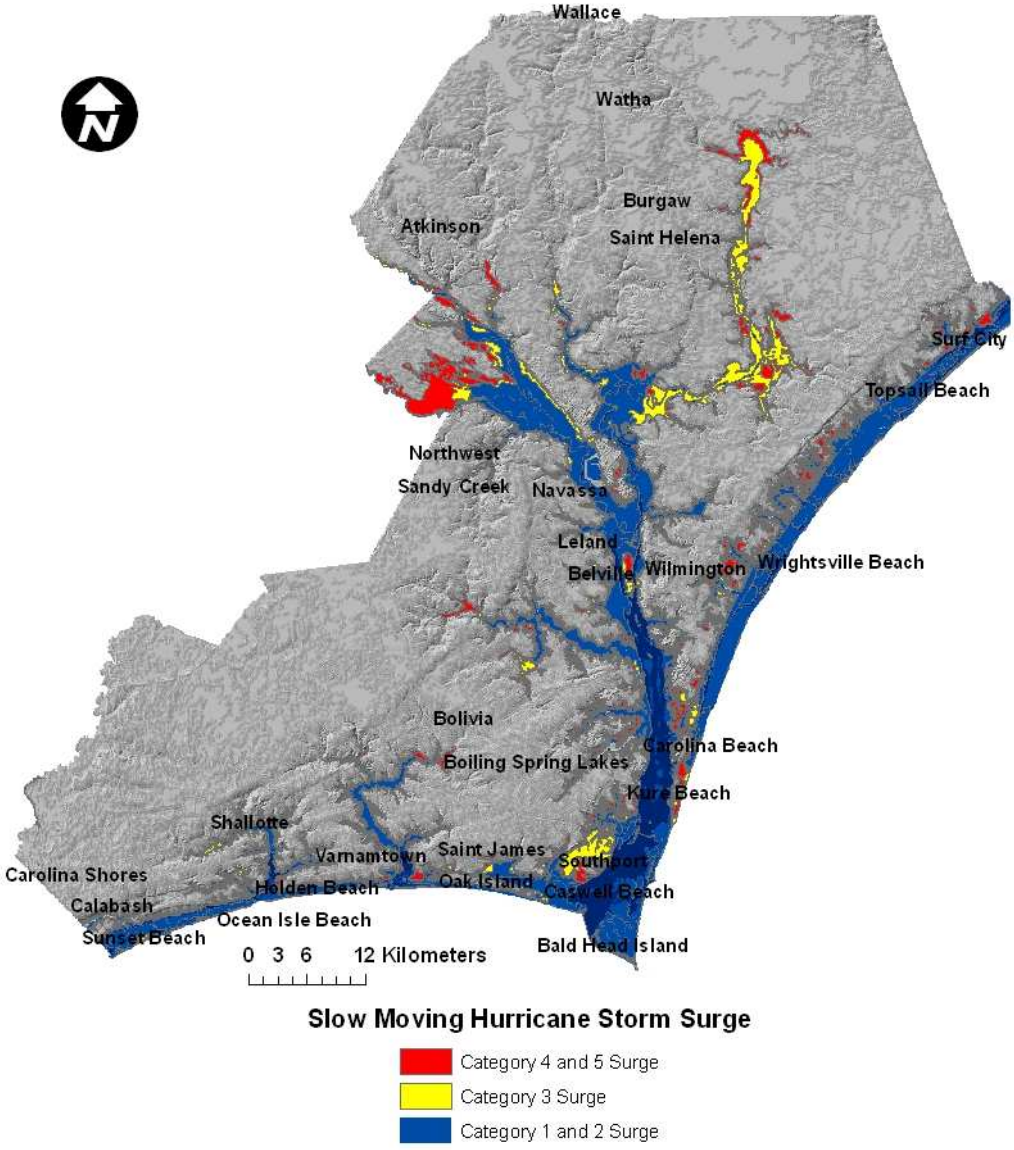

Brunswick, New Hanover and Pender Counties, North Carolina

## EXHIBIT 3 – Regional Characteristics Elevation Profile of the Region



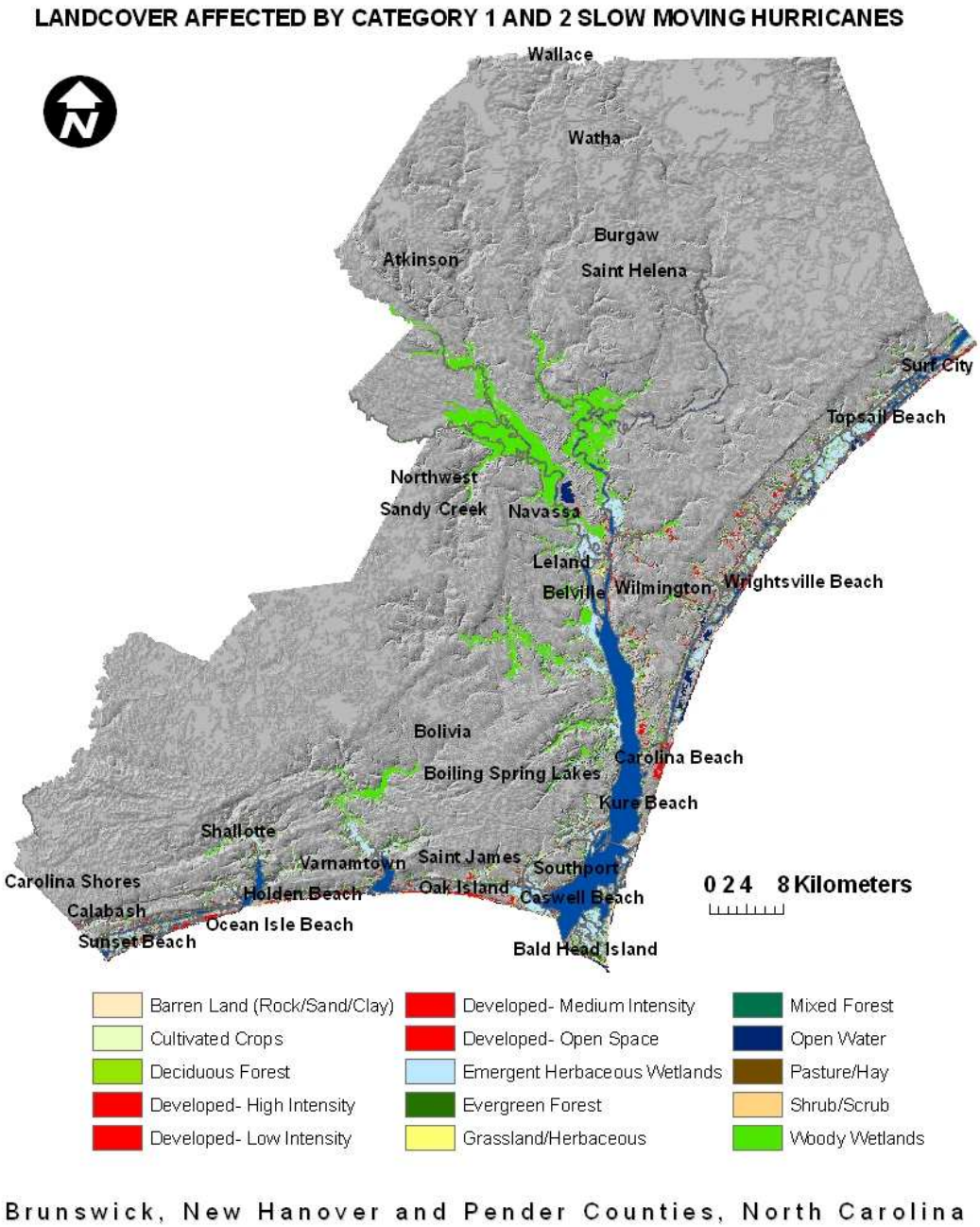

Brunswick, New Hanover and Pender Counties, North Carolina

## EXHIBIT 4 – Storm Surge



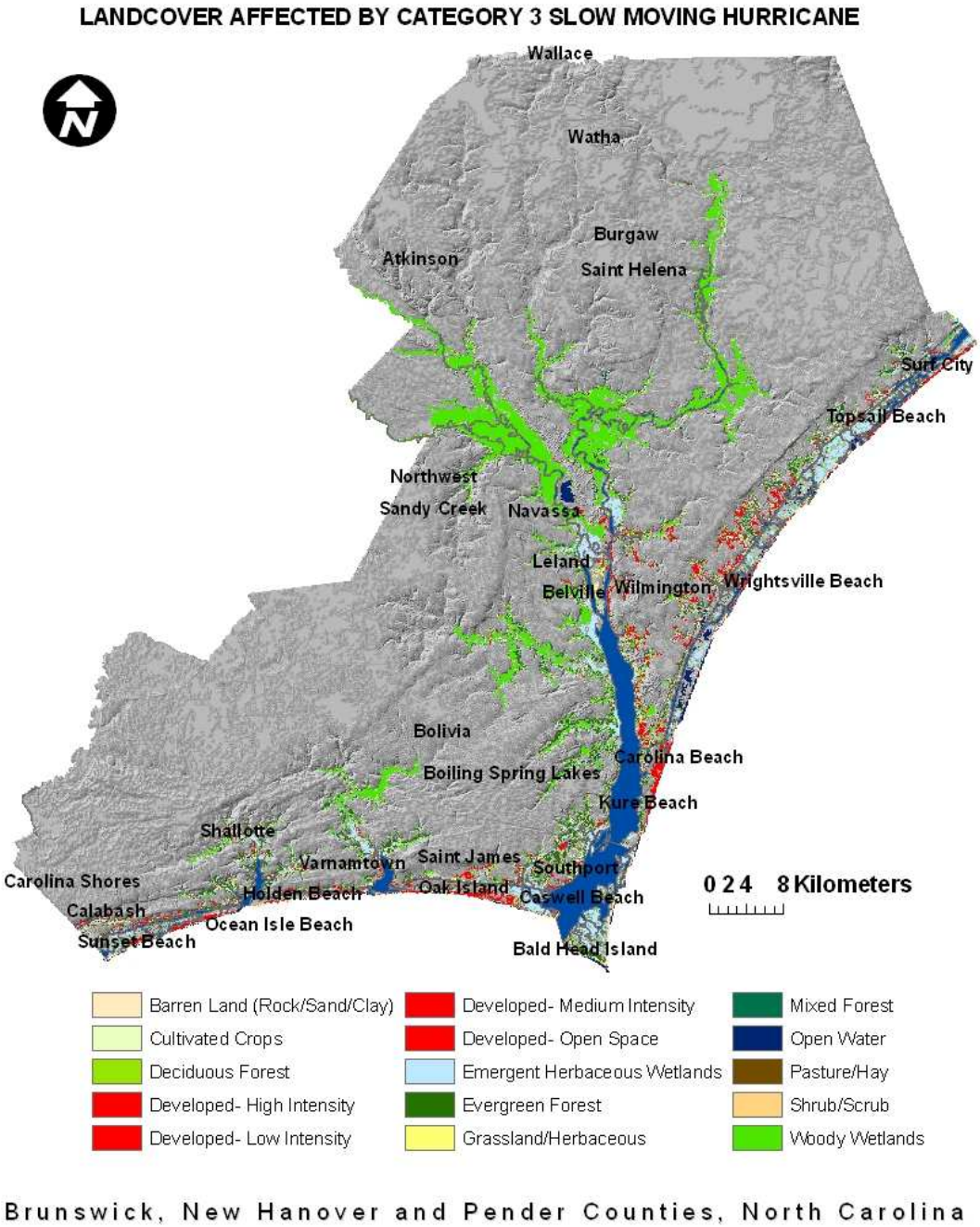

Brunswick, New Hanover and Pender Counties, North Carolina

**EXHIBIT 5 – Land Cover affected by Category 1 and 2 Storm Surge**



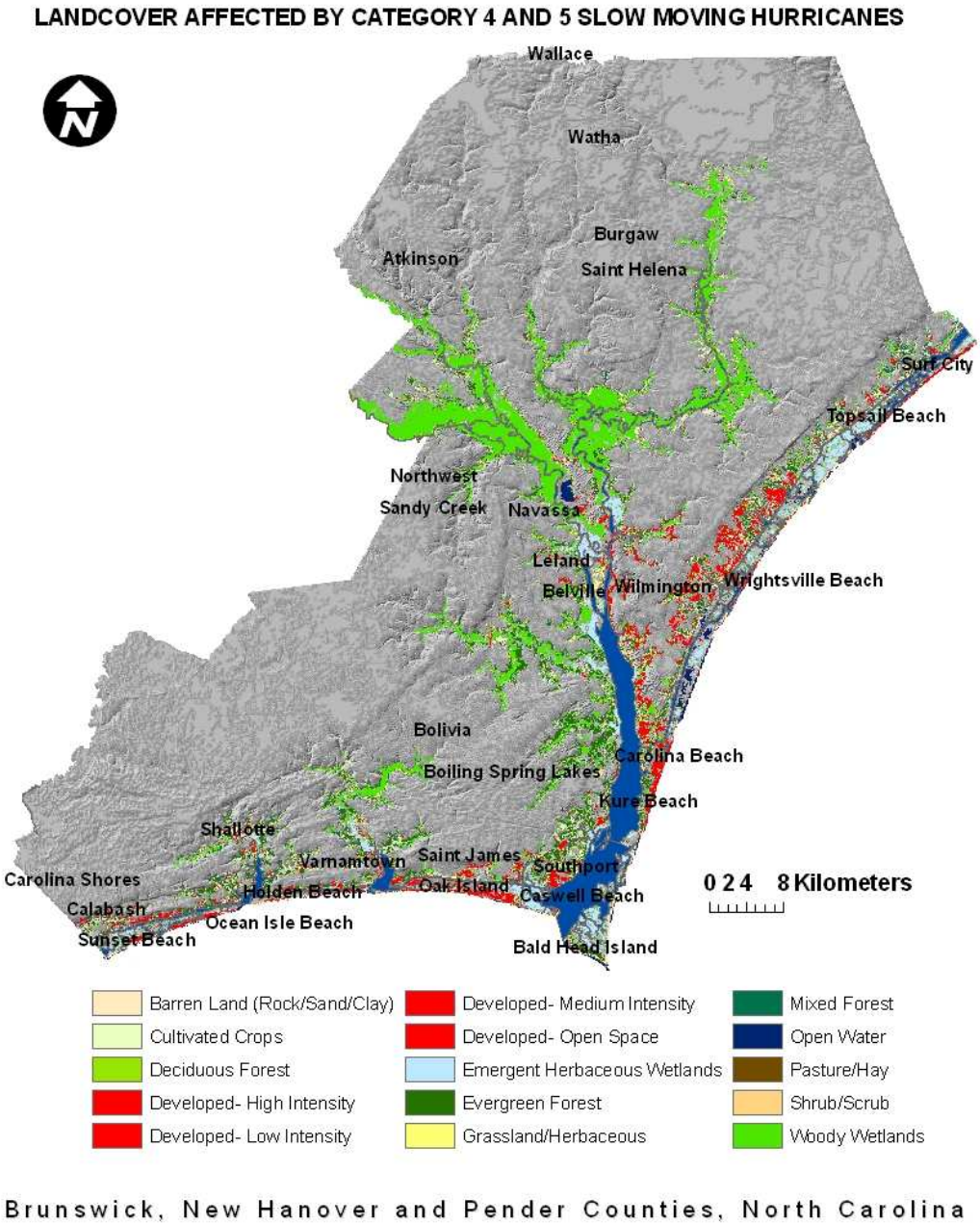

Brunswick, New Hanover and Pender Counties, North Carolina

**EXHIBIT 6 – Land Cover affected by Category 3 Storm Surge**



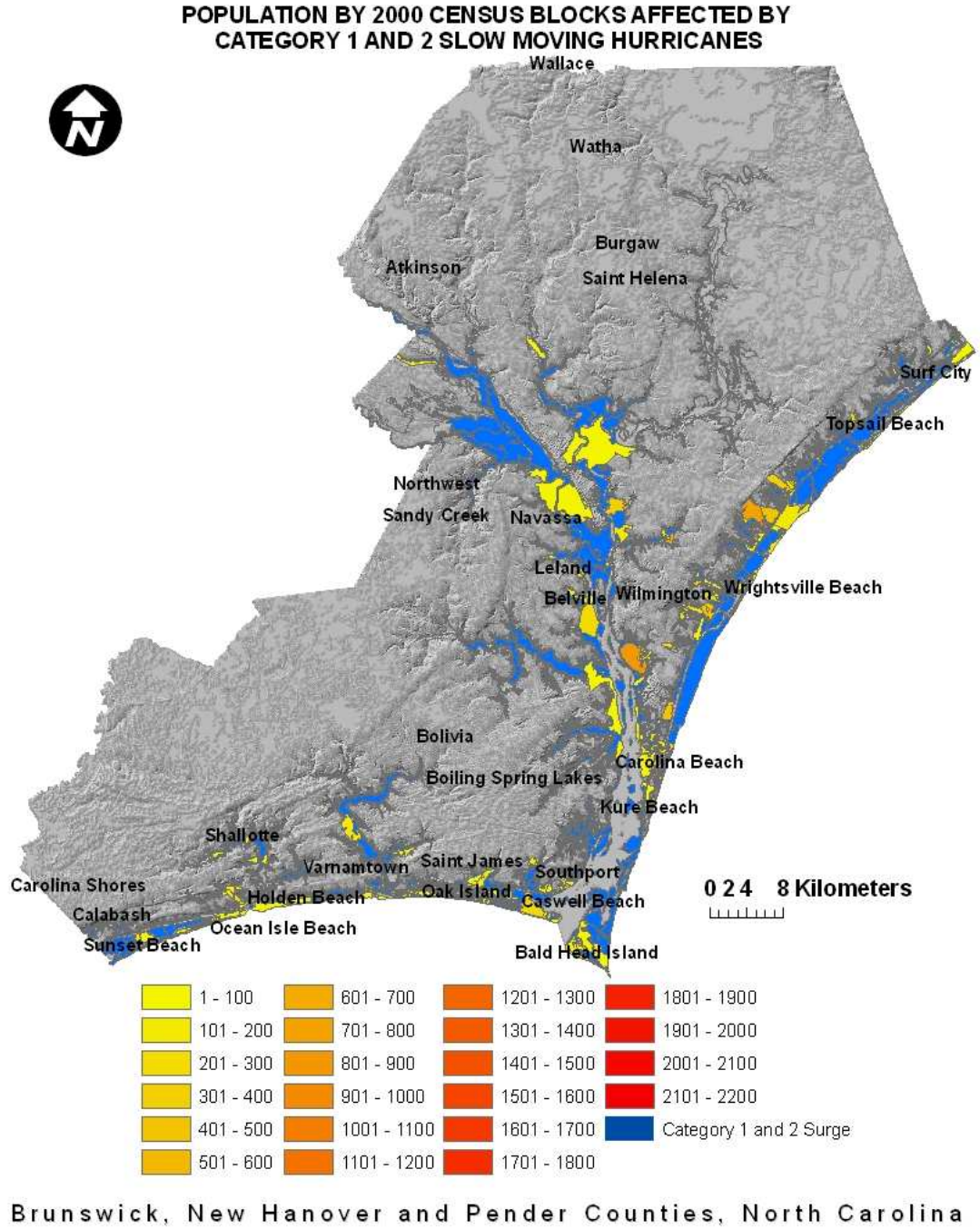

Brunswick, New Hanover and Pender Counties, North Carolina

## EXHIBIT 7 – Land Cover affected by Category 4 and 5 Storm Surge



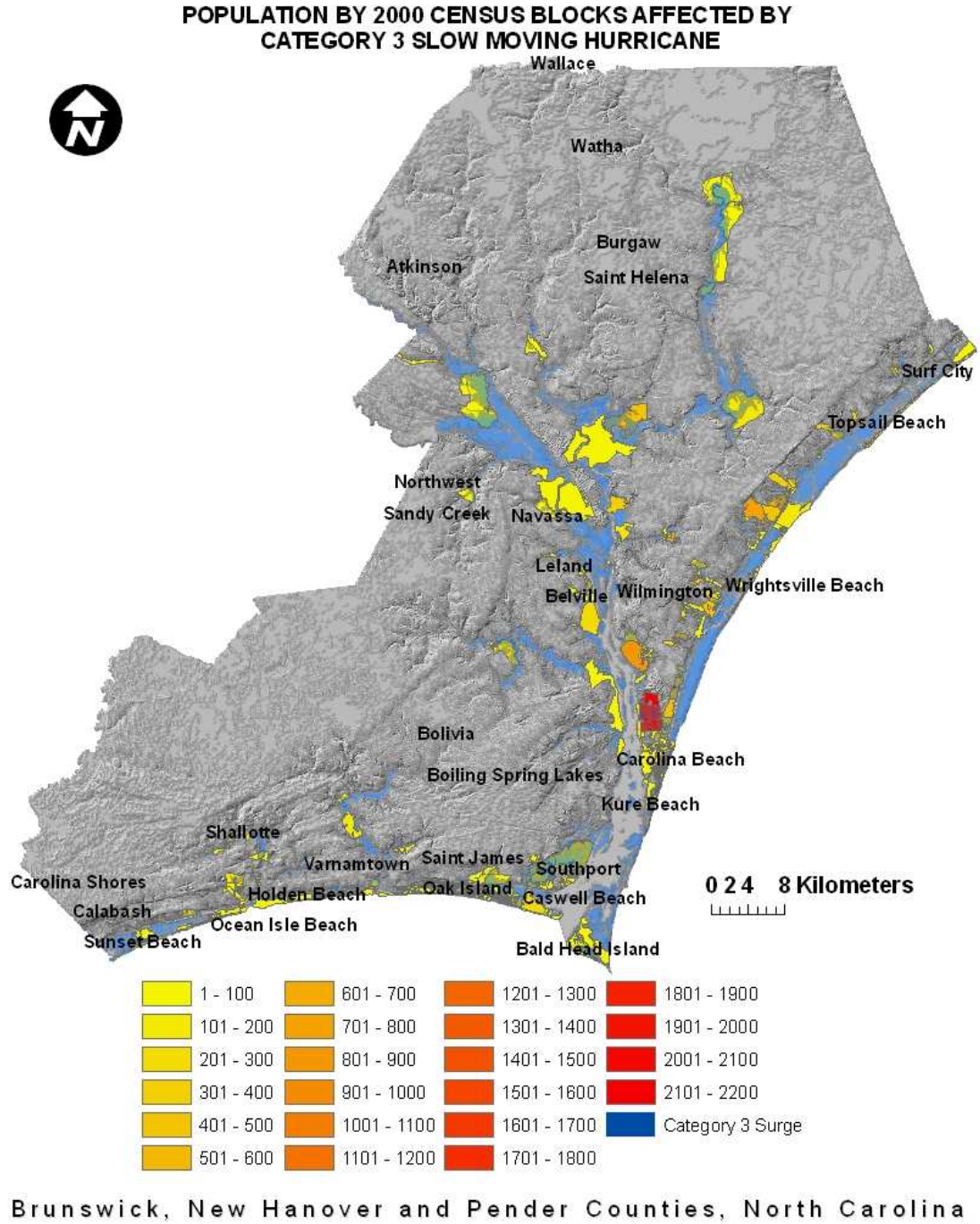

Brunswick, New Hanover and Pender Counties, North Carolina

## EXHIBIT 8 – Population affected by Category 1 and 2 Storm Surge




Brunswick, New Hanover and Pender Counties, North Carolina

## EXHIBIT 9 – Population affected by Category 3 Storm



## EXHIBIT 10 – Population affected by Category 4 and Storms

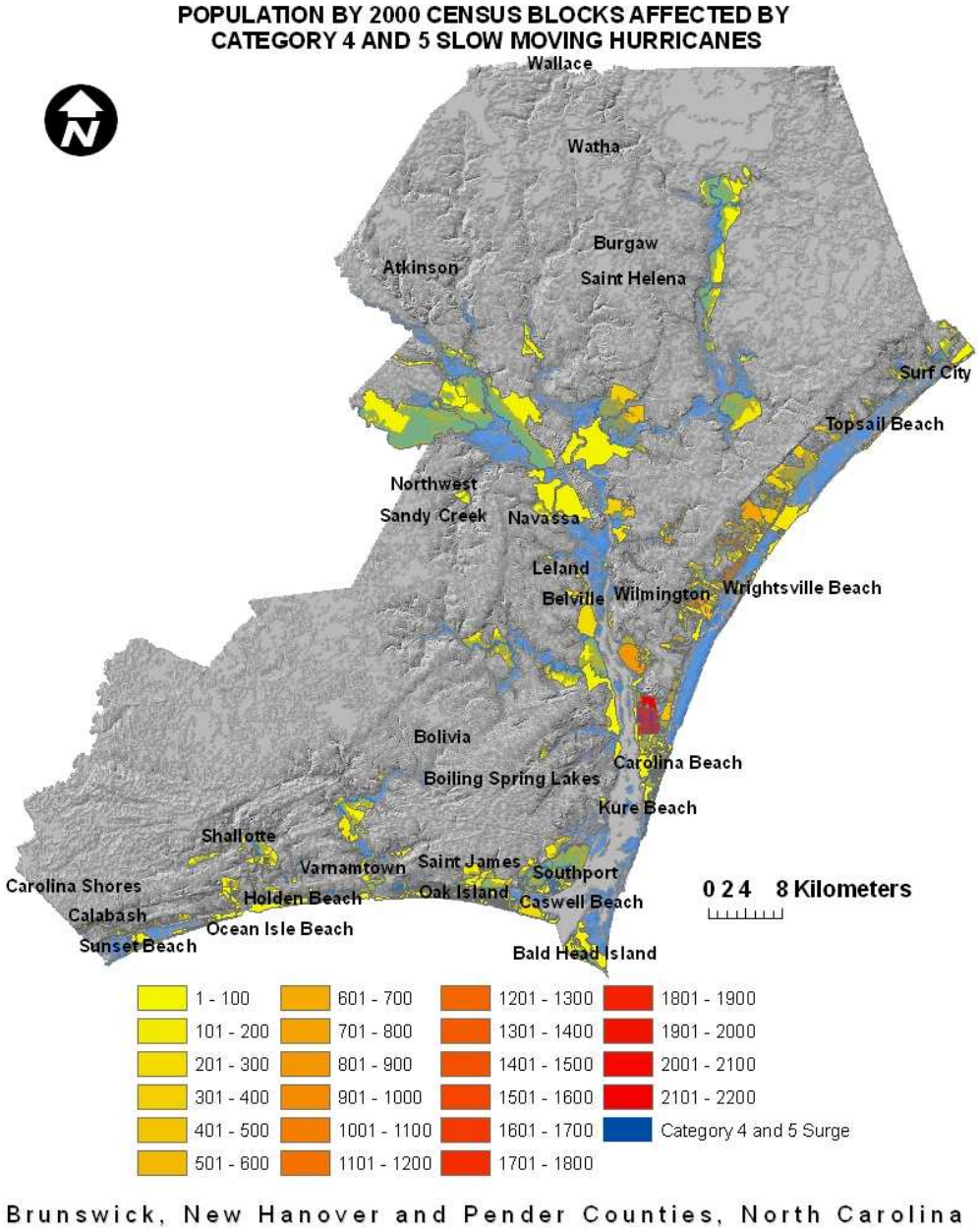
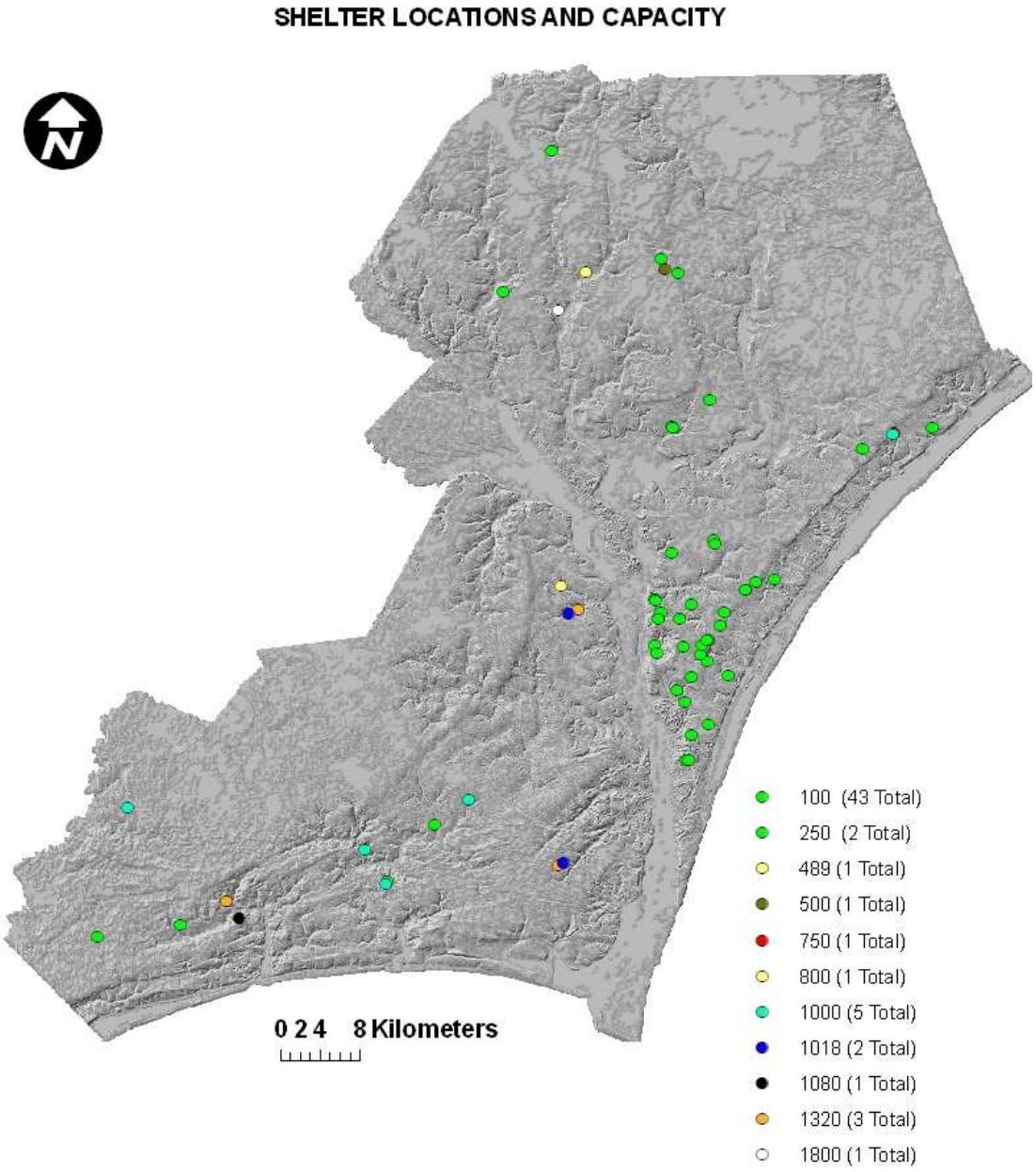


**EXHIBIT 11 – Shelter Locations and Capacity**




Brunswick, New Hanover and Pender Counties, North Carolina

**EXHIBIT 12 – Historical Hurricane Landfalls in North Carolina**

In summary, North Carolina has been stuck by 48 Hurricanes since 1857. Of these storms there were twelve Category 1, eight Category 2, eighteen Category 3, eight Category 4 and two Category 5 storms.

| *Storm Name* | *Maximum Classification* | *Year* | *Maximum Winds* |
|---|---|---|---|
| Ophelia | Category 1 | 2005 | 75 |
| Charley | Category 4 | 2004 | 125 |
| Alex | Category 3 | 2004 | 105 |
| Isabel | Category 5 | 2003 | 145 |
| Floyd | Category 4 | 1999 | 135 |
| Bonnie | Category 3 | 1998 | 100 |
| Fran | Category 3 | 1996 | 105 |
| Bertha | Category 3 | 1996 | 100 |
| Emily | Category 3 | 1993 | 100 |
| Charley | Category 1 | 1986 | 70 |
| Gloria | Category 4 | 1985 | 125 |
| Diana | Category 4 | 1984 | 115 |
| Ginger | Category 2 | 1971 | 95 |
| Donna | Category 5 | 1960 | 140 |
| Ione | Category 3 | 1955 | 105 |
| Diane | Category 3 | 1955 | 105 |
| Connie | Category 4 | 1955 | 125 |
| Hazel | Category 4 | 1954 | 120 |
| Carol | Category 2 | 1954 | 85 |
| Barbara | Category 2 | 1953 | 95 |
| Unnamed | Category 2 | 1949 | 95 |
| Unnamed | Category 4 | 1944 | 120 |
| Unnamed | Category 1 | 1944 | 80 |
| Unnamed | Category 3 | 1936 | 105 |
| Unnamed | Category 3 | 1933 | 105 |
| Unnamed | Category 3 | 1933 | 105 |
| Unnamed | Category 1 | 1920 | 70 |
| Unnamed | Category 1 | 1913 | 75 |
| Unnamed | Category 1 | 1908 | 70 |
| Unnamed | Category 1 | 1906 | 80 |

| *Storm Name* | *Maximum Classification* | *Year* | *Maximum Winds* |
|---|---|---|---|
| Unnamed | Category 1 | 1901 | 70 |
| Unnamed | Category 2 | 1899 | 95 |
| Unnamed | Category 4 | 1899 | 130 |
| Unnamed | Category 3 | 1896 | 110 |
| Unnamed | Category 3 | 1893 | 105 |
| Unnamed | Category 3 | 1893 | 105 |
| Unnamed | Category 3 | 1887 | 105 |
| Unnamed | Category 3 | 1885 | 100 |
| Unnamed | Category 3 | 1883 | 110 |
| Unnamed | Category 2 | 1881 | 90 |
| Unnamed | Category 1 | 1880 | 70 |
| Unnamed | Category 3 | 1879 | 100 |
| Unnamed | Category 2 | 1878 | 90 |
| Unnamed | Category 3 | 1876 | 100 |
| Unnamed | Category 1 | 1874 | 80 |
| Unnamed | Category 1 | 1861 | 70 |
| Unnamed | Category 1 | 1861 | 70 |
| Unnamed | Category 2 | 1857 | 90 |

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