

# Climate Change and Rising Sea Levels:

A Geographic Information Systems Analysis of the  
Potential Impact on Railroad Corridors in New Castle  
County, Delaware

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## **1. Abstract**

In the past century continued investment in infrastructure along the east coast of the United States has supported economic growth and development; unfortunately this investment also comes with a certain degree of vulnerability. The advanced infrastructure along the east coast combined with the impending threat of climate change and rising sea levels has led many people to prepare for the potential impacts. The resiliency of railroad corridors along the east coast has its limitations, one of which is its resistance to floods. The spatial representation and analysis capabilities of computer based geographical information systems (GIS) are used to develop a comprehensive visual illustration of the impact areas in which rail road corridors in New Castle County, Delaware are in danger of being either flooded or perhaps destroyed. The goal of this research is to possibly affect some policies involving raising the elevations of rail beds or even relocating the tracks to less flood prone locations. Moreover, the goal is to help prevent damage of the nation's infrastructure along the east coast. Based on this research, there are many possible areas of impact of sea level rise for the railroad lines in New Castle County, Delaware. More specifically, the Port of Wilmington is the most likely to be affected. However, the railroad data used assumes the rail lines are on the same elevation as the ground surface in all regions of the county. Since this is not true, further research is needed using more accurate railroad elevation data.

## **2. Introduction/ Statement of Problem**

Since the time of the Industrial Revolution, the United States has grown both in terms of the use of technology and population. This increase, coupled with the tendency of individuals and communities to locate near coastal regions, has produced an advanced infrastructure<sup>1</sup> along the east coast. The infrastructure distributed along the east coast includes several multi lane interstates, well established cities, power plants, airports, subways, bus stations, and railroad corridors. While this dense and established infrastructure along the east coast has supported economic growth and development, it also comes with a certain magnitude of vulnerability<sup>2</sup>. It is

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<sup>1</sup> The basic facilities, services, and installations needed for the functioning of a community or society, such as transportation and communications systems, water and power lines, and public institutions including schools, post offices, and prisons.

<sup>2</sup> Capable of or susceptible to being damaged or destroyed, as by a disaster; difficulty to protect

important to understand the level of resiliency<sup>3</sup> of this infrastructure. This project focuses on the railroad corridors specifically.

The resiliency of railroad corridors along the east coast has its limitations, one of which is its resistance to floods. Since these rail lines are in such close proximity to the coast, they are quite susceptible to water damage caused by floods. If a flood is severe enough, it could not only stop the trains from operating, but could also damage if not destroy the rail line itself. These concerns lead me to the topic of climate change.

The issue of climate change is that there is a gradual shift in the world's climate over decades and centuries. Moreover, there is going to be a shift in temperatures. This temperature shift has been recorded over the past century in form of an increase. An increase in global temperatures results in glaciers melting and therefore sea level rising. Another impact of climate change is the boost in severity of storms. While the warming of the planet may be gradual, the effects of extreme weather induced by climate change -- storms, floods, droughts and heat waves -- will be acute and immediate (Richardson, 2008). This produces higher storm surges<sup>4</sup> and flooding along coastal regions. The impacts of climate change on east coast are addressed in this report.

While this research is founded under the belief that climate change will occur, it must also be noted that the idea of climate change and sea level rise has been very much disputed. There is debate over the rate of climate change and some uncertainty about its impact (Richardson, 2008). Many believe that there is no proof to back the allegations of climate change

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<sup>3</sup> The ability to recover quickly from damage; or the property of a material that enables it to resume its original shape or position after being bent, stretched, or compressed.

<sup>4</sup> Offshore rise of water associated with a low pressure weather system. Storm surge is caused primarily by high winds pushing on the ocean's surface. The wind causes the water to pile up higher than the ordinary sea level.

and global warming<sup>5</sup>. Some think that it is arrogant of humans to believe that their actions could affect the Earth. However, as much as this issue has been argued, it has been more widely accepted in recent years.

The advanced infrastructure along the east coast combined with the impending threat of climate change and rising sea levels has led many to prepare for the potential impacts. But before preparations can be executed, these potential impacts must first be understood. The goal of my research is to use the spatial representation and analysis capabilities of computer based geographical information systems (GIS) to explore possible impacts on rail road corridors in New Castle County, Delaware.

### **3. Research Question**

The question addressed is: How will the impact of climate change related to sea level rise and/or increased intensity of storm surges affect the rail infrastructure in New Castle County, Delaware?

### **4. Objectives**

- Assemble information for a base map for the computer based geographical information system (GIS). This includes the county outline, topography, etc.
- Import and develop rail line data to layer on top of the base map in GIS.
- Develop a comprehensive visual illustration of the impact areas in which railroads are in danger of being either flooded or perhaps destroyed.

### **5. Literature Review**

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<sup>5</sup> Global warming refers to climate change that causes an increase in the average temperature of the lower atmosphere. Global warming can have many different causes, but it is most commonly associated with human interference, specifically the release of excessive amounts of greenhouse gases (GHG).

For my literature review, I focus on answering two questions: Why is researching climate change and its impacts important? What are the previous applications of GIS to disaster research?

### ***5.1 Why is researching climate change and its impacts important?***

The first area of literature review is to understand climate change and why it is worth researching. It has been widely accepted in recent years that climate change and global warming are going to raise the sea level around the world. Slow and steady global temperature increases over the next few decades will melt the ice caps, but more importantly, there will also be an enhancement in severe storms. While the warming of the planet may be gradual, the effects of extreme weather induced by climate change -- more storms, floods, droughts and heat waves -- will be acute and immediate (Richardson, 2008). This sense of immediacy is the reason for preparations to be made now. Murray argues that rising sea levels and warmer oceans pose a risk to Delaware (2006). She states that the sea level has risen about one foot over the last decade and an increase of anywhere from two to five feet are expected in the next century.

Climate change will impact more than just the infrastructure of the east coast. The Center for Integrative Environmental Research (CIER) in “US Economic Impacts of Climate Change: Review & Assessment” looks at how inaction will affect our economy (2008). While the report focuses on the impact in Maryland the findings are also generalized, recognizing that climate change will impact the energy supply, human health, and reliability of water supply networks for agriculture. Moreover, storms and sea level rise threaten coastal infrastructure, including the transportation corridors (CIER 2008). The article concludes that the shoreline is not stationary and will move inwards, therefore there is a cost for inaction that is likely to stay and/or increase (CIER 2008).

The National Research Council performed studies that concluded there is a 99 percent probability of occurrence for the sea level to rise. Globally, the rise will be from 0.18 meters (7.1 inches) to 0.59 meters (23.2 inches) by the year 2099 but will not be uniform. In the metropolitan areas along the east coast during the time period 1980 to 2080, it is estimated for the sea levels to rise from 0.24 meters to 1.08 meters (0.8 feet to 3.5 feet). If the event of a 100 year storm is factored in, the levels could rise up anywhere from 3.2 meters to 4.2 meters (10.5 feet to 14 feet). The most immediate impact of climate change will be on coastal roads and rail lines. These corridors will be permanently inundated in the next century and it will be up to the engineers to make the preparations to deal with erosion and subsidence of road bases and rail beds (National Research Council of the National Academies, 2008).

Since it necessary to prepare for the eventual rise in sea levels, the use of GIS is helpful in mapping out the possible impacts. In “Methods of Disaster Research”, Dash explains what GIS is and why it is important to use for disasters. She states that it is a valuable tool and if used correctly can be very beneficial (Dash 2002). The use of the spatial representation and analysis capabilities of the computer based geographical information system (GIS) will develop a clear visual representation of the railroad corridors in possible impact areas.

### ***5.2 What are the previous applications of GIS to disaster research?***

Before performing my GIS analysis of New Castle County, Delaware, I wanted to research and review what other regions around the world have attempted this process and their respective results. Overall, I found that GIS was viewed as a helpful and useful tool.

GIS has been used all over the world for many different reasons. It was used for looking into improving emergency response to blizzards and flooding in Shenandoah Valley, Virginia. It was felt that the GIS maps and data were very helpful for emergency planning, response,

mitigation, and recovery efforts and that local government should view GIS as a useful tool that can be obtained on even a small budget (Pine 1997). Another case study was used during Hurricane Fran involving GIS models. Emergency managers used these models to make decisions about potential flooding and identified which portions of the population needed to evacuate given areas (Dymon 1999).

The capabilities of GIS are also illustrated through other applications. GIS has even been used in the application of mapping tourism development (using methods of overlaying layers) in Lombok Island, Indonesia (Minagawa 1999). In the transportation literature, GIS has been used to determine the capabilities needed for transportation hazard analysis and incident management (Leposfsky, 1993) using case studies of two highways in California. On a more global scale, an extensive study was performed in developing countries around the world (South Asia, Middle East & North Africa, Latin America & Caribbean, East Asia & Pacific, Sub-Saharan Africa) using a one meter sea level rise. It summarized that most areas would be significantly impacted (Dasgupta et al., 2009).

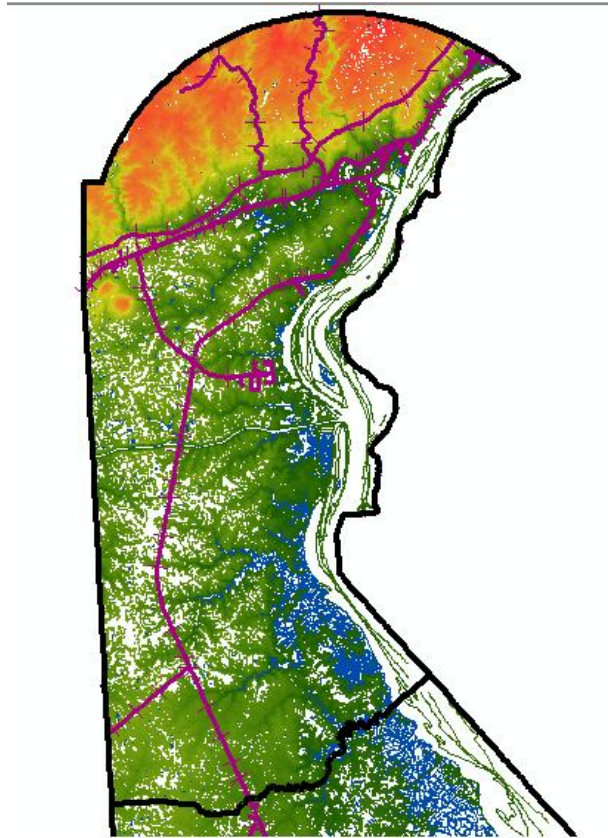
Suarez, Anderson and Mahal (2005) provide good examples (focusing on the Boston Metro area) of why we need to pay attention to climate change and the impacts on transportation. They used modeling scenarios (UTMS<sup>6</sup>) to look changes in the number of vehicle hours traveled (VHT) and vehicle miles traveled (VMT) in the event of a flood. The results showed that there were more delays and lost trips due to this flooding, but not enough to adapt to a new infrastructure. (Suarez, Anderson and Mahal, 2005). The University of Washington and King County also developed a GIS map of the city of Olympia and the inundation levels from current and projected changes in high tides (2007).

## **6. Methodology**

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<sup>6</sup> Urban Transportation Modeling System (UTMS) overlays flood maps with road networks

The main methodology used in this research uses the spatial representation and analysis capabilities of the computer based geographical information system (GIS). The base map data is the United States Geographical Survey's (USGS) Delaware DataMIL ftp web site (Delaware



DataMIL, 2009). First, information is gathered to create base map of New Castle County, Delaware. The basic data includes the state and county outline, current topography<sup>7</sup>/elevation data (using the Delaware dataMIL Website), and current sea level information. Once this data is gathered, the shapefiles<sup>8</sup> are imported into GIS to develop a general (very basic) map of New Castle County, Delaware in which is referred to as “Current Conditions” (Figure 1).

In Figure 1, the state/county outline is colored in black. The elevation data is colored coded, ranging from dark green (lower elevation) to yellow to red (higher elevation). The blue shown in Figure 1 represents areas under the current sea level. Once the base map is established, the location of the railroad lines (from the USGS Delaware DataMIL ftp web site) are added in purple.

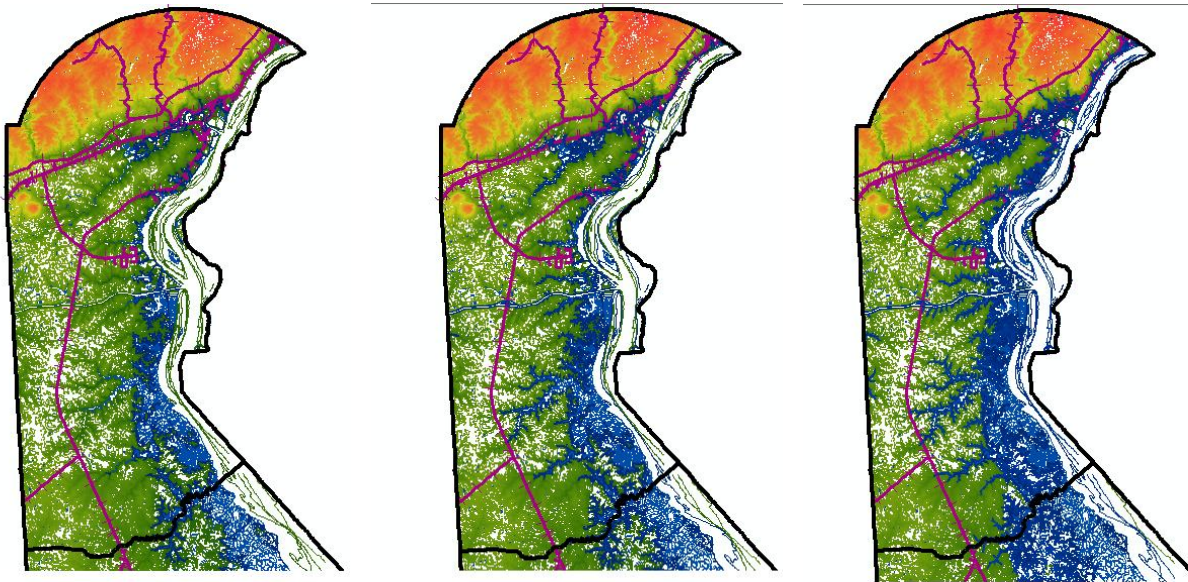
**Figure 1. Current Conditions of New Castle County, Delaware**

<sup>7</sup> the practice of graphic delineation in detail on maps of natural and man-made features of a place or region especially in a way to show their relative positions and elevation.

<sup>8</sup> A popular data format for GIS software. A "shapefile" commonly refers to a collection of files with ".shp", ".shx", ".dbf", and other extensions on a common prefix name.



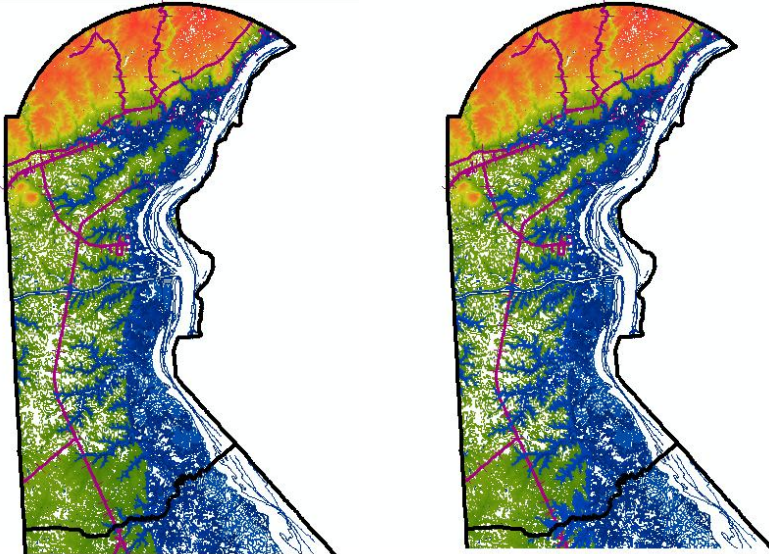
Now that the base map is established, the next step is to add and import different layers of data onto the already created map. These different layers to the map include data such as the location of the railroad lines (from the USGS Delaware DataMIL ftp web site) as well as different scenarios of sea level elevations. After this is completed, a comprehensive visual illustration of the impact areas in which rail lines are in danger of being either flooded or perhaps destroyed is developed (Figure 2).



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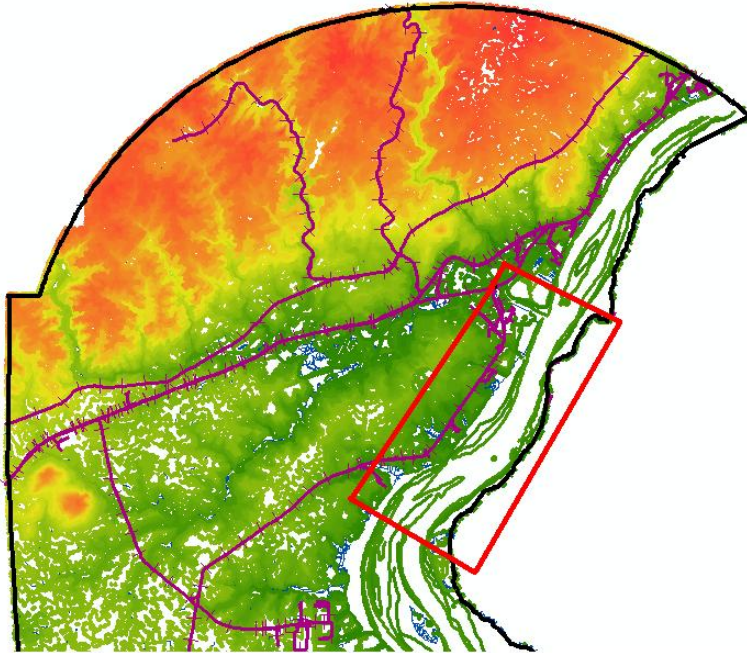
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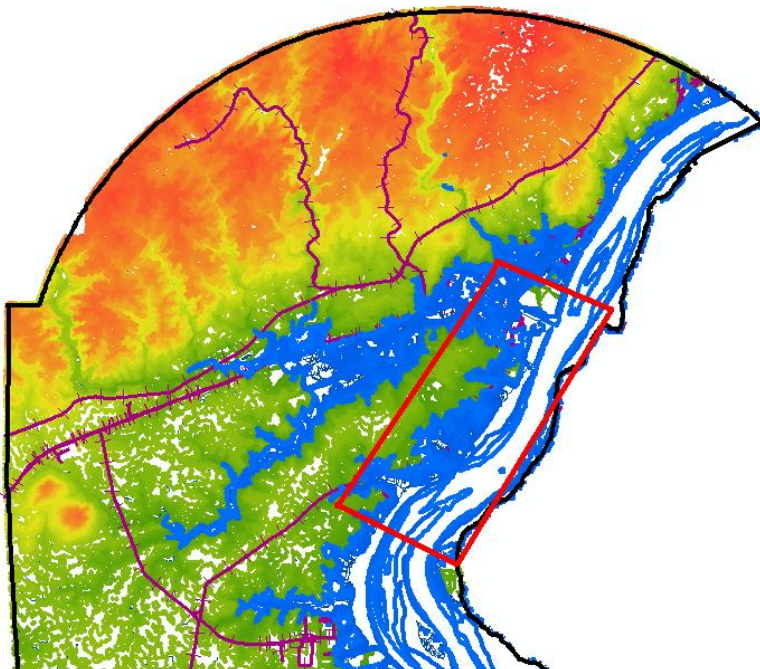
**Figure 2. Predicted visual illustrations of sea level rise ranging from 5 foot increase to 40 foot increase.**

Figure 2 shows the possible picture of what will happen when the sea levels rise. The series of maps start with a 5 foot increase move to 10 foot, 20 foot, 30 foot, and finally 40 foot increase. While most sea level predictions state anywhere from a 2 - 15 foot increase in the next century, these maps serve as a “worst case scenario” for not only this upcoming century, but years after.

As seen in Figure 2, as the sea level rises there are many possible impact areas for the railroad lines in New Castle County, Delaware. More specifically, the Port of Wilmington is the most likely to be affected.



**Figure 3. Current conditions highlighting the rail line south of the Port of Wilmington**



**Figure 4. 20 foot sea level increase affecting the area south of the Port of Wilmington**



While many different impact areas could be addressed, the impact area I wish to address is the rail line located just south of the port of Wilmington (Figure 3). This rail line is located in very close proximity to the Delaware River and is vulnerable to the rising sea levels, shown in Figure 4 (using a 20 foot increase). This rail line is completely encompassed by the sea level rise. This rail line is a single track owned by Norfolk Southern Corporation. Some photos of the rail line are shown below (Figure 5). This rail line is used mainly for the transportation of industrial goods. Figure 6 breaks down the percent of railway operating revenue (Norfolk Southern, 2009). According to the model in Figure 3 & 4, the rail line needs to be raised or moved in order to prevent damage from flooding.



**Figure 5. Photos of Rail line illustrated in figures 3 & 4, taken on site**

Coal, coke, and iron ore	29%
Intermodal	19%
Agriculture, fertilizer, and consumer products	12%
Chemicals	12%
Metals and construction	12%
Automotive	8%
Paper, clay and forest products	8%

**Figure 6. Percent of railway operating revenue for Norfolk Southern**

## **7. Conclusion/ Possible Implications of Research**

One possible benefit to this research would be to help railroad companies (such as Amtrak and Norfolk Southern) who may have railroads in impact areas. These maps provide some information that may prepare them for the future and may alter the planning and construction of these railroads. Moreover, the rail line I addressed in Figures 3 and 4 is owned by Norfolk Southern. Some policy implications that these companies may want to look into are to ask for financial assistance in raising the elevations of the rail bed or relocating the tracks to less flood prone locations.

There are many societal impacts of the sea level rise. If these rail lines are to be inundated, travelers may not be able to get to their destinations. In addition, the transportation of goods will be affected. It will be necessary to find alternative routes for these people and goods to travel throughout the east coast. For more of a “big picture” aspect of the impacts of sea level rise, it should be understood that other infrastructure (such as roads and airports) will also be affected. Therefore, alternate routes for travelers and transportation of goods may be even more difficult to locate.

## **8. Future Research**

There is some difficulty with this analysis when it comes to the rail line data. The railroad data assumes the rail lines are on the same elevation as the ground surface in all regions of the county despite the fact this is not true. Therefore more research to find more accurate data is needed. Rail line data with their respective elevations will give a better description of the future sea level rise and its impacts. This research should be continued in order to prevent damage of the nation’s infrastructure along the east coast.

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