Spread of Radioactive Surface Water After Nuclear Disaster

Turkey Point Nuclear Generation Station, Homestead FL

April Weintraub E'20, EOS104 Geological Applications of GIS

Introduction

After the 2011 earthquake and resulting tsunami in Eastern Japan, the globe has become aware of the peril presented by nuclear reactors in the wake of natural disasters. During the incident, Fukushima Nuclear Plant experienced severe damage, spreading nuclear material into the water, air, and surrounding areas. Since the event, radioactive surface water has traveled across the Pacific and has been discovered on the west coast of North America, specifically, along the coasts of California, Oregon, and Washington[5]. There is some uncertainty about the effects nuclear materials and radioactivity have on humans in contact with them, but severe effects like DNA damage, forms of radiation sickness, and certain resulting cancers are seen as untreatable[6]. As climate change progresses, natural disasters such as hurricanes will become larger and more frequent, increasing the risk of damage for nuclear generation sites. This project aims to assess a current nuclear site in Southern Florida and its risk to the surrounding coastal ocean environment during a potential leak caused by natural disaster. It specifically addresses the spread of nuclear material through surface water in the Gulf Stream and the time it would take to impact local communities and resources.

Figure 1: Location of the 2011 earthquake in Japan

Methodology

Selection and Feasibility of site:

The Fukushima reactors were located 32 feet above sea level when 50 foot waves hit the location during the tsunami in 2011[7]. 2,719 MW worth of energy generation was destroyed[7]. The selection of the site for this project was based on the following criteria: high nuclear capacity, close proximity to the coast, and low elevation. Turkey Point Nuclear Generation Plant located in Homestead Florida met all of these criteria. The plant currently generates about 1,604 MW through their reactors which are located between 15 to 20 feet above sea level[8]. It is the 6th largest nuclear plant in the US, and the largest plant in Florida, providing power to the entire southern part of the state[9].

The feasibility of a natural disaster occurring in southern Florida is relatively high. The Florida coastline is located in an area of high risk to hurricanes and sea level rise, which could easily cause damage and promote leakage from the plant. Hurricane Irma hit the Gulf of Mexico in 2017, and generated wave heights of 19 feet, which would have been in range of hitting the Turkey Point generators had it hit the eastern side of Florida[10]. The area is also at risk of experiencing the effects of continental shelf collapse (Figure 2), which could bring a range of unprecedented tsunami wave heights[11]. A mega-tsunami could also occur from a flank collapse of the Cumbre Vieja Volcano in the Canary Islands. The large displacement of water could cause wave heights of 65- 82 feet on the eastern coast of North America[12].

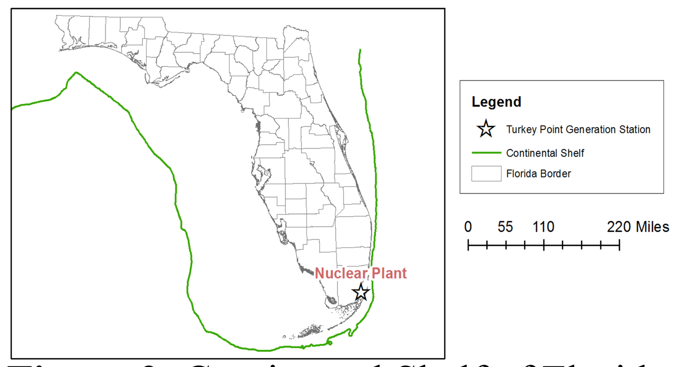

Figure 2: Continental Shelf of Florida

Modeling in ArcGIS:

First, data sets were imported from the Florida Geological Data Library of county lines, reef locations, continental shelf, and natural marine sanctuaries. An image of the Gulf Stream surface current velocity (Figure 3) was then georeferenced to the state and digitized as polygons representing average velocity.

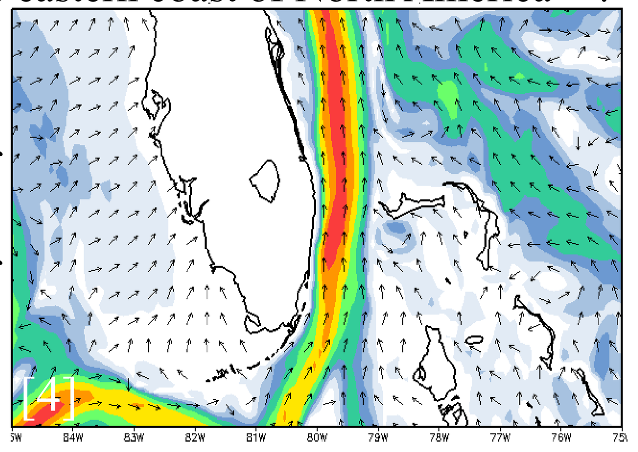

Figure 3: Image of Gulf Stream surface current

In order to visualize the spread of nuclear material through surface water, the cost distance tool in ArcGIS was used. This tool creates a cost surface raster with cells that each have a value to represent the cost that would be encountered as a particle travels over that cell. To deal with the tool's atypical use of velocity as a cost, values were converted to travel times using the following formula: Travel time per map unit = (velocity$^{(-1)}$/map unit). This transforms a higher velocity to a lower cost while still maintaining the proportionality between neighboring cells. The resultant cost surface raster that was then adjusted from travel time in seconds to days with the raster calculator (Figure 4). To visualize how the spread of radioactive material could affect populations in the state, the density of population by county was categorized from most to least concentrated.

To further visualize how quickly specific communities might be impacted, a least cost path was generated from a travel time raster creating figure 5. Inputs included: three popular beach destinations, the source nuclear plant, the cost surface raster, and a cost back link raster created using the cost back link tool in ArcGIS. Figure 6 was created by adding fish habitat polygons to the map and Figure 7 was created by highlighting parts of the national marine sanctuary and reefs that were in the direct flow path of the radioactive current.

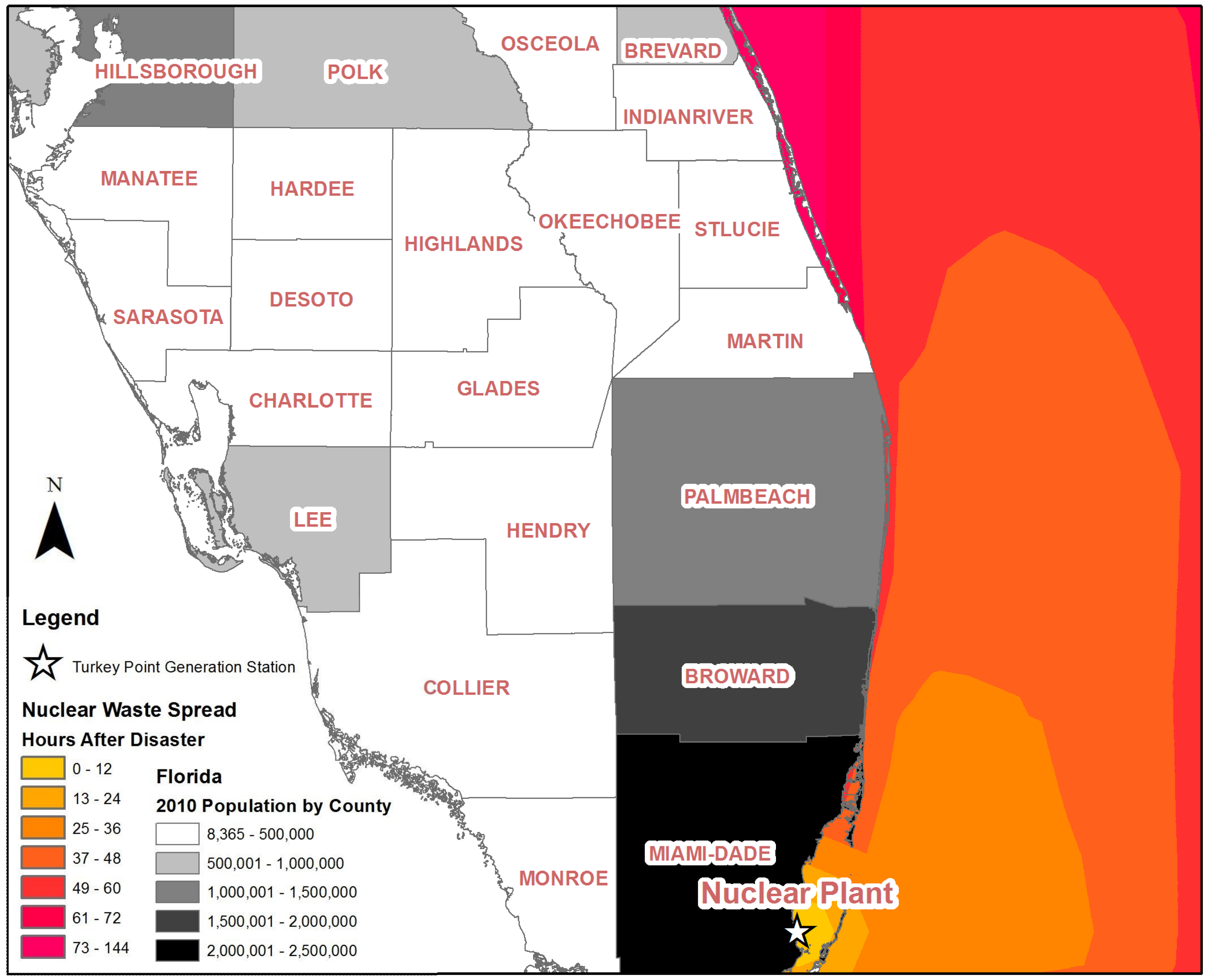

Figure 4: Spread of Nuclear Material in the Ocean Over Time

Results and Conclusion

In the days following a hypothetical natural disaster, contaminated currents would travel up the eastern coast of Florida transported by the gulf stream. This puts valuable beaches in not only environmental but also economic danger, as they are a primary source of tourism for the state. All tourism would likely then seize due to health risk from radioactivity within ocean waters.

A major concern of nuclear contaminants within the ocean is the effects to fisheries and human health from eating contaminated seafood. Since the 2011 disaster, high levels of radioactivity has been found in fish surrounding Japan, a country that relies heavily on seafood for consumption and export[13]. Figure 6 displays "essential fish habitats," (areas that have all the features an area needs to have fish survive, reproduce, and thrive[14]) that would come in contact with radioactive surface water. If this situation were to occur, the portion of commonly eaten fish in those areas would be exposed to radioactive currents and therefore expose large portions of the human population, even outside of the effected region, to radioactivity. Figure 7 shows 4 coral reefs and 34 square km of protected national marine sanctuary that would be in the direct path of the nuclear material flowing out of the cove. This would contaminate already endangered corals and valuable shallow water ecosystems.

This analysis exemplifies the timeliness of the effects of leakage from a coastal nuclear plant on surrounding environments and communities after a natural disaster. Within days, the radioactive current would spread throughout the coast of Florida and North America. Looking outside the area analyzed, the Gulf Stream could potentially carry the radioactive surface water across the Atlantic Ocean to Iceland, Europe or Africa. A large complication of nuclear contamination within the ocean is that it is extremely difficult to clean up post disaster. Amounts of radioactivity multiplies over time, as nuclear material decays and cannot dissipate on its own. The only way to contain it is to remove or transport all of the effected water and contaminated sediments and biota. Realistically, prevention is the safest protection from nuclear accidents. In a time where the US should be moving away from fossil fuels, many look to nuclear as a clean alternative. It is only "clean" until it is no longer contained. Possible disaster prevention methods include: moving nuclear plants inland or to a higher elevation, or altogether decreasing the use of nuclear energy and increasing the use of renewable sources to limit the availability of nuclear material that has the potential to contaminate.

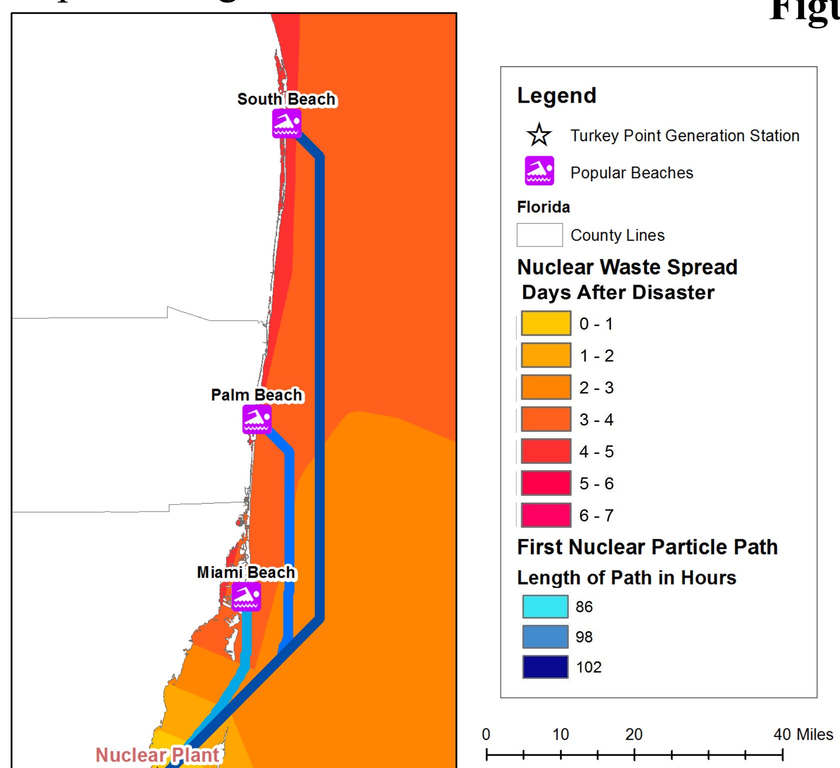

Figure 5: Quickest Surface Water Routes to Popular Beaches

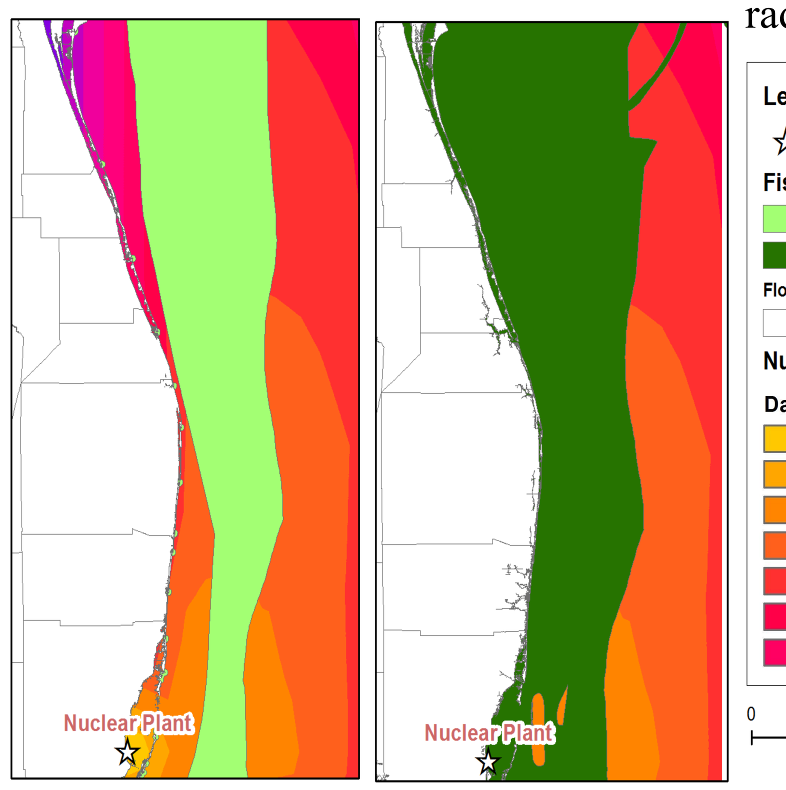

Figure 6: Essential Fish Habitats in Danger

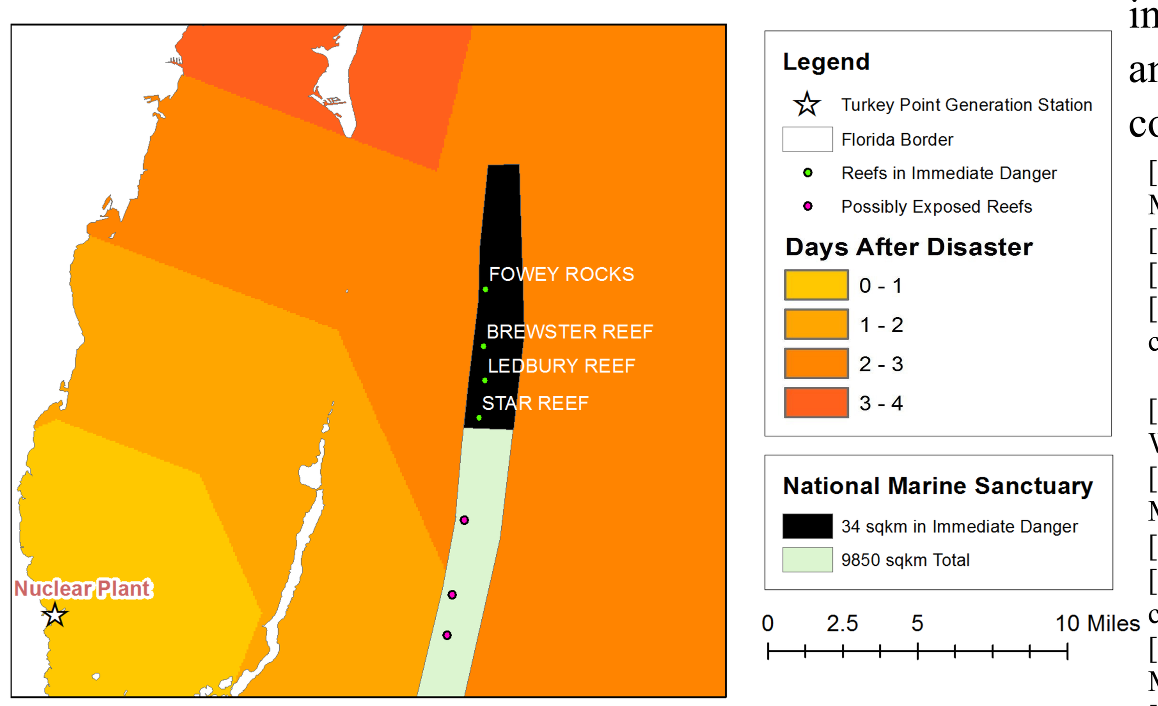

Figure 7: Reefs and Marine Sanctuaries in Direct Flow-path of Surface Water out of Cove

Image Citations:

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Data Sources:

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