Marine Incident Mapping

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Maritime Institute of Technology and Graduate Studies (MITAGS), and the Pacific Maritime Institute (PMI)

Executive Summary

The Maritime Institute of Technology and Graduate Studies (MITAGS), and the Pacific Maritime Institute (PMI) is a non-profit vocational training center. Our sponsor wanted a method to depict the marine incident data from the National Transportation Safety Board (NTSB) incident reports in a way that could be used as a resource to teach the students at the MITAGS and PMI. We created a webmap on Carto that maps the location and relevant information about every maritime incident tracked by the NTSB. Additional supporting data was added as well, to include: shipping routes and lanes, wrecks, obstructions, and US maritime limits and boundaries from NOAA. Using Carto allowed for the webmap to be well organized and easy to use, easy to maintain, and at a relatively low cost to the client. The client will be able to use this product as a training aid to teach students about maritime incidents.

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1. Background and Problem Statement

The Maritime Institute of Technology and Graduate Studies (MITAGS), and the Pacific Maritime Institute (PMI) is a non-profit vocational training center for those who seek to enter the maritime profession and for professional mariners seeking to advance their careers. PMI mission is to focus on the highest quality training using effective technologies and teaching techniques so that their students have the knowledge and skills to succeed in the current merchant marine.

Our sponsor Patrick Dougan would like to have the marine incident data from the National Transportation Safety Board (NTSB) visualized in a way that is organized and can be used as a resource to teach his students.

2. System Resource Requirements

2.1 Software Resource Requirements

There are not many required software capabilities needed to process the data for this project. The main software capability is a online web map that our client can use for training his students, and that MITAGS-PMI could use for situational awareness and analysis to provide the most up to date data to mariners to promote safety. The other software capability would be a visual representation of high risk areas and their causes, physical or environmental, in an attempt to provide mariners and MITAGS-PMI with further knowledge to help mitigate risks going forward.

2.2 Hardware Resource Requirements

Nothing is needed in the terms of hardware resources. Once the project is passed off to the client they will need to have something where they can access the webmap. However, as long as the client has access to the internet then they will be able to use a mobile phone, tablet, or basic PC for access. The client has access to his own CartoDB account to add or remove data. If PMI wants to continue to have access to edit data they will need to purchase an account and upgrade from the trial version.

2.3 Data Storage Requirements

The data storage requirement for collected data is relatively small and we will be able to store on our personal computers and/or Google Drive. The majority of our data collected, and cleanup will be done using Google Sheets on the Google Drive, which is free up to 15GB. 15GB is more than enough space for our raw data needs.

The product that we will deliver will be a web based map in CartoDB. All the storage of the final product will be store online through the CartoDB server on a trial account. After the course is over then the client will need to upgrade their account to have access to continue to edit and alter the webmap.

2.4 Data Acquisition

2.4.1 Data Source Steps

By recommendation of the sponsor incident data was collected from the National Transportation Safety Board (NTSB) website, However this data was entirely in the form of individual reports not a spatial form. This required all the attributes from each report to be manually populated into a spreadsheet. The marine incident data dates back to 1974. As time progressed, so did the way NTSB did the reporting on each incident. Some incidents have the coordinates in UTM and others are simply landmarks. All 276 reports were converted from UTM, of landmarks to decimal degrees for use in ArcMap and CartoDB. Then each attribute from the report was

We also collected additional supporting data. This included ports from NGA Maritime Safety Information, shipping routes and lanes from ArcGIS online, wrecks, obstructions, and US maritime limits and boundaries from NOAA. Additionally we collected basemap data such as land mass, oceans and marine labels from Natural Earth Data to be used for reference when analyzing data on our end before ingesting into the webmap.

2.4.2 Data Categories

Filename	Object type	Description	Source
"incidents"	point	Accident no., location, and additional details about the incident, to include the URL to the official NTSB report	National Transportation Safety Board (NTSB) https://www.ntsb.gov/investigations/AccidentReports/Pages/marine.aspx
AWOIS_Wrecks.shp	point	Location of shipwrecks	https://nauticalcharts.noaa.gov/data/wrecks-and-obstructions.html
AWOIS_Obstructions.shp	point	Locations of obstructions, to include rocks, shoreline and quality control reports	https://nauticalcharts.noaa.gov/data/wrecks-and-obstructions.html
World_port_Index.shp	point	Location, characteristics, known facilities, and services of ports, shipping facilities, and oil terminals throughout the world	NGA Maritime Safety Information https://msi.nga.mil/NGAPortal/MSI.portal?_nfpb=true&_pageLabel=msi_portal_page_62&pubCode=0015
sea_routes.shp	line	Polyline of all shipping routes across the world	http://www.arcgis.com/home/item.html?id=461e48f8b64a4e869c4b47c23da3c204

shippinglanes.shp	line		
USMaritimeLimitsAndBoundaries.shp	polygon	The low-water line along the coast as marked on the NOAA nautical charts	https://nauticalcharts.noaa.gov/data/us-maritime-limits-and-boundaries.html#access-digital-data
ne_50m_land.shp	polygon	World land polygon	http://www.naturalearthdata.com/downloads/50m-physical-vectors/
ne_50m_ocean.shp	polygon	World oceans polygon	http://www.naturalearthdata.com/downloads/50m-physical-vectors/
ne_50m_geography_marine_polys.shp	polygon	Area labels of major marine features	http://www.naturalearthdata.com/downloads/50m-physical-vectors/

Table 2.1, Marine Incidents Data Categories

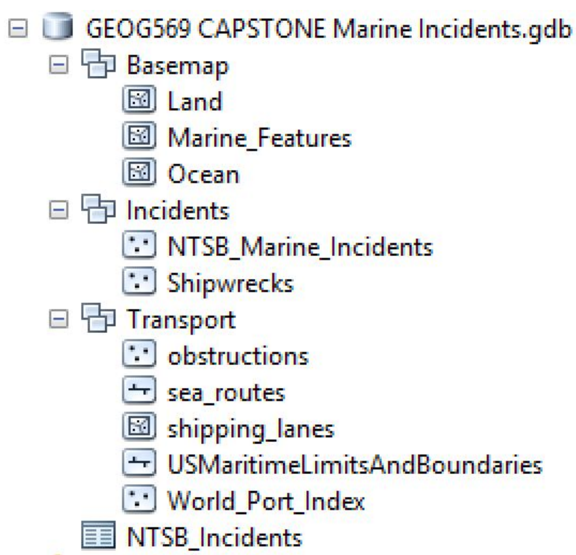

Figure 2.1 Marine Incidents Geodatabase

2.4.3 Metadata Description

Attribute Field Name	**Data Type**	**Length**	**Definition**
NTSB_Title	Text	50	Title of incident report
Report_No	Integer	-	Accident number
Location	Float	-	Decimal Degrees of incident

NTSB_InNo	Integer	-	NTSB assigned number
Injuries	Integer	-	Injuries from incident
Fatalities	Integer	-	Fatalities from incident
City	Text	50	City the incident occurred
State	Text	50	State the incident occurred
Country	Text	50	Country the incident occurred
Accident_Type	Text	50	The type of accident
Casualty	Text	50	Reason the incident occurred i.e (human error, fire, etc.)
NTSB_Link	Text	100	Link to the NTSB website for each incident
PDF/Report	Text	100	Link to the physical incident report
Accident_Date	Text	50	Date the accident occurred
Report_Date	Text	50	Date the incident report was filed
Vessel_Name	Text	50	Name of the ship
Vessel_Size	Float	-	Length of the ship in feet
Additional_Vessel	Integer	-	Number of additional vessels associated with incident
Damage	Double	-	Total cost of the damage in USD
Environmental	Text	50	Environmental damage associated with incident
Probable_Cause_Statement	Text	200	Statement explaining the nature of the incident in detail

Table 2.2, Marine Incidents Data Dictionary

3. Business Case Evaluation

Putting a price on normal day to day tasks that we all currently do was challenging for our group. The tasks we do each day at our current jobs do have a price, but we never really thought about the price tag might be. Our project seems pretty simple. However, no work is free and the work we have done thus far and until the end of the quarter does have a price outside of the classroom. Below we go into depth on the cost analysis associated with our project. We will discuss how the monthly cost of the GIS is out weighted by the benefit our sponsor will see. Then we will go over the various types of benefits.

3.1 Benefits

There are multiple benefits to this project. Two typologies developed in the 1990's will be used to compose benefits; Antenucci's 5 types of benefits, and Huxhold's three types of benefits.

Antenucci et al. *GIS: Guide to the Technology* (1991 pp 66- 72) typology 5 types of benefits:
Type 1: This type is the quantifiable efficiencies in current practice, or improvements to existing practices of this project. These benefits include improvements made by GIS graduate students to map visuals to suite the enhanced training needs. With these improved maps the sponsor will now have the ability to analyze past marine incidents anywhere in the world, which can help improve marine safety going forward. This map visual will also increase the training ability of the sponsor during his training classes with future mariners.

Type 2: This type is an expanded quantifiable benefit or added capabilities to be more effective with work activities. The benefits for this category include real time access to geographic marine incident data. This is a huge benefit because before this project the sponsor would have to search through reports from the NTSB website if they wanted details on marine incidents in an area. This was a laborious and time consuming endeavor which will now be streamlined. This project also gives the user the ability to map and manage future marine incidents as they happen.

Type 3: This type is characterized as quantifiable, unpredictable events that can take advantage of geographic information. The benefit gained for this type is an expedited response to future marine incidents if this online map is used by multiple agencies and groups.

Type 4: This type are the intangible benefits related to intangible advantages. The main benefit for this category is an increased quality of training for the sponsor. Having an online map of incidents that previously did not exist will help both students and instructors. This should help give users better situational awareness about marine incidents.

Type 5: This type is the quantifiable sale of information. Due to the fact that this online map is being created in the open source map program CartoDB, there is no quantifiable sale of information benefit for this project. This is because the online mapping project isn't being sold, it is developed to assist in training that is already being sold.

Huxhold's (1991 *Intro to Urban GIS* p. 244) benefit typology lists three types of benefits:
1) Cost reduction
-Improvement of map visuals for training
-Ability to analyze past marine incidents to to help improve safety in the future
-Increased training ability to future mariners

2) Cost avoidance
-Ability to map and track future incident data

-Project by graduate student at no cost

3) Increased revenue
   -Increase in quality of training

3.2 Costs

Capital costs (durable good with extended life over several years):
1) Database
Our group created the database from the free data that we collected from the National Transportation Safety Board website.

2) Hardware and Software
Assuming our sponsor does not already have an open computer he can use for teaching, he will need to purchase a desktop or laptop. Any basic desktop or laptop will have the capabilities needed to run the program we used to create the web map. Google makes a great laptop known as the chromebook starting around $240. Basic desktops can be purchased starting around $300. However, we already have our own personal computers so there is no cost associated with the teams use of hardware.

We decided to choose Carto as our mapping platform. Carto is significantly cheaper than ArcMap and doesn't require a high powered desktop or laptop. As a result of using Carto the cost of the actual program will be much cheaper than if we had gone with using ArcGIS. We are in the process of waiting to hear back from Carto about a grant we applied for. Carto Carto cost around $140 a month for a professional license. With the professional license you get 500 MB of storage with email and online support. Our sponsor will be able to share the published web map and store the published map on carto's servers. Currently, Carto is free to our group as a result that we are students at UW. Once the quarter is over the sponsor will need to have his own account in order to have continued use and updating rights of the final web map product.

3) Implementation
The costs for the implementation and upkeep of the database that we have created would be the time that it would take to keep the database current. Additional cost could be accrued if the sponsor chose to hire someone to keep the database current.

Operating Costs:
1) Personnel: ~$ 9210 for the 10 weeks
As a result that all of us working on this project are master's students with no actual pay rate then personnel cost would zero. However, if we assume that this is not a school project and that we are a GIS consulting firm then the normal rates would apply. According to Glassdoor.com, the average GIS analyst makes $58,000 a year. If we take in to consideration the amount of time we each have spent on this project ~ 10 hours a week and then breakdown the annual salary into the hourly wage it would be around $30.70 per hour. So with the three of us working at least 10

hours a week for entire length of the project ~ 10 weeks that would come out to ~ $3070 per GIS analyst and ~ $9210 total.

2) Overhead: $0
Due to the nature of this project there are no real overhead costs that come to mind. The sponsor already has a fully operating business. The product we produce will not add or take away to the sponsors current overhead cost.

3) Maintenance Fees: ~$140 per month
As previously mentioned the chosen mapping platform Carto would require a monthly payment for the professional license. If our sponsor ever wanted add additional personnel to maintain the map then he would need to upgrade to the enterprise license. With the additional cost each month our sponsor would also get a vast amount of features.

4) Utilities : ~$140 per month
Internet and power would be the only utilities needed for the project. Both of which I am sure the sponsor already has to for his other work tasks. However, let's assume that he doesn't. The added carto mapping platform internet usage and the additional power usage from the computer we will very small in comparison to the other tasks at his company. We assigned the value of utilities a monthly value of $60 per month and $180 per month for high speed internet with speeds up to 150mbps.

5) Supplies : ~$20 one time fee for the 10 weeks
Common supplies needed would be pens, USB drive, and a notebook. Not much else would be required.

6) Other: $0
At this time we have no other items that fall under the cost section for this business case.

3.3, Cost-Benefit Analysis

Cost (All of group)	Benefits (Accumulated within group)	Week
Software monthly license, supplies, hardware, and utilities	Weekly Pay : 30 hours	1
Utilities	Weekly Pay : 30 hours	2
Utilities	Weekly Pay : 30 hours	3
Utilities	Weekly Pay : 30 hours	4
Software monthly license, supplies, and utilities	Weekly Pay : 30 hours	5

Utilities	Weekly Pay : 30 hours	6
Utilities	Weekly Pay : 30 hours	7
Utilities	Weekly Pay : 30 hours	8
Software monthly license, supplies, and utilities	Weekly Pay : 30 hours	9
Utilities	Weekly Pay : 30 hours	10

Table 3.1, Weekly Estimates Table

There were a few issues we ran into while trying to perform a cost benefit analysis for this project. We felt like ideas of cost were more abstract for this marine incident webmap than other physical undertakings. We attempted to use software cost, utilities, and the cost of hiring a GIS analyst that wasn't working on a graduate project for the job. Due to the fact that the webmap platform is free there was no physical cost to the sponsor for implementation of this project. Another issue that we ran into is that the marine incident webmap assist already ongoing training, it doesn't provide any standalone training for itself.

This project was a worthwhile undertaking based on the cost benefit analysis. This project has a higher initial cost but after week two the benefit outweighs that initial cost (Figures 3.1 & 3.2). Other information that would of been useful for a more detailed analysis would be the actual costs of the training to the organization. As well as overhead costs associated with these courses, but that data is considered proprietary information and unavailable to us outside the organization. It's difficult to factor in benefits outside of type 1 and type 2 factored into the decision because types 3-5 are more dependent of outside circumstances.

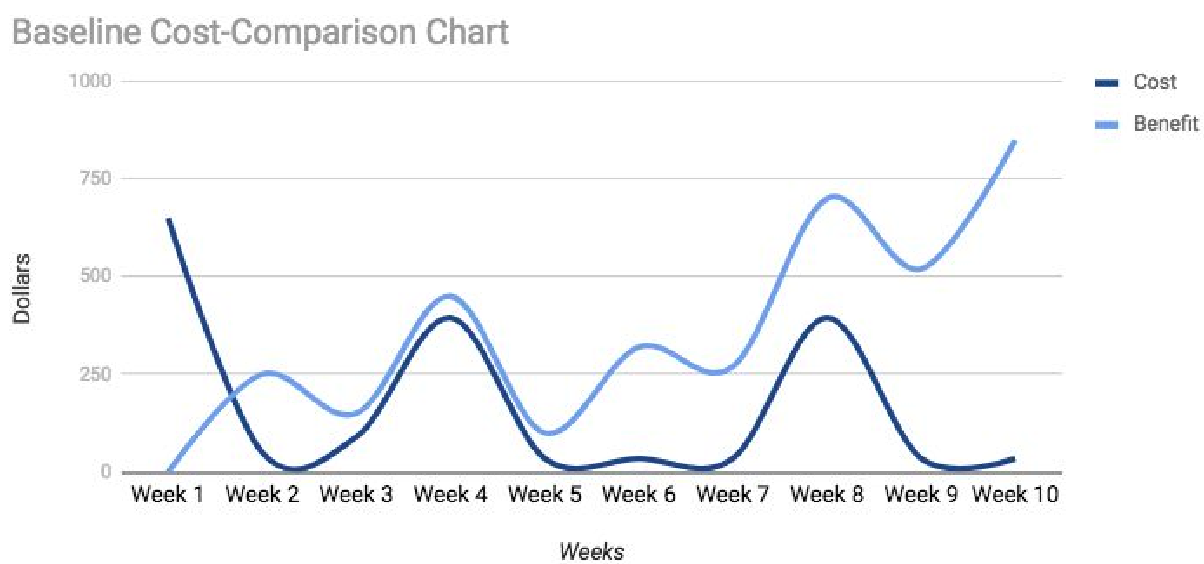

Figure 3.1, Baseline Cost-Comparison Chart for Mapping Marine Incidents

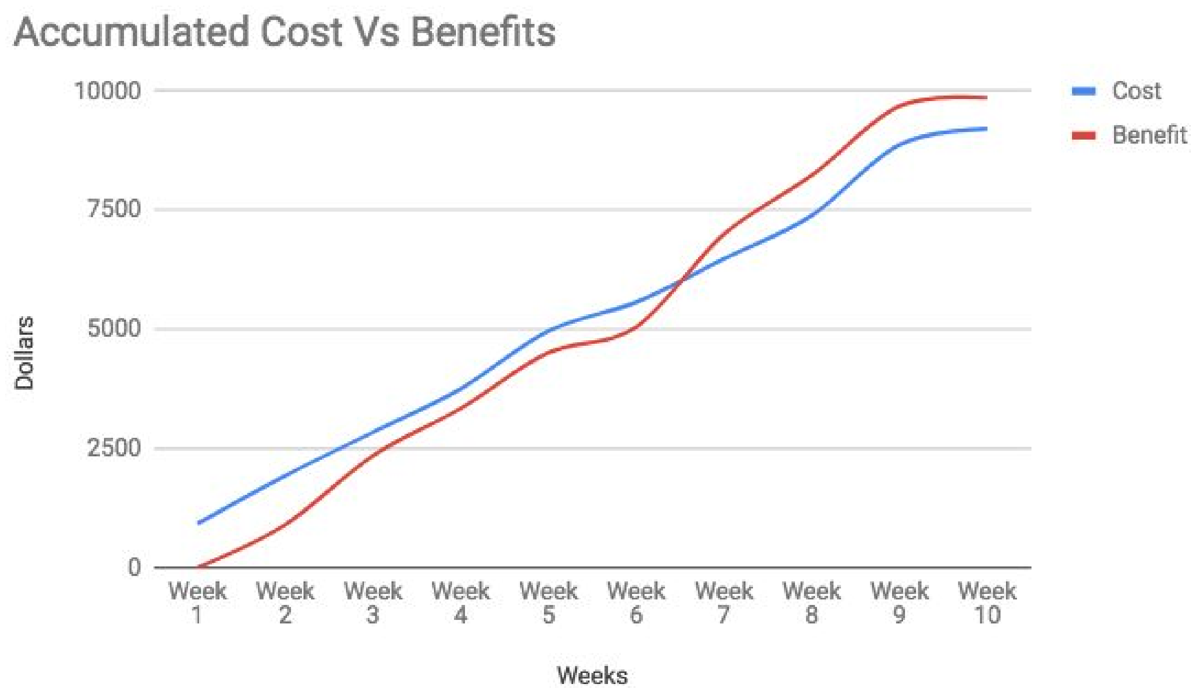

Figure 3.2, Accumulated Cost-Comparison Chart for Mapping Marine Incidents

4. Data Development (including data quality issues)

We collected the data from the NTSB and organized it in a way where we could evenly divide out each data row. After all the data was taken from the NTSB and imported into google sheets we divided up the data and scrapped the NTSB reports for information in which we deemed important. The metadata table above gives a list of all the attributes we wanted to use for the pop window the user sees. The definitions of the types of accidents and causality can be found in the technical appendices section at the end of the report.

Almost all of the data was in UTM so we needed to convert the locations from UTM to latitude and longitude. We used Google Maps for the conversion. However, some of the reports did not supply a UTM, they merely mentioned where it might have been. For example, a few of the incidents stated the accident occurred 30 miles south of such and such port. As a result of this the data quality is not a 100%. The majority of the data collected and transcribed in google maps fall within at least 100-500 feet area of where the incident took place.

5. Workflow Implementation

We took the data from the NTSB and imported into google sheets and distributed evenly as we mentioned above. In order to satisfy one of the project goals of having a clickable pop up link we needed to update the HTML to reflect this change. After a few tries we were successful in creating the pop to work correctly. We added some additional layers to the map to give it more content that we felt would be valuable information to the sponsor. With the map pretty much finished we added some widgets that carto provided that dynamic move as the user changes locations. We choose to have the widgets display the accident type and causality of the incident.

With all the goals completed and product done, we published the map and shared it with our sponsor. However, we wanted to add a little bit more to the project so we decided to run the buffer and hotspot analysis geoprocessing tools in ArcMap on the marine incidents. Also, we created some graphs and pivot tables using Google Sheets to see a complete rundown of the results. Please see the figure below which visually depicts all the information stated above.

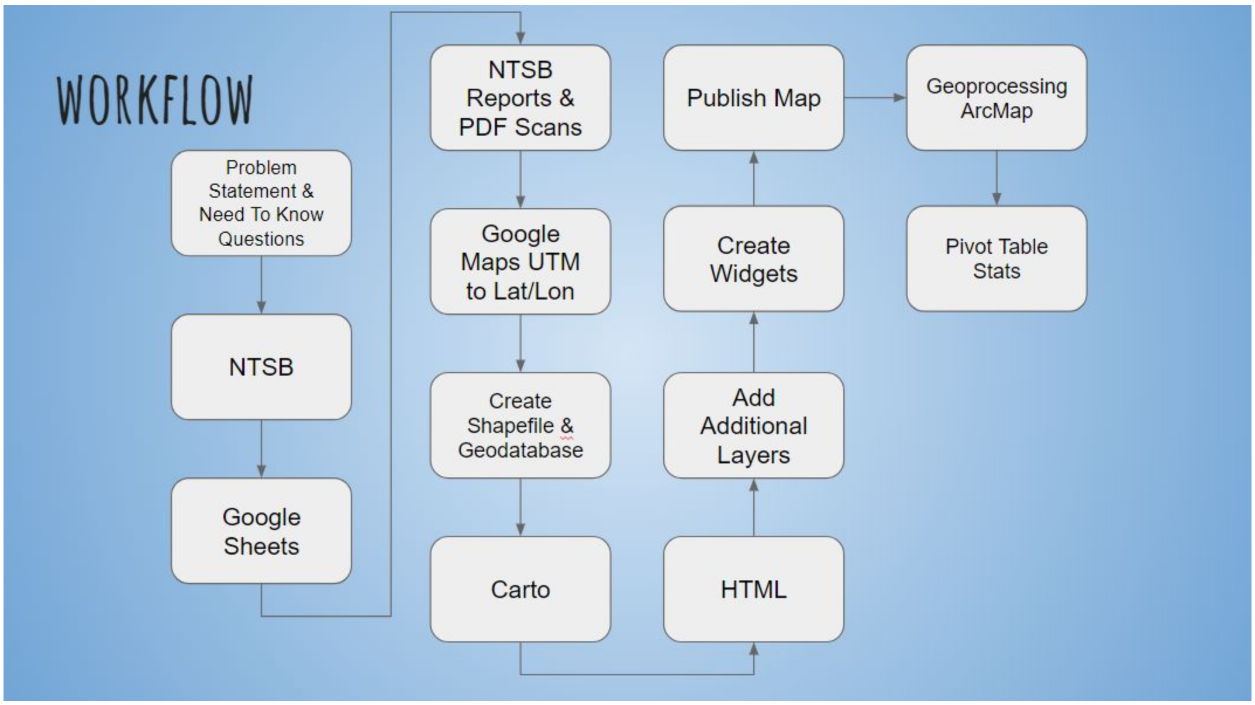

Figure 5.1, Marine Incident Mapping Workflow

6. Results

Our client was only interested in a web map application, however, we decided to go a little further with the project with some analysis. We created the web map application seen below as figure 1. We made sure to complete all the goals that we had set in order to deliver a map that would satisfy all the requests from the sponsor. He asked for a web map that would map the marine incidents provided by the NTSB. He also wanted each incident to have a pop up window that displayed key information elements associated with each incident. We also made the NTSB report and PDF document as a clickable link so the user would be directed to the forms in which all the data was derived from.

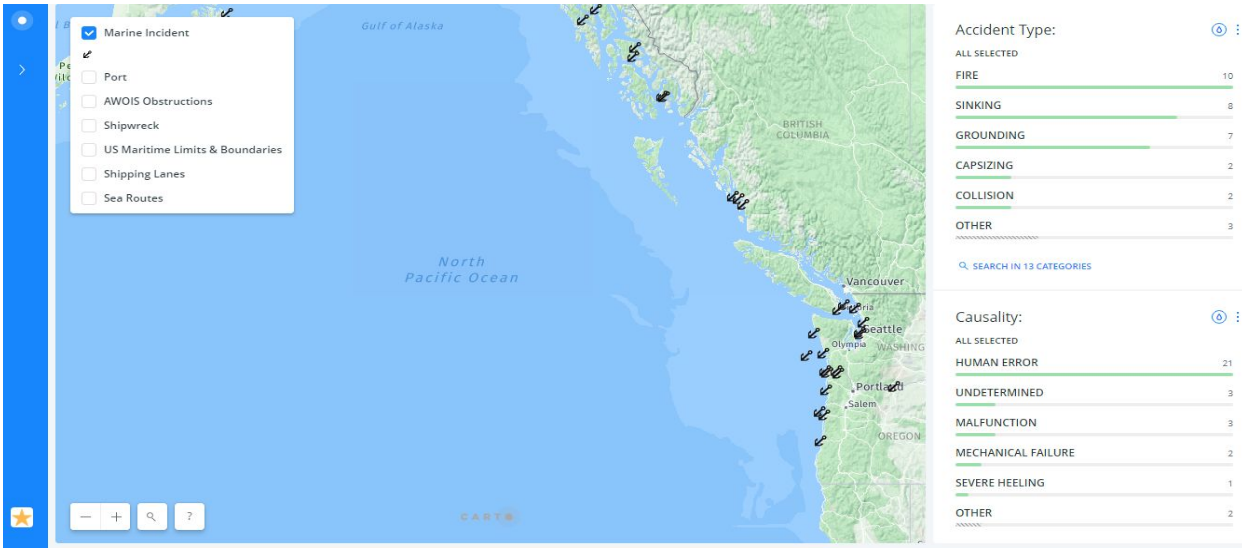

Figure 6.1, Carto Webmap

Beyond the webmap we also did some geoprocessing tools within in ArcMap. We used the Emerging Hot Spot analysis tool to conduct the analysis of the Marine Incidents. The Emerging Hot Spot tool identifies trends in the Marine Incident data based off of the date of the incident to determine if there are potentially new hot spots, intensifying hot spots, areas where incidents are diminishing, or sporadic hot and cold spots. From there the tool classifies the trends into patterns.

For the Marine Incident data, three patterns were identified (Figure 2 below): New Hot Spot (clustered on the US West coast and the Gulf of Mexico) - A location that is a statistically significant hotspot for the final time step and has never been a statistically significant hotspot before. Consecutive Hotspot (primarily along the US Northeast coast) - A location with a single uninterrupted run of statistically significant hotspot bins in the final time-step intervals. The location has never been a statistically significant hotspot prior to the final hot spot run and less than ninety percent of all bins are statistically significant hot spots. No Pattern Detected (along the Southern Alaska coast and individual incidents not within a close proximity distance/date to another incident) - Does not fall into any of the hot or cold spot patterns defined below.

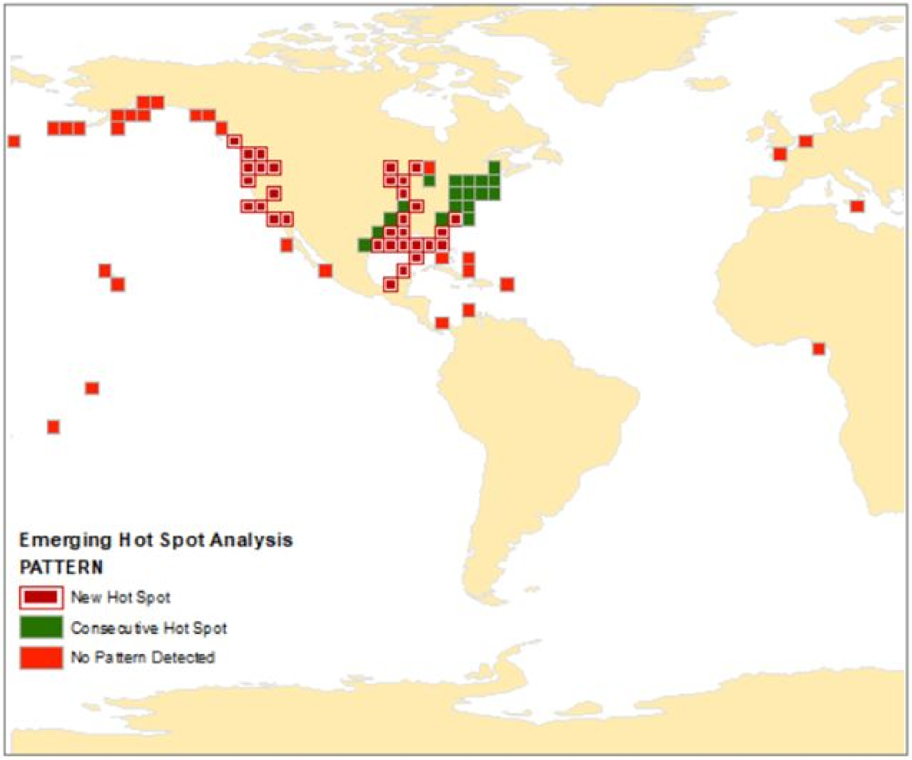

Figure 6.2, Hotspot Analysis

We were also curious as to how many marine incidents occurred near the shoreline. In order to do this we used the buffer tool in ArcMap. We created a multiring buffer around the global shoreline dataset. We choose to use the following distances: ½, 1,24,4,5,10,20,30,40, and 50 miles. This resulted in the majority of the incidents occurring within the ½ - 1 mile buffer (figure 3. These results closely mirror one of the articles we had chosen as a literature resource who found that the majority of their marine incidents occured within 2 miles or less of the shoreline near busy ports and high marine commute locations. We made a small Seattle snippet to show an example of the multiring buffer below in figure 4.

Mile(s) From Shore:	Count:
1	124
2	18
3	14
4	5
5	5
10	13
20	15
30	7
40	9
50	5

Figure 6.3, multiring buffer analysis chart

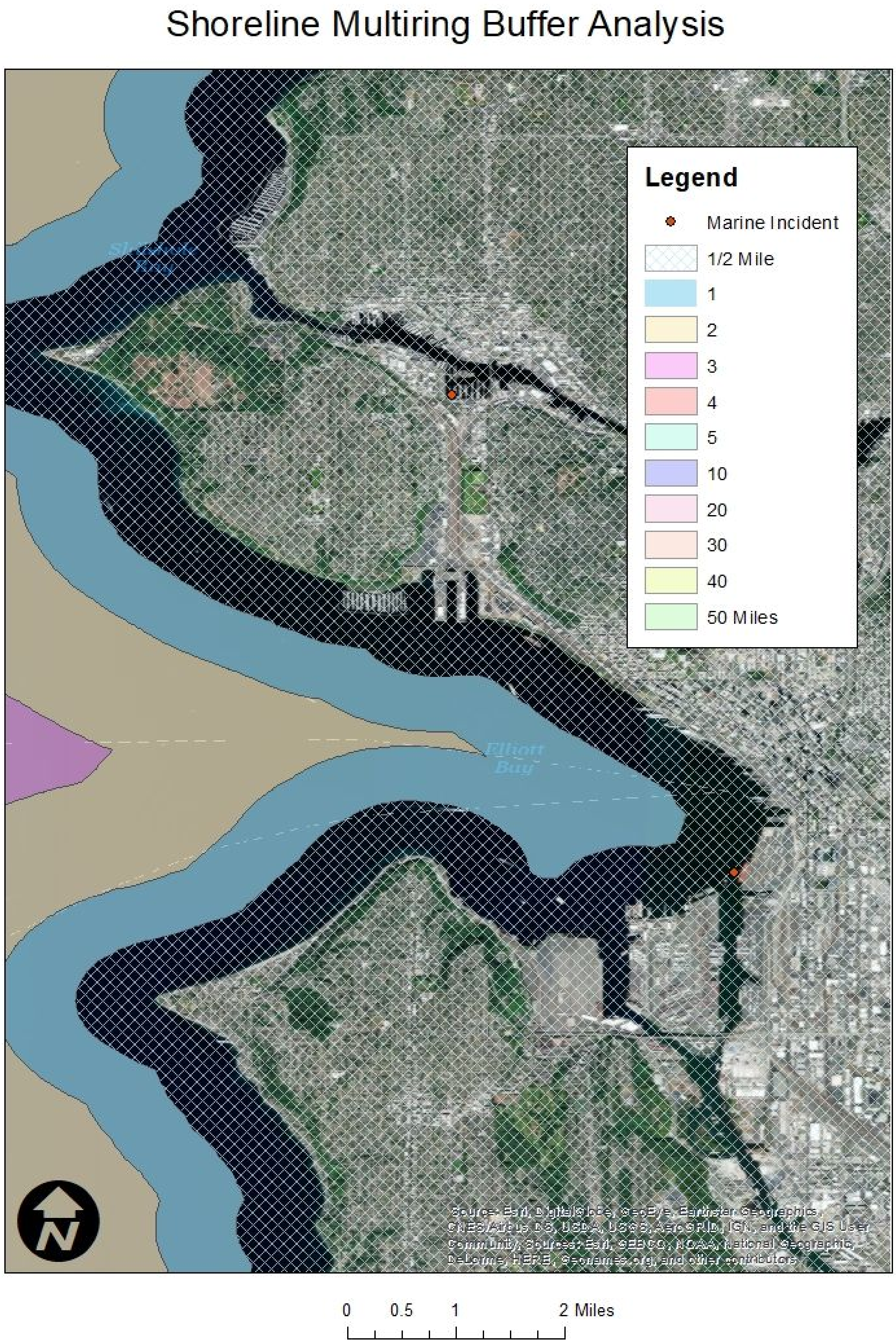

Figure 6.4, multiring buffer analysis

As previously mentioned above we wanted to go a little further with the project and run some statistics on the marine incident data. We imported the data into google sheets and created some pivot tables and charts which will in the following section below. First, we wanted to bring back up some interesting connections we had found between our results and the results we had found in a similar study we found during the scope of work assignment.

According to the study, despite improved navigation aids including charts and Global Positioning Systems (GPS), ships still have many accidents in waterways. Marine accidents cause casualties as well as loss of property. The causes of such accidents are very complex and can be categorized into human errors, mechanical errors, fire and explosion, weather and so on. It has been found that more than 80% of them are caused by human factor and lead to death or pollution of sea (Acharya, T. D., Yoo, K. W., & Lee, D. H. (2017).

We found out that 67% of the marine incidents from our dataset were found to be caused by human error (figure 5). This closely mirrors the results of the study. Not only were 67% of the marine incidents were caused by error, but that those errors lead to higher damage costs and higher deaths and injuries (figure 6). Figure 7 & 8 are the statistics on the number of accidents vs injuries and fatalities. Figure 9 displays the total number of accidents per year. We found it surprising that marine incidents were are the rise and hit a high mark in 2016 but then drastically dropped in 2017. We do not have an answer as to why this occurred, but we think it might be to lack of funding.

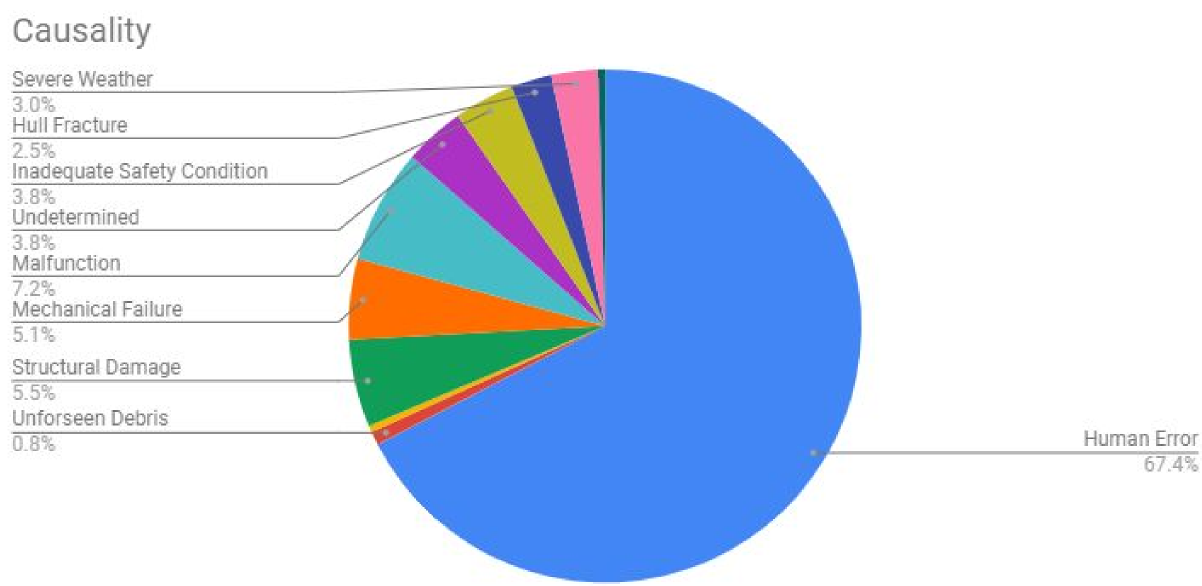

Figure 6.5, Pie chart of causality

Causality:	Total Damages:	Total Injuries:	Total Fatalities:
Human Error	$754,695,610	927	186
Malfunction	$142,171,000	9	5
Structural Damage	$86,035,000	4	15
Mechanical Failure	$53,843,000	55	55
Severe Weather	$48,687,000	7	143
Inadequate Safety Condition	$38,905,000	13	7
Undetermined	$12,376,660	10	1
Catastrophic Failure	$3,800,000	0	0
Severe Heeling	$1,340,000	2	2

Figure 6.6, Casualty Damage Cost vs Injuries and Fatalities

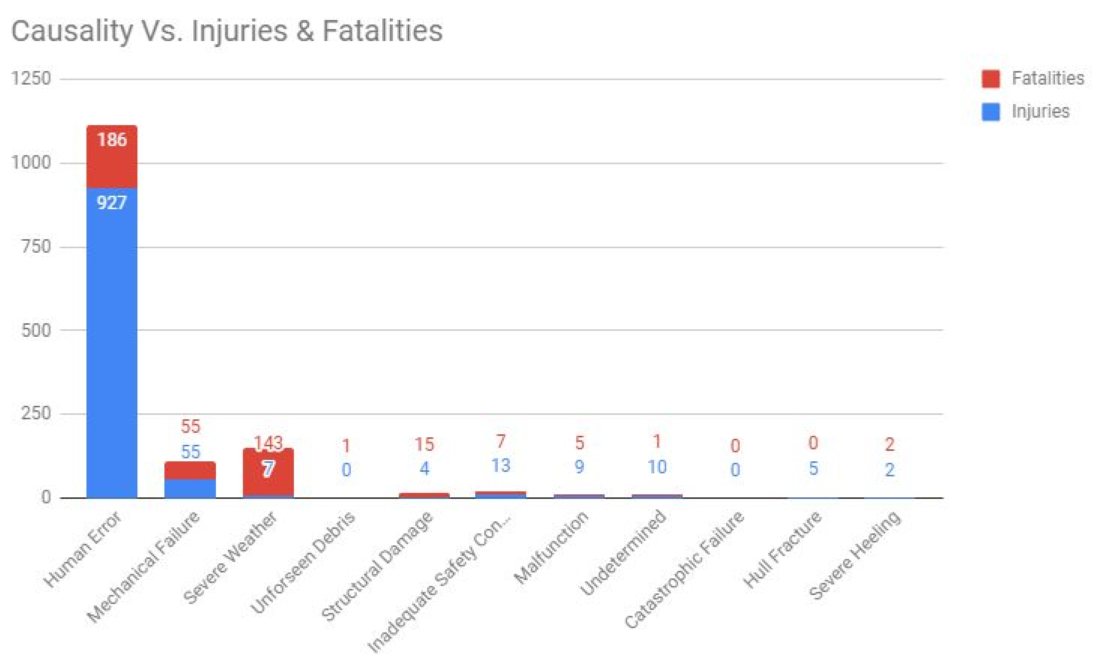

Figure 6.7

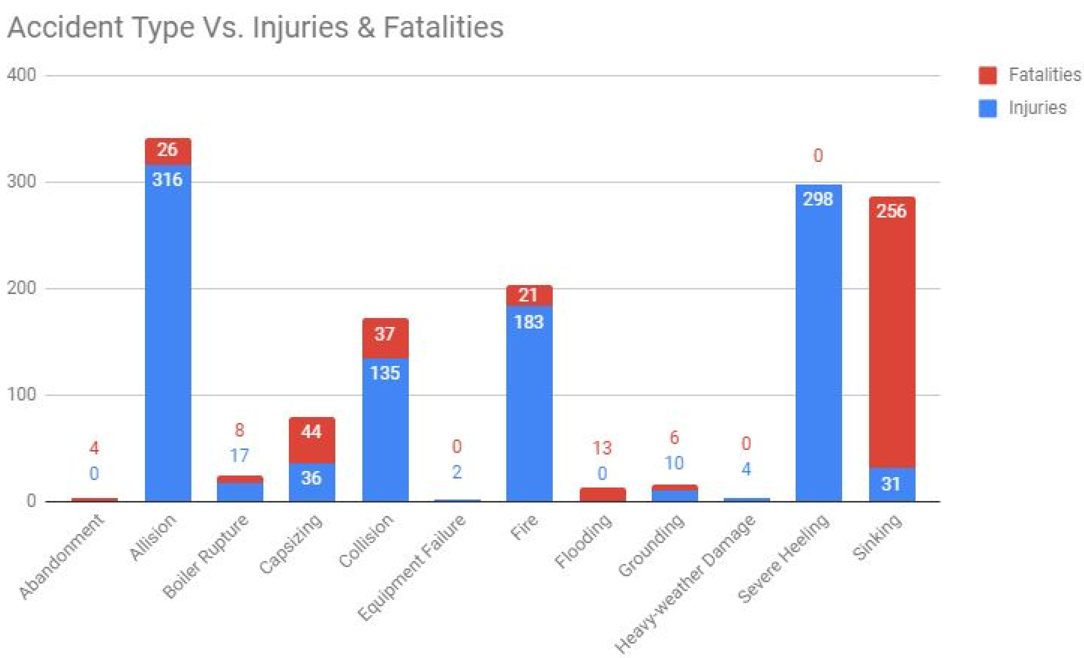

Figure 6.8

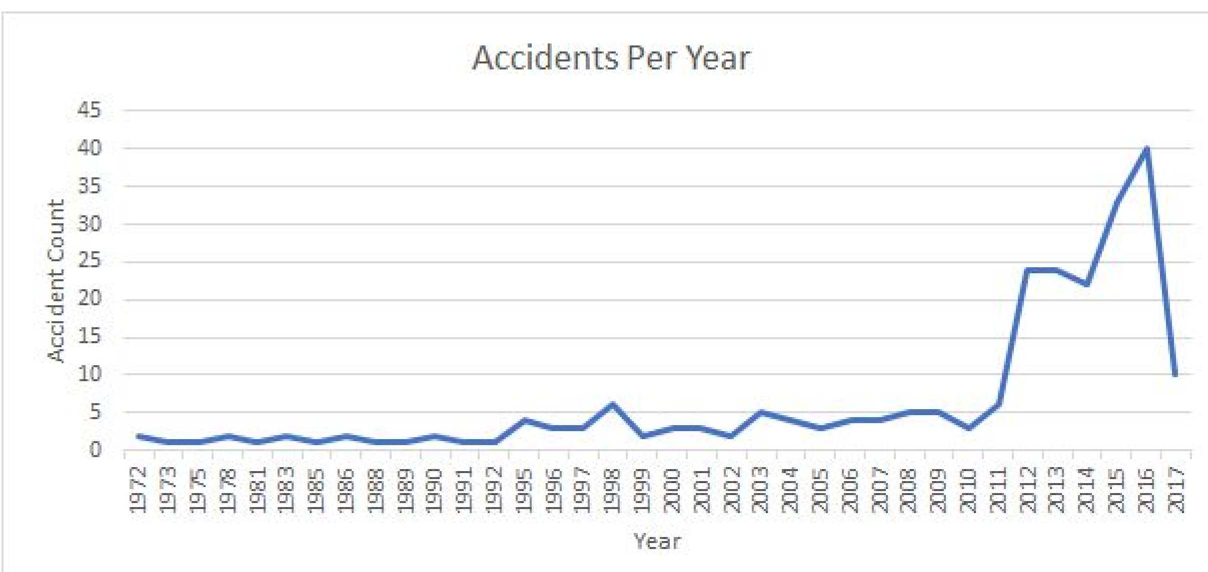

Figure 6.9, Total Accidents Per Year

7. Conclusions and Recommendations

This project will be highly beneficial to our sponsor and PMI. Not only does this webmap take every incident report from NTSB and represents is geospatially, is also does so cheap and in a way that the sponsor can continue to update for free. This map will be great for training purposes because it gives a lot of geospatial data that can help in assessing individual incidents, and can play a role in helping to prevent them in the future.

Recommendations

To continue building upon this product, we recommend upgrading to the account enterprise for Carto, which would potentially allow the use of WMTS for the navigation basemap capabilities and enterprise accounts grant the user more space, allowing for additional data or analysis layers to be displayed.Additionally it may be beneficial for the sponsor to convert the webmap to Leaflet (https://leafletjs.com/) which is a free platform and an Open-source JavaScript library that would allow the sponsor to host the site from sponsor servers, although using Leaflet does require some html skills.

Another recommendation would be to continue to work on trying to determine a method to add shapefiles into Seven C's. Seven C's is a maritime navigation software (https://www.sevencs.com/) which would aid the sponsor in adding the Marine Incident data onto a maritime navigation charts. To continue to keep the online map up to date with the most current marine incident data, a script could be created that would pull the relevant information from NTSB Reports, to update the existing dataset, saving time in keeping the dataset as current as possible.

8. References

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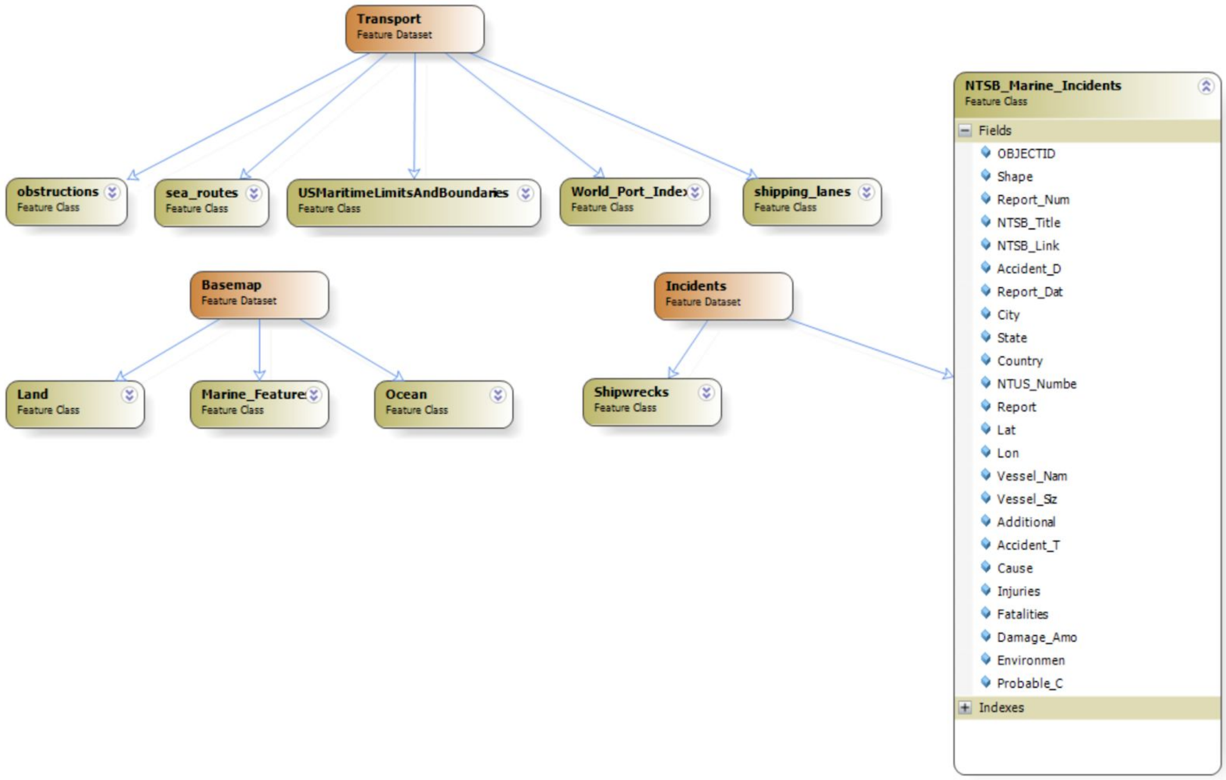
9. Technical Appendices

Appendix A: Geodatabase Schema



Appendix B: Accident Type Definition

Accident Type:	Definition:
Abandonment	Crew leaves the vessel
Allision	Vessel has a collision with stationary object such as a bridge or dock
Fire	Fire on vessel
Boiler Rupture	Rupture in boiler
Capsizing	Vessel flips over
Flooding	Vessel becomes inundated with water
Severe Heeling	Vessel goes to either side almost into a capsize
Grounding	Vessel runs aground
Heavy Weather Damage	Severe weather badly damaged
Collision	Vessel runs into another vessel

Appendix C: Causality Type Definition

Causality Type:	Definition:
Severe Weather	Extreme weather conditions such as a hurricane. For example, current duck accident.
Structural Damage	Vessel had previous damage that was unknown or ignored
Inadequate Safety Condition	Due to vessel design or crew mates that lead to a disaster. For example, floor heater installed too close to flotation device.
Undetermined	Vessel was not recoverable or no evidence of causality could be found.
Hull Fracture	Vessel hull has either crack or large hole.
Mechanical Failure	Vessel components such as valve steam or seal fail.
Unforseen Debris	Debris that is not detected by crew or navigation system.