Initial Project Proposal

Background and Motivation: Discuss your motivations and reasons for choosing this project, especially any background or research interests that may have influenced your decision.

My thesis research deals with modeling the transportation network impacts of inundation events on the Boston metro region. Inundation events (flooding events where networks are degraded or disabled) are serious threats to coastal cities around the world. Such events can have major impacts on regional transportation networks, as seen in NYC in the aftermath of Hurricane Sandy. I have sought to develop an understanding of potential inundation consequences on the Boston metro region by conducting two related analysis.

1. A GIS analysis- cataloging and quantifying likely impacts to transportation assets and driver of transportation demand (people & jobs)
2. A transportation modeling analysis using the Cube Voyager modeling platform to model the impact of inundation events on the regional multi-modal transportation system from 1ft to 6 ft.

This research has provided me with large amounts of data that I would like to display in an interactive web based format.

Thesis Defense PPT: Has more information on topic and outputs (If interested):

https://www.dropbox.com/s/o6vfy2c0fbsonvr/DefensePPT_M30.pptx?dl=0

It is a very interesting data set that provides information on:

- the location, number and extent of transportation assets inundated at water levels from 1 to 6ft.
  - Roads, transit stops, land use, population, etc.
- Modeled traffic flows given a damaged and degraded road network
- Locations of major congestion given an inundation event
- transit ridership by all transit routes and modes,
- number of trips not able to be completed due to inundation (Lost Trips & their origins and destinations)
  - by trip purpose (work, school, shopping, etc.)
- Changes in accessibility by traffic analysis zone by walk, transit and automobile.

Project Objectives. Provide the primary questions you are trying to answer with your visualization. What would you like to learn and accomplish? List the benefits.

I have analyzed much, but not all, of this data using python, ArcGIS, TransCAD and Excel already. I understand what kinds of questions the data can answer but I am trying to find ways to communicate this data more efficiently.

Furthermore I want to find ways to communicate and share the data with others who do not have the same software packages available, or possibly the technical expertise required to deal with the data.

The primary questions I would want a user to be able to answer after interacting with the visualization would be:
- The location, count, and extent of impact given inundation at different levels
- The shifts in transit ridership caused by degradation: For example of the Red Line is disabled what are some of the buses that experience increased ridership - i.e. people who are likely changing their route
- How accessibility changes for different modes given different inundation levels.
- Congestion Hot spots given inundation
- Be able to compare the results to a non-inundated scenario

Benefits:
- Provide people with an understanding of possible inundation impacts on the transport network
- Provide understanding of the impact to peoples personal modes, streets, routes of interested. For example: allow a user to examine if at a certain inundation level the streets or bus/train they use would be compromised
- Provide policy makers with broad metrics of the expected impacts of such inundation events:
  - Total Lost trips by inundation level
  - Changes in:
    - Vehicle Hours Traveled
    - Vehicle Distance Traveled
    - Congestion Hot Spots
  - Other metrics of interest

Data: From where and how are you collecting your data? If appropriate, provide a link to your data sources.
- I already have the data- most of it is in tabular format (dbf & csv).
- I also have network data that I can convert in to Shapefiles and then into GeoJSON. The only concern with the network data is that it quite large (264,000 Links). I'm not sure if D3 will be able to display this data efficiently. I don't think TopoJSON will make much of a difference since I am dealing with links, not polygons.
- Finding a way to display this data dynamically may be a challenge.

Data Processing. Do you expect to do substantial data cleanup? What quantities do you plan to derive from your data? How will data processing be implemented?

I do not expect to have substantial data cleanup but there will be some.
- I kept much of the data in csv/tsv formats but for somethings I used Pandas to convert data to JSON.
- I will need to develop a strategy for dealing with matrices – suggestions would be appreciated – I assume key value pairs (O-D) in a JSON format would likely be the fastest (?)
- Again the network data – I may have to use a smaller clipped network, or remove some of the minor links in the network.

- Some of the data is output as text report files, but I have already written a few python scripts that extract this data to PANDAS Dataframes, I may need to write a few more of these scripts, as there are different formats but I am fairly comfortable doing this.
- There will also be some data formatting and aggregation but between python & JS I do not anticipate the data cleaning to be require excessive amounts of time.

Visualization. How will you display your data? Provide some general ideas that you have for the visualization design. Include sketches of your design.

Accessibility Impacts of Inundation:
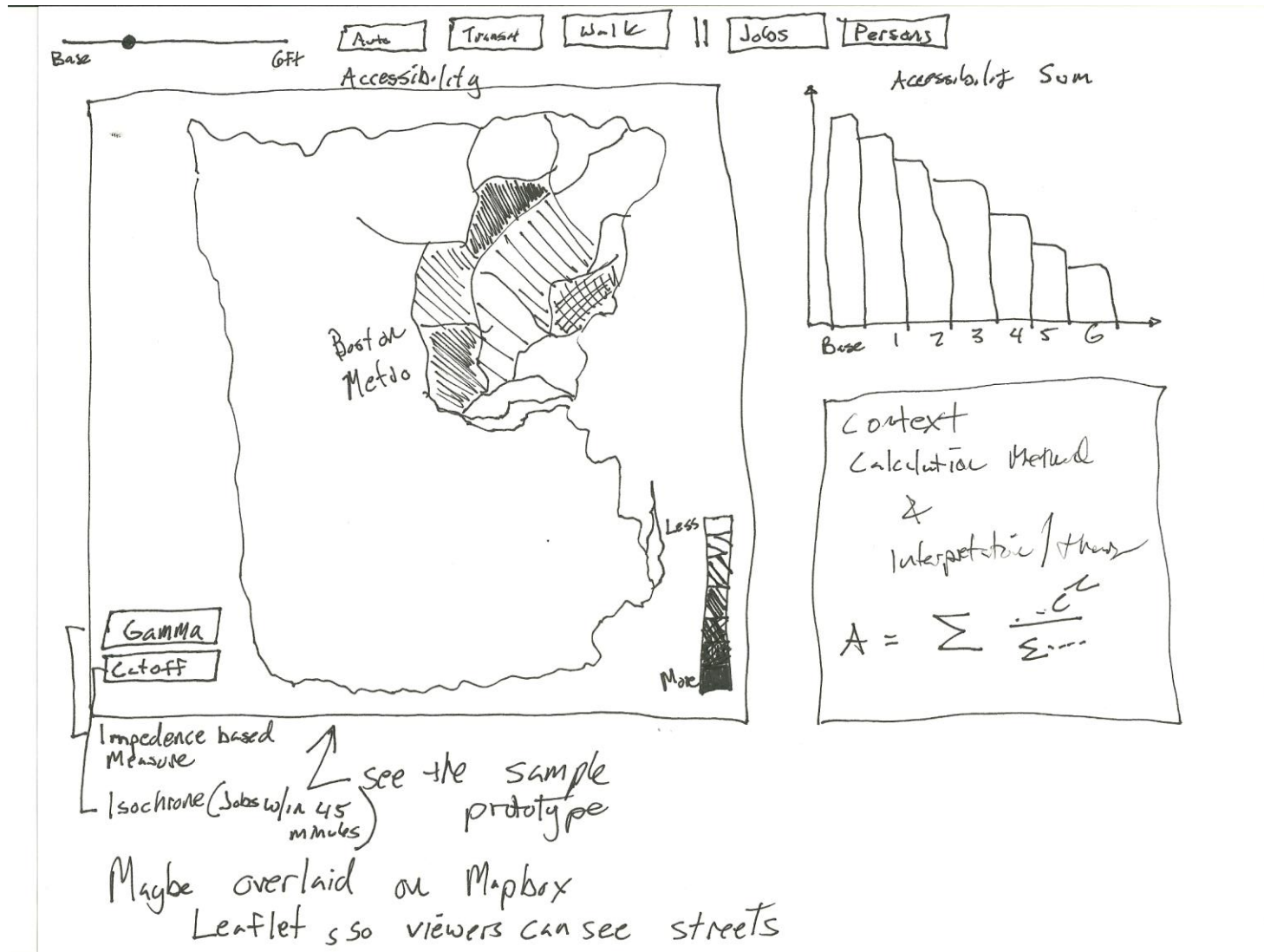
Figure 1: Accessibility Visualization Example

Example: http://mdgis.github.io/ , still needs a lot of work but I've already started trying to create this design.
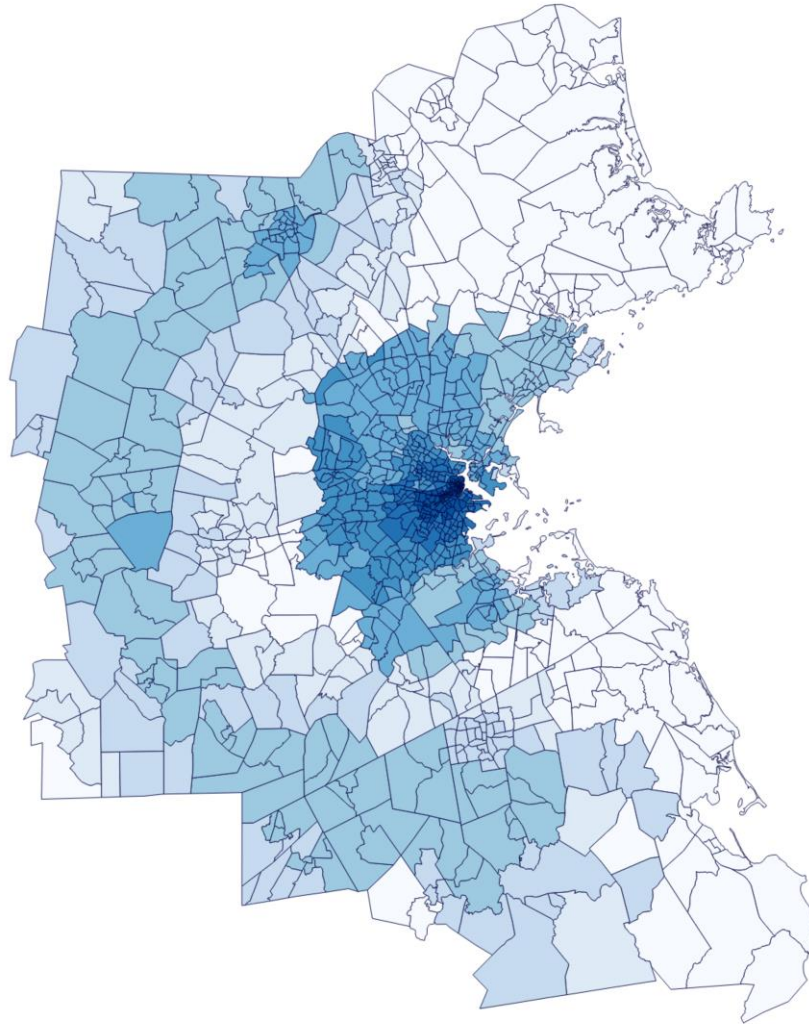
See Prototype

Figure 2: Screenshot of current prototype

This design will include information on the side about the how accessibility was calculated, the accessibility sum (a measure of regional accessibility) and a chart showing the change over the different inundation levels.

INUNDATED ASSETS

0 ———————— 6ft

Slider
Shows
Water

Zoom/Pan

Summary of GIS Results

Demographics

People

Jobs

Transport

Auto | Transit
Roads | Train Lines
Highway Exits | Train Stops
| Bus Lines
| Bus Stops

Selecting Multiple
will draw location
on map

Can
display
percent
or
Total

Chart Showing Change over all Water Levels

▾ Jobs ← dropdown

Off ——————————— 6ft

* Need to figure out how to
do the chart data source
selection Maybe a dropdown
Menu.

Figure 3: Inundated Assets
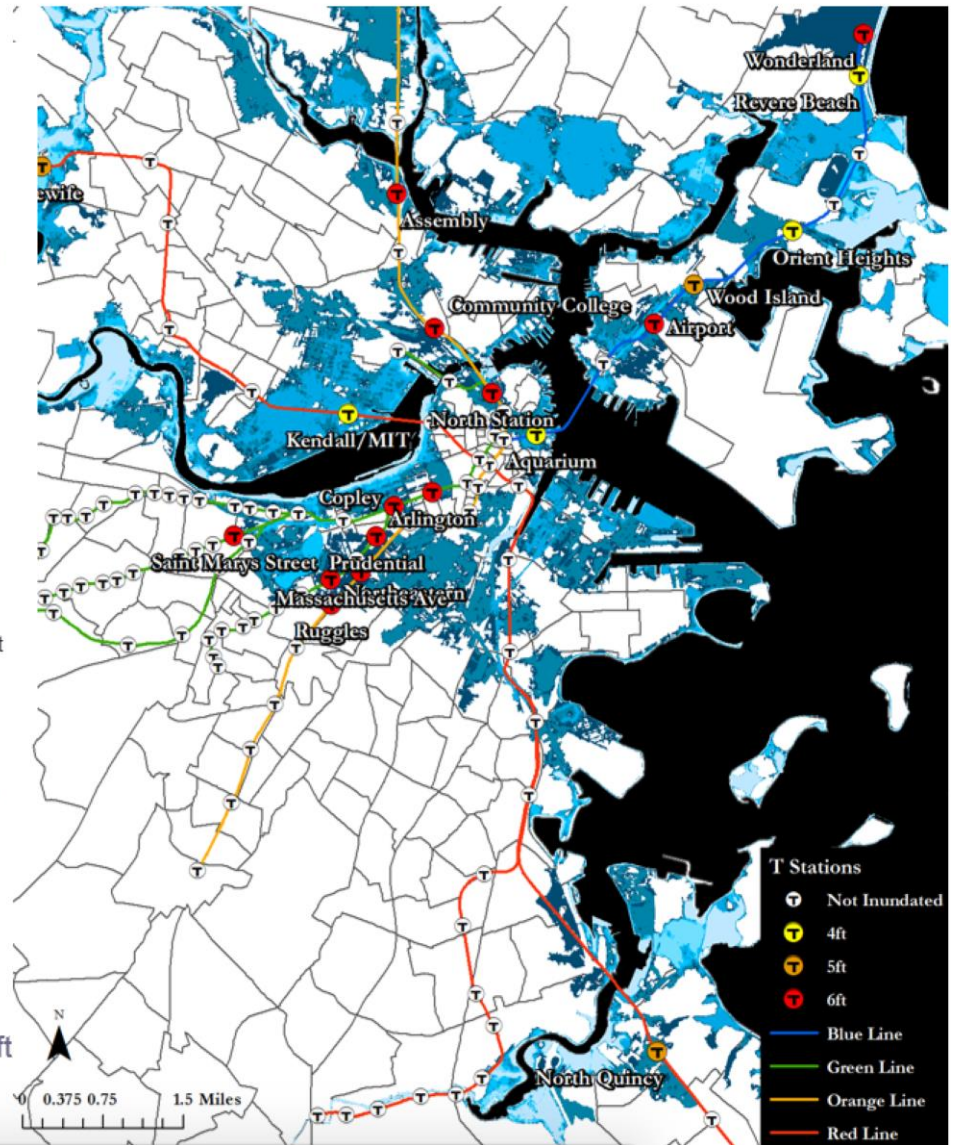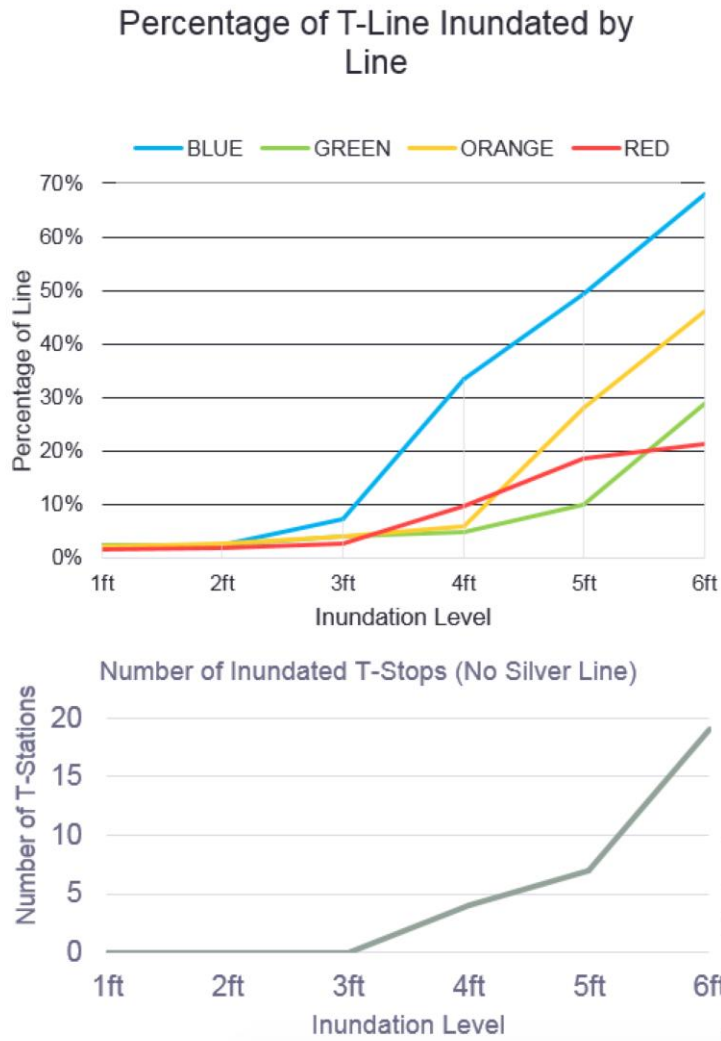
Figure 4: Example of Inundation Layers / Inundated Transit Assets / Change over Inundation Level
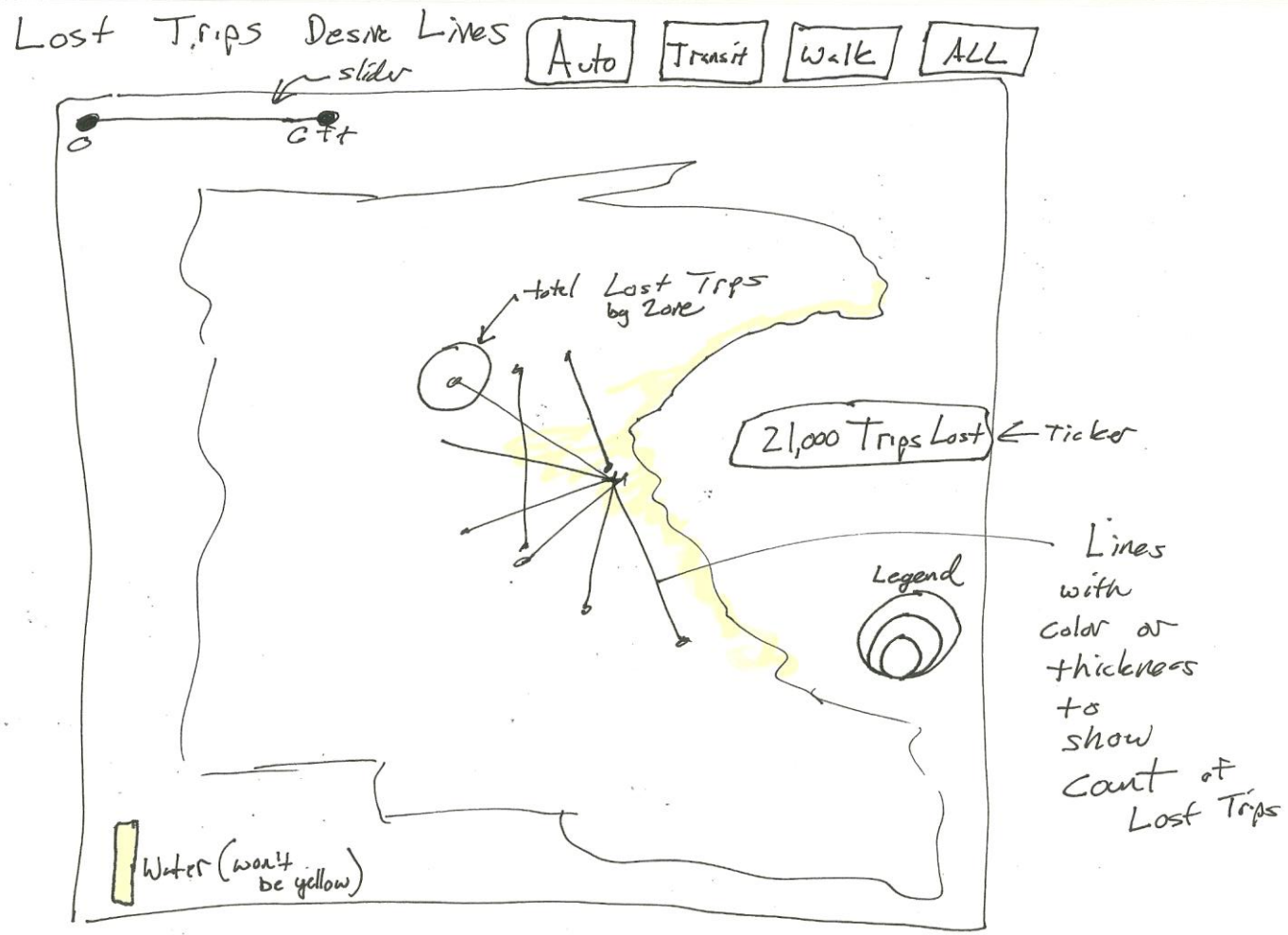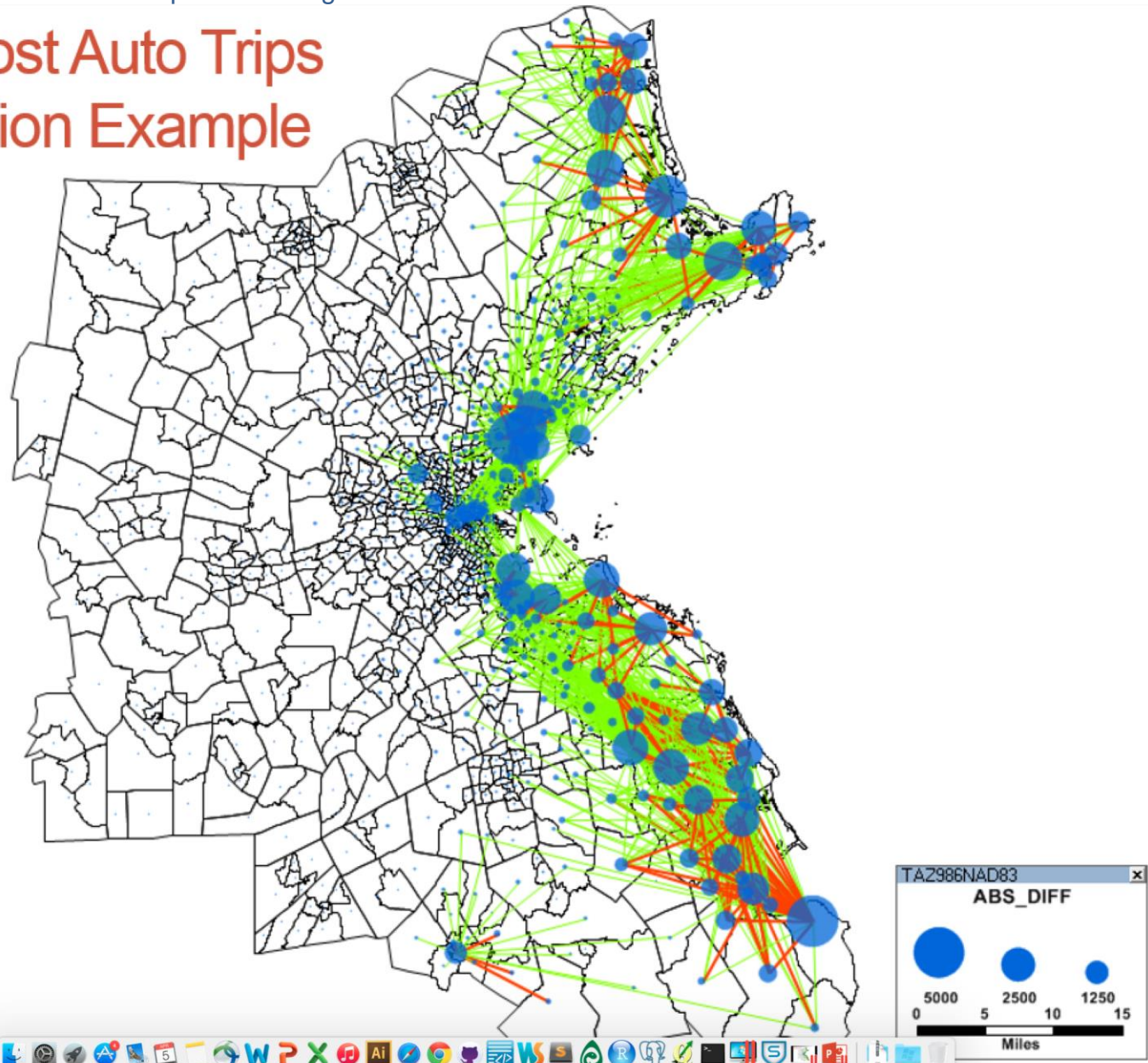
Figure 5: Lost Trips / Desire Line: Data taken from matrices with information on the trips that cannot occur because of network inundation.
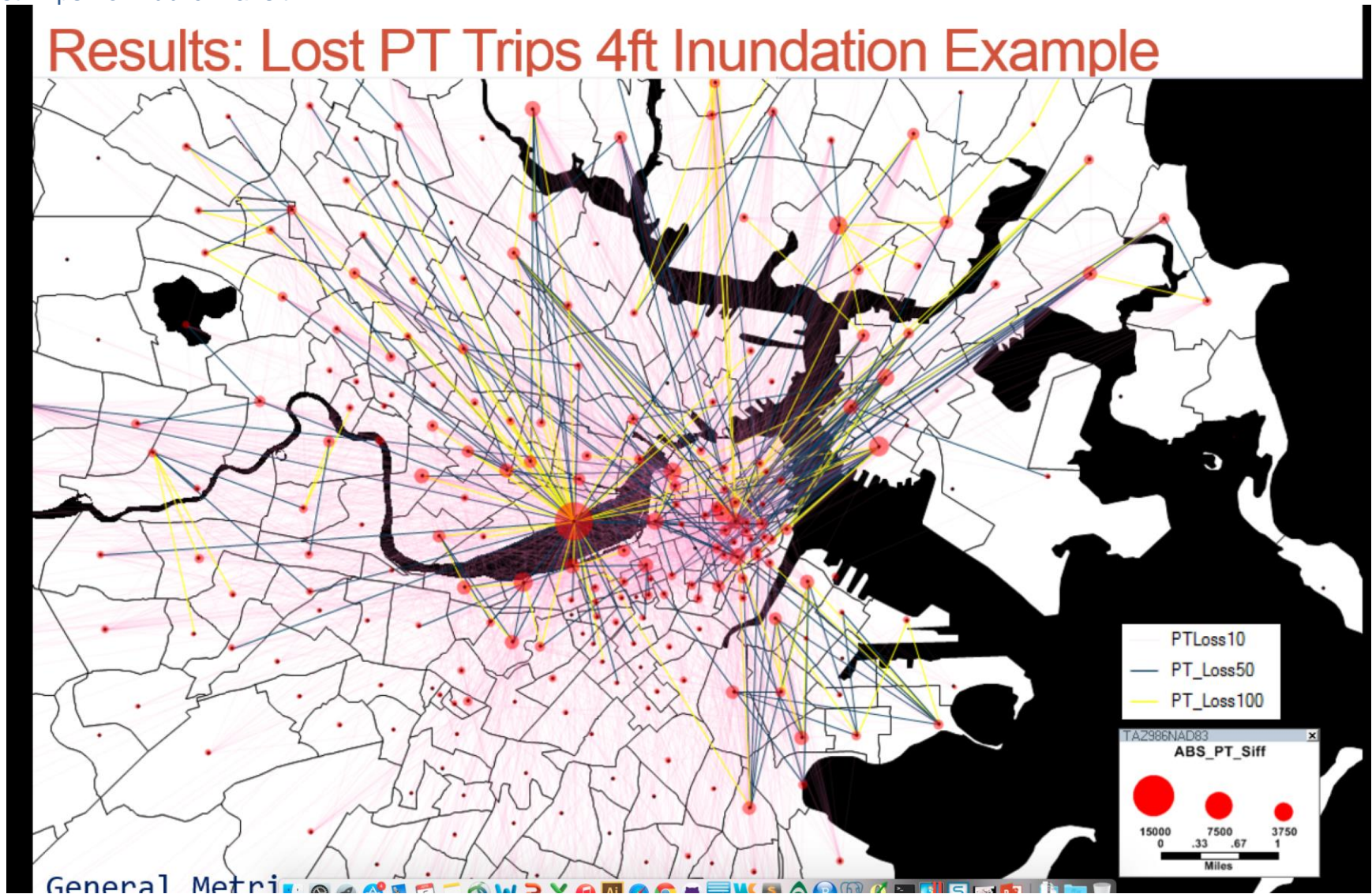
Example Generated in TransCAD Transport Modeling Software:

Figure 6: Example of lost trip by Auto Desire Lines – Line color indicates number of trips and circles indicate the total number of lost trips by Traffic Analysis Zone.
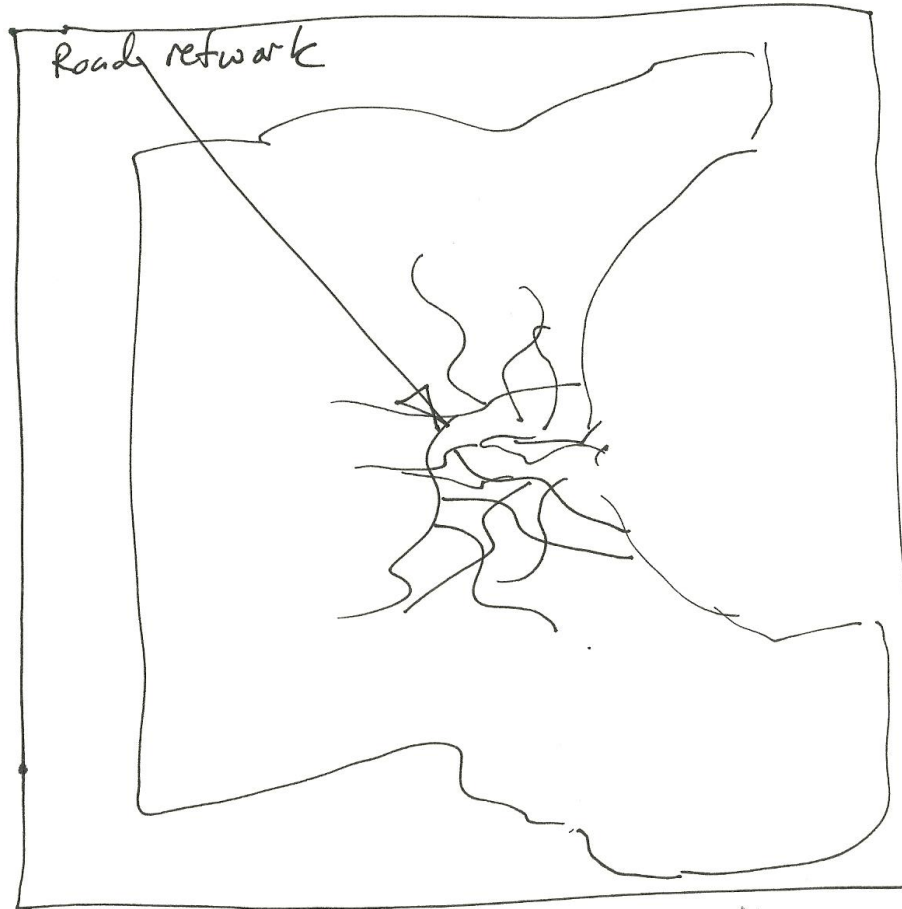
Lost Trips For Public Transit:

Figure 7: Same as previous but transit trips
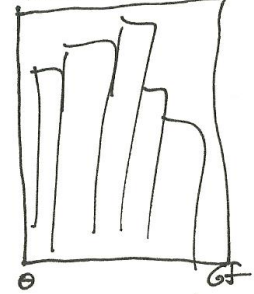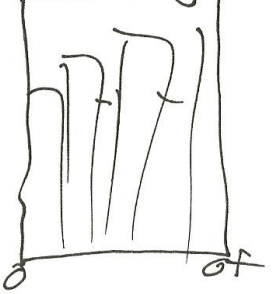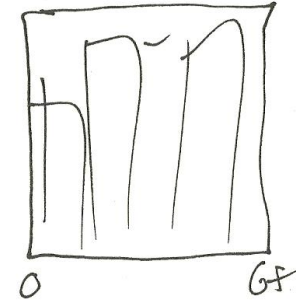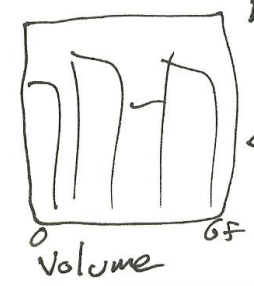
Figure 8: Auto Network Summary

Figure 9: Network (Smaller Extracted Network) Congestion Hot Spots & Queued Vehicle Chart

Must-Have Features. These are features without which you would consider your project to be a failure.

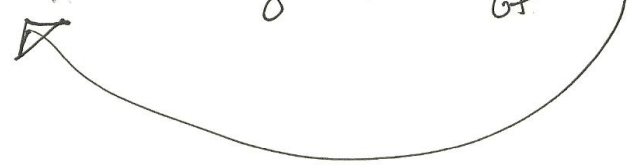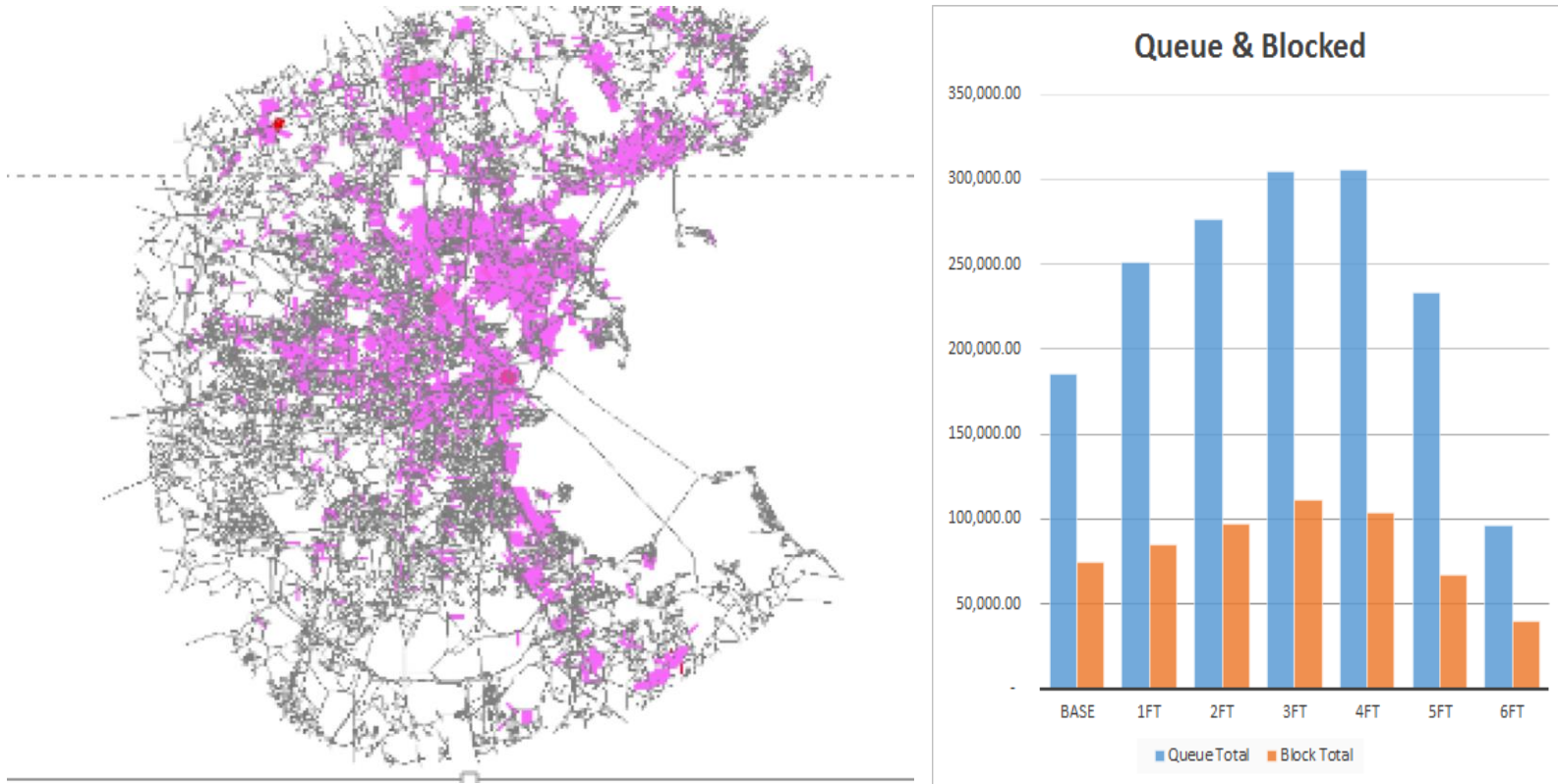- Transportation Assets inundated at 6 different inundation levels. This would be a map with charts on the side showing at each water level (1-6ft) where certain assets were located and in the chart showing the extent of the impact, likely showing both totals & percentages.
- Accessibility impact maps for walk, transit and auto.
- Network impacts charts – description of the congestion impact – if animated network visualization is problematic then a simplified version with more linked charts could be used.
- Some visualization of the number of trips lost by zone – if desire line are problematic then I may do it by simple circle shapes overlaid on the geography.

Optional Features. Those features which you consider would be nice to have, but not critical.

- Desire line chart
- Another visualization showing the changing ridership of different transit lines over the different inundation levels.
- My data has information on queues on network links for every 5 minutes totaling 90 minutes. Some sort of animation of these queues would be really interesting but may not be possible

- I also have information in "packets" of vehicles and the path the use on the network, the data comes in as a list of sequential nodes that packet used to complete its trip. Some sort of animation of these would also be wonderful, but I think it might be too challenging.

Project Schedule. Make sure that you plan your work so that you can avoid a big rush right before the final project deadline, and delegate different modules and responsibilities among your team members. Write this in terms of weekly deadlines.

April 5th – April 11th	- Data wrangling - Working prototype of accessibility maps - Early prototype of inundated asset maps w/chart
April 12th – April 18th	- Strategy and prototype of network impacts: - Figure out how to display the network while maintaining speed of visualization, highlight areas of congestion at different water levels. - Early prototype of Desire Line Lost Trips visualization
April 19th – April 25th	- Decide on Final List of Designs / if some of the optional features are not working at his point – they may have to be abandoned. - Finished Accessibility / Inundated Assets Visualization
April 26th – May 2nd	Finalizing Designs / Polishing
May 3rd – May 5th	Polish things up / Screen cast

The Process Book

Overview and Motivation:

My thesis research deals with modeling the transportation network impacts of inundation events on the Boston metro region. Inundation events (flooding events where networks are degraded or disabled) are serious threats to coastal cities around the world. Such events can have major impacts on regional transportation networks, as seen in NYC in the aftermath of Hurricane Sandy. I have sought to develop an understanding of potential inundation consequences on the Boston metro region by conducting two related analysis.

1. A GIS analysis- cataloging and quantifying likely impacts to transportation assets and driver of transportation demand (people & jobs)
2. A transportation modeling analysis using the Cube Voyager modeling platform to model the impact of inundation events on the regional multi-modal transportation system from 1ft to 6 ft.
3. This research has provided me with large amounts of data that I would like to display in an interactive web based format.

Inspiration

Below are some examples of various mapping visualizations that I examined (code & style). These examples provide both inspiration, as well as technical hints for my implementation. I initially focused on developing maps because my data is spatial. Furthermore, I have a great deal of experience with GIS and mapping applications but very little experience with web mapping. This project offered the opportunity to develop my web mapping skills.

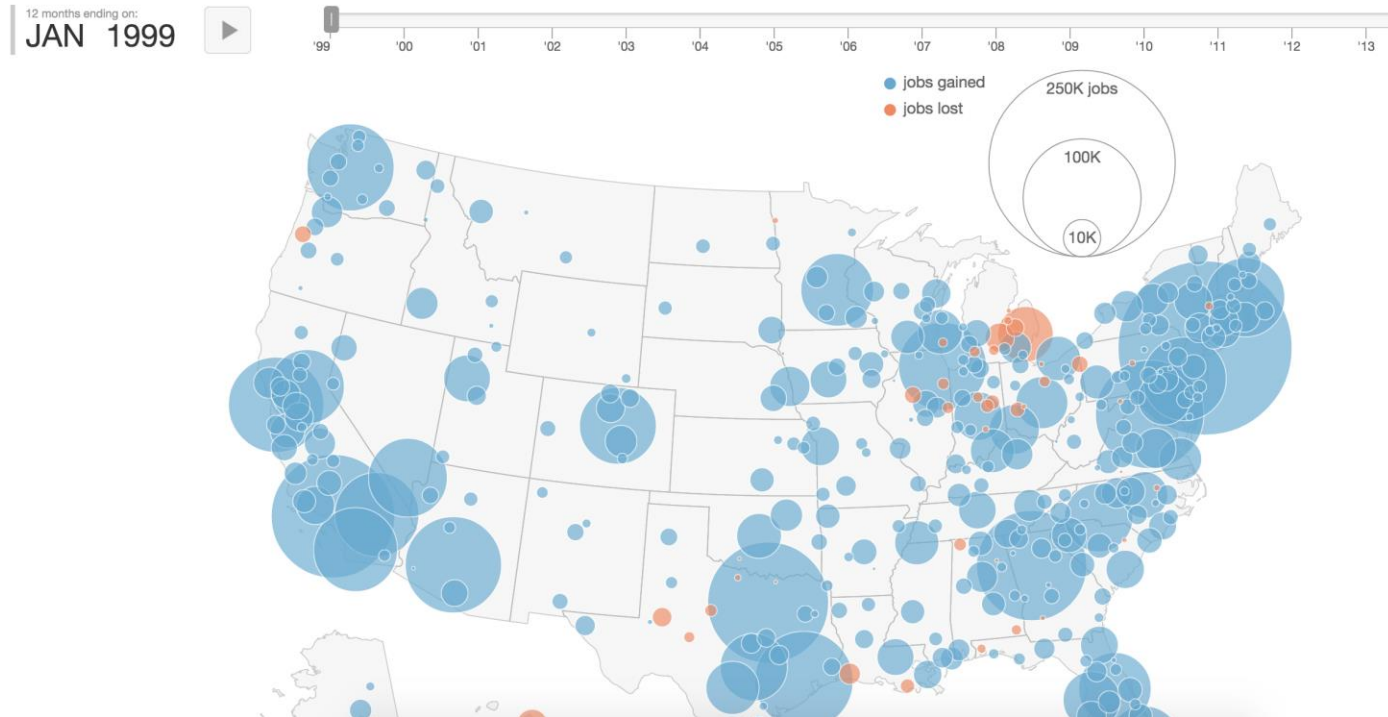**Figure 10: http://tipstrategies.com/interactive/2014_map/**

This visualization is pure D3 (as in no leaflet, etc.). I found this helpful both in the application of the slider, symbol levels, and legend. I do not have time series data but I am presenting six different sets of data at times (1-6ft of inundation). This has a very clean and clear presentation and message, something I needed to strive for in my project.

d3.js circles fixed in geographic location on leaflet map but constant size

Figure 11: http://www.d3noob.org/2014/03/leaflet-map-with-d3js-elements-that-are.html
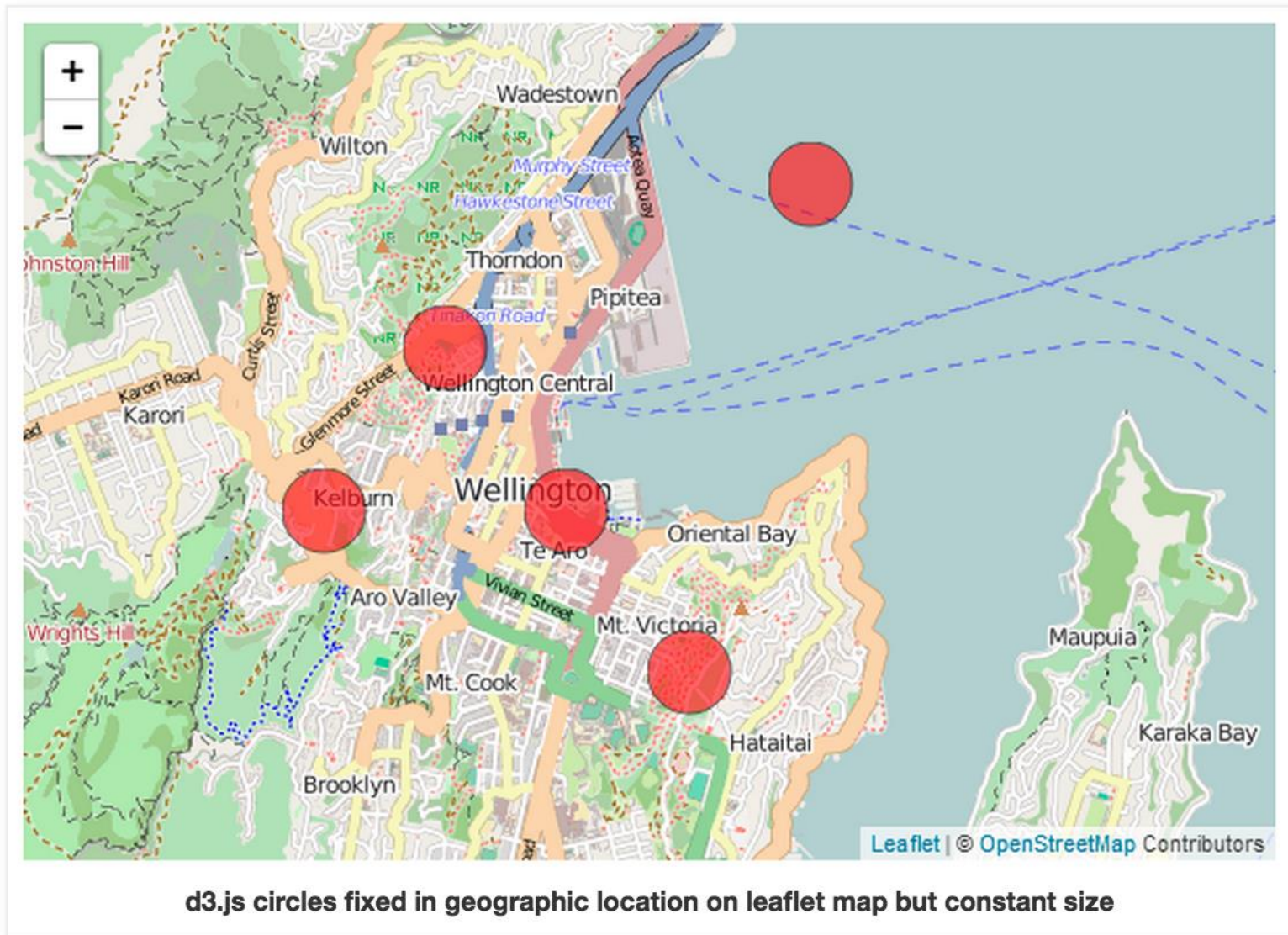
Some Leaflet / D3 examples that were helpful. It was a challenge to find the best method of displaying the data. Some datasets are more efficient to load directly into leaflet even if the file size is larger, while other data sets needed to be converted to TopoJSON and overlaid on the leaflet background maps.

Here is what the finished product looks like:

Figure 12: http://zevross.com/blog/2014/09/30/use-the-amazing-d3-library-to-animate-a-path-on-a-leaflet-map/

Interesting piece on animating D3 on top of Leaflet.

Figure 13: http://www.tnoda.com/flightanimation
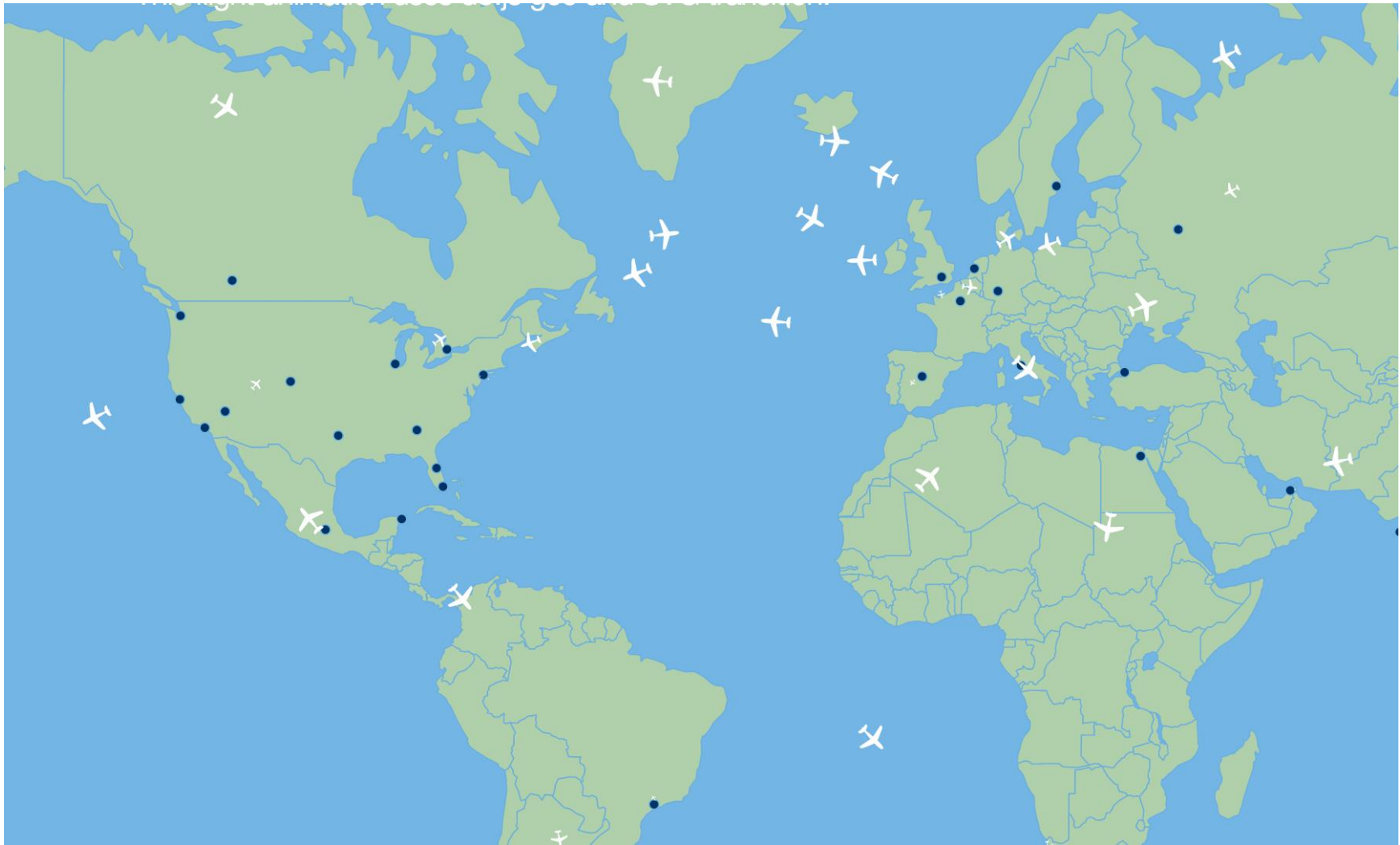
Another interesting piece on animating D3, though not on leaflet.

Dot Density Maps with Python and OGR

If you use Python for GIS sooner or later you'll use GDAL for manipulating raster data and its vector cousin OGR for working with vector data. OGR has a Python API for most of the methods in the C++ library and even provides some basic geometry analysis. And most importantly it can read/write and therefore convert data in a variety of vector file and database formats.
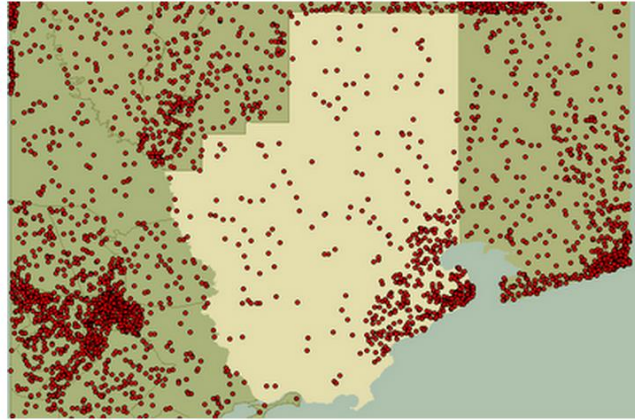
Figure 14: http://geospatialpython.com/2010/12/dot-density-maps-with-python-and-ogr.html

I would have liked to present zonal data as dot density maps rather than as chloropleth maps, but time, complexity and browser speed made this option unrealistic.

Voronoi Arc Map

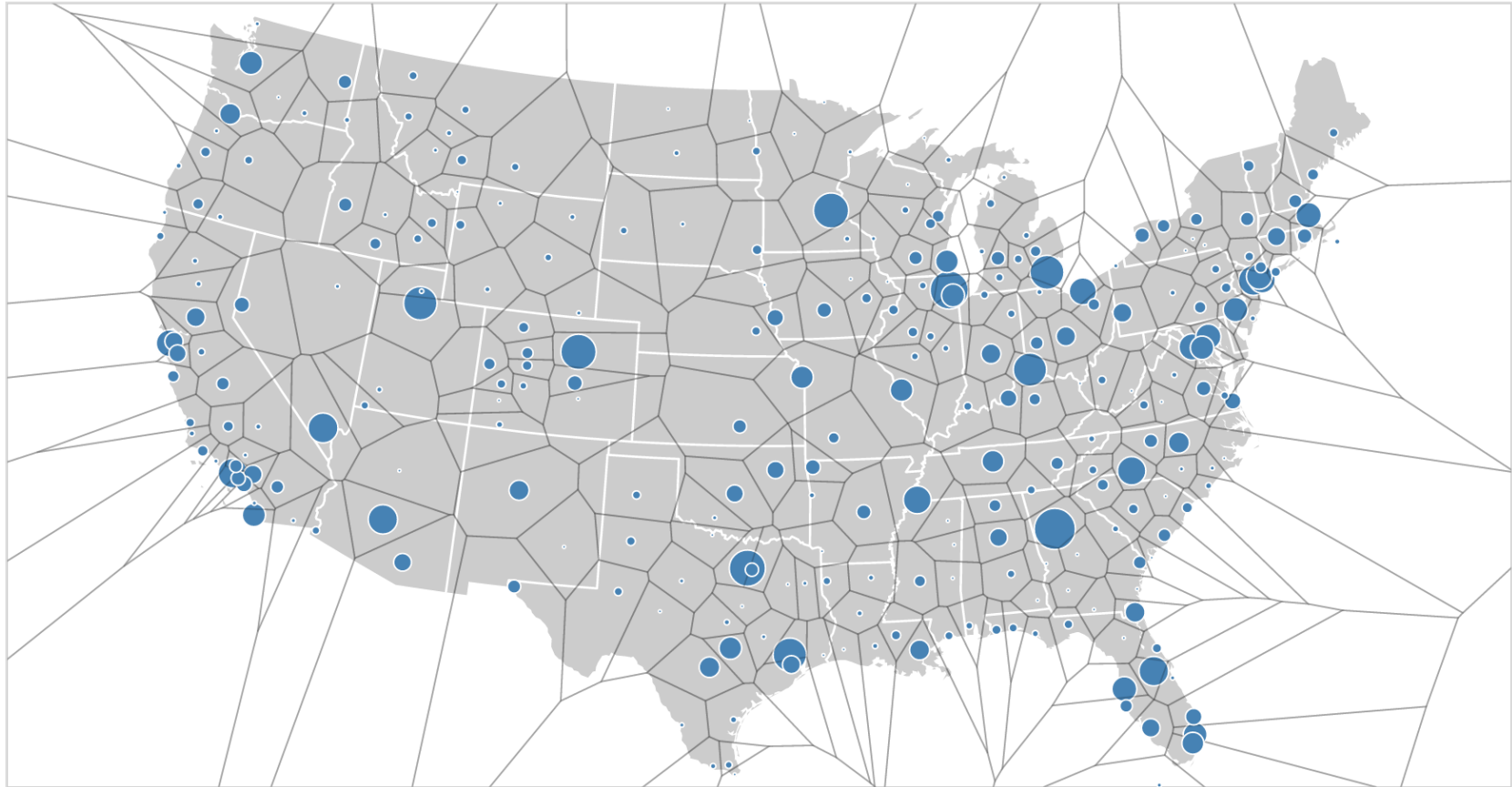This was very helpful for setting up the Desire Line / Spider Line chart. I would have like to implement to Voroni polygons but just use them for selecting specific nodes. Initial tests did not work, it might be because of Leaflet overlay. I decided that the Voroni was unnecessary at this time and I did not implement a version of this.

What questions are you trying to answer? How did these questions evolve over the course of the project? What new questions did you consider in the course of your analysis?

> The primary questions I would want a user to be able to answer after interacting with the visualization would be:
> - What are the location, count, and extent of impact given inundation at different levels?
> - What are the shifts in transit ridership caused by degradation?
>   - For example of the Red Line is disabled what are some of the buses that experience increased ridership - i.e. people who are likely changing their route
> - How does accessibility change for different modes given different inundation levels?
> - Where are congestion hot spots given inundation?
> - What are the number of trips lost by different modes by inundation and where are their origin and destination?

Data: Source, scraping method, cleanup, etc.

Exploratory Data Analysis: What visualizations did you use to initially look at your data? What insights did you gain? How did these insights inform your design?

> I have been working with this data intensely in excel, R, Python, ArcMAP, TransCAD and Cube Voyager. I have done a great deal of exploratory data analysis. Please reference my thesis defense presentation for more examples of how I have explored this data and presented findings. Some of the visualizations are direct translations of previous exploratory analysis. Though, I have improved upon the initial analysis.
>
> https://www.dropbox.com/s/o6vfy2c0fbsonvr/DefensePPT_M30.pptx?dl=0

Design Evolution: What are the different visualizations you considered? Justify the design decisions you made using the perceptual and design principles you learned in the course.
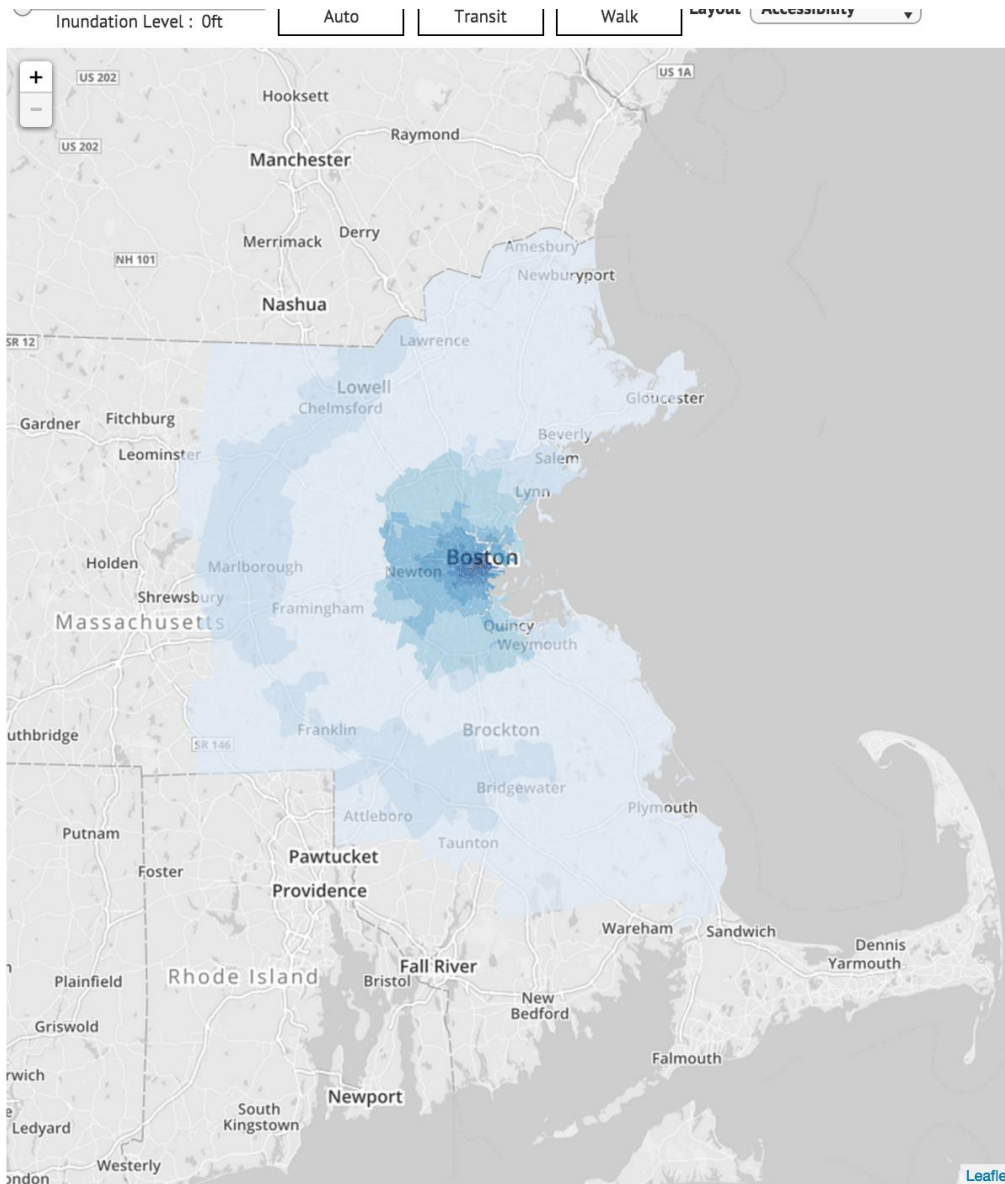
Accessibility Chart
This is the accessibility chart. I have linked it to the slider and the buttons above. I started with this visualization as I had previously developed 24 different maps that showed the same data. Now I can see all of the data in a single window. This viz did not change substantially over time though I did add in tool tips and path highlighting. I wanted to link it to another chart – so I eventually introduce a linked histogram that can be seen in the implementation description.
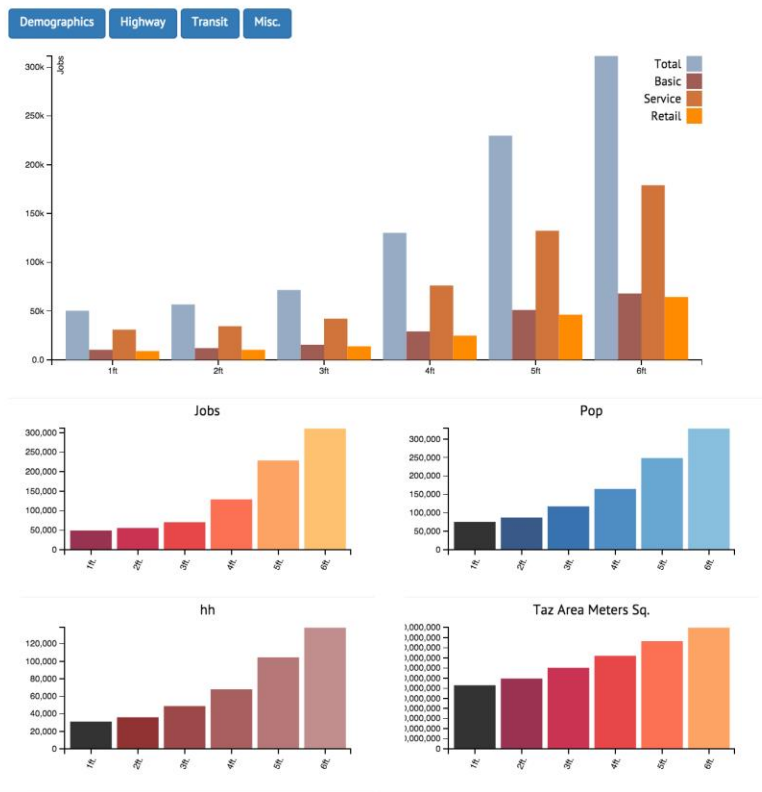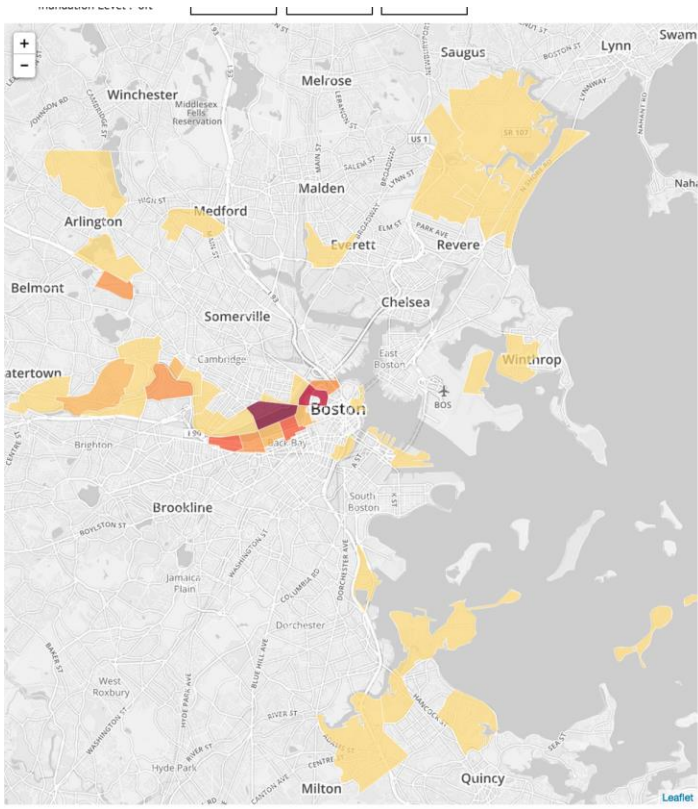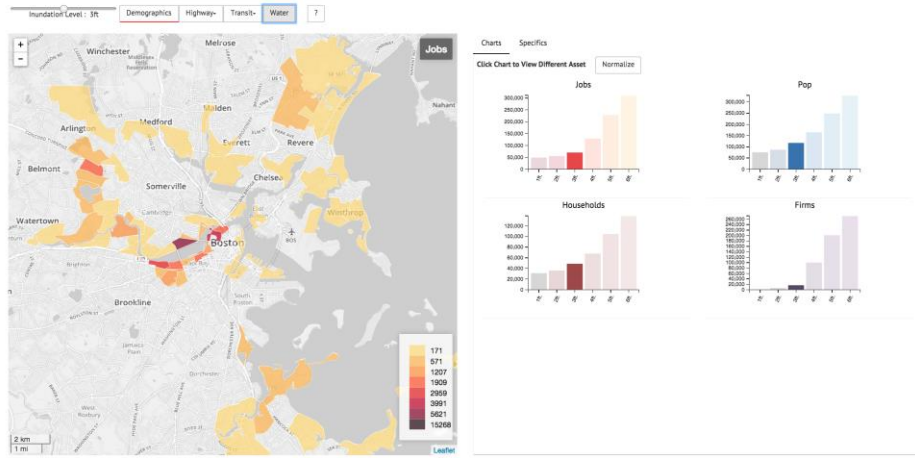
This is the Inundated Asset map, it shows the total number of inundated assets, if you click on the lower charts to the right of the map on the left will update. I wanted to use dot density here but realized it would be too many dots for D3 to handle and I would need to pull in python. Transit & Highway data is presented as points or lines while demographic data is presented as chloropleths.

I initially had the small chart bars update the content of the map. When I presented this to people without explaining it they often did not understand hwo to update the data. Therefore I then linked the inundation data to the slider, and the little charts only change the data dimension (jobs, population, etc) when a user is viewing the Demographics data section.

This visualization remained fairly constant, with the main changes occurring being related to the linking of data and attempting to clarify the relationship between the charts on the right and the map on the left.

Lost Trips Visualization:
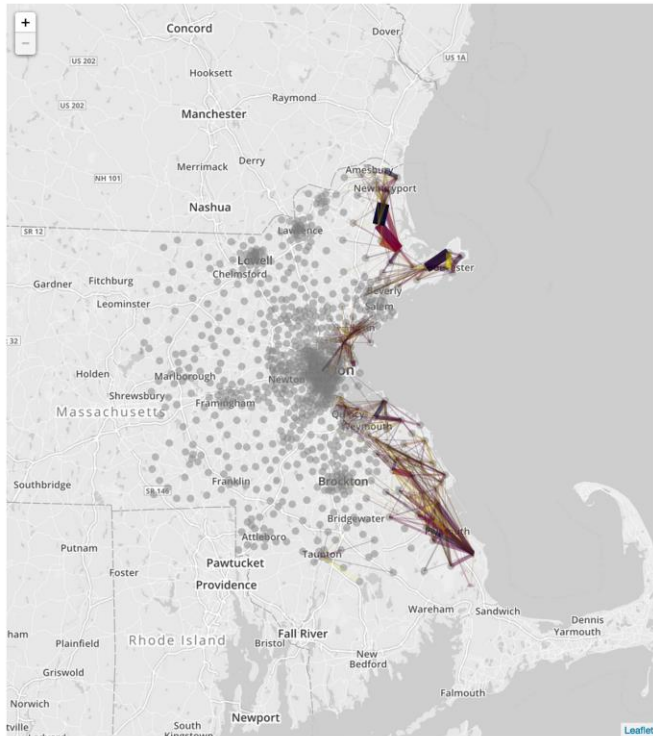
The lines indicate areas where trips area lost. This is a traditional way to show the relationship between origin and destination flows. This visualization stayed somewhat static over the course of the project. I added options to show different modes and a brushable histogram layout that shows the distribution of lost trips for each inundation level.
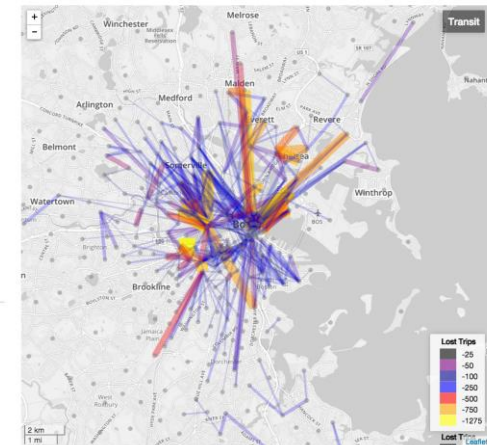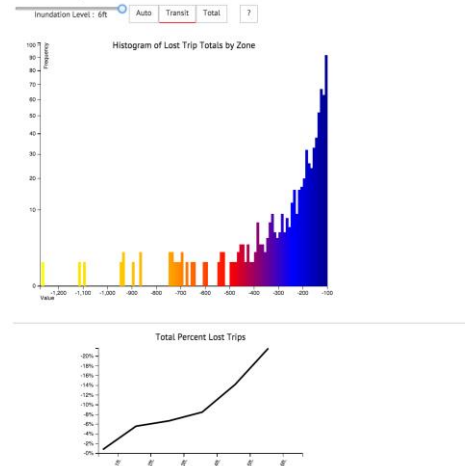
I think the visualization is striking to look at and interesting, though I wish I could have added some edge bundling, or perhaps converted the lines to paths that came to a point at their beginning and terminus.

Transit Ridership Change

Inundation Level : 0ft

LOWE. ROCK. PLYM.

NEWB. NEED. MIDD.

FAIR. KING. HAVE.

FRAN. FRAM. FITC.

STOU. ATTL.

Green	Orange	Blue
Red		

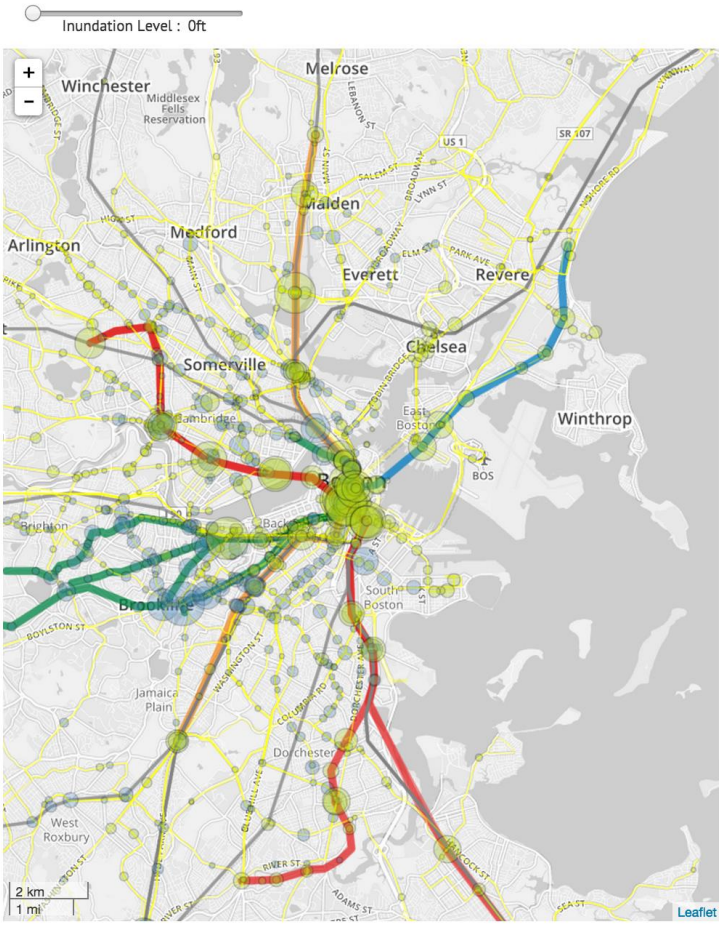| SLIVER	SL1	SILVER	Logan	CT2	1	4	5	7	8	9	11	14	15
16	17	18	19	20	21	22	23	24	27	28	29	30	31
32	45	47	50	51	52	55	57	59	60	62	64	65	
33													
34	66	77	78	79	80	83	85	86	87	88	89	90	
35	67 68	91	100	101	101	104	105	106	108	109	110		
36	69	92											
37	70	93	111 114	134	136	137	210	211	214	215			
39	71	94	116	216	238	240	350	354	411	426			
40	72	95	117	220									
41	73	96	119	222	429	441	442	450	455				
42	74	97	120	225	430	459	504	505					
43	75	99	131	230	435	501							
44	76	100	132	236	436	502	553	554					
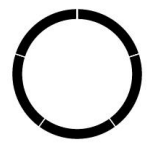
Lorem ipsum dolor sit amet, consectetur adipiscing elit. Cras ornare orci a finibus pulvinar. Donec dapibus magna a nunc accumsan mattis. Duis eu rhoncus quam. Vestibulum in tortor sed nisl

This map shows transit ridership change at stops, Orange circles are decreases in boardings at these stops and blue circles indicate increases in boardings at these stops. I will have this data linked to a display on the right of the map.
I initial set up a tree map to use as a selector for the different transit routes. It was effective for subway and commuter rail lines but the buses were organized haphazardly (even when sorted) and the layout provided no information. I move to a dynamic table layout (Figure 16: Transit Ridership Final) which provides valuable information and is much cleaner looking.

Transit Ridership Change Given 4ft of Inundation

Reset | View Water | Ridership Increase | Ridership Decrease | ?

Route	Mode	Base Ridership	4ft Ridership	Difference
Red	The T	275,114	65,868	-209,246
Orange	The T	241,823	134,760	-107,063
Green	The T	259,869	187,477	-72,392
Blue	The T	61,199	4,043	-57,155
111	Bus	16,046	4,202	-11,844
86	Bus	20,199	8,710	-11,489
Framingham	Commuter Rail	13,039	2,735	-10,303
39	Bus	24,197	15,193	-9,004
71	Bus	10,207	1,410	-8,797
7	Bus	9,662	971	-8,690
1	Bus	13,775	5,901	-7,874
Fairmount	Commuter Rail	7,497	528	-6,969
Haverhill	Commuter Rail	7,286	475	-6,810
77	Bus	10,113	3,934	-6,179
Attleboro	Commuter Rail	15,674	9,913	-5,761
9	Bus	22,591	17,195	-5,396
Franklin	Commuter Rail	14,105	8,926	-5,180
70	Bus	7,604	2,442	-5,162
Middleboro	Commuter Rail	4,243	184	-4,060
96	Bus	10,673	6,786	-3,887
93	Bus	11,766	8,043	-3,723
501	Bus	4,587	931	-3,657
504	Bus	3,872	317	-3,555
73	Bus	6,564	3,085	-3,479
Newburyport	Commuter Rail	3,436	153	-3,283
116	Bus	3,568	332	-3,037
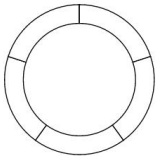
Figure 16: Transit Ridership Final

   The Transit Ridership map proved to be the most complicated one to implement. I found that the visualization could become too crowded and difficult to interpret especially when specific routes were selected. Therefore, I implemented a distance-based calculation that only shows nodes within about a half mile of any point on the selected line. I was worried that this distance calculation would be cause the visualization to be very slow. I was able to solve this problem by using some code I found on stack overflow that claimed to be able to quickly calculate distances between two points.

Link: http://stackoverflow.com/questions/27928/how-do-i-calculate-distance-between-two-latitude-longitude-points

I tested this code with a few points and then tried it on the full data set. Each line is composed of from about 20-50 nodes, I calculate the distance from each of these nodes to all other nodes and if they are within ½ mile then they are visualized. The processing time is not noticeable and it greatly improves the readability of the visualization.
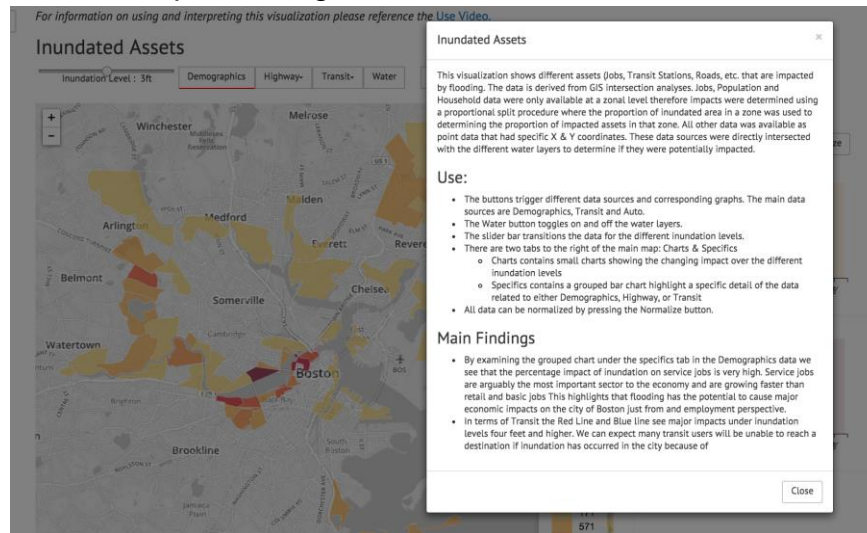
Auto Network

The network chart has limited evolution because of the size of the data. Most of the work on this visualization was in data processing and in leaflet/TopoJSON troubleshooting.

Implementation: Describe the intent and functionality of the interactive visualizations you implemented. Provide clear and well-referenced images showing the key design and interaction elements.

Modals & Navigation

Implementing a context material into the visualization was very challenging. My web design skills are very limited so it took a great deal of time to develop a strategy for showing context information. Initially I had lots of text above and around all of the visualizations. I decided that this was distracting and took up valuable screen real estate. Therefore I implemented a series of Bootstrap Modals into the webpage. Each visualization has a box containing "?", if the user clicks on these boxes: an explanation of the visualization, the use of the visualization and main findings. I would have like to implement an animated "Test Drive" of the site and may try to add this feature in the future. I believe the modals are effective.

Initially, focused on developing prototypes. by developing the prototypes first, I now know what visualizations I would have time to develop more, and make work better. I did not want to commit to a visualization that would end up being too difficult to implement in the time available

I have also added a navigation side bar that can be triggered by pressing the button in the upper right corner with the triple bar symbol.

Visualizing Inundation Impacts on Transportation Networks

A major source of uncertainty for many cities and regions throughout the world is the potential impacts of climate change. These impacts include, but are events, changes in global temperature, droughts, and sea level rise. Of these many potential impacts sea level rise is perhaps the most relevant to transpo levels coupled with extreme weather hold the potential for inundation of transportation networks and resulting impacts to the people that live, work and

My thesis research focuses on modeling inundation impacts on transportation networks in the Boston Metro Region. The data for the "Inundated Assets" v analysis in Arcmap. All other charts have data derived from the MIT - Cube Voyager Four Step Transportation Model. Four Step models are used to estima The output of these models includes origin destination matrices by different modes, as well as network (Transit & Highway) attributes that describe the p the number of users in the system. For more information on four step models please see the basic description for a more the detailed description of meth source or contact Michael Dowd.

Assumptions

When modeling inundation in the Cube model system, I assume that all users of the sytem will attempt to complete their trip even if portions of the regio normal day where the transport network is compromised but people still attempt to complete their normal trips if possible.

For information on using and interpreting this visualization please reference the Use Video.

Inundated Assets

I initially had all visualizations in the same screen space and just switched between them with different buttons and drop down menus. I decided to switch to more of "newspaper" story layout though because it allows people to move back and forth and examine inundation impacts across visualizations. I did add a side bar for navigation use Bootstrap.

Inundated Assets

Inundated Assets
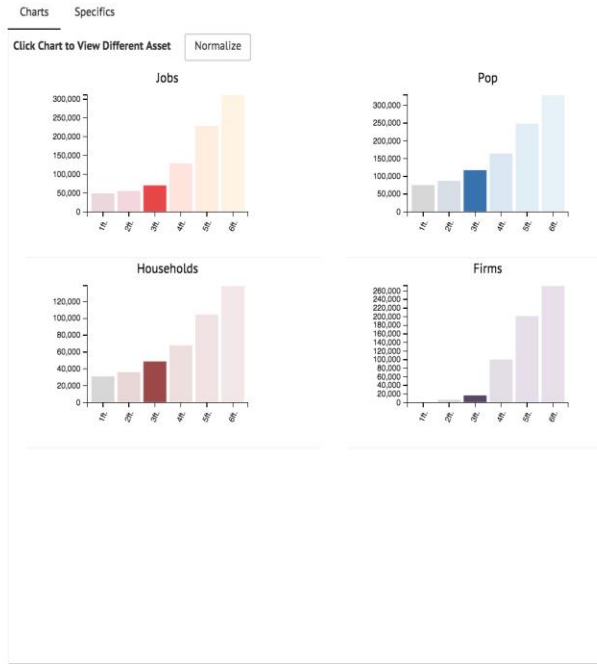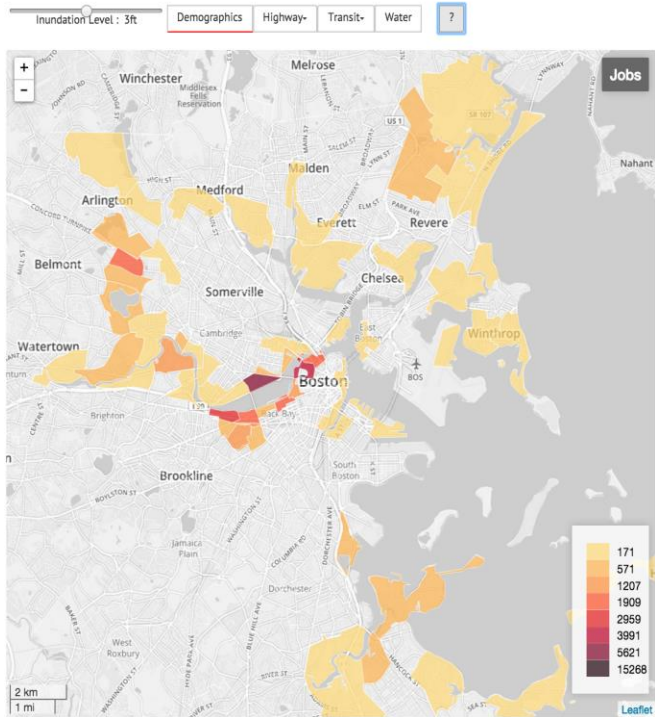
- The buttons trigger different data sources and corresponding graphs. The main data sources are Demographics, Transit and Auto.
- The Water button toggles on and off the water layers.
- The slider bar transitions the data for the different inundation levels.
- There are two tabs to the right of the main map: Charts & Specifics
  - Charts contains small charts showing the changing impact over the different inundation levels
  - Specifics contains a grouped bar chart highlight a specific detail of the data related to either Demographics, Highway, or Transit
- All data can be normalized by pressing the Normalize button.
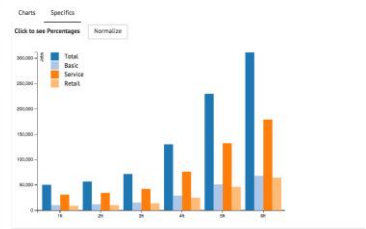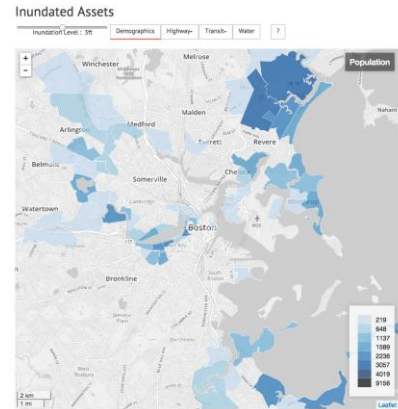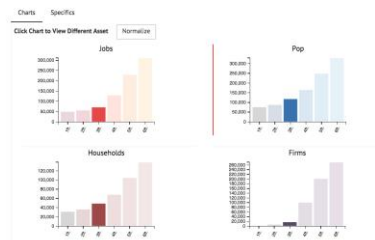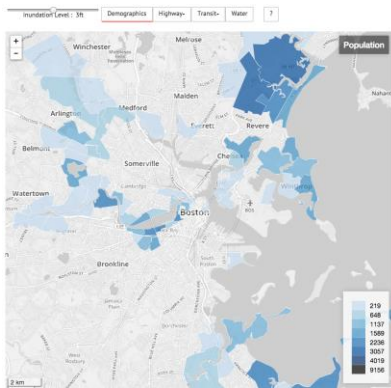
Transit Ridership Change

Transit Ridership Change Given 4ft of Inundation

Reset | View Water | Ridership Increase | Ridership Decrease | ?

Route	Mode	Base Ridership	4ft Ridership	Difference
Red	The T	275,114	65,868	-209,246
Orange	The T	241,823	134,760	-107,063
Green	The T	259,869	187,477	-72,392
Blue	The T	61,199	4,043	-57,155
111	Bus	16,046	4,202	-11,844
86	Bus	20,199	8,710	-11,489
Framingham	Commuter Rail	13,039	2,735	-10,303
39	Bus	24,197	15,193	-9,004
71	Bus	10,207	1,410	-8,797
7	Bus	9,662	971	-8,690
1	Bus	13,775	5,901	-7,874
Fairmount	Commuter Rail	7,497	528	-6,969
Haverhill	Commuter Rail	7,286	475	-6,810
77	Bus	10,113	3,934	-6,179
Attleboro	Commuter Rail	15,674	9,913	-5,761
9	Bus	22,591	17,195	-5,396
Franklin	Commuter Rail	14,105	8,926	-5,180
70	Bus	7,604	2,442	-5,162
Middleboro	Commuter Rail	4,243	184	-4,060
96	Bus	10,673	6,786	-3,887
93	Bus	11,766	8,043	-3,723
501	Bus	4,587	931	-3,657
504	Bus	3,872	317	-3,555
73	Bus	6,564	3,085	-3,479
Newburyport	Commuter Rail	3,436	153	-3,283

Figure 17: Transit Ridership Change Initial View

See below for explanation and use.

Transit Ridership Change Given 4ft of Inundation

Reset | View Water | Ridership Increase | Ridership Decrease | ?

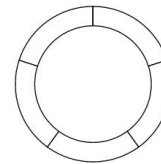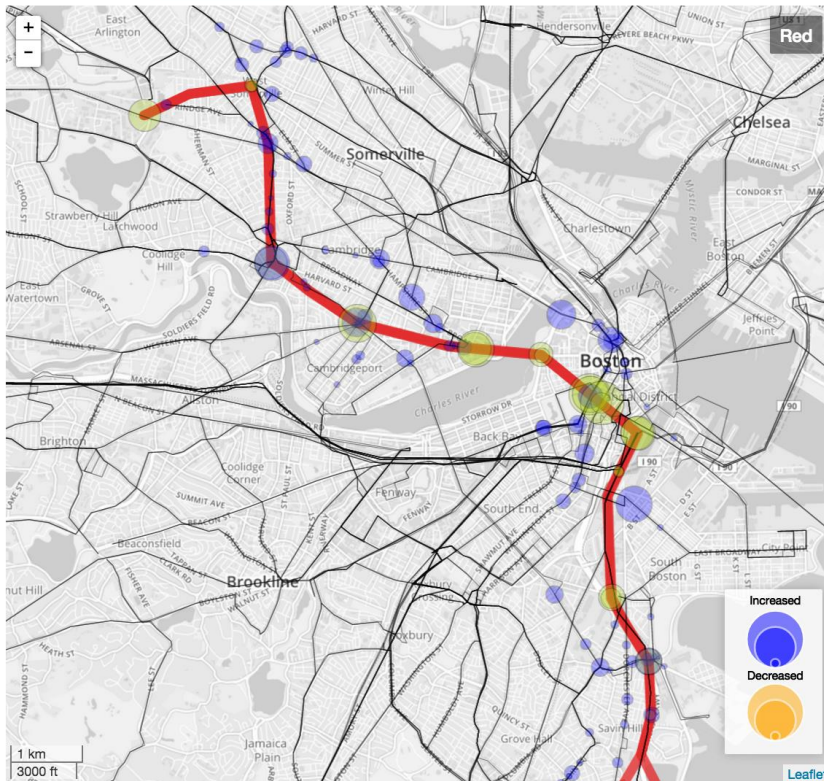| Route	Mode	Base Ridership	4ft Ridership	Difference
Framingham	Commuter Rail	13,039	2,735	-10,303
Fairmount	Commuter Rail	7,497	528	-6,969
Lowell	Commuter Rail	1,355	15	-1,340
Stoughton	Commuter Rail	7,020	5,329	-1,692
Kingston	Commuter Rail	1,922	72	-1,849
Plymouth	Commuter Rail	1,922	72	-1,849
Rockport	Commuter Rail	2,723	120	-2,604
Fitchburg	Commuter Rail	3,488	763	-2,725
Haverhill	Commuter Rail	7,286	475	-6,810
Needham	Commuter Rail	16,756	18,410	1,653
Newburyport	Commuter Rail	3,436	153	-3,283
Middleboro	Commuter Rail	4,243	184	-4,060
Franklin	Commuter Rail	14,105	8,926	-5,180
Attleboro	Commuter Rail	15,674	9,913	-5,761
Green	The T	259,869	187,477	-72,392
Red	The T	275,114	65,868	-209,246
Orange	The T	241,823	134,760	-107,063
Blue	The T	61,199	4,043	-57,155
SILVER	Bus	16,768	13,878	-2,889
LoganCirc	Bus	390	0	-390
SIIVERS	Bus	15,509	16,091	582
SL1	Bus	3,031	0	-3,031
97	Bus	1,582	2,403	821
57	Bus	13,789	14,608	819
27	Bus	71	805	734

Figure 18: Transit Ridership Change Selection View

This visualization shows the difference between ridership on transit routes given no inundation and four feet of inundation. Inundation causes some routes to be heavily impacted or inoperable in some regions. The model allows portions of a route to operate even if other portions are inundated. The four foot inundation level is presented because there are major impacts while much of the region is still free of inundation. I do not present all six inundation levels because of data size constraints.

This visualization allows us to examine possible shifts in ridership due to inundation impacts. A possible question that can be examined with this visualization is "If the Red Line is inundated what other routes might persons use to reach their destination?" Such answers could be used to preemptively bolster service on specific bus routes or rail lines

Use
The Table
The table contains data on:

- Each transit route, and its specific mode, present in the model system

- Ridership on these routes given no inundation (Base Ridership)
- Ridership on these routes given 4ft inundation (4ft Ridership)
- Difference in Ridership (4ft Ridership - Base Ridership)
- Clicking a route in the table will display the boardings and alightings at stops along that route - as well as nearby (1/2 Mile) stops that had either *Ridership Increases* or *Ridership Decreases*. (see Figure 18: Transit Ridership Change Selection View)

Ridership Increase

When this button is selected if a route is selected from the table the only stops visualized will be those stops along the selected route and those stops within 1/2 mile of the selected route that had increases in ridership. This allows a user to search for routes that possibly gained ridership because of inundation on another route. (See Red Line)

Ridership Decrease

When this button is selected if as route is selected from the table the only stops visualized will be the stops on the selected route and those stops within 1/2 mile of the selected route that had decreases in ridership. This allows a user to search for routes that may have gained riders in response to other nearby routes being inundated. (See CT2)

Accessibility to Jobs
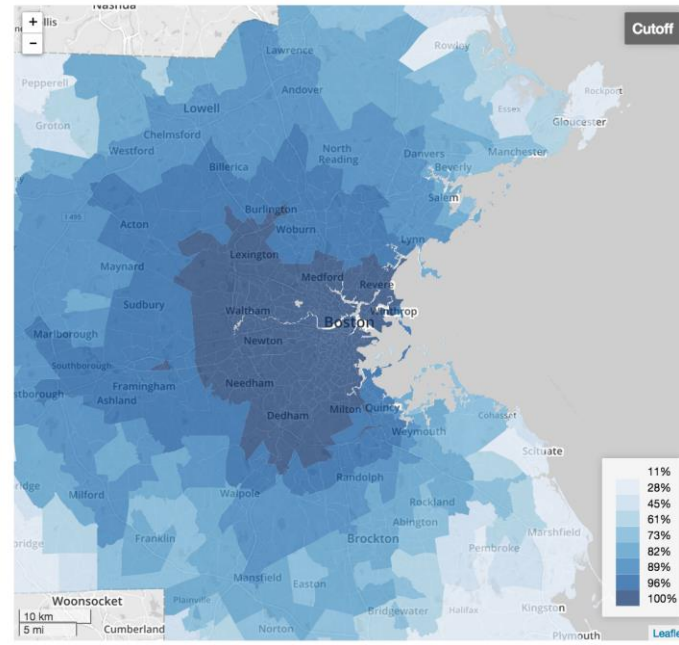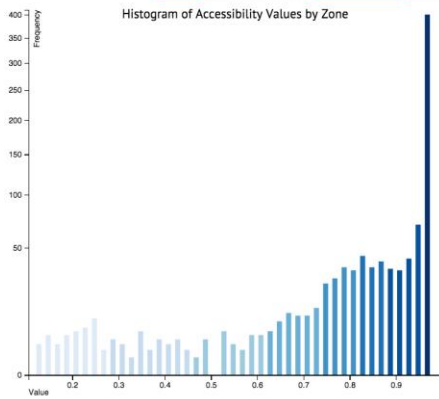
Accessibility metrics attempt to quantify the ability to reach assets (in this case Jobs) from a zone. The simplest accessibility measure is a cutoff measure which communicates the number of jobs a person in a given zone can reach within a certain amount of time. These are sometimes called Isochrones. I have normalized to sum of all jobs accessible from each zone in an hour by diving by the total number of jobs in the model region.

There are many other accessibility metrics that vary in complexity, I have included a measure that incorporates an impedance function, a Gamma Measure. This accessibility counts jobs that take longer to access less than those that take a shorter time. There is no time cutoff in this measure, though at high travel times the contribution of a zones jobs to the total sum of weighted jobs is close to zero. The gamma measure output values can only be interpreted relative to other gamma function values.

Use

The slider will display the accessibility changes over the different inundation levels. One can view the accessibility for Walk, Transit and Auto. The scale for each mode is fixed to facilitate comparison over inundation levels.

The Accessibility Histogram is "brushable" and will show only those zones with corresponding values in the map.

Lost Trips

Lost Trips Given 4ft of Inundation
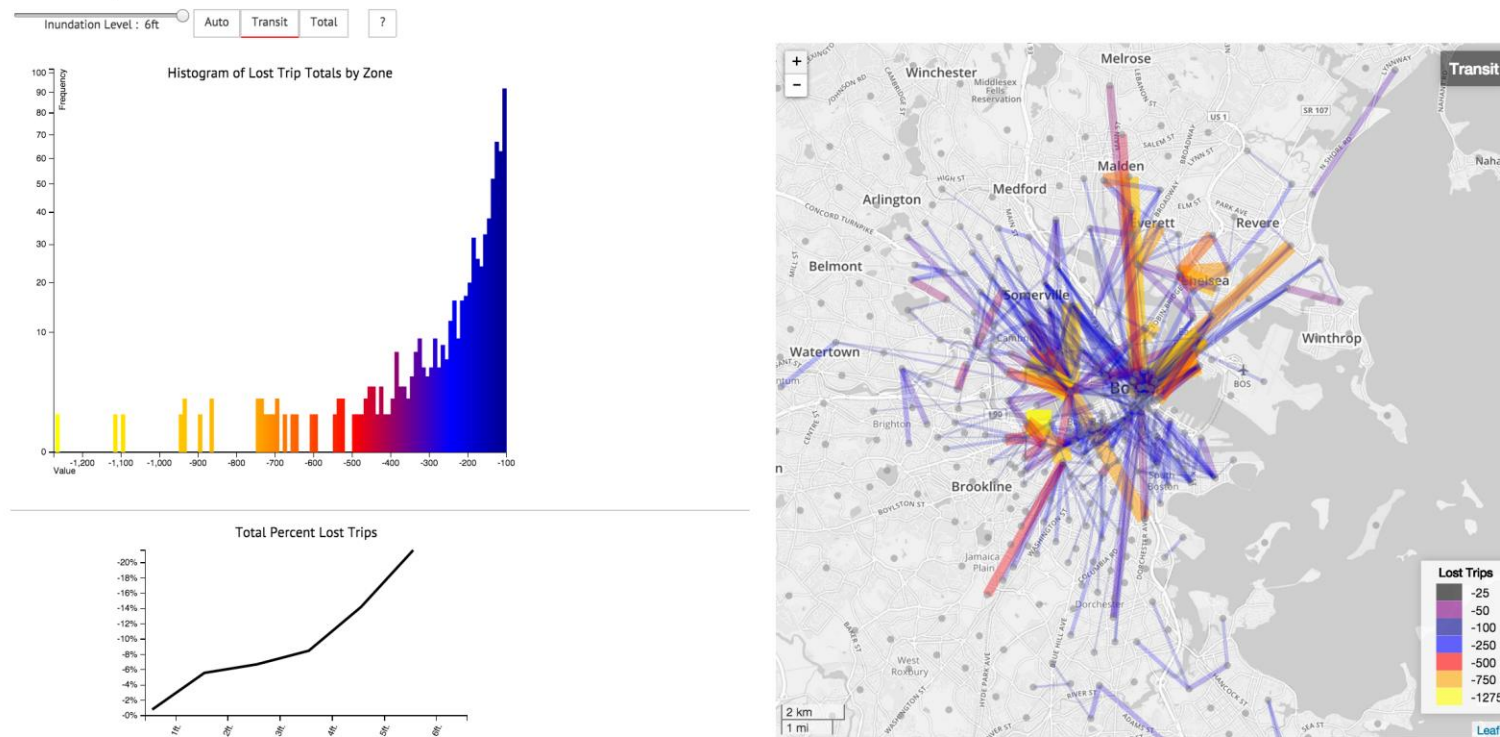
Many trips can no longer be completed given inundation of the road and transit networks. This visualization shows those origin and destination pairs that lost the most trips. I used a cutoff value of 50 trips to prune the dataset down plus the direction of flow is collapsed as well to reduce the size of the data. Meaning that trips lost between zones O & D are grouped with trips lost between zones D & O. If the total lost trips between a given Origin and Destination was less than 50 then a line is not drawn. The thickness of the lines indicate the number of lost trips they are further redundantly encoded by color to make them visually clear. This type of visualization is sometimes called a "Desire Line" map and is usually generated in proprietary transport modeling software packages.

Use
Click the Buttons to change between Transit, Auto, Total.

Total is just the sum of Transit and Auto.

The Lost Trips Histogram is "brushable" and linked to the map. When brushed only those brushed values will appear in the map.

The *Total Percent of Lost Trips* is included for reference. About 16.4 Million total number of trips occur in one day in the model region.

Auto Network Impacts

Please Click on Slider Circle Icon and Use Arrow Keys to Switch Between Inundation Levels

Inundation Level : 0ft | Volumes | Queues | ?
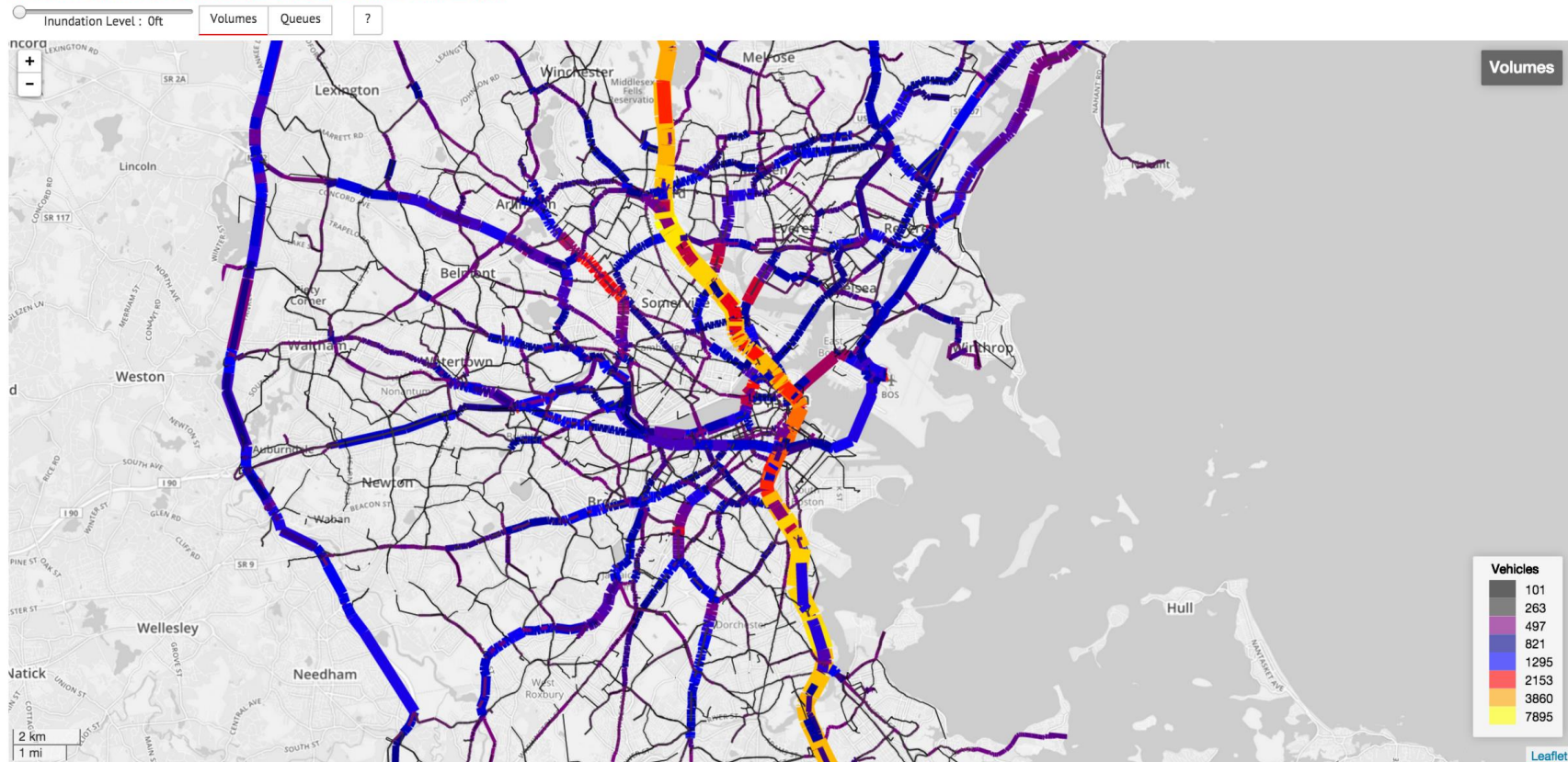
This visualization shows the modeled highway volumes and queues of vehicles across the six different inundation levels.

Volumes
Modeled auto volumes each link. The unit of measurement is vehicles per link.

Queues
Queuing vehicles are those vehicles that can pass through given link because of congestion on the highway network. Areas of high queues would be areas that are heavily congested (i.e. standstill traffic).

Use: The visualization has a slider that updates the data that is shown to reflect the modeling volumes or quietest for each inundation level. The data is quite large so it is best to click the slider icon and use the arrow keys to select different levels.

Evaluation:

What did you learn about the data by using your visualizations?

Overall

I leaned a great deal from my visualizations. Each on offers some unique insights. The inundated assets map is most useful for people to examine the impact of inundation on themselves. I have presented it to some people and they immediately look for where they live and the transit lines they use. I found the normalized group bar charts to be very interesting. Each one shows a different relationship when normalized compared to when viewing just total numbers. For example the grouped roads chart shows that the heavily impacted road type (as defined by MassDOT) is minor roads, but there are far more minor roads in the region. When normalized we see that tunnels are heavily impacted. This makes sense since tunnels go under water generally. We also see that mult-lane highways are heavily impacted (10%) that will have major consequences on the transport system.

The transit-ridership change map offers the most insights to me. I have been developing / creating this this data for about a year so I am familiar with what the results usually look like. D3 and web mapping though allowed a much better environment to explore the ridership change. I find this visualization to be the most effective and am very pleased with the result. Some interesting findings were that the CT2 appears to be alternative for some riders of the Red Line that can no longer use the Red.

The other visualizations are effective in answering my other questions. I have shared them with many people that do not have transport modeling experience and people can effectively locate inundated assets, explore ridership change, identify areas of lost trips, explore the accessibility change across inundation levels and identify areas of congestion in the network.

Main Findings Inundated Assets:

- By examining the grouped chart under the specifics tab in the Demographics data we see that the percentage impact of inundation on service jobs is very high. Service jobs are arguably the most important sector to the economy and are growing faster than retail and basic jobs This highlights that flooding has the potential to cause major economic impacts on the city of Boston just from and employment perspective.
- In terms of Transit the Red Line and Blue line see major impacts under inundation levels four feet and higher. We can expect many transit users will be unable to reach a destination if inundation has occurred in the city because of

Main Findings Transit Ridership Change:

- The visualization provides a unique opportunity to see potential shifts in route choice given inundation in the area and on the network.
- Fixed rail lines see major decreases in ridership that is not accounted for in increases in bus ridership.
- The bus routes CT2 and 85 see increases in ridership that are likely coming from Red Line users who can no longer reach their destination on that route.

Main Findings Accessibility to Jobs:

- Auto always has the highest accessibility and is much less impacted by inundation because of the dense and redundant road network in the region
- Transit and Walk accessibility to jobs is always drastically smaller than Auto accessibility and is concentrated region's inner core.
- Transit accessibility to jobs is drastically impacted by inundation.

Main Findings Lost Trips:

- The greatest number of lost auto trips occur north of the inner core. Though the total number summed by the inner core is likely larger but the trips are split up into many different zones.
- Transit Lost trips are far fewer but very concentrated in the inner core.
- Lost trips occur where inundation occurs (reference inundated assets map)

Main Findings Auto Network Impacts:

- As inundation increases volumes move to outer ring roads (MA Route 128 & HWY 95 & HWY 93)
- As inundation increases queues move toward these outer ring roads as well, though there are other links that become heavily congested in the inner core area. These links are likely congested because other alternative links are inundated.
- At six feet of inundation there is much less congestion in the network because there are far fewer vehicles in the network overall

How well does your visualization work

I believe my visualization works quite well. I believe I have removed all major bugs, though, I assume there must be a bug in there somewhere. There are some issues related to the speed of the visualization. Some of the datasets are very large and this causes sliders to be quite slow. Furthermore, it may not work well on slow network connections or older/slower computers. I am not sure how to rectify this issue. I wonder if a server side solution would help in speeding up the visualization. If I had another month, or another two weeks there are improvements I would make. I will touch on these in the following section. Overall though, I think it works quite well. I had no web development experience before starting this project and I have created a large complicated series of visualizations contained within a functioning website.

How could you further improve it?

There are many ways that I could improve this visualization further:

Operationally:
- I would like to make my code more efficient and readable. Working alone meant that only I had to understand the code on a day-to-day basis. I think this has been a detriment to my overall coding skills. Given more time, I would rework and standardize some of the code and attempt to comment more thoroughly.
- I would like to speed up the visualization. I am not sure how this could be accomplished but I am sure there are ways to optimize the site.

Visualizations:
- I have a lot more data then is presented in this project and I would have like to develop even more visualizations. But, given the time available and the fact that I chose to do a project alone- doing more was not feasible. I would have liked to mix up the little graphs and charts a bit more introducing more variety. Further, I would have liked to introduce coordination between the line charts and the map in the inundated assets map(transit and highway).

Reflection:
- I am very proud of this project. I believe that I took on too much and tried to do too many things, but it has allowed me to learn so much. I would have liked to spend more time developing contextual information. My data is very niche and this may make my project difficult for some people to interpret. I actually think if I could have done more it may have been more understandable to lay audiences and I may continue working on it this summer. Given more time I would have polished the process book more, I made the visualization my top priority.
- Overall, I am very happy that I took this course and completed this project. I have done a tremendous amount of work and am very proud of what I have produced.