Paper SAS2192-2018

Natural Disaster Planning and Recovery Using SAS® Visual Analytics on SAS® Viya®

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ABSTRACT

Planning for natural disasters, evacuation processes, and recovery is always a top priority for local governments and relief organizations. They must mobilize in an instant to set up shelters and provide supplies for victims. After a disaster, the often lengthy recovery phase begins. They must work to help people return to their homes by ensuring that areas are safe, while also working to restore power and communications. Using SAS® Visual Analytics on SAS® Viya® and integrating with Esri tools, local governments and relief organizations can use location analytics to analyze storm predictions, search for shelter locations, plan evacuation routes, and enrich their existing data with Esri demographic data to stay informed and quickly make mission-critical decisions.

INTRODUCTION

Every part of the world is touched by natural disasters. Some natural disasters, like earthquakes, tornados, and tsunamis have minimal amounts of warning and time to prepare. Other weather-related disasters, like hurricanes, have a bit more advanced warning. Local governments have disaster plans in place, but natural disasters can be unpredictable. How can local governments be more prepared to handle potential disasters? SAS Visual Analytics on SAS Viya can empower local governments with capabilities to explore data during all phases of a disaster, from anticipation of an event through recovery, allowing them to be more agile in the event of a catastrophe.

This paper focuses on data from hurricanes Harvey and Maria during the 2017 Atlantic hurricane season.

PLANNING FOR A NATURAL DISASTER

In the early stages of an Atlantic tropical weather event, all eyes are on the ocean. Water temperature, the trade winds, and variations in barometric pressure drive these powerful storms toward their final destination. The United States National Hurricane Service (NHC) collects storm data and compiles it into advisories in Esri shapefile formats. Each advisory is released as an individual collection of shapefiles and includes all of the cities deemed to be within the “cone of uncertainty”. The NHC posts archived storm advisory data here: https://www.nhc.noaa.gov/gis/

EXPLORING HURRICANE ADVISORY DATA

As is typical with most data exploration projects, the data in the NHC shapefiles requires some manipulation to be useful in SAS® Visual Analytics. To explore the shapefile data, it must be read into a SAS data set using PROC MAPIMPORT. Next, PROC GINSIDE is used to compare the imported map polygons in the shapefile data set to a data set of X and Y coordinates. In the case of the NHC shapefiles, the polygon data was compared with the world_cities data set that is shipped with SAS/GRAPH. The process is repeated to create an individual data set for each advisory. Hurricane Harvey had 43 advisories, so the end result was 43 data sets. Those data sets can be appended into a single table that can then be used in Visual Analytics. The process revealed a problem with advisory 11, so the data for that advisory has been omitted.

The COMBINEDHARVEYADVISORIES data set can be easily imported into Visual Analytics and is ready for exploration. Data from shapefiles can be used in two ways. PROC MAPIMPORT creates a SAS data set with latitude and longitude points. That data set can be used in the same manner as any other SAS data set.

To begin, look at the entire history of hurricane Harvey (Figure 1) as told through the NHC advisory data. In this example, the data from the shapefile is plotted on a map as bubbles. The larger the bubble, the more frequently that point was included in advisories.

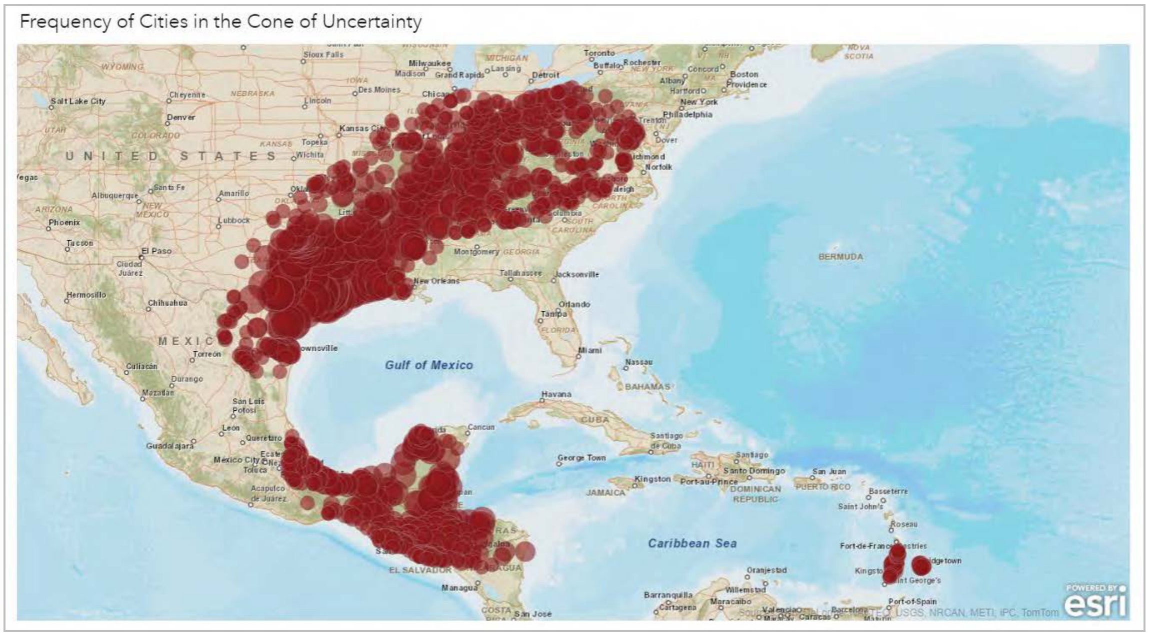


Figure 1. Frequency of Cities in the Cone of Uncertainty during Hurricane Harvey

The actual storm track shows more variation than the advisories (Figure 2). In this example, the data is plotted on the map as coordinate points.

Figure 2. Official Storm Track for Hurricane Harvey

Given the wide variation between the cities in the advisories and the actual storm track, how can local governments prepare their citizens for a possible disaster? It's a delicate balancing act. Weather is unpredictable and people are even more unpredictable.

PREPARING FOR NATURAL DISASTERS

Part of the planning for natural disasters, both prior to and after, is evacuation and shelter strategy. All cities have emergency plans and contingency plans. The majority of those plans go for years before having to be enacted. As the populations and landscapes change, the plans are updated. The plans cover a wide array of activities including traffic analysis. They have to determine when to convert major highways to contraflow—where all lanes move in the same direction. They take into account the population—who has cars, who relies on public transportation, who might need additional help? Even more broadly, they have to try to predict who will evacuate to shelters versus heading to other locations, like hotels. They need to consider pet owners. What happens to the elderly, the disabled, or the infirm? Ultimately, evacuation is planned in stages to try to keep the roadways from becoming too congested.

Cities have emergency management teams who run the numbers and analyze the data, but it can be difficult to predict the unpredictable. What they hope for is to arm their cities and citizens with information, so they can make the best decision possible given the circumstances.

Schools and community centers are often opened as primary shelters. Local churches might also open their doors to evacuees. As the need for shelters grows, emergency managers might decide to open larger venues like stadiums or convention centers as mega-shelters. Mega-shelters typically remain activated longer than traditional shelters and provide living space for a larger number of people who are displaced for long periods of time. The Louisiana Superdome and the Houston Astrodome became mega-shelters during Hurricane Katrina.

Figure 3 shows community centers, schools, and stadiums by ZIP code in the Houston area. There are also over 1,000 churches in Houston. With so many potential shelter sites, how does an emergency manager make the decision on which sites will be used? How can they get information about their citizens to ensure that people are able and willing to leave their homes for shelters?

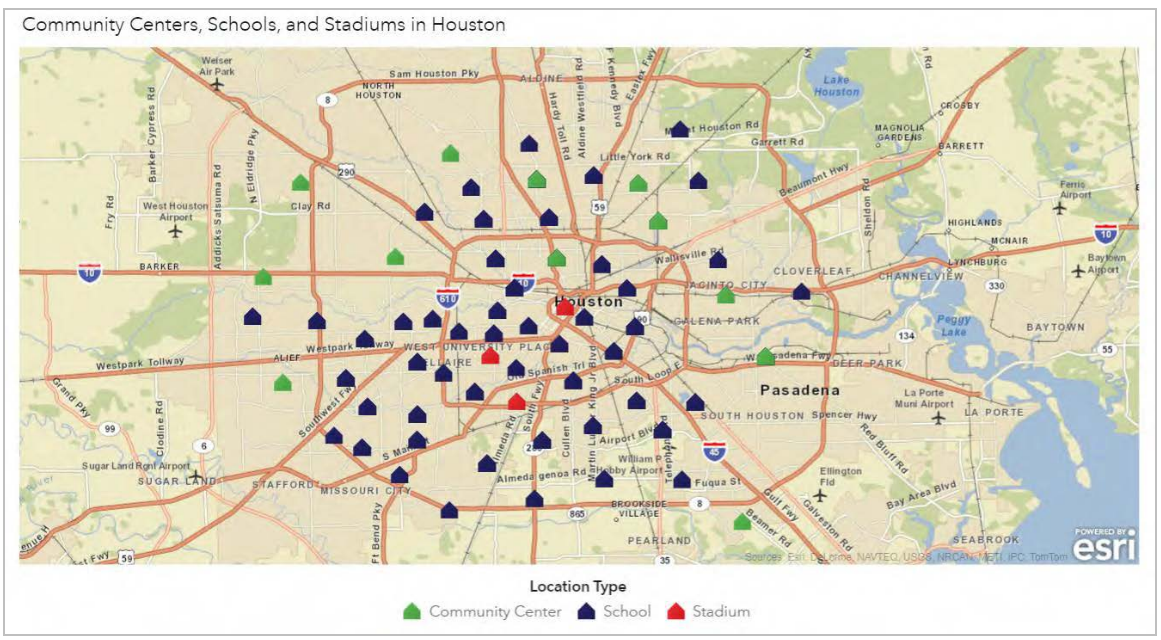


Figure 3. Community Centers, Schools, and Stadiums in Houston by Location Type

There are multiple factors to consider when deciding on locations for shelters, from geographic to demographic. Shelters should not be established in areas prone to flooding or storm surge. They must be able to withstand high winds.

The local populations have to be considered. The Red Cross recommends 40-square feet of space per resident. The space requirement can be reduced to 15-square feet per resident in short-term sheltering situations. It’s important to maximize the available space while accommodating as many people as possible.

During the early stages of hurricane Harvey, 38 shelters were opened (Figure 4). Many more were added as the initial ones reached capacity and the flooding began.

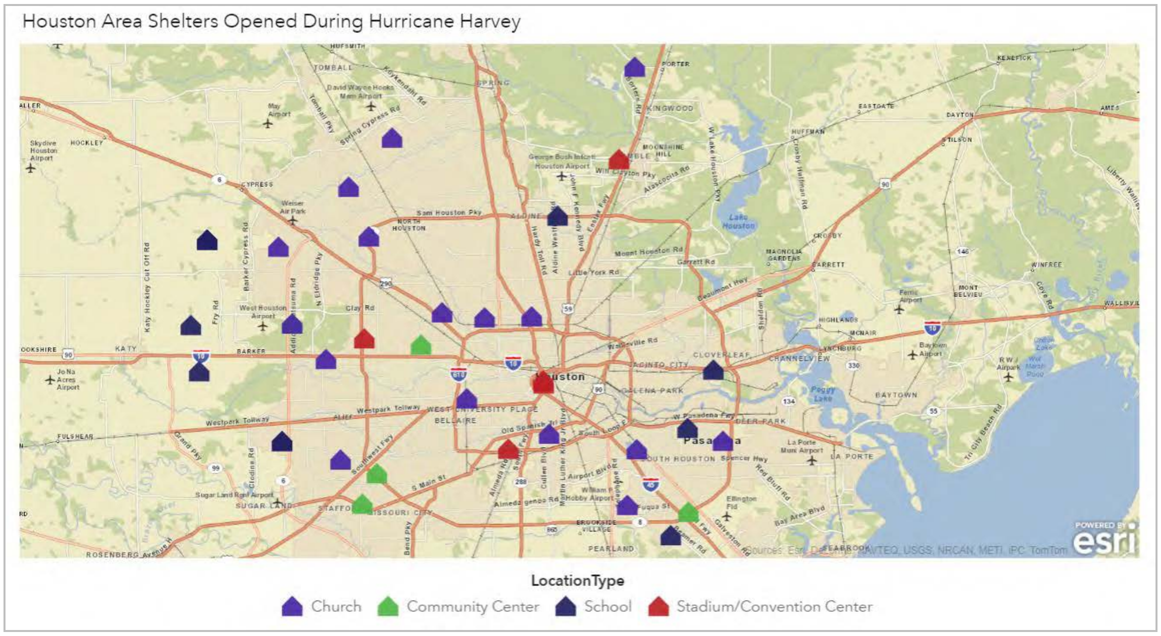


Figure 4. Houston Area Shelters Opened During the Early Stages of Hurricane Harvey

Figure 5 displays both potential shelters and actual shelters opened during hurricane Harvey. The overlaps can be a bit difficult to detect—they appear more orange. Note the flyover in Figure 6.

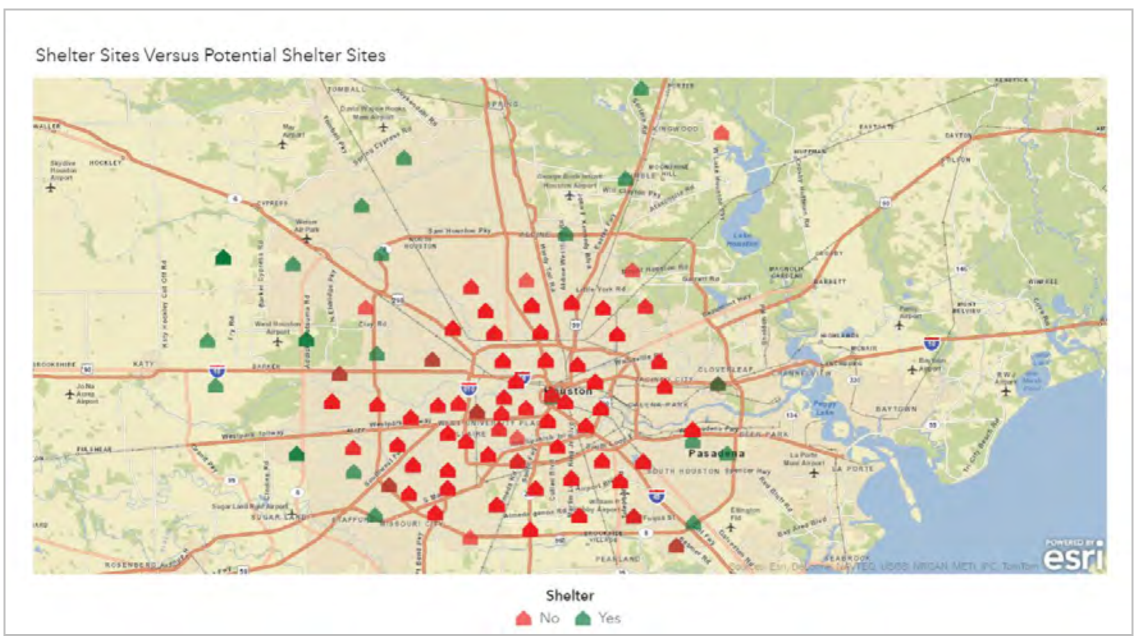


Figure 5. Actual Shelter Sites Versus Potential Shelter Sites

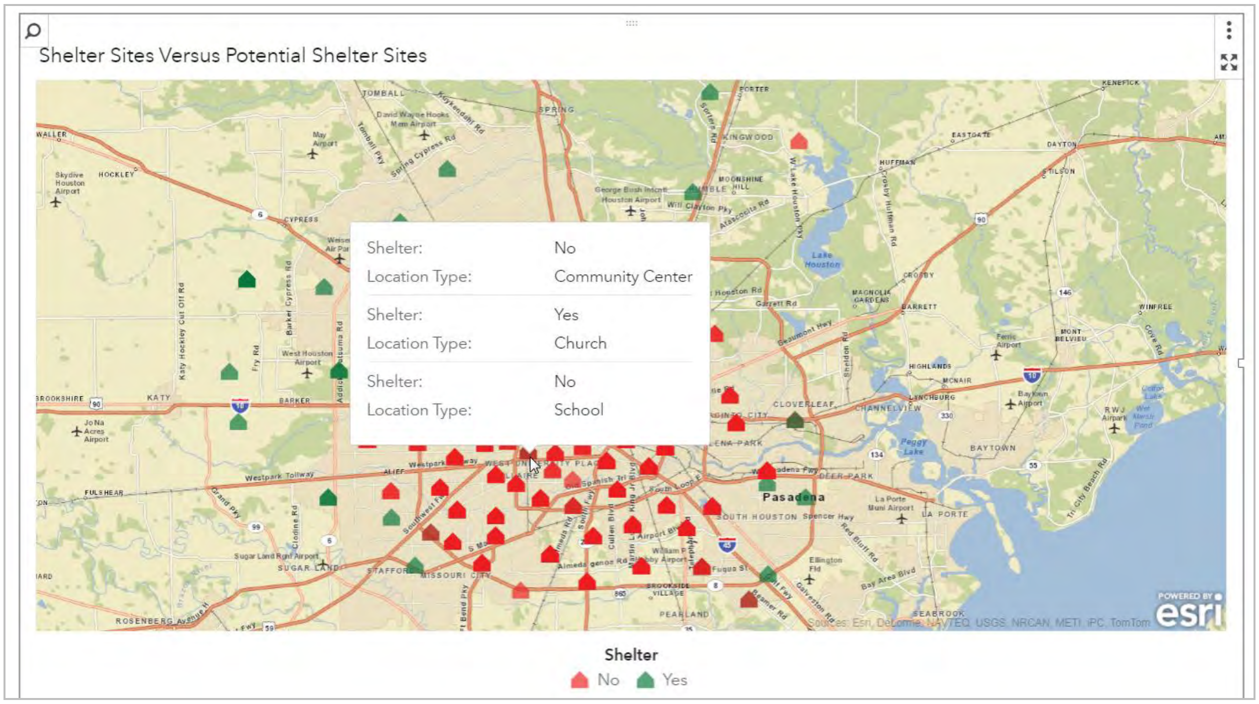


Figure 6. Overlap of Ppotential Shelter Sites Versus Actual Shelter Sites

The city of Houston has an open data initiative and publishes a variety of data sets and geographic shapefiles (http://data.houstontx.gov/sv/). One of these shapefiles includes hurricane evacuation zones. In addition to providing latitude and longitude points that can be plotted on a map, shapefiles also contain geographic boundaries. Visual Analytics can ingest shapefiles and render region-based visualizations. When used to provide geographic boundaries, shapefiles can be combined with report level data. Figure 7 shows a regional map based on the hurricane evacuation zone shapefile.

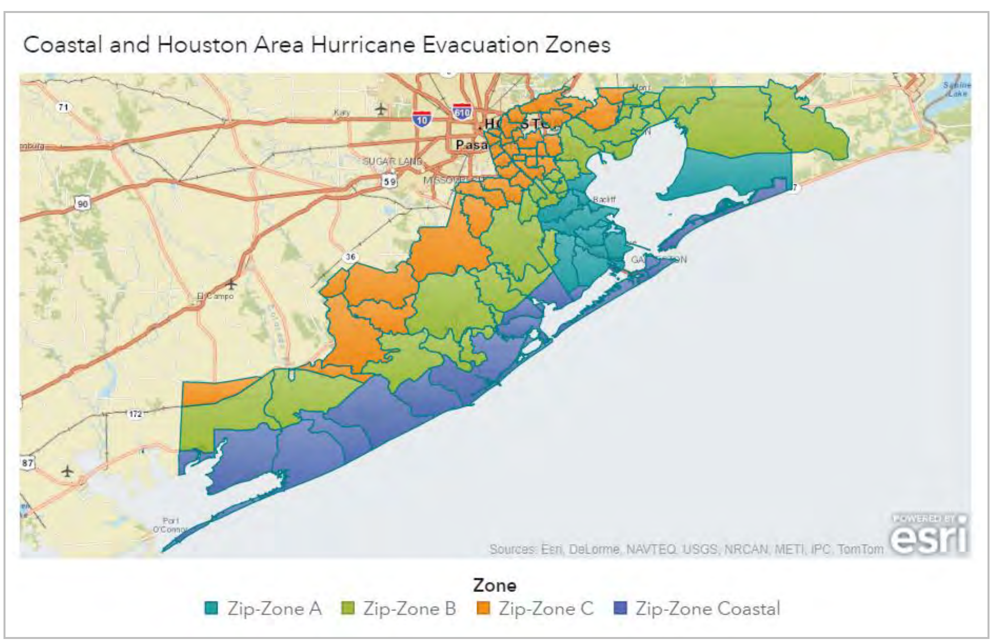
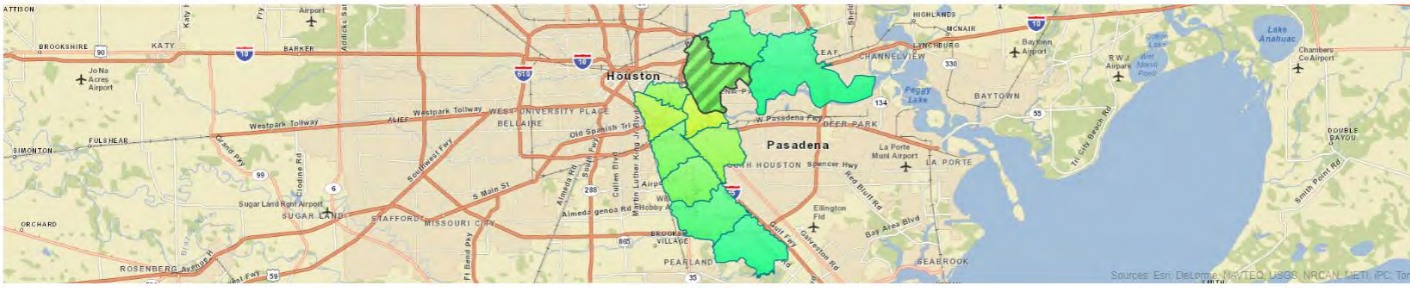


Figure 7. Region Map Showing Coastal and Houston Area Hurricane Evacuation Zones

Emergency managers could use the evacuation zone shapefile alongside data about potential shelter locations to identify potential shelters that might be in areas that would not be ideal (Figure 8). This could help eliminate possibilities that might be unsuitable based on their location.

Filters: 77029

Frequency of Potential Shelter Locations in the Hurricane Evacuation Zone



Frequency

Location_Type	Location_Name	Address
Community Center	Clinton Community Center	200 Mississippi St
School	Holland Middle School	1600 GELLHORN
Community Center	J Robinson Sr Community Center	1422 Ledwicke St
School	Pleasantville Elementary	1431 GELLHORN DR
School	Port Houston Elementary	1800 MCCARTY ST

Figure 8. Frequency of Potential Shelter Locations in the Hurricane Evacuation Zone

Figure 9 shows 6 shelters that were opened during hurricane Harvey that were in the evacuation zone. In the case of hurricane Harvey, shelters were opened during and after the storm to accommodate people needing to move to higher ground because of the flooding. That could account for the decision to operate shelters in an evacuation zone. Emergency managers have to consider travel distances, road and weather conditions, and the viability of buildings, and have to make judgment calls in less than ideal situations.

Hurricane Evacuation Zones in the Houston Area that Contain Shelter Locations

Location Name	Location Type	Shelter
Dobie High School	School	Yes
Golden Acres Baptist Church	Church	Yes
Islamic Center/Masjid Abu-Bakr	Community Center	Yes
Pasadena High School	School	Yes
St. Christopher Catholic Church	Church	Yes
Vietnamese Martyrs Church	Church	Yes

Figure 9. Hurricane Evacuation Zones in the Houston Area that Contain Actual Shelter Locations

There are other capabilities that combine the power of Visual Analytics and Esri to offer emergency managers more information so that they can better plan for natural disasters. Visual Analytics offers the ability to search for locations. Emergency managers could do a search for area hospitals to view proximity to shelter locations, in case evacuees need emergency care. Search results are indicated with black pins. Figure 10 shows that some shelters are quite a distance from medical facilities.

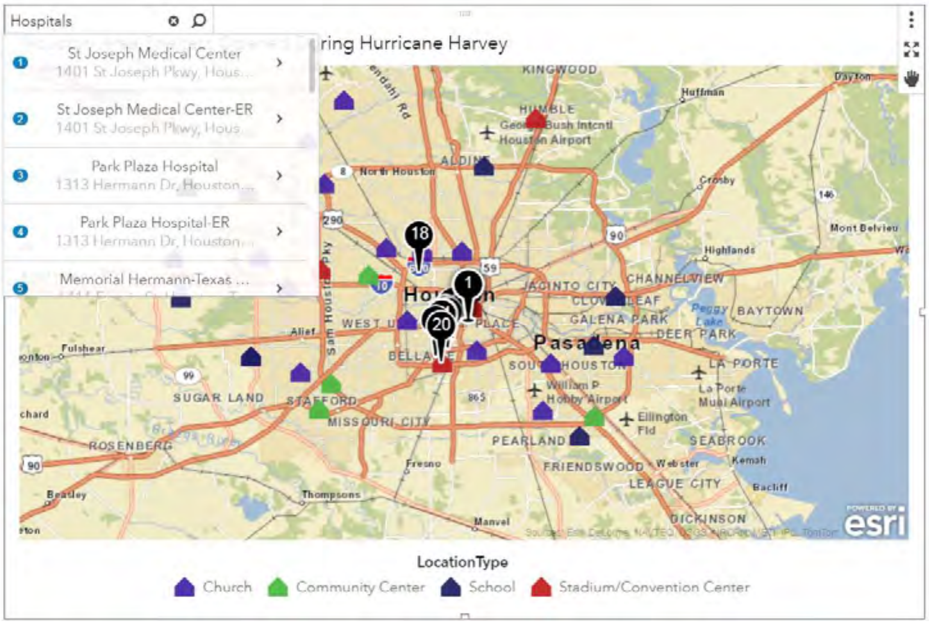


Figure 10. Search for Hospitals

During a disaster, if shelters start to reach capacity, emergency managers could search for other potential locations and identify alternate locations that might be in a close proximity to shelters reaching capacity. Figure 11 shows a search for community centers in the Houston area.

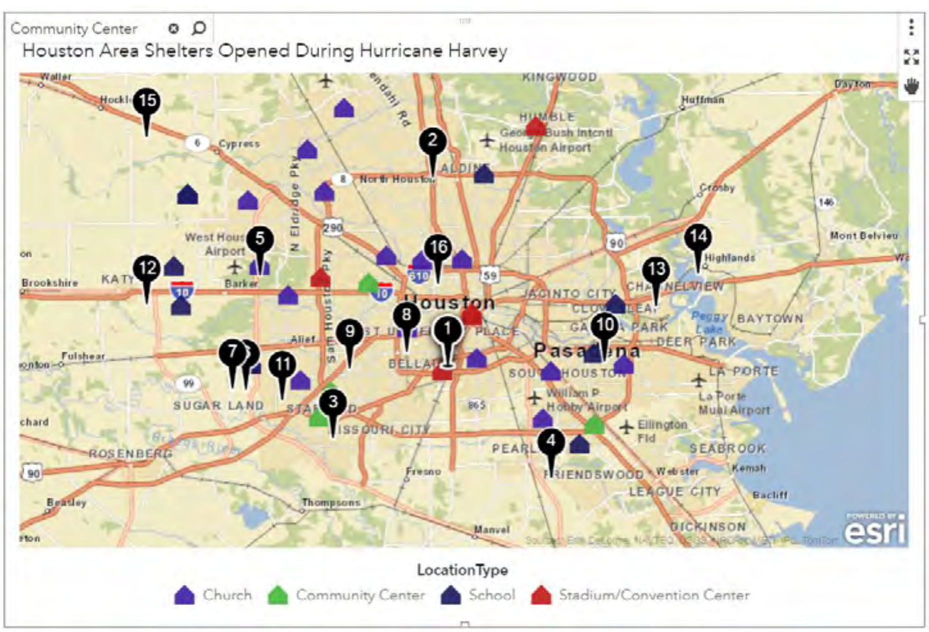


Figure 11. Search for Community Centers

Search can be combined with straight-line distance, travel distance, and travel time calculations. Figure 12 shows a point search for Houston, TX.

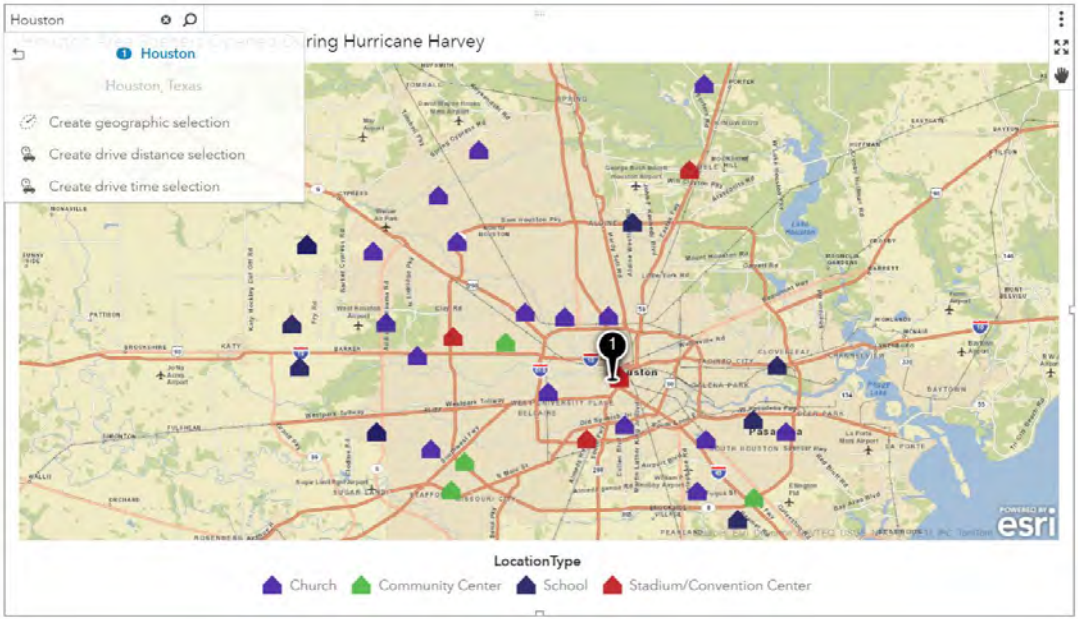


Figure 12. Point Search for Houston, TX

The next step is to create a geographic selection. Geographic selections can be based on distance (as the crow flies), travel distance, or travel time. For the first example, travel distance is going to be explored. Multiple distances can be specified and will appear in the output as gray-shaded, ragged concentric circle-like shapes. In this example, distances of 5, 10, and 20 miles are specified (Figure 13).

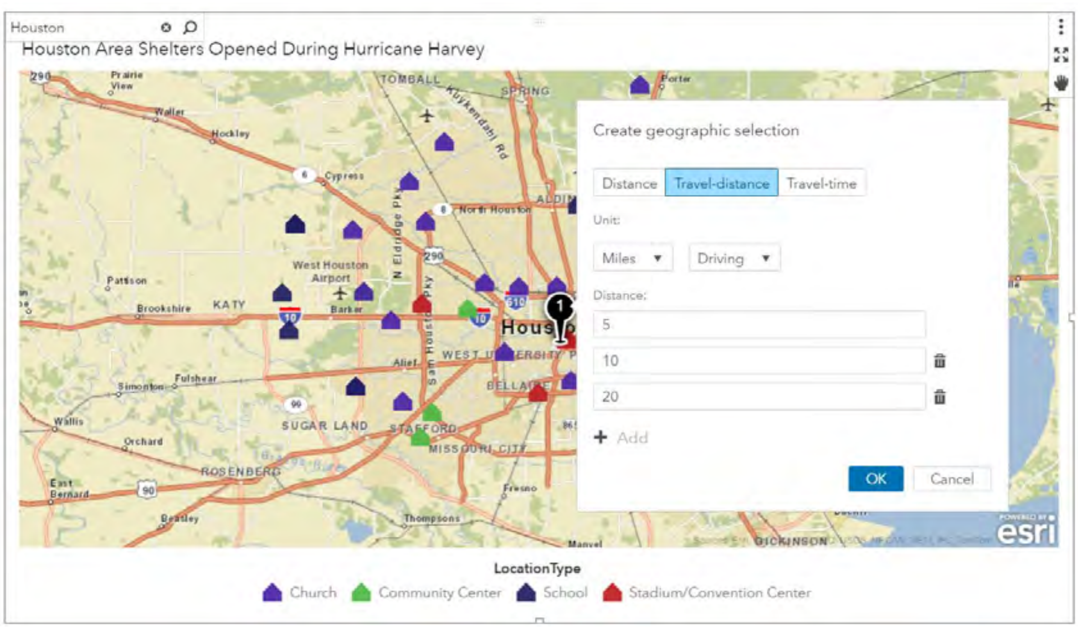


Figure 13. Travel-Distance Selection

Clicking OK renders the result seen in Figure 14. The shaded concentric shapes show the shelters within a 5-, 10-, and 20-mile drive distance of the center of Houston. It appears that most of the shelters opened during the early stages of hurricane Harvey were within a 20-mile drive distance from the central point of Houston.

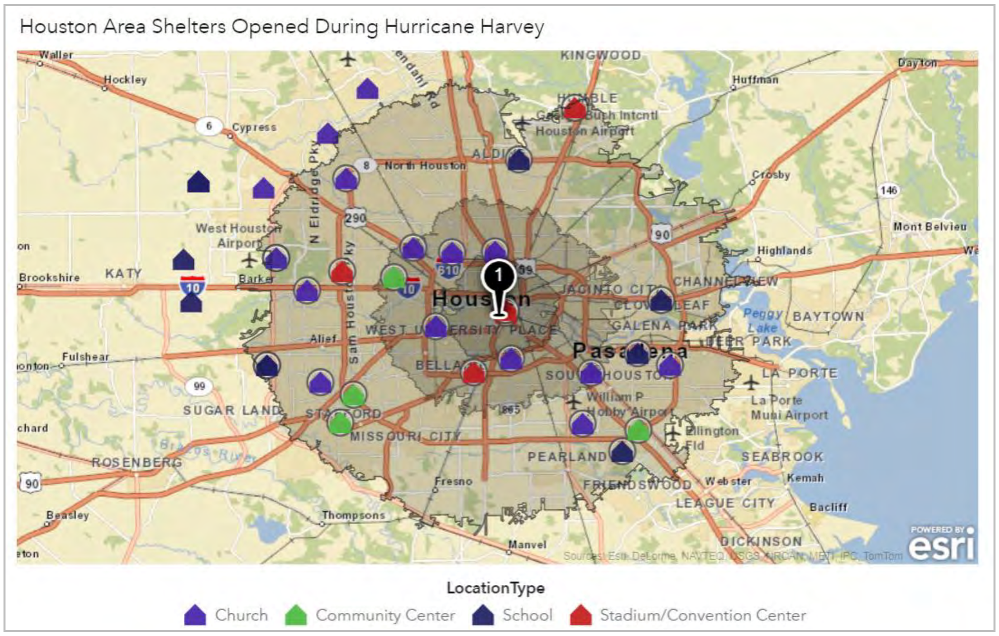


Figure 12. Shaded Concentric Areas Indicating a 5-, 10-, and 20-mile Drive distance from the Center of Houston

An emergency manager might want to better understand the populations within those zones. Visual Analytics offers the option to explore a wide variety of demographic data within a geographic selection.

Right-mouse clicking on the pin reveals the option to show demographics, which opens a window with both basic and advanced demographics tabs (Figure 13). The data is global, but it is important to note that some countries have richer data than others.

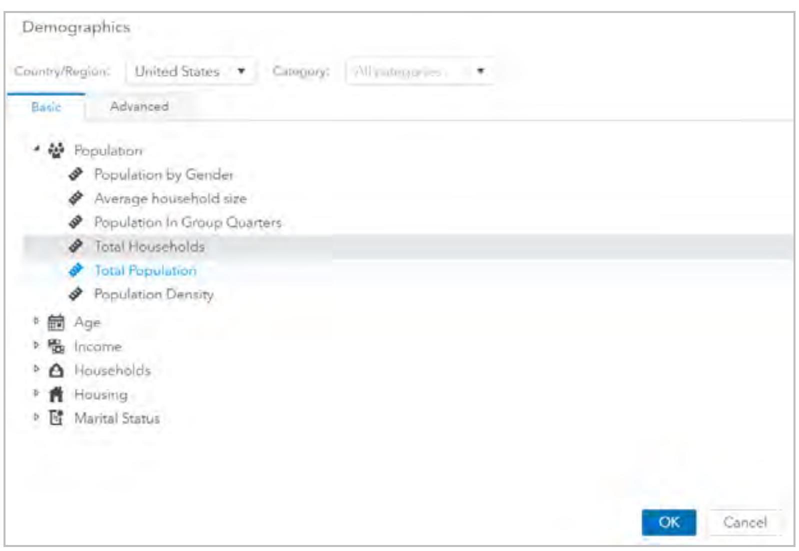


Figure 13. Demographics Pop-Up Window

Selecting Total Households and Total Population creates a flyover with an arrow to scroll through the metrics (Figures 14 and 15). The metrics encompass the largest travel distance specified in the travel distance box, which in this case is 20 miles.

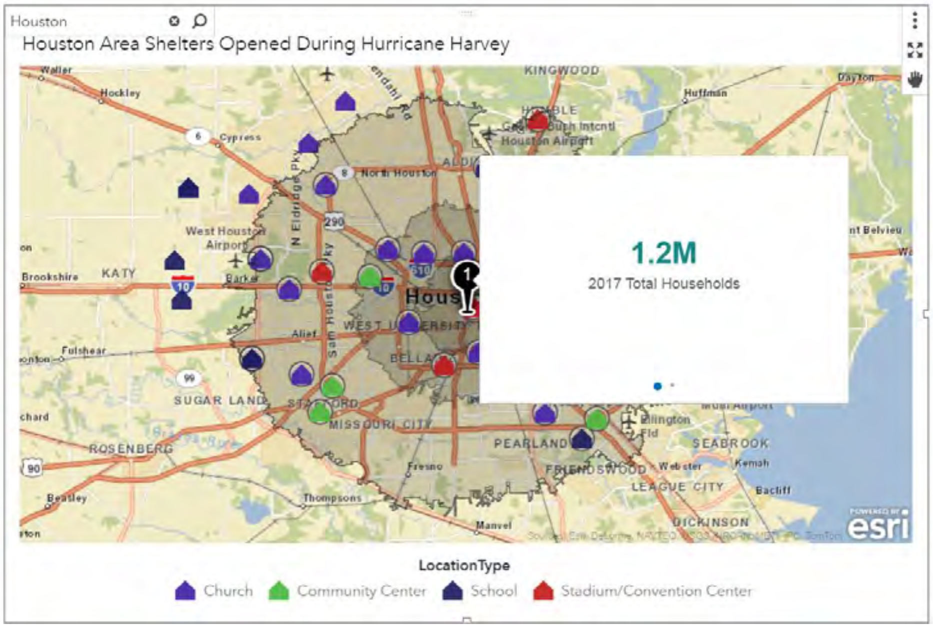


Figure 14. Total Households Within a 20-mile Drive Distance from the Center of Houston

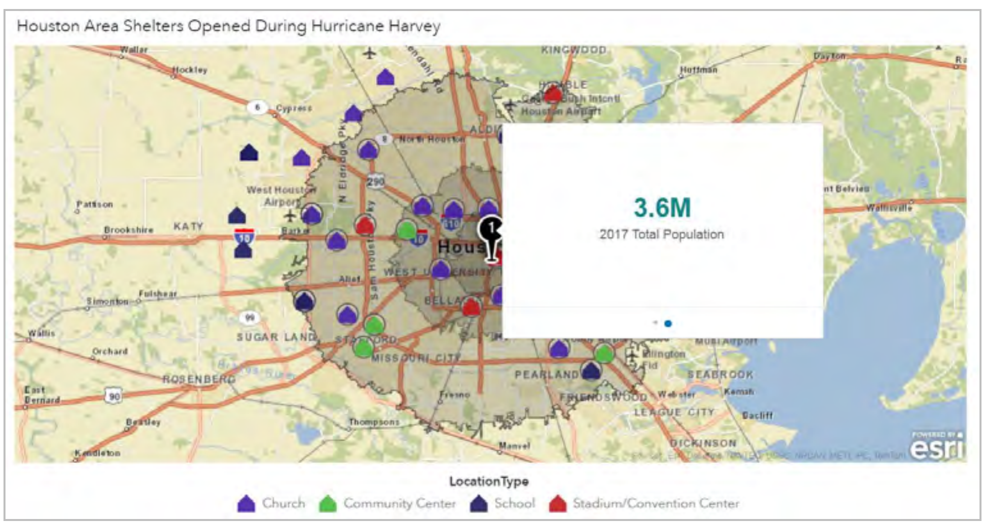


Figure 15. Total Population Within a 20-mile Drive Distance of Houston

There are over 7,000 demographic based data items available to enhance geographic visuals in the United States, in Visual Analytics. There are many, beyond population, which could be beneficial to an emergency manager as they plan for natural disasters.

Emergency managers learned a lot from hurricane Katrina in 2005. One of those lessons was that people with pets were less likely to evacuate unless accommodations could be made for their pets. People would rather stay put and remain in harm's way than abandon their animals. Before Katrina, pet-friendly evacuation shelters were largely unheard of. In 2006, because of Katrina, Congress passed legislation requiring local and state authorities receiving federal emergency grants to include pets in their disaster plans. The legislation authorized the use of federal funds for pet-friendly shelters.

In the advanced tab of the demographics pop-up, there is a section for behaviors. Under behaviors, there is information about pets and pet products, including information about pet ownership (Figure 16).

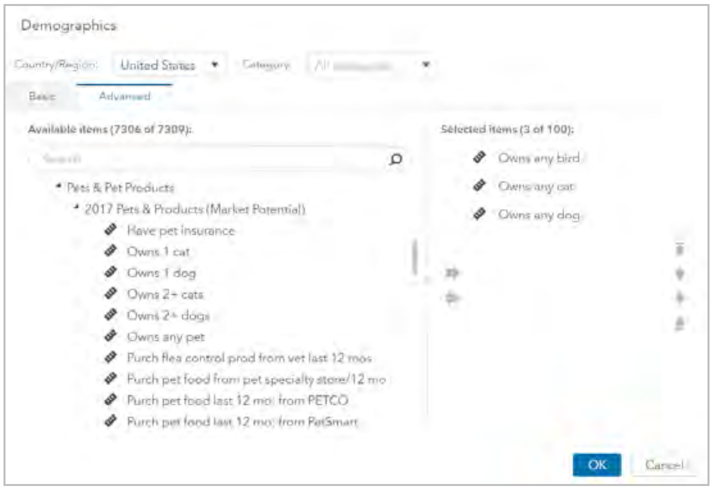


Figure 16. Advanced Demographics with Pet Selections

Figure 17 shows that in an area with 1.2 million households, there are nearly 700K pets. When looking to establish shelters, this baseline information would be key to ensuring there are enough pet-friendly shelters for the surrounding areas.

Figure 17. Pet Ownership Within a 20-mile Drive Distance of the Central Point of Houston

While the data can be explored interactively, it is sometimes useful to enrich an original data set with the demographic data from Esri to explore more holistically. This can be done in Visual Analytics as a part of the data import capabilities (Figure 18). All of the data elements that are available interactively are available as a part of the data enrichment process.

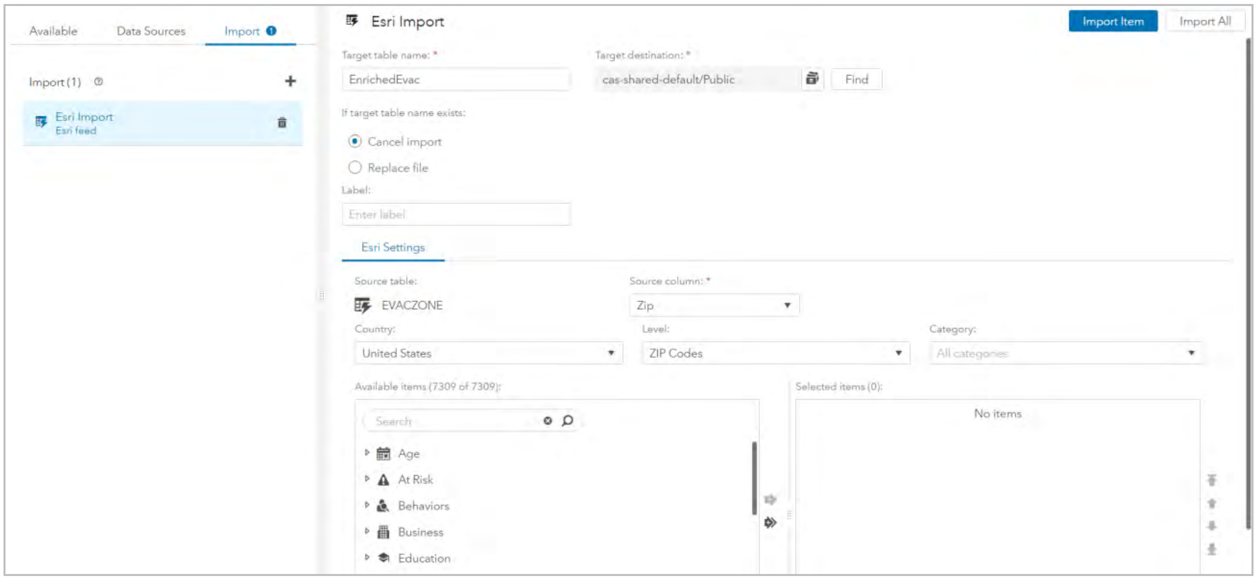


Figure 18. Esri Data Enrichment Import Process Window

In addition to the overall population and pet information, emergency managers might want to look at other factors about their constituents that might make evacuation difficult, like vehicle ownership, aging populations, populations in poverty, and disabled populations. Figure 19 shows those populations in the hurricane Harvey evacuation area.

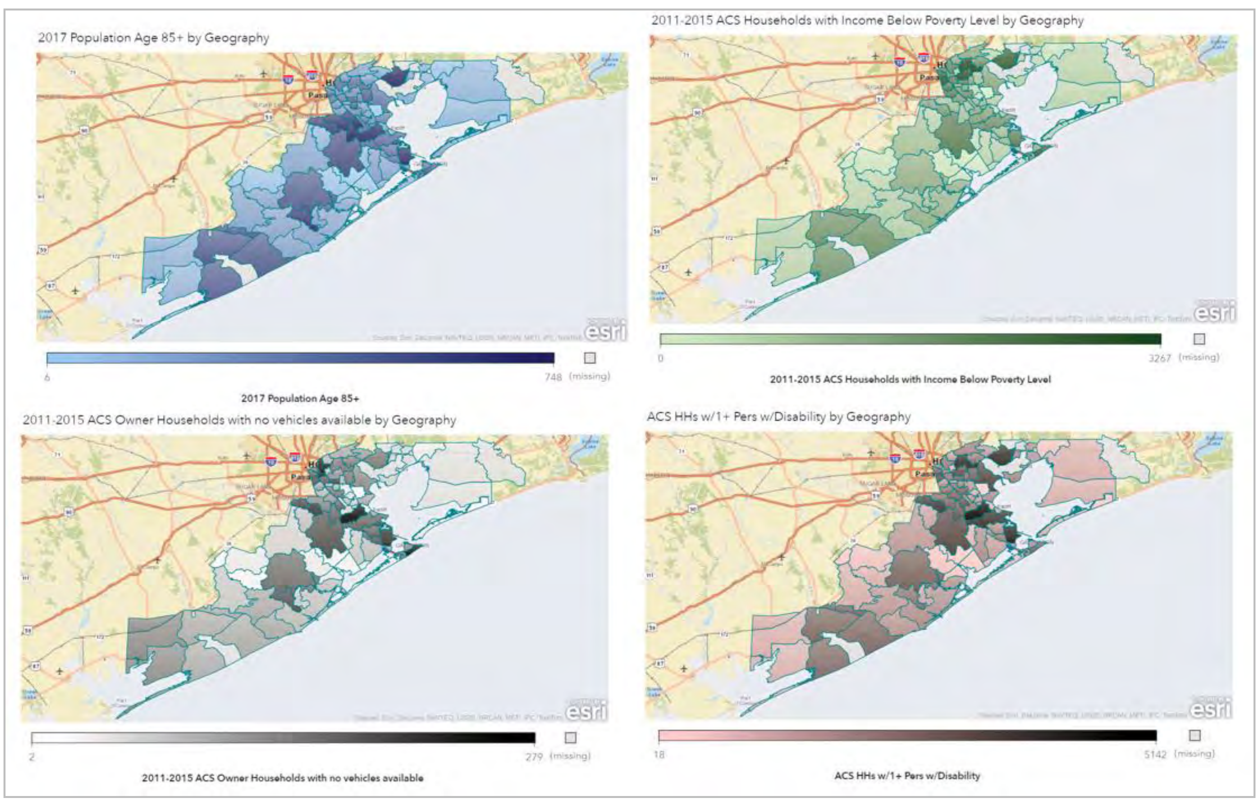


Figure 19. Maps of Enriched Data Points Relating to Population

They might also be interested in understanding how their constituents access information—do they have smartphones, televisions, or access to the internet at home (Figure 20)?

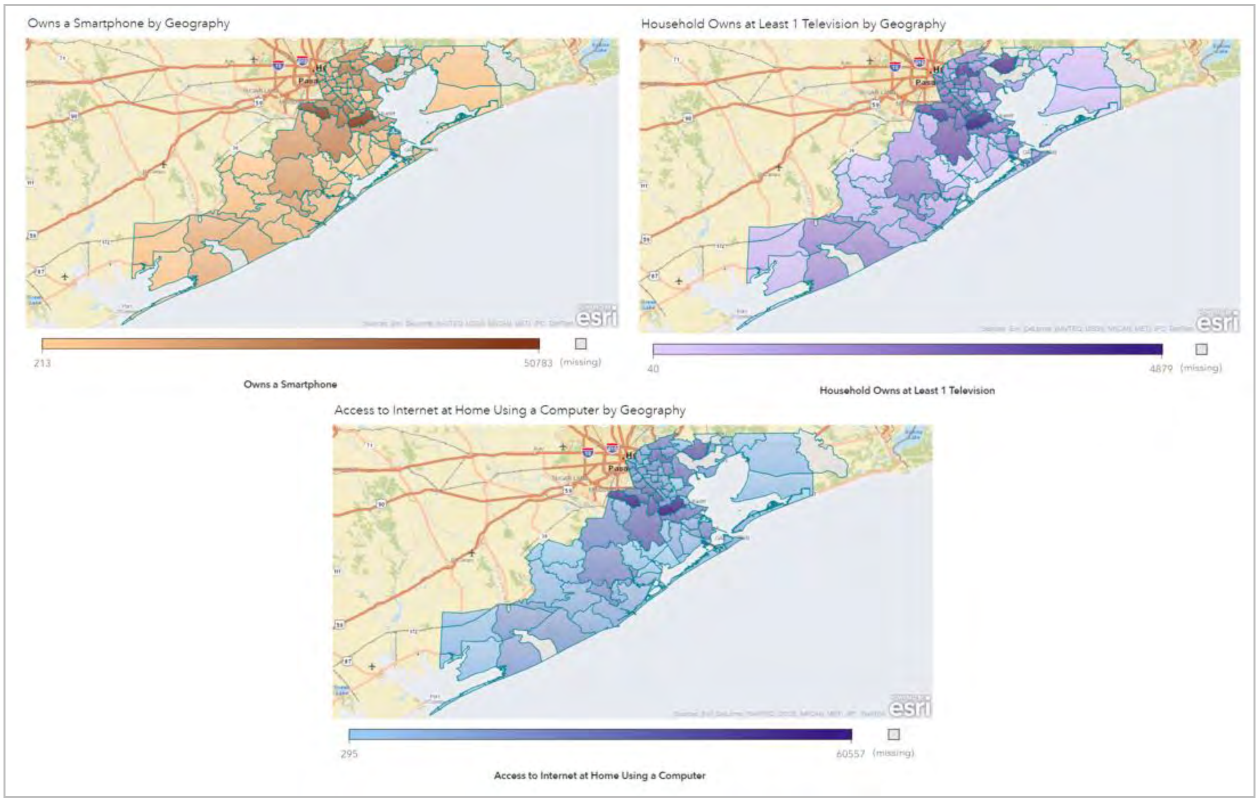


Figure 20. Maps of Enriched Data Relating to Communication

Additionally, all of the information about pets can be mapped in a holistic manner (Figure 21).

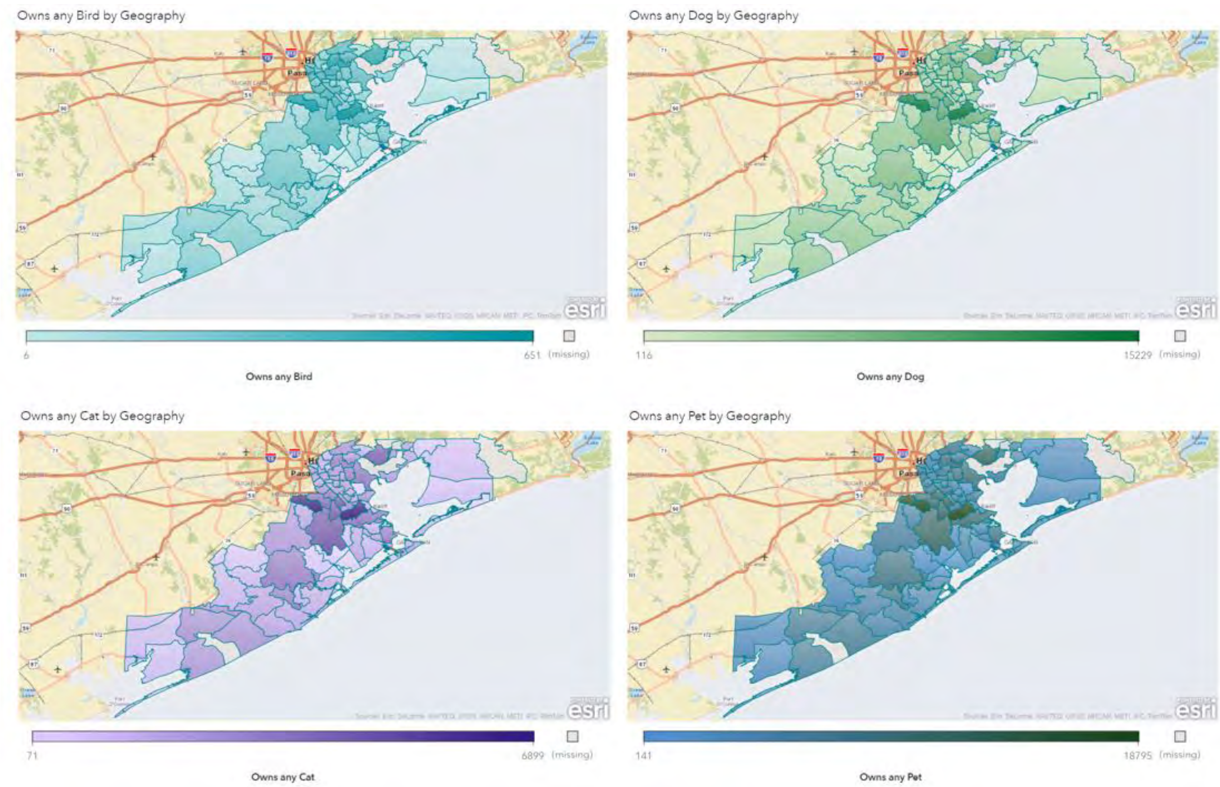


Figure 21. Maps of Enriched Data Regarding Pets

Looking at all of these maps, there is an incidental finding. There is one ZIP code area that seems to have high concentrations of nearly every metric except households below poverty level. A quick search reveals that that area is League City, TX (Figure 22).

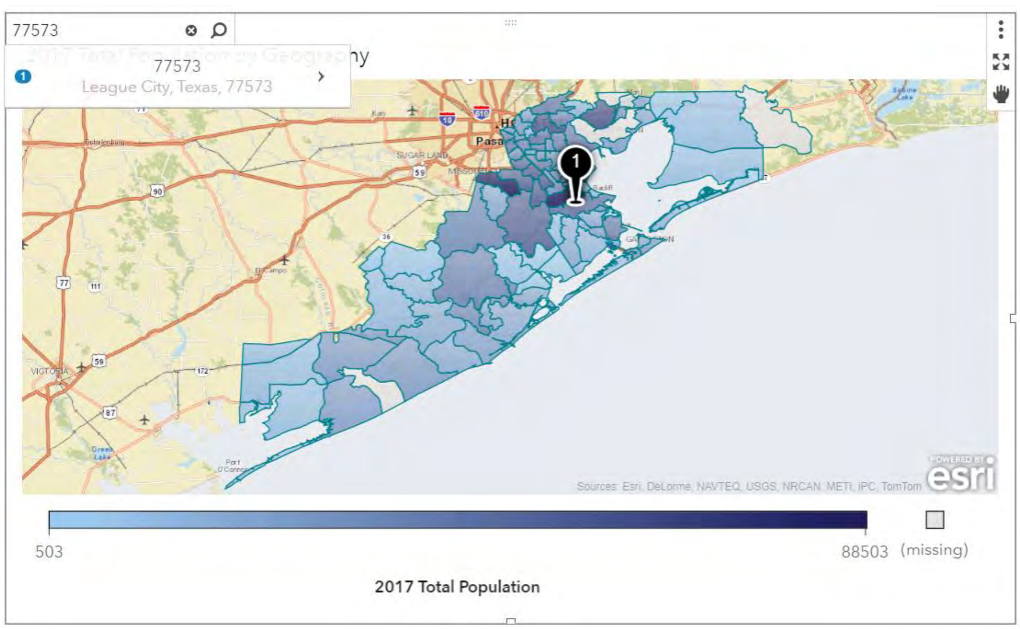


Figure 22. Search for ZIP Code of Interest

Since there are a variety of interesting populations within that area, it might be prudent to see how long it would take people in that area to evacuate to the shelters that were opened during the early stages of hurricane Harvey. Right mouse clicking on League City on the map gives the option to calculate travel time.

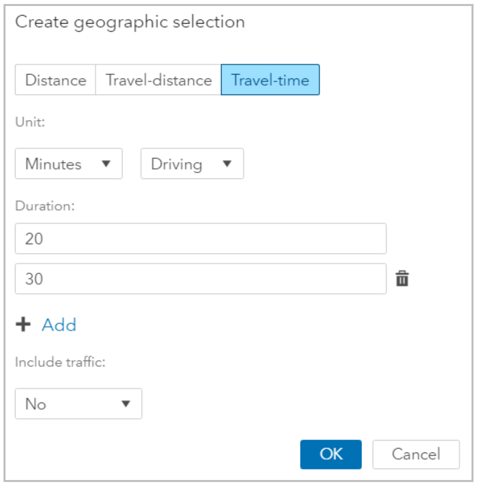


Figure 23. Travel Time Options

There were two shelters within a 20-minute travel time, and 4 within a 30-minute travel time (Figure 24). Because the data indicates that many of the residents in League City might not have access to vehicles, emergency managers might want to arrange transportation options for those citizens.

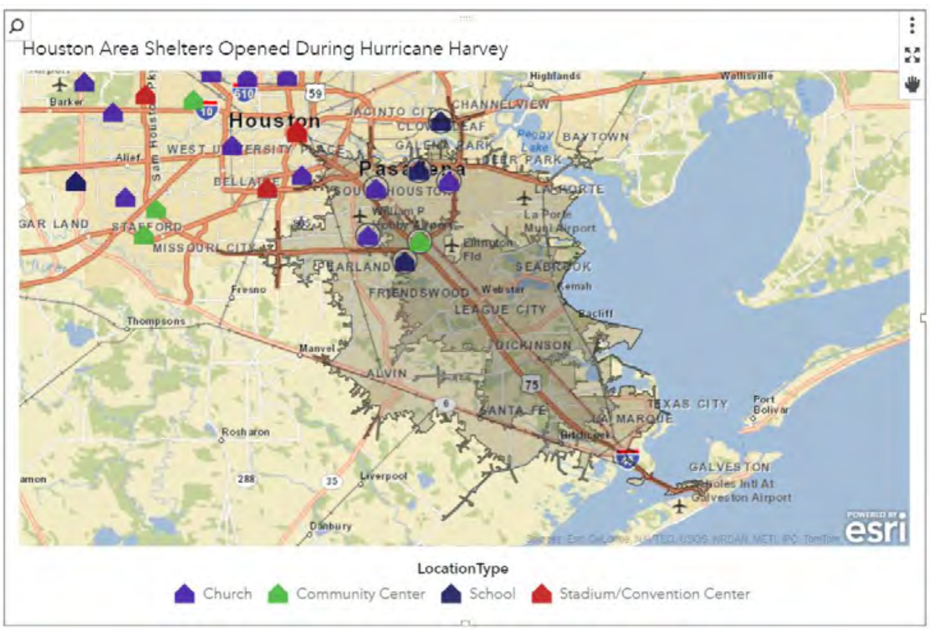


Figure 24. Shelters Within a 20- and 30-minute Drive Time of League City, TX

NATURAL DISASTER RECOVERY

It is difficult to anticipate what a natural disaster recovery process will entail until the event completes. There is no good way to predict how much damage will be done, which areas will be hit the hardest, or where the greatest need for aid will be.

The 2017 hurricane season was particularly damaging to small islands in the Caribbean. Puerto Rico was affected by hurricane Irma, then devastated by hurricane Maria two weeks later. Puerto Rico’s power grid was destroyed and communication networks were badly damaged. This left the people of Puerto Rico in the dark without any effective means of communication.

In the first world, we do not often face widespread, long-term communication outages. Many island nations have aging infrastructure that can be more prone to serious damage from weather events. Recovery after hurricane Maria has been particularly difficult because of the challenges with communication.

Without effective communication after a natural disaster, people do not have the ability to call for help. It is lonely and terrifying not knowing when or if help is going to come. It is difficult for relief workers because they have no way to stay in contact with their teams. When communications are down, that includes mobile phones. No network means no cell service.

In the aftermath of hurricane Maria, I began working with NetHope, a technology consortium working with over 50 global non-governmental organizations and nonprofits, in partnership with the largest technology companies to restore internet connectivity and other technology solutions in developing countries and areas affected by disaster.

NetHope shared a report containing latitude and longitude for the cell towers in Puerto Rico and their associated status—repairs completed, repairs planned, and repairs identified (Figure 25).

Figure 25. Map of Completed, Identified, and Planned Cell Tower Repairs

Each tower has around a 1-mile reach. Using the same process outlined in the planning phase, travel distances of 1 mile can easily be explored (Figure 26).

Figure 26. One-mile Drive Distance Around a Cell Tower Identified for Repairs

Some organizations might use demographic information to ensure that vulnerable populations—the very young, the elderly, pregnant women, the disabled, and so on receive service first. Other organizations might prioritize based on the overall population, with the goal to bring service back to the larger populations first. The demographic data in Puerto Rico is not as rich as the data for the United States, but there are still helpful data points, like total population and total households (Figure 27).

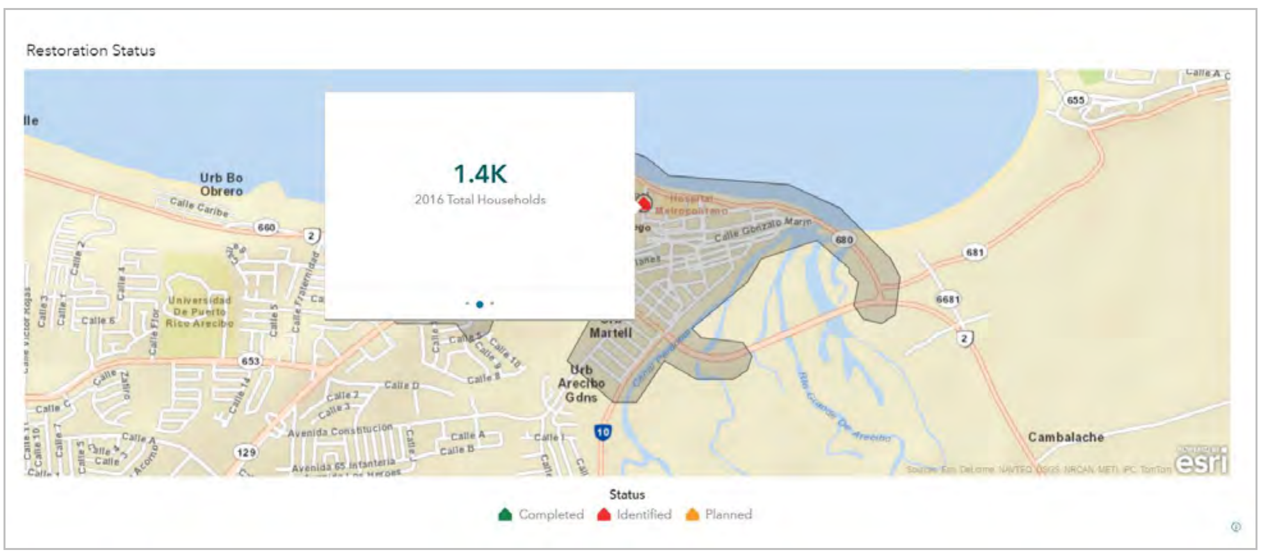


Figure 27. Total Households Within a 1-mile Drive Distance of a Cell Tower Identified for Repairs

NetHope initially had funding to bring 26 of 71 towers back online. What is the best way to prioritize in that situation? Higher populations might make sense. Because the infrastructure was destroyed, they had other options.

Figure 28 shows an aggregate view of the towers with a 1-mile drive distance. The map background can be changed to enhance the view (Figure 29).

Figure 28. Aggregate View of All Tower Locations With a 1-mile Drive Distance

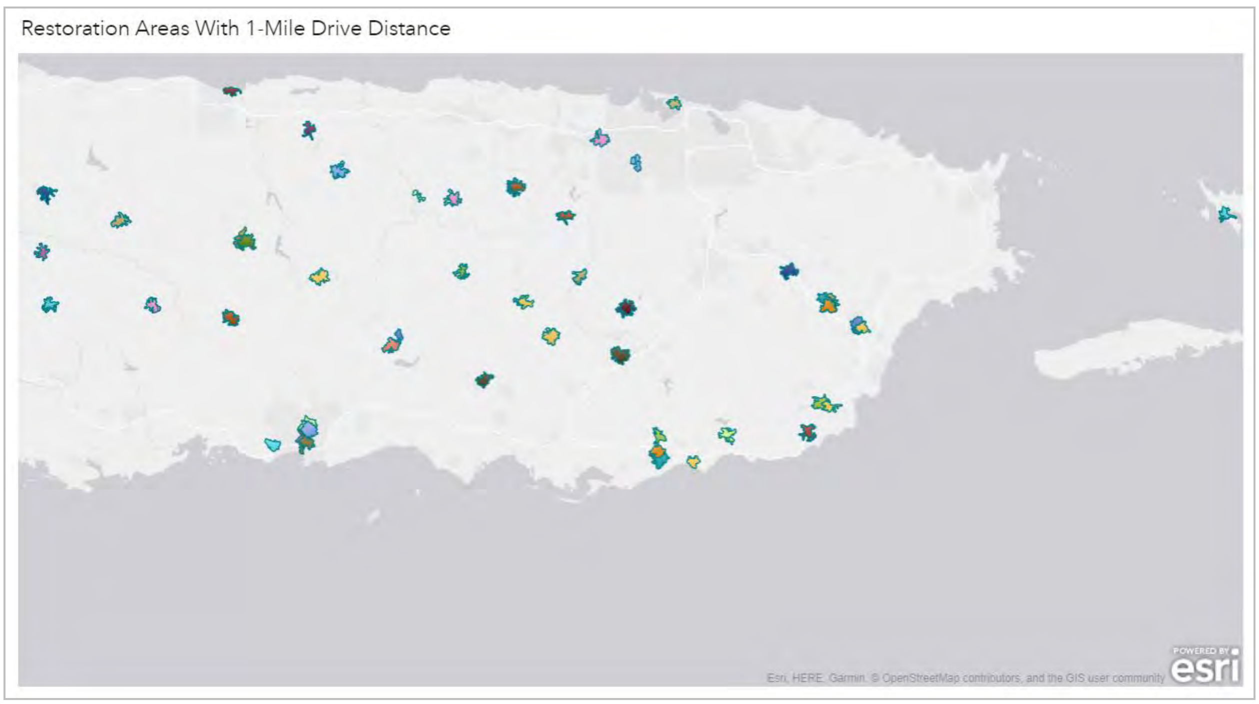


Figure 29. Canvas Map Background to Enhance the Visualization of Points

Figure 29 shows that there are several areas that have overlapping service areas. Zooming in (Figure 30) makes it easier to see the overlaps.

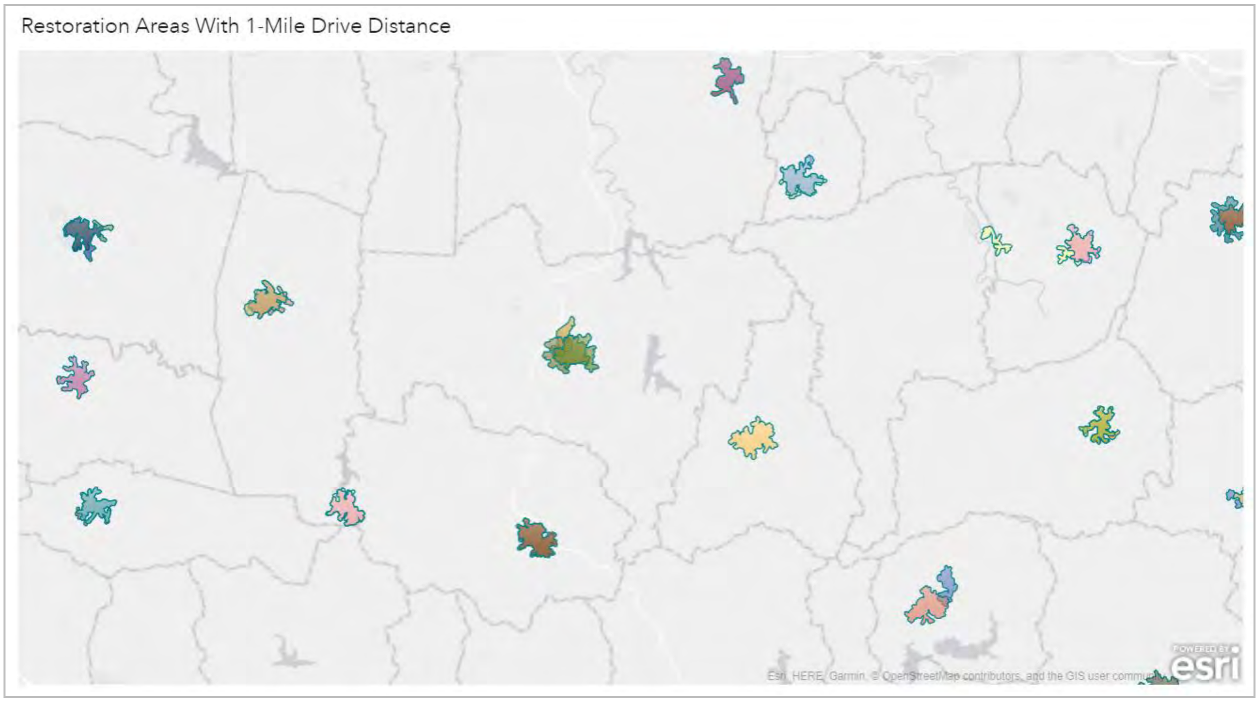
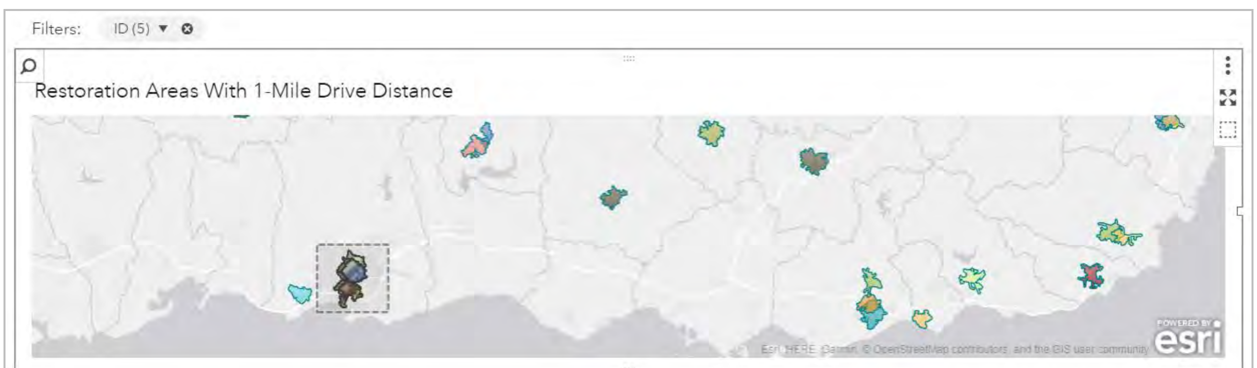


Figure 30. Zoomed View to See More Detail.

There were several overlaps. In some cases, as many as 5 areas overlapped (Figure 31), meaning it was possible to address multiple areas with one repair. That ability to prioritize based on good information and a variety of data views can significantly aid in the recovery process.



Location	Description	Status	Population ▲
Ponce - RSA 6	Provide wirless access at regional staging area to responders and community	Planned	8651
Ponce - MED CENTRO - Ciudad /...	Federally funded clinic	Planned	9380
Ponce - MED CENTRO - Centro S...	Federally funded clinic	Planned	16537
Ponce City Hall	Connect city hall to internet + public hotspot at the plaza in front	Planned	20067
Ponce - MED CENTRO - La Cantera	Federally funded clinic	Planned	20447

Figure 31. Five Tower Areas Overlapping and Their Detail

CONCLUSION

Every community will be affected at some point by a natural disaster, whether it's violent storms, earthquakes, mudslides, or wild fires. Data is often plentiful and tells a story that can aid in the planning and recovery from natural disasters. SAS Visual Analytics on SAS Viya provides a wide variety of capabilities from geographic visualizations to approachable analytics that can empower emergency managers and recovery teams to quickly make decisions that can have a positive impact on peoples' lives.

ACKNOWLEDGMENTS

I'd like to recognize Robert Allison, Adam Maness, Falko Schulz, Jeff Phillips, Eric Short, and I-Sah Hsieh for their responsiveness, ideas, and help deciphering geographic information and data. Just when I felt like I was drowning in latitudes, longitudes, shape files, maps, and charts, one of these guys would lend a hand to pull my head back above the water. I would not be able to complete most of my side projects without the help of the people in my network! Thank you!

RECOMMENDED READING

- *SAS/GRAPH Beyond the Basics*

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