Appendix J: Baltimore County Transportation Analysis

Technical Description and Maps

Roads and bridges are important assets to the County, necessary for economic development and a high quality of life for its residents. A screening assessment was conducted to itemize road segments that are at risk of flooding in both coastal and inland areas based on location within the Federal Emergency Management Agency (FEMA) mapped Special Flood Hazard Areas (SFHA). The screening assessment identified nearly 90 miles of roadways. In order to prioritize the road segments for resiliency upgrades (e.g., raising the road elevations), a methodology was developed based on emergency response time impacts from flooded roads. The goal of this analysis was to identify the top approximately 20 roads that would provide the greatest improvement to emergency response travel times for fire, police and medical when flooding obstructions were mitigated.

In this Baltimore County Transportation Analysis (BCTA), the Arcpy Python site package was used in conjunction with the ESRI ArcGIS Online Generate Service Area (GSA) tool to identify high-priority roads in Baltimore County, which are currently susceptible to flooding. The following assessment approach was developed to identify candidate roadways for future flood resilience capital improvement projects.

1. Identify road segments within the FEMA SFHA, which has a one percent probability per year of being flooded (i.e., 100-year flood event).
2. Calculate the service areas for multiple time of travel bins for Baltimore County emergency service facilities (hospitals, police stations, and fire stations) during normal and flood conditions.
3. Determine areas in which emergency response times increased due to road obstruction from flooding and select nearby roads to use in the analysis.
4. Iteratively compute changes to emergency response times and service areas when a flood obstruction is removed from an individual road such that it is no longer susceptible to flooding.
5. Compare the metrics of the service area and time of travel improvements for individual roads for each class of emergency service. Select the roads that provide the highest community benefit with respect to emergency response time for prioritization.

Step 1: Identify Roads Vulnerable to Flooding

Water surface elevation grids for the SFHA are available from FEMA. These elevation grids were compared to the County-provided digital elevation model (DEM), which is based on LiDAR.[1] The following equation was used to calculate the depth of inundation along the road centerlines.

$$\Delta E = WSE - Z$$

Where ΔE is the inundation depth, WSE is the FEMA SFHA water surface elevation and Z is the DEM elevation. Roadway segments in the flood zone with ΔE values greater than or equal to one foot were considered obstructed and included in the analysis. Bridges were reviewed using aerial photos to confirm that elevations in the DEM for the structures appeared accurate. In some cases, elevated bridges across deep valleys were incorrectly shown at the ground surface elevation and were removed from the flooded roadway layer.

Step 2: Develop Baseline Service Areas

There is no defined standard for emergency response times. Response time bins for the analysis were developed from available literature and through discussions with County staff on factors affecting response times. The response times used in the analysis are based solely on travel time along County roads and were selected to get near complete coverage of the County.

- 0 to 5 minutes
- 5 to 10 minutes
- 10 to 20 minutes
- 20 to 30 minutes

The ESRI GSA tool was run for each bin for each emergency service class. Figure J-1 presents the map of travel times from locations in the County to the four hospitals.[2]

---

[1] LiDAR is a method for measuring distances using laser light, which is used to measure elevations over large areas from airplanes. The LiDAR data is Quality Level 1 with a vertical accuracy of 10 cm.

[2] Because there are few hospitals in the County and they are generally located in the southern and central parts of the County, there are some areas to the north that are outside of the response bins selected. An additional bin could be added to capture these areas but is not expected to change the results of the analysis.

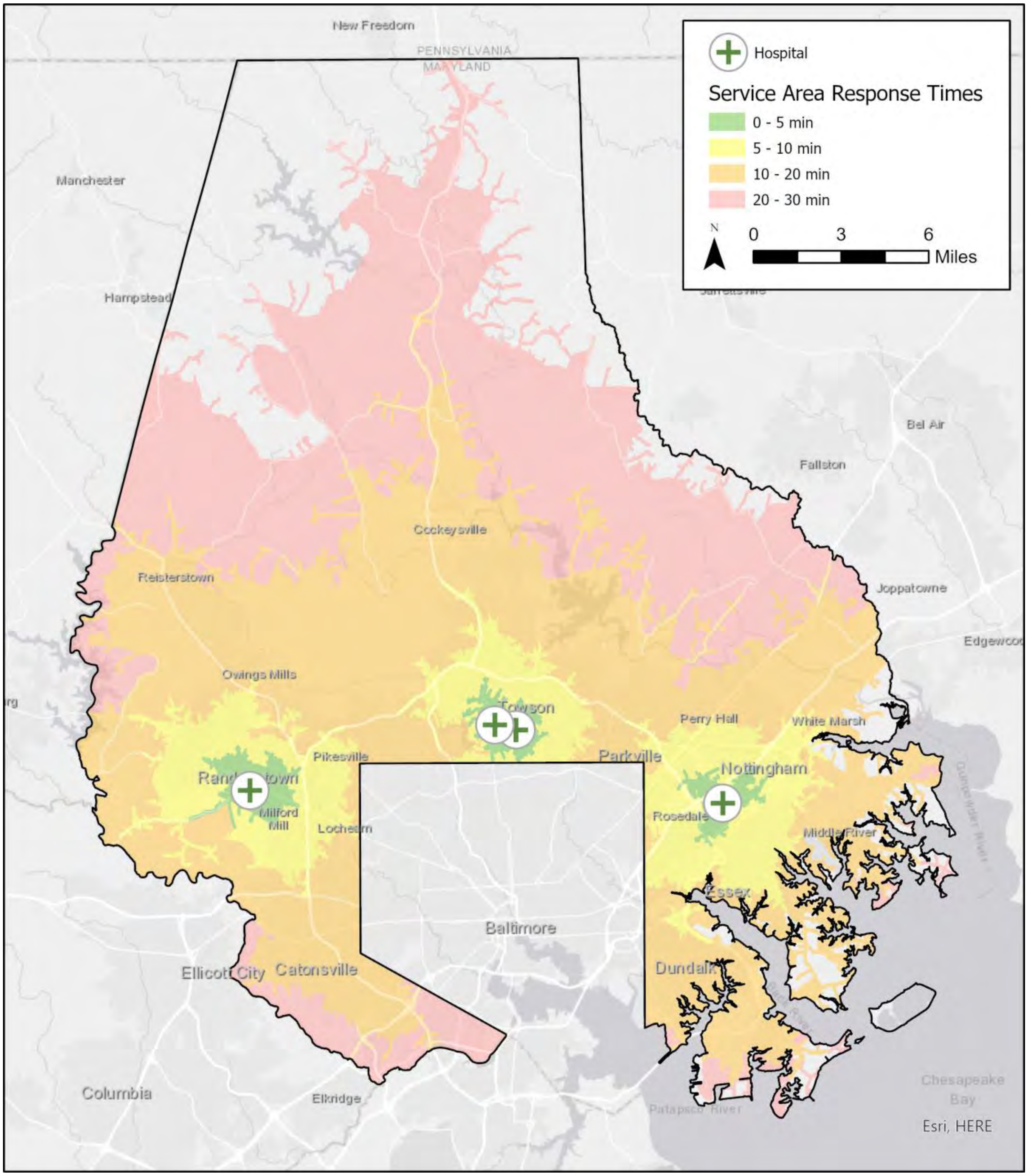


Figure J-1: Response Time Areas for the County Hospitals with No Flood Obstructions

Step 3: Compute Obstructed and Unobstructed Service Areas

The ESRI GSA tool was initially run for each class of emergency service (four hospitals, 10 police stations, and 56 fire stations). The ESRI GSA tool draws polygon boundaries that encompass all streets accessible within the user-defined time period from the facilities. The GSA tool computes these drive times using ESRI's road network database and allows users to add specific travel restrictions. For example, a user can specify that the tool only computes service areas where emergency vehicles are allowed. Additionally, users can define barrier features so the tool computes service areas that exclude blocked routes.

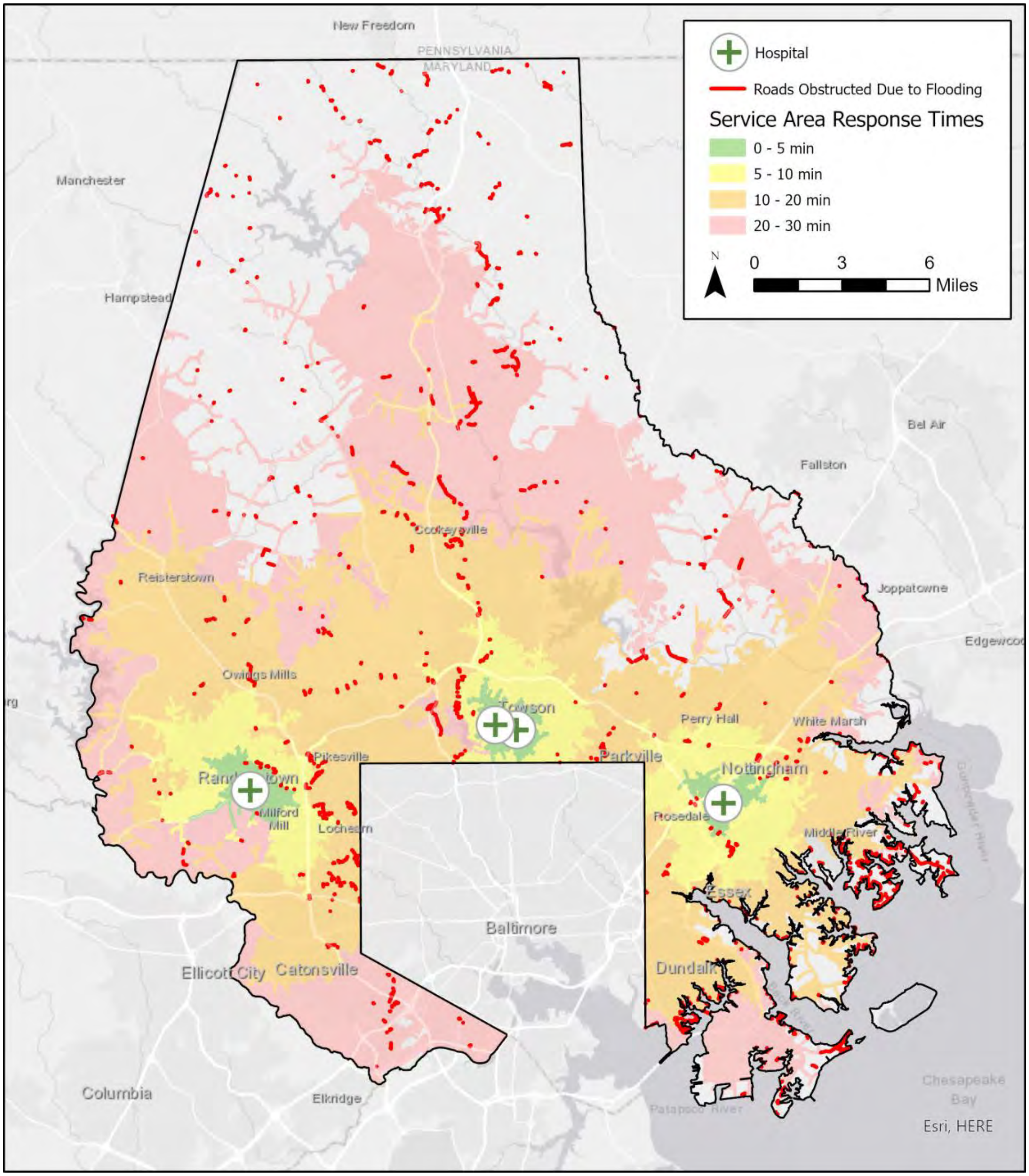
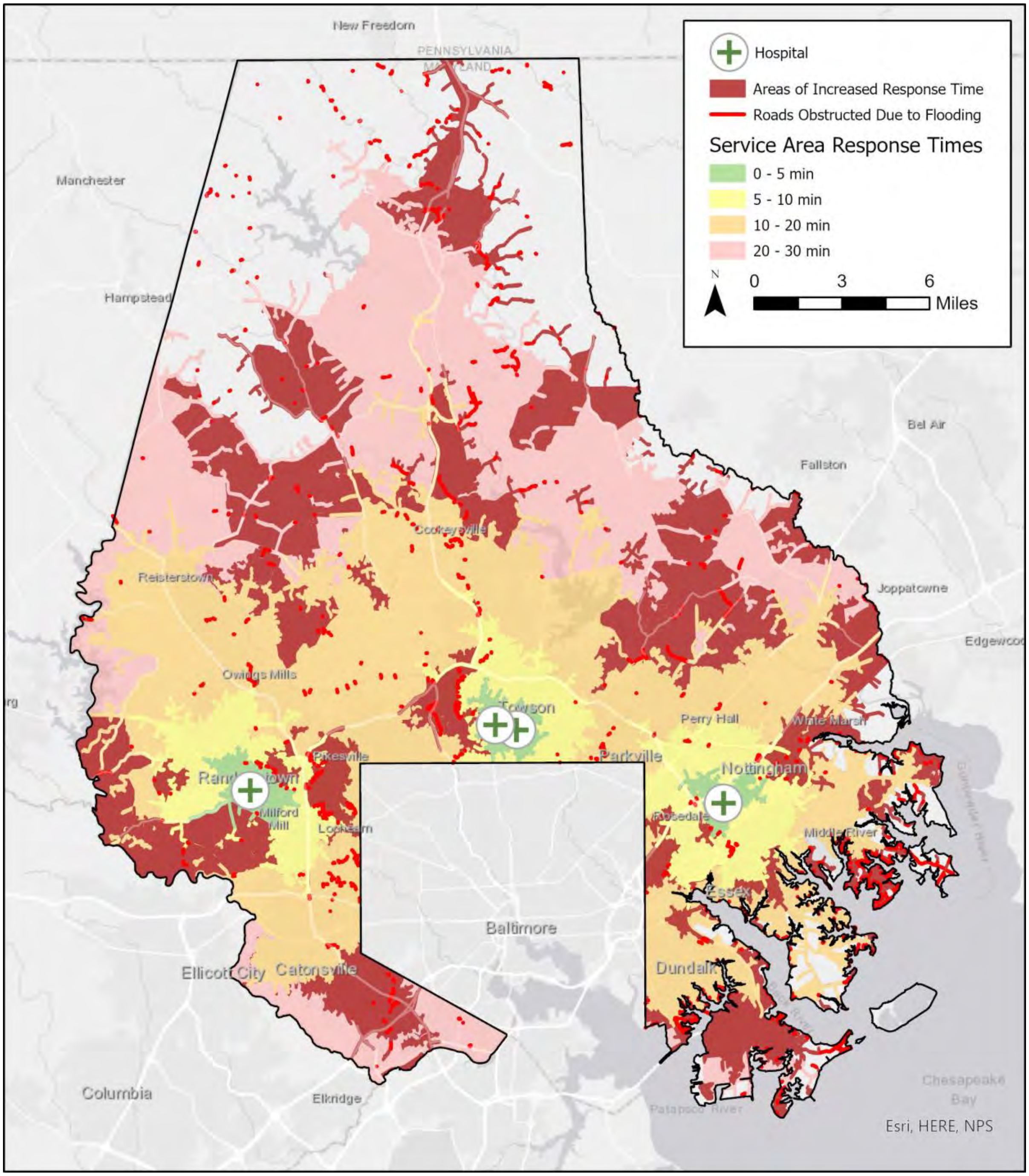


Figure J-2: Response Time Areas for the County Hospitals with All Flooded Roads as Obstructions

Unobstructed service areas maps that encompass all streets accessible by emergency vehicles within the user-defined time periods under normal conditions (i.e., no flooding) were developed for each set of emergency facilities (example shown for hospitals in Figure J-1). Similar maps were developed for each class of emergency service with all roads vulnerable to flooding set as obstructed. (i.e., when every section of flooded roadway identified in Step 1 is treated as an impassable barrier) An example is shown for hospitals in Figure J-2.



FigureJ-3: Areas of Increased Response Time Highlighted for the County Hospitals with All Flooded Roads as Obstructions

If a region is accessible by multiple facilities within the user-defined time periods, the fastest response time is assigned to the area; for example, a location that is five minutes away from one fire station and 20 minutes away from another fire station, the area would fall within the 5-minute service area boundary.

Step 4: Select Subset of Roads Vulnerable to Flooding

The maps of unobstructed and obstructed response time zones were compared to identify areas where response times worsened (Figure J-3). These areas of slower response times were used to screen out flooded road segments in areas with no service change. This step was included to avoid unnecessary computing time and ArcGIS credit spending on analysis of roads that would have no effect on response times if improved. Roads that fell more than 1000 feet outside of these regions of increased response time were excluded from further analysis. Because the goal of the assessment was to improve emergency service response time for the maximum number of County residents, the selection of roads was further refined by excluding areas with low impervious surface and few buildings indicative of low population.

Step 5: Perform Iterative Service Area Analysis

Once the roadway segments that would be used in the BCTA were selected, the iterative service area analysis was performed, beginning with the four hospitals in the County. The hospitals were selected for the first analysis because there are the fewest facilities, and the service areas would be most sensitive to blocked roadways. A Hazen-developed Python script was used to iteratively compute the service area maps for hospitals when all but one of the flooded road segments were obstructed and repeated for each flooded road segment.[3] This step estimated the service area improvement from raising a road that is vulnerable to flooding. The results of the hospital analysis identified 54 roads that would improve emergency service response time if flood vulnerabilities were addressed. The iterative analysis was then repeated to create maps showing areas of improvement in emergency service response times for the police stations and fire stations. Figure J-4 shows an example of the changes to the police station service areas from unobstructed roads, flood obstructions and target improvement of York Road in the vicinity of Cockeysville.

---

[3] Because an individual road can be flooded at multiple locations, all obstructions for a given road were removed during the iteration step so the road would be fully open and available during flood conditions.

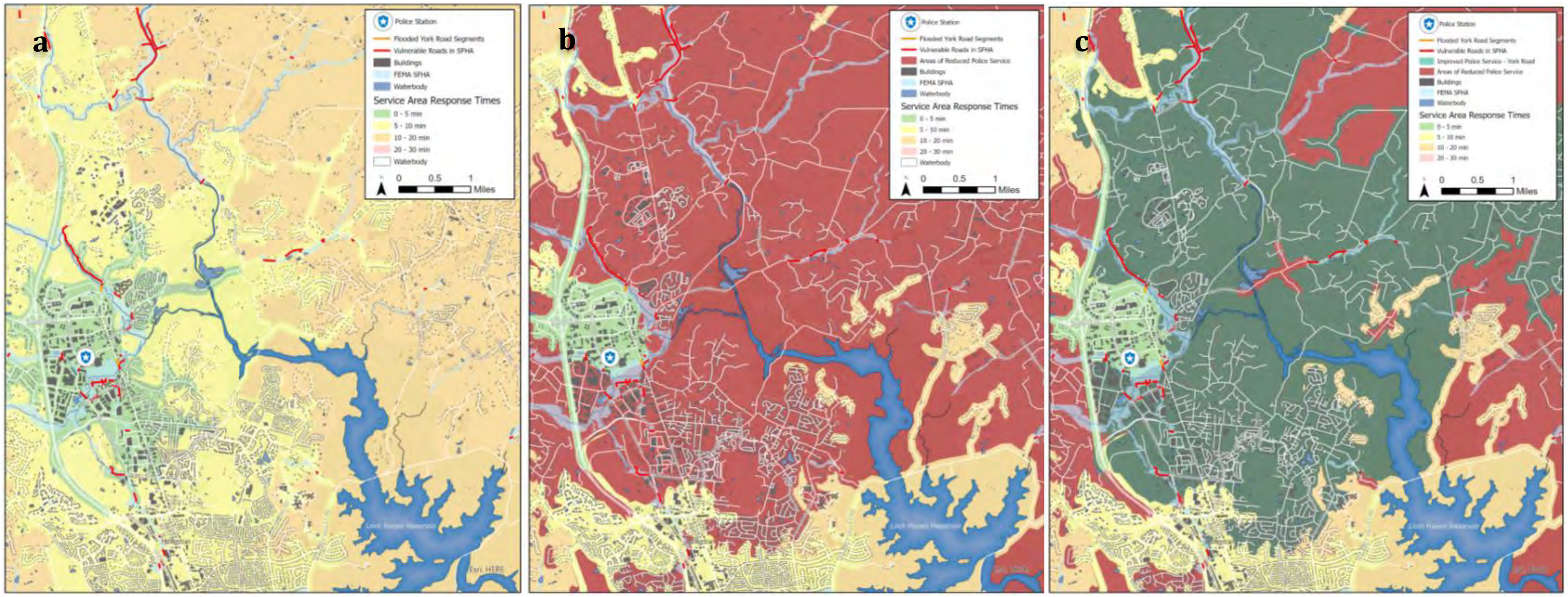


Figure J-4: Example Showing (a) Unobstructed Police Station Service Areas, (b) Obstructed Police Station Service Areas and (c) Service Area Improvement from Removing Flood Obstructions along York Road

Step 6: Compare Results and Develop Prioritization

For each analyzed road, a GIS script was used to compute the land area of regions of improvement, the number of structures in the regions of improvement, and the building footprint area in the regions of improvement. The land area of improvement was ultimately rejected because some roads improved large areas of open space. The building count and building area metrics were determined to be similar. Therefore, the final prioritization was based on the count of buildings as the best surrogate for population served. Figure J-5 through J-7 present the results of the iterative analysis. For each class of emergency service there were a number of roads that clearly provided the most benefit. Additionally, the order of magnitude for the highest benefit roads for fire stations was lower than for hospitals and police stations because of the substantially higher number of stations in the County.

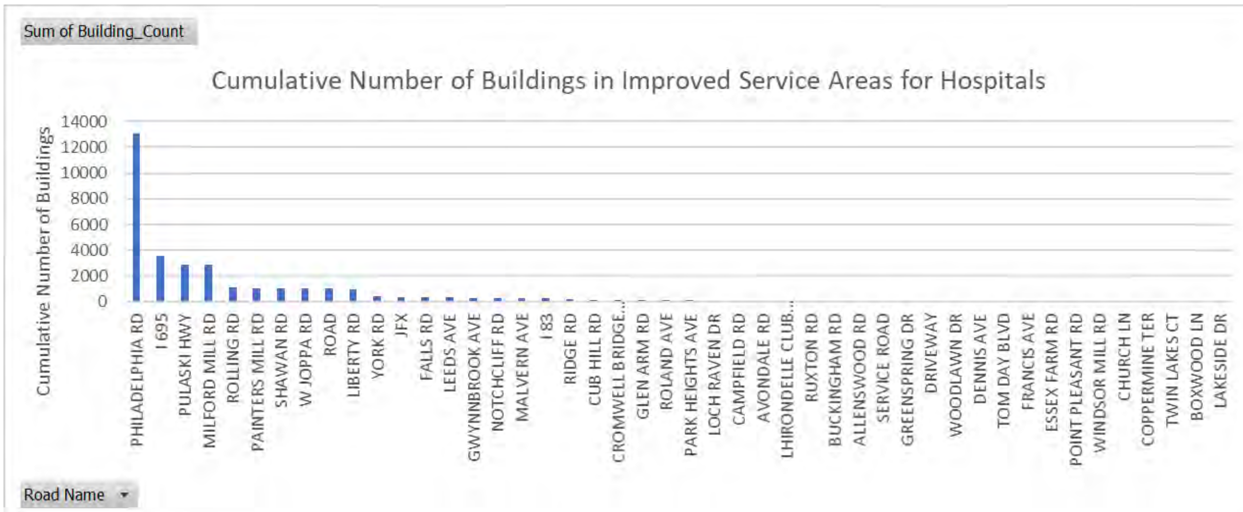


Figure J-5: Cumulative Number of Buildings in Improved Service Areas for Hospitals

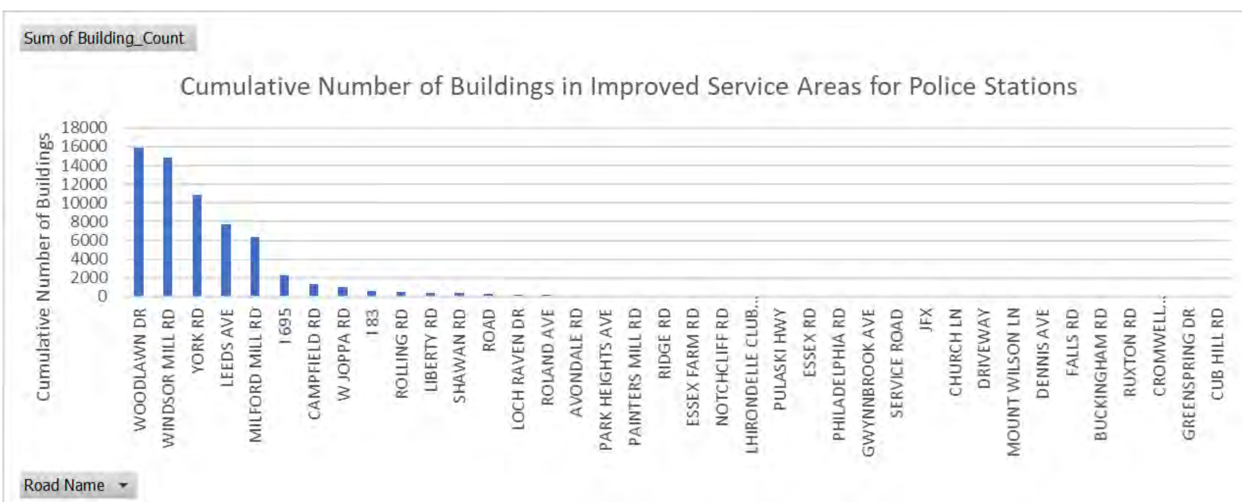


Figure J-6: Cumulative Number of Buildings in Improved Service Areas for Police Stations

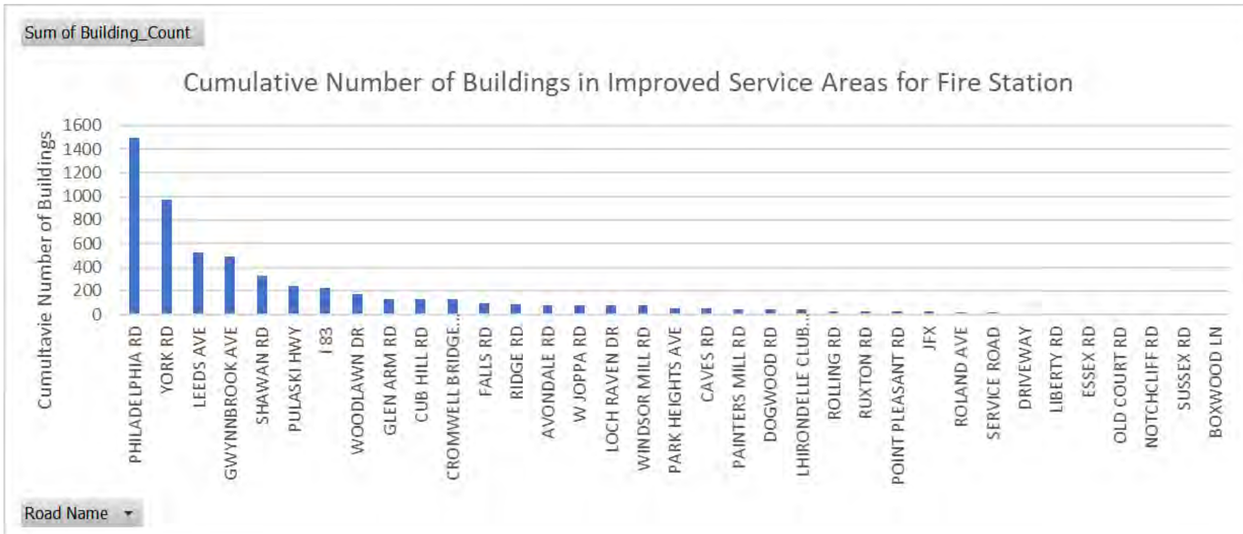


Figure J-7: Cumulative Number of Buildings in Improved Service Areas for Fire Stations

Table J-1 presents the 22 highest ranked roads from the BCTA that provide the most improvement in emergency response times for the County. The table highlights six roads that provided the highest benefits across one or more service areas.

Table J-1: Prioritized Roadway Segments from Emergency Response Time Analysis for Flooding (Pink highlighting indicates the highest priority roads)

Roadway Name	Previously Reported Roadway Flooding	Roadway Name	Previously Reported Roadway Flooding
Campfield Rd		Painters Mill Rd	
Caves Rd		Park Heights Ave	
Cromwell Bridge Rd	X	Philadelphia Rd	X
Falls Rd		Pulaski Hwy	
Gwynnbrook Ave		Ridge Rd	
I-695		Rolling Rd	
I-83		Shawan Rd	
Leeds Ave	X	W Joppa Rd	
Liberty Rd		Windsor Mill Rd	
Milford Mill Rd		Woodlawn Dr	
Notchcliff Rd	X	York Rd	

Maps of each of the flooded road segments from the roads in Table J-1 are included on the following pages.

Road Name	Latitude (Start)	Longitude (Start)	Latitude (End)	Longitude (End)
CAMPFIELD RD	39.342276	-76.725532	39.34316	-76.725432

N

0 50 100 150 200 Feet

CAMPFIELD RD
Section 1 of 1

Hazen

Print Date: 4/15/2021 5:25 PM
Printed By: T. Howard
Reviewed By: B. Wright

Baltimore County Climate Action Plan

Prioritized Roadways in SFHA
CAMPFIELD RD

Appendix J

Hazen Project Number: 31466-001
Plot date: 4/15/2021 5:25 PM By: thoward
Service Layer Credits: Maxar, Microsoft, VITA, Esri, HERE, Garmin, iPC, Esri, HERE, Garmin, NGA, USGS, NPS

File = O:\GIS\Projects\31466-001\ArcGISPro\BaltimoreCountyCAP_Transportation_GIS_Updated\Transportation_Analysis_20201228\Transportation_Analysis_20201228.aprx Saved by thoward Save date = 4/15/2021 5:24 PM

Road Name	Latitude (Start)	Longitude (Start)	Latitude (End)	Longitude (End)
CAVES RD	39.436738	-76.734262	39.436454	-76.734507

CAVES RD
Section 1 of 2

Hazen

Print Date: 4/15/2021 5:25 PM
Printed By: T. Howard
Reviewed By: B. Wright

Baltimore County Climate Action Plan

Prioritized Roadways in SFHA
CAVES RD

Appendix J

Hazen Project Number: 31466-001
Plot date: 4/15/2021 5:25 PM By: thoward
Service Layer Credits: Maxar, Microsoft, VITA, Esri, HERE, Garmin, iPC, Esri, HERE, Garmin, NGA, USGS, NPS

File = O:\GIS\Projects\31466-001\ArcGISPro\BaltimoreCountyCAP_Transportation_GIS_Updated\Transportation_Analysis_20201228\Transportation_Analysis_20201228.aprx Saved by thoward Save date = 4/15/2021 5:24 PM

Road Name	Latitude (Start)	Longitude (Start)	Latitude (End)	Longitude (End)
CAVES RD	39.436832	-76.734165	39.436816	-76.734181

N

0 50 100 150 200 Feet

CAVES RD
Section 2 of 2

Hazen

Print Date: 4/15/2021 5:25 PM
Printed By: T. Howard
Reviewed By: B. Wright

Baltimore County Climate Action Plan

Prioritized Roadways in SFHA
CAVES RD

Appendix J

Hazen Project Number: 31466-001
Plot date: 4/15/2021 5:25 PM By: thoward
Service Layer Credits: Maxar, Microsoft, VITA, Esri, HERE, Garmin, iPC, Esri, HERE, Garmin, NGA, USGS, NPS

File = O:\GIS\Projects\31466-001\ArcGISPro\BaltimoreCountyCAP_Transportation_GIS_Updated\Transportation_Analysis_20201228\Transportation_Analysis_20201228.aprx Saved by thoward Save date = 4/15/2021 5:24 PM

Road Name	Latitude (Start)	Longitude (Start)	Latitude (End)	Longitude (End)
CROMWELL BRIDGE RD	39.42214	-76.535293	39.424884	-76.529257

N

0 150 300 450 600 Feet

CROMWELL BRIDGE RD
Section 1 of 1

Hazen

Print Date: 4/15/2021 5:25 PM
Printed By: T. Howard
Reviewed By: B. Wright

Baltimore County Climate Action Plan

Prioritized Roadways in SFHA
CROMWELL BRIDGE RD

Appendix J

Hazen Project Number: 31466-001
Plot date: 4/15/2021 5:25 PM By: thoward
Service Layer Credits: VITA, Esri, HERE, Garmin, iPC, Maxar, Esri, HERE, Garmin, NGA, USGS, NPS

File = O:\GIS\Projects\31466-001\ArcGISPro\BaltimoreCountyCAP_Transportation_GIS_Updated\Transportation_Analysis_20201228\Transportation_Analysis_20201228.aprx Saved by thoward Save date = 4/15/2021 5:24 PM

Road Name	Latitude (Start)	Longitude (Start)	Latitude (End)	Longitude (End)
FALLS RD	39.375041	-76.650588	39.375442	-76.650686

N

0 50 100 150 200 Feet

FALLS RD
Section 1 of 6

Hazen

Print Date: 4/15/2021 5:25 PM
Printed By: T. Howard
Reviewed By: B. Wright

Baltimore County Climate Action Plan

Prioritized Roadways in SFHA
FALLS RD

Appendix J

Hazen Project Number: 31466-001
Plot date: 4/15/2021 5:25 PM By: thoward
Service Layer Credits: Maxar, Microsoft, VITA, Esri, HERE, Garmin, iPC, Esri, HERE, Garmin, NGA, USGS, NPS

File = O:\GIS\Projects\31466-001\ArcGISPro\BaltimoreCountyCAP_Transportation_GIS_Updated\Transportation_Analysis_20201228\Transportation_Analysis_20201228.aprx Saved by thoward Save date = 4/15/2021 5:24 PM

Road Name	Latitude (Start)	Longitude (Start)	Latitude (End)	Longitude (End)
FALLS RD	39.387913	-76.659397	39.394192	-76.662183

N

0 260 520 780 1,040 Feet

FALLS RD
Section 2 of 6

Hazen

Print Date: 4/15/2021 5:25 PM
Printed By: T. Howard
Reviewed By: B. Wright

Baltimore County Climate Action Plan

Prioritized Roadways in SFHA
FALLS RD

Appendix J

Hazen Project Number: 31466-001
Plot date: 4/15/2021 5:25 PM By: thoward
Service Layer Credits: VITA, Esri, HERE, Garmin, iPC, Maxar, Esri, HERE, Garmin, NGA, USGS, NPS

File = O:\GIS\Projects\31466-001\ArcGISPro\BaltimoreCountyCAP_Transportation_GIS_Updated\Transportation_Analysis_20201228\Transportation_Analysis_20201228.aprx Saved by thoward Save date = 4/15/2021 5:24 PM