Resilient Connecticut 2.0 Synthesis Report Appendix B

GIS Analysis Methodology

CIRCA
Connecticut Institute for Resilience and Climate Adaptation

GIS Analysis Methodology

Appendix B

Data Tool Development:

CIRCA developed and expanded the below tools as part of the Resilient Connecticut 2.0 initiative to support comprehensive climate resilience planning across the state. These resources are designed to assist planners, municipal officials, and stakeholders in making informed decisions by providing critical data, assessment methodologies, and visualization tools.

1) **Zones of Shared Risk (ZSR):** Zones of Shared Risk were delineated within each municipality in ArcGIS and shared through an interactive map viewer using ArcGIS Online. ZSRs were identified based on text and action items listed in each community's hazard mitigation plan, as well as the Coastal Resilience Plan for those municipalities in RiverCOG and SECOG that previously created such a plan. Additional ZSRs were drawn as needed by CIRCA staff to reflect concerns identified by municipal staff as well as to encompass areas with limited points of egress that might be isolated by flooding based on an overlay of road data and flood zone data.

   These Zones of Shared Risk were utilized in the subsequent overlay spatial analysis to identify Resilience Opportunity Areas (ROARs). All "ROARs recipes" related to flooding needed to intersect with a ZSR in order to be selected as a final ROAR (see #3 for an explanation of the "recipe" approach). This criterion was included in the recipes for Regional Assets, Critical Facilities, Resilient Corridors, Transit-Oriented Development, Historic Resources, Affordable Housing, Wastewater Treatment Plants, Sewersheds Upstream of At-Risk Pumping Stations (pumping station had to be located within a ZSR), Public Water Supply Watersheds, Public Water Supply Wells, Brownfields, Septic Systems, and Home Elevation Unmet Needs. A 500-ft buffer was added to each ZSR before the ROARs spatial analysis was completed, in order to ensure that slight inconsistencies in polygon digitization would not inadvertently exclude a possible ROAR just outside of a ZSR boundary.

   Please see Appendix C for a full inventory of Zones of Shared Risk delineated during Resilient Connecticut 2.0.

2) **Climate Change Vulnerability Index (CCVI):** An index-based spatial model that identifies community vulnerability to flood, and heat-related impacts of climate change. The CCVI characterizes areas based on an equation using sensitivity times exposure, divided by adaptive capacity. The results of this model are represented using a grid of over 330,000 cells that covers the entire state of Connecticut within a GIS environment. More information about the CCVI can be found in Appendix D, as well as on the Resilient Connecticut CCVI webpage, which includes links to web viewers: https://resilientconnecticut.uconn.edu/ccvi/

CCVI scores were utilized in the subsequent overlay spatial analysis to identify Resilience Opportunity Areas (ROARs). Some ROARs recipes only utilized either flood or heat CCVI scores, while others used both, as indicated in Table 1 below. A grid cell is considered to be of moderate-high flood or heat vulnerability if its value falls in the highest three categories of scores, using a classification system with 5 classes split by natural breaks:

- For the flood CCVI, this value is 0.13 and above in the attribute "Flood_Vuln_Score_Normalized"
- For the heat CCVI, this value is 0.21 and above in the attribute "Vulnerability Score Normalized"

Table 1. CCVI overlay requirements for each ROAR recipe.

ROAR Recipe	Mod-High Flood Overlay	Mod-High Heat Overlay
Regional Assets	Yes	Yes
Critical Facilities	Yes	Yes
Resilient Corridors	Yes	No
TOD	Yes	Yes
Historic Resources	Yes	Yes
Affordable Housing	Yes	Yes
WWTP	Yes	No
Sewersheds upstream of at-risk pumping stations	Yes	No
PWS Watershed	Yes	No
PWS Wells	Yes	No
Dams	Yes	No
Brownfields	Yes	Yes
Septic Systems	Yes	No
Livestock and chicken operations	Yes	Yes
Home elevation unmet needs	Yes	No

3) **Resilience Opportunity Areas (ROARs)**: A ROAR is a Resilience Opportunity Area representing the intersection of climate-induced flooding and heat risks with vulnerable populations and planning priorities. For Resilient Connecticut 2.0, these priorities were shaped by shared concerns that emerged from CIRCA meetings with municipalities and tribes, as well as GIS data availability from state, COG, and other sources. For each identified priority, a "recipe" was developed and implemented within ArcGIS Pro to identify areas within each of the three 2.0 COG regions that meet criteria corresponding to that priority, in addition to the ZSR and CCVI criteria described above. The data layers utilized in each recipe are listed in Table 2 below, along with the data sources for each; as much of the data layers were provided by COGs, the recipes varied somewhat by COG based on data availability. The steps of each recipe are outlined in Table 3.

Table 2. Spatial data layers utilized in each ROARs recipe, with data sources indicated in parentheses.

"Recipe"	Data Used for SCCOG	Data Used for RiverCOG	Data Used for CRCOG
Regional Assets	• Points of Interest (COG) • Transportation Assets (COG)	• Major employers (COG) • Recreation/tourism (COG)	• CRCOG bus stops (COG) • CRCOG bus routes (COG) • Hartford Line route (COG)

	• Commercial Assets (COG) • Institutional Assets (COG) • WRTD routes/stops (COG) • SEAT routes/stops (COG) • NineTT (COG) • CT Transit routes/stops (COG) • Greyhound stops (COG) • ECTC stops (COG) • Amtrak route (COG) • Ferry port (COG)	• Regional freight rail line (COG) • Regional area rail (COG) • MAT existing service routes (COG) • MAT potential service routes (COG)	• Fastrak Guideway (COG) • Hartline Riverlink (COG) • CT Greenways (COG) • CRCOG Multi-Use Trails (COG) • Areas of Regional Significance (COG)
Critical Facilities	• Cooling Centers (CIRCA) • Critical facilities layer (Resilient Land & Water)	• Cooling Centers (CIRCA) • Town Centers (COG) • Schools (COG) • Federally qualified health centers (COG) • Hospitals (COG) • Fire stations (COG) • Nursing homes (COG) • Police stations (COG) Notes: Only the Middletown point from the EOC layer was used to avoid double-counting (as the other towns have their EOC in PDS or town halls).	• Critical facilities layer (COG, with some organization and identification of cooling centers by CIRCA) • Schools (COG) • Food access locations (COG)
Resilient Corridors	• State roads functional classification layer (DOT)	• State roads functional classification layer (DOT)	• State roads functional classification layer (DOT)
TOD	• Amtrak stations (COG)	• Regional rail stations (COG)	• Transit Hubs (COG)
Historic Resources	• SHPO Historic Resources Inventory (Dewberry)	• SHPO Historic Resources Inventory (Dewberry)	• SHPO Historic Resources Inventory (Dewberry)
Affordable Housing	• Affordable Housing plan points and polygons (COG) • Public Housing Buildings (HUD)	• Housing authorities points layer (COG) • Private affordable housing (COG) • HUD Public Housing Buildings (HUD)	• Affordable housing locations (COG) • Public Housing Buildings (HUD)
WWTP	• Wastewater treatment facility locations (COG)	• Sewer treatment plant locations (COG)	• Wastewater facilities (COG)
Sewersheds upstream of at-risk pumping stations	• State sewer services areas (DEEP) • Pump station locations (COG)	Pump station location data unavailable. Recipe was not completed for this COG.	Pump station location data unavailable. Recipe was not completed for this COG.
PWS Watershed	• State drinking water watershed layer (DEEP)	• State drinking water watershed layer (DEEP)	• State drinking water watershed layer (DEEP)
PWS Wells	• PWS Wells (CIRCA)	• PWS Wells (CIRCA)	• PWS Wells (CIRCA)
Dams	• Dams (DEEP)	• Dams (DEEP)	• Dams (DEEP)
Brownfields	• Hazardous waste inventory 2021 (DEEP)	• Hazardous waste inventory 2021 (DEEP)	• Hazardous waste inventory 2021 (DEEP)

	• Hazardous waste parcels (DEEP)	• Hazardous waste parcels (DEEP)	• Hazardous waste parcels (DEEP)
Septic Systems	• State sewer no-service areas (DEEP) • Building footprints (Microsoft Maps)	• State sewer no-service areas (DEEP) • Building footprints (Microsoft Maps)	• State sewer no-service areas (DEEP) • Building footprints (Microsoft Maps)
Livestock and chicken operations	• Chicken and egg farm layer (COG)	Data unavailable and no RiverCOG municipalities raised this concern. Recipe not completed for this COG.	Data unavailable and no CRCOG municipalities raised this concern. Recipe not completed for this COG.
Home elevation unmet needs	• FEMA flood zones (FEMA) • EJ census block groups (DEEP/CIRCA) • Building footprints (Microsoft Maps)	• FEMA flood zones (FEMA) • EJ census block groups (DEEP/CIRCA) • Building footprints (Microsoft Maps)	• FEMA flood zones (FEMA) • EJ census block groups (DEEP/CIRCA) • Building footprints (Microsoft Maps)

Table 3. GIS model steps for each ROARs recipe.

Recipe	GIS Model
Regional Assets	1) From each of the point layers of regional assets, select the assets that are within ZSR+500ft buffer polygons. 2) From the selection in Step 1, select the assets that occur in areas of high-mod combined heat and flood CCVI. 3) Merge into one point layer for convenience. 4) Repeat same approach for routes (lines) that *intersect* ZSR+500ft buffer polygons, and (in the case of CRCOG) for areas of regional importance (polygons) that overlap with ZSR+500ft buffer polygons.
Critical Facilities	1) Select the ZSR+500ft buffer polygons that intersect with areas of high-mod combined heat and flood CCVI. 2) Use "Summarize Within" to find the number of critical facilities within each selected ZSR+500ft buffer polygon from Step 1. 3) Select only the ZSR+500ft buffer polygons that contain at least 2 critical facilities. 4) Manually check for double-counting between cooling centers layer and critical facilities layer, adjust accordingly.
Resilient Corridors	1) Select roadways (see above table for details on road classifications) that intersect with ZSR+500ft buffer polygons and are categorized as interstates, other freeways/expressways, collectors, or arterials. 2) From the selection in Step 1, select the roadways that intersect with areas of high-mod flood CCVI. 3) Manually review for any cases where segmentation of the polylines has resulted in selecting only partial corridors, and manually added the missing segments to the selection to ensure that a full corridor is selected rather than just one patch of road with segmented data.
TOD	[This model was completed in ArcGIS Online, instead of ModelBuilder like the other models in this table, in order to take advantage of the Generate Travel Areas tool.] 1) Input the TOD points into the Generate Travel Areas tool on ArcGIS Online. 2) In the Generate Travel Areas tool, set the parameters to Travel Mode = Driving Distance and Cut-off Distance = 0.75 miles. Leave all other parameters in the default. Note: Driveshed of 0.75 miles was used to be consistent with 1.0 methodology.

Affordable Housing	1) Select the ZSR+500ft buffer polygons that intersect with areas of high-mod combined heat and flood CCVI. 2) Use "Summarize Within" to find the number of HUD Public Housing Buildings within each selected ZSR+500ft buffer polygon from Step 1. 3) From the layer produced by Step 2, select only the polygons that contain 2 or more affordable housing assets. 4) Manually add-to-selection any polygons with 2 or more COG-provided points (or in the case of SCCOG, a COG-provided polygon) that have not already been selected (do this manually to avoid double-counting points that appear in both the COG-provided layers and the HUD layers).
Historic Resources	1) Select the ZSR+500ft buffer polygons that intersect with areas of high-mod combined heat and flood CCVI. 2) Use "Summarize Within" to find the number of historic resources within each selected ZSR+500ft buffer polygon from Step 1 (using Dewberry/SHPO 2022 historic resources layer). 3) From the selected ZSR+500ft buffer polygons in Step 2, select only the polygons that contain 10 or more historic resources.
WWTP	1) Select the ZSR+500ft buffer polygons that intersect with areas of high-mod flood CCVI. 2) From the selection in Step 1, select the ZSR+500ft buffer polygons that contain a WWTP. 3) Manually review to remove any WWTPs that do not serve an EJ community, after discussion with CIRCA team.
Sewersheds upstream of at-risk pumping stations	1) Select the pumping stations that are located within the ZSR+500ft buffer polygons. 2) From the selection in Step 1, select the pumping stations that are located in areas of high-mod flood CCVI. 3) Select the connected sewer services areas that intersect with the pumping stations selected in Step 2. Note: This recipe was only competed for SCCOG due to data availability.
PWS Watershed	1) Select the PWS watersheds that intersect with the region of the COG in question. 2) From the selection in Step 1, select the PWS watersheds that intersect with ZSR+500ft buffer polygons. 3) From the selection in Step 2, select the PWS watersheds that intersect with areas of high-mod flood CCVI. 4) Manually review selection from Step 3 to remove any watersheds that do not serve EJ communities (or to add watershed polygons that are contiguous with selected polygons, as part of a larger watershed serving the same area).
PWS Wells	1) Select the ZSR+500ft buffer polygons that intersect with areas of high-mod flood CCVI. 2) Select the PWS well points that intersect with the selection of ZSR+500ft buffer polygons from Step 1. 3) From the selection in Step 2, select the PWS well points that intersect with EJ municipalities or census tracts.
Dams	1) Select from the DEEP dam layer only the dams that are Class A or lower and that are not state-owned, federally-owned, or utility-owned. 2) From the selection in Step 1, select only the dams within the COG region in question. 3) From the selection in Step 2, select only the dams that intersect with high-mod flood CCVI areas.
Brownfields	1) Select the ZSR+500ft buffer polygons that intersect with areas of high-mod combined heat and flood CCVI. 2) Use "Summarize Within" to find the number of hazardous site points within each selected ZSR+500ft buffer polygon from Step 1.

	3) Using the "Summarize Within" to find the number of hazardous site polygons within the shapefile produced by Step 2 (so that the counts of points and polygons are both included in the same attribute table). 4) Create a new field to hold the sum of the hazardous points + polygons in each ZSR+500fit buffer polygon. Calculate this sum by adding the Count of Points from Step 2 to the Count of Polygons from Step 3. 5) Based on the calculation in Step 4, select the ZSRs+500ft buffer polygons that have at least 2 hazardous sites (whether point or polygon) within them.
Septic Systems	1) Intersect ZSR+500ft buffer polygons and no-sewer areas. 2) Use the "Multi-part to Single-part" tool on the output file from Step 1. 3) From the output file from Step 2, select all the polygons that intersect with high-mod flood CCVI areas. 4) Use "Summarize Within" to find the number of building footprints within each selected polygon from Step 3 (using Microsoft Bing building footprints layer). 5) Select the polygons containing more than 10 building footprints. Note: The data for building footprints do not indicate building type.
Livestock and chicken operations	1) Select from the chicken/egg operation layer the parcels that intersect with high-mod combined heat and flood CCVI areas. Note: This model was only completed for SCCOG due to data availability and municipal interest.
Home elevation unmet needs	1) Use the Intersect tool to find the areas of overlap between the EJ Census Block Group Layer and the ZSR+500ft buffer polygon layer. a. EJ Census Block Group layer includes all census block groups that meet the EJ income criteria set by DEEP, including those within distressed municipalities. The final layer includes all census block groups for which the percent of the population below 200% of the federal poverty level was greater than or equal to 30% in 2022. 2) Use the Select By Location tool to find all polygons in the layer resulting from Step 1 that intersect with any areas of high-mod flood CCVI. 3) From the FEMA flood zone layer, select only the areas A, AE, or VE flood hazard zones. 4) Use the Intersect tool to find the areas of overlap between the selection resulting from Step 2 and the layer resulting from Step 3. 5) Use the Dissolve tool to dissolve the layer resulting from Step 4 based on the ZSR ID field. 6) Use the Summarize Within tool to count the number of building footprints within each polygon resulting from Step 5. 7) Select the polygons containing more than 10 building footprints. Note: The data for building footprints do not indicate building type.

After Recipe Models Have Been Run, Count ROARs in Each ZSR:

1) Within the attribute table for the ZSR+500ft buffer polygon layer, create a new field corresponding to whether or not each polygon overlaps with the results of each ROAR recipe above. Use Selection by Location settings of "identical" rather than "intersects" for any of the recipes that are based on zone polygons, in order to avoid overcounting due to zones that overlap each other or are nested.
2) Set the above field's value to 0 if there is no overlap and 1 if there is an overlap.
3) Create a new field for the total count of overlapping ROARs for each polygon, and calculate this field by finding the sum of all of the fields for each ROARs recipe.

Internal Review and Preliminary ROARs Prioritization

CIRCA staff met to review all of the results of the "ROARs Recipes" above and identify areas to move to the next stage of ROARs identification, which included digitization. Priority review was given to places in which the results of at least five recipes overlapped, places in which critical facilities were located in flood-vulnerable areas, and/or places that were directly mentioned by name as a climate-related concern by municipalities during CIRCA meetings, as outlined below.

1) The initial overlay analysis based on counting co-occurring recipes resulted in 17 ROARs digitized in the RiverCOG region, 24 ROARs digitized in the SCCOG region, and 50 ROARs digitized in the CRCOG region.
2) Additional ROARs identification based only on critical facilities directly in FEMA flood zones was completed as follows:
    a. Selected only the areas in FEMA flood zones A, AE, VE
    b. Selected the critical facilities that are within the flood zones selected above
    c. Manually removed any that are already counted within an existing ROAR (for example, a ROAR for Stonington Borough already existed due to Step 1, so any Borough facilities in flood zones will be included in that ROAR and do not need to be separately counted.
    d. This identified 9 additional possibilities in SCCOG, 2 in RiverCOG, and 11 in CRCOG. One of the RiverCOG possibilities was removed, as the Town of Old Saybrook explained that the privately-owned facility has been operating under-capacity and there is some uncertainty about the facility's role in the region's future. For this reason, the Town would rather identify ROARs where critical facilities, infrastructure, assets, and/or resources are clustered.
    e. The list of possibilities in SCCOG was compared against the previous SCCOG assessment of critical facilities funded by the MRGP, and any facilities listed in the SCCOG assessment were removed from the list of possible ROARs (as these facilities already have resiliency actions outlined for them). One facility was included even though it was also listed in the SCCOG assessment, based on input from CIRCA staff and previous meetings with Norwich.
    f. 17 additional ROARs were digitized across the three COGs using this approach. Some of these ROARs contained more than one of the identified facilities.
3) Additional ROARs identification based on municipality priorities was completed as follows:
    a. Two ROARs were digitized to reflect specific access concerns raised by two municipalities after CIRCA presented the preliminary ROARs map. Both represent areas where the frequent flooding of a single road cuts off emergency vehicle access to a community area prioritized by the municipalities.
    b. One ROAR was digitized to reflect a specific flooding concern raised by the City of Groton.
    c. One ROAR was digitized to reflect a specific flooding concern on Lantern Hill Road from Whitford Brook, which was raised in multiple municipal meetings with Ledyard, Stonington, and North Stonington.
    d. One ROAR was digitized to reflect a DEEP Climate Resilience Fund project slated to commence soon in New Britain.

e. One ROAR was digitized to reflect a municipal concern related to flood vulnerability of the Plainville Water Pollution Control Facility.
f. Seven existing ROARs in the CRCOG region had their boundaries adjusted to reflect additional municipal concerns.

Other notes related to "counting" ROARs:

- There is some overlap in what is considered a critical facility and what is considered a regional asset. WWTPs are considered both. Bus routes (but not each bus stop) are counted as regional assets. Some sites also have multiple assets within the same site (ex: Avery Point campus). Asset and facility numbers should thus be taken as approximate. The final profile pages name the major assets/facilities in each ROAR rather than exact counts, due to the potential for confusion.
- Occasionally CIRCA staff used discretion about whether or not to count a recipe as present within a ROAR (such as when there is only a very small sliver of an overlapping polygon).

Total ROARs Identified:

At the end of these two GIS processes, there were 114 total ROARs identified (20 in RiverCOG, 31 in SCCOG, and 63 in CRCOG).

- 91 of the 114 were identified through the overlapping recipes approach (17 in the RiverCOG region, 24 in the SCCOG region, and 50 in the CRCOG region)
- 17 of the 114 were identified through the direct overlay of critical facilities and flood zone layers (1 in the RiverCOG region, 5 in the SCCOG region, and 11 in the CRCOG region)
- 6 of the 114 were identified due to specific municipal priorities (2 in the RiverCOG region, 2 in the SCCOG region, and 2 in the CRCOG region).

A full inventory of ROARs from Resilient Connecticut 2.0 can be found in Appendix E.

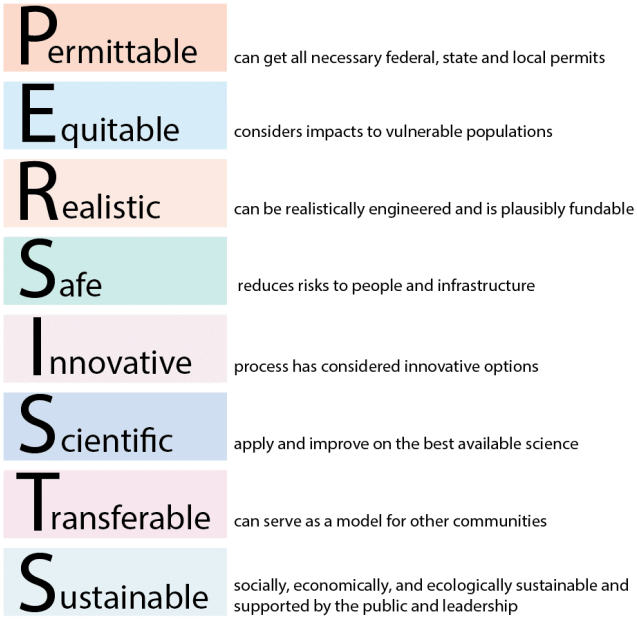
Of the 114 ROARS identified, 7 were advanced to Phase III for site-specific projects. See below for further details on how these selections were made. The ROARs that were not selected to advance may nonetheless yield fruitful Phase III projects in the future if additional funding becomes available.

Further ROARs Prioritization and Information-Sharing:

Municipal staff play a critical role in the Resilient Connecticut project pipeline from an identified need to a fully realized climate resiliency project. As a result, the high number of CRCOG ROARs was narrowed down at this point from 63 to 32, to include only those ROARs that contained an area of concern discussed during the local planning meetings with each CRCOG municipality, in order to focus attention on the projects most likely to receive municipal support. Multiple types of information resources were also developed for sharing with the municipalities and COGs to gauge the level of local and regional support for potential projects at the ROARs sites.

During the Phase I stage of the Resilient Connecticut 1.0 program, CIRCA developed a multi-criteria evaluative framework for potential climate resiliency projects known as PERSISTS, in collaboration with stakeholders during a Resilient Connecticut workshop in May 2019. Each ROAR identified through the preceding GIS analysis was then scored using the PERSISTS framework, which consists of the eight categories below:

- Permittable: Can get all necessary federal, state, and local permits
- Equitable: Considers impacts to vulnerable populations
- Realistic: Can be realistically engineered and is plausibly fundable
- Safe: Reduces risks to people and infrastructure
- Innovative: Process has considered innovative options
- Scientific: Applies and improves on the best available science
- Transferrable: Can serve as model for other communities
- Sustainable: Socially, economically, and ecologically sustainable and supported by the public and leadership



More information about the PERSISTS framework can be found on the Resilient Connecticut website: https://resilientconnecticut.uconn.edu/phase-i/

The ROARs were organized into multiple tiers based on the PERSISTS scoring, and lists of the ROARs sorted by PERSISTS scoring were used to develop informational sheets for presentation to the municipalities and COGs in the 2.0 region. These information sheets included a snapshot of recipe results for each listed ROAR as well as a map of all ROARs within a COG's region. Full size information sheets for all COGs in the 2.0 region can be found in Appendix E.

An individual profile page was also developed for each identified ROAR, providing a brief assessment of the flood vulnerability, heat vulnerability, and social vulnerability of each ROAR. The flood and heat vulnerability scores were based on the Climate Change Vulnerability Index (CCVI), with 5 possible scores corresponding to a classification system with 5 classes split by natural breaks. The social vulnerability scores were based on the Sensitive Population scores of the Connecticut Environmental Justice Screening Tool for the census tract containing each ROAR (or an average score if the ROAR crossed tract boundaries), with 5 possible scores corresponding to equal intervals of the percentile-based EJ Screen scores. Each profile page also included a close-up map, a list of notable critical facilities and/or regional assets within the ROAR, and a brief description of the climate-related concerns in the area. An example profile page is shown below. Full size profile pages for all identified ROARs in the 2.0 region can be found at https://resilientconnecticut.uconn.edu/roar-maps-index/.

Resilient Connecticut 2.0 Phase II

Regional Adaptation/Resilience Opportunity Areas

Name: Portland Critical Facilities
Location: Portland

Consideration	Characteristics of Area
Flood Vulnerability	● ● ● ○ ○
Heat Vulnerability	● ● ● ● ●
Social Vulnerability	● ● ● ○ ○

Three of Portland's critical facilities and associated parking lots -- the police department, the library, and the senior center -- experience shallow pluvial flooding after intense precipitation events. The senior center is the cooling center, warming center, and public food pantry for Portland. The area that floods is a topographic depression located on the east of Main Street and the south side of Waverly Avenue. Middletown Area Transit bus access is located on Main Street, Route 66, and High Street. Resiliency solutions for the town could have key co-benefits to advance cooling opportunities along the pedestrian accessways from transit lines to the senior center.

Portland Senior Center	Portland Care & Rehab Center
Portland Police Department	Portland Company 1 Station
Portland Public Library	Brownstone Intermediate School
Portland Town Hall	

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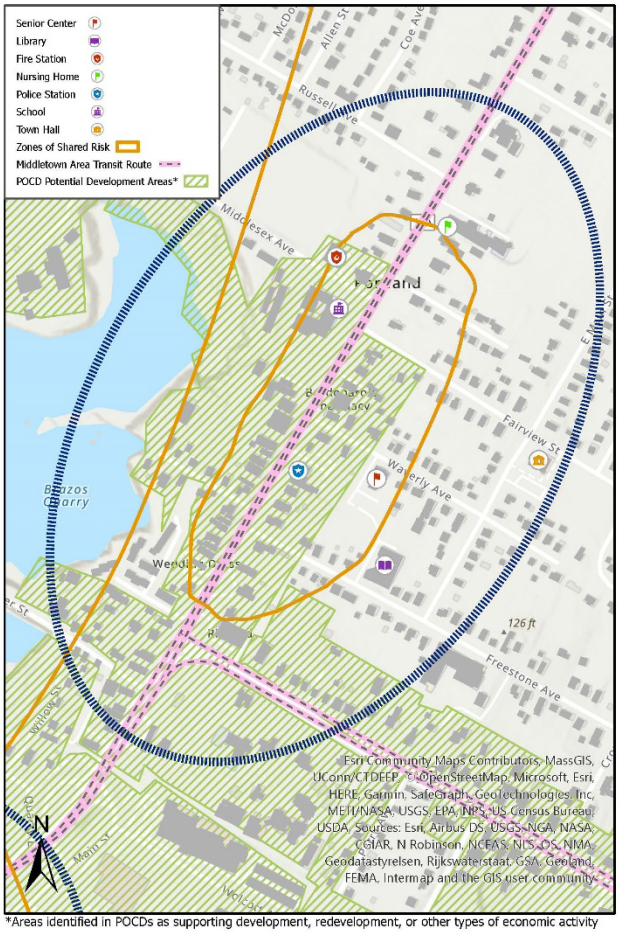

*Areas identified in POCDs as supporting development, redevelopment, or other types of economic activity