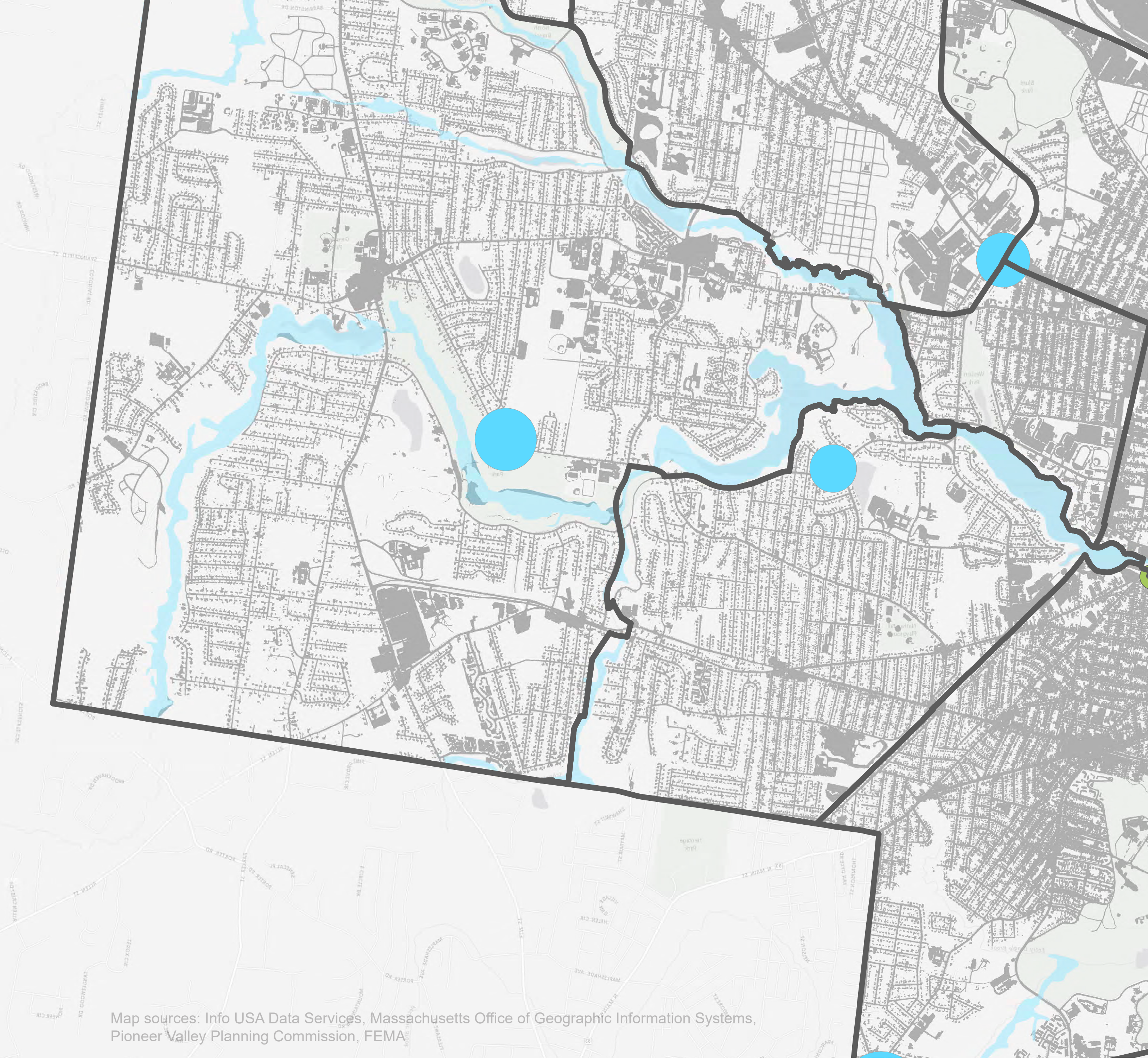
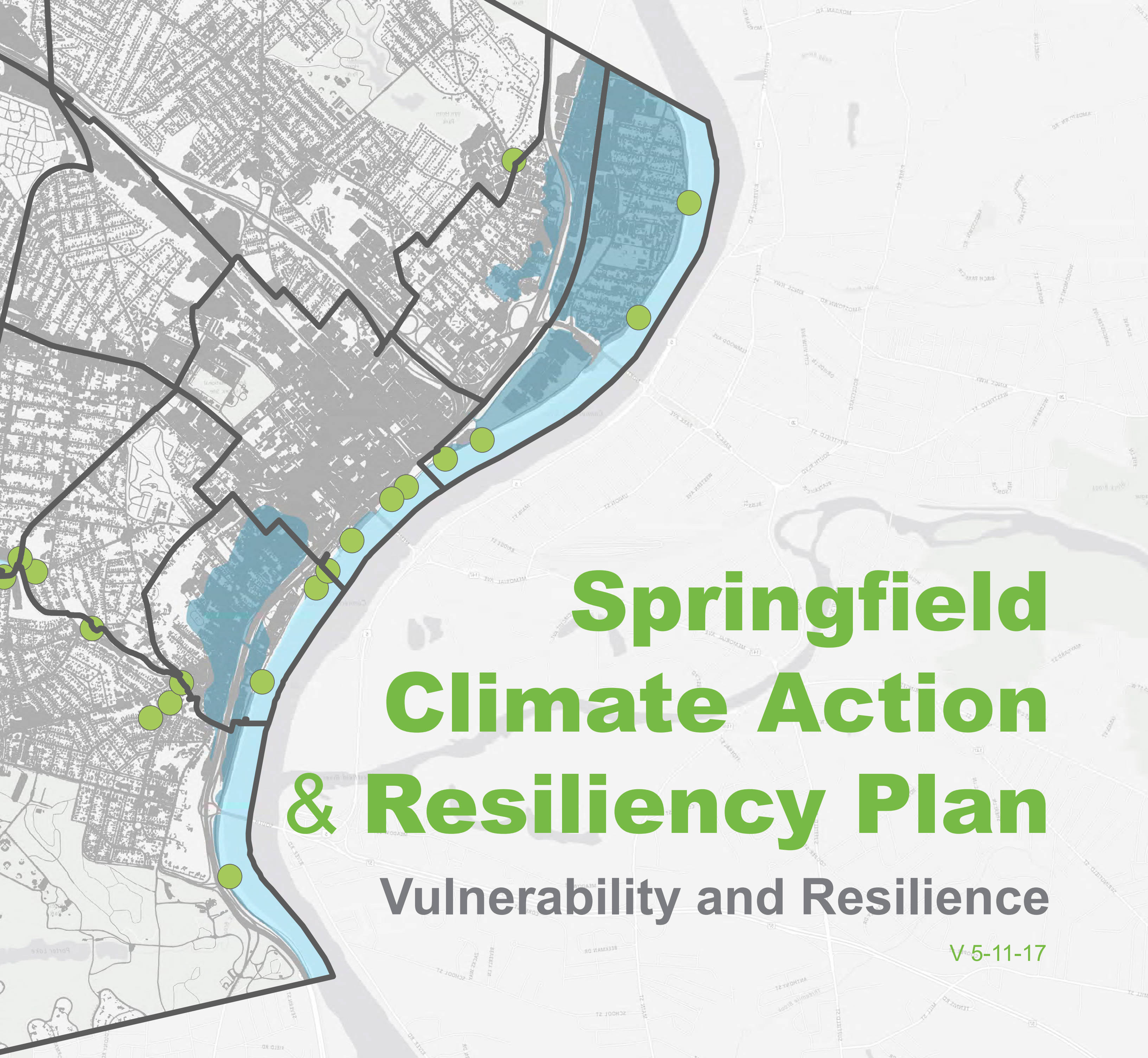


Map sources: Info USA Data Services, Massachusetts Office of Geographic Information Systems, Pioneer Valley Planning Commission, FEMA



Springfield Climate Action & Resiliency Plan

Vulnerability and Resilience

V 5-11-17

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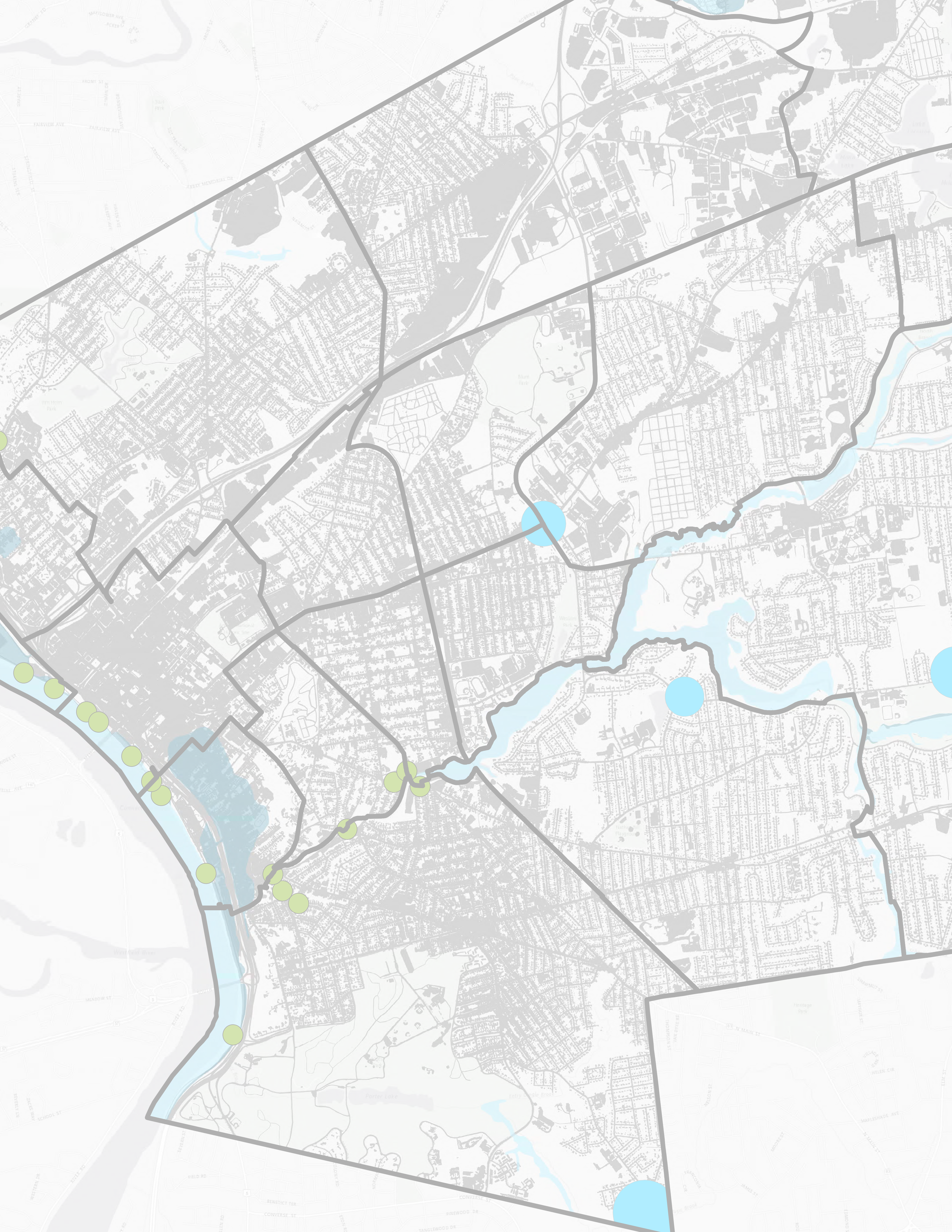

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GOALS
Resiliency for Springfield
1

The City of Springfield is developing its Climate Action and Resilience Plan (CARP) to implement the National Disaster Resilience Funding it received from HUD in 2017. This funding responds to the City's five presidentially-declared disasters in the period from 2011-2013, including a tornado, snow and ice storm, and floods. The City seeks to overcome remaining damage from these events and make itself more resilient to future events under a changing climate, while achieving important goals of climate justice, furthering other existing plans, and providing co-benefits from projects. One way to visualize this is presented in Figure 1, below.

This report begins by presenting the most recent science on climate projections for our region. We then identify the most vulnerable neighborhoods in Springfield as well as exploring assets that increase resilience to a disaster. Vulnerability here includes low social capacity from such issues as low income, limited English proficiency and car ownership, and other related demographic characteristics. It also includes higher geographic risk based on location in floodplains or with low tree canopy cover leading to more experience of heat and similar place-based issues. Resilience comes from the community, neighborhood or individual's assets such as being near to cooling centers and flood shelters, food stores, public transit and bike share, and similar services that enable safety and quick recovery in the event of a disaster. It concludes with recommendations on areas of risk that rise to the highest level of need.

While global and regional trends are challenging, it can be helpful to realize that their impacts can be reduced through good design, and careful infrastructure and services. Average temperature is increasing, but providing better tree canopy can counter that trend and reduce the experienced heat of residents. Rainfall may intensify, but designing floodable parkland that can absorb more sheet flow can mitigate that increase. In addition, there are very concrete current benefits to many actions that also help over the long term. Local reduction of greenhouse gas emissions will reduce particulates and bring better health now to the most vulnerable populations, while helping the long-term global climate trends. Infrastructure investments can bring good jobs to local residents and over time reduce energy expenditures by the city. While climate change will clearly create difficult situations, actions taken now can bring benefits and co-benefits that create a climate of hope.

Figure 1: Community safety and wellbeing is at the center of resiliency. Working from the outer ring, the diagram shows that hazards are the climate events that put communities at risk. Shown are coastal hazards; for Springfield key hazards are flooding and heat waves. Exposure refers to the things that are at risk from a hazard – the people, the homes, the infrastructure, the ecosystems. Transformational infrastructure, which can include social systems and regulations, provides the buffer or hazard protection that reduces impacts from a hazard on the exposed people, things, and places. But the best projects also achieve other community goals including greenhouse gas reductions (co-benefits), are equitable in both process and outcome, and are cost effective. Together these reduce overall community exposure and help achieve broader community goals. Graphic by Y. Abunnasr in Hamin et al (2017). 1

1 Hamin, E., et al (2017). Transformational Infrastructure for Coastal Resilience: The Adaptive Gradients Framework. A. Under review. University of Massachusetts.

CLIMATE PROJECTIONS 2

Summary

Springfield is projected to become warmer all year, with longer, hotter summers including many more days over 90 degrees and warmer, shorter winters; winter rainfall will likely increase. Rain that comes will occur in more intense storm events, raising flood risks. Heat and flooding will thus be Springfield's greatest climate challenges.

Background

The direction of our future climate will be largely determined by our individual and collective decisions. The extent of changes in temperature, precipitation, and extreme weather that may occur are greatly dependent on the efficacy of global actions to curb greenhouse gas (GHG) emissions. However, certain changes are already occurring and will continue in the future, due to the current levels of GHGs in the atmosphere. 2016, for instance, was the third year in a row to set a record for global average temperatures, with temperatures already averaging 2 degrees Fahrenheit warmer than the late 19th century average. [2] But increases and impacts are not evenly distributed across the globe -- average global warming will bring greater temperature increases in some areas, less in other areas of the globe. Here's what these changes may look like for Springfield, based largely on new regional projections.

Temperature and Extreme Heat

The most up-to-date regional data, released by A. Karmalkar and R. Bradley of the Northeast Climate Science Center (NECSC) in January 2017, shows that the Northeast region is warming at a much faster rate than most of the rest of the world and the rest of the contiguous US. By the time the globe reaches an average annual warming of 2°C (3.6°F) above pre-industrial levels (the warming limit set by the 2015 Paris Agreement) it's likely that the Northeast will have already reached an annual warming of 3°C (5.4°F). In fact, the region is projected to cross the 2°C threshold by 2040, roughly 20 years before the global average does. [3]

What does this mean in the near future? According to the NECSC, from 2020-2039 the Northeast will likely see increases of 2-2.8°C (3.6-5.04°F) in average summer temperatures, and 2.1-3.2°C (3.78-5.76°F) in winter temperatures. From the mid-2030s to 2055, it will likely experience increases of 2.5-3.5°C (4.5-6.3°F) in summer, and 2.9-4°C (5.22-7.2°F) in winter. On average, this will translate to longer, hotter summers, and shorter, warmer winters. [4]

Extreme heat is also projected to increase. The 2014 National Climate Assessment (NCA) predicts that between 2041-2070, the region is likely to have 30-40 days per year above 90°F—compared to 10-15 days

2 Northon, K. (Ed.). (2017, January 18). NASA, NOAA Data Show 2016 Warmest Year on Record Globally. Retrieved May 10, 2017, from https://www.nasa.gov/press-release/nasa-noaa-data-show-2016-warmest-year-on-record-globally

3 Karmalkar, A. V. and R. S. Bradley (2017). "Consequences of Global Warming of 1.5 ˚C and 2 ˚C for Regional Temperature and Precipitation Changes in the Contiguous United States." PLOS one 12(1).

4 ibid

per year historically (1971-2000). [5]These days are more likely to occur consecutively, and bring hotter overnight temperatures that give more vulnerable populations a hard time recovering from heat during the day; multiple hot nights in a row create particular health risk. [6] [7] These patterns will likely be more intense in Springfield due to the urban heat island effect (UHI), in which high concentrations of impervious surfaces and buildings trap and retain more heat than their greener, less urban surroundings.

Precipitation Patterns: Drought and Heavy Rains

Although changes in precipitation are more difficult to model than temperature increases, there is some agreement that overall, the Northeast will experience increased precipitation annually. However, it won't be evenly distributed: summers will likely be drier while winters become wetter, and more winter precipitation will fall as rain, rather than snow. The NECSC predicts that, compared to historical levels, from 2020-2039 the Northeast will likely receive roughly 0-5% more precipitation in summer, but 5-15% more in the winter. From 2036-2055, summer precipitation will be similar to the 2020-2039 period, but winter precipitation may increase 10-20% above historical levels.

Heavy rainfalls will also likely occur more often. In the Northeast, heavy rainfall events (defined by the NCA as "the heaviest 1% of all daily events from 1901 to 2012,") have already increased 71% in frequency from 1958-2012, and will likely continue increasing. However, the region may also experience a 10% increase in consecutive days without rain. [8] This uneven rainfall pattern could worsen the length and frequency of both floods and drought conditions surrounding Springfield, affecting infrastructure, agriculture and the local food economy.

Floods, Hurricanes, and Storms

The relationship between climate change and extreme weather is still more difficult to determine. Nevertheless, recent trends have been documented. The NCA estimates that the Northeast has experienced an increased flood magnitude of 6-12% between 1920-2008, and this trend is predicted to continue. [9] Floods will likely occur in spring, when soil moisture is higher and riverbanks are less able to absorb rising water.

Exact projections are unavailable for hurricanes and milder summer/winter storms. Similarly to flooding, however, hurricanes have been increasing in intensity, frequency, and duration since the 1980s and are expected to continue increasing—especially the strongest storms, Categories 4 and 5. Thunderstorms may also increase in frequency, and there is evidence that winter storms have already increased in frequency and intensity since 1950, and will likely continue doing so. [10]

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5 Easterling, W., et. al. (2014, May 6). Northeast Region. Retrieved March 18, 2017, from http://nca2014.globalchange.gov/report/regions/northeast

6 Stone, B. (2012). The City and the Coming Climate: Climate Change in the places we live. Cambridge, University of Cambridge Press.

7 Semenza, J. C., C. H. Rubin, K. H. Falter, J. D. Selanikio, W. D. Flanders, H. L. Howe, and J. L. Wilhelm (1996). "Heat-related deaths during the July 1995 heat wave in Chicago." New England Journal of Medicine 335(84-90).

8 Easterling, W., et. al. (2014, May 6). Northeast Region. Retrieved March 18, 2017, from http://nca2014.globalchange.gov/report/regions/northeast

9 Ibid.

10 Ibid.

METHOD FOR MAPPING VULNERABILITY IN SPRINGFIELD 3

Summary

By combining demographic data with geographic and infrastructural data on several maps, we can tell which neighborhoods would face the greatest exposure and difficulty in responding to climate hazards. Data is summarized into four maps: social vulnerability, geographic vulnerability, resilience, and critical infrastructure.

As recognized by the climate justice focus of the CARP, climatic and environmental hazards affect different populations unequally. Generally, communities of color with fewer socioeconomic resources and less access to services are more vulnerable to flooding, extreme heat, and other climate concerns. They may have less financial and other capacity to overcome hardship. Overall, the city is affected by vulnerabilities in infrastructure. Taking these issues together, this report maps three categories that impact vulnerability and resilience of residents themselves, and one that focuses on the larger institutional and infrastructural issues. We divided each data set listed below into five categories, from lowest vulnerability to highest vulnerability, then assigned each category an index of 1 - 5 for level of vulnerability for each factor. Then we summed the indices of all the layers to arrive at one index for each neighborhood, which we mapped to create a single measure of vulnerability for each neighborhood. The basic unit of analysis is the census block group, which is the smallest unit of data the US Census collects; a typical block group has between 600 and 3000 people in it. We used these factors:

1. Social vulnerability: challenges of income, race, age, and other abilities that pre-exist in a block group (a local neighborhood) and that compound the impacts of adverse events; stronger colors on the maps below indicate more social vulnerability.[11] Specifically, we map these factors and sum them up into our SoVu index:
    a. Median home value - an indicator of socioeconomic status that focuses on wealth rather than income; also describes housing quality and resilience to hazards[12]
    b. Percent of population under 5 years old and over 65 years old - young children and the elderly are less mobile during disasters, and have higher burdens of care for their family or healthcare institutions afterwards
    c. Percent female - due to wage inequalities and family care responsibilities, women can experience greater difficulty during recovery
    d. Race (as percent nonwhite) - these populations can experience cultural barriers in their access to care, resources, and political processes, and are often spatially concentrated in high-risk neighborhoods
    e. Percent Latino - Latino populations are categorized by ethnicity, rather than race, in the US Census--but they face similar barriers to those described above.

11 For social layers, we adapted the most important variables used by the Hazards and Vulnerability Research Institute (HVRI) at the University of South Carolina to construct the Social Vulnerability Index (SoVI). Based on research literature that identifies various socioeconomic aspects of a community that contribute to its vulnerability, the SoVI uses a statistical analysis to generate a vulnerability score for every county in the US. The Institute began creating this Index in 2000, and has since released four updated and refined iterations.

12 Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social Vulnerability to Environmental Hazards*. Social Science Quarterly, 84(2), 242-261. doi:10.1111/1540-6237.8402002

f. Percent speaking English as a second language with limited English proficiency - linguistic isolation creates similar barriers to those faced by populations of color
g. Percent in poverty - poorer populations have fewer financial resources to recover from a disaster, and can have less access to insurance and other social support
h. Percent housing units with no access to a vehicle - creates reduced mobility during a disaster, and causes greater dependence on public transportation which may be shut down or overcrowded during and after disasters
i. Percent of housing units occupied by renters - renters are often (but not exclusively) short-term residents or lacking in financial resources for homeownership; transience can imply less access to or information about recovery services, and fewer resources reduces recovery ability
j. Length of occupancy in neighborhood - populations with longer tenures in a neighborhood often enjoy stronger social support networks that can provide immediate assistance during and after disasters, and complement access to formal support structures; the opposite can be true for more recent residents.

2. Geographic vulnerability: location in a floodplain or far from parks or other open spaces that provide cooling or clean the air, and other related environmental conditions that increase risk. Note that floodplains are based on FEMA maps, and show history, not future. Under climate change areas that historically only had a 1% chance of flooding in any given year will be prone to flooding more often, and areas that previously rarely flooded will be more likely to flood in severe weather events. Specifically, we map these factors and sum them up into our Geographic Vulnerability index:
a. Areas vulnerable to regular flooding (current 100-year floodplain)
b. Areas vulnerable to flooding under severe events (current 500-year floodplain)
c. Tree canopy cover
d. Impervious surfaces
e. Localized flooding from rain events and CSO overflows (CSO: combined sewer overflows, in which heavy rain events overwhelm the sewer system, mixing stormwater and sewage and creating polluted water that gets sent directly into the river, and locally often backs-up around storm drains)

3. Measures of resilience: these are key indicators that would facilitate recovery in the event of an emergency. The ability to walk to a grocery store, to reach a bus stop, to get to a cooling center are the sorts of things measured here. Stronger colors on the map show areas with less measures of resiliency. Factors in our Resilience index:
a. Emergency shelters within a half mile walk
b. Urgent care centers within a half mile walk
c. Cooling centers within a half mile walk
d. Grocery stores within a half mile walk
e. Public transportation stations
f. Bike share stations

4. Critical infrastructure: these maps show the location of the most important infrastructure in the city, so that they can be evaluated for risk by geographic vulnerability and impact on residents and businesses. Factors in our critical infrastructure index:
a. Bridges and roads in the floodplains
b. Dams + culverts (in floodplains or noted by City engineers as problematic)
c. Emergency response: fire stations, police stations, hospitals, highway/public works departments
d. Power plants
e. City Hall

The individual indices (collected in Appendix A) provide important information; the sum of them provides a clear measure of which neighborhoods face multiple and overlapping risks. Mapping of the indices gives visual impact and communication. Places with concentrations of high-risk populations that coincide with flooding or heat risks may experience climate-related impacts and can then be prioritized for climate adaptation efforts going forward. Areas with few resiliency services can be easily identified and compared to those with the most social and geographic vulnerability.

For comparison going forward, we show here an aerial view of the city from Google Earth.

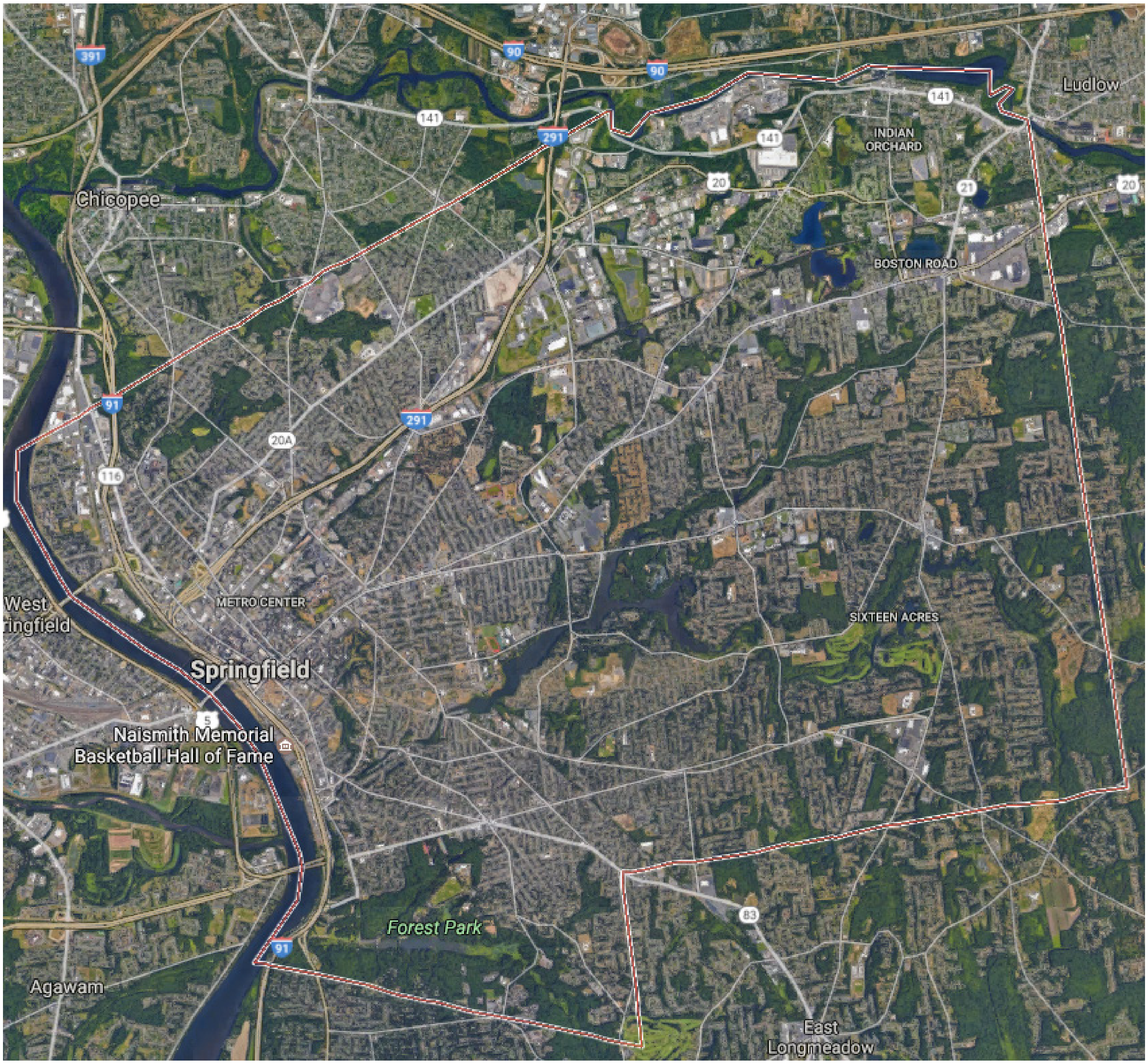

Figure 2: Springfield as seen from Google Earth

4 RESULTS AND ANALYSIS
Resiliency and Vulnerability in Springfield

Summary

The spatial intersection of social and geographic vulnerability, along with the presence of vital infrastructure for the City's emergency management system, strongly supports Springfield's emphasis on the Watershed Resilience Zone for its Climate Action and Resilience Plan (see Figure 3) and suggests the possible additional inclusion of Indian Orchard as an area of focus.

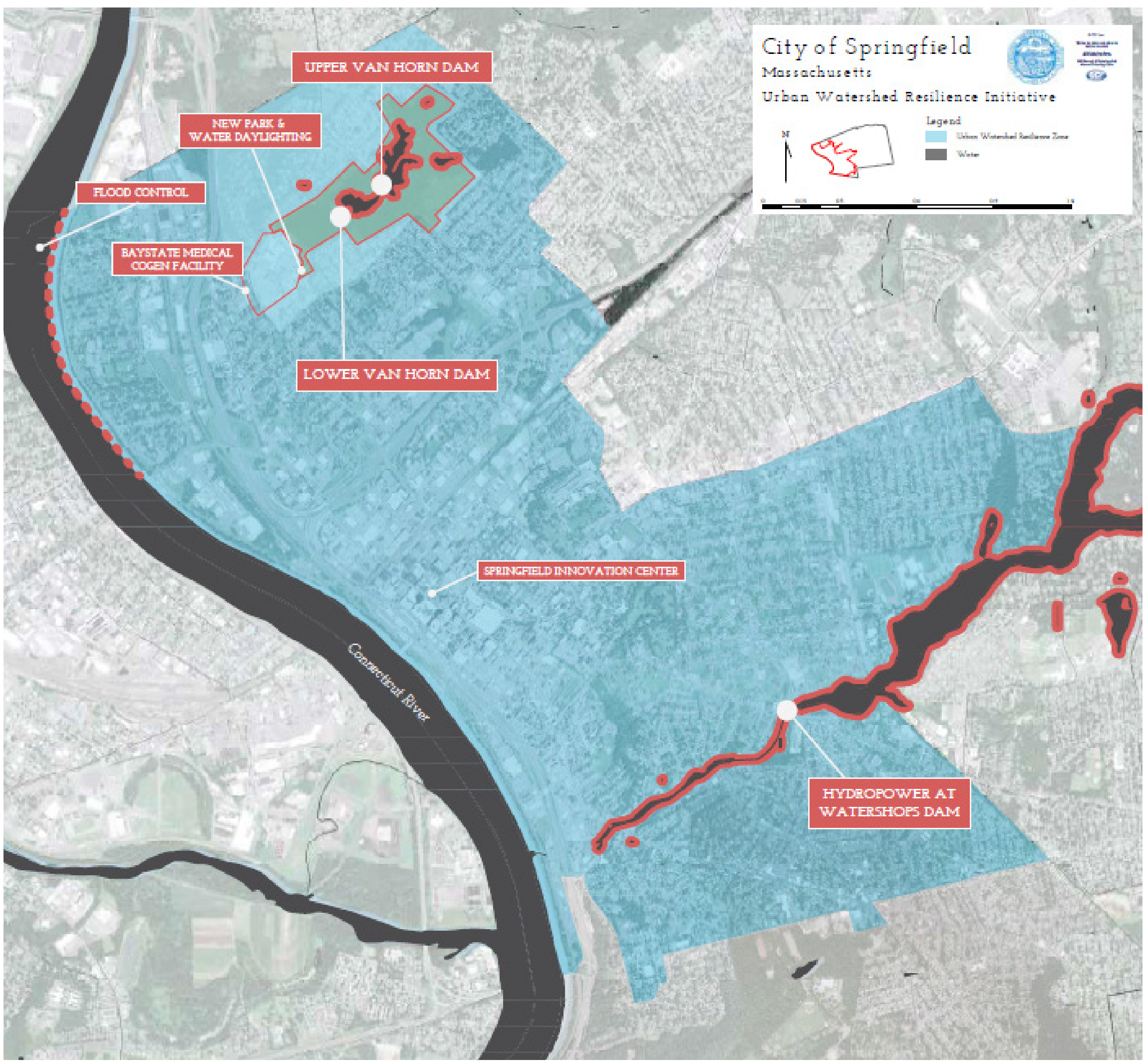

Figure 3. Springfield's Urban Watershed Resilience Zone, from NDRC application.

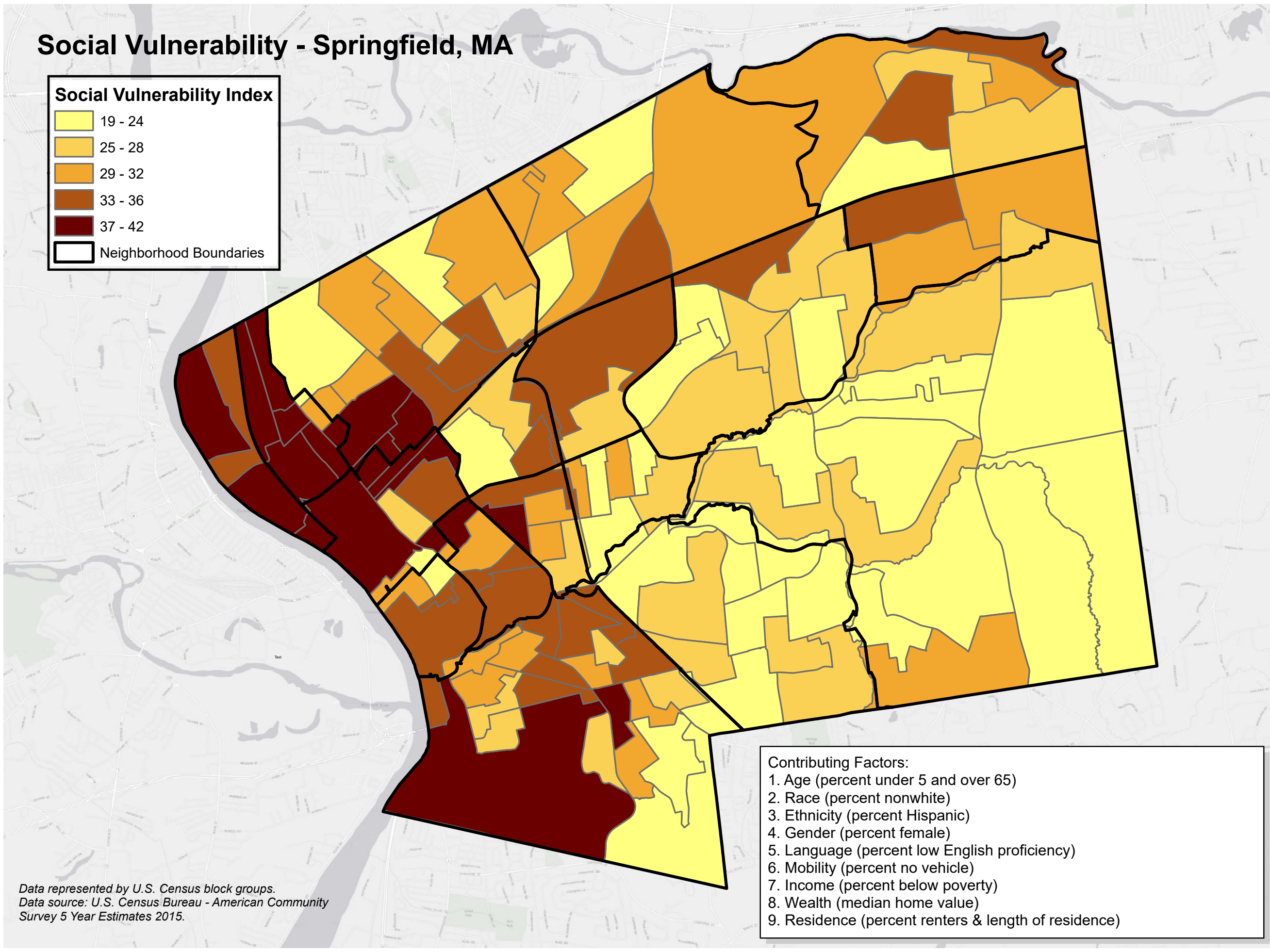

Figure 4. Springfield Social Vulnerability Index. More intense color indicates more risk for that census block group resulting from multiple contributing factors, listed in the box. Contributing Factors are evenly weighted in the index. The index score is meaningful as a comparison among the neighborhoods.

The Social Vulnerability Index map (see Fig. 4) shows a concentration of the highest-range vulnerability block groups within the Zone, in neighborhoods such as Memorial Square, Brightwood, Metro Center, and Old Hill. Forest Park has high income, but also a significant percentage of female-headed households. The Zone also contains a number of second highest-range vulnerability block groups in the South End, Six Corners, Bay, and Liberty Heights neighborhoods. The only neighborhood outside the Watershed Resilience Zone that indicated high vulnerability was Indian Orchard, in the northeast corner of Springfield. The individual social variables that contribute to the total high vulnerability can be explored in the maps that display each variable's distribution around the city, located in Appendix A.

One of the risk factors for health impact from heat waves is not having access to air conditioning. This data is not available in the census, unfortunately, but we have some estimates based on region and income. In Massachusetts in 2009, almost 80% of households had an air conditioner, often a window unit, but those units only used 1% of total energy expended in the state. [13] A recent national dataset from the US Energy Information Administration indicates that only 36% of households with annual incomes under $40,000 (and only 15% under $20,000) use air-conditioning equipment of any

13 US Dept. of Energy, Energy Information Administration. 2013. Household Energy Use in Massachusetts. Retrieved April 28, 2017, from https://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/ma.pdf

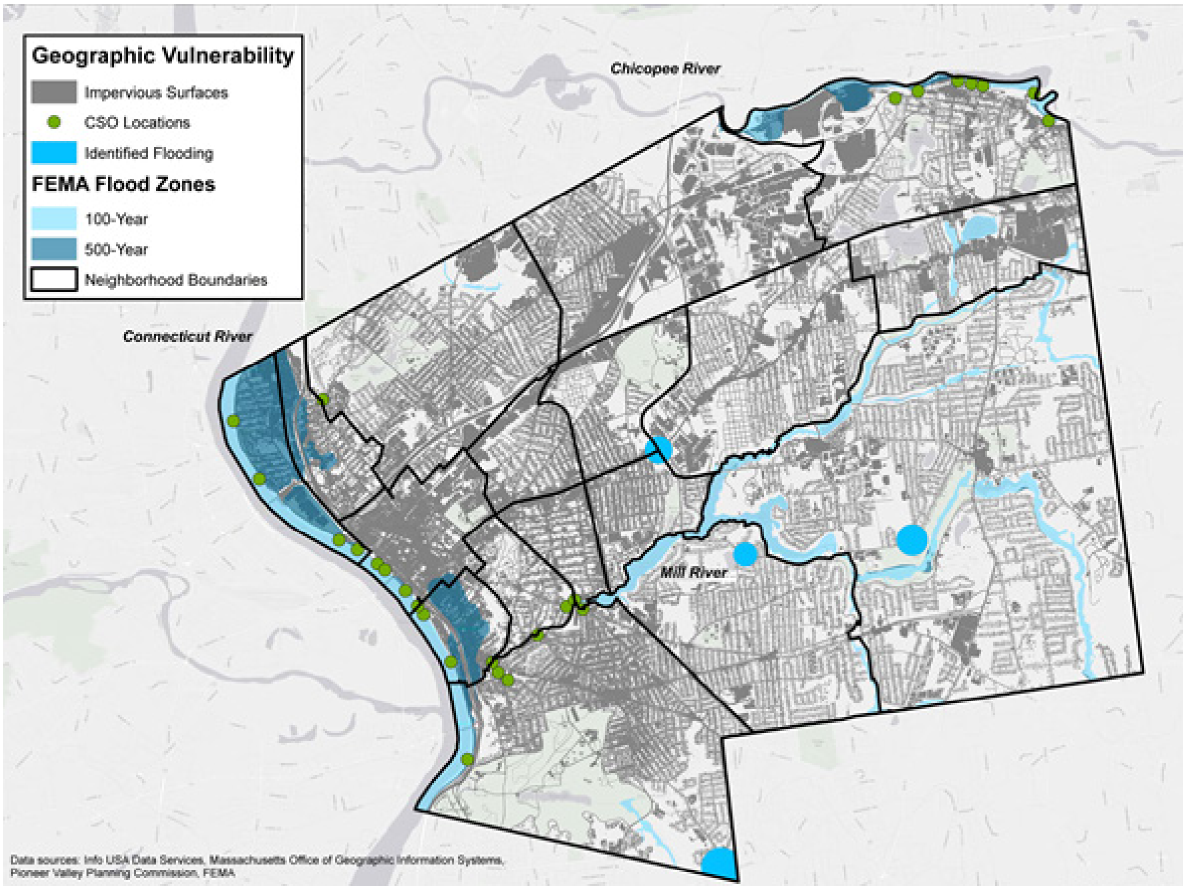

Figure 5. Geographic Vulnerability in Springfield.

kind. [14] As there are 30,846 households in Springfield that make less than $40,000 per year, it's possible that only 11,105 households have air-conditioning equipment.[15] This increases the vulnerability of lower-income households to rising heat levels.

The flood zones on Figure 5 are based on current FEMA maps, which do not include future flood projections and therefore do not address climate change. The same geographies in the city are expected to flood under climate change, they will just flood more often. Flooding under climate change is expected to more frequent and intense, so the designation of '100 year' and '500 year' should be understood as showing locations where fairly frequent flooding and rarer (but still likely) flooding should be expected.

Impervious surfaces are also shown in Figure 5, as grey. These are paved areas like parking lots and streets as well as built structures. Asphalt and similar materials intensify the effect of sunshine, absorbing sunshine during the day and reflecting it back out overnight. This exacerbates high temperatures well into the evening on a calm summer night. Impervious areas also prevent infiltration of rainwater, leading to more flow of water across sites and potential flooding.

Brightwood, South End, and to a lesser extent Memorial Square and Indian Orchard have the largest areas subject to flood risk. Properties along the city's rivers are also at risk of fairly frequent flooding under climate change. Areas containing CSO outfalls may also experience backup flooding during heavy rain events.

14 US Dept. of Energy, Energy Information Administration. 2017. 2015 Residential Energy Consumption Survey. Retrieved March 30, 2017, from https://www.eia.gov/consumption/residential/data/2015/#ac

15 United States Census Bureau. 2015. S1901: Income in the past 12 months. 2011 – 2015 American Community Survey. Retrieved March 25, 2017, from https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

Areas with low tree canopy are clearly visible on the map. Most cities have low canopy in core commercial areas such as Metro Center. Of more concern are more residential areas such as South End, Memorial Square, East Springfield and residential parts of Metro Center, which should be evaluated for potential tree planting on city property and/or help to residents for planting trees near their houses for cooling and air quality.

By cross-referencing the Social Vulnerability Index (Fig. 4) with the Geographic Vulnerability Map and Tree Canopy map (Figs. 5 and 6), it's apparent that the most socially vulnerable neighborhoods mentioned above (including Indian Orchard) are also the most geographically vulnerable. They have the highest exposure to flooding from both the Connecticut and Chicopee Rivers, and except for Indian Orchard, these neighborhoods also possess the lowest levels of tree canopy and the highest concentration of impervious surfaces. These neighborhoods are therefore both vulnerable to flooding through sheetflow (rainwater running over land) in severe storms and also have the least ability to mitigate intense urban heat. Combined sewer overflow events (CSOs) are also distributed exclusively along the waterfront areas of these neighborhoods, suggesting that high volumes of stormwater may be moving through them during intense rain events.

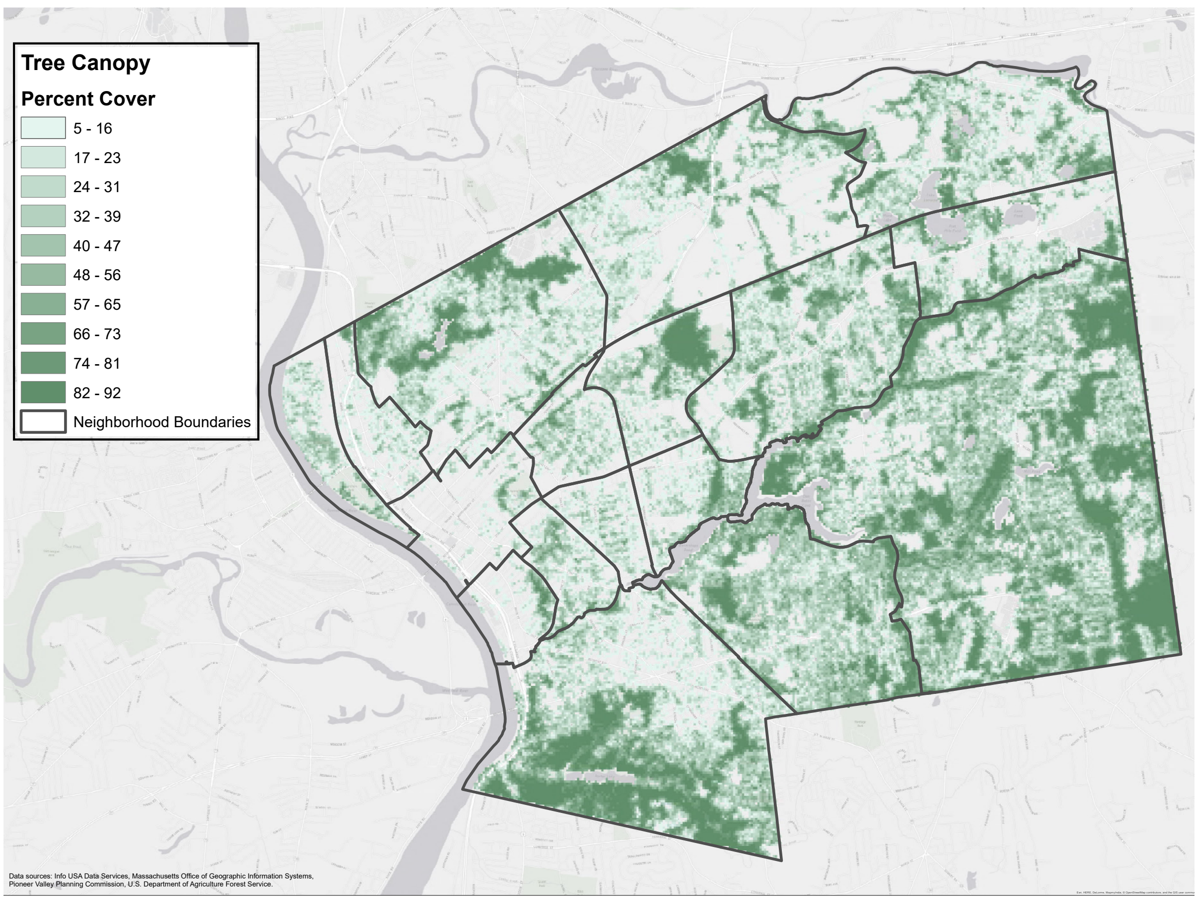

Figure 6. Tree canopy in Springfield. Trees reduce the temperatures around them, naturally providing a cooling effect to their immediate surroundings. They also trap particulates, improving air quality. Deciduous trees shading the west and northwest sides of a building are particularly helpful in cooling. [16]

16 Arbor Day Foundation. How to Plant Trees to Conserve Energy for Summer Shade. (n.d.). Retrieved April 18, 2017, from https://www.arborday.org/trees/climatechange/summershade.cfm

This area is also home to a high degree of critical infrastructure (see Fig. 7). Fire Station 10 is within the 500-year flood zone, and City Hall, Baystate Medical Center are both located immediately adjacent to that zone, meaning they may be more at-risk in the future as flooding becomes more frequent and more powerful. Additionally, Indian Orchard is home to MassPower, which is exposed to flood risk from the Chicopee River. Lastly, the Watershed Resilience Zone also hosts the Lower Van Horn Dam and the Watershops Pond Dam, both of which are noted to be in High Hazard condition. If these dams were to be breached during a flood event, impacts to the Zone could be severe.

Springfield's critical infrastructure for responding to a disaster, including fire stations, is distributed across the city. The Chicopee River puts many culverts into flood zones, reducing their utility in a big storm but also increasing their importance to stormwater management. Increasing permeability near these may be particularly helpful. The importance of steps planned to improve the disaster-readiness of Bay State Hospital are supported by these findings.

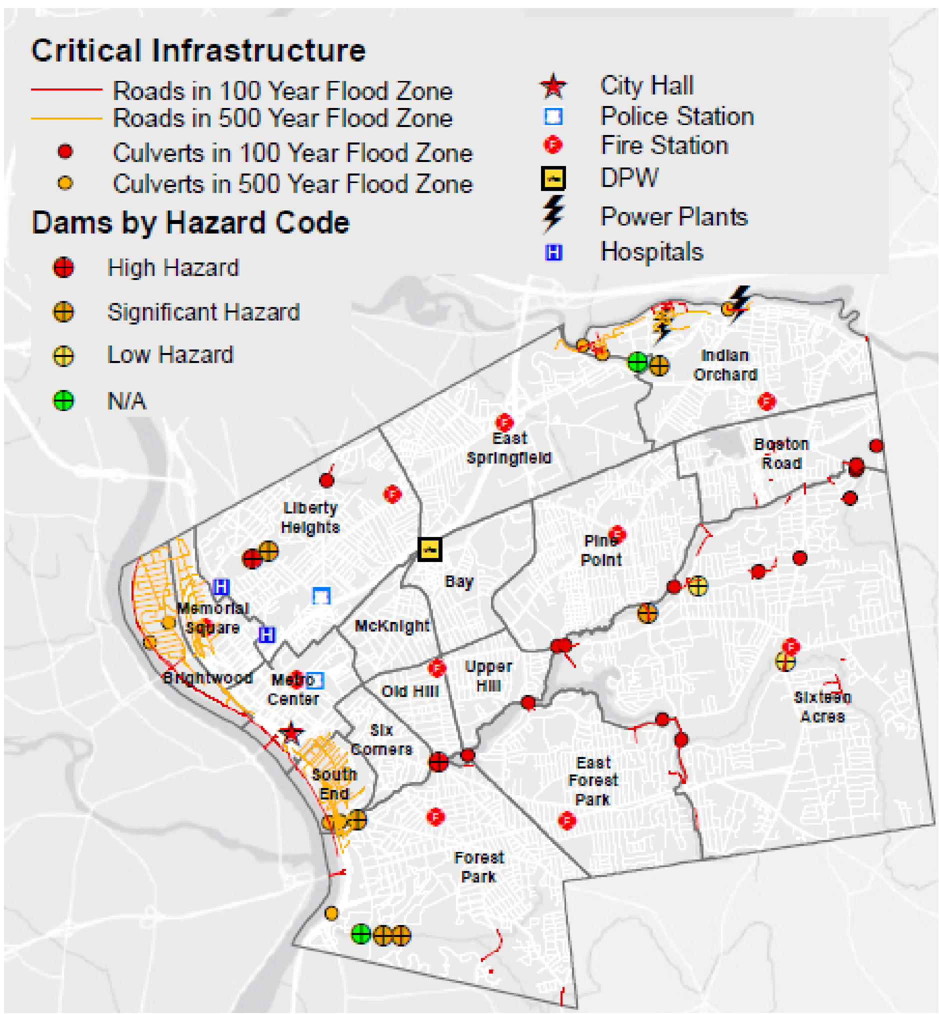

Figure 7. Critical Infrastructure.

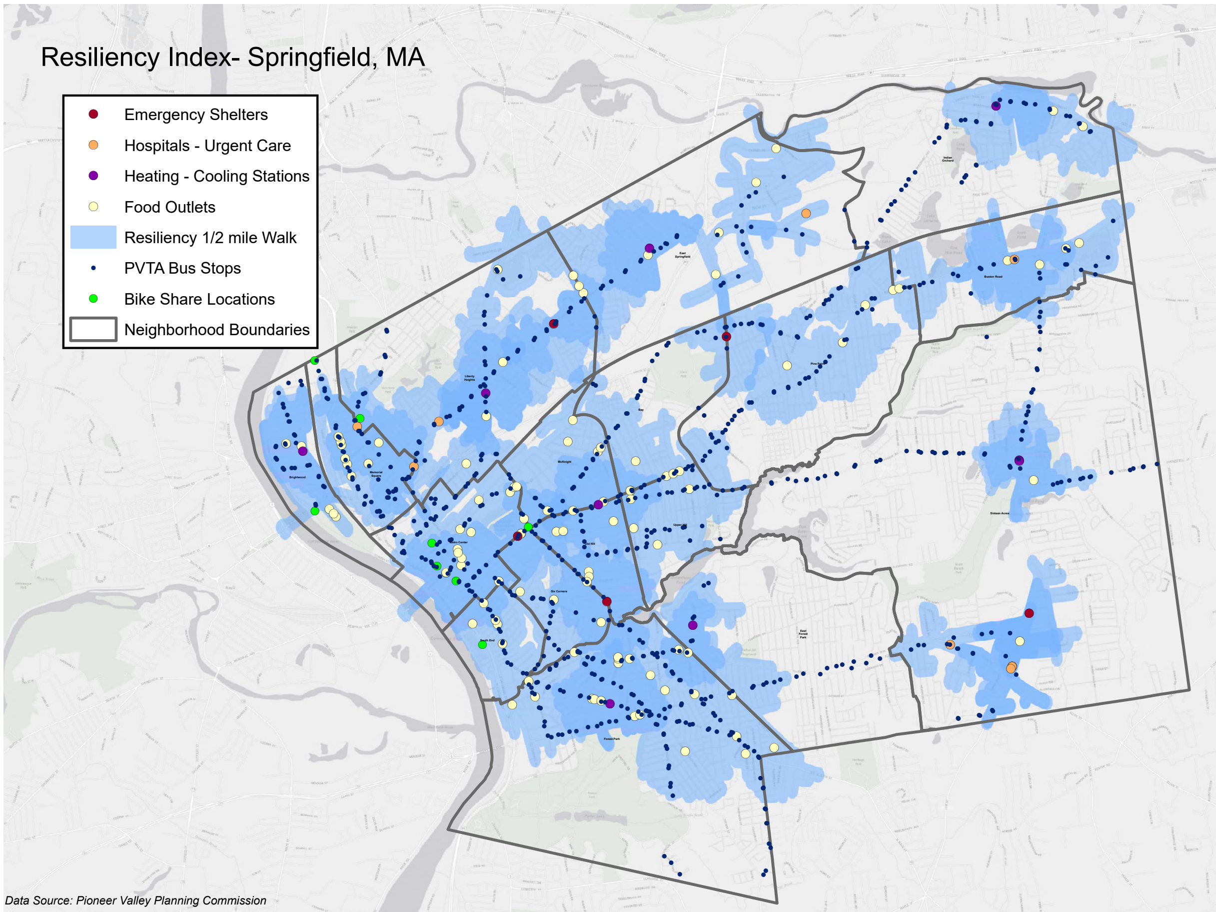

Figure 8. Resiliency Index -- Facilities and Services Useful in a Disaster.

The Resiliency Index map (see Fig. 8) reveals a cluster of heating/cooling centers, emergency shelters, and hospitals/urgent care centers in the most vulnerable neighborhoods, all of which are located along PVTA routes. This indicates the city's already substantial presence of facilities essential to recovery from climate hazards, which will provide a useful foundation for additional work under the CARP. Food outlets are also critical due to their role in providing food and water before, during, and after disasters. Specific types of outlets represented in this analysis include both full service grocery stores and neighborhood bodegas/convenience stores—the latter may or may not provide healthy food options that contribute to greater resilience, but they may help residents meet their daily needs. Ensuring food outlets remain open during disasters is essential to making sure they truly contribute to local resilience.

In the City's application to Phase 2 of the National Disaster Resilience Competition, Springfield pioneered the creation of the Urban Watershed Resilience Zone--an area encompassing the entire western portion of the city that represents higher concentrations of poverty and at-risk residents (see Fig 2 at start of section).

Our analysis affirms the focus on this Zone as the most vulnerable, highest priority region in Springfield, with likely the greatest exposure to climate hazards. This spatial intersection of social and geographic vulnerability, along with the presence of vital infrastructure for the City's emergency management system, strongly supports Springfield's emphasis on the Watershed Resilience Zone for its Climate Action and Resilience Plan and suggests the possible addition of Indian Orchard.

5 RECOMMENDATIONS

As the City of Springfield has detailed in their NDRC application, they have planned an integrated set of grey and green infrastructural solutions to climate risks in the Urban Watershed Resilience Zone. This approach includes efforts such as dam restoration and hardening alongside park enhancements for stormwater retention and upgrades to flood control systems. Our assessment supports this multifunctional design, as it will provide significant co-benefits in addition to climate adaptation. In the paragraphs below we suggest additional steps that can be taken to support both justice and resiliency.

Flooding is widely recognized as a significant and increasing risk under climate change. Heat waves are also an important public health concern, as they can directly result in illness and death among vulnerable populations. Addressing both of these will increase the resiliency of the City and its residents. Generally, the City has identified the most vulnerable neighborhoods for investment and provision of resiliency services, although our maps also encourage consideration of Indian Orchard as a neighborhood of concern.

There is an array of green and grey infrastructural solutions, as well as non-structural approaches (zoning, building codes, etc) to address the primary challenges to resilience.

Common green infrastructure solutions to flooding focus on allowing water into an area deemed "floodable" to allow natural infiltration and also the movement of rainwater across the ground (sheetflow). These kinds of approaches can include parks designed for water retention. When it is not wet, parks serve all their social functions and cool nearby homes. When significant rain occurs, the park is closed to use and simply allows water to infiltrate into the aquifer. This approach should also help with CSO problems, as it diverts water from sewer systems. Careful design is needed to get the right elevation and planting to ensure all these functions. Memorial Square, Brightwood, South End and Indian Orchard would appear to benefit from evaluation for this, due to proximity to flood zones and high concentrations of impervious surfaces.

Across the broader community, water infiltration can be encouraged through landscape elements such as bioswales (ditches with the right plantings that hold rainwater and let it infiltrate) or rain gardens (somewhat larger than swales but the same idea), which can help halt sheetflow and allow rains to infiltrate back into the groundwater before they flood nearby neighborhoods. Some cities are using vacant lots or sidelots for this purpose, or for small agricultural plots which also provide permeable surface. [17] Building bioswales/ rain gardens can be a job training and employment program for residents in neighborhoods looking to build skills. Maintenance of this sort of dispersed infrastructure can be challenging for city departments with strapped budgets, however. The proposed Tree Steward program in the National Disaster Resilience Competition application could be extended to include resident training maintenance of rain gardens.

Green infrastructure also offers many opportunities to reduce heat. Increasing the urban tree canopy by planting street trees can help provide a cooling effect to the buildings next to them, while reducing particulates in the air and sequestering carbon. This serves important justice roles when the trees are planted in denser, less wealthy neighborhoods that have fewer trees (South End, residential portions of Metro Center, Memorial Square, East Springfield). Green roofs (specially constructed rooftops designed to be covered in plants) reduce both ambient heat and the amount of energy needed to cool their specific building; these could be implemented specifically on public housing units to further achieve a justice focus. Where green roofs are infeasible, flat rooftops can be repainted white to lower the heat they retain; this can be particularly helpful in the densest parts of town, where extensive tree canopy is not spatially feasible or suited to the

17 Cuyahoga Land Bank. Side Yard Program. (n.d.). Retrieved April 29, 2017, from http://www.cuyahogalandbank.org/sideYard.php

urban scale (e.g. parts of Metro Center).
Common green infrastructural solutions to flooding and heat can be considered together, because they often create positive synergies that reinforce the effectiveness of each. For example, creating a waterfront park with a berm along the banks of a flood-prone river can reduce flood risk, while creating a multi-use running/bicycling trail atop the berm; and street trees with large pervious growing areas around them can reduce heat while also retaining stormwater during heavy rains. Additionally, community gardens can be considered a form of green infrastructure that reduces temperatures and infiltrates stormwater, while also building community and addressing local food insecurity, and they represent a useful opportunity to transform vacant lots.

Grey infrastructure refers to more traditional forms of engineering that usually aim to prevent flooding from entering areas used by people. This can take the form of dams and levees, retractable floodgates, or other constructed barriers against rising waters. Green and grey infrastructure can be thoughtfully combined--for instance, levees with foundations and water-facing walls of concrete can be topped with soil and grass to create a waterfront trail for walking, jogging and biking.

Non-structural solutions, policies like zoning and building codes as well as services, and social capacity building programs, can and should play an accompanying role. For instance, a proactive approach to building and zoning codes can encourage more environmentally conscious siting of new buildings so that residents benefit from cross-breezes. Codes can also require or provide incentives for putting mechanical systems on the second floor in case of floods – this is sometimes called 'floodable design'. Opening and publicizing cooling centers (air-conditioned public spaces) and establishing longer seasons for public pools can mitigate the effects of heat waves. "Pop-up pools," quickly constructed swimming facilities like the one built in Brooklyn Bridge Park[18] can expand pool capacities in existing parks without permanent commitments of land. Areas where there are more elderly without cars, such as Forest Park, may benefit from social capacity building, such as programs to be sure people know which neighbor to check on in case of flooding or a heat wave. To support seasonal employment, teams of residents can be trained and paid to visit the elderly across the city during heat episodes to make sure all is well. The City can provide helpful assistance to potential garden-starters by transferring City-owned property at low cost, or by purchasing privately-owned lots from willing owners.

Pricing and other subsidies have a role to play. Expanding enrollment in renter's insurance can be a key recovery mechanism for those who don't own homes. However,paying for such insurance is a challenge for low-income families who may move often. There may be ways to develop cooperatives to increase the likelihood of renters being able to afford such insurance. An incentive program that lowers the cost of air-conditioning for lower-income or aged individuals can increase resilience to higher temperatures. One innovative idea is to connect energy audits with the provision of very low cost air conditioners to low-income residents who complete whatever energy improvements are recommended for them; this would achieve the health benefits of air conditioning during extreme heat events, while minimizing the net energy used to do so. Incentives for tree planting on residential or small commercial lots may also be helpful.

Neighborhood-level solar microgrids, owned and operated by residents, have also been proposed in cities like New York.[19] These energy systems can provide redundant power in the event of outages, and allow residents to produce their own energy (and potentially sell surplus power back to the utility's grid, or to each other[20]). The cost of solar panels can be subsidized by the City as a means of further reducing reliance on fossil fuel-based electricity, in addition to the expansion of local hydropower.

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18 Brooklyn Bridge Park. Pop-Up Pool. (n.d.). Retrieved April 10, 2017, from http://www.brooklynbridgepark.org/attractions/pop-up-pool

19 WE ACT for Environmental Justice. Northern Manhattan Climate Action Plan. (n.d.). Retrieved March 5, 2017, from https://www.weact.org/campaigns/nmca/

20 Cardwell, D. 2017, March 13. Solar Experiment Lets Neighbors Trade Energy Among Themselves. Retrieved April 10, 2017, from https://www.nytimes.com/2017/03/13/business/energy-environment/brooklyn-solar-grid-energy-trading.html

Project Evaluation

As Springfield seeks to select which steps to take, a holistic evaluation that considers the level of risk reduction but also the social and justice benefits of any particular investment will be helpful. One way to evaluate any individual project or portfolio approach is to think of the project along various gradients, or scales, of achieving valued outcomes. These gradients or outcomes can be categorized in the following way:

Gradient Type	Gradient Definition
Hazard	Level of risk of a climate-related physical event. What is the relative likelihood of a local flood, local excess heat day potential, etc.?
Exposure	Ecological, social, and economic resources at risk from hazards. How many people, businesses, or other assets can the project help?
Social Capacity	Human strengths, attributes, and resources that reduce impacts, mitigate harm, and ensure future resilience. Does the project increase social capacity? Does the city have the capacity to do that project?
Co-Benefits	Incorporation of locally or globally desired current goals, such as jobs, ecosystem services, and social benefits into adaptation strategy. Does the project bring benefits to residents in that neighborhood?
Efficiency	Congruity between project costs and available funds, positive cost-benefit outcomes. Does the project offer good value for money invested?
Effectiveness	Project success over time, identified through monitoring and assessment and addressing changing climate. Will the project still work well under a changing climate?
Participatory Process	Community involvement and public transparency in planning, design, and implementation. Was the community involved?
Equitable Outcomes	Distribution of costs, benefits, and impacts achieves justice goals. Does the project provide a just distribution of costs and benefits?

Figure 9: Adaptive Gradients for Resilient Infrastructure.[21]

21 Hamin, E., et al (2017). Transformational Infrastructure for Coastal Resilience: The Adaptive Gradients Framework. Manuscript under review. University of Massachusetts.

If helpful, these gradients can be scored and placed on a figure that enables comparison across projects. One way to visualize this is shown below, in Figure 10.

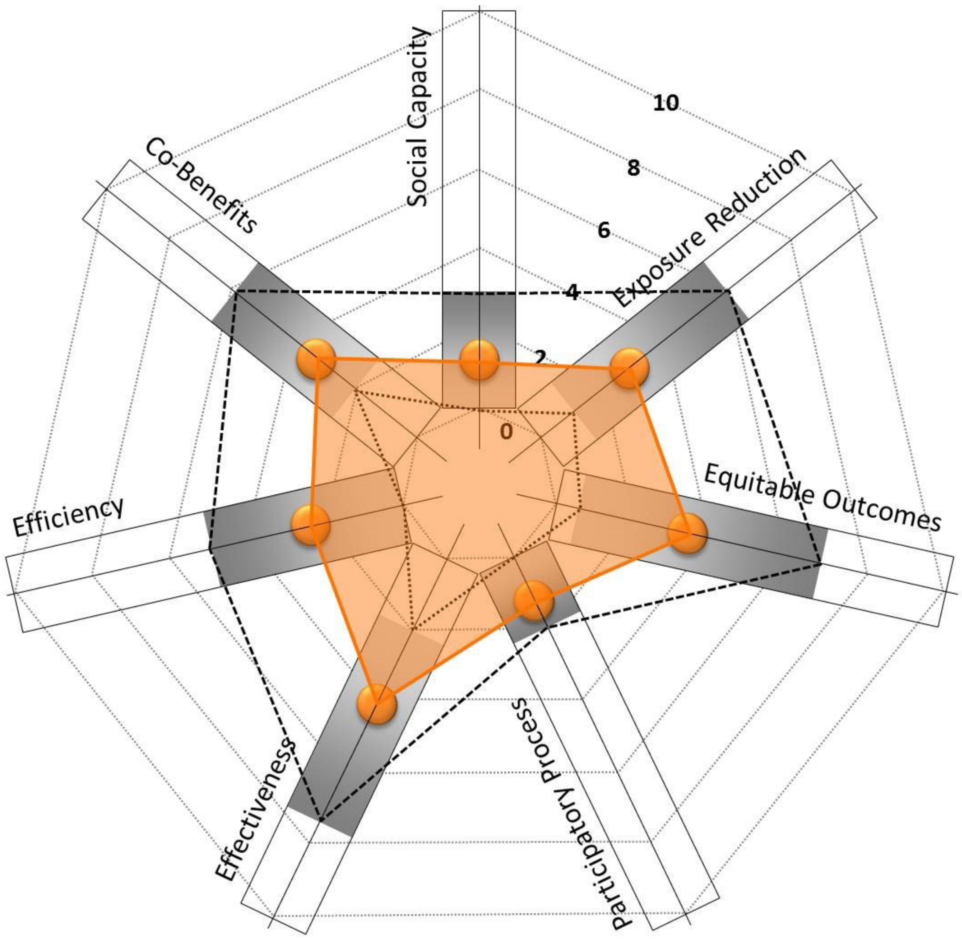

Figure 10: Diagram of Gradients, with bright color showing estimated value and the inner and outer lines showing minimum and maximum estimated value, based on a range of potential outcomes from a project.

Conclusion

Adapting to climate change is well within the abilities of Springfield and its residents, especially when informed by awareness of which residents face highest risk. Building the results of this vulnerability assessment into the climate planning process should help direct resources and outreach to the neighborhoods that need it most. The recommendations included here can accompany the efforts already proposed by the City, and stimulate further creative approaches to building Springfield's resilience.

Appendix A: Social Vulnerability Variables

Social Vulnerability Index- Springfield, MA

As recognized by the climate justice focus of the CARP, climatic and environmental hazards affect different populations unequally. Generally, communities of color and those with fewer socioeconomic resources and less access to services are more vulnerable to flooding, extreme heat, and other climate concerns, as they may have less capacity to overcome hardship.

This map examines the various social factors that contribute to vulnerability and how they are dispersed geographically in Springfield, MA.