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MEMORANDUM

TO:	Laurel Schwab, AICP, Senior Environmental Planner; Matthew Shuman, PE, City Engineer City of Watertown, Massachusetts
FROM:	Steve Roy; Rupsa Roy, PhD.; Caroline Passalacqua, EIT; Weston & Sampson
DATE:	December 20, 2021
SUBJECT:	Equity-Based Community Greening Program Task 1.5 – Urban Heat Island Assessment

Weston & Sampson Engineers, Inc. (Weston & Sampson) is pleased to present this memorandum to the City of Watertown, Massachusetts summarizing the results of the Urban Heat Island (UHI) assessment performed under Task 1.5 of the Equity-Based Community Greening Program.

1 Introduction

Watertown is densely urbanized, leaving some residents disproportionately subject to the impact of climate change. As the City has high concentrations of impervious surfaces, the heat island effect results in urban air temperatures warmer than surrounding suburban areas. The increase in annual temperatures, heat waves caused by climate change, and urban heat island effect can degrade public health, welfare, and living conditions in the City.

This memo reports the details of Urban Heat Island (UHI) modeling, measurement, and mapping along with an assessment of the capacity of green infrastructure and more vegetation to mitigate the UHI effect. As part of Task 1.3, Identify and Gather Existing Data, of the Community Greening Program, ambient air UHI maps for Watertown were developed using readily available land surface temperature data for summer days with corresponding measurements of ambient air temperature at known weather stations from the National Climatic Data Center (NCDC) website. A relationship was established by linear regression analysis between the land surface temperature and ambient air temperature in the City. The relationship was then used to show the variability of ambient air temperature through the City, focusing on a highly developed area and a park area. Ambient air temperature is a relevant indicator for extreme heat as it relates to social vulnerability and public health impacts.

The heat island analysis includes an analysis of temperature under existing and proposed conditions in the highly developed area and park area by incorporating changes in land cover, such as increasing tree canopy and decreasing impervious cover. Modeled temperature results that show spatial variability in the UHI impacts across the City are presented spatially in temperature maps and the cooling relationships are summarized graphically. A discussion of UHI mitigation strategies that may assist Watertown in lowering the ambient air temperature priority areas is also included.

2 Urban Heat Island Analysis

Urban heat island maps were developed using land surface temperature data along with ambient air temperature to compare temperature felt in the highly developed area and the park area. The land surface data was then converted into ambient air temperature to develop the UHI maps for future climate scenarios.

2.1 Source of Data and Methods

2.1.1 Determining Project Areas

The UHI maps were developed for a highly developed area and a park area in accordance with the scope of work under Task 1.5. To create consistency with other sources being used for the overall data collection task of the Community Greening Project, census block group boundaries were used to divide the City into neighborhood-sized areas. These areas were intersected with the 2016 Land Use/Land Cover data provided by MassGIS, and percent impervious and pervious coverage were calculated for each block group. The three areas with the highest percentage of impervious coverage were considered as options for the developed area, and the three with the highest percent pervious coverage were considered for the park area. From those options, the blocks that were most similar in size were chosen to be the UHI areas. The highly developed area and park area are shown in Figure 1.

Figure 1: UHI Analysis Areas

2.1.2 Calculating Urban Heat Island

The land surface temperature data used was provided by the Metropolitan Area Planning Council (MAPC). The Landsat imagery was collected on August 30th, 2010 at 10:30 AM. Land surface temperature is usually warmer than the corresponding ambient air temperature, which is felt by humans and is measured at the local weather stations. Ambient air temperature bearing the same date and time stamp when the Landsat image was captured was downloaded from the weather stations that are included within the spatial extent of the Landsat image. For each weather station, the land surface temperature data was noted, along with the ambient air temperature. A regression analysis was developed from the correlations between land surface temperature, and ambient air temperature in the study area. The regression equation was then used to estimate the calculated ambient air temperature variability from the land surface temperature for the day corresponding to the acquired Landsat data. Scale factors were determined between the future ambient air temperatures of 90°F, 95°F, and 100°F and the average of the calculated ambient air temperature at the time of the acquired Landsat data. These respective scale factors were then applied to estimate urban heat island effects on a 90°, 95°, and 100° F days respectively to determine extreme heat variability within the City under these representative scenarios. Estimated UHI considering ambient air temperature variability corresponding to a Citywide average temperature of 90°F, 95°F, and 100° F under current land cover conditions are shown in Figure 2.

2.2 Results

The analysis shows the effect of UHI effect is more pronounced in the highly urbanized area, which has less tree canopy and more buildings than the park area. These areas are usually 2°-4° F warmer than the average ambient air temperature in the City. On the other hand, green areas with garden, parks, and lakes are usually cooler than the average. Assuming a day with 60% relative humidity through the City, the heat is felt more in the highly urbanized area.

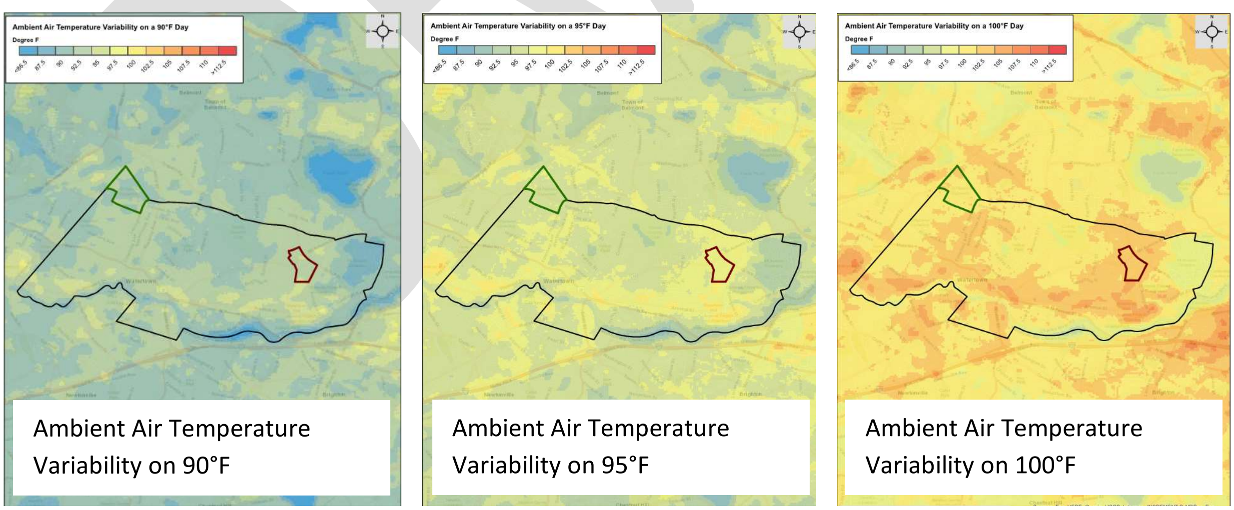


Figure 2. Ambient Air Temperature Variability on Citywide Scale on 90°, 95°, and 100° F days (Left to Right).

3 Strategies for Mitigating Urban Heat

Effects of extreme heat are widespread, and the demand for cooling will increase during extreme hot days. The Massachusetts Climate Adaptation Report (2011) indicates the potential for substantial increases in household energy consumption as the average annual temperature increases[1]. An increase in demand for electricity will either result in failure of electric grids or the need for plants to generate additional electricity to meet peak demands, both of which create negative impacts for the environment and public health. Grid failure will lead to more frequent power outages, disrupting communications and transportation services. Additional generation of electricity will increase greenhouse gas emissions from power plants and result in higher ozone levels in the atmosphere (Rosenthal et al., 2008)[2]. Hotter days will also pose hazards to outdoor workers..

Mitigating urban heat island effect is critical to avoid additional strain on the power grid or increasing emissions. This section discusses heat mitigation strategies and their potential benefits and co-benefits in the urban environment. UHI mitigation focuses on increasing urban tree canopy and decreasing impervious surfaces.

3.1 UHI Analysis Under Existing and Proposed Land Cover

This section discusses how change in type of land cover can impact the ambient air temperature variability in Watertown. Existing tree canopies and impervious surface areas were chosen for the analysis. Cooling relationships were developed between UHI and canopy cover, and UHI and impervious surface areas by intersecting datasets representing these land cover conditions with the UHI temperature grid in GIS. This analysis was performed for the project areas discussed in Section 2.1.1, not for the entire City, in accordance with the scope of work for this task.

3.1.1 Data Sources and Methods to Develop Cooling Relationships

The land cover datasets are sourced from National Land Cover Database 2016 (NLCD2016). The ambient air temperature was plotted against the percentage of tree canopy and percent impervious area under exiting conditions at the same grid resolutions as the Landsat data (30m x 30m). Linear regressions were developed on a citywide scale for each 30-meter grid in the UHI model and are presented below.

For each grid, the following calculations were performed for both tree canopy and impervious surface areas under existing conditions and proposed conditions.

$$\%\ \text{existing land cover} = \frac{\mathit{Area\ of\ the\ grid\ covered\ by\ land\ cover}}{\mathit{Total\ area\ of\ the\ grid}\ (30\ \mathit{meter})^2} * 100$$

[1] https://www.mass.gov/service-details/2011-massachusetts-climate-change-adaptation-report

[2] Rosenthal, Joyce Klein, Rob Crauderueff, and Majora Carter. 2008. Urban Heat Island Mitigation Can Improve New York City's Environment: Research on the Impacts of Mitigation Strategies on the Urban Environment. Sustainable South Bronx Working Paper.

Percent existing land cover was then plotted against ambient air temperature from UHI models to develop cooling relationships for both canopy cover and impervious surface areas. Correlation coefficient was calculated through linear regression. The same relationship is then applied to change in canopy cover and change in impervious surface areas under proposed conditions to estimate the change in temperature due to the change in the percent land cover under proposed conditions.

The change in estimated ambient air temperature ($\Delta T_{ambient}$) was then estimated using the equation below

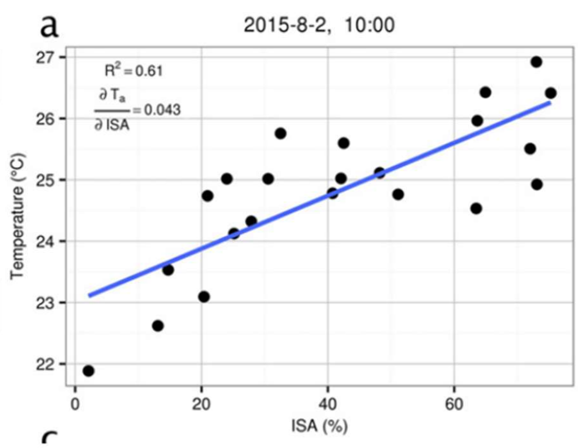
$$= (\%\, proposed\ land\ cover - \%\, existng\ land\ cover) * (cooling\ correlation\ coefficient)$$

The estimated temperature under proposed conditions was then calculated by adding the change in estimated ambient air temperature with the estimated ambient air temperature under existing conditions.

3.1.2 Cooling Relationships

The following relationships, developed by Wang et al. (2017), were used to estimate cooling benefits due to increase in canopy and decrease in impervious surfaces[3]. The relationships are presented graphically in Figure 3.

- 10% increase of tree canopy area could yield approximately 0.4°F of cooling
- 10% decrease in impervious area could yield approximately 0.4°F of cooling



Source: Wang et al (2017)

Figure 3: Ambient air and impervious area correlation

[3] *Wang, J.A., L.R. Hutyra, D. Li, and M.A. Friedl, 2017: Gradients of Atmospheric Temperature and Humidity Controlled by Local Urban Land-Use Intensity in Boston. Journal of Applied Meteorology and Climatology, 56, ,doi: 0.1175/JAMC-D-16-0325.1*

The following figures show the cooling benefits using general mitigation strategies such as increased tree canopy and decreased impervious surfaces for the analysis areas on a 95°F day. The analyses quantified the cooling benefits under reduction of impervious surfaces by 10% in both the highly urbanized area and the park area. While Citywide reduction can yield overall cooling benefits, the targeted reduction of impervious surface can yield significant cooling benefits in those localized areas. Similarly, an increase in tree canopy by 10% can yield overall cooling benefits, whereas the targeted increase of canopy in areas with lower tree canopy coverage can yield significant cooling benefits in those localized areas. A threshold of 0.5 °F temperature change was chosen to represent a significant temperature change. This threshold was chosen primarily for temperature mapping purposes and to partially account for the limitations of the temperature cooling relationships.

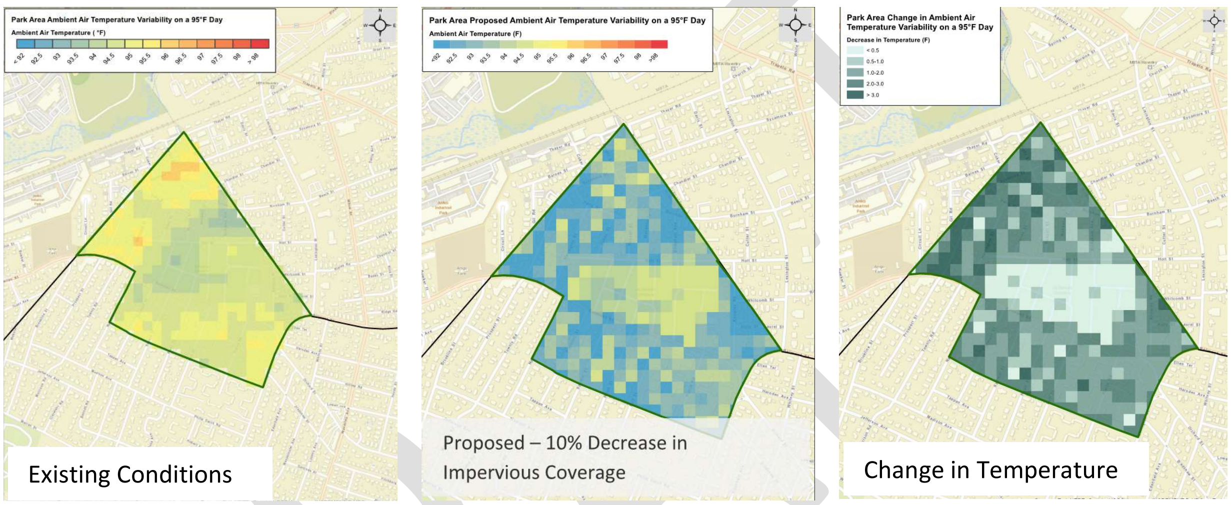


Figure 4: Change in ambient air temperature due to impervious surface reduction in Park Area

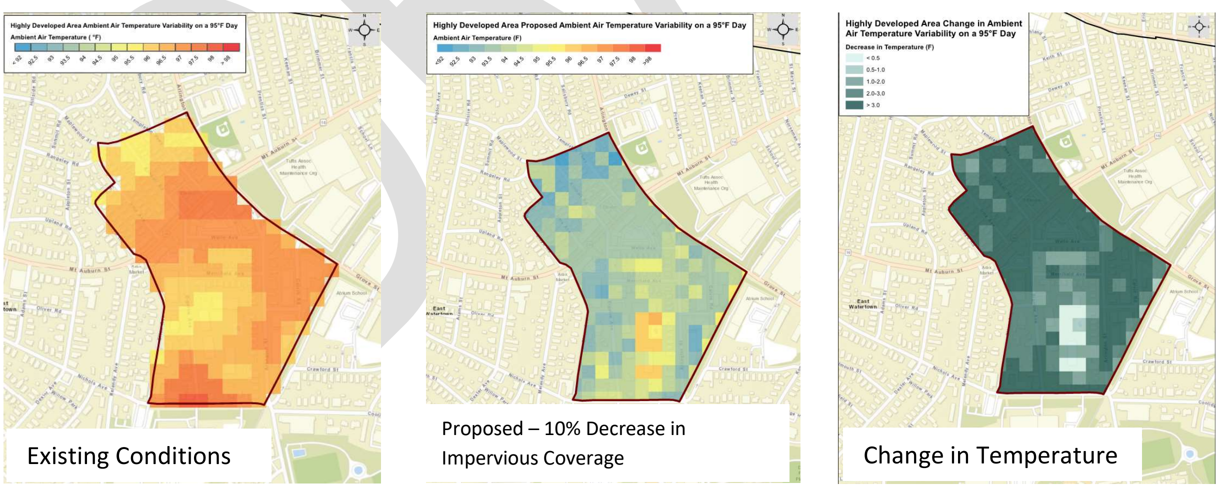


Figure 5: Change in ambient air temperature due to impervious surface reduction in Highly Developed Area

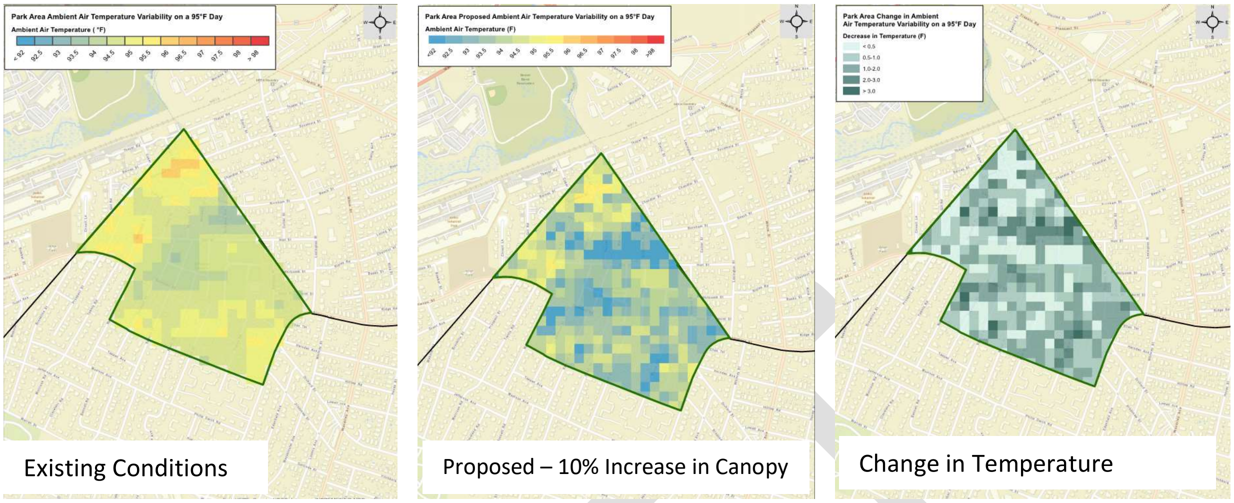


Figure 6: Change in ambient air temperature due to increase in tree canopy in Park Area

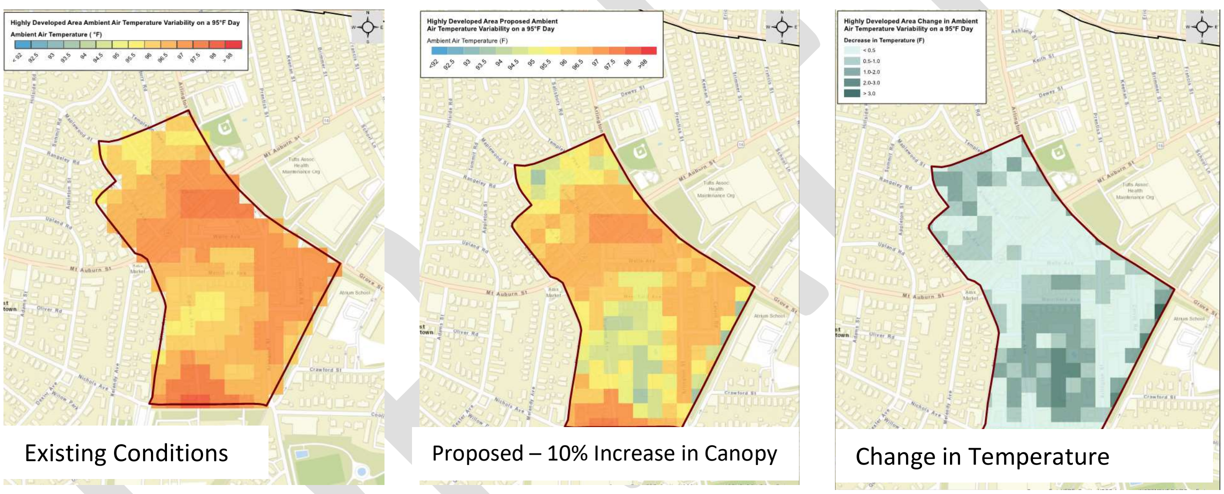


Figure 7: Change in ambient air temperature due to increase in tree canopy in Highly Developed Area

Enlargements of Figures 2-7, as well as maps at the City-boundary scale comparing the results for both project areas, are included in Attachment A.

3.2 Cooling Relationships with Light Colored Surfaces

Studies show that painting dark colored impervious surfaces with lighter colored paints or replacing darker surfaces with lighter color paved materials helps reduce the ambient air temperature. A Lawrence Berkely National Laboratory study shows that increasing the amount of materials with a higher surface reflectivity by 10-35% can reduce ambient air temperature by up to 1°F (Pomerantz et al., 2000)[4]. The Resilient Cambridge Handbook recommends that the surface reflectance index for building roofs should be at least 82 for rooftops with less than 10° slope, at least 39 for rooftops

[4] *Pomerantz, M., B. Pon, H. Akbari, and S. - C. Chang. 2000b. "The Effect of Pavement Temperatures on Air Temperatures in Large Cities." Lawrence Berkeley National Laboratory Report No. LBNL-43442, Berkeley, CA*

with more than 10° slope, and 0.33 for non-roof surfaces to meet heat protection guidelines[5]. Green roofs are encouraged where structurally possible. Leadership in Energy and Environmental Design (LEED) certification is recommended for existing buildings.

3.3 Implementation Strategies

This section discusses the implementation of different UHI mitigation strategies. The analysis conducted in Section 3.1 indicates that the combined effects of increased tree canopy and decreased impervious surfaces will mitigate the UHI effect significantly, especially in areas of Watertown that are more developed, similar to the highly developed analysis area. The effect of impervious surfaces can be reduced by adding green infrastructure and introducing light colored materials for increased surface reflectivity. Green infrastructure, while an effective UHI mitigation strategy, also reduces flooding, improves groundwater recharge, restores surface perviousness, improves water quality, and increases overall neighborhood aesthetics. The following table describes different heat mitigation strategies with their benefits and co-benefits.

Heat Mitigation Strategies				
Strategies	Level of Implementation	Definition	Co-benefits	Cost Estimates (per unit)
Tree Canopy	Sidewalks, medians, public/private properties, parking lots, playgrounds, parks	Planting low maintenance, evergreen trees with large canopies	Improves Air Quality – Trees reduce air pollutants, intercept airborne solid particles, remove CO_2 from atmosphere Flood Mitigation – Trees act as natural water filters and reduce stormwater runoff, soil erosion, and minimize flooding Promotes healthy ecosystem – Trees absorb sound waves, provide habitats for many species, and reduce stress.	Median trees: $1,200 Street Trees: $800
Tree Box Filters	Sidewalks. Option to connect to nearby leaching catch basins	Tree box filters are localized bioretention systems and contain a combination of plants, soil, mulch, and gravel.	Flood Mitigation – Tree box filters collect stormwater runoff from adjacent sidewalks and roadways, infiltrate where practical, and discharge to neighboring catch basins Improves Water Quality – Tree box filters are efficient water filters and remove pollutants.	$2,500 - $15,000
Rain Gardens & ROW Infiltration Swales	Medium-Density Residential parcels & Curbside in	Shall includelandscaped depressions consisting of plans of various species that	Flood Mitigation – Stormwater is infiltrated at collection point instead of being conveyed to a receiving water Increases Safety – The barrier between road and pedestrian	$1,000 - $40,000, feature dependent

[5] *https://www.cambridgema.gov/-/media/Files/CDD/Climate/resilientcambridge/resilientcambridgehandbook.pdf*

Heat Mitigation Strategies				
Strategies	Level of Implementation	Definition	Co-benefits	Cost Estimates (per unit)
	Right-of-Way (ROW)	collect stormwater runoff and allow infiltration.	traffic creates a safer environment. Promotes Public Health – Plans improve urban air quality by removing CO_2 from the atmosphere Improves Aesthetics – Different plant species add color and enhance neighborhood aesthetics	
Lighter-colored Pavements	Public/private parking lots, open space, walkways	Cool pavements can include application of reflective paints or coatings, or application of mixes, which reflect more than 50% of the sunlight.	Increases Safety – Reflective pavements increase visibility at night. Increases Aesthetics – Street murals promote local art and culture and improves neighborhood aesthetics.	Painted pavement mural: $2/SF Light colored (concrete) pavers: $25/SF
Shade Structures	Existing bus stops, train stops, parks, playgrounds, streetscape	Shade structures, structural shelters, or elements that provide protection from the sun. They usually consist of vertical columns or supports for the overhead cover.	Promotes Public Health and Safety – Shades protect from harmful UV rays, climate hazards such as wind, dust, rain, and snow. Reduces Carbon Footprint – Shade structures encourage people to use public transport without the fear of climate hazards. Increases Aesthetics – If designed artistically, shade structures can increase the curb appeal of the city. Placemaking – Creates outdoor community space accessible during hot weather.	$10,000-$50,000
Cool Roofs	Commercial Buildings and Public Housing	A cool roof consists of a light-colored roof instead of dark surfaces. Dark roofs can be painted with light colored paints,	Reduces Electrical Grid Strain – The reduction of cooling energy demands at the building scale reduces the peak energy demands and thus reducing the risk of power outages.	Painted white roof: $6-$35/SF based on coating to new cool roof

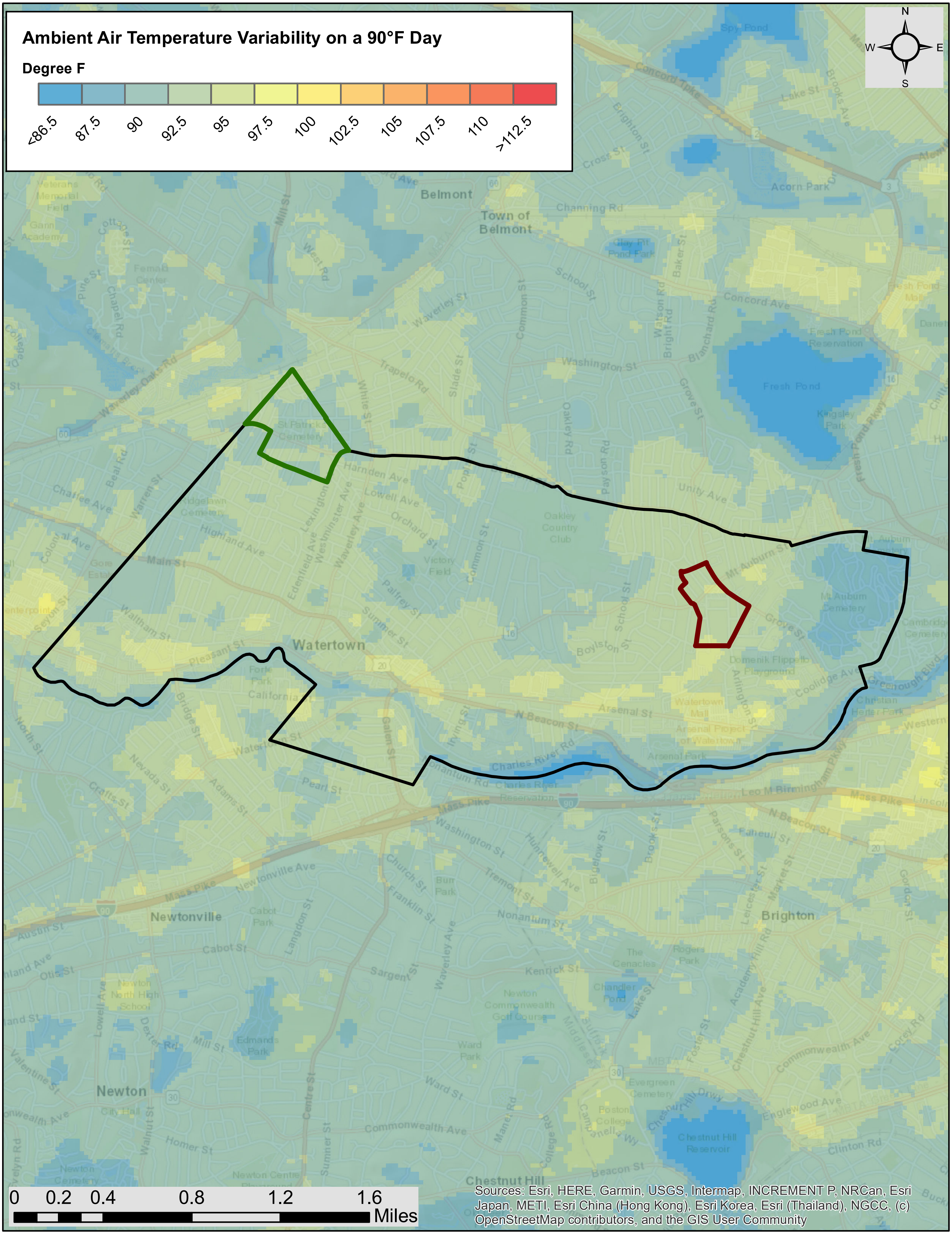
Heat Mitigation Strategies				
Strategies	Level of Implementation	Definition	Co-benefits	Cost Estimates (per unit)
		lighter colored materials can be used in roof construction, or a roof top garden can be installed.	Energy and Cost Savings – The solar reflectance and thermal emittance of cool roofs reduces cooling loads and this reduces energy consumption and costs. Flood Mitigation – Lighter-colored roofs accompanied by any stormwater detention structure (ie blue roof), stormwater retention structure (ie green roof), or rainwater harvesting can reduce stormwater runoff and mitigate peak runoff flows.	

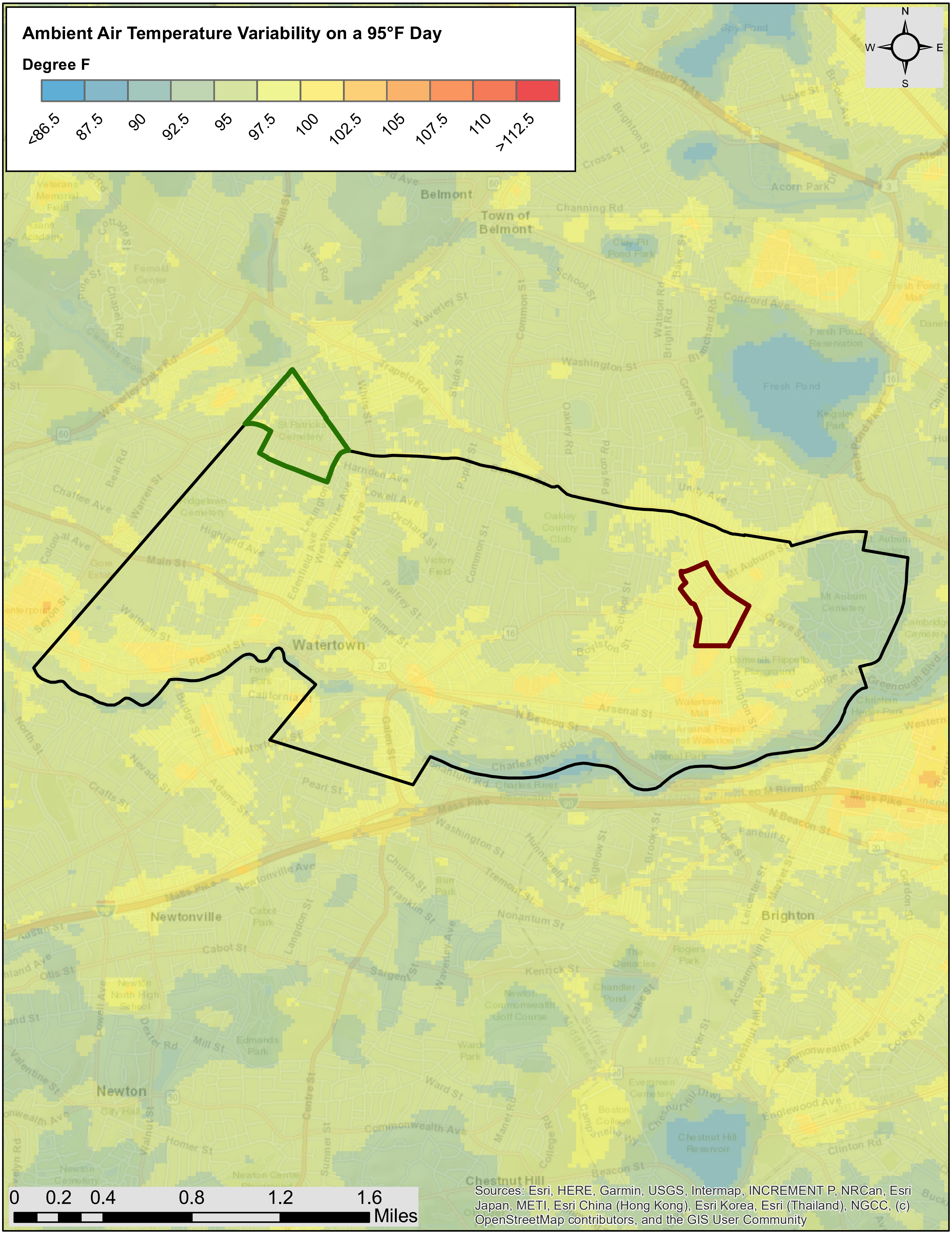
3.4 Additional Heat Mitigation Strategies

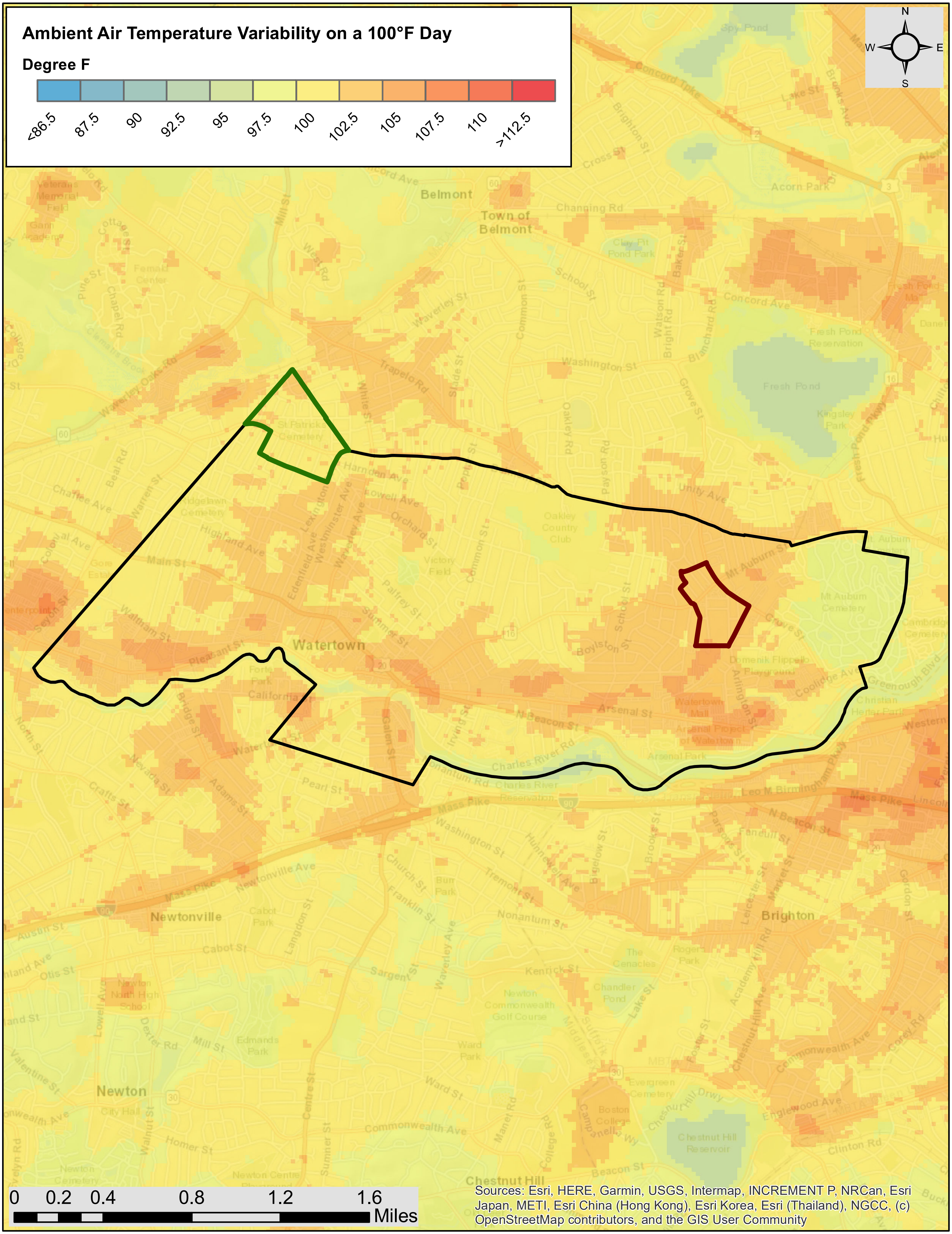
There are other more readily available heat mitigation strategies that the City can adopt to reduce heat-related morbidity and mortality impacts on residents. Commonly employed strategies include:

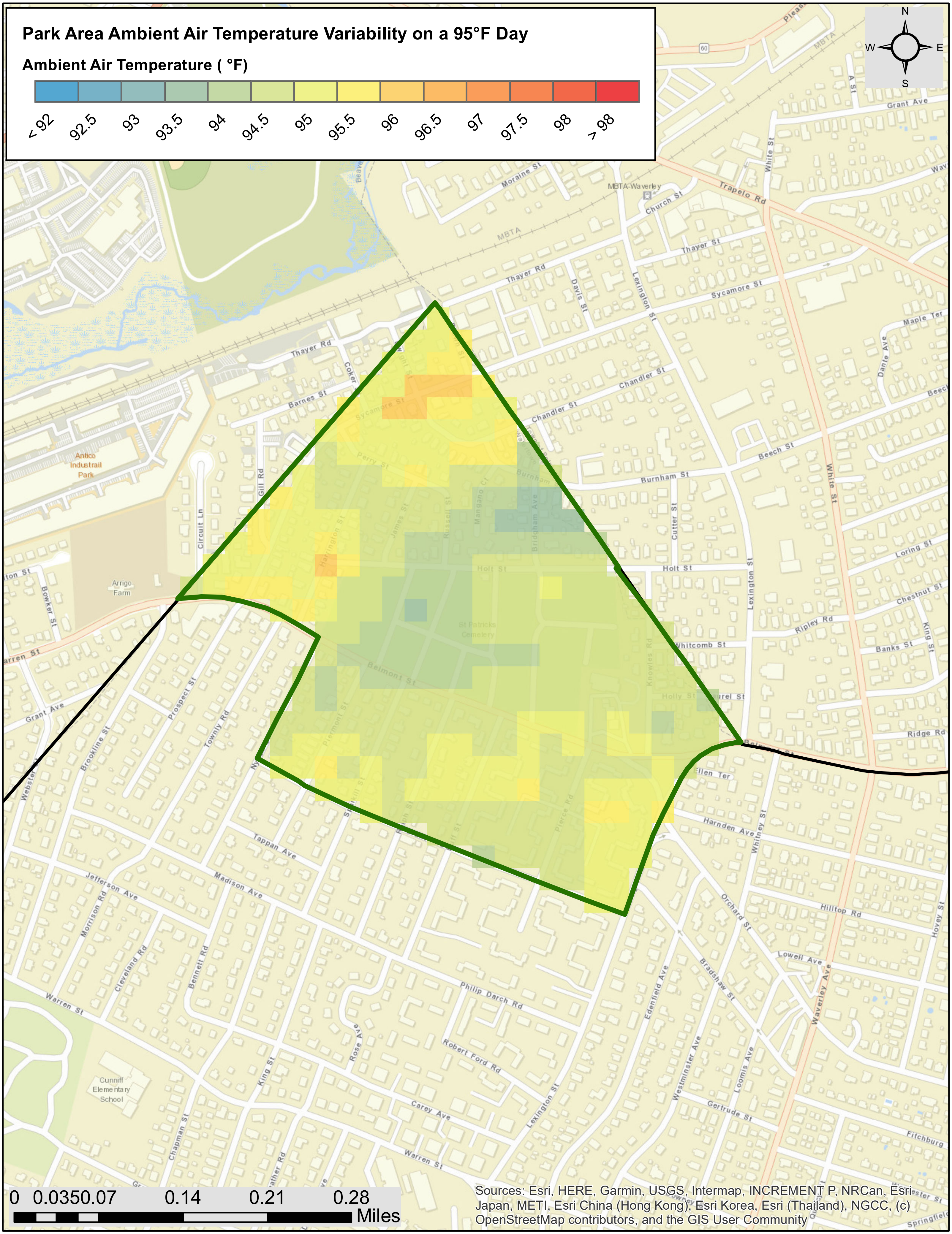
- Hydration stations in strategic areas of the City.
- Portable waters trailers that can serve vulnerable populations during heat waves (seniors, minors, homeless people, outdoor workers).
- Emergency kiosks at strategic locations within the City. The kiosks can serve as a hydrating location, and can include charging stations, emergency call buttons, basic utilities, and amenities to aid residents during extreme hot days.
- Open City Hall and other accessible public buildings as “cool cooling centers” during heat waves and inform residents about centers.
- Plan indoor City events during heat waves to encourage residents to stay indoors, and/or provide subsidized vouchers to indoor events during heat waves.

ATTACHMENT A - FIGURES

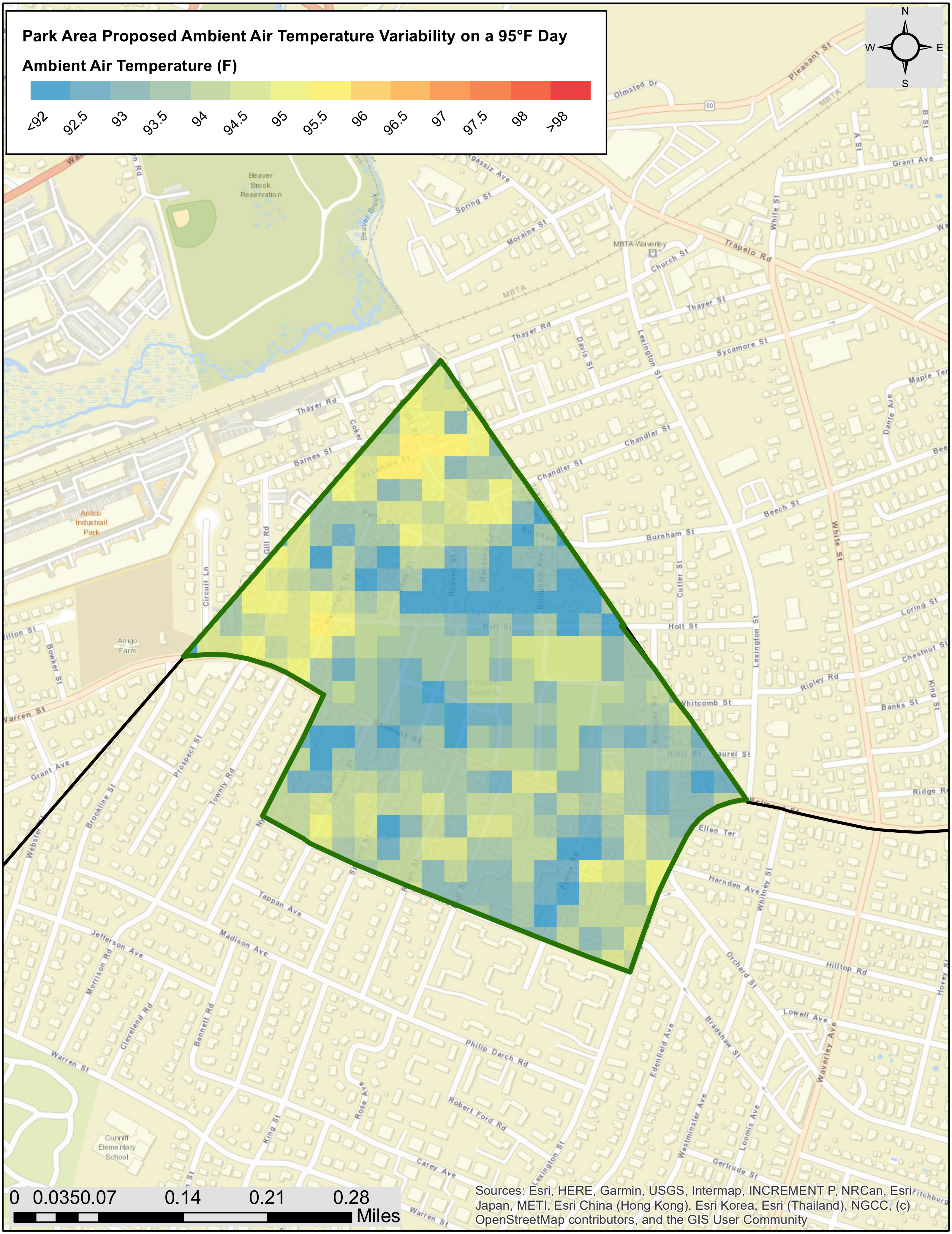

Ambient Air Temperature Variability on a 90°F Day
Degree F
<86.5
87.5
90
92.5
95
97.5
100
102.5
105
107.5
110
>112.5
N
W
E
S
Belmont
Town of Belmont
Watertown
Newtonville
Newton
Brighton
Chestnut Hill
Fresh Pond
Oakley Country Club
Mt Auburn Cemetery
Charles River Reservation
Chestnut Hill Reservoir
0
0.2
0.4
0.8
1.2
1.6
Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

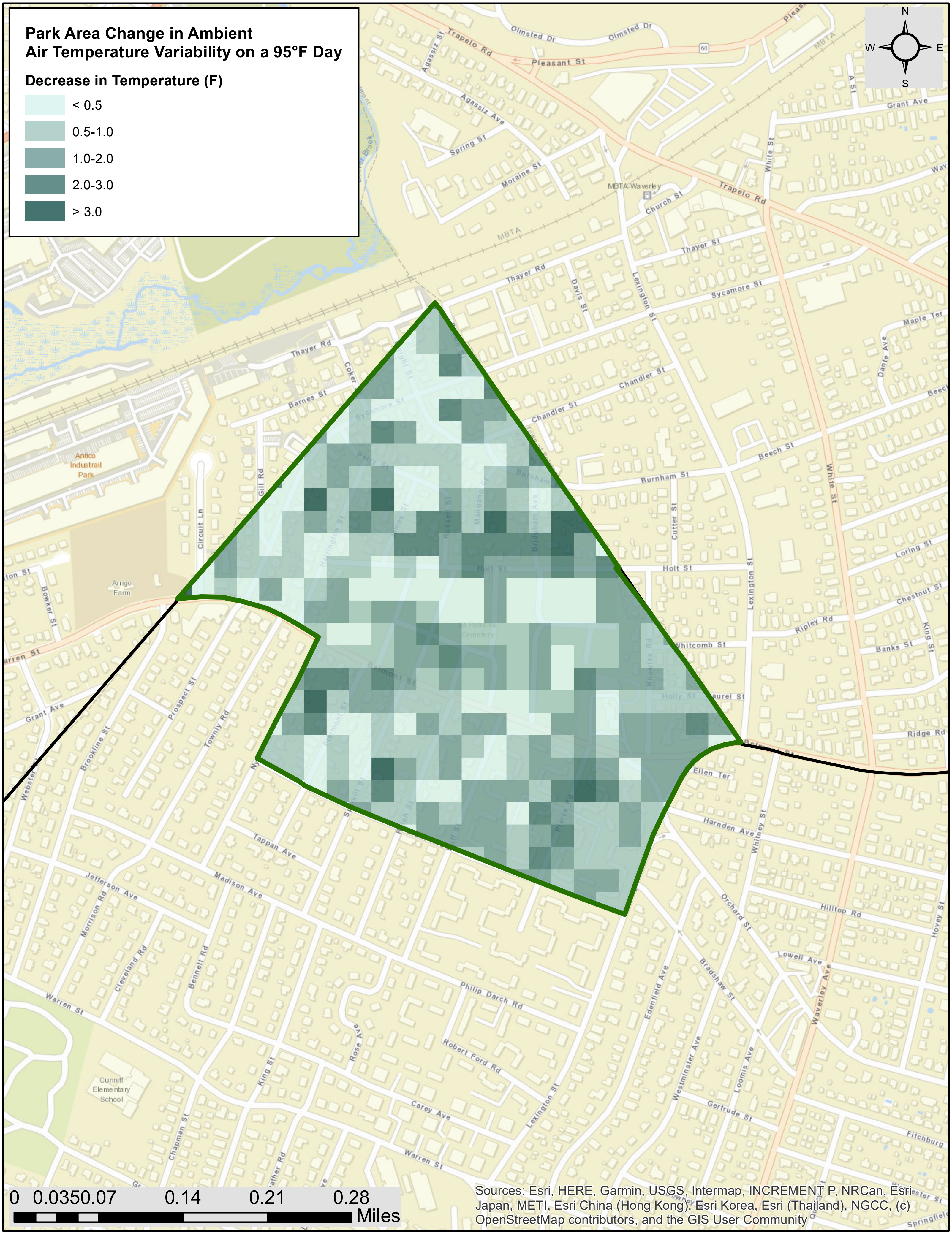

Ambient Air Temperature Variability on a 95°F Day
Degree F
<86.5
87.5
90
92.5
95
97.5
100
102.5
105
107.5
110
>112.5
N
W
E
S
Belmont
Town of Belmont
Watertown
Newtonville
Newton
Brighton
Chestnut Hill
Fresh Pond
Mt Auburn Cemetery
Charles River Reservation
Oakley Country Club
Victory Field
Watertown Mall
Arsenal Park
Chestnut Hill Reservoir
Mass Pike
0
0.2
0.4
0.8
1.2
1.6
Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

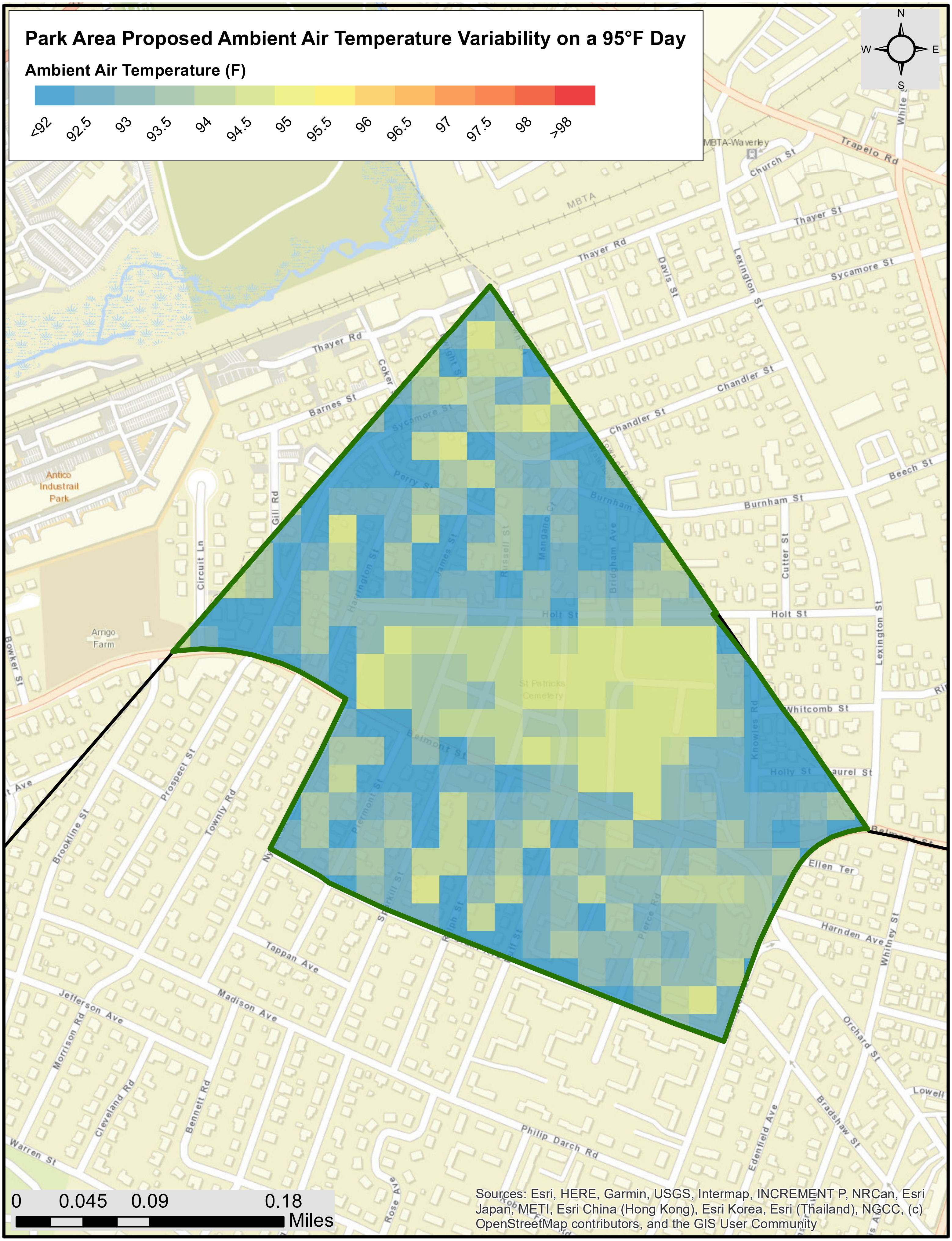

Ambient Air Temperature Variability on a 100°F Day
Degree F
<86.5
87.5
90
92.5
95
97.5
100
102.5
105
107.5
110
>112.5
N
W
E
S
Belmont
Town of Belmont
Watertown
Newtonville
Newton
Brighton
Chestnut Hill
0
0.2
0.4
0.8
1.2
1.6
Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

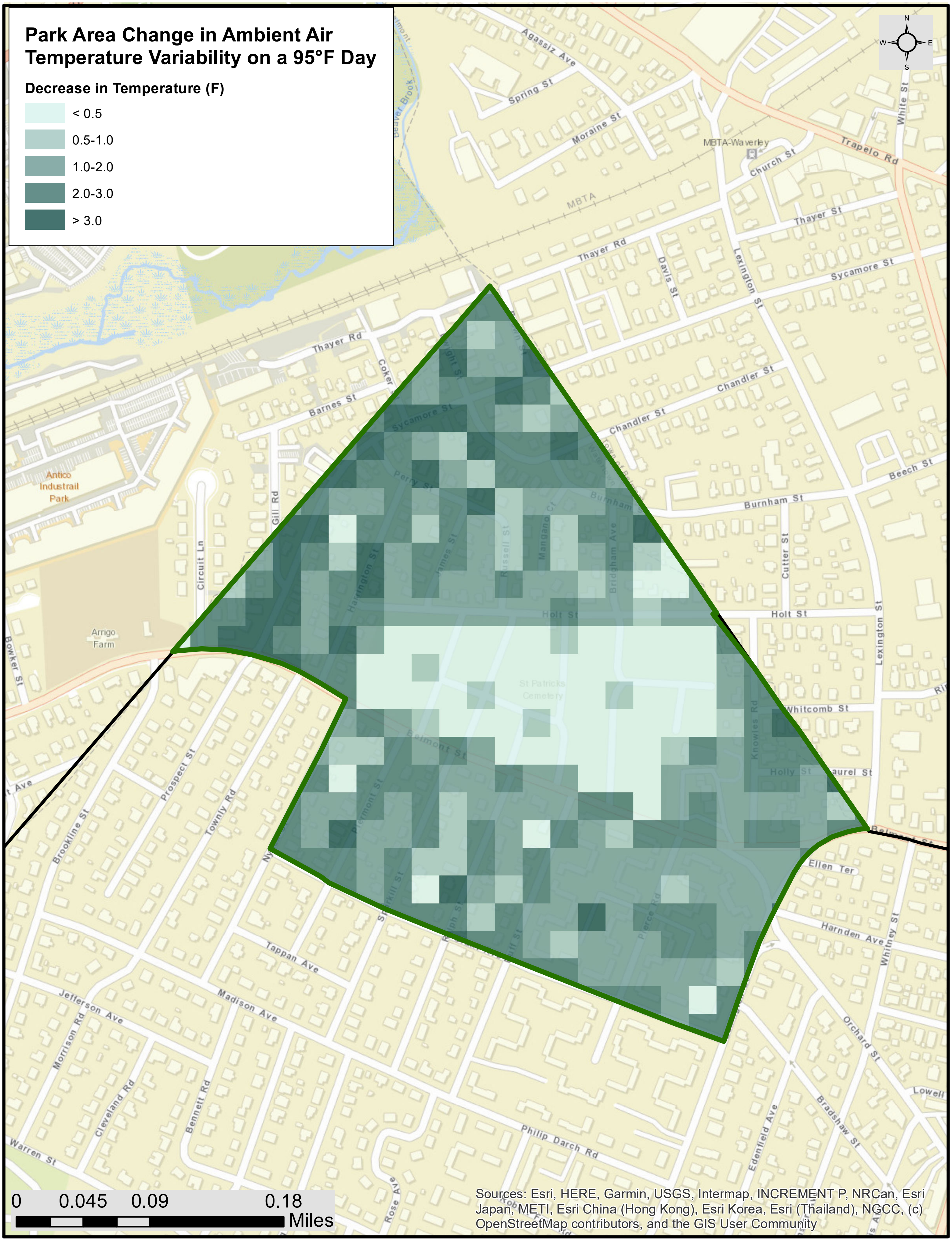


Park Area Ambient Air Temperature Variability on a 95°F Day
Ambient Air Temperature (°F)
< 92
92.5
93
93.5
94
94.5
95
95.5
96
96.5
97
97.5
98
> 98
N
S
E
W
0
0.035
0.07
0.14
0.21
0.28
Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

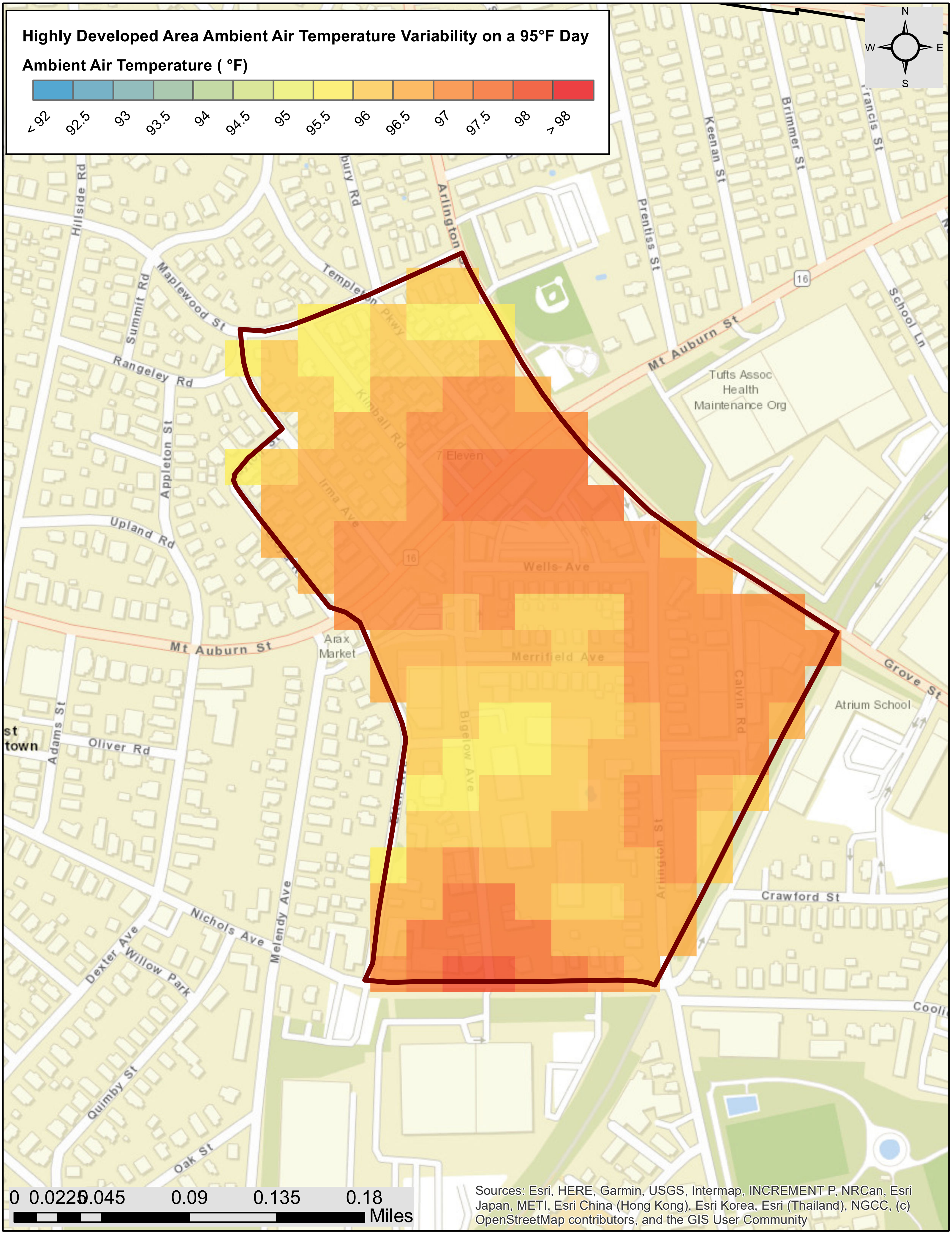

Park Area Proposed Ambient Air Temperature Variability on a 95°F Day
Ambient Air Temperature (F)
<92
92.5
93
93.5
94
94.5
95
95.5
96
96.5
97
97.5
98
>98
N
S
E
W
0 0.0350.07 0.14 0.21 0.28
Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community


Park Area Change in Ambient Air Temperature Variability on a 95°F Day
Decrease in Temperature (F)
< 0.5
0.5-1.0
1.0-2.0
2.0-3.0
> 3.0
N
W
E
S
0 0.0350.07 0.14 0.21 0.28
Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

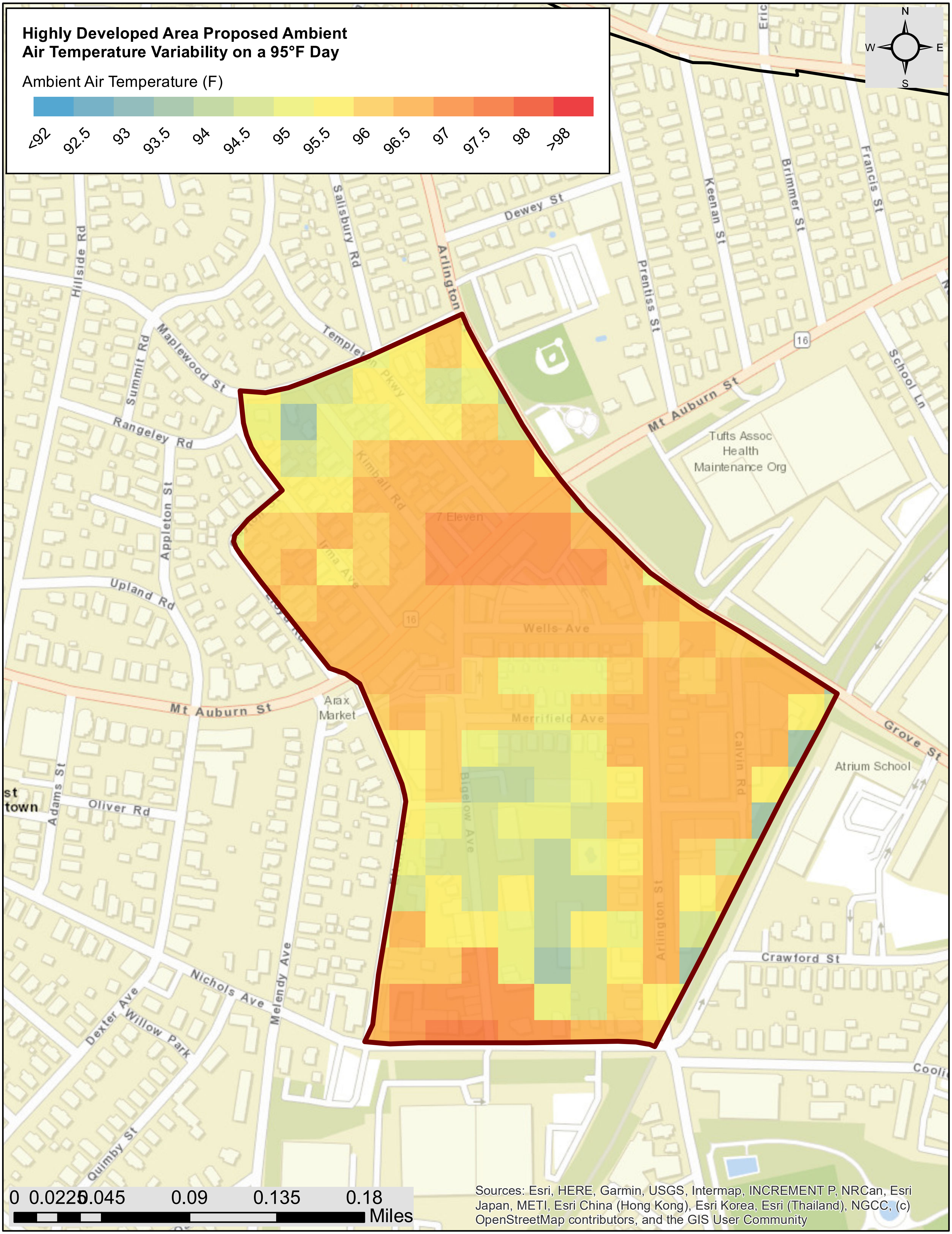

Park Area Proposed Ambient Air Temperature Variability on a 95°F Day
Ambient Air Temperature (F)
<92
92.5
93
93.5
94
94.5
95
95.5
96
96.5
97
97.5
98
>98
N
W
E
S
MBTA-Waverley
Trapelo Rd
Church St
MBTA
Thayer St
Thayer Rd
Davis St
Lexington St
Sycamore St
Thayer Rd
Coker St
Barnes St
Chandler St
Chandler St
Sycamore St
Antico Industrail Park
Perry St
Burnham St
Burnham St
Beech St
Gill Rd
Circuit Ln
Harrington St
James St
Russell St
Mangano Ct
Bridgham Ave
Cutter St
Holt St
Holt St
Lexington St
Arrigo Farm
Bowker St
St Patricks Cemetery
Whitcomb St
Knowles Rd
Belmont St
Holly St
Laurel St
Prospect St
Townly Rd
Brookline St
Ellen Ter
Harnden Ave
Whitney St
Pierce Rd
Tappan Ave
Madison Ave
Jefferson Ave
Morrison Rd
Cleveland Rd
Bennett Rd
Orchard St
Lowell
Bradshaw St
Edenfield Ave
Philip Darch Rd
Warren St
Rose Ave
0
0.045
0.09
0.18
Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



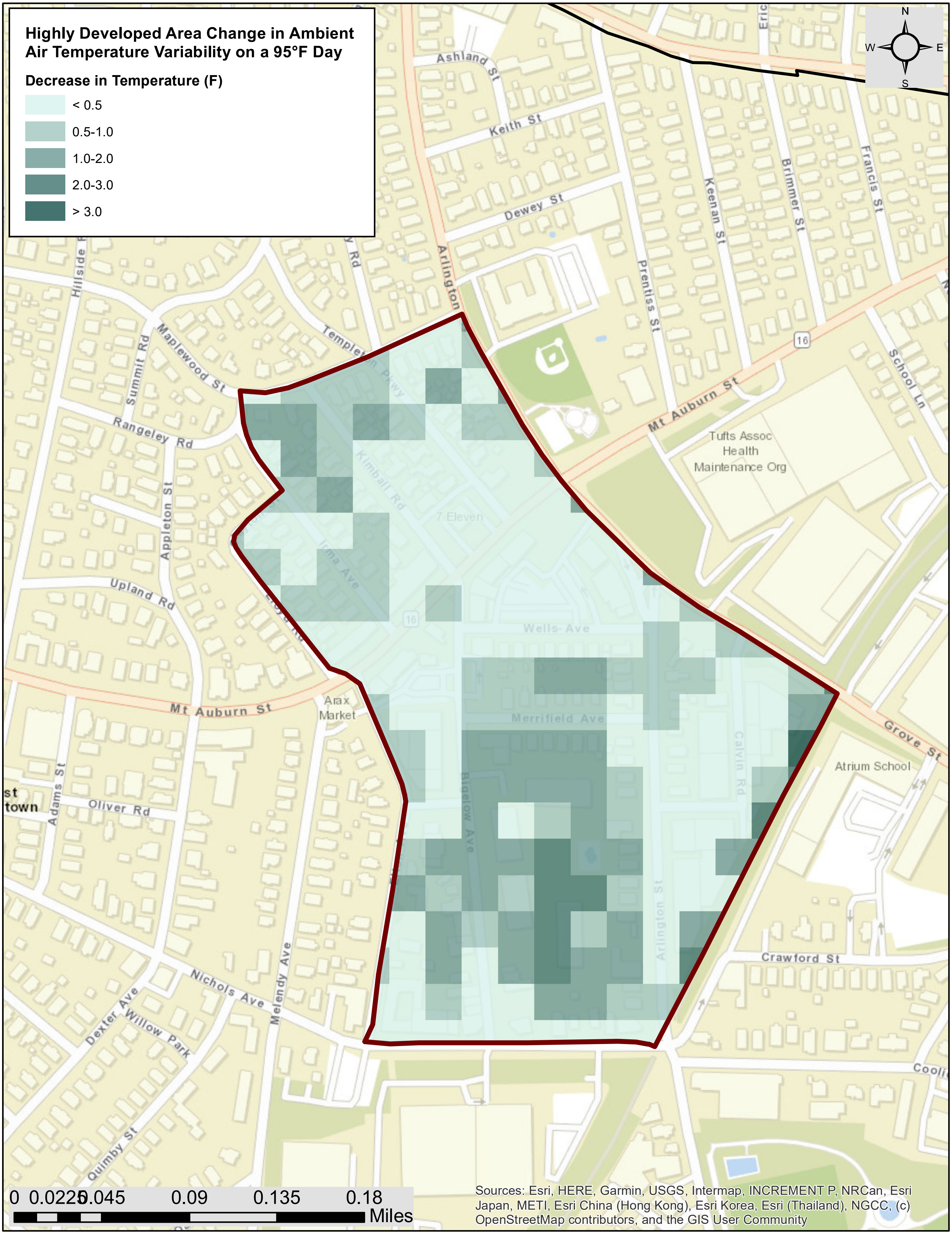
Park Area Change in Ambient Air Temperature Variability on a 95°F Day
Decrease in Temperature (F)
< 0.5
0.5-1.0
1.0-2.0
2.0-3.0
> 3.0
N
W
E
S
0
0.045
0.09
0.18
Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Highly Developed Area Ambient Air Temperature Variability on a 95°F Day
Ambient Air Temperature (°F)
< 92
92.5
93
93.5
94
94.5
95
95.5
96
96.5
97
97.5
98
> 98
N
W
E
S
Hillside Rd
Maplewood St
Summit Rd
Templeton Pkwy
Arlington St
Prentiss St
Keenan St
Brimmer St
Francis St
School Ln
Mt Auburn St
16
Tufts Assoc
Health
Maintenance Org
Rangeley Rd
Kimball Rd
Appleton St
7 Eleven
Irma Ave
Upland Rd
Wells Ave
Arax
Market
Merrifield Ave
Grove St
Calvin Rd
Atrium School
Oliver Rd
Adams St
Bigelow Ave
Crawford St
Nichols Ave
Melendy Ave
Dexter Ave
Willow Park
Quimby St
Oak St
0 0.0225 0.045 0.09 0.135 0.18
Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

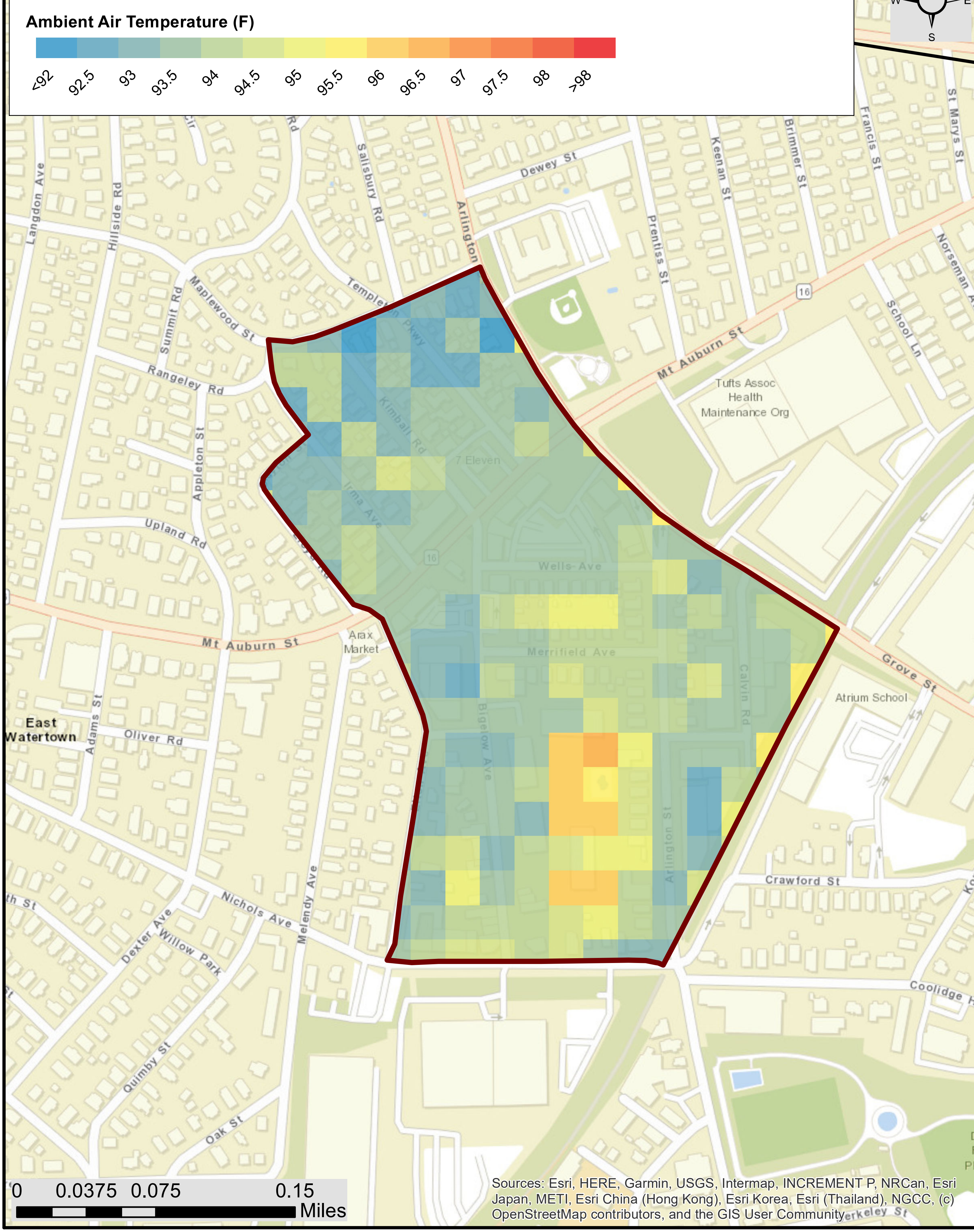


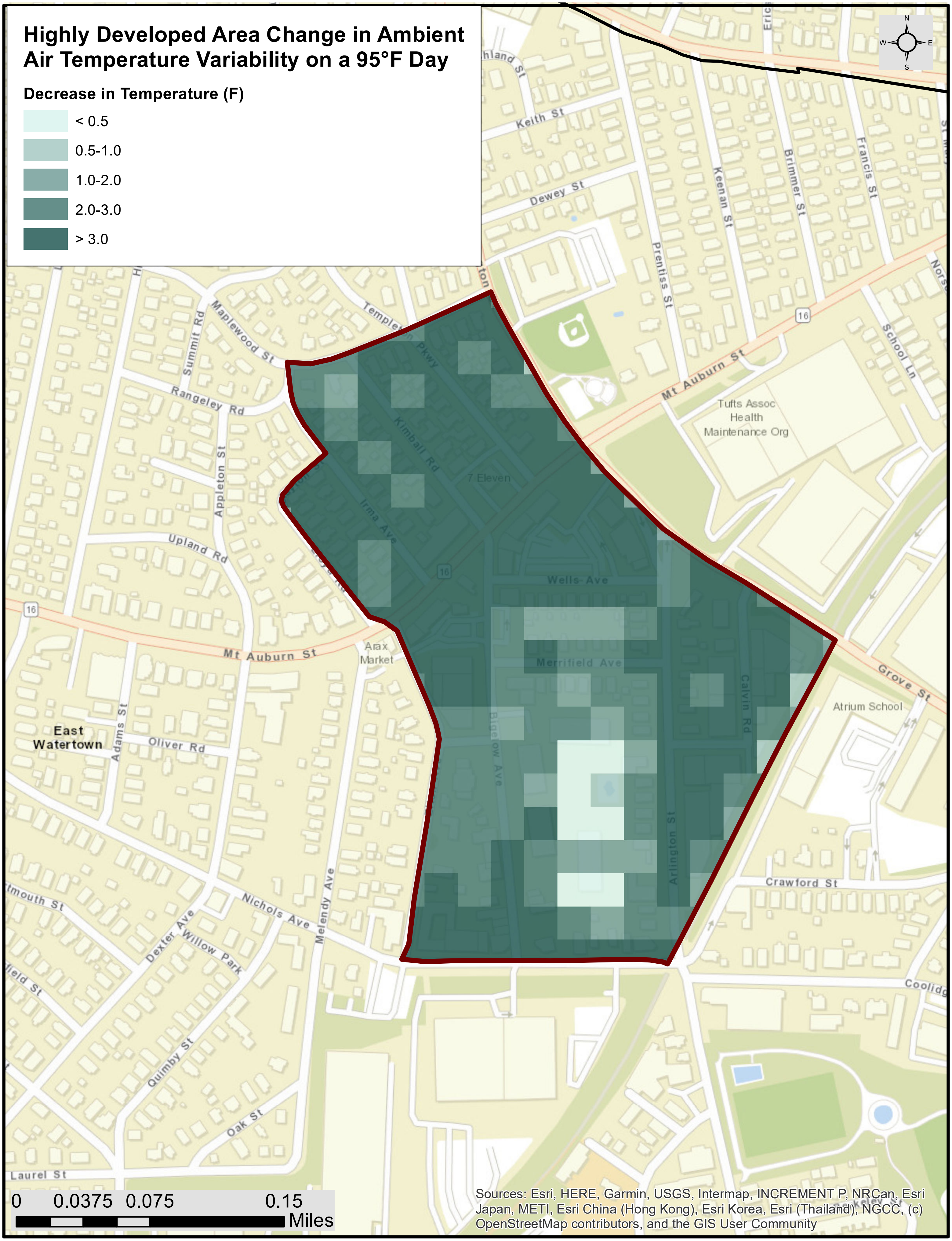
Highly Developed Area Proposed Ambient Air Temperature Variability on a 95°F Day
Ambient Air Temperature (F)
<92
92.5
93
93.5
94
94.5
95
95.5
96
96.5
97
97.5
98
>98
N
W
E
S
Dewey St
Salisbury Rd
Arlington St
Prentiss St
Keenan St
Brimmer St
Francis St
Hillside Rd
Summit Rd
Maplewood St
Templeton Pkwy
Rangeley Rd
Kimball Rd
Appleton St
Irma Ave
7 Eleven
Upland Rd
16
Mt Auburn St
Tufts Assoc Health Maintenance Org
School Ln
Wells Ave
Arax Market
Merrifield Ave
Calvin Rd
Grove St
Atrium School
Adams St
Oliver Rd
Bigelow Ave
Arlington St
Crawford St
Nichols Ave
Melendy Ave
Dexter Ave
Willow Park
Quimby St
0 0.0225 0.045 0.09 0.135 0.18
Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community



Highly Developed Area Change in Ambient Air Temperature Variability on a 95°F Day
Decrease in Temperature (F)
< 0.5
0.5-1.0
1.0-2.0
2.0-3.0
> 3.0
N
W
E
S
Ashland St
Keith St
Dewey St
Arlington St
Prentiss St
Keenan St
Brimmer St
Francis St
School Ln
Mt Auburn St
16
Tufts Assoc Health Maintenance Org
Templeton Pkwy
Maplewood St
Summit Rd
Hillside Rd
Rangeley Rd
Appleton St
Kimball Rd
7 Eleven
Irma Ave
Upland Rd
Lloyd Rd
Wells Ave
Mt Auburn St
Arax Market
Merrifield Ave
Calvin Rd
Grove St
Atrium School
Bigelow Ave
Arlington St
Adams St
Oliver Rd
Crawford St
Nichols Ave
Melendy Ave
Dexter Ave
Willow Park
Quimby St
Coolidge
0 0.0225 0.045 0.09 0.135 0.18
Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Highly Developed Area Proposed Ambient Air Temperature Variability on a 95°F Day




Highly Developed Area Change in Ambient Air Temperature Variability on a 95°F Day
Decrease in Temperature (F)
< 0.5
0.5-1.0
1.0-2.0
2.0-3.0
> 3.0
N
S
E
W
Keith St
Dewey St
Prentiss St
Keenan St
Brimmer St
Francis St
School Ln
Mt Auburn St
Tufts Assoc Health Maintenance Org
Maplewood St
Templeton Pkwy
Summit Rd
Rangeley Rd
Kimball Rd
7 Eleven
Irma Ave
Appleton St
Upland Rd
Wells Ave
Merrifield Ave
Arax Market
Calvin Rd
Grove St
Atrium School
Bigelow Ave
Arlington St
East Watertown
Adams St
Oliver Rd
Crawford St
Nichols Ave
Melendy Ave
Dexter Ave
Willow Park
Quimby St
Oak St
Laurel St
0 0.0375 0.075 0.15
Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

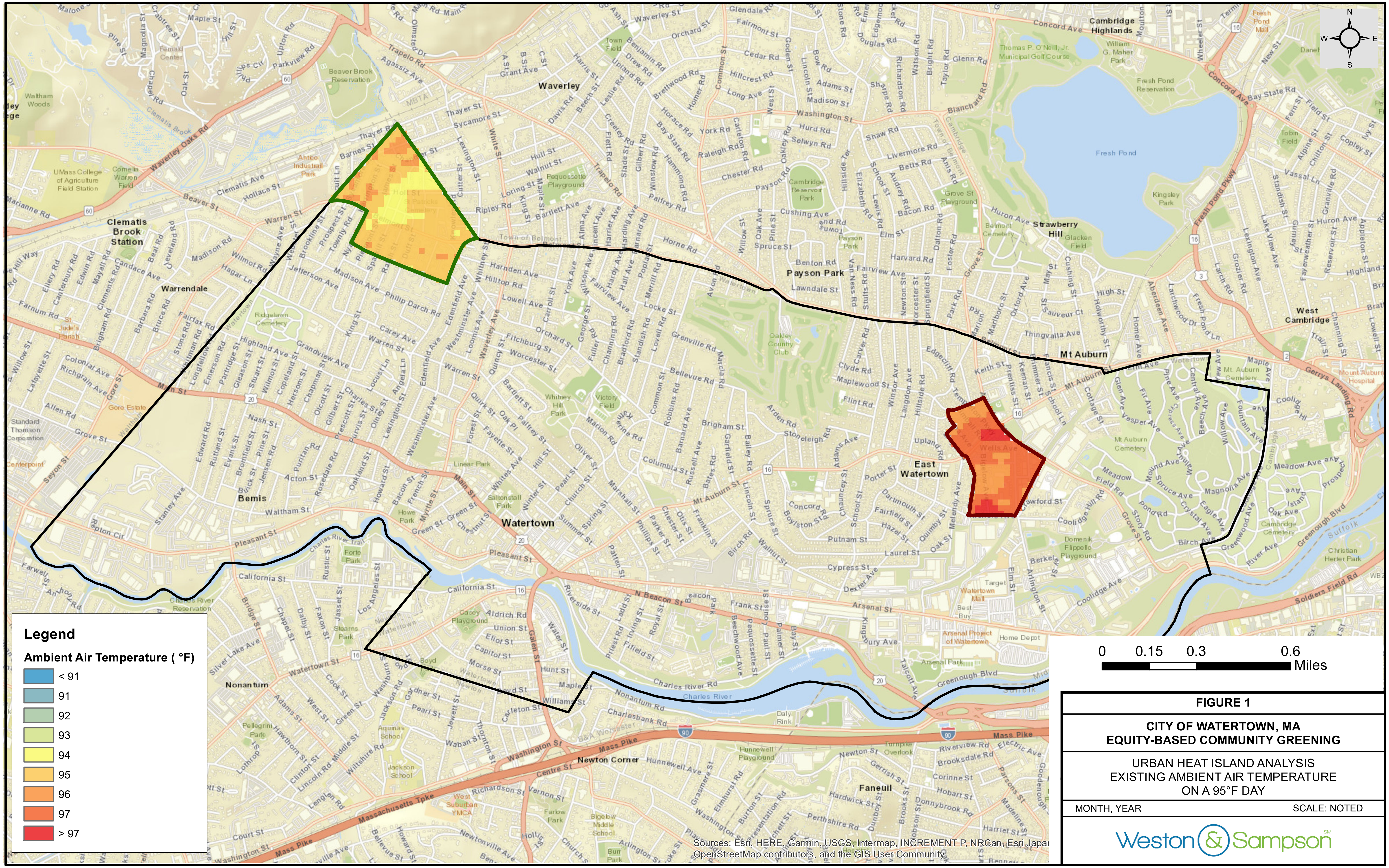


FIGURE 1

CITY OF WATERTOWN, MA
EQUITY-BASED COMMUNITY GREENING

URBAN HEAT ISLAND ANALYSIS
EXISTING AMBIENT AIR TEMPERATURE
ON A 95°F DAY

MONTH, YEAR | SCALE: NOTED

Weston & Sampson

Path: P:\MA\Watertown MA\ENG21-1144 - FY22 MVP Action Grant - Equity-Based Community Greening Program\Task 1.5 - UHI Analysis\Watertown_UHI_Analysis.mxd **User:** Passalacqua.Caroline **Saved:** 12/9/2021 3:13:09 PM **Opened:** 12/9/2021 3:22:05 PM

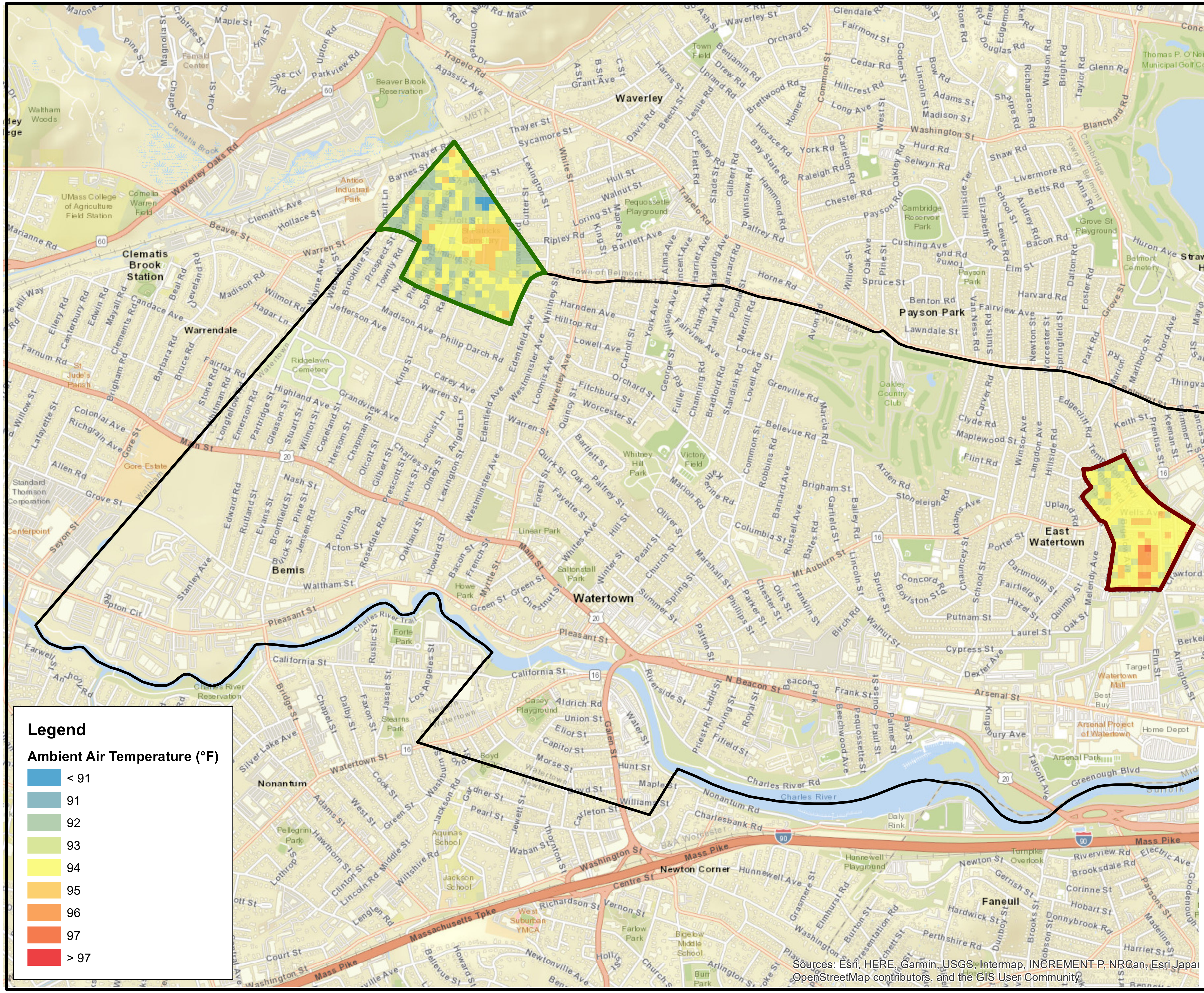


FIGURE 2

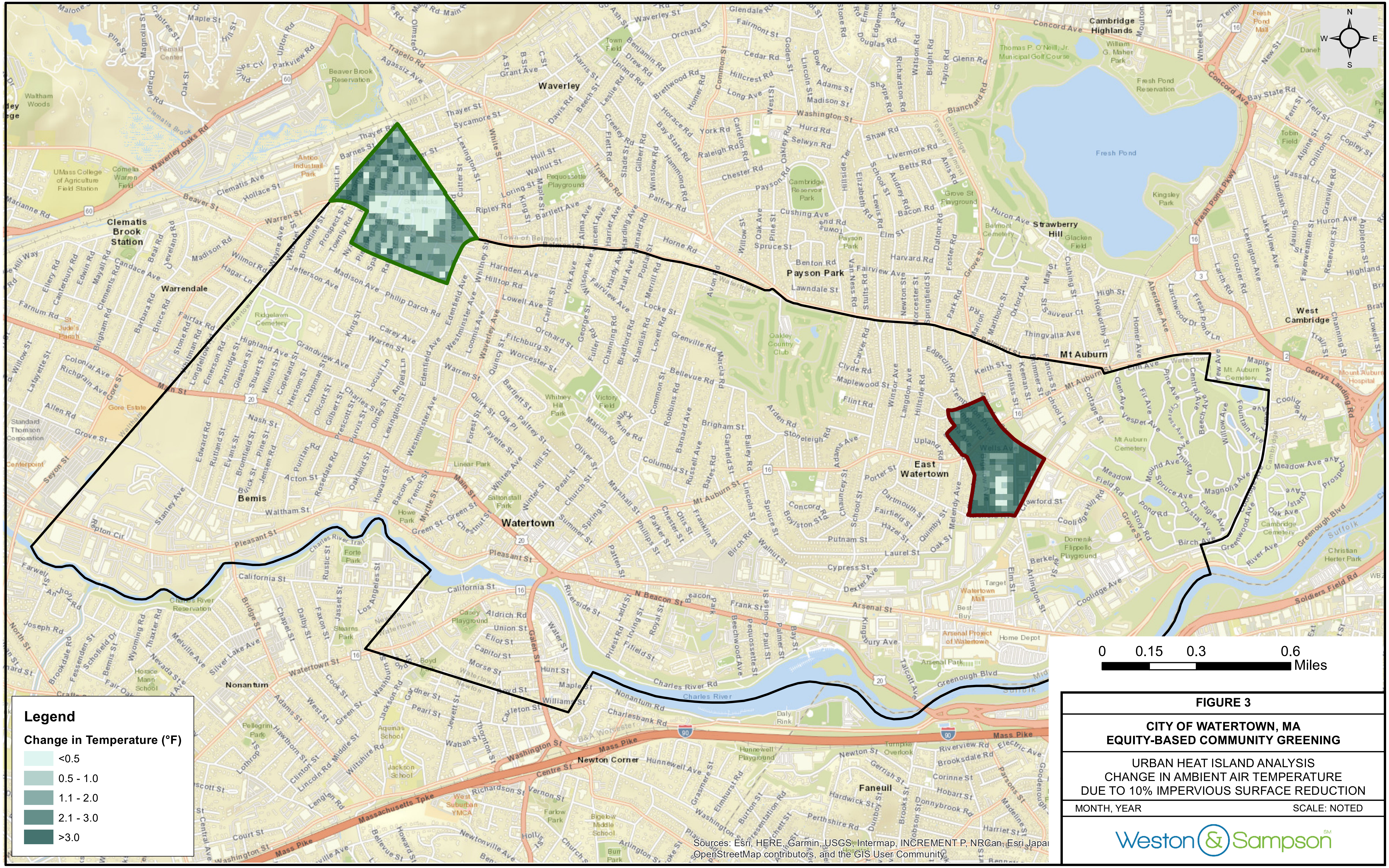
CITY OF WATERTOWN, MA
EQUITY-BASED COMMUNITY GREENING

URBAN HEAT ISLAND ANALYSIS
PROPOSED AMBIENT AIR TEMPERATURE
DUE TO 10% IMPERVIOUS SURFACE REDUCTION

DECEMBER 2021 SCALE: NOTED

Weston & Sampson

Path: P:\MA\Watertown MA\ENG21-1144 - FY22 MVP Action Grant - Equity-Based Community Greening Program\Task 1.5 - UHI Analysis\Watertown_UHI_Analysis.mxd User: Passalacqua.Caroline Saved: 12/9/2021 3:13:09 PM Opened: 12/9/2021 3:34:20 PM



Legend
Change in Temperature (°F)
<0.5
0.5 - 1.0
1.1 - 2.0
2.1 - 3.0
>3.0
0 0.15 0.3 0.6
Miles
FIGURE 3
CITY OF WATERTOWN, MA
EQUITY-BASED COMMUNITY GREENING
URBAN HEAT ISLAND ANALYSIS
CHANGE IN AMBIENT AIR TEMPERATURE
DUE TO 10% IMPERVIOUS SURFACE REDUCTION
MONTH, YEAR
SCALE: NOTED
Weston & Sampson
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan
OpenStreetMap contributors, and the GIS User Community
Watertown
East Watertown
Bemis
Waverley
Fresh Pond
Charles River

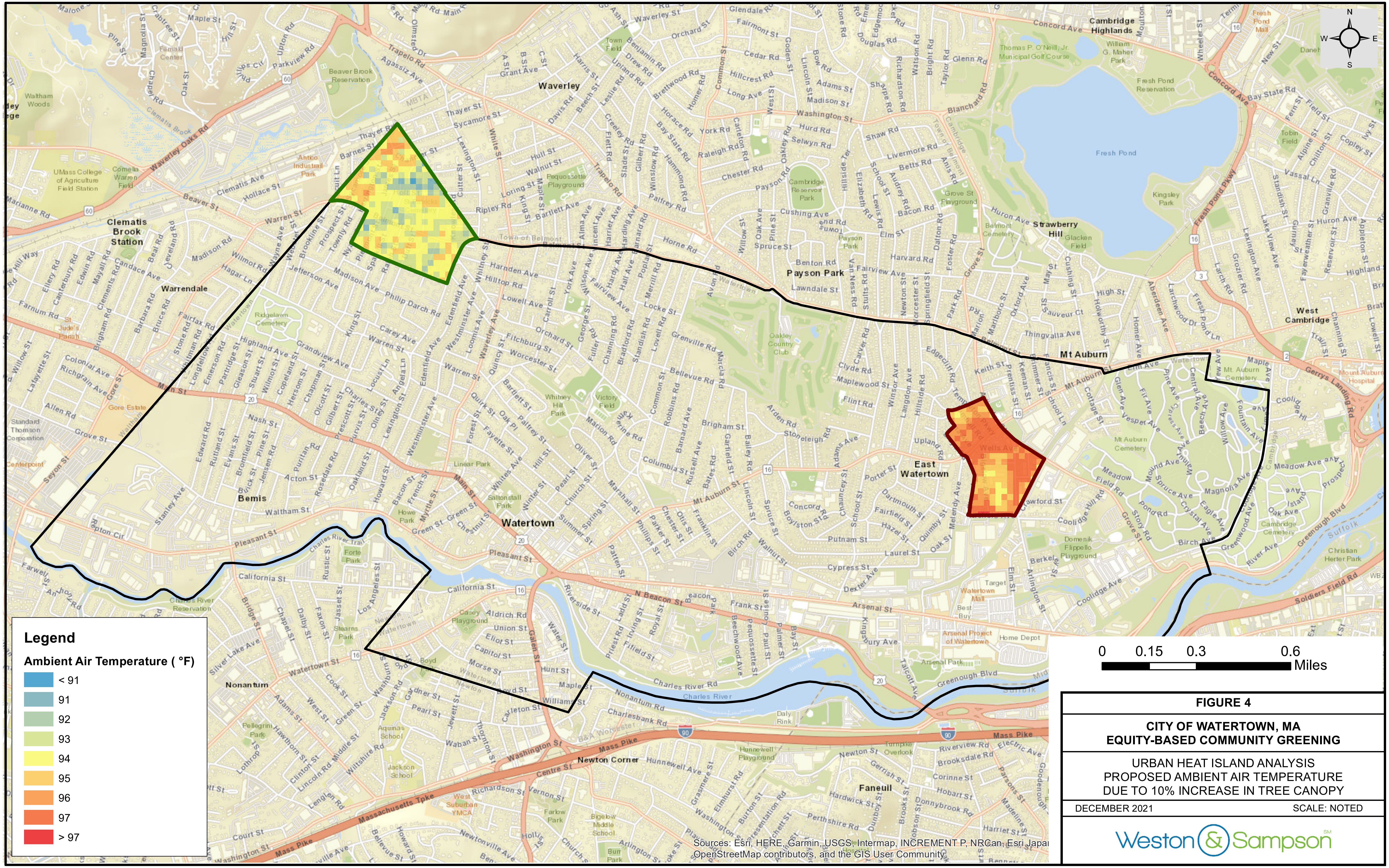


FIGURE 4

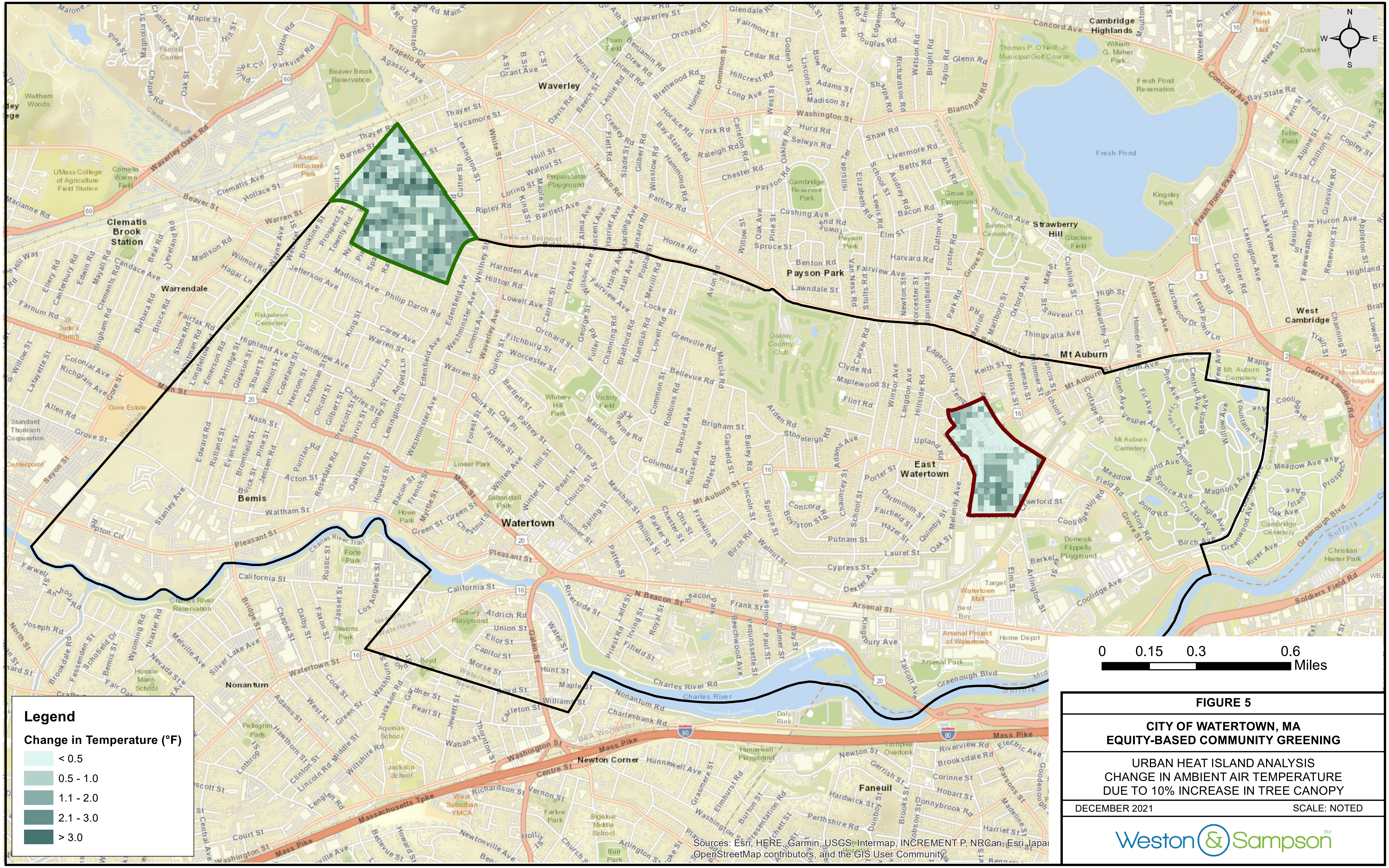
CITY OF WATERTOWN, MA
EQUITY-BASED COMMUNITY GREENING

URBAN HEAT ISLAND ANALYSIS
PROPOSED AMBIENT AIR TEMPERATURE
DUE TO 10% INCREASE IN TREE CANOPY

DECEMBER 2021 | SCALE: NOTED

Weston & Sampson

Path: P:\MA\Watertown MA\ENG21-1144 - FY22 MVP Action Grant - Equity-Based Community Greening Program\Task 1.5 - UHI Analysis\Watertown_UHI_Analysis.mxd **User:** Passalacqua.Caroline **Saved:** 12/9/2021 3:13:09 PM **Opened:** 12/9/2021 3:36:38 PM


Legend
Change in Temperature (°F)
< 0.5
0.5 - 1.0
1.1 - 2.0
2.1 - 3.0
> 3.0
0 0.15 0.3 0.6
Miles
N
W E
S
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, OpenStreetMap contributors, and the GIS User Community
FIGURE 5
CITY OF WATERTOWN, MA
EQUITY-BASED COMMUNITY GREENING
URBAN HEAT ISLAND ANALYSIS
CHANGE IN AMBIENT AIR TEMPERATURE
DUE TO 10% INCREASE IN TREE CANOPY
DECEMBER 2021
SCALE: NOTED
Weston & Sampson