City of Chelsea Massachusetts

URBAN HEAT ISLAND MITIGATION PROJECT

FINAL REPORT

Please Note:

This work was funded by the Massachusetts Municipal Vulnerability Preparedness (MVP) program and we are grateful for their support. The Urban Heat Island Mitigation report would not have been possible without the commitment and support of the City of Chelsea.
The time, effort and input of the stakeholders, and the Chelsea community as a whole, were invaluable to the development of this report.

The substance and findings of the work are dedicated to the public. The author and publisher are solely responsible for the accuracy of the statements and interpretations contained in this publication. Such interpretations do not necessarily reflect the views of the State or local Government.

Prepared for: City of Chelsea

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WBUR-FM (90.9 FM), Boston, MA

Boston Society of Landscape Architects

Weston & Sampson LLC.

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COOL BLOCK

Informed by extensive civic engagement and informed by the MVP planning process, the “Cool Block” symbolizes a modest, but meaningful step to build on past and ongoing Urban Heat initiatives, in order to reduce urban heat, mitigate air pollution, and advance equity.

Executive Summary

Introduction

Urban heat island (UHI) effect occurs when dense, urban areas with high concentrations of impervious surfaces amplify ambient air temperatures in comparison to surrounding less developed areas. The major drivers of UHI effect include release of heat from equipment, lack of vegetation, increased heat absorption by materials like concrete and asphalts, and the greenhouse effect in urban atmosphere.

The City of Chelsea is vulnerable to extreme heat events, which are projected to increase in frequency (more heatwaves) and magnitude (higher temperatures) as a result of climate change. The confluence of built environment characteristics (dense urbanization and industrialization), historical settlement patterns, and unbounded air pollution has compounded UHI effect in the City of Chelsea. The City of Chelsea is within a mapped Environmental Justice neighborhood, which indicates that residents are disproportionately more vulnerable to extreme heat due to factors such as access to transportation, income level, disability, racial inequity, health status, or age. The community has historically experienced disproportionate harm from environmental pollution and more recently the COVID-19 pandemic. The increase in annual temperatures and heat waves driven by climate change combined with the UHI effect is likely to degrade public health, welfare, and living conditions in the City.

The City of Chelsea is dedicated to pursuing equitable UHI mitigation and climate adaptation projects that are grounded in science, rooted in community engagement, and replicable at a meaningful scale. Extreme heat and air pollution were identified through the Municipal Vulnerability Preparedness (MVP) planning process as a risk to residents. The "Urban Heat Island Mitigation" project completed in 2022 was funded by the MVP program and informed by a multi-year history of studying heat impacts in the City of Chelsea, on-going research by Boston University School of Public Health and GreenRoots, and extensive civic engagement.

The UHI Mitigation project team led by Weston & Sampson developed a model to analyze UHI using sensors from the on-going heat research and land surface data. The UHI analysis identified known and emerging "hot spot" zones through the City in conjunction with community feedback.

COOL BLOCK

Multiple heat mitigation strategies were analyzed through the model, and a pilot "Cool Block" project was identified to move forward with implementation. The Cool Block included improvements to the public right-of-way including roadway reconstruction using light-colored aggregates and accent reflective surface treatments, sidewalk reconstruction with light-surface materials and ADA compliant ramps, infiltration swales, and additional tree canopy and shade features. The project team worked closely with Holcim, a hot mix asphalt (HMA) pavement supplier in the region, to identify and analyze mix strategies that will perform in the extreme cold of our winters and increasing extreme heat events.

The Cool Block started construction in spring/summer of 2022 and will serve as a proof-of-concept for implementing these heat mitigation strategies in Chelsea and in the region. The UHI effect will continue to be monitored to assess the efficacy of the right-of-way interventions over time through continued research by Boston University School of Public Health and GreenRoots.

Background

Urban Heat & the City of Chelsea

Urban heat islands are endemic in areas with dense concentrations of impervious surfaces, such as the City of Chelsea (the City), and will worsen with climate change (2018, NECS). Building roofs, roadways, sidewalks, and masonry absorb heat. This storage subsequently warms surrounding air, which results in air temperatures that are 1.8 degrees to 5.4 degrees F warmer than surrounding rural and suburban locales (2020, EPA), particularly in urban areas with a prevalence of industrial land uses. The City's dense housing stock, of which 58% was erected before 1940, was constructed primarily out brick, stone, and masonry with asphalt or dark colored roofs (2018, U.S. Census ACS 5-Year Est.). The development patterns of the City consist of narrow public rights-of-way, dense buildings, and large swathes of impervious surfaces with limited open green spaces. Disproportionately the City hosts critical regional infrastructure, such as Route 1, and is close to Logan Airport. The confluence of emissions, impervious surfaces and scarcity of green space, coupled with low lying industrial buildings, amassed in the center of parcels and encircled by parking lots, exacerbate urban heat.

Temperature and Land Cover

According to a 2017 spatial analysis conducted by the Trust for Public Land shown in Figure 1, summertime land surface temperatures in the City of Chelsea are upwards of 140 degrees F, while the ambient air temperature is generally 80 degrees F. Throughout Chelsea land surface temperatures are often 75% higher than the ambient air temperatures (2017, Trust for Public Land), as impervious surface cover comprises over 80% of the City's geography (2020, City of Chelsea).

Figure 1. City of Chelsea Land Surface Temperatures, Source: Trust for Public Land

ENVIRONMENTAL JUSTICE

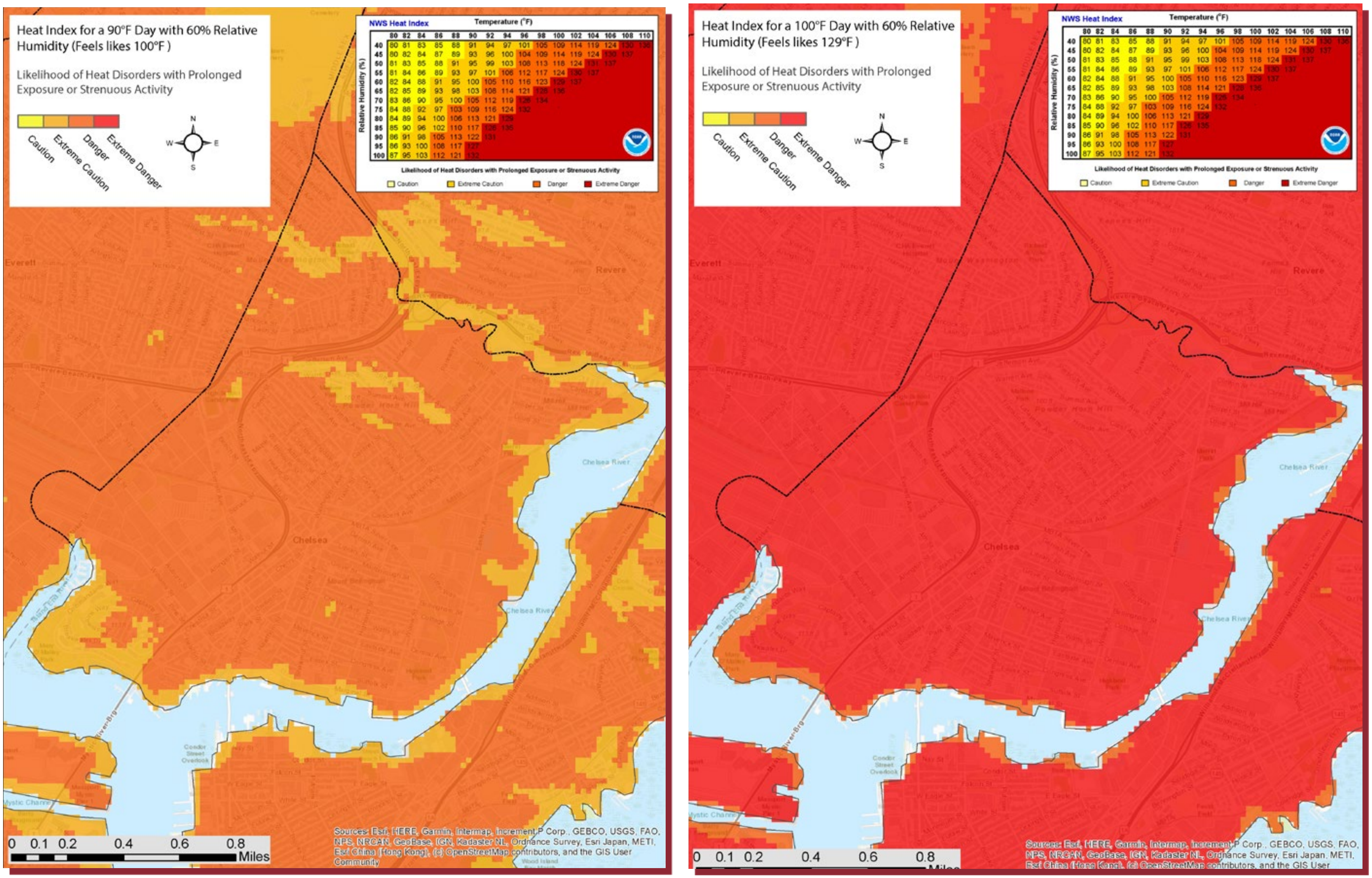
Environmental Justice populations typically include climate vulnerable populations, who may have lower adaptive capacity or higher exposure and sensitivity to climate hazards like flooding or heat stress due to factors such as access to transportation, income level, disability, racial inequality, health status, or age. (2022, RMAT)

According to the EPA, urban heat islands increase summertime energy usage; elevate levels of air pollution; impair water quality; cause heat related illnesses, such as respiratory illness, kidney failure, dehydration, heart disease, and asthma; inhibit cognitive functions; and severely erode the public health (2020, EPA; 2020, CDC) of a population with underlying health conditions, due to decades of inequitable public policy, planning, and investment. The invisibility of heat, often referred to as a "silent killer," poses a further risk, as the vast underreporting of heat related illnesses, coupled with the annual average of 65,000 heat induced emergency room visits, has led to the neglect of the issue at the federal level (Centers for Disease Control and Prevention).

Social And Public Health Implications

Climate change will disproportionately impact Environmental Justice communities. The City of Chelsea's racial, economic, social, and public health inequities were especially magnified during the COVID-19 pandemic. The COVID-19 pandemic acutely affected vulnerable residents, including people with disabilities, people with underlying health issues, such as asthma, and elderly residents. Rising annual and summer temperatures as a result of climate change will increase the severity of urban heat islands, which will have similar widespread impacts to vulnerable residents. Urban Heat effects are projected to worsen, with the rise of annual average daytime temperatures and the number of days with temperatures over 95 degrees, which will affect the Heat Index (or "real feel") as shown in Figure 2.

Figure 2: Heat index variability across Chelsea on a 90ºF (left) and on a 100ºF day (right)



Recent Urban Heat Assessment Studies

Background

In 2018 the City of Chelsea, in conjunction with Worcester Polytechnical Institute, undertook an urban heat island assessment. This assessment highlighted contributors of urban heat islands and mitigation strategies warranting exploration. Subsequently, in partnership with the Urban Land Institute, the City embarked on an urban heat island planning study of the Second St. corridor, a major freight trucking and industrial artery that sustains regional commerce. Furthermore, the City identified
extreme heat and air pollution as a climate hazard that places residents at risk through the Municipal Vulnerability Preparedness Program.

Air pollution, exacerbated by extreme heat, are correlated with the City's high hospitalization rates for asthma, as well as high rates of respiratory illness and cardiovascular disease. The report outlined green infrastructure design principles and strategies to counter the effects of urban heat islands(2018, City of Chelsea, Summary of Findings).

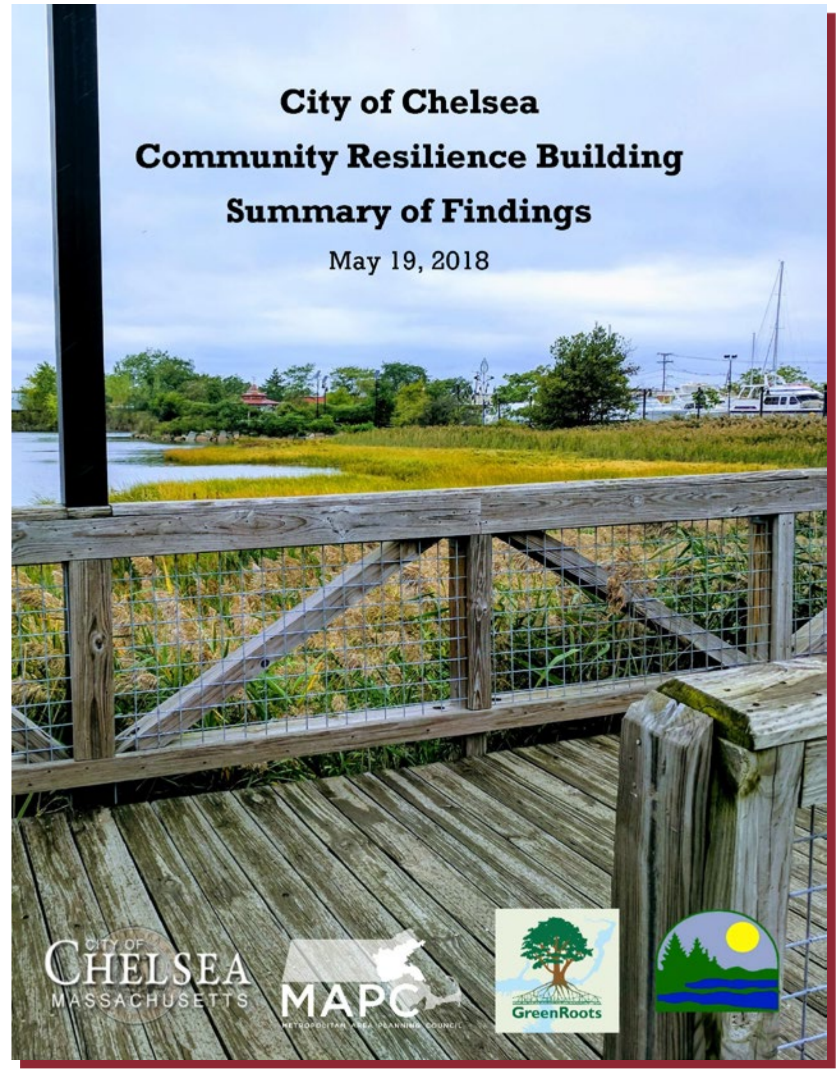


Figure 3: City of Chelsea Summary of Findings

Municipal Vulnerability Preparedness (MVP) Action Grant Program

In fiscal year 2020, the City of Chelsea sought funding to advance a city-wide urban heat island (UHI) mitigation initiative through the MVP Action Grant Program. The funding resulted in the UHI Mitigation project, which aimed to:

- complement ongoing regional efforts by analyzing ambient air & land surface temperatures
- perform a social vulnerability assessment
- prioritize corridors for public and private heat mitigation interventions
- devise and carry out five (5) pilot heat mitigation projects on public properties

Chelsea and East Boston Heat Study (C-HEAT)

Complimentary to the MVP Program project, and organized by Boston University School of Public Health and GreenRoots Chelsea, the Chelsea and East Boston Heat Study (C-HEAT) is undertaking a "collaborative research project," with the main goal to "build capacity for these communities to respond to extreme heat events."[1] Through the C-HEAT project, a temperature sampling campaign was conducted in the summer of 2020 and 2021 throughout the City of Chelsea. The sensors measured temperature, relative humidity, and dew point on rooftops of buildings, in trees, and at other outdoor locations.

1 https://www.c-heatproject.org/

Public Engagement Strategies and Results

The City of Chelsea is a densely settled, urban community with a population of approximately 40,000, which doesn't include the full spectrum of the City's undocumented, uncounted residents. The City takes pride in its diversity; approximately 67% of residents identify as Latinx, over 45% of the population is foreign born, and 54% of residents speak Spanish as a first language. The entirety of the City of Chelsea is mapped as an environmental justice community1. The absence of resident participation in setting policy and decision-making compounds the effects of urban heat island effects and ramifications.

The City has prioritized involving the public in planning, design, and implementation projects that are centered on their neighborhoods and affect their daily lives.

The City of Chelsea and GreenRoots developed a meaningful strategy for civic engagement, modeled after ongoing initiatives, such as the Island End River Flood Resilience Project, so that the community was equitably and meaningfully represented in the project. Community engagement was conducted in a bilingual, culturally competent manner. Media content and meeting materials were highly visual and translated into English and Spanish. Interpretation services and refreshments were provided at public meetings. Public meetings were hosted at accessible venues in the community, as opposed to City Hall.

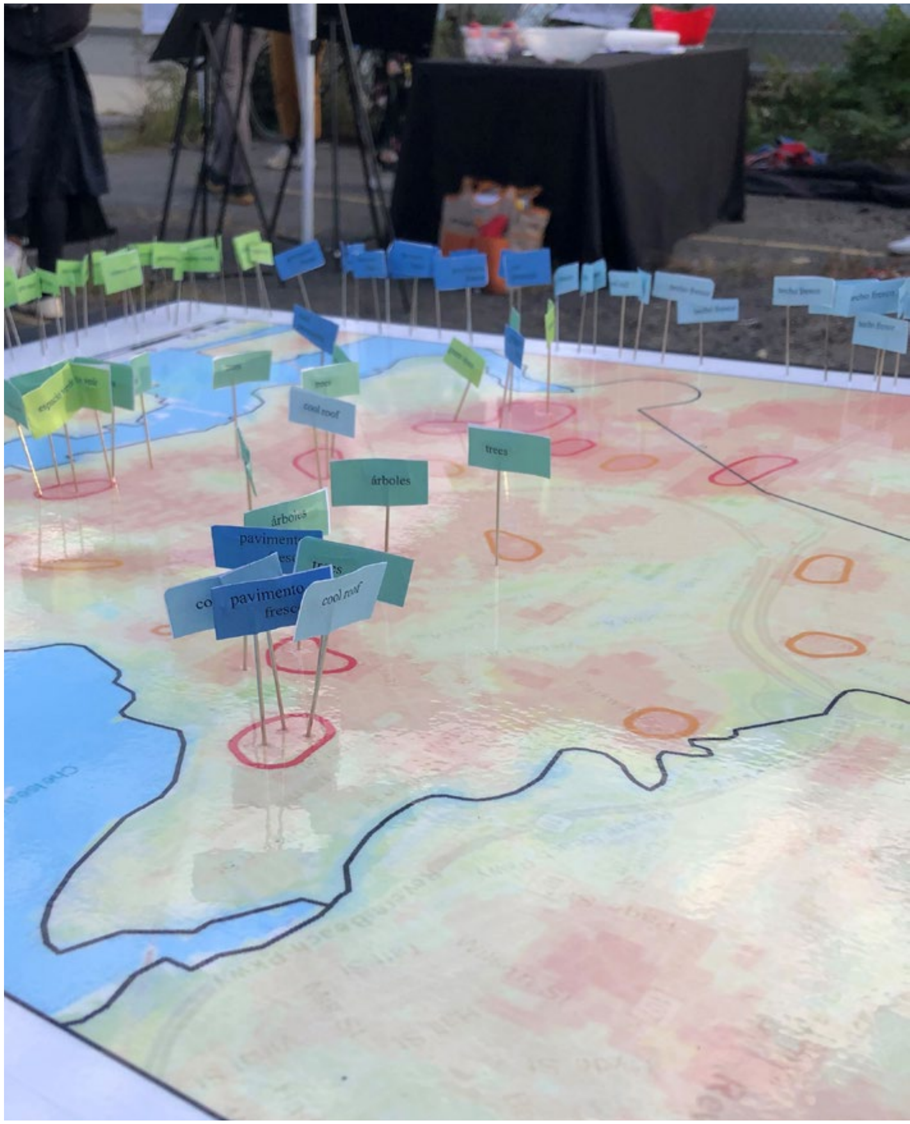


Figure 4: "Cool Block" Community Charette

1 https://mass-eoeea.maps.arcgis.com/apps/webappviewer/index.html?id=1d6f63e7762a48e5930de84ed4849212

Engagement Completed

- Reach out by GreenRoots [1 page summary of project, what they did, and graphics] BSLA Charette (shown in Figure 4)
- Completed by BU and C-Heat Program integrated with GreenRoots heat campaign efforts, leading to BSLA Charette.
- Made connection with Boys & Girls Club and the schools
- Charettes & events at the cool block
- IER Community Advisory group
- Facilitating and attending meetings, organizing events in collaboration with the MVP team to talk about heat
- Participatory mapping at a GreenRoots meeting over Zoom
- Reached GreenRoots membership through the members meetings

(This was in the middle of COVID-19 pandemic; the format and how we engaged with people changed throughout this period)

Coverage

The project team worked with videographers from Trillium Studios Film to raise awareness and educate over the Chelsea Cool Block Project. The film is part of the grant-funded TURNAROUND FILMS project about innovative approaches to mitigating and adapting to the effects of climate change. The series is available at no cost to educators, environmental nonprofits, and municipalities. The films are designed to be downloaded and used in presentations, in classrooms, in town meetings, or embedded in websites and social media—anywhere that well-told stories might inspire people to feel more empowered to become part of the solutions to problems caused by climate change. The project team met with film team representatives for interview and supported access by the film crew to the site for filming during construction.

The project was also featured in articles from the Boston Globe and WBUR. In June 2021, the Boston Globe published an article titled, “With extreme heat increasingly in the forecast, how can we adapt?” written by Sabrina Shankman. The text highlighted a Chelsea resident, the experiences of her family living in Chelsea as temperatures rise, and detailed the efforts included in this project. WBUR’s article, “In Chelsea, cooling an urban heat island one block at a time” by Martha Bebinger described the "Cool Block” project and captured tree planting on Maverick Street (May, 2022).

Urban Heat Island (UHI) Analysis Findings

The City of Chelsea engaged Weston & Sampson to develop, design and implement UHI mitigation strategies in collaboration with GreenRoots. Data from the ongoing C-HEAT project sensor network were used as part of the urban heat island analysis. Ambient Air Temperature and Heat Index Maps were developed (as shown in Figure 5) and focus areas were identified for UHI mitigation in the public right-of-way and on private parcels (as shown in Figure 6).

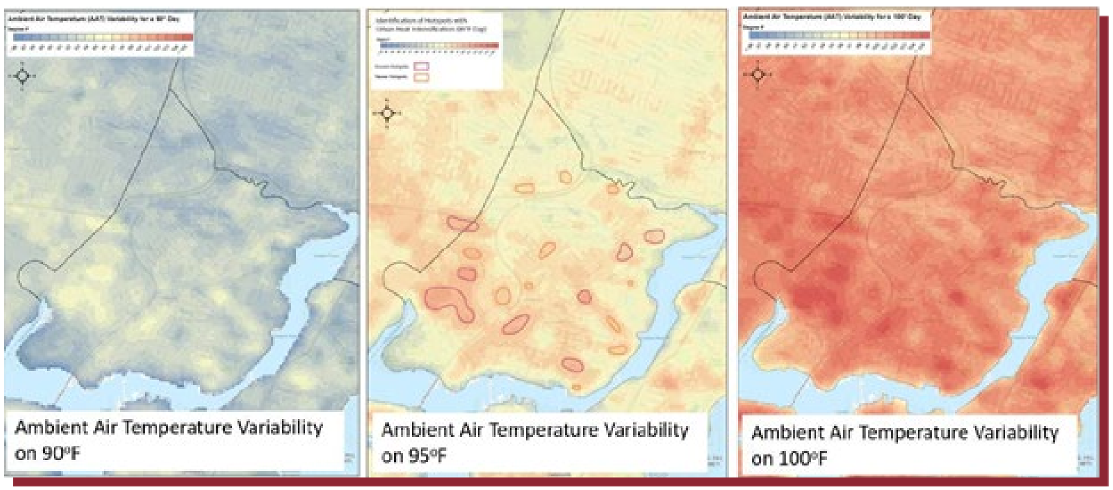


Figure 5. Ambient Air Temperature Variability on Citywide Scale on 90°, 95°, and 100° F days (Left to Right).

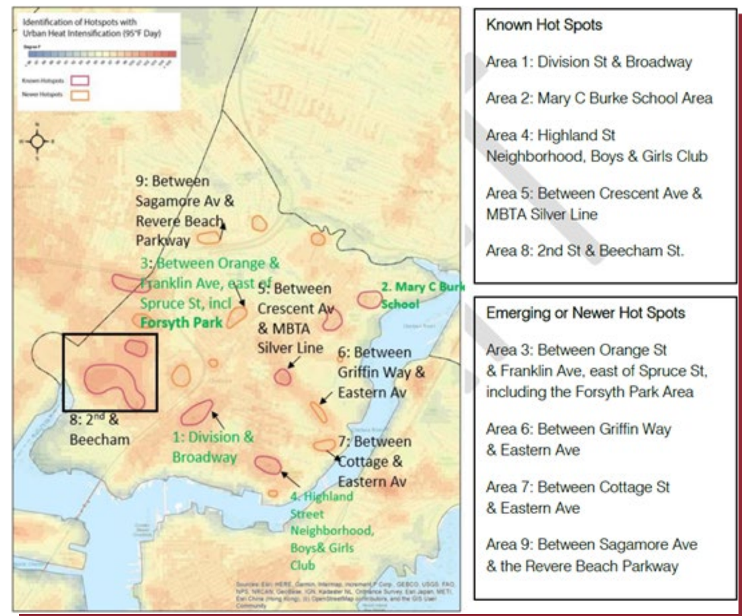


Figure 6. Locations of identified "hot spots." Red boundaries indicate existing high heat areas ("Known Hot Spots"), and orange boundaries indicate potential high heat areas ("Emerging or Newer Hot Spots")

Cooling Strategies

The team conducted a high-level cost-benefit analysis using typical cooling measures to estimate the efficacy of the following cooling strategies on a City-wide scale and in targeted areas:

- Increase tree canopy
- Reduce impervious cover (shown in Figure 7 and Figure 8)
- Use lighter-colored paving materials
- Increase green infrastructure in public right-of-way and public open spaces

The cooling strategies modeled also considered co-benefits, such as flood reduction, water quality improvements and carbon sequestration, which informed design prioritization.

ANALYZING ALBEDO

Albedo, or *solar reflectance*, is a measure of a material's ability to reflect sunlight.

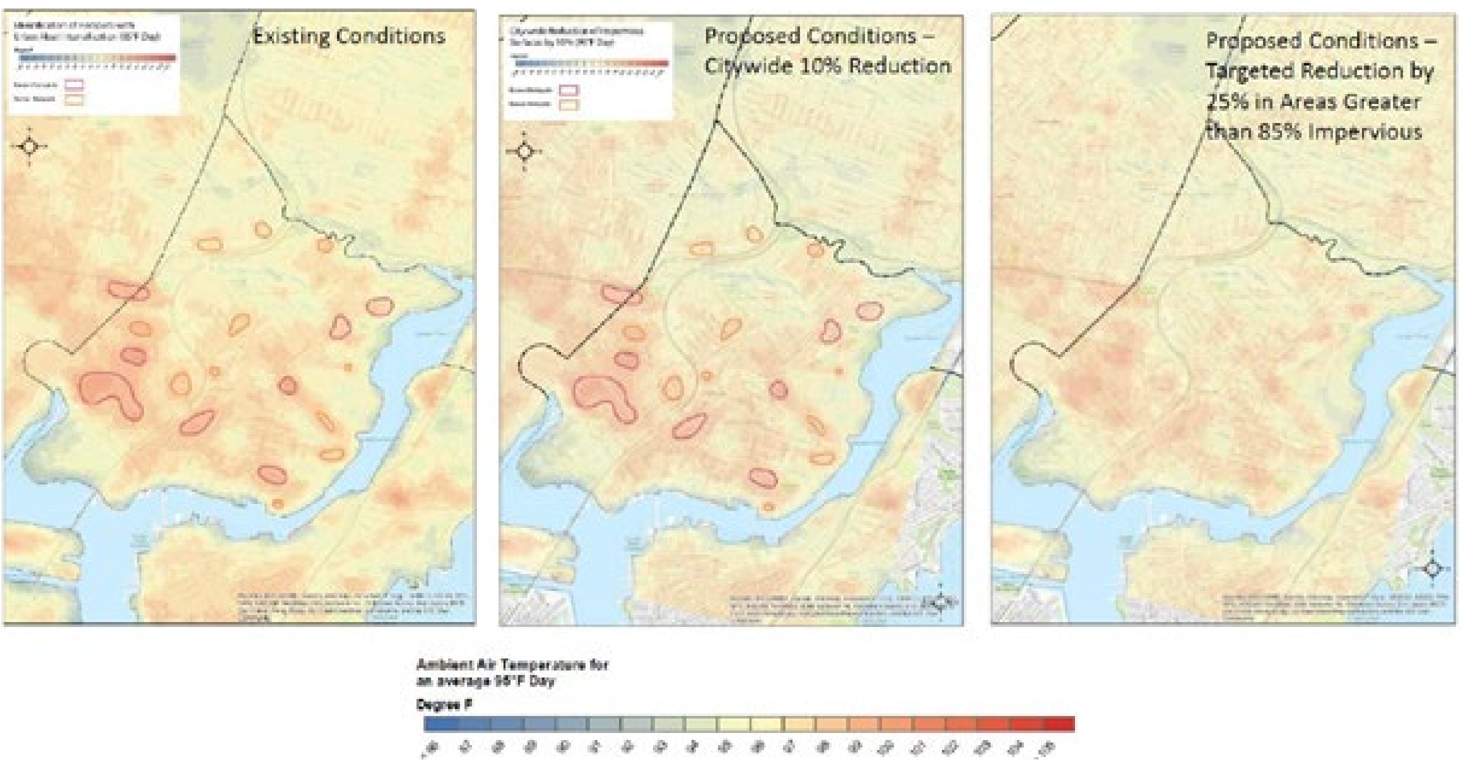
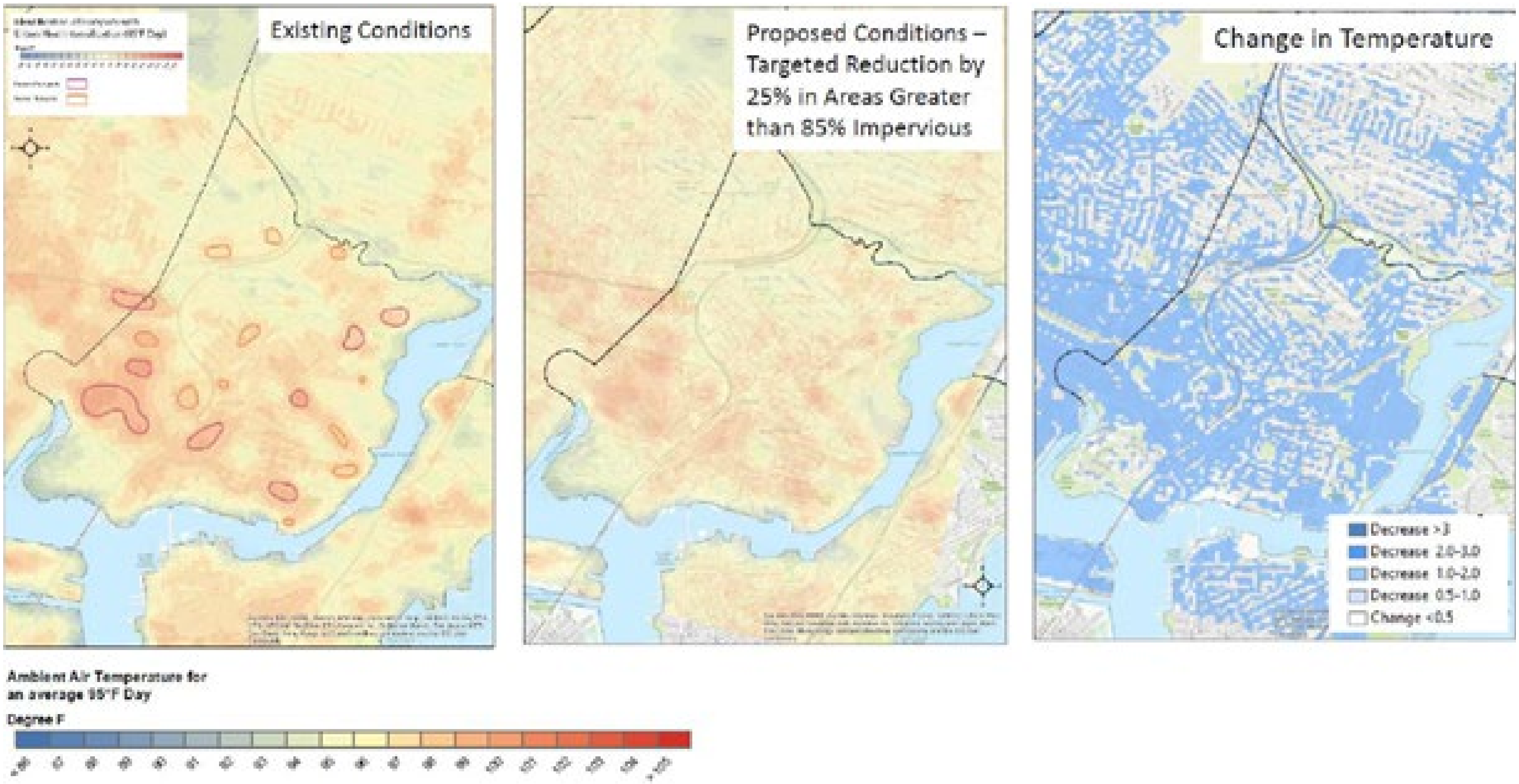


Figure 7: Existing ambient air temperature on a 95° F Day (Left), ambient air temperature on a 95° F Day due to impervious surface reduction on a Citywide scale (center) and in Targeted areas (right)

Cooling Strategies

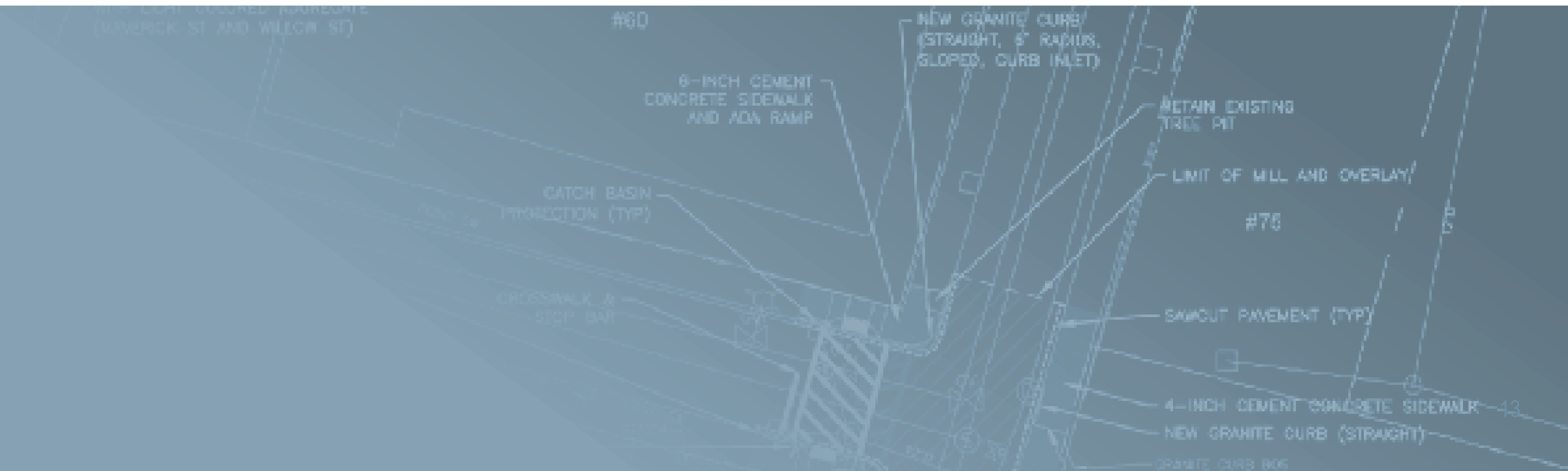
Figure 8. Existing ambient air temperature on a 95° F day (Left), ambient air temperature on a 95° F day due to impervious surfaces reduction in targeted areas (center) and change in ambient air temperature due to impervious surfaces reduction in targeted areas



Design Approach

The UHI analysis identified several priority areas for urban heat island mitigation programming as shown in Figure 6. The pilot "Cool Block" project represents the area bounded by Maverick Street, Highland Street, Willow Street, and Congress Avenue; it was selected for its presence in a priority area, co-benefits in infrastructure and community need, and for having a ready partnership with Boys and Girls Club for public/private trials. The space also has comparatively fewer perceived risks than some of the other priority areas identified (traffic/density, industrial contaminations, regulated resource areas, substantial development, or late-phase infrastructure capital improvements). Co-benefits of the proposed scope include enriching important community spaces around the Boys & Girls Club of Chelsea, fixing sidewalk and roadway surface consistency issues, improving drainage, improving pedestrian safety in crossings and walks, and safety improvements through traffic calming. The project team visited the site on June 17, 2021, to observe site features and infrastructure condition to inform feasibility of pilot mitigation measures.

The pilot design considered the strategies presented in Table 1: reflective roof coating technologies; reconstruction of roadways with light colored aggregates and accent reflective surface treatments; reconstruction of sidewalks with city standard cement concrete sidewalks, ADA compliant ramps, and right-of-way infiltration swales; and additional tree canopy and shade features. These systems addressed community feedback over surface condition, traffic speed/safety, and shading.



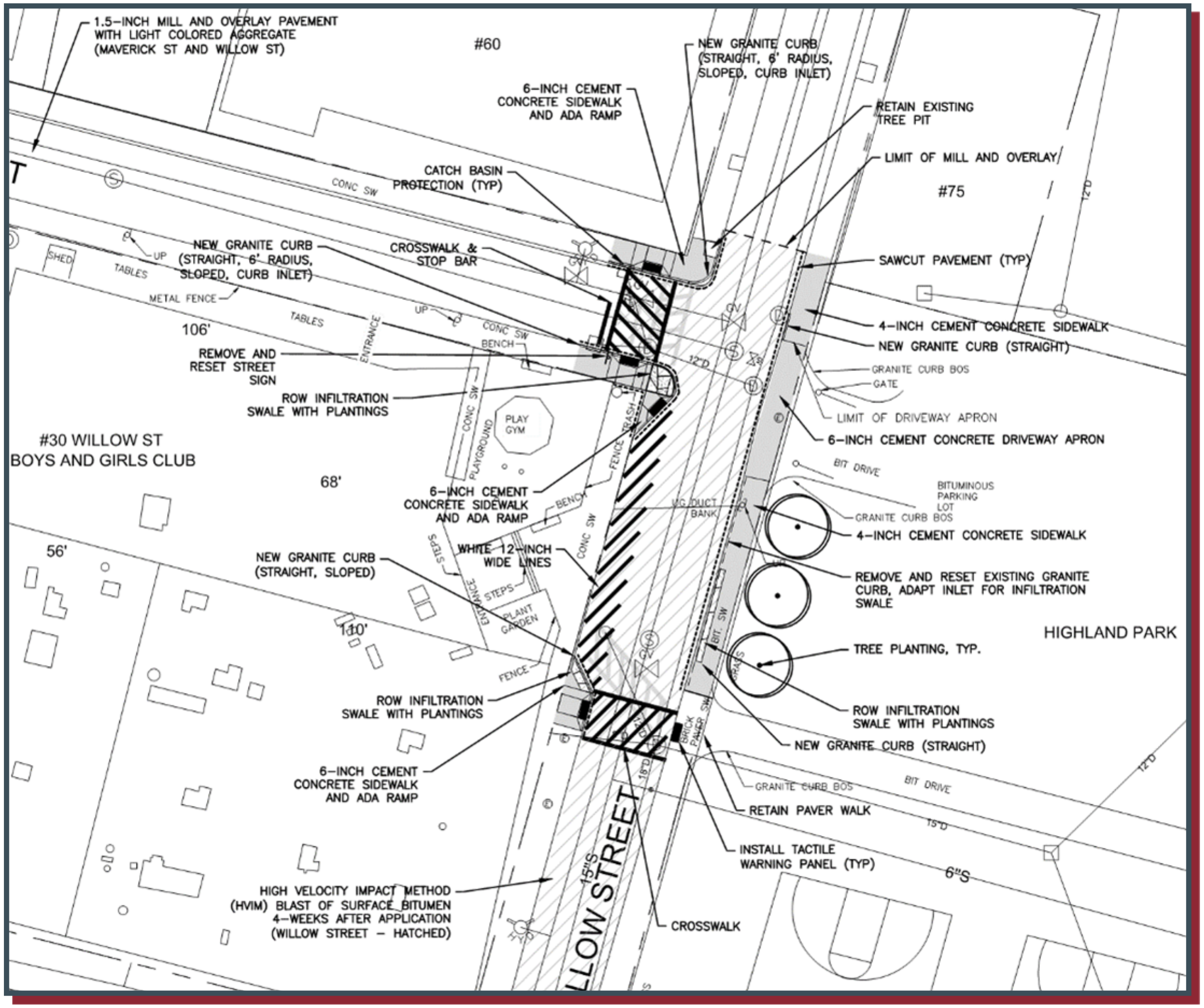
Design Approach

Strategy	Observations/Existing Condition	Proposed Approach & Benefit
REFLECTIVE ROOFS	• The Owner noted the gymnasium of the Boys and Girls Club gets very hot in the summer and is challenging to keep cool. • Heating and cooling expenses are a substantial burden to this organization which runs on donations and has limited resources. • The gymnasium has a dedicated rooftop unit which heats and cools the space. This roof space has comparatively very few rooftop features to complicate application of reflective coatings. • The black rubber EPDM roof was mid-lifecycle in fair condition.	• Reflective roof coatings applied to black EPDM (rubber) roof mid-lifecycle, which is a comparatively low-cost proof of concept. • This roof retrofit scenario is a low barrier to entry (cost) option that might be eligible for application at a high volume of properties in urban heat island target-areas in the City.
INFILTRATION SWALE, TREES AND SHADE STRUCTURES	• The bump-out and corner areas in the project area are subject to stormwater ponding due to grade and catchment issues. • This area gets substantial sun exposure, and no tree canopy cover is available. • Collector drains in Congress Ave and Maverick St discharge to the Massachusetts Water Resources Authority (MWRA) sewer interceptor at Congress St.	• Add infiltration via right of way infiltration swale, reconstruct sidewalks and curbing around these features, and add trees and a shade structure to serve the public using the pick-up/drop-off area, bench, and park area. • Co-benefit of infiltration is reducing wastewater volume to Deer Island Wastewater Treatment Plan and the harbor.
LIGHTER-COLORED PAVED SURFACES	• Pavement surfaces in the space included typical hot mix asphalt (HMA) roadway and sidewalks (mid-lifecycle). • The sidewalks were in poor condition and tree pits were not observed. • The ADA ramps are not marked well in the street, and the ramps do not contain tactile warning panels.	• Reconstruct sidewalks with light colored cement concrete sidewalk in compliance with ADA requirements and code. • Test and try best regionally available, asphalt grade, light-colored aggregates in streetscape HMA mixtures, and to explore efficacy of post-application blast treatments to scour surficial bitumen and quickly expose the light-colored aggregate (aggregate exposure naturally happens by late-lifecycle). • Apply hot mix asphalt pavements with light-colored aggregates in streets then treat half of the work zone with surficial blast treatment to remove surficial bitumen to for side-by-side comparison of treated and untreated systems. • Cement concrete sidewalks naturally have lower albedo than bituminous pavements. Roadway coatings and striping were considered to highlight crossings and pick-up/drop-off areas.

Table 1. Summary of Proposed Strategies for Known Hot Spot (Area 4: Highland Street neighborhood, Boys & Girls Club of Chelsea)

Design Approach

Separate specification for roof coating was prepared. Figure 9 shows an overview plan of the scope of work in the right-of-way.



The design team employed a multi-disciplinary approach, partnering with experienced market vendors and material suppliers, for the development of specification and program requirements. The program sought to test a variety of measures so that design considerations, cost, and efficacy could be reviewed for further application and development in the City of Chelsea.

This effort was coordinated with a "**Cool Block**" initiative underway by the City of Chelsea and their partners which included extensive tree plantings in the Maverick Street and Congress Avenue areas. This pilot will have limited ability to measure impact attributable to individual measures, but may be effective to assess impact of features deployed in-aggregate.

Figure 9. Overview of Design Plan showing improvements for Willow Street and Maverick Street

Commentary on noteworthy design decisions and features are provided below.

Reflective Roof Retrofit Design Considerations

The project team characterized reflective roof approaches, local case studies, and opportunities. Discussions with Boys and Girls Club facility management and owners identified several priorities: the selected system would be maintainable/repairable by local service providers with readily available equipment/materials, warranty expectations were clearly communicable and enforceable, and that the surface would hold-up through typical rooftop access by technicians for maintenance.

The black rubber EPDM roof was mid-lifecycle in fair condition. The team reviewed product selections for extending the life of a roof with these characteristics that could also be delivered broadly by local service providers and be supplied at competitive cost by more than one vendor. After reviewing several treatment schedules, the team identified acrylic roller or spray applied coatings, which are available at low cost, do not require proprietary installation methods, and have been successfully applied nationally to extend roof service life, promote reflectivity, and improve HVAC efficiency. This method is acceptable for a roof in good-condition with a well-draining pitch, such as was observed in the curved roof surface over the Boys and Girls Club Gymnasium.

Road Pavement Materials Design Considerations

This project prioritized maintaining use of hot mix asphalt pavement for roadway surface treatment. Hot mix asphalt is affordably purchased in this region and local public works and construction contractors are experienced in its installation and maintenance. It is repairable to comply with routine buried infrastructure maintenance and it is resilient in freeze-thaw and settlement. Alternative pavement materials exist with naturally lower albedo, such as reinforced cement concrete, but this pilot did not seek to change wholesale from HMA pavement, instead reviewing opportunities for adapting schedule and treatment.

The design effort revealed that there is little practical familiarity with assessing light-albedo pavement mixtures in this region. Albedo is not parameter measured or characterized at regional quarries and aggregate production plants, nor is it specified in MassDOT pavement material specifications which drive much of municipal pavement specification in the region. Weston & Sampson worked with Holcim (previously known as Aggregate Industries), a large regional pavement supplier, to understand regional capacity around light color aggregate pavements and surface treatments.

Three approaches to adapting hot mix asphalt pavement albedo were considered. One approach was to supplement mix bitumen with pigments to effectively change the color of the hot mix asphalt mix. The second approach was to select light-colored aggregate then blast treat to remove surficial bitumen and “reveal” aggregate early in the product’s lifecycle. The final option was painting surfaces to lighten color and promote reflectivity. Pigmented asphalt was abandoned as a measure for application at scale due cost burden and efficacy limitations. At the time of design, typical HMA pavements could be delivered to the site and installed for approximately $100 per ton. Pigmented pavements were estimated to cost approximately $400 per ton for the same limited volume. The production plant cited that pigmenting requires flushing the drum and waste to scour pigmented bitumen after mixing a batch of custom colored mix. This process is time consuming and wasteful. Pigmenting of the asphalt also has a limited ability to achieve a truly light or reflective surface, as a yellow pigment is the lightest offering available.

Curb to curb painting of pavement has been applied in the City and the region in roadways with limited traffic volume. However, painted areas require high maintenance to sustain a consistent cover and reflectivity. The team selected the light-colored aggregate pavement with surficial blast treatment approach for the pilot project.

Approach to Albedo Specification for HMA Pavements

This project aimed to develop solutions that could support municipal-grade applications at cost comparable to regionally available commodity HMA pavements. Mixtures that could be supported by regional suppliers were prioritized. Two approaches to color/albedo specification were identified during design. One was visual comparison of aggregate to graded color scale. The other was to consider laboratory measure of albedo. The second approach would be more comprehensive and representative of true albedo, however, the application and technique are not yet accepted in the industry. Regional quarries do not have the ability for screening and certification of their supply. With the limited project timeline, it would have been challenging to canvass regional facilities and test albedo to specify the region’s best albedo. Therefore, the team worked with Holcim to assess color gradation of quarry stone from their portfolio of regional source quarries. The Wrentham quarry produces aggregates of a “salt” color scale consistency, compared to their Saugus quarry (closest to the City of Chelsea and would otherwise be their default) which produces aggregates of a “pepper” color scale consistency. Weston & Sampson analyzed the color of Wrentham quarry aggregates against a graded color scale and keyed specification around aggregates of color “equal or lighter” in gradation.

High Velocity Impact Method (HVMI) Blast Treatment & Aggregate Size

This method of asphalt treatment blasts surficial bitumen from newly set pavement, effectively “revealing” aggregates early in the asphalt lifecycle. The revealing of aggregates over time is common with HMA pavements but may take until the second half of product lifecycle for aggregates to fully present. Examples of municipal grade blast treatment applications were seen in Europe, but similar applications in the United States for public rights-of-way were not identified by the project team. Service providers that utilized the blast treatment method in private sector applications were identified and consulted during the project development. The volume of service providers and scale of equipment available was found to be limited.

Blast treatment should occur around 5-weeks after pavement application to provide time for sufficient setting of pavement. The team expects that a treated surface will result in a materially different presentation in Willow Street, which will result in a rougher pavement surface for recreational roadway users of small-wheel devices (e.g., skateboards). Top course aggregate gradation was adjusted versus typical MassDOT mix design to boost ratio of 3/8-inch coarse aggregate by around 10% to give a higher volume larger aggregate to promote presentation.

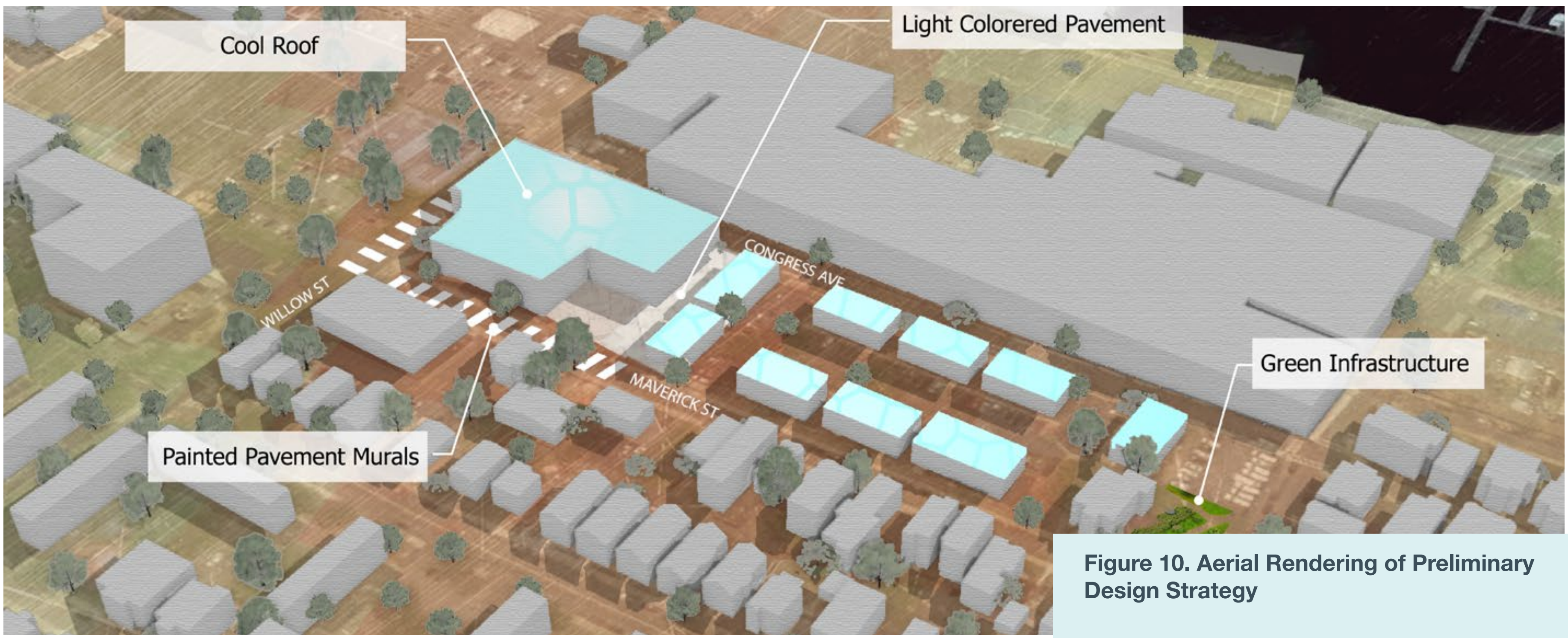


Figure 10. Aerial Rendering of Preliminary Design Strategy

Constructing the "COOL BLOCK"

Bid contract documents were prepared for the public right-of-way contract. Three bids were received for the City of Chelsea's bid project "Urban Heat Island Pilot Program – ROW Infrastructure Improvements, Contract No. 2022-35" on March 31, 2022. This project was bid during a time of escalating construction costs nation-wide. The engineer's estimate for the job was significantly exceeded by bid prices received from contractors. Table 2 provides a breakdown of the engineer's estimated scope and unit pricing, with comparison to the low bid contractor lump sum cost breakdown unit prices.

Costs appear to represent escalated material costs, perceived labor around novelty of some selected treatments, and for a comparatively small job scale in a time of a saturated construction market. The contractor stated that cement concrete and granite curb costs were significantly escalated at the time of bid. The market is subject to escalating hot mix asphalt pavement costs and vehicle expense as fossil fuel costs rise. Costs for milling and pavement appear escalated as portions of specialty subcontractor expense are keyed around day-rate mobilization, so limited scale partial-day operations in a small work zone result in comparatively escalated unit costs.

The City was able to award the construction contract by supplementing grant funding with local resources. The City issued Notice of Intent to Award on April 6, 2022. The City chose not to bid (deferred) reflective roof retrofit improvements at Boys and Girls Club due to funding availability constraints.

Construction Progress

The project constructed curb, sidewalk, and right-of-way infiltration swales in May 2022. This was followed by milling on June 7, 2022 and the top course pavement application on June 16, 2022. Plantings and landscaping were performed on June 23, 2022. Blast treatment of roadway is scheduled for July 14, 2022, and pavement markings will follow.

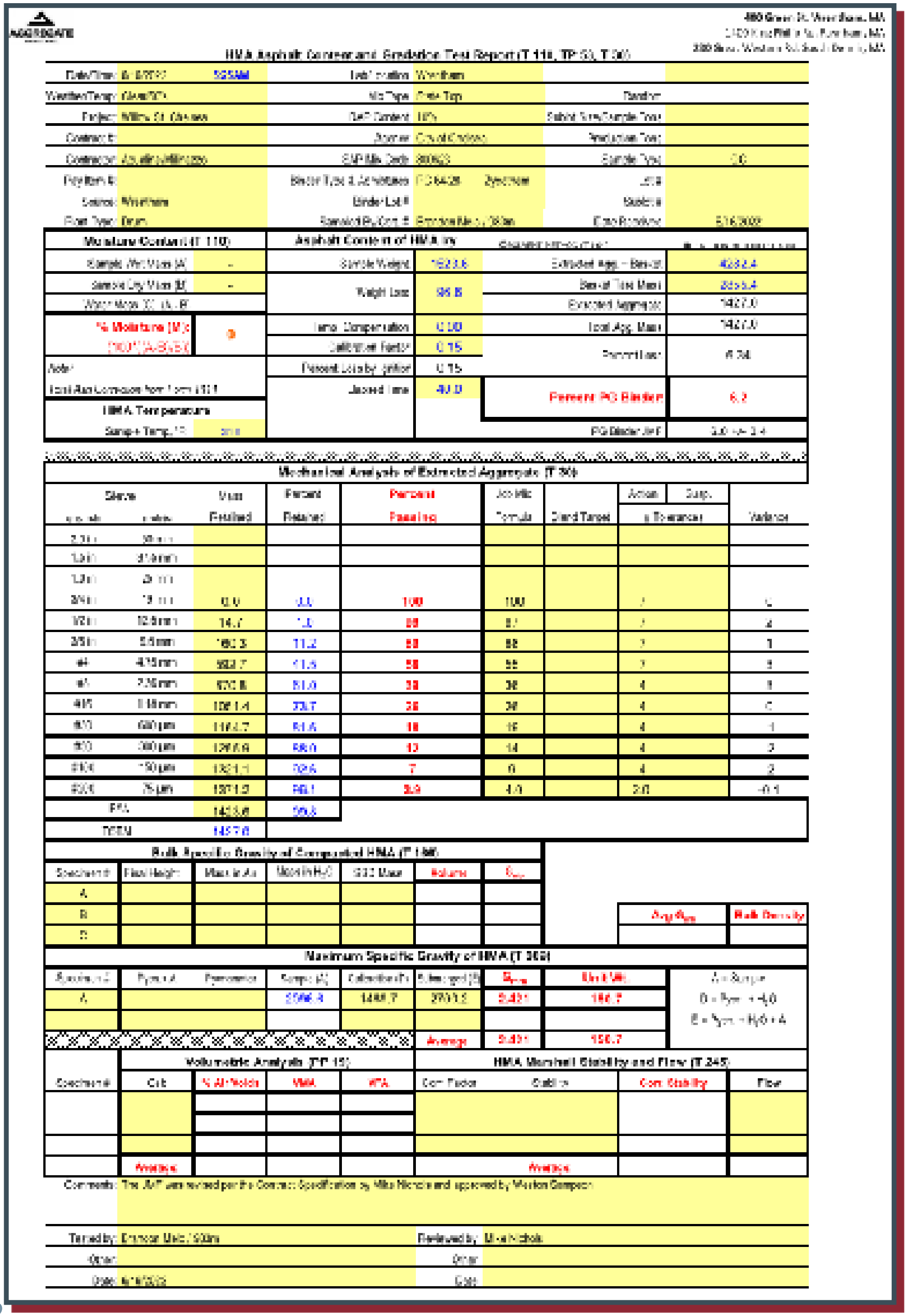
Construction Progress

Item No.	Description	Quantity	Estimated Unit Price	Estimated Total Cost	Actual Bid Value	Variance Value
1	ENVIRONMENTAL PROTECTION					
a	Catch basin protection, per catch basin	6	$120.00	$720.00	$5,000.00	($4,280.00)
2	PAVEMENT REPLACEMENT					
a	Pavement Milling, per sq. yd.	1,630	$11.00	$17,930.00	$25,850.00	($7,920.00)
b	High Velocity Impact Method (HVIM) Blast, lump sum	1	$14,000.00	$14,000.00	$25,000.00	($11,000.00)
c	Pavement with Light Colored Aggregate, per ton	140	$175.00	$24,500.00	$44,800.00	($20,300.00)
3	PAVEMENT MARKINGS					
a	12 inch reflectorized white line (thermoplastic), per lf	420	$5.00	$2,100.00	$4,000.00	($1,900.00)
4	LANDSCAPING					
a	Tree, per tree	3	$750.00	$2,250.00	$1,500.00	$750.00
b	Infiltration Swale w plantings, each	3	$3,500.00	$10,500.00	$1,500.00	$9,000.00
5	CURB AND SIDEWALK					
a	Remove and Reset Granite Curb, per linear foot	65	$60.00	$3,900.00	$10,000.00	($6,100.00)
b	New Granite Curb, Straight, per linear foot	90	$75.00	$6,750.00	$20,000.00	($13,250.00)
c	New Granite Curb, Specialty (Radius, Transition, Inlet), per linear foot	110	$100.00	$11,000.00	$25,000.00	($14,000.00)
d	4-inch cement concrete sidewalk, per sq. yd.	70	$75.00	$5,250.00	$15,000.00	($9,750.00)
e	6-inch cement concrete sidewalk with W.W.M., per sq. yd	100	$95.00	$9,500.00	$25,000.00	($15,500.00)
f	Concrete sealant, per sq. yd.	170	$6.00	$1,020.00	$1,500.00	($480.00)
6	PRICE ADJUSTMENTS					
a	Price Adjustment for Liquid Asphalt used in hot mix asphalt mixtures, where price variance is five (5) percent or greater, per ton	8	$60.00	$480.00	$0.00	$480.00
7	MOBILIZATION					
a	Mobilization (not to exceed 5% other items), lump sum	1	5%	$5,500.00	$10,000.00	($4,500.00)
			Subtotal:	**$115,400.00**	**$214,150.00**	**($98,750.00)**

Table 2: Breakdown of estimated costs compared to low-bid contractor costs

Grade sensitivity of right-of-way infiltration swales required careful management and correction during construction. Infiltration beds had to be re-built by the contractor so that the elevation of the geofabric wrapped crushed stone well was lowered to allow runoff from the gutter into a sufficient depth of topsoil cover in the swale. Aggregate within the well had to be removed and replaced due to incorrect material application. The grade of taper and planter topsoil elevation required care to grade for catchment and pedestrian safety. Planter locations were selected to optimize siting within the sidewalk layout. Tree planting locations were adjusted to improve tree cover distribution and two additional smaller trees were supplied by others for application in spaces under overhead wire, per consultation of the City's arborist (5 trees planted). Plantings were sequenced to follow milling and paving to protect new plantings from heat and spray associated with those processes.

Figure 11. ROW Infiltration Swales, Trees, and ADA Compliant Ramps in Boys & Girls Club Frontage Willow Street


HMA Asphalt Content and Gradation Test Report (T 110, TP 53, T 30)

Mechanical Analysis of Extracted Aggregate (T 30)

Maximum Specific Gravity of HMA (T 209)

Figure 12. HMA Pavement Test Report

Pavement and Gradation Testing

Pavement milling revealed an existing pavement course in some locations and "blowout" of underlying pavement base. The underlying base was a macadam base, which is a legacy pavement base often overlayed by a thin course of hot mix asphalt pavement.

Blowouts were repaired ahead of top course paving. Top course paving was supervised at the production plant by Holcim's Technical Services Manager for Asphalt, Contracting & Liquid Asphalt. The job mix prepared and delivered was in accordance with the specification and of constitution noted in the test reports (Figure 12 and 13).

S H O T

product	7	8	10	12	14	16	18	20	25	30	35	40	45	50	80	120	200
S780	AP		85% min	97% min													
S660		AP		85% min	97% min												
S550			AP		85% min	97% min											
S460			AP	5% max		85% min	96% min										
S390				AP	5% max		85% min	96% min									
S330					AP	5% max		85% min	96% min								
S280						AP	5% max		85% min	96% min							
S230							AP	10% max		85% min	97% min						
S170								AP	10% max		85% min	97% min					
S110										AP	10% max		80% min	90% min			
S70												AP	10% max		80% min	90% min	
Screen Number	7	8	10	12	14	16	18	20	25	30	35	40	45	50	80	120	200
Screen Size (mm)	2.80	2.36	2.00	1.70	1.40	1.18	1.00	0.85	0.71	0.60	0.50	0.425	0.355	0.30	0.180	0.125	0.075
Screen Size (inches)	0.111	0.0937	0.0787	0.0661	0.0555	0.0469	0.0394	0.0331	0.0278	0.0234	0.0197	0.0165	0.0139	0.0117	0.007	0.0049	0.0029

Figure 13. HMA Product Cost Matrix

Blast Treatment Cost Estimation

The blast treatment subcontractor notes that they will use Blastrac products. A video animation of the shotblast process available online through Blastrac's website. (https://www.blastrac.com/machines/shot-blasting)

The subcontractor will use an attached dust collector module. They will employ 20" and 30" blasting machines and 330 or 390 steel shot.

Next Steps / Future Work

The **"Cool Block"** serves as a proof-of-concept for modeling urban heat, identifying heat mitigation strategies that are informed by the community, and testing and implementing new strategies. A key part of climate resilience is monitoring, so the work continues in the City of Chelsea, as well as with key stakeholders and partners of this project.

Holcim

Holcim (previously known as Aggregate Industries) is a large regional pavement supplier, and plans to use this project area as a pilot study and as an evaluation opportunity for nation-wide clients considering similar urban heat applications.

C-HEAT Planned Summer 2022 Work

Funded by Barr Foundation and in collaboration with GreenRoots, the C-HEAT team will continue monitoring temperatures in key neighborhoods in the City of Chelsea with a focus on areas where cooling interventions have been implemented or are planned. C-HEAT will install ambient and surface temperatures sensors to record data hourly in Summer 2022 and Summer 2023, take instant surface temperature measurements on hot days, and analyze land surface temperature data from satellites (e.g., Sentinel and Landsat 8 satellites at 10 and 30 m resolution).

<u>Results will be shared with the City of Chelsea. Proposed locations for monitoring include the following:</u>

1. **"Cool Block" at Maverick, Willow, Highland and Congress Streets (<u>Figure 14</u>)**
2. **Bellingham Sq. & Bosson Playground (<u>Figure 15</u>)**
3. **Quigley Park (<u>Figure 16</u>)**

Legend

Ambient Sensors

Surface sensors (envloggers and/or handheld sensors)

Figure 14. "Cool Block" at Maverick, Willow, Highland and Congress Streets

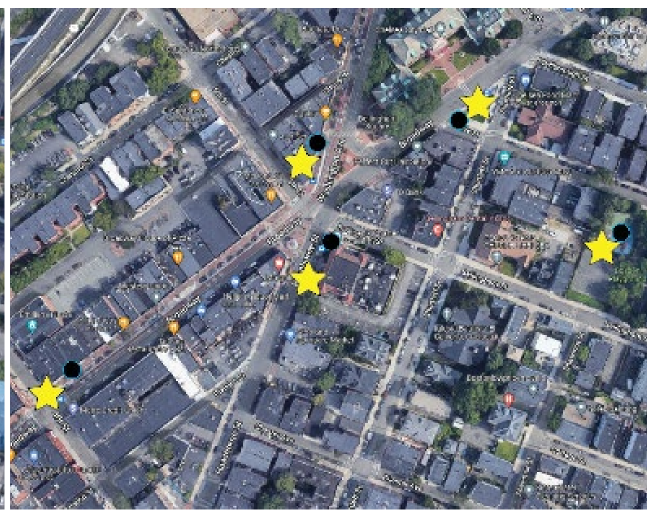


Figure 15. Bellingham Sq. & Bosson Playground

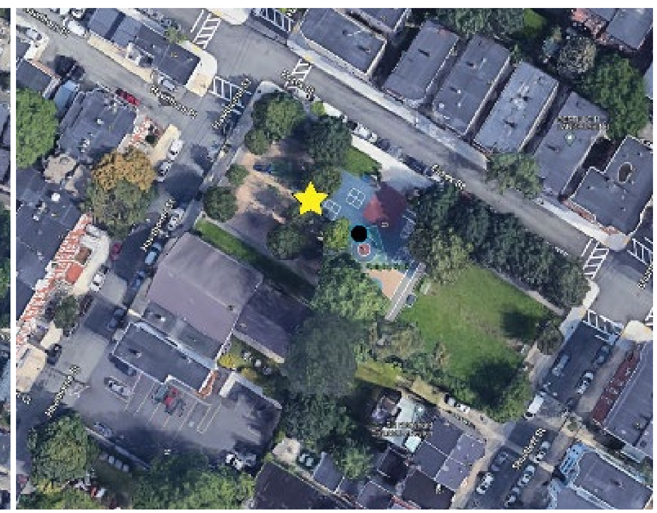


Figure 16. Quigley Park

Figure 19: Boston Society of Landscape Architects "Cool Block" Charette

Proposed Locations

In areas where interventions are planned, measurements will provide baseline temperatures to compare over time.

Additionally, during Summer 2022, data will be used to evaluate the impact of cooling interventions on temperature metrics around the "Cool Block".

The table below details monitoring location and sensors that will be installed around the "Cool Block".

Location	Intervention	Temperature Measurements			
		LST (satellite)	ST (Envlogger)	ST (hand-held)	Ambient
Willow St. sidewalk	Lighter-colored paved surfaces	☑	☑	☑	
Maverick St. & Congress Ave.	Tree plantings	☑	☑	☑	☑
Willow St.	Crosswalk paint	☑	☑	☑	
Highland St. empty lot	Temporary shade	☑			☑
Boys and Girls Club	Reflective roof	☑	☑		☑
Cool block overall	All	☑			

LST = land surface temperature from Landsat 8 satellite, ST = surface temperature

Table 3. Monitoring locations and sensors around the "Cool Block"

Limitations

The Urban Heat Island (UHI) analysis and heat mitigation strategies presented in this report were informed by the information available at the time of this study, which included information provided from the City of Chelsea, C-HEAT, and MAPC; studies performed as part of this study; visual observations made at the times and locations documented in our site visit; documented input from the community and key stakeholders; and the projected impacts of extreme heat analyzed by others.

The information and conclusions presented within this report are not intended as final opinions and should continue to be vetted with experts in the field, with updated climate projections. Within the limitations of scope, schedule, and budget, our services have been executed in accordance with the generally accepted practices in this area at the time this report was prepared. No warranty, expressed or implied, is given.

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