City of Newark

Urban Heat Island Assessment

Prepared for the
City of Newark Environmental Commission
by
Sustainable Jersey and the
Sustainability Institute, The College of New Jersey

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(rev 2/15/2018)

About this project

This report identifies urban heat islands in the City of Newark, using surface temperatures obtained from the US Geological Services (USGS) Landsat 8 data, and converted into digitized maps by Sustainable Jersey and the Sustainability Institute of The College of New Jersey. The report posits the contributing source(s) of the heat islands and offers suggested cooling strategies for mitigating the effects. The lessons learned in the mapping and assessment of heat islands in this pilot project will be used by Sustainable Jersey and the Sustainability Institute at The College of New Jersey to develop a similar process for inclusion in the Sustainable Jersey municipal certification program.

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Newark Urban Heat Island Study and Mitigation Action Plan

The City of Newark is the largest city in New Jersey with over 278,000 residents. It is a dense urban environment with approximately 11,500 people per square mile, and includes a sizable downtown, the largest port in the northeast and one of the busiest airports in the country. Like other post-industrial cities there are many factories, warehouses, and surface parking lots as result of industrialization and slum removal. The city is also home to a large socially vulnerable population with close to 30% of the residents living in poverty. All of these characteristics are important in assessing the impacts of climate change on the city, particularly extreme heat and urban heat islands.

Many areas of Newark experience above average temperatures in the summer (and winter) due to urban heat islands (UHI).[1] UHI is primarily caused by the absorption of solar radiation by large amounts of dark surfaces (principally buildings and asphalt), and a lack of vegetation, particularly shade trees. In the summer, UHIs have caused extremely high temperatures resulting in heat-related illnesses such as heat cramps, heat exhaustion, heat stroke and even death[2]. Warm air can also carry a higher concentration of pollutants, leading to an increase in asthma rates and other respiratory diseases. Further, UHI requires more energy to cool buildings, which in turn may cause additional greenhouses gasses to be emitted, exacerbating climate change. This assessment identifies UHIs in the City of Newark through surface temperature mapping and offers a menu of mitigation strategies to "cool" the city. Mitigating UHI is critical for improving public health and the general quality of life in Newark.

There have been a number of studies about UHI in Newark of which this report builds upon. In 2000, Artigas et al published *Asthma Distribution patterns and their relationship with the urban landscape and social conditions in Newark NJ*, which studied the correlation of asthma rates to UHI in Newark. In 2005, Rosenzweig et al, published *Characterizing the urban heat island in current and future climates in New Jersey*, which described and compared UHI in Newark and Camden, NJ, and discussed the implications of climate change on UHI. That paper was followed up with *Mitigation of the heat island effect in urban New Jersey* by Solecki et al (same authors), which discussed various mitigation strategies and used CITYgreen, a GIS computer model to evaluate various interventions and their impact on UHI. More recently, the Rutgers University Edward J. Bloustein School of Planning and Public Policy's Environmental Analysis and Communications Group prepared a document for discussion purposes called *Mapping Analysis for ICC 7-6* as part of the of the Newark Resiliency Action Planning process. This document mapped many of characteristics of the city related to resiliency including aspects that may contribute to UHI such as impervious surfaces, tree canopy, census information about vulnerable populations, and emergency response agencies. Land surface temperatures were not mapped in the report.

Approach

For this study, Landsat 8 thermal imagery was used to develop Land Surface Temperature (LST) maps. While thermal imagery/LST maps are not a comprehensive (or perfect) way to measuring the UHI effect, using them is one of the best available standards due to fact the imagery is readily available through the USGS and the maps can be easily used to compare the surface temperatures of the city to other

[1] http://www.nytimes.com/2011/07/22/nyregion/newark-is-hotter-than-its-neighbors.html
[2] https://www.osha.gov/SLTC/heatstress/heat_illnesses.html

communities in the region, as well as to determine hot spots within the city. Using ambient air monitoring stations on the other hand, can sometimes provide variation in temperatures between communities, but due to the limited number, don't show variation within the city. Two other approaches would be to have many temperature monitors throughout the city or to use handheld devices and take temperature measurements during the same period of time throughout the city. However, both of these other approaches would require more resources and were beyond the scope of this study.

Methodology

The land surface temperature map was created by first downloading the Landsat 8 imagery from USGS's Earth Explorer. Landsat 8 consists of 11 spectral bands that measure different wave lengths, two of which are thermal.[3] These two thermal bands along with the NDVI (Normalized Difference Vegetation Index) were used to determine surface temperature. It should also be noted that Bands 1 through 9 are sensed at 30-meter resolution while Bands 10 and 11 are sensed at 100 and then down sampled; therefore, it is difficult to pinpoint smaller sources of heat such as smaller single family homes as opposed to larger facilities; though, if there is a concentration of small sources it does become noticeable. The image selected for this study was taken on June 25th, 2016 at 3:39 pm because it represented a typical summer day and had little cloud cover. The Band 4 (red) and Band 5 (infrared) data were processed to create an NDVI layer and then combined with Band 10 & Band 11 (thermal Infrared) using a series of calculations to create a thermal infrared image with temperature values in Celsius. Finally, we classified the temperature values in 2-degree intervals ranging from 24 to 39 degrees Celsius and used a typical thermal blue to red color ramp in order to visualize the temperature gradient.

Results

Based on an assessment of the processed Landsat 8 thermal imagery taken on June 25th 2016 at 3:39 pm, Newark experiences average surface temperatures of approximately 6 degrees Celsius (10 degrees Fahrenheit) higher than its suburban neighbors and 12 degrees Celsius (20 degrees Fahrenheit) higher than a rural forested community in the nearby Highlands region. Within the city, the difference in temperature can range up to 8 degrees Celsius (15 degrees Fahrenheit) between some of the larger parks and the various hot spots. These readings are similar to the results in *Characterizing the urban heat island in current and future climates in New Jersey,* and confirm the existence of heat islands within the city. According to the historical record, the air temperature high on June 25th, 2016 in Newark, NJ was 82 degrees. According to the surface temperature map, the approximate average *surface* temperature was 95 Fahrenheit – highs were approximately 103 degrees.

Identifying Hot Spots in Newark

While Newark as a whole experiences higher than average temperatures compared to other communities in the region (See Figure 1), there are certain areas within the city that have even higher temperatures (See Figure 2), known as urban heat islands, or referred herein as "hot spots" due to the report's site-specific analysis. The hot spots include surface temperatures over 100 degrees Fahrenheit (dark red) on the day measured. This temperature was chosen as a threshold for identification because

[3] https://landsat.usgs.gov/what-are-band-designations-landsat-satellites

it represents a level of heat that shows concentrations of UHI that are not only hot locally, but also increase the temperature of the surrounding areas and can serve as priority targets for mitigation.

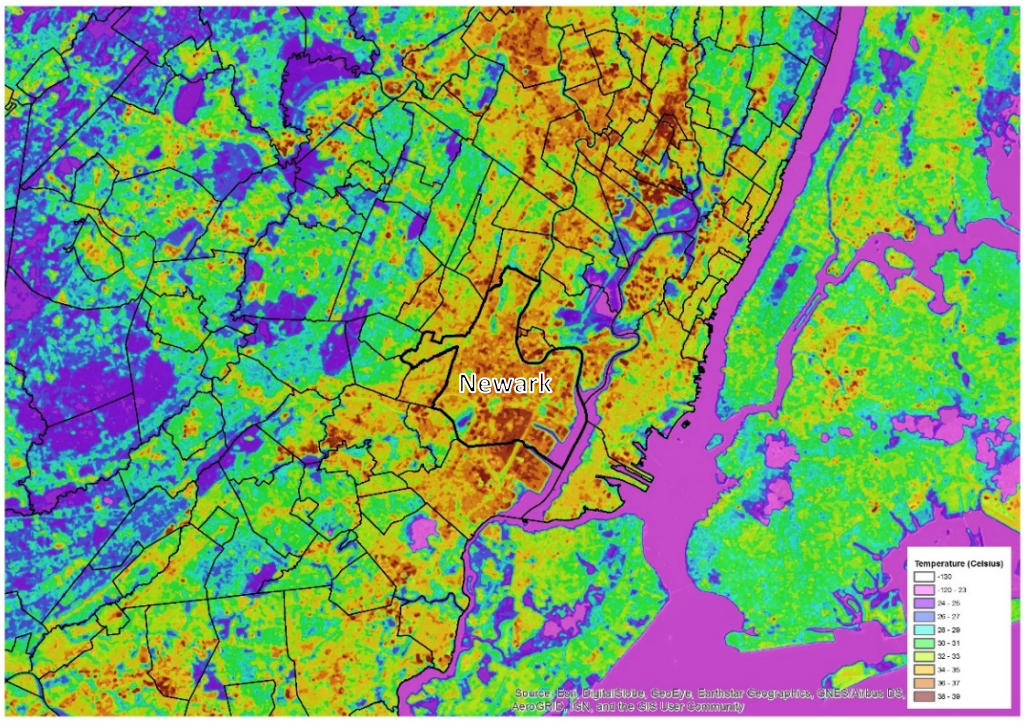
This reports profiles some of the most notable hot spots, or hot spot clusters, in the city, with brief descriptions. The hot spots are numbered throughout the city (Figure 2) and correspond to profile numbers below, and further in the report. It is important to keep in mind there are many other hot spots throughout the city that should also be considered for mitigation. These can be viewed on Sustainable Jersey's **New Jersey Heat Island Map**.

Newark Hot Spots

1. Newark Schools Stadium and Kasberger Field
2. University Hospital
3. 60 Lister Ave
4. Central High School / Nat Turner Park and American History High School
5. Edison Parking
6. South Ironbound
7. North Ironbound Cluster
8. Waterfront Cluster
9. Lower Clinton Hill / South South Broad Street Cluster
10. Newark Airport
11. Dayton/Weequahic
12. Port Newark

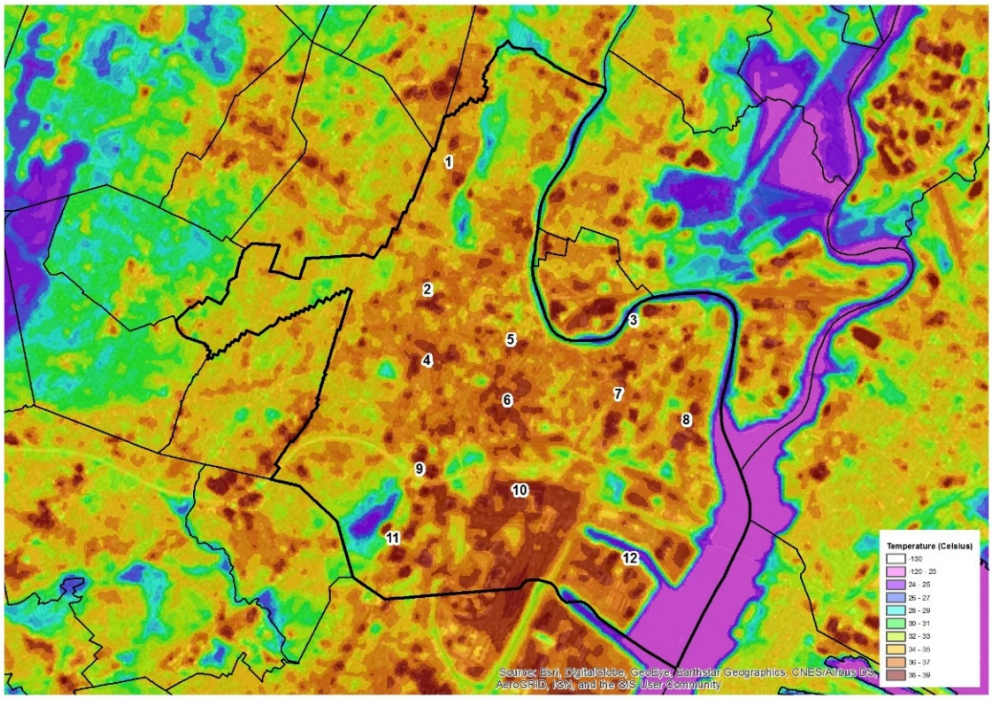
The above twelve hot spots are also identified on vegetation and social vulnerability maps (Figures 3 and 4). These maps are important first steps in understanding potential cooling strategies and prioritizing projects to mitigate (reduce) the heat. For example, if there is no vegetation around a hot spot, shade trees could be an effective way of reducing the heat. A site inspection would reveal more details about existing physical conditions and opportunities for cooling the site. The social vulnerability maps are also important because some populations (children and seniors) are higher health risks during extreme heat, and low-income residents may not be able to afford (or install) air conditioning in their residences. Cooling strategies should be prioritized for these social vulnerable populations.

Maps depicting the hot spots, socially vulnerable populations and vegetation are shown on the following pages.



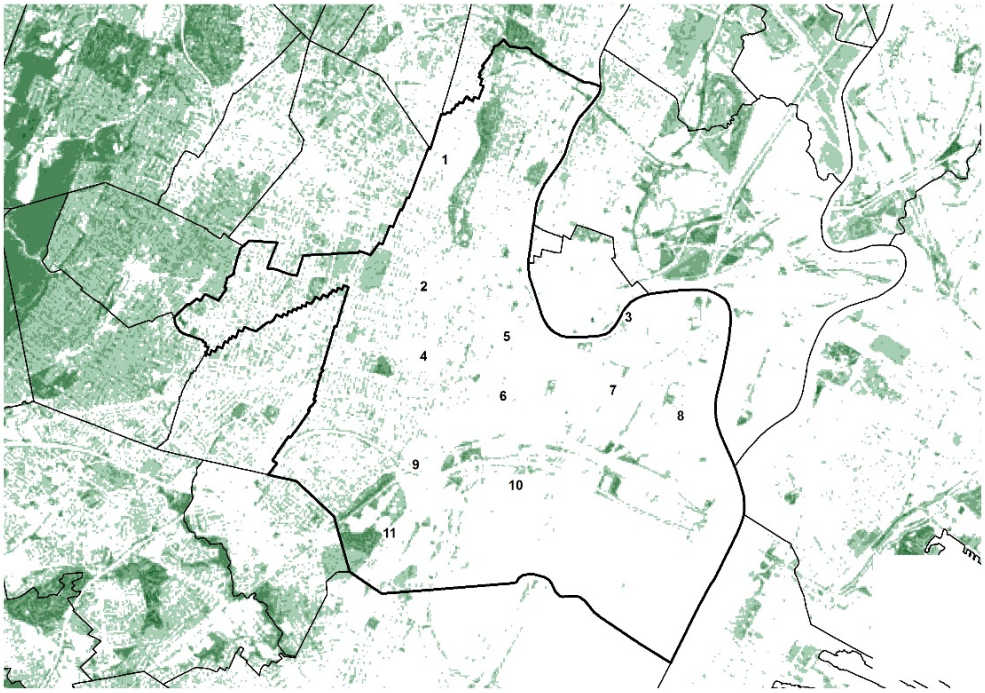
Source: USGS Landsat 8 Thermal Infrared

Figure 1. Surface Temperature of the Newark area



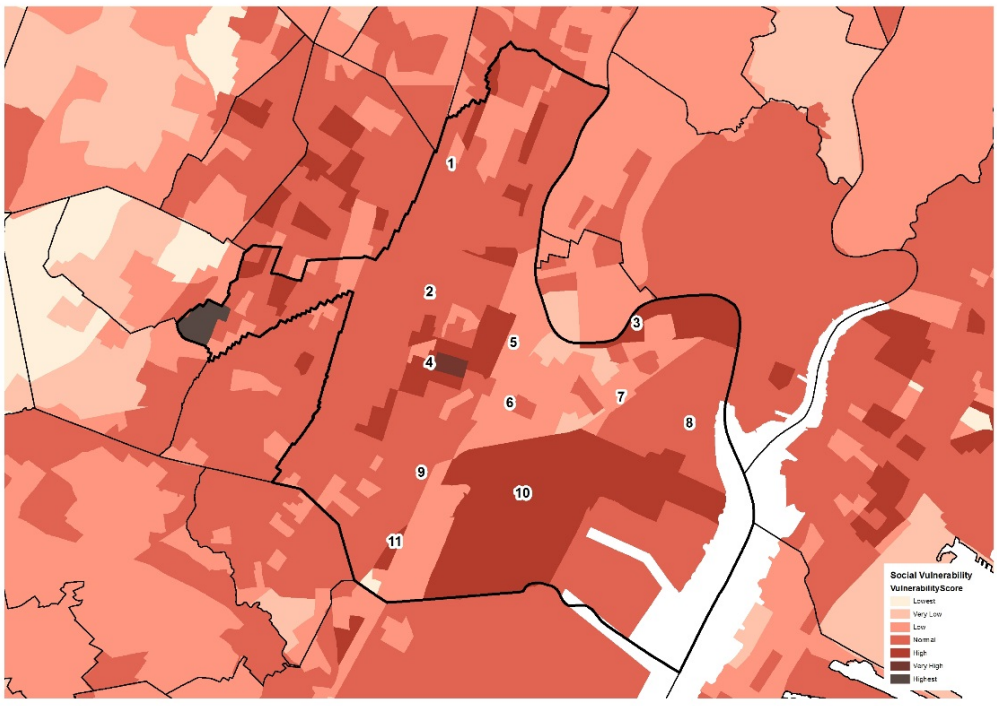
Source: USGS Landsat 8 Thermal Infrared

Figure 2. Surface Temperature of Newark (The hotspot numbers correspond to the number on the citywide map.



Source: USGS Landsat 8 Thermal Infrared

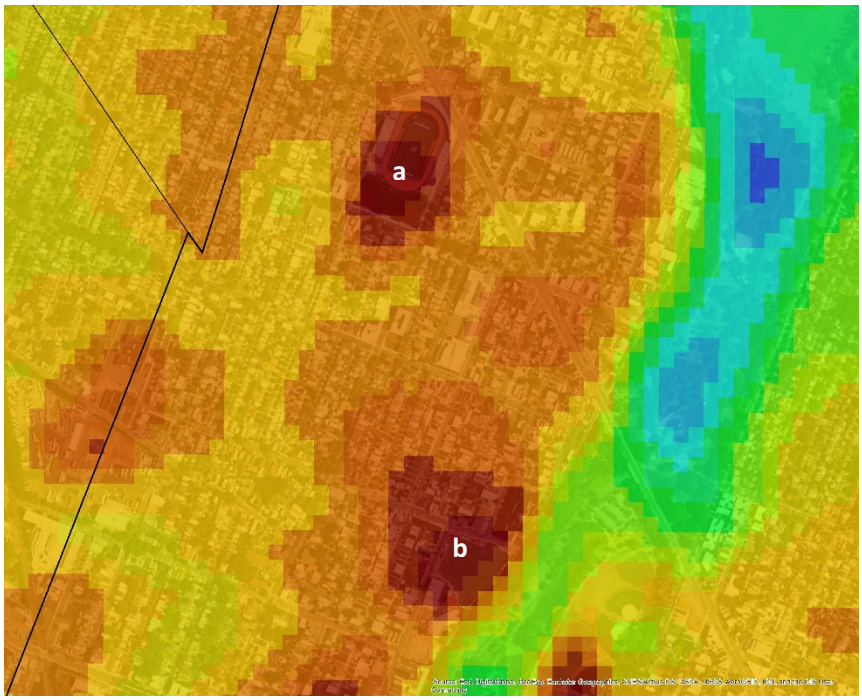
Figure 3. Normalized Difference Vegetation Index (NDVI) Map of Newark, NJ (Shows vegetation levels)



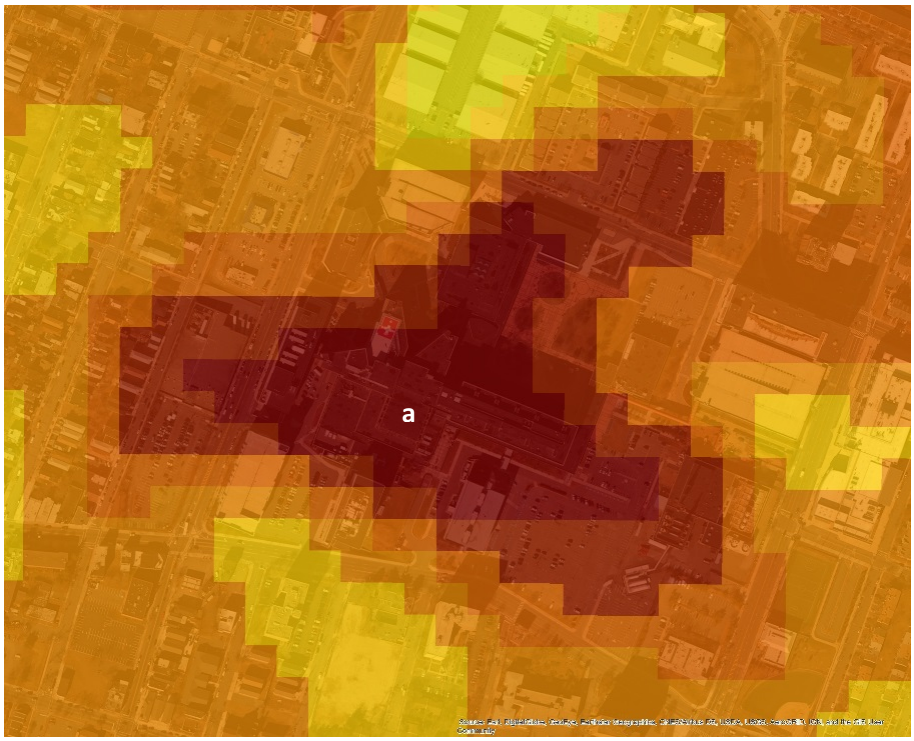
Source: www.sovius.org

Figure 4. 2010 Social Vulnerability (Social Vulnerability Index [SoVi], Block Group)

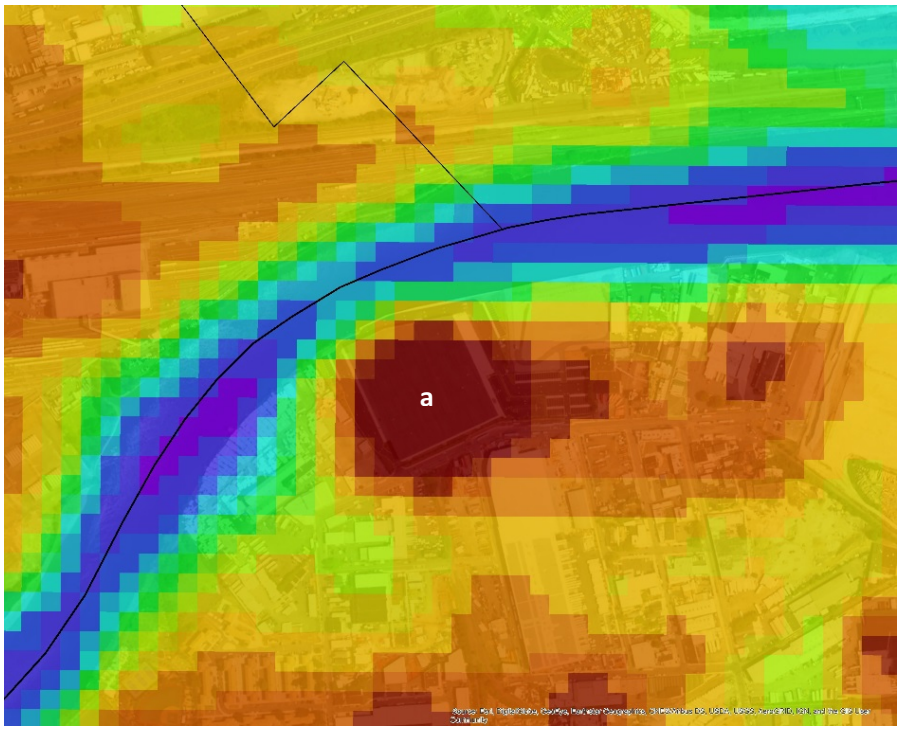
1. Newark Schools Stadium and Kasberger Field - The athletic fields (a) Newark Schools Stadium (135 N 10th Street) and (b) Kasberger Field (415 N 5th Street) are two of the hottest spots in northern Newark. They both are AstroTurf fields.



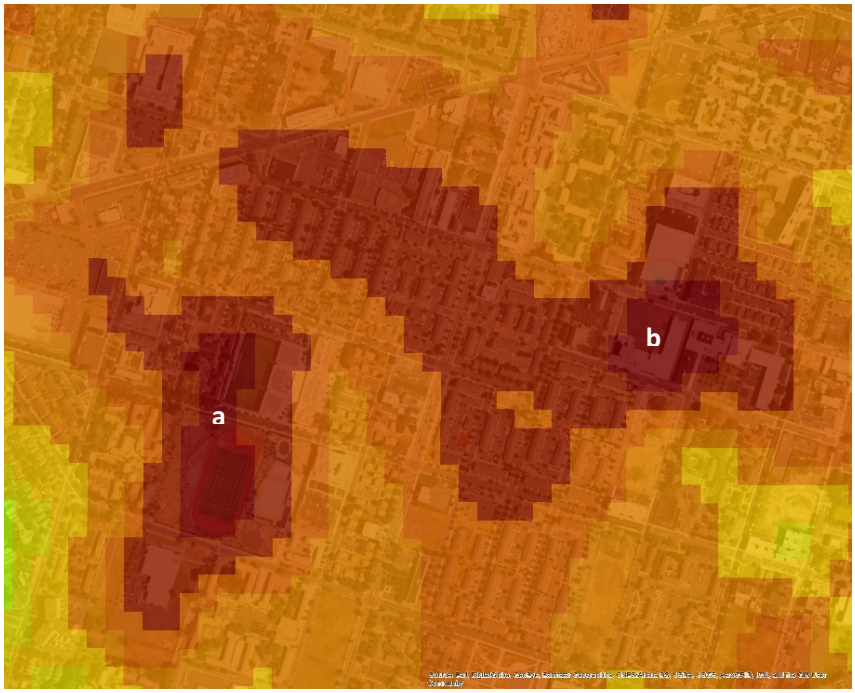
2. University Hospital - Perhaps one of the largest buildings in Newark with a dark roof, the (a) University Hospital (150 Bergen Street) creates the most noticeable hot spot in the city from a single building.



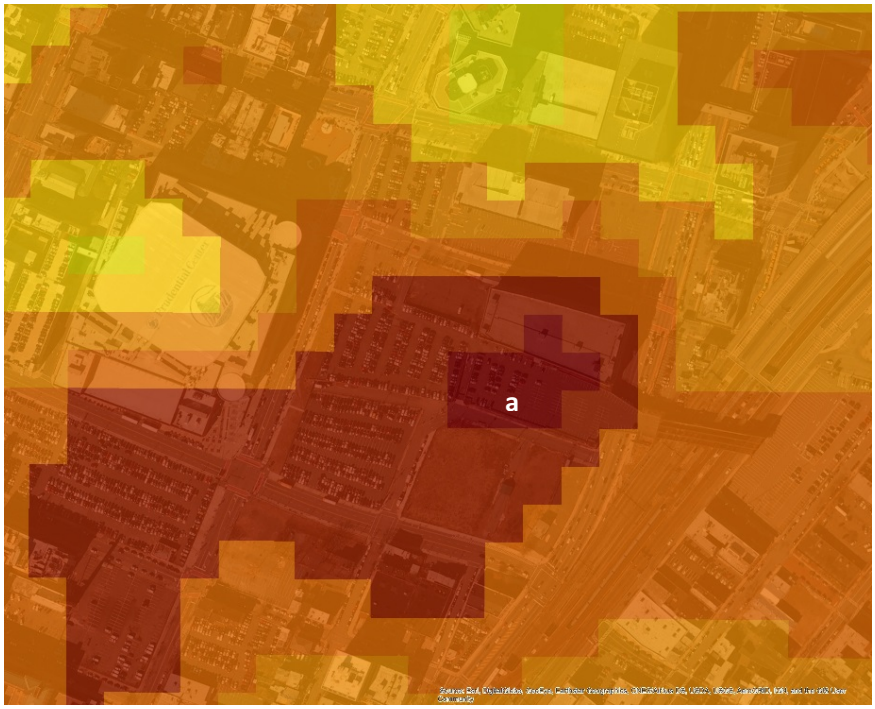
3. 60 Lister Ave - Previously the Diamond Alkali superfund site, the property was recently remediated and is now a giant warehouse with a dark roof and parking lot (a). It is also one of the larger buildings in Newark.



4. Central High School / Nat Turner Park and American History High School - Both high schools show up as hot spots. Though in the case of (a) Central High School (246 18th Ave) it's likely that the heat is primarily coming from the two adjacent synthetic turf fields. In the case of (b) American History High School (74 Montgomery Street), the heat appears to come from the parking/asphalt play area and some of the neighboring roofs and parking lots. This area also happens to be one of the most socially vulnerable areas in the city (See Social Vulnerability Map).

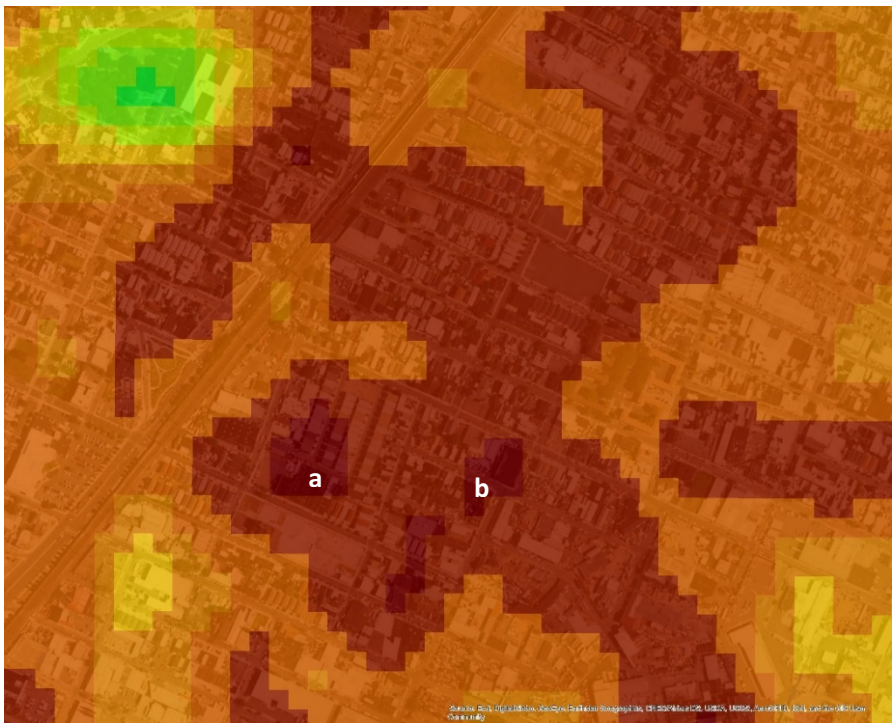


5. Edison Parking – This is currently a downtown surface lot owned by Edison Properties (81 Edison Place). This parking lot is slated to become the new Mulberry Commons (Formally referred to as Triangle Park), which will include a large park and a new apartment building with a partial green roof.[4]

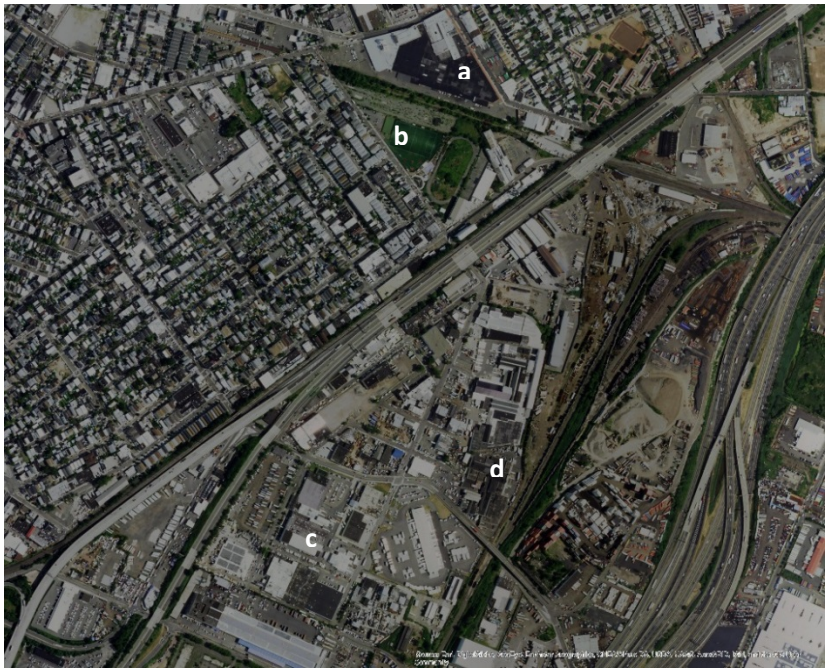


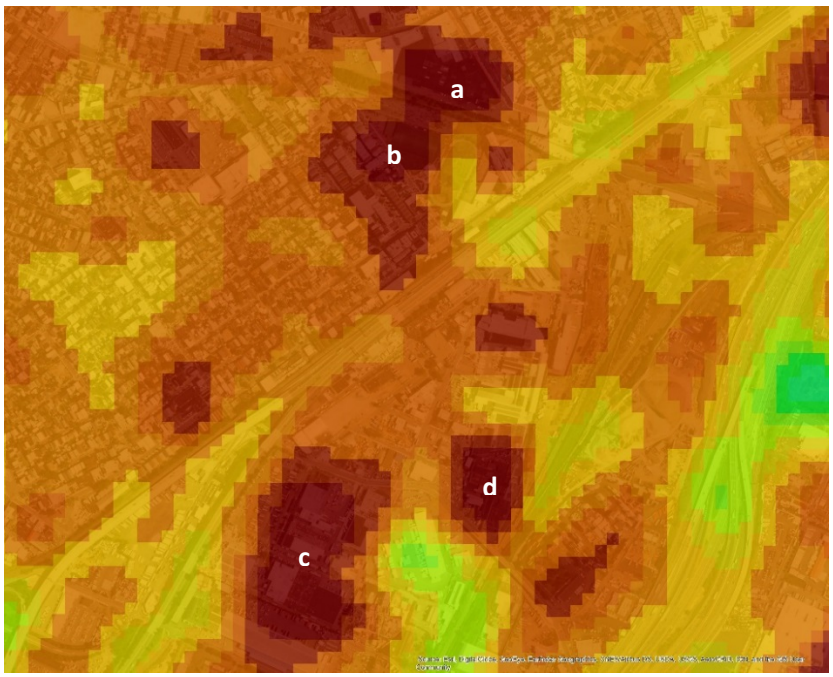
[4] http://www.nj.com/essex/index.ssf/2017/01/this_newark_park_is_getting_a_major_makeover.html

6. South Ironbound - While there are several mid-sized buildings in the neighborhood with dark roofs such as (a) Onyx Tile & Mosaic (488 Mulberry Street) and (b) Ecua Hanivar Body Shop (218 Thomas Street), the whole area appears to be a hot spot due to lack of vegetation and smaller buildings with dark roofs.

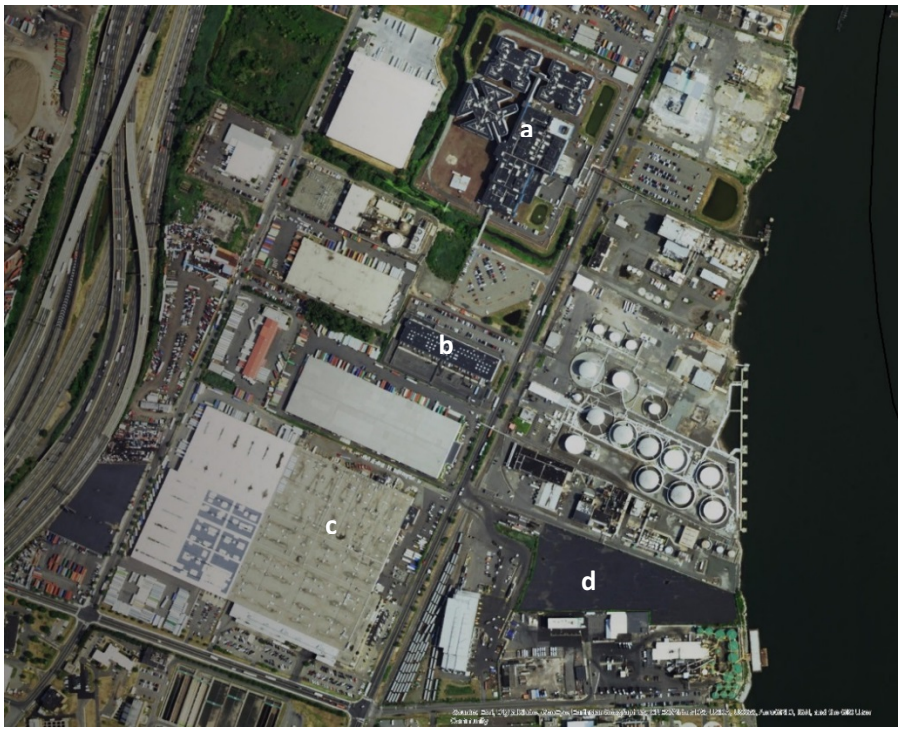


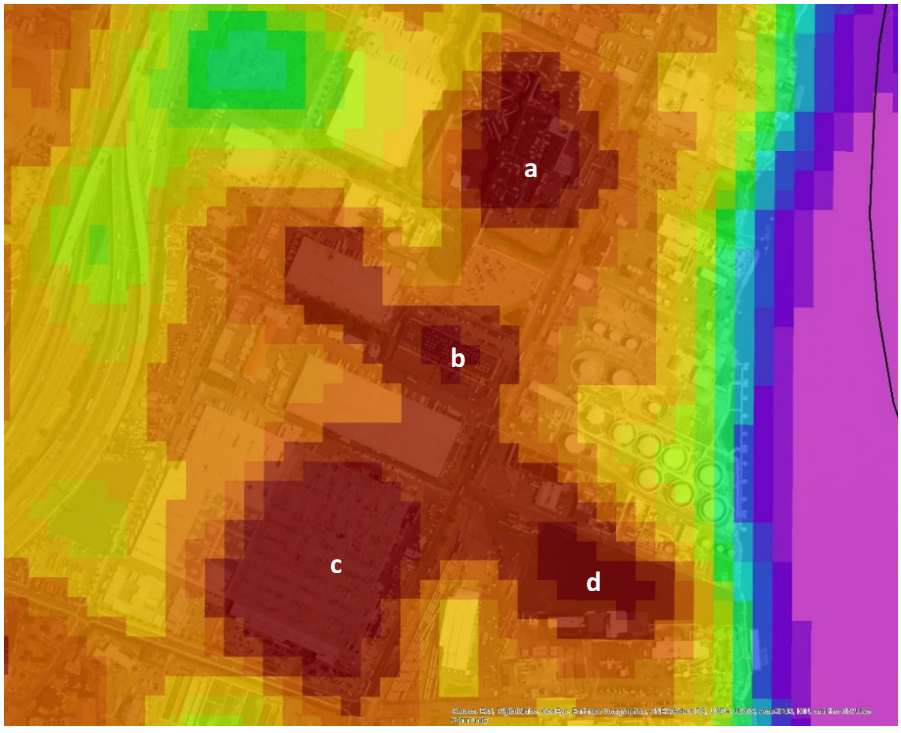
7. North Ironbound Cluster - This cluster of hot spots includes an industrial facility at (a) 425 Ferry Street and (b) two AstroTurf fields at the Ironbound Recreation Center in the north, and two industrial facilities, (c) 74 Avenue L and (d) 357 Wilson Avenue in the south.



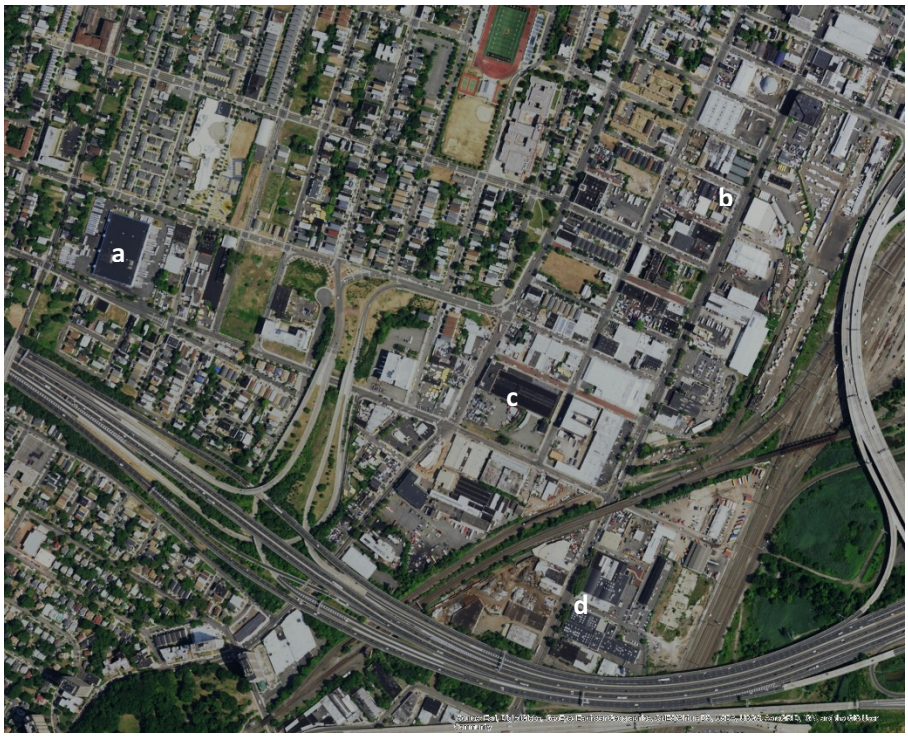


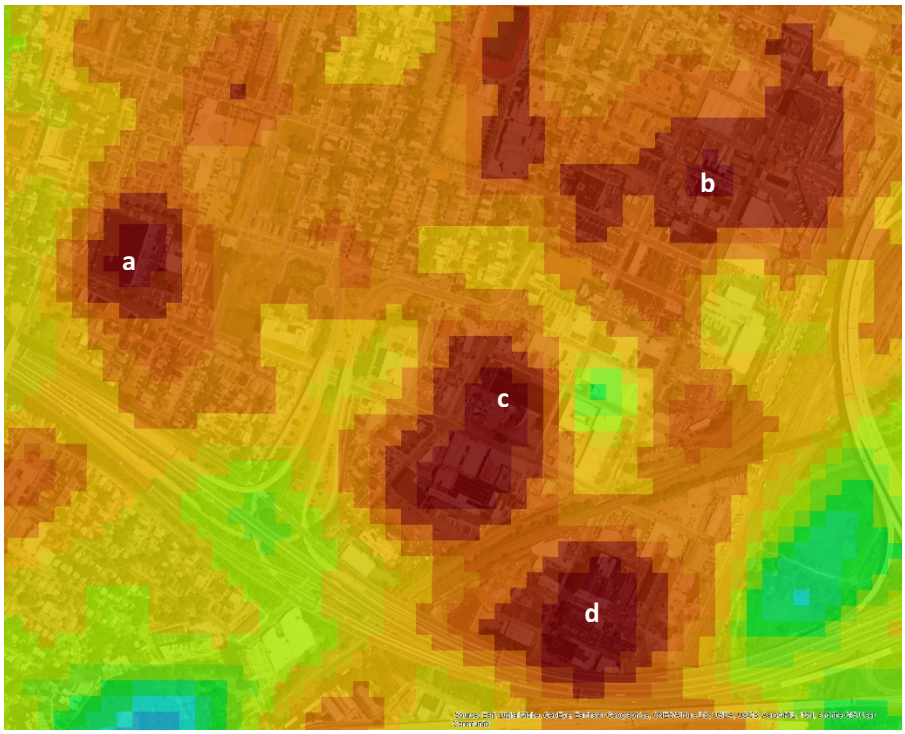
8. Waterfront Cluster - There are a number of buildings on the eastern waterfront of Newark that appear to be hot spots. These facilities include the (a) Essex County Correctional Facility (354 Doremus Avenue), (b) Delaney Hall (451 Doremus Avenue), (c) Newark Bus Complex and (d) DART (Doremus Avenue Recycling and Transfer) complex.



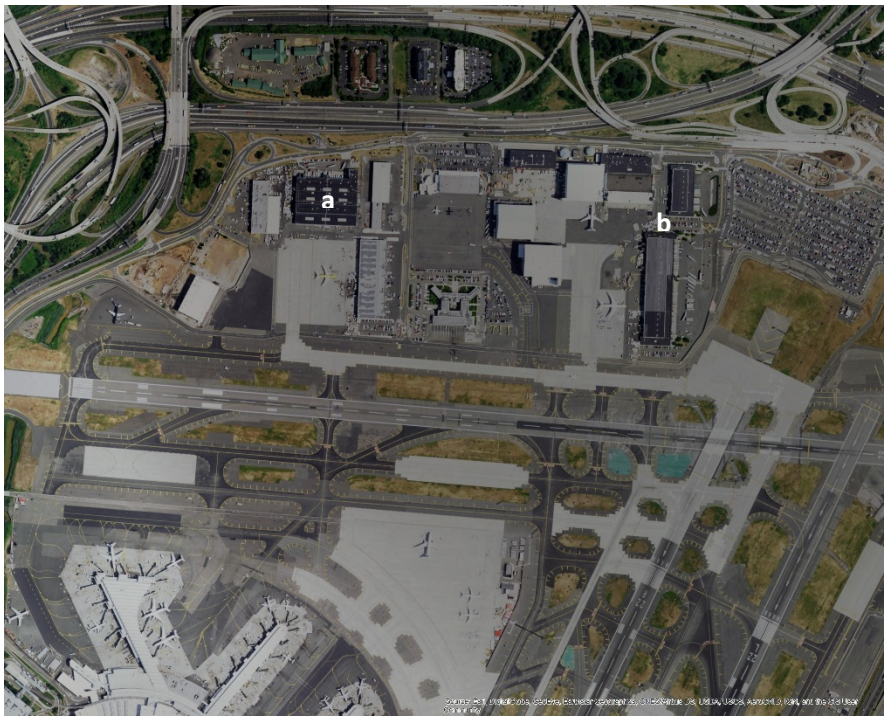


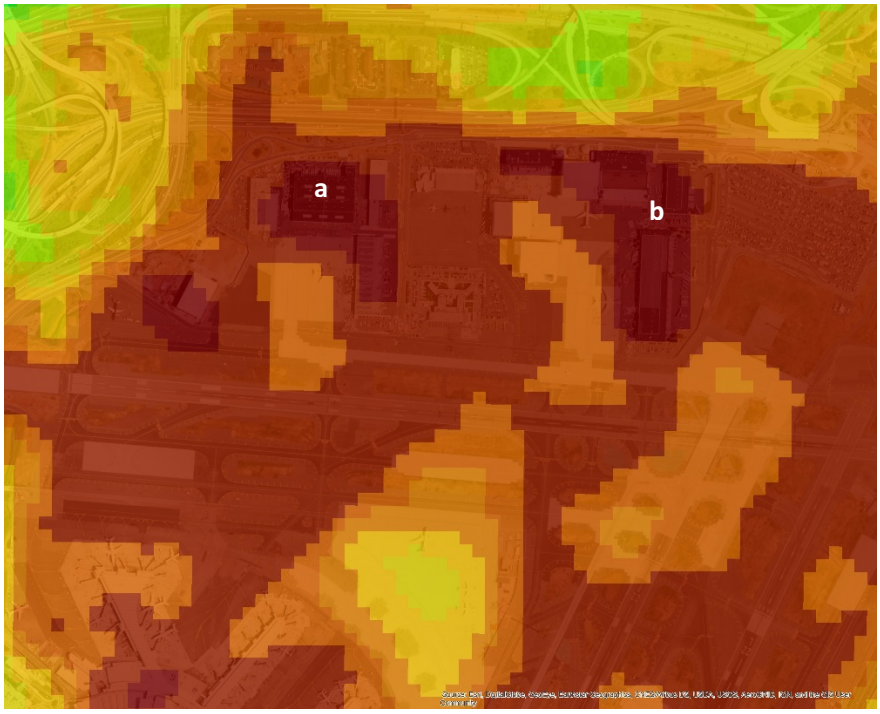
9. Lower Clinton Hill / South South Broad Street Cluster - This area includes a number of industrial facilities that show up as hot spots, including (a) Bartlett Distribution Warehouse (802 Bergen Street), (b) Decor Corporate Services Inc (254 Elizabeth Avenue), (c) Newark MVC (228 Frelinghuysen Avenue), (d) Tully House (300 Frelinghuysen Avenue) and Logan Hall (20 Toler Place).



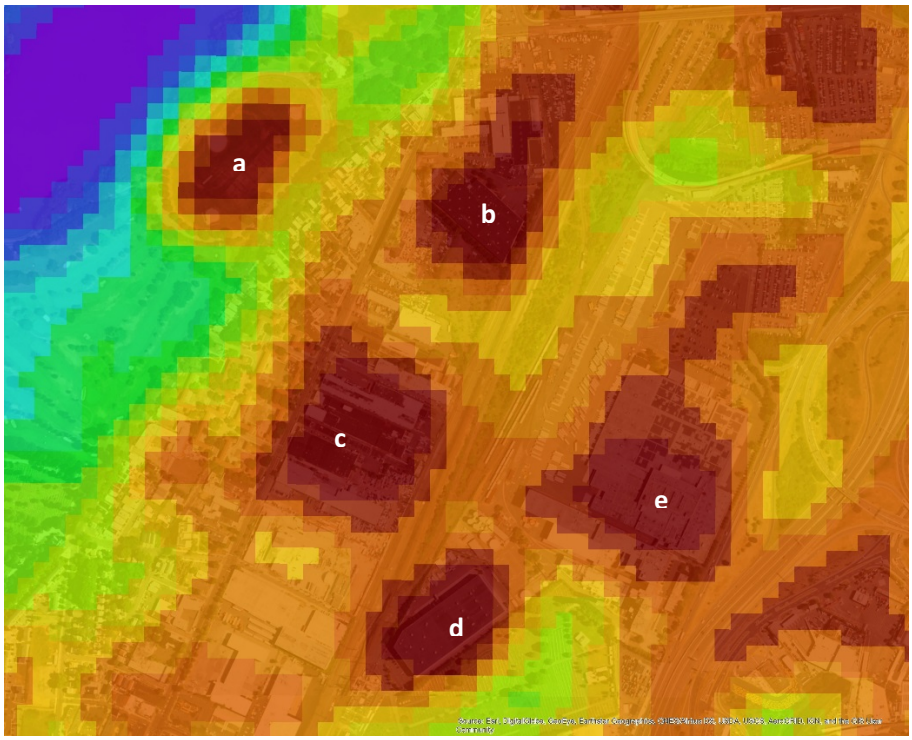


10. Newark Airport - Perhaps the largest hot spots in the city, and in the region, the Newark Airport (3 Brewster Road) absorbs and produces a significant amount of heat since it's almost entirely composed of built surfaces. Several (a & b) dark roofed buildings in the northern portion are some of the hottest part of the airport. Though surprisingly, the temperature is much where there is white tarmac.

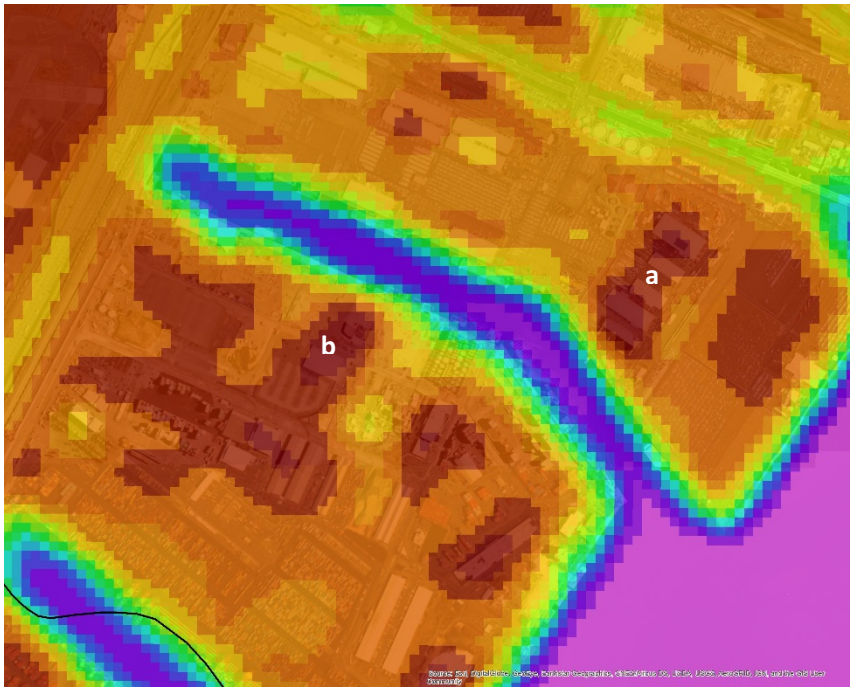




11. Dayton/Weequahic - This area between Weequahic Park and Newark Airport has several hot spots, which include an (a) synthetic turf field in the park, (b) 646 Frelinghuysen, (c) 768-780 Frelinghuysen, (d) Beltmann Relocation Group (158 Mt Olivet Ave), and the (e) Anheuser-Busch Budweiser Plant (200 U.S. 1).



12. Port Newark (241 Calcutta Street) - Like the Anheuser-Busch Budweiser Plant the port has a number of buildings with gray roofs which appear to be hot spots. The port also has a substantial amount of asphalt that show elevated temperatures.



Overview of Hot Spot Types

The following are descriptions of the types of hot spots found in Newark and locations associated with each type. There are some areas that may have multiple types of hot spots:

Synthetic Turf Fields - Perhaps the most noticeable and most common hot spots found throughout the city are synthetic turf fields. The excessive heat generated by synthetic turf fields has been known for many years[5], and was recently documented in the NPR article and radio segment: High Temps on Turf Fields Spark Safety Concerns. Despite the green color, synthetic turf fields absorb high amounts of solar energy due to their plastic composition and can become extremely hot in the summer. Synthetic fields can reach up to 160 degrees Fahrenheit, which can be quite hazardous to people, and may also release toxic gasses.

Hot Spots

1. Newark Schools Stadium and Kasberger Field, 4. Central High School / Nat Turner Park and American History High School, 7. North Ironbound Cluster, 11. Dayton/Weequahic

Dark Roofs - The next most common hot spots are dark roofs, where the dark colors of the roofing material absorb a large percentage of solar radiation, generating heat. What's particularly notable is that the roofs do not need to be that dark to create excessive heat; gray roofs can generate high levels of heat. While people are not directly exposed to roofs, hot roofs increase the indoor temperature of a building as well as ambient temperatures in the surrounding area.

Hot Spots

2. University Hospital, 3. 60 Lister Ave, 7. North Ironbound Cluster, 8. Waterfront Cluster, 9. Lower Clinton Hill / South South Broad Street Cluster, 10. Newark Airport, 11. Dayton/Weequahic

Parking Lots / Large Areas of Asphalt – Other typical hot spots are parking lots and large areas of asphalt such as school play areas. While parking lots may not be as dark as black roof tops the gray color can still absorb a substantial amount of solar radiation and create extreme heat. And unlike roofs, parking lots and especially school asphalt play areas are directly used by people and pose a major hazard.

Hot Spots

4. Central High School / Nat Turner Park and American History High School, 10. Newark Airport, 5. Edison Parking, 12. Port Newark

[5] http://plantscience.psu.edu/research/centers/ssrc/documents/temperature.pdf

Areas with Few Trees/Vegetation - Similar to parking lots and other large areas of asphalt, places with little tree cover or vegetation may come up as hot spots. While the source of the hot spot is not as focused as the other types, they still can be noticeable on the maps. One of the most notable examples is the South Ironbound where there is very little tree cover.

Hot Spots

6. South Ironbound

Mitigation Action Plan

While there are many actions that can be done to address urban heat islands, this report focuses on cooling strategies and actions to retrofit properties and public spaces. These strategies include alternatives to existing synthetic turf fields, converting dark roofs to cool roofs and green roofs, and planting trees and vegetation. When identifying cooling strategies, it is important to keep in mind the difference between hot spots on public versus private property, as the city does not have as much control over private property. Below is a description of both, as well as potential cooling strategies and actions for the city to consider.

Privately Owned Properties

The majority of the properties profiled in this report are privately owned or leased by semi-private entities (e.g.the airport and the port); therefore, the municipality is limited in what it is able to do. However, it is possible to contact property owners and educate them about the negative impacts of urban heat islands, such as the increase indoor temperatures and cooling costs. The municipality can also provide grants for businesses to adapt their property as well as encourage cooling strategies in zoning and site plan review.

Publicly Properties

There are a number of municipal properties within the profiled hotspots that can be addressed by the City of Newark. These include Nat Turner Park and the Ironbound Recreational Center as well as Newark Schools Stadium and Kasberger Field as well as Central High School and American History High School. There are also a number of municipal properties that are not in the hot spots profiled in this report but should be considered for urban heat island mitigation. These properties include the Newark City Hall Parking Lot, the Orange Street Complex and the Newark Police Station on 311 Washington Street. It should be noted that this is not a comprehensive list of properties and there are likely other sites that contribute to urban heat islands that should be considered for mitigation. The city should conduct a further detailed analysis of all city owned properties with dark roofs, large parking lots and/or areas with general lack of vegetation.

Select Cooling Strategies and Actions

This section includes suggested cooling strategies for each type of hot spot or urban heat island.

1. **Consider alternatives to existing Synthetic Turf fields and/or provide heat warnings or restrictions for existing fields** - While synthetic turf fields are easier to maintain than natural grass, they may be hazardous during the summer months, when people are more likely to use them. It is recommended that the city uses natural grass for future field construction, and removes existing synthetic turf fields when they need to be replaced. Until the synthetic turf has been removed and replace, signs

advising of heat warnings and restricted access should be place on the fields on hot days and heat waves.

Actions

a. Place signs warning about the dangers of extreme heat at every synthetic turf field
b. Adopt a policy banning the construction of new synthetic turf fields
c. Return old synthetic turf fields to natural grass
d. Work with Board of Education to institute the same actions on school properties

2. **Convert dark roofs to Cool Roofs**[6] or **Green Roofs** - Cool roofs are designed to reflect more sunlight and absorb less heat. Simply painting a roof white or using a reflective material decreases the temperature of a roof surface significantly. As demonstrated in the maps, the facilities that have lighter color roofs can be almost ten degrees cooler than the dark roofs. Lowering the roof temperature can reduce both indoor and ambient air temperatures. We recommend that the city work with owners of buildings with dark roofs to paint them white or where possible construct green roofs. Green roofs can also dramatically decrease roof temperatures, as well as retain stormwater and provide insulation to the building.

Actions

a. Convert all public buildings with dark roofs to Cool Roofs or Green Roofs
b. Reach out to all the hot spot businesses with dark roofs and request they convert to Cool Roofs or Green Roofs
c. Provide grants to businesses willing to paint roof white

3. **Remove dark asphalt and add Cool Pavements and Green Infrastructure** - While it would be difficult to completely remove all dark parking and asphalt, there are ways to Cool Pavements and Green Infrastructure to parking lots and streets. For example, many of the spaces in parking lots such as parking islands, buffers, and spaces between spots could be landscaped by adding trees, bioswales and rain gardens. And on streets, there are many Green Streets streetscape design elements that could be used such as stormwater planters, above ground planters and street trees. These interventions not only help mitigate UHI effect but also stormwater and improve the general quality of life.

Actions

a. Convert dark asphalt to Cool Pavements
b. Add landscaping/green infrastructure to public parking lots and streets
c. Request that developers include green infrastructure in site plans

4. **Plant more street trees -** Similar to the previous recommendation, simply adding more street trees and maintaining existing street trees can dramatically improve UHI effect. It is recommended that the city continue to plant new street trees – especially in hot spot areas. As well as continue

[6] https://energy.gov/energysaver/cool-roofs

maintaining the health of existing trees. Maintenance is critical, to making sure trees are effective at cooling.

Actions

a. Conduct iTree assessment and prioritization in order to understand where it tree planting is most needed.
b. Conduct a tree census/inventory and identify trees that need to be replaced
c. Support the maintenance of street trees
d. Continue to support the Greenstreets Intiative[7] and to provide community groups and residents with street trees

For more information about strategies to reduce Urban Heat Island see: https://www.epa.gov/heat-islands/reduce-heat-island-risks

Selecting the Appropriate Cooling Strategy

Suggested cooling strategies for each of the city's hot spots are listed in the Cooling Strategies Action Table on the following page. Note that these are only suggestions, and further research is necessary to determine the best strategy. The physical conditions of the site or building should be inspected to determine whether a certain strategy is feasible. For example, not all structures are able to withstand green roofs; and in areas of extreme pollution, white roofs may need to be repainted or replaced frequently; and, shade trees require areas with sufficient pit width and depth to survive. Finally, the costs of cooling strategies vary, according to material needs, construction costs and maintenance. All of these factors must be considered before selecting a cooling strategy for a particular site or building. (See, for example, the articles on costs of cool roofs in the References section of this report.)

Preparing for Extreme Heat

Finally, it should be mentioned that along with retrofitting properties and public space for mitigation, it is also important to plan for adapting to extreme heat events. Planning for cooling stations, emergency response and public education campaigns are key aspects of dealing with urban heat islands. The following Sustainable Jersey municipal "actions" address these important considerations: *Extreme Temperature Event Plan*, *Vulnerable Populations Identification for Emergencies*, and *Emergency Communications Planning*. Visit Sustainable Jersey at www.sustainablejersey.com.

More information about adapting to extreme heat can be found on the EPA heat island website (https://www.epa.gov/heat-islands/adapting-heat) , and other resources listed at the end of the report.

[7] A partnership with the City of Newark, the US forest Service and a number of non-profits.

Cooling Strategies Action Table

Hot Spot	Hot Spot Type	Ownership Type	Recommended Action
1. Newark Schools Stadium and Kasberger Field	Astro Turf Fields	Public	Add heat warnings, limit use on hot days, eventually remove synthetic turf field
2. University Hospital	Dark Roof	Private	Convert to green or "cool roof"
3. 60 Lister Ave	Dark Roof	Private	Convert to green or "cool roof"
4. Central High School / Nat Turner Park and American History High School	Astro Turf Fields, Asphalt School Yard	Public	Add heat warnings, limit use on hot days, eventually remove synthetic turf field; add vegetation and green infrastructure
5. Edison Parking	Parking Lot	Private	Add vegetation and green infrastructure
6. South Ironbound	Lack of Tree Cover	Private	Convert to green or "cool roof"; add vegetation and green infrastructure; plant more street trees
7. North Ironbound Cluster	Dark roofs	Private	Add heat warnings, limit use on hot days, eventually remove synthetic turf field. Convert to green or "cool roof"
8. Waterfront Cluster	Dark roofs	Mixed	Convert to green or "cool roof"
9. Lower Clinton Hill / South South Broad Street Cluster	Dark roofs	Private	Convert to green or "cool roof"
10. Newark Airport	Dark roofs and paving	Semi-Private	Convert to green or "cool roof"; add vegetation and green infrastructure
11. Dayton/Weequahic	Astro Turf field, Dark roofs	Mixed	Add heat warnings, limit use on hot days, eventually remove synthetic turf field; convert to green or "cool roof"
12. Port Newark	Large Areas of Asphalt	Semi-Private	Convert to green or "cool roof"; add vegetation and green infrastructure

Final Thoughts

As global temperatures continue to rise due to climate change, so will the temperature of already hot urban surfaces. These temperatures are a major hazard to the residents of Newark and especially vulnerable populations. We recommend the city take action in reducing urban heat islands to protect public health and make the city a more livable and pleasant place to live, work and visit.

To complement this assessment of surface temperatures and urban heat islands, the city should consider measuring and mapping **air** temperatures during hot days and nights to further understand the urban heat island effects and detect any additional hot spots. There are various ways to do this, but it could be done using handheld measurement devices and by walking or driving throughout the city. Samples should be taken at five feet above the ground, all within the same timeframe. The data points

could then be used to create an isotherm map or any other visualization. Another option is to set up temperature sensors throughout the city to compare areas over a long period of time. See the US EPA's page on measuring urban heat islands here: https://www.epa.gov/heat-islands/measuring-heat-islands

Resources/References

Mitigation Strategies

EPA – Reducing UHI Risks
https://www.epa.gov/heat-islands/reduce-heat-island-risks

Heat Island Community Actions Database
https://www.epa.gov/heat-islands/heat-island-community-actions-database

Articles on urban heat islands

Asthma Distribution patterns and their relationship with the urban landscape and social conditions in Newark NJ
http://cimic.rutgers.edu/rac/IHGC2000-new.ppt

Characterizing the urban heat island in current and future climates in New Jersey
http://www.sciencedirect.com/science/article/pii/S1464286705000057

Mitigation of the heat island effect in urban New Jersey
http://www.sciencedirect.com/science/article/pii/S1464286705000045

Articles on the Costs of Cool Roofs

Cool Roofs Reduce Heat Islands (EPA)
https://www.epa.gov/heat-islands/using-cool-roofs-reduce-heat-islands

Are Cool Roofs More Expensive than Normal Roofs?
https://globalcoolcities.org/are-cool-roofs-more-expensive-than-normal-roofs/

What a Green Roof Costs You on the Way to Saving Everything
https://www.thestreet.com/story/13161050/1/what-a-green-roof-costs-you-on-the-way-to-saving-everything.html

Green Roof Costs
http://www.lid-stormwater.net/greenroofs_cost.htm

Green Roof Technology - FQA
http://www.greenrooftechnology.com/green-roofs-explained

Articles on the methodology used in this report

USGS's Page on Landsat 8
https://landsat.usgs.gov/what-are-band-designations-landsat-satellites

Video about creating NDVI in ArcGIS
https://www.youtube.com/watch?v=dH0eH8rcS-s

Video Estimating Land Surface Temperature Using ArcGIS
https://www.youtube.com/watch?v=uDQo2a5e7dM

Deriving temperature from Landsat 8 thermal bands (TIRS)
https://blogs.esri.com/esri/arcgis/2014/01/06/deriving-temperature-from-landsat-8-thermal-bands-tirs/

ArcGIS Model to Convert Radiance to Celsius -
https://www.arcgis.com/home/item.html?id=bd13c860a9b14c7bab0dca6ee2100cb6