Urban Infrastructure Design and Heat Vulnerability

Rethinking Infrastructure in Mesa, Arizona

A project by Arizona State University's Spring 2015
Urban Infrastructure Anatomy and Sustainable Development Course

28 April 2015

Urban Infrastructure Anatomy and Sustainable Development

CEE598: Civil, Environmental, & Sustainable Engineering

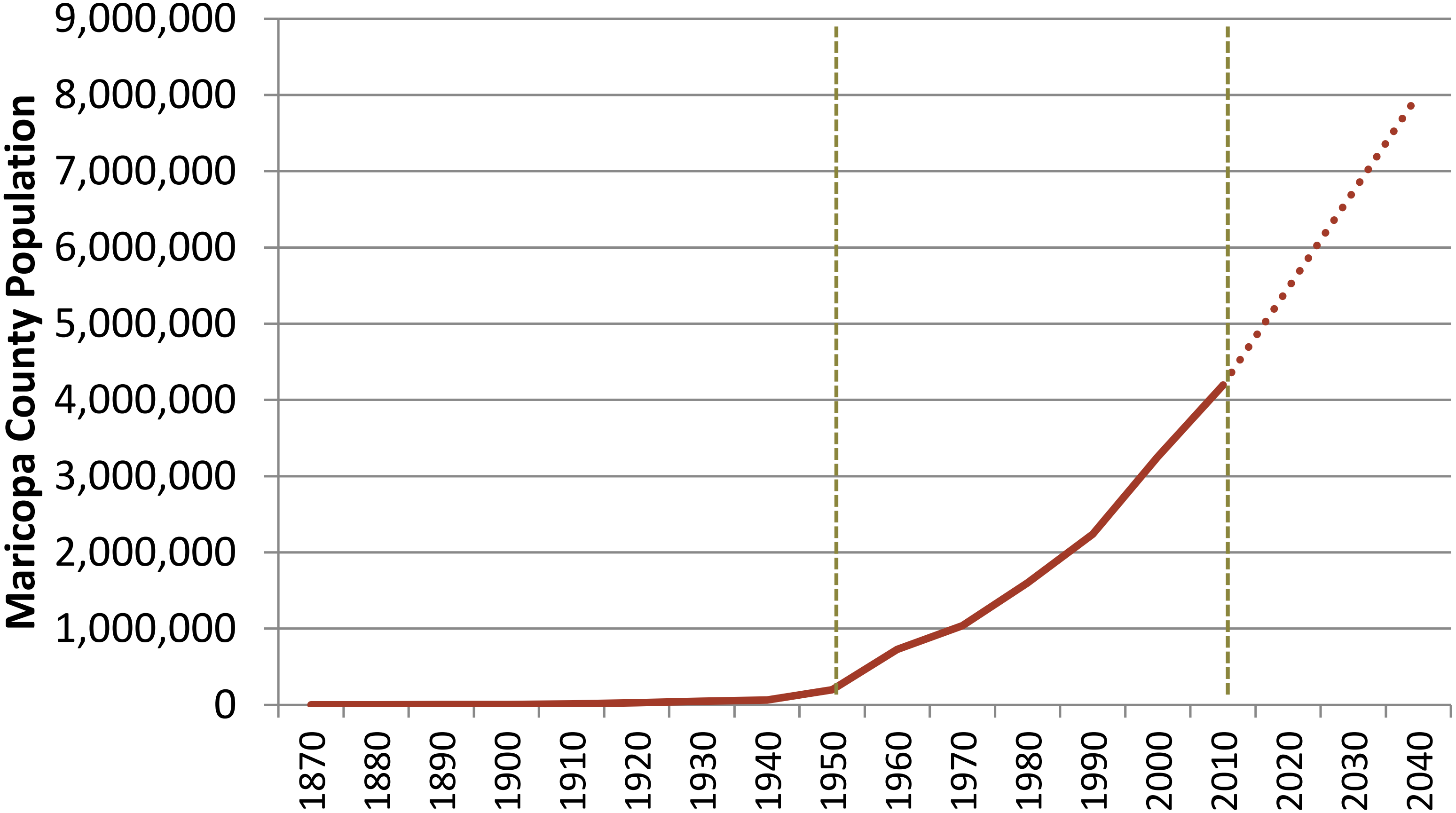
PUP598: Geography and Urban Planning

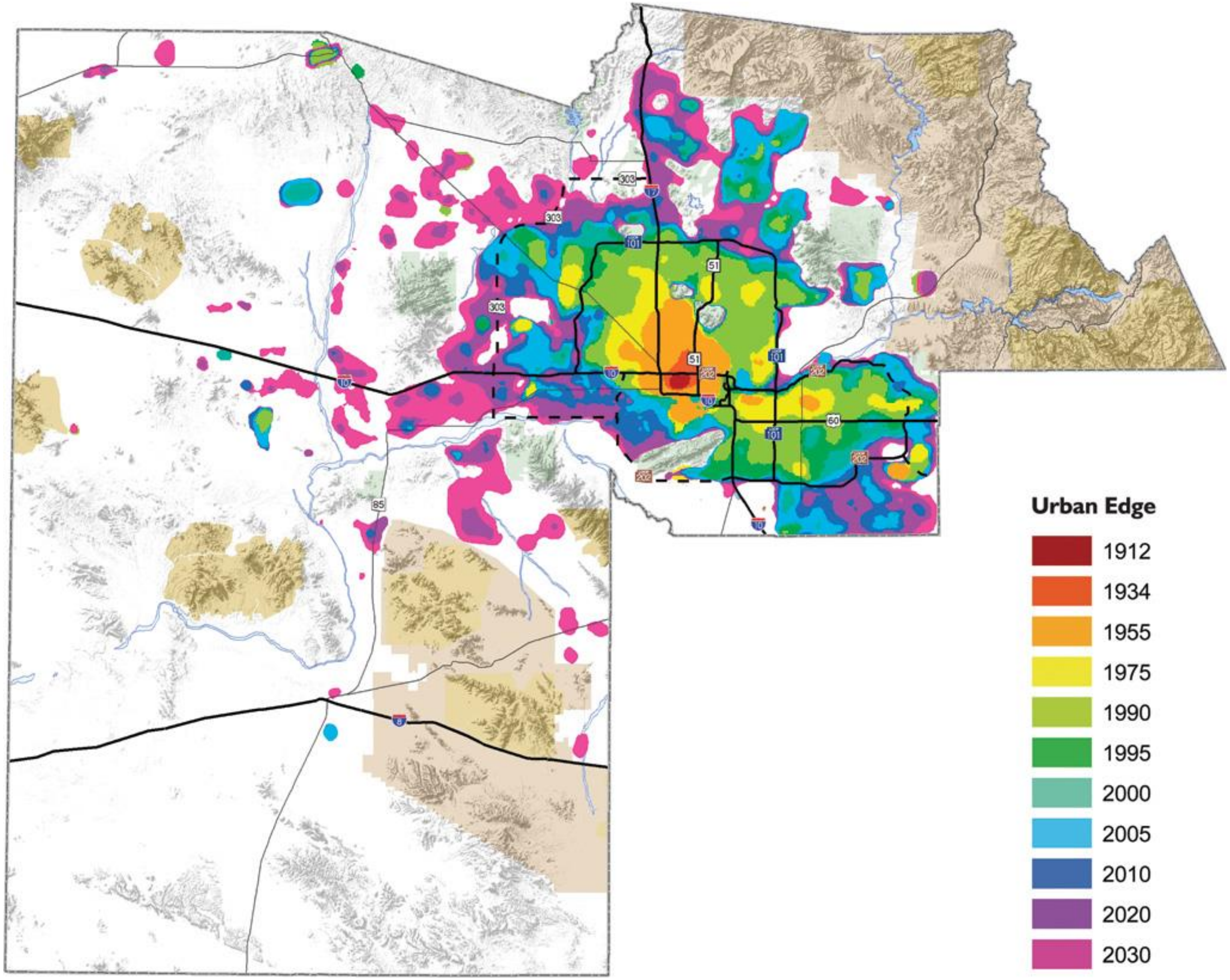
SOS598: School of Sustainability

CON252: Construction Methods, Materials, and Equipment

National Science Foundation

Population Growth

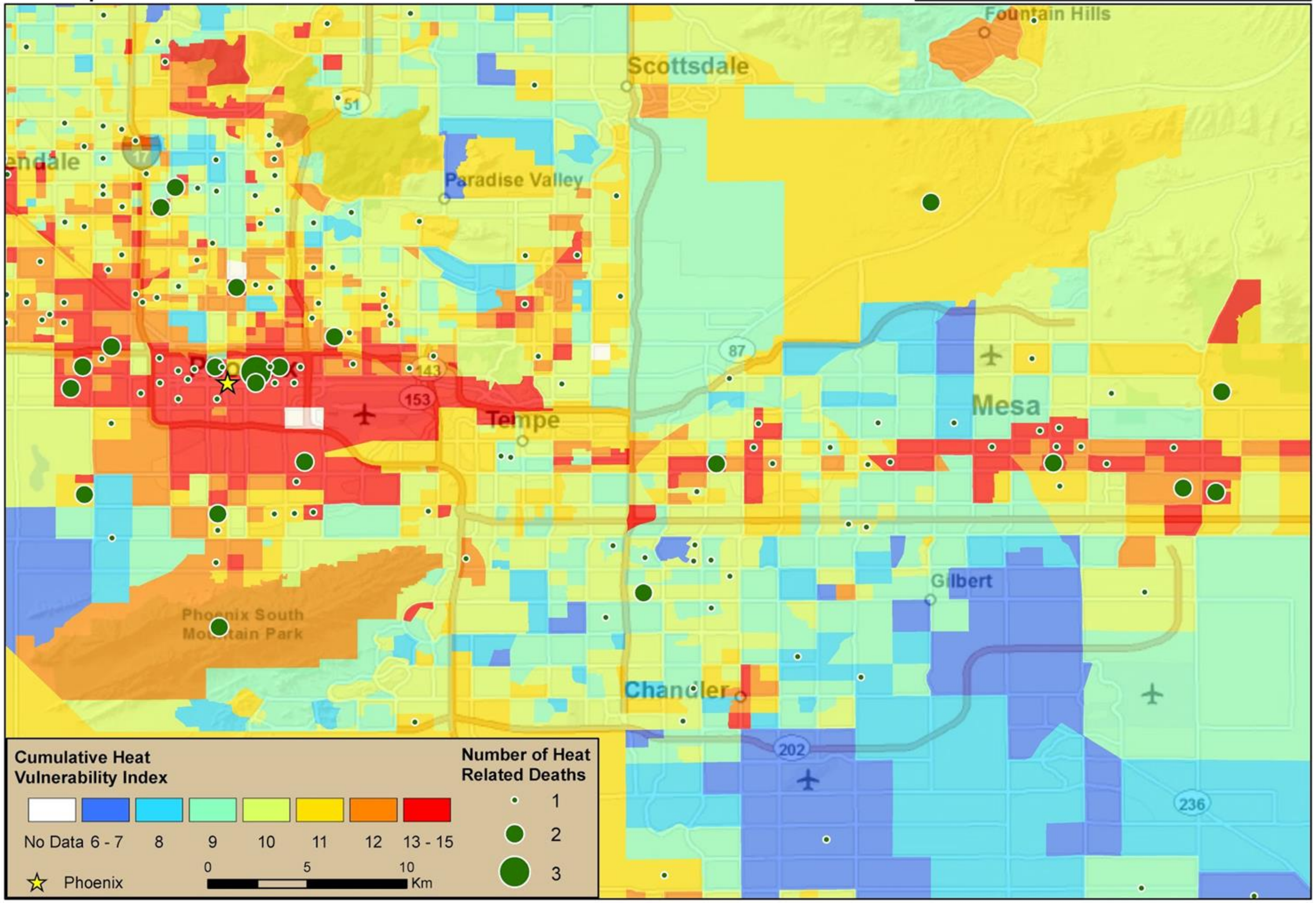




Urban Edge
1912
1934
1955
1975
1990
1995
2000
2005
2010
2020
2030

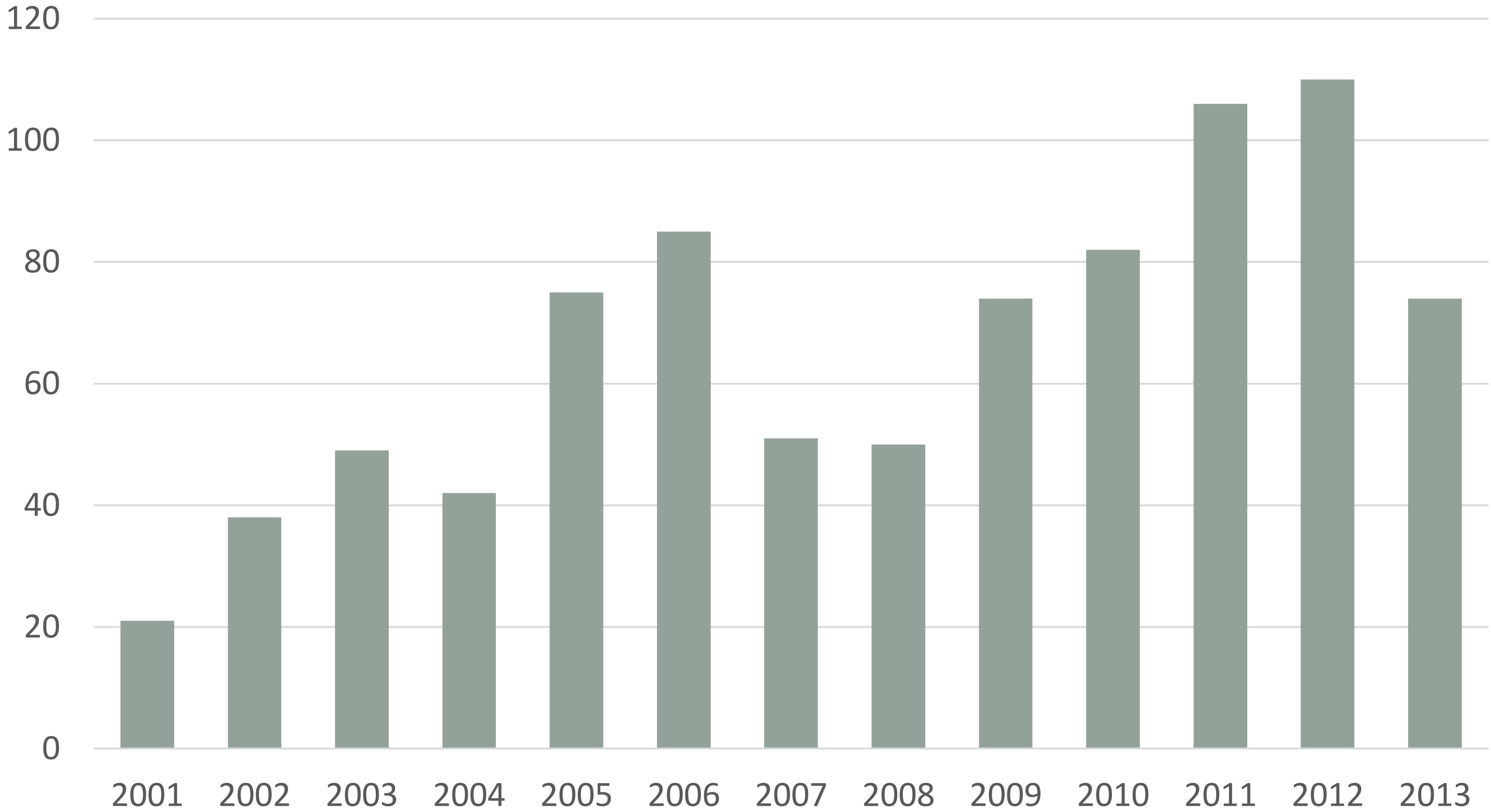
Cumulative Heat Vulnerability Index and Heat-Related Deaths (2000-2008) in Census Block Groups in Eastern Phoenix Metropolitan Area

Cartography by Juan Declet-Barreto for the Urban Vulnerability to Climate Change project, Arizona State University. This material is based upon work supported by the National Science Foundation under Grant No. 0816168.



Source: S Harlan, J Declet-Barreto, W Stefanov, and Diana Petitti, 2013, Neighborhood Effects on Heat Deaths: Social and Environmental Predictors of Vulnerability in Maricopa County, Arizona, Environmental Health Perspectives, 121(2).

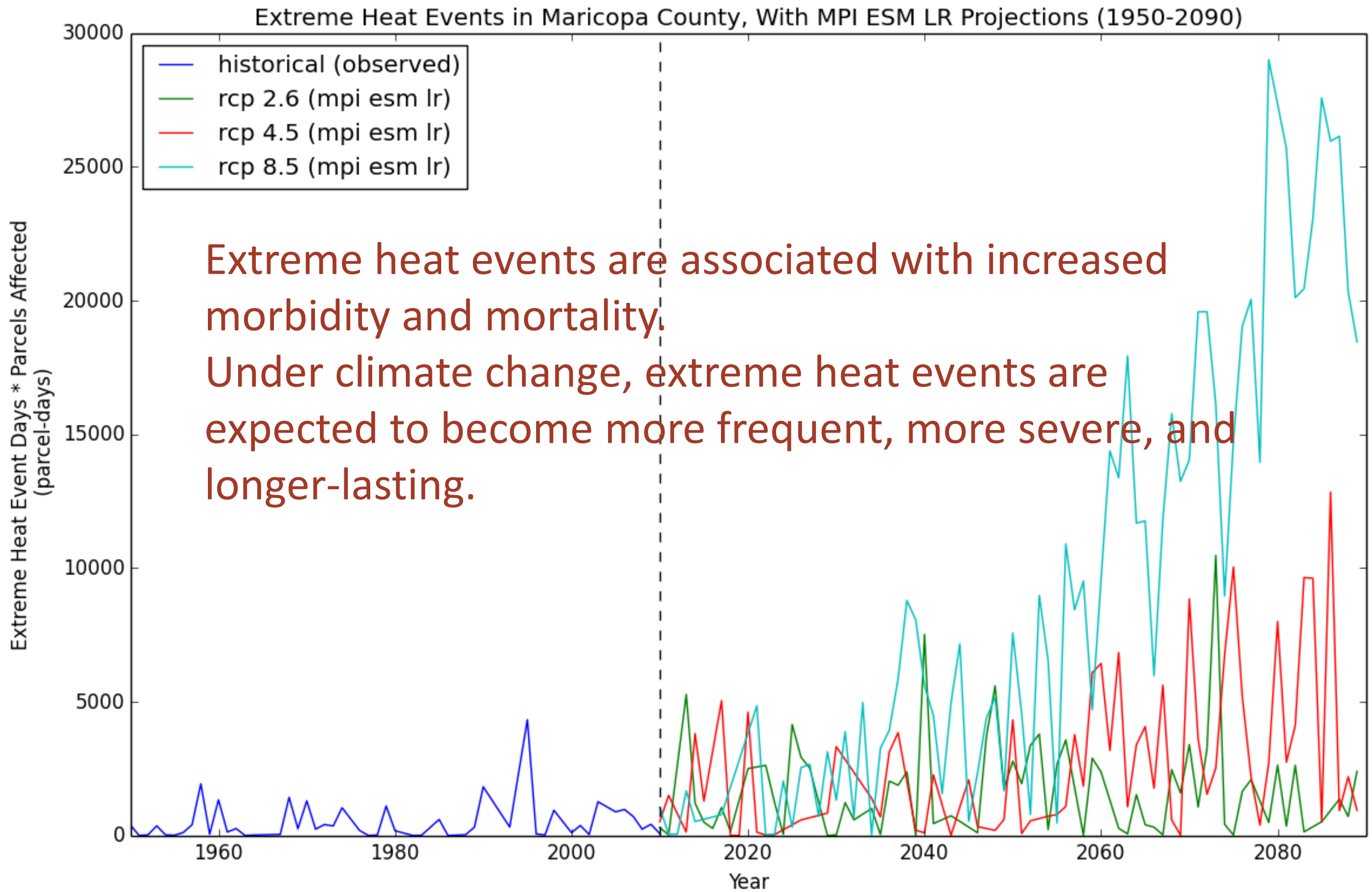
Maricopa County Heat-Associated Deaths



Maricopa County, 2013, Heat-Associated Deaths in Maricopa County, AZ, http://www.maricopa.gov/publichealth/Services/EPI/pdf/heat/2013annualreport.pdf

Hurricane Sandy:
273 deaths

More Frequent Extreme Heat Events

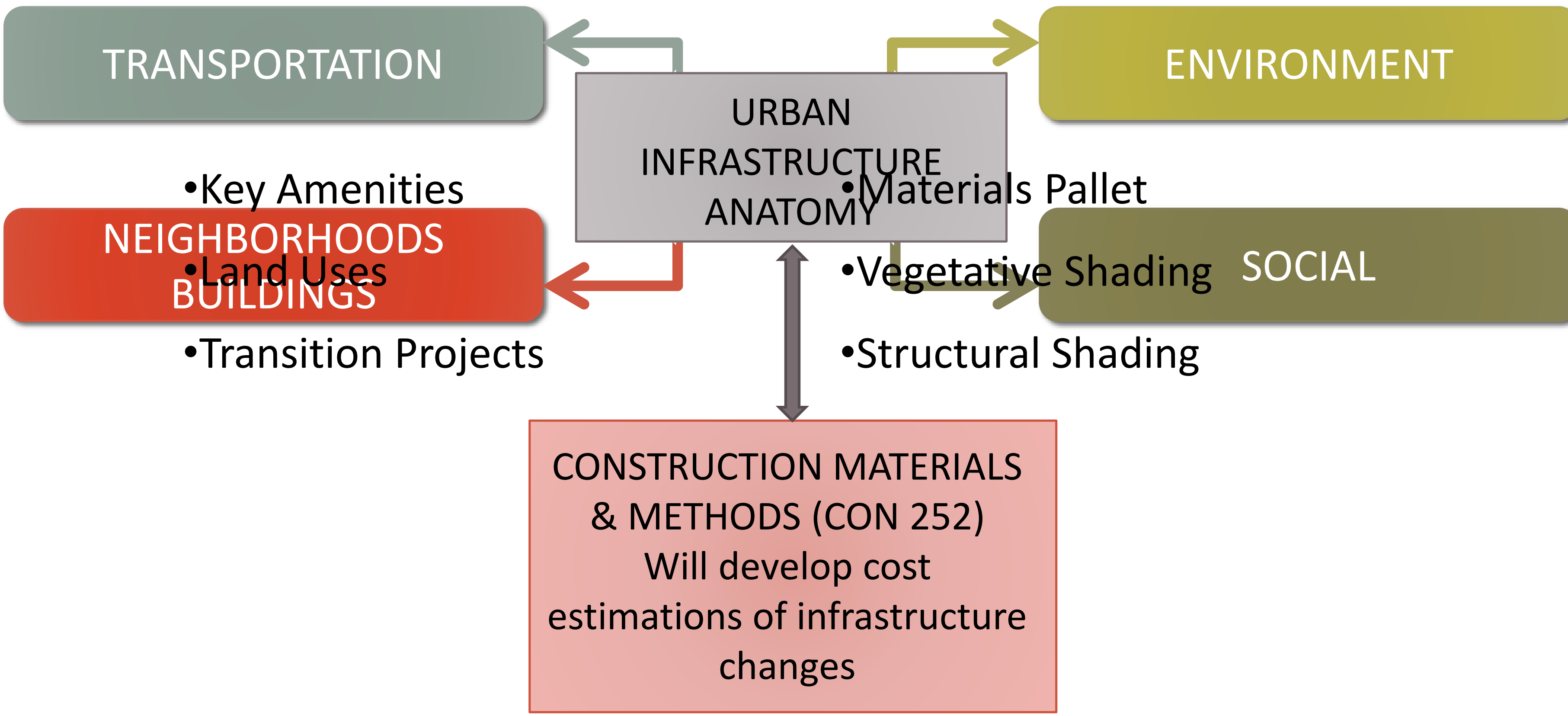


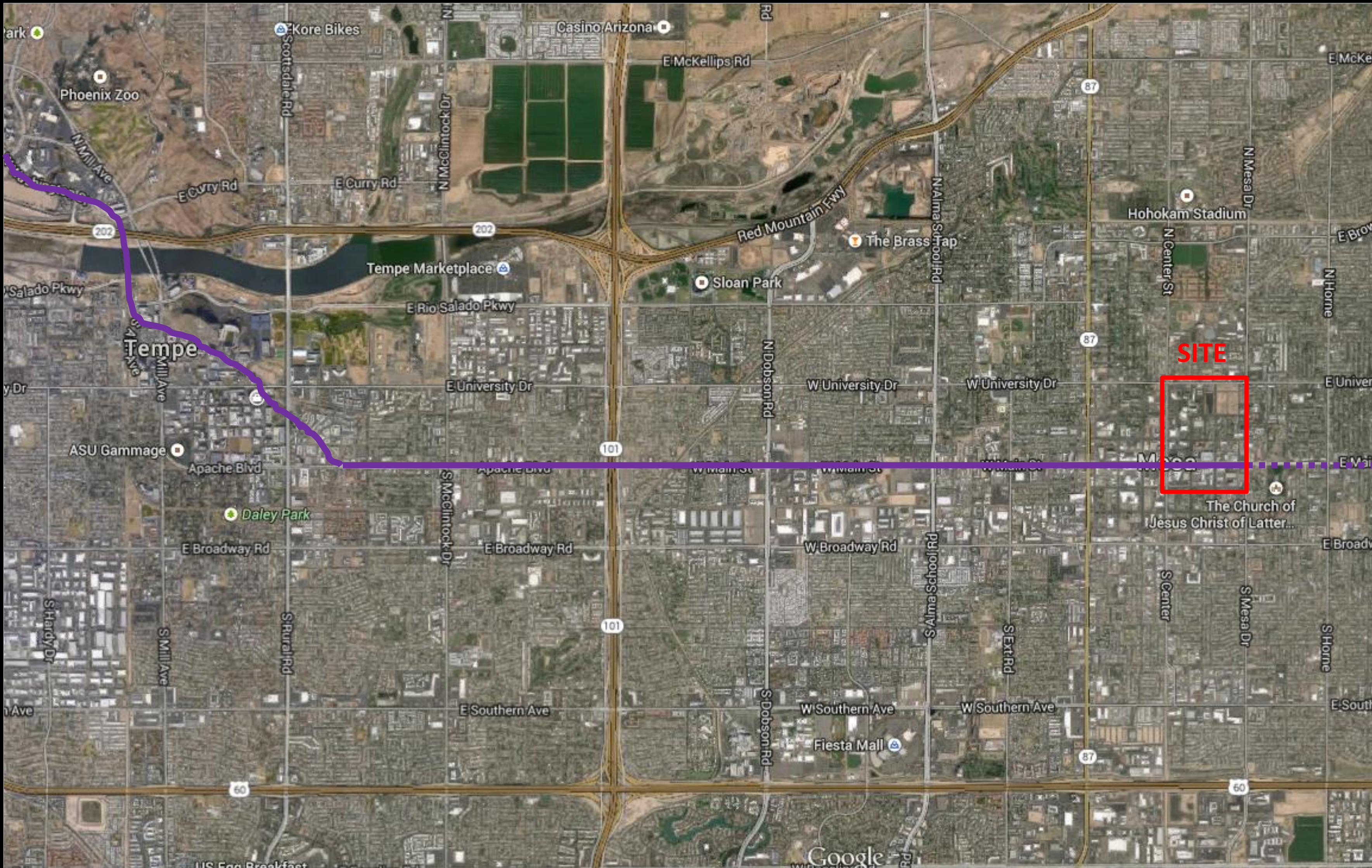
Extreme heat events are associated with increased morbidity and mortality.
Under climate change, extreme heat events are expected to become more frequent, more severe, and longer-lasting.

MARICOPA - RCP 2.6: 340—415% increase; RCP 4.5: 380-510% increase; RCP 8.5: 1200-1800% increase.

M Bartos and M Chester, 2014, "Assessing Future Extreme Heat Events at Intra-Urban Scales: A Comparative Study of Phoenix and Los Angeles", Arizona State University Report No. ASU-CESEM-2014-WPS-001. http://repository.asu.edu/items/25228

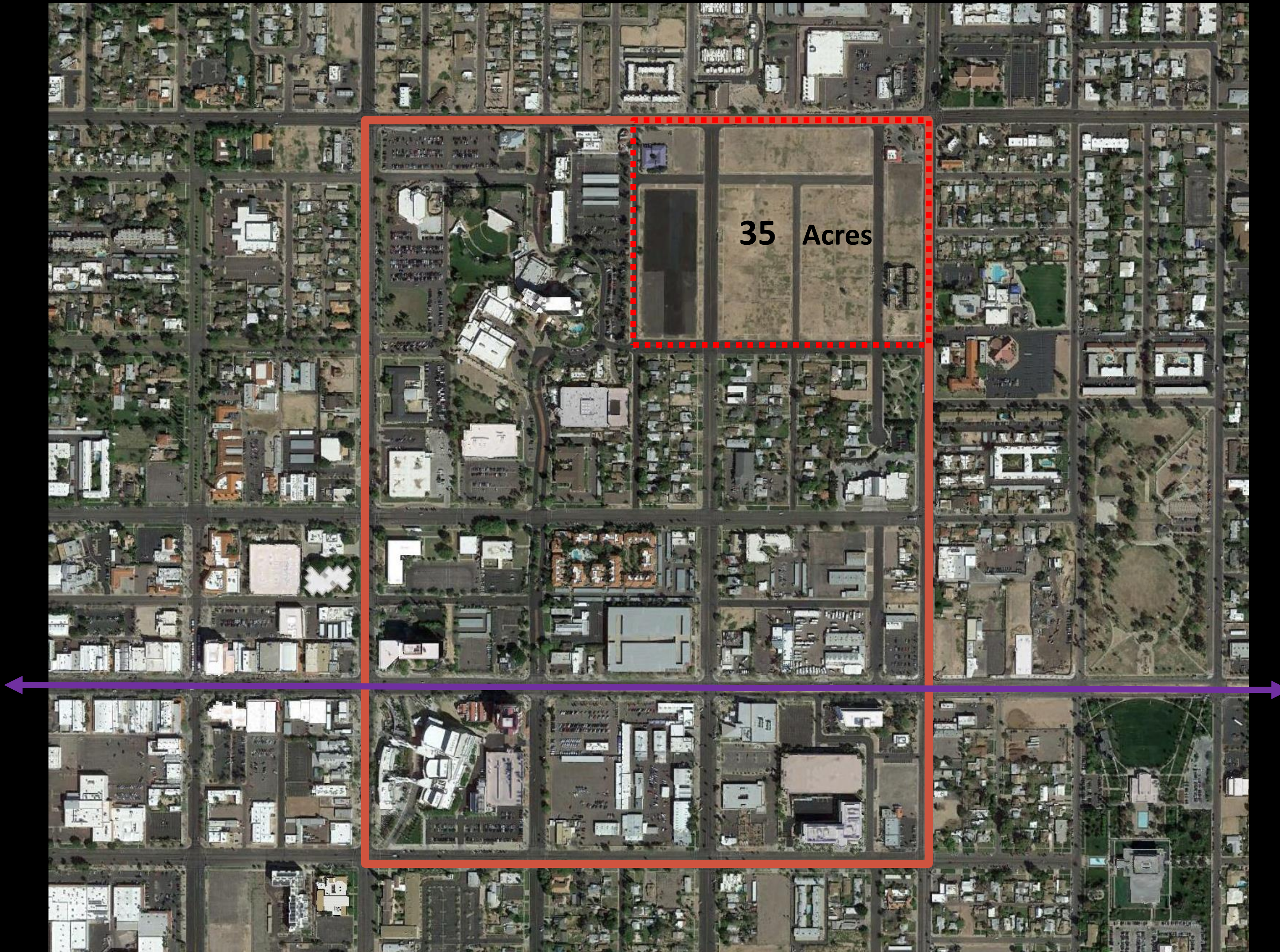
Project Overview





EXISTING LIGHT RAIL

LIGHT RAIL EXTENSION

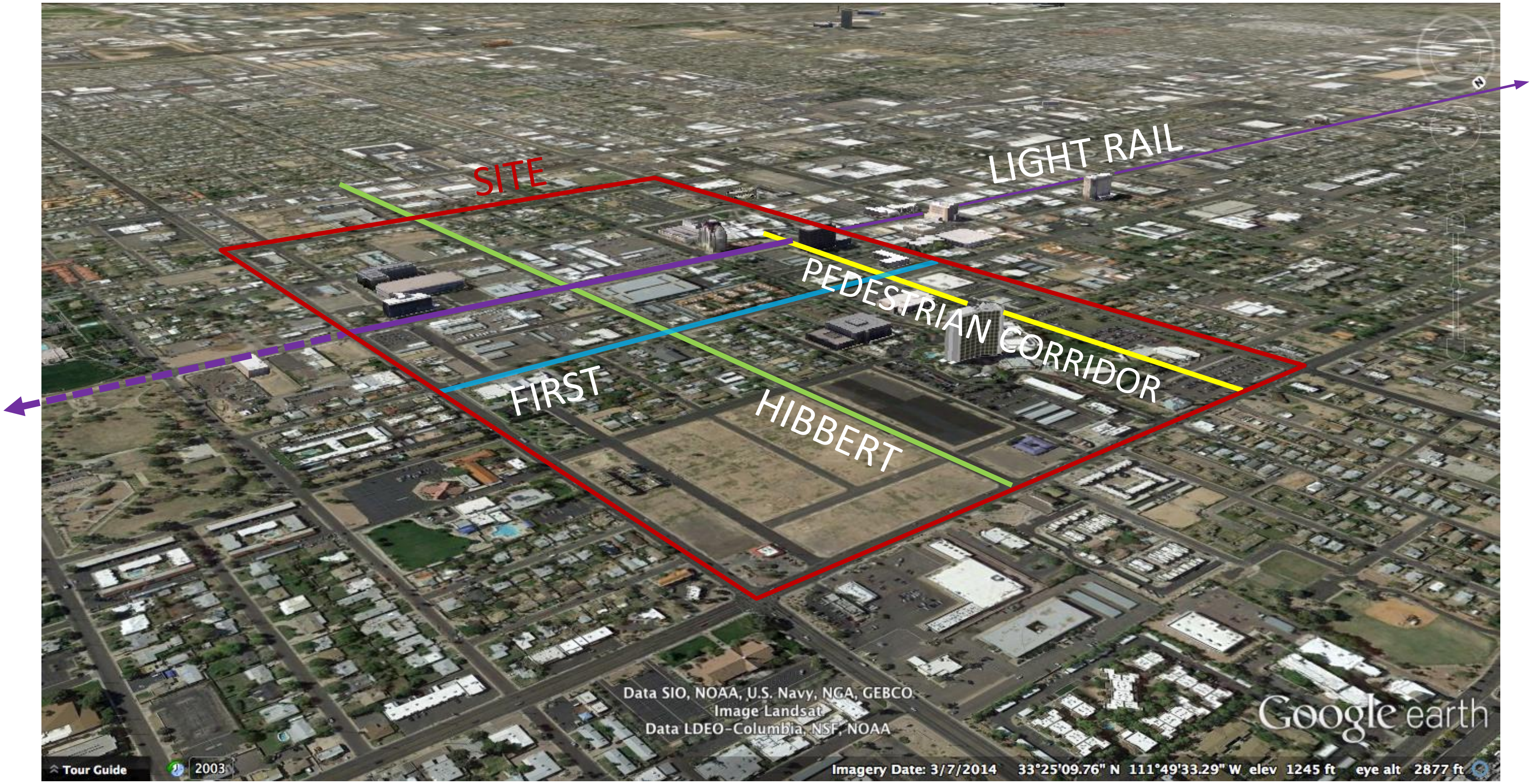

35 Acres

Neighborhoods & Buildings

Core Values - Assets within the City of Mesa

Neighborhoods & Buildings

Key transitions that can enable a Sustainable Community



Neighborhoods & Buildings

Overview

- Key Existing **Neighborhood Components** prime for improvement
- General Land **Areas** that could improve the local **built environment**
- Specific **Spaces** that can serve to **enhance the community**
- Unique **transformational** development projects that contribute towards SOS
- Aspects of **building composition** that relate to the **Health** of communities

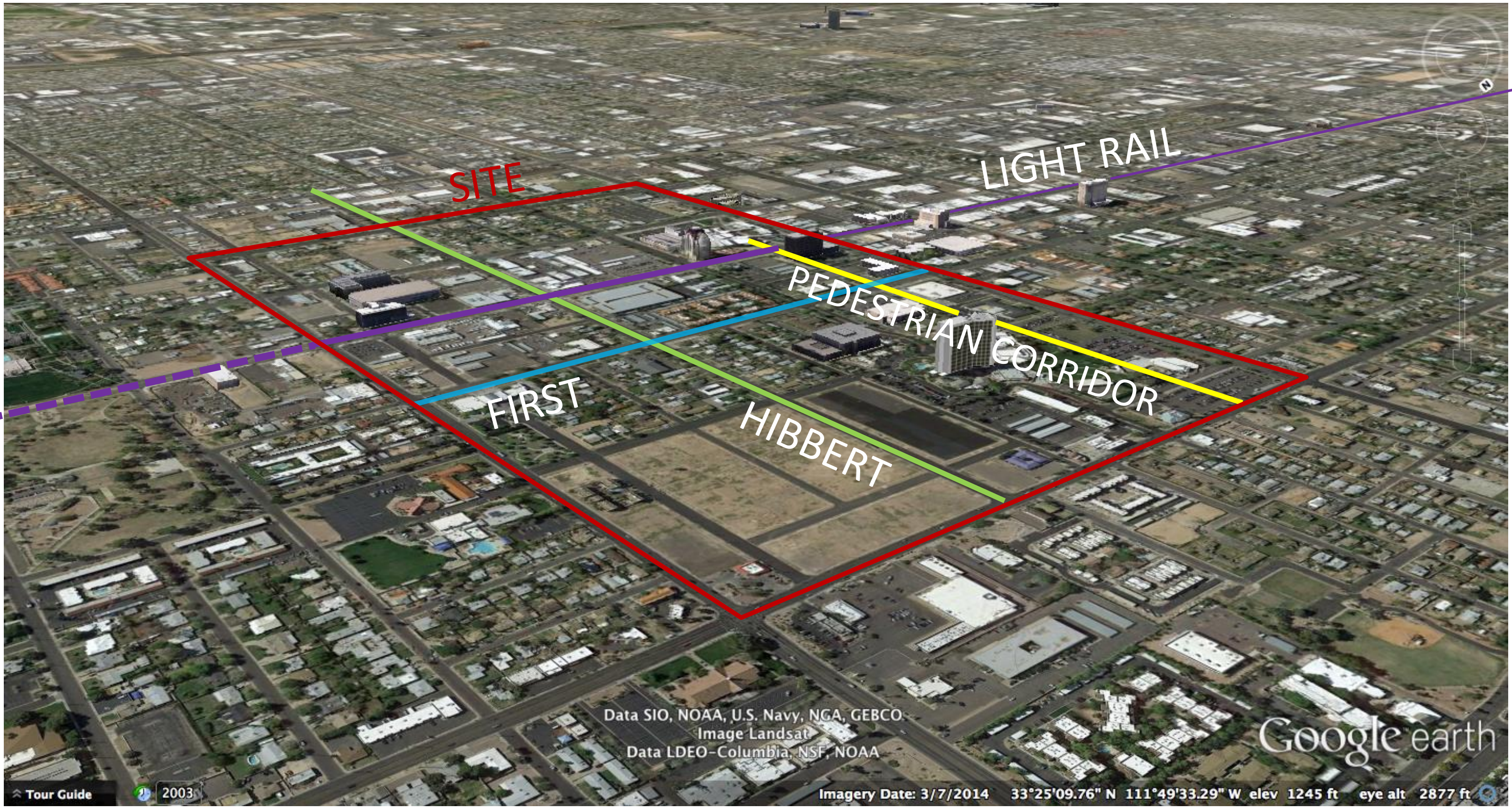
Neighborhoods & Buildings

Goals

- Promote Community Development Projects that reinforce local values
- Improve the local Environment through Heat mitigation strategies
- Encourage Rethinking of the Right of Way to reduce heat and increase safety
- Discuss alternative building compositions that could enhance quality of life
- Recommendations for addressing health of communities through materials

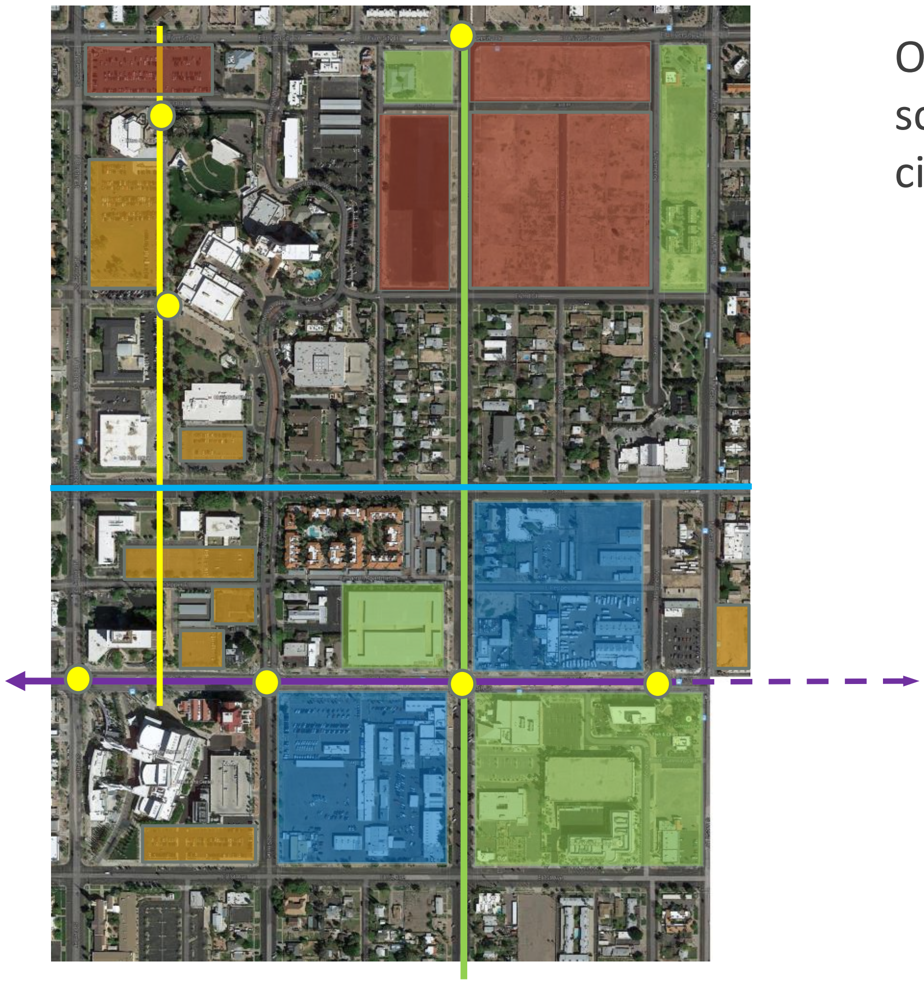
Neighborhoods & Buildings

Key components that can be leveraged to reduce heat exposure



Neighborhoods & Buildings

Urban Community Enhancements

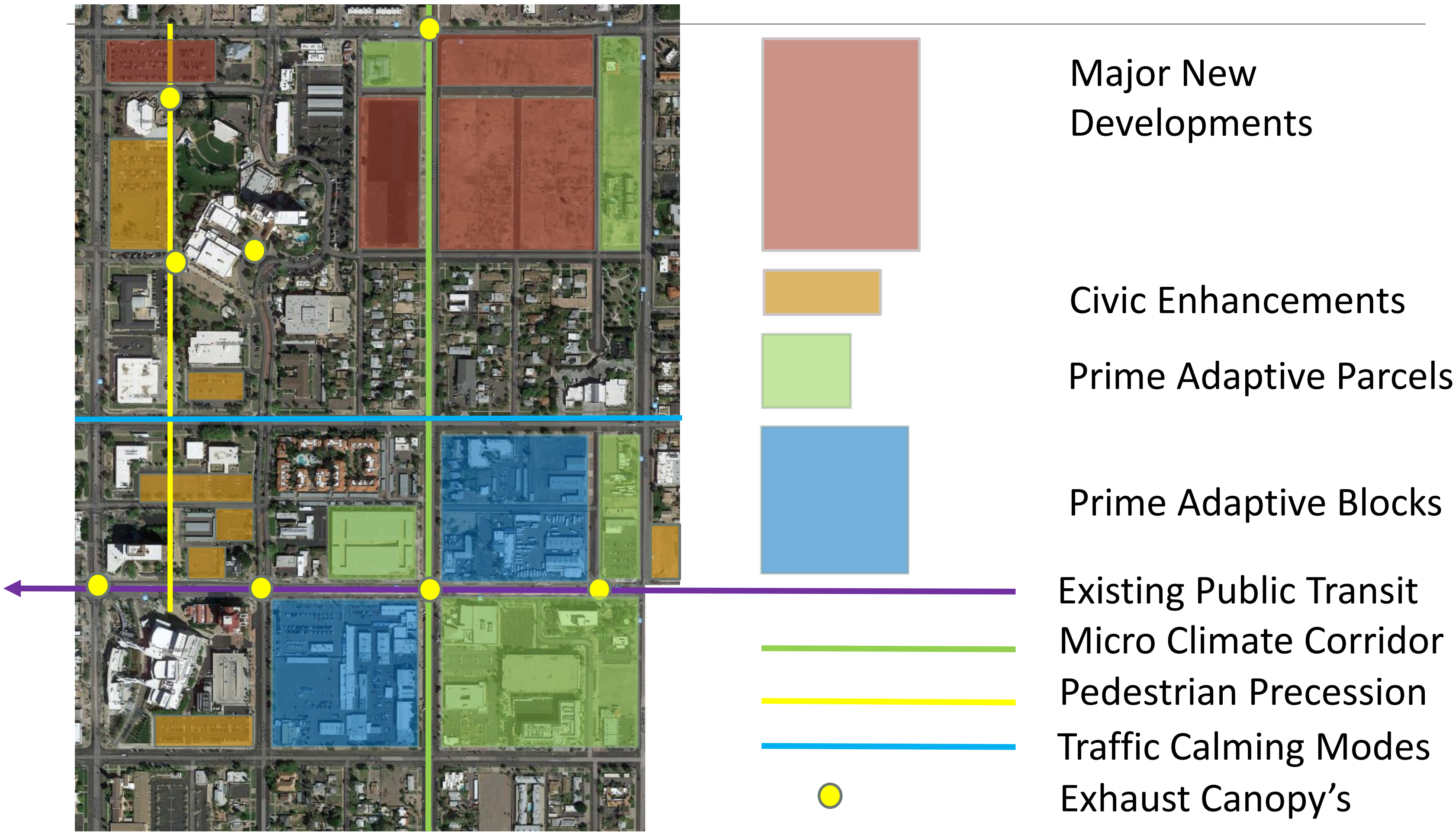


Opportunities within our project scope represent just a fraction of the cities areas to encourage investment

mixed use buildings
consolidate parking
providing shade
cleaner energy production
cooling refuge areas
enhanced amenities
safety and security
new building forms
proper material pallets

Neighborhoods & Buildings

Neighborhood Transformations



Neighborhoods & Buildings

Unique Development Projects w/n project boundaries

- *NWC of project area* for adaptive commercial use
- Mesa Center multifunctional canopy's (shade energy shelter)
- Main street revitalization and adaptive land uses
- Intersection prototypes for exhausting emissions and heat that create areas of refuge for the public

T
- Hibbert (NS) New developments and street design (shade vege h20 access)

T
- 1st street (EW) traffic calming and multi-modal paths

Neighborhoods & Buildings

Prototype for Mixed-Use Commercial Spaces

Location - *NWC of project area* |SEC of university and center

Reality that parking is a powerful force in our auto dominated region of Maricopa county

Alternative response for a prime parcel could be a building typology that responds to local needs

Flexibility of retail spaces and commercial offices while supporting vehicle related functions such as food trucks pop up markets and even overflow parking

Neighborhoods & Buildings

Giles Spaces - Mixed-Use Community Areas

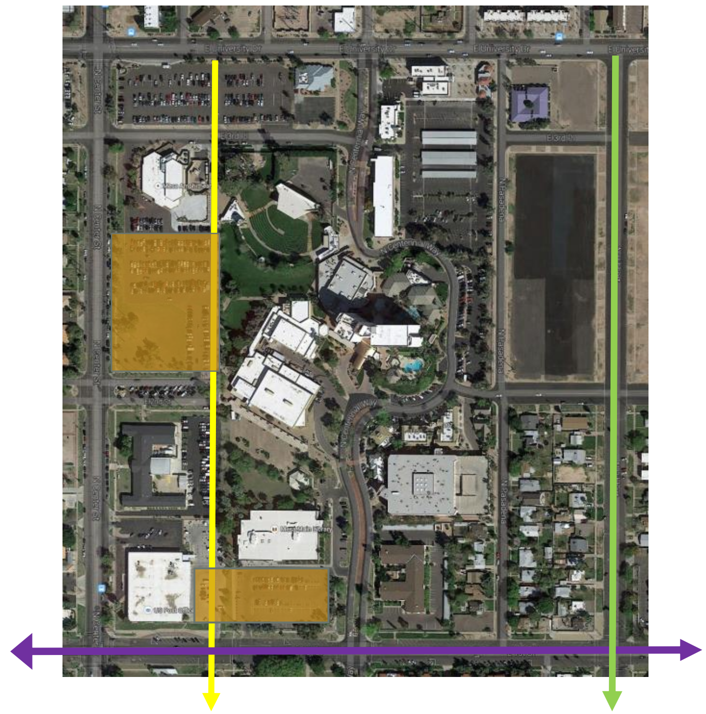
Location – Mesa Convention Center

Approx. size 3.6 acres

Est. cost 5.5 million

Municipally owned property

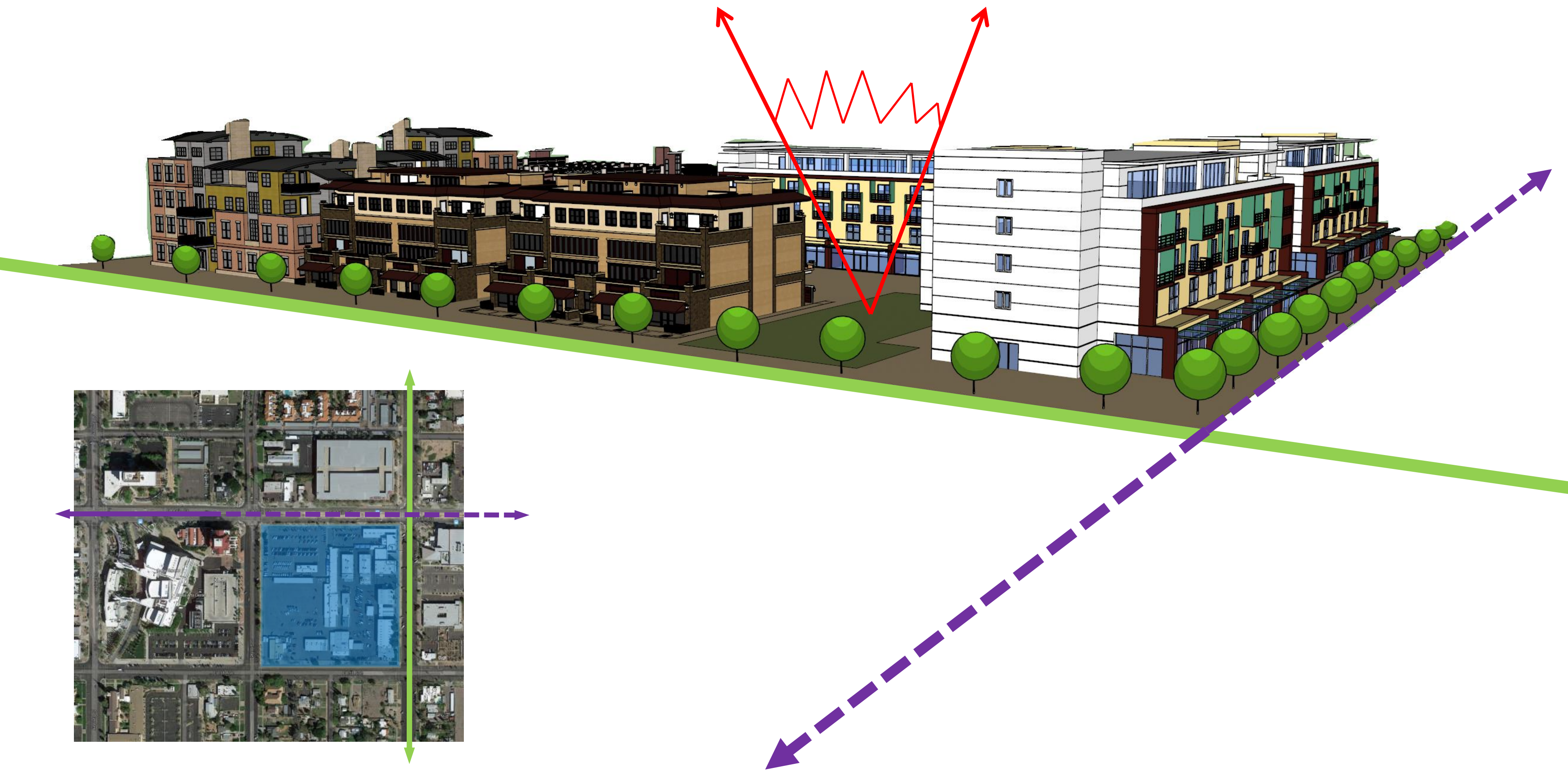
ROI Est. at 17 years



Opportunity to provide areas of refuge through public open space that could showcase amenities under solar shading

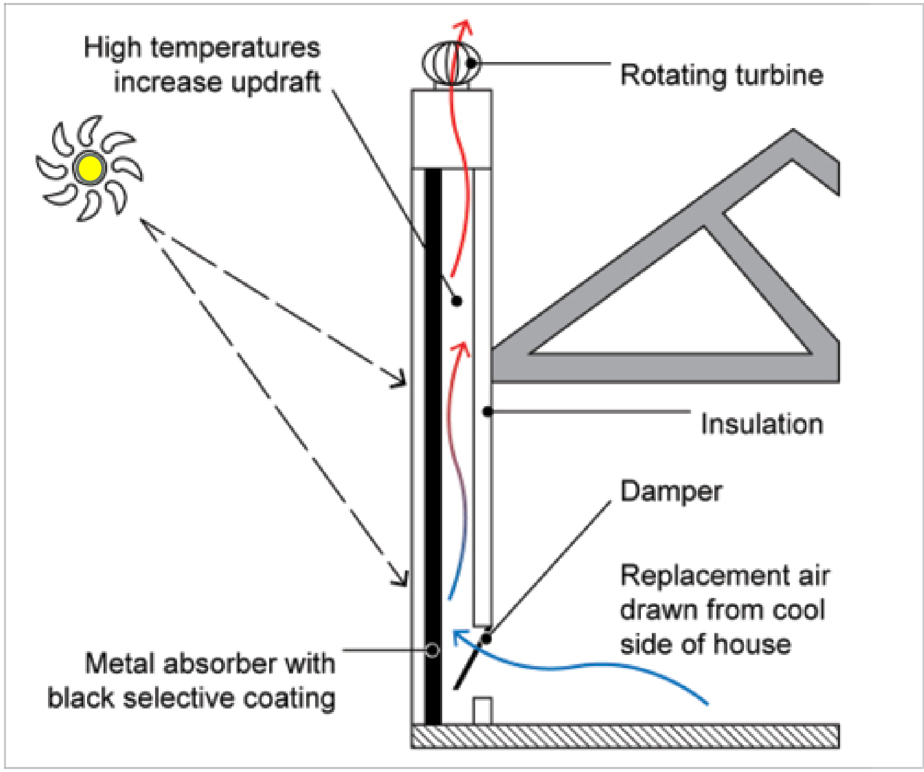
Neighborhoods & Buildings

Example New Developments along Main street



Neighborhoods & Buildings

Example Prototypes for Street Level enhancements



Neighborhoods & Buildings c

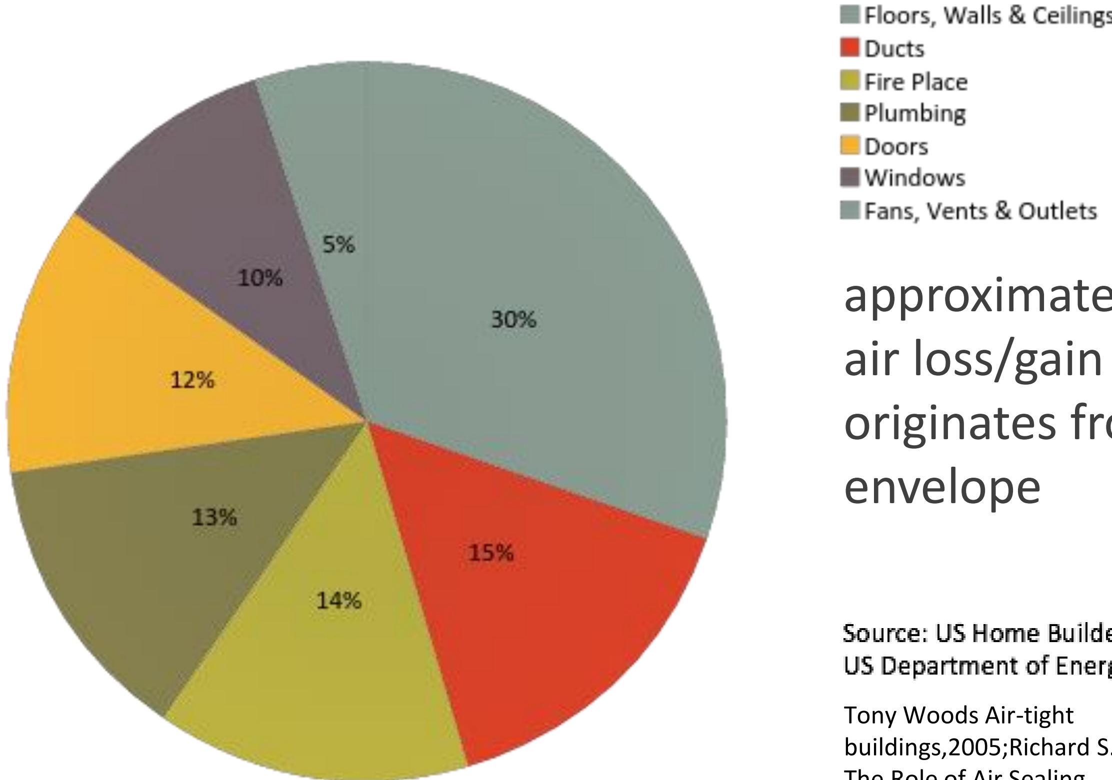
Material strategies for reducing heat

The Utah Olympic Oval used cool roof technology.

Using light colors and alternative envelopes such as louvers we can reduce the heat being absorbed and radiated at a meso-scale

Neighborhoods & Buildings

Representation of heat lost through building components



approximately 40% of air loss/gain originates from the envelope

Source: US Home Builders Association and US Department of Energy

Tony Woods Air-tight buildings,2005;Richard S. Duncan, Phd, PE The Role of Air Sealing

> *"As the green design field matures, it becomes ever more clear that integration is the key to achieving energy and environmental goals especially if cost is a major driver."*
>
> Building Green Inc. (1999)

Alternative Material Recommendations

EXISTING/ CONVENTIONAL

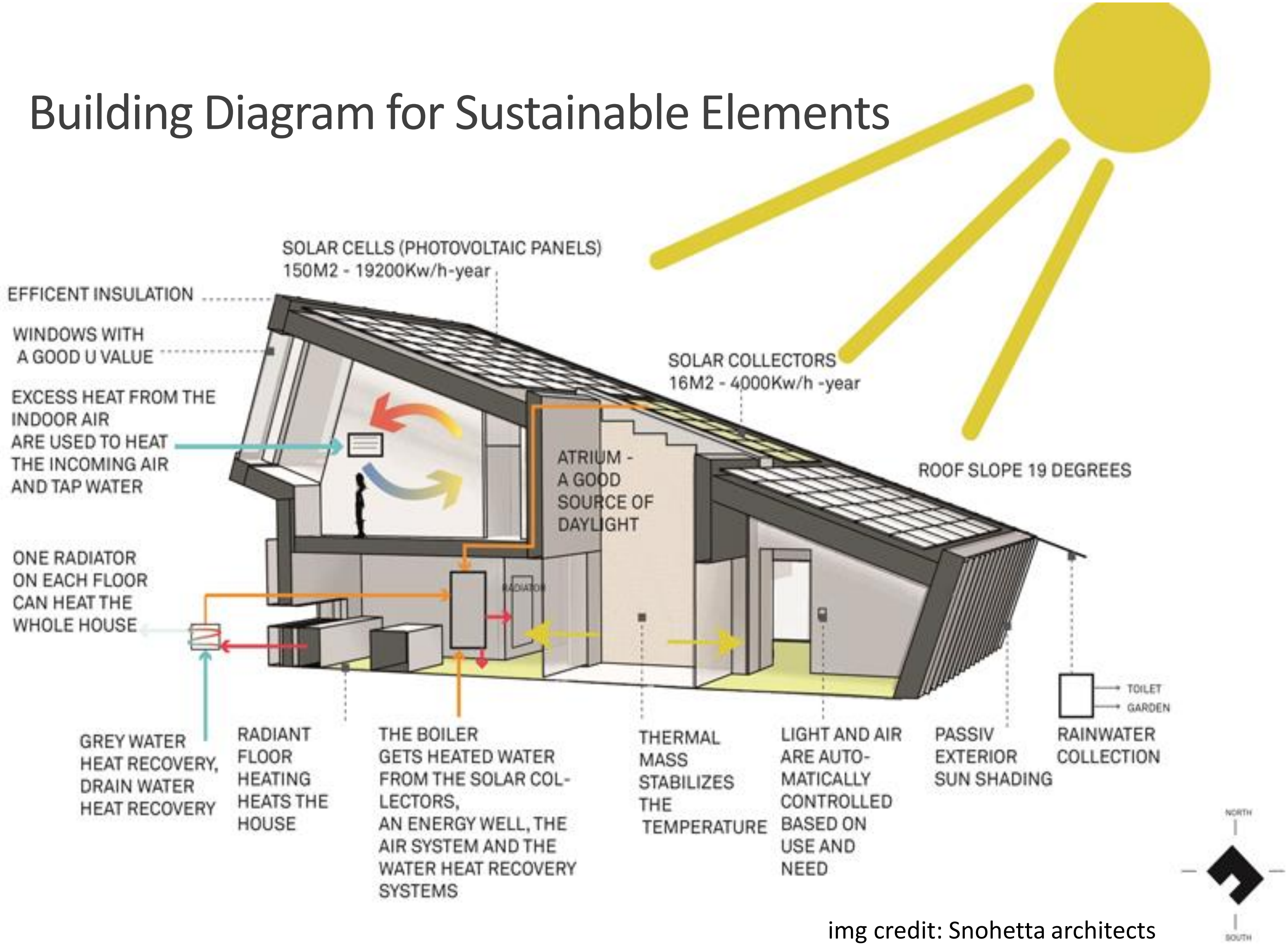
1. Bricks Walls $40/sq. ft.
2. Concrete - Based of Portland Cement
3. Paint
4. Wood products
5. Lighting
6. Windows regular glazing
7. Glazing $12 per sq. ft.
8. Roof-absorbance 0.7
9. HVAC coupled with min req'd insulation
10. Flooring - Regular Carpets
11. Energy codes – IECC

UPGRADE/ SUSTAINABLE

1. CMU with Brick veneer $23 per sq. ft.
2. Fly ash/Slag based concrete - More Durable and slightly less expensive by 0.5-1$ per ton
3. Low-emitting & Recycled paint can cost $3 less/gallon
4. Certified Wood door costs is $150 less expensive
5. Solar tubes and LED lighting
6. Optimized wall to window ratio, U-factor 0.31 & Shading Coefficient of 0.39
7. Spandrel glass $18 per sq. ft.
8. Cool/White Roofs - Absorbance of 0.3
9. Highly efficient Active system Integrated with Passive cooling (Solar chimney, Cooling towers & fans)
10. Carpets with recycled contents costs $15 per yard less than traditional carpet
11. ASHRAE has higher efficiency (10% higher R-Value)

Neighborhoods & Buildings

Building Diagram for Sustainable Elements



img credit: Snohetta architects

Neighborhoods & Buildings

Material Cost Estimates & Guide

- Alternative sustainable materials are durable and less vulnerable to heat
- Most materials have lesser payback period. (Favorable cost-benefit analysis)
- Table below shows Energy Efficiency measured in a Building prototype showing energy cost reduction by 37% as compared to conventional design

	Base-Case Building Annual Energy Cost	Sustainable Building Annual Energy Cost	Percent Reduction
Lighting	$6,100	$3,190	47.7
Cooling	$1,800	$1,310	27.1
Heating	$1,800	$1,280	28.9
Other	$2,130	$1,700	20.1
Total	$11,800	$7,490	36.7

(Source: United States Department of Energy)

Transportation

Transportation Group
Overview

- Preliminary Design of Improved Corridors
- Increased Mobility for Pedestrians and Bicyclists
- Enhanced Transit Connectivity
- Protecting Pedestrians and Bicyclists from Heat Exposure

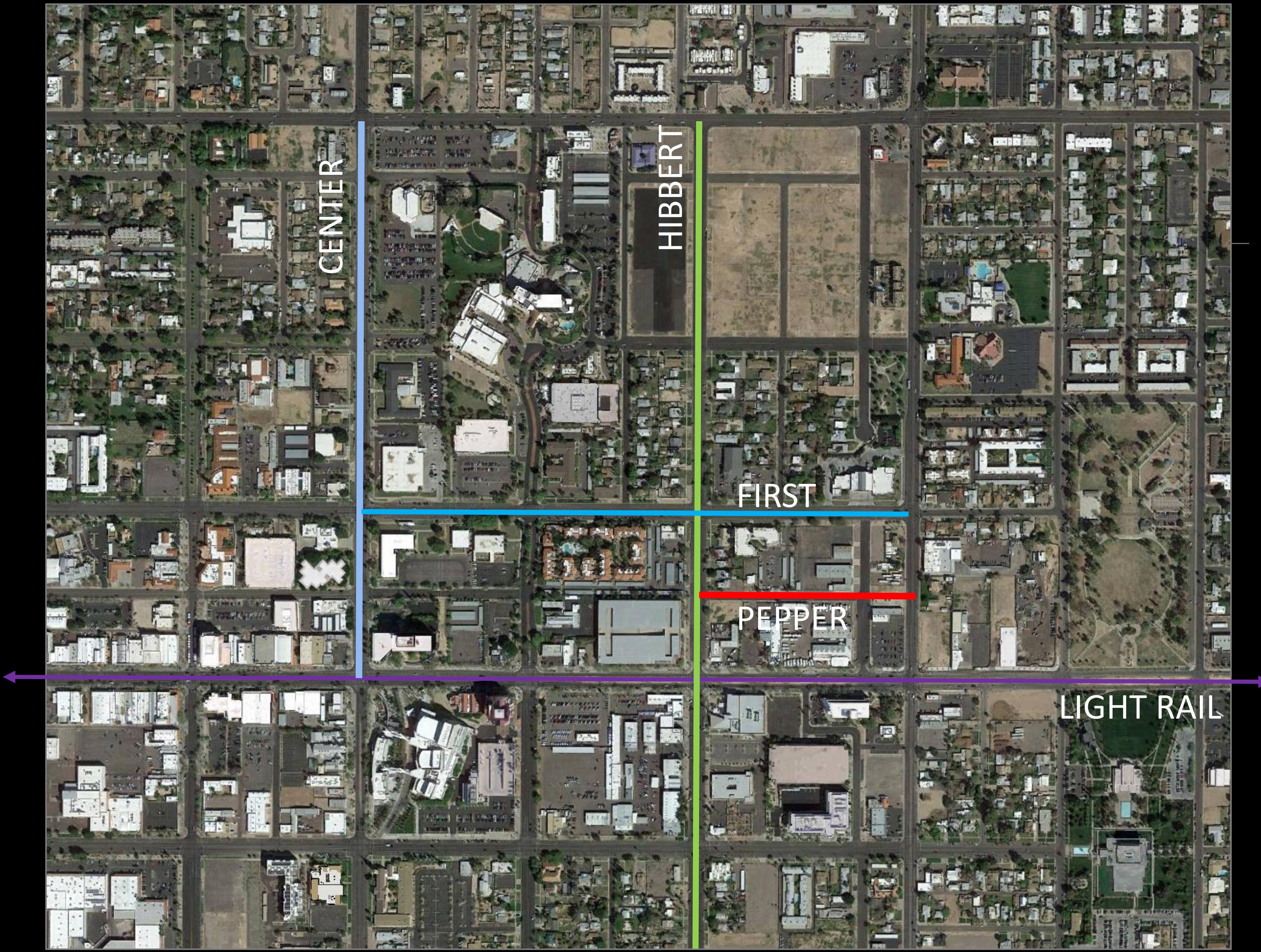
Transportation Group
Goals

- Completion of Mesa Light Rail Extension will increase pedestrian and bicycle traffic to Downtown Mesa

- Reconfigure significant corridors to serve this pedestrian and bicycle traffic

- Encourage further walking and biking with upgraded facilities

- Benefits businesses and promotes vibrant community


CENTER
HIBBERT
FIRST
PEPPER
LIGHT RAIL

Transportation Group
Design Improvements

- Right Sizing First Street
- Rethinking Hibbert as Multimodal Corridor
- Bike Lanes on Center and Mesa Drive
- Connect Pepper to Mesa Drive
- Bicycle Marking Improvements

Transportation Group
Asphalt & UHI

- Soil, grass, vegetated, or xeriscaping areas can reduce release of solar radiant energy (heat flux) by 50-75%

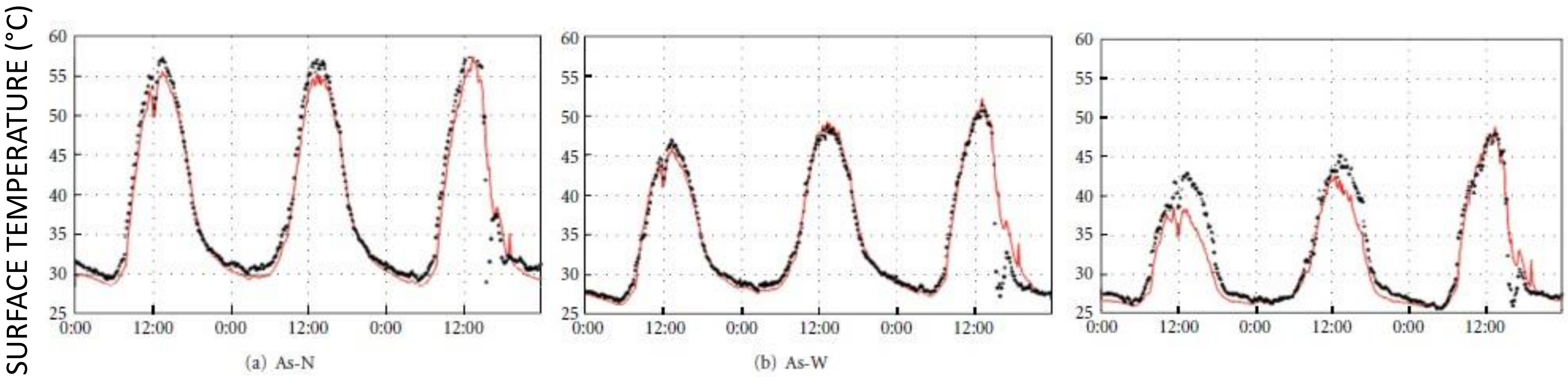
- Vegetation near sidewalks reduces reflected heat and lowers temperature in pedestrian microclimate

- Together, these measures can lower ambient air temperatures by 5 to 15 degrees for pedestrians

*Takebayashi, 2012; Rosheidat, 2014; Santamouris, 2012

Transportation Group
Asphalt & UHI

Surface Temperatures by Type of Material



Conventional Asphalt

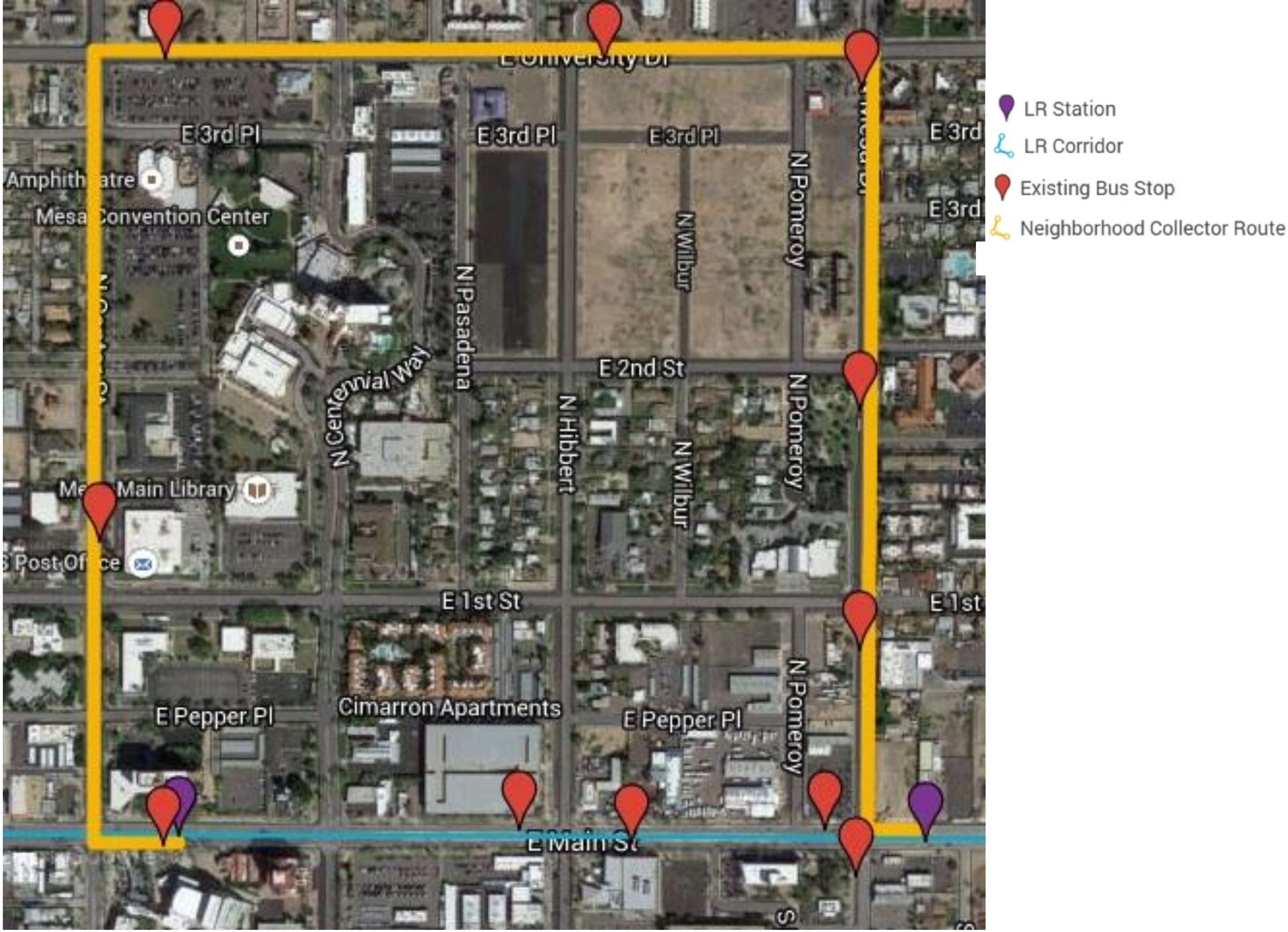
Reflective Asphalt

Xeriscaping

Source: Takebayashi, 2012

Transportation Group
Pedestrian & Bicyclist Mobility

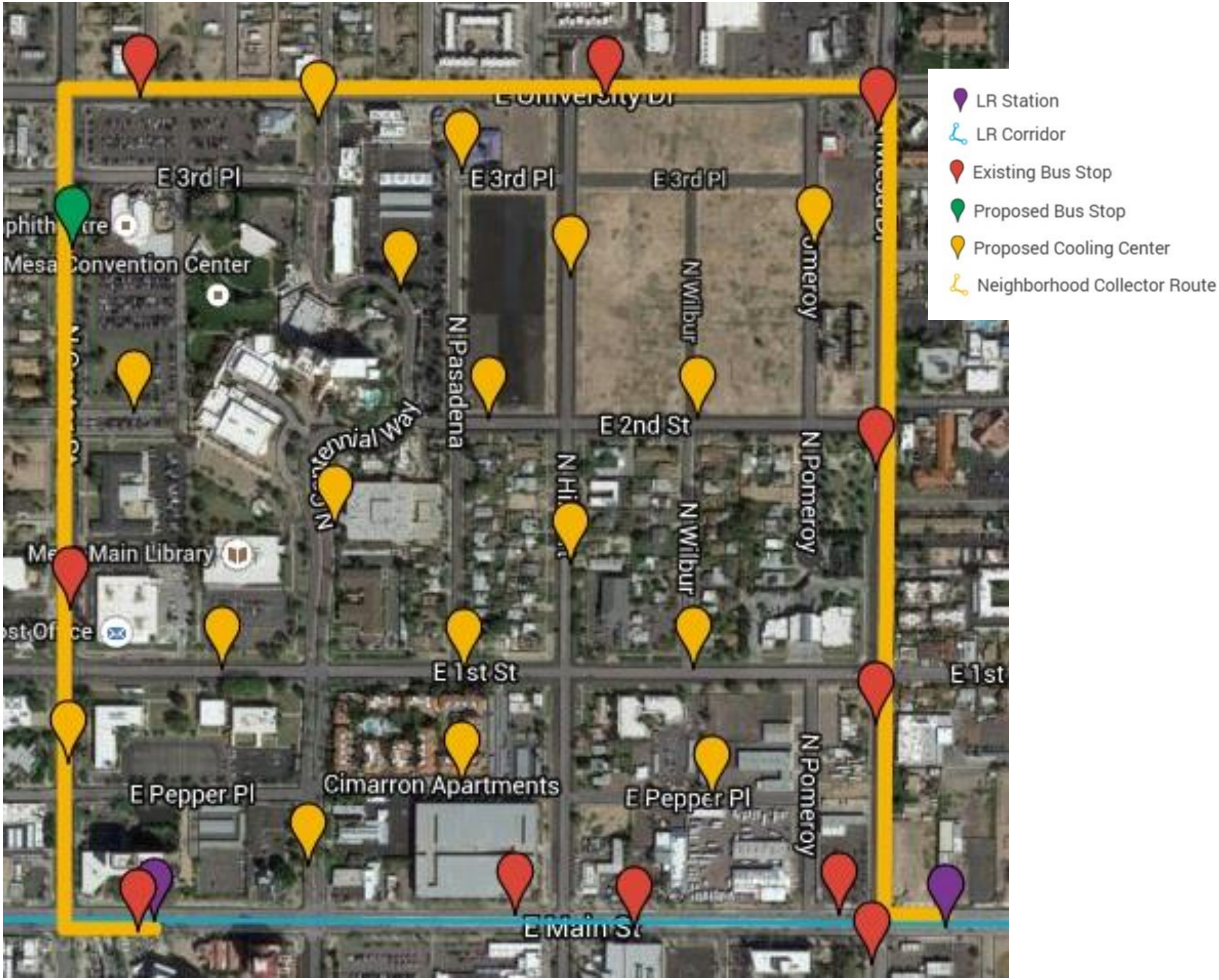
Hibbert Road – Current Configuration

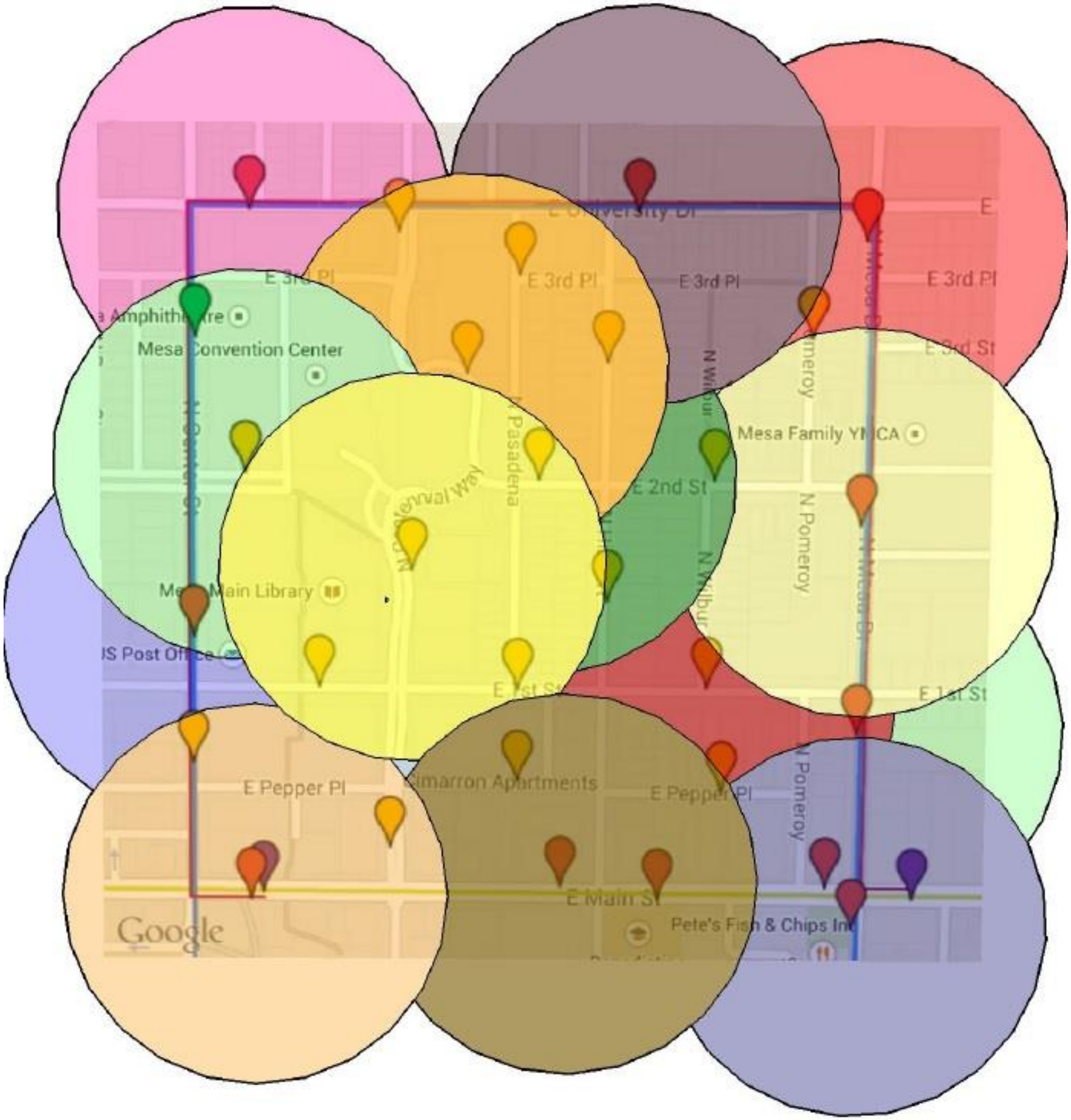

E University Dr
E 3rd Pl
E 3rd Pl
E 3rd Pl
E 3rd
E 3rd
Amphith atre
Mesa Convention Center
N Pasadena
N Wilbur
N Pomeroy
N Centennial Way
E 2nd St
N Hibbert
N Wilbur
N Pomeroy
Me Main Library
S Post Of ce
E 1st St
E 1st
Cimarron Apartments
E Pepper Pl
E Pepper Pl
N Pomeroy
E Main St
LR Station
LR Corridor
Existing Bus Stop
Neighborhood Collector Route

Transportation Group
Heat Vulnerability and Exposure

- Assessing Walking Routes and Exposure Limits

- OSHA: Outside activity less than 15 minutes in heat
- General population needs more protection, 5 minutes
- Corresponding walking distance at 3 ½ feet per second is roughly 1,000 feet.
- People walk in cardinal directions, radial equivalent is 750 feet.
- Analyze map for appropriate coverage and locating heat refuges.
- Final design distance to be determined in collaboration with public health officials


LR Station
LR Corridor
Existing Bus Stop
Proposed Bus Stop
Proposed Cooling Center
Neighborhood Collector Route
E University Dr
E 3rd Pl
E 3rd Pl
E 3rd Pl
Mesa Convention Center
Main Library
N Pasadena
N Wilbur
N Pomeroy
E 2nd St
E 1st St
E 1st
E Pepper Pl
E Pepper Pl
Cimarron Apartments
N Pomeroy
N Wilbur
E Main St

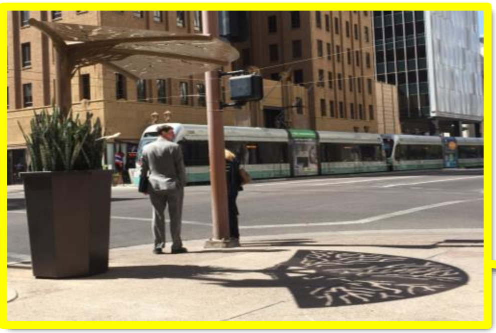

E University Dr
E 3rd Pl
E 3rd St
Mesa Convention Center
Mesa Family YMCA
N Pasadena
N Pomeroy
E 2nd St
E 1st St
E Pepper Pl
Cimarron Apartments
E Main St
Pete's Fish & Chips Inc
Google

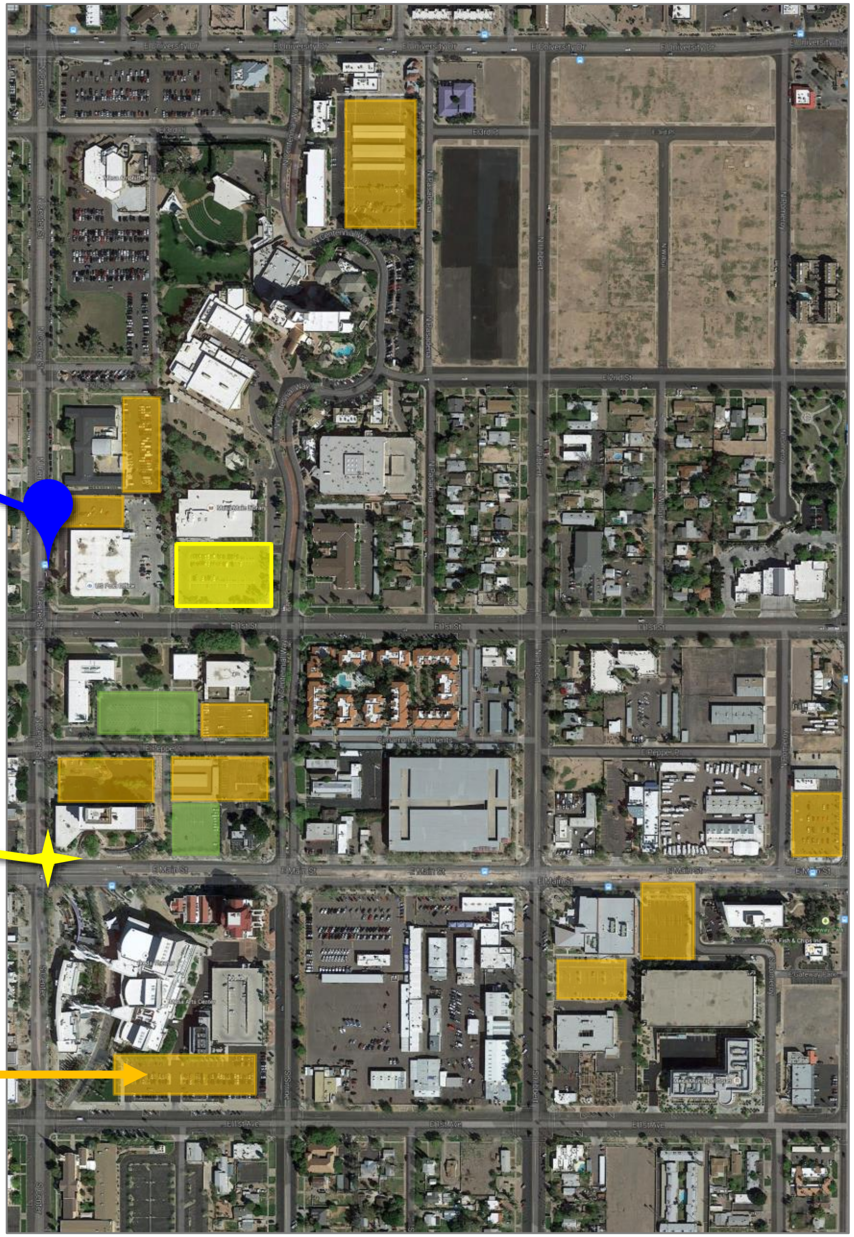
Transportation Group Recommendations

- Reconfigure streets to promote walking and biking while reducing vulnerability to heat
- Increase the accessibility of the neighborhood by adding improved pedestrian access at Hibbert/University, First/Mesa, Pepper/Mesa
- Operate a neighborhood circulator bus route that connects the neighborhood to light rail while reducing walking/exposure durations
- Heat refuges to be placed at walking interval determined by coordination with public health officials


Landscaping, Shading, and Exterior Environments

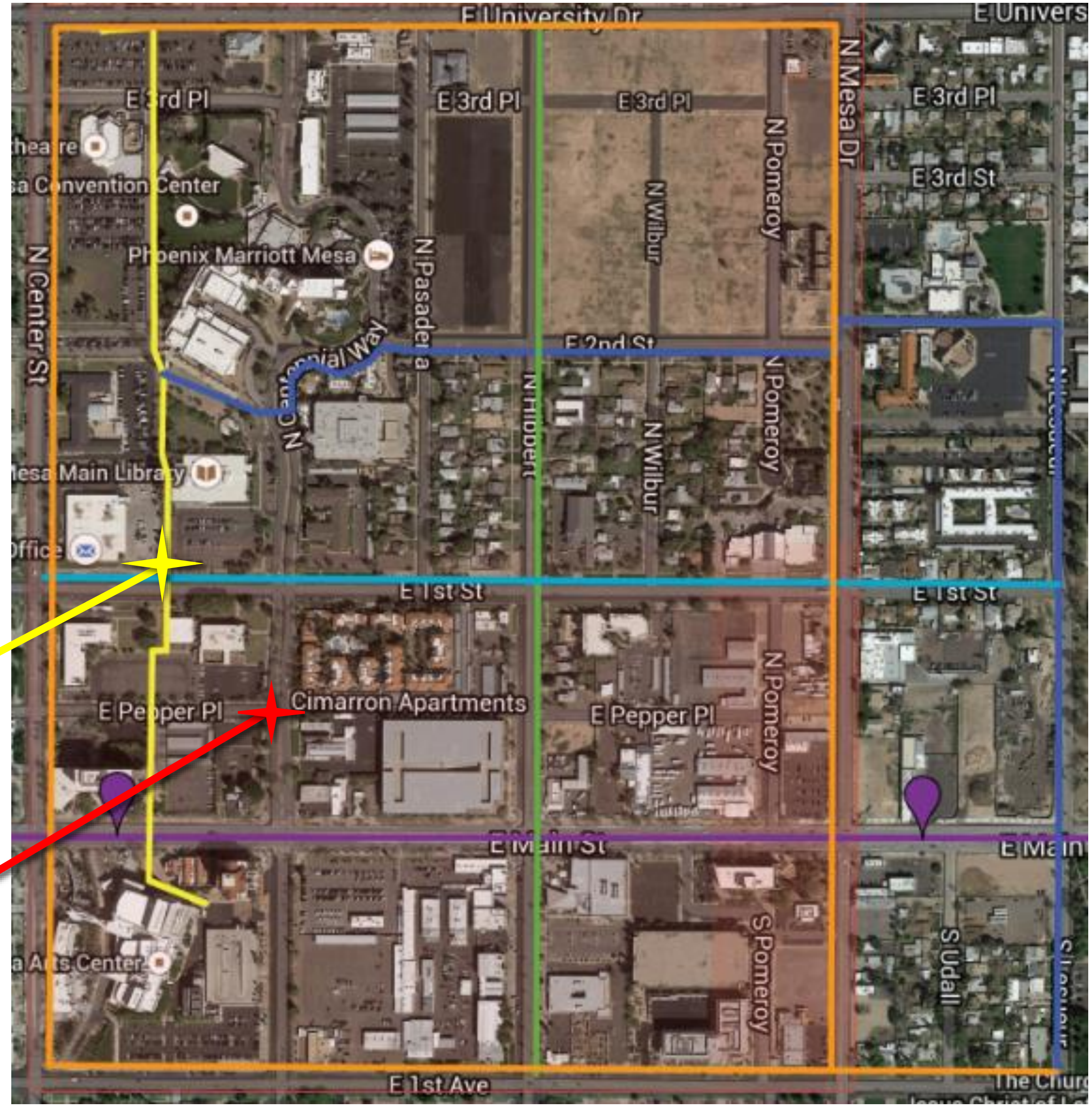
Shading





Shading


90 M


E University Dr
E 3rd Pl
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E 3rd St
N Mesa Dr
N Pomeroy
N Wilbur
N Pasadena
N Center St
Phoenix Marriott Mesa
E 2nd St
N Hibbert
N Wilbur
N Pomeroy
E 1st St
E 1st St
E Pepper Pl
Cimarron Apartments
E Pepper Pl
N Pomeroy
E Main St
S Pomeroy
S Udall
E 1st Ave

Surfaces

Sidewalks: Rubbersidewalks™

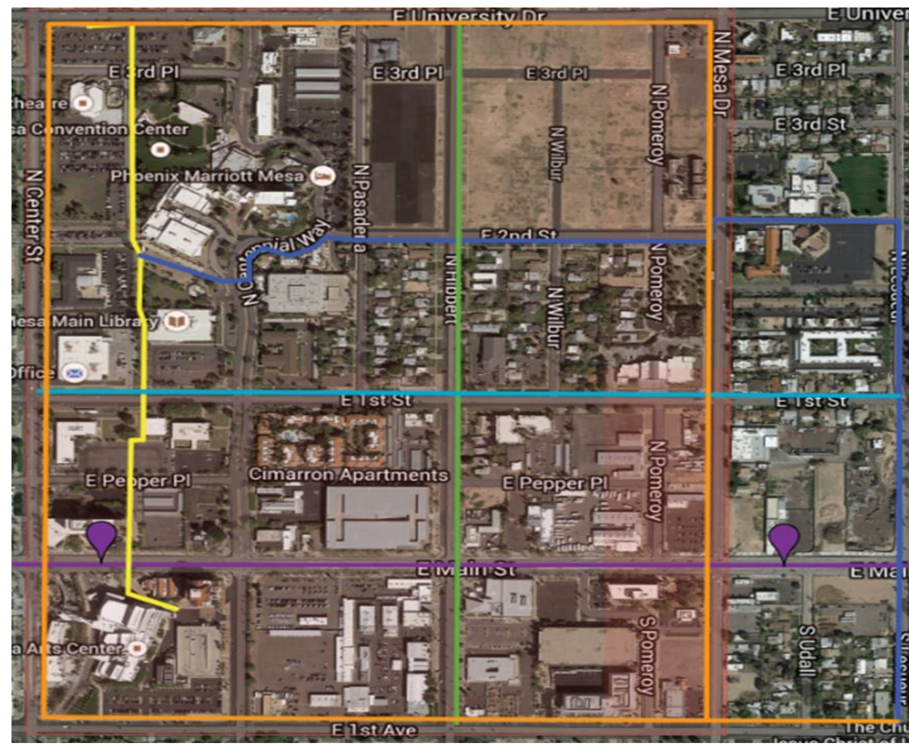
- Maintenance requirements are significantly less in terms of **life cycle costs** than concrete.
- Rubber is 10 times less thermally conductive than concrete resulting in less heat release.

Benefits of rubber in pedestrian corridors (5.5 mi):

Labor Costs:
\$8 per sq ft for **Concrete** => 2.11 million dollars
\$1.5 per sq ft for **Rubber** => 396 thousand dollars

Using Fourier's Law:
Thermal Conductivity of **Concrete** 1.5
Thermal Conductivity of **Rubber** 0.15

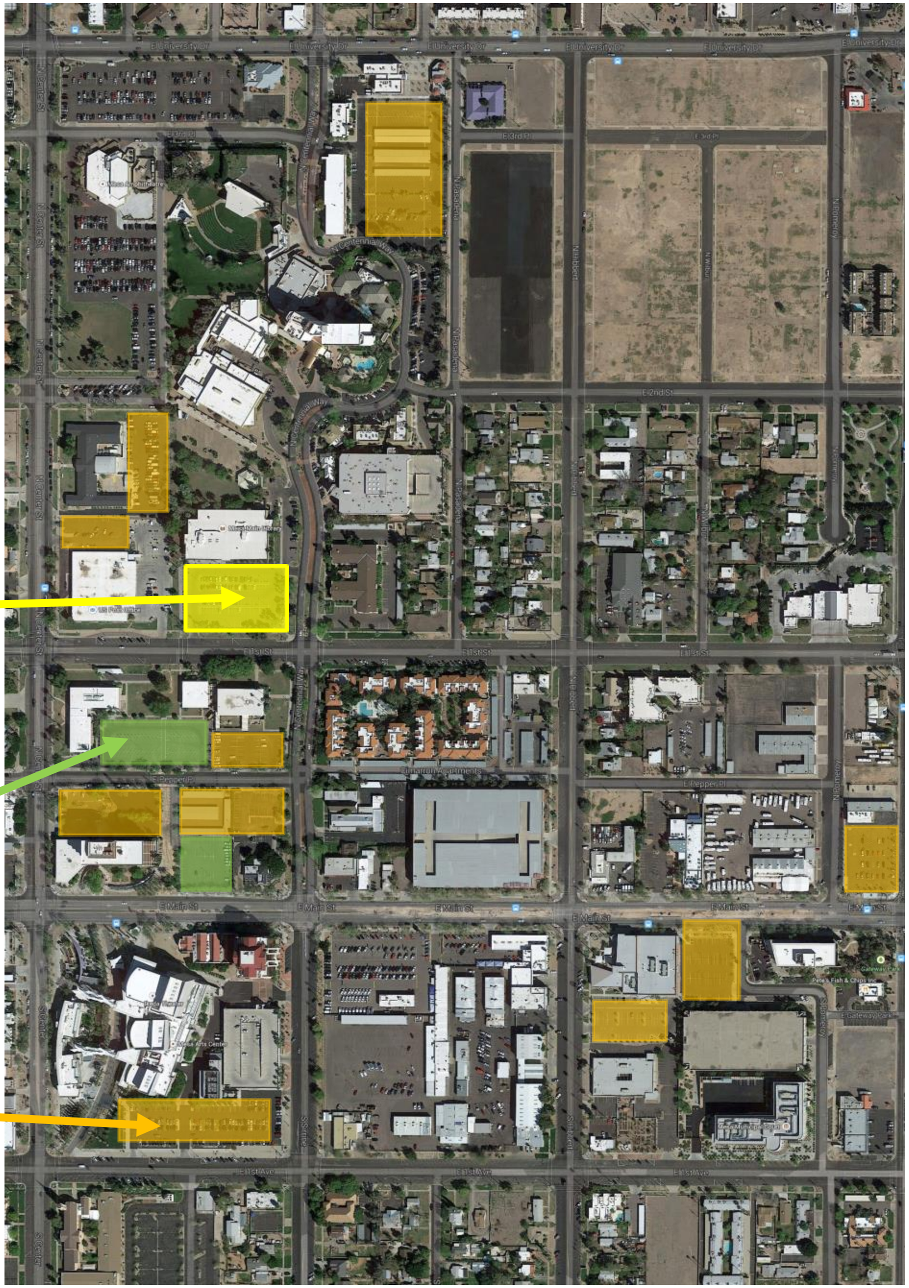
Absorbed heat for pedestrian corridor (5.5 miles):
Concrete: ~40,000 Watts/Kelvin
Rubber: ~4,000 Watts/Kelvin



Surfaces

Parking Lots: Consolidated parking structures or permeable surface lots.

Convert to green space



Improvements to existing infrastructure

Expand existing incentives:

Xeriscaping – low water use vegetation

- 500 sq ft - 1,250+ sq ft
- $1000 - $3000

Reflective coatings

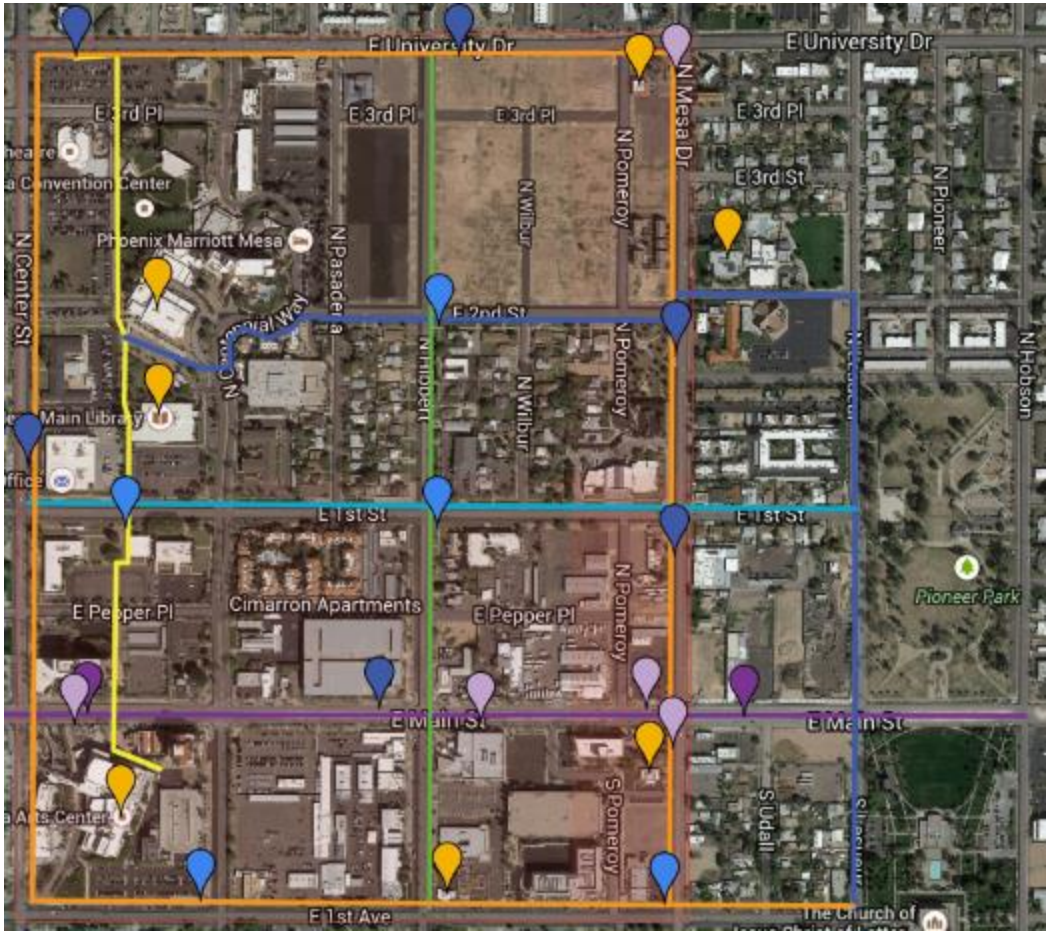
Green walls

Encouragement – permitting, mailings, event flyers, public classes, etc.

Stormwater Capture

Pedestrian Corridors & Heat Refuges

Pedestrian Corridor placement and implementation would be prioritized into 3 “Phases” with Heat Refuges positioned in strategic locations to support pedestrian travel.



Social and Institutional Considerations

Mitigation Plan

Goal: Reduce social vulnerability to heat in Mesa

Expand local incentives and programs

Seek external resources, funding, partnerships

Identify locations of vulnerability

Establish cooling centers & hydration stations

Internal and institutional support

Local Incentives and Programs

Green Building Programs

- Scottsdale and Chandler
- City, commercial, and residential buildings
- International Green Construction Code (IcGG) Heat Island Mitigation Worksheet
- Expedited priority plan review

Xeriscaping Incentives

- Glendale - up to **$750** to convert 500 sq. ft. of turf to low water use landscape
- Scottsdale - up to **$1,500** for turf removal at residential properties
  - up to **$3,000** for commercial properties
- Peoria - up to **$1,650** to convert 500 sq. ft. of turf to low water use landscape

Public Communication & Education

- Scottsdale: Green Buildings Lecture Series

Institutional Support

Federal Funding

- EPA Sustainable Skylines (Dallas, TX; Kansas, KS; Philadelphia, PA)
- Federal General Services Administration – Green Roof (Florence, SC)
- Department of Energy – “Trees for Energy Saving” (Denver, CO)

Partnerships – local municipalities, private and non-profit

- Local Energy Suppliers
  - “Trees for Tucson” tree subsidies (Tucson Electric Power, Trico Electric co-op, Kinder Morgan; Tucson, AZ)
  - Reflective roof rebates (Austin Energy, -Austin, TX; Cool Houston! - Houston, TX)
- Local non profits
  - Urban Forestry Program (Groundwork Elizabeth, Elizabeth, NJ)
- Gilbert, AZ currently seeking partnerships with other municipalities

Institutional Support

New building and development guidelines

- Green building codes for city and commercial buildings
- Requirements of cool roofs, shade and/or vegetative cover

Community outreach and involvement

- Educational meetings and workshops
- “Adopt-a-Median” tree planting program (Dallas, TX)
- Development of heat island and cool community task forces (Atlanta, GA; Philadelphia, PA, Austin, TX, others)

Public Survey

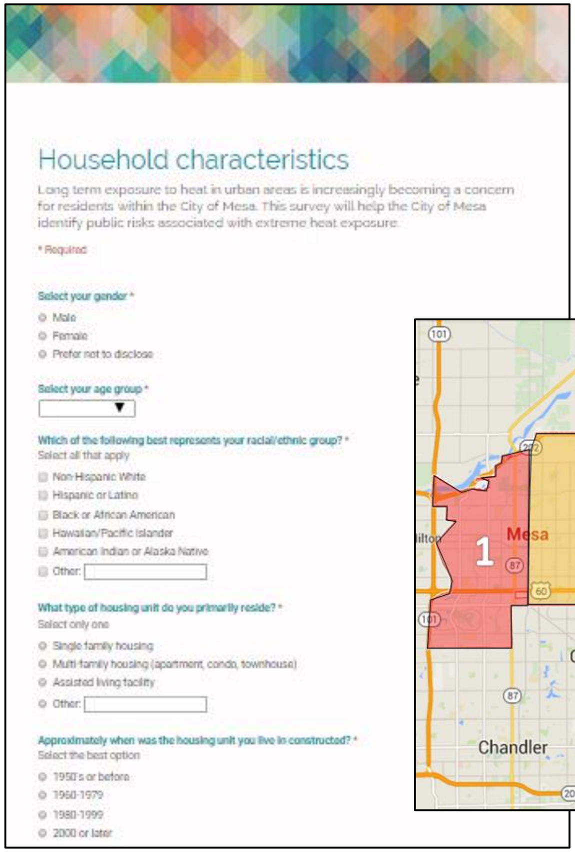
Goal: Assess socio-technical vulnerabilities at household level

Identify vulnerable social groups

- Income levels
- Housing styles
- Ethnicity
- Neighborhood
- Health

Evaluate technology & services

- Building use
- Hours of operation
- Transportation
- Marketing
- Services offered



Household characteristics

Long term exposure to heat in urban areas is increasingly becoming a concern for residents within the City of Mesa. This survey will help the City of Mesa identify public risks associated with extreme heat exposure.

* Required

Select your gender *

- Male
- Female
- Prefer not to disclose

Select your age group *

Which of the following best represents your racial/ethnic group? *
Select all that apply

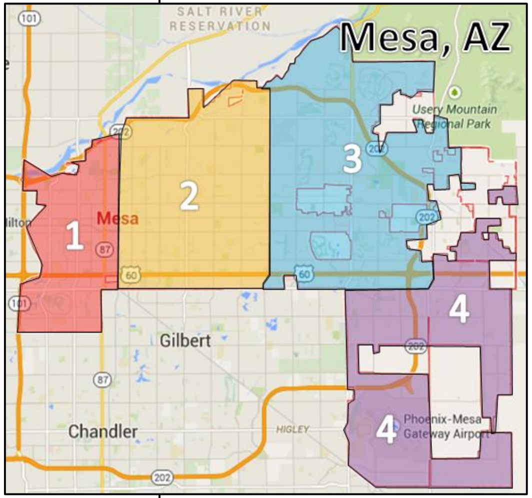
- Non Hispanic White
- Hispanic or Latino
- Black or African American
- Hawaiian/Pacific Islander
- American Indian or Alaska Native
- Other:

What type of housing unit do you primarily reside? *
Select only one

- Single family housing
- Multi family housing (apartment, condo, townhouse)
- Assisted living facility
- Other:

Approximately when was the housing unit you live in constructed? *
Select the best option

- 1950's or before
- 1960-1979
- 1980-1999
- 2000 or later



Cooling Centers & Hydration Stations

Cooling Centers

Access Issues

- Proximity
- Availability ≤ 50% on Saturday and Sunday

Building Use

- Religious (13%)

Limited Services

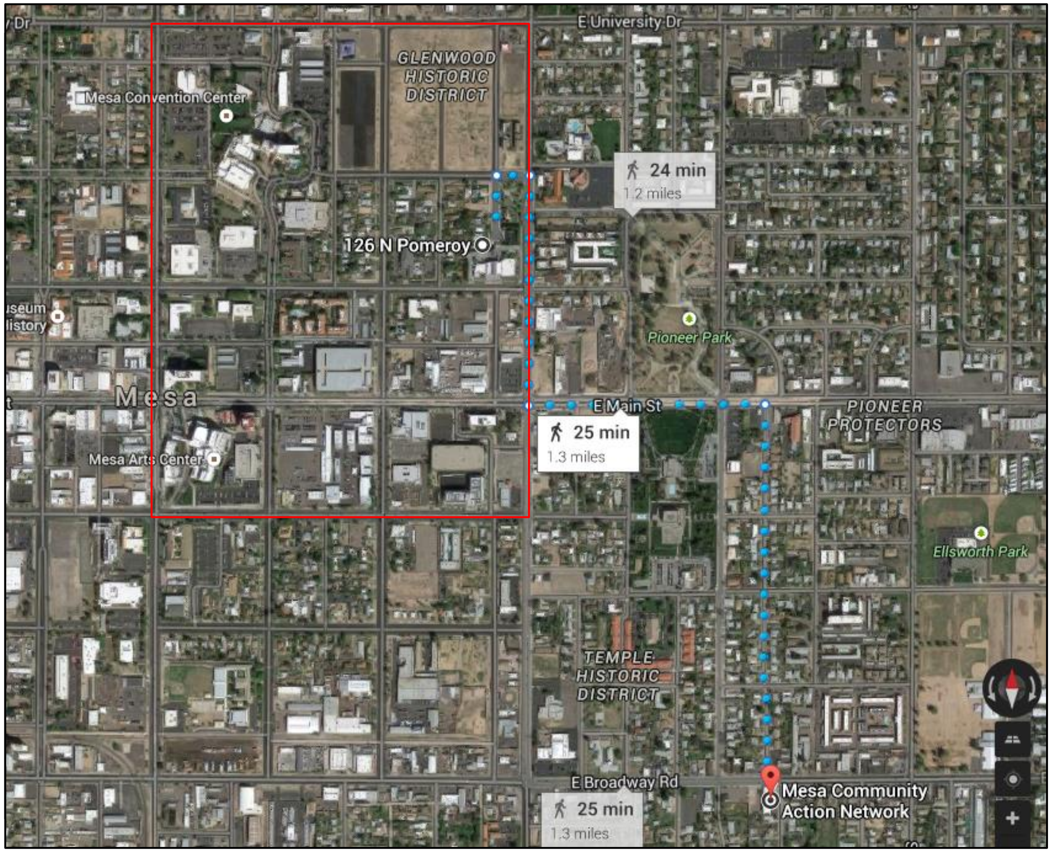
- Conduct personal business
- Community engagement

Water distribution

Access Issues

- Proximity
- Seasonal

Waste produced



Improvements



Hydration Stations

Goal: Increase accessibility to water, improve water distribution

Solutions

- Water bottle filling stations
- Commercially endorsed water bottles

Benefits

- Quick, easy access
- Reusable – reduce waste
- Reduce distribution issues
- New image for old fountains

Continue to promote Mesa Hydration Donation Campaign

Heat Risk Education & Communication

Education Efforts

- Symptoms of heat illness
- Maximum safe exposure time
- When to seek medical help
- General safety tips

Communicate Available Resources

- Hydration and water bottle refill stations
- Cooling center locations
- Emergency information

Communication Methods

- Broadcast media
- Voluntary Emergency Message System
- Post information
- MesaAZ.gov website

Heat Vulnerability Council

Goal: Manage Heat Vulnerability Mitigation Plan & support program success

Small team comprising of
- City of Mesa officials
- Community stakeholders
- Concerned citizen volunteers

Successful Examples
- Philadelphia Heat Task Force
- El Paso’s Heat Task Force

Roles and Duties
- Review EHE best practices
- Update Heat Vulnerability Mitigation Plan
- Evaluate measures of success

Measures of Success

Goal: Develop measures to evaluate the effectiveness of efforts to reduce social heat vulnerability in Mesa, Arizona

Measures of Effectiveness

- # of heat-related hospitalizations (morbidity)
- # of heat-related deaths (mortality)
- Heat related emergency costs
- Ratio of person/sq. ft. area of accessible air conditioning
- # of persons utilizing cooling centers and hydration stations

Overview of Recommendations

TRANSPORTATION

- Roadway Improvements
- Expand transit services
- New paving materials
- Multimodal services

NEIGHBORHOODS & BUILDINGS

- Cool roofs
- Energy Production
- Heat Reduction
- Solar Light Tubes
- Facades

ENVIRONMENT

- Shading
- Tree Shading
- Improved Surfaces
- Stormwater infrastructure Improvement

SOCIAL & INSTITUTIONAL

- Education
- Heat Vulnerability Adaptation Plan
- Measures of Effectiveness
- Heat Vulnerability Council