

Resilience, Water and Tools

Technical Session 7 - June 07

NEWEA Spring Meeting 2017

Perkins+Will

Andy Bennett, Senior Associate | Senior Project Architect

AIA College of Fellows Latrobe Research Prize: 2015-2017

Drylands Resilience Initiative [DRI]:

**Digital Tools for Sustainable Urban Design in
Arid and Semi-Arid Urban Centers**

2015-2017 LATROBE RESEARCH PRIZE TEAM

ARIDLANDSINSTITUTE

Hadley Arnold

Executive Director, Arid Lands Institute

Peter Arnold

Research Director, Arid Lands Institute

PERKINS+WILL

Justin Brechtel AIA LEED AP

Senior Computational Designer, Perkins+Will

Leigh Christy AIA LEED AP BD+C

Associate Principal, Perkins+Will

John Haymaker, PhD, AIA LEED AP

Director of Research, Senior Associate, Perkins+Will



Rowan Roderick-Jones PE CSci ENV SP

Director of Urban Green Infrastructure Partnerships, NatureVest at The Nature Conservancy



Deborah Weintraub AIA

Chief Deputy City Engineer, City of Los Angeles, Bureau of Engineering, Department of Public Works

WE GRATEFULLY ACKNOWLEDGE

American Institute of Architects College of Fellows



LEARNING OBJECTIVES

Understand how **climate change impacts** water supply in arid and semi-arid urban centers;

Understand new opportunities and techniques **building water supply**;

Understand **outcomes of Latrobe Prize** Research Objectives:

Research Objective 1: Tool Development: Data and Metrics; and

Research Objective 2: User Interface: Design, Testing, and Outreach;

Understand **application of digital tool** to architectural design process;

Understand decision-support tool in **public policy context**.

OUTLINE AGENDA

1. Why Hazel?

Climate Challenges to Resilient Water Supply in Drylands

2. What is Hazel? Decision-Support at Multiple Scales

Data, Metrics, and Analytics: Latrobe Research Objective 1

3. How to Hazel? Elevating the Design Process

User Interface Design, Testing, and Outreach: Latrobe Research Objective 2

4. Hazel in Policy Context

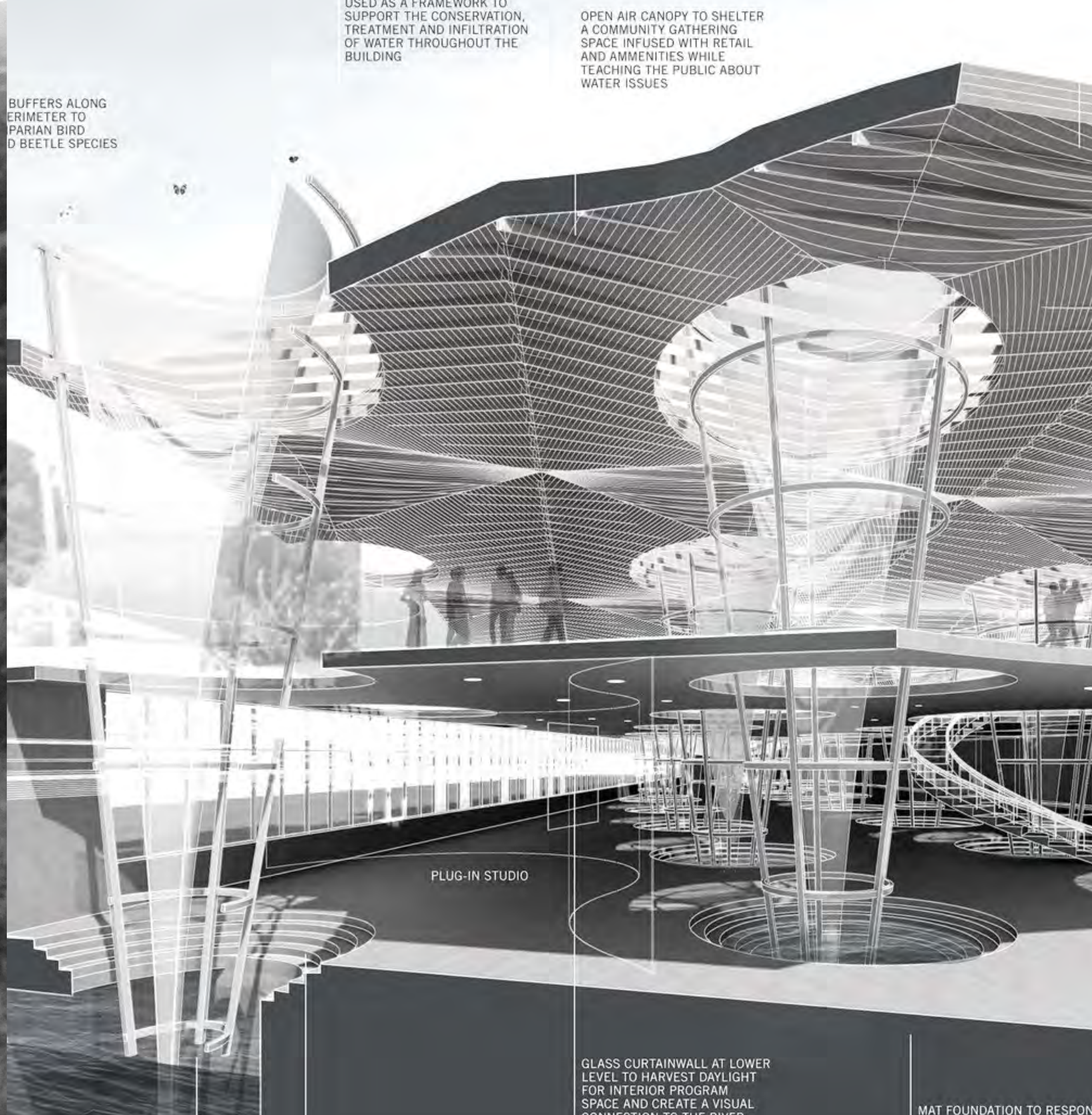
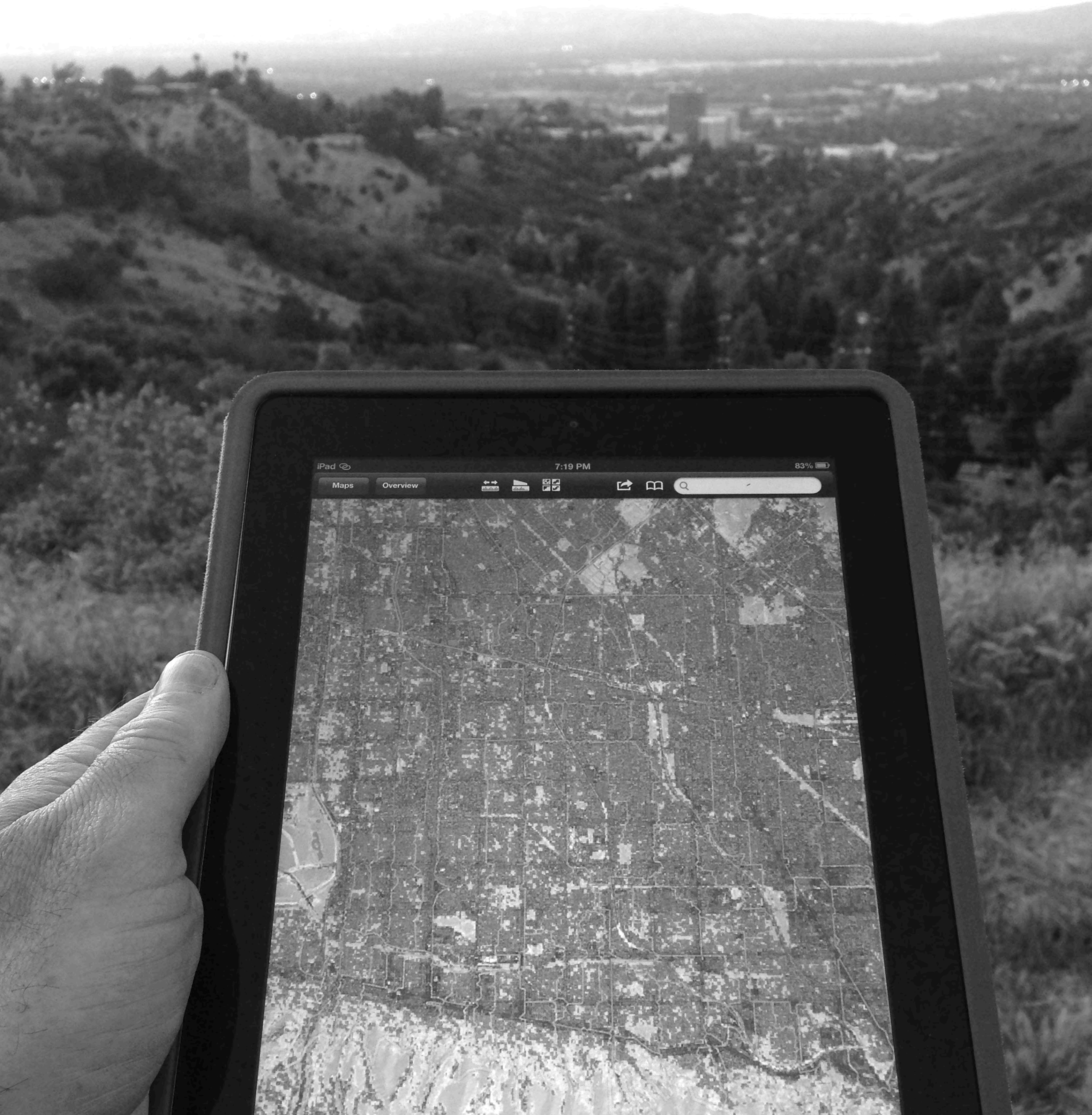
Public-private partnerships and healthy credit markets

5. Q+A

1

Why Hazel? Intro and Overview

Climate Challenges to Resilient Water Supply in Drylands



DRI: Drylands Resilience Initiative

esri

ALI [left], Doug Bergert, Anne Smith, Alex Sands, Water Towers, Perkins+Will, DLC First Prize Winner, 2014 [right]



The global water cycle is changing.

US Drought Monitoring Conditions, October 13, 2015, NDMC, NOAA, USDA
El Niño Southern Oscillation, Ocean Temperature Departure from Average, October 10, 2015, NOAA

SERIOUS DROUGHT
HELP SAVE WATER

Dry will be dryer.





Wet will be wetter.



**Conservation, recycling, and stormwater
can meet 82% of LA's water needs.**





Nearly half will come from stormwater.





Where? How?



An aerial photograph of a city grid with a river winding through it. A semi-transparent teal banner is overlaid across the middle of the image, containing the main text. The city below shows a dense network of streets and buildings, with some green spaces and a large open area on the right side.

Where do we prioritize investment in distributed green infrastructure?

An aerial photograph of a city grid with a river winding through it. A semi-transparent teal banner is overlaid across the middle of the image, containing the text 'How do we evaluate impacts and outcomes?'.

How do we evaluate impacts and outcomes?



How do we make disparate data integrated and accessible for designers?



2

What is Hazel?

Decision-Support at Multiple Scales

Hazel is:

A digital decision support tool for optimizing distributed **stormwater capture** within arid urban centers.

+ Esri World Geocoder -

Home

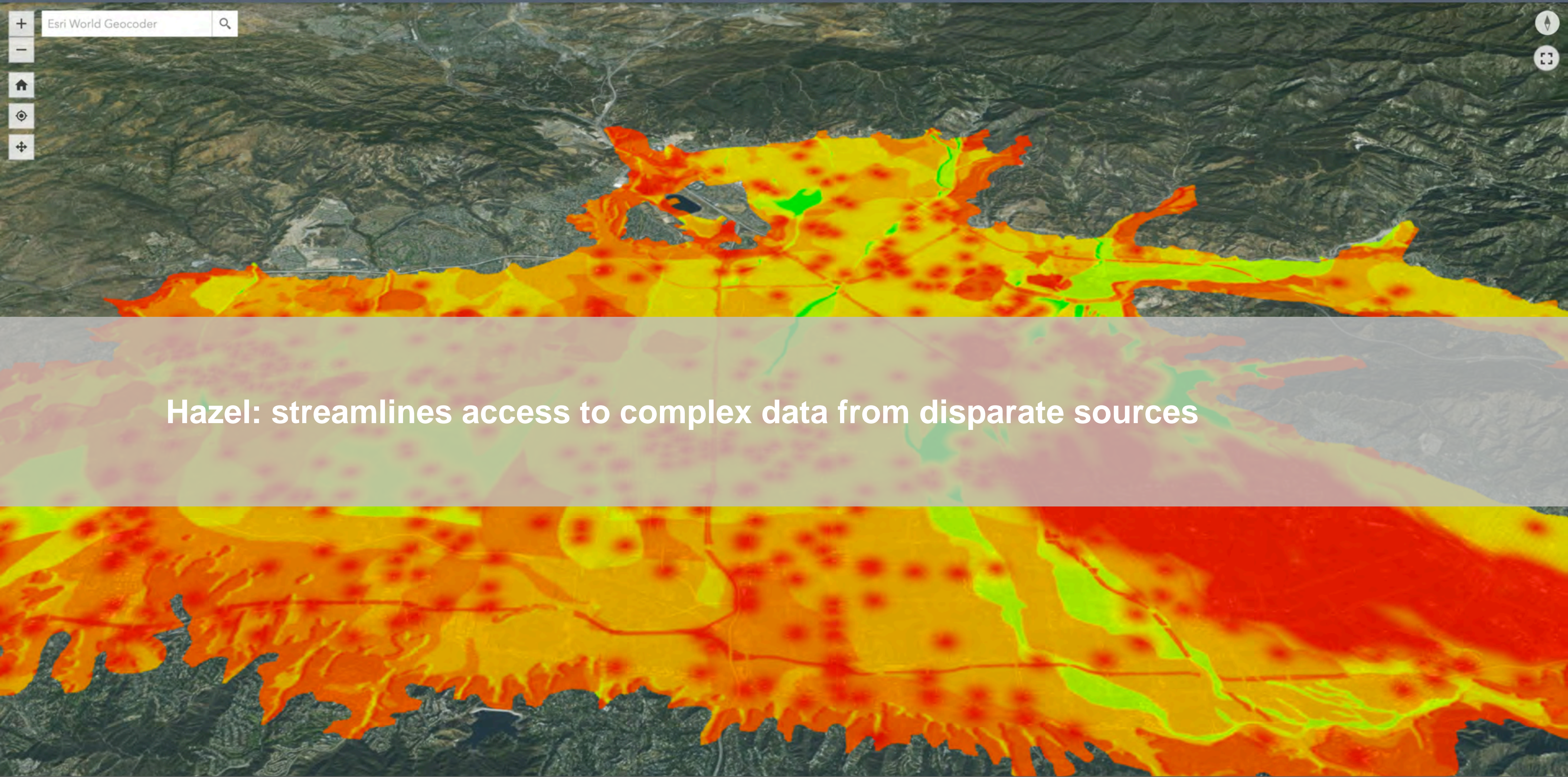
Target

Full Screen

Layers

Compass

Full Screen



Hazel: streamlines access to complex data from disparate sources

DRI: Drylands Resilience Initiative

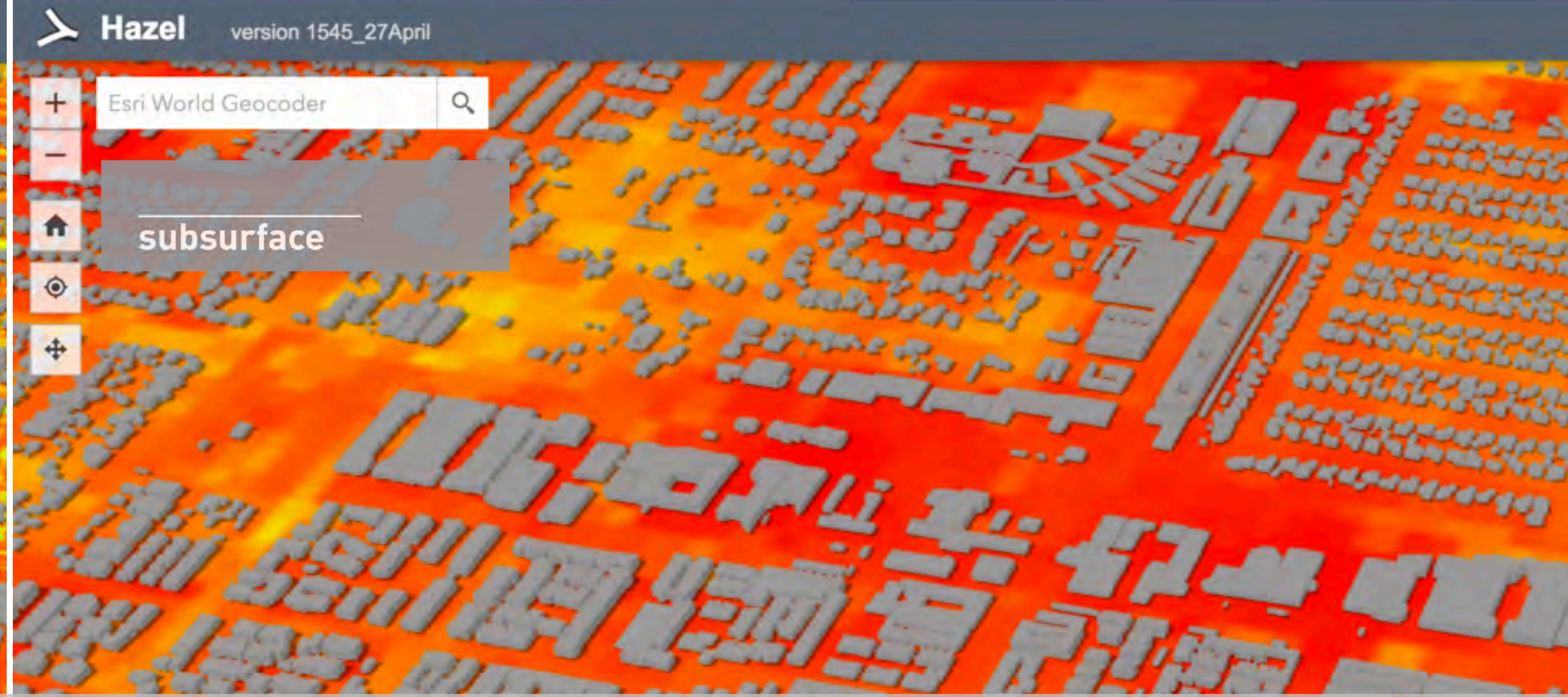
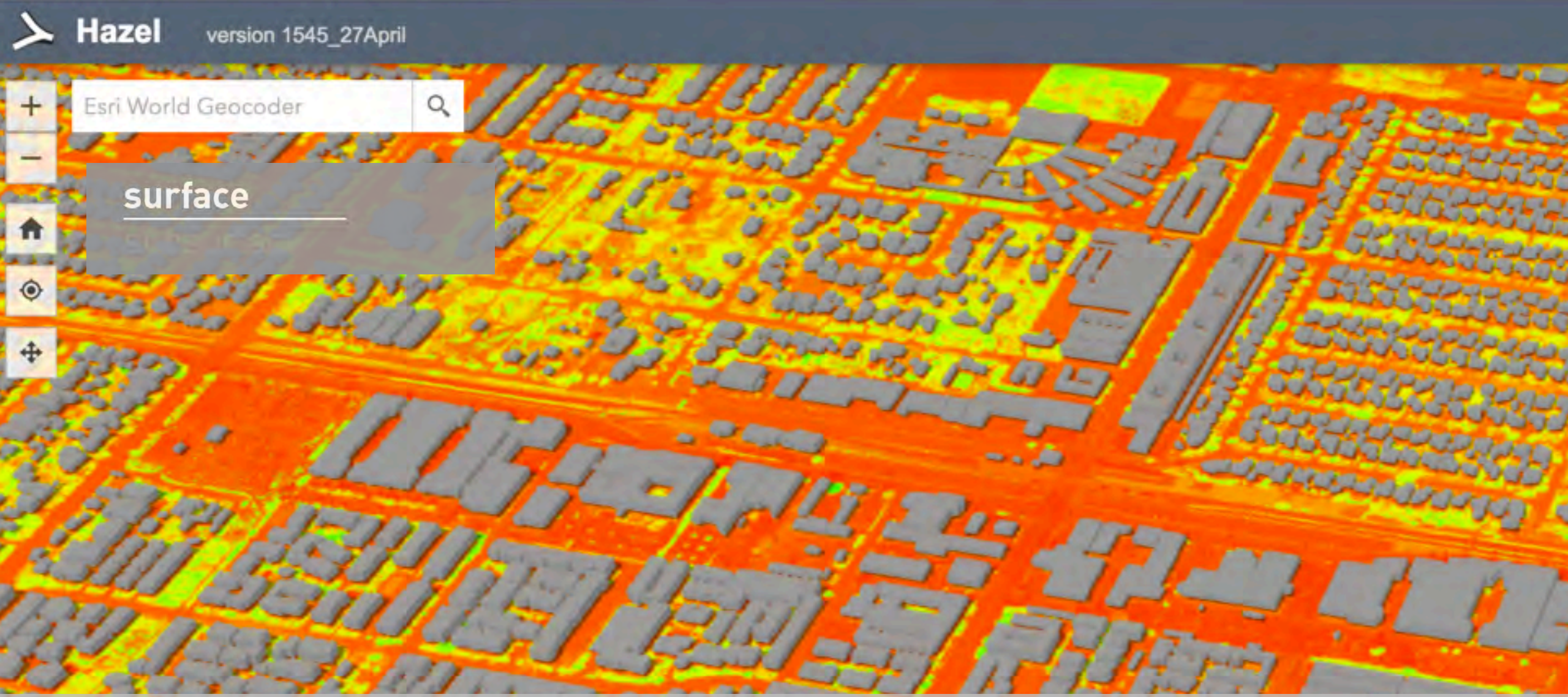
Esri World Geocoder



Hazel: operates at both local and regional scales



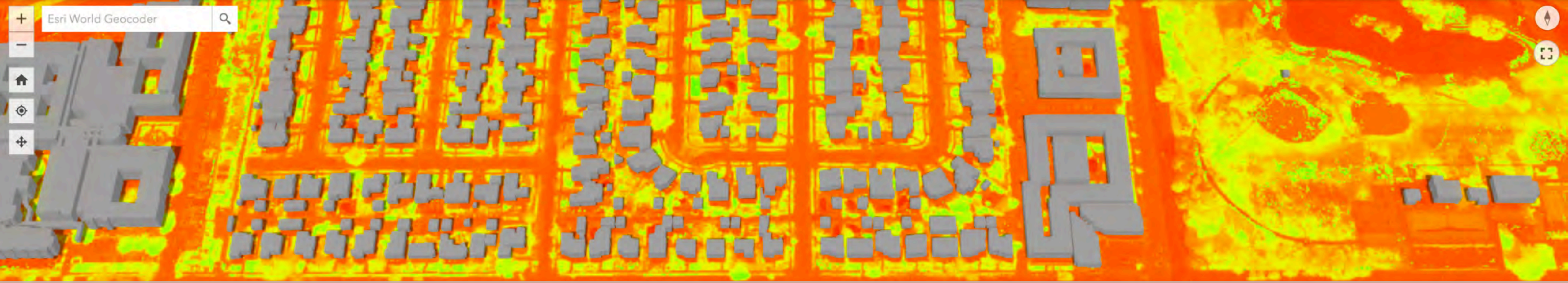
DRI: Drylands Resilience Initiative



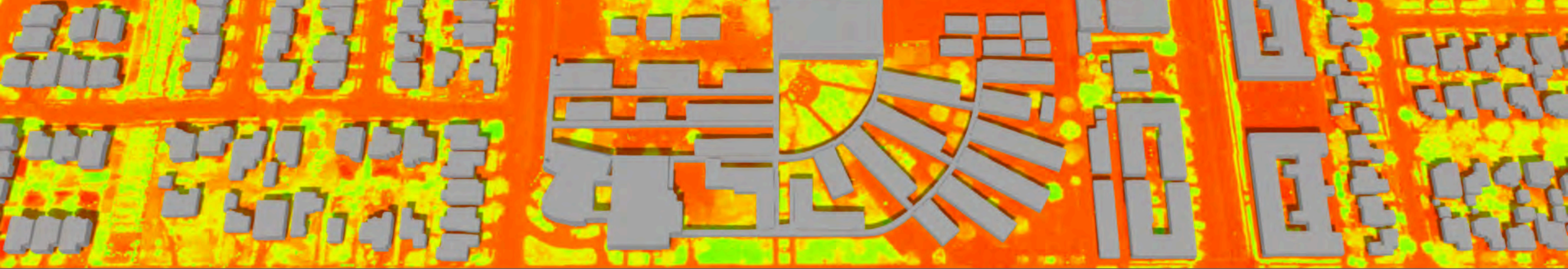
Hazel: couples surface and subsurface data at high resolution;



DRI: Drylands Resilience Initiative



Hazel: evaluates costs/benefits of design scenarios;



Hazel enables users to:

Hazel: rapidly test multiple design scenarios;

Development Area - Draw Closed Polyline

Proposed Buildings - Region(s) as closed polyline(s)

Planted Areas - Region(s) as a closed polyline(s)

Draw Infiltration BMP - Region as closed polyline

Draw Capture and Convey BMP - Region as closed polyline

Infiltration

Bioswale (Rain Garden)

BMP Media Depth (in Feet) 2.0

Surface Infiltration Capacity (gal) 5560 Cost \$ \$88600 - \$119800

Capture and Convey

Green Roof (Extensive)

BMP Media Depth (in Feet) 0.5

Surface Capture Capacity (gal) 0 Cost \$ \$ - \$

Retention

Select BMP Measure

Retention Capacity (gal) 0 Cost \$ \$ - \$

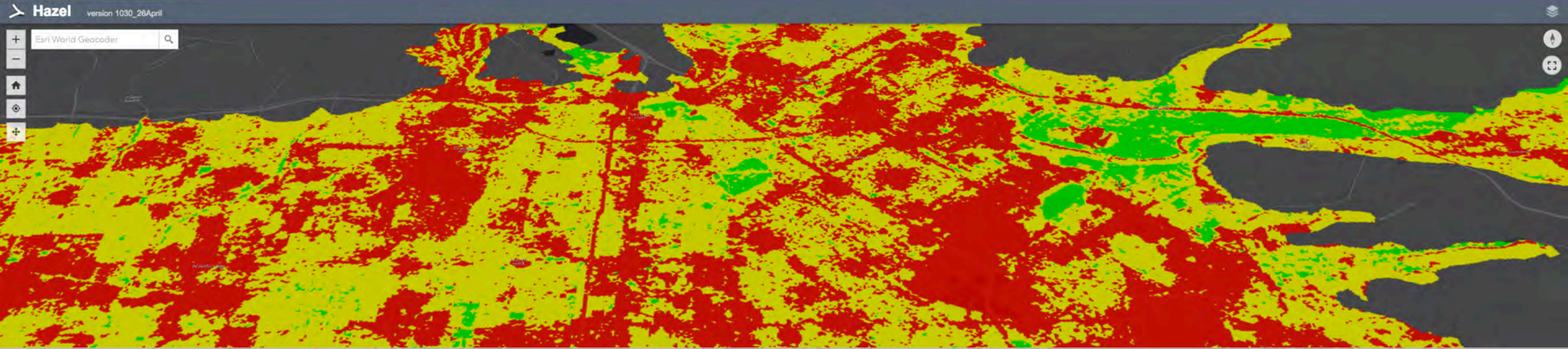
100%

Total Estimated Cost Range:
\$88600 - \$119800

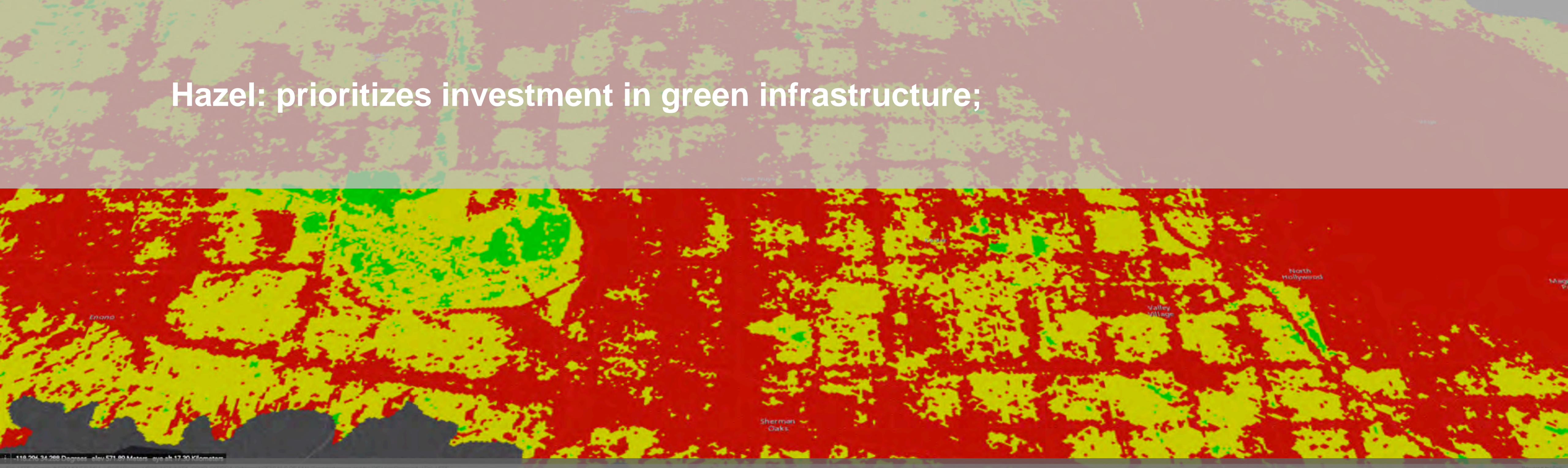
Output Site Geometry Provide Site Name Save to Rhino

Output Layer Name Subcatchment Name Save to Rhino

ARID LANDS INSTA-BUILD PERKINS + WILL The Nature Conservancy



Hazel: prioritizes investment in green infrastructure;



DRI: Drylands Resilience Initiative

Hazel: Reporting Metrics

Hazel: evaluates impacts on water, energy, and carbon conservation objectives;

Hazel: Reporting Metrics

Water Infiltrated

GALLONS (or acre/feet)

GHG Reduced:

TONS of CO₂E

Energy Saved:

kWH OFFSET

Economic Cost/Benefit:

DOLLARS EXPENDED
TREATMENT COSTS AVOIDED
PAYBACK PERIOD
JOBS CREATED

Who will benefit from **Hazel**?

1

Public Sector

Public Agencies and Utilities

METROPOLITAN-SCALE WATER DISTRICTS
MUNICIPAL STORMWATER and SANITATION BUREAUS
MUNICIPAL PUBLIC WORKS and ENGINEERING

2

Private Sector

Design Professionals

ARCHITECTS, URBAN PLANNERS, LANDSCAPE ARCHITECTS

1 Public Sector

Public Agencies and Utilities

METROPOLITAN-SCALE WATER DISTRICTS
MUNICIPAL STORMWATER and SANITATION BUREAUS
MUNICIPAL PUBLIC WORKS and ENGINEERING

NEEDS

Provide basin-scale distributed water infrastructure economic and suitability evaluation;

2 Private Sector

Design Professionals

ARCHITECTS, URBAN PLANNERS, LANDSCAPE ARCHITECTS

NEEDS

**Provide property / lot-scale code compliance;
Assess pilot sites for private / public investment.**

1 Public Sector

Public Agencies and Utilities

METROPOLITAN-SCALE WATER DISTRICTS
MUNICIPAL STORMWATER and SANITATION BUREAUS
MUNICIPAL PUBLIC WORKS and ENGINEERING

Governmental Water Regulatory Agencies

USEPA, USBoR, USACE
STATE REGULATORY BOARDS, HEALTH and HUMAN SAFETY

NGOs

GREEN-TECH, LAND USE and ENVIRONMENTAL QUALITY,
ENVIRONMENTAL JUSTICE

Elected Officials

2 Private Sector

Design Professionals

ARCHITECTS, URBAN PLANNERS, LANDSCAPE ARCHITECTS

Technical Service Providers

CIVIL and ENVIRONMENTAL ENGINEERS

Insurance Companies

REINSURANCE and RISK ASSESSMENT UNDERWRITING

Developers

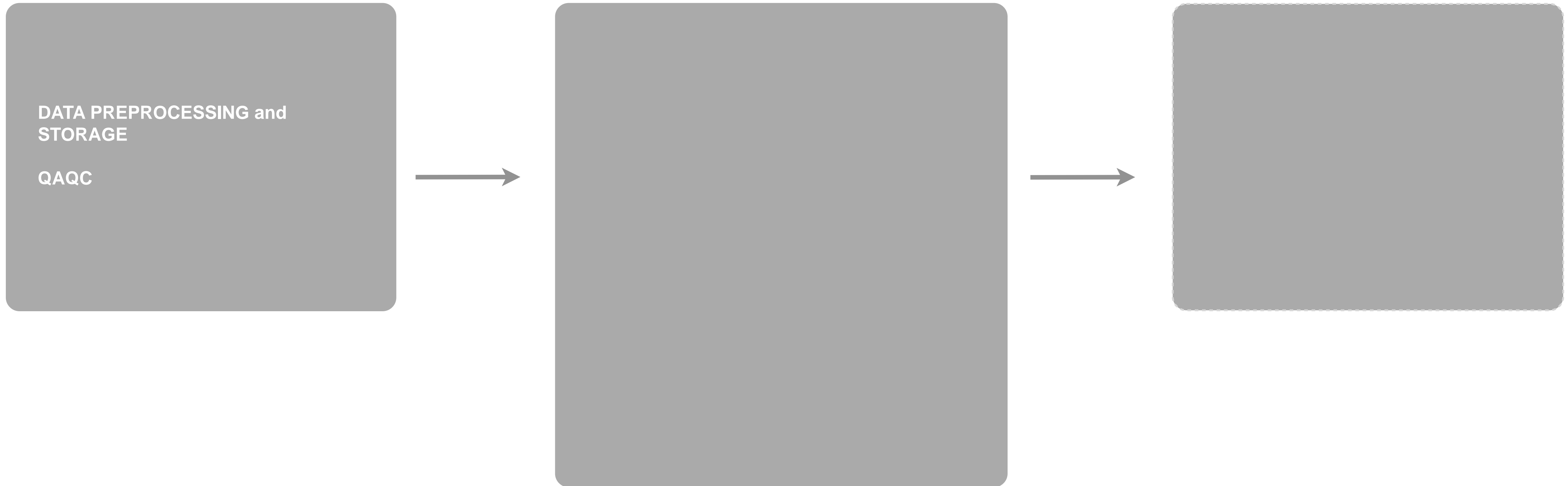
Educated Citizenry

PRIVATE PROPERTY OWNERS
CONCERNED PUBLIC

How does **Hazel** work?

Conceptual Diagram of **Hazel**

CENTRAL DATABASE

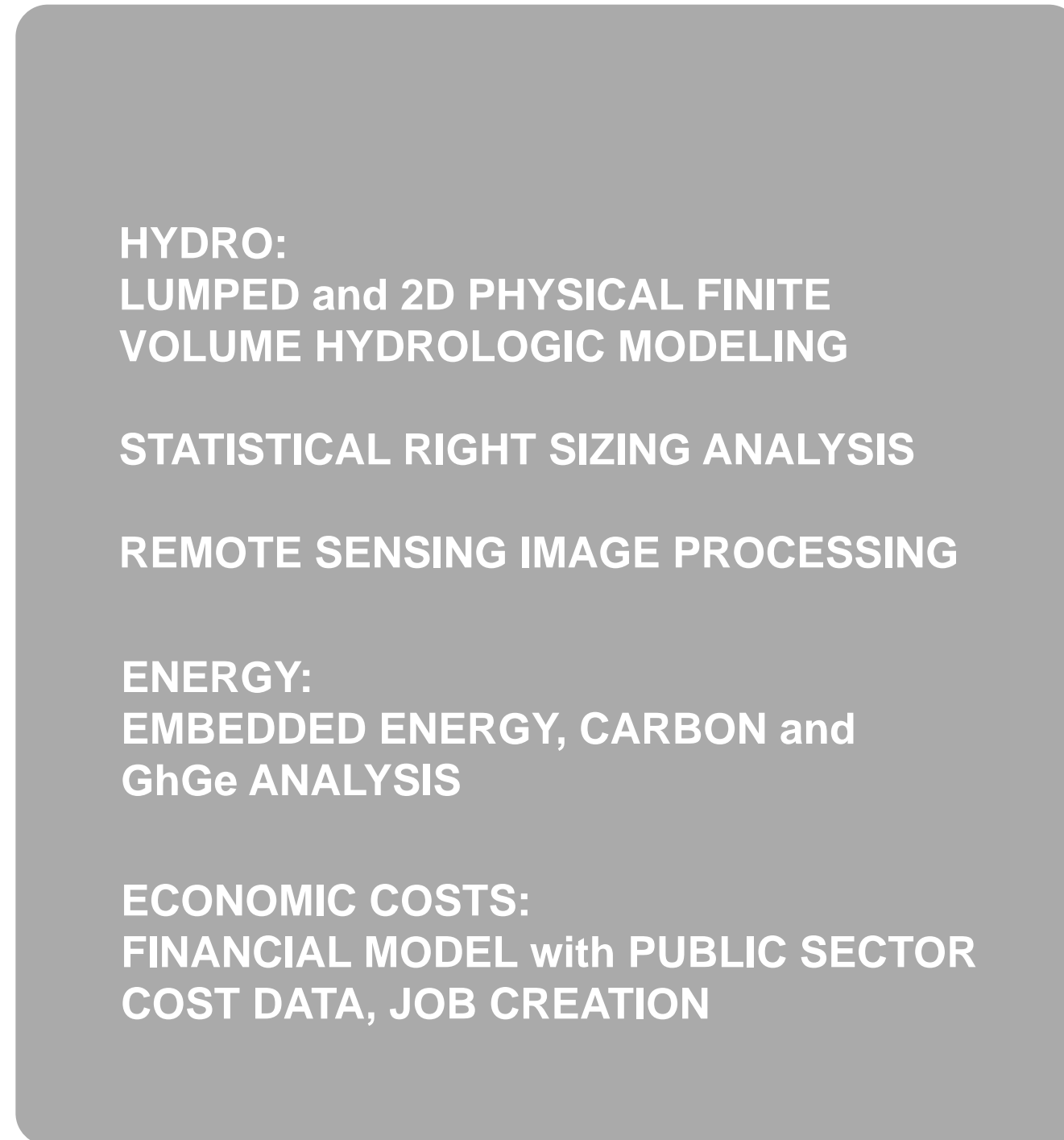


Conceptual Diagram of **Hazel**

CENTRAL DATABASE



COMPUTATION

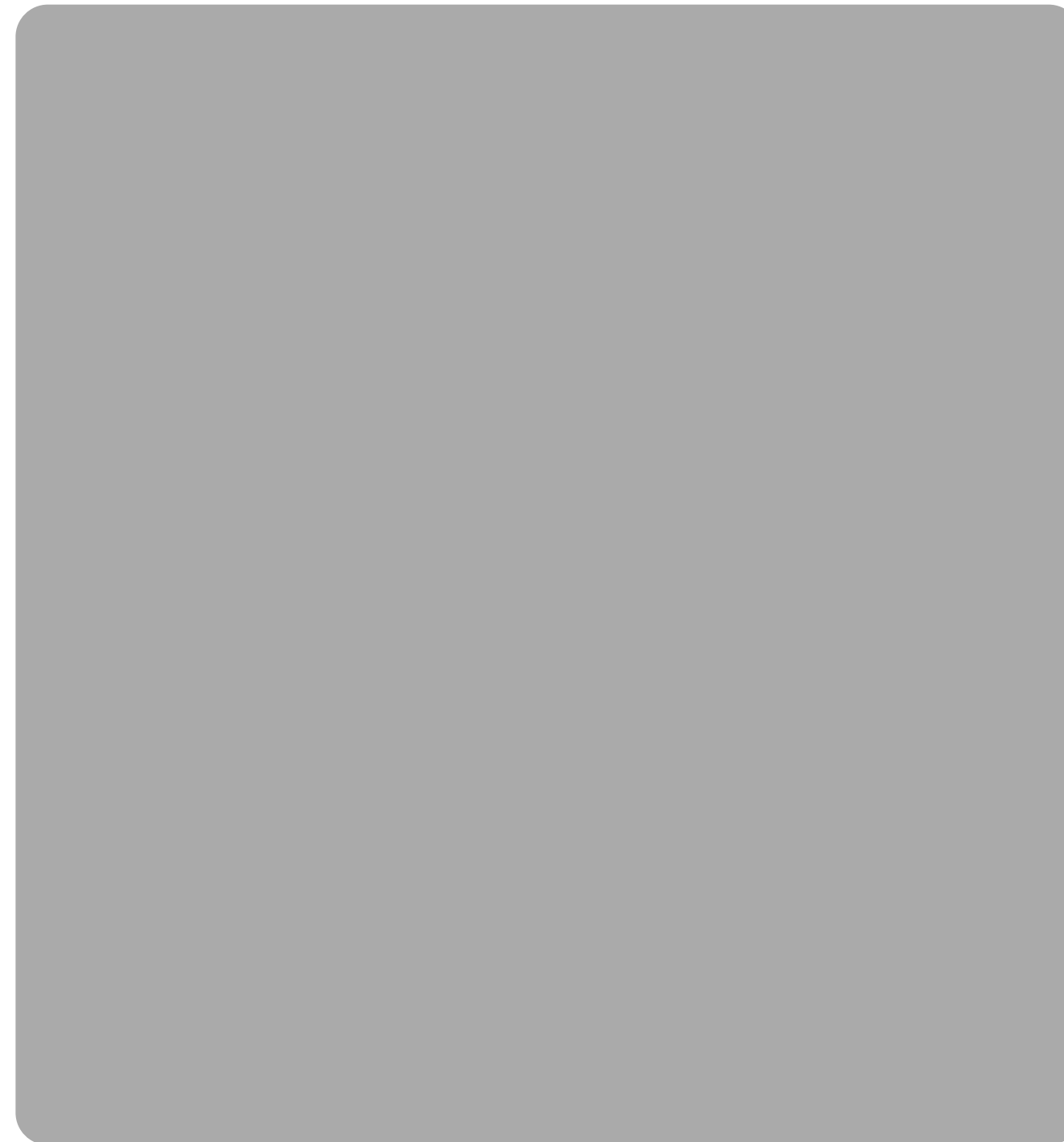


Conceptual Diagram of **Hazel**

CENTRAL DATABASE



COMPUTATION



REPORTING



WEB-BASED VISUALIZATION;

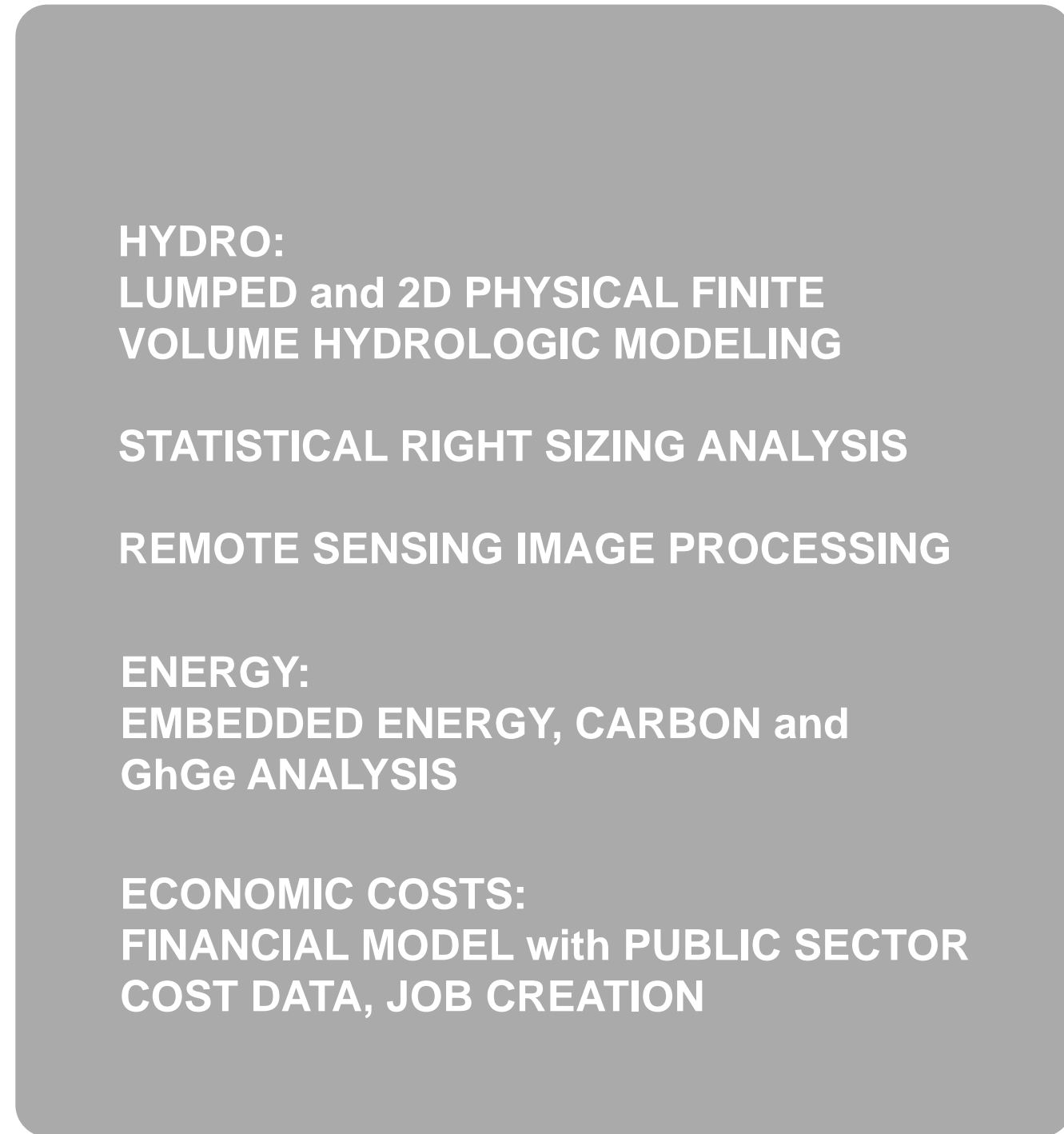
DATA PORTED TO RHINO-
GRASSHOPPER

Conceptual Diagram of Hazel

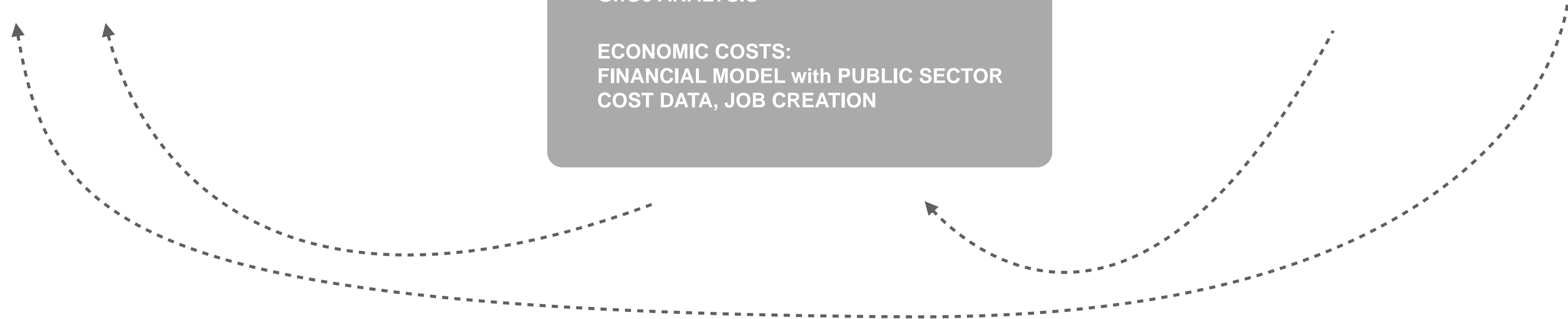
CENTRAL DATABASE



COMPUTATION



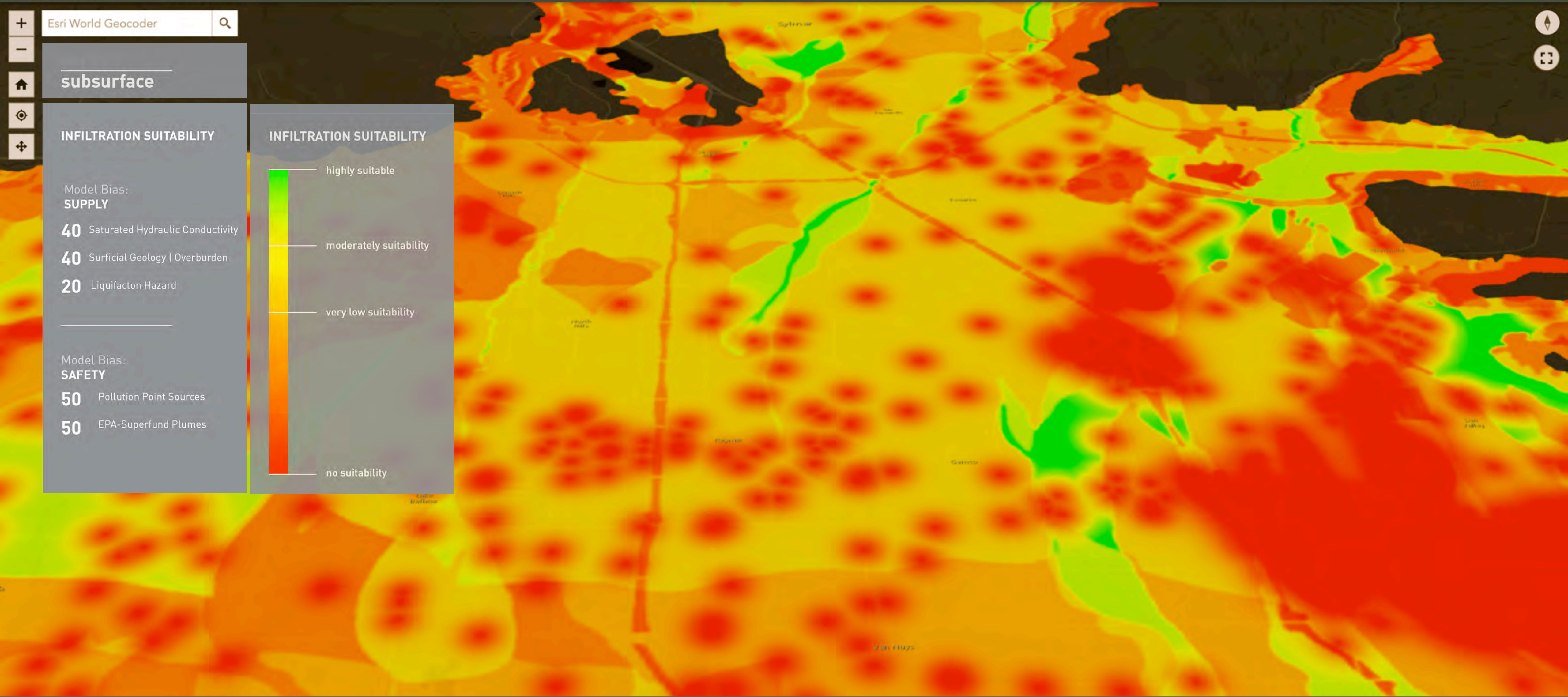
REPORTING

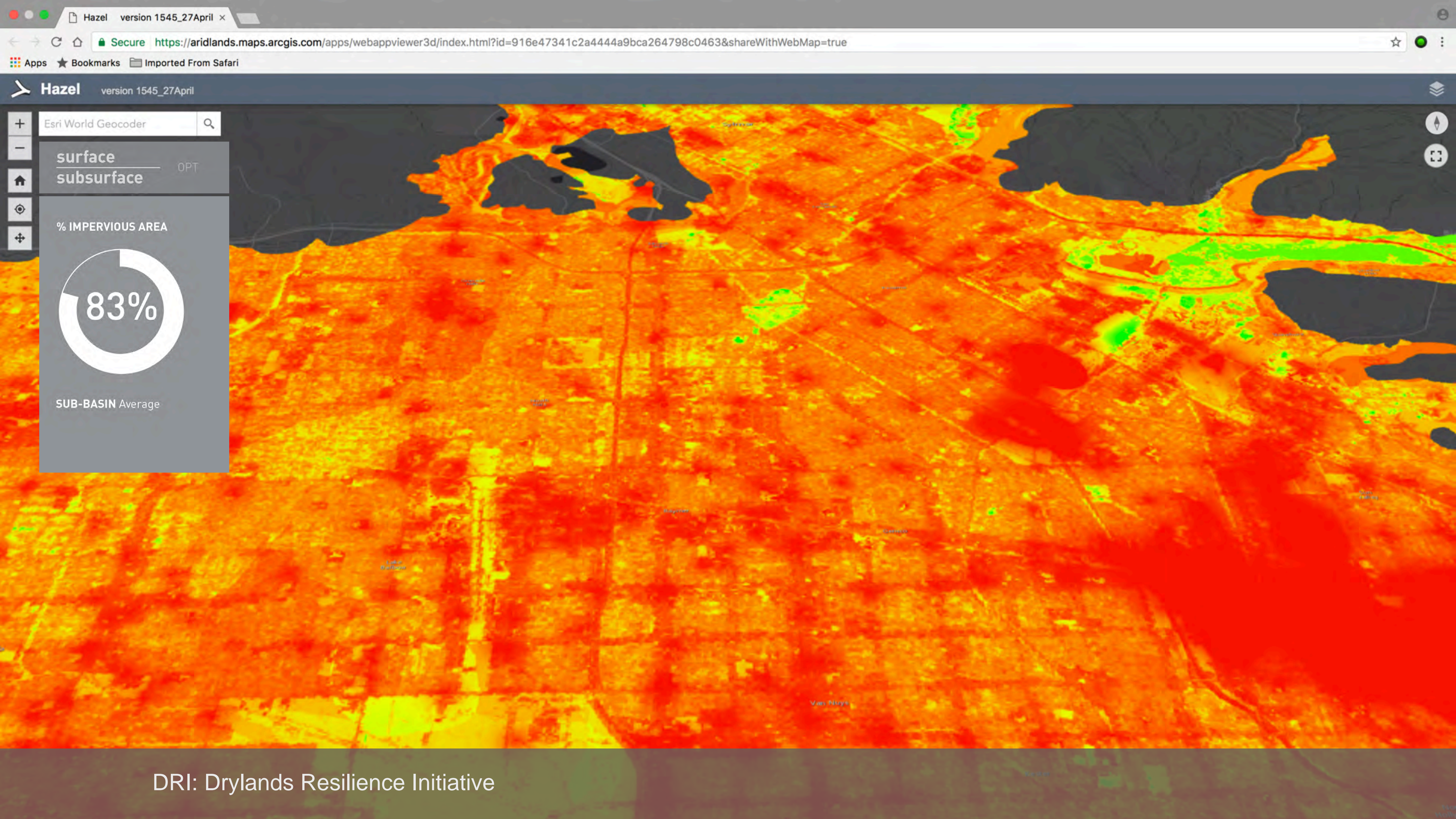


Hazel at work @ basin-scale



DRI: Drylands Resilience Initiative










+ Esri World Geocoder

HAZEL ZONE

[HYDROLOGIC ZONING]

H_z 1

- #### STORMWATER BMPs
-  Infiltration: Infiltration Basins
 -  Infiltration: Dry Ponds
 -  Infiltration: Porous Pavements



Esri World Geocoder

HAZEL ZONE
[HYDROLOGIC ZONING]

Hz
1

STORMWATER BMPs

STORMWATER RUNOFF

Lot ID:

RUNOFF VOLUME
STORM TYPE

3/4" / 24 hr [inches / 24 hr]
62,465,626 gal
 236,458 m³
 191.7 acre-ft

85th % [inches / 24 hr]
83,300,766 gal
 315,327 m³
 255.6 acre-ft





Esri World Geocoder

HAZEL ZONE [HYDROLOGIC ZONING]

H_z
3

STORMWATER BMPs



On-Site Capture + Use:
Cisterns
Rainbarrels



On-Site Retention
Bioretention Cell



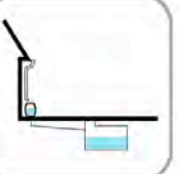





On-Site Remediation:
Urban Forests

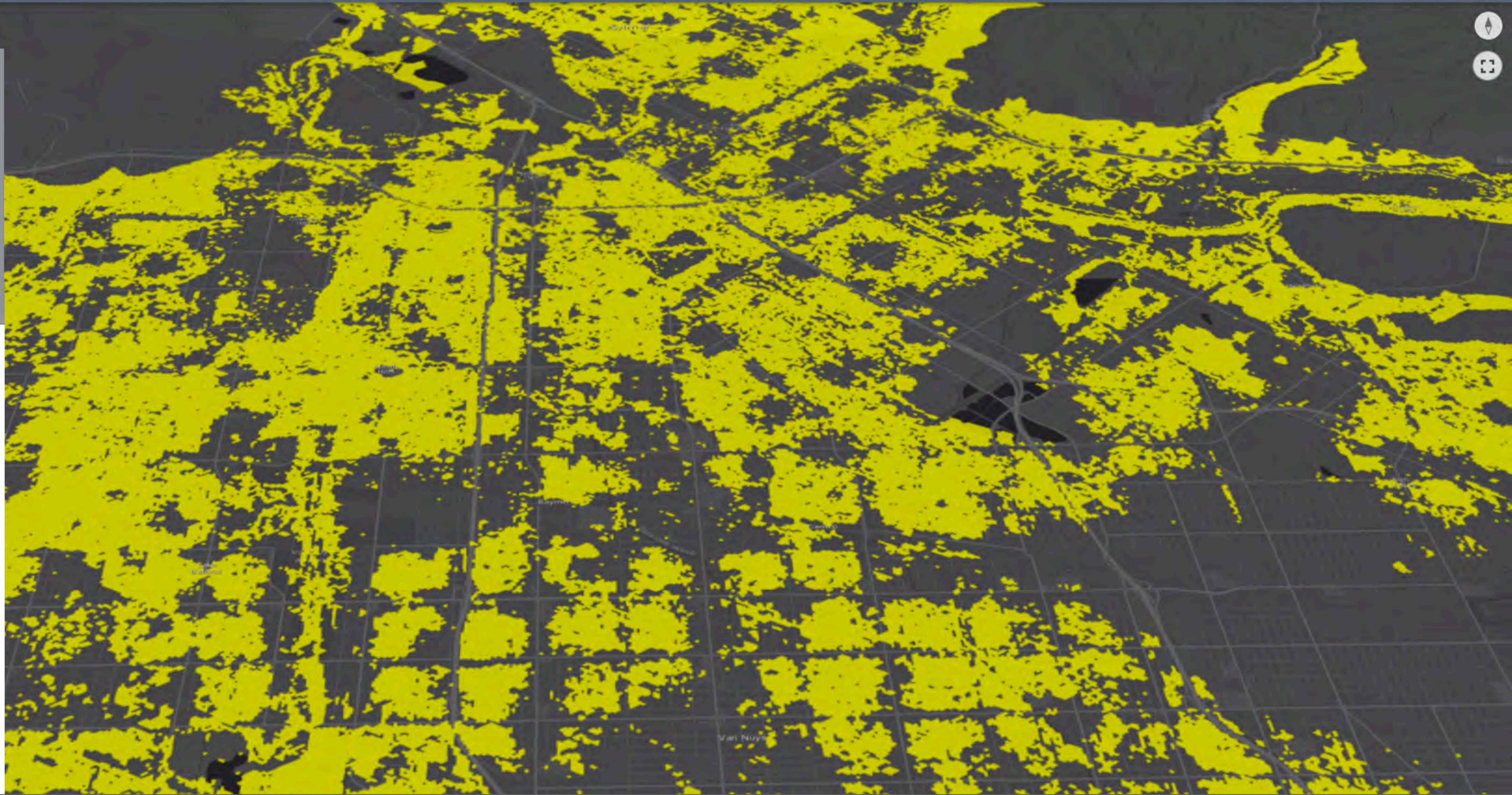
Esri World Geocoder

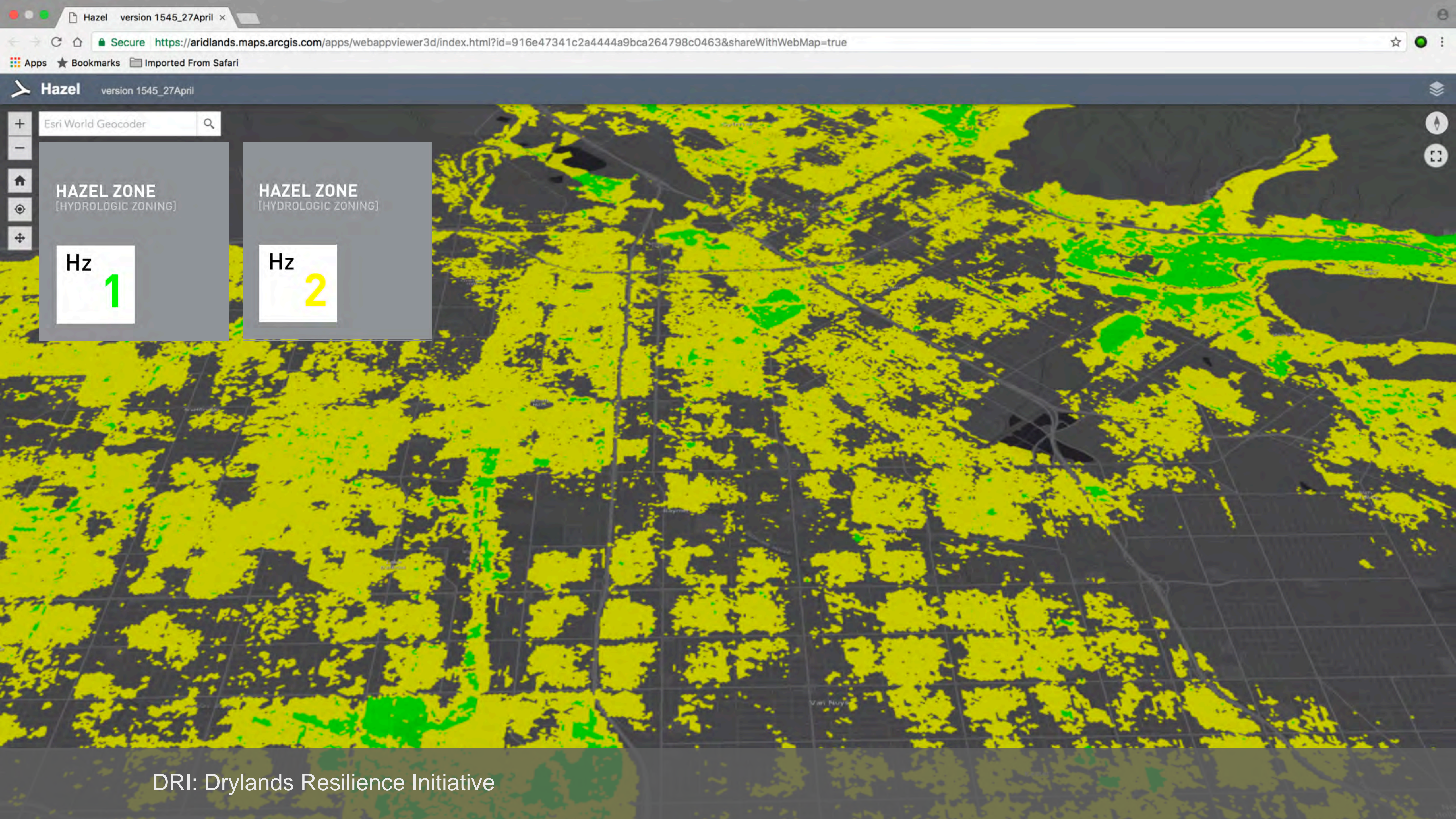
HAZEL ZONE [HYDROLOGIC ZONING]

Hz
2

STORMWATER BMPs

-  On-Site Capture + Use:
Cisterns
Rainbarrels
-  Capture + Convey
Smart Streets, Curb
Extensions
-  Infiltration:
Infiltration Basins
-  Infiltration:
Dry Ponds
-  Infiltration:
Porous Pavements
-  On-Site Retention
Bioretention Cell





Esri World Geocoder

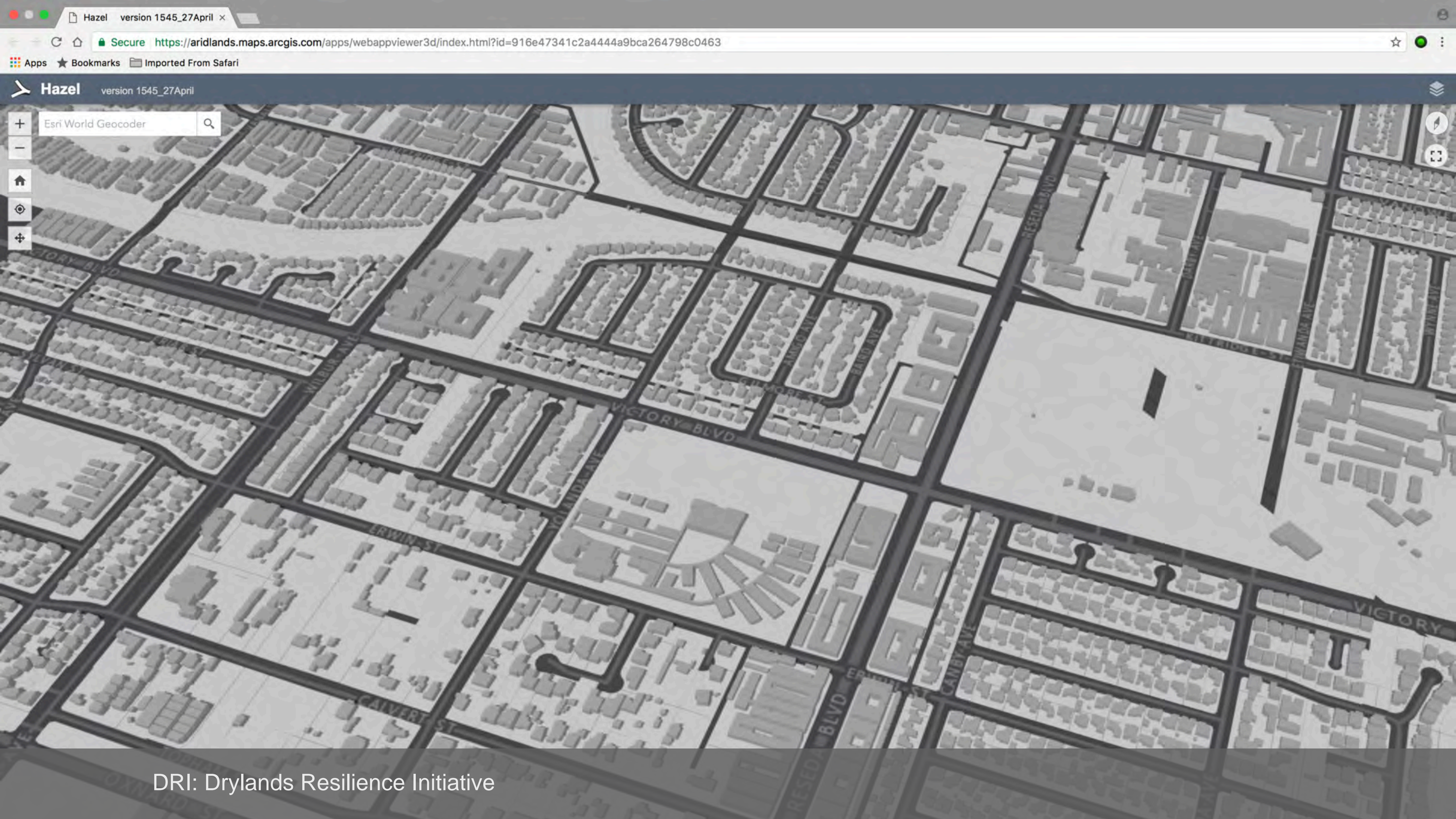
HAZEL ZONE
[HYDROLOGIC ZONING]

Hz
1

HAZEL ZONE
[HYDROLOGIC ZONING]

Hz
2

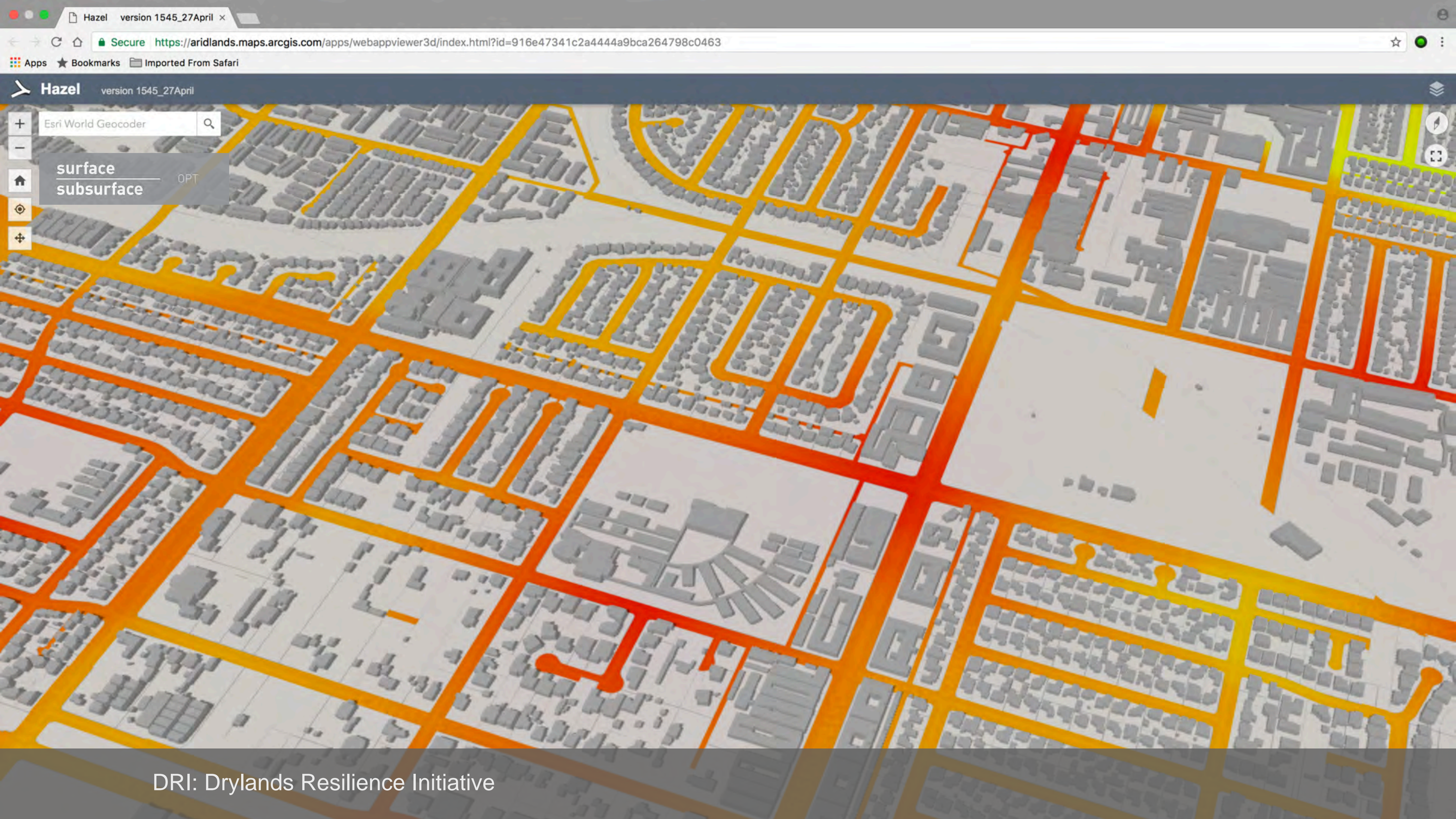
Hazel at work @ lot-scale



Esri World Geocoder

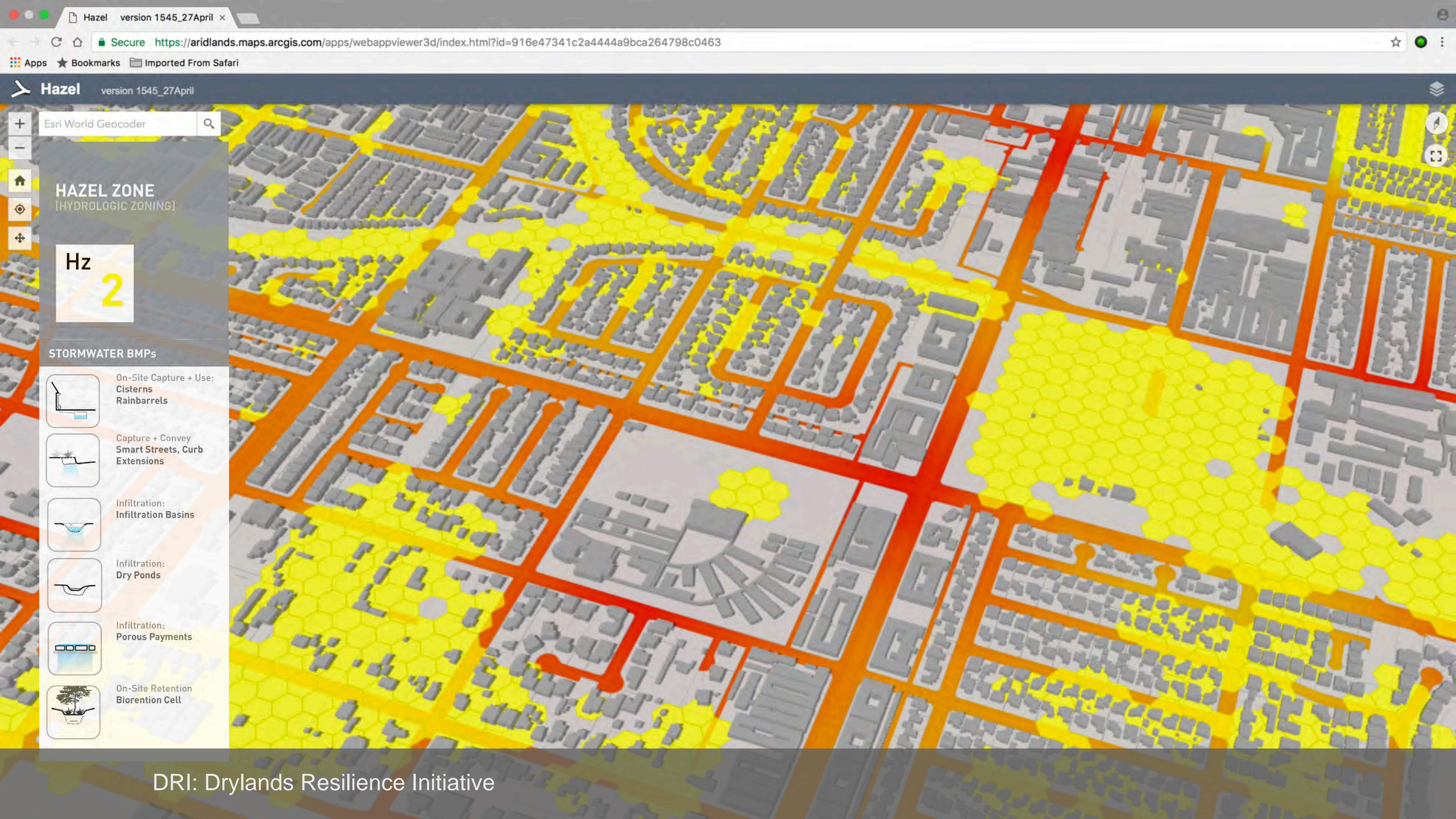
Map navigation controls: +, -, Home, Location, Full Screen

DRI: Drylands Resilience Initiative



Esri World Geocoder

surface
subsurface OPT









Esri World Geocoder

HAZEL ZONE (HYDROLOGIC ZONING)

Hz 2

STORMWATER BMPs

-  On-Site Capture + Use:
Cisterns
Rainbarrels
-  Capture + Convey
Smart Streets, Curb
Extensions
-  Infiltration:
Infiltration Basins
-  Infiltration:
Dry Ponds
-  Infiltration:
Porous Pavements
-  On-Site Retention
Bioretention Cell



Esri World Geocoder

surface

% IMPERVIOUS AREA



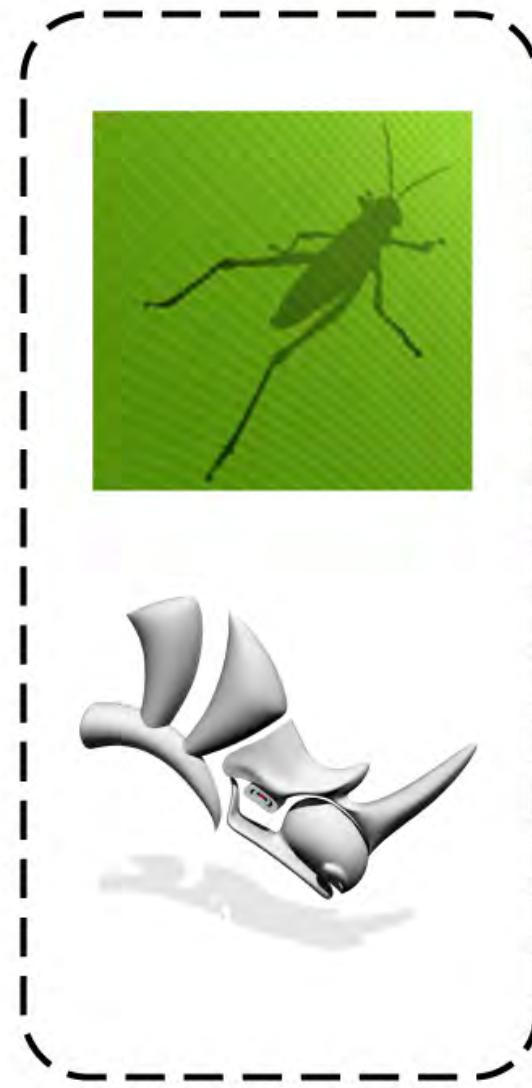
LOT Average

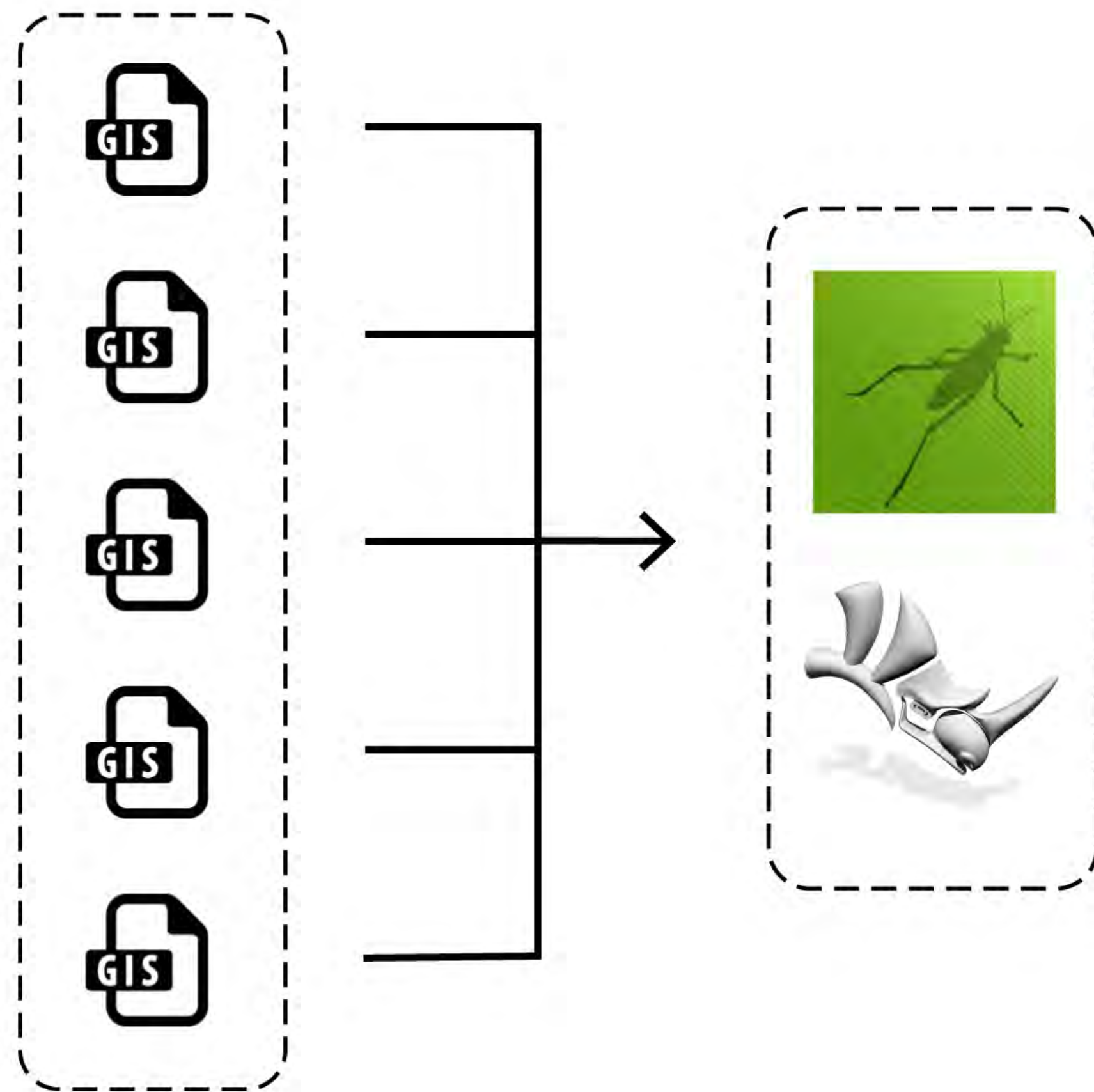


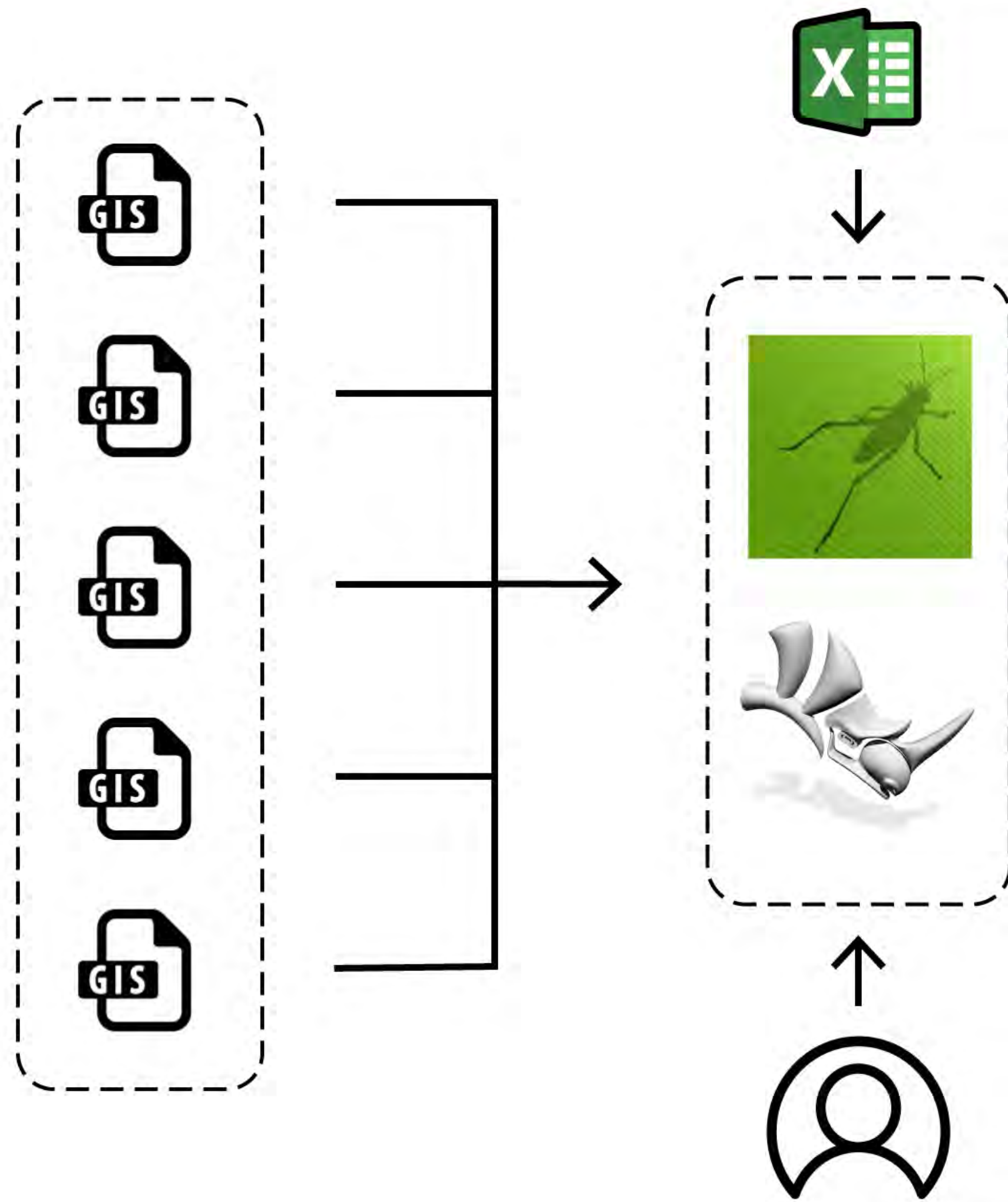
3

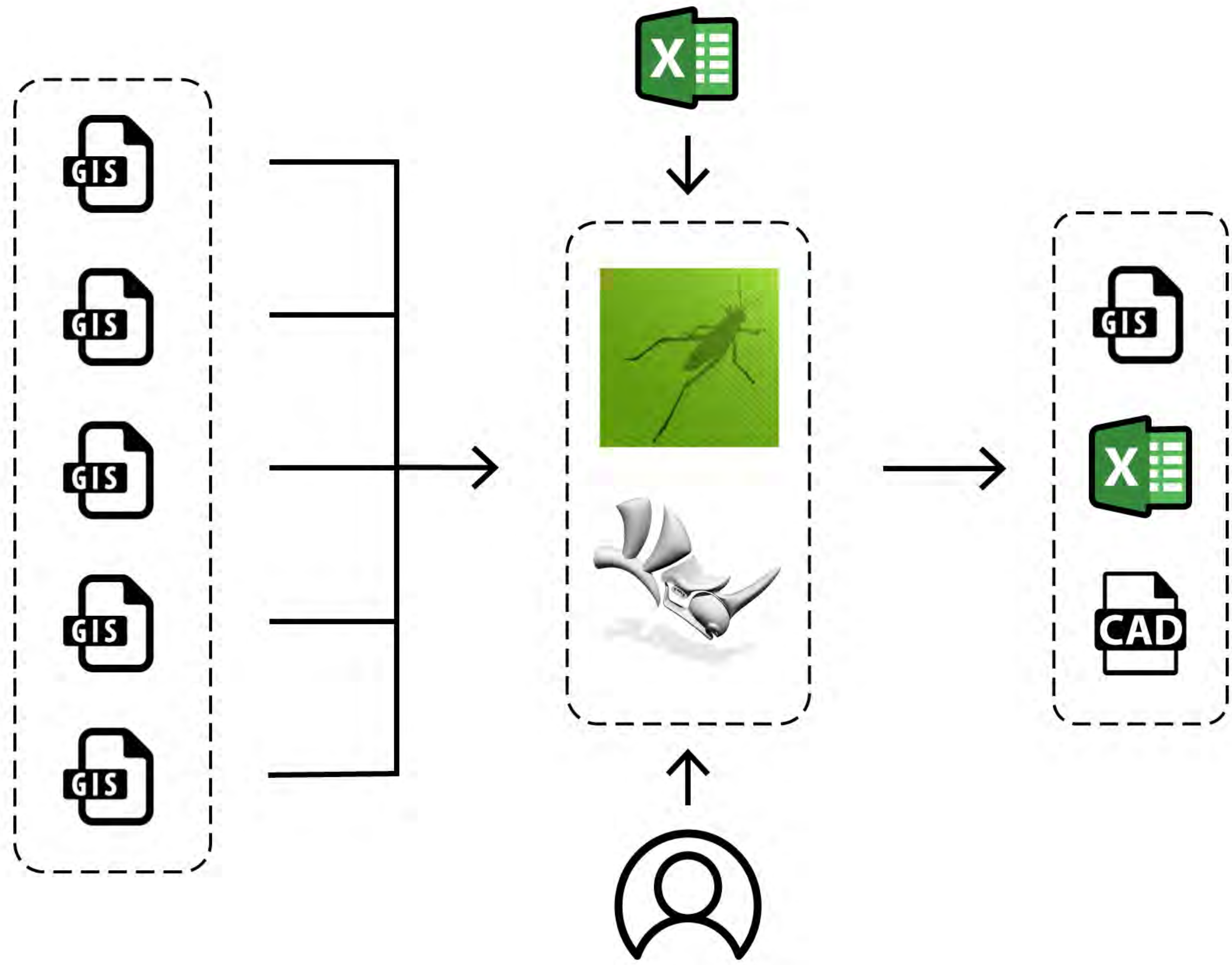
How to Hazel?

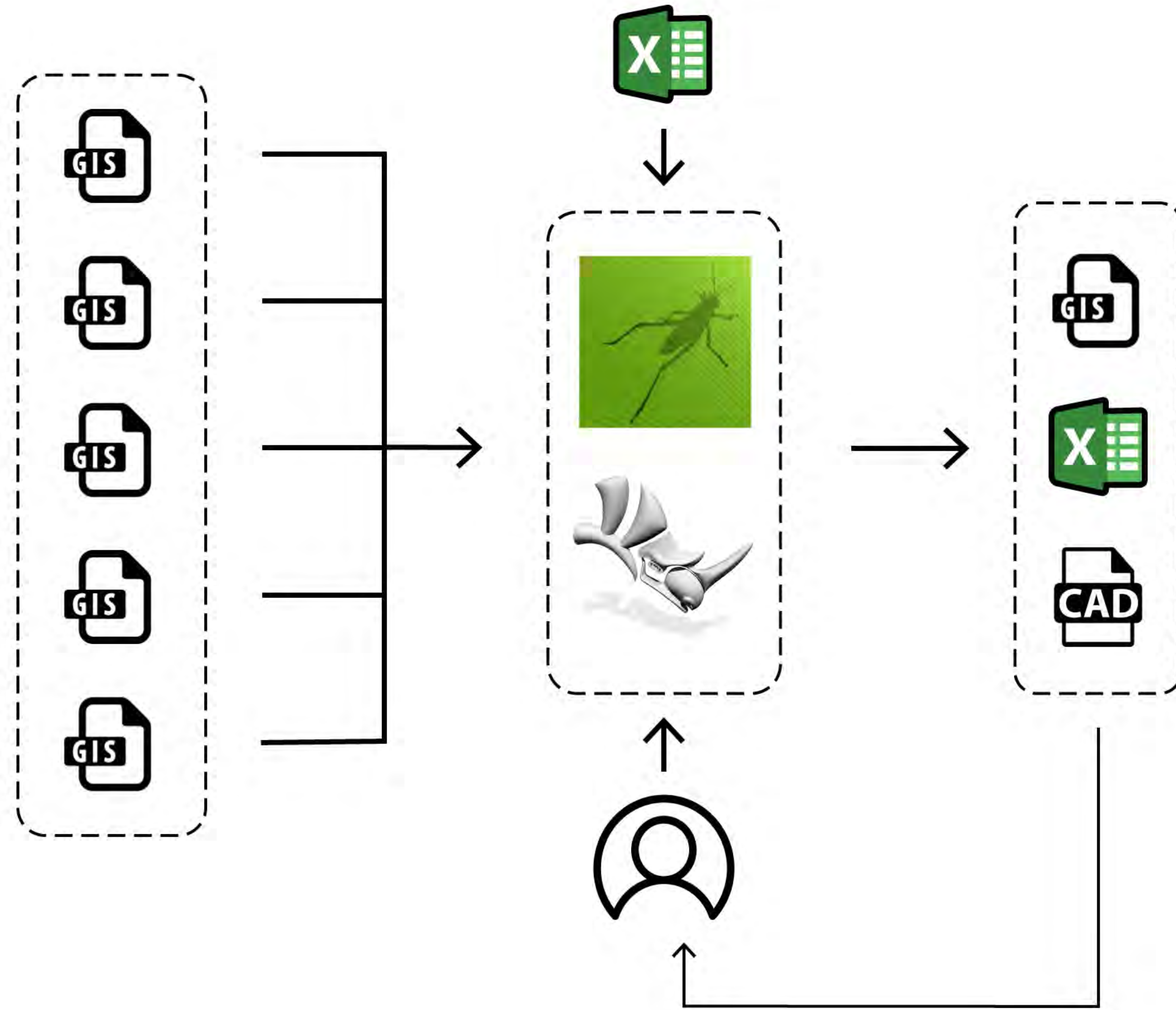
Elevating Design Process

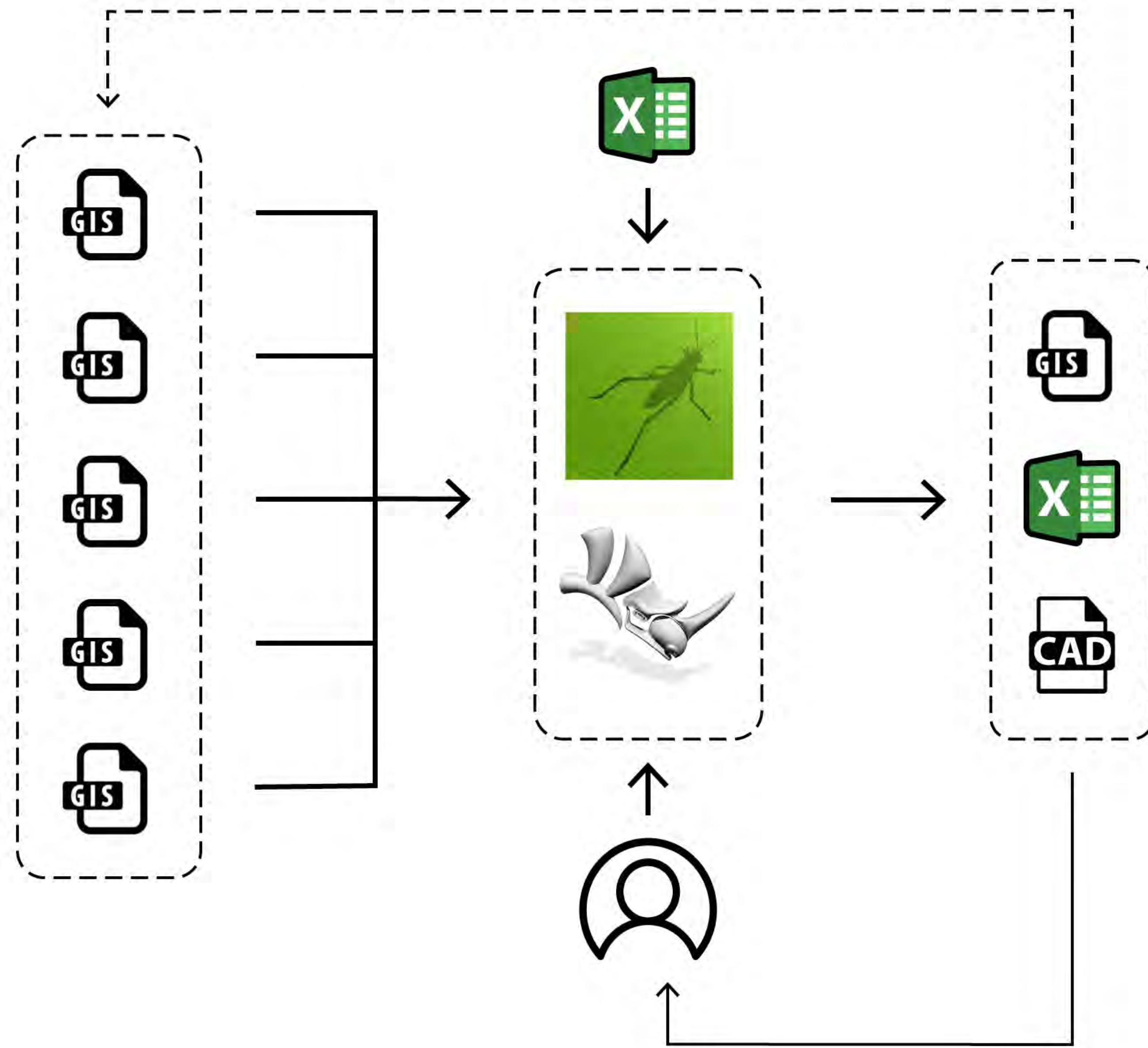


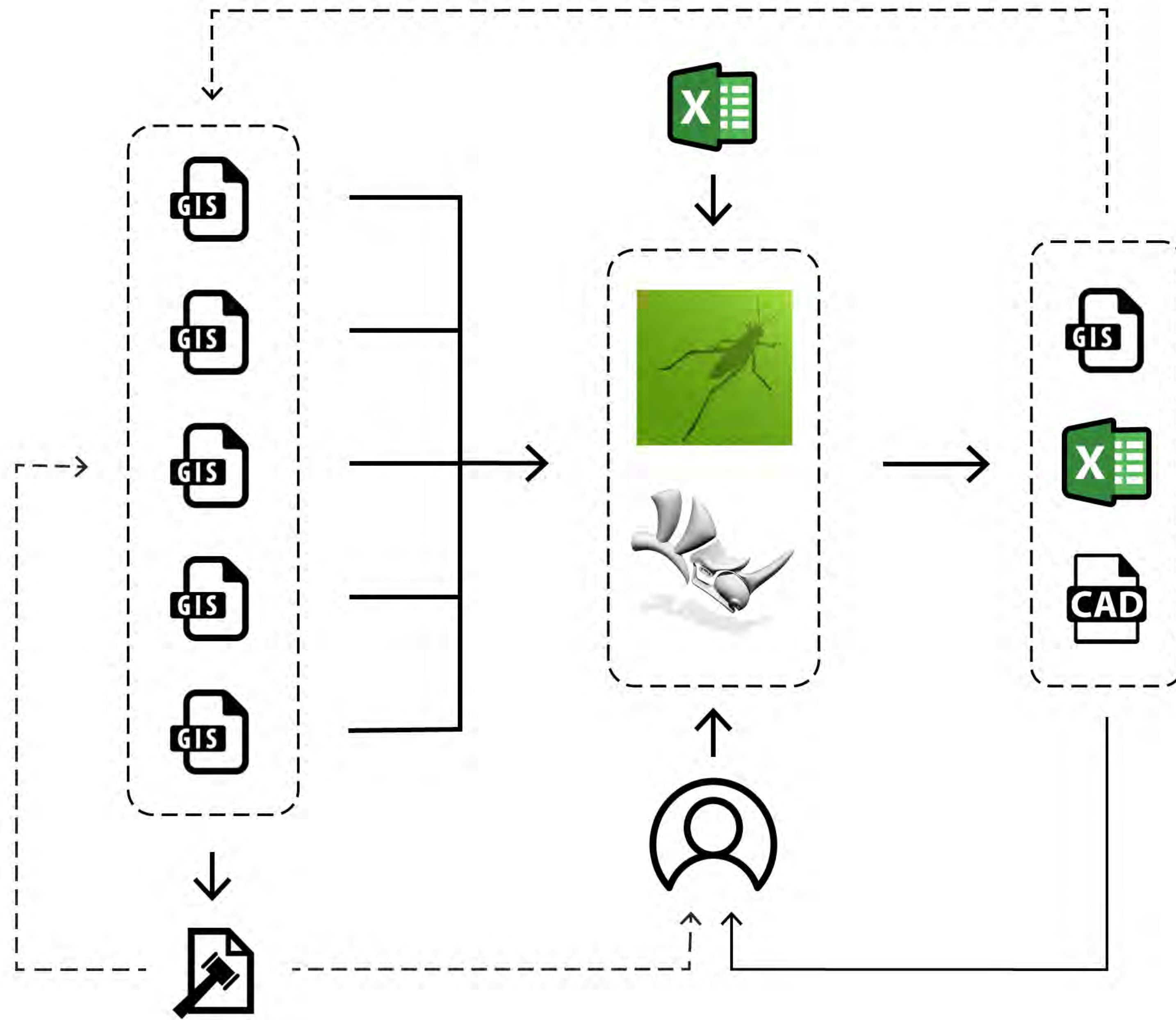






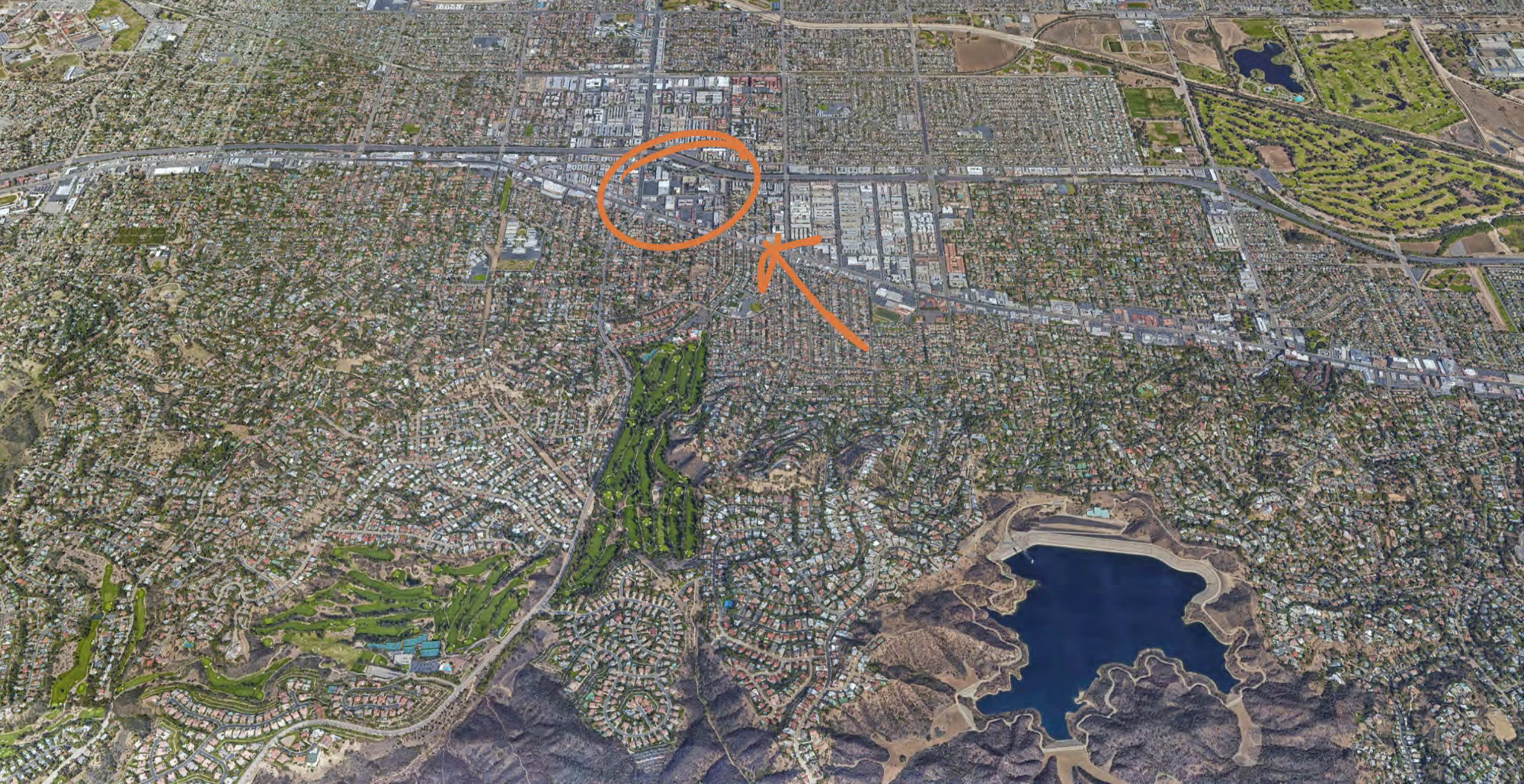






CASE STUDY: PROTOTYPE SITE

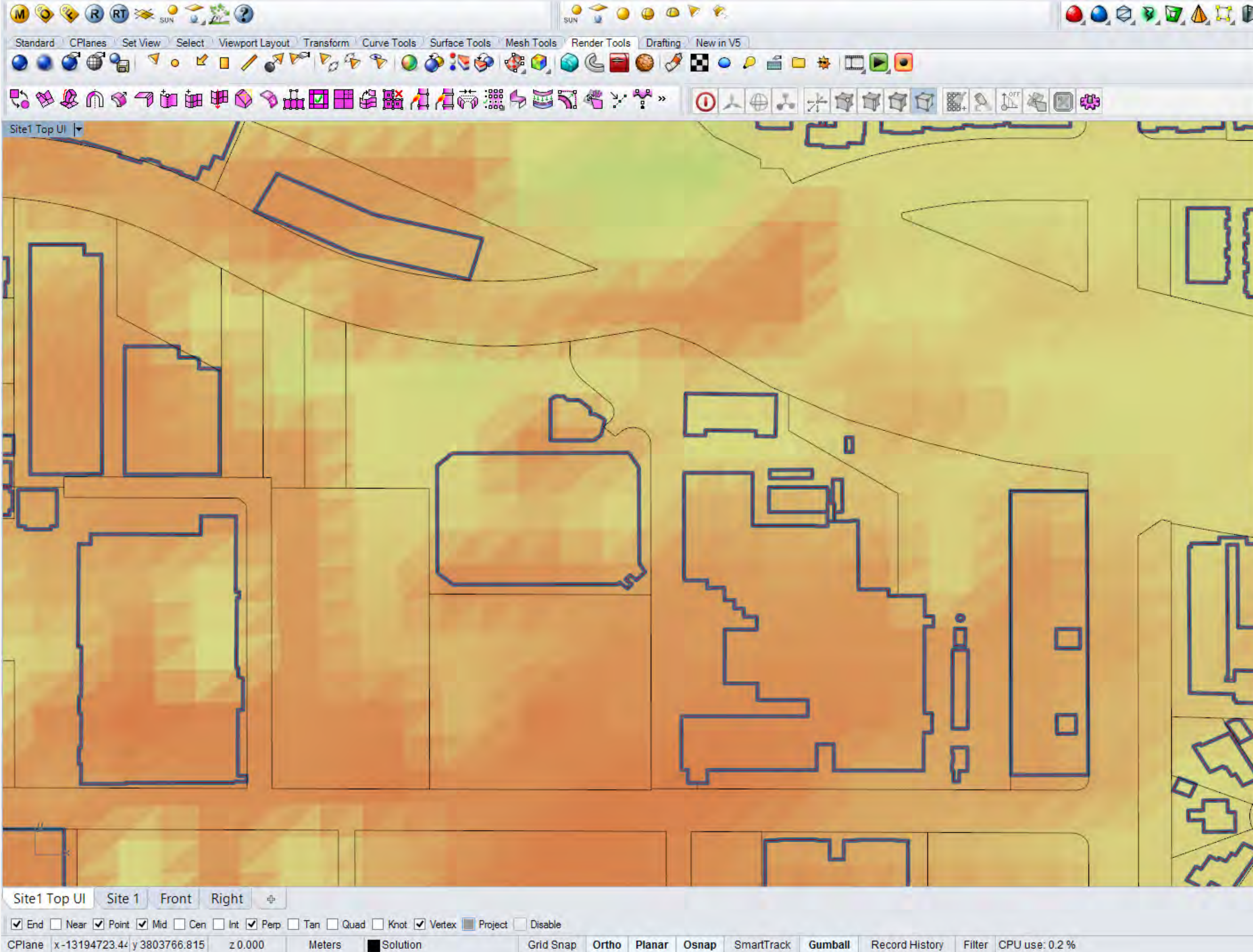




CASE STUDY: PROTOTYPE CAMPUS SITE



CAMPUS SITE : GIS EXTRACT



HAZEL CONTROL WINDOW

Inputs Data

- Select Lot(s) - Place point(s)
- Buildings to be removed - Draw Closed Polyline
- Development Area - Draw Closed Polyline
- Define Subcatchment(s) - Draw Closed Polyline(s)
- Proposed Buildings - Region(s) as closed polyline(s)
- Planted Areas - Region(s) as a closed polyline(s)
- Draw Infiltration BMP - Region as closed polyline
- Draw Capture and Convey BMP - Region as closed polyline

Infiltration

Select BMP Measure

BMP Media Depth (in Feet)

Surface Infiltration Capacity (gal) 0 Cost \$ \$-\$

Capture and Convey

Select BMP Measure

BMP Media Depth (in Feet)


Surface Capture Capacity (gal) 0 Cost \$ \$-\$

Retention

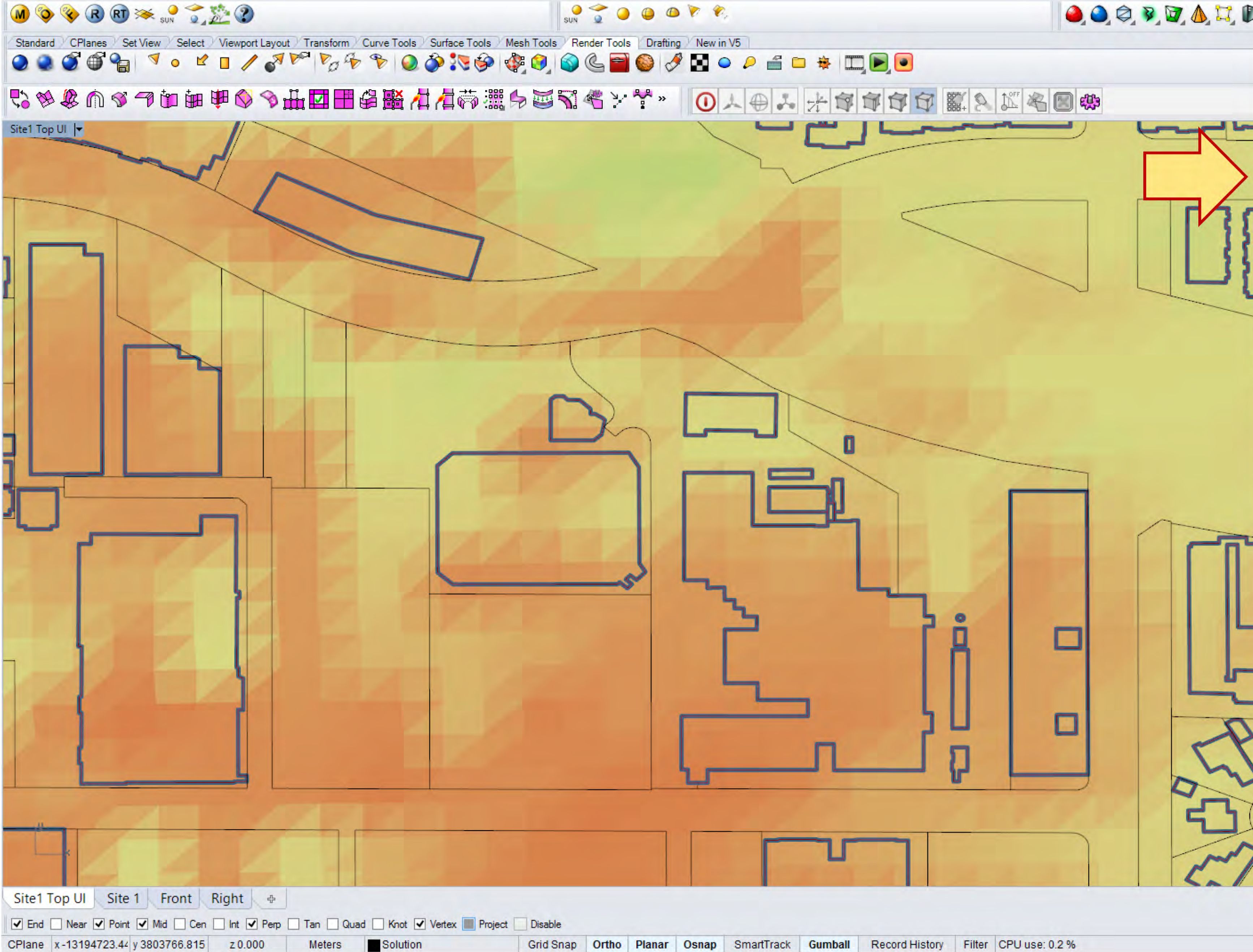
Select BMP Measure

Retention Capacity (gal) 0 Cost \$ \$-\$

Percentage LID satisfied Total Estimated Cost Range:
\$ - \$



ARID LANDS INSTITUTE PERKINS + WILL The Nature Conservancy



HAZEL CONTROL WINDOW

Inputs Data

- Select Lot(s) - Place point(s)
- Buildings to be removed - Draw Closed Polyline
- Development Area - Draw Closed Polyline
- Define Subcatchment(s) - Draw Closed Polyline(s)
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Infiltration

Select BMP Measure ▼

BMP Media Depth (in Feet)

Surface Infiltration Capacity (gal) 0 Cost \$ \$-\$

Capture and Convey

Select BMP Measure ▼

BMP Media Depth (in Feet)

Surface Capture Capacity (gal) 0 Cost \$ \$-\$

Retention

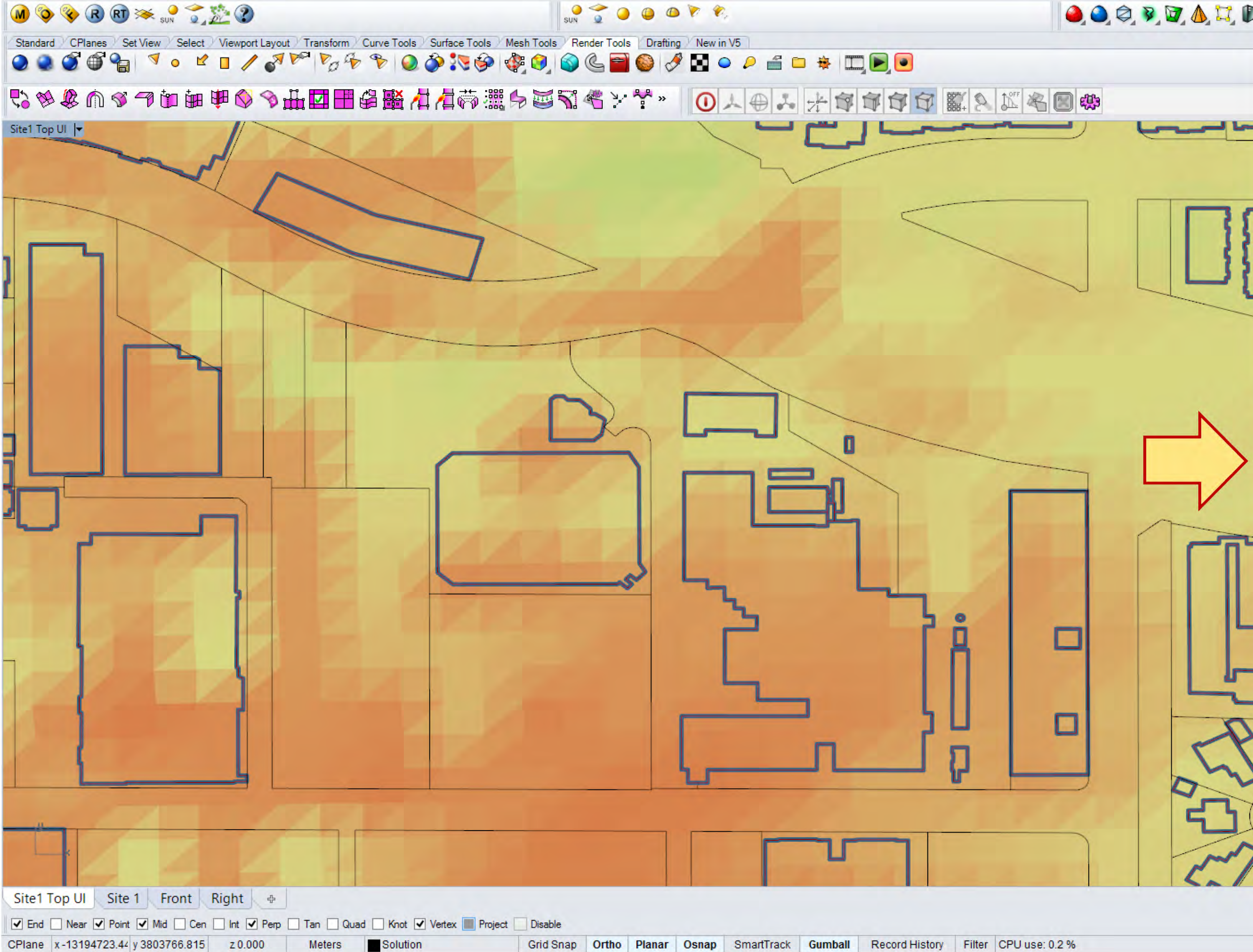
Select BMP Measure ▼

Retention Capacity (gal) 0 Cost \$ \$-\$

Percentage LID satisfied Total Estimated Cost Range:
\$ - \$

0%

ARID LANDS INSTITUTE PERKINS + WILL The Nature Conservancy



HAZEL CONTROL WINDOW

Inputs Data

- Select Lot(s) - Place point(s)
- Buildings to be removed - Draw Closed Polyline
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- Draw Infiltration BMP - Region as closed polyline
- Draw Capture and Convey BMP - Region as closed polyline

Infiltration

Select BMP Measure

BMP Media Depth (in Feet)

Surface Infiltration Capacity (gal) 0 Cost \$ \$-\$

Capture and Convey

Select BMP Measure

BMP Media Depth (in Feet)


Surface Capture Capacity (gal) 0 Cost \$ \$-\$




Retention

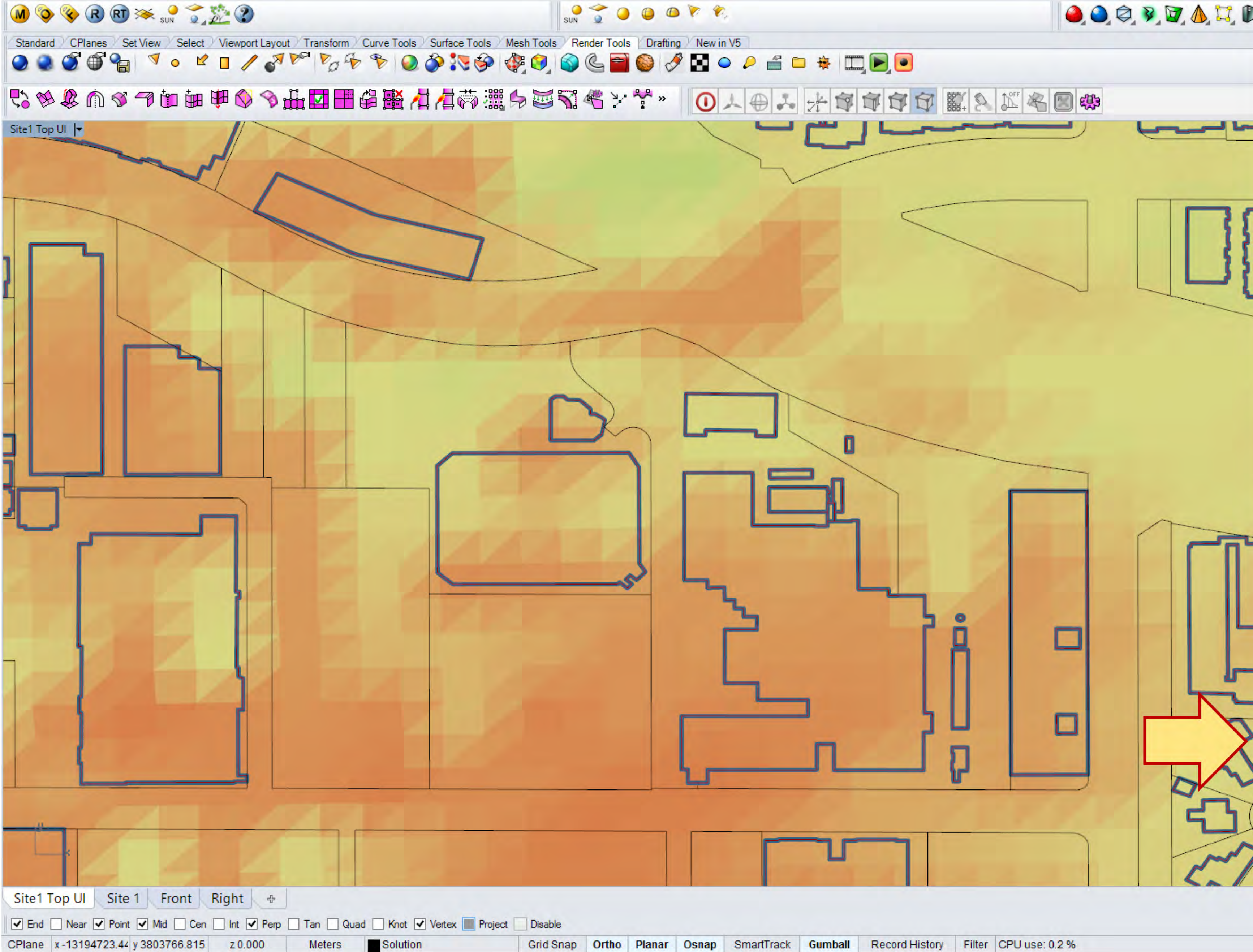
Select BMP Measure

Retention Capacity (gal) 0 Cost \$ \$-\$

Percentage LID satisfied Total Estimated Cost Range: \$ - \$







HAZEL CONTROL WINDOW

Inputs Data

- Select Lot(s) - Place point(s)
- Buildings to be removed - Draw Closed Polyline
- Development Area - Draw Closed Polyline
- Define Subcatchment(s) - Draw Closed Polyline(s)
- Proposed Buildings - Region(s) as closed polyline(s)
- Planted Areas - Region(s) as a closed polyline(s)
- Draw Infiltration BMP - Region as closed polyline
- Draw Capture and Convey BMP - Region as closed polyline

Infiltration

Select BMP Measure [Dropdown]

BMP Media Depth (in Feet) 0.3

Surface Infiltration Capacity (gal) 0 Cost \$ \$-\$

Capture and Convey

Select BMP Measure [Dropdown]

BMP Media Depth (in Feet) 0.3

Surface Capture Capacity (gal) 0 Cost \$ \$-\$


Retention

Select BMP Measure [Dropdown]

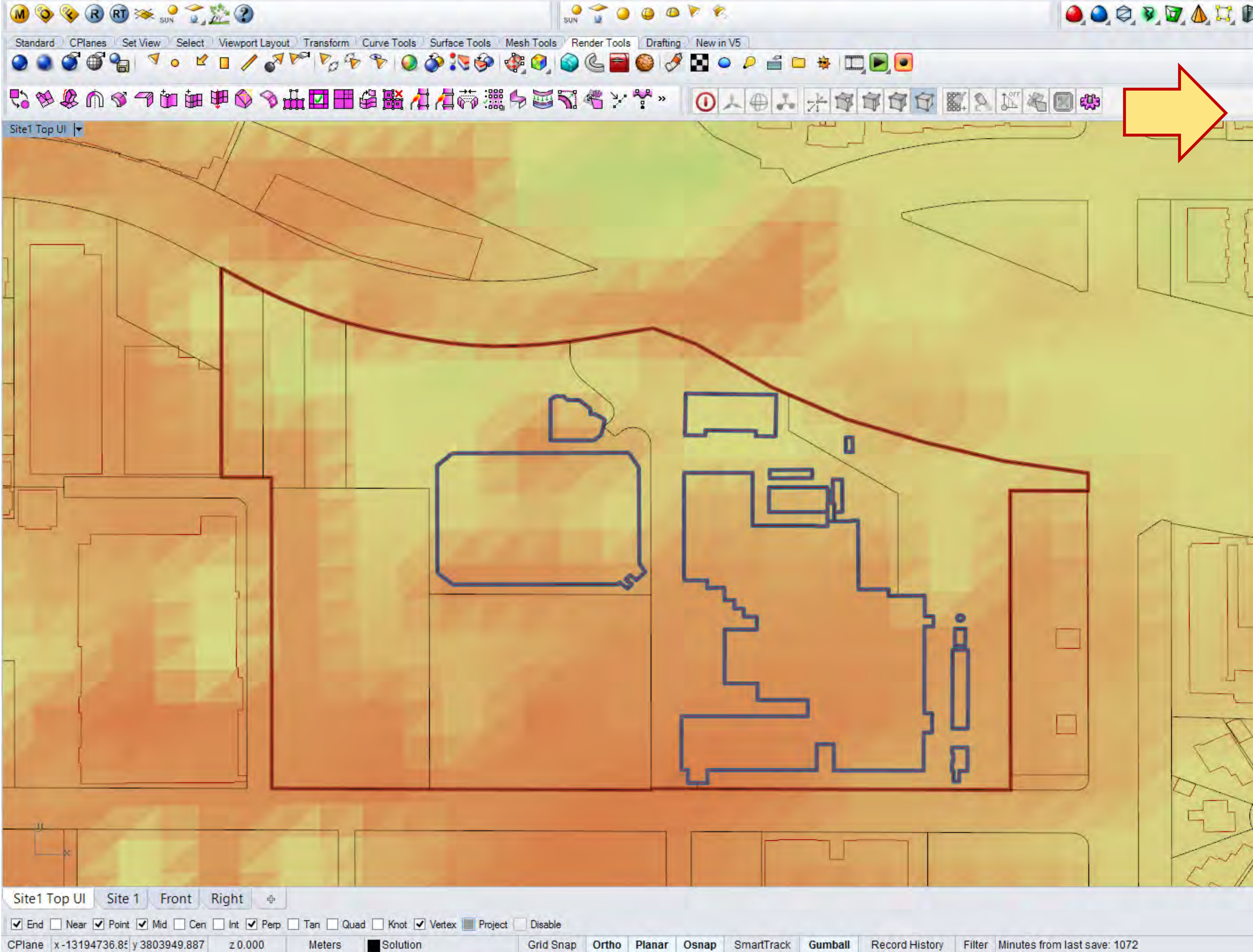
Retention Capacity (gal) 0 Cost \$ \$-\$

Percentage LID satisfied Total Estimated Cost Range:

\$ - \$



ARID LANDS INSTITUTE PERKINS + WILL The Nature Conservancy



HAZEL CONTROL WINDOW

Inputs Data

Select Lot(s) – Place Points

Buildings to be removed - Draw Closed Polyline

Development Area - Draw Closed Polyline

Define Subcatchment(s) - Draw Closed Polyline(s)

Proposed Buildings - Region(s) as closed polyline(s)

Planted Areas - Region(s) as a closed polyline(s)

Draw Infiltration BMP - Region as closed polyline

Draw Capture and Convey BMP - Region as closed polyline

Infiltration

Select BMP Measure

BMP Media Depth (in Feet) 0.3

Surface Infiltration Capacity (gal) 0 Cost \$ \$-\$

Capture and Convey

Select BMP Measure

BMP Media Depth (in Feet) 0.3

Surface Capture Capacity (gal) 0 Cost \$ \$-\$

Retention

Select BMP Measure

Retention Capacity (gal) 0 Cost \$ \$-\$

Percentage LID satisfied

Total Estimated Cost Range: \$-\$

ARID LANDS INSTITUTE PERKINS + WILL The Nature Conservancy

The image shows the HAZEL software interface. The main window displays a site plan with various colored regions and building footprints. A yellow arrow points from the 'Building to be removed' button in the control panel to a specific building footprint on the site plan. The control panel on the right, titled 'HAZEL CONTROL WINDOW', contains the following sections:

- Inputs Data:**
 - Select Lot(s) - Place point(s)
 - Building to be removed - Draw Closed Polyline** (highlighted with a red dashed border)
 - Development Area - Draw Closed Polyline
 - Define Subcatchment(s) - Draw Closed Polyline(s)
 - Proposed Buildings - Region(s) as closed polyline(s)
 - Planted Areas - Region(s) as a closed polyline(s)
 - Draw Infiltration BMP - Region as closed polyline
 - Draw Capture and Convey BMP - Region as closed polyline
- Infiltration:**
 - Select BMP Measure
 - BMP Media Depth (in Feet) 0.3
 - Surface Infiltration Capacity (gal) 0 Cost \$ \$-\$
- Capture and Convey:**
 - Select BMP Measure
 - BMP Media Depth (in Feet) 0.3
 - Surface Capture Capacity (gal) 0 Cost \$ \$-\$
- Retention:**
 - Select BMP Measure
 - Retention Capacity (gal) 0 Cost \$ \$-\$
- Percentage LID satisfied:** 0% (indicated by a circular gauge)
- Total Estimated Cost Range:** \$ - \$

Logos for ARID LANDS INSTITUTE, PERKINS + WILL, and The Nature Conservancy are visible at the bottom right of the control panel.

USING HAZEL : BUILDINGS TO BE REMOVED

The image shows the HAZEL software interface. The main window displays a site plan with a yellow polygon highlighting a specific area, which is identified as the 'Development Area' in the control window. A red arrow points from the control window to this area. The control window, titled 'HAZEL CONTROL WINDOW', contains several input fields and sections:

- Inputs Data:**
 - Select Lot(s) - Place point(s)
 - Buildings to be removed - Draw Closed Polyline
 - Development Area - Draw Closed Polyline** (highlighted with a red dashed border)
 - Define Subcatchment(s) - Draw Closed Polyline(s)
 - Proposed Buildings - Region(s) as closed polyline(s)
 - Planted Areas - Region(s) as a closed polyline(s)
 - Draw Infiltration BMP - Region as closed polyline
 - Draw Capture and Convey BMP - Region as closed polyline
- Infiltration:**
 - Select BMP Measure
 - BMP Media Depth (in Feet) 0.3
 - Surface Infiltration Capacity (gal) 0 Cost \$ \$-\$
- Capture and Convey:**
 - Select BMP Measure
 - BMP Media Depth (in Feet) 0.3
 - Surface Capture Capacity (gal) 0 Cost \$ \$-\$
- Retention:**
 - Select BMP Measure
 - Retention Capacity (gal) 0 Cost \$ \$-\$
- Summary:**
 - Percentage LID satisfied: 0% (indicated by a small circle)
 - Total Estimated Cost Range: \$-\$

At the bottom of the control window, there are logos for ARID LANDS INSTITUTE, PERKINS + WILL, and The Nature Conservancy. The software interface also includes a top toolbar with various tools, a bottom status bar with coordinates and settings, and a bottom-left corner with view options like 'Site1 Top UI', 'Site 1', 'Front', and 'Right'.

USING HAZEL : DEVELOPMENT AREA

The screenshot displays the HAZEL software interface. The main workspace shows a site plan with various colored zones: a central yellow-green area, a large orange area, and several blue-outlined building footprints. A red line indicates a boundary or path. The interface includes a top toolbar with various tools, a bottom status bar with coordinates and settings, and a right-hand control panel.

HAZEL CONTROL WINDOW

Inputs Data

- Select Lot(s) - Place point(s)
- Buildings to be removed - Draw Closed Polyline
- Development Area - Draw Closed Polyline
- Define Subcatchment(s) - Draw Closed Polyline(s)
- Proposed Buildings - Region(s) as closed polyline(s)
- Planted Areas - Region(s) as a closed polyline(s)
- Draw Infiltration BMP - Region as closed polyline
- Draw Capture and Convey BMP - Region as closed polyline

Infiltration

Select BMP Measure [Dropdown]

BMP Media Depth (in Feet) 0.3

Surface Infiltration Capacity (gal) 0 Cost \$ \$-\$

Capture and Convey

Select BMP Measure [Dropdown]

BMP Media Depth (in Feet) 0.3

Surface Capture Capacity (gal) 0 Cost \$ \$-\$

Retention

Select BMP Measure [Dropdown]

Retention Capacity (gal) 0 Cost \$ \$-\$

Percentage LID satisfied Total Estimated Cost Range: \$-\$

ARID LANDS INSTITUTE PERKINS + WILL The Nature Conservancy

Site1 Top UI Site 1 Front Right

End Near Point Mid Cen Int Perp Tan Quad Knot Vertex Project Disable

CPlane x-13194752.2 y 3804065.491 z 0.000 Meters BMP02 Grid Snap Ortho Planar Osnap SmartTrack Gumball Record History Filter Memory use: 1173 MB

USING HAZEL : RECOMMENDED INFILTRATION ZONE

The screenshot displays the HAZEL software interface. The main workspace shows a site plan with several development areas outlined in different colors: blue, green, and red. A yellow arrow points from the 'Proposed Buildings - Draw Closed Polyline(s)' option in the control panel to a blue-outlined area on the site plan. The control panel on the right, titled 'HAZEL CONTROL WINDOW', contains the following sections:

- Inputs Data:**
 - Select Lot(s) - Place point(s)
 - Buildings to be removed - Draw Closed Polyline
 - Development Area - Draw Closed Polyline
 - Define Subcatchment(s) - Draw Closed Polyline(s)
 - Proposed Buildings - Draw Closed Polyline(s)** (highlighted with a red dashed border)
 - Planted Areas - Region(s) as a closed polyline(s)
 - Draw Infiltration BMP - Region as closed polyline
 - Draw Capture and Convey BMP - Region as closed polyline
- Infiltration:**
 - Select BMP Measure
 - BMP Media Depth (in Feet) 0.3
 - Surface Infiltration Capacity (gal) 0 Cost \$ \$-\$
- Capture and Convey:**
 - Select BMP Measure
 - BMP Media Depth (in Feet) 0.3
 - Surface Capture Capacity (gal) 0 Cost \$ \$-\$
- Retention:**
 - Select BMP Measure
 - Retention Capacity (gal) 0 Cost \$ \$-\$
- Summary:**
 - Percentage LID satisfied: 0%
 - Total Estimated Cost Range: \$-\$

At the bottom of the control panel, logos for ARID LANDS INSTITUTE, PERKINS + WILL, and The Nature Conservancy are visible. The software interface also includes a top toolbar with various tools and a bottom status bar with project information.

USING HAZEL : DEVELOPMENT AREA

The screenshot displays the HAZEL software interface. The main workspace shows a site plan with various colored catchment areas: a large blue area, a yellow area, and a green area. A red arrow points from the 'Define Catchment - Draw Closed Polyline(s)' option in the control window to the yellow catchment area on the site plan.

HAZEL CONTROL WINDOW

Inputs Data

- Select Lot(s) - Place point(s)
- Buildings to be removed - Draw Closed Polyline
- Development Area - Draw Closed Polyline
- Define Catchment - Draw Closed Polyline(s)**
- Proposed Buildings - Region(s) as closed polyline(s)
- Planted Areas - Region(s) as a closed polyline(s)
- Draw Infiltration BMP - Region as closed polyline
- Draw Capture and Convey BMP - Region as closed polyline

Infiltration

Select BMP Measure

BMP Media Depth (in Feet) 0.3

Surface Infiltration Capacity (gal) 0 Cost \$ \$-\$

Capture and Convey

Select BMP Measure

BMP Media Depth (in Feet) 0.3

Surface Capture Capacity (gal) 0 Cost \$ \$-\$

Retention

Select BMP Measure

Retention Capacity (gal) 0 Cost \$ \$-\$

Percentage LID satisfied Total Estimated Cost Range: \$-\$

ARID LANDS INSTITUTE PERKINS + WILL The Nature Conservancy

Site1 Top UI Site 1 Front Right

End Near Point Mid Cen Int Perp Tan Quad Knot Vertex Project Disable

CPlane x-13194727.7 y 3803831.916 z 0.000 Meters Solution Grid Snap Ortho Planar Osnap SmartTrack Gumball Record History Filter CPU use: 2.6 %

USING HAZEL : SUBCATCHMENT AREA

The image shows the HAZEL software interface. The main window displays a site plan with various colored regions (blue, green, red, white) and a yellow arrow pointing from a region on the plan to the 'Define BMP - Draw Closed Polyline(s)' button in the control panel. The control panel is titled 'HAZEL CONTROL WINDOW' and contains several sections:

- Inputs Data:**
 - Select Lot(s) - Place point(s)
 - Buildings to be removed - Draw Closed Polyline
 - Development Area - Draw Closed Polyline
 - Define Subcatchment(s) - Draw Closed Polyline(s)
 - Define BMP - Draw Closed Polyline(s)** (highlighted with a red dashed border)
 - Planted Areas - Region(s) as a closed polyline(s)
 - Draw Infiltration BMP - Region as closed polyline
 - Draw Capture and Convey BMP - Region as closed polyline
- Infiltration:**
 - Select BMP Measure
 - BMP Media Depth (in Feet) 0.3
 - Surface Infiltration Capacity (gal) 0 Cost \$ \$-\$
- Capture and Convey:**
 - Select BMP Measure
 - BMP Media Depth (in Feet) 0.3
 - Surface Capture Capacity (gal) 0 Cost \$ \$-\$
- Retention:**
 - Select BMP Measure
 - Retention Capacity (gal) 0 Cost \$ \$-\$
- Summary:**
 - Percentage LID satisfied
 - Total Estimated Cost Range: \$ - \$

At the bottom of the control panel, there are logos for ARID LANDS INSTITUTE, PERKINS + WILL, and The Nature Conservancy.

The software interface also includes a top toolbar with various tools, a bottom status bar with coordinates and units, and a bottom menu bar with options like 'End', 'Near', 'Point', 'Mid', 'Cen', 'Int', 'Perp', 'Tan', 'Quad', 'Knot', 'Vertex', 'Project', 'Disable', 'Grid Snap', 'Ortho', 'Planar', 'Osnap', 'SmartTrack', 'Gumball', 'Record History', 'Filter', and 'Absolute tolerance: 0.001'.

USING HAZEL : DEFINE BMP REGION

The screenshot displays the HAZEL software interface. The main workspace shows a site plan with several colored outlines: a red rectangle, a green rectangle, and a blue irregular shape. A yellow arrow points from the right side of the plan towards the control panel.

HAZEL CONTROL WINDOW

Inputs Data

- Select Lot(s) - Place point(s)
- Buildings to be removed - Draw Closed Polyline
- Development Area - Draw Closed Polyline
- Define Subcatchment(s) - Draw Closed Polyline(s)
- Proposed Buildings - Region(s) as closed polyline(s)
- Planted Areas - Region(s) as a closed polyline(s)
- Draw Infiltration BMP - Region as closed polyline
- Draw Capture and Convey BMP - Region as closed polyline

Infiltration

Bioswale (Rain Garden)

BMP Media Depth (in Feet) 2.0

Surface Infiltration Capacity (gal) 3462 Cost \$ \$55100 - \$74600

Capture and Convey

Select BMP Measure

BMP Media Depth (in Feet) 0.3

Surface Capture Capacity (gal) 0 Cost \$ \$ - \$

Retention

Select BMP Measure

Retention Capacity (gal) 0 Cost \$ \$ - \$

Percentage LID satisfied Total Estimated Cost Range:
\$55100 - \$74600

40%

ARID LANDS INSTITUTE PERKINS + WILL The Nature Conservancy

Site1 Top UI Site 1 Front Right

End Near Point Mid Cen Int Perp Tan Quad Knot Vertex Project Disable

CPlane x-13194752.1 y 3803957.556 z 0.000 Meters Solution Grid Snap Ortho Planar Osnap SmartTrack Gumball Record History Filter CPU use: 11.2 %

USING HAZEL : SELECT BMP TYPE

The screenshot displays the HAZEL software interface. The main workspace shows a site plan with various colored outlines (blue, green, red, white) representing different areas or features. The right-hand side features a 'HAZEL CONTROL WINDOW' with several input fields and a summary section.

HAZEL CONTROL WINDOW Inputs Data:

- Select Lot(s) - Place point(s)
- Buildings to be removed - Draw Closed Polyline
- Development Area - Draw Closed Polyline
- Define Subcatchment(s) - Draw Closed Polyline(s)
- Proposed Buildings - Region(s) as closed polyline(s)
- Planted Areas - Region(s) as a closed polyline(s)
- Draw Infiltration BMP - Region as closed polyline
- Draw Capture and Convey BMP - Region as closed polyline

Infiltration:

- Bioswale (Rain Garden)
- BMP Media Depth (in Feet): 2.0
- Surface Infiltration Capacity (gal): 3462 Cost: \$ \$55100 - \$74600

Capture and Convey:

- Select BMP Measure
- BMP Media Depth (in Feet): 0.3
- Surface Capture Capacity (gal): 0 Cost: \$ \$ - \$

Retention:

- Select BMP Measure
- Retention Capacity (gal): 0 Cost: \$ \$ - \$

Summary:

- Percentage LID satisfied: 40% (indicated by a gauge and a yellow arrow pointing from the site plan)
- Total Estimated Cost Range: \$55100 - \$74600

Logos: ARID LANDS INSTITUTE, PERKINS + WILL, The Nature Conservancy

Bottom Panel: Site1 Top UI, Site 1, Front, Right, +
 End Near Point Mid Cen Int Perp Tan Quad Knot Vertex Project Disable
 CPlane x-13194752.1f y 3803957.556 z 0.000 Meters Solution Grid Snap Ortho Planar Osnap SmartTrack Gumball Record History Filter CPU use: 11.2 %

USING HAZEL : PERCENTAGE IN COMPLIANCE

The screenshot displays the HAZEL software interface. The main workspace shows a site plan with various colored outlines (blue, green, red, white) representing different areas and features. The right-hand side features a 'HAZEL CONTROL WINDOW' with the following sections:

- Inputs Data:** A list of actions to be performed on the site plan, such as 'Select Lot(s) - Place point(s)', 'Buildings to be removed - Draw Closed Polyline', 'Development Area - Draw Closed Polyline', 'Define Subcatchment(s) - Draw Closed Polyline(s)', 'Proposed Buildings - Region(s) as closed polyline(s)', 'Planted Areas - Region(s) as a closed polyline(s)', 'Draw Infiltration BMP - Region as closed polyline', and 'Draw Capture and Convey BMP - Region as closed polyline'.
- Infiltration:** A dropdown menu set to 'Bioswale (Rain Garden)', with a 'BMP Media Depth (in Feet)' of 2.0. Below this, it shows 'Surface Infiltration Capacity (gal)' as 3462 and a 'Cost' range of \$55100 - \$74600.
- Capture and Convey:** A dropdown menu for 'Select BMP Measure', with a 'BMP Media Depth (in Feet)' of 0.3. It shows 'Surface Capture Capacity (gal)' as 0 and a 'Cost' of \$-\$.
- Retention:** A dropdown menu for 'Select BMP Measure', with 'Retention Capacity (gal)' as 0 and a 'Cost' of \$-\$.
- Summary:** A section showing 'Percentage LID satisfied' as 40% (represented by a gauge) and a 'Total Estimated Cost Range' of \$55100 - \$74600, which is highlighted with a red dashed box.
- Logos:** Logos for ARID LANDS INSTITUTE, PERKINS + WILL, and The Nature Conservancy are displayed at the bottom of the control window.

The bottom of the software interface shows a status bar with various settings like 'Site1 Top UI', 'Site 1', 'Front', 'Right', and 'Solution', along with a CPU usage indicator of 11.2%.

USING HAZEL : ESTIMATED COST RANGE

The screenshot displays the HAZEL software interface. The main workspace shows a site plan with several colored outlines: a red outline for a large area on the left, a blue outline for a central area, and a yellow outline for a complex area on the right. A large yellow arrow points from the yellow-outlined area to the control panel on the right.

HAZEL CONTROL WINDOW

Inputs Data

- Select Lot(s) - Place point(s)
- Buildings to be removed - Draw Closed Polyline
- Development Area - Draw Closed Polyline
- Define Subcatchment(s) - Draw Closed Polyline(s)
- Proposed Buildings - Region(s) as closed polyline(s)
- Define Planted Areas - Draw Closed Polyline(s)**
- Draw Infiltration BMP - Region as closed polyline
- Draw Capture and Convey BMP - Region as closed polyline

Infiltration

Bioswale (Rain Garden)

BMP Media Depth (in Feet) 2.0

Surface Infiltration Capacity (gal) 3462 Cost \$ \$55100 - \$74600

Capture and Convey

Select BMP Measure

BMP Media Depth (in Feet) 0.3

Surface Capture Capacity (gal) 0 Cost \$ \$ - \$

Retention

Select BMP Measure

Retention Capacity (gal) 0 Cost \$ \$ - \$

Percentage LID satisfied Total Estimated Cost Range:
\$55100 - \$74600

48%

ARID LANDS INSTITUTE PERKINS + WILL The Nature Conservancy

Site1 Top UI Site 1 Front Right

End Near Point Mid Cen Int Perp Tan Quad Knot Vertex Project Disable

CPlane x-13194728.6 y 3803936.050 z 0.000 Meters Solution Grid Snap Ortho Planar Osnap SmartTrack Gumball Record History Filter Memory use: 1272 MB

USING HAZEL : DEFINE LANDSCAPE AREAS

The screenshot displays the HAZEL software interface. The main workspace shows a site plan with various colored outlines (blue, green, red, white) representing different areas. A yellow arrow points from the site plan to the control panel on the right.

HAZEL CONTROL WINDOW

Inputs Data

- Select Lot(s) - Place point(s)
- Buildings to be removed - Draw Closed Polyline
- Development Area - Draw Closed Polyline
- Define Subcatchment(s) - Draw Closed Polyline(s)
- Proposed Buildings - Region(s) as closed polyline(s)
- Planted Areas - Region(s) as a closed polyline(s)
- Draw Infiltration BMP - Region as closed polyline
- Draw Capture and Convey BMP - Region as closed polyline

Infiltration

Bioswale (Rain Garden)

BMP Media Depth (in Feet) 2.5

Surface Infiltration Capacity (gal) 4328 Cost \$ \$64300 - \$87000

Capture and Convey

Select BMP Measure

BMP Media Depth (in Feet) 0.3

Surface Capture Capacity (gal) 0 Cost \$ \$ - \$

Retention

Select BMP Measure

Retention Capacity (gal) 0 Cost \$ \$ - \$

Percentage LID satisfied Total Estimated Cost Range:
\$64300 - \$87000

60%

ARID LANDS INSTITUTE PERKINS + WILL The Nature Conservancy

Site1 Top UI Site 1 Front Right

End Near Point Mid Cen Int Perp Tan Quad Knot Vertex Project Disable

CPlane x-13194738.2; y-3804003.356 z-0.000 Meters Solution Grid Snap Ortho Planar Osnap SmartTrack Gumball Record History Filter Memory use: 1285 MB

USING HAZEL : ADJUST BMP DEPTH

The screenshot displays the HAZEL software interface. The main workspace shows a site plan with various colored outlines (blue, red, green, white) representing different areas. The right-hand side features a 'HAZEL CONTROL WINDOW' with the following sections:

- Inputs Data:** A list of actions to be performed on the site plan, such as 'Select Lot(s) - Place point(s)', 'Buildings to be removed - Draw Closed Polyline', 'Development Area - Draw Closed Polyline', 'Define Subcatchment(s) - Draw Closed Polyline(s)', 'Proposed Buildings - Region(s) as closed polyline(s)', 'Planted Areas - Region(s) as a closed polyline(s)', 'Draw Infiltration BMP - Region as closed polyline', and 'Draw Capture and Convey BMP - Region as closed polyline'.
- Infiltration:** A dropdown menu set to 'Bioswale (Rain Garden)'. Below it, 'BMP Media Depth (in Feet)' is set to 2.5. The 'Surface Infiltration Capacity (gal)' is 4328, and the 'Cost' is \$64300 - \$87000.
- Capture and Convey:** A dropdown menu set to 'Select BMP Measure'. Below it, 'BMP Media Depth (in Feet)' is set to 0.3. The 'Surface Capture Capacity (gal)' is 0, and the 'Cost' is \$ - \$.
- Retention:** A dropdown menu set to 'Cistern and Rain Barrels'. Below it, 'Retention Capacity (gal)' is 2945, and the 'Cost' is \$56900 - \$77100.

At the bottom of the control window, there is a summary section:

- Percentage LID satisfied:** 100% (represented by a teal donut chart).
- Total Estimated Cost Range:** \$121300 - \$164100.

Logos for ARID LANDS INSTITUTE, PERKINS + WILL, and The Nature Conservancy are visible at the bottom right of the control window. The software interface also includes a top toolbar with various tools, a bottom status bar with coordinates and settings, and a bottom-left corner with view and snap options.

USING HAZEL : SELECT RETENTION BMP

The screenshot shows a CAD software interface with a site plan. A yellow arrow points to the HAZEL CONTROL WINDOW on the right side of the screen. The window displays the following data:

HAZEL CONTROL WINDOW

Inputs Data

Save to Rhino

Output Site Geometry Site01

Output Layer Name Catchment01

Results

Site Area	683981 sqft
Development Area	332209 sqft
Percentage of Site	49 %
Subcatchment Area	93974 sqft
New Permeable Area	32993 sqft
New Impermeable Area	60981 sqft
New Landscape Area	14352 sqft
Required Infiltration Volume	7273 gal
Provided Infiltration Volume	7273 gal
Additional Required Volume	0 gal

Site1 Top UI

Site1 Front Right

End Near Point Mid Cen Int Perp Tan Quad Knot Vertex Project Disable

CPlane x-13194719.41 y 3803741.353 z 0.000 Meters Solution Grid Snap Ortho Planar Osnap SmartTrack Gumball Record History Filter Memory use: 1267 MB

USING HAZEL : RESULTING DATA

Workshops: Testing the Tool + User Interface



USING HAZEL : WORKSHOP 1

“Give Ability to check Civil Engineer”

“Explore scenarios, options, alternatives”

“Scope of magnitude of challenge and problem definition up front”

“Cost data very valuable”

“Power of data - lots of it in one place - FAST”





USING HAZEL : WORKSHOP 2

Infiltration

Bioswale (Rain Garden)

BMP Media Depth (in Feet) 2.0

Surface Infiltration Capacity (gal) 7680 Cost \$ \$122400 - \$165500

Capture and Convey

Select BMP Measure

BMP Media Depth (in Feet) 0.3

Surface Capture Capacity (gal) 0 Cost \$ \$ - \$

Retention

Select BMP Measure

Retention Capacity (gal) 0 Cost \$ \$ - \$

Percentage LID satisfied

125%

Total Estimated Cost Range: \$122400 - \$165500

Output Site Geometry Provide Site Name Save to Rhino

BMP Media Depth (in Feet) 0.3

Surface Capture Capacity (gal) 0 Cost \$ \$ - \$

Retention

Select BMP Measure

Retention Capacity (gal) 0 Cost \$ \$ - \$

Percentage LID satisfied

128%

Total Estimated Cost Range: \$115100 - \$155700

Output Site Geometry Provide Site Name Save to Rhino

Output Layer Name Subcatchment Name Save to Rhino

Development Area - Draw Closed Polyline

Proposed Buildings - Region(s) as closed polyline(s)

Planted Areas - Region(s) as a closed polyline(s)

Draw Infiltration BMP - Region as closed polyline

Draw Capture and Convey BMP - Region as closed polyline

Infiltration

Bioswale (Rain Garden)

BMP Media Depth (in Feet) 2.0

Surface Infiltration Capacity (gal) 5560 Cost \$ \$88600 - \$119800

Capture and Convey

Green Roof (Extensive)

BMP Media Depth (in Feet) 0.5

Surface Capture Capacity (gal) 0 Cost \$ \$ - \$

Retention

Select BMP Measure

Retention Capacity (gal) 0 Cost \$ \$ - \$

Percentage LID satisfied

100%

Total Estimated Cost Range: \$88600 - \$119800

Output Site Geometry Provide Site Name Save to Rhino

Planted Areas - Region(s) as a closed polyline(s)

Draw Infiltration BMP - Region as closed polyline

Draw Capture and Convey BMP - Region as closed polyline

Infiltration

Bioswale (Rain Garden)

BMP Media Depth (in Feet) 2.0

Surface Infiltration Capacity (gal) 6256 Cost \$ \$99700 - \$134800

Capture and Convey

Select BMP Measure

BMP Media Depth (in Feet) 0.3

Surface Capture Capacity (gal) 0 Cost \$ \$ - \$

Retention

Select BMP Measure

Retention Capacity (gal) 0 Cost \$ \$ - \$

Percentage LID satisfied

104%

Total Estimated Cost Range:

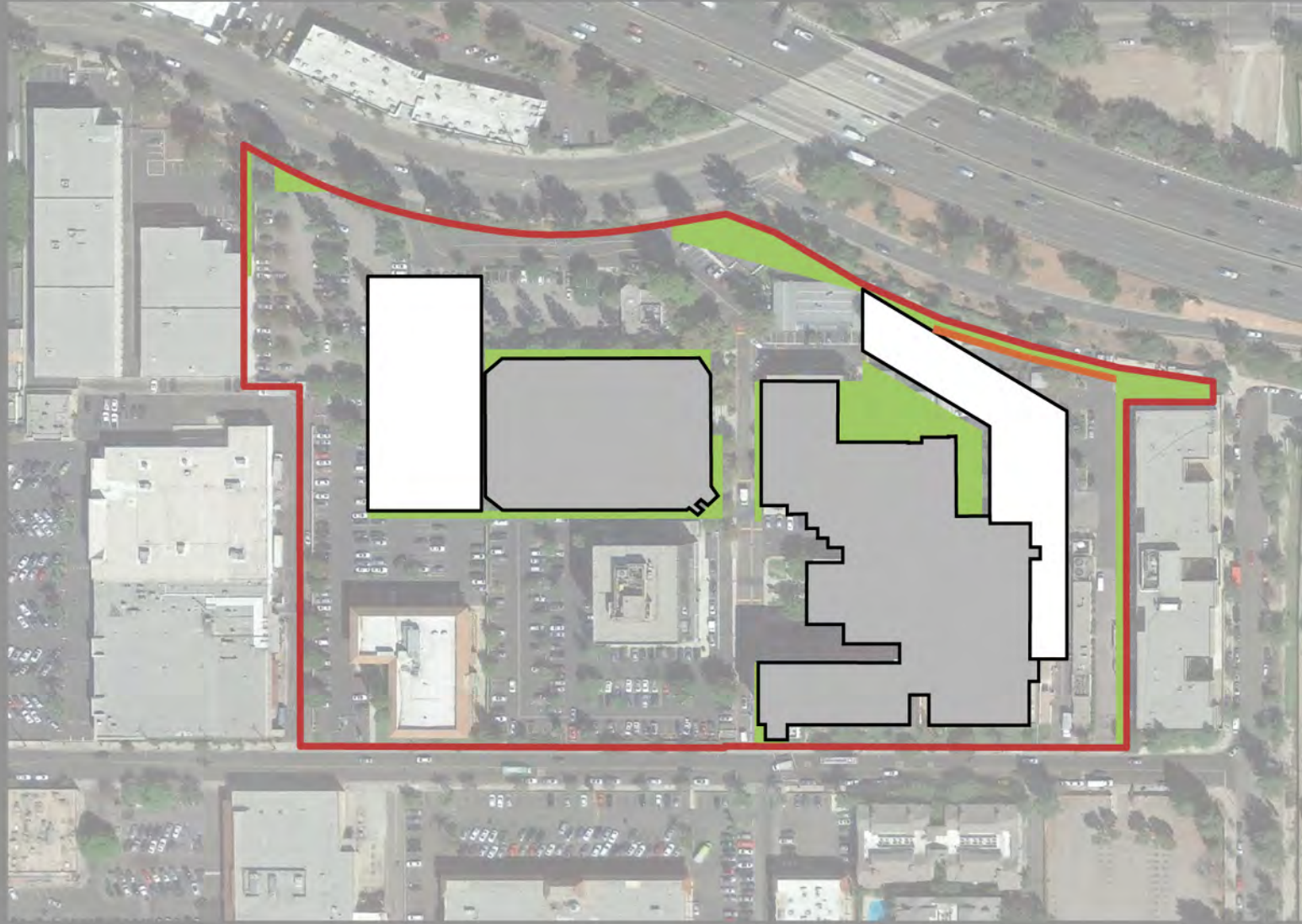
“Likely to accelerate significantly more exploration in much shorter time”

“Good tool for decision-making at planning stage”

“More time could be spend exploring design option rather than spent on calculations and research”

“Hazel allows for quick analysis of a site early on without needing extensive background on the subject”





BIORETENTION BASIN

2.0	STORMWATER INFILTRATED (Acre-ft/year)	5.7 homes
9.5	ENERGY SAVED (MWh/year)	
7.9	GHG / CARBON AVOIDED (Tonnes CO2e/year)	1.9 cars
0.04	HABITAT CREATED (Acres)	
0.2	HEAT ISLAND REDUCED (Acres)	



PERVIOUS PAVING

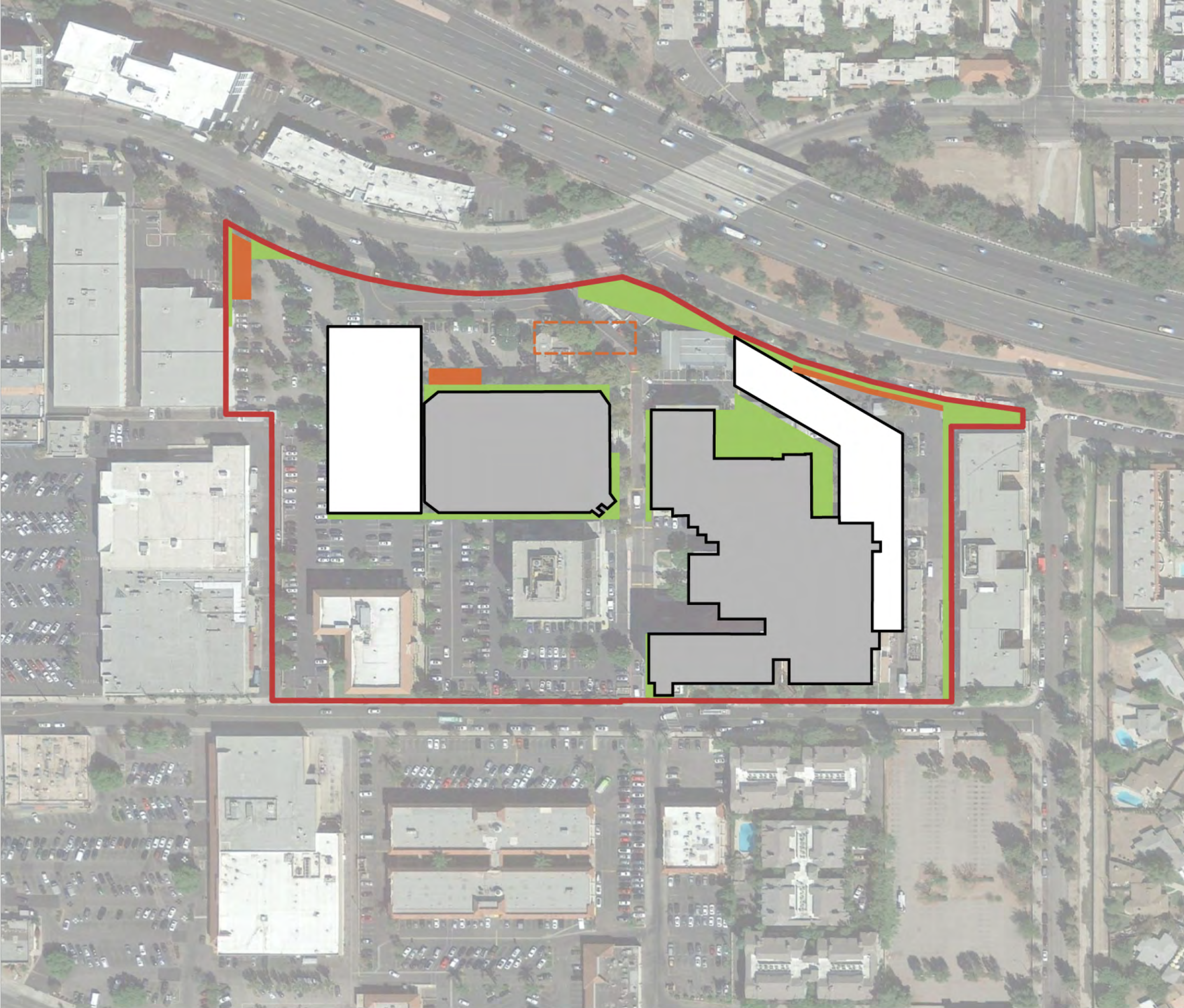
3.9	STORMWATER INFILTRATED (Acre-ft/year)	10.9 homes
18.1	ENERGY SAVED (MWh/year)	
15	GHG / CARBON AVOIDED (Tonnes CO2e/year)	3.6 cars
0	HABITAT CREATED (Acres)	
0	HEAT ISLAND REDUCED (Acres)	



CISTERN

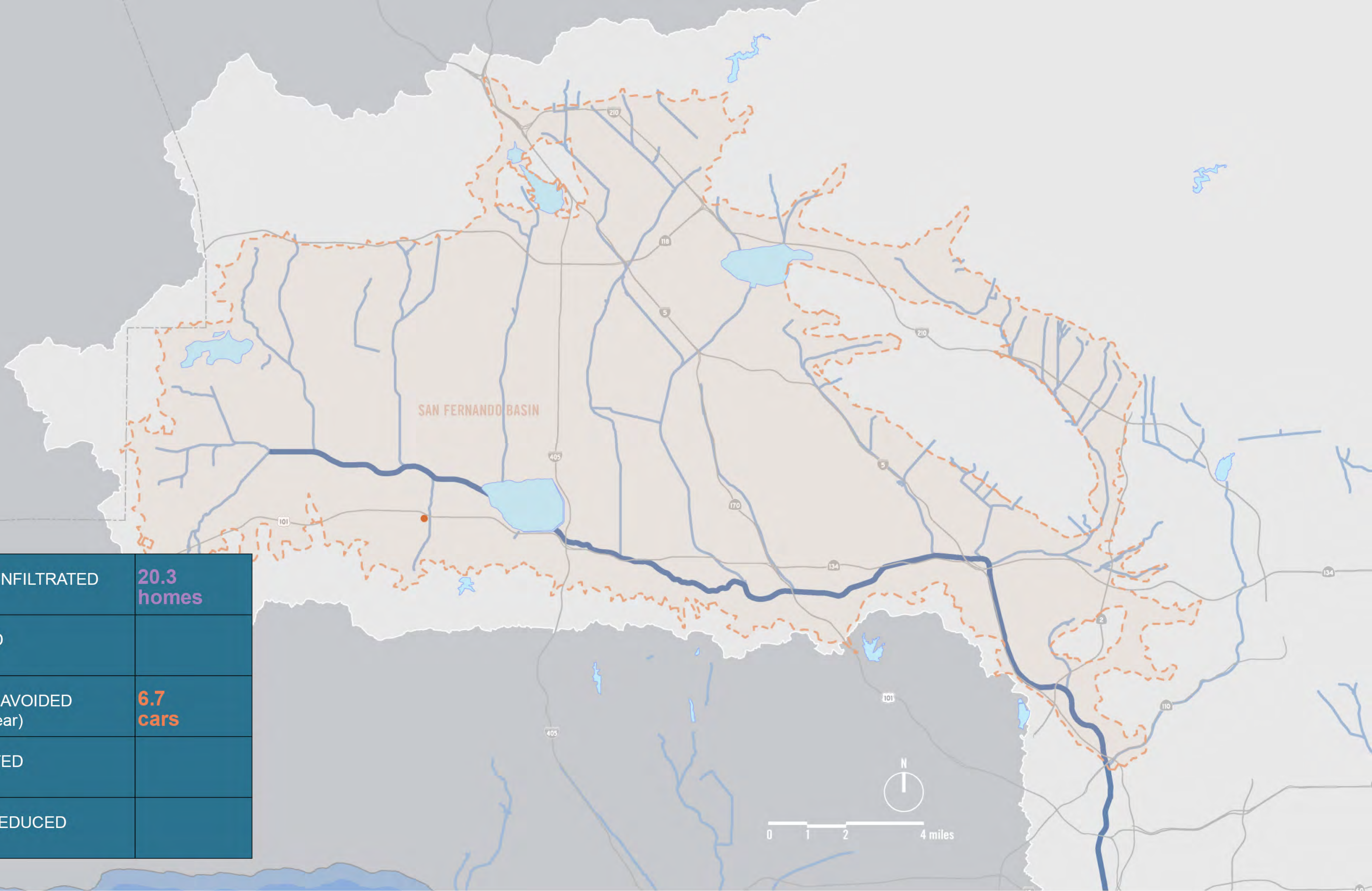
1.3	STORMWATER INFILTRATED (Acre-ft/year)	3.7 homes
6.0	ENERGY SAVED (MWh/year)	
5.0	GHG / CARBON AVOIDED (Tonnes CO2e/year)	1.2 cars
0	HABITAT CREATED (Acres)	
0	HEAT ISLAND REDUCED (Acres)	

IMPLICATIONS



\$513,800- \$696,000	ESTIMATED CONSTRUCTION COST RANGE	
7.2	STORMWATER INFILTRATED (Acre-ft/year)	20.3 homes
33.6	ENERGY SAVED (MWh/year)	
27.8	GHG / CARBON AVOIDED (Tonnes CO2e/year)	6.7 cars
0.04	HABITAT CREATED (Acres)	
0.2	HEAT ISLAND REDUCED (Acres)	

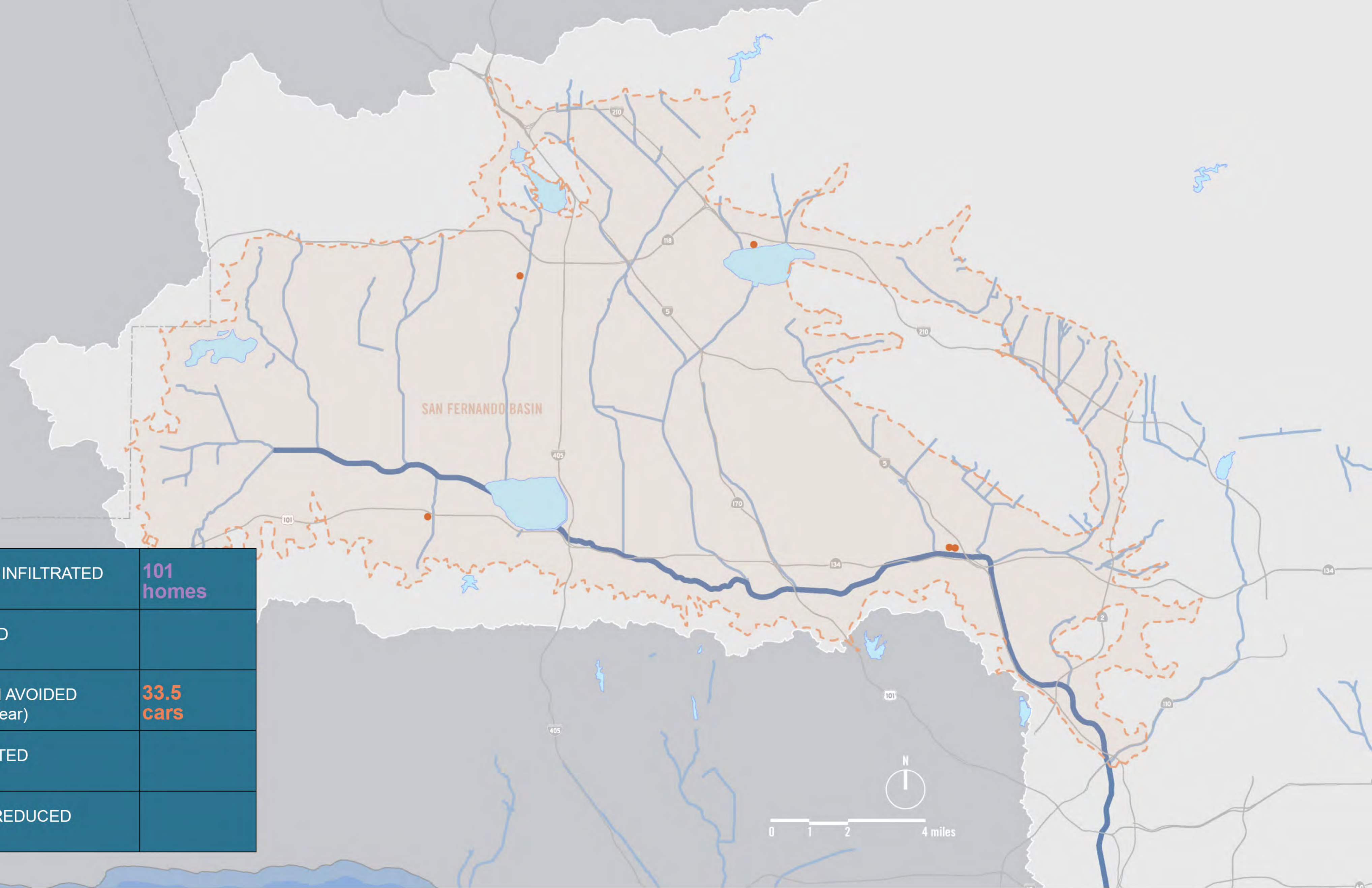
COMPLETE SOLUTION



SAN FERNANDO BASIN

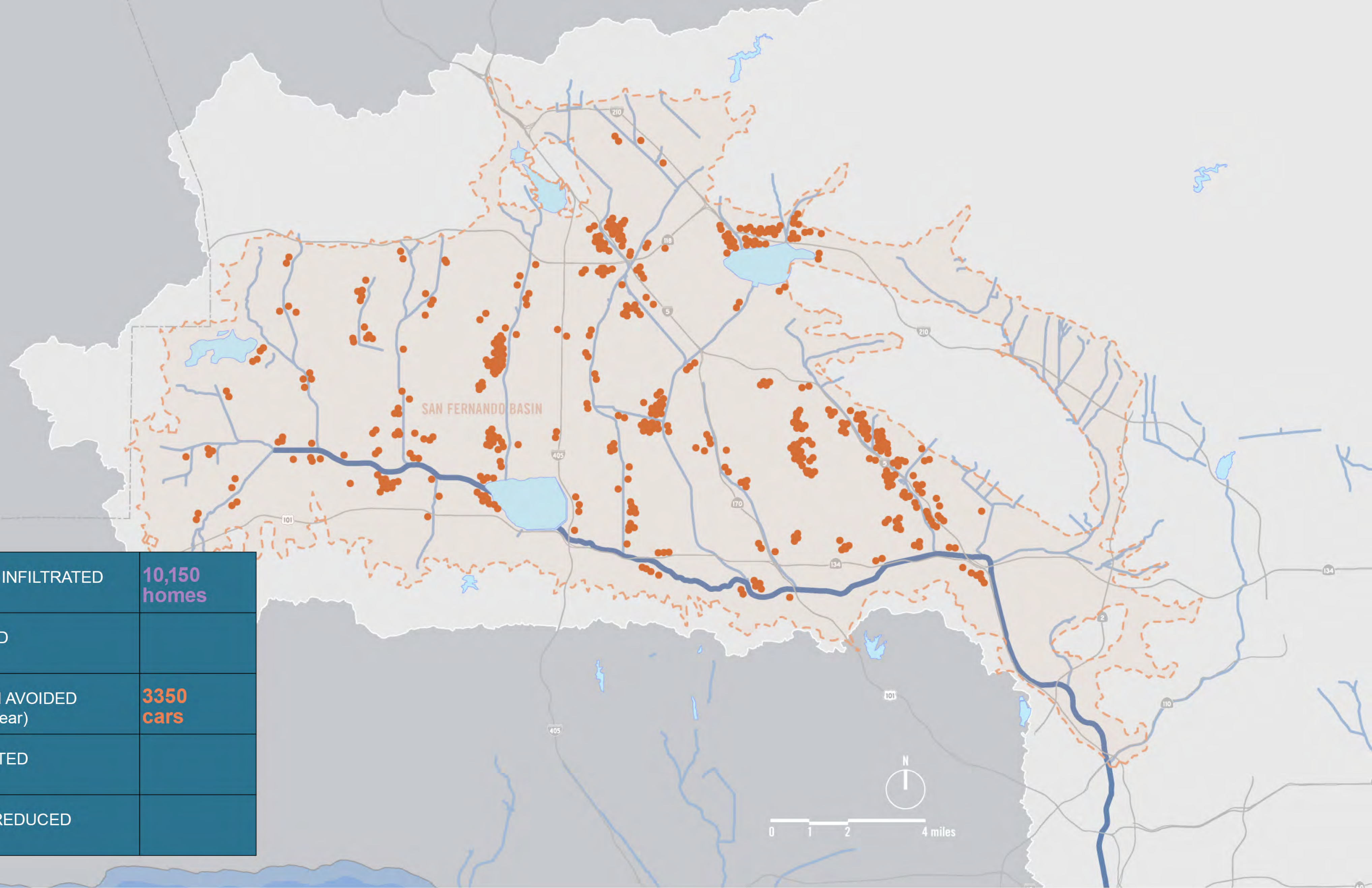
7.2	STORMWATER INFILTRATED (Acre-ft/year)	20.3 homes
33.6	ENERGY SAVED (MWh/year)	
27.8	GHG / CARBON AVOIDED (Tonnes CO2e/year)	6.7 cars
0.04	HABITAT CREATED (Acres)	
0.2	HEAT ISLAND REDUCED (Acres)	

REGIONAL IMPLICATION: 1 BMP



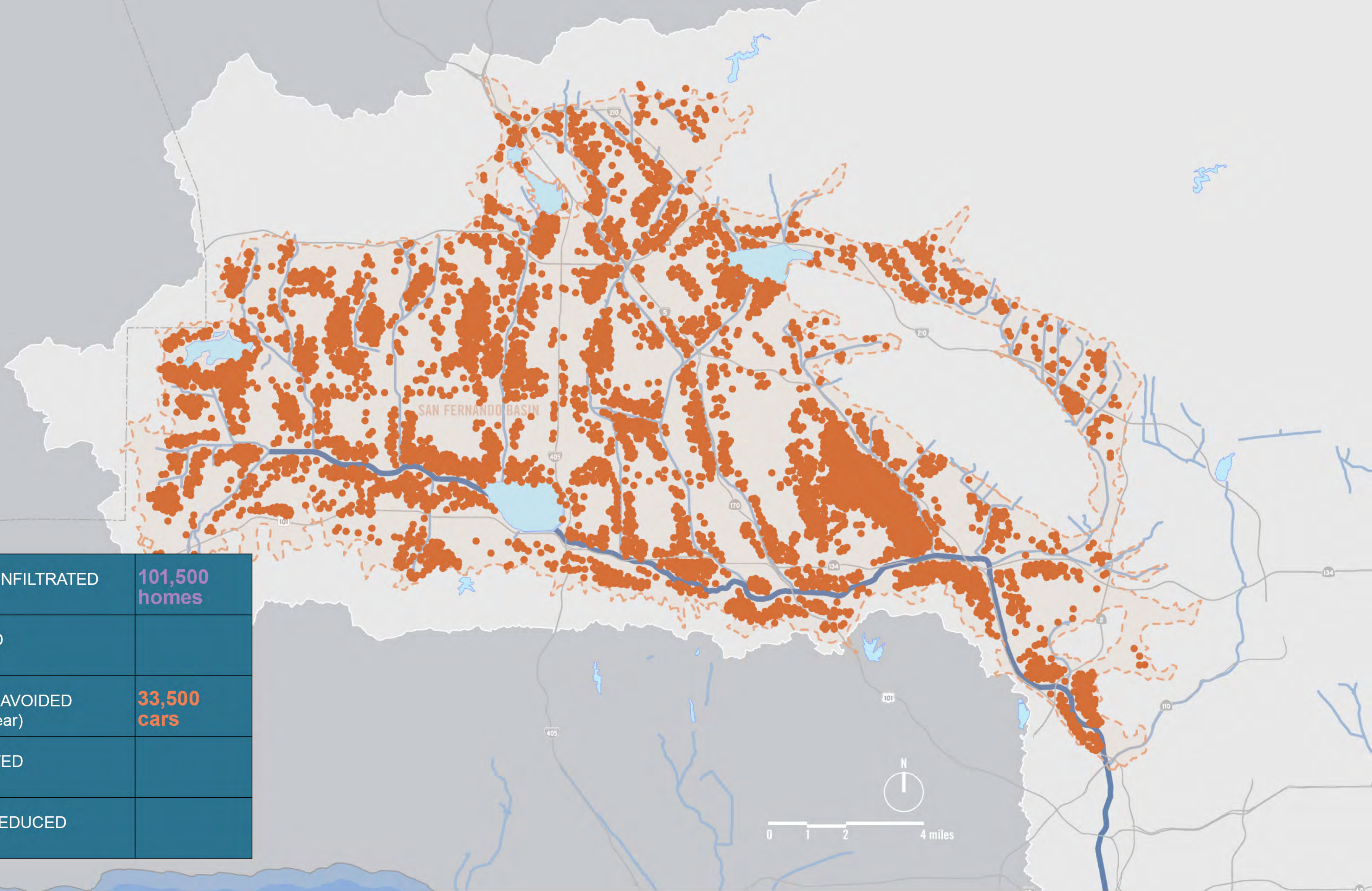
36	STORMWATER INFILTRATED (Acre-ft/year)	101 homes
168	ENERGY SAVED (MWh/year)	
139	GHG / CARBON AVOIDED (Tonnes CO2e/year)	33.5 cars
0.2	HABITAT CREATED (Acres)	
1	HEAT ISLAND REDUCED (Acres)	

REGIONAL IMPLICATION: 5 BMPs



3,600	STORMWATER INFILTRATED (Acre-ft/year)	10,150 homes
16,800	ENERGY SAVED (MWh/year)	
69,500	GHG / CARBON AVOIDED (Tonnes CO2e/year)	3350 cars
20	HABITAT CREATED (Acres)	
100	HEAT ISLAND REDUCED (Acres)	

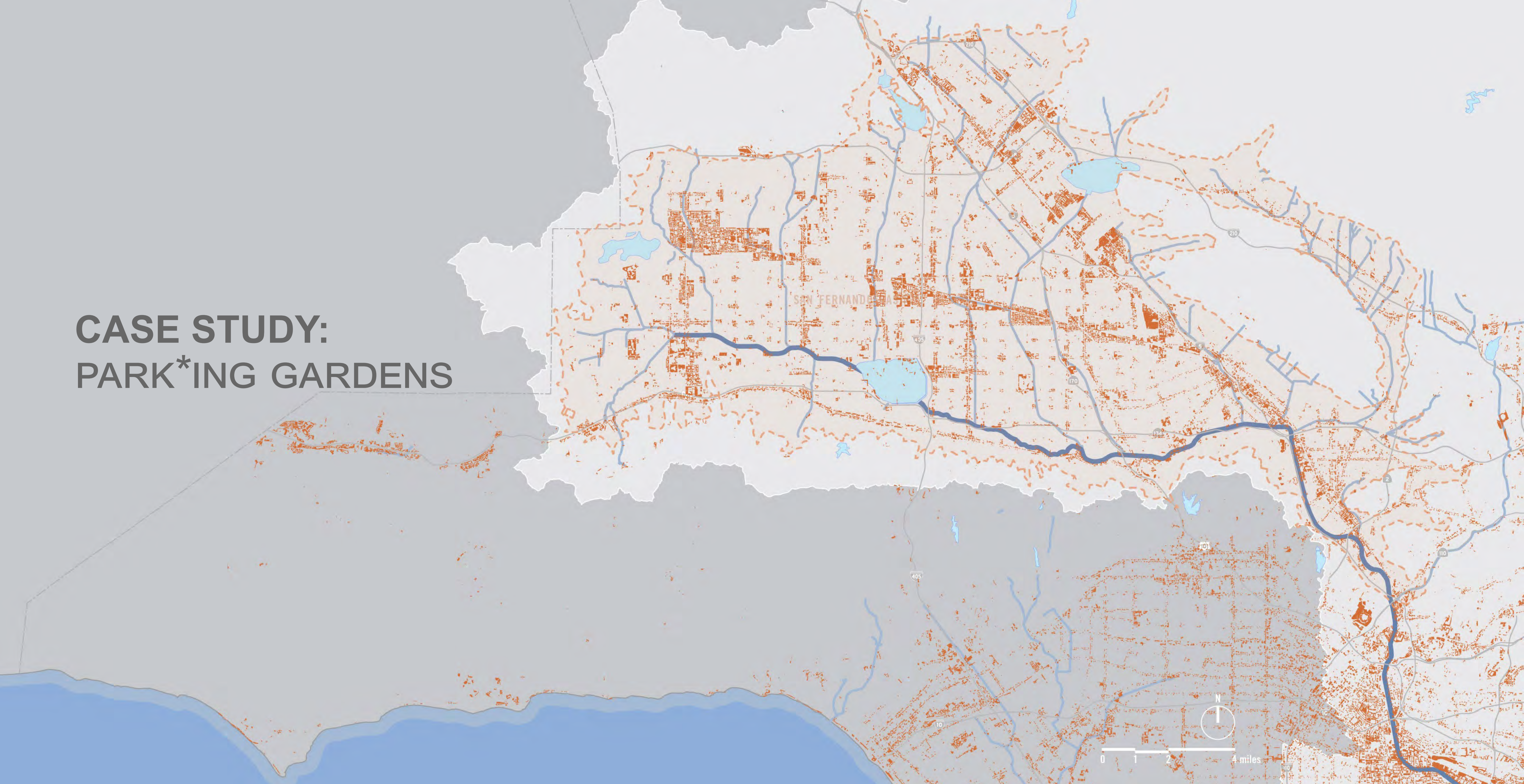
REGIONAL IMPLICATION: 500 BMPs



36,000	STORMWATER INFILTRATED (Acre-ft/year)	101,500 homes
168,000	ENERGY SAVED (MWh/year)	
1,390	GHG / CARBON AVOIDED (Tonnes CO2e/year)	33,500 cars
200	HABITAT CREATED (Acres)	
1,000	HEAT ISLAND REDUCED (Acres)	

REGIONAL IMPLICATION: 5000 BMPs

CASE STUDY: PARK*ING GARDENS



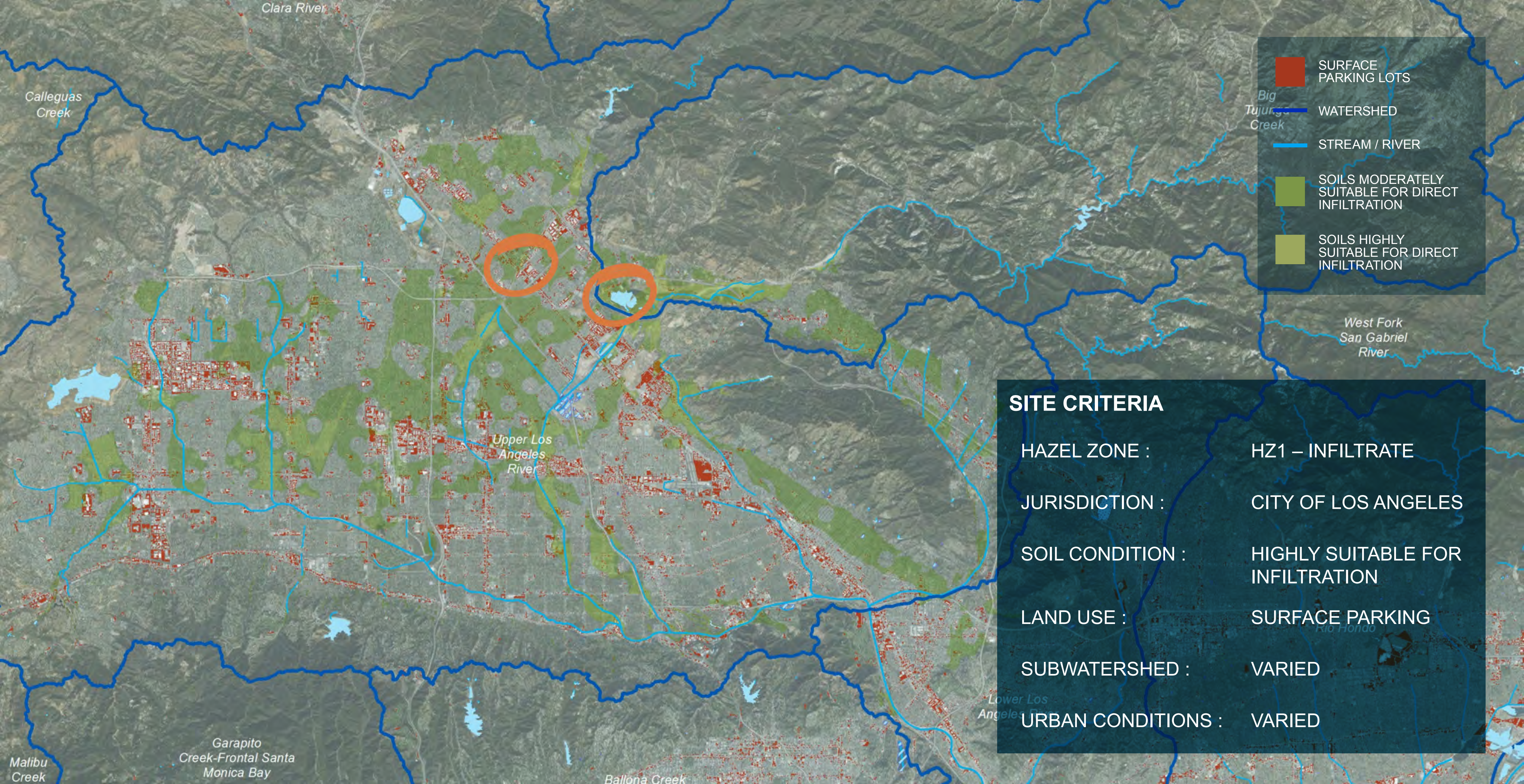


*Cultural Institute of Tampico
Tampico, Mexico*



*Beiqijia Technology Business District 1
Beijing, China*

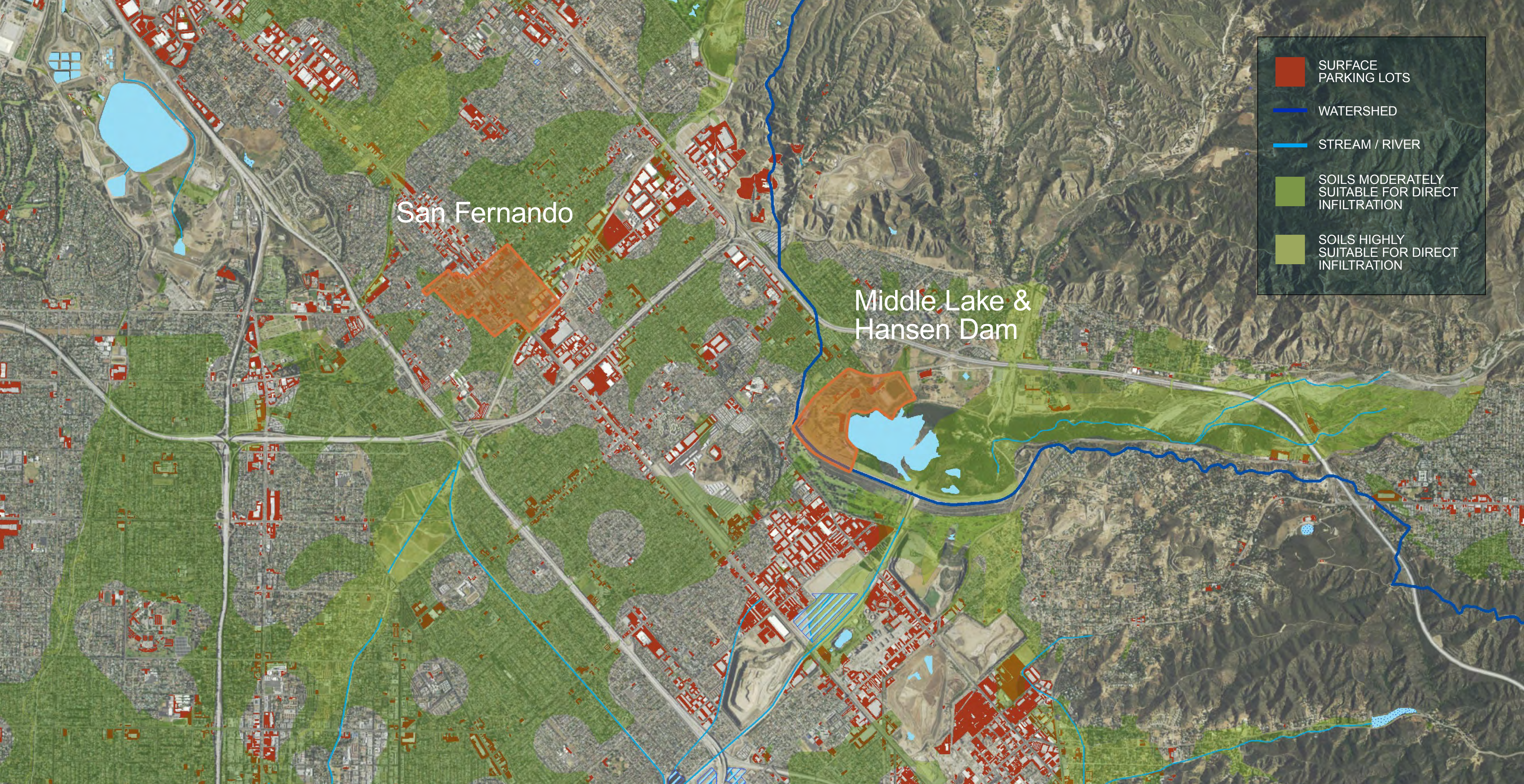
PARK*ING GARDENS: PRECEDENTS

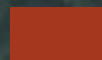
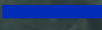
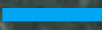
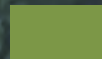



- SURFACE PARKING LOTS
- WATERSHED
- STREAM / RIVER
- SOILS MODERATELY SUITABLE FOR DIRECT INFILTRATION
- SOILS HIGHLY SUITABLE FOR DIRECT INFILTRATION

SITE CRITERIA	
HAZEL ZONE :	HZ1 – INFILTRATE
JURISDICTION :	CITY OF LOS ANGELES
SOIL CONDITION :	HIGHLY SUITABLE FOR INFILTRATION
LAND USE :	SURFACE PARKING
SUBWATERSHED :	VARIED
URBAN CONDITIONS :	VARIED

PARK*ING GARDENS: SAN FERNANDO VALLEY



-  SURFACE PARKING LOTS
-  WATERSHED
-  STREAM / RIVER
-  SOILS MODERATELY SUITABLE FOR DIRECT INFILTRATION
-  SOILS HIGHLY SUITABLE FOR DIRECT INFILTRATION

San Fernando

Middle Lake & Hansen Dam



1: *Gleditsia triacanthos*



2: *Festuca rubra*



3: *Triglochin striata*



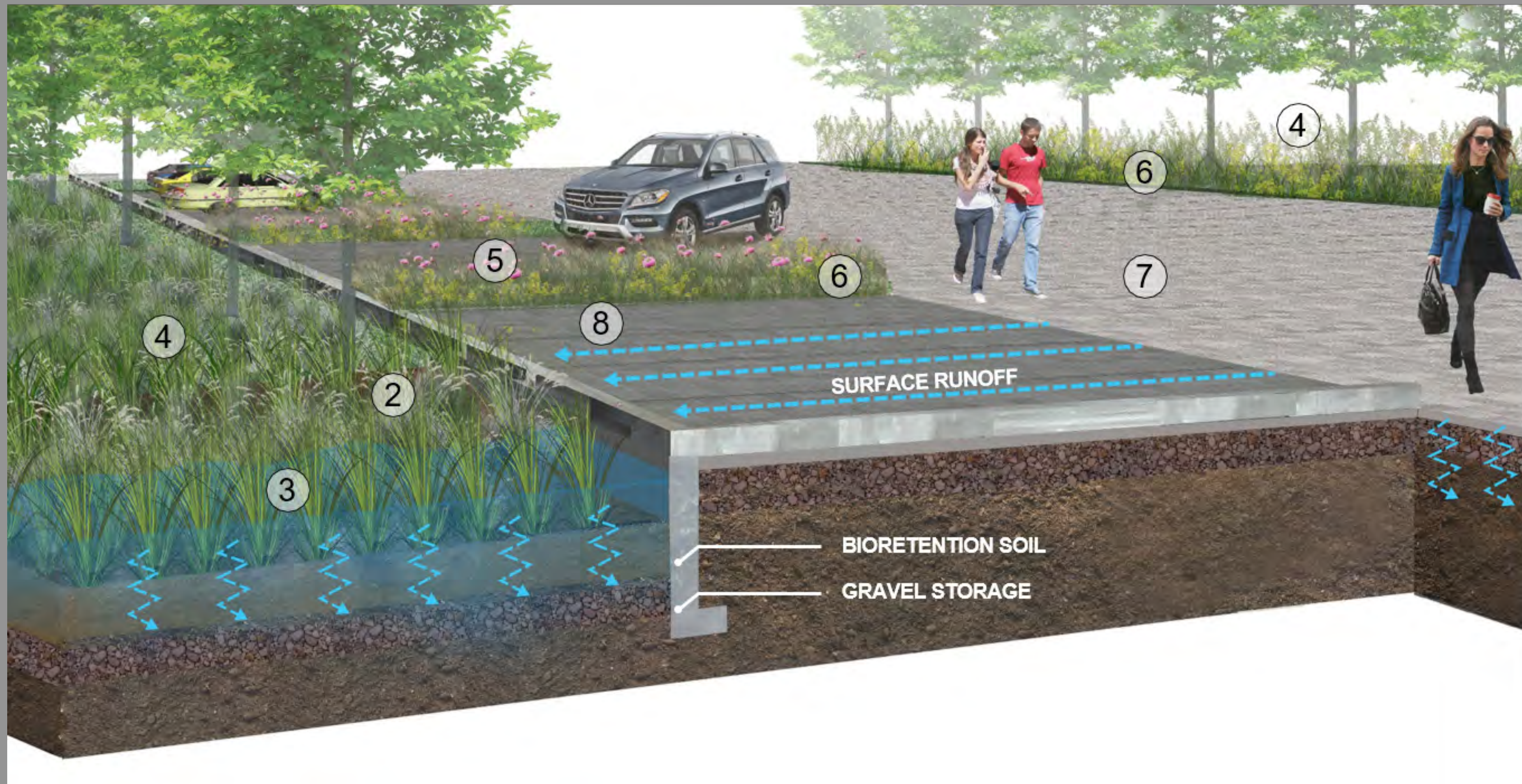
4: *Stipa austroitalica*



5: *Silybum marianum*



6: *Sinapis arvensis*



- PETROCHEMICALS
- LEAD (Pb)
- 7: PERVIOUS PAVERS
- 8: IMPERVIOUS PAVERS

PARK*ING GARDENS: SAN FERNANDO VALLEY

4

Hazel in Policy Context: How Cities are Making Stormwater Work

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CITIES FACING LEGAL
ACTION BY EPA

\$100B

NEEDED TO FIX
U.S. STORMWATER
INFRASTRUCTURE



42%

OF U.S. URBAN LAND WILL
BE REDEVELOPED BY
2030

\$20B/y

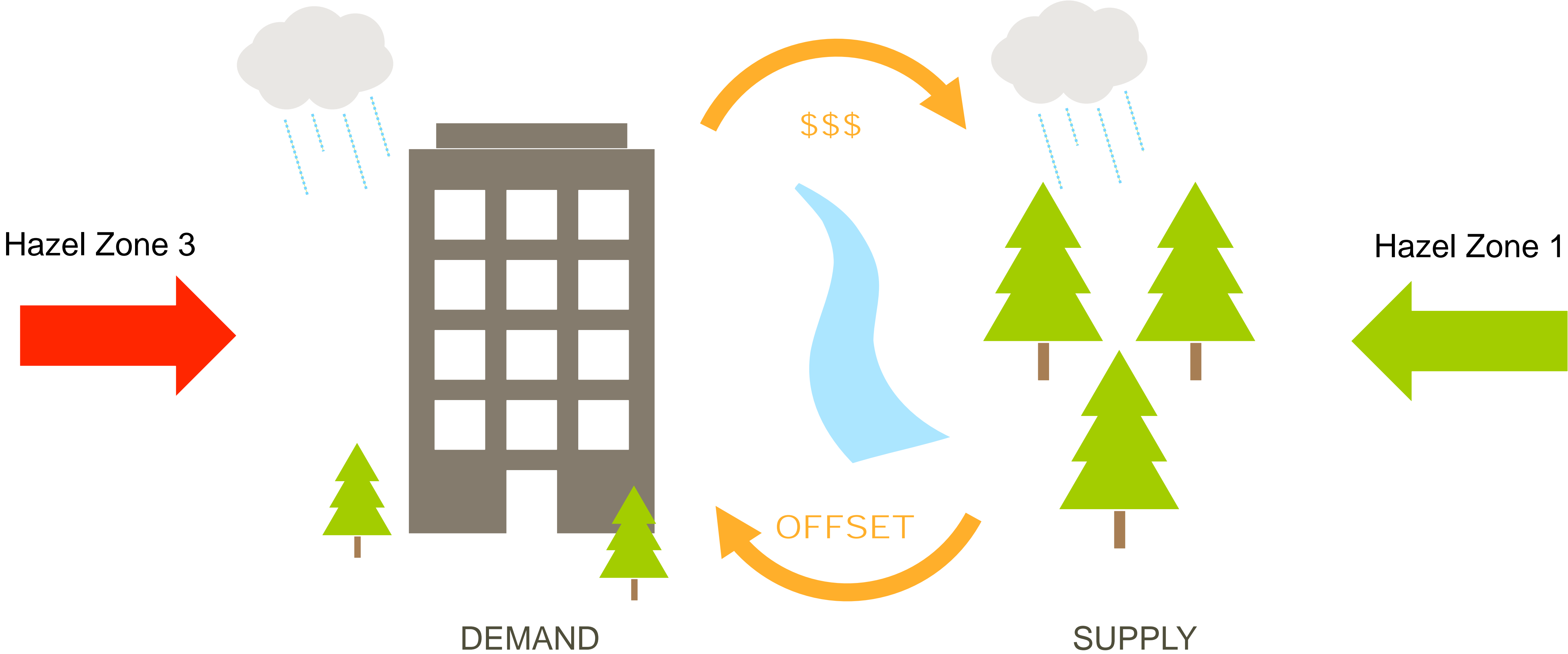
INVESTMENT IN GI COULD
CLEAN UP 20% OF URBAN
RUNOFF



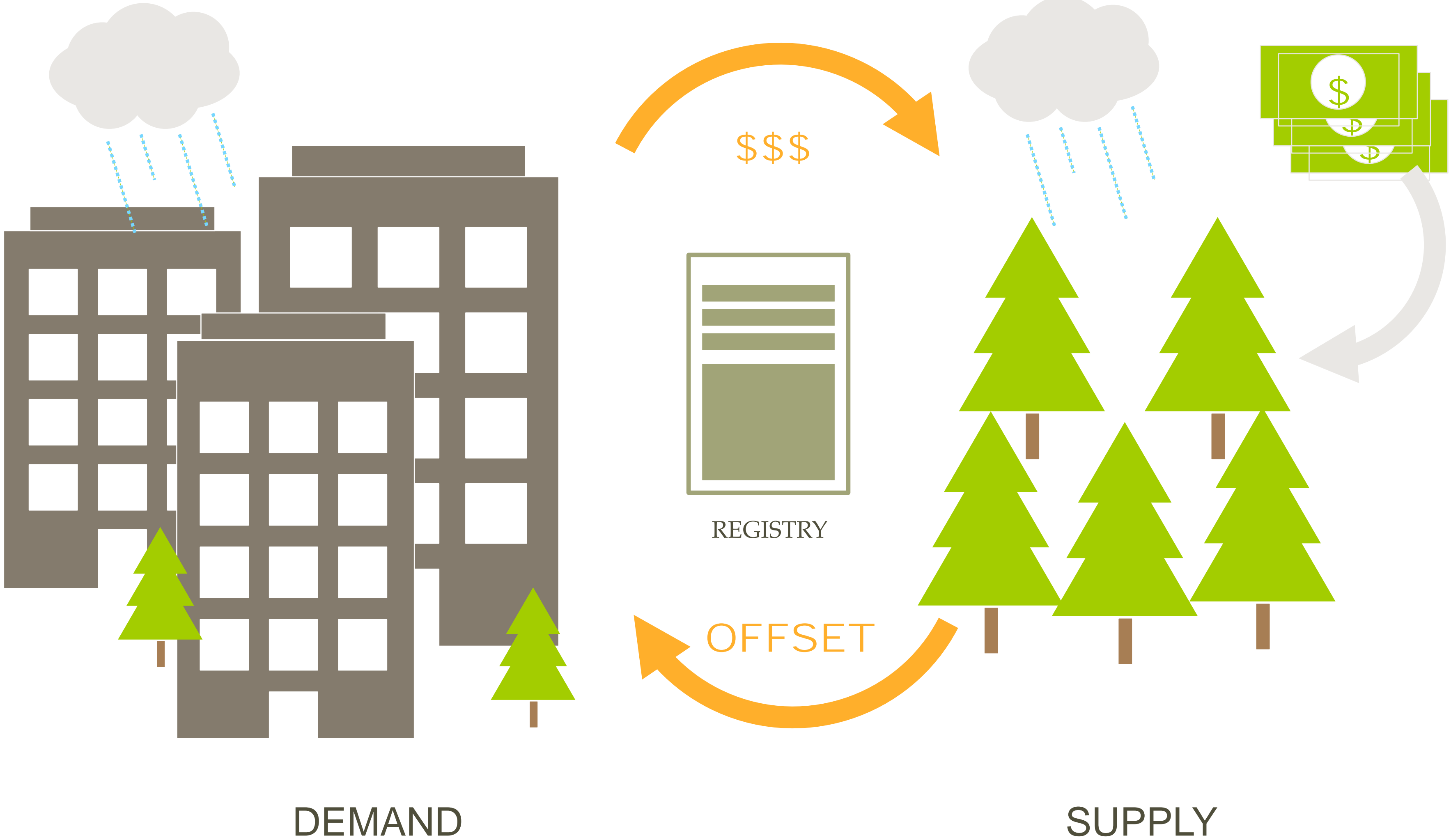
Public Private Partnership



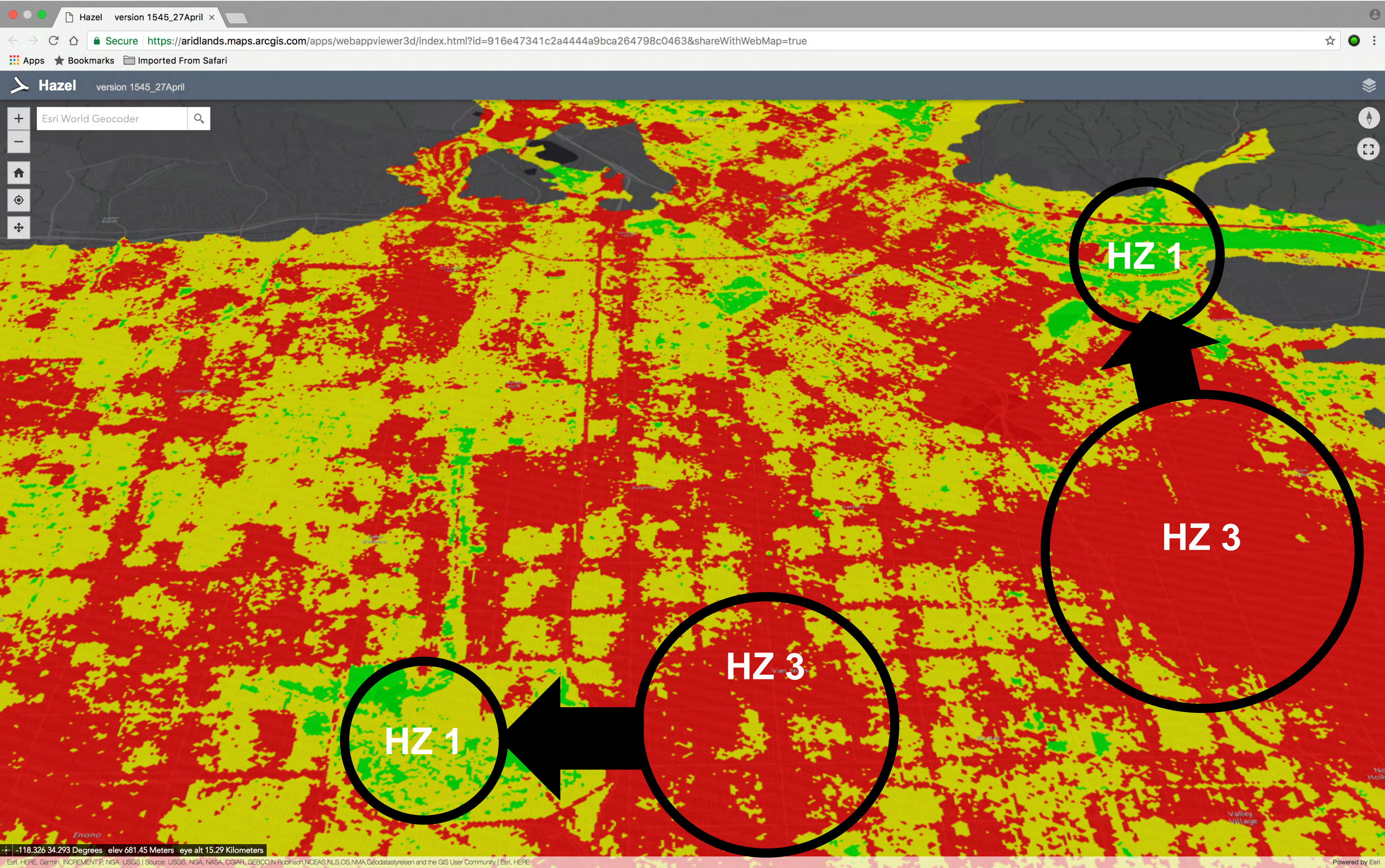
Credit Trading



Creating a Healthy Market

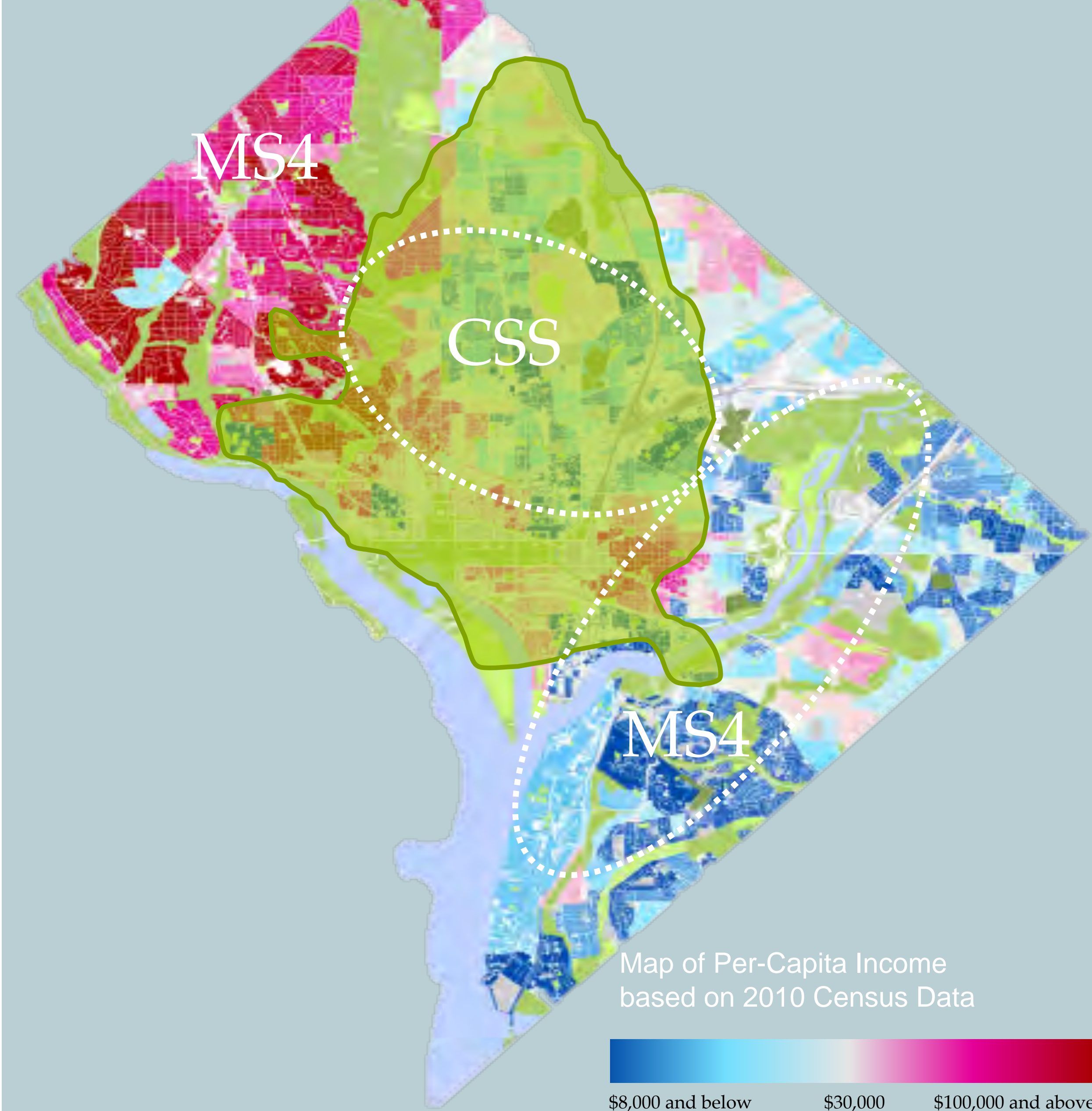


Transferring Priorities



Case Study: Washington, D.C. How a Healthy Credit Market Helps DC Meet its Stormwater Objectives

Development in dense urban core finances/
transfers positive social and environmental
outcomes to other parts of the city.

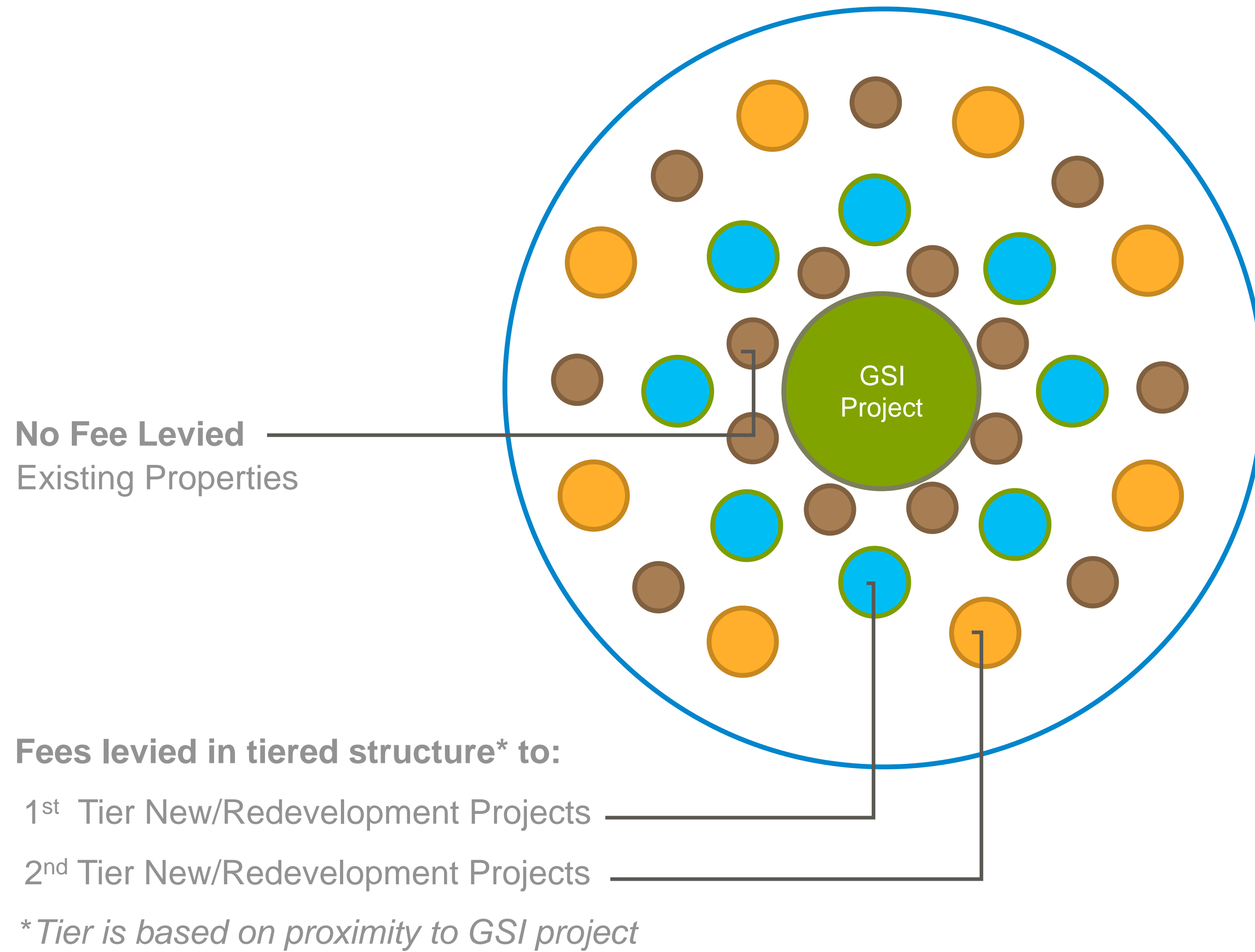




HZ3-equivalent development parcel:
Off-site: Buys stormwater credit in HZ1-equivalent voluntary green infrastructure site.
On-site: Increased revenues from more underground parking and rooftop amenities.

HZ1-equivalent voluntary green infrastructure site:
P3 builds cost-effective infiltration with environmental and social equity co-benefits.
Increased local revenues, open space access, urban heat island reduction, habitat.

Special Assessment District: Impact Fee Concept





Detroit: Watershed Improvement Districts – P3 delivery



Washington, DC: Stormwater Credit Trading



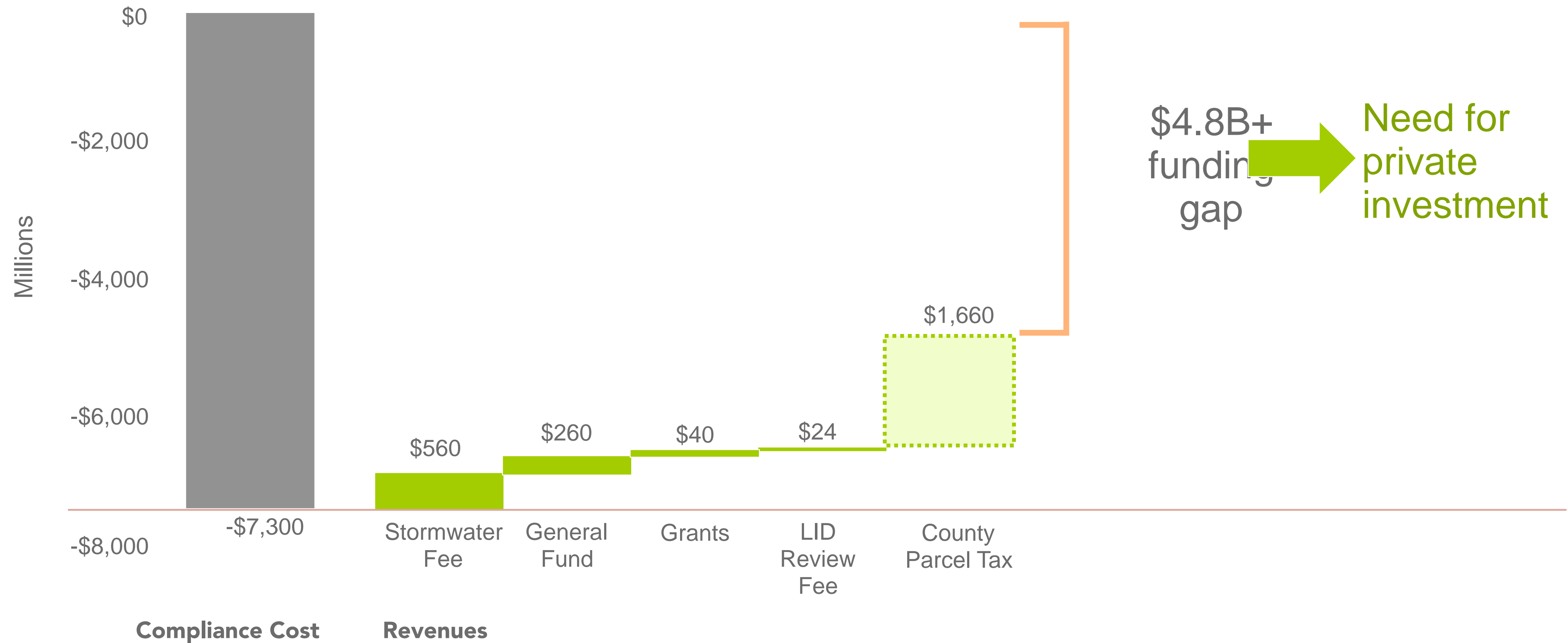
Philadelphia: Greened Acres - P3



Atlanta GA: 4th Ward Special Assessment District

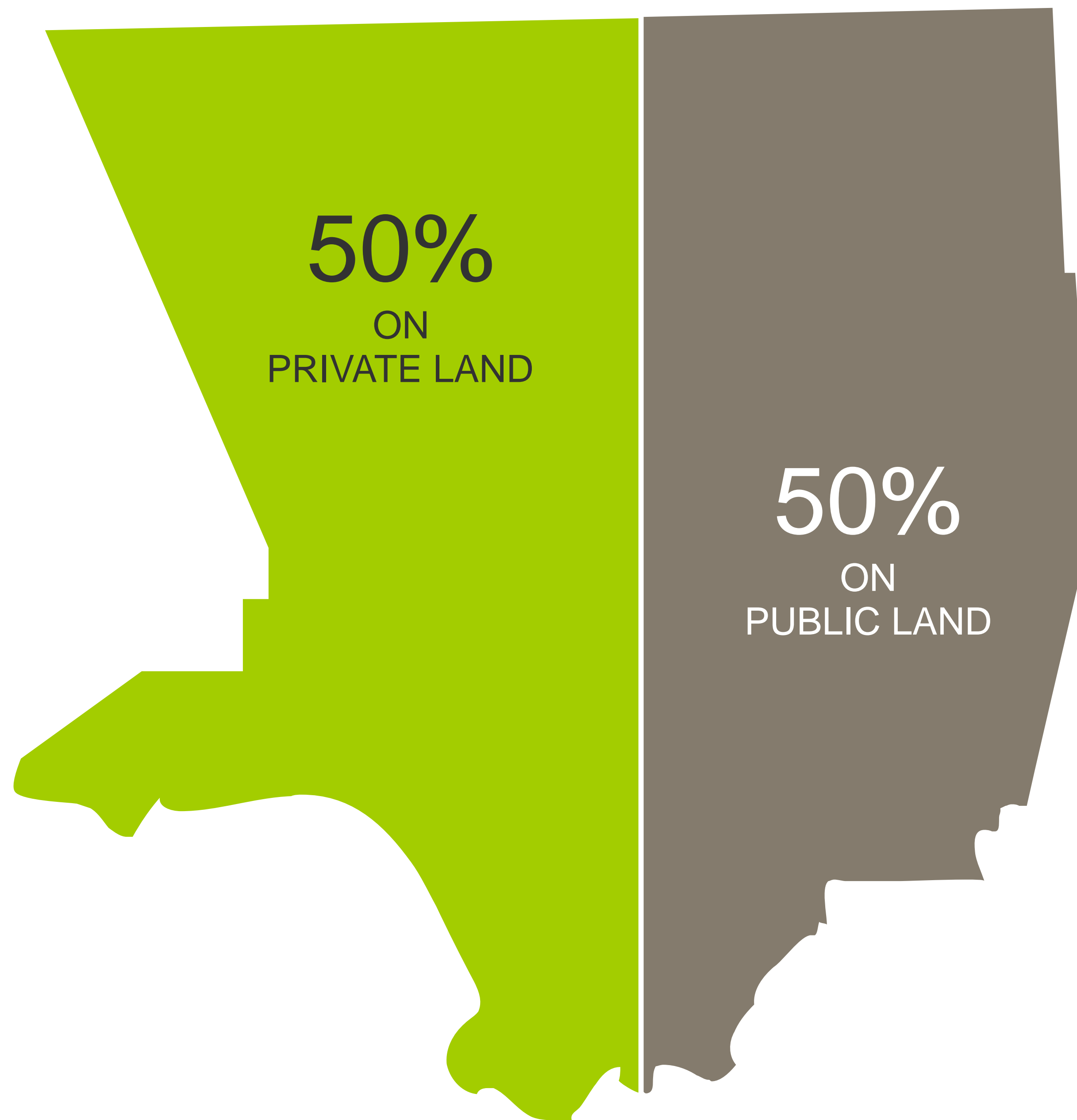
City of LA's Stormwater Funding Gap

Costs and Revenues Over 20 Years



The Need for Private Investment

Proposed Natural Infrastructure Projects in Los Angeles County





performance-based **HYDROLOGIC ZONING**

Sandy Ghalli, ALI MSArch Thesis
Hydrologic Performance-Based Code

DRI: Drylands Resilience Initiative



cooperative **GOVERNANCE FRAMEWORKS**

Coopelluvia, Stephanie Newcomb, ALI MSArch 2016



enhanced **WATER LITERACY**



*Connect the Dots | Van Nuys, February 2016
City of Los Angeles Great Streets Initiative Challenge Grant Winner
Aja Bulla-Richards, Arid Lands Institute, Connect the Dots Creative Director
Photo by SRA Photo*



enriched **ARCHITECTURAL LEXICON**

*The Arid Lands Institute: House of Retention
2014 Design Leadership Council Competition
Los Angeles, CA | ALI and Perkins+Will*



*The Arid Lands Institute: House of Retention
2014 Design Leadership Council Competition
Los Angeles, CA | ALI and Perkins+Will*

DRI: DRYLANDS RESILIENCE INITIATIVE

5

Q + A

THANK YOU