ANALYZING COMPOUND FLOODING, EXTREME HEAT, & WATER QUALITY RISKS IN MIAMI

Client: Miami Waterkeeper

Challenge

Miami faces increasing risks from compound flooding, extreme heat, and declining water quality, all of which disproportionately impact vulnerable communities.

Solution

Working with Miami Waterkeeper and using our resilience analytics frameworks, Mērak Labs integrated geospatial data on flood hazards, urban heat, and infrastructure vulnerability to identify high-risk areas and develop targeted, multi-benefit adaptation strategies.

Key Objectives

• **Identify** where physical risks—flooding, extreme heat, and water quality issues—are most severe.

• **Determine** the intersections of these risks with social vulnerability.

• **Guide** decision-making for high-impact adaptation strategies.

Adaptation Strategies
- Preserve
- Mitigate
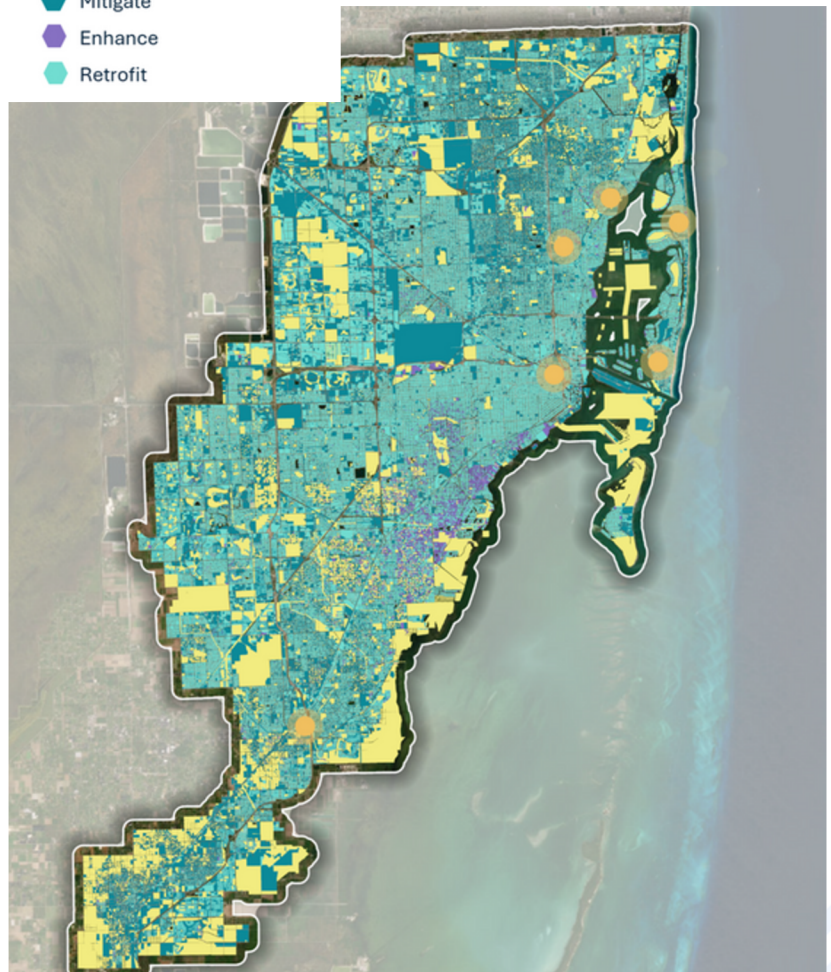- Enhance
- Retrofit

Figure 1: The adaptation strategies map for Miami's urban area categorizes parcels based on a combination of ecosystem services value (ESV) and assessed property value.

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Compound Flooding: Coastal and Rain-Induced Risks

Compound Flood Risk
(FEMA, SLR, >75th Percentile Composite Risk, Storm Surge)

- Low Flood Risk
- At Least 1 Type of Flood Risk
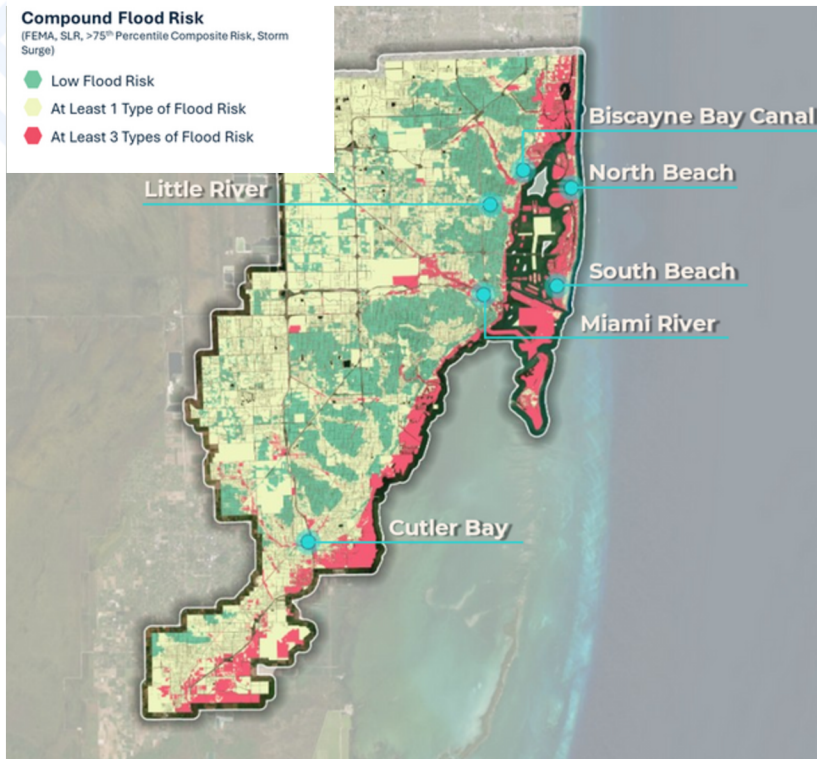- At Least 3 Types of Flood Risk

Figure 2: Parcels exposed to three or more types of flood risk represent some of the most vulnerable regions to compound flooding.

Compound flooding in Miami results from a combination of storm surge, high tides, heavy rainfall, and aging drainage infrastructure.

Our analysis revealed that flood risks are highest in low-lying urban areas where coastal flooding coincides with stormwater flooding, exacerbating the severity of flood events.

Key Insights

• Areas experiencing **high-frequency tidal flooding** also struggle with stormwater drainage due to impervious surfaces.

• **Compound flooding** intensifies in locations where riverine overflow meets coastal surge, overwhelming drainage systems.

• **High-risk areas:** Little River, Miami Beach, and Cutler Bay.

Extreme Heat and Urban Heat Islands

Urban heat islands (UHIs) intensify Miami's heat risks, particularly in neighborhoods with dense development and minimal tree cover.

By analyzing impervious area per person (IA/person), we identified locations where extreme heat is most severe and cooling resources are limited.

Key results

• Areas with **high IA/person values** fall into "High Impact" and "Very High Impact" heat risk categories.

• **The absence of green infrastructure** exacerbates heat stress.

• **High heat zones** often overlap with high flood risk, making them particularly vulnerable.

- Tree Canopy
- Impervious Surface

Impervious Area per Person (unitless)

- 0 – 100 Low Impact, Good
- 101-150 Moderate Impact, Fair
- 151-200 High Impact, Concerning
- 201-250 Very High Impact, Problematic
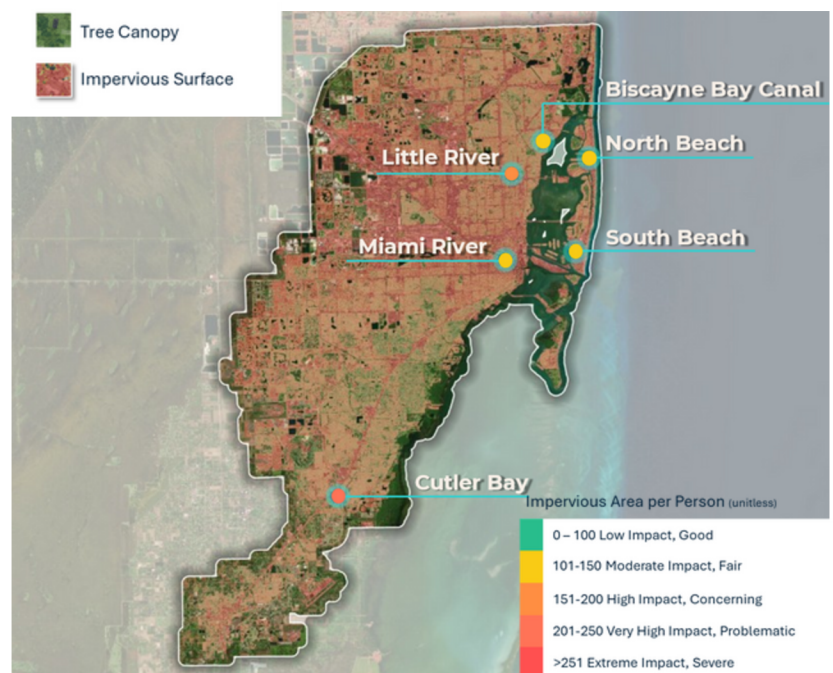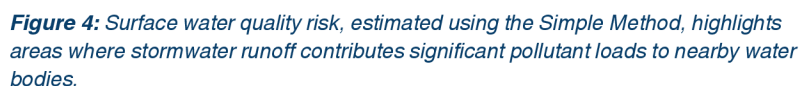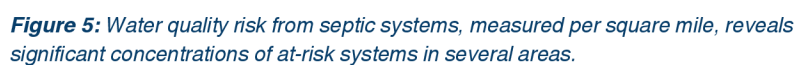- >251 Extreme Impact, Severe

Figure 3: An area-wide visualization of tree canopy and impervious surfaces highlights the stark contrast between green, shaded areas and densely developed urban regions.

Water Quality Risks: Septic Failures and Stormwater Runoff

Surface Water Quality Risk

High Water Quality Risk (>75th percentile)

Figure 4: Surface water quality risk, estimated using the Simple Method, highlights areas where stormwater runoff contributes significant pollutant loads to nearby water bodies.

Septic system failures and stormwater pollution contribute to widespread water quality degradation in Miami.

Our analysis pinpointed areas where these issues overlap with high flood and heat risks, worsening environmental and public health conditions.

395,418 Parcels

56,411 Parcels within the 75th percentile risk category

N   P   TSS

Commercial   Residential

Key Insights

• **Septic system failures** release nutrient pollution and enterococci bacteria, especially in flood-prone areas where groundwater infiltration is common.

• **Stormwater runoff** carries pollutants from roads and impervious surfaces directly into waterways, further degrading water quality.

• **High-risk areas**: Cutler Bay, Little Haiti, and parts of Miami-Dade County.

Figure 5: Water quality risk from septic systems, measured per square mile, reveals significant concentrations of at-risk systems in several areas.

Multi-Benefit Adaptation Strategies

Using the resilience analytics framework, we aligned risk data with adaptation strategies that provide multiple co-benefits:

Green Stormwater Infrastructure for Flood and Heat Reduction

- **Install bioswales** and rain gardens in flood-prone urban zones to absorb stormwater, filter pollutants, and cool surrounding areas.

- **Increase tree canopy** coverage in high-heat areas to mitigate urban heat islands while improving stormwater infiltration.

- **Prioritize GSI** where flooding and heat risks intersect.

Hybrid Infrastructure Solutions

- **Upgrade drainage systems** with permeable pavement to reduce runoff and enhance groundwater recharge.

- **Retrofit stormwater basins** with natural filtration to improve water quality and reduce localized flooding.

- **Implement** flood-resilient septic solutions in areas prone to inundation.

Targeted Investments in High-Risk Zones

- **Replace** failing septic systems with modern wastewater treatment solutions to protect water quality.

- **Establish** urban cooling corridors with shade structures, reflective pavements, and strategically placed cooling centers.

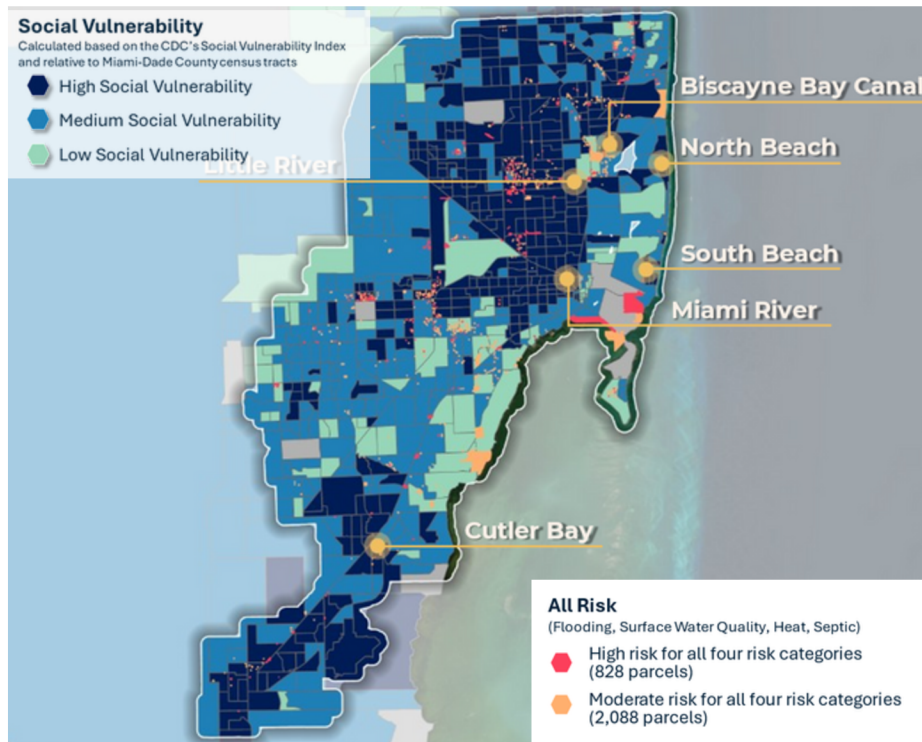- **Direct funding** where compounded risks are highest.

Figure 6: Parcels with a combination of flood, heat, and water quality risks are often concentrated in neighborhoods with higher levels of social vulnerability.

Benefits

By integrating environmental, infrastructure, and social vulnerability data, this case study demonstrates how resilience analytics can prioritize high-impact adaptation strategies for Miami. The findings reinforce the need for nature-based solutions, infrastructure upgrades, and targeted investments to mitigate compounding risks effectively.

Next Steps

By leveraging data-driven insights and multi-benefit strategies, we can build a more resilient Miami that is better equipped to withstand extreme events and chronic environmental challenges.

Future steps include:

• **Expand geospatial risk modeling** to track long-term trends in flood, heat, and water quality risks.

• **Implement a pilot** adaptation project in one of the high-risk neighborhoods.

• **Develop a community resilience toolkit** for local decision-makers and stakeholders.

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