Extreme Events, Insurance, and Resilience: Board on Atmospheric Sciences and Climate 2025 Fall Meeting

Modeling extreme events in a changing climate

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EXTREME EVENTS, INSURANCE, AND RESILIENCE: BOARD ON ATMOSPHERIC SCIENCES AND CLIMATE 2025 FALL MEETING

A PRESENTATION FOR THE NATIONAL ACADEMIES OF SCIENCES, ENGINEERING AND MEDICIINE
NOVEMBER 3, 2025

Physical climate risk data products must be built on accuracy, resolution, and trust.

1

Purpose Built Models

We use Open Science to create physics-based, deterministic models that calculate property-level risk statistics today, and into the future in a changing climate.

2

Building Specific

We use structure characteristics to estimate a building's damage and downtime from any event. This asset-specific risk information is generally unavailable from government sources.

3

Beyond the Property

We quantify risk to nearby infrastructure, roads, and social facilities, along with projected population and demographic shifts, and changes in property valuations.

4

Validated Methodology

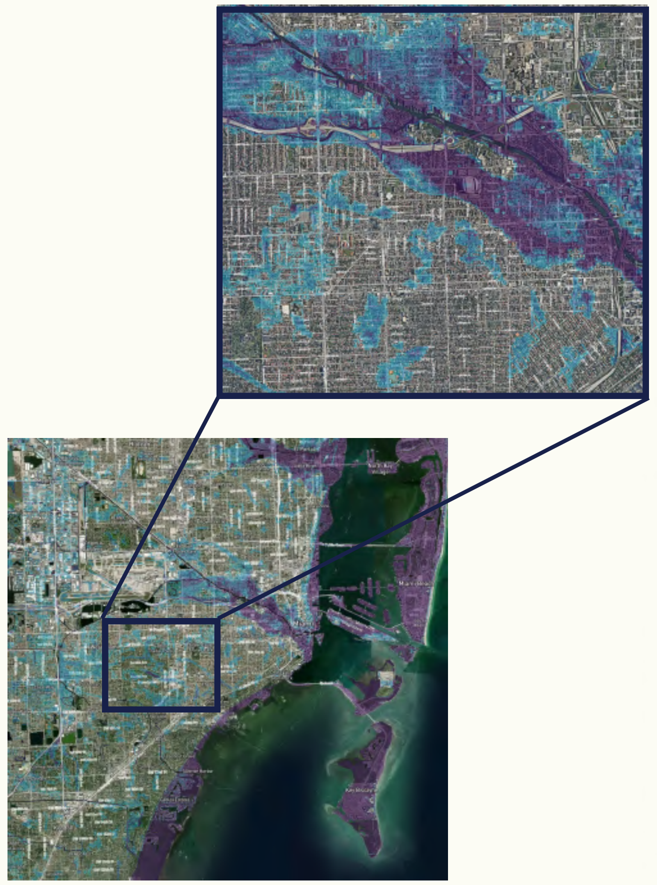
We created climate risk models that are peer-reviewed, transparent, and validated repeatedly against real-world events.

5

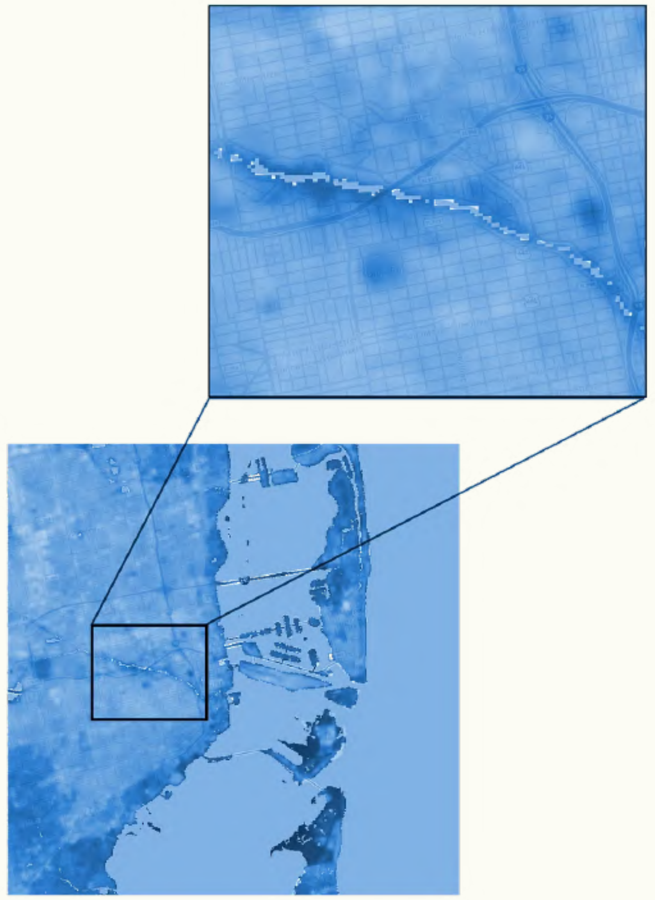
Translated to Financial Impacts

We translate the physical risk to financial risks for businesses, investors, governments, and individuals.

Approach: use climate model outputs **as *inputs*** to physics-based models to produce useful, high resolution risk information.



3 METER RESOLUTION FSF
HYDRAULIC FLOOD MODEL



2 KM DOWNSCALED
PRECIPITATION CLIMATE MODEL

FLOOD MODEL LEVERAGES HYDRAULIC MODELS (HEC-RAS AND LISFLOOD)

Riverine, Rainfall, and Coastal Flood Components.

Simulate the flow of water across the earth's surface.

Allows us to resolve water on the Surface at 3m-30m resolution.

WILDFIRE MODEL LEVERAGES A FIRE BEHAVIOR MODEL (ELMFIRE)

A Monte Carlo simulation of wildfires across the land surface to build up estimates of burn probability and flame length at 30m across the landscape.

Allows fire to penetrate into the Wildland Urban Interface (WUI) to assess risk to homes in those areas.

HURRICANE WIND MODEL LEVERAGES THE EMANUEL (2006) TECHNIQUE FOR HURRICANE BEHAVIOR SIMULATIONS

Use synthetic hurricanes o increase the number of storms available for analysis.

Estimate the damage from 3-sec wind gusts on buildings.

Reliable input data are needed to drive physics-based models.

First Street uses US Government open data from NOAA, NASA, USGS, USDA, USFS, EPA, USACE, and FEMA for its hazard modeling, as well as data from the EU's Copernicus system.

CLIMATE FORECASTS

- WCRP CMIP6 simulation outputs (SSP245 (mid), SSP585 (high), SSP126 (low))
- Downscaled climate model data from NASA NEX-GDDP

HISTORIC

- USGS High Water Mark data
- NFIP flood claims (aggregate)
- FEMA significant flood hazard area designations
- FEMA Individual Assistance claims
- EPA Ozone and PM2.5 observations

IMAGERY

- USGS Landsat satellite data
- USDA NAIP aerial imagery
- EU Sentinel 2

TIDE & SURGE DATA

- NOAA Water Level and Tide Gauges

FUELS AND FIRE

- US Forest Service/DOI LANDFIRE Fuels
- US Forest Service Fire Occurrence Database
- US Forest Service Fire Suppression Difficulty Index

WINDS

- NOAA IBTrACS Historical Hurricane tracks
- ETCs from EU's ERA5

ELEVATION DATA

- USGS National Elevation Database, 3DEP lidar inputs
- Copernicus GLO-30

RIVER FLOWS

- USGS Stream Gauge data

PRECIPITATION

- NOAA ASOS rain data
- GloH20's MSWEP global precipitation*

When US Government data are insufficient we create new inputs to achieve model accuracy — and publish those methods.

1. RAINFALL CLIMATOLOGY

First Street calculated a new rainfall climatology for the US that properly resolves recent climate change impacts on rain-driven flood events. NOAA's Atlas 14 does not capture climate change impacts.

2. FLOOD ADAPTATION

First Street assembled the first-ever database of over 23,000 US flood adaptation features (levees, seawalls, pumps) from local, regional, and Federal sources, the effects of which are incorporated into the hazard estimates. USACE's National Levee Database only has a subset of these features.

3. WILDFIRE FUEL LAYERS

First Street replaced nonburnable fuels in the USFS/DOI LANDFIRE database within the Wildland Urban Interface (WUI) to resolve fire risk to those communities. LANDFIRE was not built for WUI or urban issues.

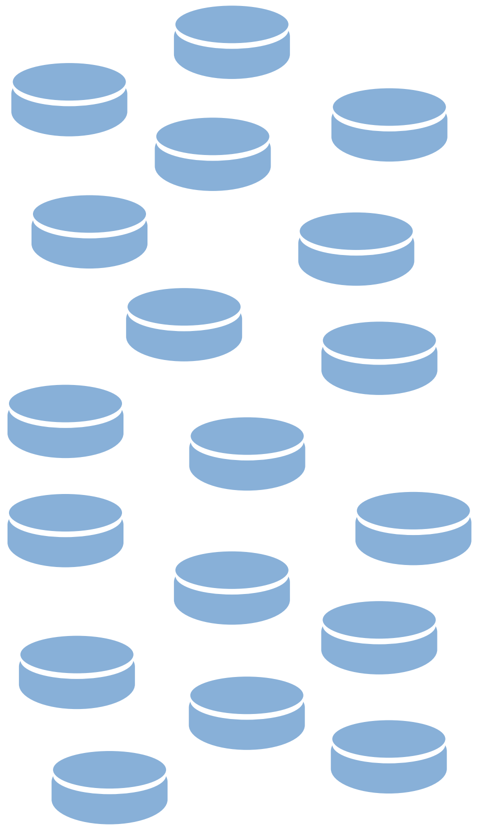
4. WILDFIRE MITIGATION

Annually, First Street compiles recent fuel treatments and disturbances, including fire breaks, prescribed burns, forest thinning, and any wildfires that have occurred, into its fuel estimates. LANDFIRE updates are not usually annual. Additionally, First Street calculates our own estimates of defensible space around each US building using aerial/satellite imagery.

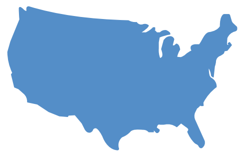
5. ELEVATION AND SURFACE ROUGHNESS

First Street constructed a digital terrain model (DTM) of all land use (built environment) and land cover (natural environment) for flood modeling and wind impact asessments.

Distill data into asset-specific climate risk statistics, using hazard model,s and climate model outputs, for individual or groups of assets.

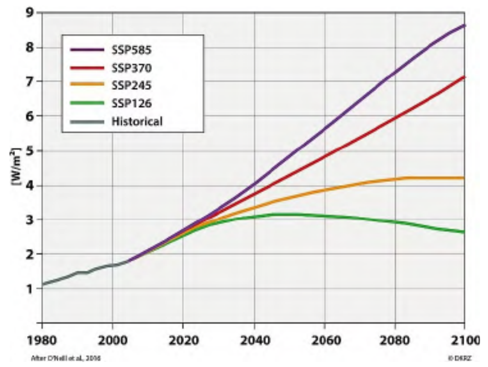


Data inputs



Hazard model

Spatial and economic analysis



Climate models for mutiple SSPs

Property and damage claims Information

Communication

Every property is assigned:

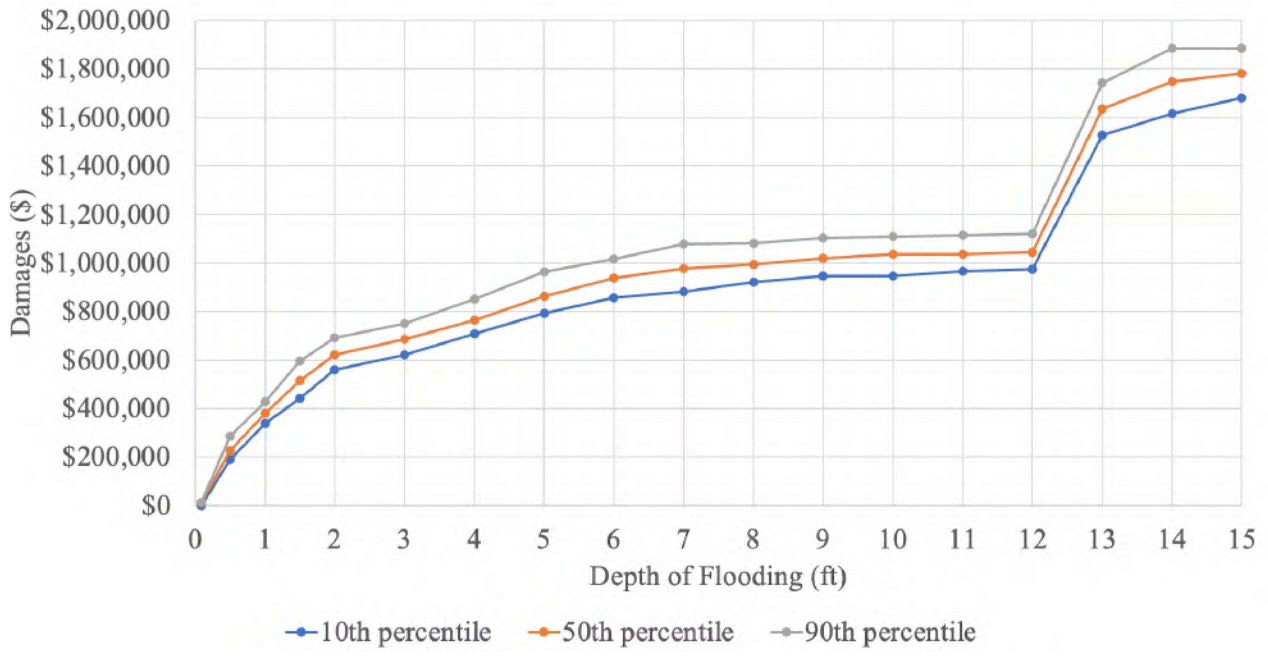
1. Risk Score
2. Expected Annual Losses $

Feed analytical tools to show:

A. Financial loss probabilities
B. Porfolio-scale risk
C. Organization-specific risk

Depth, damage, and downtime calculations are used to translate hazards to losses.

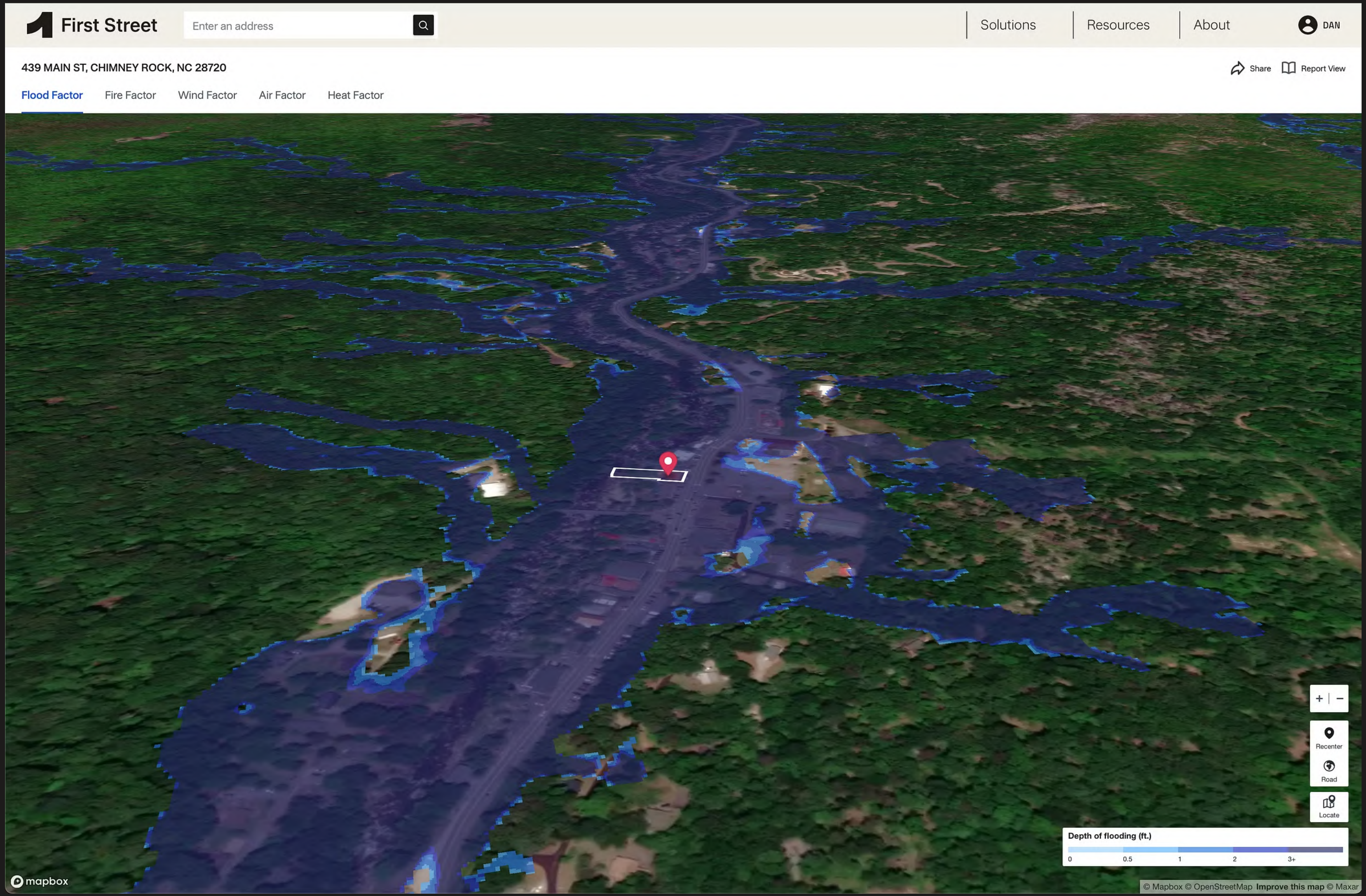
Leveraging our partnership with the world renowned consulting and engineering firm Arup, we have continued to build on the first principles of engineering approach to enhance our building archetypes and associated fragility curves. Using the known structure characteristics database to reverse engineer the building construction materials we identify the likely location of all critical components of the structure.



Reverse engineered building plan with location of critical components

Hurricane Helene, an unprecedented precipitation event in WNC

SEP 27, 2024 - FLOOD IMPACTS HURRICANE HELENE

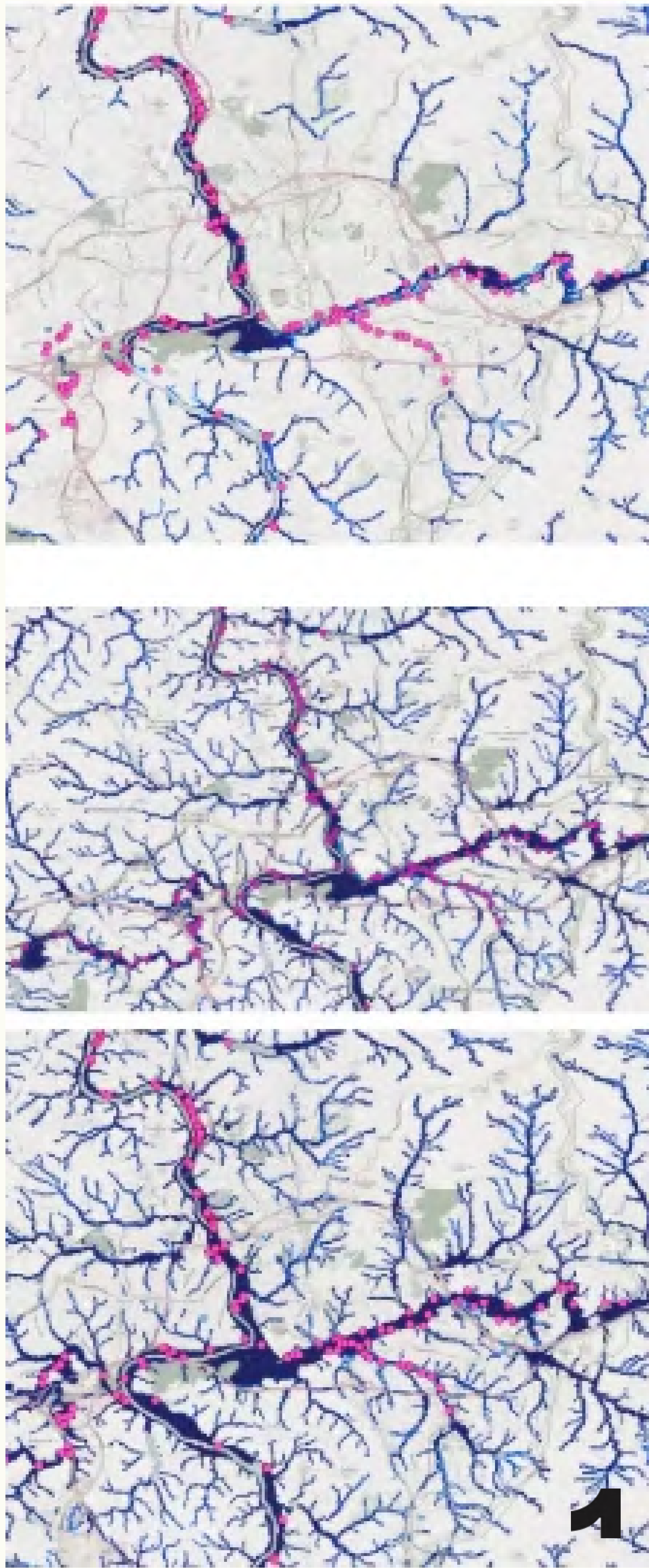


High Water Marks from Hurricane Helene and other recent extreme flood events

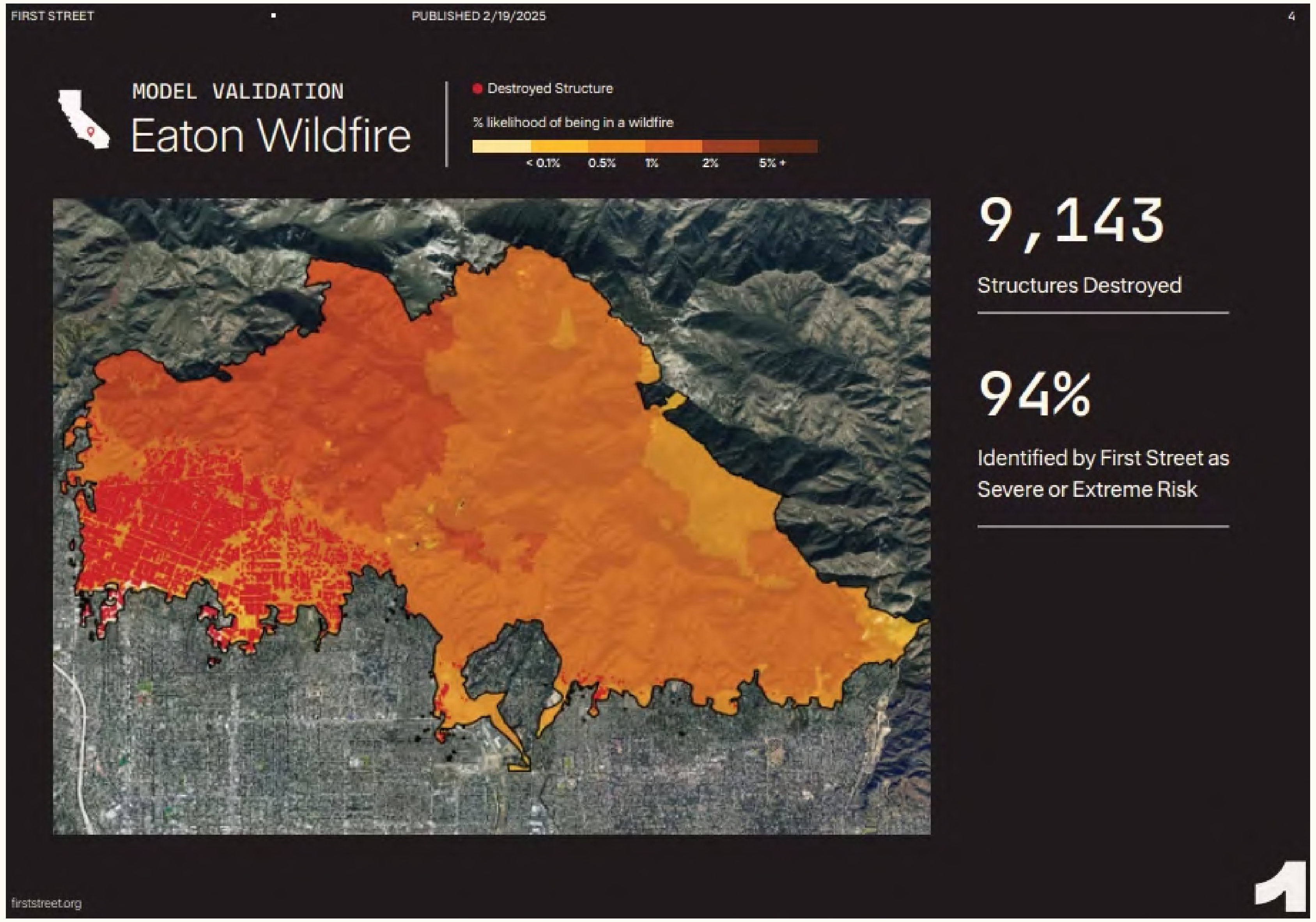
Key Takeaways: Comparisons of flood extent between the locations of USACE-surveyed High Water Marks and the projections of flood extents from the First Street Flood Model are useful in discerning the accuracy of those projections in real world conditions:

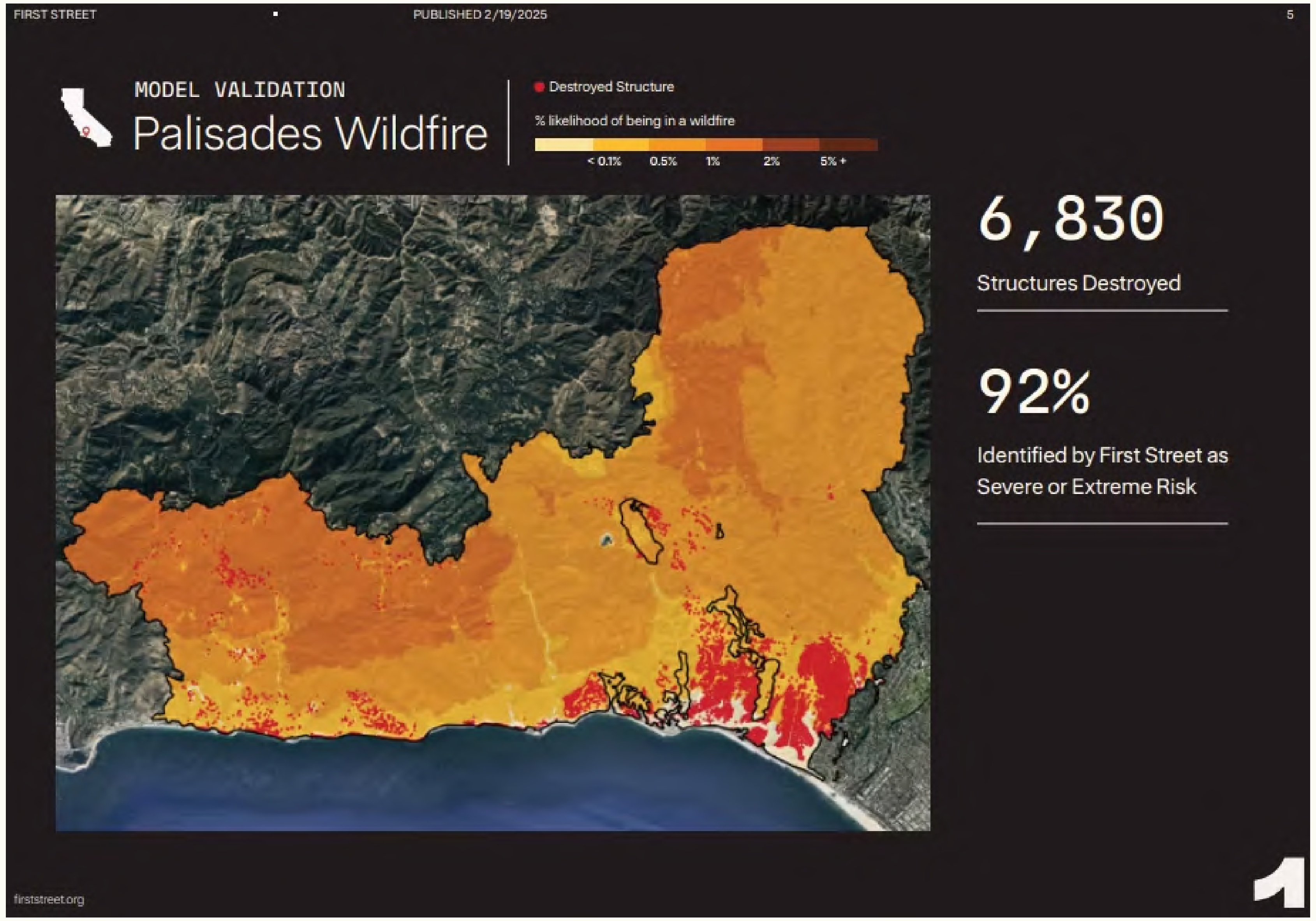
- The analysis of over 2,500 High Water Marks collected by surveyors from the US Army Corps of Engineers (USACE) within Western North Carolina and Eastern Tennessee following Hurricane Helene in Sep 2024 showed that First Street's 1-in 500 year flood extent predictions had a 98% correspondence at 3m horizontal resolution with the USACE observations.

- For 22 recent extreme flood events across multiple US states, the First Street flood extent predictions were shown to have a 92% correspondence with over 2,400 high water marks collected by the US Geological Survey (USGS) and USACE.



LA Times 3rd Party Validation: 2025 Los Angeles County Wildfires





Thank you