Assessing Flooding Hazard Exposure

Walter Gillis Peacock peacock@tamu.edu
Douglas Wunneburger d-wunneburger@tamu.edu
Alexander Abuabara abuabara@tamu.edu

TEXAS A&M UNIVERSITY
Hazard Reduction & Recovery Center

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United States™ Census Bureau

Presentation Outline

- FEMA flood hazard data
- Geoprocessing: data cleaning and reclassification
- Case study to illustrate this process and quantification of exposed elements
- Conclusions and some possible alternatives to assess flooding exposure

Flood Hazard Data Sources

- A hazard can be studied in different ways:
  - By **models** or **simulation** of extreme events (deterministically or stochastically);
    - Engineering or physics-based models (hydrological and hydraulic).
  - By **specific occurrences** (historical events, but often not well documented, even today).
  - By **local knowledge.**
- FEMA provides flood hazard data to support the National Flood Insurance Program (NFIP).
  - **National Flood Hazard Layer** (NFHL) is a **geospatial database** that contains current effective flood hazard data for a variety of official policies/programs.
  - These data establish **flood insurance requirements** (often imposed by federally backed mortgage lenders).
  - Help communities develop strategies and programs to reduce flood risk, understanding **risk exposure** and evaluating/quantifying exposure.
- NFHL data is not uniformly available, but covers the area occupied by 90% of US population.

History of FEMA Flood Maps

- In 1968 the US Congress created the NFIP.
  - FEMA has been creating and updating flood hazard maps for the program after its creation.
- These maps are based on the combination of a variety of methods:

  historical occurrences and insurance claims; meteorological, hydrologic, and hydraulic data; and can incorporate assessment of land-use/land cover conditions, flood-control infrastructure, and development.
- Updates to flood maps are a collaboration between the communities and FEMA.
  - Every community that participates in the NFIP has a floodplain administrator who works with FEMA during the mapping process.
  - After their creation they are subject to public review/comment, amendment, prior to adoption.

History of FEMA Flood Maps

Over time, FEMA has produced **two** digital flood map products

Paper Maps	**Q3 Flood Data**	**DFIRM** (Digital Flood Insurance Rate Maps)
• **Flood Hazard Boundary Maps** (FHBM), later **Flood Insurance Rate Maps** (FIRM). • Essential tool for the **Mitigation Directorate** (now the Federal Insurance and Mitigation Administration (FIMA), responsible for the NFIP and a range of programs designed to mitigate against future losses from all hazards including floods, earthquakes, tornadoes, and other natural disasters.	• Started as **digitization** of paper maps, for the entire US. • **Less precise scale 1:24,000 (±40 ft.)** • Was available for over 1,300 counties • Q3 **cannot** be used as the official NFIP map for **site design** or **flood risk determinations**. • Last updated late **1999.**	• Started in **2000.** • **More precise scale 1:12,000 (±33 ft.)** • **NFHL** (National Flood Hazard Layer) geospatial database. • New counties and updates to existing ones are an ongoing process. • Currently covers the area occupied by 90% of US population.

Current FEMA Websites

- FEMA Flood Map Service Center
  - https://msc.fema.gov/portal/home
  - Dynamic map
  - Document/letters of revisions, amendments, and revalidations
- National Flood Hazard Layer (NFHL) Status
  - https://www.floodmaps.fema.gov/NFHL/status.shtml
  - NFHL inventory: table with the most updated DFIRMs for download (by county)

Observations Regarding the NFHL Data

- Areas likely to have additional wave action (**flood with velocity** are identifiable).
- Generally speaking, **there is limited flood depth data**;
  - Some flood classifications indicate depth ranges,
    but mostly they reflect a dichotomous classification.
- NFHL boundaries are **not perfectly aligned** with Census TIGER shapefiles.
  - Data are presented by county, but county boundaries (and hence other geographies) can be **inconsistent** with Census boundaries.
  - Since flooding designations are distributed county by county,
    neighboring, cross-county areas, can have different flood risks.
  - This can be potentially problematic when places, cities, metro-areas, are cross counties.
- Data are presented to capture probabilities of flooding, **annual exceedance probability**.

FEMA Floodplain Designations

- Special Flood Hazard Areas (SFHA)
  - Areas subject to flood inundation at **1.0% *or greater chance*** in any given year.
    - Sometimes referred to as having a 1.0% chance of flooding per year.
    - "*100-year floodplain*"
- Moderate Flood Hazard Areas
  - Areas subject to flood inundation between the **limits of the SFHA** and **0.2%** chance of flooding in any given year.
    - "*500-year floodplain*"
- Areas of Minimal Flood Hazard
  - Areas **outside the SFHA** and higher than the elevation of the 0.2% chance of flooding in any given year.

Floodplain Reclassification

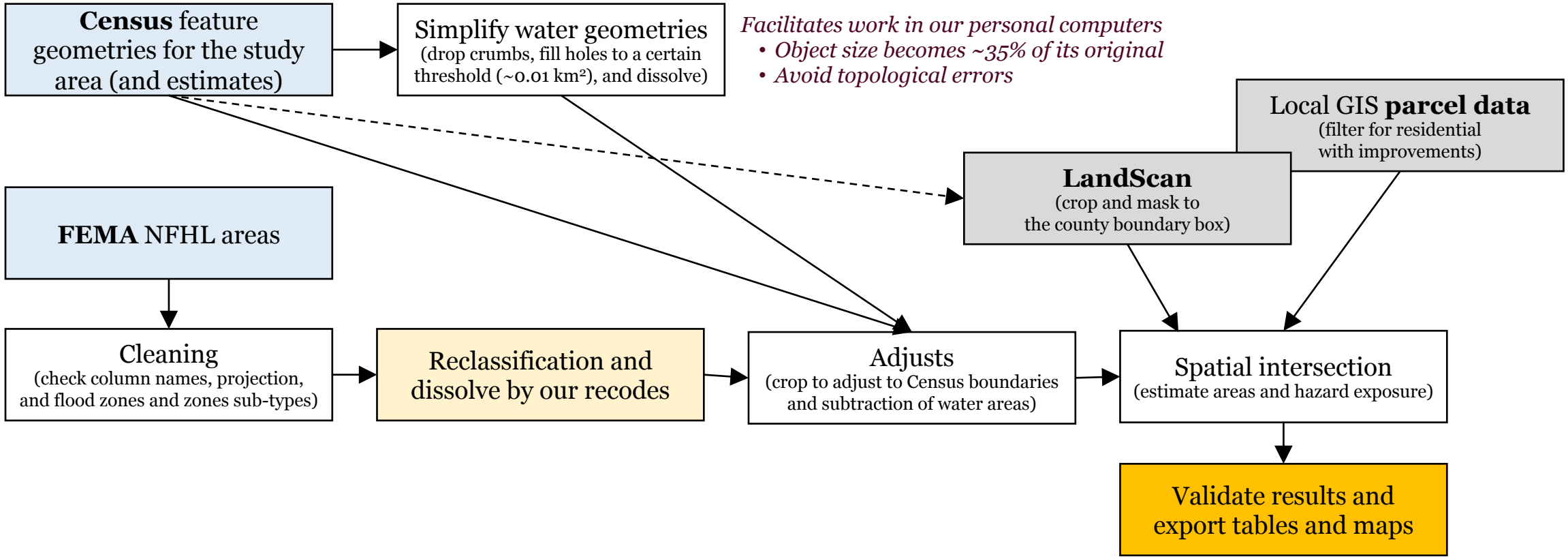
Q3 and NFHL flood zones and subtypes and our simplified recodes …

Q3 classification	NFHL classification	*Reclassification**
V, VE	VE	100-year (with velocity)
A, A1-A30, A99, AE, AH, AO, AR	A, AE, AH, AO	100-year
B, X500, X (shaded)	X (0.2 pct annual chance flood hazard)	500-year
X (reduced flood risk due to levee)	Area with reduced flood risk due to levee	Levee protected
C, D, X, X (unshaded), UNDES	X (area of minimal flood hazard), ANI (area not included)	Out of the floodplain

Many sources … ultimately referring to FEMA, such as:
- https://help.**riskfactor**.com/hc/en-us/articles/360048256493-Understand-the-differences-between-FEMA-flood-zones
- http://www.**floodmaps**.com/zones.htm
- http://www.**mass.gov**/anf/docs/itd/services/massgis/q3floodzonescodetable.pdf

Data Cleaning and Geoprocessing

Load, tidy, reclassify, dissolve, adjust and water subtraction, and quantification of exposure



Case Study: Flooding Hazard Exposure in Galveston Co.

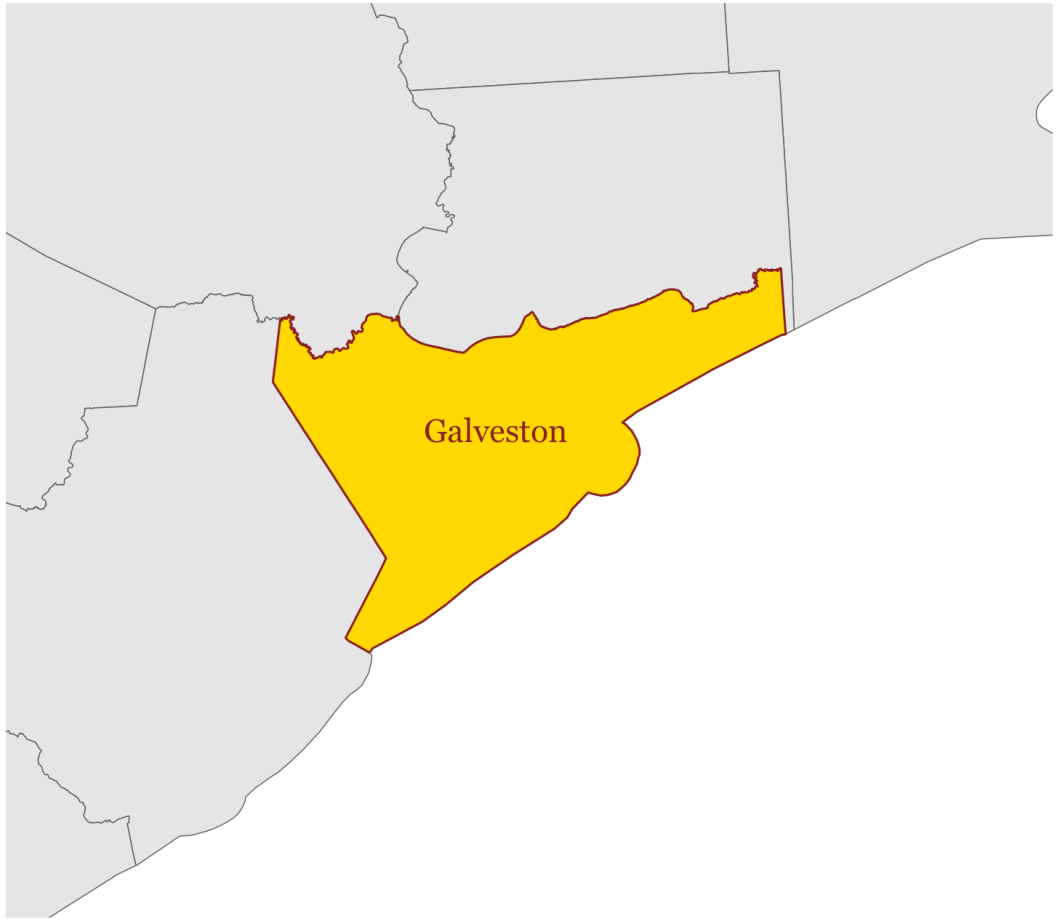
R-script for this case study: https://github.com/abuabara/flooding_hazard_exposure.git

Data sources

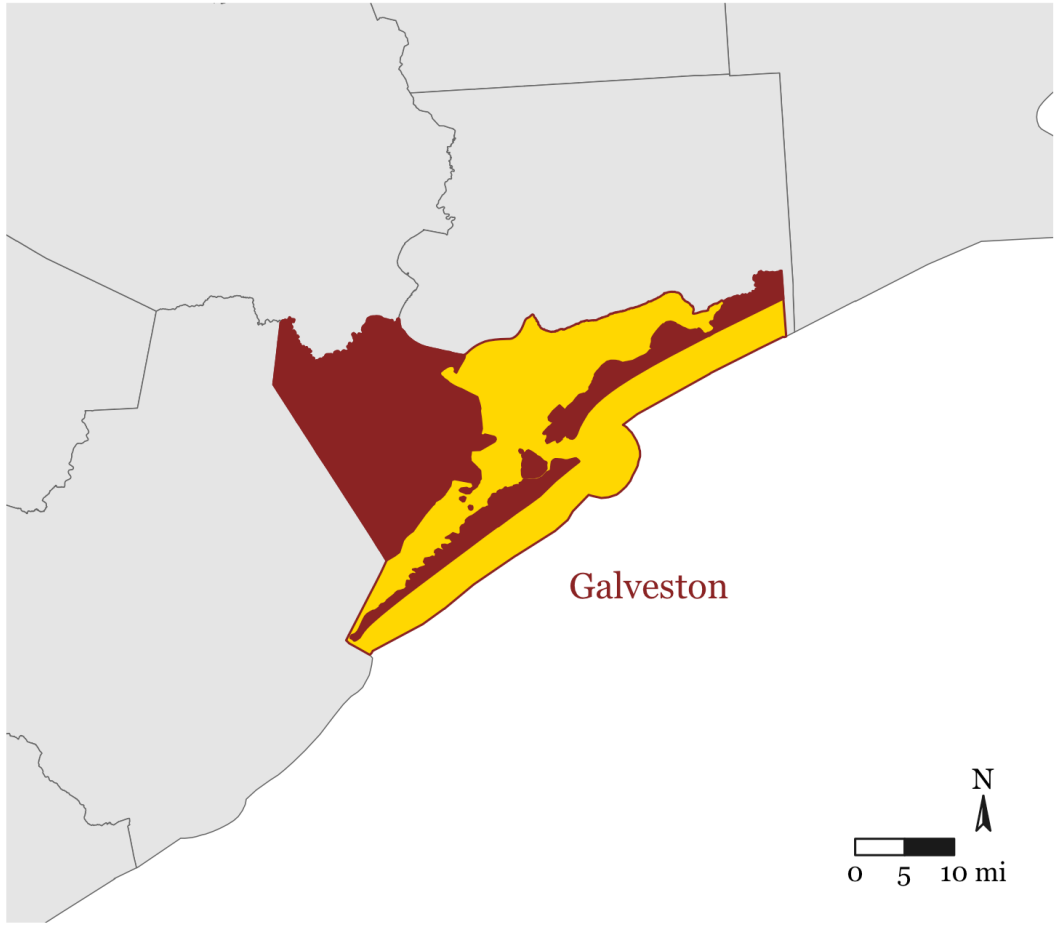
- **Census** boundaries and perennial and intermittent areas of hydrography features
  - R/tigris https://github.com/walkerke/tigris
- **ACS** estimates
  - R/tidycensus https://github.com/walkerke/tidycensus/
- **FEMA NFHL Flood Maps**
  https://www.floodmaps.fema.gov/NFHL/status.shtml
- **ORNL LandScan USA Conus Night**
  Raster dataset that provides population estimates for the Homeland Infrastructure Foundation-Level Data (HIFLD) database: https://landscan.ornl.gov
- **Galveston Central Appraisal District – Parcel Information**
  https://galvestoncad.org/gis-data/

Case Study: Flooding Hazard Exposure in Galveston Co.

Case Study

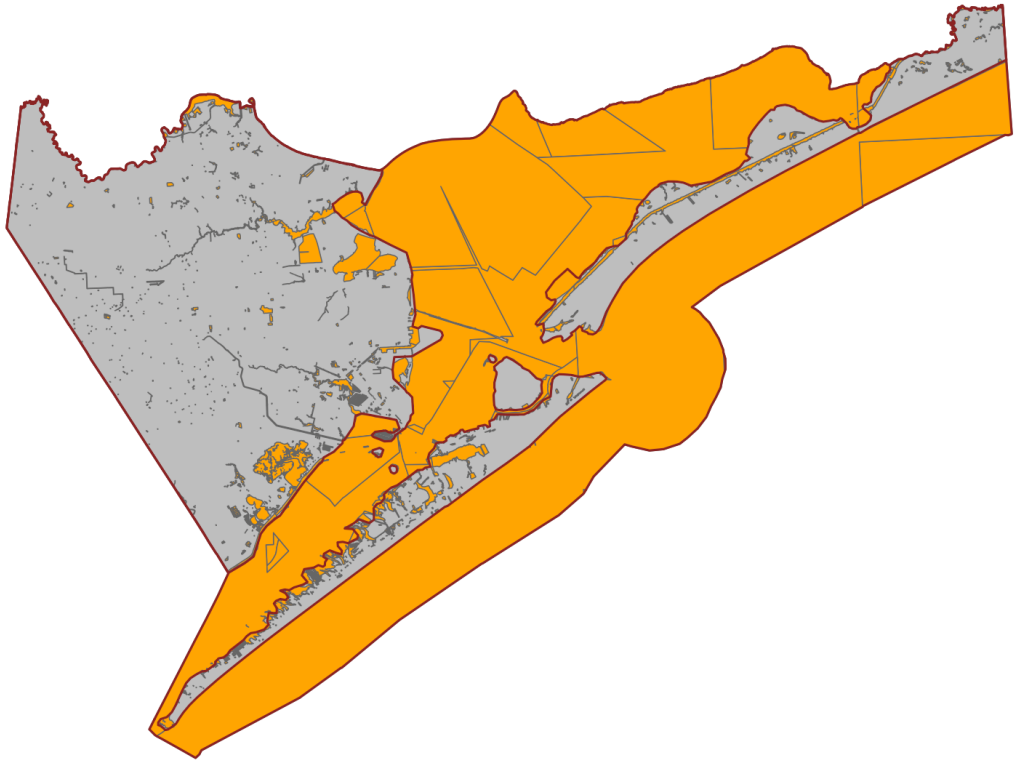


Cartographic Boundary

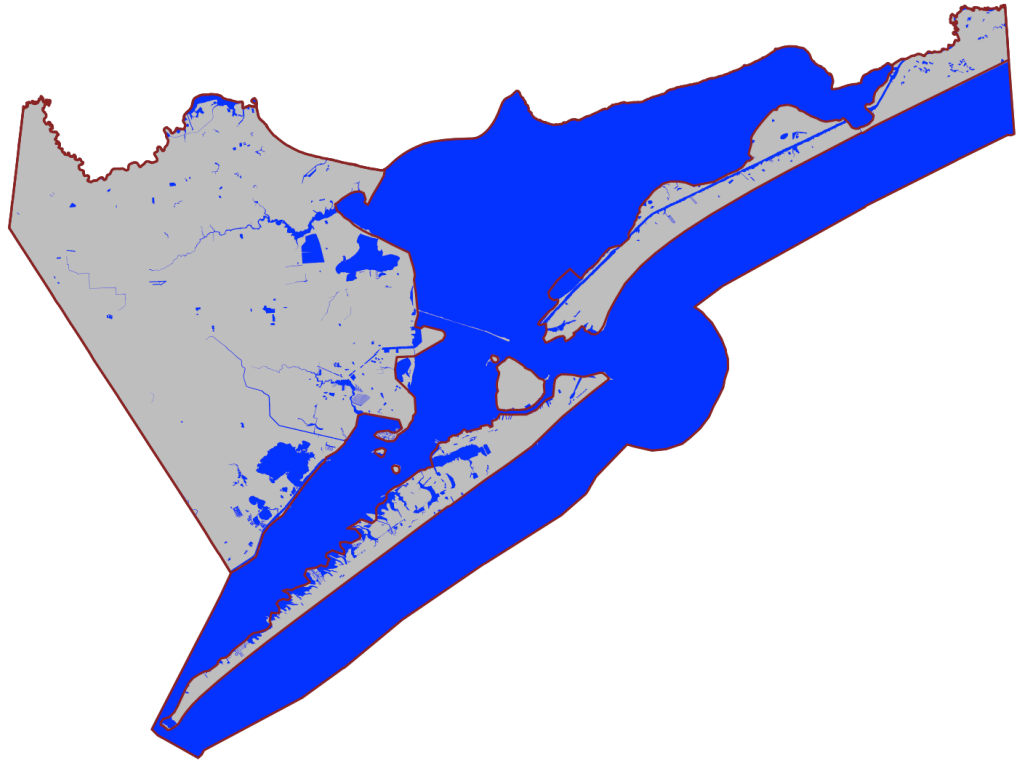


Case Study: Flooding Hazard Exposure in Galveston Co.

Original Census County Water

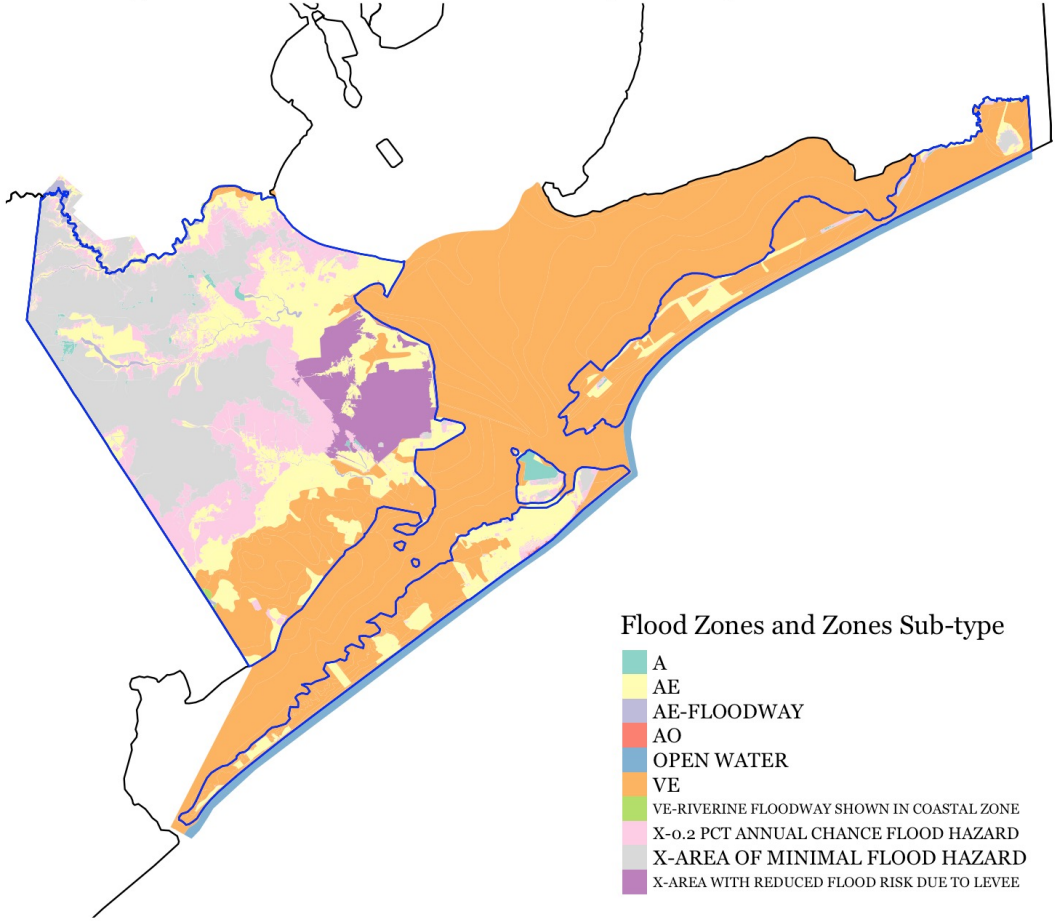


Simplified County Water

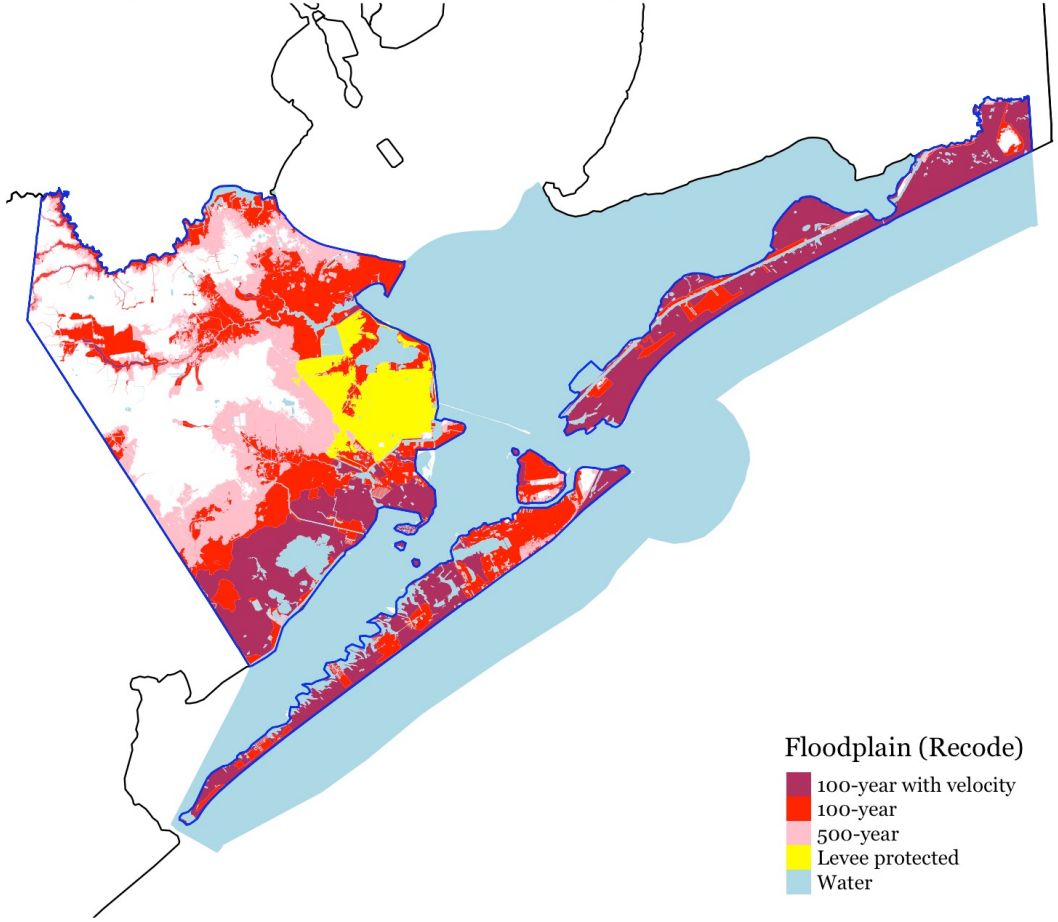


Case Study: Flooding Hazard Exposure in Galveston Co.

Floodplain in Galveston County (Original)



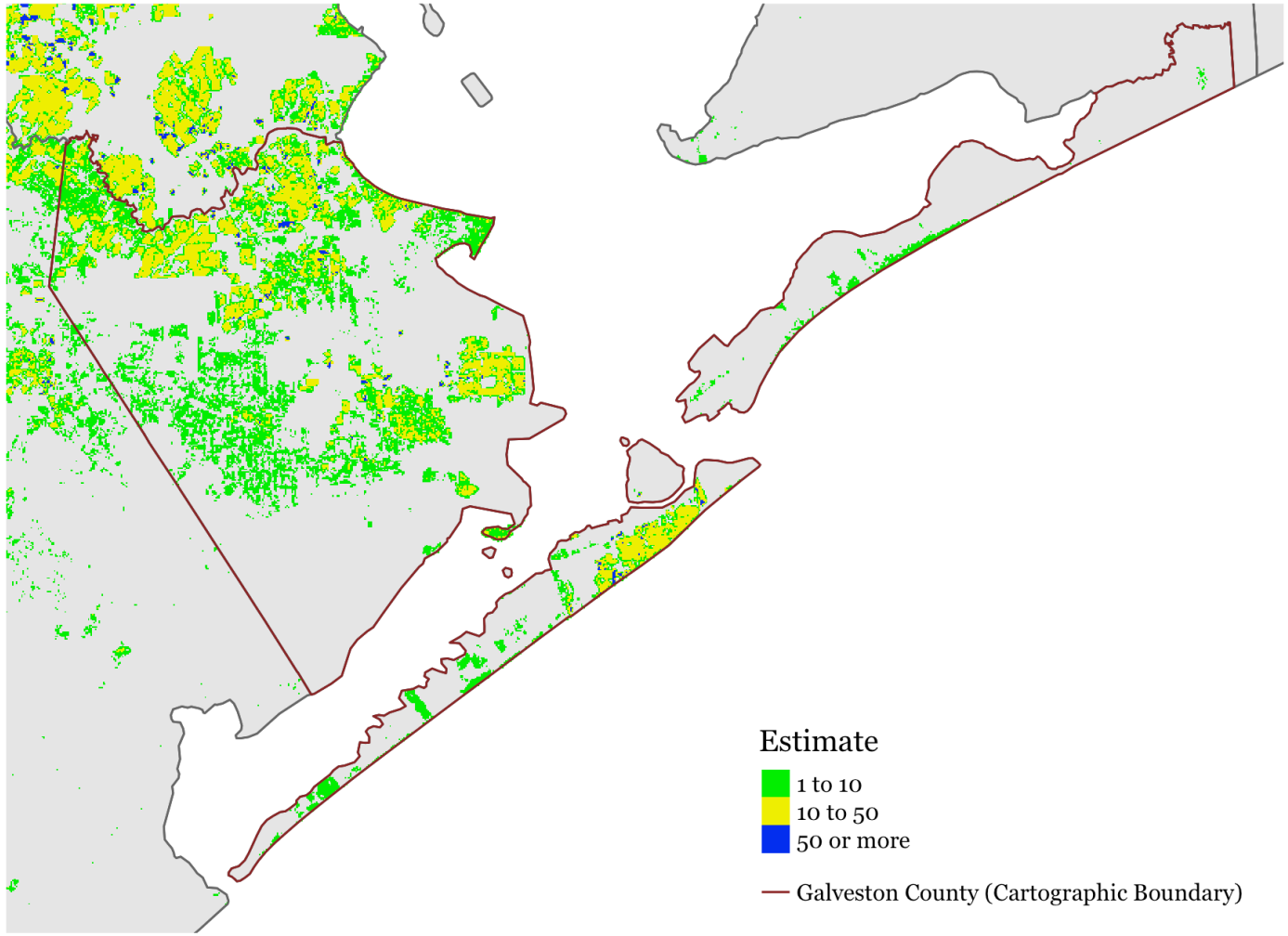
Floodplain in Galveston County (Reclassified)



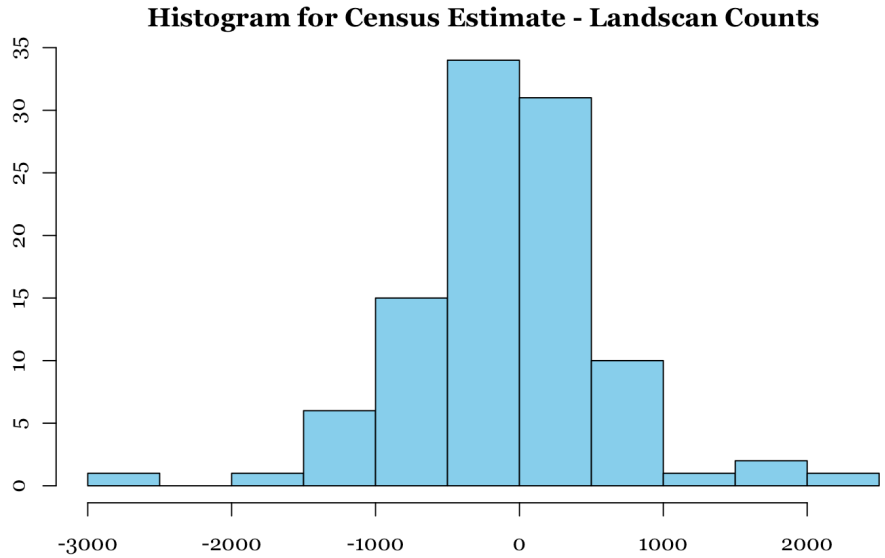
NFHL update date: 2022-11-20

PS: need to use LandScan that is the mid-year of the 5-year ACS estimate

Landscan 2019 Population Counts (Conus Night)



Census Tracts



Paired t-test

Data: Census Estimate and Landscan Counts (Population)

t = -1, df = 101, p-value = 0.3

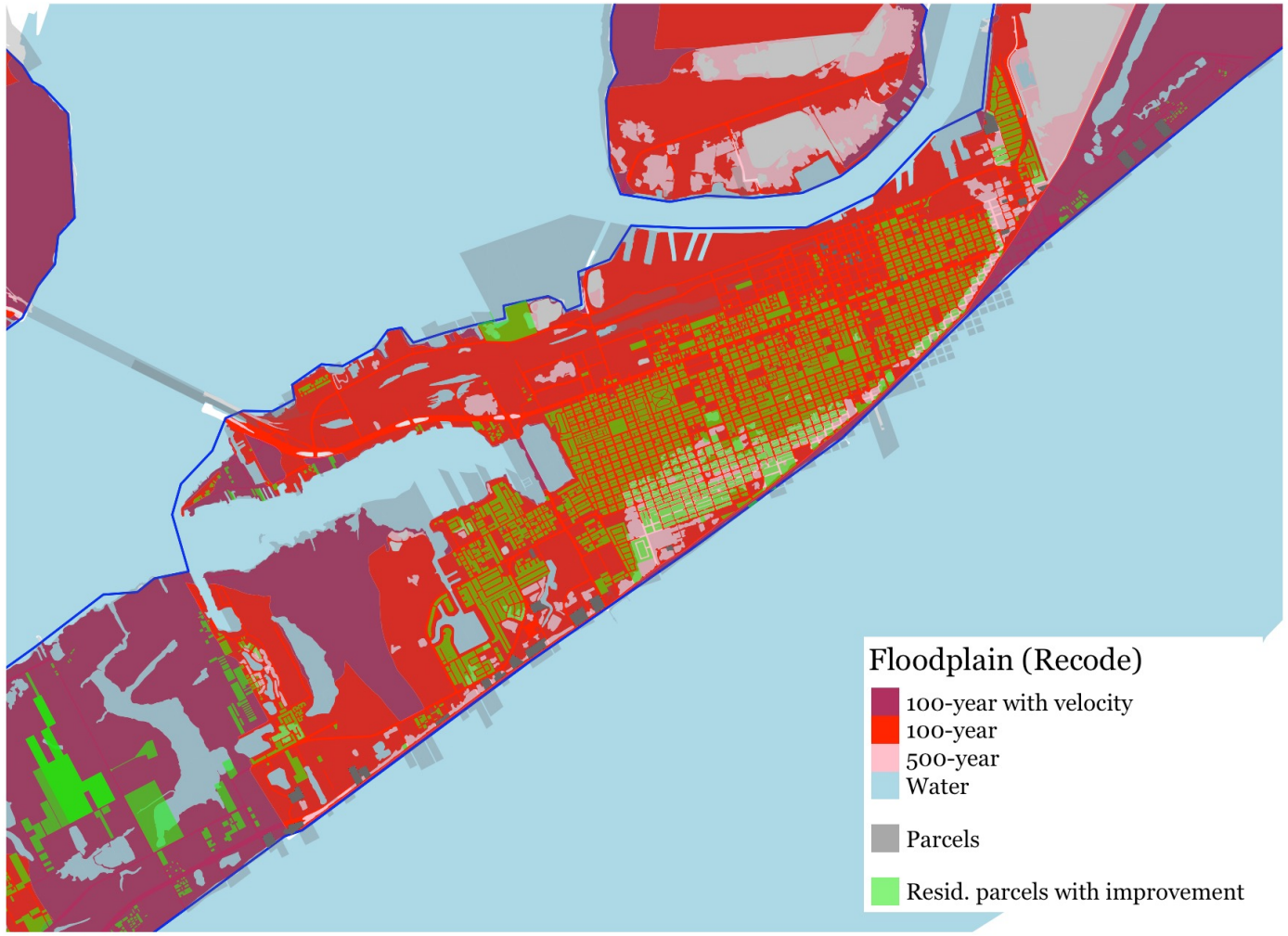
Alternative hypothesis: true mean difference is not equal to 0

95 percent confidence interval: **-203.28 65.55**

Sample estimates: mean difference **-68.87**

	Census 2021-2017 ACS 5-Year	**Landscan** 2019
Total County Population	347,084 (MOE 38,817)	354,112

View of Galveston Island Downtown Area



Galveston County

(–*Illustrative Estimates*–)

Floodplain	**Population Count*** 2019 LandScan	**Residential Parcels**** Appraisal District	**Area***** (sq mi)
Water	–	–	493.0
100-year (with velocity)	12,854	5,289	103.0
100-year	99,136	27,387	93.9
500-year	81,637	24,867	61.1
Levee protected	40,243	11,540	24.8
Out of floodplain	120,242	42,795	171.6
Total	**354,112**	**111,878**	**775.8**

* Landscan pixel is **aerial weighted** to estimate the population estimate in the area covered by the flood category.
** Total of **parcel centroids** that are within each floodplain area. Land use coded as **residential (R) with improvement value greater than $0 in 2022**.
*** Projection used **EPSG:3081** NAD83 / Texas State Mapping System

Image features part of Galveston Island to illustrate the location of parcels and residential parcels with improvement.

Possible Alternatives to Assess Flooding Risk

Commercial

- *Katrisk*
  - https://www.katrisk.com/hazard-data
  - Inland flood data at **multiple return periods**.
  - 2-d hydraulic **modeling** of pluvial (surface water) and fluvial (riverine) flooding.
  - Resolution varies by region dependent on available DTMs, down to 10 meters in the US.

Academic

- Wing, O. E., Bates, P. D., Smith, A. M., Sampson, C. C., Johnson, K. A., Fargione, J., & Morefield, P. (2018). Estimates of present and future flood risk in the conterminous United States. *Environmental Research Letters*, 13(3), 034023.
  - https://www.unisdr.org/preventionweb/files/57470_wing2018environ.res.lett.13034023.pdf
  - 30 m resolution **model** of the entire conterminous US with a 2-d representation of flood physics to produce estimates of flood hazard.
  - Match to within **90% accuracy** the skill of local models built with detailed data.