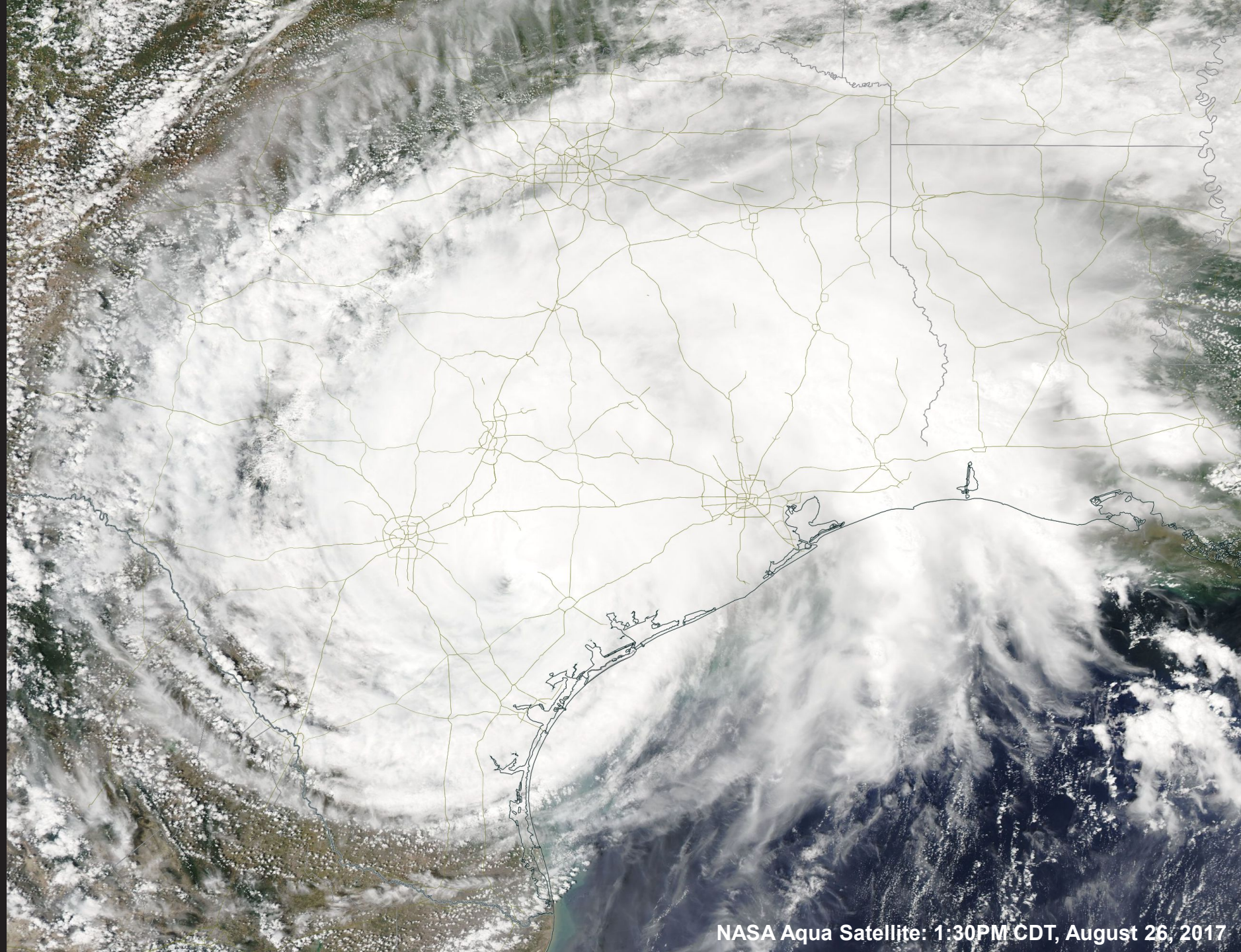
Stantec

2019 Ohio Stormwater Conference

Calibrating 2D Models to Hurricane Harvey



Agenda

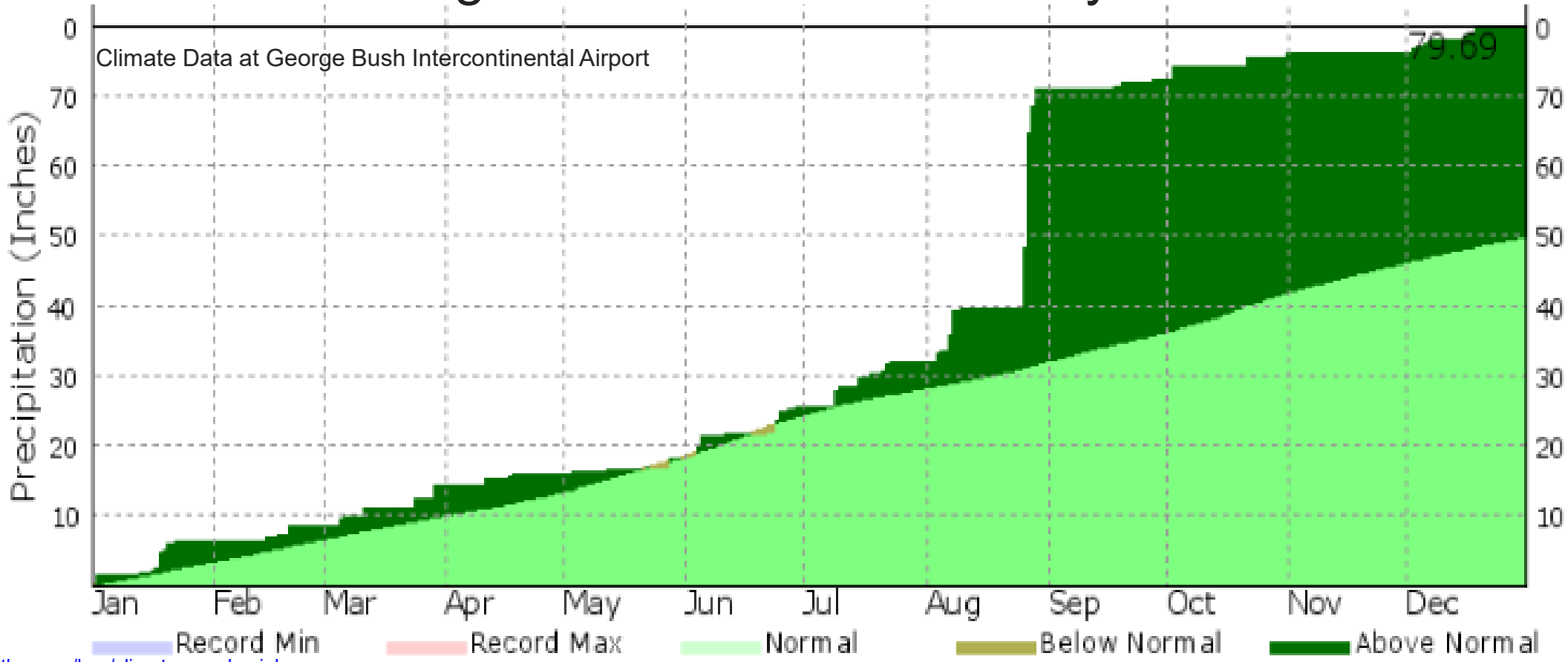
- Magnitude and Impacts of Hurricane Harvey
- Post-Hurricane Harvey Studies
- 2D Model Development and Calibration
- Validation and Model Application
- Regulatory Impacts of Hurricane Harvey

Photo Source: Community Impact Newspaper; Courtesy Dan M. via Nextdoor

Magnitude and Impacts of Hurricane Harvey

Total Rainfall

- Average Annual Rainfall = ±50 inches
- Maximum Precip Gage Reading = 47.4 inches
- 68% of Average Annual Rainfall in 4 days

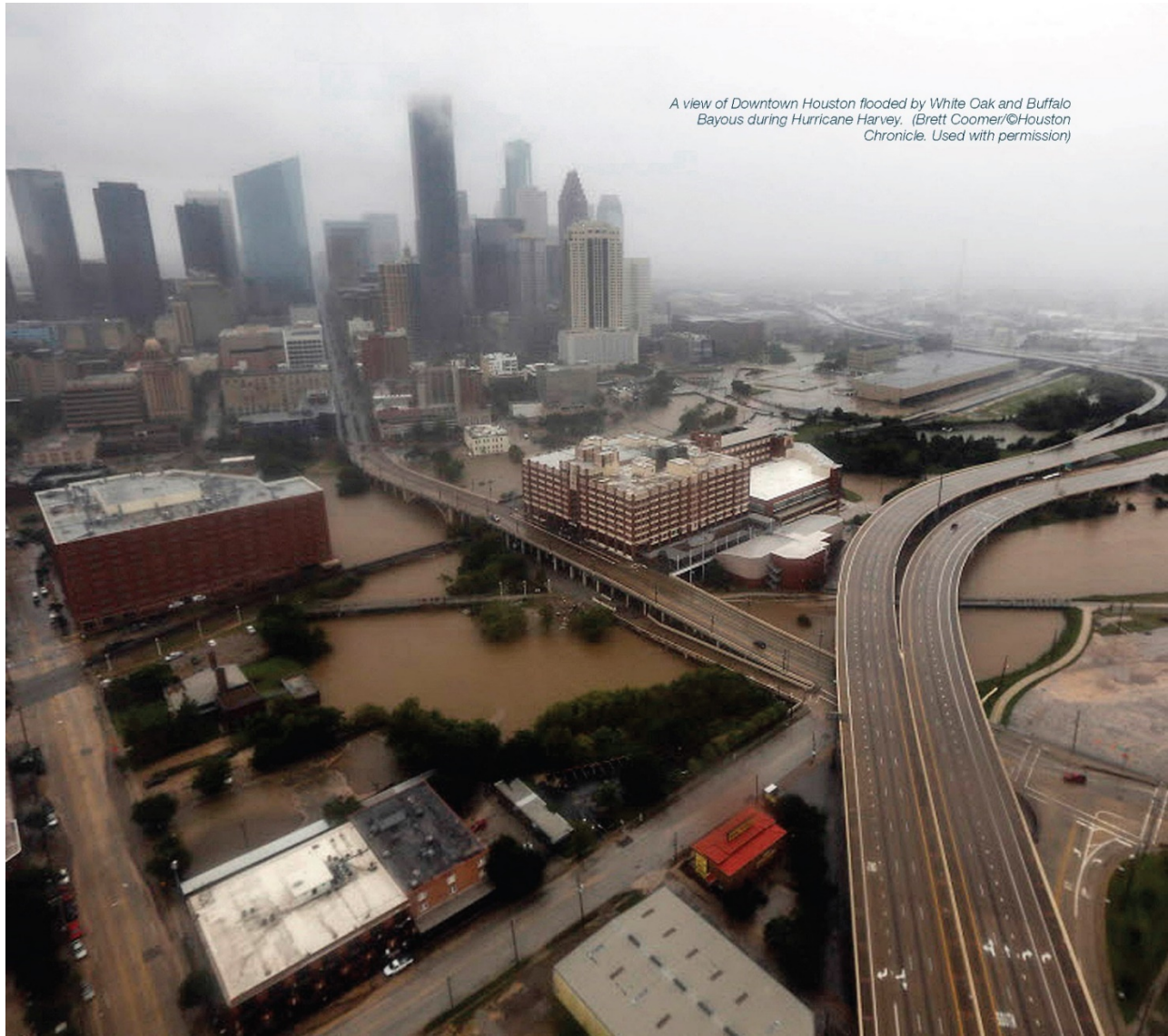


https://www.weather.gov/hgx/climate_graphs_iah

Magnitude

Harvey's Record-Setting Volume

- Total Volume ≈ 1 Trillion Gallons
- Average Depth across Harris County = 33.7”
- Fill NRG Stadium 1,472 times
- Run Niagara Falls for 15 days

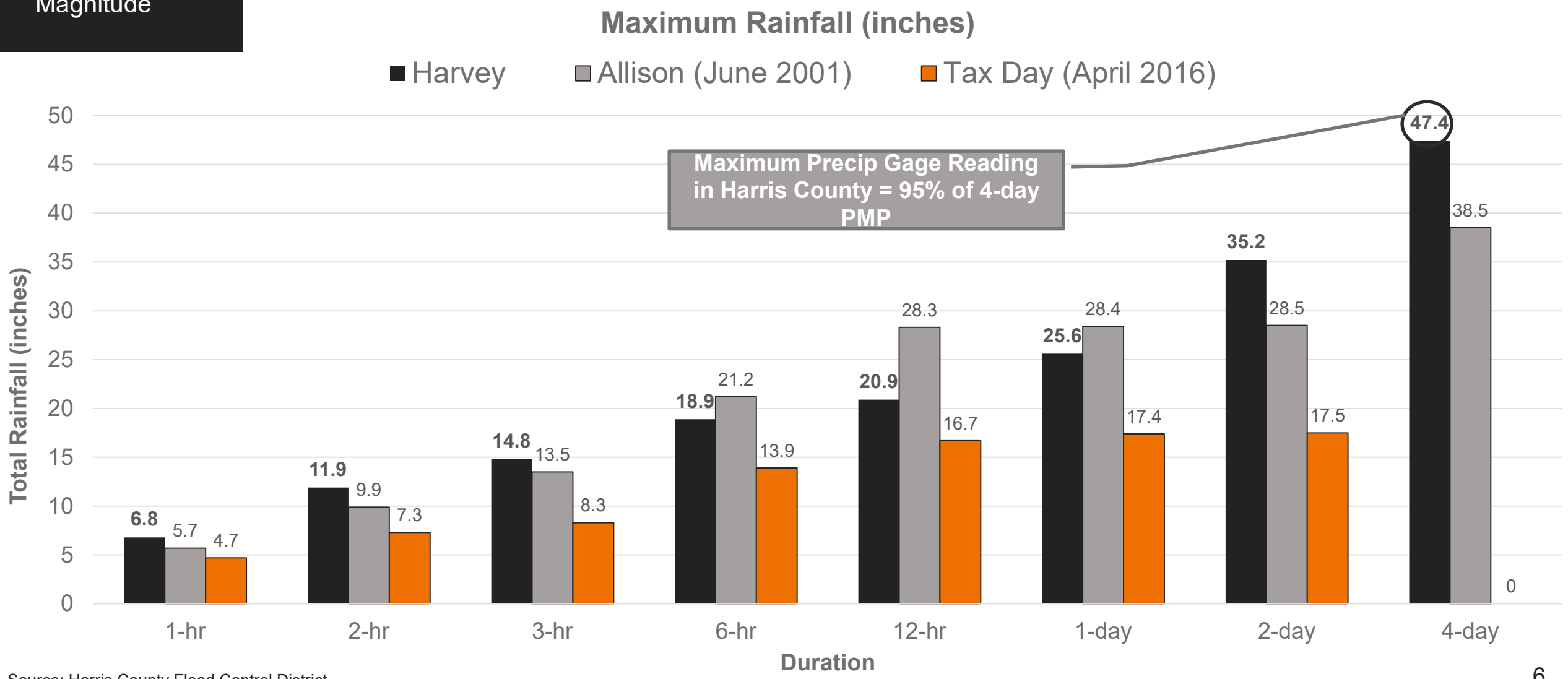


A view of Downtown Houston flooded by White Oak and Buffalo Bayous during Hurricane Harvey. (Brett Coomer/©Houston Chronicle. Used with permission)

Source (text and photo): Harris County Flood Control District

Magnitude

Harvey vs. Historic Events



Source: Harris County Flood Control District

Magnitude

Exceedance Probability

Duration	Rainfall Amount – inches	Return Interval – years (Exceedance Probability)
1-Hour Maximum	6.8	1,500 (0.0667%)
24-Hour Maximum	25.6	5,000 (0.02%)
2-Day Maximum	35.2	12,000 (0.08%)
4-Day Maximum	47.4	50,000 (0.002%)

Source: Harris County Flood Control District

Impact

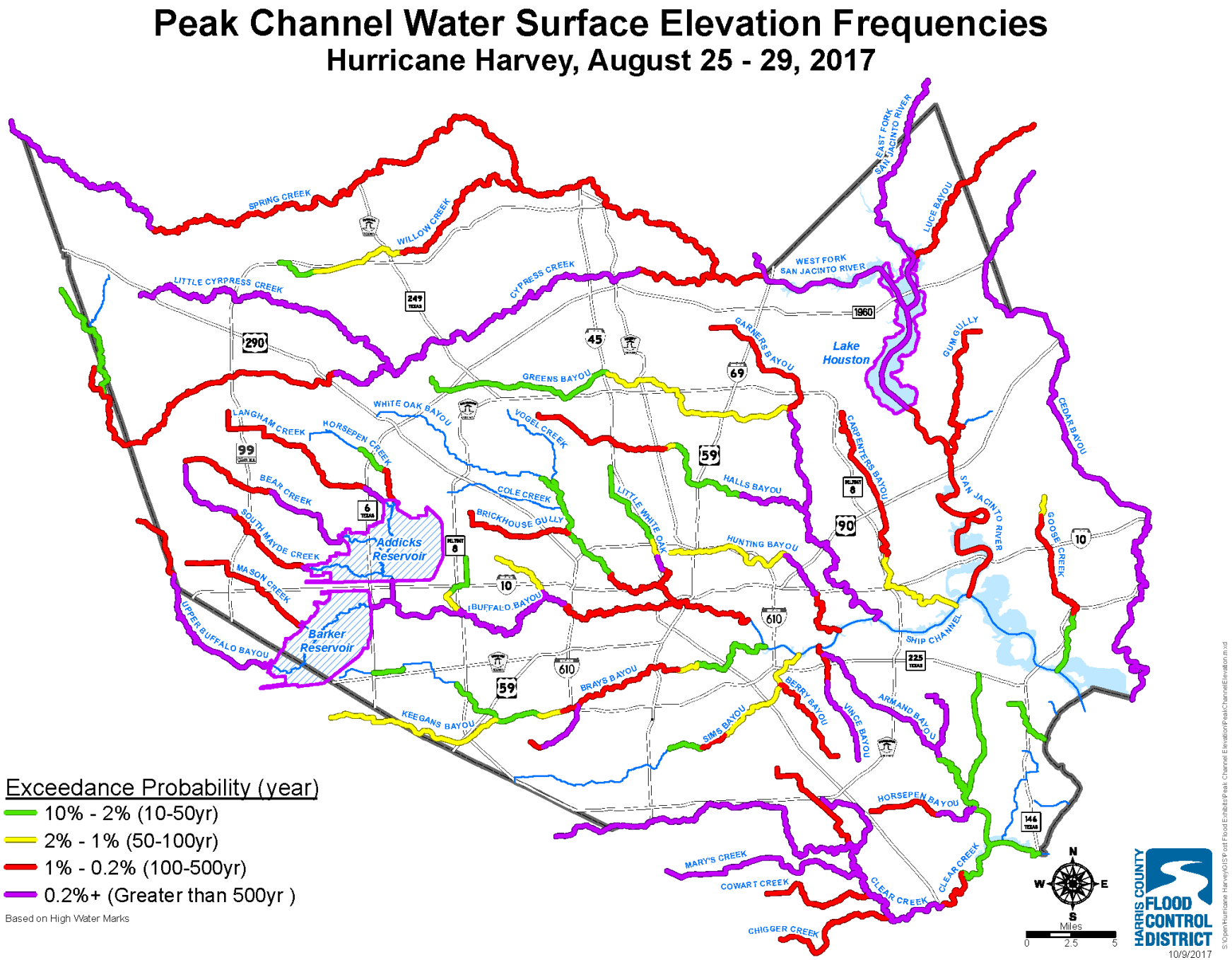
Damage and Loss (Harris County, TX)

- > 150,000 flooded structures
- 600,000 vehicles
- 37,000 people relocated to shelters
- $125 Billion in Damages

Apartment complex on the fringe of Barker Reservoir; Katy, Texas, August 30, 2017

Source (text): Harris County Flood Control District, NOAA Coastal Management; Source (photo): Amy Dziuk, used with permission

Post-Hurricane Harvey Studies



Studies

- "Forensic" H & H Studies
- Diagnostic H & H Studies
- Flood Damage Reduction Studies
- Infrastructure Upgrades

Source: Harris County Flood Control District

2D Model Development and Calibration

Building and Calibrating a 2D Model

1. Geometry Data
2. 2D Grid Development
3. Rainfall/Flow Data
4. Boundary Conditions
5. Calibration Points and Targets
6. Calibration Process
7. Challenges
8. Troubleshooting
9. Hydrograph Timing Adjustments
10. Hydrologic Calibration and Sensitivity
11. Hydraulic and Geometric Adjustments

2D Grid Development

- Grid Cell Size Considerations
  - Model purpose
  - Run times
    - Cell size vs Timestep (Courant Number)
- Manning's n in 2D Areas

Photo Source: Stantec, Example Model

2D Grid Development

XP-SWMM

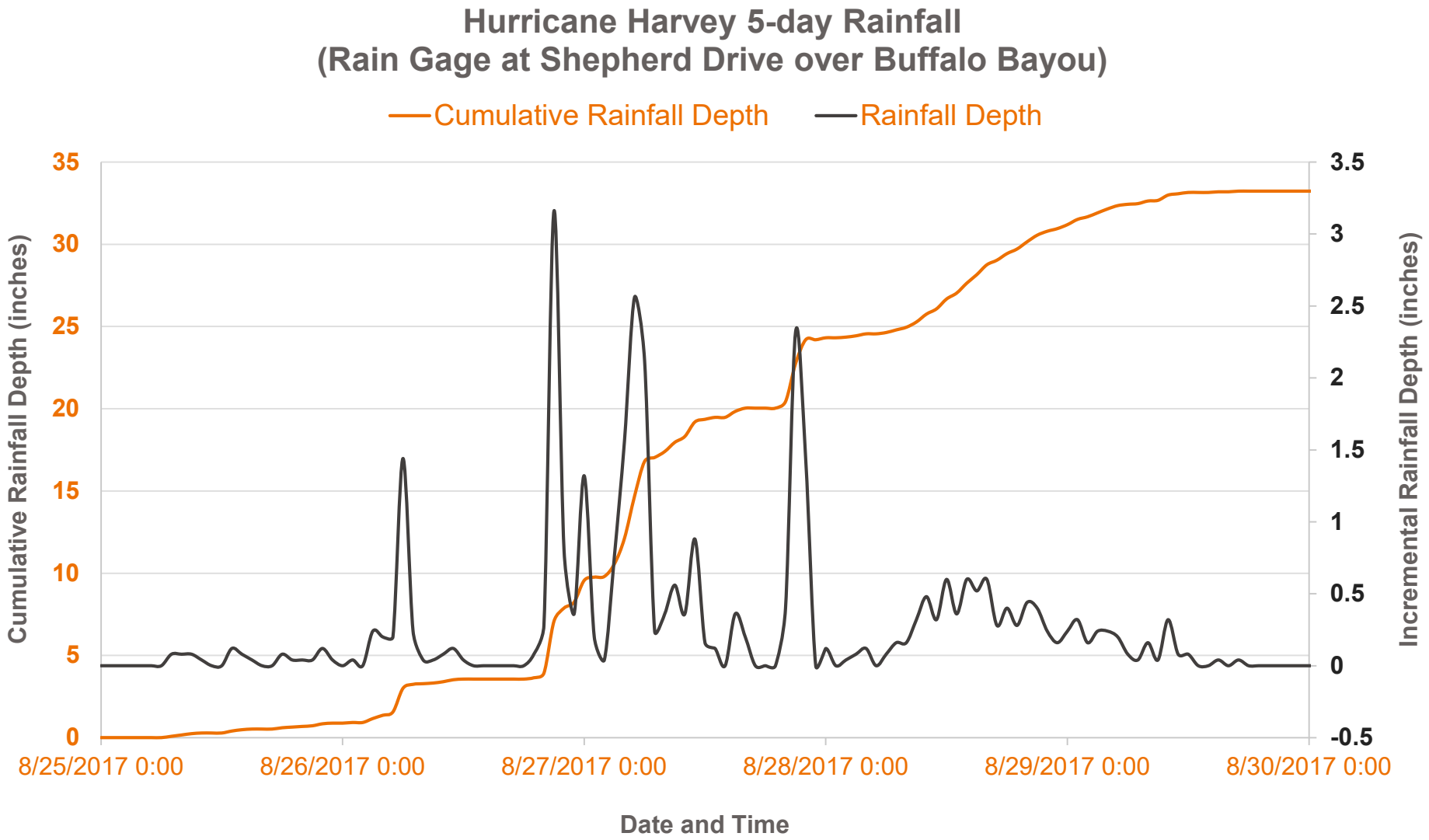
- Cell size generally greater than LiDAR cells
- Impacted by LiDAR file size
- Cell size impacts accuracy
- Cells can ONLY be wet OR dry

HEC-RAS

- Cell size generally greater than LiDAR cells
- Cell sizes have less impact on accuracy
- Cells can be partially wet

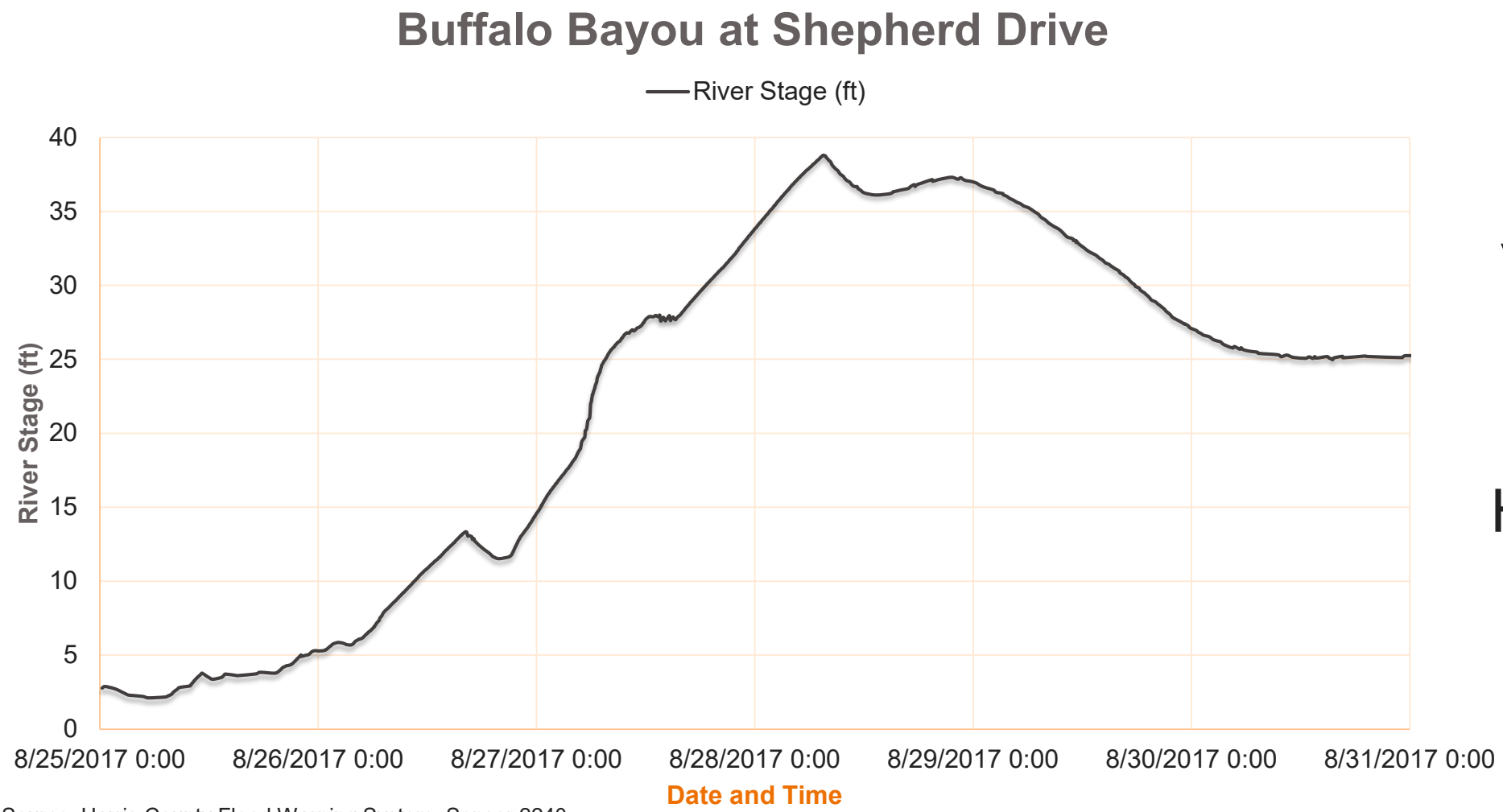
Rainfall Data

- Rain/Stream Gages
- Gage Adjusted Radar Rainfall (GARR)



Sources: Harris County Flood Warning System, Sensor 2239

Boundary Conditions



Source: Harris County Flood Warning System, Sensor 2240

Stage Gages

Variable Tailwater Curves

High Water Marks

Calibration Points

- Limited High Water Marks
- Crowd Sourcing
- Data Aerial Imagery (NOAA & NASA)

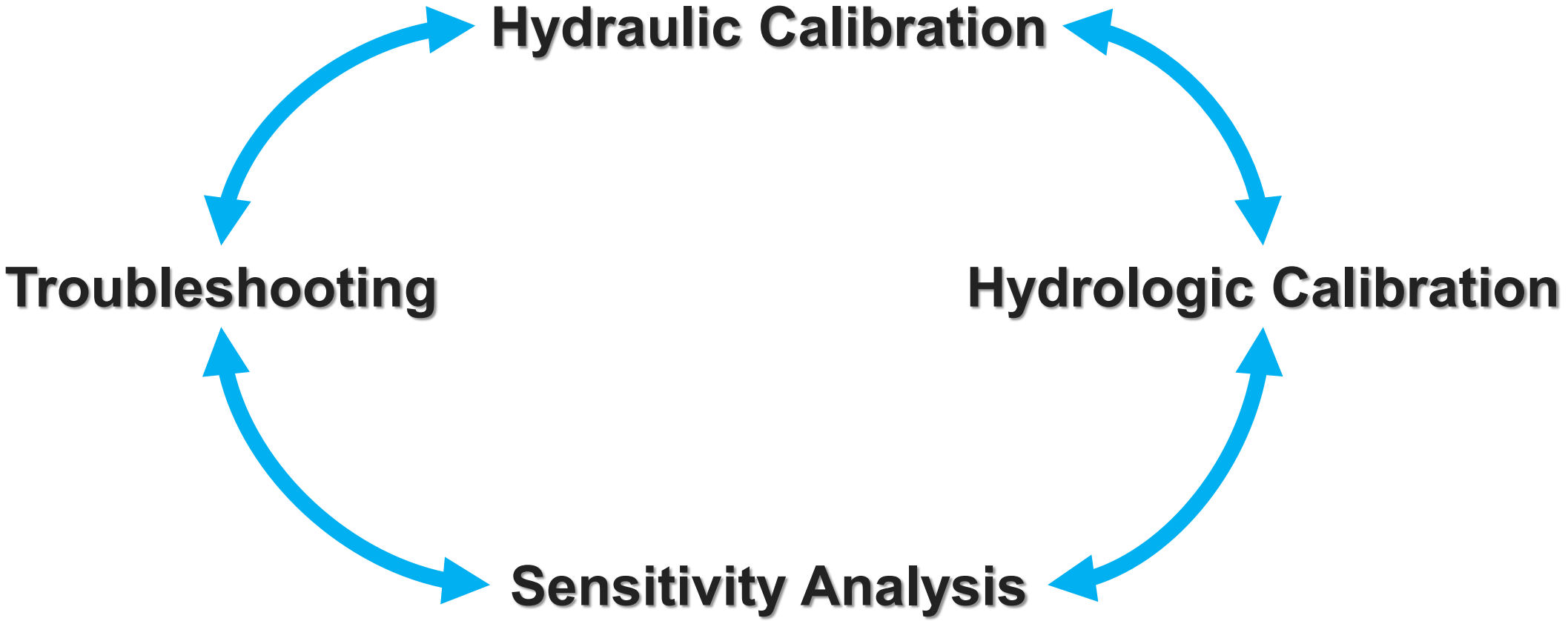
- https://www.youtube.com/watch?v=xwsljn5Aqmk
- https://storms.ngs.noaa.gov/storms/harvey/index.html#17/29.77413/-95.68787

Harvey's Calibration Targets

- Water Surface Elevation
  - Multiple interim peaks and maximum water surface elevation
  - <0.5-ft for XP-SWMM
  - <1-ft for HEC-RAS
- Timing
  - Interim and maximum peaks occur at the right time
  - Peaks should occur within 2-3 hours of actual event timing

Photo Source: M. Nunley; August 27, 2017

Typical Calibration Process



Calibration

Harvey's Calibration Challenges

- Volume
  - Soil Losses
  - % Impervious
  - 1D Storage Assumptions
- Synthetic Hydrographs vs Rainfall on Grid
  - Dependent on Study type
  - Dependent on Model type
    - HEC-RAS – Rainfall-runoff or Rainfall on Grid
    - XP-SWMM – Rainfall-runoff more efficient

Photo Source: NOAA (https://storms.ngs.noaa.gov/storms/harvey/index.html#18/29.76113/-95.40854), Buffalo Bayou, Houston, Texas

Troubleshooting

- Steady Flow: water surface elevation is too high
- Unsteady & 2D: water surface elevation is too low
- Peak Timing is off
- Review results from multiple angles
  - Flow hydrographs
  - Velocity
  - Animation
  - Results tables

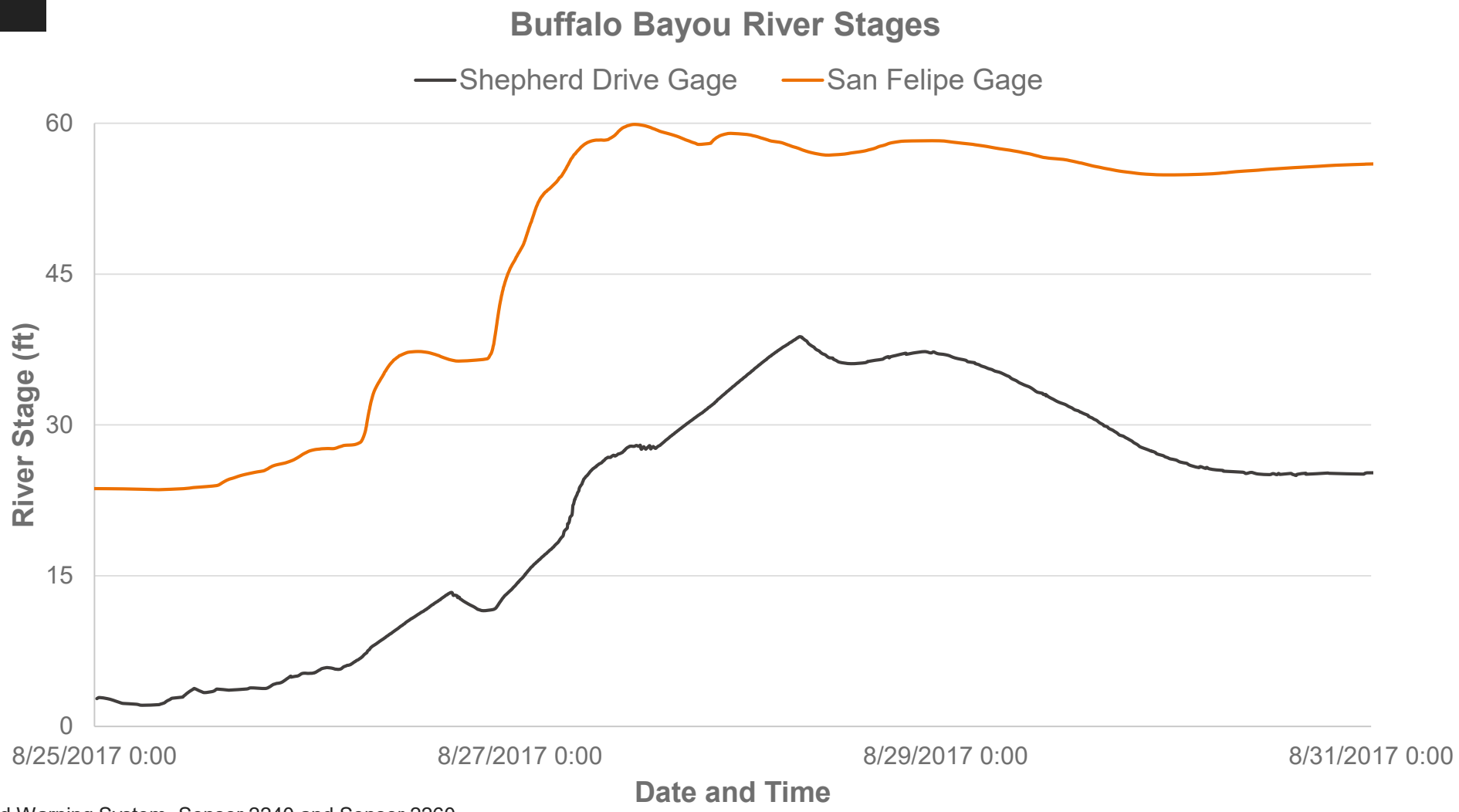
Hydraulic and Geometric Adjustments

Source: Amy Dziuk, used with permission

- Manning's n Values
- Minor Losses
- Add Geometric Features
- Edit 2D Grid and 1D/2D Connections

Hydrograph Timing Adjustments

Variable Tailwater Curves

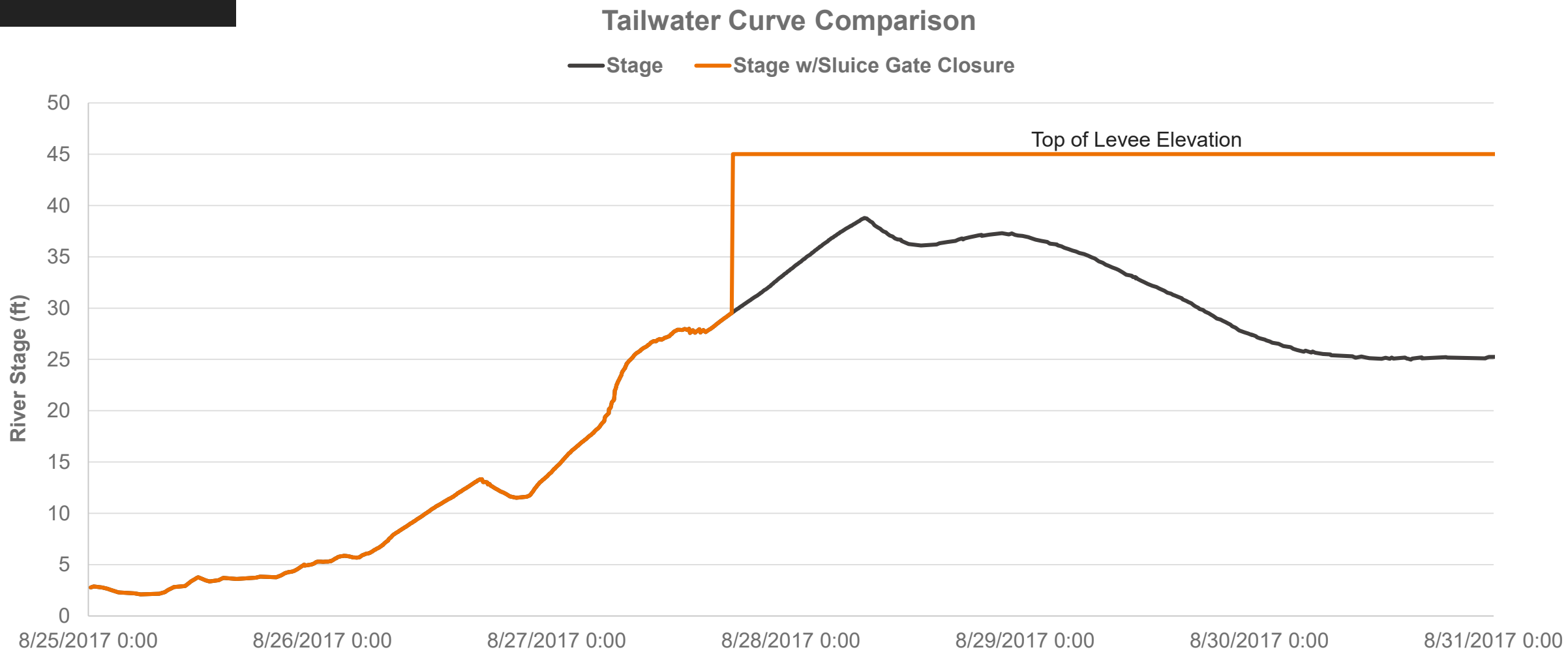


Source: Harris County Flood Warning System, Sensor 2240 and Sensor 2260

Calibration

Hydrograph Timing Adjustments

Levee Protected Areas

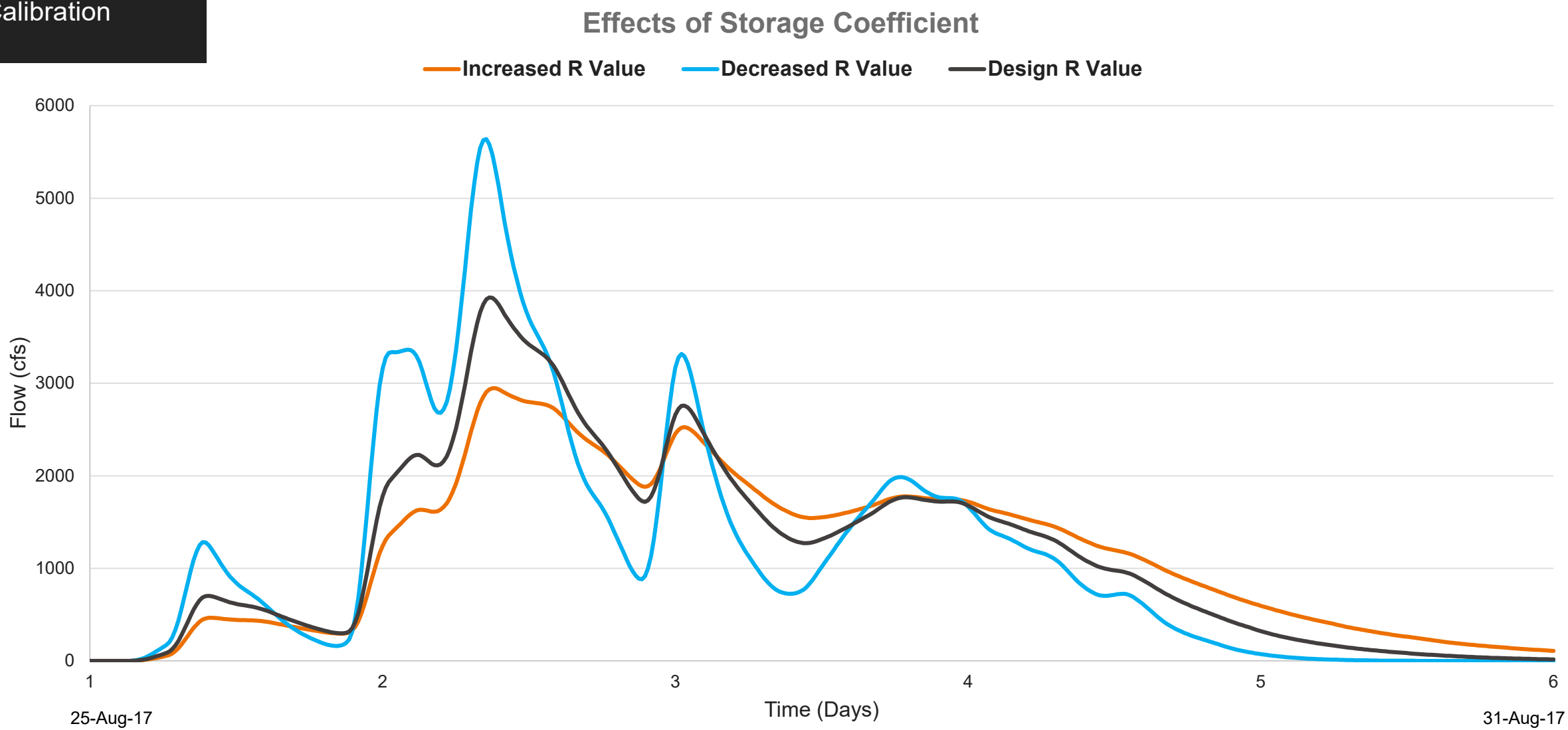


Source: Harris County Flood Warning System, Sensor 2240

Calibration

Hydrologic Calibration and Sensitivity

Internal Hydrograph Timing



Validation and Model Application

Validation Methods

- Comparison of Model WSE and High Water Marks
- Crowd Sourced Data
- Imagery
  - Approximate floodplain extent
  - Use landmarks to estimate elevation
- Peer Review

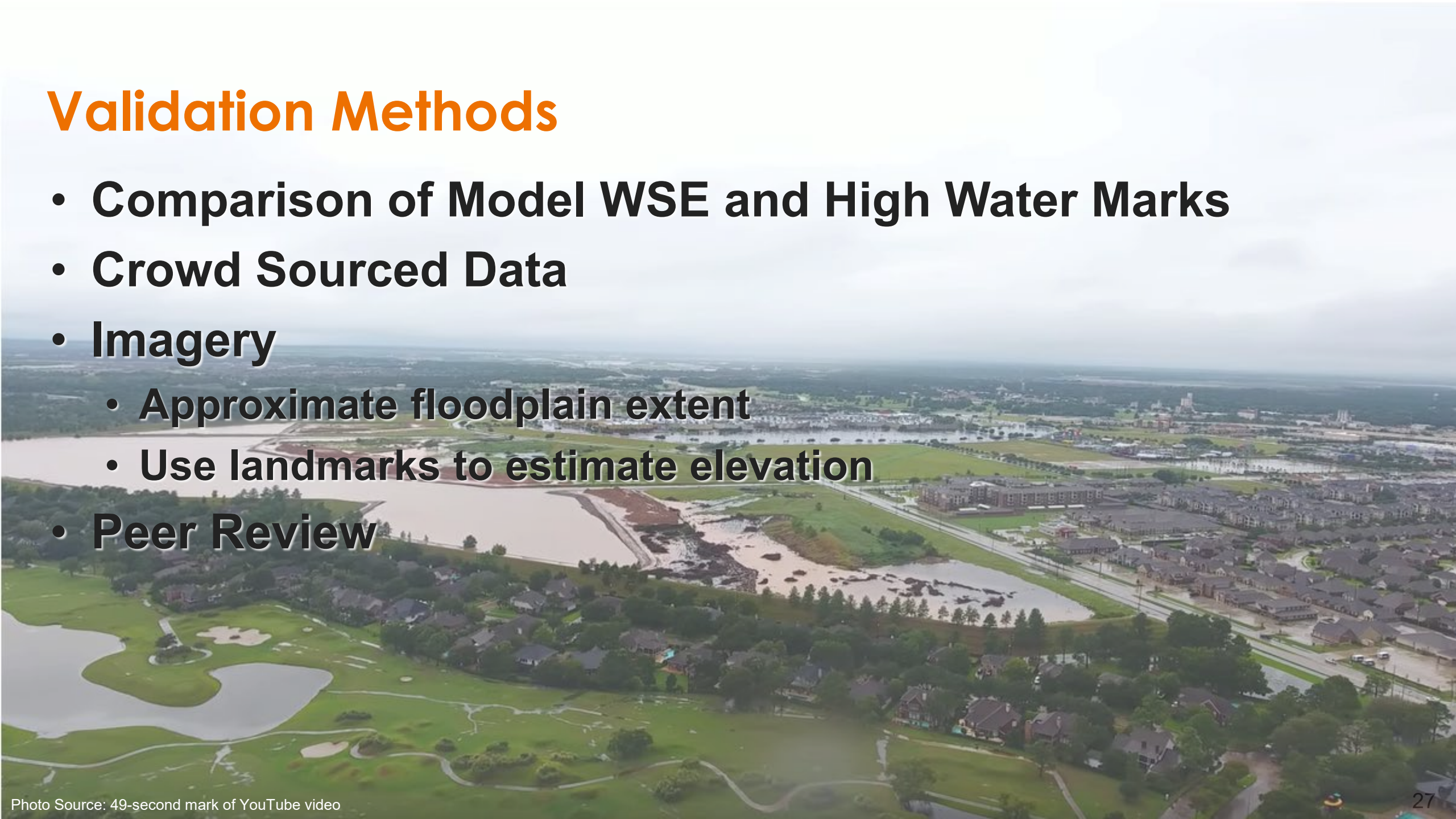


Photo Source: 49-second mark of YouTube video

Model Application

Practical Applications for Calibrated Models

- Design storms and Historic Events
- Infrastructure Performance
- Regulatory

Photo Sources: Google Street View (Left); M. Nunley; August 27, 2017 (Right)

Practical Application Example

Stormwater Pump Station for Levee District

- Run Hurricane Harvey with existing system
- Determine pump station capacity
- Run other historic storm events
- Coincidental events for Levees
- Design storms (100-year, 500-year)

Practical Application Example

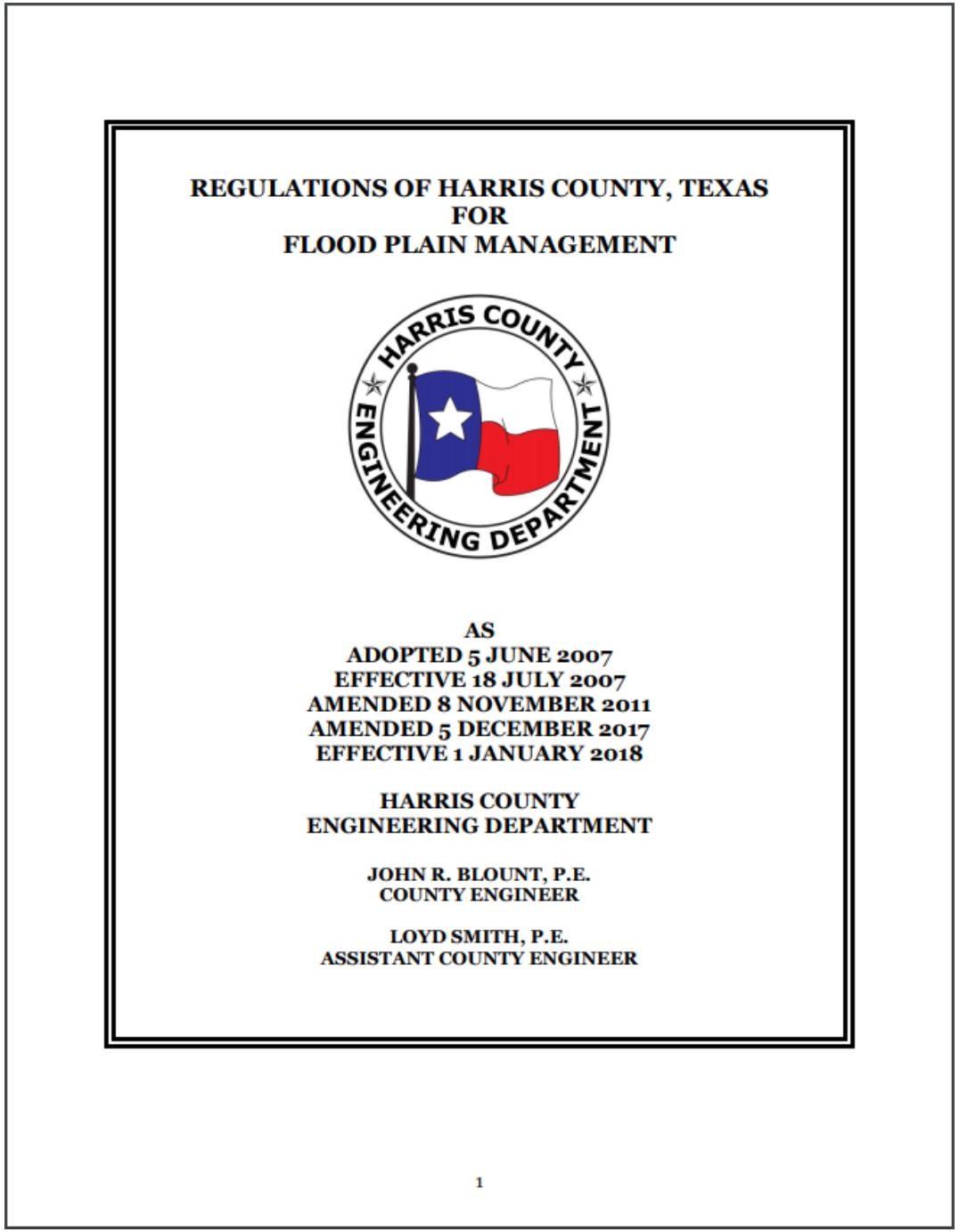
Stormwater Pump Station for Levee Protected Community

Results and Observations

- Rainfall intensity
- Total volume
- Reasonable design target

Photo Source: NOAA (https://storms.ngs.noaa.gov/storms/harvey/index.html#15/29.5780/-95.6874) Brazos River, Sugar Land, Texas

Regulatory Impacts of Hurricane Harvey



REGULATIONS OF HARRIS COUNTY, TEXAS
FOR
FLOOD PLAIN MANAGEMENT

AS
ADOPTED 5 JUNE 2007
EFFECTIVE 18 JULY 2007
AMENDED 8 NOVEMBER 2011
AMENDED 5 DECEMBER 2017
EFFECTIVE 1 JANUARY 2018

HARRIS COUNTY
ENGINEERING DEPARTMENT

JOHN R. BLOUNT, P.E.
COUNTY ENGINEER

LOYD SMITH, P.E.
ASSISTANT COUNTY ENGINEER

1

Regulatory Impacts

City of Houston

- New structure FFE ≥ 2-ft above the **500-year** floodplain;
- fill in the 500-year floodplain mitigated at 1:1 rate

Harris County

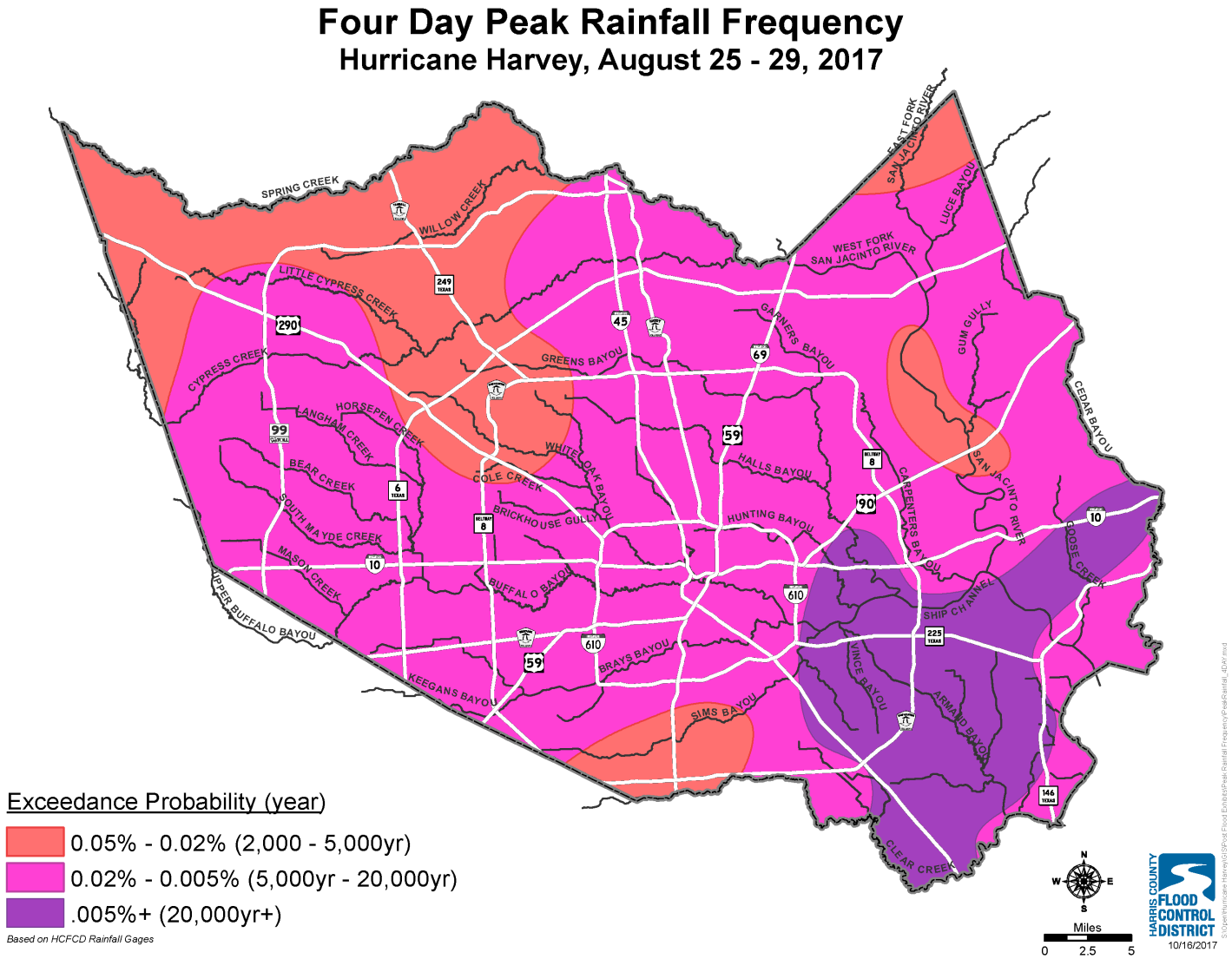
- New structure FFE ≥ 2-ft above the **500-year** floodplain

http://www.eng.hctx.net/Portals/33/Publications/FPMRegs120517.pdf

Impact

Regulatory – Atlas 14

- Pre-Harvey 100-year 24-hour storm = 12.4”-13.5”
- Post-Harvey 100-year 24-hour storm = 16”-18”
- 500-year 24-hour rainfall > 25” (downtown Houston)



Source: Harris County Flood Control District

Maegan Nunley, P.E., CFM
Senior Project Engineer
maegan.nunley@stantec.com

Questions?

Stantec