BACKGROUND

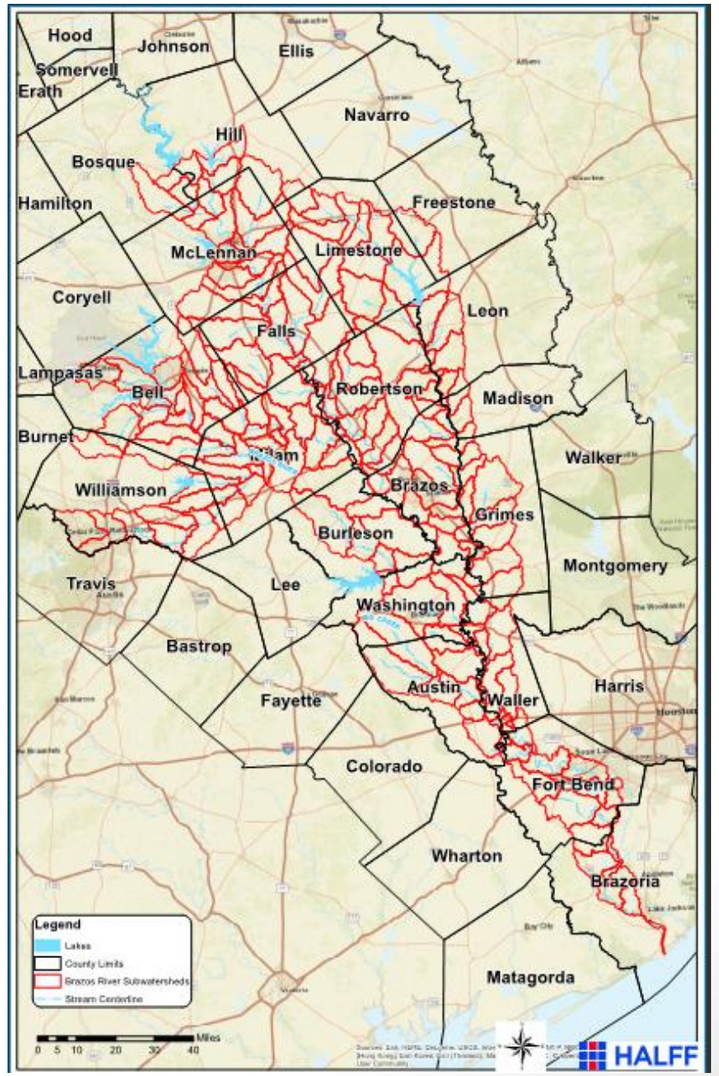
- **Lower Brazos River Floodplain Protection Planning Study**
  - **Began in 2014 with initial agreement between BRA and stakeholders**
  - **Funded through Texas Water Development Board with Brazos River Authority as 50/50 grant**
  - **BRA match made up of key stakeholders**
  - **Goals included**
    - **Update hydrologic and hydraulic data for the lower Brazos River (above Hempstead gauge to the mouth across 5 counties)**
    - **Calibrate new models to historical events and provide flood volumes, flood depths, and flood durations**
    - **Facilitate land use planning, emergency response, and sound floodplain management**
    - **Quantify existing flooding issues and flood damage reduction alternatives**

BACKGROUND

- **Brazos River Erosion Study**
  - **Began in 2016 as a high level look at impacts to the river through Sugar Land related to past events (2015-16 floods)**
  - **Expanded after Hurricane Harvey in 2017**
  - **Included expertise in Geomorphology**
  - **Goals/Objectives**
    - **Improve our knowledge regarding the river geomorphology from the City perspective**
    - **Gain an understanding of the magnitude of the problem and what is at risk**
    - **Develop a scientific methodology that would provide us the ability to predict the most highly impacted areas for prioritization based off of risk and consequence of failure**
    - **Develop a pro-active approach to the river erosion**
    - **Bring together stakeholders with interests along the river to share its findings and future projected movements of the river**

WHY

- Lower basin approximately 9,766 sq. miles
  - Approximately 8,000+ sq. miles are upstream of Sugar Land
  - Approximately 9 miles of the Brazos River runs through Sugar Land
- Lower basin has no reservoir on the main stem of the Brazos but several on major tributaries
- Nine levee districts border the river and
  - protect an estimated $15 B in appraised value
  - Estimated over $1 billion in infrastructure
- Total population in these areas est. 80k to 90k
- Need for consistent modeling methodology across county boundaries
- Need to asses lower Brazos watershed from comprehensive basinwide perspective

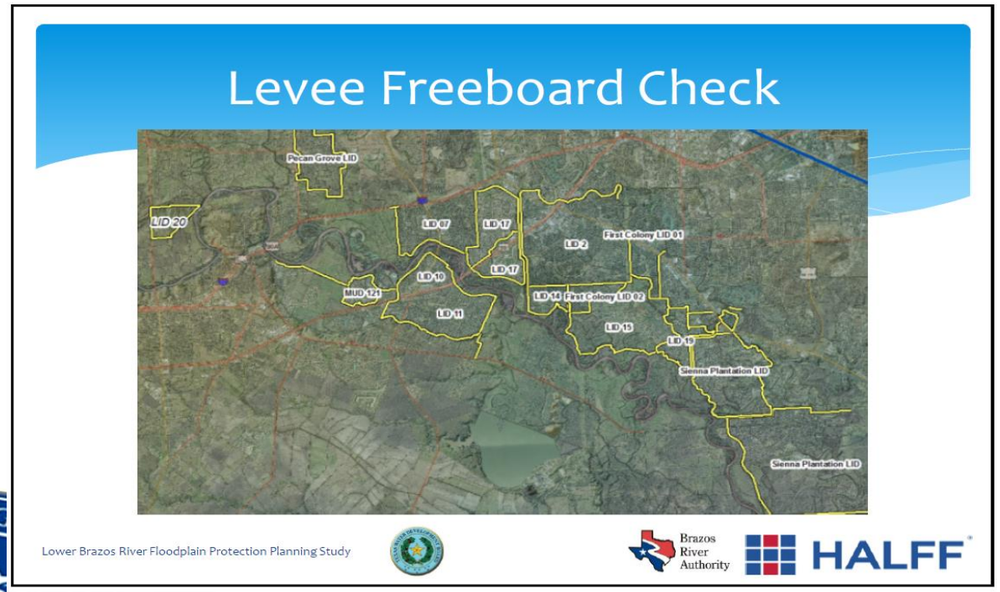


LOWER BASIN STUDY

- Utilized the USACE rainfall methodology
  - Detailed analysis on certain tributaries
- Three years of work and many meetings between stakeholders, the public and technical groups
- Modeled both the 2016 flood and Hurricane Harvey events for calibration purposes
- Combined a HEC-RAS unsteady model with 2D modeling
  - 2D identified areas where flood waters are stored within the river basin
  - These areas not currently identified as floodplain
  - These basin areas need further investigation
  - Provide attenuation of runoff
- Draft report being prepared – August 2018

KEY FINDINGS

- **USGS Gauge Comparison**
  - **Richmond Gauge 100-year increase – 1.65 ft**
- **Levee Freeboard Check**
  - **Most levee's range between 2.4 to 5.3 ft.**



Richmond Comparison

Flows (cfs)

Return Period	2014 Ft. Bend Co. FIS	Gage Freq. Storm Analysis	HEC-RAS Design Storm Analysis
10-Year	103,000	88,000	**87,000**
50-Year	147,000	117,000	**123,000**
100-Year	164,000	127,000	**139,600**
500-Year	202,000	148,000	**187,000**

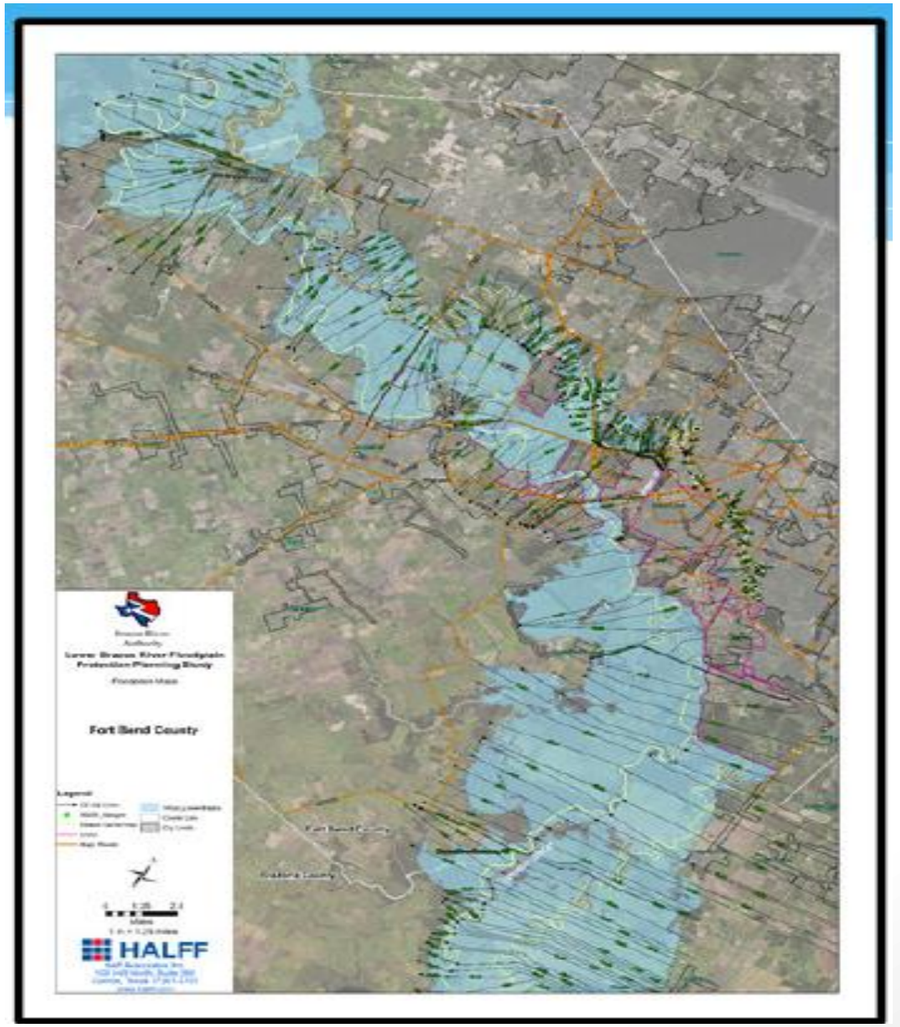
Elevation NAVD88 (feet), 27.02 feet above USGS Gauge

Return Period	2014 Ft. Bend Co. FIS	HEC-RAS Unsteady Model
10-Year	76.7	**77.18**
50-Year	81.3	**82.82**
100-Year	82.8	**84.45**
500-Year	85.2	**87.69**

Brazos River Authority HALFF

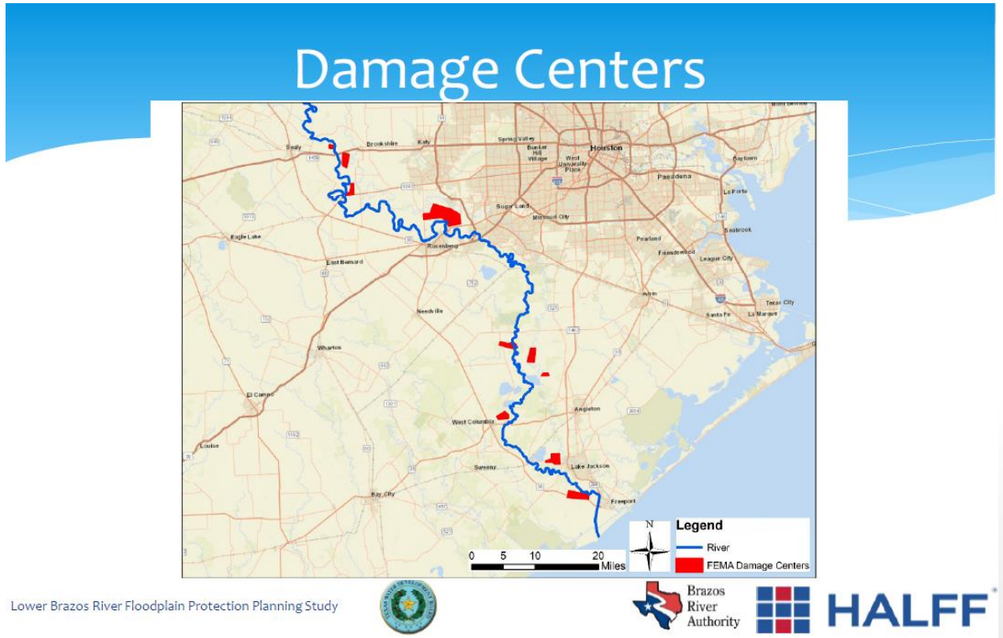
KEY FINDINGS

- **Updated 100-year inundation maps**
- **BRA model being run with most recent survey information from erosion study**
- **Will be the best available base flood elevation information for Sugar Land**



KEY FINDINGS

- **Flood Reduction Alternatives Considered (High Level)**
  - Large scale detention
  - Channelization of the river
  - Bypass channel
- **More detailed analysis required**
- **Several challenges**
  - Environmental
  - Cost
  - Property Issues



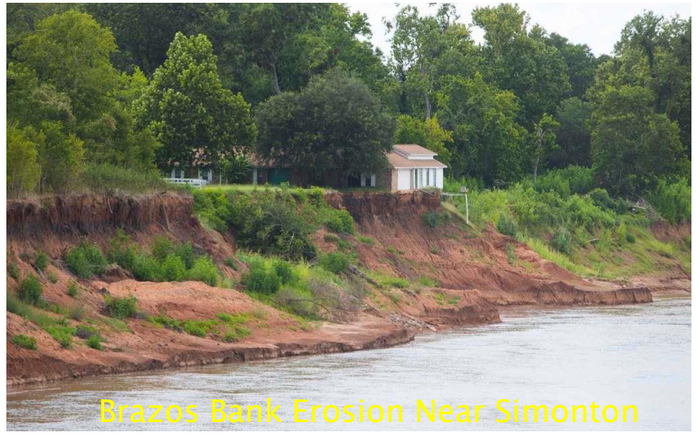
Next Steps

- Stakeholder final review and comment
- Final Report December 2018
- Fort Bend County Watershed study will include streams, creeks, bayous, drainage districts, levee districts and infrastructure within the watershed.
- Scope next phase
  - Continue upstream portion of basin
  - Include Navasota River Tributary
  - Model inflow/outflow of upstream reservoirs
  - Evaluate development impacts within the basin
  - Engage NWS on utilization of model for flood forecasting
  - Expand stream gauge network

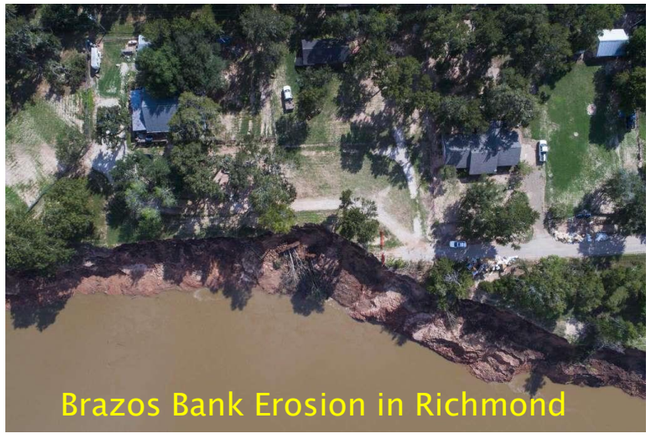
EROSION STUDY

- 2011 City took a more detailed approach to riverine flooding
  - Developed an Emergency Action Plan (EAP)
  - Plan coordinated with all LID's and Fort Bend County
  - Utilized the FEMA model for flow and base flood elevations
  - Tied LID outfall elevations to critical river elevations and USGS gage data at the Richmond location
- 2015 rain event and flood
- 2016 rain event and flood
- City initiates first contract on river evaluation
- 2017 Hurricane Harvey

PROJECT BACKGROUND



Brazos Bank Erosion Near Simonton



Brazos Bank Erosion in Richmond

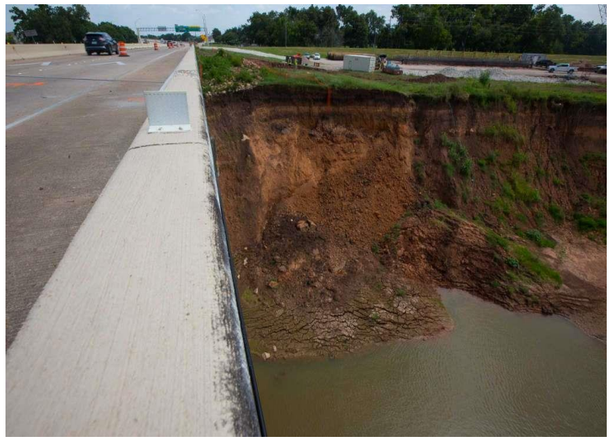
TXDOT US 59 Turn Around

Property Damage in Richmond

Brazos Bank Erosion at Jodie Stavinoha (Grand Parkway Bridge

TXDOT US 59 Turn Around post Harvey after emergency repairs

PROJECT BACKGROUND

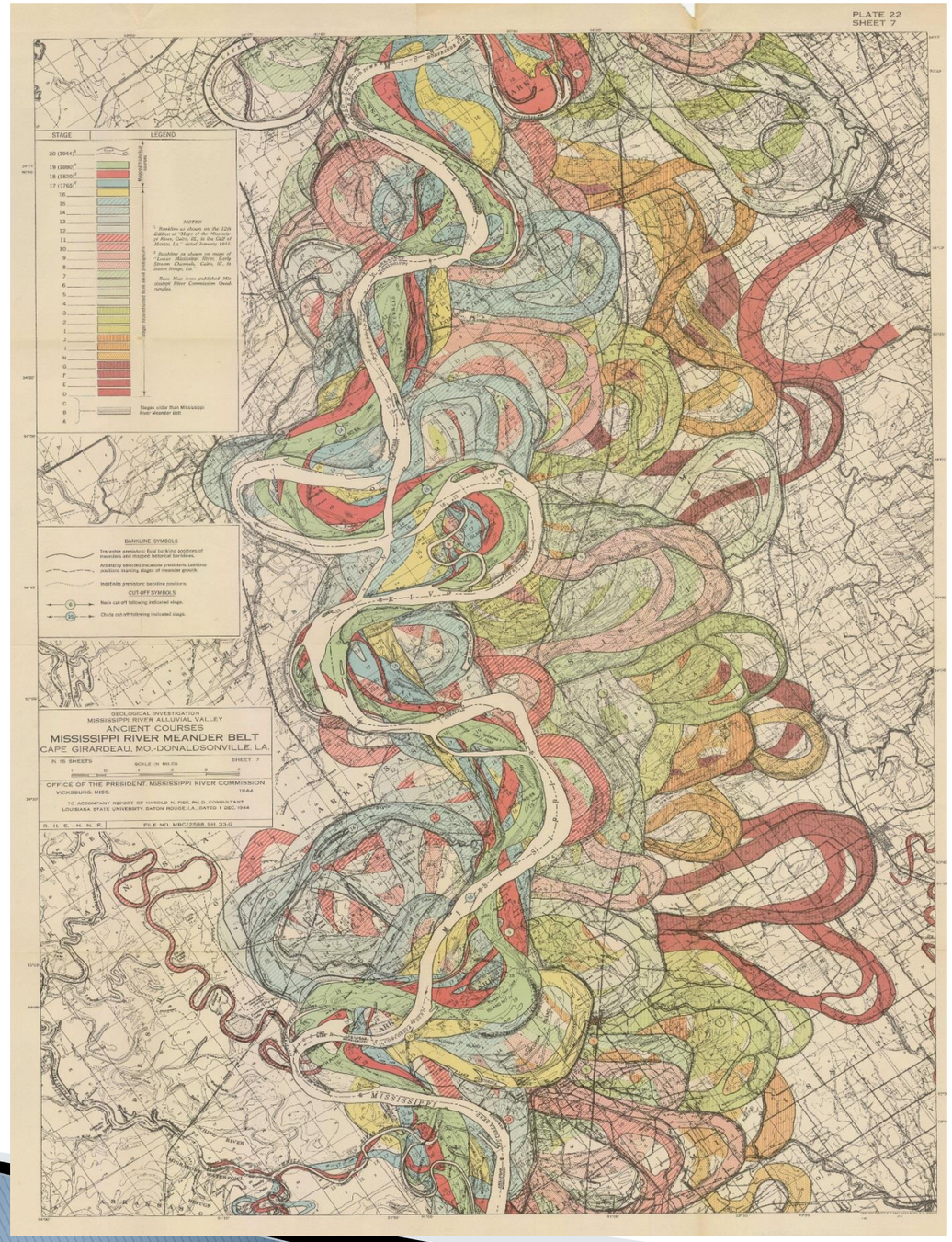


Brazos River Bridge Erosion Project

PROJECT BACKGROUND VIDEO

PROJECT UPDATE & FINDINGS

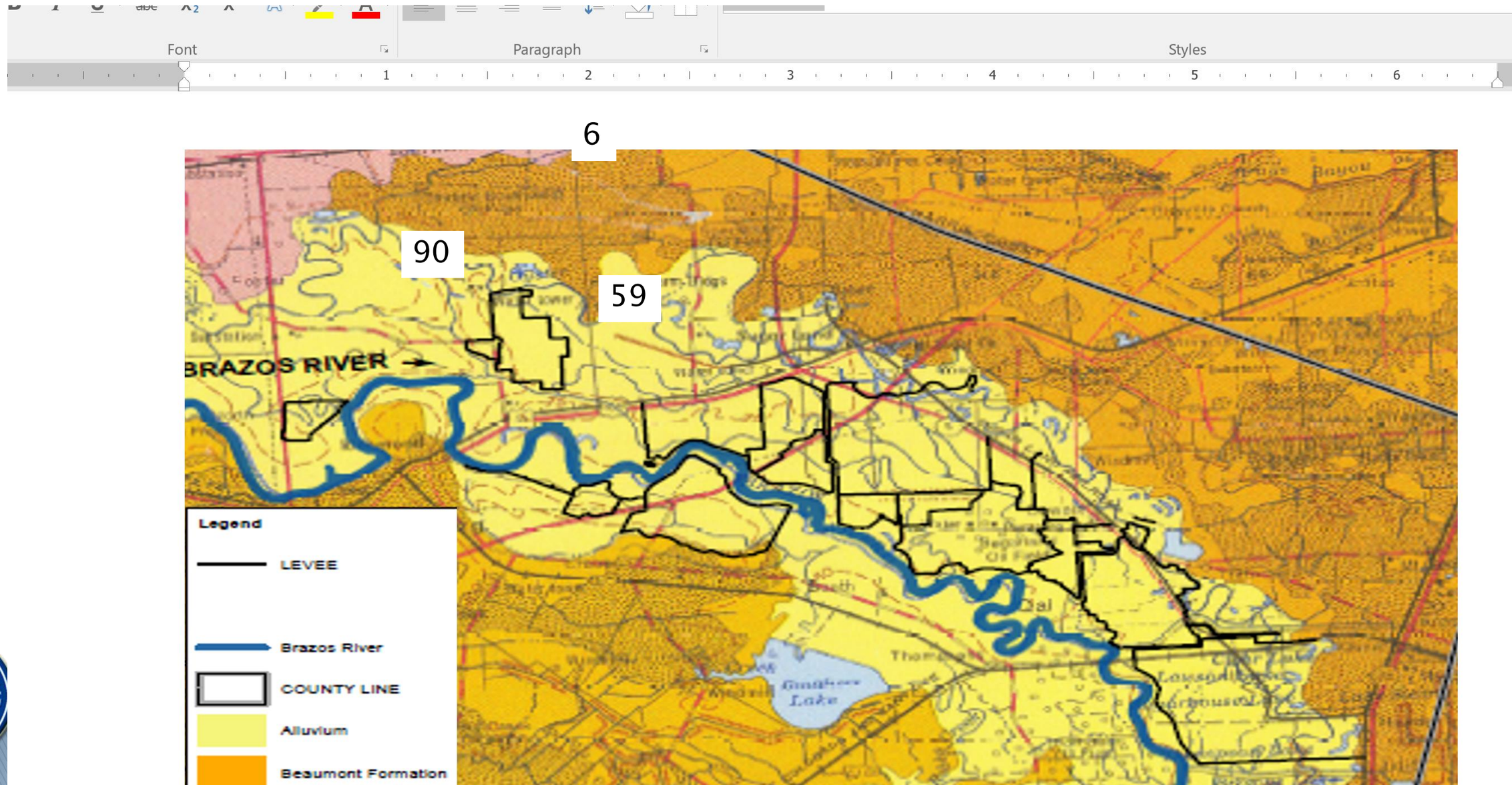
- City Council approved contract with Huitt-Zollars in November 2017 to perform the Brazos River Erosion Study along the 9 miles of River within City limits
- Huitt-Zollars with the support of Dr. Briaud, Texas A&M University initiated the Study in December 2017
- Stakeholder's Workshop on May 10, 2018
- Presented at Rebuild Texas (TDEM) on May 31, 2018
- Presentation to Texas Engineering Extension Service – Texas Task Force 1 – August 3, 2018



Geologic Meander Belt

Mississippi River (Fisk, 1944)

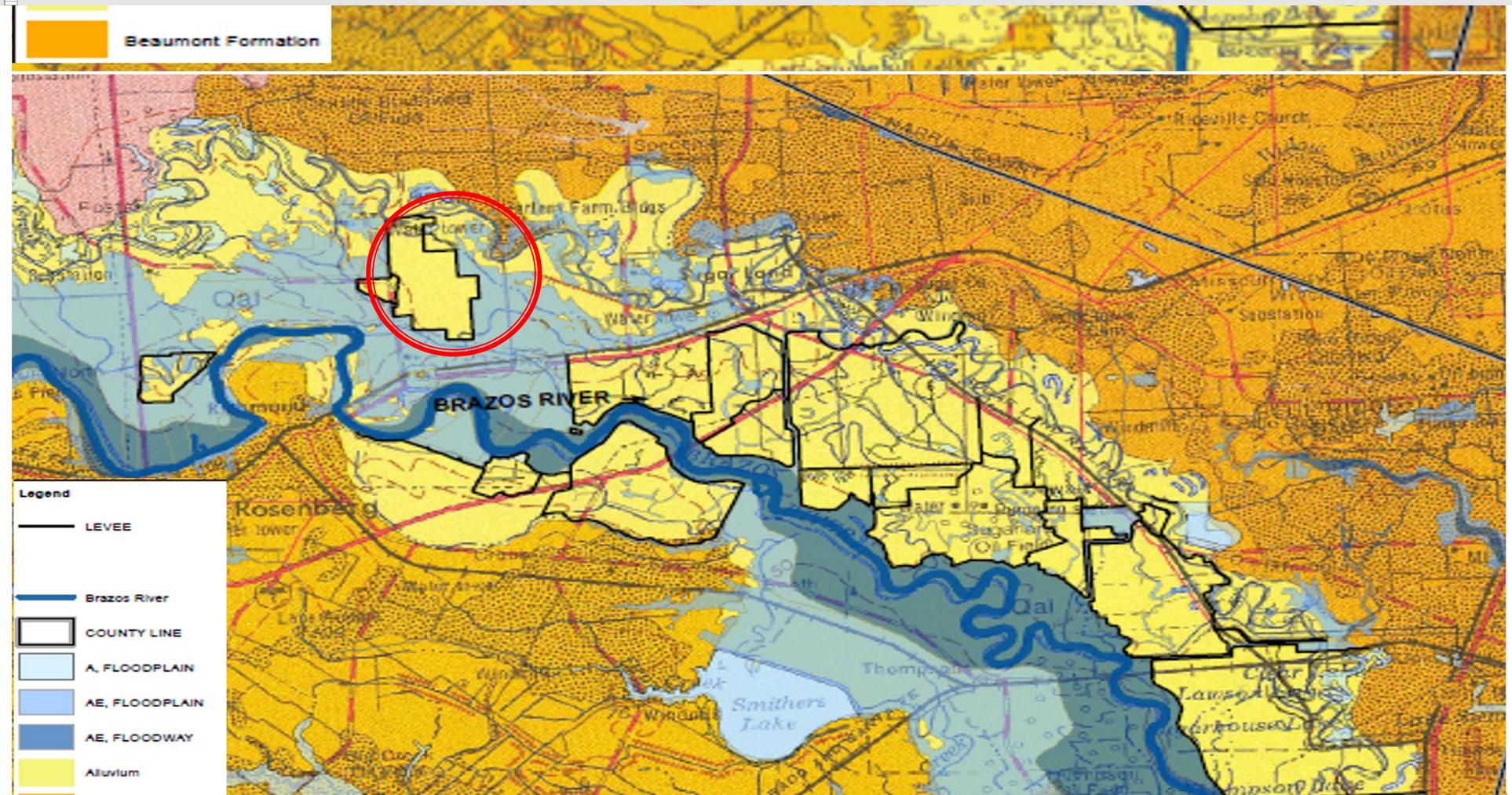
Geologic Meander Belt (Floodplain)



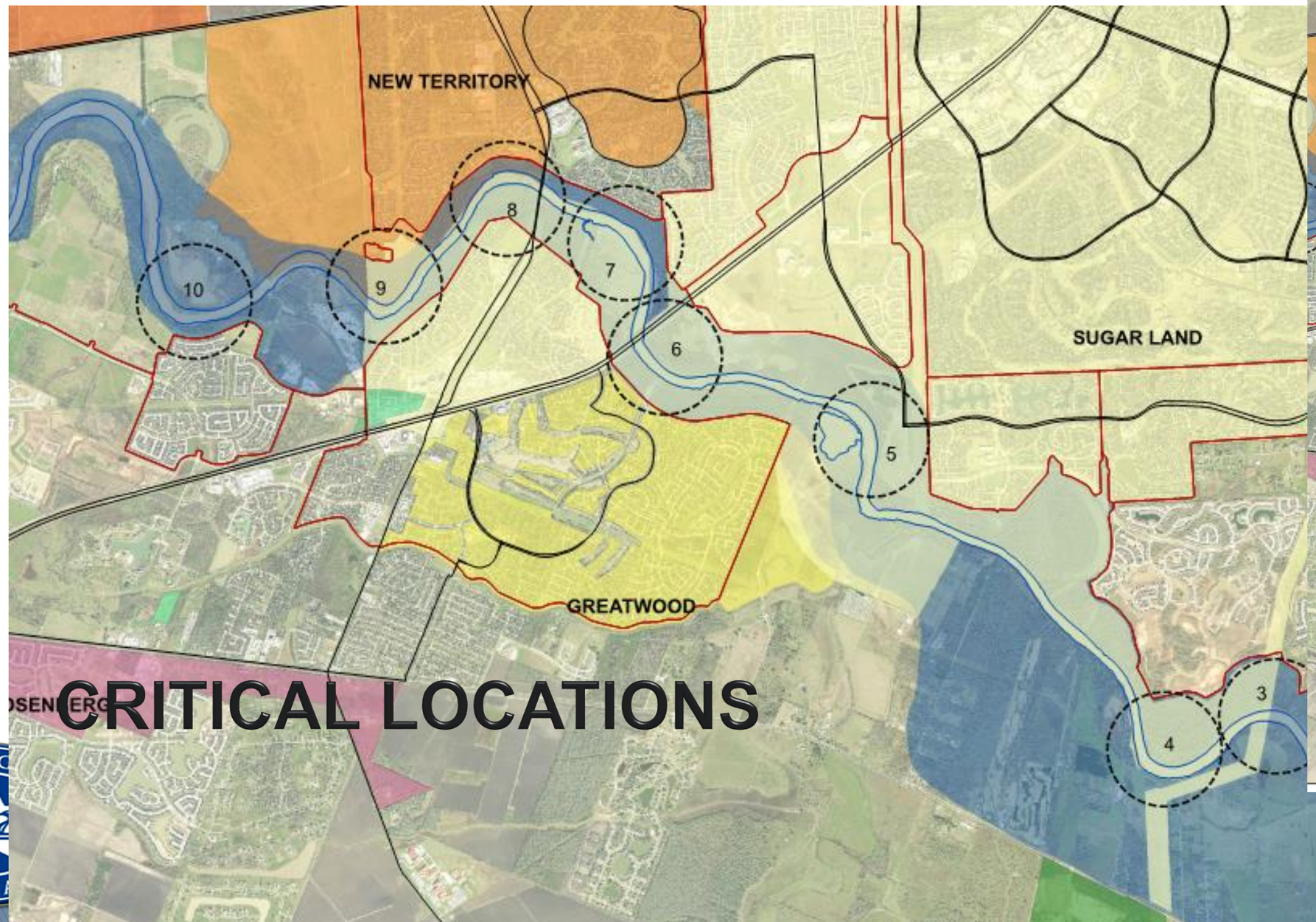
Meander Belt

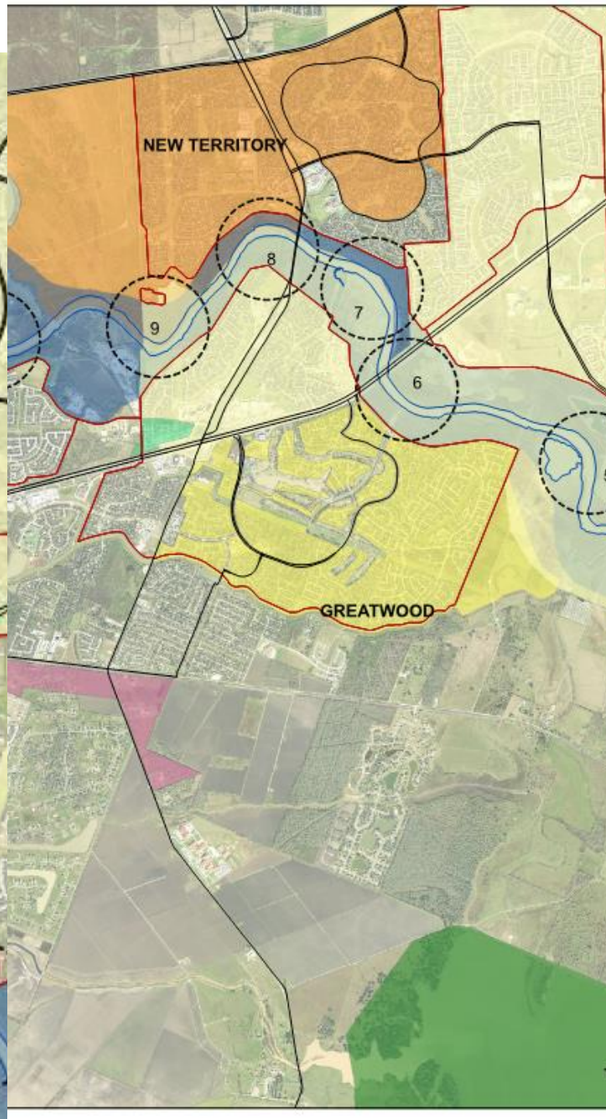
- For a typical river, width of Meander Belt is around 12 to 20 times the width of the river.
- Mississippi River – Width of Meander Belt is about 10 miles, river's width is around 4,000' which equals 13 times.
- Brazos River – Width of Meander Belt is around 6 miles, river's width is around 400' which is over 70 times.
- Conclusion, through time, the Brazos River meanders a distance of 3-4 times that of a typical river.

Current Floodplain Boundary



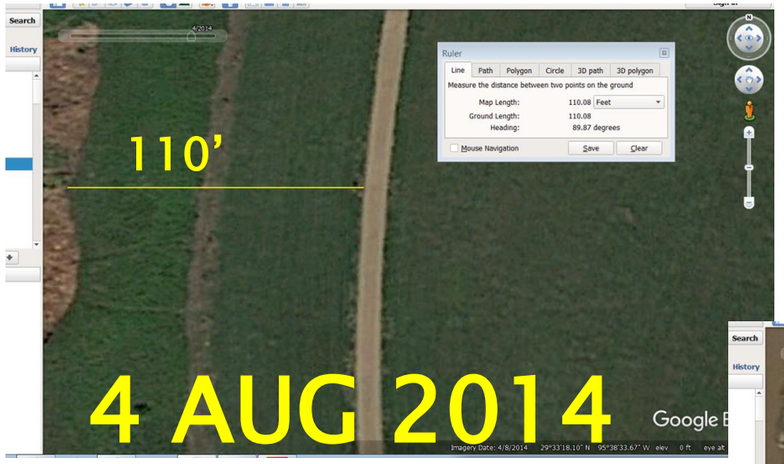
CRITICAL LOCATIONS

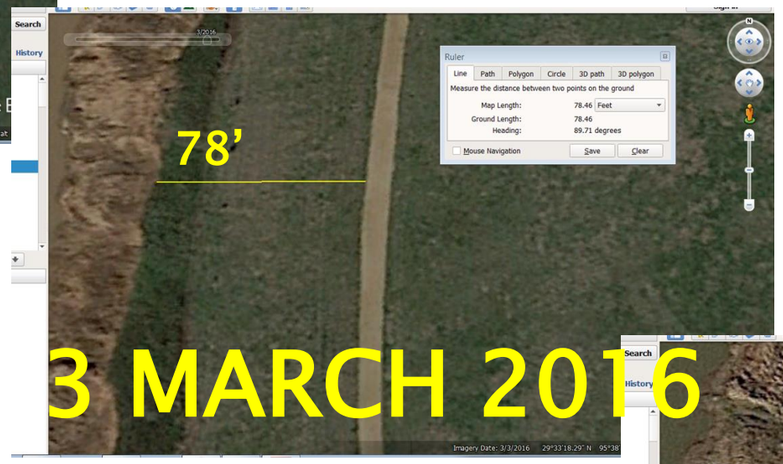




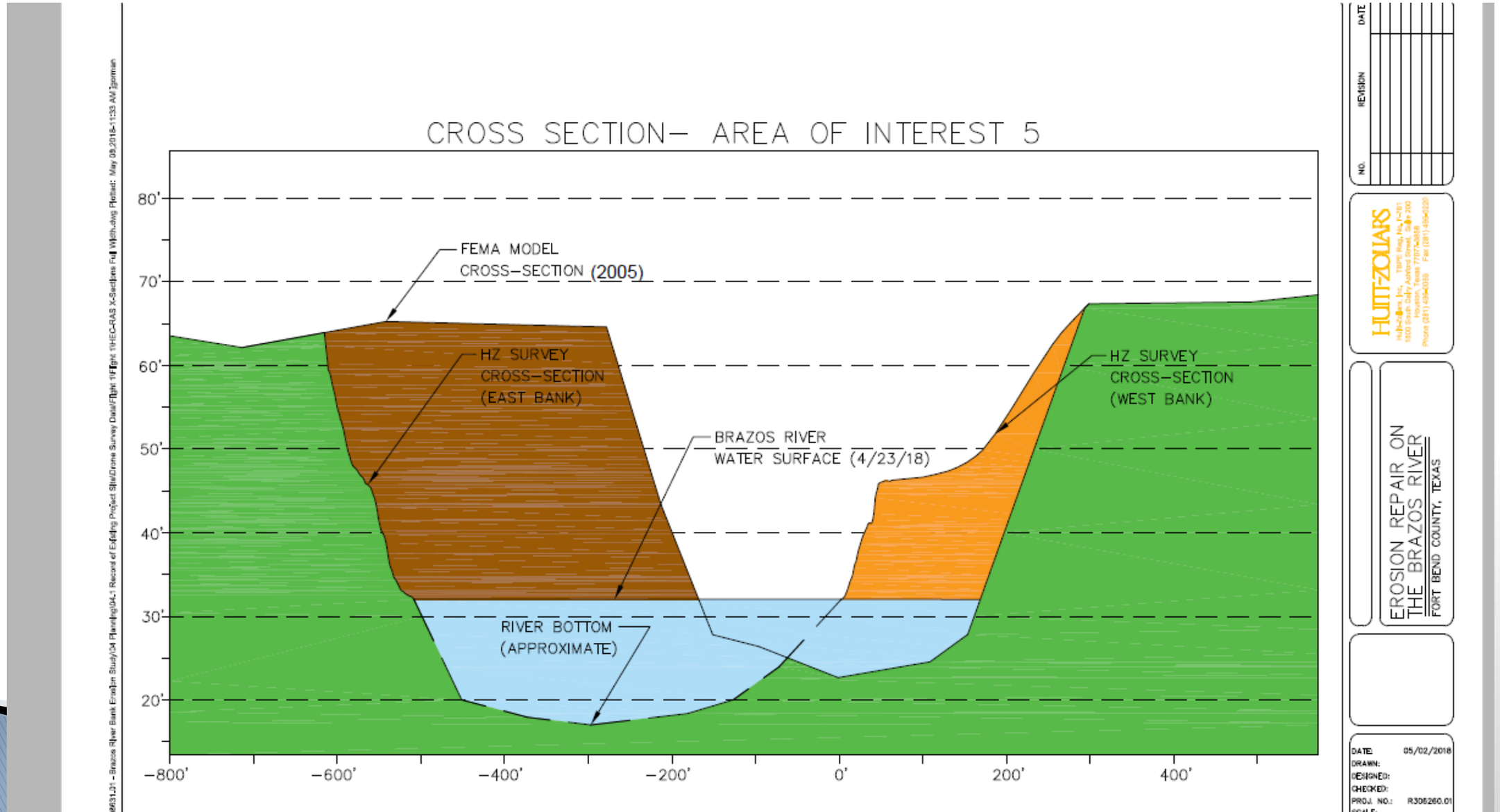
TIME SEQUENCE & EXTRAPOLATION

From 2014 to 2017

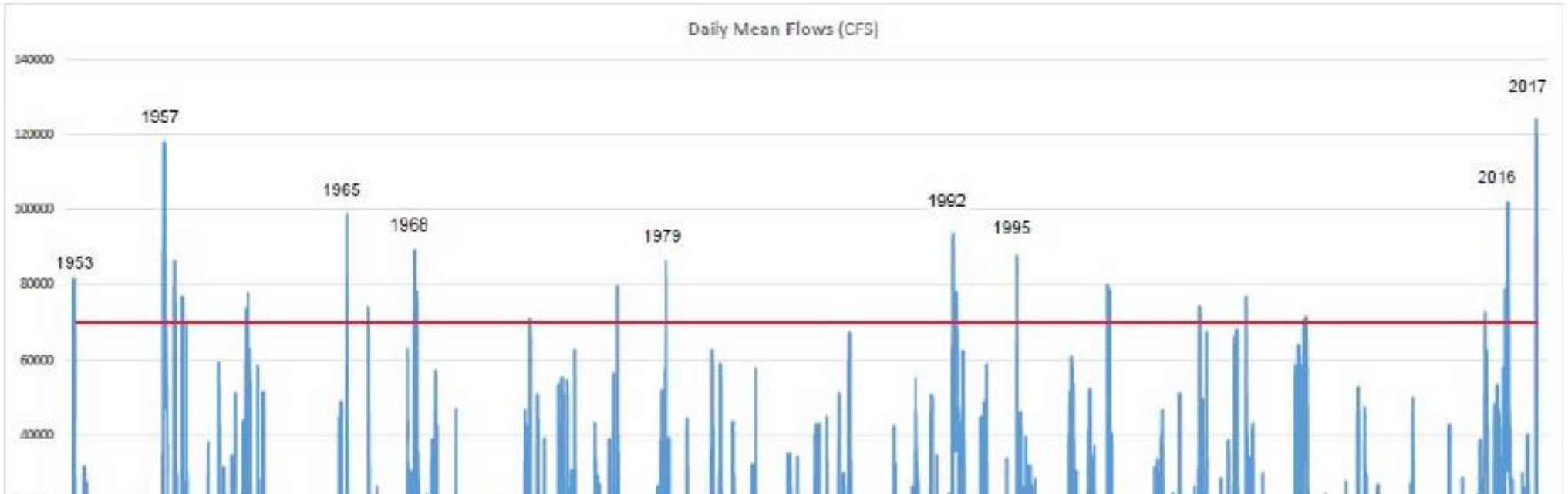




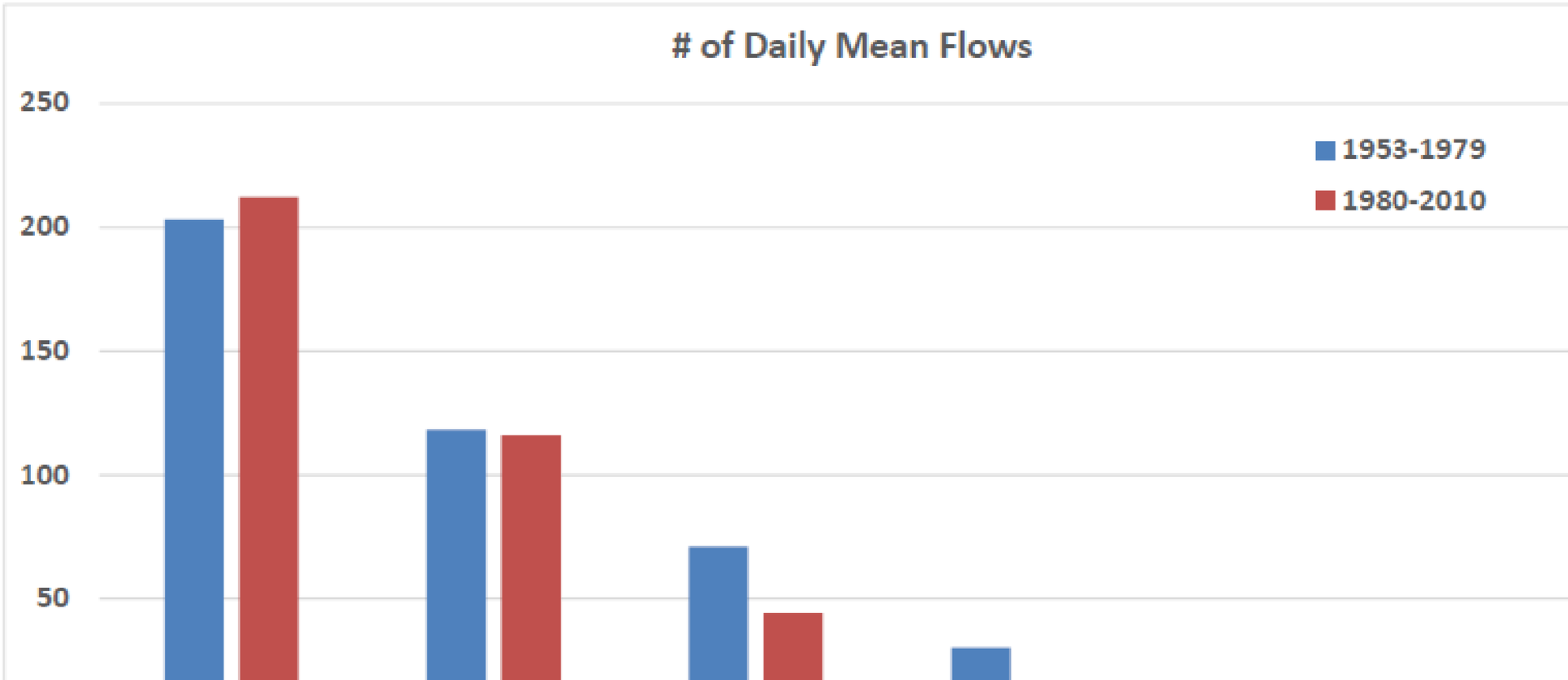
CROSS SECTIONS – HZ TOPO & FEMA



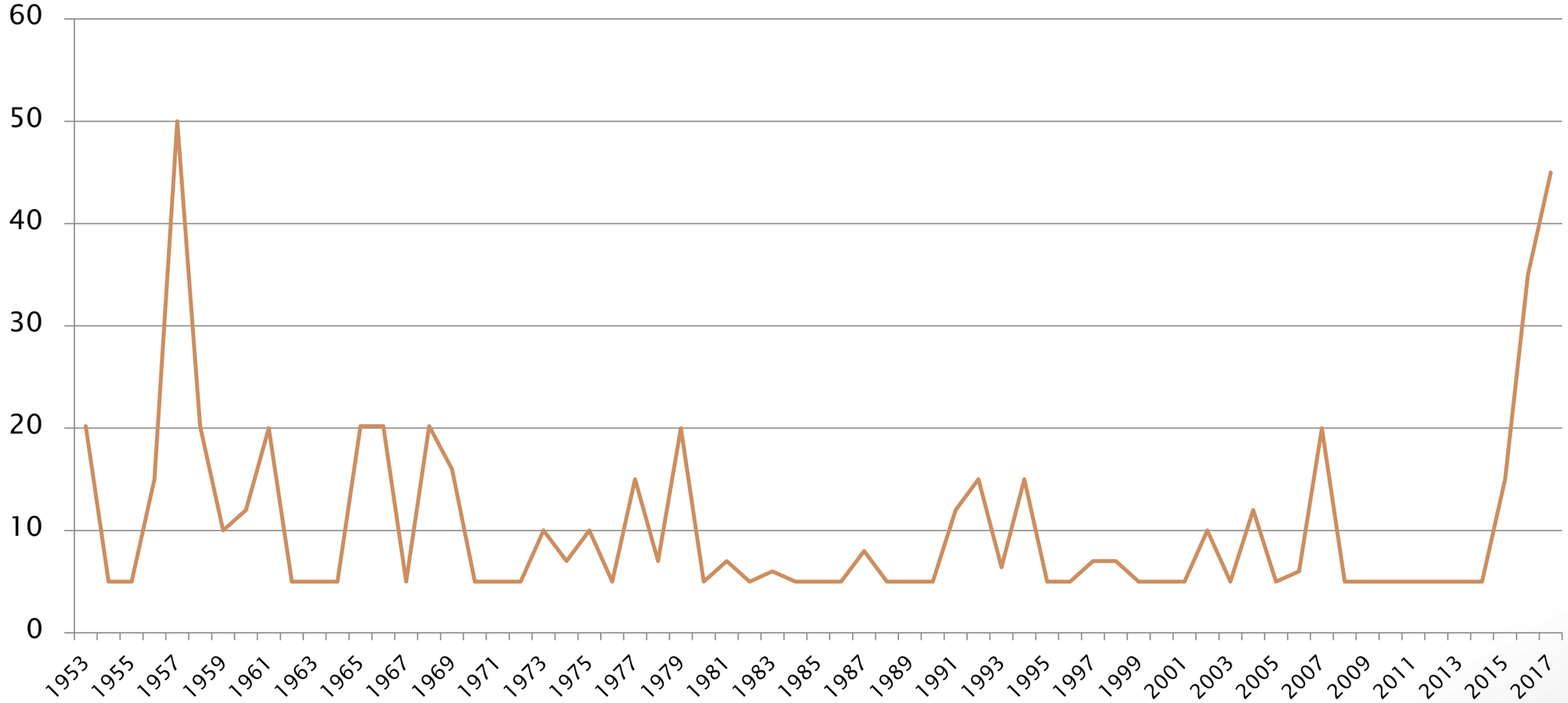
FLOW HISTORY OF THE BRAZOS RIVER



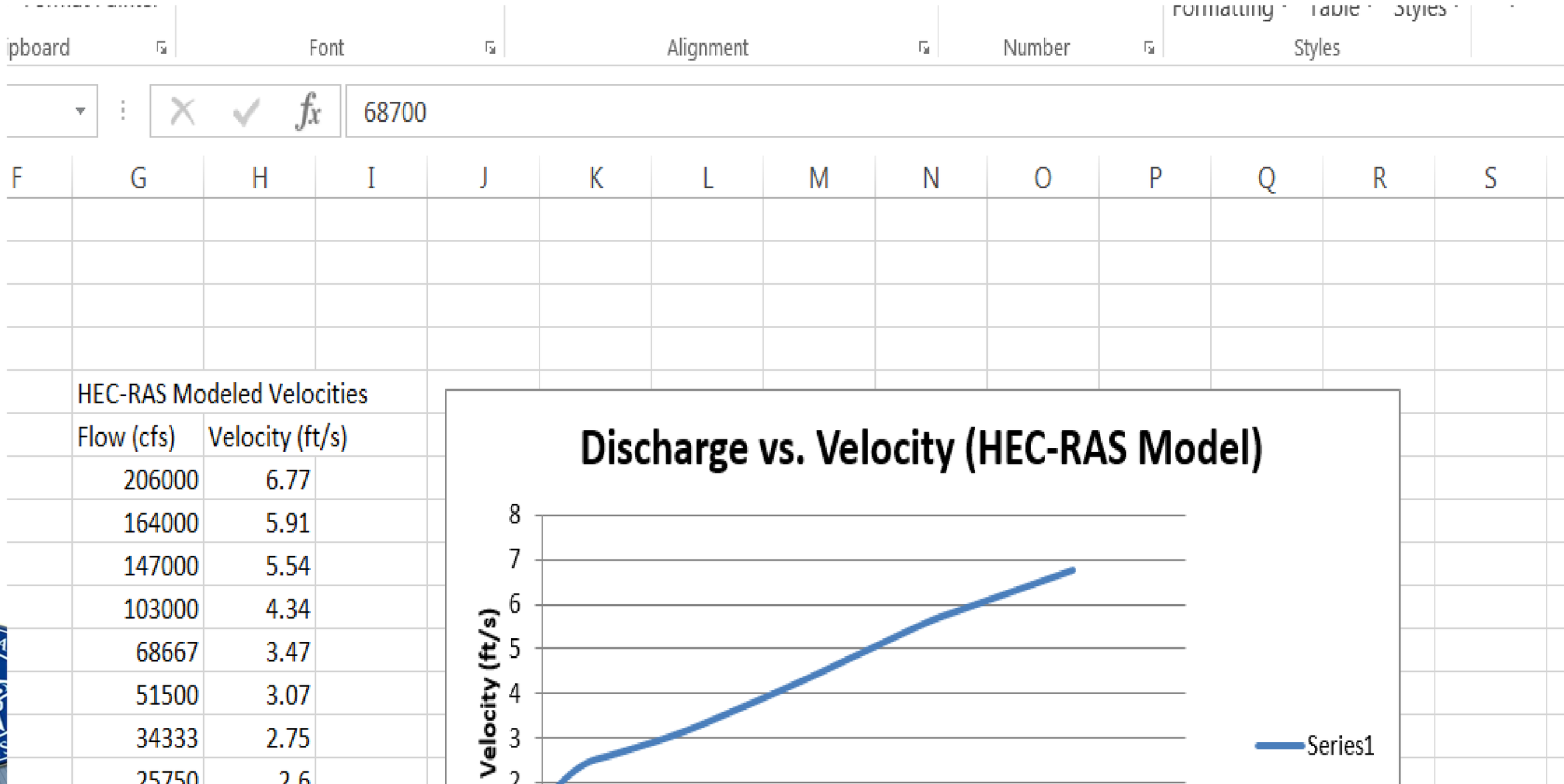
Number of Daily Mean Flows Occurrences



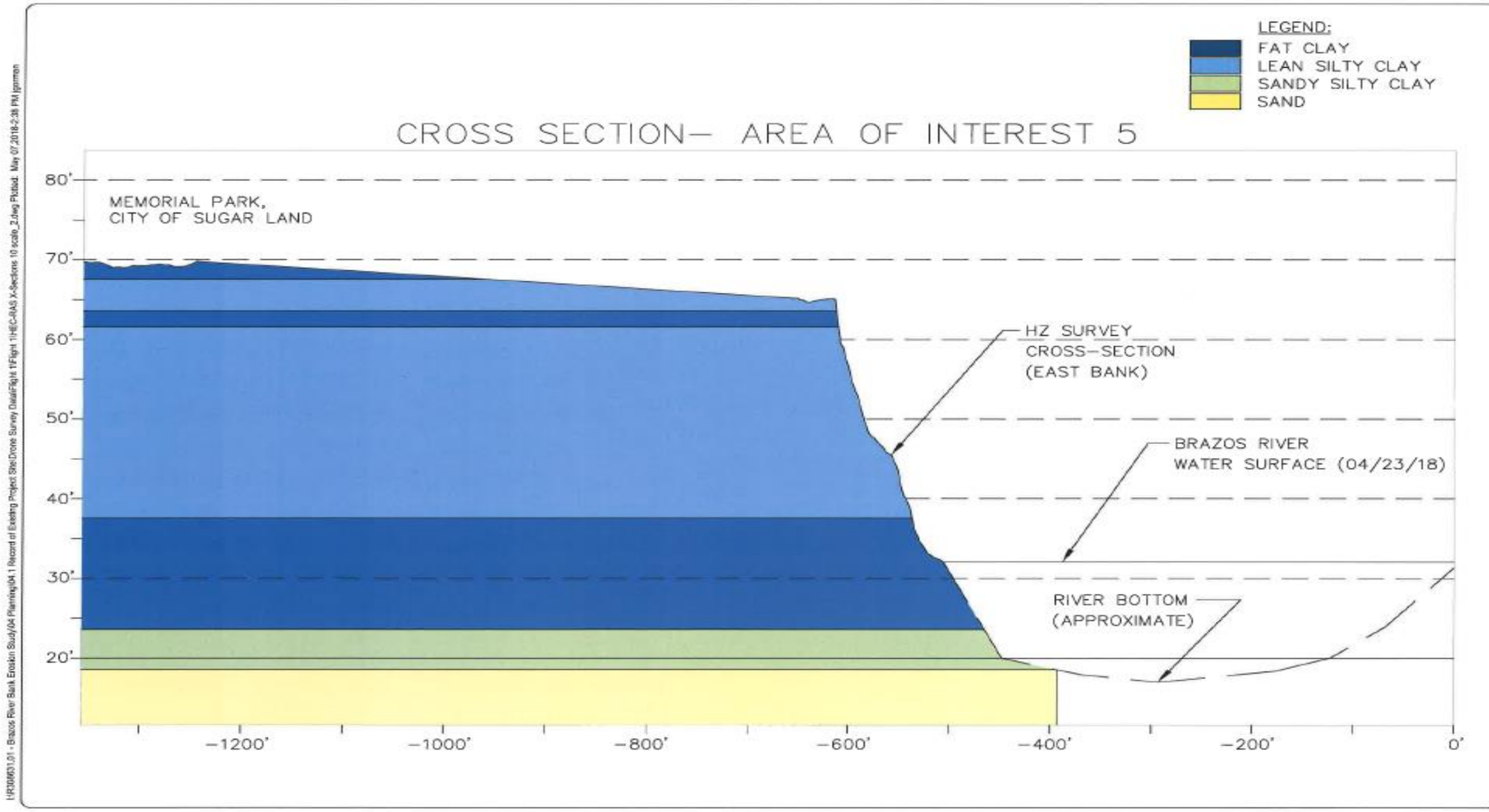
Estimated Migration Rate (ft/yr)



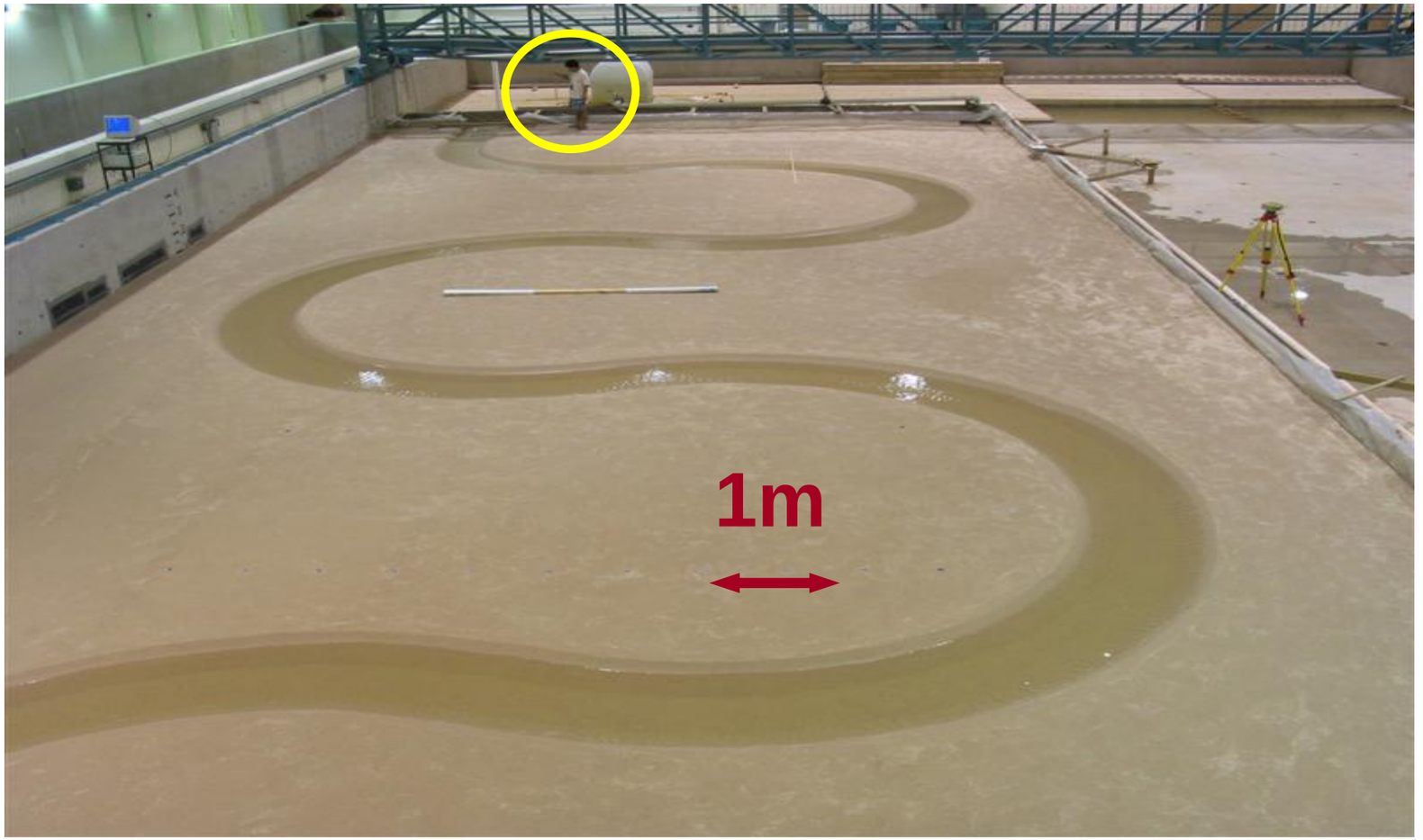
Correlating Flows to Velocity



SOIL PROFILE

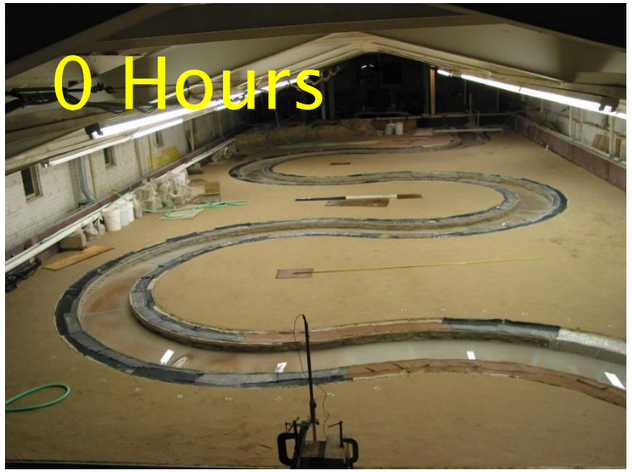


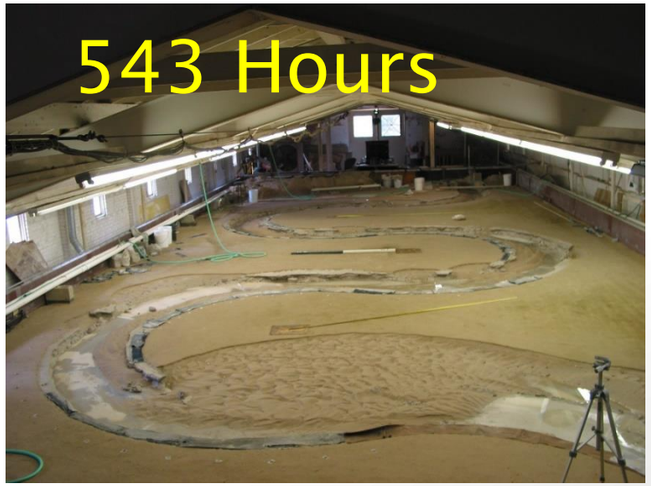
Large Scale Flume Tests in Sand



MEANDER EXPERIMENTS IN SAND AT TEXAS A&M UNIV

MEANDER EXPERIMENTS IN CLAY AT TEXAS A&M UNIV





OBSERVATION METHOD FOR MEANDER MIGRATION PREDICTION (OMM)

1. **Obtain the movement of the meander over years of migration**

2. **Obtain representative samples of the soil bank**

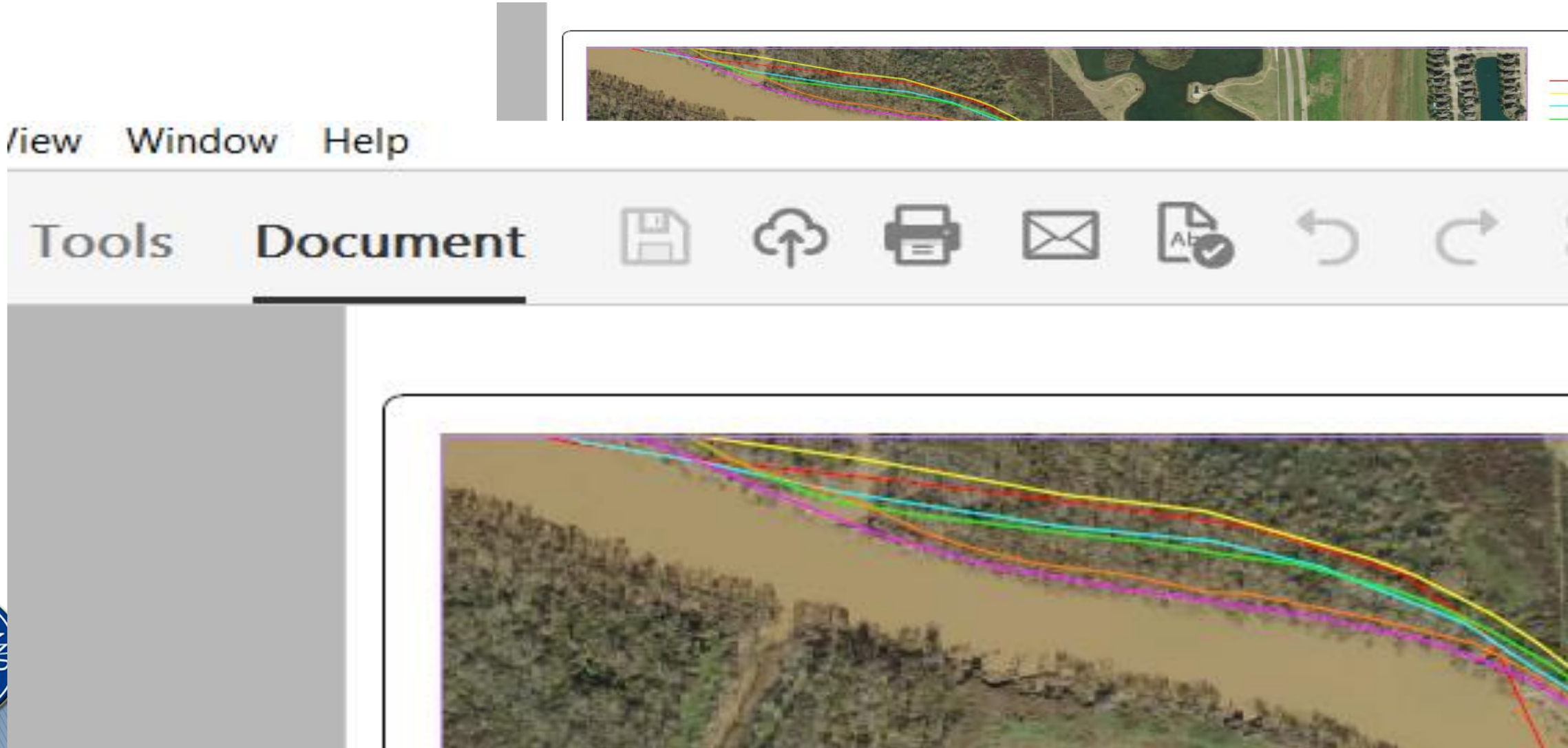
3. **Quantify the erodibility of the soil (EFA tests)**

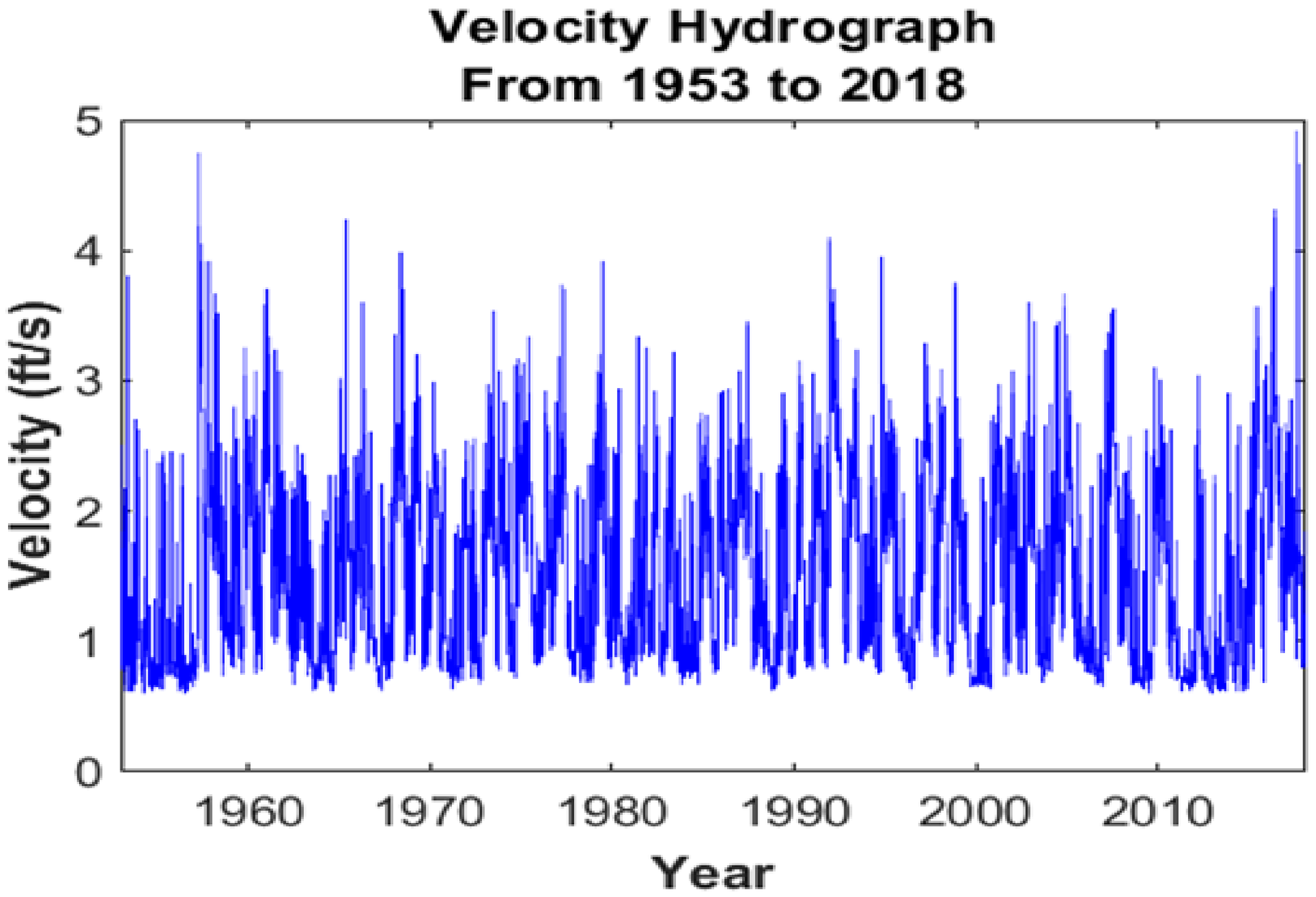
4. **Obtain velocity hydrograph for the period of observed migration**

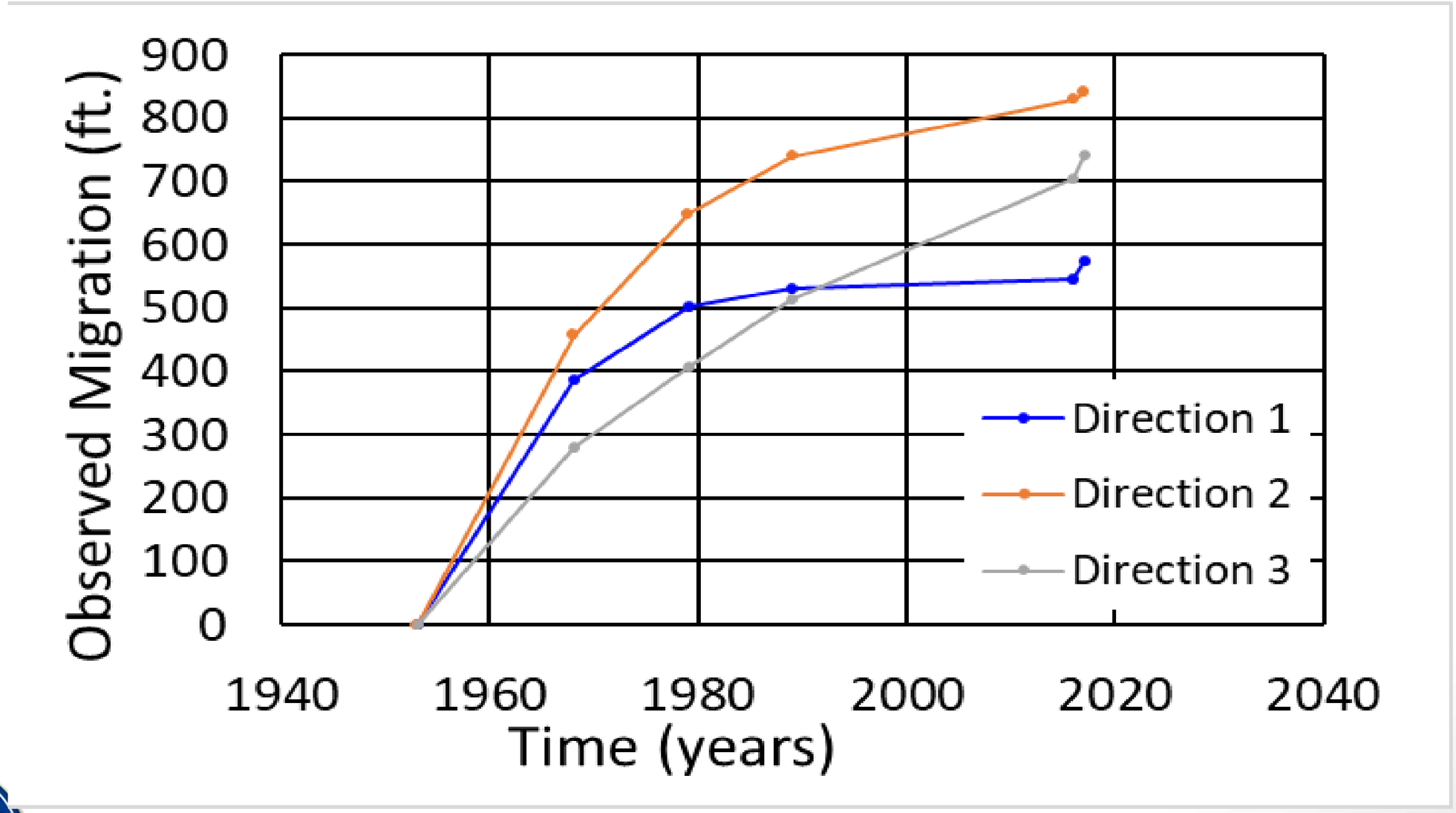
OBSERVATION METHOD FOR MEANDER MIGRATION PREDICTION (cont'd)

5. **Match observed past migration with predicted past migration using TAMU-OMM software and 3 and 4 above**
6. **Construct future hydrograph**
7. **Predict average future migration using the fitted soil erosion model obtained in 5 above**
8. **Option: perform probabilistic prediction to obtain probability that river meander will migrate to a certain position or further**

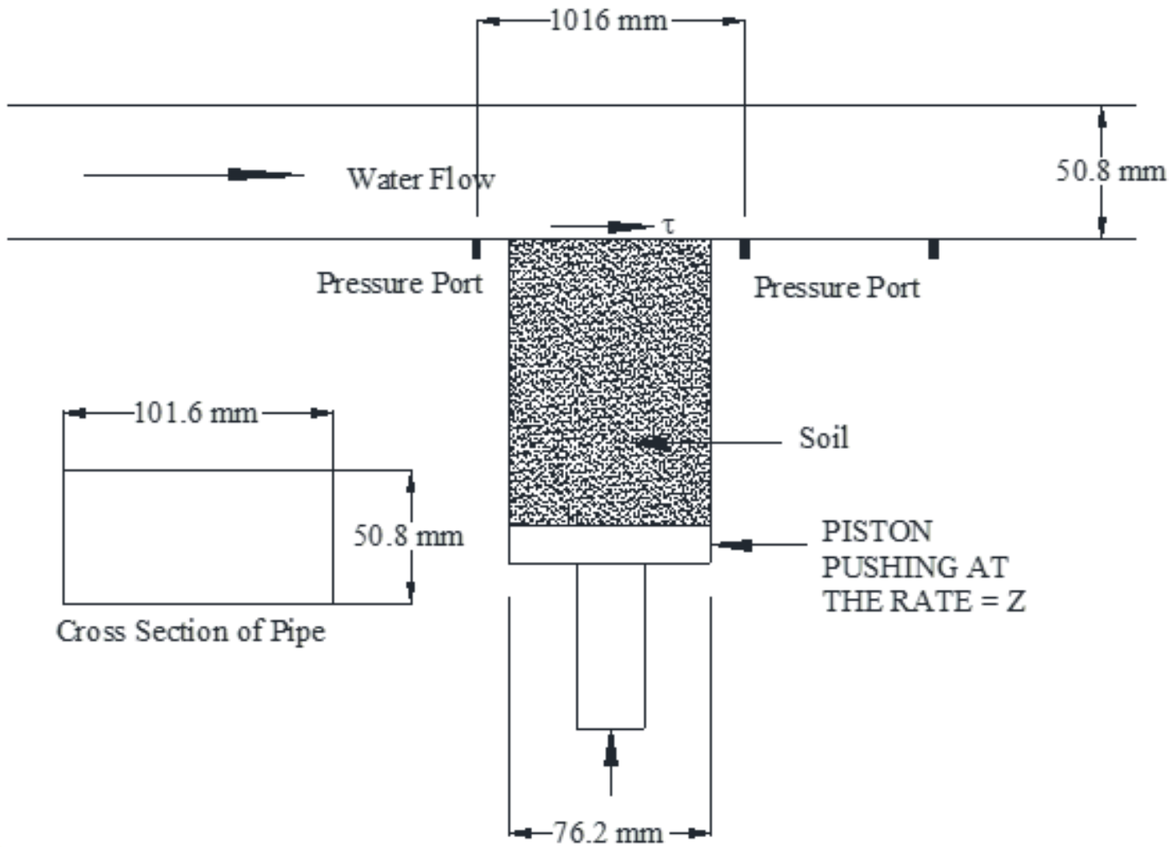
BRAZOS RIVER AT MEMORIAL PARK



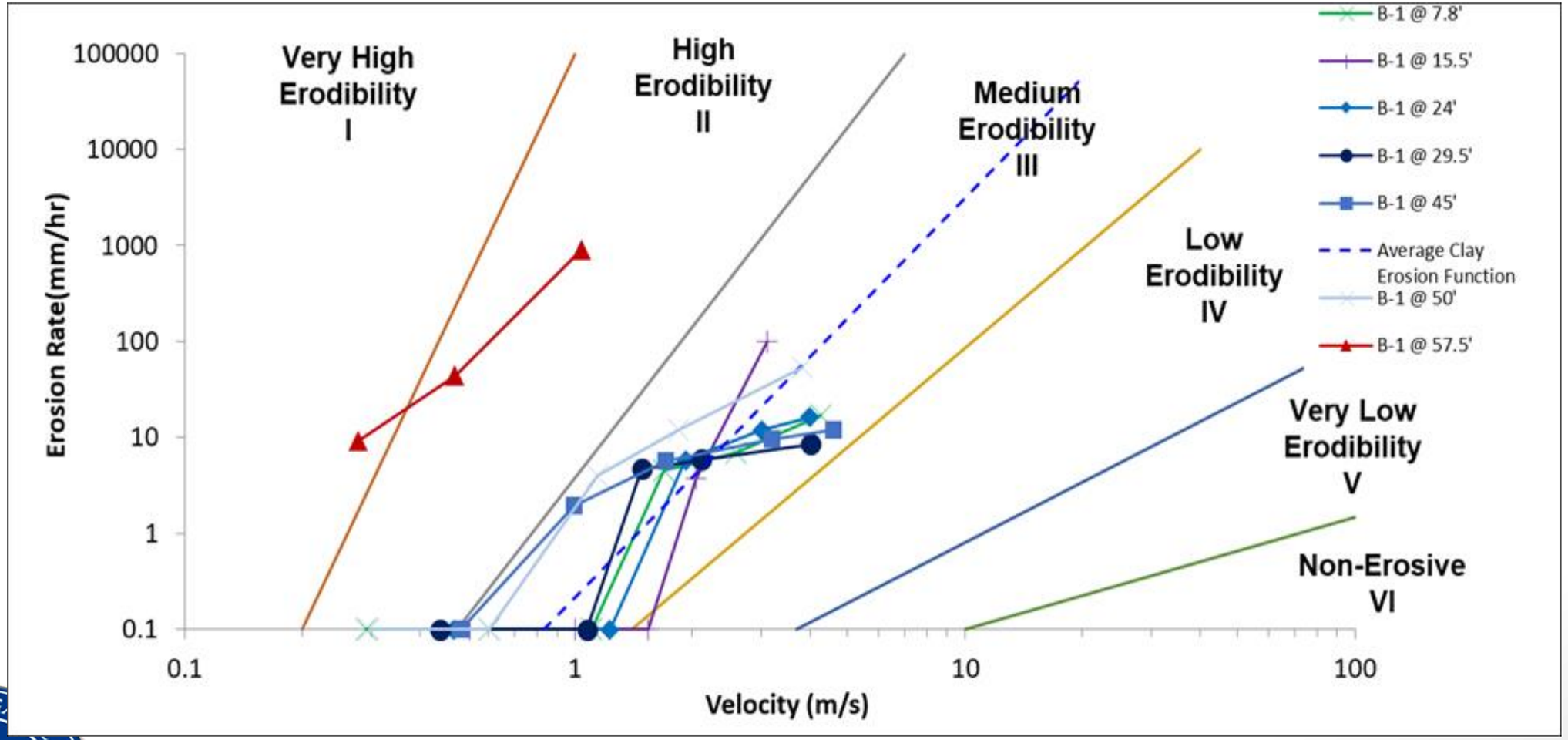

Velocity Hydrograph
From 1953 to 2018
Velocity (ft/s)
0
1
2
3
4
5
1960
1970
1980
1990
2000
2010
Year


Observed Migration (ft.)
900
800
700
600
500
400
300
200
100
0
1940
1960
1980
2000
2020
2040
Time (years)
Direction 1
Direction 2
Direction 3

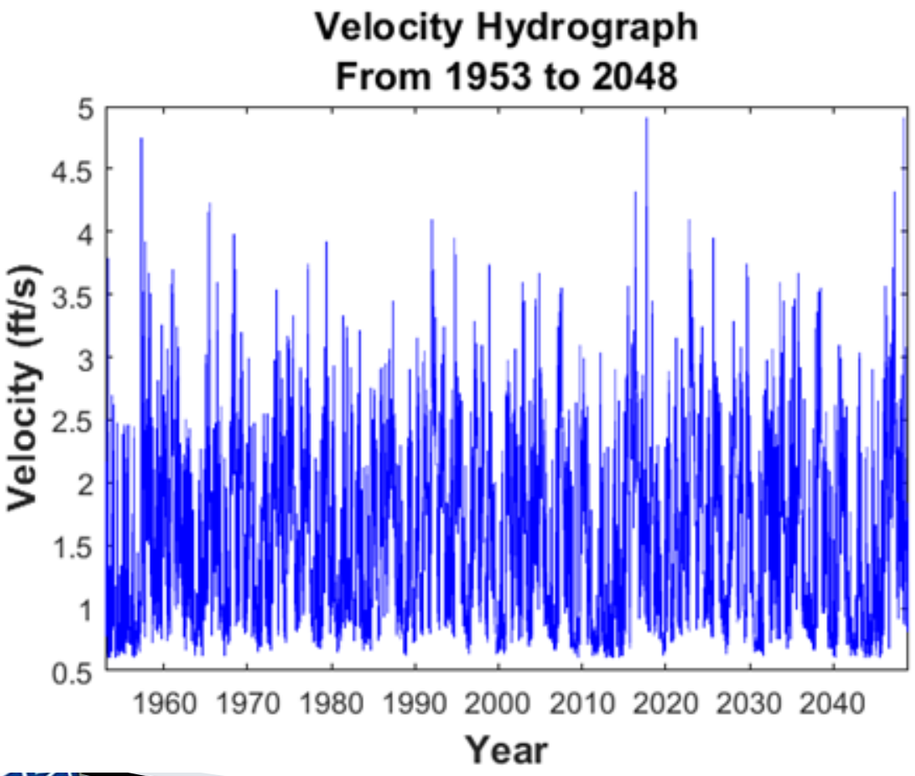
EFA - EROSION FUNCTION APPARATUS

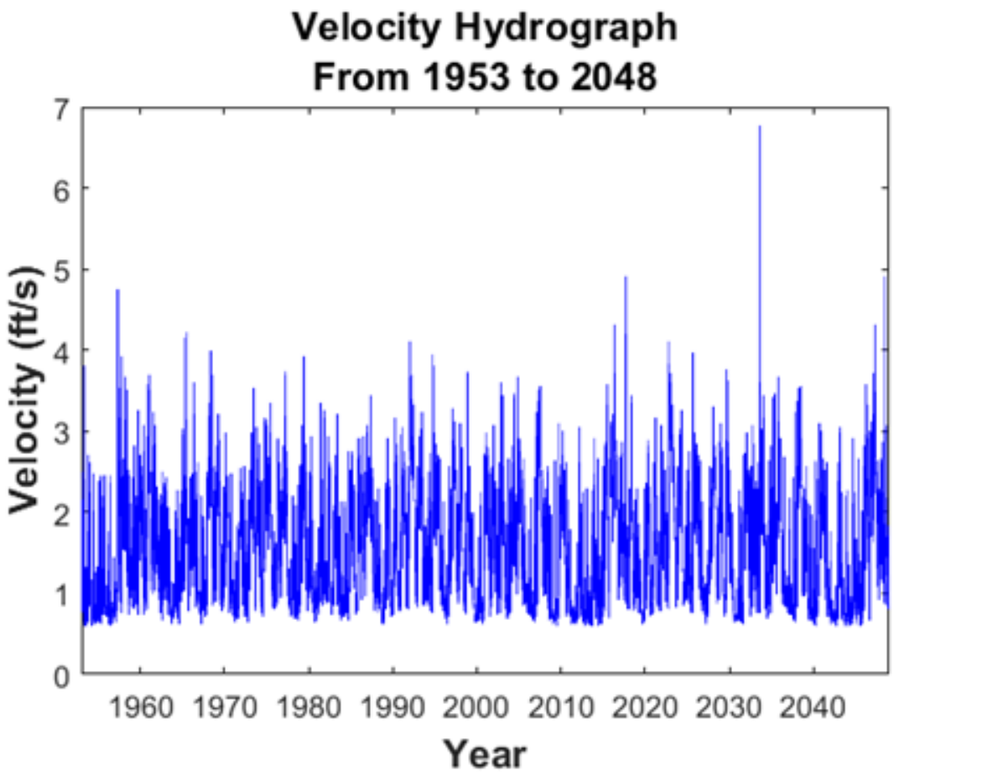


EFA TESTS RESULTS

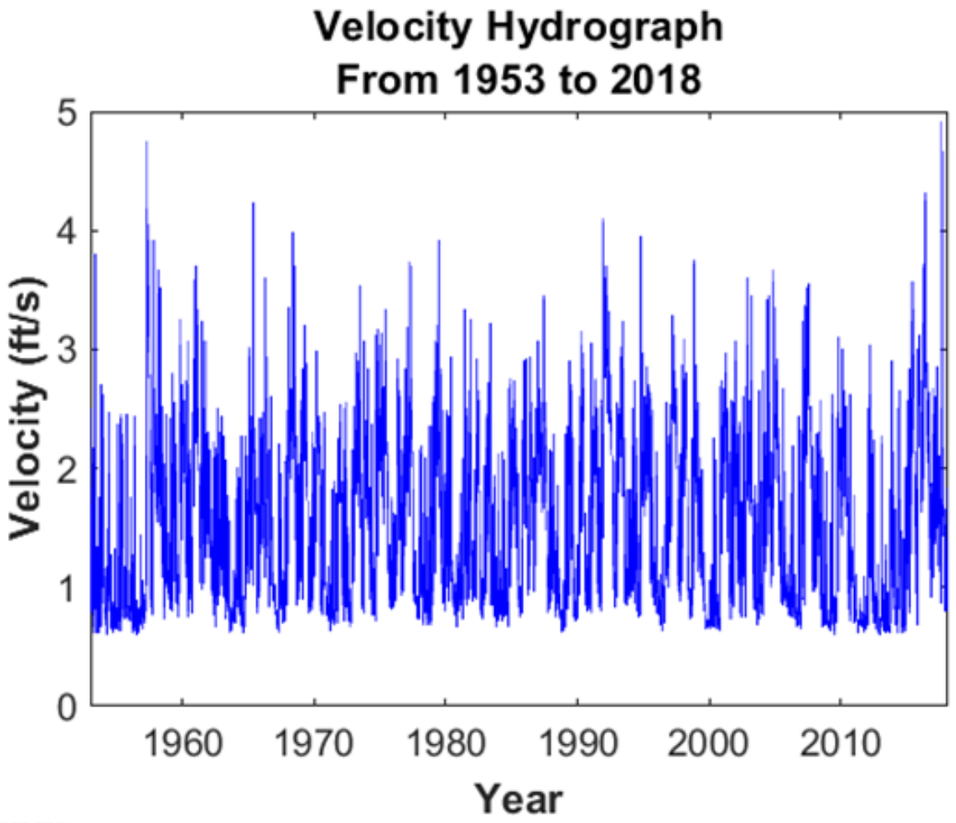


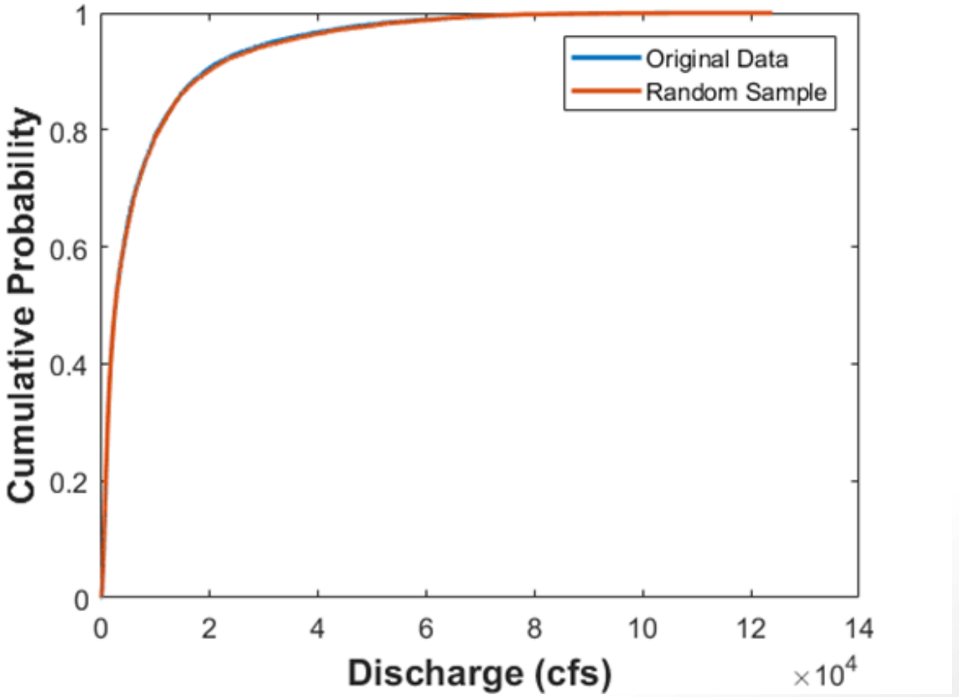
CREATING A FUTURE HYDROGRAPH
DETERMINISTIC APPROACH



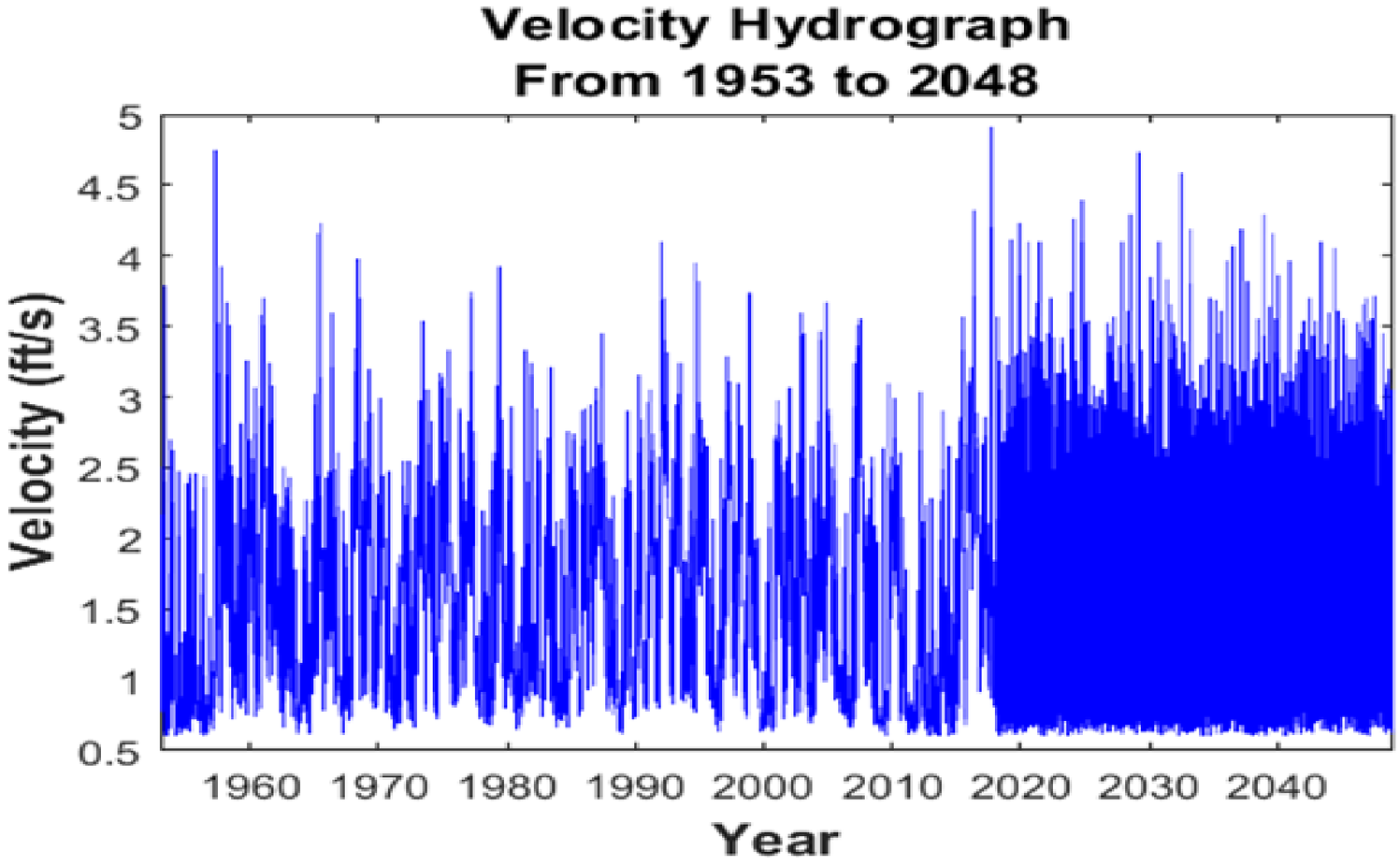


CREATING A FUTURE HYDROGRAPH
PROBABILISTIC APPROACH





EXAMPLE OF PROBABILISTIC FUTURE HYDROGRAPH



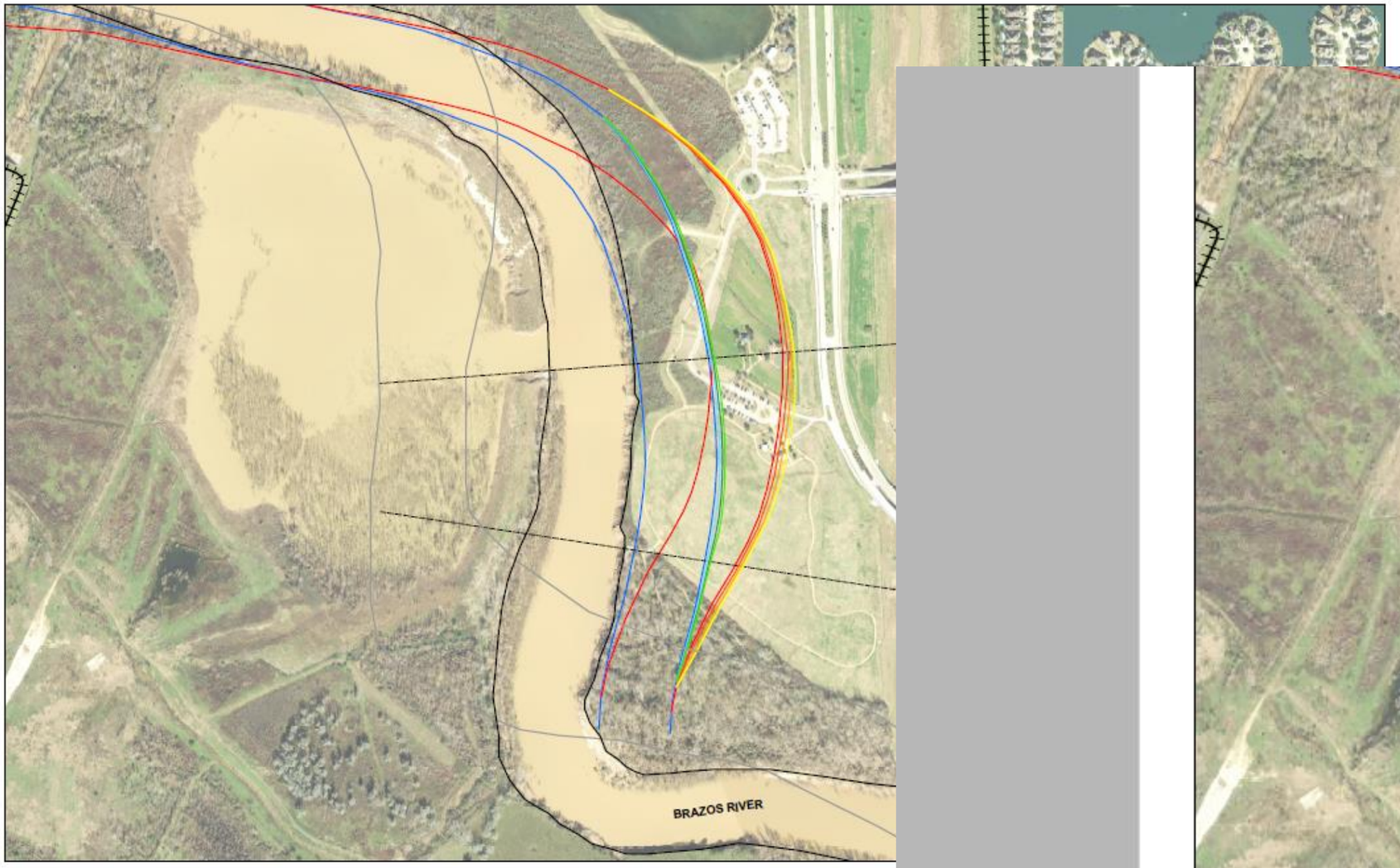
PROBABILISTIC PREDICTION OF RIVER MIGRATION

Prediction 1 best matches 1953 to 1980

Prediction 2 best matches 1980 to 2018

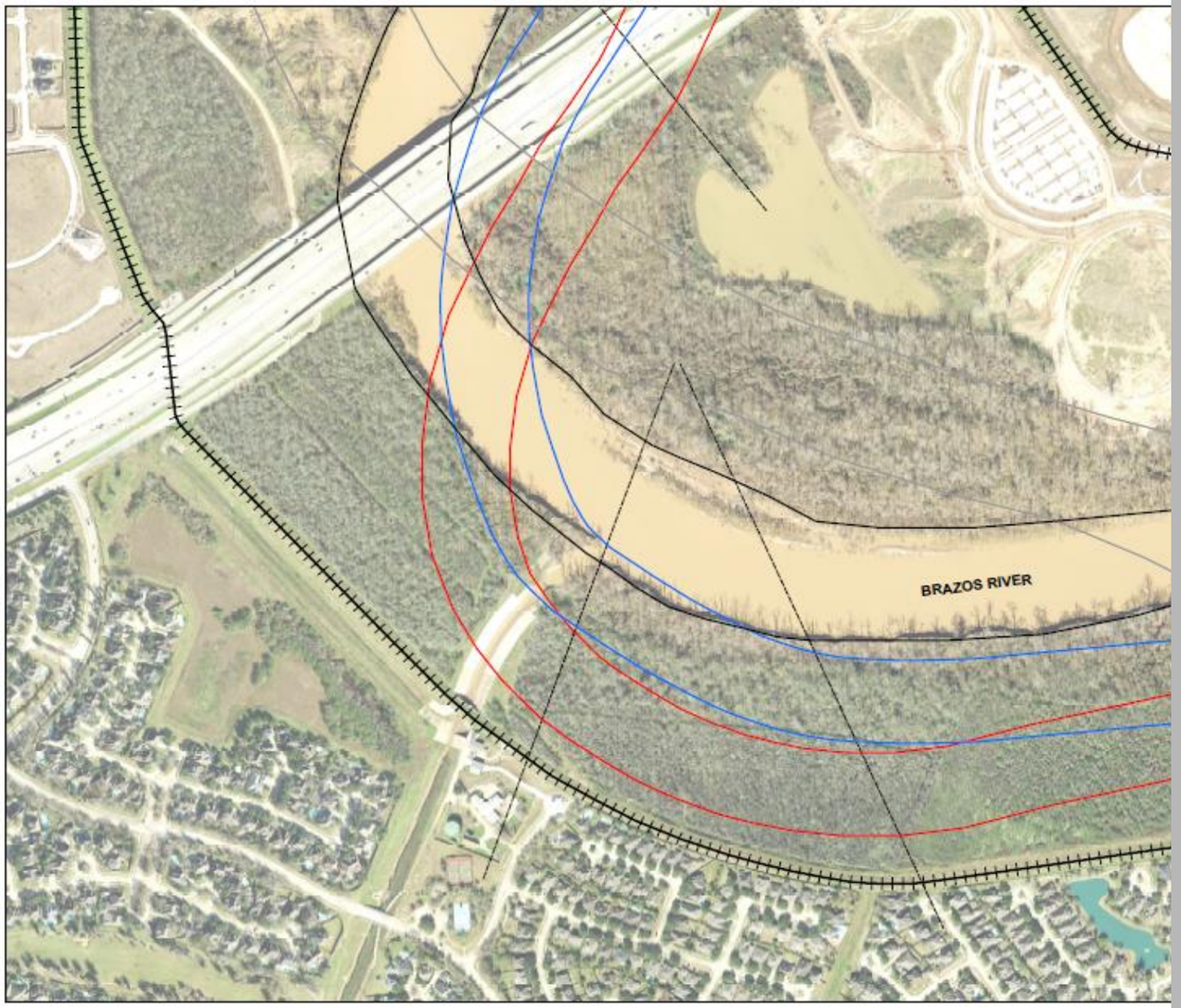
	Exceedance Probability	M (ft.)
Prediction 1	0.5	641.93
	0.1	662.10
	0.01	678.56
	0.001	690.58
Prediction 2	0.5	168.75
	0.1	174.32
	0.01	178.86
	0.001	182.17

Probable positions of the Brazos River bank in 2048



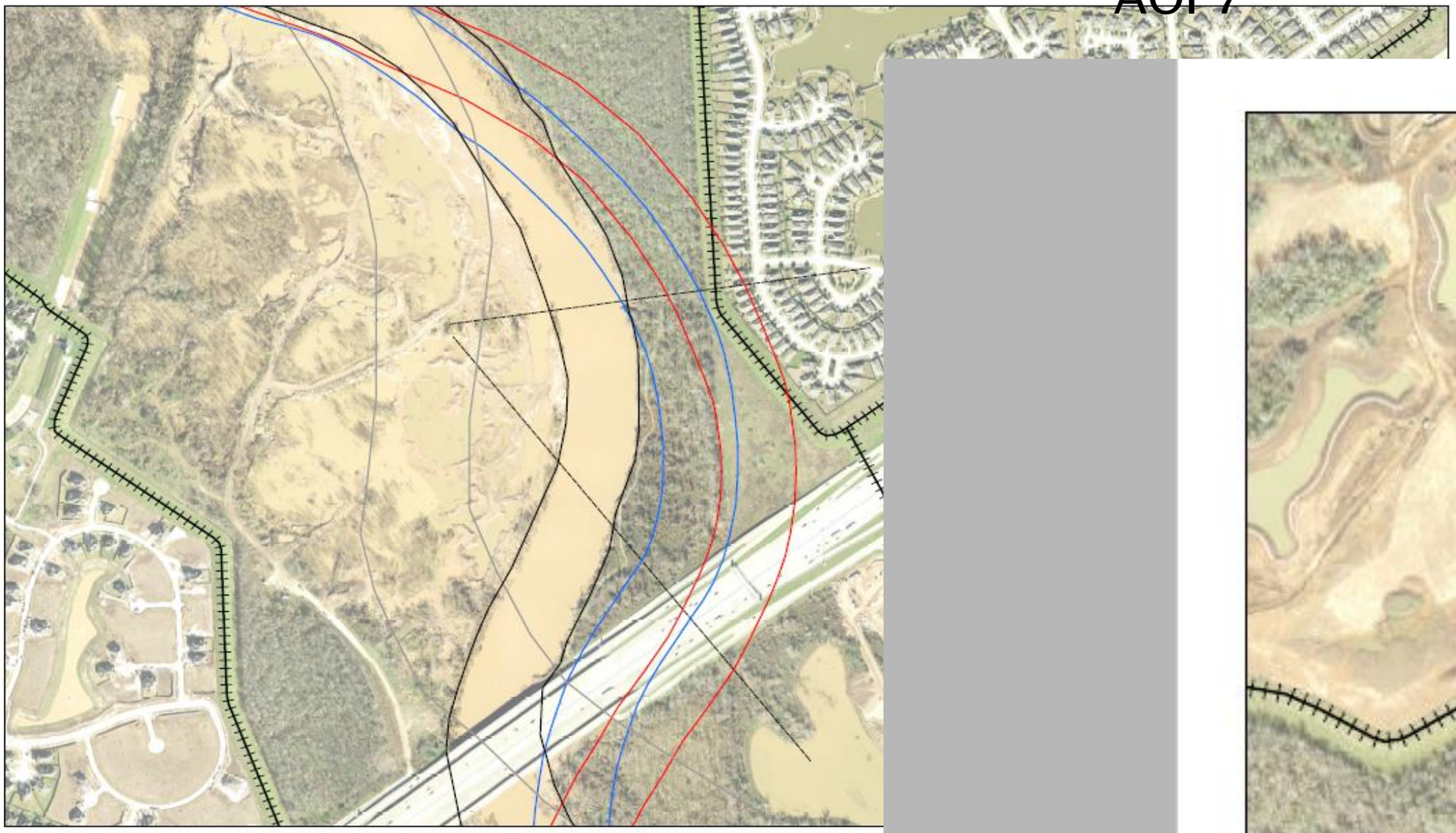
Probable positions of the Brazos River bank in 2048

AOI 6

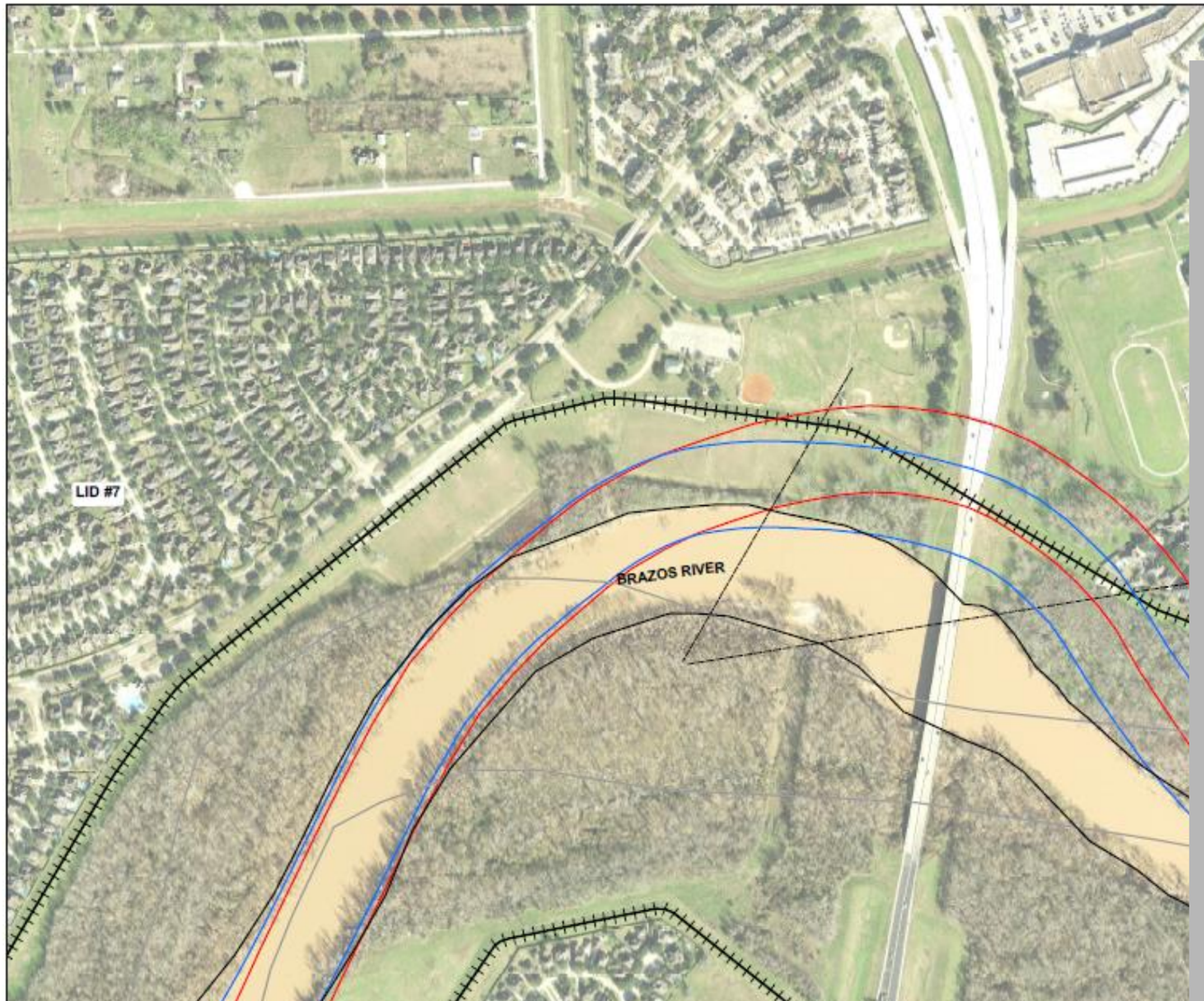


Probable positions of the Brazos River bank in 2048

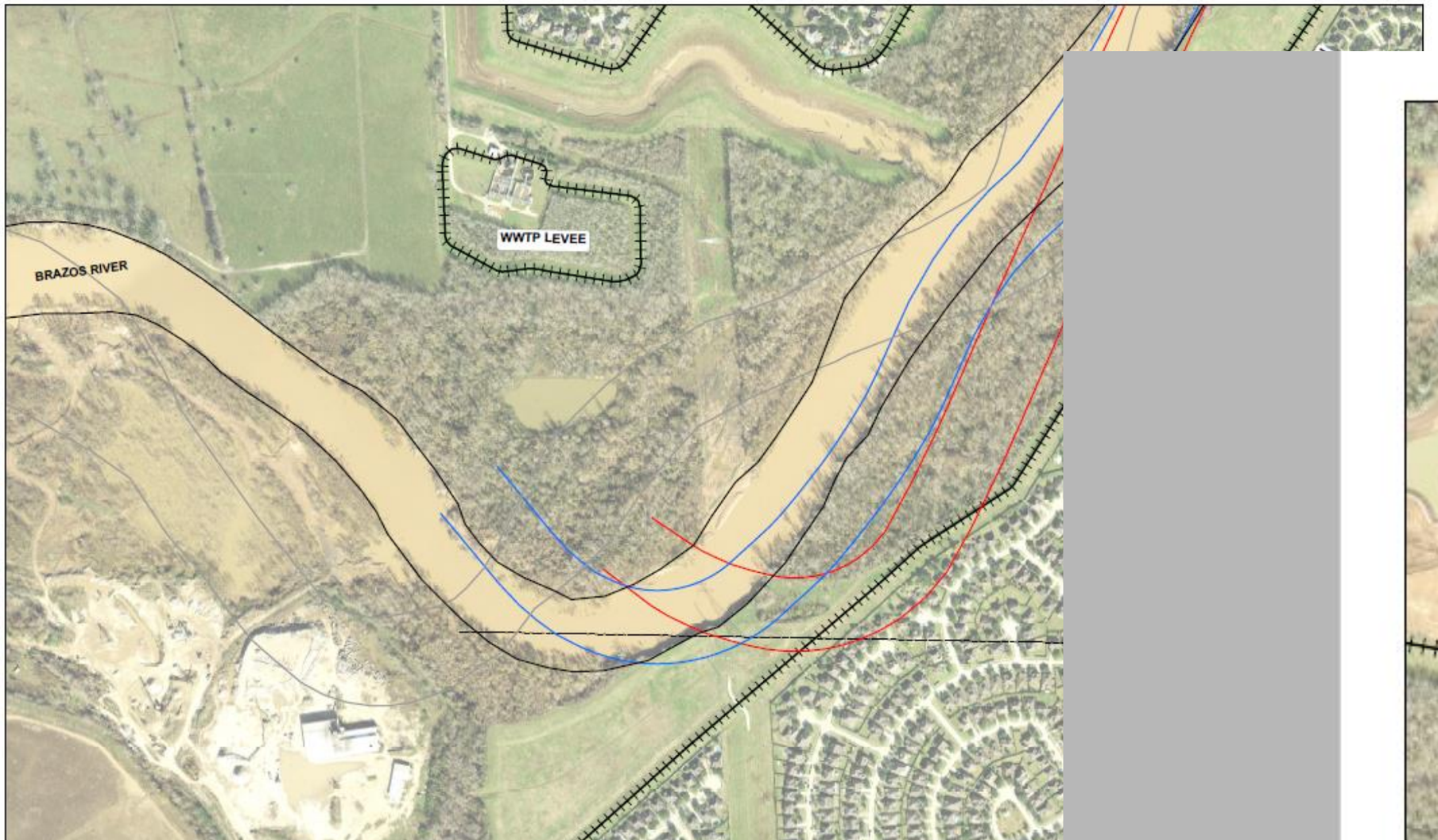
AOI 7



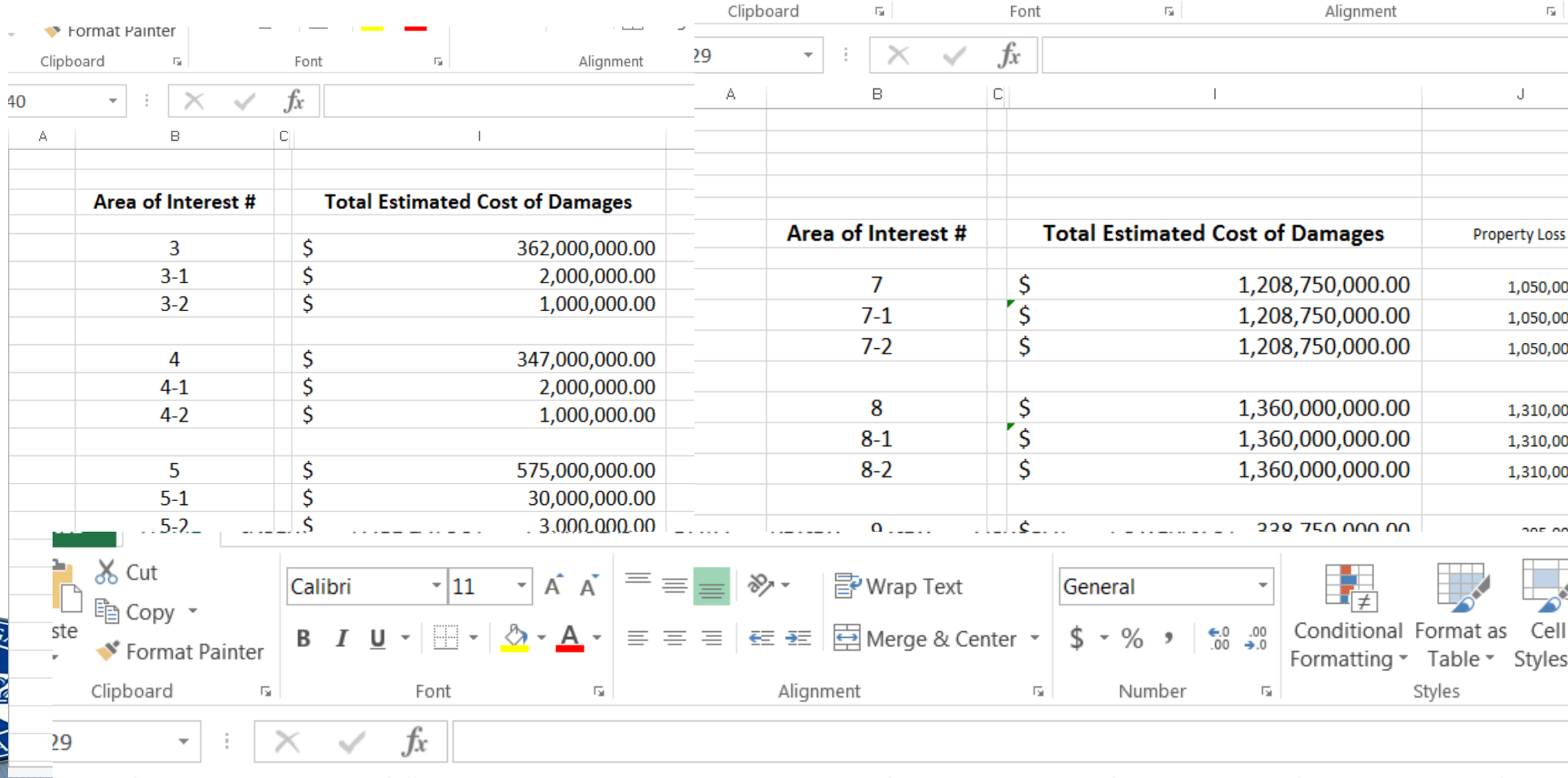
Probable positions of the Brazos River bank in 2048



Probable positions of the Brazos River bank in 2048



Value of Consequences ($)

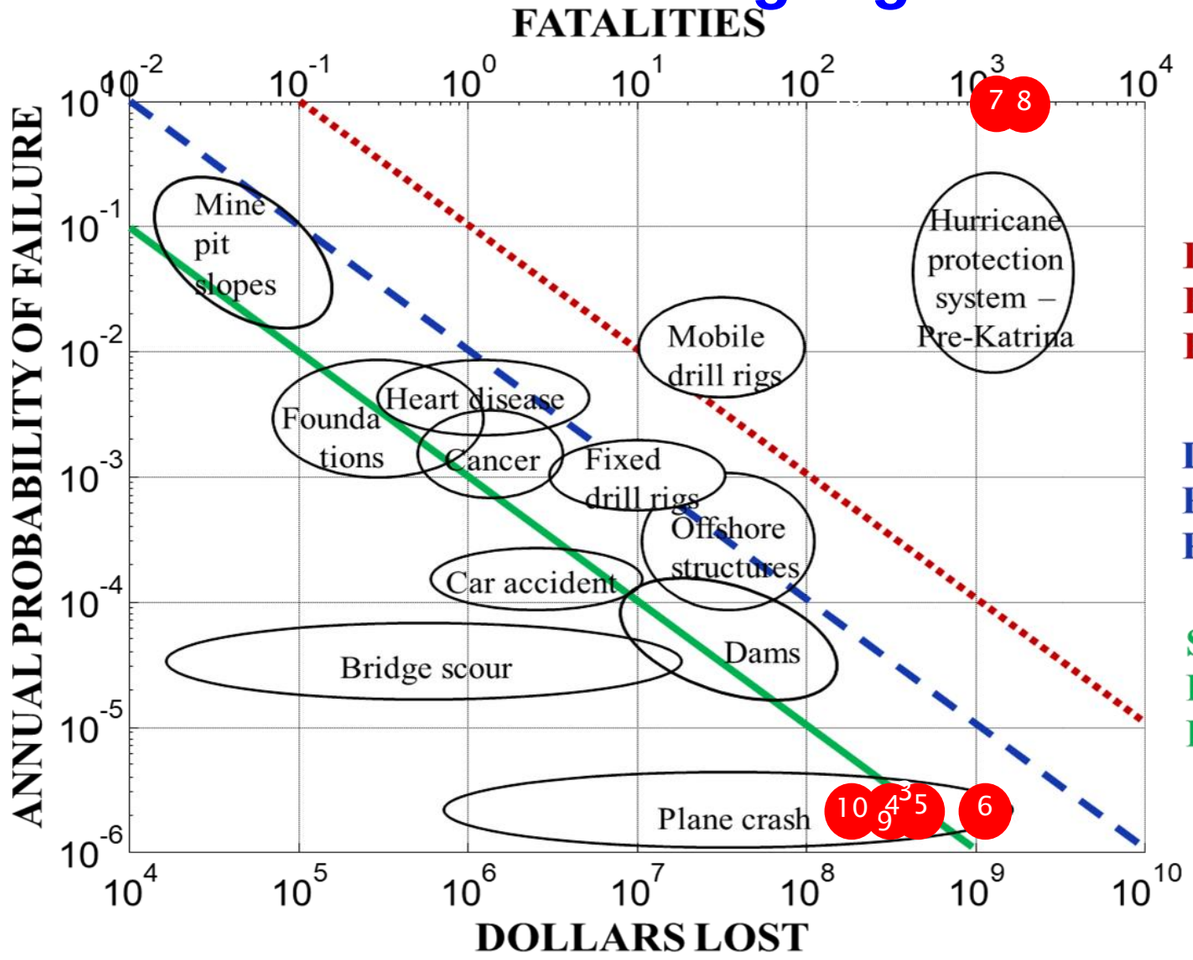


Area of Interest #	Total Estimated Cost of Damages
3	$ 362,000,000.00
3-1	$ 2,000,000.00
3-2	$ 1,000,000.00
4	$ 347,000,000.00
4-1	$ 2,000,000.00
4-2	$ 1,000,000.00
5	$ 575,000,000.00
5-1	$ 30,000,000.00
5-2	$ 3,000,000.00

Area of Interest #	Total Estimated Cost of Damages	Property Loss
7	$ 1,208,750,000.00	1,050,00
7-1	$ 1,208,750,000.00	1,050,00
7-2	$ 1,208,750,000.00	1,050,00
8	$ 1,360,000,000.00	1,310,00
8-1	$ 1,360,000,000.00	1,310,00
8-2	$ 1,360,000,000.00	1,310,00

$R = P \times C$ $\log P = -\log C + \log R$

Therefore P vs. R on log log scale is a line



Reach Levee

Dotted line
Risk = 0.1 Fat/yr
Risk = 100000$/yr

Dashed line
Risk = 0.01 Fat/yr
Risk = 10000$/yr

Solid line
Risk = 0.001 Fat/yr
Risk = 1000$/yr

CREDITS: Whitman 1984, Marr 1995, Christian, Baecher 2003, Briaud et al. 2013, Gilbert 2016

Potential Funding Sources

- **USACE CAP Program**
  - **Emergency Streambank & Shoreline Protection (Section 14)**
  - **Flood Damage Reduction Projects (Section 205)**
- **FEMA Hazard Mitigation Grant Program (Section 404)**

Possible Remediation Alternatives

- **Structural – sheet piling**
- **Erosion Protection – sloped/terraced banks with rock protection**
- **Bendway weirs**
- **Diversion channels**

NEXT STEPS

- Coordinate with Levee Districts and the County to establish a monitoring program for river bank erosion risk and mitigation
- Develop monitoring program for meander migration and upstream development that would affect the City
- Develop remediation alternatives
- Investigate regulatory permitting requirements
- Submit to TX General Land Office – Potential Hurricane Harvey Research Grant Opportunities (COSL+HZ+TAMU)
- Pursue funding possibilities with USACE and TDEM
- Possibly submit to National Science Foundation for the Coastlines and People Research Grant Program (COSL+HZ+TAMU)

QUESTIONS