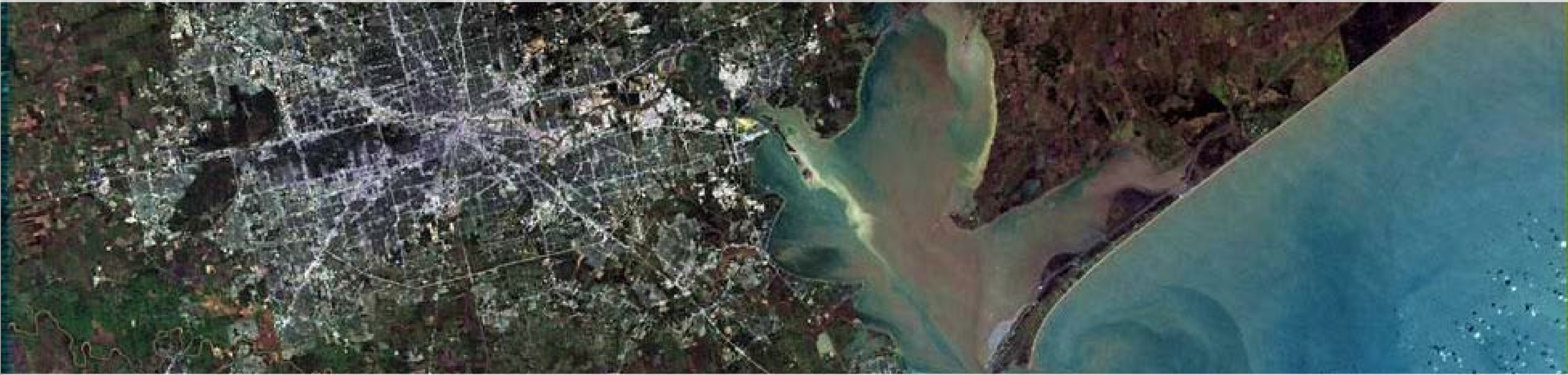
A Five-Year Observation on the Spatial and Temporal Distributions of PFAS in Galveston Bay, TX, USA



Yina Liu

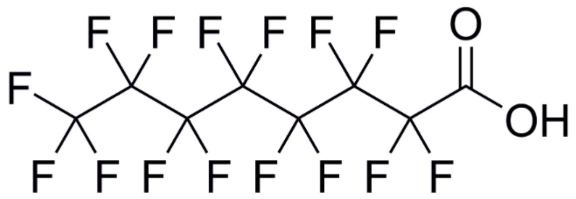
Michael Shields, Sangeetha Puthigai, Xiaolei Xu, Yaseen Zaky, and Shari Yvon-Lewis

TEXAS A&M UNIVERSITY
Oceanography

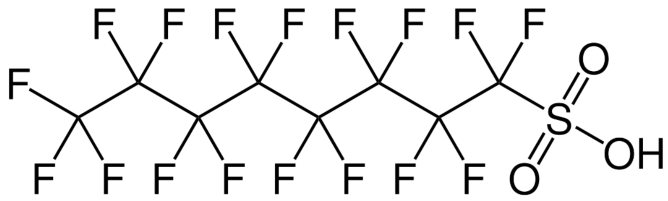
TEXAS A&M UNIVERSITY
Geochemical & Environmental Research Group

Background on PFAS

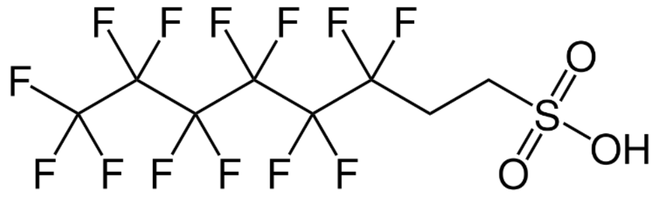
- Per- and polyfluoroalkyl substances (PFAS) are a group of man-made chemicals (>15,000 known chemicals)
- 3 key groups are measured in this project: perfluorinated carboxylic acids (PFCAs), perfluorinated sulfonic acids (PFSAs), and fluorotelomer sulfonates (FTS)



Perfluorooctanoic acid(PFOA)

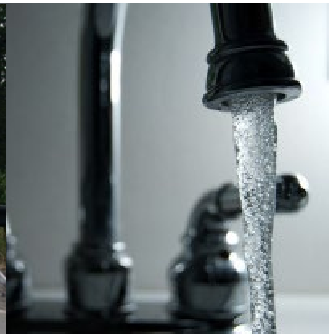


Perfluorooctanesulfonic acid (PFOS)

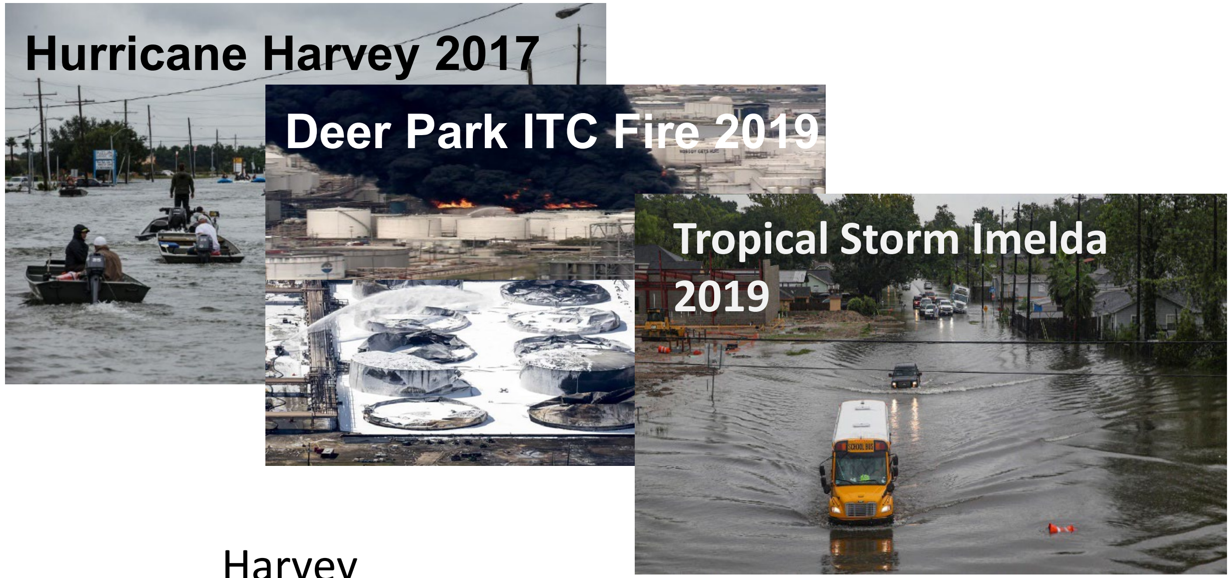


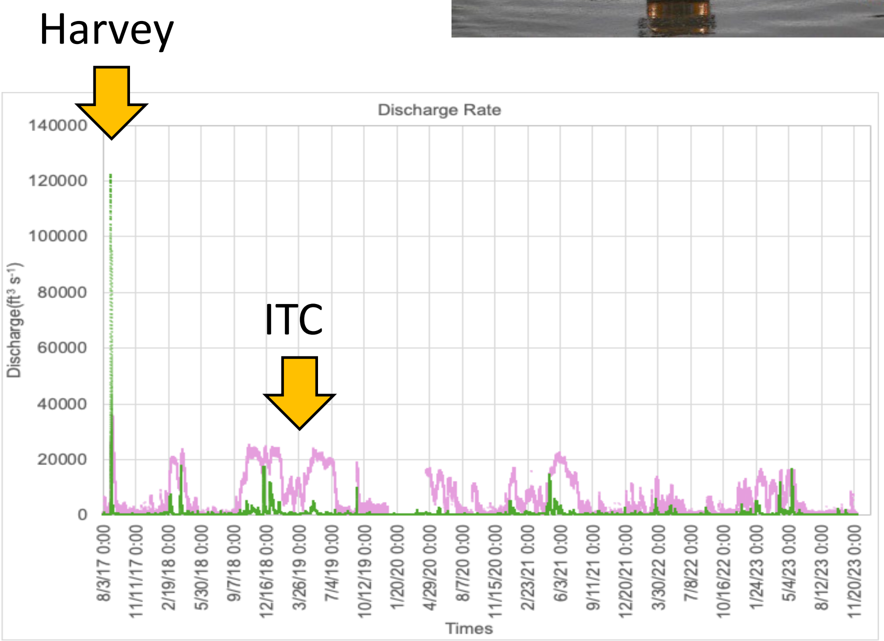
6:2 fluorotelomer sulfonic acid (6:2 FTS)

- Produced in the US since the 1940s for different consumer products
- Bioaccumulative in humans and marine life, and potentially toxic



Emerging Contaminants in Galveston Bay



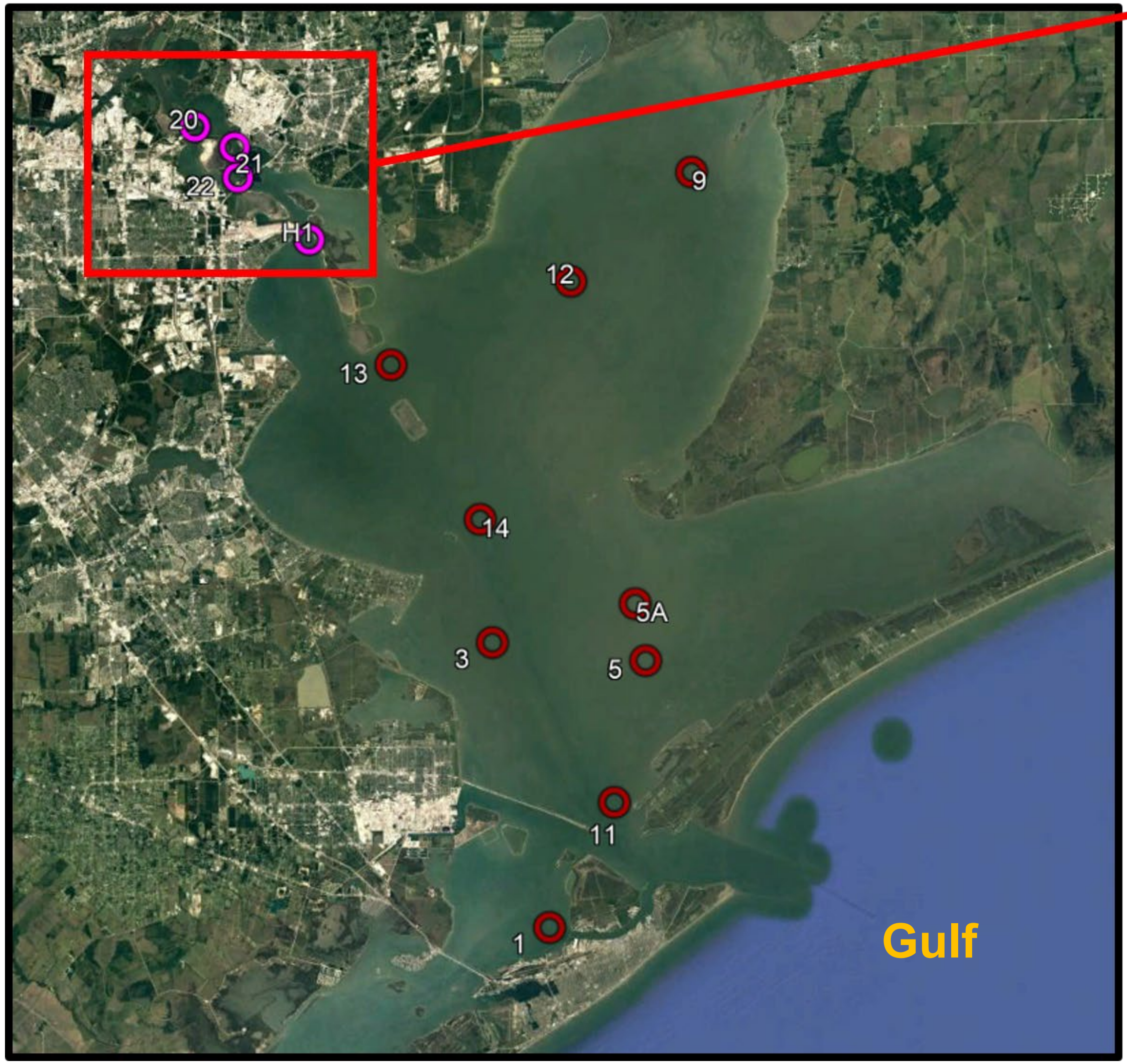


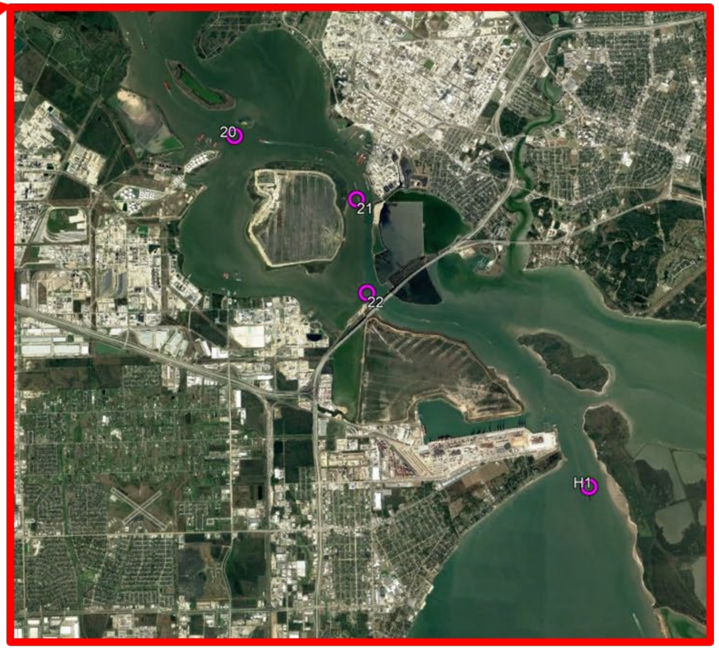
What can we learn about the Bay's resiliency towards extreme conditions that contribute to emerging contaminants?

- ❑ Are extreme events affecting Galveston Bay's water quality?
- ❑ How long does it take for the Galveston Bay system to recover?
- ❑ Monitoring of traditional contaminants have led to effective policies and treatments, but what about **emerging contaminants**?
- ❑ We monitored 30 PFAS.
- ❑ The first time series of PFAS in Texas.

Galveston Bay Observation Cruises

San Jacinto River **Trinity River** **Houston Ship Channel**





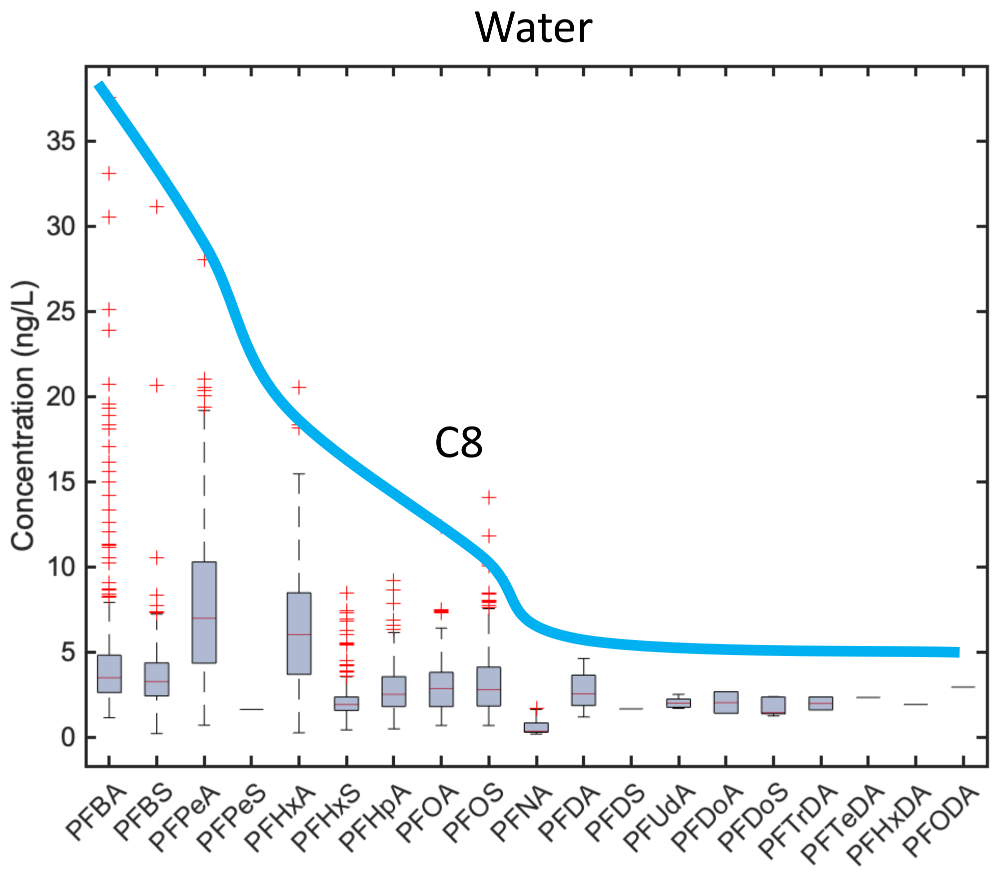
Quarterly Occupied Stations

Houston Ship Channel Stations Added Since March 2019

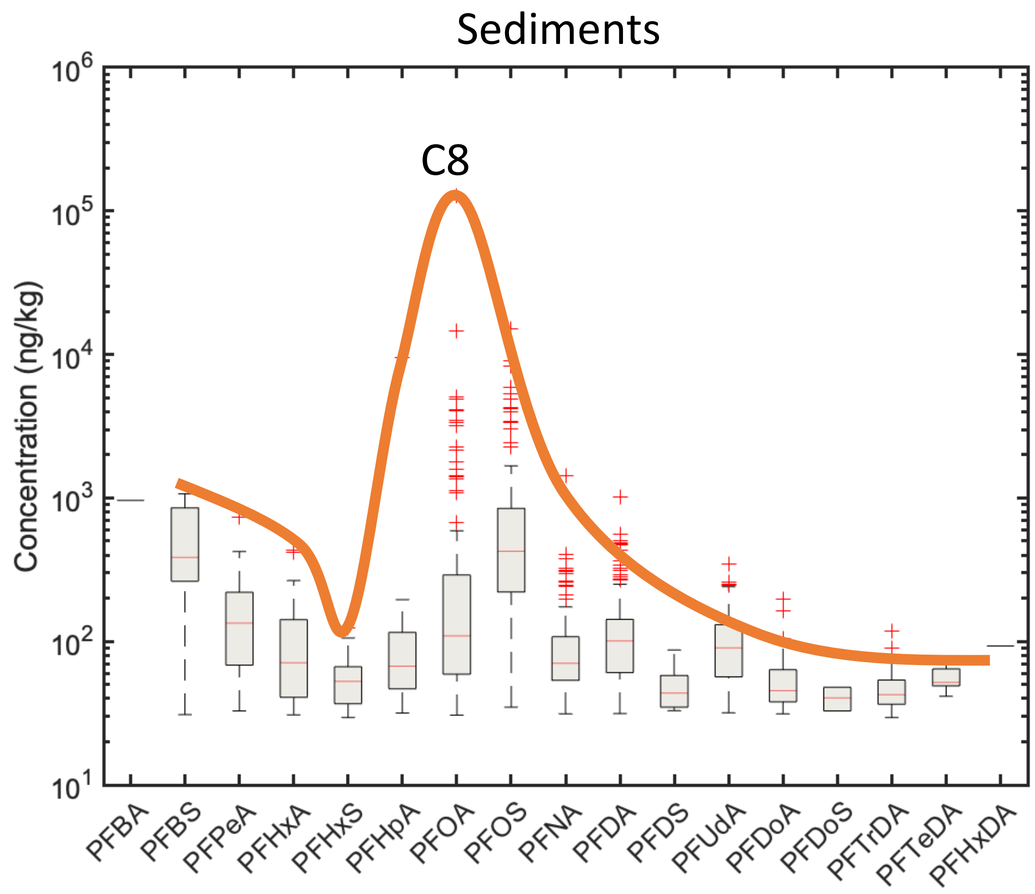
Sediment grab samples
Water from surface and bottom

Molecular Weight Factors?

Data excluded ITC fire



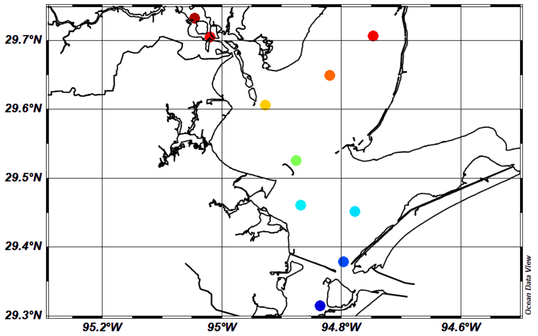
Mostly <C8 PFAS found in water

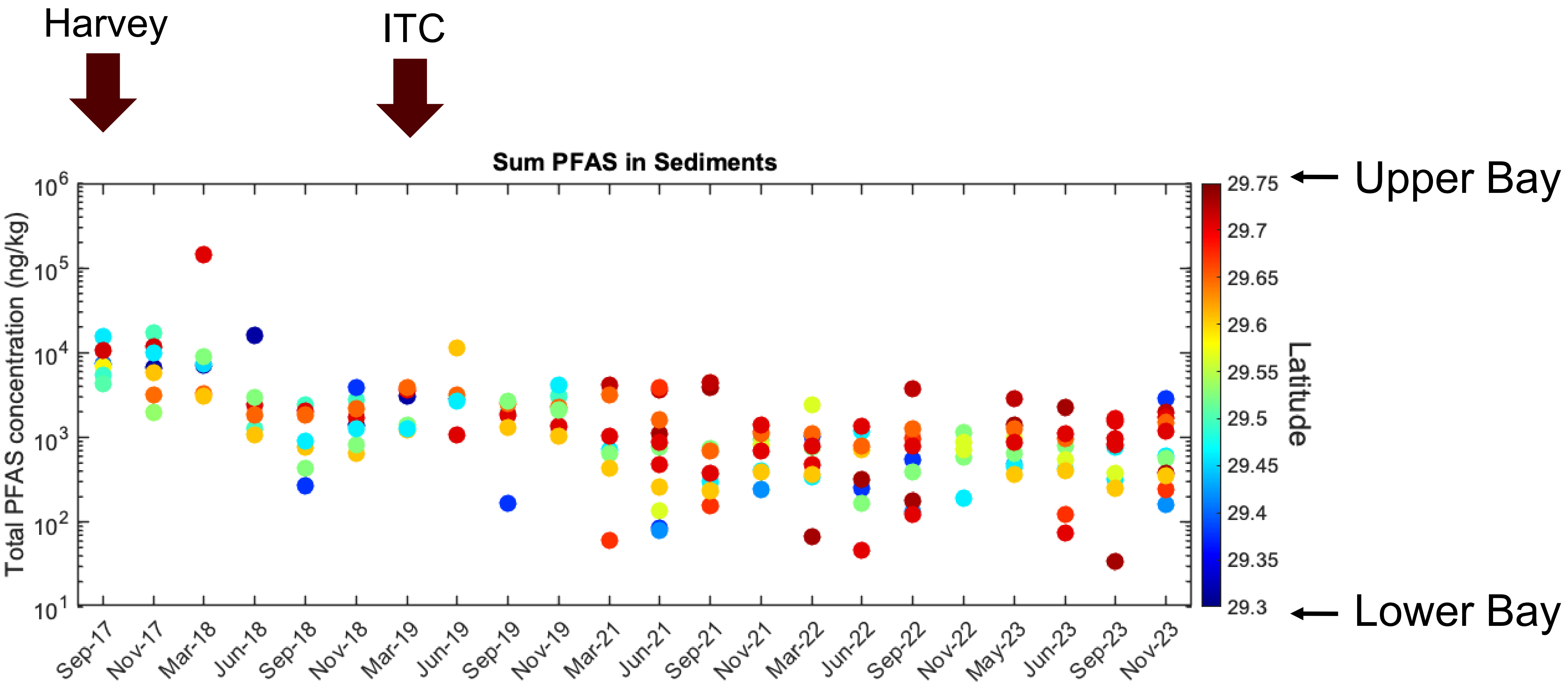


Mostly C8 PFAS found in sediments

Sediment PFAS concentrations were higher than water

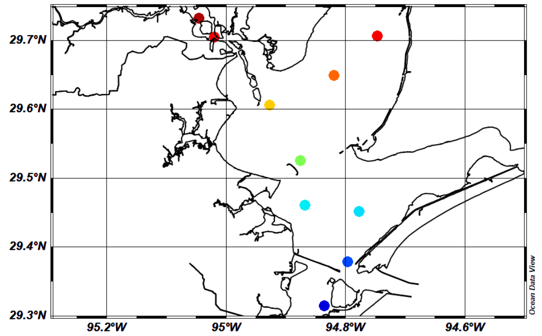
Spatial and Temporal Variability of PFAS in Sediment

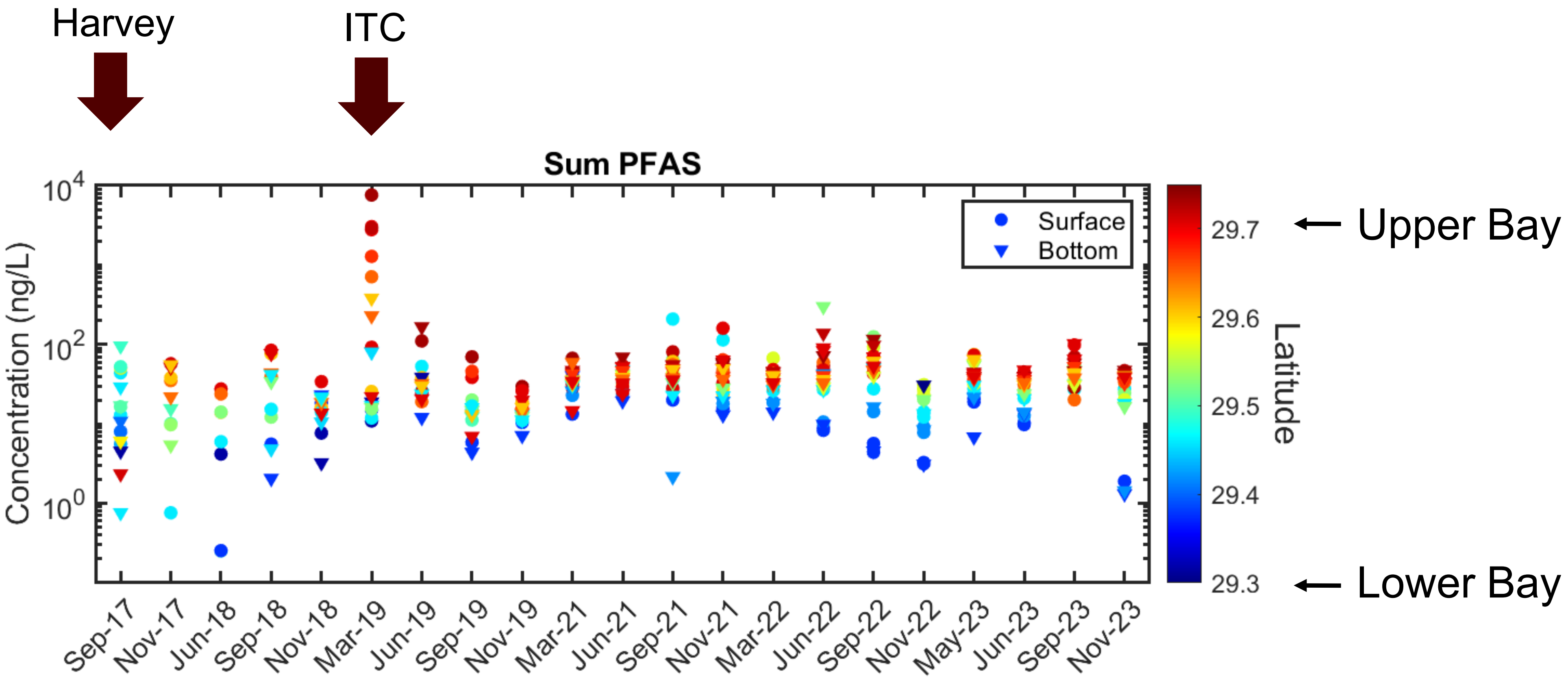




- But seem to be de-coupled with events that led to high water concentrations.
- **PFAS found in sediments are mostly C8.**

Spatial and Temporal Variability of PFAS in Water

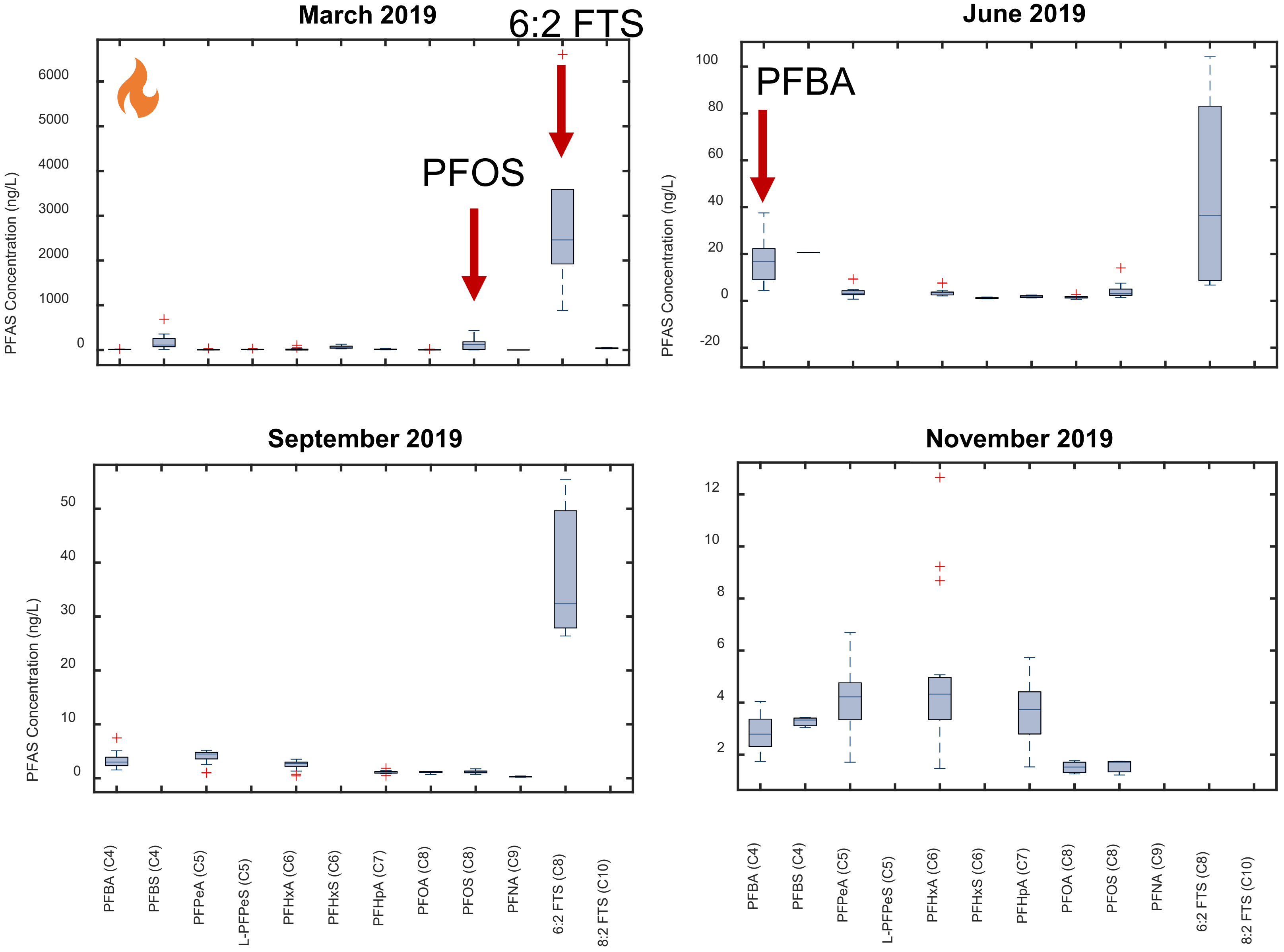




- Total PFAS in water exhibits significant spatial and temporal variabilities.
- **PFAS found in water are C8 or less.**
- We saw significantly elevated total PFAS during the Intercontinental Terminals Company (ITC) fire that occurred in March 2019.

Capturing the Anomaly - The ITC Fire

Latitude

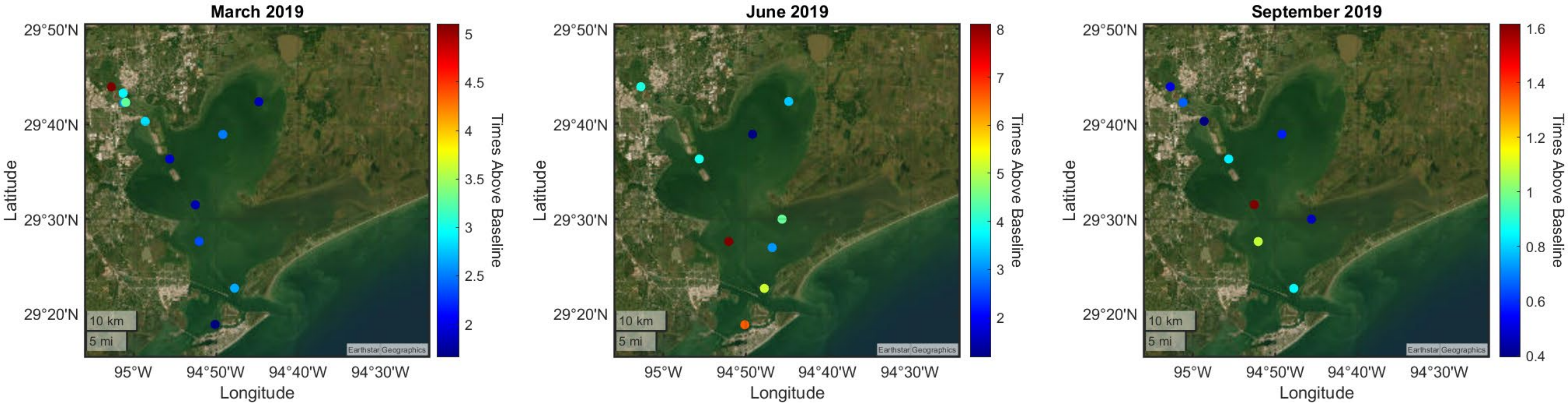


Aqueous Film Forming Foam (AFFF) was used during ITC fire.

6:2 FTS was significantly elevated.

Before ITC fire, 6:2 FTS was not detected in Galveston Bay, TX.

PFBA as a Product of Precursor PFAS Degradation?



PFBA was ~5 times higher than baseline (4.63 ng L^{-1}) near the ITC site during the fire (March 2019).

But, it was ~8 times higher than the baseline in lower Galveston Bay 3 months after the ITC fire (June 2019).

June 2019 elevated PFBA may be from precursor (e.g., 6:2 FTS) transformation and transport to lower Galveston Bay.

Baseline Values for PFAS in Galveston Bay Water

- Baseline PFAS concentrations in water were estimated as the mean values for PFAS detected in more than 20% of water samples after ITC data exclusion.

- PFOA and PFOS have been phased out, and they are both regulated

Compounds Name	Mean Concentration (ng/L)	Frequency (%)
PFBA	4.63	89.22
PFBS	3.65	67.66
PFPeA	7.86	94.95
PFHxA	6.32	95.18
PFHxS	2.15	65.60
PFHpA	2.83	79.82
PFOA	2.94	84.17
PFOS	3.27	71.33

Summary

- PFAS concentrations varied significantly spatially and temporally in water and sediment but were more variable in water.
- The types of PFAS in water and sediments are different.
- The ITC Fire in March 2019 contributed significant amounts (**above** “normal”) of PFOS and 6:2 FTS to Galveston Bay, and it took months to return to normal.
- Elevated PFBA could be from AFFF and degradation of precursors (e.g., FTS).
- This work shows the importance of a time series study to establish what is “normal,” and understand fate and transport of contaminants in ecosystems.
- Non-targeted analyses are underway.

Acknowledgement

PRESIDENT'S EXCELLENCE FUND SYMPOSIUM
T3 X-GRANTS

GALVESTON BAY ESTUARY PROGRAM
A PROGRAM OF TCEQ

NSF

NIH NIEHS

TEXAS A&M UNIVERSITY SUPERFUND RESEARCH CENTER

Oceanography Trident Cruise Team

- Dr. Jessica Fitzsimmons (Chief Scientist of the Trident cruises and T3 PI)
- Dr. Kathryn Shamberger (T3 PI)
- Dr. Shari Yvon-Lewis (T3 co-PI and current TCEQ project co-PI)
- Oceanography students' heroic effort in all the cruises – Garrett Walsh, Alyssa Alsante, Tacey Hicks, Daianne Hofig, Janelle Steffen, Serena Smith, Nina Mangor, Hunter Adams, and more!

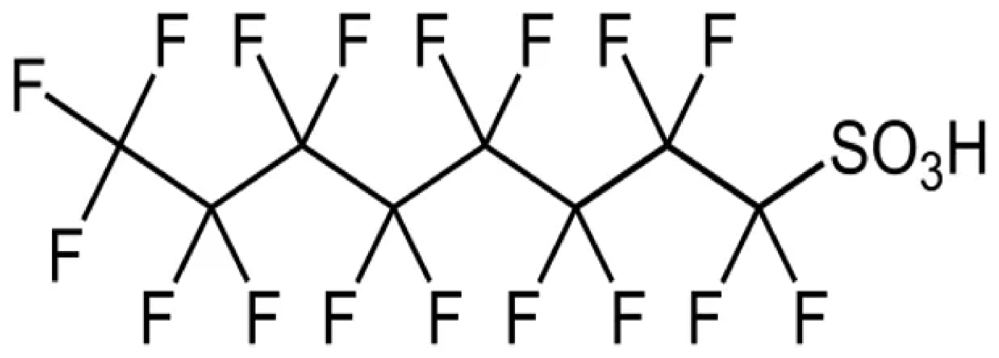
PFAS in Texas and Galveston Bay Waters: Where are we Now?

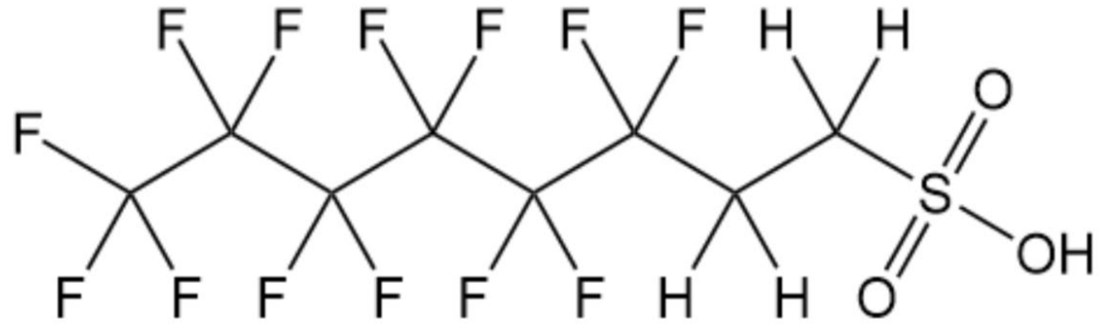
Vanessa Hulse, Erin Kinney

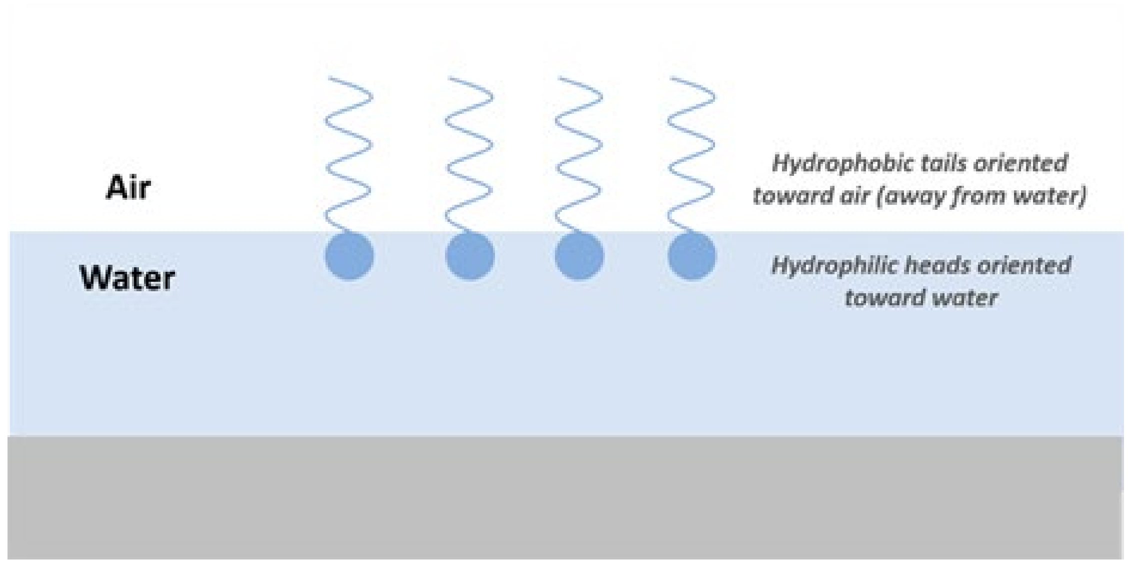
HARC

What is PFAS and why Should we Care?

- PFAS
  - Perfluoro-: All C-H bonds replaced with C-F bonds
  - Polyfluoro-: At least one C-H bond replaced with a C-F bond
- Properties of PFAS
  - Chemically and thermally stable
  - Hydrophobic and lipophobic
    - Leads to wide applications

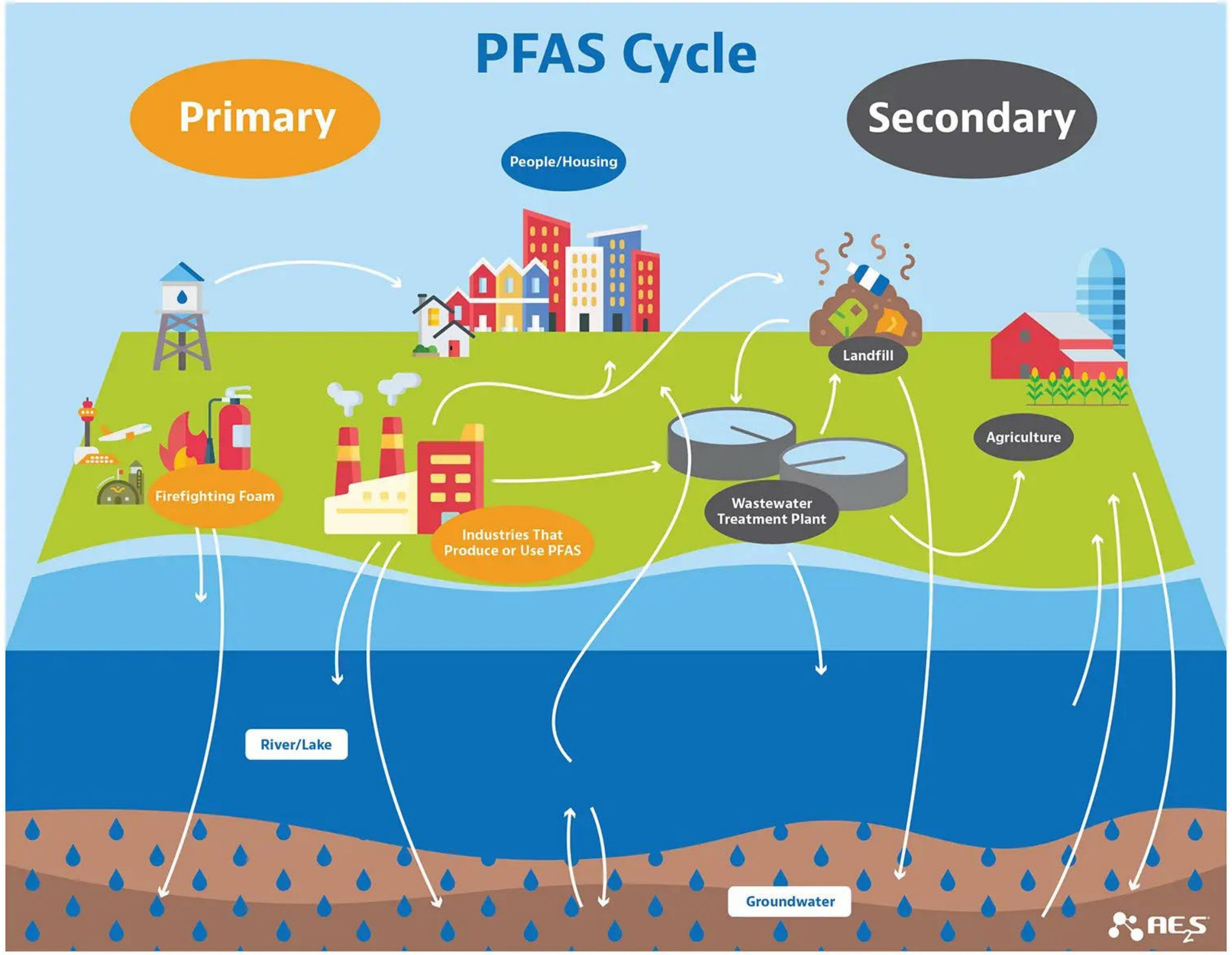






Relationship to Water

Where is PFAS Found?



www.ae2s.com/perspectives-and-insights/pfas/

PFAS Facts | FAYPWC.COM
: FAYPWC.COM

HARCresearch.org

EPA National Primary Drinking Water Regulation for 6 PFAS

Compound	Final MCL (enforceable levels)
PFOA	4.0 parts per trillion (ppt)
PFOS	4.0 ppt
PFHxS	10 ppt
PFNA	10 ppt
HFPO-DA (commonly known as GenX)	10 ppt
Mixtures containing two or more of PFHxS, PFNA, HFPO-DA, and PFBS	1 (unitless) Hazard Index

EPA Aquatic Life Criteria

Criteria Component	Acute Water Column (CMC)[1] (mg/L)	Chronic Water Column (CCC)[2] (mg/L)	Invertebrate Whole-Body (mg/kg ww[3])	Fish Whole-Body (mg/kg ww[3])	Fish Muscle (mg/kg ww[3])
PFOA magnitude	3.1	0.10	1.18	6.49	0.133
PFOS Magnitude	0.071	0.00025	0.028	0.201	0.087
Duration	1-hr average	4-day average	Instantaneous	Instantaneous	Instantaneous
Frequency	Not to be exceeded more than once in 3 years, on average	Not to be exceeded more than once in 3 years, on average	Not to be exceeded	Not to be exceeded	Not to be exceeded

1 Criterion Maximum Concentration
2 Criterion Continuous Concentration
3 Wet Weight

Fact Sheet: Final Recommended Aquatic Life Criteria and Benchmarks for Select PFAS

Caroline Emery, TCEQ

EPA National Primary Drinking Water Regulation for 6 PFAS

Compound	Final MCL (enforceable levels)
PFOA	4.0 parts per trillion (ppt)
PFOS	4.0 ppt
PFHxS	10 ppt
PFNA	10 ppt
HFPO-DA (commonly known as GenX)	10 ppt
Mixtures containing two or more of PFHxS, PFNA, HFPO-DA, and PFBS	1 (unitless) Hazard Index

EPA's recommended criteria for PFOA and PFOS fall below detectable thresholds of current available technology and laboratory methods

Caroline Emery, TCEQ

EPA Aquatic Life Criteria

Criteria Component	Acute Water Column (CMC)[1] (mg/L)	Chronic Water Column (CCC)[2] (mg/L)	Invertebrate Whole-Body (mg/kg ww[3])	Fish Whole-Body (mg/kg ww[3])	Fish Muscle (mg/kg ww[3])
PFOA magnitude	3.1	0.10	1.18	6.49	0.133
PFOS Magnitude	0.071	0.00025	0.028	0.201	0.087
Duration	1-hr average	4-day average	Instantaneous	Instantaneous	Instantaneous
Frequency	Not to be exceeded more than once in 3 years, on average	Not to be exceeded more than once in 3 years, on average	Not to be exceeded	Not to be exceeded	Not to be exceeded

1 Criterion Maximum Concentration
2 Criterion Continuous Concentration
3 Wet Weight

Fact Sheet: Final Recommended Aquatic Life Criteria and Benchmarks for Select PFAS

A neonatal loggerhead sea turtle in sargassum floats in the Gulf Stream. BRIAN LAPOINTE/Florida Atlantic University

PFAS in Wildlife

- What is exposure zone?
  - Tend to accumulate at air/water interface
  - Highly mobile, move with groundwater plumes
- PFAS accumulation in wildlife

Specific Issues Related to the Gulf/Texas

- **Surface Accumulation ("Salting-Out")**
- **Sea Spray, Sea Foam and Air Transport**
- **Surface Concentration:**
  - **Up to 62,000x higher in sea spray**
  - **Surface water 6x higher than deep-water**
  - **Sargassum accumulation**

Image: Galveston Daily News

Image: Colorado State University

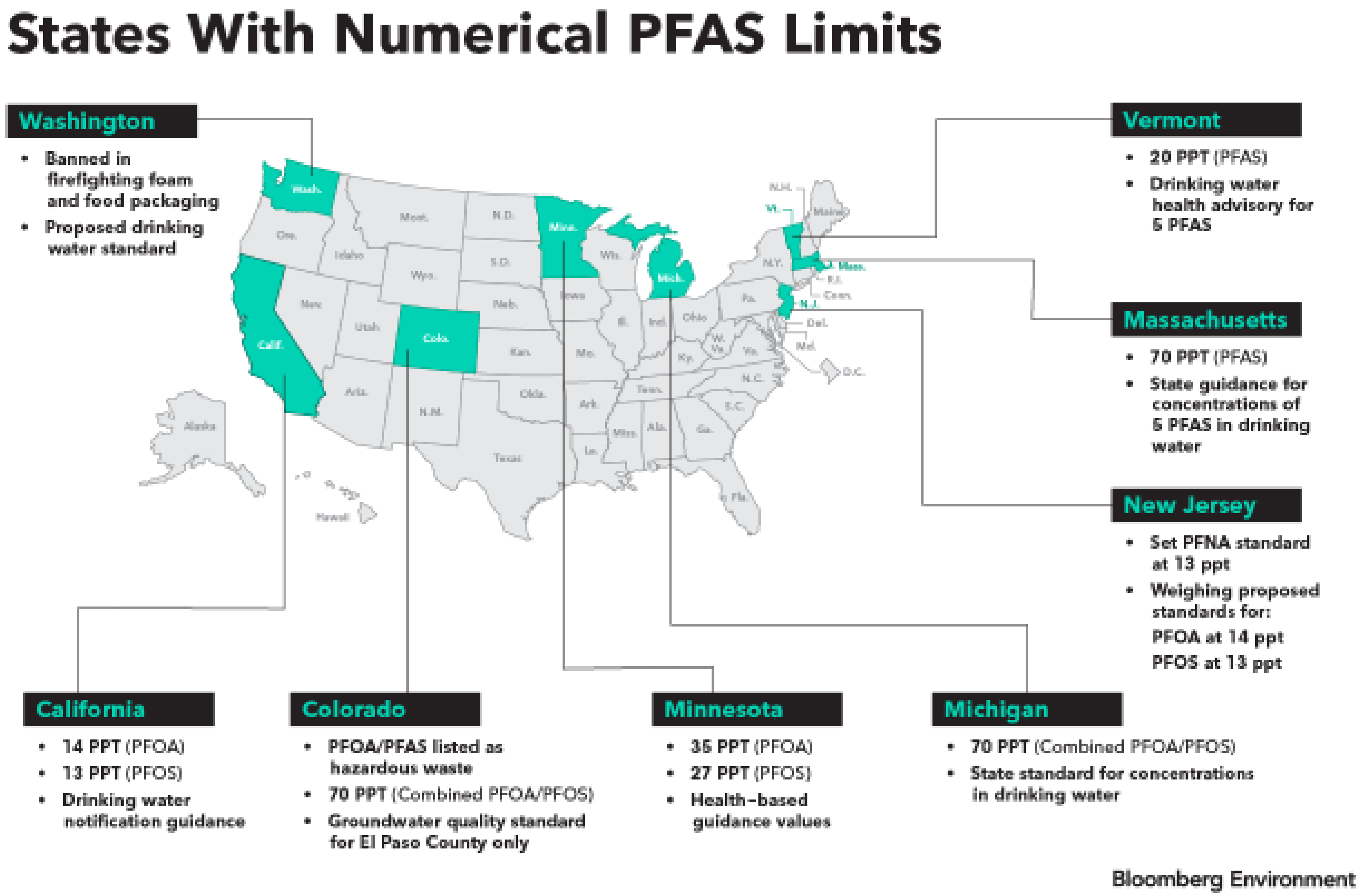
ITC Fire and Fires in the Gulf

- Issues with finding information on fires
  - Adjacent to Bayous
  - In Galveston Bay
  - in the Gulf
- Disclosure of chemicals burned and used for fire suppression

Image: ABC 13

Regulations on PFAS

- Federal
  - EPA limits on 4 PFAS molecules (reduced from 6)
  - Over 5,000 compounds banned by EPA
- State
  - Texas currently follows EPA
- Other states
- But what's left out?



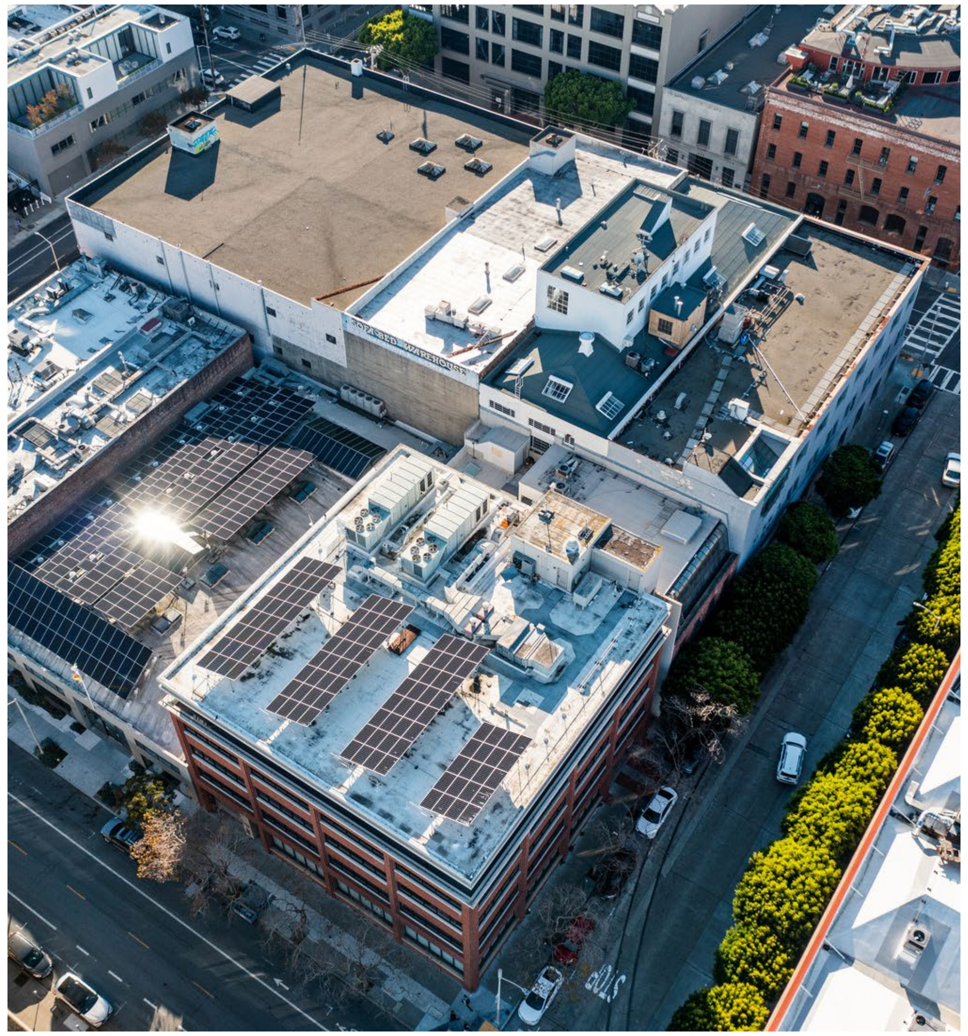
PFAS Project, Silverman 2018

PFAS Regulation Issues

- Specificity
  - PFAS not regulated past main 6 compounds
  - Named PFAS regulations lead to loopholes for new compounds to be manufactured
- Challenges of the Texas regulatory environment

HARCresearch.org

EPA has MCLs for 4 PFAS molecules that are intended to be phased out by manufacturers



Texas regulatory environment – following EPA

Removal technologies	Pros	Cons
Activated carbon (AC)	High adsorption capacity Effective for a variety of PFAS compounds Relatively low operational costs	Requires replacement/regeneration Generates secondary waste
Adsorptive membrane	Combines filtration and adsorption	Membrane fouling can increase operational costs
Electrocoagulation (EC)	In situ coagulant generation Minimal chemical usage	Energy consumption can be high Potential for secondary contaminants
Advanced oxidation processes (APOs)	Potential for secondary contaminants	Potential formation of toxic by-products
Reverse osmosis (RO)	High rejection rates for PFAS Effective for various contaminants	Membrane fouling can occur
Ion Exchange	Selective removal of charged PFAS	Can be costly, especially with specialized resins

Removal/Remediation

Hassan, R.K., Sallam, N.A., Alrefaey , K.A. *et al.* Enhancing PFAS removal: feasibility of an integrated electrocoagulation and adsorptive membrane approach. *Discov Chem Eng* 5, 23 (2025)

State of the Science

Removal/Remediation

- New removal techniques for mineralization
  - Methods to remove and then treat
- PFAS size issues
  - Degradation techniques make smaller PFAS molecules
- Detection vs. removal techniques
  - Detection requires a small amount of PFAS rather than removing all the contaminant
- Prevention is the only reliable method
  - Consumer Pressures

Resources and Future Directions

HARCresearch.org

Contamination Levels

More work needs to be done to determine where/what specific compounds are present in Texas/Galveston Bay, including in wildlife

Regulation

EPA and Texas have loose regulations that can cause more contaminations, especially contaminations that are unknown (new compounds)

Prevention

Removal of PFAS in new products, especially new PFAS molecules, will reduce contamination levels

Remediation

New remediation methods are needed, especially for small PFAS molecules

CONTACT US

For further information, contact HARC at
(281) 364-6000 or visit www.HARCresearch.org.

Connect with HARC via Instagram, LinkedIn, Facebook or Twitter. Like or follow @HARCresearch.

VaHulse02@gmail.com
ekin[illegible]@harcresearch.org

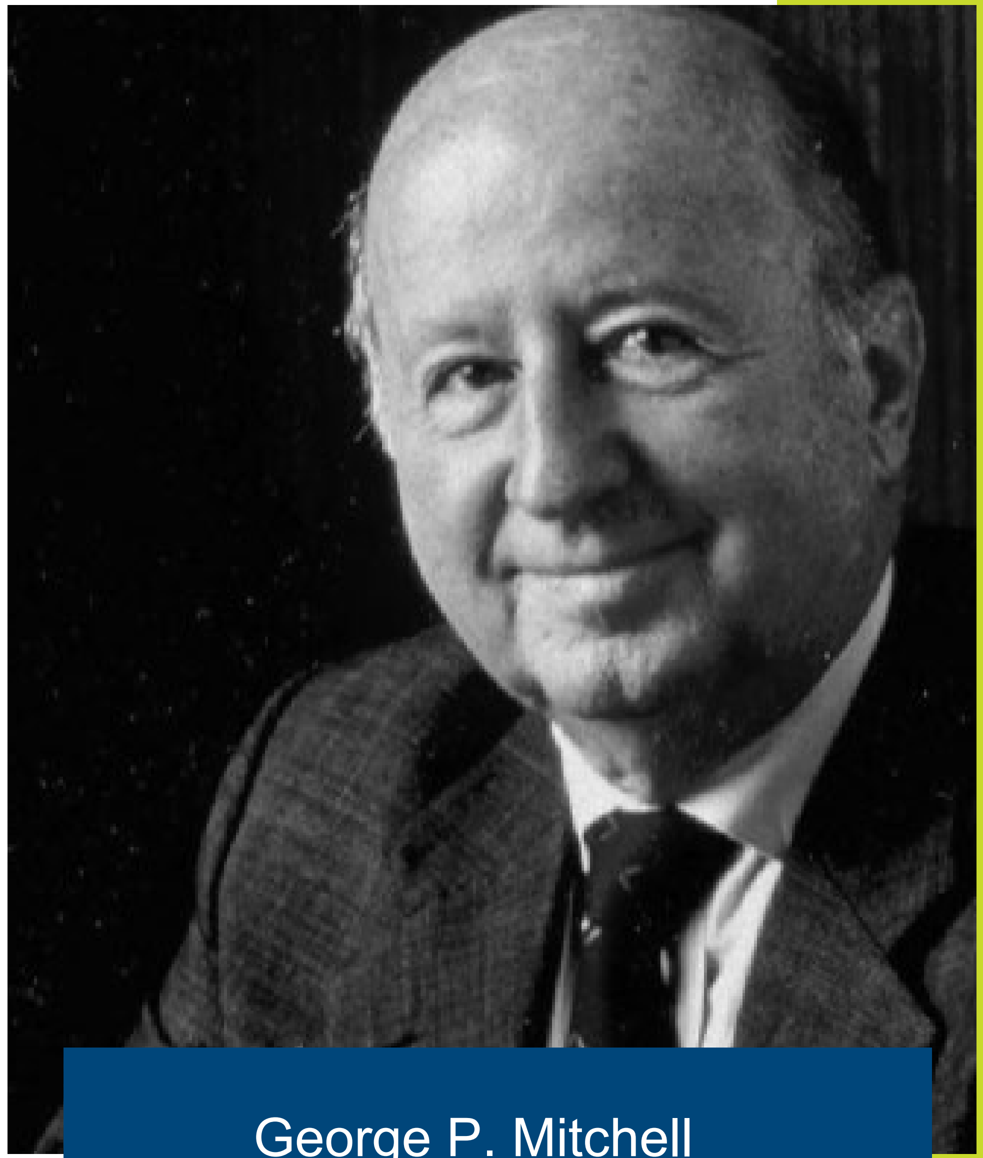
Our Mission

HARC applies science to drive energy, air, water, and resilience solutions for a sustainable and equitable future.

HARCresearch.org

Rooted in Sustainability

HARC owes its origins to the vision and initiative of Houston businessman and philanthropist George P. Mitchell, who established the organization in 1982 as a non-profit university consortium and technology incubator, bridging basic research and market applications.



George P. Mitchell

Sustainability Requires a Commitment

HARC defines sustainability as engaging in practices that consider and support ecological, societal, and economic health and vitality. Sustainability presumes that resources are finite and must be conserved, protected, and distributed in a manner that meets the needs of the present without compromising the ability of future generations to meet their own needs.

HARCresearch.org

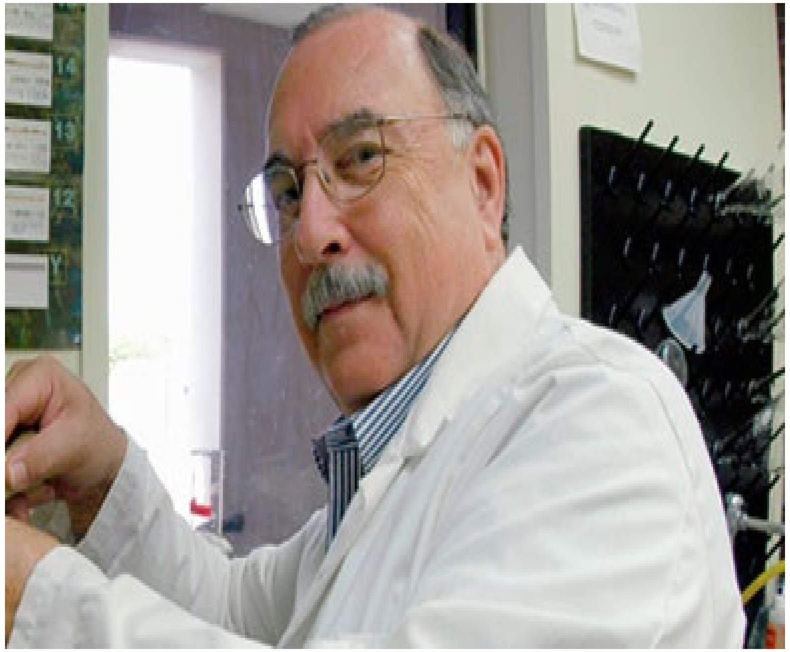
Applied Time Series Analyses (2000–2017) of *Vibrio vulnificus* And *Vibrio parahaemolyticus* (Pathogenic and Non-Pathogenic Strains) in the eastern oyster, *Crassostrea virginica*

Dr. Antonietta Quigg

Texas A&M University Galveston

TEXAS A&M UNIVERSITY
GALVESTON CAMPUS

https://www.texassaltwaterfishingmagazine.com/



Acknowledgements

Aurora Gaona-Hernández, Mona S. Hochman,
John R. Schwarz, and Sammy M. Ray

Dept of Marine Biology

TEXAS A&M UNIVERSITY
GALVESTON CAMPUS.

- Concerns about the health consequences of **seafood born human pathogens** are ongoing given their occurrence, prevalence and ability to cause infections, and sometimes death in humans

- These pathogens are also associated with seafood morbidity and mortality worldwide

- Climate change

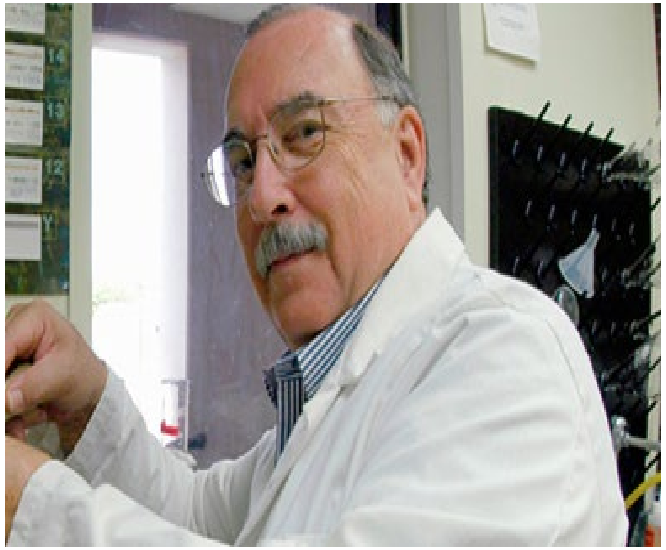
- Growing aquaculture industry

V. vulnificus

- estuarine bacterium
- naturally found in brackish waters
- concentrated by filter-feeding oysters

- illness range from gastroenteritis to grievous wound infections or septicemia and death, particularly in individuals with predisposing conditions





First reported studies in Galveston Bay in the 1990's

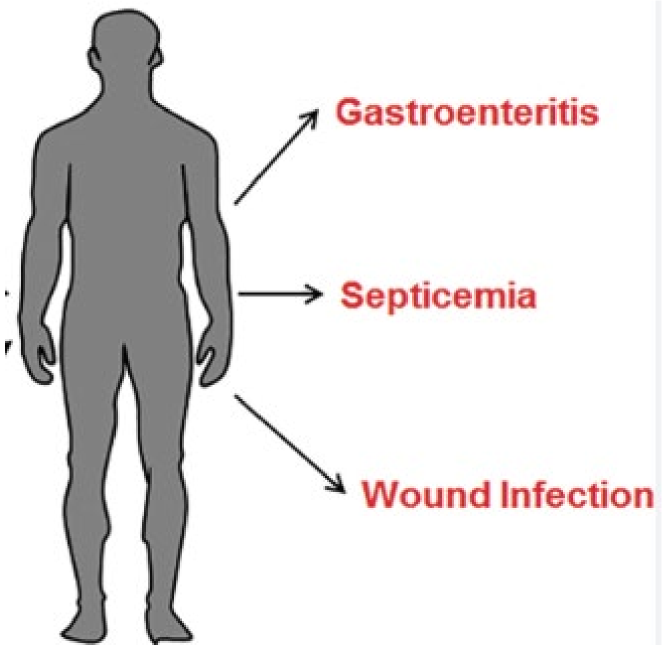
https://www.tamug.edu/seafoodsafetylab/index.html

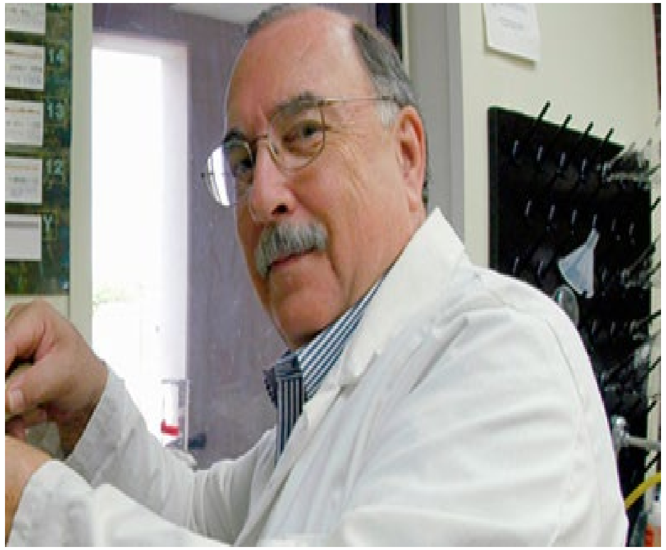
V. parahaemolyticus

- estuarine & coastal bacterium
- only some strains are pathogenic (denoted as tdh+)
- concentrated by filter-feeding oysters

- illness range from gastroenteritis to grievous wound infections or septicemia and death, particularly in individuals with predisposing conditions

First reported in Galveston Bay in 1998





https://www.tamug.edu/seafoodsafetylab/index.html

Perkinsus marinus

(formerly *Dermocystidium marinum* or Dermo)

- parasite
- result in poor oyster body condition and survival

- surveys in Galveston Bay oysters have revealed higher infection levels (prevalence, infection intensity, and weighted prevalence) during periods of warm and saline conditions

- ***does not*** harm people that ingest the oysters

Healthy versus infected oyster

https://oystersentinel.cs.uno.edu/

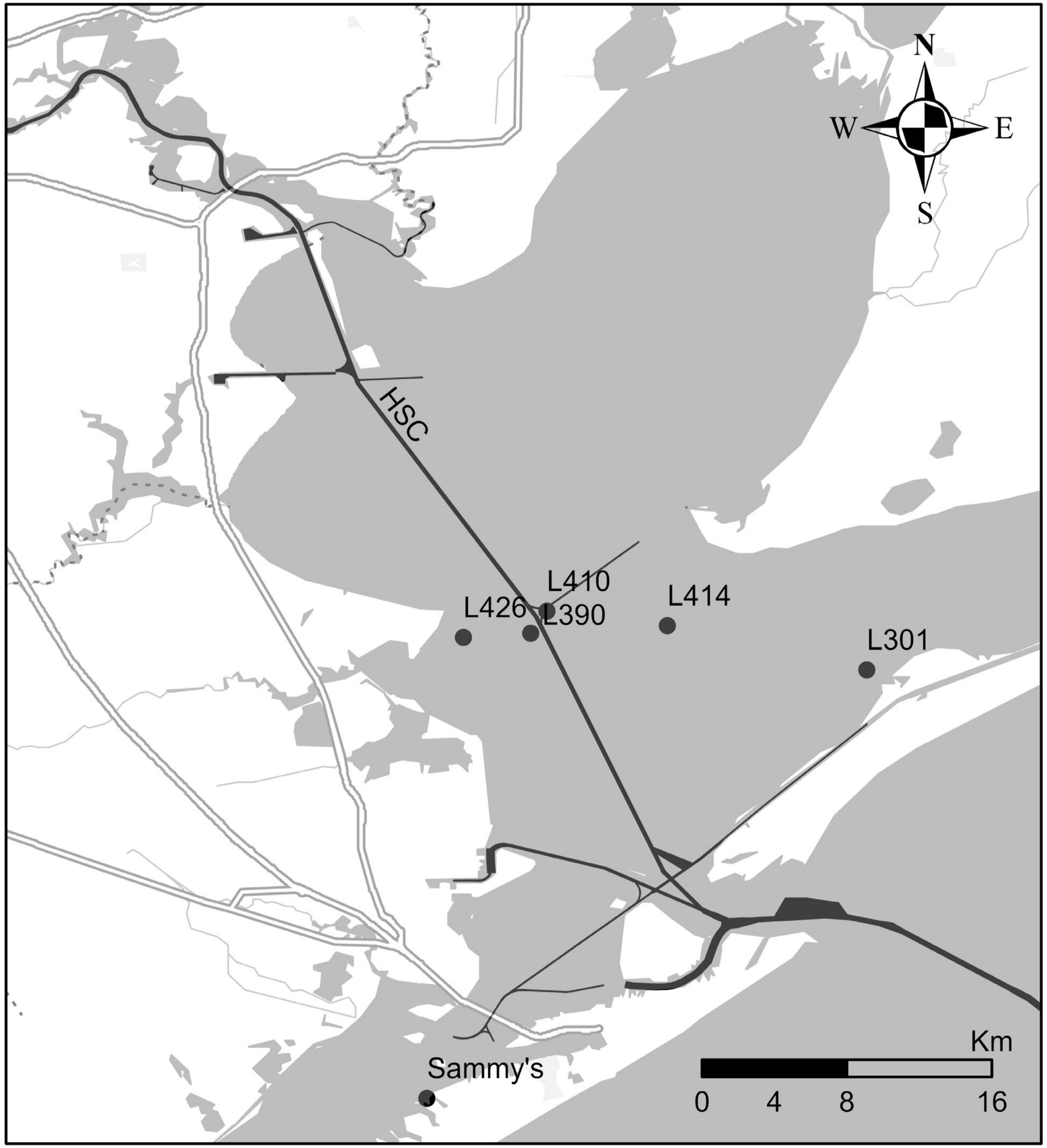
https://library.enaca.org/Health/FieldGuide/html/mp045per.htm

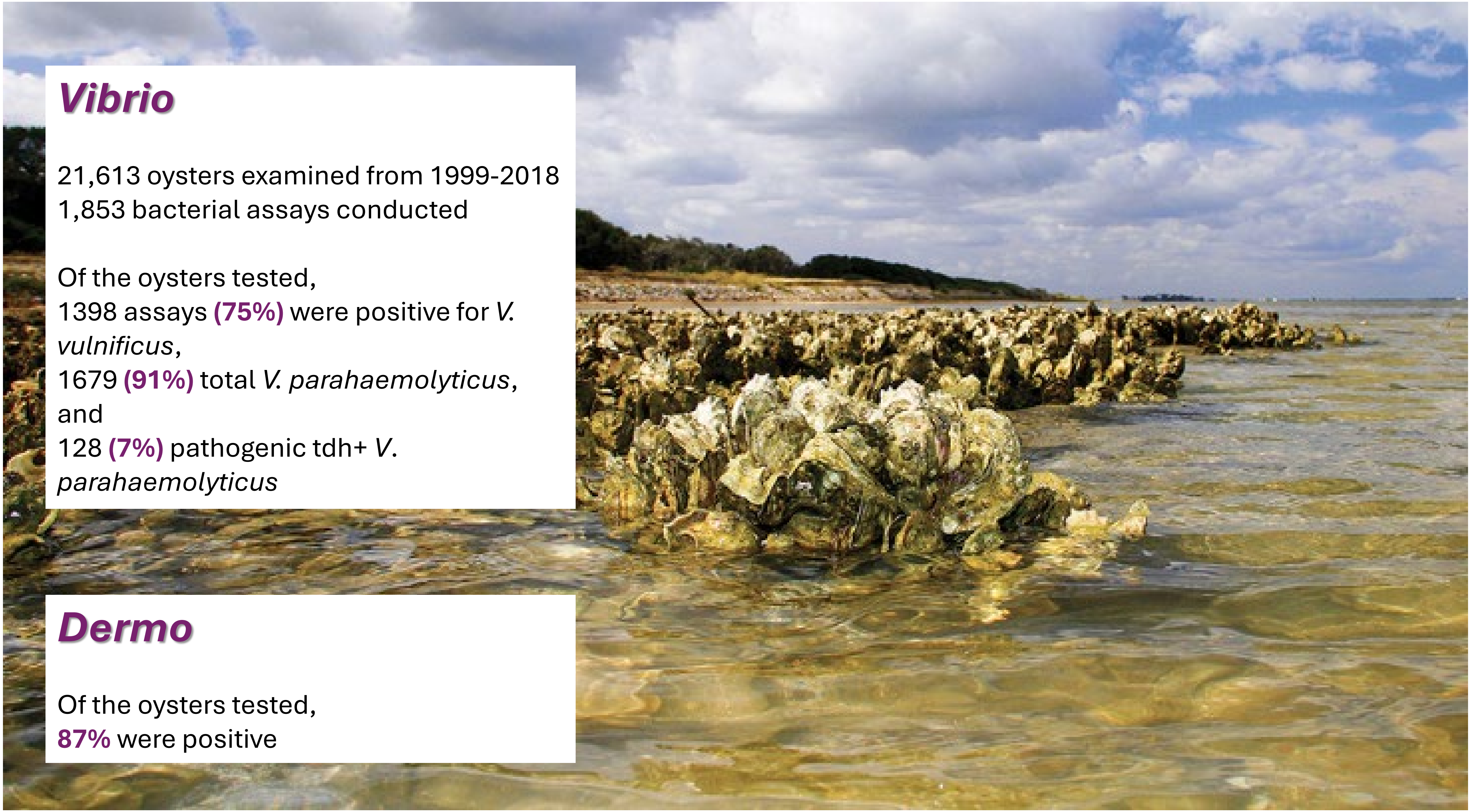
Examinations of oyster microbiomes in response to environmental and water quality variables

H1: The co-occurrence of dermo in oysters increases the prevalence of Vibrio

Galveston Bay

- Five private, commercial reef sites in the central part of the bay where the oysters were collected from 2000 to 2017. And Sammy's Reef in West Bay





Vibrio

21,613 oysters examined from 1999-2018
1,853 bacterial assays conducted

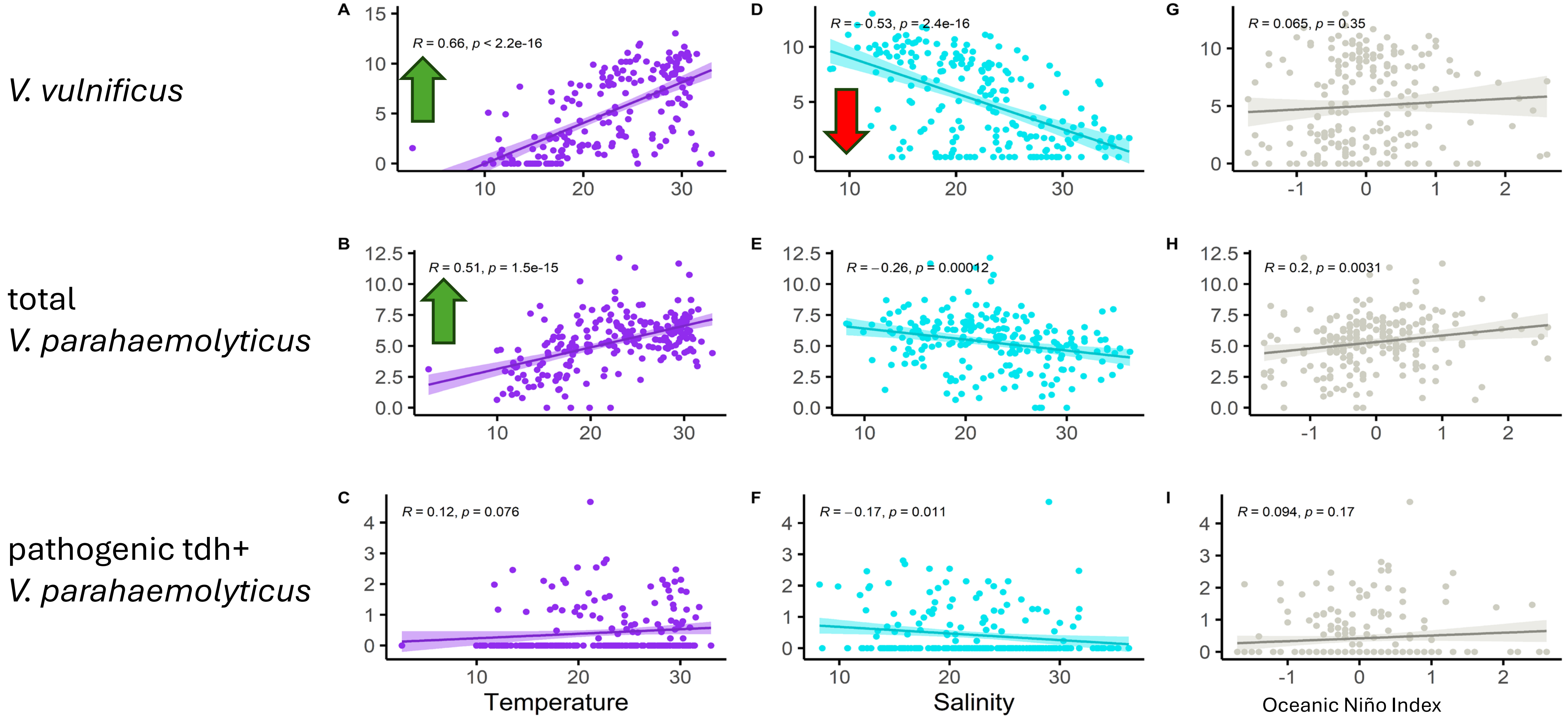
Of the oysters tested,
1398 assays **(75%)** were positive for *V. vulnificus*,
1679 **(91%)** total *V. parahaemolyticus*, and
128 **(7%)** pathogenic tdh+ *V. parahaemolyticus*

Dermo

Of the oysters tested,
87% were positive

Environmental variables and *Vibrio* spp.

Pearson correlation coefficients; solid color lines represent linear regression and color bands the 95% of confidence interval



Vibrio

21,613 oysters examined from 1999-2018
1,853 bacterial assays conducted

Of the oysters tested,
1398 assays **(75%)** were positive for *V. vulnificus*,
1679 **(91%)** total *V. parahaemolyticus*, and
128 **(7%)** pathogenic tdh+ *V. parahaemolyticus*

Dermo

Of the oysters tested,
87% were positive

Time series analyses

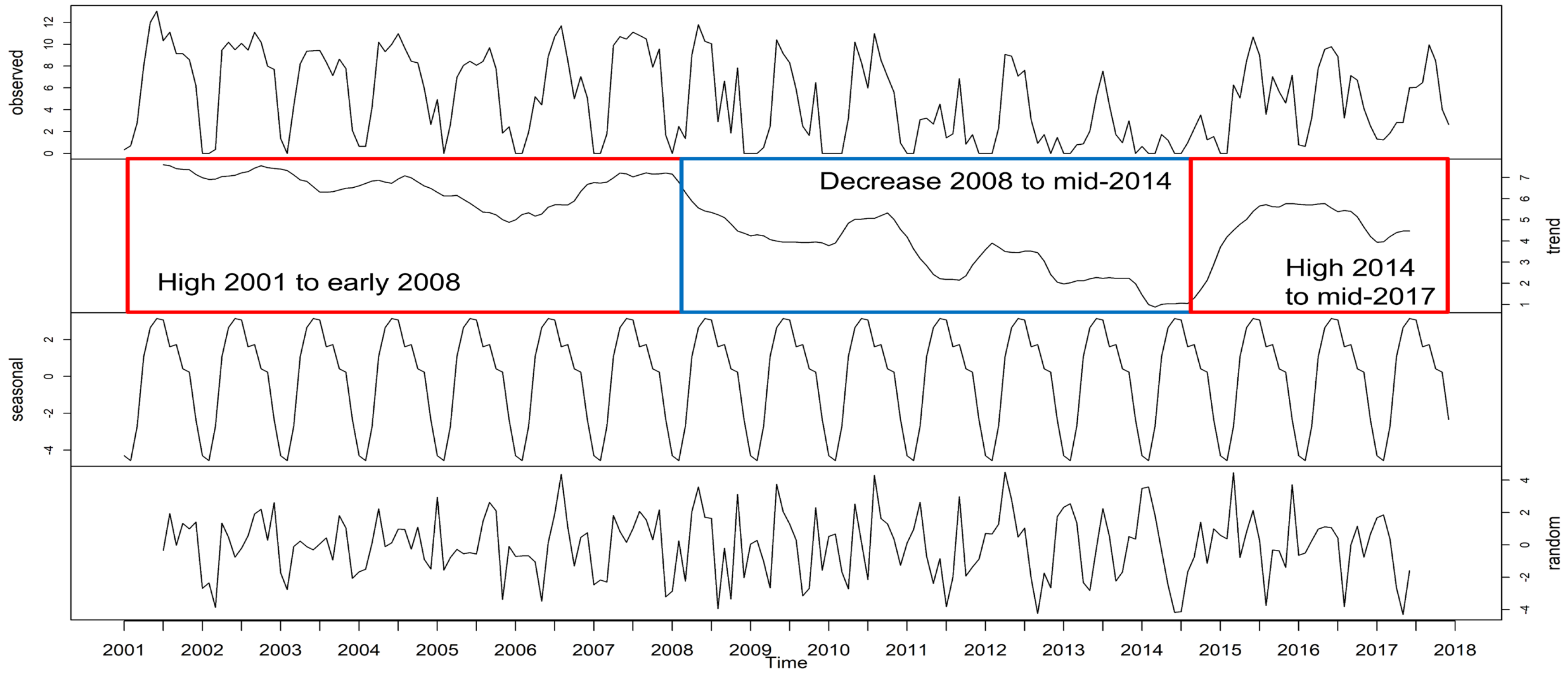
Decomposition of *V. vulnificus* time series (2001-2017)

Original data (monthly averages)

Trends

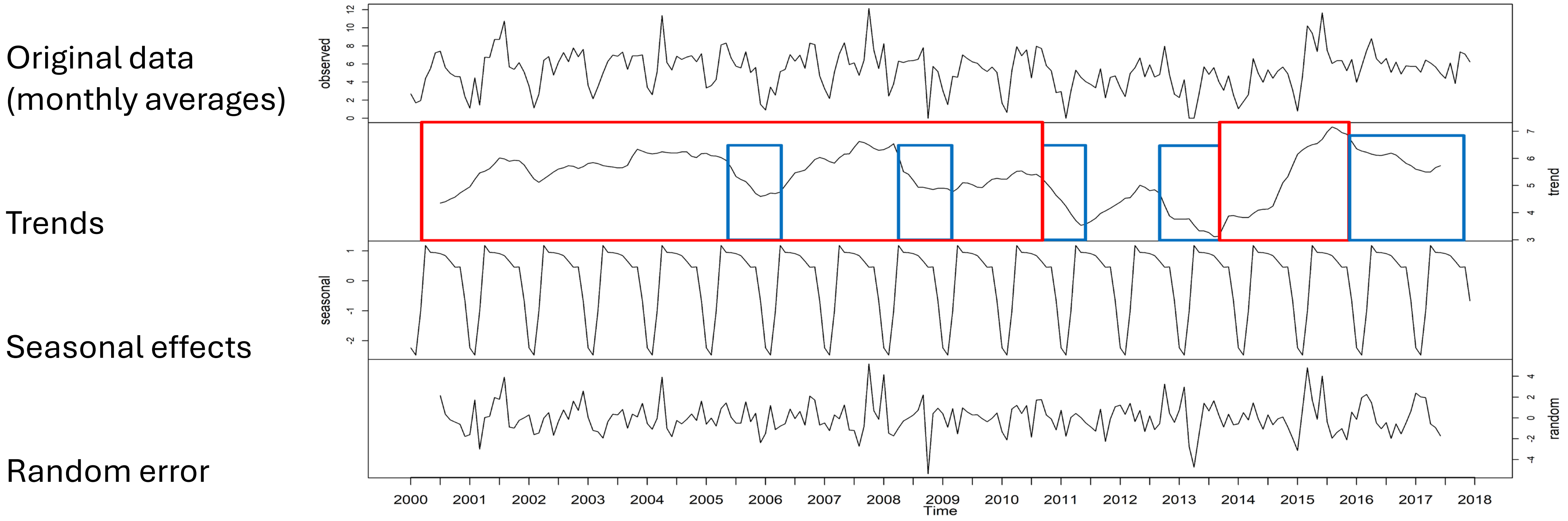
Seasonal effects

Random error



- High abundances were observed during the early and mid-2000's, and then again in the mid and late 2010's
- Observed seasonal abundances, with the peak during the late spring and summer

Decomposition of **<u>total</u>** *V. parahaemolyticus* time series (2001-2017) in Galveston Bay



- No clear trend
- Observe periods with either high (red) or lower (blue) abundances
- Step increase associated with the end of the drought in 2010-2014

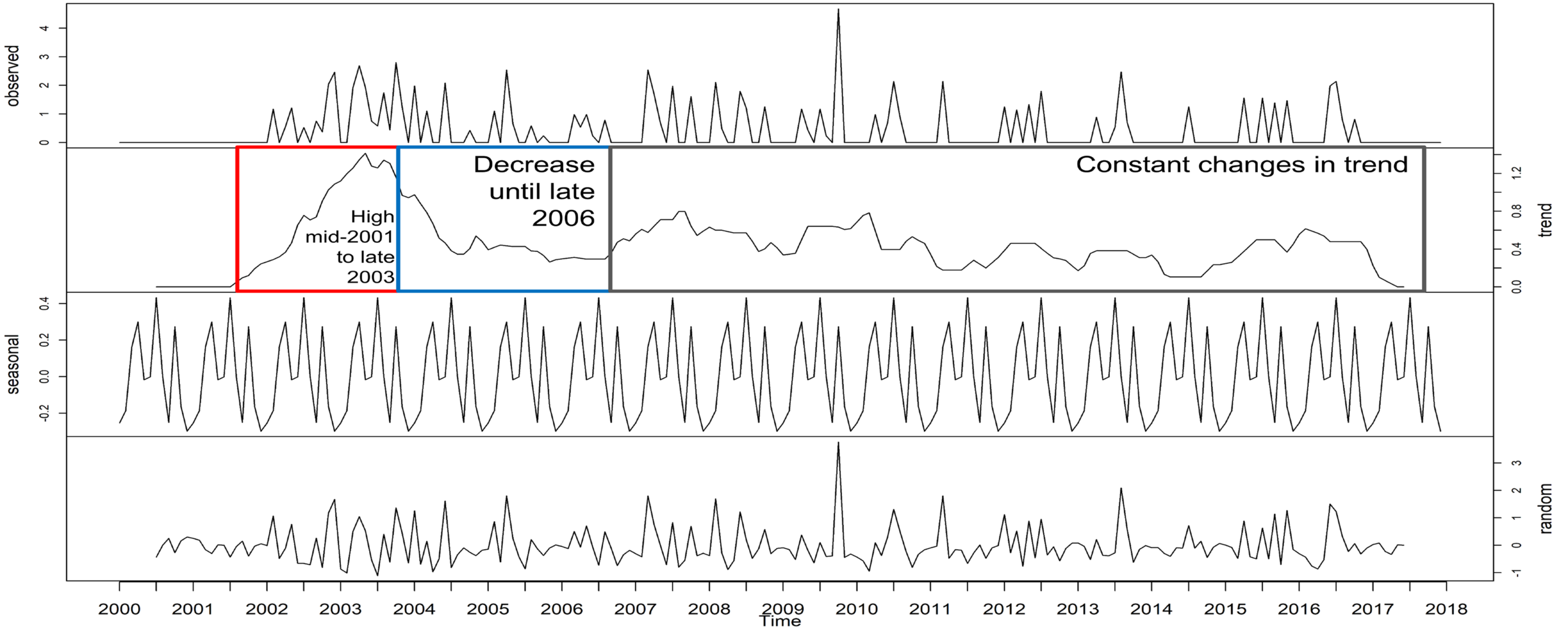
Decomposition of **pathogenic tdh+ *V. parahaemolyticus*** time series (2001-2017) in Galveston Bay

Original data (monthly averages)

Trends

Seasonal effects

Random error

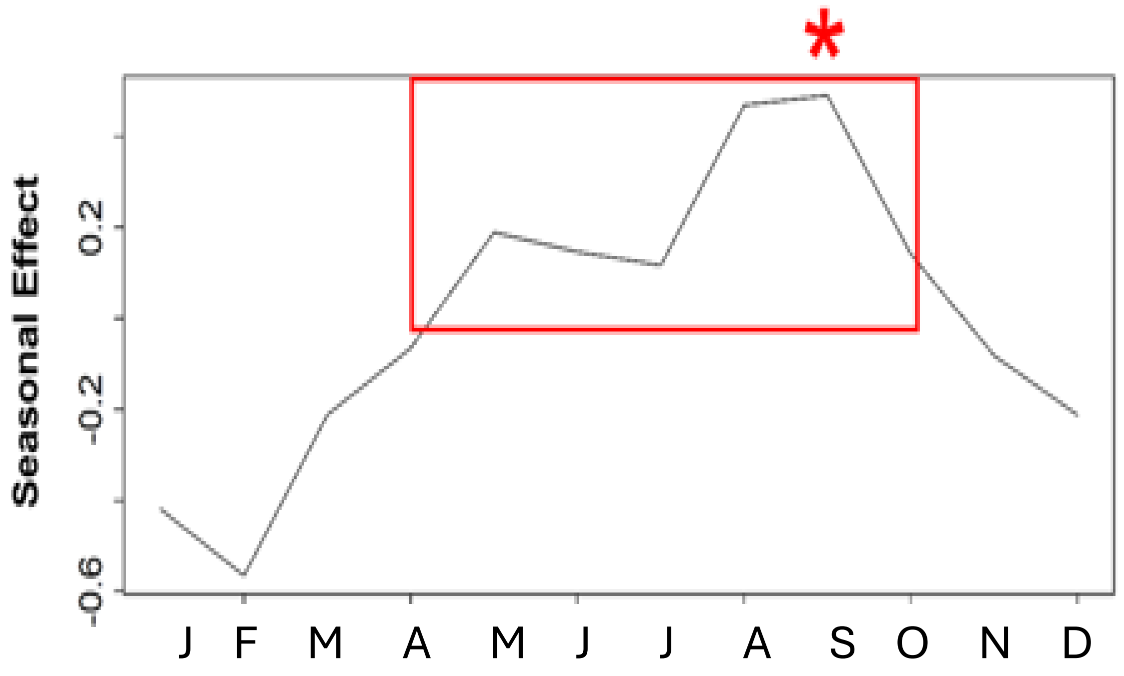


- High abundance (red) in early 2000's, which then decreased, and stayed lower
- Summer season has the highest abundance of pathogenic tdh+ *V. parahaemolyticus* – *but not significant*

Cross-correlations between time series

Step 1:

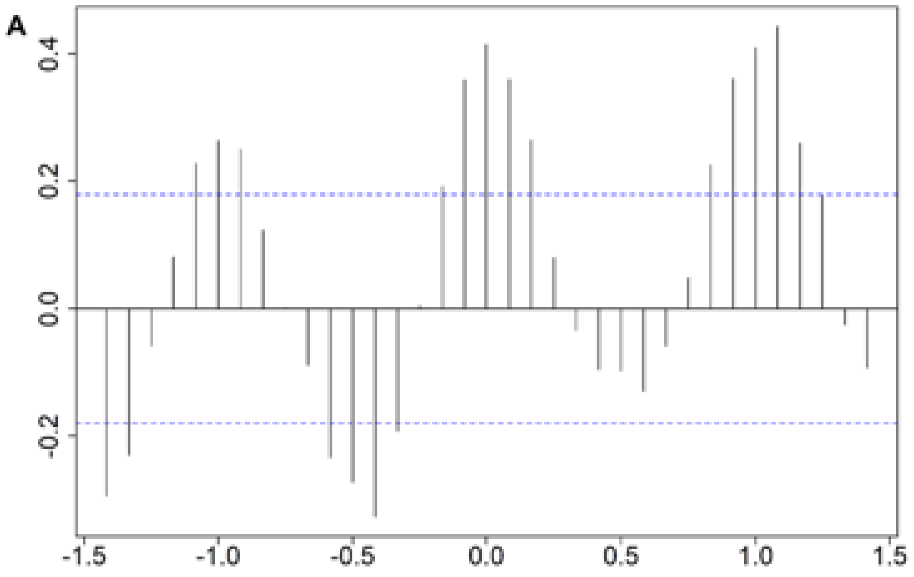
Seasonal abundance of *P. marinus*

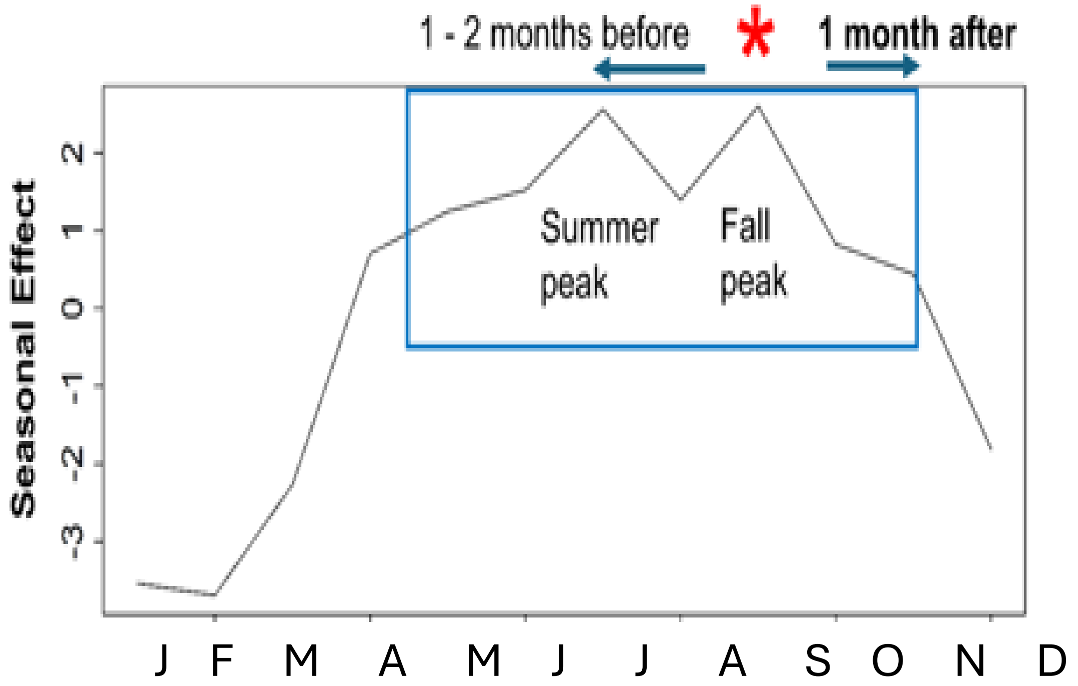


- Densities increase from spring into summer, with peak levels measured at the end of summer
- Thrives with higher temperatures and salinities
- Red star corresponds to peak *P. marinus* densities

Cross-correlations between time series

Step 2: Seasonal abundance of *V. vulnificus* relative to *P. marinus*

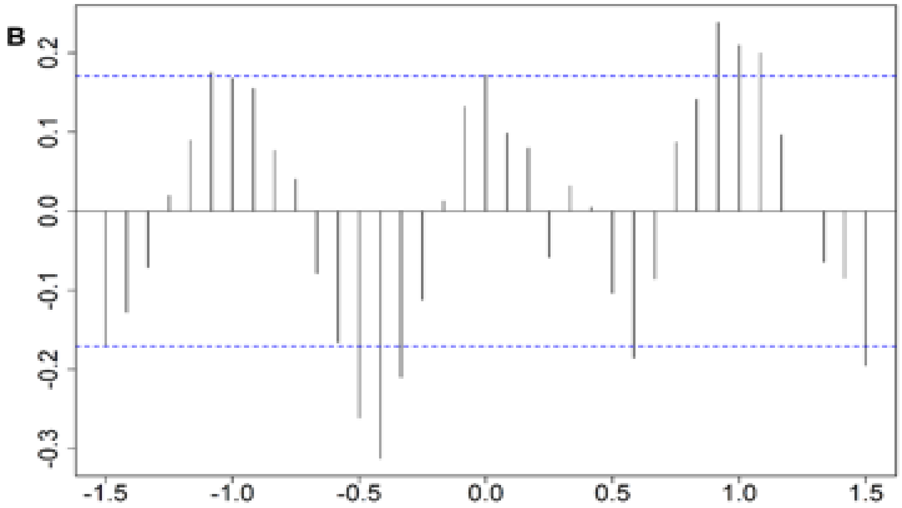


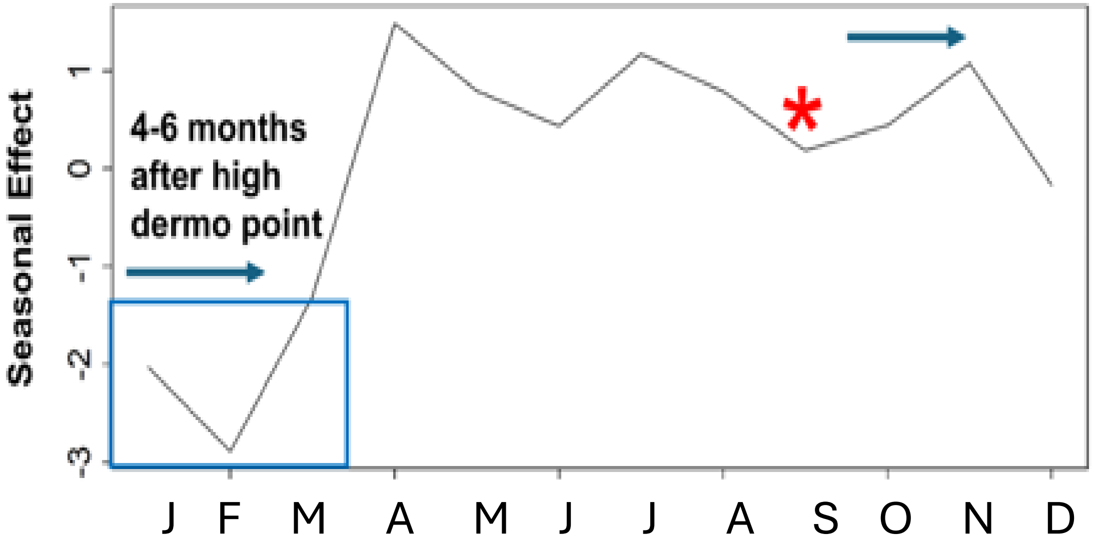


- *V. vulnificus* numbers are high during high *P. marinus* infections (lag 0), and 1 month after high *P. marinus* infections (lags -1)
- High *V. vulnificus* correlations one and two months before *P. marinus* high infection (lag 1 and 2) shows that the summer peak of *V. vulnificus* coincides with increasing infection intensities of *P. marinus* during the summer

Cross-correlations between time series

Step 3: Seasonal abundance of total *V. parahaemolyticus* relative to *P. marinus*

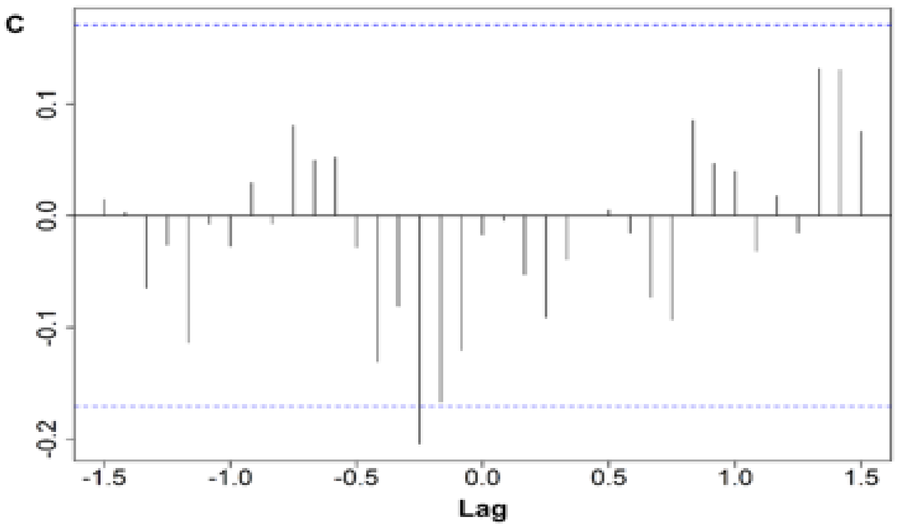


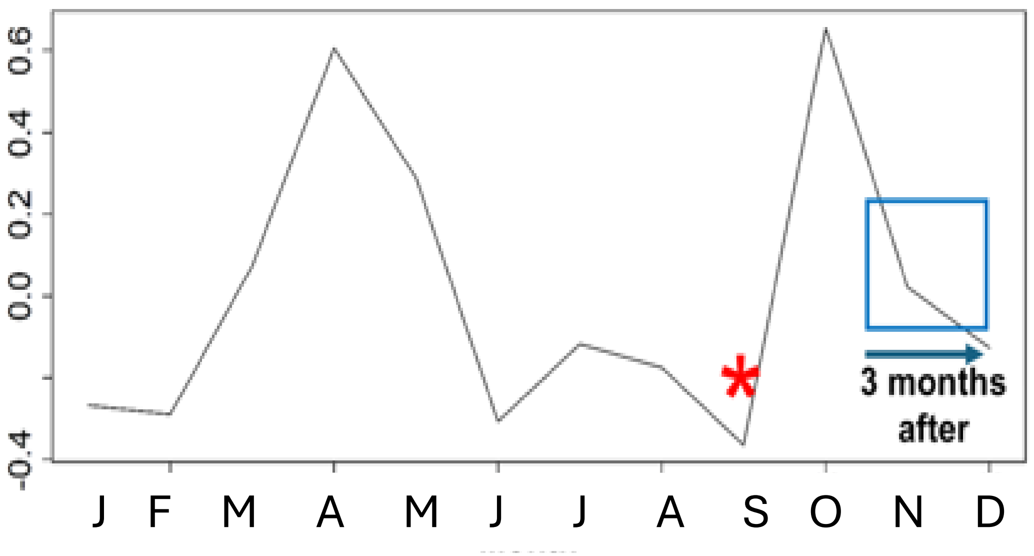


- Weak seasonal pattern in the co-occurrence of both species
- Shows low bacterial abundance after 4 to 6 months of high *P. marinus* infections

Cross-correlations between time series

Step 4: Seasonal abundance of pathogenic tdh+ *V. parahaemolyticus* relative to *P. marinus*





- Show NO seasonal pattern between the two-time series
- Shows pathogenic tdh+ *V. parahaemolyticus* decrease after 3 months of high *P. marinus* infections

Conclusions:

Oyster microbiomes vary in response to environmental and water quality variables, but not always in response to the presence of the parasite, *P. marinus*

- The positive lags point to a relationship between the abundance of *V. vulnificus* and *P. marinus*
- We did not find a similar pattern for total or pathogenic tdh+ *V. parahaemolyticus* with *P. marinus* infections

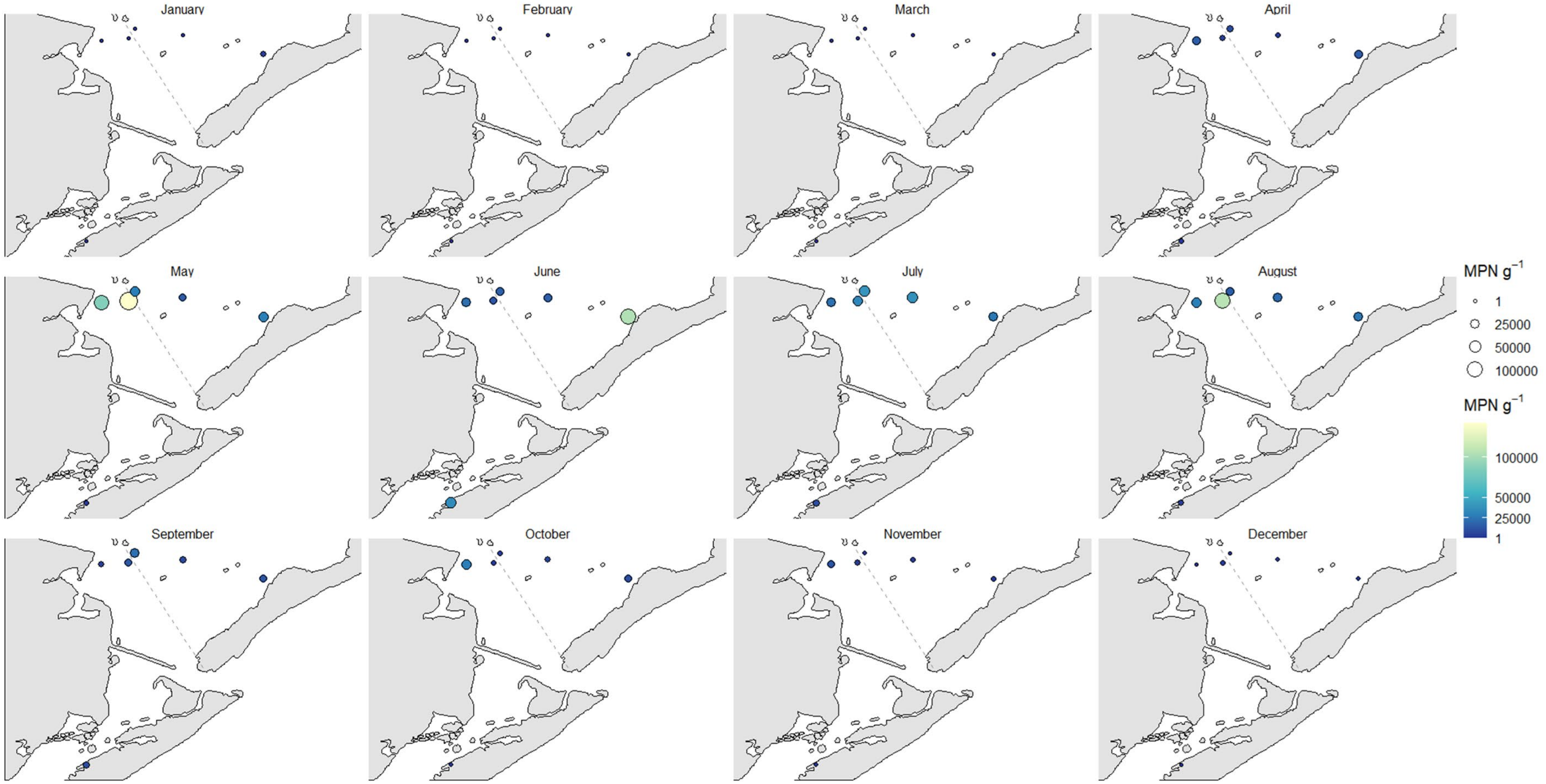
Conclusions:

- ENSO driven climate variability and local salinity patterns influence oyster survival – these have been shown to also influence *Vibrio* spp. elsewhere

- In terms of the aquaculture industry, oysters, their microbiome and their pathogens offer a wealth of information, making them excellent sentinels or bioindicators of oyster health

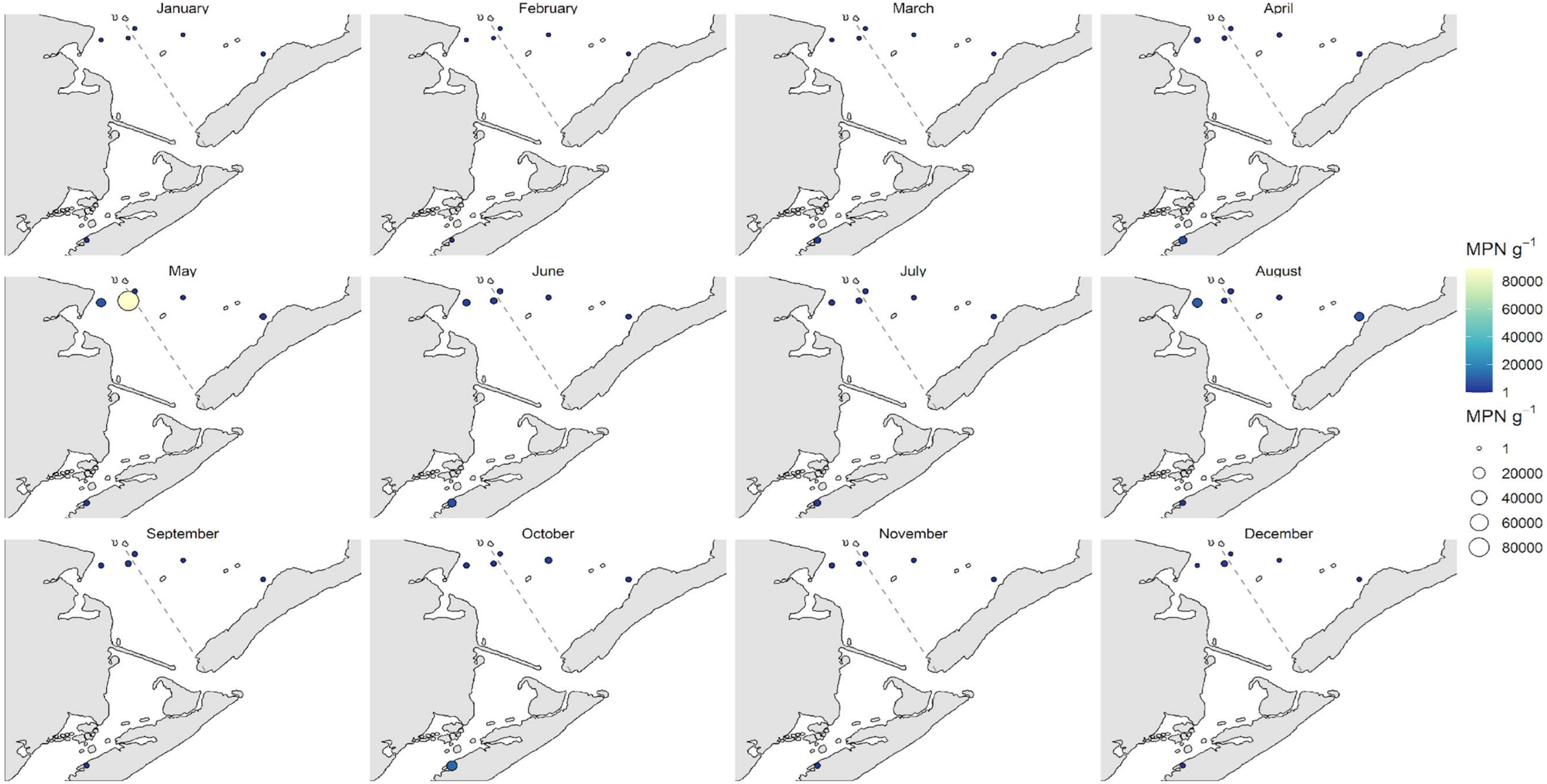

bacteria
2025, 4, 17. https://doi.org/10.3390/bacteria4020017
MDPI
Article
Applied Time Series Analyses (2000–2017) of Vibrio vulnificus and Vibrio parahaemolyticus (Pathogenic and Non-Pathogenic Strains) in the Eastern Oyster, Crassostrea virginica
Antonietta Quigg *, Aurora Gaona-Hernández, Mona S. Hochman, Sammy M. Ray and John R. Schwarz
Department of Marine Biology, Texas A&M University at Galveston, Galveston, TX 77553, USA;
TEXAS A&M UNIVERSITY
GALVESTON CAMPUS
Thank you!

Monthly spatial distribution of ***V. vulnificus*** (2001-2017) .



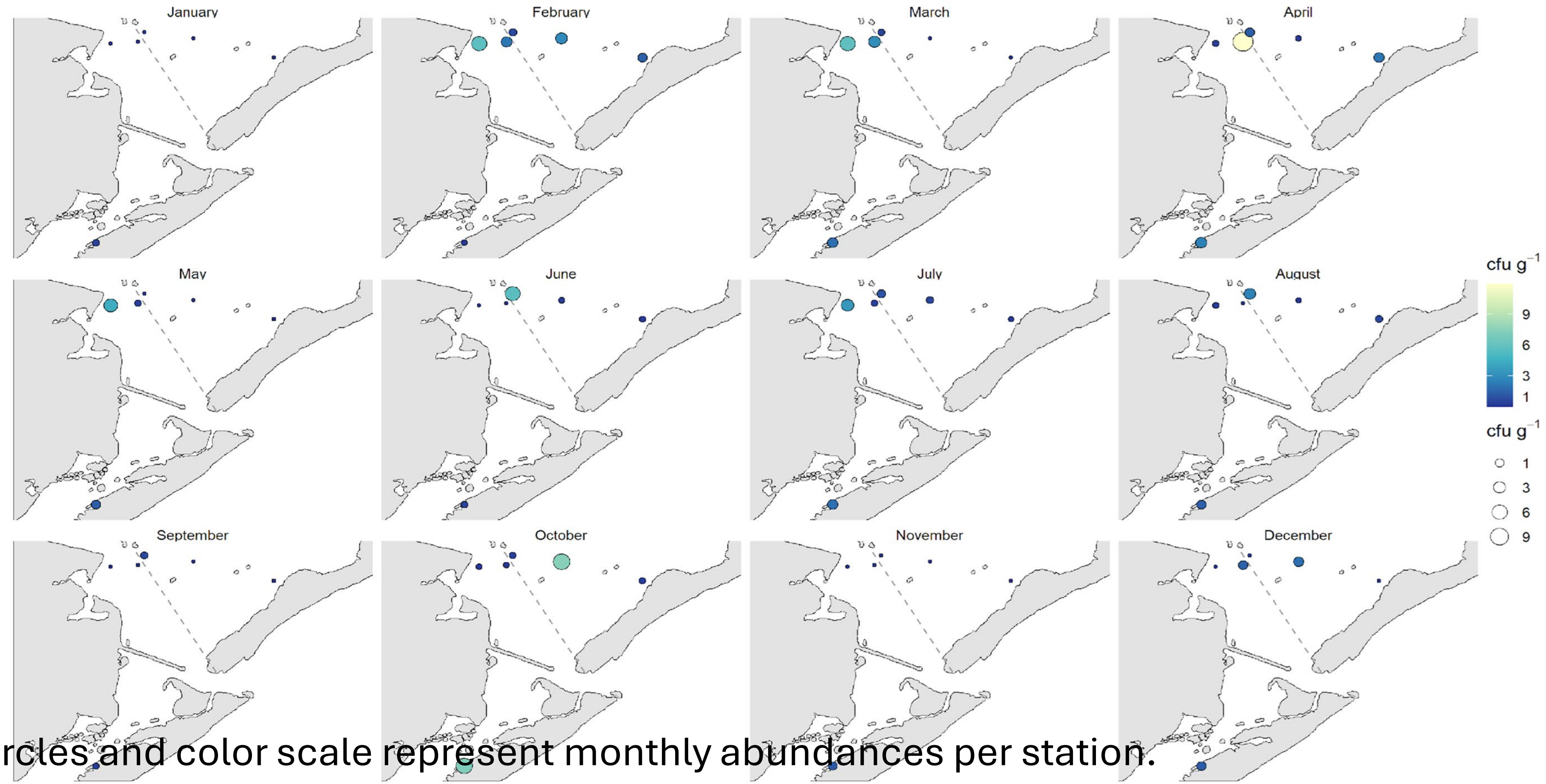
Circles and color scale represent monthly abundances per station. Units are MPN g^{-1} for *V. vulnifus*.

Monthly spatial distribution of ***total V. parahaemolyticus*** (2000 to 2017).



Circles and color scale represent monthly abundances per station. Units are MPN g^{-1} for total *V. parahaemolyticus*.

Monthly spatial distribution of pathogenic tdh+ *V. parahaemolyticus* (2000 to 2017).



Circles and color scale represent monthly abundances per station.
Units are cfu g^{-1} transformed to log (x+1) for pathogenic tdh+ V. *parahaemolyticus*.

Cross-correlations between *P. marinus* and *Vibrio* spp. timeseries

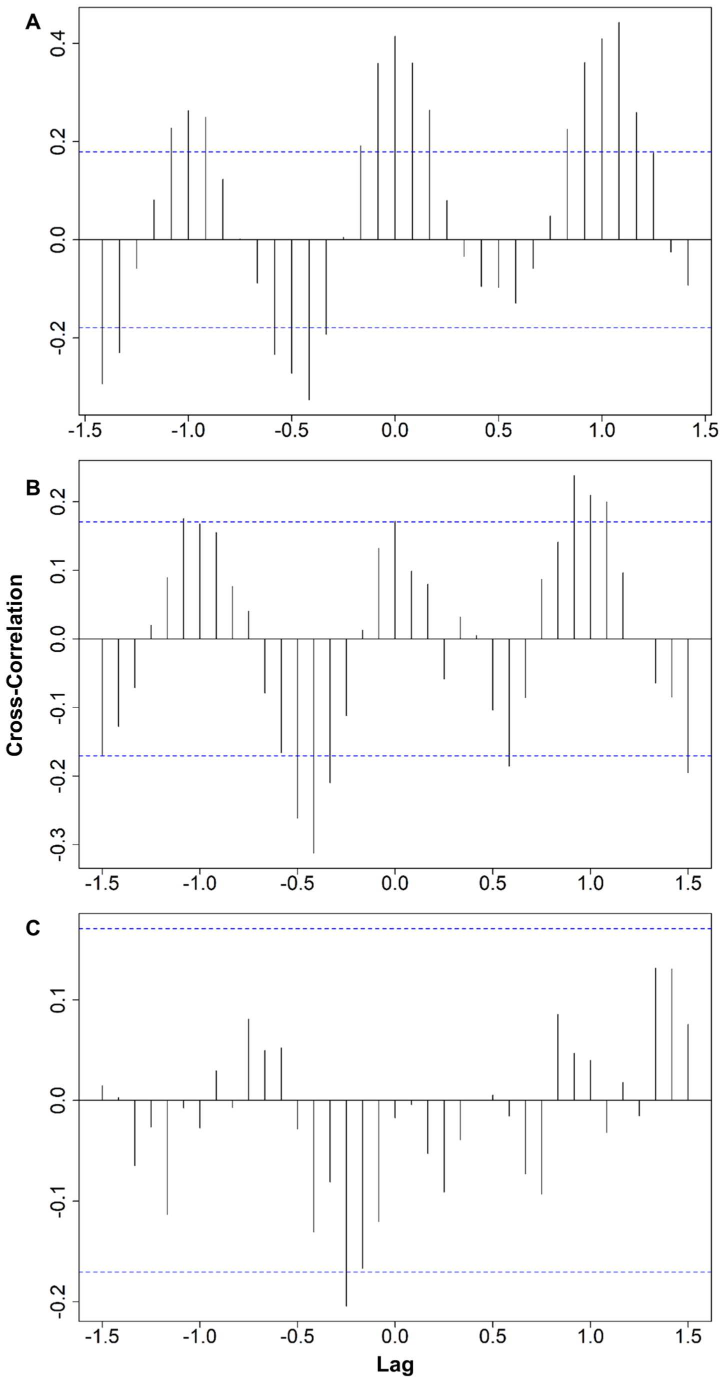
- Plots show cross-correlations with

a) *V. vulnificus*, significant correlations occurred at lags -1, -2, -4, -5, -6 and -7,

b) total *V. parahaemolyticus*, significant correlations at lags -4, -5 and -6,

c) pathogenic tdh+ *V. parahaemolyticus,* significant correlations at lag -3.

- Blue lines indicate the 95% confidence intervals (any bars outside the interval suggests a significant correlation).



STATE OF THE BAY: LEGACY, EMERGING CHEMICAL AND BIOLOGICAL CONTAMINANTS IN AQUATIC ECOSYSTEMS PART II

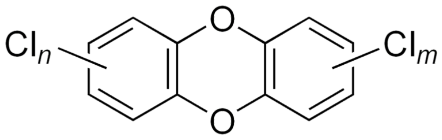
DIOXIN AND POLYCHLORINATED BIPHENYLS: LESSONS LEARNED FROM TWO DECADES OF MONITORING, DATA ANALYTICS, AND MODELING

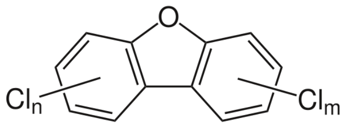
Hanadi S. Rifai, PhD, PE, Fellow ASCE
Civil and Environmental Engineering
University of Houston

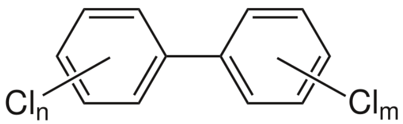
2026 State of The Bay Symposium
February 24-25, 2026

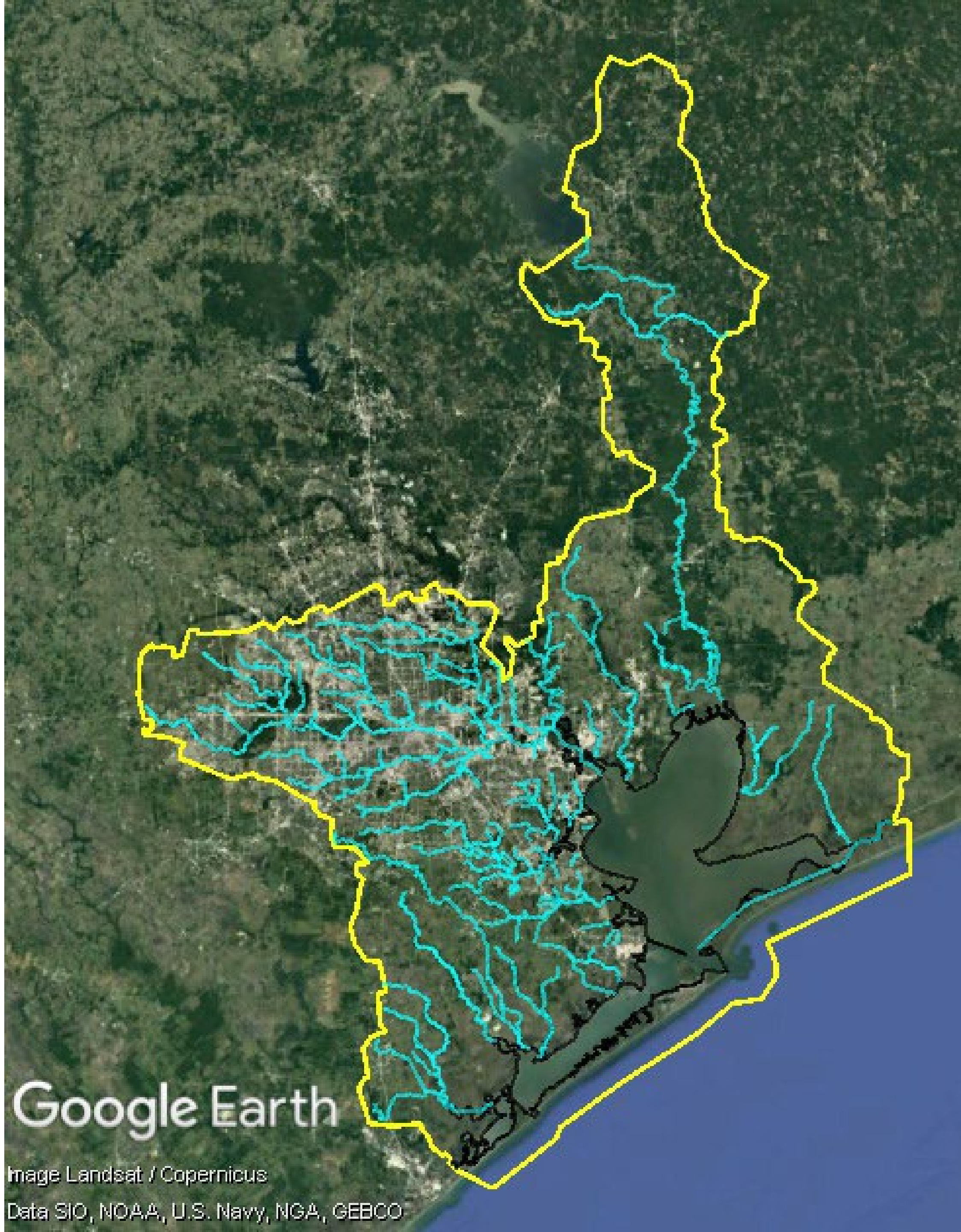
The Lower Watershed of the Galveston Bay Estuary

- Home of the City of Houston and the industrialized Houston Ship Channel
- Highly developed and populated
- Vulnerable to natural disasters: flooding, hurricanes, drought, and extreme heat
- Water quality challenges:
  - Indicator pathogens
  - Seafood advisories for polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibezofurans (PCDFs) and polychlorinated biphenyls (PCBs)



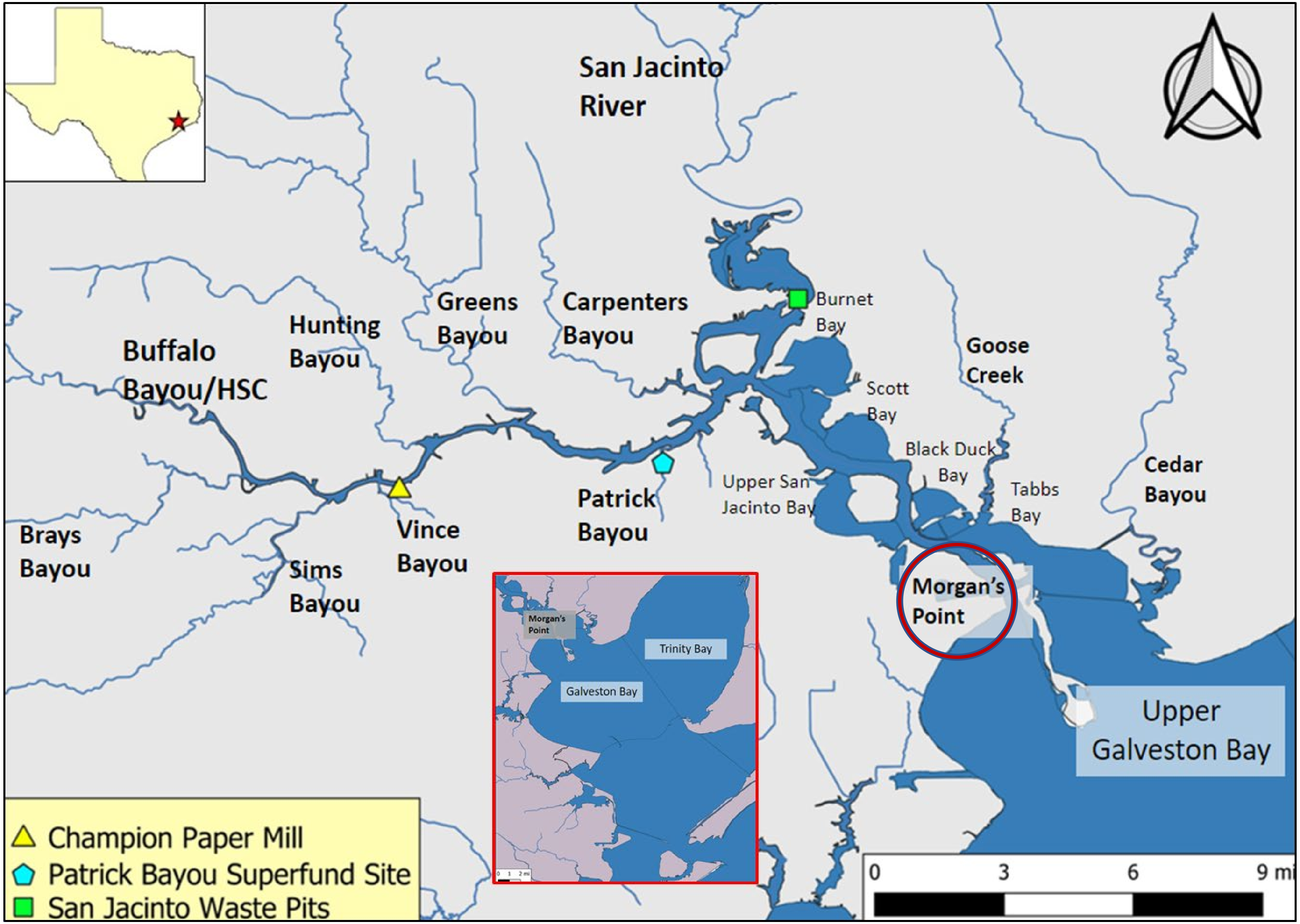






The Houston Ship Channel (HSC) System and its Tributaries

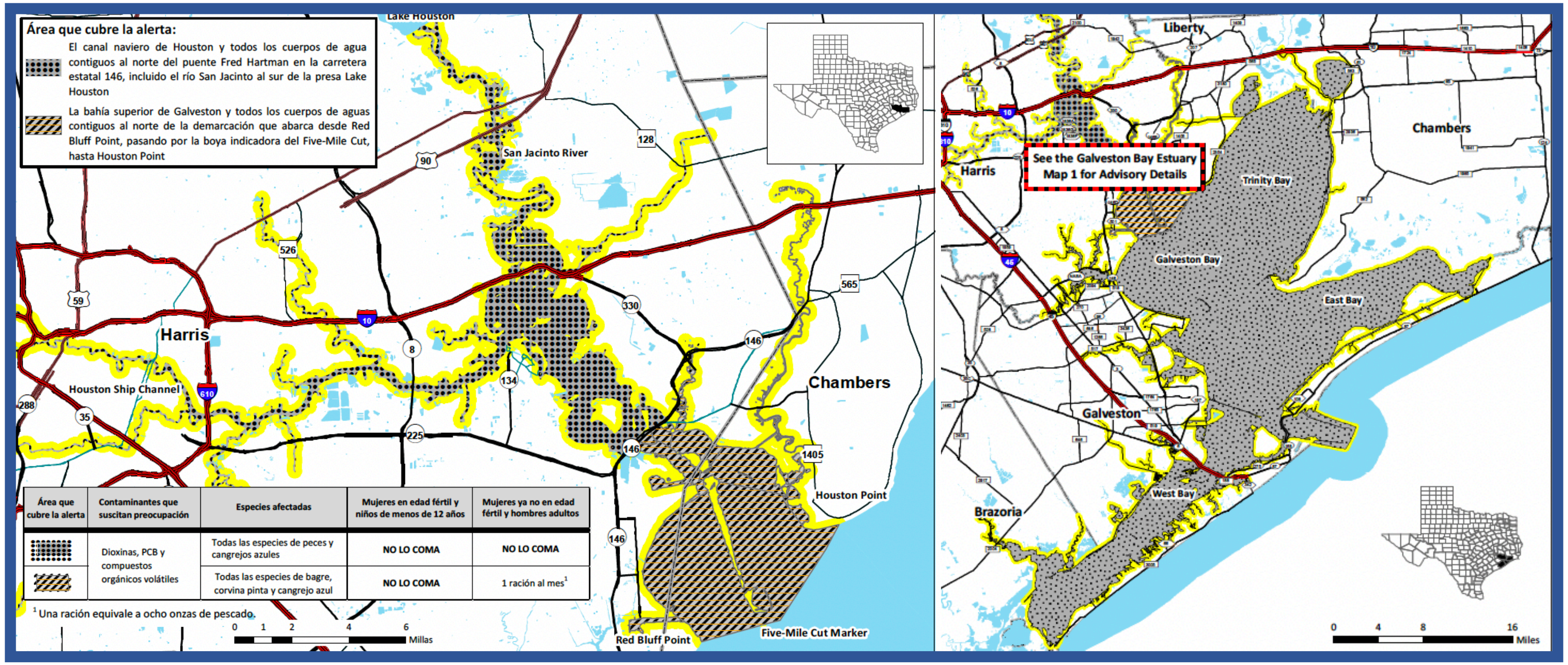
- The dredged channel opened in 1914
- Maintenance dredging of the deeper channel continuous
- Currently proposed widening and deepening of the navigational channel



Context for PCB and Dioxin in Galveston Bay

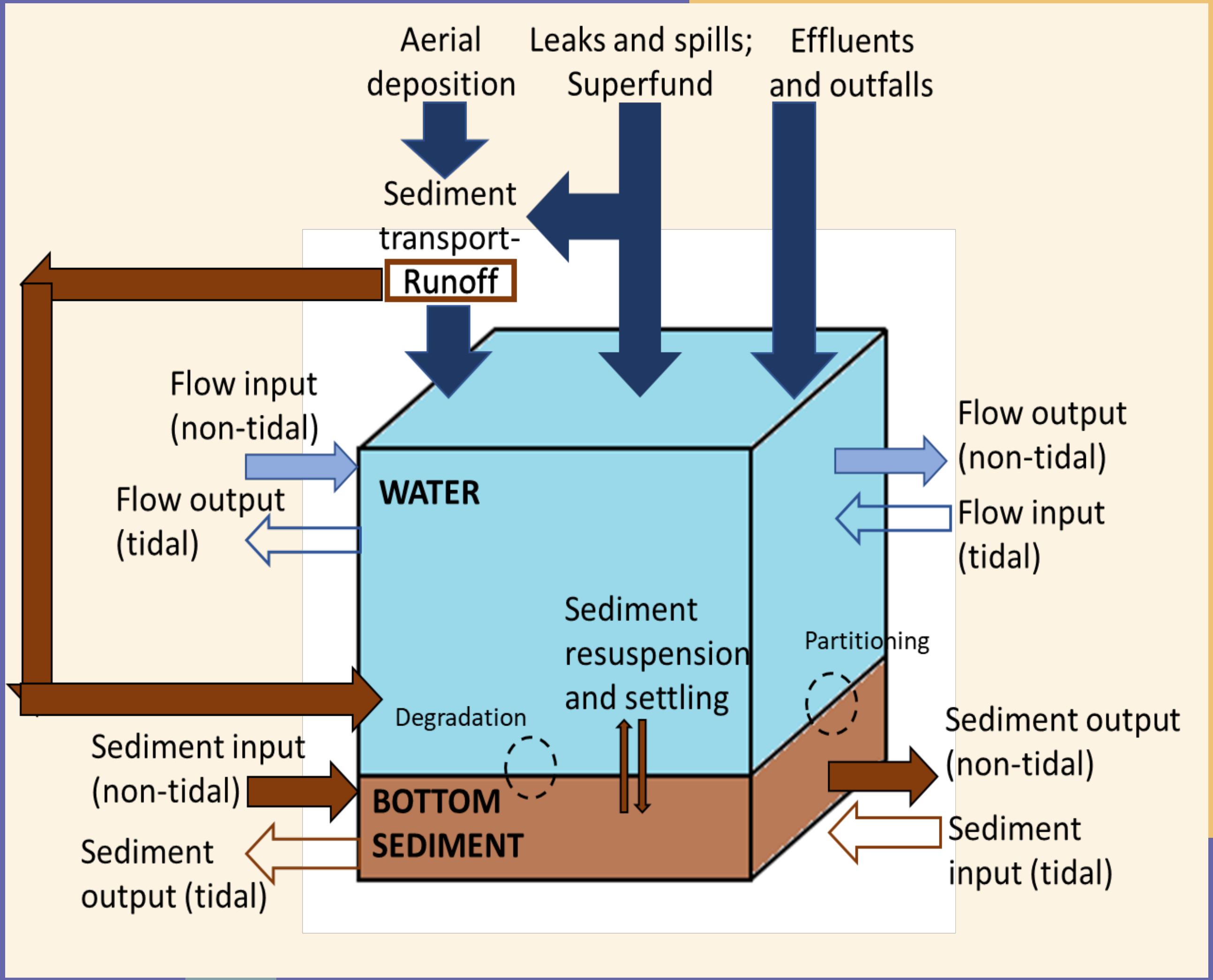
- The 1994 1st State of the Bay Report for Galveston Bay identified 17 priorities, including:
  - ***#5 – toxic substances have contaminated water and sediment, and***
  - ***#9 – Seafood from some areas may pose a public health risk as a result of potential presence of toxic chemicals***
- A dioxin Total Maximum Daily Load (TMDL) process was launched in 2002, PCB data collection added in 2003
- Sampling from 2002 – 2021
- Water, Sediment, tissue

Seafood advisories have been issued for much of the Galveston Bay System for PCBs and dioxin in crab and fish tissue



OUTLINE

- **Sources Context**
- Longitudinal/Loading Context
- Flow Dynamics Context
- Natural Hazards Context



SOURCES CONTEXT

Legacy Sources

- Contaminated sediment from historical disposal practices
- Discharges to water
- Superfund and other hazardous waste sites

Continuing Sources

Air Deposition

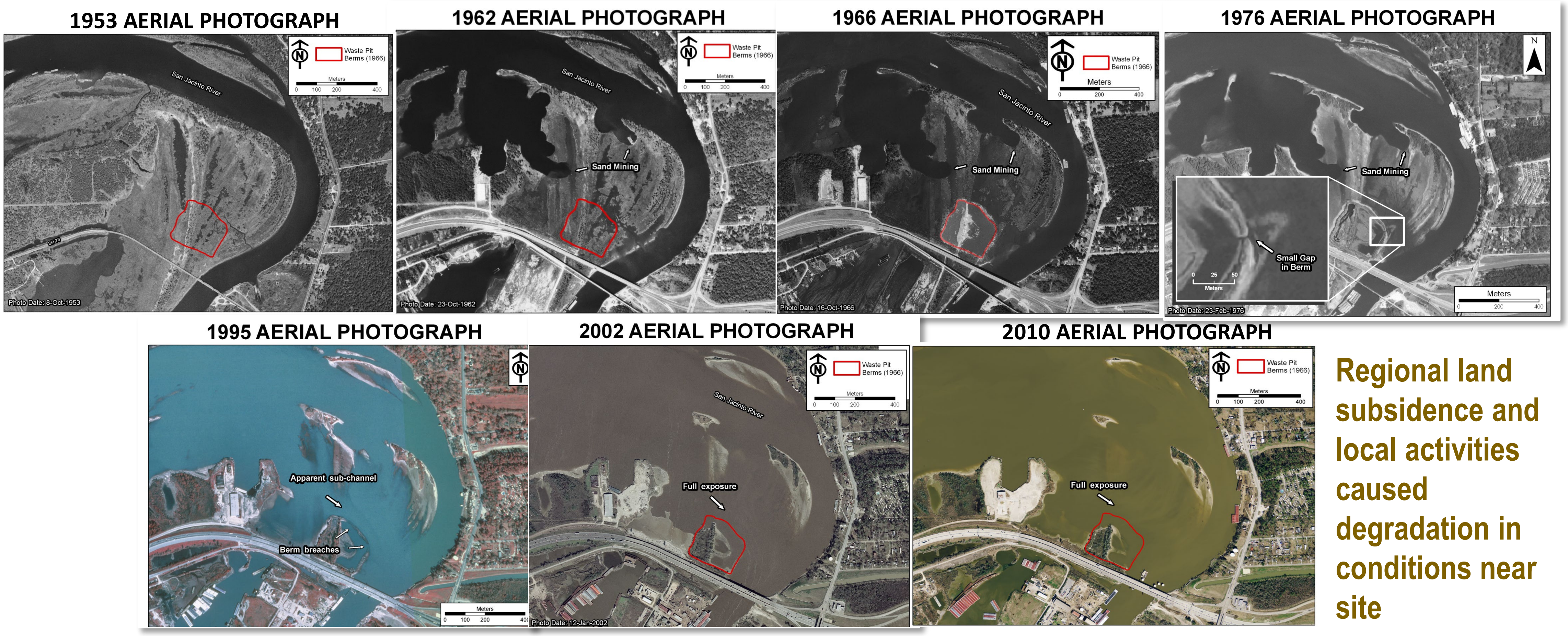
Polluted Runoff

Industrial/ Municipal Discharges

Source Apportionment and Profiling Studies

Legacy Source: The San Jacinto River Waste Pits Superfund Site

1965 & 1966 wastes from the Champion Paper Mill in Pasadena, TX, were disposed in pits that subsided over time



Regional land subsidence and local activities caused degradation in conditions near site

By 2002, the waste pits were in direct, constant contact with SJR waters

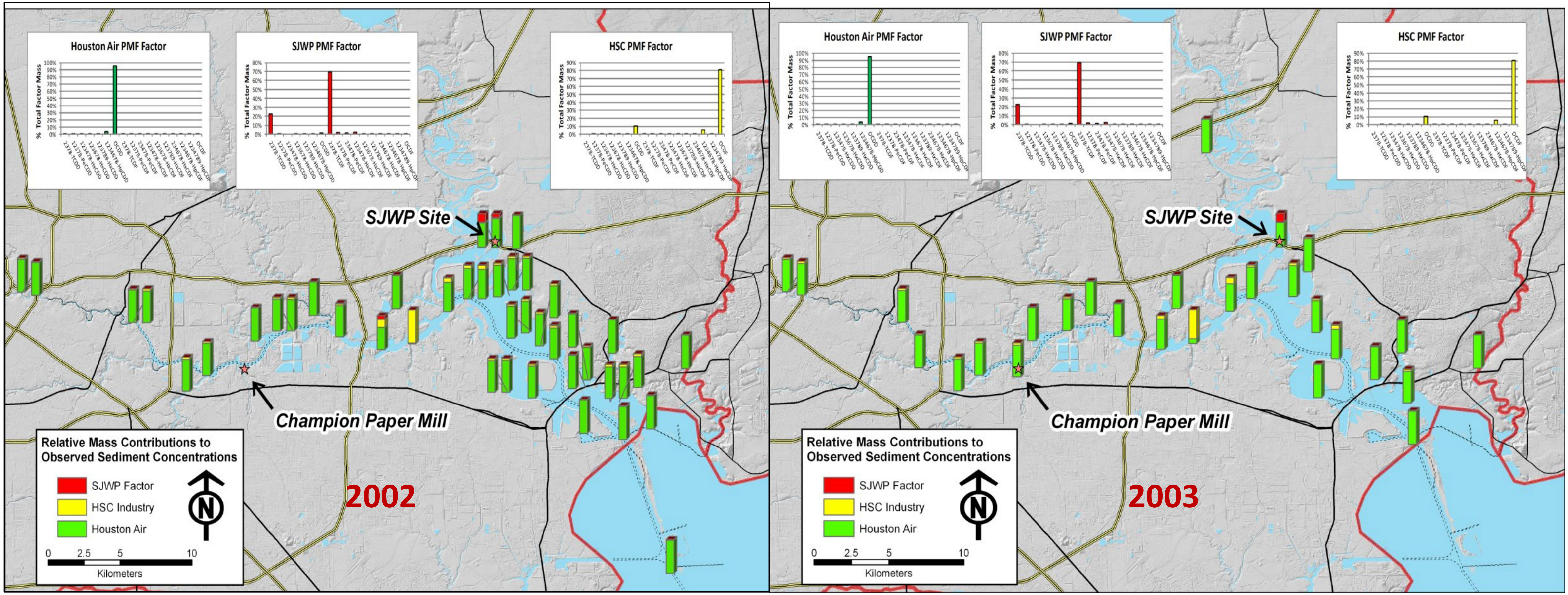
The San Jacinto River Waste Pits Superfund Site

Lessons learned

Dioxin releases due to overtopping berms between 1965 and 1995

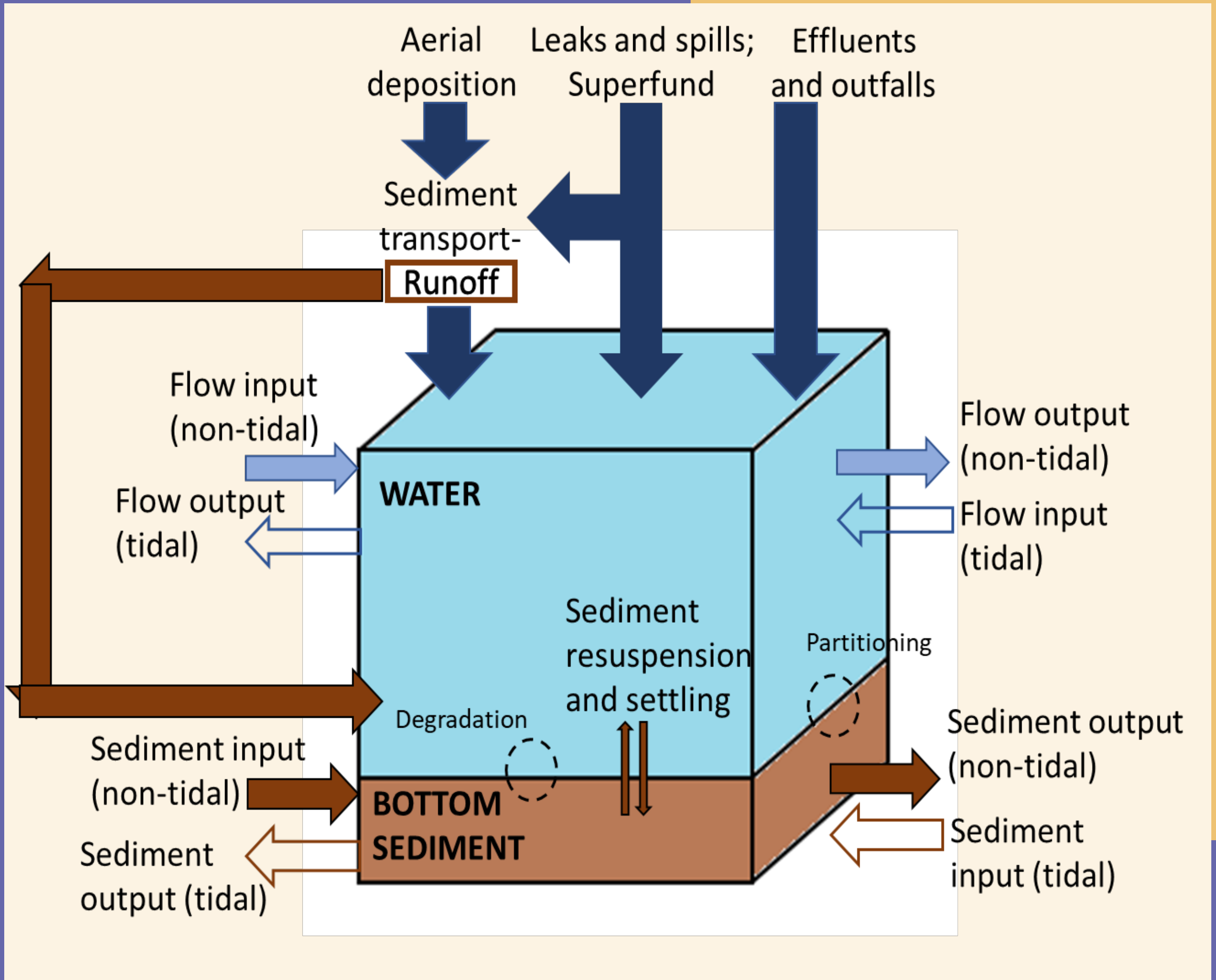
Lower Estimate TEQ Flux (g/yr)	0.28
Upper Estimate TEQ Flux (g/yr)	26.6

GB assimilative capacity 1.49 g TEQ/yr

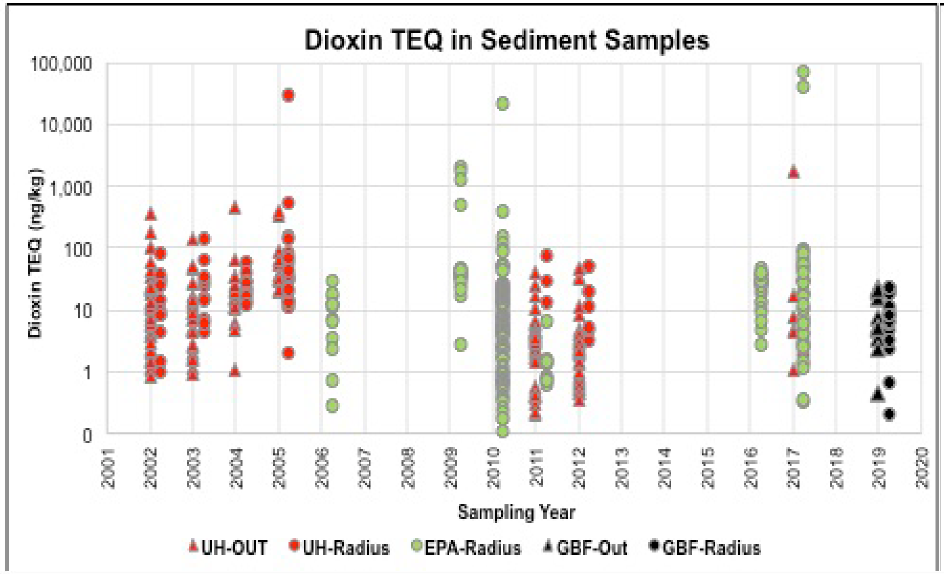


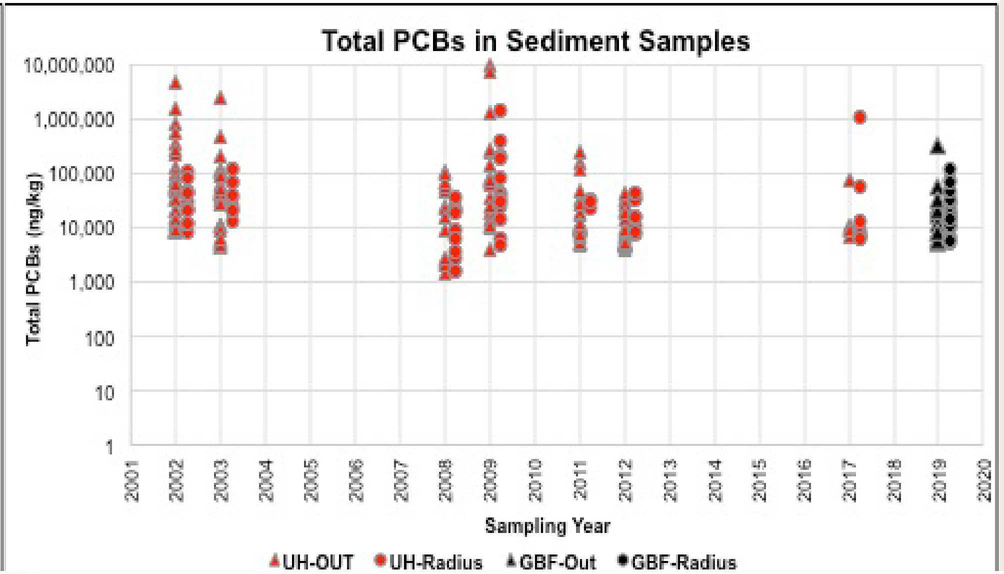
OUTLINE

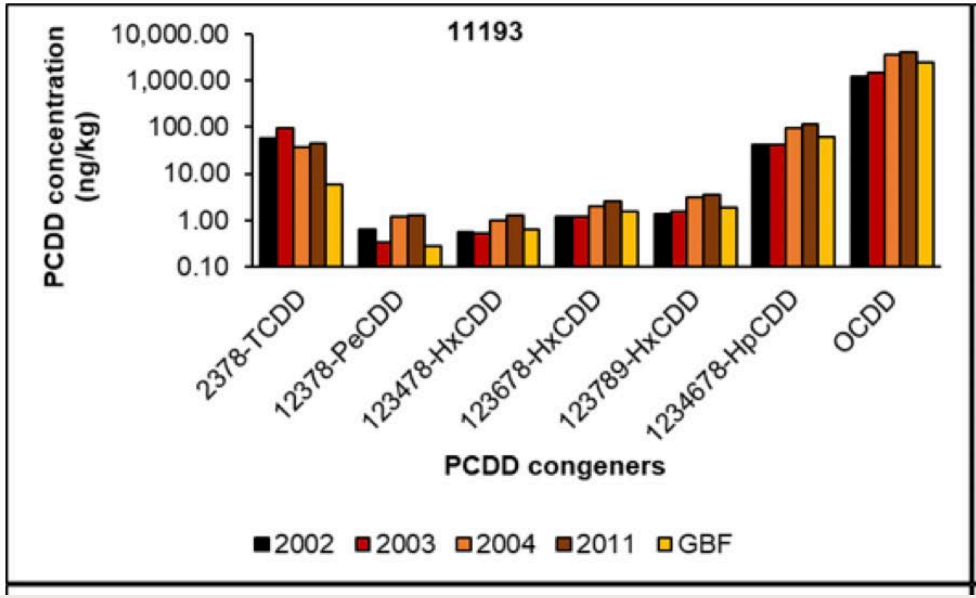
- Sources Context
- **Longitudinal/Loading Context**
- Flow Dynamics Context
- Natural Hazards Context

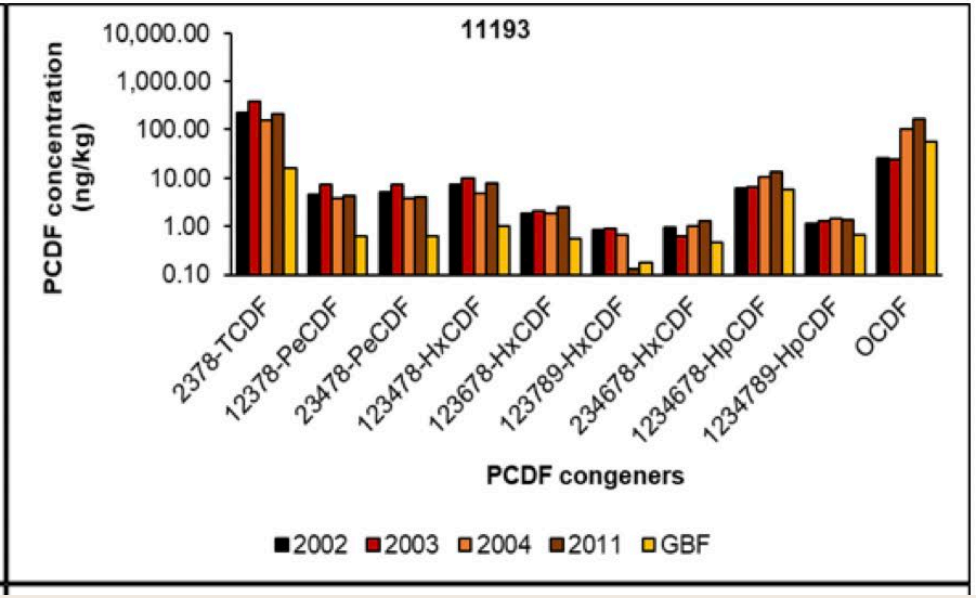


Longitudinal Context: Spatial and temporal and congener change over time



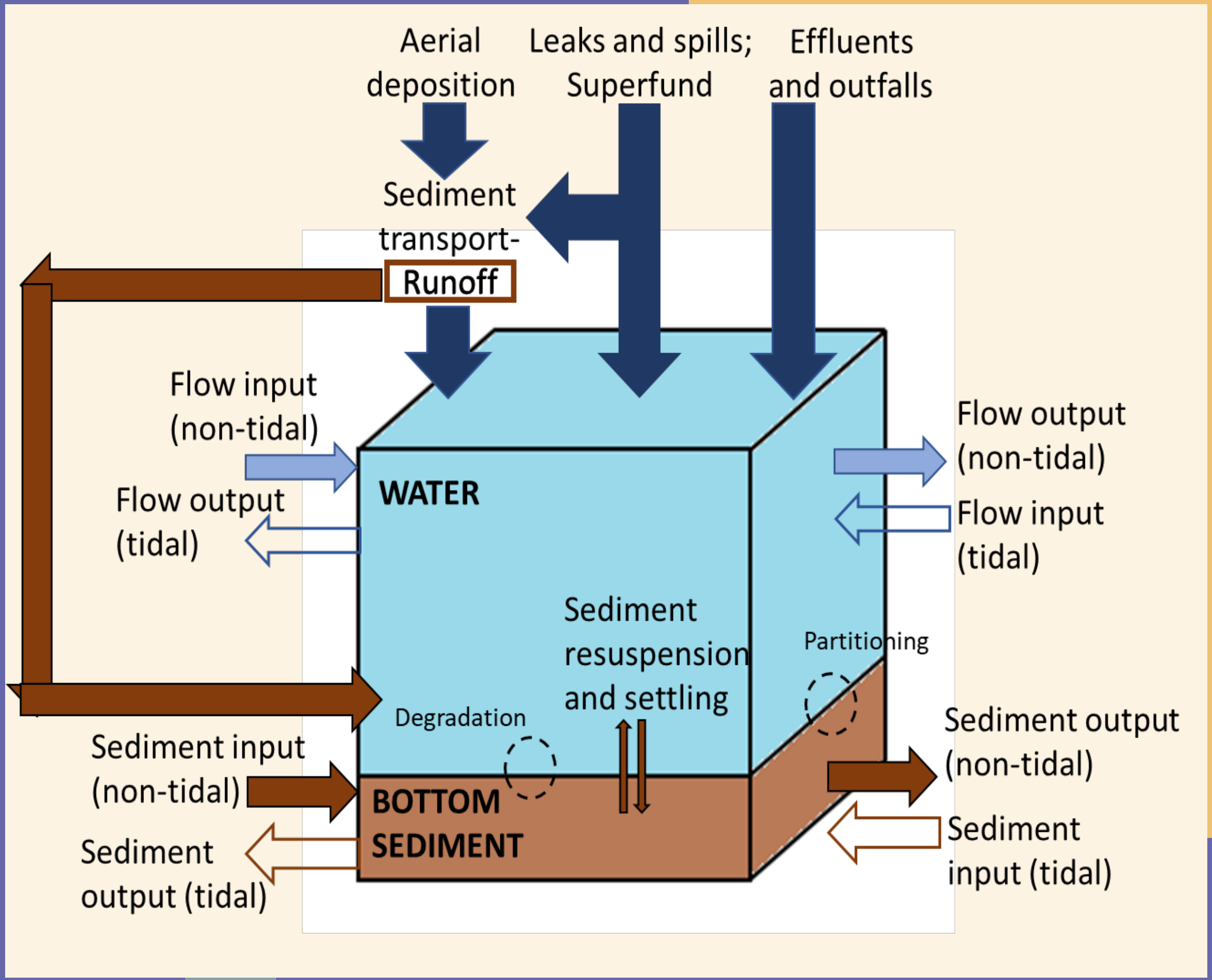




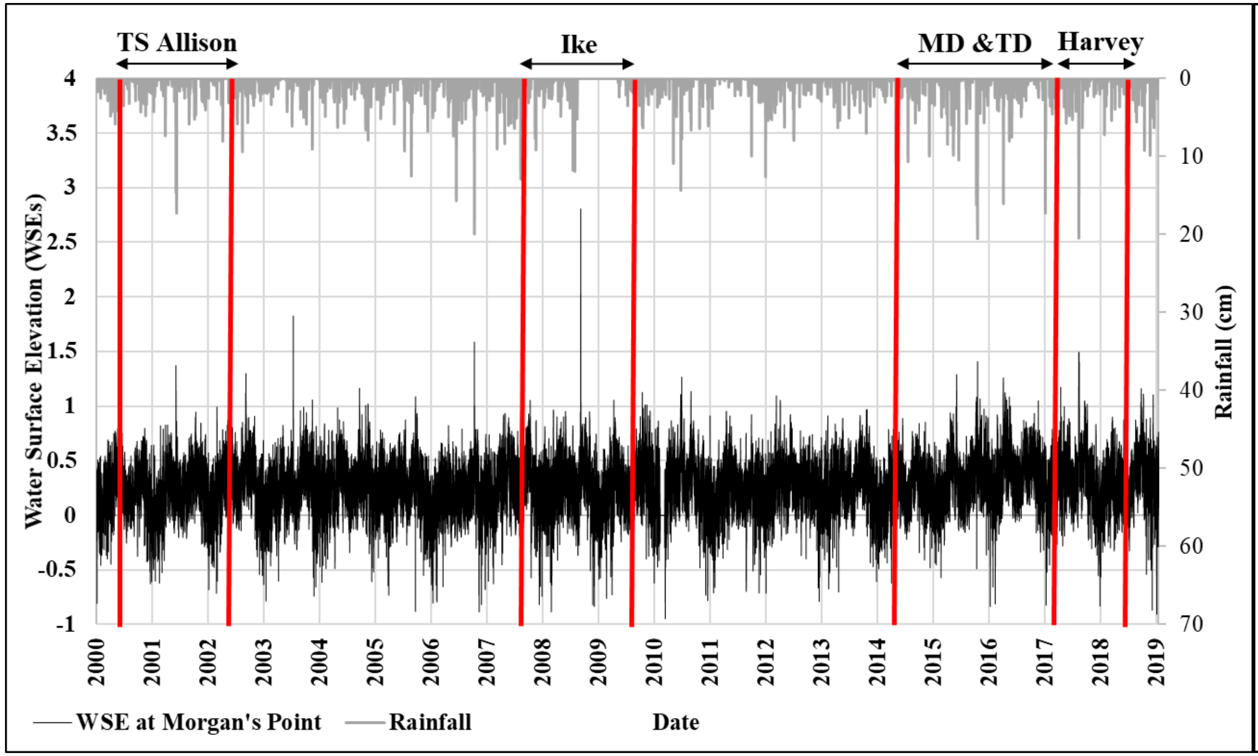


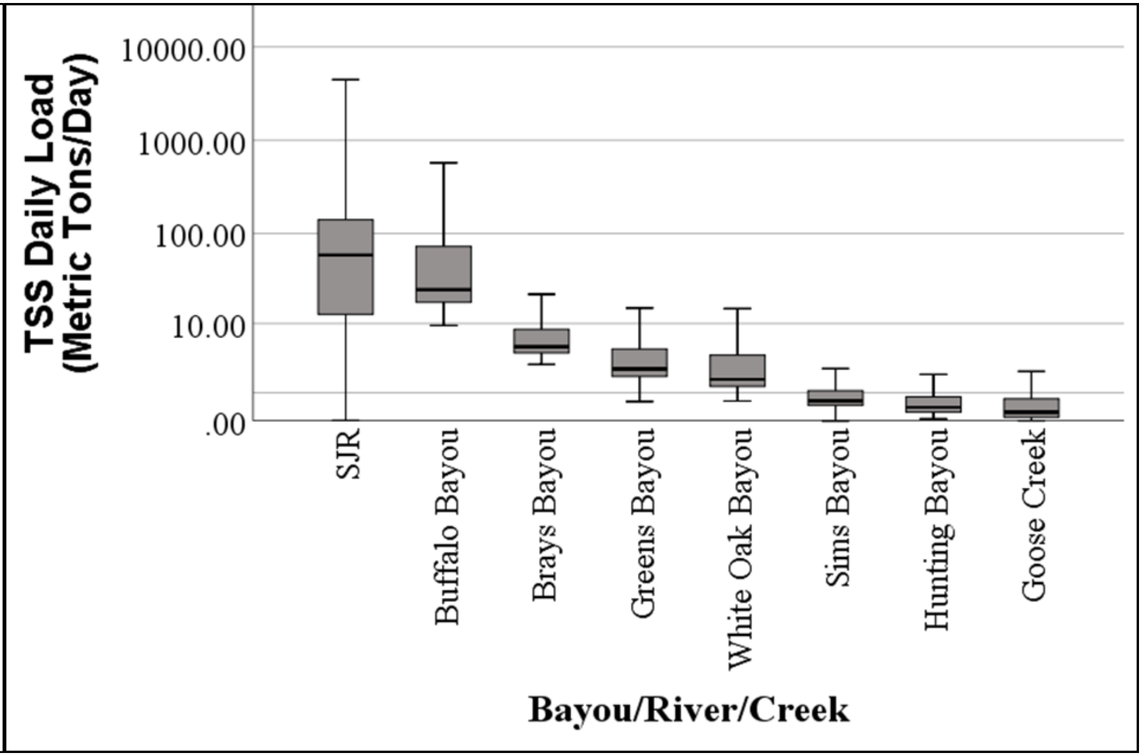
OUTLINE

- Sources Context
- Longitudinal/Loading Context
- **Flow Dynamics Context**
- Natural Hazards Context

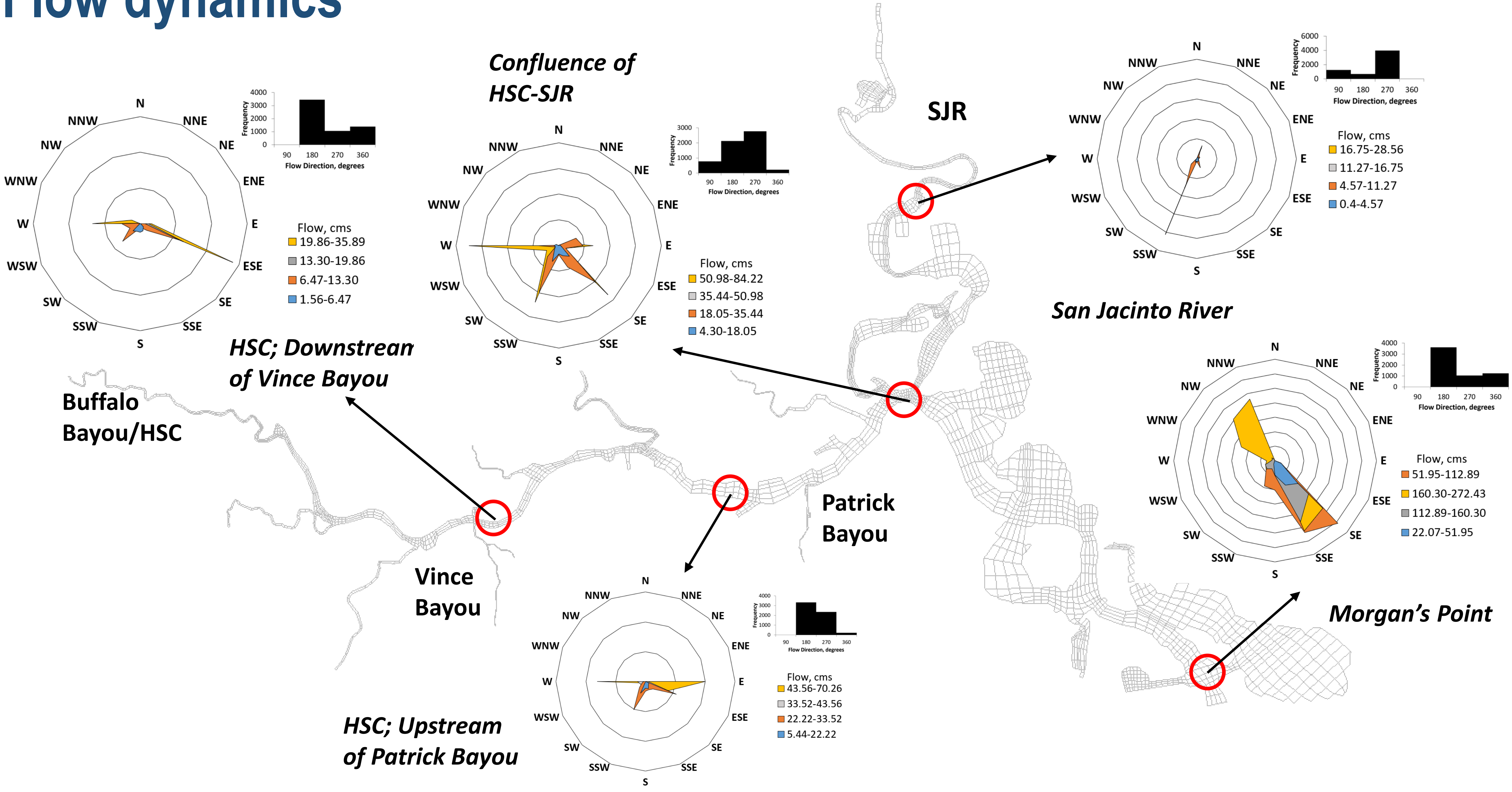


Daily variability and system inputs critical to understanding system behavior

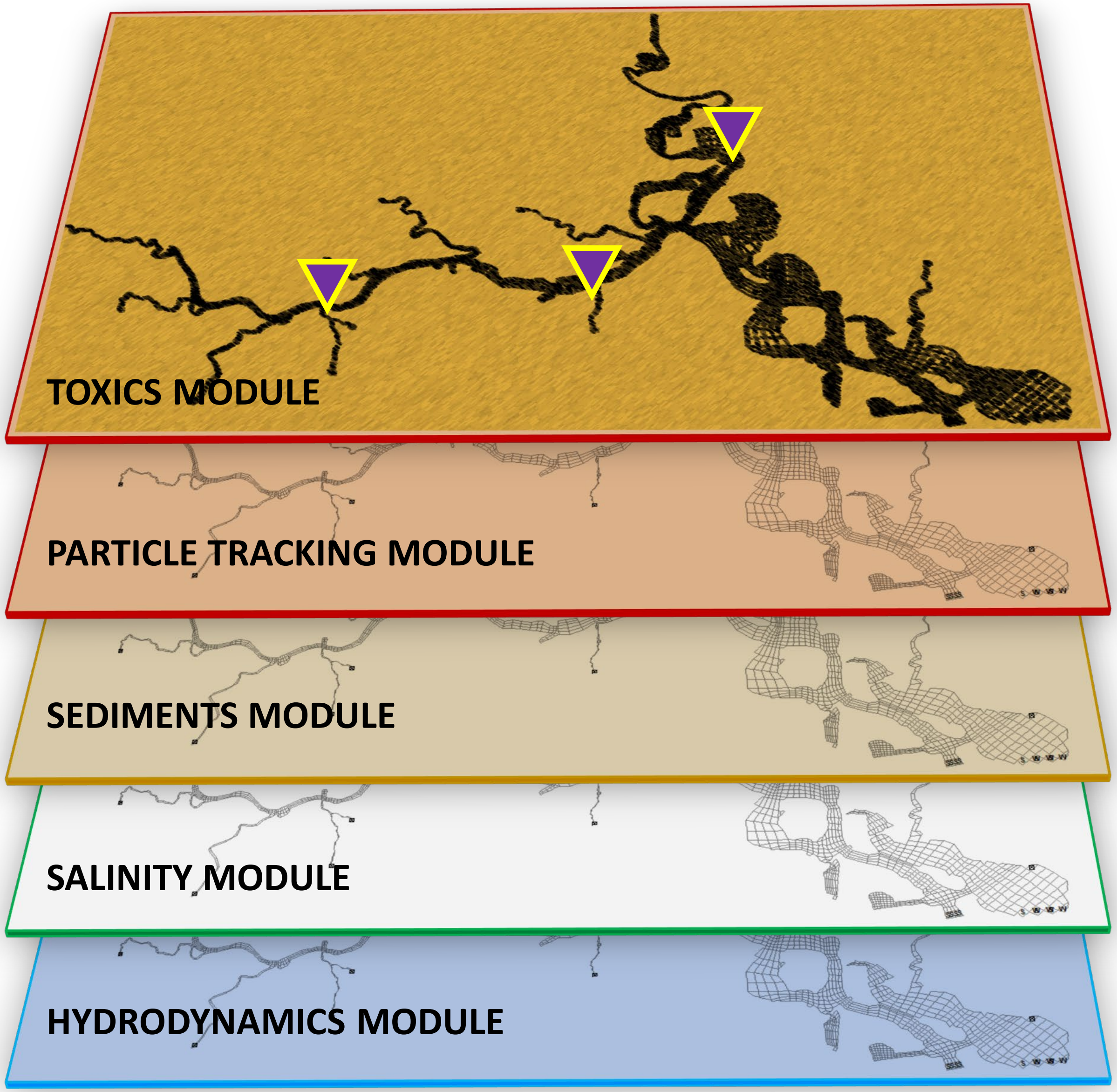




Flow dynamics



Modeling the HSC-SJR: EFDC modules and variables



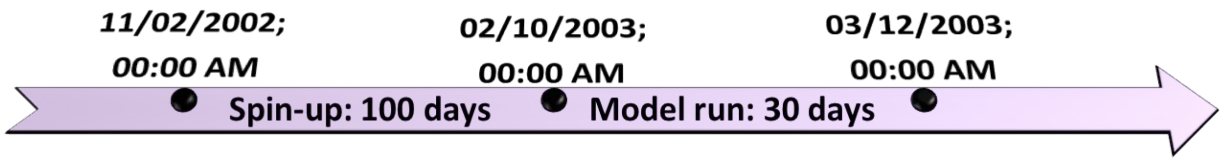
Primary module inputs

- Organic carbon
- Partition coefficients

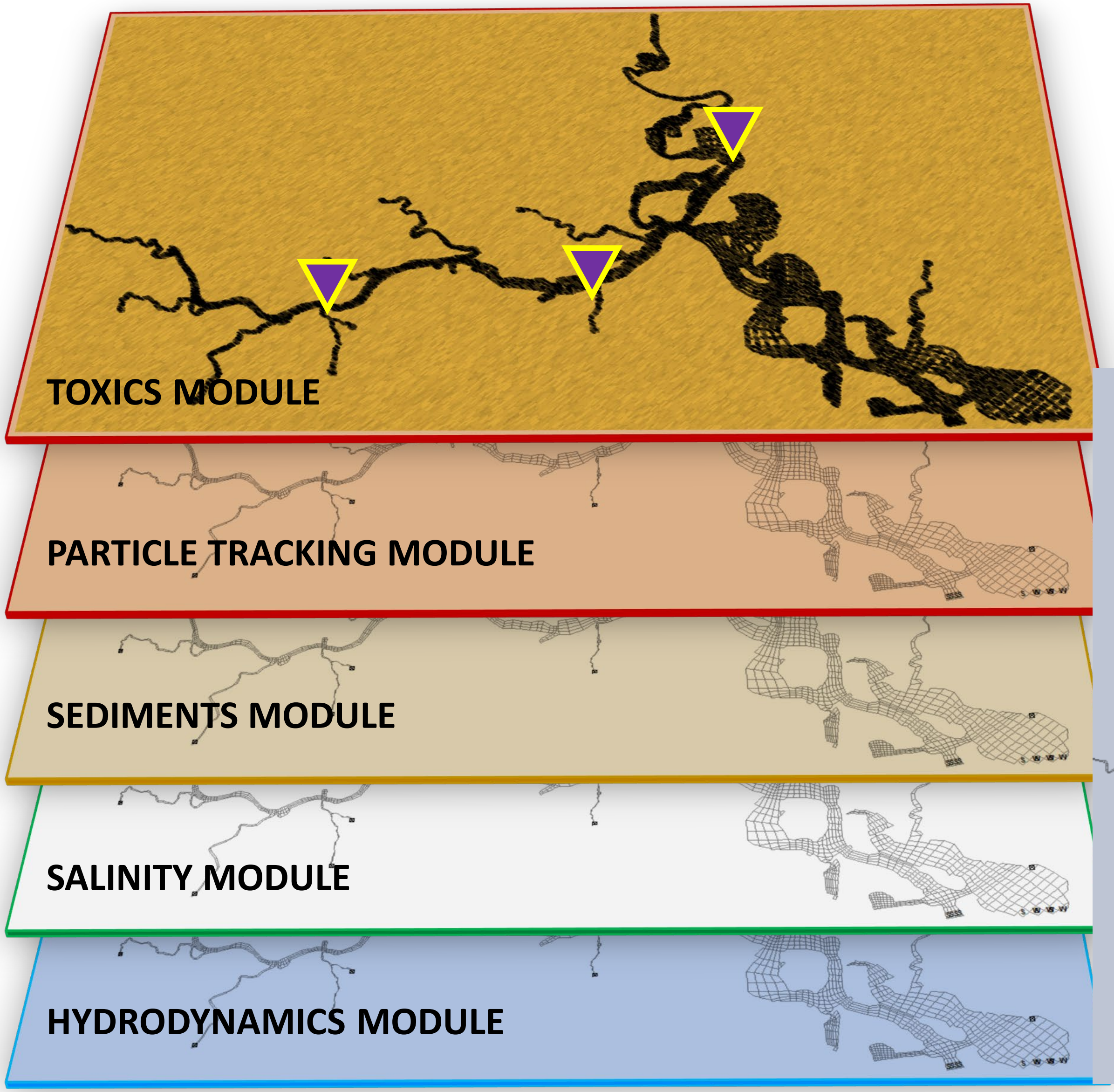
Modeled parameters

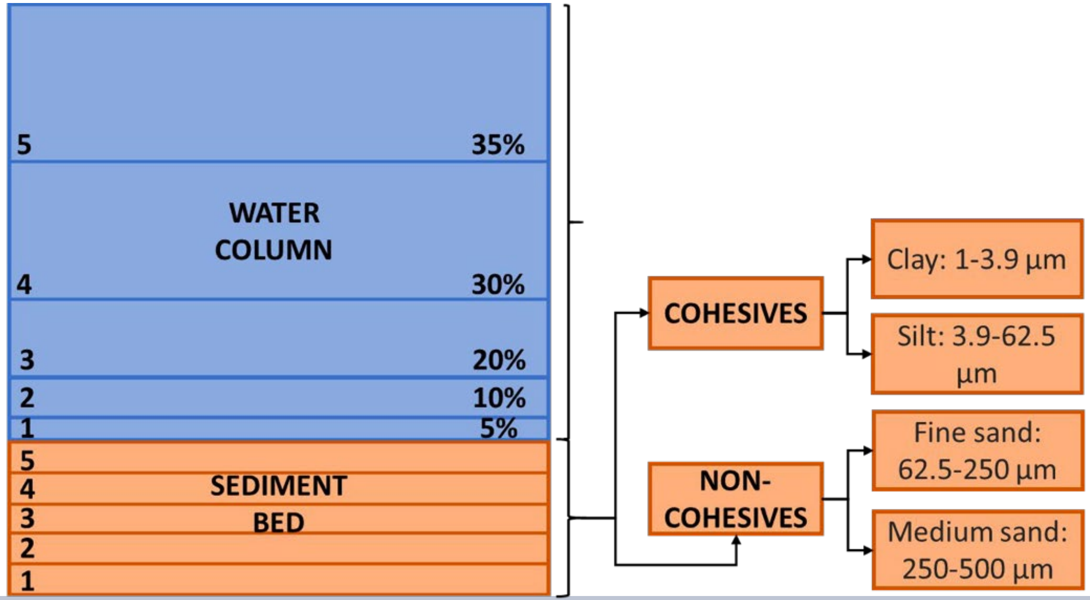
- Dissolved toxics
- Sediment toxics

PCB-1 simulated at specific point sources



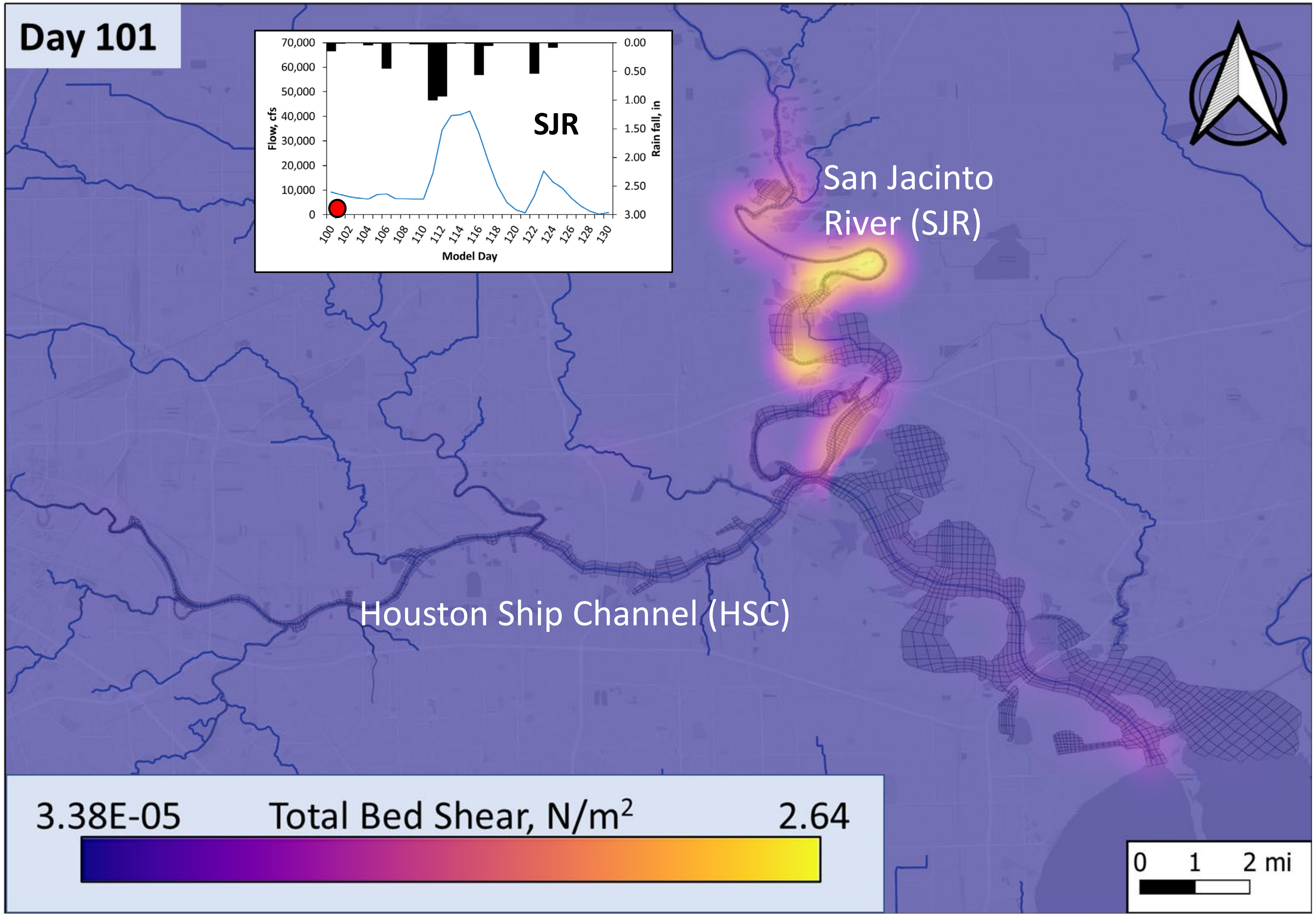
EFDC Model for the HSC-SJR



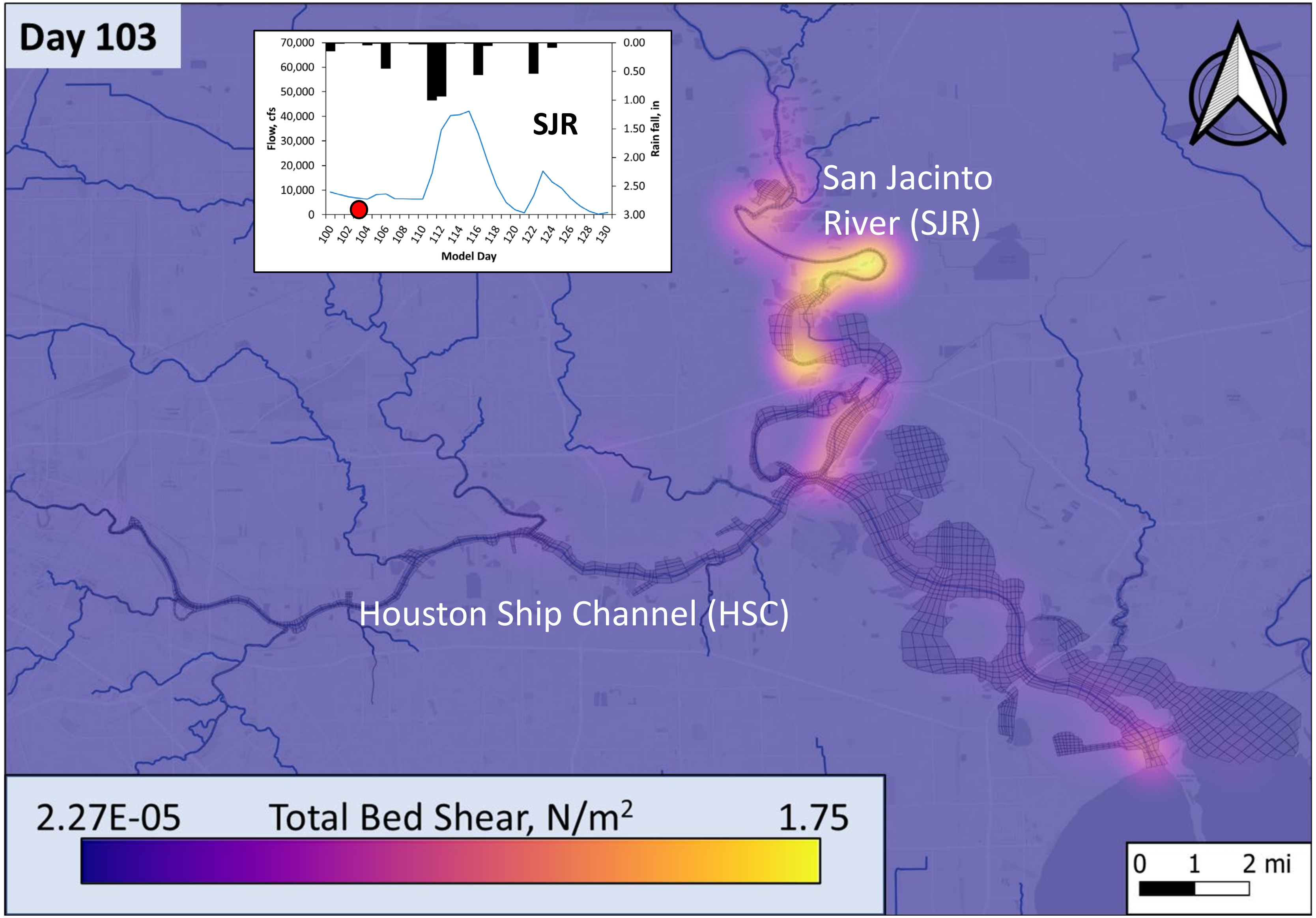


Shear stress: Model Day 101 (No rain)

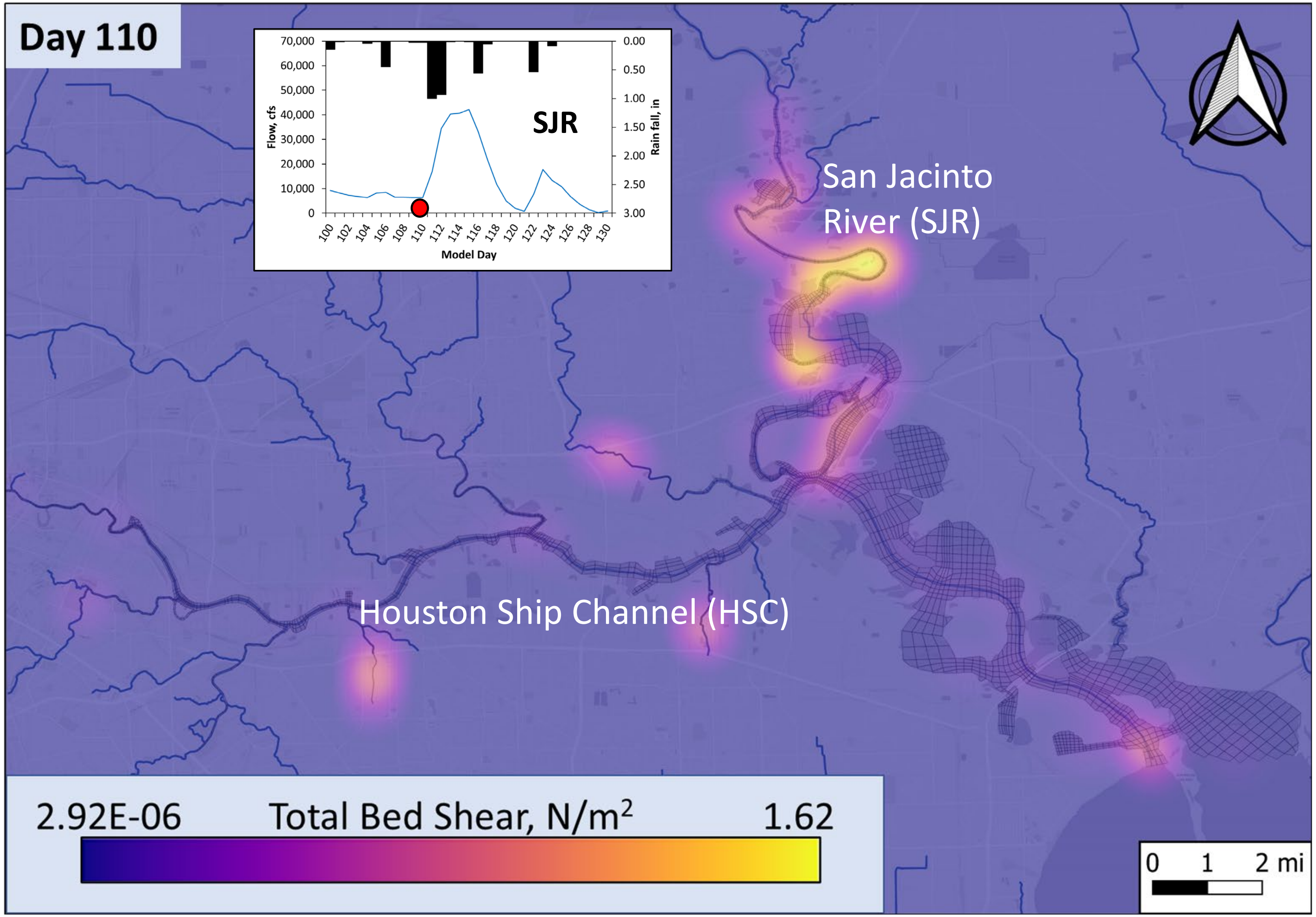
Force dragging sediment particles



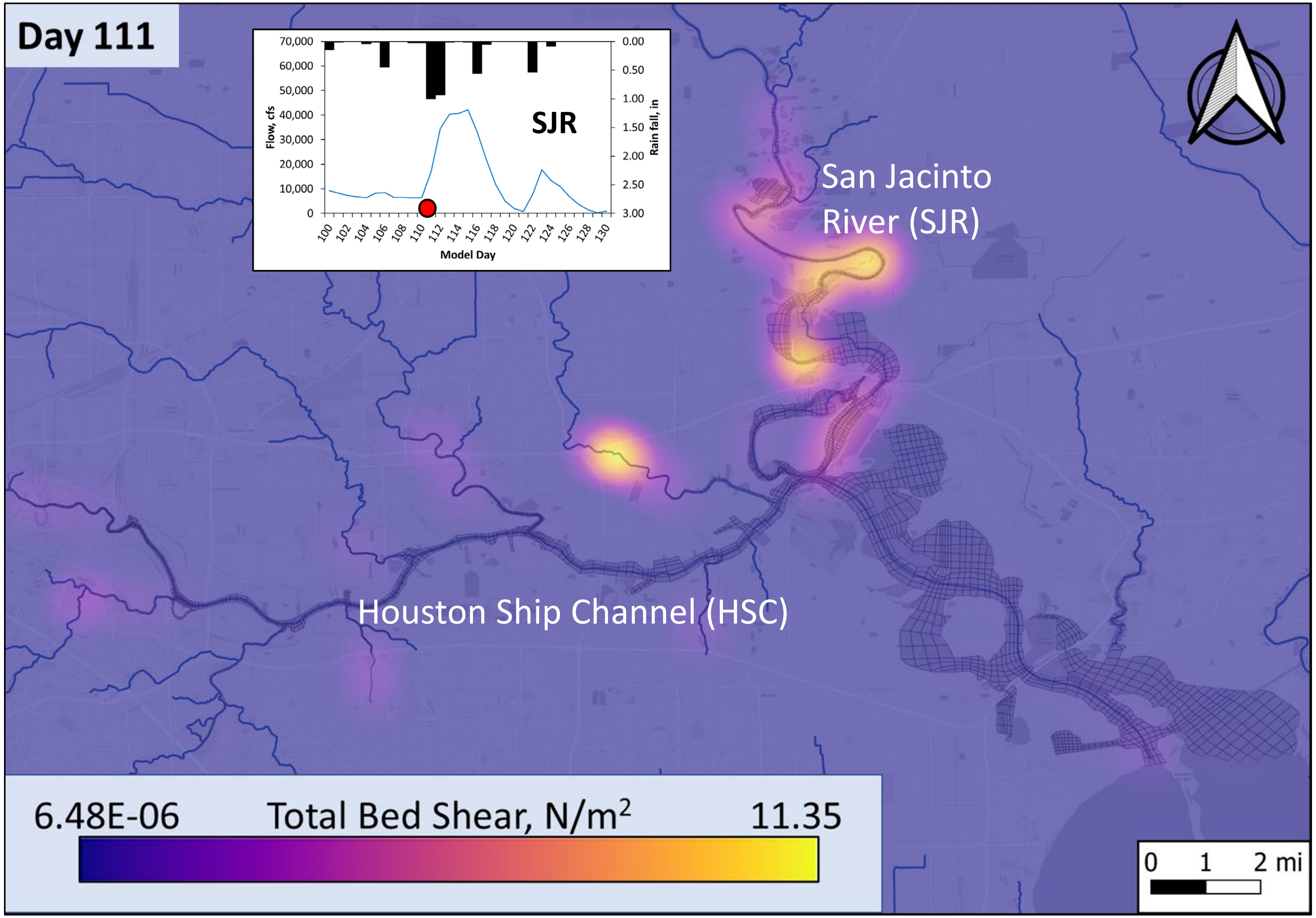
Shear stress: Model Day 103 (No Rain)



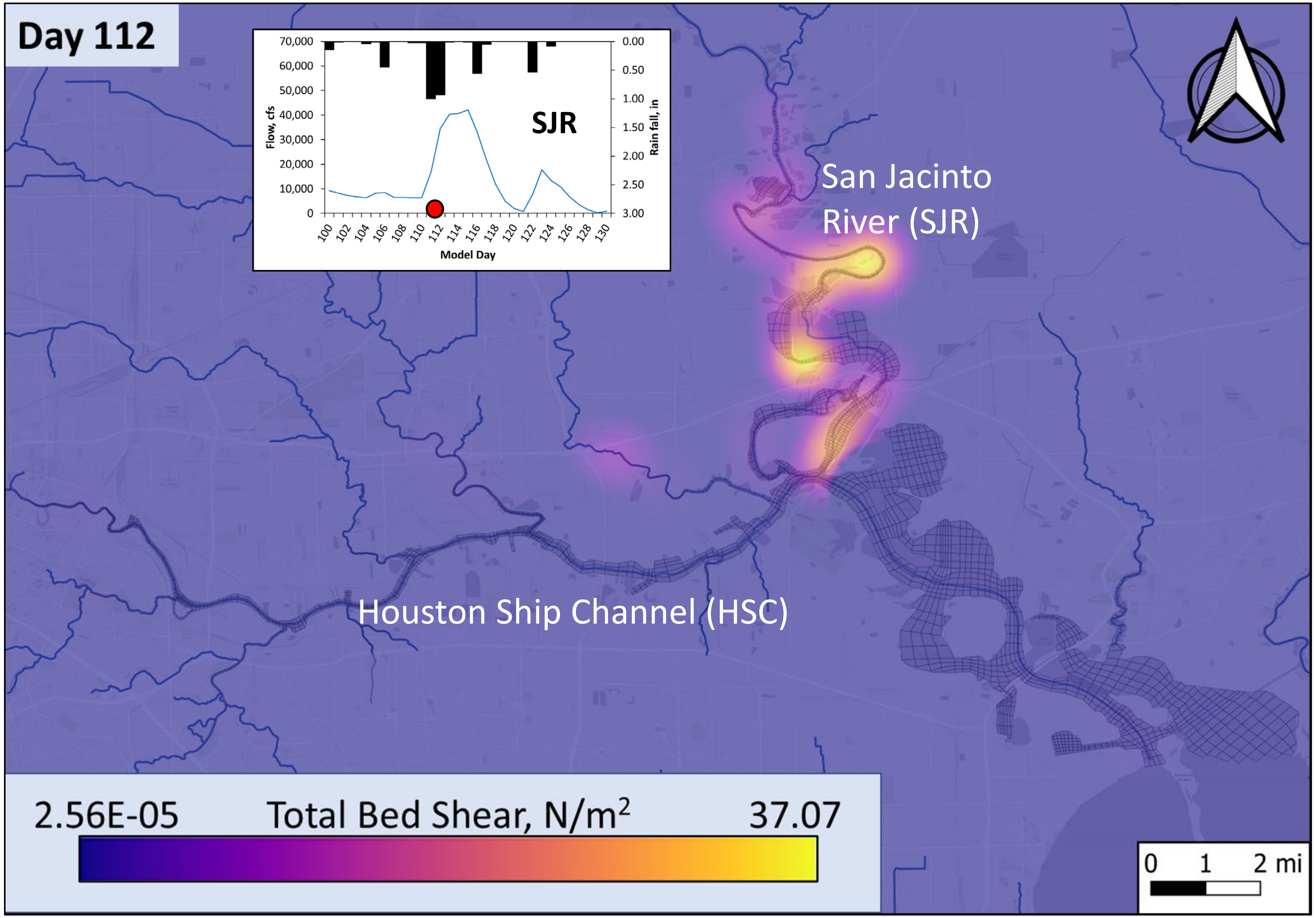
Shear stress: Model Day 110 (Rain)



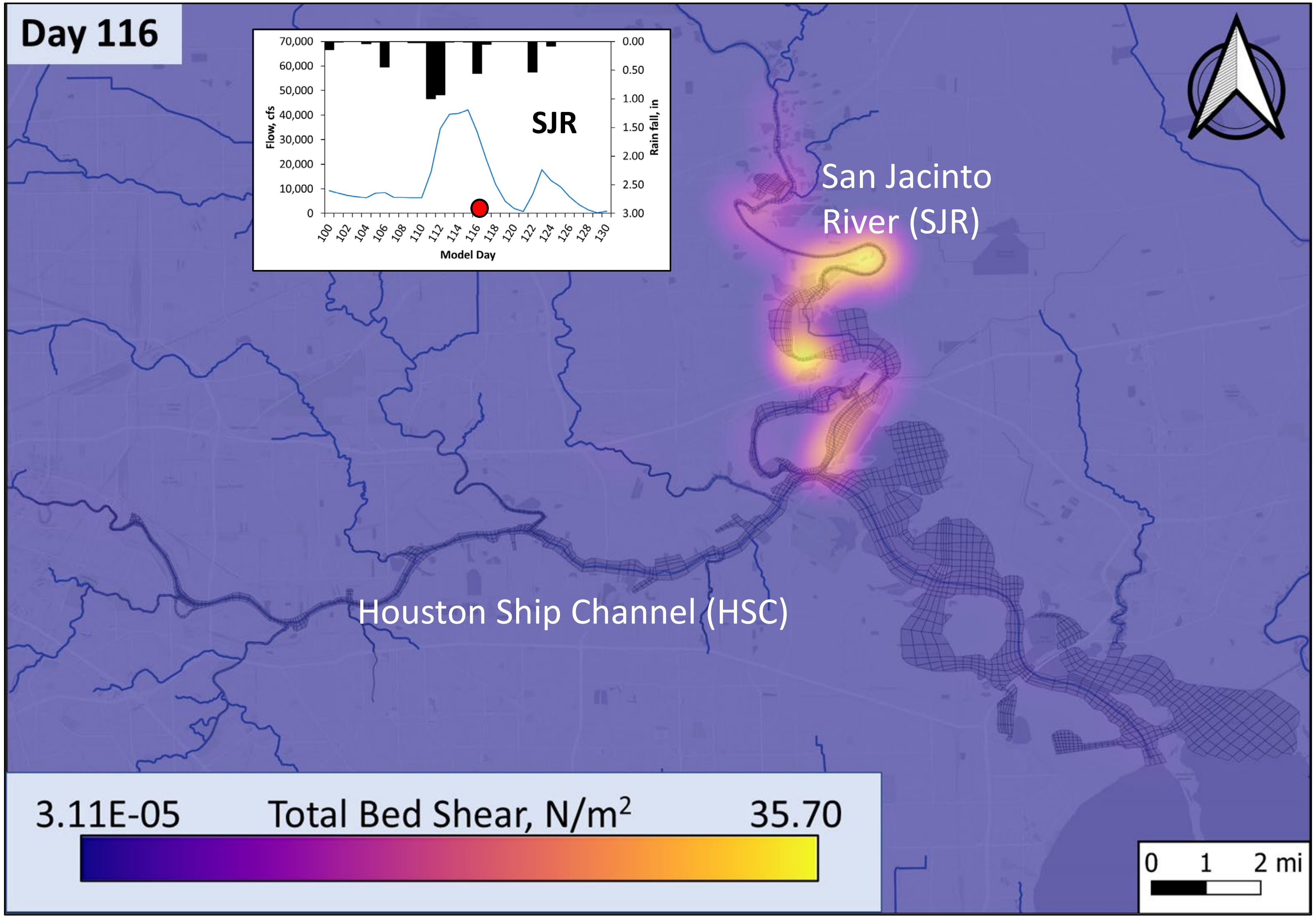
Shear stress: Model Day 111 (Rain)



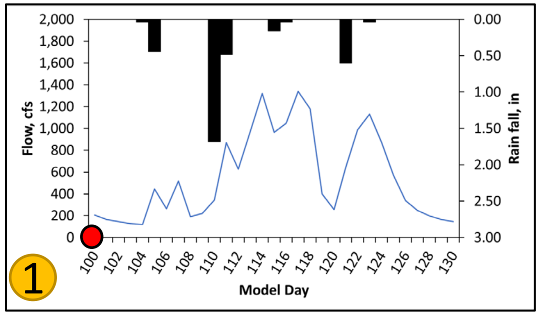
Shear stress: Model Day 112 (Rain)



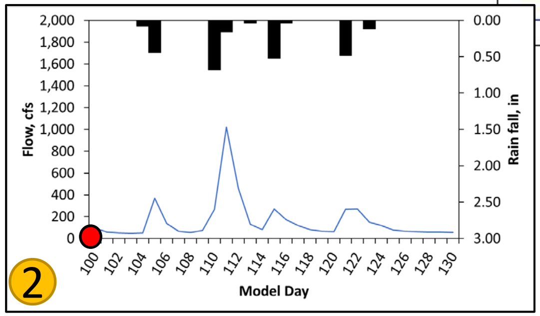
Shear stress: Model Day 116 (Rain)



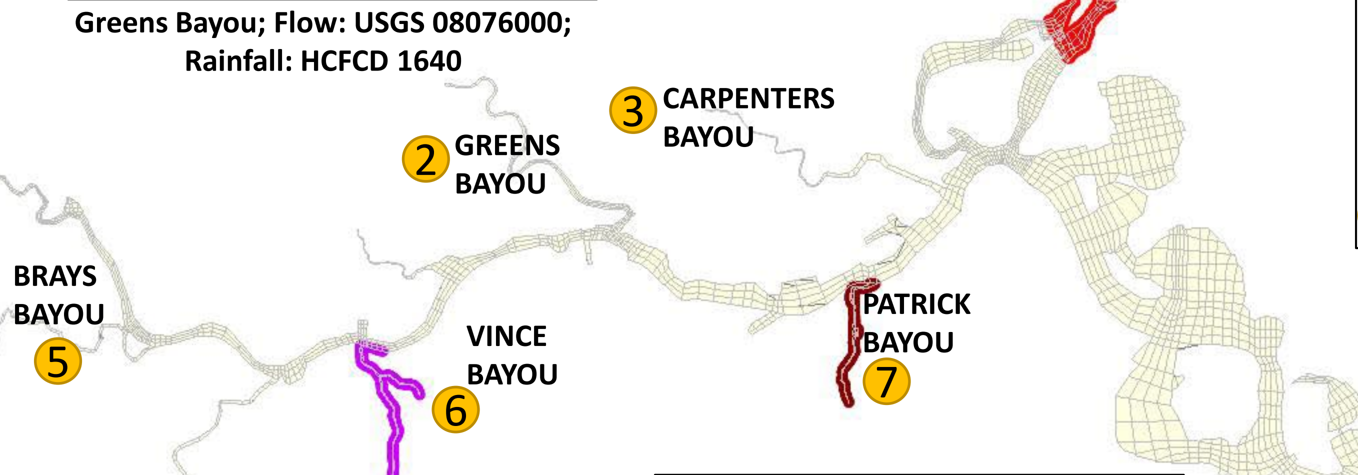
Particle Tracking: Day 100

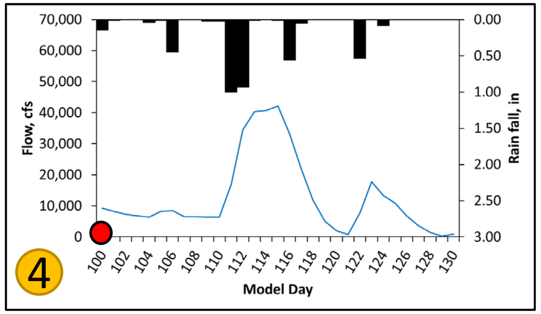


Buffalo Bayou; Flow: USGS 08073700; Rainfall: HCFCD 2210

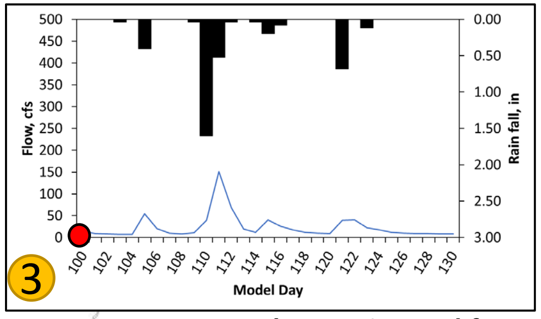


Greens Bayou; Flow: USGS 08076000; Rainfall: HCFCD 1640

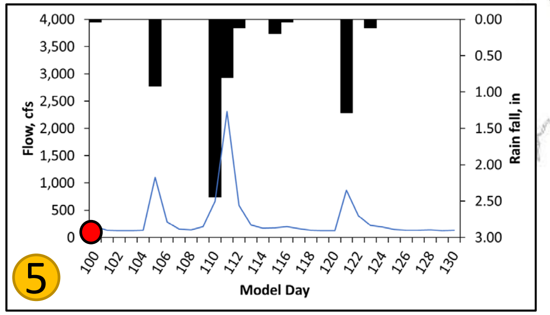




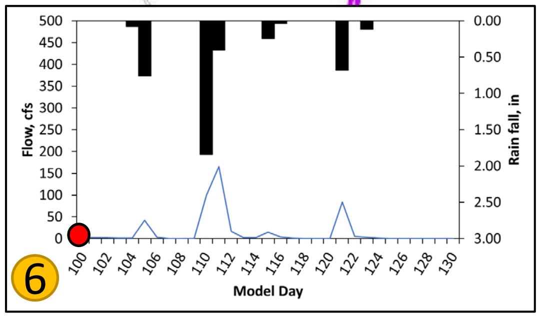
San Jacinto River; Flow estimated from TWDB Rating curve; Rainfall: HCFCD 710

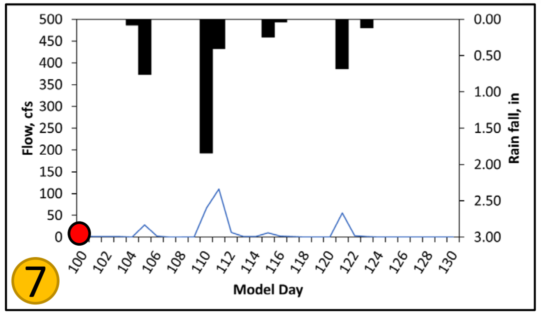


Carpenters Bayou; Flow estimated from USGS 08076000; Rainfall: HCFCD 1420



Brays Bayou; Flow: USGS 08075000; Rainfall: HCFCD 420

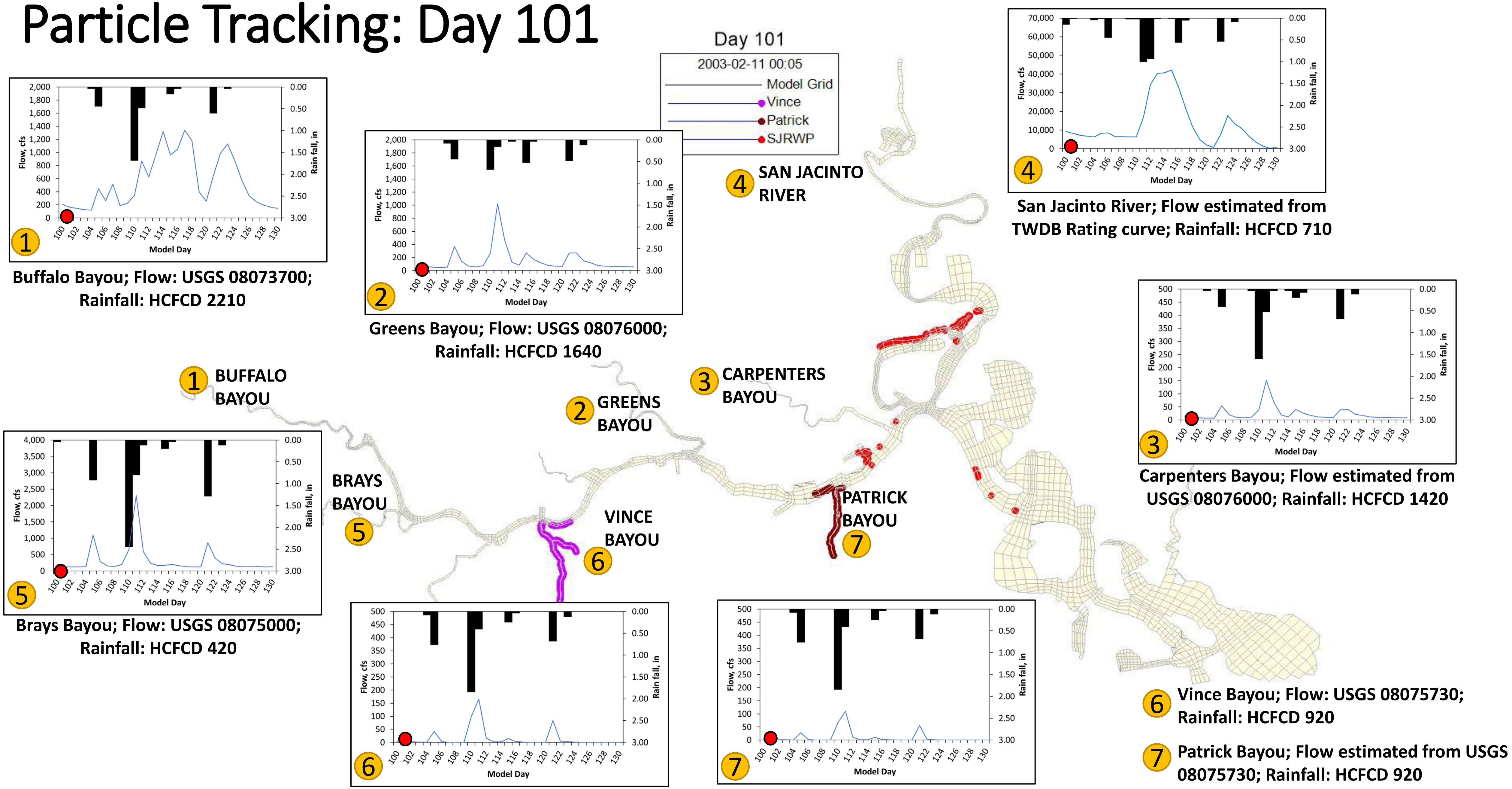




6 Vince Bayou; Flow: USGS 08075730; Rainfall: HCFCD 920

7 Patrick Bayou; Flow estimated from USGS 08075730; Rainfall: HCFCD 920

Particle Tracking: Day 101



Buffalo Bayou; Flow: USGS 08073700; Rainfall: HCFCD 2210

Greens Bayou; Flow: USGS 08076000; Rainfall: HCFCD 1640

San Jacinto River; Flow estimated from TWDB Rating curve; Rainfall: HCFCD 710

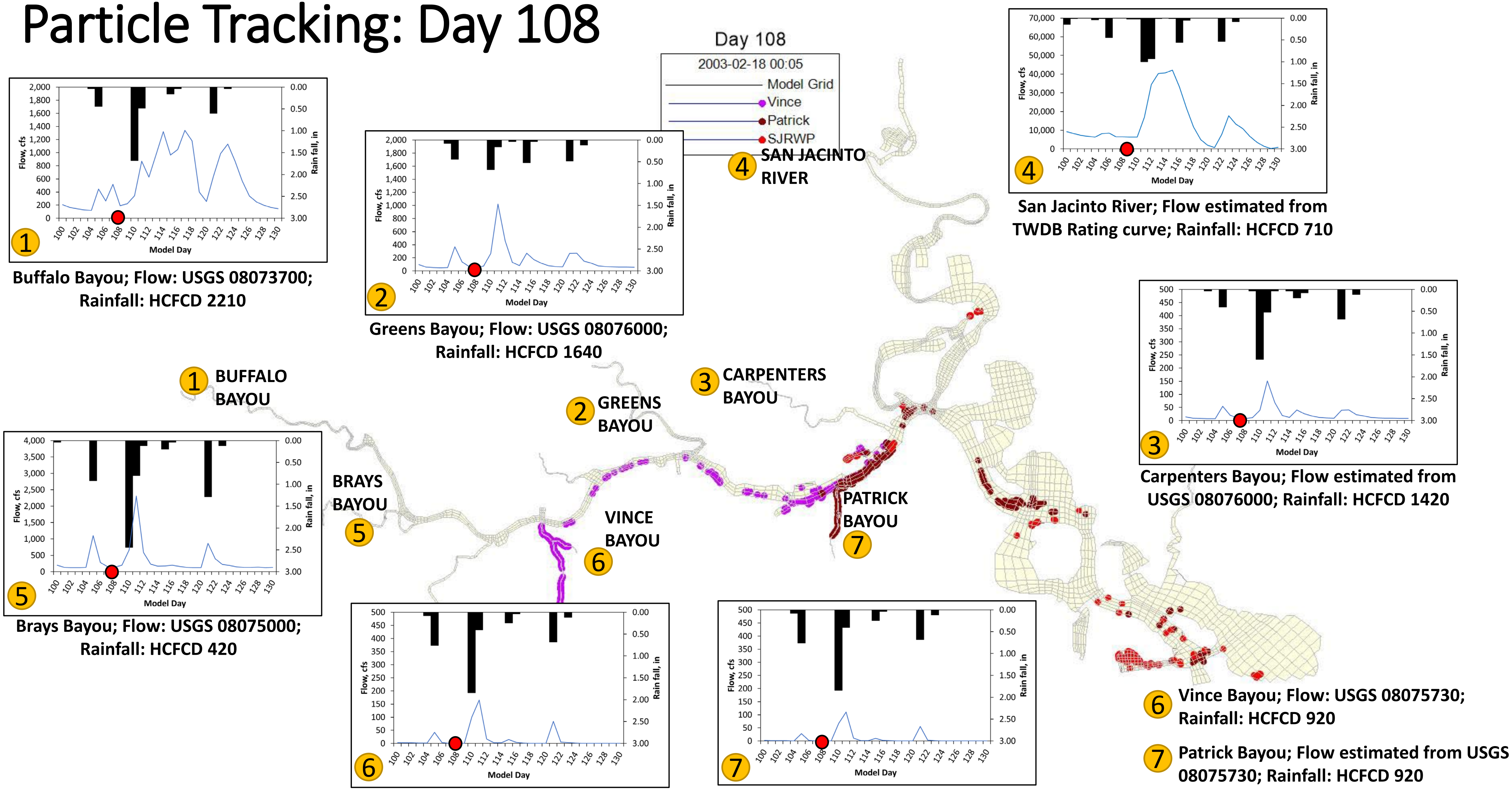
Carpenters Bayou; Flow estimated from USGS 08076000; Rainfall: HCFCD 1420

Brays Bayou; Flow: USGS 08075000; Rainfall: HCFCD 420

6 Vince Bayou; Flow: USGS 08075730; Rainfall: HCFCD 920

7 Patrick Bayou; Flow estimated from USGS 08075730; Rainfall: HCFCD 920

Particle Tracking: Day 108



Buffalo Bayou; Flow: USGS 08073700; Rainfall: HCFCD 2210

Greens Bayou; Flow: USGS 08076000; Rainfall: HCFCD 1640

San Jacinto River; Flow estimated from TWDB Rating curve; Rainfall: HCFCD 710

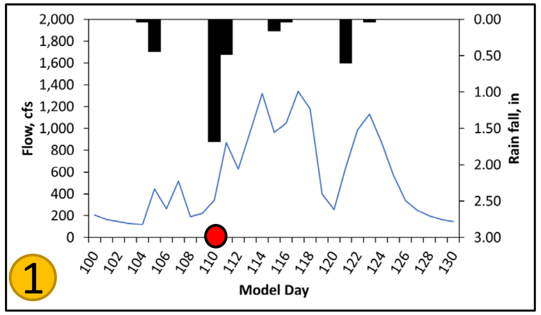
Carpenters Bayou; Flow estimated from USGS 08076000; Rainfall: HCFCD 1420

Brays Bayou; Flow: USGS 08075000; Rainfall: HCFCD 420

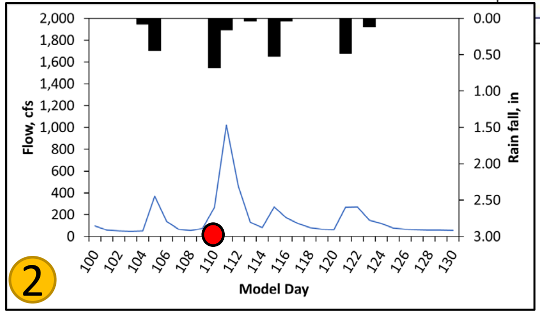
6 Vince Bayou; Flow: USGS 08075730; Rainfall: HCFCD 920

7 Patrick Bayou; Flow estimated from USGS 08075730; Rainfall: HCFCD 920

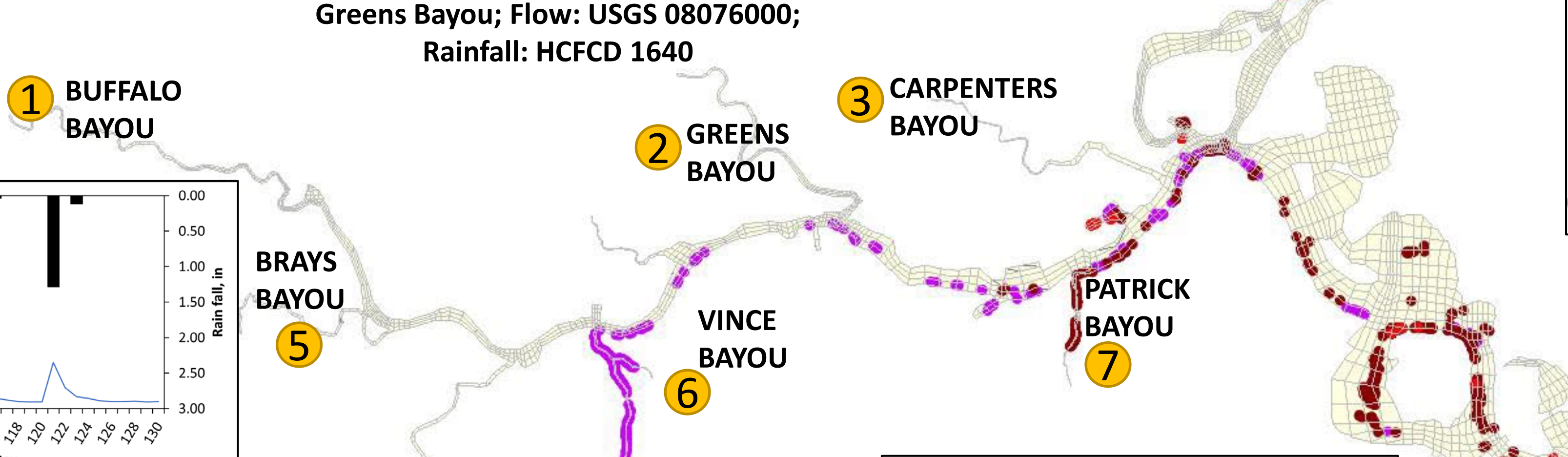
Particle Tracking: Day 110

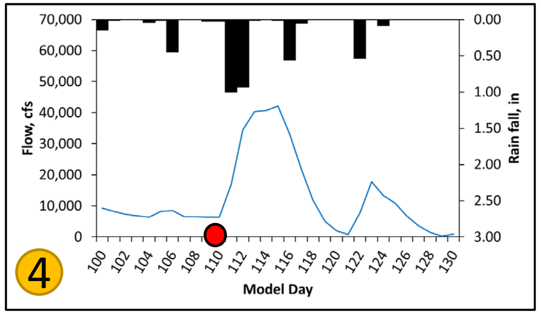


Buffalo Bayou; Flow: USGS 08073700;
Rainfall: HCFCD 2210

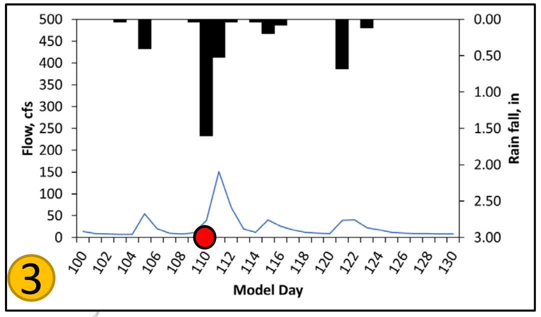


Greens Bayou; Flow: USGS 08076000;
Rainfall: HCFCD 1640

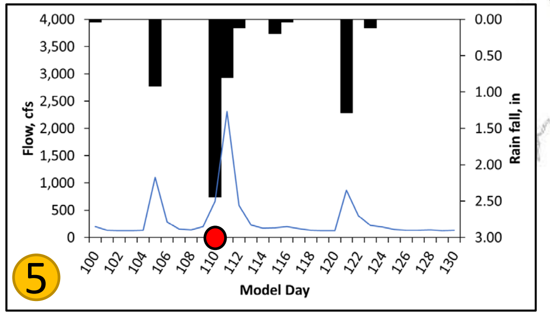




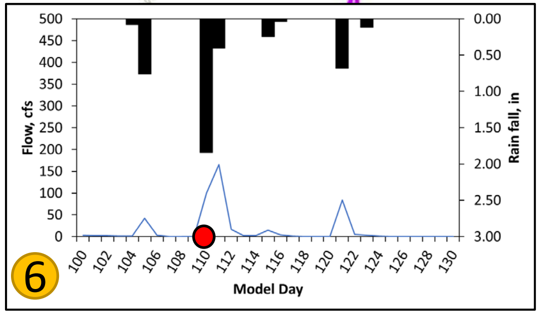
San Jacinto River; Flow estimated from
TWDB Rating curve; Rainfall: HCFCD 710

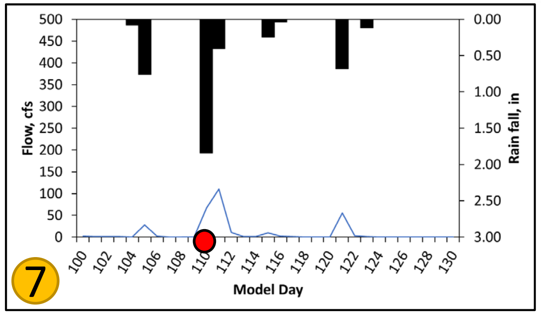


Carpenters Bayou; Flow estimated from
USGS 08076000; Rainfall: HCFCD 1420



Brays Bayou; Flow: USGS 08075000;
Rainfall: HCFCD 420

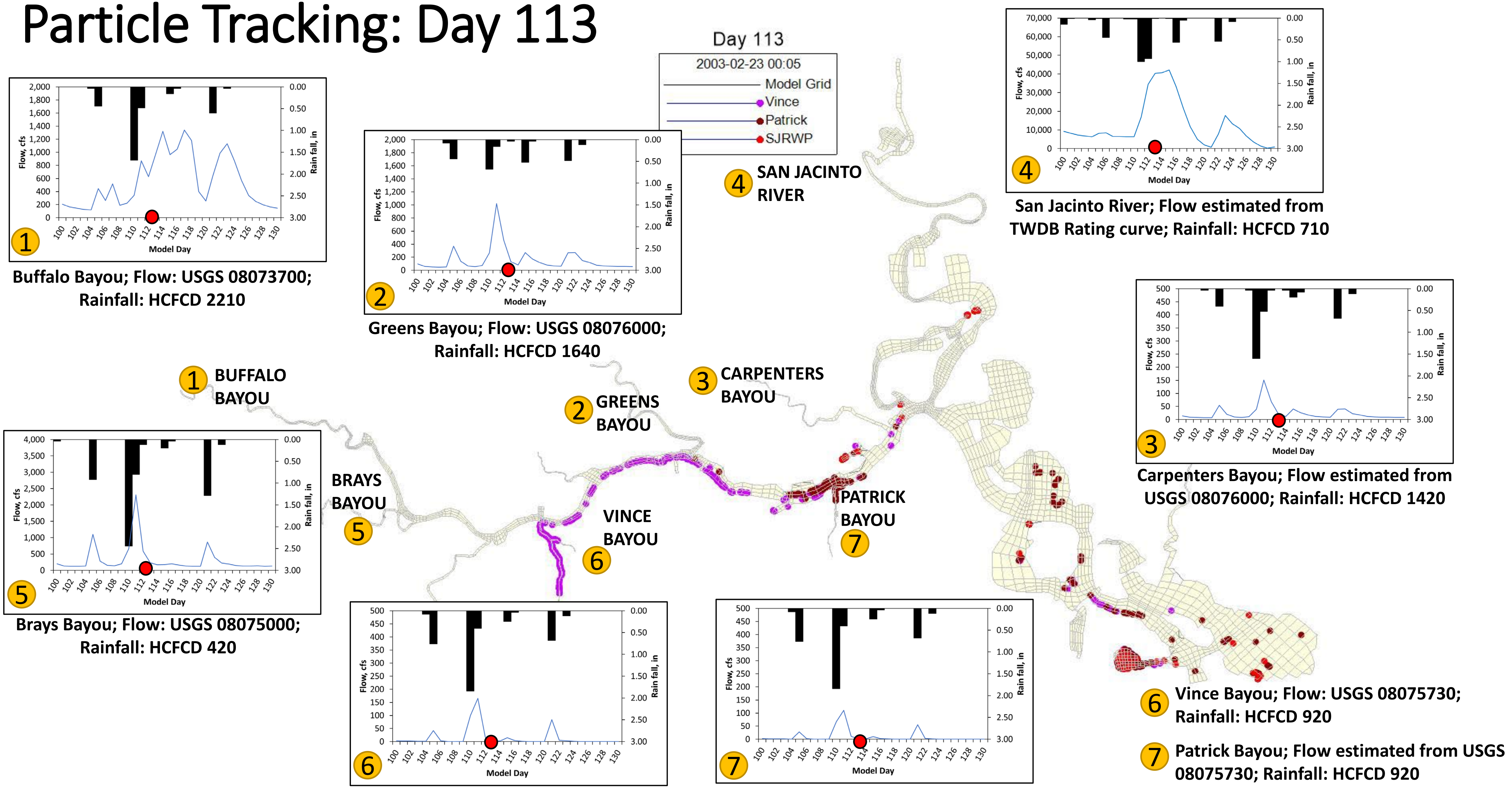




6 Vince Bayou; Flow: USGS 08075730;
Rainfall: HCFCD 920

7 Patrick Bayou; Flow estimated from USGS
08075730; Rainfall: HCFCD 920

Particle Tracking: Day 113



1 Buffalo Bayou; Flow: USGS 08073700; Rainfall: HCFCD 2210

2 Greens Bayou; Flow: USGS 08076000; Rainfall: HCFCD 1640

3 Carpenters Bayou; Flow estimated from USGS 08076000; Rainfall: HCFCD 1420

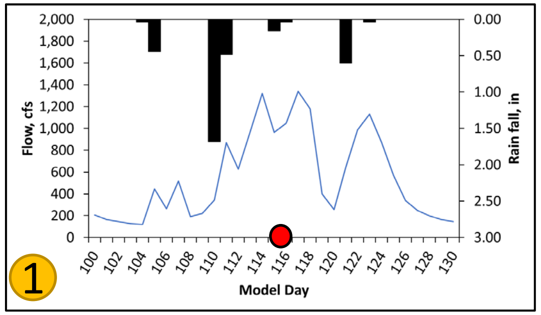
4 San Jacinto River; Flow estimated from TWDB Rating curve; Rainfall: HCFCD 710

5 Brays Bayou; Flow: USGS 08075000; Rainfall: HCFCD 420

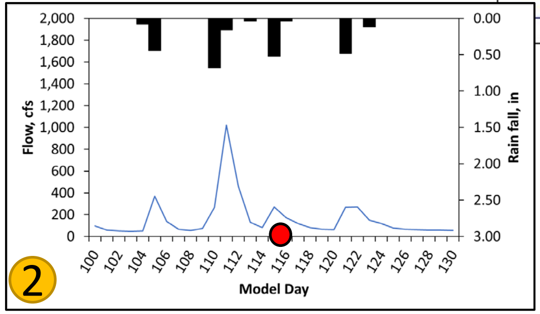
6 Vince Bayou; Flow: USGS 08075730; Rainfall: HCFCD 920

7 Patrick Bayou; Flow estimated from USGS 08075730; Rainfall: HCFCD 920

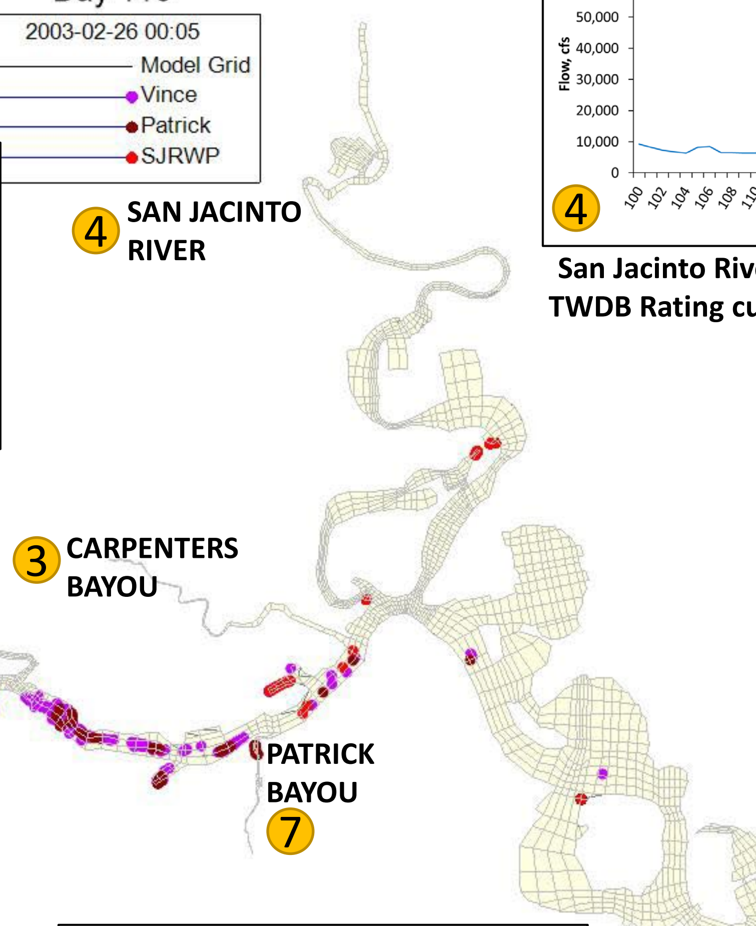
Particle Tracking: Day 116

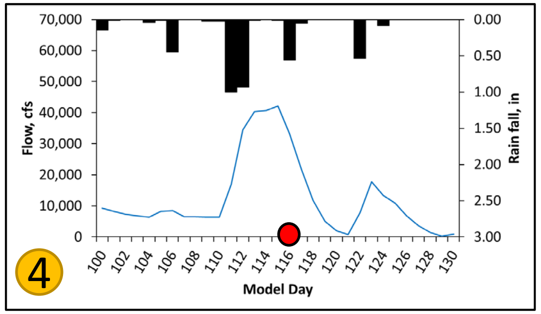


Buffalo Bayou; Flow: USGS 08073700; Rainfall: HCFCD 2210

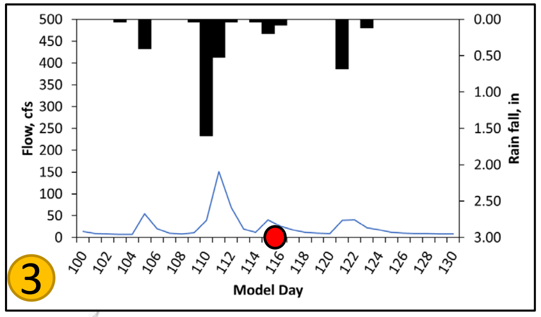


Greens Bayou; Flow: USGS 08076000; Rainfall: HCFCD 1640

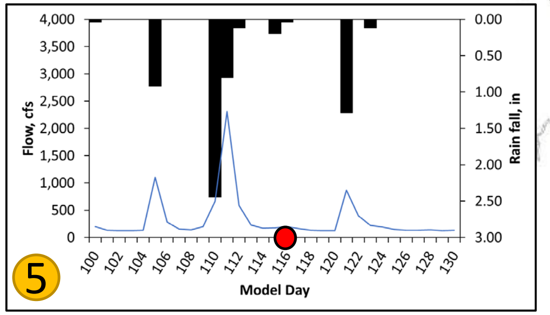




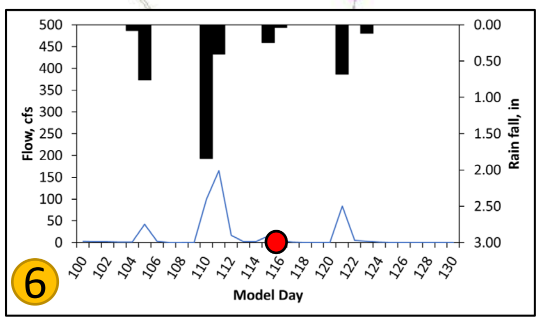
San Jacinto River; Flow estimated from TWDB Rating curve; Rainfall: HCFCD 710

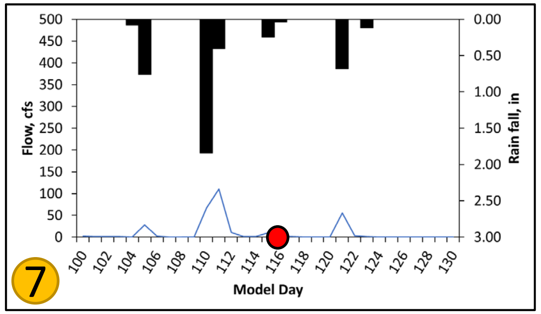


Carpenters Bayou; Flow estimated from USGS 08076000; Rainfall: HCFCD 1420



Brays Bayou; Flow: USGS 08075000; Rainfall: HCFCD 420

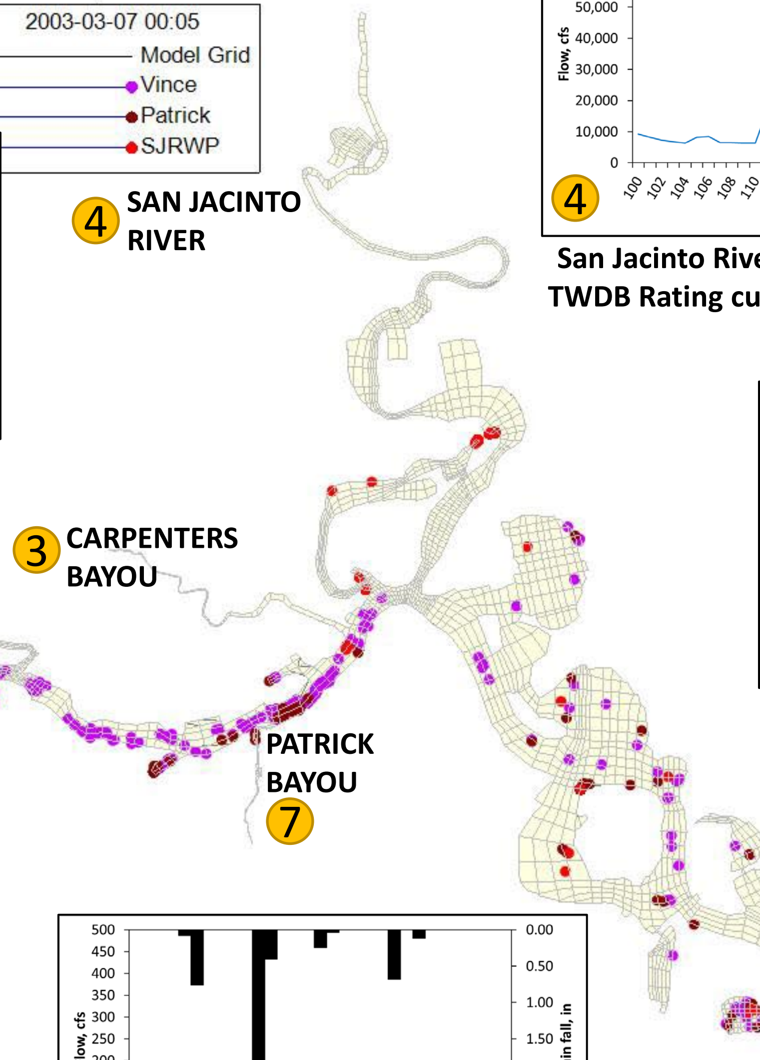


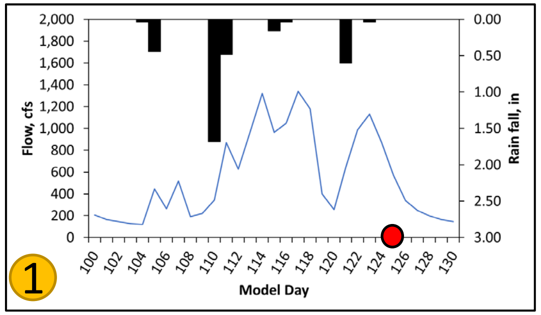


6 Vince Bayou; Flow: USGS 08075730; Rainfall: HCFCD 920

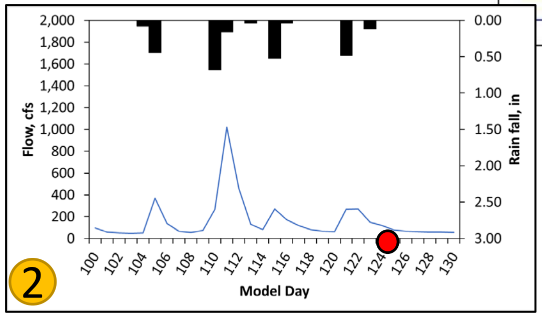
7 Patrick Bayou; Flow estimated from USGS 08075730; Rainfall: HCFCD 920

Particle Tracking: Day 125

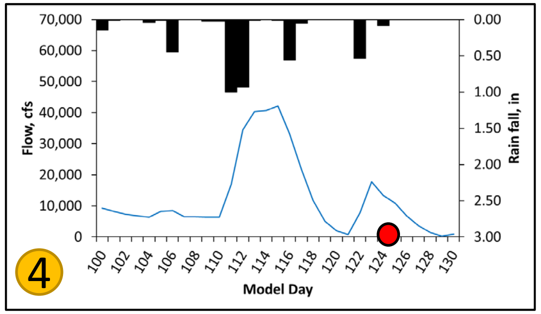




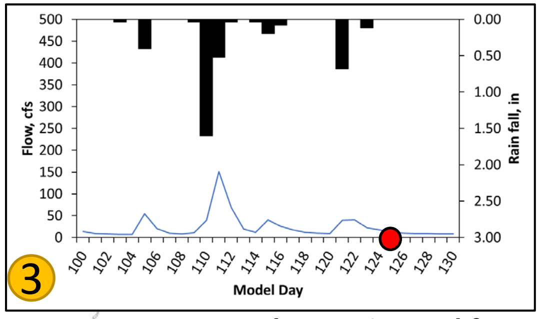
Buffalo Bayou; Flow: USGS 08073700; Rainfall: HCFCD 2210



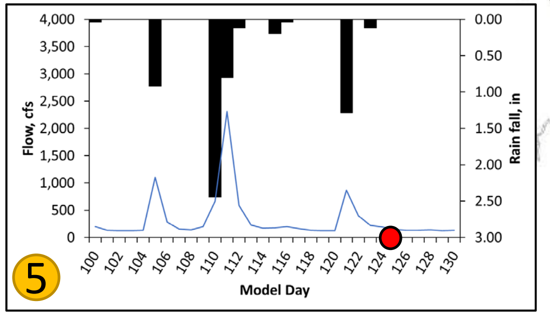
Greens Bayou; Flow: USGS 08076000; Rainfall: HCFCD 1640



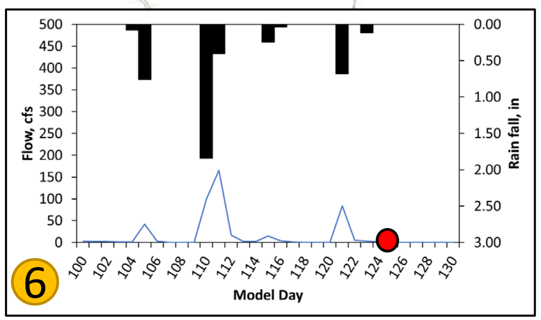
San Jacinto River; Flow estimated from TWDB Rating curve; Rainfall: HCFCD 710

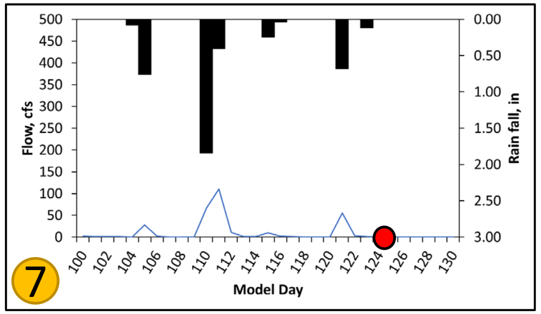


Carpenters Bayou; Flow estimated from USGS 08076000; Rainfall: HCFCD 1420



Brays Bayou; Flow: USGS 08075000; Rainfall: HCFCD 420

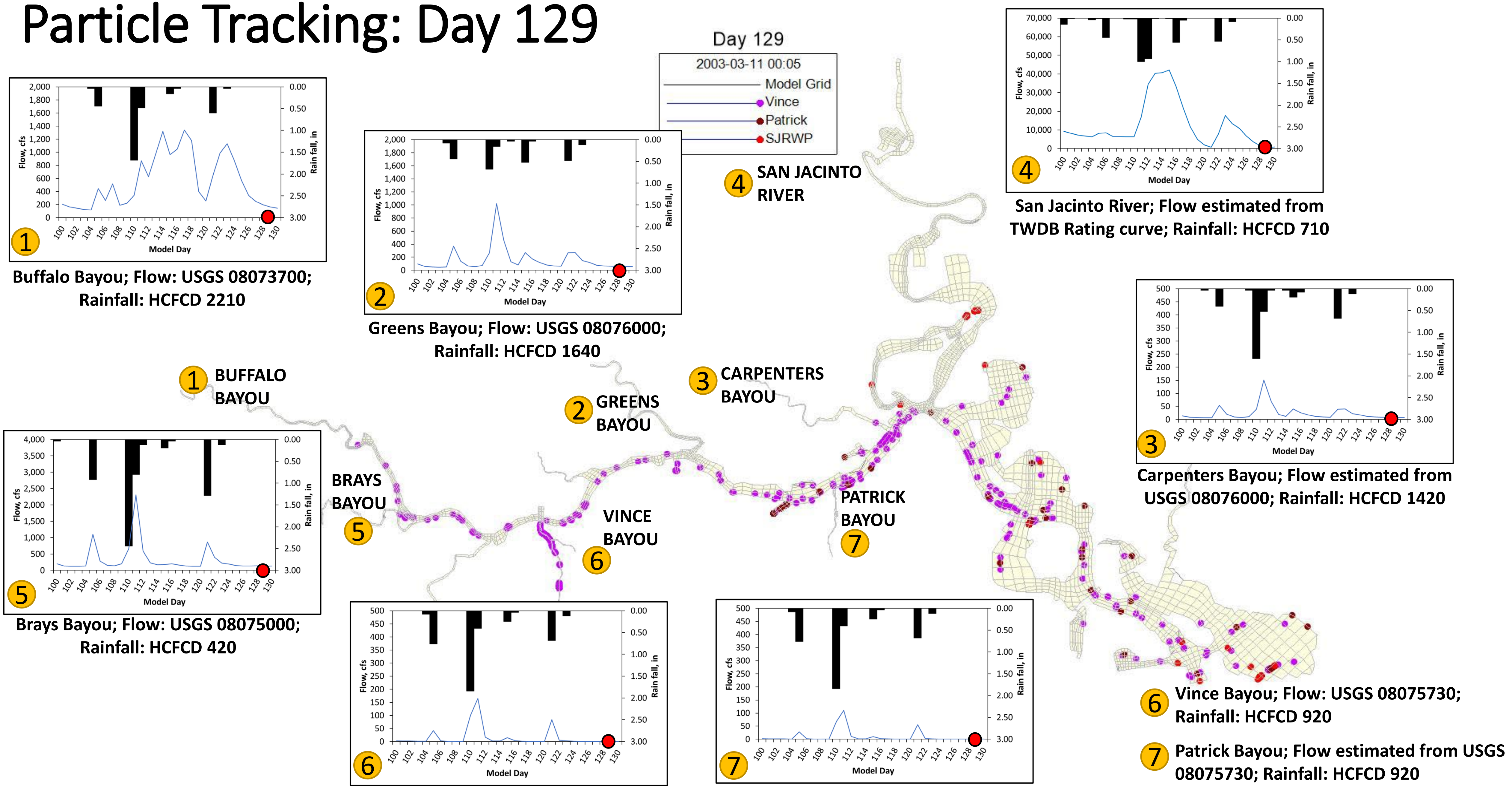




6 Vince Bayou; Flow: USGS 08075730; Rainfall: HCFCD 920

7 Patrick Bayou; Flow estimated from USGS 08075730; Rainfall: HCFCD 920

Particle Tracking: Day 129



Buffalo Bayou; Flow: USGS 08073700; Rainfall: HCFCD 2210

Greens Bayou; Flow: USGS 08076000; Rainfall: HCFCD 1640

San Jacinto River; Flow estimated from TWDB Rating curve; Rainfall: HCFCD 710

Carpenters Bayou; Flow estimated from USGS 08076000; Rainfall: HCFCD 1420

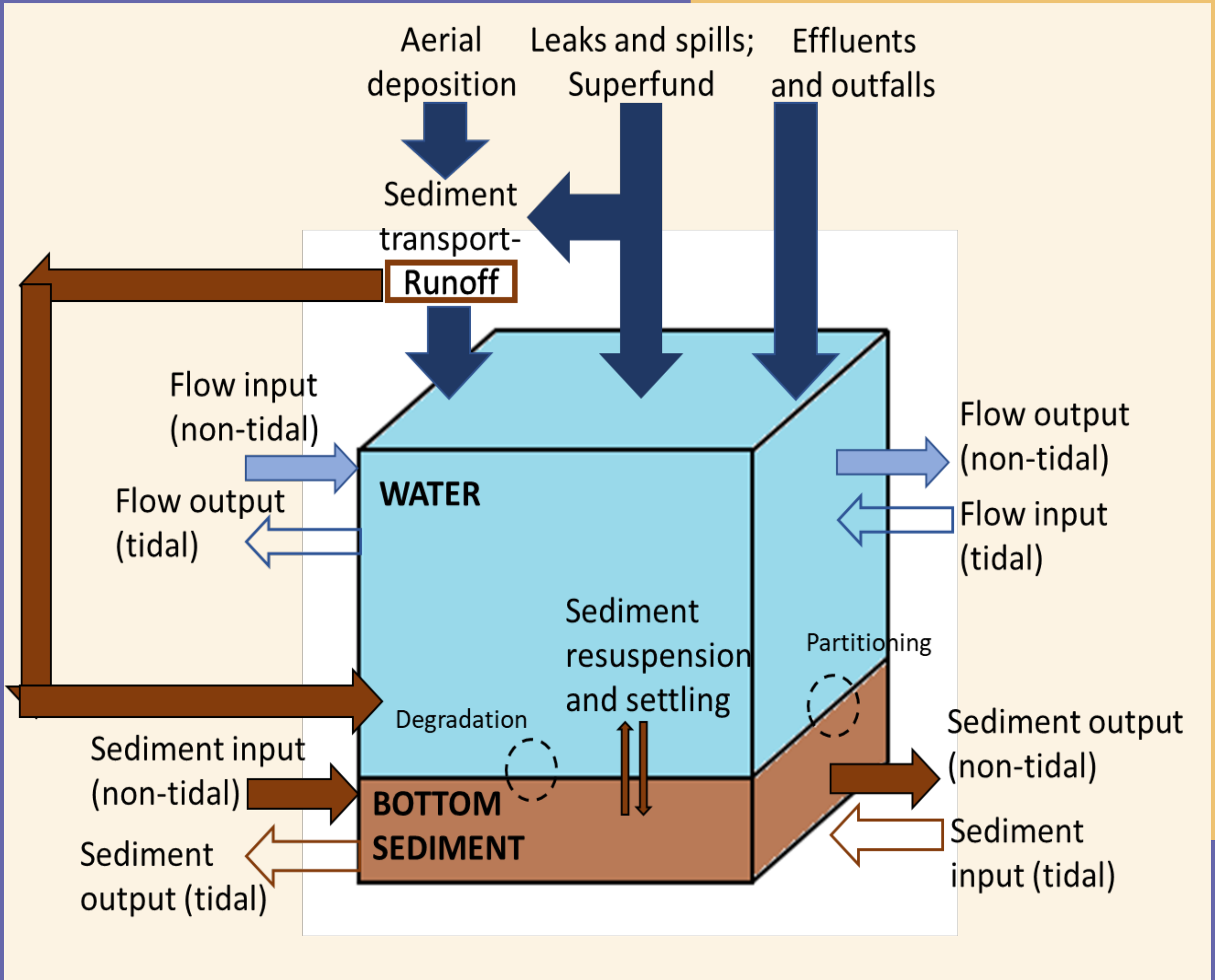
Brays Bayou; Flow: USGS 08075000; Rainfall: HCFCD 420

6 Vince Bayou; Flow: USGS 08075730; Rainfall: HCFCD 920

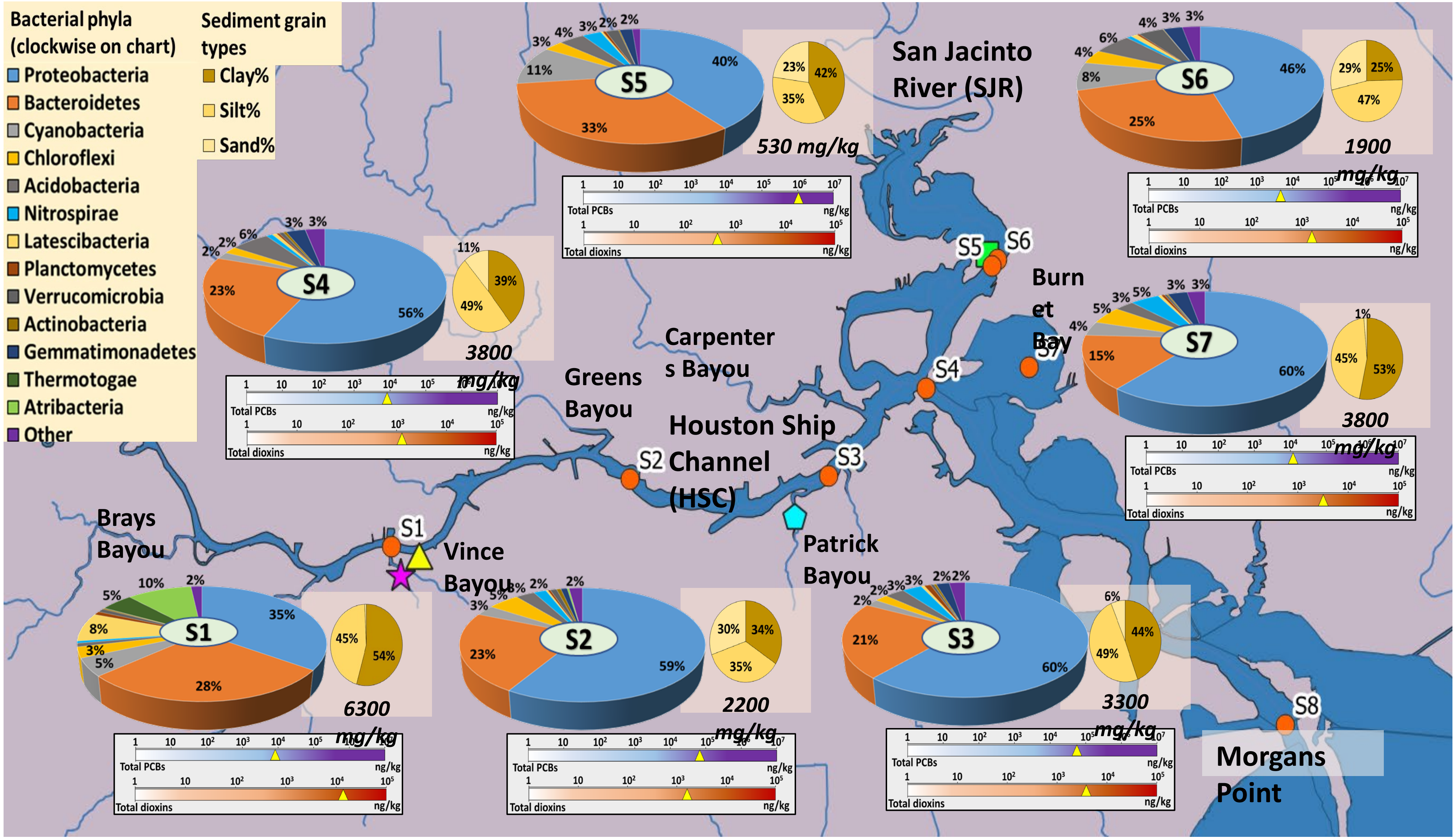
7 Patrick Bayou; Flow estimated from USGS 08075730; Rainfall: HCFCD 920

OUTLINE

- Sources Context
- Longitudinal/Loading Context
- Flow Dynamics Context
- **Natural Hazards Context**



Microbial dynamics, sediment characteristics, organic carbon, pollutant concentrations as indicators of system health



LESSONS LEARNED

- Legacy and continuing source characterization necessary for understanding role of sediments and guiding their management and remediation
- Longitudinal data are critical for understanding system dynamics and response to external forcings such as severe storms or hurricanes
- Concentrations, mass fluxes, and partitioning behavior need to be considered as one continuum towards holistic management and remediation of sediment contamination
- Microbial dynamics in sediment within natural water systems aids in understanding system pollutant state and change over time
- Organics are not equal even though persistent and bioaccumulative and share common sources

Acknowledgements

NSF

GK-12 &
RAPID Grant

United States Environmental Protection Agency

DSI LLC

NATIONAL ACADEMIES
GULF Research

HOUSTON ENDOWMENT

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

NIH
National Institutes of Health

HuRRI
Hurricane Resilience Research Institute

Galveston Bay Estuary Program

GALVESTON BAY FOUNDATION