Priorities and places for nature-based solutions to reduce flood and chemical exposure risks in Galveston Bay

Stakeholder information meeting

June 14, 2021

Agenda

- 2:00 pm Welcome!
  - Project description – general overview/background
  - Upcoming engagement opportunities and how to provide feedback
  - Description of each Aim and brief Q&A
- End at 3:15 pm

Break (15 mins)

- 3:30 pm Technical Advisory meeting (and breakout sessions)
  - Deeper dive on each aim and project approach

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Elena Craft, PhD
Project Lead

Cloelle Danforth, PhD
Project Manager,
Aims 1 & 2

Sepp Haukebo
Aim 1

Shannon Cunniff
Aim 4 & 5

Lauren Padilla, PhD
Aim 3

Devyani Kar, PhD
Aim 4 & 5

Weihsueh Chiu, PhD
Aim 2

James Kaihatu, PhD
Aim 3

Galen Newman, PhD
Aim 4

Garett Sansom, PhD
Aim 4

Thomas McDonald, PhD
Aim 1

Scott Jones
Aim 1 & 5

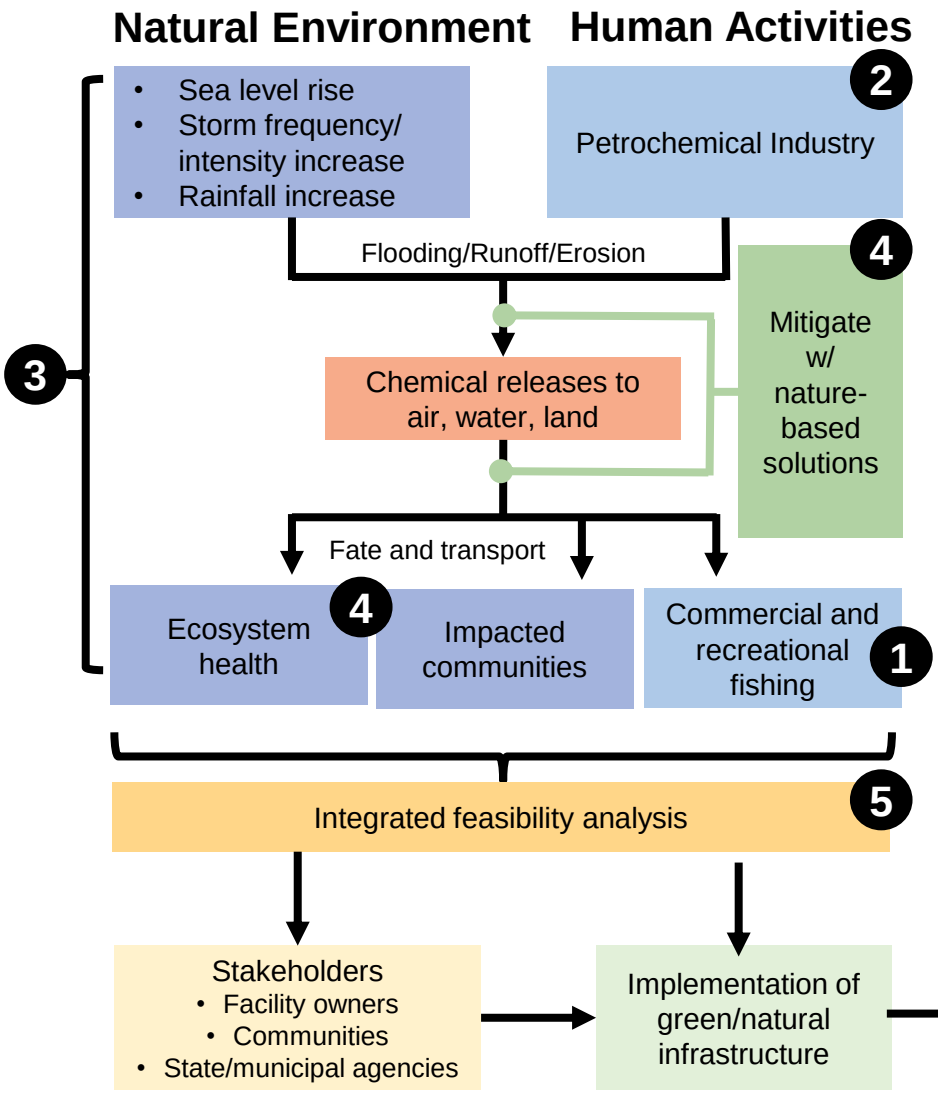
Charlotte Cisneros
Aim 1 & 5

Overarching project goals/motivation

- Improve understanding of toxic releases due to flooding and sea-level rise in the Galveston Bay area
- Explore nature-based solutions (NBS) that can mitigate risks and promote resilience of coastal communities and ecosystems.

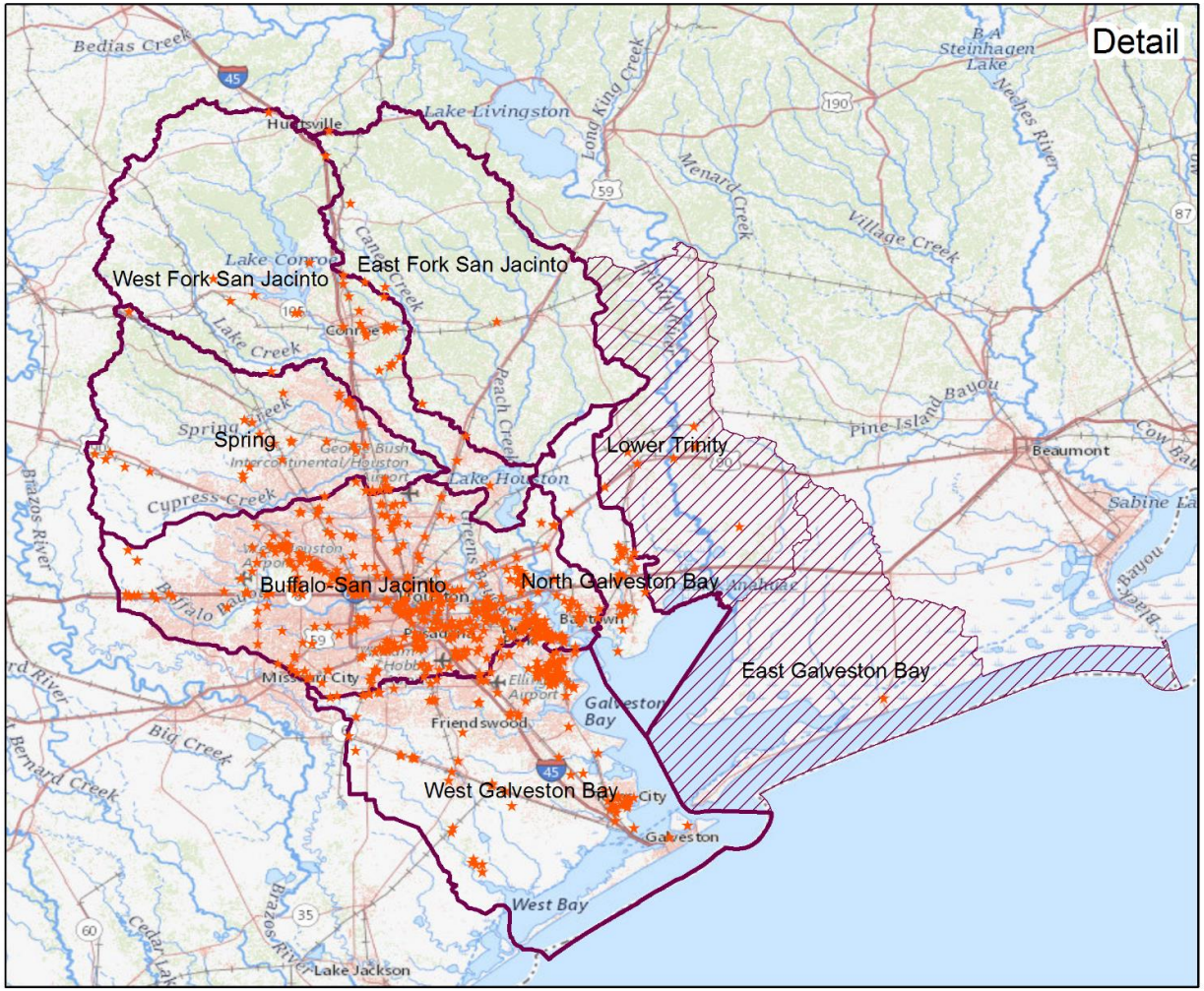
https://www.fractracker.org/2020/02/national-energy-petrochemical-map/

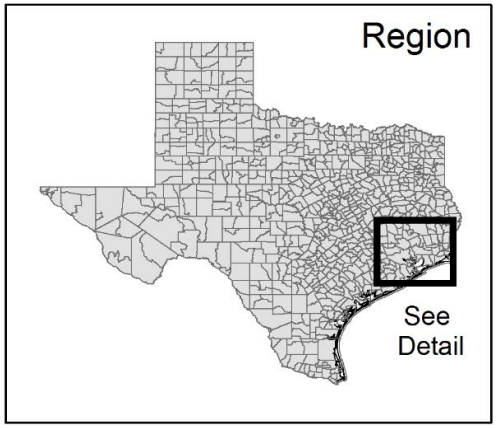
Project aims and overview



1. **Baseline sampling of existing chemical contamination in recreationally caught fish**
2. **Prioritization and characterization of petrochemical facilities using baseline data and risk metrics of chemical hazards**
3. **Computational modeling of flooding, chemical releases, fate and transport**
4. **Development of green/nature-based solutions for high priority facilities**
5. **Integrated feasibility analysis outlining planning and design criteria for nature-based solutions to mitigate impacts from chemical releases**

Study area





- Petrochemical facilities
- HUC8 Watersheds
- Lower Trinity
- East Galveston Bay

Data sources: Risk management facilities, Right-to-Know Network database of RMPs; HUC8 watersheds, USGS WBD; Basemap, USGS National Map

Meeting objectives

Flooded Arkema plant in Crosby, Texas. Image: Arkema
https://www.reutersevents.com/downstream/supply-chain-logistics/flood-impact-lessons-vital-next-construction-wave

- **Initiate engagement** with a diverse set of community members, area representatives, and technical experts
- **Describe** project scope and objectives
- **Get** feedback
- **Begin to build** public support for implementation of findings and uptake by facilities/municipalities

How to engage

- During this meeting
  - Jamboard!
  - Q&A during and after presentation
  - TAC breakout sessions
- Ongoing
  - Email, website (TBD)

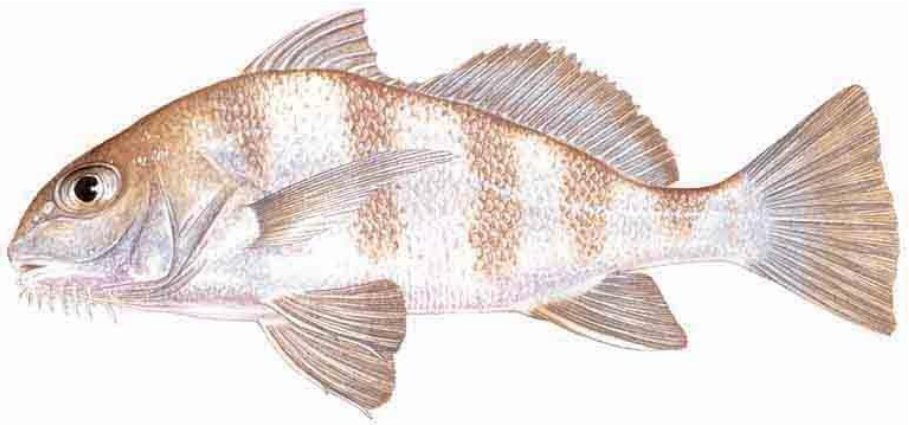
- Upcoming meetings:
  - Technical Advisory Committee Meeting on initial findings (TBD spring 2022)
  - Opportunity to provide feedback on NBS decision tool (TBD summer 2023).

Clear Lake Forest Park - located on the eastern shoreline of Armand Bayou/Mud Lake
Credit: Galveston Bay Foundation
https://galvbay.org/work/habitat-restoration/

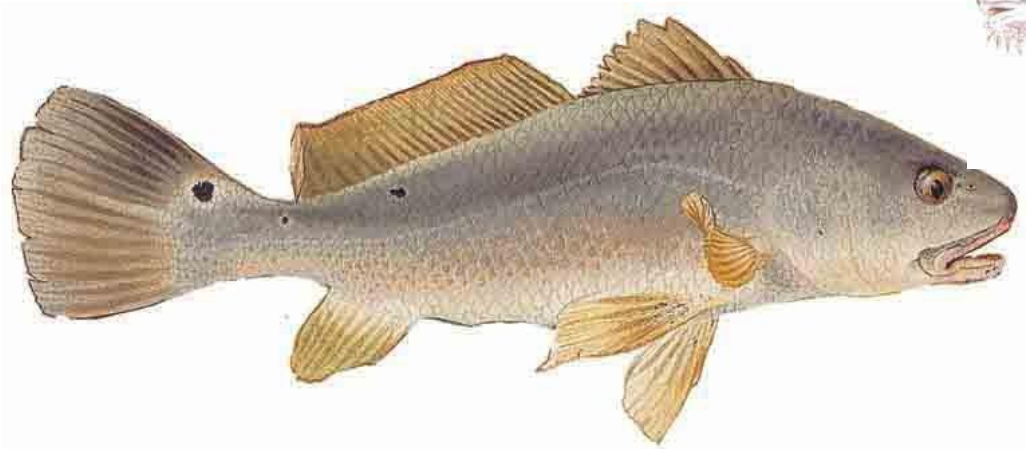
Aim 1

Galveston Bay Ecosystem Survey

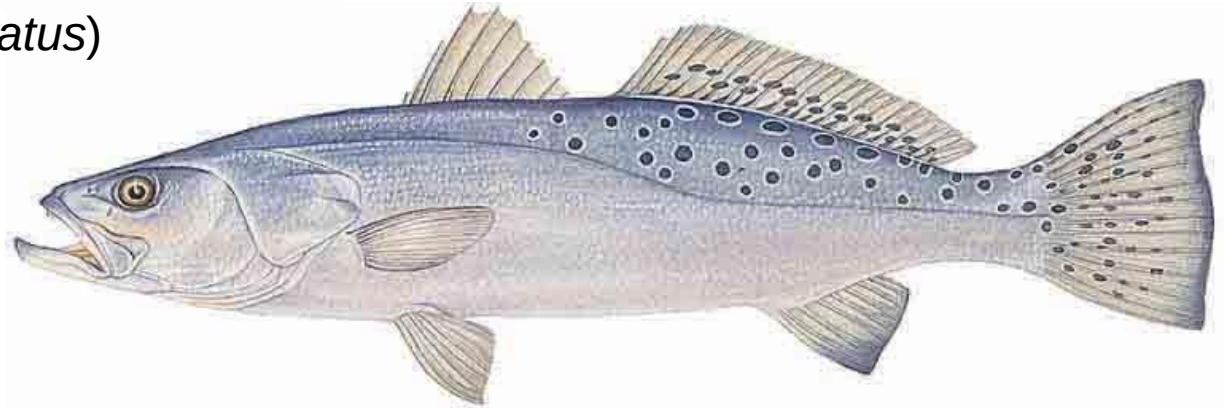
Measure environmental impacts through bioindicators



Black Drum (*Pogonias cromis*)



Red Drum (*Sciaenops ocellatus*)



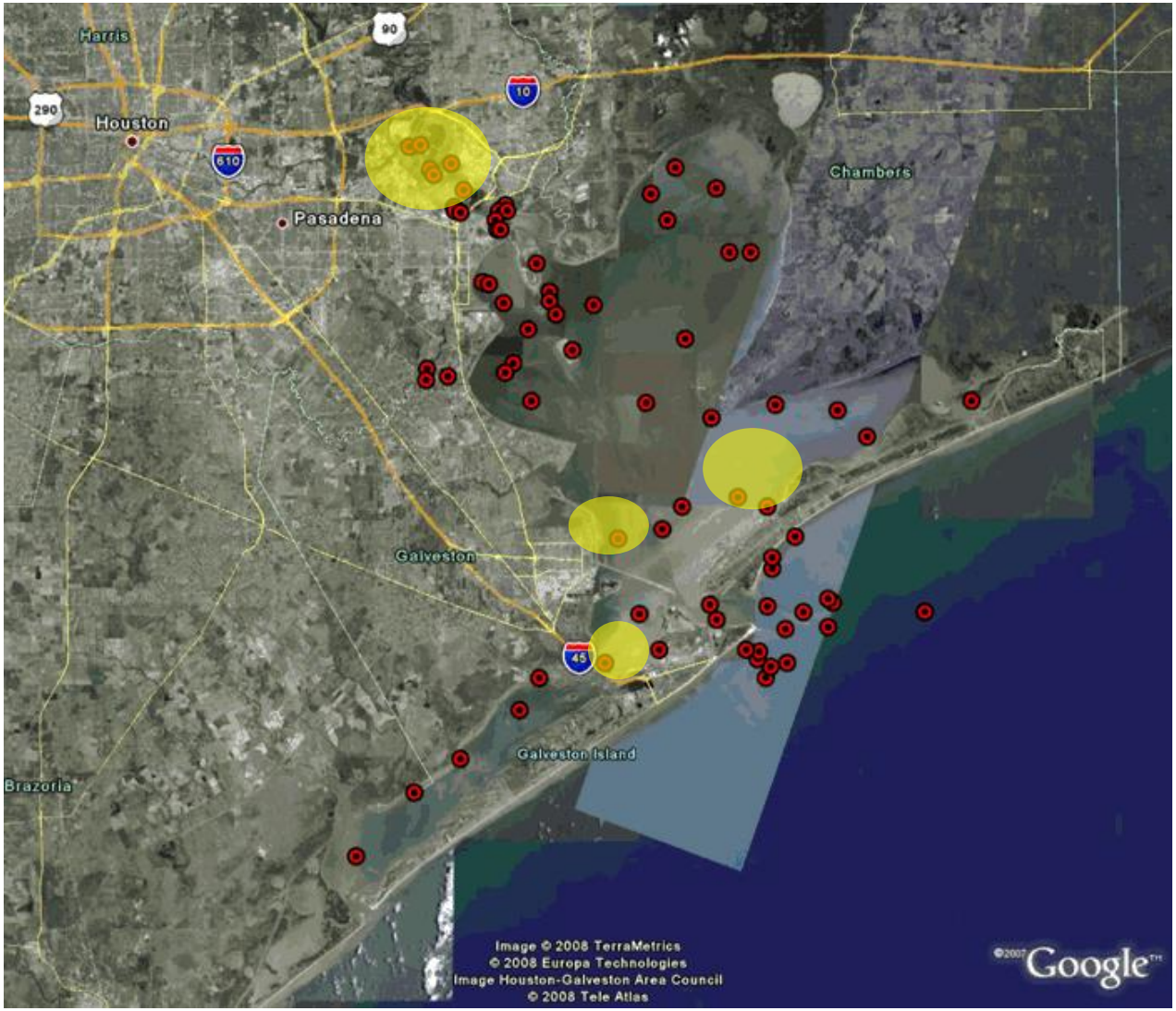
Spotted Sea Trout (*Cynoscion nebulosus*)

https://tpwd.texas.gov/regulations/outdoor-annual/fishing/saltwater-fishing/saltwater-bag-and-length-limits

Mussel Watch

https://oceanservice.noaa.gov/news/feb15/mussel-watch.html

Sample sites in Galveston Bay



Fish sample sites

Historic mussel watch sample locations

Photo Credit: Sepp Haukebo

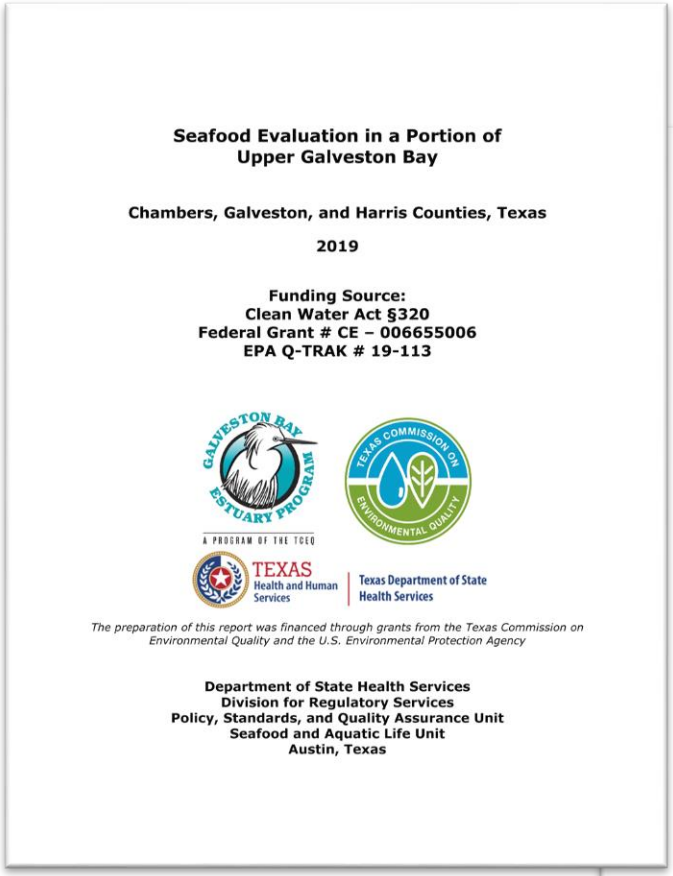
Photo Credit: Steve Gonzales, Houston Chronicle Staff photographer
https://www.houstonchronicle.com/news/houston-texas/environment/article/Scientists-fish-Galveston-Bay-for-clues-to-16216253.php

Target Chemicals

Compounds	Sources	Why we chose these
PAHs	Incomplete combustion associated with industrial activities, iron and steel production, aluminum production, cement manufacturing, coal-tar pitch production, dye manufacturing, asphalt industries, rubber tire manufacturing, fungicide and insecticide production, exhaust from refineries [1]	Legacy compounds, historically sampled
PFAS/PFOAs	**Industrial Surfactants, Resins, Molds, Plastics:** Manufacture of plastics and fluoropolymers, rubber, and compression mold release coatings; plumbing fluxing agents; fluoroplastic coatings, composite resins, and flame retardant for polycarbonate; **Class B Firefighting Foams** [2]	These are long-lived, persistent chemicals
Metals	Catalysts for manufacturing (styrene, polyethylene), refinery sludge [3]	Legacy compounds, historically sampled
Chlorinated dioxins (PCDDs/PCDFs)	Dioxins from as by-products of industrial and chemical production processes and by incomplete combustion. Primarily introduced through sediment deposition [4].	Legacy compounds. historically sampled

[1] Polycyclic Aromatic Hydrocarbons: Sources, Toxicity, and Remediation Approaches. 2020. https://www.frontiersin.org/articles/10.3389/fmicb.2020.562813/full
[2] https://www.enviro.wiki/index.php?title=PFAS_Sources
[3] https://www.tceq.texas.gov/assets/public/comm_exec/pubs/gbnep/gbnep-20/gbnep_20_5-30.pdf; see also C&EN. Hurricane Harvey flushed toxic metals into Houston's waterhttps://cen.acs.org/environment/water/Hurricane-Harvey-flushed-toxic-metals/97/i16
[4] TCEQ. 2020. Source Characterization of Dioxin Loads in the Houston Ship Channel and Upper Galveston Bayhttps://www.tceq.texas.gov/assets/public/waterquality/tmdl/26hscdioxin/26-hsc-dioxin-characterization2020-11-20-final.pdf

Informed by historic seafood sampling campaigns



Seafood Evaluation in a Portion of Upper Galveston Bay

Chambers, Galveston, and Harris Counties, Texas

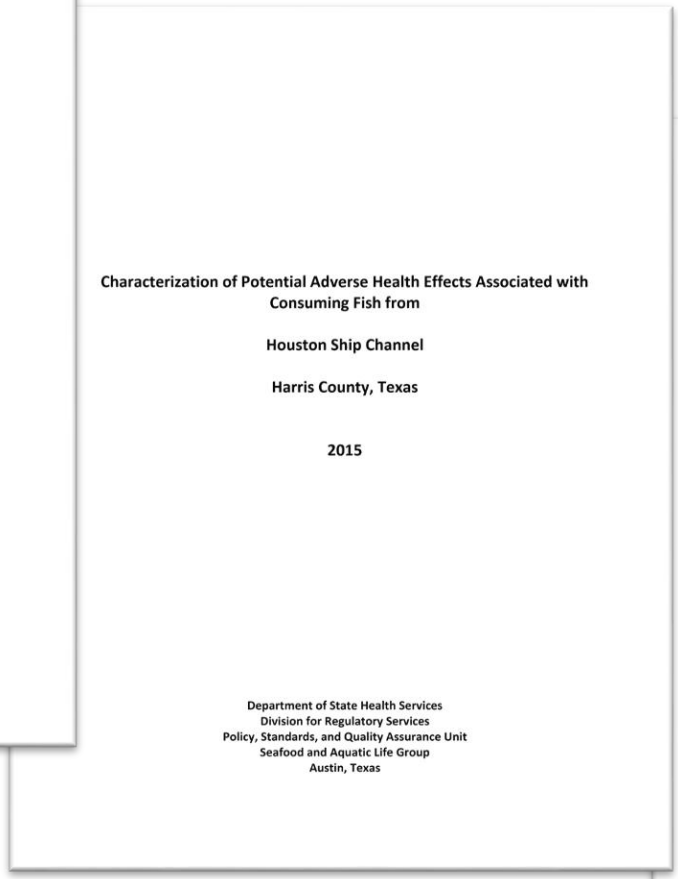
2019

Funding Source:
Clean Water Act §320
Federal Grant # CE – 006655006
EPA Q-TRAK # 19-113

The preparation of this report was financed through grants from the Texas Commission on Environmental Quality and the U.S. Environmental Protection Agency

Department of State Health Services
Division for Regulatory Services
Policy, Standards, and Quality Assurance Unit
Seafood and Aquatic Life Unit
Austin, Texas

https://gbep.texas.gov/wp-content/uploads/2020/04/18-80234-Final-Report.pdf



Characterization of Potential Adverse Health Effects Associated with Consuming Fish from

Houston Ship Channel

Harris County, Texas

2015

Department of State Health Services
Division for Regulatory Services
Policy, Standards, and Quality Assurance Unit
Seafood and Aquatic Life Group
Austin, Texas

https://www.dshs.state.tx.us/seafood/PDF2/Risk-Characterization/Houston-Ship-Channel-RC-2013.pdf

Characterization of Potential Adverse Health Effects Associated with Consuming Fish from

Galveston Bay

Brazoria, Chambers, Galveston, and Harris Counties, Texas

2013

Department of State Health Services
Division for Regulatory Services
Policy, Standards, and Quality Assurance Unit
Seafood and Aquatic Life Group
Austin, Texas

https://dshs.texas.gov/seafood/PDF2/Risk-Characterization/GalvestonBay-RC-2010.pdf

Discussion & Questions for Aim 1

- Jamboard or Q&A
- Potential topics for discussion and/or areas for feedback:
  - Communication strategies?
  - Other sample locations?
  - How will you use this information/these data?

Aim 2

Identify/prioritize vulnerable petrochemical facilities

Which Facilities?
Petrochemical facilities in GB watershed

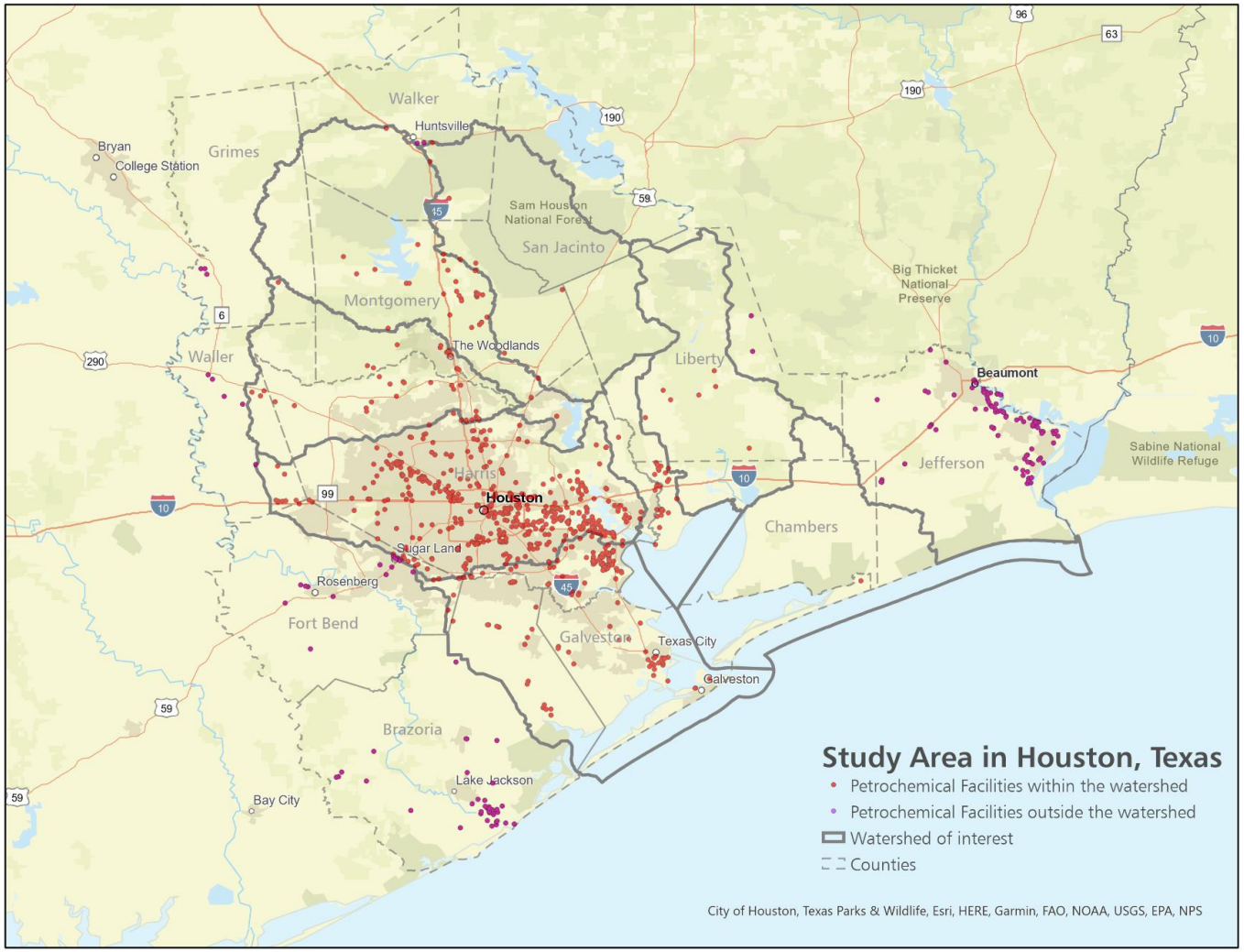
Galveston Bay Watershed

↓

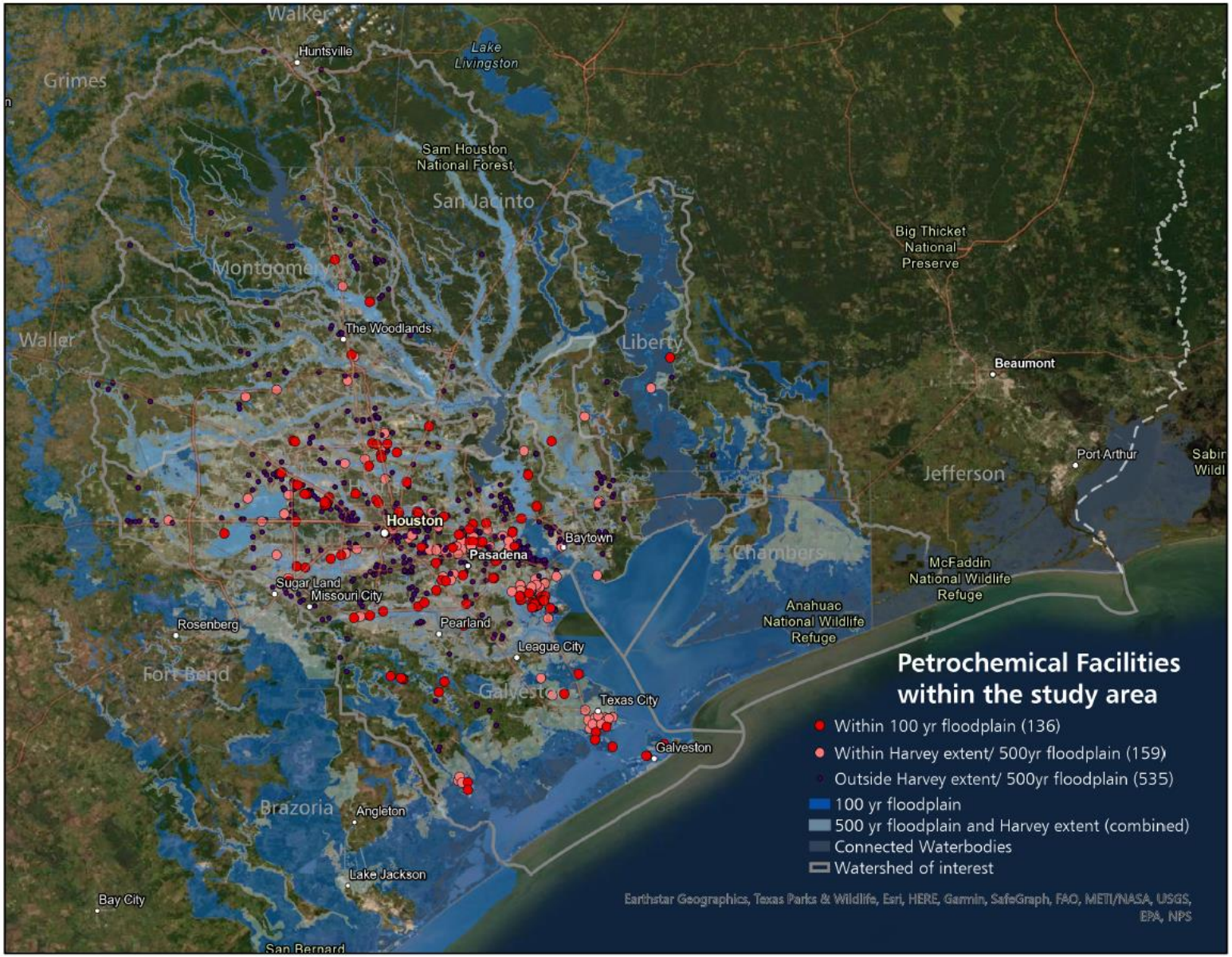
Petrochemical facilities

↓

Vulnerable to flood



Petrochemical facilities in GB watershed



Prioritization indices

Flood Vulnerability

Vulnerability to inundation from inundation and flooding in the context of sea-level rise and increased storm frequency

Types of indicators

- Flood maps
- Historical and future inundation maps

Exposure Potential

Potential for releases of hazardous chemicals into the environment and subsequent exposure

Types of indicators

- Identity and quantity of chemicals on-site
- Number and mass of reportable on- and off-site chemical releases
- History of accidents and violations
- Proximity to human populations
- Proximity to waterbodies with high-risk designated uses

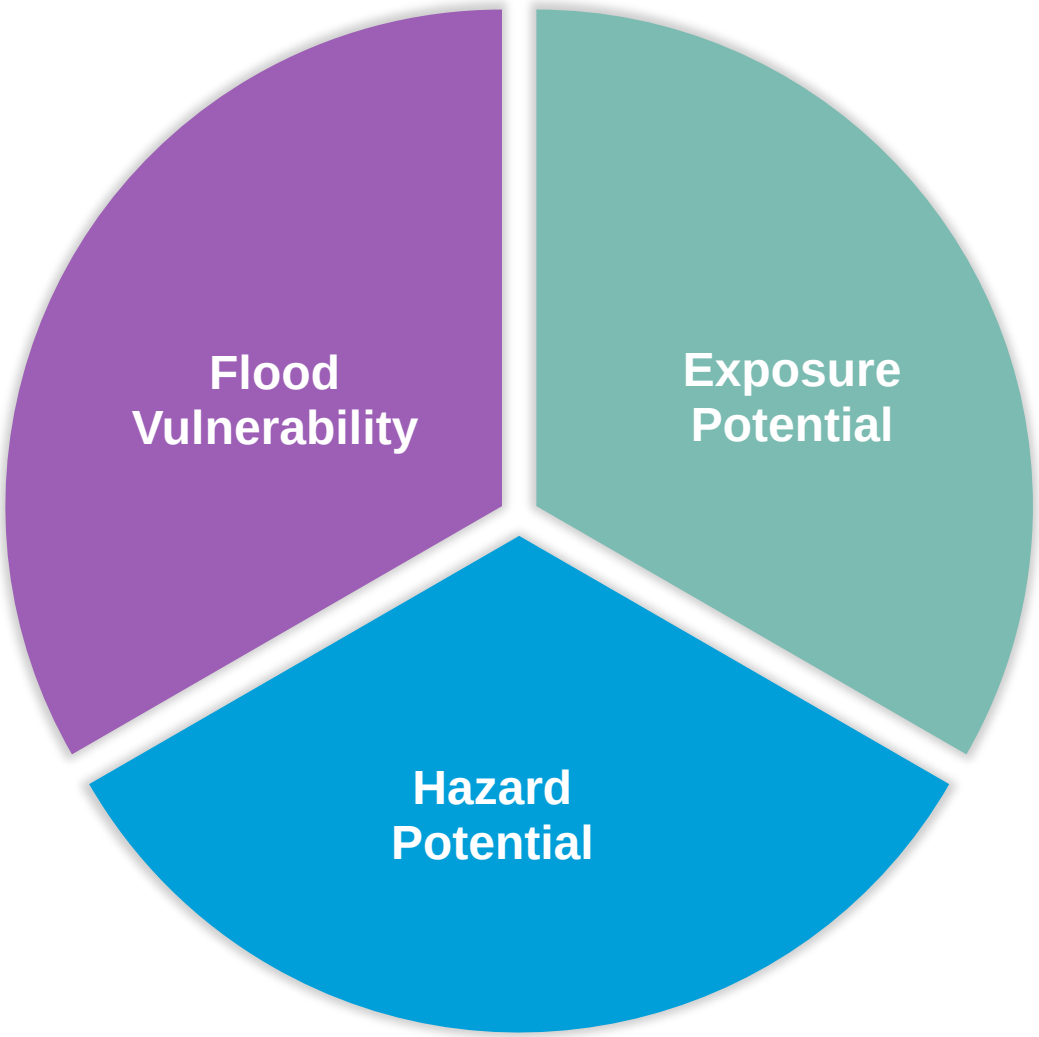
Hazard Potential

Intrinsic chemical hazard information from the “universe” of chemicals across all facilities.

Types of indicators

- Human health toxicity values
- Ecotoxicity values
- Physical dangers (flammability, corrosivity, reactivity)
- Physical-chemical properties (partitioning, volatility, mobility, degradation, bioaccumulation potential, eutrophication potential)

Identification of Vulnerable Facilities



Discussion & Questions for Aim 2

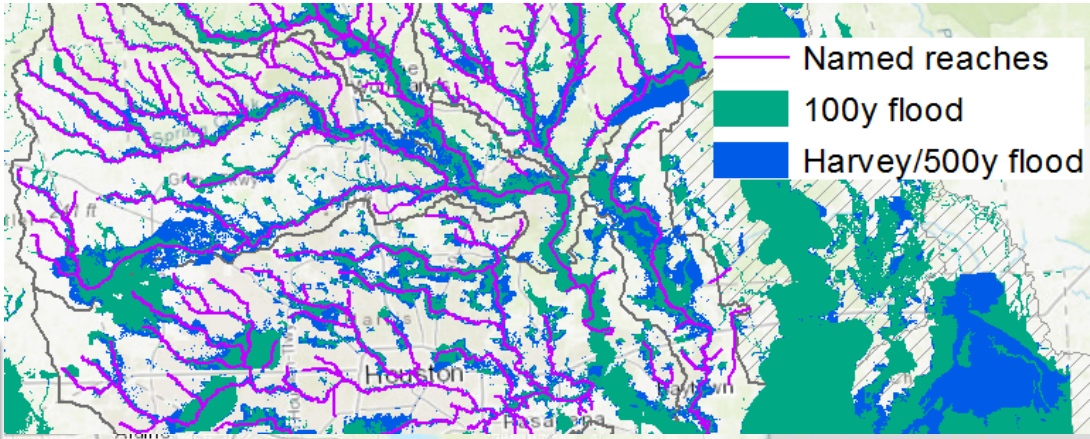
- Jamboard or Q&A
- Potential topics for discussion and/or areas for feedback:
  - What other sources of data on facilities should we consider? What kinds of data are available?
  - What other considerations should we include for understanding risk to facilities to prioritize protective strategies?
  - How will you use this information/these data?

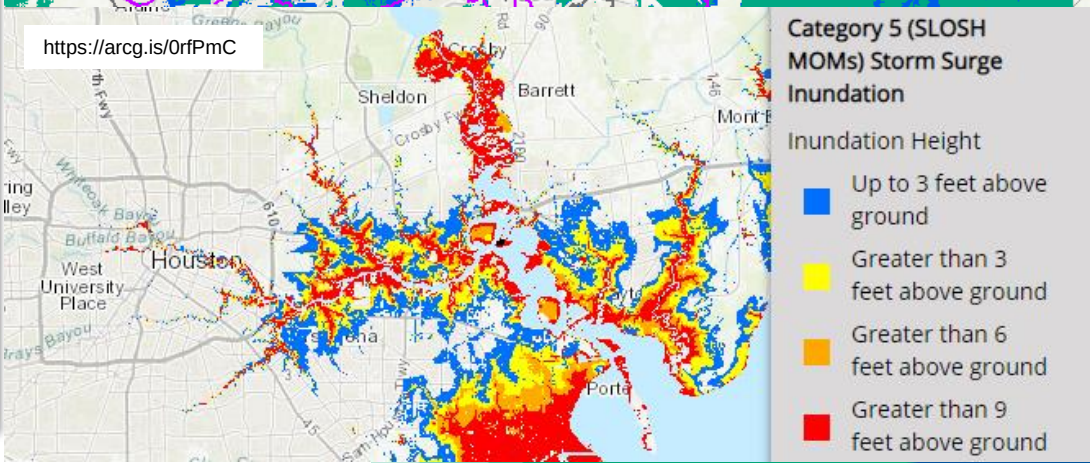
Aim 3

Petrochemical contaminant fate and transport modeling for varied facilities and weather scenarios

Modeling goals

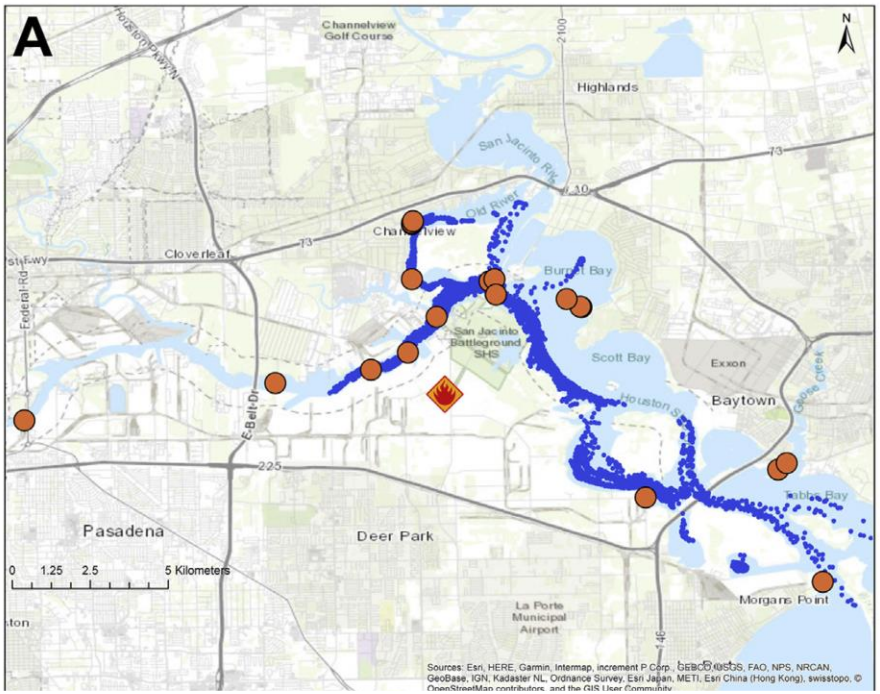
1. To assess potential for contaminant discharges to upland freshwater bodies, Buffalo Bayou and Galveston Bay from both,
   - Flood-damaged facility releases
     - Freshwater flooding
     - Stormsurge
   - Residues in runoff and eroded soil

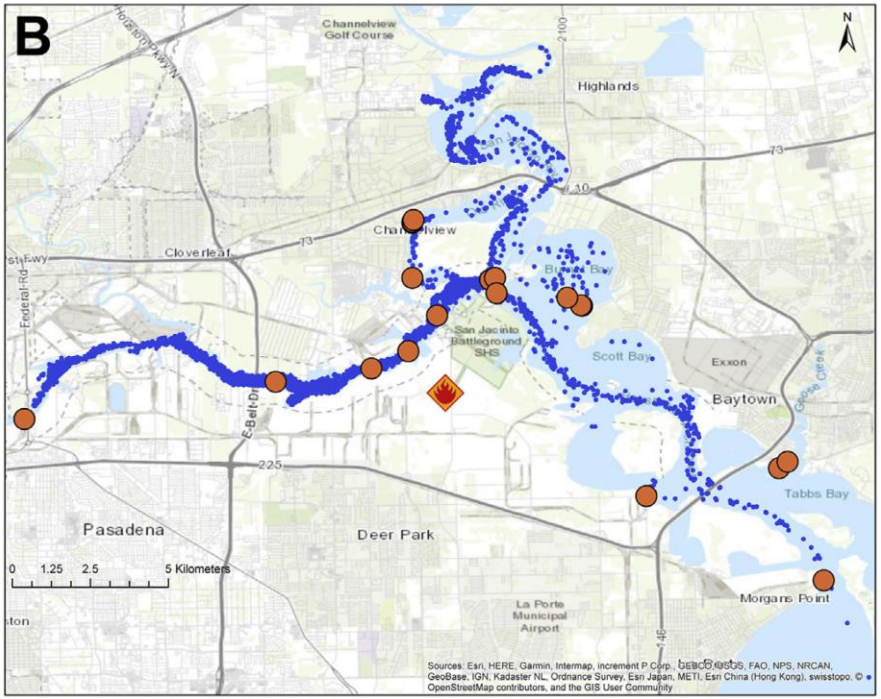




Modeling goals

2. To estimate where contaminants travel and how long they reside in riverine and coastal waterbodies

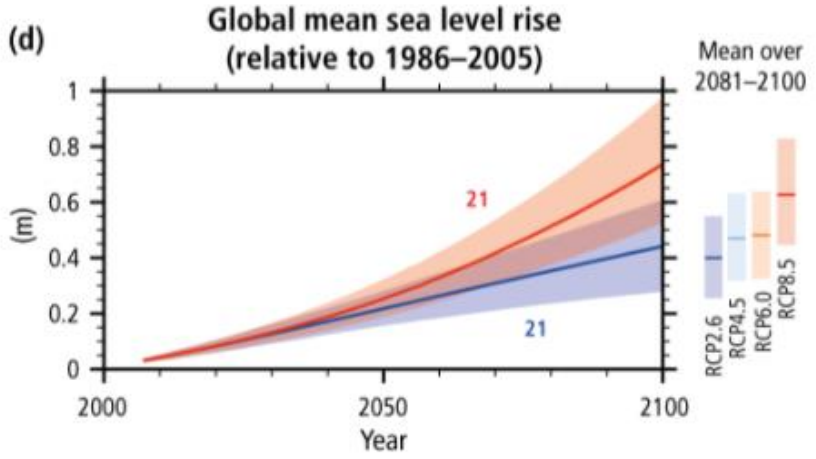




Scenarios

Currently defining these and seeking input

- Historic
  - Past storms including hurricane Harvey
  - Long term historic simulations with a variety of antecedent conditions
- Potential
  - Land use and sea level changes
  - USACE Design Storms
  - RCP 8.5 (business-as-usual future climate model predictions)



Time series of global annual change for the 1900–2300 period (relative to 1986–2005) from CMIP5
Credit: IPCC AR5
https://ar5-syr.ipcc.ch/topic_futurechanges.php

Soil and Water Assessment Tool (SWAT)

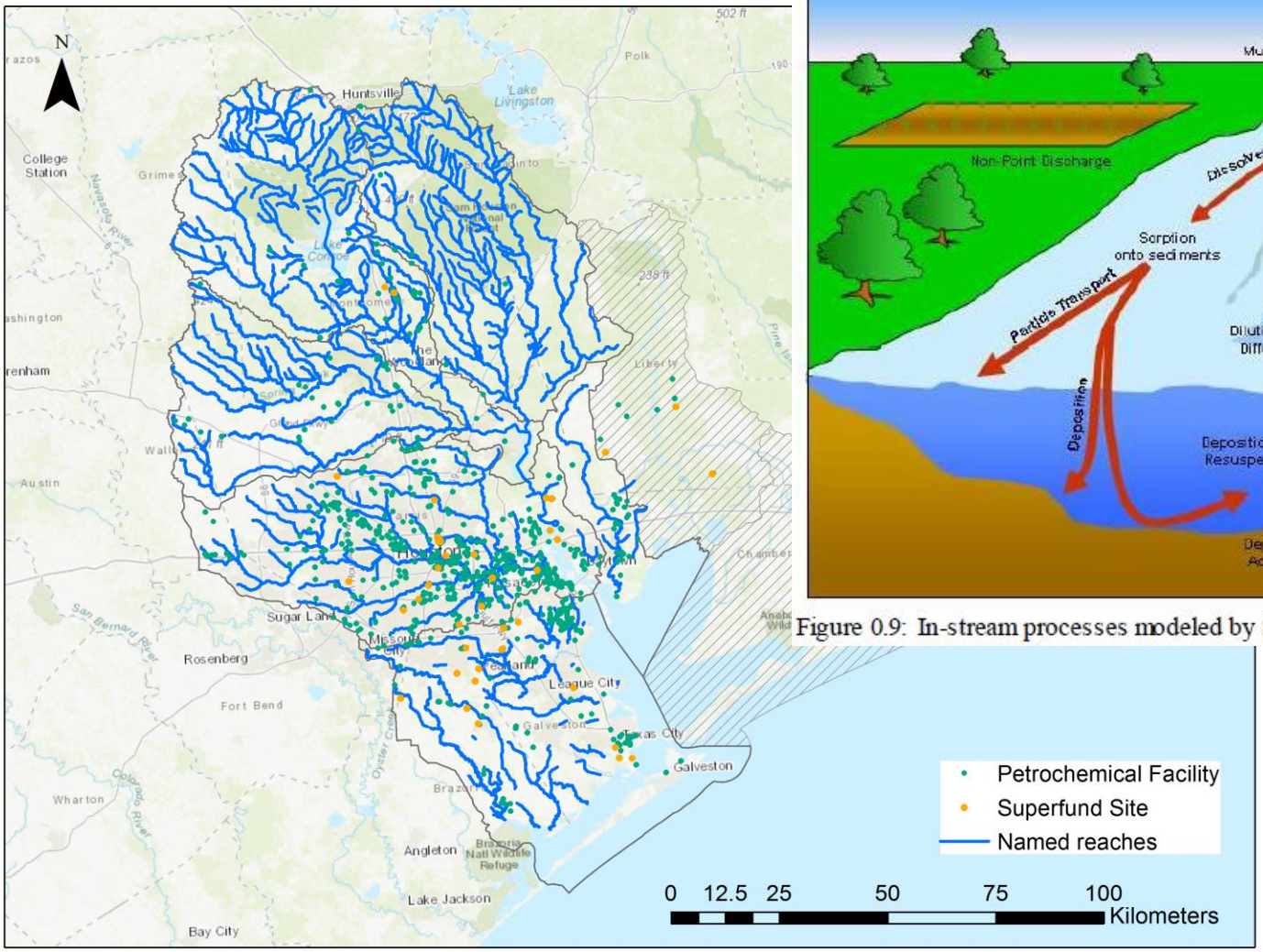
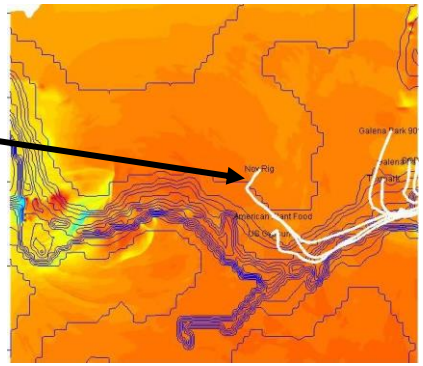


Figure 0.9: In-stream processes modeled by SWAT

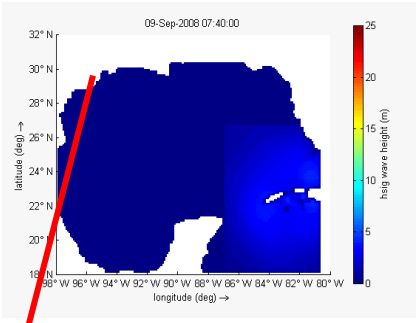
S.L. Neitsch et al., Soil and Water Assessment Tool Theoretical documentation version 2009 (2011). https://swat.tamu.edu/media/99192/swat2009-theory.pdf

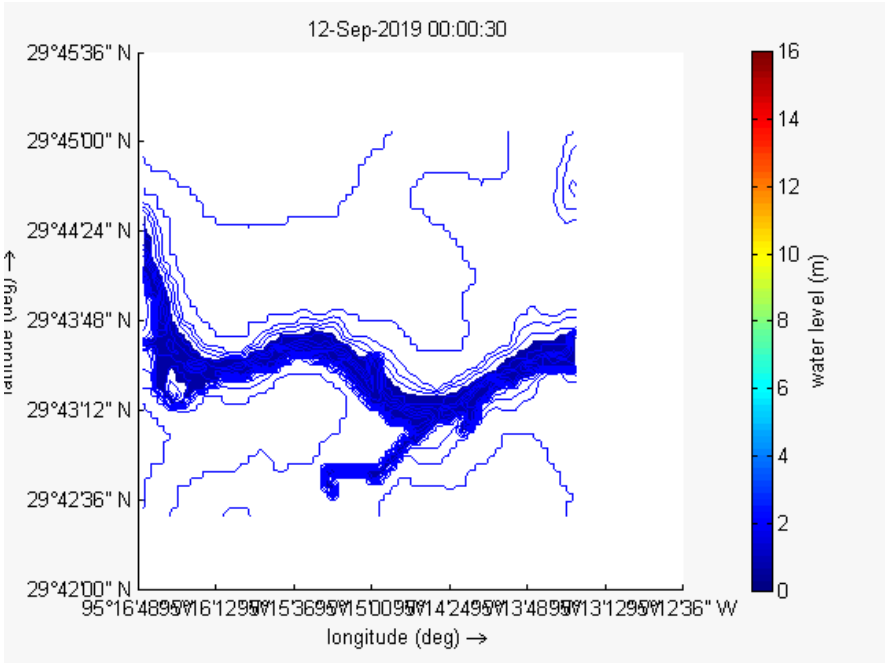
Delft3D

Water transport paths during flooding from various industries in Galena Park

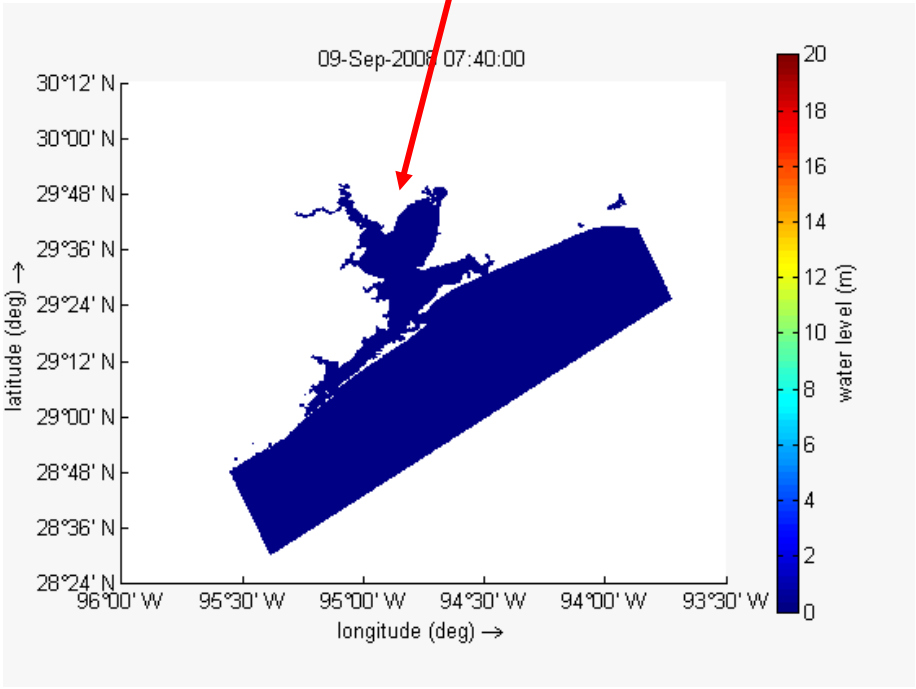


Wave heights from "Super" Ike





Flooding Simulation for Galena Park, TX
(Water level relative to sea level)



Surge in Galveston Bay from "Super" Ike (Ike wind speeds doubled)
(Water level relative to sea level)

Discussion & Questions for Aim 3

- Jamboard or Q&A
- Potential topics for discussion and/or areas for feedback:
  - How can we best integrate with current planning processes, risk assessments, and development projects?
  - How can we ground-truth our findings?
  - How will you use this information/these data?

Aim 4

Nature-Based Solutions (NBS) Assessment: Health and Environment

Nature-Based Solutions

Reduce the impacts of floods while producing other community & ecological benefits

For industrialized areas of Galveston Bay area:

- Oyster beds
- Wetlands
- Vegetated dunes
- Wider, reconnected, vegetated floodplains
- Raingardens & bioswales

Oyster reef example

Wetland example

Bioswale example

Benefits

Flood risk reduction:
- **Reduce wave energy**
- **Attenuate waves**
- **Block surge**
- **Capture, redirect, absorb water to reduce flood height**
- **Slow water speed**
- **Reduce erosion**
- **Complement gray infrastructure to create multiple lines of defense**

Social:
- **Green space**
- **Recreational space**
- **Green jobs**

Other:
- **Cleaner water**
- **Carbon sequestration**
- **Toxics sequestration***
- **Can cost less than gray infrastructure**

* Where managed/removed

How to choose the right nature-based solution

1. Identify current and future **risks of chemical spills** in flood-prone study areas.

2. Develop appropriate NBS **mitigation strategies** and their future impacts.

3. Prioritize and recommend the most **cost-effective** NBS strategies.

Motiva Port Arthur Texas August 31, 2017
https://www.bicmagazine.com/industry/refining-petchem/motiva-move-petrochemicals/

Establish Community Health Conditions and Risk Factors

Utilize existing and primary data to complete a general health assessment for conditions associated with exposures linked to industry and urban planning pursuits within the study area

Data Sources:

- Centers for Disease Control and Preventions (CDC) 500 Cities Project
- 1,250 health surveys collected January 2021
- Texas Department of State Health Services

TEXAS
Health and Human Services

Texas Department of State Health Services

Landscape Performance

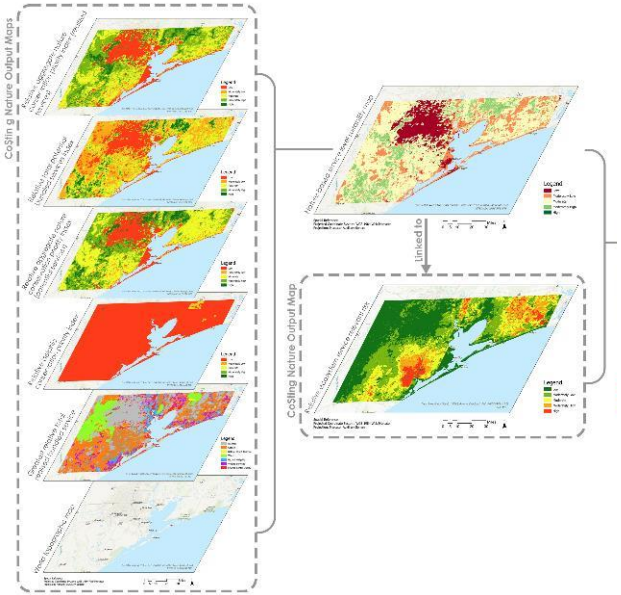
A quantitative approach to assess present conditions, proposed urban growth master plans, and potential benefits from incorporating nature-based solutions into these plans.

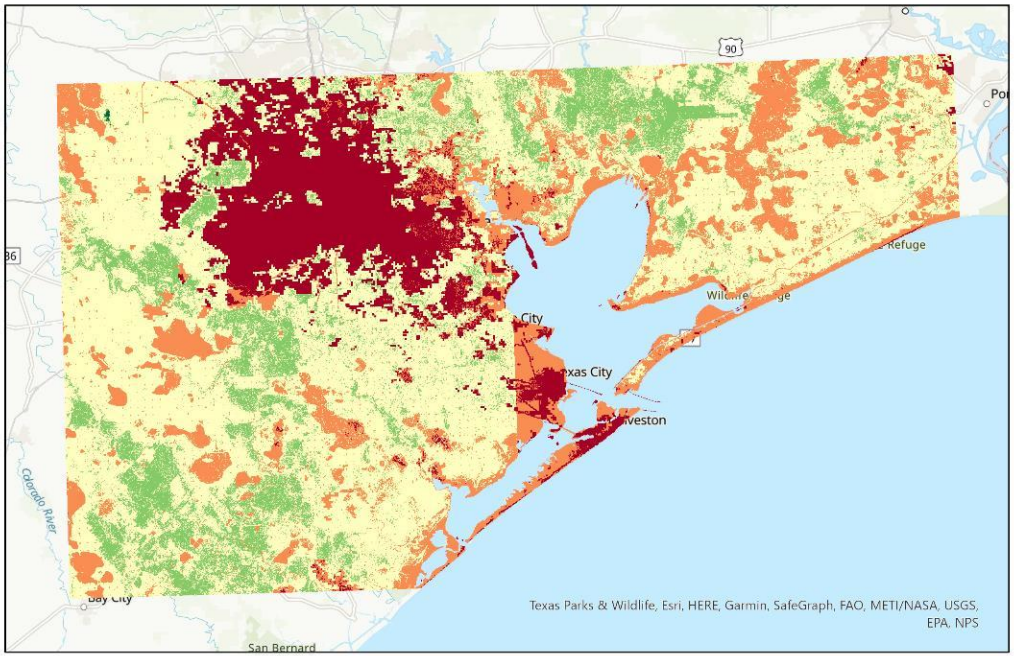
Deliverables:

- **Identify** ecosystem services & beneficiaries
- Monetary **value** of nature-based features
- **Optimize** NBS to improve environmental and human health
- **Visualize** residential, commercial, industrial, and geographical data, including ecosystem indices
- **Compare** cost effectiveness of NBS options under various economic growth and climate scenarios

Strategies/Tactics: Co$ting Nature

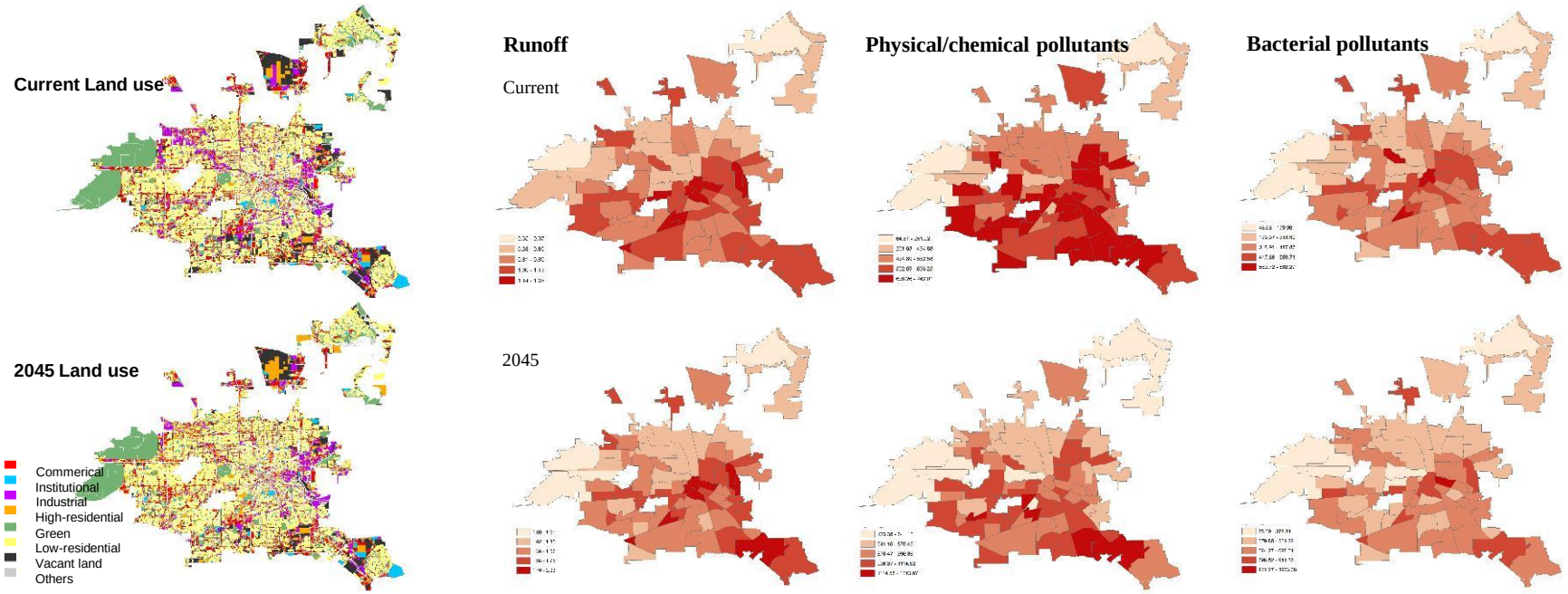
***Co$ting Nature*: quantifies ecosystem services for water, carbon, and hazard mitigation and shows where there are critical ecosystem requirements**





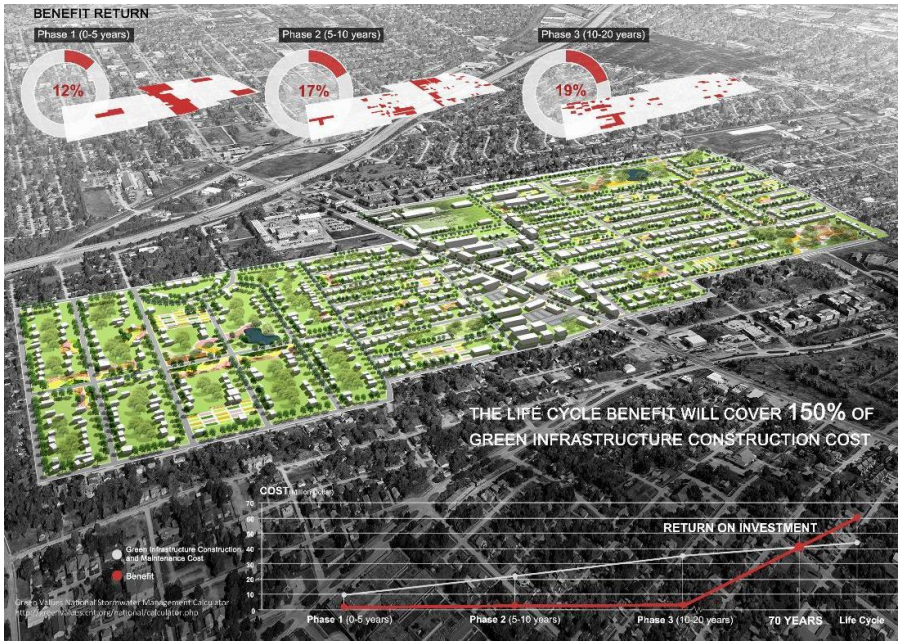
Strategies/Tactics: L-THIA

***Long-Term Hydrologic Impact Analysis (L-THIA) Low Impact Development Spreadsheet*: estimates the average annual runoff and pollutant loads for land use based on 30+ years of data**



Strategies/Tactics: The Center for Neighborhood Technology's National Green Values Calculator

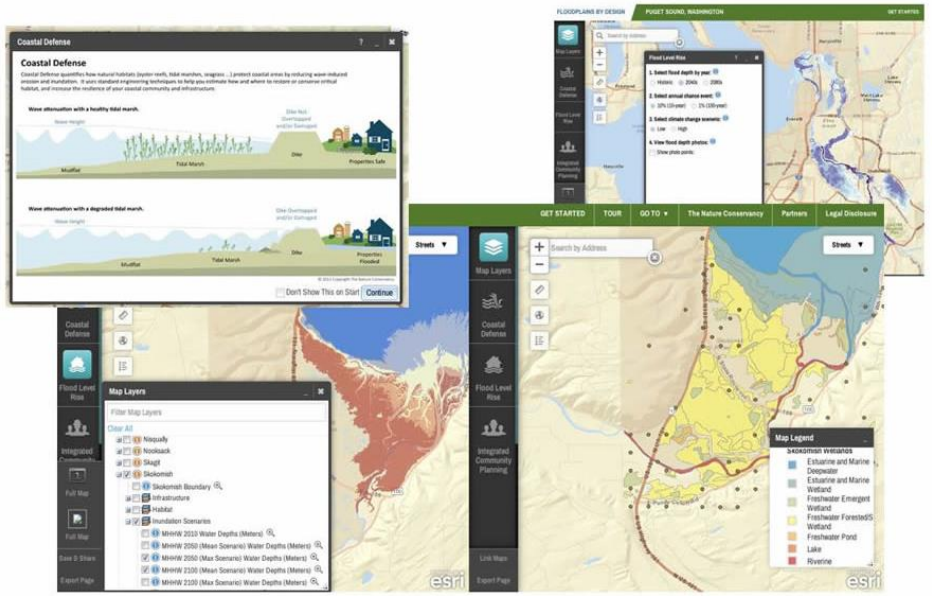
***The Center for Neighborhood Technology's National Green Values Calculator*: compares nature-based solutions to conventional development, based on specific runoff reduction goals and local environmental conditions**



Green Infrastructure	South Park	Sunnyside	Manchester
Green Infrastructure Life Cycle Impact	Output	Output	Output
% Vacant Land Decrease	85%	100%	100%
% Green Space Increase	15%	11%	8%
Annual Stormwater Retention (gal)	19,497,528	40,391,716	6,739,497
Green Infrastructure Construction Cost ($)	29,874,528	8,116,667	6,501,722
Green Infrastructure Annual Maintenance Cost ($)	180,097	44,672	95,929
Green Infrastructure Life Cycle Cost ($)	43,000,000	18,567,090	41,934,270
Total Annual Green Benefits ($)	2,606,415	5,053,001	1,099,719
Life Cycle Green Benefits ($)	60,020,100	116,359,684	87,150,810
Return on Investment Time	70 years	20 years	30 years

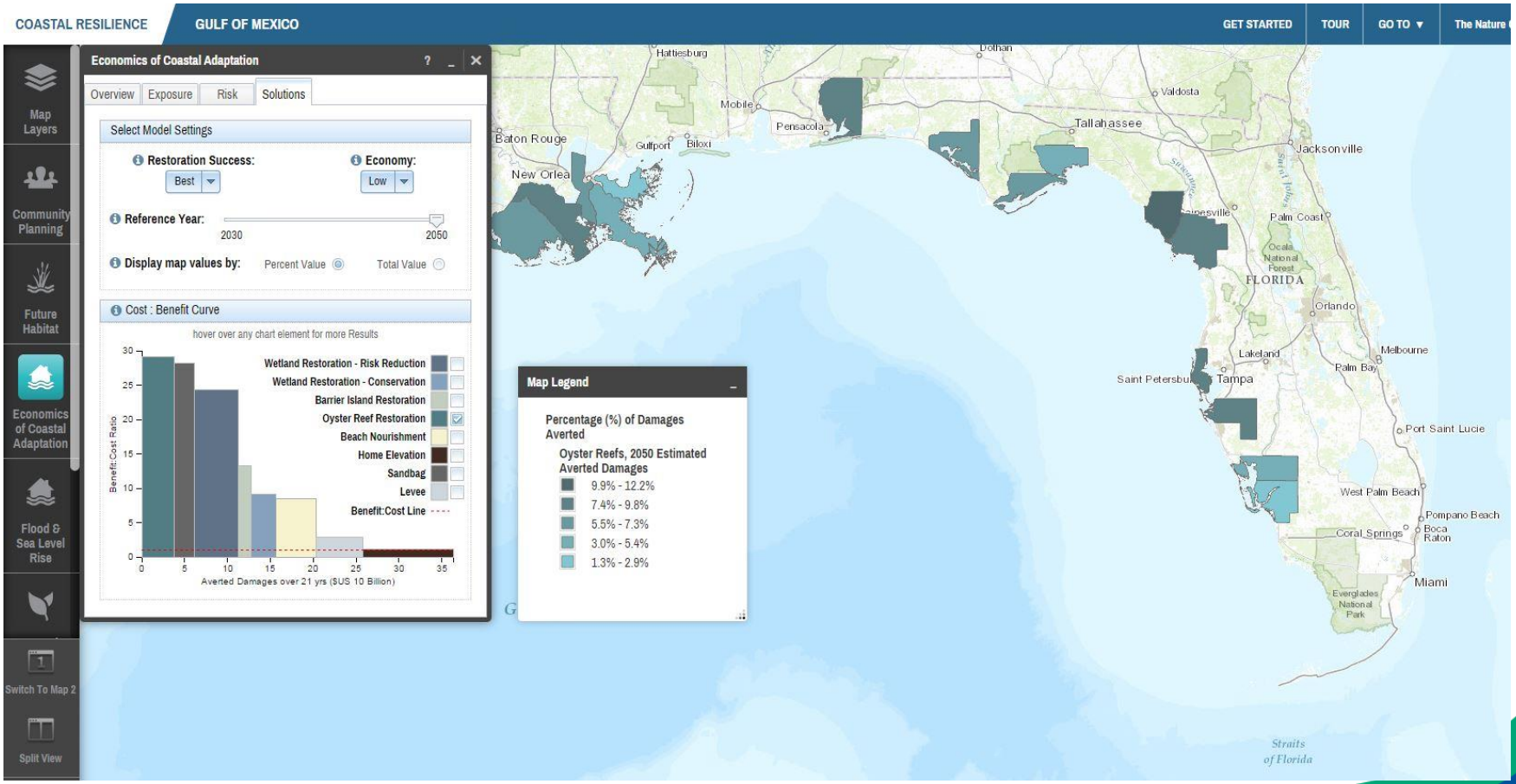
Strategies/Tactics: The Coastal Defense App

***The Coastal Defense App*: identifies areas at risk of coastal erosion and inundation from waves and surge and evaluates the roles of NBS (e.g., oyster reefs, wetlands, and vegetated dunes) in attenuating wave height and help determine appropriate adaptation strategies**



Strategies/Tactics: The Economics of Coastal Adaptation:

<u>The Economics of Coastal Adaptation</u>: assesses current and future coastal hazard risks and compares the cost-effectiveness of nature-based, engineered, and policy-based solutions to reduce risks and damages under various economic growth and climate scenarios



Quantifying Changes in Health Outcomes Based on Landscape Plans

Utilize health risk models and calculations

- Incremental Lifetime Cancer Risk
- BenMAP estimates on air pollutants
- Regulatory health benefits analyses
- Walkability Analysis

Based on most common outcomes associated with exposures

- Asthma
- COPD
- Obesity
- Cancers (Lung, breast, liver, and pancreatic cancer)

Discussion & Questions for Aim 4

- Jamboard or Q&A
- Potential topics for discussion and/or areas for feedback:
  - What types of NBS are currently used in your neighborhood and what do you see as their primary benefits/drawbacks?
  - Are you aware of any incentives such as tax breaks for implementing NBS in your individual yards or when pursuing new developments?
  - How will you use this information/these data?

Aim 5

Gulf Guideline for Reducing Chemical Risks from Floods

Built for Texas – usable across the Gulf of Mexico

- Based on Aims 1, 2, 3, and 4 data and analyses.
- Guide to identify nature-based solutions to:
  - Reduce flood hazards
  - Improve public health
  - Improve community and ecosystem resilience to climate change
- Decision tool to help select feasible nature-based solutions

Credit: The Nature Conservancy
https://www.eurekalert.org/multimedia/pub/167432.php

Outcome: Improved community and environmental resilience to increasing flood risks and reduce chemical exposure

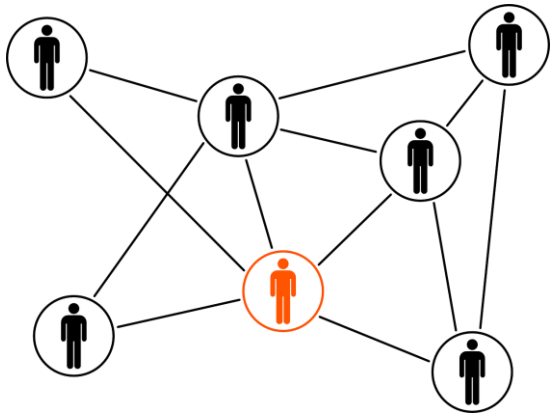
To answer questions like:

https://www.carbonstories.org/allblogposts/j5gcfkzucq8ht72g19v8e2k6lrkdny2162020

- Where are more protective measures needed with increasing flood risk?
- Which sites need most attention to reduce ecological and community risks of chemical exposure?
- Which nature-based solutions will mitigate flooding events that pose a risk to release and transport of contaminants?
- What other benefits might be derived from nature-based solutions?

Multiple end users

- **Chemical risk managers**…
  to update facility risk management plans.
- **Coastal planners, floodplain managers, and emergency managers**…
  to enhance flood hazard mitigation plans and secure funding.
- **Community groups**…
  to support exploration of new ideas that benefit public health.
- **Environmental groups**…
  to build understanding of solutions that reduce flooding impacts, address environmental justice, and improve coastal ecosystems.
- *and others*.



Discussion & Questions for Aim 5

- Jamboard or Q&A
- Potential topics for discussion and/or areas for feedback:
  - How would you use this tool in your day-to-day? In what way?
  - What is the best/most ideal format?
  - How can you use to plan/prepare to create shovel-ready project ideas?

How to engage

- Jamboard!
- TAC breakout sessions
- Ongoing
  - Email, website (TBD)

- Upcoming meetings:
  - Technical Advisory Committee Meeting on initial findings (TBD spring 2022)
  - Opportunity to provide feedback on NBS decision tool (TBD summer 2023).

Break

We will return in 15 minutes for the breakout sessions – feel free to mute your screens/mics and rejoin at 3:30 pm (same Zoom link)

EDF ENVIRONMENTAL DEFENSE FUND®

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Breakout rooms

Room 1 - Aims 1 & 2

Galveston Bay Ecosystem Survey & Identify/prioritize vulnerable petrochemical facilities

- Fish sampling areas
- Flow of communication
- Sources of data
- Considerations for prioritizing facilities
- Ground-truthing findings
- Data flow/integration
- Usefulness of this tool (from these aims specifically)

Room 2 - Aims 3 & 4

Contaminant fate and transport modeling for varied and weather scenarios & Nature-Based Solutions (NBS) Assessment

- What is already well known?
- Area where modeling can contribute greatest added-value
- Types of model outputs that are of interest
- Ground-truthing findings
- Integration with current planning processes, risk assessments, and development projects
- Incentives/policy developments around NBS planning

Report back

- Aim 1
- Aim 2

Report back

- Aim 3
- Aim 4

Review of Aim 5

Objective

- Improved community and environmental resilience to increasing flood risks and reduce chemical exposure

Deliverable

- Guide to identify nature-based solutions to:
  - Reduce flood hazards
  - Improve public health
  - Improve community and ecosystem resilience to climate change
- Decision tool to help select feasible nature-based solutions, which can be:
  - Incorporated into facility risk management plans, community and state flood hazard mitigation plans
  - Used to support petitions for state and federal funding

Discussion & Questions for Aim 5

- Jamboard or Q&A
- Potential topics for discussion and/or areas for feedback:
  - How would you use this tool in your day-to-day? In what way?
  - What is the best/most ideal format?
  - How can you use to plan/prepare to create shovel-ready project ideas

Notes on Aim 5 discussion

How to engage

- Jamboard!
- Email Cloelle: cdanforth@edf.org

- Upcoming meetings:
  - Technical Advisory Committee Meeting on initial findings (TBD spring 2022)
  - Opportunity to provide feedback on NBS decision tool (TBD summer 2023).

Clear Lake Forest Park - located on the eastern shoreline of Armand Bayou/Mud Lake
Credit: Galveston Bay Foundation
https://galvbay.org/work/habitat-restoration/

BACKUP SLIDES FOR BREAKOUT ROOMS & TAC DISCUSSION

Technical Session

Aim 1

Galveston Bay Ecosystem Survey

Aim 2

Identify/prioritize vulnerable petrochemical facilities

Aim 1 - Galveston Bay Ecosystem Survey recap

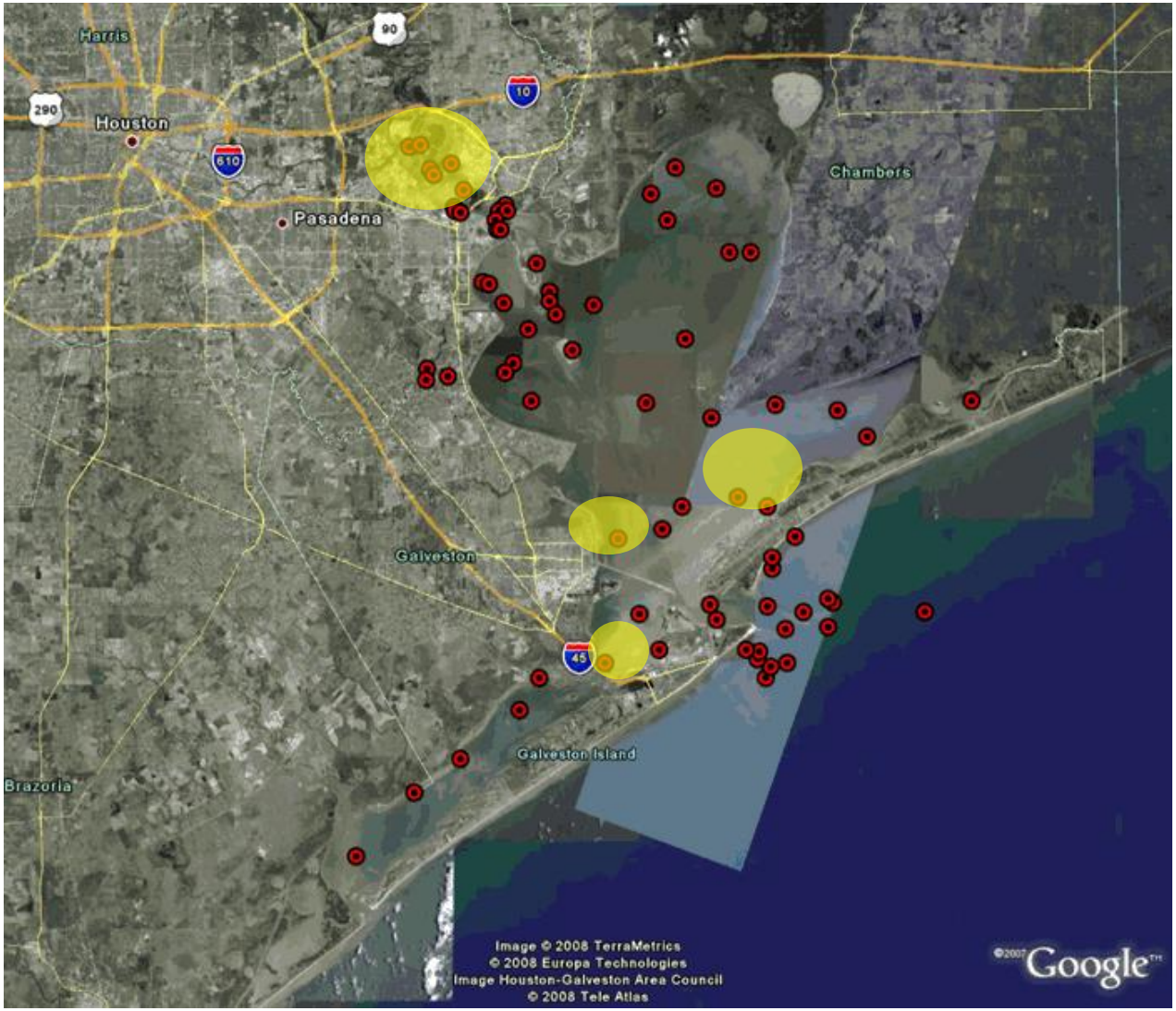
Objectives

- identify spatial contamination across species to understand overall environmental contamination
- Identify key COCs to support/integrate with Aim 2 & 3

Scope

- Sample campaign to collect red & black drum and spotted trout
- Sample for PAHs, PFAS/PFOA, metals, dioxins
- Integrate with mussel watch data (and historical sample data)

Sample sites in Galveston Bay



Fish sample sites

Historic mussel watch sample locations

Aim 1 Questions

What are the opportunities for you to use this work? What is the best way to communicate our findings or get these tools into your hands?

Aim 1: Galveston Bay Ecosystem Survey

- Communication strategies? Other community/municipalities we should be engaging with (and how)?
- Other sampling areas?

Aim 2 - Vulnerable facilities recap

Objective

- Characterize and rank vulnerable petrochemical facilities by risk for potential chemical releases in context of sea level rise, increased storm frequency and intensity, and increased flooding.

Scope

- Identify petrochemical facilities within Galveston Bay watershed
- Collect key data associated with facilities to describe risk to communities and environment in terms of flood vulnerability, exposure potential, and hazard potential
  - Types and quantity of chemicals on site
  - Hazards associated with chemicals
  - Types of releases (historical, on-going), proximity to populations and sensitive ecosystems
  - Iterative process, closely integrated with Aim 3 – identify vulnerability to inundation and fate/transport of chemicals if released
- Use findings to identify and support NBS siting and placement

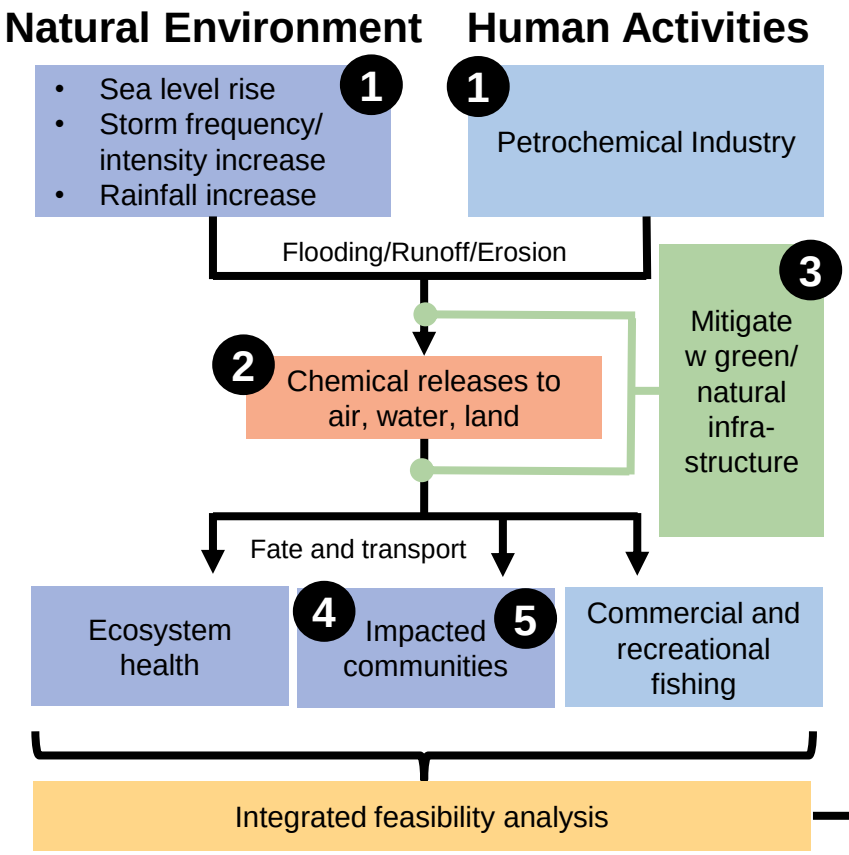
Aim 2 Questions

What are the opportunities for you to use this work? What is the best way to communicate our findings or get these tools into your hands?

Aim 2: Identify/prioritize vulnerable petrochemical facilities

- What is already well known?
- What other considerations should be made to prioritize these facilities?
- How can we best integrate with current planning processes, risk assessments, and development projects?
- Who are the key people that we should engage with more closely throughout this aim?
- How can we ground-truth our findings?

Data integration across aims



1. **Environmental Exposure from flooding**
2. **Environmental Hazard from chemicals**
3. **Ecosystem services from NBS**
4. **Social vulnerability**
5. **Baseline health**

Technical Session

Aim 3

Petrochemical contaminant fate and transport modeling for varied facilities and weather scenarios

Aim 4

Nature-Based Solutions (NBS) Assessment: Health and Environment

Aim 3 & 4 Questions

What are the opportunities for you to use this work? What is the best way to communicate our findings or get these tools into your hands?

How can we ground-truth our findings?

Aim 3: Contaminant fate and transport modeling

- What is already well known?
- What are areas where modeling can contribute greatest added-value?
- What model outputs are of greatest interest?
- How can we best integrate with current planning processes, risk assessments, and development projects?
- Who are the key people that we should engage with more closely throughout the modeling aim?

Aim 4: Nature-Based Solutions (NBS) Assessment

- What types of NBS are currently used in your neighborhood and what do you see as their primary benefits/drawbacks?
- Are you aware of any incentives such as tax breaks for implementing NBS in your individual yards or when pursuing new developments?

Aim 3 - Modeling recap

- Ensemble of flood damage/precipitation scenarios characterizing historic and potential (climate change, nature-based solutions) conditions
- Calibrated Galveston Bay watershed and estuary models
- Flood/surge and affected facility maps, potential for contaminant discharges to freshwater bodies and Galveston Bay
- Riverine and estuary transport of contaminants (residence times, spatial extent)
- Characterization of ecosystem vulnerability from petrochemicals for varied scenarios

Aim 3 - Models

SWAT Soil & Water Assessment Tool

- Watershed hydrology
- https://swat.tamu.edu/
- Free and open-source
- Upland riverine fate and transport
- Semi-distributed, 2-dimensional
- Runoff/curve-number-based

Delft3D

- Estuary/Coastal hydraulics
- https://oss.deltares.nl/web/delft3d
- Free and open-source
- Galveston Bay, Buffalo Bayou fate and transport
- 2-or-3-dimensional modeling possible

Aim 3 - Key questions

- What is already well known?
  - Previous work we should be aware of?
  - Mitigation efforts already underway?
  - Facilities of concern?
- What are areas where modeling can contribute greatest added-value?
- What model outputs are of greatest interest?
  - Are there any preferred output formats? Existing tools that could integrate the data? Need for new tools?
- How can we ground-truth our findings?
- How can we best integrate with current planning processes, risk assessments, and development projects?
- Who are the key people that we should engage with more closely throughout the modeling aim?

What are the opportunities for you to use this work? What is the best way to communicate our findings or get these tools into your hands?

Soil and Water Assessment Tool (SWAT)

- Input development
  - Chemical: facilities, releases, fate and transport properties
  - Landscape: elevation, soil, land cover
  - Hydrology: streams, reservoirs
  - Weather: precipitation, temperature, evapotranspiration
- Calibration
  - USGS surface water gage stations
- Simulation
  - Multiple weather scenarios and chemical classes
- Outputs
  - Chemical loading to sediment and surface water
  - Critical source areas
  - Transport time scales
  - Chemical, sediment and freshwater flows to Delft3D
- Visualization and analysis

Key datasets

Model input	Source Datasets
Hydrology	Harvey flood maps USGS National Hydrography Data* NOAA FEMA Floodplains* USGS gage data
Landscape	Soils - NRCS STATSGO\SSURGO Land cover - NLCD – latest available Elevation – High resolution LIDAR or USGS NED
Weather	USDA Agricultural Research Service Weather data
Management	Reservoir spillway dimensions and management practices and information on other engineered systems from flood control experts

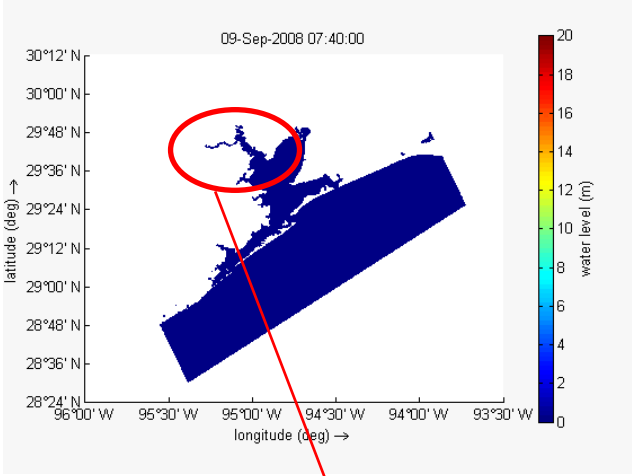
Delft3D - FLOW

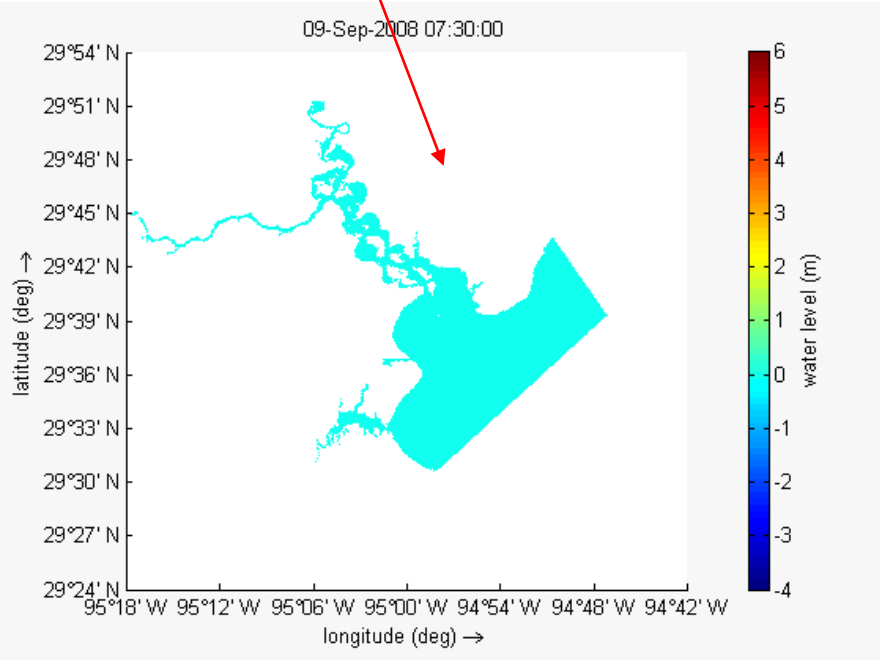
- Input development
  - Chemical: facilities, releases, fate and transport properties
  - Landscape: elevation, underwater topography (bathymetry)
  - Hydrology: streams, reservoirs
  - Weather: precipitation, temperature, evapotranspiration, extreme events
  - Oceanography: tides, waves, currents
- Calibration
  - NDBC buoys
  - NOAA coastal water levels
- Simulation
  - Multiple weather scenarios and chemical classes
- Outputs
  - Contaminant transport pathways
  - Flooding elevation and residence (local depressions)
  - Drainage routing
  - Flooding water levels and sediment transport / deposition (as required)
- Visualization and analysis

Key datasets

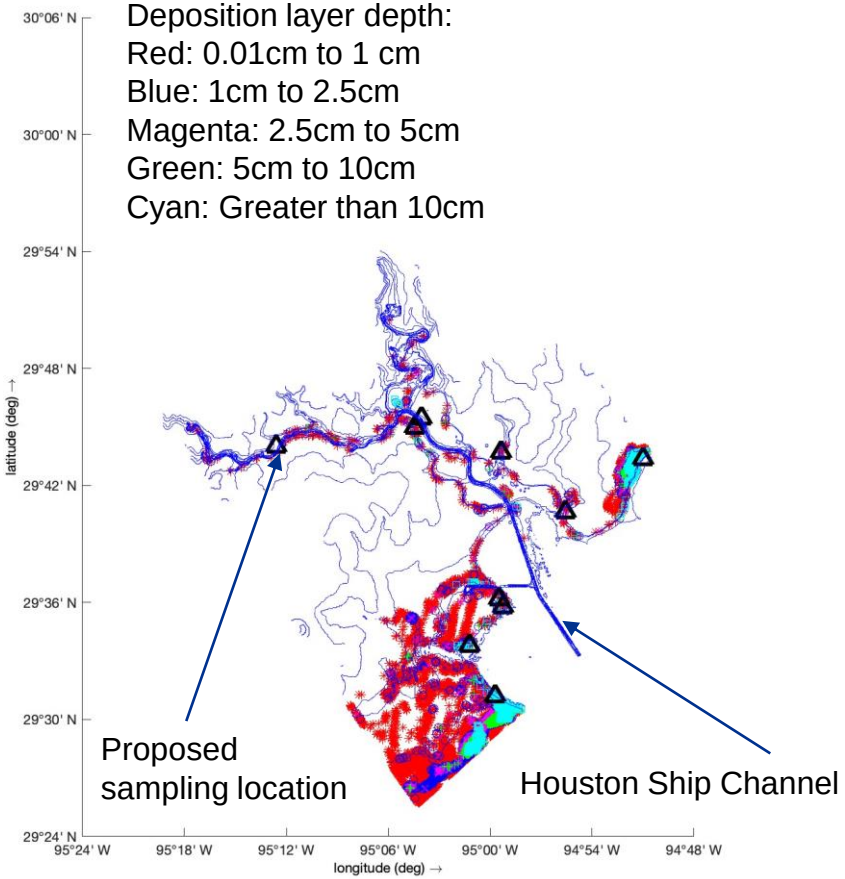
Model input	Source Datasets
Oceanography	OSU Inverse Tide Model NOAA NCEP WAVEWATCH-III wave model output NOAA / Navy HYCOM model for currents (if needed)
Landscape	Bathymetry: GEBCO, Coastal Relief Model (both from NGDC / NOAA) Elevation – High resolution LIDAR or USGS NED GIS data of infrastructure, as needed
Weather	NOAA NCEP hindcast / forecast winds
Management	Any existing flood control infrastructure

Sedimentation from Delft3D and "Super Ike"

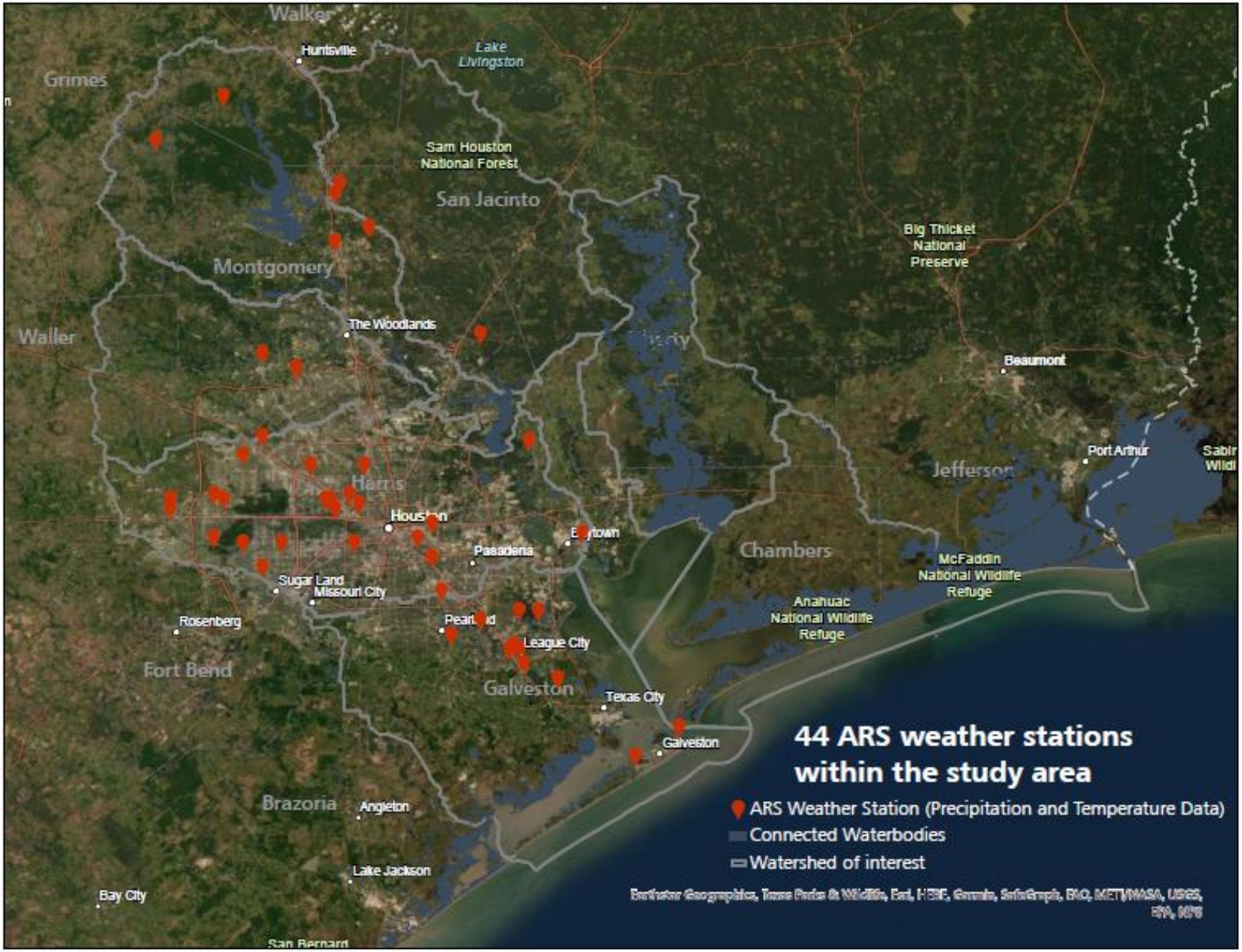




Deposition layer depth:
Red: 0.01cm to 1 cm
Blue: 1cm to 2.5cm
Magenta: 2.5cm to 5cm
Green: 5cm to 10cm
Cyan: Greater than 10cm



Historic weather stations



Hydrology

- Reservoirs
  - Addicks Reservoir, Barker Reservoir, Lake Conroe and Lake Houston;
  - capacity, spillway height, surface area, management practices, historical discharges

- Other flood control structures/engineered flow
- Stream channel dimensions

Land cover

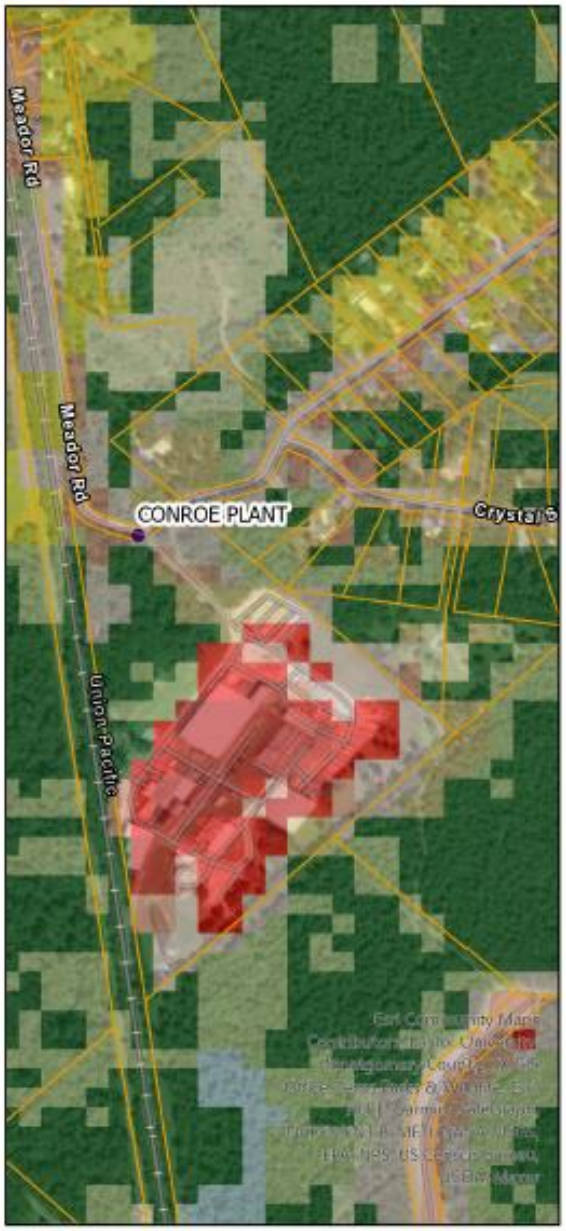
Example of a Facility in Harris County with Highly Developed Land Cover

Parcels

NLCD_2016_Land_Cover_L48

- 0
- Open Water (11)
- Perennial Ice/Snow/ (12)
- Developed, Open Space (21)
- Developed, Low Intensity (22)
- Developed, Medium Intensity (23)
- Developed, High Intensity (24)
- Barren Land (Rock/Sand/Clay) (31)
- Unconsolidated Shore (32)
- Deciduous Forest (41)
- Evergreen Forest (42)
- Mixed Forest (43)
- Dwarf Scrub(AK only) (51)
- Shrub/Scrub (52)
- Grasslands/Herbaceous (71)
- Sedge/Herbaceous(AK only) (72)
- Lichens (Ak only) (73)
- Moss (AK only) (74)
- Pasture/Hay (81)
- Cultivated Crops (82)
- Woody Wetlands (90)
- Emergent Herbaceous Wetlands (95)

Land cover



Example of a Facility in Montgomery County with Mostly Forest and Pasture/ Hay Land Cover

Parcels

NLCD_2016_Land_Cover_L48

- 0
- Open Water (11)
- Perennial Ice/Snow/ (12)
- Developed, Open Space (21)
- Developed, Low Intensity (22)
- Developed, Medium Intensity (23)
- Developed, High Intensity (24)
- Barren Land (Rock/Sand/Clay) (31)
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- Cultivated Crops (82)
- Woody Wetlands (90)
- Emergent Herbaceous Wetlands (95)

Aim 4: Nature-Based Solutions (NBS) Assessment - Recap

- **Objectives:** Evaluate and compare current conditions to proposed urban growth plans to develop detailed estimates on changes in potential risks to related populations.
- **Strategy/Tactics:** Five different tools to assess NBS
  - Co$ting Nature
  - Long-Term Hydrologic Impact Analysis (L-THIA) Low Impact Development Spreadsheet
  - The Center for Neighborhood Technology's National Green Values Calculator
  - The Coastal Defense App
  - The Economics of Coastal Adaptation
- **Deliverables:**
  - Identification of ecosystem services for water, carbon, and hazard mitigation and their beneficiaries
  - The monetary value of nature-based features using stormwater reduction, carbon sequestration, decreased energy costs, and related variables
  - Identification of optimal nature-based approaches to improving environmental and human health
  - Visualizations of residential, commercial, industrial, and geographical data, including ecosystem indices
  - Comparison of the cost effectiveness of different NBS options for flood damage aversion under various economic growth and climate scenario

Aim 4 – key questions/discussion points

- What types of NBS are currently used in your neighborhood and what do you see as their primary benefits/drawbacks?
- Are you aware of any incentives such as tax breaks for implementing NBS in your individual yards or when pursuing new developments?

What are the opportunities for you to use this work? What is the best way to communicate our findings or get these tools into your hands?