

# Critical Infrastructure Vulnerability: What is at Risk?

H. Rifai

Civil and Environmental Engineering

University of **Houston**

# Vulnerability

- Measure of system susceptibility to:
  - hazard
  - loss and damage
  - risk

*Vulnerability = Susceptibility to a scenario*  
*Risk = severity of scenario consequences*



# Critical Infrastructure

- Electric Power Supplies
- Gas and Oil - Industry
- Telecommunications
- Banking and Finance
- Transportation - Shipping
- Water Supply Systems
- Emergency Services
- Government

# Vulnerabilities of Water Systems during IKE

- Interrupted water service
- Nonfunctioning sewer systems
- Some Public water systems had no backup generators
- Many private water districts had no generators
  - Did not maintain running water in their communities
  - Did not maintain enough water in elevated tanks for gravity flows

# COH Wastewater Infrastructure

- 39 Wastewater Treatment Plants (WWTP)
- 420 Lift Stations
- 3 Wet Weather Facilities
- 33 million linear feet of gravity sewers
- 1.5 million linear feet of force mains
- Approximately 130,000 manholes

Service area ~ 625 square miles

Population ~ 3 million persons



# Wastewater Infrastructure Vulnerabilities

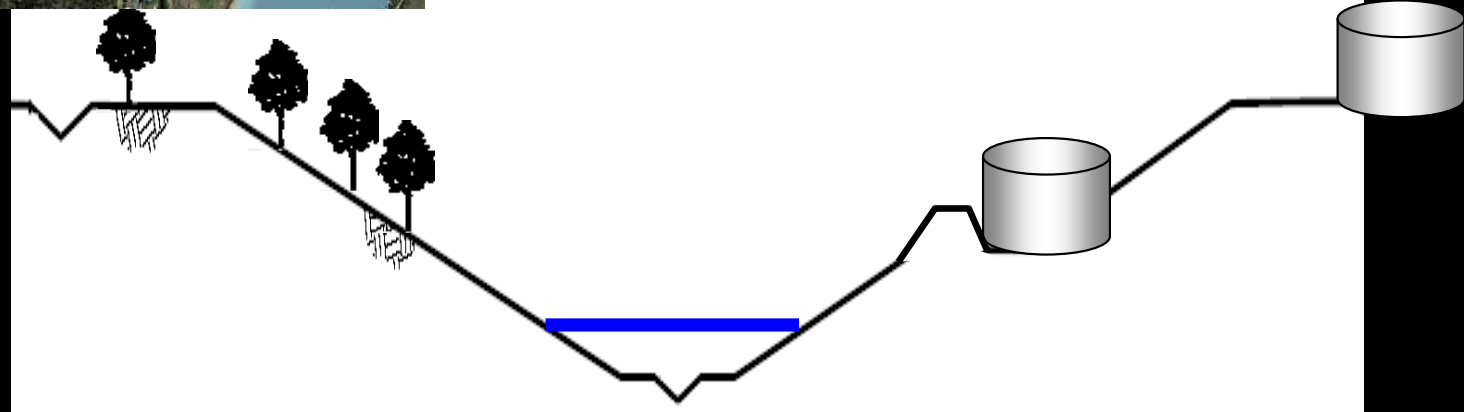
- Dramatic increase (~ 30%) in Sanitary Sewer Overflows (SSOs) due to power outages at lift stations and treatment plants
- Sewage in the collection system turned septic >> odor
- Equipment damages at several facilities
- Communication systems affected
- Numerous fences and gates damaged >> less security
- Facilities had major damages
  - Sims Bayou WWTP (permitted capacity 25 mgd)
  - Clinton Drive lift station (firm capacity 400 mgd)
- Minor damages throughout the system including several gravity main breaks





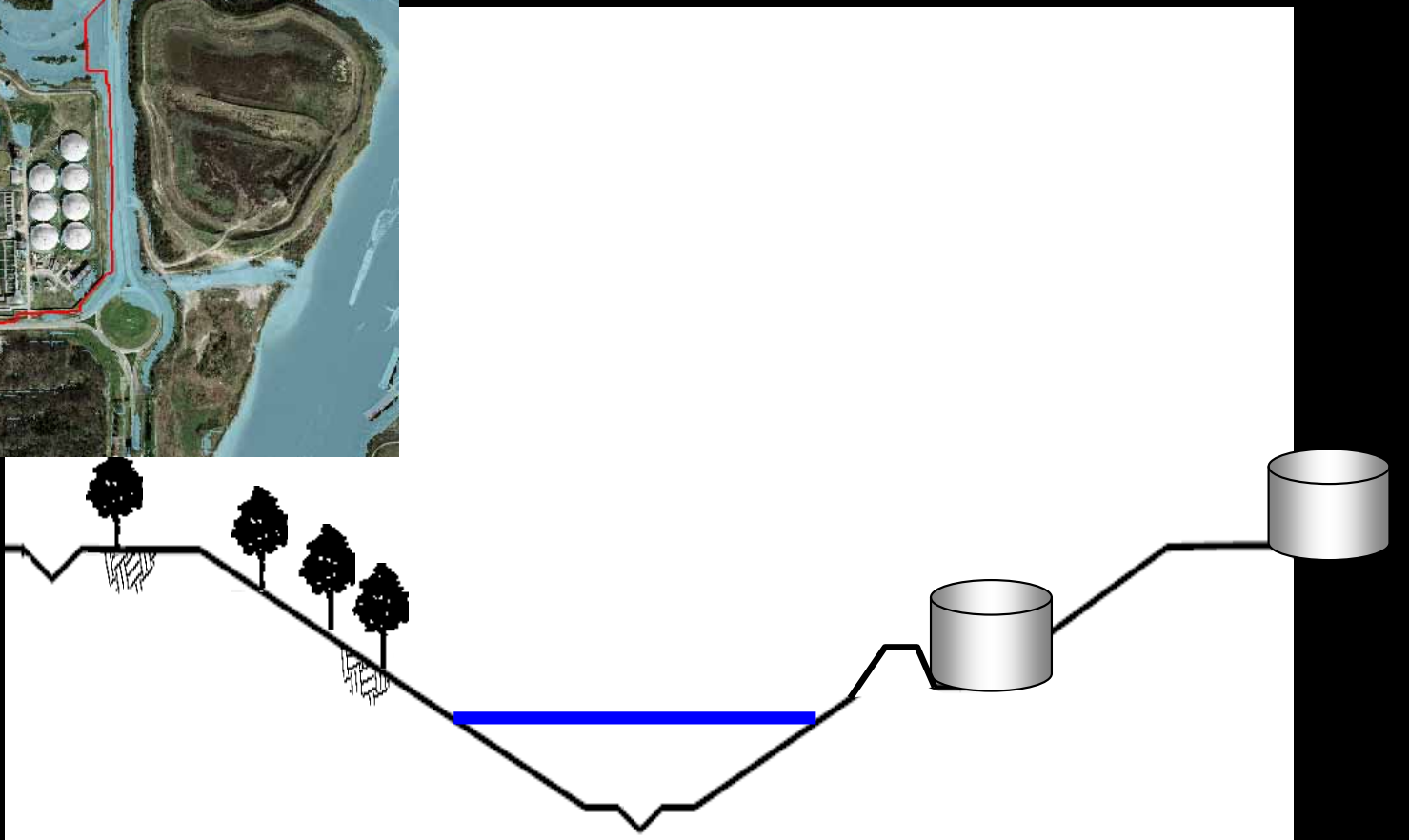


+5 FT MSL



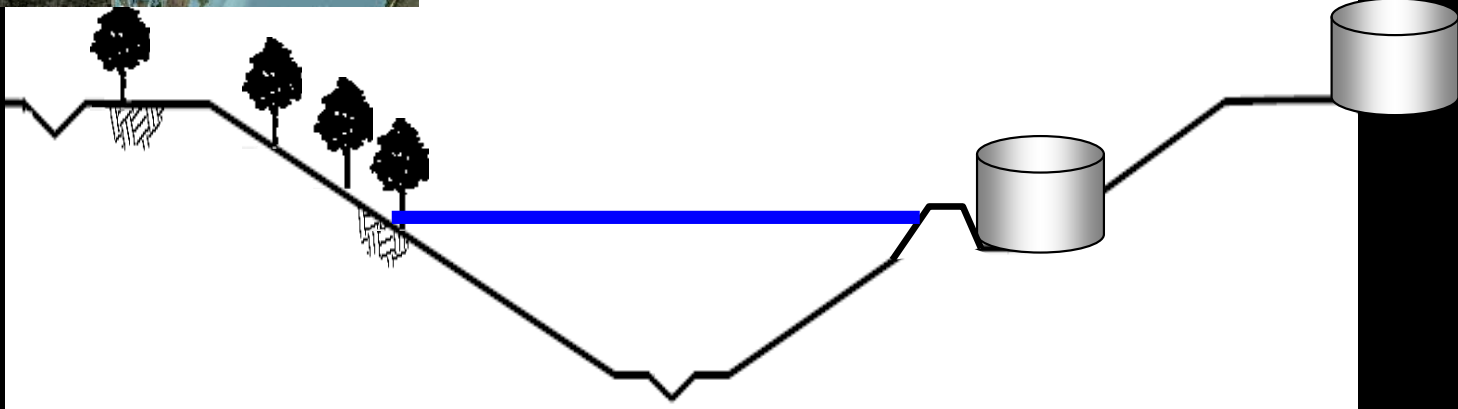


**+10 FT MSL**

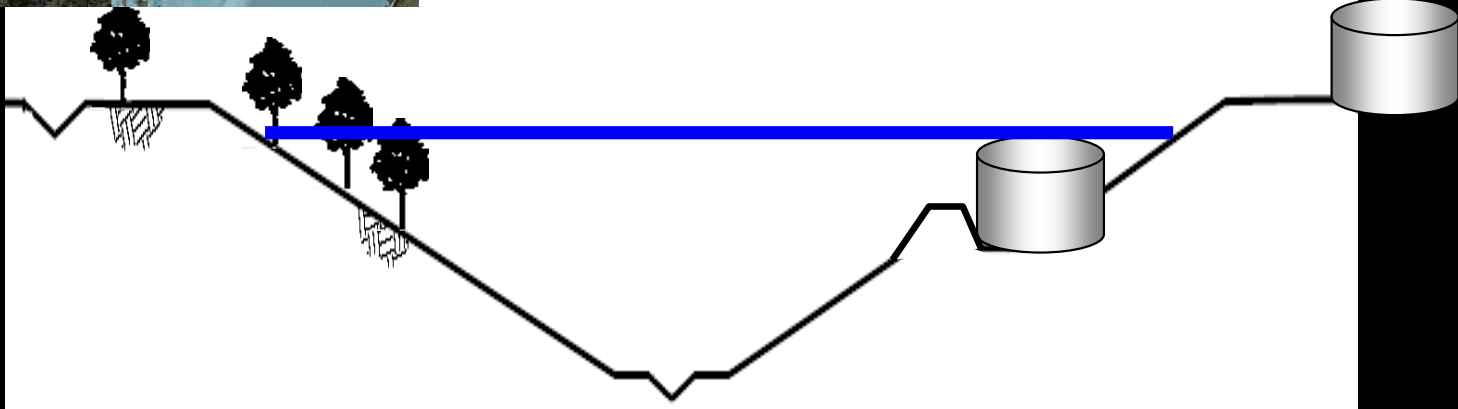




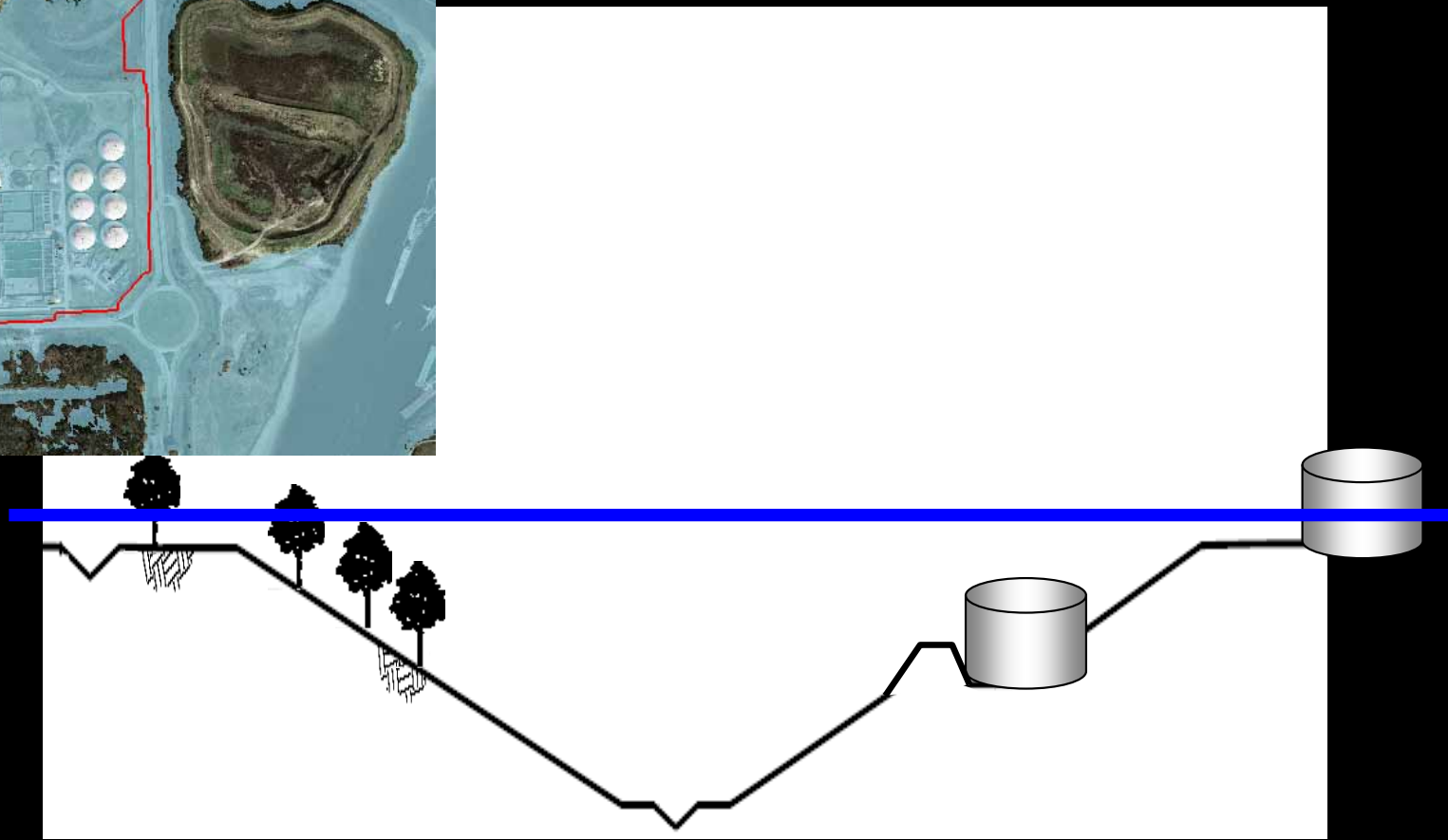
**+15 FT MSL**



**+20 FT MSL**







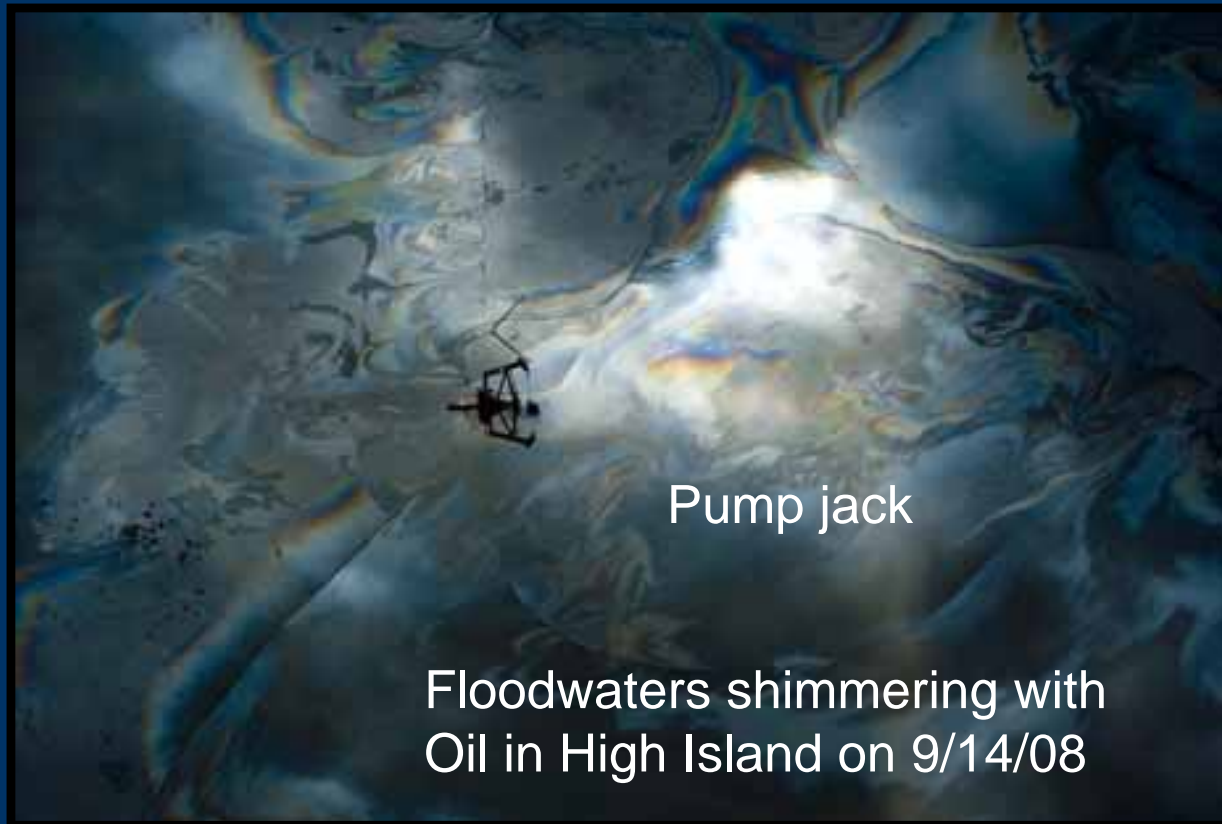


# Industrial Consequences of IKE

- Refineries and chemical plants shut down
- Burned off hundreds of thousands of pounds of organic chemicals and toxics
- Power failures sent chemicals such as ammonia directly into atmosphere
- Environmental rules typically suspended in extreme events
- Containers w. chemicals floated in HSC
- sheens reported, abandoned drums ...
- Air quality monitors for industrial complex destroyed



# Oil/Chemical Spills and Impacts



- **Destroyed oil platforms (52) + 32 damaged severely**
- **Tossed storage tanks**
- **Punctured pipelines**
- **1/2 mil + gal oil spilled in Gulf**
- **448 releases reported mostly in Port Arthur and industrial corridor in Houston**
- **1500+ sites need cleanup**

# St. Mary Land and Exploration Co. on Goat Island

- surge from the storm flooded the plant
- leveled its dirt containment wall
- snapped off pipes connecting its eight storage tanks that held oil and water produced from two wells in Galveston Bay
- 266,000 gallons of oil spilled



**1960s era levees (15 ft) surround our most critical industrial infrastructure**

# IKE at POH

- ❑ No significant damages
- ❑ Reopened after five days
  - downed trees
  - broken glass
  - saltwater intrusion to Galveston Bay-side facilities
  - downed power lines





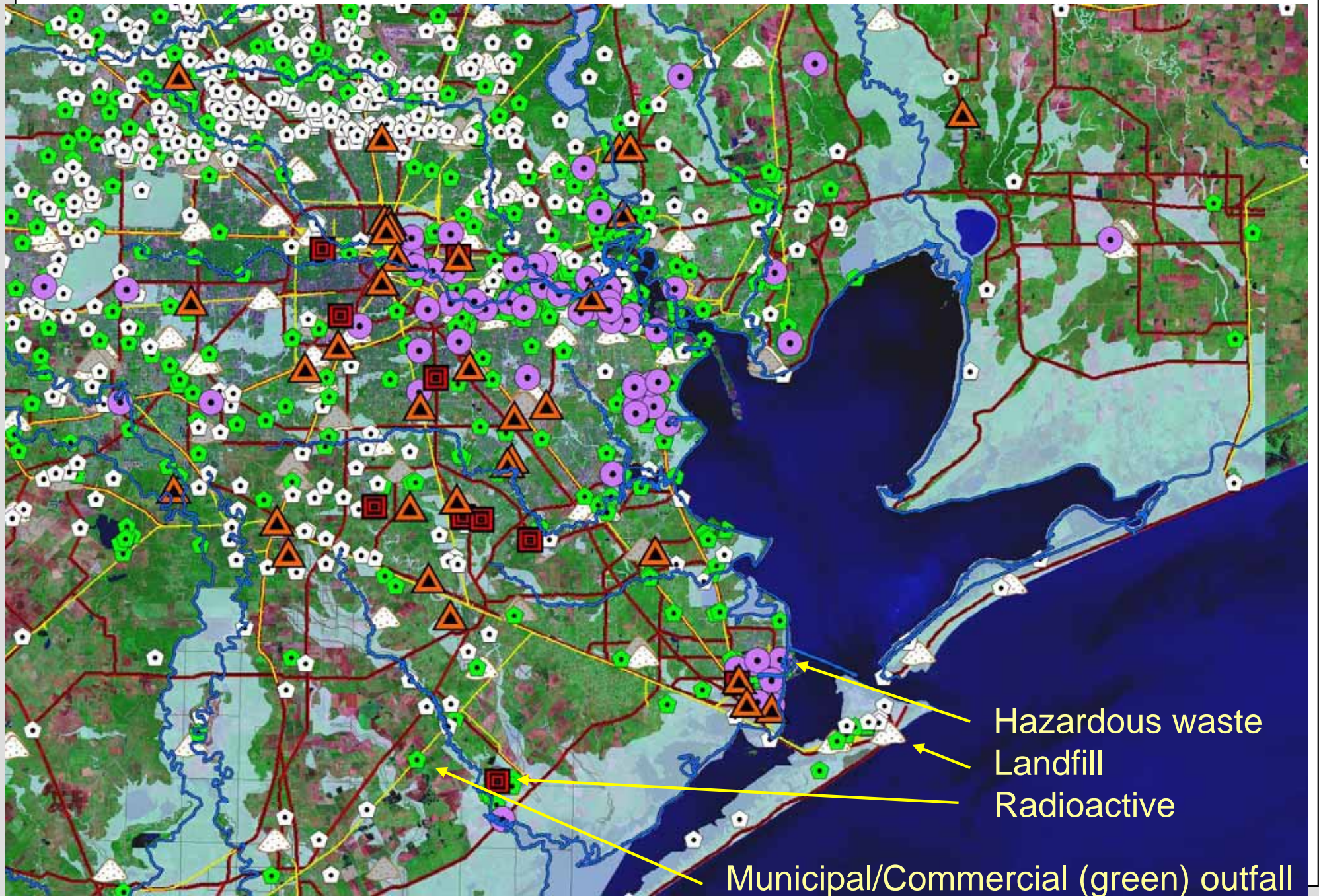
# POH Vulnerabilities during IKE

- Absence of permanent electricity
- City of Houston lift station serving Turning Basin terminals knocked out by IKE (1 of 23)
- Water breached docks of Turning Basin's southside and Manchester terminals
- 100 mph winds, waves & backwash within 2 ft of breaching upstream docks

Damage to navigational channels in Texas: 1 Billion



# Waste Management Resources





# Geodatabase for Infrastructure Resilience and Sustainability

- Collaborative effort in SSPEED Center
- Funding from Houston Endowment
- Goals
  - Identify critical infrastructure
  - Assess vulnerabilities
  - Plan for sustainability and resilience



# Ike Geodatabase Feature Datasets



# Chemical Data in Ike Geodatabase

The screenshot displays a GIS interface with a geodatabase tree on the left, a map in the center, and an identify window in the foreground. The geodatabase tree shows a folder named 'HSC\_IKE\_Risk\_Base\_Data.gdb' containing various layers. The 'HarrisCountyFacilityChemicalNames' layer is highlighted with an orange circle. The map shows a network of roads and water bodies with numerous brown diamond-shaped points representing chemical facilities. The identify window shows the following data for a selected facility:

Field	Value
OBJECTID	26389
Shape	Point
Facility_I	77536MPKNC2759B
Facility_N	VOPAK LOGISTICS SERVICES USA INC DEER PARK
Address	2759 BATTLEGROUND RD
City	DEER PARK
County	HARRIS
State	TX
Zip_Code	77536
Chemical_N	ACRYLONITRILE
ChemicalID	107131
Latitude	29.743333
Longitude	-95.096667
Parent_Com	VOPAK NORTH AMERICA INC
Assigned_A	
Assigned_F	C

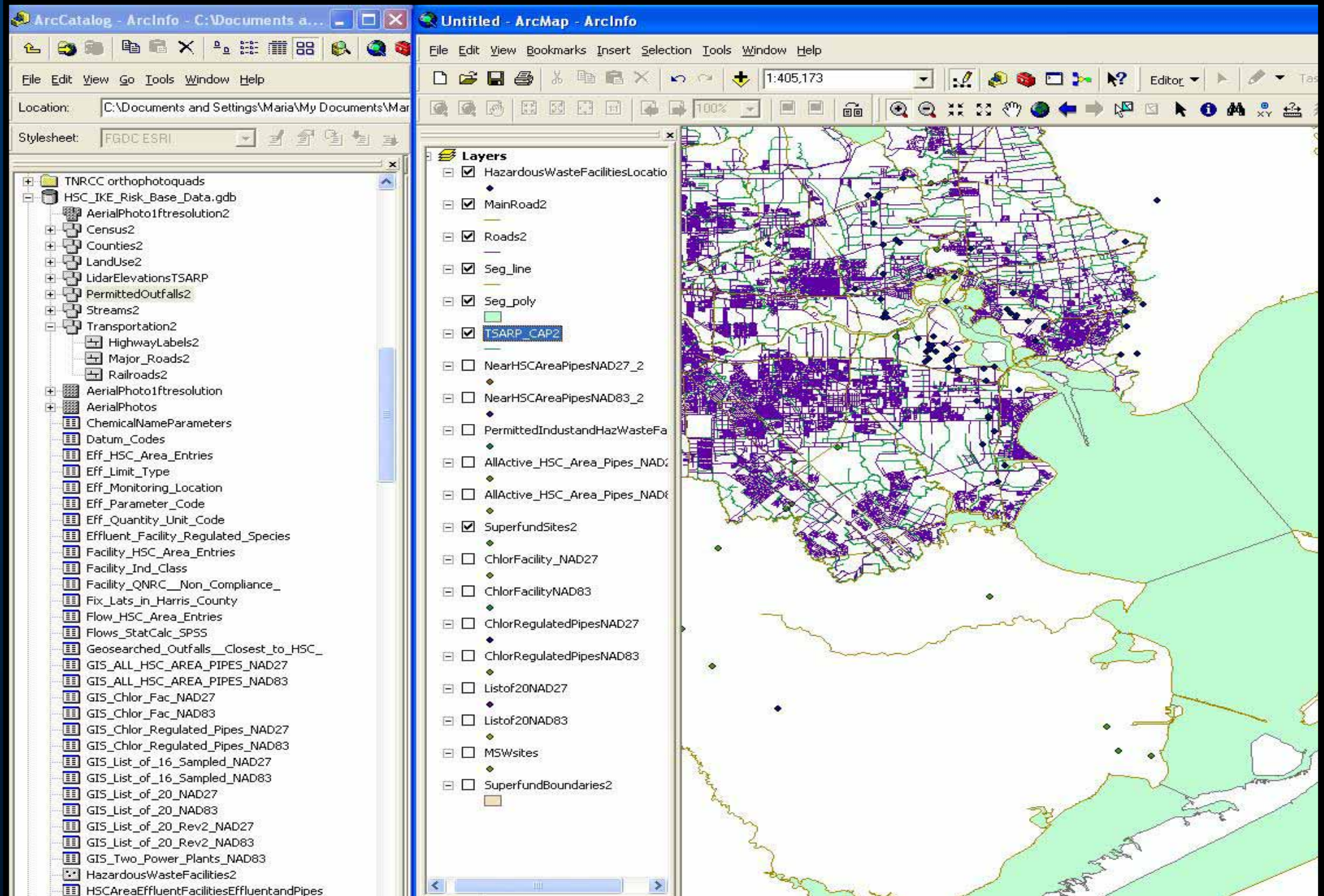
# Haz Waste Facilities in Ike Geodatabase

The screenshot displays the ArcGIS interface with a map of hazardous waste facilities. The left pane shows the 'PermittedOutfalls2' folder expanded, with 'HazardousWasteFacilitiesLocations' selected and circled in orange. The right pane shows the 'PermittedOutfalls2' folder expanded, with 'HGACRegion2' selected and circled in orange. The map shows several purple point features representing hazardous waste facilities. An 'Identify' window is open, showing the details for a facility named 'CHEVRON CHEMICAL CO.' with the following information:

Field	Value
OBJECTID	8
Shape	Point
FACILITY_N	CHEVRON CHEMICAL CO.
ADDRESS	1515 S. SHELDON RD.
CITY	CHANNELVIEW
COUNTY	HARRIS
STATE	TX
ZIP_CODE	77530
PARENT_COM	CHEVRONTEXACO CORP.
Latitude	29.75
Longitude	-95.122222



# Permitted Outfalls in Ike Geodatabase





# Parcel Ownership in Ike Geodatabase

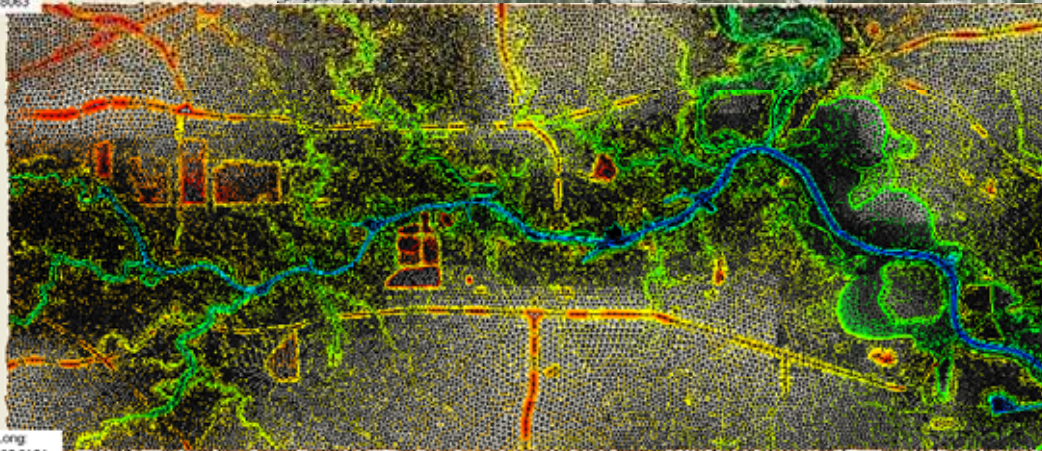
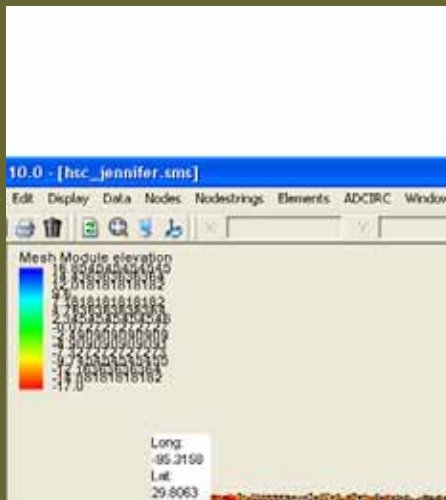
The screenshot displays the ArcGIS interface with the following components:

- Stylesheet:** FGDC ESRI
- Layers:** C:\Documents and Settings\Maria\M...
  - LandUse2
  - Refineries2
  - Easement2
  - EasementName2
  - Parcels2
  - Utilities2
  - Parks2
- Map:** Aerial photo with overlaid parcel boundaries. A specific parcel is highlighted in yellow.
- Identify Window:** Shows details for the selected parcel.

Field	Value
OBJECTID	1248434
Shape	Polygon
OBJECTID	1372860
HCAD_NUM	0410320010008
BLK_NUM	
LOT_NUM	
CONDO_FLAG	0
owner_name	PORT OF HOUSTON AUTHORITY
str_num	15500
str_name	JACINTOPORT
Shape_Length	0.054484
Shape_Area	0.000155



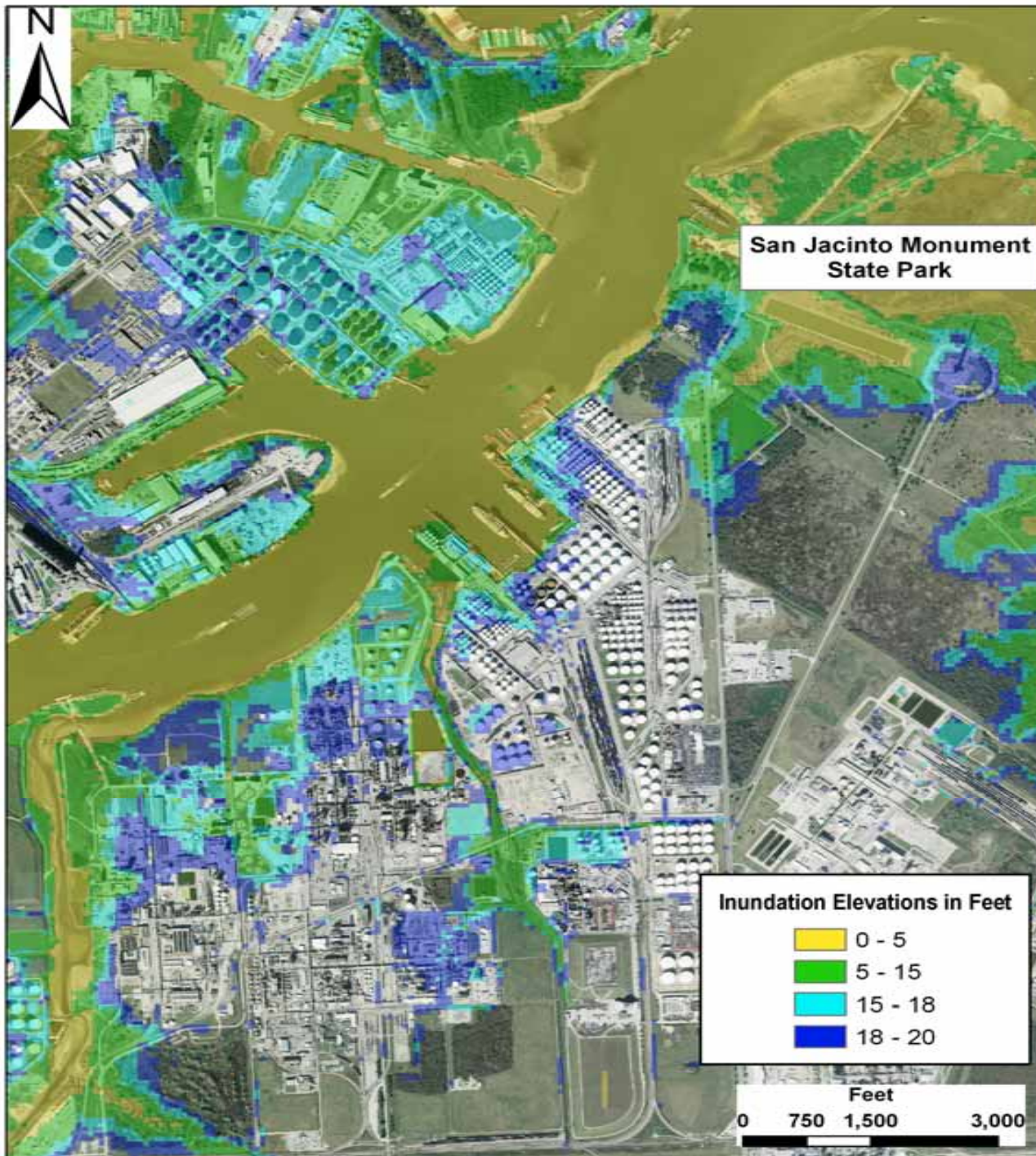
# Model Grid – Elevations & Bathymetry



Long: -95.3154  
Lat: 29.806



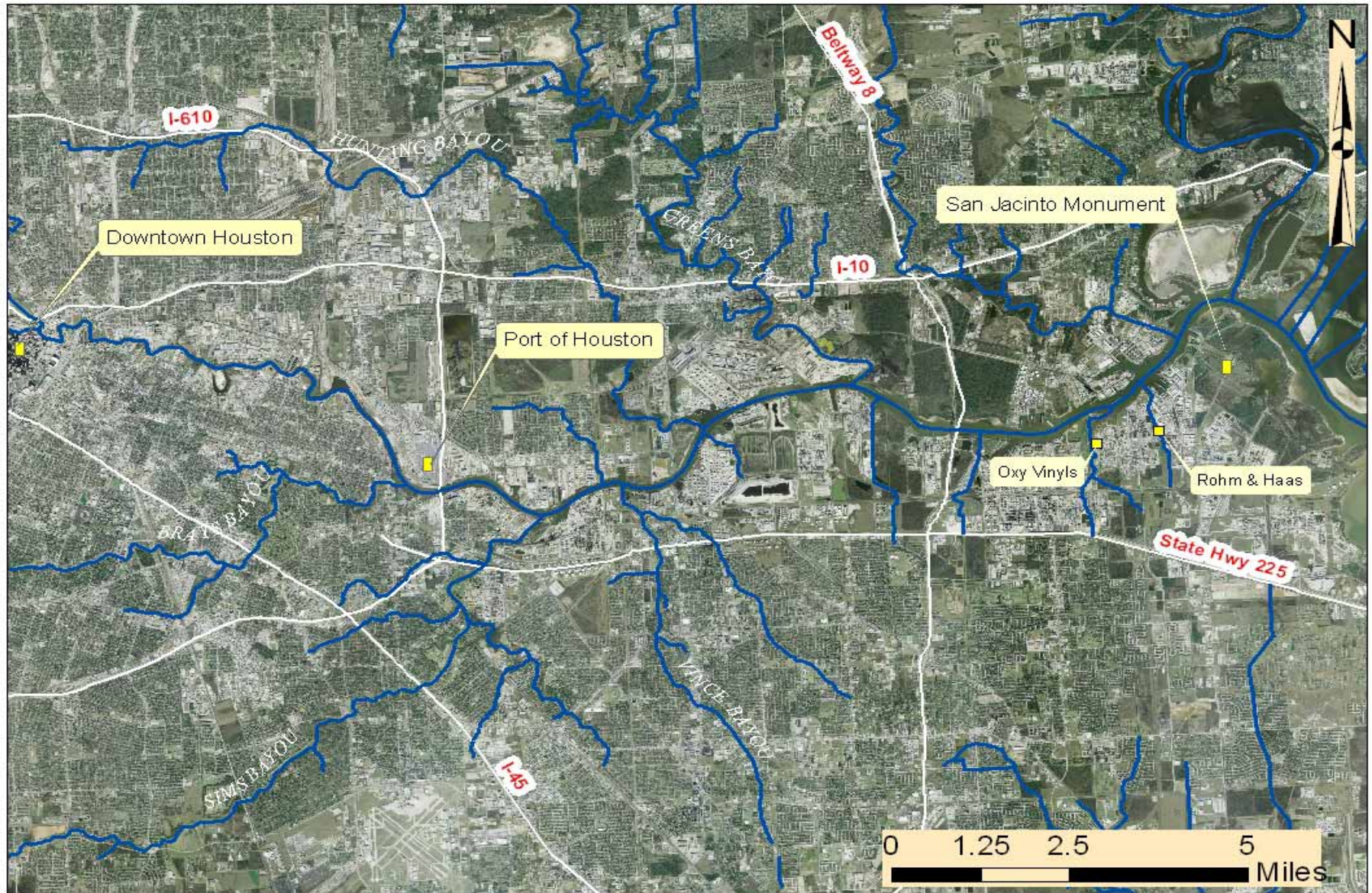




# Inundation Elevations In Ike Geodatabase

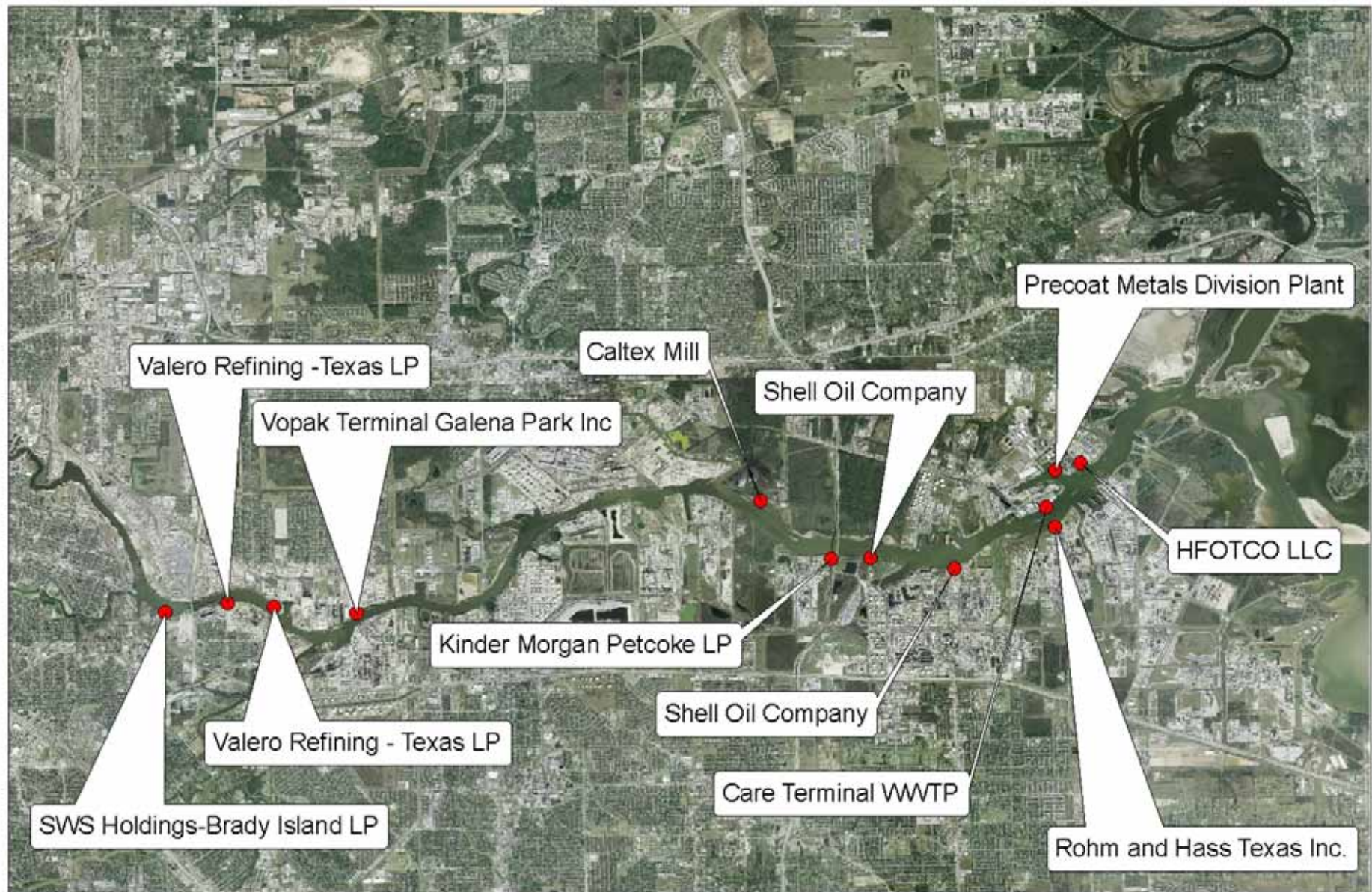


# HSC Industrial Complex



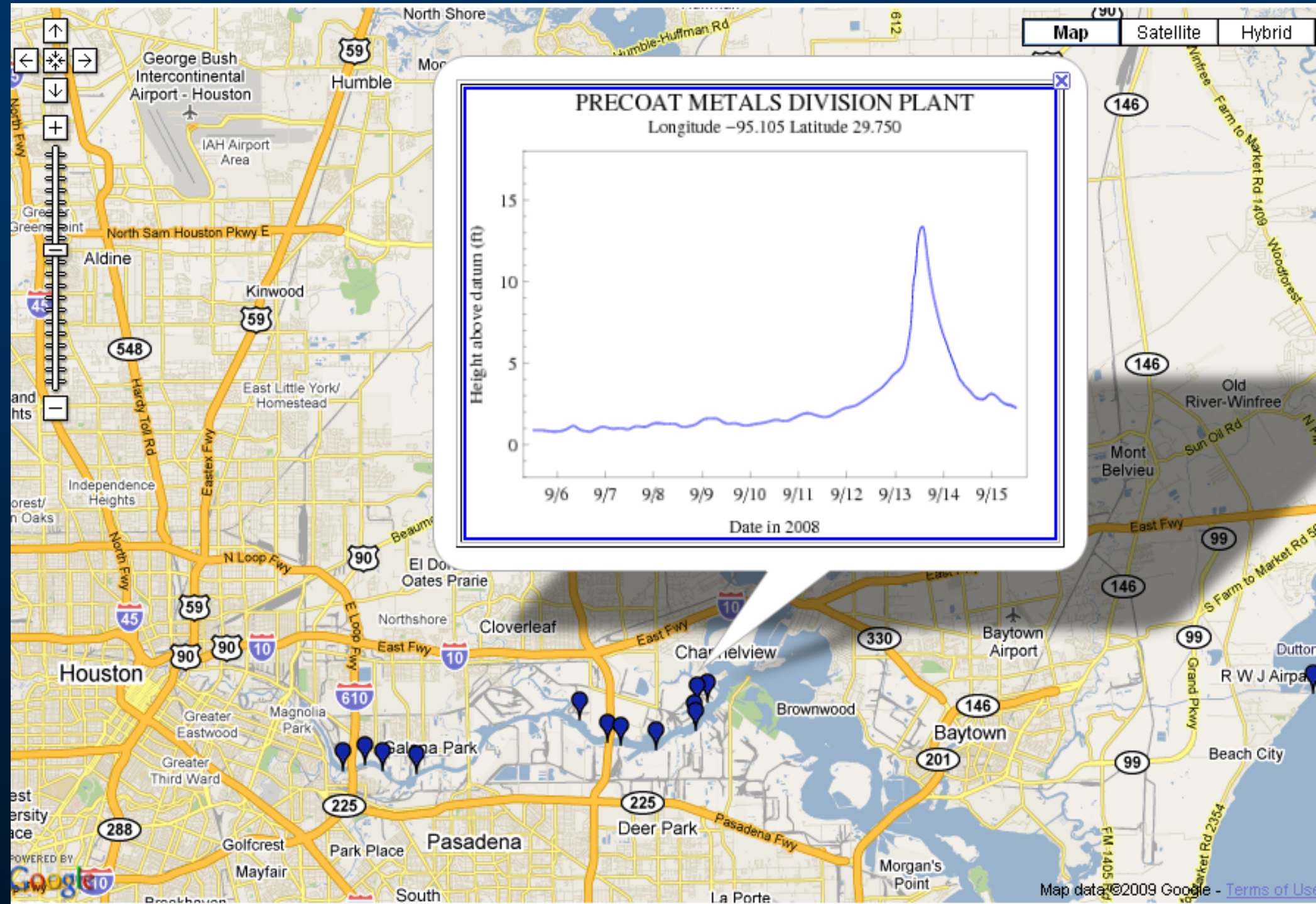


# Case Study Industries along HSC



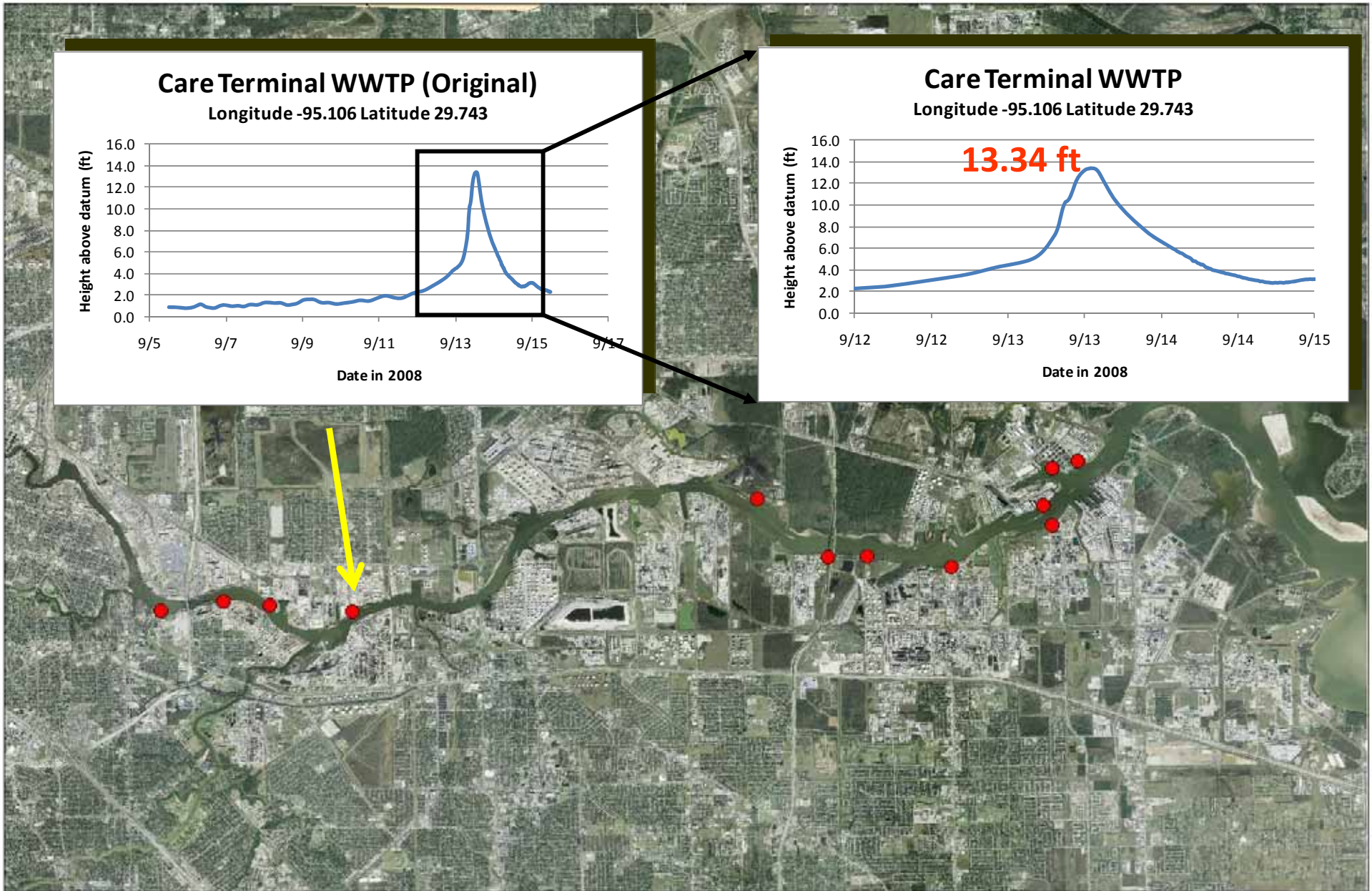


# Surge levels during Hurricane Ike at Precoat Metals



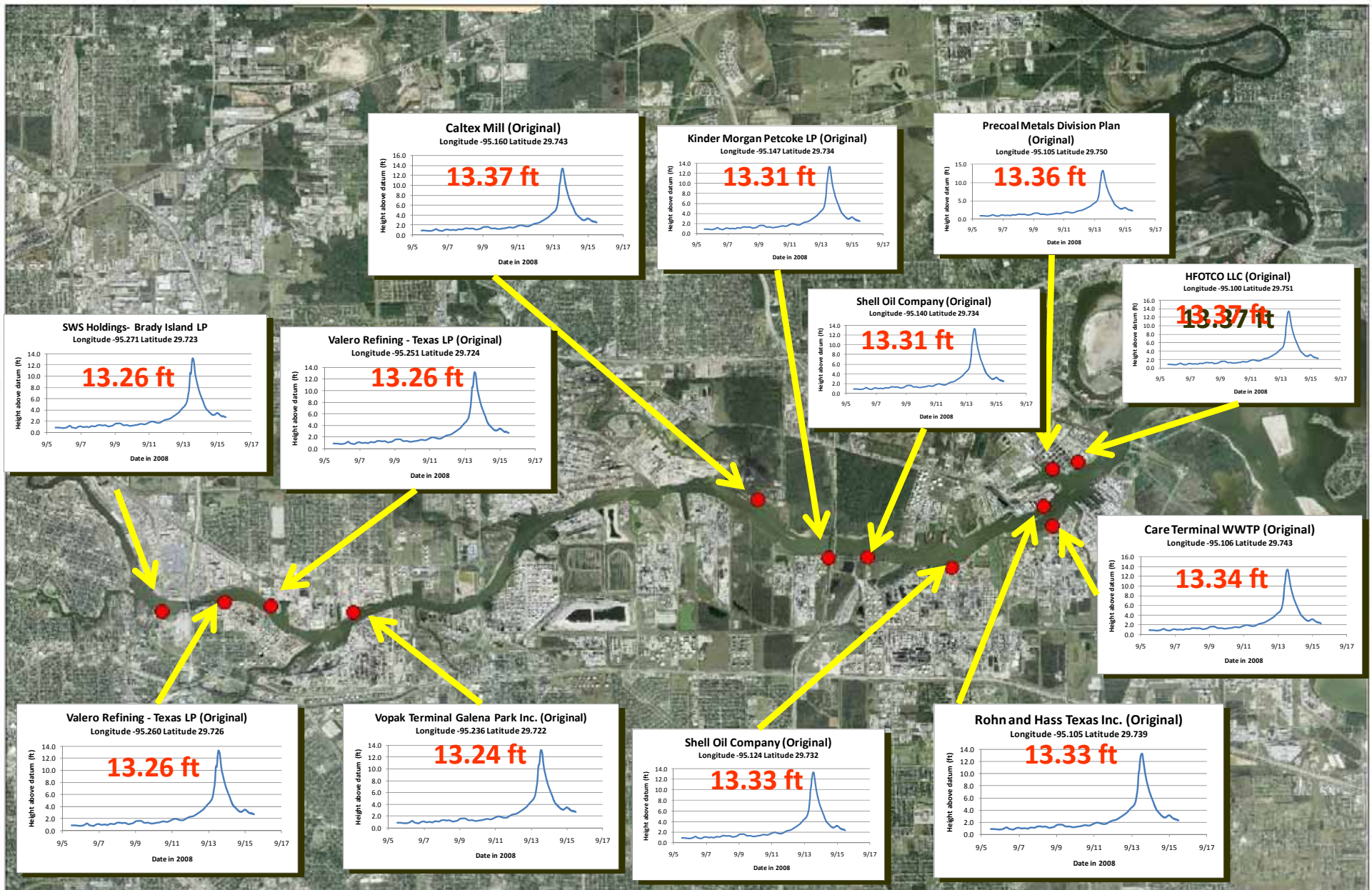


# Hurricane Ike Surge at Care Terminal





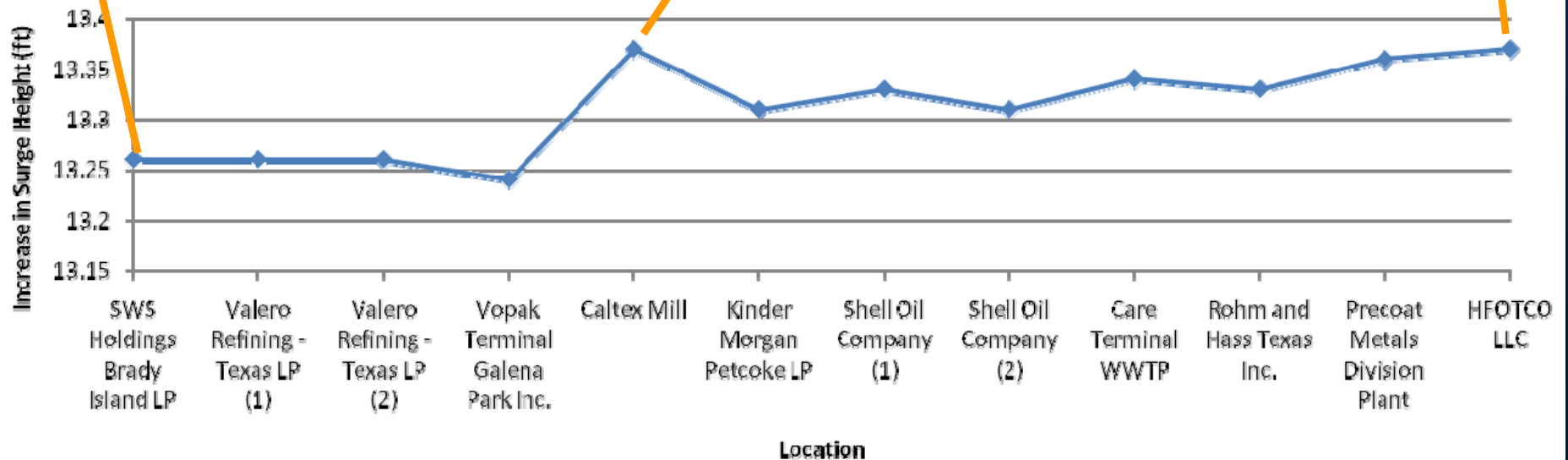
# Hurricane Ike Surge in HSC



# Hurricane Ike Surge Along HSC



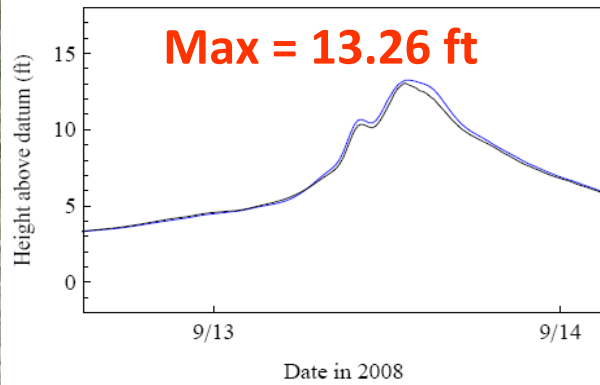
**Max. Surge Heights Along Houston Ship Channel**



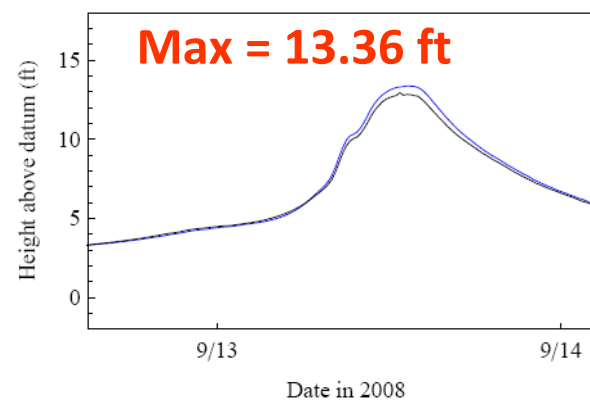


# Not much effect - Waves & No Waves

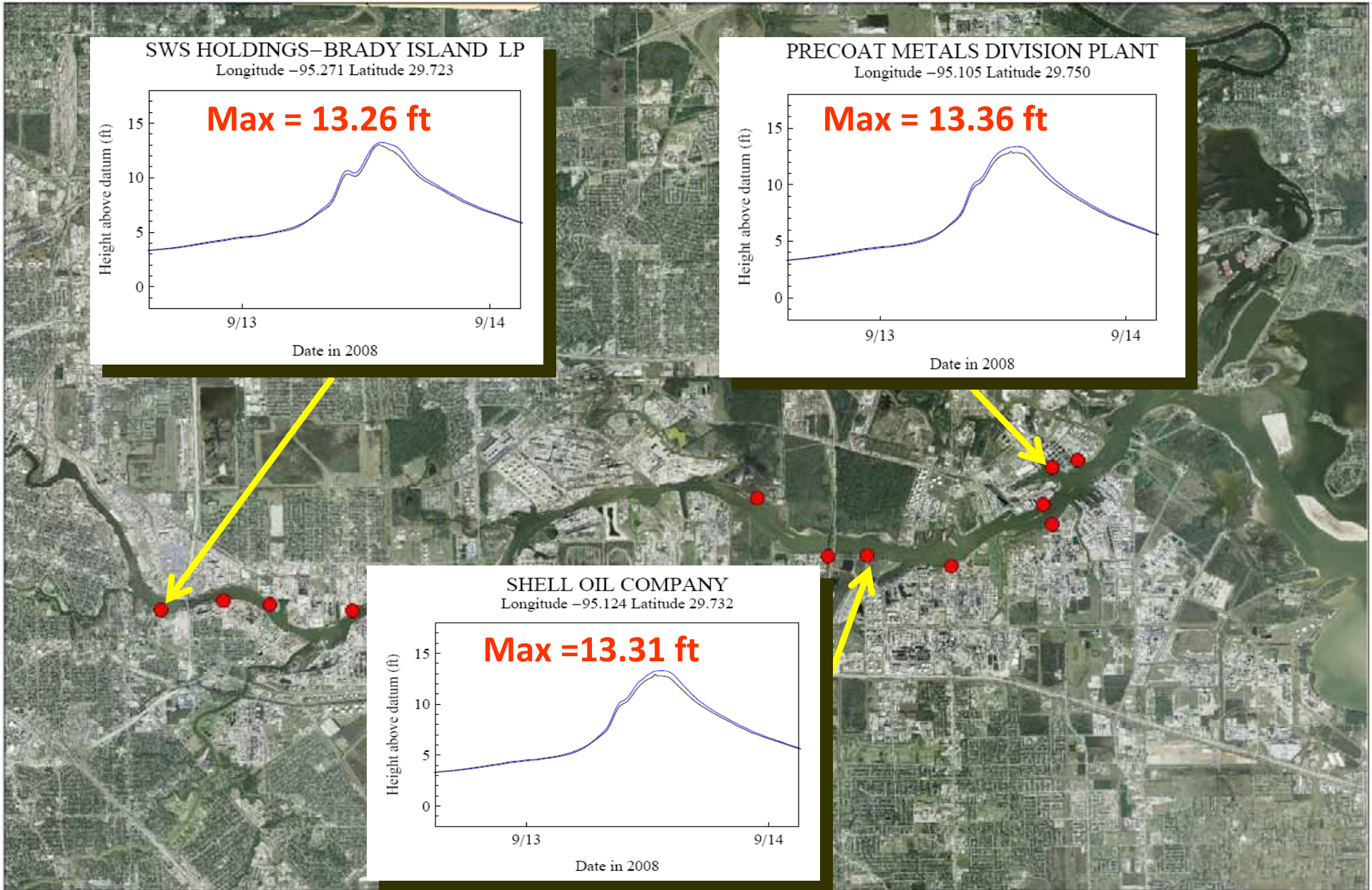
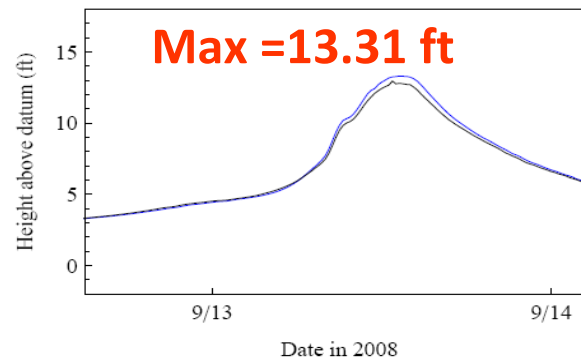
SWS HOLDINGS-BRADY ISLAND LP  
Longitude -95.271 Latitude 29.723



PRECOAT METALS DIVISION PLANT  
Longitude -95.105 Latitude 29.750



SHELL OIL COMPANY  
Longitude -95.124 Latitude 29.732



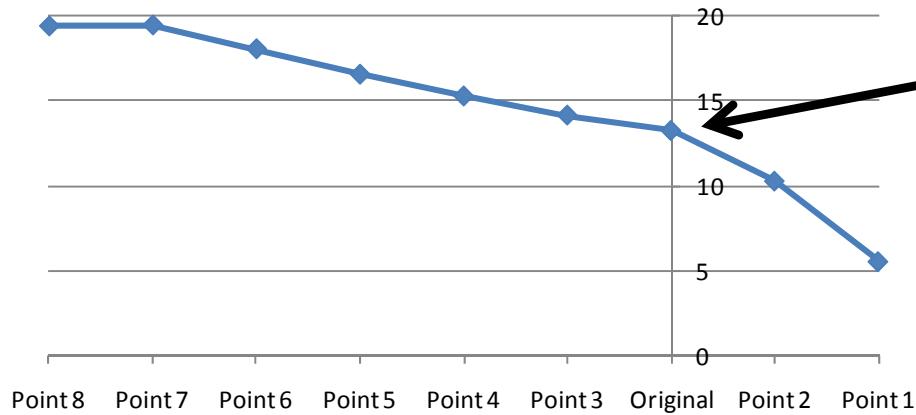


# Hurricane Ike Scenarios

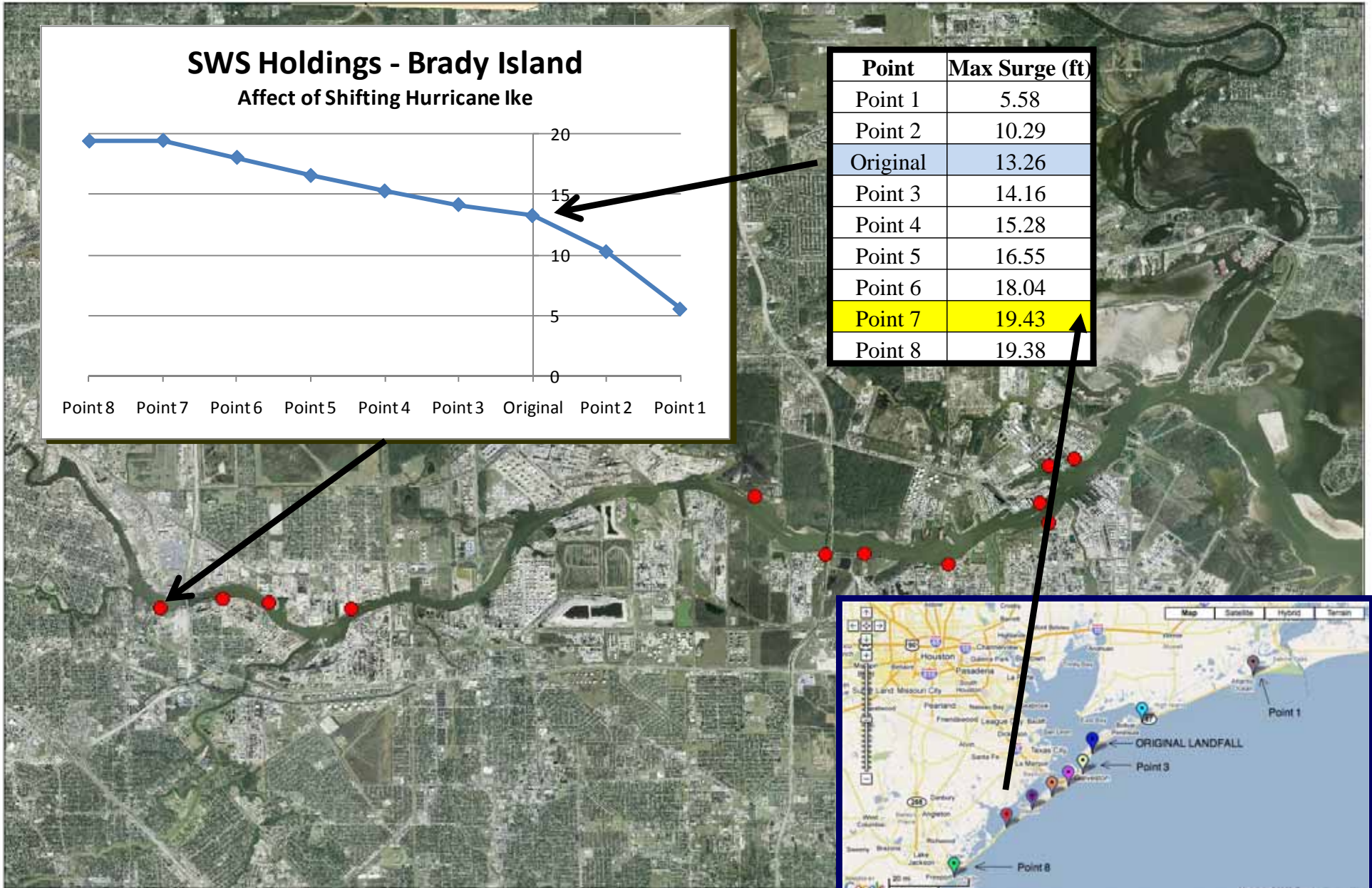


# Ike Scenarios at SWS Holdings

**SWS Holdings - Brady Island**  
Affect of Shifting Hurricane Ike



Point	Max Surge (ft)
Point 1	5.58
Point 2	10.29
Original	13.26
Point 3	14.16
Point 4	15.28
Point 5	16.55
Point 6	18.04
Point 7	19.43
Point 8	19.38

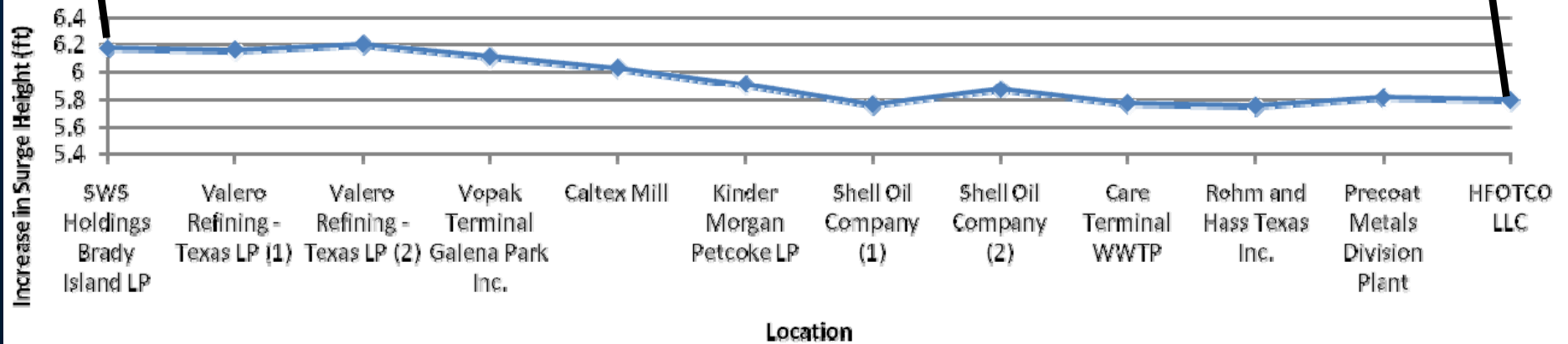




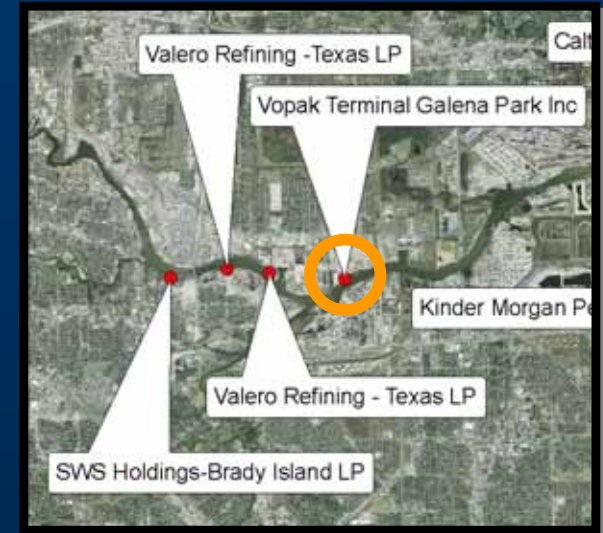
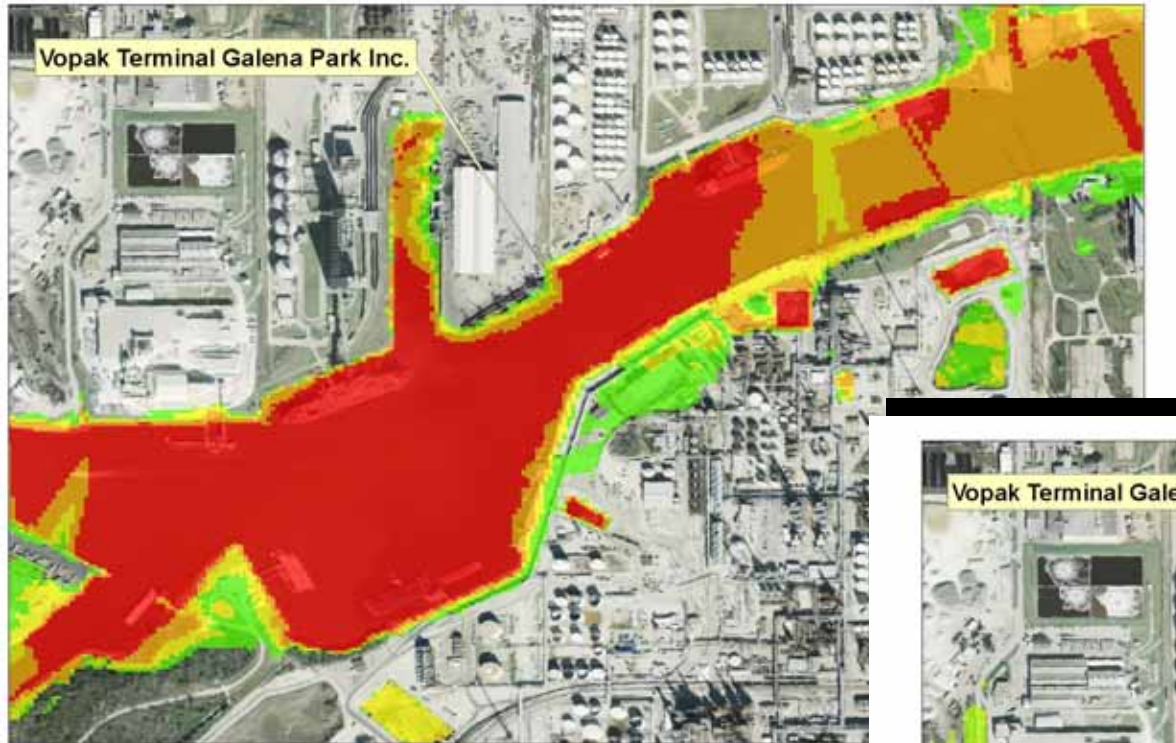
# Hurricane Ike Scenario 7 Along HSC



**6 – 8 ft increases**



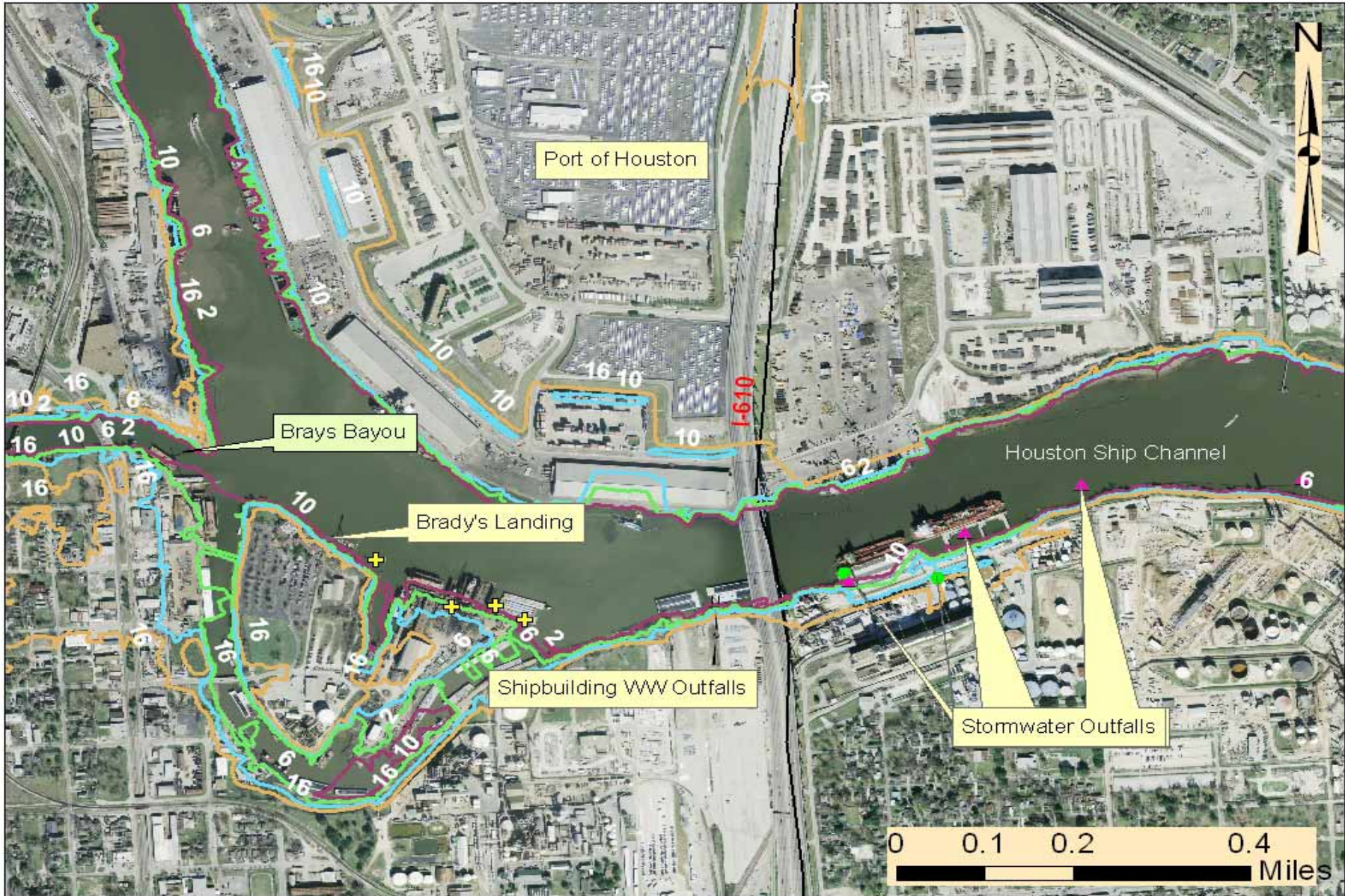
# Increased Vulnerability between Ike and Point 7 Landfall





# Vulnerability of Port of Houston @ 19+ ft Surge

14 ft surge during IKE





# Dike or No Dike

- Understanding vulnerabilities allows better decision making
- Risks from various hurricane scenarios should be analyzed
- Decisions should be based on combined  
**Surge Zones + Flood Zones + Wind**

