

# WHAT IS THIS!!!!???



Image source: The Center for Land Use Interpretation photo archive. Used with permission.

# Hurricane Katrina: August 2005, Atlantic

# Hurricane Rita: Sept 2005, Gulf of Mexico



Image sources: Wayneys Sailing World. Used with permission.

# Hurricane Gustav: Aug 2008, Gulf of Mexico

## Hurricane Ike: Sept 2008, Gulf of Mexico



Source: The Beaumont Enterprise. Used with permission.

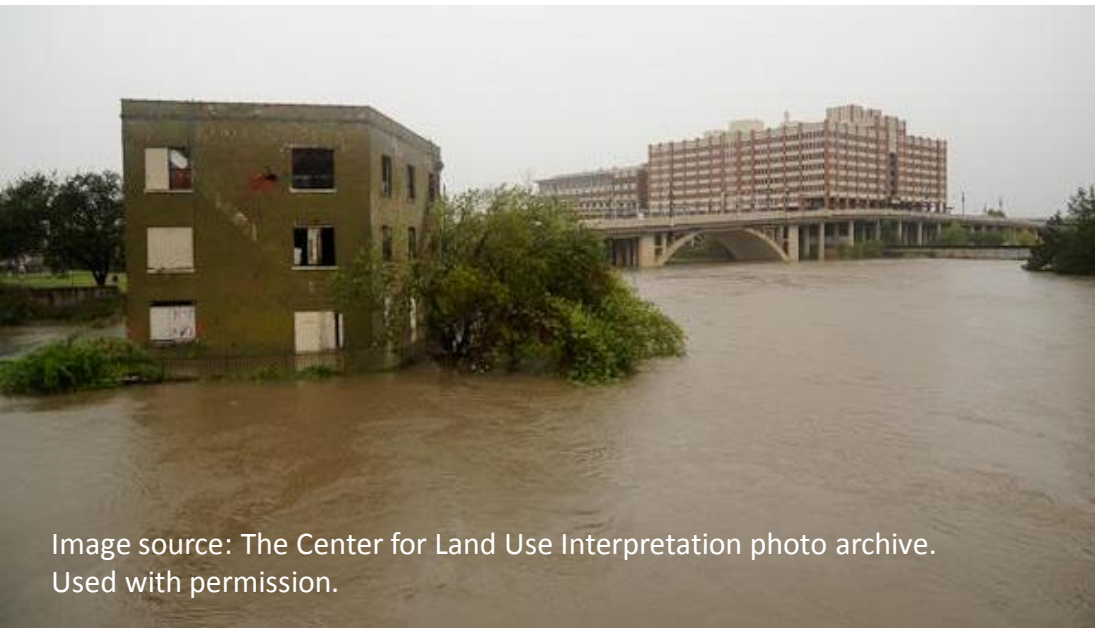
# AST FAILURE IN STORMS

**What are the consequences when above-ground storage tanks (ASTs) are damaged in storms?**

- **Pollution:** Environmental impact from spillage of hazardous materials
- **Extensive costs:**
  - To clean up material from the natural environment
  - For losses due to irrecoverable produce & vegetation
  - To repair ASTs
  - To replace ASTs

# FLOODING

- The U.S. federal government paid for flood control structures like Addicks Reservoir, Barker Reservoir, etc., following a disastrous 1935 flood
- Fairly effective, exceptions: tropical storm Allison in 2001 and Hurricane Ike in 2008
- Buffalo Bayou was 20+ feet above normal levels



← The Sunset Coffee Company building, future Bayou visitor contact station, and occasional island seen here after Hurricane Ike in 2008.

# FLOODING



Image source: NOAA. Used with permission.

# AST DISPLACEMENT

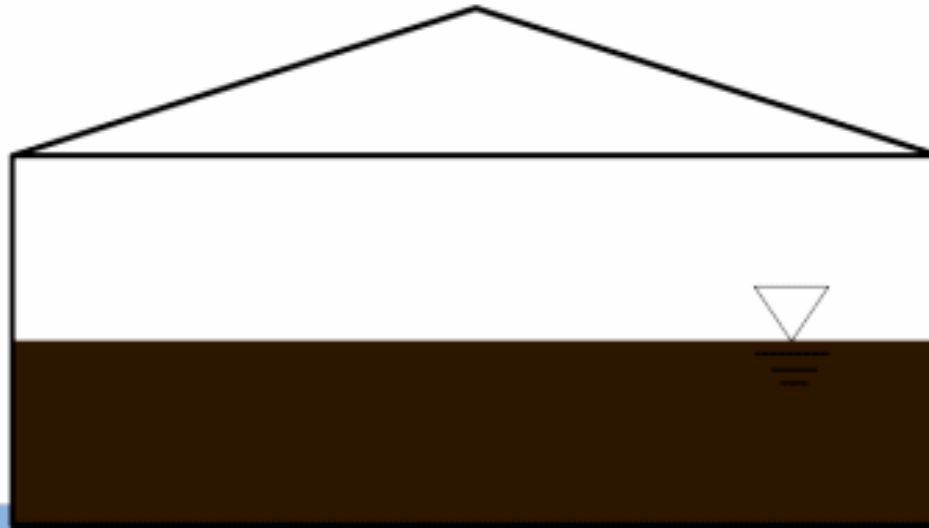


Image source: Jamie Padgett and Sabarethinam Kameshwar, "Structural Integrity of Storage Tanks" SSPEED Center Conference September 24-25, 2013.

# BUCKLING

- Flooding causes external water pressure on tank shell
- **PLUS: *Debris and wave impact*** and external **wind pressure**



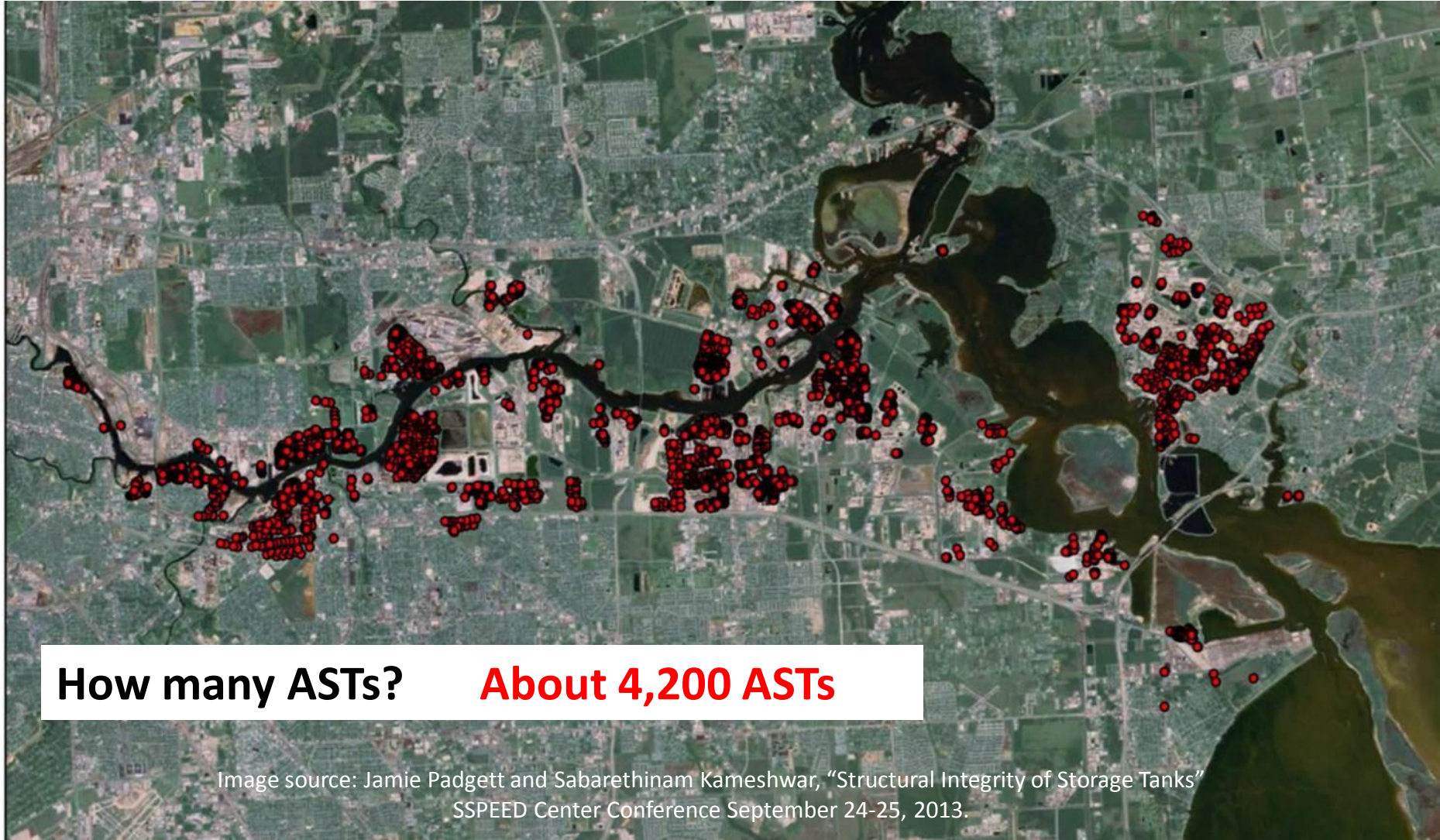
Image source: E-Learning from Engineering Failures. Used with permission.



# HOUSTON SHIP CHANNEL (HSC)

- Largest port of foreign water-borne cargo in the country; it ships out more goods internationally than any other U.S. port
- 75% of cargo is petrochemicals — largest petrochemical production zone in the nation
- Along the 50-mile HSC from near downtown Houston to the Gulf of Mexico you'll find:
  - ~300 industrial facilities
  - more explosive materials, toxic gases and deadly petrochemicals than anywhere else in the U.S.
  - production of nearly half the nation's supply of gasoline and half its petrochemicals
- Many facilities are only protected to 14-16 feet above mean sea level
- Damaged facilities along the HSC could be shut down for months
- In the event of large hurricanes, economic and environmental damage to the region and national economy could be catastrophic...

# AST LOCATIONS ALONG THE HOUSTON SHIP CHANNEL



**How many ASTs?**

**About 4,200 ASTs**

Image source: Jamie Padgett and Sabarethinam Kameshwar, "Structural Integrity of Storage Tanks"  
SSPEED Center Conference September 24-25, 2013.

# TYPICAL TANK DIMENSIONS

Fixed roof tank (flat roof)

Tank diameter: 62 feet

Aspect ratio (H/D): 0.4

Shell thickness: 0.394 inches

Tank height: 25 feet

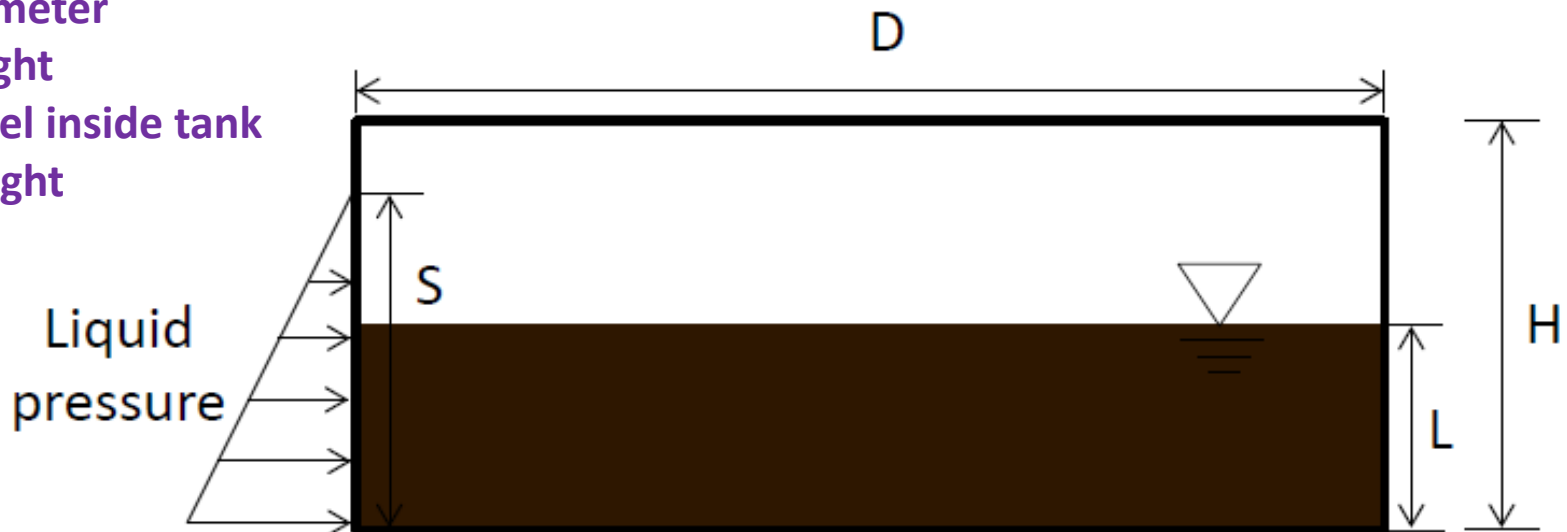
Vary S and L

D: tank diameter

H: tank height

L: liquid level inside tank

S: surge height



# SAFETY CODES AND PROVISIONS

**ASTs are regulated by several agencies in Texas:**

- **U.S. Environmental Protection Agency (USEPA)** “spill prevention” code
- **The Texas Commission on Environmental Quality (TCEQ)** has rules, but has a “limited regulatory program” for ASTs
- Some additional regulation by the **State Fire Marshal’s Office**
- **Industry associations** provide “best practices” for designing and constructing storage tanks
- Standards for tanks built in earthquake zones but few for tanks built where hurricanes are a risk
- **The American Petroleum Institute (API)** said they do everything possible to protect the environment, but offer no specifics

**Researchers say the work they’re now doing might make a case for creating some new rules that would require better ways to anchor the big tanks to keep them from floating away...**

# API Standard 650 (2013):

## WELDED TANKS FOR OIL STORAGE

- **5.2.1 I(1) includes provisions for external pressure and flotation**
  - States that the purchaser shall state the magnitude and direction of external loads or restraint for which the shell must be designed
- **E.6.2.1 includes provisions for anchorage due to seismic activity**
- **F.1.3 includes provisions for anchorage due to internal pressure**
- **No provisions for shell buckling or uplift due to flooding**