WHAT IS THIS!!!???
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.
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
The U.S. federal government paid for flood control structures like Addicks Reservoir, Barker Reservoir, etc., following a disastrous 1935 flood.


Buffalo Bayou was 20+ feet above normal levels.

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

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.
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

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

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 l(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