LEARNING FROM SANDY
Webinar 3

Securing Boats in the Water:

Lessons learned

March 26, 2013

Beth A. Leonard
Director of Technical Services
BoatU.S.

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Boat Owners Association of The United States

Association of Marina Industries

BoatU.S. Catastrophe (CAT) Teams

- First deployed after Hurricane Alicia hit Houston in 1983
- Team of experienced surveyors, salvors, and claims adjustors
- On the ground after every major weather event where large numbers of boats were destroyed for the past 30 years
- Debrief after the fact to develop hurricane preparation best practices
- First members reached marinas in NY and NJ less than 24 hours after Sandy made landfall; CAT Teams in the field through Christmas
- Past two months debriefing to determine what we can learn from this storm

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Webinar series objective

To share lessons coming out of Sandy that will help marine facilities in storm-damaged areas rebuild smarter and those in other areas prepare better for future storms

The **first** webinar tried to answer three questions:

1. Why were so many boats and so much marina infrastructure destroyed DESPITE good forecasting and days of preparation based on industry "best practices?"
2. How did the various methods of securing boats fare in Sandy's high surge?
3. What are the key lessons learned for marine facilities?

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Webinar series objective

To share lessons coming out of Sandy that will help marine facilities in storm-damaged areas rebuild smarter and those in other areas prepare better for future storms

The **second** webinar focused on securing boats on land, specifically:

1. How can you quantify the wind and surge risks for your marina?
2. Based on our experience to date, what methods of securing boats on land work best for different kinds of storms?
3. Would any of those methods have worked in Sandy?

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Four take aways

1. Surge matters.
2. Preparations matter… but we have to prepare for the real risks.
3. Hurricane planning needs to become more marina and storm specific.
4. Lessons from Florida marinas and new ideas coming out of Sandy could have reduced the damage in this storm.

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Webinar series objective

To share lessons coming out of Sandy that will help marine facilities in storm-damaged areas rebuild smarter and those in other areas prepare better for future storms

This webinar will focus on securing boats in the water, specifically:

1. How can you evaluate your marina's risks?
2. Based on our experience to date, what methods for securing boats in the water work best for different kinds of storms?
3. What are the final lessons learned?

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Securing boats in the water

- Assessing your marina's risks
- Failure modes and solutions for securing boats in the water
- Final lessons learned: revising your hurricane plan

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Fighting the last war

It has been said critically that there is a tendency in many armies to spend the peace time studying how to fight the last war.

January-February 1929, *The Military Engineer*, "Some Notes on the World War" by J. L. Schley (Lieutenant Colonel, Corps of Engineers), pg. 55, col. 1L

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Goals of hurricane preparation

- Prevent loss of life
- Limit damage to boats
- Limit damage to marina infrastructure
- Limit damage to other infrastructure
- Limit damage to the environment

PRIORITIES

Keep the boats on land:

(1) From going over the bulkhead
(2) On the premises
(3) Upright
(4) Watertight

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Goals of hurricane preparation

- Prevent loss of life
- Limit damage to boats
- Limit damage to marina infrastructure
- Limit damage to other infrastructure
- Limit damage to the environment

PRIORITIES

Keep the boats in the water:

(1) **In place**

(2) Upright

(3) Watertight

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Analyzing your marina's risks

- Wind risk
- Surge risk
- Wave risk
- Debris risk
- No man's land

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What you would like to know

- To decide how to rebuild: 1% or 1 in 100 year risk
  - Wind – Rough guidance based on historical data
  - Surge – ABFEs where available, "SLOSH plus" elsewhere
- To decide how to prepare for a coming storm: best available forecast
  - Wind – National Hurricane Center forecasts
  - Surge – Good tools coming soon…

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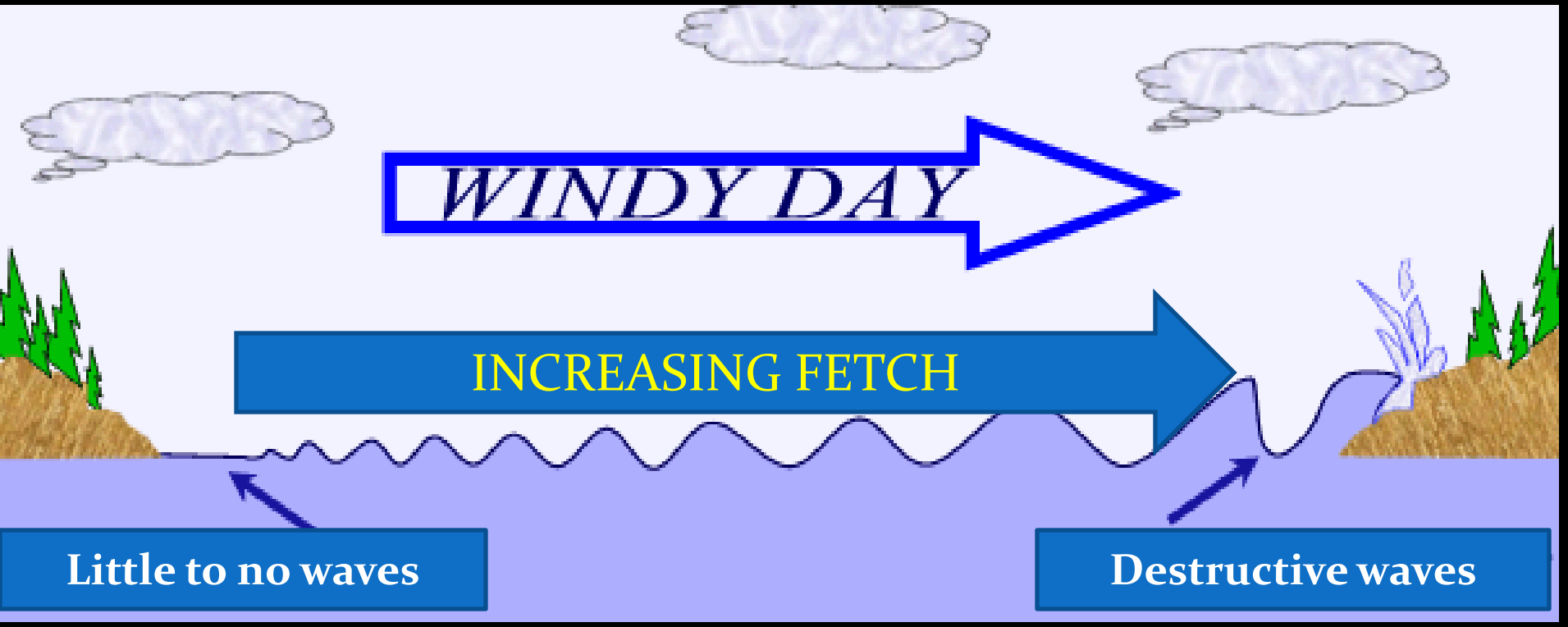
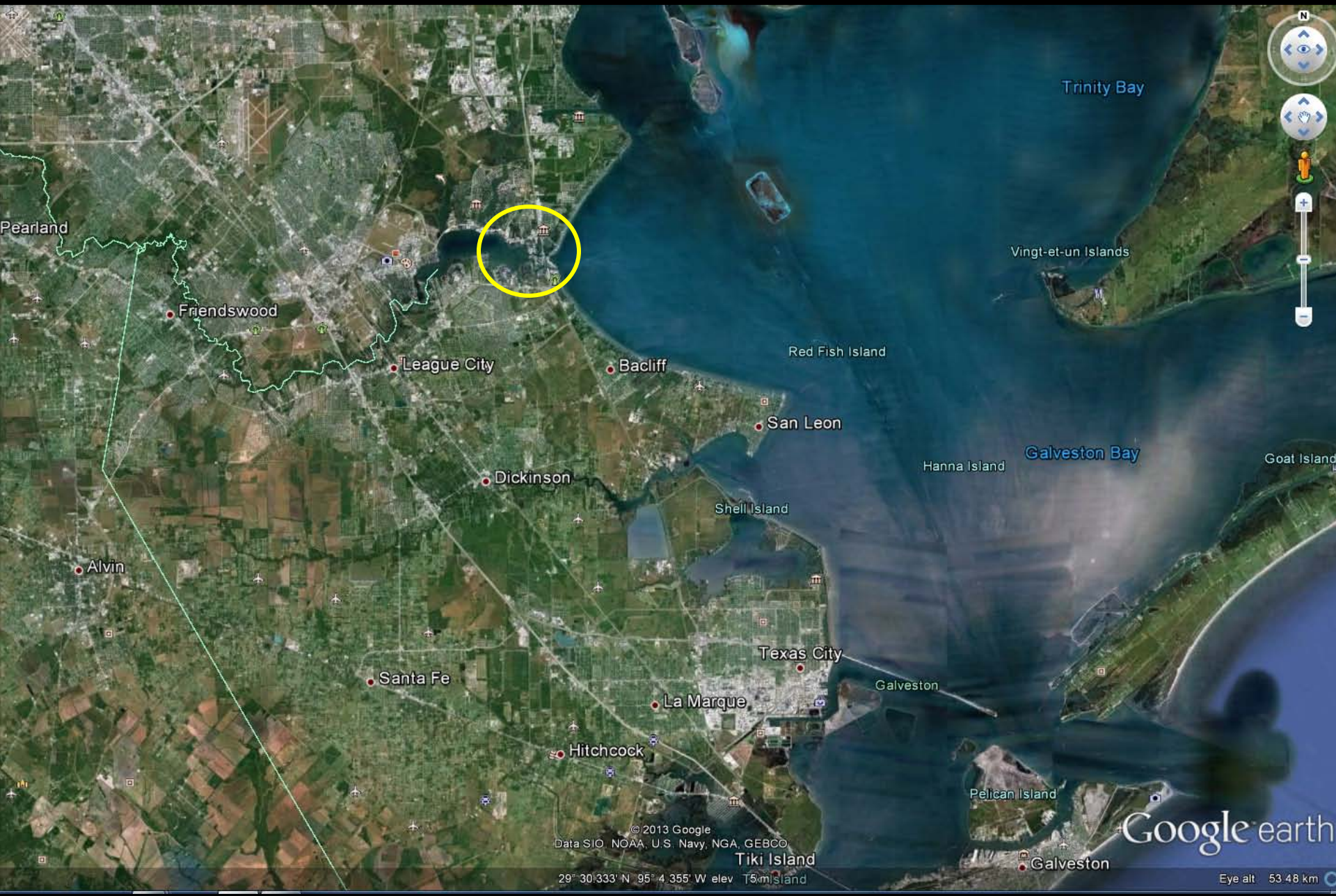
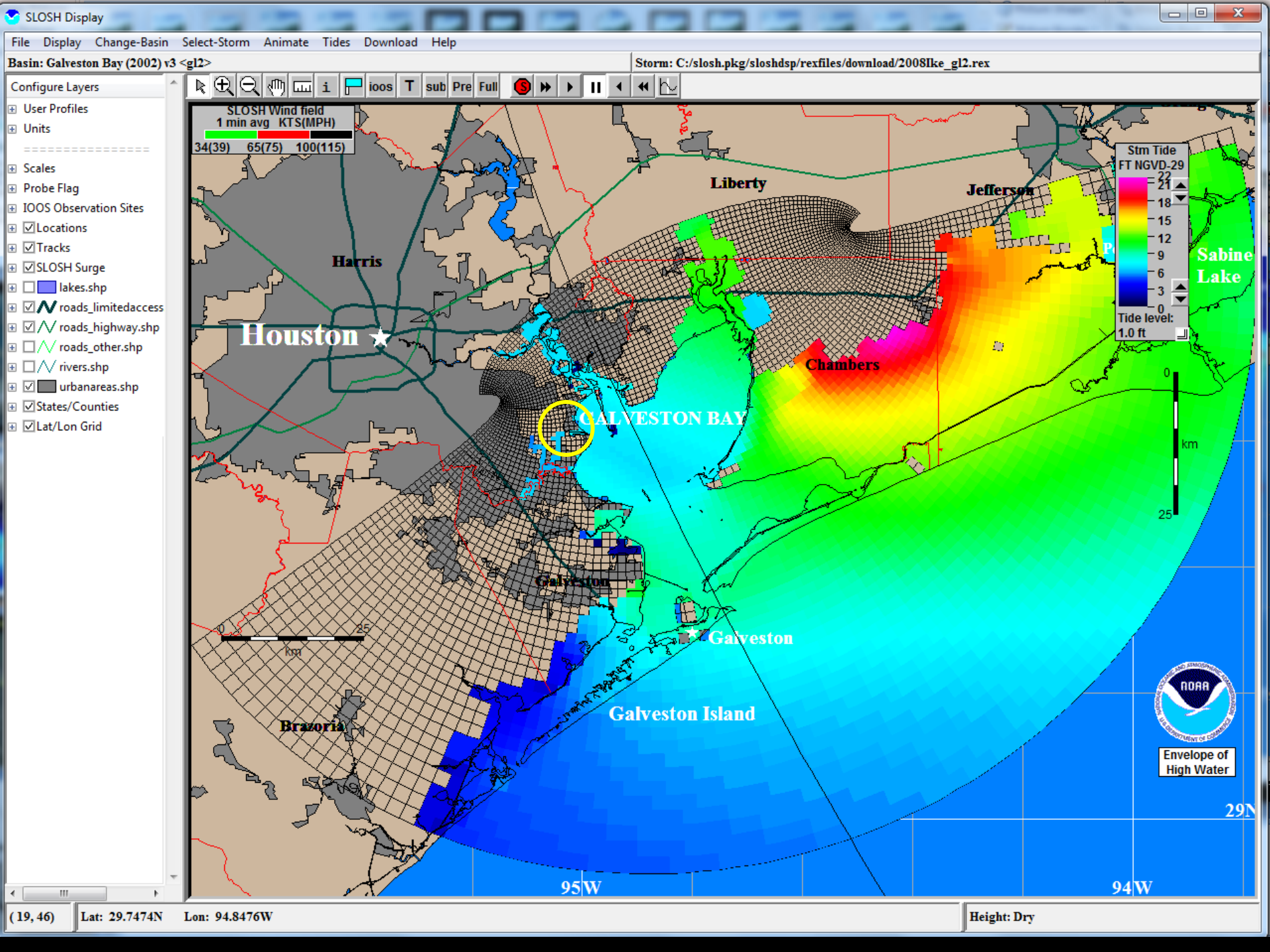

WINDY DAY
INCREASING FETCH
Little to no waves
Destructive waves


Trinity Bay
Vingt-et-un Islands
Red Fish Island
Galveston Bay
Hanna Island
Goat Island
Shell Island
Pearland
Friendswood
League City
Bacliff
San Leon
Dickinson
Alvin
Texas City
Galveston
Santa Fe
La Marque
Hitchcock
Pelican Island
Tiki Island
Galveston
© 2013 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
29° 30' 33.33" N 95° 4' 35.55" W elev 15 m
Eye alt 53.48 km
Google earth


SLOSH Display
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Probe Flag
IOOS Observation Sites
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Tracks
SLOSH Surge
lakes.shp
roads_limitedaccess
roads_highway.shp
roads_other.shp
rivers.shp
urbanareas.shp
States/Counties
Lat/Lon Grid
SLOSH Wind field
1 min avg KTS(MPH)
34(39) 65(75) 100(115)
Stm Tide
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22
21
18
15
12
9
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3
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Tide level:
1.0 ft
Liberty
Jefferson
Harris
Houston
Sabine Lake
Chambers
GALVESTON BAY
Galveston
Galveston
Galveston Island
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0
25
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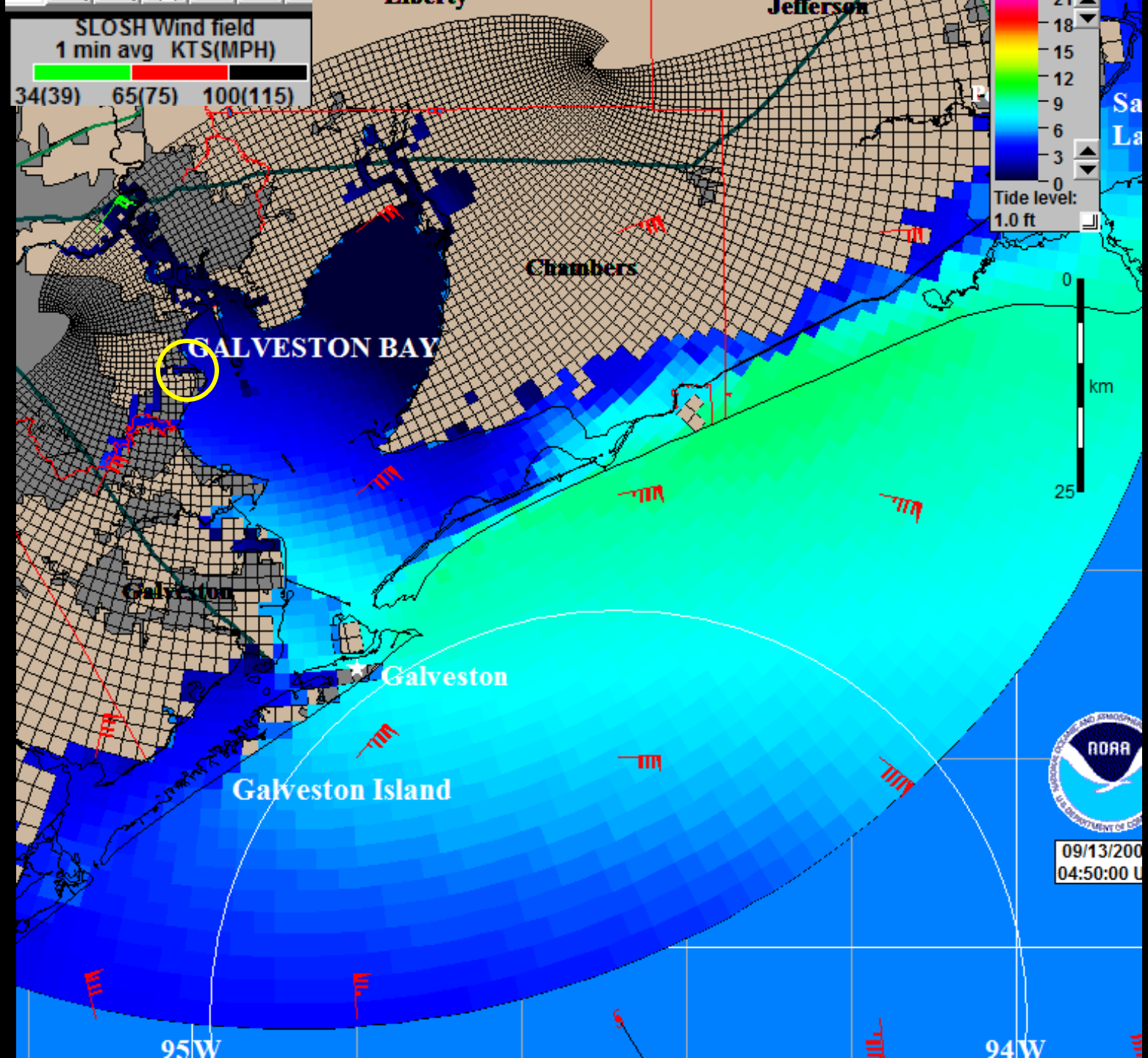
Envelope of High Water
29N
95W
94W
(19, 46)
Lat: 29.7474N
Lon: 94.8476W
Height: Dry


SLOSH Wind field
1 min avg KTS(MPH)
34(39) 65(75) 100(115)
Liberty
Jefferson
Chambers
GALVESTON BAY
Galveston
Galveston
Galveston Island
18
15
12
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6
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Tide level:
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km
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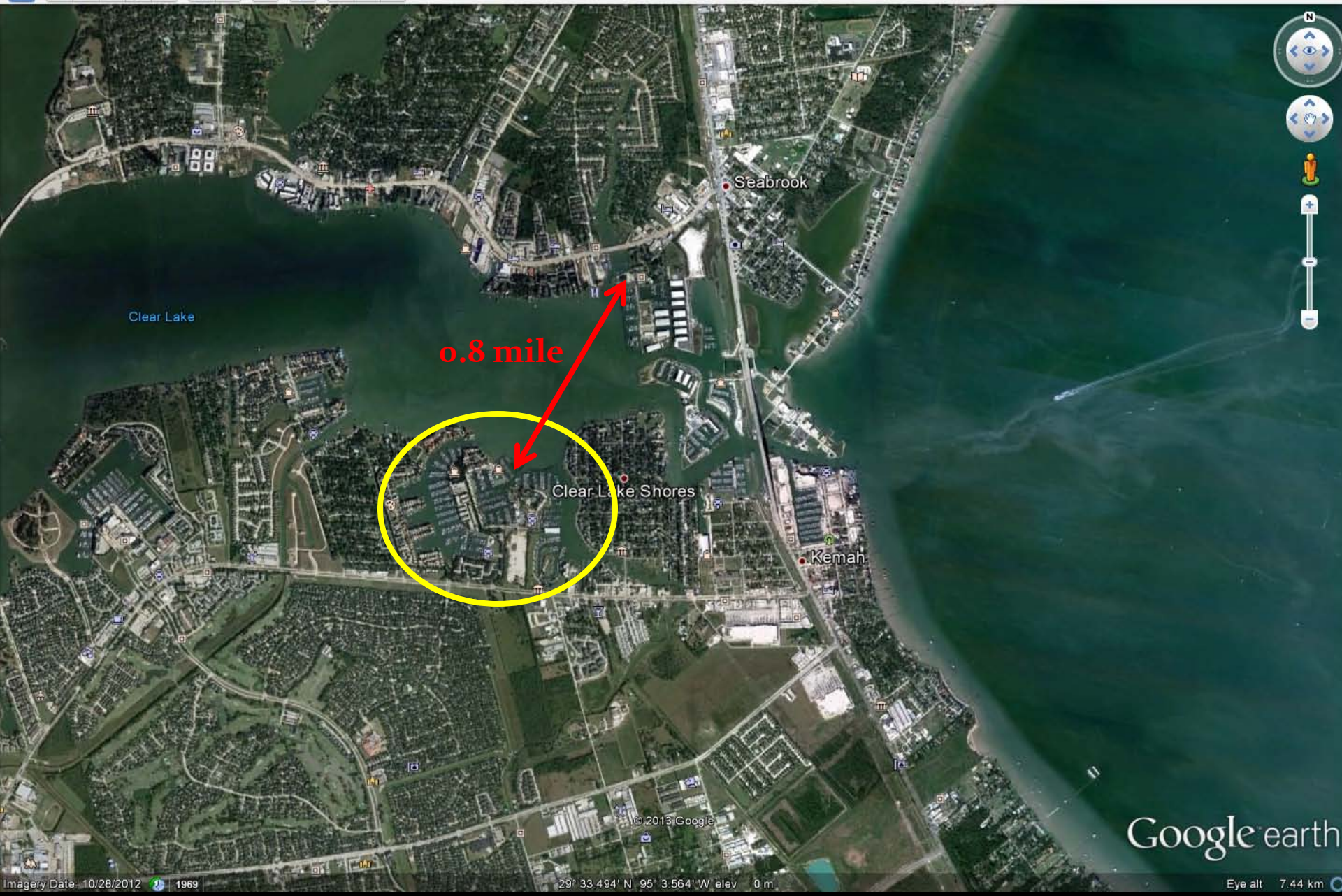
Seabrook
Clear Lake
0.8 mile
Clear Lake Shores
Kemah
© 2013 Google
Google earth
Imagery Date 10/28/2012 1969
29° 33.494' N 95° 3.564' W elev 0 m
Eye alt 7.44 km

Waterford Harbor Marina and Watergate Yachting Center


CAUTION
CAUTION

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Analyzing your marina's risks

- Wind risk – likelihood of high wind event, exposure
- Surge risk – SLOSH models, FEMA ABFEs
- Wave risk – fetch, breakwalls, wave attenuators
- Debris risk – 360-degree assessment
- No man's land – insurance coverage

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Securing boats in the water

- Assessing your marina's risks
- Failure modes and solutions for securing boats in the water
  - Fixed docks
  - Floating docks
  - Moorings
- Final lessons learned: revising your hurricane plan

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Fixed docks: Failure modes and solutions

- Piling failure
- Decking failure
- “Landing” failure

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Piling failure modes

- Piling not strong enough to withstand maximum loads
- Piling not secured properly
  - Substrate issues
  - Drilling/depth issues
  - Engineering issues
- **Piling failed due to age and deterioration**

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Piling solutions

- Engineering for substrate and most extreme conditions
- Maintaining/upgrading existing pilings, for example, sleeving with lower maintenance material
  - Composite
  - Fiberglass
  - Steel filled with concrete

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Composite pilings

http://www.pearsonpilings.com

http://www.harbortech.us

Fiberglass pilings

Piling solutions

- Engineering for substrate and most extreme conditions
- Maintaining/upgrading existing pilings, for example, sleeving with lower maintenance material
  - Composite
  - Fiberglass
  - Steel filled with concrete
- Installing pilings on helical anchors


http://www.helixanchors.com/


http://www.helixanchors.com/

Piling solutions

- Engineering for substrate and most extreme conditions
- Maintaining/upgrading existing pilings, for example, sleeving with lower maintenance material
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Fixed docks: Failure modes and solutions

- Piling failure
- Decking failure
- “Landing” failure

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Thru Flow

http://www.thruflow.com/

http://www.aqua-dek.com/

Fixed docks: Failure modes and solutions

- Piling failure
- Decking failure
- "Landing" failure

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“Landing” issues

- Long lines necessary to allow boat to rise with surge but does not keep boats centered as surge recedes
  - Can come down on a piling or a dock
  - Can get caught under dock with multiple surges
- Short lines will not allow boat to rise with surge
- Lines fixed to a piling can trap boat as surge comes up
- Lines can come off the top of the piling with high enough surge

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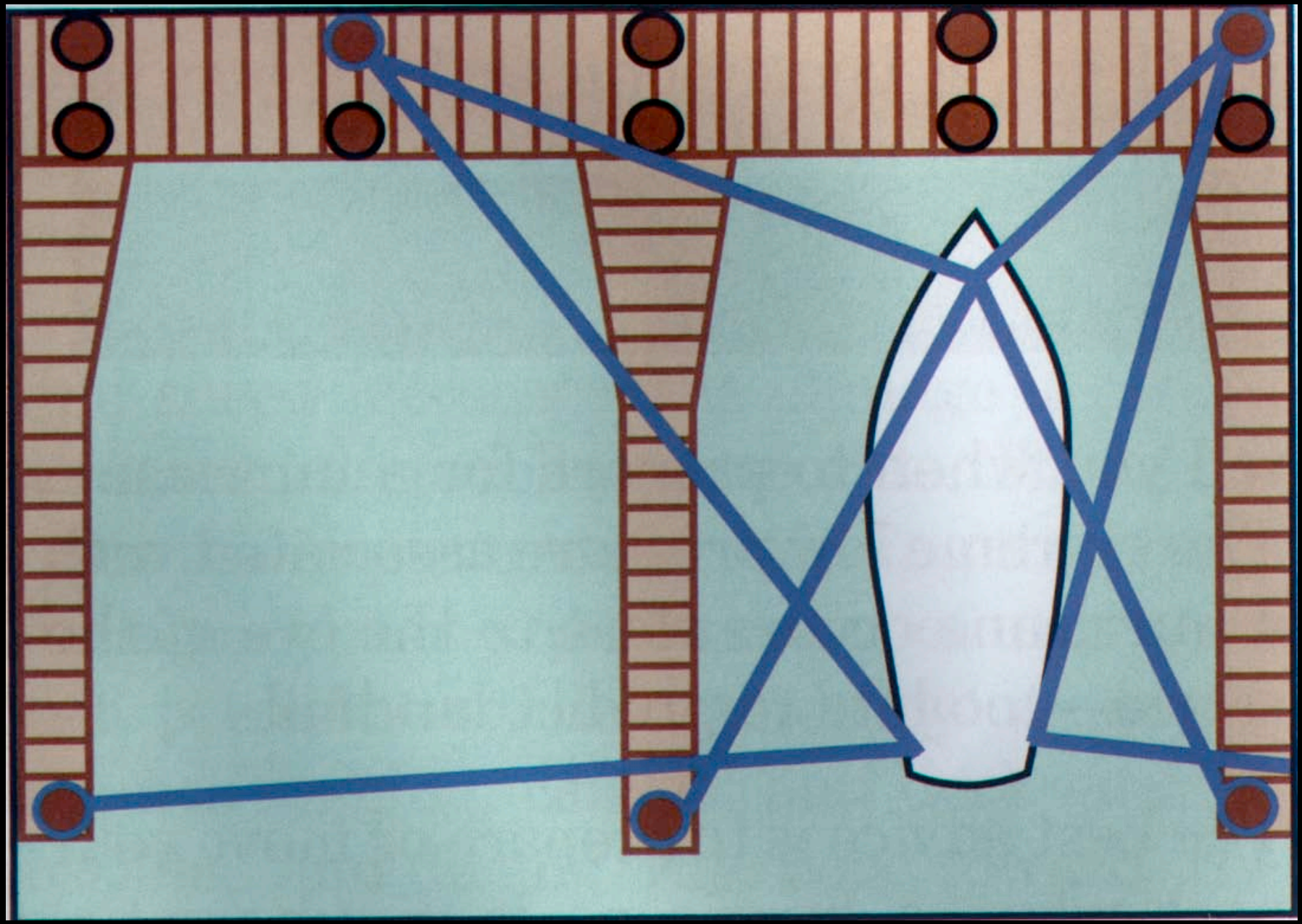

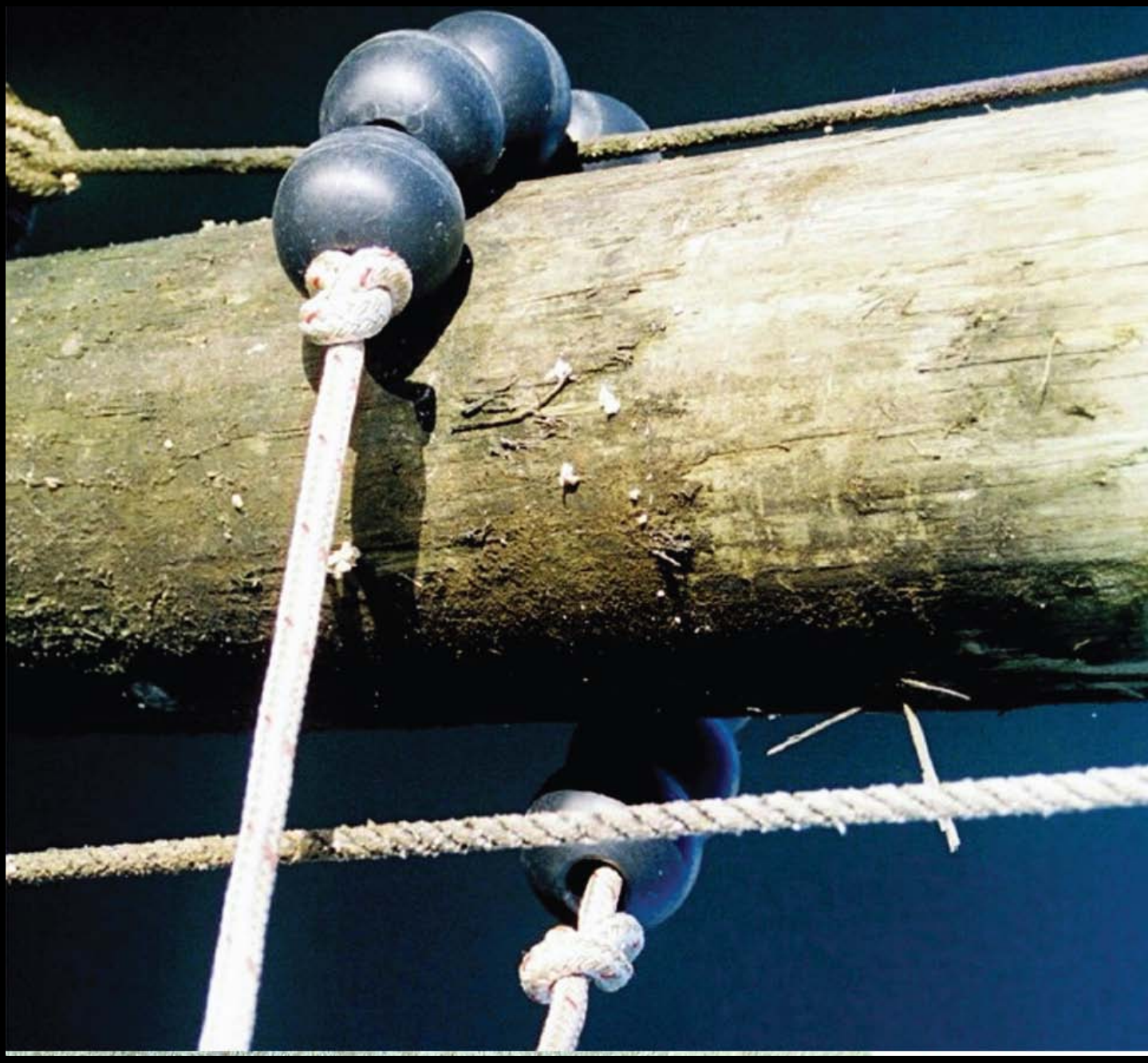

http://www.tideminders.com/


Premium
http://www.tideslide.com


http://www.tideslide.com

“Landing” solutions

- Secure boats in the middle of slips with plenty of room around them – best one boat to two slips
- Long lines taken as far from boat as possible to allow for maximum rise with the surge but minimal movement within the slip
- Create a way for lines to go up and down with the boat and secure them so they cannot come off the top of the pilings

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Securing boats in the water

- Assessing your marina's risks
- Failure modes and solutions for securing boats in the water
  - Fixed docks
  - Floating docks
  - Moorings
- Final lessons learned: revising your hurricane plan

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Floating docks: Failure modes and solutions

- Piling failures
- Twisting of docks not secured by pilings
- Breaking away of ramps to bulkheads

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Piling failure modes

- **Piling too short for surge**

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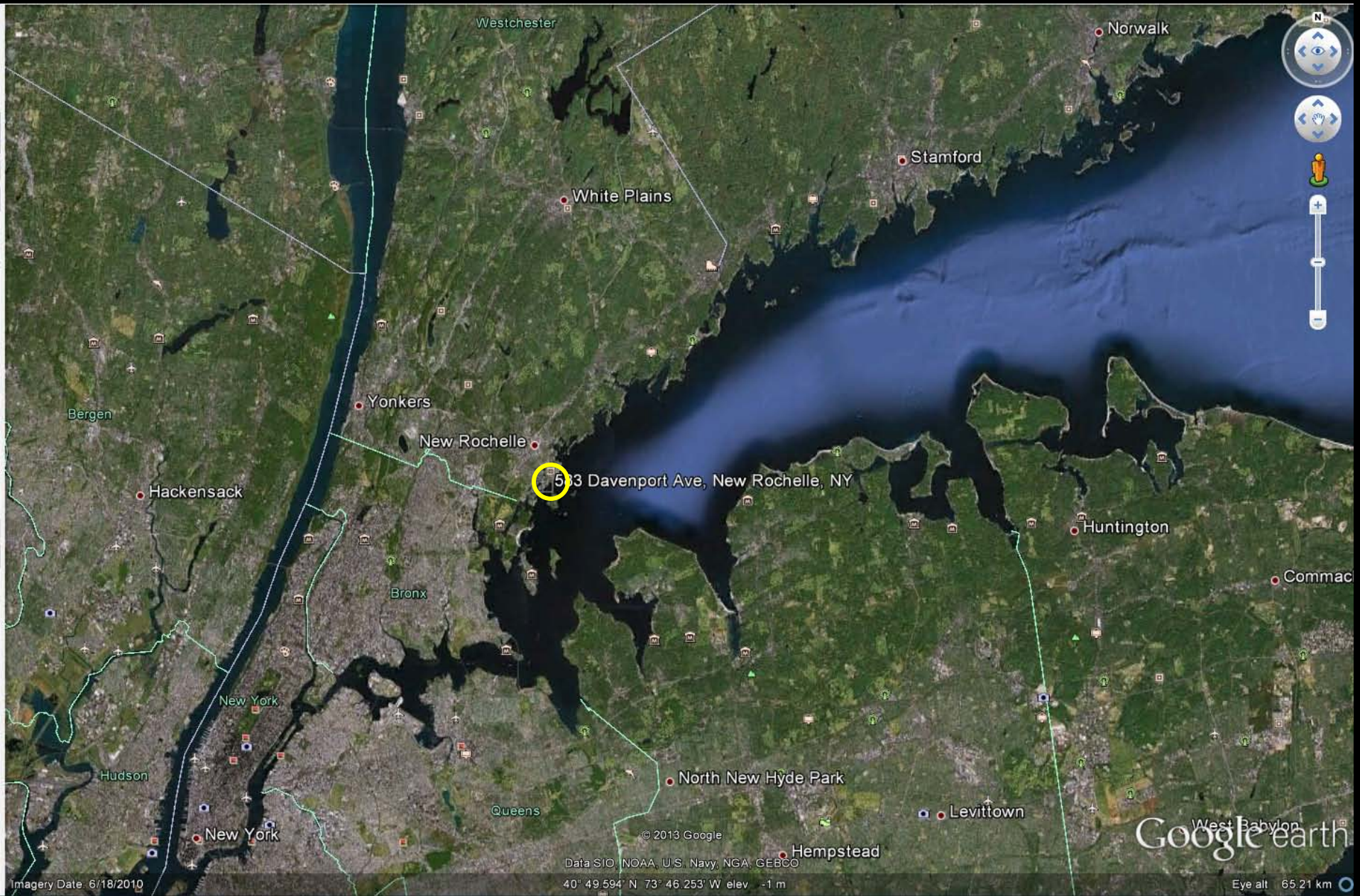
Imperial Yacht Club, New Rochelle, NY



Imperial Yacht Club, New Rochelle, NY

Courtesy John Giacobbe

Courtesy John Giacobbe

Courtesy John Giacobbe


09/07/2004

Piling failure modes

- Piling too short for surge
- Piling not strong enough to withstand maximum loads
- Piling not secured properly
  - Substrate issues
  - Drilling/depth issues
  - Engineering issues
- Piling failed due to age and deterioration

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Piling solutions

- Engineering for substrate and most extreme conditions
- Maintaining/upgrading existing pilings, for example, sleeving with lower maintenance material
  - Composite
  - Fiberglass
  - Steel filled with concrete
- Installing pilings on helical anchors

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Piling solutions

- Engineering for substrate and most extreme conditions
- Sleeving existing pilings
  - Composite
  - Fiberglass
  - Steel filled with concrete
- Pilings installed on helical anchors
- **Secure floating docks without pilings**

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http://www.hazelettmarine.com/

http://www.seaflex.net/

Floating docks: Failure modes and solutions

- Piling failures
- Cleat failures
- Twisting of docks not secured by pilings
- Breaking away of ramps to bulkheads

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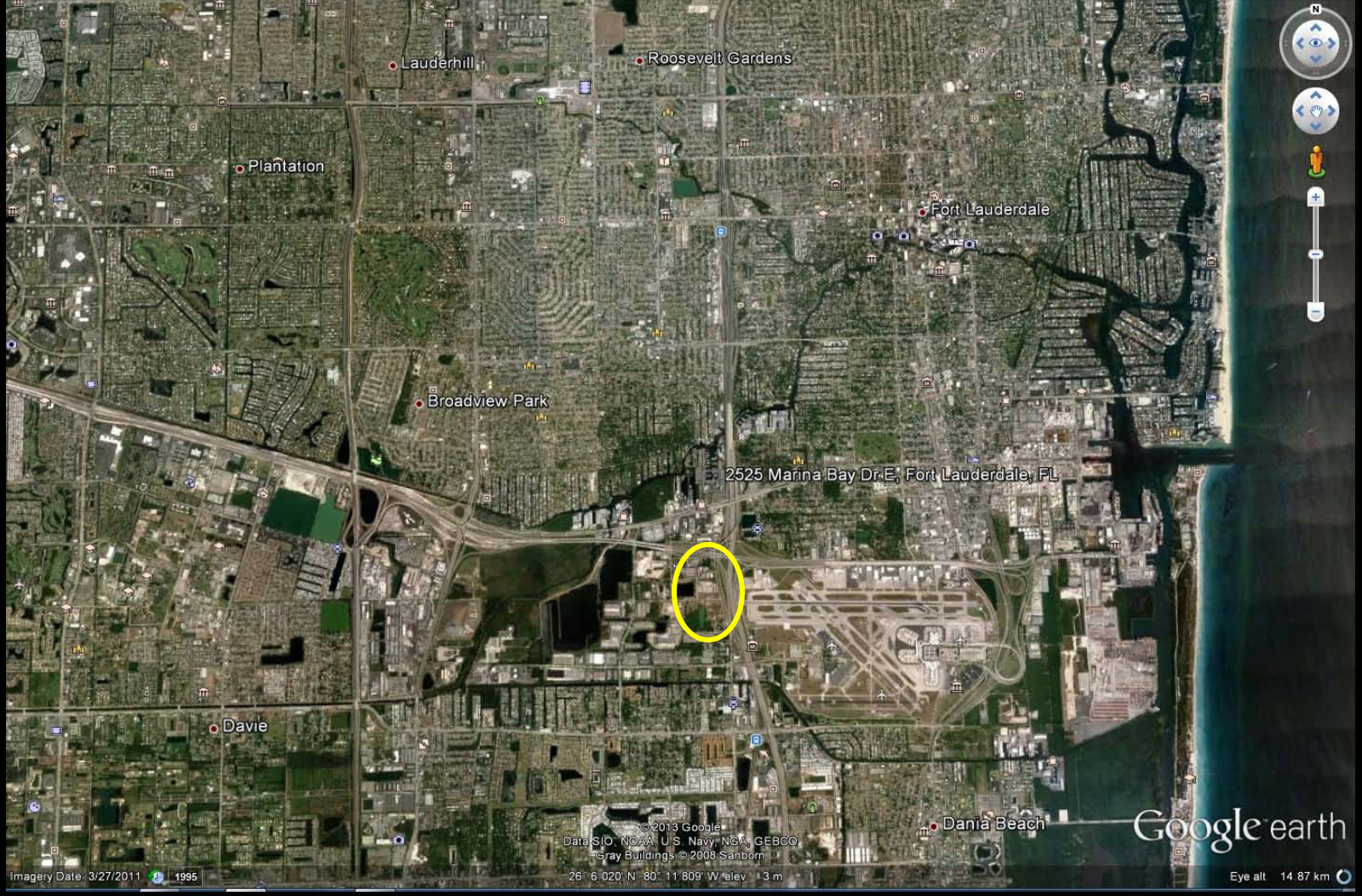
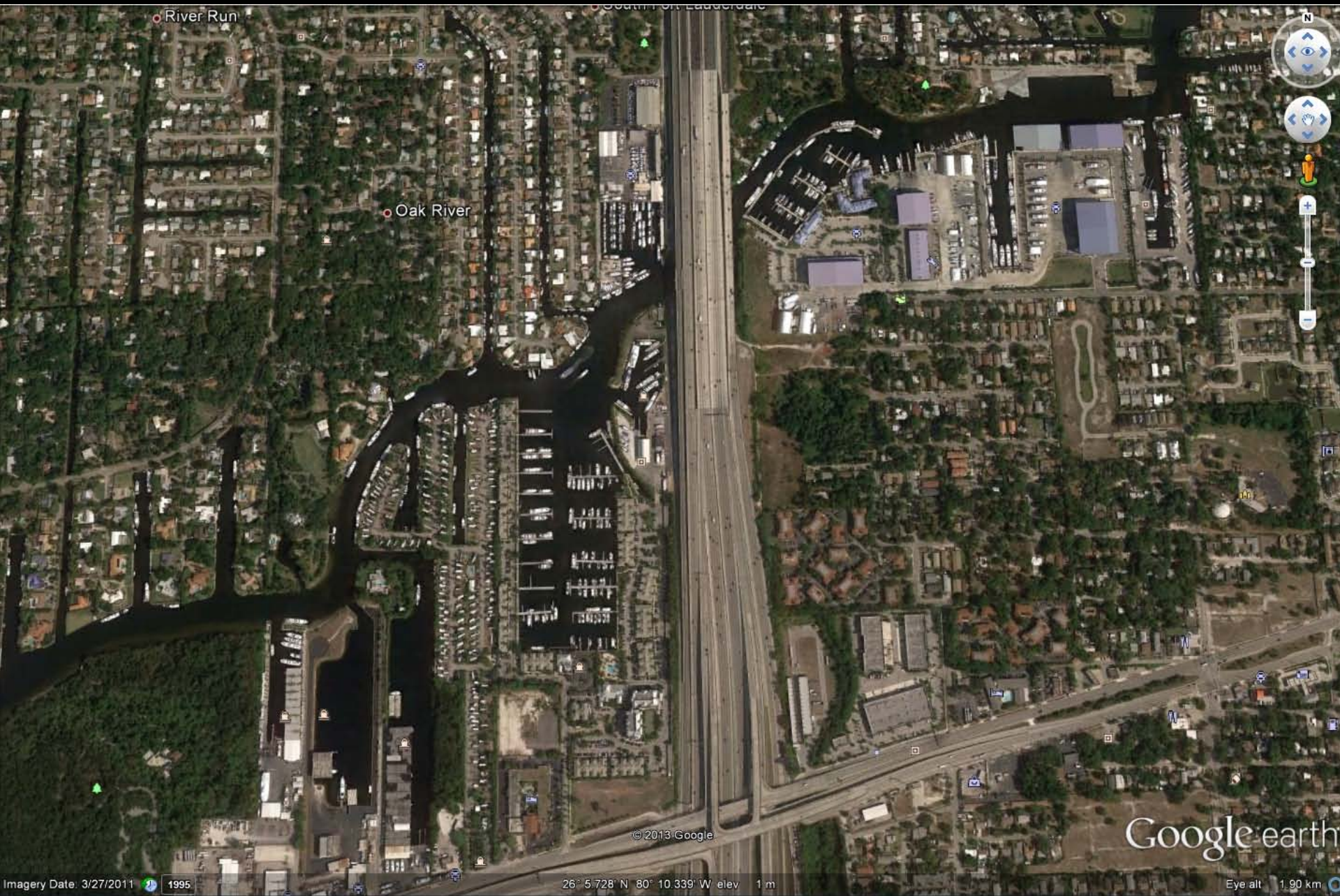


Marina Bay, Ft. Lauderdale, FL

- Abandoned quarry well protected by infrastructure
- On canal four miles inland, six miles through canals
- Large hardstand stowage not far above water
- Superyacht marina with many boats >60 feet

Marina Bay, Ft. Lauderdale, FL



Marina Bay, Ft. Lauderdale, FL

Floating docks: Additional solutions

- Secure lines to pilings to reduce dependence on cleats/deck hardware; use method that allows line to slide
- In the absence of pilings, over-engineer to limit twisting in strong wave/wind events
- Remove ramps between bulkheads and docks in high surge events

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Palm Harbor Marina, Pensacola, FL

A hurricane “resistant” marina

- Mahogany Landing Marina built in 1986 with fixed wooden docks
- Renovated in 2003 with 64 slips, fixed wooden docks
- Completely destroyed in Hurricane Ivan in September 2004
  - Cat 3 winds
  - Storm surge of 12-16 feet
  - 43 of 50 boats destroyed
- Decided to rebuild as a hurricane “resistant” marina in 2005-2006; hurricane “proof” marina simply too expensive

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Mahogany Landing Marina 2005

Palm Harbor Marina 2007

Cost comparison (2005-2006)

Rebuild as:

- Fixed wooden docks: $285,000 quote
- New floating docks: $495,000 quote
- Hurricane "resistant" marina: $685,000 quote, $850,000 actual
  - Engineering versus "good ole boy" construction
  - Certified by licensed engineer with 10-year warranty
  - Overbuilding as philosophy
  - 70-foot long pilings, aluminum docks with Ipe decking
  - Survived Dennis (Cat 3, 20 miles from eye) without boat or dock damage

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Securing boats in the water

- Assessing your marina's risks
- Failure modes and solutions for securing boats in the water
  - Fixed docks
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  - Moorings
- Final lessons learned: revising your hurricane plan

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Mooring System

- Mooring
- Lower Chain
- Swivel
- Shackles
- Upper Chain
- Mooring Pendant
- Point of Attachment to Boat

The mooring is only as good as its weakest link

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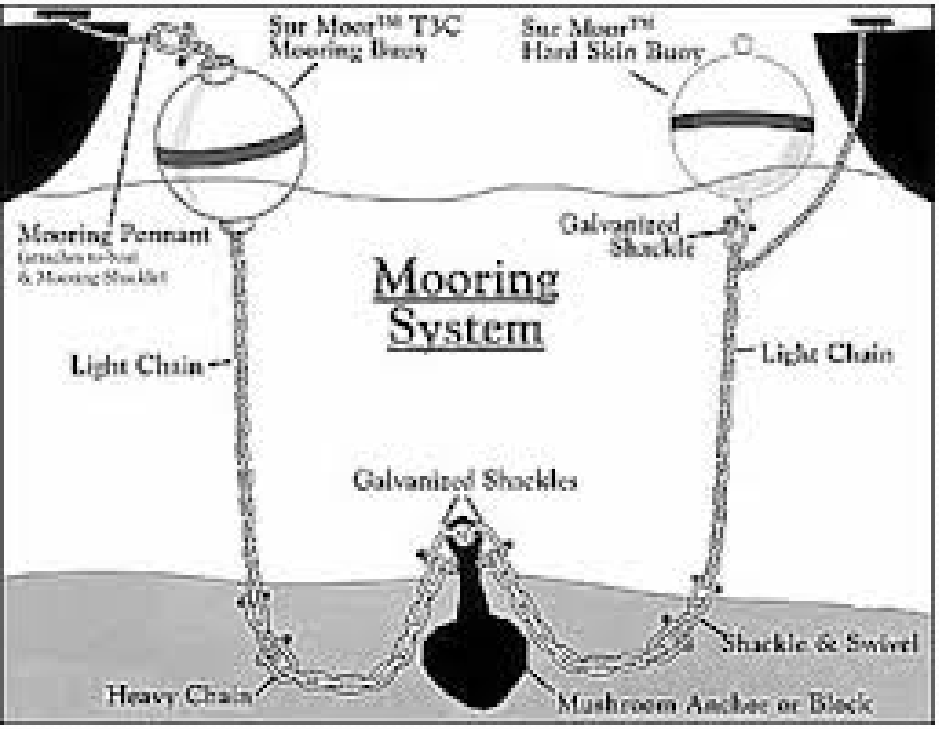
The mooring revolution



http://www.sailboatstuff.com/mor_moorbuoy.html

http://www.oldportmarine.com/hazlett.htm

Conservation Moorings Study Jan. 2013

- Conservation moorings may hold vessels better than conventional moorings when designed and installed properly.
- Conservation moorings are likely to cost more than conventional moorings in terms of upfront costs, but may be more economical over the lifetime of a mooring.
- Conservation moorings appear to cause minimal impacts to eelgrass beds.
- It is less expensive to install a conservation mooring in an eelgrass bed to minimize eelgrass loss than it is to try to restore the eelgrass of a mooring scar once it has been lost.

http://www.uhi.umb.edu/pdf_files/FINAL_MOORING_REPORT_JAN_2013.pdf

Source: Urban Harbors Institute, University of MA, Boston

The mooring revolution

Traditional solution

- Nylon pendant with chafe protection shackled to chain
- Mooring buoy
- Light chain shackled to heavy chain
- Concrete block or mushroom anchor

Emerging solution

- Spectra at chock with soft eye-to-eye splice to nylon line
- Mooring buoy
- Habitat-friendly tethering system
- Helical anchors

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Failure Modes: Moorings

1. Chafe at the pendant
2. Dragging the mooring
3. Chain failure

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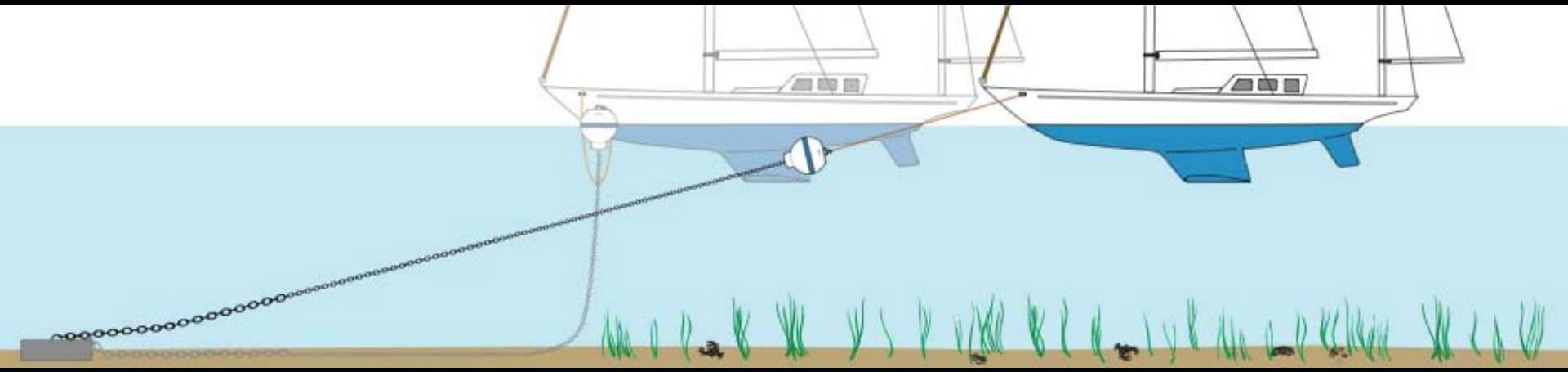


boatmooring.com
helixanchors.com

Hazelett Elastic Mooring Pendant

Failure Modes: Moorings

1. Chafe at the pendant
2. Dragging the mooring
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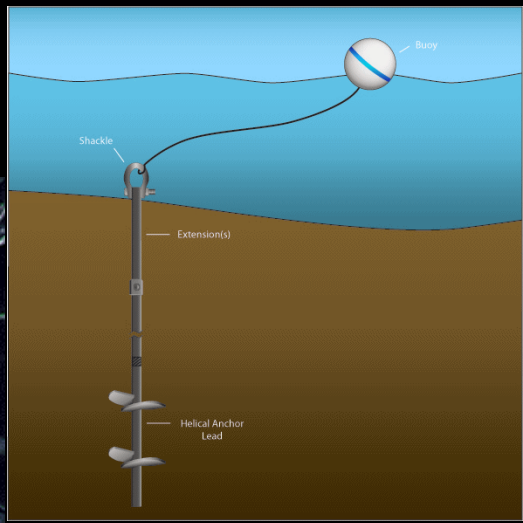
Concrete loses almost ½ its weight in water, granite loses 1/3 its weight, steel only loses 1/8 its weight… Helical anchor only solution that does not depend upon weight for holding power.

Mushroom

Ann's mushroom

Dor-Moor

Helical anchor



Comparison of mooring anchor types

	Helix	Dor-Mor (650 lbs.)	Mushroom (500 lbs.)	Single block (2,000 lbs.)	Double block (8,000 lbs.)
Resisting force (lbs.)	12,000+*	4,500	1,200	800	4,000
Water depth (ft.)	20	18	15	14	35
Scope	4:1	3:1	3.5:1	3:1	3:1
Est. cost**	$850	$1,125	$1,100	$350	$550

*Did not break out

** http://www.boatmoorings.com/whyhelix.php

Results not entirely comparable:
Bottoms differed; helix had most scope

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Practical Sailor

Independent Tests of Boats and Gear for the Serious Sailor

August 2009

PS VALUE GUIDE MOORING ANCHORS

MAKER	NEWPORT, R. I. 1994					SARASOTA, FLA. 2007		
	HELIX SCREW ★	MANTA RAY ★	DOR-MOR (650 lbs.) ✓	MUSHROOM (500 lbs.)	CONCRETE BLOCKS (2,000 lbs.)	CONCRETE BLOCKS (1,500 lbs.)	10" HELICAL SCREW 1	14" HELICAL SCREW 2
BREAKOUT LOAD	12,000 lbs. (no breakout)	12,000 lbs. (no breakout)	4,500 lbs.	1,200 lbs.	800 lbs.	800 lbs.	10,000 lbs.	10,000 lbs.
WATER DEPTH	20 ft.	19 ft.	18 ft.	15 ft.	14 ft.	12 ft	12 ft.	12 ft.
SCOPE	4:1	4:1	3:1	3.5:1	3:1	1:1	1:1	1:1
COST INSTALLED	$1,000	$1,000	$1,000	$1,000	$600	$500	$1,000	$1,000

★ Best Choice ✓ Recommended

Moorings: Solutions and recommendations

- Modern pendants that combine low stretch and high strength of modern fibers at the chock with high stretch and high durability at the buoy offer significantly more holding power with great reduction in chafe
- Helical anchors are the most reliable way to secure a mooring to most sea floors
- As we transition to eco-friendly gear between the anchor and the buoy, we will get more data on what works and what doesn't

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Moorings in high-surge events

Always a tension between allowing enough scope and packing boats into the mooring field

- Need to know your mooring scope in normal conditions and what predicted surge will do to it
- In many cases, will need to add scope to maintain angle of pull at peak surge
- That may mean thinning the mooring field to avoid boats making contact with one another when surge recedes

Securing boats in the water

- Assessing your marina's risks
- Failure modes and solutions for securing boats in the water
- Final lessons learned: revising your hurricane plan

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Four take aways

1. Surge matters.
2. Preparations matter… but we have to prepare for the real risks.
3. Hurricane planning needs to become more marina and storm specific.
4. Lessons from Florida marinas and new ideas coming out of Sandy could have reduced the damage in this storm.

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Final conclusions: Securing boats

- Storing boats on land is the least expensive option and has the greatest chance of minimizing damage to boats, infrastructure, and the environment, **so long as the boats can be kept on the premises**
- Securing boats in the water requires a large investment in engineering and infrastructure to keep the boats in place; with dock systems **any failure is more likely to be catastrophic**
- Given the reality of how many boats can be secured on land in three to five working days, many marinas will need to have a **comprehensive plan that involves both land and water storage**

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Final conclusions: Hurricane plans

- **Proper risk assessment** must underlay all other planning: wind risk, surge risk, wave risk, debris risk, other risks
- Hurricane plan should reflect **your marina's clientele**: type of boat (sail vs. power), size of boat, affluence of customers
- Hurricane plan needs to include **contingency planning for different types of storms**: wind vs. surge vs. both
- **Ultimate storm plan:** What will you do with just 24 hours?

Webinar series objective

To share lessons coming out of Sandy that will help marine facilities in storm-damaged areas rebuild smarter and those in other areas prepare better for future storms

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Additional resources

- Gulf of Mexico Alliance, Clean and Resilient Marinas Program: http://www.gulfofmexicoalliance.org/announcements/news.php#story-1050
- Preparing marinas for storms: http://www.boatus.com/hurricanes/YCMarinasPrep.asp
- Downloadable preparation guides for boaters and marinas: http://www.boatus.com/hurricanes/hurr_prep.asp
- BoatUS Hurricane Plan Checklist and sample hurricane plans: http://www.boatus.com/hurricanes/marina_plans.asp
- Hurricane advisory emails: http://www.boatus.com/hurricanes/signup.asp

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Boating Resource

Goal: To make sure boaters know what marinas are up and running in storm-damaged areas this summer so business doesn't pass boating facilities by.

- BoatU.S., AMI, and Dozier's Waterway Guide
- See web page at: **http://www.waterwayguide.com/superstorm-sandy/**
- To report updates: **superstormsandy@waterwayguide.com**

Association of Marina Industries

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BoatU.S. and AMI want to wish all those who suffered damage from Sandy the best of luck in the coming year.

THANK YOU!

Association of Marina Industries

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