Oyster Reef Mitigation for the Bayport Ship Channel Improvement Project

Western Dredging Association, Dredging Summit & Expo 2015
June 23, 2015

Carl A. Sepulveda, P.E.
Ashley Judith, P.E.
Dana Cheney
David Casebeer, P.E.

PORT of HOUSTON AUTHORITY

Agenda

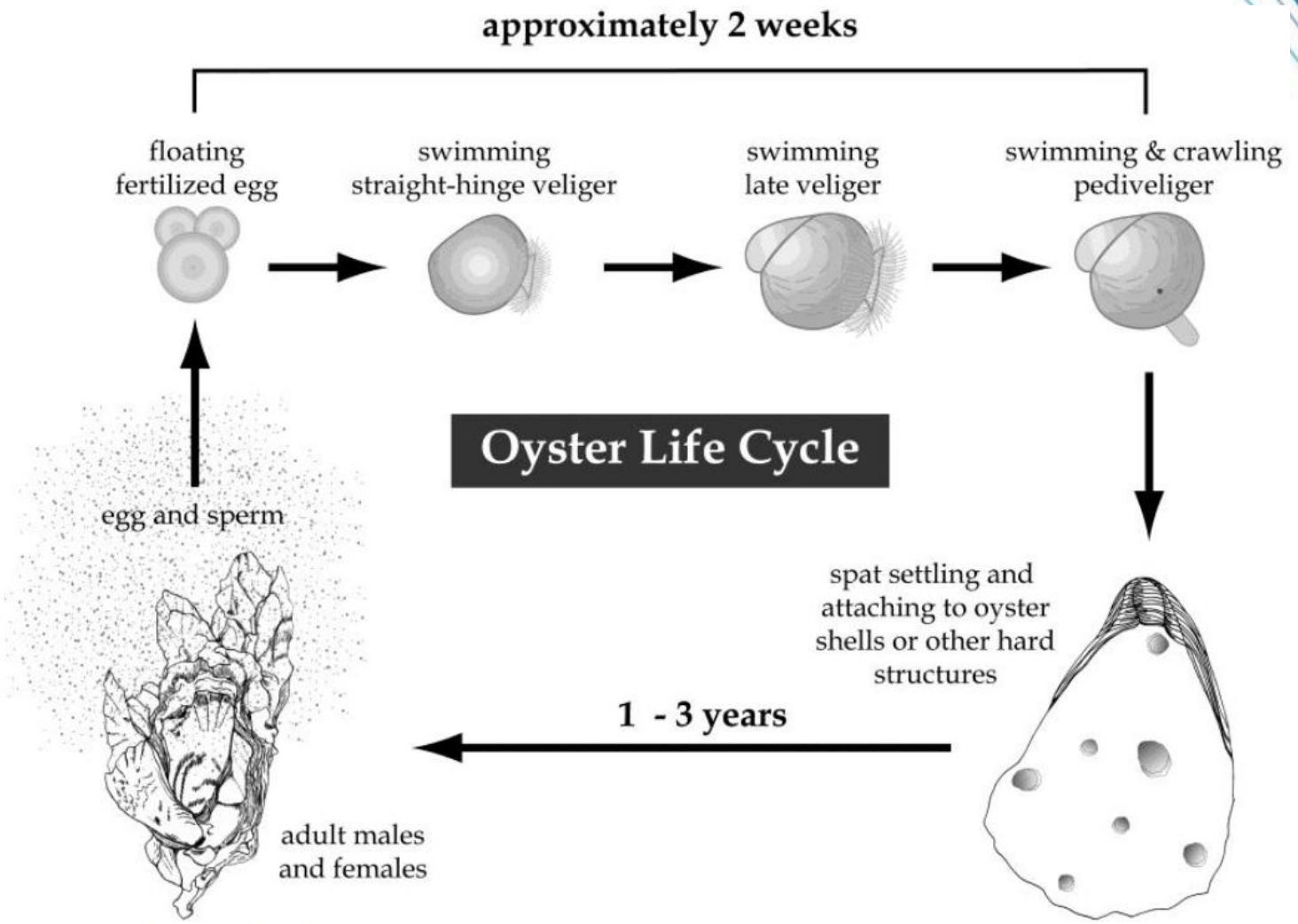
- Background
- Where They're Found in Galveston Bay
- BSC Project Overview
- Oyster Resource Agencies
  - Regulatory Authority
  - What they focus on
- Existing Reef Survey
- Mitigation Plan & Design
- Mitigation Construction

Background – General

- Oysters Ecological
  - Water quality – filter
  - Aquatic habitat structure – for fish, etc.
    - Fish: Gobies, blennies, skilletfish etc. lay eggs in shells
    - Invertebrates such as brown and white shrimp hide from predators
  - Part of several species diet such as Blue crab, stone crab, and black drum fish
  - Fosters and attracts large predatory fish
  - Primarily Eastern oyster (*Crassostrea virginica*) in Galveston Bay
- Galveston Bay Oyster Reefs
  - Produces more oysters than any single water body in US*
  - Rivals the combined production of Louisiana and Washington*
  - Before Ike, the Bay represented 80% of oysters harvested in Texas*
  - Harvest totaled approximately 3 million pounds worth nearly $10 million*

*Galveston Bay Estuary Program

Background – Eastern Oyster Life Cycle

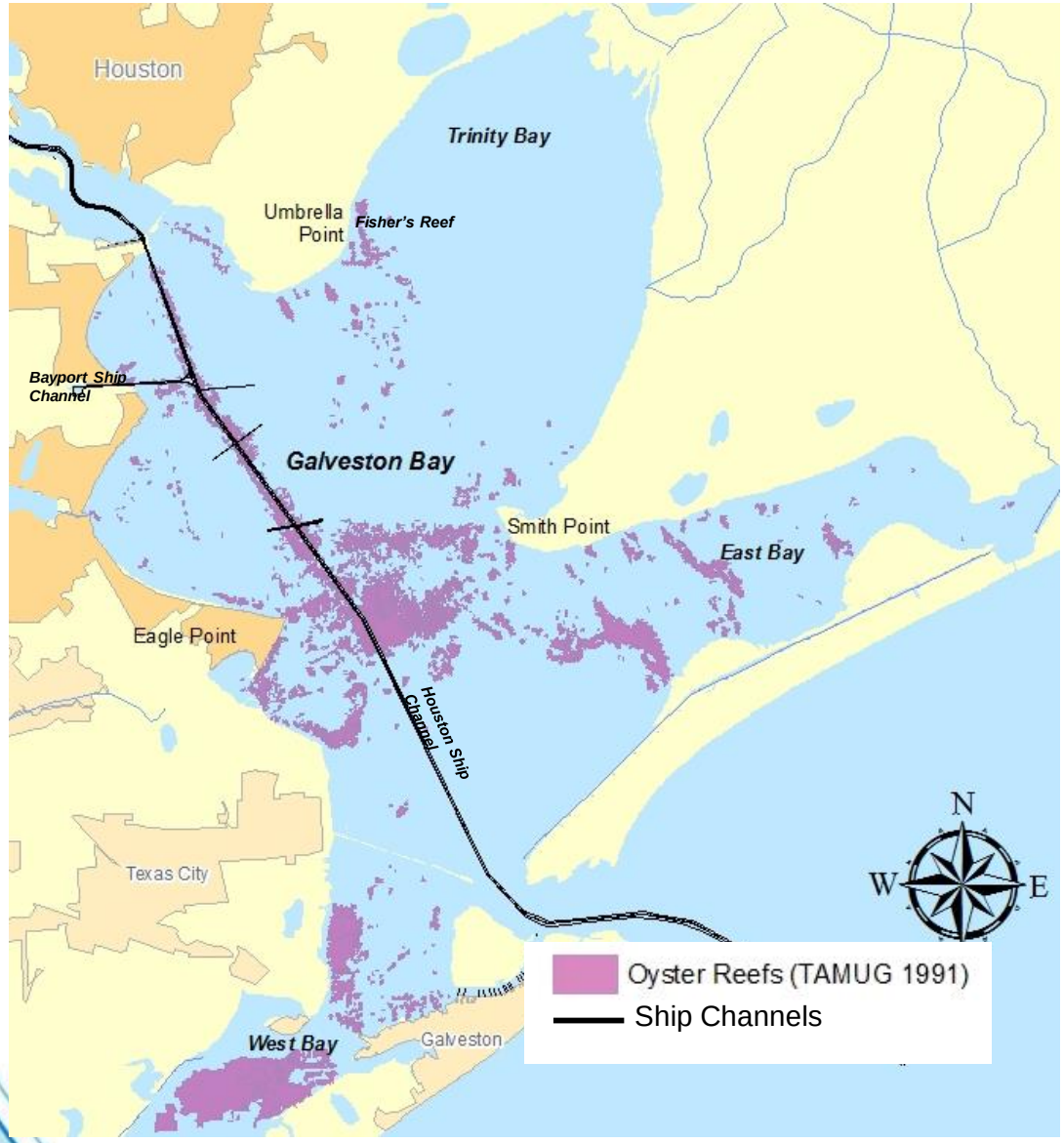


Source: Karen R. Swanson, COSEE SE/NSF

Background – Eastern Oyster Life Cycle (continued)

- Spat set has two peaks a year related to Bay conditions passing through the optimal water temperature and salinity conditions for mass spawning
- For Gulf of Mexico oysters
  - water temperature $\geq$25°C initiates mass spawning
  - water temperature > 35°C may limit this
- In Galveston Bay
  - first (and largest) peak between April through June
  - second, smaller peak around August

Where Oysters Are Found in Galveston Bay



Oyster Resource Agencies

- Texas Parks and Wildlife Department (TPWD)
  - Primary resource manager in state
  - Focus on balance between reefs as fisheries and as ecological resources
  - All natural oyster reefs are considered public resources
    - open to recreational and commercial harvesting from November through April
    - except for private leases, which have no closed season
  - Broad authority under 31 TAC 69 to "seek full restitution for and/or restoration of fish, wildlife and habitat loss occurring as a result of human activities"
  - Primary source of technical guidance
    - For survey requirements to determine reef presence/extent
    - Mitigation requirements – i.e. restoration extent/configuration
- Texas General Land Office (TxGLO)
  - Manage Texas Coastal Management Program (TCMP)
  - Under TCMP, oyster reefs designated as
    - coastal natural resource areas (CNRA) and,
    - "critical areas"
  - These require compensatory mitigation for adverse impacts

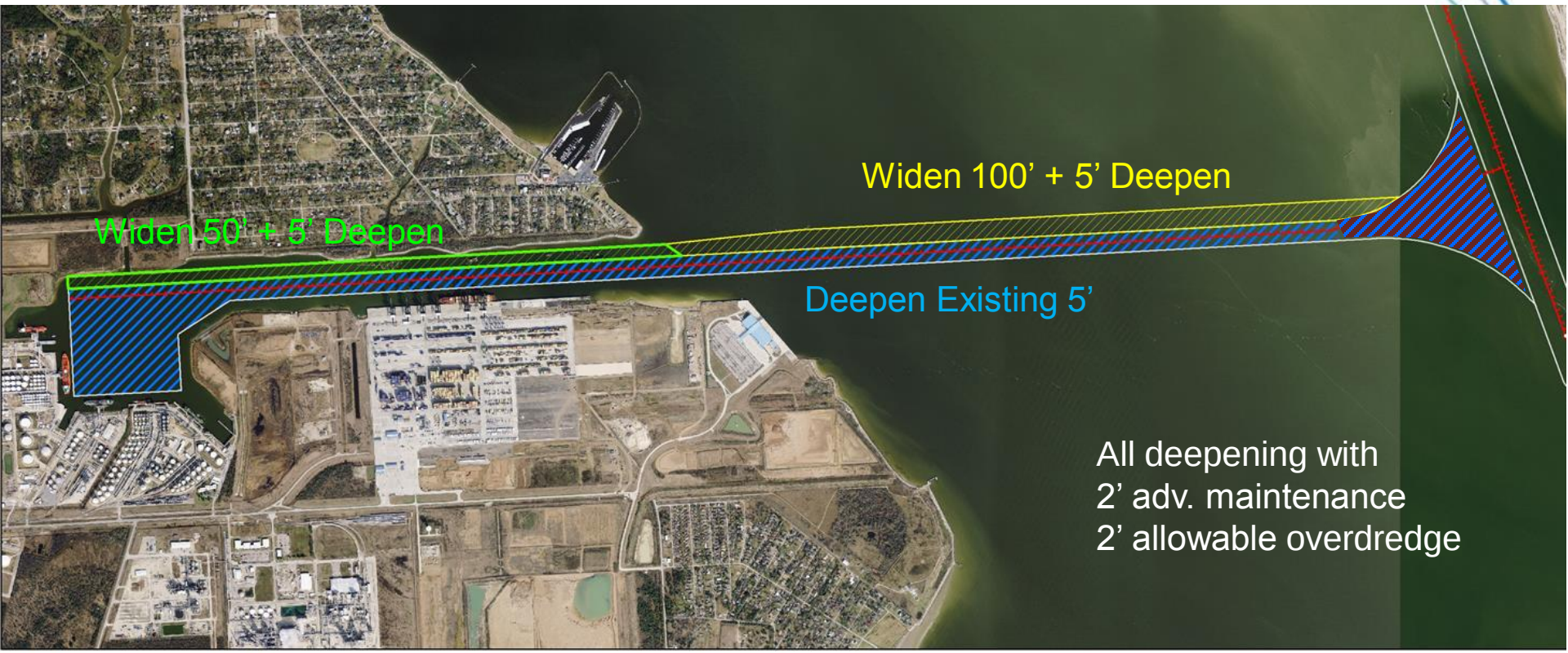
Oyster Resource Agencies

- National Marine Fisheries Service (NMFS), NOAA
  - Administers compliance w/ Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA)
  - Oyster reefs are Essential Fish Habitat (EFH) under MSFCMA
    - Within the regulated boundaries in Gulf of Mexico
    - This includes bays and tidal waters i.e. Galveston Bay
  - NMFS consultation
    - Required for Federal permit approvals that could adversely impact EFH
    - Including EFH assessment and **proposed mitigation if applicable**
- U.S. Army Corps of Engineers
  - Authority on permit and mitigation for impacts to aquatic resources under Section 404 of the Clean Water Act (CWA)
  - Regulates discharges to Waters of the U.S. (WOUS), including those from dredging
  - Includes regulation and compensation for impacts to Special Aquatic Sites
    - Some districts, may interpret definition for coral reefs to include oyster reef
    - Update: Galveston District has historically not interpreted it that way, but it depends on who's reviewing application
  - Consults with TPWD on survey & mitigation technical aspects

Oyster Resource Agencies

- In Texas
  - most of these overlapping authorities are pulled together by the CWA Section 404 permitting process
  - TPWD takes the lead in providing technical guidance on surveys and mitigation for impacts to reefs.
- Texas State Department of Health Services
  - Regulates consumption and related restrictions on harvesting
  - Sets time/space boundaries governing restricted harvesting
    - In concert with TPWD
    - Seasonal restrictions due to pathogens

Bayport Ship Channel Improvements Project



Legend
- ORIGINAL CHANNEL TOE LIMITS
- CHANNEL CENTERLINE
- 45 FEET DEEPENING & 100 FEET WIDENING*
- 45 FEET DEEPENING & 50 FEET WIDENING*
- 45 FEET DEEPENING

*Top of Bank Limits Shown for Widening

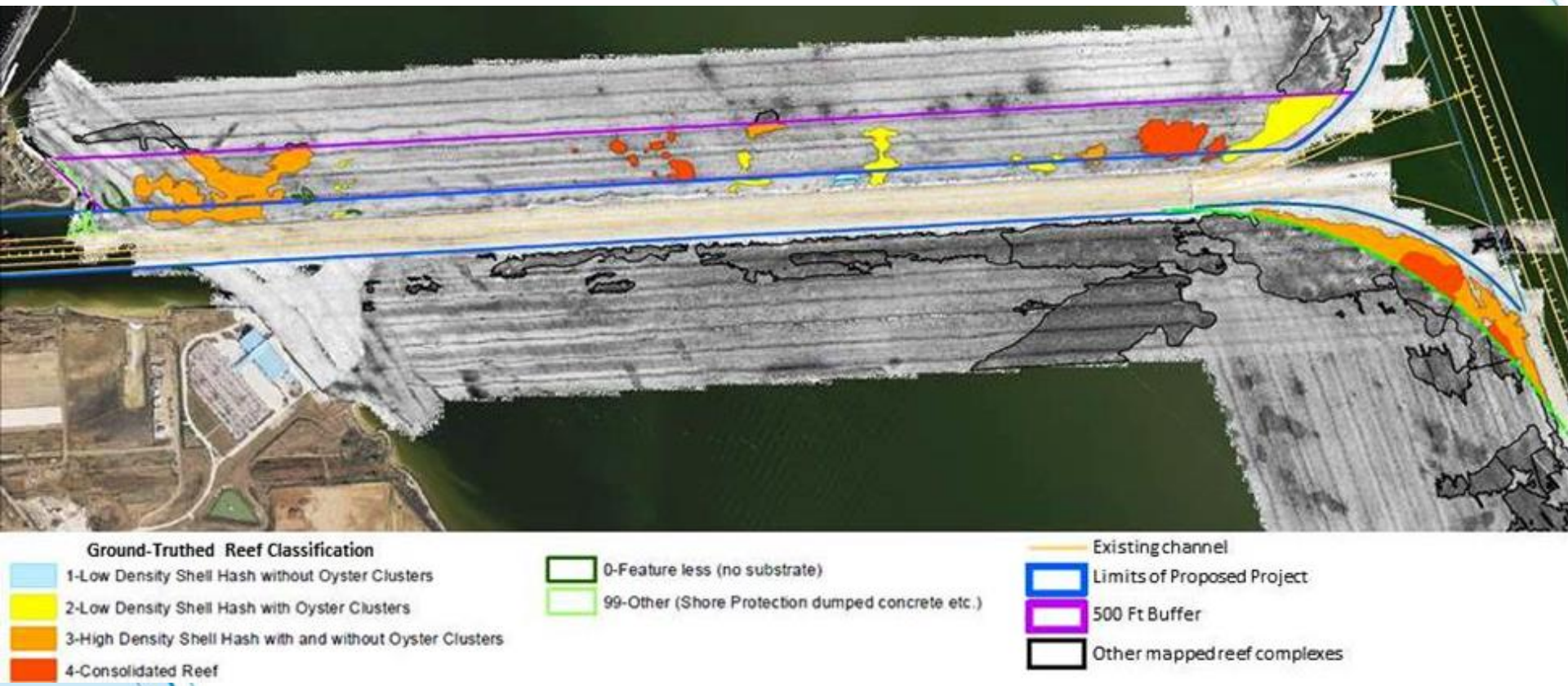
N W E S

0 1,500 Feet

Planning Considerations of Oyster Reef Impact

- 9K TEU vessels already calling on Bayport not to mention increasing large vessel presence due to industry shift and possibly Panama Canal expansion
- Improvements needed to be permitted and constructed expeditiously
- Planning for channel improvements had to consider these time constraints
- At each planning phase, oyster reef was considered along with other constraints, in the selection of channel improvement alternatives
- **Initial Screening of Alternatives**
  - Land cut and existing HSC depth formed one set of constraints
  - Presence and location of oyster reef was the other
  - Oyster reef survey conducted for the channel area
  - Survey identified substantially more reef on south than north side
  - initial array of 11 combinations of
    - deepening to -13.7 m (-45 feet) MLT
    - various increments of widening from 7.6 m (25 feet) to 30.5 m (100 feet) on one or both sides
  - Evaluated against constraints and general planning criteria of navigation efficiency, cost effectiveness, constructability, and minimizing environmental impacts
  - Oyster mitigation costs estimated as part of cost criteria evaluation, using
    - geospatial survey data
    - escalated mobilization and unit costs derived from previous HSC reef restoration project
  - 7 options eliminated due to various criteria including two involving widening solely to the south eliminated partially due to reef impacts (3X as much impact as north

Oyster Survey Results for BSC Improvements Project



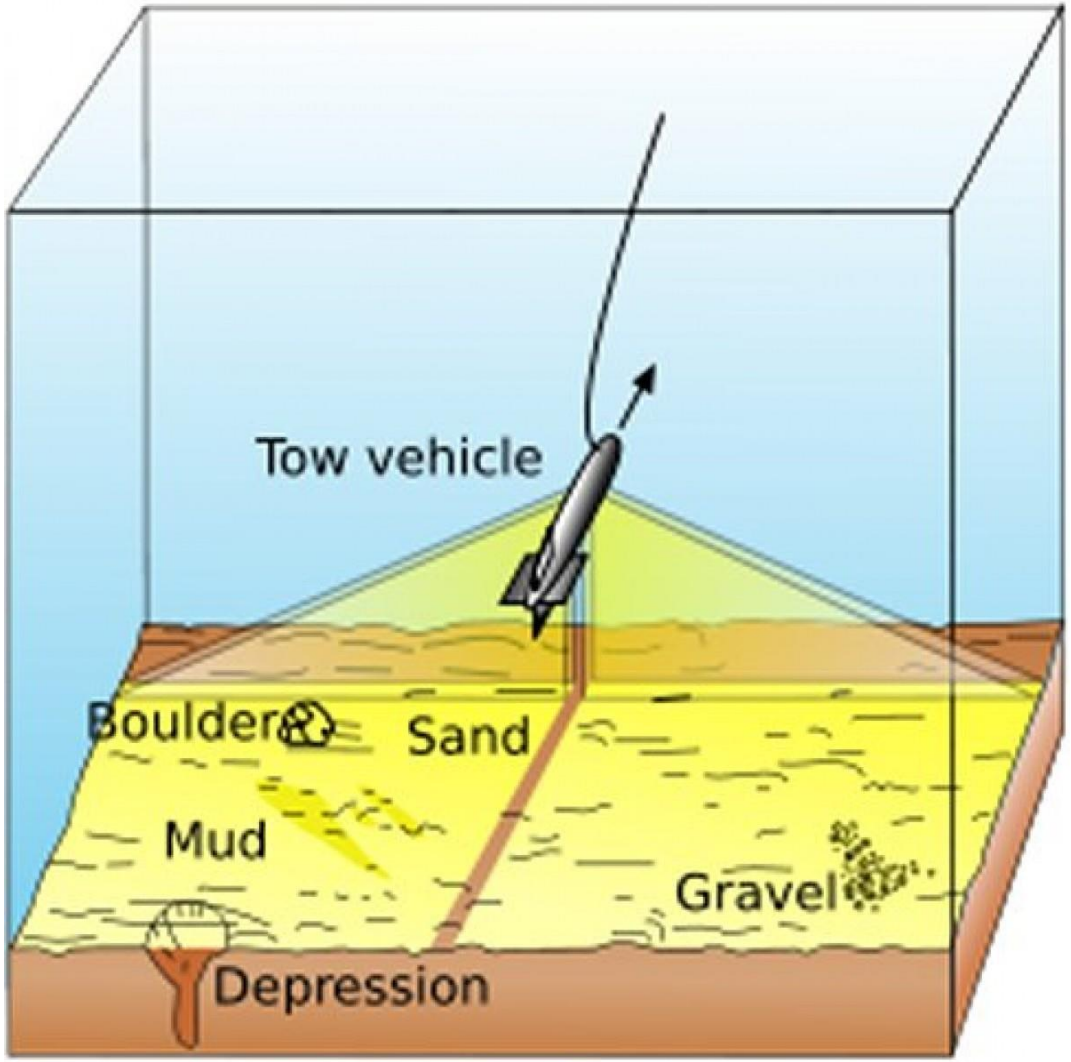
Planning Considerations of Oyster Reef Impact

- **Final Alternatives**
  - 4 remaining alternatives and No Action evaluated in more detail
  - Maritime Institute of Technology and Graduate Studies (MITAGS) ship simulations
  - Total construction costs, including oyster reef mitigation were estimated
  - Evaluated in more detail with same previous criteria
  - Results
    - No Action and Widen 50' to the North did not substantially increase navigation efficiency
    - Widen 50' Both Sides (Total 100') and the Widen 100' to North both substantially increase navigation efficiency
    - However, the Widen 100' to the North
      - least costly and is dredge efficient
      - fulfills constructability criterion better by not being potentially subject to more dredge delays
      - and minimizes environmental impacts the most by impacting the least oyster acreage
    - Therefore, on the balance of these criteria, the alternative to Widen 100' to the North was chosen as the preferred channel improvement alternative to permit and construct
  - Oyster reef impact was one of the key decision factors for selection

EXISTING REEF SURVEY

- TPWD provided survey guidelines for determining extent of oyster reef
  - Adapted from recommendations for surveying reef on pipeline projects
  - Prescribed 3 basic field survey methods and recommended transect spacing and mapping paired with a ground-truthing method consisting of
    1. side-scan sonar with sub-bottom profiler ground-truthed by oyster dredge or diver
    2. towed chain probing (e.g. feeling of chain impact/vibration by hand) ground-truthed by oyster dredge or diver
    3. sampling by oyster dredge (no ground-truthing since substrate and oysters directly sampled)
  - First method with ground truthing by diver preferred by TPWD and chosen
- Side-scan sonar survey performed first to
  - provide basic extent information for general impact assessment & cost estimation
  - aid in the design of the ground-truthing survey by scientific divers
- System used
  - SonarBeam DSME Utech S-150 dual-frequency digital Side Scan tow fish
  - Oceanic Imaging Consultants (OIC) Geodas data collection/processing software
  - Test runs Ponar-truthed and correlated well
- Survey area
  - Encompass widest channel options north and south of BSC
  - Plus 500-ft survey buffer

Side Scan Sonar Illustrated



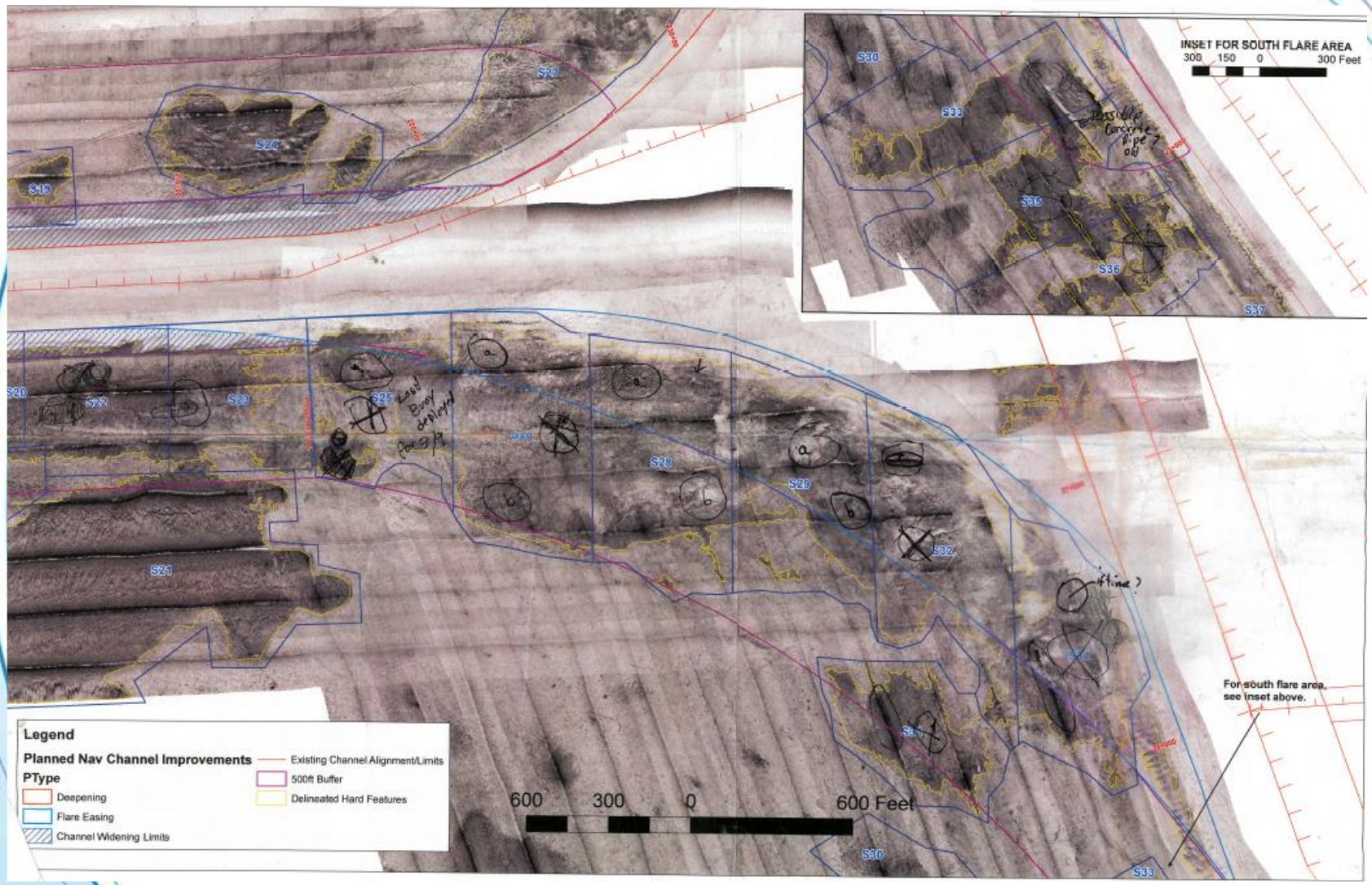
EXISTING REEF SURVEY (continued)

- Signal post-processing
  - OIC's "Cleansweep" software
  - Offsets checked, gains normalized
  - Images merged together into final georectified mosaic TIFF at 2 pixels per meter
- Raster Data Analysis and geospatial processing
  - ERDAS Imagine geospatial software used
  - Further TIFF analysis to characterize hard bottom habitat signatures from featureless habitats comprised primarily of silt
  - Classified into contiguous contrasting signature features using to generate geospatial features
    - pixel clumping routines
    - raster clump sieving
    - iterative sizing processes
  - Polygons generated were cleaned up
    - Small remnants trimmed
    - Cavity anomalies filled
  - Results 

EXISTING REEF SURVEY (continued)

- Ground Truthing by Diver Survey
  - Side-scan results and reef polygons used to pick target sampling locations
  - Ground-truth by direct diver observation
  - Features were divided into multiple general survey areas drawn to define and capture potential major complexes or groups of potential smaller reef features
  - Two large continuous reef complexes south of BSC and Flare were methodically broken up into 152 m (500-foot) or 305 m (1000-foot) segments
  - Each survey areas would have at least one dive location
  - Many were targeted with multiple dive locations according to size or difference in shape or signature
  - Each sampling location
    - 10-foot swath along 100-ft transects
    - shell hash percent cover, oyster cluster size, oyster cluster distance
    - qualitative observations of sediment composition
    - presence of consolidated oyster reef
    - presence of aquatic flora and fauna
    - parameters such as water visibility and water velocity

Example of Groundtruthing Map with survey area divisions



EXISTING REEF SURVEY (continued)

- Ground Truthing by Diver Survey (continued)
  - Habitat Classification
    - Class 4 – Consolidated Reef - Consolidated reef and/or habitat with numerous, closely spaced, large oyster clusters <15 percent visible substrate between oyster clusters if not completely consolidated reef.
    - Class 3 – High Density Shell Hash with or without Oyster Clusters - Predominantly Category III and/or Category IV shell hash substrate with or without visible oyster clusters.
    - Class 2 – Low Density Shell Hash with Oyster Clusters - Predominantly Category I and/or Category II shell hash substrate with visible oyster clusters.
    - Class 1 – Low Density Shell Hash without Oyster Clusters - Predominantly Category I and/or Category II shell hash substrate without visible oyster clusters.
    - Class 0 – Featureless - Lack of visible shell hash and oyster clusters. Sand waves, sand ripples, or tunicate covered seafloor
  - Shell Hash Density Category
    - Category IV – 75-100% of the seafloor covered in oyster shell hash
    - Category III – 50-<75% of the seafloor covered in oyster shell hash
    - Category II – 25-<50% of the seafloor covered in oyster shell hash
    - Category I - >1-<25% of the seafloor covered in oyster shell hash
    - Category 0 – No shell hash, only silty mud, sand or sand with tunicates
  - Results 

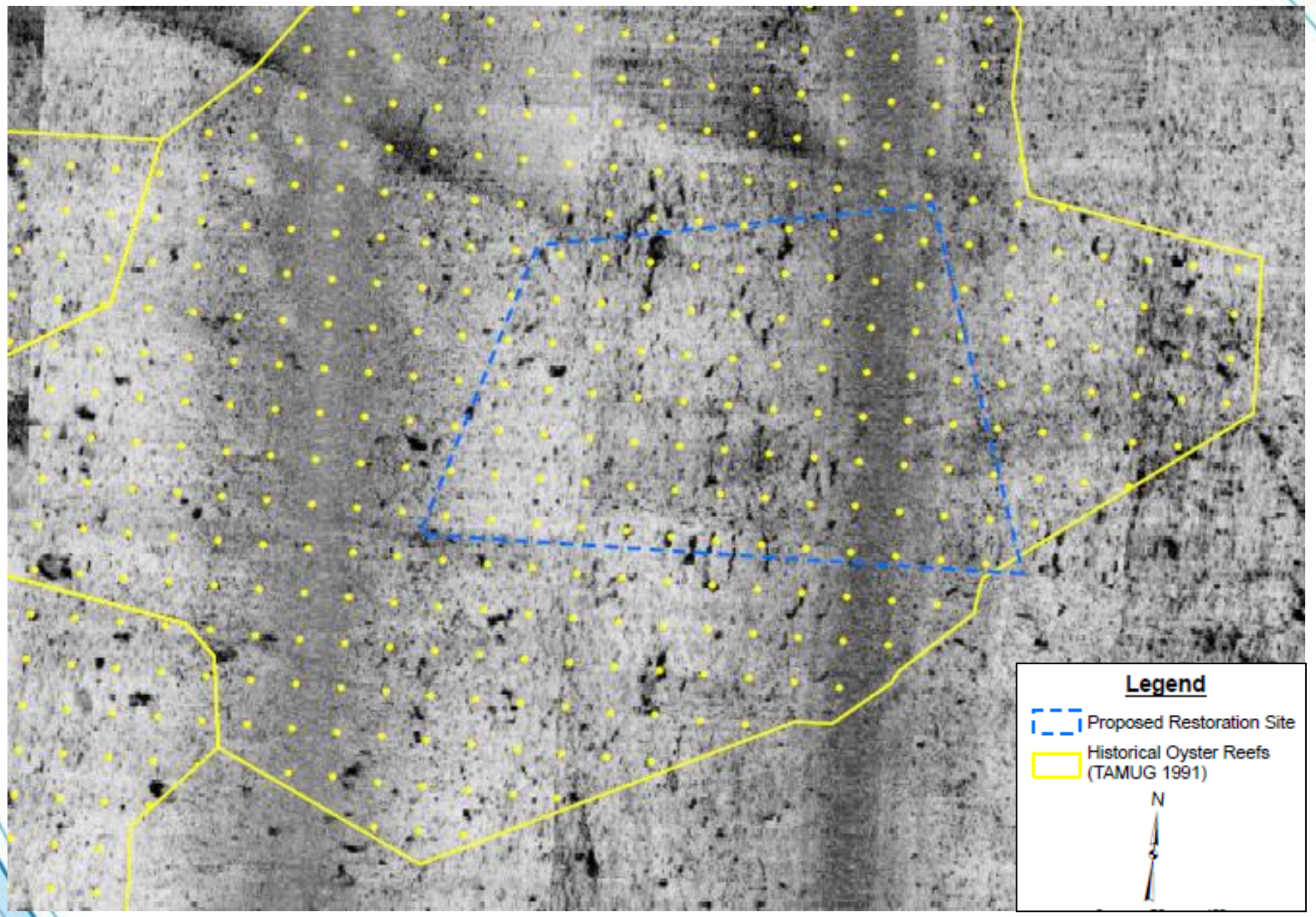
MITIGATION PLAN AND DESIGN – Permitting and Mitigation Plan

- 1.87 hectares (4.63 acres) of oyster reef would be impacted by BSC project
- Beneficial Use Group (BUG) coordination
  - TPWD, USACE, NMFS, TxGLO, USFWS, TCEQ and others
  - Long-standing group for HGNC project
  - Presented reef survey results, and consulted with TPWD and other agencies on desired location for oyster reef mitigation
- Fisher's Reef site identified
  - Roughly 30-acre site
  - Impacted by Hurricane Ike in 2008
  - Area of historical and recent formerly living, intact reef
  - This helped ensure location was in an area with appropriate water and oyster recruitment (e.g. larvae and currents) conditions
- Mitigation Plan – required for Sect 404 CWA Permit
  - Basic guidelines and criteria in consultation with TPWD
  - Place suitable cultch to provide 15.2 cm (6 in.) of relief above existing bay bottom
    - Clean limestone, crushed concrete rubble, or other suitable substrate deemed acceptable
    - Spread over 1.87 hectares (4.6 acres) → one-to-one acre impact mitigation
  - Plan drafted to meet the required 12 elements in 40 CFR 230.94 covering
    - Site selection and protection, baseline and credit determination, proposed plan
    - Mitigation objectives, monitoring, performance standards
    - Long-term & adaptive management, financial assurances

MITIGATION PLAN AND DESIGN – Mitigation Project Planning

- Two major constructability aspects for cultch planting
  - Sea floor foundation conditions dictate
    - How much short term settlement of cultch can be expected
    - Therefore how much material may be needed to produce desired relief
  - Water depth defines
    - Draft available for rock barges to transport material to site
    - Can affect efficiency of construction, since it affects how heavy barges can be loaded
- Original 12 hectare (30-acre) site identified by TPWD
  - Consisted of two rectangular areas straddling a harvesting restriction boundary
  - Identified this way primarily for future comparison of reef growth in areas subject to different harvesting pressure
- Existing bathymetry reviewed to ID smaller approximately 18-acre area
  - with depths of 1.7 m (5.5 feet) or greater
  - 1.8 m (6 feet) of depth would be ideal for loaded rock barge access, but no less than 1.7 m (5.5 feet) should be available to prevent unreasonable light-loading
  - This area was identified for foundational probing
- TPWD ID'd area as sedimented over 15.2 cm (6 inches)
- Therefore, soft, unconsolidated bottom >6 in. was expected

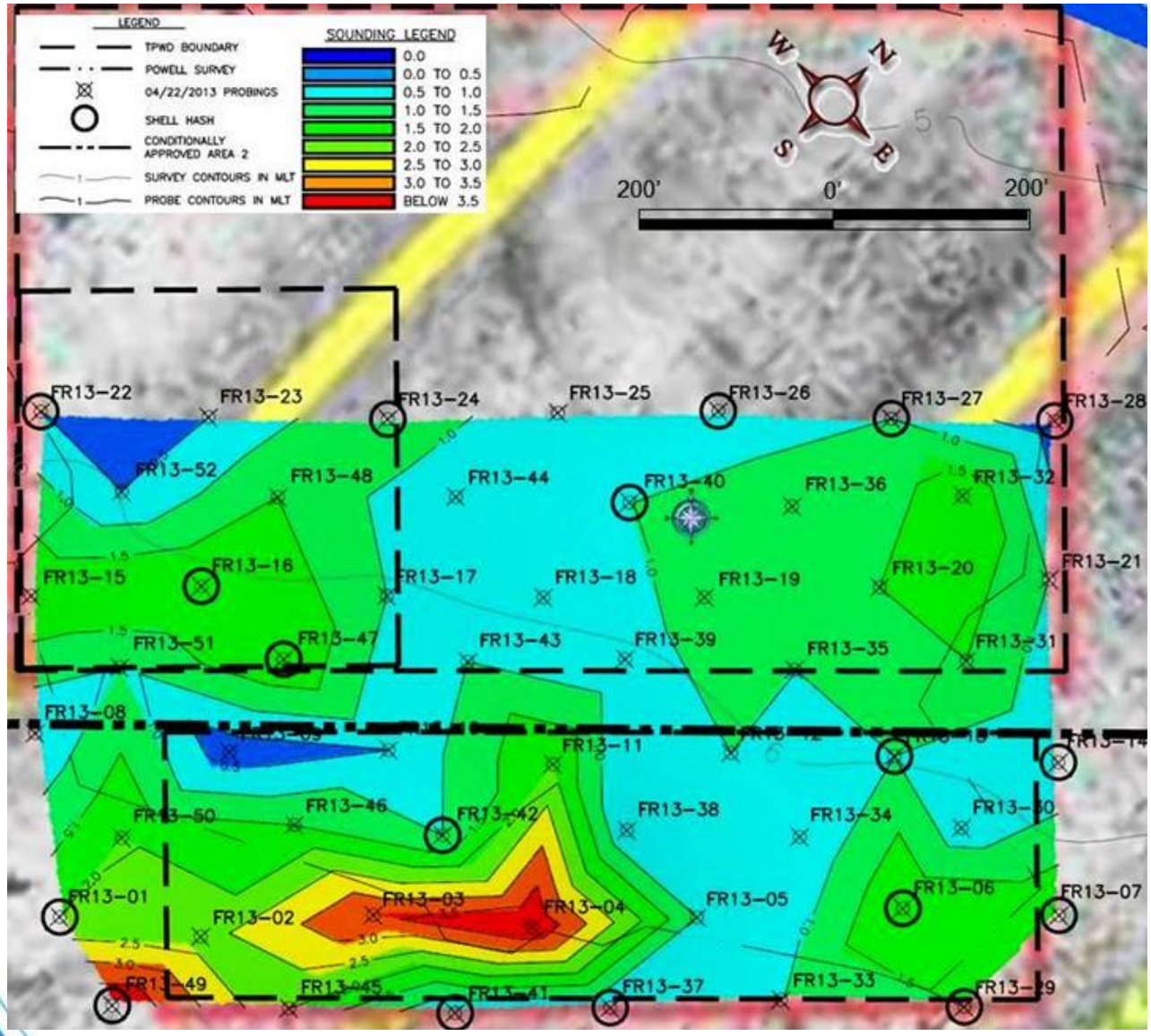
Fisher's Reef Preconstruction Side Scan Sonar



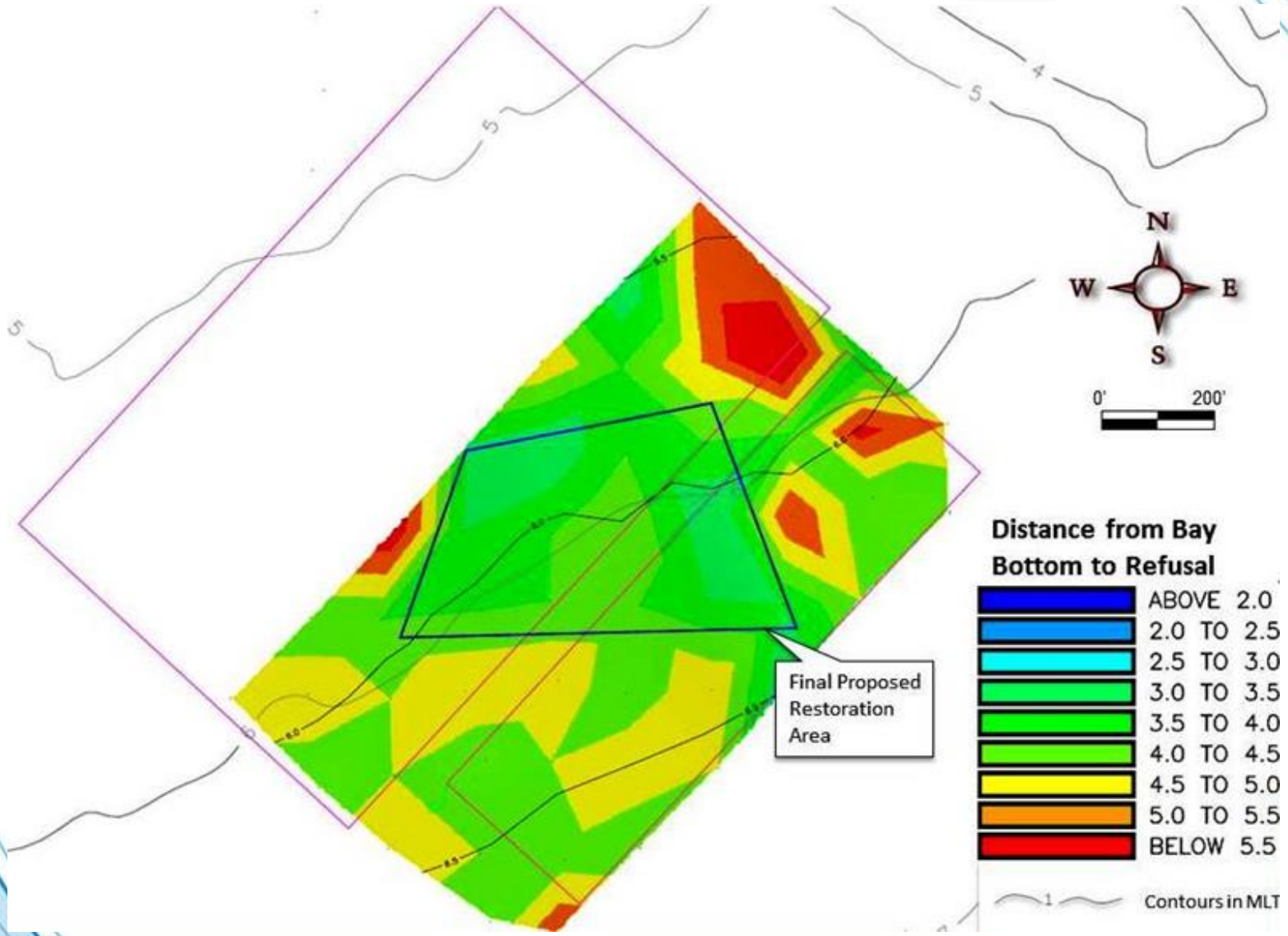
MITIGATION PLAN AND DESIGN – Mitigation Project Planning (continued)

- Sea floor probings done over target area
  - with standardized weighted rod
  - 50 probings evenly spaced over area at roughly 130 feet
- Three key elevations defined
  - Bay bottom – elevation at the surface of the sea floor
  - Weight-of-rod (WOR) – elevation at point where rod ceases penetrating under its own weight (no forcing)
  - Refusal – elevation at point where rod can be pushed no further manually
- Results
  - Most of area has $\geq$ 0.5 feet of WOR thickness, with much 1 foot or more
  - Corroborates TPWD's assessment of area having 6 in. or more of sedimentation
  - Distance to refusal $\geq$2.5 feet with most of the area from 3 to 4.5 feet
- Using these results and more detailed bathymetry, final footprint picked

Vertical Distance from Bay Bottom to WOR Material

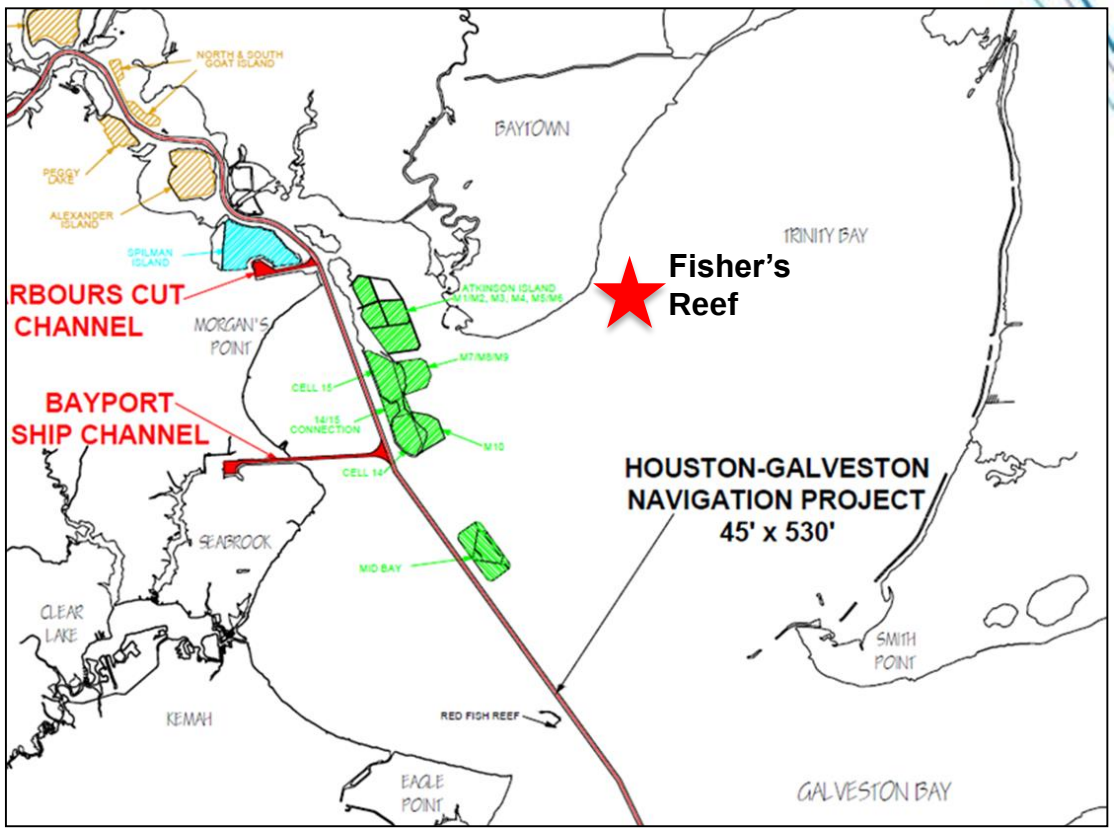


Vertical Distance from Bay Bottom to Refusal Material



MITIGATION PLAN AND DESIGN – Mitigation Project Planning (continued)

- Other factors considered
  - Material delivery routes
  - Equipment staging
    - Rock barges
    - Tugs
    - Offloading equipment
  - Construction timing
    - Catch spat peak



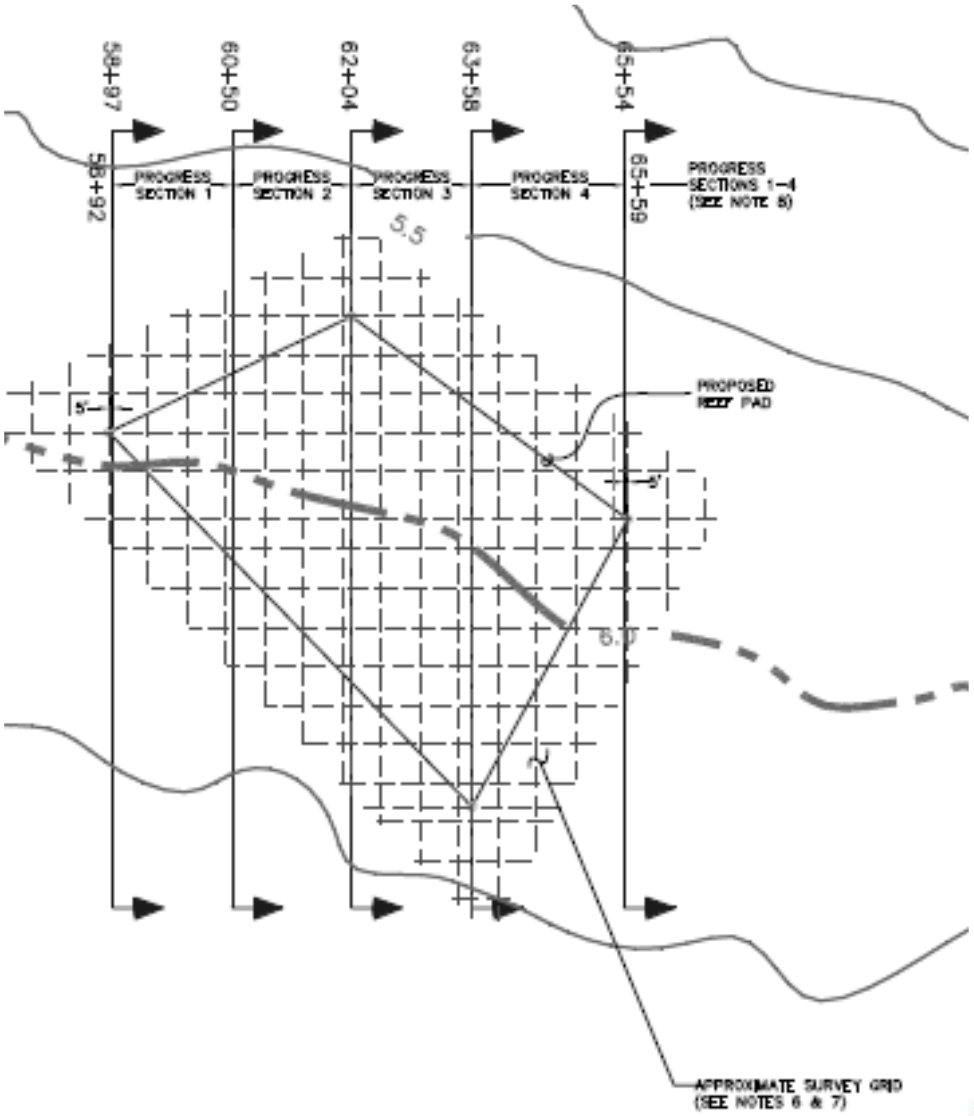
MITIGATION PLAN AND DESIGN – Plans and Specs

- Houston and Galveston Navigation Channels Project Oyster Mitigation
  - Successful construction and colonization in the Bay
  - Served as starting template for this effort
- Key Fisher's Reef Specs:
  - Provision of minimum of 6 inches of relief above the existing bay bottom
  - Maximum relief tolerance of 6 inches beyond the minimum relief
  - Specification of either
    - clean crushed limestone or crushed concrete
    - allowance of other materials to be considered, but only if approved and acceptable to TPWD and USACE
  - Cultch size gradation of ½ inch to 3 inches determined by ASTM Standard C136 and ASTM E11.
- Other key provisions
  - Progress surveys
  - Survey method and monumentation
  - Bulk dry density testing to get cultch density
  - Barge displacement readings to track tons placed
  - QA/QC cultch thickness layer probing

Hydrographic Progress Surveys

- Used to asses relief in progress so adjustments could be made due to variable foundation condition
- Odom Echotrac CV100 single frequency Echosounder operated at 200 kilohertz
- Survey lines spaced on a 15 m (50-foot) grid
- Four progress sections, each previous section resurveyed as new one reached, to detect changes in between

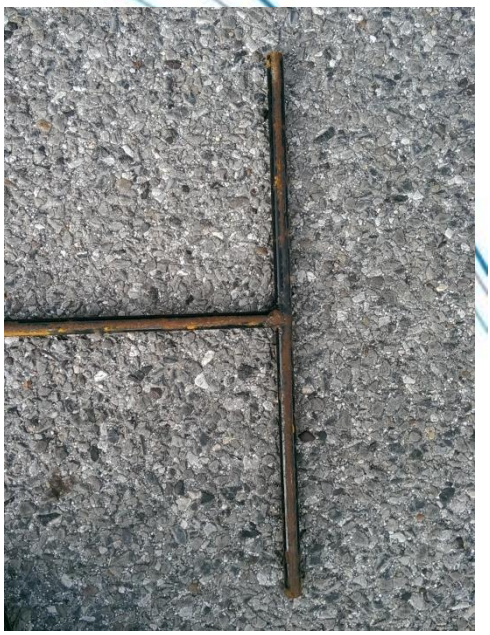
Progress Survey Sections



TON AUTHORITY

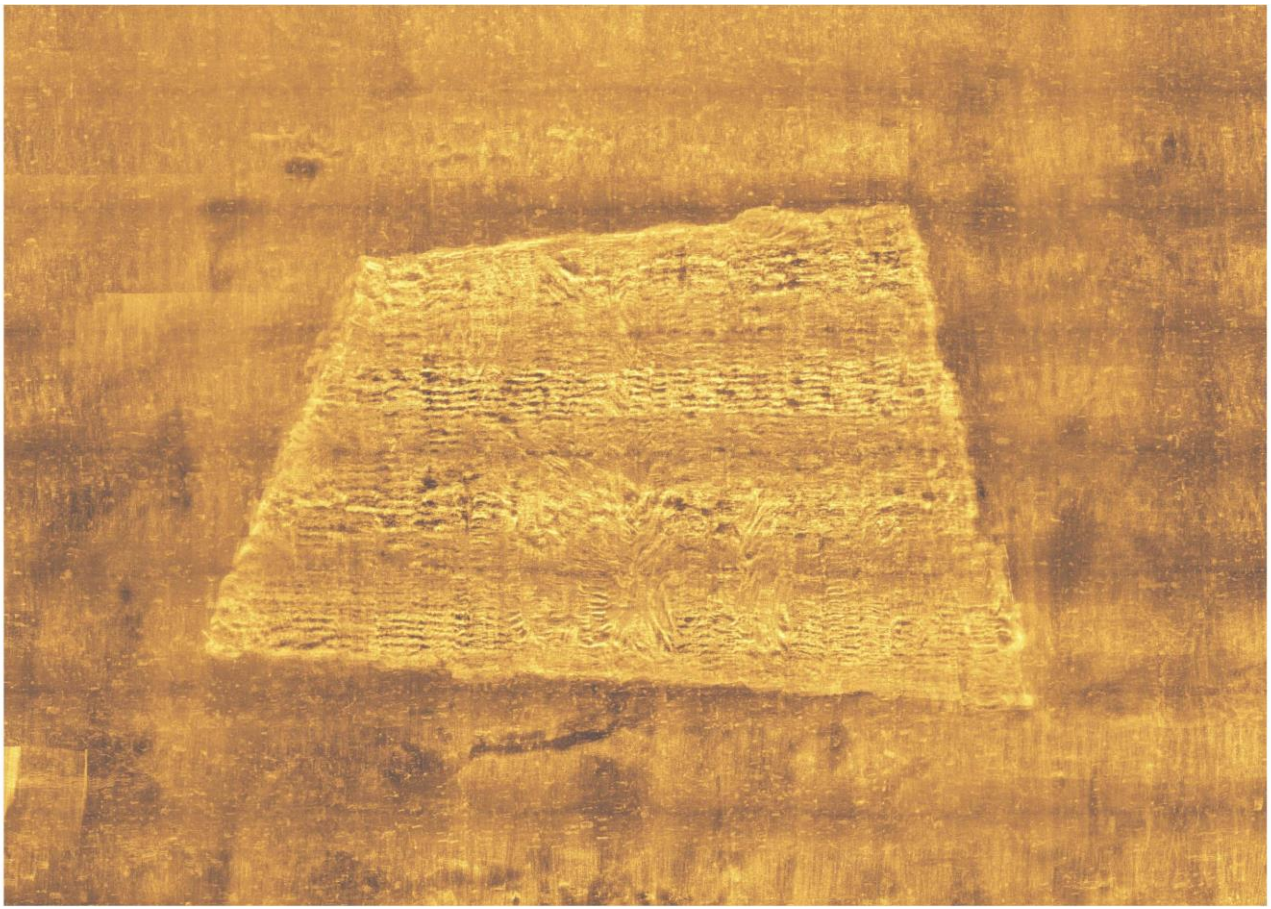
Thickness Probing Rod

- ½ inch steel smooth rod
- Welded handle
- Tip tapered by table grinder
- Alternate color taping every ½ ft
- Length determined by
  - Water depth over site & planned pad
  - How much survey boat will draft
  - Use avg. tide info at time of year
  - Ours was 10’ at top tape mark for ~6-8 ft of water depth
- Probing by:
  - Let probe drop to resting at top of cultch
  - Read mark at water
  - Take several small successive jabs penetrating cultch rock until hard impact not felt
  - Keep focus on tape marks during jabs
  - Note tape mark for jab that broke through to soft stuff
  - Practice to get hang of it
  - Repeat for a few readings within 10’
  - Take avg. and subtract from top of cultch = cultch thickness
  - ½ ft accuracy expected



Typical Construction Process

Side-scan Sonar of Constructed Reef



Construction Observations

- Cultch didn't exhibit as much short term settlement as anticipated
  - Areas of relief exceeding max tolerance were identified after 1st progress section
  - Settlement not really observed after 2nd progress survey
  - Old underlying reef may be influencing foundation strength
    - Presence of former reef shell in unconsolidated WOR material observed in probings
    - May be acting much like aggregate does to increase soil or concrete strength
- Areas exceeding max relief tolerance and below minimum relief identified
  - Most of it was over max tolerance
  - A few peripheral areas below minimum target relief
- Corrective action consisted of
  - grading with the excavator on areas of excess relief
  - addition of material to areas below the target minimum relief
- After field adjustments to placement and corrective action
  - some areas exceeding the max. remained, most 1 to 1.5 ft
  - though reduced in magnitude and extent
  - few small isolated areas just below minimum target relief
    - verified to at least have 6 inches of pad thickness
    - not a problem for providing exposed attachment sites
  - Areas coordinated with agencies to ensure no remaining concerns

Construction Observations (continued)

- Final barge readings → about 13,000 tons of material placed
  - Using average measured density, uniform thickness of 1.54 ft over 4.63 acres
  - Corroborates relief data
  - When using actual cultch density of 84 pcf, instead of 100 pcf used in specs,
    - estimated actual placement rate was closer to low end of range used in developing specifications
    - So, we were in range of planning numbers useed

Lessons Learned

- Progress surveys critical to
  - be aware of achieving target reliefs
  - providing opportunity for corrective action
  - before work accepted and construction demobilized
- QA/QC procedures come in handy
  - such as barge gaging and thickness probing
  - provided other lines of evidence for how much was being placed underwater that may help address construction issues
  - provided more direct evidence of how thick and how much cultch had been placed
- Explicit discussion or demonstration of proposed corrective action by prospective contractors during bid process recommended if
  - water depth matters and requires tolerances on maximum relief
  - and foundation conditions are variable or approximated
- If maximum tolerances or overplacement are of critical concern
  - and foundation conditions are variable and only qualitatively established
  - quantitative assessment of geotech properties paired with calculated bearing pressures of proposed materials would help reduce settlement uncertainties

Conclusion

- Oyster reef presence can affect project decision on channel widening
- Close and early coordination with principal authorities is key to getting clear and timely agreement to proper mitigation
- Side-scsan sonar and groundtruthing were invaluable to identifying extent over large area expediently
- Foundation probing is recommended in variable bottom conditions
- QA/QC checks on relief and placement rate help eliminate guesswork
- Mitigation is now in monitoring phase, which will involve oyster density quadrat surveys to ensure the expected colonization and eventual growth to a mature, productive reef is achieved