NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Geotechnical Exploration and Workflow for Scour and Erosion Risk Assessment

October 26, 2023

1:00 – 2:30 PM

NOVEMBER 2022 UPDATE

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP.

ENGINEERING RCEP
REGISTERED CONTINUING EDUCATION PROGRAM

AICP Credit Information

1.5 American Institute of Certified Planners Certification Maintenance Credits

You must attend the entire webinar

Log into the American Planning Association website to claim your credits

Contact AICP, not TRB, with questions

Purpose Statement

This webinar will describe the use of geophysical techniques for subsurface exploration and subsequent data analysis along with application for subaquatic characterization of historical and existing scour conditions.

Learning Objectives

At the end of this webinar, you will be able to:

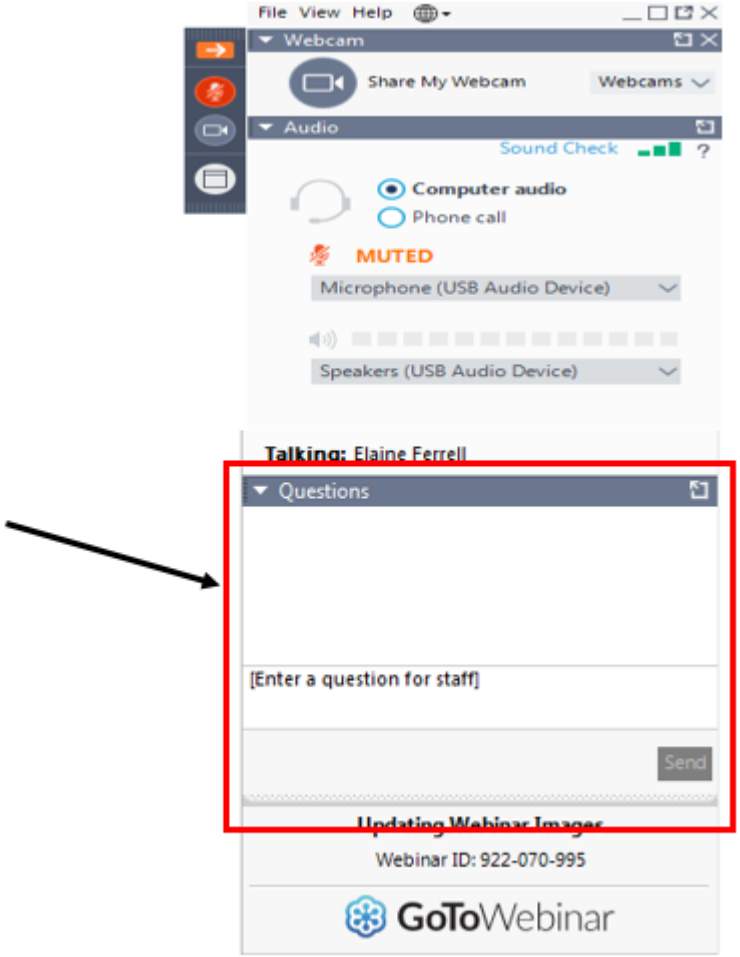
(1) Understand acoustic methods for shallow and surficial seabed soil characterization in scour and erosion risk assessment application

(2) Identify the benefits of integrated geophysical characterization

(3) Describe the advantages of an integrated geotechnical, geological, and geophysical data approach for a holistic understanding of subsurface conditions

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

Derrick Dasenbrock
derrick.dasenbrock@dot.gov
U.S. Department of Transportation
Federal Highway Administration

Laura Quigley
laura.quigley@seequent.com
SEEQUENT

Dr. Nina Stark
nina.stark@ufl.edu
UF Herbert Wertheim College of Engineering
Engineering School of Sustainable Infrastructure & Environment
UNIVERSITY of FLORIDA

Matt Art
matt.art@e4sciences.
e4sciences

NATIONAL ACADEMIES Sciences Engineering Medicine

Application of Low- to High-Frequency Acoustic Methods for Seabed Characterization regarding Scour and Erosion Risk Assessment

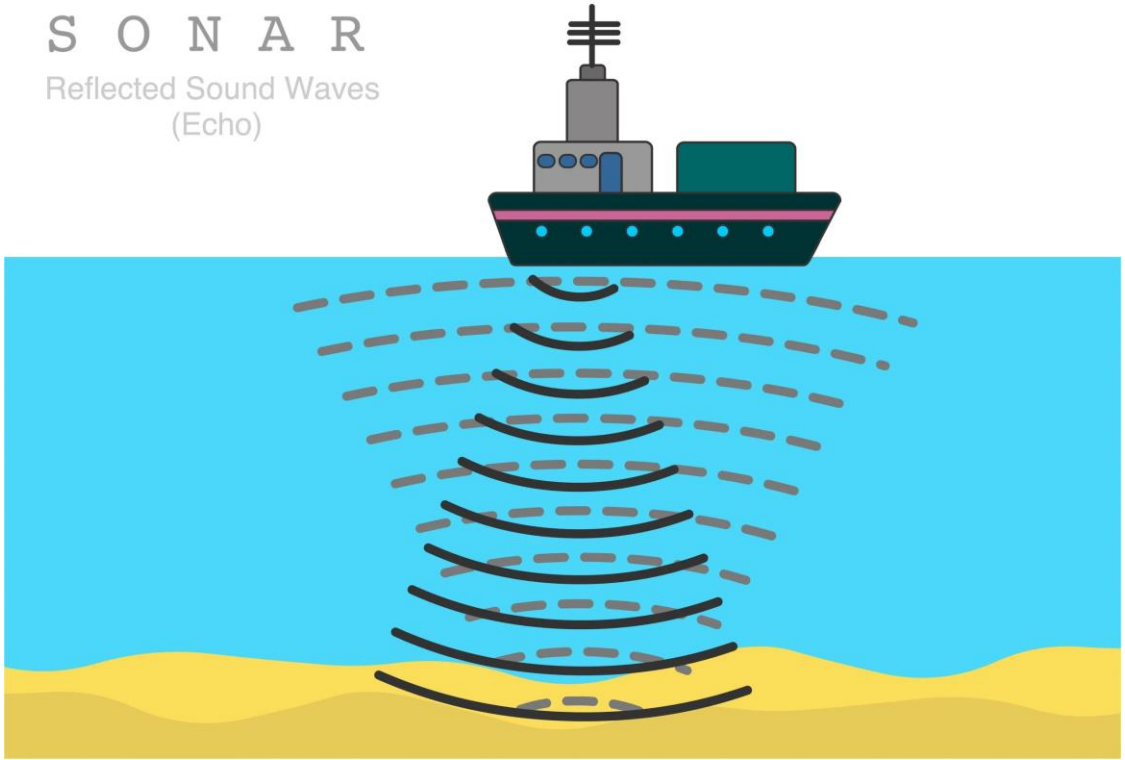
Nina Stark
nina.stark@essie.ufl.edu

UF Herbert Wertheim College of Engineering
Engineering School of Sustainable Infrastructure & Environment
UNIVERSITY of FLORIDA

Assessment/monitoring goals for erosion and scour

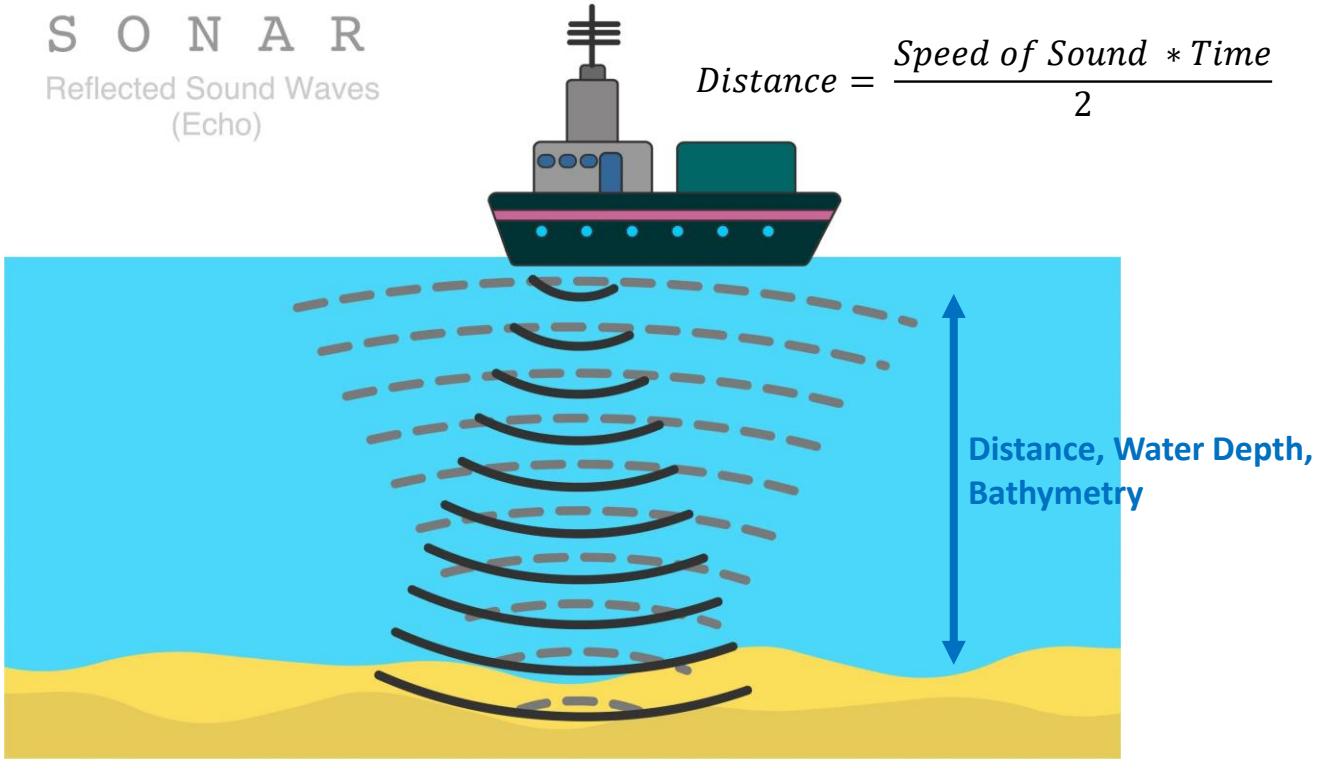
- **Elevation change or scour hole depth**
- **Mapping of scour hole extent, erosion/deposition features, possible bedforms, mitigation measures, and debris**
- **Characterization of sediment type and properties**
- **Geomorphological setting**
- **Hydraulic conditions (not included here but not less important!)**

Sonars for Seabed Characterization



https://www.americanoceans.org/facts/what-is-sonar/

Sonars for Seabed Characterization



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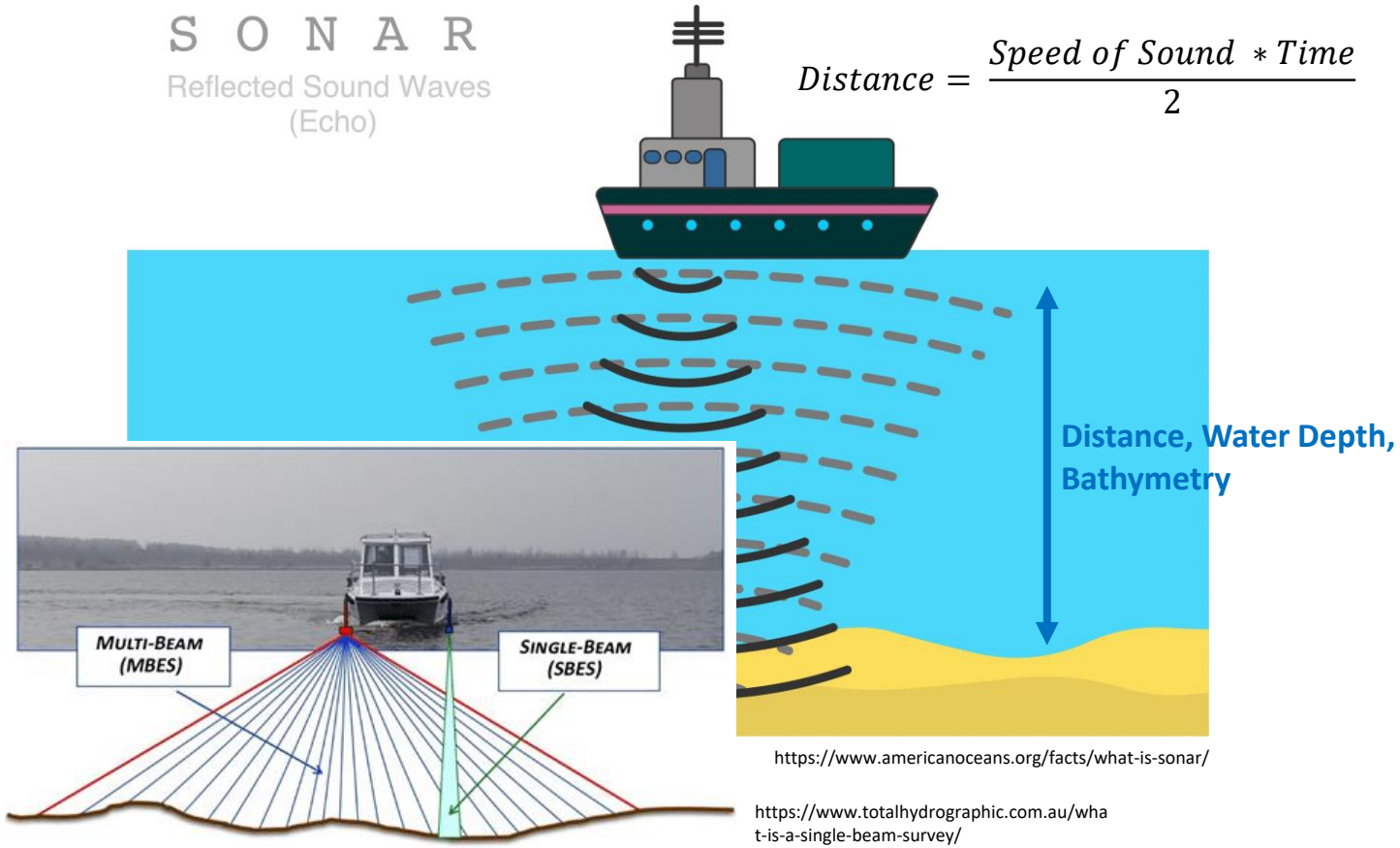
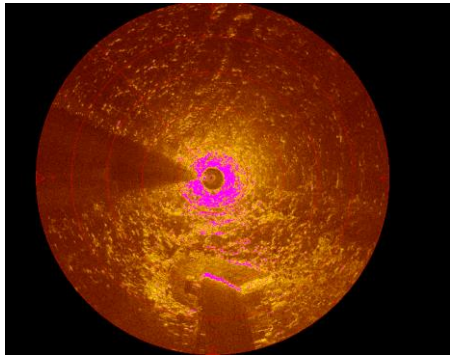


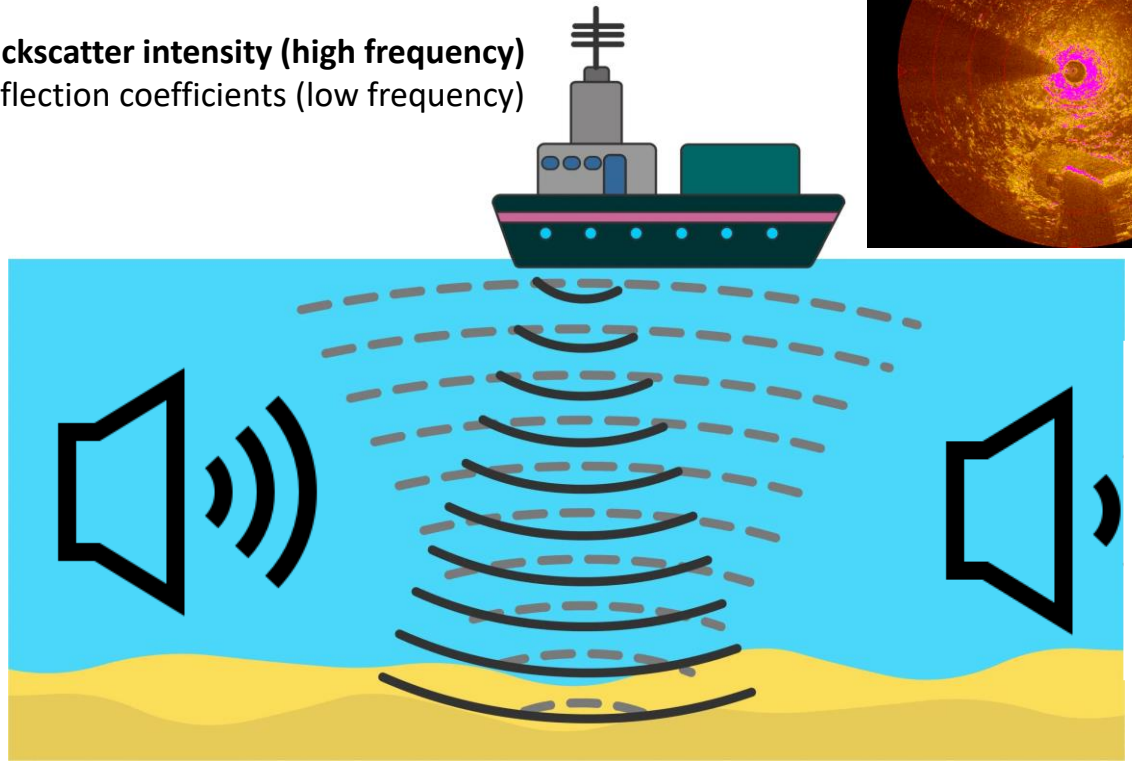
https://www.americanoceans.org/facts/what-is-sonar/

https://www.totalhydrographic.com.au/what-is-a-single-beam-survey/

Sonars for Seabed Characterization

Backscatter intensity (high frequency)
Reflection coefficients (low frequency)





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Sonars for Seabed Characterization

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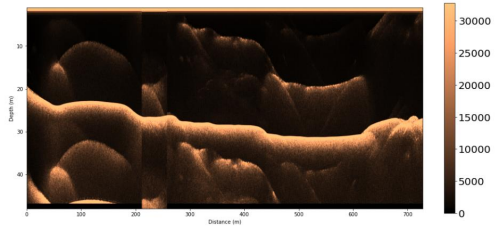

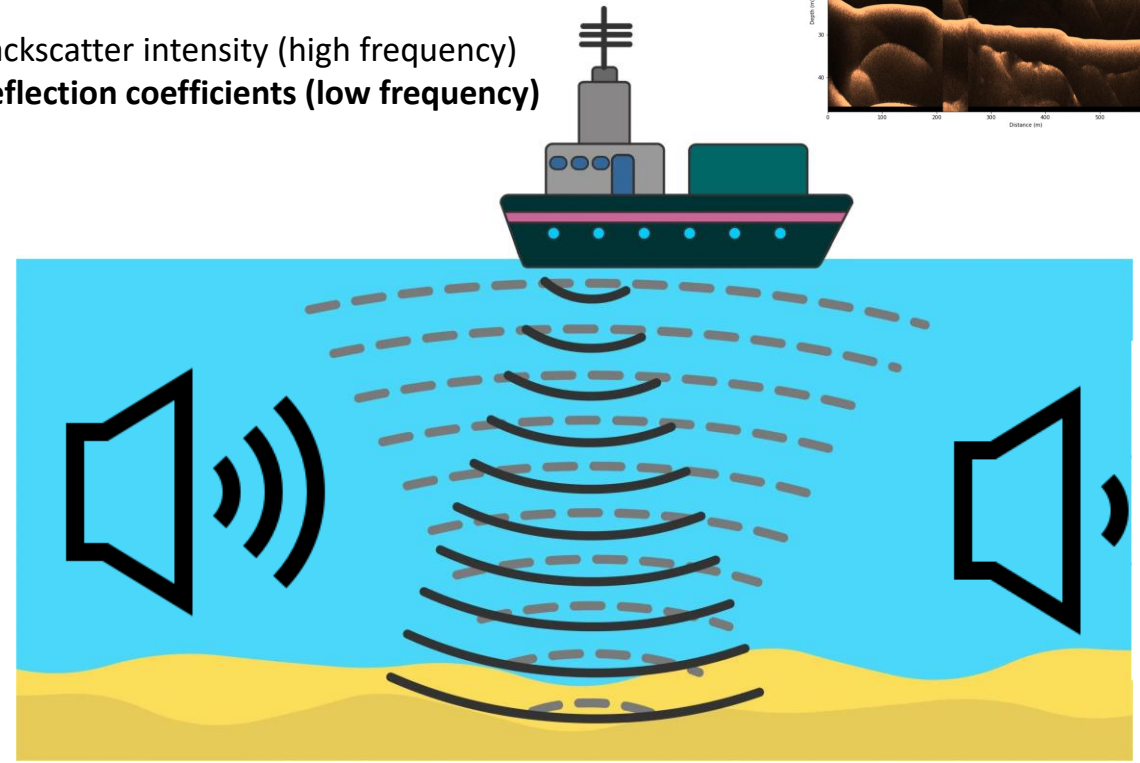

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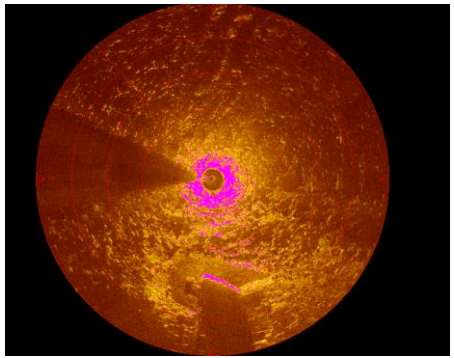
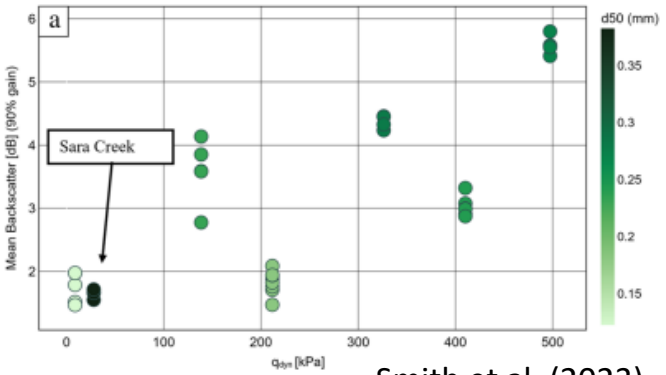
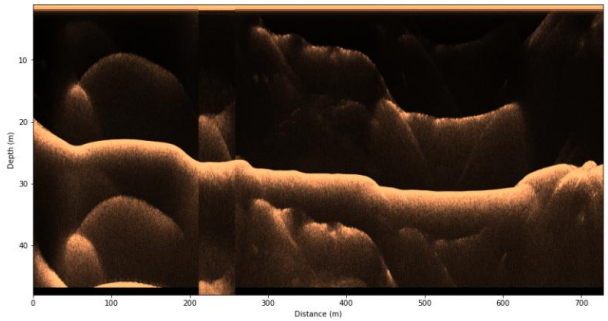
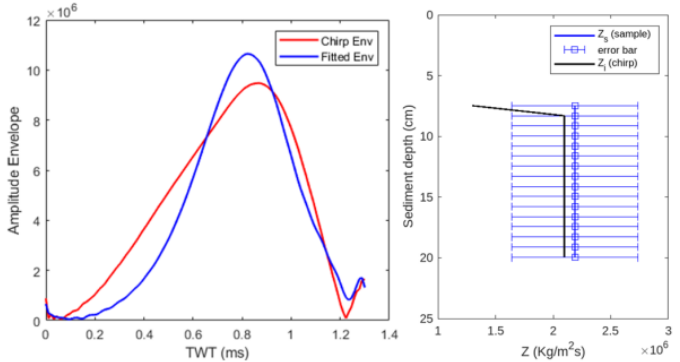




Smith et al. (2023)





Jaber et al. (in review)

Deployment platforms

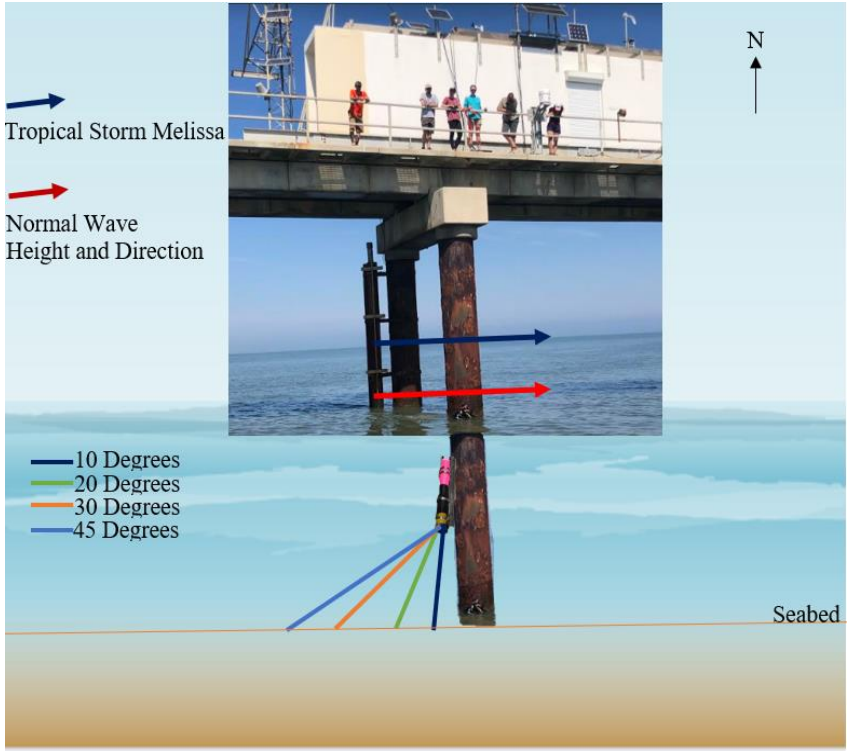
- **boat**

Deployment platforms

- **Boat**
- **Remotely controlled/autonomous surface/underwater vehicle**

Deployment platforms

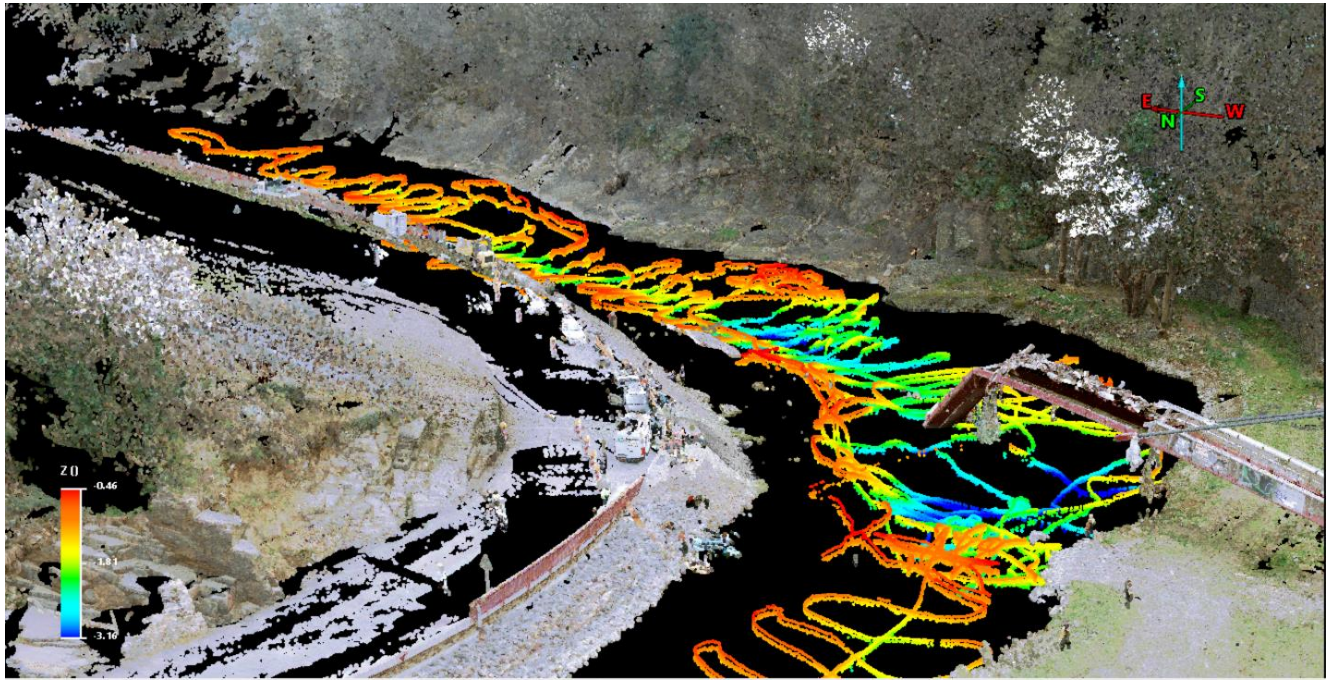
- **Boat**
- **Remotely controlled/autonomous surface/underwater vehicle**
- **Fixed on infrastructure systems**



Deployment platforms

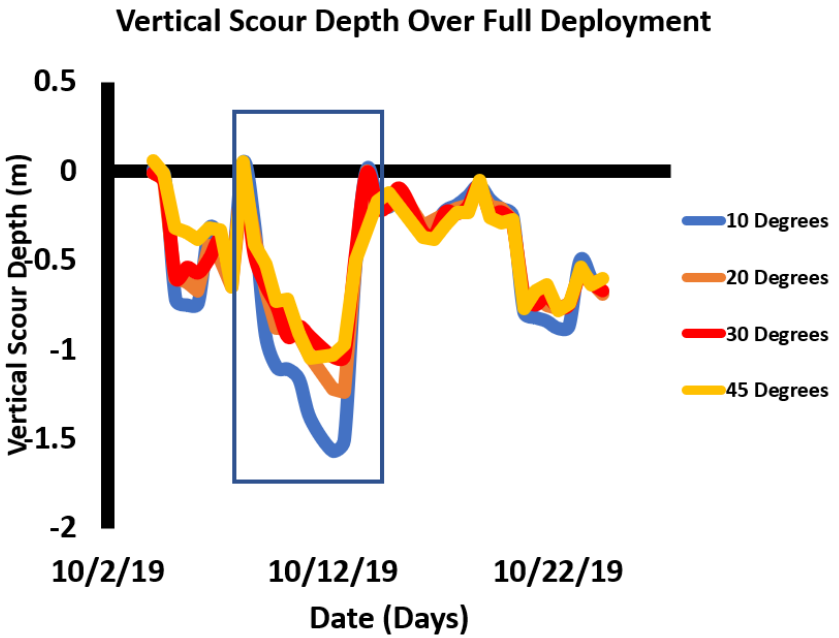
- **Boat**
- **Remotely controlled/autonomous surface/underwater vehicle**
- **Fixed on infrastructure systems**
- **Placed on seabed**

Data Products: SBES



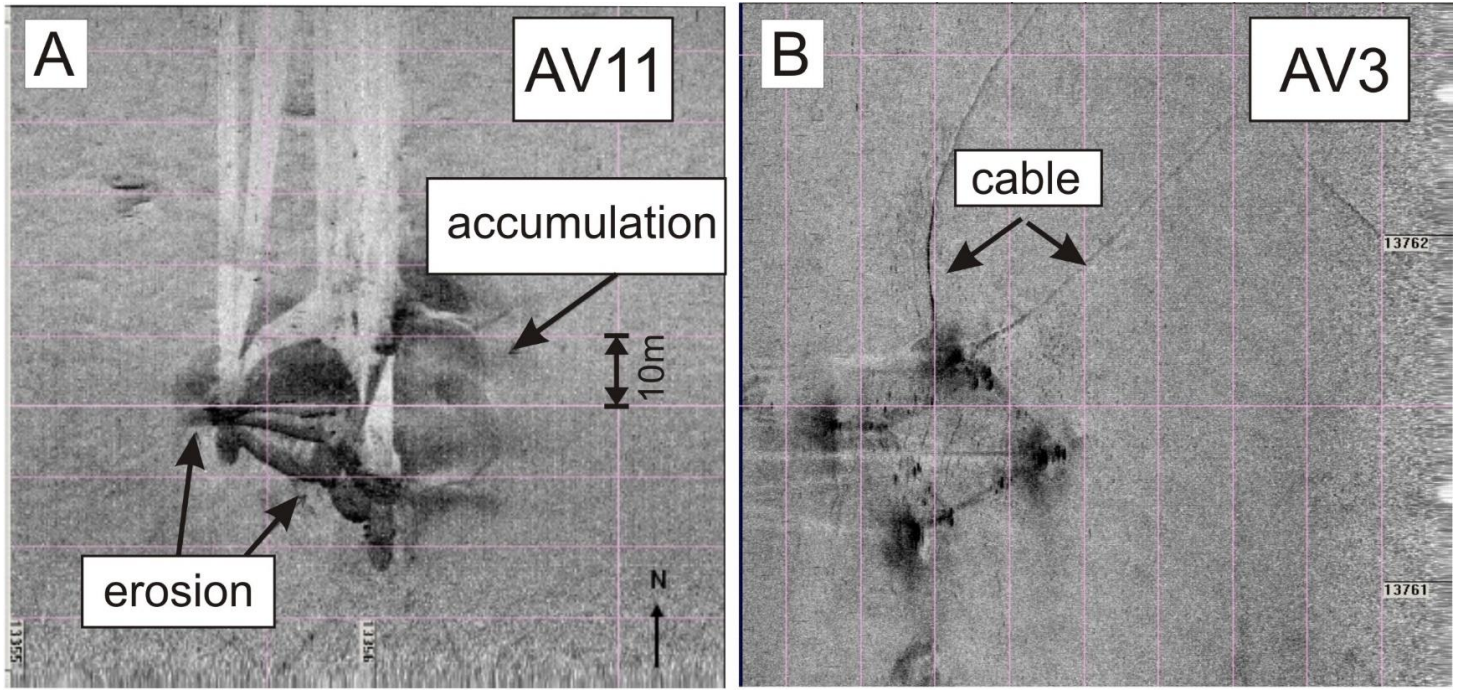
Stark et al. (2023)
Image Courtesy by UW NHERI RAPID

Data Products: Scour Monitor (4-SBES)

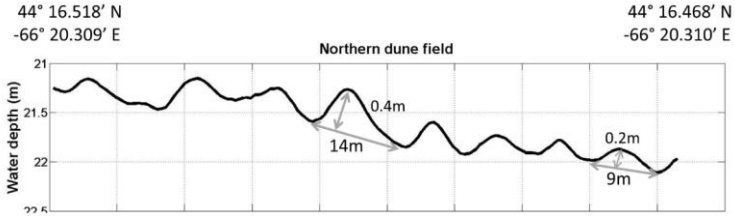


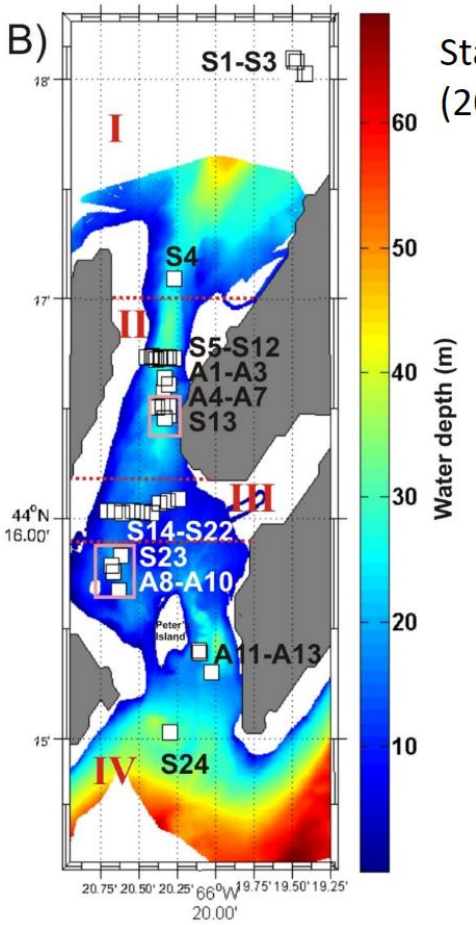
Popelka et al. (2020)

Data Products: MBES



Data Products: MBES

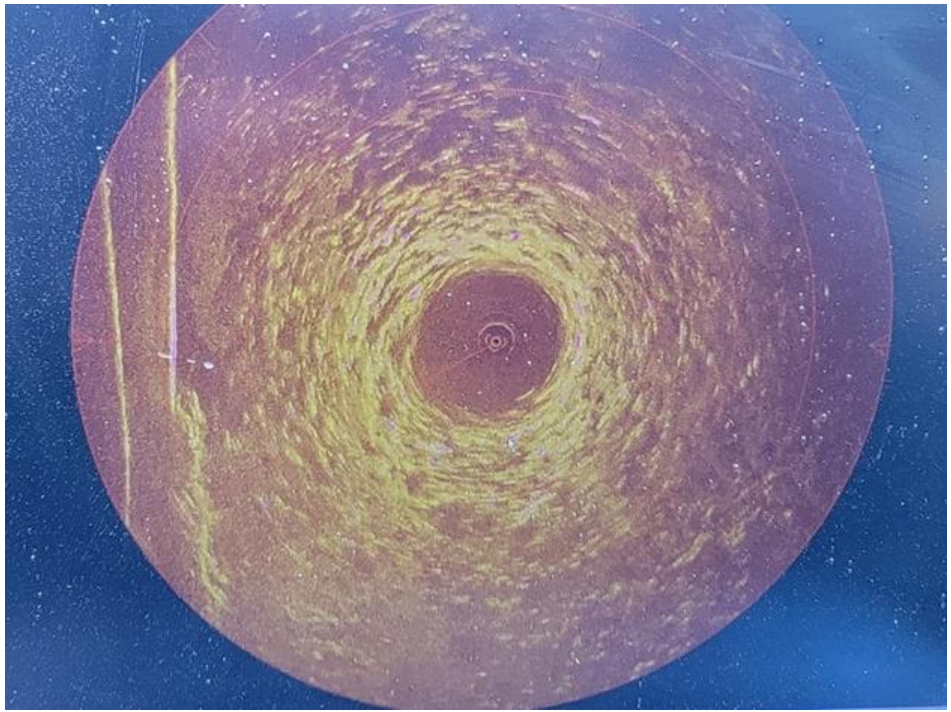




Stark et al. (2013)

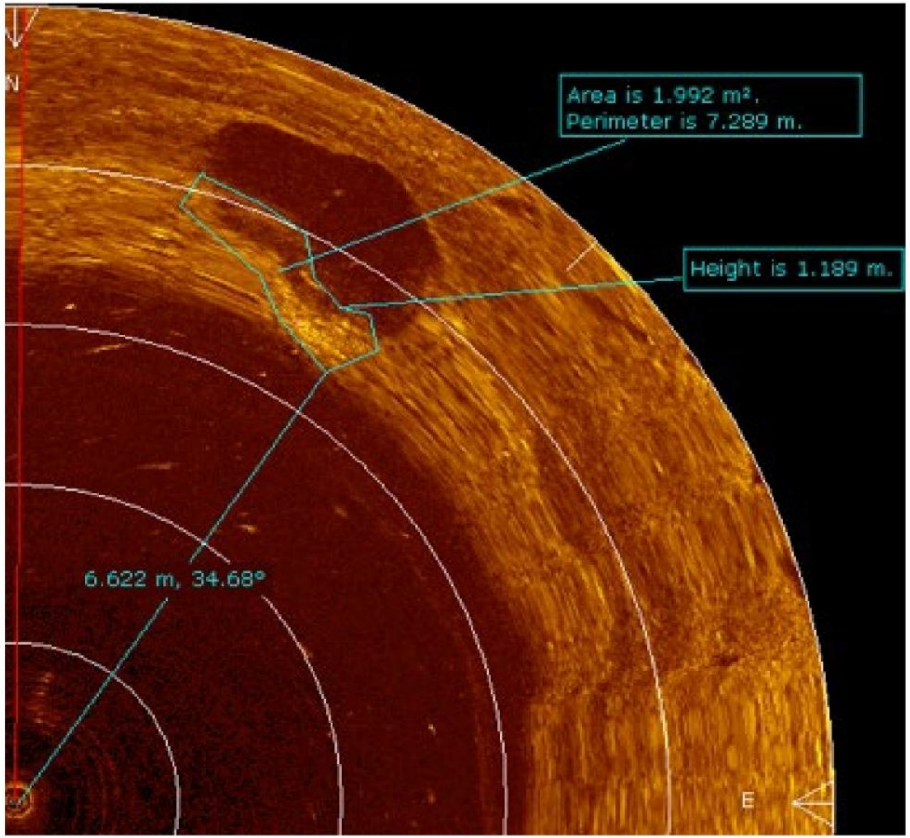
Grand Passage, NS

Data Products: Side Scan Sonar



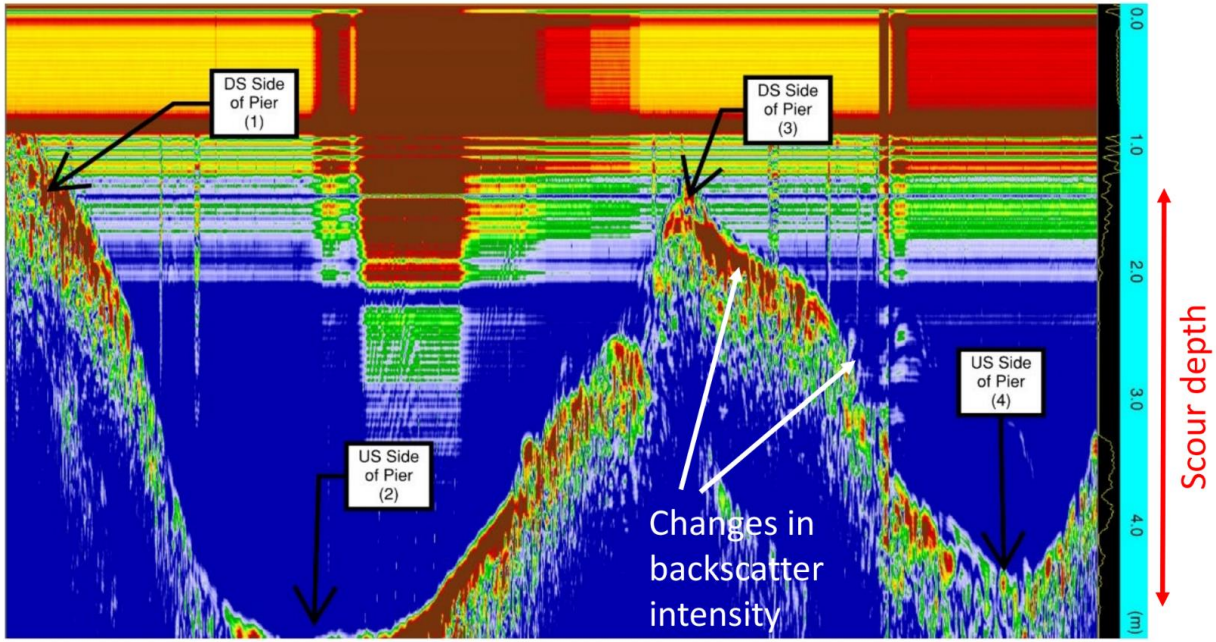
Stark et al. (2023)

Data Products: Side Scan Sonar



Stark et al. (2020)

Data Products: Chirp Sonar



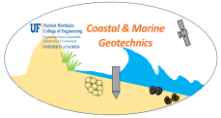
Stark et al. (2020)

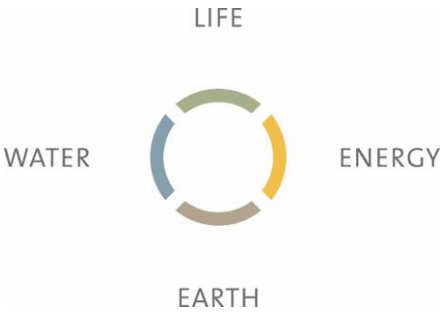
Concluding remarks

- Geoacoustic surveying is a common technique for offshore environments and new technologies enable deployment in ultra-shallow (< 1m) water environments more and more.

- It can serve
  - Bathymetric mapping (scour hole depth/ elevation change)
  - Imaging of the seabed (map erosion/deposition/scour features or map debris and mitigation feature placement)
  - Sediment classification (identify dominant sediment type and changes in deposit types)
  - Scanning into the seabed (stratigraphy of native layers, deposit thickness, buried features)

- It is essential to identify the appropriate tool (and settings!) for the desired outcome.



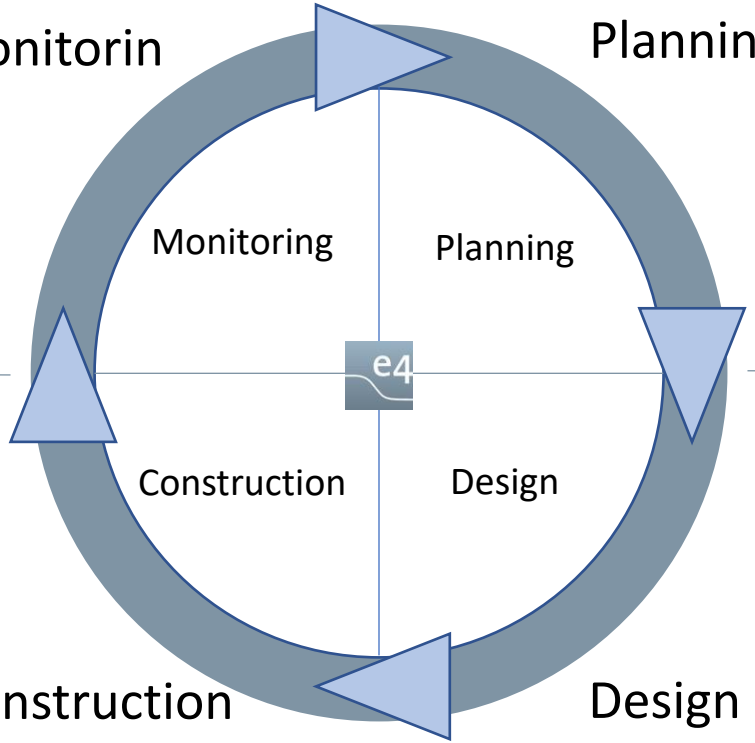


Marine Geo-investigations – Scour, Stratigraphy, and Structural inspection

Matthew Art
e4sciences, LLC
(203) 820-7320
(203) 312-4943
matt.art@e4sciences.com

Integrate Geophysics into Engineering Lifecycle

- Assess condition
- Monitor behavior of asset
- Change over time
- Monitor geomorphology
- Objective measurement vs. subjective evaluation



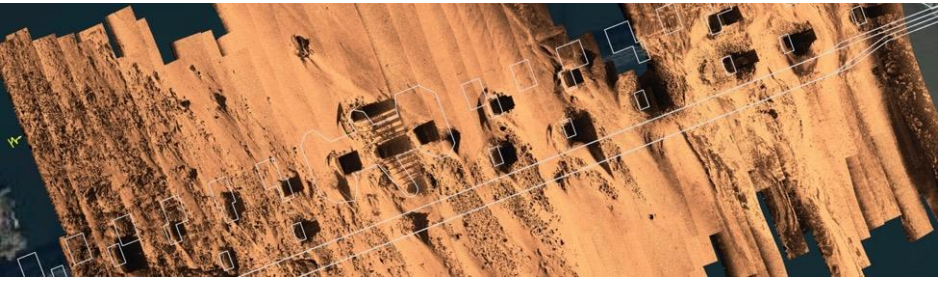
- Broad area subsurface characterization
- Anticipated conditions
- Primary and Alternative analysis
- Optimize geotechnical subsurface investigations

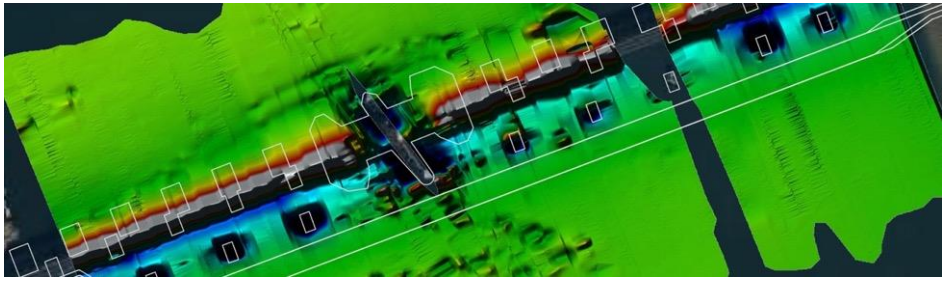
- Quality Assurance / Quality Control
- Locate obstructions
- Delineate geo-hazards
- Characterize unexpected conditions
- Track progress
- Produce as-builts

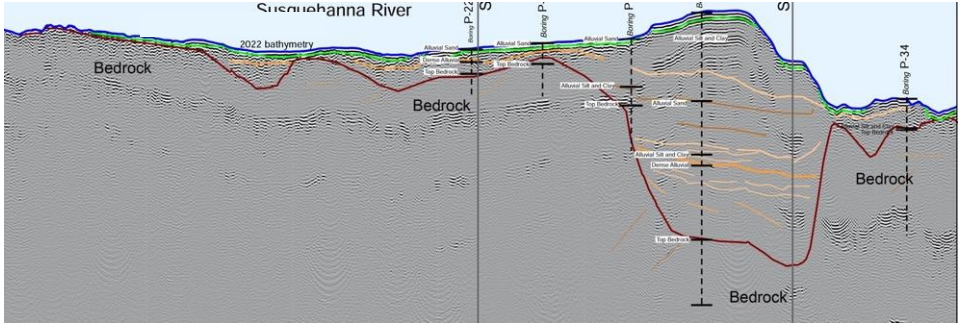
- Relic infrastructure
- Delineate geo-hazards
- Locate obstructions
- Refine alternatives
- High-definition subsurface characterization
- V_s for seismic design
- Optimize means and methods

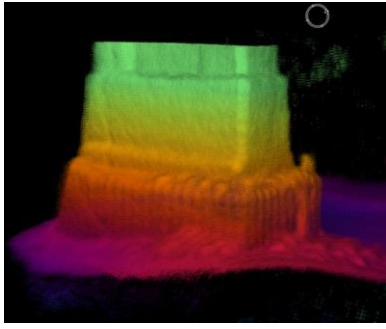
Data solutions - From spire to foundation

Data solutions - From spire to foundation





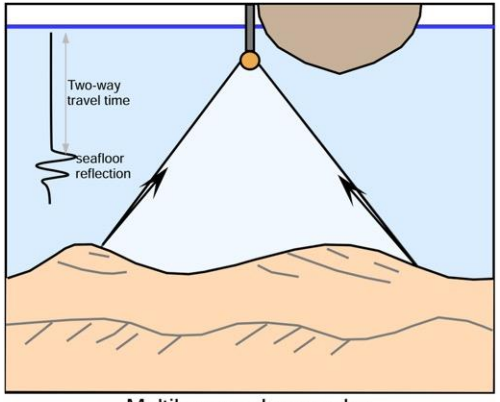




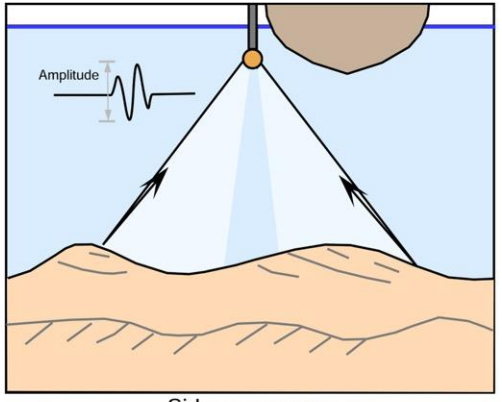
Multi-spectral, multi-frequency measurements

- Sonar
  - Phase
  - Amplitude
- Seismology
  - SBP
  - S-UHRS
  - Parallel Seismic
- Magnetic Field
  - Magnetometry
  - Gradiometry
  - Resistivity
- Optical
  - LiDAR
  - Photogrammetry

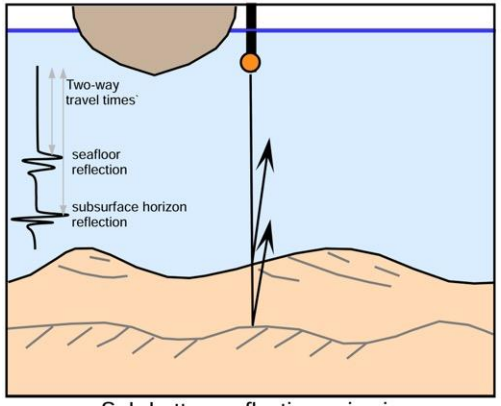
Physical Confirmation



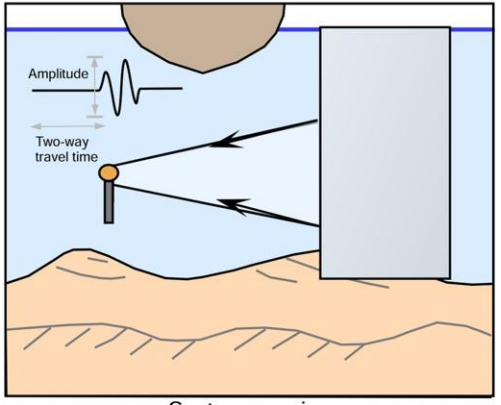
Multibeam echosounder



Side-scan sonar



Sub-bottom reflection seismic

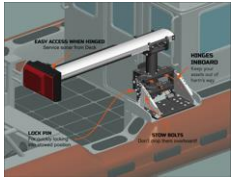


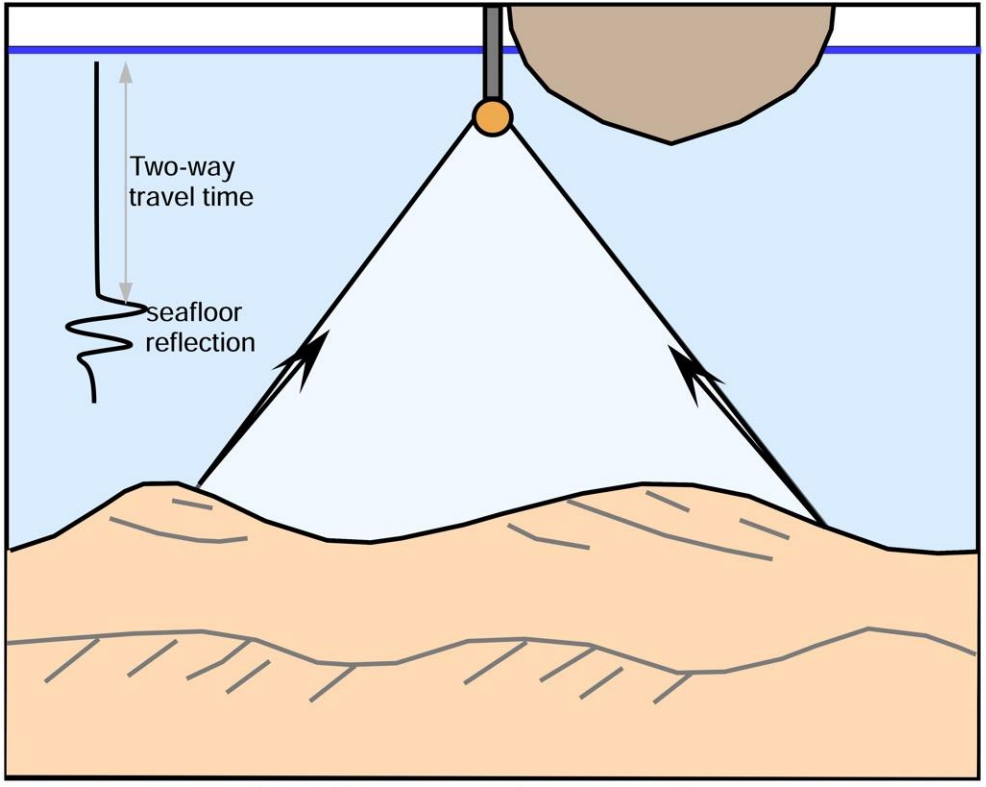
Sector scanning

Measurements

Sonar

- **Phase**
- Amplitude



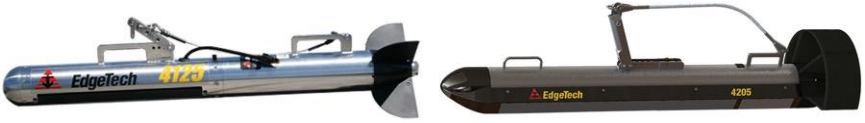


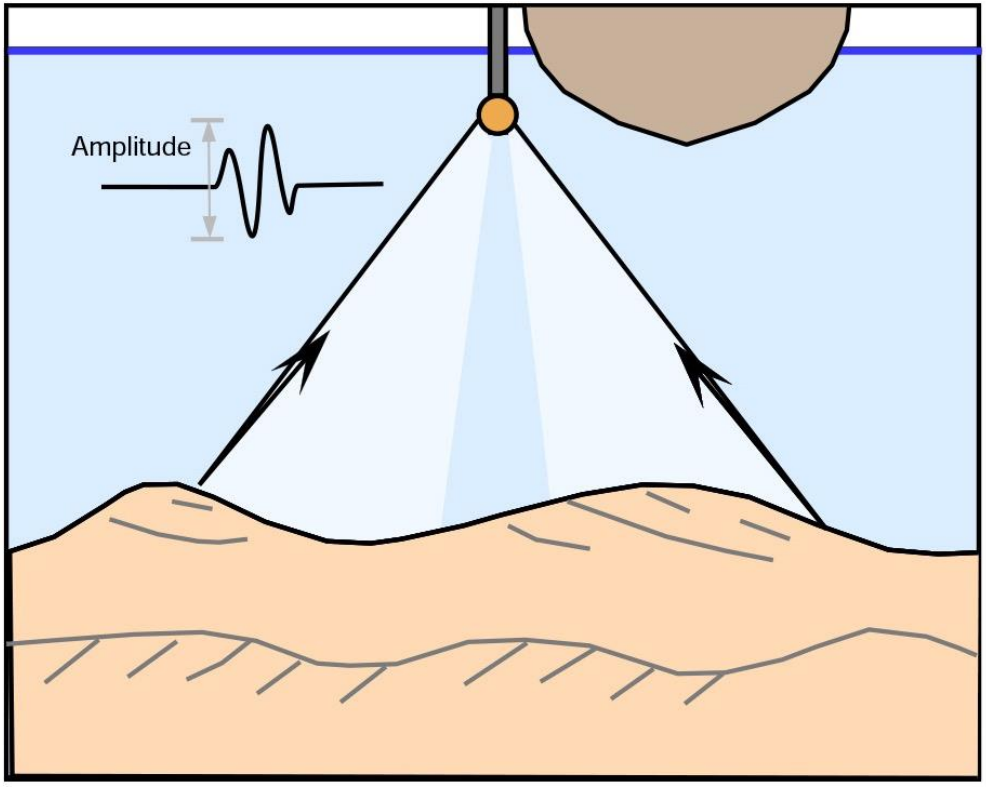
Multibeam echosounder

Measurements

Sonar

- Phase
- **Amplitude**



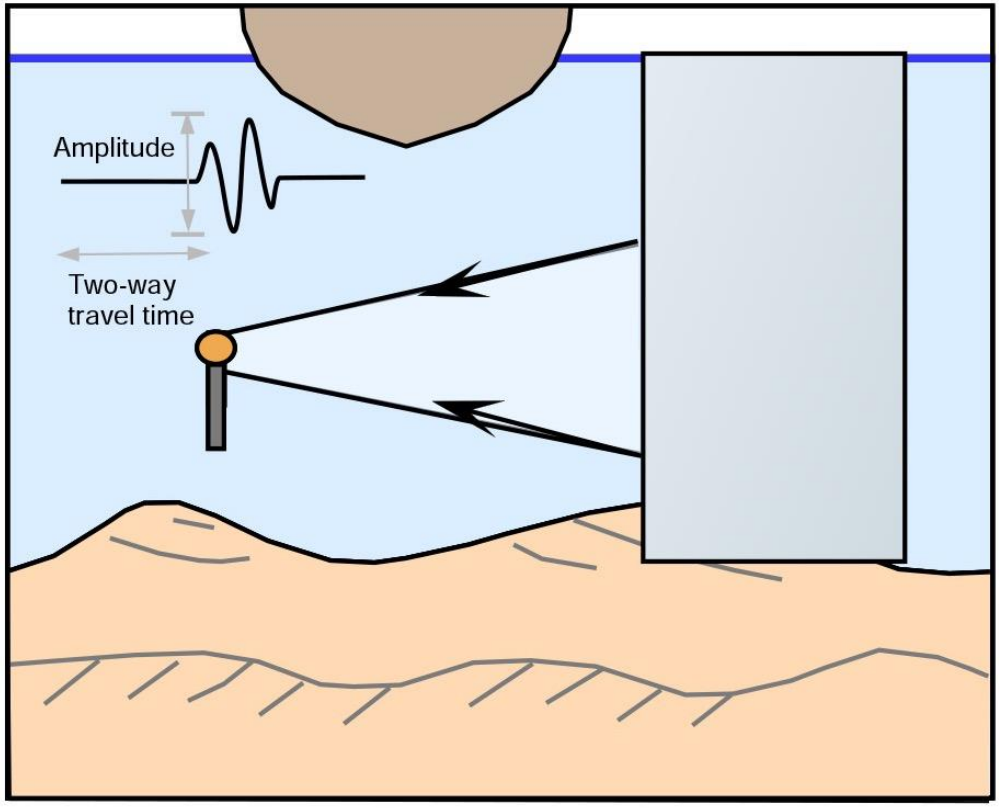


Side-scan sonar

Measurements

Sonar

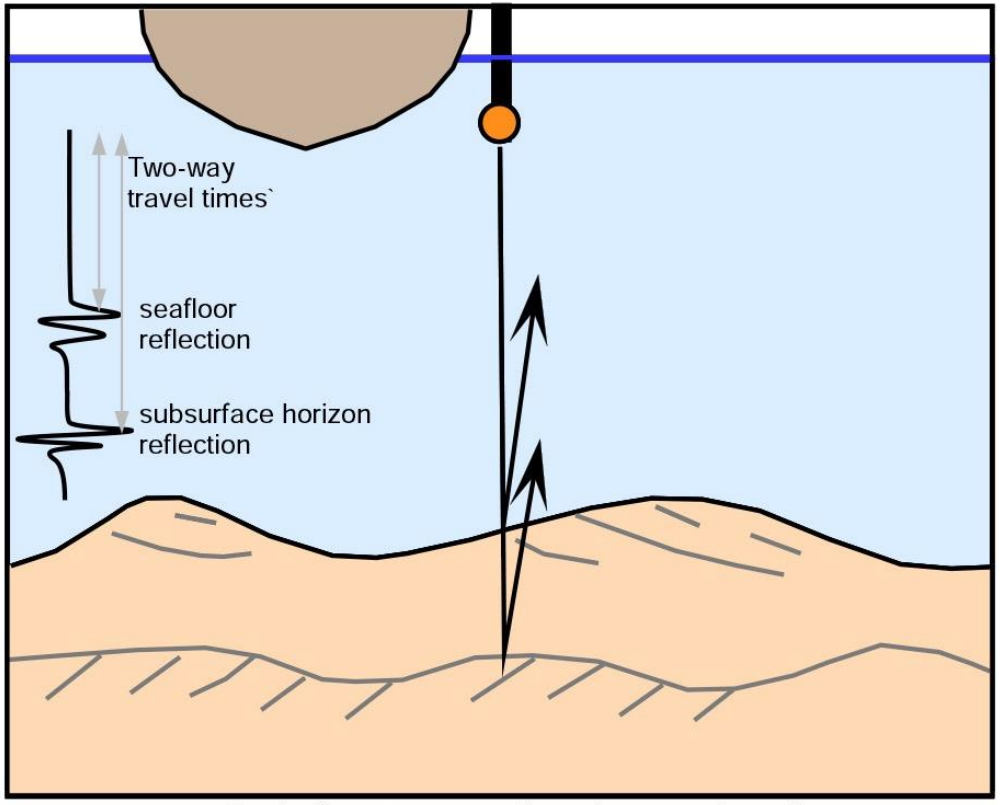
- Phase
- **Amplitude**



Sector scanning

Measurements

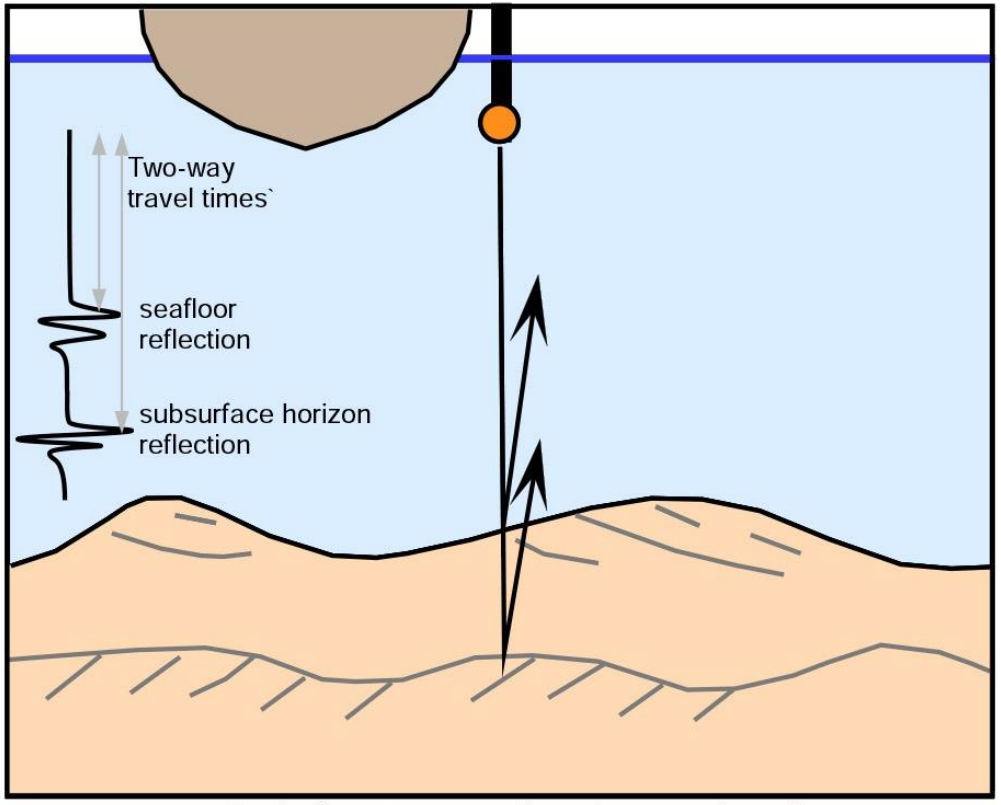
Seismology
- **SBP**
- S-UHRS



Sub-bottom reflection seismic

Measurements

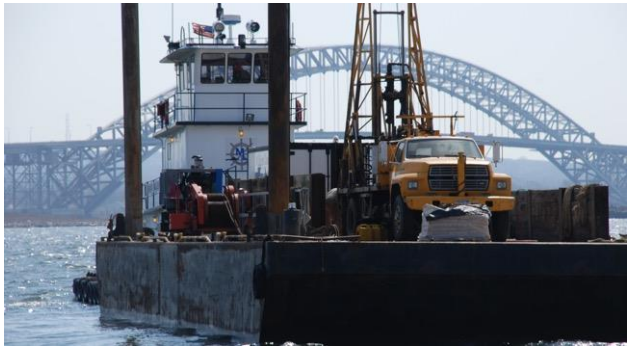
Seismology
- SBP
- **S-UHRS**



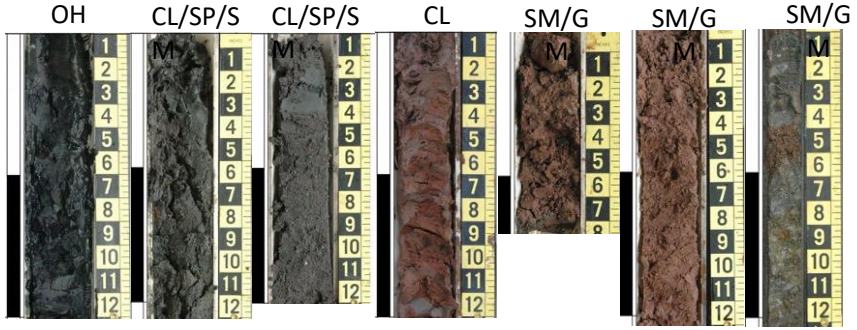
Sub-bottom reflection seismic

Sampling

- Sediment cores – SPT, Vibracore, drop samples
- Environmental sampling
- CPT
- SPI imagery

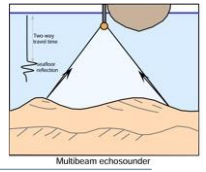


Representative NE Harbor Samples

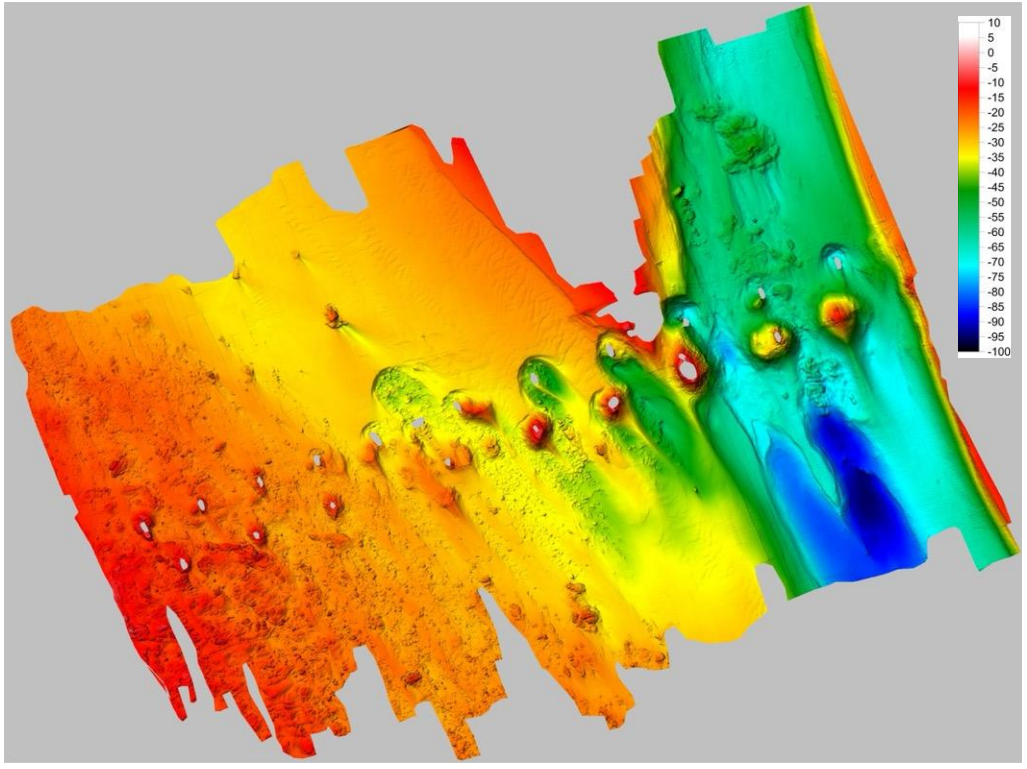


Vessels

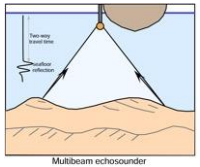
Multibeam bathymetry



- X,Y,Z Bathymetry surface map
- 1 ft by 1ft grid
- Coordinates and datums tied to project systems
- Spectral color scale (red high, blue low)
- Mapping the geometry of the bedforms and bottom features
- Boulders
- Sand waves
- Scour
- Trailing bars
- Exposed rock outcrops

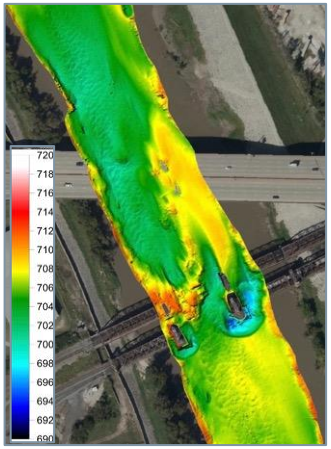


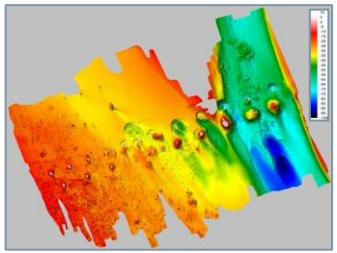
Multibeam bathymetry



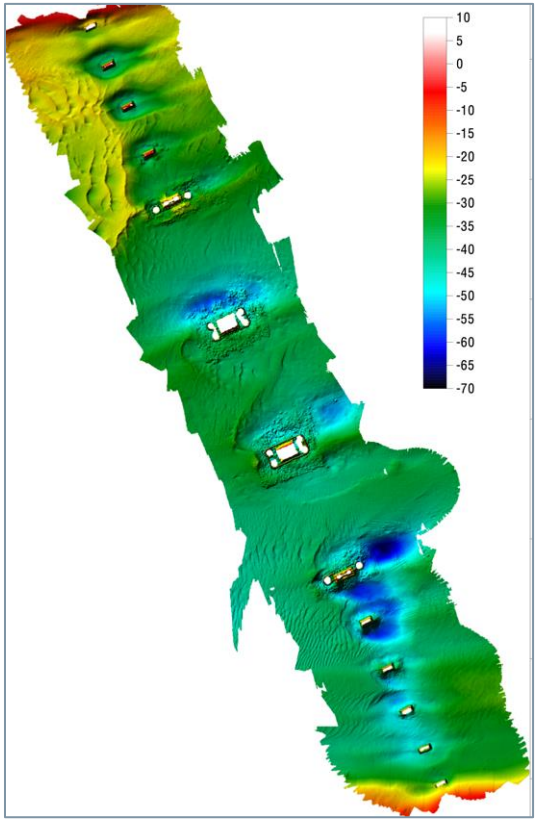
Multibeam echosounder

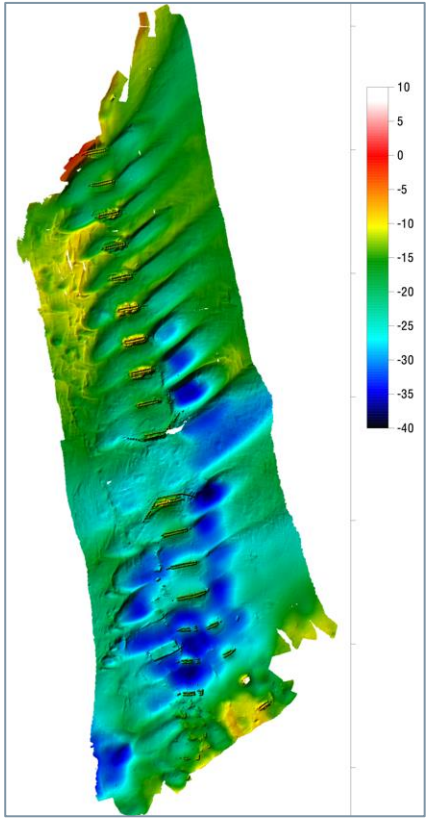
- Every bridge complex is different
- Coastal, estuarine, riverine
- Deepest bathymetry is not necessarily the deepest scour, scour is a dynamic and cyclical process.
- Peak scour not recorded
- Snapshot in time





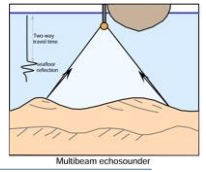
Riverin



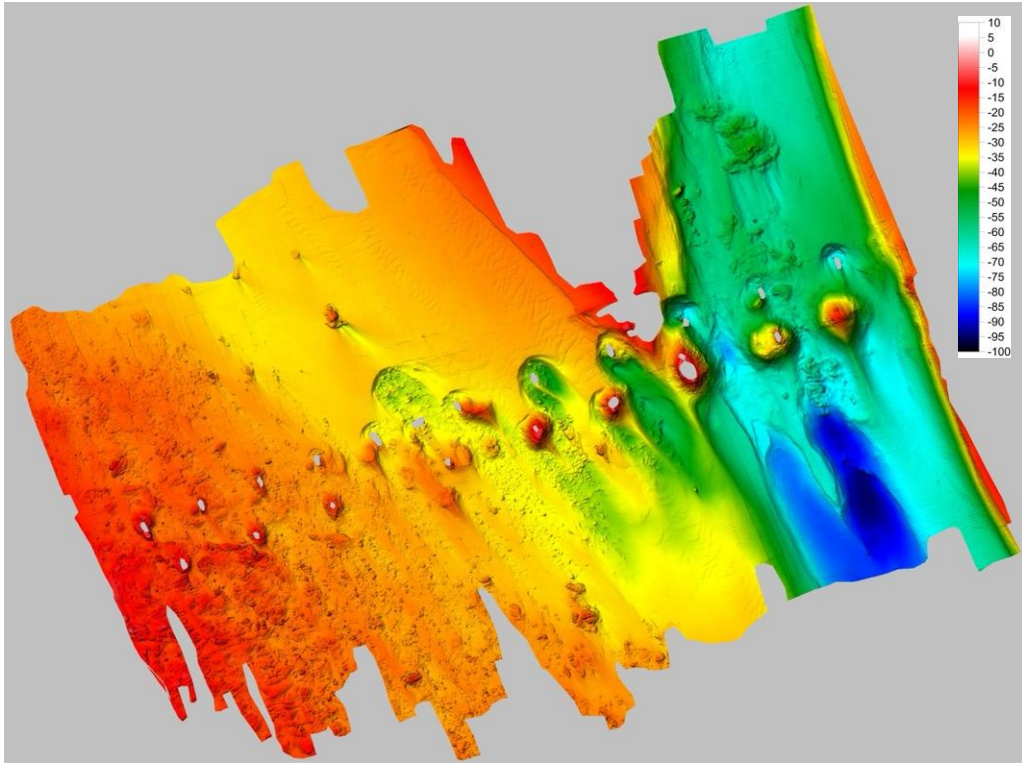


Estuarine

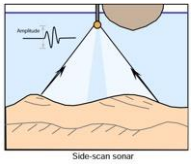
Multibeam bathymetry



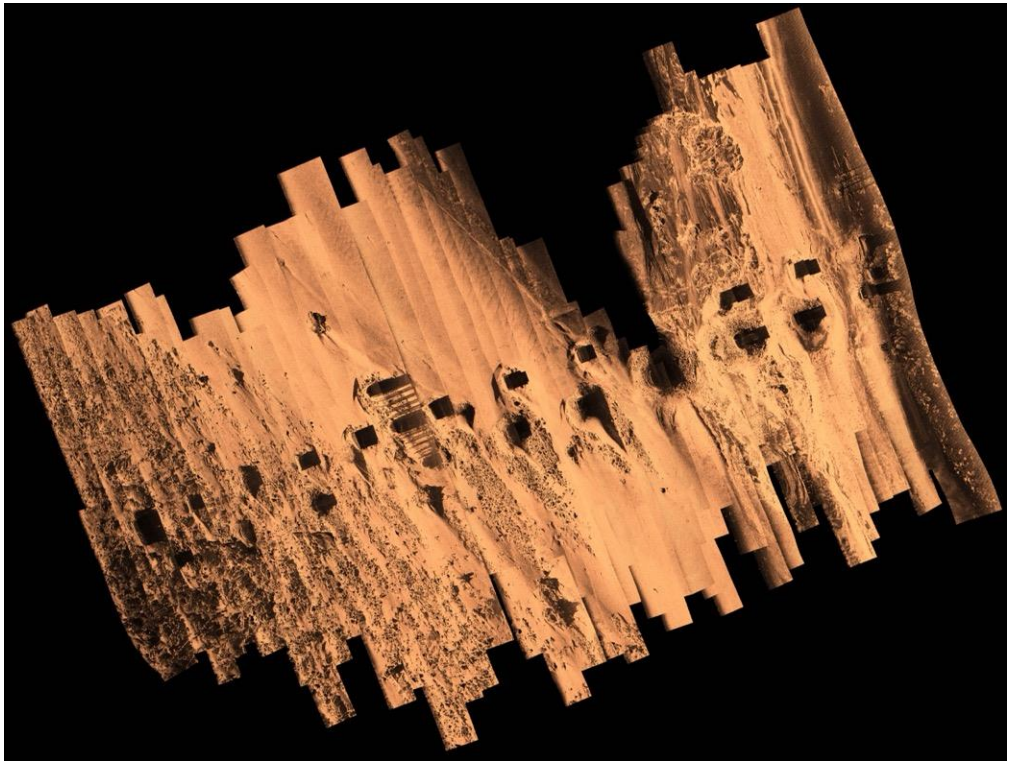
- X,Y,Z Bathymetry surface map
- 1 ft by 1ft grid
- Coordinates and datums tied to project systems
- Spectral color scale (red high, blue low)
- Mapping the geometry of the bedforms and bottom features
- Boulders
- Sand waves
- Scour
- Trailing bars
- Exposed rock outcrops



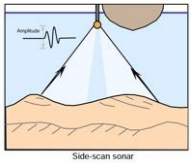
Side-scan orthosonography

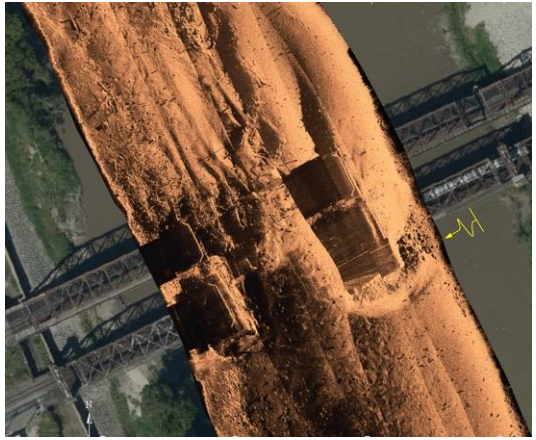


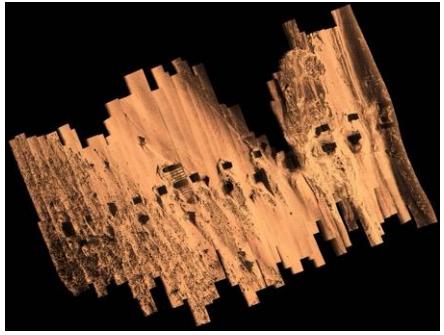
- Reflectivity map
- 0.3 ft by 0.3 ft resolution
- Coordinates and datums tied to project systems
- Intensity color scale (Light - high, dark - low, black - shadows or absence of data)
- Mapping the reflectivity of the bedforms and bottom features
- Boulders
- Sand waves
- Scour
- Trailing bars
- Exposed rock outcrops
- Utilities, debris, structures



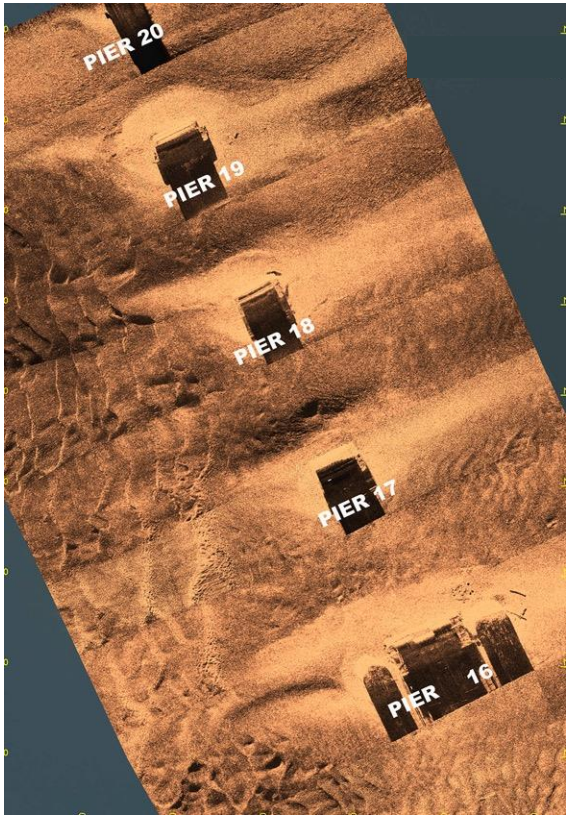
Side-scan orthosonography

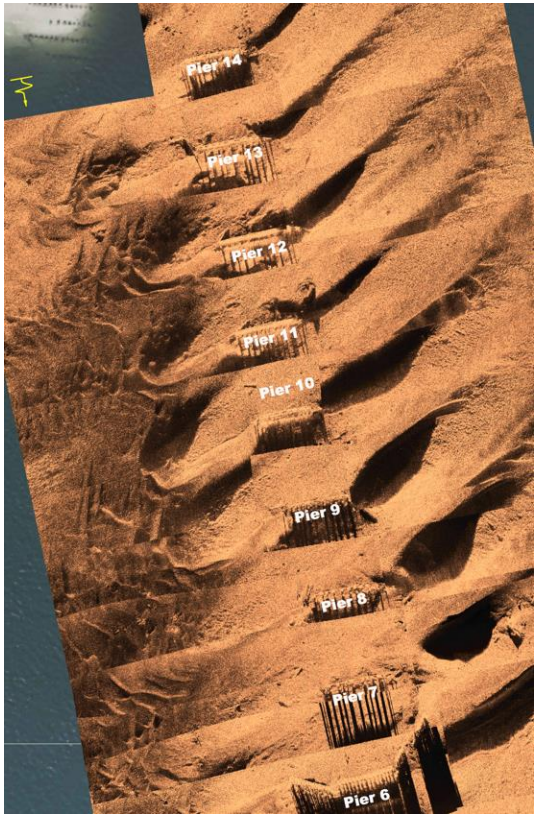






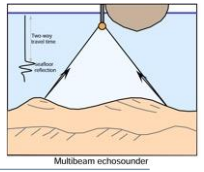
Riverine





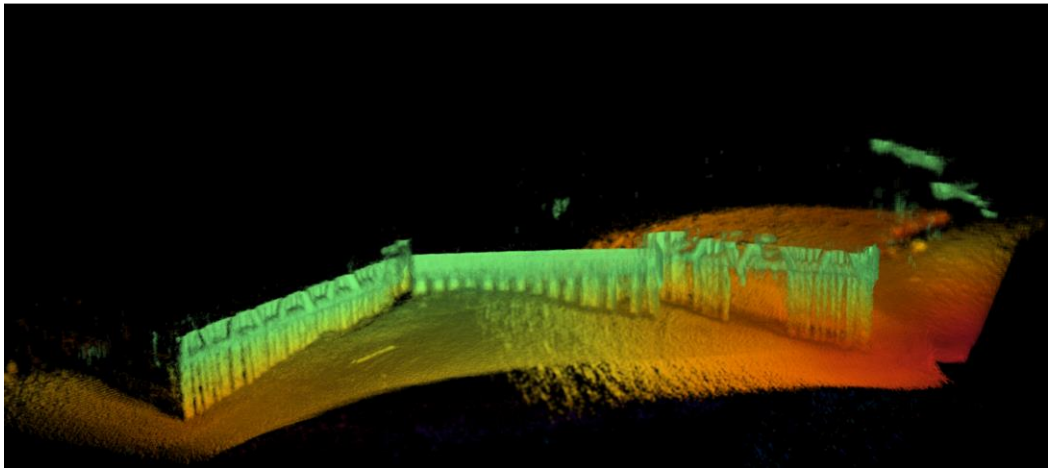
Estuarine

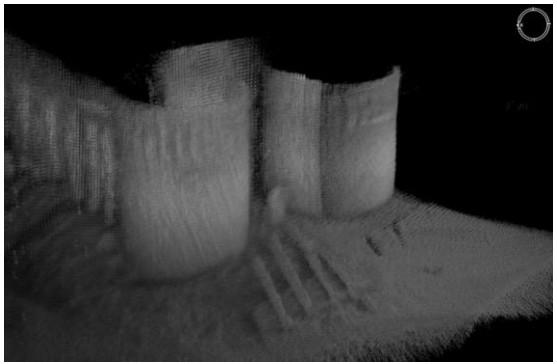
Structural Imaging and mapping

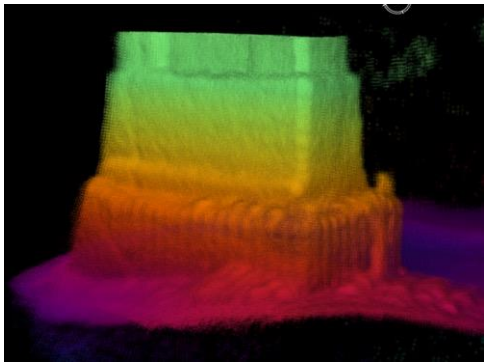


Multibeam echosounder

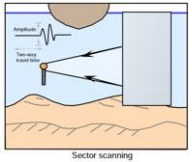
- Scour investigations are frequently combined with underwater structural inspection.
- Divers in the water have limitations
- Dive inspections carry risk
- Multibeam imaging captures the entire structure.
- As a first order inspection geophysics allows structural engineers to target deficiencies
- Dive confirmation is imperative – damage grading.
- Scour and structural investigations should not be decoupled
  - Local structures – Existing, Extant
  - Regional / Local geology and geomorphology



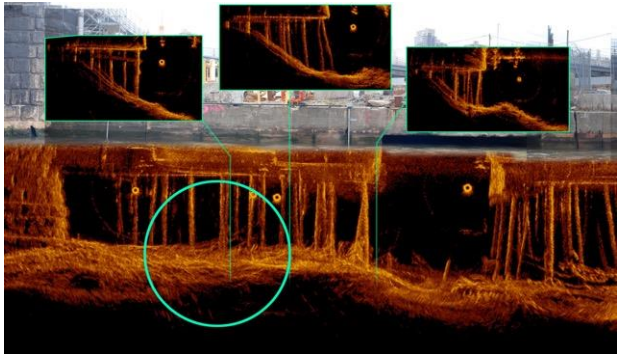


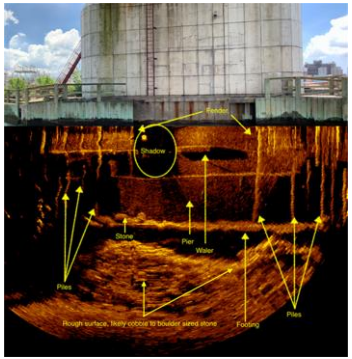


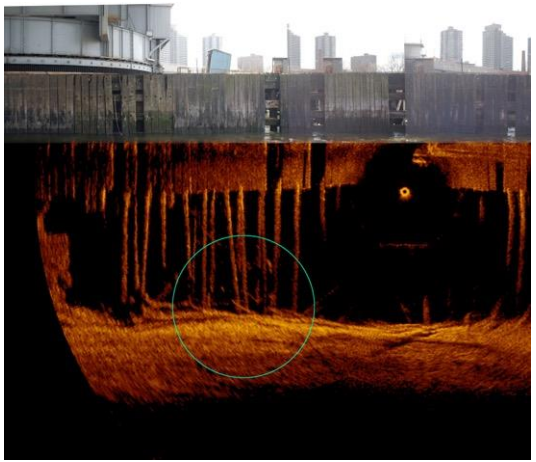
Structural Imaging and mapping



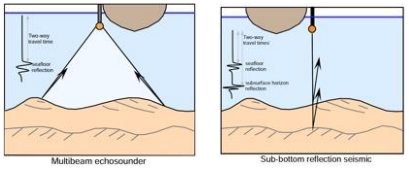
- Scour investigations are frequently combined with underwater structural inspection.
- Divers in the water have limitations
- Dive inspections carry higher risk
- Multibeam imaging & mapping captures the entire structure.
- Reflectivity imaging provides texture, detail, and
- As a first order inspection geophysics allows structural engineers to target deficiencies
- Dive confirmation is imperative – damage grading.
- Scour and structural investigations should not be decoupled
  - Local structures – Existing, Extant
  - Regional / Local geology and geomorphology







Reflection seismology



- Impedance contrasts between different materials
- Collects subsurface data along track lines
- 1Hz to 12Hz collection rate
- Subsurface imaging is critical to understand how scour is behaving
- What sediments are moving through the area, how thick are the active sediments?
- What are the deepest cross cutting bodies or disconformities in the subsurface, at what elevation are the subsurface constraints to scour?

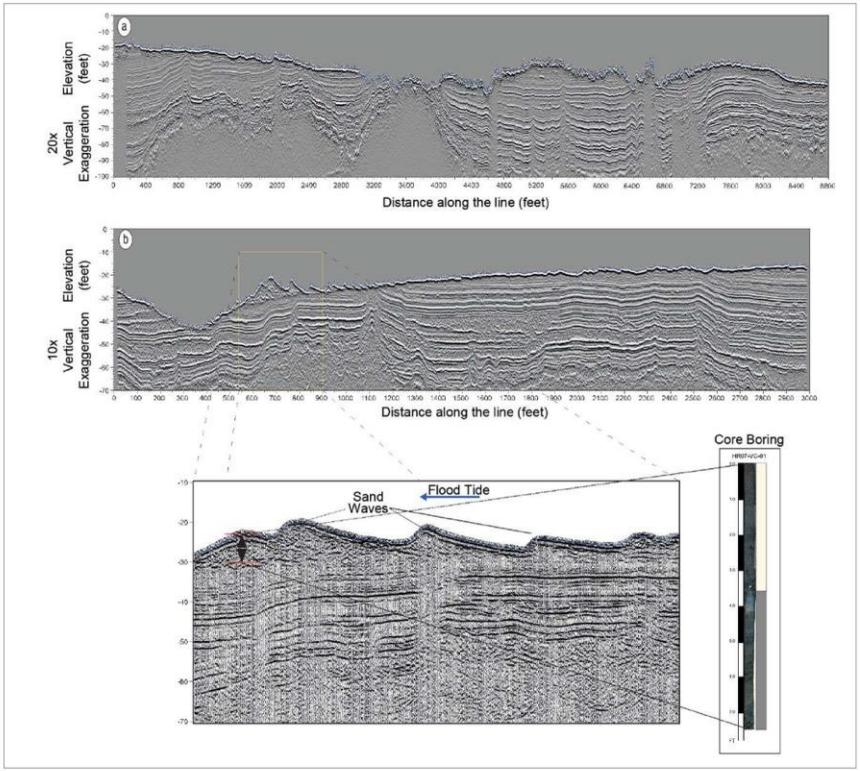
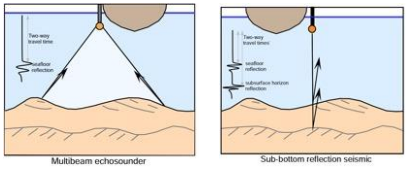
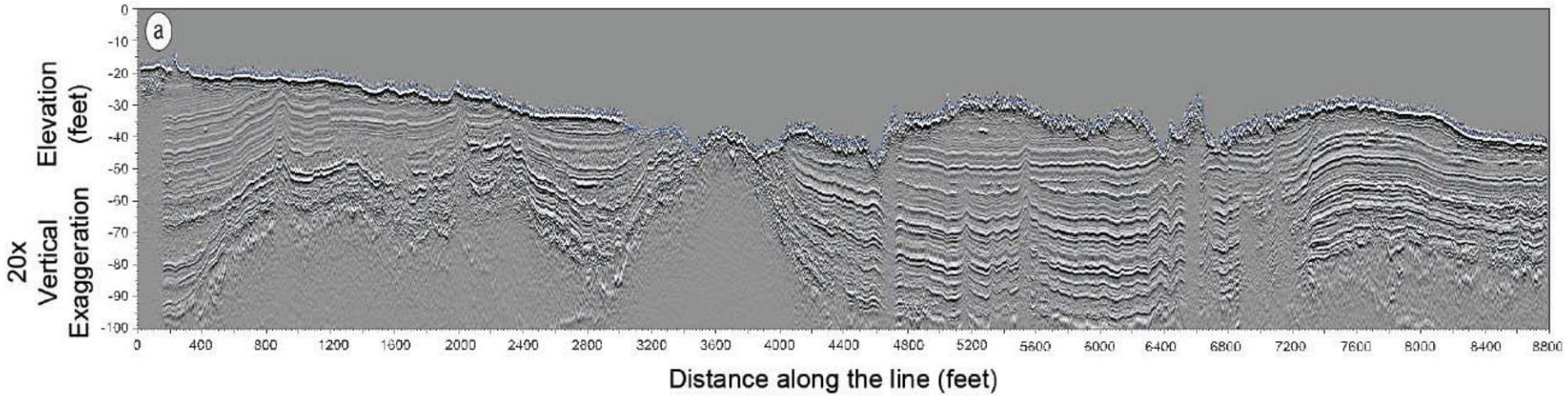


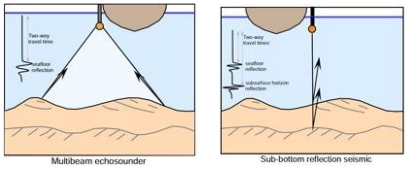
Figure 8. *Sub-bottom seismic images (1–10 kHz) of sediments above diabase rock. The ordinate is the elevation; the negative sign indicates elevation below the mean-low-water (MLW) datum. (a) The diabase penetrates though the sediment and is exposed. (b) Stacking of sand waves moving up stream (to the left). The lower image shows the topset layering internal to each of the sand waves moving in the direction of the flood tide. Core borings provide ground truth to the images.*

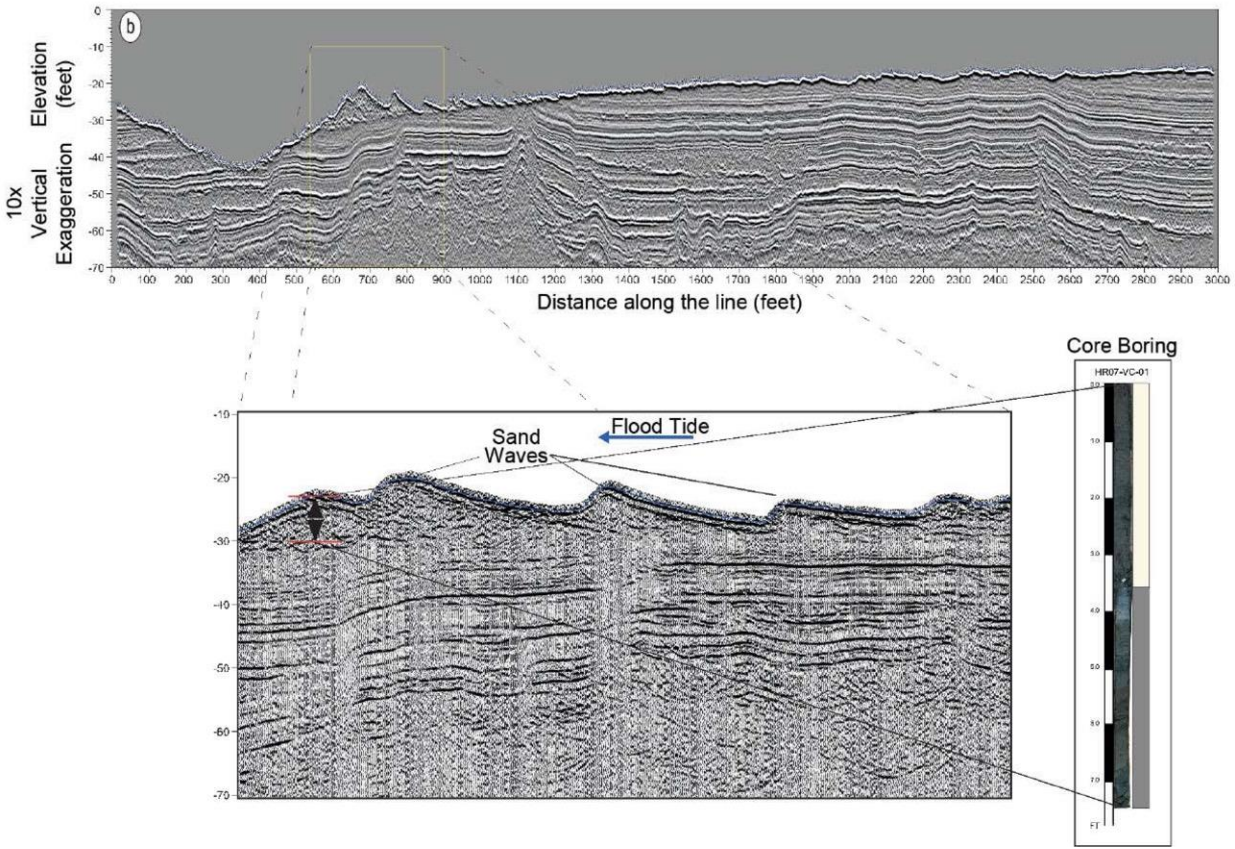
Reflection seismology



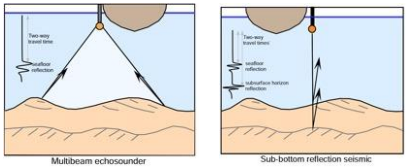


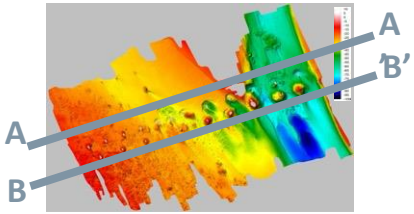
Reflection seismology

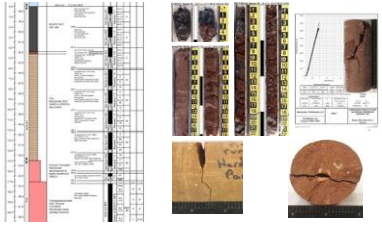


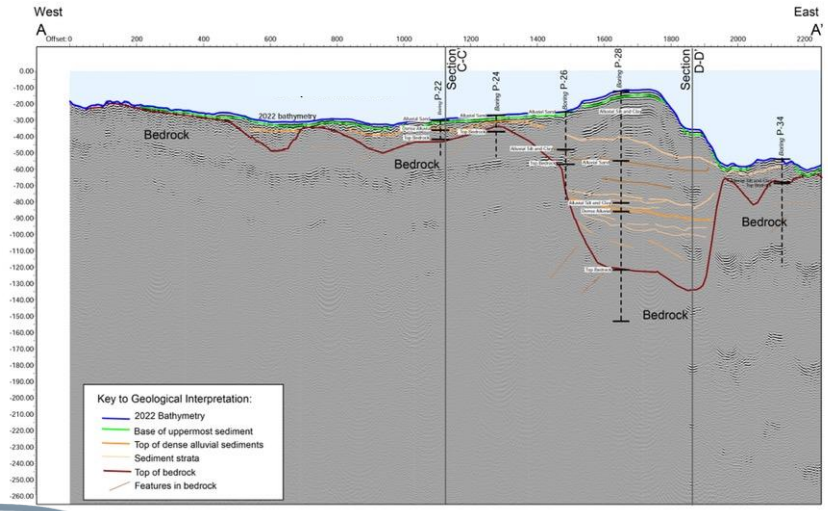


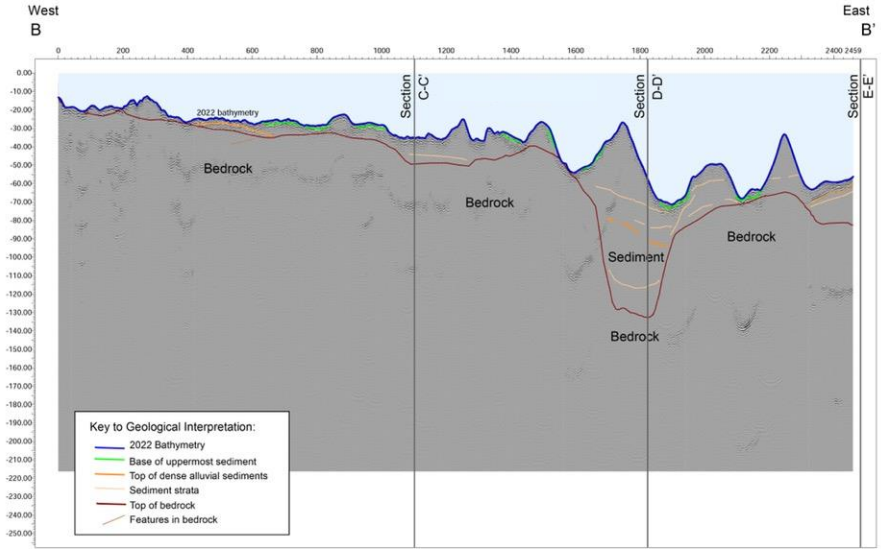
Stratigraphic interpretation



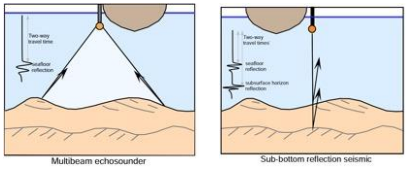


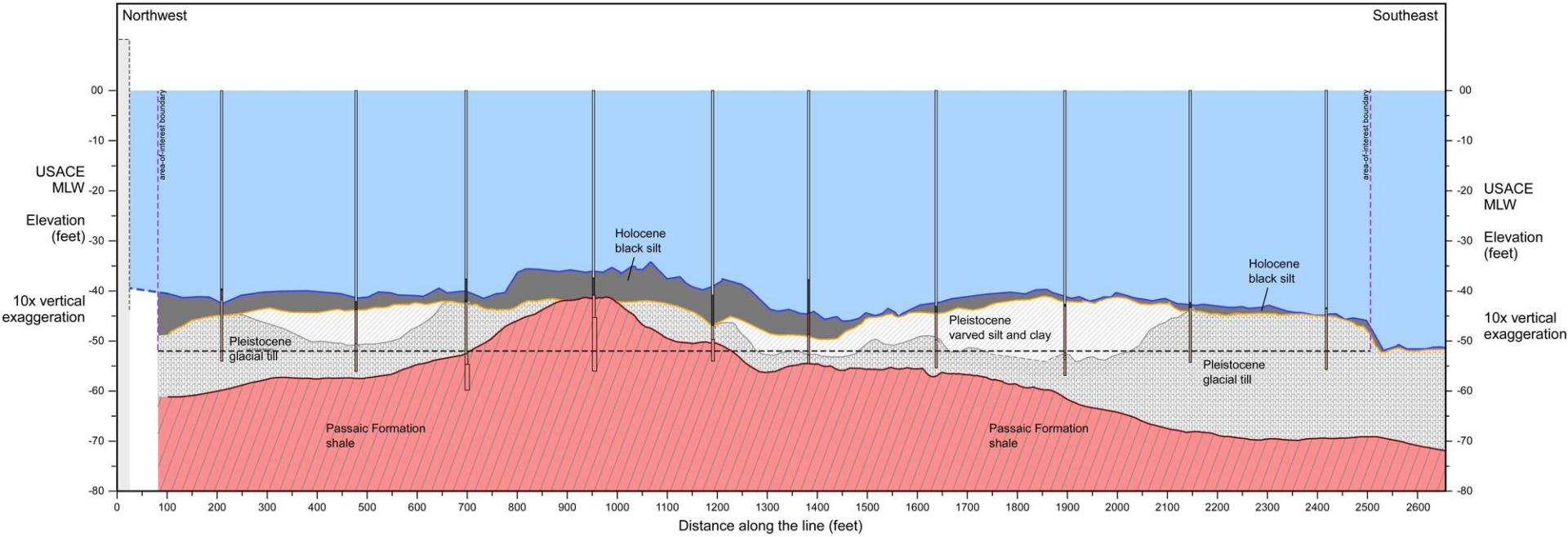




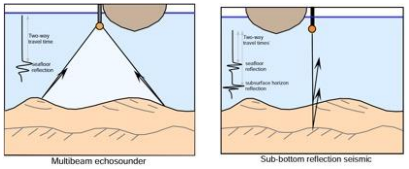


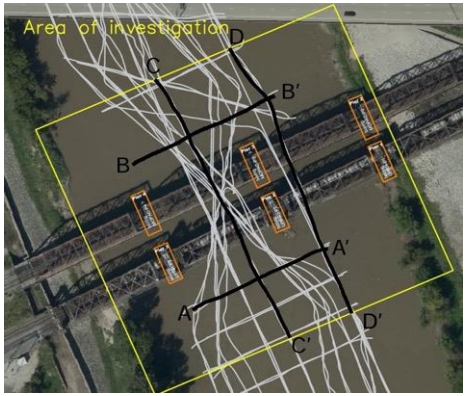
Stratigraphic interpretation – Geological Cross Sections

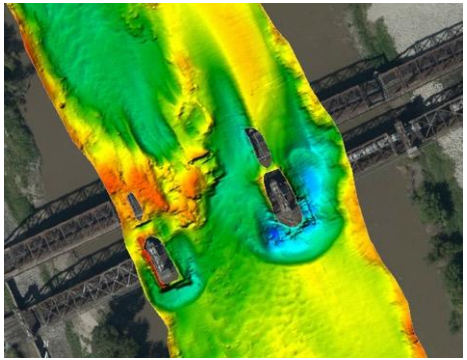


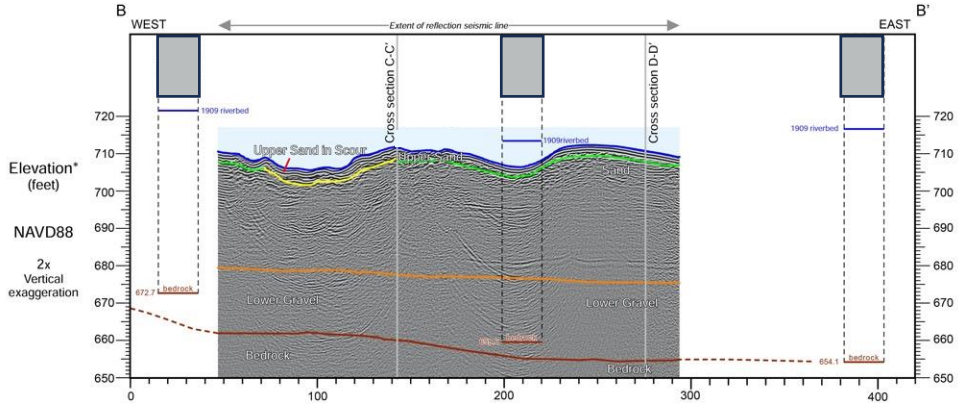


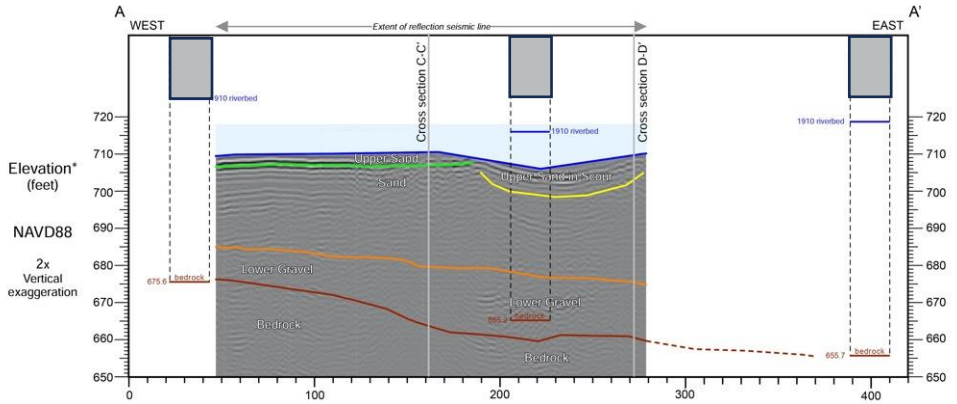
Stratigraphic interpretation – Seismic Cross Sections



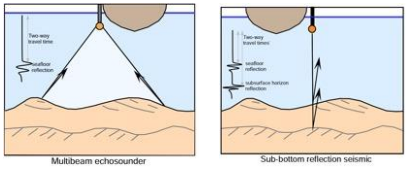


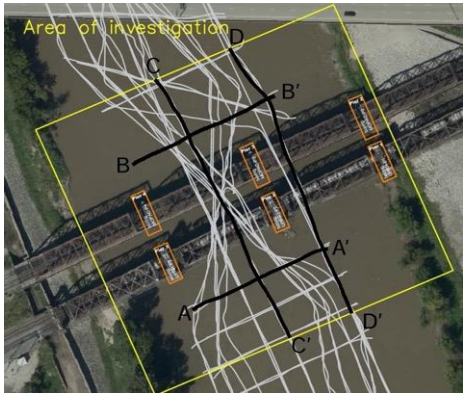


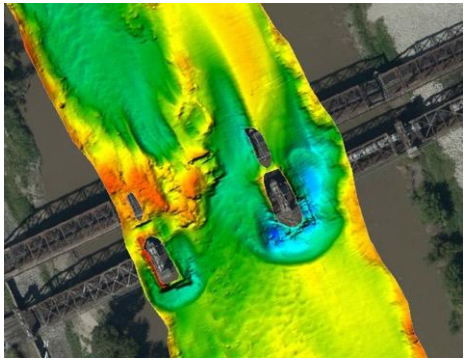


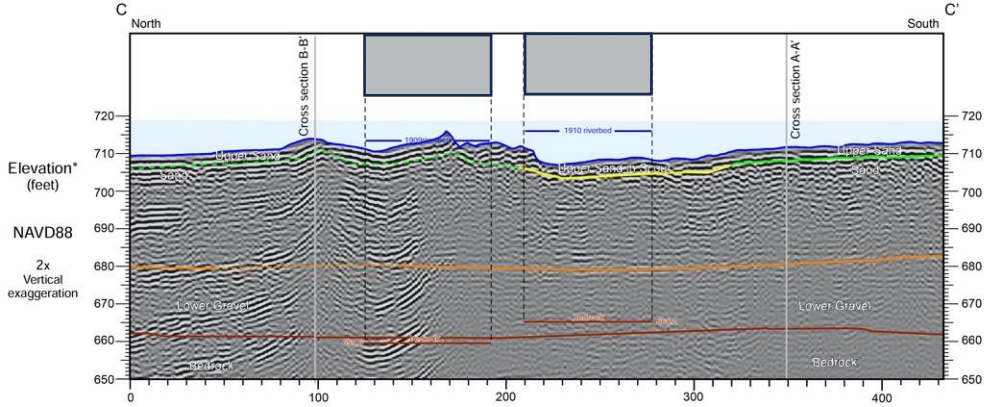


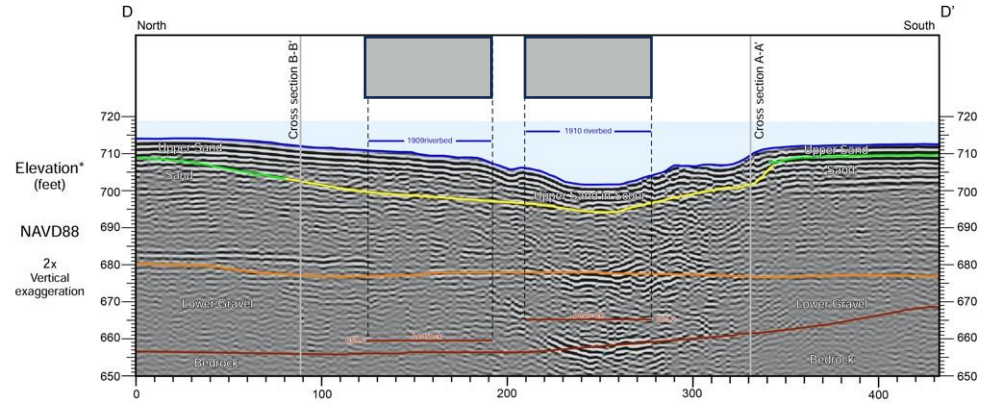
Stratigraphic interpretation – Seismic Cross Sections



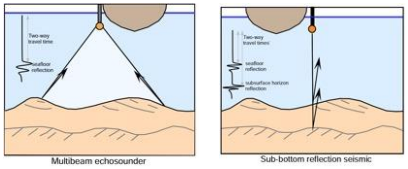


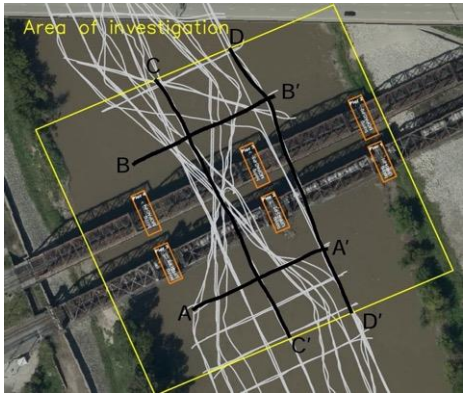


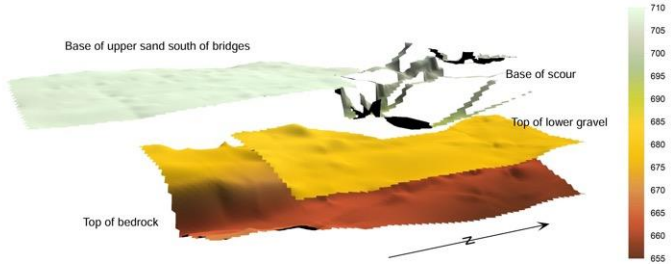


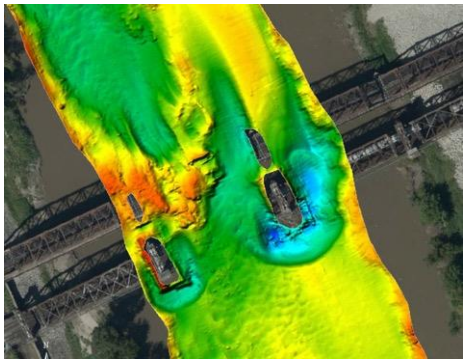


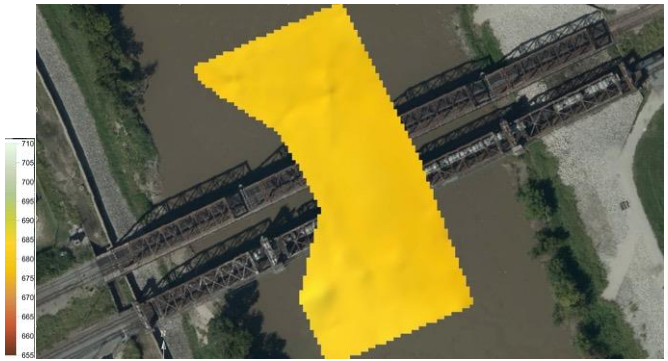
Stratigraphic interpolation – Stratigraphic surfaces

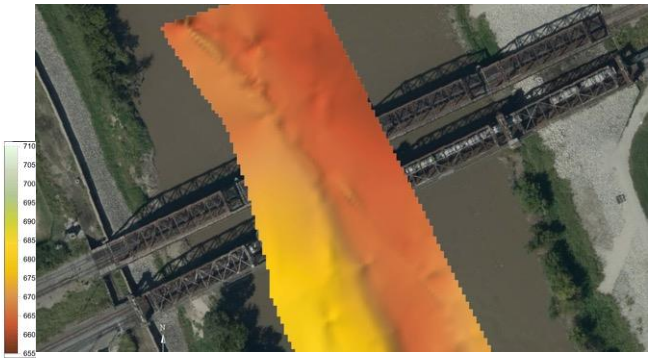




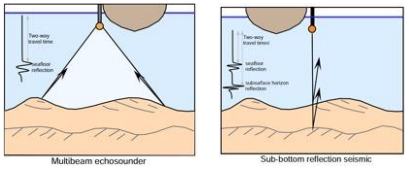


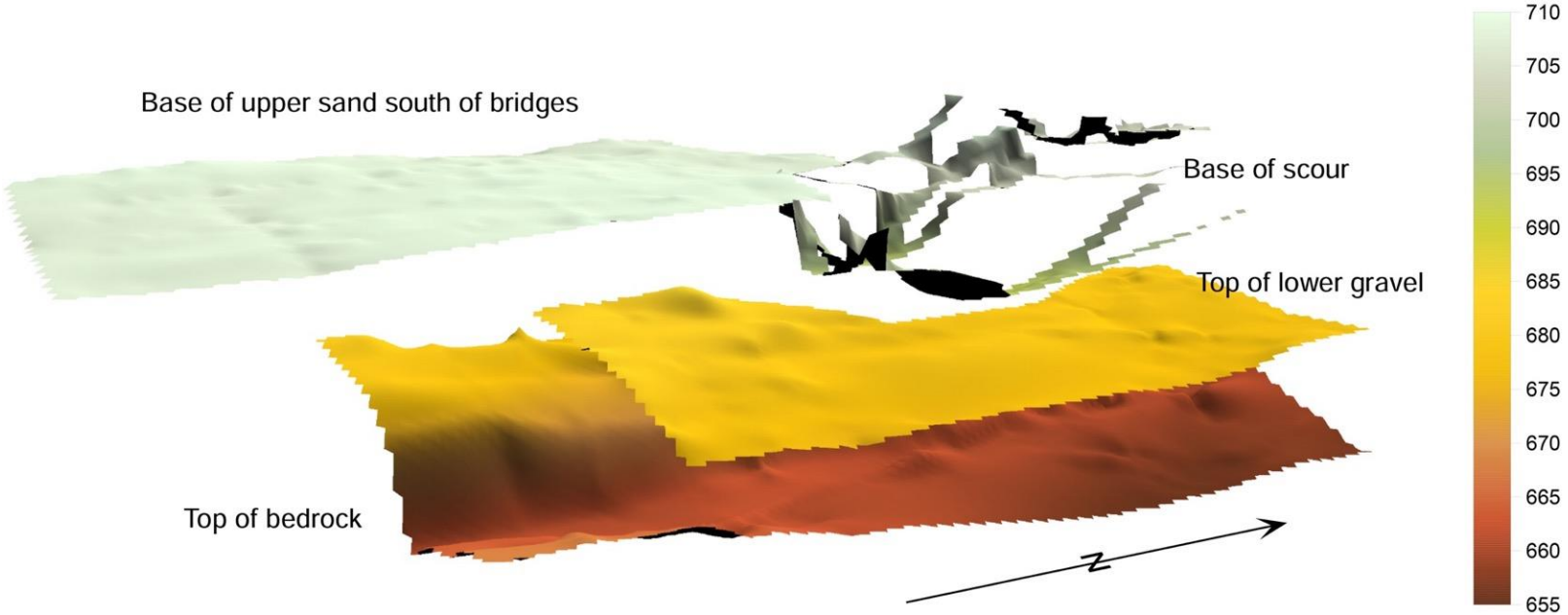




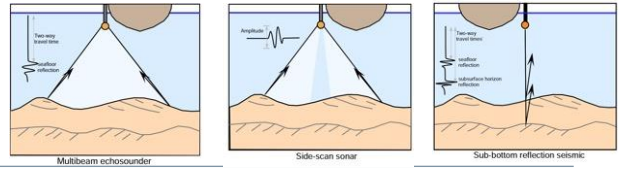


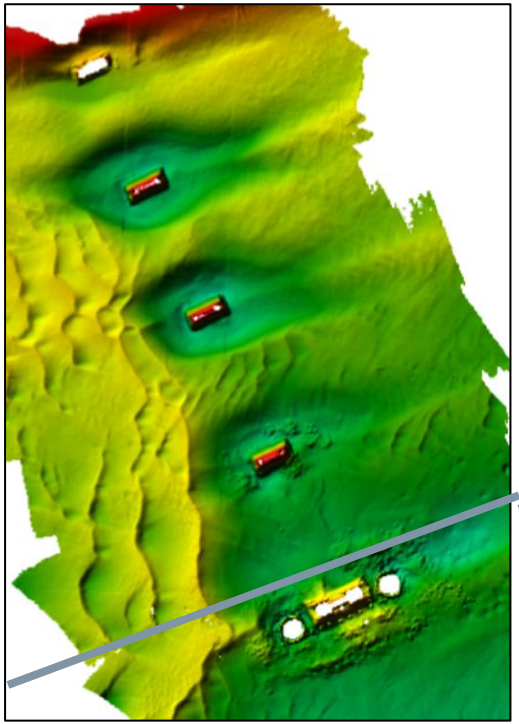
Stratigraphic interpolation – Stratigraphic surfaces

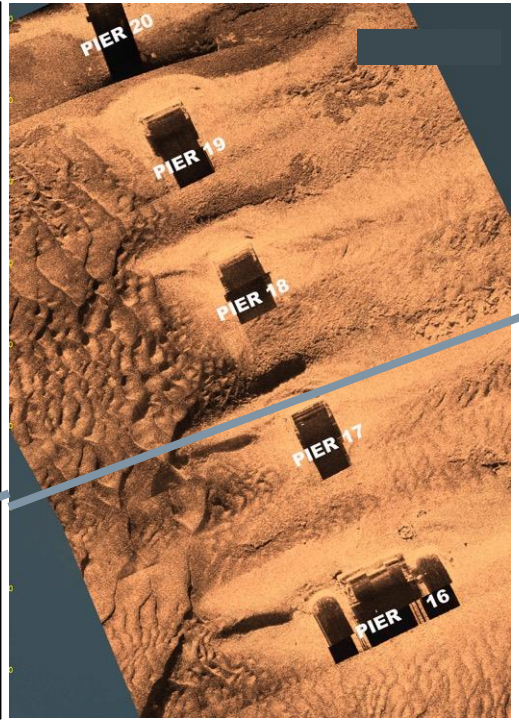


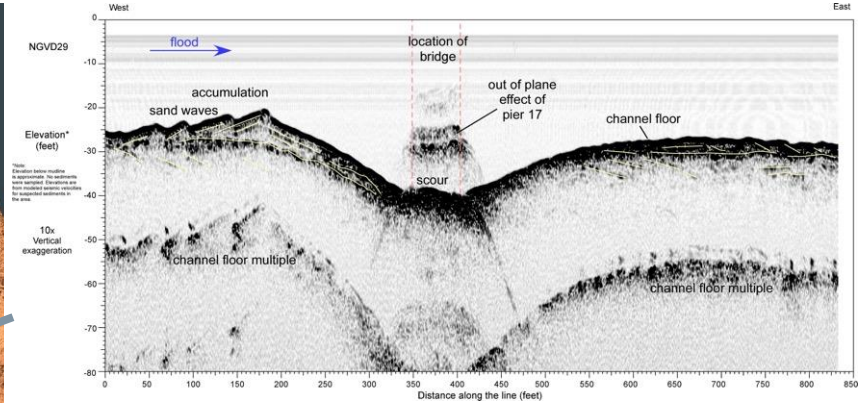


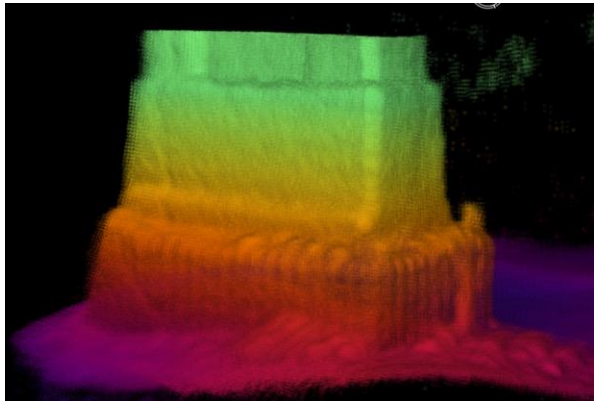
Scour Example – Integrated interpretation



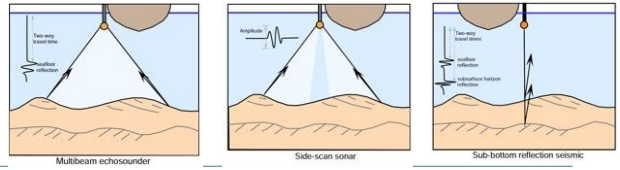


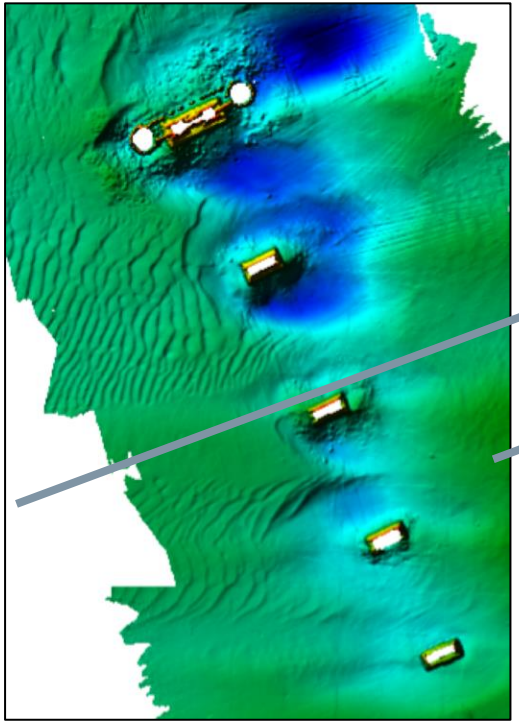


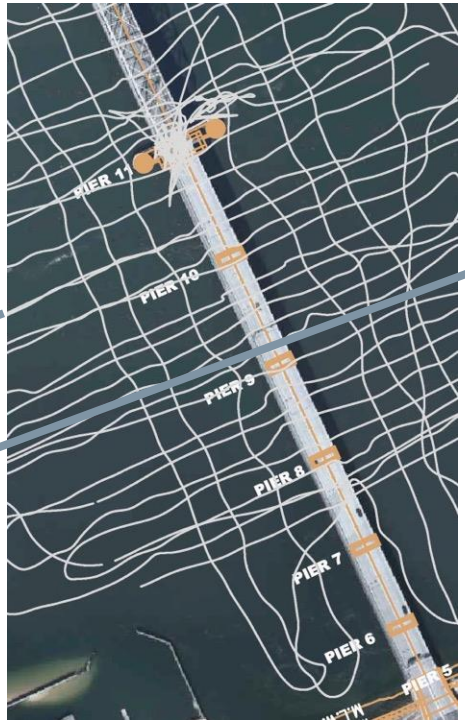


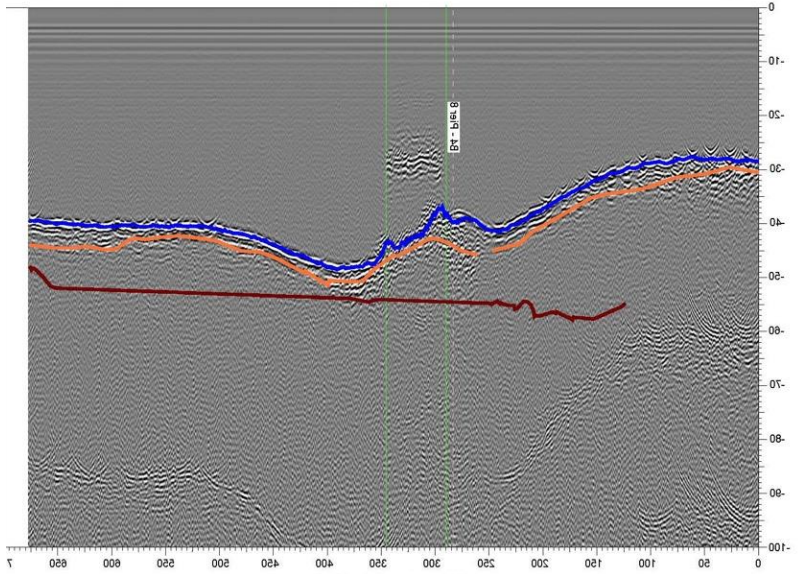


Stratigraphic interpolation – Stratigraphic surfaces

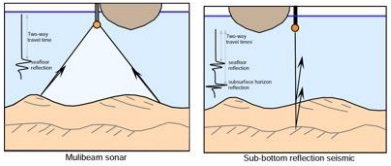


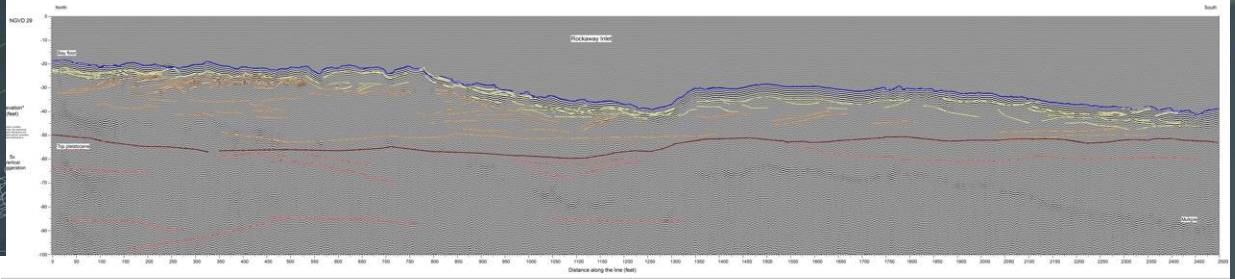


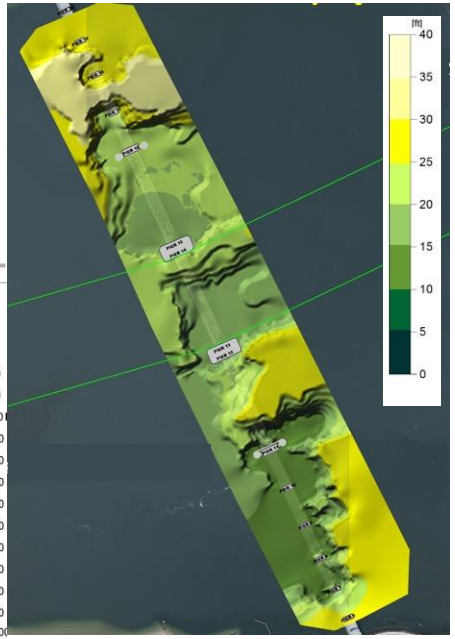


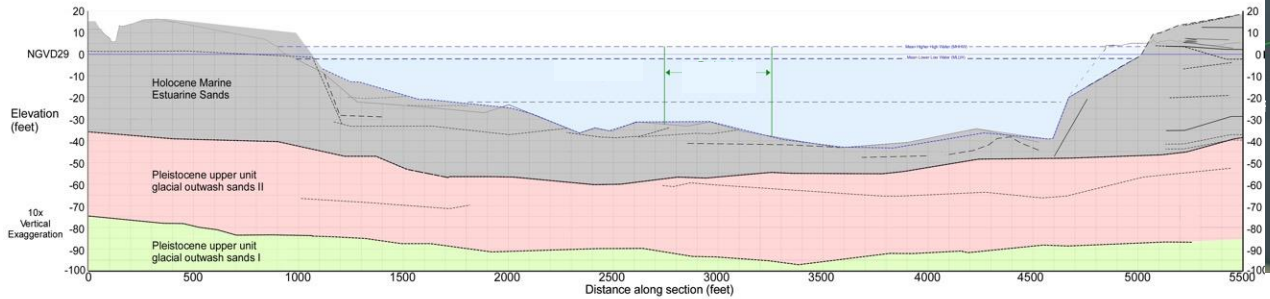


Scour Example – Integrated interpretation



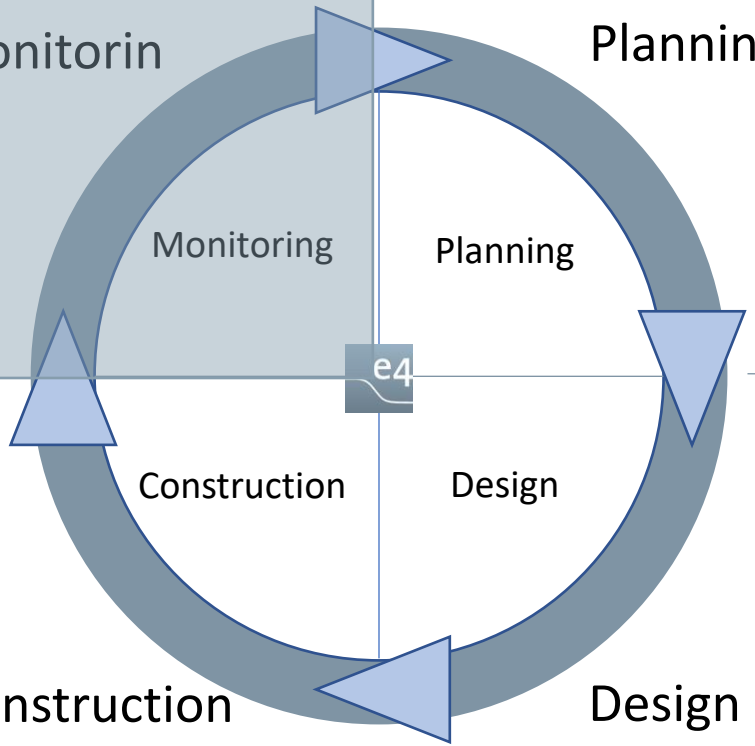






Integrate Geophysics into Engineering Lifecycle

- Assess condition
- Monitor behavior of asset
- Change over time
- Monitor geomorphology
- Objective measurement vs. subjective evaluation

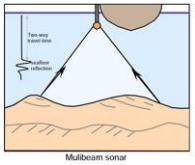


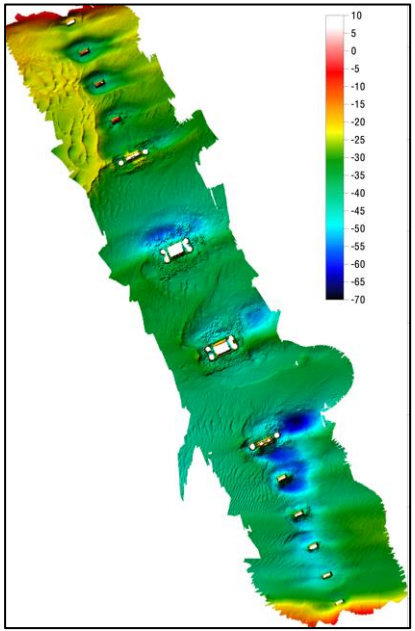
- Broad area subsurface characterization
- Anticipated conditions
- Primary and Alternative analysis
- Optimize geotechnical subsurface investigations

- Quality Assurance / Quality Control
- Locate obstructions
- Delineate geo-hazards
- Characterize unexpected conditions
- Track progress
- Produce as-builts

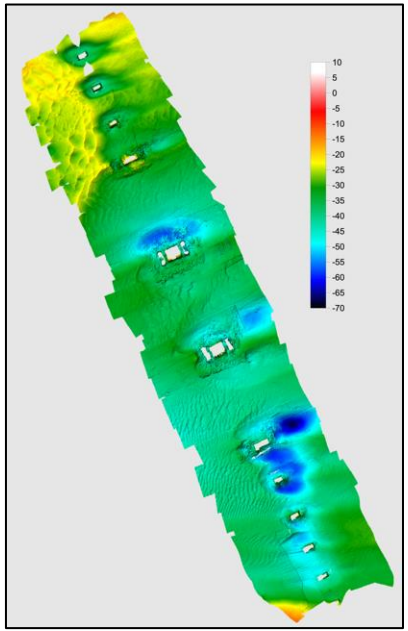
- Relic infrastructure
- Delineate geo-hazards
- Locate obstructions
- Refine alternatives
- High-definition subsurface characterization
- V_s for seismic design
- Optimize means and methods

Dynamics

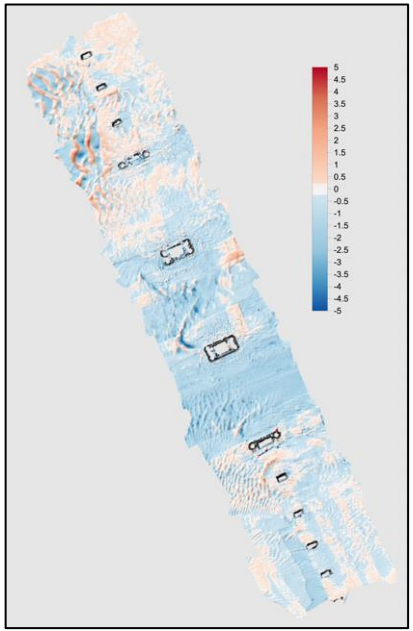




T0



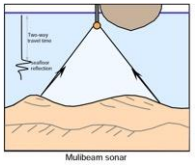
T0 + 1.5yr

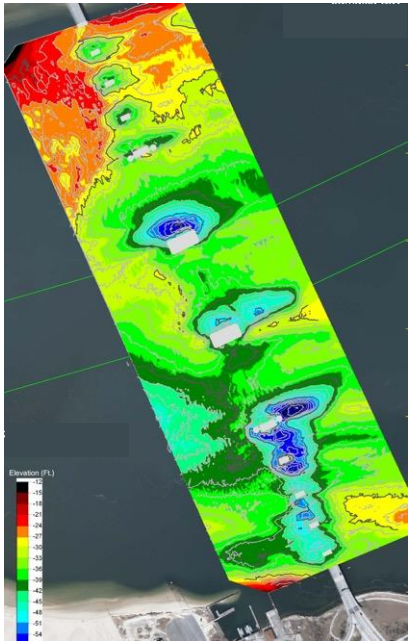


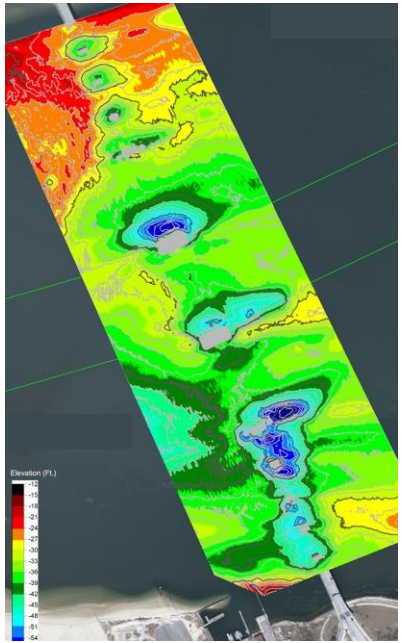
Difference

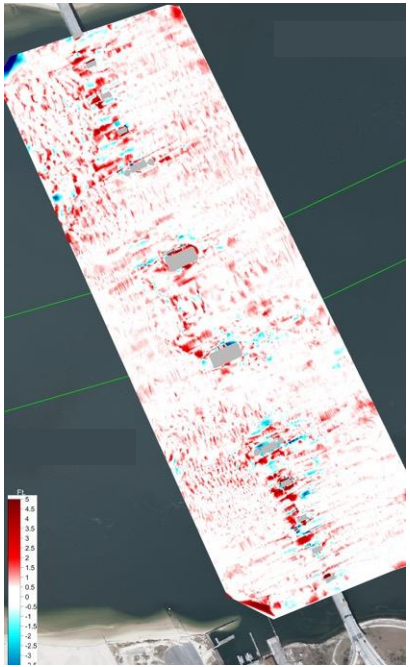
Yearly variation no major events

Dynamics



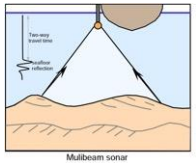




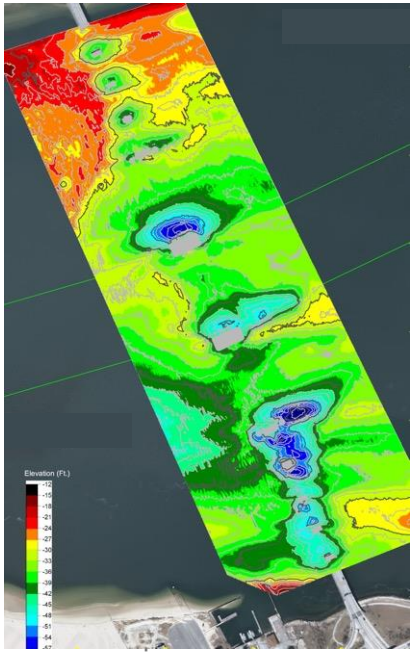


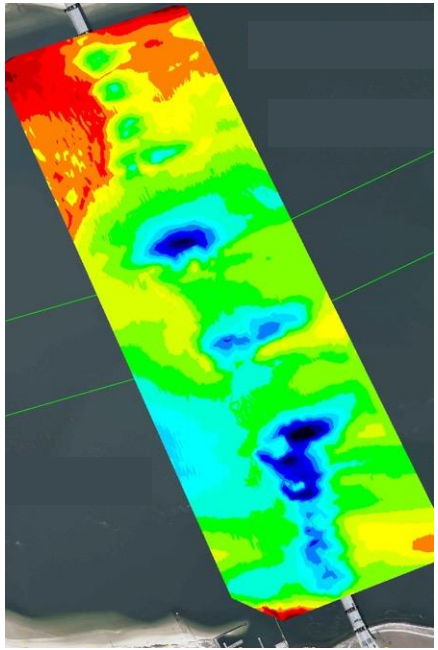
Yearly variation Event “A”

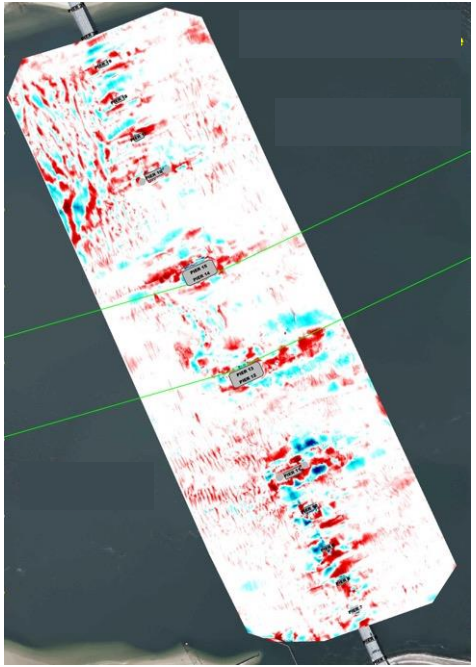
Dynamics



Multibeam sonar

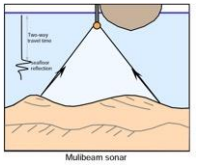


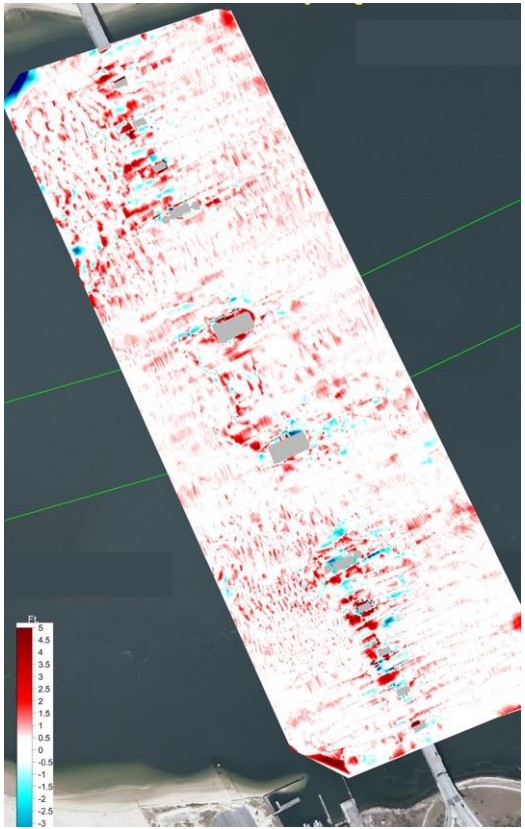




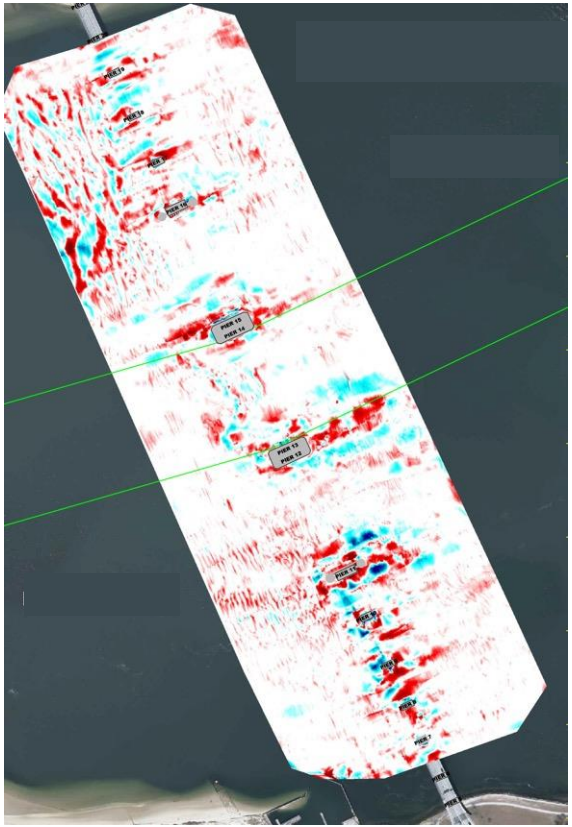
Yearly variation Event “b”

Dynamics



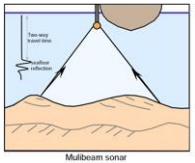


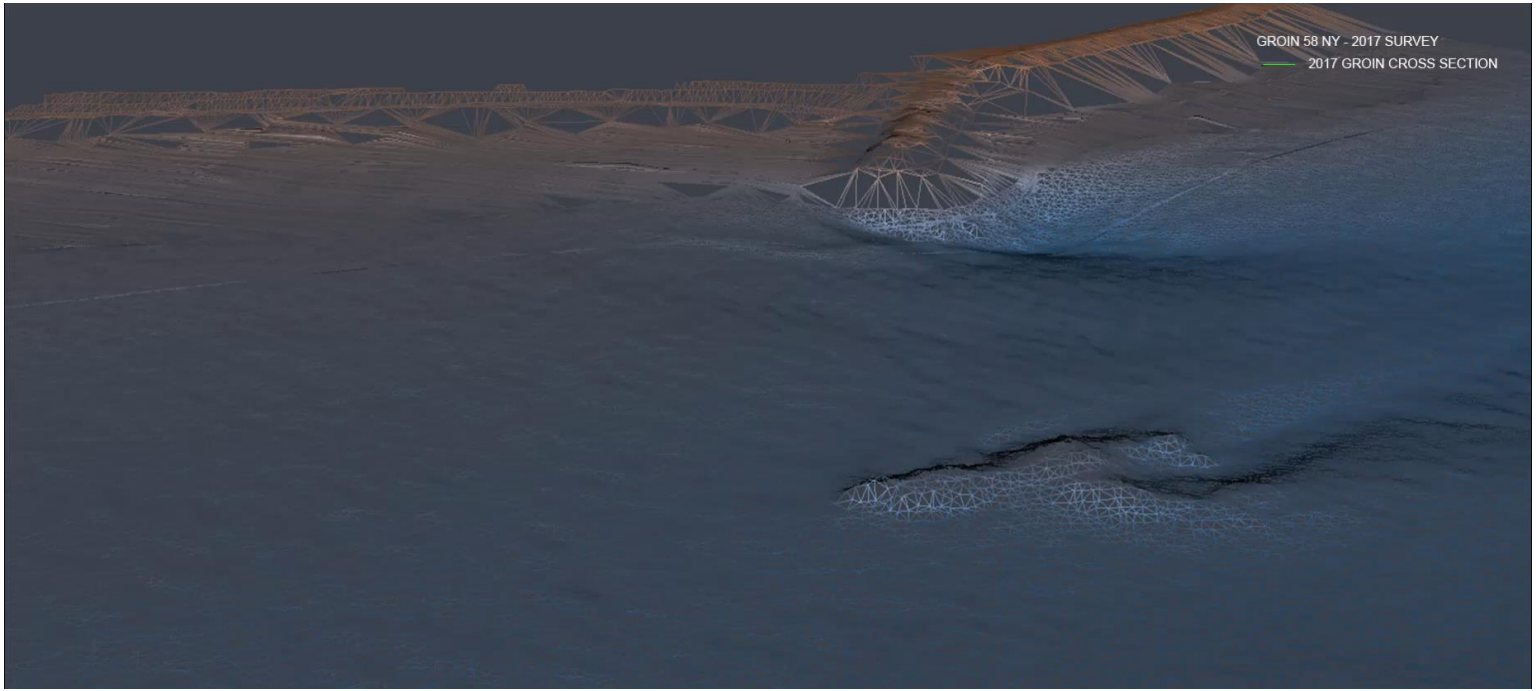
Storm Event A



Storm event B

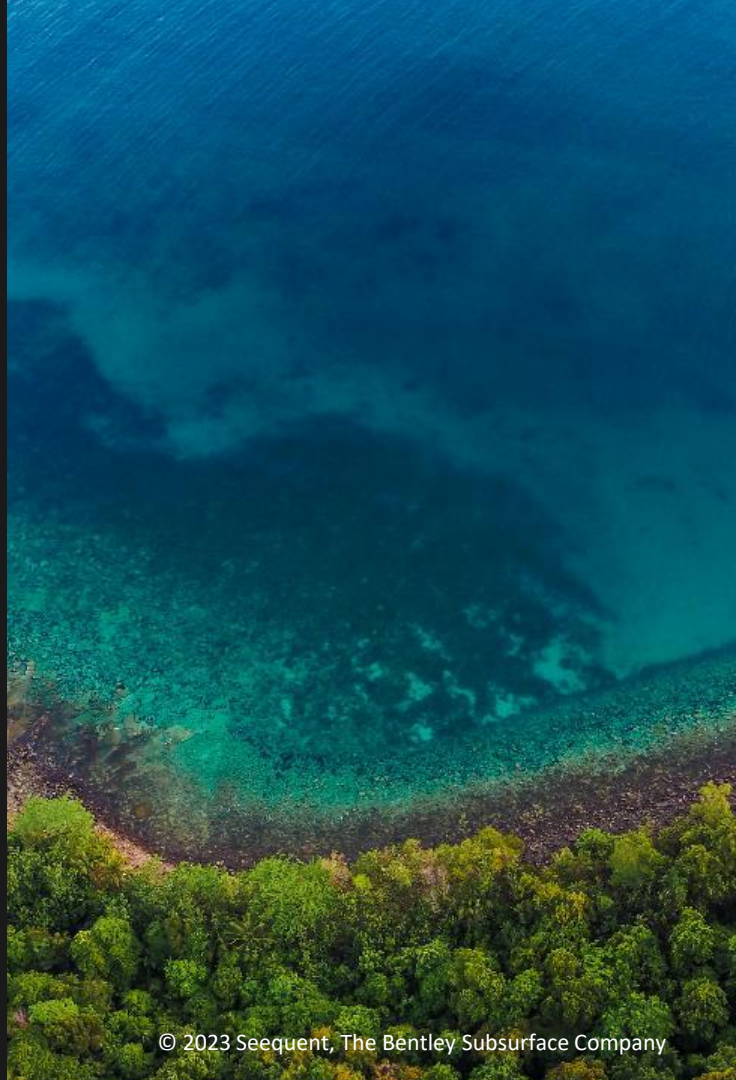
Dynamics – Timelapse scour modeling



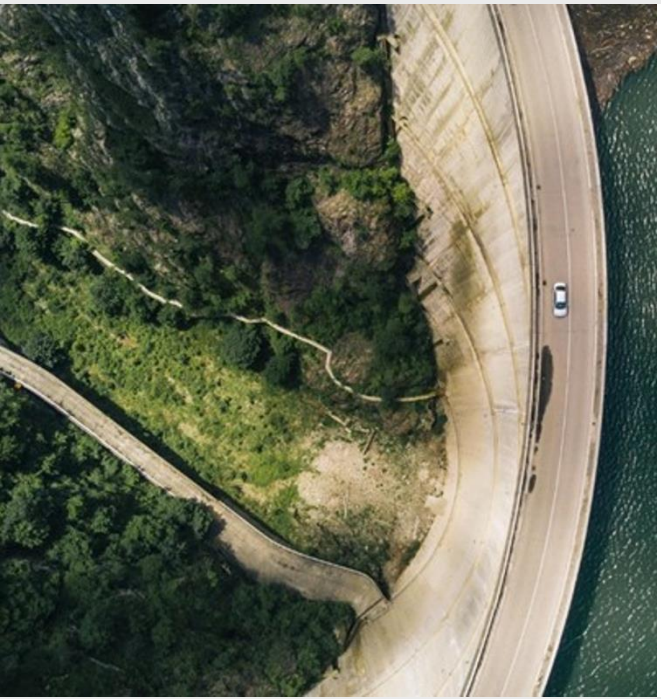


A cloud connected field-to-design workflow for transportation infrastructure ground engineering

Laura Quigley - Seequent



Overview



- Cloud-based, Geotechnical Data management (GIM)
- Dynamic Geological Modelling (data connection to Cloud)
- Geophysics – seamlessly incorporate into Geological Models

- Geotechnical Data Management

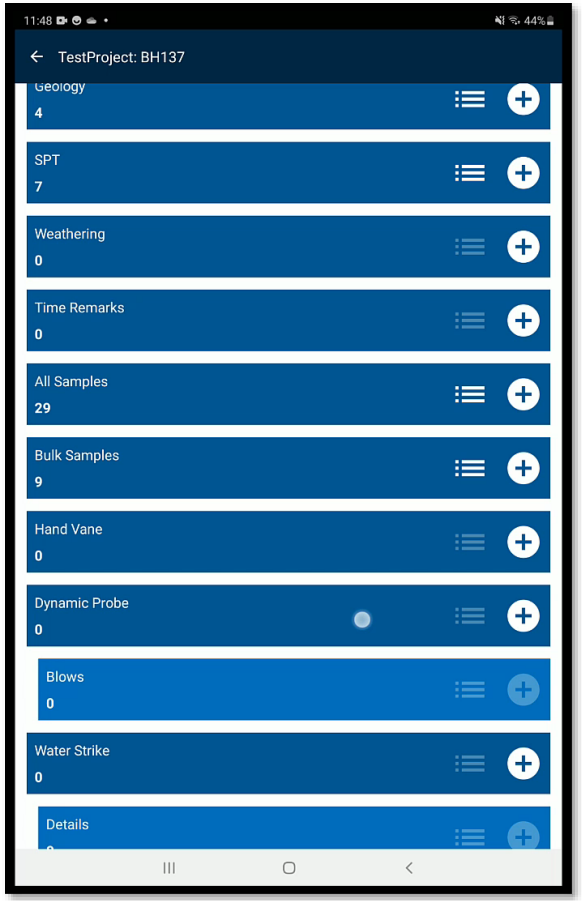
Digital Data Collection – In the Field

OpenGround Data Collector

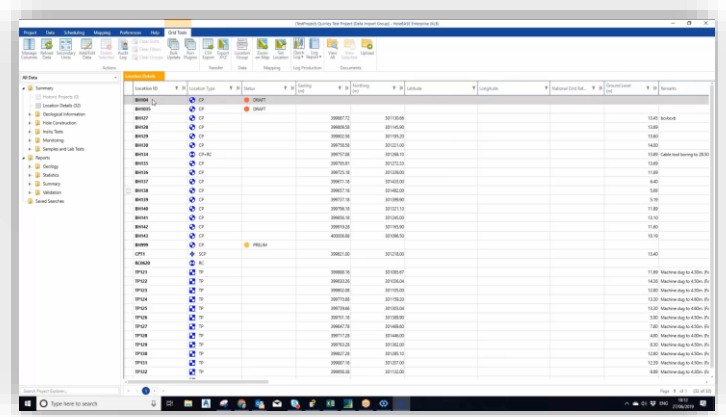
Problem/Pain: Inefficient data entry or multiple points of data entry. Disconnected approach between data contractors and consultants.

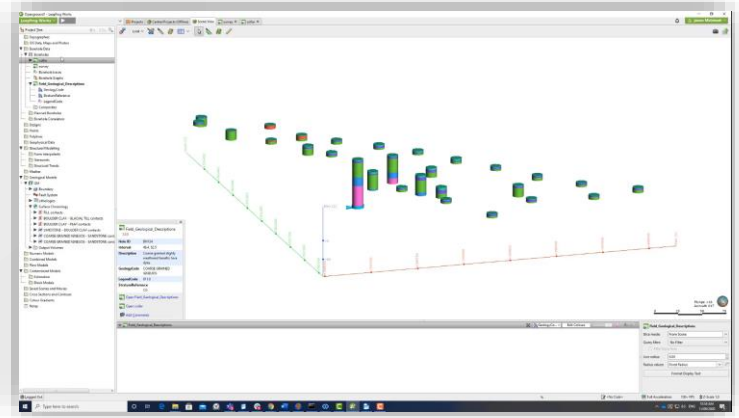
For: Drillers/ Site Engineers

Value: Ability to electronically collect data onsite and automatically sync data into the database. Significant amount of time saved as well as reducing the possibility of errors.



Cloud Connected Workflow





- Dynamic Geological Modelling

- Geophysical Data

Thank-you – any questions?

Today's presenters

Derrick Dasenbrock
derrick.dasenbrock@dot.gov
U.S. Department of Transportation
Federal Highway Administration

Laura Quigley
laura.quigley@seequent.com
SEEQUENT

Dr. Nina Stark
nina.stark@ufl.edu
UF Herbert Wertheim College of Engineering
Engineering School of Sustainable Infrastructure & Environment
UNIVERSITY of FLORIDA

Matt Art
matt.art@e4sciences.
e4sciences

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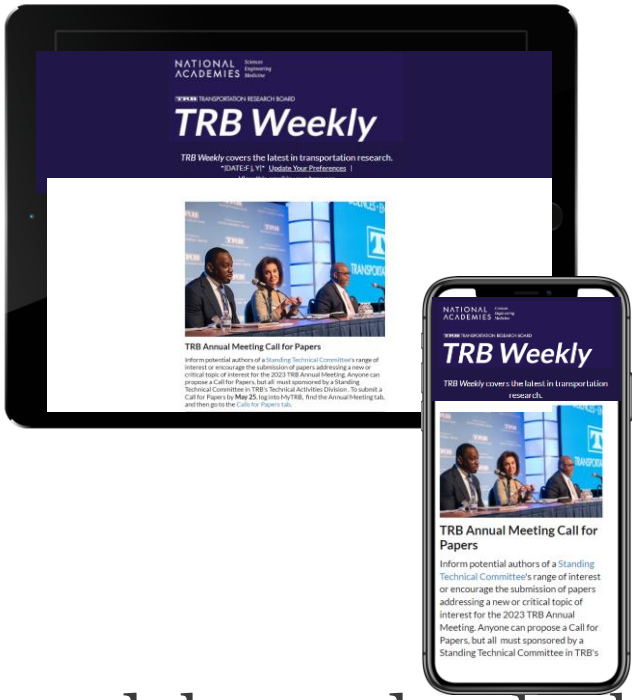

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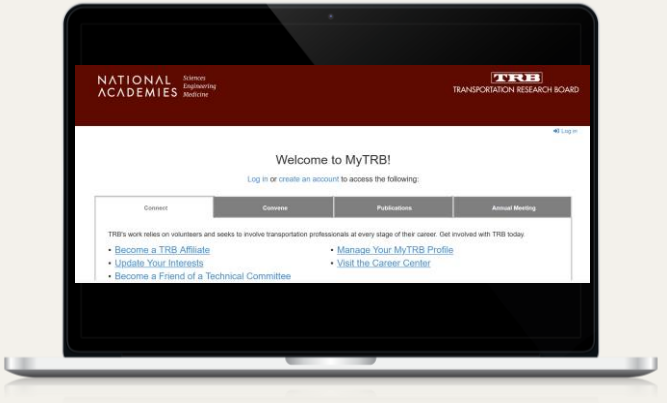

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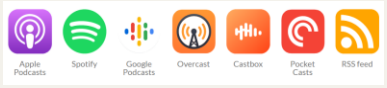

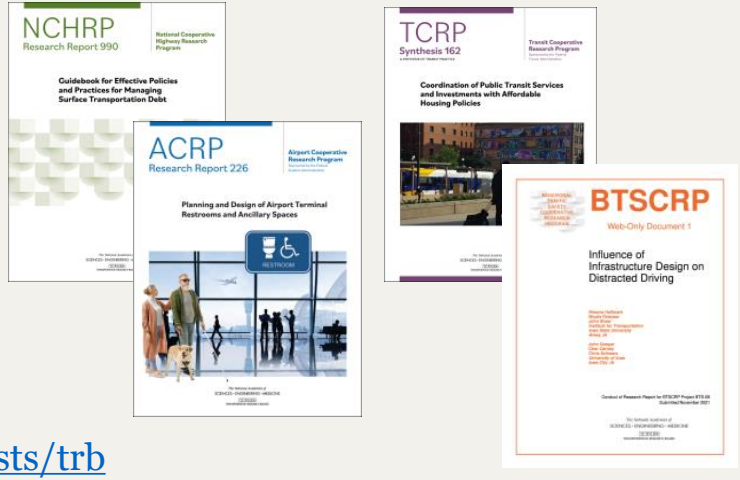

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