Marine Geophysical Methods:

What Can and Cannot Be Done to Identify Hazards to Dredging & Marine Construction

Sham or Savior?

Seen alternatively as the silver bullet or snake oil, marine geophysical techniques use a variety of different methods to identify conditions and features on and below the seabed.

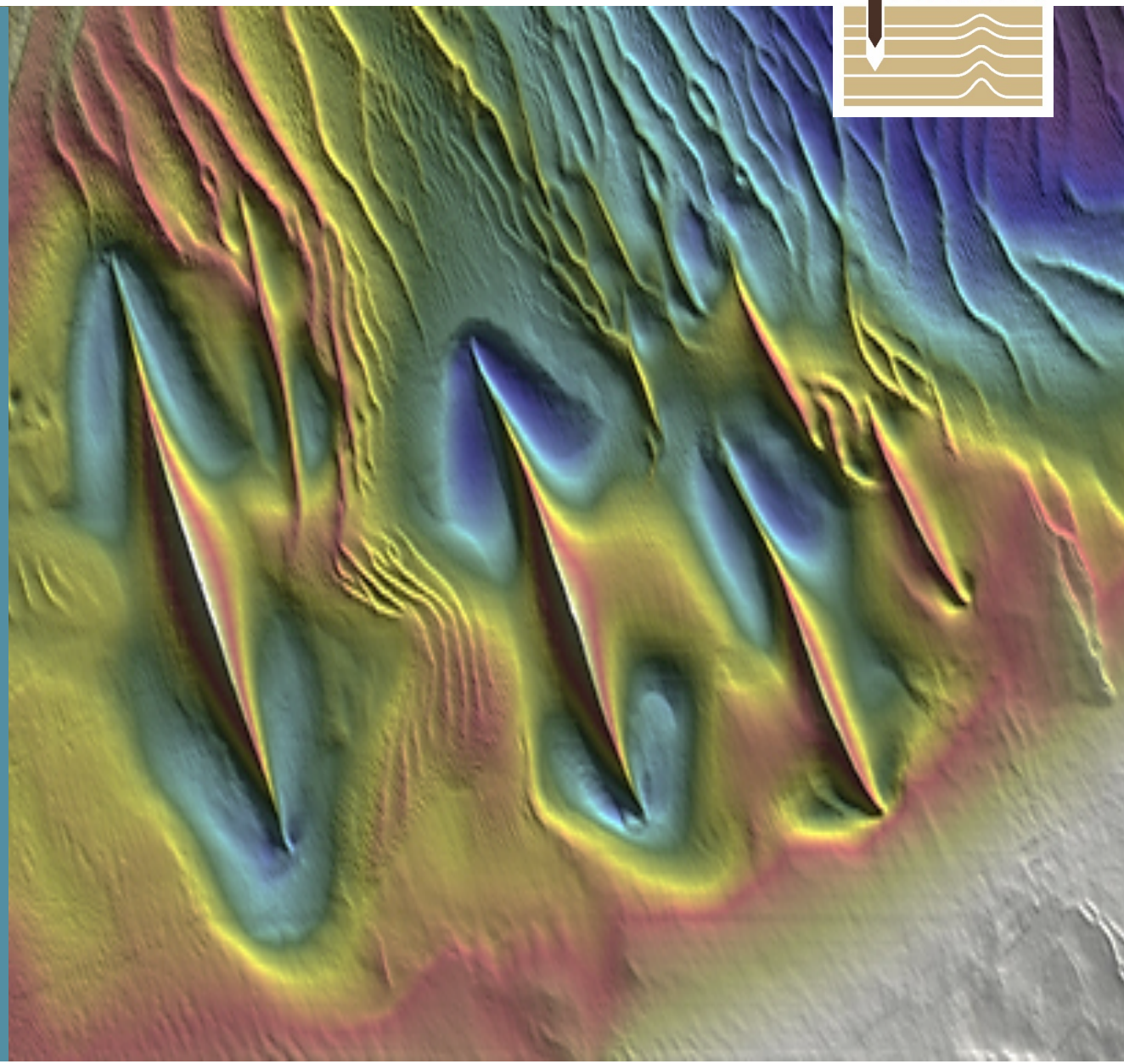
Sham or Savior?

Therefore it is very important to understand that there are a variety of geophysical techniques.

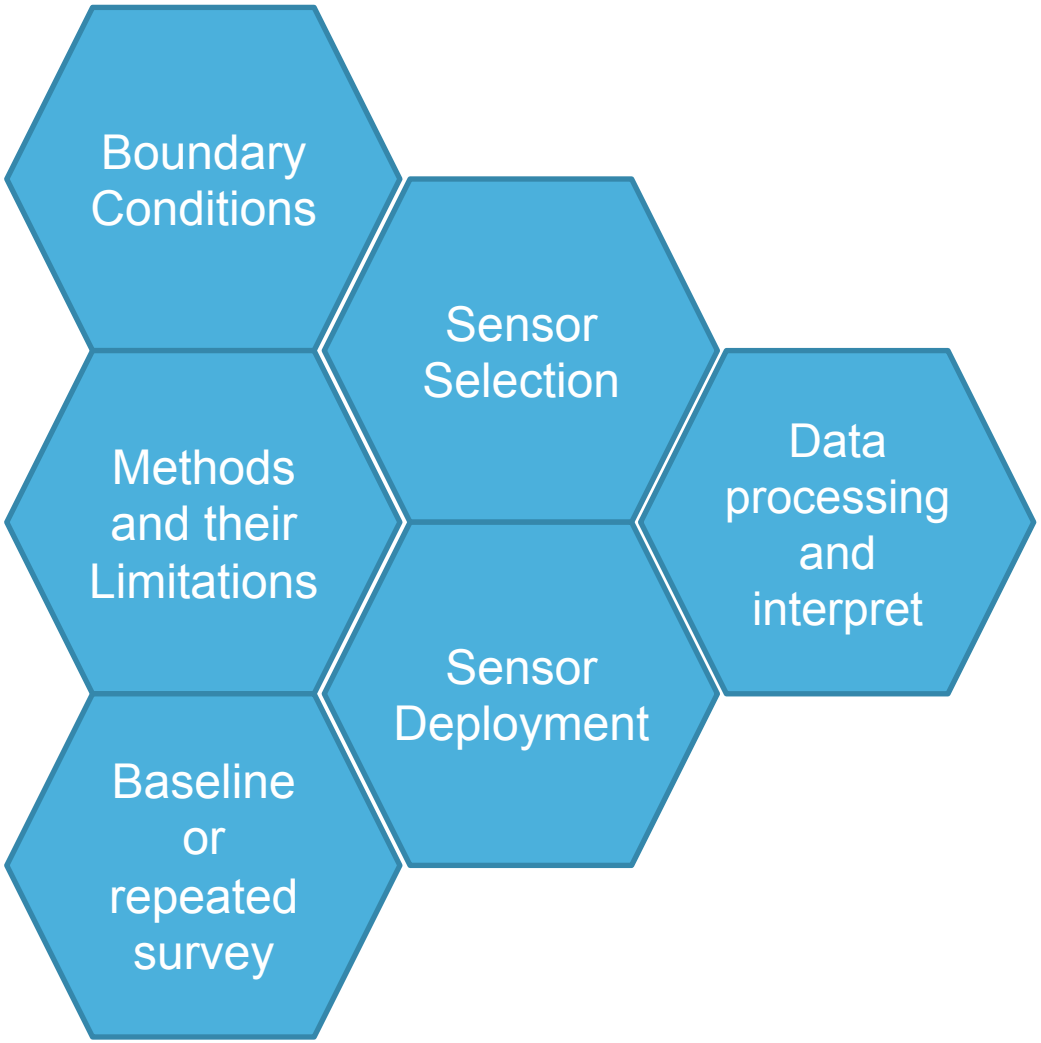
Not one size fits all.

And some problems simply cannot be solved by geophysics.

Quick Method Summary



How to Select the Right Tool?



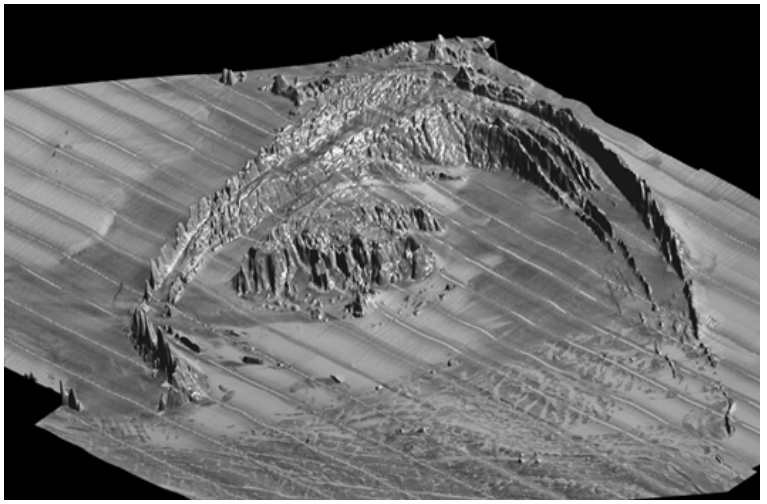
Presentation of results

Report Charts

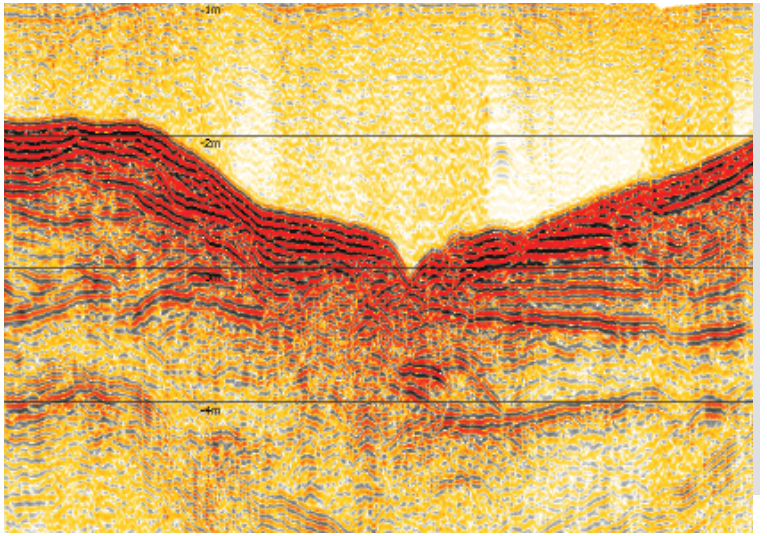
Marine Geophysical Methods

Generally, geophysical methods use remote sensing to investigate seabed & substrate.

- Surface Expression

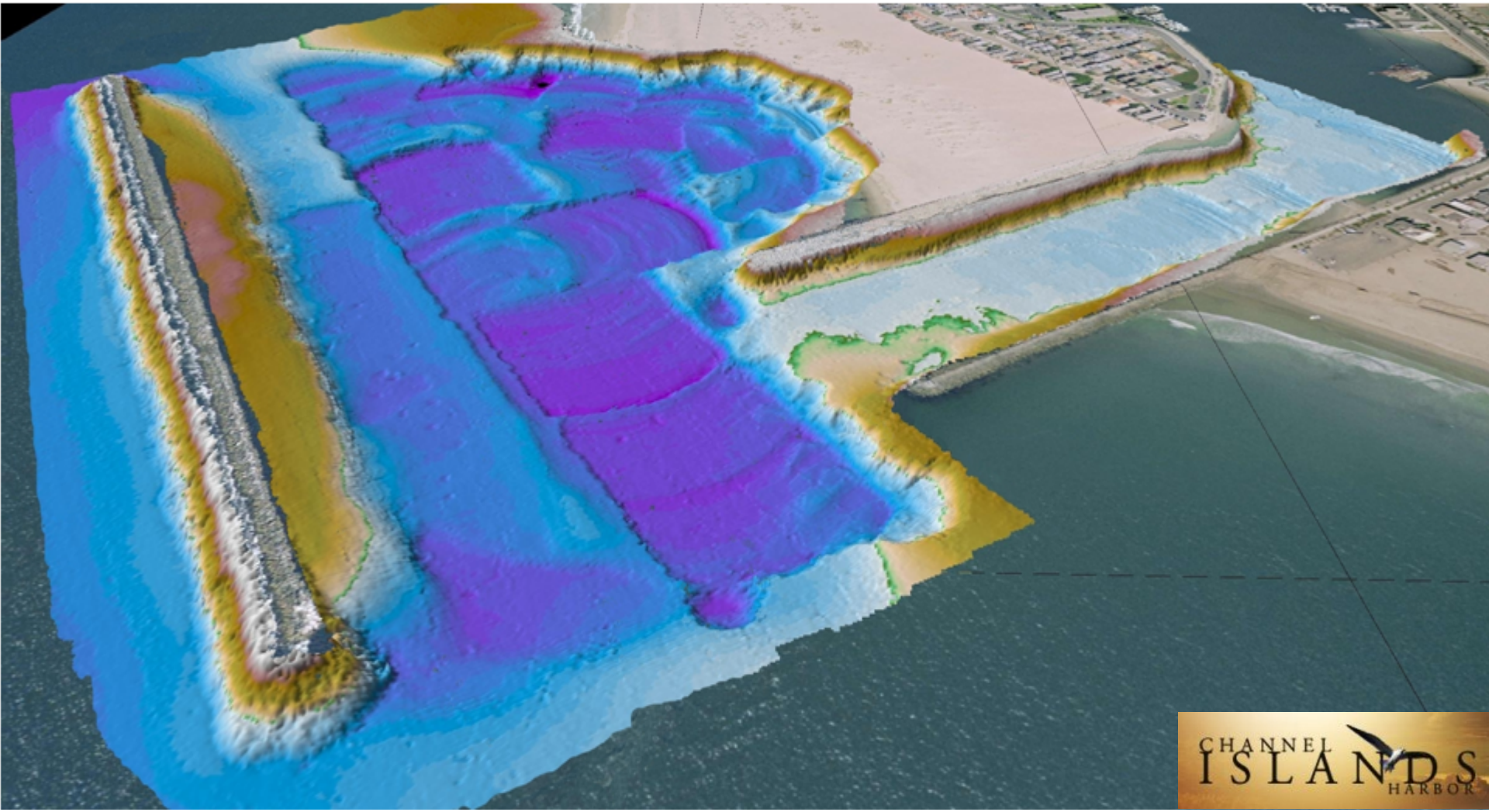


- Subsuface Expression

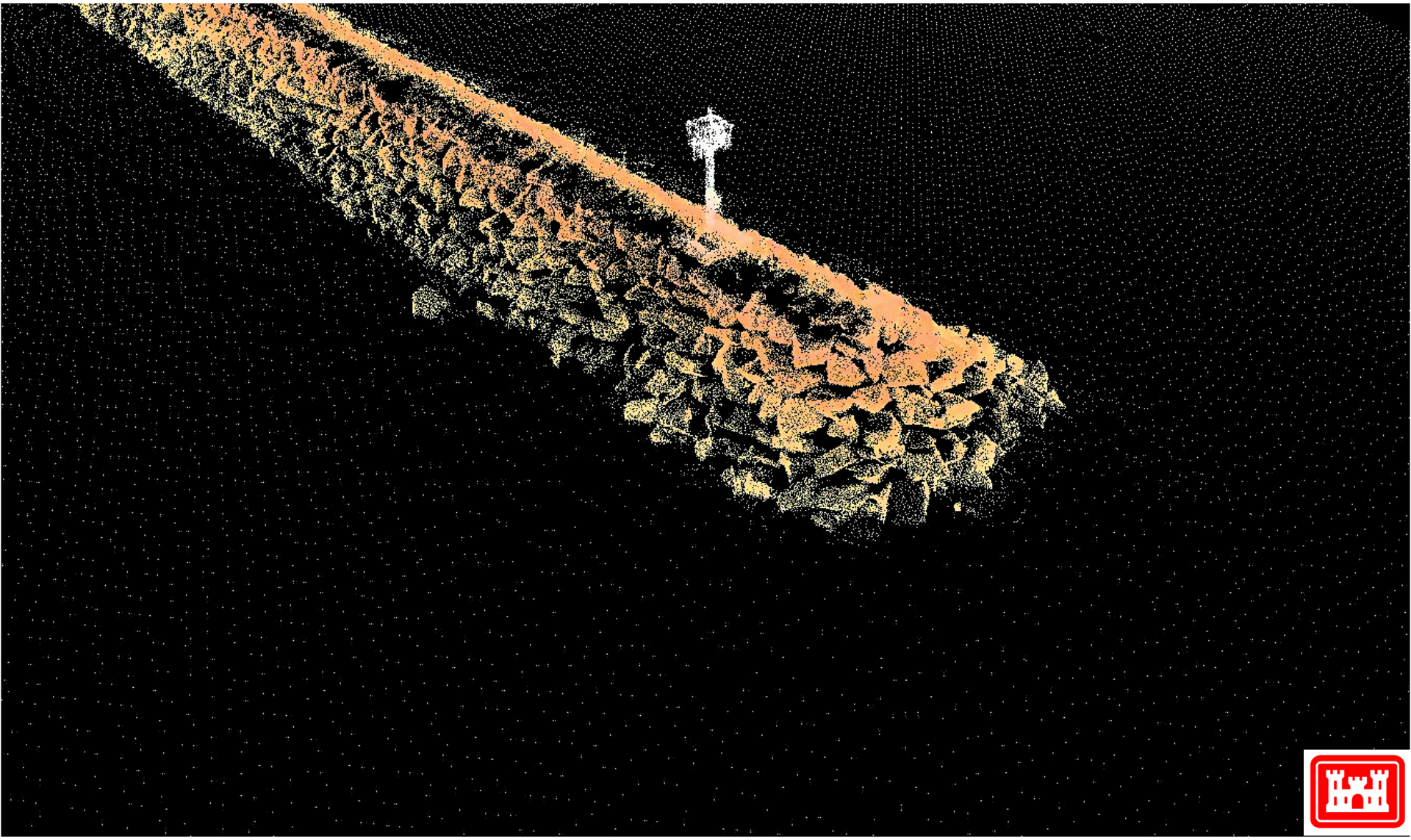


Surface expressions can be readily visualized. Subsurface data requires processing and interpretation.

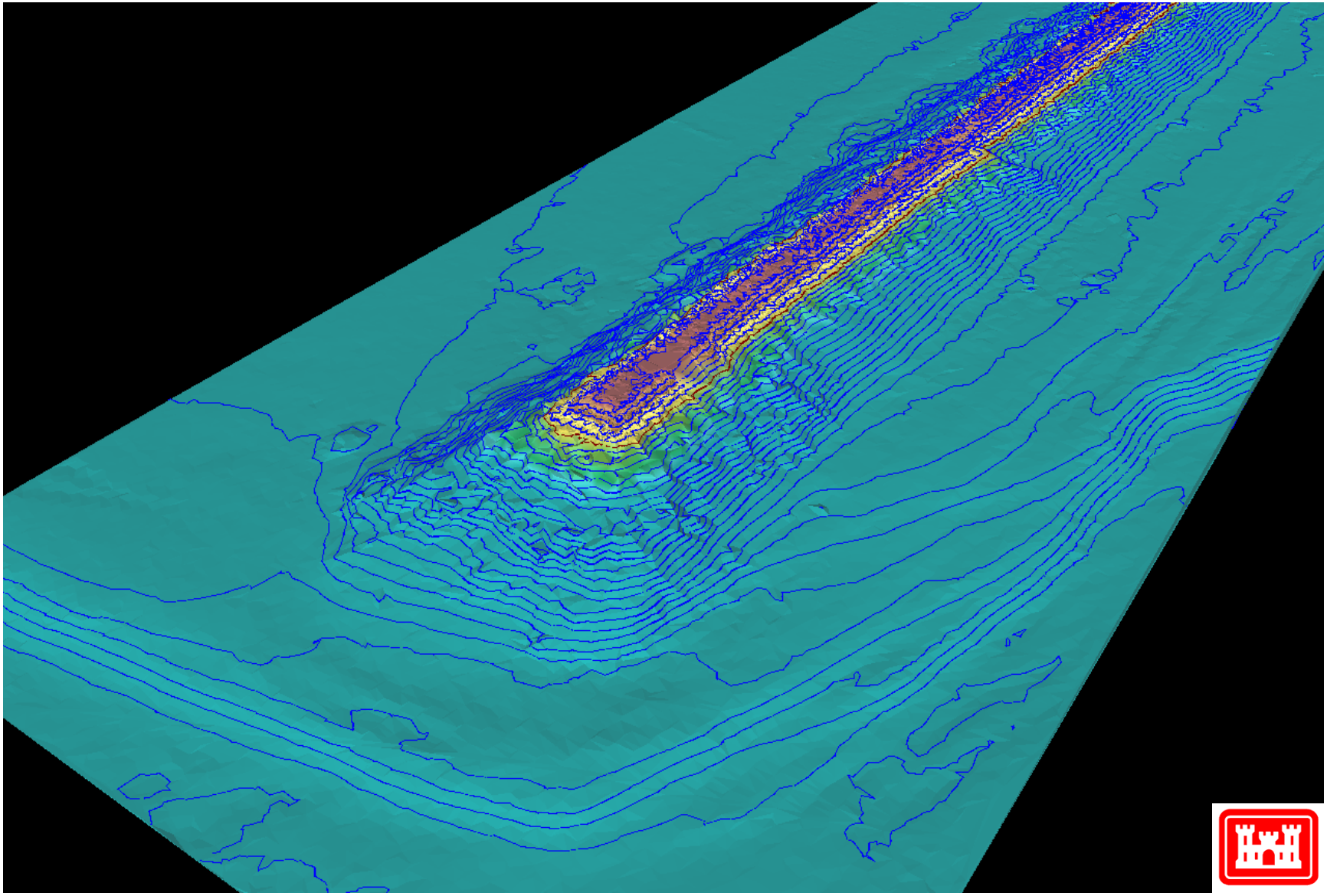
This is What We Are Used to Seeing from Marine Surveys



Technology Now Allows Broader and More Detailed Applications

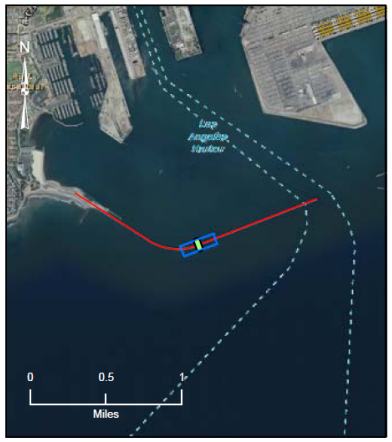


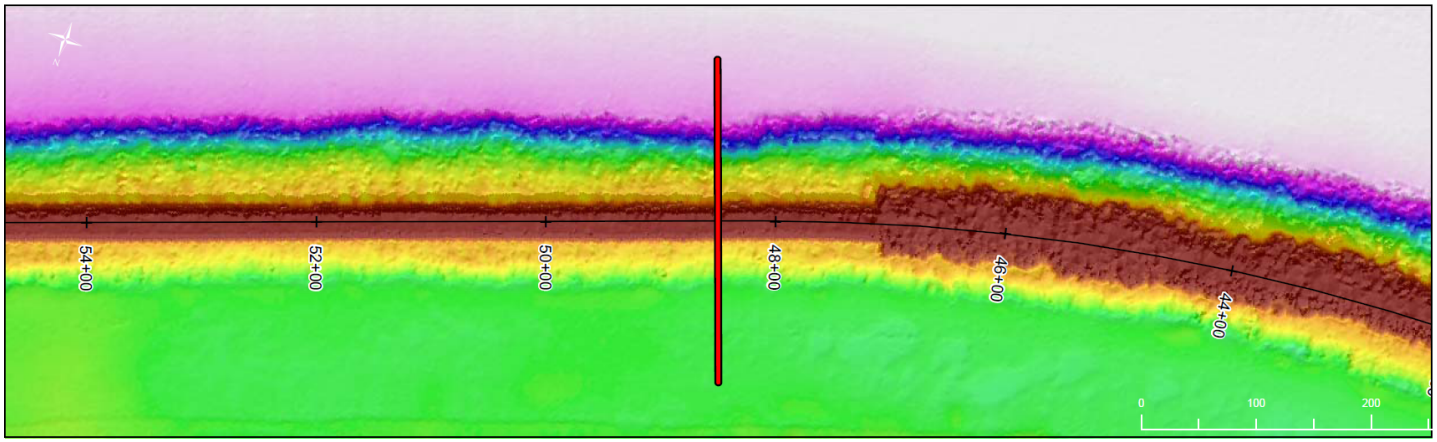
Technology Now Allows Broader and More Detailed Applications

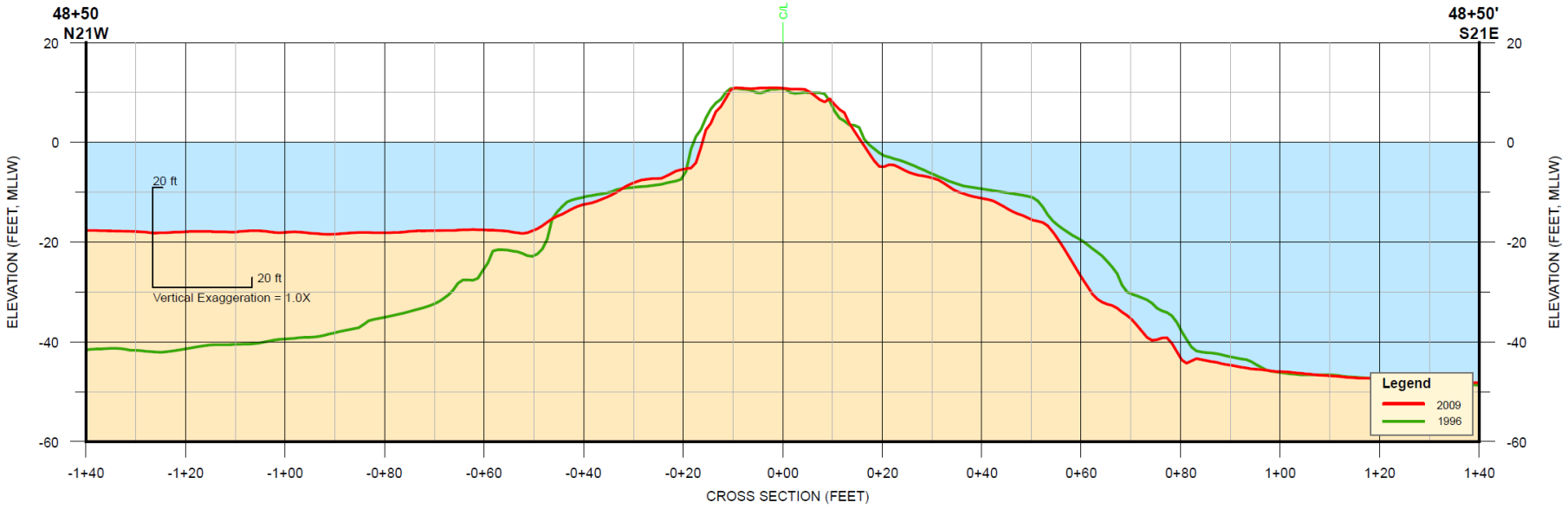


Cross-Section Comparisons: Present vs. Historical

USACE SAN PEDRO BREAKWATER COMPREHENSIVE CONDITION SURVEY
STATION NUMBER 48+50

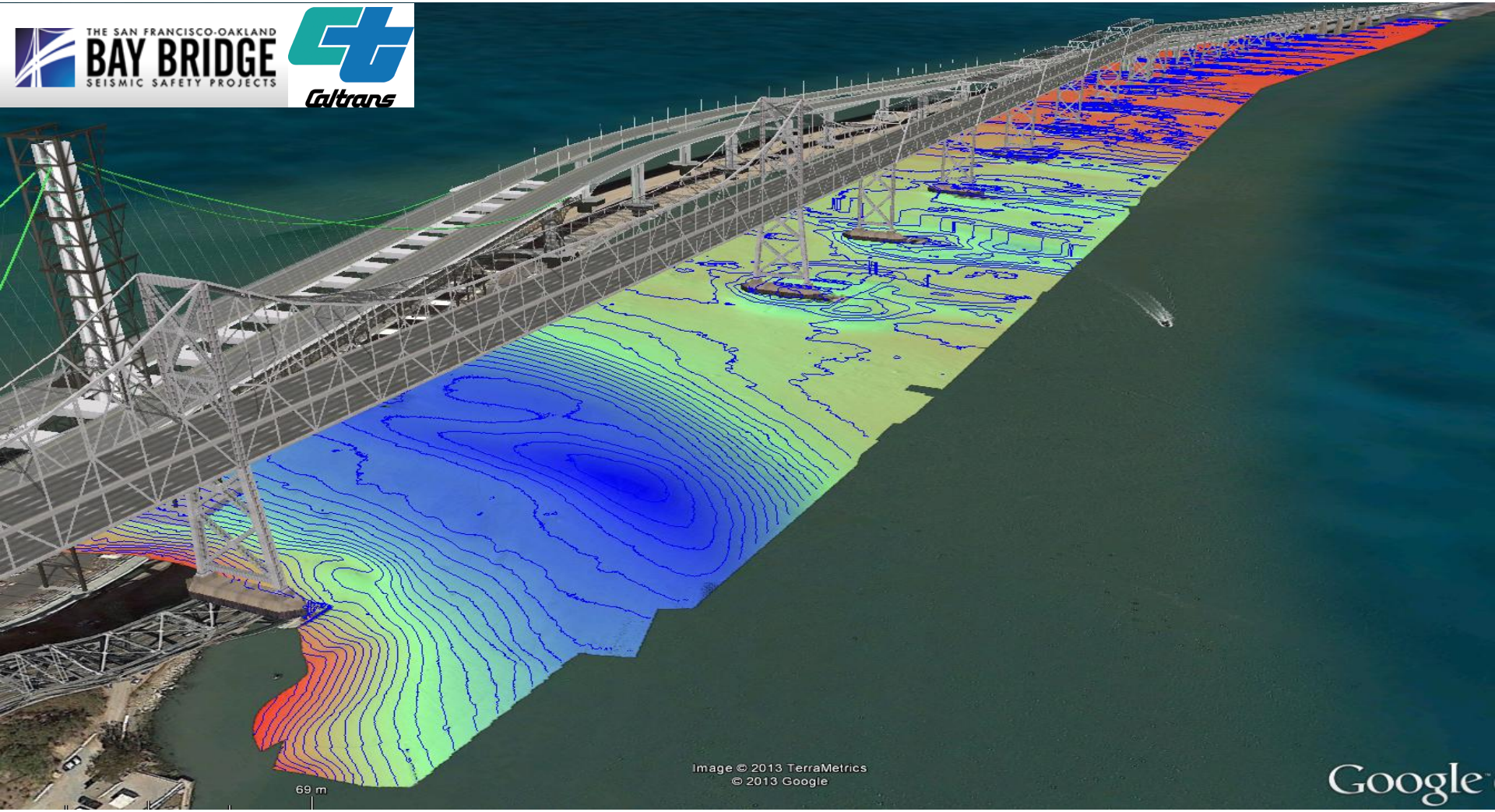






PDF Map Book

Surveying for Site Investigation / As-Built / Demolition



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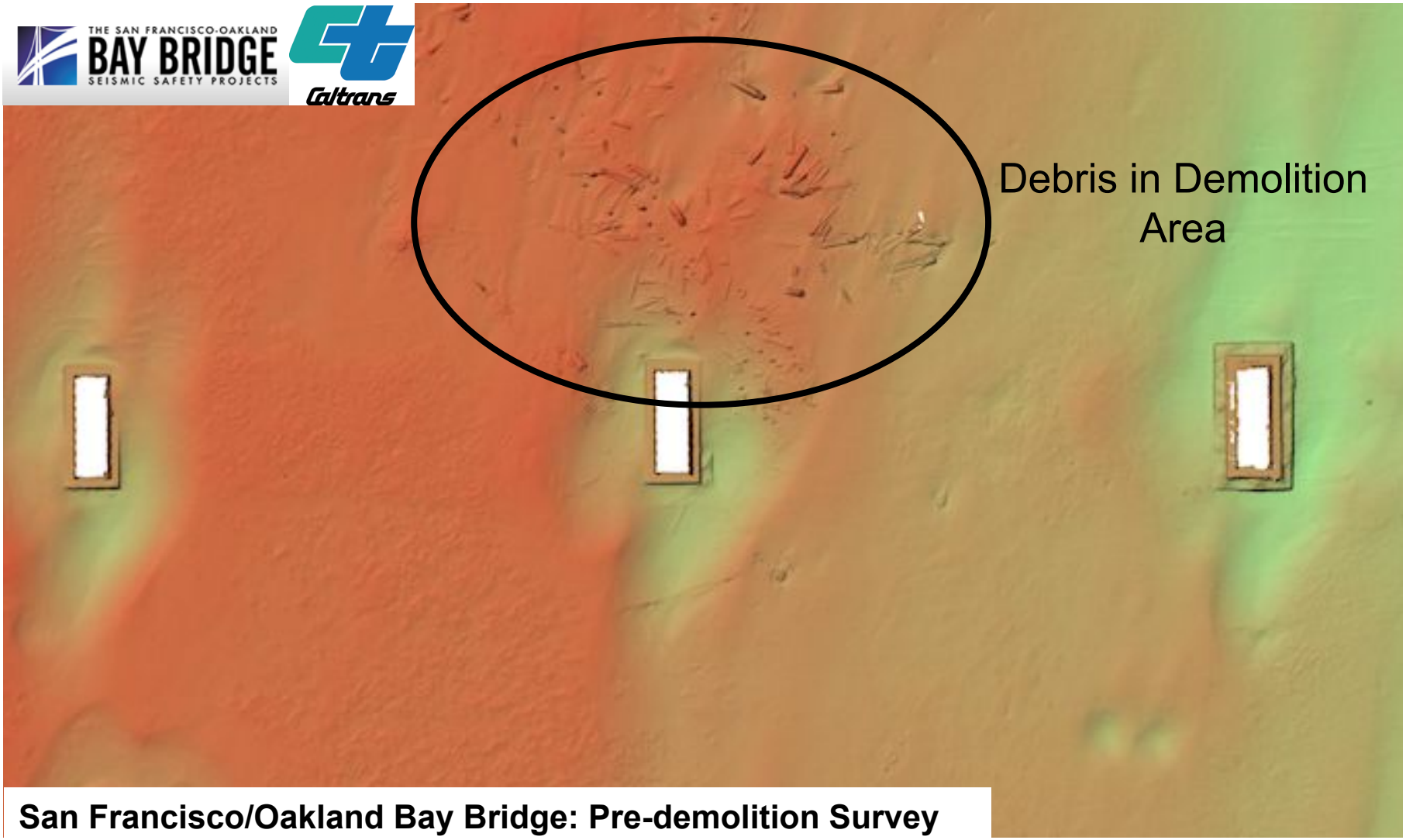
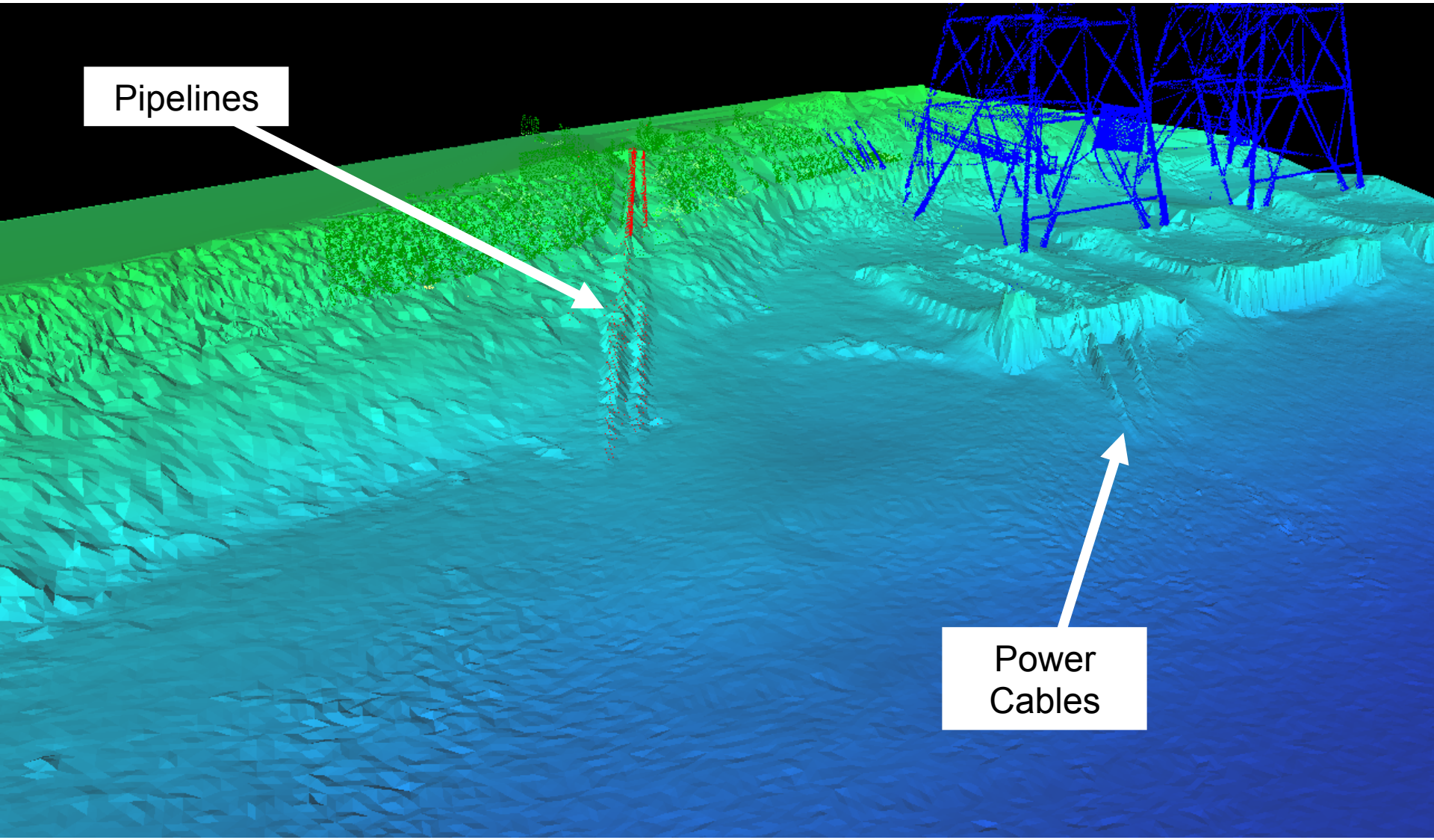


San Francisco/Oakland Bay Bridge: Pre-demolition Survey

Surface Expression – Visible in Multibeam or Side-Scan Sonar



Cerritos Channel

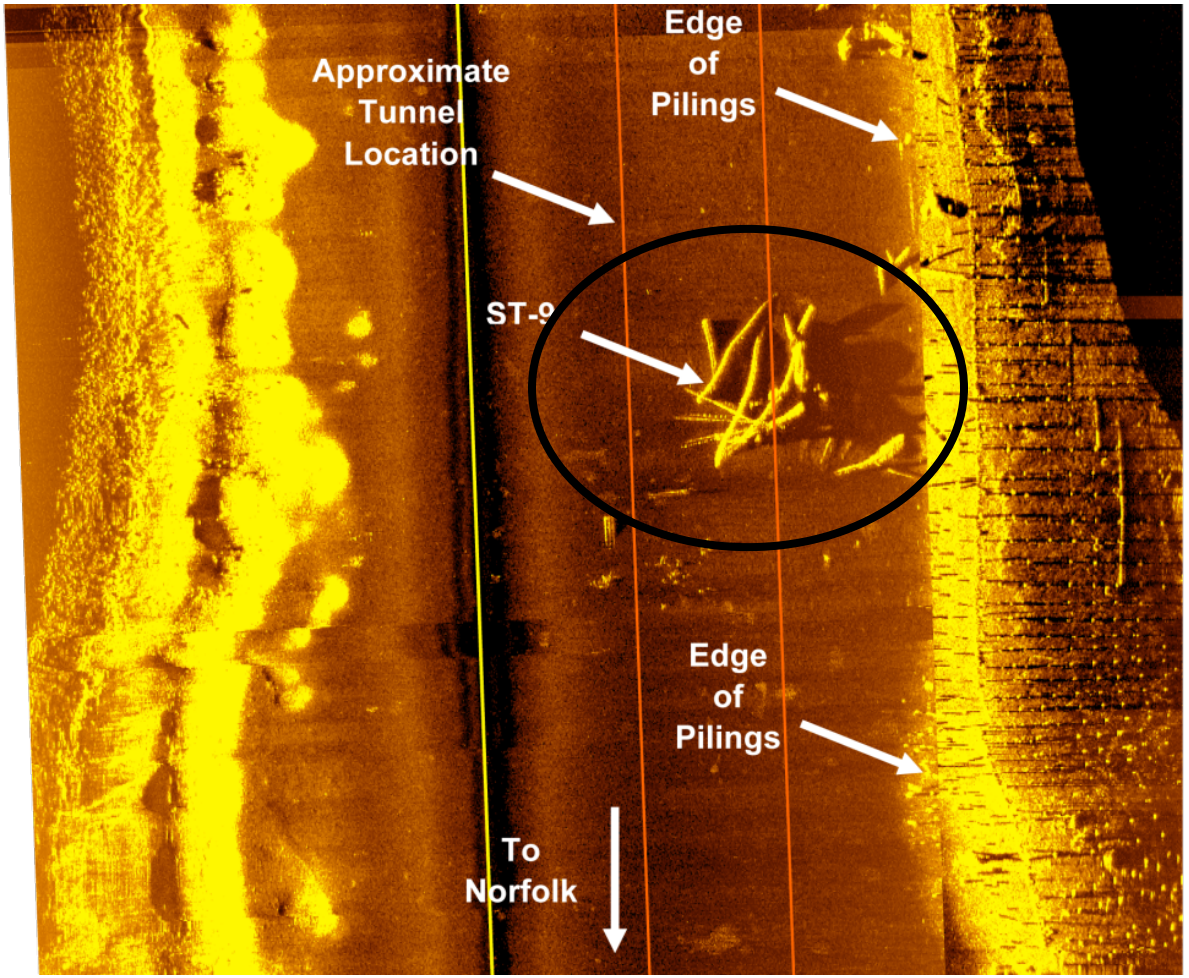
Surface Expression – Visible in Multibeam or Side-Scan Sonar

You can find even very small objects.

Surface Expression – Visible in Multibeam or Side-Scan Sonar

You can find even very small objects...like tires.

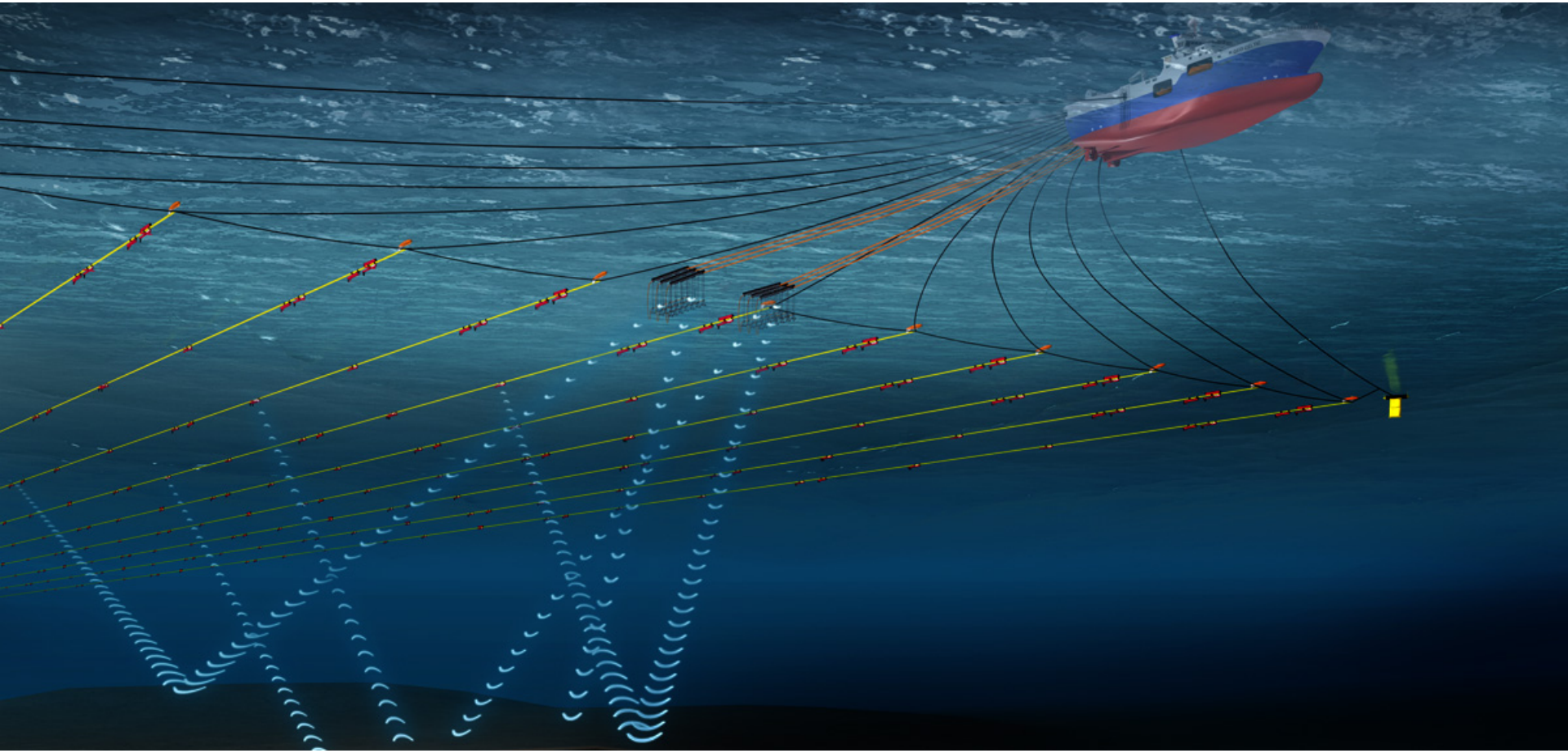
Surface Expression – Visible in Multibeam or Side-Scan Sonar



Norfolk Light Rail at Broad Creek

- 260 rail pilings found in construction area
- (20 initially reported to construction contractor)
- $369k change order to remove piles

Seabed (Sub-surface) Geophysical Surveys



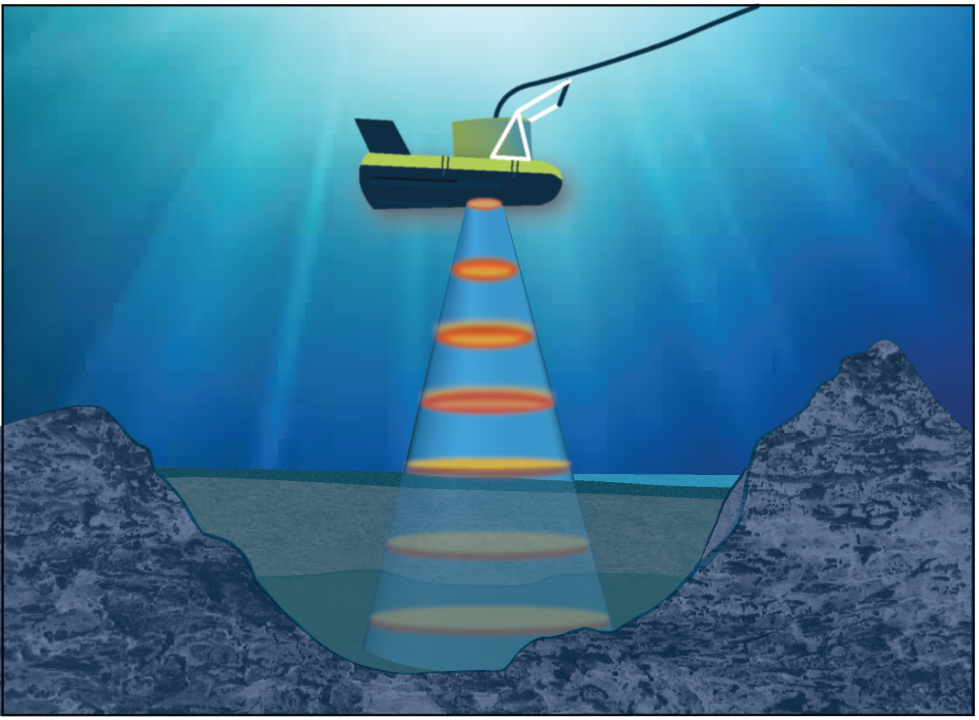
Seabed geophysics may use active or passive methods. Acoustic signal reflection, refraction, electro-magnetic resistivity and passive magnetometers make up the most common methods.

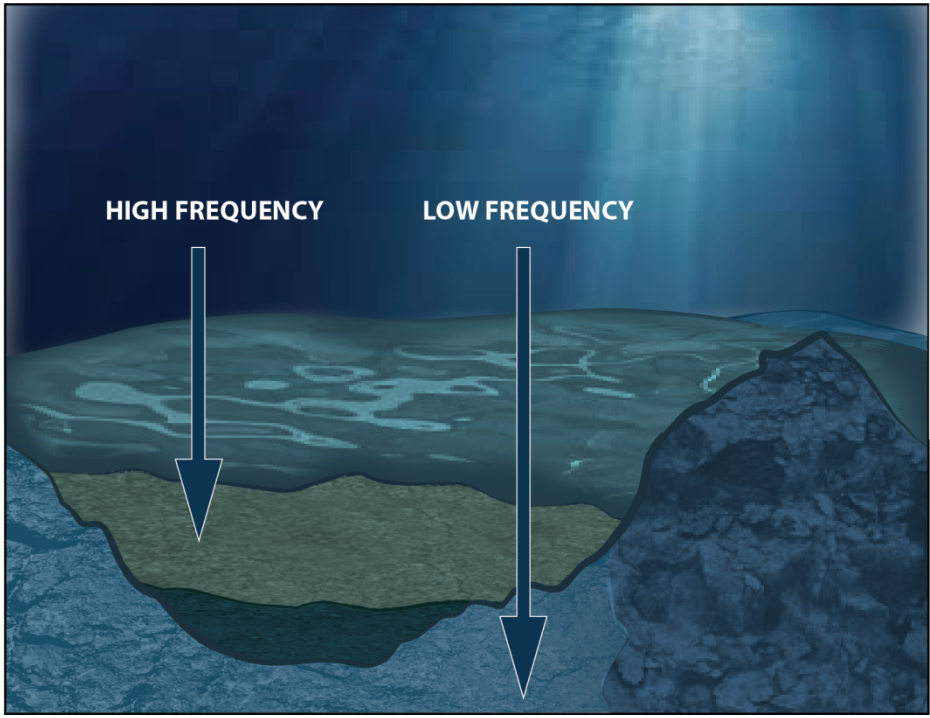
Acoustic Geophysics: Sub-Bottom Profiling

Low-frequency acoustic reflection is used for deep substrate penetration

High-frequency (such as CHIRP technology) is used for identifying different sediment layers in the shallow seabed (e.g. silt, gravel, bedrock).

It CAN also find hard objects buried near the seafloor…sometimes…

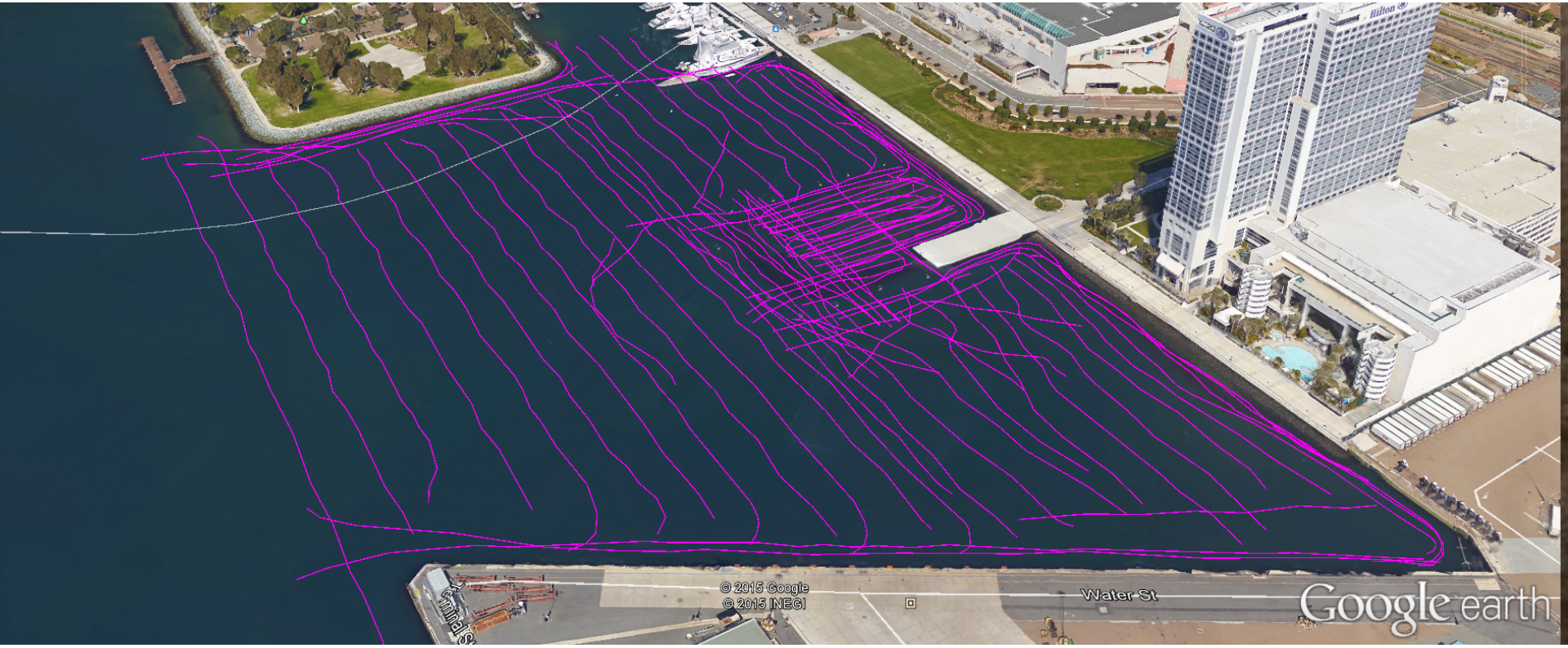




Acoustic Geophysics: Sub-Bottom Profiling

BUT sub-bottom is a profiling technology.

The sensor detects only what is immediately below it.

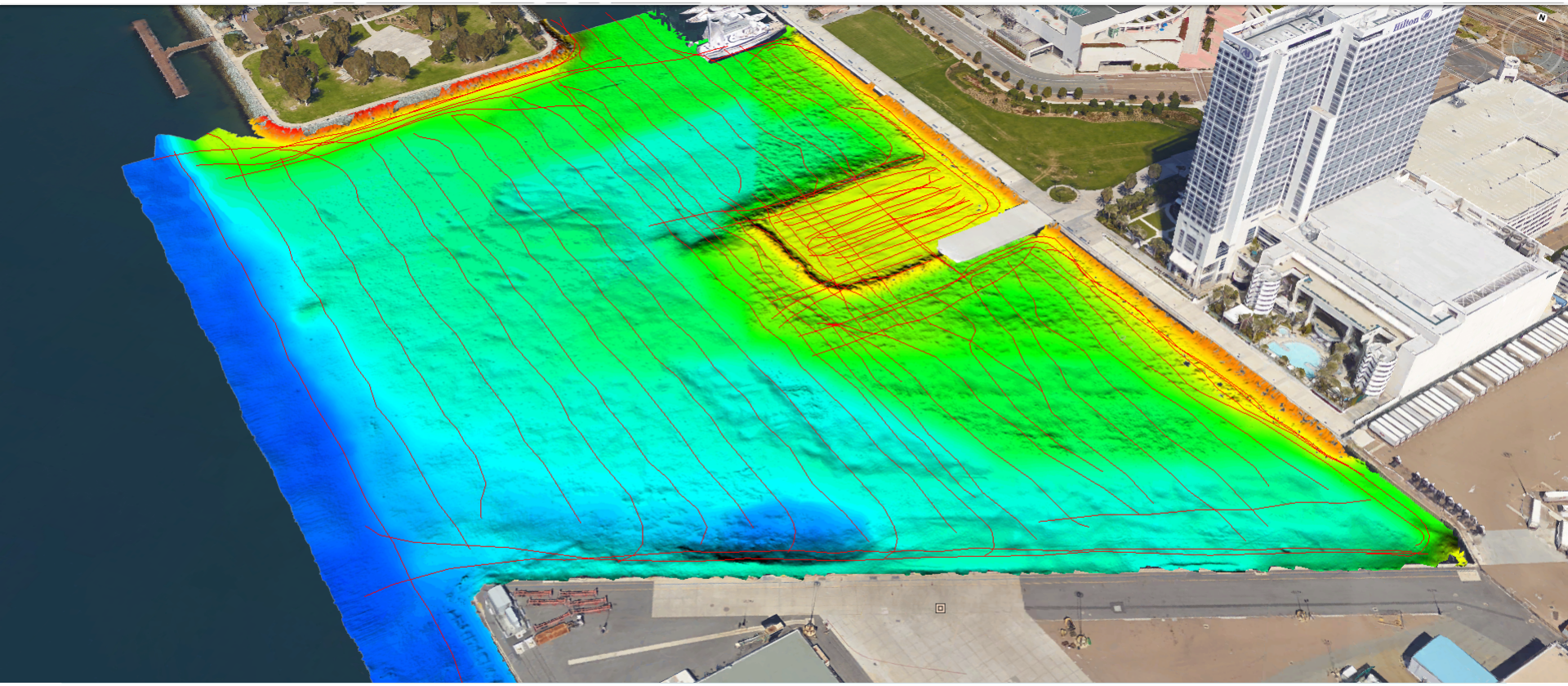


Acoustic Geophysics: Sub-Bottom Profiling

BUT sub-bottom is a profiling technology.

The sensor detects only what is immediately below it.

Yet, we expect knowledge of the complete seabed.

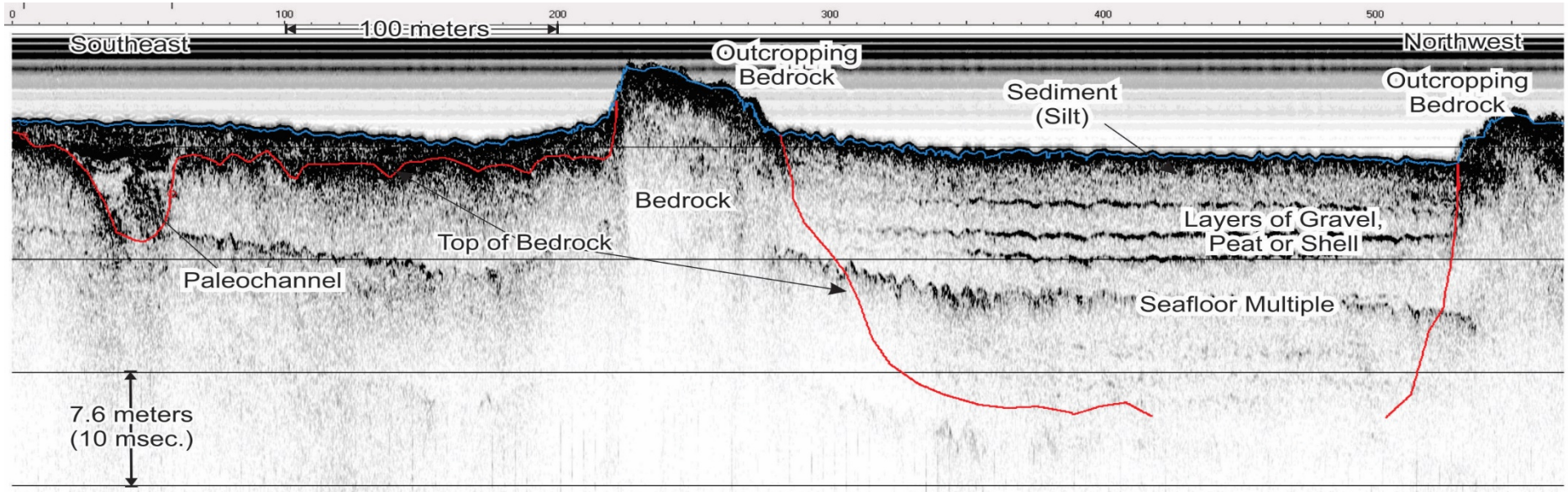


BUT sub-bottom is a profiling technology.

The sensor detects only what is immediately below it.

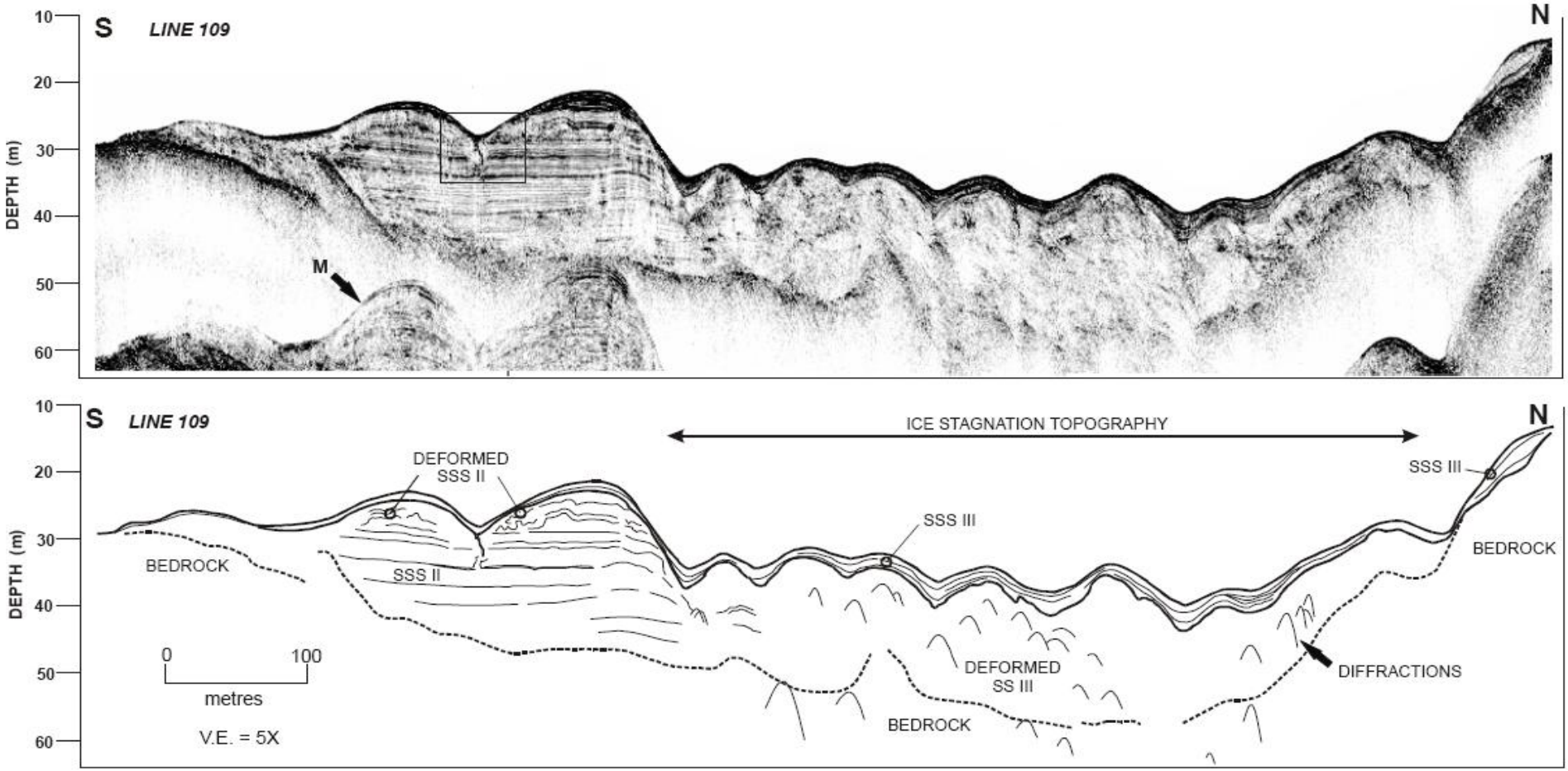
And interpretation is not always obvious.

And penetration is limited by the seabed material.



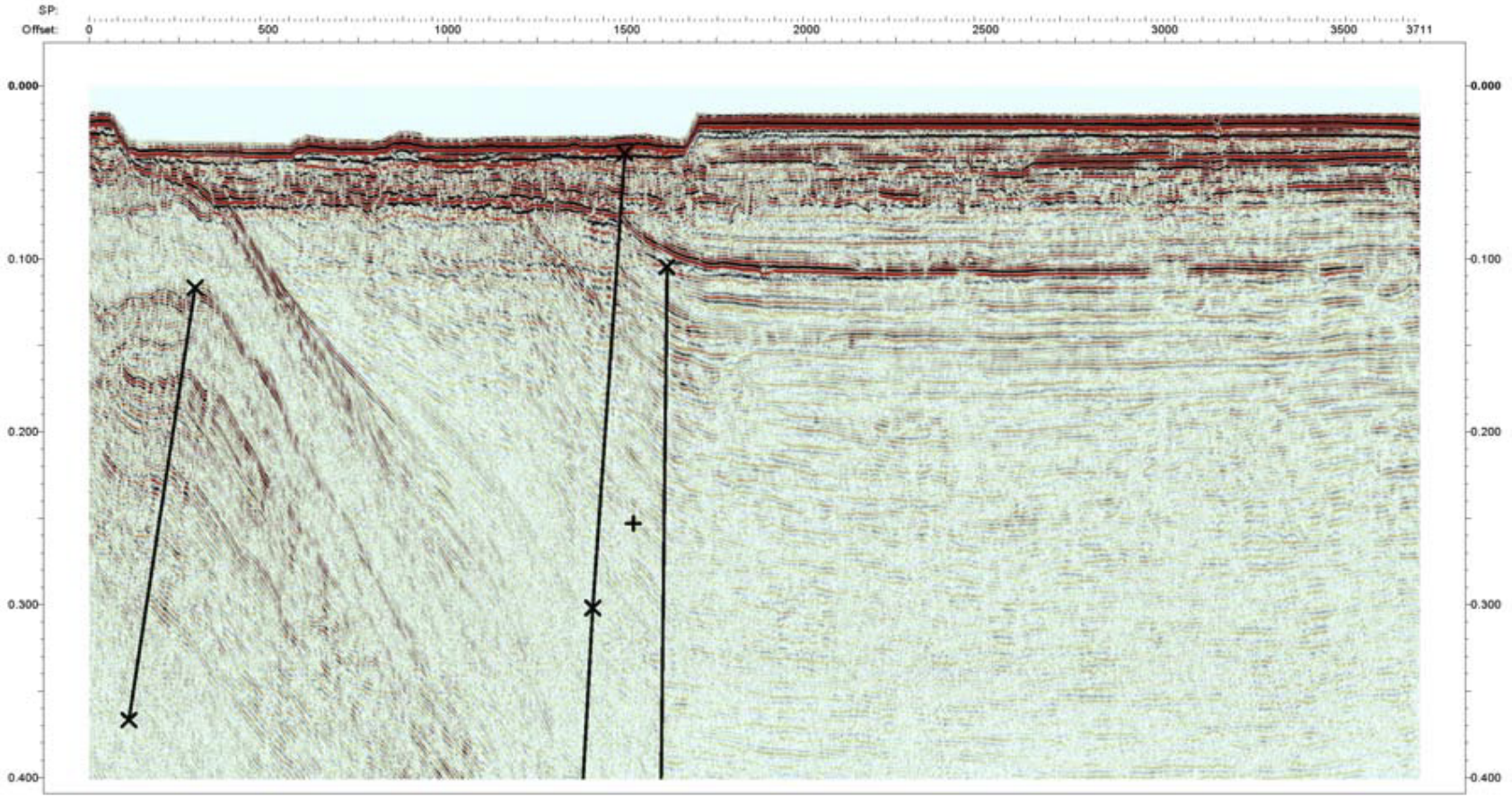
Acoustic Geophysics: Sub-Bottom Profiling & Seismic Reflection

Different seismic sources: chirp, boomer, sparker or air-gun
Different receivers: single/multi-channel/digital/analogue
Data interpreted with core samples to produce geological maps



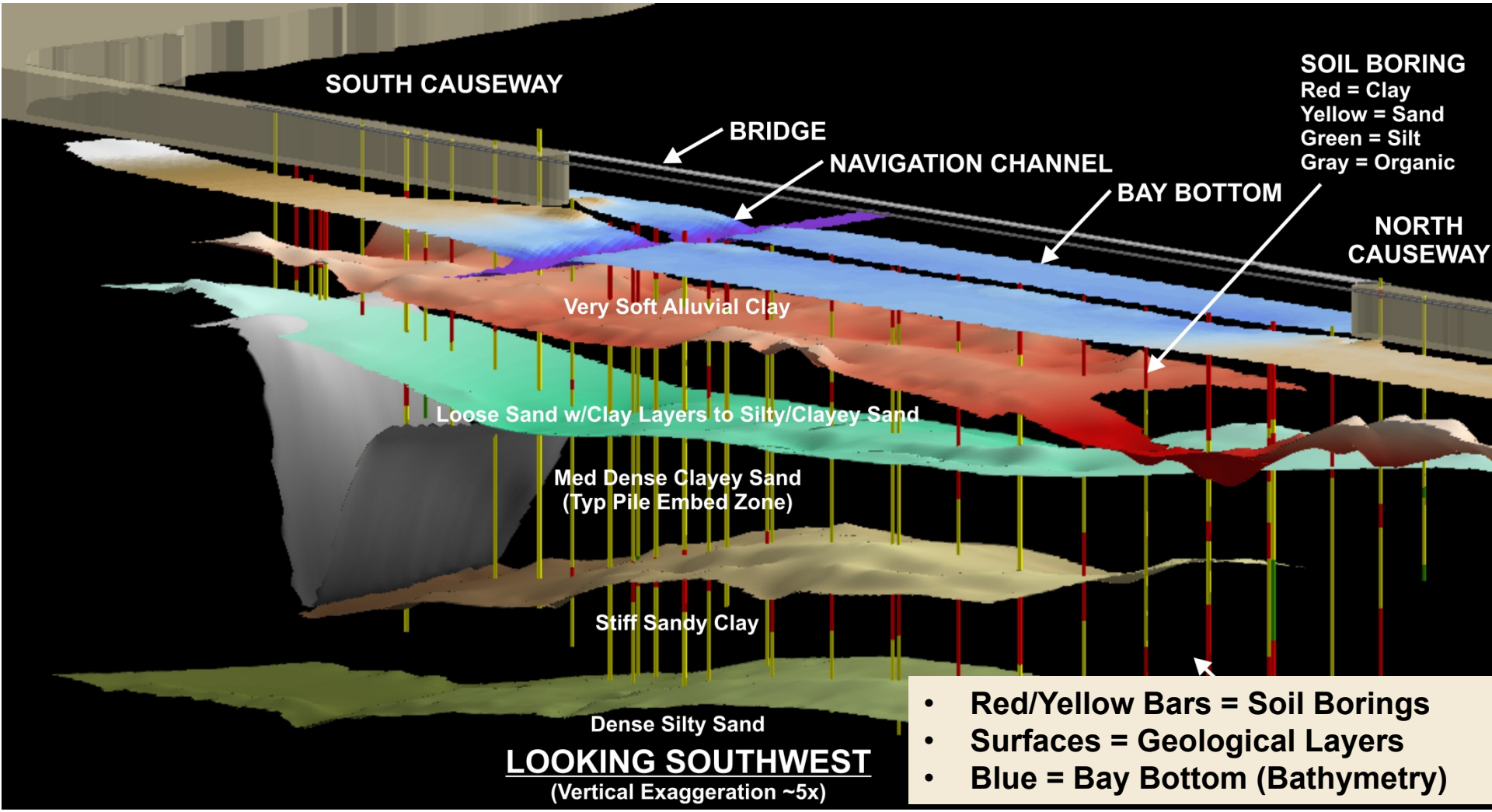
Acoustic Geophysics: Seismic Reflection Example

Data collected at the Port of Los Angeles with a Boomer plate acoustic source and digital streamer configured w/36 channels. Note near-surface faulting, folding, and dredging



2-D Line Density Can Create a 3-D Geological Model

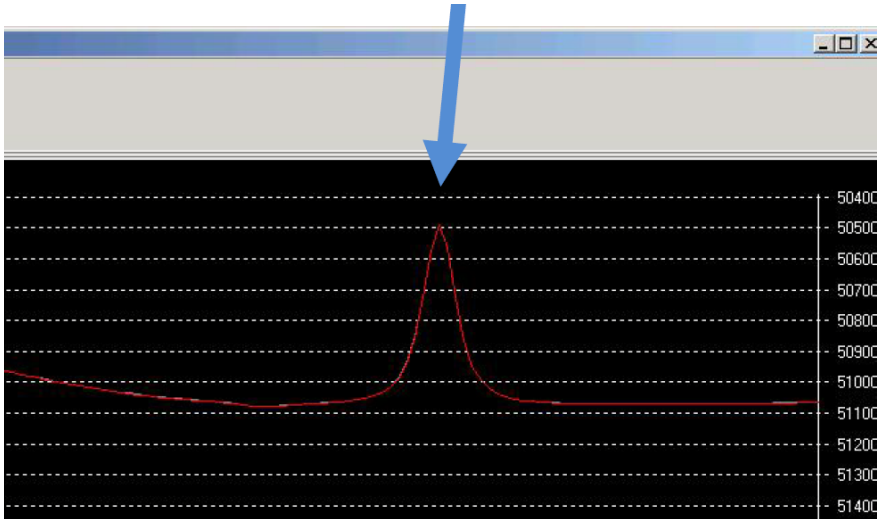
3-D Subsurface: Integration of Geophysics and Geotechnics

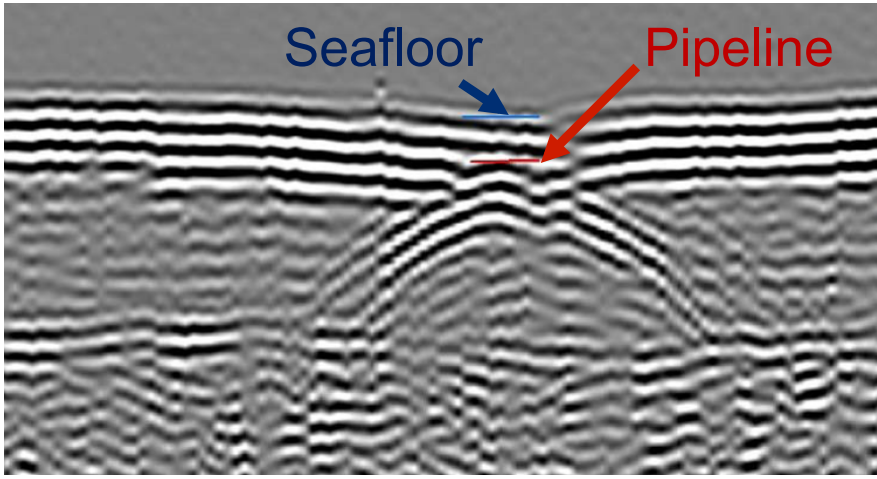


Identify location of utilities below the seabed detecting:

- Magnetic characteristics
- Surface expressions
- Geophysical signature

Specialized tools for determining depth of burial in active development.

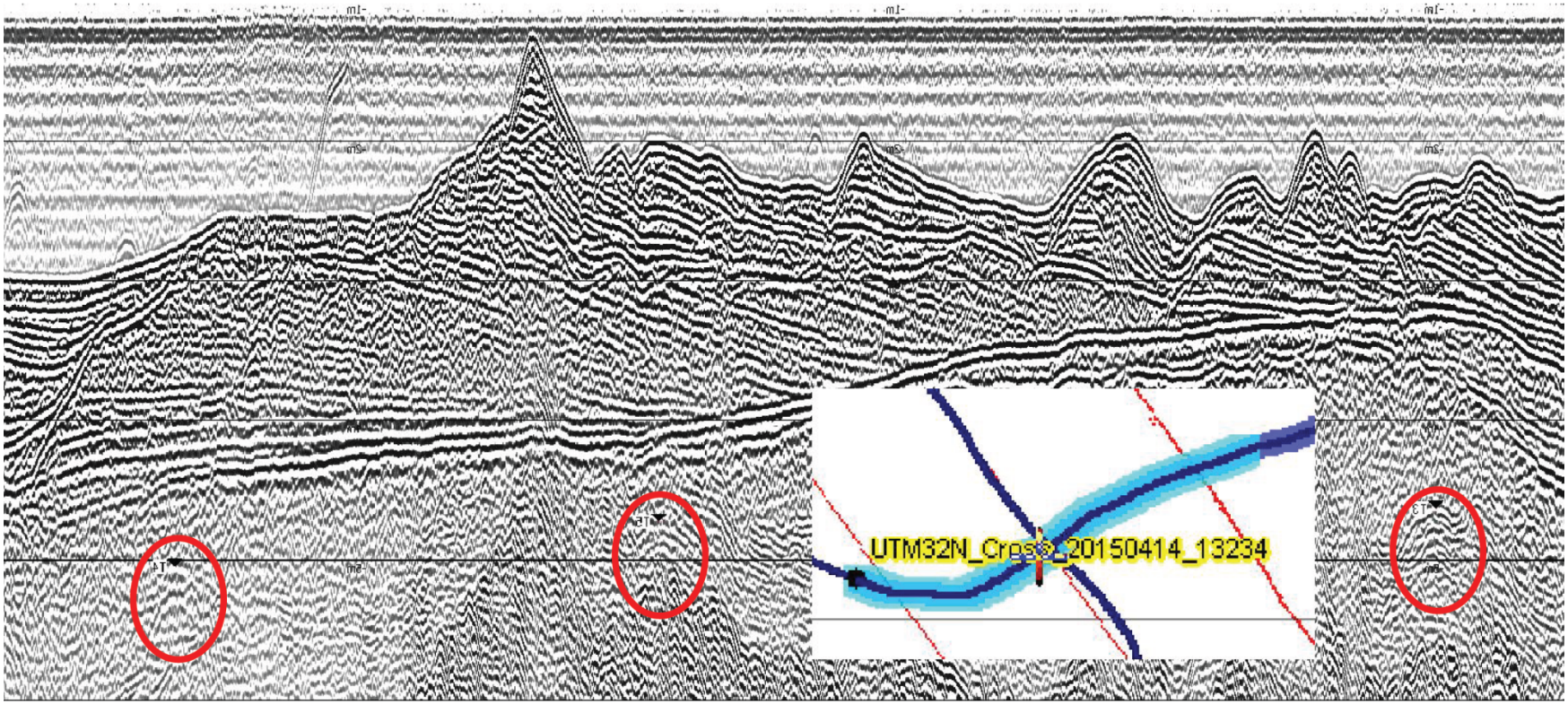




Sub-Bottom Geophysics for Object Identification

Sub-bottom profiling for identifying cables and pipelines is very challenging. Without knowing that a feature is present already, identifying the object can be extremely challenging. Even harder in very shallow water.

Example below is a SBP line perpendicular crossing of DC electric cable. Outside diameter 6”

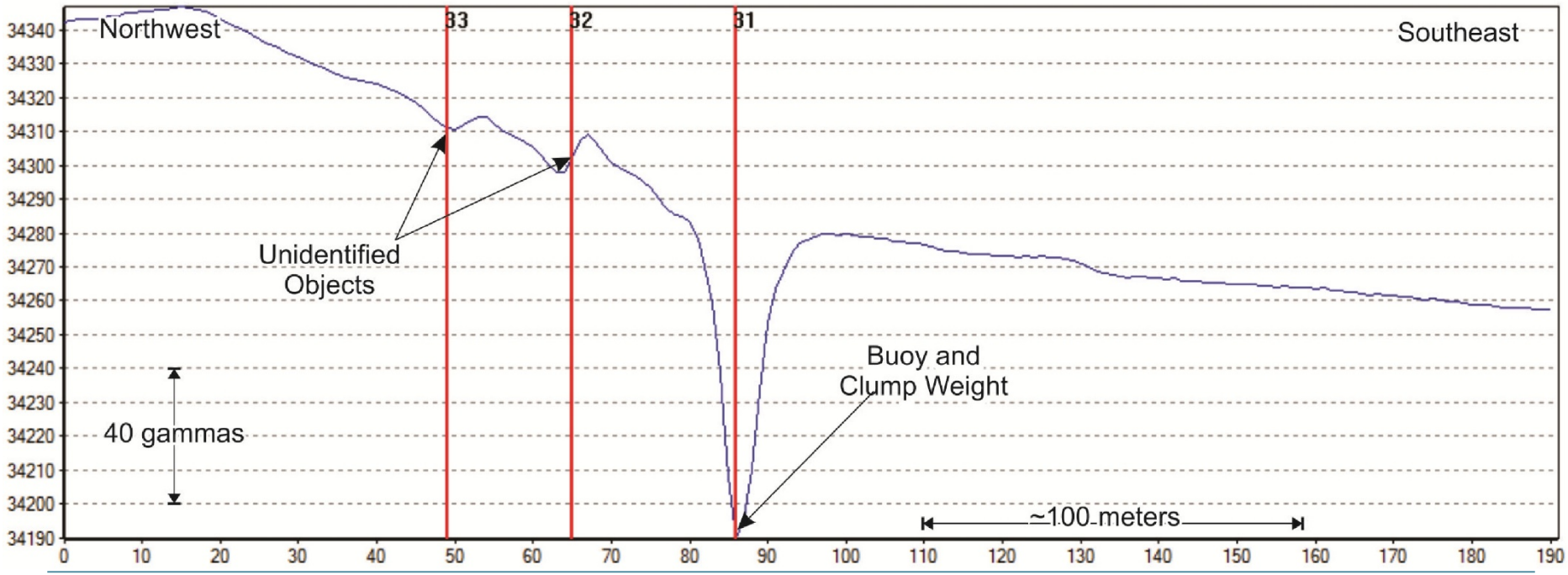


Magnetometry

Passive magnetometry systems act like metal detectors to identify **ferrous metals** on/below the seabed. Non-metallic objects are invisible.

There are different methods of magnetic detection (cesium vapor, PPM, Overhauser).

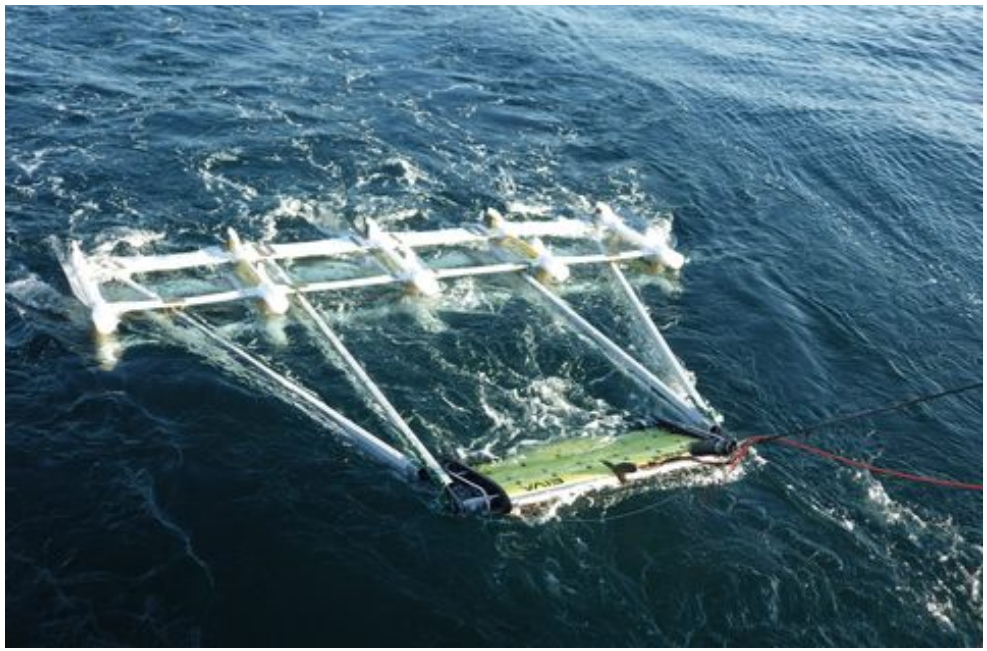
Sensitivity is affected by range to target, metallic mass, soil composition and nearby objects. Also impacted if energized/active.



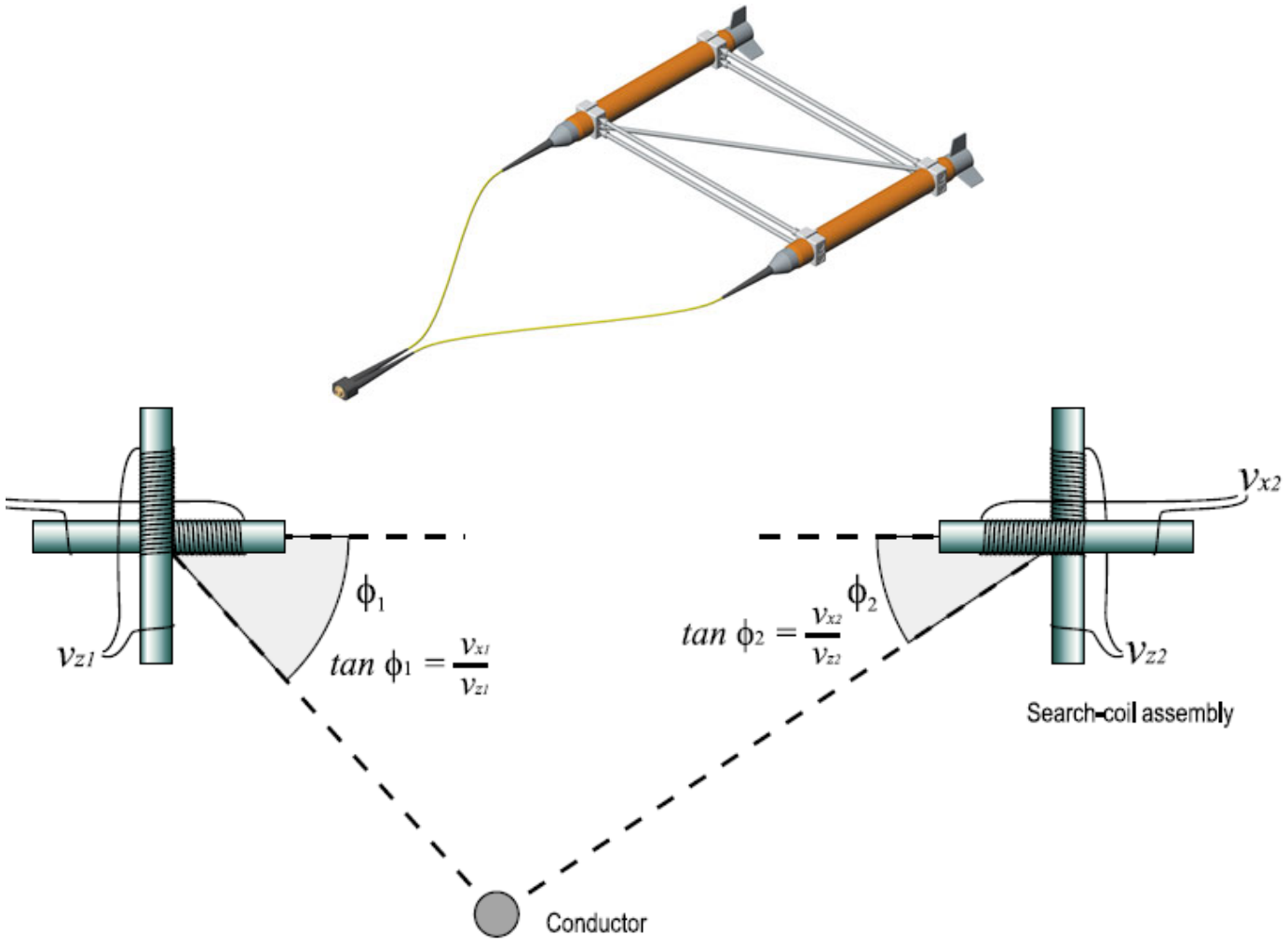
Magnetometry

Magnetic Gradiometer measures magnetic gradient (direction) by using multiple magnetometers in an array.

An array can detect variations in both vertical and transverse magnetic gradient, which enables the ferrous signature from background geology and motion noise to be significantly removed during data processing.



Triangulation of the gradient between units can be used to calculate depth of burial.



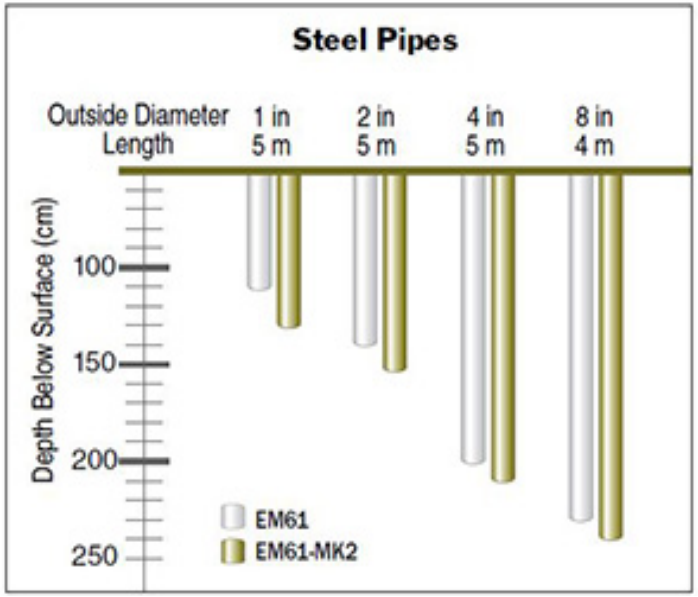
Electromagnetic Induction

Marine Transient Electromagnetic Induction surveys introduce transient currents through the conductive water column and into the seabed to generate secondary magnetic fields.

This secondary EM field can be used to detect metallic objects, such as buried pipes, cables, unexploded ordnance or debris. However, powered cables introduce interference impacting the data.

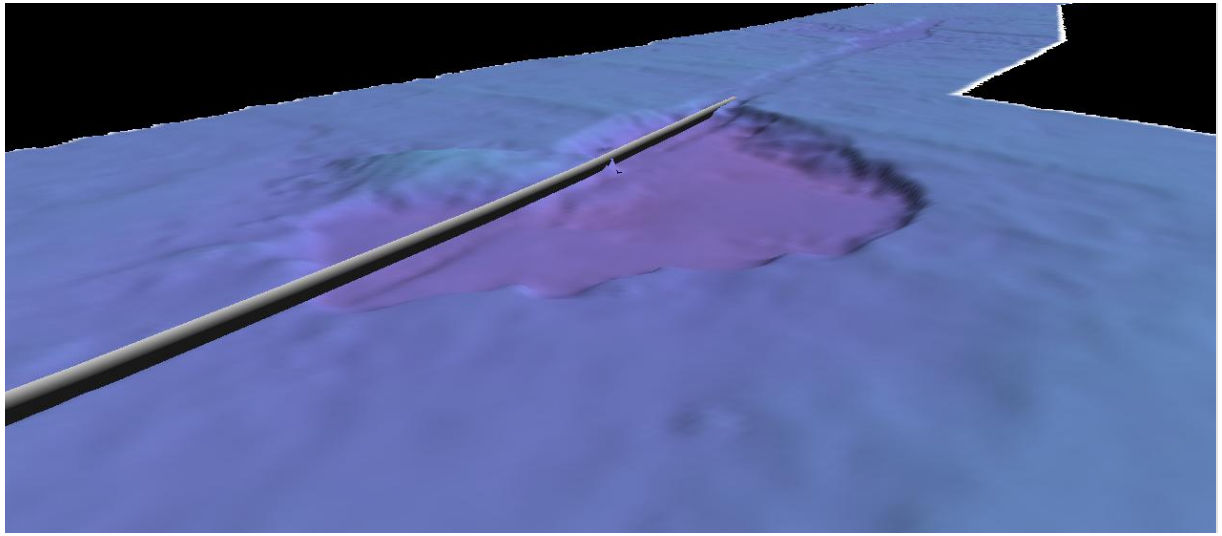
Teledyne TSS 440 EMI Pipe & Cable Tracking

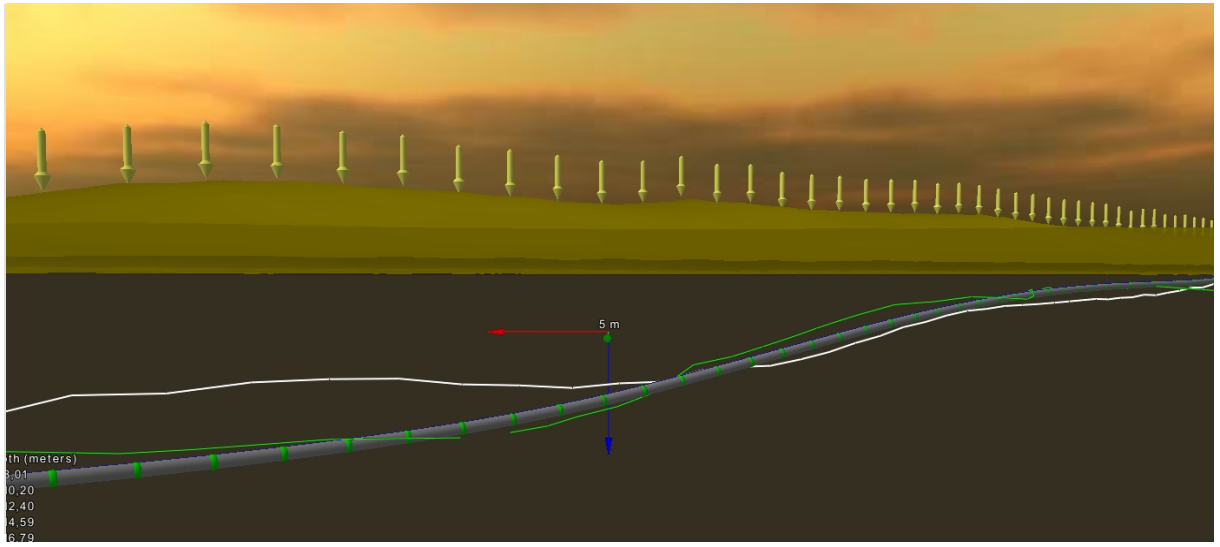
Geomatrix EM-61S System



Geomatrix EM-61S: Detection depth for Steel Pipe

Data Deliverables





Maps/charts that integrate the seabed and the position of features are generally the desired product.

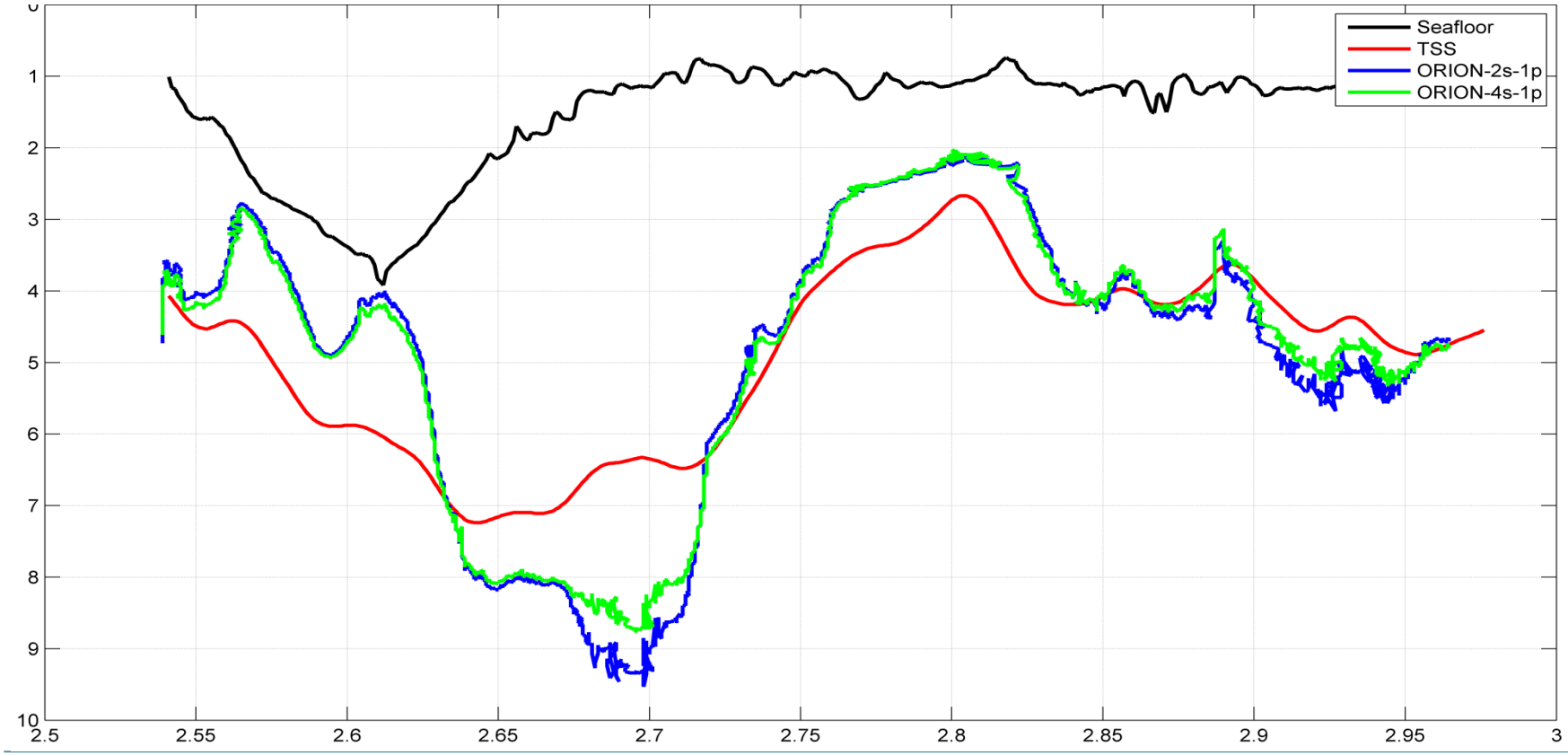
Data can be presented as hard copy plots, digital PDF files, CAD drawings, GIS layers, rendered in 3-D, etc.

Data can also be viewed in vessel navigation programs onboard vessels for real-time avoidance assurance.

Depth of Burial – the Great Unknown

Depth of burial is often not repeatable between system types. They may generally trends similarly, but absolute values are often different. Therefore technique is better suited to change detection – and using the same system each time.

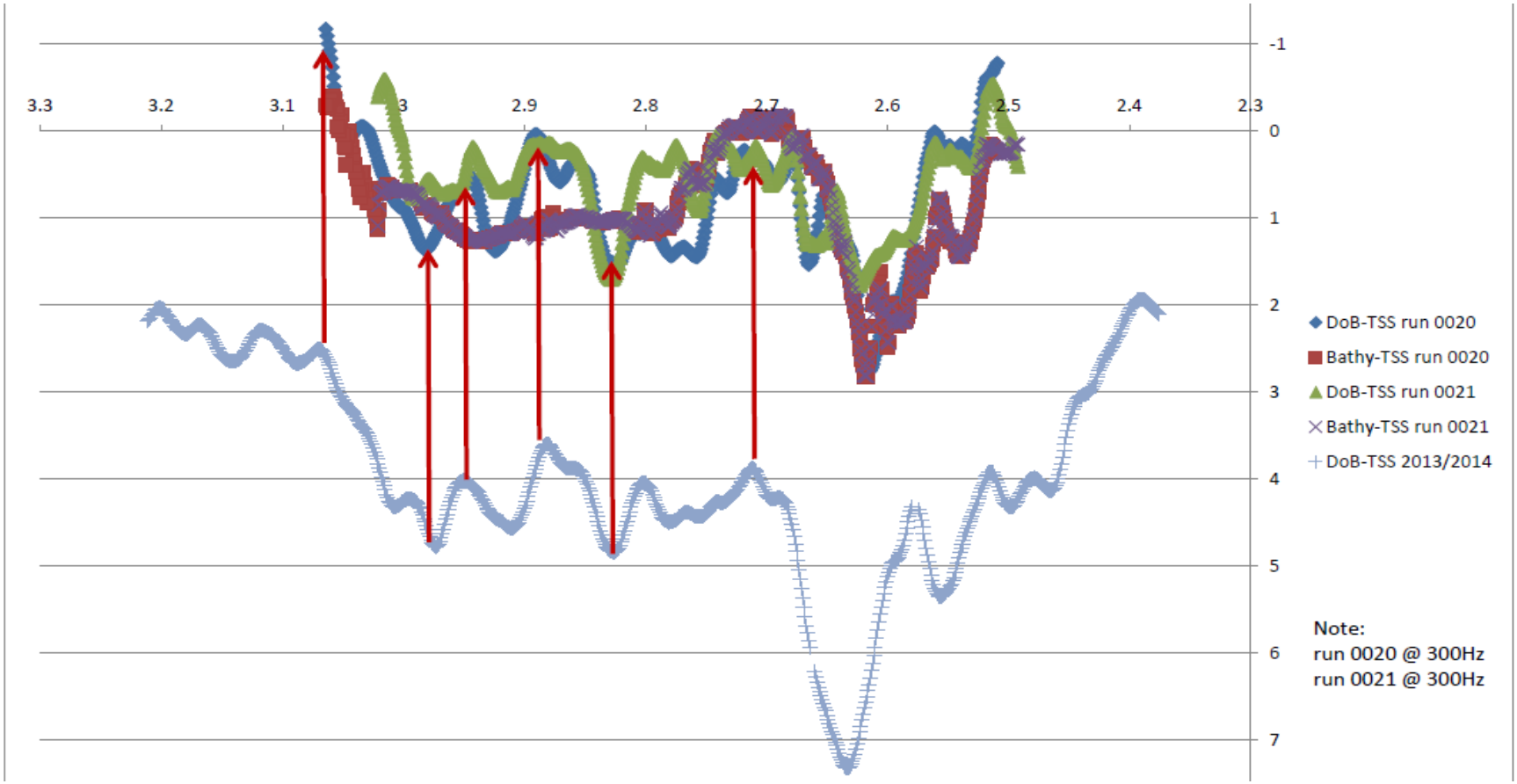
Below is a comparison between Teledyne TSS 350 (red) and OR ORION with 2 sensors (blue) / 4 sensors (green) array.



Depth of Burial – the Great Unknown

Similarly, cable condition at the time of survey affects Depth of Burial.

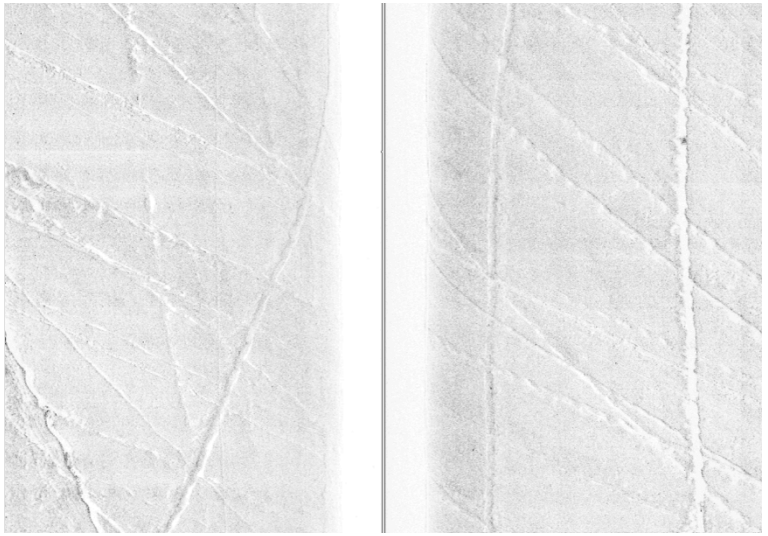
Below, the blue line represents the cable inactive with a tone generator. All others, the cable is in active service.



Example: Seafloor Cable Detection

Cable avoidance/cable protection

- Cable may be visible in surface expression (easiest to detect). Can be cable itself, can be rock armouring, seabed mattresses…
- Cable may be energized (active power) or can be manually energized to detect (radio detection
- Cable can be detected by magnetometer (array needed to detect depth)
- Cable can *possibly* be identified by sub-bottom profiling (very unreliable method)



Example: Seafloor Cable Detection: Boundary Conditions

Operating status?
(energized, out-of-service)

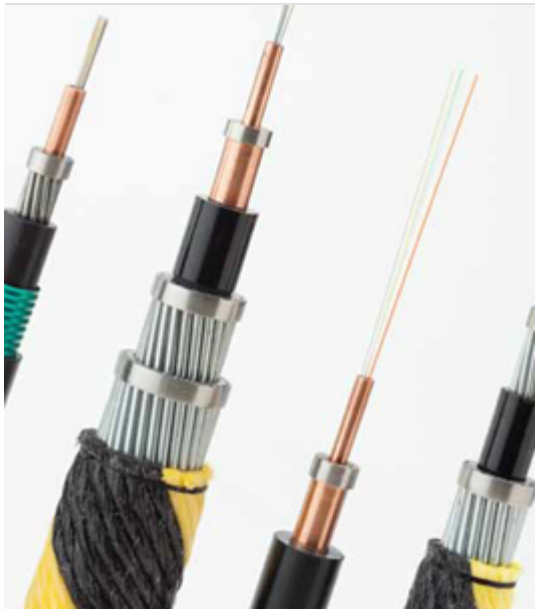
Accessibility?
(signal induction)

Type of cable?
(AC / DC / FO)

Design of cable?
(diameter, conductor, shielding, armoring)

Expected coverage, burial depth?

Seafloor morphology, sediment structure?



Example: Cable Detection: Methods and their Limitations

Method Evaluation:

- Multibeam/Side-Scan Sonar
  - must be a physical expression of the cable on the seafloor
  - horizontal positioning; vertical position generally very shallow or on top of seabed
- Magnetometer / Gradiometer
  - horizontal positioning possible; vertically inaccurate
  - detection range is dependant on magnetic mass & armoring
- Active cable tracking system (*)
  - horizontal and vertical positioning (coverage in combination w/ Altimeter)
  - detection range typically < 2 m
- Passive energized cable tracking system (**)
  - horizontal and vertical positioning (coverage in combination w/ Altimeter)
  - detection range typically 5+ m
- Magnetometer / Gradiometer (magnetized cable)
  - horizontal und vertical positioning (coverage in combination w/ Altimeter)
  - detection range typically 2 m
- Acoustic cable tracking system
  - horizontal und vertical positioning (coverage in combination w/ Altimeter)
  - detections range typically 5+ m, strongly dependant on soil conditions

(*) pulse induction; (**) tone detection

Example: Seafloor Cable Detection: Sensor Selection

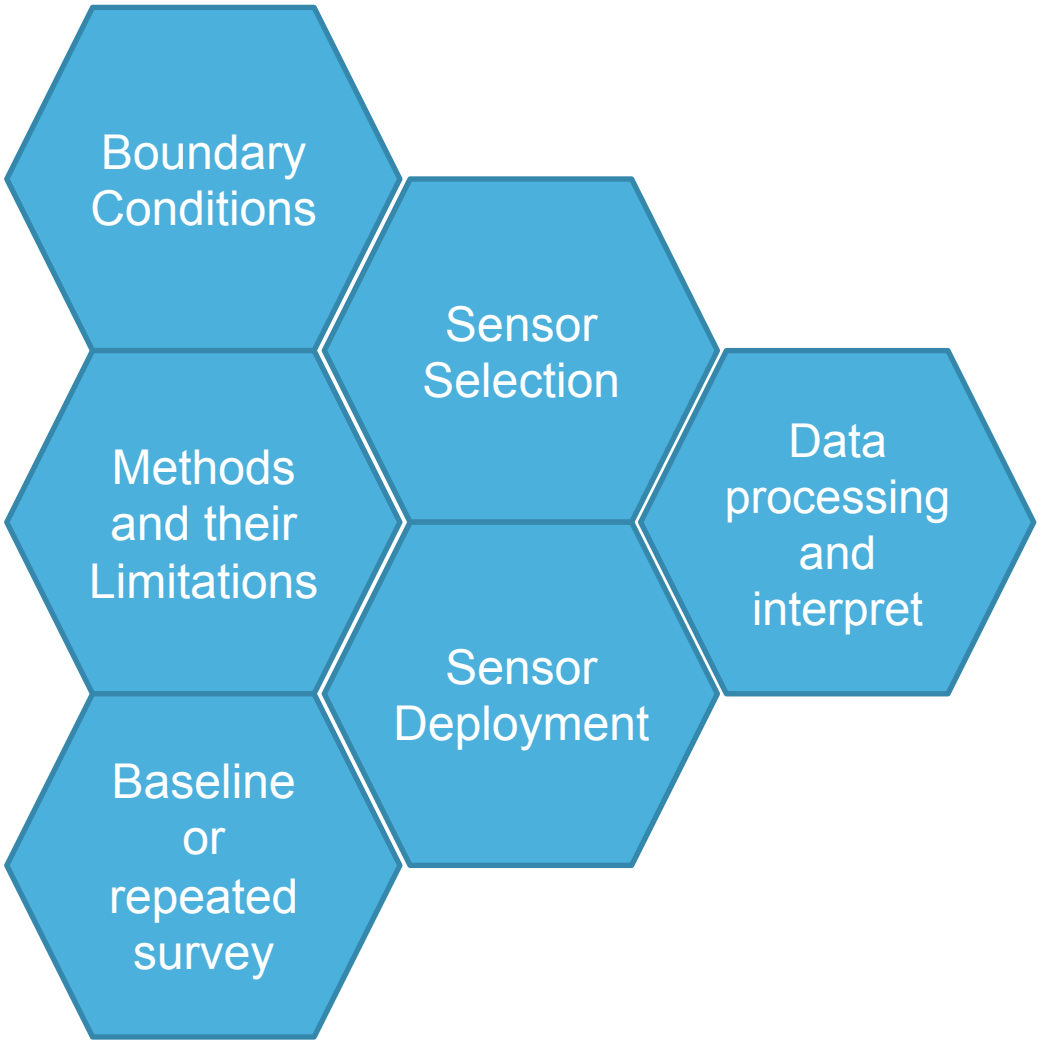
System	Technology	HVAC in operation	HVAC out of service	HVDC in operation	HVDC out of service	widely tested	easy to operate
Teledyne TSS 350	tone detection	✓	✓	✗	✓	✓	✓
Teledyne TSS 440	pulse induction	✗	✓	✗	✓	✓	✓
Innovatum Smartrak 9	mag+gradiometer tone detection	✓	✓	✓	✓	✓	✓
Pangeo SBI	acoustic	✓	✓	✓	✓	✓	✗
Optimal Ranging FieldSens/Orion	tone detection	✓	✓	✗	✓	✗	✓


Source: Teledyne TSS Ltd.


Source: Innovatum Ltd.


Source: Pangeo Inc.

Review



Presentation of results

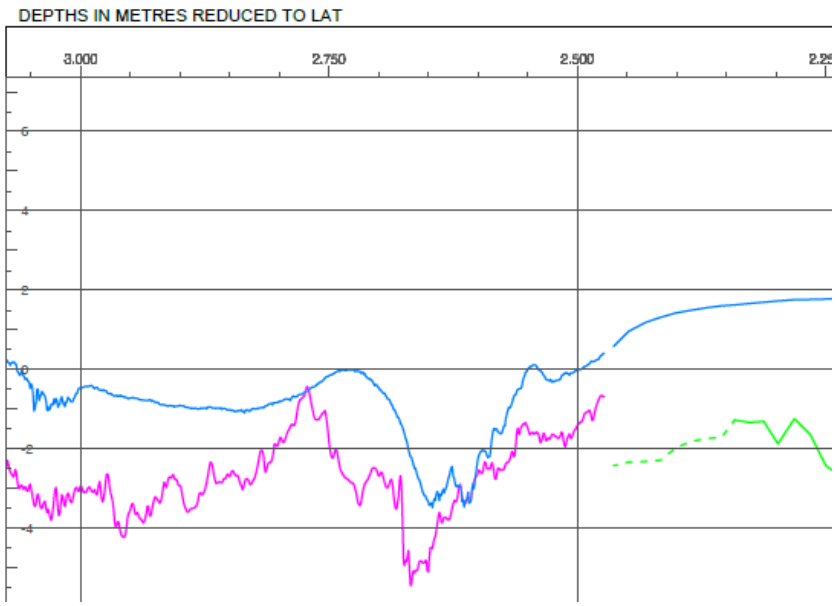
Report Charts

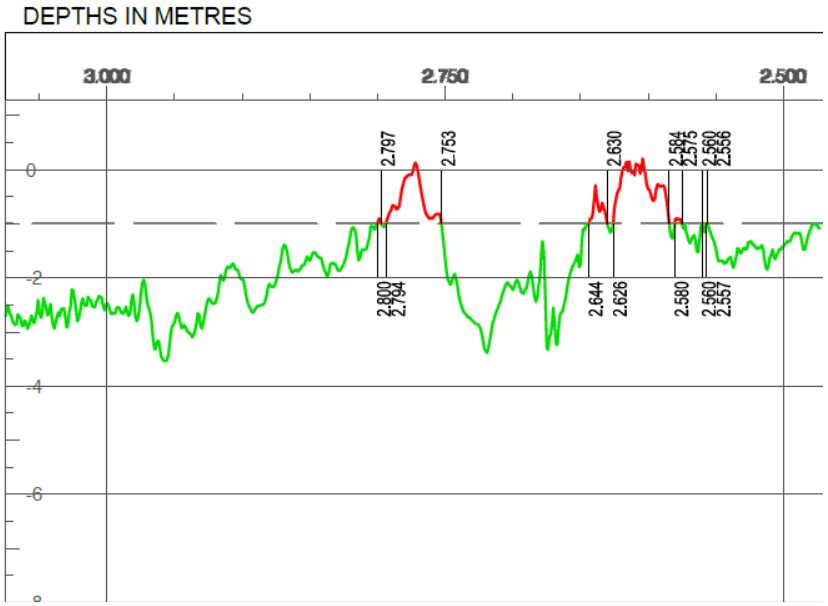
Summary? No Silver Bullet Here

Unfortunately, there's no silver bullet to finding hidden objects in the seabed.

Different techniques offer different capabilities applicable to differing conditions.

However, when the feature sought is known, selecting the appropriate sensor can go a long way to identifying it and averting a disaster.





Thank you for your time

Questions?

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