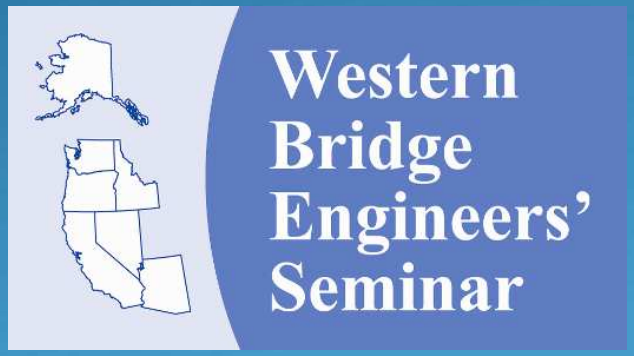
Underwater Bridge Inspections in the 21st Century: Research Status on the Latest Technologies



Sept. 25 – 28, 2011

By:

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Chief Engineer-Diver
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Division Manager
Collins Engineers, Inc.

Submerged Foundations Must be Deemed Safe with "Certainty".

Black Water

Underwater Imaging Provides Better Documentation of that "Certainty"

Underwater Inspections in the 21st Century are Integrating Underwater Imaging Technology to Observe and Document Underwater Conditions.

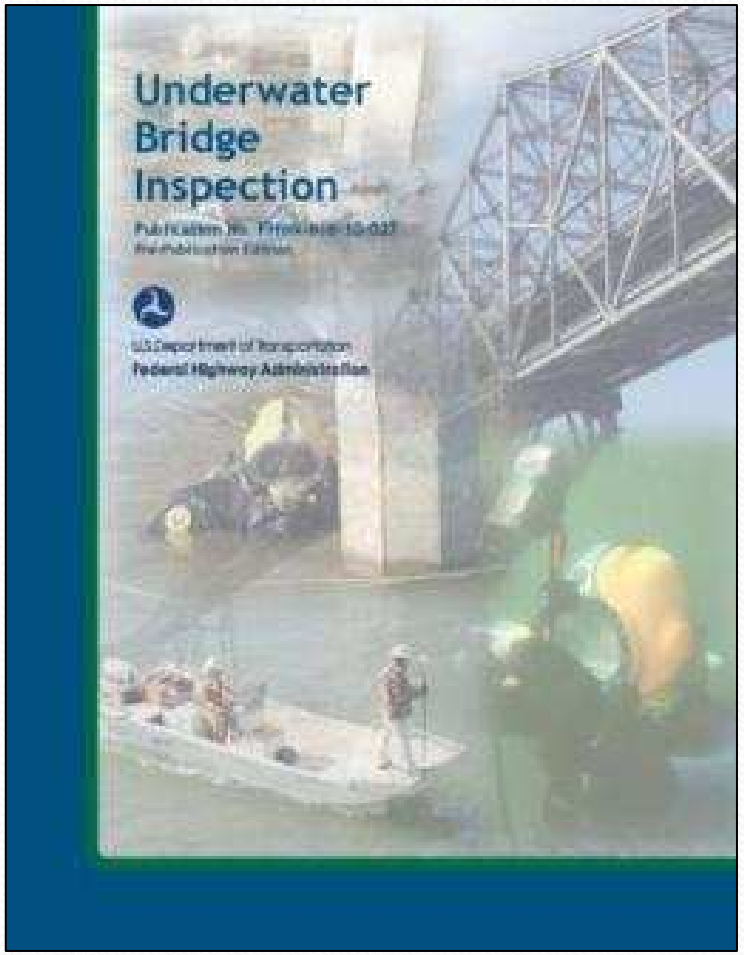
Presentation Overview

- Underwater Bridge Inspection Practices
- Current Underwater Imaging Practices
- Underwater Imaging Research & Development
- Conclusions / Questions

Protecting People and Assets by Researching and Implementing Underwater Technological Advances.

Underwater Imaging Observations

- Structure
  - Surface Condition (Level I & II)
  - Concrete, Masonry, Steel, Timber, and FRP Composites
- Channel
  - Surface Location / Probing
  - Sand, Clay, Gravel, Rock, Organics / Debris, and Installed Countermeasures



Current Underwater Imaging Practices

- Diver Observations
- Optical Devices
  - Photography
  - Videography
- Sonar / Acoustic
  - #1: Side Scan
  - #2 Multibeam
  - #3 Sector Scanning
- Lidar / Green Lasers
- Geophysical Methods
  (GPR / Sub-Bottom Profiling)

Consideration of Operational Factors	Echo-Beam Sonar on Articulated Arm / Board Performance*	Scanning or Multi-beam Sonar Performance
1. Flow velocities > 3.5 m/s	Excellent	Excellent
2. High sediment concentrations	Fair	Good
3. Floating debris	Poor	Good
4. Ice accumulation	Poor	Excellent
5. Limited clearance	Good	Excellent
6. Pressure flow	Good	Good
7. Overhanging geometries	Good	Excellent
8. Deployment Higher than 15 m	Fair	Poor
9. Air entrainment	Good	Good
10. Easily used and affordable	Excellent	Excellent
11. Transportable (pickup or van)	Excellent	Excellent
12. Accuracy to 30 cm	Good	Excellent
13. Visual Observation	N/A	Excellent
14. 2-D or 3-D Record	N/A	Excellent
15. Scalable / Measurements	N/A	Excellent

NCHRP 515 Summary Comparison*

Diver Observations

- Numerous Hazards to the Inspector
- Constrained by Time, Air Supply, Temperature, and Diver Physiology
- Extensive Equipment and Staff Support Operations Required
- Practical Current Limit of < 4 fps
- Max Water Depth of 220 Feet (Air)
- Chamber On-Site if Depth > 100ft

Characteristics of Diver Observations

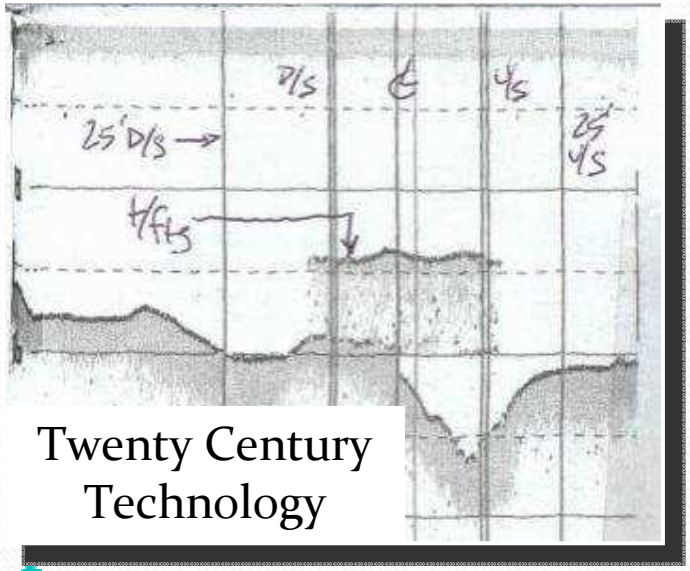
- Limited Time (Air, Depth, Temp., etc.)
- Limited by Environmental Factors
  (Current, Pollution, Turbidity, etc.)
- Constrained Maneuverability / Mobility
- Excellent Visual Acuteness, Depth-Perception, Motion Control, and Tactile Ability

Characteristics of Optical Devices

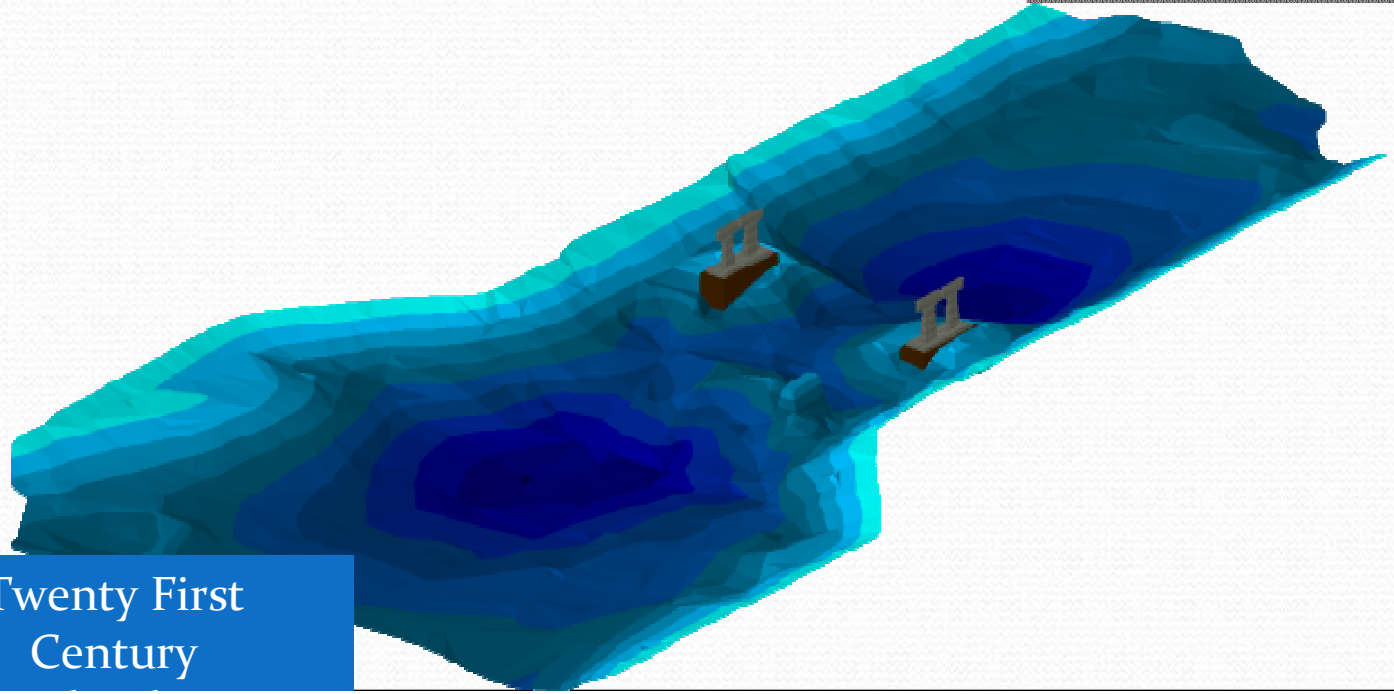
- Equipment / Operator Dependent
- Restricted Observations
  - Restricted by Environment (Current, Turbidity, etc.)
  - Restricted Maneuverability and Motion Control
  - Restricted Field of View and Tactile Ability

Echosounder Sonar

- Useful Visualization
- Documentation, but not Imaging for Observations
- Data Gaps / Loose Tolerances



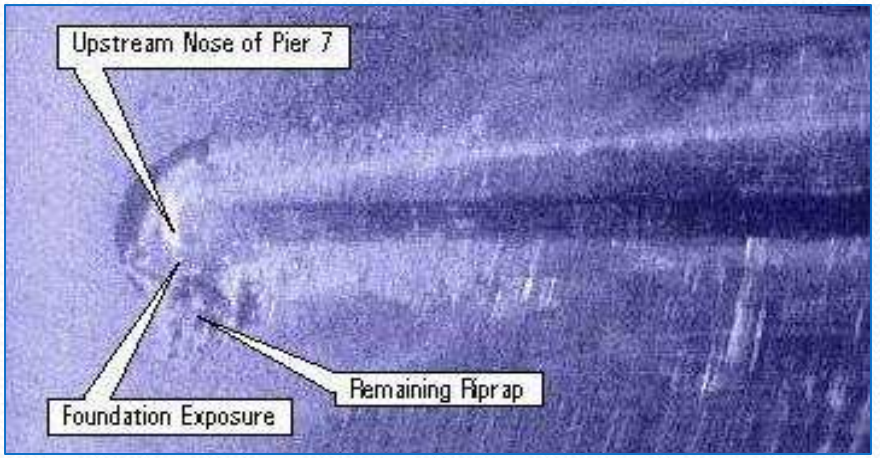
Twenty Century Technology



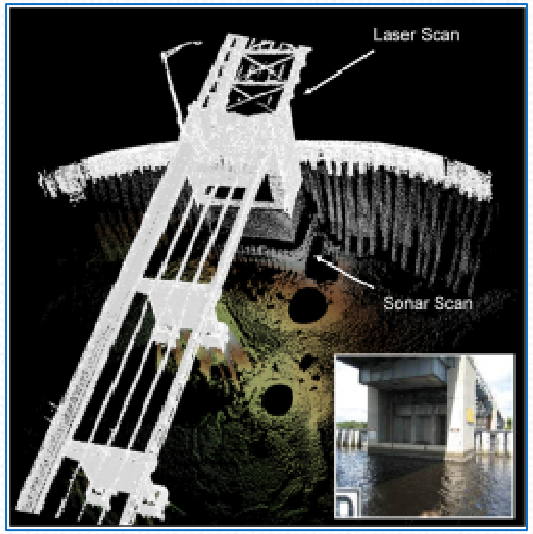
Twenty First Century

Sonar (Acoustic) Imaging Technologies

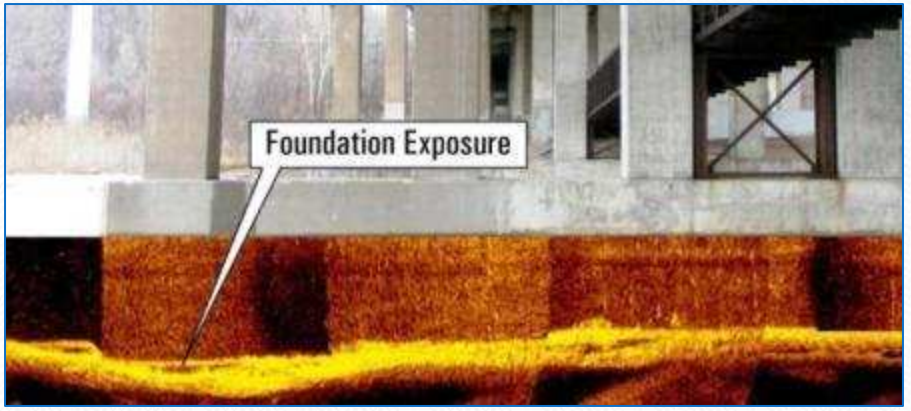
- #1: Side Scan Sonar



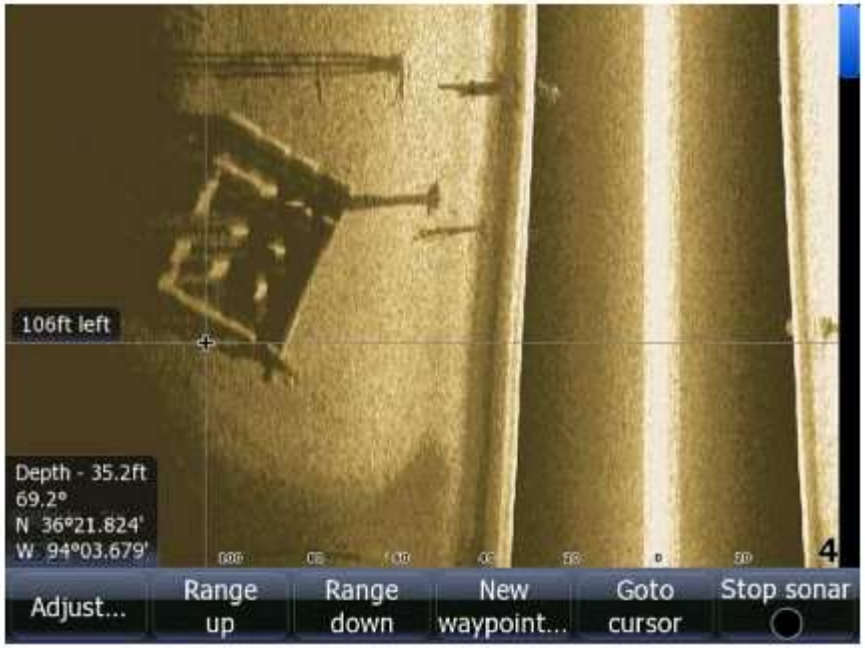
- #2: Multi-Beam Sonar



- #3: Sector Scanning Sonar

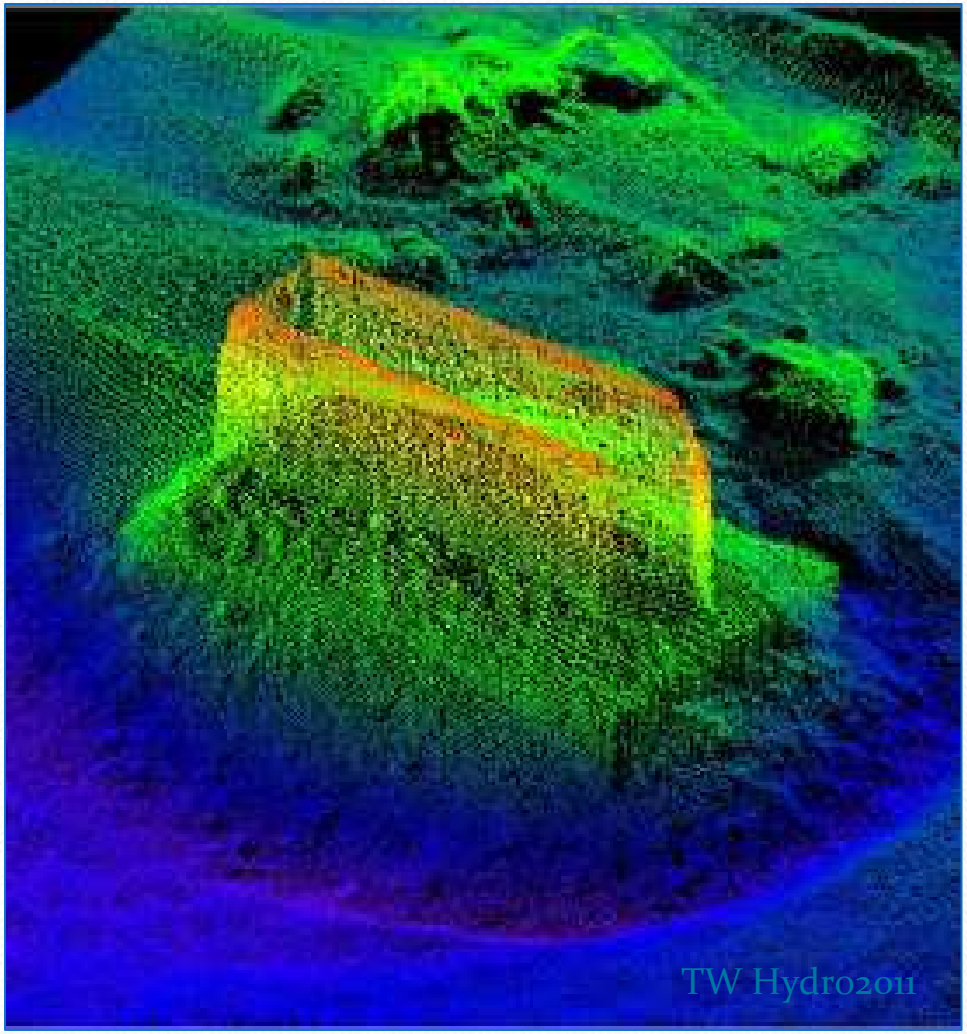


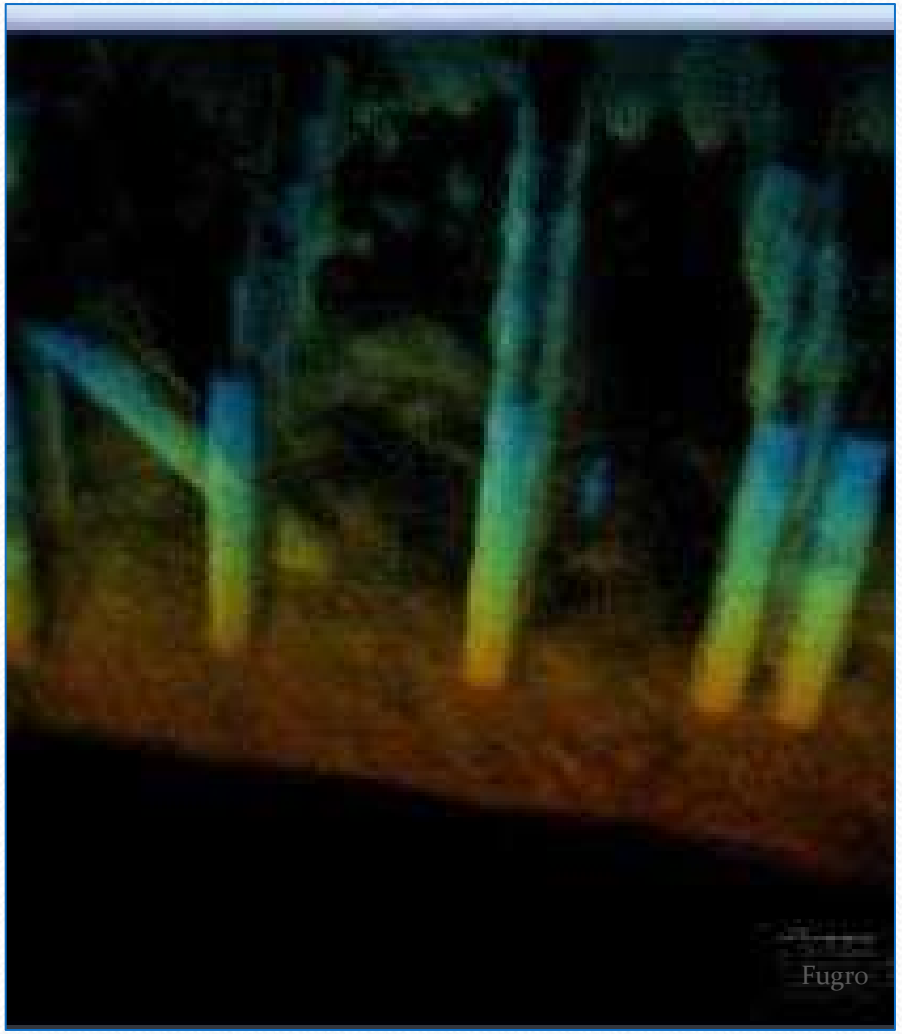
#1: Side Scan / Side Imaging Sonar



- FHWA Strock Report

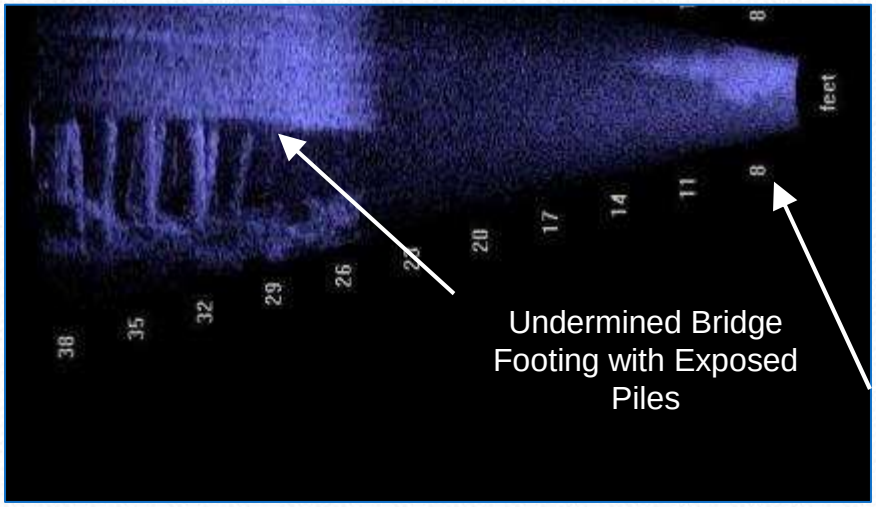
#2a: Vessel-Mounted Multibeam





#2b: Stationary Multibeam Sonar

#2c: Diver Held Multi-beam Devices



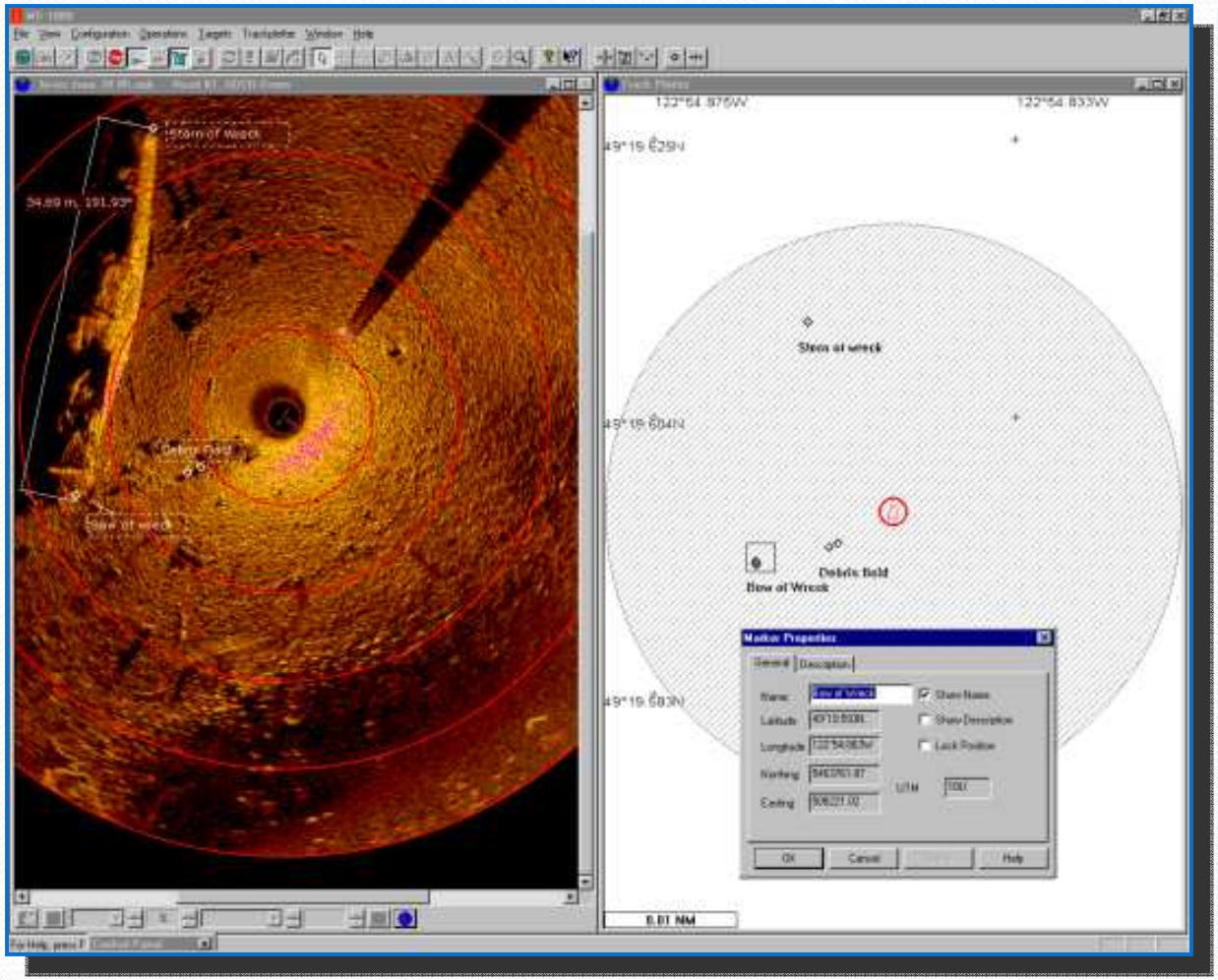
Undermined Bridge Footing with Exposed Piles

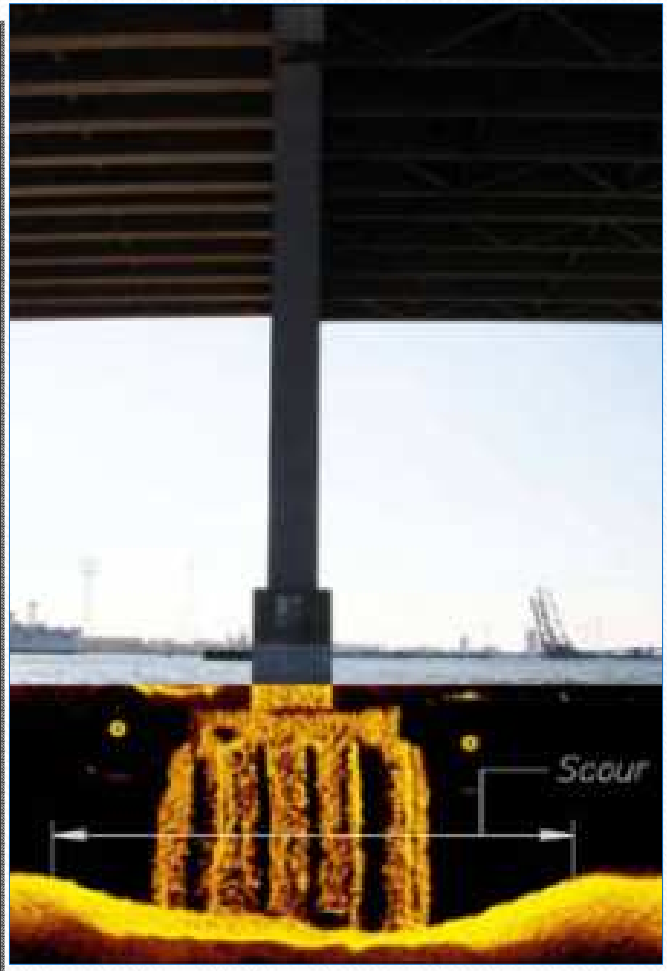
Diver Viewing Screen

Distance From Diver to Object

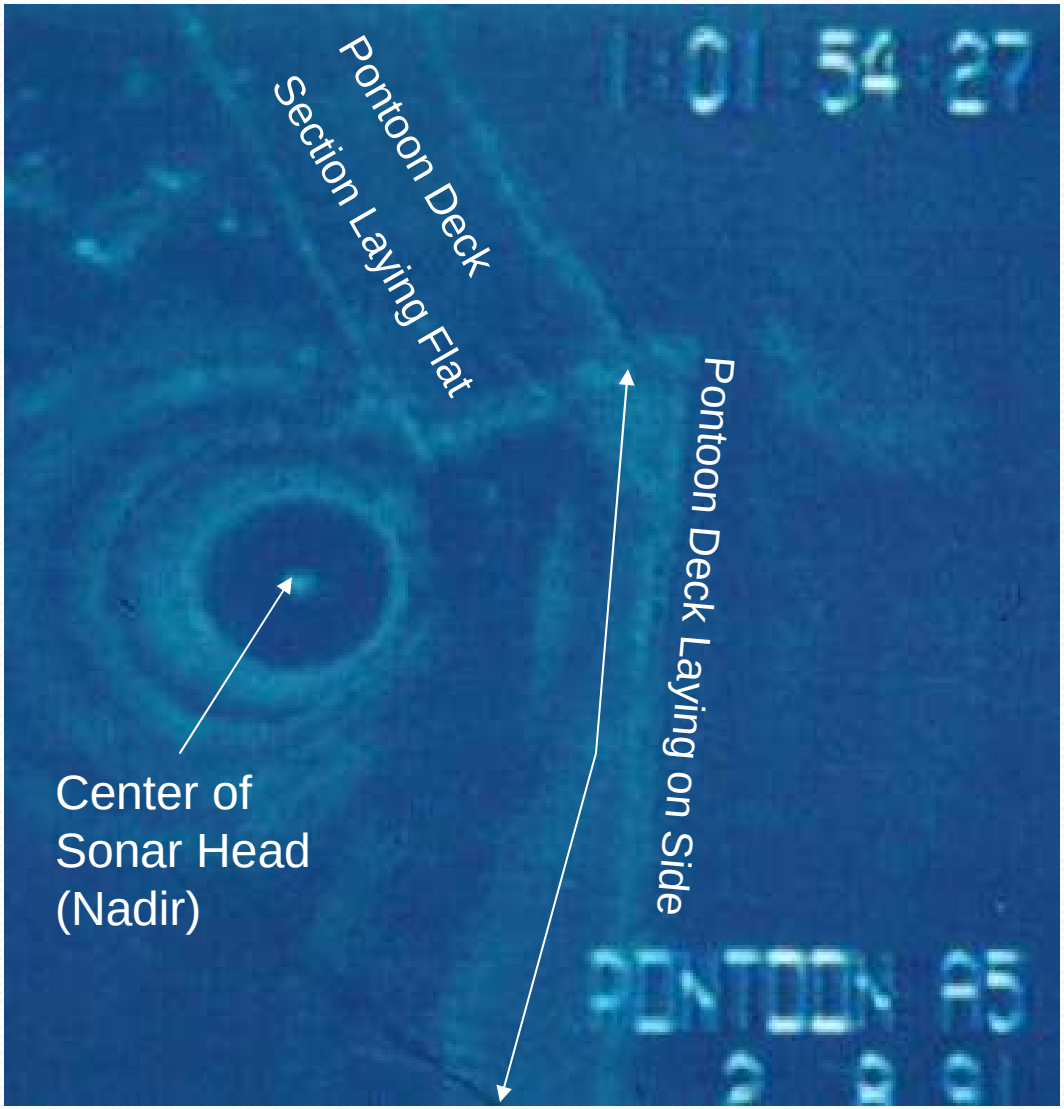
Diver Held Transducer

#3: Sector Scanning Sonar

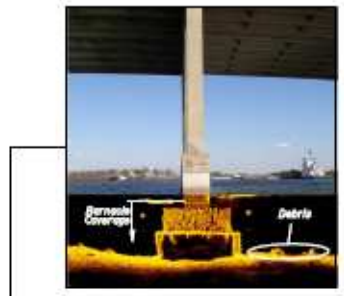




I-90 Bridge Failure on November 25, 1990



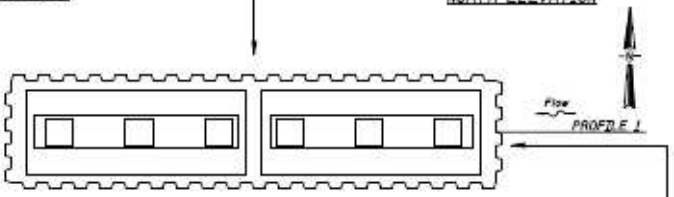
Inventory and As-Built Documentation



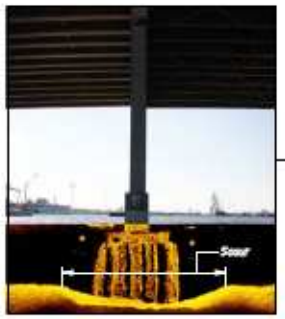
DOWNSTREAM NOSE

NORTH ELEVATION

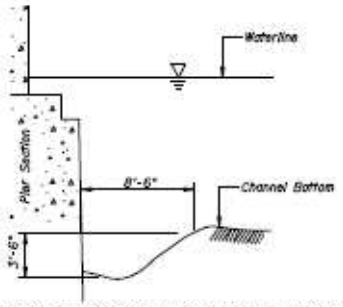
OVERALL VIEW OF BRIDGE



SOUTH ELEVATION



UPSTREAM NOSE



PROFILE 1: UPSTREAM NOSE LOOKING NORTH

VIRGINIA
DEPARTMENT OF TRANSPORTATION

SR-168 (CAMPOSTELLA RD.)
OVER EASTERN BRANCH ELIZABETH RIVER
IN NORFOLK, VIRGINIA

BRIDGE PIER VISUALIZATION
USING SCANNING SONAR

Drawn By: BPG	COLLINS ENGINEERS	Date: FEB., 2008
Checked By:		Scale: As Noted
Code:		Figure No.

Channel Bottom Documentation

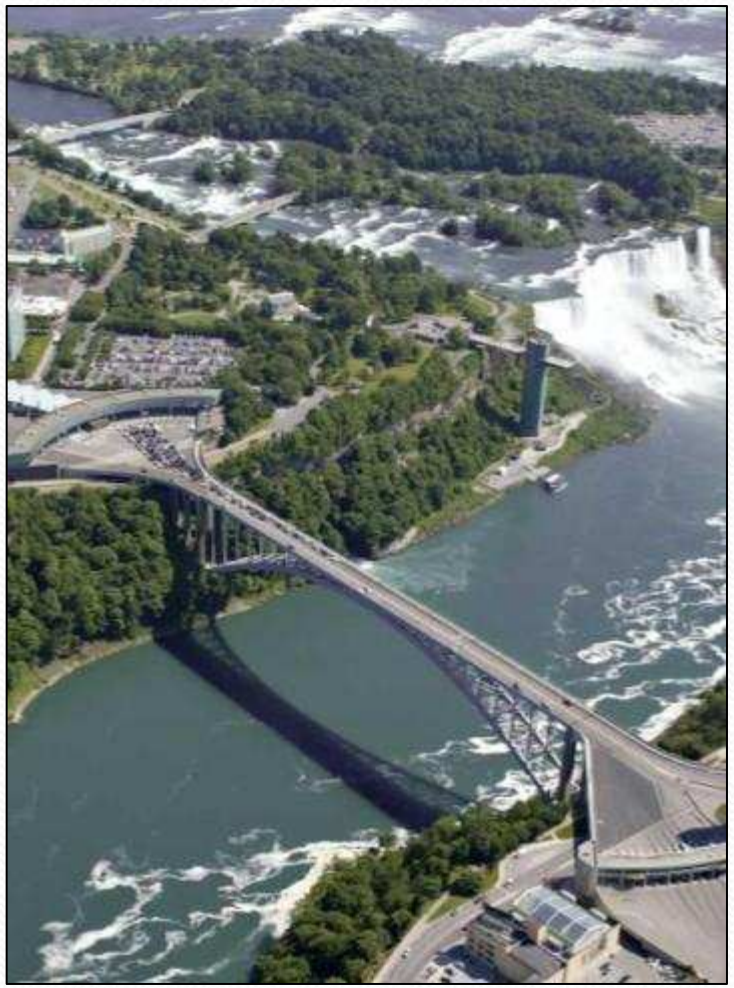
Presentation Overview

- Underwater Bridge Inspection Practices
- Current Underwater Imaging Practices
- Underwater Imaging Research & Development
- Conclusions / Questions

Protecting People and Assets by Researching and Implementing Underwater Technological Advances.

Considerations with Underwater Imaging

- Turbulence Resulting in Aerated Water (Bubble Issues w/ Sonar)
- Backshadowing Issues (Limited Depth of Field)
- Georeferencing Issues (Spatial Registration)
- Image Trail Coding (Raw, Modified, Enhanced)
- Post-Processing Quality Expectations (Reality or Picture)



Research Studies on Underwater Bridge Imaging

- MassDOT – Collins Engineers BURT Study (Boston Underwater Research Technology) Study for Bridge Imaging, 2008
- Queens University – Collins Engineers KTP (Knowledge Transfer Program) Study on Underwater Technologies, 2009-2011
- Idaho DOT – Collins Engineers Contract Study on Underwater Bridge Imaging Criteria and Guidelines, 2011
- WisDOT – Collins Engineers Comparison Report with Diver Measurements vs. Acoustic Images, 2008-2011
- Transportation Pooled Fund Study TPF – 5(131) (FHWA, California, Missouri, North Dakota, South Carolina, Texas, Wisconsin), 2011-2012

massDOT Massachusetts Department of Transportation Highway Division

Queen's University Belfast

IDAHO TRANSPORTATION DEPARTMENT

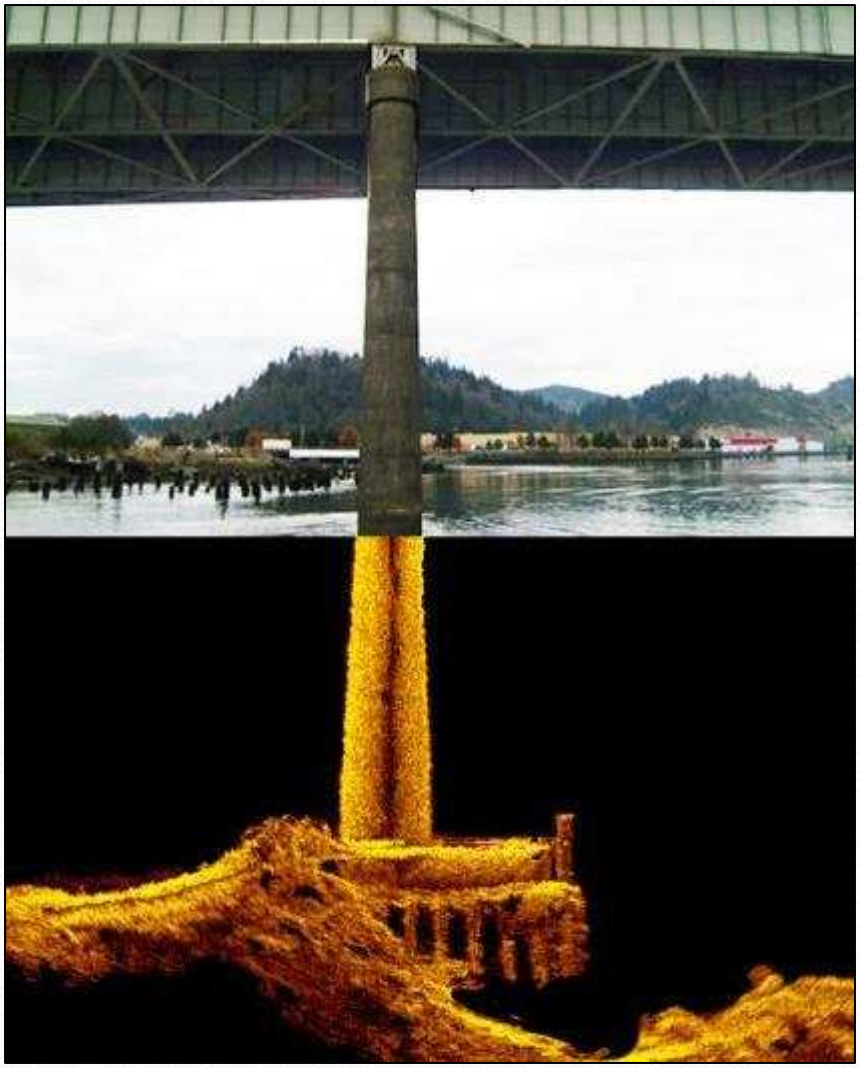
WISCONSIN DEPARTMENT OF TRANSPORTATION

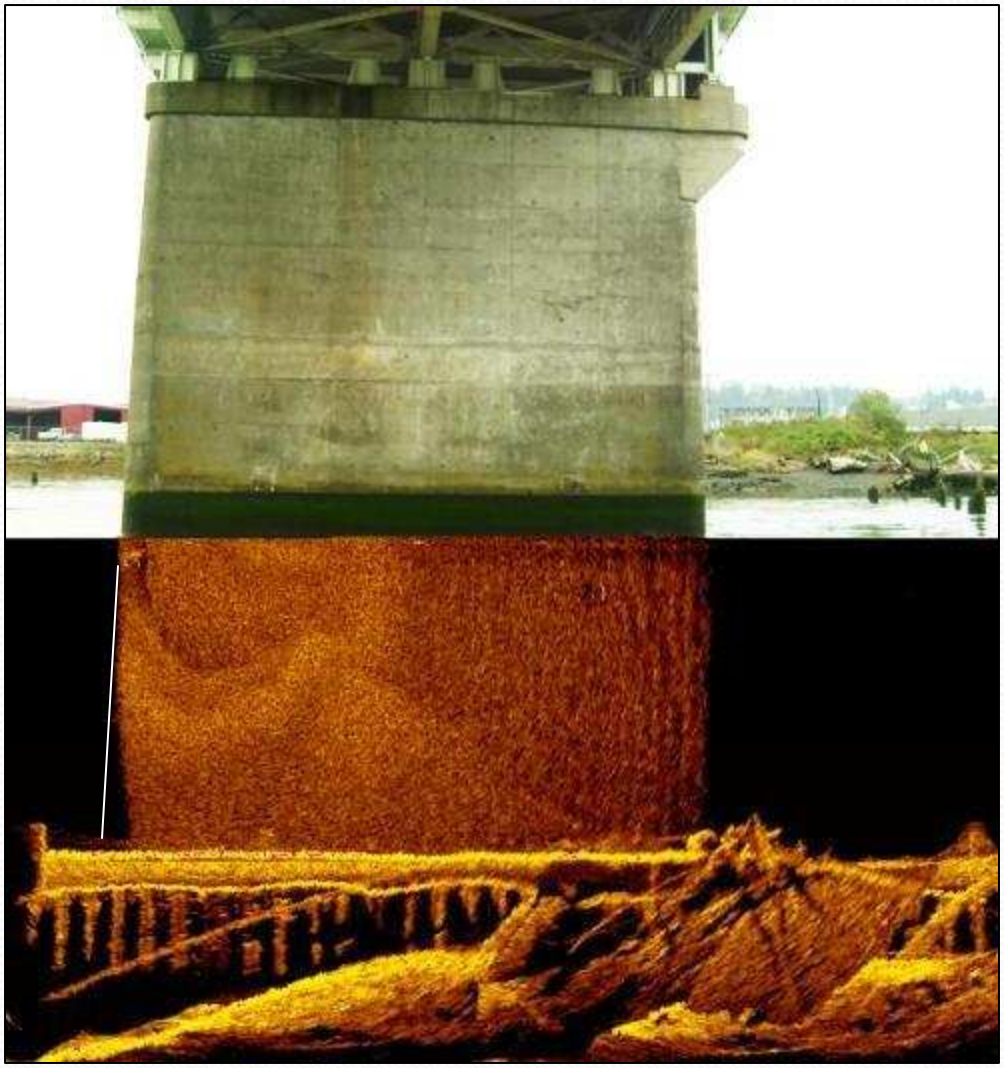
U.S. Department of Transportation Federal Highway Administration

Underwater Technology Database Analysis

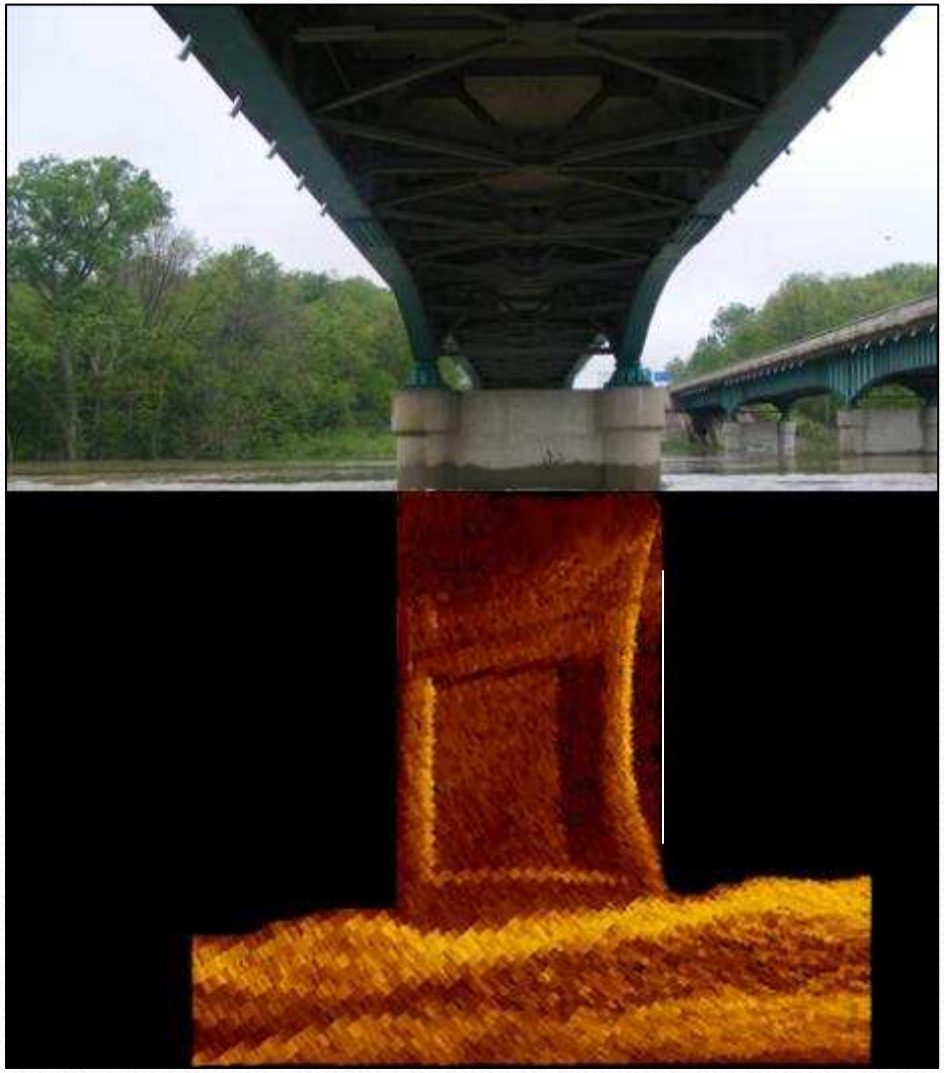
COMPANY		DESCRIPTION	STATED APPLICATIONS	Scan Channel and/ or Scan Structure	APLICABLE USES	UNIT	COST	PROS	CONS
R2 Sonic (www.r2sonic.com)	Manufacturer and Supplier	Manufacturers of Multibeam Echo sounders	**MULTIBEAM SONAR** Bathymetry with optional Snippets and Forward Looking Sonar Imagery •Hydrographic mapping •Offshore site surveys •Pre-Post Dredge surveys •Historical site surveys •Fisheries habitat, marine research •Coastal monitoring	Y/N	Not detailed enough, will scan for pipeline locations but not in detail	2024B (variant on 2024 less selectable options)		High Accuracy, provide training and installation	Probably requires dedicated boat
				Y/N		2024	150K	High Accuracy, provide training and installation	Probably requires dedicated boat
				Y/N		2022	110K	High Accuracy, provide training and installation	Probably requires dedicated boat
ODOM	Manufacturer and Supplier	Manufacturers of Single Beam and Multibeam Echosounders, Velocimeters, Software, Accessories, Transducers and OEM	**MULTIBEAM SONAR** Scan scour around bridges. Detect wrecks and lost equipment.	Y/Y	Detailed surveying of scour around structures	ES3-M25	$62K	No ongoing calibration required. Provide training and installation (1-60m). Dedicated boat not required.	Not quiet as accurate as R2 Sonic or RESON. More portable. Depth limitations. Don't Hire out equipment. Not a tool for structural monitoring. Need 7 days of training on its use
				Y/Y		ES3M	$75K		
RESON	Manufacturer and Supplier	Specialize in the design, and development of advanced multibeam sonar systems, single beam echo sounders, transducers and hydrophones as well as software	**MULTIBEAM SONAR** Downward looking SeaBat models enable fast and accurate bathymetric mapping across a wide swath of the seafloor, whereas RESON's forward looking multibeam systems provide highly detailed imagery of underwater structures	Y/N	Underwater monitoring, guidance & navigation,	SeaBat7101 (upgrade on 8101)	140-170K	High Accuracy, provide training and installation. Lightweight and small system	Probably requires dedicated boat
				Y/Y		SeaBat7121	269K	High Accuracy, provide training and installation	Probably requires dedicated boat
				Y/Y	Underwater monitoring, guidance & navigation,	SeaBat8101		High Accuracy, provide training and installation	Probably requires dedicated boat
				Y/Y	Hydrographic, offshore, military, bathymetric, sidescan & snippets applications	SeaBat7125 and SeaBat7111		High Accuracy, provide training and installation	Probably requires dedicated boat
Kongsberg	Manufacturer and Supplier	A range of Sonar technologies and software packages available.	**MULTIBEAM ECHO SOUNDERS** Mapping of harbours, inland waterways and shipping channels with critical keel clearance • Inspection of underwater infrastructure • Detection and mapping of debris and other under-water objects • Detailed surveys related to underwater construction work or dredging • Environmental seabed and habitat mapping • Mapping of biomass in the water column	Y/N	Not suitable for our requirements, deep sea bathymetry	Simrad EM 122	£1mill		Not a Rental option
				Y/Y		Simrad EM 2040	Not Available until Summer	Brings the advanced features of deep water multibeams to the near bottom sounding environment.	
				Y/Y	Inspection of underwater infrastructure, mapping of harbours, inland waterways and detailed surveys related to underwater construction and dredging	Simrad EM 3002	£150-250K Rental approx £800/day	High resolution and suited for scans in water depths of <1m to 200-300m	
				Y/N	Seabed mapping and wreck detection	EM 710 Multibeam echosounder	£300-600K Rental approx £1500/day	Very high resolution, very popular unit sold, The model with the highest specification of 0.5° x 1° beam widths	
				Y/Y	Best system for scanning structures in there range	MS1000	£20-30K		
CodaOctopus (www.codaoctopus.com)	Manufacturer and Supplier	High resolution 3d real time sonar	**MULTIBEAM ECHO SOUNDER** Sonar Monitoring. Inspection of bridges, dams, harbour walls. Bathymetry. Underwater construction.	Y/Y	Produces 3D cloud works of underwater structures, useful in the inspection of underwater construction and bathymetry	Coda Echoscope-UI5	£140K for sonar itself	Compact and portable (size of a briefcase) rapidly deployed on most vessels with an over the side or bow mounting. attach to digger bucket also.	Don't hire equipment directly, third party rental approx £500 per day
Blueview Technologies (www.blueview.com)	Manufacturer and Supplier	Manufactures 2D and 3D multibeam imaging sonar systems	**3D Ultra-High Resolution MICRO BATHYMETRY** •Bridge & Dam Inspection •Seawall Inspection •3D Structure Rendering •Environmental Assessment •Hull Inspection	Y/Y	Site surveying, 3D rendering	MB-1350-45			
				Y/Y		MB2250-45			
				Y/Y	Suitable for underwater structure inspection and 3D modelling	BV-5000 1350	$120,750	Very compact and lightweight, similar to above water LIDAR. Produce 3D point cloud data	Don't Hire or Rent equipment
				Y/Y		BV-5000 2250	$105253		

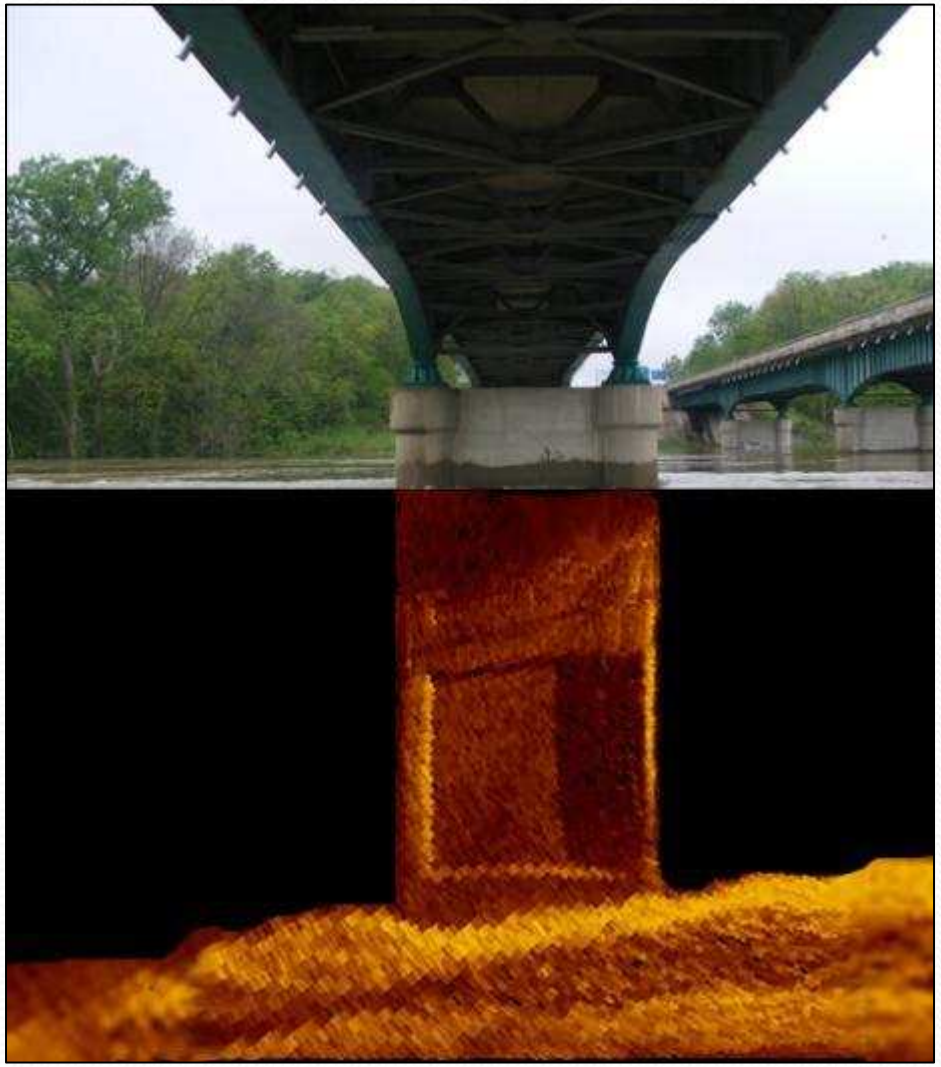
Limitations of Acoustic Imaging Devices



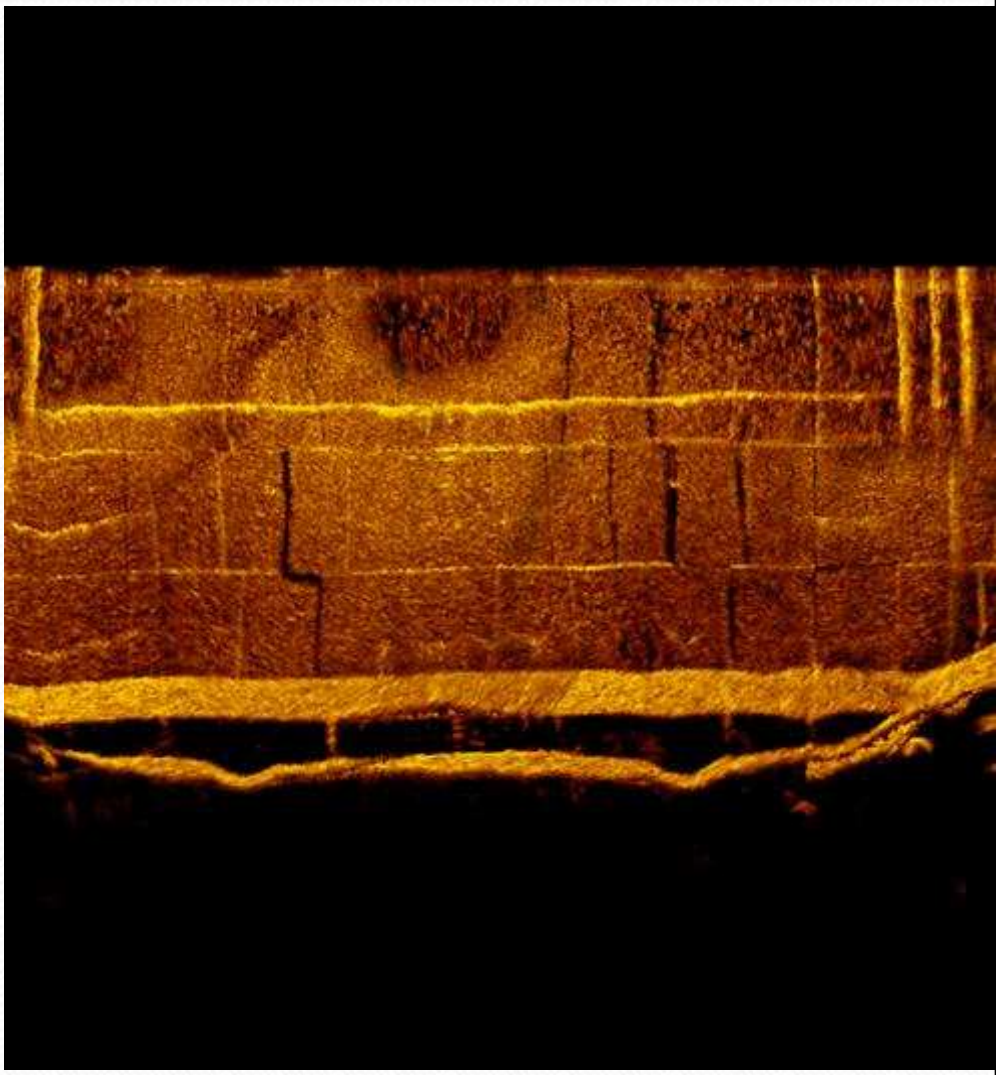


Fast Current Challenges & Coding Stds.





Detection of Joints and Cracks



Future Underwater Imaging Practices

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- Optical Devices
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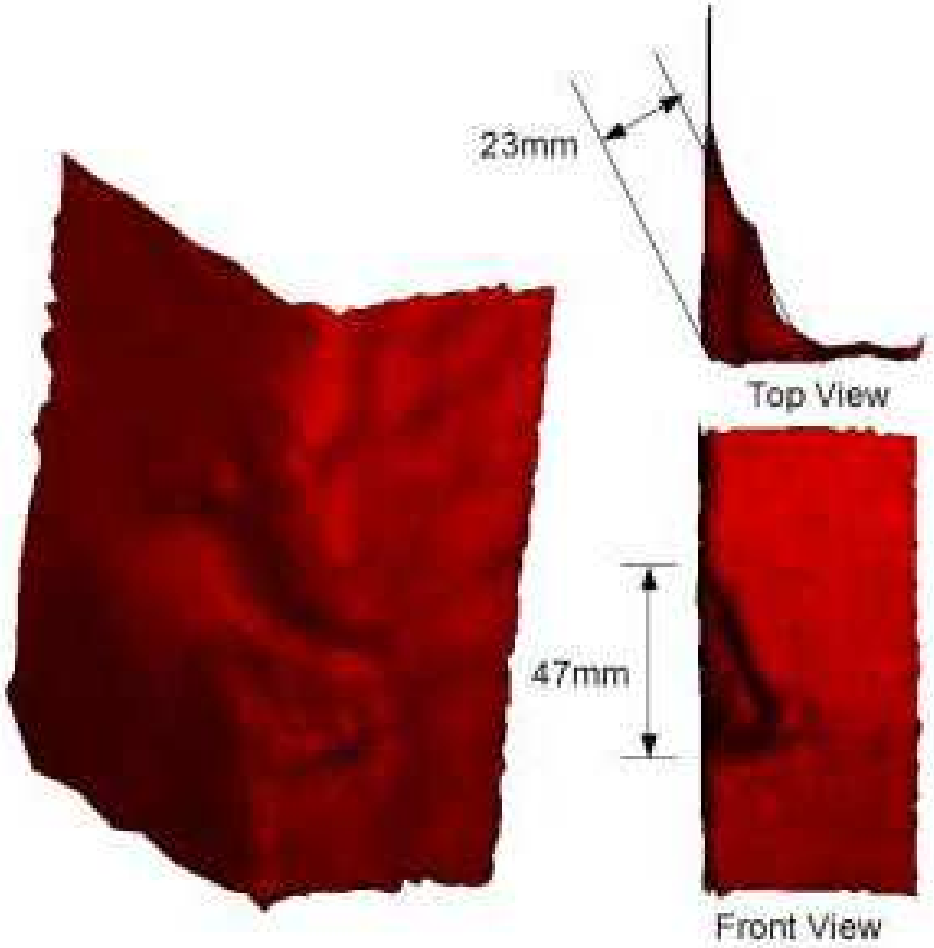
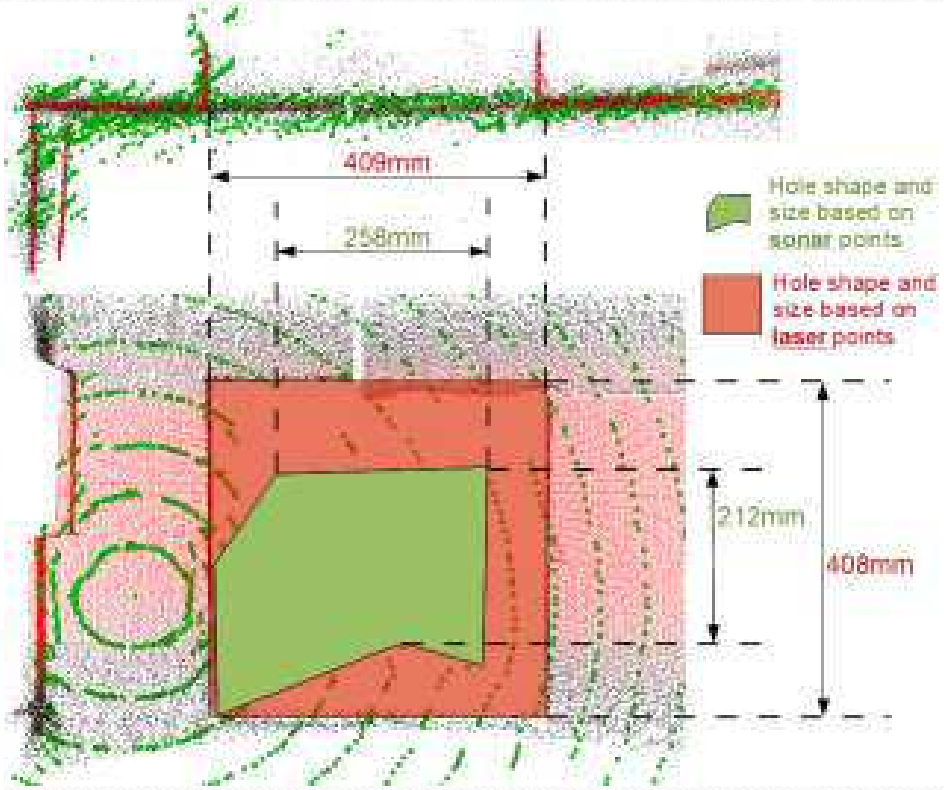
14. 2-D or 3-D Record	N/A	Excellent
15. Scalable / Measurements	N/A	Excellent

NCHRP 515 Summary Comparison*

Underwater LIDAR / Laser Scanning

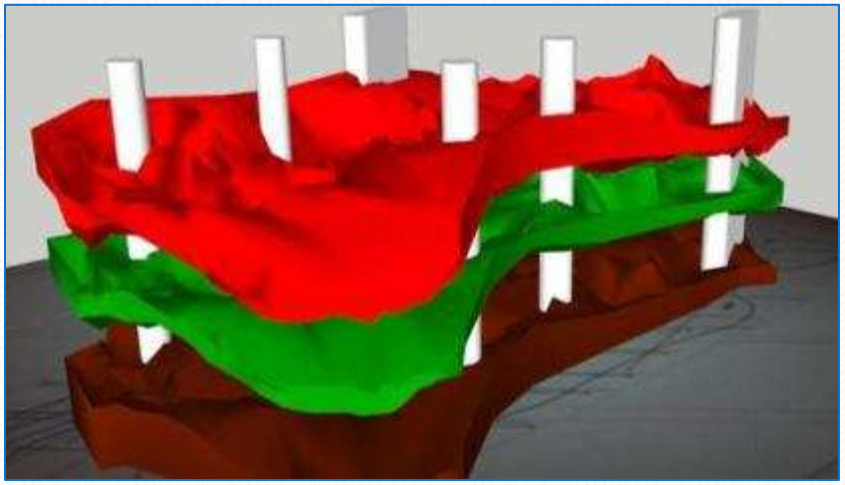
Research Study Findings

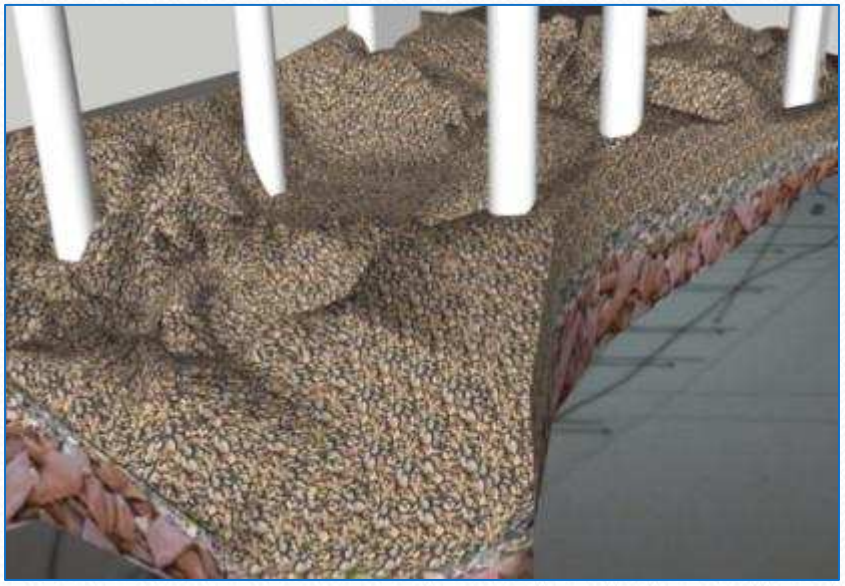


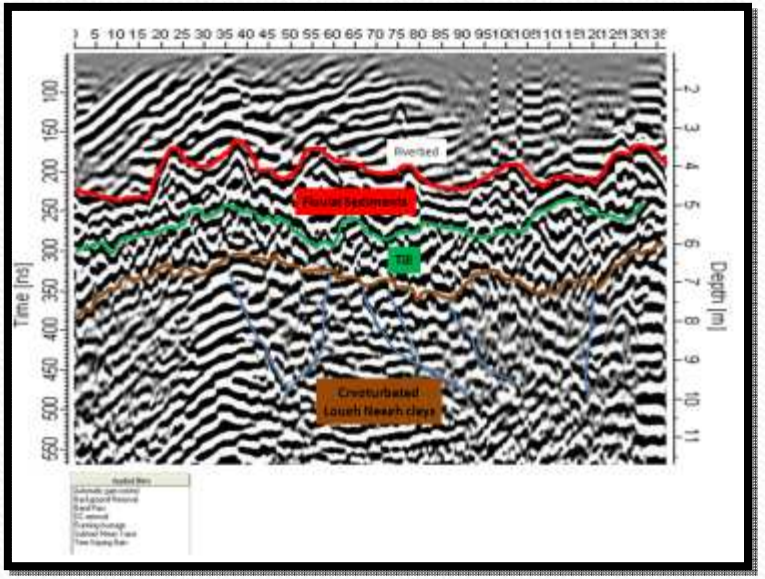


	Laser Scanner	Sonar
Range	0-5m	>1m
Resolution	<1mm	~5cm

Underwater GPR







Technology Status to Date

- Vast Amounts of Expensive Equipment Available
- Relatively Easy to Operate but Requires Skilled Operator to Master Use and Interpret Results
- Innovative Tools Supplement Diver's Observations
- Use of Underwater Imaging Technology
  - Training, Standards, Guidelines and Acceptance
  - FHWA still requires 10% Level II Examination by Diver
  - Diver Verification of Findings as Part of Level I Effort
- Research & Development Continues for 21st Century

Questions

Please Feel Free to Contact:

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1-877-FIND-CEI (24-hr Emergency Hotline)