1660

1950

1960

1970

1980

1990

2004

History of Structure Inspection Program Development in the U.S. and the World

By
Terry Browne, P.E.
Collins Engineers, Inc.

January 16, 2004
Columbia, Missouri
Midwest Transportation Consortium

1660

1950

1960

1970

1980

1990

2004

Agenda

- Focus on the United States
- Focus on International Systems

1660

1950

1960

1970

1980

1990

2004

Over <u>100,000</u>
Railway Bridges

Over <u>570,000</u>
Highway Bridges

1660

1860's

1950

1950's

1960

1970

1980

1990

2004

"Bridge Construction Boom in the United States"

- Railways (1860's)
- Highways (1950's)
- Little emphasis placed on **safety**
- Little emphasis placed on **maintenance**

Maintenance and safety were the responsibility of the Owners

1660

1800's

1950

1960

1970

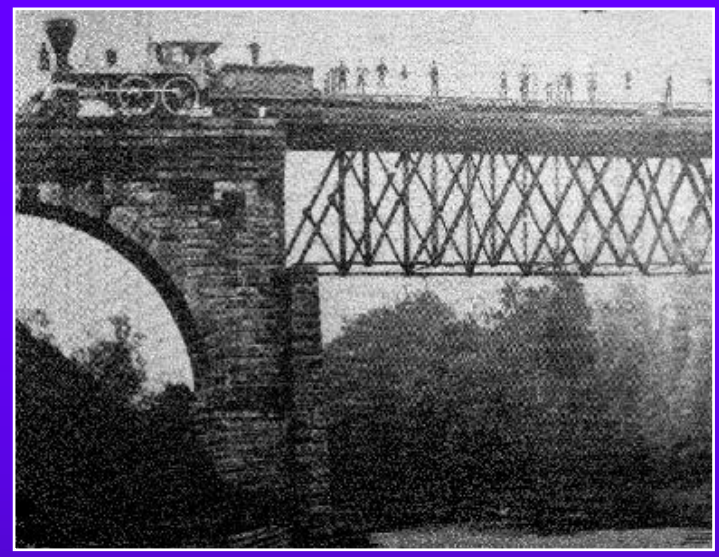
1980

1990

2004

Ashtabula Railway Bridge

- Built in 1865
- Collapsed in 1876
- **Worst** Bridge Failure in U.S.
- 100 Died, 64 Injured
- Could Have Been Prevented by an **Inspection Program**



1660

1950

1960

1970

1980

1990

2004

An Infant Inspection Program Is Born

- Interstate Commerce Commission (ICC) Was Developed to Regulate Safety of Railway Companies.

- U.S. DOT – Federal Railway Administration.
  (Later Developed Out of the ICC)

"Focus Was On Safety To The Traveling Public"

1660

1900's

1950

1960

1970

1980

1990

2004

American Railway Engineering and Maintenance-of-Way Association (AREMA)

- Published Manuals from 1905 - Present

American Association of State Highway and Transportation Officials (AASHTO)

- Published Manuals from 1921 - Present

1660

1950

1960

1960's

1970

1980

1990

2004

Railway Bridge Inspections

- Over 95% Bridges on Annual Basis (Min.) per AREMA Study
- AREMA also Published Book on "Structural Fatigue and Steel Bridges"

Highway Bridge Inspections

- Random Inspections Performed
- Very Little Consistency

1660

1950

1960

1967

1970

1980

1990

2004

Until…

December 15, 1967

Silver Bridge Collapsed

- Ohio River at Point Pleasant, West Virginia
- 46 people killed

1660

1950

1960 1967

1970

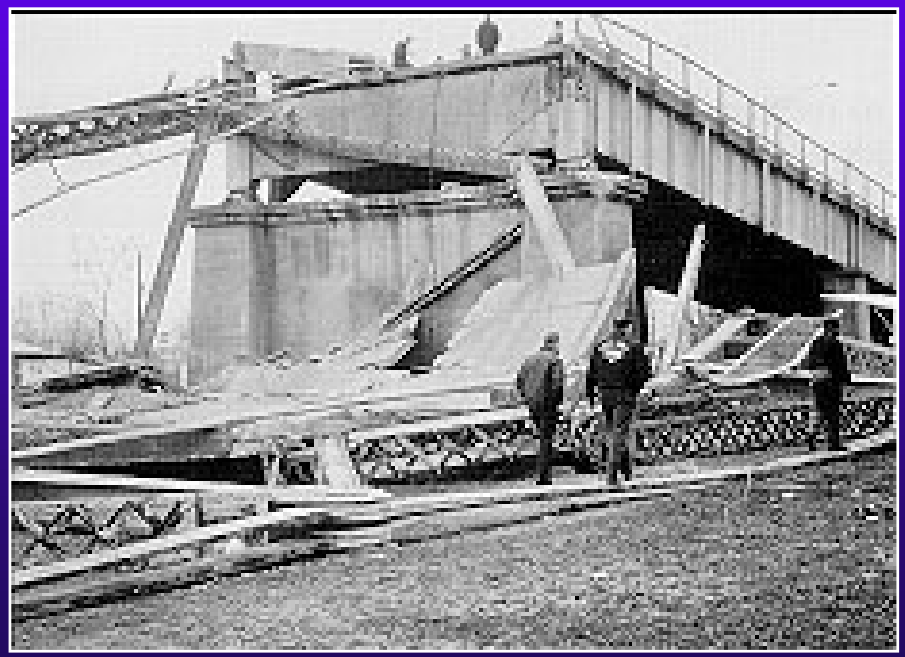
1980

1990

2004

This Catastrophic Failure Focused National Attention on Bridge Safety

December 15, 1967



1660

1950

1960

1970

1980

1990

2004

Congress Asked

- How many bridges are there in the US?
- Where are they located?
- What is their condition?
- Is there another Silver Bridge waiting to happen?

1660

1950

1960

1968

1970

1972

1980

1990

2004

Railroad Bridge Safety Committee Formed on January 8, 1968

- 16 Days After Silver Bridge Collapse
- However, Final Publication of "Recommended Rules for Railroad Bridge Inspections" Not Finished until March 6, 1972

1660

1950

1960

1968

1970

1980

1990

2004

Merrillan Railway Bridge Collapse

1660

1950

1960

1970

1971

1980

1990

2004

Congress Took Action

Federal Aid Highway Act - April 27, 1971

- National Bridge Inspection Standards (NBIS)
  - All States must perform routine inspections of bridges (maximum interval 24 months)
  - Inspector qualifications defined
  - Inspector training program developed
  - Report formats developed
  - Inspection and rating procedures defined
- National Bridge Inventory (NBI) Development

“Focus Was on Safety to the Traveling Public”

1660

1950

1960

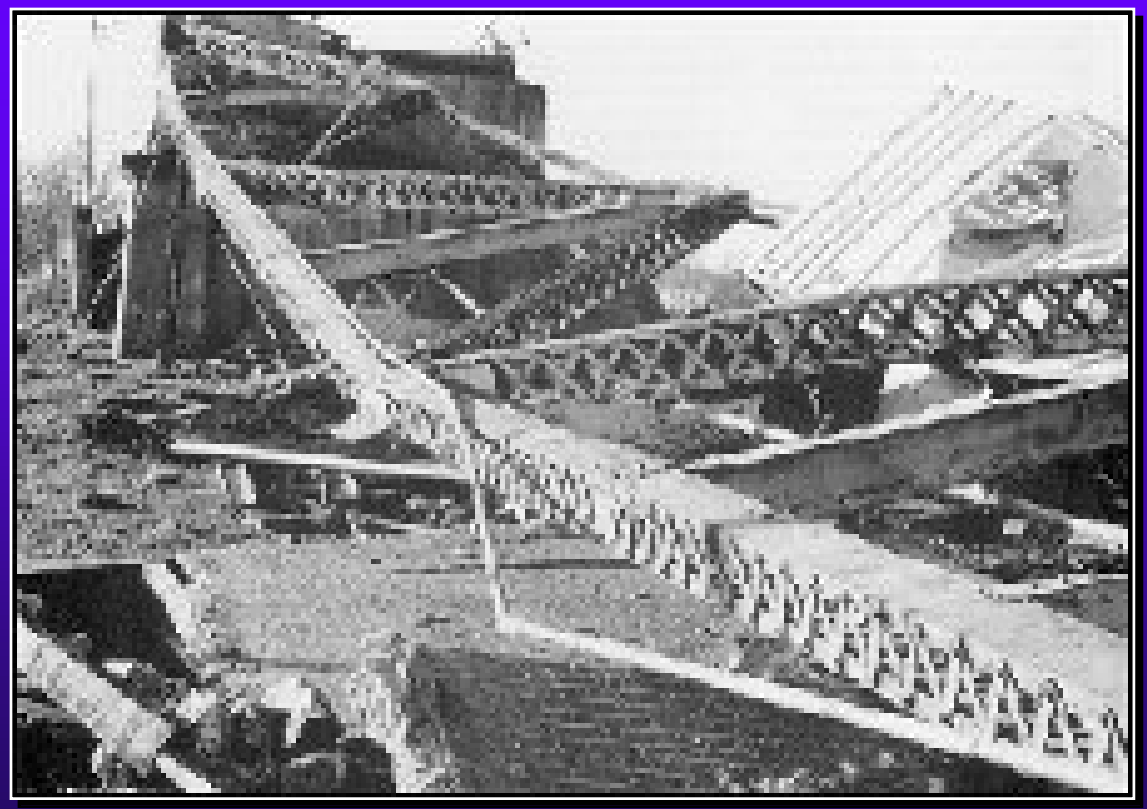
1970

1980

1990

2004

Federal Funding for Replacement of Bridges in the Federal Aid Highway System Was Established



1660

1950

1960

1970

1970's

1980

1990

2004

Manuals Were Developed for the Transportation Industry

- Bridge Inspector's Training Manual 70 (BITM) (FHWA; 1970)
- Manual for Maintenance Inspection of Bridges (AASHTO; 1970)
- Recording and Coding Guide for the Structure Inventory and Appraisal for the Nation's Bridges (FHWA; 1972)
- Bridge Inspector's Manual for Movable Bridges (FHWA; 1977, Supplement to Manual 70)

1660

1950

1960

1970

Mid 1970's

1980

1990

2004

As States Implemented the NBIS Program, Two Critical Issues Developed:

- Bridge Replacement Needs Exceed Available Funding
- No Incentive for States to Inspect Bridges Off the Federal Aid System

1660

1950

1960

1970

1978

1980

1990

2004

Congress Again Took Action

Surface Transportation Assistance Act

- Provided more funding to the States for all bridges for **rehabilitation** and **replacement**.
- Required all public bridges with spans equal to or greater than 20.0 feet in length to be inspected.

“Focus Was Still On Safety To The Traveling Public”

1660

1950

1960

1970

1978-1979

1980

1990

2004

Manuals Were Updated

- ***Manual for Maintenance Inspection of Bridges***
  (AASHTO; Updated 1978)

- ***Recording and Coding Guide for the Structure Inventory and Appraisal for the Nations Bridges***
  (FHWA; Updated 1979)

State DOT's now have "definite" guidelines for compliance with the NBIS

1660

1950

1960

1970

1980

1983

1990

2004

Mianus River Bridge Collapse

- Pin and hanger failure
- Collapse of main span carrying I-95 in Connecticut
- Several fatalities
- Disruption of traffic for months

1660

1950

1960

1970

1980

1983
1986

1990

2004

Mianus River Bridge Collapse

FHWA Response

- National focus on “Fracture Critical Bridges”
- Expanded inspection data collection requirements
- Additional inspector training
- New fatigue research
- Supplement to Manual 70
  Inspection of Fracture Critical Bridge Members
  (FHWA; Added September 1986)

1660

1950

1960

1970

1980

1985

1990

2004

Collapse of the U.S. Route 43 Bridge

- Occurred in April of 1985
- Over Chickasawbogue Creek – Mobile, Alabama
- Lead to FHWA issuance of memo stressing
  - The importance of **Underwater Inspections**
  - Ordering steps to ensure each state has a well-founded underwater inspection program

1660

1950

1960

1970

1980

1986

1990

2004

Culvert Failures

- Loss of Life Occurred
- Led to the Development of Supplement to Manual 70
  - *Culvert Inspection Manual* (FHWA; July 1986)

1660

1950

1960

1970

1980

1987

1990

2004

New York's Schoharie Creek Bridge Collapse

April 1987

1660

1950

1960

1970

1980

1987

1990

2004

Schoharie Creek Bridge Collapse

- Center Pier Scour Failure
- Collapse of Main Span Carrying I-90 in New York
- 10 Fatalities and Significant Disruption of Traffic
- “Inspection 1 Week Earlier Did Not Detect Scour Due to Silt Infilling.”

1660

1950

1960

1970

1980

1988

1990

2004

Response to Schoharie Creek Bridge Collapse

- New focus on “Bridges Over Waterways” (approximately 86% of bridges on the NBI)
- Technical advisory published - *Scour at Bridges* - (FHWA; 1988)
- “Scour Critical” bridge inspections required
- Analytical procedures to predict bridge scour were published - *Hydraulic Engineering Circular No. 18* - (FHWA)

1660

1950

1960

1970

1980

1990

2004

Scour

The Result of Erosive Action of Running Water, Excavating and Carrying Away Material From the Bed and Banks of Streams and Rivers.

1660

1950

1960

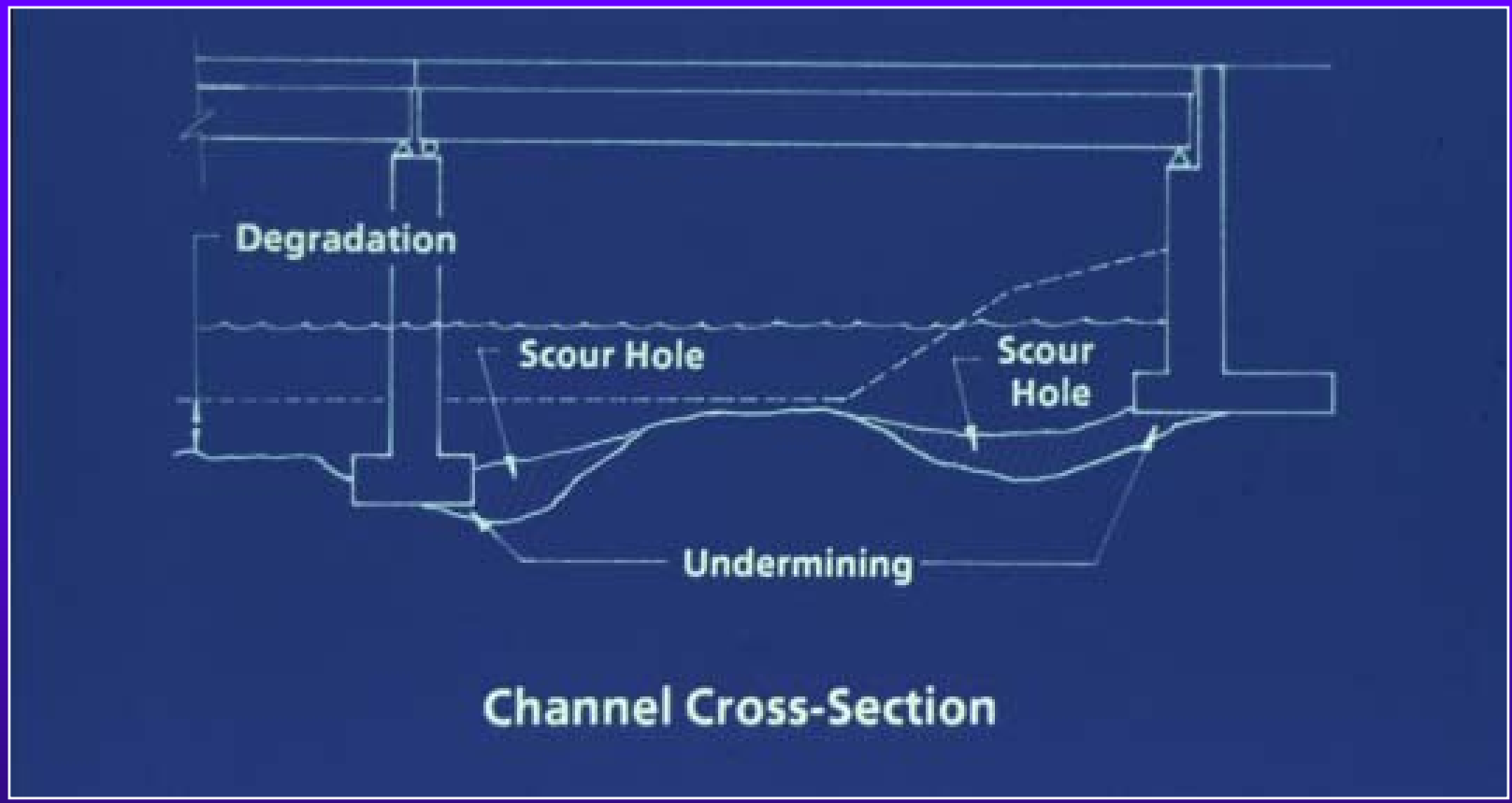
1970

1980

1990

2004

Scour (Cont'd.)



1660

1950

1960

1970

1980

1990

2004

Scour (Cont'd.)

1660

1950

1960

1970

1980

1990

2004

Scour (Cont'd.)

1660

1950

1960

1970

1980

1990

2004

Conducting the Field Investigation

- **Purpose of Scour Investigation**
  - Establish Existing Conditions
  - Obtain Data to Use in Engineering Analysis

1660

1950

1960

1970

1980

1990

2004

Conducting the Field Investigation (Cont'd.)

- **When to Conduct Investigation**
  - During Major Flood is Desirable but Difficult
  - After Major Flood
  - As Part of Scheduled Inspection

1660

1950

1960

1970

1980

1990

2004

Lead Lines and Sounding Poles

1660

1950

1960

1970

1980

1990

2004

Disadvantages of Simpler, Traditional Methods

- Extensive Note Taking
- Current Problems
- Depth Limitations
- May be Misleading

1660

1950

1960

1970

1980

1990

2004

Depth Sounders

- Sonar (50KHZ & 200KHZ)
- Black & White Chart Recorder
- Various Transducer Angles
- Simple to Elaborate Equipment ($500 - $15,000 +)

1660

1950

1960

1970

1980

1990

2004

1660

1950

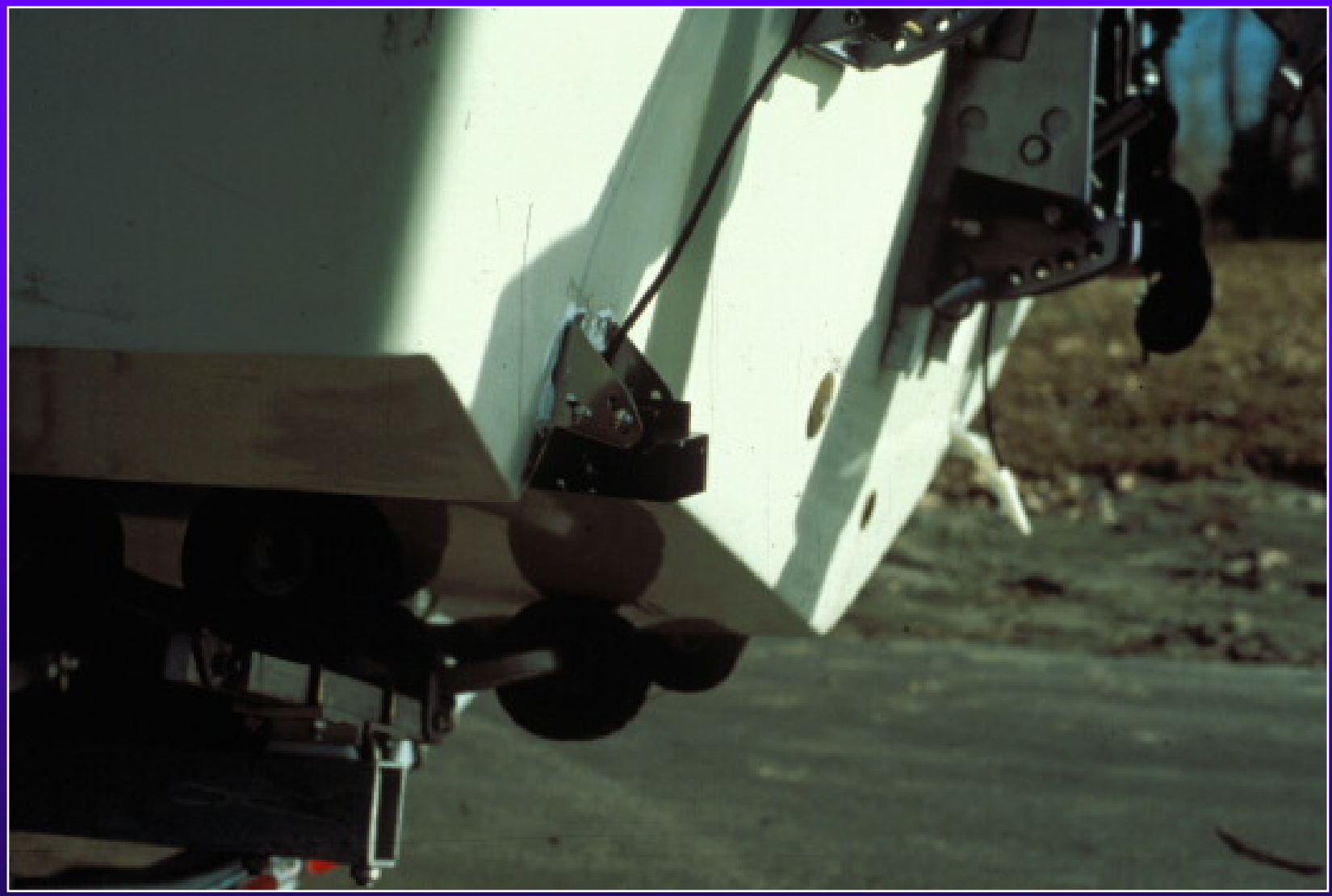
1960

1970

1980

1990

2004



1660

1950

1960

1970

1980

1990

2004

Accuracy of Soundings

- Depth
- Location

1660

1950

1960

1970

1980

1990

2004

Advantages

- Accurate
- Fast & Simple
- Permanent Record
- Good Definition

1660

1950

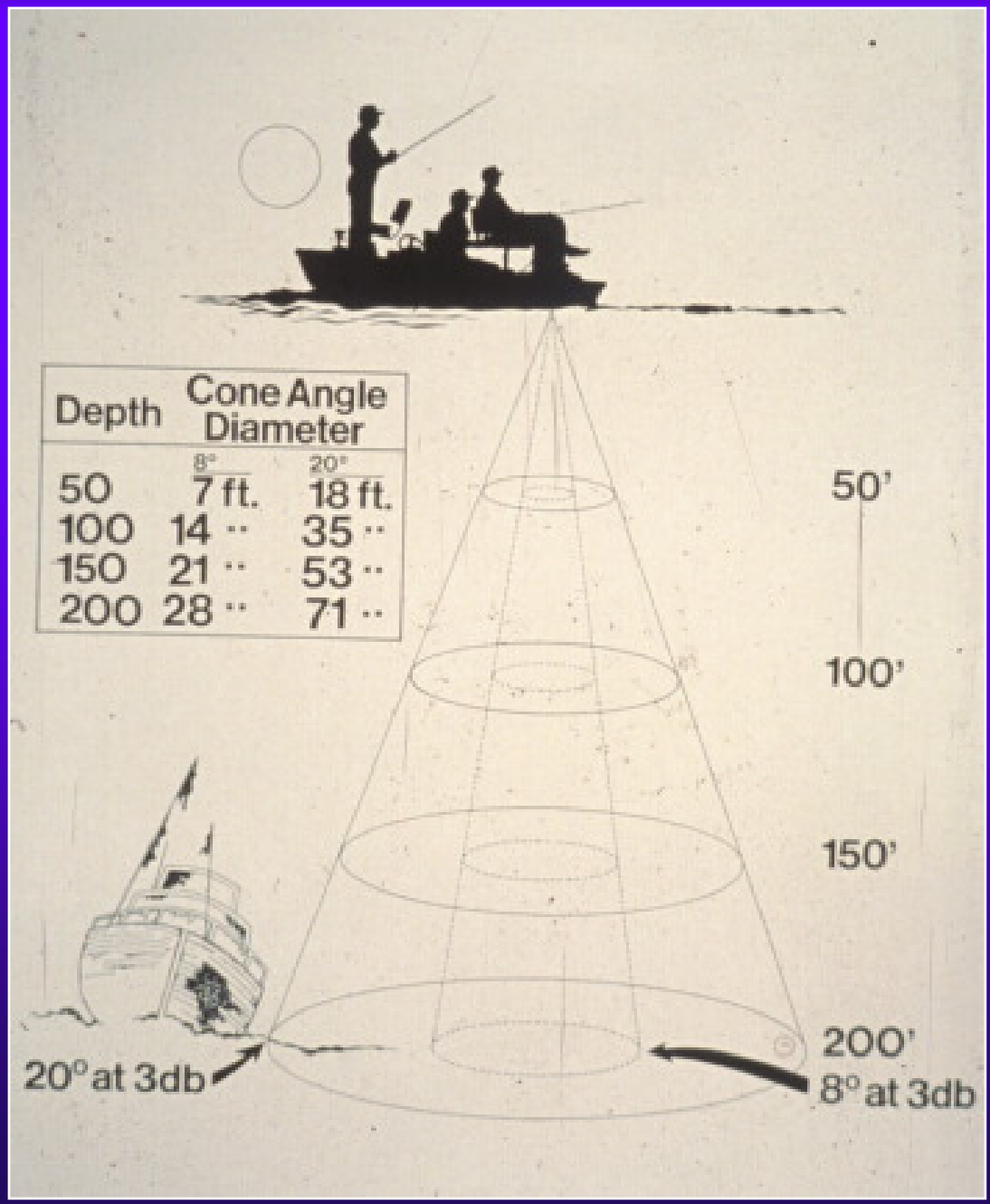
1960

1970

1980

1990

2004



1660

1950

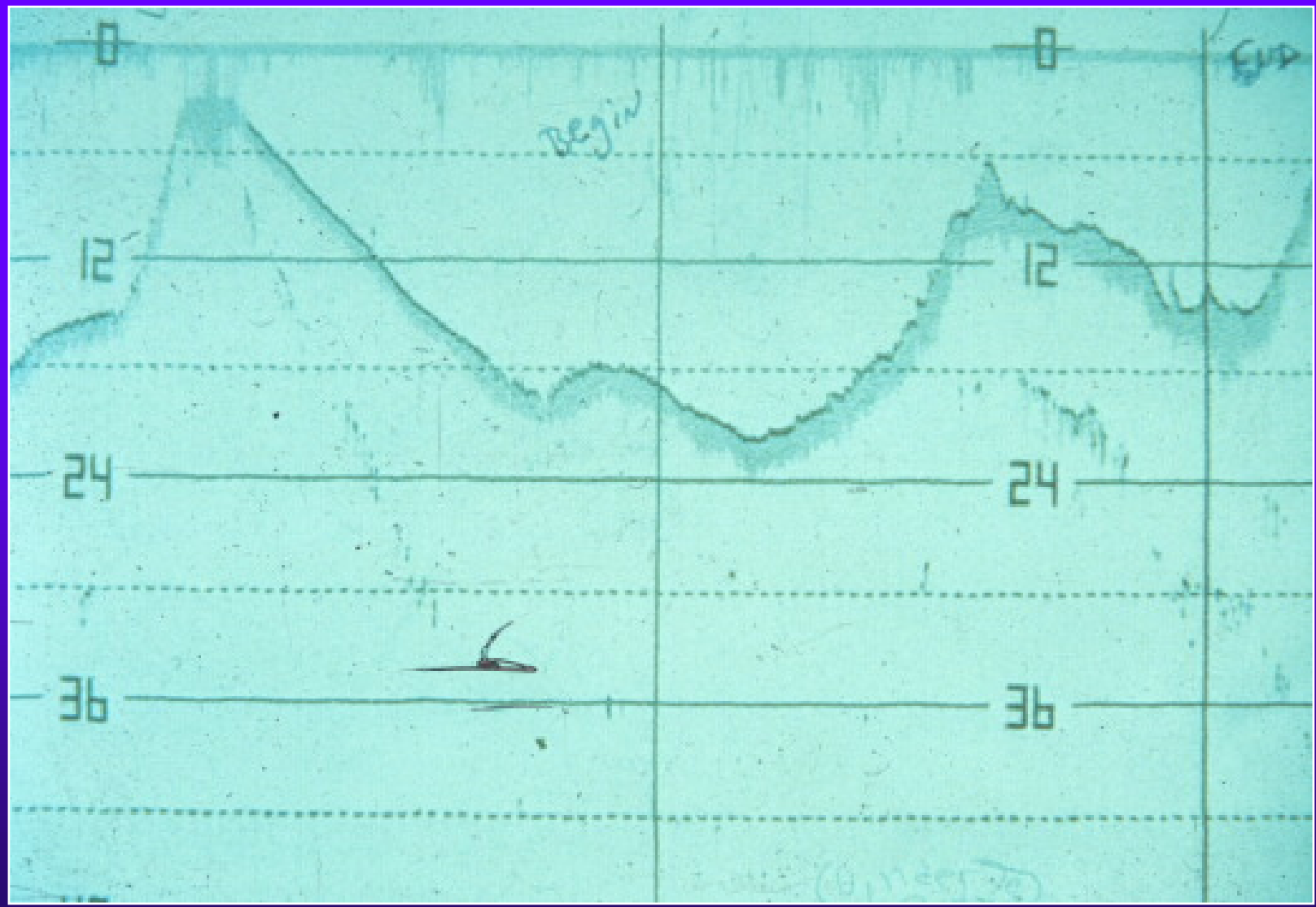
1960

1970

1980

1990

2004



1660

1950

1960

1970

1980

1990

2004

Soundings

- Plot Plan
- Plot Cross Sections
  + Channel Bottom
  + Foundations
- Plot Historical Record

1660

1950

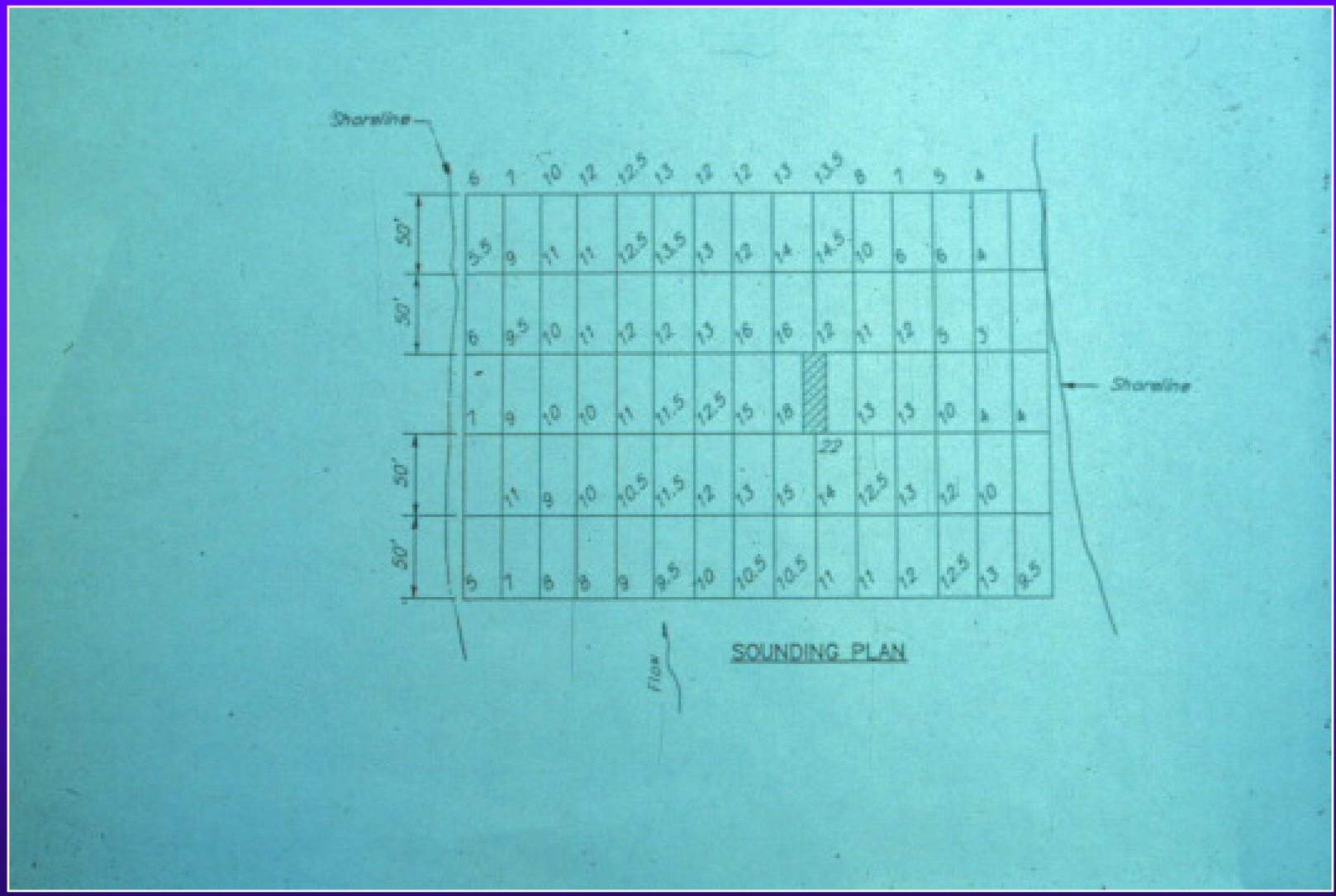
1960

1970

1980

1990

2004



1660

1950

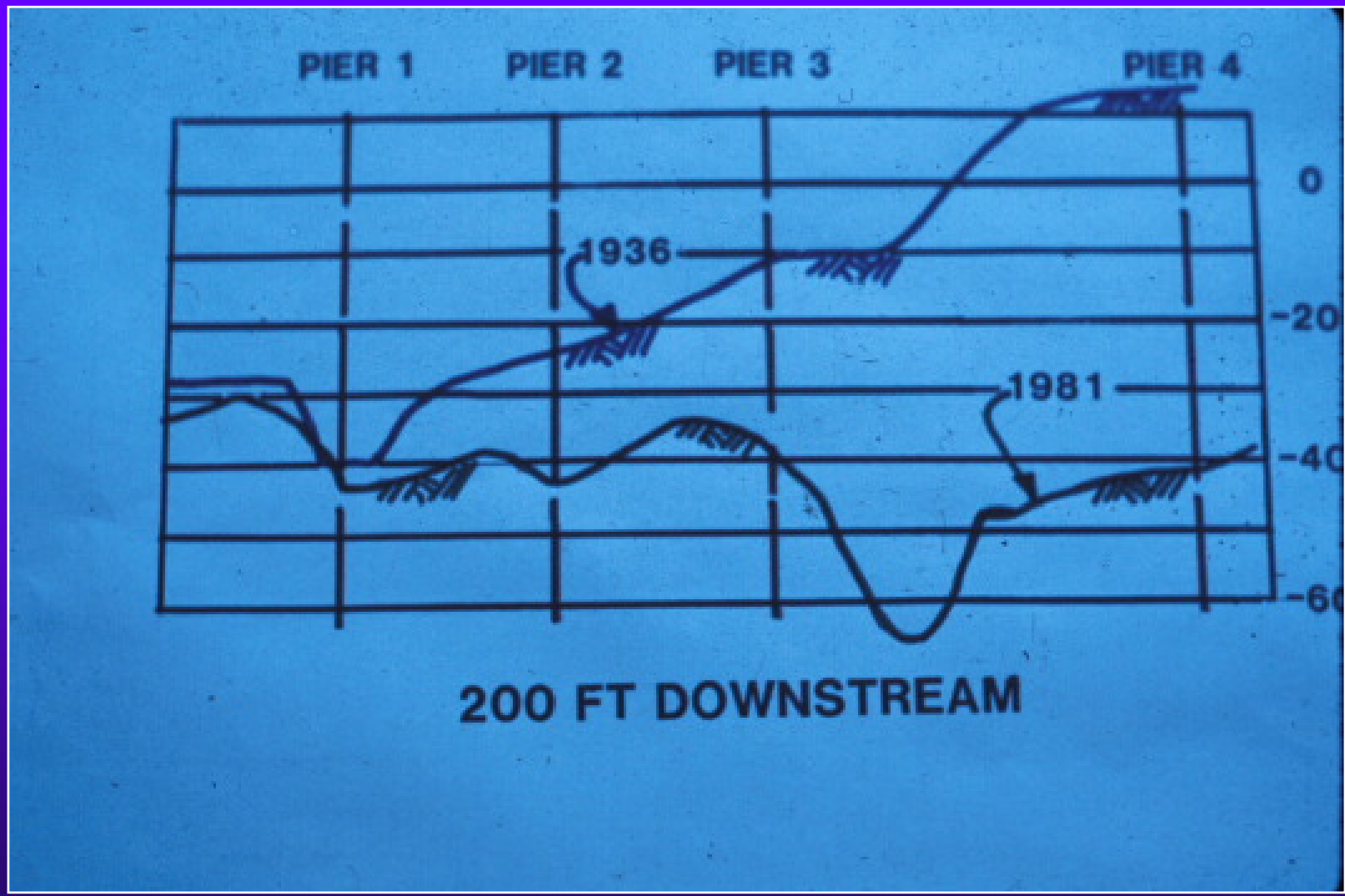
1960

1970

1980

1990

2004



1660

1950

1960

1970

1980

1990

2004

1660

1950

1960

1970

1980

1990

2004

1660

1950

1960

1970

1980

1990

2004

Post Processing

- Soundings
- Contour Lines
- Cross Sections
- Quantities

1660

1950

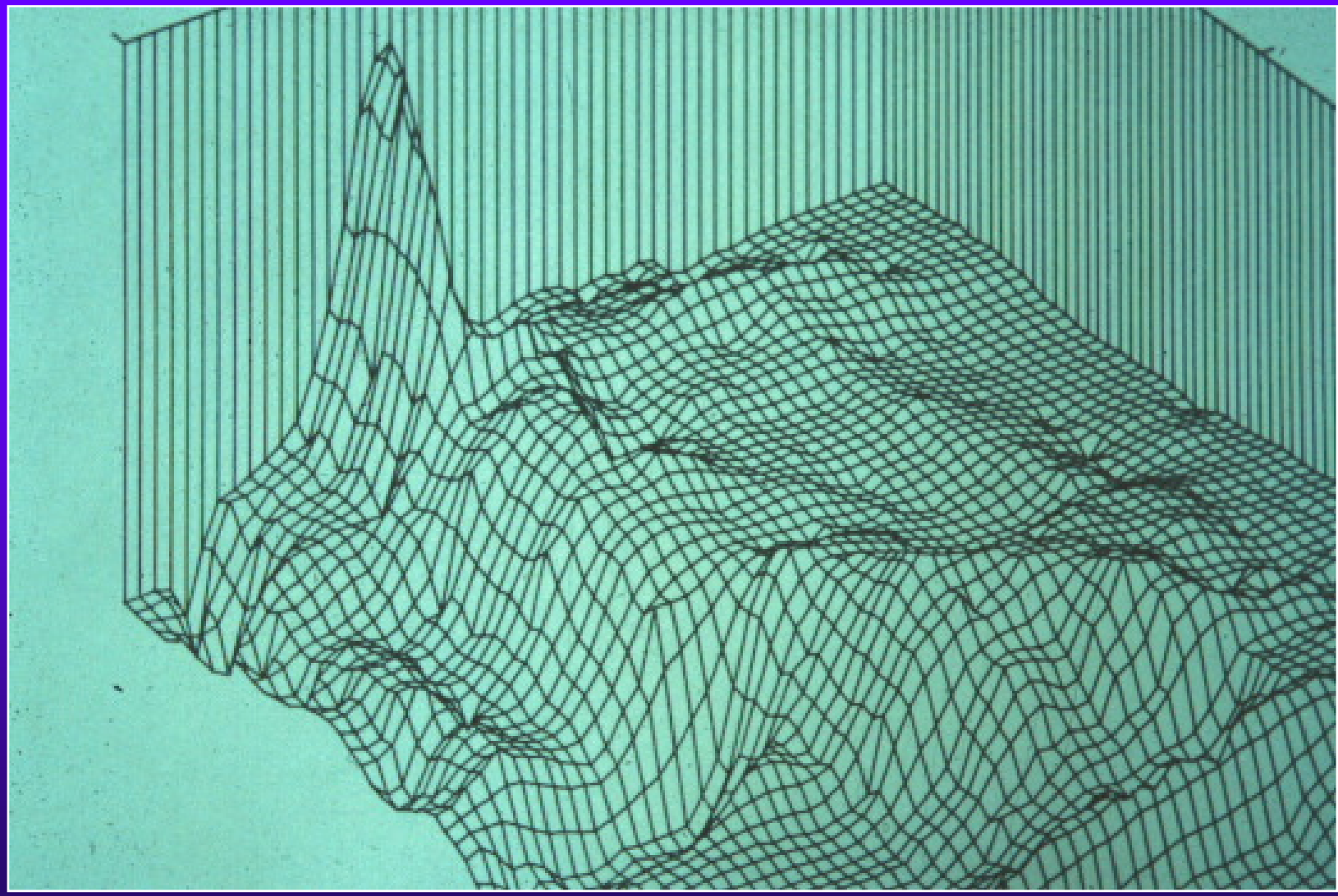
1960

1970

1980

1990

2004



1660

1950

1960

1970

1980

1990

2004

Scour

Scour Can Only be Measured With Certainty During High Flood Events;
Infilling may Occur During Lower Flows

1660

1950

1960

1970

1980

1990

2004

1660

1950

1960

1970

1980

1990

2004

1660

1950

1960

1970

1980

1990

2004

During Flood

After Flood

1660

1950

1960

1970

1980

1990

2004

Geophysical Methods

- Sonar Fixed-Tuned Transducer
- Swept-Frequency Continuous Seismic Reflection Profiling (CSP)
- Ground Penetrating Radar (GPR)
- CHIRP Color Sonar
- Side-Scan Sonar

1660

1950

1960

1970

1980

1990

2004

1660

1950

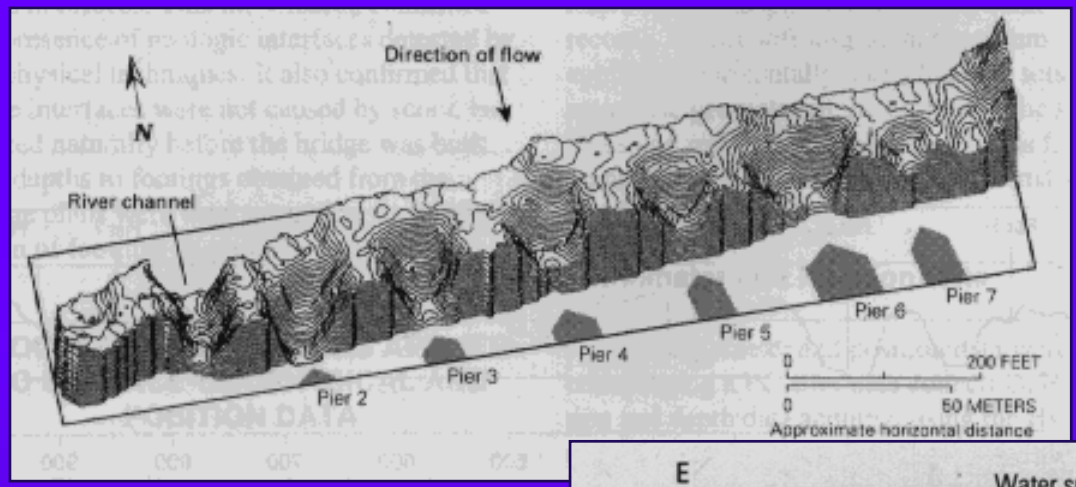
1960

1970

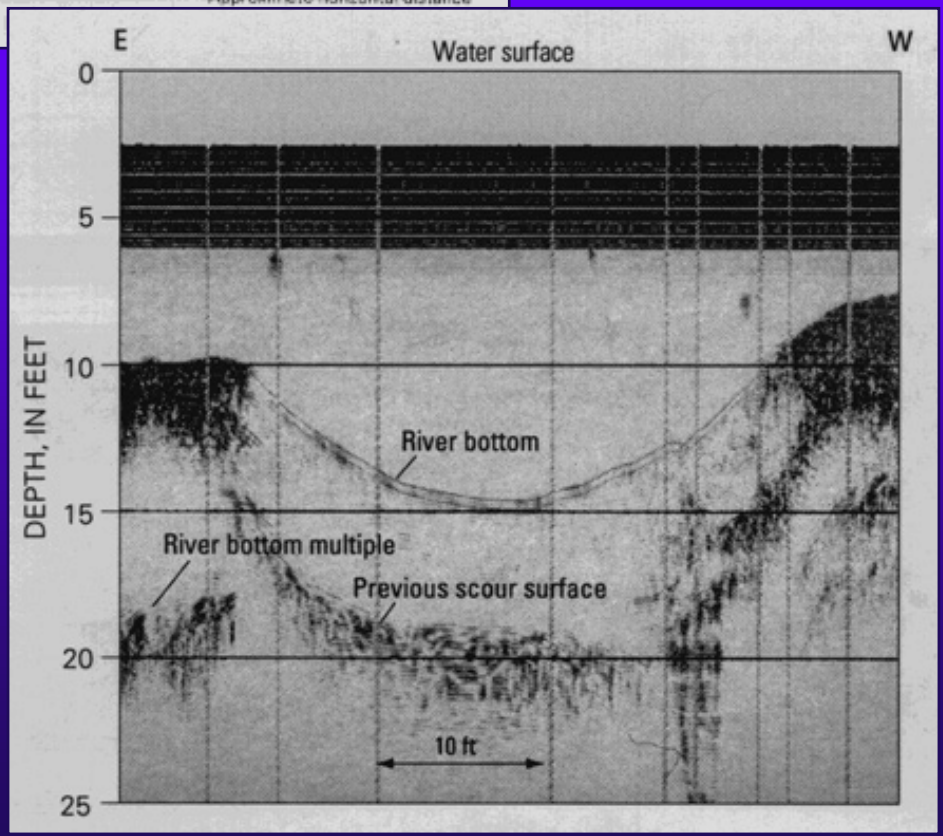
1980

1990

2004



3-D Bathymetric Contour Plot



Unprocessed CSP Data

1660

1950

1960

1970

1980

1990

2004

Scour

"Detecting Defects Is Only the First Step"

1660

1950

1960

1970

1980

1988

1990

2004

S.R. 675 Bridge Over Pocomoke River

- *Collapsed on August 17, 1988*
- *"Cause Determined to be Inadequate Response to Deficiencies Noted in the Underwater Inspection Report"*

1660

1950

1960

1970

1980

1988

1990

2004

October 1988 Modifications to NBIS

- Based on requirements of **"1987 Surface Transportation and Uniform Relocation Assistance Act"**
- FHWA mandated development of "Master List" of all bridges that require **"Underwater Inspections"**
- Underwater inspection frequency maximum interval 60 months
- Mandated development of "Master List" of all bridges that require **"Fracture Critical Inspections"** (initially 60 months, now 24 months)
- NICET Level III and Level IV certifications allowed for bridge inspection team leaders

1660

1950

1960

1970

1980

1989

1990

2004

Hatchie River Bridge Collapse

- April 1989 – Covington, Tennessee
- 8 fatalities
- Disruption of traffic

Response

- Illustrated critical importance for Underwater Bridge Inspections
- Focused attention on taking appropriate corrective action when deficiencies are discovered

"Forensic Analysis Performed"

1660

1950

1960

1970

1980

1989

1990

2004

Miamitown Bridge Collapse

- *May 26, 1989*
- *2 Fatalities*

“Failure Caused by Significant Lateral Debris Loading During Flood”

1660

1950

1960

1970

1980

1990 1990-2000

2004

Bridge Inspection Program Continues to Evolve Through the 1990's and Into the Next Millennium

- Bridge Inspectors Training Manual 90 (FHWA; Updated in 1990)
  - State of the art inspection techniques
  - Expanded coverage on culverts, fracture critical, cable-stayed bridges, prestressed segmental bridges, and underwater inspections

- Manual for Condition Evaluation of Bridges (AASHTO; 1994 - Updated thru 2000)

- Recording and Coding Guide for the Structure Inventory and Appraisal for the Nation's Bridges (FHWA; Updated 1995)

1660

1950

1960

1970

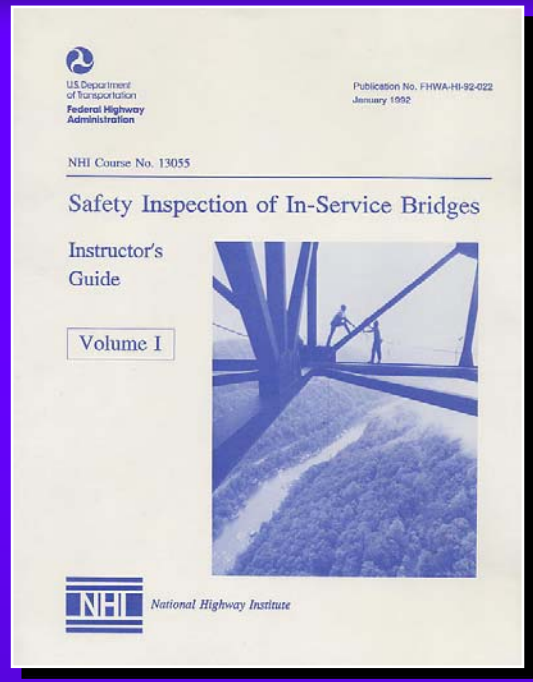
1980

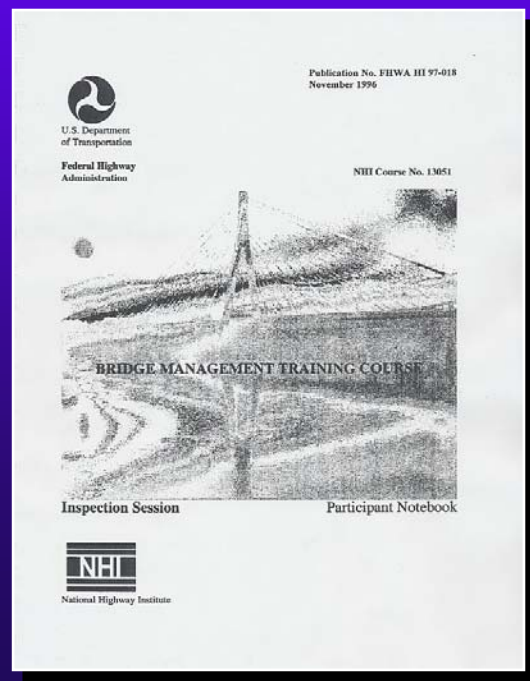
1990

2004

NHI Courses

- NDT Methods for Steel Bridges (FHWA-HI-88-006, June 1986)
- Safety Inspection of In-Service Bridges (No. 13055, 1992/1994, “80-Hour Course”)
- Bridge Management Training (No. 13051)
- Fracture Critical Inspection Techniques for Steel Bridges (No. 130078)





1660

1950

1960

1970

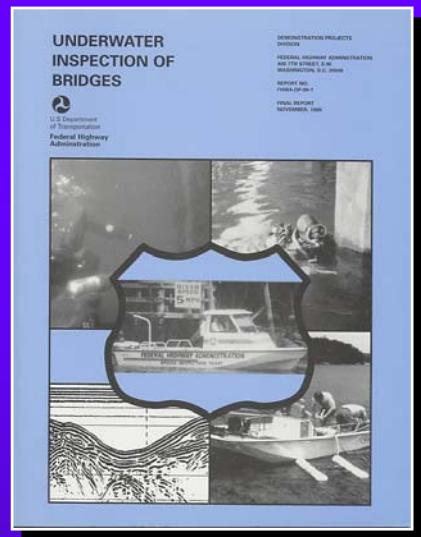
1980

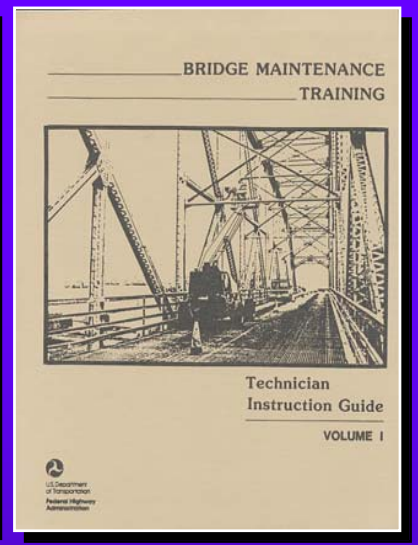
1990

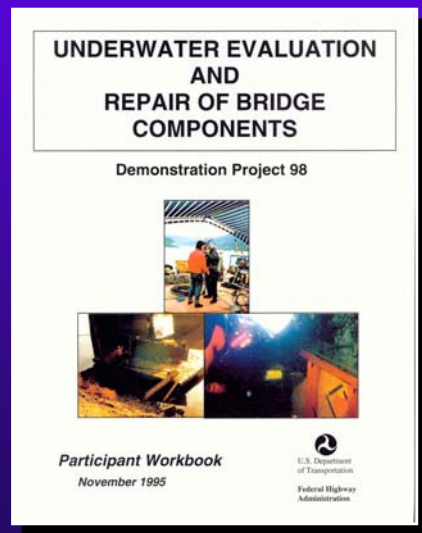
2004

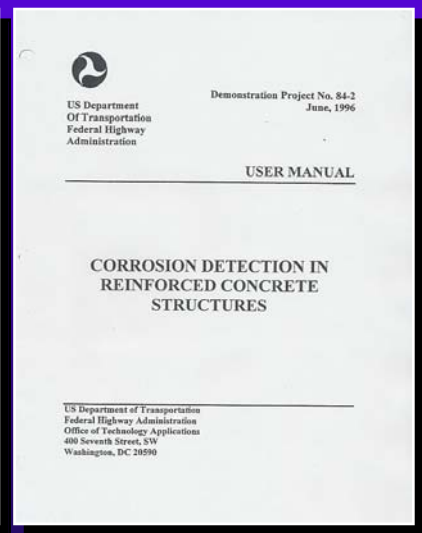
FHWA Demonstration Projects

- Bridge Maintenance Training (1980's)
- 80 – Underwater Inspection of Bridges (FHWA-DP-80-1)
- 98 – Underwater Evaluation and Repair of Bridge Components
- 84-2 – Corrosion Detection in Reinforced Concrete Structures









1660

1950

1960

1970

1980

1990

2004

Underwater Inspection Issues

- Structural Deterioration (Cracks, Spalls, Splits, Missing Blocks, Corrosion, Etc.)
- Surrounding Environment (Scour, Undermining, Debris Accumulation, Etc.)

1660

1950

1960

1970

1980

1990

2004

Means of Access

- Dry
- Scuba
- SSA

1660

1950

1960

1970

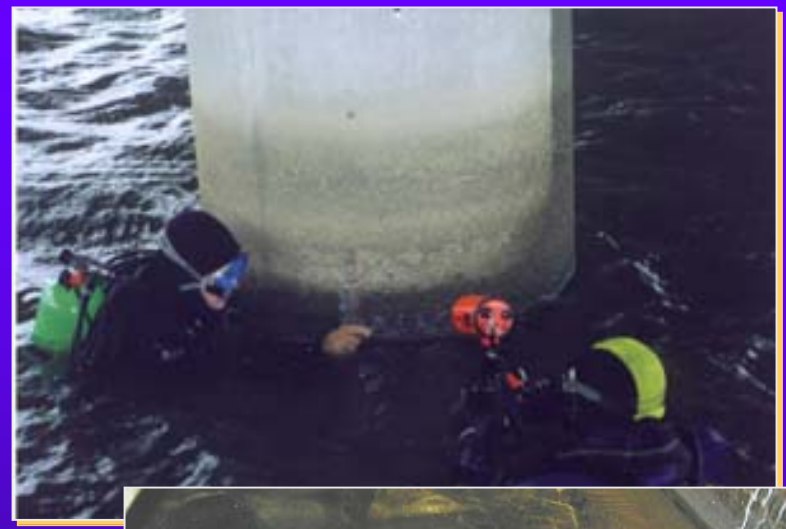
1980

1990

2004

Underwater Structural Deterioration

- Level I
  Visual; Minimal Cleaning
- Level II
  Limited Cleaning & Measurement
- Level III
  High Detailed; NDT



1660

1950

1960

1970

1980

1990

2004

Personnel

- Engineer-Divers – Team Leaders
- Construction Divers Reporting to Engineers – Team Leaders

Equipment

- Advancement in Technology
- Remote Operated Vehicles
- Geophysical/Graphical Display Operators

1660

1950

1960

1970

1980

1990

2004

Expectations of Team Leaders

- Accurate assessments
- Understanding of structural significance and loading ramifications
- Formulate and prioritize repairs or replacement options
- Develop accurate reports, plans and specifications

The engineer's knowledge of what to look for and the ability to recognize the structural significance of anomalous conditions greatly enhances the technical value of the inspection and often saves time and money.

1660

1950

1960

1970

1980

1990

2004

1660

1950

1960

1970

1980

1990

2004

1660

1950

1960

1970

1980

1990

2004

Engineer-Diver

- Diving Skills
- Engineering Skills
  - Inspection
  - Testing
  - Evaluation
- Professional Responsibility

1660

1950

1960

1970

1980

1990

2004

“Alligator Gar”

- 215 pounds, 7 ft. long.
- Caught May 3, 2003 in the Mississippi River.
- Second largest gar ever caught, Mississippi River record.

1660

1950

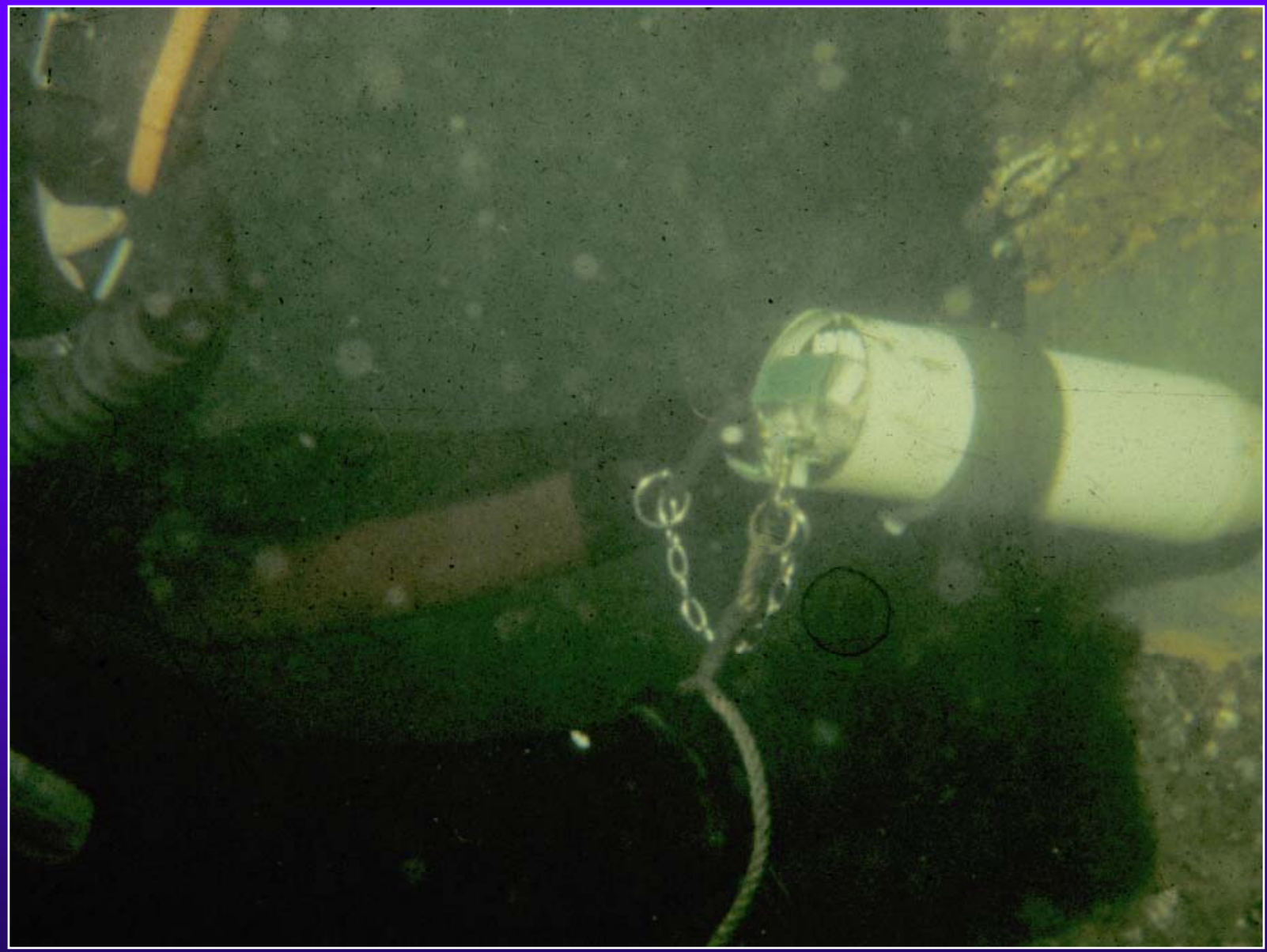
1960

1970

1980

1990

2004



1660

1950

1960

1970

1980

1990

2004

1660

1950

1960

1970

1980

1990

2004

Engineering Requirements for Diving

- American Society of Civil Engineers – Underwater Investigations Standard Practice Manual
- U.S. Navy's Worldwide Underwater Assessment Program
- U.S. Department of Transportation National Bridge Inspection Standards

1660

1950

1960

1970

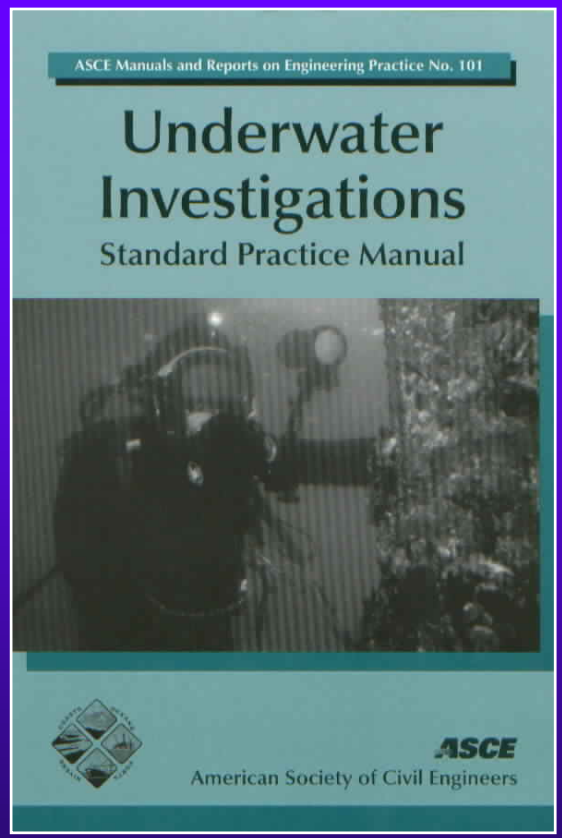
1980

1990

2004

Engineering Requirements for Diving (Cont'd.)

- Type and Frequency of Inspection
- Personnel Qualifications
  - Registered Engineer-Diver Conducts at least 25% of Diving
  - Inspectors
    - Graduate Engineer
    - Technician with 80-hour Structures Training



1660

1950

1960

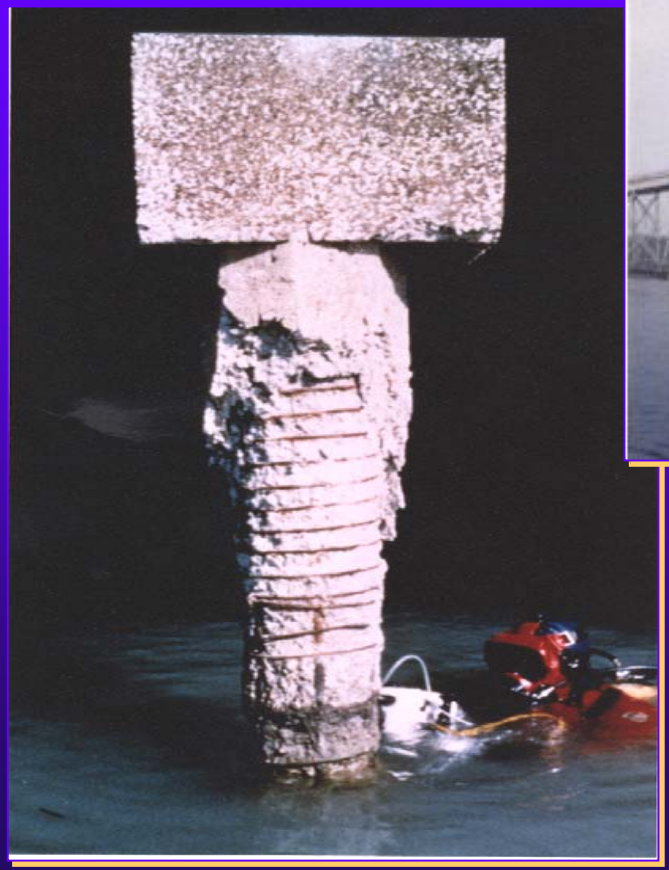
1970

1980

1990

2004

Safety, Accuracy, and Project Success



1660

1950

1960

1970

1980

1990

2004

Remote Operated Vehicles (ROV's)

1660

1950

1960

1970

1980

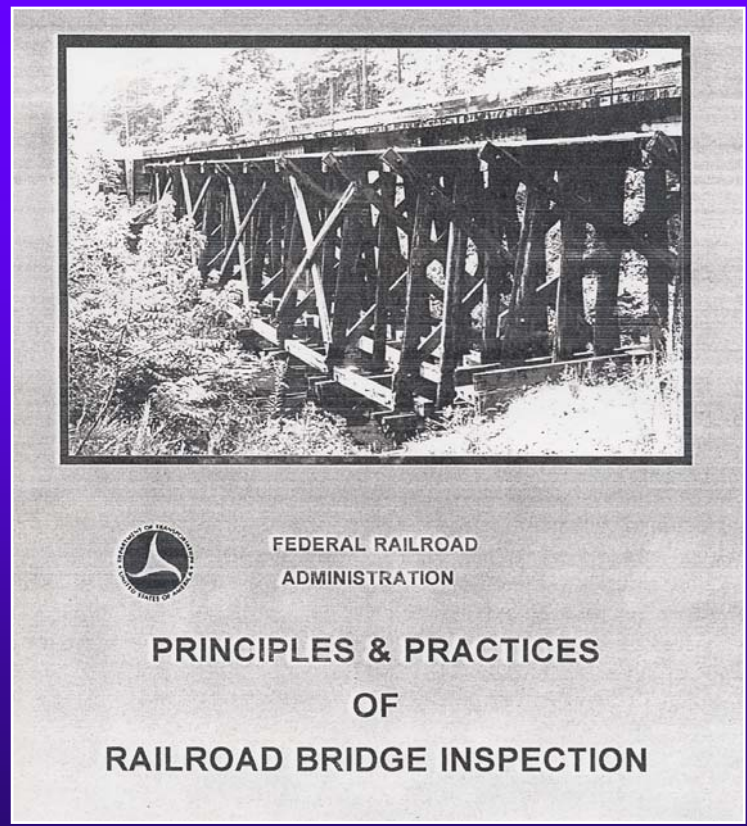
1990

1992

2004

Federal Railroad Administration

- Principles and Practices of Railroad Bridge Inspections (1992)
- Railway Specific and Very Comprehensive



1660

1950

1960

1970

1980

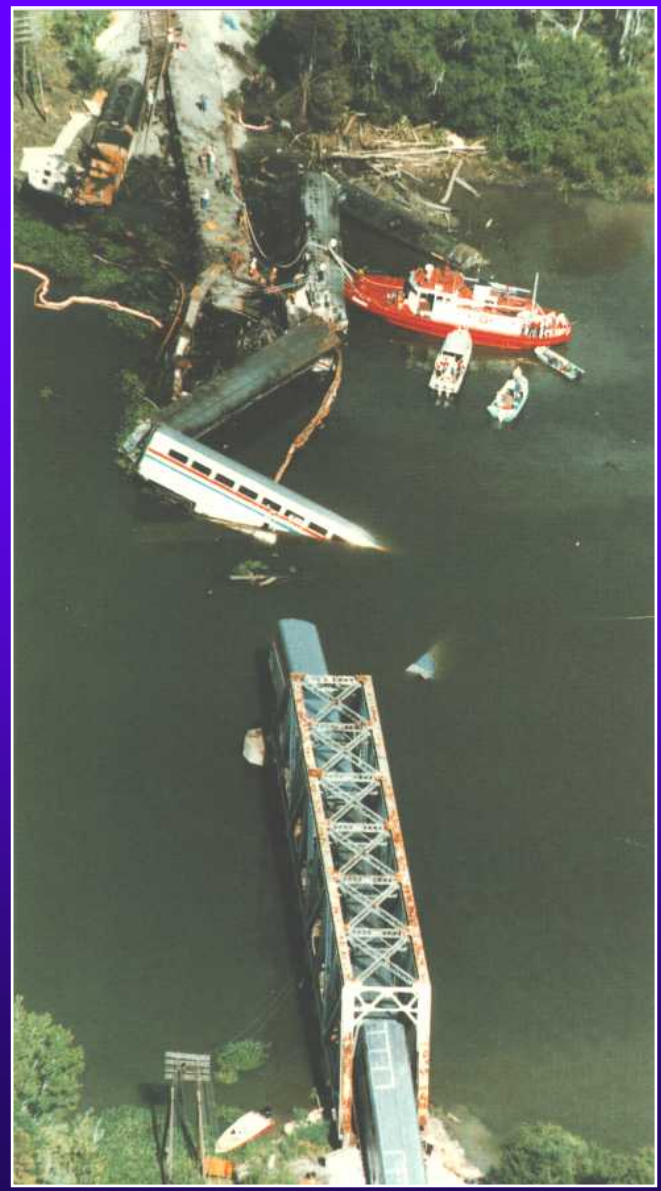
1990

1993

2004

Amtrak Railway Bridge Collapse

- September 22, 1993
- Mobile, AL
- 47 Deaths



1660

1950

1960

1970

1980

1990

1993

2004

1993 Great Midwest Flooding

- Several Railway Bridges Washed-Away
- BNSF Railway Bridge on Mississippi Exhibited Half of Pile Length

“Scour Up To 50 Feet Deep”