Tacoma Narrows Parallel Bridge

Project Overview

Stan Polasik, PARSONS

Famous Bridge

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Found It

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Purpose

- Provide Background for Scour Design Case Study
- Discuss the Design/Build Complications

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Finished Product

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Tacoma Narrows Parallel Bridge Project

- Existing and New Suspension Bridge – Main Span 2,800’ over a 5,400’ Main Channel
- Channel Depth 225’, 115’ to 125’ at Piers
- Project Cost – Exceeds $800 million
- Undertaken with a Design/Build Contract

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Tacoma Narrows Bridge

- Constructors

  Tacoma Narrows Constructors
  (Bechtel and Kiewit Joint Venture)

- Designers

  Parsons/HNTB Joint Venture

  - OEA, Inc. (Max Sheppard)
  - Colorado State University
  - Washington State University

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Initial Design

- Gain Environmental Clearance
- Set Project Cost
  - Structure Studies
  - Preliminary Bridge Hydraulic Report
  - Cost Estimates
  - Negotiations

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Design/Build Challenges

- Time Critical – Design Concurrent with Construction
  - Final Design began August 2002
  - Scour Elevation Set - December 2002
  - Caisson Floated - March 2003
  - Planned Landing - November 2003

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Design/Build Challenges

- Scour Analysis
  - Design and Review Fast Paced
  - Task Force Meetings
  - Scour Elevation Needed for Seismic and Foundation Design
  - Hydraulic Analysis Needed for Anchorage System Design

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Design/Build Challenges

- Task Force Meetings
  - Designers, Constructors and Reviewers meet as the design progresses to provide input and shorten the overall process.
  - Reviewers have no surprises.
  - 5 Meetings Held (One at the CSU Lab)

Design/Build Challenges

- Basic Conclusion
  - Design methods are the same
  - Design is fast paced
  - Reviewer integrated with the design process through Task Force Meetings

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Scour Analysis

- Bridge and Pier Configuration
- Channel Bed Properties
- Design Velocity
- Determine Scour
  - Contraction Scour
  - General Scour
  - Original Bed Elevation
  - Local Scour (By Max)

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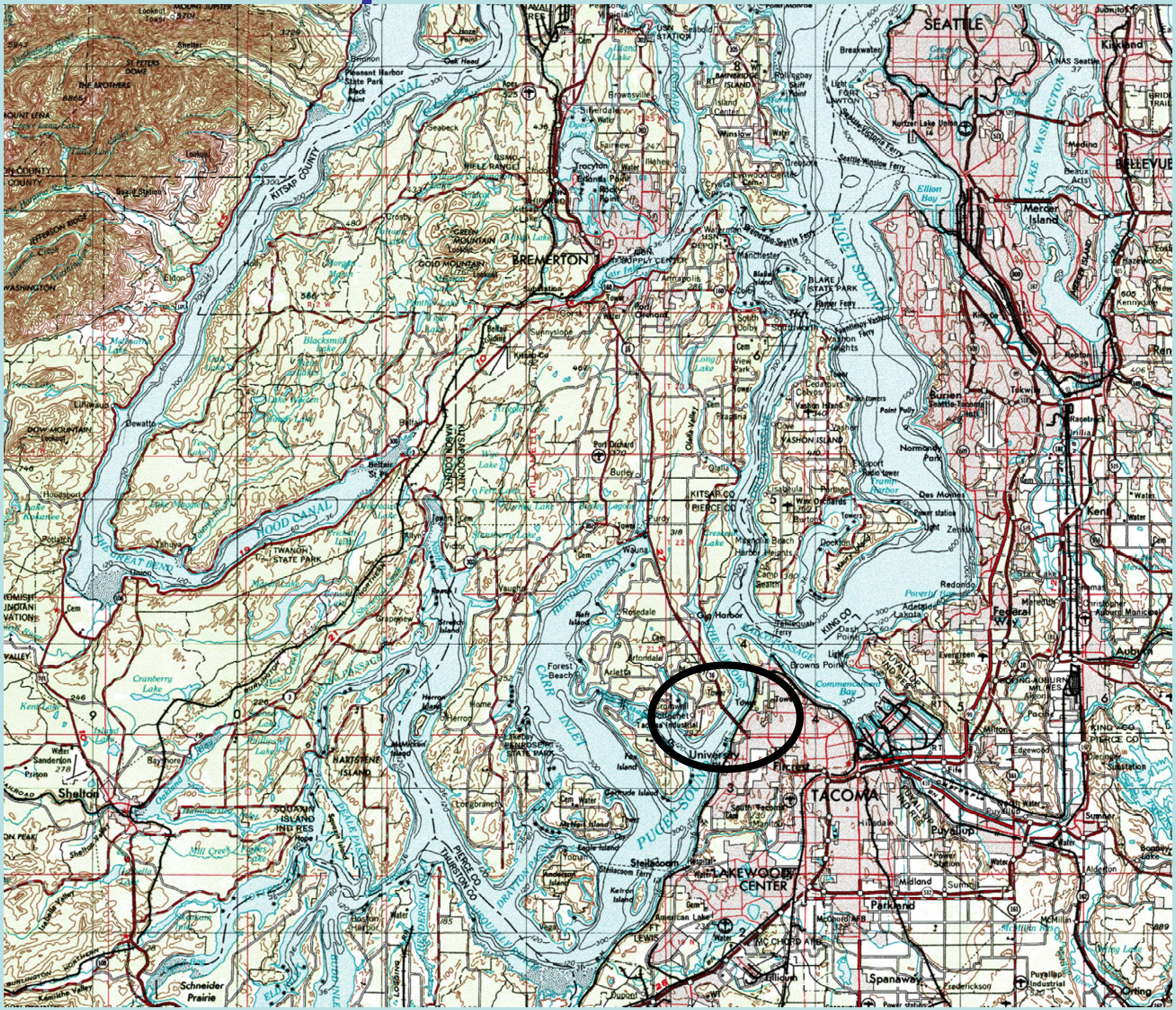
Project Location



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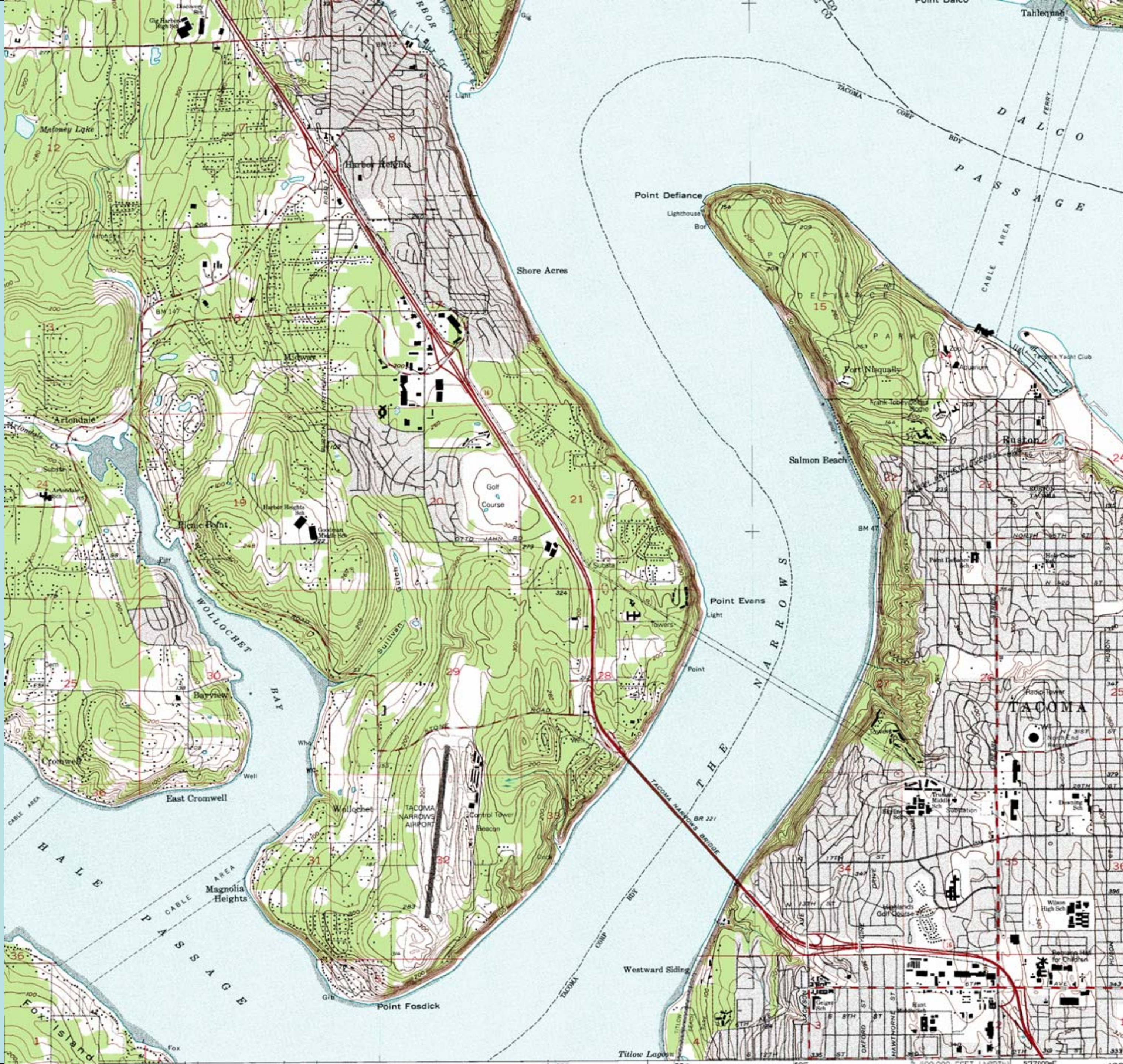

Tahlequah
Maloney Lake
Harbor Heights
Point Defiance
Lighthouse
Shore Acres
DALCO PASSAGE
CABLE AREA
FERRY
TACOMA CORP BDY
POINT DEFIANCE PARK
Fort Nisqually
Zoo
Aquarium
Tacoma Yacht Club
Ruston
Salmon Beach
Arletta
Artondale
Midway
Picnic Point
Harbor Heights Sch
Golf Course
Point Evans
Light
Towers
Point
THE NARROWS
WOLLOCHET BAY
Bayview
Cromwell
East Cromwell
Well
Wollochet
TACOMA NARROWS AIRPORT
Control Tower
Beacon
TACOMA NARROWS BRIDGE
HALE PASSAGE
Magnolia Heights
Point Fosdick
Westward Siding
Fox Island
Fox
Titlow Lagoon
TACOMA
Radio Tower
Point Defiance Sch
Holy Rosary Sch
Highlands Golf Course
Wilson High Sch
Downing Sch
Remann Hall for Children
Sullivan Gulch

Project Location

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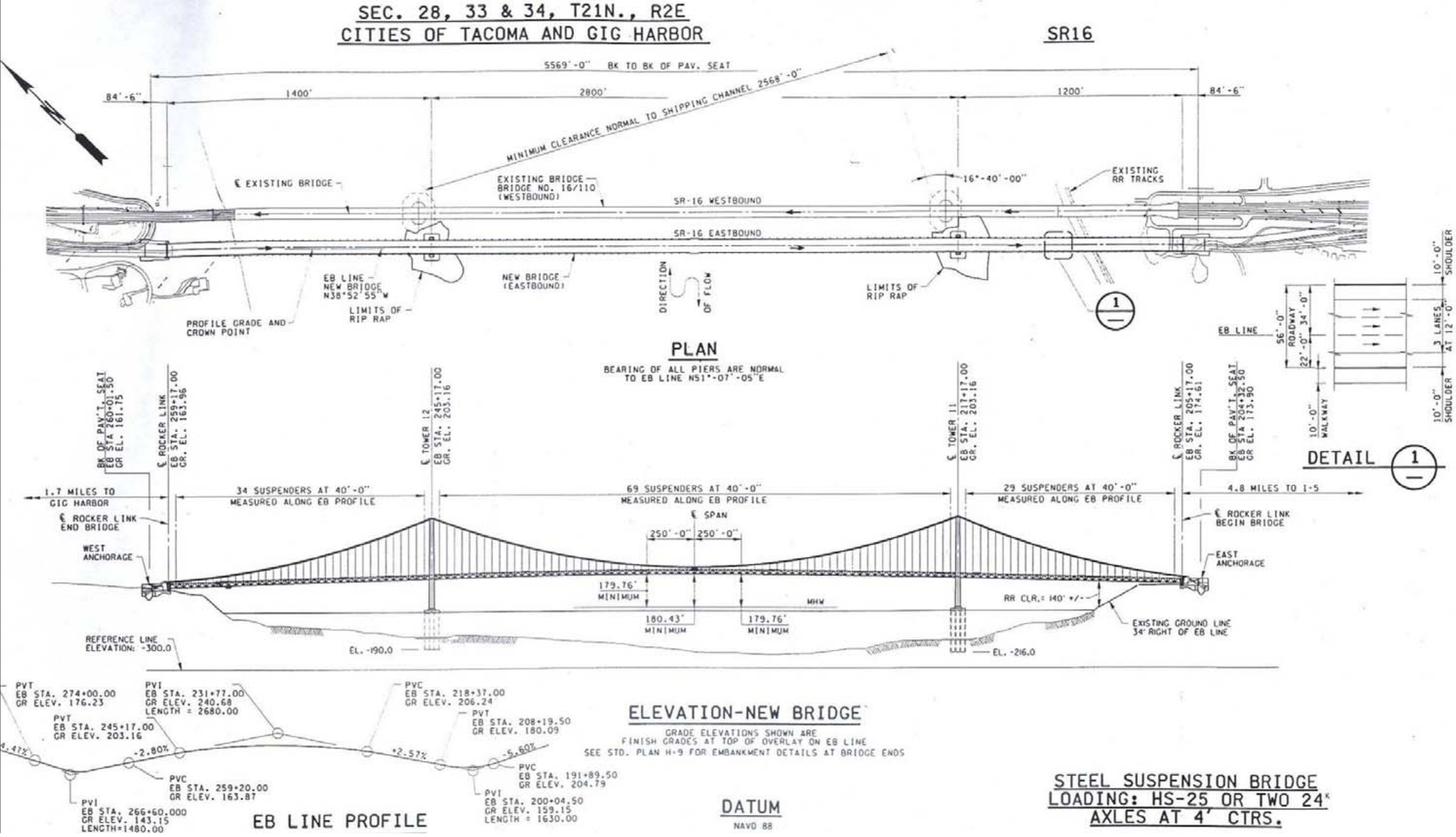
SEC. 28, 33 & 34, T21N., R2E
CITIES OF TACOMA AND GIG HARBOR
SR16
5569'-0" BK TO BK OF PAV. SEAT
84'-6"
1400'
2800'
1200'
84'-6"
MINIMUM CLEARANCE NORMAL TO SHIPPING CHANNEL 2568'-0"
℄ EXISTING BRIDGE
EXISTING BRIDGE BRIDGE NO. 16/110 (WESTBOUND)
16°-40'-00"
EXISTING RR TRACKS
SR-16 WESTBOUND
SR-16 EASTBOUND
EB LINE NEW BRIDGE N38°52'55"W
NEW BRIDGE (EASTBOUND)
DIRECTION OF FLOW
LIMITS OF RIP RAP
LIMITS OF RIP RAP
PROFILE GRADE AND CROWN POINT
PLAN
BEARING OF ALL PIERS ARE NORMAL TO EB LINE N51°-07'-05"E
EB LINE
56'-0" ROADWAY
22'-0" 34'-0"
10'-0" SHOULDER
3 LANES AT 12'-0"
10'-0" SHOULDER
10'-0" WALKWAY
DETAIL 1
BK OF PAV'T. SEAT EB STA 260+01.50 GR EL. 161.75
℄ ROCKER LINK EB STA. 259+17.00 GR. EL. 163.96
℄ TOWER 12 EB STA. 245+17.00 GR. EL. 203.16
℄ TOWER 11 EB STA. 217+17.00 GR. EL. 203.16
℄ ROCKER LINK EB STA. 205+17.00 GR. EL. 174.61
BK OF PAV'T. SEAT EB STA 204+32.50 GR. EL. 173.90
1.7 MILES TO GIG HARBOR
34 SUSPENDERS AT 40'-0" MEASURED ALONG EB PROFILE
69 SUSPENDERS AT 40'-0" MEASURED ALONG EB PROFILE
29 SUSPENDERS AT 40'-0" MEASURED ALONG EB PROFILE
4.8 MILES TO I-5
℄ ROCKER LINK END BRIDGE
℄ SPAN
250'-0" 250'-0"
℄ ROCKER LINK BEGIN BRIDGE
WEST ANCHORAGE
EAST ANCHORAGE
179.76' MINIMUM
180.43' MINIMUM
179.76' MINIMUM
MHW
RR CLR.= 140' +/-
EXISTING GROUND LINE 34' RIGHT OF EB LINE
REFERENCE LINE ELEVATION: -300.0
EL. -190.0
EL. -216.0
PVT EB STA. 274+00.00 GR ELEV. 176.23
PVI EB STA. 231+77.00 GR ELEV. 240.68 LENGTH = 2680.00
PVC EB STA. 218+37.00 GR ELEV. 206.24
PVT EB STA. 245+17.00 GR ELEV. 203.16
PVT EB STA. 208+19.50 GR ELEV. 180.09
4.47%
-2.80%
+2.57%
-5.60%
PVC EB STA. 259+20.00 GR ELEV. 163.87
PVC EB STA. 191+89.50 GR ELEV. 204.79
PVI EB STA. 266+60.000 GR ELEV. 143.15 LENGTH=1480.00
PVI EB STA. 200+04.50 GR ELEV. 159.15 LENGTH = 1630.00
EB LINE PROFILE
ELEVATION-NEW BRIDGE
GRADE ELEVATIONS SHOWN ARE FINISH GRADES AT TOP OF OVERLAY ON EB LINE
SEE STD. PLAN H-9 FOR EMBANKMENT DETAILS AT BRIDGE ENDS
DATUM
NAVD 88
STEEL SUSPENSION BRIDGE
LOADING: HS-25 OR TWO 24K AXLES AT 4' CTRS.

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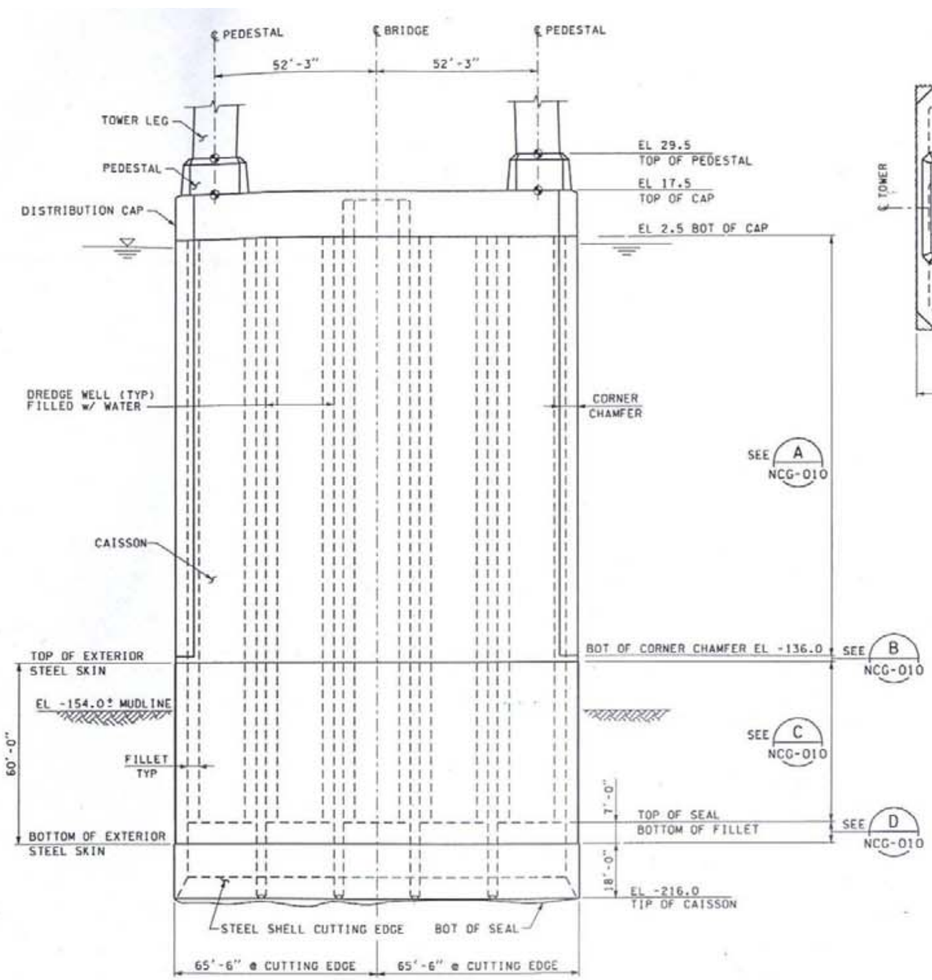
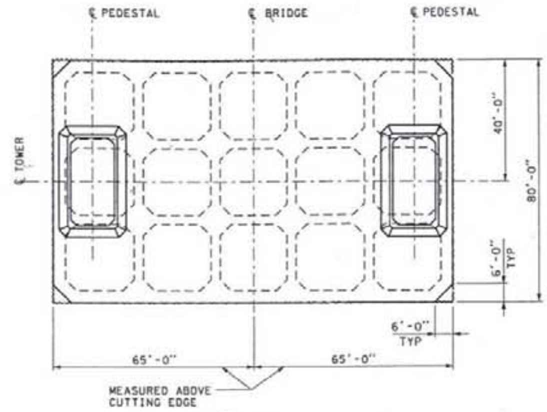


CAISSON ELEVATION

1" = 20'



PLAN

1" = 20'

CAISSON AND DISTRIBUTION CAP GENERAL NOTES:

1. CONCRETE UNLESS OTHERWISE NOTED:
   CLASS 4000 P, f'c = 4000 psi AT 28 DAYS.

   SEAL SLAB CONCRETE: CLASS 4000 W,
   SPECIFIED STRENGTH f'c = 4000 psi AT 28 DAYS.
   DESIGN STRENGTH f'c = 2400 psi AT 28 DAYS.

2. REINFORCEMENT: ASTM A615 (GRADE 60) OR ASTM A706 (GRADE 60) UNLESS OTHERWISE NOTED.

   HEADED BARS: ASTM A706 (GRADE 60).
   LIGHTNING PROTECTION, DOWN CONDUCTOR WELDED TO EXTERIOR STEEL SKIN AND WHERE WELDED CONNECTION IS USED
   ASTM A706 (GRADE 60)

3. STRUCTURAL STEEL UNLESS OTHERWISE NOTED:
   ASTM A36 (GRADE 36).
   EXTERIOR SKIN: ASTM A572 (GRADE 50)
   INTERNAL TRUSS CHORDS: ASTM A572 (GRADE 50)
   PIPE: ASTM A53, TYPE E OR S, GRADE B
   TUBE: ASTM A500, GRADE B
   ANCHOR ROD: WILLIAMS THREAD BAR, ASTM A722
   BOLTS: ASTM A325

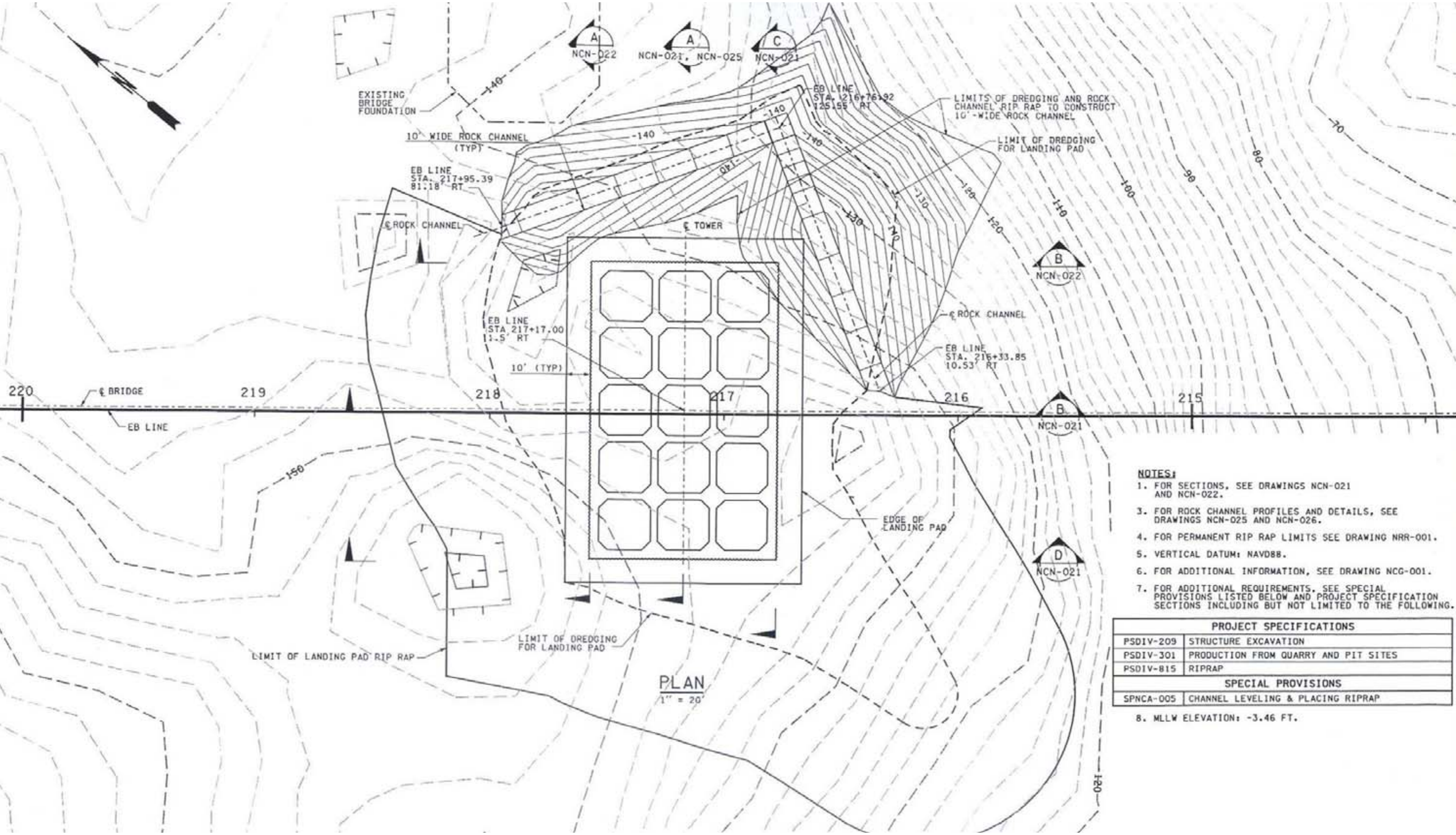
4. INTERIOR WALLS ARE DESIGNED FOR 30' OF DIFFERENTIAL WATER PRESSURE.

5. FOR ADDITIONAL REQUIREMENTS, SEE SPECIAL PROVISIONS LISTED BELOW AND PROJECT SPECIFICATION SECTIONS INCLUDING BUT NOT LIMITED TO THE FOLLOWING.

	PROJECT SPECIFICATIONS
PSDIV-209	STRUCTURE EXCAVATION
PSDIV-301	PRODUCTION FROM QUARRY AND PIT SITES
PSDIV-302	STOCKPILING AGGREGATES
PSDIV-303	SITE RECLAMATION
PSDIV-601	GENERAL REQUIREMENTS
PSDIV-602	CONCRETE STRUCTURES
PSDIV-603	STEEL STRUCTURES
PSDIV-604	TIMBER STRUCTURES
PSDIV-607	PAINTING
PSDIV-900	DEFINITIONS AND TESTS
PSDIV-901	PORTLAND CEMENT
PSDIV-903	AGGREGATES
PSDIV-906	STRUCTURAL STEEL AND RELATED MATERIALS
PSDIV-907	REINFORCING STEEL
PSDIV-908	PAINTS
PSDIV-909	TIMBER AND LUMBER
PSDIV-923	CONCRETE CURING MATERIALS AND ADMIXTURES
PSDIV-925	WATER
PSDIV-930	WATER DISTRIBUTION MATERIALS
	SPECIAL PROVISIONS
SPNCA-003	CAISSON AND DISTRIBUTION CAP
SPNCA-004	STRUCTURAL STEEL SKIN

NOTES:

1. FOR DISTRIBUTION CAP, SEE DRAWING NDC-001.
2. FOR EXTERIOR STEEL SKIN, SEE DRAWING NCN-007.
3. FOR SEAL SLAB, SEE DRAWING NSL-001.
4. VERTICAL DATUM: NAVD88.
5. MUDLINE ELEVATION INDICATES FINISHED GROUND ELEVATION FOLLOWING CHANNEL LEVELING PRIOR TO PLACING RIPRAP.
6. FOR CHAMFER LIMITS SEE NRF-001, NRF-002.



NOTES:

1. FOR SECTIONS, SEE DRAWINGS NCN-021 AND NCN-022.
3. FOR ROCK CHANNEL PROFILES AND DETAILS, SEE DRAWINGS NCN-025 AND NCN-026.
4. FOR PERMANENT RIP RAP LIMITS SEE DRAWING NRR-001.
5. VERTICAL DATUM: NAVD88.
6. FOR ADDITIONAL INFORMATION, SEE DRAWING NCG-001.
7. FOR ADDITIONAL REQUIREMENTS, SEE SPECIAL PROVISIONS LISTED BELOW AND PROJECT SPECIFICATION SECTIONS INCLUDING BUT NOT LIMITED TO THE FOLLOWING.

PROJECT SPECIFICATIONS	
PSDIV-209	STRUCTURE EXCAVATION
PSDIV-301	PRODUCTION FROM QUARRY AND PIT SITES
PSDIV-815	RIPRAP
SPECIAL PROVISIONS	
SPNCA-005	CHANNEL LEVELING & PLACING RIPRAP

8. MLLW ELEVATION: -3.46 FT.

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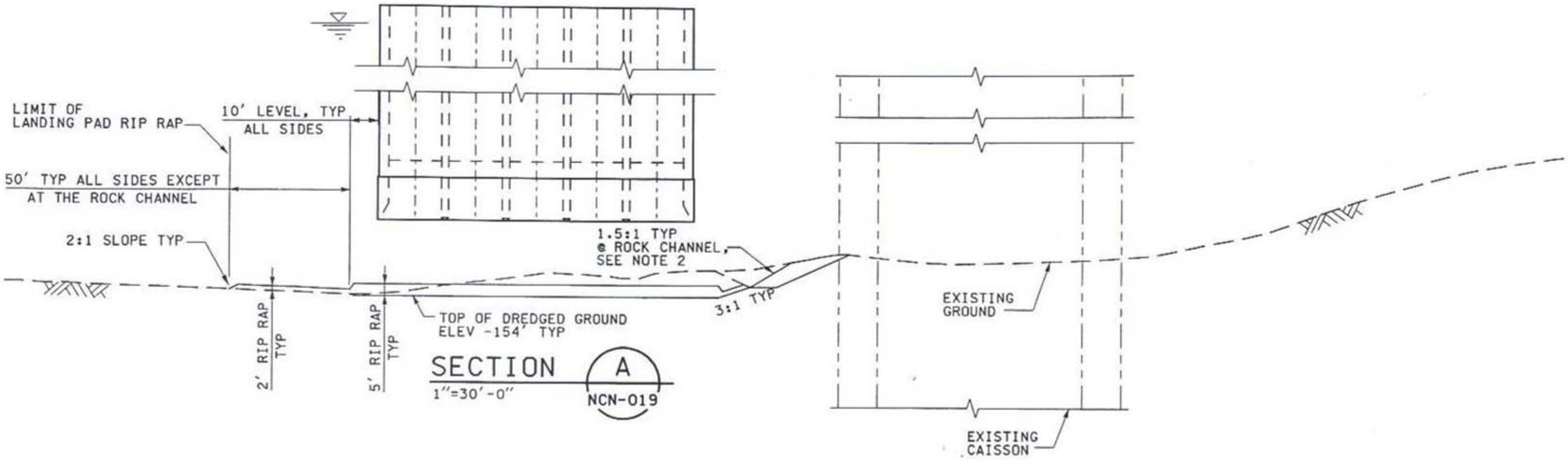
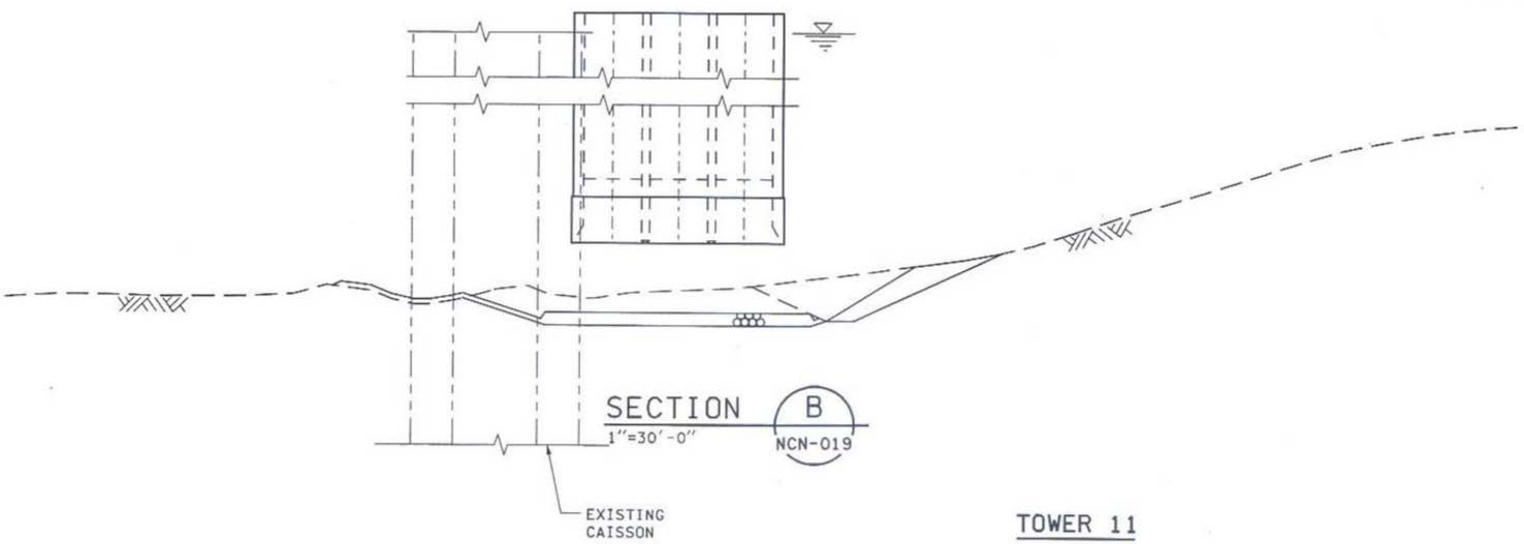


NOTE:

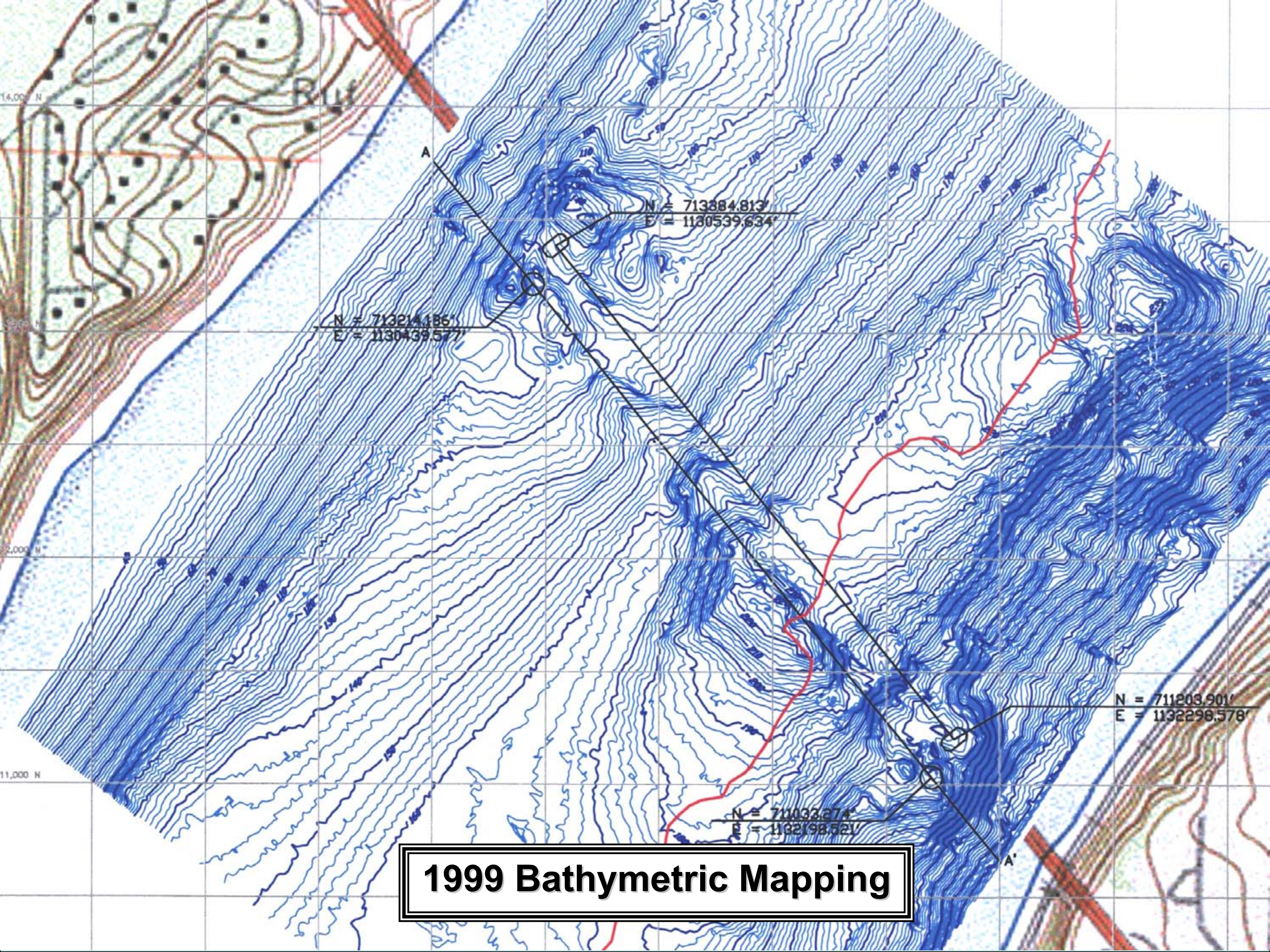
1. FOR NOTES, SEE NCN-021.
2. EXCAVATED ROCK CHANNEL RIP RAP ANTICIPATED TO HOLD A 1.5:1 SLOPE OR STEEPER.



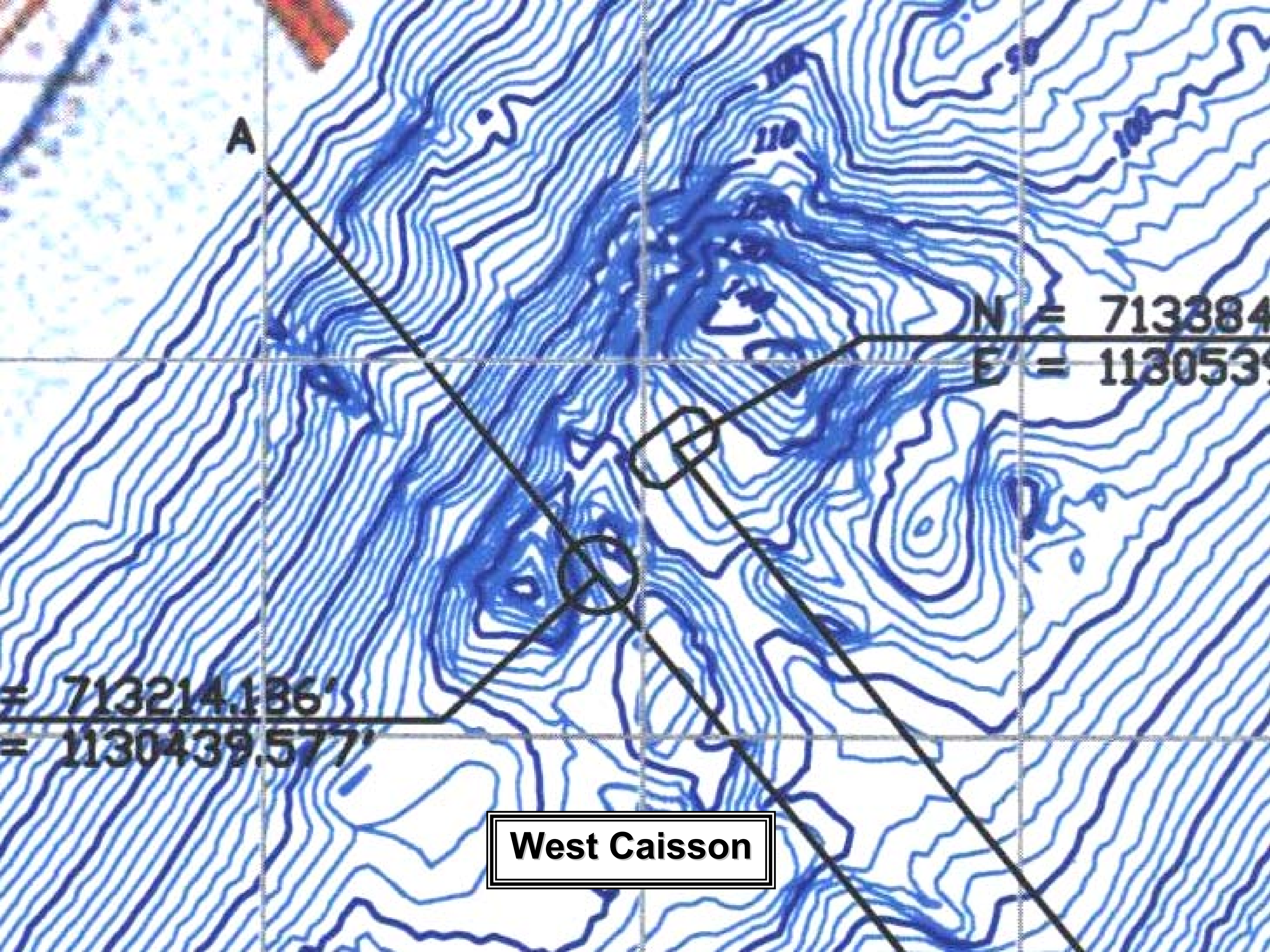
TOWER 11

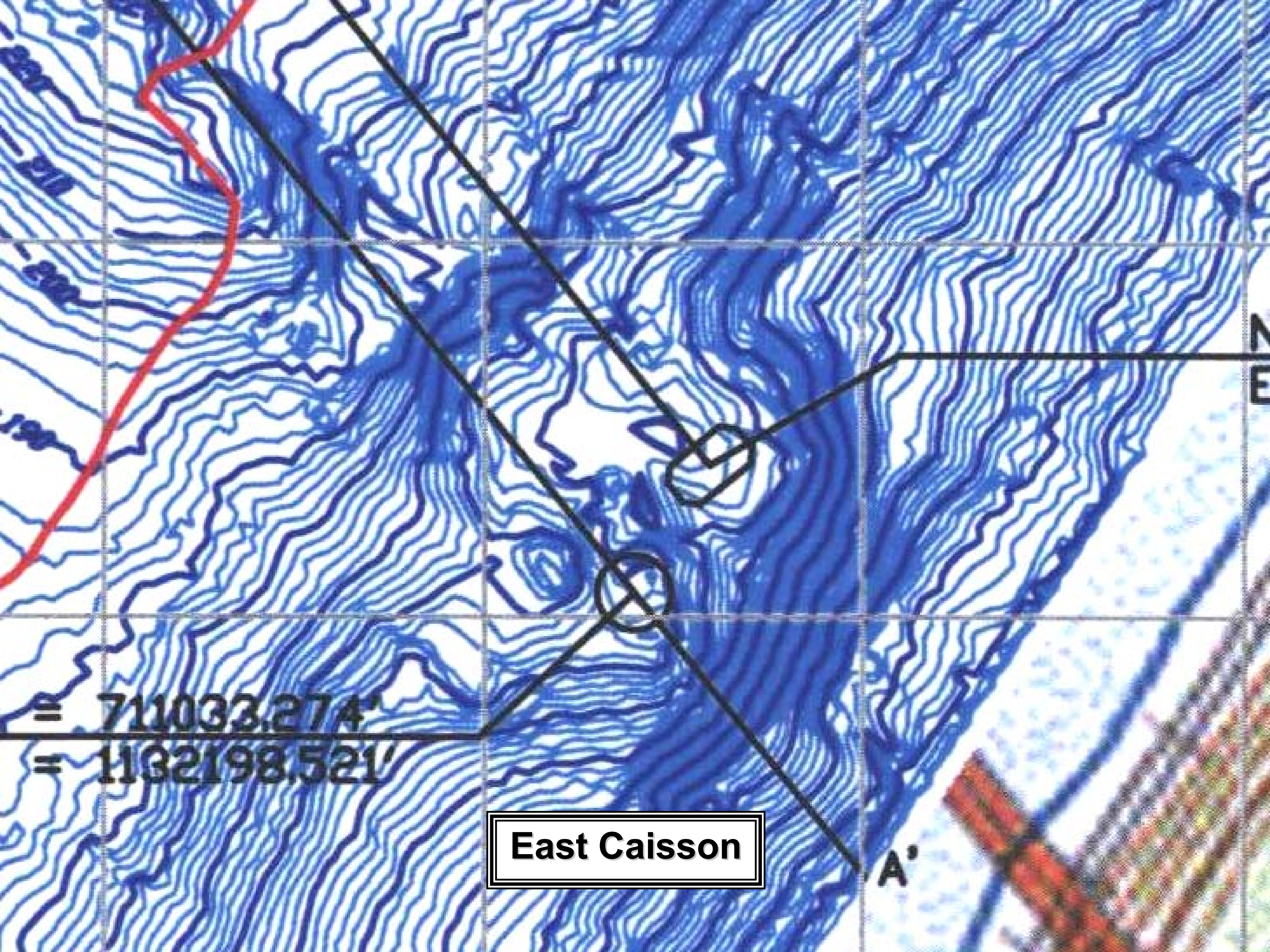
Scour Analysis

- Bridge and Pier Configuration
- Channel Bed Properties
- Design Velocity
- Determine Scour
  - Contraction Scour
  - General Scour
  - Local Scour (By Max)

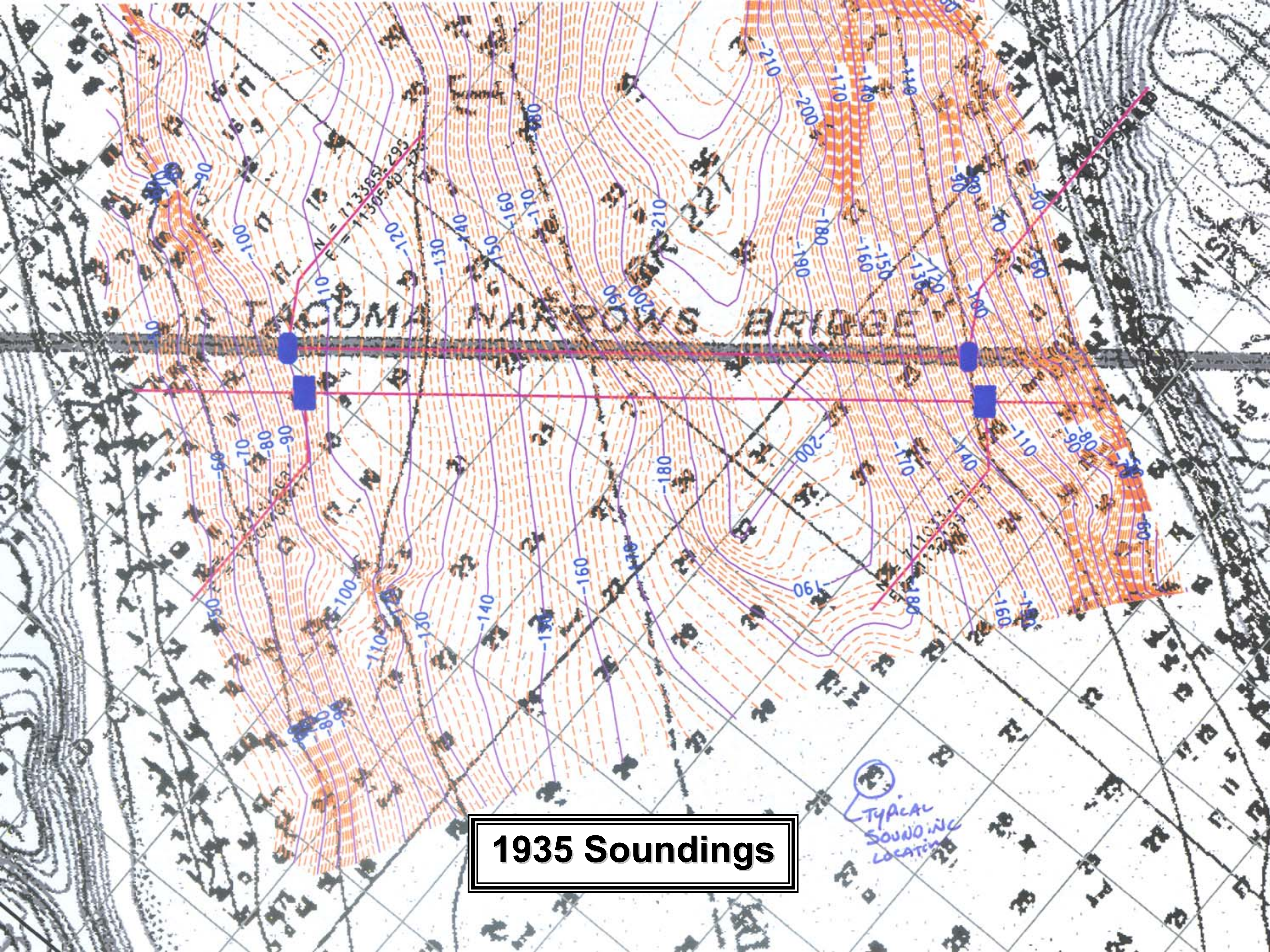


1999 Bathymetric Mapping


A
N = 713884
E = 1130539
= 713214.186'
= 1130439.577'
110
100
90
West Caisson



= 711033.274'
= 1132198.521'
A'
East Caisson



1935 Soundings

Bed Properties

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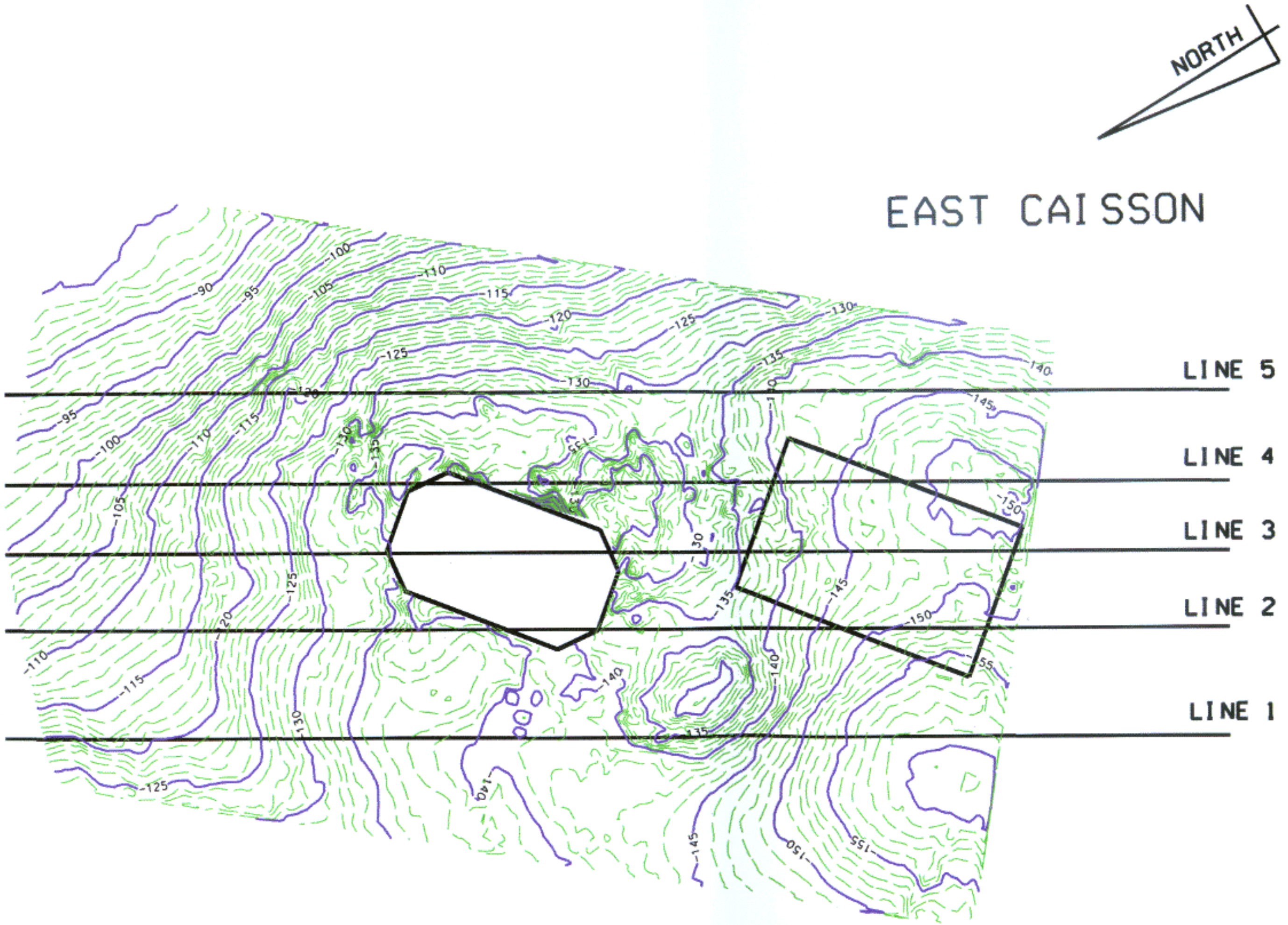
EAST CAISSON



EAST

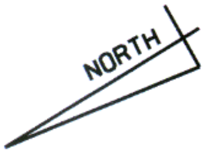
SLACK (1.0 KTS EBB)
6:21 TO 6:47

DATUM NAVD 88

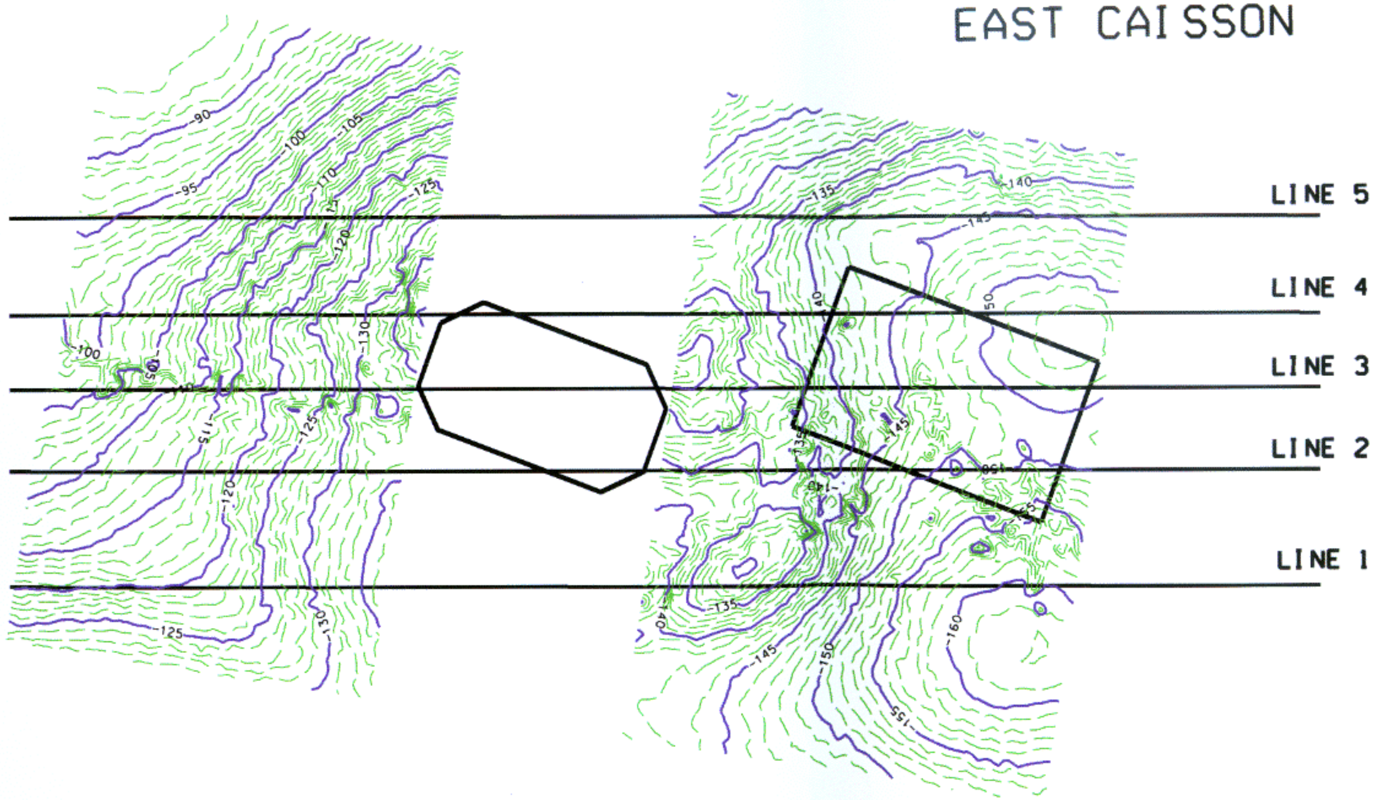
TACOMA NARROWS BRIDGE

BATHYMETRIC STUDY
FLOW MAY 27, 2002

BY: POLASIK 12/12/02



EAST CAISSON



EAST 04

3.2 KTS EBB

7:32 TO 7:39

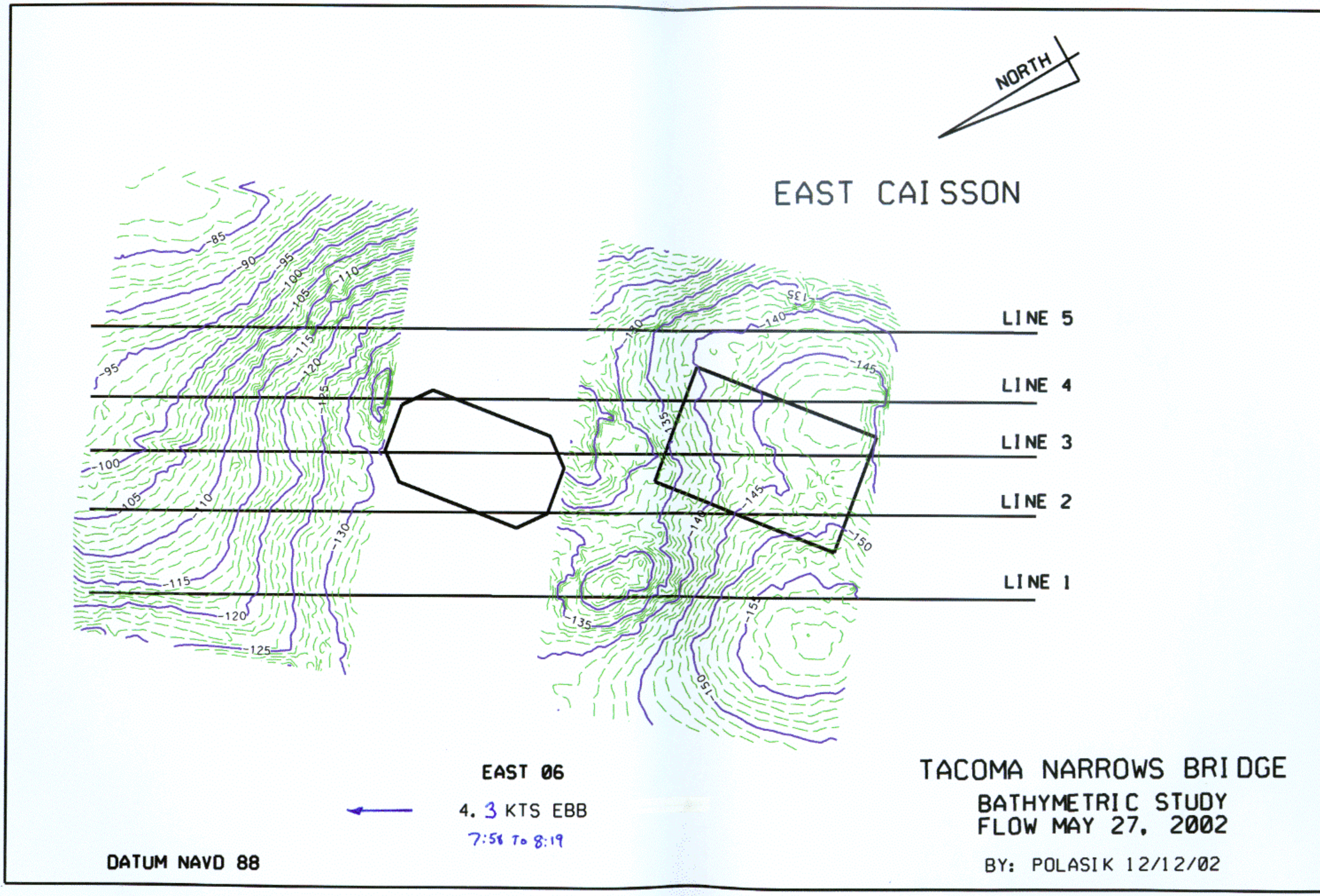
DATUM NAVD 88

TACOMA NARROWS BRIDGE

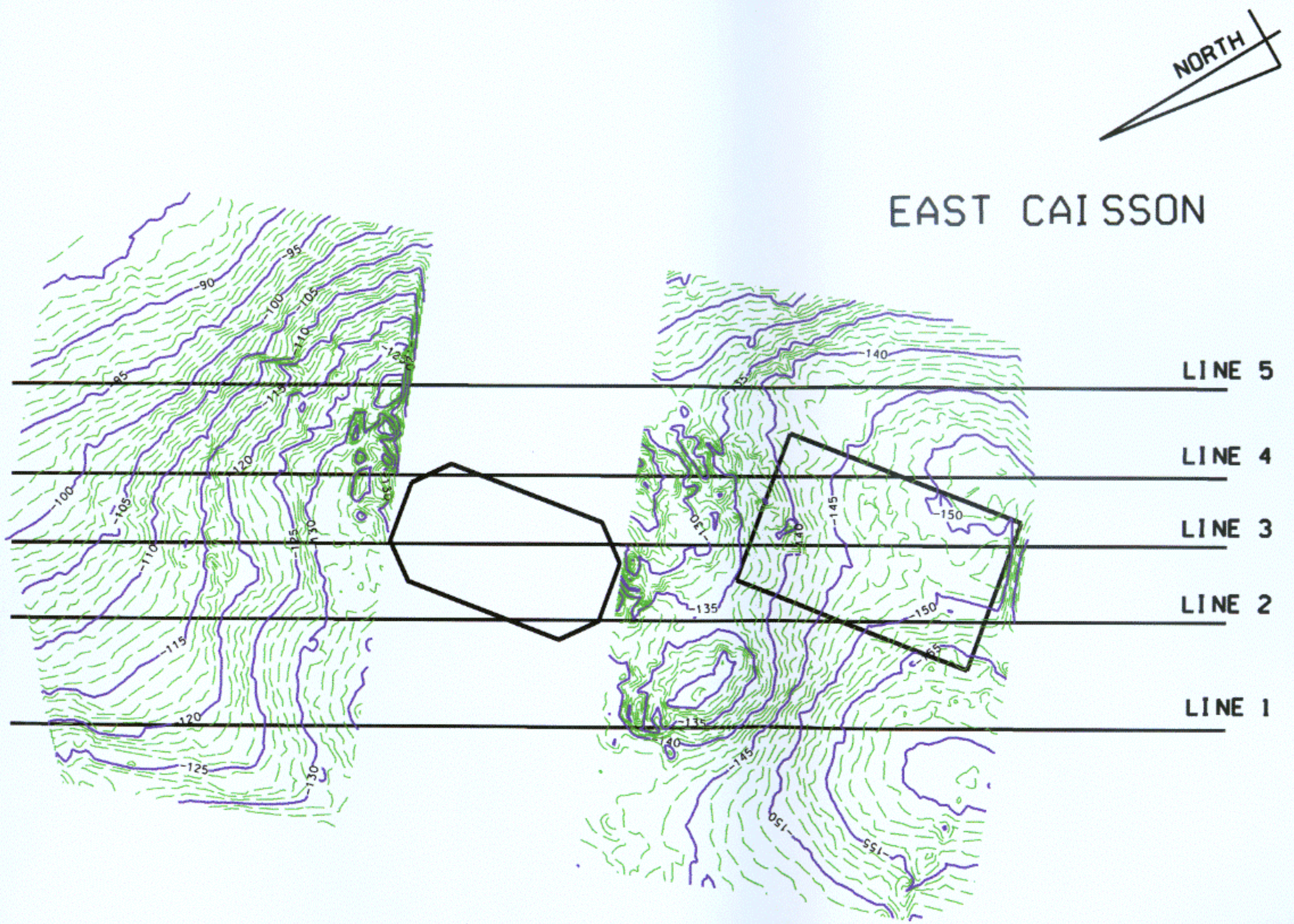
BATHYMETRIC STUDY
FLOW MAY 27, 2002

BY: POLASIK 12/12/02

PARSONS


NORTH
EAST CAISSON
LINE 5
LINE 4
LINE 3
LINE 2
LINE 1
-85
-90
-95
-100
-105
-110
-115
-120
-125
-130
-135
-140
-145
-150
EAST 06
4. 3 KTS EBB
7:58 To 8:19
DATUM NAVD 88
TACOMA NARROWS BRIDGE
BATHYMETRIC STUDY
FLOW MAY 27, 2002
BY: POLASIK 12/12/02

PARSONS



EAST 09

5.7 KTS FLOOD →

15:03 To 15:28

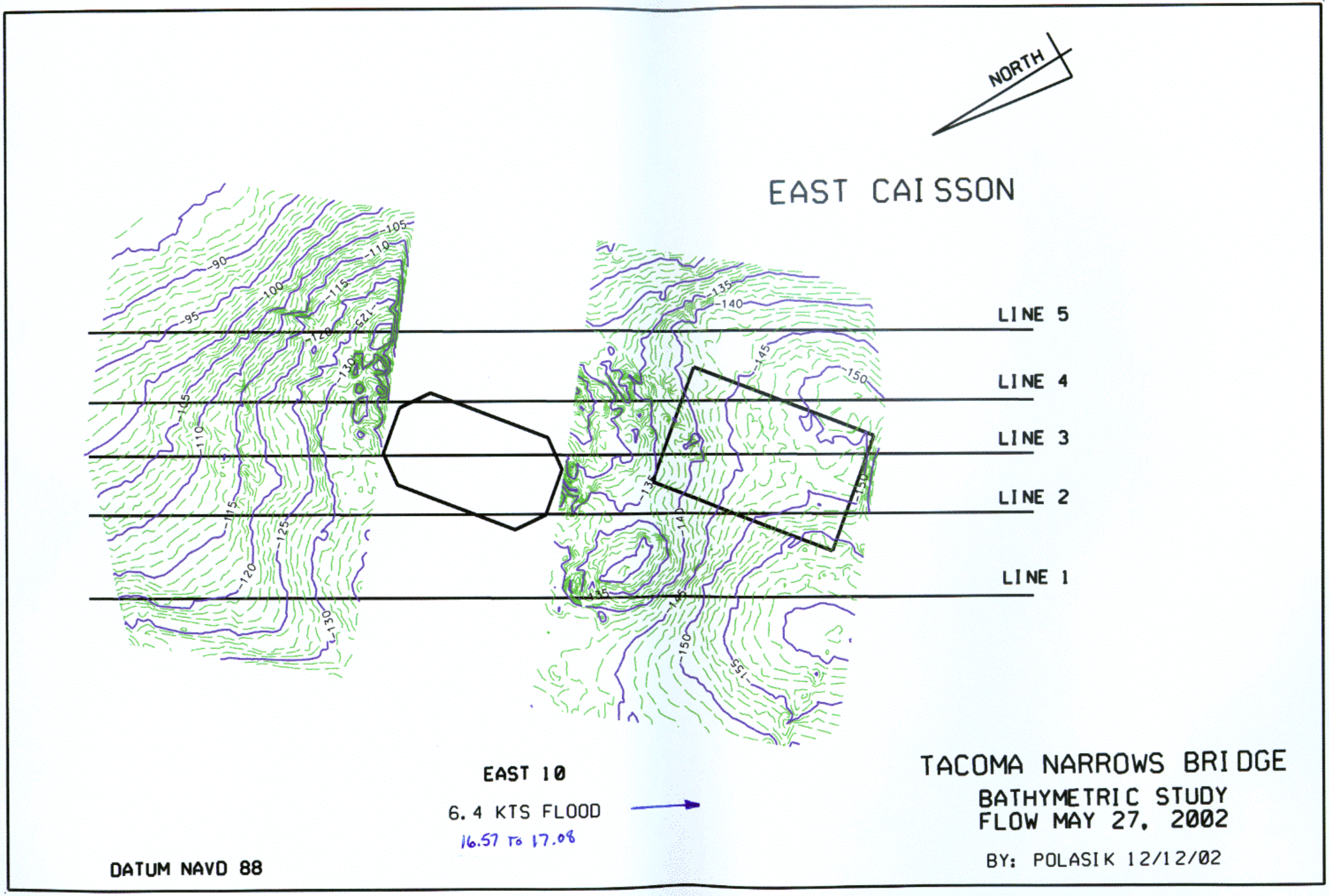
DATUM NAVD 88

TACOMA NARROWS BRIDGE

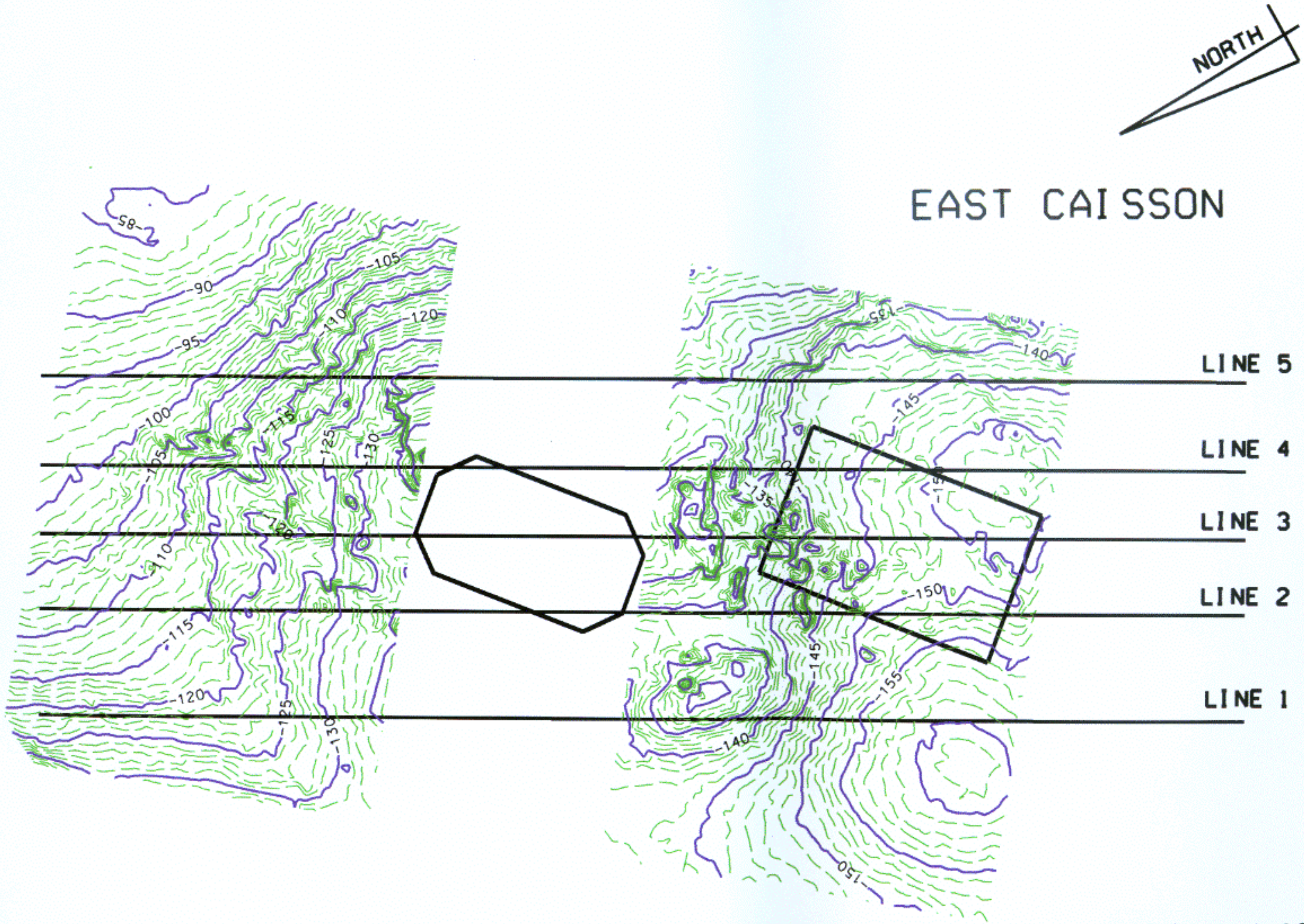
BATHYMETRIC STUDY
FLOW MAY 27, 2002

BY: POLASIK 12/12/02

PARSONS


NORTH
EAST CAISSON
LINE 5
LINE 4
LINE 3
LINE 2
LINE 1
-90
-95
-100
-105
-110
-115
-120
-125
-130
-135
-140
-145
-150
-155
EAST 10
6.4 KTS FLOOD
16.57 TO 17.08
DATUM NAVD 88
TACOMA NARROWS BRIDGE
BATHYMETRIC STUDY
FLOW MAY 27, 2002
BY: POLASIK 12/12/02

PARSONS



EAST 11

3.0 KTS FLOOD

18:51 To 19:06

DATUM NAVD 88

TACOMA NARROWS BRIDGE

BATHYMETRIC STUDY
FLOW MAY 27, 2002

BY: POLASIK 12/12/02

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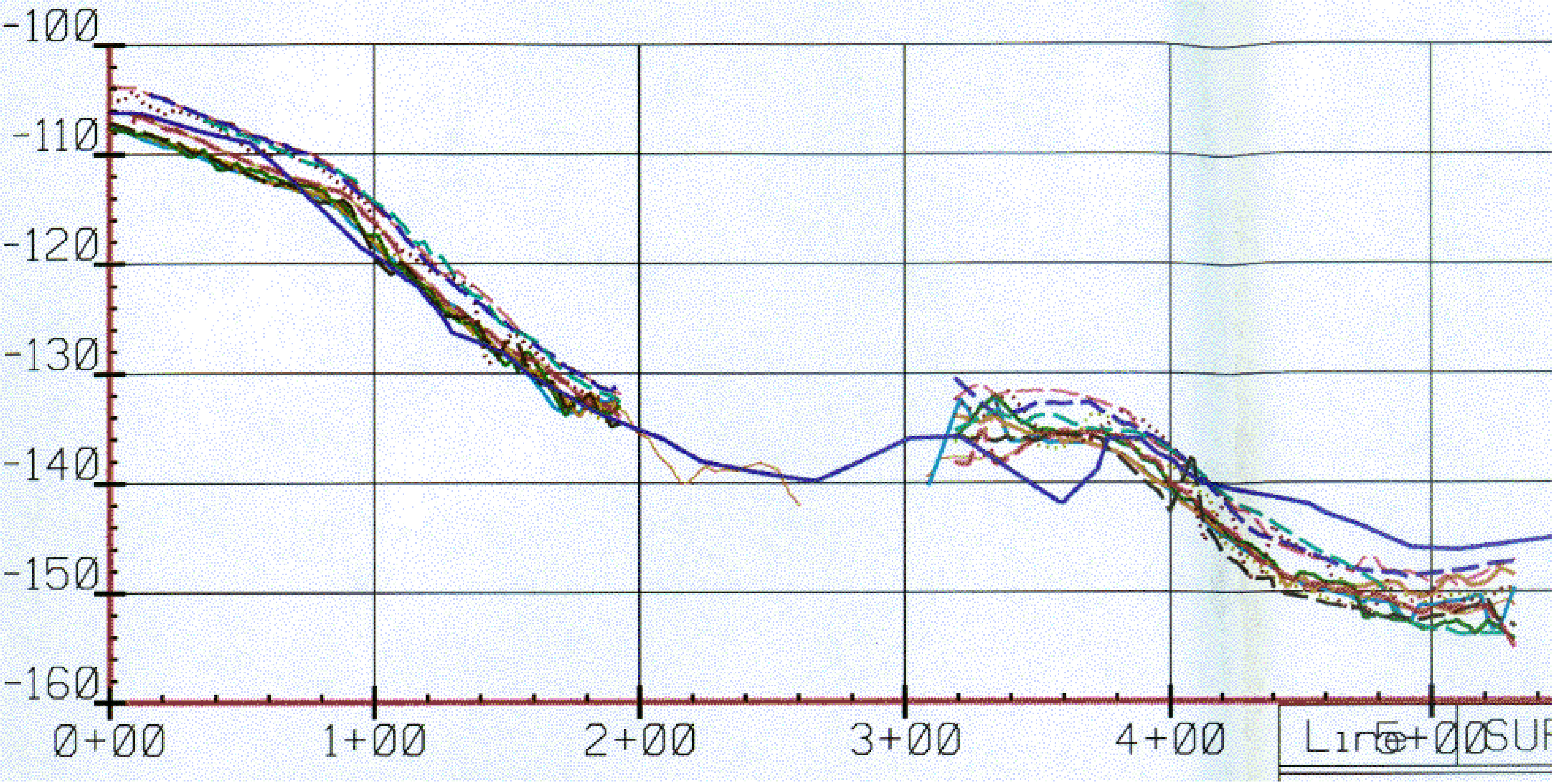
Line 2 Profile



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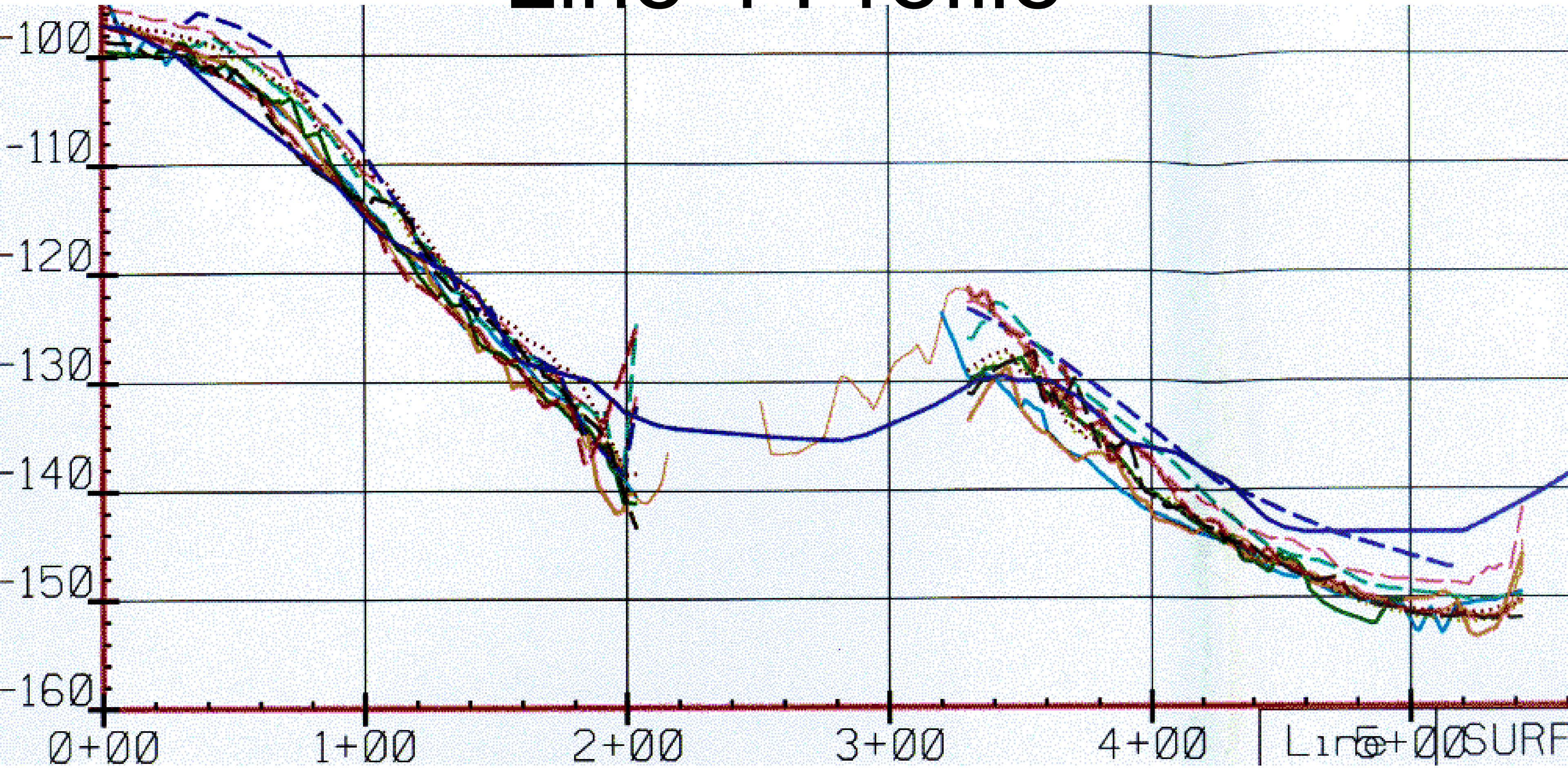
Line 4 Profile



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Scour Analysis

- Bridge and Pier Configuration
- Channel Dimensions and Bed Properties
- Design Depth and Velocity
- Determine Scour
  - Contraction Scour
  - General Scour
  - Local Scour (By Max)

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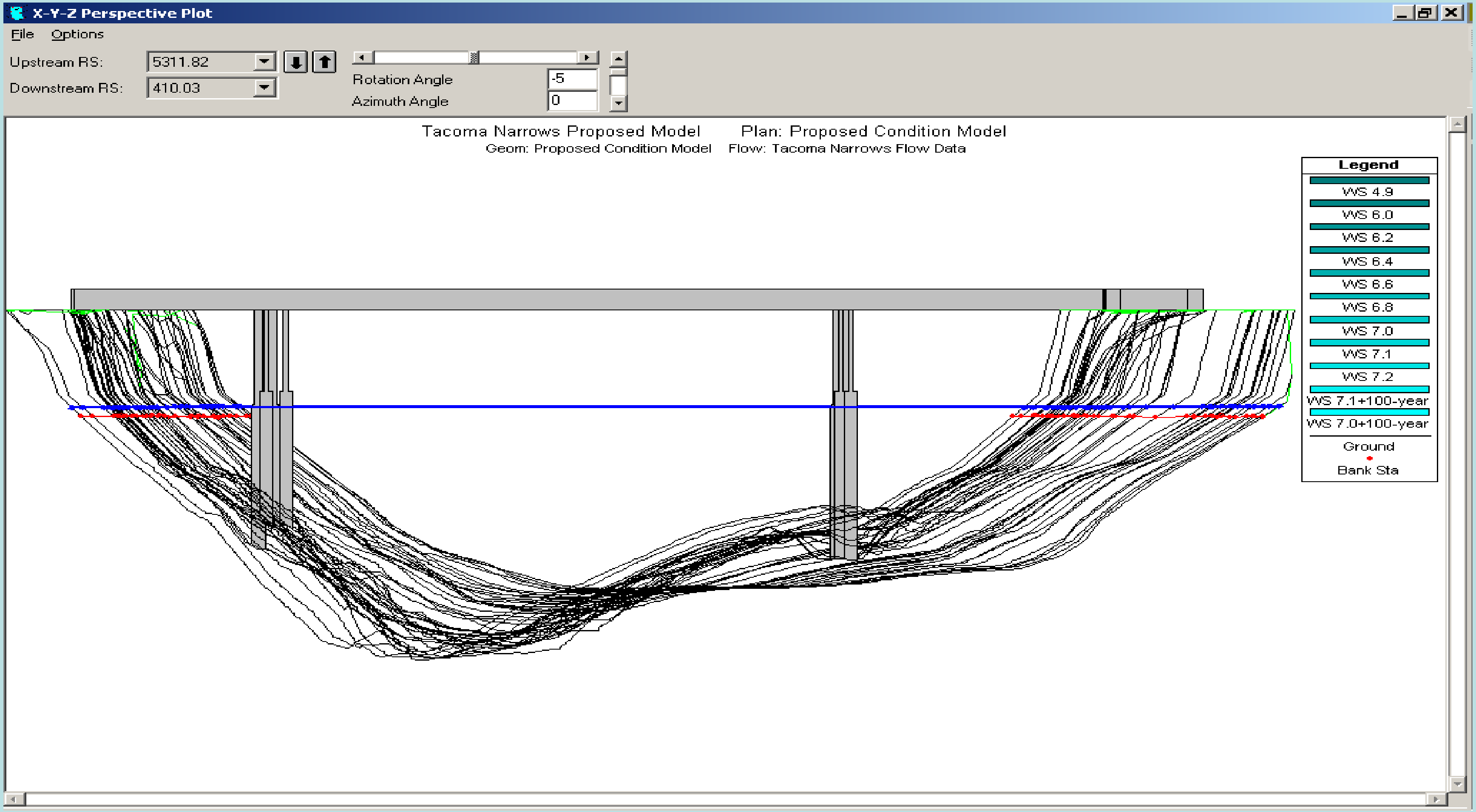
Channel Cross Sections



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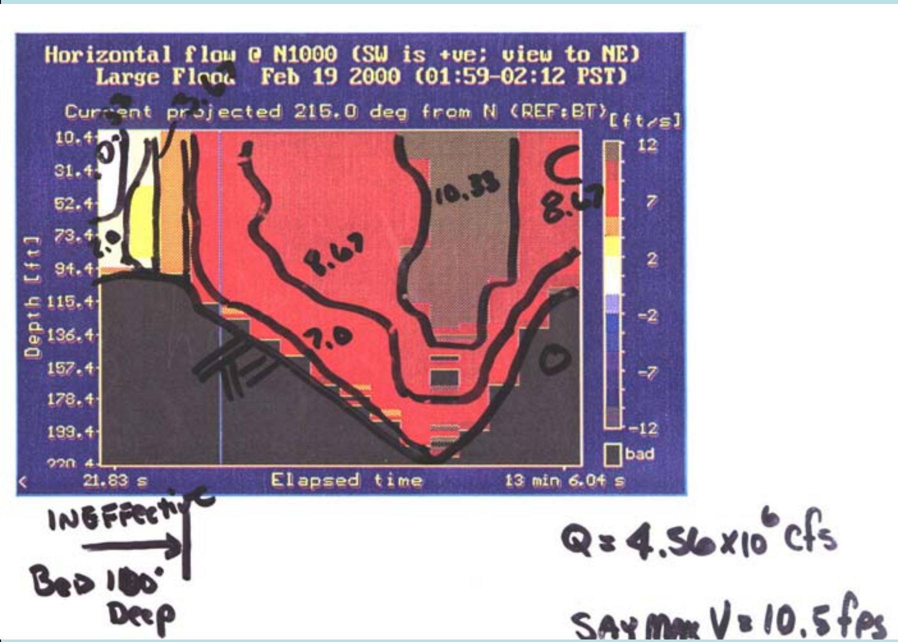
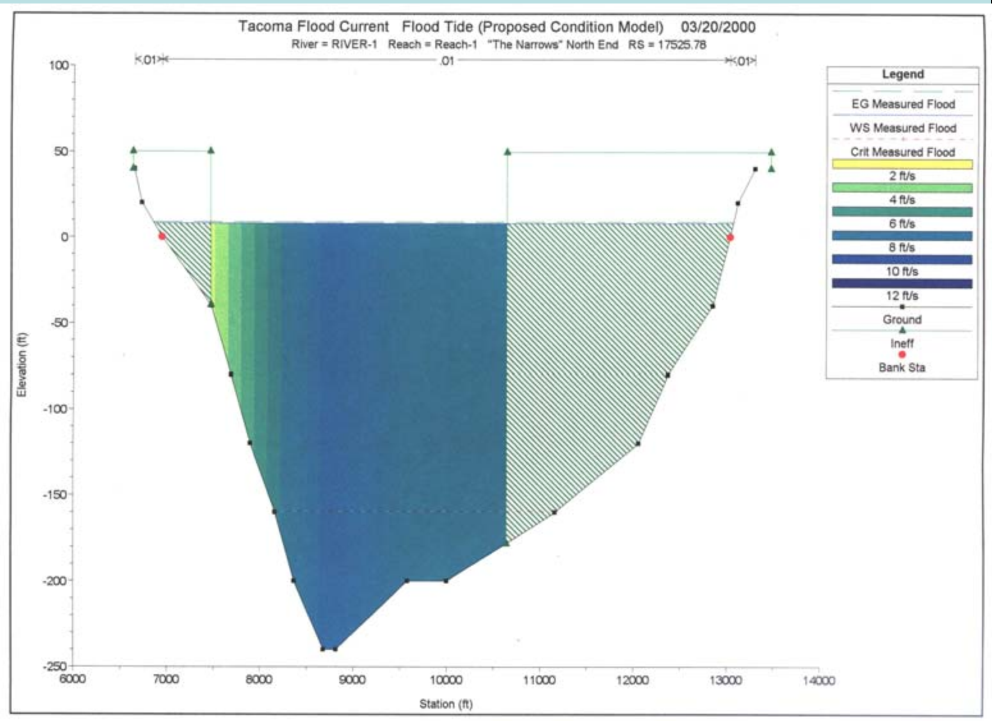
3-D Velocity Vectors





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Design Event

- Tide Frequency Analysis – Design Height and Maximum Rate of Change
- Measured Currents vs Tide Rate of Change
- Unsteady State HEC-RAS Model
- 2-D RMA2 Model

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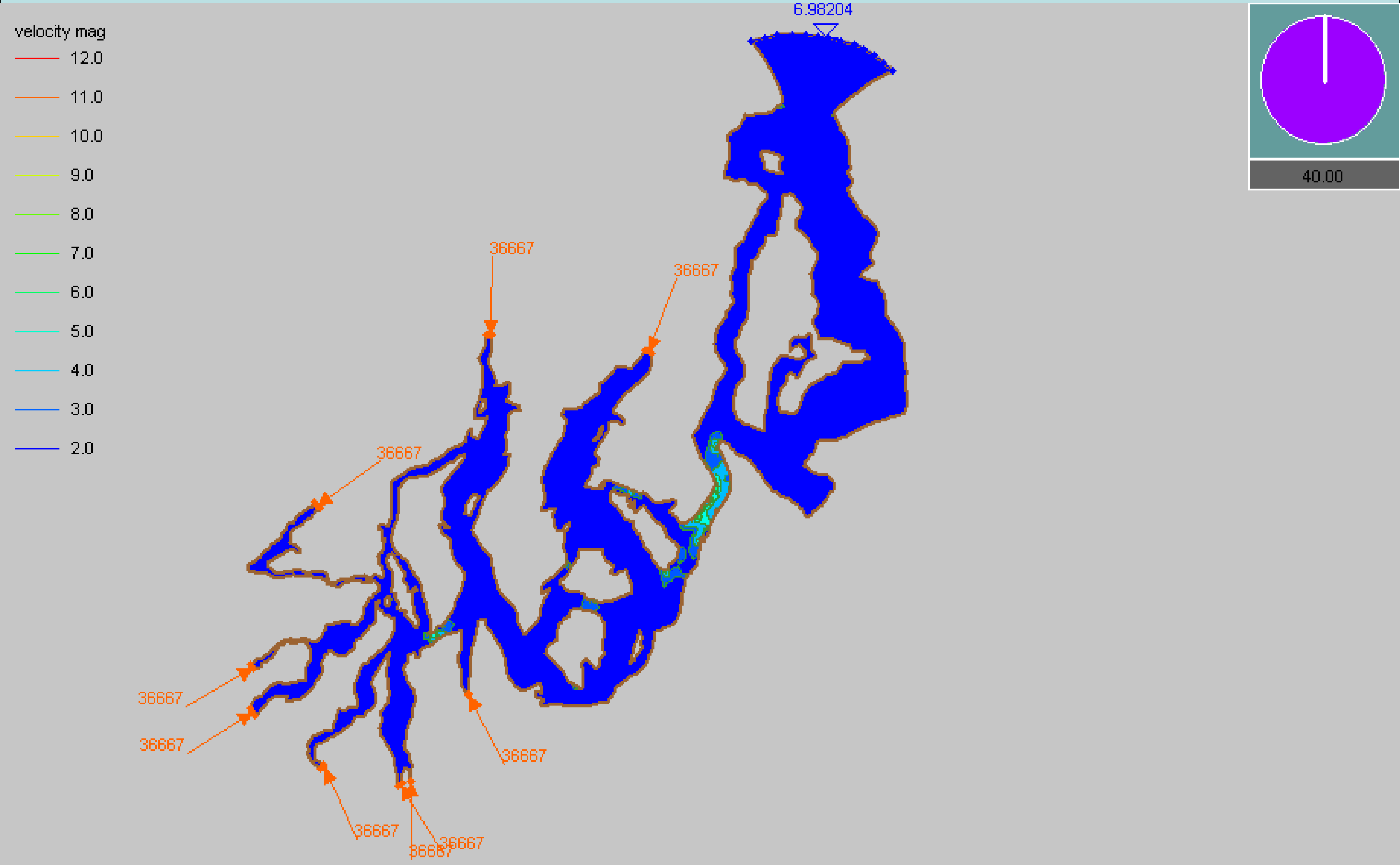
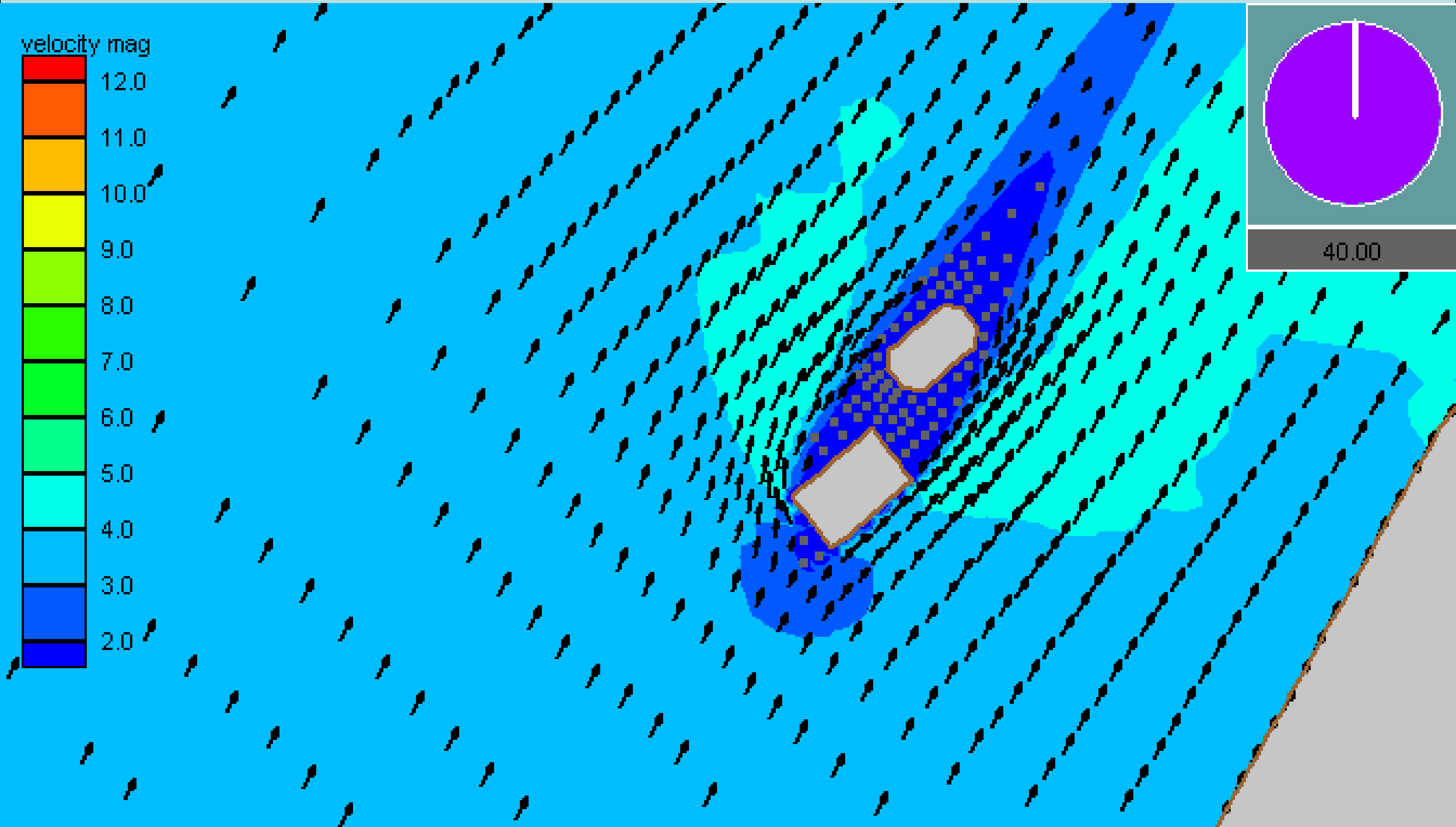
2-D Hydraulic Model

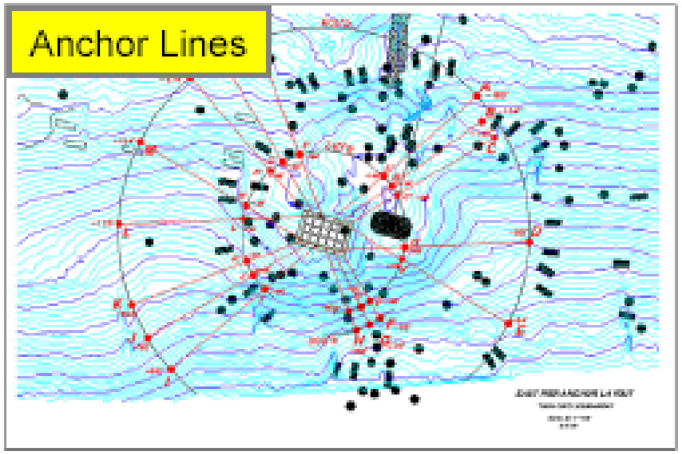


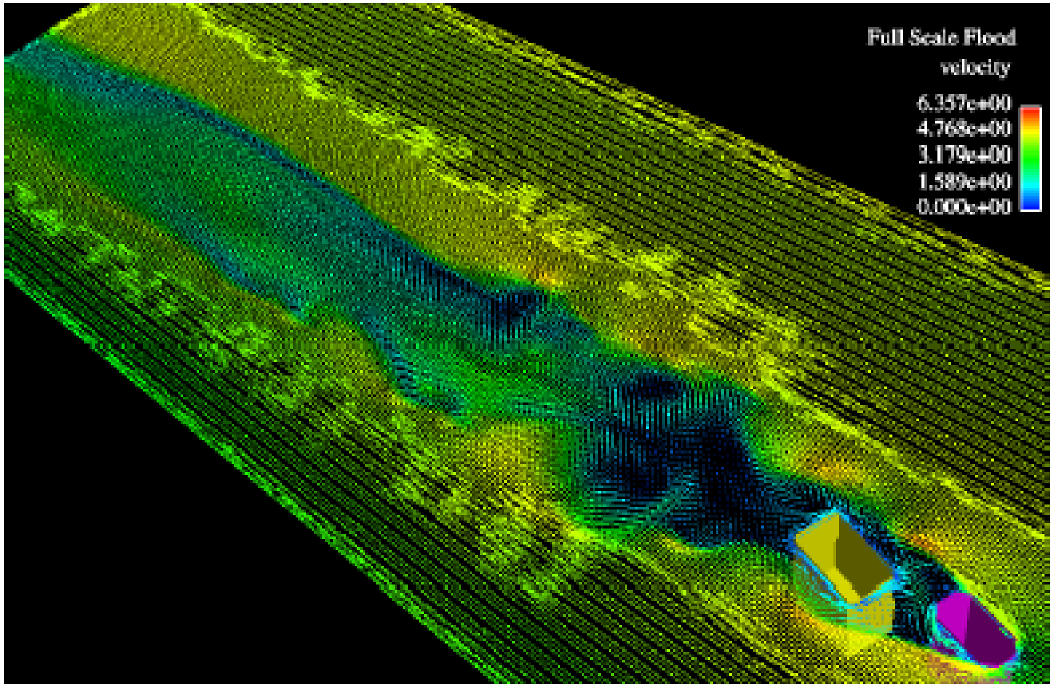
2-D Hydraulic Model

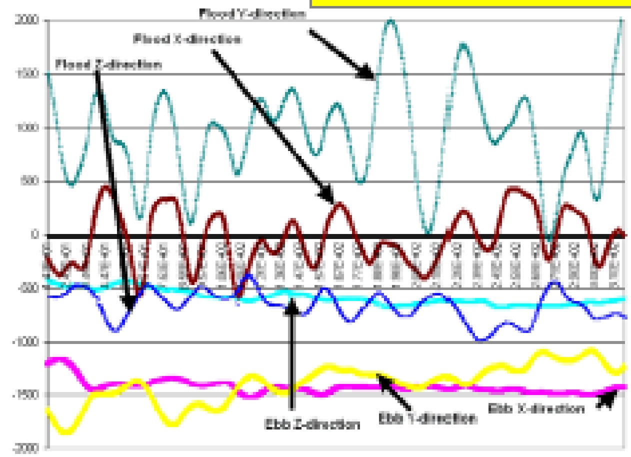


2-D Hydraulic Model

Tacoma Narrows Bridge Upgrade Project







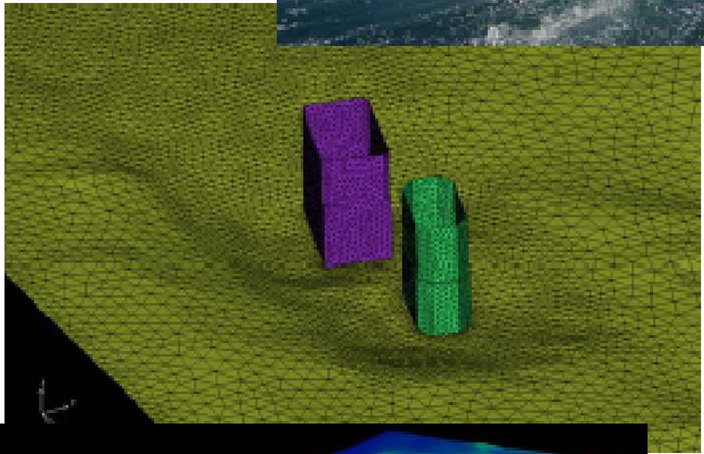
Tacoma Narrows Bridge Upgrade Project
CFD Model

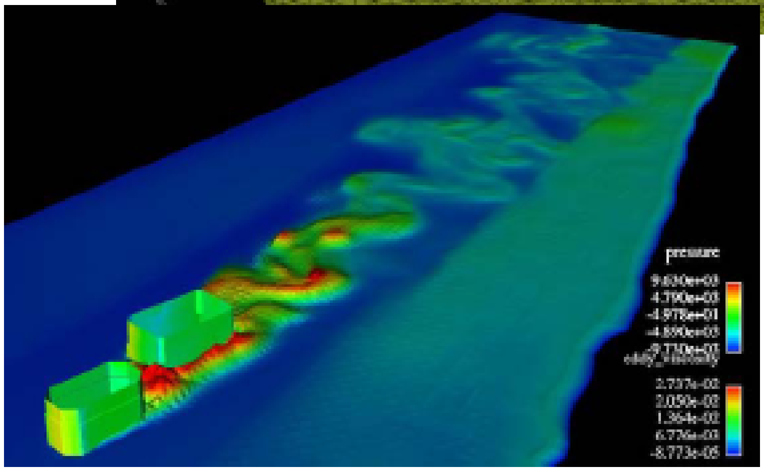
This is a "first of a kind" design problem

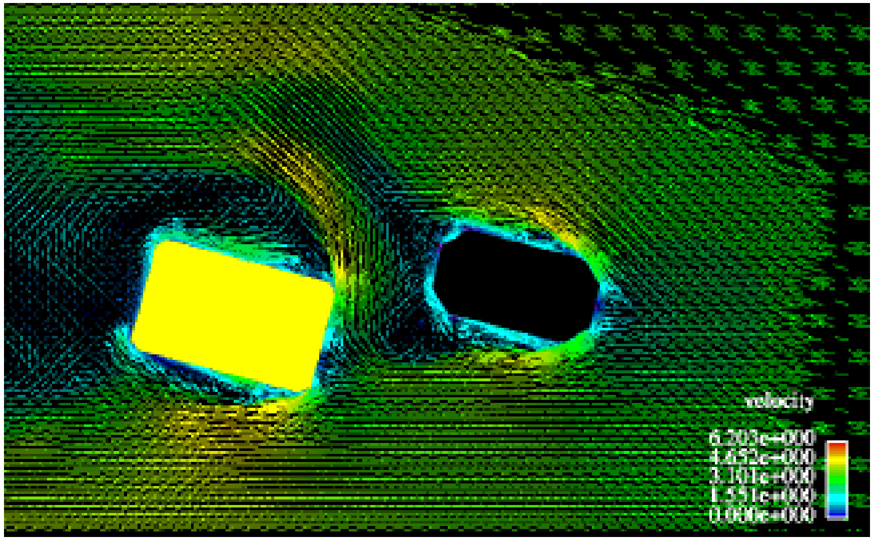
- Current-induced loads on the caisson are large and highly variable – they may critically affect the stability of the structure

CFD used to support caisson mooring analysis and anchor system design

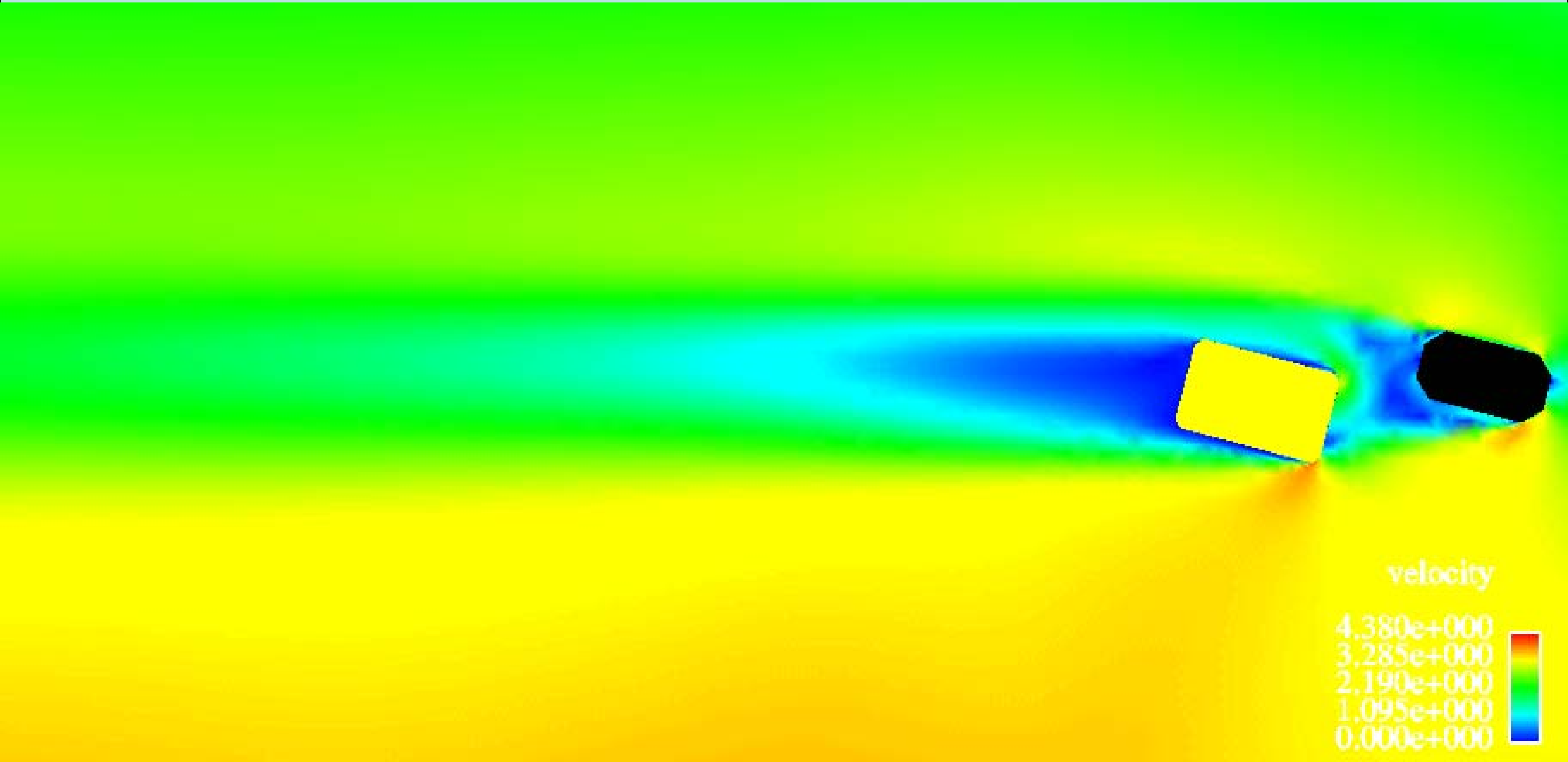
- Rapid turnaround and high level of confidence required



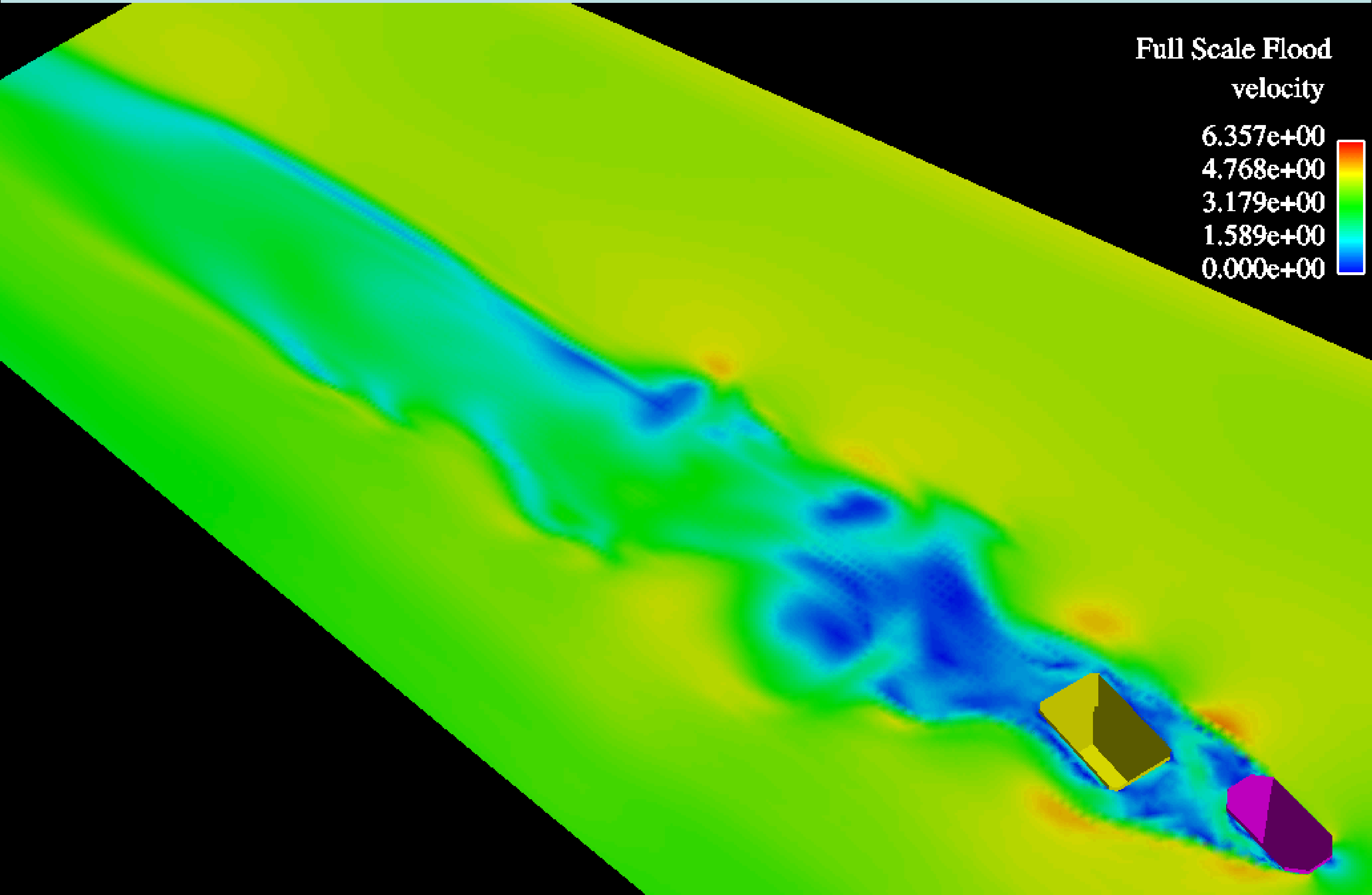




CFD Model



CFD Model


Full Scale Flood
velocity
6.357e+00
4.768e+00
3.179e+00
1.589e+00
0.000e+00

Scour Analysis

- Channel Dimensions and Bed Properties
- Bridge and Pier Configuration
- Design Velocity
- Determine Scour
  - Contraction Scour
  - General Scour
  - Original Bed Elevation
  - Local Scour

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Preliminary Hydraulic Investigation

- Bathymetric Mapping
- 3d-Vector Current Study Feb 2000
- Tide and Current Predictors
- Used HEC-RAS and HEC-18 to Estimate Scour Depths
  - East Caisson 110’
  - West Caisson 109’

Final Hydraulic Investigation

- Continuous Bathymetric Mapping
- Video Channel Bottom
- Tide Frequency Analysis
- 2-D RMA2 Model
- Physical Model Study
- Scour Depth
  - East Caisson 68’ (El -191)
  - West Caisson 70’ (El -177)

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Conclusions

- Design Build
  - Work is the Same, Just Fast Paced
  - Task Force Meetings with Designers, Constructors and Reviewers Work
- Scour Analysis
  - Channel Bed is Armored
  - Developed Frequency Based Design Event
  - Developed 2-D Hydraulic Model
  - Conducted Physical Model Testing
  - Reduced Expected Scour Depths by 40 feet

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Western Hydraulic Conference April 2003

- Bonus Photos

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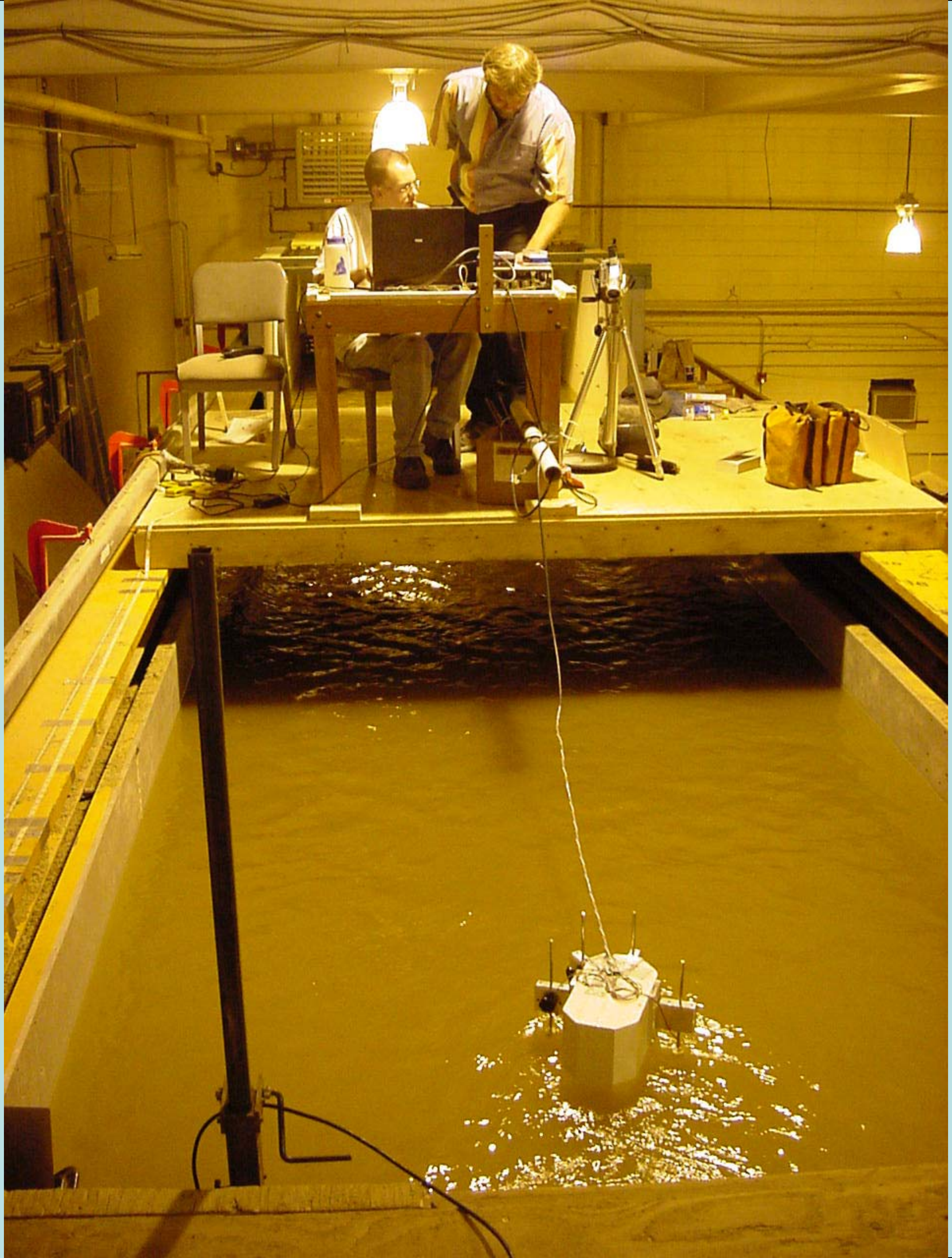

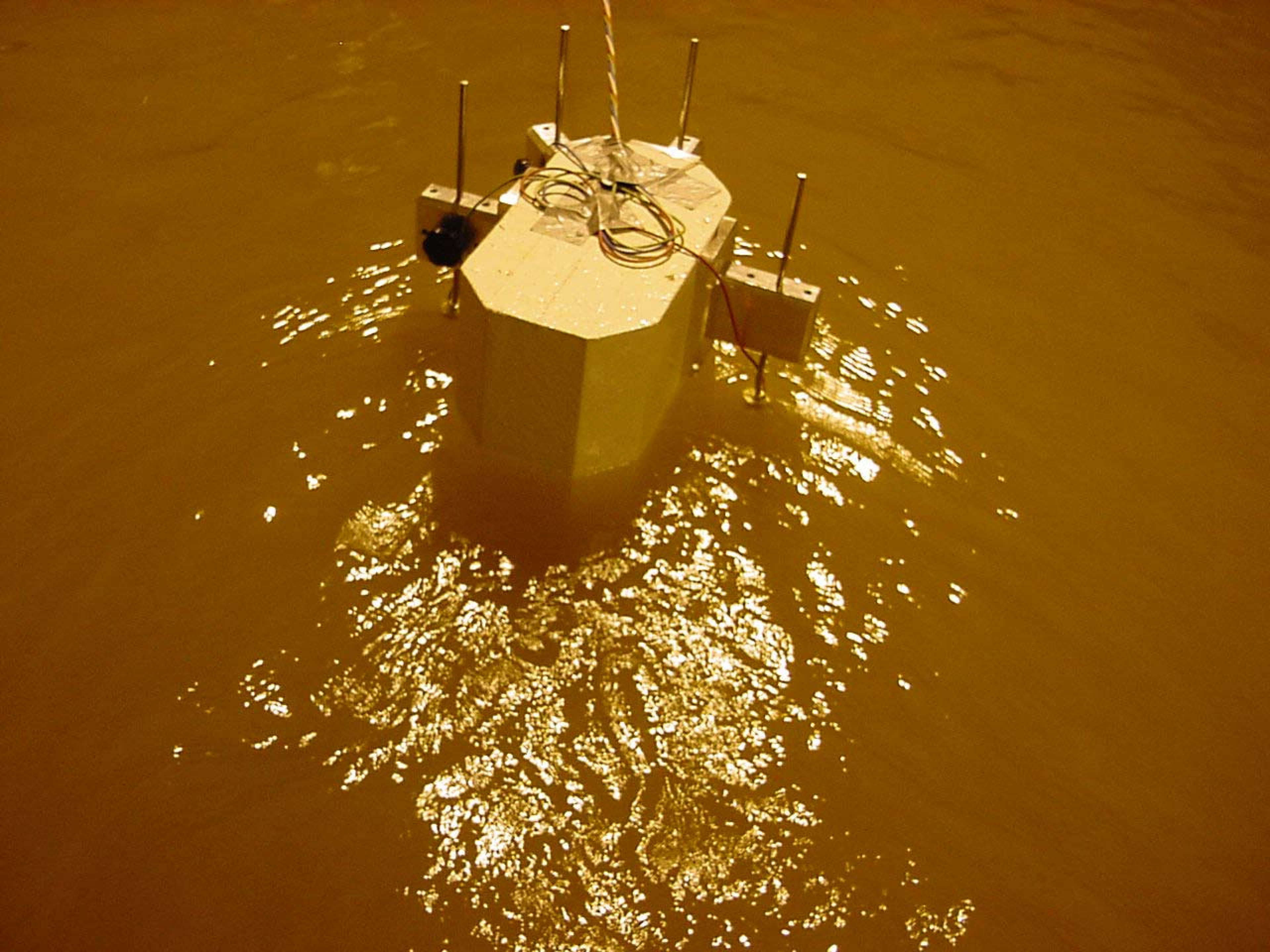

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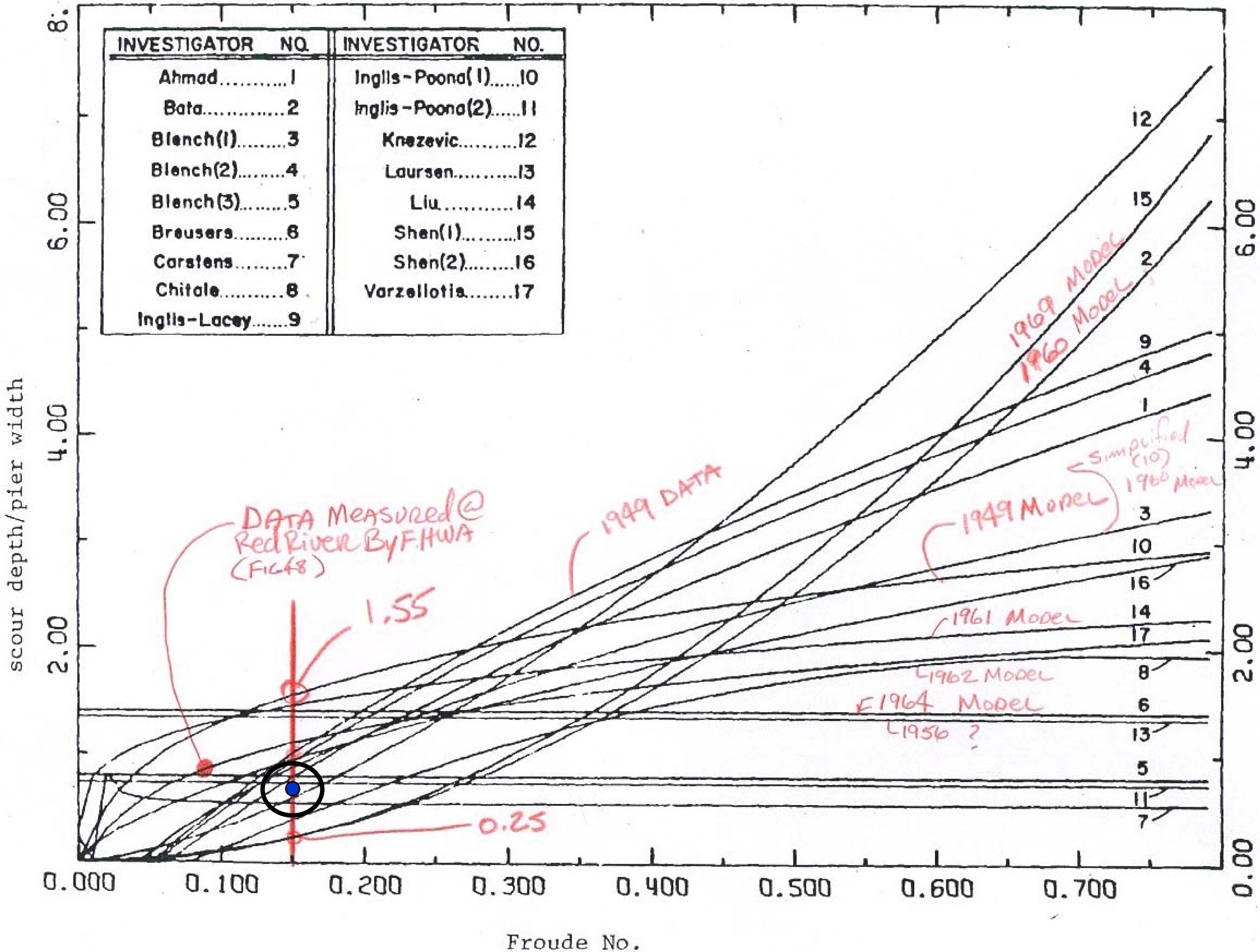

Figure 3. Scour prediction curves: $\frac{D}{b}$ vs Froude No. for stage/pier width = 1.

Scour Task Force

- Included Ultimate Project Reviewer, Designer and Construction personnel.
- 5 Meeting
  1. Project Orientation
  2. Physical Model Design and General Analysis Procedures
  3. Physical Model Testing and Agreement on Procedures
  4. Initial Data Analysis and Peer Review Meeting
  5. Initial Draft Report Comment Review

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May 2000 Data Collection

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