FORT STREET BASCULE BRIDGE GEOTECHNICAL CONSIDERATIONS

Richard O. Anderson, P.E., Dist M. ASCE
Somat Engineering, Inc.

INTRODUCTION

- This project involved the replacement of a 90 year old double leaf bascule bridge over the Rouge River in Southeast Michigan
- Owner = Michigan Department of Transportation (MDOT)
- Design Prime Consultant = Hardesty & Hanover, LLC (H&H)
- Geotechnical Consultant = Somat Engineering, Inc. (SEI)
- Many of the slides, diagrams and photographs in this presentation are used with permission of MDOT and H&H. Their assistance is greatly appreciated.

GENERAL LOCATION OF FORT STREET BRIDGE

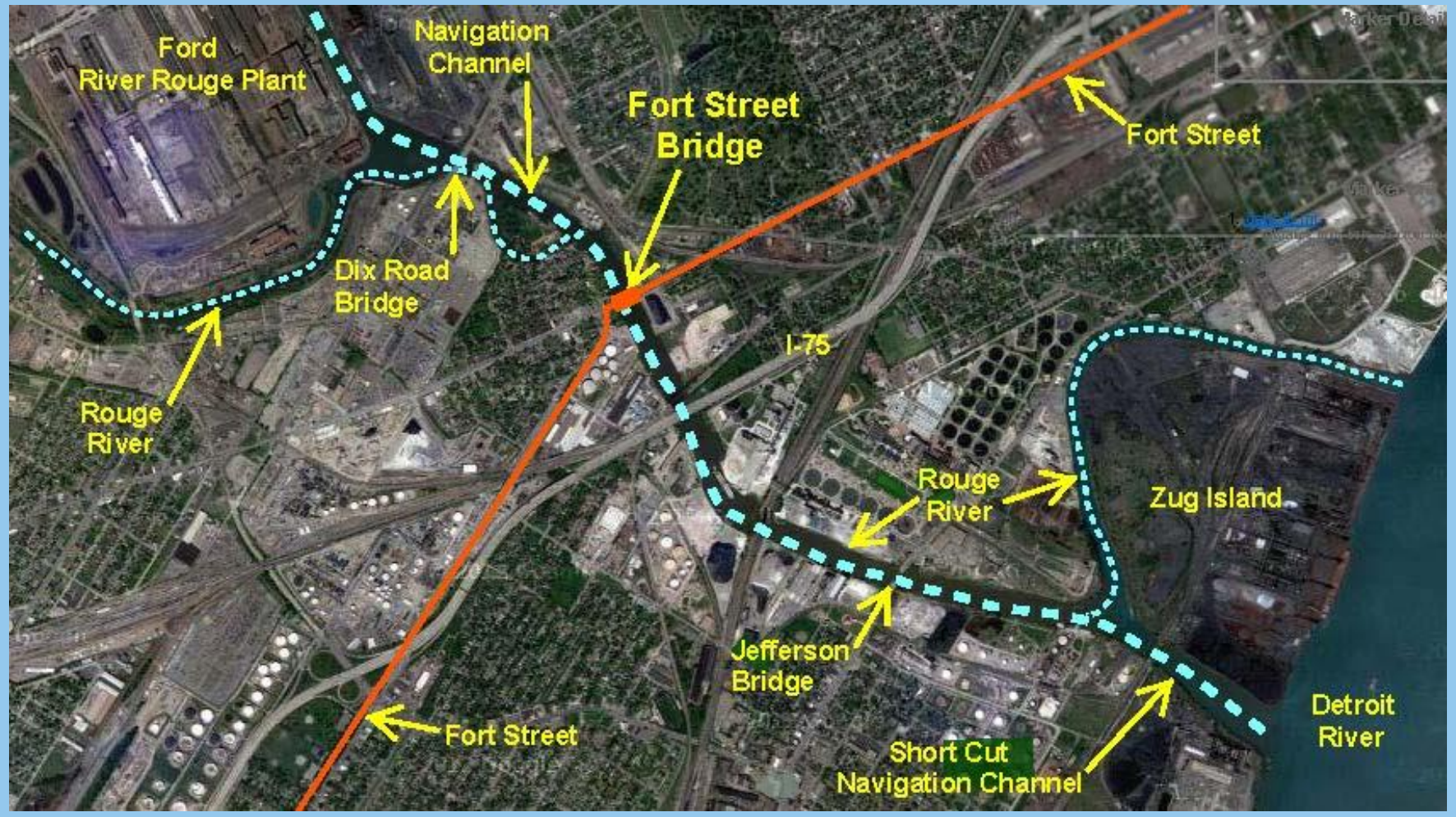
HISTORICAL PERSPECTIVE

- Prior to the 2nd decade of the 20th Century, the Rouge River in this area was a commercially non-navigable, low gradient, shallow river flowing through the marshy wetlands of Wayne County to the Detroit River
- In 1915 Henry Ford bought 2000 acres along the banks of the Rouge River upstream of Fort Street to build a complex to make coke and smelt iron and make tractors
- The site was serviced by railroads and the highway system, but water access was needed to bring in the heavy bulk materials
- The existing bridges downriver over the Rouge River were impediments and the Rouge River was not accessible to the Great Lakes bulk carriers

HISTORICAL PERSPECTIVE

- By 1917 the first large structure was built at the Rouge plant, as it came to be known
- Over the next 10 years, the Rouge complex grew tremendously and by 1927 this was the main manufacturing facility for Ford
- The answer to the challenges of marine access to the Rouge was to build new bridges and “fix” the river
- Concurrently, several new bridges were designed and constructed and the Rouge River was dredged, widened, and straightened

IMPROVEMENTS TO THE ROUGE RIVER



THE “NEW” FORT STREET BASCULE BRIDGE

- The new bridge was designed and constructed from 1920 to 1922
- The main span was 164 feet and 278 feet overall
- Roadway width 56 feet and 74 feet overall
- 4 lanes of traffic
- 2 trolley lanes
- 8’-6” sidewalks

EXISTING FORT STREET BASCULE BRIDGE

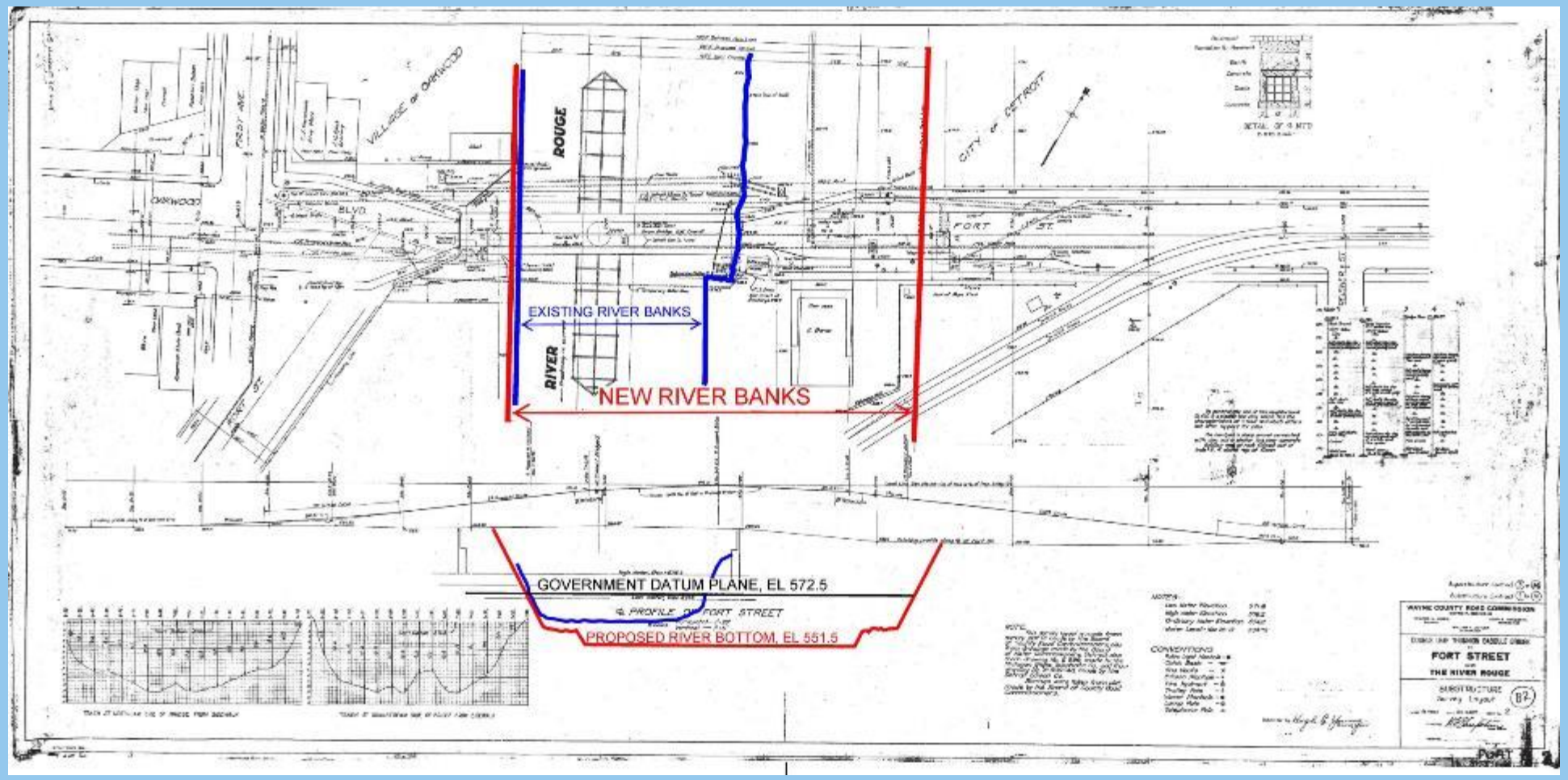
FOUNDATIONS FOR THE BASCULE BRIDGE

- The bridge was supported on four 12 foot square caissons on each side of the river

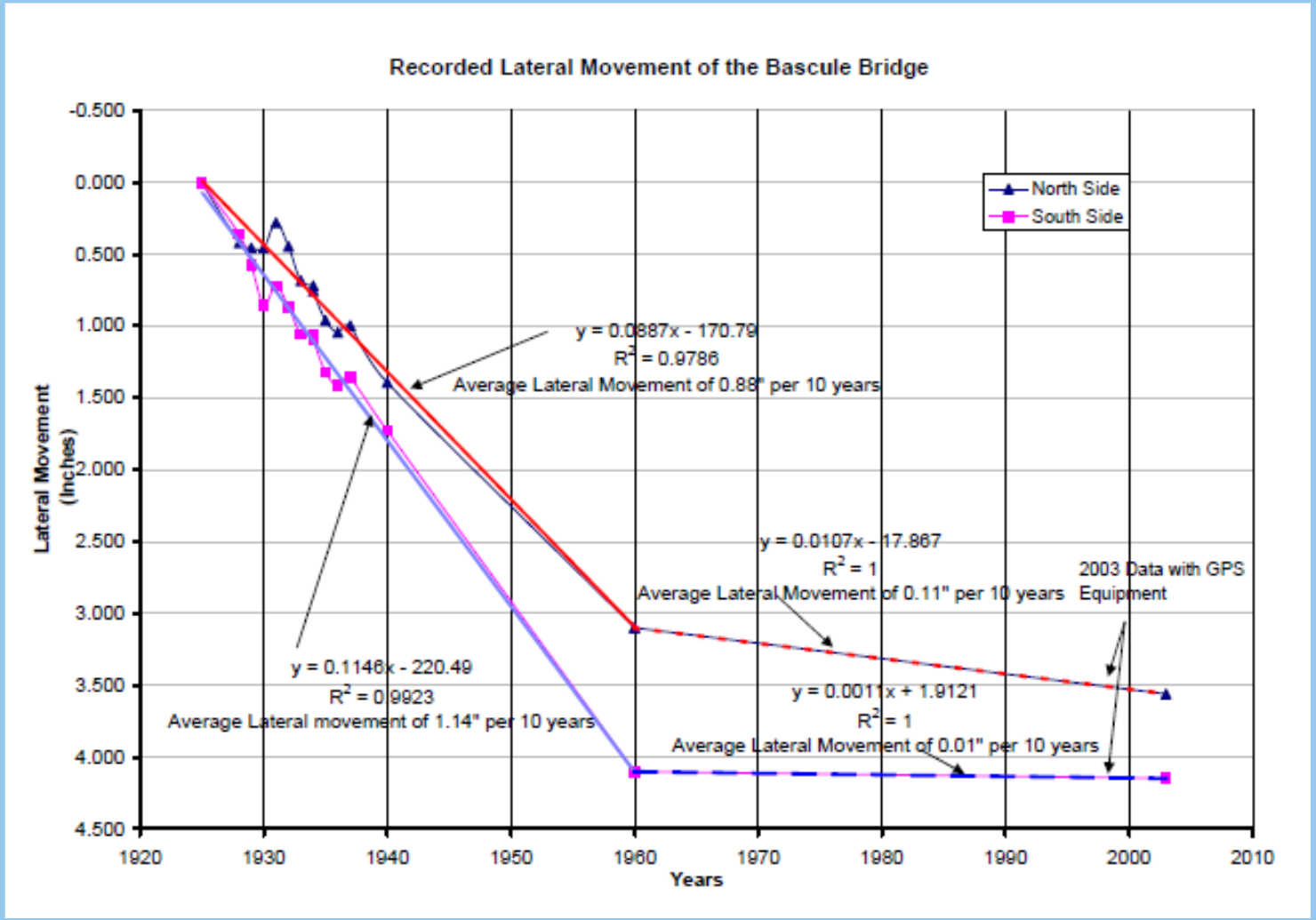
WHY WAS A NEW BRIDGE NEEDED?

- The bridge was showing its age by the first decade of the 21st Century, corrosion and aging of the metal parts, deterioration of the bridge structure, etc.
- More importantly, the fingers on the closure joint of the bridge could no longer be adjusted to accommodate the lateral movement of the piers; the piers had been continuously moving closer together since it was constructed
- Remember the deepening and the widening of the river to permit Great Lakes ore carriers to access the Rouge plant?

DREDGING OF THE ROUGE RIVER



MOVEMENT OF THE BRIDGE PIERS WITH TIME



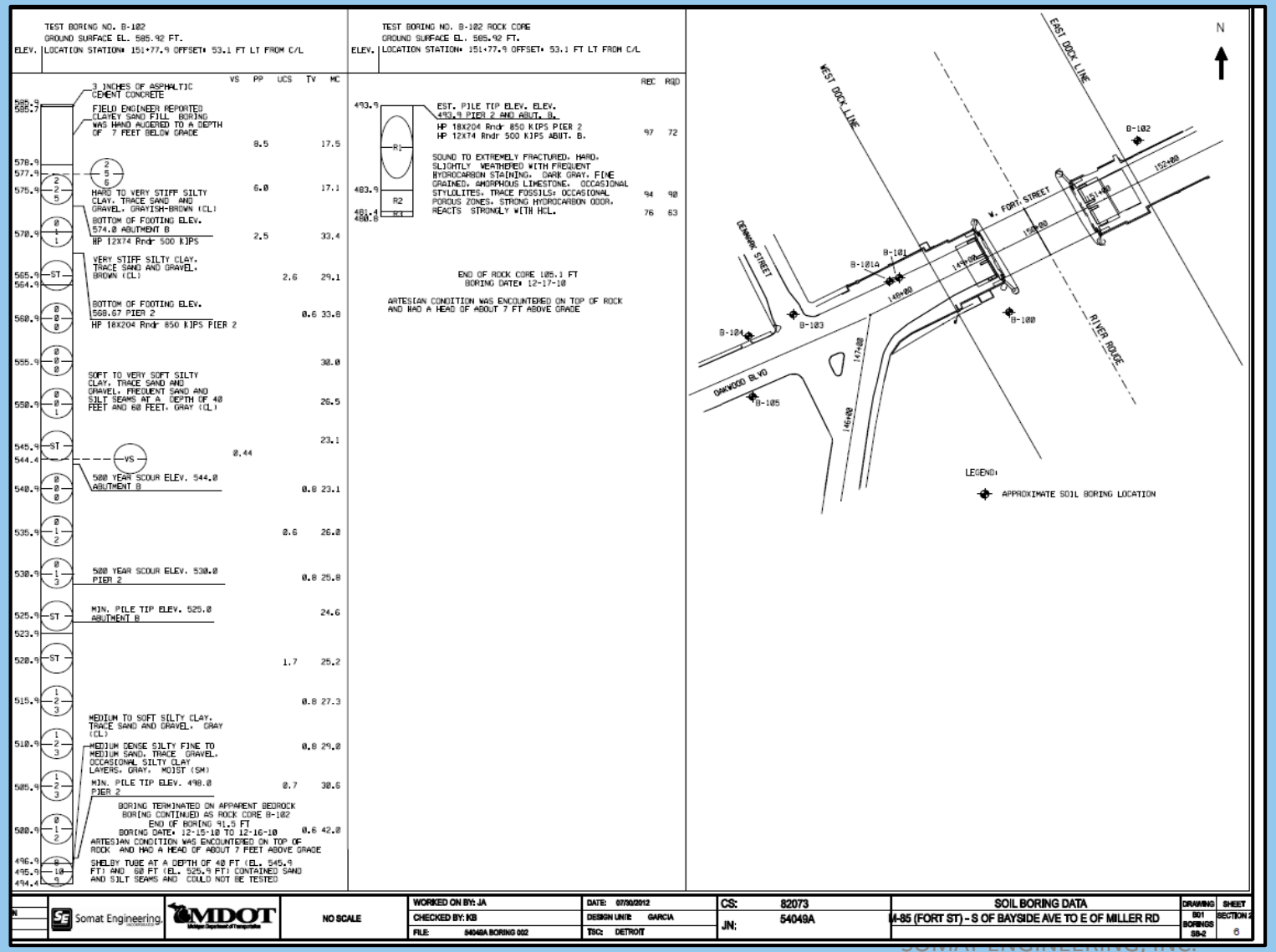
GEOTECHNICAL CONDITIONS

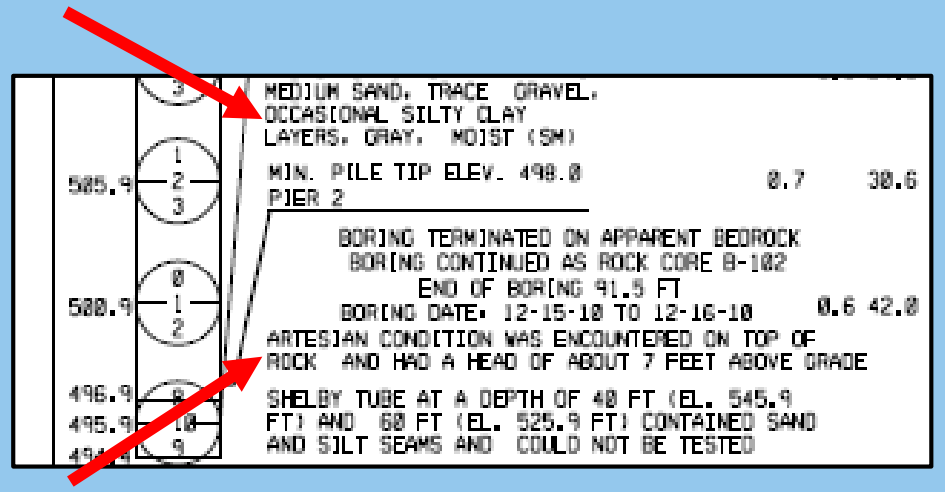
There was little doubt that the initial and subsequent periodic dredging of the river, in addition to the soil fill that was placed on the approaches, destabilized the banks of the river

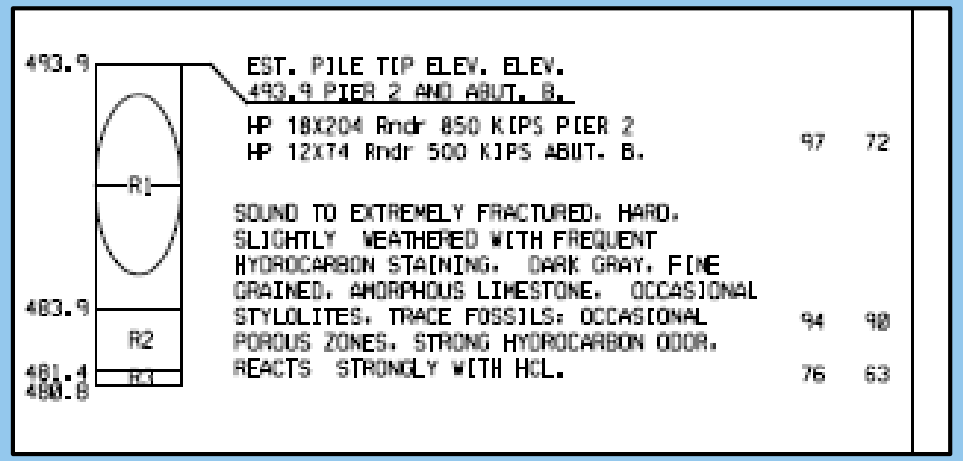
GEOTECHNICAL CONDITIONS

- Based on our previous experience with many projects in the immediate vicinity, we knew the soils along the Rouge River were extremely soft and normally consolidated in certain areas
- In conjunction with H&H, SEI instituted an extensive geotechnical investigation at the site
- 12 structure borings, including 4 from barges in the river
- 6 of the borings were cored into the limestone bedrock from 3’ to 20’

2010 SOIL BORING LOG FOR BASCULE BRIDGE



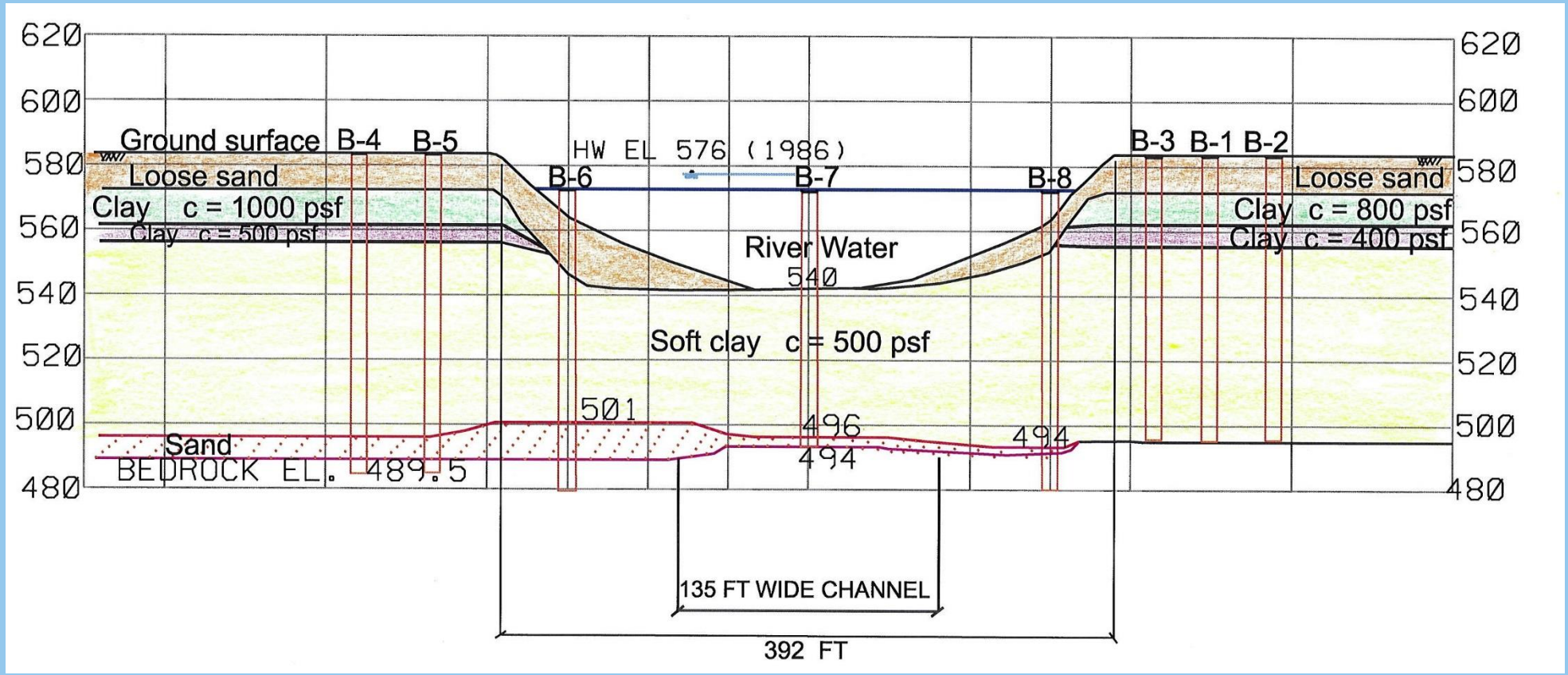




GEOTECHNICALLY RELATED CHALLENGES

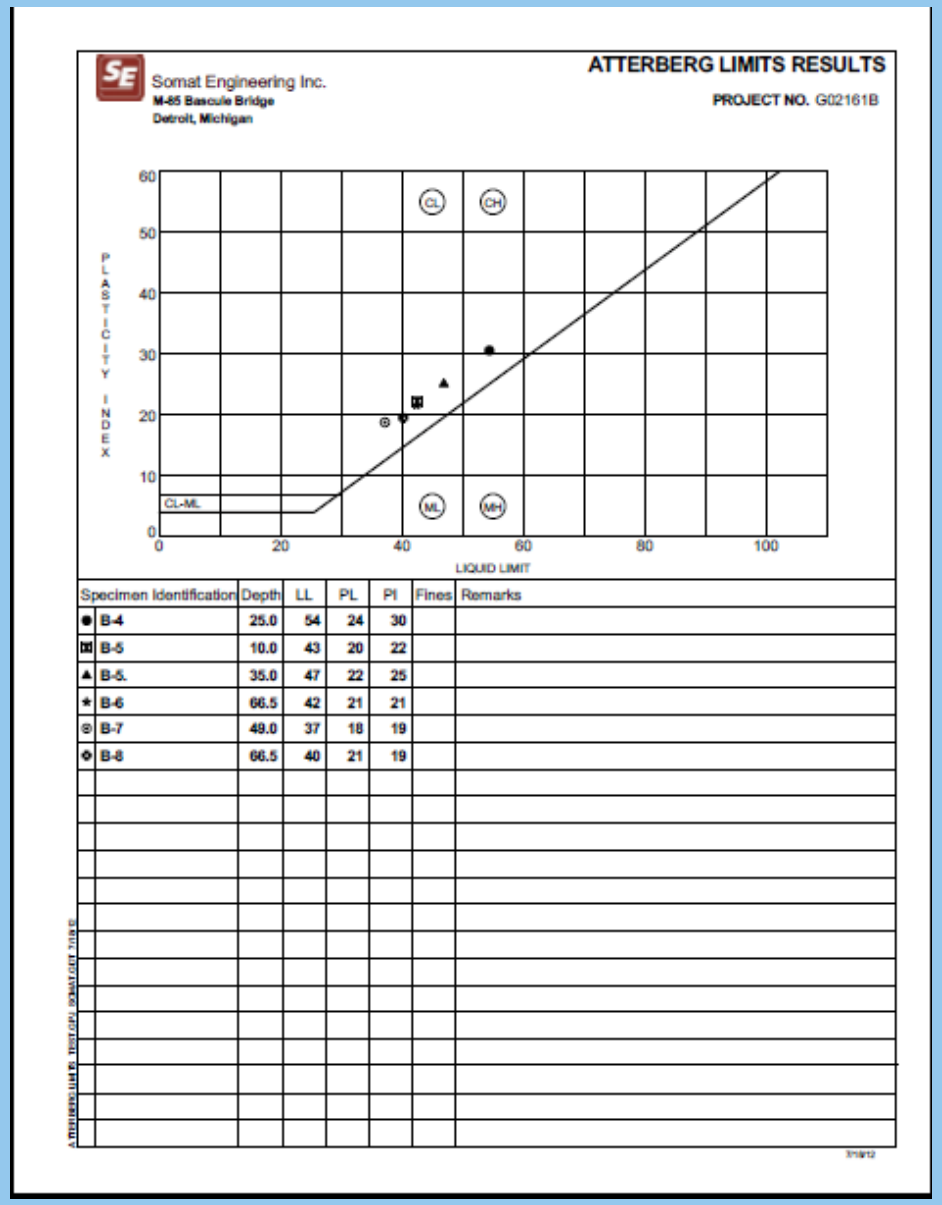
- Very soft clay
- Granular stratum below the clay above the bedrock
- Artesian groundwater in the granular stratum above the bedrock and in the limestone bedrock
- Hydrogen sulfide in the artesian groundwater
- Methane gas
- Contaminated soil

GENERALIZED SOIL PROFILE



ATTERBERG LIMITS

Generally a “CL” clay with more plasticity than the typical glacial till normally encountered in Southeast Michigan



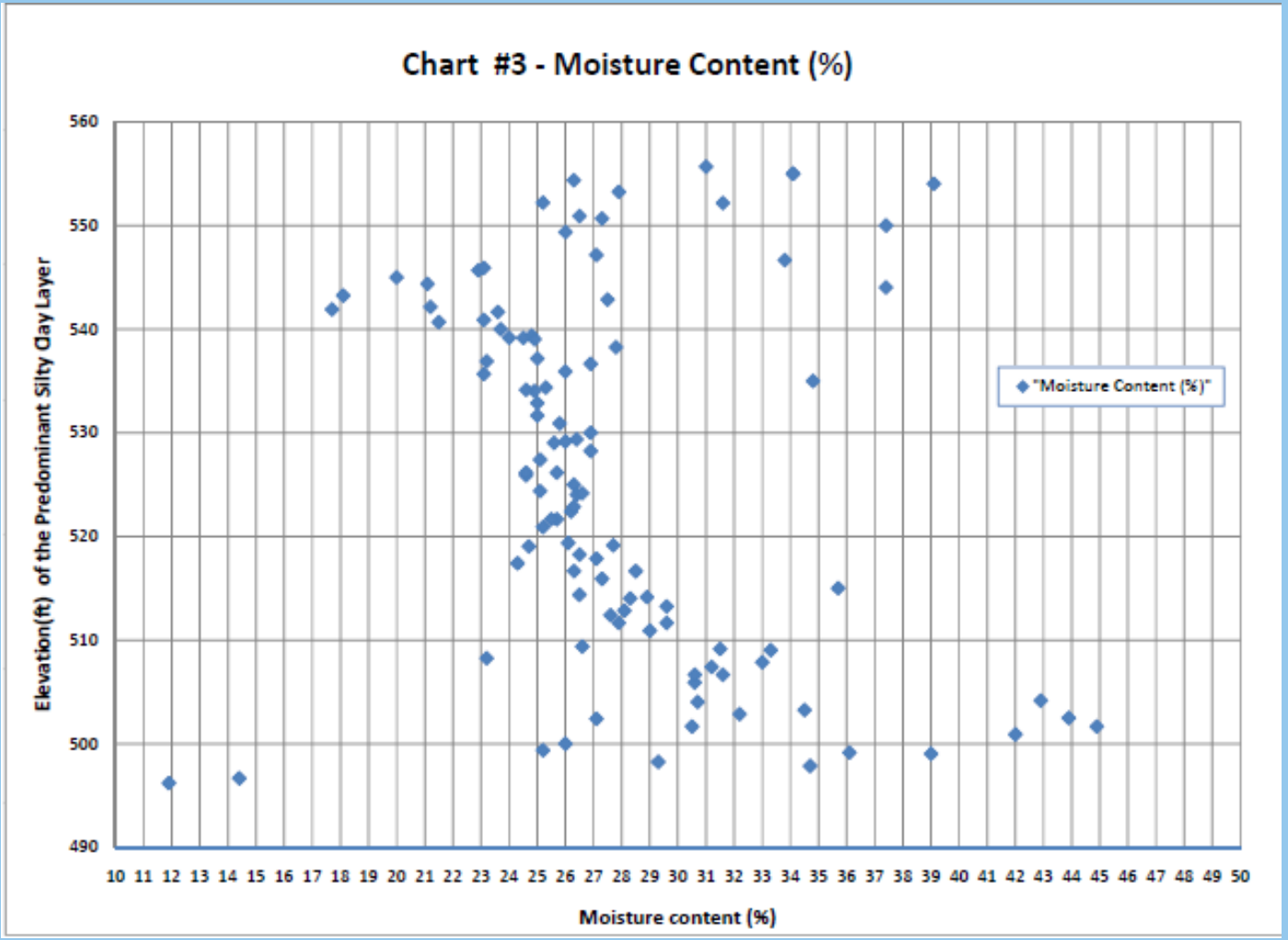
Somat Engineering Inc.
M-85 Bascule Bridge
Detroit, Michigan

ATTERBERG LIMITS RESULTS

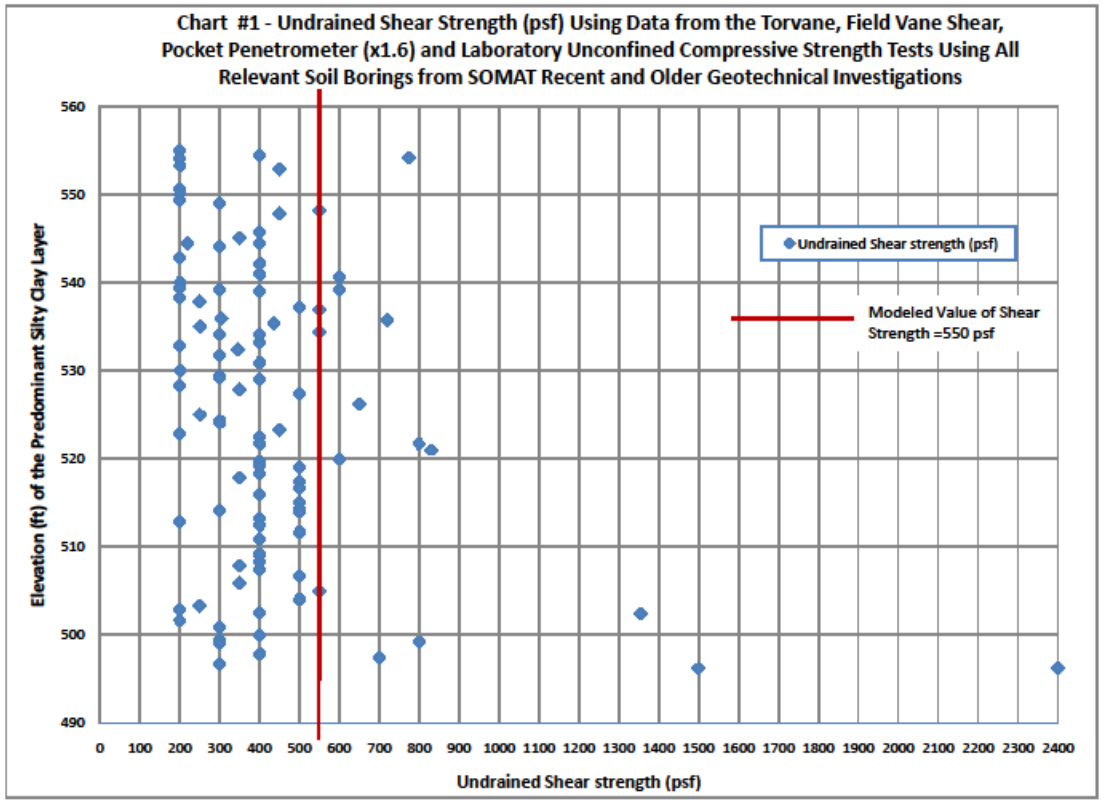
PROJECT NO. G02161B

	Specimen Identification	Depth	LL	PL	PI	Fines	Remarks
●	B-4	25.0	54	24	30		
⊠	B-5	10.0	43	20	22		
▲	B-5.	35.0	47	22	25		
★	B-6	66.5	42	21	21		
⊗	B-7	49.0	37	18	19		
✿	B-8	66.5	40	21	19		

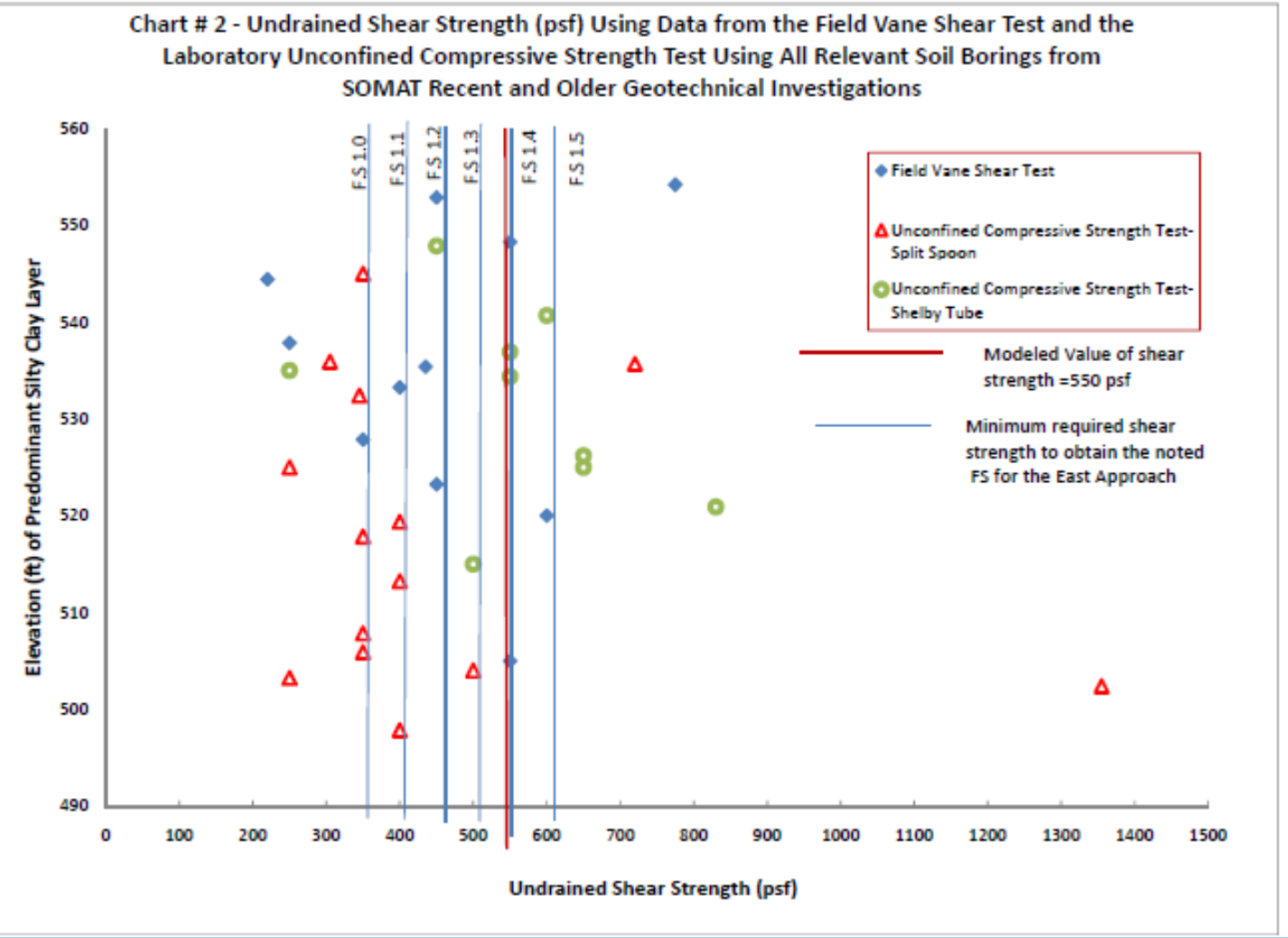
MOISTURE CONTENT OF SOIL SAMPLES



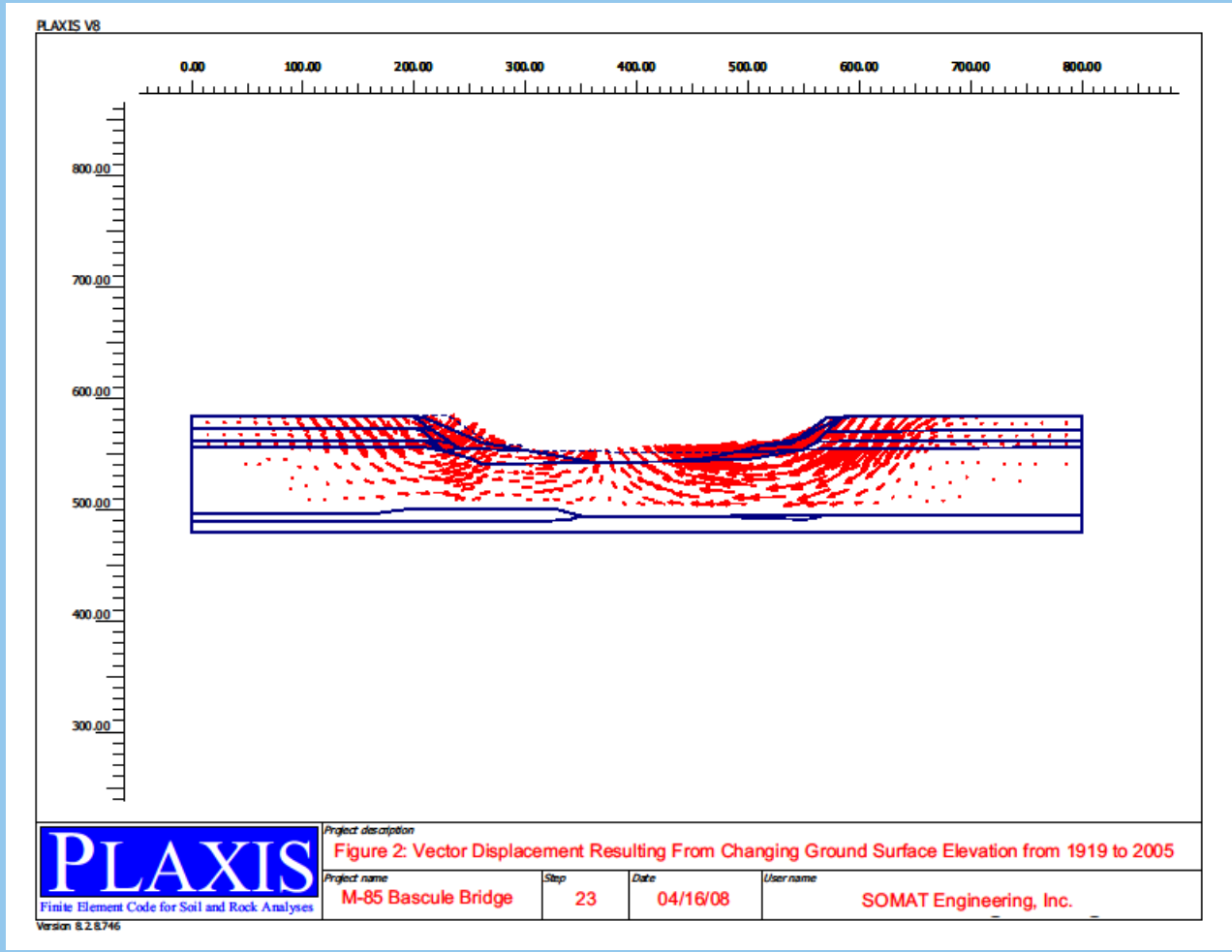
SHEAR STRENGTH



SHEAR STRENGTH IMPACT ON GLOBAL STABILITY



PLAXIS ANALYSIS OF PARTICLE MOVEMENT



GLOBAL STABILITY

- The reinforcing effect of the piles was ignored
- Used both Bishop Simplified and Swedish Slip Circle with Circular and Sliding Block failure surfaces
- Calibration was accomplished by varying the parameters until the ambient factor of safety was in the range of from 0.85 to 1.0
- To improve the FS to consistently over 1.0, required a resisting force from the piers of 24 kips per foot of pier width
- To improve the FS to consistently over 1.2, required a resisting force from the piers of 55 kips per foot of pier width
- Current MDOT guidelines require a FS of 1.5+

TYPICAL GLOBAL STABILITY RESULT

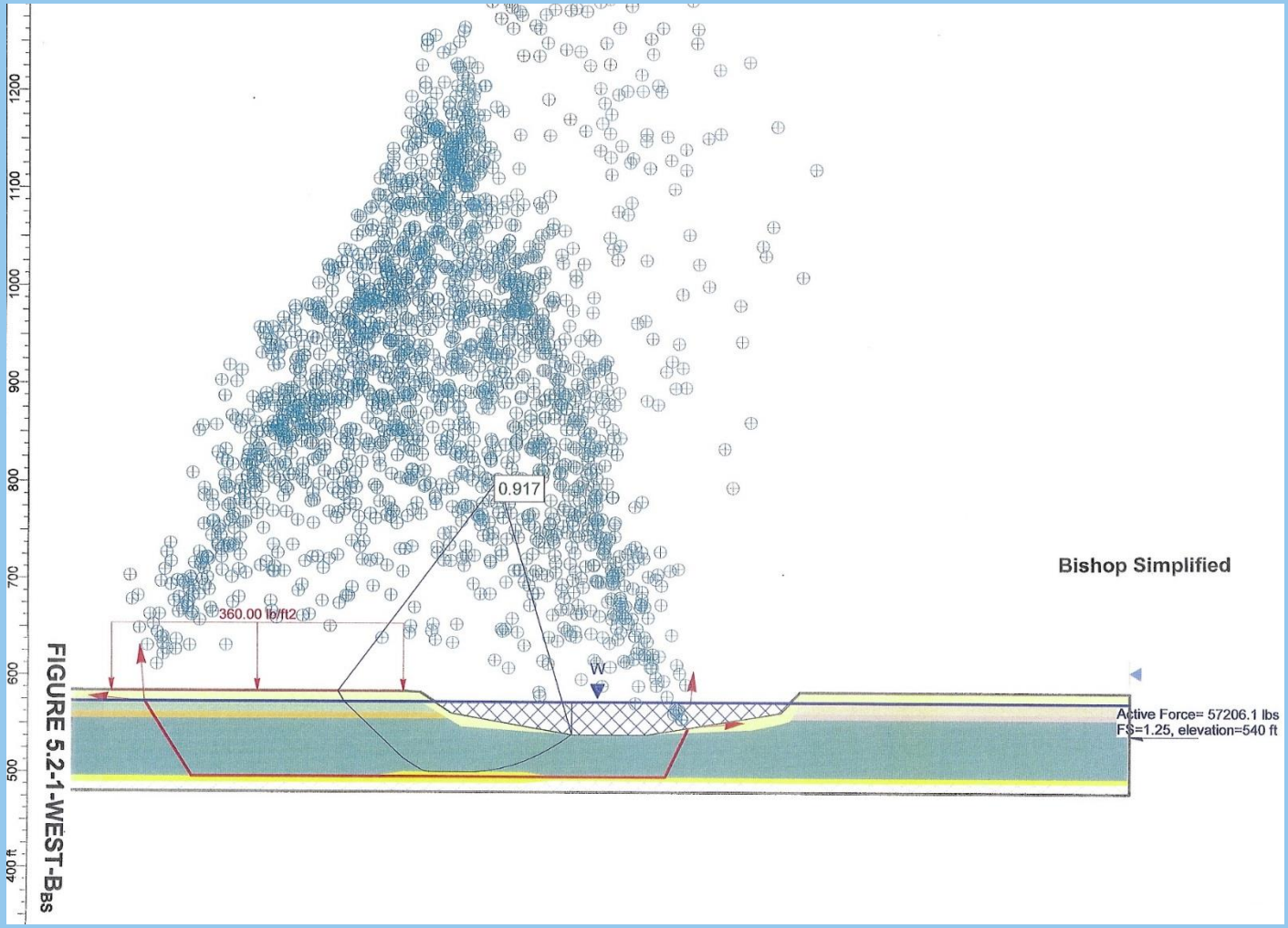
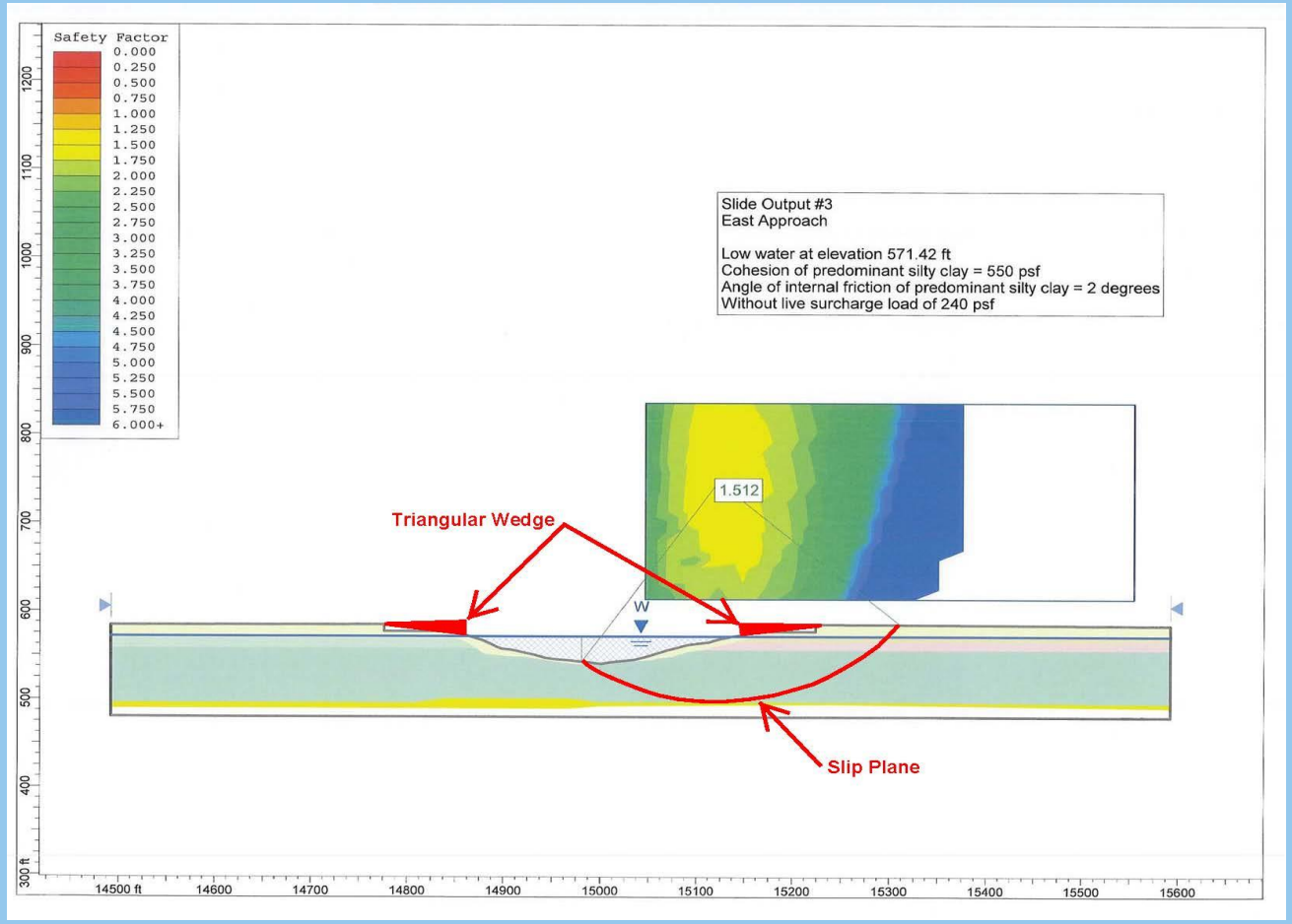
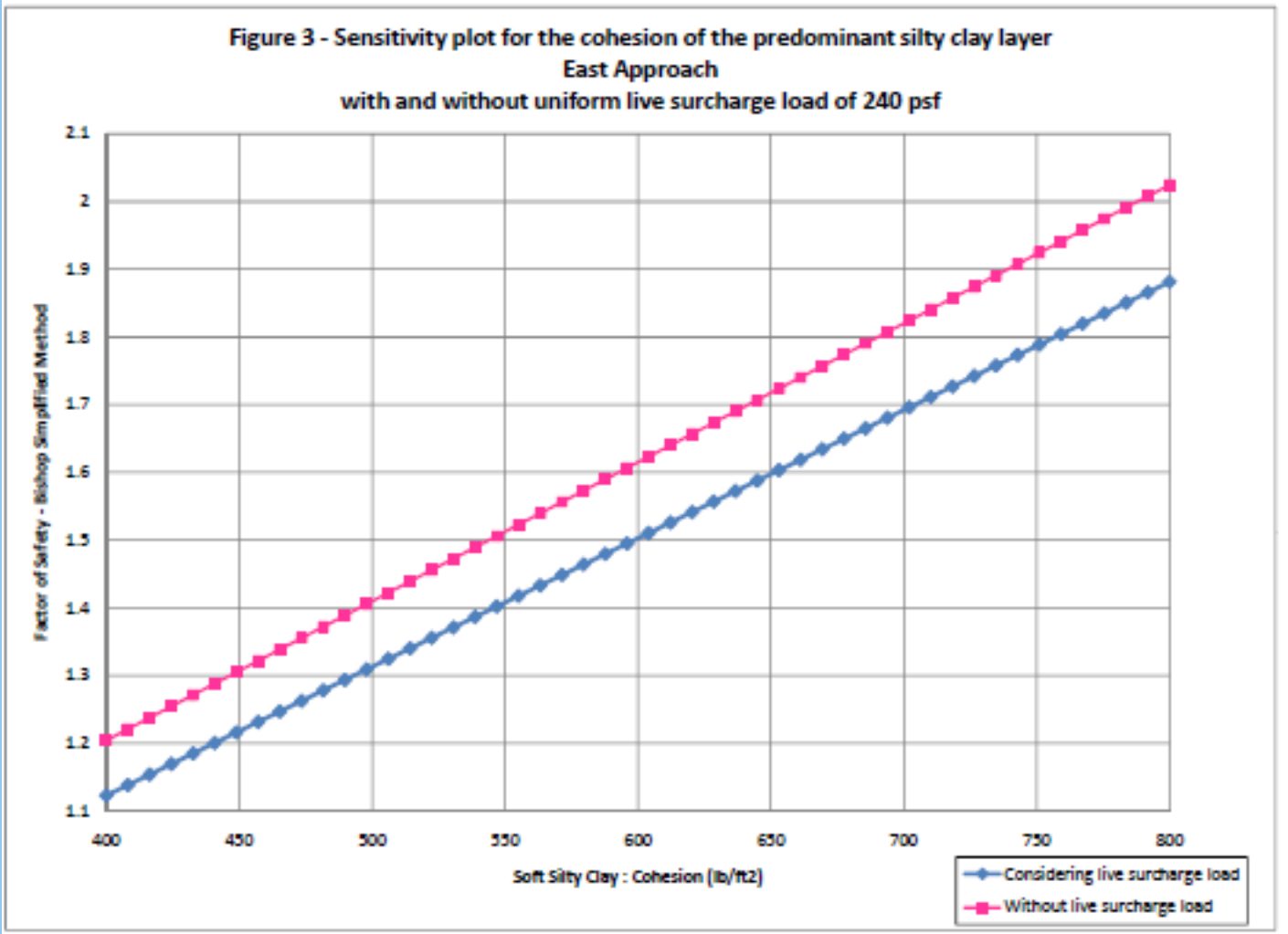


FIGURE 5.2-1-WEST-BBS

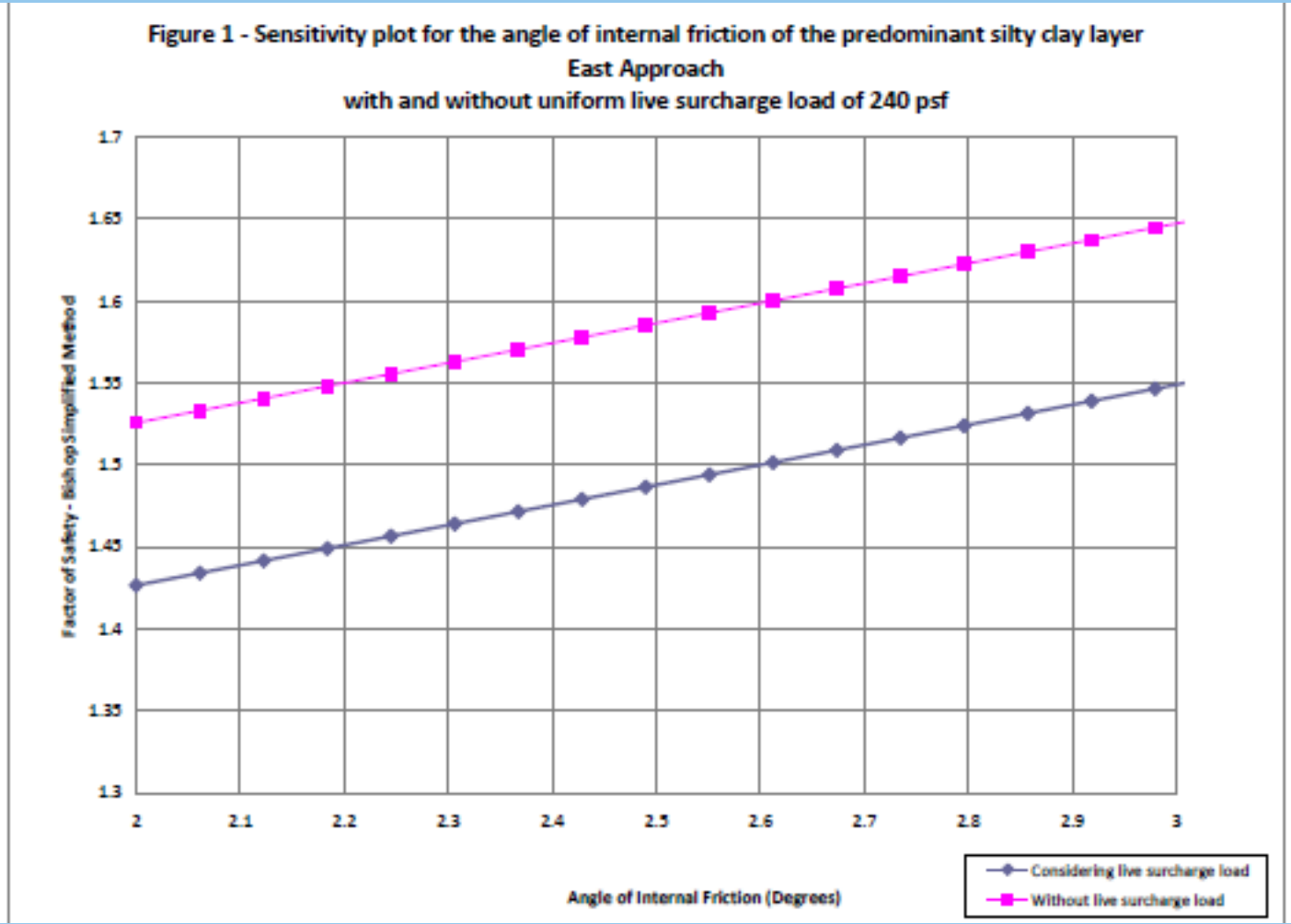
GLOBAL STABILITY MODIFIED PROFILE



GLOBAL STABILITY SENSITIVITY vs STRENGTH

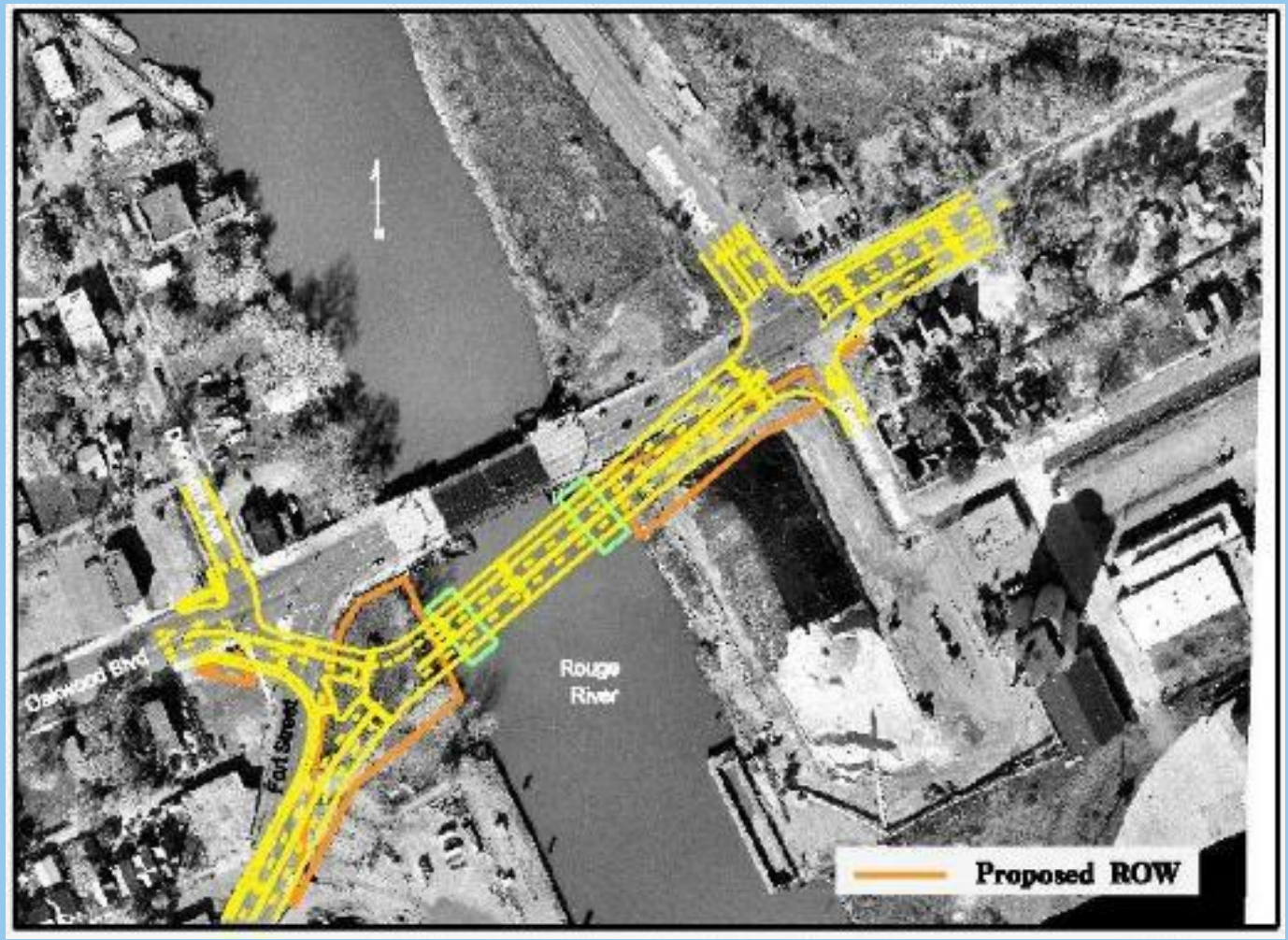


GLOBAL STABILITY SENSITIVITY WITH Φ



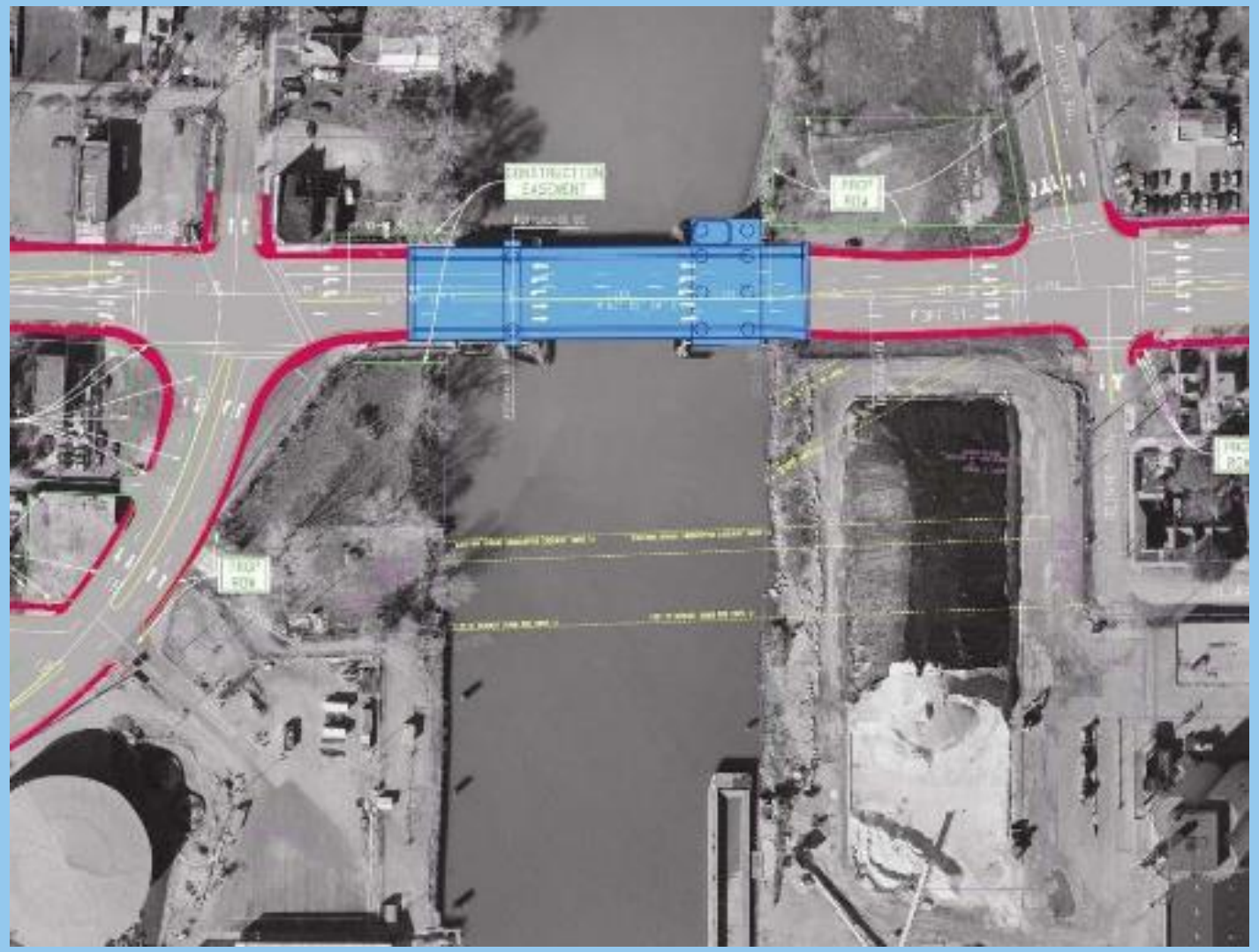
CHANGE IN ALIGNMENT OF BRIDGE

- Original alignment proposed for new bridge was skewed to the river to improve the local traffic situation on both sides of the river
- Route had to revert to old alignment due to land acquisition problems

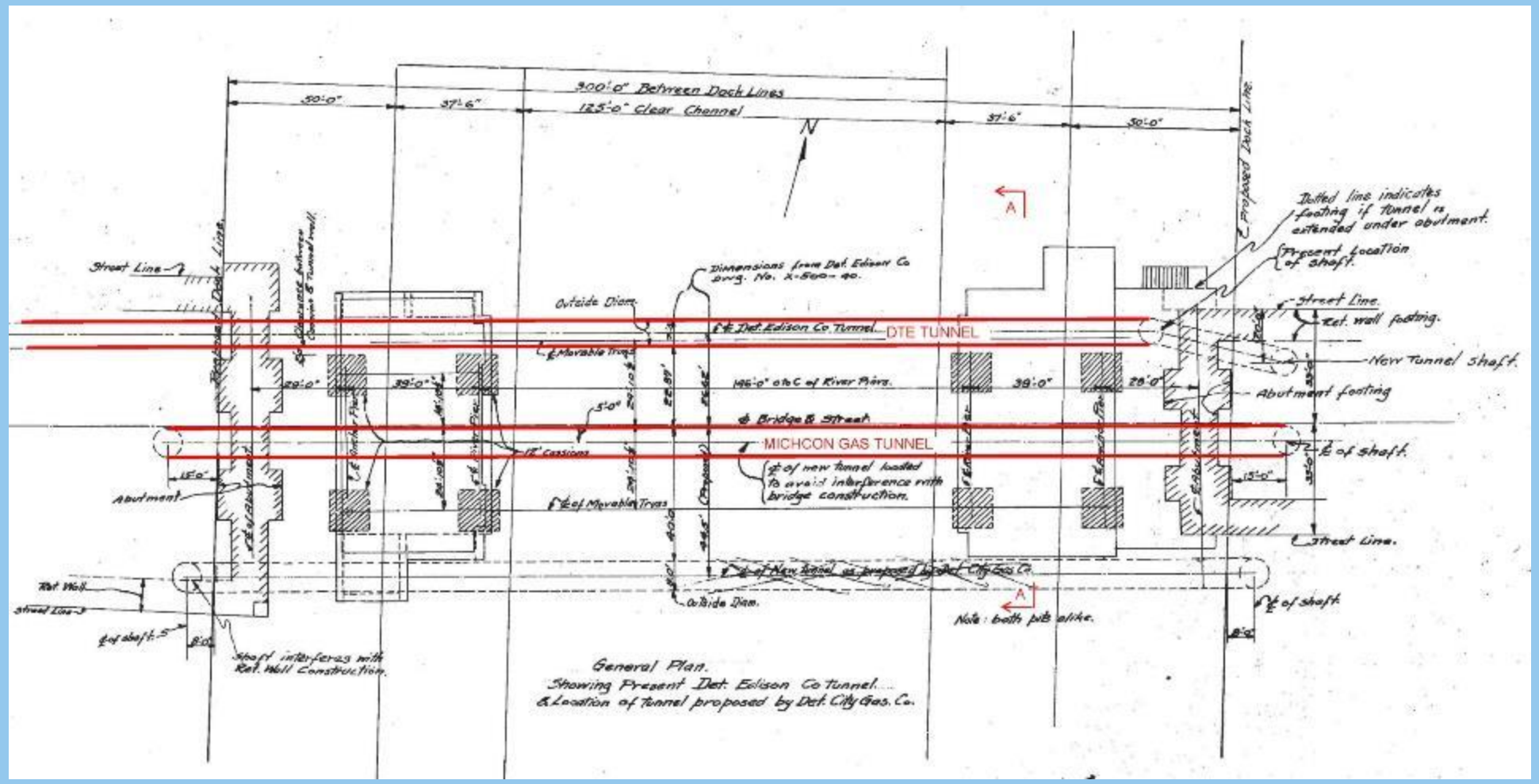


NEW "OLD" ALIGNMENT

- No significant difference in geotechnical conditions from skewed to perpendicular alignment
- Forces easier to design for with perpendicular alignment vs skewed alignment
- Now had to contend with foundations from old bridge & utility tunnels
- Not much room for improving the local traffic situations



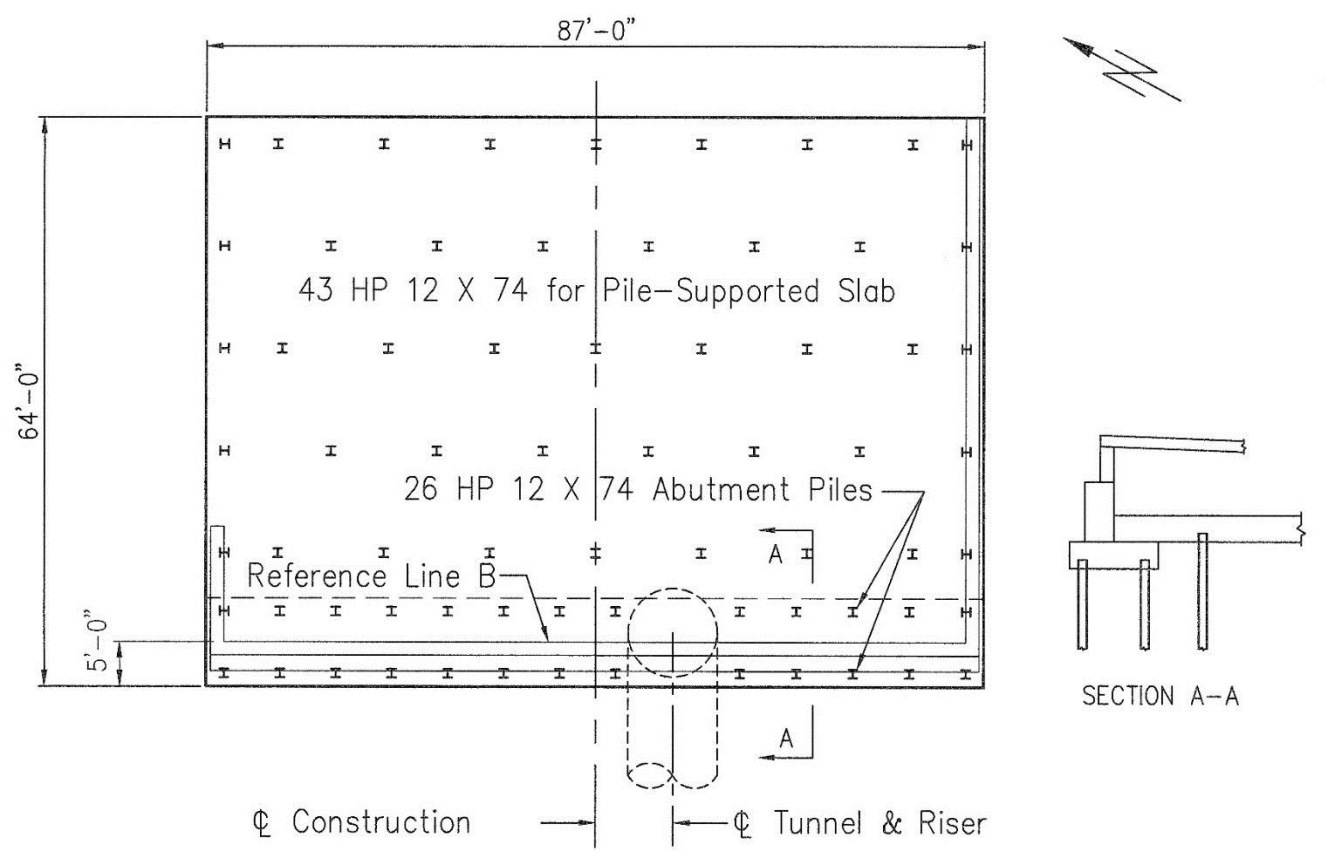
EXISTING UTILITIES UNDER ALIGNMENT



HOW TO STABILIZE THE NEW BRIDGE

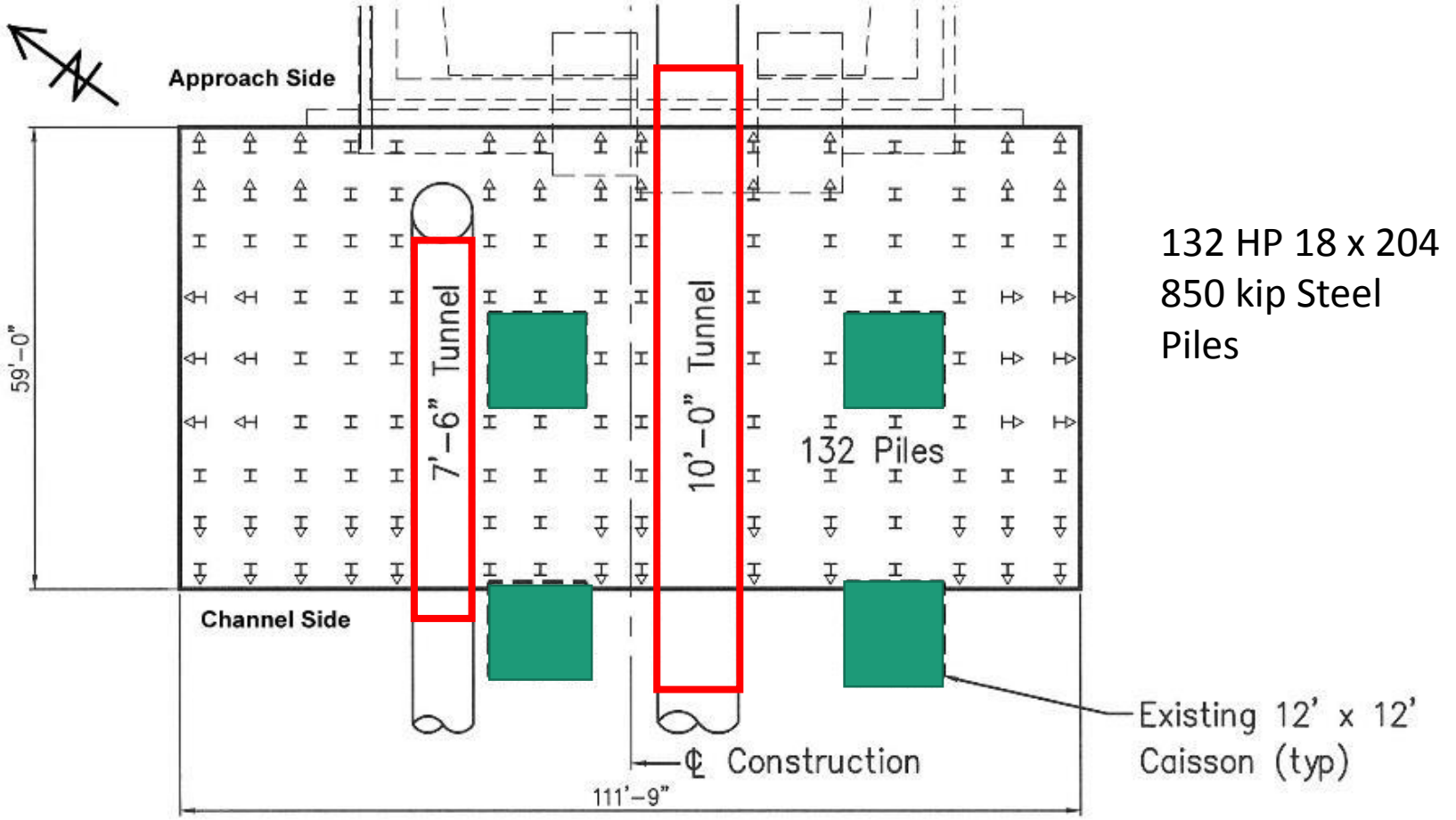
- Underwater concrete compression struts between the piers
- Improve the global stability
  - Increase the resisting force-not feasible with river
  - Decrease the driving force-excavate soil, replace with EPS foam, structural approach slabs for approaches
- Soil improvement
- Soil or rock anchors
- Structurally with the foundations
  - Existing piers – unknown bearing conditions
  - Drilled shafts
  - Driven piles

STRUCTURAL APPROACH SLAB



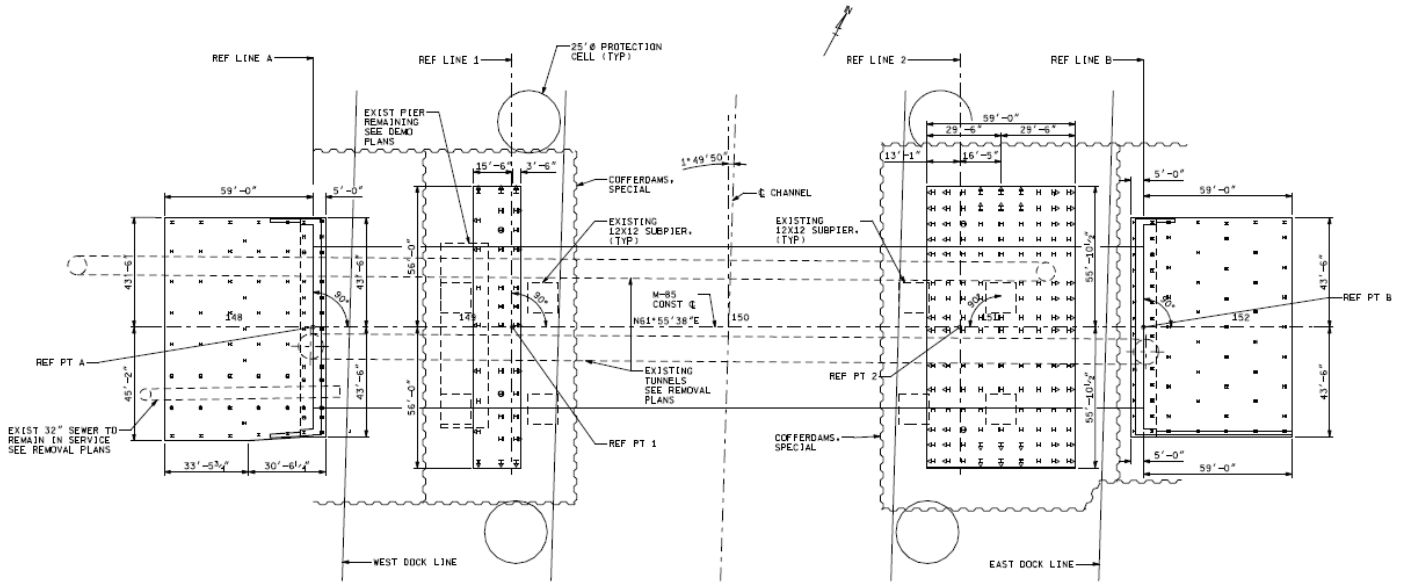
PLAN OF PILE-SUPPORTED SLAB

FINAL DESIGN RECOMMENDATION



132 HP 18 x 204
850 kip Steel
Piles

FINAL FOUNDATION PLAN



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1. COFFERDAMS ARE REQUIRED. CONSTRUCT PARTIAL OR FULL SHEET PILE ENCLOSURES IN ACCORDANCE WITH SECTION 704 OF THE STANDARD SPECIFICATIONS, PERMITS, AND ENVIRONMENTAL RESTRICTIONS NOTED ON THE PLANS. ALTERNATIVE MEANS AND METHODS OTHER THAN SHEET PILING AT SEWERS, TUNNELS, OR OTHER AREAS WILL NOT BE PAID FOR SEPARATELY BUT ARE INCLUDED IN THE ITEM "Cofferdams, Special (B01 of 82073)".
2. SUBMIT WORKING DRAWINGS AND CALCULATIONS FOR COFFERDAMS TO THE ENGINEER A MINIMUM OF 45 CALENDAR DAYS PRIOR TO ANTICIPATED START OF INSTALLATION.
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PLAN REVISIONS					
AUTH	DESCRIPTION	NO.	DATE	AUTH	DESCRIPTION

HARDESTY & HANOVER, LLP ENGINEERING

MDOT

NO SCALE

DRAWN BY: JLS | DATE: JULY 30, 2012 | CS: B01 OF 82073
CHECKED BY: DWE | DESIGN UNIT: GARCIA | JN: 54049 A
FILE: ...M85Foundation Layout.dgn | TSC: DETROIT

GENERAL FOUNDATION LAYOUT
FORT ST (M85) OVER THE ROUGE RIVER

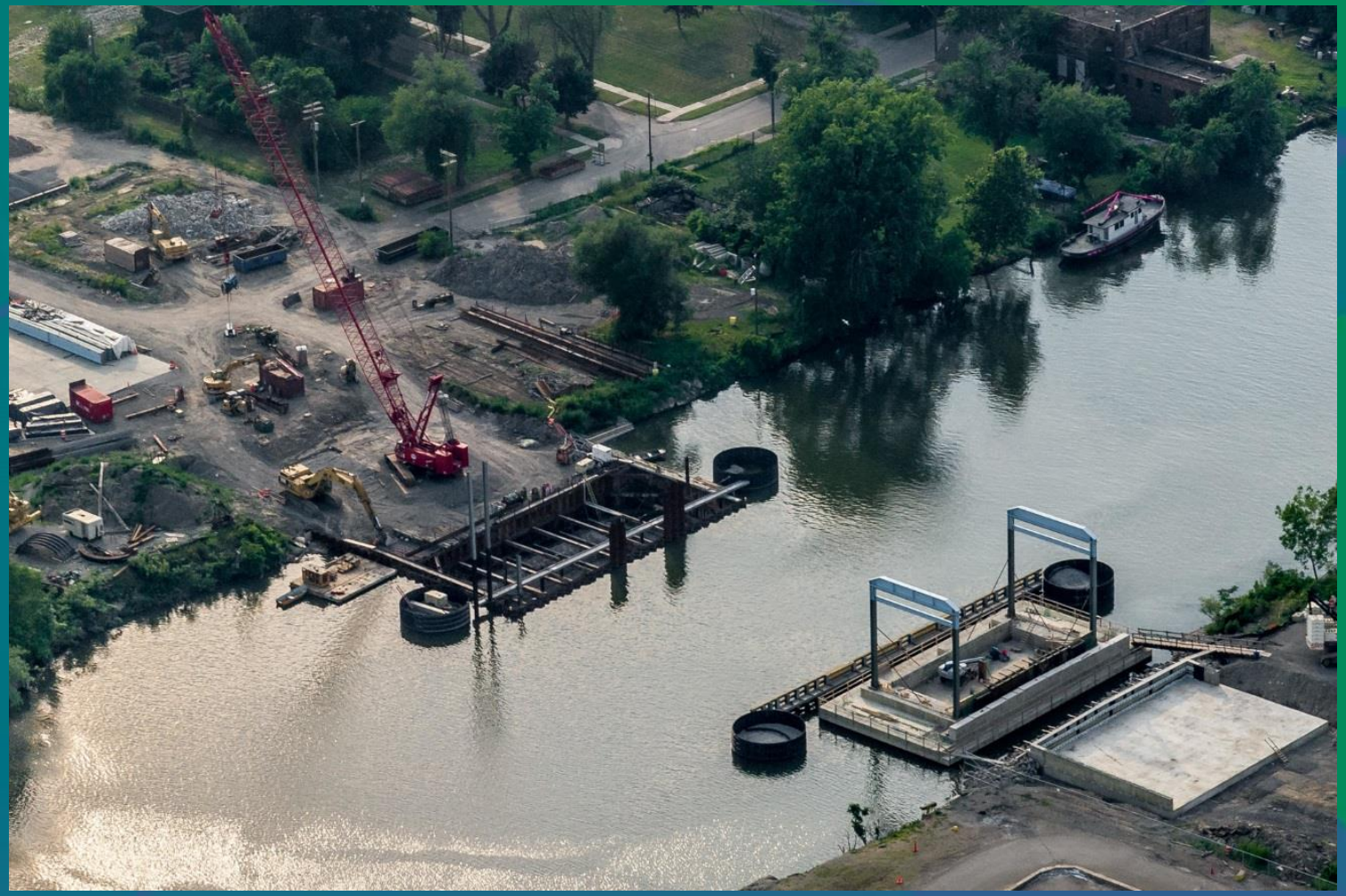
DRAWING: B01 GEN G-115 | SHEET: SECT 2 26

Now Tony Pietrangelo of MDOT will describe how the new bridge was constructed.

Thank You

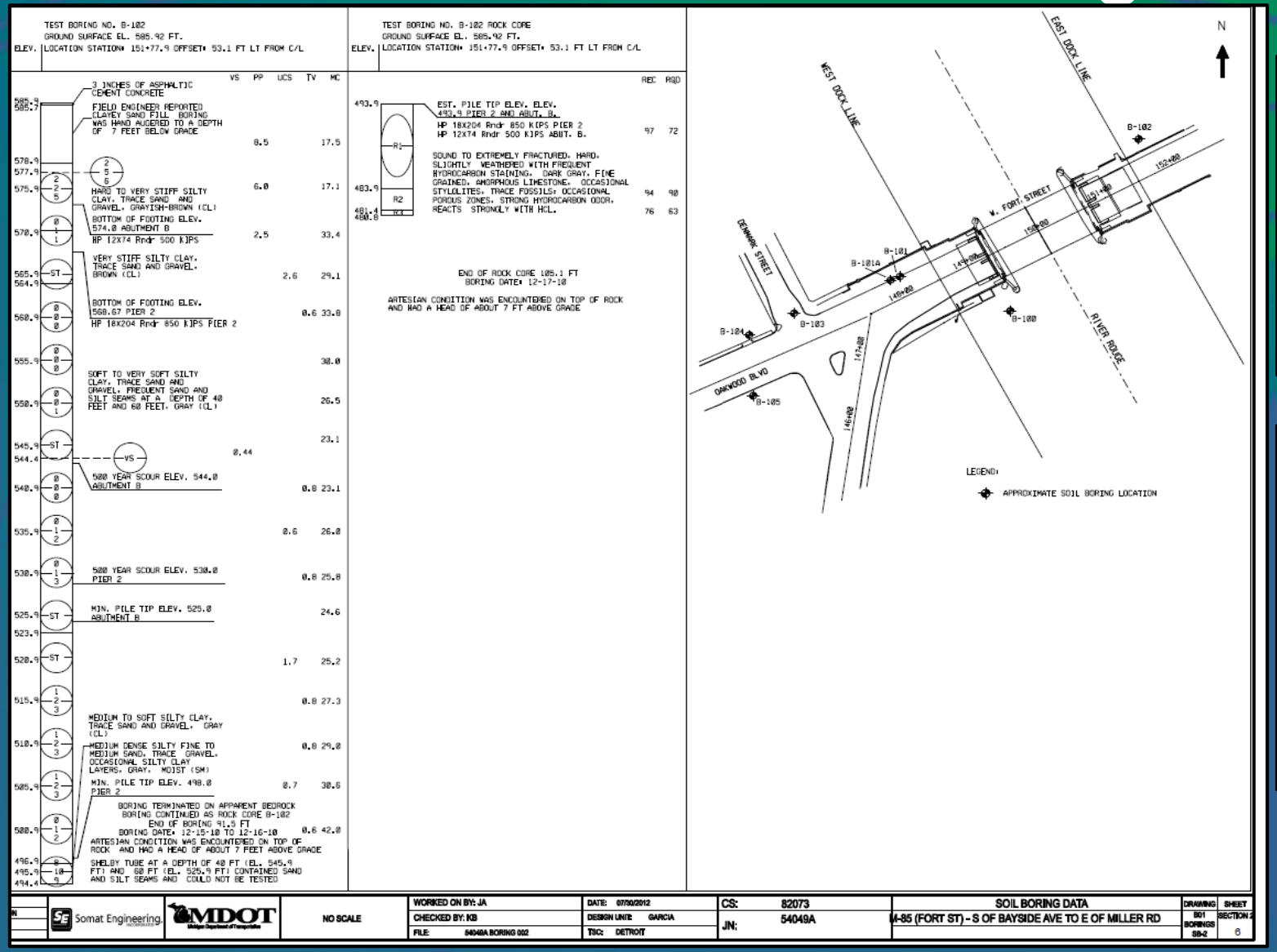
M-85 (Fort Street) Bascule Bridge

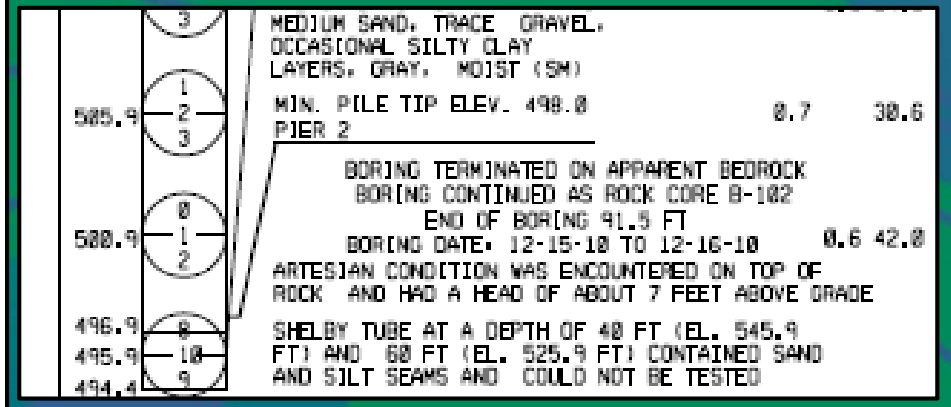
Naturally Occurring Geotechnical Hazards During Construction

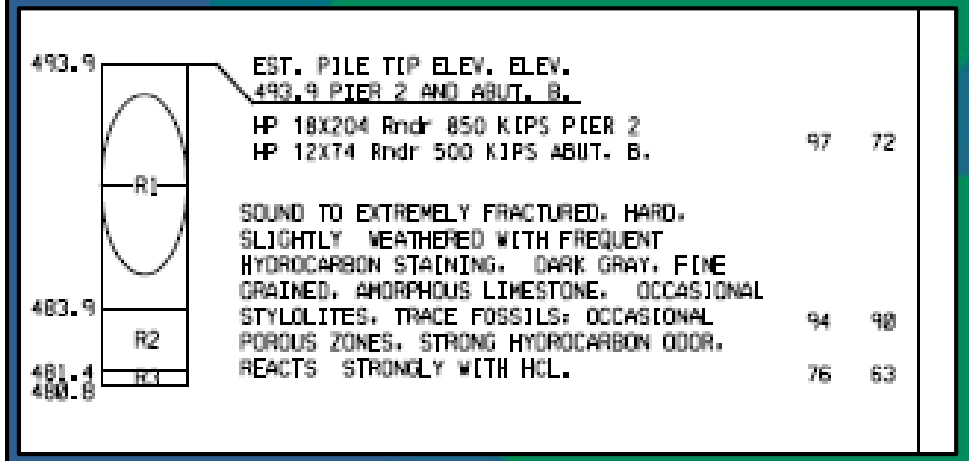


Tony Pietrangelo, P.E.,
Geotechnical Construction Support Engineer
October 18th, 2016

M-85 (Fort St.) Bascule Bridge
Soil Boring Logs







M-85 (Fort St.) Bascule Bridge - Special Provision for Plugging Artesian Flows

MICHIGAN
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION
FOR
PLUGGING ARTESIAN FLOW

DES:JAG 1 of 1 C&T:APPR:::XX-XX-12

a. Description. This work consists of designing, furnishing materials, and providing equipment to plug artesian flow that may occur along the surfaces of cofferdam piles, foundation piles, or fender system piles.

Refer to the special provision for Cofferdams, Special and to the Notice to Bidders Data Report on Geotechnical Investigation for information on artesian conditions observed at the site.

If artesian flow should occur and does not self-arrest to the satisfaction of the Engineer, then the Engineer may, at his/her discretion, instruct the Contractor to take the necessary steps to plug the artesian flow.

b. Materials. Provide the appropriate grout or other material to plug artesian flow.

c. Construction. Prepare a plan to plug artesian flow if that occurs and does not self-arrest. The plan must include a description of the proposed plugging materials and the methods to be used to plug artesian flow. Submit the plan to the Engineer for review and approval.

If and when directed by the Engineer, provide the materials and equipment as identified in the approved plan. Inject the plugging material until the artesian flow has stopped.

d. Measurement and Payment. The completed work, as described, will be measured and paid for at the contract unit price using the following pay items:

Pay Item	Pay Unit
Plugging Artesian Flow, H-Piles	Each
Plugging Artesian Flow, Sheet Piles	Foot

Payment for **Plugging Artesian Flow, H-Piles** will be for each successful plugging of artesian flow at an individual H-pile as determined by the Engineer, and includes all labor, equipment, and materials.

Payment for **Plugging Artesian Flow, Sheet Piles** will be for each successful plugging of artesian flow along a sheet pile wall, measured along the plugged length of the wall as determined by the Engineer, and includes all labor, equipment, and materials.

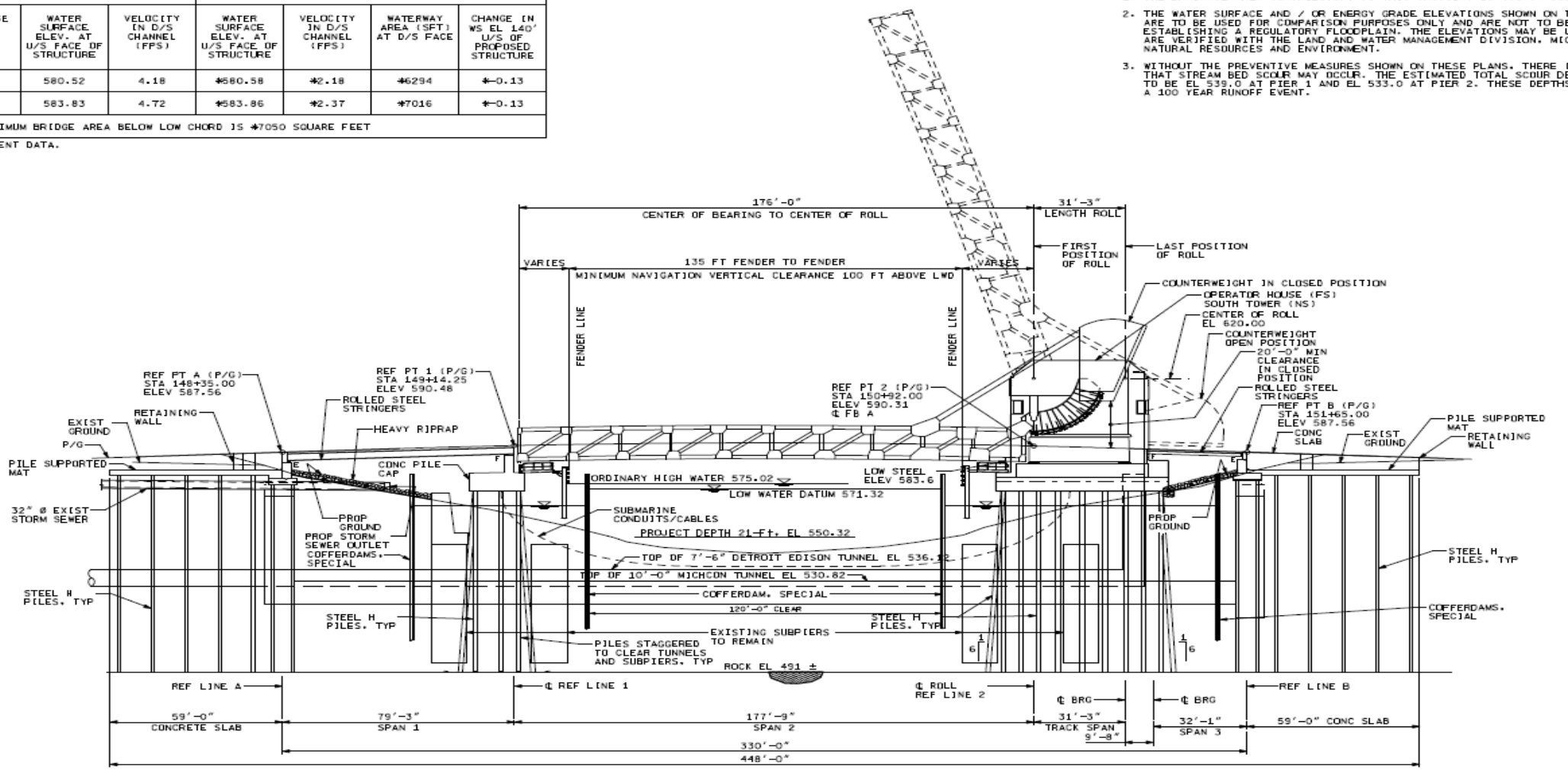
M-85 (Fort St.) Bascule Bridge

SUMMARY OF HYDRAULIC ANALYSIS							
EXISTING				PROPOSED			
FLOOD DATA	DISCHARGE (CFS)	WATER SURFACE ELEV. AT U/S FACE OF STRUCTURE	VELOCITY IN D/S CHANNEL (FPS)	WATER SURFACE ELEV. AT U/S FACE OF STRUCTURE	VELOCITY IN D/S CHANNEL (FPS)	WATERWAY AREA (SFT) AT D/S FACE	CHANGE IN WS EL 140' U/S OF PROPOSED STRUCTURE
50 YEAR	17000	580.52	4.18	*580.58	*2.18	*6294	*-0.13
100 YEAR	21000	583.83	4.72	*583.86	*2.37	*7016	*-0.13
MAXIMUM BRIDGE AREA BELOW LOW CHORD IS *7050 SQUARE FEET							

* VALUES BASED ON CURRENT DATA.

NOTES:

1. THE DRAINAGE AREA CONTRIBUTORY TO THIS CROSSING IS 450.87 SQUARE MILES.
2. THE WATER SURFACE AND / OR ENERGY GRADE ELEVATIONS SHOWN ON THE HYDRAULIC TABLE ARE TO BE USED FOR COMPARISON PURPOSES ONLY AND ARE NOT TO BE USED FOR ESTABLISHING A REGULATORY FLOODPLAIN. THE ELEVATIONS MAY BE USED PROVIDED THEY ARE VERIFIED WITH THE LAND AND WATER MANAGEMENT DIVISION. MICHIGAN DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENT.
3. WITHOUT THE PREVENTIVE MEASURES SHOWN ON THESE PLANS. THERE IS A POSSIBILITY THAT STREAM BED SCOUR MAY OCCUR. THE ESTIMATED TOTAL SCOUR DEPTH IS CALCULATED TO BE EL 539.0 AT PIER 1 AND EL 533.0 AT PIER 2. THESE DEPTHS ARE BASED ON A 100 YEAR RUNOFF EVENT.



SOUTH ELEVATION – 176-FOOT SINGLE-LEAF BASCULE WITH OVERHEAD COUNTERWEIGHT

RAILING NOT SHOWN FOR CLARITY.
NEAR SIDE STAIR TOWERS NOT SHOWN FOR CLARITY.
FENDERS AND DOLPHINS NOT SHOWN FOR CLARITY.

PLAN REVISIONS							
NO.	DATE	AUTH	DESCRIPTION	NO.	DATE	AUTH	DESCRIPTION

BARDSETT & RANOVEL, LLP ENGINEERING

MDOT

NO SCALE

DRAWN BY: E. Oliver | DATE: JULY 30, 2012 | CS: B01 OF 82073

CHECKED BY: J. Roulson | DESIGN UNIT: GARCIA | JN: 54049 A

FILE: ...\CADD\00_Gen\M\GP Str-Elev.dgn | TSC: DETROIT

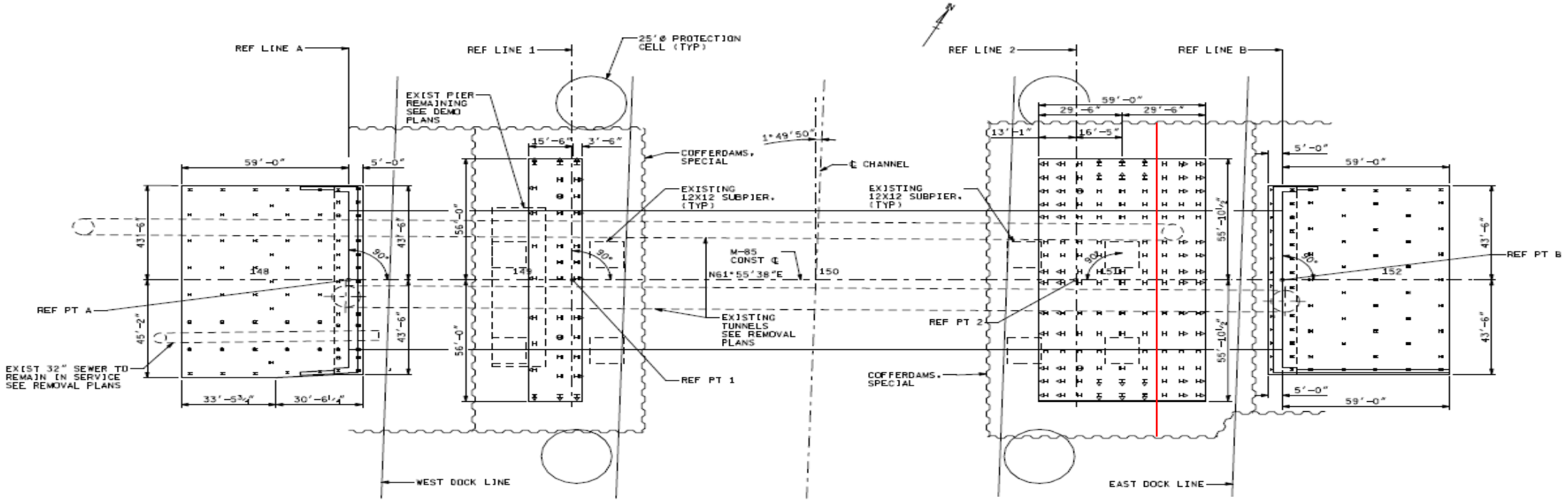
GENERAL PLAN OF STRUCTURE

FORT ST (M85) OVER THE ROUGE RIVER

DRAWING: B01 GEN G-105

SHEET: SECT 2 16

M-85 (Fort St.) Bascule Bridge



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HARDESTY & HANOVER, LLP ENGINEERING

MDOT Michigan Department of Transportation

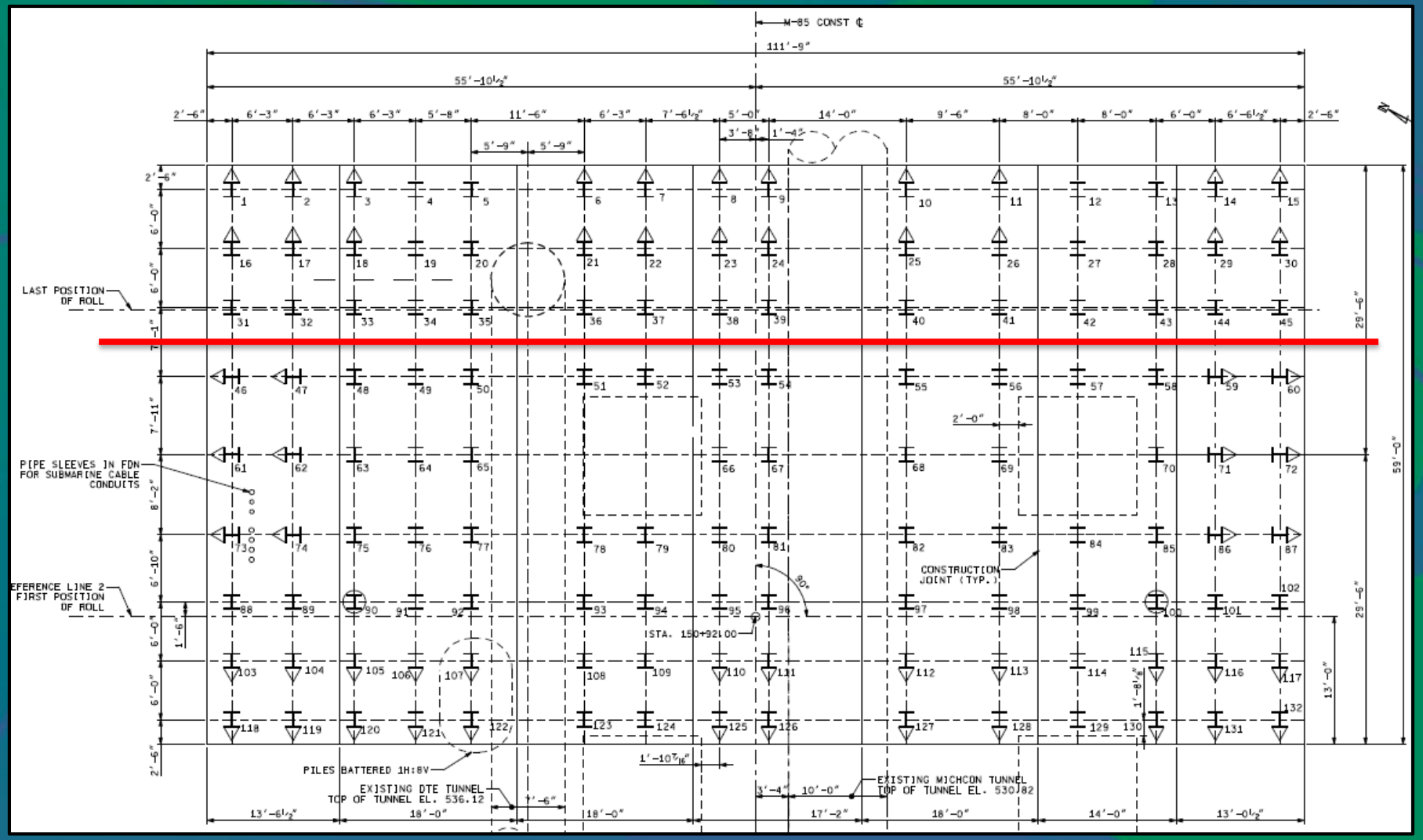
NO SCALE

DRAWN BY: JLS	DATE: JULY 30, 2012	CS: B01 OF 82073	GENERAL FOUNDATION LAYOUT	DRAWING	SHEET
CHECKED BY: DWE	DESIGN UNIT: GARCIA	JN: 54049 A	FORT ST (M85) OVER THE ROUGE RIVER	B01 GEN G-115	SECT 2 26
FILE: ...W8Foundation Layout.dgn	TSC: DETROIT				

M-85 (Fort Street) Bascule Bridge

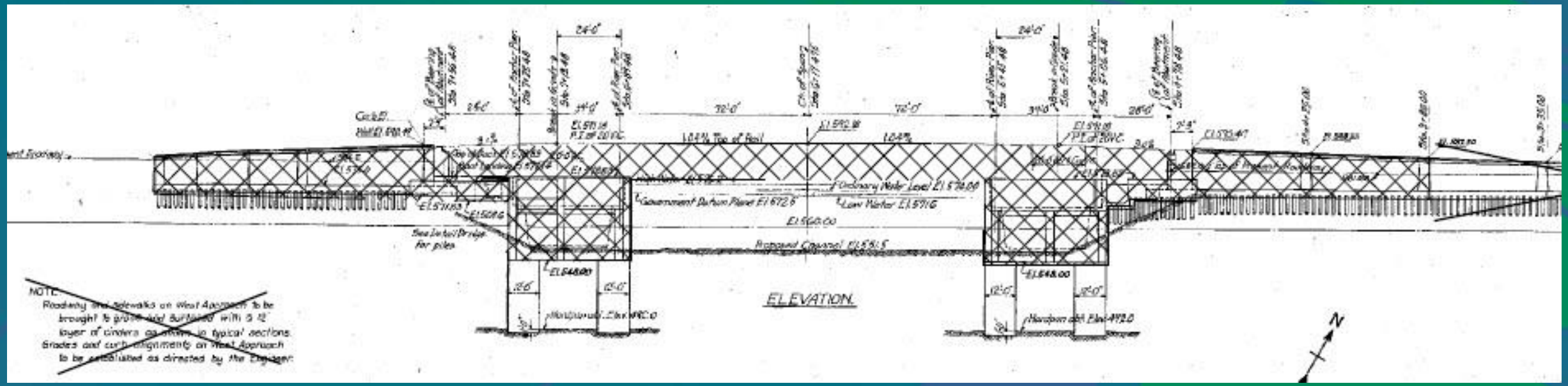
M-85 (Fort St.) Bascule Bridge – Pier 2

- 850 Kip Nominal Pile Driving Resistance
- HP 18 X 204
- Full Length Piles
- New pier in same location as old pier and existing abutment and return walls supported on timber piles
- Timber piles in conflict with proposed piles



M-85 (Fort St.) Bascule Bridge

Existing layout showing foundation piles.



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M-85 (Fort St.) Bascule Bridge

Construction Quick Facts

- Abutment A and Pile Supported Approach
  - 500 kips
  - HP 12X74 section
  - PDA Testing required
  - Installed using a BSP CX85 Hydraulic Hammer

- Abutment B and Pile Supported Approach
  - 500 kips
  - HP 12X74 section
  - PDA Testing required
  - Installed using a Pileco D30-32 OED Hammer

- Pier 1
  - 600 kips
  - HP 18X204 section
  - PDA Testing required
  - Installed using a BSP CX85 Hydraulic Hammer

- Pier 2
  - 850 kips
  - HP 18X204 section
  - PDA Testing required
  - Installed using a Pileco D46-32 OED Hammer

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M-85 (Fort St.) Bascule Bridge

Construction Quick Facts

Construction Costs

- Cofferdams, Special – $1,900,000.00
- HP 18X204 Piling
  - 13,234.48 lft @ $170 per ft. = $2,249,861.60
- HP 12X74 Piling
  - 11,989.82 lft @ $48.53 per ft. = $581,865.96
- Pile Driving Equipment, Furn. - $125,000.00
- Pile Points, Steel
  - 303 @ $150 each = $45,450.00
- Test Pile Dynamic Analysis
  - 8 @ $1,200.00 each = $9,600.00
- Test Pile Furnish Dynamic Analysis Equipment
  - 8 @ $600.00 each = $4,800.00

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M-85 (Fort St.) Bascule Bridge: HP 18 x 204

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M-85 (Fort St.) Bascule Bridge: HP 18 x 204

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M-85 (Fort St.) Bascule Bridge

M-85 (Fort St.) Bascule Bridge

- Received a call that a hydrogen sulfide gas artesian flow was encountered during pile driving
  - Result of conflict with the existing timber piles
  - Existing timber piles were driven to rock into/through the artesian bearing soil layer
  - Contractor removed one (1st) timber pile in conflict with proposed piling and the artesian flow, flowed up the vacant hole left be removing the timber pile

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M-85 (Fort St.) Bascule Bridge

- Contractor attempted to place the timber pile back in the hole in an attempt to plug the artesian
  - Contractor had already cut the existing timber pile in to 20 ft. pieces to remove from site
  - Was able to place 40 ft. back in the hole, two pieces got jammed up, artesian still flowed
  - Site smelled like rotten eggs
  - Contractor notified their safety officer; all operations at pier 2 were suspended
  - Location was caution taped off

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M-85 (Fort St.) Bascule Bridge

- Contractor put together a monitoring plan; employees had to wear gas monitoring devices
- Once gas levels decreased to a safe level, the existing timber piles were surveyed for their exact locations and the proposed pile layout was revised accordingly
  - Because these were special order pile sizes and lengths, designers had to revise proposed layout using the same number and length of piles as original design - no additional pile could be added
  - Changes were received and pile driving continued…

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M-85 (Fort St.) Bascule Bridge

- Noticed there were fewer battered piles than before???
- Revised PDF drawings that construction received did not show the battered pile arrows that were on the CADD drawings - battered piles appeared as vertical piles
- Re-revise proposed pile layout based on what was driven as vertical pile and keeping the same number and length as original

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M-85 (Fort St.) Bascule Bridge

- Plugging the artesian
- SP included in contractor
- MDOT asked contractor for a plan to plug the artesian; contractor was reluctant to submit a plan to plug the artesian
- Bid the item at a dollar a piece
- Because the clay was so soft, the artesian was slowly decreasing until the soft clay completed closed off the artesian flow
- No additional plugging work was needed
- Because the contractor removed one existing timber pile…all the other artesian and construction related issues occurred

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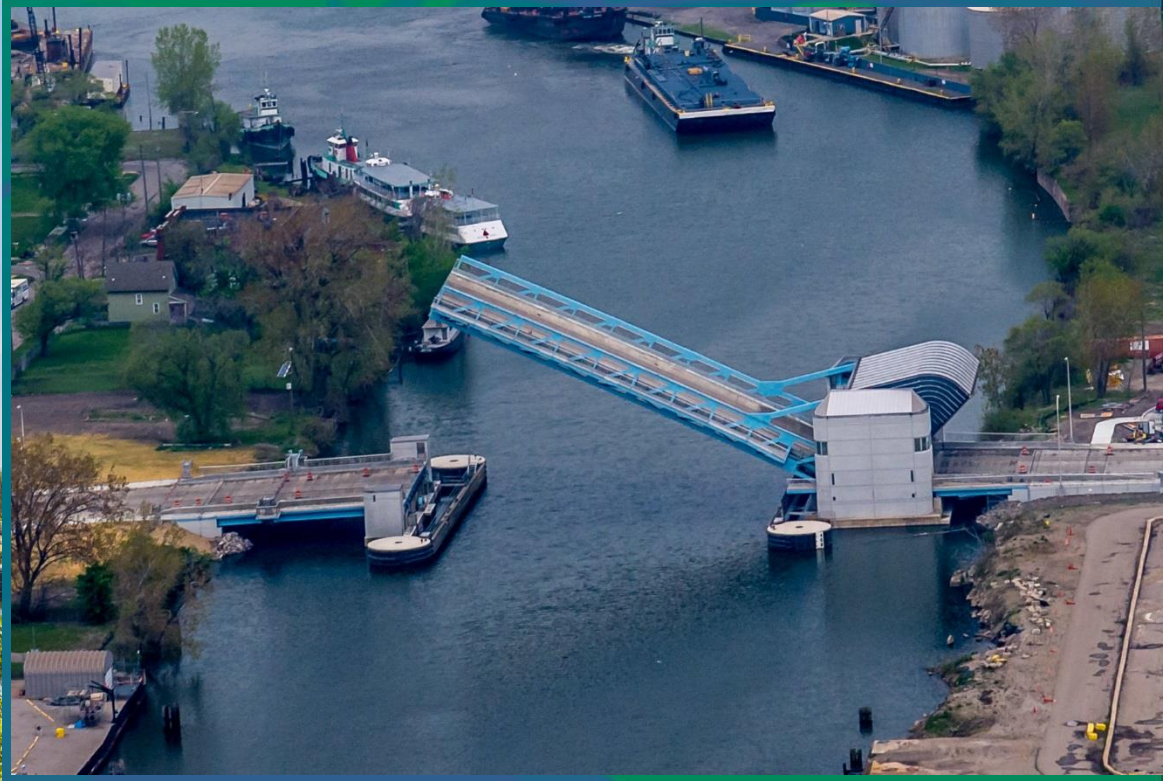
M-85 (Fort St.) Bascule Bridge

Completed Project



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M-85 (Fort St.) Bascule Bridge

Completed Project

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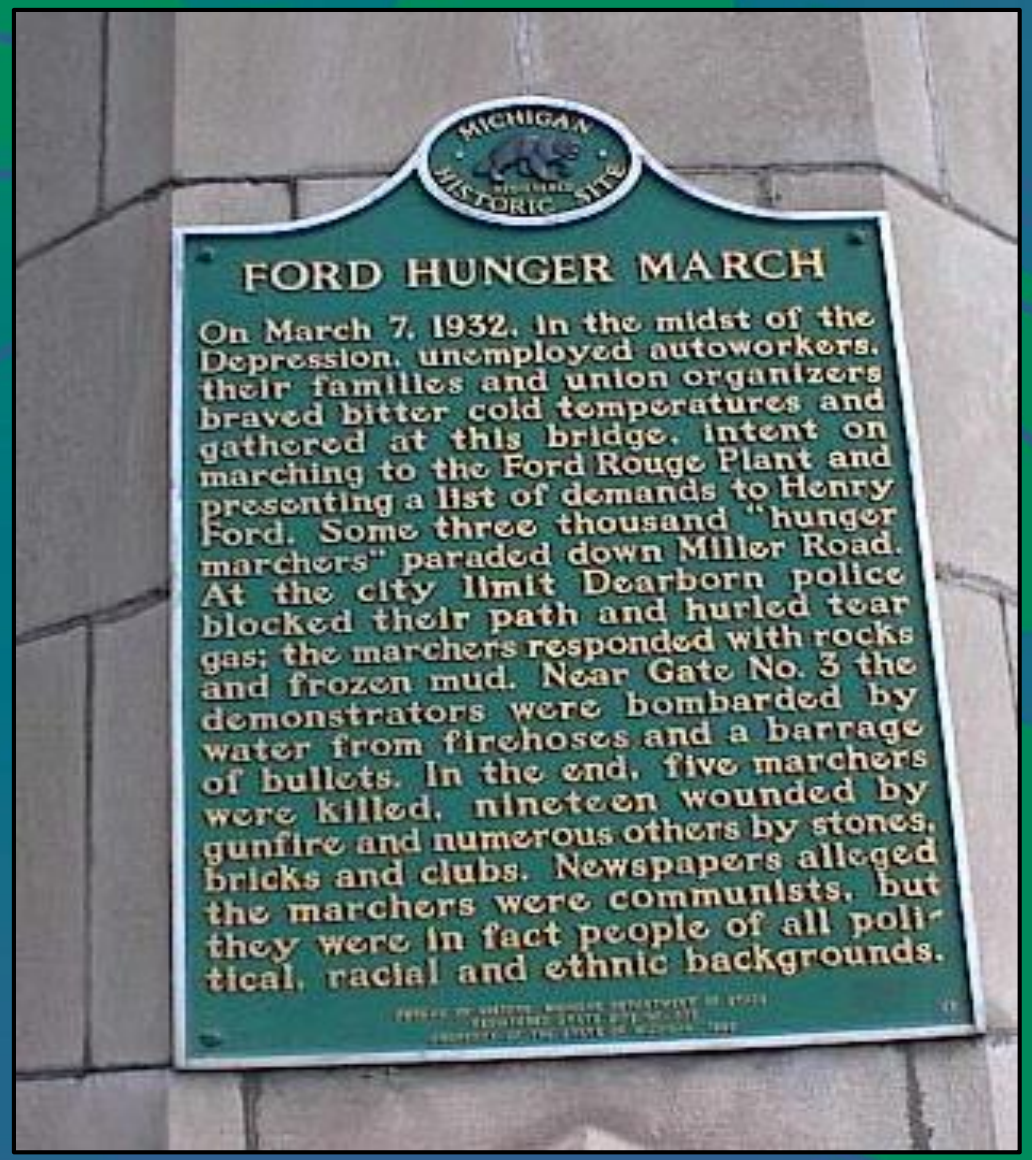
M-85 (Fort St.) Bascule Bridge

- Questions?



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