Approaches to Historic Bridge Rehabilitation

Case Study #2

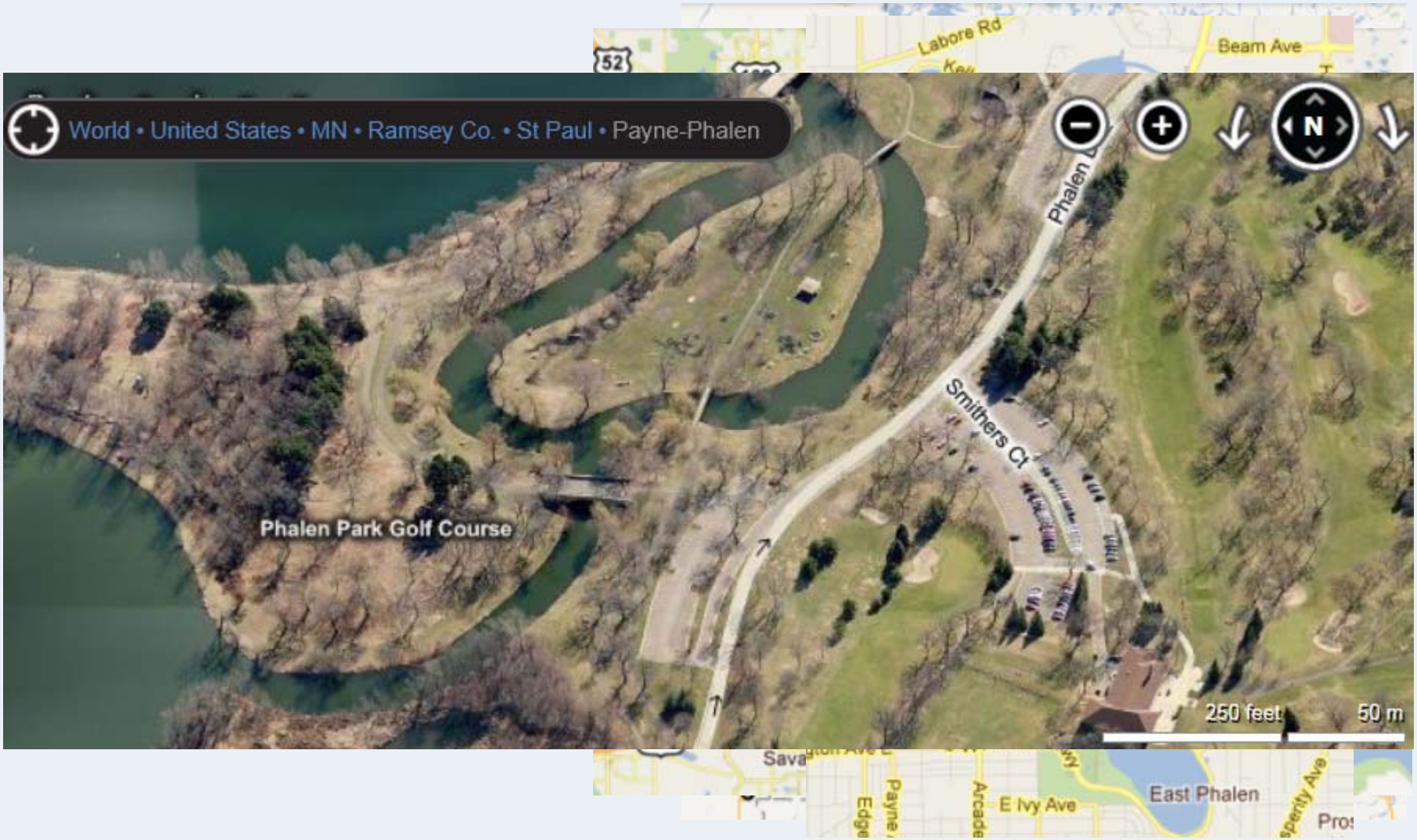
Rehabilitation of the Phalen Park Arch Bridge

Saint Paul, Minnesota

Steve Olson

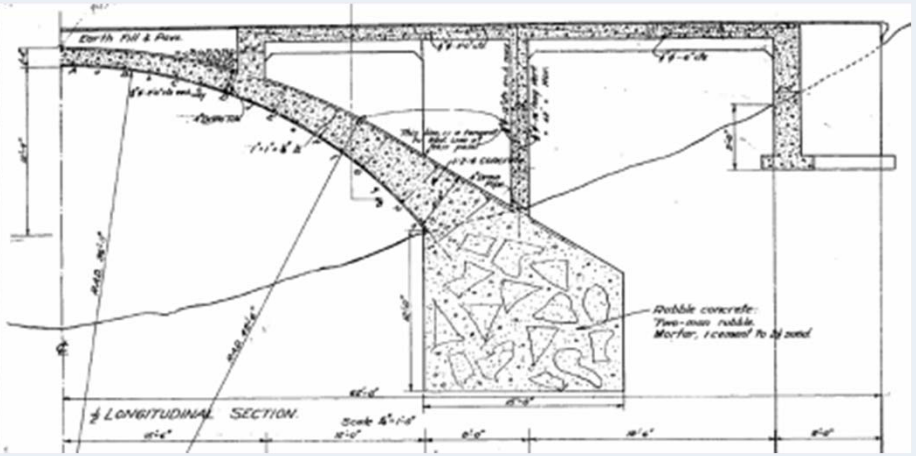
OLSON & NESVOLD ENGINEERS, P.S.C.

Location and Setting

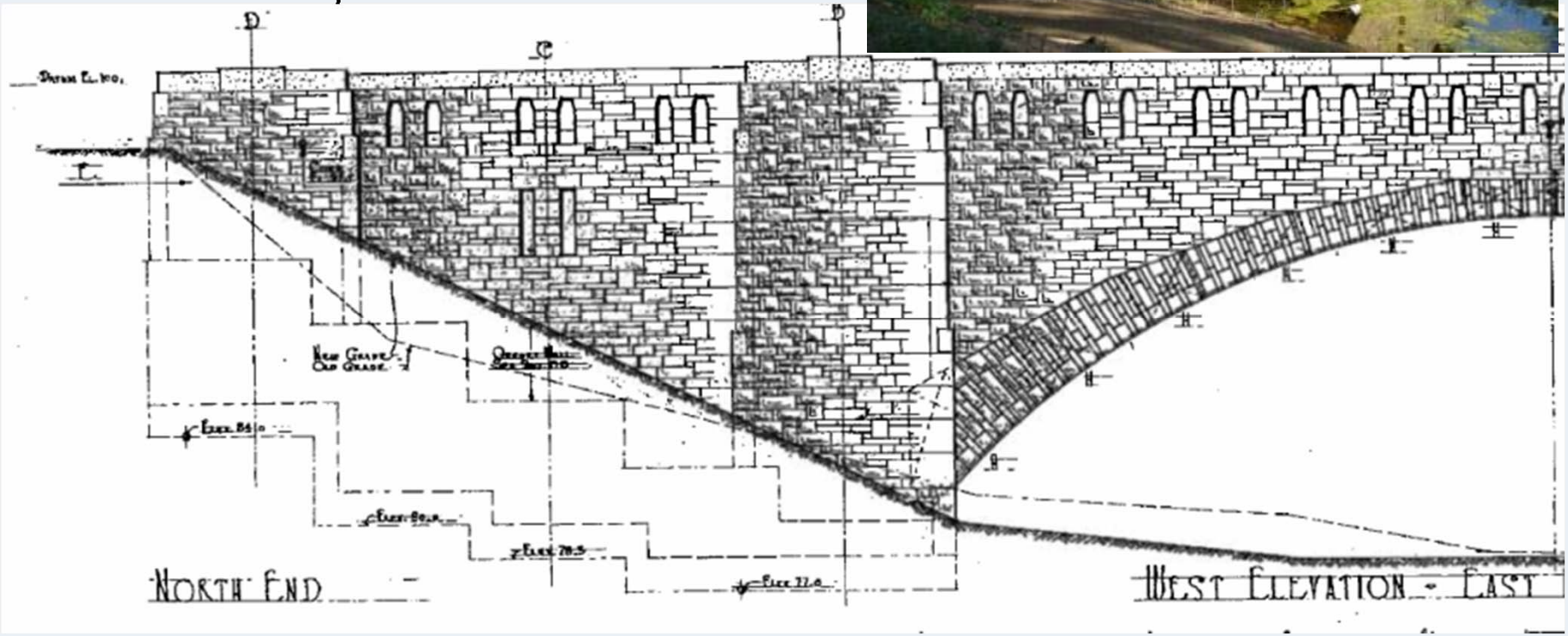


Phalen Park Arch Bridge

- Reinforced Concrete Open Spandrel Barrel Arch
  - Constructed in 1910
  - Overall length 124', out-to-out width 42'
  - 55' arch span, two 18.5' slab spans
  - Designer of Regional Significance
    - C.A.P. Turner – would later design the Mendota Bridge (1926) and several other notable structures in the Midwest



- 1934 rehab to the “deteriorated” concrete bridge
- Open spandrel walls filled in with stone
- Concrete balustrade railings replaced with stone railings
- Shotcrete repairs to the barrel



Deteriorated components forced the City to close the waterway below the bridge.

Extensive deterioration of the concrete barrel

Due to barrel deterioration and deterioration near each edge, no vehicles were permitted on the bridge

Stone railing was in poor condition. It was too short for current standards and had openings that were too large for current standards.

“Pervious” pavement led to the deterioration of the lower bridge components at concrete joints. A water main sat on the west sidewalk.

Friends of Lake Phalen

"Working to protect and enhance Lake Phalen, Phalen Park and surrounding areas"

- Secured City funding for a rehabilitation study
- "Can you save it? Our sons and daughters were married on this bridge?"
- After the study was complete, they applied for and received a St. Paul HPC "Confidence Award"
- Secured City funding for rehabilitation construction

Rehabilitation Project Details

- *Owner:* City of Saint Paul, Parks and Recreation Department
- *Prime Consultant / Bridge Engineers:* Olson & Nesvold Engineers
- *Architects / Stone Masonry:* MacDonald & Mack
- *Civil Design / Construction Administration:* TKDA
- *Geotech / Material Testing:* Braun Intertec
- *Historians:* Mead & Hunt
- *General Contractor:* Global Specialty Contractors
- *Timeline and cost:*
  - Design 2009-2010
  - Reconstruction 2010-2011 ($1.3 million) – No federal dollars

Precast Concrete Panel Liner System

Robust structural support system for both the barrel and the spandrel walls

New Arch Ring and Façade Stone

MacDonald & Mack selected a single source that best matched the 1934 stone

Concrete Deck with Approach Panels

Waterproof cap on the top of the bridge to protect lower elements.

Approach panels carry water off the ends of the bridge. Sidewalks removed.

Railing Details

Reused cap stones. Curb integrated into the bottom of the railing for the vertical curve.

Old opening size “too big” to meet standards. Inner stones pinch in to reduce opening size.

Section 106 Issues

- Two periods of significance – original construction in 1910 and rehab in 1934
- Rehabilitation could have been to either period of significance.
- "Friends of Lake Phalen" preferred the 1934 stone version.
- Project historians coordinated the project with the Saint Paul Heritage Preservation Commission.
- Saint Paul Heritage Preservation Commission asked MN State Historic Preservation Office (SHPO) to review.
- SHPO's only concern was the amount of stone being replaced.
- Once SHPO learned that Bob Mack had recommended replacement of the stone, there were no additional concerns. [Bob is the author of National Park Service Preservation Briefs on masonry]

Section 4(f)

- No federal dollars were used for the project. Consequently, there was no Section 4(f) analysis or environmental document.
- "Can you save it?" is not the same as selecting the most reasonable and prudent alternative.
- The owner did consider a replacement structure.
- A narrower "Conspan" structure would have been significantly less expensive.
- In the end, City bonds were secured to pay for the rehabilitation.

Conclusions

- The benefit of a strong project champion ("Friends of Lake Phalen") cannot be overstated. They made the project happen.
- A good owner, a strong consultant team, and a good contractor all helped make this project successful.
- A construction sequence video was used as a communication tool throughout the project.
- It's very satisfying to work on a project embraced by the community. A canoe/kayak parade is planned for next spring's grand "re-opening" festivities.

Historic Bridge Rehabilitation Strategies – 3 Project Examples

Steve Olson
Principal Bridge Engineer

OLSON & NESVOLD ENGINEERS, P.S.C.

Strategies

- Laser-scanning
  - Lack of original plans
  - Modifications after original construction
- Integrating new materials
  - Lightweight concrete
  - Self-consolidating concrete
- Structure-in-a-structure techniques
  - Cast-in-place arch
  - Cast-in-place T-beams

Example Projects

- Bridge 82524 (A.K.A., Bridge 5721, or Silverdale, or Manning Avenue). Construction to be complete by July 2011
- Bridge L8560 (C.A.P. Turner arch bridge in Phalen Park). Construction to be complete summer 2011.
- Bridges L8920 and L8921 – Concrete T-beam bridges over the Midtown Greenway – Design is 95% complete

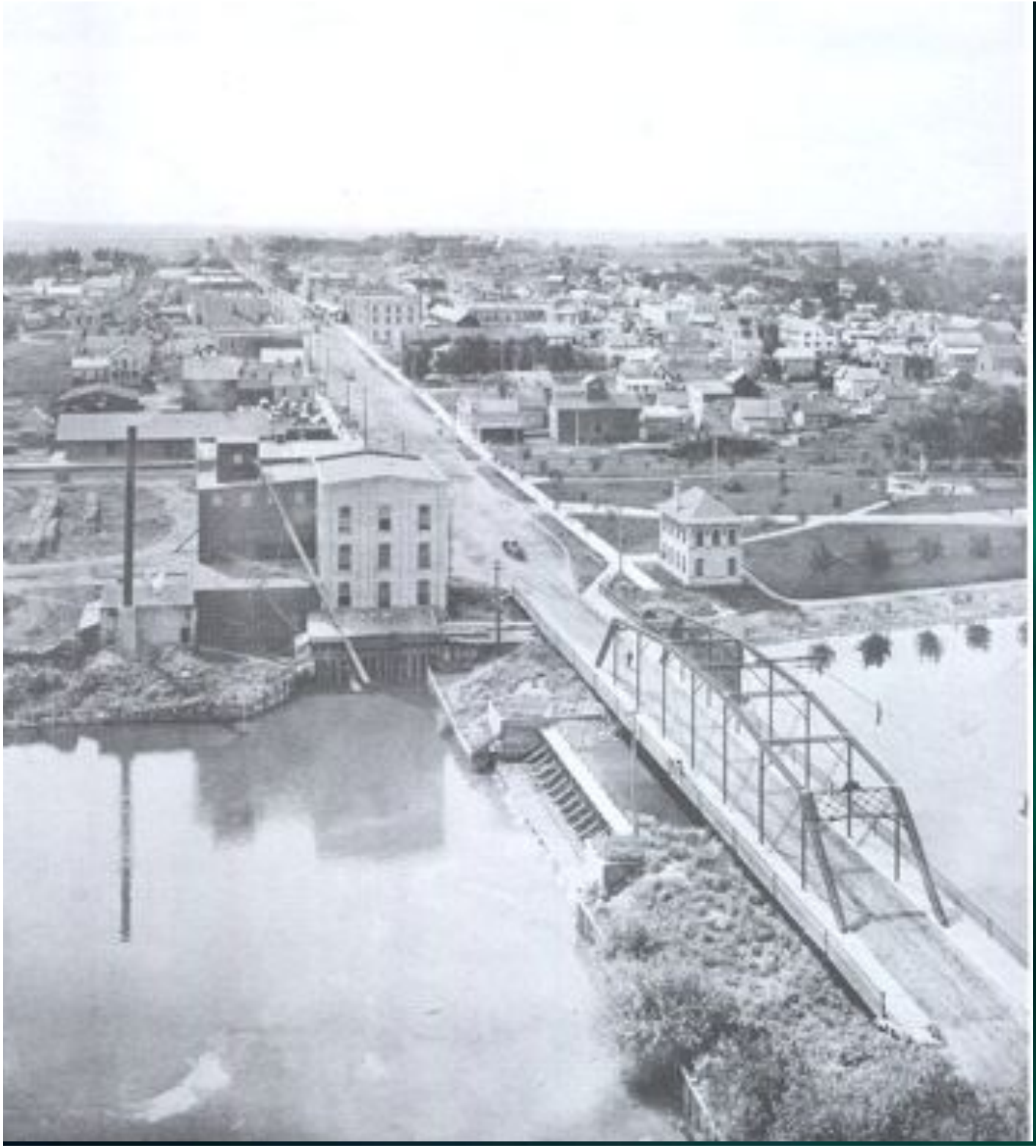
Rehabilitating the Silverdale Bridge (an 1870s Iron Truss)

Introduction to Bridge 82524

- One of 24 Historic Bridges owned by Minnesota to be preserved indefinitely.
- Originally assembled in Sauk Centre in the 1870s. In the 1930s it was dis-assembled and later moved to Koochiching County in northern Minnesota. It carried State Highway 65 over the Little Fork River at this site until 2009
- In 2011 it will begin its third service life


Steinbach
International Falls
Thief River Falls
Quetico Provincial Park
Crookston
Chippewa National Forest
Ely
Virginia
Hibbing
Bemidy
Fargo
Duluth
St Cloud
Blaine
Minneapolis
Woodbury
Eau Claire
Burnsville
Brookings
Mankato
Rochester
La Crosse
Sioux Falls

Location 1



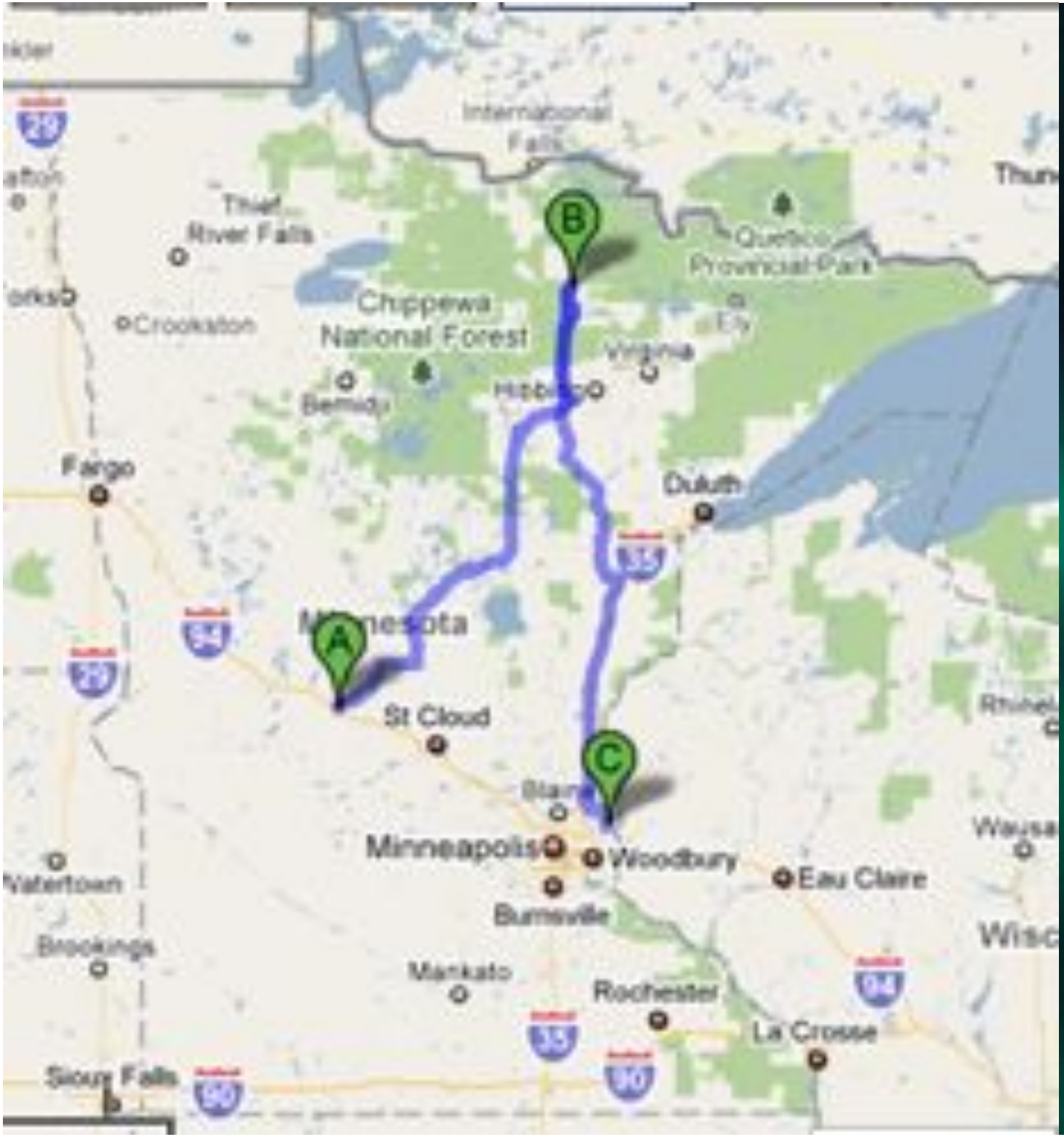
Location 1
1870s to 1930s

Location 1 to Location 2

Location 2
1937 to 2009


Location 2


Location 2



Location 2 to Location 3


Location 2 to
Location 3

Location 3

1870s Plans

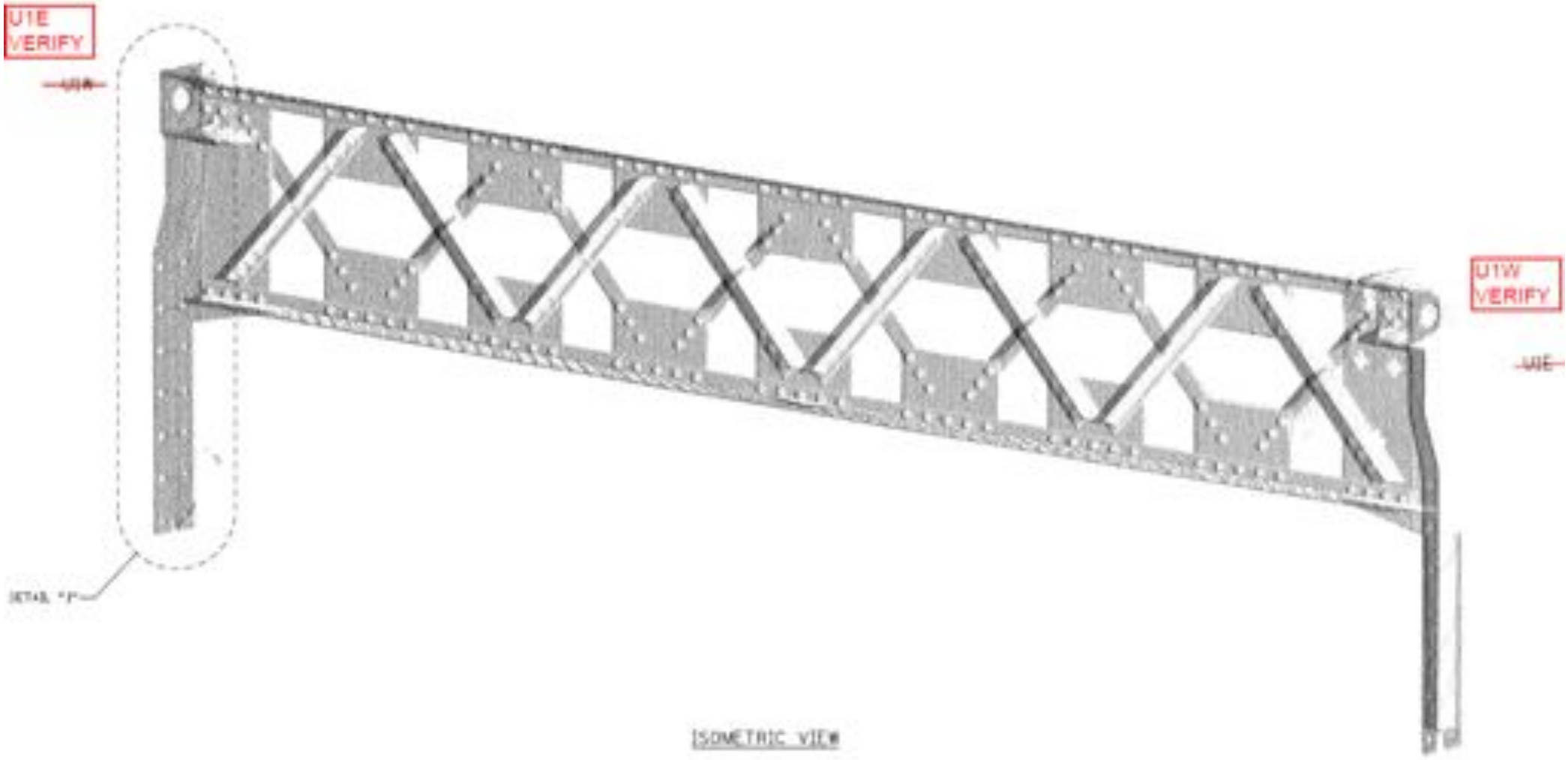
Laser Scanning Data Collection

1. First data collected on the complete bridge in-place prior to disassembly
2. Second wave of data collected on pieces as they were removed from the bridge during disassembly (used to get fastener patterns etc.)

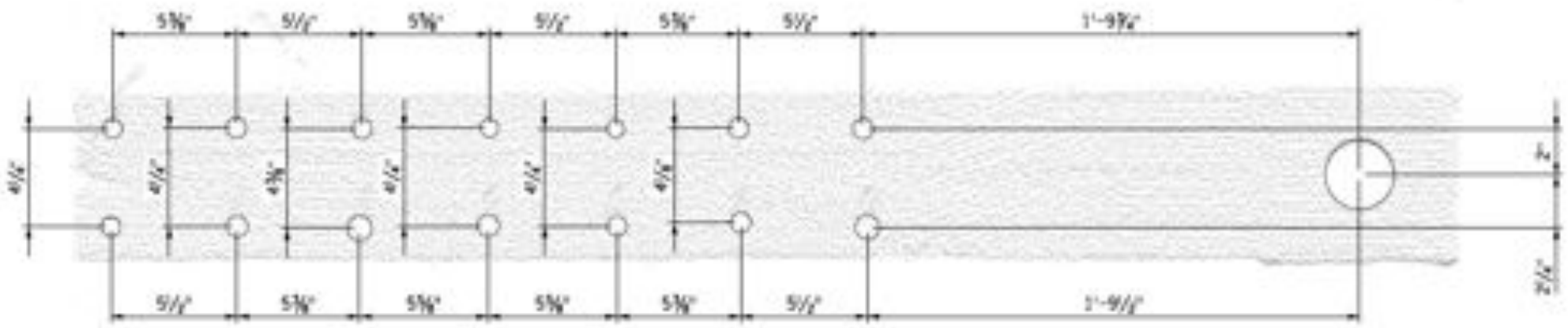
Silverdale Laser scan Data Used For:

- Replacement Portals
- Replacement End Floor beams
- Evaluation of Damaged Eyebars
- Rehabilitated/Reused Railing

Individual Portal Scan

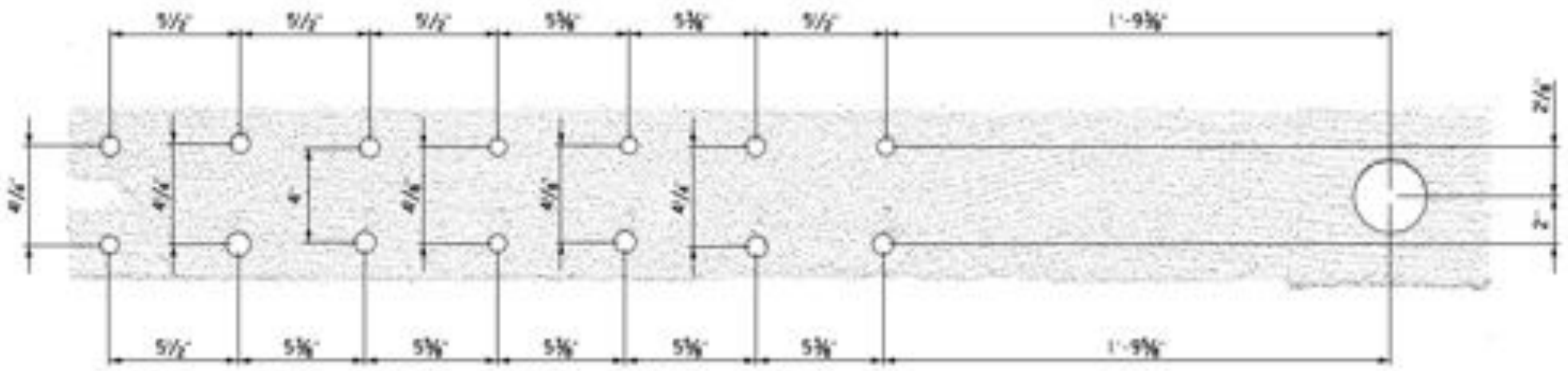


Portal Fastener Pattern 1



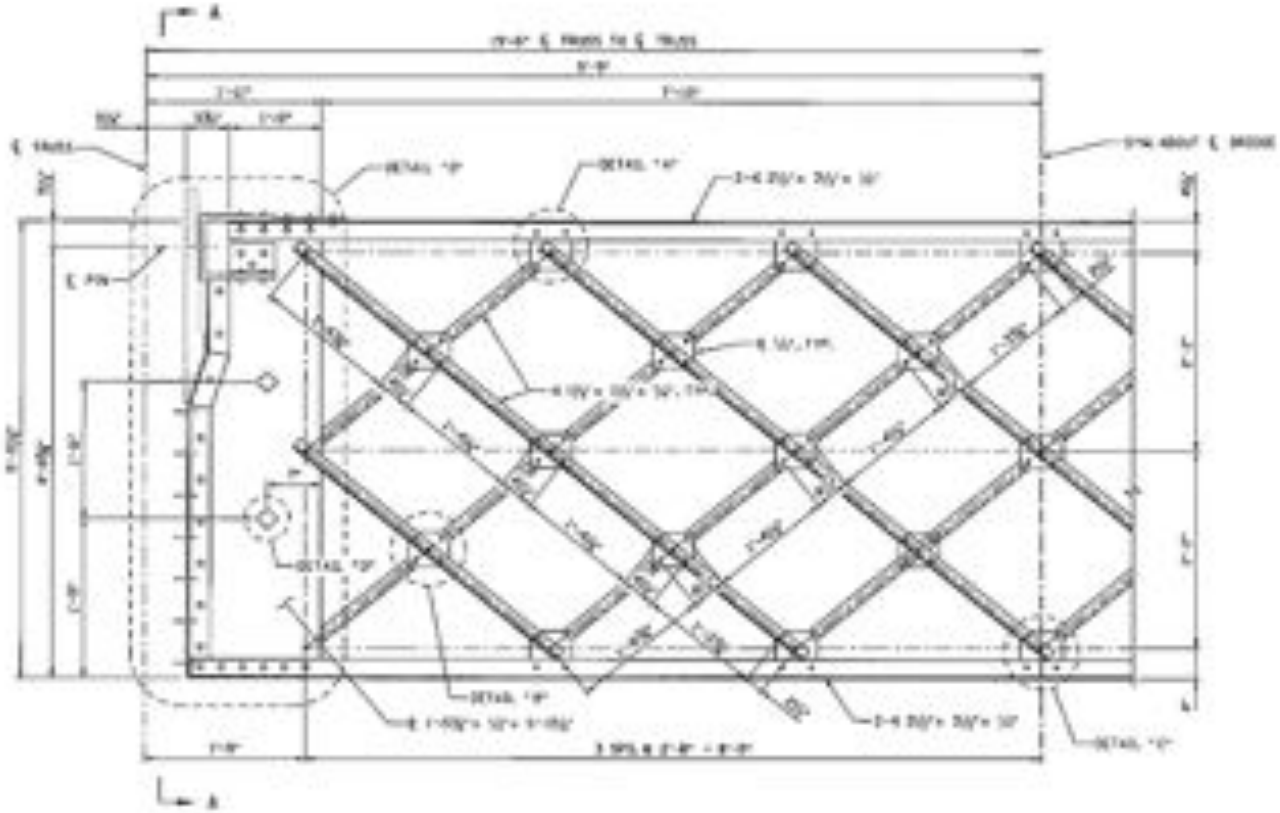
DETAIL "1"

Portal Fastener Pattern 2

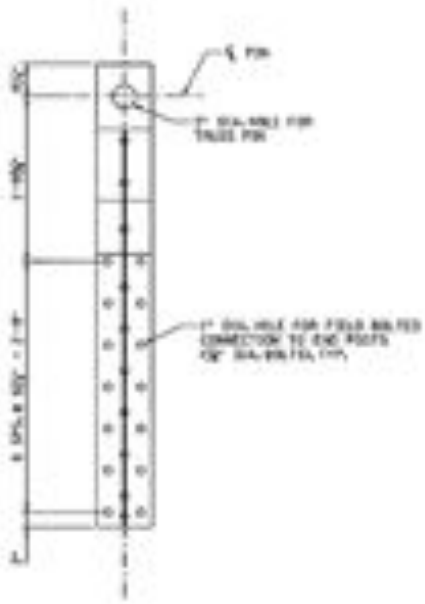


DETAIL "I"

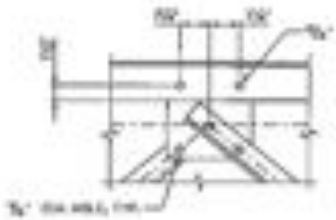
Replacement Portals -1



HALF ELEVATION

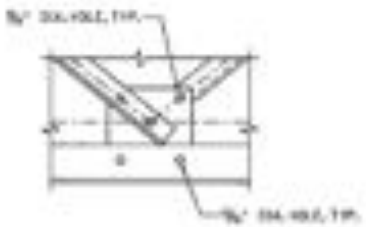


ELEVATION A-A

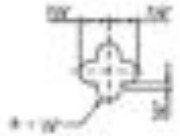


DETAIL "A"

DETAIL "B"



DETAIL "C"



DETAIL "D"

NOTES:

SEE SHEET 24 FOR DETAIL "E".

ALL PORTAL BRACING SHALL BE PERFORMED IN A FABRICATION SHOP.

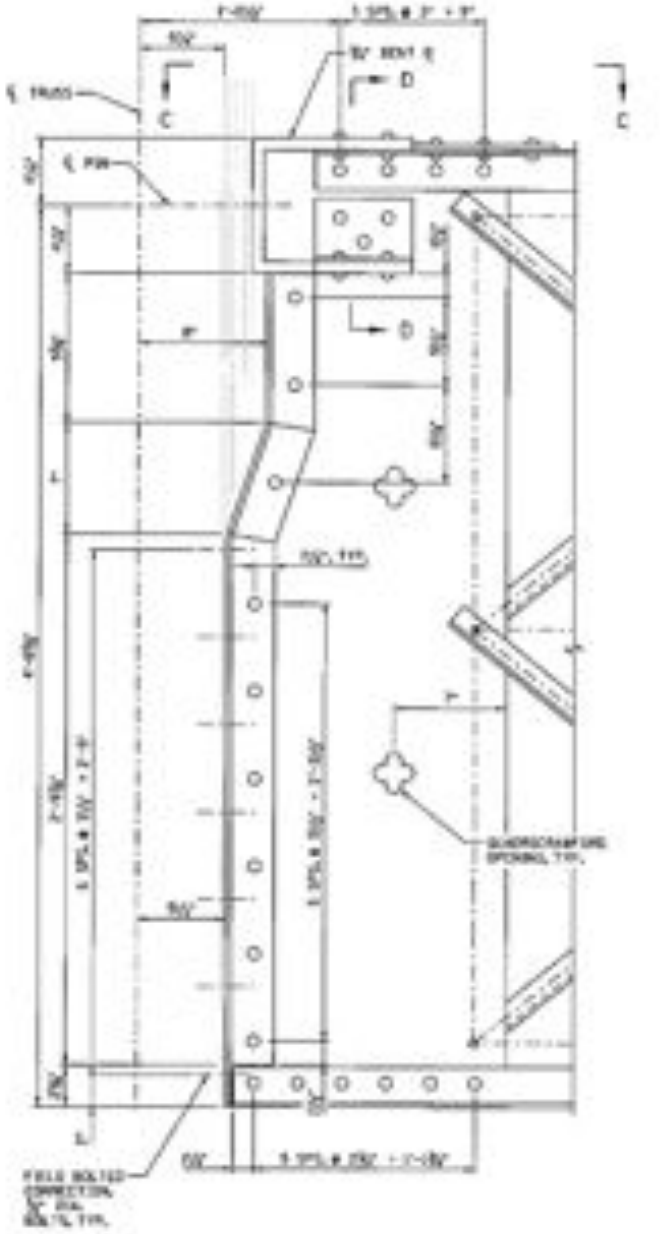
¾" RIVETS SHALL BE INSTALLED IN ¾" DIAMETER HOLES.

⅞" RIVETS SHALL BE INSTALLED IN ⅞" DIAMETER HOLES.

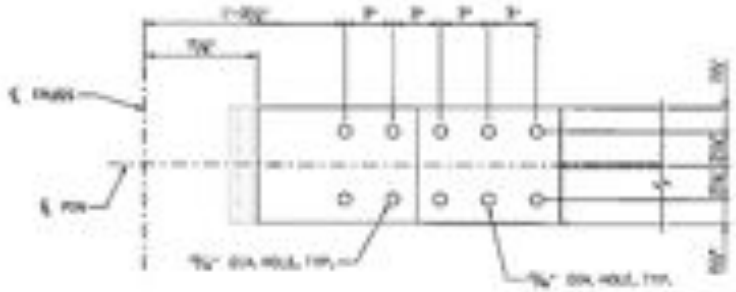
ALL ANGLES AND PLATE MATERIAL FOR NEW PORTALS TO BE A36/A36T STEEL.

THE PORTALS ARE DESIGNED TO ITEM 24501.601 "REHABILITATE HISTORIC TRUSS".

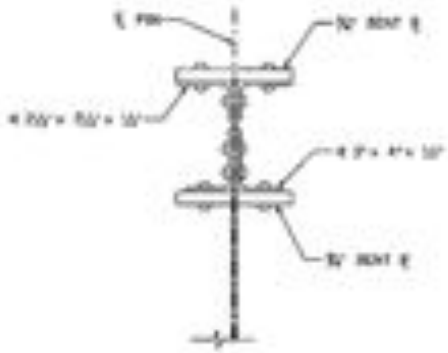
Replacement Portals - 2



DETAIL "E"



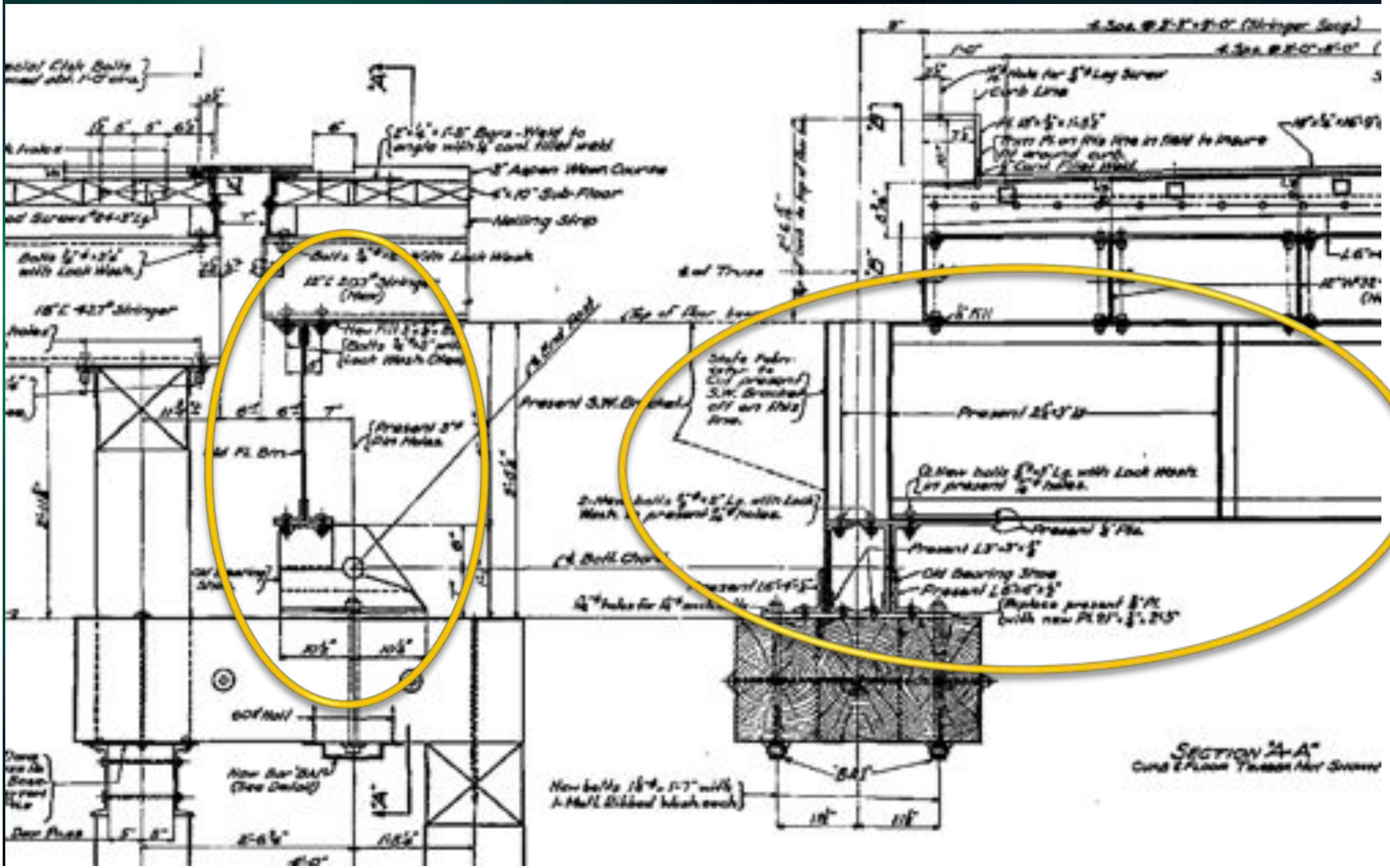
SECTION C-C



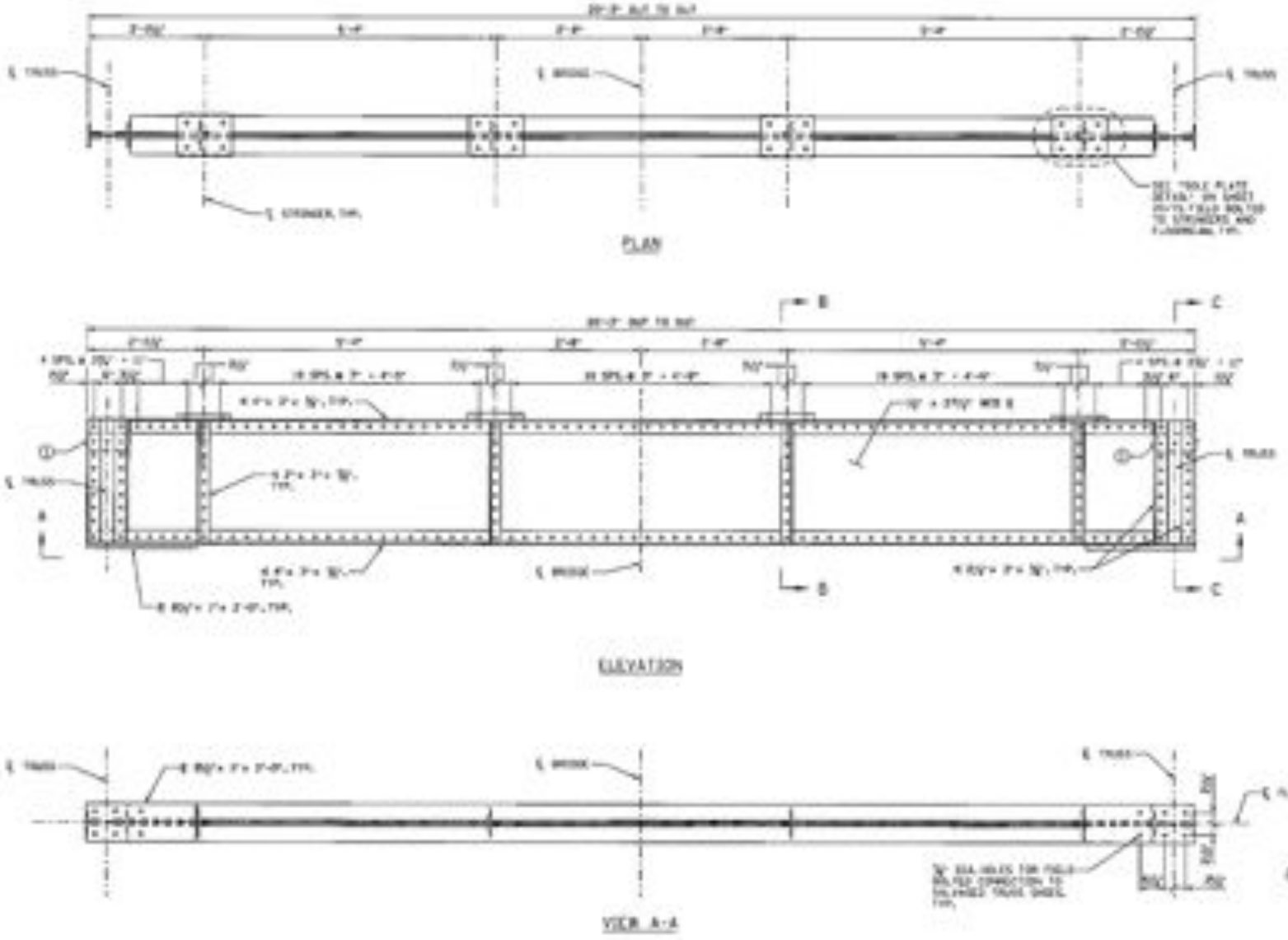
SECTION D-D

NOTE:

1937 Plans – End Floorbeams



Replacement Floor beams

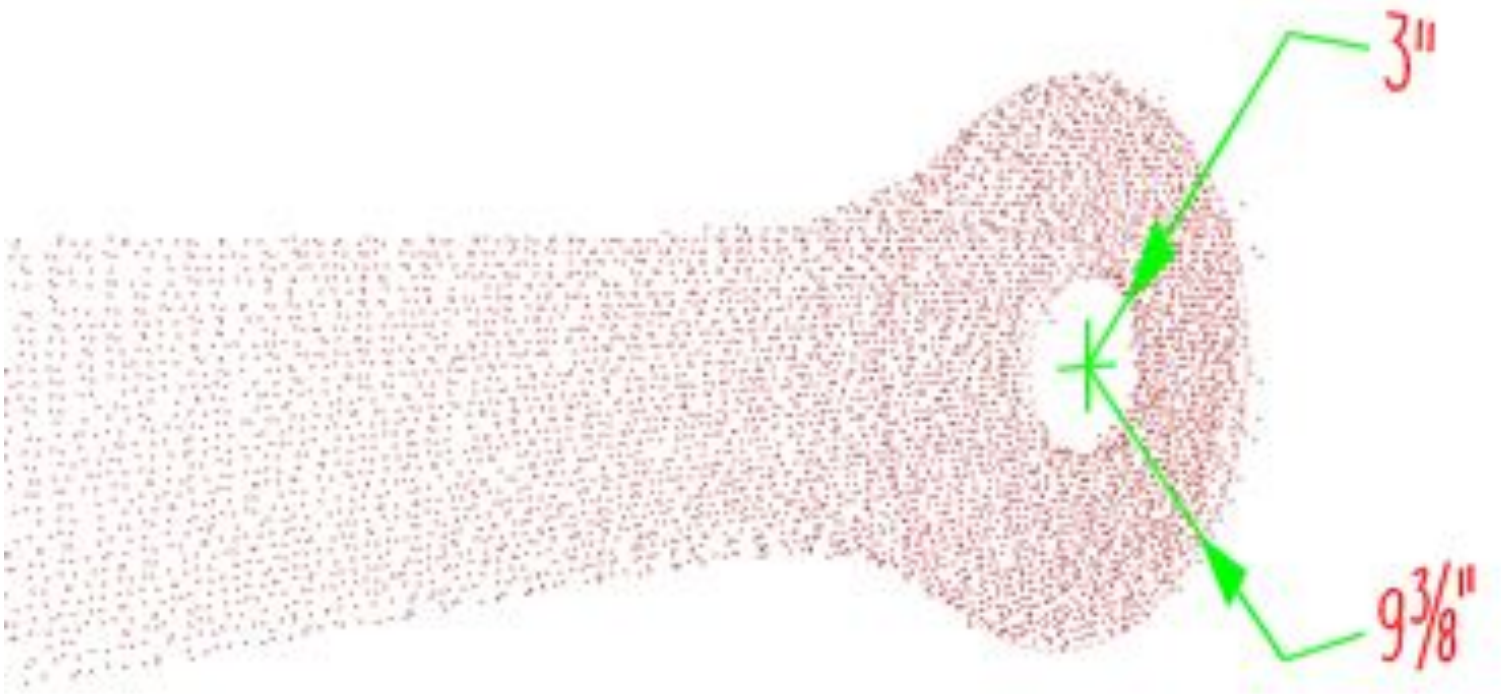


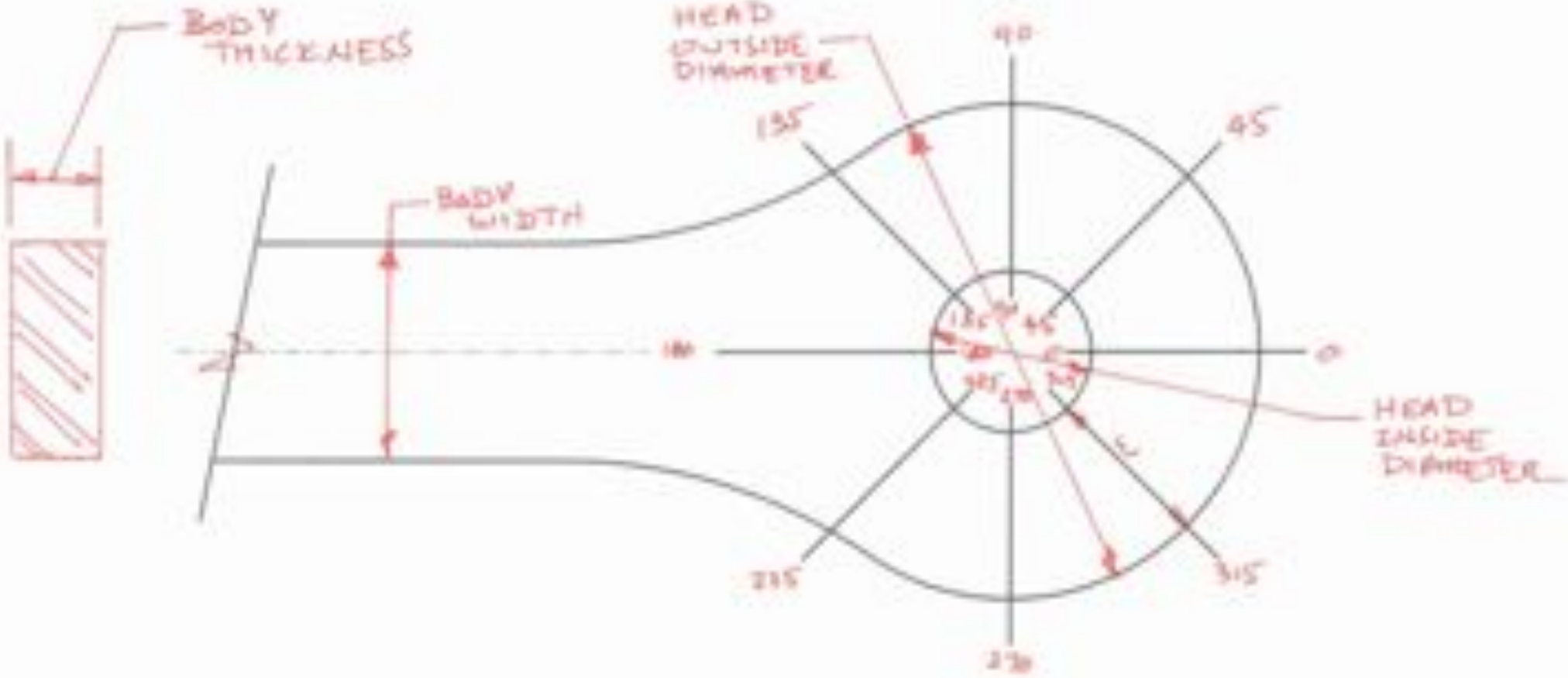

L4N U5N

Eyebar Acceptance Criteria

- Started out assuming a stress approach would be used
- Conversation with Dr. Galambos
- Computed some stresses with Timoshenko equations. But what is an acceptable stress?
- Reversed course and ended up using a geometric criteria based on AASHTO/AISC specs
  - Area at the sides needs to be at least 135% of body area
  - Area behind pin needs to be at least 75% of body area

Scan of an eyebar head





EYEBAR HEAD KEY DIAGRAM

90-90 - 1" wide x 1/2" wide gitting x 1/8" deep; 0-0 2" transverse to body x 2" along body x 1/8" deep; diameter at 0-0 is 3-5/16"

REQUIRED AREAS AT DIFFERENT HEAD SECTIONS

Section 0-0	Width	Thickness	Area
Nominal	3.25	1.13	3.66
Full Body Capacity	3.25	1.05	3.41
Minimum Body Capacity	3.25	1.05	3.41
Shop Measured	3.25	1.13	3.38042

Section 180-180	Width	Thickness	Area
Nominal	N/A	1.13	N/A
Full Body Capacity	N/A	1.05	N/A
Minimum Body Capacity	N/A	1.05	N/A
Shop Measured			

Section 45-45	Width	Thickness	Area
Nominal	3.25	1.13	3.66
Full Body Capacity	3.25	1.00	3.25
Minimum Body Capacity	3.25	1.00	3.25
Shop Measured			

Section 225-225	Width	Thickness	Area
Nominal	3.25	1.13	3.66
Full Body Capacity	3.25	1.00	3.25
Minimum Body Capacity	3.25	1.00	3.25
Shop Measured			

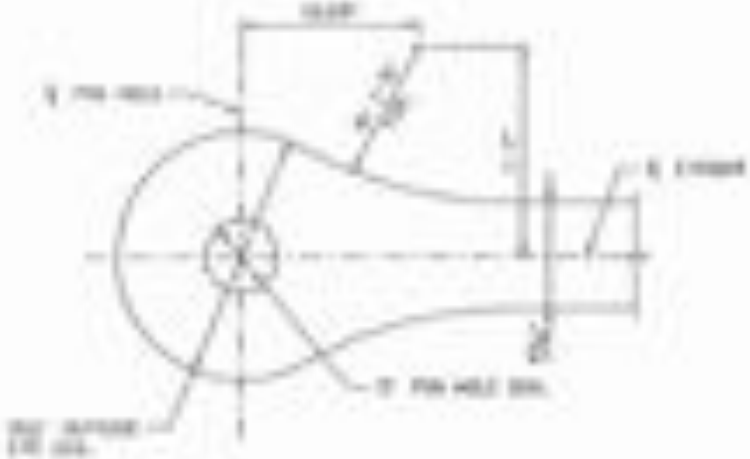
Section 90-90	Width	Thickness	Area
Nominal	3.25	1.13	3.66
Full Body Capacity	3.25	0.95	3.08
Minimum Body Capacity	3.25	0.95	3.08
Shop Measured	3.25	1.13	3.59375

Section 270-270	Width	Thickness	Area
Nominal	3.25	1.13	3.66
Full Body Capacity	3.25	0.95	3.08
Minimum Body Capacity	3.25	0.95	3.08
Shop Measured			

Section 135-135	Width	Thickness	Area
Nominal	3.25	1.13	3.66
Full Body Capacity	3.25	1.00	3.25
Minimum Body Capacity	3.25	1.00	3.25
Shop Measured			

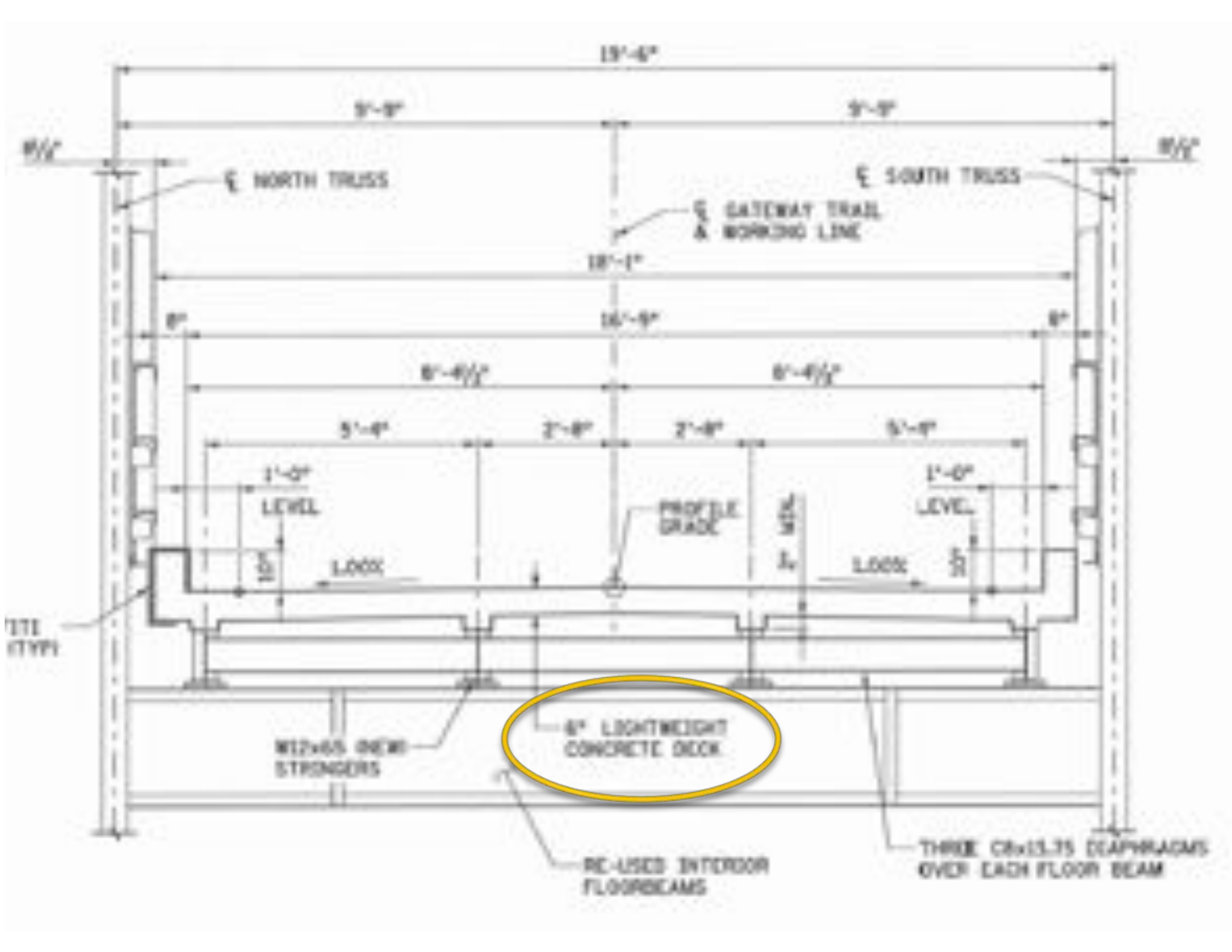
Section 315-315	Width	Thickness	Area
Nominal	3.25	1.13	3.66
Full Body Capacity	3.25	1.00	3.25
Minimum Body Capacity	3.25	1.00	3.25
Shop Measured			

EYEBAR ELEVATION



TYPICAL END DETAIL

NEW LOWER CHORD MEMBERS						


19'-6"
9'-9"
9'-9"
8½"
8½"
℄ NORTH TRUSS
℄ SOUTH TRUSS
℄ GATEWAY TRAIL
& WORKING LINE
18'-1"
8"
16'-9"
8"
8'-4½"
8'-4½"
5'-4"
2'-8"
2'-8"
5'-4"
1'-0"
LEVEL
1'-0"
LEVEL
PROFILE
GRADE
LOOK
LOOK
W12x65 (NEW)
STRINGERS
6" LIGHTWEIGHT
CONCRETE DECK
RE-USED INTERIOR
FLOORBEAMS
THREE C8x13.75 DIAPHRAGMS
OVER EACH FLOOR BEAM


RSC
S-60


Genie S-60


Genie S-60

Gateway Trail over Manning Ave.

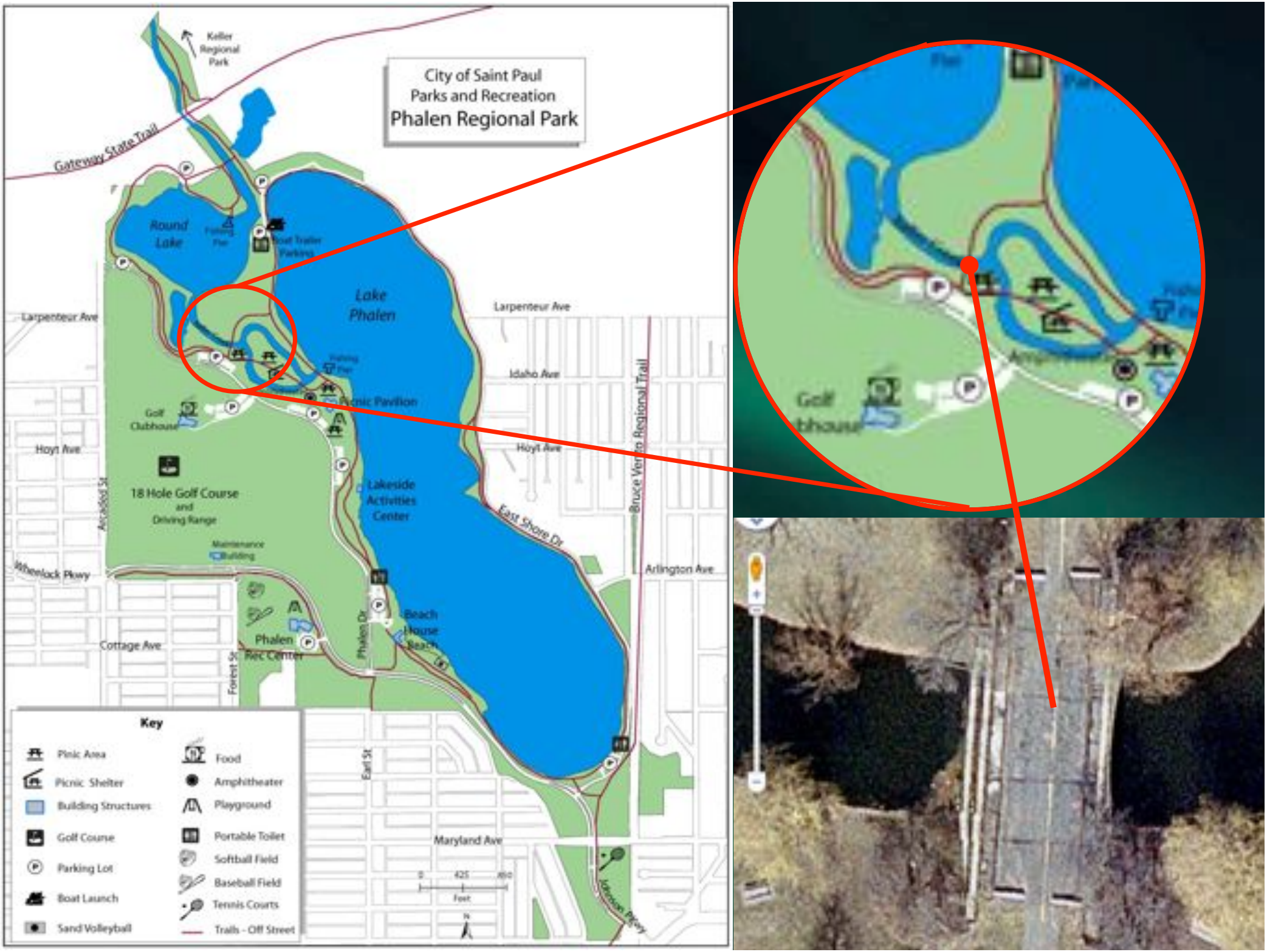
Bridge lift - 05/20/2011

Benefits of Laser-scanning

- Dramatically cut the amount of field time required to collect geometric data for the rehabilitation project. In addition, more information was collected than what we would have planned for up front using older methods.
- Allowed us to readily detail replacement portals
- Allowed us to readily detail replacement floor beams
- Helped us evaluate the eyebars. Eyebar head geometry was pulled from the laser scans.

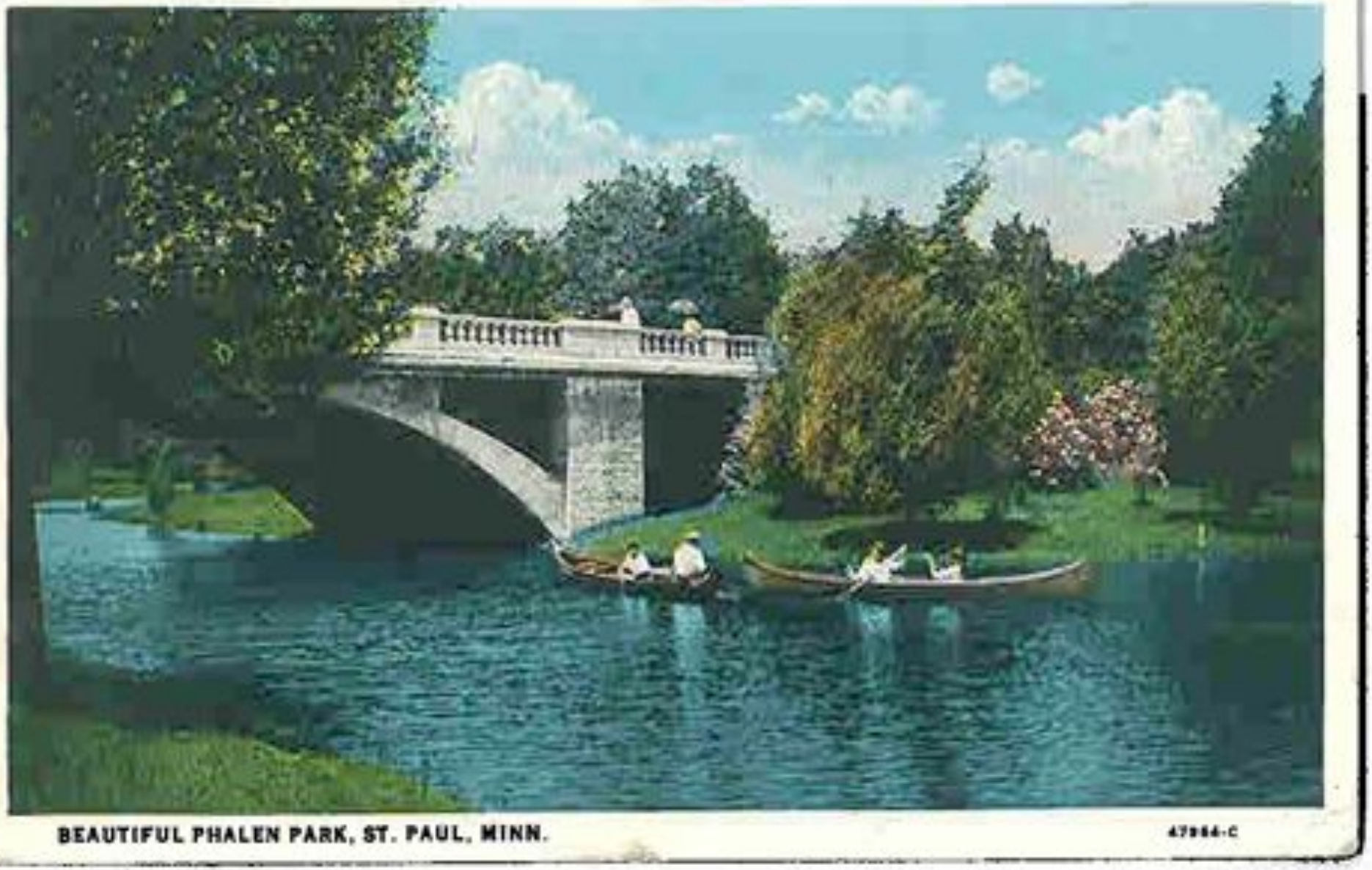
Rehabilitation of the Phalen Park Arch Bridge (L8560)

Saint Paul Parks and Recreation

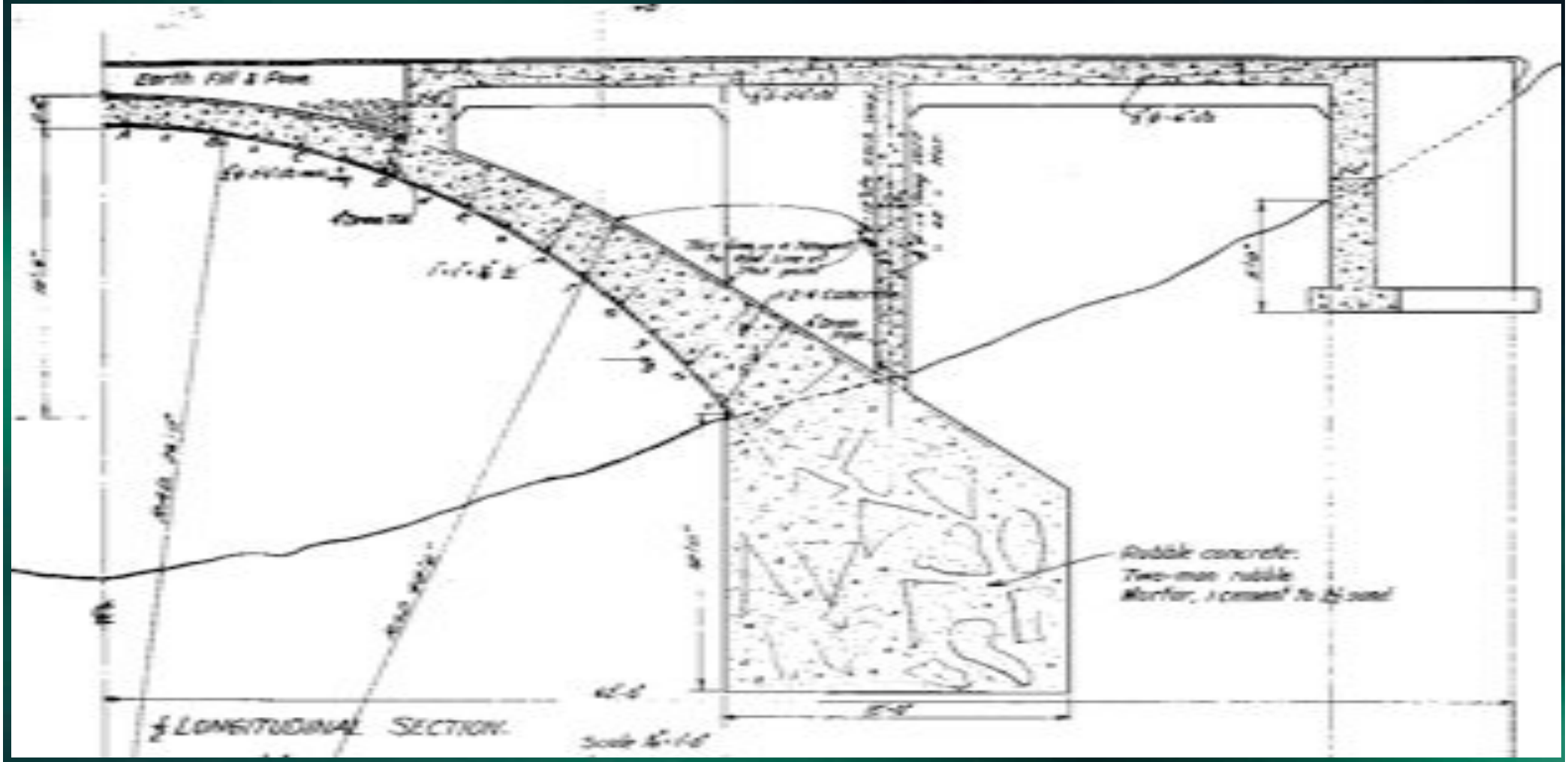

City of Saint Paul
Parks and Recreation
Phalen Regional Park
Keller Regional Park
Gateway State Trail
Round Lake
Fishing Pier
Boat Trailer Parking
Lake Phalen
Larpenteur Ave
Idaho Ave
Hoyt Ave
Golf Clubhouse
Picnic Pavilion
18 Hole Golf Course and Driving Range
Lakeside Activities Center
Maintenance Building
Wheelock Pkwy
Arcadia St
East Shore Dr
Bruce Vento Regional Trail
Arlington Ave
Phalen Dr
Beach House
Beach
Phalen Rec Center
Cottage Ave
Forest St
Earl St
Maryland Ave
Johnson Pkwy
0 425 850
Feet
N
Key
Pinic Area
Picnic Shelter
Building Structures
Golf Course
Parking Lot
Boat Launch
Sand Volleyball
Food
Amphitheater
Playground
Portable Toilet
Softball Field
Baseball Field
Tennis Courts
Trails - Off Street


BRIDGE
CLOSED

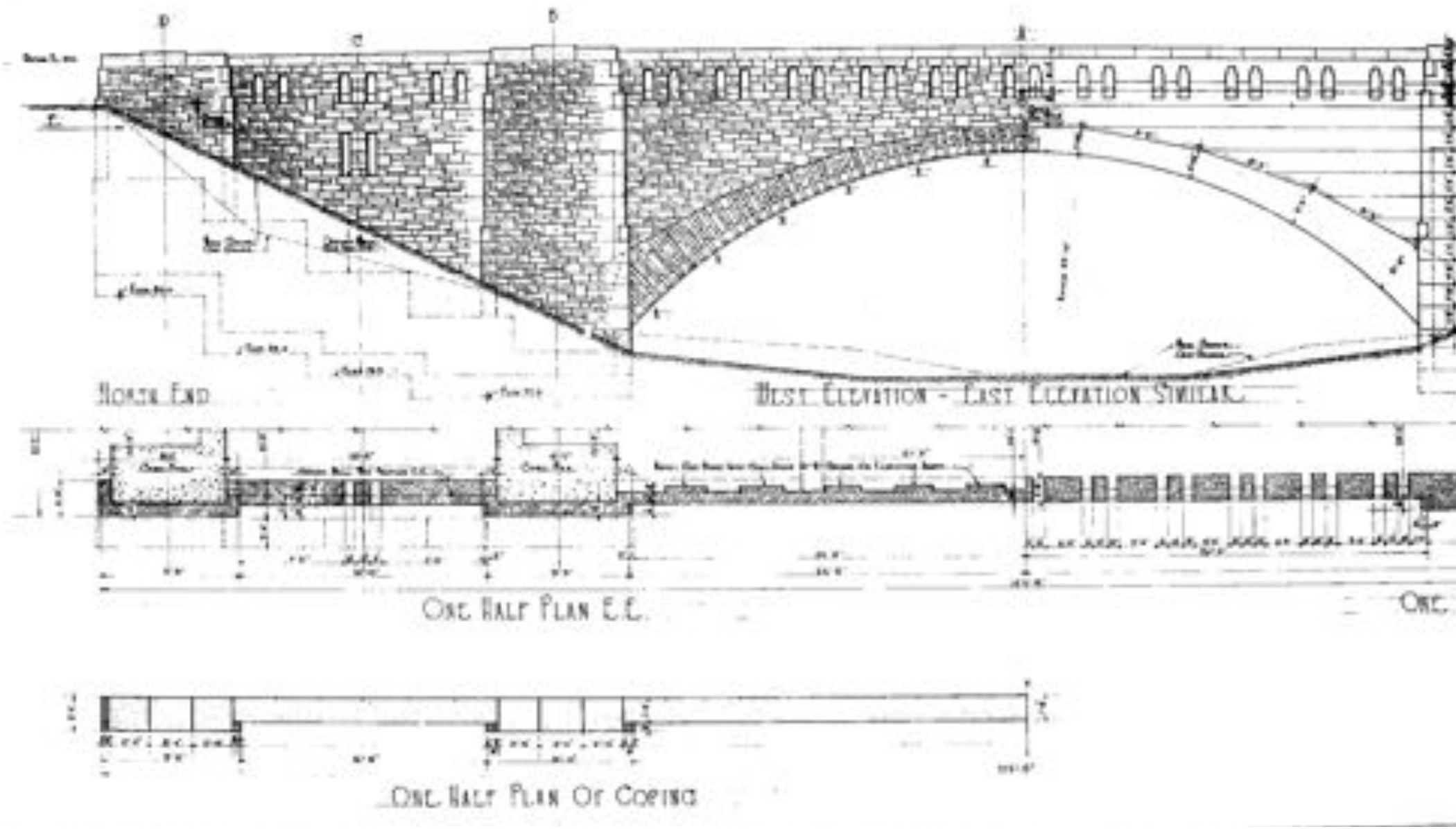
2007 Study


BEAUTIFUL PHALEN PARK, ST. PAUL, MINN.
47984-C

Original 1910 Concrete Arch Details



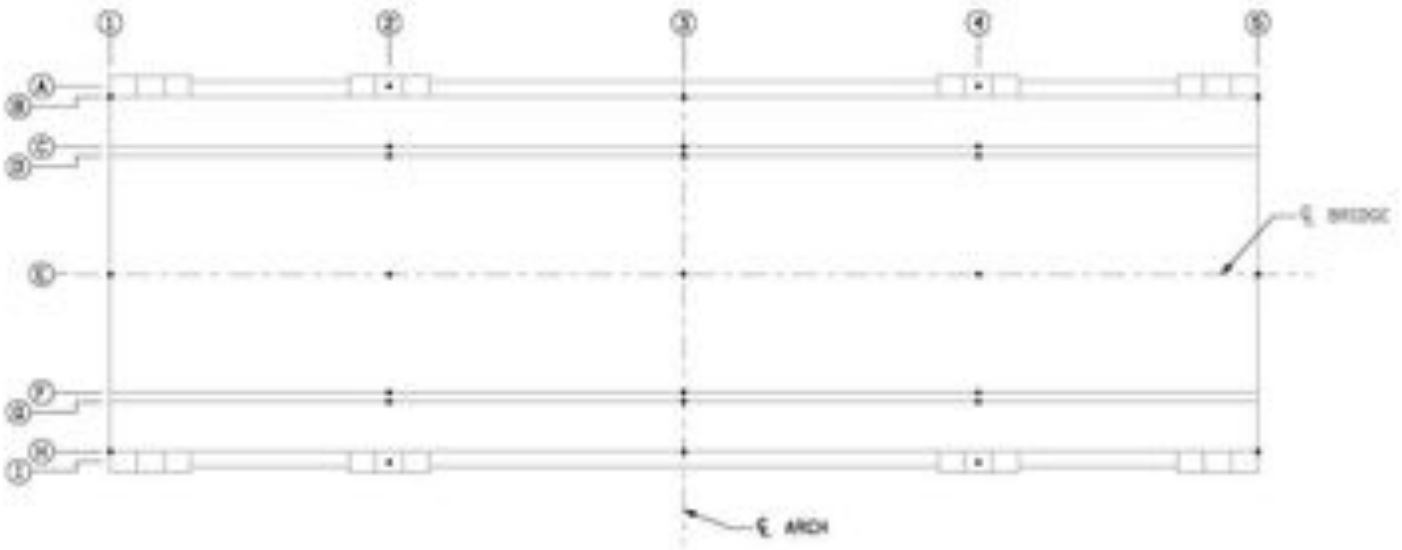
1934 CWA Rehab



2007 Study

COLUMN	APPROX. DISTANCE BETWEEN COLUMNS
1-2	30'-8"
2-3	31'-1"
3-4	31'-1"
4-5	30'-8"

ROW	APPROX. DISTANCE BETWEEN ROWS
A-B	1'-2"
B-C	4'-3"
C-D	1'-0"
D-E	13'-1"
E-F	13'-1"
F-G	1'-0"
G-H	4'-3"
H-I	1'-2"

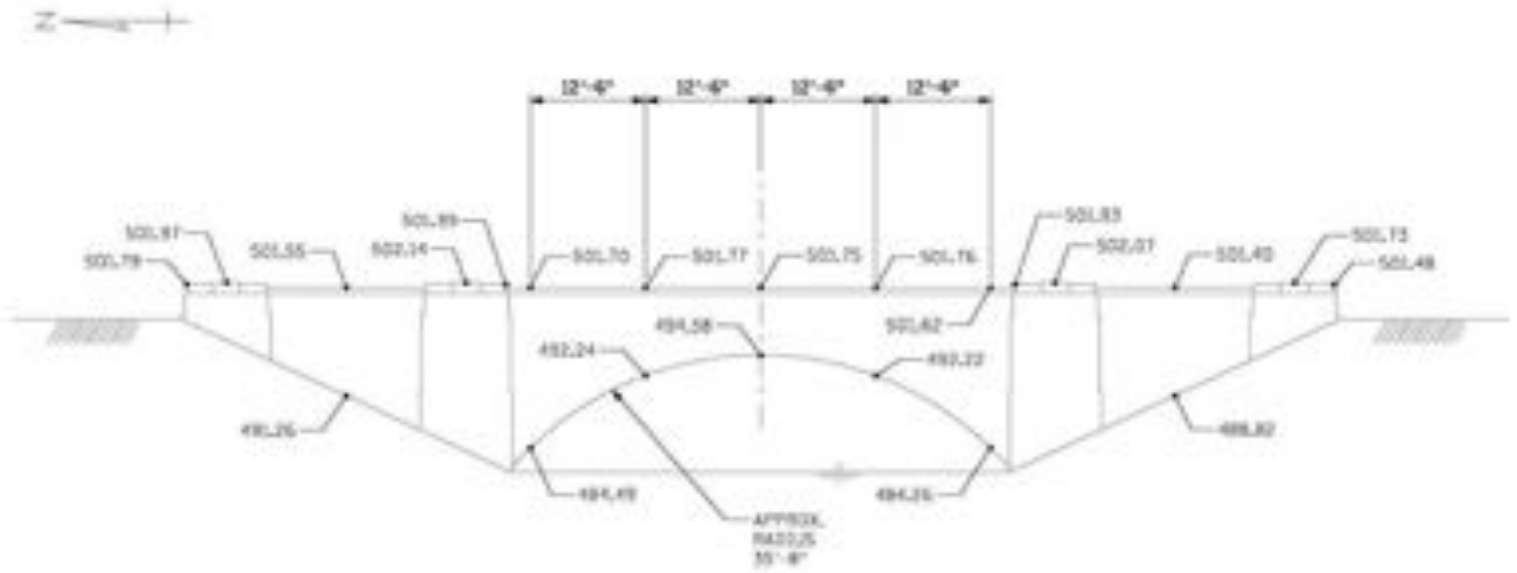


PLAN

ELEVATIONS						
		COLUMN				
		1	2	3	4	5
ROW	A	---	502.03	---	502.01	---
	B	501.47	---	501.77	---	501.77
	C	---	498.48	498.64	498.57	---
	D	---	498.01	498.26	498.19	---
	E	497.72	498.06	498.27	498.19	497.98
	F	---	497.95	498.19	498.13	---
	G	---	498.41	498.64	498.49	---
	H	501.65	---	501.65	---	501.81
	I	---	502.04	---	502.06	---

PHALEN PARK
ARCH BRIDGE
SURVEY
FIGURE 1
1-19-07

HNTB



WEST ELEVATION

PHALEN PARK
ARCH BRIDGE
SURVEY
FIGURE 2
1-19-07

HNTB

Compressive Strength Test Results

Sample Number	Core Number	Compressive Strength (PSI)
1	5- to 4-inch-diameter core	7,430
2	7- to 3-inch-diameter core	4,290

Note: core number 6 was not testable due to the poor condition of the core

Results

Chloride Ion Content

Sample Number	Core Number/Location	Sample Depth	Chloride Ion Content (PPM)
1	1 – topside, gutter	0-1 inches	640
2	1	1-2 inches	240
3	2 – topside, roadway	0-1 inches	130
4	2	1-2 inches	130
5	3 – topside, gutter	0-1 inches	91
6	3	1-2 inches	94
7	4 – topside, sidewalk	0-1 inches	510
8	4	1-2 inches	400
9	7 – underside, arch	0-1 inches *	470
10	7	1-2 inches *	860

*Core number 7 was taken from the underside of the concrete arch. Sample depths were referenced to the underside not the topside.

Rehabilitation Strategy

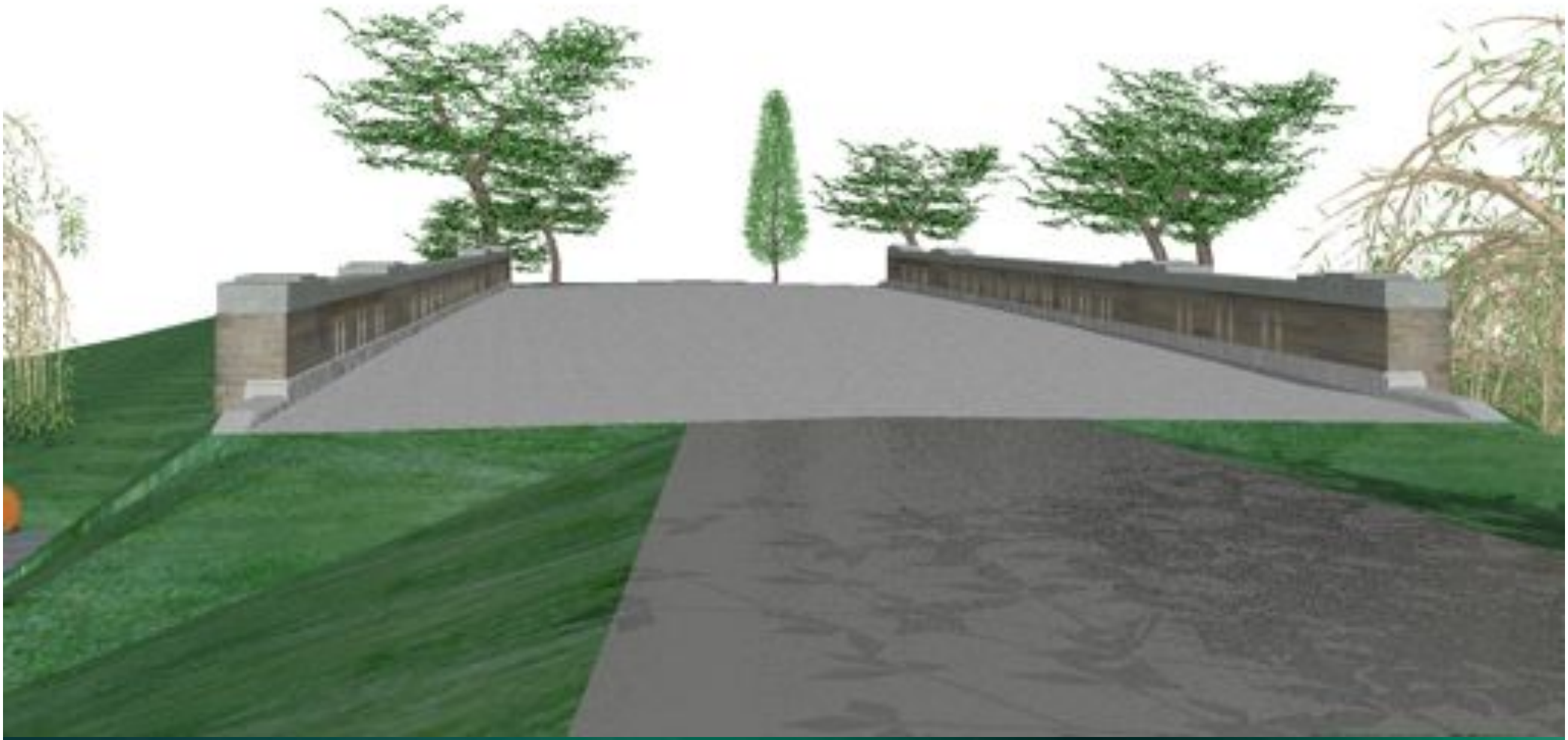
The proposed rehabilitation strategy is based on the following assumptions:

1) The arch concrete itself is too delaminated and contaminated with chlorides to be considered a candidate for rehabilitation. Any rehabilitation process is likely to meet a similar fate to that of the earlier applied shotcrete, a fix with a modest service life and future headaches.
2) To prevent the continued intrusion of water into the concrete components of the bridge, it is imperative that a new concrete deck system be used to seal the top of the bridge.
3) The existing arch structure has sufficient strength to facilitate the construction of the arch liner system

STONE ARCH BRIDGE REHABILITATION

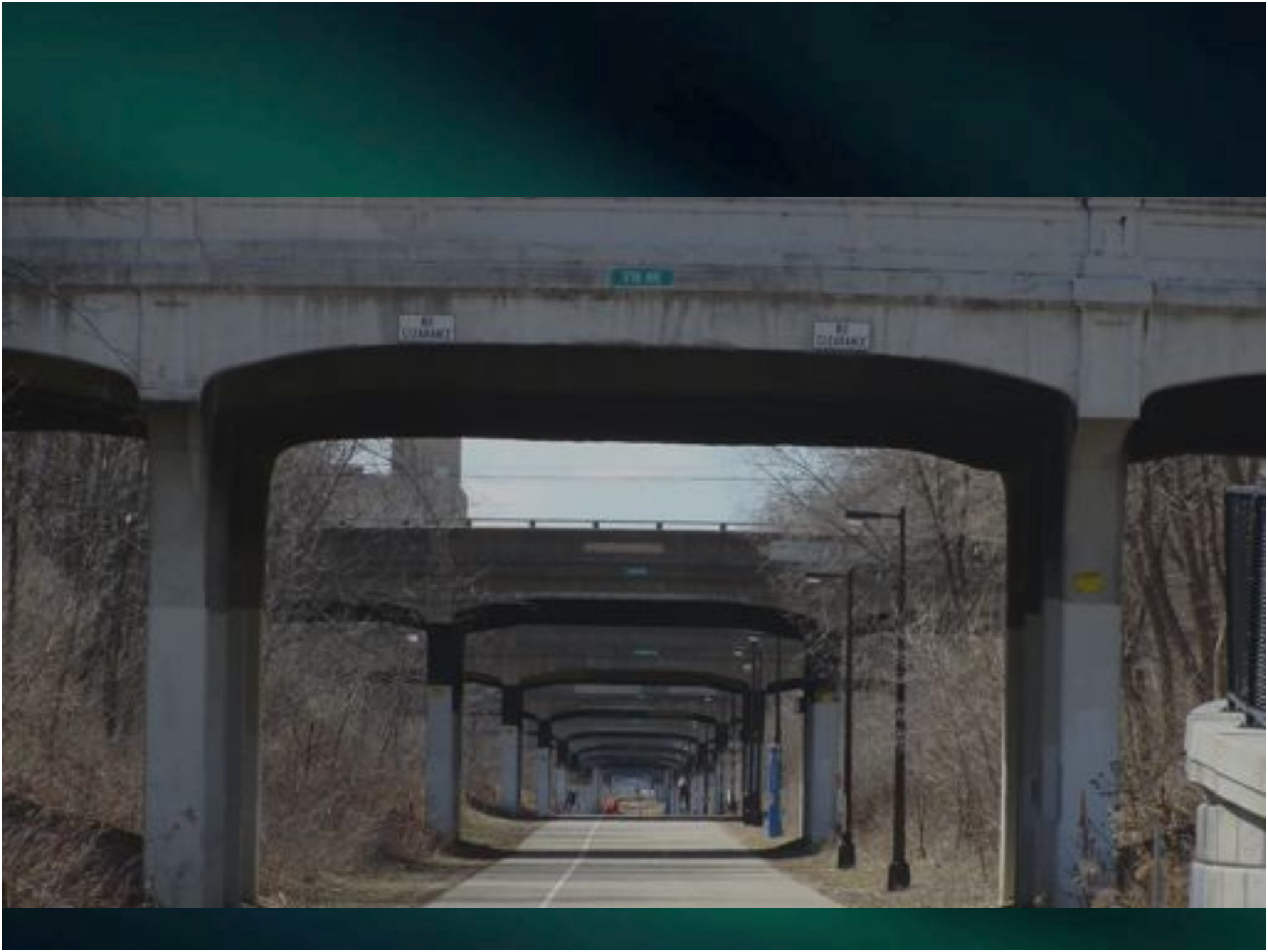
LAKE PHALEN PARK

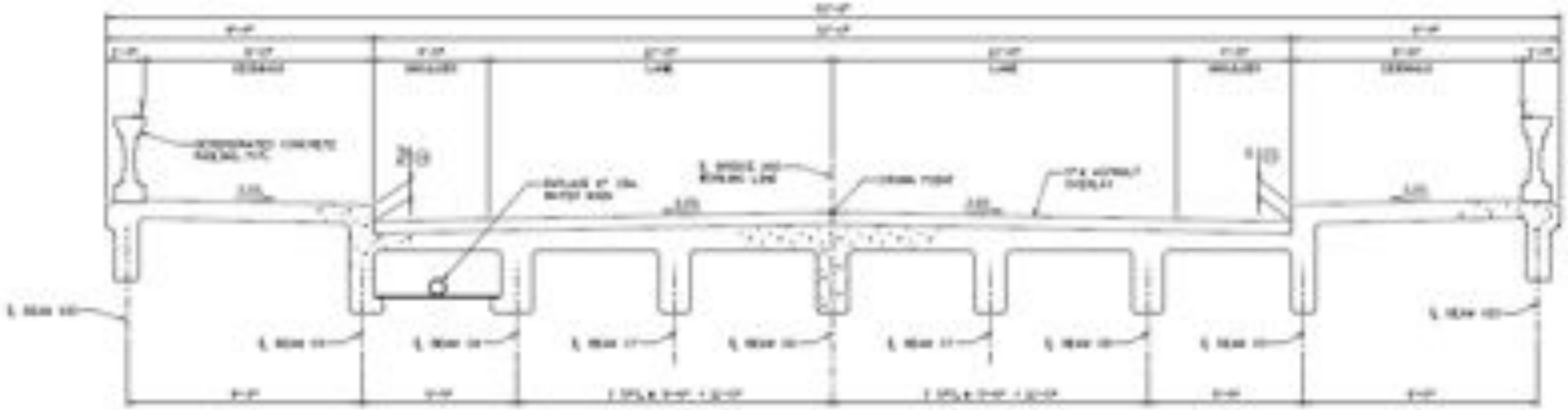
ST. PAUL, MN



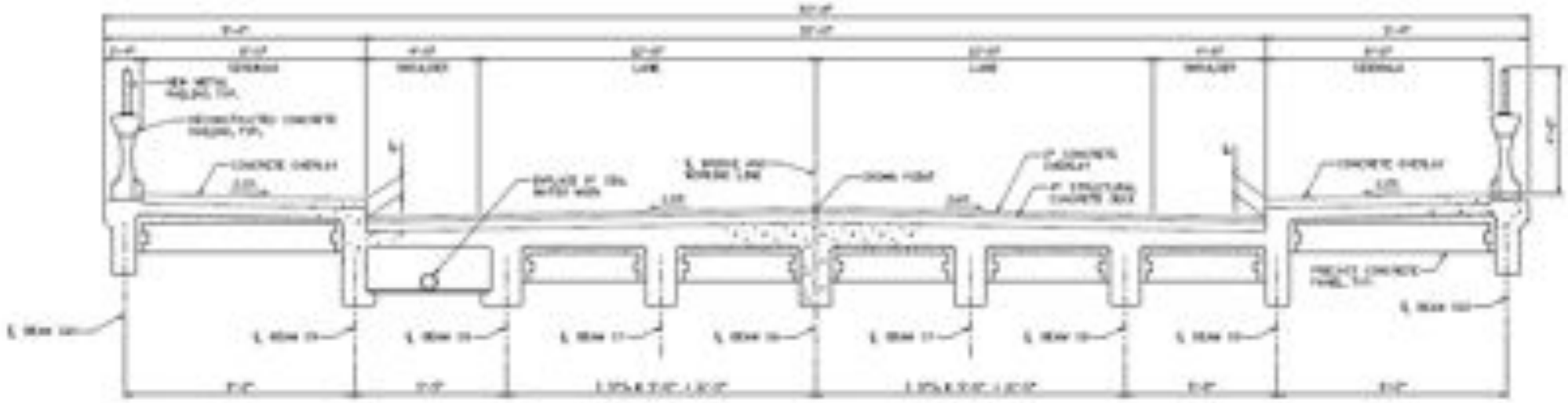
Rehabilitating the 15th and 16th Avenue Bridges over the Midtown Greenway (1916 Reinforced Concrete T-beam bridges)

Midtown Greenway Historic District



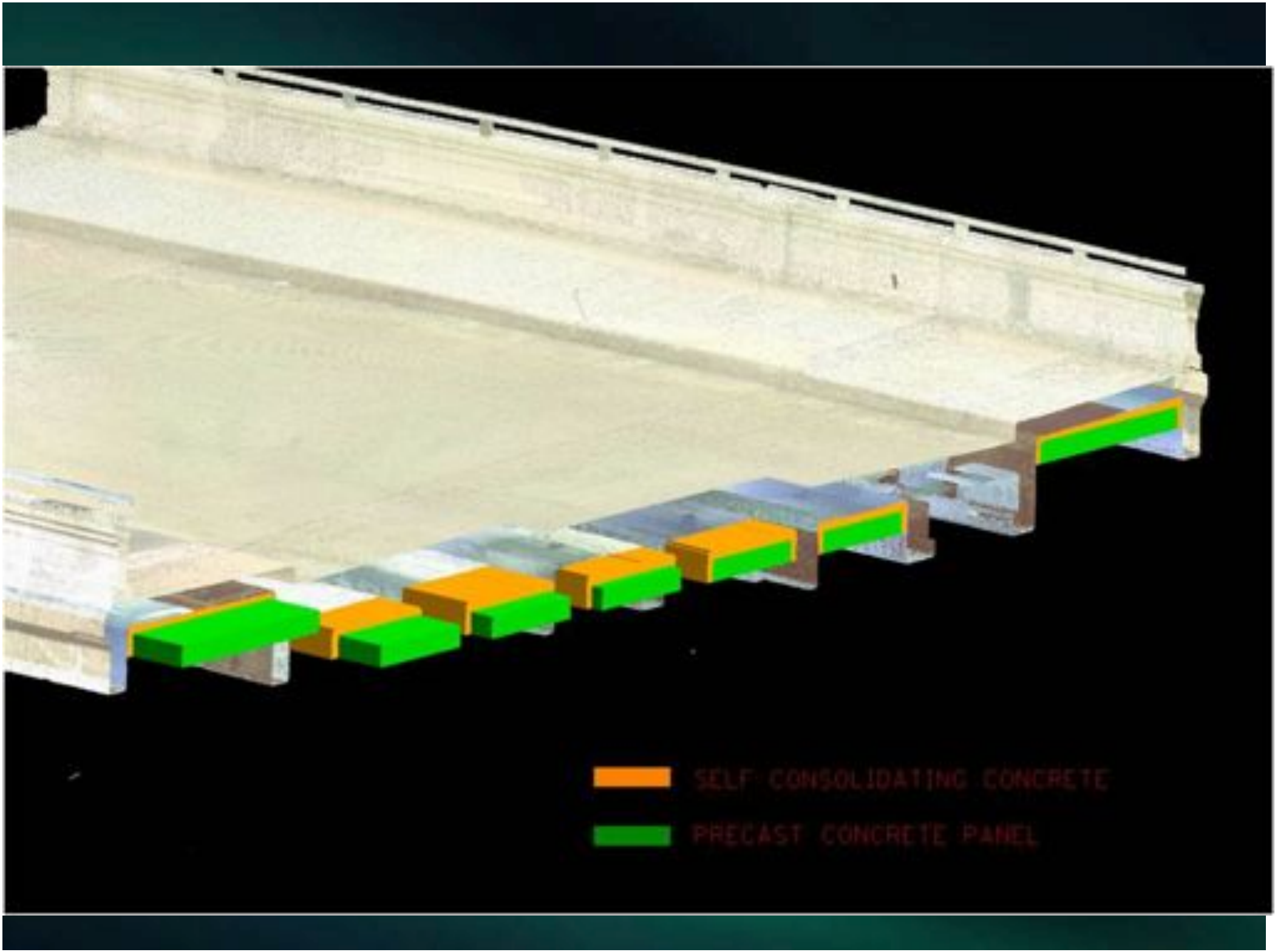


EXISTING TRANSVERSE SECTION



PROPOSED TRANSVERSE SECTION

NOTES:


SELF CONSOLIDATING CONCRETE
PRECAST CONCRETE PANEL

In summary

- For many structures, laser-scanning may prove to be a very cost-effective method to collect field data
- Consider using new materials such as lightweight concrete and self-consolidating concrete
- Be creative and consider providing alternate load paths