Kennedy Bridge Planning Study

Technical Memorandum:

Bridge Replacement Options

MnDOT S.P. No. 6018-02

Prepared for:

Minnesota Department of Transportation

FINAL

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Prepared by:

Report Purpose:
This memorandum presents an assessment of potential bridge replacement options that were developed, including preliminary plan and profile, bridge type evaluation, and preliminary cost estimates, for comparison to the preliminary rehabilitation alternatives that are also part of this study.

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
DNR	Department of Natural Resources
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
LRFD	Load and Resistance Factor Design
MnDOT	Minnesota Department of Transportation
NDDOT	North Dakota Department of Transportation
USACE	U.S. Army Corps of Engineers

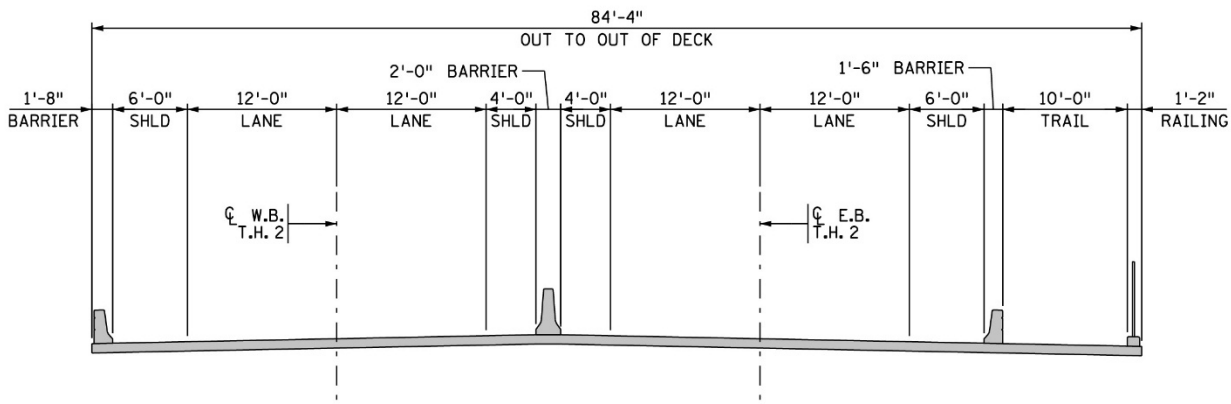
SECTION 1

Bridge Replacement Options

Complete replacement of the existing Kennedy Bridge over the Red River of the North is considered in this memorandum as an initial comparison to the conceptual-level rehabilitation alternatives. Replacement could be selected over rehabilitation for future project development, but only if a rehabilitation project cannot provide a feasible and prudent solution that meets the primary need of maintaining a structurally sound crossing at this location. Replacement can only occur after a thorough process that follows Minnesota Department of Transportation (MnDOT), Federal Highway Administration (FHWA), and State Historic Preservation Office protocols, and National Historic Preservation Act Section 106 regulations evaluating impacts to the existing bridge and historic properties in the vicinity.

A replacement bridge would provide for carrying two lanes of traffic in each direction with shoulders, a center barrier dividing eastbound and westbound traffic, and at least a 10-foot-wide shared-use path (potentially on the south side). The result would be an overall bridge deck width of approximately 85 feet as shown in Figure 1-1.

FIGURE 1-1
Proposed Bridge Deck Cross Section



Bridge replacement options include consideration of several different roadway alignments and bridge superstructure types. In addition to the description of the bridge in the previous paragraph, each option should satisfy the design parameters listed in the following subsection in order to be considered viable. A description and evaluation of the bridge replacement options considered viable, including construction costs and duration, are provided in Section 1.2, Bridge Replacement Options.

1.1 Design Parameters

The design parameters described in the following subsections are the primary requirements for the bridge replacement options. They were developed by coordinating with MnDOT, North Dakota Department of Transportation (NDDOT), FHWA, and several regulatory agencies.

1.1.1 Fixed Pier near the Center of the Red River

There is a history of the river banks sloughing-in towards the center of the river channel. The sloughing occurs relatively slowly over time and carries with it anything embedded in the soil, including bridge piers.
The movement appears to be minimal near the center of the main channel, so it is desirable to locate the main river pier at that location.

A bridge replacement project at this location is not over a navigable waterway used for or susceptible to use for substantial interstate commerce, and it is not on the list of waterways requiring bridge permits in Minnesota.

1.1.2 Accommodate Horizontal Earth Movement

Due to the historic horizontal sloughing of the river banks, which is not expected to stop, the bridge must be able to accommodate a future horizontal movement. Refer to the *Geotechnical Conditions Memorandum* and the *Technical Memorandum: Summary of Pier 6 Movement Records* for additional information on the historic record of movement and inclinometer data. The allowed movement will be a minimum of 4 feet towards and 1 foot away from the center of the river channel. The bridge superstructure, substructure, foundation, and bearings must be designed to accommodate the movement, or have features to allow structural adjustments to be made in the field by maintenance crews. For example, the bridge superstructure shall have a constant depth near the piers to allow bearings to be adjusted, if necessary.

1.1.3 Structural Redundancy

The replacement bridge will have a structurally redundant superstructure. Specifically, all superstructure members will be load-path redundant. Load-path redundant means that if any one structural member fails at a given time, the bridge or deck will not collapse.

1.1.4 Bridge Type and Aesthetics

This evaluation identifies replacement options that are cost efficient for various bridge types, provide for the necessary roadway geometrics, and meet a variety of design parameters. Preference will be given to using standard construction procedures and types familiar to bridge construction firms in the area. It will be designed in accordance with current American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) and MnDOT bridge specifications for a design life of 75 years. The design will have relatively low long-term maintenance costs and will easily accommodate future widening of U.S. Trunk Highway 2. Bridge-mounted light poles are expected for traffic safety and scuppers for bridge deck drainage.

A signature-type cable bridge or bridge with spans exceeding 300 feet are not desired because of the likely high cost. The aesthetics of the underside of the bridge over the Greenway trails and other recreational amenities is a consideration. Specific aesthetic features beyond general bridge type are not addressed in this early scoping-level study. If the project moves to replacement as the necessary option, a detailed evaluation of aesthetic features and possibilities would be undertaken.

This study development of the most promising bridge types is not intended to be a final selection; however, it provides a reasonable range of options to make comparisons to rehabilitation in future project development. Final identification of bridge type and aesthetics would need to include assessment of the effect on surrounding historic properties and avoidance, reduction, and/or mitigation of the effect per Section 106 (and Section 4(f)).

1.1.5 River Hydraulics

The replacement bridge will need to meet the requirements of the Federal Emergency Management Agency (FEMA), MnDOT, NDDOT, the Department of Natural Resources (DNR), and the U.S. Army Corps of Engineers (USACE). Since the bridge is located within a Flood Insurance Study Zone AE, FEMA requires that a no-rise in the 100-year flood elevation be provided by the replacement bridge compared to the existing conditions. The state DNRs require that a 3-foot vertical clearance (freeboard) be provided over the main channel between the low chord of the bridge and the 50-year flood elevation. Also, USACE has requirements for construction near levees. In addition, the replacement bridge will need to be designed to accommodate predicted scour of the riverbed.

1.1.6 Roadway Alignment and Profile

Alignments and profiles must tie into the existing roadway systems on both sides of the river with acceptable geometrics for the given design speed. Impacts to historic properties, including St. Michael's Hospital and Nurses' Residence and the Riverside Neighborhood Historic District, the State Park and campground, and utilities are desired to be minimized. Four potential alignments, A-D were identified for consideration, and an evaluation matrix was developed (see Exhibit 1-1).

After evaluation by the study team, including MnDOT and other stakeholders, Alignment D was dropped from further consideration. Alignment D would require significant horizontal curvature to shift the alignment south and then north again. There is also a conflict with a high-mast power transmission line that makes the alignment less desirable than those to the north of the existing bridge. A replacement bridge along Alignment A, the existing Kennedy Bridge alignment, would have major impacts to traffic operations during construction. Construction challenges include the need to build a temporary bridge to maintain traffic at this location during construction. Alignment A will also have significant additional costs for the temporary bridge and impacts to traffic during transitions from existing, to temporary, to the final bridge configuration.

Alignments B and C remain as the more viable options and provide for evaluating a range of potential costs for bridge replacement alternatives. Both alignments allow the existing bridge to continue to carry traffic throughout most of the construction of the replacement bridge. Alignment B closely parallels the existing bridge on the north side and ties back into the existing roadway alignment as quickly as possible at each end. Alignment C also parallels the existing bridge on the north side, but extends to the east beyond the existing 4th Street NW interchange, and includes replacing the bridge over 4th Street NW. Preliminary roadway profiles for the steel deck girder superstructure options (as shown in Exhibit 1-2) were developed for alignments B and C. The profiles satisfy the requirements for providing adequate freeboard over the 50-year flood elevation and adequately tying into the existing roadways at each end of the bridge.

1.1.7 Traffic Impacts

It is desirable that two lanes of traffic in each direction be maintained throughout the majority of the construction process. It is acceptable to have short durations of one lane of traffic in each direction, or brief complete closure, during tie-in activities to the existing roadway system at each end.

1.1.8 Project Risk

The replacement bridge type selected should minimize project risk for MnDOT, NDDOT, and the local communities. Minimizing risk involves controlling costs, construction duration, traffic flow, and impacts to sensitive cultural, historical, and environmental areas. Risk can also be reduced by having clear design plans with minimal errors, and using construction materials and techniques that are routinely used by area contractors.

1.2 Bridge Replacement Options

Multiple bridge types were considered and evaluated for the bridge replacement to determine practical and cost-effective choices demonstrating a range of alignment options. Regarding the bridge superstructure, a “Superstructure-Type Evaluation Matrix,” was developed to review several different superstructure types for use (see Exhibit 1-3). Superstructure types included on the matrix include steel I-girder, tub girder, truss, and arch. The matrix also includes prestressed concrete beams and cast-in-place concrete box girders. The project team reviewed this matrix over the course of several months and agreed that the concrete superstructures were not practical for use on this project. The primary reason for eliminating them from further consideration is their difficulty in accommodating the expected horizontal earth movement. Prestressed concrete beams are typically not continuous over piers, which would make it difficult to shift the support locations over a horizontally moving pier. Also, the increased weight of the concrete superstructures compared to steel would make jacking the superstructure and moving the bearings more difficult if maintenance adjustments are required. Moving forward, the steel superstructure types shown in the matrix were all considered viable for use.

Bridge piers and abutments will need to be designed and detailed to support the superstructure, resist flow and debris loads from the Red River, and accommodate the expected horizontal earth movement. It is expected that the piers within levees of the river will be a solid concrete wall-type aligned mostly with the flow of the river. The pier caps will likely be wide enough to account for any anticipated shifting of the bearings that is required due to horizontal movement of the superstructure. Alternative substructure types and shapes are not addressed in this memorandum.

The foundations for the replacement bridge are assumed to be driven-steel HP or pipe pile extending to the glacial till soil layer approximately 130 feet beneath the riverbed. Drilled shafts could be an option, but past construction experience in the near area has shown difficulties with their use. The preferred type of foundation will be investigated further if the replacement of the bridge becomes the necessary future project.

The following subsections describe the bridge options considered viable for replacement of the existing bridge. Each of the options includes two alignments and variable superstructure types. The intent of the options is to present a range of bridge replacement alternatives and corresponding costs while adhering to the required design parameters.

1.2.1 Bridge Option 1—Steel Deck Girders

Bridge Option 1 encompasses two different superstructure types (steel I-girders and tub girders) and two different roadway alignments (B and C). The intent is to capture the features and costs for the two different viable roadway alignments while using what is considered to be the less costly of the viable superstructure types. Preliminary bridge cross sections of the steel I-girder and tub girder superstructures are shown in Figures 1-2 and 1-3, respectively. The shoulder and path width dimensions shown will be evaluated and finalized in future project development steps.

FIGURE 1-2
Bridge Option 1 Steel I-Girder

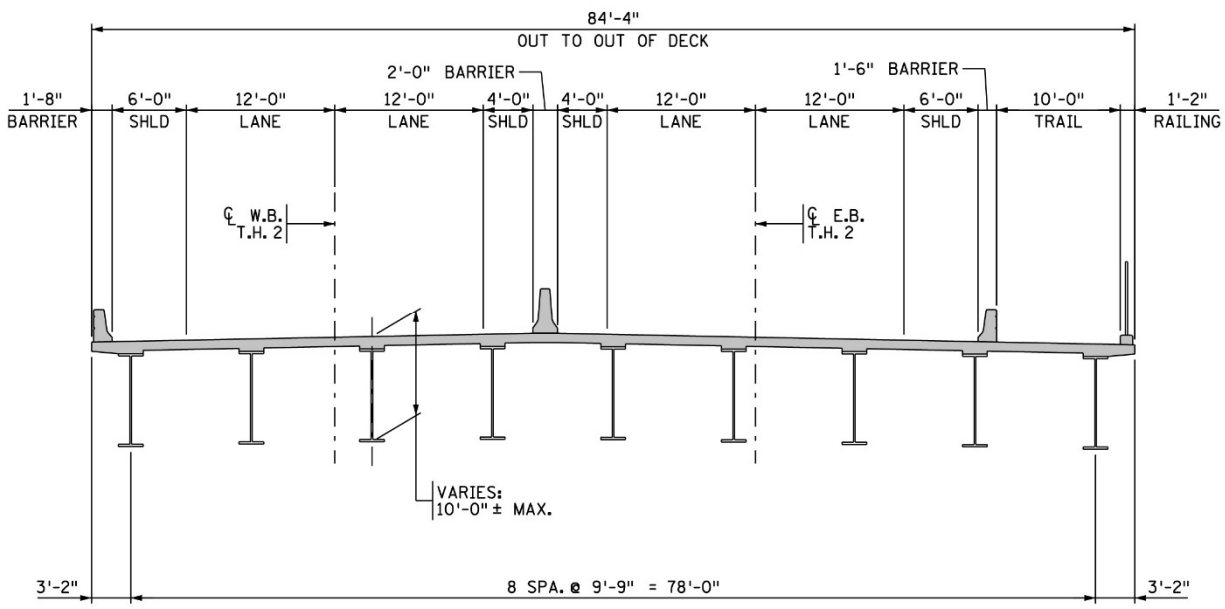
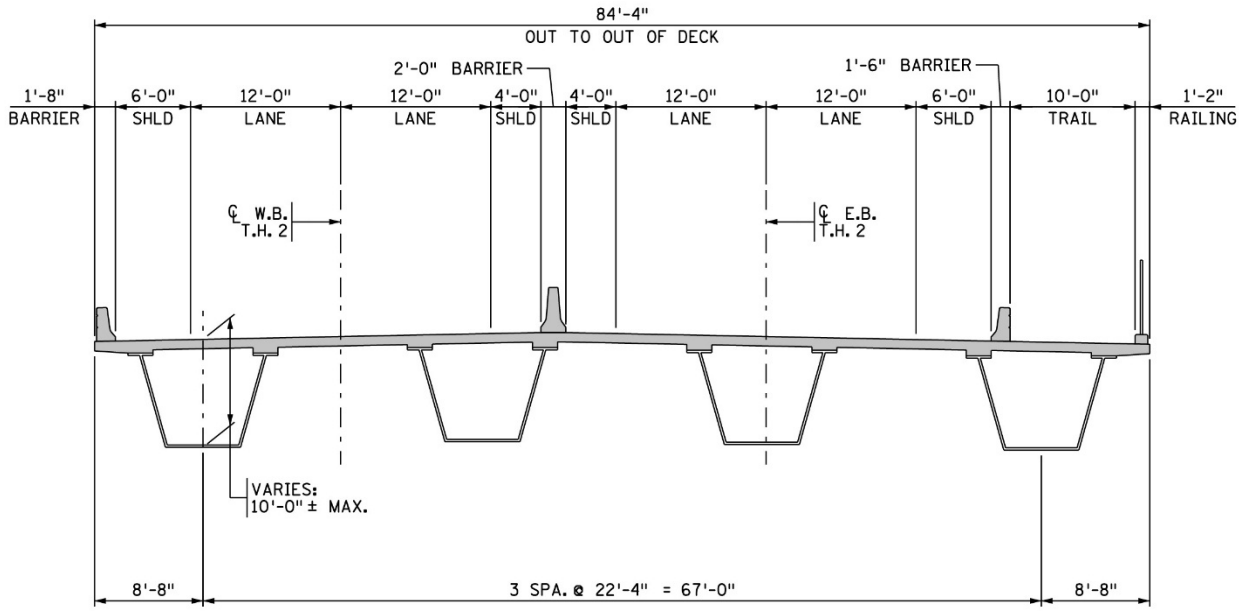


FIGURE 1-3
Bridge Option 1 Steel Tub Girder



A. Steel I-Girders, Alignment B

Steel I-Girders, Alignment B, consists of a seven-span bridge with an overall length of 1,310 feet with two 250-foot-spans over the main channel of the Red River (see Exhibit 1-4). The approach spans range in length from 110 to 190 feet. The superstructure depth ranges from 6 to 10 feet depending upon the span. Girder depth could be reduced in the shorter end spans if considered practical, but the depth transition would need to take place away from the piers to allow for bearing adjustment due to horizontal movement. The piers are skewed to align with the river flow.

Advantages: Lowest construction cost, shortest construction duration, inherently structurally redundant, structure type very common, can accommodate horizontal curvature and movement easily, low risk.

Disadvantages: Reverse curve alignment, underside aesthetics poor, moderate long-term maintenance costs.

B. Steel I-Girders, Alignment C

Steel I-Girders, Alignment C, consists of a seven-span bridge with an overall length of 1,310 feet with two 250-foot-spans over the main channel of the Red River (see Exhibit 1-5). The approach spans range in length from 110 feet to 190 feet. The superstructure depth ranges from 6 to 10 feet depending upon the span. Girder depth could be reduced in the shorter end spans if considered practical, but the depth transition would need to take place away from the piers to allow for bearing adjustment due to horizontal movement. The piers are skewed to align with the river flow. Replacement of the existing interchange and bridge over 4th Street NW on the east side of the river is also included in this alignment. Prestressed concrete I-beams are anticipated to be used for this bridge replacement consisting of two spans with a 270-foot-length and approximately 85-foot-width. The replacement will likely have to be staged to accommodate keeping U.S. 2 open to traffic.

Advantages: Straighter roadway alignment, replaces 4th Street NW Bridge during same project, inherently structurally redundant, structure type very common, can accommodate horizontal curvature and movement easily, low risk.

Disadvantages: Higher cost due to replacing the 4th Street NW Bridge and ramps, longer construction duration, underside aesthetics poor, moderate long-term maintenance costs.

C. Steel Tub Girders, Alignment B

Steel-tub Girders, Alignment B, consists of a seven-span bridge with an overall length of 1,310 feet and two 250-foot-spans over the main channel of the Red River (see Exhibit 1-4). The approach spans range in length from 110 feet to 190 feet. The superstructure depth ranges from 6 to 10 feet depending upon the span. Girder depth could be reduced in the shorter end spans if considered practical, but the depth transition would need to take place away from the piers to allow for bearing adjustment due to horizontal movement. The piers are skewed to align with the river flow.

Advantages: Lower construction cost, shorter construction duration, inherently structurally redundant, underside aesthetics good, structure type somewhat common, low long-term maintenance costs, can accommodate horizontal curvature and movement easily.

Disadvantages: Reverse curve alignment, higher cost due to tub girders, moderate risk due to steel tub fabrication.

D. Steel Tub Girders, Alignment C

Steel Tub Girders, Alignment C, consists of a seven-span bridge with an overall length of 1,310 feet with two 250-foot-spans over the main channel of the Red River (see Exhibit 1-5). The approach spans range in length from 110 feet to 190 feet. The superstructure depth ranges from 6 to 10 feet depending upon the span. Girder depth could be reduced in the shorter end spans if considered practical, but the depth transition would need to take place away from the piers to allow for bearing adjustment due to horizontal movement. The piers are skewed to align with the river flow. Included is the replacement of the existing ramps and bridge over 4th Street NW on the east side of the river. Prestressed concrete I-beams are anticipated to be used for this bridge replacement consisting of two spans with a 270-foot-length and approximately 85-foot-width. The replacement will likely have to be staged to accommodate keeping U.S. 2 open to traffic.

Advantages: Straighter roadway alignment, replaces 4th Street NW bridge during same project, inherently structurally redundant, underside aesthetics good, structure type somewhat common, low long-term maintenance costs, can accommodate horizontal curvature and movement easily.

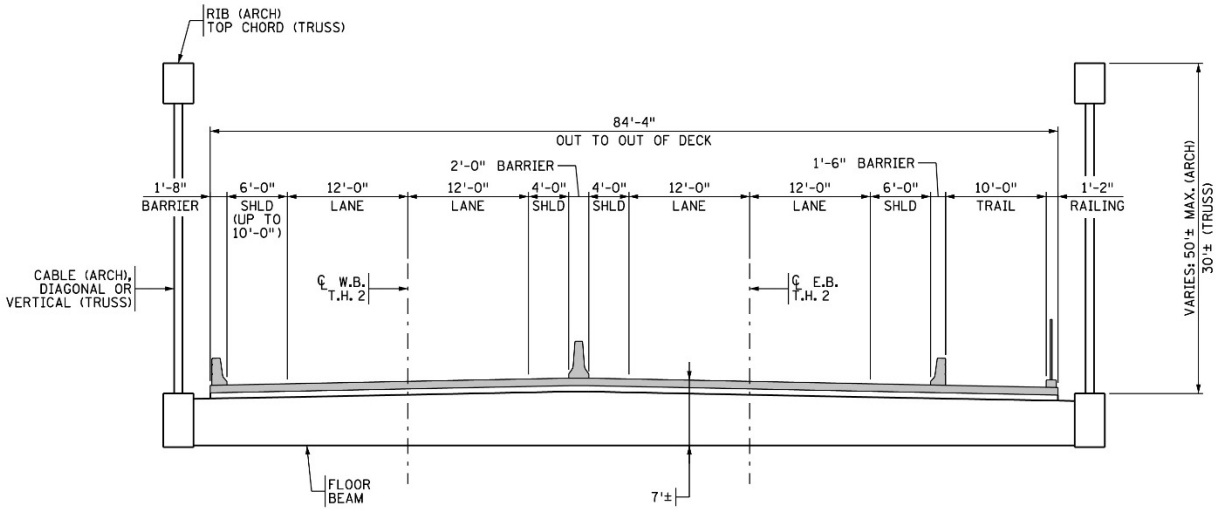
Disadvantages: Higher cost due to replacing the 4th Street NW Bridge and use of tub girders, longer construction duration, moderate risk due to steel tub fabrication underside aesthetics poor, moderate long-term maintenance costs.

1.2.2 Bridge Option 2—Truss or Arch Main Spans

Similar to Option 1, Option 2 also encompasses the use of different superstructure types interchangeably for the main river channel spans, steel truss, and arch. Either of the superstructure types would provide significant above-deck structure, distinct aesthetics, and increased span capabilities, but at a cost premium. At this conceptual stage of development, the construction cost and associated risks for the truss and arch superstructure types are assumed to be equal. The arch is assumed to be a tied arch system with a parabolic profile that extends approximately 50 feet above deck level. Vertical or network hanger cables could be used to support the bridge deck. The truss is assumed to have a constant height of approximately 30 feet above the deck. Both the arch and truss systems could have optional upper-lateral bracing oriented transversely and transverse floor beams supporting the bridge deck.

The approach spans could have approach spans of steel I-girders or tub girders. The intent is to capture the features and costs for the two different viable roadway alignments combined with several combinations of bridge superstructure types. Proposed bridge cross sections of the steel truss or arch, steel I-girder, and tub girder superstructures are shown in Figures 1-4, 1-2, and 1-3, respectively. Also, similar to Option 1, Option 2 includes the use of the two different roadway alignments, B and C.

FIGURE 1-4
Bridge Option 2 Steel Arch or Truss



A. Steel Truss/Arch Main Spans with Steel I-Girder Approach Spans, Alignment B

Steel Truss/Arch Main Spans with Steel I-Girder Approach Spans, Alignment B, consists of a seven-span bridge with an overall length of 1,310 feet with two 300-foot-spans over the main channel of the Red River (see Exhibit 1-6). The approach spans range in length from 95 feet to 165 feet. The superstructure depth below the deck ranges from approximately 7 feet on the arch/truss spans to 4 to 6 feet on the approach spans. The piers supporting the arch/truss spans have no skew in order to avoid complicating the design and construction. However, the approach span piers are skewed to align with the river flow.

Advantages: Roadway profile can be lower due to smaller superstructure depths, truss/arch spans can be considered more aesthetically pleasing and somewhat reflect the existing bridge.

Disadvantages: Moderate to high construction cost due to truss/arch span complexity, reverse curve alignment, underside aesthetics poor with I-girders, higher long-term maintenance costs, more complexity to achieve structural redundancy in arch/truss spans, moderate to high risk due to arch/truss fabrication, not as common as girder bridges, longer construction duration, pier orientation for main spans not ideal, more difficult to accommodate horizontal curvature and movement.

B. Steel Truss/Arch Main Spans with Steel I-Girder Approach Spans, Alignment C

Steel Truss/Arch Main Spans with Steel I-Girder Approach Spans, Alignment C, consists of a seven-span bridge with an overall length of 1,310 feet with two 300-foot-spans over the main channel of the Red River (see Exhibit 1-7). The approach spans range in length from 95 feet to 165 feet. The superstructure depth ranges from approximately 7 feet on the arch/truss spans to 4 to 6 feet on the approach spans. The piers supporting the arch/truss spans have no skew in order to avoid complicating the design and construction. However, the approach span piers are skewed to align with the river flow.

Replacement of the existing interchange and bridge over 4th Street NW on the east side of the river is included in this alignment. Prestressed concrete I-beams are anticipated to be used for this bridge replacement, consisting of two spans with a 270-foot-length and approximately 85 foot width. The replacement will likely have to be staged to accommodate keeping U.S. 2 open to traffic.

Advantages: Straighter alignment, replaces 4th Street NW bridge during same project, roadway profile can be lower due to smaller superstructure depths, truss/arch spans can be considered more aesthetically pleasing and somewhat reflect the existing bridge.

Disadvantages: Higher cost due to truss/arch span complexity and replacing the 4th Street NW bridge, underside aesthetics poor with I-girders, higher long-term maintenance costs, more complexity to achieve structural redundancy in arch/truss spans, moderate to high risk due to arch/truss fabrication, not as common as girder bridges, longer construction duration, pier orientation for main spans not ideal, more difficult to accommodate horizontal curvature and movement.

C. Steel Truss/Arch Main Spans with Steel Tub Girder Approach Spans, Alignment B

Steel Truss/Arch Main Spans with Steel Tub Girder Approach Spans, Alignment B, consists of a seven-span bridge with an overall length of 1,310 feet with two 300-foot-spans over the main channel of the Red River (see Exhibit 1-6). The approach spans range in length from 95 feet to 165 feet. The superstructure depth below the deck ranges from approximately 7 feet on the arch/truss spans to 4 to 6 feet on the approach spans. The piers supporting the arch/truss spans have no skew in order to avoid complicating the design and construction. However, the approach span piers are skewed to align with the river flow.

Advantages: Roadway profile can be lower due to smaller superstructure depths, truss/arch spans can be considered more aesthetically pleasing and somewhat reflect the existing bridge, steel-tub girder underside aesthetics good.

Disadvantages: High construction cost due to truss/arch and steel tub spans, reverse curve alignment, higher long-term maintenance costs, more complexity to achieve structural redundancy in arch/truss spans, moderate to high risk due to arch/truss fabrication, not as common as girder bridges, longer construction duration, pier orientation for main spans not ideal, more difficult to accommodate horizontal curvature and movement.

D. Steel Truss/Arch Main Spans with Steel Tub Girder Approach Spans, Alignment C

Steel Truss/Arch Main Spans with Steel Tub Girder Approach Spans, Alignment C, consists of a seven-span bridge with an overall length of 1,310 feet with two 300-foot-spans over the main channel of the Red River (see Exhibit 1-7). The approach spans range in length from 95 feet to 165 feet. The superstructure depth ranges from approximately 7 feet on the arch/truss spans to 4 to 6 feet on the approach spans. The piers supporting the arch/truss spans have no skew in order to avoid complicating the design and construction. However, the approach span piers are skewed to align with the river flow.

Included is the replacement of the existing interchange and bridge over 4th Street NW on the east side of the river. Prestressed concrete I-beams are anticipated to be used for this bridge replacement consisting of two spans with a 270-foot-length and approximately 85 foot width. The replacement will likely have to be staged to accommodate keeping U.S. 2 open to traffic.

Advantages: Straighter alignment, replaces 4th Street NW bridge during same project, roadway profile can be lower due to smaller superstructure depths, truss/arch spans can be considered more aesthetically pleasing and somewhat reflect the existing bridge, steel tub girder underside aesthetics good.

Disadvantages: Highest cost due to truss/arch complexity, steel tub spans and including replacement of the 4th Street NW bridge, higher long-term maintenance costs, more complexity to achieve structural redundancy in arch/truss spans, moderate to high risk due to arch/truss fabrication, not as common as girder bridges, longest construction duration, pier orientation for main spans not ideal, more difficult to accommodate horizontal curvature and movement.

1.3 Replacement Bridge Construction Costs and Durations

The costs and durations shown in Section 1.3 reflect the use of conventional construction methods typically employed by local bridge contractors. No accelerated-type construction methods or financial incentives are assumed to be used. The use of accelerated-type construction methods or financial incentives could likely reduce the durations, but increase costs.

1.3.1 Opinion of Probable Construction Costs

The costs in Table 1-1 are for bridge and roadway construction only, do not include costs for right-of way, engineering, construction inspection, and are in 2014 dollars.

TABLE 1-1

Bridge and Roadway Construction Costs

	Bridge Construction and Removals	Approach Roadway	20% Contingency	Total
Bridge Option 1				
A. Steel I-Girders, Alignment B	18,000,000	1,000,000	4,000,000	$23,000,000
B. Steel I-Girders, Alignment C	21,000,000 *	2,000,000	5,000,000	$28,000,000
C. Steel Tub Girders, Alignment B	20,000,000	1,000,000	4,000,000	$25,000,000
D. Steel Tub Girders, Alignment C	23,000,000 *	2,000,000	5,000,000	$30,000,000
Bridge Option 2				
A. Steel Truss/Arch Main Spans with Steel I-Girder Approach Spans, Alignment B	26,500,000	1,000,000	5,500,000	$33,000,000
B. Steel Truss/Arch Main Spans with Steel I-Girder Approach Spans, Alignment C	29,500,000 *	2,000,000	6,500,000	$38,000,000
C. Steel Truss/Arch Main Spans with Steel Tub Girder Approach Spans, Alignment B	27,500,000	1,000,000	5,500,000	$34,000,000
D. Steel Truss/Arch Main Spans with Steel Tub Girder Approach Spans, Alignment C	30,500,000 *	2,000,000	6,500,000	$39,000,000

* Includes costs for staged removal and replacement of the 4th Street NW bridge and ramps

1.3.2 Opinion of Probable Construction Durations

The durations in Table 1-2 are planning-level estimates from initiation of construction to completion. Time for right-of-way acquisition, engineering design, and environmental document preparation and permitting is not included. Actual durations are dependent on seasonal weather conditions, flood events, and start date.
The “Total Duration of Project” includes the construction and demolition of the bridge(s) and approach roadways. The “Portion of Project where there are Impacts to Traffic” includes the tie-in to the existing roadway system at the ends of the project.

The estimated durations include the staged removal and construction of the 4th Street NW Bridge where applicable. During construction, it is likely that there will be traffic lane modifications and short periods of two-lane traffic and closures.

TABLE 1-2

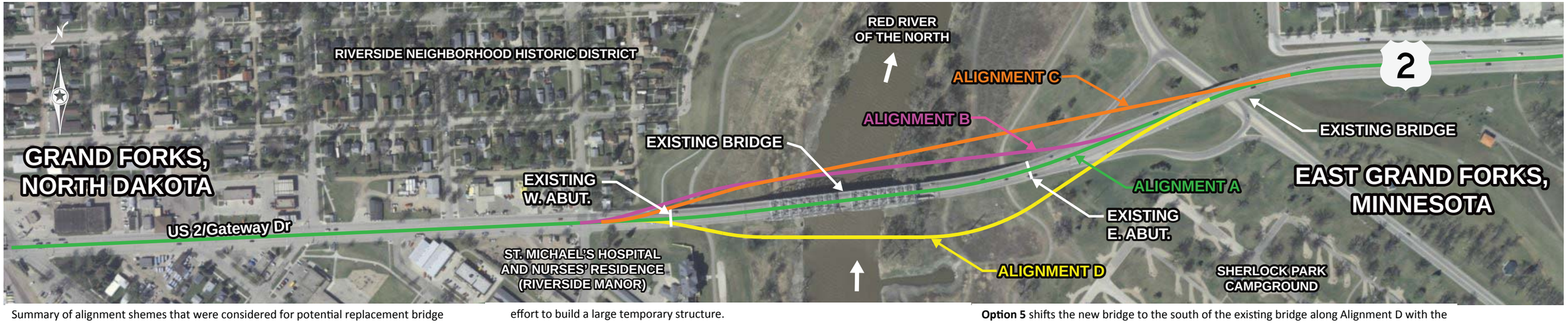
Estimated Durations

	Total Duration of Project	Portion of Project where there are Impacts to Traffic
Bridge Option 1		
A. Steel I-Girders, Alignment B	24 months	3 months
B. Steel I-Girders, Alignment C	33 months *	9 months
C. Steel Tub Girders, Alignment B	24 months	3 months
D. Steel Tub Girders, Alignment C	33 months *	9 months
Bridge Option 2		
A. Steel Truss/Arch Main Spans with Steel I-Girder Approach Spans, Alignment B	33 months	3 months
B. Steel Truss/Arch Main Spans with Steel I-Girder Approach Spans, Alignment C	42 months *	9 months
C. Steel Truss/Arch Main Spans with Steel Tub Girder Approach Spans, Alignment B	33 months	3 months
D. Steel Truss/Arch Main Spans with Steel Tub Girder Approach Spans, Alignment C	42 months *	9 months

* Includes staged removal and replacement of the 4th Street NW bridge and ramps

September 2, 2013

Option	Alignment [Description]	Construction Process [Estimated Duration]	Impacts					Comments
			Traffic	Historic	Right-of-Way	Approach Roadway	Other	
1	**Alignment A** [Replacement bridge along existing alignment]	Close existing bridge and remove, construct new bridge and approaches on same alignment, open to traffic. [2.0 years]	US 2 river crossing closed to traffic for duration of project.	Possible impact to Riverside Historic District if raised profile required	Low/Moderate - Possibly wider R/W and potential impacts at west end if raised profile required.	Use existing alignment, update widths, possible raised profile. No mpact to existing 4th St. bridge, minimal impact to ramps at 4th St.		- Shortest construction duration - Greatest impact on traffic requiring closing of this crossing throughout construction - Likely lowest cost
2	**Alignment A** [Replacement bridge along existing alignment - temporary bridge provided]	Construct temp. bridge adjacent to existing bridge utilizing existing truss spans, remove existing approach spans, construct new bridge and approaches on same alignment and open to traffic, remove temp. bridge. [3.0 years]	US 2 river crossing open for duration of project except for closures for moving truss spans and shifting of traffic to/from temporary bridge.	Possible impact to Riverside Historic District if raised profile required. Potential Historic District impacts at west end of temporary bridge.	Low/Moderate - Possibly wider R/W and potential impacts at west end if raised profile required.	Use existing alignment, update widths, possible raised profile, construct approaches to temporary bridge. No mpact to existing 4th St. bridge, minimal impact to ramps at 4th St.		- Medium/long construction duration - Medium temporary impacts on traffic - Significant cost for construction and removal of temporary bridge
3	**Alignment B** [New alignment to north of existing - tie-in west of 4th St.]	Construct new bridge adjacent to existing bridge, stage construction as-needed where overlap with existing bridge at west end, remove existing bridge. [2.5 years]	US 2 river crossing open during most of construction except for short closures when shifting traffic from existing to new bridge. Potential lane reductions during construction due to overlap at west end of existing bridge.	Likely impact to Riverside Historic District for shift in alignment to north.	Moderate - Additional/wider R/W for new alignment and potential impacts at west end for shift in alignment and raised profile.	New alignments, update widths, possible raised profile. Not likely to impact 4th St. Bridge. Realignment of ramps required at 4th St..	Replacement bridge could be similar in length to the existing bridge.	- Medium construction duration - Low (temporary) impacts on traffic
4	**Alignment C** [New alignment to north of existing - tie-in east of 4th St.]	Construct new bridge adjacent to existing bridge, stage construction as-needed where overlap with existing bridge at west end, stage/re-construct 4th St. bridge, remove existing bridge. [3.5 years]	US 2 river crossing open during most of construction except for short closures when shifting traffic from existing to new bridge. Potential lane reductions during construction due to overlap at west end of existing bridge and at 4th St. bridge.	Likely impact to Riverside Historic District for shift in alignment to north.	Moderate - Additional/wider R/W for new north alignment and potential impacts at west end for shift in alignment and raised profile.	New alignments, update widths, possible raised profile.Requires widening or replacement of 4th St. bridge. Realignment of ramps required at 4th St..	Replacement bridge would likely be longer than existing bridge.	- Longest construction duration - Additional impact on traffic for 4th St. modifications - Likely highest cost
5	**Alignment D** [New alignment to south of existing - tie-in west of 4th St.]	Construct new bridge adjacent to existing bridge, stage construction as-needed where overlap with existing bridge at west end, remove existing bridge. [2.5 years]	US 2 river crossing open during most of construction except for short closures when shifting traffic from existing to new bridge. Potential lane reductions during construction due to overlap at west end of existing bridge.	Possible impact to St. Michael's property for shift in alignment to south.	Moderate/High - Likely impacts to State Park Campground and potential impacts at west end historic St. Michael's property	New alignment, update widths, possible raised profile. Not likely to impact 4th St. Bridge. Realignment of ramps required at 4th St..	High mast power line to south of east approach is in conflict with any new south alignment and would need to be moved.	- Medium construction duration - Low (temporary) impacts on traffic - Power line conflict increases cost



Summary of alignment shemes that were considered for potential replacement bridge options as part of this Study.

Option 1 considers replacing the bridge along the existing alignment after closing and demolision of the existing bridge. This would close the crossing to traffic for the duration of construction (2 years). The long closure, possibly during seasonal flooding, makes this option impractical and it was eliminated from further consideration.

Option 2 also uses the existing bridge alignment, but would have a temporary bridge, built adjacent to the existing, to maintain traffic during construction of the new bridge. This has the advantage of keeping the bridge in the same location, but has increased cost and effort to build a large temporary structure.

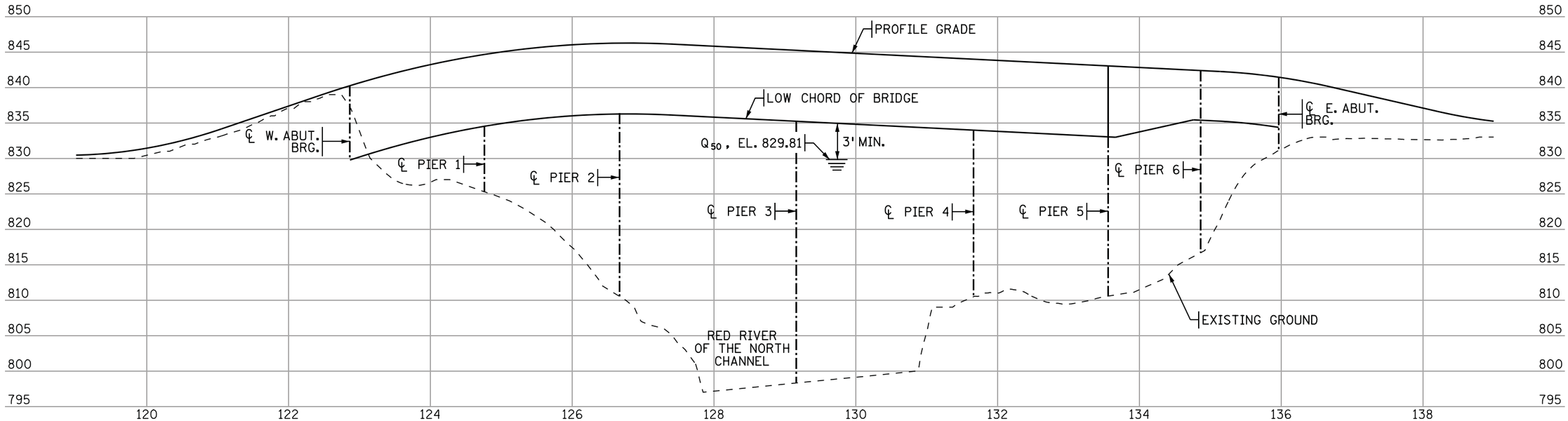
Option 3 allows the existing bridge to remain open to traffic while a new bridge is constructed on Alignment B just north of the current alignment. This option will require staged construction at the overlap with the existing bridge at the west end (similar to Options 4 and 5). The east approach will tie into the existing roadway west of the 4th St. bridge, allowing that bridge to remain in place.

Option 4 is similar to Option 3, but Alignment C is further north and ties in just east of the 4th St. bridge. This would require widening or replacement of the 4th St. bridge and more substantial changes to the ramps than for Options 3 and 5.

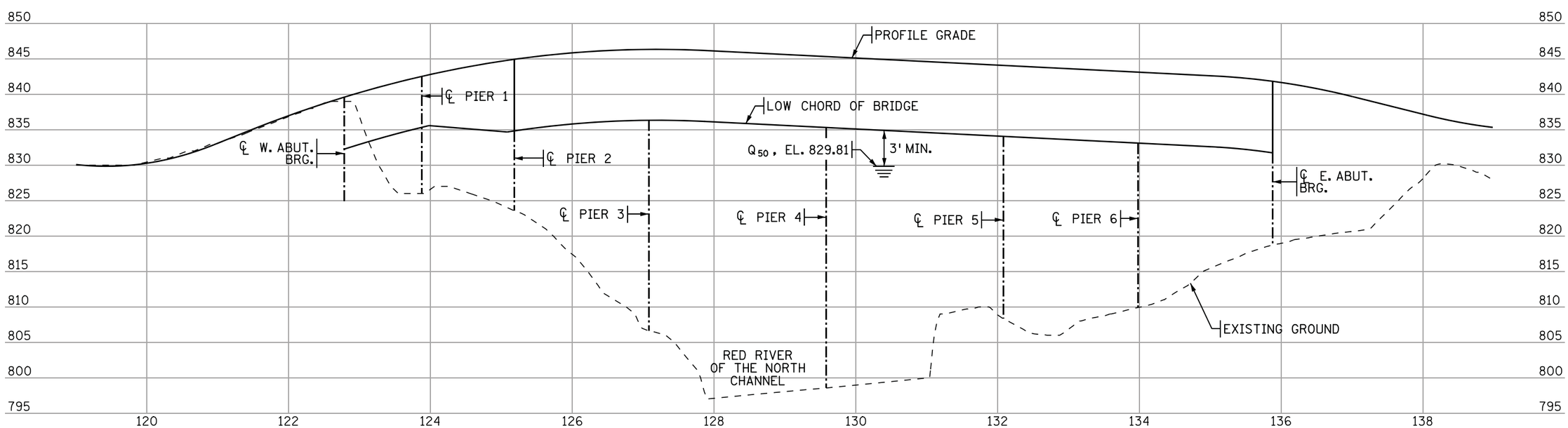
Option 5 shifts the new bridge to the south of the existing bridge along Alignment D with the east approach tied in west of the 4th St. bridge. This alignment follows a less direct route, when traveling east, the alignment shifts south and then north to connect up with US 2 on the Minnesota side. There is also a high mast power line along the south side at the east approach spans that would need to be relocated for this alignment.

Conclusion: Option 3 along Alignment B has fewer potential impacts and does not include added costs of a temporary bridge, reconstruction of the 4th St. bridge, or conflict with the power line. Option 3 is the most reasonable for comparison to the rehabilitation alternatives.

Exhibit 1-1
Replacement Bridge Alignment Evaluation Matrix

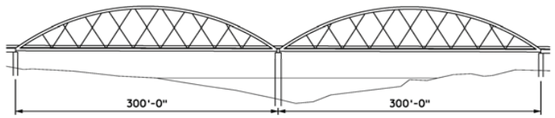
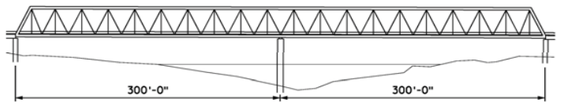
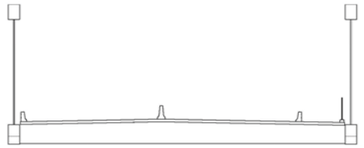
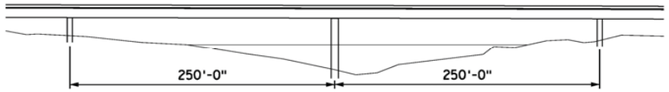
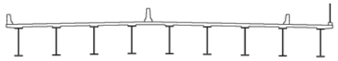
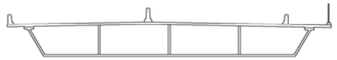


ALIGNMENT B PROFILE - STEEL DECK GIRDER
(LOOKING NORTH)



ALIGNMENT C PROFILE - STEEL DECK GIRDER
(LOOKING NORTH)

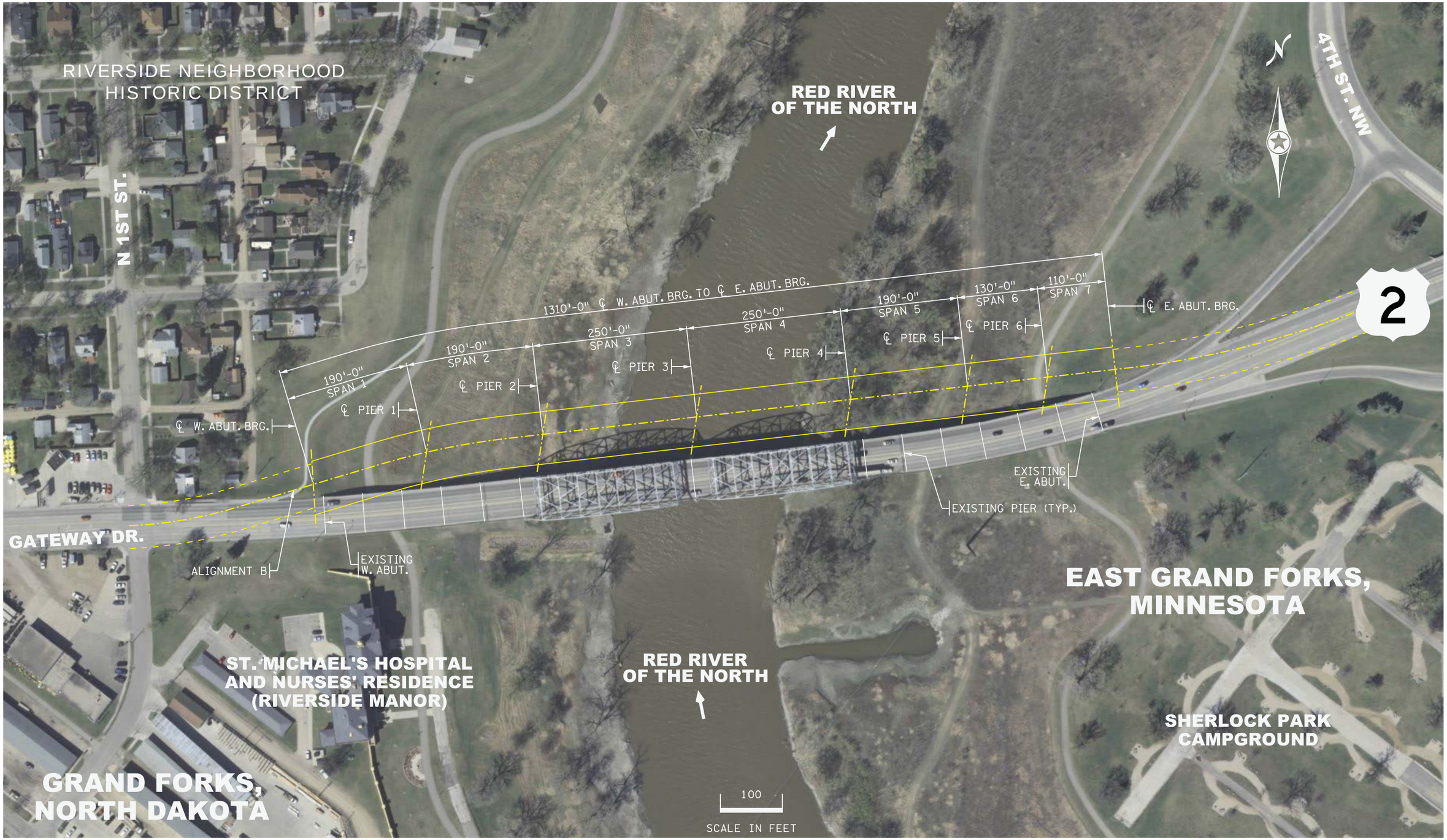
Exhibit 1-2
Profile View – Alignment B and C
Steel Deck Girder

Bridge Types	Through Type Bridge Superstructures	Deck Type Bridge Superstructures
	 Tied Arch  Truss 	  Steel I-Girder Prestressed Concrete Beam Steel Tub Girder  Post-Tensioned Concrete Box Girder
Evaluation Criteria		
Vertical Profile & Horizontal Alignment	Shallower depth below deck allows for lower roadway profile. Very difficult to accommodate horizontally curved alignment. Difficult to accommodate skewed piers	Deeper depth below deck requires higher profile to provide freeboard over floods. Horizontally curved alignments can be accommodated easily, but prestressed concrete beams are limited to gentle curves.
Structural Redundancy	Load path redundancy is difficult and expensive to achieve.	Inherently load path redundant with little extra cost.
Construction Duration	2 - 2.5 years including demolition of existing bridge.	2 years including demolition of existing bridge.
Construction Cost (factor)	1.3 - 1.5	1.0 (prestressed concrete I-beam) - 1.3 (steel tub or concrete box girder)
Traffic Impacts	Maintain two lanes of traffic in each direction except for 2-3 months of one lane in each direction during tie-in at ends of bridge.	Maintain two lanes of traffic in each direction except for 2-3 months of one lane in each direction during tie-in at ends of bridge.
Long-Term Maintenance	Moderate/high effort and cost. Critical structural details that must be properly maintained.	Low (prestressed concrete I-beams) to Moderate (concrete box and steel superstructures) effort and cost.
Accommodation of Earth Movement	Moderate/difficult on longer and heavier spans.	Ability to design for and accommodate on steel superstructures good. Concrete is more difficult due to weight and I-beams that typically have beam ends over the piers.
Accommodation of Future Widening	Difficult.	Concrete box is difficult, others are good.
Project Risk (Construction Methods, Cost and Schedule)	Moderate to high.	Low (prestressed concrete I-beams and steel I-girders) to moderate (steel tubs and concrete box girder).
Bridge Underside Aesthetics	Can vary from I-beams and bracing (cluttered) to box beams and minimal bracing (good).	Steel tubs and concrete box girders typically have smooth undersides with minimal ledges for birds (good). Steel and concrete I-beams typically have significant bracing and ledges for birds (cluttered).

Notes:

1. All bridges have a fixed pier in the center of the river channel
2. All bridge superstructures are designed to accommodate a future horizontal movement (4' towards and 1' away from) the center of the river channel.
3. All bridges will provide a pedestrian/bikeway shared use path.
4. All bridges have deck width of approximately 84 feet (4-12' lanes, 4'/6' inside and outside shoulders, median barrier and 10' shared use path).
5. All bridges will meet hydraulic and levee regulations and requirements.
6. All bridges will have a deck type superstructure on spans not over the main river channel.
7. Bridge foundations will likely consist of steel pipe or H-pile driven to glacial till (approximately 130 feet below ground surface).

Exhibit 1-3
Superstructure Type Evaluation Matrix



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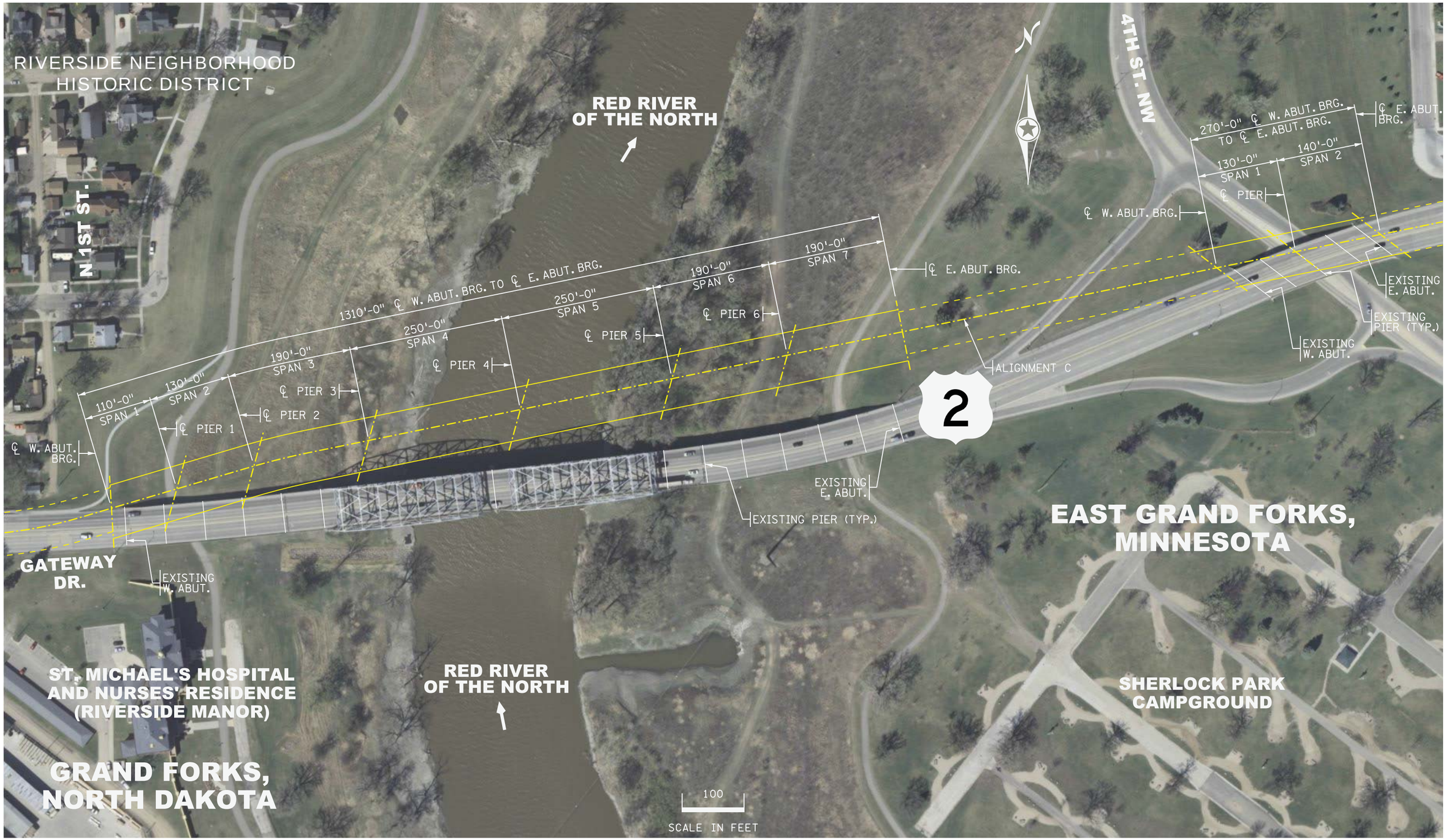
TBG011514142833MKE 1-4_KBPS_AlignB_SteelDeckGirder_v3 04.21.14 sls

Exhibit 1-4
Bridge Option 1A and 1C: Steel Tub or I-Girders on Alignment B



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TBG011514142833MKE 1-5_KBPS_AlignC_SteelDeckGirder_v3 04.21.14 sls

Exhibit 1-5
Bridge Option 1B and 1D: Steel Tub or I-Girders on Alignment C

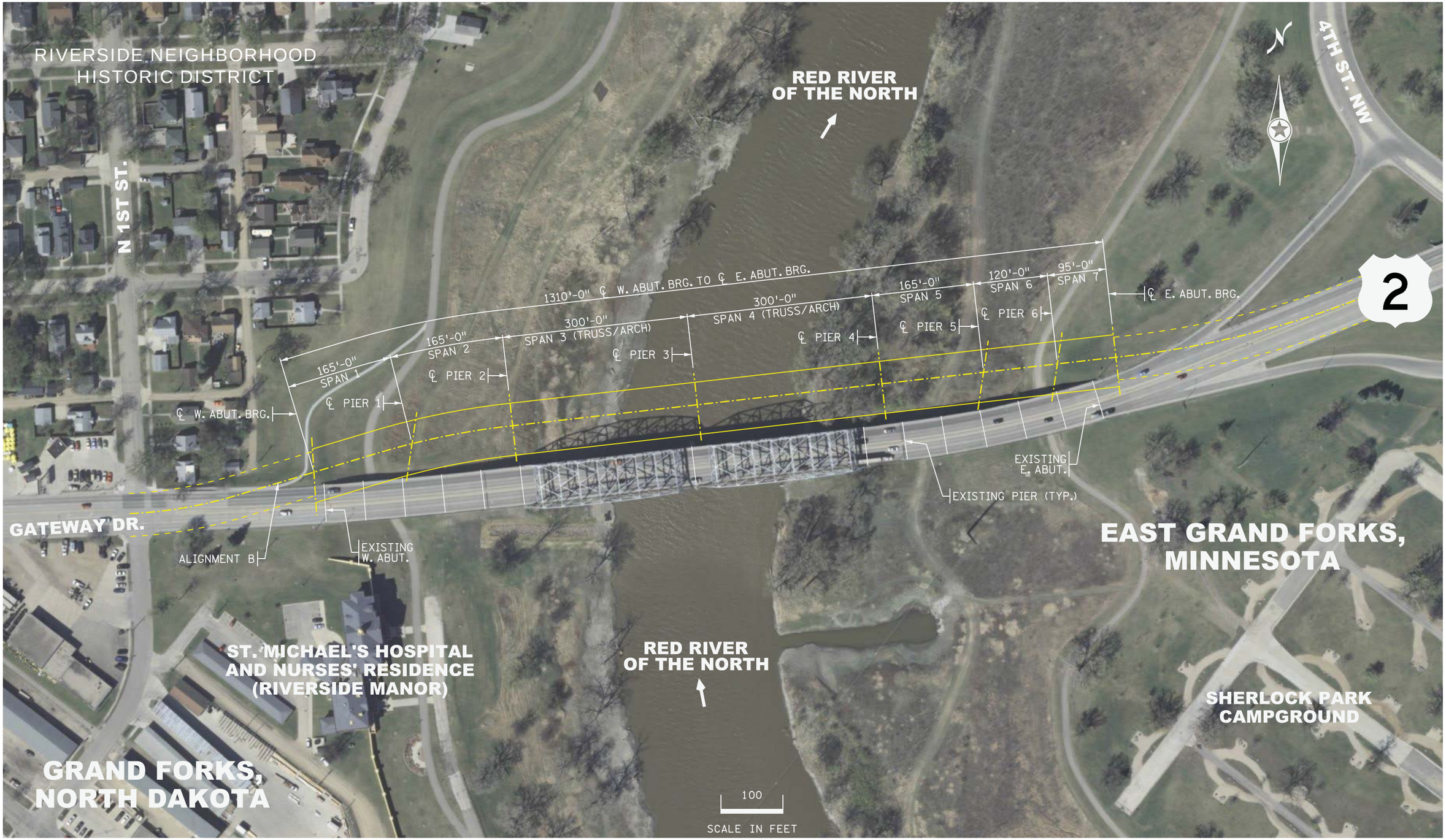
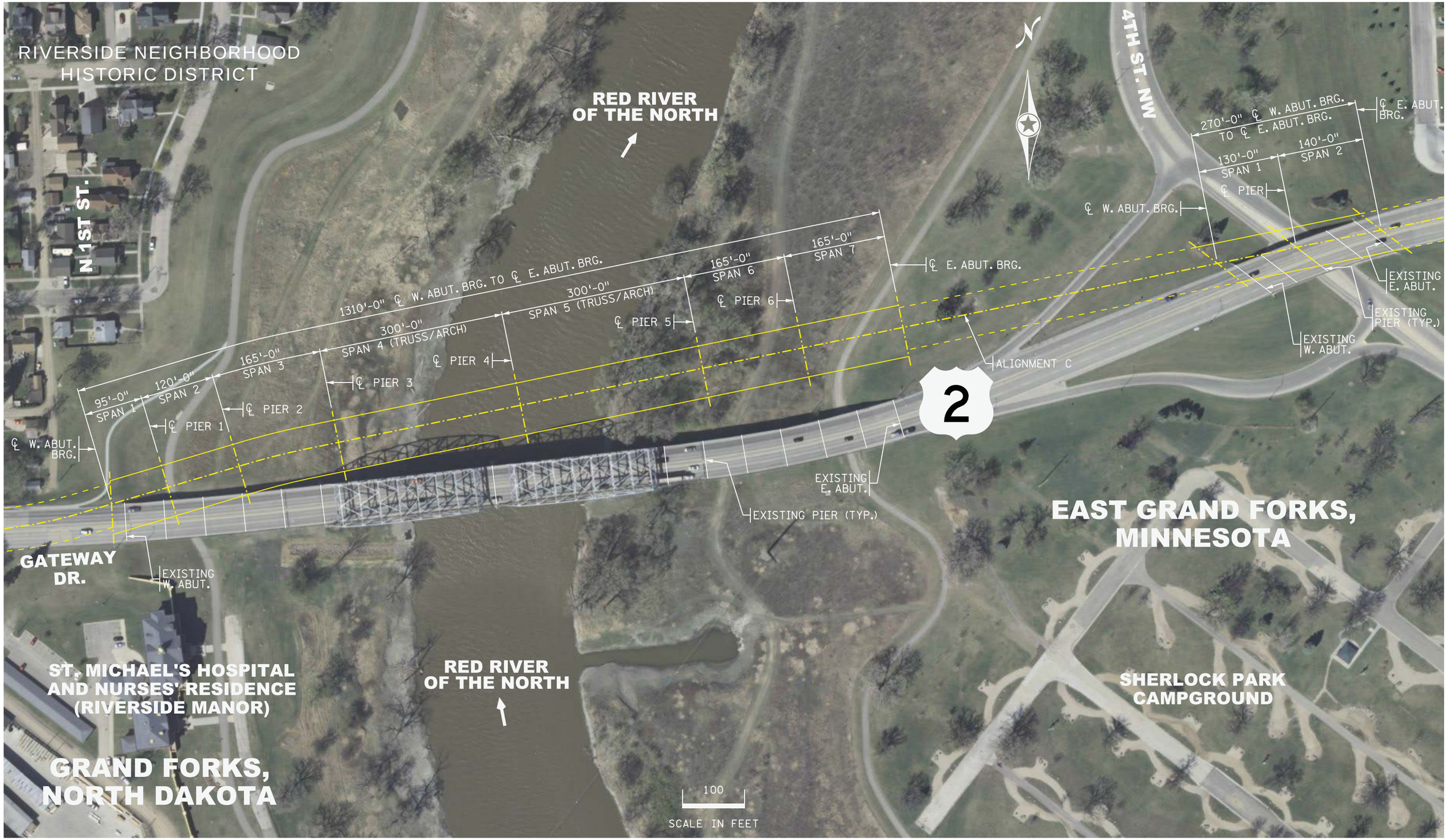


Exhibit 1-6
Bridge Option 2A and 2C: Steel Truss or Arch on Alignment B



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TBG011514142833MKE 1-7_KBPS_AlignC_SteelArchTruss_v3 04.21.14 sls

Exhibit 1-7
Bridge Option 2B and 2D: Steel Truss or Arch on Alignment C

SECTION 2

Summary

Section 2 identifies eight bridge replacement options for consideration. The eight options include two different roadway alignments, four different superstructure types, and options to include the replacement of the 4th Street NW Bridge. Required design parameters for the bridge replacement are outlined, and construction costs and durations are estimated. Advantages and disadvantages of each bridge replacement option are also presented. Construction cost estimates range from $23 million to $39 million. Estimated construction durations range from 24 to 42 months.

The replacement options are conceptual and are intended to provide a basis for comparison to the rehabilitation evaluation effort that is also part of the study. The range of potential options and estimated costs will be used in the future project development process when following the Section 106 regulations and deciding if it is prudent to rehabilitate the existing Kennedy Bridge. The bridge replacement options will be developed further, but only if it is determined that there is no feasible and prudent rehabilitation alternative to meet the requirements of a structurally sound crossing at this location.