MEMORANDUM

TO: Dale Thomas, P.E. - CH2M HILL

FROM: Jeff Davis, P.E.

LOCATION: U.S. Highway 2 (Kennedy) Bridge over the Red River of the North, East Grand Forks, Minnesota

SUBJECT: Kennedy Bridge Planning Study S.P. No. 6018-02
Qualitative Bridge Scour Review

DATE: April 25, 2014

This memorandum provides general assessment of bridge scour conditions for the U.S. Trunk Highway 2 Bridge, Bridge No. 9090, Kennedy Bridge, spanning over the Grand Forks, North Dakota and East Grand Forks, Minnesota. River bed information obtained from original as-built bridge plans (1962) to more recent inspections (2007/2008/2012) were considered when analyzing the long-term degradation of the river bed and local scour to piers/abutments. This memorandum supports the Kennedy Bridge Planning Study prepared by CH2M HILL for MnDOT.

A - River Hydraulics

The January 2003 U.S. Army Corps of Engineers Report documents the 20 highest recorded discharge events in the region based on the U.S. Geological Survey gage station. The documented discharges range from 35,000 cubic feet per second (cfs) in 1947 to 144,000 cfs in 1826. Flow velocity in the channel for a 100 year event as documented in the HEC-RAS model is as follows:

- left overbank 1.41 ft/s,
- thalweg 5.5 ft/s,
- right overbank 1.60 ft/s

This memorandum does not address the subject of river hydrology/hydraulics beyond these statements of fact as a flood control project has been constructed in the cities of Grand Forks/East Grand Forks. A separate section of the report provides detailed hydraulic modeling and the hydraulic conditions of the river are presented in a separate document “Hydraulic analysis in Support of the Kennedy Bridge Planning Study.

B – Bridge Scour

This memorandum addresses the concern of scour at the Kennedy Bridge from a qualitative perspective. The 2011 Bridge Inspection Report indicates the river channel is stable. Our review of various Kennedy Bridge and/or Red River of the North related documents listed in this memorandum support that statement.

Our assessment is based on the review of the inspection report(s) and river bed cross sections taken at the bridge over its service life. Additional consideration was given for the bridge replacement options, particularly the new pier orientation angle in relation to the flow stream line.

The analysis follows the guidelines and procedures outlined in the Federal Highway Administration, HEC-18 Evaluating Scour at Bridges, Fifth Edition. HEC – 18, Chapter 3 addresses total scour at a highway crossing and considers its three primary components:

1. Long-term degradation of the river bed
2. Contraction scour at the bridge
3. Local scour at the piers or abutments

Addressing long term degradation and contraction scour are beyond the scope of this assessment but should be considered if substructure modifications or replacement of the Kennedy Bridge occurs.

C - **Local Scour at Piers for Replacement Options**

This memorandum's focus for this qualitative review is primarily pier orientation. Refer to the Technical Memorandum: Bridge Replacement Options for the concept layouts of a range of bridge types and alignments. Since our focus is the pier orientation, HZ United simply addresses the pier alignments based the concept level layouts.

> Exhibit 1-4: Bridge Option 1A and 1C: Steel Tub or I-Girders on Alignment B- Pier orientation aligned with river flow.
> Exhibit 1-5: Bridge Option 1B and 1D: Steel Tub or I-Girders on Alignment C – Pier Orientation aligned with river flow.
> Exhibit 1-6: Bridge Option 2A and 2C: Steel Truss or Arch on Alignment B – Pier orientation (main spans) skewed to river flow.
> Exhibit 1-7: Bridge Option 2B and 2D: Steel Truss or Arch on Alignment C – Pier Orientation skewed to river flow.

Pier orientation of the steel arch truss options is similar to the existing pier alignment for the existing bridge, which are skewed to the river flow. Pier orientations for the steel tub or I-girder options are more in line with the river flow. Bridge concept layouts for the steel tub or I-girder options depict the piers at 15 to 20 degrees right of perpendicular to the bridge centerline.

As part of our assessment we reviewed pg. 3.7, paragraph 5 of HEC-18 which states pier length has no appreciable effect on local scour as long as the pier is aligned with the flow. When the pier is skewed to the flow, the pier length has a significant influence on scour depth. For example, doubling the length of the pier increases scour depth from 30 to 60 percent (depending on the angle of attack).

Our assessment also included a review of pg. 3.8; paragraph 8 of HEC-18 which states the shape of the nose of a pier can have up to a 20 percent influence on scour depth.

Streamlining the front end of a pier reduces the strength of the horseshoe vortex thereby reducing the scour depth. Streamlining the downstream end of the piers reduces the strength of the wake vortices. A square-nose pier will have maximum scour depths about 20 percent greater than a sharp-nose pier and 10 percent greater than a cylindrical or round-nose pier. The shape effect is negligible for flow angles in excess of five degrees. As constructed, the upstream edges of the existing Kennedy Bridge piers have a sharp-nose configuration. However, based on the HEC-18 criteria, the streamlining effect of the sharp-nose configuration is rendered negligible as the flow angle is greater than five degrees.

Based on a graphic analysis, the estimated flow angle (angle of attack) for the existing Kennedy Bridge associated with the concept arch or truss replacement options is 15 to 20 degrees. Pier orientation for these configurations could significantly increase the scour over that of the steel tub or I-girder alignments. This suggests that orientating the piers to coincide with the river alignment should reduce the probability of scour in the vicinity of the river piers where the flow velocity is the highest.

D - Bridge Scour Memorandum and Inspection Report

MnDOT's bridge scour memorandum dated August 4, 1997 indicates a predicted local scour at the existing centerline pier of approximately 10 feet is anticipated. Should that depth of scour occur, the scour would extend about 2.8 feet below the bottom of the footing. The memorandum also states the 1996 underwater inspection of the Pier 7 indicates a slight exposure of the pier footings with debris at the upstream pier nose.

MnDOT's "Underwater Bridge Inspection Report, Structure 9090 (Kennedy Bridge)", Dated August 29, 2012 states the footing exposure at the upstream column has slightly decreased since the last inspection with a maximum vertical exposure reduced from 8 inches in 2008 to no exposure in 2012. The top of the downstream column along the north and east sides remains partially exposed with no vertical exposure. Timber debris accumulation around both columns of Pier 7 was moderate in extent and comparable to timber accumulation levels of 2008. Recommendations section of the report suggests monitoring the footing exposure and placement of riprap around the exposed footing may become warranted if further exposure continues. HZ United concurs with the suggested "continue monitoring recommendation."

Attached are two graphics that provide a historic perspective of the river channel at the Kennedy Bridge. They show the river profile (cross section) at the upstream and downstream bridge fascia ground in comparison to the bridge centerline profile at the time of construction.

E - Pressure Scour Consideration

When constructed in the early 1960's the Kennedy Bridge's hydraulic design was based on a 50 year recurrence interval, a maximum discharge of 80,000 cfs and a high water elevation of 830.1. Low steel elevation is depicted on the construction plans at an elevation of 831.0.

FEMA's LOMR for Grand Forks, North Dakota, dated August 02, 2007, substantiates a 100 year water surface elevation in excess of 831 and a discharge rate of 108,000 cfs in the vicinity of the Kennedy Bridge.

MDNR January 2003 Red River Flood Assessment Report stated that the Historical Flood High Water Mark 1997 = 832.05 @ River Mile 296.95 (Table 7, pg. 28).

MDNR document also listed the 100 Year Water Surface Elev. = 830.90 (x-sec 153, Kennedy Bridge) Q=108,000 cfs (Table 8).

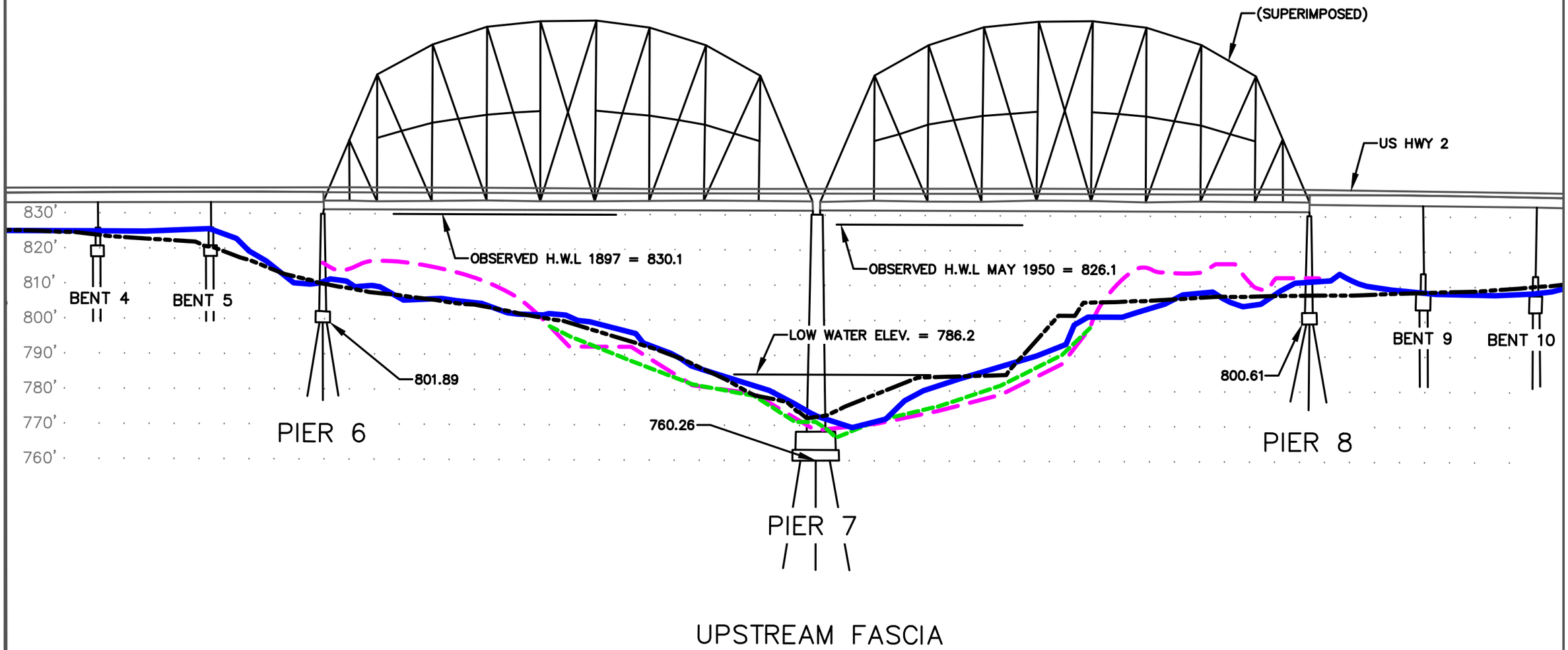
By comparison of the low steel elevation and the model predicted 100 year water surface, it appears that pressurized flow through the bridge opening could be an issue.

If the bridge is reconstructed based on a 50 year recurrence interval, the model predicts a peak flow at Grand Forks of 87,600 cfs with a water surface elevation of approximately 828.6 (Table 8 water surface elevation 828.37). Under these conditions, pressure scour is probably not of concern. Note that should ice or debris buildup upstream of the bridge at the water surface and impact the low steel, pressure scour could occur. Based on visual observation of the referenced layouts, it appears that both Alignment B and Alignment C Profiles (steel tub and I-girders) depict the low chord at a minimum elevation of about 832 for the vast majority of the bridge's length which reduces the probability of pressure scour occurring. HEC-18 does state that scour depth of pressure flow can be significantly greater than non-pressure flow conditions and as such, pressure flow should be avoided or accounted for when evaluating scour related to the bridge piers and footings.

F – Reference Documents

The following documents were reviewed and referenced as part of HZ United's scour evaluation:

1. USACE, Regional Red River Flood Assessment Report, January 2003
2. FEMA, LOMR, August 02, 2007
3. Houston Eng., Grand Forks/East Grand Forks FIS, January 2007
4. MnDOT, Kennedy Bridge Planning Study, Tech Memo: Pier 6 Movement Capacity, May 21, 2013
5. MnDOT, BR 9090 Bridge Scour Memo, August 05, 1997
6. MnDOT, Kennedy Bridge 9090, Construction Drawings, 1962
7. MnDOT, Underwater Bridge Inspection Report, Trunk Highway 2 Over the Red River of the North, August 29, 2012
8. USGS, Estimated Level 1.5 Bridge Scour at Selected Sites in North Dakota, 1999 - 2002



LEGEND

- 1962 RIVER BED AT BRIDGE ℄ (N.D.S.H.D)
- 2012 RIVER BED (AYERS)
- 2008 RIVER BED (AYERS)
- 2007 RIVER BED (HEC-RAS)

GENERAL NOTES:

1962 RED RIVER OF THE NORTH PROFILE INFORMATION OBTAINED FROM ORIGINAL 1962 AS-BUILT PLANS PROVIDED BY THE NORTH DAKOTA STATE HIGHWAY DEPARTMENT (N.D.S.H.D). 2008 AND 2012 RIVER PROFILE INFORMATION OBTAINED FROM THE "UNDERWATER BRIDGE INSPECTION REPORT, STRUCTURE 9090, DATED AUGUST 29, 2012, BY AYERS ASSOCIATES AND COLLINS ENGINEERS, INC." 2007 RIVER PROFILE INFORMATION OBTAINED FROM HEC-RAS.

VERTICAL DATUM = NGVD 1929

KENNEDY BRIDGE - S.P. NO. 6018-02

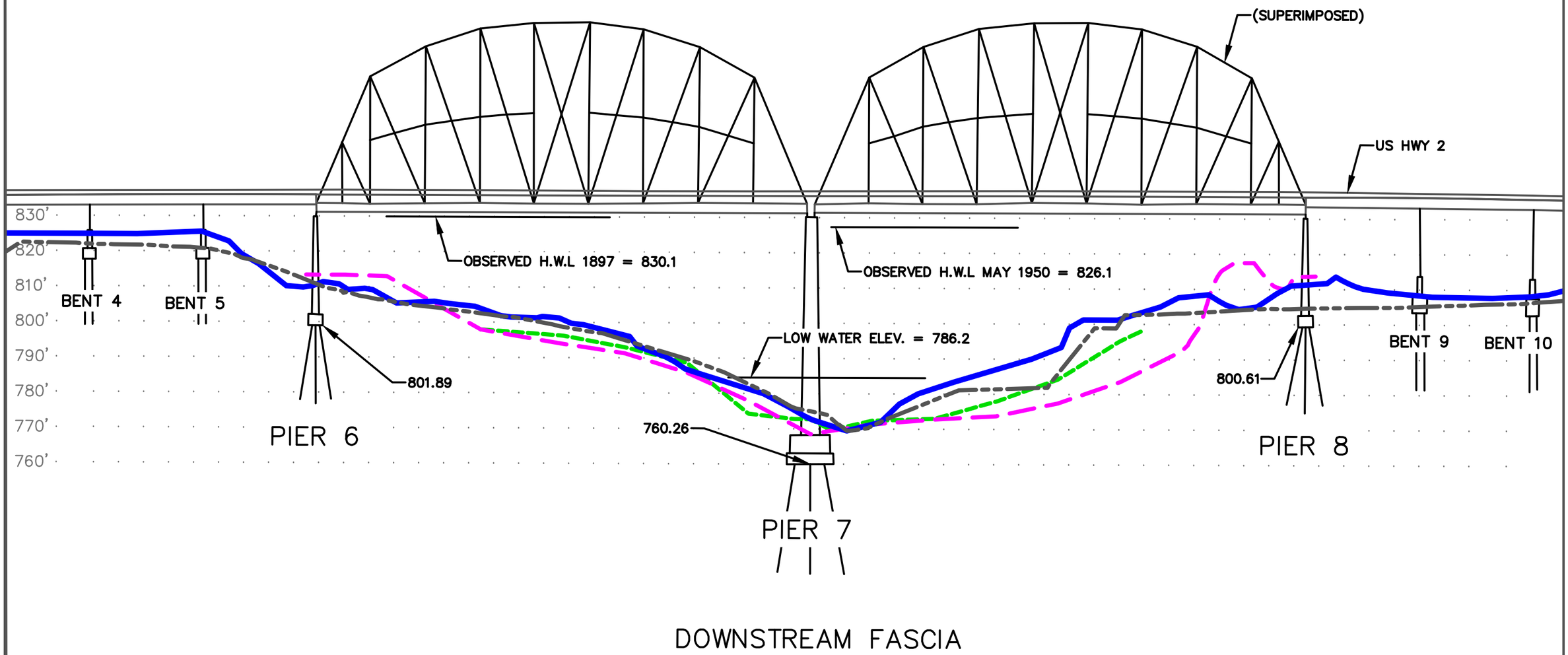
UPSTREAM FASCIA GROUND PROFILE FACING NORTH

DATE : 04/25/2014

NOT TO SCALE

HZ UNITED, LLC

CH2MHILL



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KENNEDY BRIDGE - S.P. NO. 6018-02 DOWNSTREAM FASCIA GROUND PROFILE FACING NORTH	DATE : 04/25/2014	NOT TO SCALE	HZ UNITED, LLC	CH2MHILL