Geosyntec consultants

9595 Six Pines Drive
Building 8, Level 2, Suite 8210
The Woodlands, TX 77380
PH 1-346-298-7950

www.geosyntec.com

Memorandum

Rev. A - Issued for Review by Gulf Interstate

Date: 7 September 2022

To: David Ammerman, PE (Gulf Interstate)

From: David Vance, PG[1]; Jeremy Yeglin, PE[2]; and Robert Dunn

Cc: Al Preston, PhD, PE[3]; Brandon Klenzendorf, PhD, PE[4]; Muhammed Mustafa, PhD, PE[3]; Morgan L'Hoste (EIT); and Jai Panthail

Subject: Hydrotechnical Assessment (Sheyenne River HDD Crossing)
Geosyntec Project No. TXG0320

INTRODUCTION

The following is a summary of the hydrotechnical assessment for Gulf Interstate Engineering, Inc.'s (Gulf Interstate) proposed Sheyenne River horizontal directional drilling (HDD) crossing, which is part of the 2,000-mile pipeline system being installed by Summit Carbon Solutions in North Dakota. The crossing is located at milepost (MP) 27.3 in Richland County, North Dakota. Geosyntec completed this hydrotechnical assessment to evaluate the lateral setbacks and riverine scour and define the lateral and depth hazards the river possesses at the proposed crossing. The methods, calculations, results, and recommendations of this assessment are described herein.

DATA SOURCES REVIEWED

The following data sources have been reviewed as part of the hydrotechnical assessment as of the date of this memorandum:

- 2016 1-meter (m) resolution LiDAR from the state of North Dakota's LiDAR database; collected by the U.S. Army Corps of Engineers (St. Louis District).
- Bathymetric survey data collected by TRC Companies (TRC) dated August 12, 2022.

---

[1] Licensed in GA
[2] Licensed in ND, TX, and OK
[3] Licensed in CA
[4] Licensed in TX and LA

- Available Google Earth™ aerial imagery, generally spanning the timeline from September 1997 to September 2021.
- United States Geologic Survey (USGS) 7.5 minute topographic quadrangle maps for the segment.
- Federal Emergency Management Agency (FEMA) *Richland County, North Dakota and Incorporated Areas Flood Insurance Study* dated December 18, 2009.

METHODS

Geosyntec conducted a scour analysis and lateral migration assessment of the Sheyenne River crossing. The methods for the scour analysis and lateral migration assessment are described below.

Scour Analysis

The scour analysis consisted of evaluating appropriate burial depth based on the depth of anticipated total (vertical) scour at the Sheyenne River crossing location. Scour calculations required hydraulic analyses for the crossing. The methods and results of the hydraulic and scour analyses are summarized below based on the following assumptions:

- Longitudinal peak flows associated with the 100-year return period were taken from the *FEMA Richland County, North Dakota and Incorporated Areas Flood Insurance Study* dated December 18, 2009. The 100-year peak flow used for the hydraulic modeling was 7,340 cubic feet per second (cfs).
- Site-specific cross sections of the active channel were modeled upstream, downstream, and at the pipeline crossing location based on a mosaic digital elevation model (DEM) of the North Dakota LiDAR and the TRC bathymetric survey data.
- Longitudinal slope of 1.29% was estimated from the TRC bathymetry data.
- Median grain size (D_{50}) of the stream bed was estimated to be 0.125 millimeter (mm), which is representative of a fine sand bed dominated system.
- Manning's n-value was estimated to be 0.035, which is representative of a clean, winding river, with some weeds and stones.

Hydraulic analysis was performed using the Hydrologic Engineering Center River Analysis System (HEC-RAS) software program to calculate hydraulic design parameters (e.g., flow depth, width, velocity, and effective shear stress) for the peak flow obtained from the FEMA Flood Insurance Study. The flow profile modeled includes peak discharge associated with the 100-year return period. The one-dimensional (1-D) HEC-RAS model was populated with channel geometry parameters (i.e., longitudinal slope and cross section) and Manning's roughness coefficient described above. The HEC-RAS model is representative of normal flow depth calculations at the stream crossing and was analyzed at three cross sections (upstream, at the pipeline crossing, and downstream). Additional cross sections were modeled farther upstream and downstream for model stability and to minimize the influence of boundary conditions at the pipeline crossing. The cross section geometry is based on the LiDAR and bathymetry data and is representative for the crossing. Known water surface elevations for the 100-year base flood elevation were obtained from the *FEMA Richland County, North Dakota and Incorporated Areas Flood Insurance Study* dated December 18, 2009 and assigned as the downstream boundary conditions. These water surface elevations are representative of normal depth conditions.

Total scour (z_{ts}) is the total depth of scour at a given location. It is applied to the thalweg of the channel and is the sum of all scour components that are applicable for the given location. Scour components considered include the following, which are described in the subsequent sections:

- **Long-Term Degradation (z_{lt})**
- **General Scour (z_{gs})**
- **Bend Scour (z_{bs})**
- **Local Scour (z_{ls})**
- **Contraction Scour (z_{cs})**
- **Bedform Scour (z_{bfs})**

Note these components of scour were included where applicable. For the Sheyenne River, bedform scour was not considered applicable and therefore not included in total scour. The scour components were calculated using applicable scour equations. If multiple scour equations were considered applicable for a component of scour, results were averaged. The average scour value for each component was then summed to generate a final total scour (z_{ts}) depth. The components of scour are described below.

Long-Term Degradation (z_{lt})

Long-Term degradation (z_{lt}) is the progressive lowering of the channel bed due to scour. This permanent or continuing degradation is an indicator that a change in the stream's discharge and sediment load characteristics is taking place. Degradation of the stream bed occurs due to downstream bed elevation changes or excess sediment-transporting capacity relative to the size of bed-material (e.g., resistance to movement) and quantity of bed-material sediment delivered from upstream reaches. Degradation continues until the existing longitudinal slope of the channel decreases to an equilibrium (stable) slope or until an armor layer (i.e., comprised of gravel and/or cobble-sized particles) that mitigates long-term degradation develops on the stream bed.

Typically, long-term degradation scour is calculated by multiplying the channel distance to the nearest downstream grade control point (e.g., exposed bedrock or manmade drop structure) by the difference in the existing and equilibrium longitudinal slopes. This estimation requires understanding the distance to a grade level control, a process that requires individual assessment at each stream with access to extended portions of the stream upstream and downstream of the pipeline crossing. For this assessment, data are not readily available. Instead, Geosyntec estimated degradation associated with observed natural geomorphic processes associated with natural degradation described below. Long-term degradation was conservatively estimated to be 2 feet.

General Scour (z_{gs})

General scour is the lowering of the stream bed across the channel over relatively short time periods and is associated with the passing of a single flood. The Lacey Regime Equation (ASCE 2005), Zeller equation (USACE, 2021), U.S. Bureau of Reclamation (USBR) Envelope Curve (USACE, 2021), and the Neill competent velocity equation (USACE, 2021) were used to calculate general scour for this study. The average value of all four equations was used to estimate general scour depth. Calculated general scour (averaged from applicable equations) was 3.57 feet.

Bend Scour (z_{bs})

Bend scour is associated with meandering channels that can induce transverse or secondary currents. It is the scour associated with the outside of a bend. The USBR equation for sand bed rivers (USBR, 2019), which summarizes the charts for scour prediction contained in Plate B41 of Engineer Manual 1110-2-1601 (USACE, 1994), was used to calculate bend scour for this study. The estimated bankfull depth (based on the apparent channel dimensions identified from the bathymetric survey) at the upstream cross section was used to calculate bend scour. The Thorne (Thorne, 1988), Maynord (Maynord, 1996), and Zeller (USACE, 2021) equations were also calculated and considered in this study. The average value of all four equations was used to estimate bend scour depth. Calculated bend scour (averaged from applicable equations) was 9.26 feet.

Local Scour (z_{ls})

Local scour is the scour that results from an obstruction and abrupt change in the direction of flow. It is caused by an acceleration of flow and resulting vortices induced by the obstruction. The component of local scour considered in this analysis is large woody debris (LWD). Local scour from LWD was applied for the stream crossing to consider the potential for accumulation of LWD at or near the crossing that could lead to scour and pipeline exposure.

Large woody debris was considered as part of this analysis due to the prevalence of forested land cover throughout the pipeline alignment and in vicinity of the crossings and its associated watersheds. An equation for pier scour, based on Hydrologic Engineering Circular No. 18 (FHWA, 2012), was used as a basis for estimating scour associated with in-stream LWD. Calculated local scour from LWD was 2.11 feet.

Contraction Scour (z_{cs})

Contraction scour is the scour that results when the flow area of a stream is reduced by a natural contraction or a bridge constricting the flow. An equation for contraction scour, based on

Hydrologic Engineering Circular No. 18 (FHWA, 2012), was used as a basis for estimating contraction scour. Calculated contraction scour was 2.24 feet.

Bedform Scour (z_{bfs})

Bedform scour is the scour that results when flow passes dunes and antidunes in sand bedded streams. Antidunes are generally associated with high velocity stream approaching supercritical flow (USACE, 2020). Hydraulic analysis performed using HEC-RAS demonstrated that flows at the Sheyenne River crossing did not approach supercritical, and Froude numbers stayed well below a value of 1.0. Therefore, bedform scour was not considered applicable and not included in total scour.

Total Scour (z_{ts})

Geosyntec calculated total scour depth by summing the average scour value for each component. Total scour results are presented in **Table 1** below.

Table 1. Summary of Calculated Scour Components and Total Scour

Scour Component	Calculated Scour Depth (ft)
Long-term Scour	2.0
General scour	3.6
Bend Scour	9.3
Local Scour	2.1
Contraction Scour	2.2
Bedform Scour	0.0
Total Scour	**19.2**

Lateral Migration Analysis

Geosyntec completed a lateral migration analysis of the crossing to assess potential lateral migration hazards relative to the proposed lateral setback locations. The lateral migration analysis revealed significant lateral migration. Using aerial recent and historical imagery, Geosyntec observed approximately 50 feet of lateral bank migration on both the north and south banks of the Sheyenne River over the observation period of aerial imagery (**Figure 1**). Additionally, Geosyntec observed significant channel avulsion potential as evident from the presence of meander cutoffs which have formed oxbow lakes within the floodplain in the vicinity of the crossing and the presence of meander scrolls in the LiDAR signature (**Figure 2**). The Sheyenne River has the potential to rapidly shift its planform within the valley bottom and lateral migration hazard exists from valley wall to valley wall.

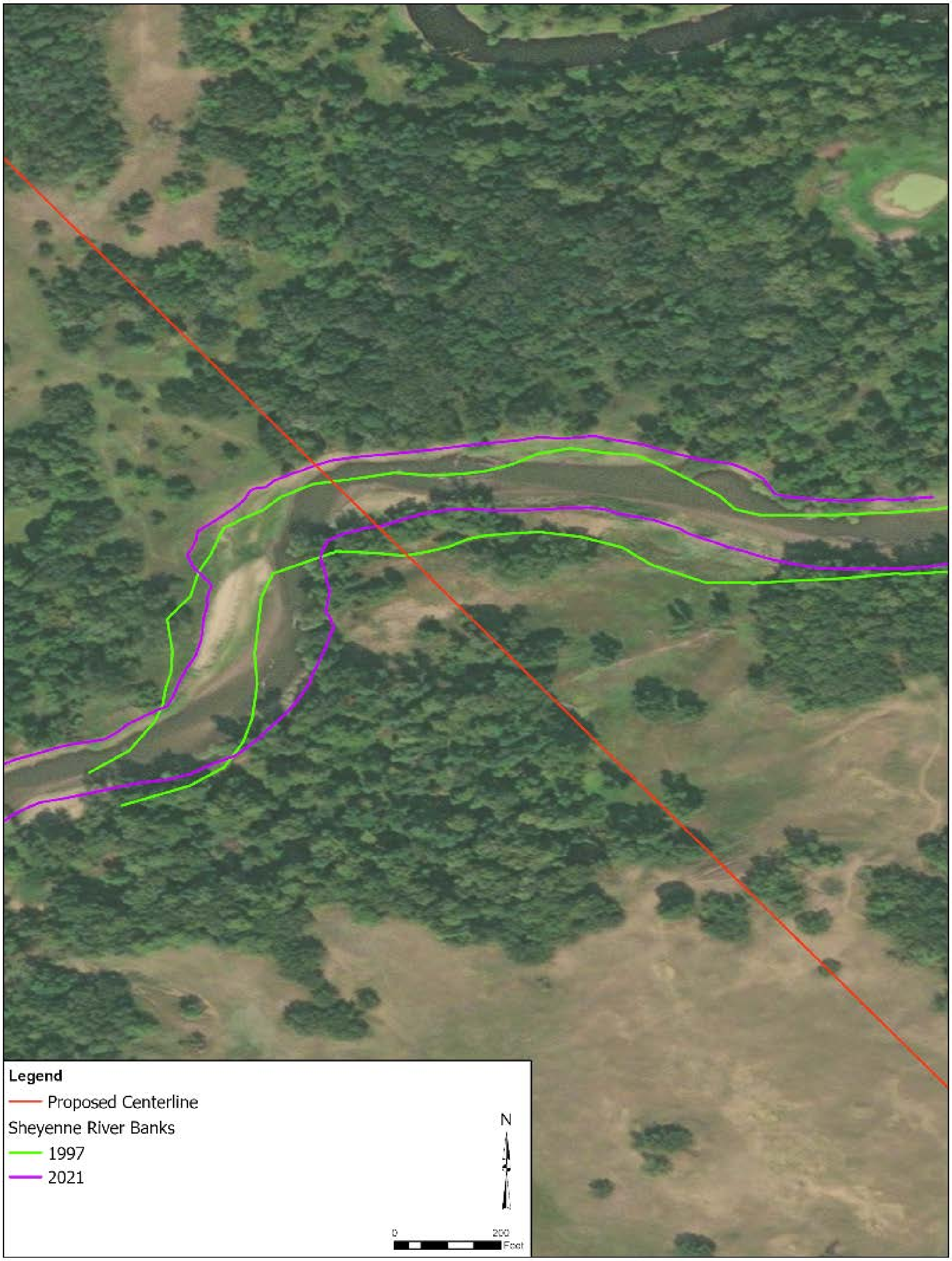

Figure 1. Sheyenne River Lateral Historic Streambank Delineation

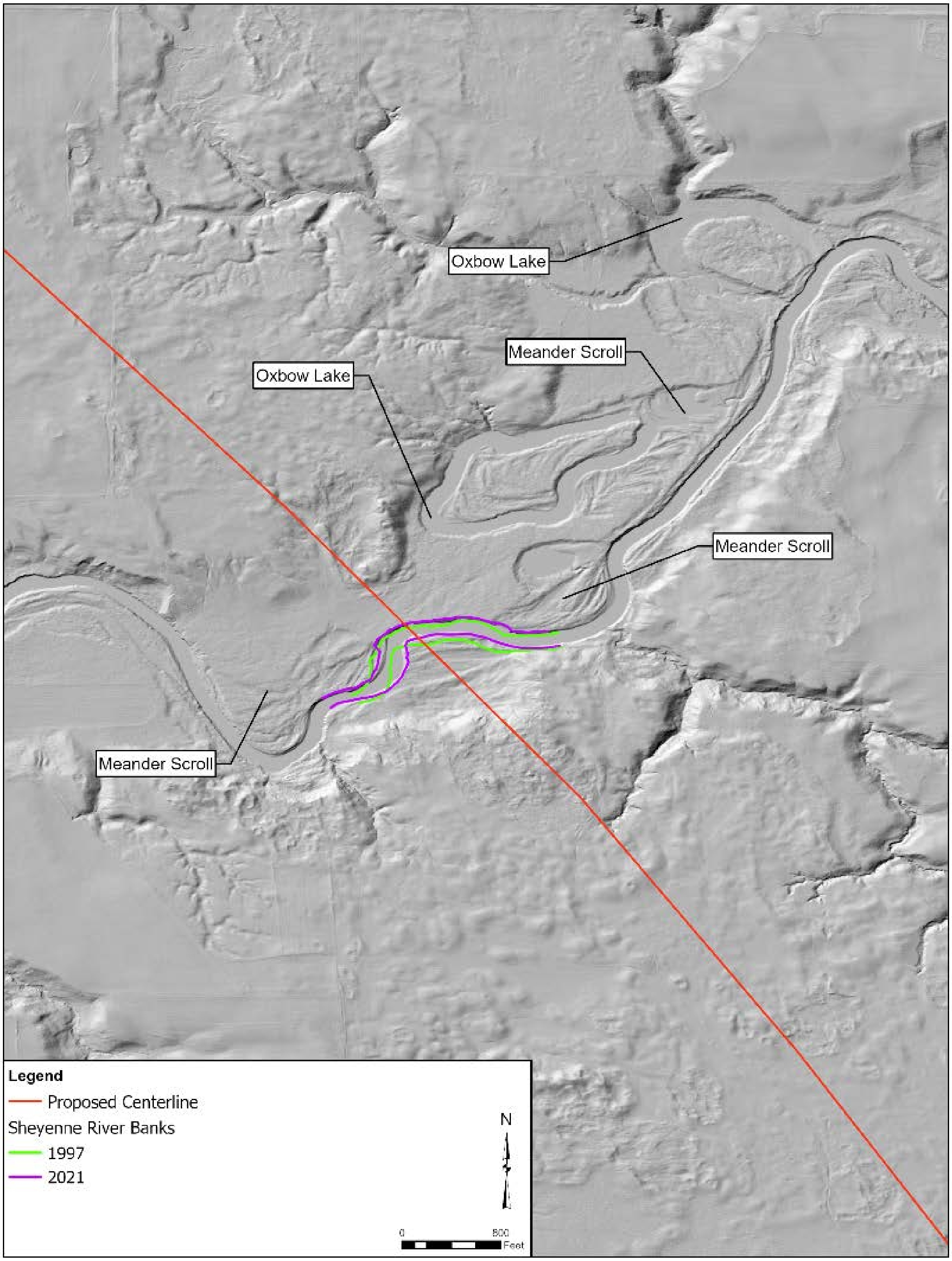

Figure 2. Sheyenne River Channel Avulsion Observations

RECOMMENDATIONS

Total scour depth was calculated to be 19.2’. Based on the current bathymetric data (supplied by TRC), the channel bottom elevation is 931.84’ NAVD88 and the proposed HDD burial elevation is 913.57’ NAVD88. A scour depth of 19.2’ below the existing bed would result in a fully exposed pipe subjected to hydrotechnical forces. Given the estimated minimal amount of cover at the proposed HDD elevation, Geosyntec recommends lowering the HDD elevation by approximately 10.5 (ELEV 903.04’) ft to provide for a minimum factor of safety of 1.5.

Based on the lateral migration analysis, the north bank point of inflection (PI) at station 1442+21.8 and the south bank PI at station 1445+01.7 are not sufficient to mitigate against the lateral migration hazards observed at the Sheyenne River crossing. Geosyntec recommends moving the north bank PI approximately 221 feet north to station 1440+00 and moving the south bank PI approximately 200 feet south to station 1447+00. The recommended burial depth elevation of 903.04’ should be maintained between these PIs. This will result in shifting the HDD entry and exit points further to the south and north, respectively.

CLOSING

We greatly appreciate the opportunity to support Gulf Interstate on this project. Should you have any questions or need additional information, please do not hesitate to contact David at Dvance@Geosyntec.com or (678) 361-4801 or Jeremy at JYeglin@Geosyntec.com or (832) 455-3684.

Sincerely,

September 7, 2022

Jeremy Yeglin, P.E.(ND, TX, OK)
Principal Engineer

David Vance, P.G.(GA)
Principal Geologist

REFERENCES

ASCE. 2005. *Predicting Bed Scour for Toe Protection Design for Bank Stabilization Projects*. American Society of Civil Engineers.

FHWA. 2012. *Evaluating Scour at Bridges*, *Fifth Edition*. Publication No. FHWA-HIF-12-003, Hydraulic Engineering Circular No. 18 (HEC-18), Federal Highway Administration Washington, D.C. (L.A. Arneson, L.W. Zevenbergen, P.F. Lagasse, P.E. Clopper). April.

Maynord, S. 1996. "Toe Scour Estimation on Stabilized Bendways." *Journal of Hydraulic Engineering*, American Society of Civil Engineers, 122(8).

Thorne, C.R, 1988. Bank Processes on the Red River between Index, Arkansas and Shreveport, Louisiana; Final Report to the US Army European Research Office, contract number DAJA45-88-C-0018; Department of Geography, Queen Mary College: London, UK.

US Army Corps of Engineers (USACE), 1994. Hydraulic Design of Flood Control Channels. Washington, DC: Department of the Army.

USACE, 2020. Hydrologic Engineering Center River Analysis System User's Manual Version 6.0. Institute for Water Resources, U.S. Army Corps of Engineers.

USACE, 2021. Approaches for Assessing Riverine Scour. Coastal and Hydraulic Laboratory. ERDC/CHL TR-21-7. May 2021.

US Bureau of Reclamation (USBR), 2019. Guidelines for Evaluating Pipeline Channel Crossing Hazards to Ensure Effective Burial. Denver, CO: US Department of the Interior.