CROWLEY | FLECK PLLP
ATTORNEYS

Casey A. Furey
100 West Broadway, Suite 250
P.O. Box 2798
Bismarck, ND 58502-2798
701.223.6585
cfurey@crowleyfleck.com

October 29, 2020

Via Electronic Mail

Mr. Steve Kahl
Executive Director
North Dakota Public Service Commission
600 East Boulevard, Dept. 408
Bismarck, ND 58505-0480
ndpsc@nd.gov

In re: Belle Fourche Pipeline Company
8-inch Wilson-Bowline Pipeline Conversion Project
Case No. PU-18-404
Our File No. 013084-000013

Dear Mr. Kahl:

Enclosed for filing in the above-referenced matter please find the Geohazard Evaluation Report.

Please do not hesitate to contact me with any questions.

Sincerely,

Casey A. Furey

CAF/lh
Enc.

cc: Adam Renfandt (via email)
Ken Dockweiler (via email)
Robert Stamp (via email)

84 PU-18-404 Filed 10/29/2020 Pages: 48
Geohazard Evaluation Report
Belle Fourche Pipeline Company
Casey Furey, Crowley Fleck PLLP

Report of Geohazard Evaluation Wilson to Bowline Pipeline Segments West Central North Dakota

Tetra Tech Project No. 117-0533085

October 27, 2020

PRESENTED TO

Belle Fourche Pipeline, LLC
Attn: Mr. Kevin Pena
455 North Poplar Street
Casper, Wyoming 82601

PRESENTED BY

Tetra Tech
2525 Palmer Street, Suite 2
Missoula, MT 59808

P +1-406-543-3045
F +1-406-543-3088
tetratech.com

Prepared by:

Andrew Warren, P.E.
Geotechnical Engineer

Reviewed by:

Jeremy Dierking, P.E.
Project Geotechnical Engineer

Reviewed by:

Heather Phelan
Project Geoscientist

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ACRONYMS / ABBREVIATIONS

Acronyms/Abbreviations	Definition
BMP	Best Management Practice
ESRI	Environmental Systems Research Institute
GIS	Geographic Information Systems
RTK GPS	Real-Time Kinematic Global Positioning System
USGS	United States Geological Survey

1 INTRODUCTION

At the request of Belle Fourche Pipeline, LLC (Belle Fourche Pipeline), a field geologic hazard evaluation has been completed at three (3) sites of concern identified by Belle Fourche Pipeline along the existing Wilson to Bowline pipeline segments in the Little Missouri Badlands area of west central North Dakota. The field evaluation locations along the pipeline routes are included in Figure 1. This report describes the preliminary field evaluation results of slope geohazards in the evaluation area.

The existing Wilson to Bowline pipeline segment is an 8-inch diameter pipeline spanning approximately 20 miles from the Wilson Station south of Watford City to the Bowline Station southwest of Arnegard. The Wilson to Bowline pipeline segment was placed into service in 2012.

1.1 PURPOSE AND SCOPE OF FIELD EVALUATIONS

A field evaluation was completed for slope geologic hazards at three (3) locations of concern selected by Belle Fourche Pipeline along the Wilson to Bowline pipeline segment in McKenzie County, North Dakota. The purpose of the evaluations was to observe and document site conditions and assign slope failure potential rankings to each selected slope geohazard location along the existing pipeline routes.

The field evaluations and rankings included in this report are intended to be used by Belle Fourche Pipeline as a pipeline management tool to monitor potential geologic hazard areas and reduce the potential risk presented by the identified hazards. Understanding the geologic hazard behavior presented in this report will allow contingency plans relative to pipeline operations to be formulated and implemented by Belle Fourche Pipeline to manage pipeline performance and minimize potential pipeline failures.

This report presents the results of the geologic hazard field evaluations, summaries of findings, conclusions of risk, and next steps in the geohazard evaluation process.

2 SLOPE SELECTION AND DATA COLLECTION

2.1 SLOPE SELECTION

The list of potential slope crossings evaluated in the field by Tetra Tech for the Wilson to Bowline pipeline segment was developed by Belle Fourche Pipeline, derived from potential areas of concern to the pipeline segments. Three (3) potential slopes were selected by Belle Fourche Pipeline and were provided to Tetra Tech for evaluation. Each site was subsequently visited and evaluated for potential geohazards. Summaries of the completed field evaluations and slope failure potential rankings, based on field evaluations and background data, are discussed in Section 5.

2.2 DATA COLLECTION

Multiple public and private data sources were reviewed and utilized as part of the field evaluations and subsequent evaluation of the sites identified by Belle Fourche Pipeline, listed in the following sub-sections.

2.2.1 PUBLIC SOURCES AND TYPES

- Environmental Systems Research Institute (ESRI)

- Aerial imagery
- Topographic maps

- North Dakota GIS Hub Data Portal
  - LiDAR elevation dataset
- United States Geological Survey (USGS)
  - The National Map
  - National Geologic Map Database
  - Topographic maps
  - Mineral Resources Data System, which provides surficial and bedrock geology information

2.2.2 PRIVATE SOURCES AND TYPES

Belle Fourche Pipeline provided GIS data related to the existing pipelines in the assigned geographic area. Data included:

- Pipeline polylines
- Pump stations
- Valves

3 GEOHAZARD IDENTIFICATION

3.1 GEOLOGIC SETTING

A basic understanding of the geology of a region or locale is important for evaluating geohazard concerns. Following is a brief description of the regional geology.

The project is located within the semi-arid climate of the northern Great Plains, on the southwestern side of the Williston Basin. The existing pipeline segments cross McKenzie County is in west central North Dakota. The project area is located in the Little Missouri Badlands area of the unglaciated Missouri Plateau. Topography is characterized by gently rolling uplands interrupted by buttes and ridges capped by resistant rock types and steep badlands created by the network of small tributaries draining to the Little Missouri River.

The regional geology can be summarized as predominately weathered sandstone, siltstone, and shale (claystone) locally overlain by unconsolidated soil deposits. Unconsolidated deposits at the surface consist of clay, silt, sand, and gravel of irregular thickness within the valleys and typically thin deposits in upland areas. Most of the bedrock exposed at the surface and encountered below the surficial soils consists of relatively flat-lying sedimentary formations. The vast majority of the exposed bedrock consists of the Sentinel Butte and Bullion Creek Formations (Paleocene), which consists of alternating layers of weathered claystone, siltstone, sandstone, and lignite. The Sentinel Butte Formation is described as fine- to medium-grained, gray to tan and yellowish gray, clay, silt, sand, and lignite. The Bullion Creek Formation is described as fine- to medium-grained, yellow-brown, silt, sand, clay, and lignite.

The Bullion Creek Formation typically forms more rounded, vegetated slopes than the overlying Sentinel Butte Formation. Deposits of bentonitic claystone/shale and their derivative clay soils from the Sentinel Butte Formation are historically susceptible to landslide deformations when slopes approach 25 percent or greater, especially when moisture content increases seasonally due to snowmelt and spring rains. Bentonite typically forms a desiccated “popcorn” structure when dry at the surface.

The project area has the potential for localized subsidence related to collapse of burned out lignite layers, which can be indicated by the presence of clinker beds or chimneys, although available mapping does not indicate any such features in the project area. Karst subsidence is not noted in the area due the small percentage of limestone deposits, although surface runoff can develop localized "pseudo-karst" piping features including small tunnels and caves that are sometimes observed in badland topography. Localized features such as burned out lignite layers and piping features are not mapped and can only be evaluated after identification in the field.

Geologic hazards can be caused by man-made impacts such as road construction, regrading, fill placement, and altering natural drainage patterns. Such activities can contribute to existing areas of slope instability and initiate new landslides.

3.2 GEOHAZARD RANKING CRITERIA

Tetra Tech assigned a ranking to each of the three (3) potential slope crossing geohazard locations ranging from very low to very high potential of instability. The geohazard ranking criteria is summarized below in Table 4-1: Slope Geohazard Ranking Criteria.

Table 4-1. Slope Geohazard Ranking Criteria

Rank	Ranking Criteria Description
Very Low	Very low potential of slope movement. Typically, gentle (<12 degrees) slopes. Slope has a very low potential for mass movement. Well vegetated (>80%), stable soil type. No obvious erosion or movement features - slope less than 12 degrees.
Low	Low potential of slope movement. Typically, gentle to moderate (12 to 20 degrees) slopes. Low potential for mass movement. Possible minor rills, erosion, and creep. Well vegetated (>80%), stable soil type.
Medium	Moderate potential of slope movement. Typically, moderate (20 to 30 degrees) slopes. Moderate potential for mass movement. Slope has evidence of creep, erosion, minor slumping, or seepage. Sparse vegetation (<50%). Stratigraphy and soil type are favorable for slope movement.
High	High potential of slope movement. Typically, moderate to steep (20 to >45 degrees) slopes. Evidence of slope movement, major erosion, slumping, seepage, etc. Proximal to other areas of mass movement. Stratigraphy and soil type are favorable for slope movement. Area should be evaluated within the next 6-12 months.
Very High[1]	Very high potential of slope movement. Typically, moderate to steep (20 to >45 degrees) slopes. Material is unstable. Visible evidence of recent mass movement. Recommend site specific evaluation. Area may need immediate attention and should be evaluated within 1-2 months.

Note: [1]Slope stability features assigned a hazard rating of high or very high based on specific criteria should be further evaluated by direct field observation. Some rankings were modified based on engineering judgement, with comments provided in the geohazard table.

A geohazard intersect map (Figure 1) is included in the Appendix. Specific slope geohazard points are consecutively numbered by county, generally from west to east then north to south along the existing pipeline alignment.

4 FIELD EVALUATION

4.1 FIELD EVALUATION SUMMARY

A field evaluation consisting of observation and data gathering was conducted by Tetra Tech for three (3) potential geohazard locations identified and selected by Belle Fourche Pipeline for the existing Wilson to Bowline pipeline segment.

Prior to the field work, Tetra Tech prepared an Incident Prevention Plan. The document included anticipated safety issues that the Tetra Tech field team might encounter while performing the field work within the pipeline right-of-way. All project access to the pipeline right-of-way and requisite landowner notifications were performed by Belle Fourche Pipeline personnel or their designated land agents for all locations prior to the field work beginning. A one (1) person Tetra Tech field crew performed the requested field evaluations on July 6th and 7th, 2020, with mobilization and de-mobilization occurring on July 5th and July 8th, respectively. The field crew was accompanied by two (2) Belle Fourche Pipeline representatives throughout the duration of the program.

The field evaluations were conducted to determine if remedial measures are necessary to reduce the slope failure potential. Tetra Tech collected site specific information for each potential geohazard location to establish a baseline of current conditions. Site specific information included; geohazard identification, distance of the geohazard from the existing pipeline, geohazard location (latitude/longitude), location description, soil and/or rock lithology, slope type, slope inclination and dimensions, slope aspect relative to the pipeline direction, erosion potential, surface water (if applicable), vegetation cover, existing pipeline depth of cover (if available), location photos, and comments on the specific geohazard. Location and direction of field photos shown on accompanying maps at end of each field form in the appendix. Field equipment included: Real-Time Kinematic Global Positioning System (RTK GPS), mobile tablet, utility line locator (for depth of cover measurements), and laser rangefinder/inclinometer.

4.2 FINDINGS AND CONCLUSIONS

Slope instability (landsliding) is the most common and frequent type of geologic hazard along the pipeline segments. Landsliding and the other identified hazards have the potential to damage or rupture the pipelines within the evaluated areas. The relationships of geologic unit, slope angle, slope length, and slope aspect are important relative factors for understanding previous landsliding, existing landsliding, and future landsliding potential.

The field geohazard evaluation of the various sites indicates steep slopes with poor vegetation and fine-grained surficial soils are susceptible to slope movement and erosion. Specifically, areas of unconsolidated soils overlying highly weathered sandstone and claystone bedrock of the Bullion Creek and Sentinel Butte Formations are more susceptible to slope instability. Slopes with poorly established vegetation are susceptible to surficial raveling, rilling, gully erosion, and surficial slump failures. Slope failures above the pipeline can continue to load slide mass and debris on to the pipeline alignment adding weight and increasing the potential for slope failure below the pipeline. Slope movements may also start lower on the slope and propagate head-ward upslope to intersect the pipeline alignment. Historic slope movements may provide information and insight on hazards most likely to affect the pipeline in the future.

Many of the areas which have moved in the past may be temporarily stable but have the potential to reactivate. A previous slide will often remain stable unless a present condition changes. Direct condition changes generally involve construction on or adjacent to a landslide or adjacent slopes. Indirect condition changes generally involve the behavior of surface water, infiltration and groundwater on or near a landslide or slopes prone to landsliding. Recent development near the pipeline, or on-going construction activities can present a potential impact to the pipeline corridor both immediate and ancillary. For these investigations a corridor width of 200 feet total, 100 feet either side of centerline, was considered.

5 GEOHAZARD SUMMARIES, MITIGATION ALTERNATIVES, AND RECOMMENDATIONS

5.1 GEOHAZARD SUMMARIES

Three (3) potential geohazard locations were evaluated in the field on July 6th and 7th, 2020 and are discussed and described briefly below with the information tabulated in summary tables. The slope crossing field forms include detailed data, descriptions, and photos of each evaluated geohazard location and are included in the Appendix. Conceptual mitigation alternatives are also summarized should Belle Fourche Pipeline determine it necessary. Note that suggested mitigation actions here may differ from those discussed on the field form; the actions in the report take into account field observations and subsequent review and should be considered the most recent and inclusive suggestions.

5.1.1 POTENTIAL SLOPE 1, MCKENZIE COUNTY, NORTH DAKOTA

A small stream intersects the Wilson to Bowline pipeline alignment near toe of the slope. The slope appears that it was graded and flattened during original construction of the pipeline but has since revegetated. The slope is approximately 200 feet long at 6 degrees, with locally steep areas up to 15 degrees. Approximately 105 feet west of the existing pipeline, a large landslide was observed, extending approximately 100 feet across and 65 feet long with very steep sides, encompassing nearly the entire slope length at that location. An approximately 20-foot long associated tension crack was observed on the northern edge of the scarp. At the toe of the slide mass, the stream is actively eroding and cutting, causing subsequent slumping. The slope was ranked as a high potential for slope movement due to the moderate slope, active slope movement to the west of the pipeline, and apparent active erosion of the stream bank at the toe of the slope. The risk for potential impacts to the existing Wilson to Bowline pipeline is medium due to the proximity of the existing pipe to the slide mass encroaching to the north. Potential mitigation may include regrading the slide area and installing erosion control measures.

Location	Geohazard Rating	Slope (deg)	Down-slope Length (ft)	Distance from Pipeline to Geohazard (ft)	Slope Aspect	USCS Soil Class	Geology
Potential Slope 1, McKenzie County	Medium	6-15	200	105	SW	CL-ML	Bullion Creek Formation

5.1.2 POTENTIAL SLOPE 2, MCKENZIE COUNTY, NORTH DAKOTA

A small unnamed steam intersects the pipeline at the toe of the slope. The graded slope extends down to the west approximately 180 feet at an angle of 14 degrees, then flattens to 9 degrees for approximately 400 feet. Then, the slope steepens again to 15 degrees for 130 feet where it intersects the steam at the toe. Overall, the slope within the pipeline corridor showed minimal signs of erosion and was well vegetated throughout. There was, however, some minor erosion and bare areas observed along the upper portion of the slope. To the north and south of the pipeline corridor, steeper slopes showing more extensive erosion were observed. The steeper slopes were 80 to 100 feet or more from the pipeline corridor. This slope was ranked as a low potential for slope movement due to its relatively shallow slope, minimal erosion along the slope, and no apparent indication of instability. Due to the distance from steeper ungraded slopes outside of the pipeline corridor, the risk for potential impacts to the Wilson to Bowline pipeline is low.

Location	Geohazard Rating	Slope (deg)	Down-slope Length (ft)	Distance from Pipeline to Geohazard (ft)	Slope Aspect	USCS Soil Class	Geology
Potential Slope 2, McKenzie County	Low	9 – 15	710	30	W	ML	Sentinel Butte Formation

5.1.3 POTENTIAL SLOPE 3, MCKENZIE COUNTY, NORTH DAKOTA

The slope extends approximately 175 feet to the northeast from its crest at an average of 27 degrees, with the pipeline extending parallel to the slope. At the toe of the slope is a local tributary drainage with signs of intermittent water. Near the slope toe, there is an approximate 25-foot wide by 25-foot long historic slump, extending up to 3 feet in height above the surrounding soil. Approximately 100 feet north of the pipeline corridor at the confluence of the tributary, an approximately 50-foot wide landslide was observed extending roughly 75 feet down the slope. Some erosion was noted outside the pipeline corridor and near the toe of the slope. The slope was ranked as a medium potential for slope movement due to its steep angle, minor slumping near the toe of the slope, and proximity to a slide mass. The risk for potential impacts to the Wilson to Bowline pipeline is moderate. Potential mitigation may include regrading the slump and erosion areas and installing erosion control measures.

Location	Geohazard Rating	Slope (deg)	Down-slope Length (ft)	Distance from Pipeline to Geohazard (ft)	Slope Aspect	USCS Soil Class	Geology
Potential Slope 3, McKenzie County	Medium	27 – 35	175	35	NE	ML	Sentinel Butte Formation

5.2 MITIGATION ALTERNATIVES SUMMARY

Should erosion and slope movement continue to occur at the locations above and Belle Fourche Pipeline determines that mitigation is necessary, potential mitigation alternatives are presented and discussed in more detail below for further consideration. All slope stabilization methods include one or more of the following goals; reduce driving forces, increase resisting forces, or avoid the failure area.

Typically, mitigation alternatives fall into three primary categories: avoidance, slope modification (reduce the driving forces/increase the resisting forces), and slope reinforcement (increase the resisting forces).

Avoidance consists of avoiding areas of potential or existing hazards. Avoidance can be accomplished by re-routing around the hazard area, trenching or horizontal directional drilling to a depth sufficiently below the hazard, or spanning over the hazard area.

Slope Modification includes; slope re-grading (slope flattening, benching, toe berm/buttress), removal and replacement of unstable material (may include shear key trench or light-weight fill material), surficial reinforcement (re-vegetation, erosion control fabric, geocell, rip rap), and surface water controls (interception ditches, BMP berms). Slope flattening is often the simplest method for improving the stability.

Drainage Improvements includes; surface water diversion, interception, and collection ditches or berms, subsurface drainage galleries, horizontal drains, and dewatering wells.

Slope Reinforcement can include a wide variety of reinforcement types or combinations of different types. Ground anchors, tieback walls, micropiles, soil nails, retaining walls, soldier piles, sheet piles, and reinforced soil slopes are examples of the types of reinforcement techniques typically used to repair unstable slopes.

Slope modification and structural reinforcement are often combined to some degree to optimize the slope mitigation method. Slope modification and structural slope reinforcement techniques typically include measures to address surface and ground water drainage, such as underdrains, cut-off drains, horizontal drains, diversion and interception ditches, de-watering wells, and impermeable membranes. A more complete and detailed list of possible mitigation alternatives are summarized in the following table.

Mitigation Alternative	Effectiveness	Cost	Brief Description
Earthworks			
Slope Re-grading	High	Low to High	Improves stability by flattening or benching slope to uniform and stable geometry. Often includes cutting material from top of slope and placing it as fill at toe of slope.
Toe Buttress	High	Low to High	Construction of soil berm at toe of slope to resist driving forces of slide mass. Typically benched into the slope and keyed into the toe area.
Shear Key Trench	High	Low to High	Excavation or large trench or series of trenches into slope to intercept the failure plane. Replace native materials with compacted higher strength, free-draining, granular material. Typically included in conjunction with re-grading or buttressing.
Rip Rap Armoring	Moderate	Low	Placing large cobbles and boulders or engineered hard armor products along stream bank or across slope to provide erosion and provide surface protection.
Lightweight Fill	Medium	High	Replacement of native soils with light-weight material to reduce weight of slide mass and reduce driving forces in slide area. Lightweight material can consist of geofoam, polystyrene blocks, wood fiber, shredded rubber tires, or other materials.
Ground Improvement (stone columns, jet grouting, etc.)	High	High	Replacing or strengthening existing soil within the slide area or across the slide plane by drilling and replacement or mixing soil with cement to increase shear strength.
Surface Protection			
Geocell	High	Low to Moderate	Shallow cellular confinement system used to prevent erosion on slopes up to 45 degrees. Permeable and allows water to flow between cells, improving drainage and promoting vegetation growth for erosion control.
Erosion Control Fabric	Moderate	Low	Prevent erosion by protecting surface and promoting vegetation.
Drainage Improvement			
French Drains	Moderate	Low	Excavated trenches perpendicular to slope and filled with gravel wrapped in filter fabric. Improves stability by draining near surface soils and reducing pore pressures.
Horizontal Drains	Moderate	Moderate	Drilling into slope at low angle and installation of drain pipe. Improves stability by lowering groundwater levels and decreasing pore pressure. Can be susceptible to freezing or clogging, which may require periodic maintenance. Can be damaged by slide movement and become inoperative.
Dewatering Wells	High	Moderate	Drilling vertical wells and pumping to lower groundwater levels and decrease pore pressures. Requires electricity to run pumps and outfall system.
BMP ditches and Interception ditches	Low to Moderate	Low	Construction of berms and/or ditches to collect and divert surface water flow away from failure area. Controls surface water flow to reduce infiltration and erosion.
Structural Reinforcement			
MSE Wall	Low to Moderate	Moderate	Construction of reinforced retaining wall on slope below pipeline. Welded wire mesh, gabions, and geogrid wrapped faces are typical applications.

Mitigation Alternative	Effectiveness	Cost	Brief Description
Soil Nails	High	High	Installation of steel bars grouted into place with a steel mesh and shotcrete slope facing. Provides additional shearing resistance along failure plane and surface protection.
Ground Anchors	High	High	Installation of anchor strands or bars grouted into place and pre-tensioned against a reaction block at the slope face. Provides additional shearing resistance and normal force across the failure plan.
Micropiles	High	High	Installation of small diameter steel and grout piles through slide mass to provide additional shearing resistance across failure plane. Often installed in 'A-frame" type pattern with a concrete pile cap.

Geohazard locations with a 'high' or 'very high' potential for slope movement with potential to affect the pipeline can be monitored and instrumented to provide observation and characterization of factors that may contribute to slope instability (precipitation, groundwater elevation, stream flow), and slope movement (magnitude and direction of movement, and depth of shear zone). This information can be useful as an 'early-warning' system indicating impending pipeline damage and for design of a long-term mitigation design. The simplest method of monitoring consists of periodic field inspection and documentation of basic site conditions.

Additional monitoring techniques include topographic survey, fixed survey points, rain gauges, stream gages, crack monitoring, piezometers, extensometers, inclinometers, and aerial and terrestrial photography. These techniques can be utilized at specific locations on a case by case basis.

A significant factor to consider for improving slope stability is subsurface water, surface run-off, and infiltration control. Saturated soil conditions can reduce soil strengths and contribute to slope instability. To minimize these conditions, surface water runoff must be controlled both during construction and after construction of any mitigation system. Mitigation methods will perform more effectively with a drainage system installed to intercept and control surface water flow.

The mitigation alternatives summarized above are general "tried and true" methods for slowing or arresting slope movement within slide areas and have proven effective on similar projects. However, given the relatively unknown subsurface conditions, the overall lifespan and the effectiveness to arrest movement through mitigation is not completely predictable without additional geotechnical investigation, slope monitoring, and analysis. New or existing slides can be reactivated due to many factors beyond the geotechnical engineer's control such as seismic activity and vibration, relaxation of the mitigation system, or increased infiltration due to 'above normal' precipitation. Other factors include variations in subsurface soil or rock properties and groundwater elevations not encountered during the limited field investigation.

5.3 GENERAL RECOMMENDATIONS

The following recommendations are based on information obtained from the data review, geohazard mapping, and geohazard description. The recommendations below are for general consideration at high instability, erosion potential, and/or active geohazard locations along the pipeline corridor.

The intent of a monitoring program is to identify slope movements before the pipeline is affected. The monitoring program should consist of both visual monitoring, and movement monitoring if deemed necessary. One of the three potential geohazard locations in McKenzie County of North Dakota evaluated during the July 2020 field evaluations were observed to have slope movement or erosional features with potential to encroach toward and pose risk to the pipeline. At a minimum, geohazard locations ranked as 'high' or 'very high' with potential to affect the pipeline should be monitored to observe, document, and characterize factors that may contribute to slope instability and movement. Monitoring should include measuring the physical dimensions of the failure areas to determine movement over time.

Movement monitoring could be performed by in-situ instruments or surveyed movement monitoring. Systematic visual monitoring could be performed by Tetra Tech's geotechnical staff. The program would monitor active and pre-existing landslides and slopes with high potential for instability that would affect the pipeline, if deemed necessary by Belle Fourche Pipeline. The program would be structured similar to the initial field inspections completed as part of this evaluation. Each visual monitoring event would be recorded and evaluated so monitoring events can be compared through time. In-situ movement and movement surveys would also be recorded and evaluated. This monitoring information will also be useful for design of a long-term mitigation design. If subsequent monitoring indicates the slope failure is active and encroaching on the pipeline, a geotechnical investigation is recommended to provide full mitigation recommendations.

The slope movements and movement susceptible slopes along the project segment are most directly affected by water. Future monitoring should focus on recording water features on or near the slopes, as well as any loading, erosion, or moving at susceptible slopes.

In unstable slopes and landslides, it is critical to understand the failure mechanism before making recommendations for mitigation and stabilization. Otherwise, construction activities can often be ineffective or further instigate additional instability. Survey monitoring points can be installed within slope movement areas to monitor and document magnitude, rate, and direction of future movement. In areas where seepage or groundwater appears to affect stability, temporary piezometers can be installed in boreholes and monitored to document groundwater levels and identify the shear plane depth in the event of future movement. Geotechnical evaluation/investigation may be necessary for geohazard locations where ongoing active slope movement occurs with the potential to damage the pipeline. Geotechnical evaluation/investigation may include a combination of the following elements; field inspection, field monitoring, geophysical exploration, subsurface exploration (boreholes and/or test pits/trenches), laboratory testing, slope stability analysis, and slope mitigation design alternatives.

Stabilization measures can be extensive and repairs costly depending on the mechanism of failure, combinations of slope geometry, slide size, access, and location of the failure plane. Therefore, it is important to recognize that based on actual slope and subsurface conditions, recommendations for slope stabilization measures may be too extensive or cost prohibitive to implement. In such a case, other less-conservative alternatives can be considered that would be less costly, but also less certain to provide long-term stabilization.

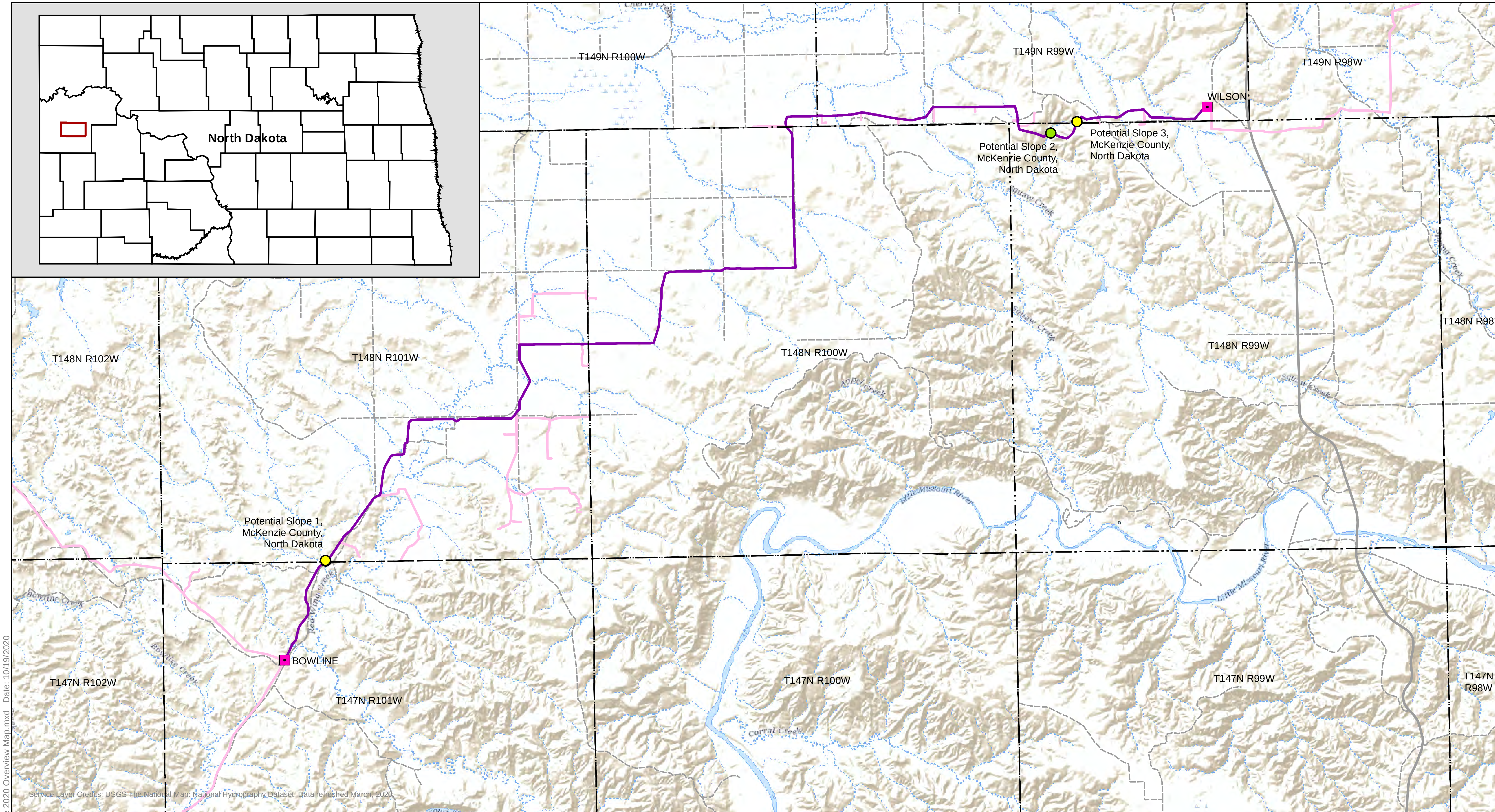
6 LIMITATIONS

This assessment has been conducted in accordance with generally accepted geotechnical engineering practices in the region where the work was conducted; however, no guarantees or warranties are provided or implied. The conclusions and preliminary recommendations submitted in this report are based upon project information provided to Tetra Tech, and data obtained from the desktop assessment.

This report has been prepared exclusively for our client. This report and the data included herein shall not be used by any third party without the express written consent of both the client and Tetra Tech. Tetra Tech is not responsible for technical interpretations by others. As the project evolves, Tetra Tech should provide continued consultation and field services to review and monitor the implementation of our recommendations and verify that our recommendations have been appropriately interpreted.

APPENDIX A

Wilson to Bowline - Overview and Slope Crossing Map (Figure 1) & Field Forms



N
W E
S

0 1 2 Miles

Wilson to Bowline Potential Slopes

Mass Failure Potential

- Very High
- High
- Medium
- Low

- Station
- Wilson to Bowline
- Other Active Line
- Other Inactive Line
- County Road
- State or Federal Road
- County Boundary
- PLSS Township

Wilson to Bowline
2020 Slope Field Inspection Locations

Belle Fourche Pipelines

FIGURE 1

E:\Bridger Pipeline\Wilson to Bowline 2020 Overview Map.mxd Date: 10/19/2020

2020 Belle Fourche Slope Crossing Field Form

Potential Slope 1, McKenzie County, North Dakota

Crossing Summary

Pipeline at Crossing: Wilson to Bowline

Mass Failure Potential:
Medium

Narrative Summary:
The slope is moderately steep to very steep and generally well vegetated. There is a large slide mass located approximately 40 to 50 feet northwest of the existing pipeline. The slide is roughly 100 feet across, 65 feet long, and 20 to 25 feet deep. An unnamed stream also exists at the toe of the slope and is actively eroding the toe of the slope toe and slide mass.

Action Items

Suggested Action Items:
Regrade, Install Erosion Control Measures, Additional Geotechnical Evaluation

Action Item Comments:
Regrade the slope to remove the large slide mass and reconstruct the slope to a less steep angle to help prevent future slope movement. Additionally, erosion control measures such as riprap should be installed to prevent further loss of material at the toe of the slope. The slope should be regularly monitored for potential additional slope movement and such movement should be documented.

Location, Date, and Time

Target Crossing Coordinates: 47.588459, -103.560041

Region:	Belle Fourche	**Inspection Date:**	Jul 6, 2020
State:	North Dakota	**Time Arrived:**	17:42
County:	McKenzie	**Time Departed:**	18:32

Access and Parking

Access Coordinates: 47.58766, -103.56082
Parking Coordinates: 47.58766, -103.56082

Access and Parking Comments: Parked on side of County Road 27 and walked to pipeline corridor.

Field Crew:

Andrew Warren (team lead, Tetra Tech)
Kyle Koppinger (Belle Fourche)
Kevin Peña (Belle Fourche)

Access Method: Walk

Access Difficulty: Easy

Depth of Cover (DOC)

Wilson to Bowline

Valid DOC measurement achieved? Yes.

Approximate Minimum DOC Location: Top of Slope

DOC Coordinates: 47.588859933, -103.55948085

DOC Source: Line Locator

Line Locator Reading Quality: Good

Depth of Cover: 8.5 ft (2.6 m)

Ground Elevation: 2,121.7 ft (646.7 m), NAVD88 (+/- 1.6 ft)

Top of Pipe Elevation: 2,113.2 ft (644.1 m), NAVD88 (+/- 1.6 ft)

DOC Comments: Pipeline No. 3.

Assessment Area Start Coordinates: 47.58864, -103.55943

Assessment Area End Coordinates: 47.58819, -103.55985

Evidence of Mass Failure

Slides

Description: A large slide mass is located between the existing pipeline (Pipeline No. 3). The approximate slide mass dimensions are 100 feet across, 65 feet along the slope, and approximately 20 to 25 feet deep.

Slumping

Description: Multiple slumps near the unnamed creak were observed associated with movement of the large slide mass.

Surface Tension Cracks

Description: A tension crack was observed just beyond the head scarp on the northwest side of the slide and was approximately 20 feet in length. The tension crack was roughly 4 to 6 inches in width.

Bedrock Geology

Exposed Bedrock: No

Soil Conditions

USCS Soil Category: CL (lean clay) with Sand

Soil Condition Comments: Lean clay to silty clay with occasional gravel.

Water Conditions

Proximate water source(s) with potential to affect the slope:

Perennial Waterways

Description: Unnamed perennial stream located at the toe of the slope.

Site Topography/Landforms

Landform Type: Ridge

Slope Profile: Linear

General Slope Aspect: West

Crossing Angle: Parallel

Crossing Angle Description: The existing pipeline is parallel to the slope.

Average Slope Angle: 33 degrees

Maximum Slope Angle: 66 degrees

Length of Entire Slope: 70 ft (21.3 m)

Length of Slope at Maximum Slope Angle: 20 ft (6.1 m)

Topography Landform Comments: The measured slope length and angle was taken where just northwest of the slide mass and east of the pipeline alignment. The slope length is approximately 100 feet at 18 degrees directly over the alignment. The pipeline will be located in a less steep crescent-shaped area northwest of the large slide mass.

Vegetation Cover

5% shrubs

80% forbs/groundcover

15% bare

Tree Fall Evidence: No

Potential Slope 1, McKenzie County, North Dakota Photo Log

Photo Type: Looking upslope | **Photo Bearing**: 25 degrees
Photo Description: Looking at slope from access location.

Photo #1

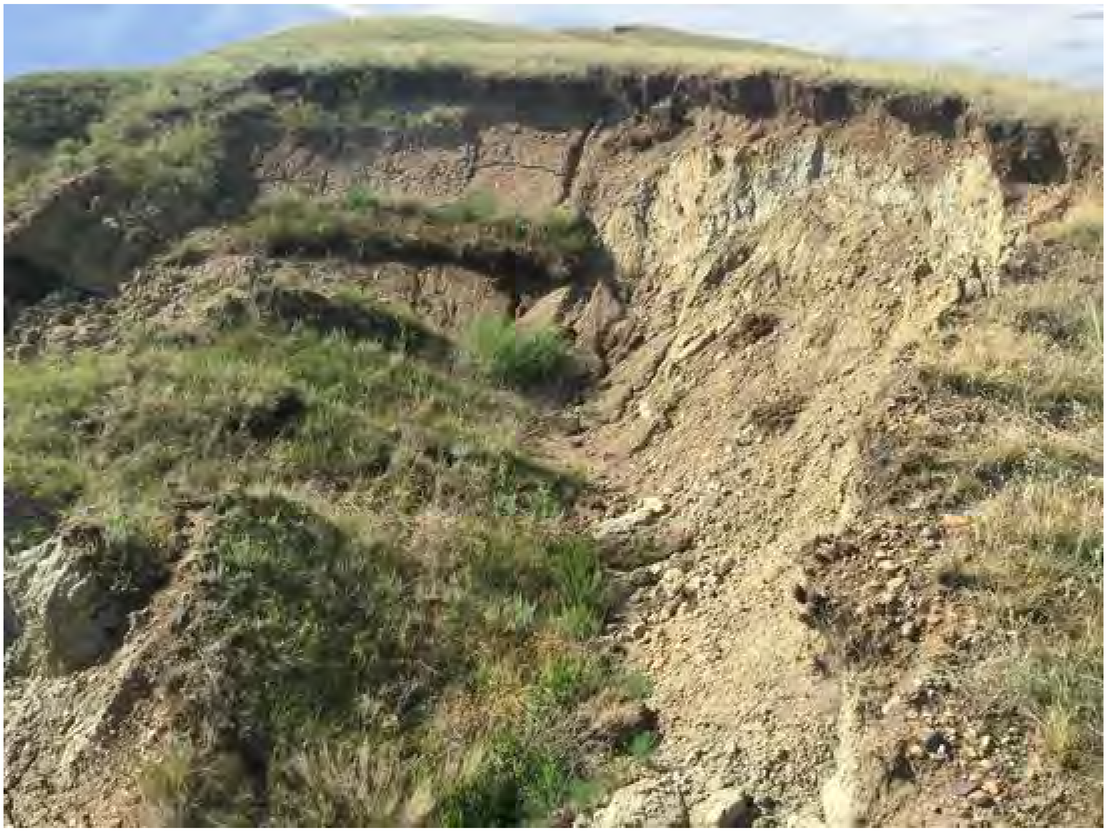


Photo Type: Slope movement evidence | **Photo Bearing**: 322 degrees
Photo Description: Large slide mass between existing pipeline.

Photo #2

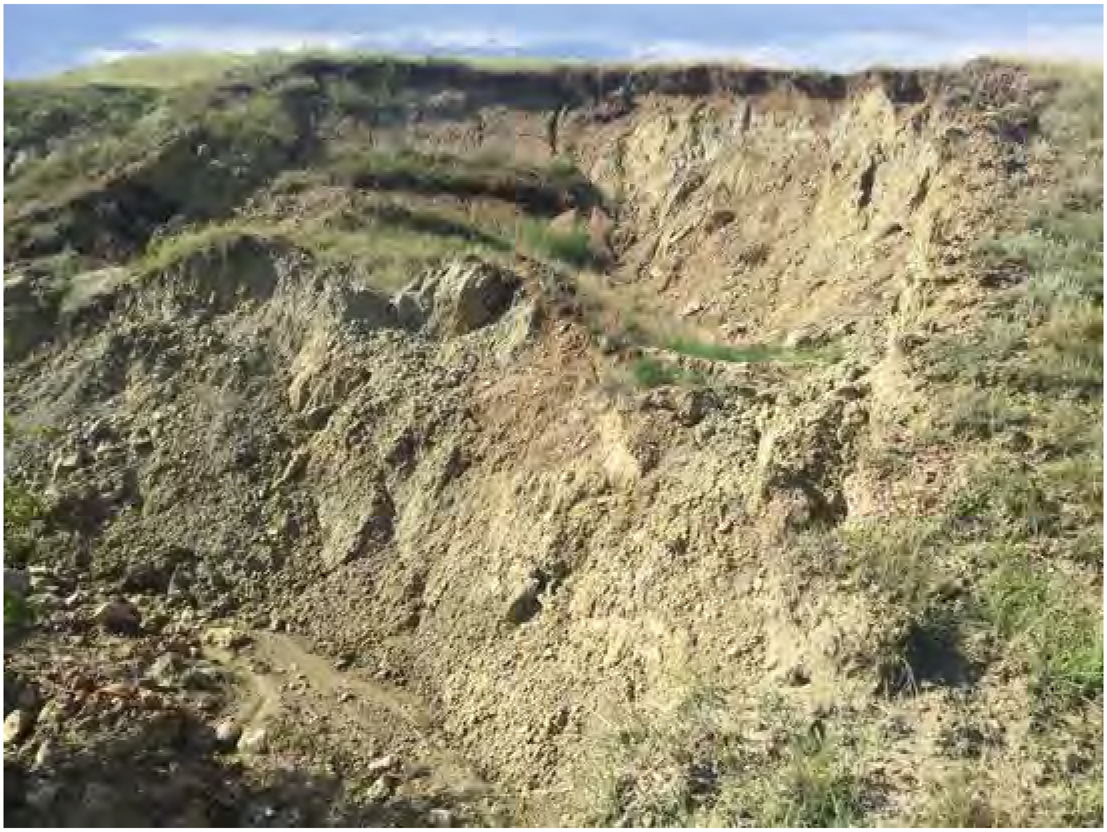


Photo Type: Slope movement evidence | **Photo Bearing**: 333 degrees
Photo Description: Looking at scarp and slide mass.

Photo #3

Photo Type: Looking downslope | **Photo Bearing**: 221 degrees
Photo Description: Looking down slope at slide mass.

Photo #4

Photo Type: Slope movement evidence | **Photo Bearing**: 126 degrees
Photo Description: Looking at slide mass.

Photo #5

Photo Type: Slope movement evidence | **Photo Bearing**: 64 degrees
Photo Description: Looking at tension crack.

Photo #6

Photo Type: Looking downslope | **Photo Bearing**: 228 degrees
Photo Description: Looking down slope along pipeline alignment.

Photo #7

Photo Type: Looking upslope | **Photo Bearing**: 13 degrees

Photo #8

Photo Type: Slope movement evidence **|** **Photo Bearing**: 61 degrees
Photo Description: Looking upslope at slide mass.

Photo #9

N W E S

0 40 80 Feet

- DOC Measurement Location
- Slope Start Point
- Slope End Point
- Slope Crossing Coordinates Provided
- Photo Location and Direction
- Wilson to Bowline
- 15 ft Contour
- 3 ft Contour

Wilson to Bowline
Potential Slope 1, McKenzie County, North Dakota
Belle Fourche Pipelines
FIGURE 2

E:\Bridger Pipeline\Potential Slope 1, McKenzie County, North Dakota.mxd Date: 10/19/2020

2020 Belle Fourche Slope Crossing Field Form

Potential Slope 2, McKenzie County, North Dakota

Crossing Summary

Pipeline at Crossing: Wilson to Bowline

Mass Failure Potential:
Low

Narrative Summary:
The slope is shallow to moderate and well vegetated throughout. There is a small unnamed perennial stream at the toe of the slope with minimal water at the time of assessment. There was minimal surficial erosion along the slope face and no apparent signs of mass failures at the time of assessment.

Action Items

Suggested Action Items:
None

Location, Date, and Time

Target Crossing Coordinates: 47.672478, -103.342168

Region:	Belle Fourche	**Inspection Date:**	Jul 6, 2020
State:	North Dakota	**Time Arrived:**	16:10
County:	McKenzie	**Time Departed:**	17:04

Access and Parking

Access Coordinates:	47.67575, -103.3303
Parking Coordinates:	47.67539, -103.33135

Access and Parking Comments: Used the same access and parking location as "Potential Slope 3, McKenzie County, North Dakota".

Field Crew:

Andrew Warren (team lead, Tetra Tech)
Kyle Koppinger (Belle Fourche)
Kevin Peña (Belle Fourche)

Access Method: Walk

Access Difficulty: Moderate

Depth of Cover (DOC)

Wilson to Bowline

Valid DOC measurement achieved? Yes.

Approximate Minimum DOC Location: Bottom of Slope

DOC Coordinates: 47.672630, -103.342981

DOC Source: Line Locator

Line Locator Reading Quality: Good

Depth of Cover: 8.1 ft (2.5 m)

Ground Elevation: 2,171.9 ft (662.0 m), NAVD88 (from 2014 LiDAR)

Top of Pipe Elevation: 2,163.7 ft (659.5 m), NAVD88 (based on 2014 LiDAR)

DOC Comments: Pipeline No. 3.

Assessment Area - Start Coordinates: 47.67185, -103.33998

Assessment Area - End Coordinates: 47.67259, -103.34301

Evidence of Mass Failure

None

Bedrock Geology

Exposed Bedrock: No

Soil Conditions

USCS Soil Category: ML (lean silt) with Sand

Soil Condition Comments: Silt with sand and clay, some gravel- to cobble-size fragments of sedimentary rock scattered along the slope.

Water Conditions

Proximate water source(s) with potential to affect the slope:

Perennial Waterways

Description: Small unnamed perennial stream at toe of slope.

Site Topography/Landforms

Landform Type: Valley

Slope Profile: Interrupted

General Slope Aspect: West

Crossing Angle: Parallel

Crossing Angle Description: The pipeline is parallel to the slope.

Average Slope Angle: 9 degrees

Maximum Slope Angle: 15 degrees

Upper Slope Angle: 14 degrees

Lower Slope Angle: 15 degrees

Length of Entire Slope: 710 ft (216.4 m)
Length of Slope at Maximum Slope Angle: 130 ft (39.6 m)
Length of Upper Slope: 180 ft (54.9 m)
Length of Lower Slope: 130 ft (39.6 m)

Topography Landform Comments: The middle portion of slope is approximately 400 feet long at 9 degrees.

Vegetation Cover

5% trees
5% shrubs
85% forbs/groundcover
5% bare

Tree Fall Evidence: No

Potential Slope 2, McKenzie County, North Dakota Photo Log

Photo Type: Looking upslope | **Photo Bearing**: 77 degrees

Photo #1

Photo Type: Looking upslope | **Photo Bearing**: 82 degrees

Photo #2

Photo Type: Looking downslope | **Photo Bearing**: 292 degrees

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Photo #3

Photo Type: Looking upslope | **Photo Bearing**: 80 degrees

Photo #4

N
W E
S

0 50 100
Feet

DOC Measurement Location
Slope Start Point
Slope End Point
Slope Crossing Coordinates Provided
Photo Location and Direction
Wilson to Bowline
15 ft Contour
3 ft Contour

Wilson to Bowline
Potential Slope 2, McKenzie County, North Dakota
Belle Fourche Pipelines
FIGURE 3

E:\Bridger Pipeline\Potential Slope 2, McKenzie County, North Dakota.mxd Date: 9/24/2020

2020 Belle Fourche Slope Crossing Field Form

Potential Slope 3, McKenzie County, North Dakota

Crossing Summary

Pipeline at Crossing: Wilson to Bowline

Mass Failure Potential:
Medium

Narrative Summary:
The slope is steep and well vegetated and located along the southern edge of a local finger drainage with intermittent water. A historic slump was observed near the toe of the slope with dimensions on the order of 25 feet by 25 feet, with the maximum height of the mass being roughly 3 feet. A slide was observed roughly 100 feet northwest of the slope and pipeline corridor near the confluence of a larger drainage, with approximate dimensions of 50 feet wide by 75 feet long and 5 feet deep. The slope appeared stable at the time of assessment with no apparent indications of recent slope movement.

Action Items

Suggested Action Items:
Other (see comments)

Action Item Comments:
Monitor the slope for signs of changing conditions or movement during future site visits. A slide was observed approximately 100 feet northwest of the pipeline corridor at the confluence of a larger drainage, suggesting this slope may also be susceptible to sliding.

Location, Date, and Time

Target Crossing Coordinates: 47.674658, -103.334337

Region:	Belle Fourche	**Inspection Date:**	Jul 6, 2020
State:	North Dakota	**Time Arrived:**	14:25
County:	McKenzie	**Time Departed:**	16:04

Access and Parking

Access Coordinates:	47.67575, -103.3303
Parking Coordinates:	47.67539, -103.33135

Access and Parking Comments: Parked on access road and walked to corridor.

Field Crew:

Andrew Warren (team lead, Tetra Tech)

Kyle Koppinger (Belle Fourche)
Kevin Peña (Belle Fourche)

Access Method: Walk

Access Difficulty: Moderate

Pipeline Corridor Comments: The pipeline corridor extends through multiple drainages with steep sides.

Depth of Cover (DOC)

Wilson to Bowline

Valid DOC measurement achieved? No.

Reason for inability to get a valid DOC: Too deep (but not HDD). Attempted multiple times at multiple locations to get a DOC measurement with no success. The pipeline is possibly too deep to get a valid reading, or the mapped location of the existing pipeline location is not accurate.

Depth of Cover: Unknown

Assessment Area - Start Coordinates: 47.67410, -103.33471

Assessment Area - End Coordinates: 47.67456, -103.33441

Evidence of Mass Failure

Slumping

Description: Historic slump observed near toe of the slope. Slump is approximately 25 feet wide and 25 feet long, with its mass extending up to 3 feet above surrounding areas. No recent movement was apparent.

Bedrock Geology

Exposed Bedrock: No

Other Bedrock/Surficial Geology Comments: Sandstone and siltstone fragments up to boulder size were observed throughout the slope.

Soil Conditions

USCS Soil Category: ML (lean silt) with Clay

Soil Condition Comments: Silt with clay and gravel

Water Conditions

Proximate water source(s) with potential to affect the slope:

Intermittent Waterways

Description: Drainage with intermittent water located at the toe of the slope.

Site Topography/Landforms

Landform Type: Valley
Slope Profile: Linear
General Slope Aspect: Northeast
Crossing Angle: Parallel
Crossing Angle Description: Pipe is parallel to slope.

Average Slope Angle: 27 degrees
Maximum Slope Angle: 35 degrees

Length of Entire Slope: 175 ft (53.3 m)
Length of Slope at Maximum Slope Angle: 45 ft (13.7 m)

Topography Landform Comments: Maximum slope angle and length are on the upper portion of the slope on the west edge of the corridor.

Vegetation Cover

5% trees
15% shrubs
75% forbs/groundcover
5% bare

Tree Fall Evidence: No

Potential Slope 3, McKenzie County, North Dakota Photo Log

Photo Type: Looking upslope | **Photo Bearing**: 223 degrees
Photo Description: Looking at slope from opposite drainage slope.

Photo #1

Photo Type: Looking upslope | **Photo Bearing**: 234 degrees

Photo #2

Photo Type: Water source | **Photo Bearing**: 141 degrees
Photo Description: Looking upstream at drainage located at the toe of the slope.

Photo #3

Photo Type: Slope movement evidence | **Photo Bearing**: 224 degrees
Photo Description: Slump near the toe of the slope.

Photo #4

Photo Type: Looking across slope | **Photo Bearing**: 290 degrees

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Photo #5

Photo Type: Looking downslope | **Photo Bearing**: 24 degrees

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Photo #6

Photo Type: Looking downslope | **Photo Bearing**: 59 degrees

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Photo #7

N W E S

0 50 100 Feet

- DOC Measurement Location
- Slope Start Point
- Slope End Point
- Slope Crossing Coordinates Provided
- Photo Location and Direction
- Wilson to Bowline
- 15 ft Contour
- 3 ft Contour

Wilson to Bowline
Potential Slope 3, McKenzie County, North Dakota
Belle Fourche Pipelines
FIGURE 4

E:\Bridger Pipeline\Potential Slope 3, McKenzie County, North Dakota.mxd Date: 9/24/2020