National Fuel Gas Supply Corporation

Cowanesque River HDD

HDD Feasibility Report

DOCUMENT No. 4418-ENG-RPT-0001
CCI PROJECT No. 4418

Prepared for:
Brent A. Hoover
814.871.8606
HooverB@natfuel.com

CCI Contact:
Gunnar Busch
832.888.2686
Gunnar.Busch@cciandassociates.com

Date: 2025/06/24
Revision: B

Edmonton Area Office
10239 178th Street NW
Edmonton, AB T5S 1M3
P: 780.784.1990

Calgary Area Office
2600, 520 – 5th Ave. SW
Calgary, AB T2P 3R7
P: 403.932.0560

Vancouver Area Office
1000, 700 West Pender Street
Vancouver, BC V6C 1G8
P: 604.500.0909

Houston Area Office
20445 State Hwy 249 Suite 250
Houston, TX 77070
P: 832.210.1030

Revision Log

Revision	Issue Status	Prepared by	Reviewed by	Approved by	Date Approved
A	IFR	A. Dumas	A. Faghih	G. Busch	2024-07-19
B	IFR	Q. Wen	R. Martinez	G. Busch	2025-06-24

Prepared by:

Qixuan Wen, E.I.T.
Junior Project Engineer

Reviewed by:

Raymundo Martinez, P.G.
Geologist

Approved by:

Gunnar Busch, P.E.
Trenchless Engineering Lead (U.S.)
PA P.E. # PE091005

CCI & Associates Inc.

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1 INTRODUCTION

National Fuel Gas Supply Corporation (NFG) is currently developing the Tioga Pathway Project, which aims to increase transportation capacity for Marcellus and Utica Shale gas from the Appalachian Basin into the interstate pipeline grid. The project includes constructing approximately 19.5 miles of new pipeline (Line YM59) in Harrison, Brookfield, Westfield, Deerfield, and Chatham Townships, as well as in Tioga and Potter Counties, Pennsylvania. Additionally, about 4 miles of existing pipeline facilities on Supply's Line Z20 pipeline system in Bingham and Harrison Townships, Potter County, Pennsylvania, will be replaced.

The new pipeline design and construction will require a FERC 7C permit application. The route for the new Line YM59 pipeline crosses the Cowanesque River and State Route 49 (SR 49) in Tioga County, PA, requiring a trenchless pipeline installation. This crossing will use an NPS 20 steel pipeline, and NFG plans to employ Horizontal Directional Drilling (HDD) methodology for this installation.

This report provides a feasibility assessment of site conditions, incorporating available geotechnical information and a geometric review of the proposed NPS 20 Cowanesque River HDD alignment and design. It also outlines the challenges the contractor may face and proposes mitigation strategies to minimize project risks.

2 DESIGN PARAMETERS

The parameters utilized in the design of the crossing are as follows:

a) The Pipeline Research Council International (PRCI) design guidelines (PR-277-144507-R01) and ASME B31.8 2022 requirements were utilized to model the bending, external hoop, tensile, and combined stress cases for the installation and operating conditions imposed on the pipe. The calculations consider the pipe diameter, wall thickness, grade, depth, and geometric design of the crossing.
b) The NFG Engineering Design Manual, Chapter 3, Section 3.15 – Horizontal Directional Drilling (HDD), Revision 01, dated 01/31/17, was referenced during the design process in order to ensure adherence to NFG requirements.
c) The HDD has been designed with consideration given to and meeting the requirements of the Federal Energy Regulatory Commission (FERC) Guidance for Horizontal Directional Drill Monitoring, Inadvertent Return Response, and Contingency Plans, Dated October 2019.
d) The geotechnical conditions at the site were considered in an effort to design the drill for progression primarily through formations that are favorable for horizontal directional drills, with consideration given to potential terrain instability and the provided "no-drill" zone (NDZ).
e) The HDD crossing was designed by completing an assessment of the annular pressure to minimize the risk of hydraulic fracture to the surface or water body during drilling of the pilot hole. The annular pressure calculation models the potential fracture pressure of the overburden formation versus the downhole pressures created during the pilot hole phase of the construction.
f) Space limitations associated with the right of way (ROW), constraints such as points of inflection (PI), and achievable temporary workspace (TWS) were also considered. Additional temporary workspace has been requested to ensure that the required equipment can be set up on site to complete the work.

g) The entry and exit positions have been identified as per drilling convention rather than pipeline placement convention. The entry point is the location where the drill rig is set up and in general, the start of drilling activities. Conversely, the exit location is the location where the HDD bottom hole assembly (BHA) will exit the formation and generally where the pipe section is laid out for installation.

h) The drawings have been designed with consideration of the pullback section and available layout. These plans will be updated (if required) to allow for grading of the layout space, safety for pullback, multiple sections, curved layout, and/or contractor input to ensure the proper design is used in all situations.

3 CROSSING LOCATION AND SITE DESCRIPTION

As part of the Tioga Pathway Project, NFG is planning to cross the Cowanesque River and State Route 49 using HDD methodology in Tioga County, PA. The crossing location is approximately 1.30 miles east of Westfield, PA. The crossing will require a FERC 7C permit application.

The proposed NPS 20 HDD crossing will traverse the Cowanesque River, State Route 49, some identified wetlands, and overhead powerlines, following a southeast to northwest alignment. The topography along the HDD alignment varies significantly, with some areas having over 30 ft of grade variation. The entry point of the drill is on the south side of the alignment, south of the Cowanesque River, on a southern slope that will require grading and leveling to accommodate the HDD equipment. The exit point is north of State Route 49 and the river, in a farm field parallel to Brace Hollow Road, where the pullback pipe string will be laid out.

There are residences near the proposed alignment, situated between State Route 49 and the Cowanesque River. Access routes to the entry and exit workspaces have been identified, branching off State Route 49 and Brace Hollow Road, respectively.

The proposed crossing location is shown in Figure 1 below.

Figure 1. Proposed HDD Crossing Location

4 GEOTECHNICAL REVIEW

A site-specific geotechnical investigation was completed by Endeavor Professional Services, LLC (Endeavor) along the proposed crossing alignment. The associated geotechnical report (Report No. 004240.0429) entitled “Geotechnical Investigation Report – Cowanesque HDD Investigation,” dated March 2024 and March 2025, was reviewed for HDD design purposes. The report references six (6) boreholes, B-1 through B-6, drilled to depths between 50 and 182 ft. Two report amendments, dated June 2024 and May 2025, containing additional lab testing were also provided. The site-specific geotechnical boreholes are shown in Figure 2 below.

Figure 2. Borehole Location Plan for Cowanesque River HDD Crossing

The geotechnical borehole depths and coordinates, as staked in the field, are shown below in Table 1.

Table 1. Geotechnical Borehole Coordinates for Cowanesque River HDD Crossing

Borehole	Depth (ft)	Latitude	Longitude
B-1	100.0	41.923767°	-77.515589°
B-2	100.0	41.924468°	-77.515372°
B-3	100.0	41.925459°	-77.516254°
B-4	50.0	41.926988°	-77.516573°
B-5	168.0	41.925840°	-77.517018°
B-6	182.0	41.927464°	-77.517113°

With the exception of Borehole B-4, similar subsurface conditions were encountered, which generally consisted of 24 to 54 ft of granular material and 23 to 37 ft of “unconsolidated overburden” overlying bedrock to the final depths. However, in Borehole B-2, no unconsolidated overburden was encountered. In Borehole B-4, 20 ft of sandy/gravelly clay was encountered overlying compact to dense sandy silt, which extended to the final depth of 50 ft.

The granular material predominantly consisted of sandy clayey gravel. The unconsolidated overburden was described as a mixture of gravel and fractured bedrock with washed away fines. Limited recovery of physical samples was obtained within this zone, therefore, some characterization of this material was inferred from observations during drilling activities. It was also noted that casing was required in order to advance the drill bit through much of the gravelly or unconsolidated overburden layer. The bedrock consisted of either siltstone or fine-grained sandstone with rock quality designation (RQD) generally ranging between 38% and 100%; however, localized fractured zones with a 0% RQD were also encountered.

A summary of the generalized borehole descriptions is presented in Table 2.

Table 2. Summary of Borehole Logs and Primary Concerns for Cowanesque River HDD Crossing

Borehole	Approximate Location	Description	Primary Geotechnical Concerns
B-1	150 ft N of HDD Entry, 10 ft offset E of CL	0-24 ft: Clayey Sandy Gravel 24-61 ft: Unconsolidated Overburden 61-100 ft: Siltstone (bedrock)	Gravel causes drilling difficulties and borehole wall to slough. Fractured bedrock can result in fluid losses.
B-2	390 ft N of HDD Entry, 115 ft E of CL	0-40 ft: Clayey Sandy Gravel 40-54 ft: Gravelly Sand 54-100 ft: Siltstone (bedrock)	Gravel causes drilling difficulties and borehole wall to slough. Fractured bedrock can result in fluid losses.
B-3	790 ft N of HDD Entry, 50 ft W of CL	0-40 ft: Clayey Sandy Gravel 40-48 ft: Gravel 48-71 ft: Unconsolidated Overburden 71-86 ft: Siltstone (bedrock) 86-100 ft: Sandstone (bedrock)	Gravel causes drilling difficulties and borehole wall to slough. Fractured bedrock can result in fluid losses.
B-4	290 ft S of HDD Exit, 30 ft W of CL	0-10 ft: Sandy Clay 10-20 ft: Gravelly Clay 20-50 ft: Sandy Silt	Granular material can result in sloughing of borehole wall. Silt can affect fluid properties.
B-5	680 ft S of HDD Exit, 230 ft W of CL	0-78 ft: Silty Sand with Gravel 78-168 ft: Siltstone	Gravel causes drilling difficulties and borehole wall to slough. Fractured bedrock can result in fluid losses.
B-6	95 ft S of HDD Exit, 145 ft W of CL	0-35.5 ft: Silty Sand with Clay 35.5-115.5 ft: Unconsolidated Overburden 115.5-182 ft: Siltstone	Gravel causes drilling difficulties and borehole wall to slough. Fractured bedrock can result in fluid losses.

No standpipes were installed. Instead, groundwater was observed during drilling operations. Groundwater was encountered at depths of 15.0, 2.0, 5.0, 28.0, 3.5 and 13 ft in Boreholes B-1, B-2, B-3, B-4, B-5 and B-6 respectively. It is expected that the groundwater is hydraulically connected with the river.

The proposed HDD path is anticipated to predominantly pass through unconsolidated overburden and granular deposits along the entirety of the entry and exit tangents with the vertical curves and bottom tangent encountering the siltstone or sandstone bedrock formation. The risks and challenges due to the subsurface conditions and the mitigation strategies to minimize them will be discussed later within this report.

5 HDD CROSSING CONSIDERATIONS

5.1 PIPE SPECIFICATIONS

The pipeline specifications provided by NFG are summarized in Table 3. These parameters were used in the engineering design of Cowanesque River HDD crossing.

Table 3. Pipe Specifications for Cowanesque River HDD Crossing

Pipe Specifications	Value
Pipe Size	NPS 20
Outer Diameter (OD) (inches)	20
Wall Thickness (WT) (inches)	0.500
Material	Steel
Grade	X65
Specification	API 5L
Product	Natural Gas
Maximum Allowable Operating Pressure (psi)	1,440
Minimum Installation Temperature (°F)	30
Maximum Operating Temperature (°F)	100
Internal Coating	None
Outer Coating	FBE / PRW
Class Location	1
Joint Factor	1
Temperature Factor	1

5.2 HDD ALIGNMENT

The proposed Cowanesque River HDD crossing follows the proposed YM59 pipeline alignment centerline, which is centered within a 50 ft ROW. The proposed HDD is planned to have a southeast-to-northwest drilling alignment, measuring 1,646 ft horizontally, and will cross beneath the south river valley slope, the Cowanesque River, Wetland W23, State Route 49, some overhead powerlines and Wetland W59. The proposed entry point, approximately 530 ft south of the Cowanesque River's edge of water, is located directly on the YM59 pipeline centerline point of inflection (P.I.) on the south river slope, where some leveling and clearing work will be required to construct the entry pad. The exit point is located approximately 173.2 ft north of Wetland W59 and 93.3 ft south of Wetland W58, in a farm field parallel to Brace Hollow Road, where the pullback pipe string will be laid out. According to available survey information, the proposed HDD does not cross any existing buried utilities.

The exit point extends approximately 258 ft to the north of the planned P.I. in the YM59 pipeline alignment which was a determining factor in selecting the HDD length, as the pipeline alignment needed to be maintained within the proposed ROW, therefore, lengthening further would have required the HDD to incorporate a horizontal curve into the alignment which would have added complexity to construction. The exit-side tie-in will have to be completed within a pit near the eastern edge of the easement due to the extension of the exit point beyond the P.I.

Based on available LiDAR data, the topography along the alignment consists of a mix of gentle slopes and more pronounced elevation changes, typical of the region's rolling hills. There is an elevation difference of 4.8 ft between the proposed entry and exit points along the pipeline alignment. The southern end of the alignment is situated on the river valley slope, with the Cowanesque River being the lowest elevation point between the entry and exit. As the alignment approaches SR 49 towards the exit point, the terrain gradually ascends, reflecting the area's characteristic undulating topography, and reaches the agricultural fields on the other side of SR 49.

The details of the design are shown on drawing 4418-EG-0101 provided in Appendix A.

5.3 HDD WORKSPACES

Temporary workspace (TWS) is required at the entry and exit areas to facilitate drilling operations and product pipe installation. The entry side pad irregular TWS is located on a slope at the south end of the proposed pipeline alignment within the 50 ft wide proposed ROW and 25 ft of ATWS on either side of the ROW. There is irregular TWS around the entry point, allocated on the slope, which will be used to construct, grade, and level the entry pad. It is anticipated that the available TWS footprints will be adequate for the HDD equipment setup, though the risks related to the construction of the entry pad on the slope should be considered.

The exit point is located on the north side of the crossing alignment and extends approximately 110 ft to the north of the planned P.I. in the YM59 pipeline alignment, which will require adjustments to match the HDD alignment and tie-ins. The exit point is located within the 25 ft wide ATWS adjacent to the pipeline ROW. There is a 100 x 194 ft ATWS located east of the P.I., and a 25 x 60 ft ATWS to the west. The exit pad is currently in a field near Wetland W59 (PEM) and will require additional TWS due to the exit point being off the YM59 pipeline alignment to ensure all equipment stays within the approved workspace. The exit pad construction requirements within or near an identified wetland should be carefully reviewed and considered.

The proposed pipe staging and stringing area for pullback is located northeast of the exit pad and is discussed further in Section 5.4. The HDD contractor should confirm their equipment workspace requirements and mobilization plan in their drilling execution plan.

5.4 LAYDOWN AREA

Pipe pullback is planned to be completed behind the exit point to the northwest of the HDD alignment along the proposed ROW. Generally, the workspace must be wide enough to accommodate staging and assembly of the pipe string, pipe supports, equipment, welding and inspection operations, as well as safe vehicle access along the length of the workspace. The length of the laydown area must be equal to the total crossing length with additional space on either side of the pipe section for equipment access.

The proposed laydown area would consist of irregular temporary workspace behind the exit point for a length of approximately 1,500 ft with varying width. Given that the total drill length is 1,694 ft, it is expected that the pullback string will be laid out in two (2) separate sections and will require an intermediate weld. Overall, the proposed workspace is considered suitable for pipe staging, assembly, and pullback operations. Pipe lifting stresses and pullback recommendations are provided in Section 6.2.4.

The proposed pipe pullback workspace is illustrated in Figure 3, below

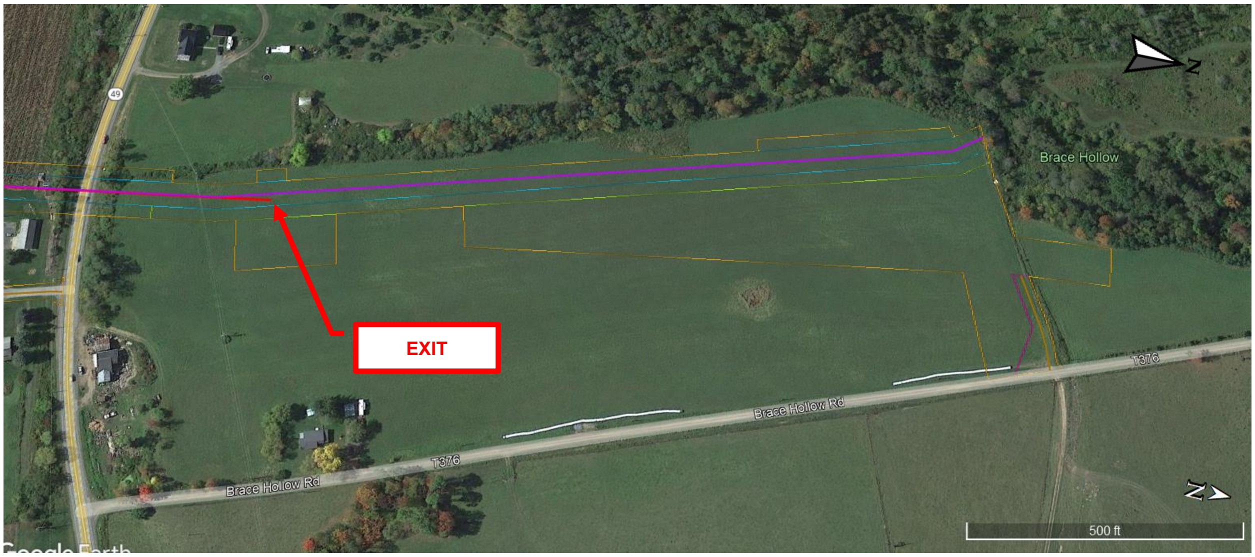


Figure 3. Proposed Pullback Workspace for Cowanesque River HDD

5.5 BOREHOLE SIZE

The final borehole diameter must be larger than pipe outer diameter to facilitate pipeline installation and reduce drag forces acting on the pipe while allowing for proper drilling fluid circulation within the annulus. The general industry standard for pipes with diameters less than 20 inches is a final borehole diameter of 1.5 times larger than the pipe outer diameter. For larger installations, a borehole with an OD of 12 inches larger than the pipe outer diameter is recommended. The final ream size may be dependent on the size of reamer that is available to the contractor, however, CCI would recommend that the contractor adhere to the minimum industry standard as described above.

For the proposed NPS 20 HDD crossing, the final borehole diameter is expected to be 30”.

5.6 ENTRY AND EXIT ANGLES

The entry and exit angles were determined based on stress analysis, bending restrictions, surface casing length, the support of the pullback section, workspace requirements, and slope of the topography above the entry and exit tangents. The entry angle of 19° is optimal for minimizing the crossing length while achieving the necessary depth below the river to reduce the risk of hydraulic fracture. Additionally, this angle helps minimize the surface casing length needed to reach the anticipated bedrock interface and is suitable for the required rig size for this crossing while helping to ensure that the casing can be properly seated into the bedrock given the angle of intersection with top-of-bedrock surface.

The exit angle, set at 16° for the Cowanesque River HDD, was selected to optimize the HDD length, ensure safe support of the section during installation, and reduce the surface casing length required to reach the anticipated bedrock interface. The exit angle produces a higher overbend, however, due to the upslope of the hill north of the exit point minimizes the length and height of overbend, reducing the support requirements.

5.7 HDD DEPTH OF COVER

The selection of an appropriate HDD depth is based on several parameters, including geological formation, the required overburden pressure to overcome drilling fluid annular pressure, buried facilities in the area, watercourse/roadway/rail geometric parameters, pipe geometry, and space limitations. The proposed installation depths were chosen to allow the drill path to progress through favorable materials for directional drilling while maximizing borehole stability during hole opening and pipe installation.

Table 4 lists the provided depths of cover beneath the identified critical features that are crossed by the proposed HDD, based on the current design drill path geometries, in order from the entry point to the exit point. The current design depth of cover is expected to provide adequate overburden pressure to minimize the risk of hydraulic fracture to the surface, with the help of surface casing installation, as well as minimizing the impact on buried utilities and settlement or heave at the surface, assuming proper construction methods are utilized during construction. Further details about annular pressure modeling are discussed in Section 6.1.

Table 4. HDD Depths of Cover

Feature	Depth of Cover Beneath Centerline (ft)
Cowanesque River C/L	120.0
Wetland W23	143.0
State Route 49 (SR 49)	94.1
Wetland W59	40.7

5.8 DESIGN RADIUS

The standard practice in HDD industry is to utilize 100 times (in feet) the nominal pipe diameter (in inches) as the radius of curvature (ROC). For instance, a 12-inch diameter pipe would utilize a ROC of 1,200 feet. This is a conservative general “Rule of Thumb” for quick calculations which is developed over years based on constructability as opposed to pipe stress limitations. The minimum radius calculated from stress limiting criteria are often substantially smaller (and sometimes larger) than the general rule of thumb as the latter does not consider pipe materials, bending stress, combination of stress or strain within the pipe section itself.

For the proposed Cowanesque River HDD, a 1,500 ft vertical curve radius was selected as the design ROC. A tighter than industry standard vertical curve radius was required due to the length restrictions for the crossing and also to provide sufficient tangent lengths at entry and exit to facilitate the installation of surface casing through the unconsolidated materials. Although this is smaller than the typical industry guideline for this pipe size, stress analysis indicates that it meets the necessary criteria, resulting in a maximum bending stress of 36.7% of allowable and a maximum operational shear stress of 85.1% of allowable (according to PRCI and ASME limits). The minimum allowable 100-ft (3-joint) design radius (MADR) has been calculated to be 1,200 ft, with a bending stress of 45.9% of allowable and an operational shear stress of 92.1% of allowable. The minimum allowable 30-ft (single joint) design radius has been calculated to be 1,000 ft, with a bending stress of 55.1% of allowable and an operational shear stress of 99.1% of allowable.

Detailed discussions on the contributing bending, combined, and operational stresses imposed on the pipe are found in Section 6.2.

An essential part of the engineering design of HDD crossings is to provide the contractor with minimum steering tolerances during the pilot-hole phase of the construction, based on an acceptable level of stress on the pipe. These tolerances are designed to allow the contractor to follow the designed drill path as close as possible and avoid any variation that could cause overstressing of the pipe. CCI recommends the minimum radius specifications as seen in Table 5 below.

Table 5. Minimum Radius Allowances

Case	Radius Specification
Design Radius	1,500 ft
100-ft Average (3-joint) / MADR	1,200 ft
30-ft (single joint)	1,000 ft

Assuming the Contractor adheres to these minimum radius specifications, the product pipe will be within allowable stress limits during installation and operation.

5.9 SURFACE CASING

The geotechnical investigation at this project location revealed a significant amount of unconsolidated and gravelly materials overlying the bedrock. These challenging conditions pose several considerable risks during HDD construction, mainly borehole instability during drilling/reaming and the risk of poor hydraulic conductivity and high potential for hydraulic fracture. To mitigate these risks, CCI proposes installing temporary surface casing at both the entry and exit locations to reach competent bedrock interface and isolate the problematic overburden material. Based on the available information, it is anticipated that a minimum of 295 ft of surface casing will need to be installed on the entry side and 452 ft of casing on exit side until the bedrock interface is reached.

It is recommended that the casing size be a minimum of 12 inches larger than the final borehole diameter in order to facilitate the final ream size and pipe pullback. In the case of this crossing, a 42-inch OD casing should be suitable for the proposed final 30-inch ream size. It is expected that the welded steel casing would be installed using a pneumatic hammer which would consist of hammering the casing until refusal, augering out the soil within the driven casing, and then repeating the process until the desired length of final refusal is met by the casing. It is recommended that a centralizer be installed within the casing during pilot hole to establish a borehole that is concentric and centered with the end of the casing which will prevent the possibility of tooling, drill pipe, or product pipe damage from striking the lip of the casing during drilling and installation. It is understood that the final length of installed casing would be determined based on field conditions; however, it is expected that the installation of the casing through the gravel is feasible based on the available geotechnical information. It is to be noted that the contractor should independently evaluate and determine the need to upsize or telescope the casing to achieve the minimum final diameter.

Other risks and considerations relating to the surface casing are discussed further within Section 7.

5.10 INTERSECT METHODOLOGY

Typically, the pilot hole begins at the prescribed entry point located in front of the HDD rig. As the bit advances into the ground and away from the rig, a continuous string of drill pipe is created by adding individual joints in succession. This process allows for the drill pipe to be inside the drilled hole at all times. With proposed temporary surface casing installed along the exit tangent, it would be difficult for the entry-side pilot hole to steer along the proposed HDD profile and intersect the center of the 42-inch diameter casing located more than 1,200 ft away from the entry point within bedrock conditions. If the pilot hole is not centered within the casing, the pipe would be at risk of damage from striking the lip of the casing during pullback, therefore, utilizing intersect pilot hole is recommended to ensure that the exit-side rig could drill through the center of the casing and prevent the risk of produce pipe damage.

The HDD intersect method consists of two HDD rigs drilling simultaneously at both the entry point and exit point of the designed drill path. Both HDD rigs will drill the pilot hole from their respective sides until the two bits meet at a common point along the bottom tangent of the drill path, generally near the center of the HDD alignment. After intersection of the two bits is successful, one of the rigs will begin tripping out of the borehole as the other bit follows in the same direction and advances along the drill path towards the opposite rig. With this methodology, drill string will remain within the entire length of the borehole ensuring that it will not be lost should borehole sidewall stability become compromised. The crew of the rig that tripped out will remove both bottom hole assemblies (BHAs) from the respective drill strings and insert a reamer between them. Both drilling rigs will be active during the reaming process with one rig providing rotary and drilling fluid while the other provides tension on the drill string, allowing the reamer to follow the drilled pilot hole regardless of formation strength. The ream direction can be reversed for successive ream sizes utilizing both rigs, one pulling while the other provides torque. Risks and mitigations regarding the HDD intersect construction are outlined further in Section 7.

It is recommended that the contractor independently evaluate the need for intersect pilot hole in order to mitigate this risk as it may be possible to drill into the exit-side casing from entry. Given the length constraints of the HDD and tighter vertical curve radius, completing the intersect for the proposed HDD crossing will require an experienced and qualified HDD contractor. If determined to be required, the HDD Contractor should determine the best means of completing the intersect as well as the most feasible intersect location along the HDD alignment.

6 HDD ENGINEERING ANALYSES

The proposed Cowanesque River HDD has been designed by incorporating all specified design considerations including supplied topographical, geotechnical, and survey information, as well as other site information as noted in the previous sections. In addition to these considerations, detailed annular pressure analysis and pipe stress analysis calculations have been completed as outlined below.

6.1 ANNULAR PRESSURE MODELLING

Annular Pressure (AP) modeling was developed to model the expected drilling pressure that is required to drill a pilot hole along a proposed path. This information has been modeled very accurately as confirmed by many HDD installations using pressure monitoring tools. CCI has modeled the potential overburden or confining pressure and used this information to assist in the choice of HDD depth and placement of the entry and exit locations. Over the last several years, this has been relatively successful in that there has been a reduced number of drilling fluid releases to the waterbody, highway, or railroad as well as improving the reliability and consistency of the design and construction process.

The ability to accurately assess when the HDD will fracture to surface is highly dependent on the homogeneous nature of the formation, level of fracturing in the bedrock (if present) and type/consistency of the overburden. It is also important to note that the information provided by borehole investigations is accurate at that specific location but may vary significantly some distance away. A vertical borehole may not identify the vertical fractures that can significantly affect risk of fluid migration from the borehole. This potential inaccuracy is accounted for by being conservative in the modeling assessment and considering the AP pressure model as a process to reduce drilling fluid releases (generally) based on the quality of information provided.

HDD construction begins with drilling a pilot hole (typically 9 7/8 to 12 1/4 inches in diameter) along the proposed drill path. The method of installing the pilot hole is highly dependent on the size of the crossing and type and quality of soils along the drill path. Installing the pilot hole within softer, weaker soils is generally completed using a jetting assembly. A jetting assembly uses a high-pressure jet of fluid to open the hole ahead of the bit and pushes its way through the soil to create the borehole. Installing the pilot hole within harder and stronger soils or bedrock may require a mud motor assembly to complete the hole, which utilizes a positive displacement mud motor with an appropriately sized rotating drill bit to mechanically shear through the soil or rock at the face of the bit to create the hole.

Based on the available geotechnical information it is expected that a mud motor assembly will be utilized for the pilot hole installation of the proposed HDD, however, tooling and techniques utilized in the field will be dependent on actual subsurface conditions.

Drilling fluid properties are dependent on construction practices of the HDD contractor, field conditions, and interpretations of the drilling fluid technician. Annular drilling fluid pressures can significantly change with changes in drilling fluid properties. Therefore, it is important to re-evaluate drilling fluid pressures based on fluid properties during HDD operations and compare them with estimated limiting pressures of the formation. Additionally, annular pressure measurement tools should be used to monitor annular pressure during the HDD installation.

The AP simulation was conducted with CCI's analysis tools which have been developed with industry standard calculation models (Bingham Plastic, General Overburden, and USACE/Delft model) and additional modified safety factors based on extensive experience.

CCI completed the annular pressure analysis for the proposed HDD crossing using a mud motor drill assembly. The drill assemblies utilized to model the annular pressure during pilot hole construction of the HDD are as follows in Table 6:

Table 6. Drill Parameters Used for Annular Pressure Model

Parameter	12 1/4" Mud-Motor Assembly
Pilot Hole Size (in)	9.875
Drill Pipe Size (in)	5
Pump Rate (gal/min)	400
Drilling Fluid Density (lb/gal)	9.6
Drilling Fluid Plastic Viscosity (cP)	20
Drilling Fluid Yield Point (lb/100 ft^2)	25

CCI has developed geotechnical parameters for the crossings that closely represent the geologic formations observed in the geotechnical borehole logs, as summarized in Section 4 of the report. Based on the geotechnical investigation provided, CCI has identified three (3) geological formations used for this analysis, as shown below. The geologic formations utilized in the analysis include a layer of Clayey Gravel that extends to approximately 40 ft below the river, followed by a layer of disintegrated, poor-quality Siltstone right above the bedrock interface, mainly represented by the unconsolidated overburden identified in the geotechnical report, and finally a layer of blocky, fair-quality Siltstone, through which the bottom portion of the HDD will progress. The geotechnical parameters utilized by CCI for the Clayey Gravel were as follows:

- 0° Internal Friction Angle
- 0.0 psf Cohesion
- 135 pcf Unit Weight
- 0.0 ksi Shear Modulus
- 0.0 ksi Youngs Modulus
- 1,050 psf Undrained Shear Strength

The geotechnical parameters utilized by CCI for the Disintegrated Siltstone were as follows:

- 23° Internal Friction Angle
- 302.6 psf Cohesion
- 130.0 pcf Unit Weight
- 0.9 ksi Shear Modulus
- 2.6 ksi Youngs Modulus

The geotechnical parameters utilized by CCI for the Blocky Siltstone were as follows:

- 27° Internal Friction Angle
- 1426.4 psf Cohesion
- 135 pcf Unit Weight
- 7.8 ksi Shear Modulus
- 21.2 ksi Youngs Modulus

The water table was conservatively assumed to be at ground surface along the crossing alignment so that the entire soil layer contributes its effective unit weight to the total limiting pressure. CCI has modeled the geologic formations along the drill paths with what we consider to be conservative physical properties to account for anomalies and discrepancies that may exist between the soil types described in the site investigation and actual field conditions.

CCI utilized the Undrained Equation model to calculate the limiting pressure for the Clayey Gravel formation and the modified Delft Equation model to calculate the limiting pressure for the Siltstone formations identified. The anticipated annular pressure was calculated using conservative assumptions for the drilling fluid properties and flow rates as described above. It is important to note that the annular pressure model created by CCI is only valid based on the geotechnical and drilling parameters utilized herein, and it is recommended that the annular pressure analysis be re-evaluated with the contractor's proposed drilling fluid parameters, bit size, and drill stem. Figure

4 below shows the formation parameters and expected annular pressure for the HDD during the pilot hole phase of construction at the current designed depth. The analysis was completed based on the conservative case of a pilot hole being drilled from entry to exit, without the use of an intersect. It is important to note that the annular pressures along the first roughly 295 ft and last 450 ft of drill would be encased, therefore, the pressures would be contained within the casing.

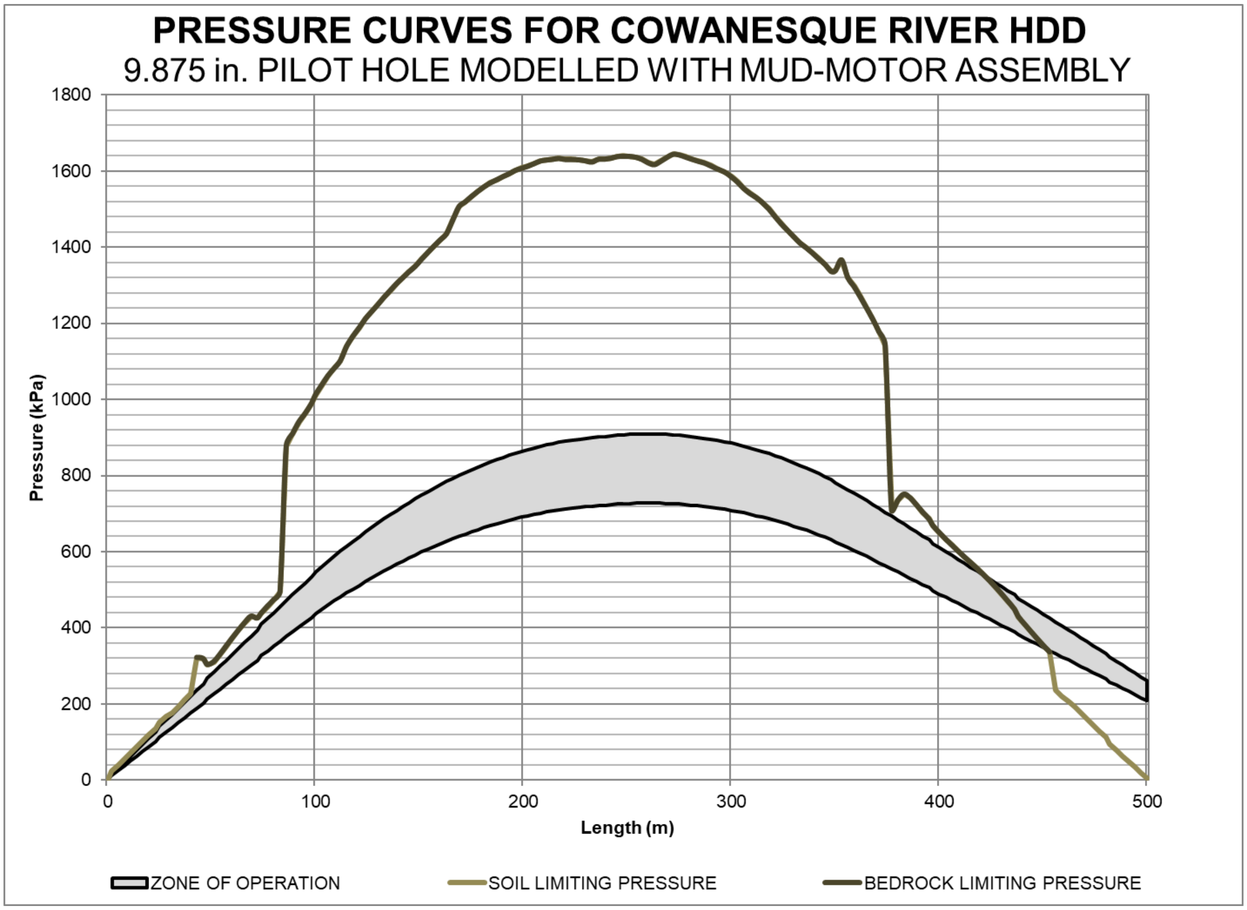


Figure 4. Annular Pressure Curves for Cowanesque River HDD

The Annular Pressure Analysis performed by CCI indicates a low overall risk of hydraulic fracture. The primary risk area for the Cowanesque River HDD crossing is the final roughly 200 ft approaching the exit point, where the soil limiting pressure is exceeded by the upper and lower limits of drilling fluid pressure. This indicates a risk of hydraulic fracture within this zone. Additionally, this length of the HDD is planned to be encased, which will help mitigate the risk of fracture within this zone by shielding the surrounding soil from experiencing the drilling fluid pressures along the encased length of bore.

The risk of fracture near the exit point is expected for HDD crossings, as drilling fluid pressures increase towards the exit point while the overburden strength decreases with depth. Since the drilling pressures remain below soil limiting pressures beneath Cowanesque River and along the majority of the drill length, with the exception of the final roughly 200 ft, the overall risk of hydraulic fracture for this HDD installation is considered low and manageable with proper planning and construction practices. The installation of surface casing will significantly mitigate the risk of hydraulic fracture for this crossing near entry and exit sides. This concern should be noted by the contractor, but the Annular Pressure Analysis indicates that the design for Cowanesque River HDD is feasible from a geological standpoint with good construction practices.

The relevance of the annular pressure model depends heavily on the accuracy of the geotechnical information available along the HDD alignment. The geotechnical parameters used in the annular pressure analysis are conservative. It is recommended that the annular pressure model be re-evaluated after completion of the supplemental geotechnical investigation planned by NFG, as is likely that the exit-side subsurface model may require adjustment. It is also recommended that the contractor independently evaluate the geotechnical information provided and properly assess the site conditions prior to construction.

6.2 HDD STRESS ANALYSIS

The installation and operating conditions imposed on the HDD sections of pipeline during and after installation have been calculated in compliance with PRCI (PR-277-144507-R01) and ASME B31.8. The HDD stress modeling determines if given pipe specifications are adequate for the design.

6.2.1 Pulling Load

The load required to pull the product line inside the borehole must overcome several resisting forces including effective weight of the pipe, fluidic drag, frictional drag between the pipe and the borehole walls and between the pipe and the rollers, drag due to length of drill strings in the hole and the reamer assembly in front of the pull section.

The theoretical pull force was calculated under the assumption that buoyancy control would not be used during HDD installation. Buoyancy control is generally advised for HDD installations involving pipelines larger than NPS 20 because the buoyancy of larger pipes can significantly increase the required pull force. Achieving neutral or near-neutral buoyancy could reduce this force and minimize the risk of pipe and coating damage during installation.

For larger pipelines, the uplift forces due to the submerged weight of the pipe within the borehole can be substantial. Implementing buoyancy control measures can effectively reduce these forces and, consequently, the required pulling load. However, a buoyancy control plan is not recommended for this specific HDD crossing.

CCI recommends utilizing a safety factor of 1.5 when calculating anticipated pull force to account for variations in the field regarding drilling practices, geology, etc. and to account for the addition of the reamer and swivel in the pullback bottom hole assembly.

The maximum expected pull load for the proposed Cowanesque River HDD crossing as well as the minimum recommended rig size (capable of the required length and ream size that will provide adequate torque, pull/push force, and flow rates, if equipped with suitable pumps and drill stem) are listed below in Table 7.

Table 7. Calculated Theoretical Pull Forces & Recommended Rig Size for HDD Installation

Theoretical Pull Force[1] (without Buoyancy Control, lbs)	Minimum Recommended HDD Rig Size (Pull Capacity, lbs)
238,000	440,000

Note 1: Theoretical pull forces calculated using PRCI Calculation methods with F.S. of 1.5 applied

6.2.2 Installation Stresses

As the pipeline is installed through the final borehole, it is subjected to three primary loading conditions: tension, bending and external pressure. As part of the design process, the individual stresses and their combined effect on the pipe were evaluated to check the pipeline potential failure. The maximum combined installation stress for the crossing was calculated to be 30% of allowable. The results of the installation stress analysis completed for Cowanesque River HDD crossing are illustrated in Table 8, below.

Table 8. Calculated Installation Stresses for Cowanesque River HDD

Maximum Stress Case	Stress (psi)	% Allowable
Tensile (PRCI 5.1.1, 5.5)	5,171	8.8
Bending (PRCI 5.2.2)	16,389	36.7
Hoop (PRCI 5.2.3)	2,468	22.8
Combined (Tensile and Bending) (PRCI 5.2.4)	45%	
Combined (Tensile, Bending, and Hoop)(PRCI 5.2.4)	26%	

6.2.3 Operating Stresses

During operation, the stress imposed on a pipeline installed by HDD is similar to a conventionally installed pipe with the exception of the elastic bending resulting from a continually welded pipeline pulled through a curved borehole. The operating loads including bending, net hoop stress (difference between external and internal pressures), thermal expansion and the combined stresses were checked to evaluate the risk of pipeline failure.

The maximum combined operating stresses at the design radius of 1,500 ft was calculated to be and 85.1% of allowable, as per PRCI and ASME allowable limits, which is considered to be acceptable. A summary of the maximum expected operating stresses, and their allowable limits are presented for the design radius as well as minimum 3-joint and 1-joint radii are provided within Appendix B.

6.2.4 Pipe Lifting Stress Modelling

The following guidelines are recommended to be followed by the Contractor in order to prevent over-stressing of the NPS 42 product pipe and overloading of the support equipment during pullback:

Table 9. Pullback Recommendations for Cowanesque River HDD

Parameter	Value
Minimum Allowable Overbend Radius (ft)	850
Maximum Support Spacing (ft)	75
Maximum Roller Spacing (ft)	60
Maximum Unsupported Overhang (ft)	65

A minimum allowable vertical overbend radius of 850 ft has been chosen for the NPS 20 product pipe during pullback. A maximum support spacing of 75 ft through the overbend and 60 ft roller spacing are recommended for the safe pipeline installation. These spacings have been chosen to ensure that the product pipe and supporting equipment will not be overstressed at any point during staging and pullback operations, however, it is recommended that the selected Contractor verify that the pipe lifting and supporting equipment are rated for the intended loads and reduce the spacing if required. The maximum unsupported length at leading and tailing ends of the pipeline should not exceed 65 ft to avoid overstressing the pipe due to excessive bending from its own weight or overloading the supports. A summary of the maximum expected support loading and pipe stress is presented in Appendix C.

Care should be taken when incorporating a horizontal curve into the pipe layout, as the supporting equipment would need to be sized properly to support and anchor the pipe in place through the elastic bending. Incorporating a horizontal curve into the pipe layout may also create a compound curve, if simultaneously bent vertically, which would produce a bending radius smaller than the individual horizontal and vertical radius of curve. It is also recommended that the product pipe is properly anchored and restrained from sliding down any gradients that exist where it is staged, assembled and installed. Other risks associated with the pipe pullback phase of construction are discussed in Section 7.

6.3 DESIGN SUMMARY

For the proposed Cowanesque River HDD, the operating stresses govern the design of the pipe, and not the installation stresses. Calculations carried out by CCI indicate that a wall thickness of 0.500” for the NPS 20 pipe using Grade X65 steel is suitable for the crossing, based upon the operating conditions supplied. Table 10 shows a summary of the design for the proposed crossing as part of the Cowanesque River HDD Project.

Table 10. Design Summary for Cowanesque River HDD HDD Crossing

Parameters	Value
Pipe Specification	NPS 20 x 0.500 in W.T.
Entry Angle (Degrees from Horiz.)	19
Exit Angle (Degrees from Horiz.)	16
Design Radius of Curvature (ft)	1,500
MADR (ft)	1,200
Length (ft)	1,694
Borehole Size (in)	30
Pull Force (lbs) (incl. 1.5 SF with Buoyancy Control)	238,000
Minimum Recommended Rig Size (lbs)	440,000
Installation Stress (% Allowable)	45.0%
Operating Stress (% Allowable)	85.1%
Overall Risk of Hydraulic Fracture	Low

7 HDD CONSTRUCTION RISK ASSESSMENT

The main construction risks and challenges for Cowanesque River HDD crossing were identified based on the risk assessment conducted by CCI and previous experience. The risk items are ranked into the risk categories ranging from low risk to very high risk based on the probability and the consequence of each risk factor.

The descriptions of risk items and a summary of the risk assessment for the crossing detailing the risks prior to any mitigation and after mitigation are presented in Appendix D.

8 RECOMMENDATIONS

The following recommendations outline the main action items that should be completed in order to ensure smooth progression of the project into the construction phase:

a) Review of information by all stakeholders and issuance of the Issued for Construction (IFC) drawings to chosen Contractors.
b) Ensure all required ROW and TWS, environmental notifications and permits, and water withdrawal and disposal sites are acquired.
c) Review the Contractor prepared Execution Plan, including but not limited to Pilot hole drilling and intersect operations, Pullback and Buoyancy Control Plans, Water Management and Drilling Fluid Disposal Plan, Drilling Rig Anchoring Plan, Casing Plan, Engineered Drilling Fluid Plans, and Site-Specific Environmental Plan.
d) Scope of construction inspection, turbidity monitoring (if required) and fluid disposal management services should be identified.
e) Review any new environmental concerns with respect to the crossings and develop contingency plans if required.
f) Select an appropriate level of qualified supervision on site for all stages of the drill to ensure that the drill profile is adhered to within the radius limits set forth on the IFC drawing, the proper drilling techniques and equipment are utilized, and schedule and costs are controlled.

9 CONCLUSIONS

This assessment details the design selection and analysis conducted for the Cowanesque River HDD crossing. It also underscores identified risks, emphasizing that implementing effective mitigation measures will minimize their impact on the project. Based on the available data, constructing the 20-inch Cowanesque River HDD crossing along the proposed alignment of the Cowanesque River HDD Project is deemed feasible.

10 LIMITATIONS

This report has been prepared based on the available site-specific information for the exclusive use of NFG in the construction of the proposed Cowanesque River HDD crossing. No other warranty is expressed or implied and the information presented within this report shall not be applied to other projects.

Although subsurface conditions are not expected to vary significantly from those shown on the drawings, it should be appreciated that extrapolation of subsurface conditions between boreholes and to depths below the depth of exploration is subject to interpretation and could be at variance with actual field conditions.

11 REFERENCE DOCUMENTS

This report is based on the following HDD design drawings.

Description	Drawing Number
HDD Plan and Profile	4418-EG-0101
HDD Pullback Design	4418-EG-0102
HDD Construction Notes	4418-EG-0103

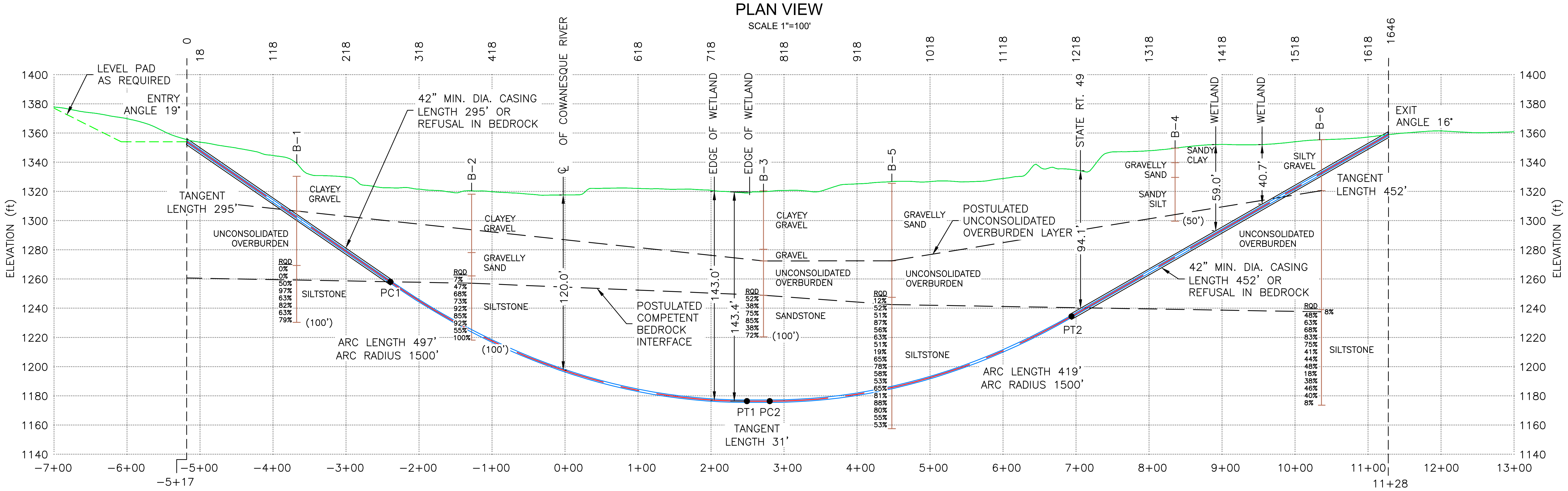
The following documents were referenced during the development of the design and report:

- Geotechnical Report: Endeavor Professional Services, LLC. Report No. 004240.0429 entitled “Geotechnical Investigation Report – Cowanesque HDD Investigation,” dated May 2025.

APPENDIX A – HDD DRAWINGS

PLAN VIEW

SCALE 1"=100'



PROFILE ALONG PROPOSED PIPELINE

SCALE 1"=100' HORIZONTAL
SCALE 1"=50' VERTICAL

TOTAL DRILL LENGTH 1694'

Pilot Hole Tolerances

Item	Tolerance
Pilot entry angle	Increase angle up to 1° (higher), but no decrease in angle allowed or adjust as required as long as design profile radius is not compromised.
Pilot entry location	As staked by COMPANY. No change without COMPANY approval.
Pilot exit angle	Increase angle up to 1° (higher). Decrease up to 2° (flatter), but design profile radius cannot be compromised.
Pilot exit location	Up to 20 feet longer or 10 feet shorter than exit stake. Between 5 feet left and 5 feet right of COMPANY survey centerline.
Pilot depth	Up to 5 feet decrease in pipe design depth allowed except under critical areas such as roads, utilities, etc., near the entry and exit points. Up to 10 feet increase in depth allowed. Best efforts shall be made to stay at or below pipe design profile depth.
Pilot alignment	Shall remain within 5 feet left or right of COMPANY centerline survey.

GEOTECHNICAL BOREHOLE DATA

NAME	B–1	B–2	B–3	B–4	B–5	B–6
GROUND ELEV.	1,330.30	1,318.11	1,320.35	1,394.88	1,325.47	1,355.52
NORTHING	640300.53	640556.18	640916.40	641473.60	641054.75	641646.47
EASTING	2032293.08	2032351.63	2032110.63	2032022.26	2031902.13	2031874.68
LATITUDE	N41° 55' 25.56"	N41° 55' 28.09"	N41° 55' 31.65"	N41° 55' 37.16"	N41° 55' 33.02"	N41° 55' 38.87"
LONGITUDE	W77° 30' 56.12"	W77° 30' 55.34"	W77° 30' 58.51"	W77° 30' 59.66"	W77° 31' 01.26"	W77° 31' 01.61"

HORIZONTAL DIRECTIONAL DRILL DATA
COWANESQUE RIVER

DESCRIPTION	HORIZONTAL DRILL STATION (ft)	DIRECTIONAL DRILL STATION (ft)	ELEVATION (ft)
ENTRY @ 19°	−5+17.9	0+00.0	1354.0
PC1 = 1500' RADIUS	−2+39.1	2+94.86	1258.0
PT1	2+49.2	7+92.27	1176.3
PC2 = 1500' RADIUS	2+80.5	8+23.5	1176.3
PT2	6+93.9	12+42.39	1234.4
EXIT @ 16°	11+28.1	16+94.08	1358.9
HORIZONTAL DISTANCE (ft) = 1646			
DIRECTIONAL DRILL PIPE LENGTH (ft) = 1694			

REFERENCE DOCUMENT NO.	DATE
1. 01-Cowanesque_River_LiDAR	2024-05-06
2. 2024-0517_TPP_Aquatics shps	2024-05-17
2024-0920_TPP_YM59	2024-09-20
2024-0927_TPP_YM59 LOD	2024-09-27
4418-01-STEEL STRESS-00	2025-06-17

CCI & Associates Inc.
20445 State Highway 249, Suite 250
Houston, TX 77070

ENGINEER AND PERMIT STAMPS

PRELIMINARY
NOT FOR
CONSTRUCTION

1"=100'
FT 0 100 200 400

PIPELINE SPECIFICATIONS

	NPS 20
OUTSIDE DIAMETER (OD)(in)	20
WALL THICKNESS (WT)(in)	0.500
GRADE	X65
PRODUCT	GAS
MATERIAL	STEEL
SPECIFICATIONS	API 5L
INTERNAL COATING	N/A
OUTER COATING	FBE/PRW
MAX. OPER. PRESSURE (psi)	1,440
MIN. TEST PRESSURE (psi)	1,800
MAX. OPER. TEMP (°F)	100
MIN. INSTALLATION TEMP (°F)	30

1"=50'
FT 0 50 100 200

STEERING TOLERANCES

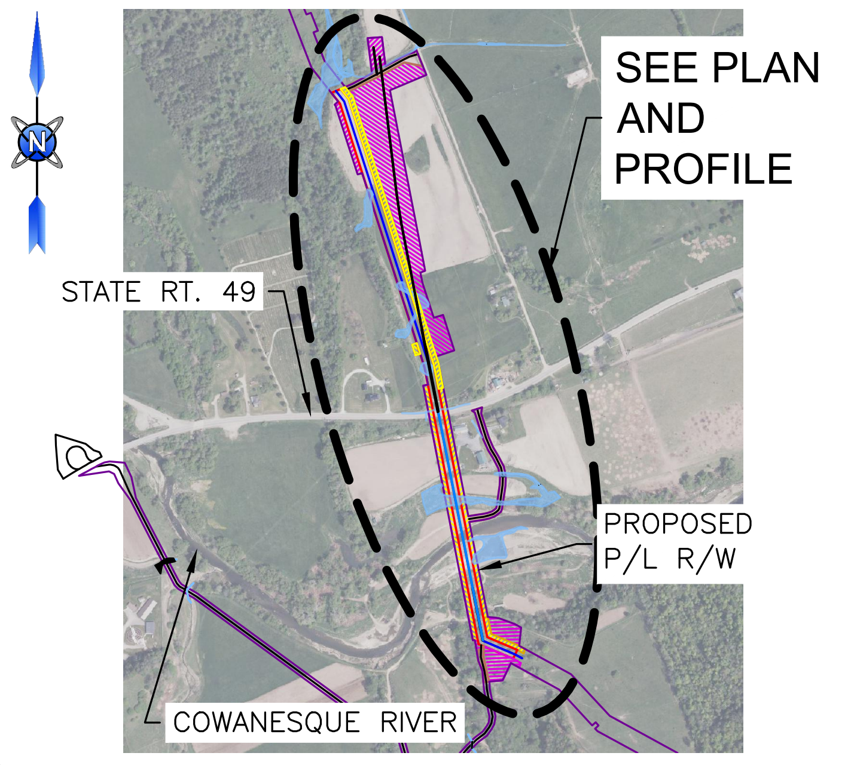
	DESIGN	100ft	30ft
MINIMUM RADIUS (ft)	1500	1200	1000

PULL FORCE / RIG SIZE / STRESS

PULL FORCE (w/o BUOYANCY CONTROL):	238,000 lbs (w/sf)
MINIMUM RECOMMENDED RIG SIZE:	440,000 lbs
COMBINED STRESS UNITY CHECK:	0.45
OPERATING STRESS:	85.1%

DRAWING STATUS	DATE	DRN	CHK	DES	GEO	APR	CR
ISSUED FOR REVIEW (90% DESIGN)	2025-06-17	AD	GB	QW	LC	GB	LR
ISSUED FOR REVIEW (60% DESIGN)	2024-07-03	MS	AD	TY	LC	GB	MM
PRELIMINARY (30% DESIGN)	2024-05-10	MS	AD	TY	LC	GB	MM

LOCATION PLAN (1"=1000')



HARN/PA.PA-NF

National Fuel®

FERC 7C TIOGA PATHWAY PROJECT

COWANESQUE RIVER HDD CROSSING
HDD PLAN AND PROFILE - NPS 20

POTTER COUNTY, PENNSYLVANIA

SCALE	DWG. #	REVISION	SHEET
AS SHOWN	4418-EG-0101	C	1 OF 3

PULLBACK PLAN VIEW

SCALE 1"=70'

PIPE STRING 1: 1554'
PIPE STRING 2:140'
Total Pullback Length: 1694'

PULLBACK DETAIL

SCALE 1"=30' HORIZONTAL
SCALE 1"=30' VERTICAL

REFERENCE DOCUMENT NO.	DATE
1. 01-Cowanesque_River_LiDAR	2024-05-06
2. 2024-0517_TPP_Aquatics shps	2024-05-17
2024-0920_TPP_YM59	2024-09-20
2024-0927_TPP_YM59 LOD	2024-09-27
4418-01-STEEL STRESS-00	2025-06-17

CCI & Associates Inc.
20445 State Highway 249, Suite 250
Houston, TX 77070

ENGINEER AND PERMIT STAMPS

PRELIMINARY
NOT FOR
CONSTRUCTION

1"=30'
FT 0 30 60 120

PIPELINE SPECIFICATIONS

	NPS 20
OUTSIDE DIAMETER (OD)(in)	20
WALL THICKNESS (WT)(in)	0.500
GRADE	X65
PRODUCT	GAS
MATERIAL	STEEL
SPECIFICATIONS	API 5L
INTERNAL COATING	N/A
OUTER COATING	FBE/PRW
MAX. OPER. PRESSURE (psi)	1,440
MIN. TEST PRESSURE (psi)	1,800
MAX. OPER. TEMP (°F)	100
MIN. INSTALLATION TEMP (°F)	30

1"=70'
FT 0 70 140 280

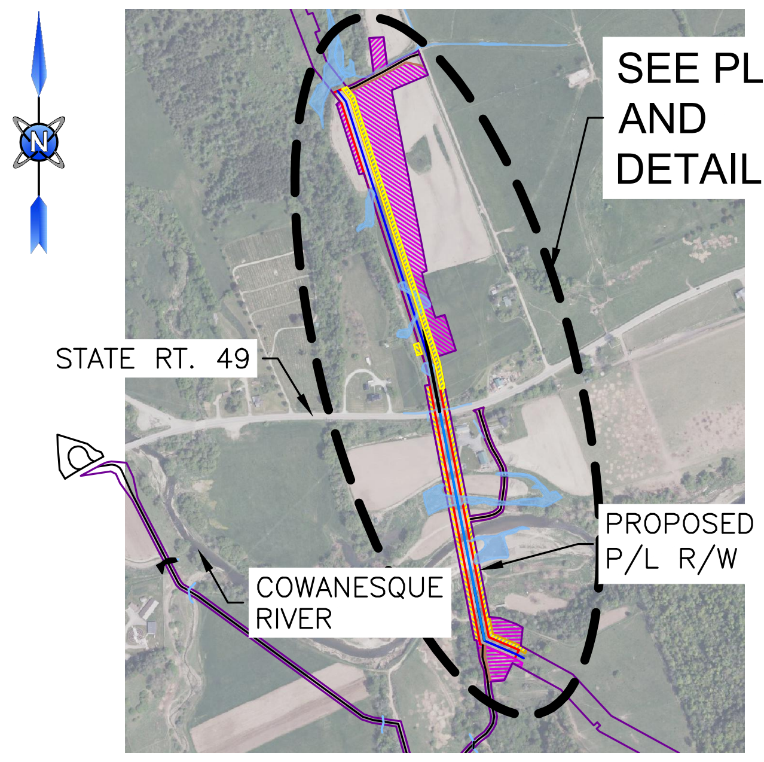
STEERING TOLERANCES

PULL FORCE / RIG SIZE / STRESS

PULL FORCE (w/o BUOYANCY CONTROL):	238,000 lbs (w/sf)
MINIMUM RECOMMENDED RIG SIZE:	440,000 lbs

DRAWING STATUS	DATE	DRN	CHK	DES	GEO	APR	CR
ISSUED FOR REVIEW (90% DESIGN)	2025-06-17	AD	GB	QW	LC	GB	LR

LOCATION PLAN (1"=1000')



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National Fuel®

FERC 7C TIOGA PATHWAY PROJECT

COWANESQUE RIVER HDD CROSSING
PULLBACK PLAN AND DETAIL - NPS 20

POTTER COUNTY, PENNSYLVANIA

SCALE	DWG. #	REVISION	SHEET
AS SHOWN	4418-EG-0102	A	2 OF 3

NOTES

1. All dimensions are in feet unless otherwise specified. All dimensions are to the centerline of borehole unless otherwise specified.
2. All drill path lengths are rounded to the nearest foot and angles are rounded to the nearest degree, unless otherwise specified.
3. This drawing is based on information provided from various sources. Consulting company does not take responsibility for the accuracy of information provided by others.
4. The crossing shall be constructed in accordance with ASME B31.8 2022.

CONSTRUCTION

5. The estimated theoretical pull force (including safety factor) for this HDD crossing has been calculated to be 238,000 lbs without the consideration of pipeline buoyancy control.
6. Assumed final borehole size is 30".
7. The Contractor shall submit a Drilling Execution Plan for Company approval (prior to start of drilling operations) meeting the minimum requirements of the Contract Documents. Any deviation from the Execution Plan shall only be allowed with Company approval.
8. The Contractor shall verify topographical survey information represented on this drawing in the field prior to construction. Contractor shall inform the Owner of any topographical discrepancies identified.
9. The design drill path and existing utilities being crossed shall have a minimum separation of 10ft.
10. Contractor shall supply and use an approved annular pressure tool capable of operating within the expected pressure range. Annular pressure information provided is based on a mud motor assembly for a 9 7/8" pilot hole.
11. The locations of existing utilities, pipelines and structures shown on the drawing are approximate and shall be verified in the field by the Contractor prior to start of any excavation or pilot hole operations. Verification shall be in accordance with Company specifications and procedures. The Contractor shall ensure any utilities, pipelines and structures in the area are protected and not damaged by the construction.
12. The Contractor shall take specific precautions in protecting existing utilities, pipelines and structures at the entry and exit sites. Such precautions may include: entry/exit pits excavated below existing utilities, casing or sheet piling used to protect pipelines, ramping/matting and special drilling precautions employed during drilling. These precautions shall be used to ensure the drilling tools, pipe and product pipe maintain a safe distance from the existing pipelines, utilities and structures.
13. The current design proposes that surface casing be installed on entry and exit and seated into bedrock, however, the Contractor shall independently assess the need for temporary casing, including both small diameter "wash–over" type casing during pilot hole, and large diameter hammered–in place casing. Temporary casing shall be sized to accommodate the final ream pass and shall utilize centralizer casing within the temporary conductor casing. Casing diameter, wall thickness, grade, and drive shoe design shall be determined by the Contractor. A Contractor's Casing Plan shall be submitted and approved by Company prior to casing installation.
14. Casing final position should be surveyed after final length is installed prior to beginning pilot hole installation.
15. All temporary casings shall be removed at completion unless otherwise noted.
16. The pilot hole shall be drilled along the design drill path with the designated design radius of curvature shown in the drawing. The pilot hole shall be within the tolerances shown in the HDD drawing.
17. The design radius for this crossing is 1500 ft. The pilot hole drilling shall adhere to the following tolerances:
    30–ft (single joint) radius shall not be less than 1000 ft
    100–ft (3–joint) average radius shall not be less than 1200 ft
18. This engineered design is based on the following minimum equipment requirements that the Contractor shall have onsite:
    a. Drilling Equipment:
      - Drilling Rig with a minimum pull force of 440,000 lbs;
      - If using a forward reaming methodology, a device shall be supplied to provide tension on the drilling string on exit side (excavator, winch or second drill rig);
      - Drill Pipe 5" (inspected as per the HDD specification);
      - Drill Bit – 9 7/8" in diameter or larger (provide details, condition, and supplier);
      - 6 1/2" Mud Motor or larger capable of running within its specified maximum load range (provide details, condition, and supplier);
      - Annular Pressure Tool (0 to 510 psi range);
      - Reamers designed for the formation (provide manufacturer's operating specifications, condition, and supplier);
      - Magnetic and/or gyroscopic steering system;
      - Casing (specifications and details to be provided for approval).
    b. Drilling Fluid Recycling Equipment:
      - Pump Capacity (Operable Rate – 530 gpm);
      - Shakers (Operable Rate – 530 gpm);
      - Centrifuge/Desander/Desilter (Minimum Capacity of 400 gpm per minute).
      - Engineered Drilling Fluid Plan must be able to be implemented in the field with the proposed equipment.
    c. This is a minimum list of equipment and should not be considered a directive on how to complete the work. The Contractor is responsible for the execution of the work under its Approved Execution Plan and shall supply all necessary equipment to complete its plan at its own cost. All equipment shall be supplied in good working order, maintained, fueled and serviced.
19. Drilling Fluid is assumed to have a maximum density of 10 lbs/gallon and 1.0% sand content;

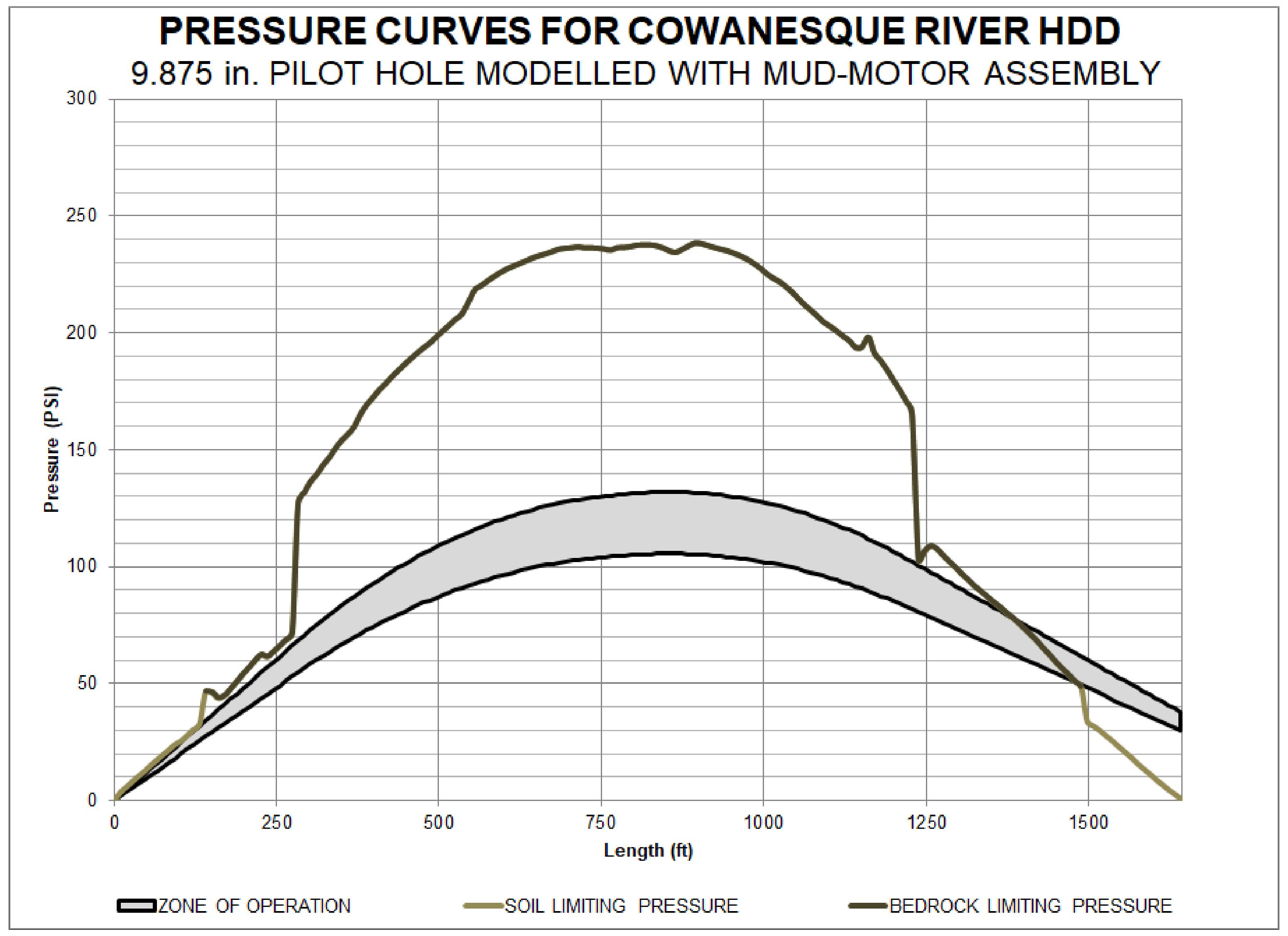
ENVIRONMENTAL

20. Emergency response spill kits must be on–site and available for use for the duration of the project.
21. Terrestrial "inadvertent return walks" shall be initiated every 4hrs. (at a minimum), or immediately following a loss of fluid event.
22. Contractor's proposed drilling fluid composition, including all expected additives, shall be reviewed and approved by the Owner's representative prior to construction.
23. The watercourse must be monitored for a potential release of drilling fluid and to assess the immediate effects of the works on the aquatic environment in accordance with applicable Federal and State regulations.
24. The Contractor shall ensure that the following documentation is on–site and readily available at all times (at a minimum):
    a. Emergency Response Procedure (ERP);
    b. Environmental Protection Plan (EPP);
    c. MSDS for all on–site material;
    d. Copies of Land Use Agreements.

GEOTECHNICAL

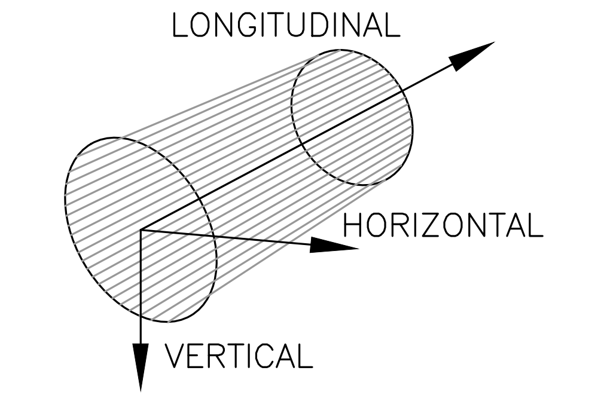
25. A geotechnical investigation was completed at this site by Endeavor Professional Services, LLC (Endeavor). Refer to the report titled "Geotechnical Investigation Report for Cowanesque HDD Investigation," dated June 12, 2024 with additional logs dated May 2, 2025.
26. The soil and bedrock stratigraphy shown is based on interpretation of data from six (6) boreholes, drilled at the locations shown and the designer's understanding of the local geology. Due to natural variations in subsurface conditions and inherent uncertainties associated with the interpretation of subsurface data, some variation in stratigraphy between boreholes and along the length of the bore should be expected.
27. The Contractor should independently evaluate the crossing with due consideration given to the suitability of its proposed equipment and construction procedures. Proposed construction means and methods shall be submitted to Company for approval but remain the sole responsibility of the Contractor.

ANNULAR PRESSURE CHART

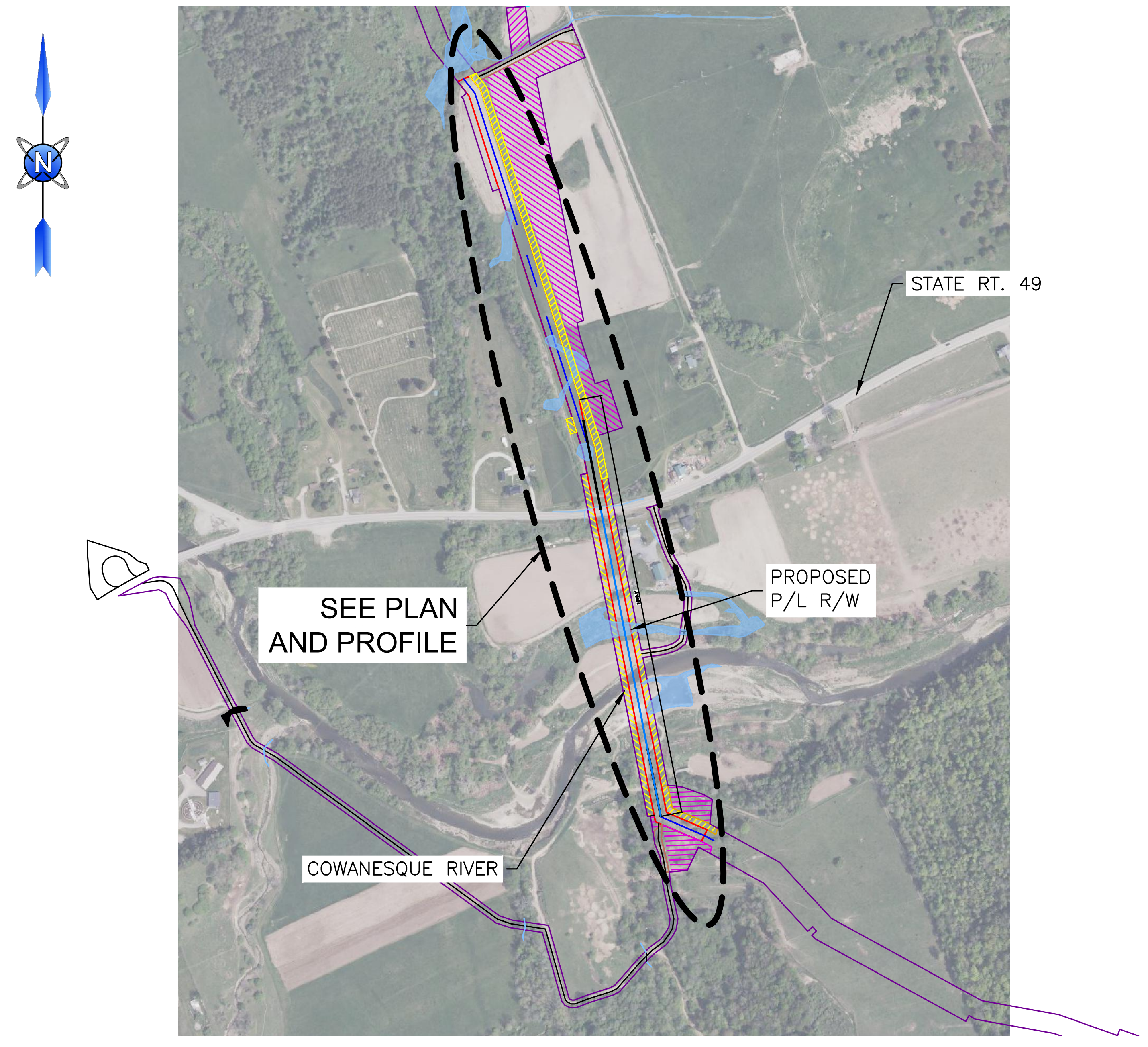


PULLBACK NOTES

1. This drawing is engineered and designed to ensure the pipe section is not overstressed during the installation process.
2. This drawing is developed to inform the Contractor of the maximum spacing, anticipated lifting heights, minimum loading requirements and the minimum amount of support equipment to be provided by the Contractor. It is expected that the Pipeline Contractor will choose the type and size of equipment to manage the minimum loads provided.
3. The shown spacing and heights of supports represent a modeled maximum total stress on the pipe (including tension, bending and shear stress at the supports) of 60% of SMYS.
4. The support placement and spacing shown is based on publicly available LiDAR data. The Contractor shall field fit equipment according to the terrain or other on–site requirements adhering to a maximum spacing provided of 75ft between any two supports.
5. This drawing is based on information provided by various sources. The contractor shall confirm the accuracy of information prior to construction.
6. All loads shown assume that no buoyancy control will be utilized for this pullback.
7. All dimensions are to the bottom of pipe.
8. It is anticipated that all support equipment will utilize roller cradles during the pullback operation. Load capacity of each roller cradle is 28,667lbs (Darby 12"–24" double roller cradle model).
9. Equipment shall be sized with an adequate safety factor (2.0x or greater) to safely handle expected loads and to suit the heights recommended to facilitate the proper radius of curvature. It is expected that extended boom lengths or ramping under the side–booms may be necessary.
10. Shown pipe roller spacing based on roller load capacity of 8,000lbs. Roller spacing shall be adjusted to suit model of roller used.
11. It is the Contractor's responsibility to ensure they have crossing agreements from all utility and pipeline companies in the area where work will be performed overtop or in the vicinity of high pressure pipelines or utilities.
12. Proper padding/ramping above existing lines is required for all areas in which heavy equipment is moved or placed where the equipment may impact these lines.
13. Contractor shall ensure that there is minimal public disturbance and disruption during all parts of the work.
14. Contractor shall be prepared to work with other Contractors in the area.
15. Care shall be taken in manipulating the first and last section of pipe throughout the pullback. The maximum unsupported length at the leading and trailing ends of the pull section shall not exceed 65ft in order to prevent overstressing of the pipe.
16. Contractor shall implement an adequately sized catch off tractor as an anchor when the pipe section involves a slope, horizontal curve and/or a high to low installation. The tractor must be secured to the pipe section in an acceptable manner such as a pull head.
17. Contractor shall consider other factors such as weather conditions (wind, rain, snow, etc.) and site conditions on the pullback operations to ensure a safe lift and installation.
18. Contractor shall secure the load lines on cranes (if required) to the ground to minimize movement of the cradles along the pipe.
19. Contractor to take all precautions to minimize damage to pipe coating during pullback. Any damage to coating shall be repaired as specified in contract documents.
20. Contractor shall modify this plan (as required) to ensure the pipe pull section is sufficiently supported at all times during pullback. Contractor must provide a Pullback Plan for approval by the owner's representative two weeks in advance of commencing the work.
21. For the support design shown, the largest expected forces are:
    Single Cradle Support
    a. Vertical 14,600lbs
    b. Horizontal 1,827lbs
    c. Longitudinal 1,460lbs
22. The loads on the supports during pullback resolve to three directions; vertical, horizontal and longitudinal. The vertical direction is the weight of the pipe, the horizontal direction results from horizontal curves and the longitudinal direction results from the pipe being pulled through the cradles. A diagram can be seen in the detail to the right.



DIRECTIONAL FORCE DIAGRAM
N.T.S.



LOCATION PLAN

SCALE 1"=500'

REFERENCE DOCUMENT NO.	DATE
1. 01-Cowanesque_River_LiDAR	2024-05-06
2. 4418-01-STEEL STRESS-01	2025-05-20
3. 4418-01-AP-01	2025-05-19

CCI & Associates Inc.
20445 State Highway 249, Suite 250
Houston, TX 77070

ENGINEER AND PERMIT STAMPS

PRELIMINARY
NOT FOR
CONSTRUCTION

PIPELINE SPECIFICATIONS

	NPS 20
OUTSIDE DIAMETER (OD)(in)	20
WALL THICKNESS (WT)(in)	0.500
GRADE	X65
PRODUCT	GAS
MATERIAL	STEEL
SPECIFICATIONS	API 5L
INTERNAL COATING	N/A
OUTER COATING	FBE/PRW
MAX. OPER. PRESSURE (psi)	1,440
MIN. TEST PRESSURE (psi)	1,800
MAX. OPER. TEMP (°F)	100
MIN. INSTALLATION TEMP (°F)	30

STEERING TOLERANCES

	DESIGN	100ft	30ft
MINIMUM RADIUS (ft)	1500	1200	1000

PULL FORCE / RIG SIZE / STRESS

PULL FORCE (w/o BUOYANCY CONTROL):	238,000 lbs (w/sf)
MINIMUM RECOMMENDED RIG SIZE:	440,000 lbs
COMBINED STRESS UNITY CHECK:	0.45
OPERATING STRESS:	85.1%

DRAWING STATUS	DATE	DRN	CHK	DES	GEO	APR	CR
ISSUED FOR REVIEW (90% DESIGN)	2025-06-17	AB	BO	QW	LC	GB	SM
ISSUED FOR REVIEW (60% DESIGN)	2025-05-23	AB	BO	QW	LC	GB	SM

HARN/PA.PA-NF

National Fuel®

FERC 7C TIOGA PATHWAY PROJECT

COWANESQUE RIVER HDD CROSSING
CONSTRUCTION NOTES - NPS 20

POTTER COUNTY, PENNSYLVANIA

SCALE	DWG. #	REVISION	SHEET
AS SHOWN	4418-EG-0103	B	3 OF 3

File Name: W:\US Current Jobs\4418–National Fuel Gas Supply–Cowanesque River HDD\Eng\Drawings\01–Cowanesque River\IFP (90% Design)\4418–EG–0101–C.dwg Date/Time: 17–Jun–25 / 3:20:39 PM Last Saved By: Qixuan.Wen

APPENDIX B – HDD STRESS ANALYSIS SUMMARIES

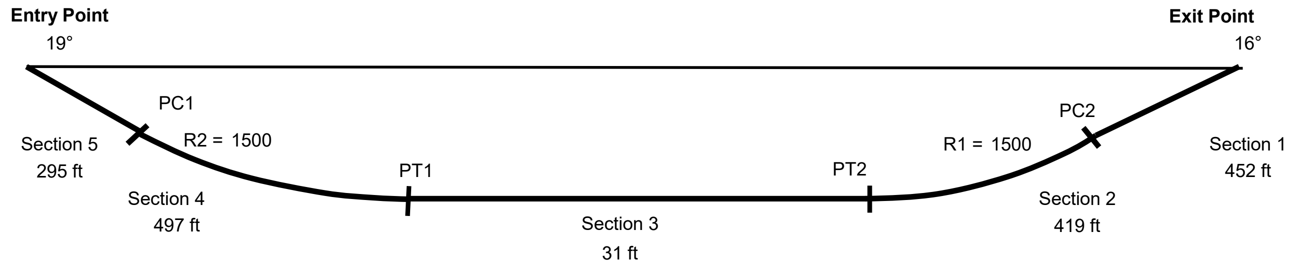
DESIGN RADIUS

Owner:	National Fuel Gas Supply Corporation
Project:	Tioga Pathway Project
Date:	5/19/2025
Calculation Description:	Stress Assessment NPS 20 HDD
Applicable Crossings:	Cowanesque River HDD

CCI & Associates Inc.

Completed By: QW | Reviewed By: GB | Sheet Revision: R20

Pipe Information			**Design Criteria**					**Crossing Characteristics**	
Pipe Diameter (in)	**Pipe W.T. (in)**	**Pipe Grade (psi)**	**MOP (psi)**	**Max. Operating Temperature (°F)**	**Installation Temperature (°F)**	**Design Radius 1 [R1] (ft)**	**Design Radius 2 [R2] (ft)**	**Maximum Depth From Entry Location (ft)**	**HDD Length (ft)**
20.00	0.500	65000	1,440	100	30	1500	1500	178	1694



Design Radius Installation Stresses

Tensile Stress:

		% of Allowable
5	2179.2 psi	3.7%
4	3600.4 psi	6.2%
3	3643.7 psi	6.2%
2	5075.0 psi	8.7%
1	5170.7 psi	**8.8%**

PRCI 5.1.1, 5.5

Allowable Tensile Stress

$F_t = (0.9) * F_y$

= 58500 psi

Bending Stress:

		% of Allowable
5	245.8 psi	0.6%
4	16388.9 psi	**36.7%**
3	245.8 psi	0.6%
2	16388.9 psi	**36.7%**
1	245.8 psi	0.6%

PRCI 5.2.2

$f_b = (E/D)/(2R)$

Allowable Bending Stress

F(b)=[0.84 - {1.74 Fy D / (E t)}] Fy

= 44631.9 psi

Hoop Stress:

		% of Allowable
5	1743.5 psi	16.1%
4	2467.8 psi	**22.8%**
3	2467.8 psi	**22.8%**
2	2467.8 psi	**22.8%**
1	1449.0 psi	13.4%

PRCI 5.2.3

$f_h = P_{ext}D/2t$

Allowable Hoop Stress

F(hc) = F (he) for F(he) <= 0.55 x Tensile Strength

= 10816.7 psi

Combined Stress (Tensile and Bending)

		% of Allowable
5	0.04	4%
4	0.43	43%
3	0.07	7%
2	0.45	**45%**
1	0.09	9%

PRCI 5.2.4

$f_t/0.9F_y+f_b/F_b \leq 1$

Combined Stress (Tensile, Bending, and Hoop)

		% of Allowable
5	0.03	3%
4	0.23	23%
3	0.06	6%
2	0.26	**26%**
1	0.03	3%

PRCI 5.2.4

$A^2+B^2+2v|A|B \leq 1$

$A = ((f_t+f_b-0.5f_h)1.25)/F_y$

$B = 1.5f_h/F_{hc}$

Operating Stresses

Operating Stresses:

		% of Allowable
5	16825.7 psi	57.5%
4	24897.3 psi	**85.1%**
3	16825.7 psi	57.5%
2	24897.3 psi	**85.1%**
1	16825.8 psi	57.5%

PRCI 5.4.4.2:

Allowable Shear Stress

$F(v) = 45\%$ of F_y

F(v) = 29250 psi

Estimated PullForce (without Buoyancy Control)

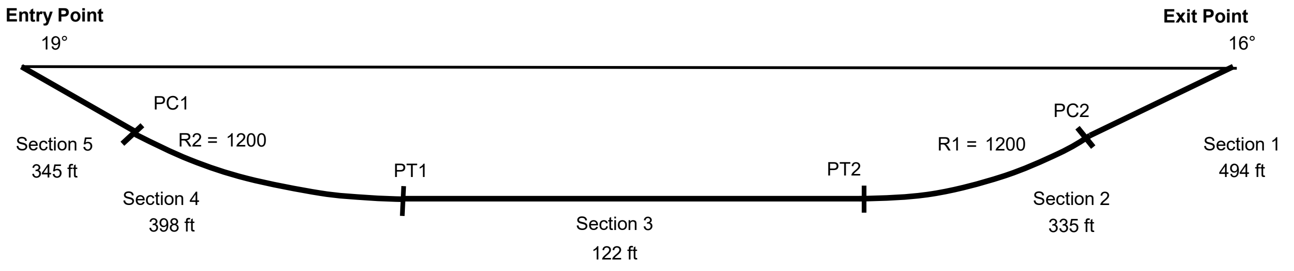
158,302 lbs 237,453 lbs (including 1.5x Safety Factor)

3-JOINT MADR

Owner:	National Fuel Gas Supply Corporation
Project:	Tioga Pathway Project
Date:	5/19/2025
Calculation Description:	3-Joint Stress Assessment NPS 20 HDD
Applicable Crossings:	Cowanesque River HDD

Completed By: QW Reviewed By: GB Sheet Revision: R20

Pipe Information			Design Criteria					Crossing Characteristics	
Pipe Diameter (in)	**Pipe W.T. (in)**	**Pipe Grade (psi)**	**MOP (psi)**	**Max. Operating Temperature (°F)**	**Installation Temperature (°F)**	**Design Radius 1 [R1] (ft)**	**Design Radius 2 [R2] (ft)**	**Maximum Depth From Entry Location (ft)**	**HDD Length (ft)**
20.00	0.500	65000	1,440	100	30	1200	1200	178	1694



3-Joint Installation Stresses

Tensile Stress:

		% of Allowable
5	2270.2 psi	3.9%
4	3591.2 psi	6.1%
3	3760.7 psi	6.4%
2	5170.7 psi	8.8%
1	5282.7 psi	**9.0%**

PRCI 5.1.1, 5.5

Allowable Tensile Stress

$F_t = (0.9) * F_y$

= 58500 psi

Bending Stress:

		% of Allowable
5	245.8 psi	0.6%
4	20486.1 psi	**45.9%**
3	245.8 psi	0.6%
2	20486.1 psi	**45.9%**
1	245.8 psi	0.6%

PRCI 5.2.2

$f_b = (E/D)/(2R)$

Allowable Bending Stress

F(b)=[0.84 - {1.74 Fy D / (E t)}] Fy

= 44631.9 psi

Hoop Stress:

		% of Allowable
5	1888.4 psi	17.5%
4	2467.8 psi	**22.8%**
3	2467.8 psi	**22.8%**
2	2467.8 psi	**22.8%**
1	1652.9 psi	15.3%

PRCI 5.2.3

$f_h = P_{ext}D/2t$

Allowable Hoop Stress

F(hc) = F (he) for F(he) <= 0.55 x Tensile Strength

= 10816.7 psi

Combined Stress (Tensile and Bending)

		% of Allowable
5	0.04	4%
4	0.52	52%
3	0.07	7%
2	0.55	**55%**
1	0.10	10%

PRCI 5.2.4

$f_t/0.9F_y+f_b/F_b \leq 1$

Combined Stress (Tensile, Bending, and Hoop)

		% of Allowable
5	0.03	3%
4	0.31	31%
3	0.06	6%
2	0.34	**34%**
1	0.04	4%

PRCI 5.2.4

$A^2+B^2+2v|A|B \leq 1$

$A = ((f_t+f_b-0.5f_h)1.25)/F_y$

$B = 1.5f_h/F_{hc}$

Operating Stresses

Operating Stresses:

		% of Allowable
5	16825.7 psi	57.5%
4	26945.9 psi	**92.1%**
3	16825.7 psi	57.5%
2	26945.9 psi	**92.1%**
1	16825.8 psi	57.5%

PRCI 5.4.4.2:

Allowable Shear Stress

$F(v) = 45\%$ of F_y

F(v) = 29250 psi

Estimated PullForce (without Buoyancy Control)

161,730 lbs 242,595 lbs (including 1.5x Safety Factor)

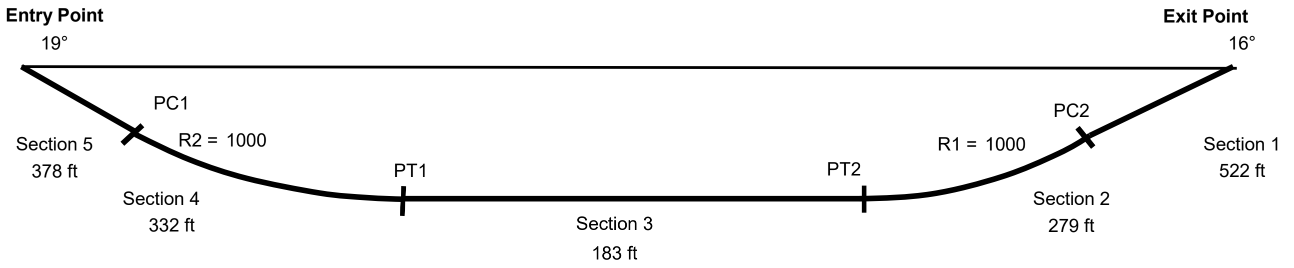
MINIMUM ALLOWABLE 1-JOINT

Owner: National Fuel Gas Supply Corporation
Project: Tioga Pathway Project
Date: 5/19/2025
Calculation Description: Single-Joint Stress Assessment NPS 20 HDD
Applicable Crossings: Cowanesque River HDD

CCI & Associates Inc.

Completed By: QW Reviewed By: GB Sheet Revision: R20

Pipe Information			Design Criteria					Crossing Characteristics	
Pipe Diameter (in)	Pipe W.T. (in)	Pipe Grade (psi)	MOP (psi)	Max. Operating Temperature (°F)	Installation Temperature (°F)	Design Radius 1 [R1] (ft)	Design Radius 2 [R2] (ft)	Maximum Depth From Entry Location (ft)	HDD Length (ft)
20.00	0.500	65000	1,440	100	30	1000	1000	178	1694



Single-Joint Installation Stresses

Tensile Stress:

		% of Allowable
5	2330.9 psi	4.0%
4	3614.3 psi	6.2%
3	3867.8 psi	6.6%
2	5295.4 psi	9.1%
1	5418.3 psi	**9.3%**

PRCI 5.1.1, 5.5

Allowable Tensile Stress

$F_t = (0.9) * F_y$

= 58500 psi

Bending Stress:

		% of Allowable
5	245.8 psi	0.6%
4	24583.3 psi	**55.1%**
3	245.8 psi	0.6%
2	24583.3 psi	**55.1%**
1	245.8 psi	0.6%

PRCI 5.2.2

$f_b = (E/D)/(2R)$

Allowable Bending Stress

F(b)=[0.84 - {1.74 Fy D / (E t)}] Fy

= 44631.9 psi

Hoop Stress:

		% of Allowable
5	1985.0 psi	18.4%
4	2467.8 psi	**22.8%**
3	2467.8 psi	**22.8%**
2	2467.8 psi	**22.8%**
1	1788.7 psi	16.5%

PRCI 5.2.3

$f_h = P_{ext}D/2t$

Allowable Hoop Stress

F(hc) = F (he) for F(he) <= 0.55 x Tensile Strength

= 10816.7 psi

Combined Stress (Tensile and Bending)

		% of Allowable
5	0.05	5%
4	0.61	61%
3	0.07	7%
2	0.64	**64%**
1	0.10	10%

PRCI 5.2.4

$f_t/0.9F_y+f_b/F_b \leq 1$

Combined Stress (Tensile, Bending, and Hoop)

		% of Allowable
5	0.04	4%
4	0.39	39%
3	0.06	6%
2	0.43	**43%**
1	0.04	4%

PRCI 5.2.4

$A^2+B^2+2v|A|B \leq 1$

$A = ((f_t+f_b-0.5f_h)1.25)/F_y$

$B = 1.5f_h/F_{hc}$

Operating Stresses

Operating Stresses:

		% of Allowable
5	16825.7 psi	57.5%
4	28994.5 psi	**99.1%**
3	16825.7 psi	57.5%
2	28994.5 psi	**99.1%**
1	16825.7 psi	57.5%

PRCI 5.4.4.2:

Allowable Shear Stress

F(v) = 45% of F_y

F(v) = 29250 psi

Estimated PullForce (without Buoyancy Control)

165,882 lbs 248,823 lbs (including 1.5x Safety Factor)

APPENDIX C – PIPE LIFTING STRESS ANALYSIS SUMMARY

Owner: National Fuel Gas Supply Corporation
Project: Tioga Pathway Project
Date: 5/20/2025
Calculation Description: HDD Pipe Pullback Analysis NPS 20
Applicable Crossings: Cowanesque River HDD

CCI
& Associates Inc.

Completed By: QW | Reviewed By: GB | Sheet Revision: R20

Pipe Information			Design Criteria					
Pipe Diameter (in)	**Pipe W.T. (in)**	**Pipe Grade (psi)**	**Overbend Radius (ft)**	**Total Supported Weight (lbs/ft)**	**Maximum Support Spacing (ft)**	**Roller Spacing (ft)**	**Maximum Unsupported Overhang (ft)**	**Estimated Pullforce (lbs)**
20.00	0.500	65000	850	103.6	75	60	65	237,453

The pipe pullback is modelled such that the pipe is not over-stressed due to the combination of bending, tensile, and shear stresses throughout the pullback section, both in the spans between supports and at the support locations. The pullback is also modelled such that the supports are not overloaded with the weight of the pipe at any point during the pipe installation, including as the tailing end passes from support to support.

Definitions:

SMYS	- Specified Minimum Yield Strength
Overhang	- Where Unsupported Tail End of Pipe Extends Beyond Support
Full Span	- Where Pipe Is Supported Between 2 Supports at Maximum Support Spacing Shown Above

SUPPORT LOADING

Vertical Load at Each Boom/Crane Support — **% of Support Capacity ***

At Support With Full Span:

5,300 kg	11,700 lbs		40.8%

At Support With Overhang:

6,600 kg	14,600 lbs		**50.8%**

Longitudinal Load at Each Boom/Crane Support

660.0 kg   1,460 lbs

* based on load capacity of Darby 12" - 24"D Rolli-Cradle

Horizontal Load at Each Boom/Crane Support		**Horizontal Load at Each Roller Support**	
1,036 kg	2,284 lbs	829 kg	1,827 lbs

PIPE STRESS

Bending Stress	**% SMYS**	**% of Allowable (PRCI)**
At Support With Full Span:		
32922.1 psi	50.6%	75.7%
At Support with Overhanging Pipe:		
36285.4 psi	55.8%	**83.5%**
Tensile Stress		
1145.8 psi	1.8%	**2.0%**
Combined Stress (Tensile and Bending)		
34067.9 psi	52.4%	**78%**

APPENDIX D – RISK ASSESSMENT SUMMARY

Risk Assessment Legends

Probability		
Value	**Description**	**Chance**
1	Rare	≤ 5%
2	Unlikely	~ 25%
3	Possible	~ 50%
4	Likely	~ 75%
5	Almost Certain	≥ 95%

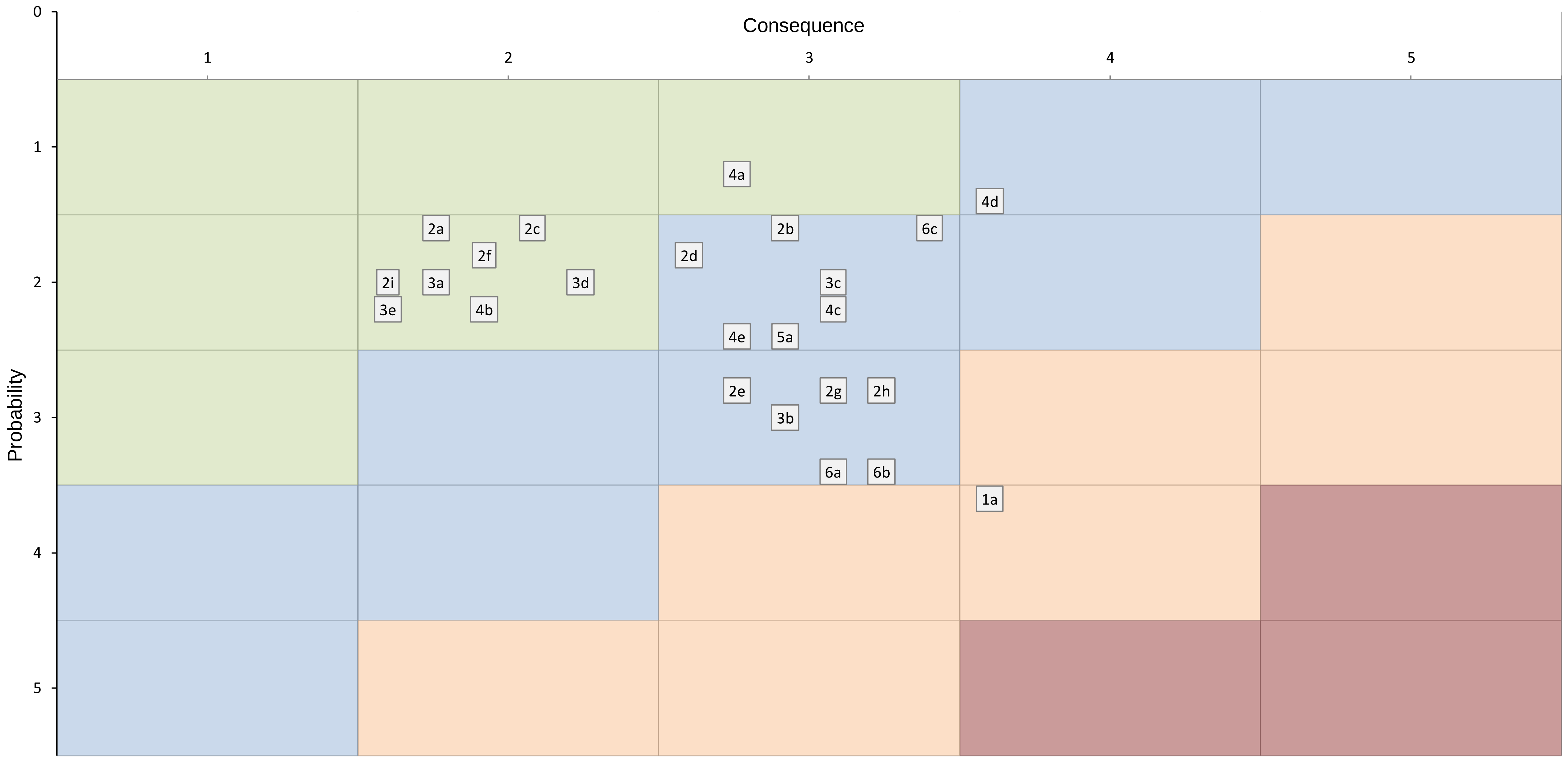
Consequence	
Value	**Description**
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catastrophic

Risk Types	**1 - Insignificant**	**2 - Minor**	**3 - Moderate**	**4 - Major**	**5 - Catastrophic**
Safety and Health	**First Aid Case**	**Minor Injury** - Medical treatment case with/or Restricted Work Case	**Serious Injury** or Lost Work Case	**Major or Multiple Injuries** - permanent injury or disability	**Fatality**
Environment	**No Impact** on baseline environment. Localized to point source. No action required.	**Localised** within site boundaries. Recovery measureable within 1 month of impact	**Moderate** harm with possible wider effect. Recovery in 1 year	**Significant** harm with local effect. Recover longer than 1 year	**Significant** harm with widespread effect. Recovery longer than 1 year. Limited prospect of full recovery
Financial	1 - 5% over Budget	5 - 20% over Budget	20 - 50% over Budget	50 - 100% over Budget	> 100% over Budget
Production/Schedule	< 1 - 5 days	6 days - 2 weeks	3 - 4 weeks	5 - 6 weeks	> 6 weeks
Reputation	Localised temporary impact	Localised, short term impact	Localised, long term impact but manageable	Localised, long term impact with unmanageable outcomes	Long term regional impact
Business Impact	Impact can be absorbed through normal activity	An adverse event which can be absorbed with some management effort	A serious event which requires additional management effort	A critical event which required extraordinary management effort	Disaster with potential to lead to collapse of the project

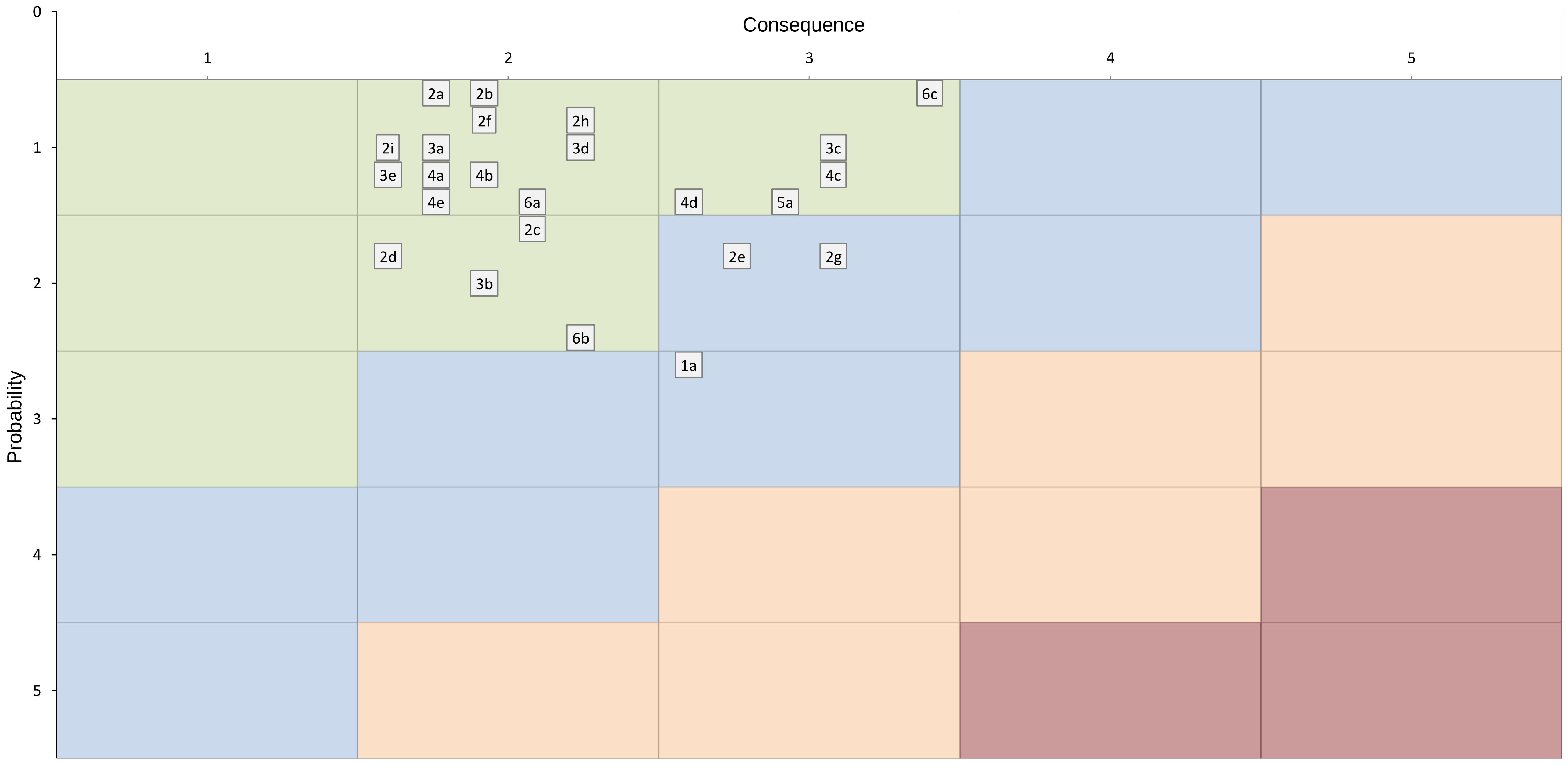
		Consequence				
Probability		**1**	**2**	**3**	**4**	**5**
	1	L	L	L	M	M
	2	L	L	M	M	H
	3	L	M	M	H	H
	4	M	M	H	H	VH
	5	M	H	H	VH	VH

L	Low Risk - Managed by routine procedures
M	Medium Risk - Planned Mitigation Strategy Required
H	High Risk - Prioritized Mitigation Strategy Required
VH	Very High Risk - Immediate Mitigation Strategy Required

Cowanesque River HDD Risk Assessment Before Mitigation



Cowanesque River HDD Risk Assessment After Mitigation



Cowanesque River HDD Risk Assessment Summary

Phase	#	Description	Safety and Health Risk	Environmental Risk	Financial Risk	Production/Schedule Risk	Reputation Risk	Business Impact Risk	Risk Before Mitigation	Risk After Mitigation
Installation of Casing (Entry and Exit Points)	1a	Casing not Being Installed to Depth		✓	✓	✓			High Risk	Medium Risk
Pilot Hole	2a	Fracture to Surface	✓	✓	✓	✓			Low Risk	Low Risk
	2b	Fracture to Water Body	✓	✓	✓	✓			Medium Risk	Low Risk
	2c	Large Fluid Loss to the Formation (>25% of total volume)	✓	✓	✓	✓			Medium Risk	Low Risk
	2d	Unstable Borehole (swelling, broken up, etc.)	✓	✓	✓	✓			Medium Risk	Low Risk
	2e	Steering Control Issues	✓	✓	✓	✓			Medium Risk	Medium Risk
	2f	Annular Pressure Issues	✓	✓	✓	✓			Low Risk	Low Risk
	2g	Over-Schedule Risk	✓	✓	✓	✓			Medium Risk	Medium Risk
	2h	Disposal of Drilling Fluid	✓	✓	✓	✓			Medium Risk	Low Risk
	2i	Water Ingress to Borehole	✓	✓	✓	✓			Low Risk	Low Risk
Reaming Operations	3a	Unstable Borehole	✓	✓	✓	✓			Low Risk	Low Risk
	3b	Over-Schedule Risk	✓	✓	✓	✓			Medium Risk	Low Risk
	3c	Loss of Equipment in Borehole		✓	✓	✓			Medium Risk	Low Risk
	3d	Poor Removal of cuttings		✓	✓	✓			Low Risk	Low Risk
	3e	Drilling Fluid Control		✓	✓	✓			Low Risk	Low Risk
Pullback Operations	4a	Pipe Section Gets Stuck in Borehole		✓	✓	✓			Low Risk	Low Risk
	4b	Pull Forces Exceed Theoretical Model		✓	✓	✓			Low Risk	Low Risk
	4c	Coating Damaged during Installation		✓	✓	✓			Medium Risk	Low Risk
	4d	Product Pipe is Damaged during Installation		✓	✓	✓			Medium Risk	Low Risk
	4e	Pipe Handling on Exit	✓	✓	✓	✓			Medium Risk	Low Risk
Pipeline Contractor - Pipe Preparation and Support	5a	HDD Takes Longer than Scheduled to Complete		✓	✓	✓			Medium Risk	Low Risk
Construction Access and Pad Preparation	6a	Construction Access	✓	✓	✓	✓			Medium Risk	Low Risk
	6b	Pad Layout & Construction	✓	✓	✓	✓			Medium Risk	Low Risk
	6c	Travel Safety							Medium Risk	Low Risk
Other Risks	7a									
	7b									
	7c									
	7d									

Probability

Value	Description	Chance
1	Rare	≤ 5%
2	Unlikely	~ 25%
3	Possible	~ 50%
4	Likely	~ 75%
5	Almost Certain	≥ 95%

Consequence

Value	Description
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catastrophic

L	Low Risk - Managed by routine procedures
M	Medium Risk - Planned Mitigation Strategy Required
H	High Risk - Prioritized Mitigation Strategy Required
VH	Very High Risk - Immediate Mitigation Strategy Required

Attendance: Steve Meaders, Gunnar Busch, Landon Cels, Justin Taylor

Cowanesque River HDD

Date: July 18, 2024
Rev: 0

Mud Motor HDD Risk Assesment

No.	Risk/Issue	Type of Risk/Issue		Pre-Mitigation Probability	Pre-Mitigation Consequence	Post-Mitigation Probability	Post-Mitigation Consequence	Review Cost Needed?
Installation of Casing (Entry and Exit Points)								
1a	Casing not Being Installed to Depth	Safety and Health	-	4	4	3	3	Select
		Environment	Yes	High Risk		Medium Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Geotechnical conditions identified gravels, unconsolidated overburden material and rock fragments above bedrock interface which could cause some issues installaling the casing to depth into competent bedrock. Geotechnical boring on north side of crossing near the exit point does not extend into competent bedrock, therefore, exact length of exit-side casing is approximate.		It would be recommended to excavate at the entry and exit locations to shorten the length of the casing that may be required. Contractor should consider telescoping casing to allow desired length of minimum size casing to be installed. Contractor shall provide inspected casing and casing shoe with casing installation plan and ensure proper equipment is on site at all times. It is also recommended that an additional boring be completed near the exit point which extends into competent bedrock to allow for planning of required casing length		
		Reputation	-					
		Business Impact	-					
Pilot Hole								
2a	Fracture to Surface	Safety and Health	Yes	2	2	1	2	Select
		Environment	Yes	Low Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	[Assuming casing installed to depth] Granular/unconsolidated material near surface can pose a potential risk for conduit where drilling fluid migrates to surface as drill bit nears surface. The geotechnical investigation identified gravels, unconsolidated overburden and rock fragments in which the HDD drill will be progressing through before reaching the bedrock interface.		Surface casing installation will help mitigate most of the Fracture to Surface risks by isolating the problematic geotechnical materials and allow the drilling fluid to be containted within the casing to keep an open borehole. Contractor shall have necessary fluid containment equipment at the entry and exit to prevent the fluid from spilling out from the pits. Ensure the drill operator adheres to the required tolerances for the HDD path and reduces fluid pressures—mechanical trip as necessary. Follow EDFP		
		Reputation	-					
		Business Impact	-					
2b	Fracture to Water Body	Safety and Health	Yes	2	3	1	2	Select
		Environment	Yes	Medium Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Fractured bedrock can provide a potential path for drilling fluid migration to the river where drill bit is crossing underneath the waterbody. A low risk of IR has been identified beneath the identified river. Based on available geo data, the HDD is expected to remain embedded within siltstone bedrock under the river. Unclear of what specific UCS testing of rock is due to limited testing.		Ensure Contractor adheres to the required tolerances for the HDD path and reduce fluid pressures. Mechanical trip as necessary. Follow EDFP.		
		Reputation	-					
		Business Impact	-					
2c	Large Fluid Loss to the Formation (>25% of total volume)	Safety and Health	Yes	2	3	2	2	Select
		Environment	Yes	Medium Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	[Assuming casing installed to depth] Drilling fluid has a potential to migrate outside of the designed drill path in heavily fractured rock, which is anticipated near the bedrock interface. Large fluid loss may have permitting implications.		The Contractor shall ensure that the surface casing is installed to depth into competent bedrock to avoid losing fluid into the fractured bedrock interface. The Contractor shall ensure not to over pressurize the borehole with excessive drilling fluid pressures. Follow EDFP.		
		Reputation	-					
		Business Impact	-					
		Safety and Health	Yes	2	3	2	2	Select
		Environment	Yes	Medium Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		

2d	Unstable Borehole (swelling, broken up, etc.)	Production/Schedule	Yes	[Assuming casing installed to depth] Limited geotechnical information near the exit point may pose difficulty/uncertainty for casing installation throgh loose granular materials. During drilling operations this material can become unstable. Potential for rock fragments within the bedrock.		Surface casing installation will help mitigate most of the Unstable Borehole risks by isolating the problematic geotechnical materials and allow the drilling fluid to be containted within the casing to keep an open borehole. The Contractor shall trip/clean the hole within the bedrock to ensure proper hole integrity. It is also recommended that an additional boring be completed near the exit point which extends into competent bedrock to allow for planning of required casing length		
		Reputation	-					
		Business Impact	-					
2e	Steering Control Issues	Safety and Health	Yes	3	3	2	3	Select
		Environment	Yes	Medium Risk		Medium Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Design radius was selected to be 1,600ft. It is possible that the drill bit could deflect or have a hard time entering the bedrock interface if the surface casing has not properly reached competent bedrock. Casing installed on both ends would require the rig on entry to steer the bit into the 42" casing nearer the exit point which could be very difficult.		Utilize experienced Contractor to complete the work. Ensure surface casing is installed to depth into competent bedrock and utililize centralizer. The Contractor shall ensure that steering equipment is calibrated before construction and adhere to steering tolerances. Ensure that the steering coil can be laid out across the River and road. Contractor to have contingency plan to use Gyro if unable to lay out coil. Intersect pilot hole (rigs on either end) is highly recommended to ensure that the pilot hole can be centetered within the casing from either end. Casing final position should be surveyed after final length is installed prior to beginning pilot hole installation.		
		Reputation	-					
		Business Impact	-					
2f	Annular Pressure Issues	Safety and Health	Yes	2	2	1	2	Select
		Environment	Yes	Low Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	[Assuming casing installed to depth] Drilling operations require soil cuttings to be cleaned out of the bore and hydro-transported back to the rig by the drilling fluid. This process requires large volumes of pressurized drilling fluid to be pumped downhole.		Utilize experienced Contractor to complete the work. Ensure surface casing is installed to depth into competent bedrock. Ensure drilling fluid pumping equipment is working properly and adjust the drilling fluid properties as needed. Mechanical tripping to clear borehole. Mud engineer on site is recommended. Adhere to EDFP.		
		Reputation	-					
		Business Impact	-					
2g	Over-Schedule Risk	Safety and Health	Yes	3	3	2	3	Select
		Environment	Yes	Medium Risk		Medium Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Unknown geotechnical conditions, groundwater, equipment failure, permitting, and environmental issues can all contribute to delays in the schedule. Casing is required on both ends of the crossing due to poor geotechnical conditions which will add significantly to the schedule.		Utilize experienced Contractor to complete the work. Contractor to develop a detailed casing installation plan to ensure surface casing is installed to depth into competent bedrock. Ensure all communication with relevant stakeholders is maintained and that the Contractor is planned for routine mechanical tripping. Minimize downtime as much as possible while drilling beneath river into the bedrock. Additional boring recommended near exit point which identifies depth of bedrock.		
		Reputation	-					
		Business Impact	-					
2h	Disposal of Drilling Fluid	Safety and Health	Yes	3	3	1	2	Select
		Environment	Yes	Medium Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Drilling fluid needs to be stored and disposed of. Running out of temporary storage can lead to schedule delays and environmental concerns. PADEP enforces strict requirements for mud and cuttings disposal.		Ensure drilling fluid waste management plan created and approved of prior to construction & approved disposal site is selected meeting PADEP and other stakeholder/regulatory body requirements.		
		Reputation	-					
		Business Impact	-					
2i	Water Ingress to	Safety and Health	Yes	2	2	1	2	Select
		Environment	Yes	Low Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Ground water tends to migrate to where soil has been cut/ displaced				

	<u>Borehole</u>	Reputation	-	Ground water tends to migrate to where soil has been cut/ displaced. Water within the boreholes were noted to be near the elevation of the flowing water within the river at the time of the geotechnical investigation.		Control drilling fluid properties to account for groundwater ingress. Recommend mud engineer on site. EDFP shall be in put place and followed.		
		Business Impact	-					
Reaming Operations								
3a	<u>Unstable Borehole</u>	Safety and Health	Yes	2	2	1	2	Select
		Environment	Yes	Low Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	[Assuming casing installed to depth] Limited geotechnical information near the exit point may pose difficulty/uncertainty for casing installation throgh loose granular materials. During drilling operations this material can become unstable. Potential for rock fragments within the bedrock.		Surface casing installation will help mitigate most of the Unstable Borehole risks by isolating the problematic geotechnical materials and allow the drilling fluid to be containted within the casing to keep an open borehole. The Contractor shall trip/clean the hole within the bedrock to ensure proper hole integrity. It is also recommended that an additional boring be completed near the exit point which extends into competent bedrock to allow for planning of required casing length. Contractor to make note of any issues encountered during the pilot hole installation phase.		
		Reputation	-					
		Business Impact	-					
3b	<u>Over-Schedule Risk</u>	Safety and Health	Yes	3	3	2	2	Select
		Environment	Yes	Medium Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Unknown geotechnical conditions, groundwater, equipment failure, permitting, and environmental issues can all contribute to delays in the schedule.		Ensure all communication with stakeholders is maintained and that the Contractor is planned for routine mechanical tripping to ensure competent clean borehole.		
		Reputation	-					
		Business Impact	-					
3c	<u>Loss of Equipment in Borehole</u>	Safety and Health	-	2	3	1	3	Select
		Environment	Yes	Medium Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Reaming or enlarging the bore to the desired diameter may cause instability areas. These areas may cause downhole tooling to get stuck or lost.		Ensure all connections are properly torqued and all reaming tools have the ability to cut in both directions. Contractor shall use tail string at all times to allow extraction of tooling from either end in the event that a twist off does occur. Contractor should make sure hole is clean and maintain full returns, utilize proper Rate of Penetrations (ROPs) and pump rates. [If intersect pilot hole is used, second rig would assist]		
		Reputation	-					
		Business Impact	-					
3d	<u>Poor Removal of cuttings</u>	Safety and Health	-	2	2	1	2	Select
		Environment	Yes	Low Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Cuttings need to be efficiently removed from the borehole. Failure to remove the cuttings due to properties of the geological formation can lead to blockages in the bore path and increased fluid pressure.		Develop EDFP to monitor drilling fluid properties to ensure the fluid is the right consistency to remove the cuttings effectively. Recommend mud engineer on site. Contractor should make sure hole is clean and maintain full returns, utilize proper Rate of Penetrations (ROPs) and pump rates.		
		Reputation	-					
		Business Impact	-					
3e	<u>Drilling Fluid Control</u>	Safety and Health	-	2	2	1	2	Select
		Environment	Yes	Low Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	As the volume of drilling fluid within the borehole increases, it becomes more difficult to change its properties with drillng fluid additives.		Develop EDFP to monitor drilling fluid properties to ensure the fluid is the right consistency to effectively remove the cuttings. Mud engineer recommended on site.		
		Reputation	-					
		Business Impact	-					
Pullback Operations								
4a	<u>Pipe Section Gets Stuck in Borehole</u>	Safety and Health	-	1	3	1	2	Select
		Environment	Yes	Low Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	[Assuming casing installed to depth] There is a risk that the pipe section will become stuck in the borehole		Install casing to depth. Effectively remove cuttings from borehole		

	Borehole	Reputation	-	There is a risk that the pipe section will become stuck in the borehole due to borehole instability, blockages, or irregularities. Prolonged stoppages during installation could cause borehole to constrict around pipe in these formations.		Install casing to depth. Effectively remove cuttings from borehole, perform a swab pass, and effective scheduling of pullback operations to minimize downtime. Track pullforce and torque values during swab pass.		
		Business Impact	-					
4b	Pull Forces Exceed Theoretical Model	Safety and Health	-	2	2	1	2	Select
		Environment	Yes	Low Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	There is a risk that pull forces exceed the theoretical model. Contributing factors can include cuttings in the borehole, having to temporarily halt line pull, borehole instability, and heavy drilling fluid.		Maintain favorable drilling fluid properties and effectively remove cuttings from borehole. Ensure adequate rig size and perform a swab pass.		
		Reputation	-					
		Business Impact	-					
4c	Coating Damaged during Installation	Safety and Health	-	2	3	1	3	Select
		Environment	Yes	Medium Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Gravel, cobbles, boulders, and bedrock interfaces within the bore path pose a risk that the pipe coating is damaged during line pull. Gravels and rock fragments were identified within the unconsolidated overburden material, which will be mostly isolated by the surface casing. If borehole is not centered within casing and casing is not properly sized for product pipe then the pipe may be dragged along the mouth of casing during pullback.		Perform a swab pass prior to pullback to confirm that borehole is clear of obstructions or debris. Monitor the bottom sections of surface casing during drilling to get an idea of how rough the transition might be, and if there will be bedrock fragments to get past. Monitoring of torque and pullforce during swab pass. Contractor to follow approved casing plan and ensure borehole is centered within properly sized casing.		
		Reputation	-					
		Business Impact	-					
4d	Product Pipe is Damaged during Installation	Safety and Health	-	1	4	1	3	Select
		Environment	Yes	Medium Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Gravel, cobbles, boulders, and bedrock interfaces within the bore path pose a risk that the pipe is damaged during line pull. Gravels and rock fragments were identified within the unconsolidated overburden material, which will be mostly isolated by the surface casing. If borehole is not centered within casing and casing is not properly sized for product pipe then the pipe may be dragged along the mouth of casing during pullback.		Perform a swab pass prior to pullback to confirm that borehole is clear of obstructions or debris. Monitor the bottom sections of surface casing during drilling to get an idea of how rough the transition might be, and if there will be bedrock fragments to get past. Monitoring of torque and pullforce during swab pass.Contractor to follow approved casing plan and ensure borehole is centered within properly sized casing.		
		Reputation	-					
		Business Impact	-					
4e	Pipe Handling on Exit	Safety and Health	Yes	2	3	1	2	Select
		Environment	Yes	Medium Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Pipe will be made-up on exit side and made ready to be pulled into the borehole. This involves many construction crews and lifting equipment to be safely coordinated and operated. Ground slope encounters a gradual incline away from the exit along the pullback alignment.		The contractor needs to develop and approve the pipe lifting plan and entry and exit side crews should stay in communication with one another. Ensure that work-on-slope procedures can be followed to ensure that pipe segments don't slip down the slope.		
		Reputation	-					
		Business Impact	-					
Pipeline Contractor - Pipe Preparation and Support								
5a	HDD Takes Longer than Scheduled to Complete	Safety and Health	-	2	3	1	3	Select
		Environment	Yes	Medium Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Unknown geotechnical conditions, groundwater, equipment failure, permitting, and environmental issues can all contribute to delays in the schedule.		Proper schedule communication between the rig, HDD contractor, and pipeline contractor. Contractor to prep the pullback area prior to construction.		
		Reputation	-					
		Business Impact	-					
Construction Access and Pad Preparation								
		Safety and Health	Yes	3	3	1	2	Select
		Environment	Yes	Medium Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		

6a	Construction Access	Production/Schedule	Yes	Constructing new access for entry location located on the north side of the river on a steep hill to bring all necessary equipment to entry location. Exit location will be accessible from public roads, though access roads will need to be built appropriately. Entry-side access requires crossing over the Cowanesque River which may require a temporary bridge. Old bridges may be required to be crossed over with heavy equipment which the bridges may not be rated for.		Ensure the necessary equipment (casing installation & drilling operations) can reach the workspace. Development of suitable access plan prior to construction that is approved by owner and stakeholders. Ensure proper traffic control plan. Check weight requirements for all roads and bridges to be used for access and that proper vehicles/equipments are used for access routes.		
		Reputation	-					
		Business Impact	-					
6b	Pad Layout & Construction	Safety and Health	Yes	3	3	2	2	Select
		Environment	Yes	Medium Risk		Low Risk		
		Financial	Yes	**Description**		**Mitigation Strategy**		
		Production/Schedule	Yes	Constructing entry pad will require leveling and clearing work due to the steep hill on the entry side. The exit side is located within a field which looks flat and clear of trees which would likely require minimal efforts to prep for construction.		Ensure the necessary equipment (casing installation & drilling operations) can reach the workspace. Development of suitable access plan prior to construction that is approved by owner and stakeholders. Ensure proper traffic control plan. Contractor should develop an approved grading plan for the entry pad to allow rig and equipment setup.		
		Reputation	-					
		Business Impact	-					
6c	Travel Safety	Safety and Health	-	2	3	1	3	Select
		Environment	-	Medium Risk		Low Risk		
		Financial	-	**Description**		**Mitigation Strategy**		
		Production/Schedule	-	Contractor will have to travel to site on public and private roads in remote areas. River will need to be crossed to access entry site.		Make sure the contractor knows where they're going and drives safely. Respect and follow signage. Have proper PPE. Clearly mark or flag access routes. Traffic control during heavy traffic. Ensure that river can safely be crossed.		
		Reputation	-					
		Business Impact	-					
Other Risks								
7a		Safety and Health	-	0	0	0	0	Select
		Environment	-	Risk Weighting		Risk Weighting		
		Financial	-	**Description**		**Mitigation Strategy**		
		Production/Schedule	-					
		Reputation	-					
		Business Impact	-					
7b		Safety and Health	-	0	0	0	0	Select
		Environment	-	Risk Weighting		Risk Weighting		
		Financial	-	**Description**		**Mitigation Strategy**		
		Production/Schedule	-					
		Reputation	-					
		Business Impact	-					
7c		Safety and Health	-	0	0	0	0	Select
		Environment	-	Risk Weighting		Risk Weighting		
		Financial	-	**Description**		**Mitigation Strategy**		
		Production/Schedule	-					
		Reputation	-					
		Business Impact	-					
7d		Safety and Health	-	0	0	0	0	Select
		Environment	-	Risk Weighting		Risk Weighting		
		Financial	-	**Description**		**Mitigation Strategy**		
		Production/Schedule	-					
		Reputation	-					
		Business Impact	-					