Wapiti River Preliminary HDD Feasibility Assessment Report

08C7138-PL-RPT-0014, Rev. 1

08-Jun-2010

Enbridge Northern Gateway Project

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ENBRIDGE NORTHERN GATEWAY PROJECT – WAPITI RIVER PRELIMINARY HDD FEASIBILITY ASSESSMENT REPORT

REV	DESCRIPTION	ORIGINATOR	REVIEWER	WORLEYPARSONS APPROVAL	DATE (dd-Mmm-yyyy)
1	Issued for Implementation	Jim Murphy	Clive MacKay	Louis McIver	08-Jun-2010

EXECUTIVE SUMMARY

This *Wapiti River Preliminary HDD Feasibility Assessment Report* (this report) was prepared by WorleyParsons Canada Services Ltd. (WorleyParsons) for Northern Gateway Pipelines Inc. (Northern Gateway) in support of a regulatory application for approval to construct and operate the Enbridge Northern Gateway Project (the Project).

This report discusses the feasibility of using a horizontal directional drilling (HDD) construction technique to cross the Wapiti River. Based on a review of the available geological and / or geotechnical information, site visits, site photos and ground profiles, an HDD technique appears to be a feasible crossing method. This crossing will require a detailed survey and geotechnical investigations during detailed engineering to further assess the feasibility of an HDD and to prepare the detailed designs. The contingency plan is to cross the Wapiti River using an open cut method during November to February.

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1. INTRODUCTION

This *Wapiti River Preliminary HDD Feasibility Assessment Report* (this report) was prepared by WorleyParsons Canada Services Ltd. (WorleyParsons) for Northern Gateway Pipelines Inc. (Northern Gateway) under the Enbridge Northern Gateway Project (the Project).

The pipelines will cross approximately 773 identified watercourses having defined bed and banks. An initial screening process identified 83 of these crossings requiring more detailed review to determine the preferred crossing method. Currently, the horizontal directional drilling (HDD) method is the preferred crossing method for the Wapiti River.

This report has been prepared to comply with the National Energy Board (NEB) filing requirements regarding proposed HDD crossings, specifically to provide a preliminary feasibility report detailing the assessment that was done to determine that HDD could be successfully completed and a description of the contingency plan to be used if the HDD is not successful.

1.1 Purpose

This report discusses the feasibility of using a HDD trenchless construction technique to cross the Wapiti River. Based on a review of existing geological and / or geotechnical information where available, site visits, site photos and ground profiles, an HDD technique appears to be a feasible crossing method. This crossing will require a detailed survey and geotechnical investigations to further assess the feasibility of an HDD and to prepare the detailed designs.

The location of the crossing with respect to the pipeline alignment is shown in Table 1

Table 1: Wapiti River Crossing Location

Crossing	Site No.	KP (Rev. R)	Province
Wapiti River	3038	493.3	AB

1.2 Project Description

Northern Gateway Pipelines Inc. (Northern Gateway), a subsidiary of Enbridge Pipelines Inc., initiated the regulatory phase of the Enbridge Northern Gateway Project (the Project) to obtain regulatory approvals to construct and operate the Project. The Project is being developed to provide pipelines and associated facilities for the transportation of approximately 83,400 m^3/d (525,000 bbl/d) of oil from Bruderheim, Alberta to Kitimat, British Columbia and the transportation of approximately 30,700 m^3/d (193,000 bbl/d) of condensate from Kitimat to Bruderheim.

The Project includes the following major components:

- an oil pipeline, 914 mm OD (NPS 36), approximately 1172 km long extending from the outlet of the Bruderheim station to the Kitimat Terminal
- a condensate pipeline, 508 mm OD (NPS 20), approximately 1172 km long, located in the same right-of-way as the oil pipeline, extending from the Kitimat Terminal to the Bruderheim Station
- the Bruderheim Station, consisting of the oil initiating pump station and the condensate receiving facilities
- eight intermediate pump stations located at intervals along the pipelines
- two tunnels, approximately 6.5 km and 6.6 km long, to route the oil and condensate pipelines between the Clore River and Hoult Creek valleys
- the Kitimat Terminal which will comprise the following:
    - a tank terminal including oil tanks, condensate tanks and associated infrastructure
    - a marine terminal including two tanker berths and one utility berth
    - an initiating condensate pump station
    - oil receiving facilities

For an overview map showing the locations of these project facilities, see Figure 1.

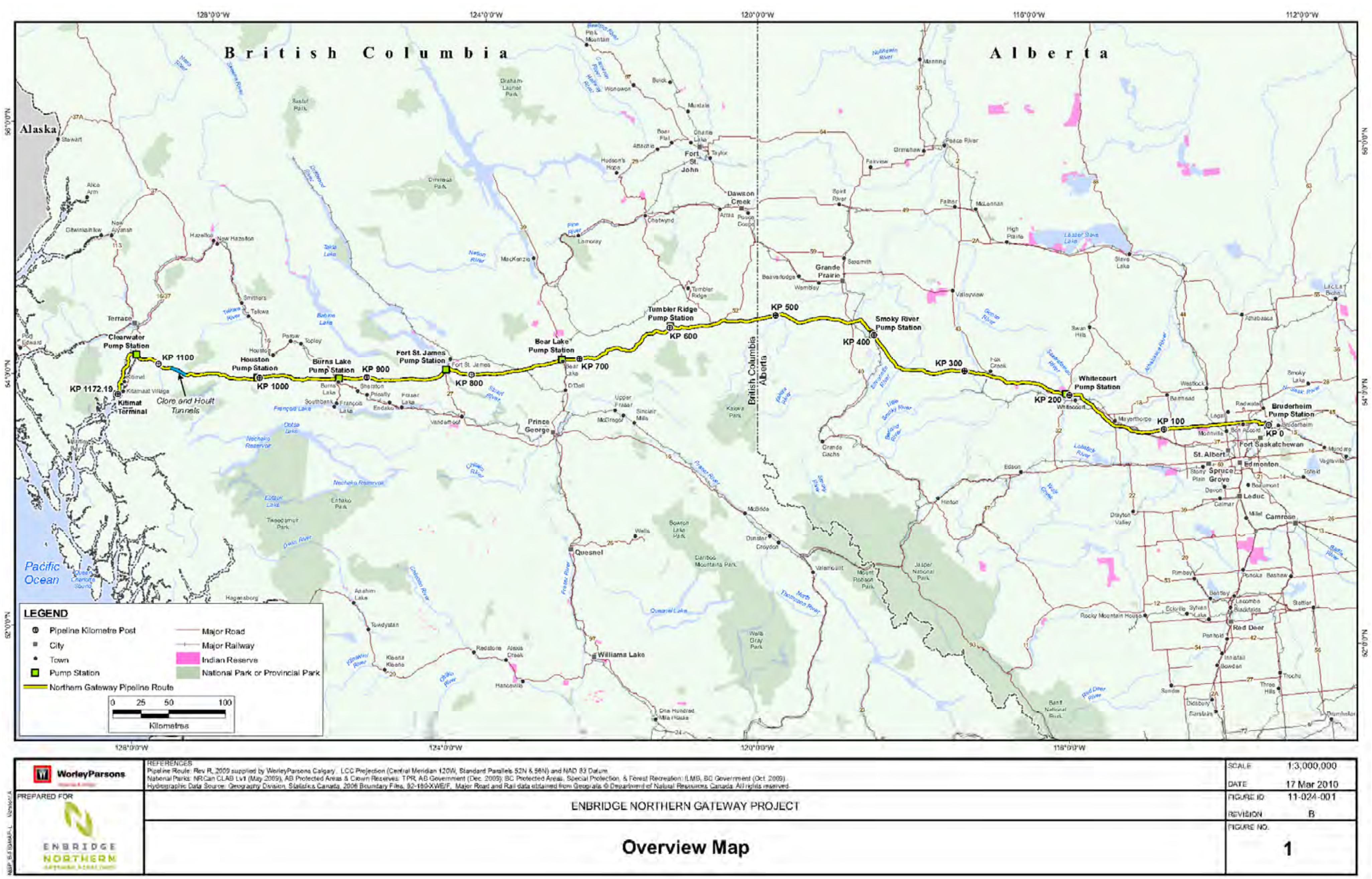


Figure 1: Overview Map Showing the Locations of the Project Facilities

1.3 Terminology

Appendix A lists abbreviations used in this report.

2. HORIZONTAL DIRECTIONAL DRILLING DESIGN

Horizontal Directional Drilling (HDD) is a trenchless crossing technique widely used for the installation of pipelines below watercourses, as well as below other infrastructure such as railways, highways and foreign pipelines. Under appropriate conditions, the HDD technique is practical for installations up to about 2000 m long for the pipeline diameter ranges under consideration on the Project.

The Wapiti River crossing, at a horizontal length of 729 metres and with pipe diameters of 914 mm OD (NPS 36) and 508 mm OD (NPS 20), falls within current practical length limits. The feasibility of HDD rests primarily upon the geotechnical conditions encountered at a particular site. Other items critical factors are suitable topography and availability of temporary workspace for laydown of the makeup section of pipeline.

The HDD design for a 914 mm OD (NPS 36) steel heavy wall pipe requires a preliminary design bend radius of at least 1,100 m. The entry and exit angles range from 12° to 16° and minimum entry and exit tangent lengths are 50 m. This basic limiting geometry, site topography, the no-drill zone (NDZ) established by the geotechnical engineer and other drilling and construction requirements will determine, in most cases, the overall length of the HDD. For this Project, the minimum practical length will be about 500 m (depending on topography and the results of the final geotechnical investigations).

The geotechnical engineer's report will typically specify the extent and shape of a NDZ as a guide for the HDD design engineer. The NDZ includes an assessment of the drill profile required both to prevent release of drilling fluids to the ground surface during drilling and to avoid potential zones of slope instability. An HDD profile will be a minimum of 10 m below a watercourse and could be substantially deeper. The minimum drill depth below surface to prevent release of drilling fluid to the surface is dependent on hydrostatic mud pressures and the permeability and strength of overlying soil and rock. Generally, most HDD crossings are drilled with the entry point on the low elevation side to minimize the fluid pressure in the pilot hole while maximizing fluid return to the drill rig. Drilling fluid, typically made up of bentonite and water, is cleaned of drill cuttings at the drill rig and then reused in the drilling process.

Since full circulation of drilling fluids is not possible in permeable soils such as coarse sand and gravel, steel pipe 'casing' driven through the surficial sand and gravel materials is used to isolate and seal the drill bore profile from these porous materials. Typically, casing is sealed into a lower competent soil or rock.

3. WAPITI RIVER (SITE NO. 3038) PRELIMINARY DESIGN

3.1 Site Location and Access Details

The Wapiti River crossing is located at KP 493.3, about 25km east of the Alberta, British Columbia border within the Alberta Plateau Physiographic Region, (see Attachment 1 in Appendix B). The Wapiti River originates at Tuck Lake in the Rocky Mountains within Wapiti Lake Provincial Park, British Columbia, about 80 km to the west. It flows east to northeast across the Southern Alberta Uplands and Alberta Plateau, eventually joining the Smoky River near Grand Prairie, approximately 64 km northeast of the proposed crossing.

Near the proposed crossing, the Wapiti River flows through a deeply incised, meandering valley that is 89 to 120 m deep and 650 to 900 m wide at the valley crest through the proposed corridor. The large incised meander bends and associated steep parallel river valley slopes along the river form a series of interlocking upland terrain areas inside each meander loop (meander spurs) that, together with stability conditions, constrain the route alignment through the valley area.

The uplands on both sides of the crossing location are accessed by existing gas lease service roads. Existing roads on the east side of the river intersect the proposed pipeline corridor approximately 1.8 km from the crossing. On the west side of the river, an existing road to a gas lease passes within 75 m of the proposed pipeline corridor and within 550 m of the river crossing. Farmland is located approximately 3 km north of the crossing on the western side of the Wapiti River.

3.2 Route Revision R Centreline Alignment

The proposed HDD alignment is shown in Attachment 2 (see Appendix B) and is not coincident with the Route Rev. R centreline. The HDD has a horizontal crossing length of 729 m. A minor route revision is recommended to align with the HDD alignment.

At the Rev. R centreline, the Wapiti River Valley bottom is approximately 350 m wide including the active channel and adjacent areas of floodplain, bars and low elevation terraces.

3.3 Design Profile and Parameters

One preliminary HDD design drawing has been prepared (see Attachment 2 in Appendix B) for both the 914 mm OD (NPS 36) and the 508 mm OD (NPS 20) watercourse crossings. The preliminary radius of curvature used on the HDD design drawing for both pipes is 1,100 m, the industry standard for 914 mm OD (NPS 36) pipe. The design of the 508 mm OD (NPS 20) pipe crossing will be reviewed during detailed engineering, when site-specific geotechnical and survey information is available. A smaller design radius, in the range of about 600 m is feasible for the 508 mm OD (NPS 20) pipe which can potentially result in a shorter HDD drill length, depending on the detailed subsurface conditions and the joint design considerations of the two pipelines. The entry and exit angles for the 508 mm OD (NPS 20) HDD can be increased compared to the 914 mm OD (NPS 36) pipe, providing additional flexibility in the final design of the drill profile.

The two crossings are proposed to be within a common 25-m wide right-of-way (ROW). Within the ROW, the current plan proposes that the HDDs for the two parallel pipelines will have a horizontal separation distance of 15 m. Additional workspace is needed on the entry side of the drill. The drawings show a 50 m by 60 m combined temporary working rights (TWR) space and ROW area at the entry and a 35 m by 20 m combined space on the exit side. This space is required for the rig setup and for the required work at the entry and exit sites. Additional workspace may be required at entry and exit for various construction and topographic considerations.

This HDD assessment is preliminary, pending more detailed site survey and geotechnical information.

3.4 Design Considerations for the 914 mm (NPS 36) and 508 mm (NPS 20) Pipe

The crossing location has been visited on a number of occasions for route selection purposes. Geotechnical information for the Wapiti River crossing is contained in the report *Preliminary Geotechnical HDD Feasibility Assessment Wapiti River (Crossing #3038)*. This report contains results of a review of the existing geological information as well as observations made during the site visits. The report also provides preliminary NDZ recommendations.

Based on the centreline Route Rev. R alignment and the geotechnical recommendations, including the proposed no-drill zone, a preliminary crossing design has been carried out. Three drawings have been prepared for the crossing:

- Preliminary Proposed HDD Watercourse Crossing Location D-5.8-HDD-3038 (see Attachment 2 in Appendix B)
- Preliminary Proposed HDD Watercourse Crossing D-5.8-HDD-3038R (see Attachment 3 in Appendix B)
- Hydrofracture Analysis D-5.8-HDD-3038R-HYD (see Attachment 4 in Appendix B)

Due to the proposed crossing location and alignment a change in the Route R alignment will be required, in particular on the entry site. The Rev. R alignment across the river would not be suitable for an HDD.

As shown on the proposed HDD crossing drawing, the preliminary proposed drill path will be about 736 m long. The total heavy wall pipe length will be 769 m, including an additional 33 m to allow for the tie-ins. The pipe will cross the Wapiti River at a depth of about 49 m below the higher ground surface elevation on the south side of the crossing. The deepest point below the riverbed will be 27.2 m. The pipe will enter and exit the ground at an angle of 12°. The entry and exit locations are setback from the centre of the river by approximately 467 m and 262 m respectively. The north side has been selected as the entry side as it is more or less 12 m lower in elevation than the south side. The makeup section will be strung out on the exit side, or south side. Additional TWR will be required to lay out the makeup section in a relatively straight line. Because of the proposed new ROW alignment, it will not be possible to place the makeup area entirely along the existing route Rev. R alignment. Existing road right of ways and clear-cuts will be used where possible. Grading of the TWR in the makeup sections is anticipated to meet pipe roping requirements.

The hydrofracture calculation curve is shown on the drawing in Attachment 4 (see Appendix B). This drawing demonstrates that the drill profile provides sufficient depth to minimize the risk of fluid release to the surface based on the preliminary parameters chosen for the design. It is typical for this drawing to be used by the drilling contractor in conjunction with a required annular pressure monitoring tool to control the potential for drilling fluid release and loss of drill fluid circulation

Casing may be planned for the entry side. The requirement for casing on the exit side will be reviewed during detailed design when subsurface information is available. If casing is required on both sides of the crossing to penetrate sand and gravel, then a drill intersect will most likely be required. Casing size is anticipated to be a minimum of 1372 mm (NPS 54) in diameter with a minimum of 19 mm wall thickness for the NPS 36 pipeline. If telescoping of the casing is required, then the initial casing size may be 1524 mm (NPS 60) or greater with a wall thickness of about 25.4 mm. Casing will be suitably sized for the NPS 20 pipeline.

3.5 Drilling Schedule

Construction of the 914 mm OD (NPS 36) crossing may require a schedule of four months of drilling excluding time to install casing. The 508 mm OD (NPS 20) pipe may require a drilling schedule of up to three and a half months. A total time of, approximately seven and a half months will be required to complete back-to-back drills. Consideration may be given to drilling the two crossings simultaneously, within the timeframe required for the larger drill. HDD construction activities will include clearing, grading, mobilization, casing installation, pilot hole drilling, reaming, product pipe pull, demobilization and site restoration.

The calculations in Attachment 5 (see Appendix B) show that the pull loads are estimated to be 465,000 lb. (excluding buoyancy control). The pull force for the 914 mm OD (NPS 36) pipe with buoyancy water reduces to about 186,000 lb. Assuming the same drill length the pull force calculated for the 508 mm OD (NPS 20) pipe is 206,000 lb. without buoyancy control and 101,000 lb. with buoyancy control. Buoyancy control should be considered for the two drills to minimizing the pull loads and drill rig size requirements.

The location of the proposed HDD crossing should allow for drilling to occur in either winter or summer. Year round access is preferable and would eliminate the need to drill the 508 mm OD (NPS 20) and 914 mm OD (NPS 36) simultaneously, although this could be an option for the HDD contractor. If drilling is only possible in a single season then the crossings would need to be drilled simultaneously. Detailed design will include a review of the temporary working rights at entry to ensure that sufficient room is available for two drill rigs to be working on site simultaneously. The elevation difference between entry and exit dictates the two HDDs need to be drilled from the same side. However, it is anticipated that the 508 mm OD (NPS 20) drill path can be designed to allow the entry points to be staggered. Additional workspace will be required for a simultaneous drill.

3.6 Contingency Plans

If, during detailed engineering, the HDD crossing method is determined to be not feasible, or if the attempted HDD installation fails, the contingency method of pipeline installation at the Wapiti River is an open cut crossing method during November to February.

4. CONCLUSIONS

Based on the available data and information, the preliminary assessment indicates that an HDD crossing of the Wapiti River is feasible at this location for both the 508 mm OD (NPS 20) and 914 mm OD (NPS 36) pipelines. A separation of pipeline crossings of 15 metres is considered acceptable; however, this will need to be reviewed once more detailed geotechnical information is obtained. Additional survey and geotechnical investigation and laboratory testing will be required to further assess the feasibility of an HDD and for preparation of the detailed designs. Final design will consider drill profiles for both the 508 mm OD (NPS 20) and 914 mm OD (NPS 36) pipeline crossings.

The contingency plan is to cross Wapiti River using an open cut crossing method during November to February.

REFERENCES

AMEC Earth & Environmental. *Preliminary Geotechnical HDD Feasibility Assessment Wapiti River (Crossing #3038)*

APPENDIX A: ABBREVIATIONS

This appendix lists abbreviations used in this report.

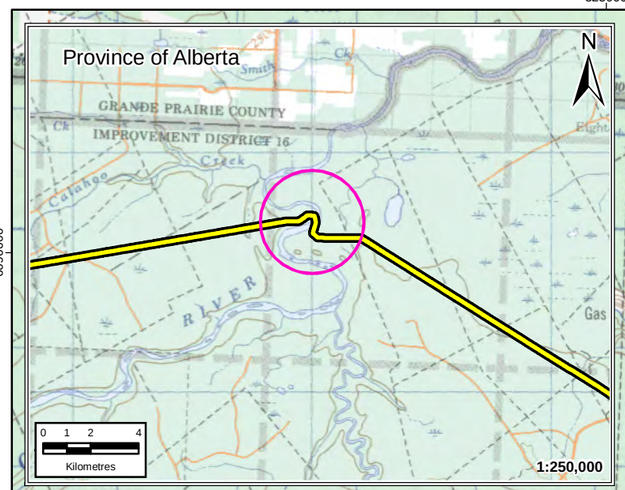
Term	Spelled Out
°	degree(s)
AB	Alberta
bbl/d	barrels per day
HDD	horizontal directional drilling
km	kilometre(s)
KP	kilometre post
m	metre(s)
m^3/d	cubic metres per day
mm	millimetre(s)
NDZ	no-drill zone
Northern Gateway	Northern Gateway Pipelines Inc.
NPS	nominal pipe size
OD	outside diameter
ROW	right-of-way
the Project	the Enbridge Northern Gateway Project
this report	this *Wapiti River Preliminary HDD Feasibility Assessment Report*
TWR	temporary work right
WorleyParsons	WorleyParsons Canada Services Ltd.

APPENDIX B: LIST OF ATTACHMENTS

This appendix lists attachments to this report.

No.	Description	Filename
1	Proposed Watercourse Crossing Wapiti River Location Map	03-332-004_REVA.pdf
2	Preliminary Proposed HDD Watercourse Crossing Location D-5.8-HDD-3038	D-5.8-HDD-3038.pdf
3	Preliminary Proposed HDD Watercourse Crossing D-5.8-HDD-3038R	D-5.8-HDD-3038R.pdf
4	Hydrofracture Analysis D-5.8-HDD-3038R-HYD	D-5.8-HDD-0-3038R-HYD.pdf
5	Horizontal Directional Drilling Pipe Stress Analysis Summaries	Wapiti River-Stress Calculations.pdf

ATTACHMENT 1: PROPOSED WATERCOURSE CROSSING WAPITI RIVER LOCATION MAP



325000 330000 335000

6090000 6085000

Eighteenth Base Line

RIVER

WAPITI

WAPITI RIVER
PROPOSED HDD
KP 493.3 (ROUTE REV. R)

KP 482 KP 483 KP 484 KP 485 KP 486 KP 487 KP 488 KP 489 KP 490 KP 491 KP 492 KP 493 KP 494 KP 495 KP 496 KP 497 KP 498 KP 499 KP 500 KP 501 KP 502 KP 503

0 500 1,000 2,000
Metres

\\WORLEYPARSONS.COM\CALGARY\DATA2\CGSL\PROJECTS\ENBRIDGE\GATEWAY\07_ESRI_PROJECTS\MXD\WORKING\03_PIPELINE\03-332-004_REV0.MXD
NGP_B-MAP-L Version: A

ENBRIDGE NORTHERN GATEWAY PIPELINES

LEGEND

- Proposed Gateway Pipeline KP (Jul. 29, 2009)
- Proposed Gateway Pipeline Route (Jul. 29, 2009)

NORTHERN GATEWAY

NOTES:
- Centreline updated July 29, 2009 (REV R). Kilometre posts correspond to July 29, 2009 (REV R) slack alignment.
- Topographic map background based on 1:50K CanMatrix NTS Scans published 2003-2007. © Department of Natural Resources Canada. All rights reserved.
- Topographic map background based on 1:250K CanMatrix NTS Scans published 2003-2007. © Department of Natural Resources Canada. All rights reserved.

Produced by WorleyParsons Calgary. The information used to create this product is based on the most current data available on the date of issue, and is considered reliable only at the scale at which the data was created and the scale at which the map was published.

This drawing is prepared solely for the use of the contractual customer of WorleyParsons Calgary and WorleyParsons assumes no liability to any other party for any representations contained in these drawings. This map must be printed at full scale (100%) in order for the scale to remain correct.

DRAWN	CHECK	DESIGN	APPR.
CS	JK	CS	CM

ENBRIDGE NORTHERN GATEWAY PROJECT
PROPOSED WATERCOURSE CROSSING
WAPITI RIVER LOCATION MAP

PROJECTION	DATUM	CONTRACTOR NAME	MAP NUMBER	REV.
UTM 11N	NAD83	WORLEYPARSONS CALGARY	03-332-004	0

SCALE	DATE	PROJECT NUMBER	ORIG.PAGE SIZE
1:50,000	7 Jun 2010	08C7138	11X17

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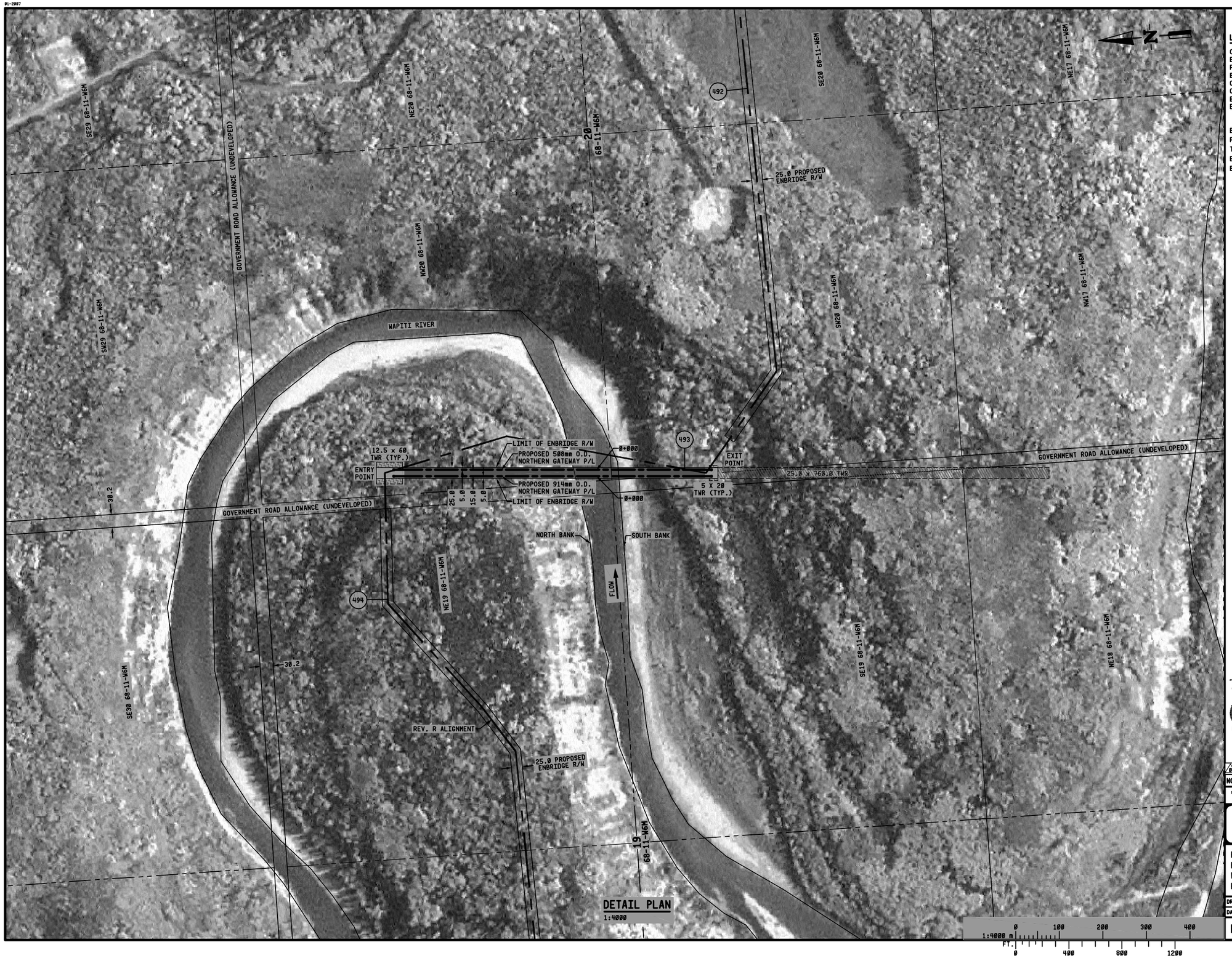
ATTACHMENT 2: PRELIMINARY PROPOSED HDD WATERCOURSE CROSSING LOCATION D-5.8-HDD-3038

01-2087



LEGEND:

- CHAINAGES ARE HORIZONTAL
- EXISTING PIPELINE
- PROPOSED PIPELINE
- BARBED WIRE FENCE
- CENTRE LINE OF ROAD
- OVERHEAD POWER
- BURIED POWER
- BURIED FOREIGN PIPELINES
- BURIED TELEPHONE
- PROPOSED RIGHT-OF-WAY (R/W)
- TEMPORARY WORKING RIGHTS (TWR)
- EXTRA TEMPORARY WORKING RIGHTS (TWR)
- BOREHOLE LOCATION

Colt Engineering Corporation

NO	REVISION	DATE/BY	APPROVE
A	ISSUED FOR NEB APPLICATION	15 APR 10 TH/MPC	

ENBRIDGE NORTHERN GATEWAY PIPELINES

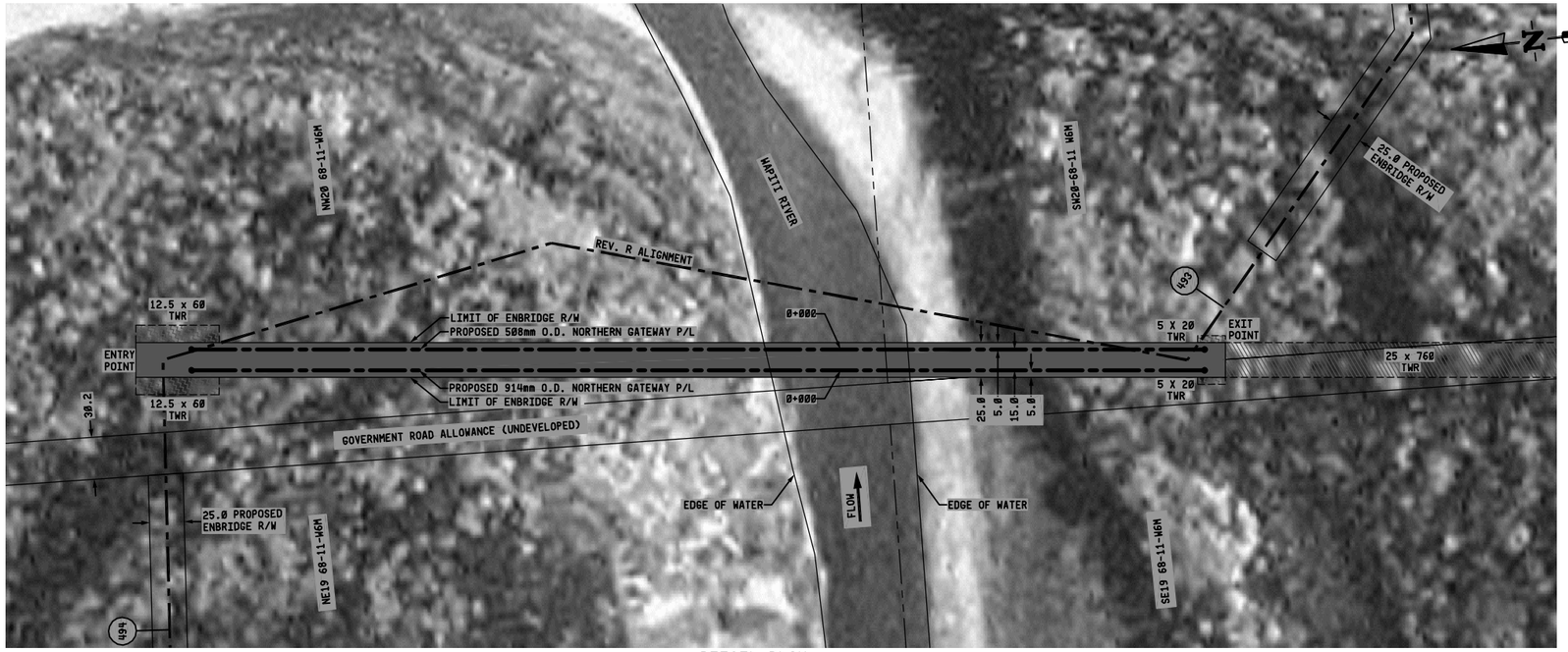
KP 493.3 (ROUTE REV. R) - SITE No. 3038
ENBRIDGE NORTHERN GATEWAY PROJECT
WAPITI RIVER - NW20-68-11 W6M
PROPOSED HDD WATERCOURSE CROSSING LOCATION

DRAWN	TH	CHECK	MDF/JPH	APPROVE	LM
DATE	30 OCT 08	SCALE	AS SHOWN	APPROVE	

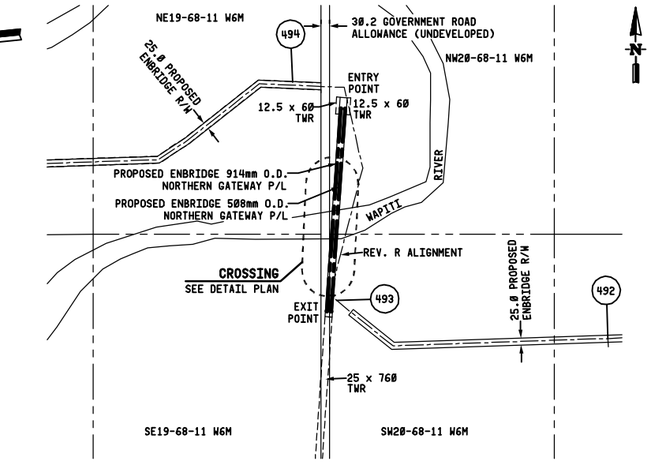
D-5.8-HDD-0-3038

ATTACHMENT 3: PRELIMINARY PROPOSED HDD WATERCOURSE CROSSING D-5.8-HDD-3038R

01-2087



DETAIL PLAN
1:2000



LOCATION PLAN
1:10000

PROPOSED 914mm O.D. - NORTHERN GATEWAY PIPELINE SPECIFICATIONS TABLE

PIPELINE DATA	O.D. mm	W.T. mm	PIPE SPECIFICATION	M.O.P. kPa	HOOP STRESS MPa	MAXIMUM OPERATING TEMP. (°C)	COATING	CATHODIC PROTECTION
HEAVY WALL	914	21.4	CSA Z245.1 Gr 483	15,424	329	50	DPS	YES

PROPOSED 508mm O.D. - NORTHERN GATEWAY PIPELINE SPECIFICATIONS TABLE

PIPELINE DATA	O.D. mm	W.T. mm	PIPE SPECIFICATION	M.O.P. kPa	HOOP STRESS MPa	MAXIMUM OPERATING TEMP. (°C)	COATING	CATHODIC PROTECTION
HEAVY WALL	508	8.8	CSA Z245.1 Gr 483	11,459	331	50	DPS	YES

PROPOSED 914mm O.D. - NORTHERN GATEWAY PIPELINE COORDINATES TABLE

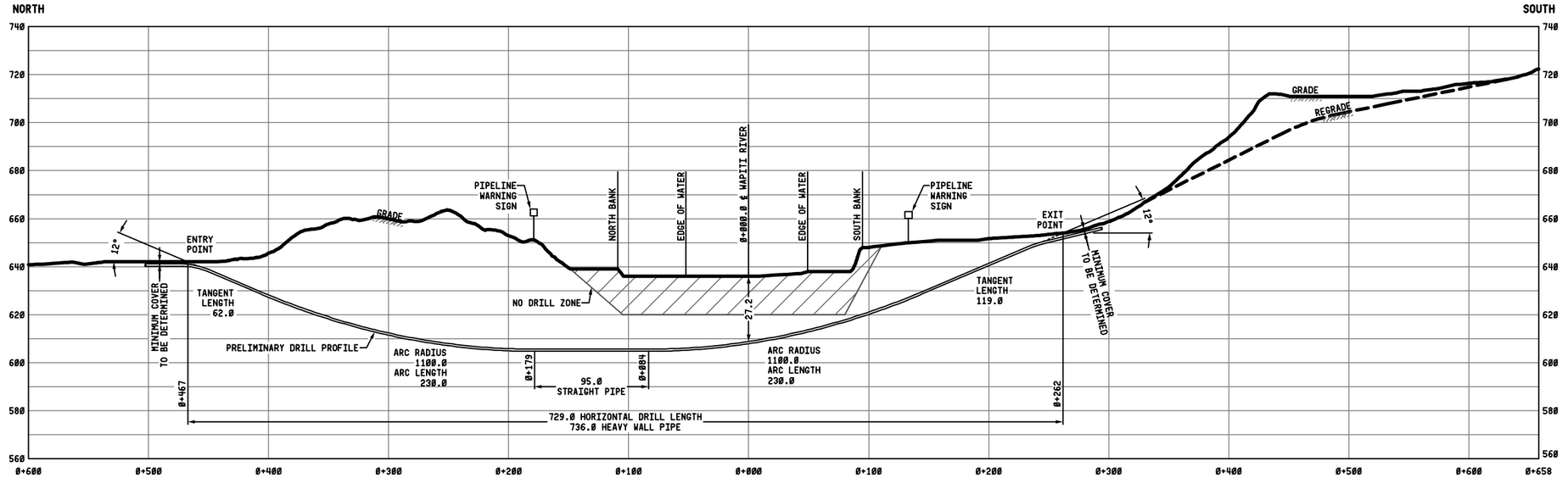
COORD. SYSTEM	DATUM	ZONE
UTM	NAD 83	11
CROSSING COORDINATES: 0+000 N 6087884.6 E 329925.9		

PROPOSED 508mm O.D. - NORTHERN GATEWAY PIPELINE COORDINATES TABLE

COORD. SYSTEM	DATUM	ZONE
UTM	NAD 83	11
CROSSING COORDINATES: 0+000 N 6087883.0 E 329940.8		

LEGEND:

- CHAINAGES ARE HORIZONTAL
- EXISTING PIPELINE
- PROPOSED PIPELINE
- BARBED WIRE FENCE
- CENTRE LINE OF ROAD
- OVERHEAD POWER
- BURIED POWER
- BURIED FOREIGN PIPELINES
- BURIED TELEPHONE
- PROPOSED RIGHT-OF-WAY (R/W)
- TEMPORARY WORKING RIGHTS (TWR)
- EXTRA TEMPORARY WORKING RIGHTS (TWR)
- BOREHOLE LOCATION



PROFILE ALONG PROPOSED 914mm & 508mm O.D. NORTHERN GATEWAY PIPELINES
SCALE: HORIZONTAL - 1:2000, VERTICAL - 1:1000

NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THE SCALES OF THIS DRAWING ARE CONSIDERED RELIABLE ONLY AT ANSI D SIZE. WHEN PRINTING 11x17, THE VALUE FOR THE SCALES WILL BE APPROXIMATELY DOUBLE (I.E. 1:1000 BECOMES 1:2000).
3. THIS DRAWING TO BE READ IN CONJUNCTION WITH THE WAPITI RIVER PRELIMINARY HDD FEASIBILITY ASSESSMENT REPORT, DATE APRIL 2010.
4. REFER TO AMEC REPORT, PRELIMINARY GEOTECHNICAL HDD FEASIBILITY ASSESSMENT, WAPITI RIVER (CROSSING # 3038) FOR GEOTECHNICAL INFORMATION.
5. CROSSING SHALL BE CONSTRUCTED AND MAINTAINED IN ACCORDANCE WITH CSA-Z662 AND NEB REGULATIONS, THE ENVIRONMENTAL PROTECTION PLAN, THE APPLICABLE CROSSING APPROVAL CONDITIONS AND CONTRACT DOCUMENTS. APPROVAL COPIES TO BE ON SITE.
6. THIS DRAWING IS PRELIMINARY IN NATURE, ADDITIONAL GEOTECHNICAL WORK WILL BE REQUIRED PRIOR TO FINALIZING THE DESIGN. ONCE GEOTECHNICAL DATA IS AVAILABLE, THE DRILL DESIGN WILL BE ADJUSTED TO MATCH THE SOIL CONDITIONS RESULTING FROM THE GEOTECHNICAL INVESTIGATION.
7. THE PROFILE AND TOPOGRAPHIC DATA WAS DERIVED FROM LIDAR DATED 2006.

NO	REVISION	DATE/BY	APPROVE
0	ISSUED FOR NEB APPLICATION	14 APR 10 TH/WPC	

ENBRIDGE NORTHERN GATEWAY PIPELINES

KP 493.3 (ROUTE REV. R) - SITE No. 3038
ENBRIDGE NORTHERN GATEWAY PROJECT
WAPITI RIVER - NW20-68-11 W6M
PROPOSED HDD WATERCOURSE CROSSING

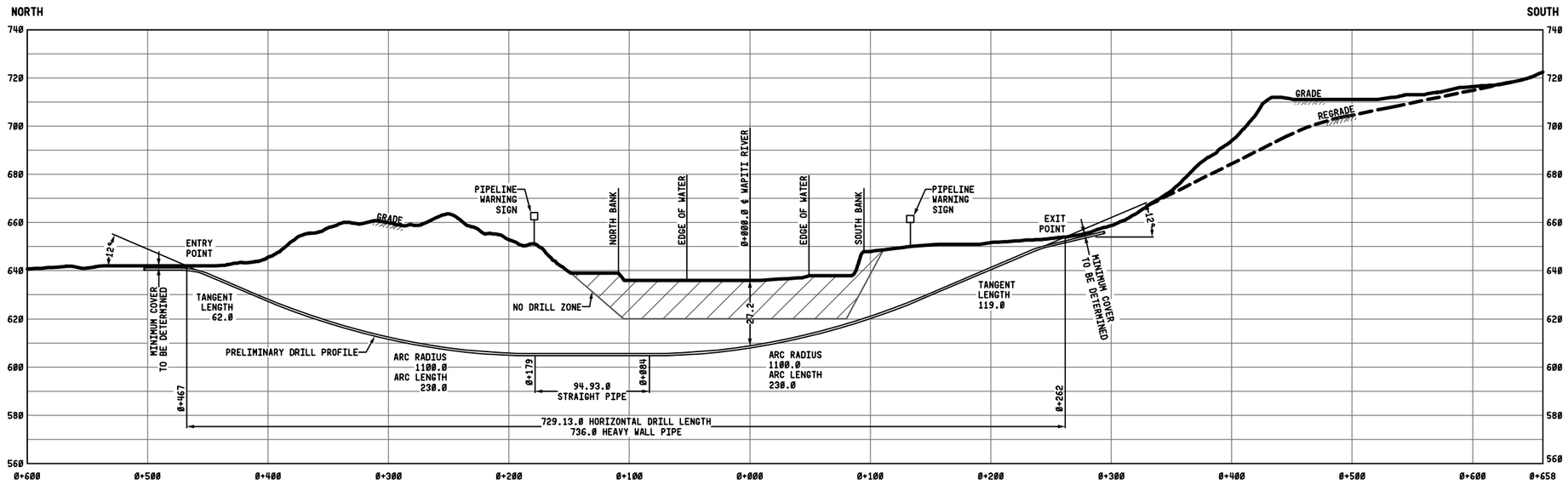
Colt Engineering Corporation
WorleyParsons

DRAWN	TH	CHECK	MDF/JPM	APPROVE	LM
DATE	28 OCT 08	SCALE	AS SHOWN	APPROVE	

1:2000 @ FT.
0 50 100 200
0 100 200 300 400 500 600

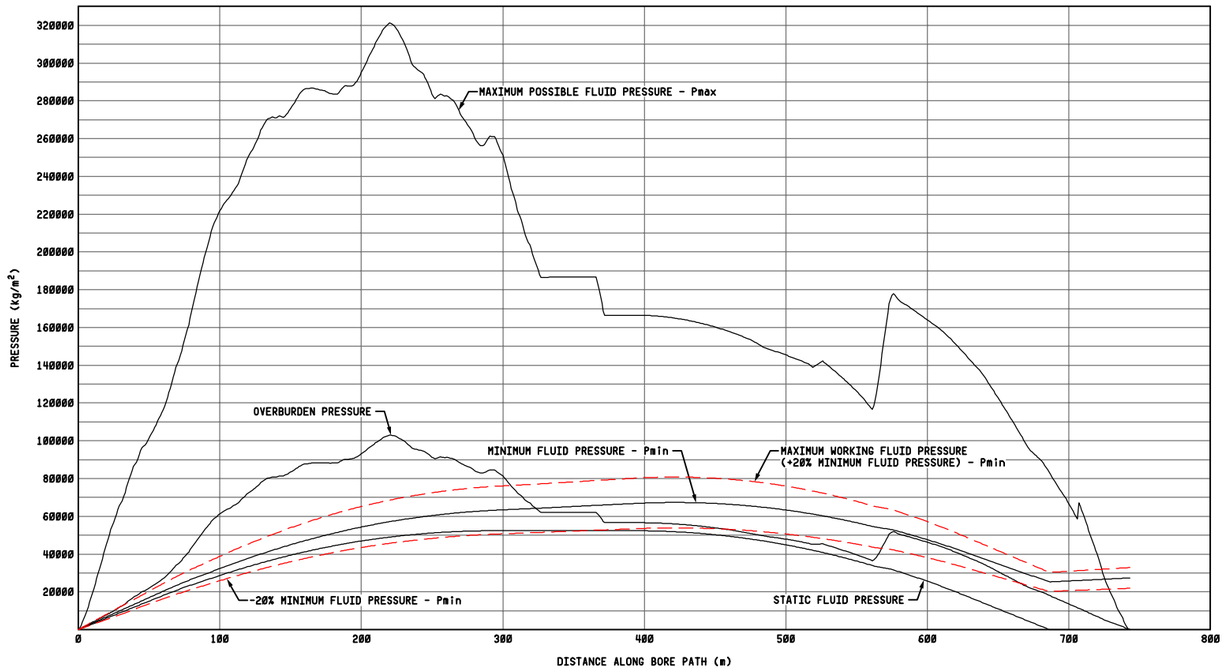
D-5.8-HDD-0-3038R

ATTACHMENT 4: HYDROFRACTURE ANALYSIS D-5.8-HDD-3038R-HYD



PROFILE ALONG PROPOSED 914mm & 508mm O.D. NORTHERN GATEWAY PIPELINES

HORIZONTAL - 1:2000, VERTICAL - 1:1000



HYDROFRACTURE ANALYSIS - WAPITI RIVER

HORIZONTAL - 1:2000, VERTICAL - AS SHOWN

SOIL AND FLUID PARAMETERS USED FOR ANALYSIS	
MATERIAL	HARD CLAY
WT. OF SOIL	1,842 kg/m^3
WT. OF DRILLING FLUID	1,426 kg/m^3
WT. OF WATER	1,000 kg/m^3
FRICTION ANGLE	28°
POISSON'S RATIO	0.3
YOUNG'S MODULUS	43 MPa
FLOW RATE OF DRILL BIT	1.5 m^3/min
DIAMETER OF BOREHOLE	251 mm
DIAMETER OF DRILL PIPE	168 mm
VISCOSITY OF DRILLING FLUID	35 cp
YIELD POINT OF DRILLING FLUID (RETURNS)	20 Pa

UNITS

CP - CENTIPOISE
Pa - NEWTON PER SQUARE METER
min - MINUTE
kg/m^3 - KILOGRAM PER CUBIC METER
mm - MILLIMETER

D-5.8-HDD--3038R WAPITI RIVER HDD

REFERENCE DRAWINGS

NO	REVISION	DATE/BY	APPROVE
0	ISSUED FOR WEB APPLICATION	16 APR 18 MM/WPC	

ENBRIDGE NORTHERN GATEWAY PIPELINES

KP 493.3 (ROUTE REV. R) - SITE No. 3038
ENBRIDGE NORTHERN GATEWAY PROJECT
WAPITI RIVER - NW20-68-11 W6M
HYDROFRACTURE ANALYSIS

DRAWN	NM	CHECK	MDF/JPH	APPROVE	LM
DATE	16 APR 18	SCALE	AS SHOWN	APPROVE	

D-5.8-HDD-0-3038R-HYD

ATTACHMENT 5: HORIZONTAL DIRECTIONAL DRILLING PIPE STRESS ANALYSIS SUMMARIES

WorleyParsons resources & energy

Horizontal Directional Drilling Pipe Stress Analysis

Preliminary

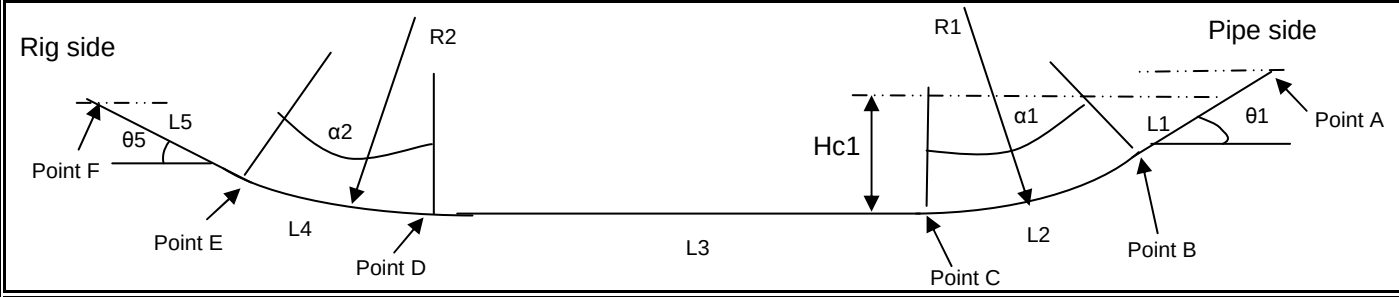
Client	Northern Gateway Pipelines Inc.	Date	12-Apr-10
Project Name	Enbridge Northern Gateway Project Wapiti River Crossing	Prepared by	Jim Murphy, Peter Liang
Project Number	08C7138	Approval by	Phil Kormann

Design information input (NPS 20 Without Buoyancy Control)

Outside Diameter D =	**20**	inch =	**508.0 mm**	μ_{soil}	0.3	
Pipe Wall Thickness t =	**0.35**	inch =	**8.80 mm**	μ_{mud}	0.05	
D/t =	57.73			Jacket Thickness: t_j		inch
Insulation + Jacket Thickness: t_i =		inch		Insulation weight with jacket		lb/ft
Pipe net weight =	75.36	lb/ft		Buoyancy Water in pipe	0.00	lb/ft
Pipe effective weight: W_s =	-120.46	lb/ft		Friction coefficient between pipe and roller at start-up	0	
Pipe Grade =	**X 70**	**Gr. 483**		Mud weight value.Y_{mud}	89.76	lb/ft^3
SMYS =	70,000	psi		Drill Stem: D_r =	6.625	in
Pipe modulus of elasticity: E=	2.90E+07	psi		Coating =	DPS	
Buoyancy Control	0 % of pipe section capacity of water fill			Pipe Poisson's ratio v =	0.3	
Construction Tem. T_c =	32	^0F		α-the coefficient of thermal expansion	6.50E-06	$1/^0F$
Operating Tem. T_o =	**122**	^0F		MOP	**1,662**	psi
Temperature Factor. T =	1			Slurry Flow Rate: Q =	0.88	ft^3/s
Jacket modulus of elasticity: E_e=		psi		Ground water height	82.03	ft
Viscosity of Slurry: μ_p =	25	cp		Yield Point of Slurry: T_y =	42	$lb/100ft^2$
Location Factor=	1	Max. Cover Depth = 180 ft		Joint Factor= 1	Soil Internal Angle of Friction = 30	

HDD Pilot Hole Profile Information Input

Section	Type	Angle			Length			Force direction
A to B	Straight	θ_1	12	Degree	L_1=	559	ft	Down
B to C	Curved	θ_2	6	Degree	L_2=	419	ft	Down
R_1(ft)=	**2,001**	α_1	12	Degree				
C to D	Straight	θ_3	0	Degree	L_3=	646	ft	Horizontal
D to E	Curved	θ_4	6	Degree	L_4=	419	ft	Up
R_2(ft)=	**2,001**	α_2	12	Degree				
E to F	Straight	θ_5	12	Degree	L_5=	372	ft	Up
H_{c1} =	141.88	ft			Total Length =	2,416	ft	



HDD Stress Analysis Results

Pulling Load	Total Pulling Load at Point F :			205,939	lb
Installation Stress Check	Point E	Point C	Point D		
Tensile Stress	Pass	Pass	Pass		
Bending Stress	Pass	Pass	Pass	**Hydro Test Stress Check: Pass**	
External Hoop Stress	Pass	Pass	Pass	Minimum pipe wall thickness Based on CSA Z662 (Clause 4.3.5.1)=	7.53 mm
Combined tensile and bending	Pass	Pass	Pass		
Combined tensile,bending and external hoop	Pass	Pass	Pass		
Operating Stresses Curve B-C	The pipe specification is acceptable.			H.S. / SMYS =	69 %
Operating Stresses Curve D-E	The pipe specification is acceptable.				
Allowable Minimum Installation Radius = R_A =	1,201 ft	**=366m**	The Pipe Specification is acceptable		60% of design

Note: 1. The design radius of 610 meter is shown in the profile. 366 meter (60% of design) is the allowable minimum installation radius during the steering process, which will need to be considered while monitoring during the pilot hole drilling.
2. Use 366 meter radius to check installation stresses, operation stresses and collapse.
3. Fluid level = ground surface at entry point (Lower elevation) for Installation stresses analysis.
4. H_c = ground surface at exit point (Higher elevation) for pipe collapse check.

WorleyParsons resources & energy

Horizontal Directional Drilling Pipe Stress Analysis

Preliminary

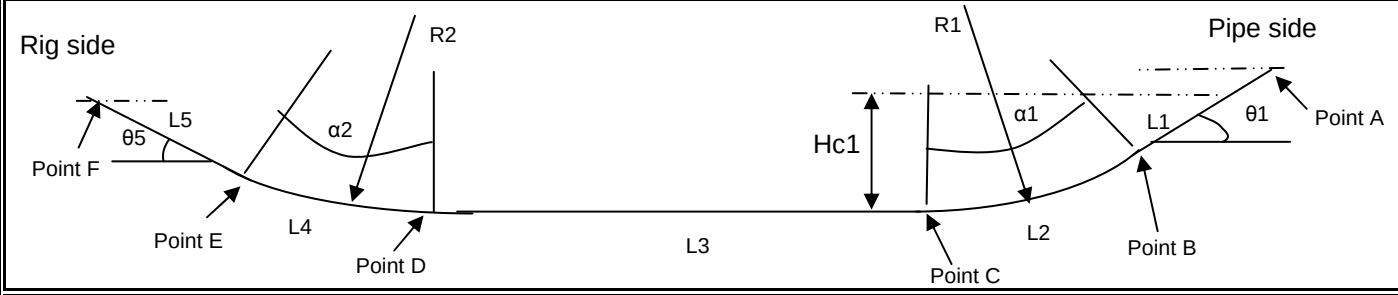
Client	Northern Gateway Pipelines Inc.	Date	12-Apr-10
Project Name	Enbridge Northern Gateway Project Wapiti River Crossing	Prepared by	Jim Murphy, Peter Liang
Project Number	08C7138	Approval by	Phil Kormann

Design information input (NPS 20 With Buoyancy Control)

Outside Diameter D =	**20**	inch	= **508.0 mm**	μ_{soil}	0.3		
Pipe Wall Thickness t =	**0.35**	inch	= **8.80 mm**	μ_{mud}	0.05		
D/t =	57.73			Jacket Thickness: t_j		inch	
Insulation + Jacket Thickness: t_i =		inch		Insulation weight with jacket		lb/ft	
Pipe net weight =	75.36	lb/ft		Buoyancy Water in pipe	119.46	lb/ft	
Pipe effective weight: W_s =	-1.00	lb/ft		Friction coefficient between pipe and roller at start-up	0		
Pipe Grade =	**X 70**	**Gr. 483**		Mud weight value.Y_{mud}	89.76	lb/ft^3	
SMYS =	70,000	psi		Drill Stem: D_r =	6.625	in	
Pipe modulus of elasticity: E=	2.90E+07	psi		Coating =	DPS		
Buoyancy Control	94 % of pipe section capacity of water fill			Pipe Poisson's ratio v =	0.3		
Construction Tem. T_c =	32	^0F		α-the coefficient of thermal expansion	6.50E-06	$1/^0F$	
Operating Tem. T_o =	**122**	^0F		MOP	**1,662**	psi	
Temperature Factor. T =	1			Slurry Flow Rate: Q =	0.88	ft^3/s	
Jacket modulus of elasticity: E_e=		psi		Ground water height	82.03	ft	
Viscosity of Slurry: μ_p =	25	cp		Yield Point of Slurry: T_y =	42	$lb/100ft^2$	
Location Factor=	1	Max. Cover Depth = 180 ft		Joint Factor= 1	Soil Internal Angle of Friction = 30		

HDD Pilot Hole Profile Information Input

Section	Type	Angle			Length			Force direction
A to B	Straight	θ_1	12	Degree	L_1=	559	ft	Down
B to C	Curved	θ_2	6	Degree	L_2=	419	ft	Down
R_1(ft)=	**2,001**	α_1	12	Degree				
C to D	Straight	θ_3	0	Degree	L_3=	646	ft	Horizontal
D to E	Curved	θ_4	6	Degree	L_4=	419	ft	Up
R_2(ft)=	**2,001**	α_2	12	Degree				
E to F	Straight	θ_5	12	Degree	L_5=	372	ft	Up
H_{c1} =	141.88	ft			Total Length =	2,416	ft	



HDD Stress Analysis Results

Pulling Load	Total Pulling Load at Point F :			101,438	lb
Installation Stress Check	Point E	Point C	Point D		
Tensile Stress	Pass	Pass	Pass		
Bending Stress	Pass	Pass	Pass	**Hydro Test Stress Check: Pass**	
External Hoop Stress	Pass	Pass	Pass	Minimum pipe wall thickness Based on CSA Z662 (Clause 4.3.5.1)=	7.53 mm
Combined tensile and bending	Pass	Pass	Pass		
Combined tensile,bending and external hoop	Pass	Pass	Pass		
Operating Stresses Curve B-C	The pipe specification is acceptable.			H.S. / SMYS =	69 %
Operating Stresses Curve D-E	The pipe specification is acceptable.				
Allowable Minimum Installation Radius = R_A =	1,201 ft	**=366m**	The Pipe Specification is acceptable		60% of design

Note: 1. The design radius of 610 meter is shown in the profile. 366 meter (60% of design) is the allowable minimum installation radius during the steering process, which will need to be considered while monitoring during the pilot hole drilling.
2. Use 366 meter radius to check installation stresses, operation stresses and collapse.
3. Fluid level = ground surface at entry point (Lower elevation) for Installation stresses analysis.
4. H_c = ground surface at exit point (Higher elevation) for pipe collapse check.

WorleyParsons resources & energy

Horizontal Directional Drilling Pipe Stress Analysis

Preliminary

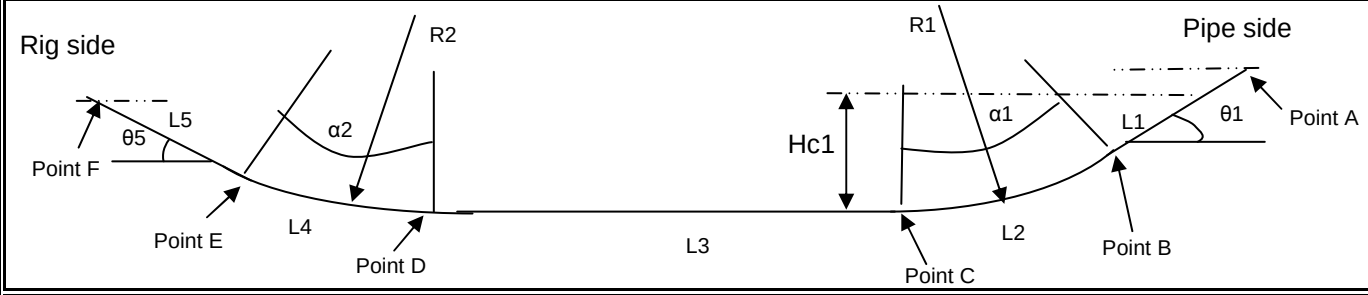
Client	Northern Gateway Pipelines Inc.	Date	12-Apr-10
Project Name	Enbridge Northern Gateway Project Wapiti River Crossing	Prepared by	Jim Murphy, Peter Liang
Project Number	08C7138	Approval by	Phil Kormann

Design information input (NPS 36 Without Buoyancy Control)

Outside Diameter D =	**36**	inch	= **914.0 mm**	μ_{soil}	0.3		
Pipe Wall Thickness t =	**0.84**	inch	= **21.40 mm**	μ_{mud}	0.05		
D/t =	42.71			Jacket Thickness: t_j		inch	
Insulation + Jacket Thickness: t_i =		inch		Insulation weight with jacket		lb/ft	
Pipe net weight =	331.72	lb/ft		Buoyancy Water in pipe	0.00	lb/ft	
Pipe effective weight: W_s =	-302.20	lb/ft		Friction coefficient between pipe and roller at start-up	0		
Pipe Grade =	**X 70**	**Gr. 483**		Mud weight value.Y_{mud}	89.76	lb/ft^3	
SMYS =	70,000	psi		Drill Stem: D_r =	6.625	in	
Pipe modulus of elasticity: E=	2.90E+07	psi		Coating =	DPS		
Buoyancy Control	0 % of pipe section capacity of water fill			Pipe Poisson's ratio v =	0.3		
Construction Tem. T_c =	32	^0F		α-the coefficient of thermal expansion	6.50E-06	$1/^0F$	
Operating Tem. T_o =	**122**	^0F		MOP	**2,237**	psi	
Temperature Factor. T =	1			Slurry Flow Rate: Q =	0.88	ft^3/s	
Jacket modulus of elasticity: E_e=		psi		Ground water height	82.03	ft	
Viscosity of Slurry: μ_p =	25	cp		Yield Point of Slurry: T_y =	42	$lb/100ft^2$	
Location Factor=	1	Max. Cover Depth = 180 ft		Joint Factor= 1		Soil Internal Angle of Friction = 30	

HDD Pilot Hole Profile Information Input

Section	Type	Angle			Length			Force direction
A to B	Straight	θ_1	12	Degree	L_1=	390	ft	Down
B to C	Curved	θ_2	6	Degree	L_2=	756	ft	Down
R_1(ft)=	**3,609**	α_1	12	Degree				
C to D	Straight	θ_3	0	Degree	L_3=	312	ft	Horizontal
D to E	Curved	θ_4	6	Degree	L_4=	756	ft	Up
R_2(ft)=	**3,609**	α_2	12	Degree				
E to F	Straight	θ_5	12	Degree	L_5=	203	ft	Up
H_{c1} =	131.48	ft			Total Length =	2,417	ft	



HDD Stress Analysis Results

Pulling Load	Total Pulling Load at Point F :			464,968	lb
Installation Stress Check	Point E	Point C	Point D		
Tensile Stress	Pass	Pass	Pass		
Bending Stress	Pass	Pass	Pass	**Hydro Test Stress Check: Pass**	
External Hoop Stress	Pass	Pass	Pass	Minimum pipe wall thickness Based on CSA Z662 (Clause 4.3.5.1)=	18.24 mm
Combined tensile and bending	Pass	Pass	Pass		
Combined tensile,bending and external hoop	Pass	Pass	Pass		
Operating Stresses Curve B-C	The pipe specification is acceptable.			H.S. / SMYS =	68 %
Operating Stresses Curve D-E	The pipe specification is acceptable.				
Allowable Minimum Installation Radius = R_A =	2,165 ft	**=660m**	The Pipe Specification is acceptable		60% of design

Note: 1. The design radius of 1,100 meter is shown in the profile. 660 meter (60% of design) is the allowable minimum installation radius during the steering process, which will need to be considered while monitoring during the pilot hole drilling.
2. Use 660 meter radius to check installation stresses, operation stresses and collapse.
3. Fluid level = ground surface at entry point (Lower elevation) for Installation stresses analysis.
4. H_c = ground surface at exit point (Higher elevation) for pipe collapse check.

WorleyParsons resources & energy

Horizontal Directional Drilling Pipe Stress Analysis

Preliminary

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Project Number	08C7138	Approval by	Phil Kormann

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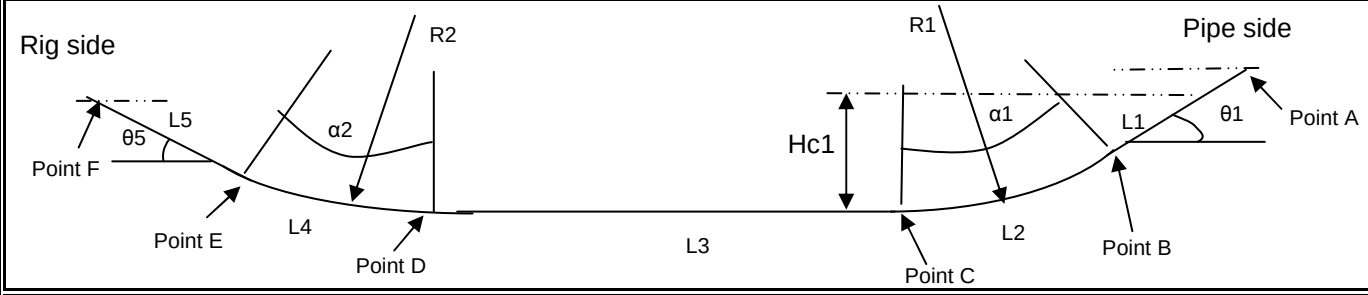
Outside Diameter D =	**36**	inch	= **914.0 mm**	μ_{soil}	0.3		
Pipe Wall Thickness t =	**0.84**	inch	= **21.40 mm**	μ_{mud}	0.05		
D/t =	42.71			Jacket Thickness: t_j		inch	
Insulation + Jacket Thickness: t_i =		inch		Insulation weight with jacket		lb/ft	
Pipe net weight =	331.72	lb/ft		Buoyancy Water in pipe	302.10	lb/ft	
Pipe effective weight: W_s =	-0.10	lb/ft		Friction coefficient between pipe and roller at start-up	0		
Pipe Grade =	**X 70**	**Gr. 483**		Mud weight value.Y_{mud}	89.76	lb/ft^3	
SMYS =	70,000	psi		Drill Stem: D_r =	6.625	in	
Pipe modulus of elasticity: E=	2.90E+07	psi		Coating =	DPS		
Buoyancy Control	75 % of pipe section capacity of water fill			Pipe Poisson's ratio v =	0.3		
Construction Tem. T_c =	32	^0F		α-the coefficient of thermal expansion	6.50E-06	$1/^0F$	
Operating Tem. T_o =	**122**	^0F		MOP	**2,237**	psi	
Temperature Factor. T =	1			Slurry Flow Rate: Q =	0.88	ft^3/s	
Jacket modulus of elasticity: E_e=		psi		Ground water height	82.03	ft	
Viscosity of Slurry: μ_p =	25	cp		Yield Point of Slurry: T_y =	42	$lb/100ft^2$	
Location Factor=	1	Max. Cover Depth = 180 ft		Joint Factor= 1	Soil Internal Angle of Friction = 30		

HDD Pilot Hole Profile Information Input

Section	Type	Angle			Length			Force direction
A to B	Straight	θ_1	12	Degree	L_1=	390	ft	Down
B to C	Curved	θ_2	6	Degree	L_2=	756	ft	Down
R_1(ft)=	**3,609**	α_1	12	Degree				
C to D	Straight	θ_3	0	Degree	L_3=	312	ft	Horizontal
D to E	Curved	θ_4	6	Degree	L_4=	756	ft	Up
R_2(ft)=	**3,609**	α_2	12	Degree				
E to F	Straight	θ_5	12	Degree	L_5=	203	ft	Up
H_{c1} =	131.48	ft			Total Length =	2,417	ft	



HDD Stress Analysis Results

Pulling Load	Total Pulling Load at Point F :			186,100	lb
Installation Stress Check	Point E	Point C	Point D		
Tensile Stress	Pass	Pass	Pass		
Bending Stress	Pass	Pass	Pass	**Hydro Test Stress Check: Pass**	
External Hoop Stress	Pass	Pass	Pass	Minimum pipe wall thickness Based on CSA Z662 (Clause 4.3.5.1)=	18.24 mm
Combined tensile and bending	Pass	Pass	Pass		
Combined tensile,bending and external hoop	Pass	Pass	Pass		
Operating Stresses Curve B-C	The pipe specification is acceptable.			H.S. / SMYS =	68 %
Operating Stresses Curve D-E	The pipe specification is acceptable.				
Allowable Minimum Installation Radius = R_A =	2,165 ft	**=660m**	The Pipe Specification is acceptable		60% of design

Note: 1. The design radius of 1,100 meter is shown in the profile. 660 meter (60% of design) is the allowable minimum installation radius during the steering process, which will need to be considered while monitoring during the pilot hole drilling.
2. Use 660 meter radius to check installation stresses, operation stresses and collapse.
3. Fluid level = ground surface at entry point (Lower elevation) for Installation stresses analysis.
4. H_c = ground surface at exit point (Higher elevation) for pipe collapse check.