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March 20, 2018

VIA EMAIL

Alberta Energy Regulator
Suite 1000, 250 – 5th Street S.W.
Calgary, Alberta T2P 0R4

Attention: Anastasia Shukalkina

Dear Ms. Shukalkina:

Re: White Spruce Pipeline Project ("Project")
Decision 2018 ABAER 001 ("Decision")
Technical Review Submission for Condition 7 of the Decision

TransCanada PipeLines Limited (TransCanada) requests a technical clarification from the panel for Proceeding ID 353 (Hearing Panel) regarding Condition 7 of the Decision, which states that:

> *TransCanada must install one additional isolation valve between valve IMLV 4 and valve IMLV 5. TransCanada must conduct a study to find a location for the additional valve to reduce the magnitude of a maximum release between valve IMLV 4 to valve IMLV 5. The study must be provided to the AER and the AER must authorize the final location of the valve before operation of the pipeline.*

TransCanada is seeking to understand the requirement for an additional isolation valve. TransCanada understands from paragraph 169 of the Decision that the Hearing Panel is concerned "about the potential impact of a 16,500 bbl release in the immediate vicinity of the Mackay River". TransCanada respectfully submits that the potential impact of outflow release is limited to 3,612 bbl at Mackay River by valves IMLV 3 and 4, and as per the Dynamic Risk October 13, 2017 Outflow Report White Spruce submitted for AER IR Response 2.10 on October 16, 2017.

Selection of Valve Locations

The selection of valve locations for the Project, meets the Canadian Safety Association (CSA) requirements for valve location and spacing. The Project is designed to carry synthetic crude oil, and is designated as Low Vapour Pressure (LVP) pipeline. Per Section 4.4 – Table 4.7 of *CSA Z662*, shown below, there is no required maximum valve spacing for a LVP pipeline.

Table 1 – Table 4.7 of CSA Z662

Type of pipeline	Maximum valve spacing, km			
	Class 1 location	Class 2 location	Class 3 location	Class 4 location
Gas	NR	25	13	8
HVP	NR	15	15	15
LVP	NR	NR	NR	NR
CO_2	NR	15	15	15

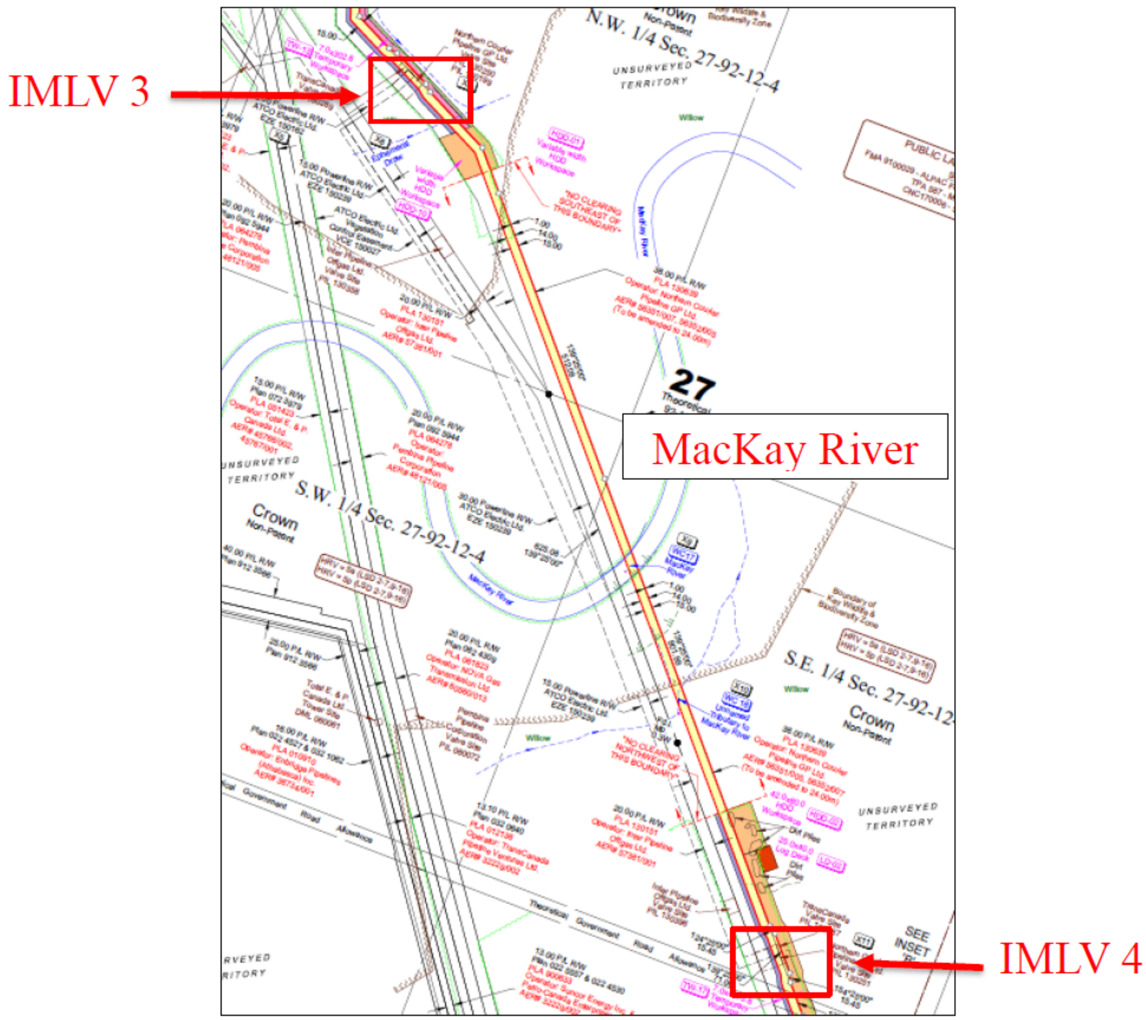
Note: *NR = not required.*

Although no maximum spacing is specified for an LVP pipeline, valve spacing is based upon project-specific factors that include, operational, maintenance, access, and system design considerations. Per TransCanada's AER IR response 1.18, the project-specific criteria for selecting the optimal valve site locations includes:

- assessing environmental features along the pipeline route;
- locating valves at or near existing infrastructure to minimize impact on the environment;
- assessing the availability of local infrastructure, including access and proximity to local power supply;
- evaluating local topography and geotechnical suitability of the site.

An additional consideration in selecting valve locations is the *CSA Z662* section 4.4.9 requirement for valve placements on both sides of major water crossings. TransCanada has identified the Mackay River as a project-specific main watercourse crossing. To ensure compliance with the CSA requirements, the Project has located the valves in close proximity to the river at IMLV 3 and IMLV 4, at 0.94km upstream and 0.72 km downstream of the river, as shown in Figure 1 below.

Figure 1 – IMLV sites 3 and 4 in relation to Mackay River



AER Precedent Pipeline Approval

In AER Decision 2016 ABAER 004 (Pembina Decision) for Pembina Pipeline Corporation's (Pembina) applications for two pipelines for the Fox Creek to Namao Pipeline Expansion Project (Pembina Fox Creek) at paragraph 134 the AER states that:

> "The panel accepts that the proposed number and location of block valves is in compliance with CSA standards, as required by the AER. The panel acknowledges that the AER does not specify what constitutes a major river crossing or what a regulated maximum acceptable spill volume would be."

At para. [129] of the Pembina Decision, the AER states that:

> "Pembina confirmed through questioning that *CSA Z662* required installation of valves upstream and downstream of major water crossings. Pembina stated that when considering outflow based on the initial CH2M Hill valve locations, it did not consider the pipelines to cross any major rivers……"

As a result, the Panel required Pembina to install an additional block valve to further reduce potential release volumes into the Paddle River. TransCanada in contrast, for the Project, did consider the Mackay River to be a main watercourse crossing, and as such, placed IMLV 3 and IMLV 4 in close proximity on either side of the Mackay River, including a planned trenchless crossing of this river with increased depth of cover and greater pipe wall thickness.

As shown in Table 2 below, the Project's proposed valve spacing and modelling parameters are already more conservative than the Pembina Fox Creek applied for parameters, when comparing average valve spacing, waterbody spill thresholds, and remainder of pipeline potential spill thresholds. Even without an additional isolation valve, located between IMLV 4 and IMLV 5, the Project has a significantly lower potential spill threshold at the Mackay River.

Table 2: Comparison Table – Pembina and TransCanada Pipeline Thresholds and Valve Spacing

	Line Size (NPS)	Length (km)	**Avg. Valve Spacing (km)**	**MacKay River Potential Spill Threshold (bbl)**	**Remainder of Pipeline Spill Threshold (bbl)**
TransCanada White Spruce	20	71	**17.0**	**3,612**	**16,504**
Pembina Foxcreek	24	270	**22.8**	**10,000***	**20,000***

**values from 2016 ABAER 004 – Pembina Pipeline Application*

IMLV 4 to IMLV 5 Spill Volume Modeling

Given the Hearing Panel's focus on the immediate vicinity of the MacKay River, as per paragraph 169 of the Decision, an additional assessment was completed by a third-party engineering firm (Third Party Assessment). The Third Party Assessment concluded that an additional isolation valve between IMLV 4 and IMLV 5 does not result in any improvements to the interaction with stream networks, watercourses or high consequence areas leading to the Mackay River. As shown in Figure 2 below, the largest modeled potential spill plumes that could occur, during a potential worst-case spill scenario, would be located downstream of IMLV 4.

Figure 2: Project-Specific Outflow Analysis

Figure 2 modelled above illustrates volumetric representations of the potential outflow volumes, but does not include any time-based components. In the hearing process, TransCanada has confirmed planned response times of 2-hours (AER IR response 1.20 on September 7, 2017). Therefore, the spill modelling shown above, considered to be a potential worst-case pipeline failure scenario, would be further reduced through the 2-hour response time commitment and the implementation of the TransCanada emergency response procedures.

Additional Measures for Mitigating Impacts of a Potential Release

For context, in the Pembina Decision at paragraph 135 the AER states:

> "…block valves are only one of the measures used to reduce the impacts of a potential pipeline release. Operating practices, leak detection systems, and pipeline integrity management systems play an equally important role in reducing the risk of a pipeline release."

Per TransCanada's response to FMFN IR 25 on August 18, 2017, the leak detection strategy for the Project consists of a multi-layered approach of overlapping methodologies, which includes computation systems and various methods of periodic inspection, including:

- Real-Time Transient Model (RTTM)
- Compensated mass balance system
- 24/7 remote monitoring by the operations control center
- Instrumented inspections using inline inspection tools
- Direct observations through aerial patrols, site inspections and
- ROW maintenance activities

TransCanada's Project pipeline leak detection system parameters include a computational system designed to detect leaks of 1.5 – 2.0% of flow within 2 hours. Leaks of a slower rate would be detected by other methods such as, remote monitoring, instrumented inspections, and direct observations. Having used this overall approach on other operating pipelines, TransCanada is confident that the majority of small leaks can be recognized and responded to by facilities staff with less than 0.16 m^3 (1 bbl) of product spilled. In addition to its leak detection strategy for the Project, TransCanada's operating practices, Emergency Response Plan, Geographic Response Plan, and Integrity Management System provide additional mitigation measures to minimize any potential impacts of a pipeline leak or rupture.

Implications of Adding a New Valve

The results of the Third Party Assessment of the impact of placing one additional valve between IMLV 4 and IMLV 5 is shown in Table 3 below. The proposed additional valve has been optimally located based on proximity, ease of access, and minimizing environmental impacts. The right-of-way by this segment is primarily muskeg and difficult to access in non-winter months. Locating the valve close to the access road would minimize the difficulty in accessing this location during non-winter months.

Table 3: Comparison of Outflow Modelling - Design Basis vs. Addition of New Valve

Model Description	Mackay River Crossing Potential Worst-Case Scenario Spill Volume (bbl)
White Spruce Pipeline (Design Basis)	**3,612**
White Spruce Pipeline with an Additional Valve	**3,796**

In certain cases, placing the valve closer to the watercourse does not help to lower the potential outflow in an area due to the local geography. In these cases, the water crossing may already be protected by local land topography, which limits the value of a valve when considering the potential effects of installation (e.g. access road development, and nearest power source).

The placement of an additional valve at KP 40.5 (i.e. between IMLV 4 and IMLV 5) does not result in any improvement in relation to the interaction with any watercourses leading to the Mackay River, which is already protected by IMLV 3 and IMLV 4. In fact, the results demonstrate that the potential worst-case scenario spill volume at the Mackay River is increased by the placement of an additional valve between IMLV 4 and IMLV 5. The increase is due to a change in the reference point used to calculate mass flow rate and friction with the additional valve placement. The reduced friction causes a mass flow rate increase upstream between IMLV 3 and 4 at the Mackay River, as compared to the design basis.

Clarification of Condition 7

TransCanada located the valves at IMLV 3 and IMLV 4, in accordance with CSA requirements, to protect the Mackay River and immediate vicinity. The above analysis demonstrates that the installation of an additional valve downstream of IMLV 4 increases the potential worst-case pipeline failure spill scenario between IMLV 3 and IMLV 4. Therefore, TransCanada seeks clarification regarding the need for an additional isolation valve. If the AER does mandate the installation of an additional isolation valve, TransCanada proposes to install a combination of a check and manual isolation valve, as was assessed in the Third Party Assessment.

Should the AER require additional information with respect to the technical clarification of Condition 7 of the Decision, please contact Paige Dodd at (587) 933-3573 or by email at paige_dodd@transcanada.com.

Sincerely,

Jeff Binda, P. Eng.
Project Manager, White Spruce Pipeline Project
TransCanada Pipelines Ltd

FINAL REPORT

R-TRP-20180316

NPS 20 White Spruce Pipeline Analysis of a Potential Additional Valve

TransCanada Pipelines

03/16/2018

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1. Background

In response to the Alberta Energy Regulator (AER) condition #7 of "Applications for the White Spruce Pipeline Project Fort McKay Area", TransCanada Pipelines (TCPL) retained Dynamic Risk Assessment Systems, Inc. (Dynamic Risk) to perform a technical analysis on the effects of placing one (1) potential additional valve located between IMLV 4 and IMLV 5 along the proposed White Spruce pipeline; a 71 kilometer (km) length Nominal Pipe Size[1] (NPS) 20 synthetic[2] crude oil pipeline, extending from a tie-in point at a receipt meter station northwest of Fort MacKay, Alberta to a tank terminal termination point located approximately 45 kilometers west of Fort McMurray, Alberta.

The objective of this analysis was to quantify the effects of placing one additional valve in a feasible location between IMLV 4 and IMLV 5 at KP 40.5 just north of the AOSTRA access road and the estimated potential product outflow volumes that would occur in the event of a worst-case pipeline release.

TCPL provided planned placement locations for seven pipeline valves, (the "design basis scenario"), valve closure times[3] and product specifications[4] (all of which are considered to be conservative in nature), and the pipeline centerline data used to establish the elevation profile of the pipeline. The "design basis scenario" was previously evaluated by Dynamic Risk in the separate outflow report, "*FINAL Outflow Report White Spruce 2017-10-13*".

The analysis was completed by initially establishing a design basis product volume outflow scenario that included the seven (7) valve locations (and types), modeled as a full-bore, worst-case[5] condition pipeline rupture and product release.

A follow-up comparison reassessed the potential product spill volumes in application with one additional valve installed between IMLV 4 and IMLV 5; this analysis was performed in order to determine the potential product outflow reduction under the same operating conditions and conservative assumptions.

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[1] NPS is a North American set of standard sizes. Pipe size is specified with a non-dimensional number; a nominal pipe size (NPS) for diameter based on inches.

[2] *A mixture of hydrocarbons, similar to crude oil, derived by upgrading bitumen from oil sands*, as defined by the Canadian Association of Petroleum Producers (http://www.capp.ca/publications-and-statistics/glossary#S.

[3] International Society of Automation, ISA-96.02.01-2007, Guidelines for the Specification of Electric Valve Actuators, 2007, Para. 5.1.3. "When not specified, operating times are generally provided as 10-12 inches of linear stroke per minute or 5 seconds per inch of valve bore (part-turn)"- for TCPL, equates to 2 minutes (or less), to achieve full closure for an NPS 20 pipeline. As a conservative approach, TCPL provided Dynamic Risk a closure time of 4-minutes for the proposed remote valves on the pipeline system.

[4] American Petroleum Institute (API), Product viscosity and product density values as reported by TCPL are representative of "light crude oil" classification; light crude oils will attain maximum flow distance in application with gravitational flow modeling.

[5] Pipeline product release modelling is based upon TCPL product specifications and the pipeline operating at full volume and flow capacity. This operating condition, when applied with the application of a full bore (~20-inch internal diameter) pipeline rupture, occurring at the 6 o'clock orientation position, at the lowest elevation point within the pipeline segment, would allow for release of maximum spill volumes and is considered to represent a low potential, worst case failure scenario.

The pipeline system considered as part of this analysis is displayed in Figure 1.

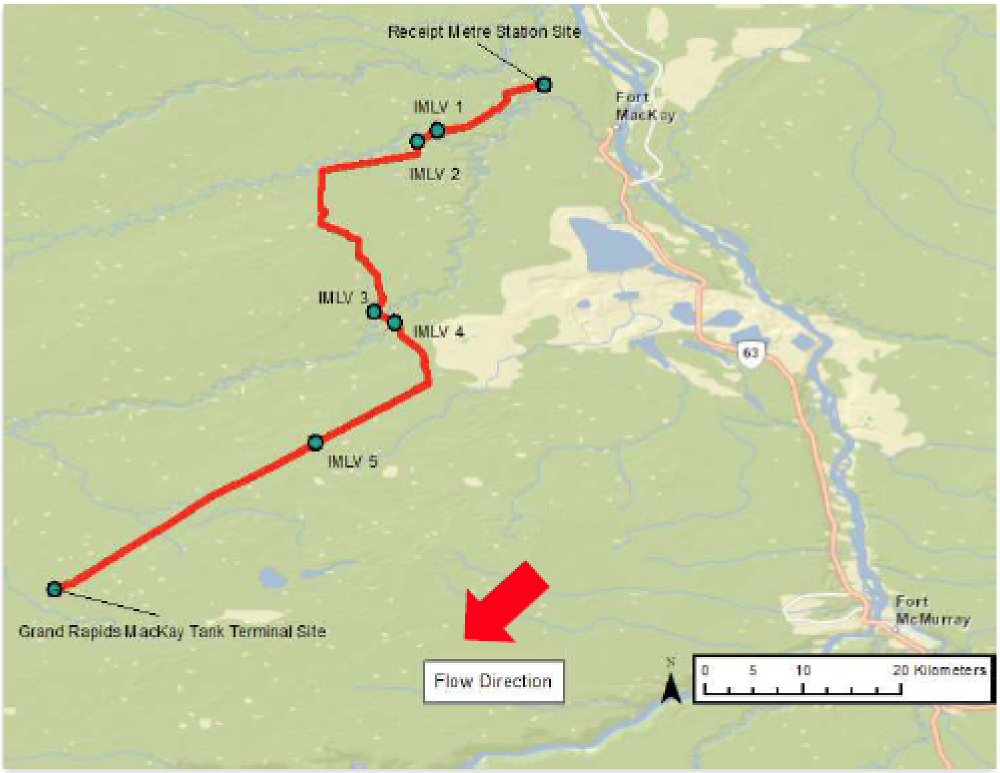

Figure 1: Proposed Pipeline System Map

Note: Figure 1 depicts the proposed pipeline system prior to the placement of an additional valve between IMLV 4 and IMLV 5.

2. Methodology

2.1. Overland Spill Model

Using the product outflow results from the previously submitted report by Dynamic Risk to TCPL on October 13, 2017, "NPS 20 White Spruce Pipeline Outflow Analysis", an overland spill analysis was performed to model the potential trajectory of a spill corresponding to the established product outflow volume.

A transient three-dimensional overland spill model[6] has been applied to model the trajectory of the overland product spill. The spill simulation model uses a digital elevation model to determine the flow path of a spill, accounting for the transient rate of spreading and the width of the lateral spread. The spill area is plotted with ArcGIS[7] software based on the calculated extent of the spill using the data provided.

The spill simulations have been modeled at 30-meter intervals along the pipeline. For pipe segments less than 30 meters in length, the release points have been modeled at the start and end of that portion. The spill simulation utilizes a digital elevation model to determine the flow path of each spill, accounting for the transient rate of spreading and the width of the lateral spread. Note that the spill simulation models the elevation profile as provided and assumes the pipeline to be located on the ground surface, i.e., no depth of cover.

The detailed methodology used in the overland spill model is provided in Appendix A.

2.2. Quality Assurance

The Dynamic Risk overland spill application calculates a relative estimation of pipeline product overland spill magnitude, trajectory and dispersion limits as based upon inputs and variables as provided by the pipeline operator. The calculation includes considerations for undulant topography and stream networks within the pipeline segment, creating complexities that make precise manual validation of the overland spill results impractical. It should be noted that the overland spill results, while projected to be conservative in nature, are subject to a degree of inherent uncertainty due to various unknown conditions, i.e., unique terrain, beaver dams, unanticipated soil conditions. Please also note that the overland spill results are provided within a format that is unprotected (not locked), to allow for data integration, manipulation and selected viewing by the client. A master data set is retained by Dynamic Risk as a replacement for the client, should any unintentional edits be made to this formal delivery.

[6] Zuczek, P., Deng, C., Adams, K., and Mihell, J. "An overland-hydrographical spill model and its application to pipeline consequence modeling" IPC2008-64389.

[7] ArcGIS is a geographic information system used for the management, analysis, and display of geographic information.

3. System Information and Data Inputs

TCPL provided Dynamic Risk with the pipeline right of way location centerline and valve locations as well as conservative system information regarding detection times and shutdown schedules.

The product version 0.97.0.4300 of the Dynamic Risk Outflow Proprietary Calculator has been used in this analysis.

The pipe and flow property data inputs used to conduct the analysis are as follows:

- Pipeline Length
- Outside Diameter
- Wall Thickness (utilizing the thinnest wall thickness on the proposed pipeline)
- Flow Rate (utilizing the maximum design capacity)
- Product Viscosity (proprietary information)
- Product Density (proprietary information)
- Failure Detection Time
- Pipeline Shutdown Time
- Valve Closure Time

3.1. Valves

For the pipeline section included in this analysis, the respective closure time for each remotely operated valve is four (4) minutes and the potential additional valve is presumed to be a check valve with an immediate closure time. The complete list of valves included in this analysis are provided in Table 1.

Table 1: Valve Locations and Types

Valve Name	Location		Approximate Kilometre Post (3D Chainage rounded to nearest kilometre)	Valve Type
	Latitude	Longitude		
Receipt Metre Station Site	57.221997	-111.699126	0	Remote[8]
IMLV 1	57.179783	-111.796332	8	Remote
IMLV 2	57.169771	-111.814081	10	Remote
IMLV 3	57.013942	-111.853639	33	Remote
IMLV 4	57.003882	-111.835263	35	Remote
Potential Additional Valve	56.957211	-111.80594	40.5	Check[9]
IMLV 5	56.895302	-111.907587	50	Remote
Grand Rapids MacKay Tank Terminal Site	56.761645	-112.145977	71	Remote

[8] Remote valves are mechanically actuated valves controlled by an external device, motor or other force.

[9] A check valve allows flow in one direction and automatically prevents flow in the reverse direction (back flow). Valve closure time is assumed to be immediate.

4. Results

4.1. Outflow Profiles

The outflow area under the curve values are shown below in Table 2. The addition of the potential additional valve at KP 40.5 results in potential product outflow volume reductions when compared to the design basis scenario (22.1%).

Table 2: Area Under the Curve[10]

Scenario	Area Under the Curve	Area Under the Curve % Reduction	Max Peak Outflow (bbl)	Average Outflow (bbl)
Design Basis	283,761	N/A	16,504	4,061
With Proposed Additional Valve at KP 40.5	221,024	22.1	10,245	3,206

Note: the placement of an additional valve at KP 40.5 has minimal impact on the outflow modeling results upstream of IMLV 4 or downstream of IMLV 5.

Figure 2 and Figure 3 are plotted with the corresponding elevations to provide for visualization of the outflow profile with respect to elevation and valve locations. Figure 4 is a comparison plot that displays the overall reduction in product outflow volume from the design basis scenario in comparison to the potential additional valve scenario.

[10] The area under the curve (distance x volume) is measured by calculating the total area under the outflow profile curve along the pipeline centerline. Max peak outflow is the largest potential product outflow volume that could be released from the pipeline in the event of a pipeline rupture. Average outflow is obtained by the summation of all outflow volumes modeled at each spill point divided by the total number of spill points along the entire pipeline.

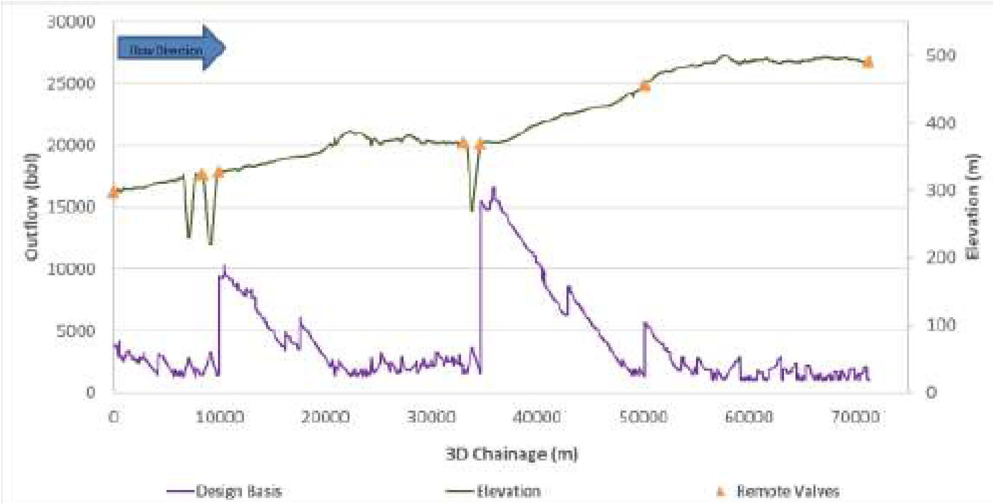

Figure 2: Outflow Profile – Design Basis

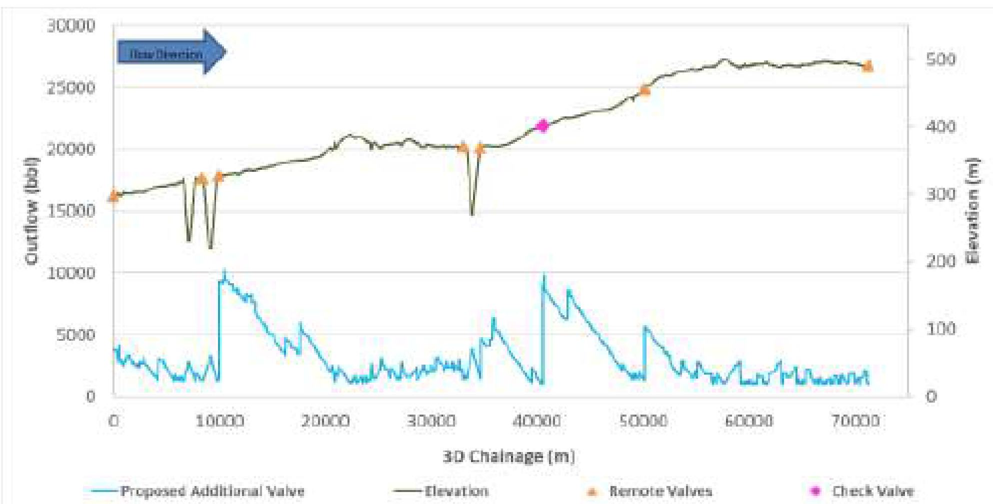

Figure 3: Outflow Profile – With Proposed Additional Valve at KP 40.5

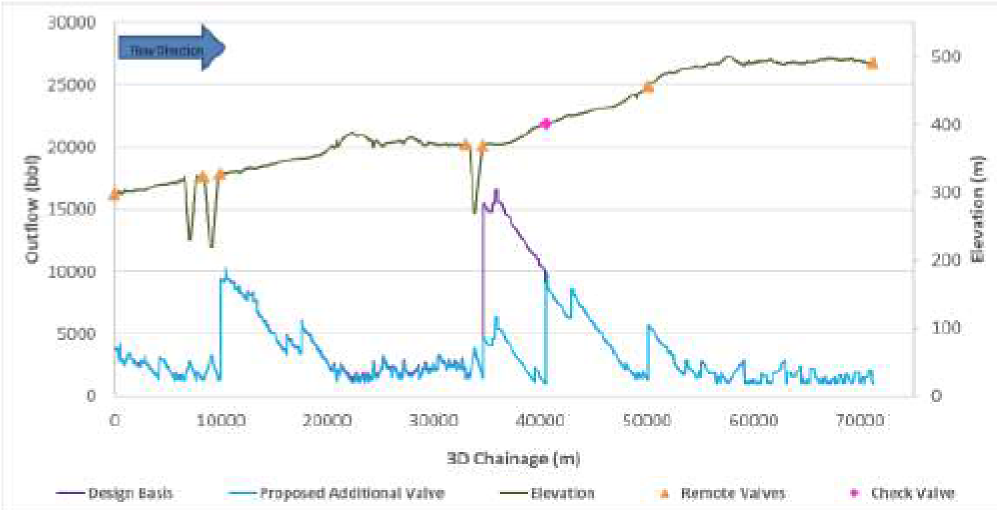

Figure 4: Outflow Profile – Scenario Comparison Plot

4.2. Overland Spill Modeling

Dynamic Risk performed an overland spill modeling analysis on the proposed White Spruce pipeline to assess the potential surrounding overland spill impact that would be predicted to occur in the event of a pipeline rupture, as based upon the TCPL provided planned valve placement locations, valve closure times and product specifications considered to be conservative in nature, and the pipeline centerline data used to establish the elevation profile of the pipeline.

The modeled overland spill plumes in the analysis are volumetric representations of the potential product outflow volumes and do not include any time based components. Where the overland spill plumes intersect with a hydrological feature (creek, river, lake, etc.); the model does not account for the hydrological transport beyond that point.

Figure 5 through Figure 7 below, are examples of the preliminary results of the modeling analysis. These figures can be used to visually identify land areas affected by the spill plumes. Given that the additional valve has minimal impact on the areas upstream of IMLV 4 and downstream of IMLV 5, the spill plumes located outside of the isolatable section IMLV4 to IMLV5 are not displayed in any of the figures. Note that these spill plume results are based on the design basis scenario without a potential additional valve.

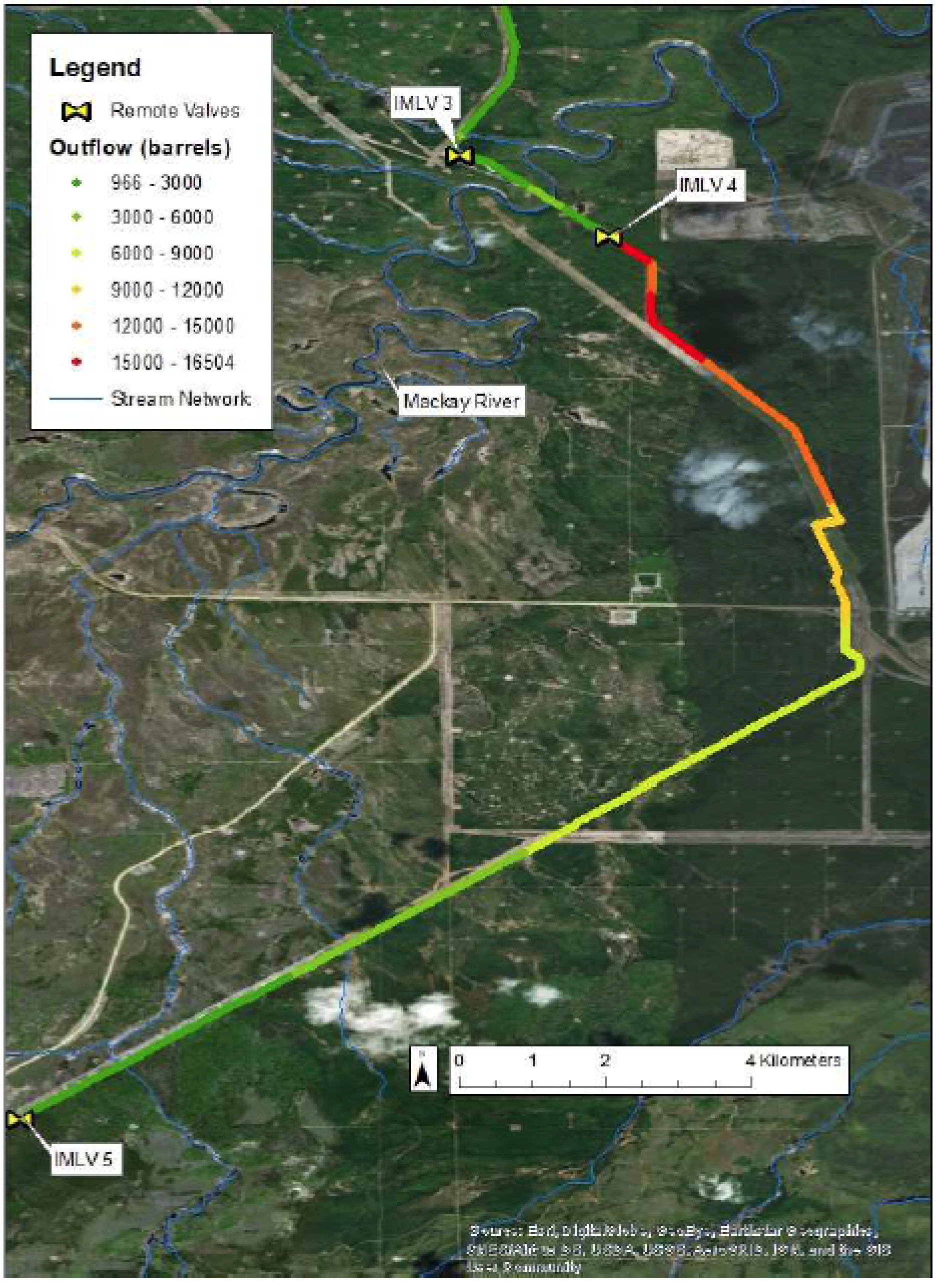

Figure 5: Gradient Map of Isolatable Section IMLV 4 to IMLV 5

Figure 5 is a volume gradient that displays the established outflow volumes between IMLV 4 and IMLV 5 identifying areas where the largest amount of potential product release could occur in the case of a rupture. The largest outflow volumes that could potentially spill are located downstream of IMLV 4.

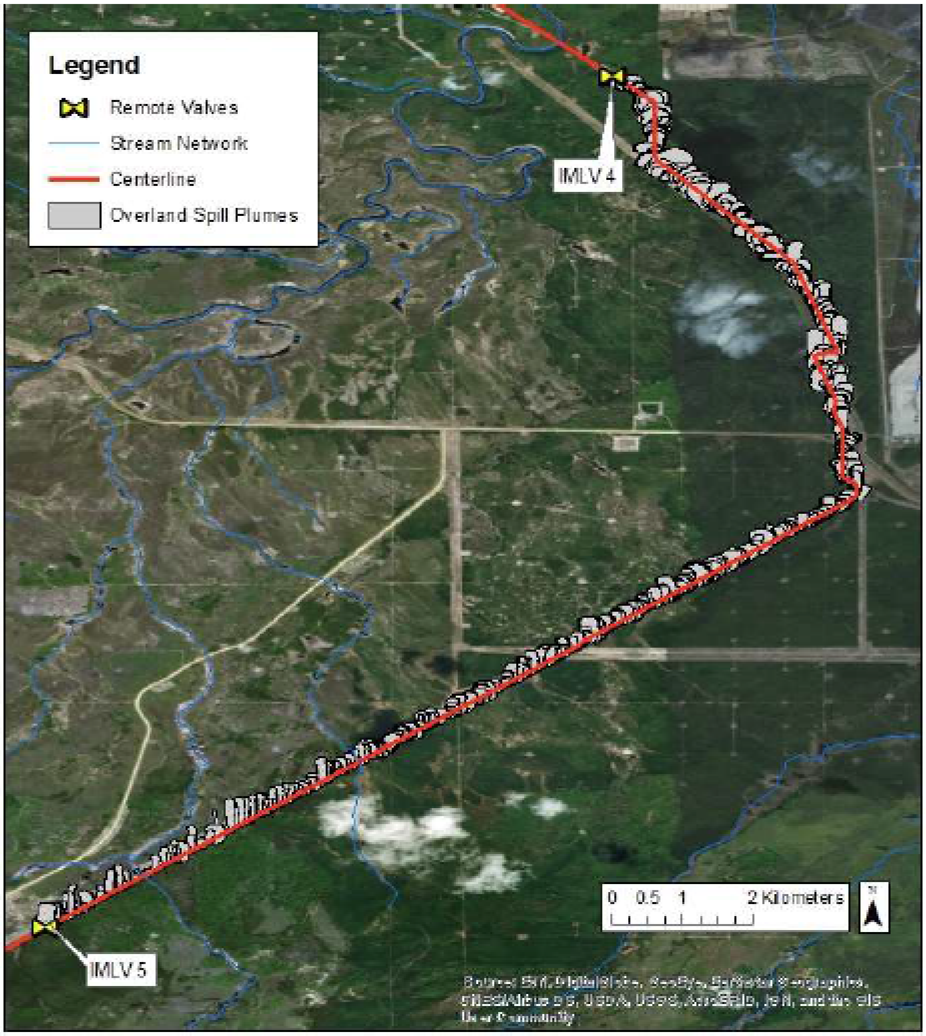

Figure 6: Overview of Isolatable Section IMLV 4 to IMLV 5

Figure 6 displays the distribution of the overland spill plumes located between IMLV 4 and IMLV 5 and shows that spill plumes do not directly reach or interact with the MacKay River in this isolated segment. Spill plumes located outside of this isolatable section are not shown in the figure.

Figure 7: Close up of largest potential spill plumes on the pipeline system

The largest potential spill plumes that could occur on the White Spruce pipeline are located just downstream of IMLV 4. As depicted in Figure 7, these potential spill plumes do not reach any stream networks or watercourses.

5. Conclusions

The objective of this analysis was to quantify the effects of placing one additional valve in a feasible location between IMLV 4 and IMLV 5 at KP 40.5 and the estimated potential product outflow volumes that would occur in the event of a worst-case pipeline release. TCPL provided planned valve placement locations, valve closure times[11] and product specifications[12] considered to be conservative in nature, and the pipeline centerline data used to establish the elevation profile of the pipeline.

The addition of an additional valve located at KP 40.5 results in potential product flow reductions when compared to the design basis, as follows:

- An average overall pipeline outflow volume reduction from 4,061 bbls to 3,206 bbls, an average outflow reduction of 21.1%.
- A total overall pipeline area reduction under the curve from 283,761 to 221,024 bbls, a total area reduction of 22.1%, or
- A total overall pipeline peak outflow volume reduction from 16,504 bbls to 10,245 bbls, a peak outflow volume reduction of 37.9%.

The seven (7) intermediate pipeline valves, as per the pipeline design and the conservative operating elements applied within the analyses, are considered to be located at optimal locations to significantly reduce product outflow to a level as low as reasonably practicable.

The addition of a new valve located at KP 40.5 results in moderate product outflow reduction, however does not result in any changes or improvements in relation to the interaction with stream networks, watercourses or high consequence areas leading to the MacKay River.

[11] International Society of Automation, ISA-96.02.01-2007, Guidelines for the Specification of Electric Valve Actuators, 2007, Para. 5.1.3. "When not specified, operating times are generally provided as 10-12 inches of linear stroke per minute or 5 seconds per inch of valve bore (part-turn)"- for TCPL, equates to 2 minutes (or less), to achieve full closure for an NPS 20 pipeline. As a conservative approach, TCPL provided Dynamic Risk a closure time of 4-minutes for the proposed remote valves on the pipeline system.

[12] American Petroleum Institute (API), Product viscosity and product density values as reported by TCPL are representative of "light crude oil" classification; light crude oils will attain maximum flow distance in application with gravitational flow modeling.

Table 3 below displays a maximum potential outflow volume comparison for the design basis scenario and the scenario involving the additional valve.

Table 3: Maximum Potential Outflow Volumes Comparison Table[13]

Isolated Valve Section	Maximum Peak Outflow Design Basis	Maximum Peak Outflow with Additional Valve
Start Station Valve to IMLV 1	4,251	4,193
IMLV 1 to IMLV 2	3,252	3,240
IMLV 2 to IMLV 3	10,320	10,245
IMLV 3 to IMLV 4	3,612	3,796
IMLV 4 to New Valve	16,504 (IMLV 4 - 5)	9,048
New Valve to IMLV 5		9,854
IMLV 5 to End Station Valve	5,680	5,680

[13] The addition of the valve causes a slight increase in outflow upstream due to its effect on the reference point used to calculate mass flow rate and friction. With no check valve, the reference point used to determine downstream mass flow rate and friction is 57,765 meters (the highest downstream point). When the check valve exists, the reference point either moves to the location of the check valve at 40,500 meters for a leak downstream of 22,140 meters or 22,140 meters for leaks upstream of 22,140 meters. The reduced friction has a greater effect on the mass flow rate than the difference in elevation, causing the mass flow rate to increase as compared to the design basis run.

Appendix A – Dynamic Risk Overland Spill Model Methodology

A transient three-dimensional overland spill model[14] is used to model the trajectory of an overland product spill. The spill simulation model uses a digital elevation model to determine the flow path of a spill, accounts the transient rate of spreading and the width of the lateral spread. The spill area is plotted with ArcGIS software based on the calculated extent of the spill using the data provided.

Spill Trajectory

The trajectory of the overland spill is based on the steepest downhill slope path, until the spill reaches a local depression where it will pool. The slope may be calculated from the elevation values of a Digital Elevation Model (DEM) or using a Flow Direction raster which may be created from a DEM. The slope is calculated from one DEM cell to the next cell (or from the flow direction raster which is already computed on a cell-by-cell basis) and is continually updated as the spill advances. Figure A-1 represents the spill path based on the cell – to – cell spill trajectory and the maximum downhill slope.

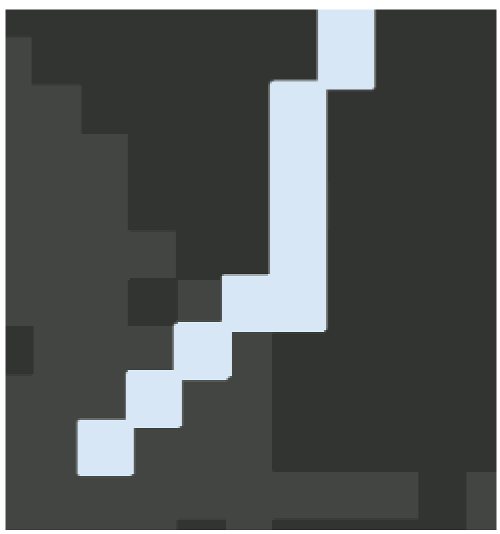

Figure A-1: Primary Spill Path

[14] Zuczek, P., Deng, C., Adams, K., and Mihell, J. "An overland-hydrographical spill model and its application to pipeline consequence modeling" IPC2008-64389.

Pooling Algorithm

The pooling algorithm is initiated when the spill reaches a local depression. The basic concept for pooling is outlined in the Figure below, Figure A-2 shows a representation of a spill when it reaches a local depression; the spill will fill the pool rising to the next highest elevation until it overflows the depression and continues a downhill trajectory.

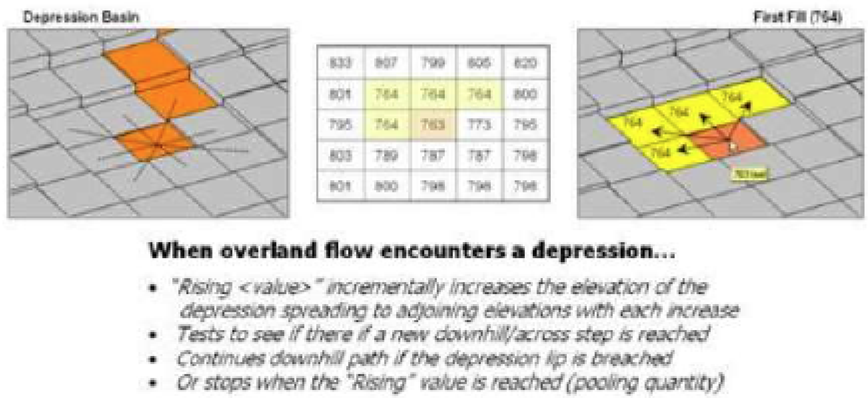

Figure A-2: Model Pooling in Overland Flow[15]

The algorithm in the Overland Spill Model detects a local depression when the flow direction advances to an area which has already been determined as part of the spill. If the flow direction raster reaches a local minimum, it will set the flow direction to the next highest elevation. This pattern will continue until a new downhill path is determined.

However, the next highest elevation will have a flow direction pointing back in the direction of the local minimum, creating a loop. Therefore, when the algorithm detects pooling, the pool will be created to consist of two cells: the cell at the bottom of the pool and the next highest elevation cell.

To determine the next cell in the pool, the cells surrounding the entire pool are considered and the cell with the next highest elevation is added to the pool. As each cell is added to the pool, the flow direction is checked to see whether the spill is still flowing back into the pool (i.e. the depression is still filling) or whether the pool has found a downhill flow path, in which case the algorithm goes back to modeling the spill as a downhill trajectory.

[15] Berry, J.K. "Incorporating Grid-Based Terrain Modeling Into Linear Infrastructure Analysis" New Century Mapping. GITA 2005

Stream Tracing (Vector Hydrography Data)

The stream tracing model is commonly used and follows a simple methodology. Where the spill intersects a vector waterway, the spill traces all the downstream paths. The requirement for this type of analysis is a stream/river geometric network which includes the flow direction and connectivity between streams (junctions).

The distance that the spill travels downstream is given by: stream velocity * time remaining until emergency response begins. The spill model specifies an Emergency Response Time (ERT) and the ERT remaining after spread of the spill will be used for the remaining time. The stream tracing ends when the calculated distance is reached.