Q. The project justification in its entirety (Section 3.0 of the Muskrat Falls to Happy Valley Interconnection Report – Revised January 25, 2018) is copied below.

> *Analysis of the present 138 kV transmission system configuration serving the Upper Lake Melville area indicates that the system is capable of delivering 77 MW to the Happy Valley 25 kV bus when the system is no longer providing construction power to the Muskrat Falls Project. For load levels beyond 77 MW, system voltages will deteriorate ultimately resulting in system voltage collapse and customer outages. The projected peak load for the area is expected to increase from 79.9 MW in 2017 to 104 MW in 2042. To support load levels beyond 77 MW in the Upper Lake Melville area, the capacity of the transmission system supplying the area must be increased. Refer to Appendix A, Eastern Labrador Transmission System Planning Report.*

Although the above project justification appears to be based on load, recent discussions with Hydro indicate that the reliability of the system is a critical concern. Hydro also pointed out that the project was listed as a $75 million 2018/2019 reliability improvement project within the 5-year plan as part of Hydro's 2017 Capital Budget Application and, as such, appears to have been planned to be undertaken in the absence of the addition of the recent data centre loads and the anticipated DND load in 2020.

Please provide the justification for the project based on reliability alone. Please include any technical reports and analyses completed supporting the project on the basis of reliability.

A. Section 3.0 of Appendix A, Eastern Labrador Transmission System Planning Report (2018 Capital Budget Application, Volume 2, Tab 13, Appendix 1, henceforth referenced as "the Report") details the configuration of the transmission system in eastern Labrador. In essence a single 230/138 kV, 75/100/125 MVA transformer at Churchill Falls is used to supply the eastern Labrador transmission system. A second, 230/138 kV, 25/33.3/42 MVA transformer is located in Churchill Falls as a "hot" spare to supply limited power to the Upper Lake Melville are for loss of the 125 MVA unit. A single, 269 km long, 138 kV transmission line connects Churchill Falls to the Happy Valley Terminal Station in eastern Labrador. The Happy Valley Terminal Station consists of three 138/25 kV transformers (two rated at 28 MVA and one rated 50 MVA), a 25 MW gas turbine that normally operates in synchronous condenser mode to provide the much needed voltage support for peak load transfers, and an 11.4 MVAR, 25 kV four stage switched shunt capacitor bank. With the Muskrat Falls construction power relocated to the 315 kV transmission system, the Muskrat Falls construction power station transformer and associated 21.6 MVAR of switched shunt capacitors are utilized to supply the load in the Upper Lake Melville area. The Report states at bottom of page 6:

> *Analysis of the existing 138 kV transmission system in Eastern Labrador indicates that it is capable of delivering 77 MW to the Happy Valley 25 kV bus, with Muskrat Falls construction complete.*

The 77 MW transfer limit is depicted in the Power versus Voltage (PV) Curve provided in the response to question 9 from "Attachment 2 – Response to Labrador Interconnected Group Questions" submitted by Hydro on March 6, 2018. The PV curve (see Figure 1) provides the relationship between the power delivered to

Happy Valley and the resultant voltage on the 138 kV bus at the Happy Valley Terminal Station. At the 77 MW load level the system voltage reaches the knee point of the curve. This indicates that for loads beyond 77 MW voltage collapse of the transmission system in eastern Labrador will occur. From a reliability perspective, voltage collapse is unacceptable and therefore mitigation measures are required.

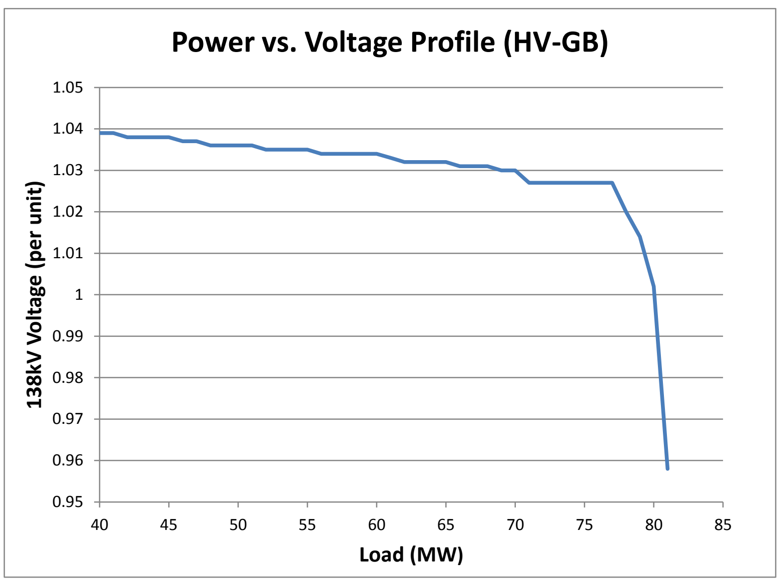

Figure 1: Power versus Voltage Happy Valley-Goose Bay

Relocation of the Muskrat Falls construction power load from the existing 138 kV transmission system to the 315 kV system yields the same effect as construction being completed, in that construction power will be provided by the 315 kV system that will be in-service for the Muskrat Falls Project, and only the customers fed from the Happy Valley Terminal Station will be limited to 77 MW. The 77 MW transfer limit, as depicted in Figure 3 on page 7 of the Report, requires that all equipment must be in-service. Consequently, an outage to any one transmission element will result in a reduction in the transfer capacity (i.e. load service capability) of the transmission system in eastern Labrador. Section 5.0 discusses the transmission system in eastern Labrador and the transfer capacity during equipment contingencies. Page 11 of the Report states:

> *With respect to transformer contingencies, loss of the 125 MVA unit at Churchill Falls leaves the 42 MVA "hot" standby unit in service to supply the Happy Valley Load. Combined, the 42 MVA unit at Churchill Falls and the Happy Valley 25 MW combustion turbine provide a maximum power delivery of 62 MW[1] when the 42 MVA T32 load reaches 100% of rating, as shown in Figure 6. Under this contingency, the 2018 winter peak load would exceed system capacity.*

This capacity exceedance is valid under any of the forecasted load variations listed in Table 1 on page 9 of the Report. Page 14 of the Report states:

> *The addition of new transformer capacity at Happy Valley is required due to the fact that loss of the largest unit (T1-50MVA) combined with operation of the gas turbine at 25 MW would provide 81 MW of transfer capacity. The load forecast shows that the 81 MW transfer capacity with the largest transformer out of service will be exceeded in 2019,*

[1] This value becomes 67 MW if the North Side Diesel Plant is considered.

> *prior to the proposed DND conversion to all-electric. Addition of a 50 MVA unit (T5) will provide a firm capability of 104 MW in the event of loss of the largest transformer at the Happy Valley Terminal Station and would not require the start-up of the gas turbine for back-up for this contingency.*

This indicates that for loss of a 138/25 kV transformer at Happy Valley, Hydro would run the gas turbine to prevent overload of the remaining transformers as per the transmission planning criteria. Increased load beyond 81 MW requires the addition of additional transformer capacity to avoid transformer overload during a transformer outage. This additional transformer capacity is included in the project proposal, with a planned in-service in 2019.

The loss of the 269 km long 138 kV transmission line results in an outage to customers in the Upper Lake Melville area. The local generation in Happy Valley consists of the 25 MW gas turbine and the two existing 2.5 MW diesels at the north plant. This capacity is much lower than the existing peak load.

What is not specifically stated in the Report is the impact on load transfer capacity for the loss of the gas turbine due to an issue with the gas turbine itself, including the engine, the power turbine, or its step up transformer. Page 5 of the Report states:

> *By 1989 load in the region had grown to the level that system reinforcement was required. To meet the forecast load growth Hydro installed 11.4 MVAR of 25 kV switched shunt capacitors on*

> *the 25 kV bus at Happy Valley and added a 25 MW gas turbine with synchronous condenser capability in 1991. In normal mode of operation the gas turbine would operate as a synchronous condenser enabling the transmission system to deliver up to 63 MW to Happy Valley.*

Based on this information and the fact that the maximum transfer capacity equals 77 MW with all equipment in service, the loss of the gas turbine as a synchronous condenser will result in a transfer capacity less than 63 MW excluding the impact of capacitor banks at Muskrat Falls construction power station. Certainly, the realization is one of inability to supply all existing load with the synchronous condenser out of service, and the synchronous condenser requires the gas turbine engine and power turbine to be operational to start the synchronous condenser.

The information provided in the Report demonstrates the limitations of the power supply to eastern Labrador. In order to improve the reliability of supply to the customers in the Upper Lake Melville area, system reinforcement is required such that a single equipment contingency does not result in loss of supply to the customer, or at the very least, reduces the unavailability of the system and expected unserved energy to a reasonable level.

From a reliability perspective, there are only three options to improve reliability:

1. Construct a new 138 kV line parallel to the existing line from Churchill Falls;
2. Install a new gas turbine that, when combined with the existing gas turbine, is capable of carrying the required load, and;

3. Interconnection to Churchill Falls via the newly installed terminal station at Muskrat Falls.

Conceptually the construction of a second line from Churchill Falls, a distance of 269 km, would ensure that the loss of a 138 kV transmission line does not result in loss of load up to the 77 MW transfer capacity of a single line. Construction of 269 km of 138 kV transmission would appear cost prohibitive (approximately $250M) and unnecessary given the location of a 138 kV connection at Muskrat Falls, a distance of 36 km from the Happy Valley Terminal Station.

Notionally the addition of a 60 MW gas turbine in operation with the existing 25 MW gas turbine would permit the support of up to 85 MW of load in the Upper Lake Melville area with either the 230/138 kV transformer at Churchill Falls or the existing single 269 km long 138 kV line out of service. Section 5.6 of the Report provides the capital cost of the 60 MW gas turbine option at approximately $90M.

The two options listed above were always available to improve reliability to Labrador East customers, but were not proposed previously by Hydro given the substantial capital costs ($90M to $250M) investment required to provide the additional reliability. Given that the reliability improvements can be provided for $20M due to the location of the new Muskrat Falls Terminal Station, the project cost is reasonable in order to reduce the probability of expected unserved energy. The option to build a new 60 MW gas turbine was ruled out in Section 5.6, page 27 of the Report, (a high capital cost) and a parallel transmission line was also not considered (an even higher capital cost), given that there were other viable solutions that provided improved reliability with a materially lower capital cost.

Given the sizable costs to ensure that all load can be supplied for a single transmission equipment loss, the focus is really one of reduction in the unavailability and expected unserved energy, thereby accepting some limited customer outage. Section 9.0 of the Report details the Reliability Analysis of a number of transmission options to improve statistical reliability. Table 5 on page 39 of the Report, reproduced here, provides the overall comparisons.

Table 5: Unavailability/EUE Comparison of Options

Interconnection Option	Calculated Unavailability (U)	Calculated Expected Unserved Energy (MWh) [1]
1	0.00460	1747
2	0.00051	194
3	0.00061	232
3	0.000121	46
4	0.000121	46

[1.] Based upon HV-GB 2020 annual energy requirement of 379.8 GWh.

Recall that Option One is the status quo option in which incremental transfer over the existing 269 km long line to Churchill Falls is met by adding a second transformer at Churchill Falls and 138 kV shunt capacitors at Happy Valley. In essence, the calculations provide the unavailability and expected unserved energy for the existing system at 0.0046 and 1747 MWh, respectively.

Option 2 considers the construction of 6 km of 138 kV transmission line connecting Happy Valley to Muskrat Falls. This option reduces the 138 kV transmission line length from 269 km to 36 km and connects Happy Valley to Churchill Falls via two 315 kV lines and two 315/138 kV transformers. The calculations demonstrate a significant improvement over the existing system with the unavailability and expected unserved energy at 0.00051 and 194 MWh, respectively.

Option 3 considers terminating both L1301 Churchill Falls to Muskrat Falls and L1302 Muskrat Falls to Happy Valley in the new 315/138 kV station at Muskrat Falls. The calculations demonstrate a significant improvement over the existing system with the unavailability and expected unserved energy at 0.00061 and 232 MWh, respectively. The slight increases in values compared to Option 2 are attributed to the unavailability impacts of the Churchill Falls to Muskrat Falls 138 kV line.

Options 4 and 5 consider two 138 kV lines between Muskrat Falls and Happy Valley with Option 4 considering only one 138/25 kV station and Option 5 having two 138/25 kV stations with a 138 kV line between the two stations. The calculations demonstrate a significant improvement over the existing system with the unavailability and expected unserved energy at 0.000121 and 46 MWh, respectively in both Options. The comparison between the results of Option 2 and Options 4/5 are indicative of the impact a second 138 kV line from Muskrat Falls to Happy Valley will have on the overall reliability, but has a material impact on the required cost.

The analysis was conducted using the 2020 load forecast requirements. Changes in the load forecast energy will not impact the unavailability values as these are set by the outage statistics of the equipment as highlighted by the formulae provided in

Appendix K. The quantity of expected unserved energy will change with the base forecast energy used for calculation as expected unserved energy is the product of the annual forecast energy and the calculated unavailability. Consequently, a change in the forecast will not change the overall ranking with respect to reliability improvement. In this case Option 2 provides a substantial improvement over the status quo (Option 1).

Finally, Section 8.0 of the Report provides the cost benefit analysis to improve overall reliability for eastern Labrador. Table 2, page 35 of the Report, indicates a $9.9M cumulative present worth difference for the single interconnection to Muskrat Falls (Option 2) over the status quo (Option 1). Consequently, the proposed option is justified on reliability without consideration of load growth.