IR# JRP.148

Reservoir Preparation

Requesting Organization – Joint Review Panel **Information Request No.: JRP.148**

Subject - Reservoir Preparation

References:

EIS Guidelines, Section 4.3.2.2 (Alternative Means of Carrying Out the Project), Section 4.3.4 (Project Description – Construction), Section 4.5.1 (Environmental Effects) and Section 4.6.1 (Mitigation)

Related Comments / Information Requests:

CEAR # 277 (Fisheries and Oceans Canada)
CEAR # 278 (Memorial University of Newfoundland – John D. Jacobs)
CEAR # 285 (Hydro-Québec)
CEAR # 289 (Innu Nation)
CEAR # 291 (Sierra Club Atlantic)
CEAR # 292 (Environment Canada)
CEAR # 307 (Government of Newfoundland and Labrador)

IR # JRP.6, 28, 33, 37

Rationale:

The Proponent has failed to adequately justify the proposed approach to reservoir clearing as required by the EIS Guidelines and failed to provide all of the information requested by the Panel.

Section 4.3.2.2 of the EIS Guidelines requires the Proponent to "analyze and compare the design alternatives for the Project in relation to their environmental and social costs and benefits, including those alternatives which cost more to build and/or operate but which result in reduced adverse environmental effects or more durable social and economic benefits" (p. 16-17). Section 4.3.2.2 (a) further states that "a selection of reservoir preparation strategies is necessary to address (…) concerns, including economic, technical and environmental considerations which are to be evaluated in order to select and justify the proposed mitigation measures" (p. 17). Section 4.3.2.2 (g) states that the EIS "shall consider a selection of reservoir management strategies, including consideration of scheduling/timing of filling, rate of flow release, and proposed mitigative measures (…)" (p. 18). Section 4.3.4 (a) requires that the Proponent describe "(…) clearing and harvesting strategy and methods (e.g. labour requirements, transportation to processing facilities) and methods for eliminating wood debris" (p. 19).

Also, Section 4.5.1 requires a comprehensive qualitative and quantitative analysis of the predicted environmental effects (positive and negative, direct and indirect, short and long term) on the VECs of each project activity or proposed alternative. Finally, Section 4.6.1 states that the EIS "(…) shall identify and discuss the proposed mitigation measures (…)", and section 4.6.1 (d) requires a description of the approach to determine, develop and maintain minimum flow requirements (…) including fish habitat maintenance (…)" (p. 36-37).

The Department of Natural Resources (CEAR # 307) states in its review of the response to JRP.33 that since Nalcor cannot "discuss this information request" or provide the information requested (various GIS maps showing proposed infrastructure for reservoir clearing) until early January 2010, they cannot complete their analysis of the adequacy of the reservoir preparation material until that time.

Fisheries and Oceans Canada (DFO) determined that while the responses to JRP.28 are generally adequate, additional information is still required. DFO states that in response to JRP.28 (a) “minor changes in timing [of reservoir impoundment] can have significant implications for fall-spawning fish species” (CEAR # 277, p. 3). The preferred period for impoundment (August to October) extends over two seasons as defined by the Proponent in its comparative analysis (June-August and September-October). However, the Proponent does not indicate why these three months would be preferable to either July or November.

In its review of JRP.28 (c), DFO also stated that the mean annual flows in the Lower Churchill prior to the Upper Churchill are significantly lower than the flows observed in the past 30 years and that the “[m]inimum flows based on these lower flows would result in flows that have not been seen in the past 30 years”. DFO also suggested that a compensation flow based on 30% of more recent mean annual flows would be “significantly higher than the 500m3/s proposed” (CEAR # 277, p. 3).

Requesting Organization – Joint Review Panel **Information Request No.: JRP.148**

Information Requested:

The Proponent is asked to provide the following:

a. **A cost-benefit analysis of partial versus full clearing of the reservoir area;**

Response:

The Reservoir Preparation Plan (Nalcor 2010), hereafter referred to as the Plan, is appended to this IR Response. The Plan provides details and a full discussion of the reservoir preparation plan including the selected clearing alternative. The cost-benefit analysis conducted as part of the Plan includes economic and environmental considerations of partial versus full clearing. The following provides an explanation of the methodology and assumptions employed for conducting the requested cost-benefit analysis, and the resultant conclusions.

Costs

The costs associated with clearing are subdivided into three components:

- Clearing costs (capital cost);
- Debris Management (operating cost); and
- Schedule premiums (the cost of delays to obtaining first power).

Each of these components is considered below.

Clearing Costs

The first step in estimating the cost of clearing is to define the clearing methodology. The clearing process is defined as the cutting of trees within the areas designated for clearing and then transporting the trees to a location above the flood line. Only trees that have been defined as merchantable timber will be cut and moved above the flood line. Merchantable timber is defined as being 2.5 m or more in length with a top diameter not less that 9.1 cm and being of generally sound condition (i.e. no sap rot and less than 1 percent butt rot). Tree clearing will be completed with mechanical harvesters; removing the limbs and tops; using forwarders to move the de-limbed trees to the roadside; and trucking the logs to the nearest wood storage location. The tree tops, limbs and other vegetation, along with smaller deadfall on the forest floor (larger deadfall will be mechanically harvested where possible) is defined as non-merchantable timber and this material will be mechanically processed. The handling of this material is discussed further in response to IR# JRP148(b). Once the clearing methodology was determined, the next step in determining the cost of clearing was to determine the total volume of timber (both merchantable and non merchantable) that can be safely accessed, cleared and processed. Information from the following sources was used for this evaluation:

- LiDAR (Light Detection And Ranging) Survey and Orthophotography (2006);
- Bank Stability Study (AMEC 2008);
- Ecological Land Classification Study (Minaskuat 2008); and
- Reservoir Preparation Study (Enfor 1998).

The key outputs generated from the LiDAR and orthophotography included:

- Digital Elevation Model (DEM) - a grid-based model of elevation values created from the actual three dimensional location of each LiDAR data point;
- Forest type and canopy cover;
- Slope Analysis – a grid based model of topography created from the DEM;
- One metre contour lines – lines of equal elevation (1 metre intervals) created from the DEM; and
- High resolution photography – provided a detail view of the ground/forest cover.

As part of the 1998 Reservoir Preparation Study (Enfor 1998), an inventory was undertaken to assess the total volume of timber within the area to be inundated and adjacent to the new shoreline. For the forest inventory study, the area adjacent to the new shoreline was defined as those areas with an elevation within three vertical metres (m) of the full supply level (FSL). A limit on the horizontal distance that this area would extend from the new shoreline was later applied (i.e., 15 m from the new shoreline). The purpose of the inventory was to estimate the total timber volume within and adjacent to the expected flooded areas. The inventory followed the sampling procedure set out by the Newfoundland Forest Service for district-level forest management inventories. Using aerial photography, the area was classified into:

- Productive forest, consisting of various forest stand types;
- Non-productive forest; and
- Other land classes.

The productive forest class was further delineated into stand types on the basis of tree species, total stand age, and total tree height. The forest inventory data were geo-referenced.

Several ground truthing exercises were conducted to confirm the above information. For example, for the development of the forest inventory data, samples were collected from over 180 plots distributed throughout the area to be flooded. Members of a Nalcor reservoir preparation task force also visited the area in 2009 to confirm the accuracy of the forest inventory data. In addition, as part of on-going consultation with the Forest Services Branch of the Department of Natural Resources, the timber volumes are being further verified based on data collected by the Department of Natural Resources. The results of this verification exercise are not anticipated to change the overall result of the cost-benefit analysis as the initial forest inventory data was developed based on the methodology set out by the Forest Services Branch and incorporated data provided by the Forest Services Branch.

To facilitate the determination of the volumes associated with the reservoir clearing strategy selected, three reservoir zones were identified and evaluated (Figure 1):

- Ice Zone;
- Stickup Zone; and
- Flood Zone.

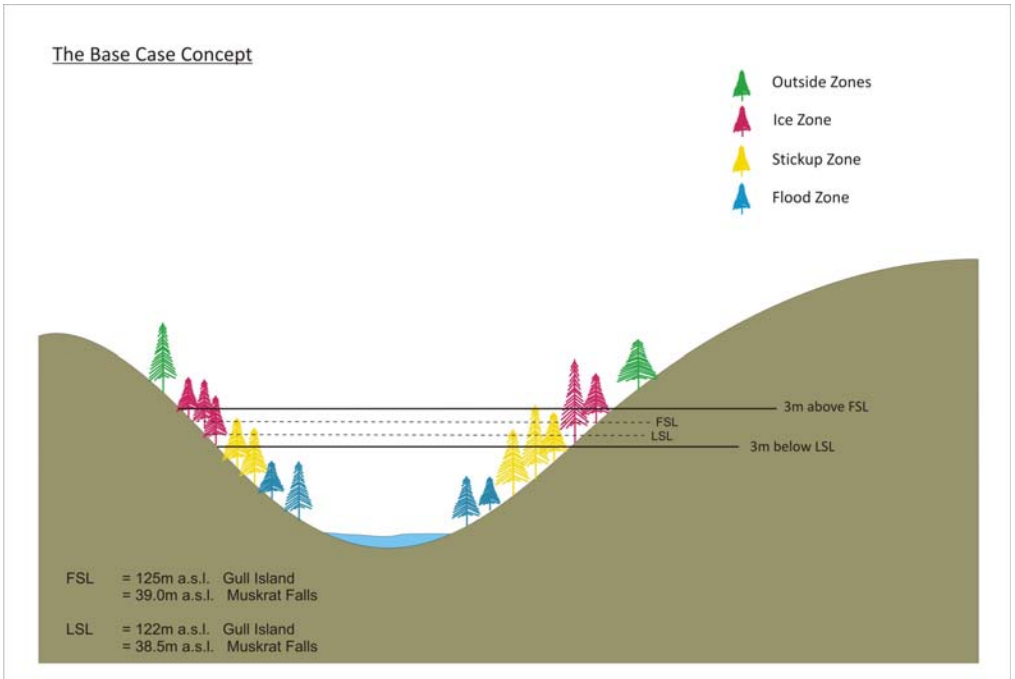

Figure 1 Reservoir Zones

The ice zone is defined as the band or zone along the shoreline on both the north and south banks of the reservoir between three metres above FSL (to a maximum of 15 m horizontally from the predicted new shoreline) and three metres below lower supply level (LSL). For the Gull Island reservoir this zone is between 128 m above sea level (masl) and 119 masl. For the Muskrat Falls reservoir this zone is between 42 masl and 35.5 masl.

As shown in Figure 1, the stickup zone is defined as the area below the ice zone where the base of a tree is below the ice zone; however, the top of a tree is sufficiently high to extend into the ice zone. These trees may be partially submerged when the reservoirs are at LSL or may be fully submerged just beneath the surface of the reservoirs. Trees in this zone can pose a hazard to navigation and may not be aesthetically pleasing. As well, ice formation around these trees when the reservoir is at LSL could result in trees being uprooted as the reservoir level rises which results in safety and navigation hazards.

The flood zone is the area below the stickup zone where the trees will be fully submerged after impoundment and the depth of submersion is sufficiently below the LSL (minimum of 3 m) such that it will not pose a hazard to navigation.

Full clearing would involve clearing of timber in all three zones, where it is safe to do so (slope ≤ 30%). Partial clearing would involve clearing of timber in the ice and stickup zones only, where it is safe to do so (slope ≤ 30%). The maximum slope upon which clearing operations could safely be conducted was lowered from the preliminary criteria provided in IR# JRP 6. This refinement was due to additional information regarding conditions in Labrador and equipment operation limitations gained through further analysis and discussions with the Forest Services Branch.

Standard forest harvesting best management practices and mitigation strategies would be applied to either clearing method to limit disturbance to the existing environment. For full clearing this would mean that a buffer zone (15 m) of undisturbed vegetation would be maintained along all existing tributaries and the main stem of the lower Churchill River to limit the potential for siltation resulting during pre-impoundment runoff events. For partial clearing, this buffer zone would be maintained along tributaries within the flood zone but would be at least 15 m along the main stem, and in most cases, much greater as it would consist of the entire flood zone area, which would not be cleared.

The following steps were followed in conducting the timber volume analysis for the partial clearing alternative to provide data on timber volumes and accessibility for each forest stand throughout the reservoir zones.

1. The first step in the process was delineation of the zones of analysis. Arcview GIS software (with Spatial Analyst extension) was used to carry out the volume analysis. The ice zone polygon file was derived from 1 m contour lines, and was defined as all areas from 3m below LSL to 3 m above FSL (to a maximum of 15 m horizontally from the new shoreline). The stickup zone polygon file was derived from LiDAR data and was defined as all areas below the elevation of the ice zone where tree tops extended above the lower elevation limit of the ice zone.

2. The second step was to ensure that forest inventory data were available throughout the zones being analyzed. The original forest inventory was extrapolated to the edge of the ice zone by reference to high resolution digital orthophotographs in those areas where the original forest inventory did not extend fully to the edge of the ice zone. In those areas where the forestry inventory data extended beyond the upper edge of the ice zone, it was clipped to the edge.

3. The third step was evaluation of accessibility of forest stands within the zones. First, slopes were calculated by reference to the LiDAR Bare Earth data, and then classified into accessible slopes (≤ 30%) and inaccessible slopes (>30%). Forest inventory polygons were processed against the slope classes to identify proportions of forest stands that were accessible which was defined as "local accessibility". In some cases, a forest stand, or part thereof, was locally accessible by reference to slopes within the stand, but was not accessible because surrounding slopes prevented construction of roads into the stand. This aspect of accessibility was defined as "global accessibility", and was evaluated with reference to the location of proposed access roads (which were located with reference to slope data and analysis of zone polygons).

Based on this analysis, the timber volumes were determined and results are presented in Table 1. Based on the timber volume estimates, a detailed cost was developed for partial clearing.

Steps 1 and 2 above, plus the global accessibility element of Step 3, were repeated for the full clearing option to develop a preliminary estimate of timber volume. The local accessibility element of Step 3 was not performed as based on its application to partial clearing, it was not expected to change the timber volume estimate appreciably. In addition, some simplifying assumptions were made in the analysis of the full clearing alternative as follows:

- While a complete inventory of timber volume was made for the full clearing option, the unit cost per cubic metre of timber for full clearing was assumed to be the same as that for partial clearing. This assumption is considered reasonable as there are no significant differences in conditions between the areas to be cleared under full clearing and partial clearing.
- No additional road construction or basic infrastructure would be required for full clearing. This assumption tends to understate the cost of full clearing as, any requirement for roads or basic infrastructure further increases the cost of full clearing.

With these simplifying assumptions, the timber volume estimates were determined and the results are presented in Table 1. Based on these timber volume estimates, the cost was developed for full clearing.

The results of this analysis concluded that full clearing would result in an additional capital cost of approximately $200 million to the Project - $150 million for the Gull Island reservoir and $50 million for the Muskrat Falls reservoir.

Debris Management

From an operational perspective, the primary benefit of any reservoir clearing for the Project is to reduce the amount of material that will contribute to trash and debris at the generating facility. Floating trees and vegetation resulting from impoundment and reservoir stabilization during operations will move downstream and collect at the intake and spillway structures of the generating facilities. This becomes an issue during operations as trees, trash and debris builds up on the trashracks; reducing the available head and lowering the efficiency of the generating facility. Floating trees and vegetation can also obstruct the proper operation of spillway gates. Eventually the trash and debris will have to be cleaned from the intake facility and disposed of. Full clearing will decrease the volume of trash and debris affecting the generating facility and associated debris management costs. However as demonstrated in the following paragraphs this reduction is predicted to be minimal.

The main zones contributing to trash and debris generation are expected to be the ice and stickup zones. By definition, these are the zones that are subject to wind, wave and other natural erosion processes (such as ice) during reservoir stabilization and operations. Timber located within the flood zone is expected to have minimal contribution to trash and debris volumes. Once the reservoir is impounded much of the timber within the flood zone will become water logged and will not float. As well, timber within the flood zone will be fully submerged and will not be subject to wind and wave action or influenced by ice formation.

Table 1 Volume Summary for Full versus Partial Clearing

Reservoir	Clearing Option	Area Cleared (ha)	Additional Clearing (ha)[1]	Volume Cleared (1000 m^3)			Area Uncleared (ha)	Volume Remaining (1000 m^3)		
				Merchantable	Non Merchantable	Total		Merchantable	Non Merchantable	Total
Gull Island	Partial	1000	400	258	33	291	8300	1113	170	1283
	Full	3800	400	655	97	752	5500	722	107	829
Muskrat Falls	Partial	1800	500	470	58	528	2500	251	33	283
	Full	3300	500	601	75	676	1000	121	16	138

Note:
[1] Limited additional clearing is expected to occur outside the reservoir zones, related to; habitat enhancement (e.g. related to hardwood habitat as described in IR# JRP.102, access roads, and wood storage areas for both reservoirs. These activities are also reflected in volume cleared values.

Once safety and environmental constraints are applied (slope restrictions and buffer zone around water bodies), the same volume of timber will remain in the ice and stickup zones, regardless of whether full or partial clearing is carried out. If full clearing were to be implemented any additional clearing would only occur in the flood zone. Based on experience on the Le Grand Project in James Bay (Societe d'Energie de la Baie James 1988), a high level comparison of anticipated levels of debris (based on volumes remaining in the reservoir) and an associated cost for debris management have been developed (Table 2). As shown in Table 2, regardless of the level of clearing selected the anticipated difference in the volume of trash and debris will be minimal. The same basic level of trash and debris handling equipment will be required regardless of the clearing option selected. The increase in the cost of debris management under the partial clearing option due to the difference in the cost of handling the small increase in trash and debris from the flood zone is predicted to be minimal.

Table 2 Cost Estimate Debris Management (Full Clearing vs Partial Clearing)

Reservoir	Clearing Option	Volume Remaining in Zone (1000 m^3)		Level of Debris Generated (1000 m^3)			Cost of Debris Management ($50/$m^3$) (millions of dollars)
		Ice and Stickup	Flood	Ice and Stickup	Flood	Total	
Gull Island	Partial	466	817	179-465	41	220-506	11.0-25.3
	Full	466	363	179-465	18	197-483	9.85-24.15
Muskrat Falls	Partial	112	171	43-112	8	51-120	2.55-6.0
	Full	112	26	43-112	1	44-113	2.2-5.65

Because the difference in the cost ranges for partial and full clearing is negligible (i.e. the cost differential is not large enough to influence the selection of the preferred option) it is not considered further in this analysis.

<u>Schedule Premium</u>

A detailed schedule for partial clearing based on the volume analysis has been developed. For partial clearing, multiple work fronts and 24 hour a day operations will be required to ensure reservoir clearing is completed prior to impoundment. As indicated in Table 1 of this response, full clearing will require the removal of almost double the volume of timber as compared to partial clearing.

If full clearing were to be carried out prior to impoundment, given the limited area within which clearing operations can be carried out, increasing crew and fleet sizes and the number of work fronts, are likely to dramatically increase the unit cost of clearing operations. Alternately, interest during construction charges will be incurred and revenue will be lost when in-service for the facilities are delayed while full reservoir clearing operations are completed. A $200 million dollar premium is considered to be an optimistic estimate of these costs. These additional costs have not been included in this cost-benefit analysis as the actual cost increases are not known and expected Project revenues are preliminary. However, based on the final conclusion of the cost-benefit analysis that partial clearing is preferred, not including these costs would not change this conclusion and would only reinforce the selection of partial clearing as the preferred option.

Benefits

There are both quantifiable and non-quantifiable benefits associated with full or partial clearing. For example, the recovery of merchantable timber is considered a quantifiable benefit, while safe navigation and environmental benefits are considered non-quantifiable, and both are important considerations in the evaluation of these alternatives.

Recovery of Merchantable Timber

The reservoir clearing process will result in the generation of a raw material widely used in the forestry industry in the form of round wood logs. Consequently, the value of round wood logs has been selected as an appropriate measure of valuing the merchantable timber volumes recovered for purposes of the cost-benefit analysis. As shown in the following paragraphs, the additional value of the merchantable timber made available through full clearing is $17 million. If non-merchantable timber could be converted to wood pellets for no incremental cost, then an additional $3 million in value could be derived.

While the forestry industry has not been fully developed in Labrador, in an effort to identify parties interested in the development of the forest resource in Labrador, the Newfoundland and Labrador Department of Natural Resources has released an Expression of Interest with a close date of April 16, 2010 seeking proposals to develop forest resources. In the absence of firm proposals to develop secondary processing for timber made available from reservoir clearing operations, appropriate price references were sought.

Halifax Global Inc. noted in a 2006 report titled "Strategic Plan to Develop Labrador Secondary Manufacturing and Value Added Wood Products Industry" that the cost of wood delivered from Labrador to Island pulp mills was in the order of $70/m^3, including roughly $20/m^3 for barge transportation. The same report concludes that the cost of transport from the harvesting site to Happy Valley Goose Bay is $9/m^3 and harvester costs would also include an administrative fee of $8/m^3. If Newfoundland paper mills were prepared to pay $70/m^3, then the timber from reservoir clearing could be sold for $33/m^3 (i.e., $70 - $20 - $17). It should be noted that the wood referenced in the Halifax Global report was sold to the paper mill in Stephenville, which has since been shut down because it was no longer competitive.

A more recent market reference can be found in the Q4 2009 "North American Wood Fiber Review," which reports that round wood sold at maritime Canada mills for an average of $96 per dry metric ton, or approximately $50/m^3 (North American Wood Fiber Review 2009). In this case, the cost at the clearing site could be no more than $13/m^3 to be competitive (i.e., $50 - $20 - $17).

The production of wood pellets for fuel is also an emerging market, and historically wood pellet facilities have used waste material as feedstock. In many cases, this material is available for free or for a nominal cost. Demand for wood pellets is growing, and the potential exists for a facility to pay as much as a paper mill would pay for round wood. If this was the case, then a large scale wood pellet facility in Labrador could pay up to $50/m^3 for raw material. This establishes the value at $33/m^3 (i.e., $50 - $17).

The maximum price from these references is $33/m^3. Based on this price and the volume of timber removed the value of merchantable timber recovered is provided in Table 3.

Table 3 Value of Additional Recovered Timber (Full Clearing vs Partial Clearing)

Reservoir	Clearing Option	Volume Recovered (1000 m^3)		Value ($million)[1]
		Merchantable	Non Merchantable	
Gull Island	Partial	258	33	$9.6
	Full	655	97	$24.8
Muskrat Falls	Partial	470	58	$17.4
	Full	601	75	$22.3

Note:
[1] Based on a value of $33/m^{3}at a storage site

Additional discussion on indirect job creation through the establishment of secondary wood processing is discussed in the context of economy, employment and business in the following section.

Non Quantifiable Benefits

The following conclusions on environmental effects are based on the assumption that standard environmental mitigation for forestry operations will be applied.

- Atmospheric

  In terms of potential environmental effects on the Atmospheric Environment during construction, the partial clearing scenario is preferred. During the operations phase, the full clearing scenario is predicted to result in a negligible decrease in atmospheric effects. Considering the potential extended schedule requirements for full clearing which would delay offsets of Green House Gas (GHG) emitting energy sources, partial clearing is preferred for the Atmospheric Environment.

  Partial clearing would result in a decrease in fuel consumption and associated GHG emissions during the construction phase as opposed to full clearing. Similarly, there would be a decrease in the potential for generation of airborne dust.

  To predict and compare GHG emissions from the reservoir during the operations phase for the full and partial clearing scenarios, a Churchill River watershed carbon model was developed to consider all major carbon stocks, processes and fluxes. This carbon model was based on the original volume estimates for full and partial clearing prior to the safety and accessibility analysis. Based on the revised timber volumes provided in the safety and accessibility analysis, the difference from the original volume estimate was pro-rated to estimate the associated changes to GHG emissions for both the full and partial clearing methods. These values are provided in Table 4.

Table 4 Net Greenhouse Gas Emissions for the Project Using Intergovernmental Panel on Climate Change (2003) Tier 3 Calculation Methods

Emissions Calculation Method	Electricity Generation[A]		Total Tonnes		Emissions per kWh	
	(GWh/yr)		(CO_2e/yr)		(g CO_2e/kWh)	
	Gull Island	Muskrat Falls	Gull Island	Muskrat Falls	Gull Island	Muskrat Falls
IPCC Tier 3 Net Emissions (Year 2 - No Clearing)	11,826	4,331	799,076	361,100	67.6	83.4
IPCC Tier 3 Net Emissions (Year 20 - No Clearing)	11,826	4,331	87,908	37,089	7.4	8.6
IPCC Tier 3 Net Emissions (Average –first 50 years - No Clearing)	11,826	4,331	194,584	85,691	16.5	19.8
IPCC Tier 3 Net Emissions (Average - first 100 years - No Clearing)	11,826	4,331	141,246	61,390	11.9	14.2
IPCC Tier 3 Net Emissions (Year 2 - Full Clearing)	11,826	4,331	710,850	321,243	60.1	74.2
IPCC Tier 3 Net Emissions (Year 20 - Full Clearing)	11,826	4,331	86,125	36,337	7.3	8.4
IPCC Tier 3 Net Emissions (Average - first 50 years - Full Clearing)	11,826	4,331	168,000	73,700	14.2	17.0

Emissions Calculation Method	Electricity Generation[A] (GWh/yr)		Total Tonnes (CO_2e/yr)		Emissions per kWh (g CO_2e/kWh)	
	Gull Island	Muskrat Falls	Gull Island	Muskrat Falls	Gull Island	Muskrat Falls
IPCC Tier 3 Net Emissions (Average - first 100 years - Full Clearing)	11,826	4,331	127,100	55,000	10.7	12.7
IPCC Tier 3 Net Emissions (Year 2 - Partial Clearing)	11,826	4,331	732,750	331,128	62.0	76.5
IPCC Tier 3 Net Emissions (Year 20 - Partial Clearing)	11,826	4,331	86,566	36,523	7.3	8.4
IPCC Tier 3 Net Emissions (Average - first 50 years - Partial Clearing)	11,826	4,331	171,400	75,200	14.5	17.4
IPCC Tier 3 Net Emissions (Average - first 100 years - Partial Clearing)	11,826	4,331	129,000	55,900	10.9	12.9

Note:
[A] Electricity generation was based on a generating capacity factor of 2,250 MW for Gull Island and 824 MW for Muskrat Falls, and an assumed capacity factor of 60 percent (Muller and George 1985)

As shown in Table 4 GHG emissions from the full and partial clearing scenarios are similar to one another. The GHG emissions from the Project will be low regardless of the clearing option selected (in relation to industry norms and in relation to the provincial, regional or national GHG emission totals (CEA Agency 2003)) as the reservoirs' configuration (deep and narrow) and location (northern climate) are governing influences. As a result, the level of clearing implemented will have minimal influence on overall levels of carbon degradation and GHG emissions. The predicted values of emissions for the clearing scenarios are provided in Figures 2 and 3.

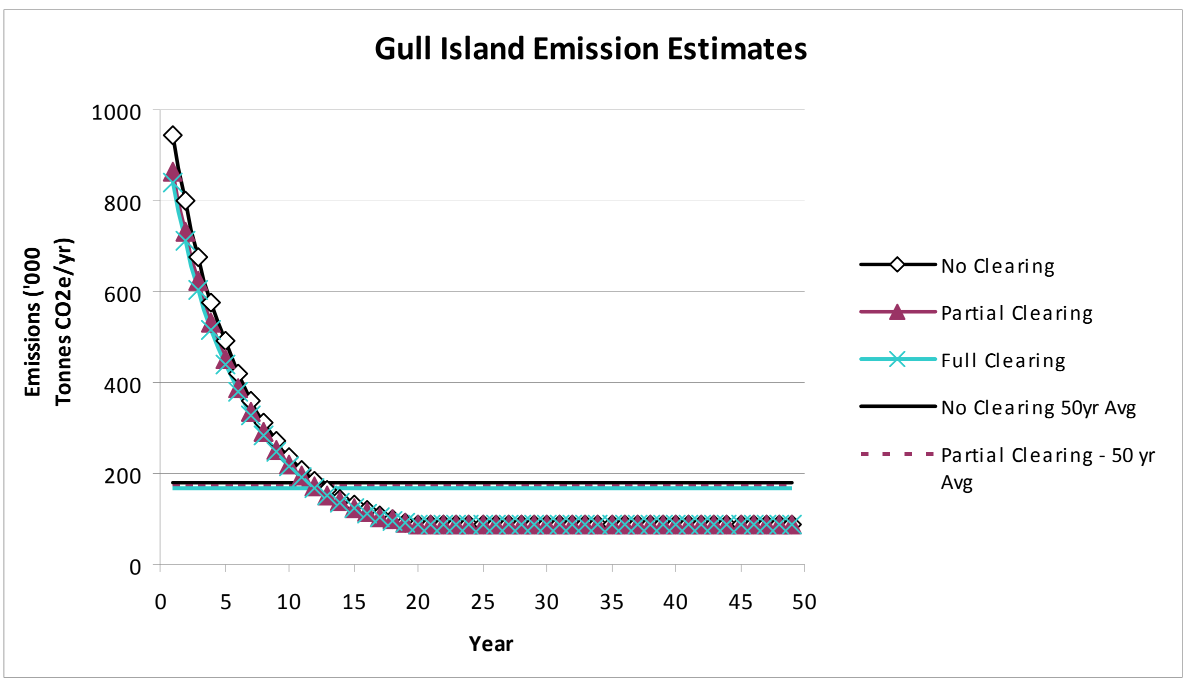

Figure 2 Gull Island CO_2e Emissions for Clearing Scenarios

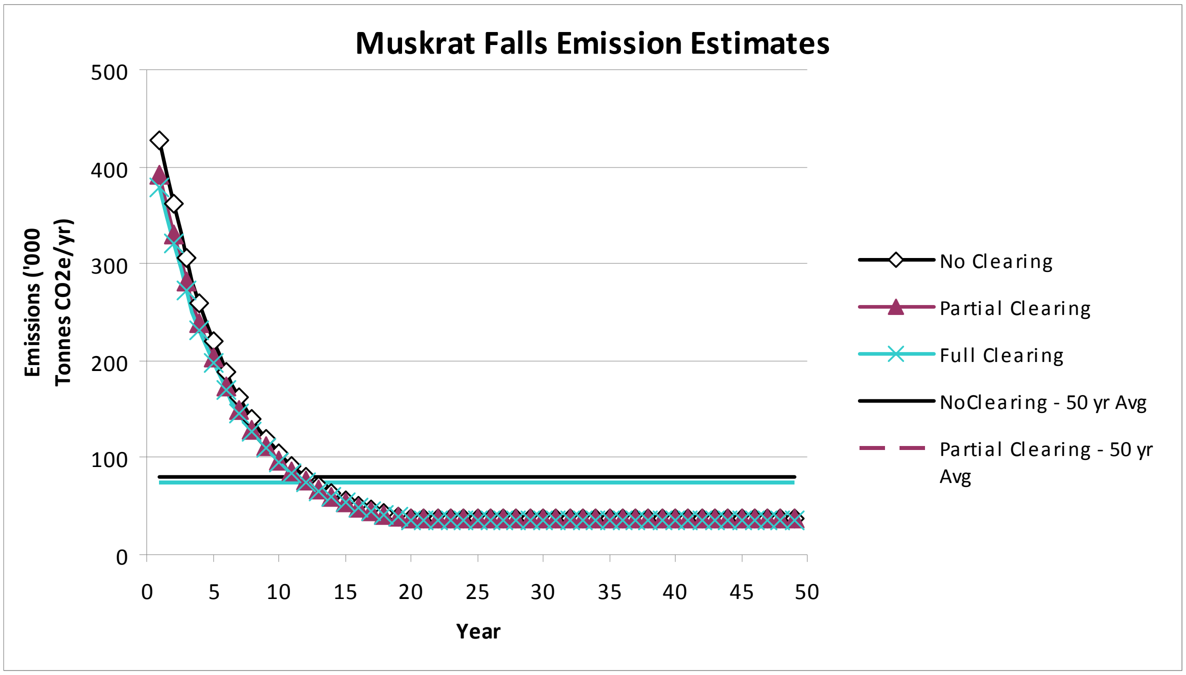

Figure 3 Muskrat Falls CO_2e Emissions for Clearing Scenarios

- **Fish and Fish Habitat**

During the operations phase of the Project, environmental effects from reservoir clearing on Fish and Fish Habitat will be the same regardless of the selected clearing option. Once impoundment occurs the fish habitat within the existing tributaries below the full supply level will be inundated. However, during the construction phase partial clearing is preferred.

Forest cover is important for the protection of Fish and Fish Habitat. The shading provided by riparian vegetation and the buffering offered by forest cover adjacent to rivers and streams helps regulate water quality and temperature through reduction of soil erosion, and moderates water level changes during periods of high run off (Scruton et al. 1997). The tributaries flowing into the Churchill River are important habitat supporting both resident fish populations and the recruitment of fish populations for the main stem of the Churchill River. It is important to maintain the existing productive capacity of the tributaries to contribute to the successful population and productivity of the newly-created reservoirs which will include engineered fish habitat. During the construction phase it is important to protect Fish and Fish Habitat during the period of time between when reservoir preparation begins, and impoundment occurs.

While both full and partial clearing alternatives include a buffer zone of undisturbed vegetation to remain adjacent to all water-bodies, only partial clearing includes extensive forest cover to remain throughout the flood zone below the LSL which is of benefit to protecting fish habitat during the construction phase. The summary in Table 1 shows substantially larger areas of uncleared forest habitat to remain in both Muskrat and Gull Island reservoirs as a result of partial clearing. The additional buffering capacity of this forest cover should help maintain more stable banks and minimize the amount of exposed soil that would be subject to erosion during the construction phase.

During the construction phase, full clearing is expected to have greater adverse effects on fish and fish habitat because the potential for erosion is substantially increased as a result of timber removal, on-site mulch disposal and the exposure of mineral soils to run off events. In addition, while full clearing includes a relatively small increase in new access roads (5%), there are extensive skidder and harvester trails required within the flood zone. The resulting increased erosion may lead to increased sedimentation and nutrient loading of water-bodies that could adversely affect water quality through increased turbidity and decreased dissolved oxygen levels, particularly in smaller tributaries. Given that reservoir preparation is expected to occur over several years, certain sections of fully cleared lands may be left exposed to erosion and severe run off events for extensive periods of time, which will increase the likelihood of degradation of fish habitats prior to reservoir impoundment.

- **Terrestrial Environment**

With respect to the Terrestrial Environment, the presence of the reservoirs and surrounding vegetation will be similar with either of the clearing scenarios post-impoundment. However, several species of wildlife could have different abundances and distribution, in the years following the formation of the reservoirs depending upon whether full or partial clearing is implemented. Of particular importance for this comparison are those species with a relatively limited range within riparian habitats (e.g., wetland sparrows) and/or those that occupy riparian habitats seasonally (e.g., moose).

The preferred alternative of partial clearing was selected, in part, due to the ability to leave important refugia such as existing riparian habitat in place while areas are being cleared to allow new riparian habitat to establish above the FSL post impoundment (Figure 1). The progress of the riparian habitat development will vary from approximately 2-7 years (from the start of reservoir clearing until impoundment) and thus offer varying degrees of suitable alternative habitat during this time frame. The removal of forest cover (up to 15 m from shoreline) in the full clearing scenario may result in a greater loss of habitat at the earlier stages of the Project, displacement of wildlife, and lowered abundance through decreased productivity and increased mortality through predation and hunting. While these Project effects will also occur with the partial clearing scenario, the magnitude would be less than with the full clearing scenario.

- **Economy, Employment and Business**

Reservoir clearing activities will create economic, employment and business opportunities. These benefits will be realized for either clearing option, with a greater increase and/or longer duration associated with full clearing. However, regardless of the clearing option selected, local businesses and services will benefit through provision of required materials and services.

As presented in the response to IR #JRP.6, the estimated employment associated with full clearing will be 20% greater than that for partial clearing. Full clearing will provide an estimated 1,580 person-years (approximately 160 average person-years annually) of employment as compared to an estimated 1,300 person-years (approximately 130 average person-years annually) of employment associated with partial clearing.

In terms of indirect benefits from reservoir clearing, Nalcor Energy is fully engaged with the Forest Services Branch and is fully committed to supporting their efforts in developing secondary wood processing in Labrador regardless of the clearing option selected. To this end Nalcor Energy will be working with the Department in the current request for Expressions of Interest (EOI) for secondary wood processing in Labrador. Nalcor Energy will meet with potential wood processors to provide information on the volumes of timber cleared and the location of material.

The labour force requirements for secondary processing will become available upon finalization of the EOI process. Employment will increase for either clearing option, with a greater increase and/or longer duration associated with full clearing as full clearing would provide more raw material.

However, implementing the partial clearing option would not preclude clearing of additional material within the flood zone by a secondary wood processor, prior to impoundment, provided safety and Project schedule are not compromised. This activity would also be facilitated by the Project as harvesters would have access to roads and bridges constructed for reservoir clearing.

- **Communities**

Regardless of the selected option (full vs. partial clearing), clearing activities will result in negligible increased demand on infrastructure and services over the duration of clearing activities. Clearing activities will be limited to within the Project area, with limited use of the Trans Labrador Highway or other infrastructure.

In terms of Community Health, clearing of the reservoir has the potential to modestly reduce peak fish mercury levels in fish, by reducing decomposition rates and the associated production of methylmercury (MeHg). However, regardless of whether full or partial clearing is implemented reservoir clearing will result in effectively the same modest reductions (within the level of accuracy possible for predictions) in peak fish mercury concentrations (as compared to peak mercury levels calculated for a no clearing scenario), on the order of 10% for full or partial clearing.

The primary cause of increased MeHg levels in new reservoirs is increased decomposition in flooded areas, resulting in more activity by microbes that methylate mercury. The ecosystem becomes more efficient at converting inorganic mercury into MeHg. Estimates of readily degradable carbon pools in vegetation and soils can be used to provide estimates of the potential for reservoir clearing to mitigate increases in decomposition and associated increases in fish mercury levels. For the Lower Churchill Project, estimates of GHG emissions (tonnes CO_2e/yr) have been made for scenarios with no clearing, partial clearing and full clearing (Table 4). These differences in estimated GHGs were used to approximate differences in peak decomposition and MeHg production rates. For the purposes of this estimate, GHG estimates for Year 2 (post flood) were used as an indicator of peak rates of decomposition and peak fish MeHg levels that would follow. With no clearing, emissions are estimated to be 1,160,176 tonnes CO_2e/yr for the combined reservoirs (799,076 Gull Island, 361,100 Muskrat Falls). With full clearing, emissions are estimated to be 11% lower than no clearing in Year 2. With partial clearing, emissions are estimated to be 8% lower than no clearing in Year 2. Thus reservoir clearing is predicted to result in a modest reduction in peak fish mercury concentrations, on the order of 10% for full or partial clearing as compared to peak mercury level concentrations for no clearing.

- **Cultural Heritage Resources**

The effect of reservoir clearing on Cultural Heritage Resources will be the same regardless of whether full or partial clearing is selected.

Historic and Archaeological Resources will be recovered through 1) systematic data recovery (SDR), 2) additional field recording (AFR), and 3) systematic field recording and subsurface sampling (SFR and SS) (Section 6.5.5.1 of Volume III of the EIS; Table 6-3 of Volume III of the EIS). The locations of these sites have been identified, and will be recovered regardless of the clearing option implemented. In addition, a Historic and Archaeological Resources Contingency and Response Plan will be in place so that all Project personnel are aware of the procedures to follow if Historic and Archaeological Resources are discovered inadvertently during Project construction or operation and maintenance (Section 6.7 of Volume III of the EIS).

- **Land and Resource Use**

Regardless of the clearing option selected, the same level of navigability will exist on reservoirs. By definition, the ice and stickup zones will be the main areas in the reservoir that will contribute to floating trash and debris during operations. Once safety and environmental constraints are applied, the same areas will remain uncleared in the ice and stickup zones regardless of the clearing option selected. The trees in the flood zone will have small contribution to floating trash and debris as shown in Table 2. As well, by definition, trees in the flood zone are sufficiently submerged below the low supply level as to not be a hazard to navigation.

Cost-Benefit Summary

A summary of the incremental costs and benefits for full clearing is provided in Table 5. Incremental costs and benefits are provided due to the commercial sensitivity of the capital cost estimates for partial clearing.

Table 5 – Summary of Cost-Benefit Analysis of Full versus Partial Clearing

Consideration	Partial Clearing	Full Clearing
Capital Cost	Baseline	Adverse. Full clearing will increase clearing costs by $200 million
Operating Costs	Baseline	Negligible difference
Schedule Risk	Baseline	Not quantified, but adverse.
Merchantable Timber Recovery	Baseline	Positive. Full clearing will harvest additional merchantable timber with a value of $17 million
Non-Merchantable Timber Recovery	Baseline	Positive. Full clearing will harvest additional non-merchantable timber with a potential value of $3 million if converted to wood pellets
Atmospheric Emissions	Baseline	Adverse. Vehicle emissions and dust will be greater than with partial clearing because of increased transportation requirements and additional road traffic.
GHG Emissions	Baseline	Similar to baseline
Aquatic Habitat	Baseline	Adverse. The larger clearing area removes buffer areas adjacent to habitat.
Terrestrial Habitat	Baseline	Adverse. Full clearing removes a refugia area during construction. Full clearing also increases the potential for erosion from the flood area and sediment deposit into the river during the construction period.
Economy, Employment, and Business	Baseline	Positive. Employment is 20% greater than for partial clearing. (Refer to response for IR#JRP.6)
Communities	Baseline	Neutral. Community health effects are neutral as methylmercury concentrations are similar for both full and partial clearing.
Cultural Resources	Baseline	Neutral. Sites locations have been identified and will be received recovered in both scenarios
Land and Resource Use	Baseline	Neutral. River navigability will be maintained in both the full and partial clearing scenarios.

The incremental economic cost of full clearing over partial clearing is ten times the value of the economic benefit derived. In considering environmental effects, the biophysical effects of full clearing are all adverse. The full clearing alternative also introduces considerable cost and schedule risk for the Project which have not been factored into the analysis, but if they were they would reinforce the conclusion that partial clearing is the preferred clearing alternative.

It should also be noted partial clearing makes a substantial amount of timber available for other uses, which could be the catalyst for some secondary forestry industry in central Labrador. In the event that timber in the flood zone is usable by a third party, Nalcor Energy will cooperate to facilitate the utilization of the timber by the third party.

To summarize, the economic cost of clearing the additional timber in the flood zone far outweighs its value as a resource, and environmental effects are generally adverse. As a result, on the whole, the costs of full clearing significantly outweigh the benefits.

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Requesting Organization – Joint Review Panel **Information Request No.: JRP.148**

Information Requested:

The Proponent is asked to provide the following:

b. **Additional information on the preferred options for storage and eventual disposition of merchantable timber and identification of the preferred option for disposal of slash and implications on methyl mercury, along with a discussion of the advantages and disadvantages of this approach;**

Response:

The preferred option for storage and eventual disposition of merchantable timber is to move the timber to an accessible designated pile down area, consistent with Provincial regulations. These designated wood storage sites will be lay down areas and will be located within the Project area, above the FSL of the reservoir. Although the preliminary locations of the wood storage yards have been determined, the locations will be finalized in the detailed design phase. The preliminary locations are included in the Reservoir Preparation Map Book which is included as part of this response as an attached report (Nalcor, 2010).

This merchantable timber will be available for removal by a secondary wood processor. Pre-impoundment, these areas could be accessed via the reservoir clearing roads. Post-impoundment, a secondary wood processor, or other land and resources user, could access these areas via a barge (the water velocity on the reservoir will be lower than the river velocity pre-impoundment, thus allowing safe access by barge); in winter via snow roads; or over the stable ice cover that will form on the reservoirs. The provision of access infrastructure post impoundment would be the responsibility of the wood processor or land and resource user. Beyond the access roads that will be constructed for the purpose of reservoir preparation, additional access will not be provided by Nalcor Energy.

The preferred alternative for disposal of slash (non-merchantable material) is mulching. However, burying of non-merchantable timber may be carried out in select areas where there is excessive windfall on the forest floor. The locations of these areas will be determined during reservoir clearing operations. Mulching will not require material to be gathered up and transported to collection points and will minimize the amount of non-merchantable material that could interfere with the operations of the generating facility post impoundment. Mulching will be done with a large, purpose built disc-type hammering device to break up the woody material so that it will lay flat on the forest floor and tend to become water logged from rain and snow cover which is expected to accelerate the rate of decomposition. The time between mulching and impoundment will be 1-2 years at a minimum and will be in the range of 2-6 years in the majority of the cleared area.

The implication of the selected method for the disposal of slash on methylmercury is small as it was estimated that this material will account for less than 4% of the total amount of material contributing to methylmercury creation, based on the following:

- As stated in IR# JRP.148a the primary cause of increased methylmercury (MeHg) levels in new reservoirs is increased decomposition in flooded areas, resulting in more activity by microbes that methylate mercury. The presence of readily degradable carbon pools in vegetation and soils contributes to increases in decomposition and associated increases in fish mercury levels. However, the portion of the carbon pool in vegetation (both merchantable and non merchantable) is lower than the portion in the soil. In a study conducted by Hydro Quebec in 2007 (Hydro Quebec, 2007) vegetation accounted for 13 to 22% of the initial pool of degradable carbon, leaving 78 to 87% in the soil layer;

- In cleared areas, merchantable timber will account for almost 90% of the vegetation present (and a similar portion of the degradable carbon) and will be removed;
- Of the 10% vegetation remaining (i.e. non-merchantable timber) it was assumed that all of this material would decompose in the early years after flooding. The total volume of cleared non-merchantable material for Gull Island and Muskrat Falls reservoirs is 91,000 m^3 for the partial clearing scenario. It was estimated that this volume would contain roughly 41,000 tonnes of carbon. This mass of carbon, if fully decomposed, is approximately 4% of the estimated 1,063,878 tonnes CO_2e/yr for the combined reservoirs and would represent a similar portion of it's overall contribution to peak mercury levels;
- In addition, some of the non-merchantable material included degradable carbon estimate will be above the FSL and will not actually be a source of degradable carbon in the reservoir; and
- Mulching of non-merchantable material from 2 to 6 years prior to flooding will also result in a portion of this carbon pool decomposing prior to flooding. Pre-flood decomposition would not contribute to increases in fish mercury levels.

Overall, it was concluded that the method of disposal of cleared non-merchantable material will not have a significant effect on fish mercury concentrations. Other advantages and disadvantages of mulching as compared to other methods of disposing of slash are summarized in Table 1.

References

Hydro-Québec. 2007. Complexe de la Romaine Étude d'impact sur l'environnement. Volume 3 - Milieu biologique (1 de 2).

Nalcor Energy. 2010. Reservoir Clearing Plan – Volume 1, 2010-04-01.

Table 1 Comparison of Approaches for Disposal of Slash

Consideration	Approach			
	Removal Above the Flood Zone	**Burial**	**Burning**	**Mulching**
Technical Feasibility	Removal of slash from the flood zone would involve transporting it over long distances to prepared pile down areas. To collect slash and move it would be very difficult, and not technically feasible.	The large scale burying of slash is not a technically feasible option because it would require a major collection effort to minimize the ground disturbance. Small scale burying of slash may be a technically feasible option in areas where slash is excessive.	On other projects there were problems with trying to burn slash. Excessive precipitation and humidity made burning difficult and created a fire hazard when conditions were ideal for burning. Burning only reduces the biomass to one third its volume; the remaining biomass would still need to be buried.	The preferred alternative is mulching. Mulching is considered the most technically feasible approach, since material collection will not be required, and will minimize the amount of slash that will become a problem as the mulch will not float after impoundment (Nalcor, 2010).
Economic Feasibility	Removal could be accomplished if the material was bundled. This would not be economically feasible unless a secondary wood-processor were to undertake this exercise as part of a wood pellet operation.	Due to irregular ground conditions and, based on the field visit conducted in October 2009, there are extensive areas of wind fallen trees. As a result, burying this material would require moving substantial volumes of additional material and would not be economically feasible. Small scale burying of slash may be an economically feasible option in areas where slash is excessive.	Burning is economically feasible.	Since material collection will not be required mulching is also considered the most economically feasible approach.
Atmospheric Effects	If slash were to be removed above the flood line a fire hazard may be created in the dry summer season (due to the piling of slash in windrows). If forest fire were to occur air quality would be affected. The removal of slash to above the flood line would result in a decrease to GHG emissions from the reservoir during operations but this amount would be small in relation to the total GHGs.	Atmospheric emissions and GHG emissions from the Project would not increase, provided that the bottom of the reservoir allows for wood waste to be buried sufficiently deep to induce anaerobic conditions and to adequately reduce soil oxygen content.	Burning will lead to increased air emissions from the Project due the burning of the material and will increase the potential for a forest fire and the associated emissions.	Similar to mercury the main source of decomposition (and GHG emissions form the reservoir) is the soil. The additional GHGs from the portion of mulch that that is submerged and has not decomposed mulch would be small in relation to the total GHGs.

Consideration	Approach			
	Removal Above the Flood Zone	**Burial**	**Burning**	**Mulching**
Aquatic Effects	The removal of slash above the flood zone would reduce woody debris within the reservoirs. While the volume of water through the reservoirs limits the potential for anoxic conditions to occur, any remaining material will slowly decompose and could potentially depress oxygen concentrations within deeper portions of the reservoirs.	There would be no increase to aquatic effects from the Project provided that erosion control is implemented where there is any risk to soil cover, and burial depths are adequate to prevent oxygen depletion of sediments.	Burning slash would not increase aquatic effects from the Project.	During the operations phase of the Project, submerged mulched material would continue to decompose and interact with the aquatic environment. During operations decomposition of material within the water column would utilize dissolved oxygen and potentially decrease its bioavailability. Given the water volume of the proposed reservoirs, as well as the high flushing rate, the limited quantity of mulch decomposition is not expected to change water quality throughout the reservoir, and any reduced dissolved oxygen which may develop is likely to be localized and temporary.
Terrestrial Effects	The removal activity would cause a certain level of human, noise and other disturbance. There would be some additional disturbance to wildlife species due to the storage of areas. There are no biophysical advantages in terms of nutrient cycling or other ecological considerations with removal as opposed to the other alternative to handle slash.	Burial would occur within the area of the inundation and hence not result in additional disturbance beyond the physical footprint of the Project. However, the burial option does not allow for any return of nutrients and organic material to the forest ecosystem.	Burning would occur within the area of the inundation and hence not result in additional surface disturbance although emissions and the potential for uncontrolled fire would increase. As the ash material would be left in place, there would be limited opportunity for the return of nutrients and organic material to the forest ecosystem.	Mulching would occur primarily within the area of inundation. As the material would be left in place within the area to be impounded, there would be no biophysical advantages in terms of nutrient cycling or other ecological considerations with mulching as opposed to the other alternatives to handle slash.

Consideration	Approach			
	Removal Above the Flood Zone	**Burial**	**Burning**	**Mulching**
Socio-Economic Effects	If the slash was collected by a secondary processor, there would be socio-economic advantages for removal of slash as a result of increased indirect employment. The remainder of the socio-economic effects would not likely be measurably different regardless of the disposal method selected for slash.	For the burial option slash would not be available for use by a secondary wood processor. The remainder of the socio-economic effects would not likely be measurably different regardless of the disposal method selected for slash.	For the burning option slash would not be available for use by a secondary wood processor. The remainder of the socio-economic effects would not likely be measurably different regardless of the disposal method selected for slash.	If the mulched material is collected by a secondary processor, there would be socio-economic benefits as a result of increased indirect employment. The remainder of the socio-economic effects would not likely be measurably different from those assessed in the EIS.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.148**

Information Requested:

The Proponent is asked to provide the following:

c. **A copy of the referenced report and material being prepared for the Department of Natural Resources on the preferred disposal methods and the environmental effects of burying wood waste as opposed to removing it from the site;**

Response:

A copy of the referenced report is attached and includes a discussion of the preferred disposal methods for wood waste and the associated environmental effects. Due to the commercially sensitive nature of contracting information and detailed cost estimates these appendices have not been provided the attached report.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.148**

Information Requested:

The Proponent is asked to provide the following:

d. Copies of the GIS maps showing proposed infrastructures for reservoir clearing;

Response:

Copies of the GIS maps showing proposed infrastructure for reservoir clearing have been provided as part of this response.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.148**

Information Requested:

The Proponent is asked to provide the following:

e. **A more detailed description of the effects of impoundment on fish and fish habitat by individual month. If the Proponent is committing not to carry out impoundment during certain months, these may be omitted;**

Response:

The optimal timing of impoundment would begin in August prior to most spawning of fall spawning species. This would minimize disturbance and maintain sustainable fish populations by protecting as many life-cycle stages as possible both within and downstream of the reservoirs. A compensation flow of 30% Mean Annual Flow (MAF) will be provided to maintain downstream fish habitat during impoundment for fish to spawn and eggs to develop. With initiation in August, it would be anticipated that impoundment of Gull Island reservoir would be completed by October. Muskrat Falls reservoir would be impounded much quicker and would likely be completed by September. Provided below is a description of the effects of impoundment on fish and fish habitat for fish within and downstream of the reservoirs.

The goal of minimizing disturbance and maintaining sustainable fish populations by protecting as many life-cycle stages as possible during impoundment was incorporated into the development of the most effective timing of impoundment. While the information request relates to a description of the effects of impoundment on fish and fish habitat by individual month, the potential effects are relative to life-cycle stage and the time period(s) associated with each. Therefore, the detailed description provided below is based on the various fish life-cycle stages, described with a monthly breakdown where it assists in the description.

The primary parameters that will affect fish and fish habitat during impoundment are:

1. The length of time required to fill the reservoirs (and hence the length of time at downstream compensatory flows); and
2. The potential effect on sensitive fish life-cycle stages.

The preferred inundation schedule from an aquatic effects perspective and disregarding other technical, economic and environmental considerations would be one that minimizes both of these potential effects listed above to the extent possible, both downstream and within the reservoirs.

The four fish life-cycle stages used by Fisheries and Oceans Canada (Newfoundland Region) are spawning, young-of-year, juvenile and adult (see Grant and Lee 2004). As stated in IR response IR# JRP.28, non-mobile life-cycle stages would be most susceptible to effects related to inundation as they cannot respond to habitat reduction/dewatering. Table 1 presents a monthly summary of interactions of sensitive fish life-cycle stages to reduced river flow during impoundment. In general, the most sensitive life-cycle stages are those that are non-mobile, associated with spawning (i.e., egg incubation/development and hatching) that cannot react to changes in water levels and/or flows. The extent of the effect on these stages are more sensitive downstream of the reservoirs, as eggs that are incubating within the reservoir footprint will not be dewatered during inundation.

Table 1 Sensitive Life History Stages of Aquatic Fauna for Reservoir Impoundment

Species	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Ouananiche	I	i	i	i	i	i	i	i	i	h	h							s	s	s	s	s	i	i
Brook Trout	I	i	i	i	i	i	i	i	i	h	h						s	s	i	i	i	i	i	i
Lake Trout	I	i	i	i	i	h	h	h									s	s	s	s	i	i	i	i
Lake Whitefish	I	i	i	i	i	i	i	i	i	h	h							s	s	s	i	i	i	i
Round Whitefish	I	i	i	i	i	i	i	h	h	h									s	s	s	s	s	s
Northern Pike								s	s	h														
Lake Chub											s	s	s	h										
Longnose Dace											s	s	h	h										
Pearl Dace									s	s	s	h	h											
Longnose Sucker											s	s	h											
White Sucker											s	s	h											
Burbot	S	s	s	s	s	s	h	h	h	h	h	h											s	s
3-spine Stickleback												s	s	s	h									
Sculpin										s	s	i	h											

Low Interaction
Moderate to High Interaction (s – spawning; i – incubation; h - hatching

As shown, there are two general spawning strategies employed by species within the lower Churchill River system; spring spawning and fall spawning.

Spring spawners typically begin activities (e.g., migration, site selection and egg deposition) after ice cover is broken and water temperatures and daylight hours begin to increase. Species that utilize spring spawning include Northern pike, Longnose and White suckers, and most of the smaller prey species. Due to increasing water temperatures during the spring, eggs laid require relatively less time to develop and hatch.

Fall spawners typically begin activities as water temperatures and daylight hours decrease. Species utilizing a fall spawning strategy in the lower Churchill River include the salmonid group (e.g., ouananiche, brook trout, lake trout and whitefish). Because water temperatures are decreasing in the fall, eggs require much more time to develop and therefore, hatching typically occurs in the spring after a relatively long incubation period.

In this respect, most species life-cycle stages are mobile during late summer (August); however, with the possible exception of May or June, reservoir inundation cannot be completed in a single month, especially during the time period when flows are typically the lowest. Impoundment during the summer low-flow period would increase the duration of impoundment activities. Estimated inundation timeframes with compensation flow are presented in Table 7 within IR response IR# JRP.28 and indicate that inundation of Gull Island reservoir will take between 28-34 days during the spring freshet (May-June) and 48-54 days in the summer low flow period (July-August). In addition to considering the timing of impoundment to offer the best protection for fish, the duration of reduced water can also have an effect; generally the shorter the time period the better. While the period of July to September would have the least overlap with non-mobile life-cycle stages, the time to impound would be the longest, and hence, fish downstream of the reservoirs will be subject to extended low-flow periods. In addition to low flows, this is also the time period when water temperatures would be highest and most stressful for fish. This would affect fish within the reservoirs less as water levels would rise during impoundment.

It should be noted that while mobile life-cycle stages are more capable of responding to reduced water flows, the potential for stranding of fish downstream of the reservoirs has also been considered in the effects of impoundment and best timing. Many species may not move quickly enough to deeper refugia habitat or may move into deeper pockets of water that become isolated and small. In this respect, mitigations such as fish relocation activities will be initiated to collect and relocate stranded fish to suitable locations, to the extent possible.

References

AMEC. 2001. HADD Determination Methodology, Churchill River Power Project (LHP00-07) Churchill River, Labrador. Prepared for Newfoundland and Labrador Hydro, St. John's, NL.

Grant, C.G.J. and E.M. Lee. 2004. Life History Characteristics of Freshwater Fishes Occurring in Newfoundland and Labrador, with Major Emphasis on Riverine Habitat Requirements. Can. Manuscr. Rep. Aquat. Sci. 2672: xii+262p.

McCarthy, J.H., C.G.J. Grant and D.A. Scruton. 2007 - Draft. Standard Methods Guide for the Classification and Quantification of Fish Habitat in Rivers of Newfoundland and Labrador.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.148**

Information Requested:

The Proponent is asked to provide the following:

f. A rationale as to why pre-upper Churchill flow levels were used as the baseline for calculating minimum flows during impoundment; and

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Response:

Pre-upper Churchill flow levels were not used as the baseline for calculating minimum flows during impoundment. The winter low-flows identified in the IR# JRP.28(c) response related to the pre-upper Churchill Development were not used in calculations to obtain the minimum flow, but rather were presented to show that flows of this magnitude (i.e., 534 m^3/s) have been experienced within the river system.

The minimum flow estimation was based on the Mean Annual Flow of the existing river at the location of the Gull Island dam (i.e., 1,780 m^3/s – see page 2-17 Volume II A of the Environmental Impact Statement). Tennant's Montana fixed flow method (Tennant 1976) and a document compiled by Fisheries and Oceans Canada (DFO) and the provincial government of Newfoundland and Labrador to understand and address instream flow needs within the province (Gosse et al. no date) were used to determine the minimum flows during reservoir filling:

$$1{,}780\ m^3/s \times 30\% = 534\ m^3/s$$

While IR# JRP.28(c) stated that the approximate flow would be 500m^3/s, the actual value is 534 m^3/s.

References

Gosse, M.M., Brown, D. Scruton and A. Beersing. No Date. A Common Approach to Understanding Instream Flow Needs Assessment in Newfoundland and Labrador. Department of Fisheries and Oceans, St. John's, NL and Government of Newfoundland and Labrador Department of Environment, Water Resources Division, St. John's NL. 10pp., 3appendices

Tennant D. L. 1976. Instream flow regimes of fish, wildlife, recreation, and related environmental resources, In: J.F. Osbornes and C.H. Allman (eds) Instream Flow Needs Symposium, Vol II Bethesda MD: American Fisheries Society.

Requesting Organization – Joint Review Panel **Information Request No.: JRP.148**

Information Requested:

The Proponent is asked to provide the following:

g. **Additional information on the potential for increased sedimentation of the reservoirs during impoundment and what mitigation is proposed.**

Response:

An increase in sedimentation (i.e., the processes of erosion, transport, and deposition of sediment) is often associated with newly formed reservoirs because new shorelines created by inundation begin to erode as they become stabilized. The eroded sediments from this, and upstream sources, settle out in the slower moving water of the reservoir. During the process of impoundment, however, the potential for increased sedimentation in the Gull Island and Muskrat Falls reservoirs is predicted to be low, especially if the time it takes to create the reservoir is relatively short.

The degree of sedimentation during impoundment is highly dependent upon multiple factors including:

- Erodibility of bank material;
    - Wave energy
    - Shoreline composition (also effects transport ability and settling velocity)
    - Shoreline geometry
- Slope failures (mass wasting); and
- Bottom substrate/Channel morphology
    - Frictional forces (affects water velocity)

Each of these factors is further influenced by the rate of reservoir impoundment. These processes and reservoir specific conditions are discussed further in the following paragraphs.

Erodibility of Bank Material

Well developed shorelines typically experience relatively slow erosion rates, due partially to the existence of offshore bars, which are typically associated with well established shorelines. The presence of the bar helps to reduce potential wave energies along the shoreline (Newbury and McCullough 1984). During reservoir impoundment it is unlikely that there will be any offshore structure available to buffer against wave action therefore the slopes of the impounded reservoir will be exposed to the full wave potential, which in reservoirs is predominantly wind driven (Kachugin 1963; AMEC 2008). During impoundment, the surface area of the water will increase, allowing for a greater overall distance over which the wind can generate and increase the size of waves (i.e. greater fetch). This typically results in larger waves within a reservoir when compared to pre-reservoir conditions. An increase in wave energy along a newly exposed stretch of shoreline will increase the amount of bank erosion, and thus allow new material to enter the developing reservoir. The rate of reservoir impoundment will also influence how much new material actually gets eroded.

The rate of water level rise during the filling of each reservoir will be relatively quick. Rate estimates for the Gull Island reservoir are as high as 21-27 m per day initially, with a minimum rate near 1 m per day as the inundation nears completion. Likewise, the Muskrat Falls reservoir fill rates are estimated to begin at 9-12 m per day with a final fill rate near 1 m per day as the reservoir is completed. These rapid fill rates will limit the amount of time the rising water level will have to interact with the shoreline and the effects of increased bank erosion due to fluvial erosion, i.e., wave scour and water flow velocity, are predicted to be minimal.

Slope Failures (Mass Wasting)

The banks along the lower Churchill River are generally high and steep, and in many cases are prone to natural slope failures. With an increase in water level, hydrostatic pressure exerted by the water body can work to add stability to the bottom portions of the bank as a reservoir fills. On the other hand, the increased weight within the bank itself due to saturation as the reservoir matures may have the reverse effect. As a whole, the banks initially become more unstable as a result of wave and water velocity effects acting on the newly exposed banks due to reservoir filling. The result of these erosional forces acting upon the new shoreline, which will essentially erode portions of the bank at the water's edge, could potentially lead to an increase in bank failures from undercutting effects. This would lead to new sediments being released into the reservoir system and would likely continue until a stable shoreline is created post impoundment. More information on the effects of reservoir creation (Muskrat Falls only) is presented in IR response IR# JRP.159.

Bottom Substrate/Channel Morphology

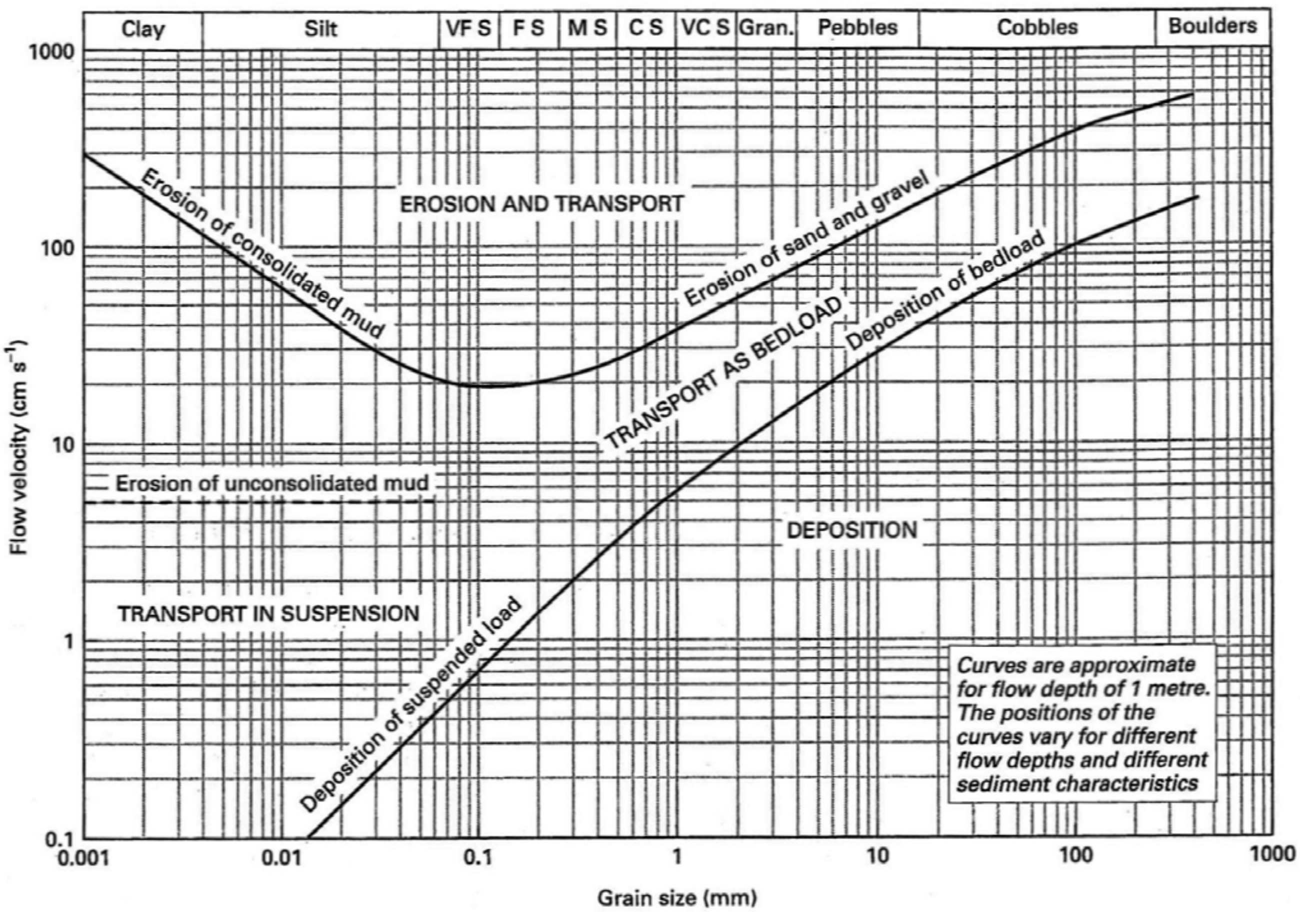
An increase in the transport and deposition of sediment in suspension and as bedload, during impoundment, is highly dependent upon the bottom substrate and channel morphology, as well as the velocity of water flow in the reservoir throughout impoundment.

- **Muskrat Falls Reservoir**

  Based on the soil types within the proposed Muskrat Falls reservoir and presented by AMEC in their 2008 slope stability report. It can be concluded that the slopes affected during inundation will be predominantly comprised of E4 and E5 soil types (see Table 1). For the most part both soil types are comprised of a very high percentage of easily transportable materials, i.e., sand, silt, and clay. Depending on the water velocity at each impoundment stage, all of these materials could potentially become suspended and transported within the water column. For instance, water velocities of approximately 1.0 m/s can transport the coarser size fractions of sand in suspension. At slower velocities, it would be deposited or potentially transported by bedload (see Figure 1). Again using coarser sands as an example, deposition would not typically occur until water velocities decrease to approximately 0.1 m/s. However, based on the slow velocities anticipated within Muskrat Falls reservoir during impoundment, i.e., order of magnitude of 0.01 m/s, it can be stated that the slit and clay size fractions, as well as some very fine sand would be transported in suspension once they enter the system with their rate of deposition depending on their settling velocity. At such low velocities, sediments larger than approximately 0.15 mm, would not likely be transported in suspension, or as bedload and would quickly be deposited; again the rate of deposition would be dependent on their settling velocity. Minaskuat (2008) determined the settling rate for silt and clay to be 21 and 0.6 meters per day, respectively. This means that silt will settle out of the water column at a much faster rate than clay, and because sand is of a larger grain size than silt, it will likely have a faster rate than that reported above.

Table 1 Soil classification and estimates of substrate composition within each, Churchill River (from AMEC 2008)

Class	Description	Estimated Substrate Composition	Habitat Classification
E1	- Blocky colluvial deposits - Terrain dominated by competent Bedrock	95% Bedrock 5% Boulder	Littoral Coarse
E2	- Morainal veneers (most rubbly colluvial deposits with high coarse fragment content)	35% Bedrock 55% Boulder 10% Rubble	Littoral Coarse
E3	- Morainal blankets - Glaciofluvial gravels - Soft, friable bedrock	30% Boulder 20% Rubble 25% Cobble 20% Gravel 5% Sand	Littoral Medium
E4	- Some morainal blankets steeper than 60%, or steeper than 30% if gullied or poorly drained - Fine textured lacustrine (silts and clays), glaciolacustrine, glaciomarine, glaciofluvial or aeolian silts, slopes less than 15% - Colluvial deposits derived from the above material with the same slope or moisture criteria - Colluvium derived from soft, friable rock steeper than 60% or steeper then 30% if gullied	5% Gravel 90% Sand 5% Clay	Littoral Fine
E5	- Fine textured lacustrine (silts and clays), glaciolacustrine, glaciomarine, glaciofluvial or aeolian silts, slopes steeper than 15%, or gullied or poorly drained - Glaciofluvial or fluvial sands with low bulk density, steeper than 30% or gullied or poorly drained - Peat, organic sols or tufa on sloping ground - Colluvial deposits derived from the above materials with the same slope or moisture criteria	40% Sand 40% Clay 20% Organics	Littoral Fine



Source: Nicholes, G. 1999. Sedimentology and Stratigraphy, Blackwell Science Ltd.

Figure 1 **Hjulström Diagram, Showing the Relationship Between the Velocity of Water Flow and the Transport of Loose Grains**

The net effect on the system during impoundment of the Muskrat Falls reservoir will likely be an increase in the amount of clay and silt that is transported in suspension, as well as deposition of sand and any larger sediments on the river bottom in localized areas, i.e., sediments larger than very fine sand would not be transported far from their source and deposition would be localized. It should be noted that due to the quick rate of filling, the quantity of material that would become eroded and enter the system and thus available for transport and deposition is predicted to be minimal; the one exception would be a potential slope failure which would have the potential to introduce a larger quantity of material into the system.

- **Gull Island Reservoir**

  Again with reference to AMEC's 2008 report, the soil types present within the Gull Island Reservoir during inundation can be classified as E2 and E3 soils (see Table 1). Of these two soil types, and in the context of the water velocity expected within the area of the Gull Island reservoir during inundation (estimated average of 0.03 m/s), sand is the only material type that could be transported. Furthermore, it would only be the medium size fraction of sand and smaller that could potentially be transported as either bedload or suspended load respectively (see Figure 1).

This would mean that the vast majority of the material, once eroded, would be deposited close to the source. Depending on the stage of reservoir impoundment and the amount of material present, the larger substrate (large cobble, rubble, and boulder) could potentially act to armor the banks against further erosion. Figure 2 shows an example of larger shoreline material armoring a portion of the existing lower Churchill River as smaller substrates are moved by suspended or bedload transport.

Again, due to the quick rate of filling, the quantity of material exposed to erosion, and thus available for transport and deposition, is predicted to be minimal. The one potential exception would be a slope failure, similar to that mentioned above. Erosion within the reservoir would have negligible effect on bedrock.

Figure 2 Armouring of Shoreline Substrates, Lower Churchill River

Mitigation Measures

Limited options exist to mitigate increased erosion and sedimentation effects during reservoir filling. Methods described in the literature relate to erosion in reservoirs once they are filled and operating as this is when the majority of erosional forces and processes occur (see Proctor and Redfern 1980; Newbury and McCullough 1984; Bestman 1992; Allen 2001; Shin and Oh 2007).

The main mitigation measures which have been attempted with other projects have been to leave trees within the flooded zone as an artificial bar in an attempt to dissipate wave energy, and to artificially armor the shoreline to reduce the erosion of finer material.

The partial clearing option can also be considered a form of mitigation, as the uncleared areas in the flood zone will not be as susceptible to erosion and sedimentation effects during construction.

Given the short periods for reservoir impoundment, no mitigation measures are proposed to avoid sedimentation during impoundment.

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