# Development projects, trans-boundary issues and cumulative impacts on the Mackenzie River's Watershed (NWT, Canada)

**Rosa Galvez[a], C.C. (Luke) Pettet[b]**

(a) Department of Civil and Water Engineering, Laval University, Quebec, Canada. Rosa.galvez@gci.ulaval.ca

(b) Eco Water Strategies, Quebec, Canada luke@pettet.ca

**ABSTRACT**

The Mackenzie River Watershed (MRW) located in the northwest of Canada is a natural water-ice-climate system that helps stabilize the Earth's climate. Its vast drainage area includes all the North West Territories (NWT) and portions of the provinces of Alberta, British Columbia, Saskatchewan and the Yukon. These provinces and territories have various levels of jurisdiction over lands and rivers forming part of the MRW.

The MRW is the most valuable water resource for the NWT. The MRW land contains numerous natural resources such as oil, gas, precious metals/stones and timber. Planet warming means milder winters so previously non-viable projects, because of excess snow, ice and cold, are now being proposed by national and international conglomerates. Any perturbation within its hydrological regime will affect directly the ecosystem and the people living in NWT. The enormous territorial extent and vulnerability of the MRW, and worldwide awareness of this region's importance, demonstrate that environmental impact assessments of new developments (e.g. hydroelectricity, pipelines) can no longer focus just on direct impacts. Indirect and cumulative impacts need to be considered in order to sustainably protect the natural resources and ecosystem of the MRW.

This paper explores a new proposed dam project (Site C) in British Columbia and its impact on the MRW. In its preliminary environmental assessment, the promoter stated the potential impacts due to Site C are negligible, except for ice regime changes requiring further study. However, this assessment covered only a limited 100 km corridor downstream from the proposed location. Further, several rehabilitation works are being conducted by BC Hydro as mitigation measures for past impacts caused by an upstream water project, the mega WAC Bennett Dam. In this study we aim at presenting key issues that demonstrate the vulnerability of the Mackenzie watershed and the need to include indirect and cumulative effects (due to other projects) during environmental impact evaluations.

**KEY WORDS:** *Transboundary water management, cumulative effects, resources, climate change, dams.*

## INTRODUCTION

The Mackenzie River Watershed (MRW) is of worldwide importance because of its vast ecological, cultural and economic values. Spanning more than 170 million hectares, 2/3 which are intact and undisturbed by development (Anielski & Wilson, 2007), the watershed encompasses over half of Alberta and the Northwest Territories (NWT) as well as portions of British Columbia (BC), Yukon and Saskatchewan. The region is ecologically diverse, representing nine of Canada's 15 eco-zones (Natural Resources Canada, 2011). More than one quarter of Canada's Boreal Forest region is located within the watershed. The Mackenzie River is the longest river in Canada at 1,738km. Its headstream, the Peace River is the second longest river in North America at 4,241 km in length. The Mackenzie and its tributaries drain 1,805,200 square kilometres. Its mean discharge is 10,700 cubic metres per second into the Mackenzie Delta. The watershed is affected by millions of people around the world who consume natural resources extracted from the region (oil, gas, heavy metals and timber). A recent assessment of the Mackenzie watershed's natural capital concluded that the ecosystem service performed by the climate regulation, water storage and wildlife habitat are worth significantly more than the gross domestic product (GPS) generated by natural resource development (Anielski and Wilson, 2007). The Peace River, and its dams within BC and Alberta, impact the MRW. Many other ongoing activities (mines and tar sands, see Fig. 1) impact the Mackenzie watershed and its sub-basins. The Peace River runs from the head of the Finlay and Parsnip rivers (now drowned in Williston Reservoir since the WAC Bennett Dam was built) to its delta at Lake Athabasca in Wood Buffalo National Park, it connects with the Slave River, which runs into Great Slave Lake, then the Mackenzie River in the Northwest Territories, which empties into the Arctic Ocean. A new BC Hydro dam project (Site C) is proposed downstream from the Bennett Dam which risks causing further impacts to the MRW.

The NWT faces competing internal challenges between resources (water, forest) and industry (mining, oil) and greater concerns from outside its borders. The Mackenzie watershed ecosystem suffers the accumulation of impacts of these industries. If NWT water becomes compromised, what happens to the health of the ecosystem and those who rely so heavily upon these natural resources; Aboriginal people have lived in the watershed for thousands of years and continue to have a close relationship with the land. This paper aims to present some key issues concerning present changes and potential impacts.

## ENVIRONMENTAL IMPACTS DUE TO DAMS

Environmental impacts are at the intersection of developmental projects and ecosystems. Most associate impacts by development, industry or infrastructure projects to be negative and adverse; environmental impacts can also be positive, usually in terms of employment generation and economic growth. More particularly, with respect to dams, positive impacts can include: flood control, electricity, irrigation water, etc. It's this double potentiality of projects, to be beneficial or detrimental to populations, which places Environmental Impact Assessments in the delicate position of being the basis for sound and sustainable decisions. Impacts can affect the environment locally, regionally or at much larger scales such as nationally or worldwide.

Generally, dam impacts are consequences of reservoir excavation and flow regulation operations that will affect upstream/downstream flow hydraulics and habitats. Potential negative impacts of large-scale hydrological alterations include:

- Changes in water volume up/downstream of the dam;
- Changes in ice formation/movement (ups/downs);
- Changes in spring water flows & flooding areas;
- Changes in water quality;
- Loss/change of habitats in floodplains, riparian zones, and adjacent wetlands;
- Habitat fragmentation within dammed rivers;
- Deterioration/loss of river deltas and ocean estuaries;
- Deterioration of irrigated terrestrial environments and associated surface waters;
- Impacts on First Nation and other resident's activities and life quality;
- Global climate change.

## SITE C AND IT'S POTENTIAL IMPACTS

The Site C project includes a dam for electricity purposes (location in fig. 1). Cost estimates range from $2 to $3.5 billion. The Site C Clean Energy Project is currently in Stage 3 - environmental and regulatory review. Construction is subject to environmental certification and required regulatory approvals to ensure the Crown's constitutional duties to First Nations are met. The environmental studies conducted by BC Hydro include: wildlife, climate monitoring, geotechnical studies, and evaluation of existing forestry roads and seismic lines, for specific areas along the Peace River between the Williston Reservoir and the Alberta border thus, only within the BC territory (BC Hydro, 2011). Referenced BC Hydro environmental studies showed the evaluation of potential impacts in a reduced study area comprising a narrow corridor upstream and downstream the potential location of the Site C reservoir.

This evaluation concluded that the potential downstream effects associated with the Site C project, with respect to downstream flows, water elevations, sediment transport and geomorphology (riverbed forms and processes that shape them) suggest relatively few notable changes beyond those within a few kilometres downstream from the dam.

It has been argued that Site C dam would be built on a river that already supports two dams, rather than a wild, untouched stream. However, it can also be argued that due to previous dams, the Peace River vulnerability is higher and therefore anthropological stresses should be reduced. Further, although potential impacts are said to be minor compared to those caused by the Bennett Dam (e.g. flow reduction, volume retained), numerous studies are still evaluating the impacts 40 years later. In fact BC Hydro is mandating studies for side channel rehabilitation along the Peace River suggesting there was damage to fish habitats.

In the absence of a proper social-economical evaluation, it appears that the decision to go ahead or postpone will be


Figure1. The Mackenzie River Watershed showing site C and other major projects in view

based on energy and economic factors (cost-benefit analysis) and less on social or environmental factors.

With the benefit of retrospection concerning legal pursuits/negotiations/mediation issues with aboriginal groups and new models of both economic and social well-being, new questions have been asked about the WAC Bennett Dam impacts. Site C project raises questions concerning hypothetical land for farming, cumulative impacts on flow changes, loss and disruption of fish and wild life habitat and true transparency behind the economics of the British Columbia energy sector.

### *Energy economic considerations*

According to BC Hydro, the new Site C dam is needed to satisfy growing electrical demands of the province. BC Hydro's Long Term Acquisition Plan identified 8,242 potential sites for electricity generation in the province. So far over 500 applications have been made by private corporations for the water licenses on these potential sites and 46 projects are now either built or under construction (BC Hydro web site).

Notwithstanding, substantial controversy opposes BC Hydro's justification for a new dam given that BC counts with abundant energy resources and that BC Hydro generates sales in lucrative adjacent markets to the US and Alberta (prices fluctuates between $20 and $140 per KWH). While the exports to US appear to follow peaks during US winter, exports to Alberta are more homogenous during the year. According to Sopinka and van Kooten (2010), BC was a net exporter prior to 1993 while between 1993 and 2008 BC was a net importer for 7 years and exporter for 8 years. However, it should be noted that the net export years presented much higher exported GWh than the imports (max export 10M versus max import of 4M). The data shows a clear correlation between these two parameters: when the price of electricity rises in Alberta, BC Hydro sends more MWh to Alberta lines.

According to information on BC electrical plants, higher capacity is already possible. BC Hydro has a current estimated capacity of 13,250 MW. To that capacity one can add the 1,000MW of the Mica dam upgrade; 500MW by the Revelstoke Dam plus all the other renewable energy projects (approx. 1,110MW) to be added in the near future. According to BC Hydro forecasts, provincial demands by the year 2027 will reach 14 000 MW. Considering the aforementioned, BC is capable of attaining electrical demands and would save in capital costs by augmenting the present installations instead of building the Site C dam.

## SITE C PROJET C AND ITS REGIONAL AND CUMULATIVE IMPACTS (MRW)

### *Transboundary agreements*

The governments of Canada, British Columbia, Alberta, Saskatchewan, and the Northwest and Yukon Territories, recognize their shared jurisdiction to manage water and the environment in the Mackenzie River Basin. They have signed the Mackenzie River Basin Transboundary Waters Master Agreement. This agreement, which came into effect in July 1997, committed the signatories to a number of overarching principles in managing their water resources and made provisions for the development of bilateral water management agreements. The agreement also established the Mackenzie River Basin Board which, among other responsibilities, implements the master agreement and any related bilateral agreements. In 2005, B.C. and Alberta signed a Memorandum of Understanding (MOU) on Bilateral Water Management Agreement Negotiations. The document laid out the process for negotiating a Bilateral Water Management Agreement. The MOU noted the agreement would focus on the Peace River watershed.

### *Hydraulic flows: Peace and Mackenzie River*

Various studies have been conducted at the PAD (Peace-Athabasca Delta). According to Leconte et al. 2006, since 1968, approximately 24% of the drainage area has been impacted by the Williston Reservoir, located 1,200 km upstream of the PAD. The PAD has experienced two major drought periods over the last three decades (Prowse et al., 2002). The first drying trend was associated with the construction and rapid filling of the Williston reservoir. Despite this considerable distance, regulation has raised flows during the fall and winter seasons and notably diminished the spring/summer peak flow at Peace Point (at the northern extreme), affecting water levels within the PAD. It is mentioned by Leconte et al. (2006) that average June flows were reduced from 8000 to 4000 $m^3/s$ following regulation, while average March flows increased approximately from 500 to 1500 $m^3/s$. To mitigate these effects of flow regulation, two weirs were installed in 1975 and 1976 to restrict the northward outflow of water. Although these measures have been largely successful in restoring the natural summer peak water levels within the PAD, average summer and minimum water levels have been raised (Aitken and Sapach, 1994).

The Mackenzie River amalgamates and moderates tributary rivers regimes to deliver spring peak flows, followed by declining summer discharge and low winter flows, to the Arctic Ocean. The mountainous sub-basins in the west (Liard, Peace, and northern mountains) contribute about 60% of the Mackenzie flow, while the interior plains and eastern Canadian Shield contribute only about 25%, even though the two regions have similar total areas (each occupying about 40% of the total Mackenzie Basin). The mountain zone is the dominant flow contributor to the Mackenzie in both high-flow and low-flow years.

The Slave River contributes over 75% of the inflow to Great Slave Lake; one of the main tributaries to the Slave River is the Peace River. Using flow measurements from 1921 to 1999, Kokelj (2003) reported that the average annual peak of the Slave River has decreased by about 18% while average annual low flow has increased about 92% after operations began at Bennett Dam. These major variations clearly show the interconnections and impacts of flow manipulations at distances far from the Bennett Dam.

Gibson *et al.* (2006) observed water levels and ran a daily water balance model to build a naturalized water level history for Great Slave Lake dating back to the 1967 completion of the WAC Bennett Dam. Comparison of water level observations since 1938, and water balance scenarios for 1964–1998, assisted in constraining the probable magnitude and likely direction of climate and regulation impacts on the lake's water level history. The findings of this study suggests that the effect of flow regulation has been to dampen annual water level variability by about 20 cm, to reduce annual maximum water levels by about 14 cm and to shift peak water levels earlier in the season by about 1 month. Meanwhile, climate has tended to enhance water level variability by 8 ± 2 cm, to enhance maximum water levels by 10 ± 3 cm and to advance the timing of maximum water levels slightly more than one week. Climatic and regulation impacts appear to have generally counter-balanced changes in amplitude of water level changes and magnitude of peak levels but have cumulatively contributed to a seasonal shift toward earlier peak water levels in the lake (Gibson J.L, T.D. Prowse and D.L. Peters (2006)).

Rawlins et al. (2009) reported that the Mackenzie River discharge was at a record low in water year (WY) 1995 (October 1994 to September 1995), was near average in WY 1996, and was at a record high in WY 1997, denoting high and abnormal variations. These changing flows and their expression in the Beaufort Sea provide insights into the nature of the Arctic's freshwater system. These complex findings may reflect a combination of spring soil moisture recharge, buffering by rising lake levels, climatic functions (precipitation, evapo-transpiration) and a massive uptake/release of water held in storage by the Bennett Dam.

Rivers of the Mackenzie Basin exhibit several seasonal flow patterns that include the nival (snowmelt dominated), proglacial (influenced by glacier melt), wetland, prolacustrine (below large lakes), and regulated flow regimes. A case at the Great Slave system demonstrates the effects of natural runoff, regulated runoff, and lake storage on stream flow, as well as the large year-to-year variability of lake levels and discharge. Despite a warming trend in the past three decades, annual runoff of the Mackenzie Basin has not changed. Significant warming at most climatic stations in April (and at some, also in May or June) could have triggered earlier snowmelt.

### *Climate changes*

According to INAC (2011), from 1948-2005 the air in the NWT Mackenzie district warmed by 2 degrees. By comparison, the temperature in Canada as a whole increased by 1.2 degrees over the same period. Precipitation in the NWT has also increased with more falling as rain than snow as temperatures increase.

The climate system is very complex and difficult to predict. Several research teams have developed their own models predicting climate change and climate change impacts. These models do not always agree in the amount of change they predict, but they do agree that warmer temperatures and increased precipitation are coming to the Western Arctic. By the 2020s, the models predict an average of almost 2 degrees of warming, and an average of about 7 percent more precipitation.

The Mackenzie watershed basin has been the subject of climatic and hydrological studies since the mid-nineties (GEWEX, Canadian Global Energy and Water Cycle Experiment, Ritchie et al. 1999). Sea ice melting projections vary; one model says the Arctic could be ice free in the summer by 2050, others put that event into the next century.

The Northern Rivers Ecosystem Initiative (NREI) studies focused on how these systems are being affected by climate change, flow regulation and land-use changes (Prowse et al. 2006). NREI models predicted increased air temperatures over the Peace and Athabasca basins with average-model values being approx. 2◦C warmer than current climate in summer and 4◦C higher in winter, although some models predicted temperatures to rise to about +5◦C for a number of winter months. All models forecast annual increases in precipitation although values varied widely between models and seasons. The largest increases were forecast to occur in spring with the average being largest in May at approximately +10 mm/month. Notably, the smallest increases were predicted for the summer months, with a number of models even showing decreases in late summer (Pietroniro et al., 2004, 2006).

Earlier freshets are predicted for most rivers, spring water levels of the major PAD lakes (Athabasca, Claire and Mamawi) are forecast to rise earlier. The overall seasonal behavior, however, varies by GCM scenario. For example, on Lake Athabasca during the summer period, the GCM scenarios that show significant precipitation increases result in a 10 (HAD) to 25 cm (CSI) water level increase. Furthermore, the winter water levels for the studied scenarios stay consistently above the current-climate levels. The cycles of flooding are likely to change with reductions in the snow pack in the Mackenzie River basin. Thawing permafrost may lead to the loss of some shallow lakes and wetlands leading to a loss of fish and wildlife habitat. Thinner ice is expected on lakes and rivers.

Climate change can impact ecosystem and community in many other aspects related as indirect or secondary impacts from those mentioned above. For example, there will be impacts on a) ice roads; b) thawing permafrost; c) industrial oil gas operations; d) wildlife species and populations; e) socio-economic changes for aboriginal populations. For example, barges along the Mackenzie are used for shipping a large number of goods given the lack of roads into many communities. The risks associated with barge traffic may increase dramatically during an extended shipping season in terms of reliability, personal safety, road failure and emergency preparedness.

At present the NWT roads lengths almost double in winter with the construction of winter roads such as the 150 kilometre road linking Inuvik and Tuktoyaktuk. The average opening date for the Mackenzie River ice crossing has been delayed by more than three weeks over the past ten years. Later opening dates and lighter load-bearing abilities will complicate winter resupply for communities and development projects as the climate warms (INAC, 2011).

Thawing permafrost is an issue in and around communities where there are layers of frozen soil, such as the Mackenzie Region. Older buildings, pipelines, and roads may suffer from slumping soil. A pilot study in Norman Wells and Tuktoyaktuk compiled available digital information on ground conditions in the communities, including a list of the infrastructure and foundation systems. A 2006 study looked at building foundations in six NWT communities to estimate what it might cost to remediate foundations in all NWT communities. It estimated a ‘worst case scenario' (remediating all NWT foundations) would cost $420 million. Given such, new facilities, such as the Inuvik Regional Health Centre, were designed with climate change in mind.

Development activities such as onshore and offshore oil and gas exploration operations will likely require adaptation to climate change. For example, during exploration, the storage of drilling waste in (disappearing, melting) permafrost may no longer be effective. Offshore drilling may require changes in the design of drilling platforms to deal with increased storm and wave activity during a shorter ice-free season. Longer shipping seasons in the Beaufort may lead to the shipping of oil and gas westward through the Bering Strait (INAC, 2011).

In mining operations, existing facilities will have to be reviewed, as tailings ponds and other contaminated areas often rely on frozen conditions to contain contaminants. The diamond mines operating in the NWT will face increased supply difficulties as winter ice roads are projected to start later and end earlier; costly all-weather roads may be the only solution. The increased coastal ice-free season may encourage mining projects near enough to the coastline to take advantage of increased access.

At the wildlife level, there are current and likely future climate change impacts on caribou and muskox. Declines in barren ground caribou herds have caused concern across the Western and Central Arctic. Close observation and the adjustment of wildlife management strategies may be necessary. The observations of trappers suggest muskrats will become more abundant in the North with the growth of more water plants. Marine mammals, such as the ringed seal, walrus, beluga, and narwhal, are identified as likely vulnerable to the effects of reduced sea ice. Other marine mammals, such as grey seals and harbour seals, may move northward. The habitat for both seals and polar bears may improve in the northern part of their range in the short term. The effects of climate change on large whales are not as well understood as other marine mammals, although the report notes that some experts think climate change is highly threatening to bowhead whales (INAC, 2011).

Some coastal communities in the NWT may be at risk from projected rises of the world's oceans due to flooding, and erosion of community shorelines. A combination of more frequent storms, less ice cover, rising seas, and melting permafrost may also compromise community stability. NWT communities likely to experience these issues include Tuktoyaktuk, Sachs Harbour and Ulukhaktok.

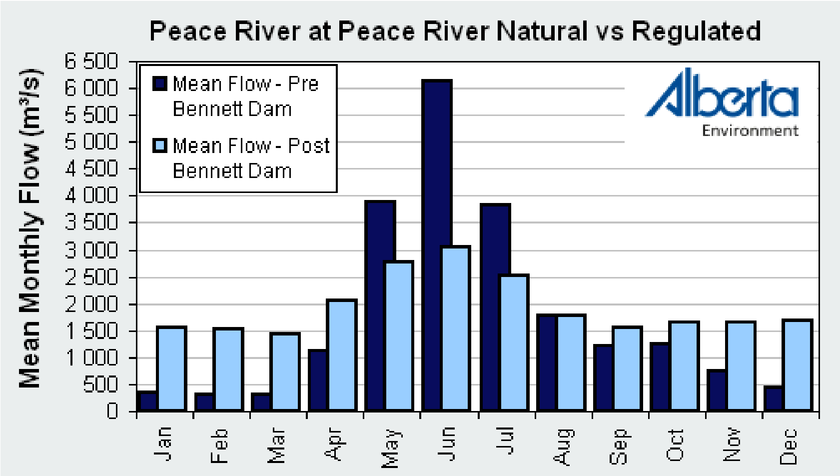


Figure 2. Peace River annual hydrograph before and after the construction of the Bennett Dam

MRBB (2003) reports that, in the Peace sub-basin, 12% of the population are First Nations. In the NWT, just over half of the population are Aboriginal, most of whom live in rural settings such as the small communities situated along significant water bodies. According to Statistics Canada, more than 70% of NWT Aboriginals hunt or fish and 96% of these people did so for subsistence purposes. Further dam construction, such as Site C being proposed by BC Hydro, could will have a significant impact upon all river flow, lake water levels, river channel change or discontinuity, and ice road reduction or vulnerability, all of which will affect human populations, especially Aboriginal lifestyles.

## CONCLUSION

From the presented studies it can be concluded that there have been impacts from Bennett Dam since its construction These impacts are not limited to the portion of Peace River within the BC territory but it has behaved like a 'pulse fading downstream effect' up to the Peace-Athabasca-Delta and further to the Mackenzie Watershed. The addition of Site C and other projects will affect the MRW in the following way: changes in the water flow upstream and downstream the dam; changes in the ice formation and ice movement (up-s/down-s); changes of the spring water-ice flows and flooding regimes; loss and change of habitat floodplains, riparian zones, and adjacent wetlands; impacts on First Nation population and non-native Canadian people. These impacts are been accentuated by global climate change.

## ACKNOWLEDGEMENT

This study was possible thanks to the NWT Government and Natural Sciences and Engineering Research Council of Canada.

## LITERATURE CITED

Anielski, M. and S. Wilson (2007) The Real wealth of the Mackenzie Region. Canadian Boreal Initiative, Ottawa

Aitken B, Sapach R. (1994) Hydraulic modelling of Peace-Athabasca Delta under modified and natural flow conditions, Northern River Basins Study, NRBS Report No. 43, Edmonton, Alberta; 45 C appendices.

BC Hydro (2011) What Is Site C? http://www.bchydro.com/planning_regulatory/site_c/site_c_an_option/what_is_site_c.html[2011-03-01 12:50:04]

BC Hydro (2009) Peace River Site C Hydro Project Stage 2. Review of Potential Downstream Changes from Site C Operations. Preliminary Findings.

British Columbia Utilities Commission, Site C Report, p.14.

Canadian Hydro and Glacier Power (CH-GP) (2007) Hydropower in Alberta: Challenges and Opportunities Forum on Hydropower, Ottawa.

Gibson J.L, T.D. Prowse and D.L. Peters (2006) Partitioning impacts of climate and regulation on water level variability in Great Slave Lake doi:10.1016/j.jhydrol 2006.02.011

INAC (2011) http://www.ainc-inac.gc.ca/enr/clc/adp/ia/nwt-eng.asp

Leconte, R., D. Peters, A. Pietroniro and T. Prowse (2006) Modelling climate change impacts in the Peace and Athabasca Catchment and delta: II—variations in flow and water levels with varying winter severity. *Hydrological Process*. 20, 4215–4230

Leduc, G. et M. Raymond (2000) L'évaluation des impacts environnementaux : un outil d'aide à la décision. Éditions Multi Mondes, 377 p. ISBN 2-921146-98-3

Mackenzie River Basin Board (MRBB, 2003) State if the Auqtic Ecosystem Report 2003.

Natural Resources Canada web site: http://atlas.nrcan.gc.ca/auth/english/maps/environment/forest/forestcanada/terrestrialecozones/1

Prowse, T. D., D. L. Peters, S. Beltaos, A. Pietroniro, L. A. Romolo, J. Töyra and R. Leconte, (2002) Restoring Ice-jam Floowater to a drying delta Ecosystem. *Water International* Vol. 27. Number 1, pages 58-69.

Ritchie, H., R. Hogue, L. Lefaivre, E. Radeva, R. Moffet, J. Mailhot, S. Bélair and B. Bilodeau (1999) CMC Model Archives and Activities in Support of GEWEX. MAGS 5th Scientific Workshop, Edmonton.

Smith, D. (2003) 1100 Years of Ice-jam Flooding in the Peace River Delta Interpreted from Flood Bed Sediments and Ice-scarred Trees CGU HS Committee on River Ice Processes and the Environment 12th Workshop on the Hydraulics of Ice Covered Rivers Edmonton, AB, June 19-20, 2003.

Sopinka, Am and G. C. van Kooten (2010) Is BC a Net Importer or Exporter of Electricity? In: Future Grid. BC's Energy Options in a Changing Environment

Yearwood-Lee, Emily (2008). The Site C Dam: Historic Overview and Key Issues. Prepared by Reference Librarian Legislative Library of British Columbia.