Peace Project Water Use Plan

Williston Debris Field Survey

Debris Management Strategy Report

Reference: GMSWORKS-18

Woody Debris – Strategic Management Plan: Planning for BC Hydro's Targeted Debris Management Program, Williston Reservoir

Study Period: 2014

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1579 – 9th Avenue
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February 10, 2015

WOODY DEBRIS STRATEGIC MANAGEMENT PLAN

BC HYDRO & POWER AUTHORITY

Prepared For: **BC Hydro & Power Authority**

Attn: **Julie Fournier**

BC hydro

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Date: **10/02/15**
DWB File: **1422-042**

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DWB Consulting Services Ltd. is pleased to submit this report for your review. This report has been prepared using sound technical and professional judgement, based on our knowledge and experience, applicable regulatory framework, industry best management practices, and current understanding of project conditions, design, and environmental setting.

Report Title: **Woody Debris - Strategic Management Plan: Planning for BC Hydro's Targeted Debris Management Program, Williston Reservoir**

Prepared for: **BC Hydro**

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EXECUTIVE SUMMARY

Debris accumulation along the Williston Reservoir has been a persistent problem since the reservoir's creation in the late 1960's. Debris results when untreated areas (during flooding) and other sources, including forestry, accumulate on the shorelines. This debris causes shoreline erosion and fish passage blockage along tributaries that stem off the reservoir. To mitigate debris, salvage programs ran until the 1980's but cost recovery was insufficient to continue operations. In 2007, the Peace Project Water Use Plan, outlined recommendations in the Integrative Management Plan for the Williston Reservoir which included debris management. As a result, In 2010, a debris management program was initiated. This program has been in operation since 2010 and involves collecting debris into piles along the reservoir shoreline. To quantify the volume of debris accumulation along the shoreline, a debris survey was completed and recommendations for managing of the debris were provided.

BC Hydro retained DWB Consulting Services Ltd (DWB) to prepare a Strategic Management Plan to deal with the bulk of the woody debris that accumulates along the foreshore area of the Williston Reservoir within 10 years. The feasibility study was broken into a three stage heuristic to develop a final strategy. The first stage included a review of various debris use methods. A review of historical debris management and a review of estimated debris volumes based on timber supply data was used for data estimates. Projected costs and cost recovery were reviewed in the second stage, but a more detailed review based on pilot studies is required to completely understand the viability of the options presented. Various regulatory requirements, permits, authorizations that would be required for implementation of the strategic options are also identified as part of the overall strategy.

Four key strategic management options were deemed most viable. These options are 1) strategic stockpile management, 2) reclamation works, 3) burning, and 4) shipping to bioenergy facilities for debris removal. It is also recommended for the strategy to work to its full potential that an outreach and monitoring program be launched prior to moving forward with the full-scope of management options. This outreach and monitoring program should be implemented over the next 10 years concomitant with the strategy to include inputs from a list of potential stakeholders that are identified in this report.

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Strategic planning, as practiced, is the articulation and implementation of categories—divisions, departments, and units—that already exist. Strategic thinking requires the invention of new categories, not merely rearrangement of current ones. Within this confusion is the heart of the issue—the most successful strategies are visions, not plans, and vision requires leadership. (Samson & Knopf, 2001, p. 872)

1.0 INTRODUCTION

BC Hydro retained DWB Consulting Services Ltd (DWB) to prepare a Strategic Management Plan for woody debris that accumulates along the foreshore area of the Williston Reservoir. This Woody Debris-Strategic Management Plan (WD-SMP) falls under the Targeted Debris Management plan for the Williston Lake Reservoir. The goal of this WD-SMP is to identify strategic options and a ten year plan of execution that will guide the targeted debris management program on the reservoir.

Debris accumulation has been a persistent management issue since the creation of the reservoir in 1968. This report short-lists options for debris removal and management that were considered in the AECOM (2011) report. The short-list was created considering the most viable options to manage the large bulk of debris over a 10 year span. The viable options determination was based on our research and understanding of the debris material and its potential use, which included conversations with potential end users of products derived from the debris, financial scenarios, and balancing the options with key stakeholders to ensure delivery of an integrated and practical management strategy.

The debris management strategy that is contained in this document falls under the rubric of BC Hydro's Targeted Debris Management Project (TDMP). The TDMP includes external documents, other research projects, and extended information or considerations that were included in the analysis and preparation of this document. The rational for the TDMP is:

(i) "Minimize damage to trial sites associated with WUP implementation projects (e.g., Dust Control Trials, Trial Wetlands, and Trial Tributaries),
(ii) Improve boat safety around boat launches,
(iii) Improve fish access to tributaries, and
(iv) Reduce shoreline erosion and destruction to riparian vegetation."[1]

This WD-SMP is a continuation of a previous work done by AECOM (2011). AECOM (2011) inventoried debris on the reservoir and based on this inventory they considered numerous options for removal, possible uses, and they also included financial cost estimates for some of the disposal methods. While a WD-SMP is the primary goal, it was determined early on that a feasibility study of a wide range of options would need to be reviewed first. These wide range options were studied in context of their potential and narrowing down a list of most-practical strategic options.

The feasibility study is broken into three stages. The first two stages are couched in strategic thinking rather than strategic planning as much of the infrastructure or pieces needed to execute the reviewed options are not yet available. The first stage of the feasibility study looks at a wide range of potential options. A historical

[1] Quoted from the BC Hydro GMSWORKS #22 Terms of Reference (2008), available from: http://www.bchydro.com/content/dam/hydro/medialib/internet/documents/planning_regulatory/wup/northern_interior/gmsworks-22_tor_november.pdf

overview of debris management in the reservoir is included in the first stage of the feasibility study to provide context on the legislative framework and to identify and then build on past efforts for dealing with the debris. Three overarching management categories were used to study the debris management options that include 1) the stock supply (or capital resource) within the reservoir and along the shoreline (and potential future under-water supplies), 2) shipping and transportation, and 3) end use. The second stage was used to narrow the options considered down to a list that seemed most viable. could be . This stage included a budget analysis of what were perceived as the most viable options. The final stage summarizes the findings of the feasibility study into a short-list of best options. The short-listing is used to devise the core of the WD-SMP. The WD-SMP includes details on permitting and regulatory requirements, costing, potential haul out sites and haul out options, potential stakeholders, and courses of action that can be implemented in the 2015 field season.

The objectives of the WD-SMP are consistent with the rational for the TDMP that include:

- Shortlisting of disposal/end use options within a 10 year time frame
- Identification of hauling options and potential haul-out sites
- Specified environmental requirements (e.g., Environmental Management Plans)
- Financial planning: estimated costs and processing rates
- Identification of potential liability and risks
- Listed requirements per Forest Act (if required, e.g., stumpage payment)
- Permit requirements (if any, e.g., road use permits)

There are five main objectives that were initially framed the scope of developing this strategic plan that we identified of prime importance that include:

1. A comprehensive review of the history of management and potential utilities of the debris;
2. Identification of the cost and benefits of different potential debris operations and utilities;
3. A determination of the best possible option for debris operations based on available evidence, scenario's, and professional assessment of that evidence;
4. To provide BC Hydro with a clear roadmap of potential clients, permit requirements, costs and logistics of attaining and utilizing the debris; and
5. To present an operational strategic plan that is easy to understand and that can be used to facilitate a consultation process as we move forward.

2.0 HISTORY OF DEBRIS MANAGEMENT ON THE WILLISTON RESERVOIR

Clearing of timber and construction of the Portage Mountain Dam, as the W.A.C. Bennett dam was called during construction, commenced in late summer 1964 (Low & Lyell, 1967; Loose, 1988). Debris accumulation on the Williston Reservoir has been a prevalent issue since flooding began in 1968, with full pool level reached in 1972, during which approximately 38,729 ha of vegetated area was treated prior to flooding (Department of Lands, Forests, and Water Resources [DLFWR], 1973). The timber cleared prior to flooding was restricted primarily to the main navigational channel, auxiliary channels, and the dam construction area (Muraro, 1966; Sebastian, Scholten, & Woodruff, 2003).

The Williston Reservoir has a current surface area equalling 177,300 hectares (“ha”) (BC Hydro, 2014). The flooded area was mostly on crown land which had a range of prime merchantable timber to non-merchantable scrub. The Ministry of Forests administered all clearing activities and the sale of merchantable timber under timber-sale contracts prior to flooding (DLFWR, 1965-1973; Loose, 1988).

In 1964, trial sections totalling 384 ha were cut, piled and burned in the Finlay Forks area (DLFWR, 1964). Site preparation works covered 2355 in 1965. The rate of timber removal was not progressing rapidly enough. A large Letourneau Tree Crusher (Figure 1) was brought into the project to speed-up the process, crushing 2298 ha in 1966 (approximately 1500 ha of pre-dominantly non-commercial timber and debris areas), whereas 1536 ha were cleared by departmental crews and 2322 ha under contract (DLFWR, 1966). Site preparation and clearing continued in 1966 covering approximately 6000 ha along the navigational channels and shoreline access areas. The volume scaled in 1966 was 421,638 m^3 (DLFWR, 1966). Salvage of floating merchantable material became a major pre-occupation by 1968 after the impoundment process was initiated. These salvage operations were administered under the Ministry of Forest (Loose, 1988).

FIGURE 1. THE TREE CRUSHER USED IN THE WILLISTON RESERVOIR ESTABLISHED AS A LANDMARK IN MACKENZIE BC.

Clearing continued through to 1970 with 6920 ha removed from the Finlay River section and 2711 ha. removed from the Parsnip River section (DLFWR, 1970). By 1971 a total of 38,445 ha had been cleared with plans for a post flooding clean-up programme (DLFWR, 1971). Based on calculations from the DLFWR (1965-1973) reports, 21.7% of the total area was treated using a combination of logging of merchantable timber in accessible stands, cabling, tree crushing, and burning (Muraro, 1966) prior to impoundment. Due to insufficient clearing, salvage operators were overwhelmed by the floating non-merchantable debris; the quantity of merchantable timber being removed was small compared to the quantity of non-merchantable debris remaining for disposal (Loose, 1988).The crushed timber and remaining stands contributed to the debris issue on the reservoir resulting in 4.8% of the total surface area of the reservoir (8256 ha) covered with floating debris (Barrett & Halsey, 1985).

A floating camp barge was used in 1970 to initiate an inventory of floating debris on the Williston Reservoir. A feasibility study for chipping and sorting of the floating debris was carried out (DLFWR, 1970); it is not known if or where data from this inventory was published. There is an estimated 143,000 ha of forested area that was flooded (Baker, Young, & Arocena, 2000). A non-merchantable debris volume reaching 622,970 m^3 was disposed in 1973, primarily stemming from the Parsnip reach (DLFWR, 1973). Submerged forest stands were still prevalent in the Williston Reservoir in 1975 and could be seen via eco sound tracings (Barrett & Halsey, 1985). Reported annual rates of salvage recovery were reported for the Williston Reservoir from 1963-71 and summarized in Table 1; after 1971, all salvage sales were reported generally under "Reservoir Waterway Improvements".

TABLE 1. CHIEF FORESTER'S FINANCIAL REPORTS ON RESERVOIR SALVAGE OPERATIONS.

Fiscal Year	Expenditure	Recovered	Balance	Salvage Rate (per m^3)	Volume (m^3)
1963/64	$ 870,794.47	$ 870,794.47	$ -	$ 1.44	602,888
1964/65	$ 593,686.00	$ 593,686.00	$ -	$ 1.48	400,269
1965/66	$ 897,534.76	$ 897,524.76	$ (10.00)	$ 1.50	598,001
1966/67	$ 2,064,210.19	$ 2,036,574.67	$ (27,635.52)	$ 1.13	1,796,551
1967/68	$ 2,332,014.54	$ 1,000,000.00	$ (1,332,014.54)	$ 2.07	483,222
1968/69	$ 2,491,773.32	$ 1,000,000.00	$ (1,491,773.32)	$ 3.12	320,326
1969/70	$ 3,474,325.05	$ 1,686,610.33	$ (1,787,714.72)	$ 1.07	1,581,437
1970/71	$ 3,778,261.24	$ 1,875,377.99	$ (1,902,883.25)	$ 1.32	1,416,125
1971/72[1]	$ 3,742,088.01	$ 1,869,954.46	$ (1,872,133.55)	$ 4.47	418,255
1972/73	$ 2,876,122.39	$ 1,183,896.30	$ (1,692,226.09)	$ 9.01	131,364
1973/74	$ 2,747,937.88	$ 2,509,411.92	$ (238,525.96)	$ 7.63	328,975
1975/76	$ 4,019,873.41	$ 3,660,449.60	$ (359,423.81)	$ 0.44	8,226,367
1976/77	$ 2,328,836.99	$ 2,328,836.99	$ -	$ 0.46	5,033,986
1977/78	$ 4,861,223.08	$ 1,156,783.01	$ (3,704,440.07)	$ 0.67	1,724,021

[1]Prices and estimates after 1971 were based on a different style of reporting, not specifically referring to the Williston Reservoir with differences in salvage price calculations.

After 17 years of operation by the BC Forest Service (DLFWR, 1978), BC Hydro assumed all responsibility for management of disposal activities by 1978 as the BC Government started to divest itself from unnecessary commitments. The engineering division of the BC Forest Service assumed responsibility for the clearing non-merchantable material as the BC Forest Service continued to administer salvage sales (Loose, 1988). Sale of all merchantable floating debris and disposal of all floating debris, except at the east end of the Peace Reach in the vicinity of the WAC Bennett dam, was now BC Hydro's responsibility. BC Hydro was also responsible for funding of the salvage and debris clean up and disposal. Disposal consisted of burning and burying the debris. BC Hydro continues to assume responsibility for the clearing and disposal of non-merchantable surface debris material (BC Hydro, 2014a).

The most recent efforts at disposal activity by BC Hydro have been conducted through contractual commitments with the Tsay Keh Dene First Nation. Debris is accessed from shore, removed from below the high water mark, and piled. To date no action has occurred with these piles. BC Hydro is concerned with liability risk associated with these piles. The AECOM (2011) and Wilson (2013) reports were reviewed as they provide an abundance of information concerning the debris quality and previous considerations for its use.

BC Hydro is seeking alternative management options that have not already been considered to develop a strategic management plan for viable options. As such, this report identifies the most immediate and best strategic options to handle and manage the debris beyond the current status quo and sets out a ten year strategy to remove the debris. This document was prepared after a comprehensive review of available background information to produce a strategic road map or short list of ideas that were derived through consultation and consideration of input from professionals, specialists, consultants, BC Hydro, First Nations, and industry.

3.0 LOCATION OF WILLISTON LAKE RESERVOIR

The Williston Lake Reservoir is located in northeast British Columbia, near the towns of Hudson's Hope and Mackenzie (Figure 2). The Tsay Keh Dene First Nation community is located at the northern end of the reservoir on the Finlay arm/basin. The reservoir consists of the Finlay, Parship and Peace basins or arms (Table 2). At full flood, the surface of the reservoir covers an area of approximately 1750 km^2 with a perimeter of approximately 425 km and a length of 251 km.

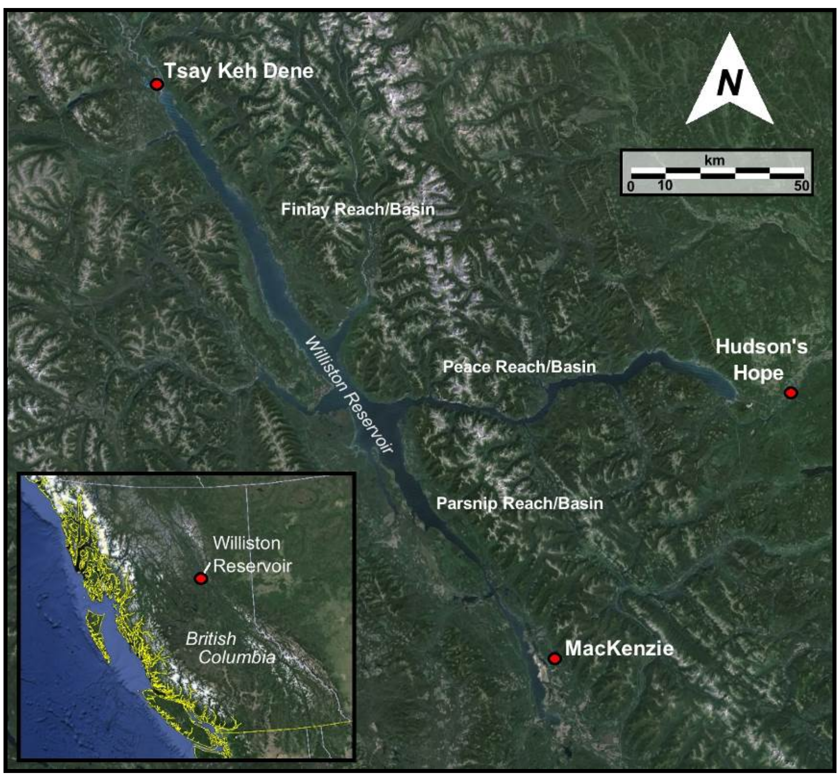

FIGURE 2: OVERVIEW OF THE WILLISTON RESERVOIR

TABLE 2. AREA (IN HA) OF BASINS IN THE WILLISTON RESERVOIR.

Basins			Total
Parsnip	Finlay	Peace	
63,653	62,852	30,462	156,967

4.0 MATERIAL PRESENT

AECOM (2011) estimated 1.3 million m^3 of debris has accumulated along the reservoir shoreline (Table 3). Most of this (approximately 1.2 million m^3) is at or near the high water mark around the edge of the reservoir. Of this, roughly 2/3^{rds} is located around the Finlay Reach (AECOM, 2011). It is important to note that the AECOM (2011) report gave estimates on the "'Timber not cleared prior to flooding' category [which] comprises the stands of dead or living trees *still located on the periphery of the reservoir*" (p. 5, emphasis added); this categorical value is reported to equal 105,260 m^3 (Table 3). Therefore, the 'Timber not cleared prior to flooding' category (AECOM, 2011; Table 3) masks a larger volume of hidden debris that could potentially move from the base of the reservoir and add to the shoreline.

TABLE 3. ESTIMATED VOLUMES OF DEBRIS WITHIN THE WILLISTON RESERVOIR (AECOM, 2011).

Reservoir Sector	Debris Categories					Total Debris (m^3)
	Shoreline: Ribbons and Piles (m^3)	Floating (m^3)	Shoreline: Scattered (m^3)	Log Boom Loses (m^3)	Timber not Cleared Prior to Flooding (m^3)	
Peace Arm	**54,425**	**--**	**60**	**400**	**1,190**	**56,075**
North	27,985	--	45	400	680	29,110
South	26,440	--	15	--	510	26,965
Finlay Arm	**714,100**	**10,830**	**6,730**	**3,900**	**68,765**	**804,325**
East	384,140	1,410	4,250	900	30,040	420,740
West	329,960	9,420	2,480	3,000	38,725	383,585
Parsnip Arm	**367,965**	**13,230**	**4,070**	**5,600**	**35,305**	**426,170**
East	120,710	13,050	390	2,500	10,340	146,990
West	247,255	180	3,680	3,100	24,965	279,180
Total	**1,136,490**	**24,060**	**10,860**	**9,900**	**105,260**	**1,286,570**

Volumes recovered through sales of salvaged wood from 1963-1978 ranged from 23.0-29.4 Mm^3 (DLFWR, 1964-1978), which covered only a smaller percentage of the total reservoir area that was left untreated through the salvage operations. A total area of 181,725 ha is obtained by adding 143,000 ha of flooded forest to 38,725 ha of pre-flood treated area. The Hudson's Hope museum reports this value at 177,300 ha. This translates into 21.3-21.8% of the total area being treated, which is in the exact range of Muraro's, (1966) reported 21.7% value.

A comparison can be made using Baker, Young, & Arocena's (2000) 143,000 ha value of forested area that was flooded and the 1966 scaling estimate of 70.3 m^3/ha (DLFWR, 1966) to give an estimate of 10 Mm^3 within the reservoir. The scaling estimate (70.3 m^3/ha) reported is likely much lower than the actual volumes of high quality timber that were within the area at that time. Data from Mackenzie Timber Supply Analysis (2014) and Mackenzie TSA Public Discussion Paper (2013) report a low volume of 150 m^3/ha and a high volume of 250 m^3/ha translating to 21.5-35.8 Mm^3 in the reservoir. A total of 23.0-29.4 Mm^3 was removed (salvaged/treated/harvested) from the reservoir prior to 1980 (DLFWR, 1964-1978; Appendix A). Since submerged forest stands were still prevalent in the Williston Reservoir in 1975 (Barrett & Halsey, 1985), an estimated 9.1-18.0 Mm^3 of debris remains in the reservoir; or 8.8-16.7 Mm^3 of debris currently rests under the water in addition to the estimated 1.3 Mm^3 shoreline value (Table 3).

5.0 POTENTIAL DEBRIS USE/METHODS

The 2011 AECOM report presented numerous potential uses for the debris from the Williston reservoir, but most are impractical due to cost limitations, a lack of adequate processing facilities (either non-existent or too costly to access due to their location) or unable to adequately address the volume of debris present within a ten year timeframe. The following priorities were used to derive the short-list of strategic options considered in this report:

- Local interest in the product;
- Potential to generate revenue or cost-recovery;
- Existence of equipment to process the debris;
- Low or reasonable capital venture for new technologies;
- Meets high quality social and environmental standards;
- Existence of a local facility to make use of the debris; and
  Potential to deal with the entire debris inventory within 10 years.

5.1 DEBRIS USES AND METHODS CONSIDERED FOR THE WD-SMP

To determine the most viable debris strategic management options, one must review the feasibility of various debris uses/methods. The following reviews debris uses/methods including; bio-energy plant at Tsay Key Dene village, wood briquettes, biochar, residual firewood, pellet market, pulp, recovery of logs, mill to dimension lumber, other chipped products, hand craft, chip and blow/bury, and do nothing.

5.1.1 BIO-ENERGY PLANT AT TSAY KEH DENE VILLAGE.

This option was considered extensively in the Wilson (2013) feasibility study. A 45 kWe Spanner Re^2 system received preliminary consideration after other biomass energy heating systems had been deemed prohibitive. Without capital investment and until a firm commitment is made, this option was not considered in this strategic management plan to provide assurance on the viability of terms. However, the recommendations on the feasibility of the Spanner system in Wilson (2013) are promising and would diversify utility options in the longer term.

Wilson (2012), published a thesis on the consideration of a bioenergy plant in Tsay Keh Village that lead to further study (Wilson, 2013). The follow-up study determined that a small-scale 45 kWe biomass gasification system from Germany may be feasible. Using values from the AECOM (2011) reporting, Wilson (2013) estimated that there was 450,000 t of debris on the shoreline (8,550 TJ, in energy) that would provide 81 year supply for the Tsay Keh community. A bioenergy plant in Tsay Keh Dene village may be a worthwhile venture to consider in future operations, but the primary goal of this strategic plan is to look at existing options.

5.1.2 Wood briquettes

Several individuals that were interviewed had expressed that they themselves conducted research into wood briquette's and had learned that the demand for this market is neither currently profitable nor feasible. There are also concerns regarding the quality of the wood that would make this market even a greater challenge.

5.1.3 Biochar

Biochar requires a high-cost permanent infrastructure for pyrolysis. Discussions were held with the Diacarbon research development team on the feasibility of this option. More portable technology may be available in the near future, but this is still under the R&D phase. This requires a high-end investment of a similar nature to the biomass heat and power plant options reviewed by Wilson (2013).

5.1.4 Residual firewood

While members of the Tsay Keh Dene village do utilize firewood, the purpose of this strategic management plan is to identify the higher throughput of the debris that is consistent with the overarching goals of sustainability that BC Hydro and the province of British Columbia has laid out. Residual firewood does not meet the criteria set out for analysis.

5.1.5 Pellet Market

The nearest facility, Pinnacle, is in Quesnel was used for our cost of transportation estimates. Another facility, Pacific BioEnergy, is located in Prince George. Strict moisture content and quality requirements and cost of transportation makes this option prohibitive.

5.1.6 Pulp

"*Differences in wood and fiber properties can affect decisions along the entire value chain because the economic value of sawlogs is largely affected by the properties of wood fiber, log shape and curvature, and number and diameter of branches; pulping quality is largely determined by the fiber length, strength, and dimensions*" (Hilker et al., 2013, p. 231).

There are specific chemical and morphological components that are required for woody material to meet the product requirements for pulp. Pine beetle killed wood, for example, has lower specific gravity, concentrations of extractives, moisture content, lignin, and cellulose content (Woo, Watson, & Mansfield, 2007). Similar qualities are expected for the woody debris along the reservoir. Wilson (2013) also found comparable qualities (e.g., moisture content) to mountain pine beetle wood and noted that the debris has been tested for timber or pulp and paper purposes and deemed unsuitable. Large stocks of pine beetle kill logs are still being recovered and used for pulp[2], so the quality of the log for pulp does not diminish immediately. Logs sitting under water would be quite usable, however, after drying in the sun the fiber morphology changes reduce the quality (high caustic conditions) and strength of the fibre. The pulp option, however, is considered in the strategically targeted approach (see Section 5.1.4).

5.1.7 RECOVERY OF LOGS (FORESTRY)

The quality of the material available (estimated 10,000 m^3 inventory) has been ranked as poor quality (Wilson, 2013). The amount of effort for collecting and delivery is prohibitive as the material is spread over such a large area.

5.1.8 MILL TO DIMENSIONAL LUMBER

Rejected on the basis of poor wood quality sharing the same limitations as recovery of logs.

5.1.9 OTHER CHIPPED PRODUCTS

This option was considered, but no viable products met the criteria set in our terms for consideration.

5.1.10 HAND CRAFT

Hand crafting furniture and arts were screened in a 2009 feasibility study (Wilson, 2013). While this option contributes to increased social value, the amount used for hand crafting would be too small to strategically reduce supplies per the goals set in this plan.

5.1.11 CHIP AND BLOW / BURY

Some potential concern with the environmental, fire and leachate risks, as well as the size of area required to dispose of the material.

5.1.12 DO NOTHING

A do nothing approach was considered. To select "doing nothing" as a viable option would need to evaluate the cost of debris management against the costs associated with the potential environmental and safety risks. Foremost, however, doing nothing does not meet the obligations set forth by BC Hydro's environmental policy that includes a commitment to *"Work to reduce historic environmental impacts"*[3] and the context of the general policy precludes this option. The debris accumulated impact shoreline through erosion, causing

[2] Mac Anderson, Mackenzie Fiber Management Corp.

[3] https://www.bchydro.com/about/sustainability/environmental_responsibility/environmental_policy.html

damage to vegetation, it blocks fish passage along tributaries, and is an ongoing environmental problem that requires management.

The above uses/methods have quality limitation and/or do not meet the priorities as set out in section 5.0 of this plan. In determining the strategic options for consideration, it is important to understand that the quality of debris is critical for the viability of its use. Quality issues include the high range of variability in piece size and quality, presence of sand, cracks, chemical content, and moisture content. Prior to use of the debris as a product, a chemical analysis needs to be conducted to ensure that the material will meet the requirements for the intended use; Wilson (2013) provides details on analysis that has been done to date.

5.2 Debris Uses/Methods Evaluated For Strategic Management

This WD-SMP looks at finding viable options in 2014 that would meet the criteria set in section 5, fit the quality criteria, and look beyond the status quo of piling of the debris. Each strategic option considered is reviewed against treatment location on the reservoir, transportation off site, and potential utilities for the material (Figure 3) with expectation to initiate strategic options as trails with scalability to be fully operational in subsequent years.

FIGURE 3. SCHEMATIC ILLUSTRATION OF DEBRIS MANAGEMENT AND FLOW OF CONSIDERATION.

The following reviews the viable strategic management options including mixed-bioenergy methods, burning, stockpiling for reclamation works, strategic target approach, air curtain incinerator with energy recovery capabilities, and bottom ash. 2015 season:

5.2.1 Mixed Bioenergy Methods

Two options considered include venting or Air Curtain Incineration (ACI) with energy recovery (combined heat and power; see Section 6.0) coupled with the creation of hog fuel for a bioenergy facility. The Conifex Timber Inc. (Conifex) electrical co-generation plant in Mackenzie is the closest facility to reduce transportation costs and is scheduled for start-up on September 20th, 2014.[4] Longer term market options may become available[5], including a community owned biomass plant at Tsay Keh Dene village as conceptualized by Wilson (2013).

ACI with energy recovery is addressed in detail in Section 6.0[6]; the estimated start-up cost with the burn box, power unit, and ash rake system is $1M. The technology can generate an estimated 100 kWh using 6-8

[4] Dr. Paul Watson (Director, Canfor Pulp Research and Innovation) was consulted and has indicated that newer technologies are under development locally that could make the bioenergy options even more marketable. The ACI option is considered for the purposes of this report as an initial start-up project until newer and proven technologies develop making the timber more marketable.

[5] Phone calls and e-mails have been sent out to other potential firms (e.g., East Fraser Fibre) to identify other potential markets within this strategic option.

[6] Nechako lumber in Vanderhoof is already using this technology (Stirling, 2009).

tonnes of debris per hour. The co-heat generation option is an additional consideration in relation to the district heating network customers identified in Wilson (2013), but the numbers for this option in terms of thermal energy are not currently available. This option would only be feasible if the location of the heat recover site was in proximity to village and would also generate emissions (noise and particulate matter). The heat could also be used for novel functions, such as heating a greenhouse.

Discussions were held with a local fiber supplier Mackenzie Fiber Management Corporation (Mackenzie Fiber). Mackenzie Fiber is in current negotiations with Conifex Timber Inc. to serve as their primary hog fuel supplier for an electrical co-generation plant in Mackenzie[7]. Initial discussions with Mac Anderson of Mackenzie Fiber suggests that the plant has enough fuel for 50% capacity and could potentially use up to 120,000m^3 (approximately 50,000 ODT [Oven dried tonnes]) annually. At this rate, the volume of material estimated in the AECOM (2011) report could be used within 10 years.

The 2014 value of hog fuel to Mackenzie Fiber is currently about $4-5/ODT, but potentially could increase over the next 5 years. For the purpose of the cost analysis in Section 7.0, only the current value was used. Mackenzie Fiber has grinders and chippers on site in Mackenzie and has the capacity to supply portable units for the field (Figure 4-7). Chu-Cho Industries LP (Est. 2012; Tsay Keh Dene) also has a portable chipper at the Tsay Keh Dene village that has been used on other BC Hydro work. Debris can be processed (chipped) by the reservoir and transported by truck or barge to Mackenzie, or the debris can be transported by truck or barge to Mackenzie to be processed. A log boom and conveyor belt system was historically set in place to transport and distribute the debris from the reservoir into Mackenzie that could be re-opened for the new bioenergy market. Mackenzie Fiber has current plans to open the reservoir to receive fiber inputs by boom to haul material into its yard.

Figure 4. Example debris pile that will be converted to hog fuel on Mackenzie Fiber lot.

Figure 5. Hog fuel chipper production on Mackenzie Fiber lot.

[7] A phone call and message was left with East Fraser Fiber in Prince George to discuss strategic options within this plan.

Figure 6. Sawdust chipper on Mackenzie Fiber lot.

Figure 7. Wood fiber supplies of various size classes stored on Mackenzie Fiber lot for processing into hog fuel or other products based on log quality.

5.2.2 Burning

There are two options for the burning of the material:

a. *Pile and burn:* The debris will be piled above the high water mark and burned. Material removed directly from the water may need to be placed in a separate pile(s) to dry out before burning, which may delay burning of those piles for one or two seasons. This option, however, raises concern over smoke generation and air quality that will need to be addressed. Pile burning management is addressed in the Environmental Management Plan for the 2014 season (DWB, 2014). Custom venting indices can be obtained to potentially extend burning periods through Enviro-BC Weather Services (250-339-4424).
b. *Commercial air burners (ACI)*: This will help to alleviate air quality issues associated with open burning (see Section 6.0). ACI burn boxes (est. $250,000 per unit) or trench burners (est. $150,000 per unit)[8] would need to be rented or purchased. The burn boxes are described in further detail below. The venting air trench burners are potable units that can be transported by a ½ tonne 4x4 to location. A trench is dug and the venting unit is placed along the edge to ensure a cleaner burn. Venting trench burners have the added advantage of lower venture capital and portability.

There would be no revenue generated from either burning method, but there would also be no transportation cost from the reservoir but there would be costs associated handling ash. In order to burn, a burn registration number (permit) will be required and may only occur under favorable venting indices. Fire prohibitions may also come into place (fire bans). This could restrict the number of days available for burning. It may be possible to get an exemption to a fire prohibition if needed. In that case, a burn plan will be required. A significant amount of ash material will be generated. There are several possible options for dealing with the ash addressed in Section 6.1.

5.2.3 Stockpiling for Reclamation Works

Debris can be used to stockpile to assist with several reclamation initiatives including:

a. Streambank restoration.
b. Coarse woody debris (CWD) for wetland, stream and fish habitat reclamation projects.

[8] These prices are based on discussions with a local distributor.

c. CWD or chipped mulch for use in dust mitigation programs, during construction works (e.g., roads, exposed soils).
d. Chipped mulch for sediment erosion control during construction works.
e. CWD for use in mine reclamation.
f. Use as a soil enhancer on reclamation sites.
g. Use as structural building material – e.g., playgrounds, signposts and other types of local infrastructural projects[9].
h. CWD for harvested areas.

The amount of debris used in this option is limited but there are returns to consider in terms of utility in environmental works, habitat creation and as compensation for the ecosystem area that was disrupted by the filling of the reservoir. These projects would be a direct cost to BC Hydro, costs could be reduced by coordinating activities with the other debris management options, and the benefit would be realized in environmental economic terms. Potential storage locations will need to be identified for this strategic option. There are a number of Special Use Permits (SUPs) sites along the reservoir (dump sites primarily) that could be used as load out points.[10]

5.2.4 Strategic Target Approach

Strategic target approach involved targeting only the high concentrated areas of debris piles that are in the vicinity of the Tsay Keh Dene village, debris around boat launches, and the debris in areas that have been flagged for high erodibility would reduce on the amount of transportation required for management. Additional piles will still need to be dealt with in the future, meaning there may be an additional cost liability (future cost). “The existing targeted debris management project is processing approximately 675 m^3 per day, over a relatively short annual operating period” (AECOM, 2011, p. i). This strategic targeting approach would also involve targeting or sorting the debris according to quality and market value; smaller volumes would be processed at lower market values and higher volumes when markets improve. The hog fuel market is expected to rise with demand as new facilities are being constructed, so this strategic option is based on discounting of supply and demand.

The fire hazard liability or environmental liability (wildlife impediment to reservoir) is expected to be very low leaving the debris piled in stockpiles. The debris has lost its canopy/leaf fuel load and the fine fuels (twigs) are significantly diminished that would otherwise sustain and increase the likelihood of ignition. Moreover, the piles would be arranged with spotty distribution. Strategic arrangement of the piles could mitigate any potential risk. These piles could also be strategically targeted for conversion into hog fuel as part of the main debris management method.

Although this method does not manage all the debris within the targeted timeframe, it could be used and is likely to be used in conjunction with other methods. The benefit of this method is the removal program would augment projects that are already dealing with debris management in areas at high risk of erosion or environmental damage, such as causing blockage to fish passage along tributaries. Moreover, this approach has the potential to generate greater revenue by targeting the markets when the debris is at its highest

[9] This option is included under the heading of reclamation works as some reclamation projects being planned (e.g., Hydro Creek) might involve scenic areas with picnic tables and interpretive signs where the wood could be of use.
[10] This information on SUPs was provided by Chief Izony.

value. It is expected that the floating debris may impact previously treated targeted areas, but as the main debris management continues, this should become less of an issue and, consequently, this method may not be required every year.

Although we pulping was not considered a strategic viable option due to quality of debris, some of the some of the debris in a smaller scale may be of use for pulp. Debris that has remained in the water will retain marketable pulp fiber quality.[11] The pulp market is not considered as a prime strategic contender nor is it considered in our cost analysis, but there remains a possibility that some of the debris could be strategically targeted for pulp if the necessary marketable qualities can be identified in the field or if the means to access debris that remains under the reservoir presents itself as a viable opportunity. Stockpiling shoreline debris for use in pulp is not an option, as solar exposure reduces its quality for this purpose. The pulp market option would require management of new recruitment logs and targeted identification of suitable pieces. The piecemeal supply presents challenges for the pulp option and the biofuel market value has been projected to match pulp values.

5.2.5 Air Curtain Incineration with Energy Recovery Capabilities

Air curtain incineration (ACI) can be performed using either a trench or a burn box system. An electric or diesel powered fan blows a curtain of air that causes a circulation of air flow that results in recirculation of the combustion by-products into the combustion region. This technology has been around since before the 1960's and has the potential to improve on the emission quality stemming from the combustion process (Miller & Lemieux, 2007).

Particulate Matter (PM) emissions raise serious health risks (Province of British Columbia, 2011) and carbon dioxide (CO_2) emissions contribute to greenhouse gases (BC Ministry of Environment, 2012). BC Hydro and the province of British Columbia have both set sustainability targets for the reduction of release of greenhouse gases[12] and improvements to air quality (Jost & Weber, 2012)[13]. These goals are also consistent with BC's professional reliance models, through the College of Applied Biology and Professional Foresters of BC codes of ethics and stewardship principles that has committed to improve our practices under these terms.[14]

The quality of ACI with regards to other types of emissions, such as volatile organic compounds, is not as well understood. Emission rates and standards are variable depending on the fuel and ACI unit being used. However, research to date indicates that the ACI process significantly reduces the amount of CO_x and PM emissions per unit mass of fuel (Miller & Lemieux, 2007), which is consistent with the provincial smoke management objectives (Province of British Columbia). While it is reasonable to assume that PM emissions will be reduced, the physical laws of chemistry would dictate that the total C emissions cannot be reduced. Hence, the reduced amounts of CO_x emissions may result from a range of other organic compound emissions

[11] Dr. Paul Watson (Director, Canfor Pulp Research and Innovation) supplied this detail and has offered further testing of the debris for this purpose.
[12] These components are regulated under BC's *Open Burning Smoke Control Regulation* through the *Environment Management Act*, and the *Greenhouse Gas Reduction Targets Act*
[13] See also: http://www.fs.fed.us/eng/pubs/html/05511303/05511303.html
[14]http://www.abcfp.ca/about_us/media_centre/documents/Pro_Leadership_in_a_Changing_Climate-Joint_Statement_20140708.pdf

(e.g., McDonald et al., 2000) that would require emissions study according to wood type and combustion parameters (e.g., large pieces v. pellets).

The current technology for the FireBox Power Module can produce 30 to 50kW of energy outputted into a local grid for electrical use[15]. This amount of energy output is similar to a wind turbine designed for larger farms[16], but would be insufficient to meet the existing demand at Tsay Keh Dene village and would have to run in parallel with BC Hydro's generators for load following. Moreover, the power module would require tying into the existing power grid, which would require its location to be situated close to the existing BC Hydro generator station or a power line would be required; additional feasibility study for cost of the different options including added debris transportation costs to the burn site.

The FireBox has dimensions equal to 6 m (20') X 2.1 m (7') and weighs over 9,000 kg[17]. It takes 15 minutes for it to heat before electrical energy is produced. It can process approximately 16 m^3 of wood per hour[18] or 5-8 tons per hour. The throughput is slowed down through energy-heat recovery that can continue for 2-3 hrs after the wood has been burned. It takes 10 minutes to remove the ash and the system can be fed by an excavator with a grappler arm and run continuously for 20-30 hrs until the ash reaches approximately 1 m in depth.[19] A rake system will be required for the power module option. A comprehensive energy balance analysis for the power module is not included in this report, however, it is important to note that the system may be able to feed power produced back into its operations to reduce on fuel consumption. Moreover, the systems require cooling that can be accomplished by refrigerants, water towers, and fresh water supplies that would alter the performance relative to the ambient temperature and modify the cost.

The ACI with energy recovery process may also be augmented by purchasing a wood briquetting press or pellet mill for Tsay Keh Dene Village; approximate starting price ranges from $5,000 for a pellet mill to $50,000 for a briquetting press. A wood briquette or pellet could potentially improve feed efficiency, burn conditions within the ACI units, and open other potential market for pellets, although the logistics would require further study. The quality of the wood for briquetting or pellets is questionable and would unlikely meet the standards for energy density, moisture, and ash content for commercial markets. The additional energy required to pellet or briquette the debris would increase the cost of the program, resulting in reducing the viability of this option (Sonja Wilson, personal communication). An in depth feasibility study looking into various energy or heat recovery options with the ACI units is needed to fully understand how this system could be used.

The ACI system would require air quality emissions monitoring for particulate matter, carbon, organics, metals, and other possible emissions to ensure regulations and standards are being met. Provincial guidelines for emissions from biomass-fired electrical power generation have set the following limits:

- >25 megawatts electrical total particulate limit 20 mg/m^3 (at 8% oxygen).

[15] Dale Mazure (Canada Powerhouse) has estimated that the more recent technology is at 105 kWh. The 30-50kW figure was obtained from the manufacturer's specifications on their website. Investigations are ongoing with Nechako Lumber in Vanderhoof where this technology is being used.
[16] http://www.endurancewindpower.com/e3120.html
[17] http://www.airburners.com/DATA-FILES_Tech/USDA-FS-Tech_Tips-0251-1317.pdf
[18] http://www.airburners.com/ab-faqe.htm
[19] http://www.airburners.net/pgfirebox/airburners_firebox-booklet_hi-res.pdf

- For <25 megawatts total particulate 50 mg/m^3.[20]

5.2.6 Bottom Ash

Bottom ash is produced through the combustion process and options will be required for its disposal or utility. Unprocessed by-products of this method including; inorganics (without carbon), ammonium salts, nitrates, silicates, metals (primarily oxides, basic materials) KTO – potash – depending on the combustion need to be considered. Approximately 32,500 tonnes of ash would be produced by burning 10 Mm^3 of debris; the debris sample in Wilson (2013) had an ash content of 0.65% dry basis with an average density of 500 kg/m^3. The following options are available:

- Application as a soil amendment[21]
    - Spread the material in the surrounding forest, cutblocks or on areas to be rehabbed.
    - Use as a soil enhancer in reclamation at mines, quarries, or any potential industrial location.
- Bury the material on site – short-term site specific environmental problems with concentrated high dose of minerals. There may be requirements to line the pit.
- Disposal in landfill
- Other potential use as additive for industrial products:
    - Portland cement,
    - Glass construction,
    - Soap works,
    - Asphalt for paving,
    - Acid neutralizer for mining tailing ponds,
    - and a long-list of historical uses for ash.

Ash as a soil addendum has been a common practice in boreal forestry as a fertilizer. There are different responses according to the physical and chemical properties of ash that is being used, which can vary according to combustion technologies. Studies on ground vegetation (e.g., bryophytes, lichens, and smaller non-woody plants) show varying responses with immediate damage and prolonged recovery (Aronsson & Ekelund, 2004). Abiola (2011) did not use ash as an additive, but tested for ash content in soils in field trials on vegetative response to nutrient trials. Biomass and height of native plants (principally *Equisetum* sp.) was significantly negatively correlated with ash content.

Abiola (2010, 2011) provides details on composting recipes using the debris, which proved effective as a nutrient supplement at field trials along the reservoir. Ash can be used as an additive to improve compost structure (Obernberger & Supancic, 2009; Noviks, 2013). Bottom ash can be used as an additive in various construction related products (Obernberger & Supancic, 2009; Noviks, 2013), such as Portland cement (Kula et al., 2002). This option would be highly dependent on the amount of bottom ash produced. Inquiries have been made to local cement manufacturers and additional markets could be considered in the long-term if ACI is put into operation.

[20] Further limits are stated for dioxins and furans for salt-laden wood, which may be applicable to the reservoir debris depending on the relative chemistry of the wood.

[21] Dr. Todd Whitcombe (UNBC prof) suggested this is the best option, but spread and distribution remains a problem.

Additional research on the utility of ash or lab analysis on the chemistry of ash from ACI may be required to examine the potential effect relative to substrate, mixtures with composting debris, ecosystem of deposition, and landfill options. The Fraser-Fort George Regional-District Mackenzie landfill can accept ash disposal at a $67/tonne disposal fee, but provided that a lab analysis is conducted on the material. The disposal fee would run up to $2.2 M based on the estimated ash production levels, not including transportation costs to the landfill.

6.0 PROJECTED COSTS AND COST RECOVERY

To determine costs for the various options for this debris management strategy, it is important first to standardize the potential scenarios of implementation of the options. For example, transportation of the debris material in either whole or processed form (hog fuel), could be done by truck, barge, or a combination of both from numerous locations. This would present too many possible scenarios to cost out. This section discusses the priority options used in our evaluation and scenario of cost estimates.

6.1 TRANSPORTATION

Although it is possible to use a combination of trucking and barging, these options are considered separately for the costing estimates that are provided in this strategic management plan. Two processing scenarios are considered in the cost for transporting the debris. The first is processing the material into hog fuel at the reservoir and then transporting it. The second is to transport the material whole, for later processing at Mackenzie or Tsay Keh Village. Transporting material whole by logging truck may not be always possible however, as much of the material is short and irregular.

Short and irregular supply of material presents a limitation on the effective use of a logging truck configuration. Using other types of trucks (i.e. dump truck) may be possible, but the amount of material that could be transported in a load would be reduced and this would increase the cost of trucking the whole material, possibly by as much as two to four times. The added cost of using other truck types has not been fully evaluated in our scenario. However, if trucking for hog fuel is considered, then processing the material prior to hauling would be the most viable option.

A common transportation start point was selected for our comparison of cost. In this case, Tsay Keh Dene village was used. Moving forward, several other points need to be assessed, including the identification of existing SUP sites along the reservoir. Potential haul out sites are identified later in this report.

Barging locations may be limited on the reservoir. As previously discussed, combining the trucking and barging of the material in either whole or hog fuel form has the potential to lower the overall transportation cost when compared to barging cost from Tsay Keh Dene village. Under ideal conditions, transportation by truck could be cheaper, with the possible exception of most of the eastern side of the Finlay Arm. Transportation by truck versus barge would have be considered on a case-by-case basis to determine the most effective or optimized cost option. A historic port for off-loading supplies from a barge is being planned for the fiber yard in Mackenzie. Having the available infrastructure for the barge may reduce some of the expected cost.

6.2 Fiber Supply

Getting material from the reservoir to the road should generally be the same anywhere along the reservoir. As a result, the same cost for this was used in the cost evaluation of all options. This may not necessarily be the case, but it is expected that any difference would be minimal in comparison to the overall cost.

6.3 Processing Debris

Whether chipping the debris into hog fuel at the reservoir or in Mackenzie, the costs should be similar. Therefore, the same cost was used in all the options that included chipping. There are various costs associated with handling of the material that might be slightly different. For example, the cost of chipping in the field may be higher, but they have not been identified at this point and based on our calculations we do not expect this to have a large impact on the overall cost of an option.

The cost of burning the debris in piles has been projected to be the same as gathering the debris and creating piles. External costs are not expected to have a large impact on this option or influence the final evaluation. The cost of burning the material should generally be the same anywhere along the reservoir. Therefore, the external costs will consist of start-up costs for Environmental, Wildfire, and Wildlife Management Plans. Monitoring of the fires would also require labor. These costs should be refined if this option is included in the debris management strategy.

6.4 Capital Investment

Burning with the use of ACI requires capital investment in the implementation of the strategy. The cost of the burners over the span of the project may be cheaper than renting due to the number of burners that may be needed in comparative relation to the rental cost of the units. A precise rental cost has not been determined at the time of writing this document. Apparently, Mackenzie Fibre Management Corporation and Duz Cho Logging Ltd. have air burners, but this needs to be reaffirmed and a rental cost determined if they are available for rental. The number available will determine if it is better to rent or purchase. Making use of the available units on a trial basis would be recommended. A single ACI unit costs $250,000.00 (6m x 1.9m x 2.2m) and the power box attachment costs $750,000.00 (9.8m x 2.4m x 3.0m)[22]. The ACI operating cost requires fuel or energy to power the venting fan motor that can be recovered with the power module attachment.

6.5 Stumpage

The influence of stumpage on the cost of any option is expected to be minimal due to the low quality of the debris material. The rate is a set rate for the salvaging of this material from a reservoir as per the current Interior Appraisal Manual.

6.6 Authorizations

There are costs associated with acquiring the necessary authorizations for implementing elements of this strategic management plan for the debris. Most of the identified authorizations identified in section 11.0 are

[22] Figures based on discussions with Dale Mazure with Canada Powerhouse Ltd. A rake attachment for an excavator to remove the ash is included in prices.

needed for all options. Therefore they have no impact on the evaluation of the strategic management options. There biggest impact is on the timing of implementation of the debris management strategy due to the time required to get the authorizations in place.

6.7 Assumptions used to Determine Projected Costs

Machine and production rates given in the assumptions were derived from three sources:

- The 2013 Interior Appraisal Manual
- The AECOM (2011) report, or
- By estimation.

Rates for most of the equipment came from the appraisal manual, which bases its' rates on the BC Road Builders and Heavy Construction Association Blue Book. Operation estimates are based on a 10 hr work day. The same hourly rates used in the AECOM (2011) report for operators, environmental monitors, archeologists, and other professional services are used in our analysis for comparative purposes. Some of the more general overhead costs are not considered since we expect high variability in competitive pricing to make these valuables reliable in our projections.

6.7.1 Fiber Supply

The determination of the cost estimate for the collecting and piling of the debris for the various options are based on the following assumptions:

- Machinery required includes two excavators, a skidder and a loader. These are all found rates (machine, fuel, operator).
- An archaeologist and biologist on-site about 50% of the time.
- A crew can process 675 m^3 per day (9 piles at 75 m^3 per pile).
- Crew is made up of 5 operators.
- It assumed that the crew work for 120 days per year.

6.7.2 Production Of Hog Fuel At The Reservoir

- Grinder rental cost of $650/hr.
- Required machinery includes an excavator.
- 2 additional crew members.
- Fuel consumption is 100 litres per hour for the grinder.
- A crew can process 800 m^3 per day.
- Crew is made up of 5 operators.
- It assumed that the crew work for 120 days per year.

6.7.3 Venting Curtain Incineration – Burn box unit only

- One ACI unit purchase price of $250,000 with an estimated 5 year life span located within Tsay Keh Dene village.
- Start-up costs for Environmental, Wildfire, and Wildlife Management Plans (est. $20,000).
- Monitoring of fires $1500/day; may not be required during high-risk seasons.
- Required machinery includes two large pieces of equipment (excavator/skidder).

- Each large piece of equipment uses 30 litres of fuel per hour.
- Fuel consumption is 14 litres per hour for an air burner at $1.35 per litre, equating to a cost of $189/day per ACI unit.
- The larger ACI unit can process 5-8 tonnes/hr or approximately 160 m^3 per day.
- Crew is made up of 3 operators.
- It assumed that the crew work for 120 days per year.
- Cost in dealing with the ash is included at 0.65% content at average density of 500 kg/m^3; only 1/3 of landfill disposal free is used to account for multi-disposal options.

6.7.4 Venting Curtain Incineration – Energy Recovery

- One ACI unit purchase price of $250,000 plus $750,000 for the power unit with an estimated 25 year life span located within Tsay Keh Dene village.
- Start-up costs for Environmental, Wildfire, and Wildlife Management Plans (est. $20,000).[23]
- Monitoring of fires $1500/day; may not be required during high-risk seasons.
- Required machinery includes two large pieces of equipment (excavator/skidder).
- Each large piece of equipment uses 30 litres of fuel per hour.
- Approximately 130 m^3 per day allowing for energy recovery during cool-down phase.
- Crew is made up of 3 operators.
- It assumed that the crew work for 300 days per year to fuel energy supplies from stockpiles.
- BC Hydro Energy Cost 300 $/MWh (Wilson, 2013) at a rate of 0.1MWh power generation. Parasitic loads reduce the power generation capability. Therefore, the estimate is reduced to 65 kW.
- Estimated 23 hrs of energy recovery / day.
- Cost in dealing with the ash is included at 0.65% content at average density of 500 kg/m^3; only 1/3 of landfill disposal free is used to account for multi-disposal options[24].
- Logistical costs for installation into a power or heating distribution grid is not included.

6.7.5 Venting Curtain Incineration – Trench units

- One portable trench ACI unit purchase price of $150,000 with an estimated 10 year life span[25].
- Start-up costs for Environmental, Wildfire, and Wildlife Management Plans (est. $20,000).
- Monitoring of fires $1500/day; may not be required during high-risk seasons.
- A 4x4 truck to mobilize and transport the trench burner; est. $90/day to operate.
- Required machinery includes an excavator.
- Excavator uses 30 liters of fuel per hour.
- Fuel consumption is 11 litres per hour for an air burner at $1.35 per litre, equating to a cost of approximately $150/day.
- Estimated to burn 100 m^3 per day.
- Cost in dealing with the ash is included at 0.65% content at average density of 500 kg/m^3; only 1/3 of landfill disposal free is used to account for multi-disposal options.

[23] These costs are based on direct recent experience through DWB for burning debris, development of plans, and monitoring.
[24] Even at full cost, ash disposal fees have minor impact on the overall cost.
[25] Shorter estimated lifespan due to transportation adding to incurred damages.

6.7.6 TRANSPORTATION

- Barging assumptions
  - Based on a 52 hr. round trip from Tsay Keh Dene community to Mackenzie.
  - The capacity of the barge is 120 tonnes.
  - The barge rental rate is $400/hr all found.
  - It is expected that the cost of loading and unloading the whole material on the barge would be higher than loading and unloading the chipped material. An estimated value of $1.50 per m^3 has been used.
- Trucking assumptions
  - Both a logging truck and a chip truck have a 20 tonne capacity. The condition of the debris material may make it improbable that a logging truck can be used.
  - Trucks to be used include a logging truck at $116.20/hr and B train chip truck at $133.55/hr.
  - In order to reduce repair cost to the chip truck, the speed by which the truck can travel has been reduced by 20%.
  - The trucking cost calculations have been included in Appendix A.
  - Loading and unloading costs have been included in the trucking cost calculations.

6.8 PROJECTED COST OF THE STRATEGIC OPTIONS

Projected costs for the various options being considered for implementation in the debris management strategy have been calculated (Table 4) and based on the assumptions given in section 5.1.

TABLE 4: PROJECTED OPERATIONAL COSTS OF THE OPTIONS IN THE STRATEGIC PLAN, $/M^3 ($/ODT)

	Barging		Trucking		Burning		
Item	**Whole Material**	**Hog Fuel**	**Whole Material**	**Hog Fuel**	**ACI**	**Trench Burner**	**ACI with Power Module**
Fibre Supply	10.85 (26.04)	10.85 (26.04)	10.85 (26.04)	10.85 (26.04)	10.85 (26.04)	10.85 (26.04)	10.85 (26.04)
Stumpage	0.25 (0.60)	0.25 (0.60)	0.25 (0.60)	0.25 (0.60)	0.25 (0.60)	0.25 (0.60)	0.25 (0.60)
Processing Costs	12.89 (30.94)	12.89 (30.94)	12.89 (30.94)	12.89 (30.94)	3.49 (8.38)	7.02 (16.85)	3.60 (8.64)
Unload	1.5 (3.60)	1.5 (3.60)	--	--	--	--	--
Transport Costs	72.22 (173.33)	72.22 (173.33)	35.62 (85.48)	51.69 (124.06)	35.62 (85.48)	--	35.62 (85.48)
Total Costs	97.71 (234.51)	96.21 (230.91)	59.61 (143.06)	75.68 (181.64)	50.21 (120.50)	18.12 (43.49)	50.32 (120.77)

Hog Fuel / Power Recovery	2.08 (5.00)	2.08 (5.00)	2.08 (5.00)	2.08 (5.00)	--	--	14.40 (34.56)
Final Costs	**95.63 (229.51)**	**94.13 (225.91)**	**57.53 (138.06)**	**73.60 (176.64)**	**50.21 (120.50)**	**18.12 (43.49)**	**35.92 (86.21)**

6.9 Project Budget for Strategic Options

In order to determine an annual budget requirement for the various debris management options presented in the Debris Management Strategy, it was necessary to determine a goal for the amount of debris to be disposed of annually. An annual rate of 120,000 m^3 (50,000 ODT) is selected and based on two factors. First, the selected rate equates to the amount of extra material that the Conifex electrical generation plant could utilize in order to reach 100% capacity, and second, at that rate the majority of the debris associated along the reservoir shoreline would be utilized within a 10 year timeframe.[26] This required a few extra assumptions for the ACI technology. For example, ten trench ACI units would be required to meet this target so the extra purchasing value for this many units was incorporated into the processing cost in Table 4. These values provided a comparative budget (Table 5) for meeting the annual utilization goal.

TABLE 5: PROJECTED BUDGET FOR THE OPTIONS IN THE STRATEGIC PLAN, $/YR

	Barging		Trucking		Burning		
	Whole Material	**Hog Fuel**	**Whole Material**	**Hog Fuel**	**ACI**	**Trench Burner**	**ACI with Power Module**
Projected Annual Budget	$11,475,500	$11,295,500	$6,903,600	$8,832,000	$6,025,200	$2,174,400	$4,310,400

6.10 Economic Summary

The economics of the options considered may be subject to change, but the most apparent result from our budget analysis is that the costs are substantial. A calculation check was made through comparison with the AECOM (2011) report. A cost result for collection and piling of $1.8 m was calculated with our methods versus the $1.75 m AECOM (2011) estimate, which indicates that the price comparisons are within a reasonable margin of error. The high costs and uncertainty suggest that the strategic target approach (see Section 5.1.4) be utilized for all options considered. Areas where the pricing has the most potential or expectations to change include:

- Pricing for trucking versus barging as Mackenzie Fiber has plans to establish a port along the reservoir to accept barged material into its yard.
- Supply and demand for hog fuel as operations start to ramp up and feed supplies become limited (i.e., market variability).
- Fluctuating cost of fuel.

[26] Note, however, that the ACI and trench burners do not have the capacity as single units to achieve this target. It would require five ACI box units operating 300 days/yr to reach this goal and 20 trench units operating 120 days/yr to achieve this target. The values provided assume that this many units would be purchased to reach this goal for comparative purposes alone. This indicates that the ACI technology would not have the capacity to achieve the ten year strategic processing target alone.

- Mixed strategies, including targeted strategic approach that may lead to annual fluctuations in use of the material used, operational costs, and pricing of the material into different markets.
- Handling and use of ash material from ACI burning.
- Venture capital for purchasing and installation of ACI units.
- Installation of ACI unit with power module into an available distribution grid.
- Access availability, construction and level of clearing that will be required.
- Variations in the quality of the debris.

7.0 STRATEGIC MANAGEMENT PLANNING

The Strategic Management Plan targets four main options for removing debris from the Williston Reservoir shoreline in the short term. These include stockpiling, reclamation works, burning, and use as hog fuel for bioenergy.

7.1 OPTION 1 – STRATEGIC STOCKPILE MANAGEMENT

Option 1 is continuing on with the current status quo of targeted removal and stockpiling. Specific consideration should be given to incorporation of the stockpiled debris as potential windbreaks as part of the Dust Mitigation Project. This option may present unknown and longer term environmental risk in terms of the unknowns, how the material will decompose, and impact to the soils in the area where it is placed. In many respects, this option will remain in place until action is taken on the existing debris piles.

There is large uncertainty with this option as there are few studies investigating the long-term consequences of numerous debris piles along a reservoir shoreline. A key piece of uncertainty is the placement of the debris. Hydrological cycles are intensifying in northern BC and are expected to increase due to climate change, including raised variation in river discharge (Déry et al., 2009). Our analysis of debris in the reservoir would suggest that a large supply remains under the water, which could continue to lift, float, and erode at the shoreline to expose piles. These dynamics could lead to the reintroduction of some debris piles into the reservoir.

This option can also be considered in terms of what is being lost. The debris holds obvious utility as wood fiber, a point of consideration throughout this report (e.g., Section 8.4), but the quality may deteriorate over time. Coarse woody debris also provides important ecosystem services that would not be capitalized on for the full potential through stockpiling, as much of it will not be accessible as habitat for wildlife or to fill a role in the carbon and nitrogen cycles of forest ecosystems (Stevenson et al., 2006; Wiebe et al., 2014). Many of the nutrients (e.g., carbon) would have been released through the initial pulse of decay and loss of smaller twiggy and leaf fragments. However, the wood would tend to be longer preserved in piles without having contact to the earth substrate where decomposition rates accelerate. Moisture levels are the key factor in the decomposition rates (Lewis & Thompson, 2011).

Therefore, we recommend that the status-quo stockpiling of the debris be investigated in greater detail. Some of this investigation will be linked into other strategic options identified below, but is clear that ongoing research into the stockpiles will be of assistance. Strategic stockpile management will require an accounting system to monitor what is being removed and if new debris is still being introduced from the floor of the reservoir. It may be determined that the quality of the debris may be of higher value in some areas and the way in which the piles are being placed might offer certain advantages. Therefore, it is recommended that a stockpile management program be implemented to pilot future studies, to track changes, and to market the material accordingly as other strategic options are being implemented.

7.2 Option 2 – Reclamation Works

This option was described in detail in Section 5.1.3. An example of this option was seen in the reclamation works for stream enhancement projects as part of the GMSWORKS-19 project[27] at Six Mile and Ole Creek (MacInnis et al., 2015). The debris was installed along and as part of structural material for the containment walls used to stabilize the stream channel. However, debris quality at Ole Creek project either had poor structural integrity that "would disintegrate or shatter when picked up or moved by an excavator" (Kerr Wood Leidal Associates, 2014, p. 4-3) or there were pieces with greater structural integrity that were used in the construction of debris catchers that "appeared to be escaped logs from prior historic logging operations elsewhere in the reservoir basin" (Kerr Wood Leidal Associates, 2014, p. 4-3); also discussed in DWB (2014).

Other reservoir projects that have made use of the debris include trials to study the effectiveness of debris piles to act as berms to protect vegetated sites at Collins Bay beach and use of debris mulch for soil enhancement[28]. Use of the debris for other similar reclamation projects is entirely feasible and efforts should be included to make full use of the debris in any future reclamation projects conducted by BC Hydro along the reservoir, but the market for this option is likely to be small. The advantage here is that the debris is being utilized structurally, which allays greenhouse gas emissions concerns. This option is included in the strategy because it is sound environmental practice and it is already being used as such, but it would not result in any appreciative volume from being treated beyond the piling.

7.3 Option 3 – Burning

While it would be more economical to burn the piles directly, this would add costs to air quality and greenhouse gas emissions. Our cost analysis (Table 4) shows that burning the material in place using ACI trench burners offers the economical option. The ACI option offers a way to burn the material, while reducing the amount of PM that would contribute to poor air quality. Other environmental concerns with the trench burning is leaving concentrated pockets of ash material on location that will require consideration for best management practices in this regard. A large concern for the trench ACI system is that the throughput cannot meet an annual goal of 120,000 m^3 per year; a single unit could potentially burn 6000 m^3 per season. The trench ACI option has the attractive feature of portability. Burning in the ACI without the power box is another lower cost economic option (potentially), but it suffers from the same throughput limitation requiring multiple units to achieve the annual goal.

7.3.1 ACI Burning with Energy Recapture

The second best option from the economic analysis is the trucking of whole material to an ACI unit with a power module at Tsay Keh Village (Table 5). This option, however, will require a considerable amount of

[27] http://www.bchydro.com/content/dam/hydro/medialib/internet/documents/environment/pdf/wup_-_peace_-_gmsworks-19.pdf

[28] GMSWORKS#21 - Vegetation Enhancement and Protection Trials http://www.bchydro.com/content/dam/hydro/medialib/internet/documents/planning_regulatory/wup/northern_interior/2011q3/gms_annual_report.pdf

venture capital. While the full scale annual goal of 120,000 m^3 per year cannot be met with the ACI unit (unless 4 units are purchased), this option has several features that make it appealing. First, the release of PM is reduced in comparison to open burning. The ACI process would still contribute to CO_x emissions that may require further investigation to determine if it is compatible with BC Hydro's environmental policy. Second, the power recovery option provides a potential economic incentive for Tsay Keh Village that may offset some of greenhouse gas emissions by making effective use of the stored potential energy.

While this option seems promising from an economic and environmental context it would require additional research into its feasibility to connect into the existing power grid. The Wilson (2013) report identifies locations where the ACI option with the power module could be integrated into the Tsay Keh Dene village in lieu of the small-scale 45 kWe biomass gasification system. Our cost analysis, however, does not account for connecting the power module into an existing power grid (or alternatively for heat distribution) and the system also requires cooling (e.g., use of reservoir water, seasonal temperature variations, coolants). Noise and air quality issues close to the community are additional considerations. These and other potential concerns are raised (e.g., source of venture capital) that would require a larger scale investigation and puts leaves this option in the feasibility analysis category rather than a strategic option.

7.4 Option 4 – Hog Fuel for Bioenergy Plants

Current plans are already under way to make use of some of the piles for the Conifex Cogen bioenergy plant in Mackenzie. Chu Cho Industries has retained an agreement with Conifex to manufacture hog using a tub grinder and to load the material on a barge that will be delivered to a port at the log yard in Mackenzie[29]. The plan is to start out small in 2015 as a trial with an expectation of delivering 2000 tonnes (~4000 m^3) at most and delivery volumes will be ramped up if the project is found viable. East Fraser Fiber has used the reservoir debris material historically. The reservoir debris was trucked and then chipped in a whole log chipper in Mackenzie. The chips were used in their mills.[30]

Pricing for the hog fuel in our cost analysis was set at $5 ODT. However, this value is very low and is expected to increase if the product is marketable. The following quote was taken from a 2014 posting from the City of Revelstoke[31] provide insight into the range of costs that might be expected:

"The City of Revelstoke has identified 220,000 odt/yr of reliable, high quality biomass that is estimated to be available (not currently committed in long term contracts) at an overall average price of $74.50/odt (oven dried tonne, not including chipping, drying etc) within a range from $0 to $125/odt fob Revelstoke plant. 50% of this supply is available at under $57.50/odt averaging $45.00/odt, and 80% is available at under $100/odt averaging $63.00/odt."

Using the $45 / ODT average in the recovery price in Table 4 levels out the costing and brings it closer to the ACI option. Any monies earned through this operation are to be fed back into the debris management program. At 2000 tonnes per year, this option would reach the 120,000 m^3 objective within 30 years. The process volume would have to be ramped up to 5,800 tonnes per year from yeas 2-10 to meet the volume objective within 10 years.

[29] Information courtesy of Dan Wiebe, Chu Cho Industries.
[30] Information kindly provided by Richard Glazier from East Fraser Fiber Co. Ltd.
[31] http://www.cityofrevelstoke.com/DocumentCenter/View/1452

8.0 STRATEGIC IMPLEMENTATION

Debris operations typically occur in the July to September period when the reservoir is higher, at, or near full pool[32]. Additional secondary uses previously discussed in section 5.1.3 should be employed as opportunities present themselves. Baseline costs for each option can be tracked as the different stages of operation are put into effect and compared to estimates provided in this report for future budgeting over the longer term (2015 to 2024). Each option should be dovetailed with ongoing debris projects to minimize incremental operational costs and additional authorization requirements. A list of authorizations that will be required to implement the strategic options are included in Section 11.0, Table 6.

Strategic option #4 will be implemented in 2015 through the agreement with Chu Cho Industries and Conifex. Processing of material deposited along the shoreline should be focused initially on the Finlay Arm (Reach) where the majority of the debris material exists and with the highest transportation costs. Debris removal at the north end of the reservoir at the mouth of Hydro Creek and on the east side of the Finlay arm in the Middle Creek area have has been flagged as high priority areas[33]. The processing method for 2015 will include the generation of hog fuel samples that can be used to better understand the feasibility and costs involved through use in the Conifex bioenergy plant in Mackenzie. We recommend that samples be generated from different locations to study the quality and marketability of the material, to compare field processing and hauling costs, to study fibre suitability and other associated environmental considerations. Samples can be shipped to Canfor's Pulp Fiber lab for an in depth analysis of what kind of variation exists in the woody quality.

Longer term strategies will be developed based on the results from the short term results as Option #4 develops and identification of future liabilities and risks moving forward. Option #3 using power recovery should be the next best strategic option to consider. Trench burners are economical and might be considered for low-quality fiber or difficult to access areas where the economic viability is intangible. However, burning of the wood subtracts from the potential for revenue through bioenergy projects. It is therefore recommended that a large feasibility study be conducted for use of an ACI unit with power recovery at the Tsay Keh Village. This study would include an analysis of the available financial capital stemming from the hog fuel markets, cost of installation into the existing power grid (or heating distribution), and consultation with Tsay Keh Dene First Nations to determine the viability (social and economic) for having ACI unit(s) installed within the Village.

All directly affected First Nations (Moberly Lake and McLeod Lake) and legislatively required consultations will take place to engage affected communities as different areas are targeted along the Mackenzie Williston reservoir area. Negotiations to distribute the material by Chu Cho Industries to other firms (e.g., East Fraser Fiber) should be encouraged and managed to ensure fair market and accessibility for the resources. BC Hydro should take the lead to ensure that a tracking system of the material being shipped off the reservoir is

[32] Information provided by Harry Brownlow – BC Hydro, 2014.

[33] Chu Cho Environmental, Chu Cho Industries, and DWB Consulting Services Ltd. have been working collaboratively to develop plans for these locations and have applied for funding from multiple external sources. The plans include similar engineering methods and research survey methodology that were adopted at Six Mile and Ole Creek in ongoing efforts to prevent debris accumulation from blocking channel access to fish populations and causing more erosion.

maintained to gain a better understanding of the debris volumes, inputs, and throughputs. If the hog fuel operations show promise and the market becomes viable, then this information can be used to better understand the debris and financial resources could feed into the overall debris management program.

Option #2 of using debris for reclamation works may not generate revenue, but it provides a means of return in terms of effective use of available natural capital. Coarse woody debris (CWD) provides an important ecological resource, which was addressed in the BC Chief Forester's (2010) guidance report on CWD management (see also, Stevenson, Jull & Rogers, 2006). Diverse class and types of CWD provide habitat for wildlife, such as salamanders to enhance their terrestrial hunting grounds or adding breeding hides within riparian areas along wetland habitats. Amphibian habitat exists under the debris along the shoreline where sufficient organic matter has accumulated from the overhang and adjacent forested areas[34].

Some of the debris that has washed up on shore and has become well integrated into a soil or organic substrate should be avoided. These best management considerations need to be integrated into the entire WD-SMP. Salamanders, for example, are known to deposit eggs into small ponds in the drawdown zone and they utilize the debris as cover and foraging sites (MacInnis et al., 2015). Hence, debris that has been firmly situated at the immediate forested margins or around wetlands should be left in place, following on the best management practices identified in the Reservoir Debris Removal Guide Book (BC Hydro, 2008), because they are providing habitat and stability functions. Environmental surveys should be completed prior to removal of the debris to ensure it is not being utilized as habitat by amphibians (BC FLNRO and BC MoE, 2014). If amphibians are present, then wildlife salvage permits will required per the BC Wildlife Act; under this Act, it is prohibited to kill, collect, or hold captive any amphibian without a permit (see Section 11.0).

Consideration for use of ash from burnt material, chipping and tillage, or direct use of the debris for CWD may require additional trial studies to determine the best options; completed trial studies (e.g., GMSWORKS #21) provide some guidance to make decisions on these options. The GMSWORKS-21 trials provide an example of different reclamation uses for the debris. Spreading the debris out in some area may make sense for the purpose of habitat creation for amphibians, small mammals, and invertebrates. Use of the debris in the sandy foreshore area, however, would have limited long-term utility as a nutrient additive for vegetation establishment[35].Use of the debris in reclamation projects would require site specific reclamation planning[36]. Hauling of some material into adjacent forested areas may provide added benefit for vegetation establishment and wildlife[37]. Adding chipped material to the transitional banks between the foreshore and forest would increase organic content, potentially enhance or increase amphibian habitat, and has the potential to increase stability to this part of the shoreline area, but will have only minor impact in terms of the bulk removal of debris. Hence, it is important that the debris piling and removal program is integrated with efforts to add stability to the shoreline that has otherwise been subject to erosion caused by the debris.

[34] M. Thompson – *personal observation*.

[35] Chuck Bulmer, FLNR, Soil Restoration Ecologist – *personal communication*.

[36] These options have been put into consideration and planning, for example, at the Hydro Creek location.

[37] Debris was hauled out at the Ole Creek site and placed into a spoil pile located on high ground outside of the reservoir drawdown zone. Some debris was spread along the eroded margins. An estimated 1500 m^3 was removed from site (Kerr Wood Leidal Associates Ltd., 2014). Follow-up studies are expected to occur at this site through the GMSMON-17 project that might give more insight into the debris as habitat.

Use of the debris for reclamation works would be of unlikely attraction for forest companies, which can easily achieve CWD stocking supplies within cut blocks[38]. This option may be applicable, however, to special reclamation projects or reclamation works at mines or quarries. Various types of treatment considerations can be envisioned in terms of debris management as it is being applied in the enhancement works associated with the GMSMON-17, GMSWORKS-16, and GMSWORKS-17 projects (BC Hydro, 2014b,c). Consideration can also be given to studying different piling options of the debris in rows to act as a windbreak and potential dust mitigation. Use of the debris in reclamation projects at sites away from the reservoir, such as mines, would require communication to potential firms that might have an expressed interest in use of the material.

Leadership is essential to the implementation of this strategy. Key leaders in the operations include Chu Cho Industries and BC Hydro. BC Hydro's involvement in this process should be similar to the management of the debris management program including providing the applicable human and information resources and the procurement of applicable permits, authorizations, research, record keeping, and follow-up reports. Environmental best management practices and appropriate guidance for what debris should be targeted, removed, and processed needs to be managed through the execution of an applicable environmental management plans ("EMP"). An overarching EMP should be developed for each arm of the reservoir. Individual EMPs should be developed for different tasks executed by different contractors to include best practices for their operations.

9.0 SITE SELECTION CRITERIA

To proceed with any type of debris management on the Williston Reservoir, it is important to choose operating sites in such a way to minimize the impact to the natural environment and to provide a safe environment for workers. The following criteria should be used in the selection process for debris management staging areas:

- Existing access to or near the site exists.
- Suitable terrain conditions exist to enable the construction of direct access to the site.
- Low gradient site.
- Avoid fine soils with high erosion and compaction issues.
- Avoid wet sites.
- Use of swamp / rigs mats to reduce compaction issues.
- Avoid areas with eroding / unstable banks.
- Avoid heavily vegetated areas if possible.
- Avoid overhanging cover, soft gravels, embedded material, and vegetated areas.
- Avoid crossing streams, their tributary channels, or wetlands that would require fording or increase risk of damage to environmentally sensitive areas.
- Avoid removing material from streams, riparian areas. Basically, if it is already anchored, leave it be.

[38] This inference is based on consultation with and feedback from experienced professional foresters having experience working in this area.

9.1 Haul Access Sites

Moving ahead in 2015, additional haul sites can be identified. Figure 8 shows forestry road access points around the Finlay basin in relation to other project areas that have been discussed in this WD-SMP as an example of potential access points. Road access to the reservoir has already been planned at four sites shown on the map (Figure 8). Licence of Occupation roadways permits will be approved allowing access to 11 additional sites in 2015.

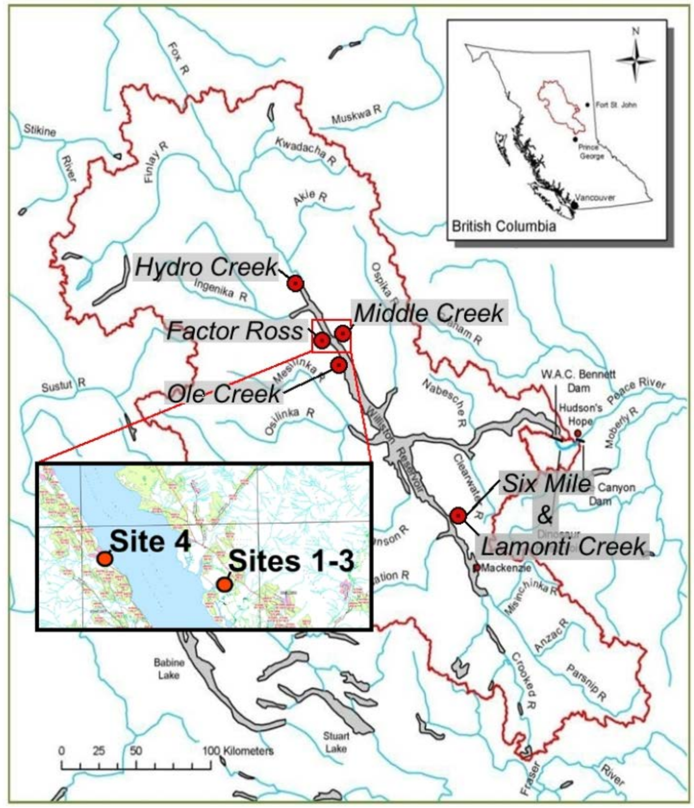

FIGURE 8. AREAS DISCUSSED IN THE DOCUMENT ARE IDENTIFIED IN THE MAIN MAP. UPPER INSET SHOWS MAP LOCATION PROVINCIALLY. LOWER LEFT INSET SHOWS POTENTIAL TRUCKING HAUL OUT LOCATIONS ALONG FORESTRY ROADS.

There are a multitude of ways to access haul sites around the reservoir. Access requirements to the sites shown on the License of Occupation map (Figure 8) involve:

- Access on Forest Service Roads - a Road Use Permit is required.
- Access on Road Permit roads issued by the MOF to Licensees will require a road maintenance agreement with the holder of the road permit (e.g., Conifex).
- Silviculture prescription ("SP") amendments to on-block roads found within a cutting authority; the holder of the SP is responsible for the amendments, but will more than likely request that BC Hydro does them on their behalf, as well as possible reporting to the Ministry.
- The type of amendment will also depend on whether the block was developed under Forest Practices Code or Forest and Range Practices Act).
- Access on all other non-status roads (i.e., roads on crown land) not under current tenure; therefore no access authority has been granted and would be obtained through the License of Occupation process. This option is administered through Lands and typically takes the most time to get approved. It may be possible to apply for a road permit under the Forest Act, depending on the tenure to allow the salvage and removal of the debris.

Long term sites throughout the reservoir will be prioritized based on BC Hydro selection criteria that is to be determined. Options that have suggested but not evaluated in the budget analysis should be investigated during an ongoing review and analysed for feasibility compared against baseline costs developed for the main options being implemented. Most of these options require involvement with third parties and issues that were unable to be overcome given the reporting time constraints.

10.0 REGULATORY AUTHORIZATIONS

Permits, authorizations and licenses that may be required in order to proceed with the implementation of a debris management strategy on the Williston reservoir are identified in Table 6; the requirement for an authorization will depend on the type of activity being considered. The issuing authority and expected timeline required to obtain them has also been included. As BC Hydro is responsible for the Williston reservoir and management of the debris associated with the reservoir, all authorizations and approvals should be obtained by BC Hydro prior to implementation of the debris management strategy.

TABLE 6: AUTHORIZATIONS FOR DEBRIS MANAGEMENT ON WILLISTON RESERVOIR

Authorization	Description	Issuing Authority	Timesframe of Expected Issuance
Occupation License to Cut (OLTC) under the Forest Act	Grants authority to salvage debris within/adjacent to the reservoir.	MoFLNRO	3 - 6 months. FN consultation and AIAs will influence time to approval.
Road Use Permit (RUP) under the Forest Act	Grants authority to use Forest Service Roads (FSRs).	MoFLNRO	Less than 1 month.
Road Use Maintenance Agreement under FRPA section 22.3	Grants authority to use another users tenured road. May be a cost to use/maintain the road.	Road tenure holder	Less than 1 month.
License of Occupation under the Lands Act	Grants authority to occupy a piece of Crown land for a specific purpose, but grants no other rights (i.e. could build a road, but not remove the timber on the road right-of-way).	MoFLNRO (Lands)	6 - 12 months. FN consultation, AIAs and clearances will influence time to approval.
Foreshore Lease under the Lands Act	Grants authority to occupy and conduct activities in the area below the high water mark on the reservoir.	MoFLNRO (Lands)	6 – 12 months. FN consultation, AIAs and clearances will influence time to approval.
Forestry License to Cut (FLTC) under the Forest Act	Grants authority to cut down crown timber or immature trees. One license required for each possible scenario. May be location specific meaning several may be required. May be a stumpage and/or damage to immature cost. To be used in conjunction with a License of Occupation. Needed to widen existing access or construct new access.	MoFLNRO	3 months each.

Burn registration number (burning permit) under the Wildfire Regulations	Grants authority to burn industrial material. Burning is only to occur within the proper venting indices.	MoFLNRO (Protection)	Immediate. Need to phone in for a burning number (1-888-797-1717) and provide requested information.
Exemption to burning prohibition under the Wildfire Regulations.	Grants authority to burn during a period when open burning is prohibited (fire ban). A burning plan is required along with a burn registration number.	MoFLNRO (Protection)	
Section 8 approval under the Water Act	Grants authority to short term use of water.	MoE	
Section 9 approval / notification under the Water Act.	Grants / enables authority to work within or adjacent to the high water mark of the reservoir.	MoE	6 months if approval required, less than a month if a notification.
Navigable Waters Protection Act	The Act requires "Notice of Works" to the Minister of Transport if the works occur in navigable waters.	Transport Canada	Much of the project works would likely fall under a Minor Works Order, which would not require a notice provided all legal requirements are followed.
DFO project review	Projects that could potentially cause harm to fisheries may require review. DFO has a self-assessment process to determine if projects require notification. Log-removal and salvage, for example, is exempt. Larger works would have to be reviewed. Discuss project with DFO to determine if a review is required.	DFO	1 - 2 months.
Wildlife Salvage Permits	Debris removal has the potential to harm wildlife; an offence under the BC Wildlife Act. Salamanders forage under debris in the foreshore where leaf-litter creates an organic substrate between the log and sand. Wood frogs and western toads also migrate through the debris. Best management practices should be followed. A salvage permit per the Wildlife Act of BC is required for translocation of amphibians if required.	MFLNRO	Website posts 30 days processing, but can take up 3 months to acquire.

MoFLNRO – Ministry of Forests, Lands and Natural Resource Operations
MoE – Ministry of Environment
DFO – Department of Fisheries and Oceans

Other items that should be in place that are not directly applicable to the above regulatory authorizations are:

- Environmental Management Plans (EMP)
- Safety plans

- Research funding for any trials

11.0 CONSULTATION AND OUTREACH

Many stakeholders have been involved in various aspects of debris management along the reservoir. It is recommended that this plan be shared and discussed widely to gather additional information that may of be value to the debris management program. It is further recommended that a meeting be held to introduce, integrate, and bring all the key stakeholders together to assist with the long-term execution of this plan. It may be worthwhile to consider the formation of a working group to meet annually to provide guidance, updates, and recommendations on the strategic management plan. Each strategic option should be reviewed after the first year of trial implementation as part of the overall strategy. This process should commence prior to full-scale implementation of any of the four debris management options and continue throughout the duration of the implementing the WD-SMP.

The following organizations are identified as primary targets for additional outreach concerning future planning and management of the debris in relation to the strategy identified herein:

- Ministry of Forest and Natural Resource Operations
- Ministry of Environment
- Department of Fisheries and Oceans
- Local industry
  - Mackenzie Fibre Management Corp.
  - Conifex Timber Inc.
  - Canfor
  - Pacific Bioenergy
  - Pinnacle Pellet
  - East Fraser fiber
  - Nechako Lumber
- Local First Nations
  - Tsay Keh Dene First Nation
  - McLeod Lake Indian Band
  - Kwadacha Nation
  - Moberly Lake Indian Band

12.0 CONCLUSION

Targeted Debris Management Project (TDMP) launched in 2010 involves collecting debris into piles along the reservoir shoreline. The GMSWORKS-18 Williston Debris Field Survey was completed in 2011 to quantify the volume of debris accumulation along the shoreline and outline recommendations debris uses (AECOM, 2011). Further to that study, BC Hydro retained DWB Consulting Services Ltd (DWB) to prepare a Strategic Management Plan to specify options that could be executed in practical manner and in the season following delivery of the report.

DWB developed the Woody Debris – Strategic Management Plan (WD-SMP) by executing a three-step feasibility study. The first step of the feasibility was used to identify a smaller list of feasible strategic options out of a wider range of options that had been considered in previous reports (e.g., AECOM, 2011). A couple new options were added that were flushed out through consultation with various stakeholders, scientists, First Nations, consultants, and industry with potential commercial interests in the debris. The wide range of options that were reviewed in this first step of the feasibility study included bio-energy potentials at Tsay Key Dene village, wood briquettes, biochar, residual firewood, pellet market, pulp, recovery of logs, mill to dimension lumber, other chipped products, hand craft, chip and blow/bury, and a do nothing approach.

The second step to the feasibility study included a budget analysis on a short list of options that had been flushed out of the first stage. The budget analysis helped to identify what kinds of costs need to be considered in the debris management options and to develop strategic plans. The third and final step was the creation of an actual strategy. The WD-SMP is based on practical options deemed viable from the heuristic feasibility study. The WD-SMP provides options to move beyond the status quo of piling of the debris, it identifies options to deal with the bulk of the existing shoreline debris within 10 years, and these selections were based on an understanding of debris quality limitations.

The WD-SMP includes four viable options for implementation: strategic stockpile management, reclamation works, burning, and use as hog fuel for bioenergy. It is further recommended that each option be reviewed after the first year of trial implementation as part of the overall strategy. This process should commence prior to full-scale implementation of any of the four debris management options. The review process would help to minimize incremental operational costs, ensure safe operations, create templates for meeting applicable regulatory requirements, and would give an opportunity to include input from various stakeholders.

Acknowledgements

The authors of this report would like to thank the following people for their input, knowledge and advice:

Chuck Bulmer	Sharon McDonald	Mac Anderson
Brian Hansen	Dave Keely	Dan Weibe
Larry Davis	Fred Streleoff	Aaron Flett
Rick Girard	Rick McCordic	Loni Arman
Brian Aitken	Dan Bedford	Melissa Steidle
Betty Jo Weaver	Geoff Chambers	
Mike Tilson	Norbert Fuhrmann	

DWB would also like to acknowledge the following individuals who provided review comments to earlier drafts of this document:

Harry Brownlow, BC Hydro
Julie Fournier, BC Hydro
Kim Hawkins, Natural Resource Specialist, BC Hydro
Dennis Izony, Band Chief, Tsay Keh Dene
Susan McKellar, R.PF., DWB Consulting Services Ltd.
Patience Rakochy, R.PF., Forester, Tsay Keh Dene
Sonja Wilson, P. Eng., Kerr Wood Leidal

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APPENDIX A – COSTING SPREADSHEETS

Cycle Time Calculation from Common Junction (Tsay Keh Dene) to Point of Appraisal (Mackenzie)

Date:	Effective Date of This Calculation:
Licence: Debris Management Plan	Initial Calculation or Update:
Timber Mark: Tsay Keh Dene Townsite (DMP location 52)	Cut Block:
Contractor:	Geographic Location:
Contractor Representative:	Licensee Representative:

Sector Number	Sector Start Point	Sector End Point	Estimated Speed (km/hr)	Empty Travel Distance	Loaded Travel Distance	Road Class	Empty Travel Time (Hours)	Loaded Travel Time (Hours)	Total Travel Time	Distance On-Highway	Distance Off-Highway
1	Tsay Keh Dene	Factor Ross Rd.	50	50.00	50.00	Gravel4	1.053	1.176	2.229	50	
2	Factor Ross Rd.	Finlay FSR	60	101.00	101.00	Gravel3	1.772	1.980	3.752	101	
3	Finlay FSR	Mackenzie	60	200.00	200.00	Gravel3	3.509	3.922	7.430	200	
4							0.000	0.000	0.000		
5							0.000	0.000	0.000		
6							0.000	0.000	0.000		
7							0.000	0.000	0.000		
8							0.000	0.000	0.000		
9							0.000	0.000	0.000		
Totals				***351.0***	***351.0***		***6.3***	***7.1***	***13.41***	***351***	***0***

Other Adjustment Factors Above appraisal allownce for safety considerations	*Frequency of Event Per Cycle*	*Time Allowance Per Event (Hours)*	*Total Adjustment Time*	*Total Adjustment Time*
Load Marking (includes applying and removing flag)	1	0.133	0.133	0.133
Wrapper Checks	2	0.083	0.167	0.167
Chains (apply, check, remove) Indicate Number of Sets	0	0.167	0.000	0.000
Mandatory Brake Checks	0	0.200	0.000	0.000
Steep Adverse Grades or Assistance Muddy Conditions	0	0.167	0.000	0.000
Re-Fuelling	0	0.167	0.000	0.000
Other				0.000
Total			0.300	**0.300**

Cycle Time (Hours) from common junction to Point of Appraisal	*13.712*
Cycle Time (Hours) from sites to common junction (see page attached)	*0.000*
Loading, Unloading, Unavoidable delay	*1.000*
Total Cycle Time (Hours)	*14.712*

Cost per tonne logging trucking rate

Hour rate / tonne: Logging truck

Rates and pricing to be determined

Signature of Contractor Representative

Cycle Time Calculation from Common Junction (Tsay Keh Dene) to Point of Appraisal (Mackenzie)

Date:	Effective Date of This Calculation:
Licence: Debris Management Plan	Initial Calculation or Update:
Timber Mark: Tsay Keh Dene Townsite (DMP location 52)	Cut Block:
Contractor:	Geographic Location:
Contractor Representative:	Licensee Representative:

Sector Number	Sector Start Point	Sector End Point	*Estimated Speed (km/hr)*	*Empty Travel Distance*	*Loaded Travel Distance*	*Road Class*	*Empty Travel Time (Hours)*	*Loaded Travel Time (Hours)*	*Total Travel Time*	*Distance On-Highway*	*Distance Off-Highway*
1	Tsay Keh Dene	Factor Ross Rd.	50	50.00	50.00	Gravel4	1.333	1.538	2.872	50	
2	Factor Ross Rd.	Finlay FSR	60	101.00	101.00	Gravel3	2.244	2.590	4.834	101	
3	Finlay FSR	Mackenzie	60	200.00	200.00	Gravel3	4.444	5.128	9.573	200	
4							0.000	0.000	0.000		
5							0.000	0.000	0.000		
6							0.000	0.000	0.000		
7							0.000	0.000	0.000		
8							0.000	0.000	0.000		
9							0.000	0.000	0.000		
Totals				***351.0***	***351.0***		***8.0***	***9.3***	***17.28***	***351***	***0***

Other Adjustment Factors Above appraisal allownce for safety considerations	*Frequency of Event Per Cycle*	*Time Allowance Per Event (Hours)*	*Total Adjustment Time*	*Total Adjustment Time*
Load Marking (includes applying and removing flag)	1	0.133	0.133	0.133
Wrapper Checks	2	0.083	0.167	0.167
Chains (apply, check, remove) Indicate Number of Sets	0	0.167	0.000	0.000
Mandatory Brake Checks	0	0.200	0.000	0.000
Steep Adverse Grades or Assistance Muddy Conditions	0	0.167	0.000	0.000
Re-Fuelling	0	0.167	0.000	0.000
Other				0.000
Total			0.300	**0.300**

Cycle Time (Hours) from common junction to Point of Appraisal	*17.579*
Cycle Time (Hours) from sites to common junction (see page attached)	*0.000*
Loading, Unloading, Unavoidable delay	*1.000*
Total Cycle Time (Hours)	*18.579*

Cost per tonne B train chip trucking rate

Hour rate / tonne: B train chip truck

Rates and pricing to be determined

Signature of Contractor Representative

Signature of Licensee Representative

TABLE A1. AIR CURTAIN INCINERATION (ACI) COST CALCULATIONS.

ACI Unit @ Tsay Keh Dene

Unit Value	Life Span	Operations[1]	Excavator	Fuel / day	Process Rate[2]	Crew / day	Plan + Monitoring	Ash[3]
$ 250,000.00	25 yrs	300 days / yr	$175.89/hr	$999.00	160 m^3 / day	$1,050.00	$1,666.67	10.4 m^3 / day

	ACI Unit	Excavator	Fuel	Ash	Total
Annual Cost (Over 3000 hrs)	$ 30,000.00	$ 527,670.00	$ 299,700.00	$ 3,484.00	$ 1,675,854.00
Rate per hr	$ 10.00	$ 175.89	$ 99.90	$ 1.16	$ 558.62

		$/m[3]
Annual goal (120,000m3) over process rate	750	$ 3.49
Three units to reach this goal annualy (answer = # processing days):	250	

ACI trench unit[4]

Value	Life Span	Operations	Excavator	Truck and Fuel	Process Rate	Crew / day	Plan + Monitoring	Ash
$ 125,000.00	10 yrs	120 days / yr	$175.89/hr 10 hrs / day	$77,220.00	100 m^3 / day	$1,900.00	$1,666.67	6.5 m^3 / day

	ACI Unit	Excavator	Fuel	Ash	Total
Annual Cost (Over 1200 /hrs)	$ 125,000.00	$ 211,068.00	$77,220.00	$ 884.40	$ 842,172.40
Rate per hr	$ 104.17	$ 175.89	$ 64.35	$ 0.74	$ 701.81

$/m[3]
$ 7.02

ACI Unit @ Tsay Keh Dene with energy recovery[6]

Value	Life Span	Operations	Excavator	Fuel*	a. Process Rate	Crew / day	Energy Generation / machine[5]	Plan + Monitoring	Ash
$ 750,000.00	25 yrs	300 days / yr	$175.89/hr 10 hrs / day	20 hrs / day $0.00	130 m^3 / day	$1,050.00	0.1 MWh	$1,566.67	8.45 m^3 / day

	ACI Unit	Excavator	Fuel[7]	Ash	Total
Annual Cost (3000 /hrs)	$ 90,000.00	$ 527,670.00	$ -	$ 2,834.10	$ 1,405,504.10
per hr	$ 30.00	$ 175.89	$ -	$ 0.94	$ 468.50

	a. Process Rate	$/m[3]
	923.0769231	$ 3.60
	230.7692308	
#units to reach this goal annualy:	4	

Energy Recovery		$/m[3]
Annual	$538,200.00	$14.40
per hr	$78.00	
No. m3 per hr:	5.416666667	

1 10 hrs/day
2 8 tonnes / hr, 1 tonne = ~2m3
3 0.5 tonne / m3 - at 0.65% -> gives 0.52 tonnes /day @ process rate
4 Annual goal (120,000m3), ten ACI trench units to reach this goal annualy.
5 Dry beech logs 650 Kg m3
6 BC Hydro Energy Cost 300 $/MWh:
7 Fuel is not needed for power recovery module - module powers the fan for the air curtain.

TABLE A2. HOG FUEL COST ESTIMATION

	Barging				Trucking			
	$/m3				$/m3			
Fibre Supply	17.64				17.64			Fibre Supply
Stumpage	0.25				0.25			Stumpage
Processing costs	16.2				16.2			Processing costs
Unload Barge	1.5		$/ODT				$/ODT	
Total	35.59	or	13.69		34.09	*or*	13.11	
Barge			173.33				57.16	Hauling (8.6 hour round trip)
			5.00	Value in Mackenzie			5.00	Value in Mackenzie
			182.02	Net Cost to BC Hydro			65.27	Net Cost to BC Hydro

Assumptions:
- Used Tsay Keh Dene Townsite to establish upper end of barge cost (confirm 900m3 still available in piles for grinding)
- Tsay keh Dene Grinder produces suitable quality hog fuel for use in Conifex bioenergy plant
- Hog Fuel produced has enough BTU for use in bioenergy plants (previous study by BC Hydro indicated BTU levels were low and should be confirmed)
- Mob and Demob costs eliminated cost assuming machinery from ongoing Dust Mitigaton Project used
- Barge costs at 400/hr all found with 52 hour round trip to Tsay Keh as cost base with Barge capacity of 120 tonne
- Haul costs from Section 8.3 data ($6.75/ton/hr or $2.6/m3/hr) - with 17 tonne capacity hog truck can use off highway system and should be verified
- 2010 fibre supply and grinding costs from report section 6.1 used and inflated 20% for 2014 costs
- Processing rate of 800m3 per day for grinder or 308 ODT(rate should be confirmed with Tsay keh Dene)
- Load hog onto barge at $1200/day (1 wheel loader at 8 hours) - confirm with Tsay Keh
- Current value of Hog Fuel at $5/odt delivered to Conifex Bioenergy plant in Mackenzie
- Cost of delivering logs to grinder based on section 8.2 and producing 800m3 per 8 hour shift
- Conversion from M3 to ODT at 2.6m3/ODT (Section 8.3 data) - verify based on ODT vs. field moisture content
- Stumpage at $0.25 $/m3 (Table 6-6 Misc stumpage rates Interior Apprasal manual)
- No permitting road use agreement or overhead costs included
- No Lumber quality material assumed based on discussion with Dan Weibe from Tsay Ken Dene - New wood recuited annually could be lumber quality
- No chip quality material assumed based on previous grinder trial conducted by Tsay Keh Dene

TABLE A3. CHIEF FORESTER REPORTED VALUES FOR DEBRIS IN RESERVOIR ESTIMATES

Williston Lake Reserviour Annual Report Volume Summary

Year	Area (Acres)	Area Treated	Volume (ft3)	Volume (Cunits)	Scaled Volume (ft3)	Reservior Expenditures	Average Stumpage Price ($/100ft3)	Average Stumpage Price ($/cunit)	Average Stumpage Price ($/m3)	Volume (m3)	Scaled Volume (m3)	Volume Treated (m3)	Comments
1962	*No Data Available*												
1963	48,144		68,137,000		*					1,929,425			
1964	81,850		118,950,000		12,386,000					3,368,289			Note: Reported in M ft3 but converted to ft3
1965	85,265		127,936,000		26,415,000					3,622,745			
1966			*		14,890,000						421,639		
1967			40,000,000		26,552,000					1,132,674			
1968			23,022,381		*					651,921			Flooding behind Bennett dam began in 1968
1969			*		26,714,553						756,473		Total of **113,000,000 ft3** has been scaled to Dec 31, 1969
1970			87,294,675			$ 3,474,328	$ 3.98			2,471,910			No data was available for volume harvested. Clearing work continued with treatment of 17,100 acres in Finlay and 6,700 in Parsnip. Average stumpage price for timber in interior is $3.98/100ft3.
1971			66,169,199			$ 3,778,261	$ 5.71			1,873,707			total of **95,000 acres** have been treated in the Williston Lake Reservior. Average stumpage price for timber in interior is $5.71/100 ft3.
1972		95,700		295,584		$ 3,742,088		$ 12.66		837,001		7,745,852	Average stumpage price in interior is $12.66/cunit. Williston Lake reached full pool with a total of **95,700** acres treated. 1 cunit = 100 ft3.
1973				112,701		$ 2,876,122		$ 25.52		319,134		622,972	Average stumpage prices in interior is $25.52/cunit. Post flood treatment at Williston Lake with disposal of 220,000 cunits of waterborne debris in Parsnip Reach. Reserviour Expenditures
1974				305,326		$ 2,747,937		$ 9.00		864,530			Average stumpage price in interior is $9.00/cunit.
1975				256,043		$ 4,019,873		$ 1.57		725,033			Average stumpage price in interior is $1.57/cunit.
1976				205,910		$ 2,328,837		$ 1.31		583,072			Average stumpage price in interior is $1.31/cunit.
1978				255,854		$ 4,861,223		$ 1.90		724,498			Average stumpage price in interior is $1.90/cunit.
1979						$ 3,152,984			$ 18.36	171,731			Average stumpage price in interior is $18.36/m3
1980						$ 6,063,746			$ 10.37	584,908			Average stumpage price in interior is $10.67/m3
		95,700	**531,509,254**	**1,431,417**	**106,957,553**					19,860,578	1,178,112	8,368,824	
										29,407,514			

*No data available

Assumptions	
Annual reports illustrated data inconsistently from year to year (i.e. volume was reported in ft3, Mft3, cunits and expenditures and average stumpage paid was reported in ($/ft3, $/100ft3 and cunits). Where pertinent data was not reported, expenditures at Williston Lake and average stumpage was used to calculate volume (m3).	
1964 annual report illustrated volume in Mft3. Volume was multiplied by 1000	
Note: Average cunit prices for 1975-1979 units are inconsistent with other year's data. The cunits were adjusted by a factor of 10 when calculating volume to align with other year's volume data. If left unchanged, the volumes exceed entire stumpage volume reported for the Prince George area in the annual Average Stumpage Price tables.	
Volume per cunits was converted to m3 using conversion site http://www.translatorscafe.com/cafe/units-converter/volume-lumber/calculator/cubic-meter-%5Bm%5E3%5D-to-cubic-foot-%5Bft%5E3%5D/	
Note: 1979 and 1980 stumpage and volume data reported in m3	
Converted acres using the following converation formula: 1 ha = 2.471 acres	
Coverted volume ft3 using the following conversion formula: 1 ft3 = 0.0283169 m3	
m3 conversion	0.0283169

TABLE A4. SUMMARY OF DEBRIS IN RESERVOIR ESTIMATIONS BASED ON AVAILABLE HARVEST SCALING REPORTS

Williston Reservoir Debris Summary												
Area (ha)		Volume/Area (m3/ha)*			Volume (m3)			Volume (m3) Removed		Volume (m3) Remaining (1980)		
Preflood	Flooded	Min	Mid	Max	Min	Mid	Max	Harvested	Treated	Min	Mid	Max
176,700		150	200	250	26,505,000	35,340,000	44,175,000		8,368,824	-2,902,514	9,136,243	17,971,243
	143,000	150	200	250	21,450,000	28,600,000	35,750,000	21,038,690		-7,957,514	-807,514	9,546,243
								Total:	**29,407,514**			
								Alternate:	23,000,000			
								Average:	26,203,757			

*Data from Mackenzie Timber Supply Analysis 2014 (pg 11) and Mackenzie TSA Public Discussion Paper 2013 (pg 11)

Williston Lake area = 1761 km2 = 176,100 ha
350,000 acres of forest was flooded (*Wikepidea, WAC Bennett Dam*) = 141,639 ha
Williston Lake Area = 1773 km2 (*Hudson Hope Museum*) = 177,300 ha
Shoreline perimeter = 1770 km (*Williston Lake Fish Compensation Program) (pg 1)*