Peace Project Water Use Plan

Williston Debris Field Survey

Baseline Debris Survey

Reference: GMSMON-16 and GMSWORKS-18

Williston Debris Field Survey: Inventory and Contribution Analysis Report

Study Period: 2010

AECOM Tecsult Inc.

June, 2010

Williston Debris Field Survey

Inventory and Contribution Analysis Report

05-18377

June 2010

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Executive Summary

Williston Reservoir is located in north-eastern British Columbia within the Mackenzie River Basin Large volumes of woody debris within the reservoir create ongoing challenges for operation of the reservoir and for recreational and community users.

Little is known about the sources of debris, how much there is, and what it could be used for. This report is the first step towards addressing these issues. The report contains three main sections:

- estimation of existing debris volume within the reservoir;
- identification of the various sources of debris and their relative contribution to the total debris volume; and
- recommendations on what the debris could be used for.

The current accumulation of woody debris within the reservoir is significant. Debris covers approximately 5,760 ha (about 4 % of the surface area) of the reservoir. The total volume of wood debris in the reservoir is approximately 1.3 million m^3. In June 2009, the vast majority of woody debris (88 %) was stacked up in ribbons and piles along the high water mark. At that time, the reservoir was approximately 10 m under the high water mark.

The distribution of debris is detailed below.

Total volume of woody debris within the interior limits of the Williston Reservoir in June, 2009

Reservoir Sector	Debris Categories					Total Debris (m^3)
	Ribbons and piles (m^3)	Floating (m^3)	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**

- represents insignificant amount, none observed

Potential Sources of Debris and Recruitment Rate

In the future, several potential sources of debris may contribute to increasing woody debris in the Williston Reservoir. Two main sources of wood debris that are likely to continue to contribute woody debris to the reservoir are:

- Shoreline erosion - Shoreline erosion is very active in the Williston Reservoir. Eroded banks border approximately 60 % of the reservoir (1,320 km/^{2},148 km). The annual shoreline retreat was established at 1.0 m, which represents an area of 132 ha. A mean volume of 100 m^3/ha was used to establish the volume of debris recruited through this source. Based on this hypothesis, the annual recruitment rate of debris is established at 13,200 m^3. It is important to note that at any given location, the variation can be extreme.

- Tributary streams - About 50 tributaries were identified as a potential source of debris. Woody debris present in these streams occurs mainly from the erosion of the stream banks in the immediate vicinity of the mouth of the stream where the banks consists of erodible material. The annual recruitment rate of debris is established at 2 000 m^3.

The "recruitment rate" for the various sources of woody debris in terms of volume/annum is small in comparison to the volume of woody debris that has accumulated in the reservoir over the past 50 years. How long the woody debris stays mobilized in the reservoir has not been answered in this study and it may make little difference from a management standpoint; however, we do understand from the condition of the debris that it remains mobilized for many years. It is clear that to reduce the volume of woody debris in the reservoir it must be stabilized in place or removed before a noticeable decrease will be observed.

Insignificant contributors to the volume of woody debris in the reservoir at present includes blow down, windfalls, lost logs from log storage or boom transport, slope slippage, land slippage on steepened slopes, and slides in forested terrain. We have also concluded that while there are numerous stands of submerged trees in the reservoir these are now likely less buoyant and will decay and lay down on the reservoir floor below the low water line, and thus do not contribute to exposed debris volumes or result in navigational issues. This study has concluded that these are not likely to be the main source of debris in the future.

Physical Wood Quality

Despite the relatively large volumes of debris in the reservoir, the opportunities for economic recovery are limited and the choice of recovery strategies must be the result of operational, technical and financial analysis. That will be a focus of the management plan in the next phase of this study.

As part of the sampling work done in the field, a number of parameters were measured and/or assessed on the logs to determine the commercial potential of woody debris in the reservoir. The key finding was that the diameter and length of the logs is extremely variable. The absence of bark and branches and large cracks on the majority of the logs studied indicate that this debris has been subjected to deposition and floatation for several years and, therefore, the physical and chemical characteristics of these logs may have been modified. The presence of roots and stumps at the ends of approximately 25 to 30 % of the logs indicates that many will require cutting before transport.

Potential uses for this quality of wood include control of erosion, habitat creation for fish and wildlife and energy production.

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1.1 Project Introduction

BC Hydro contracted AECOM to conduct a Debris Field Survey and Debris Trends monitoring program for the Williston Reservoir in British Columbia. The Debris Field Survey component of the project also includes the development of a Debris Management Strategy.

The Debris Field Survey project is a primary implementation project identified by the Peace Water Use Plan Committee in the Williston Tributary Access Management Plan and in the Williston Access and Navigation Management Plan.

1.2 Project Background

The Williston Reservoir is located in north-eastern British Columbia within the Mackenzie River Basin (Figure 1). The reservoir has three arms (Finlay, Parsnip and Peace), which cover approximately 1,773 km^2. The reservoir is currently experiencing a significant amount of woody debris in the reservoir. Deposition and floatation of this woody debris occurs on an annual basis as a result of reservoir operations. Maximum elevation of water levels occurs at the end of August and minimum levels are reached at the end of April; the total drawdown is approximately 12 m. Woody debris becomes stranded on the reservoir shoreline during drawdown and may be refloated in the spring and summer as water levels rise.

Figure 1 Location of the Williston Reservoir

Large volumes of woody debris within the reservoir can cause problems with reservoir operations. Specifically, large pieces of woody debris can block or impede discharge facilities, which could lead to overtopping of the dam. Smaller pieces of debris can block trash racks, thereby reducing power generation capacity. Other challenges caused by woody debris include impacts to navigation in the reservoir, potential safety concerns for boaters and recreational users of the reservoir, access challenges by boaters to tributary streams, and degraded aquatic and wildlife habitat. Woody debris may also contribute to bank erosion and destruction of some vegetation and wetlands. However, positive impacts of the debris are that it provides habitat for wildlife and provides dust control on reservoir beaches.

1.3 Project Description

BC Hydro requested an assessment of the sources and quantity of woody debris within Williston Reservoir and the development of a management strategy to address the challenges brought by the debris on the surrounding communities and users. AECOM is undertaking the assessment in two phases: a comprehensive inventory of existing woody debris and the development of a management strategy for the reservoir.

The purpose of the comprehensive inventory (the Williston Debris Field Survey) is to document existing woody debris within the reservoir and to investigate the sources of debris recruitment. This inventory provides BC Hydro with an estimate of the volume of debris within Williston Reservoir, identifies the various sources of debris, and provides an estimate of the relative contribution of each source to the total volume of debris. This work is now complete and is the subject of this report. The purpose of the management strategy is to define options for management of the debris. The management strategy will be presented in a second report schedule to be submitted in draft form in October 2010, with the final version planned for December 2010. The results of the management study will be used in part to develop an approach for the Targeted Debris Management Plan. The management strategy will identify the benefits of the wood debris in the reservoir and what the wood debris could be used for (commercial and non commercial). The management strategy will also look at ways to limit the redistribution of the woody debris to allow better and safer use of the reservoir. Options and input will be sought from the community.

Additionally, a monitoring program (the Williston Debris Trends monitoring program) will be conducted, as an extension of the Williston Debris Field Survey. The purpose of this monitoring program will be to provide an estimate of debris volume within the reservoir and of recruitment rates from the various sources of debris identified over time. This will enable the management team to assess changes in debris volume and recruitment over time, and to evaluate the effectiveness of the Williston Targeted Debris Management project. AECOM will produce a draft inventory and contribution analysis report for the Debris Trends component by November 2011. A final report will be submitted to BC Hydro by the end of January 2012.

1.4 Williston Debris Field Survey

This report is the first step of the Williston Debris Field Survey, and provides an estimate of debris volume and debris sources. The report contains three main sections:

- Estimation of existing debris volume within the reservoir;
- Identification of the various sources of debris and their relative contribution to the total debris volume;
- Recommendations on what the debris could be used for.

This report also includes relevant maps and photos, methodology, assumptions, analyses, results and discussion of results. Recommendations for continuing refinement of the debris inventory assessment are also included.

2 Estimation of Existing Debris Volume within the Reservoir

The current accumulation of woody debris within the reservoir is significant; however, there is very little information available concerning the location and volume of this debris.

The objective of this component of the study is to categorize, locate and estimate the amount of woody debris present within the boundaries of the reservoir.

2.1 Approach

The approach was based on the following activities:

1. Interpretation of aerial photographs for the location of debris.
2. Ground inventory for the estimation of the volume of existing debris.
3. Overflight of the reservoir and its immediate surrounding area.

Figure 2 provides a summary of the processes used to estimate volumes of existing debris fields within the reservoir.

Figure 2 Processes used to estimate volumes of existing debris fields within the reservoir

Main Tool	Source of Debris
Aerial Photography and Sampling	• Beached Debris (ribbons and piles) • Floating Debris • Scattered Debris
Aerial Photography	• Stumps and snags
Aerial Photography and Expert judgment	• Log boom losses and commercial bundles • Timber not cleared prior to flooding

2.2 Location of Debris (Beached and Floating Debris)

Debris present in the reservoir had been identified through interpretation of digital imagery produced by Group Alta. Group Alta imagery was taken in May 2009 as part of the Williston Air photos and DEM project (another project managed by BC Hydro).

To supplement the overall imagery database and guide the ground truthing, several hundred photographs were taken in June 2009 during an over flight of the reservoir as part of the inventory assessment planning process. The photographs were captured using a camera with a GPS integrated module for precise location of each photograph.

Woody debris accumulations were identified on the aerial photographs using a 3D softcopy software system. This information was then integrated within a digital map of the reservoir supplied by BC Hydro. The limits of the reservoir were updated using the maximum water level for the reservoir (672.1 m). This information will constitute the reference state for the proposed 2011 monitoring program.

All photographs acquired during the overflight of the reservoir are identified on the inventory map presented in Appendix 2 entitled "Debris Inventory - Field Sampling and Ground Truthing. This map is also available in digital format and its content as well as the photographs accompanying them can be viewed digitally using Arc Map.

Locations of the debris piles were plotted on a map entitled "Debris Inventory - Location of Debris - June 2009". This map is available only in digital format and its content can only be viewed through Arc Map. This format constraint is due to the large number of individual map sheets that would have had to be produced, given the number of locations and debris categories.

2.3 Categorization of Debris

In order to characterize the debris, six classes of debris are defined. The goal of this classification is to give greater practical definition to the state and distribution of the debris in the reservoir.

For those areas not captured by the Williston Air Photos and DEM Project (e.g., the open water area of Finlay Arm), the location and characterization of debris accumulations were determined by conducting a helicopter survey.

The results from the helicopter survey suggested that masses of debris were not present in Finlay Arm and that in general, very little floating debris was present in the reservoir at the time of the survey. Debris was found at the periphery of the water near the shore, and this has subsequently been validated in the interpretation of digital aerial photographs.

Woody debris is grouped into six categories:

- Beached debris;
- Floating debris;
- Scattered debris;
- Stumps and snags;
- Log boom losses and commercial bundles;
- Timber not cleared prior to flooding.

These categories are described below and illustrated with example photographs in Figures 3 to 9.

2.3.1 Beached debris

Beached debris is defined as accumulations of woody debris gathered in long ribbons or in piles in some shallow natural bays near the upper water limits of the reservoir. In general, this debris is pushed parallel to the shoreline by wave action.

The ribbons contain woody debris of all origins (timber not cleared prior to flooding, shoreline erosion, reservoir slopes, tributary streams, slides in harvested terrain and blow down along the shoreline).

This beached debris category is by far the most common along the edge of the reservoir and makes up the most significant volume of debris.

2.3.2 Floating debris

Floating debris is of the same nature and origin as beached debris. The variation in quantity between one or the other of these categories is a function of the reservoir water level. Deposition and floatation of the woody debris may occur on an annual basis as a result of reservoir operations. Woody debris becomes stranded on the reservoir shoreline during drawdown and may be refloated in the spring and summer as water levels rise.

Very little floating debris was sited on the reservoir in June 2009, even in the open water area of Finlay Arm where aerial photographs were not taken. This is consistent with our understanding of the seasonal redistribution of the woody debris.

2.3.3 Scattered debris

Scattered debris is defined as the woody debris stranded on the reservoir high water edges that were not concentrated in ribbons and piles. This type of accumulation was principally present on the large flatlands near the upper limit of the reservoir. These zones were easily identifiable through photo-interpretation.

2.3.4 Log boom losses and commercial bundles

Commercial logs are logs lost during boom transport. While not active at the time of the study, boom transport was in operation on the reservoir for many decades and significant quantities of logs have broken away from the rafted logs and now form a component of the wood debris on the reservoir

Commercial wood was identified as a log cut at both ends. The individual logs that broke away from the rafts have accumulated in ribbons and piles on the periphery of the reservoir and are mixed with other debris. Often they could not be specifically identified during the interpretation of aerial photographs. However, this category of debris was identified during the ground truthing.

Wood bundles are also still present on the reservoir, notably in the Mackenzie sector. These "bundles", easily identifiable by photo-interpretation, were located along the strings of booms that are currently unused. Although the bundles are not currently considered to be woody debris if these bundles are not removed from the reservoir in the long term they can break up and the logs that they hold will become debris. Some bundles of wood that have washed up on shore were identified during the overflight of the reservoir and in the interpretation of aerial photographs.

2.3.5 Stumps and snags

Stumps and snags, principally tree trunks and root bases were found in many of the shallow bays. Even though they are unlikely to become floating debris, these constitute a hazard to recreational use of the reservoir.

2.3.6 Timber not cleared prior to flooding

Stands of dead or living trees remain at the periphery of the reservoir near the upper limit of the drawdown zone. These stands are located on the flats where there is minimal impact from the action of water level fluctuations, and ice and wave action.

The overflight of the reservoir and analysis of aerial photographs revealed that these stands are not present below the low water line.

2.3.7 Area occupied by different types of debris

The area occupied by the different categories of debris is summarised in the table below.

Table 1 Area occupied by different types of debris in the Williston Reservoir

Reservoir sector	Beached debris (ha)	Floating debris (ha)	Scattered debris (ha)	Commercial bundle (ha)*	Stumps and snags (ha)	Timber not cleared prior to flooding (ha)	Total debris (ha)
Peace Arm	**51.01**	**--**	**1.17**	**0.01 (4)**	**31.13**	**13.16**	**96.48**
North	26.23	--	0.91	0.01 (4)	4.62	5.90	21.32
South	24.78	--	0.26	--	26.51	7.26	33.13
Finlay Arm	**669.26**	**10.15**	**134.54**	**0.32 (39)**	**183.55**	**941.78**	**1,939.60**
East	360.02	1.32	84.98	0.07 (9)	62.15	390.42	754.88
West	309.24	8.83	49.56	0.25 (30)	121.40	551.36	1,206.98
Parsnip Arm	**344.86**	**12.40**	**81.48**	**0.37 (56)**	**2,748.26**	**538.95**	**3,726.32**
East	113.13	12.23	7.89	0.18 (25)	1,342.10	156.75	156.39
West	231.73	0.17	73.59	0.19 (31)	1,406.16	382.20	671.14
Total	**1,065.13**	**22.55**	**217.19**	**0.70 (99)**	**2,962.94**	**1,493.89**	**5,762.40**

Notes:
(x) = Number of bundles.
* Excluding the strings of booms currently unused located near Mackenzie.
-- are insignificant amounts

The area occupied by woody debris from all sources during the month of June, 2009, was 5,762 ha, which is less than 4 % of the total area of the reservoir (1,773 km^2). Stumps and snags represents about 50 % of this area (2,963 ha) and timber not cleared prior to flooding is 26 % (1,494 ha).

The distribution was not uniform throughout the reservoir. Debris was divided between the three arms of the reservoir as follows: Finlay Arm (1,940 ha), Parsnip Arm (3,726 ha) and the Peace Arm (96 ha).

Figure 3 Photos showing ribbons of beached woody debris

AECOM, June 2009. 3-1-RIMG0053

AECOM, June 2009. 3-2-RIMG0141

AECOM, June 2009. 3-3-RIMG0175

AECOM, June 2009. 3-4-RIMG0270

Figure 4 Photos showing piles of beached woody debris

AECOM, June 2009.

4-1-RIMG0153

AECOM, June 2009.

4-2-RIMG0184

AECOM, June 2009. 4-3-RIMG0411

AECOM, June 2009. 4-4-RIMG0292

Figure 5 Photos showing floating debris

AECOM, June 2009. 5-1-RIMG0238

AECOM, June 2009. 5-2-RIMG0253

AECOM, June 2009.

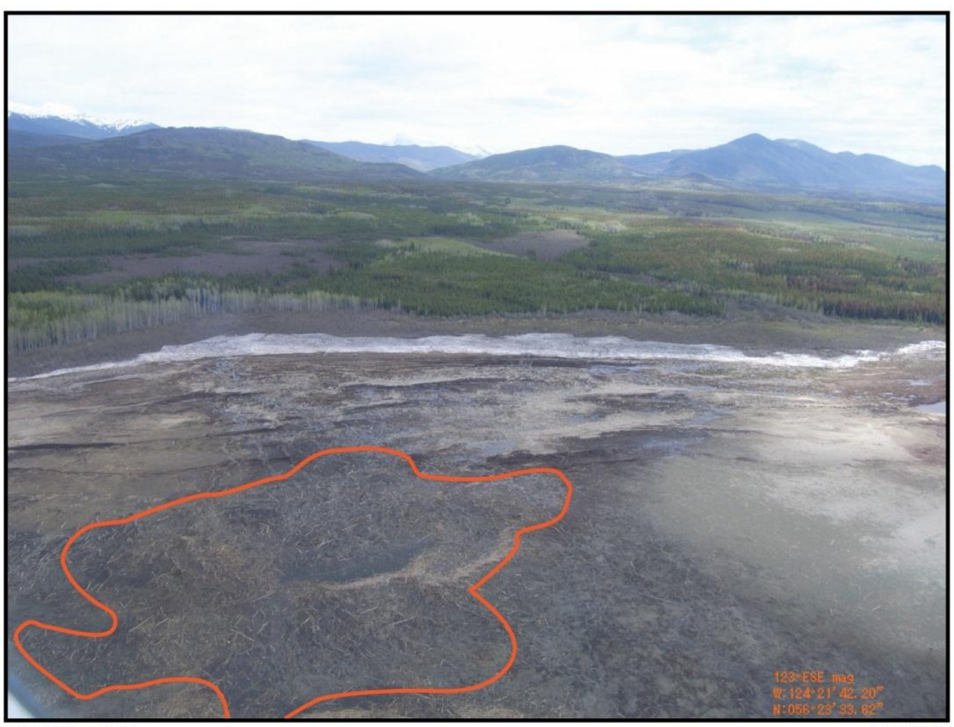
5-3-RIMG0264

Figure 6 Photos showing scattered debris

AECOM, June 2009. 6-1-RIMG0315

AECOM, June 2009. 6-2-RIMG0325

AECOM, June 2009. 6-3-RIMG0243



AECOM, June 2009. 6-4-RIMG0309

Figure 7 Photos showing stumps and snags

AECOM, June 2009. 7-1-RIMG0049

AECOM, June 2009. 7-2-RIMG0508

AECOM, June 2009. 7-3-Williston 012

AECOM, June 2009. 7-4-Williston lake 019

Figure 8 Photos showing commercial booms and lost bundles

AECOM, June 2009.

8-1-RIMG0487

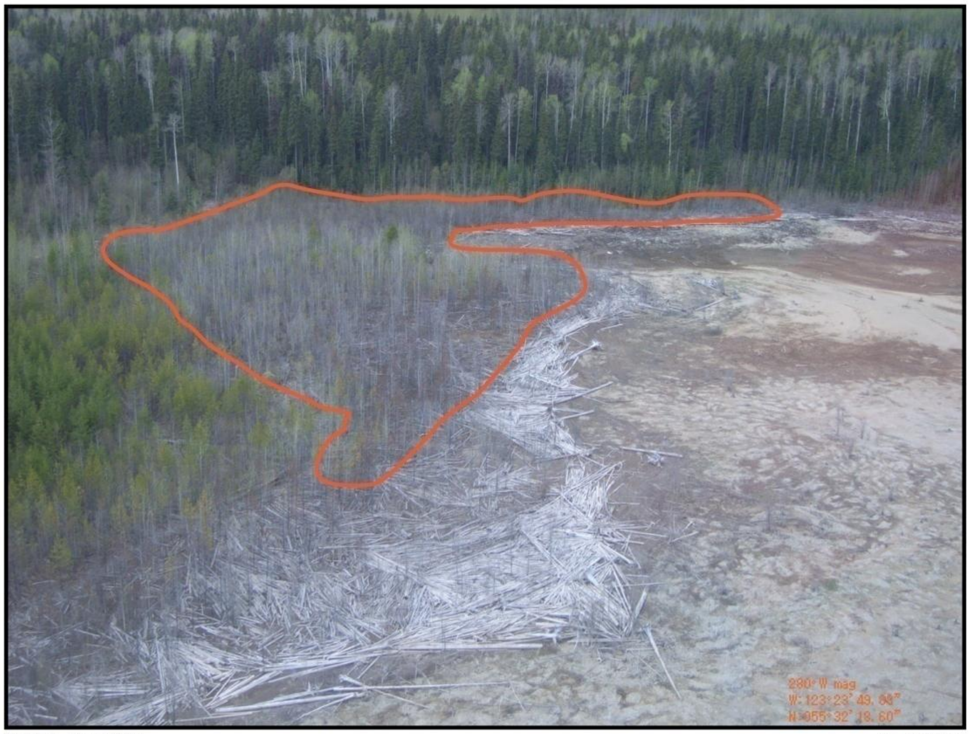
AECOM, June 2009.

8-2-RIMG0488

AECOM, June 2009. 8-3-RIMG0057

AECOM, June 2009. 8-4-RIMG0056

Figure 9 Photos showing residual trees



AECOM, June 2009.

9-1-RIMG0074

AECOM, June 2009.

9-2-RIMG0158

AECOM, June 2009. 9-3a-RIMG0172

AECOM, June 2009. 9-4-RIMG0295

2.4 Ground Inventory

The purpose of the ground inventory was to estimate the volume of beached debris accumulated in ribbons and piles amassed on the shores of the reservoir. The beached debris comprised almost all of the area of debris (excluding stumps, snags and timber not cleared prior to flooding) present on the reservoir at the beginning of June, 2009.

For the other five categories of debris that were found during the detailed analysis of aerial photographs, the volumes were estimated on the basis of hypothetical assumptions. These assumptions are described in Section 2.5.

To evaluate the volume of beached debris accumulated in ribbons and piles, a sampling survey was conducted to determine the ratio of a cubic meter of debris to a square meter of surface area (m^3/m^2). This ratio was then applied to the area estimates of debris accumulations identified by photo interpretation, in order to determine the total volume of beached debris.

2.4.1 Sample size

Based on similar work conducted by AECOM for other Canadian reservoirs, we estimated that the analysis of 80 sample plots would be required to obtain a precision of 80 %, with a 90 % level of confidence. In practice, 108 sampling plots were measured in the field to enable us to obtain a precision of 92 %, with a 90 % level of confidence.

The additional 28 sampling plots were measured due to a higher than expected level of productivity of the groundwork teams during the scheduled work period. The duration of the work period could not be modified due to logistical issues and, in order to respect the manpower training agreement reached with the Tsay Keh Dene community, the team continued to sample after the desired 80 plots were measured.

2.4.2 Sampling distribution

The sampling survey was conducted simultaneously with the acquisition of updated aerial photographs of the reservoir; these photographs were not available to aide in the development of the sampling plan. Also, the available satellite images were not sufficiently precise for creating a sampling distribution. As a result, the samples were distributed around the periphery of the reservoir. More than 150 sample plots were distributed over the entire reservoir perimeter. The GPS location was recorded at each plot. The plots were grouped in pairs in order to minimize the costs of helicopter and boat transport as well as any loss of time resulting from these movements.

Before conducting the ground sampling survey, an aerial survey of the reservoir was conducted to assure that the ribbons and piles of debris were present on the planned sampling sites. Where appropriate, the plots were repositioned and the updated GPS coordinates were recorded.

During the survey, it was unsafe to visit the Peace Arm sector by helicopter due to wind conditions. Due to the low level of wood debris identified in Peace Arm (as determined from over-flight and reported in Table 1), further opportunities for ground sampling were not pursued. Therefore, a ground sampling survey of Peace Arm has not been conducted.

2.4.3 Sampling method

Sample plots were laid directly over the debris pile, as per the photographs provided in Figure 10. The plots were one meter wide with a length equal to the debris pile width (Figure 10a). The debris stems located within the boundaries of the plot were then cut into lengths using a chainsaw (Figure 10b).

Figure 10 Photos illustrating the sampling method used to establish the unitary volume of the debris (m^3/m^2)

AECOM, June 2009. 10-1-Williston 061

Figure 10a

AECOM, June 2009. 10-2-Williston 062

Figure 10b

AECOM, June 2009. 10-3-Williston 068

Figure 10c

AECOM, June 2009. 10-4-Williston 041

Figure 10d

In each plot, the number of logs with a diameter greater than 10 cm was recorded. The diameter of each log was measured and the height of each pile was also measured to establish the average thickness of debris within the piles (Figure 10c). The volume of debris (m^3) present in each of the sample plots (m^2) was calculated, thereby enabling the calculation of the debris ratio (m^3/m^2), and the determination of the accuracy of estimated volumes.

2.4.4 Sampling results

The following results for each of the 108 sample plots, as measured on the ground, are detailed in Appendix 1 of this report: plot length, the average thickness of the debris in its interior, surface area (m^2), the volume of debris (m^3) and the ratio m^3/m^2.

The minimum, maximum and average values of each parameter, measured and/or calculated, for the entire sample area are presented in Table 2.

Table 2 Average, minimum and maximum values of the parameters measured and / or calculated for the entire sample area

Parameters	Minimum	Maximum	Average
• Length of plots	3.64 m	23.7 m	8.0 m
• Width of plots	0.16 m	1.24 m	0.48 m
• Height of plots	16 cm	124 cm	43.6 cm
• Surface area	2.40 m^2	23.70 m^2	9.2 m^2
• Volume of debris	0.11 m^3	2.41 m^3	0.86 m^3
• Ratio	0.02 m^3/m^2	0.23 m^3/m^2	0.11 m^3/m^2
• Average diameter of log samples	10 cm	121 cm	18 cm

The results indicate that the average thickness (stacked height) of debris within the sample plots was less than 50 cm and the average diameter of logs was 18 cm. On this basis, the m^3/m^2 ratio must be less than 1 m^3/m^2. Figure 11 of the next page schematically illustrates this situation.

Figures 12 to 14 chart the variation recorded for the three most significant variables: average diameter of logs, the height of the sample plot and the ratio m^3/m^2.

Figure 11 Evolution of the m^3/m^2 ratio in relation to the structure of the debris piles

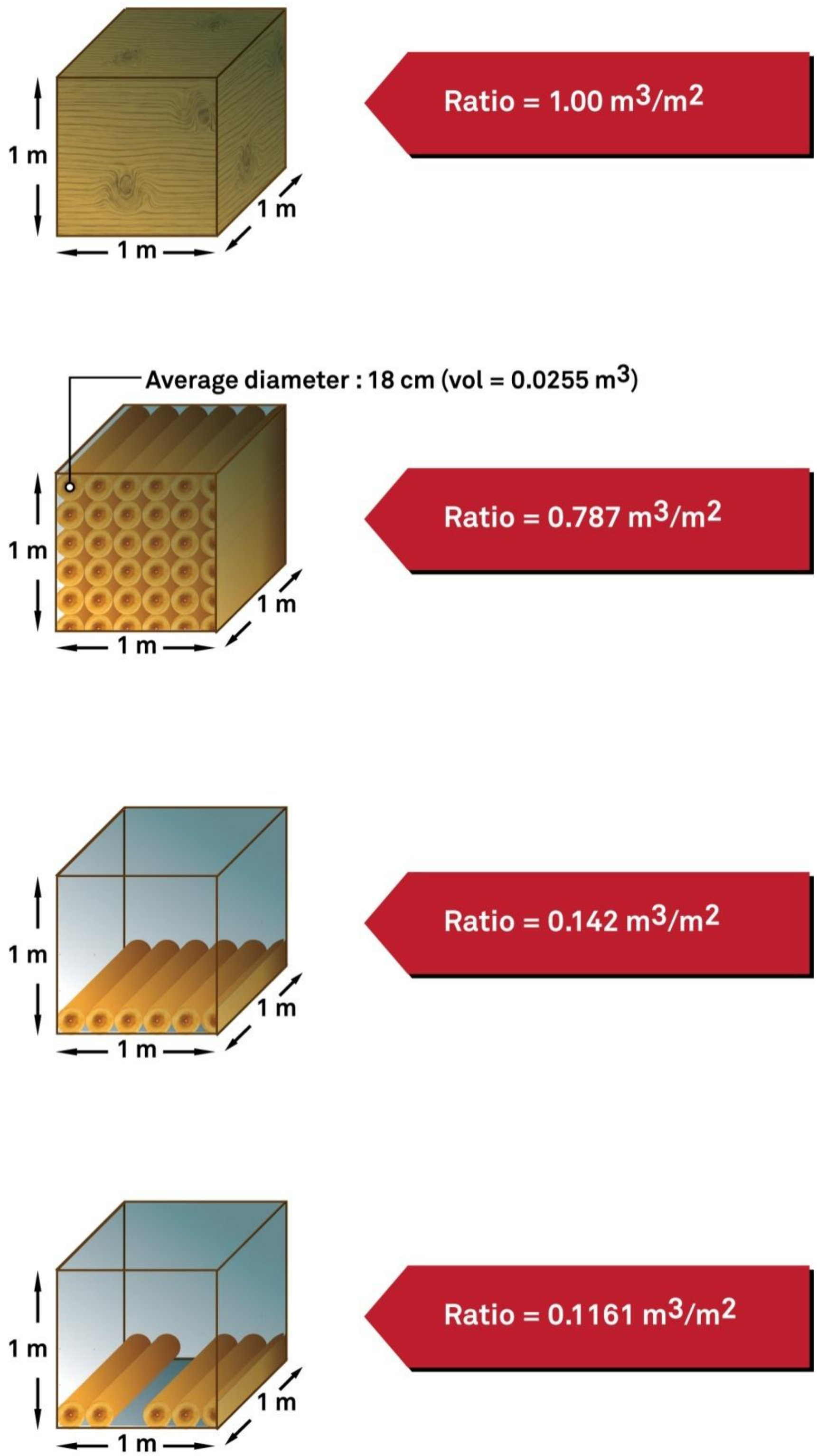


Figure 12 Distribution of log diameter in the sample plots

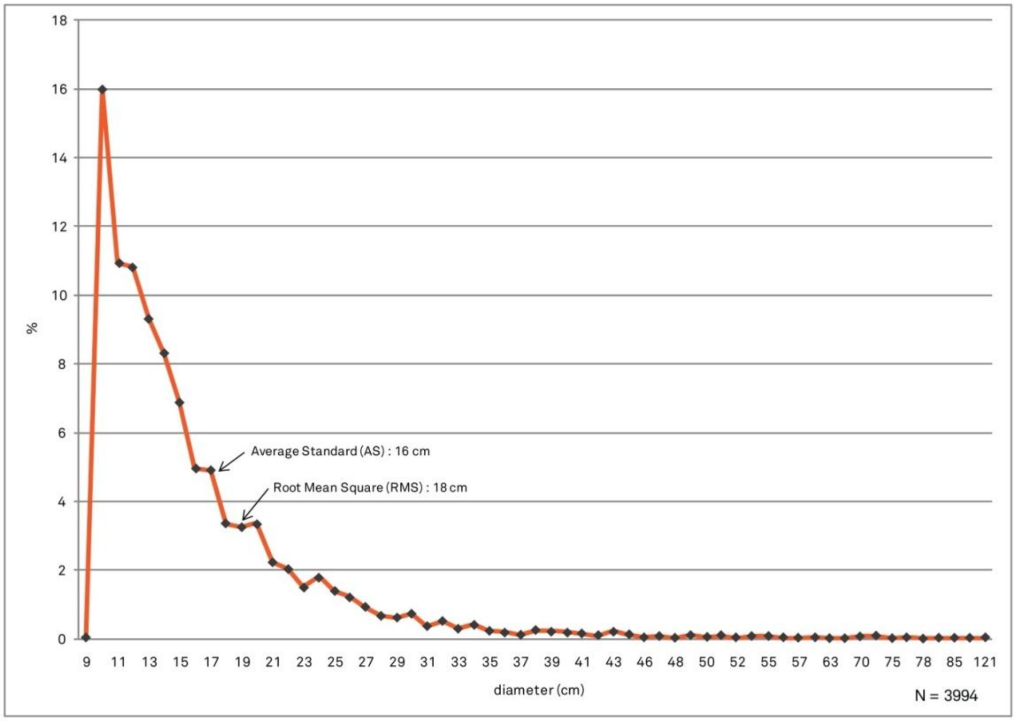


Figure 13 Height of the debris piles within the sample plots

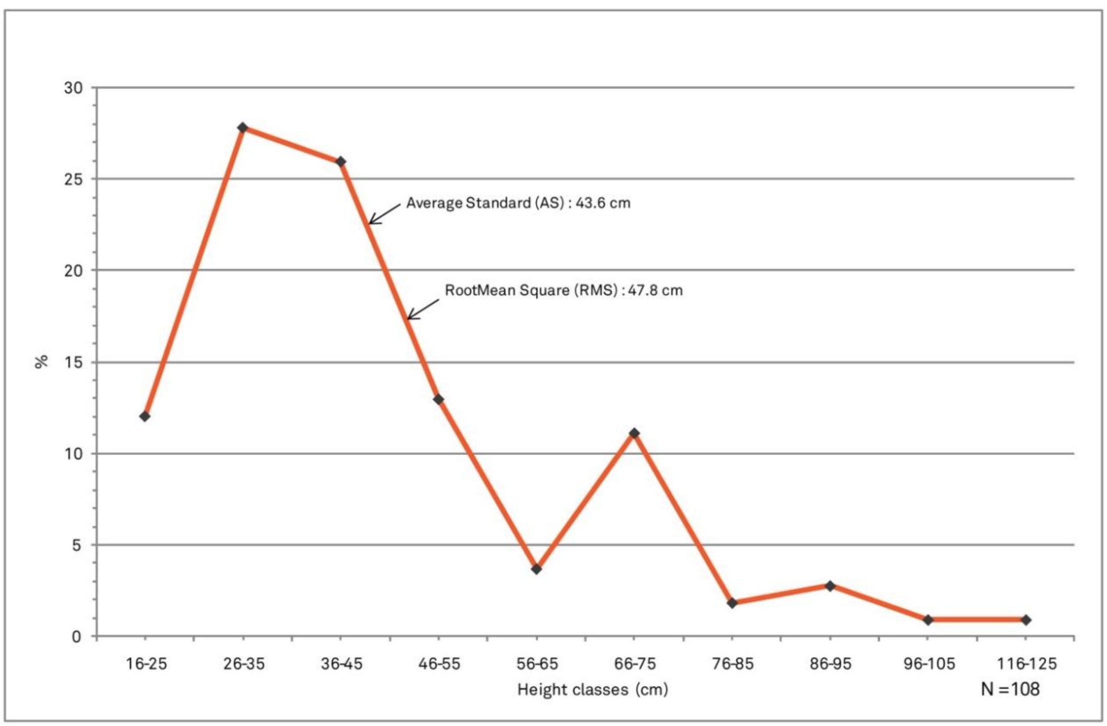
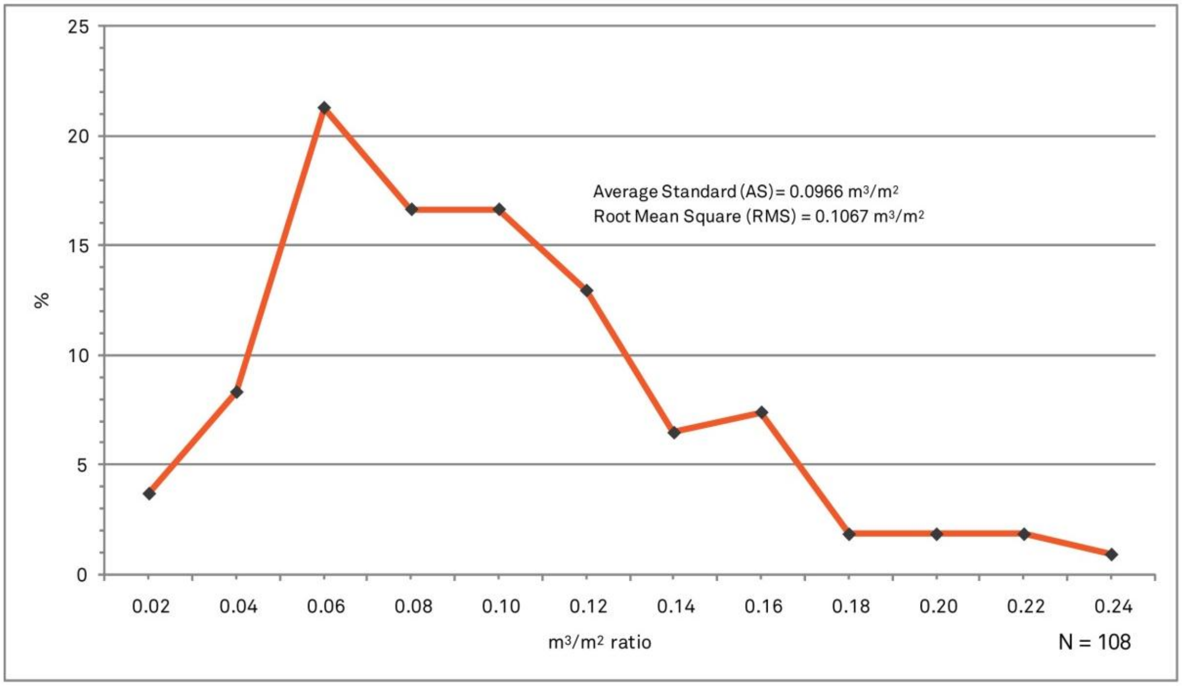


Figure 14 Distribution of m^3/m^2 ratio within the sample plots



The 108 sample plots measured at the periphery of the reservoir are located on the map in Appendix 2 entitled "Debris Inventory-Field Sampling and Ground Truthing. Photographs of each plot can be viewed digitally using Arc Map.

2.5 Volume of Existing Debris

This section describes the various calculation methods used for determining the volumes of debris and presents the results from the Debris Field Survey conducted in early June 2009. At the time of the survey the reservoir level was more than 10 m below its maximum operating level.

2.5.1 Ribbons and piles of beached debris on shore

The volume of ribbons and piles of beached debris on shore was estimated by applying the m^3/m^2 ratio (0.1067 m^3/m^2) calculated from the data obtained during the ground inventory (see Section 2.4) to the areas occupied by this category of debris as determined by the aerial photograph analysis and the overflight (see Table 1 in Section 2.3.7).

Table 3 present the results for the different sections of the reservoir.

Table 3 Volume of beached woody debris accumulated in ribbons and piles on the shores of the Williston Reservoir

Reservoir Sector	Length of Shore (km)	Volume (m^3)	Ratio (m^3/km)
Peace Arm	**456.5**	**54,425**	**119**
North	228.5	27,985	122
South	228.0	26,440	116
Finlay Arm	**741.2**	**714,100**	**963**
East	322.1	384,140	1 193
West	419.1	329,960	787
Parsnip Arm	**950.3**	**367,965**	**387**
East	392.4	120,710	308
West	557.9	247,255	443
Total	**2,148 km**	**1,136,490**	**529**

The table indicates that approximately 1,136,490 m^3 of beached woody debris was present in ribbons and piles on the shores of the reservoir in June 2009.

The distribution is not uniform over the entire reservoir. The distribution of the wood is as follows Finlay Arm (714,100 m^3), Parsnip Arm (367,965 m^3) and Peace Arm (54,425 m^3).

2.5.2 Floating debris

The volume of floating debris was estimated using the same method used for the beached debris accumulated on the shores. The ratio of 0.1067 m^3/m^2 was applied to the surface area occupied by the floating debris (22.5 ha).

The estimated volume of floating debris on the reservoir in June, 2009, was 24,060 m^3. Taking into account the insignificant volume of floating debris in the reservoir at the time of the survey, the results are not detailed in the synthesized table at the end of this section.

At the time of the survey, the majority of the floating debris was located at Finlay Arm (10,830 m^3) and Parsnip Arm (13,230 m^3).

2.5.3 Scattered debris

The volume of scattered debris on the shore was also estimated by calculating a ratio m^3/m^2.

This type of sampling was conducted by photo interpretation directly on computer screens. Transects from 40 to 100 m in length were placed within the interior of the scattered debris zones and all logs touched by the transect were enumerated. The volume of each of these logs was determined by assigning it a value of 0.0255 m^3 in volume, which corresponds to the volume of a trunk measuring 1.0 m in width with an average diameter of 18 cm. This diameter was determined during the ground truthing survey.

In total, ten transects were distributed to scattered debris areas. The compilation of data allowed us to determine that the ratio for scattered debris was 0.005 m^3/m^2. This ratio is 20 times less than that determined for the beached debris accumulation along the shores.

The estimated volume of scattered debris lying on the exposed shores of the reservoir in June, 2009, was 10,860 m^3. This debris type was completely absent in the Peace Arm because the shoreline configuration, which is steeper, is not favourable to this type of accumulation.

As with the floating debris, the total volume of scattered debris is not significant, therefore, the results are only detailed in the synthesized table at the end of this section.

2.5.4 Log boom losses "commercial bundles" (booms)

The volume of wood held in booms was estimated by counting "bundles" through photo-interpretation and applying an average unitary volume to each. This unitary volume was determined on the basis of information obtained from regional industries. The volume applied was 100 m^3/bundle[1].

The estimated total volume for this debris type was 9,900 m^3.

2.5.5 Timber not cleared prior to flooding

An average volume of 200 m^3/ha[2] was used to estimate the volume of the timber not cleared prior to flooding for the stands of high density of 100 m^3/ha and 50 m/^{3} ha for the stands of average and low density. The estimated volume for this debris type was 105,260 m^3.

2.5.6 Total volume of existing debris in the reservoir

In June 2009, the quantity of all categories of woody debris in the Williston Reservoir was estimated at 1,286,570 m^3. A little more than 88 % (1,136,490 m^3) of this volume was located on the shores in the form of ribbons and piles. The distribution of debris is detailed in Table 4.

Table 4 Total volume of woody debris within the interior limits of the Williston Reservoir in June, 2009

Reservoir Sector	Debris Categories					Total (m^3)
	Ribbons and piles (m^3)	Floating (m^3)	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**

[1] Catherwood log towing : from 100 to 500 m^3.

[2] British Columbia, Ministry of Forests, Resources Inventory Branch, *Inventory Audit Report*, MacKenzie Timber Supply Area, Revised August 1996.

3 Potential Sources of Debris and Recruitment Rate

Several sources of debris have been identified in other reservoirs operated by BC Hydro[3]. These sources are described in Figure 15 below.

The specific objective of this component of the study was to identify which of these potential sources of debris are likely to increase the volume of debris in the Williston Reservoir and estimate the amount of debris recruited on an annual basis (recruitment rate) for each of these sources.

3.1 Approach

The approach was based on the following activities:

1. Interpretation of aerial photographs for the identification and location of sources of debris.
2. Interpretation of satellite imagery for the identification and location of sources of debris.

Figure 15 provides a summary of the processes used to estimate recruitment rate in relation to different potential sources of debris.

Figure 15 Processes used to estimate recruitment rates in relation to different sources of debris

Main Tool	Source of Debris
Satellite Imagery and Aerial Photography	• Reservoir slopes • Slides in harvested terrain
Aerial Photography	• Tributary streams • Timber not cleared prior to flooding • Shoreline erosion • Blow down along shoreline
Expert Judgement	• Log boom losses • Submerged trees

3.2 Sources of Potential Debris

3.2.1 Blow down along the shoreline

Viewing the aerial photographs did not identify any blow down areas around the reservoir that could be a potential source of debris. Since no areas have been identified and given the age of the reservoir, it is considered that "blow down" does not represent a significant potential source of additional debris to

[3] BC Hydro. *Guidelines for reservoir debris management. Draft report*. January 1993. 7pp. + app.; Northwest Hydraulic Consultants Ltd., Golder Associates Ltd., Thurber Engineering Ltd. *Estimating organic debris quantities entering BC Hydro reservoirs, British Columbia. Final report*. March 31, 1992. 47pp. + app.

Williston Reservoir. However, windfalls may occur around the reservoir, though based on current findings, they may be regarded as isolated events that do not contribute significantly to the increased volume of debris in the reservoir.

Where appropriate, and depending on the importance of the event, newly generated debris could be dealt with by a specific recovery program.

3.2.2 Log boom losses

Boomed shipping of logs has virtually disappeared from Williston Reservoir, at least in the short term. Boomed logs stored in the Mackenzie area are likely to break up over time if they are not moved to solid ground. In this case, thousands of cubic meters of wood will be drifting on the reservoir. This volume could reach 210,000 m^3 (100 m^3/bundle). However, this risk can easily be controlled.

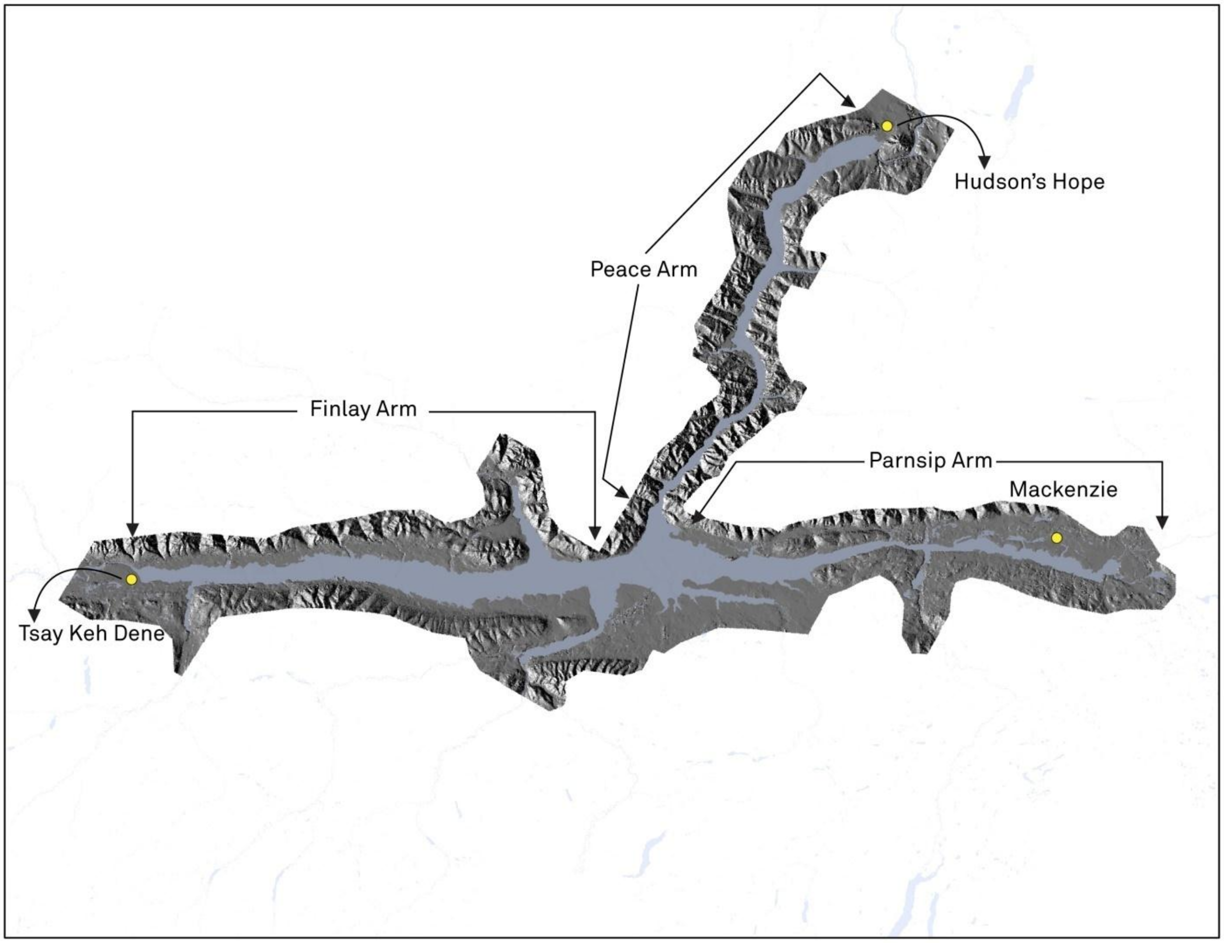
In the event that the regional forest industry is revived, booming and storing of logs on the reservoir would then constitute a potential future source of debris.

3.2.3 Reservoir slopes

Land slippage on the reservoir is a potential source of woody debris. Slopes over 20º directly facing the reservoir are most likely to contribute to producing debris.

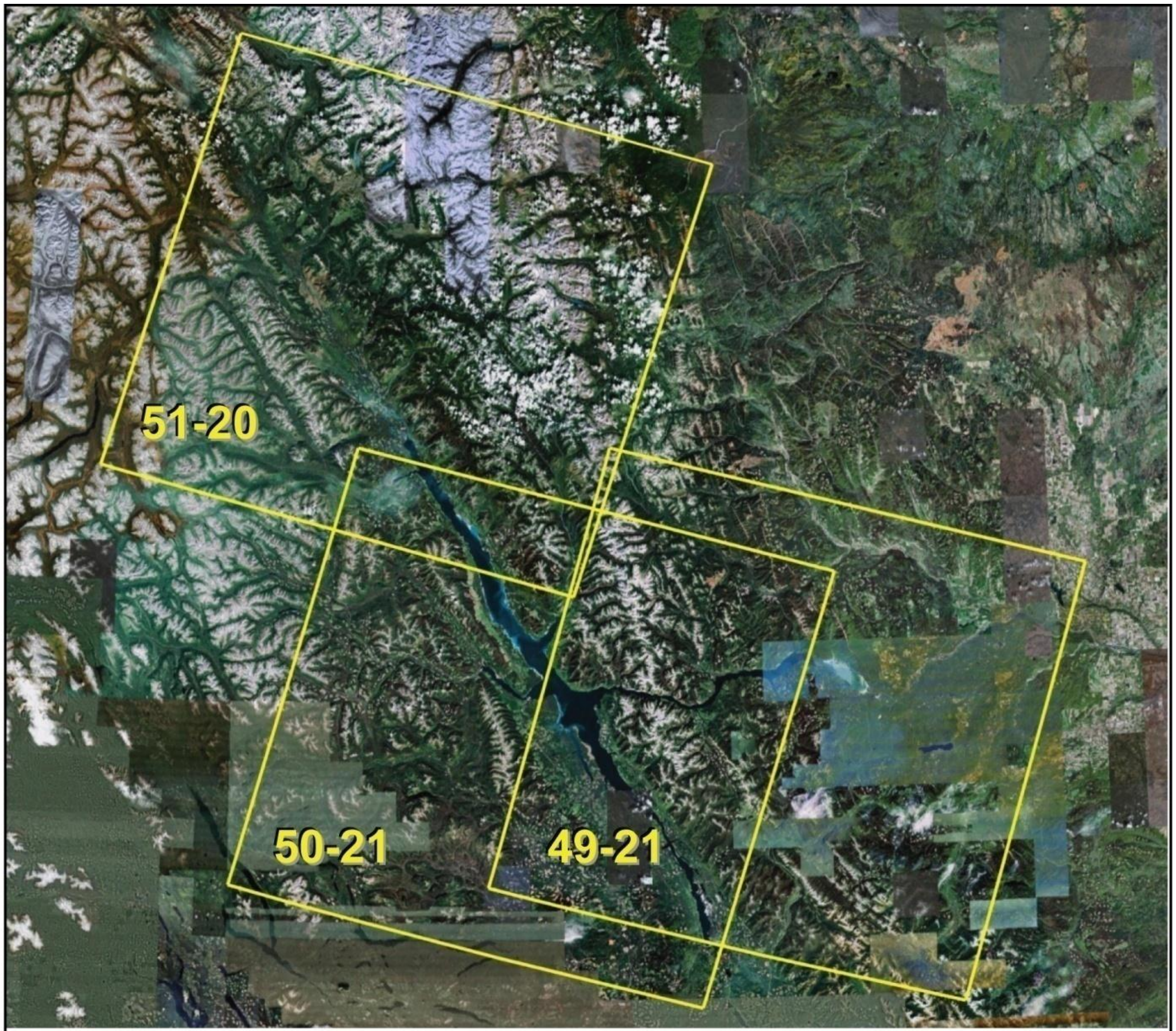
For the Williston Reservoir, these slopes are found only in the Peace Arm area. Figure 16 generated from a digital terrain model (Digital Terrain Model - DTM) illustrates this observation.

Figure 16 Location of slopes directly bordering the Williston Reservoir



Initially, analysis of aerial photographs identified landslides directly into the reservoir. In a second step, the comparison of satellite multi-date images has identified the surface area affected by slippage between two image acquisition dates. The images used for the analysis are dated from 1974 to 2009. The images used are shown in Figure 17

Figure 17 Satellite images used to identify land slippage between two image acquisition dates



Landsat Path / Row	Date	Satellite and Sensor
51-20	August 29, 1974	Landsat 1 - MSS
	September 03, 1988	Landsat 5 - TM
	September 13, 2009	Landsat 5 - TM
50-21	June 17, 1974	Landsat 1 - MSS
	August 22, 1992	Landsat 5 - TM
	August 16, 2007	Landsat 5 - TM
49-21	September 18, 1975	Landsat 2 - MSS
	August 15, 1992	Landsat 5 - TM
	August 30, 2009	Landsat 5 - TM

The analysis of aerial photographs identified several micro site slippages. However, only a few alluvial cones with significant slippage have been identified which suggests that large landslides that could carry significant volumes of woody debris are not common inside the reservoir. Furthermore, the analysis of multi-date satellite images has not identified the landslides that could have contributed significantly to an increased volume of woody debris inside the reservoir. Landslides seem to affect the same areas repeatedly, therefore preventing vegetation from growing and generating woody debris in a new slide.

In our opinion, the volume of non-woody debris from a significant landslide would be much more significant than that of woody debris and, it is likely that woody debris would be bound in the slide material for a long period, thus limiting significantly this as significant source of woody debris. Therefore, we believe that land slippage is not a significant source of debris to Williston Reservoir.

3.2.4 Slides in harvested terrain

The analysis of aerial photographs and satellite images indicates that logging on the slopes located in the area of Peace Arm are low if not nonexistent, and no trace of slippage into the reservoir associated with harvest activities has been identified. Therefore, these “harvested terrain” do not constitute a real potential source of debris for the Williston Reservoir.

3.2.5 Shoreline erosion

Shoreline erosion is very active in the Williston Reservoir. The importance of this phenomenon was observed during the over flight of the reservoir conducted in June, 2009. Many areas of erosion are visible in the photographs collected during the survey. These photos were sent under separate cover to BC Hydro. They are also identified on the inventory map presented in Appendix 2 entitled "Debris Inventory - Field Sampling and Ground Truthing" and can be viewed digitally using Arc Map.

Figure 18 shows some examples of eroded areas around the reservoir. Erosion is occurring for all sectors of the reservoir. The eventual inclusion of woody debris from the eroding surfaces is the major source of debris recruitment to the reservoir.

Eroded banks have also been identified by interpretation of the aerial photography. About 61 % of the reservoir perimeter is affected by wave action (1,320 km/^{2},148 km). These sites are located on the map entitled Debris Inventory - Location of debris - June 2009 and can be viewed using Arc Map.

3.2.6 Tributary streams

Numerous streams feed the reservoir. The rapid rise of the reservoir in the spring indicates that many streams are swollen by water from melting snow flowing down the steep slopes of mountains surrounding the reservoir rim. These mountain torrents are likely to cause erosion and transport woody debris into the reservoir.

Aerial photographs were analysed to identify the presence of woody debris in the beds or on the banks of the most important streams crossing the reservoir drawdown zone. The stream banks consisted mainly of erodible material across the flats. Piles of debris are often present at the mouth of these tributaries. The streams where debris have been identified are located on the map entitled "Debris Inventory - Location of debris - June 2009" and can be viewed using ARC Map.

The analysis suggests that woody debris present in these streams results mainly from the erosion of the stream banks in the immediate vicinity of the mouth of the creeks, where the bank consists of erodible material, rather than from sources far upstream. Also, from the fact that a trail of debris had not been identified in the drawdown zone of the reservoir between the mouths of tributaries and the reservoir, as well as to there being very little debris floating on the reservoir, we can deduce that the volume of debris from the tributaries of the reservoir is not significant.

Figure 18 Photos showing shoreline erosion on the Williston Reservoir

AECOM, June 2009. 18-3-RIMG0126

AECOM, June 2009. 18-4-RIMG0154

AECOM, June 2009. 18-5-RIMG0213

AECOM, June 2009. 18-6-RIMG0219

AECOM, June 2009. 18-9-RIMG0236

AECOM, June 2009. 18-10-RIMG0354

3.2.7 Submerged trees

Numerous forest stands were likely submerged during the impounding of the reservoir. The trees and shrubs which make up these stands still rooted during reservoir flooding. In the course of time, the air contained in the cells of these trees is replaced by water thus greatly limiting their buoyancy. In the case of whether these submerged trees add to the floating debris, these trees are now less susceptible to migrate to the surface of the reservoir. Rather, they will rest permanently on the bottom of the reservoir.

3.3 Recruitment Rate

This section discusses the "recruitment rate" for the various sources of woody debris. Based on the analysis above, the potential sources that may continue to recruit woody debris in the Williston Reservoir are limited. Some sources have been exhausted over time (timber not cleared prior to flooding) and some other sources can be considered isolated events (blow down along the shore line, reservoir slopes, and slides in harvested terrain).

As a result, rates of annual recruitment were calculated for the following two potential sources:

- shoreline erosion; and
- tributary streams,

The results are summarized in Table 5 at the end of this section.

3.3.1 Shoreline erosion

The historic reservoir limit (maximum level of the reservoir) provided by BC Hydro in April 2009 includes many inconsistencies when compared with the new limit determined by the Group ALTA (2009). Therefore, comparing the data does not constitute a valid reference for determining the rate of shoreline erosion. The available satellite imagery is not adequate as an alternative as it is not sufficiently precise to allow such an analysis. Thus, existing aerial photography could not be easily compared since the most recent (2009) are very precise softcopy photography that could not be compared to the historic hardcopy photography.

Consequently, the contribution of debris to the reservoir has been estimated from typical forest cover and an assumption of an annual shoreline retreat rate. The annual shoreline retreat rate was assumed to be at 1 m which represents an area of 132 ha considering the 1,320 km of affected shoreline. A mean volume of 100 m^3/ha was used to establish the volume of debris (see 2.5.5). Based on this hypothesis, the annual recruitment rate of debris is established at 13,200 m^3. This amount is considered at the high end of the range of possible contributions from erosion, but does illustrate how little new material is being added to the reservoir from erosion and that managing the debris in Williston Reservoir should focus on existing debris in the drawdown zone.

It is important to note that at any given location, the variation can be extreme. New softcopy imagery will be taken in 2014 and 2019 as part of the WLL Air Photo and DEM Project. Those new documents will permit the refinement of an erosion rate.

3.3.2 Tributary streams

The volume of debris recruited from tributary streams was calculated using the same method as for shoreline erosion. About 50 tributaries have been identified as a potential source of debris. Because of the limitations imposed by the imagery, it was not possible to assess the banks over 2 km radius from the mouth of the streams. Within these constraints, the annual recruitment rate of debris has been established at 2,200 m^3.

Table 5 Estimated annual recruitment of woody debris in the Williston Reservoir

Sources	**Annual volume (m^3)**
• Blow down along the shoreline	--
• Log boom losses	--
• Reservoir slopes	--
• Slides in harvested terrain	--
• Shoreline erosion	13,200
• Tributary streams	2,000
Total volume	**15,200**

4 Wood Quality/Potential Commercial Value

Despite the relatively large volumes of debris in the reservoir, the opportunities for recovery are limited and the choice of recovery strategies must be the result of serious operational, technical and financial analysis.

The high proportion of debris in the reservoir has likely been subjected to the cycle of "deposition and floatation" for several decades and necessarily affected the wood’s physical characteristics (resistance to compression, shearing, bending, etc.) and chemical characteristics (moisture content, caloric volume, chemical composition, etc.). Also, the origin of this debris is highly variable resulting in a very gradual supply, which has an influence on methods and cost recovery; methods and costs of loading and transport to processing plants; and on methods and costs of preparation and transformation into a consumer product.

In the end, there has to be an economically viable market for the targeted product.

This scope of work did not include a physical-chemical analysis or a technical and financial feasibility study, as it was not part of the objective. However, within the sampling work done in the field, a number of parameters were measured and/or assessed on the logs to broadly determine the commercial potential of woody debris in the reservoir.

4.1 Summary Description of Woody Debris

4.1.1 Sampling method

Five logs were selected from the top of each pile prior to cutting the logs in each sample plot. In total, 536 logs were measured and evaluated at 108 plots.

The diameter at the butt of the log and the total lengths were measured. Other physical characteristics were also systematically recorded, such as the presence of bark, roots, branches and the presence of butt logs. Finally, other parameters, such as potential use, were assessed for each sample based on the technician’s knowledge. Finally, observations were made when viewing photos of the plots.

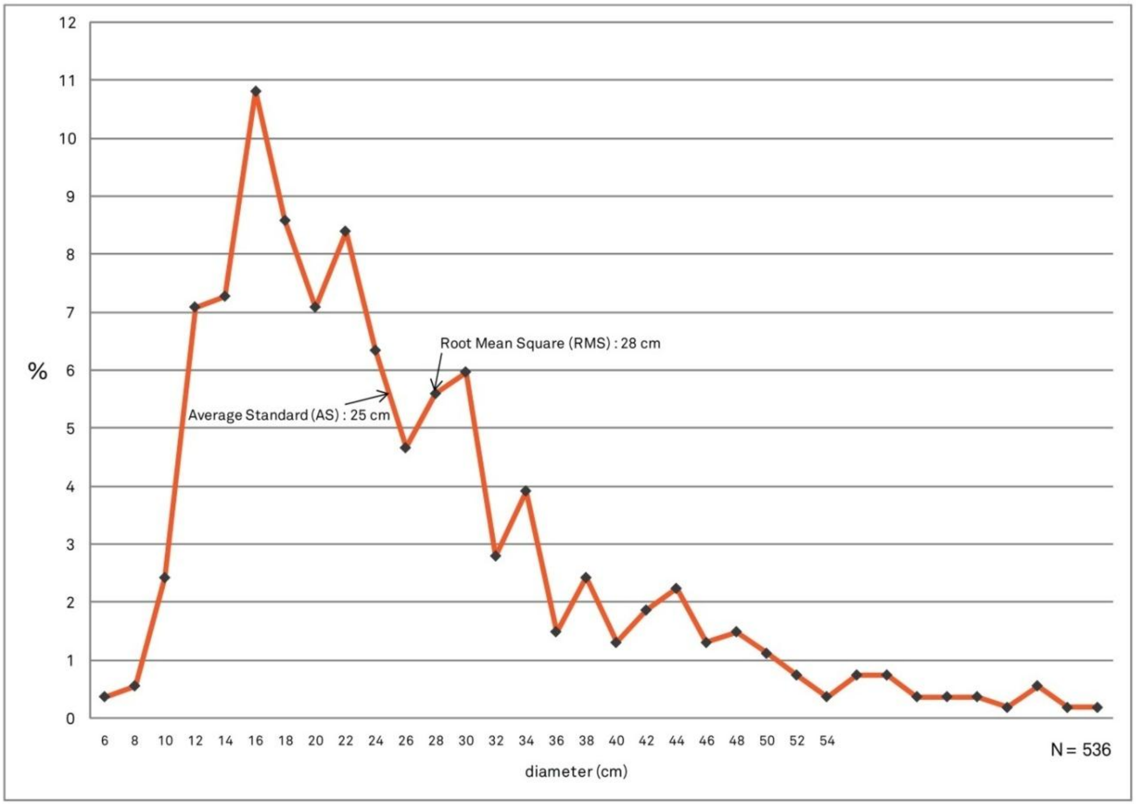
4.1.2 Results of sample log-study

4.1.2.1 Diameter at the butt of the log

The average diameter at the butt of the log was 28 cm. However, over 50 % had a butt diameter of less than 22 cm and the diameter of the logs sampled varied from 6 to 92 cm. Such variability may be an obstacle and a restriction for use in saw mills.

Figure 19 shows the distribution of log diameters.

Figure 19 Distribution of diameters in the log-study



4.1.2.2 Length of logs studied

The average length of logs studied was 10 m. The length of segments varied from 2.0 to 41.0 m and more than 50 % of the logs studied were less than 6.0 m in length.

The average length of 10.0 m does not correlate with the average diameter at the butt end of 28 cm. In natural conditions, the length of 28 cm DSH (Diameter at Stump Height) is significantly greater than 10 m. This confirms that the logs in the piles of debris have been broken by the repeated action of various forces such as ice and waves, and the length of the logs will be random.

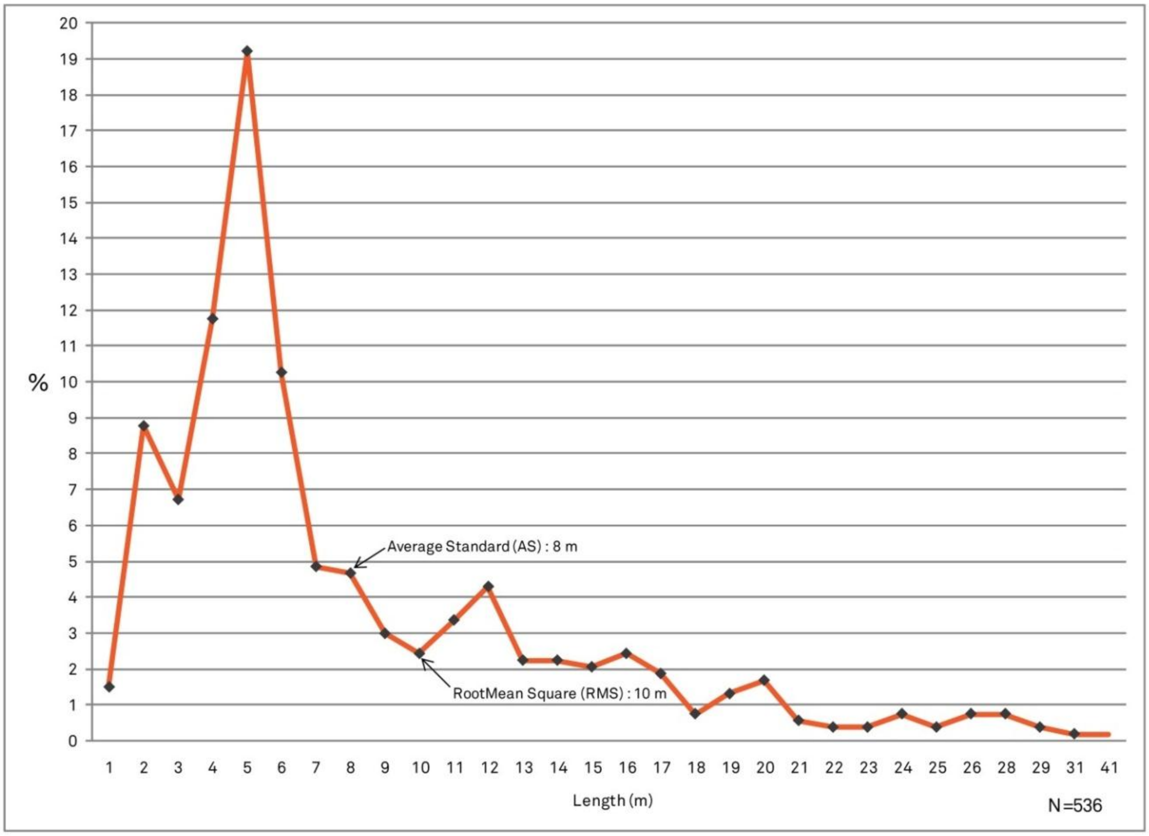
Such variability in length can lead to a considerable increase in costs of loading and transport to processing plants and a significant increase in costs of handling and preparation of logs in the plant yard.

The variation of lengths found in the log study is illustrated in Figure 20.

4.1.2.3 Limbs and bark

The absence of bark on nearly 96 % of the logs studied and the lack of branches on more than 92 % of the samples indicate that this debris has been subjected to deposition and floatation for several years and, therefore, the physical and chemical characteristics of these logs may have been modified.

Figure 20 Distribution of lengths in log study



4.1.2.4 Roots and stumps

The presence of roots and stumps at the extremities of approximately 25 to 30 % of the logs indicates that phases of preparation will be needed before transport or receipt by users in order to comply with the characteristics of targeted supplies.

The photographs provided in Figure 21 illustrate the great variability of woody debris in piles of debris from the reservoir.

4.2 Other Observations

4.2.1 Cracks in the logs

The analyses of photographs from different sample plots show that a large number of logs are affected by cracks. These cracks are a major obstacle for the supply of a sawmill. The phenomenon is illustrated in Figure 22.

Figure 21 Photos illustrating the great variability of woody debris from the Williston Reservoir

AECOM, June 2009. 21-1-Williston 054

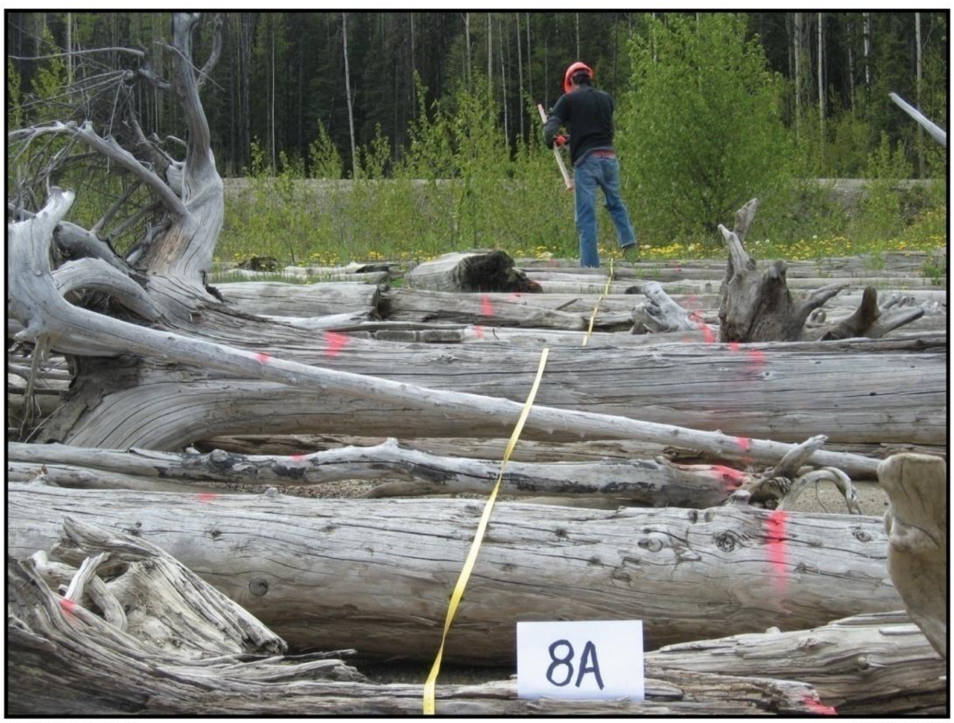
AECOM, June 2009. 21-2-Williston 050

AECOM, June 2009. 21-3-Williston 046

AECOM, June 2009. 21-4-Williston 093

Figure 22 Photos showing logs affected by cracks in the Williston Reservoir

AECOM, June 2009. 22-1-Williston 051



AECOM, June 2009. 22-2-Williston 024

AECOM, June 2009. 22-3-Williston 054

AECOM, June 2009. 22-4-Williston 076

4.2.2 Sand infiltration `

Over time, sand eventually becomes embedded in the wood fibres. This sand can be a serious problem in the preparation, processing and even the use of the product. This problem must be seriously evaluated if considering processing of debris.

For example, the presence of sand in the logs during the sampling work frequently caused the replacement of chains on chainsaws. On an industrial basis, the impact to processing machinery could be significant.

4.3 Technician Judgment

Based on their study of the parameters described above and their general knowledge, forest technicians assigned to carry out sampling work identified the most likely destination of recovery (lumber, pulp and paper, energy). In 98 % of the cases, wood-energy was identified as the best case scenario.

Appendix 1
Summary of Database sample plots-

SUMMARY OF DATABASE SAMPLE PLOTS - WILLISTON

plot_no	picture	width (m)	length (m)	heigth (cm)	area (m^2)	volume (m^3)	ratio (m^3/m^2)
02A	txt_Williston_002A.jpg	1	15,57	67,00	15,57	0,95	0,06
02B	txt_Williston_002B-2.jpg	1	4,42	40,00	4,42	0,29	0,07
03A	NOT AVAILABLE	1	7,00	24,00	7,00	0,35	0,05
03B	txt_Williston_003B.jpg	1	5,06	23,00	5,06	0,13	0,03
04A	txt_Williston_004A-2.jpg	1	13,10	41,00	13,10	0,46	0,04
04B	txt_Williston_004B.jpg	1	10,50	61,00	10,50	1,09	0,10
05A	txt_Williston_005A.jpg	1	8,12	42,00	8,12	0,75	0,09
05B	txt_Williston_005B.jpg	1	11,50	49,00	11,50	1,81	0,16
07A	txt_Williston_007A.jpg	1	11,00	31,00	11,00	0,76	0,07
07B	txt_Williston_007B.jpg	1	7,97	45,00	7,97	0,68	0,09
08A	txt_Williston_008A.jpg	1	12,20	22,00	12,20	1,15	0,09
08B	txt_Williston_008B.jpg	1	9,84	38,00	9,84	1,12	0,11
09A	txt_Williston_009A.jpg	1	5,10	67,00	5,10	0,54	0,11
09B	txt_Williston_009B.jpg	1	5,67	33,00	5,67	0,31	0,05
10A	txt_Williston_010A.jpg	1	6,79	41,00	6,79	0,52	0,08
10B	txt_Williston_010B.jpg	1	6,60	38,00	6,60	1,05	0,16
13A	txt_Williston_013A.jpg	1	9,72	43,00	9,72	0,87	0,09
13B	txt_Williston_013B.jpg	1	4,60	24,00	4,60	0,48	0,10
14A	txt_Williston_014A.jpg	1	13,00	32,00	13,00	0,82	0,06
14B	txt_Williston_014B.jpg	1	9,37	28,00	9,37	1,24	0,13
15A	txt_Williston_015A.jpg	1	7,45	19,00	7,45	0,15	0,02
15B	txt_Williston_015B.jpg	1	5,12	25,00	5,12	0,11	0,02
17A	txt_Williston_017A.jpg	1	5,00	30,00	5,00	0,59	0,12
17B	txt_Williston_017B.jpg	1	6,09	16,00	6,09	0,37	0,06
18A	txt_Williston_018A.jpg	1	12,80	38,50	12,80	0,73	0,06
18B	txt_Williston_018B.jpg	1	4,00	40,00	4,00	0,29	0,07
19A	txt_Williston_019A.jpg	1	5,63	47,00	5,63	0,55	0,10
19B	txt_Williston_019B.jpg	1	5,25	37,00	5,25	1,21	0,23
21A	txt_Williston_021A.jpg	1	5,43	40,00	5,43	0,62	0,11
21B	txt_Williston_021B.jpg	1	4,03	26,00	4,03	0,30	0,07
22A	txt_Williston_022A.jpg	1	10,97	48,00	10,97	0,79	0,07
22B	txt_Williston_022B.jpg	1	15,25	66,00	15,25	1,10	0,07
24A	txt_Williston_024A.jpg	1	5,55	53,00	5,55	0,40	0,07
24B	txt_Williston_024B.jpg	1	8,30	50,00	8,30	0,49	0,06
26A	txt_Williston_026A.jpg	1	8,00	27,50	8,00	0,54	0,07
26B	NOT AVAILABLE	1	5,95	27,00	5,95	0,51	0,09
27A	txt_Williston_027A.jpg	1	8,53	32,00	8,53	1,30	0,15
27B	NOT AVAILABLE	1	10,00	42,00	10,00	1,36	0,14
29A	txt_Williston_029A-3.jpg	1	4,89	42,00	4,89	0,65	0,13
29B	txt_Williston_029B.jpg	1	7,35	65,00	7,35	1,65	0,22
30A	txt_Williston_030A-3.jpg	1	9,20	73,00	9,20	1,20	0,13
30B	txt_Williston_030B-1.jpg	1	9,20	124,00	9,20	1,81	0,20
31A	txt_Williston_031A.jpg	1	10,17	50,00	10,17	1,32	0,13
35A	txt_Williston_035A-1.jpg	1	11,76	41,00	11,76	1,82	0,15
36A	txt_Williston_036A.jpg	1	7,74	35,00	7,74	0,52	0,07
36B	txt_Williston_036B.jpg	1	12,60	48,00	12,60	1,24	0,10
37A	txt_Williston_037A-2.jpg	1	9,42	40,00	9,42	0,95	0,10
37B	txt_Williston_037B.jpg	1	9,90	37,00	9,90	1,19	0,12
38A	txt_Williston_038A.jpg	1	8,57	51,25	8,57	0,39	0,05

SUMMARY OF DATABASE SAMPLE PLOTS - WILLISTON

plot_no	picture	width (m)	length (m)	heigth (cm)	area (m^2)	volume (m^3)	ratio (m^3/m^2)
38B	txt_Williston_038B.jpg	1	19,15	40,00	19,15	1,17	0,06
39A	txt_Williston_039A.jpg	1	5,15	52,00	5,15	0,57	0,11
39B	txt_Williston_039B.jpg	1	8,15	50,00	8,15	0,97	0,12
40A	txt_Williston_040A.jpg	1	15,56	28,00	15,56	1,01	0,07
40B	txt_Williston_040B.jpg	1	8,60	24,00	8,60	0,69	0,08
41A	txt_Williston_041A.jpg	1	12,68	80,00	12,68	1,66	0,13
41B	txt_Williston_041B.jpg	1	11,97	68,00	11,97	1,62	0,14
42A	txt_Williston_042A.jpg	1	8,97	22,00	8,97	0,58	0,06
42B	txt_Williston_042B.jpg	1	5,25	28,00	5,25	0,82	0,16
43A	txt_Williston_043A.jpg	1	8,15	28,00	8,15	0,75	0,09
43B	txt_Williston_043B.jpg	1	12,80	47,00	12,80	0,83	0,06
45A	txt_Williston_045A-2.jpg	1	9,74	67,50	9,74	1,55	0,16
45B	txt_Williston_045B-1.jpg	1	6,14	75,00	6,14	1,12	0,18
48A	txt_Williston_048A.jpg	1	8,52	54,00	8,52	1,06	0,12
48B	txt_Williston_048B.jpg	1	8,10	39,00	8,10	1,14	0,14
49A	txt_Williston_049A.jpg	1	23,70	26,00	23,70	1,18	0,05
49B	txt_Williston_049B.jpg	1	8,02	53,00	8,02	1,28	0,16
50A	txt_Williston_050A.jpg	1	5,00	71,00	5,00	1,15	0,23
50B	txt_Williston_050B.jpg	1	3,89	89,00	3,89	0,79	0,20
51A	txt_Williston_051A.jpg	1	8,10	41,00	8,10	0,64	0,08
51B	txt_Williston_051B.jpg	1	5,10	29,00	5,10	0,39	0,08
52A	txt_Williston_052A.jpg	1	12,71	30,00	12,71	1,46	0,11
52B	txt_Williston_052B.jpg	1	10,42	58,00	10,42	1,12	0,11
53A	txt_Williston_053A.jpg	1	3,64	36,00	3,64	0,25	0,07
53B	txt_Williston_053B.jpg	1	7,26	37,00	7,26	0,54	0,07
54A	txt_Williston_054A.jpg	1	23,60	38,00	23,60	1,42	0,06
54B	txt_Williston_054B.jpg	1	4,87	41,00	4,87	0,44	0,09
55A	txt_Williston_055A.jpg	1	15,56	70,00	15,56	0,70	0,04
55B	txt_Williston_055B.jpg	1	9,50	73,00	9,50	1,71	0,18
56A	NOT AVAILABLE	1	6,65	76,00	6,65	1,13	0,17
56B	txt_Williston_056B.jpg	1	11,30	63,00	11,30	0,69	0,06
57A	txt_Williston_057A.jpg	1	17,66	86,00	17,66	1,02	0,06
57B	txt_Williston_057B.jpg	1	16,73	67,00	16,73	1,38	0,08
58A	txt_Williston_058A.jpg	1	8,15	47,00	8,15	0,90	0,11
58B	txt_Williston_058B.jpg	1	8,20	103,00	8,20	0,42	0,05
59A	txt_Williston_059A.jpg	1	5,37	35,00	5,37	0,66	0,12
59B	txt_Williston_059B.jpg	1	5,90	28,00	5,90	0,73	0,12
60A	txt_Williston_060A.jpg	1	6,92	34,50	6,92	0,48	0,07
60B	txt_Williston_060B.jpg	1	8,52	24,00	8,52	0,42	0,05
61A	txt_Williston_061A.jpg	1	2,40	21,00	2,40	0,09	0,04
61B	txt_Williston_061B.jpg	1	5,00	18,00	5,00	0,10	0,02
62A	txt_Williston_062A.jpg	1	7,80	73,00	7,80	0,66	0,08
62B	txt_Williston_062B-2.jpg	1	6,00	36,00	6,00	0,24	0,04
63A	txt_Williston_063A-1.jpg	1	15,81	23,00	15,81	0,64	0,04
63B	txt_Williston_063B-2.jpg	1	12,11	27,00	12,11	0,98	0,08
64A	txt_Williston_064A.jpg	1	9,46	88,00	9,46	0,91	0,10
64B	txt_Williston_064B.jpg	1	9,85	28,00	9,85	0,90	0,09
66A	txt_Williston_066A.jpg	1	13,09	31,20	13,09	1,17	0,09
66B	NOT AVAILABLE	1	4,30	31,00	4,30	0,40	0,09

SUMMARY OF DATABASE SAMPLE PLOTS - WILLISTON

plot_no	picture	width (m)	length (m)	heigth (cm)	area (m^2)	volume (m^3)	ratio (m^3/m^2)
67A	txt_Williston_067A.jpg	1	8,20	38,00	8,20	0,74	0,09
67B	txt_Williston_067B.jpg	1	10,25	32,00	10,25	1,15	0,11
69A	txt_Williston_069A.jpg	1	11,57	33,75	11,57	1,17	0,10
69B	txt_Williston_069B.jpg	1	8,25	27,00	8,25	1,21	0,15
70A	txt_Williston_070A.jpg	1	7,32	36,00	7,32	0,55	0,08
70B	txt_Williston_070B.jpg	1	5,95	29,00	5,95	0,41	0,07
71A	txt_Williston_071A.jpg	1	10,00	30,00	10,00	0,61	0,06
71B	txt_Williston_071B.jpg	1	6,25	27,00	6,25	0,24	0,04
74A	txt_Williston_074A.jpg	1	18,00	37,50	18,00	1,86	0,10
74B	txt_Williston_074B.jpg	1	19,40	28,00	19,40	2,41	0,12

Appendix 2 Debris Inventory- Field sampling and Ground Truthing (enclosed)