



Peace Project Water Use Plan

GMSMON-16 Williston Debris Trends

Implementation Year 2

Reference: GMSMON-16

2009-2001 Analysis

Study Period: *2009-2001 Analysis*

**AECOM Canada Ltd.
3292 Production Way
Suite 330
Burnaby, BC V5A 4R4
Canada
T: 604.444.6400
F: 604.294.8597
aecom.com**

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Williston Wood Debris Trend Analysis 2009-2011

Project number: 60558464

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Prepared by	Checked by	Verified by	Approved by
Guy Parent	Annie Vaillancourt	Keith Bell, RPF, RP Bio	Keith Bell, RPF, RP Bio

Revision History

Revision	Revision date	Details	Authorized	Name	Position

Distribution List

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Prepared by:

AECOM Canada Ltd.
3292 Production Way
Suite 330
Burnaby, BC V5A 4R4
Canada

T: 604.444.6400
F: 604.294.8597
aecom.com

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Executive Summary

Williston Reservoir is located in north-eastern British Columbia within the Mackenzie River Basin. Its perimeter is partly covered by large woody debris that creates ongoing challenges for the operation of the reservoir and for recreational and community users. A baseline study was performed by photo-interpretation of aerial photographs taken in 2009 for locating and quantifying large woody debris along the coastline and on water. This study was completed using field inventory plots to determine standard values of wood per type of mapped debris. The outputs of this previous study are presented in the report "Williston Debris Field Survey – Inventory and Contribution Analysis", June 2010 (GMSMON 16). Subsequently, a Woody Debris Strategic Management Plan was prepared and implemented for cleaning targeted areas.

In order to monitor the evolution of woody debris and to identify trends, a newer set of aerial photographs, taken in 2011, was interpreted and compared with the baseline. The pixel size of the 2011 photographs is 20 cm, while the first set of 2009 was 33 cm. Since the higher resolution of the new imagery allows a better delineation and identification of woody debris, it was necessary to upgrade the level of detail of the baseline study of 2009 by reinterpreting faint details, using the 2011 imagery to confirm the presence of wood logs. The revised baseline values are presented in Figure E1 and Figure E2 should be considered as an updated version of the report "Williston Debris Field Survey – Inventory and Contribution Analysis", June 2010 (GMSMON 16). The total extent of the various debris types has increased in the revised version, but the overall distribution is similar to the 2009 baseline. Therefore, priority sectors and targeted sites remain unchanged for the Woody Debris Strategic Management Plan.

The monitoring of the evolution of woody debris between 2009 and 2011 was performed inside 620 sampling squares of 500 x 500 metres randomly distributed per sector (Parsnip Arm East, Parsnip Arm West, Finlay Arm East, Finlay Arm West, Peace Arm North and Peace Arm South). This strategy allowed to optimize the photointerpretation and to obtain statistical data adequate for extrapolating the trend to the whole reservoir.

For the sampling cells, the comparison of the extent of woody debris in 2009 and in 2011 indicates an overall reduction of 9.91 ha (or -11.2 %) for Finlay Arm East, 2.47 ha (or -2.0 %) for Finlay Arm West and 0.23 ha (or -1.6 %) for Peace Arm South, when scattered woody debris on flats are excluded in the calculation (considering that their volume of wood per hectare is quite low). However, the extent of woody debris has increased by 12.22 ha (or 27.8 %) for Parsnip Arm East, 10.09 ha (or 9.7 %) for Parsnip Arm West and 0.32 (or 3.1 %) for Peace Arm North (Figure E1).

In terms of wood volumes, the overall trends indicate a decrease in Finlay Arm East (-12 159 m³ or -18.5 %) and Finlay Arm West (-5 295 m³, or -7.1 %), in the sampling cells (Figure E1). The exclusion of the volume of scattered woody debris on flats (BF) does not significantly affect these trends, contrary to what was observed when analyzing the areas including scattered woody debris (Figure E1).

For the other sectors, the overall balance results in an increase of woody debris with the majority found in Parsnip Arm East (6 959 m³ or 23.9 %), and at a lesser extent for Parsnip Arm West (2 926 m³ or 4.6 %). Finally, the amounts of woody debris have also increased in Peace Arm North and Peace Arm South, but not significantly. Specifically, 341 m³ (7.0 %) and 392 m³ (4.7 %) were added between 2009 and 2011 for these two sectors respectively (Figure E1).

The interpretation of woody debris in 2009 and 2011 is presented in comparative view ports in atlas per sector (Figure E2).

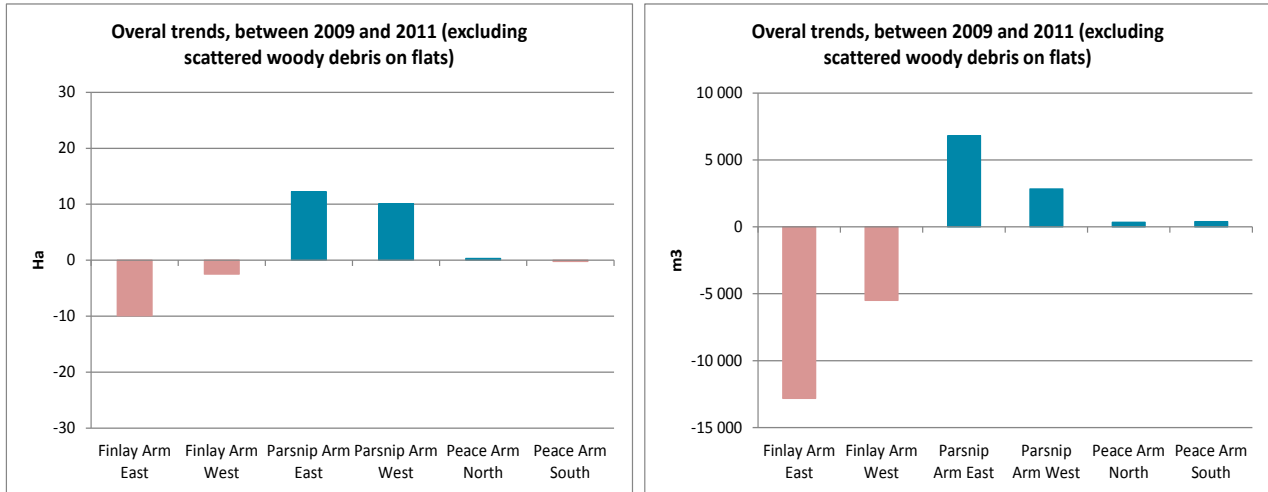


Figure E1 Graphs of the overall balance of woody debris trends in the Williston Reservoir, between 2009 and 2011, in terms of hectares and cubic meters

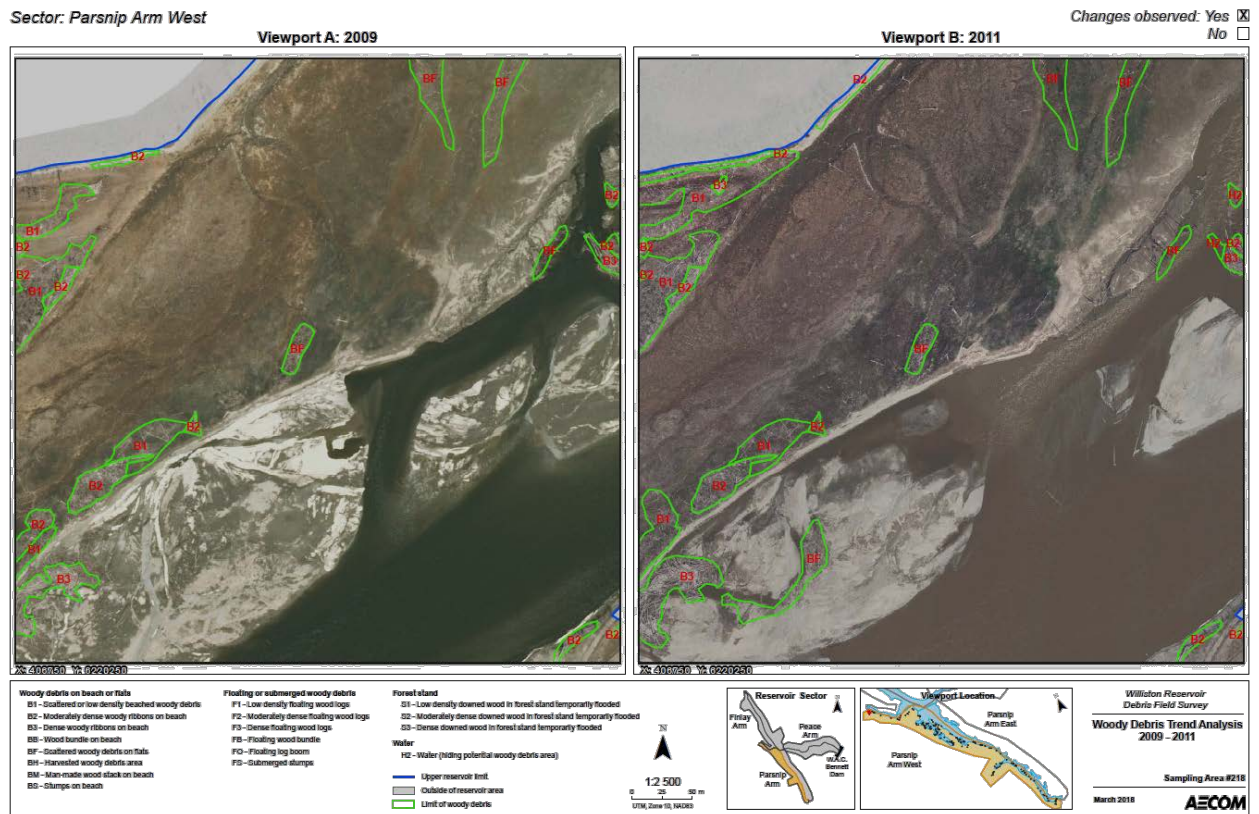


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1. Property Location

The Williston Reservoir is located in north-eastern British Columbia within the Mackenzie River Basin (Figure 1-1). The reservoir has three arms (Finally, Parsnip and Peace), which cover approximately 1,773 km². Maximum elevation of water levels occurs at the end of August and minimum levels are reached at the end of April; the total drawdown being approximately 12 m. Deposition, recruitment and floatation of woody debris occur on an annual basis as a result of these fluctuations. Woody debris becomes stranded on the reservoir shoreline during drawdown and may be refloated in the spring and summer as water level rises.

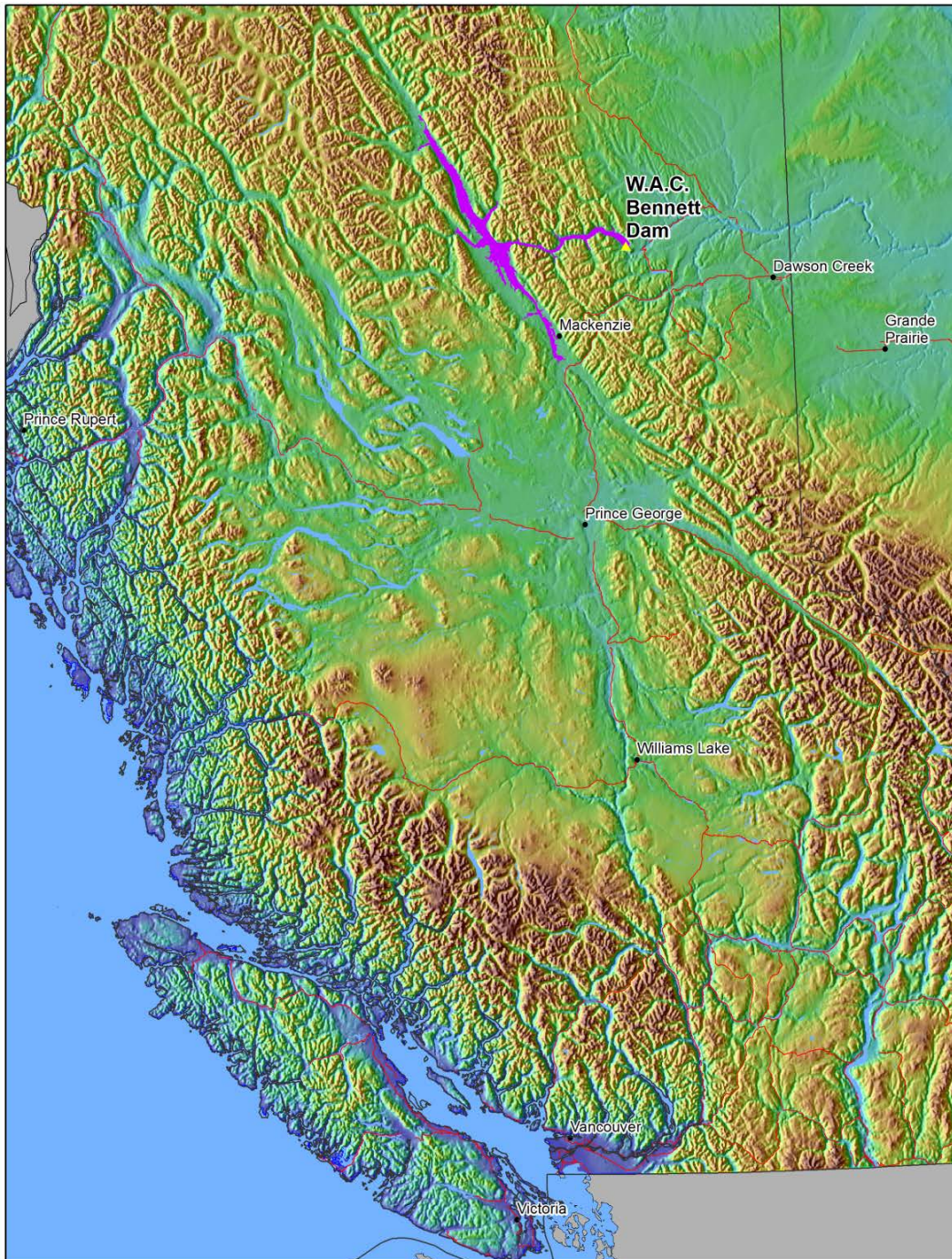


Figure 1-1 Location of the Williston Reservoir (i.e. waterbody painted in purple)

2. Context

Large volumes of woody debris within the reservoir cause problems for its operation and for recreational and community uses. More specifically, large pieces of woody debris can block or impede discharge facilities, which could lead to overtopping of the dam. Smaller woody pieces can block trash racks, thereby reducing power generation capacity. Floating woody debris is also a major safety concern for boaters and recreational users of the reservoir.

Given the negative impacts of large woody debris in the reservoir, BC Hydro requested an assessment of their sources and quantity, followed by the development of a management strategy plan and the removal of woody debris in targeted areas. The baseline map layer was prepared by AECOM by interpretation of aerial photographs taken in 2009, while the number of cubic metres of wood per type of debris was quantified through field surveys. Following the implementation of the woody debris management plan, more than 50,000 cubic metres of wood logs above the high-water mark have been removed so far, as part of the debris removal programme.

BC Hydro has recently contracted AECOM to perform a monitoring study consisting of mapping and analyzing the extent of woody debris in 2011 against the baseline of 2009. A statistical approach was applied to compare both conditions. More specifically, 620 sampling areas were randomly selected in an array of 500 m x 500 m cells that cover the whole reservoir (Figure 2-1). The sampling cells were selected, per arms and sectors, in accordance with the following proportions:

- 15 % of the cells that are touching the reservoir coastline and where woody debris were mapped in 2009;
- 15 % of the cells that are touching the coastline and where no debris were observed in 2009;
- 15 % of the cells that do not touch the coastline and that has floating debris in 2009;
- exclusion of cells that do not touch the coastline and that are without floating debris in 2009;
- 100 % of the priority sites (10) targeted by BC Hydro.

The next chapters present the results of this comparative study in Finally Arm East, Finally Arm West, Parsnip Arm East, Parsnip Arm West, Peace Arm East and Peace Arm West.

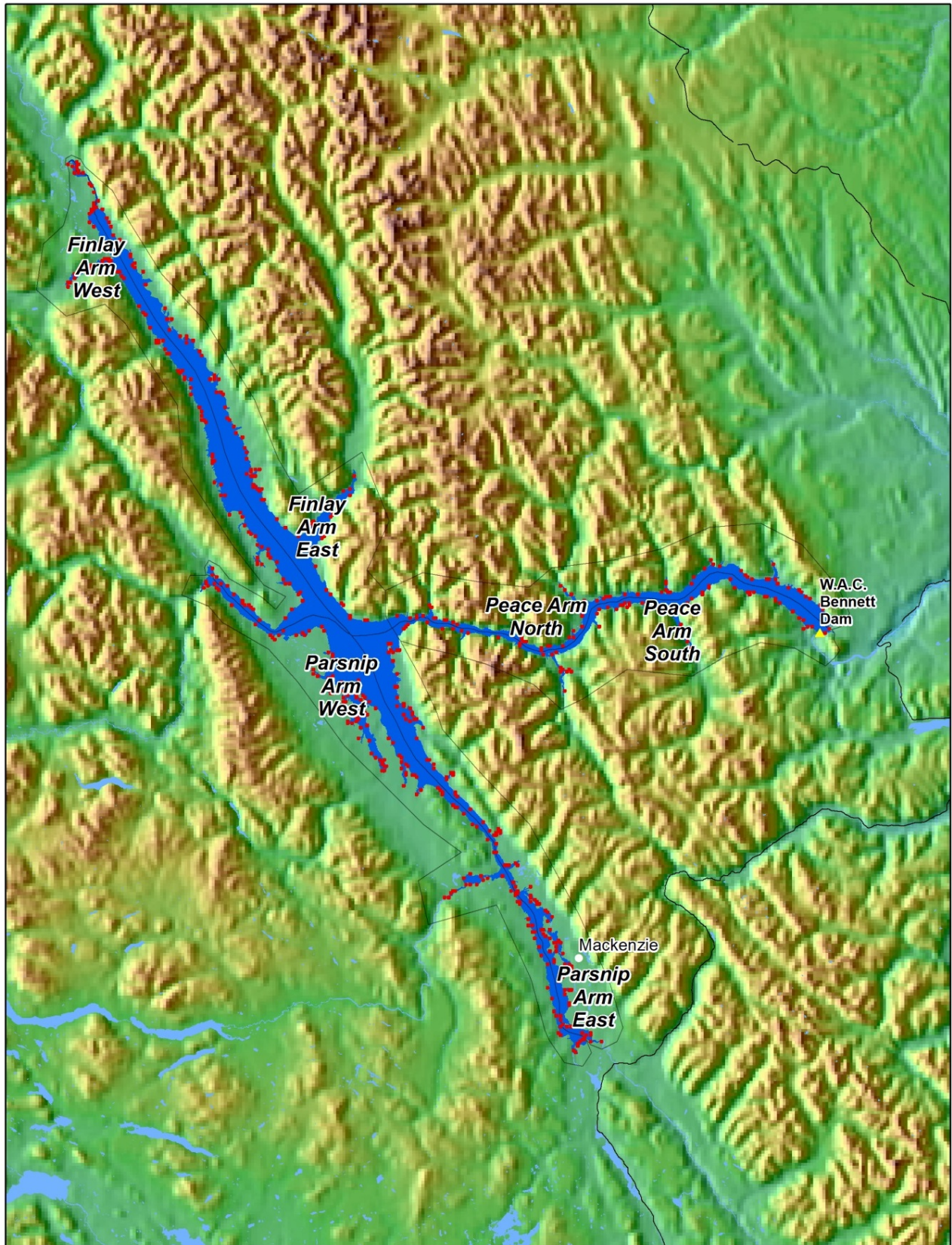


Figure 2-1 Location of the sampling areas (red dots) in the six sectors of Williston Reservoir

3. Levels of Perception of the sets of Aerial Photographs

Mosaics of aerial photographs of 2009 and 2011 were obtained from BC Hydro for performing the trend analysis. In 2009, stereo pairs of aerial photographs were used for the interpretation. The 3D view was particularly useful to delineate shoreline erosion that increases the recruitment rate of debris into the reservoir. It also eased the estimation of debris height for classifying ribbons along the coast. For comparing the states and extent of woody debris between 2009 and 2011, the grouping of photographs into a single mosaic per year is more effective for covering the whole reservoir rapidly. Furthermore, since woody debris are already classified in the baseline layer, the 2D view from the flat mosaics is proving sufficient for identifying and quantifying changes in woody debris. In fact, the main issue concerns the pixel size of the imagery that should be very similar, and sufficiently small for differentiating objects.

The resolution of the 2011 imagery is almost double that of the imagery used in the 2009 study. More precisely, the pixel size is 20 cm, while it is 33 cm for the older set. At least, this higher resolution ensures not to miss details that were observed during the baseline study. However, it was noticed that false changes are detected when the newer interpretation is compared with the baseline study, given that many faint details were undetected on the coarser imagery. In order to avoid false trends, it was decided to review the whole baseline study of 2009 by reinterpreting faint details, using the 2011 imagery to confirm if these faint clues really correspond to wood logs, and if additional debris areas have to be delineated (see example presented in Figure 3-1).



Figure 3-1 Example of the analysis of faint details on the imagery of 2009, by using the new set of 2011 to confirm the existence of woody debris

This procedure allowed the photo-interpreter to delineate and classify many debris areas that have been missed during the first study, given the coarser pixel size. It was also possible to review beach segments that were partly hidden by tree shadows or by higher features in oblique view. The same woody debris classification applied for the first version of the baseline of 2009 has been used for the revision, except that scattered logs along the coastline and on the drawdown plain were distinguished. The density of fallen trees in forest stands were also characterized in three different classes, given they indicate the rate of degradation and a potential source of debris that could be mobilized and transported to the waterbody. In order to follow more closely the dynamic of woody debris and to explain the changes that will be observed when the images of 2011 are interpreted, the classes "Water (hiding potential woody debris area detected in the other study)" and "River (new branch cutting a former woody debris area)" were added to the original classification used for the first version of the baseline survey.

The updated baseline produced by reinterpreting the 2009 imagery, giving emphasis on the detection of faint clues, is presented in the next section.

4. Updated Version of the Baseline of 2009

The classes listed in the next table (Table 4-1) and described in the next paragraphs, were used both for the revised baseline and for the interpretation of woody debris in 2011 over the sampling areas. This description will be followed by the presentation of the updated values of the revised baseline in Section 4.4 and Table 4-2.

Table 4-1 Classification applied for characterizing the woody debris in Williston Reservoir

Code	Description
Woody debris on beach or flats	
B1	Scattered or low density beached woody debris
B2	Moderately dense woody ribbons on beach
B3	Dense woody ribbons or piles on beach
BB	Wood bundle on beach
BF	Scattered woody debris on flats
BH	Harvested woody debris area (<i>i.e. area cleaned in 2011, but that was covered by man-made wood stacks in 2009</i>)
BM	Man-made wood stack on beach
BS	Stumps on beach
Floating or submerged woody debris	
F1	Low density floating wood logs
F2	Moderately dense floating wood logs
F3	Dense floating wood logs
FB	Floating wood bundle
FO	Floating log boom (<i>term is used as the place where logs are collected into booms</i>)
FS	Submerged stumps (<i>i.e. area identified as "Stumps on beach" in the other imagery, but not clearly visible in the actual view</i>)
Forest stand	
S1	Low density downed wood in forest stand occasionally flooded
S2	Moderately dense downed wood in forest stand occasionally flooded
S3	Dense downed wood in forest stand occasionally flooded
SL	Low density forest stand occasionally flooded
SM	Moderately dense forest stand occasionally flooded
SD	Dense forest stand occasionally flooded
Additional types for following the dynamic of woody debris areas	
H2	Water (hiding potential woody debris area detected in the other study, 2009 or 2011))
RN	Reservoir area without woody debris
RR	River (<i>new branch cutting a former woody debris area in 2009. This code is used for identifying the cause of the changes</i>)









4.1 Woody Debris on Beach or Flats (Drawdown Zone)

Beached debris is defined as accumulations of woody debris gathered in long ribbons or in piles along the coastline. Three classes of density are used: 1) Scattered (code: B1), 2) Moderately dense (B2) and 3) Dense woody debris (B3). For the first class, the scattered debris on the drawdown plain is identified by the code BF. Usually, the denser accumulations are observed in shallow natural bays near the upper water limits of the reservoir.

This main group of debris on beach of flats also include stumps (code BS; most of the time, former snags in these areas were already lying on the ground on the 2009 imagery). Quite often these are cut-stumps. Even though they are unlikely to become floating debris, these constitute a hazard to recreational use of the reservoir.

A few lost wood bundles (BB) could be observed, mostly on the drawdown plain. They are easily identified given that logs are cut at both ends and piles in rectangular shape. The classes "Man-made wood stack on beach" (BM) and "Harvested woody debris area" (BH) were added, given that important woody debris removal activities are conducted in the reservoir.

The next figures depict the various types of beached woody debris that are mapped for the assessment of their sources and quantity, and for the trend analysis (Figure 4-1 and Figure 4-2).

2011 Imagery	Oblique aerial picture
	
<p>Scattered or low density beached woody debris (B1)</p>	
	
<p>Moderately dense woody ribbons on beach (B2)</p>	
	
<p>Dense woody ribbons or piles on beach (B3)</p>	
	
<p>Wood bundle on beach (BB)</p>	

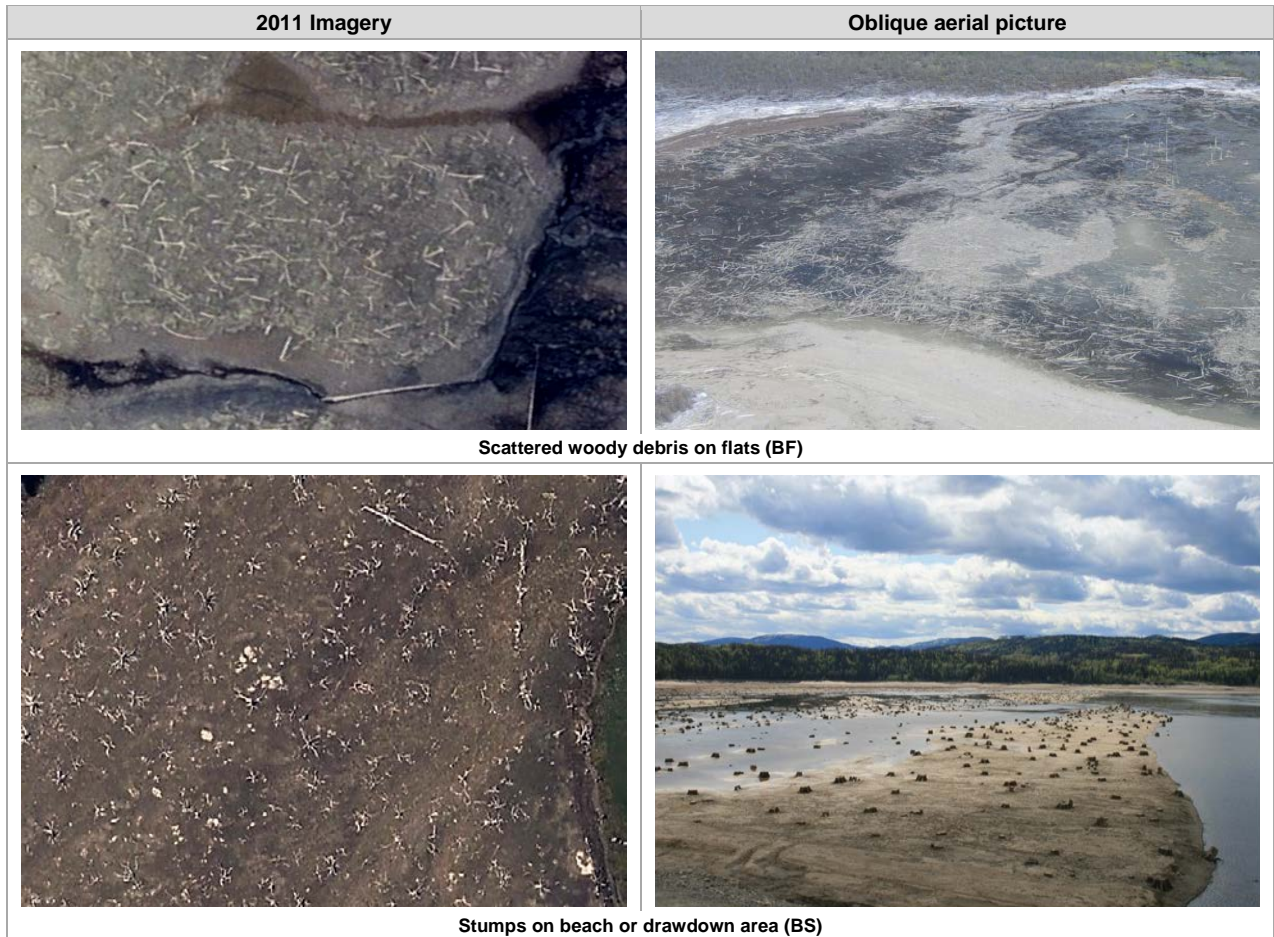


Figure 4-1 Examples of various classes of woody debris on beach or flats

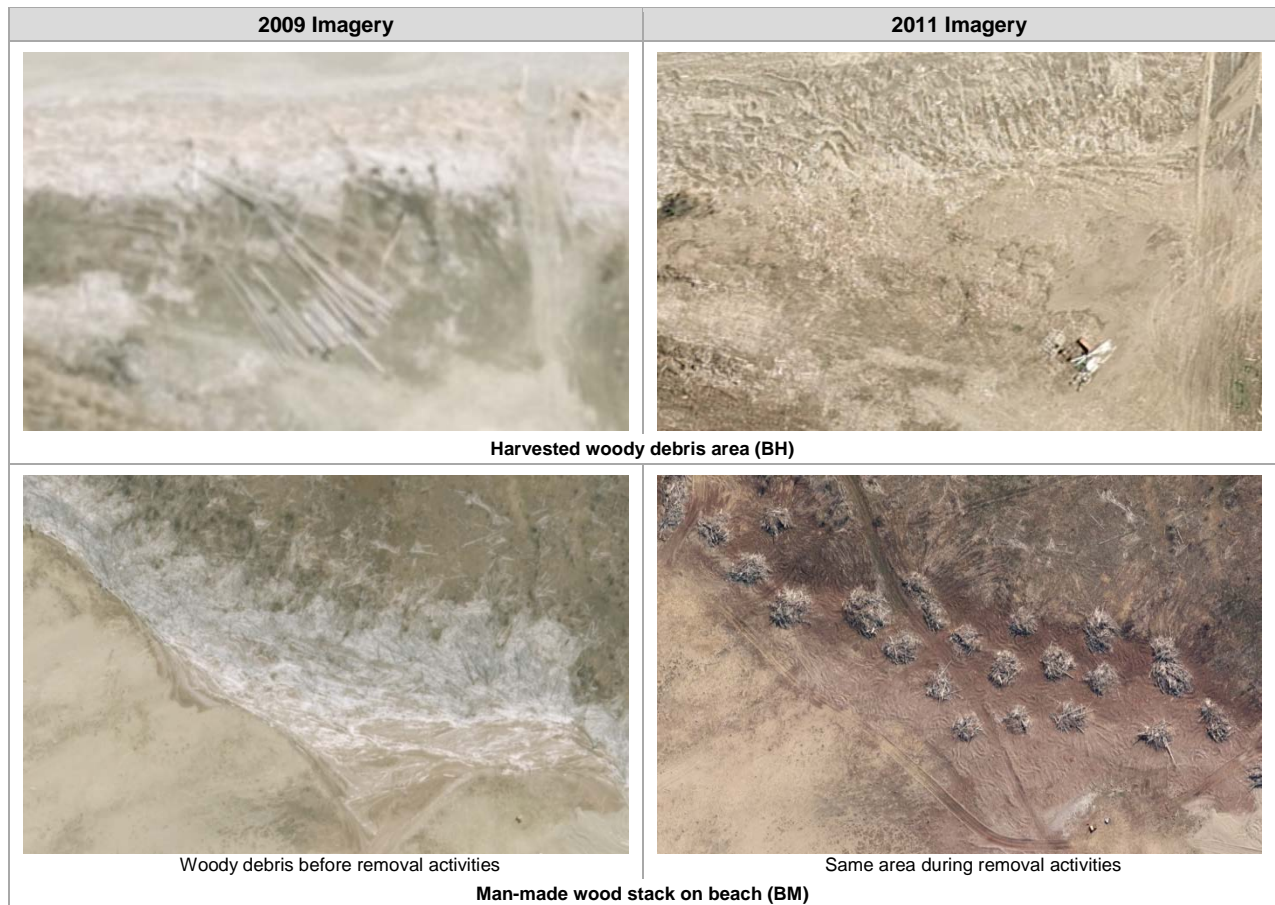


Figure 4-2 Examples of classes used in areas where wood logs are being removed

4.2 Floating Debris

Floating debris is of the same nature and origin as beached debris. The variation in quantity between one or other of these categories is a function of the reservoir water level. Deposition and floatation of 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 some of them may be refloatated in the spring and summer as water levels rise. The gradation of class densities used for the beached debris has been also applied for the floating ones: F1 (low density); F2 (moderately dense) and F3 (dense floating wood logs). For the areas not captured by the Williston Air Photos (e.g., the open water area of Finlay Arm), the location and characterization of debris accumulations were determined by conducting a helicopter survey in 2010. These polygons were conserved as they were for the revised baseline map.

Typical floating debris is found over the main waterbody, in forms of large patches of wood. However, most of them have been regrouped in log booms and recuperated during the cleaning activities (Figure 4-3). So, very little free-floating debris is observed on the reservoir during the baseline study.

For the revised version of the baseline map layer, wood debris that are floating in creeks and narrow bays have been included in this group, given that they are likely prone to be transported to the main waterbody. In general, low density and moderately dense floating wood debris consist of trees mobilized from bank erosion. They are located close to main streams and they are frequently trapped along the contact line with the drawdown area.

To facilitate the analysis of wood debris trends and dynamics, stumps on beach or drawdown area (BS), that are temporarily covered by water during the photo-interpretation of the second mosaic, have been identified as "Submerged stumps" (FS). For the scattered woody debris on the drawdown plain (BF), the polygons have been identified as "Water" (H2), given that it was not possible to confirm the presence of these debris or their removal by natural processes or anthropic activities. Therefore, the woody debris in these areas will not be considered to have changed.

The polygons where woody debris were observed in 2009 have been identified as "River" (RR), when they are located in 2011 over a new river branch or channel that has removed all woody debris.

The next figures depict the various types of floating woody debris that were identified in the mosaics of 2009 and 2011 for the assessment of their sources and quantity, and for the trend analysis (Figure 4-3).

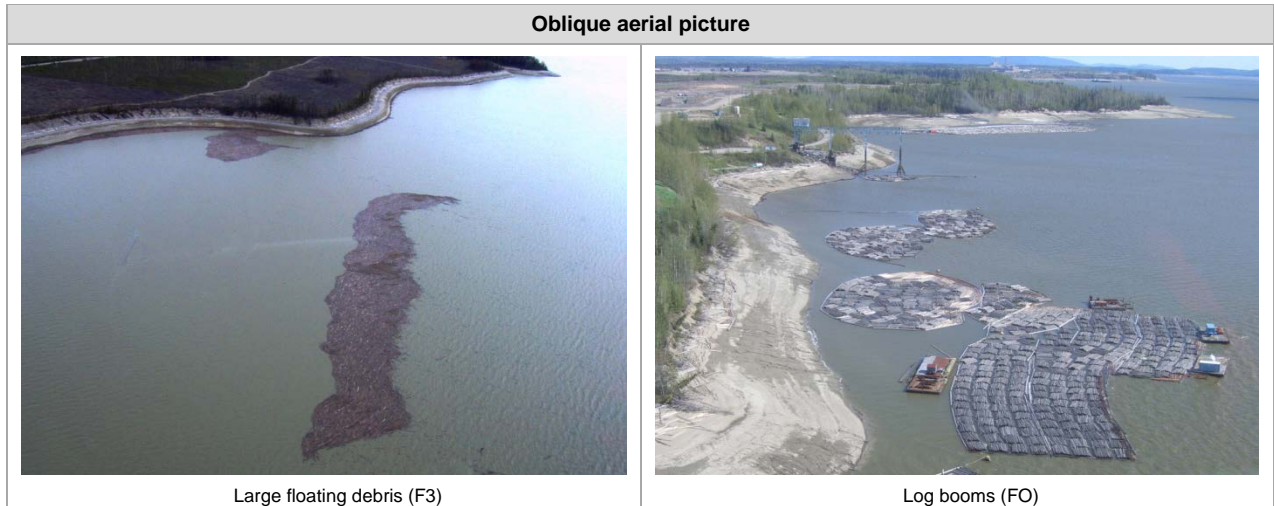


Figure 4-3 Large floating debris (F3) and log booms (FO) managed during the cleaning programme

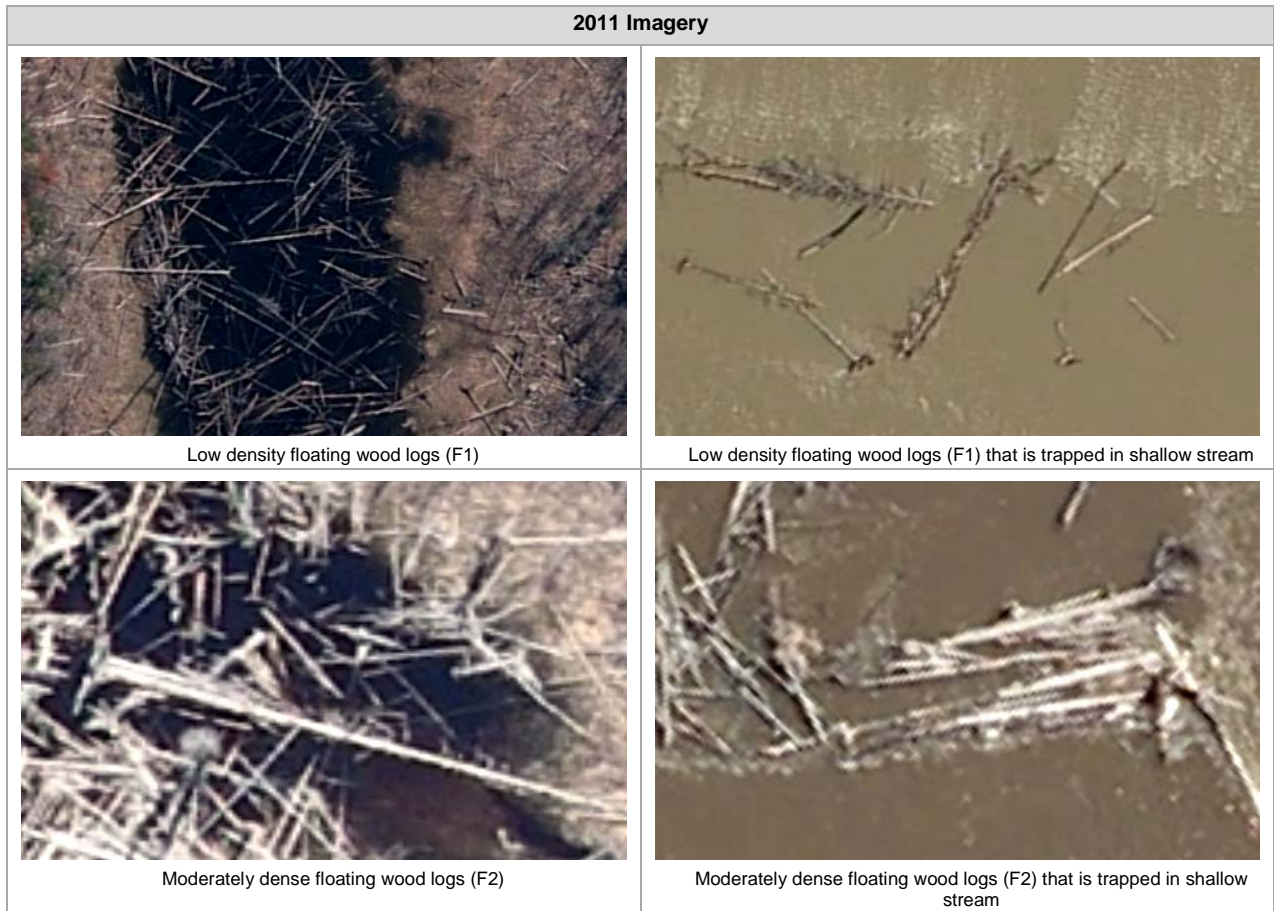




Figure 4-4 Examples of the various classes of floating woody debris

4.3 Forest Stands and Timber not cleared Prior to Flooding

Stands of dead or living trees remain at the periphery of the reservoir above the main ribbons of woody debris and the upper limit of the main drawdown zone. These stands are located in flat areas that are occasionally flooded during the maximum level of the reservoir. They are seasonally affected by waterlogging and ice, mainly in the area close to beached ribbons. As a consequence, downed trees can be observed where natural agents are more effective.

The forested areas have been delineated and characterized in accordance with the density of their standing trees (SL, SM and SD) or in accordance with the density of large woody debris on the ground (S1, S2 and S3; Table 4-1 and Figure 4-5). Realignment of logs in the form of discontinuous ribbons by wave actions is observed in the areas containing downed wood, mainly for the denser class (S3).

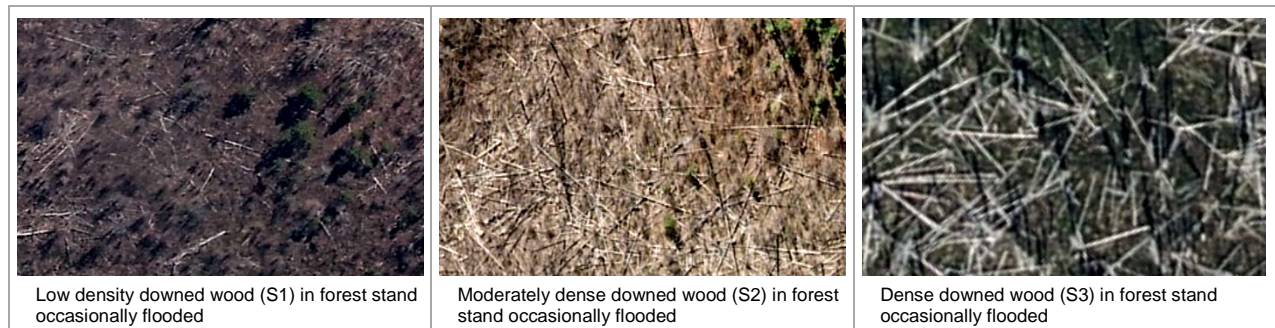


Figure 4-5 Examples of various classes of downed wood in forest stand occasionally flooded

4.4 Area Occupied by the Different Types of Woody Debris in the Revised Baseline of 2009

The extent of large woody debris is presented per sector and type. Table 4-2 provides a summary of the values by type of woody debris in hectares while, Table 4-3 presents the relative extent in percentages.

The total extent of the various debris types has increased in the revised version, but the overall distribution is similar to the 2009 baseline. It should be noted that in some locations in the 2009 imagery it was not possible to clearly detect the woody debris, without additional clues from the 2011 imagery, where only faint clues were available as to the presence or absences of woody debris due to the lower resolution air photos. Based on the finding that the overall distribution is similar to the 2009 baseline, priority sectors and targeted sites remain unchanged for the Woody Debris Strategic Management Plan.

Lost bundles are observed in the Reservoir, with 35 lost bundles are found in Parsnip Arm West, 25 in Finlay Arm West, 21 in Parsnip Arm East, 9 in Finlay Arm East and 4 in Peace Arm North (Table 4-2).

Finlay Arm East dominates in terms of the total area of beached woody debris (Table 4-4 and Figure 4-6). It is followed closely by Finlay Arm West, and then by Parsnip Arm West and Parsnip Arm East. Peace Arm North and South contain minor amounts of woody debris. The relative rank between the sectors remains almost unchanged when their total area of woody debris is reported per kilometre of coastline (Figure 4-7). In fact, this comparison differs only between Parsnip Arm East and Parsnip Arm West, since its coastline total 334 km for the East Arm, compared to 511 km for the West Arm (Table 4-5).

Table 4-2 Area (ha) occupied by general types of woody debris and forest stands mapped in 2009 in the revised baseline study of Williston Reservoir

Sector	Woody debris on beach (B1, B2, B3)	Wood bundle on beach (BB)	Man-made wood stack on beach (BM)	Scattered woody debris on flats (BF)	Floating or submerged woody debris (F1, F2 and F3)	Forest stand with woody debris on ground (S1, S2 and S3)	Forest stand without or with very few debris on ground (SL, SM and SD)	Total Woody Debris (excl. stumps)	Stumps (BS and FS)
	ha	ha Nb		ha	ha	ha	ha		
Finlay Arm East	409.50	0.07 9	0.00	216.67	10.31	100.78	401.93	1,148.26	110.09
Finlay Arm West	371.47	0.23 25	0.24	71.24	12.15	228.87	704.48	1,413.68	116.27
T total	780.97	0.30 34	0.24	287.91	22.46	329.65	1,106.41	2,561.94	226.36
Parsnip Arm East	199.34	0.14 21	0.35	35.71	15.68	38.40	140.75	451.37	566.55
Parsnip Arm West	312.41	0.20 35	0.00	127.74	4.68	181.81	461.99	1,123.83	1,135.27
T total	511.75	0.34 56	0.35	163.45	20.36	220.21	602.74	1,575.20	1,701.82
Peace Arm North	48.08	0.01 4	0.00	0.56	2.58	0.37	6.85	62.45	4.90
Peace Arm South	46.51	0.00 0	0.00	2.91	0.65	2.48	6.35	58.90	24.31
T total	94.59	0.01 4	0.00	3.47	3.23	2.85	13.20	121.35	29.21
Grand total	1,387.31	0.65 94	0.59	454.83	46.05	552.71	1,722.35	4,258.49	1,957.39

Table 4-3 Relative area (%) occupied by general types of woody debris and forest stands mapped in 2009 in the revised baseline study of Williston Reservoir

Sector	Woody debris on beach (B1, B2, B3)	Wood bundle on beach (BB)	Nb	Man-made wood stack on beach (BM)	Scattered woody debris on flats (BF)	Floating or submerged woody debris (F1, F2 and F3)	Forest stand with woody debris on ground (S1, S2 and S3)	Forest stand without or with very few debris on ground (SL, SM and SD)	Total Woody Debris	Stumps (BS and FS)
	% (sector)	% (sector)		% (sector)	% (sector)	% (sector)	% (sector)	% (sector)		
Finlay Arm East	35.7%	0.01%	9	0.00%	18.9%	0.9%	8.8%	35.0%	9.99	48.6%
Finlay Arm West	0.26	0.02%	25	0.02%	5.0%	0.9%	16.2%	49.8%	25.98	51.4%
Total	0.30	0.01%	34	0.01%	11.2%	0.9%	12.9%	43.2%	34.99	100.0%
Parsnip Arm East	44.2%	0.03%	21	0.08%	7.9%	3.5%	8.5%	31.2%	21.95	33.3%
Parsnip Arm West	27.8%	0.02%	35	0.00%	11.4%	0.9%	16.2%	41.1%	35.97	66.7%
Total	32.5%	0.02%	56	0.02%	10.4%	1.3%	14.0%	38.3%	56.96	100.0%
Peace Arm North	77.0%	0.02%	4	0.00%	0.9%	4.1%	0.6%	11.0%	4.94	16.8%
Peace Arm South	79.0%	0.00%	0	0.00%	4.9%	1.1%	4.2%	10.8%	1.00	83.2%
Total	77.9%	0.01%	4	0.00%	2.9%	2.7%	2.3%	10.9%	4.97	100.0%
Grand total	32.6%	0.02%	94	0.01%	10.7%	1.1%	13.0%	40.4%	94.98	

Table 4-4 Area (ha) occupied by woody debris types in the revised baseline of Williston Reservoir

Sector: Finlay Arm West				Sector: Finlay Arm East			
Code	Wood Debris Type	Ha	Ratio m ² /km of beach	Code	Wood Debris Type	Ha	Ratio m ² /km of beach
B1	Scattered or low density beached woody debris	69.37	1,976	B1	Scattered or low density beached woody debris	63.65	2,115
B2	Moderately dense woody ribbons on beach	133.40	3,801	B2	Moderately dense woody ribbons on beach	130.46	4,334
B3	Dense woody ribbons on beach	168.70	4,806	B3	Dense woody ribbons on beach	215.39	7,156
BB	Wood bundle on beach	0.23	7	BB	Wood bundle on beach	0.07	2
BF	Scattered woody debris on flats	71.24	2,030	BF	Scattered woody debris on flats	216.67	7,198
BM	Man-made wood stack on beach	0.24	7	BM	Man-made wood stack on beach	0.00	0
F1	Low density floating wood logs	3.91	111	F1	Low density floating wood logs	2.71	90
F2	Moderately dense floating wood logs	7.30	208	F2	Moderately dense floating wood logs	0.97	32
F3	Dense floating wood logs	0.94	27	F3	Dense floating wood logs	6.63	220
FO	Floating log boom	0.21	6	FO	Floating log boom	0.00	0
BS	Stumps on beach	114.81	3,271	BS	Stumps on beach	110.09	3,657
FS	Submerged stumps	1.46	42				
Sector: Parsnip Arm West				Sector: Parsnip Arm East			
Code	Wood Debris Type	Ha	Ratio m ² /km of beach	Code	Wood Debris Type	Ha	Ratio m ² /km of beach
B1	Scattered or low density beached woody debris	66.12	1,294	B1	Scattered or low density beached woody debris	58.07	1,739
B2	Moderately dense woody ribbons on beach	121.42	2,376	B2	Moderately dense woody ribbons on beach	78.26	2,343
B3	Dense woody ribbons on beach	124.87	2,444	B3	Dense woody ribbons on beach	63.01	1,886
BB	Wood bundle on beach	0.20	4	BB	Wood bundle on beach	0.14	4
BF	Scattered woody debris on flats	127.74	2,500	BF	Scattered woody debris on flats	35.71	1,069
BM	Man-made wood stack on beach	0.00	0	BM	Man-made wood stack on beach	0.35	11
F1	Low density floating wood logs	2.58	50	F1	Low density floating wood logs	11.94	357
F2	Moderately dense floating wood logs	0.42	8	F2	Moderately dense floating wood logs	2.36	71
F3	Dense floating wood logs	1.68	33	F3	Dense floating wood logs	1.38	41
FO	Floating log boom	0.00	0	FO	Floating log boom	9.53	285
BS	Stumps on beach	1,128.28	22,080	BS	Stumps on beach	564.11	16,890
FS	Submerged stumps	6.99	137	FS	Submerged stumps	2.44	73

Sector Peace Arm North

Code	Wood Debris Type	Ha	Ratio m ² /km of beach
B1	Scattered or low density beached woody debris	18.37	806
B2	Moderately dense woody ribbons on beach	21.94	962
B3	Dense woody ribbons on beach	7.77	341
BB	Wood bundle on beach	0.01	0
BF	Scattered woody debris on flats	0.56	24
BM	Man-made wood stack on beach	0.00	0
F1	Low density floating wood logs	0.07	3
F2	Moderately dense floating wood logs	0.00	0
F3	Dense floating wood logs	2.51	110
FO	Floating log boom	0.00	0

BS	Stumps on beach	4.90	215
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Sector Peace Arm South

Code	Wood Debris Type	Ha	Ratio m ² /km of beach
B1	Scattered or low density beached woody debris	13.74	603
B2	Moderately dense woody ribbons on beach	26.88	1,179
B3	Dense woody ribbons on beach	5.89	258
BB	Wood bundle on beach	0.00	0
BF	Scattered woody debris on flats	2.91	128
BM	Man-made wood stack on beach	0.00	0
F1	Low density floating wood logs	0.65	29
F2	Moderately dense floating wood logs	0.00	0
F3	Dense floating wood logs	0.00	0
FO	Floating log boom	0.00	0

BS	Stumps on beach	23.76	1,042
FS	Submerged stumps	0.55	24

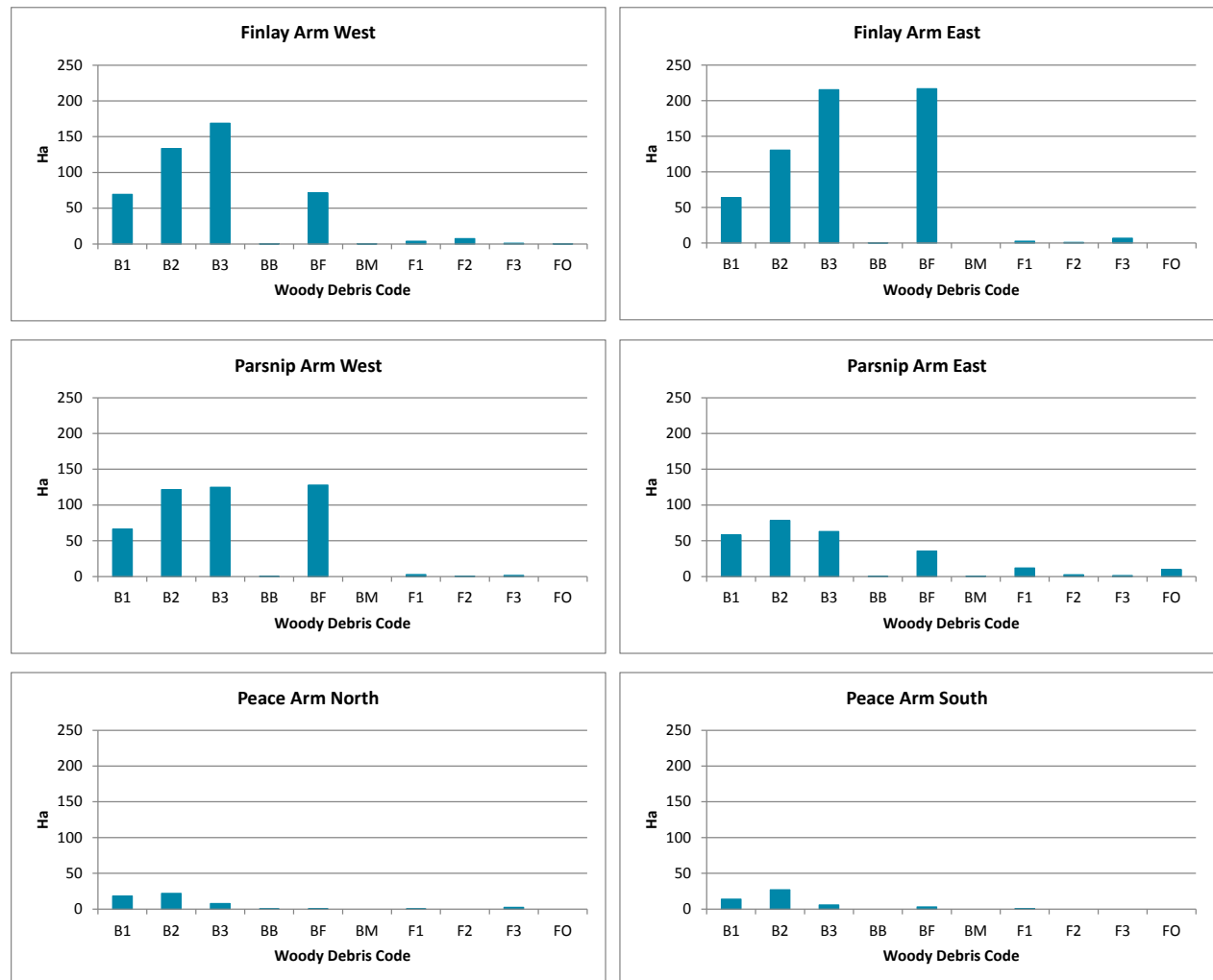


Figure 4-6 Area (ha) occupied by woody debris types in the revised baseline of Williston Reservoir

Table 4-5 Coastline length (km) used to compare the sectors per unitary length

Sector	Coastline (km) ^a
Finlay Arm East	301
Finlay Arm West	351
Parsnip Arm East	334
Parsnip Arm West	511
Peace Arm North	228
Peace Arm South	228

a : excluding the perimeter of the temporary islands

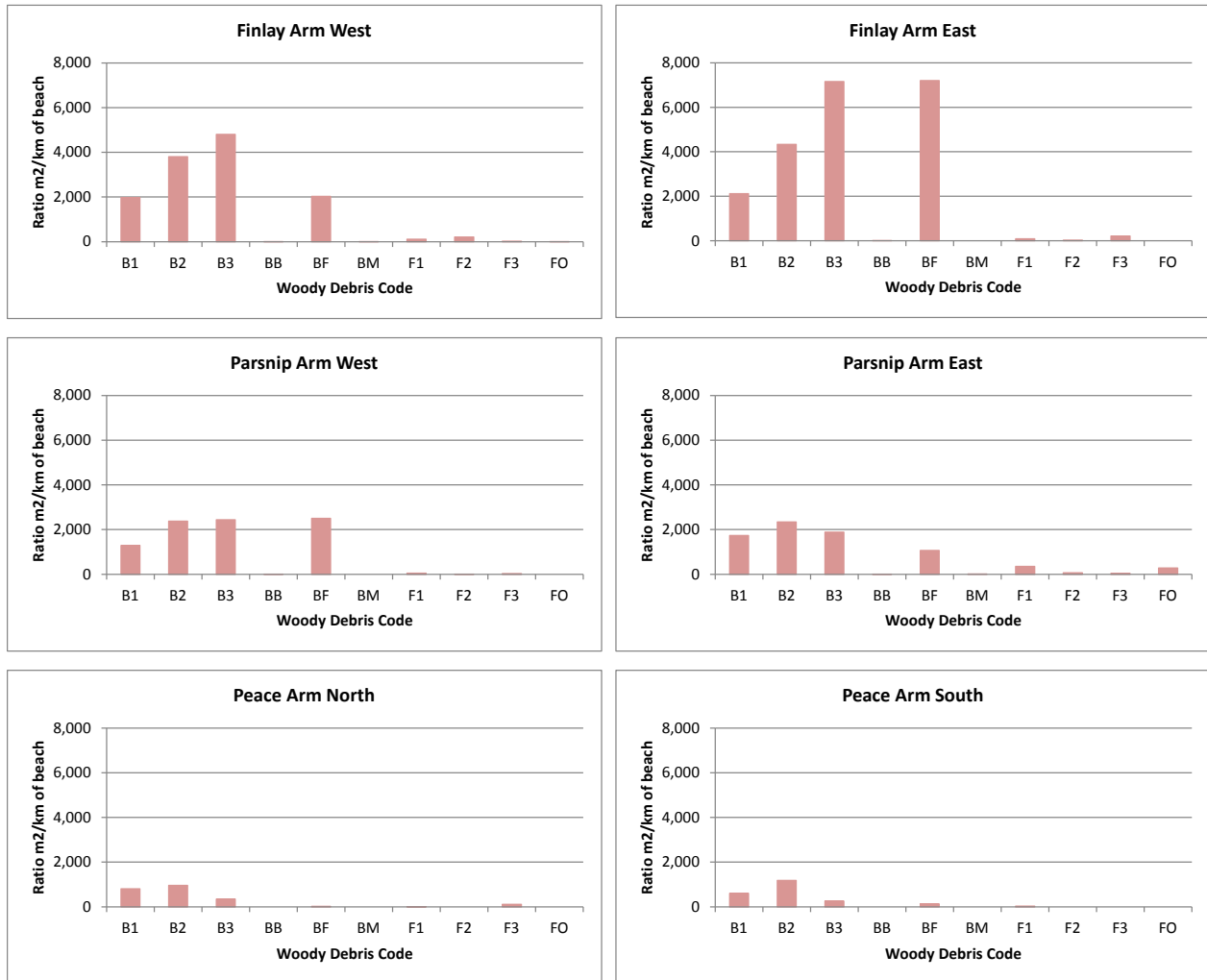


Figure 4-7 Relative extent (m²) of woody debris types per unitary length of coastline (km) in the revised baseline of Williston Reservoir

The next set of figures depicts the location of the woody debris on beach and flats (B1, B2, B3 and BF) and the floating woody debris in the Williston Reservoir (Figure 4-8, Figure 4-9, Figure 4-10, Figure 4-11 and Figure 4-12). Figure 4-8 shows the Scattered woody debris on flats (BF). The Scattered woody debris on flats are more frequent in Finlay Arm East, Parsnip Arm West and Finlay Arm West, while almost absent in Peace Arm North and South. Scattered or low density beached woody debris (B1) covers approximately the same total area in Finlay Arm East and West, and in Parsnip Arm East and West (Figure 4-9). It is important to mention that the class B1 has been added in the revised baseline for characterizing more accurately the density of woody ribbons.

Although the Moderately dense woody ribbons on beach (B2) totals larger areas than the Scattered woody debris on flats (BF) or along the beach (B1), its relative distribution remains very similar: this type of debris is more frequent in Finlay Arm East and West, then in Parsnip Arm East and West (Figure 4-10). For Peace Arm South, the Moderately dense woody ribbons on beach (B2) are about twice more frequent than the Scattered or low density beached woody debris (B1), and only 20 % more frequent in the North sector. The same pattern is observed for the Dense woody ribbons on beach (B3), although they are more abundant in Finlay Arm East (Figure 4-11). Finally, Floating woody debris (F1, F2 and F3 presented together) are located throughout the Reservoir (Figure 4-12).

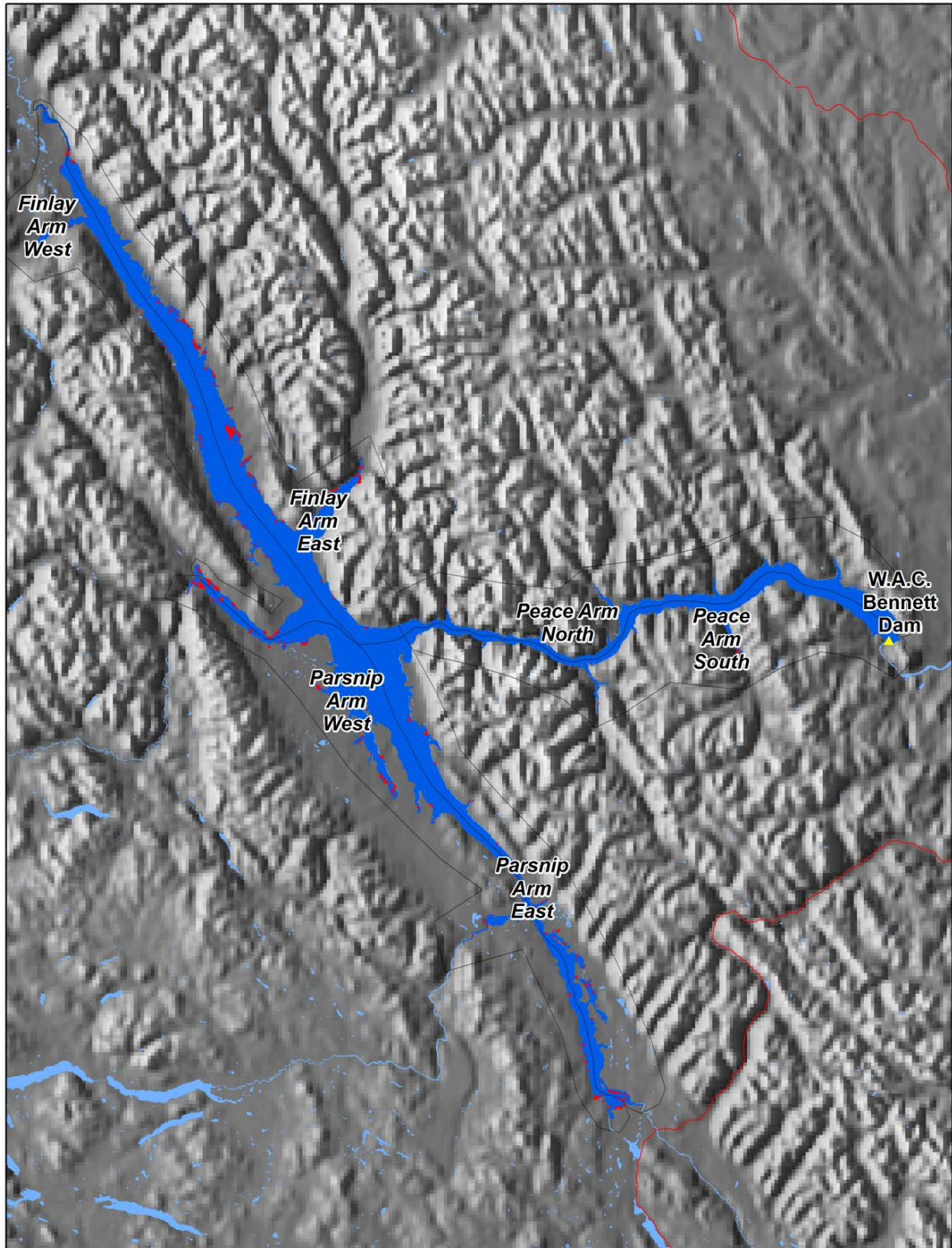


Figure 4-8 Location of Scattered woody debris on flats (BF) in the Williston Reservoir in 2009

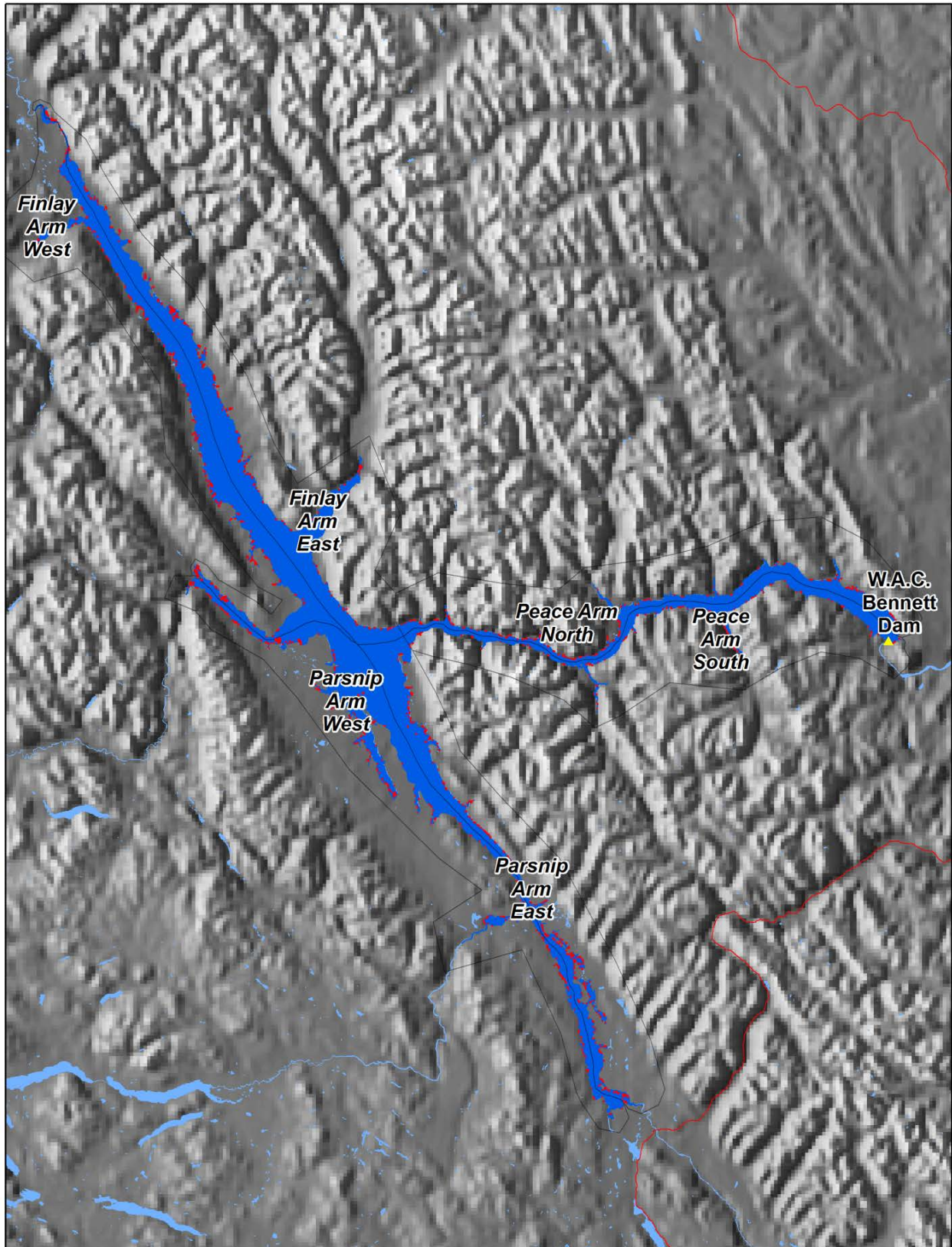


Figure 4-9 Location of the Scattered or low density beached woody debris (B1) in the Williston Reservoir in 2009

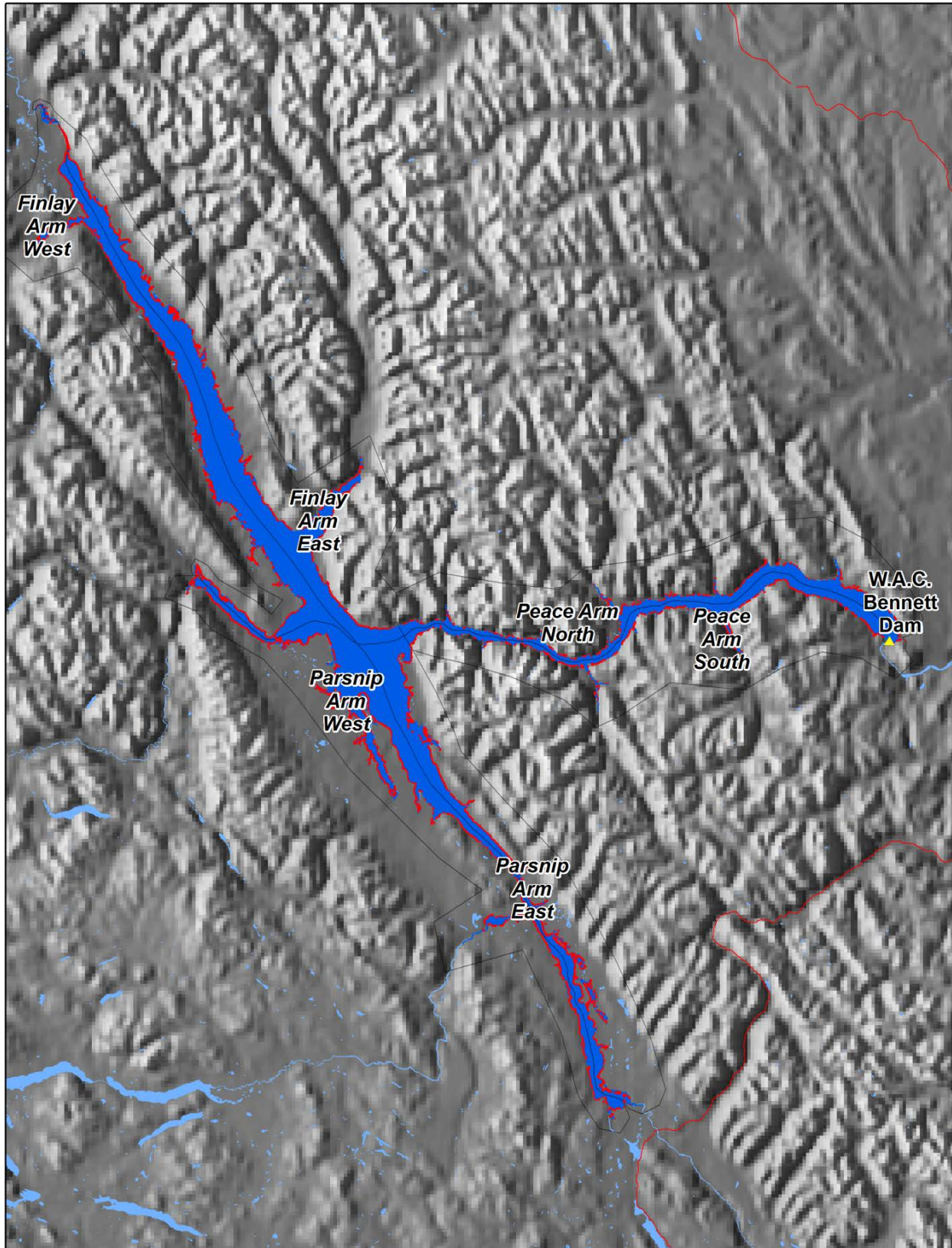


Figure 4-10 Location of Moderately dense woody ribbons on beach (B2) in the Williston Reservoir in 2009

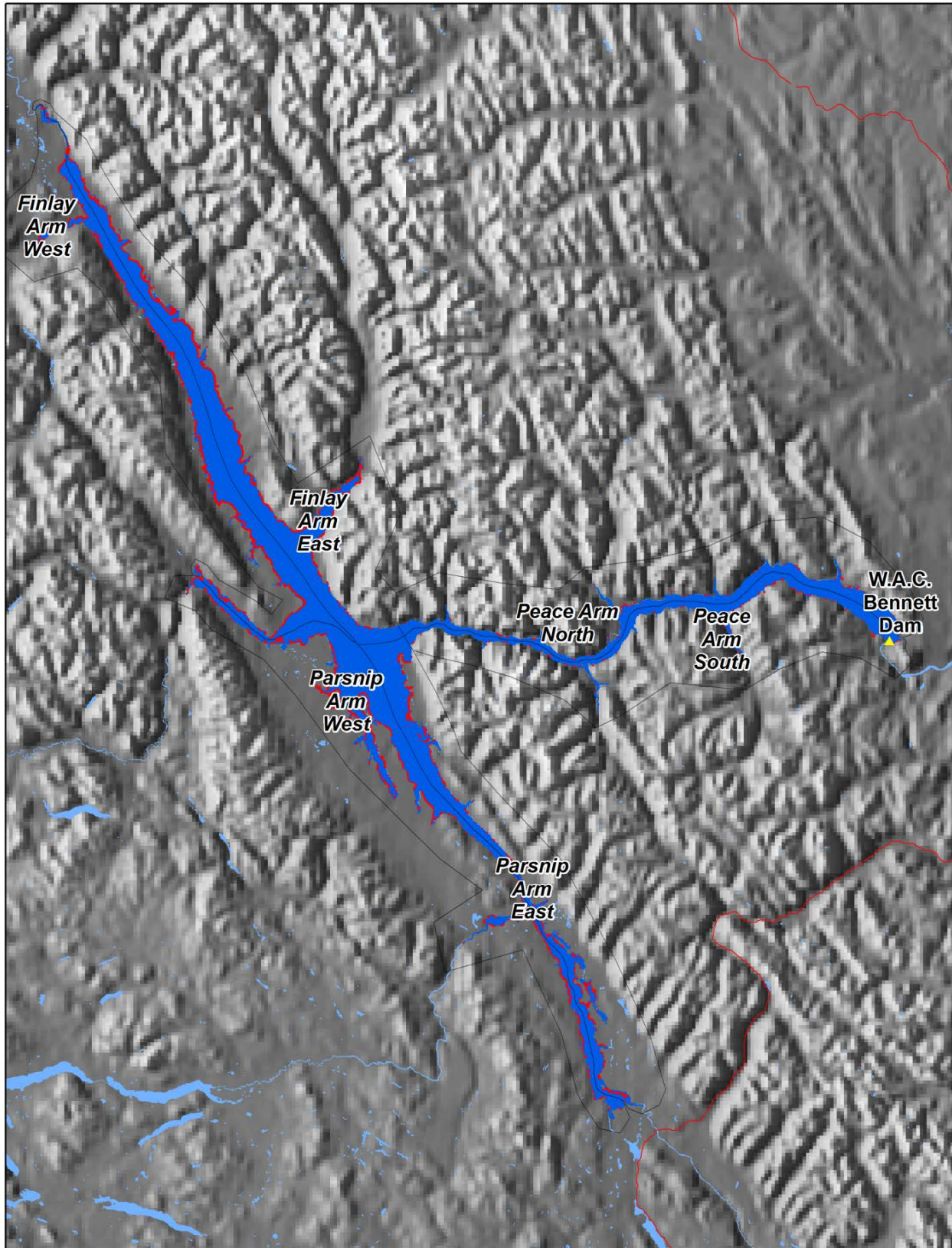


Figure 4-11 Location of Dense woody ribbons on beach (B3) in the Williston Reservoir in 2009

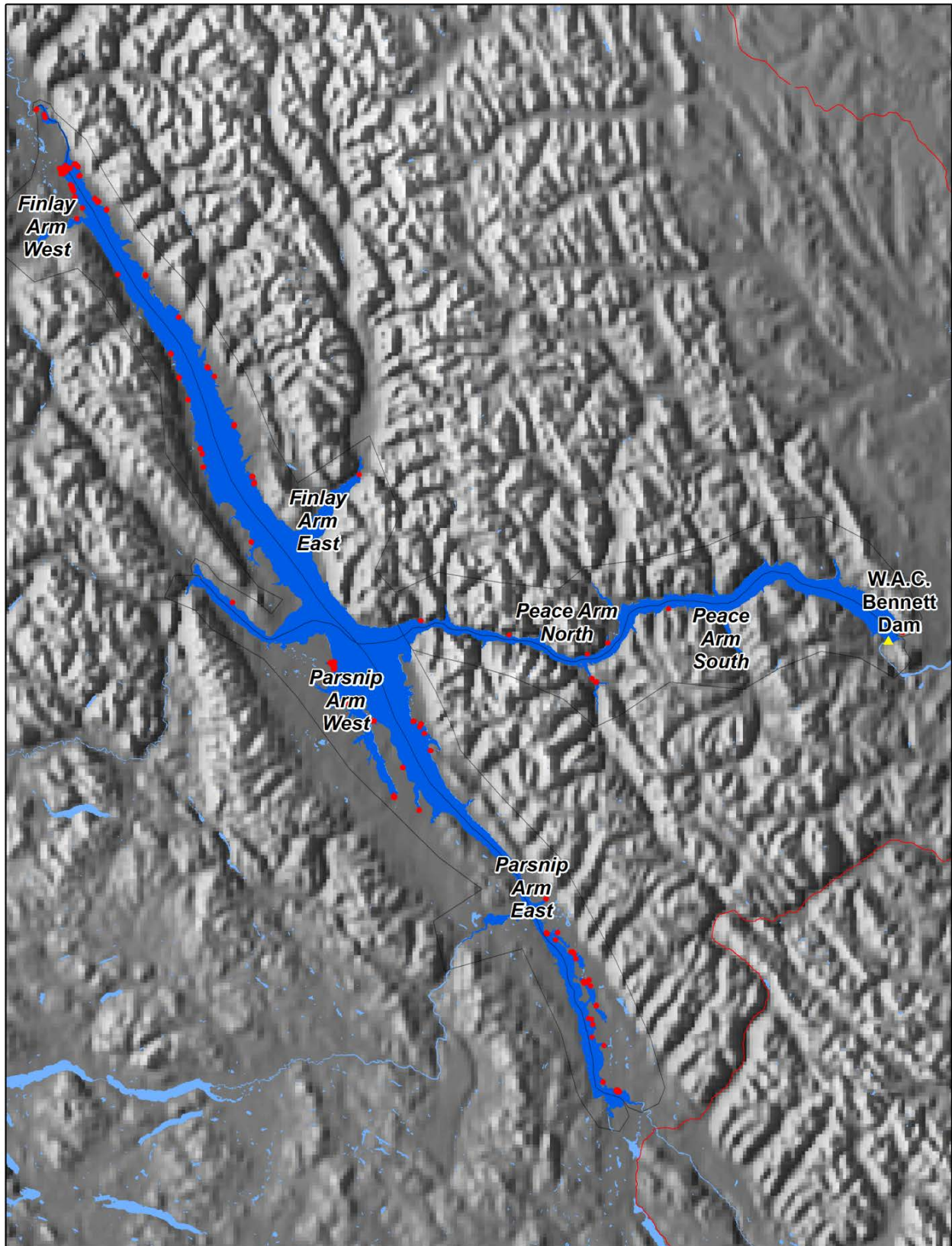


Figure 4-12 Location of Floating woody debris (F1, F2 and F3) in the Williston Reservoir in 2009

The extent of the forest stands (Figure 4-13) is presented in Table 4-6, Figure 4-14 and Figure 4-15. The majority of the stands remaining in the flooded area are of low density (SL), although moderately dense stands (SM) are also present. In all cases, forest stands are more frequent in the West region of the reservoir, more specifically in Finlay Arm West, followed by Parsnip Arm West (Figure 4-16). The East sector of Finlay Arm also contains forest areas, but at a lower degree. However, due to the small size of Parsnip Arm West when the forest cover is expressed as a ratio of the total area or in relation to the coastline length the amount of forest cover is greater (Figure 4-15).

The unharvested forest stands in the reservoir are gradually affected by the waterlogging periods. Downed trees are frequently observed close to ribbons of woody debris, along tributaries and in lower depressions remaining flooded for longer periods. As a consequence, fallen trees are observed where natural agents (wind, wave or ice) are more effective. In general, about 25 % of the remaining flooded forests contain fallen trees in 2009. These woods would probably be mobilized and transported to the main waterbody. Some realignment of fallen stems is already observed in stands where the degradation is at moderate or high levels (S2 and S3). The other phenomenon that could affect the forest stands and that participates in the recruitment of woody debris is related to the shoreline erosion. This process has been characterized for the 2009 baseline. Shoreline erosion is active in the Williston Reservoir, based on the 2009 baseline it affects approximately 60 % of the reservoir shorelines, however based on the 2011 sample analysis this may be an over estimate (1,320 km / 2,148 km, Figure 4-17). During the 2009 baseline study, the annual shoreline retreat was established at 1.0 m, which represents an area of 132 ha per year. It is recommended that the 2018 assessment reassess the level of shoreline erosion.



Figure 4-13 Forest stand (residual trees) periodically flooded in Williston Reservoir

Table 4-6 Area (ha) occupied by types of Forest Stands in the revised baseline of Williston Reservoir

Sector Finlay Arm West

Code	Forest Stand Type	Ha	Ratio m ² /km of beach
S1	Low density downed wood in forest stand temporarily flooded	186.66	5,318
S2	Moderately dense downed wood in forest stand temporarily flooded	37.22	1,060
S3	Dense downed wood in forest stand temporarily flooded	4.99	142
Sub-total		228.87	
SL	Low density forest stand temporarily flooded	454.54	12,950
SM	Moderately dense forest stand temporarily flooded	233.43	6,651
SD	Dense forest stand temporarily flooded	16.51	470
Sub-total		704.48	
Total		933.35	

Sector Parsnip Arm West

Code	Forest Stand Type	Ha	Ratio m ² /km of beach
S1	Low density downed wood in forest stand temporarily flooded	112.51	2,202
S2	Moderately dense downed wood in forest stand temporarily flooded	59.19	1,158
S3	Dense downed wood in forest stand temporarily flooded	10.11	198
Sub-total		181.81	
SL	Low density forest stand temporarily flooded	289.02	5,656
SM	Moderately dense forest stand temporarily flooded	157.39	3,080
SD	Dense forest stand temporarily flooded	15.58	305
Sub-total		461.99	
Total		643.80	

Sector Peace Arm North

Code	Forest Stand Type	Ha	Ratio m ² /km of beach
S1	Low density downed wood in forest stand temporarily flooded	0.37	16
S2	Moderately dense downed wood in forest stand temporarily flooded	0.00	0
S3	Dense downed wood in forest stand temporarily flooded	0.00	0
Sub-total		0.37	
SL	Low density forest stand temporarily flooded	2.43	106
SM	Moderately dense forest stand temporarily flooded	2.60	114
SD	Dense forest stand temporarily flooded	1.82	80
Sub-total		6.85	
Total		7.22	

Sector Finlay Arm East

Code	Forest Stand Type	Ha	Ratio m ² /km of beach
S1	Low density downed wood in forest stand temporarily flooded	59.77	1,986
S2	Moderately dense downed wood in forest stand temporarily flooded	29.57	982
S3	Dense downed wood in forest stand temporarily flooded	11.44	380
Sub-total		100.78	
SL	Low density forest stand temporarily flooded	252.69	8,395
SM	Moderately dense forest stand temporarily flooded	120.34	3,998
SD	Dense forest stand temporarily flooded	28.90	960
Sub-total		401.93	
Total		502.71	

Sector Parsnip Arm East

Code	Forest Stand Type	Ha	Ratio m ² /km of beach
S1	Low density downed wood in forest stand temporarily flooded	15.68	470
S2	Moderately dense downed wood in forest stand temporarily flooded	21.20	635
S3	Dense downed wood in forest stand temporarily flooded	1.52	45
Sub-total		38.40	
SL	Low density forest stand temporarily flooded	94.57	2,831
SM	Moderately dense forest stand temporarily flooded	40.64	1,217
SD	Dense forest stand temporarily flooded	5.54	166
Sub-total		140.75	
Total		179.15	

Sector Peace Arm South

Code	Forest Stand Type	Ha	Ratio m ² /km of beach
S1	Low density downed wood in forest stand temporarily flooded	1.64	72
S2	Moderately dense downed wood in forest stand temporarily flooded	0.84	37
S3	Dense downed wood in forest stand temporarily flooded	0.00	0
Sub-total		2.48	
SL	Low density forest stand temporarily flooded	3.98	175
SM	Moderately dense forest stand temporarily flooded	2.04	90
SD	Dense forest stand temporarily flooded	0.33	15
Sub-total		6.35	
Total		8.83	

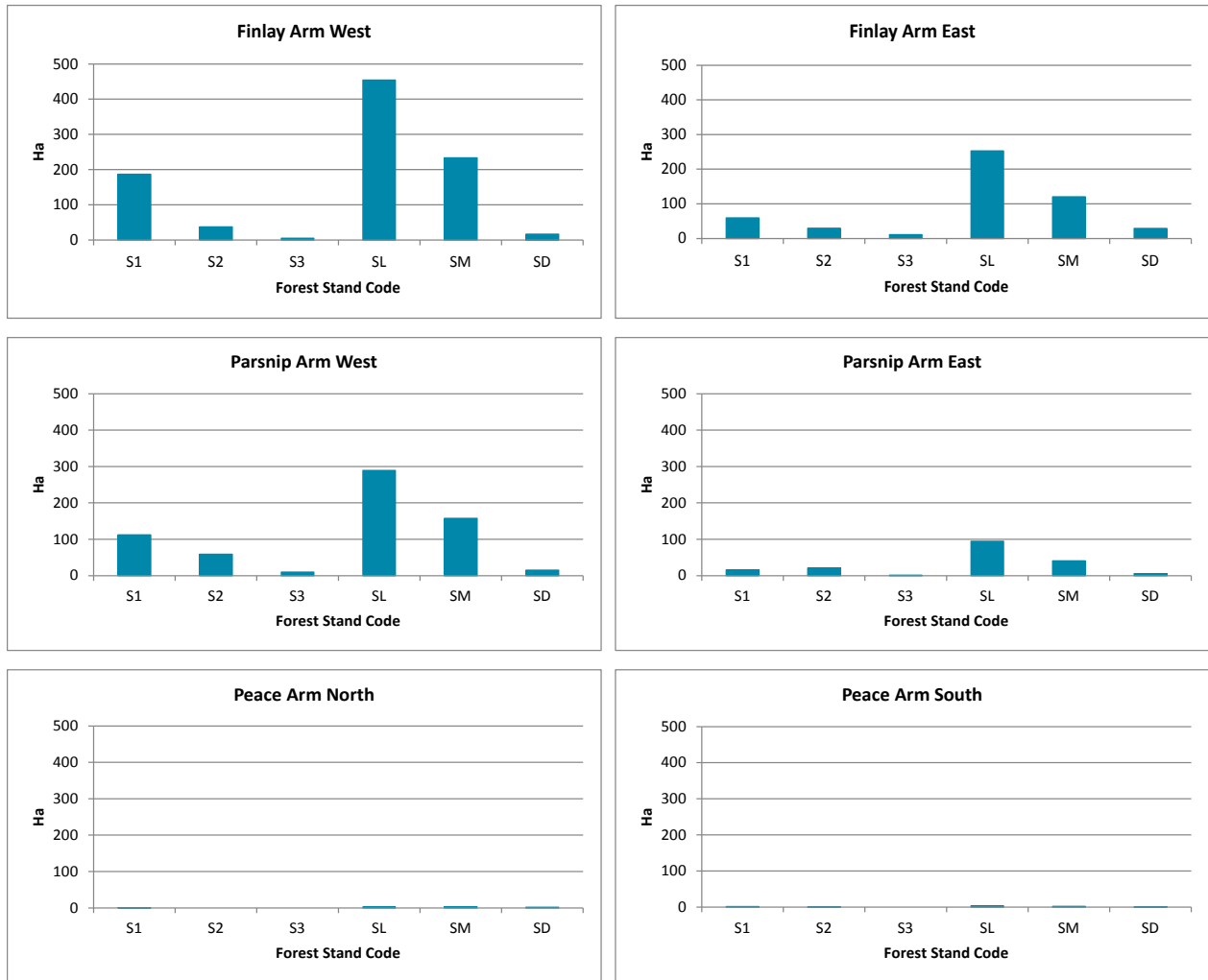


Figure 4-14 Area (ha) occupied by types of Forest Stands in the revised baseline of Williston Reservoir

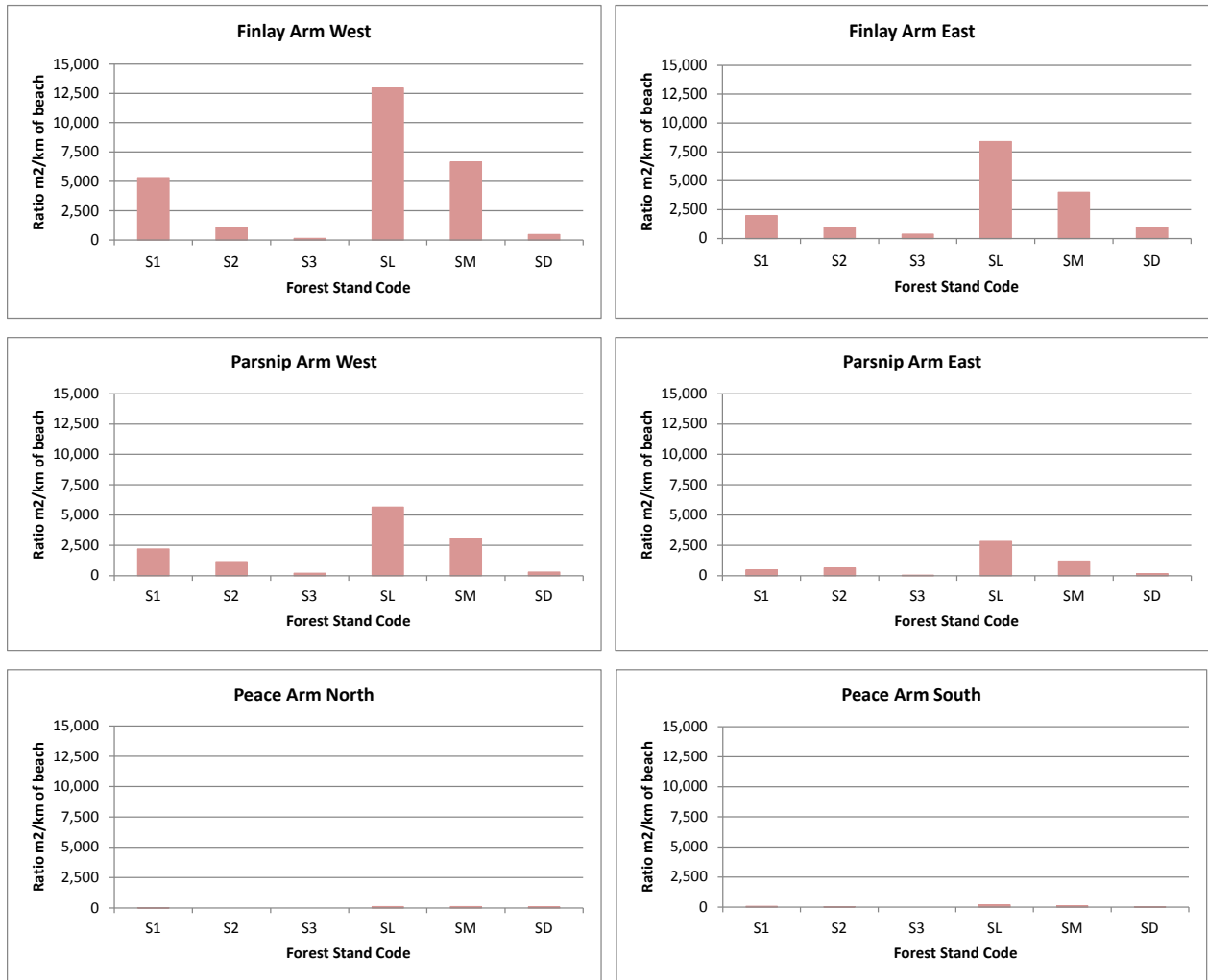


Figure 4-15 Relative extent (m²) of types of Forest Stands per unitary length of coastline (km) in the revised baseline of Williston Reservoir

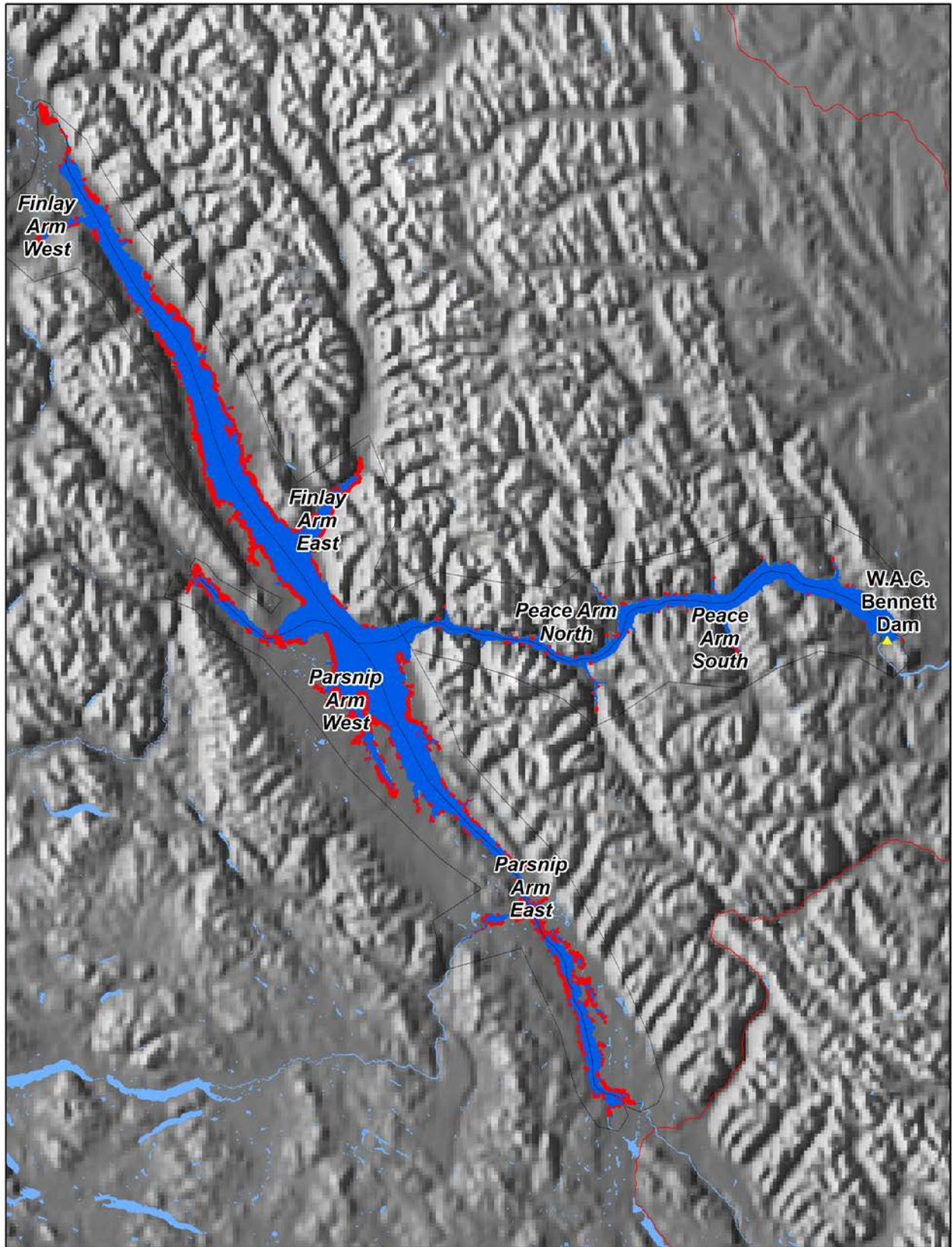


Figure 4-16 Location of Forest stands (SL, SM, SD, S1, S2 and S3) in the Williston Reservoir

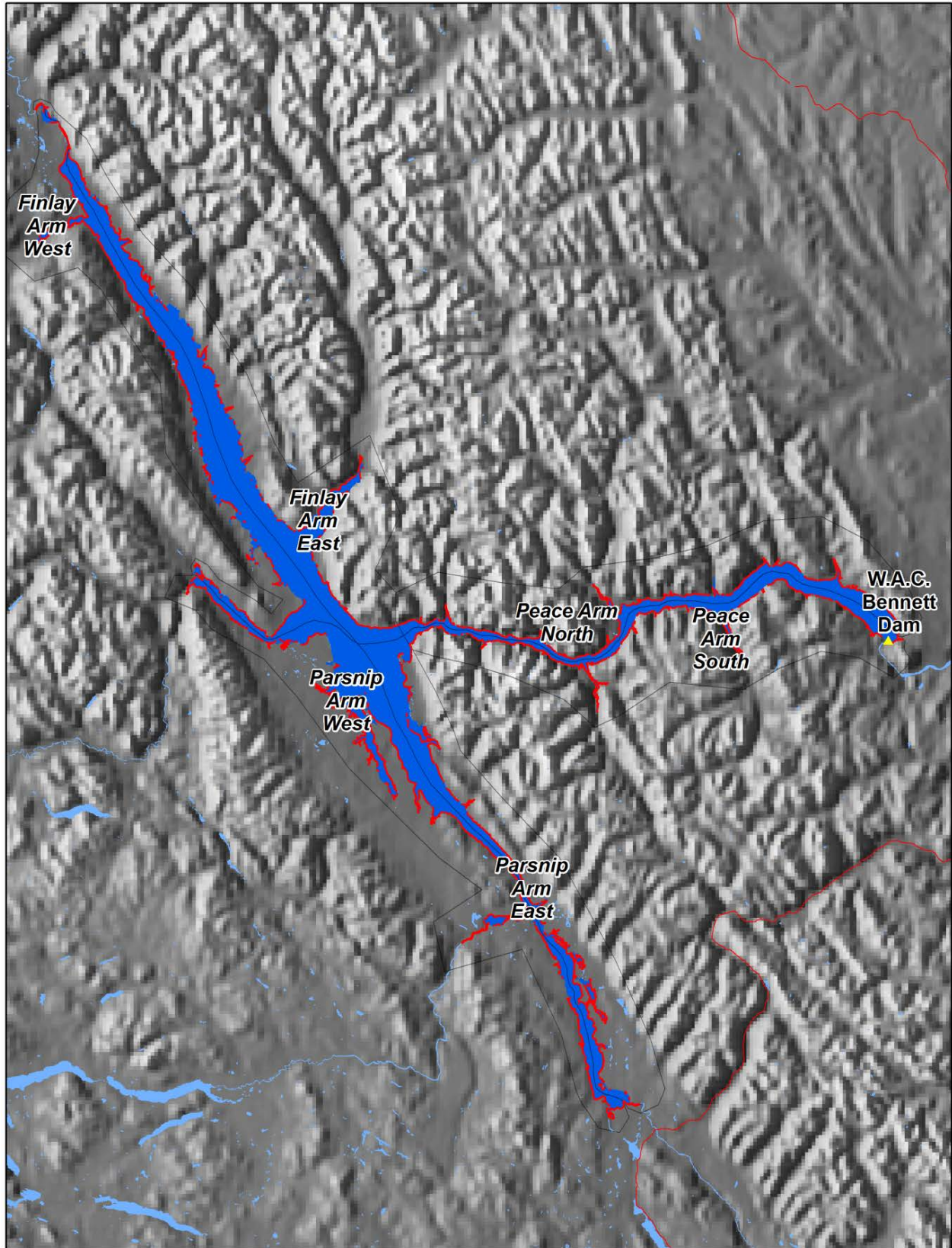


Figure 4-17 Location of Eroded shoreline in the Williston Reservoir

5. Trend Analysis of Woody Debris Areas – 2009 – 2011

As mentioned in section 2, the monitoring of changes of woody debris was performed inside 620 sampling areas of 500 m x 500 m (Figure 5-1). The overall balance indicates an increase of woody debris areas in Parsnip Arm East (15.05 ha), Parsnip Arm West (11.92 ha), Finlay Arm East (3.30 ha), Finlay Arm West (1.66 ha) and Peace Arm North (0.32 ha) (Table 5-1). Conversely, the extent of woody debris has decreased in Peace Arm South (-0.23 ha). If the scattered woody debris on flats are excluded (considering that their volume of wood per hectare is quite low), stronger tendencies are obtained for the decreasing of the area of woody debris (Table 5-2). More specifically, an overall reduction 9.91 ha is obtained for Finlay Arm East, 2.47 ha for Finlay Arm West and 0.23 ha for Peace Arm South. The level of increase is reduced at 12.22 ha for Parsnip Arm East (compared to 15.05 ha), 10.09 ha for Parsnip Arm West (compared to 11.92 ha) and 0.32 for Peace Arm North (Table 5-2). It is important to mention that the man-made wood stacks (BM) will be presented in the next table (Table 5-3, General trends of the dynamics of woody debris per sector). They are not accounted in Table 5-1 and Table 5-2 (overall balance), in order to give emphasis on the woody material that has still to be recollected).

The most important changes of woody debris areas are observed in Parsnip Arm East where beached and floating debris have increased by 12 ha (Table 5-3d and Figure 5-3d). This sector is also characterized by an increase of 3 ha in the extent of degraded forest stands. In counterparts, the extent of unaffected forest stands has decreased in a similar proportion, since the areas of degraded stands were delineated from them.

Parsnip Arm West is the second sector of importance for an increase of extent of woody debris (Table 5-3c and Figure 5-3c). The extent of beached and floating debris and the degradation of forest stands have increased respectively by 5.8 and 6.1 ha. Conversely, the extent of unaffected forest stands has decreased by 7.2 ha. The overall balance in the increase of the extent of woody debris has been greatly lowered by removal activities. In fact, 2.2 ha of beached debris were converted to man-made wood stacks (Table 5-3c). This area represents about 40 % of the total increase of beached and floating debris in the sector.

Finlay Arm East is the third sector in terms of increase of 3.5 ha, for the total area of beached and floating woody debris (Table 5-3b and Figure 5-3b). However, the overall balance corresponds to a reduction of woody debris in this sector, given that a large amount of beached debris (16.9 ha) are under removal. A similar trend is observed for Finlay Arm West where 11.3 ha of beached debris are being removed, and where only 0.5 ha of beached and floating debris have been added elsewhere (Figure 5-3a and Table 5-3a).

Peace Arm North and South contain very little wood debris compared with other sectors. For both sectors no removal activities were observed. However, the overall balance for Peace Arm South indicates a total reduction of 0.23 ha (- 1.4 %). In fact, the extent of beached and floating debris was reduced by 0.25 ha, while 0.02 ha of forest stands was degraded in this sector (Table 5-3f and Figure 5-3f). For Peace Arm North, the remaining forest stands remained stable, but 0.32 ha of beached and floating debris were added (Figure 5-3e and Table 5-3e).

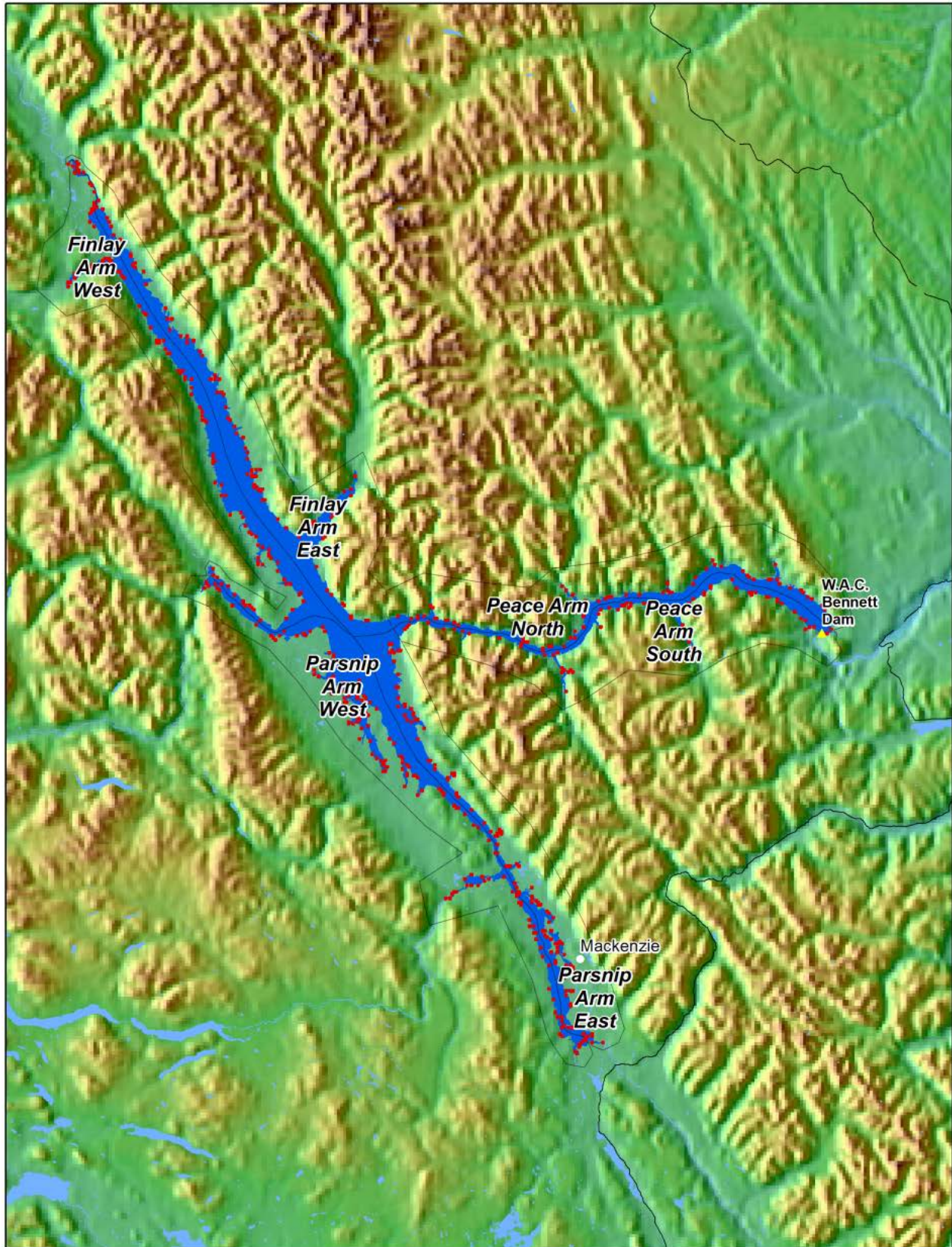


Figure 5-1 Location of the sampling areas (red dots) in the six sectors of Williston Reservoir

Table 5-1 Overall balance of woody debris trends in the Williston Reservoir, between 2009 and 2011, excluding man-made wood stacks (BM)

Wood Debris Type		Area (ha)		Change	
		2009	2011	ha	%
Sector	Finlay Arm East				
	Balance [(Beached and floating debris + degraded forest stands)]	112.10	115.40	3.30	2.9%
Sector	Finlay Arm West				
	Balance [(Beached and floating debris + degraded forest stands)]	139.41	141.07	1.66	1.2%
Sector	Parsnip Arm East				
	Balance [(Beached and floating debris + degraded forest stands)]	51.06	66.11	15.05	29.5%
Sector	Parsnip Arm West				
	Balance [(Beached and floating debris + degraded forest stands)]	127.92	139.84	11.92	9.3%
Sector	Peace Arm North				
	Balance [(Beached and floating debris + degraded forest stands)]	10.43	10.75	0.32	3.1%
Sector	Peace Arm South				
	Balance [(Beached and floating debris + degraded forest stands)]	16.32	16.09	-0.23	-1.4%

Table 5-2 Overall balance of woody debris trends in the Williston Reservoir, between 2009 and 2011, and excluding scattered woody debris on flats (BF) and man-made wood stacks (BM)

Wood Debris Type ^(a)		Area (ha)		Change	
		2009	2011	ha	%
Sector	Finlay Arm East				
	Balance [(Beached and floating debris + degraded forest stands)]	88.09	78.18	-9.91	-11.2%
Sector	Finlay Arm West				
	Balance [(Beached and floating debris + degraded forest stands)]	124.96	122.49	-2.47	-2.0%
Sector	Parsnip Arm East				
	Balance [(Beached and floating debris + degraded forest stands)]	43.98	56.20	12.22	27.8%
Sector	Parsnip Arm West				
	Balance [(Beached and floating debris + degraded forest stands)]	103.67	113.76	10.09	9.7%
Sector	Peace Arm North				
	Balance [(Beached and floating debris + degraded forest stands)]	10.31	10.63	0.32	3.1%
Sector	Peace Arm South				
	Balance [(Beached and floating debris + degraded forest stands)]	13.97	13.74	-0.23	-1.6%

(a) excluding scattered woody debris on flats

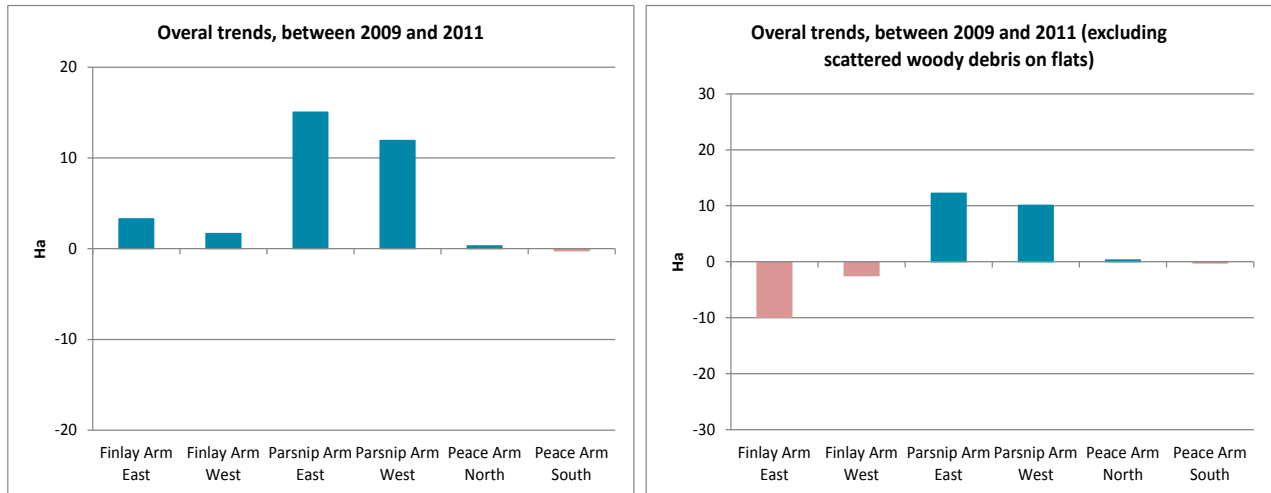


Figure 5-2 Graphs of the overall balance of woody debris trends in the Williston Reservoir, between 2009 and 2011

Table 5-3 General trends of the dynamics of woody debris per sector, between 2009 and 2011 (including the scattered woody debris on flats (BF))

a Sector Finlay Arm West

Wood Debris Type	Area (ha)		Change	
	2009	2011	ha	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	81.88	82.37	0.49	0.6%
Degraded forest stands (S1, S2 and S3)	57.53	58.70	1.17	2.0%
Forest stands without or with very few downed woods (SL, SM and SD)	127.78	125.45	-2.33	-1.8%
Man-made wood stack on beach (BM and BH)	0.22	11.47	11.25	↑
Balance [(Beached and floating debris + degraded forest stands)]	139.41	141.07	1.66	1.2%

b Sector Finlay Arm East

Wood Debris Type	Area (ha)		Change	
	2009	2011	ha	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	85.33	88.78	3.45	4.0%
Degraded forest stands (S1, S2 and S3)	26.77	26.62	-0.15	-0.6%
Forest stands without or with very few downed woods (SL, SM and SD)	93.24	87.68	-5.56	-6.0%
Man-made wood stack on beach (BM and BH)	0.00	16.84	16.84	↑
Balance [(Beached and floating debris + degraded forest stands)]	112.10	115.40	3.30	2.9%

c Sector Parsnip Arm West

Wood Debris Type	Area (ha)		Change	
	2009	2011	ha	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	81.35	87.16	5.81	7.1%
Degraded forest stands (S1, S2 and S3)	46.57	52.68	6.11	13.1%
Forest stands without or with very few downed woods (SL, SM and SD)	63.52	56.33	-7.19	-11.3%
Man-made wood stack on beach (BM and BH)	0.00	2.22	2.22	↑
Balance [(Beached and floating debris + degraded forest stands)]	127.92	139.84	11.92	9.3%

d Sector Parsnip Arm East

Wood Debris Type	Area (ha)		Change	
	2009	2011	ha	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	43.25	55.27	12.02	27.8%
Degraded forest stands (S1, S2 and S3)	7.81	10.84	3.03	38.8%
Forest stands without or with very few downed woods (SL, SM and SD)	25.90	22.82	-3.08	-11.9%
Man-made wood stack on beach (BM and BH)	0.07	0.07	0.00	0.0%
Balance [(Beached and floating debris + degraded forest stands)]	51.06	66.11	15.05	29.5%

e Sector Peace Arm North

Wood Debris Type	Area (ha)		Change	
	2009	2011	ha	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	10.37	10.69	0.32	3.1%
Degraded forest stands (S1, S2 and S3)	0.06	0.06	0.00	0.0%
Forest stands without or with very few downed woods (SL, SM and SD)	0.32	0.32	0.00	0.0%
Man-made wood stack on beach (BM and BH)	0.00	0.00	0.00	0.0%
Balance [(Beached and floating debris + degraded forest stands)]	10.43	10.75	0.32	3.1%

f Sector Peace Arm South

Wood Debris Type	Area (ha)		Change	
	2009	2011	ha	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	15.78	15.53	-0.25	-1.6%
Degraded forest stands (S1, S2 and S3)	0.54	0.56	0.02	3.7%
Forest stands without or with very few downed woods (SL, SM and SD)	1.51	1.49	-0.02	-1.3%
Man-made wood stack on beach (BM and BH)	0.00	0.00	0.00	0.0%
Balance [(Beached and floating debris + degraded forest stands)]	16.32	16.09	-0.23	-1.4%

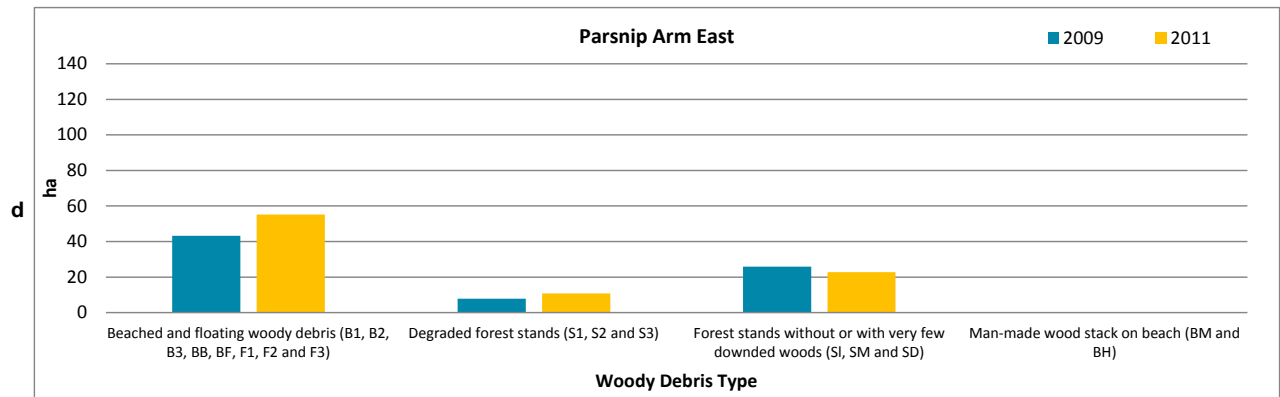
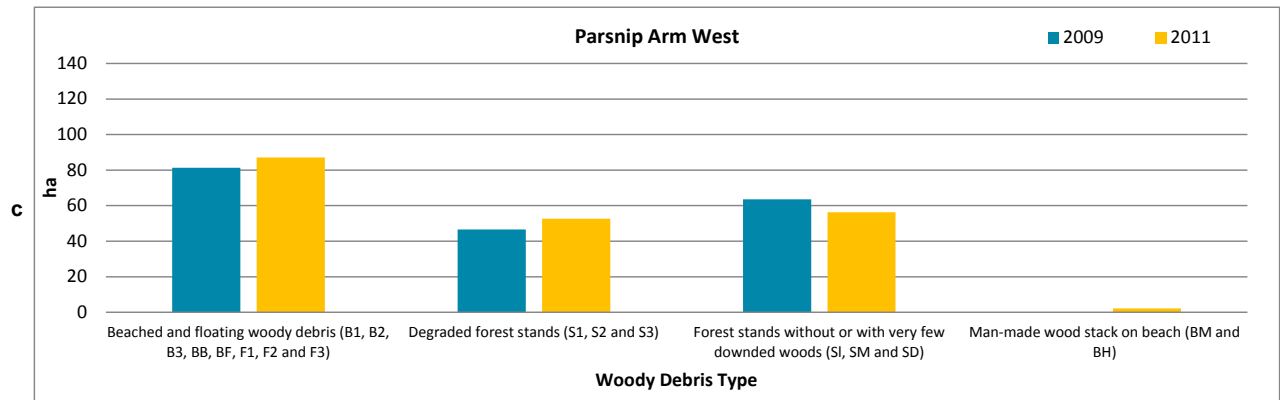
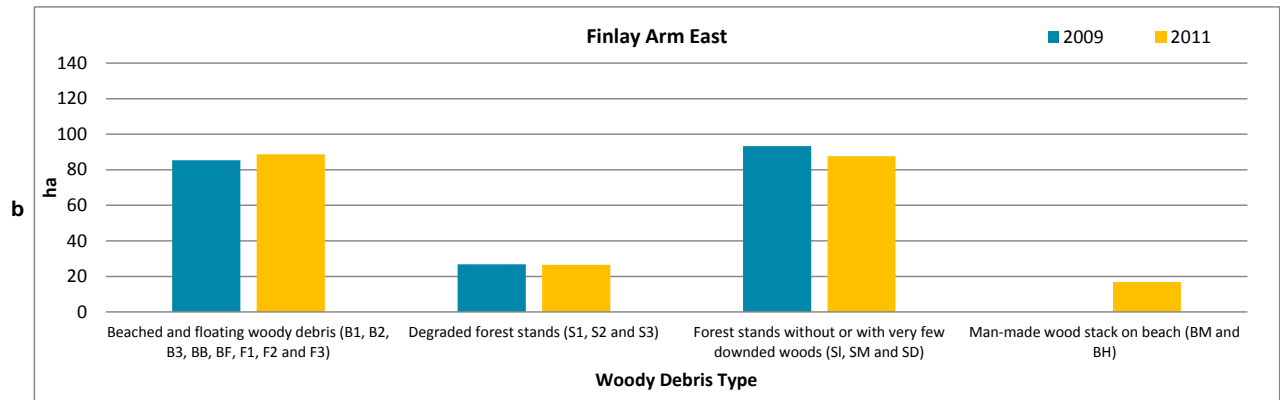
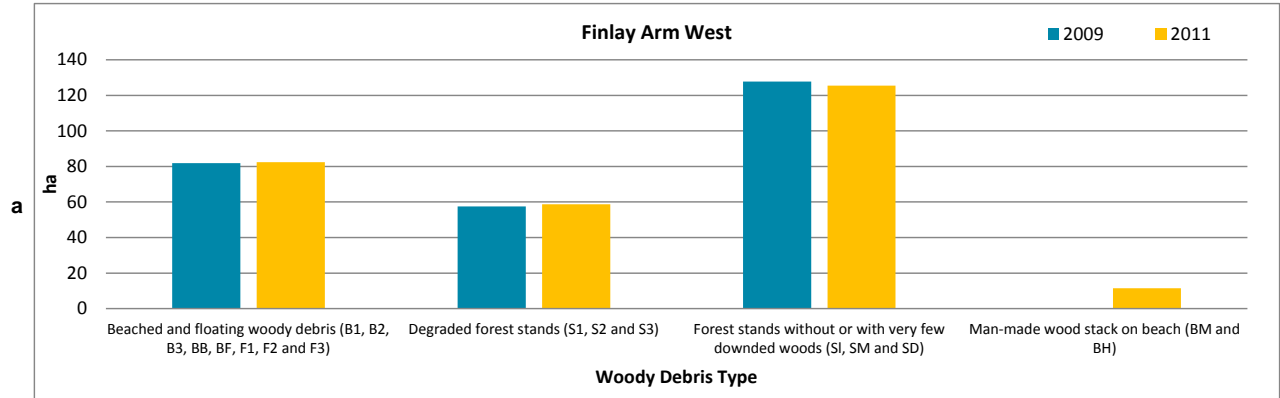




Figure 5-3 Graphs of the general trends of the dynamics of woody debris per sector, between 2009 and 2011 (including the scattered woody debris on flats (BF))

The next table and graphs give more details about the changes that occurred between 2009 and 2011 in the extent of the various types of woody debris and forest stands that were characterized in the sampling cells (Table 5-4 and Figure 5-4).

Finlay Arm West is characterized by a strong reduction of the extent of dense woody ribbons on beach. The other classes of beached debris have had minor increases, of 0.48 ha for the scattered beached debris, and 0.54 for the moderately dense ribbons (Table 5-4a and Figure 5-4a). The extent of the moderately dense stands, the low-density ones and those with scattered downed wood is reduced significantly. However, most of this reduction has been transferred to the stands with moderately dense downed woods, for an increase of 4.85 ha. Finally, wood removal activities were very intensive in the sampling zones, for a total of 11.25 ha being converted to man-made wood stacks (Figure 5-5).

Finlay Arm East shows the same tendency as its West counterpart in terms of reduction of dense woody ribbons on beach. Removal activities were quite intensive between 2009 and 2011, with a total of 16.84 ha where man-made stacks are observed (Table 5-4b and Figure 5-4b). The area classified as stands with dense downed woods was reduced by 3.17 ha, while an increase of 1.92 ha and 1.10 ha was observed respectively in the stands with a low density downed wood and with moderately dense downed wood. Finally, Finlay Arm East is characterized by a strong increase of scattered woody debris on flats.

The extent of scattered or low density beached wood debris has significantly increased in Parsnip Arm West, between 2009 and 2011 (Table 5-4c and Figure 5-4c). A similar trend is observed for the low density downed wood in forest stands occasionally flooded, and for the moderately dense woody ribbons. Specifically, the area covered by these three classes has increased by 3.77 ha, 4.87 ha and 1.85 ha. Conversely, the extent of the dense woody ribbons on beach and the low density floating wood logs has decreased respectively by 0.62 ha and 1.03 ha. The extent of the scattered woody debris on flats has increased by 1.83 ha, although the impact is less important in terms of wood volumes. Finally, the Parsnip Arm West sector has benefited from log removal activities, for a total of 2.22 ha of ribbons being treated (Figure 5-6).

Wood removal activities were not observed in the sampling cells in Parsnip Arm East. The overall balance indicates an increase of the extent of woody debris in this sector. More specifically, the extent of the moderately dense woody ribbons on beach and the scattered or low density ones have increased by 4.41 ha and 2.89 ha (Table 5-4d and Figure 5-4d). The area covered by the dense woody ribbons has also increased, but at a lower rate, for a total of 1.13 ha, between 2009 and 2011. Finally, the most significant changes are observed in the increase of the stands with a low density downed wood (2.84 ha), and of the scattered woody debris on flats (2.83 ha).

The extent of woody debris in Peace Arm North and South is quite low. In total, the North sector is characterized by a slight increase in woody debris, while it is decreasing in the South sector. The extent of the three classes of beached debris has increased in Peace Arm North by 0.05 ha, 0.08 ha and 0.19 ha for the low-density ribbons, up to the dense ribbons (Table 5-4e and Figure 5-4e). For the South sector, the extent of the low density beached woody debris and the dense beached woody debris have increased respectively by 0.09 ha and 0.40 ha. However, the area covered by the moderately dense woody ribbons has decreased by 0.19 ha (Table 5-4f and Figure 5-4f).

Table 5-4 Detailed trends of the dynamics of woody debris per sector, between 2009 and 2011

a Sector Finlay Arm West

Code	Wood Debris Type	Area (ha)		Change	
		2009	2011	ha	%
B1	Scattered or low density beached woody debris	11.84	12.32	0.48	4.1%
B2	Moderately dense woody ribbons on beach	29.40	29.94	0.54	1.8%
B3	Dense woody ribbons on beach	25.53	20.24	-5.29	-20.7%
BF	Scattered woody debris on flats	14.45	18.58	4.13	28.6%
F1	Low density floating wood logs	0.22	0.84	0.62	281.8%
F2	Moderately dense floating wood logs	0.44	0.45	0.01	2.3%
S1	Low density downed wood in forest stand temporarily flooded	53.43	49.75	-3.68	-6.9%
S2	Moderately dense downed wood in forest stand temporarily flooded	4.10	8.95	4.85	118.3%
SL	Low density forest stand temporarily flooded	75.50	74.29	-1.21	-1.6%
SM	Moderately dense forest stand temporarily flooded	50.69	49.57	-1.12	-2.2%
SD	Dense forest stand temporarily flooded	1.59	1.59	0.00	0.0%
BH	Harvested woody debris area	0.00	0.74	0.74	↑
BM	Man-made wood stack on beach	0.22	10.73	10.51	↑
BS-FS	Stumps on beach or on flats	26.98	26.32	-0.66	-2.4%

b Sector Finlay Arm East

Code	Wood Debris Type	Area (ha)		Change	
		2009	2011	ha	%
B1	Scattered or low density beached woody debris	16.75	14.62	-2.13	-12.7%
B2	Moderately dense woody ribbons on beach	16.37	16.12	-0.25	-1.5%
B3	Dense woody ribbons on beach	28.20	20.80	-7.40	-26.2%
BF	Scattered woody debris on flats	24.01	37.22	13.21	55.0%
F1	Low density floating wood logs	0.00	0.02	0.02	↑
S1	Low density downed wood in forest stand temporarily flooded	21.40	22.50	1.10	5.1%
S2	Moderately dense downed wood in forest stand temporarily flooded	2.13	4.05	1.92	90.1%
S3	Dense downed wood in forest stand temporarily flooded	3.24	0.07	-3.17	-97.8%
SL	Low density forest stand temporarily flooded	62.58	58.32	-4.26	-6.8%
SM	Moderately dense forest stand temporarily flooded	24.76	23.46	-1.30	-5.3%
SD	Dense forest stand temporarily flooded	5.90	5.90	0.00	0.0%
BM	Man-made wood stack on beach	0.00	16.84	16.84	↑
BS-FS	Stumps on beach or on flats	5.72	6.12	0.40	7.0%

c Sector Parsnip Arm West

Code	Wood Debris Type	Area (ha)		Change	
		2009	2011	ha	%
B1	Scattered or low density beached woody debris	14.09	17.86	3.77	26.8%
B2	Moderately dense woody ribbons on beach	19.10	20.95	1.85	9.7%
B3	Dense woody ribbons on beach	21.33	20.71	-0.62	-2.9%
BB	Wood bundle on beach	0.00	0.00	0.00	0.0%
BF	Scattered woody debris on flats	24.25	26.08	1.83	7.5%
F1	Low density floating wood logs	1.14	0.11	-1.03	-90.4%
F2	Moderately dense floating wood logs	0.19	0.19	0.00	0.0%
F3	Dense floating wood logs	1.25	1.26	0.01	0.8%
S1	Low density downed wood in forest stand temporarily flooded	33.28	38.15	4.87	14.6%
S2	Moderately dense downed wood in forest stand temporarily flooded	13.07	14.10	1.03	7.9%
S3	Dense downed wood in forest stand temporarily flooded	0.22	0.43	0.21	95.5%
SL	Low density forest stand temporarily flooded	32.80	25.67	-7.13	-21.7%
SM	Moderately dense forest stand temporarily flooded	26.23	26.17	-0.06	-0.2%
SD	Dense forest stand temporarily flooded	4.49	4.49	0.00	0.0%
BM	Man-made wood stack on beach	0.00	2.22	2.22	↑
BS-FS	Stumps on beach or on flats	188.55	187.87	-0.68	-0.4%

d Sector Parsnip Arm East

Code	Wood Debris Type	Area (ha)		Change	
		2009	2011	ha	%
B1	Scattered or low density beached woody debris	14.27	17.16	2.89	20.3%
B2	Moderately dense woody ribbons on beach	12.69	17.10	4.41	34.8%
B3	Dense woody ribbons on beach	8.93	10.06	1.13	12.7%
BB	Wood bundle on beach	0.00	0.00	0.00	0.0%
BF	Scattered woody debris on flats	7.08	9.91	2.83	40.0%
F1	Low density floating wood logs	0.24	0.83	0.59	245.8%
F2	Moderately dense floating wood logs	0.04	0.21	0.17	425.0%
S1	Low density downed wood in forest stand temporarily flooded	5.19	8.03	2.84	54.7%
S2	Moderately dense downed wood in forest stand temporarily flooded	2.48	1.93	-0.55	-22.2%
S3	Dense downed wood in forest stand temporarily flooded	0.14	0.88	0.74	528.6%
SL	Low density forest stand temporarily flooded	17.46	14.38	-3.08	-17.6%
SM	Moderately dense forest stand temporarily flooded	7.01	7.01	0.00	0.0%
SD	Dense forest stand temporarily flooded	1.43	1.43	0.00	0.0%
BM	Man-made wood stack on beach	0.07	0.07	0.00	0.0%
BS-FS	Stumps on beach or on flats	112.04	110.96	-1.08	-1.0%

e Sector Peace Arm North

Code	Wood Debris Type	Area (ha)		Change	
		2009	2011	ha	%
B1	Scattered or low density beached woody debris	6.57	6.62	0.05	0.8%
B2	Moderately dense woody ribbons on beach	3.54	3.62	0.08	2.3%
B3	Dense woody ribbons on beach	0.14	0.33	0.19	135.7%
BF	Scattered woody debris on flats	0.12	0.12	0.00	0.0%
S1	Low density downed wood in forest stand temporarily flooded	0.06	0.06	0.00	0.0%
SL	Low density forest stand temporarily flooded	0.05	0.05	0.00	0.0%
SM	Moderately dense forest stand temporarily flooded	0.20	0.20	0.00	0.0%
SD	Dense forest stand temporarily flooded	0.07	0.07	0.00	0.0%

BM	Man-made wood stack on beach	0.00	0.00	0.00	0.0%
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BS-FS	Stumps on beach or on flats	1.38	1.38	0.00	0.0%
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f Sector Peace Arm South

Code	Wood Debris Type	Area (ha)		Change	
		2009	2011	ha	%
B1	Scattered or low density beached woody debris	5.54	5.63	0.09	1.6%
B2	Moderately dense woody ribbons on beach	5.96	5.77	-0.19	-3.2%
B3	Dense woody ribbons on beach	1.36	1.76	0.40	29.4%
BB	Wood bundle on beach	0.00	0.02	0.02	↑
BF	Scattered woody debris on flats	2.35	2.35	0.00	0.0%
F1	Low density floating wood logs	0.57	0.00	-0.57	-100.0%
S1	Low density downed wood in forest stand temporarily flooded	0.38	0.38	0.00	0.0%
S2	Moderately dense downed wood in forest stand temporarily flooded	0.16	0.18	0.02	12.5%
SL	Low density forest stand temporarily flooded	1.20	1.18	-0.02	-1.7%
SM	Moderately dense forest stand temporarily flooded	0.31	0.31	0.00	0.0%

BM	Man-made wood stack on beach	0.00	0.00	0.00	0.0%
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BS-FS	Stumps on beach or on flats	2.39	2.39	0.00	0.0%
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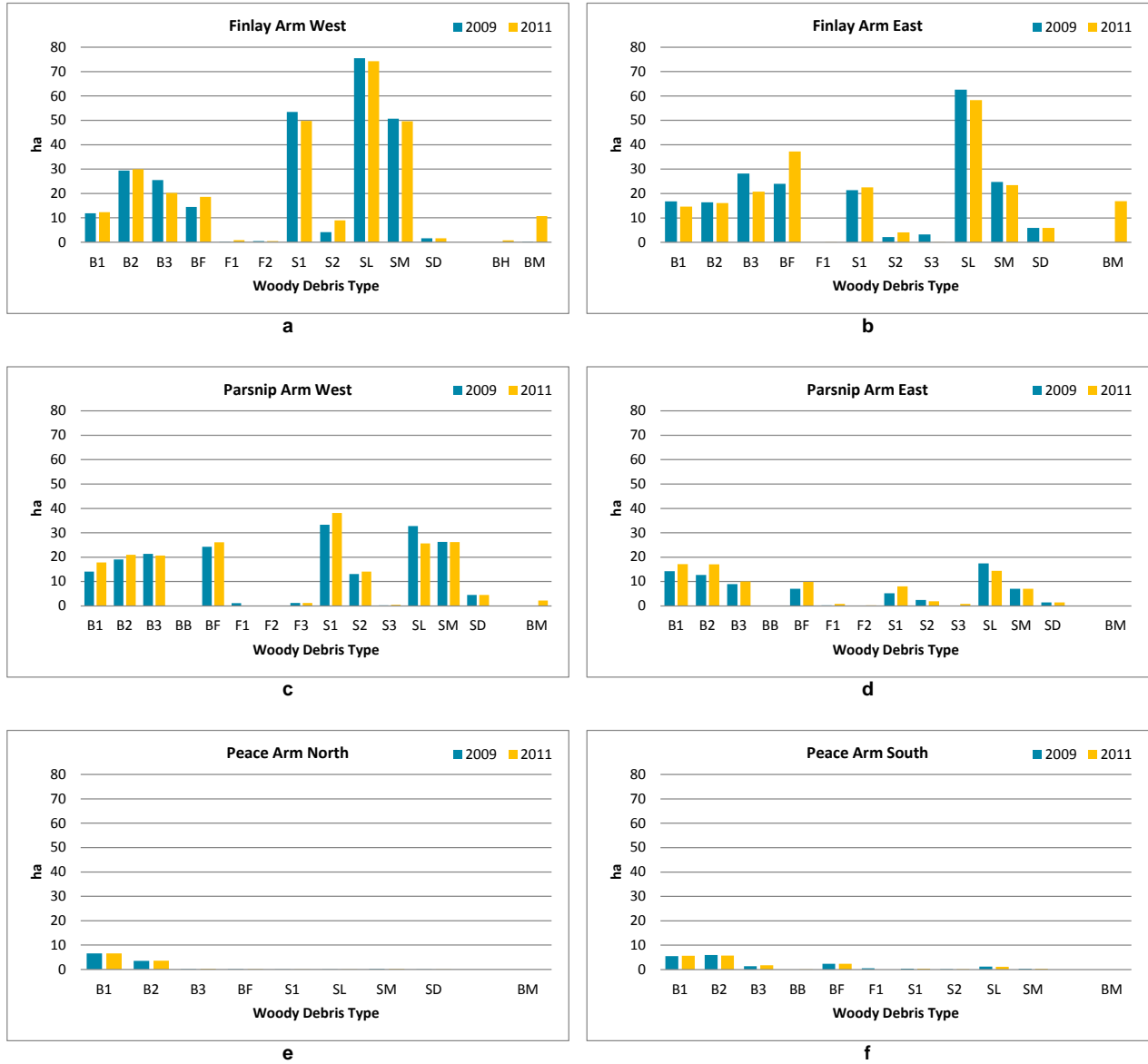


Figure 5-4 Graphs of the detailed trends of the dynamics of woody debris per sector, between 2009 and 2011

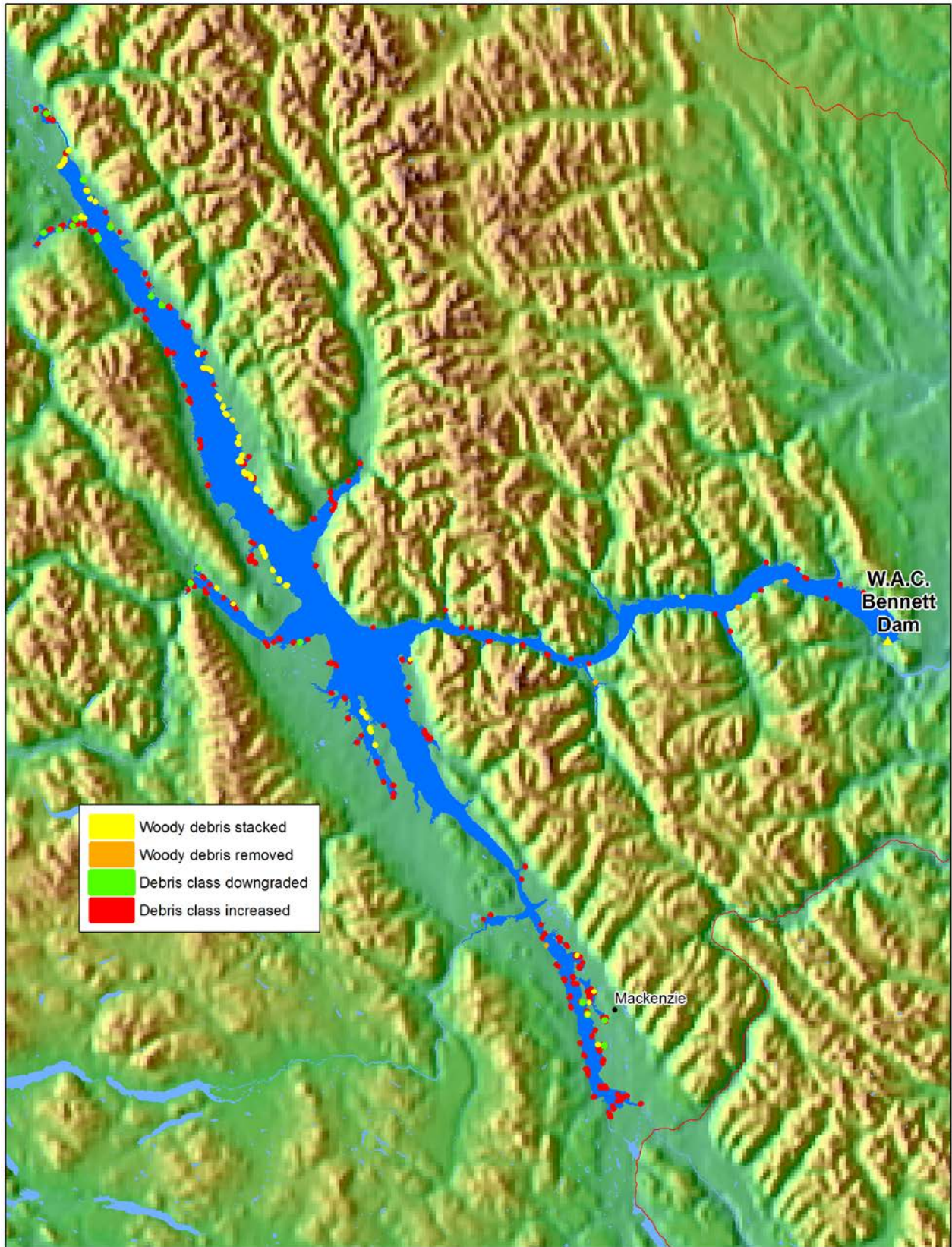


Figure 5-5 Trends in the extent of woody debris in the Williston Reservoir, between 2009 and 2011 specifically inside the 620 sampling squares (see Error! Reference source not found.)



Figure 5-6 Wood removal in the Williston Reservoir

6. Trend Analysis of Woody Debris Volumes – 2009-2011

Woody debris was inventoried in 2010 to determine the ratio of a cubic metre of debris to a square metre of surface area (m^3/m^2). The width of the sample plots was always equal to one metre-wide, while their length was equal to the debris pile width (Figure 6-1). The debris stems located were then cut with a chain saw along these boundaries. The average diameter and length of each extracted log (having a diameter greater than 10 cm) were measured and its volume was calculated by using the equation of the cylinder (see below). The thickness of the debris pile was also recorded.

$$\text{Volume (m}^3\text{)} = [\pi \times (\text{Diameter (cm)}/100)^2 \times \text{Length (m)}/4]$$

108 sampling plots were measured in the field, giving a precision of 92 % with a 90 % level of confidence. In general, the thickness of debris within the sample plots was less than 50 cm and the average diameter of logs was 18 cm (Table 6-1). On this basis, the m^3/m^2 ratio must be less than 1 m^3 per mapped squared meter, as illustrated in Figure 6-2.



Figure 6-1 Measurement of woody debris

Table 6-1 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
Diameter of log samples	10 cm	121 cm	18 cm

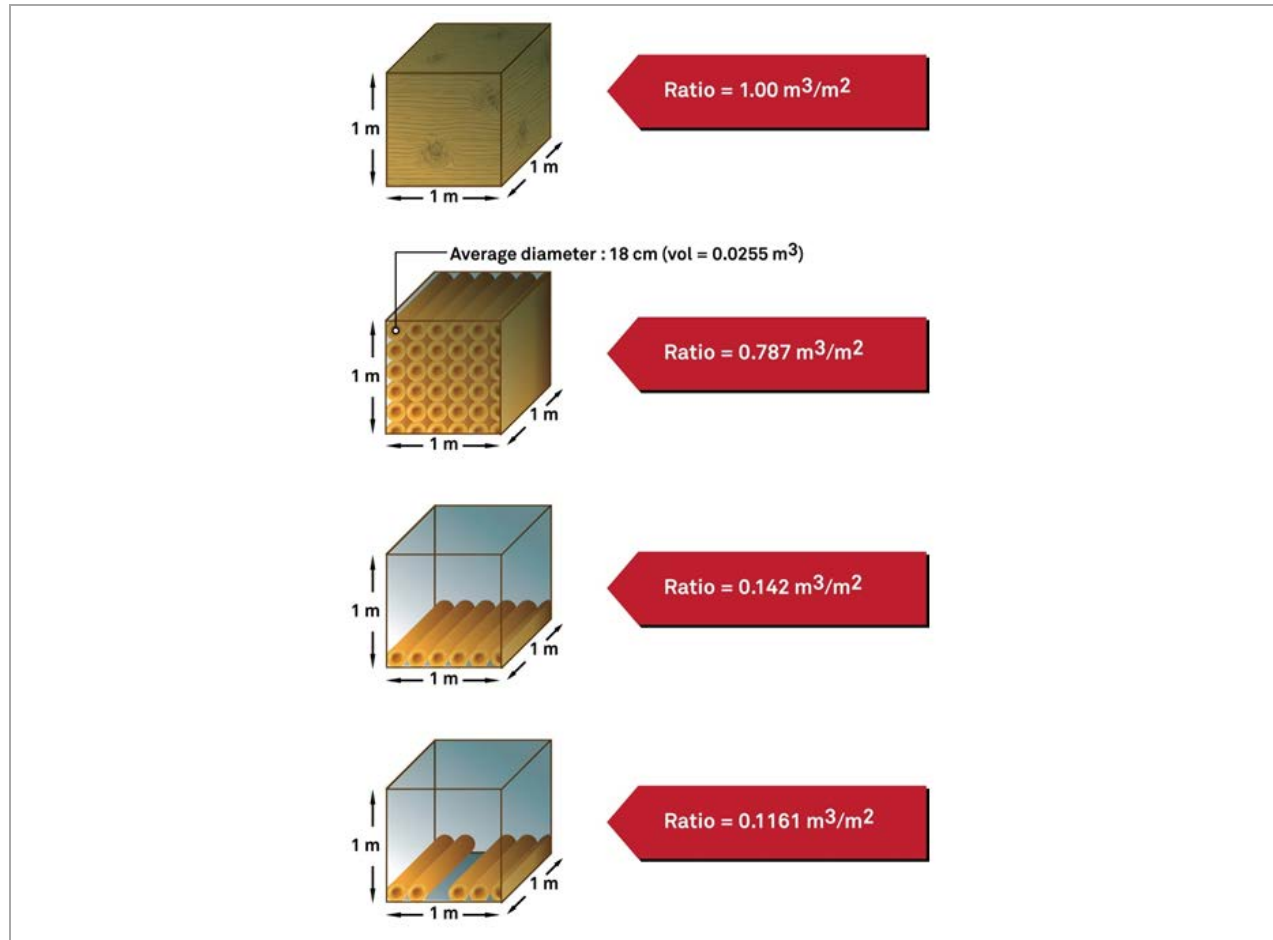


Figure 6-2 Evolution of the m^3/m^2 ratio in relation to the structure of the debris piles

The coordinates of each sample plot was recorded in the field with a GPS. These coordinates were then displayed in ArcGIS for identifying the woody debris type to which they correspond (Figure 6-3). This procedure allowed the forester to calculate the average stock per woody debris along the coastline, that is 0.03, 0.07 and $0.14 m^3/m^2$, respectively for the revised classes B1, B2 and B3 ("scattered or low density beached woody debris", "moderately dense woody ribbons on beach" and "dense woody ribbons on beach").

For the floating debris, an average ratio of around $0.11 m^3/m^2$ was used for the first version of the baseline study. Since this group consisted mainly of "dense floating wood logs" (F3), it means that its unitary amount of wood corresponds to 0.78 % its equivalent class of woody ribbons along the coastline, that is to the "dense woody ribbons on beach" (B3) (i.e. 0.11 vs. $0.14 m^3/m^2$). Given that additional classes of floating debris were distinguished in the revised baseline, this proportion was applied to the value of the B1 and B2 classes for obtaining the ratio for the new classes F1 (low density floating wood logs) and F2 (moderately dense floating wood logs).

As mentioned in the report of the baseline study, the ratio of the scattered debris on flats was determined by photo interpretation and measurements 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 these transects were enumerated. The volume of each of these logs was determined by assigning them a value of $0.0255 m^3$ in volume, which corresponds to the volume of a trunk measuring 1.0 m width with an average diameter of 18 cm, as mentioned in Table 6-1. In total, ten transects were distributed to scattered debris areas. A ratio of $0.005 m^3/m^2$ was obtained from the compilation of these measurements. It is 20 times less than the average value determined for the dense and moderately dense beached debris.

For the lost bundles (BB), a unitary volume $100 m^3/bundle$ was determined on the basis of information obtained from regional industries. For the forest stands not cleared prior to flooding, the average values of 200, 100 and $50 m^3/ha$

were used respectively for the classes SD, SM and SL ("dense forest stand temporarily flooded", "moderately dense forest stand temporarily flooded" and "low-density forest stand temporarily flooded"). Finally, for the stands affected by natural agents and where downed woods are accumulating on the ground, a factor of 0.6 was applied to the value of their similar classes B1, B2 and B3 for obtaining the unitary amount of debris for the class S1, S2 and S3 ("low density downed wood in forest stand temporarily flooded", "moderately dense downed wood in forest stand temporarily flooded" and "dense downed wood in forest stand temporarily flooded").

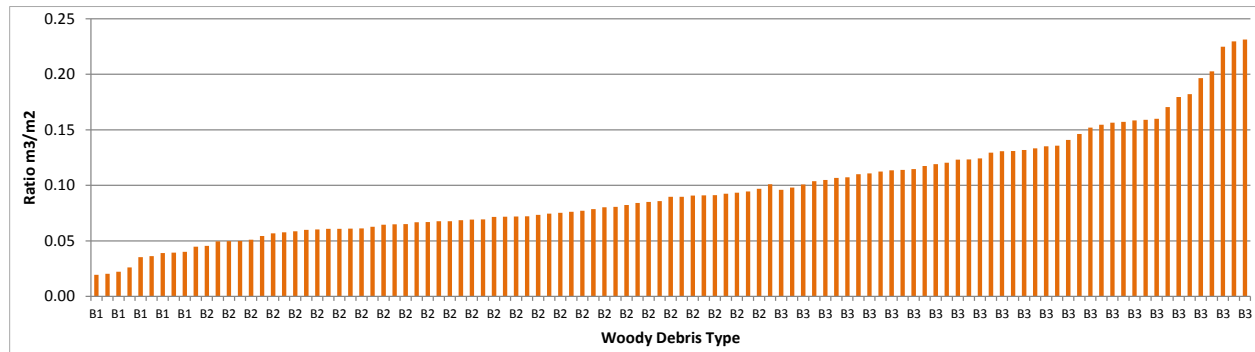


Figure 6-3 Ratio (m³/m²) obtained from the various sample plots in relation to the type of debris identified on the map

Table 6-2 Unitary value of solid wood volume (m³) per woody debris type

Code	Woody Debris Type	Unitary value
B1	Scattered or low density beached woody debris	0.032 m³/m²
B2	Moderately dense woody ribbons on beach	0.072 m³/m²
B3	Dense woody ribbons on beach	0.141 m³/m²
BB	Wood bundle on beach	100 m³/bundle
BF	Scattered woody debris on flats	0.005 m³/m²
F1	Low density floating wood logs	0.030 m³/m²
F2	Moderately dense floating wood logs	0.060 m³/m²
F3	Dense floating wood logs	0.110 m³/m²
S1	Low density downed wood in forest stand temporarily flooded	0.020 m³/m²
S2	Moderately dense downed wood in forest stand temporarily flooded	0.040 m³/m²
S3	Dense downed wood in forest stand temporarily flooded	0.080 m³/m²
SL	Low density forest stand temporarily flooded	50 m³/ha
SM	Moderately dense forest stand temporarily flooded	100 m³/ha
SD	Dense forest stand temporarily flooded	200 m³/ha
BM	Man-made wood stack on beach	<i>depends on the provenance</i>
BS-FS	Stumps on beach or on flats	0.000 m³/m²

The next tables and figures present the woody debris trends in terms of changes in wood volumes, as observed between 2009 and 2011. These values were obtained by multiplying the unitary values presented in Table 6-2 with the area of each class presented in the previous section. For the bundles, the calculation used their number, while the volumes of wood being stacked in 2011 were based on the debris type observed in 2009 for the same site.

The total amount of woody debris on the ground has been reduced in Finlay Arm East and West (Table 6-3, Table 6-4 and Figure 6-4). This reduction is related to the debris harvesting activities that are performed in these sectors. As seen in Table 6-3, the overall balance indicates a strong decrease of woody debris in Finlay Arm East (-12 159 m³) and Finlay Arm West (-5 295 m³). Conversely, woody volumes have increased in Parsnip Arm East (6 959 m³), Parsnip Arm West (2 926 m³), Peace Arm South (392 m³) and Peace Arm North (341 m³). Similar tendencies are observed if the scattered woody debris on flats is excluded. However, since the volume of wood per hectare of this

class is quite low, the change in volume is limited when the areas are compared (Table 6-4, Figure 6-4, Table 6-5, Table 6-6, Figure 6-5 and Figure 6-6). It is important to mention that these values do not include the volume of wood in the man-made stacks (BM), given they are being harvested.

The most important changes of woody volumes are observed in Finlay Arm East and West where beached and floating debris have decreased respectively by 10 611 and 6 499 m³ (Table 6-5a, Table 6-5b, Figure 6-5a and Figure 6-5b). The reduction of woody volumes in Finlay Arm East and West is mainly observed in the class B3 ("dense woody ribbons on beach"), which contains the higher density of woody debris. More specifically, this class has lost 10 409 and 7 441 m³ in these two sectors (Table 6-6 a and b, and Figure 6-6 a and b). Finlay Arm East is also characterized by a decrease of 1 548 m³ of wood volumes on ground in the degraded forest stands. Conversely, the wood volumes being stacked or harvested total 17 927 and 11 436 m³, respectively in Finlay Arm East and Finlay Arm West.

The volumes of woody debris on beach or floating have increased by 6 019 m³ in Parsnip Arm East (Table 6-5d and Figure 6-5d). They have also increased in Parsnip Arm West, but at a lower rate totalling 1 372 m³. For Peace Arm South and North, the increase of beached and floating debris totalled only 384 and 341 m³ between 2009 and 2011. Although the total amount of beached and floating wood volume in Parsnip Arm West has increased, the woody debris has decreased by 872 m³ in class B3 (Dense woody ribbons on beach).

Table 6-3 Overall balance of woody debris trends (m³) in the Williston Reservoir, between 2009 and 2011, excluding man-made wood stacks (BM)

Wood Debris Type		Volume (m ³)		Change	
		2009	2011	m ³	%
Sector	Finlay Arm East				
	Balance [(Beached and floating debris + degraded forest stands)]	65 794	53 635	-12 159	-18.5%
Sector	Finlay Arm West				
	Balance [(Beached and floating debris + degraded forest stands)]	74 285	68 990	-5 295	-7.1%
Sector	Parsnip Arm East				
	Balance [(Beached and floating debris + degraded forest stands)]	29 104	36 063	6 959	23.9%
Sector	Parsnip Arm West				
	Balance [(Beached and floating debris + degraded forest stands)]	63 714	66 640	2 926	4.6%
Sector	Peace Arm North				
	Balance [(Beached and floating debris + degraded forest stands)]	4 887	5 228	341	7.0%
Sector	Peace Arm South				
	Balance [(Beached and floating debris + degraded forest stands)]	8 424	8 816	392	4.7%

Table 6-4 Overall balance of woody debris trends (m³) in the Williston Reservoir, between 2009 and 2011, and excluding scattered woody debris on flats (BF) and man-made wood stacks (BM)

Wood Debris Type ^(a)		Volume (m ³)		Change	
		2009	2011	m ³	%
Sector	Finlay Arm East				
Balance [(Beached and floating debris + degraded forest stands)]		64 593	51 774	-12 819	-19.8%
Sector	Finlay Arm West				
Balance [(Beached and floating debris + degraded forest stands)]		73 562	68 061	-5 501	-7.5%
Sector	Parsnip Arm East				
Balance [(Beached and floating debris + degraded forest stands)]		28 750	35 567	6 817	23.7%
Sector	Parsnip Arm West				
Balance [(Beached and floating debris + degraded forest stands)]		62 501	65 336	2 835	4.5%
Sector	Peace Arm North				
Balance [(Beached and floating debris + degraded forest stands)]		4 881	5 222	341	7.0%
Sector	Peace Arm South				
Balance [(Beached and floating debris + degraded forest stands)]		8 306	8 698	392	4.7%

(a) excluding scattered woody debris on flats

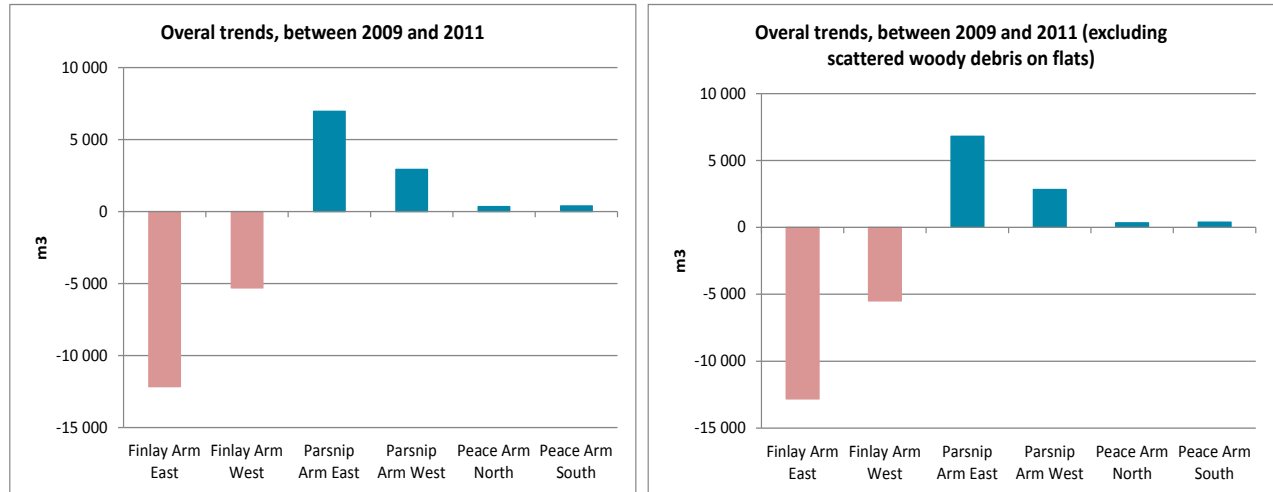


Figure 6-4 Graphs of the overall balance of woody debris trends (m³) in the Williston Reservoir, between 2009 and 2011

Table 6-5 General trends of the dynamics of woody debris (m³) per sector, between 2009 and 2011 (including the scattered woody debris on flats (BF))

a Sector Finlay Arm West

Wood Debris Type	Volume (m ³)		Change	
	2009	2011	m ³	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	61 959	55 460	-6 499	-10.5%
Degraded forest stands (S1, S2 and S3)	12 326	13 530	1 204	9.8%
Forest stands without or with very few downed woods (SL, SM and SD)	9 162	8 990	-172	-1.9%
Man-made wood stack on beach (BM and BH)	159	11 595	11 436	↑
Balance [(Beached and floating debris + degraded forest stands)]	74 285	68 990	-5 295	-7.1%

b Sector Finlay Arm East

Wood Debris Type	Volume (m ³)		Change	
	2009	2011	m ³	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	58 070	47 459	-10 611	-18.3%
Degraded forest stands (S1, S2 and S3)	7 724	6 176	-1 548	-20.0%
Forest stands without or with very few downed woods (SL, SM and SD)	6 785	6 442	-343	-5.1%
Man-made wood stack on beach (BM and BH)	0	17 927	17 927	↑
Balance [(Beached and floating debris + degraded forest stands)]	65 794	53 635	-12 159	-18.5%

c Sector Parsnip Arm West

Wood Debris Type	Volume (m ³)		Change	
	2009	2011	m ³	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	51 654	53 026	1 372	2.7%
Degraded forest stands (S1, S2 and S3)	12 060	13 614	1 554	12.9%
Forest stands without or with very few downed woods (SL, SM and SD)	5 161	4 799	-362	-7.0%
Man-made wood stack on beach (BM and BH)	0	2 232	2 232	↑
Balance [(Beached and floating debris + degraded forest stands)]	63 714	66 640	2 926	4.6%

d Sector Parsnip Arm East

Wood Debris Type	Volume (m ³)		Change	
	2009	2011	m ³	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	26 962	32 981	6 019	22.3%
Degraded forest stands (S1, S2 and S3)	2 142	3 082	940	43.9%
Forest stands without or with very few downed woods (SL, SM and SD)	1 860	1 706	-154	-8.3%
Man-made wood stack on beach (BM and BH)	50	150	100	200.0%
Balance [(Beached and floating debris + degraded forest stands)]	29 104	36 063	6 959	23.9%

e Sector Peace Arm North

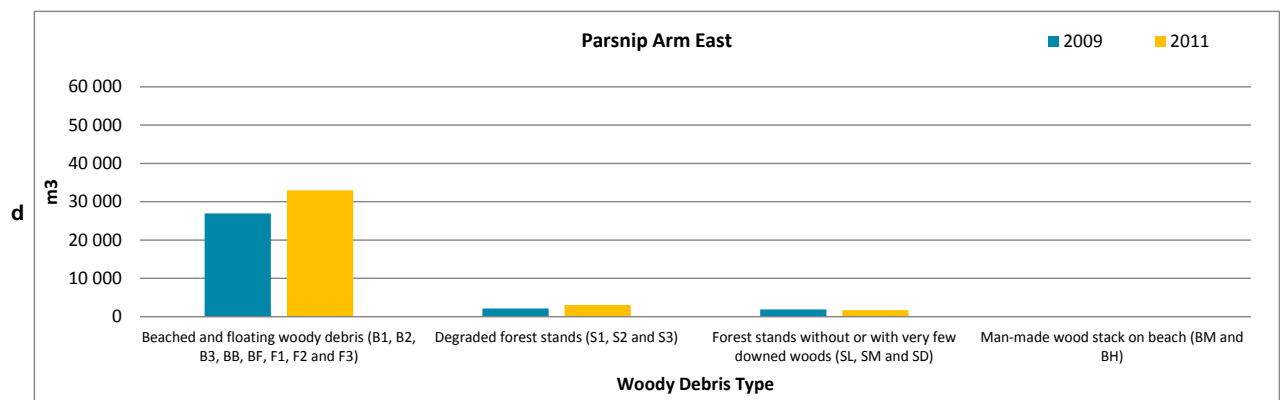
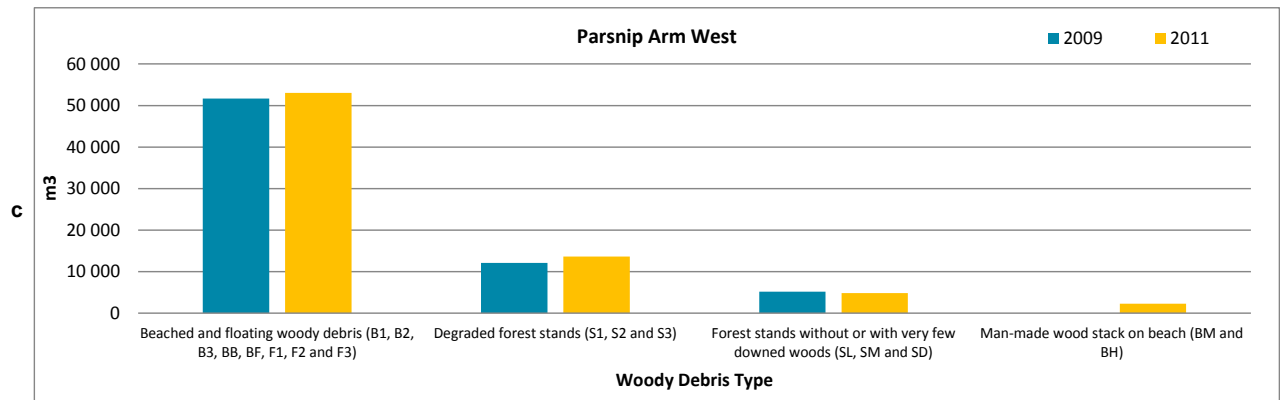
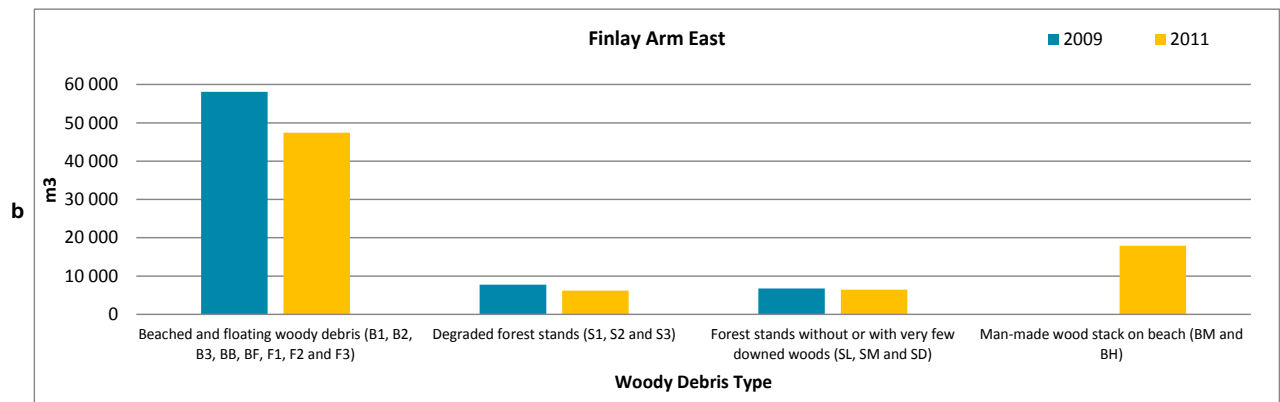
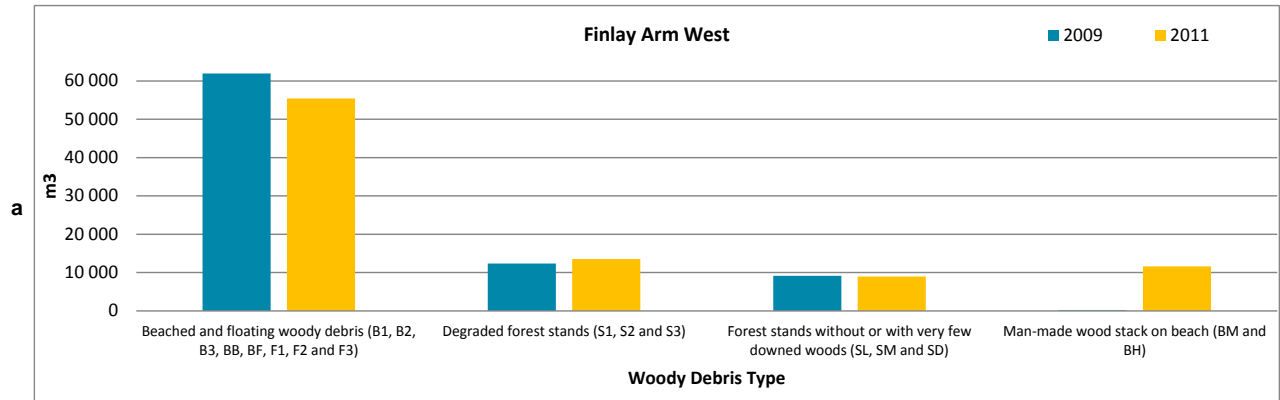
Wood Debris Type	Volume (m ³)		Change	
	2009	2011	m ³	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	4 875	5 216	341	7.0%
Degraded forest stands (S1, S2 and S3)	12	12	0	0.0%
Forest stands without or with very few downed woods (SL, SM and SD)	37	37	0	0.0%
Man-made wood stack on beach (BM and BH)	0	0	0	0.0%

Balance [(Beached and floating debris + degraded forest stands)] **4 887** **5 228** **341** **7.0%**

f Sector Peace Arm South

Wood Debris Type	Volume (m ³)		Change	
	2009	2011	m ³	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	8 284	8 668	384	4.6%
Degraded forest stands (S1, S2 and S3)	140	148	8	5.7%
Forest stands without or with very few downed woods (SL, SM and SD)	91	90	-1	-1.1%
Man-made wood stack on beach (BM and BH)	0	0	0	0.0%

Balance [(Beached and floating debris + degraded forest stands)] **8 424** **8 816** **392** **4.7%**



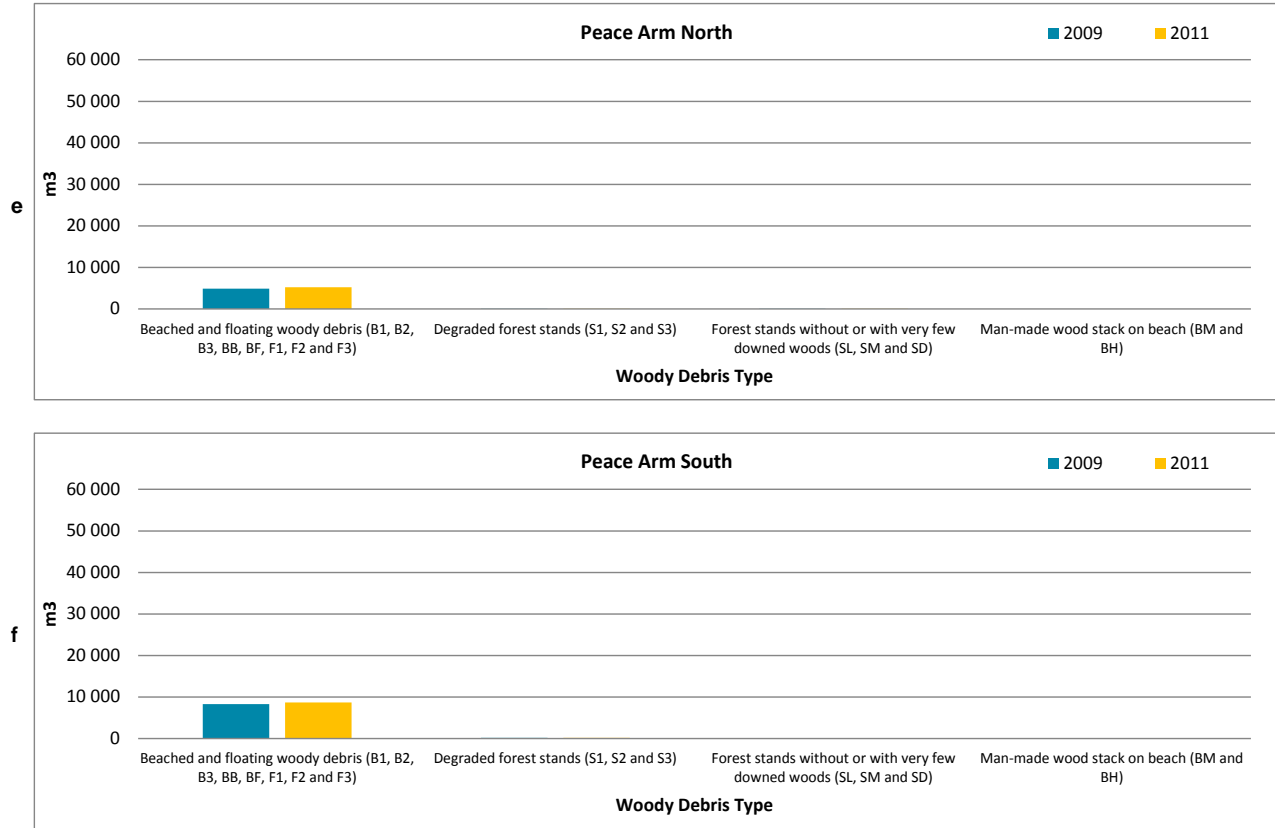


Figure 6-5 Graphs of the general trends of the dynamics of woody debris (m³) per sector, between 2009 and 2011 (including the scattered woody debris on flats (BF))

Table 6-6 Detailed trends of the dynamics of woody debris (m³) per sector, between 2009 and 2011

a Sector		Finlay Arm West			
Code	Wood Debris Type	Volume (m ³)		Change	
		2009	2011	m ³	%
B1	Scattered or low density beached woody debris	3 828	3 983	155	4.0%
B2	Moderately dense woody ribbons on beach	21 165	21 554	389	1.8%
B3	Dense woody ribbons on beach	35 913	28 472	-7 441	-20.7%
BF	Scattered woody debris on flats	723	929	206	28.5%
F1	Low density floating wood logs	66	252	186	281.8%
F2	Moderately dense floating wood logs	264	270	6	2.3%
S1	Low density downed wood in forest stand temporarily flooded	10 686	9 950	-736	-6.9%
S2	Moderately dense downed wood in forest stand temporarily flooded	1 640	3 580	1 940	118.3%
SL	Low density forest stand temporarily flooded	3 775	3 715	-60	-1.6%
SM	Moderately dense forest stand temporarily flooded	5 069	4 957	-112	-2.2%
SD	Dense forest stand temporarily flooded	318	318	0	0.0%
BH	Harvested woody debris area	0	130	130	↑
BM	Man-made wood stack on beach	159	11 465	11 306	↑
BS-FS	Stumps on beach or on flats	0	0	0	0.0%

b Sector Finlay Arm East

Code	Wood Debris Type	Volume (m ³)		Change	
		2009	2011	m ³	%
B1	Scattered or low density beached woody debris	5 415	4 727	-688	-12.7%
B2	Moderately dense woody ribbons on beach	11 785	11 605	-180	-1.5%
B3	Dense woody ribbons on beach	39 669	29 260	-10 409	-26.2%
BF	Scattered woody debris on flats	1 201	1 861	660	55.0%
F1	Low density floating wood logs	0	6	6	↑
S1	Low density downed wood in forest stand temporarily flooded	4 280	4 500	220	5.1%
S2	Moderately dense downed wood in forest stand temporarily flooded	852	1 620	768	90.1%
S3	Dense downed wood in forest stand temporarily flooded	2 592	56	-2 536	-97.8%
SL	Low density forest stand temporarily flooded	3 129	2 916	-213	-6.8%
SM	Moderately dense forest stand temporarily flooded	2 476	2 346	-130	-5.3%
SD	Dense forest stand temporarily flooded	1 180	1 180	0	0.0%
BM	Man-made wood stack on beach	0	17 927	17 927	↑
BS-FS	Stumps on beach or on flats	0	0	0	0.0%

c Sector Parsnip Arm West

Code	Wood Debris Type	Volume (m ³)		Change	
		2009	2011	m ³	%
B1	Scattered or low density beached woody debris	4 555	5 774	1 219	26.8%
B2	Moderately dense woody ribbons on beach	13 750	15 082	1 332	9.7%
B3	Dense woody ribbons on beach	30 005	29 133	-872	-2.9%
BB	Wood bundle on beach	300	200	-100	-33.3%
BF	Scattered woody debris on flats	1 213	1 304	91	7.5%
F1	Low density floating wood logs	342	33	-309	-90.4%
F2	Moderately dense floating wood logs	114	114	0	0.0%
F3	Dense floating wood logs	1 375	1 386	11	0.8%
S1	Low density downed wood in forest stand temporarily flooded	6 656	7 630	974	14.6%
S2	Moderately dense downed wood in forest stand temporarily flooded	5 228	5 640	412	7.9%
S3	Dense downed wood in forest stand temporarily flooded	176	344	168	95.5%
SL	Low density forest stand temporarily flooded	1 640	1 284	-356	-21.7%
SM	Moderately dense forest stand temporarily flooded	2 623	2 617	-6	-0.2%
SD	Dense forest stand temporarily flooded	898	898	0	0.0%
BM	Man-made wood stack on beach	0	2 232	2 232	↑
BS-FS	Stumps on beach or on flats	0	0	0	0.0%

d Sector Parsnip Arm East

Code	Wood Debris Type	Volume (m ³)		Change	
		2009	2011	m ³	%
B1	Scattered or low density beached woody debris	4 614	5 548	934	20.2%
B2	Moderately dense woody ribbons on beach	9 136	12 310	3 174	34.7%
B3	Dense woody ribbons on beach	12 562	14 152	1 590	12.7%
BB	Wood bundle on beach	200	100	-100	-50.0%
BF	Scattered woody debris on flats	354	496	142	40.1%
F1	Low density floating wood logs	72	249	177	245.8%
F2	Moderately dense floating wood logs	24	126	102	425.0%
S1	Low density downed wood in forest stand temporarily flooded	1 038	1 606	568	54.7%
S2	Moderately dense downed wood in forest stand temporarily flooded	992	772	-220	-22.2%
S3	Dense downed wood in forest stand temporarily flooded	112	704	592	528.6%
SL	Low density forest stand temporarily flooded	873	719	-154	-17.6%
SM	Moderately dense forest stand temporarily flooded	701	701	0	0.0%
SD	Dense forest stand temporarily flooded	286	286	0	0.0%
BM	Man-made wood stack on beach	50	150	100	200.0%
BS-FS	Stumps on beach or on flats	0	0	0	0.0%

e Sector Peace Arm North

Code	Wood Debris Type	Volume (m ³)		Change	
		2009	2011	m ³	%
B1	Scattered or low density beached woody debris	2 124	2 140	16	0.8%
B2	Moderately dense woody ribbons on beach	2 548	2 606	58	2.3%
B3	Dense woody ribbons on beach	197	464	267	135.5%
BF	Scattered woody debris on flats	6	6	0	0.0%
S1	Low density downed wood in forest stand temporarily flooded	12	12	0	0.0%
SL	Low density forest stand temporarily flooded	3	3	0	0.0%
SM	Moderately dense forest stand temporarily flooded	20	20	0	0.0%
SD	Dense forest stand temporarily flooded	14	14	0	0.0%
BM	Man-made wood stack on beach	0	0	0	0.0%
BS-FS	Stumps on beach or on flats	0	0	0	0.0%

f Sector Peace Arm South

Code	Wood Debris Type	Volume (m ³)		Change	
		2009	2011	m ³	%
B1	Scattered or low density beached woody debris	1 791	1 820	29	1.6%
B2	Moderately dense woody ribbons on beach	4 291	4 154	-137	-3.2%
B3	Dense woody ribbons on beach	1 913	2 476	563	29.4%
BB	Wood bundle on beach	0	100	100	↑
BF	Scattered woody debris on flats	118	118	0	0.0%
F1	Low density floating wood logs	171	0	-171	-100.0%
S1	Low density downed wood in forest stand temporarily flooded	76	76	0	0.0%
S2	Moderately dense downed wood in forest stand temporarily flooded	64	72	8	12.5%
SL	Low density forest stand temporarily flooded	60	59	-1	-1.7%
SM	Moderately dense forest stand temporarily flooded	31	31	0	0.0%
BM	Man-made wood stack on beach	0	0	0	0.0%
BS-FS	Stumps on beach or on flats	0	0	0	0.0%

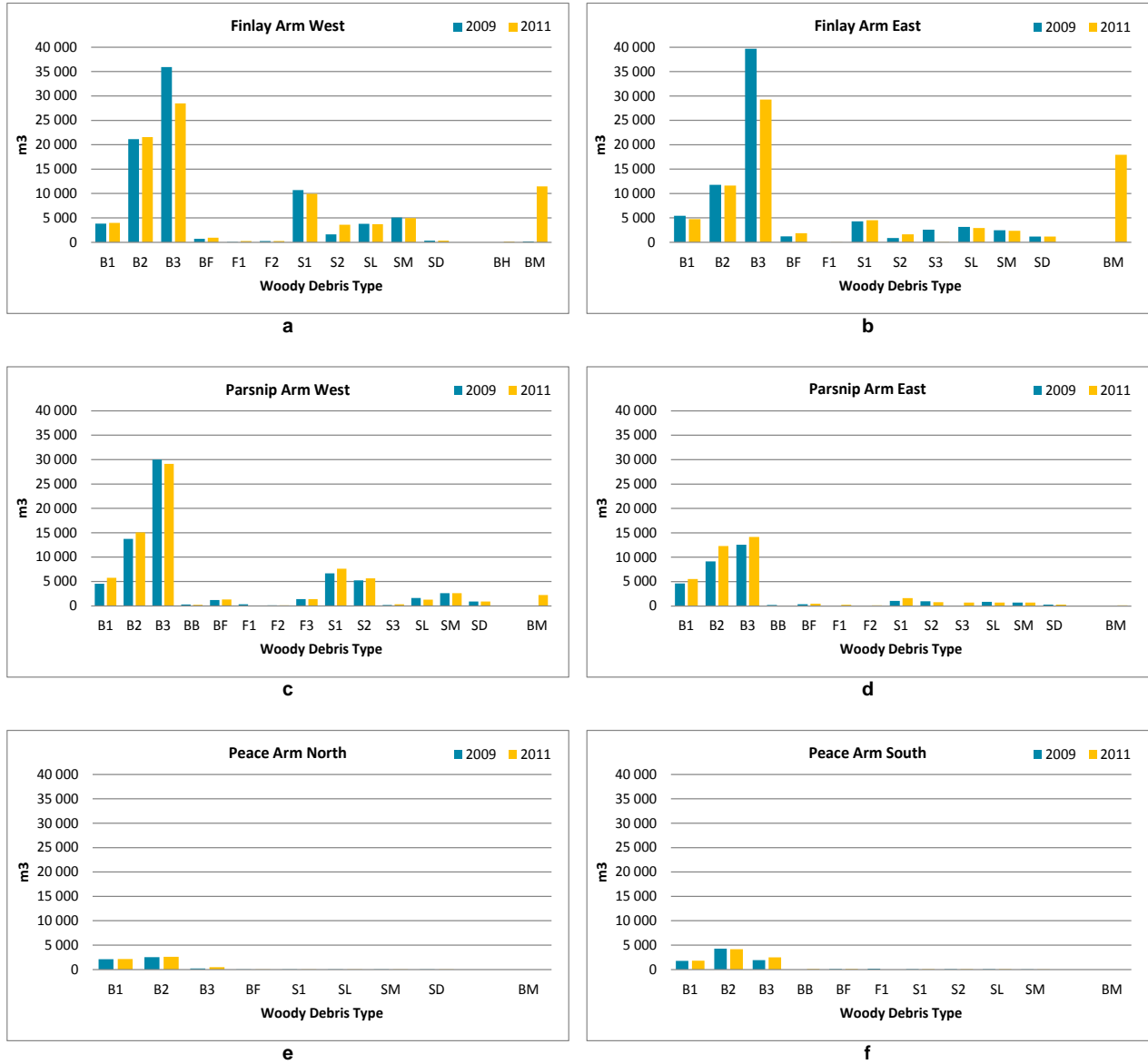


Figure 6-6 Graphs of the detailed trends of the dynamics of woody debris (m³) per sector, between 2009 and 2011

7. Trend Analysis of Woody Debris Areas and Volumes – 2009-2011, for the sites targeted by BC Hydro

Within the monitoring framework, BC Hydro has identified 41 sampling areas where trends should be analyzed specifically. These sampling areas are located in Finlay Arm West (21 cells of 500 × 500 m), Parsnip Arm West (2 cells) and Parsnip Arm East (18 cells), as presented in Figure 7-1.

The trends observed in the targeted areas in Finlay Arm West are similar to the dynamics described in the previous chapters. More specifically, wood debris are strongly decreasing, given intensive harvesting activities were under development. In this sector, the main reduction is observed in the class B3 ("Dense woody ribbons on beach"). In terms of area, 3.88 ha were harvested, which corresponds to a reduction of 5 458 m³ of wood debris (Table 7-1a and Figure 7-2a). Although these targeted areas represent 18 % of the sampling network in Finlay Arm West, they contain 73 % of the reduction of wood debris accounted for the class B3. The second main trend is observed in the class B2 ("Moderately dense woody ribbons on beach"), with a reduction of 3.8 ha, or 971.9 m³. The other classes remained quite stable in terms of area and wood volumes, as it can be observed in Table 7-2a and Figure 7-3a. The importance of the debris removal activities is clearly illustrated by the last column in Figure 7-2a and Figure 7-3a.

The targeted areas represent respectively 1 % and 17 % of the sampling network in Parsnip Arm West and Parsnip Arm East. For Parsnip Arm West, 2 sampling areas have been targeted within the 152 monitoring cells. This subsample represents only 1 % of the whole dataset. Therefore, the results from the data compilation should be considered strictly as a summary of these specific areas, and they cannot be statistically extrapolated with confidence to larger sectors.

The total amounts of wood debris have slightly increased in Parsnip Arm West and Parsnip Arm East, as it was observed for the whole sampling data. The main differences are observed in the absence of man-made stacks, and in the proportion of changes between the various classes of woody ribbons. For Parsnip Arm West, the quantities of the low density and the moderately dense beached wood debris (classes B1 and B2) have increased more intensively, that is respectively by 66 % and 19 %, while they were at 27 % and 10 % for the whole sampling cells (Table 7-1b, Figure 7-2c and Figure 7-2b). The extent of the dense woody ribbons on beach (B3) was stable in the sub-sample, while a decrease of 3 % was observed for the whole dataset. For Parsnip Arm East, the volume of wood debris has decreased by 6 % for the classes B1, while an increase of 27 % was observed for the whole sampling cells (Table 7-1c, Figure 7-2d and Figure 7-2c). The ratio of increase between the classes B2 and B3 is more uniform in the subsamples, without affecting the overall trend that indicates an accumulation of additional wood debris in these classes. The increase of wood debris reaches respectively 21 % and 24 % for the classes B2 and B3, while they were at 35 % and 13 % for the whole sampling cells.

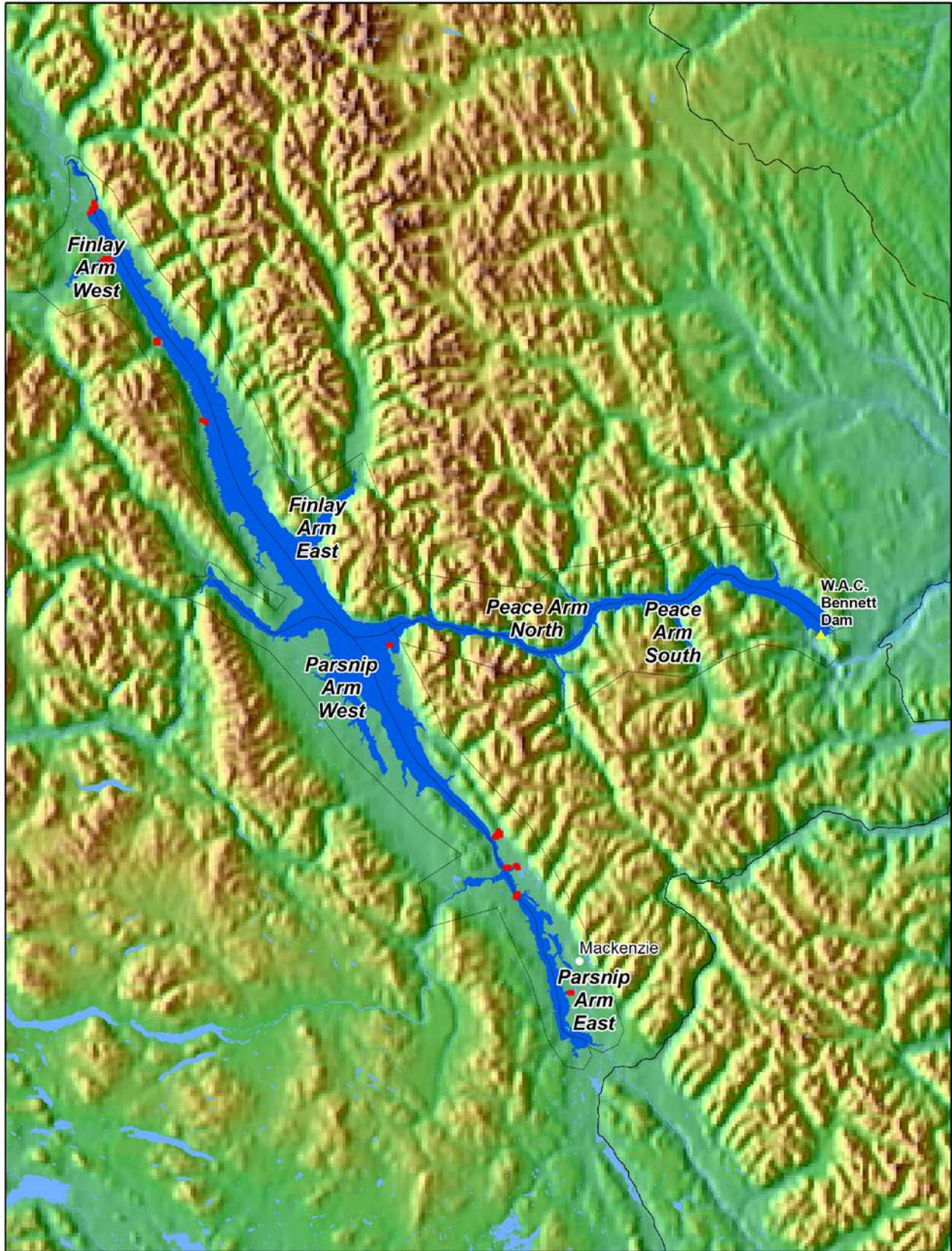


Figure 7-1 Location of the sampling areas (red dots) targeted by BC Hydro

Table 7-1 Detailed trends of the dynamics of woody debris (ha and m³) per sector, between 2009 and 2011, for the sampling areas targeted by BC Hydro

a Sector: Finlay Arm West					Sector: Finlay Arm West						
Code	Wood Debris Type	Area (ha)		Change		Code	Wood Debris Type	Volume (m ³)		Change	
		2009	2011	ha	%			2009	2011	m ³	%
B1	Scattered or low density beached woody debris	1.17	0.66	-0.51	-43.6%	B1	Scattered or low density beached woody debris	378.3	213.4	-164.9	-43.6%
B2	Moderately dense woody ribbons on beach	4.84	3.49	-1.35	-27.9%	B2	Moderately dense woody ribbons on beach	3 484.4	2 512.5	-971.9	-27.9%
B3	Dense woody ribbons on beach	7.42	3.54	-3.88	-52.3%	B3	Dense woody ribbons on beach	10 437.8	4 979.8	-5 458.0	-52.3%
BF	Scattered woody debris on flats	0.88	1.21	0.33	37.5%	BF	Scattered woody debris on flats	44.0	60.5	16.5	37.5%
F1	Low density floating wood logs	0.00	0.00	0.00	0.0%	F1	Low density floating wood logs	0.0	0.0	0.0	0.0%
F2	Moderately dense floating wood logs	0.31	0.31	0.00	0.0%	F2	Moderately dense floating wood logs	186.0	186.0	0.0	0.0%
S1	Low density downed wood in forest stand temporarily flooded	1.16	1.05	-0.11	-9.5%	S1	Low density downed wood in forest stand temporarily flooded	232.0	210.0	-22.0	-9.5%
S2	Moderately dense downed wood in forest stand temporarily flooded	0.11	0.23	0.12	109.1%	S2	Moderately dense downed wood in forest stand temporarily flooded	44.0	92.0	48.0	109.1%
SL	Low density forest stand temporarily flooded	1.00	0.83	-0.17	-17.0%	SL	Low density forest stand temporarily flooded	50.0	41.5	-8.5	-17.0%
SM	Moderately dense forest stand temporarily flooded	1.37	1.37	0.00	0.0%	SM	Moderately dense forest stand temporarily flooded	137.0	137.0	0.0	0.0%
SD	Dense forest stand temporarily flooded	0.02	0.02	0.00	0.0%	SD	Dense forest stand temporarily flooded	4.0	4.0	0.0	0.0%
BH	Harvested woody debris area	0.00	0.74	0.74	↑	BH	Harvested woody debris area	0.0	574.0	574.0	↑
BM	Man-made wood stack on beach	0.00	6.41	6.41	↑	BM	Man-made wood stack on beach	0.0	6 612.0	6 612.0	↑
BS-FS	Stumps on beach or on flats	6.72	6.23	-0.49	-7.3%	BS-FS	Stumps on beach or on flats	0.0	0.0	0.0	0.0%

b Sector: Parsnip Arm West					Sector: Parsnip Arm West						
Code	Wood Debris Type	Area (ha)		Change		Code	Wood Debris Type	Volume (m ³)		Change	
		2009	2011	ha	%			2009	2011	m ³	%
B1	Scattered or low density beached woody debris	0.32	0.53	0.21	65.6%	B1	Scattered or low density beached woody debris	103.5	171.4	67.9	65.6%
B2	Moderately dense woody ribbons on beach	0.26	0.31	0.05	19.2%	B2	Moderately dense woody ribbons on beach	187.2	223.2	36.0	19.2%
B3	Dense woody ribbons on beach	0.09	0.09	0.00	0.0%	B3	Dense woody ribbons on beach	126.6	126.6	0.0	0.0%
BB	Wood bundle on beach	0.00	0.00	0.00	0.0%	BB	Wood bundle on beach	0.0	0.0	0.0	0.0%
BF	Scattered woody debris on flats	0.00	0.00	0.00	0.0%	BF	Scattered woody debris on flats	0.0	0.0	0.0	0.0%
F1	Low density floating wood logs	0.00	0.00	0.00	0.0%	F1	Low density floating wood logs	0.0	0.0	0.0	0.0%
F2	Moderately dense floating wood logs	0.00	0.00	0.00	0.0%	F2	Moderately dense floating wood logs	0.0	0.0	0.0	0.0%
F3	Dense floating wood logs	0.00	0.00	0.00	0.0%	F3	Dense floating wood logs	0.0	0.0	0.0	0.0%
S1	Low density downed wood in forest stand temporarily flooded	0.00	0.00	0.00	0.0%	S1	Low density downed wood in forest stand temporarily flooded	0.0	0.0	0.0	0.0%
S2	Moderately dense downed wood in forest stand temporarily flooded	0.00	0.00	0.00	0.0%	S2	Moderately dense downed wood in forest stand temporarily flooded	0.0	0.0	0.0	0.0%
S3	Dense downed wood in forest stand temporarily flooded	0.00	0.00	0.00	0.0%	S3	Dense downed wood in forest stand temporarily flooded	0.0	0.0	0.0	0.0%
SL	Low density forest stand temporarily flooded	0.10	0.10	0.00	0.0%	SL	Low density forest stand temporarily flooded	5.0	5.0	0.0	0.0%
SM	Moderately dense forest stand temporarily flooded	0.00	0.00	0.00	0.0%	SM	Moderately dense forest stand temporarily flooded	0.0	0.0	0.0	0.0%
SD	Dense forest stand temporarily flooded	0.00	0.00	0.00	0.0%	SD	Dense forest stand temporarily flooded	0.0	0.0	0.0	0.0%
BM	Man-made wood stack on beach	0.00	0.00	0.00	0.0%	BM	Man-made wood stack on beach	0.0	0.0	0.0	0.0%
BS-FS	Stumps on beach or on flats	2.68	2.68	0.00	0.0%	BS-FS	Stumps on beach or on flats	0.0	0.0	0.0	0.0%

c Sector Parsnip Arm East

Code	Wood Debris Type	Area (ha)		Change	
		2009	2011	ha	%
B1	Scattered or low density beached woody debris	2.49	2.33	-0.16	-6.4%
B2	Moderately dense woody ribbons on beach	2.70	3.26	0.56	20.7%
B3	Dense woody ribbons on beach	1.32	1.64	0.32	24.2%
BB	Wood bundle on beach	0.00	0.00	0.00	0.0%
BF	Scattered woody debris on flats	2.13	2.96	0.83	39.0%
F1	Low density floating wood logs	0.24	0.24	0.00	0.0%
F2	Moderately dense floating wood logs	0.04	0.04	0.00	0.0%
S1	Low density downed wood in forest stand temporarily flooded	0.68	0.47	-0.21	-30.9%
S2	Moderately dense downed wood in forest stand temporarily flooded	0.25	0.42	0.17	68.0%
S3	Dense downed wood in forest stand temporarily flooded	0.00	0.00	0.00	0.0%
SL	Low density forest stand temporarily flooded	3.62	3.62	0.00	0.0%
SM	Moderately dense forest stand temporarily flooded	1.51	1.51	0.00	0.0%
SD	Dense forest stand temporarily flooded	0.26	0.26	0.00	0.0%
BM	Man-made wood stack on beach	0.00	0.00	0.00	0.0%
BS-FS	Stumps on beach or on flats	12.58	12.35	-0.23	-1.8%

Sector Parsnip Arm East

Code	Wood Debris Type	Volume (m³)		Change	
		2009	2011	m³	%
B1	Scattered or low density beached woody debris	805.0	753.3	-51.7	-6.4%
B2	Moderately dense woody ribbons on beach	1 943.8	2 346.9	403.1	20.7%
B3	Dense woody ribbons on beach	1 856.9	2 307.0	450.1	24.2%
BB	Wood bundle on beach	0.0	0.0	0.0	0.0%
BF	Scattered woody debris on flats	106.5	148.0	41.5	39.0%
F1	Low density floating wood logs	72.0	72.0	0.0	0.0%
F2	Moderately dense floating wood logs	24.0	24.0	0.0	0.0%
S1	Low density downed wood in forest stand temporarily flooded	136.0	94.0	-42.0	-30.9%
S2	Moderately dense downed wood in forest stand temporarily flooded	100.0	168.0	68.0	68.0%
S3	Dense downed wood in forest stand temporarily flooded	0.0	0.0	0.0	0.0%
SL	Low density forest stand temporarily flooded	181.0	181.0	0.0	0.0%
SM	Moderately dense forest stand temporarily flooded	151.0	151.0	0.0	0.0%
SD	Dense forest stand temporarily flooded	52.0	52.0	0.0	0.0%
BM	Man-made wood stack on beach	0.0	0.0	0.0	0.0%
BS-FS	Stumps on beach or on flats	0.0	0.0	0.0	0.0%

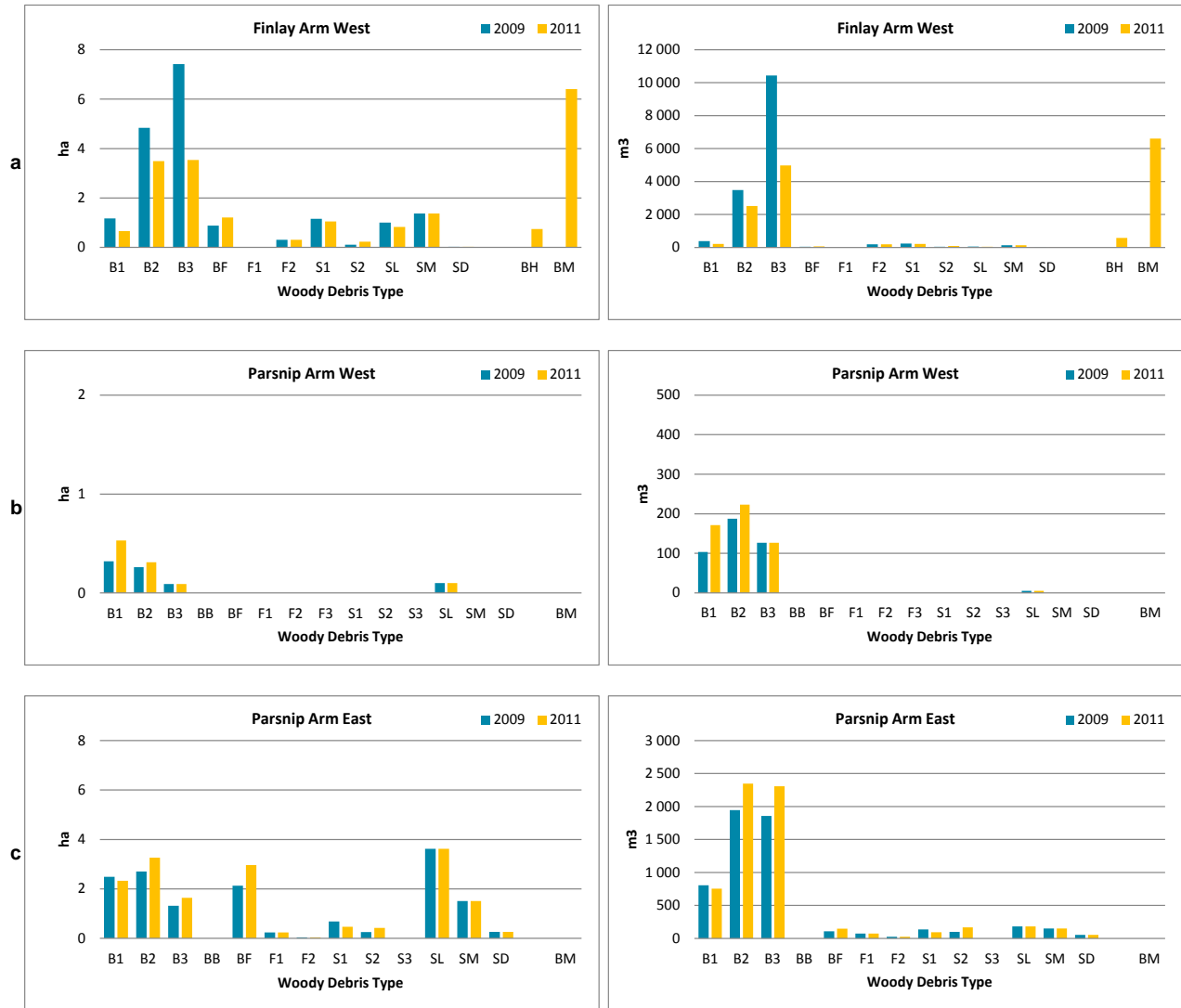


Figure 7-2 Graphs of the detailed trends of the dynamics of woody debris (ha and m³) per sector, between 2009 and 2011, for the sampling areas targeted by BC Hydro

Table 7-2 General trends of the dynamics of woody debris (ha and m³) per sector, between 2009 and 2011, for the sampling areas targeted by BC Hydro

a Sector **Finlay Arm West**

Wood Debris Type	Area (ha)		Change	
	2009	2011	ha	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	14.62	9.21	-5.41	-37.0%
Degraded forest stands (S1, S2 and S3)	1.27	1.28	0.01	0.8%
Forest stands without or with very few downed woods (SL, SM and SD)	2.39	2.22	-0.17	-7.1%
Man-made wood stack on beach (BM and BH)	0.00	7.15	7.15	↑
Balance [(Beached and floating debris + degraded forest stands)]	15.89	10.49	-5.40	-34.0%

Sector **Finlay Arm West**

Wood Debris Type	Volume (m ³)		Change	
	2009	2011	m ³	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	14 531	7 952	-6 578	-45.3%
Degraded forest stands (S1, S2 and S3)	276	302	26	9.4%
Forest stands without or with very few downed woods (SL, SM and SD)	191	183	-9	-4.5%
Man-made wood stack on beach (BM and BH)	0	7 186	7 186	↑
Balance [(Beached and floating debris + degraded forest stands)]	14 807	8 254	-6 552	-44.3%

b Sector **Parsnip Arm West**

Wood Debris Type	Area (ha)		Change	
	2009	2011	ha	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	0.67	0.93	0.26	38.8%
Degraded forest stands (S1, S2 and S3)	0.00	0.00	0.00	0.0%
Forest stands without or with very few downed woods (SL, SM and SD)	0.10	0.10	0.00	0.0%
Man-made wood stack on beach (BM and BH)	0.00	0.00	0.00	0.0%
Balance [(Beached and floating debris + degraded forest stands)]	0.67	0.93	0.26	38.8%

Sector **Parsnip Arm West**

Wood Debris Type	Volume (m ³)		Change	
	2009	2011	m ³	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	417	521	104	24.9%
Degraded forest stands (S1, S2 and S3)	0	0	0	0.0%
Forest stands without or with very few downed woods (SL, SM and SD)	5	5	0	0.0%
Man-made wood stack on beach (BM and BH)	0	0	0	0.0%
Balance [(Beached and floating debris + degraded forest stands)]	417	521	104	24.9%

c Sector **Parsnip Arm East**

Wood Debris Type	Area (ha)		Change	
	2009	2011	ha	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	8.92	10.47	1.55	17.4%
Degraded forest stands (S1, S2 and S3)	0.93	0.89	-0.04	-4.3%
Forest stands without or with very few downed woods (SL, SM and SD)	5.39	5.39	0.00	0.0%
Man-made wood stack on beach (BM and BH)	0.00	0.00	0.00	0.0%
Balance [(Beached and floating debris + degraded forest stands)]	9.85	11.36	1.51	15.3%

Sector **Parsnip Arm East**

Wood Debris Type	Volume (m ³)		Change	
	2009	2011	m ³	%
Beached and floating woody debris (B1, B2, B3, BB, BF, F1, F2 and F3)	4 808	5 651	843	17.5%
Degraded forest stands (S1, S2 and S3)	236	262	26	11.0%
Forest stands without or with very few downed woods (SL, SM and SD)	384	384	0	0.0%
Man-made wood stack on beach (BM and BH)	0	0	0	0.0%
Balance [(Beached and floating debris + degraded forest stands)]	5 044	5 913	869	17.2%



Figure 7-3 Graphs of the general trends of the dynamics of woody debris (ha and m³) per sector, between 2009 and 2011, for the sampling areas targeted by BC Hydro

8. Level of Confidence of the Trends Observed

Volumes of woody debris are likely to change over the area due to two opposite factors. Over time, natural processes are adding new wood debris; however, cleaning activities that are currently occurring remove the woody debris (as observed in Finlay Arm East and West). In order to test if the amount of woody debris has changed significantly between 2009 and 2011 over the whole area, a "paired sample t-test" has been applied to the sample (Student's t-test). This test consisted of calculating the difference (D_i) in each polygon of either total volumes or unitary values for both years. The total wood stock per polygon is estimated by multiplying its area (m^2) by the unitary stock value of the woody debris type. In contrast, unitary values do not consider the surface area of the polygon.

First, given that it has been observed that the overall debris stock is reducing in Finlay Arm sectors, differences were calculated as the value of 2011 less value of 2009. Thus, a negative difference signifies a decrease of woody debris in the polygon from 2009 to 2011. An example of the result of this calculation is presented in Table 8-1.

Table 8-1 Example of the data structure used for performing the paired sample t-test on the whole woody stock per polygon and on the unitary values

Woody Debris type in 2009	Woody Debris type in 2011	Comparison	Area (m^2)	Total wood stock -2009 (m^3)	Total wood stock -2011 (m^3)	Difference - total stock 2011-2009 (m^3)	Unitary wood stock -2009 (m^3/m^2)	Unitary wood stock -2011 (m^3/m^2)	Difference - unitary stock 2011-2009 (m^3)
B2	B2	Stable	445	320 109	320 109	0	0.072	0.072	0.000
B1	B1	Stable	965	311 879	311 879	0	0.032	0.032	0.000
B1	B2	Increase	10 437	3 374 234	7 513 378	4 139 144	0.032	0.072	0.040
B2	B3	Increase	10	7 002	13 683	6 680	0.072	0.141	0.069
B1	RN	Remove	527	170 544	0	-170 544	0.032	0.000	-0.032
B3	B1	Decrease	98	138 030	31 724	-106 306	0.141	0.032	-0.108
B1	BM	Stacked	1 041	336 612	0	-336 612	0.032	0.000	-0.032

Once the differences were calculated over all polygons for both approaches, their mean value and standard deviation were calculated according to these formulas:

$$\text{Mean value of the differences } (\bar{D}) = \frac{\sum_{i=1}^n D_i}{n}$$

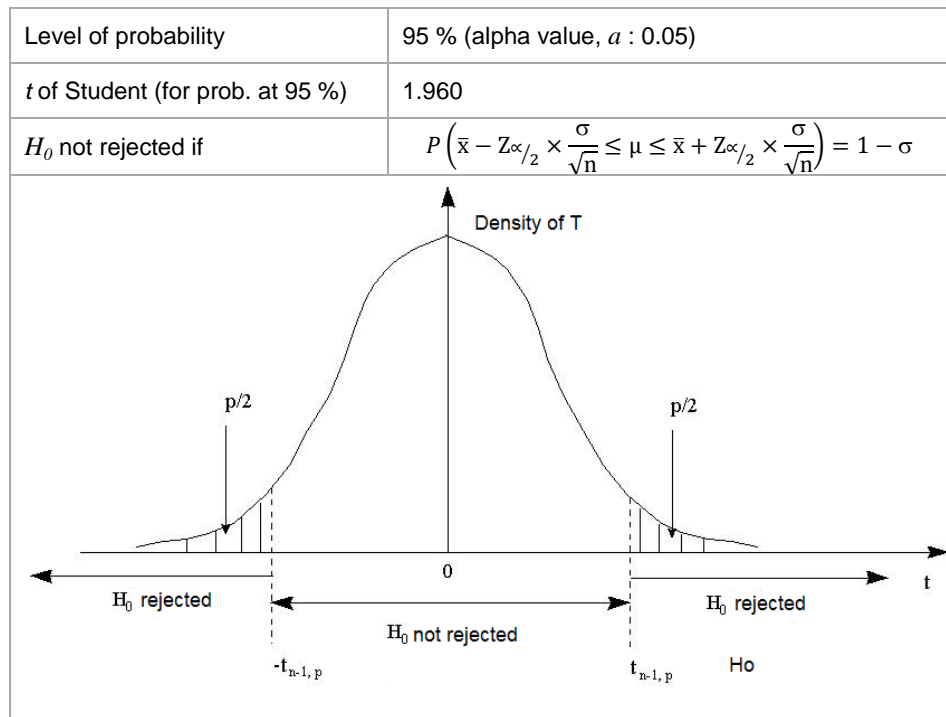
$$\text{Standard deviation } (S_D) = \sqrt{\frac{\sum_{i=1}^n (D_i - \bar{D})^2}{n - 1}}$$

Finally, assuming that the population of the amount of wood debris is normally distributed, the following hypotheses were tested:

- The null hypothesis (H_0) assumes that the true mean difference (μ_d) is equal to zero. $H_0: \mu_d = 0$ (meaning no statistical difference between 2009 and 2011)
- The two-tailed alternative hypothesis (H_1) assumes that μ_d is not equal to zero. $H_1: \mu_d \neq 0$ (two-tailed) (meaning a statistical difference between 2009 and 2011)

Table 8-2 presents the information on the test.

Table 8-2 Criteria and basic values used for the paired sample t-test



The results of the paired sample t-tests indicate that the average value of the differences of woody debris mapped in 2009 and 2011 falls outside of the range statistically defined for confirming the null hypothesis (H_0) using a $\alpha = 0.05$ (Table 8-3). Therefore, the null hypothesis can be rejected meaning that there is a significant difference between the amounts of woody debris mapped in 2009 and 2011 in the 620 sampling squares. We can conclude that the average amount of wood debris has decreased between 2009 and 2011 over the whole project area with a level of confidence of 95 %.

Table 8-3 Results of the paired sample t-test for the whole wood stocks and for the unitary values per polygon

<p>Lower limit</p> <p>-39 360</p> <p>-121 709</p> <p>average differences</p> <p>(note : outside of the required range)</p>	<p>\leq</p> <p>μ_D</p> <p>\leq</p>	<p>Upper limit</p> <p>39 360</p>		<p>Lower limit</p> <p>-0.0015</p> <p>-0.0090</p> <p>average differences</p> <p>(note : outside of the required range)</p>	<p>\leq</p> <p>μ_D</p> <p>\leq</p>	<p>Upper limit</p> <p>0.0015</p>
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9. Conclusion

The baseline of 2009 has been reviewed and updated for standardizing its level of detail with the most detailed imagery from 2011. Apart from the interpretation of woody debris (groups "B" and "F") that was done for the whole reservoir, the classification of the unharvested forest stands occasionally flooded in the imagery from 2009 has been updated in the 620 sampling cells selected for performing the trend analysis. These stands have also been reviewed in select regions outside of the sampling cells, although they should be verified again if these sectors should be compared with newer imagery.

The analysis of woody debris trends between 2009 and 2011 indicates a decrease of 9.91 ha in Finlay Arm East, 2.47 ha in Finlay Arm West and 0.23 ha in Peace Arm South, if the scattered woody debris on flats are excluded (considering that their volume of wood per hectare is quite low). For the sectors where woody debris are still increasing, the trend is at 12.22 ha for Parsnip Arm East, 10.09 ha for Parsnip Arm West and 0.32 for Peace Arm North (Table 9-1), in the 620 sampling cells that were analyzed.

In terms of changes in the amounts of woody volumes, the overall trends consist of a strong reduction in Finlay Arm East and West. More specifically, a reduction of 12 819 and 5 501 m³ is observed in these two sectors respectively, if the scattered woody debris on flats are excluded. For the other sectors, an increase of 6 817 m³ is observed in Parsnip Arm East, 2 835 m³ in Parsnip Arm West, 392 m³ in Peace Arm South and 341 m³ in Peace Arm North (Table 9-2).

The removal activities that are currently performed in the reservoir, at least in the sampling areas, have reduced significantly the extent of woody debris in Finlay Arm and Parsnip Arm sectors, as observed in Table 9-4 for the material stacked and visible on the 2011 imagery (Figure 9-1). The impacts of the cleaning activities are more obvious when the harvested amounts are expressed in wood volumes. More specifically, 17 927, 11 436, 2 232 and 100 m³ have been collected respectively in Finlay Arm East, Finlay Arm West, Parsnip Arm West and Parsnip Arm East (Table 9-3).

Part of the log recruitment and deposition along the coastline comes from tributaries, as observed in Figure 9-1 (Finlay Arm West). However, these added volumes do not seem to be very important in relation with the existing debris observed in the reservoir. Erosion along the coastline also participates to the recruitment of new debris, but at a rate lower than expected. In fact, only some of the leaning trees in 2009 are now lying on the ground in 2011. Recruitment of new debris seems quite active in the forest stands and timber not cleared prior to flooding; this phenomenon is considered separately from bank erosion. In this case, the forest stands are gradually converted to the classes S1, S2 and S3 (low density downed wood in forest stand occasionally flooded (S1), moderately dense (S2) and dense downed wood (S3)). Small ribbons of downed stems are observed inside the most affected stands, mainly in the sectors closer to the coastline. Some of these stems are probably mobilized and accumulated in the beached ribbons along the coastline, but more detailed analysis should be conducted to confirm this process. Finally, the increase of scattered woody debris on flats is mainly related to the mobilization and displacement of logs that were available along the coastline, rather than to the arrival of exotic material. Although volumes remain very low, they might be a concern for recreational activities.

Table 9-1 Overall balance of woody debris trends in the Williston Reservoir, between 2009 and 2011, and excluding scattered woody debris on flats (BF) and man-made wood stacks (BM)

Wood Debris Type ^(a)		Area (ha)		Change	
		2009	2011	ha	%
Sector	Finlay Arm East				
Balance [(Beached and floating debris + degraded forest stands)]		88.09	78.18	-9.91	-11.2%
Sector	Finlay Arm West				
Balance [(Beached and floating debris + degraded forest stands)]		124.96	122.49	-2.47	-2.0%
Sector	Parsnip Arm East				
Balance [(Beached and floating debris + degraded forest stands)]		43.98	56.20	12.22	27.8%
Sector	Parsnip Arm West				
Balance [(Beached and floating debris + degraded forest stands)]		103.67	113.76	10.09	9.7%
Sector	Peace Arm North				
Balance [(Beached and floating debris + degraded forest stands)]		10.31	10.63	0.32	3.1%
Sector	Peace Arm South				
Balance [(Beached and floating debris + degraded forest stands)]		13.97	13.74	-0.23	-1.6%

(a) excluding scattered woody debris on flats

Table 9-2 Overall balance of volumes of woody debris (m³) trends in the Williston Reservoir, between 2009 and 2011, and excluding scattered woody debris on flats (BF) and man-made wood stacks (BM)

Wood Debris Type ^(a)		Volume (m ³)		Change	
		2009	2011	m ³	%
Sector	Finlay Arm East				
Balance [(Beached and floating debris + degraded forest stands)]		64 593	51 774	-12 819	-19.8%
Sector	Finlay Arm West				
Balance [(Beached and floating debris + degraded forest stands)]		73 562	68 061	-5 501	-7.5%
Sector	Parsnip Arm East				
Balance [(Beached and floating debris + degraded forest stands)]		28 750	35 567	6 817	23.7%
Sector	Parsnip Arm West				
Balance [(Beached and floating debris + degraded forest stands)]		62 501	65 336	2 835	4.5%
Sector	Peace Arm North				
Balance [(Beached and floating debris + degraded forest stands)]		4 881	5 222	341	7.0%
Sector	Peace Arm South				
Balance [(Beached and floating debris + degraded forest stands)]		8 306	8 698	392	4.7%

(a) excluding scattered woody debris on flats

Table 9-3 Woody debris (BM and BH) being removed in 2009 and 2011 in the Sampling cells

Wood Debris Removal Activities		Area (ha)		Change	
		2009	2011	ha	%
Sector	Finlay Arm East				
	Man-made wood stack on beach and harvested woody debris area	0.00	16.84	16.84	↑
Sector	Finlay Arm West				
	Man-made wood stack on beach and harvested woody debris area	0.22	11.47	11.25	↑
Sector	Parsnip Arm East				
	Man-made wood stack on beach and harvested woody debris area	0.07	0.07	0.00	0.0%
Sector	Parsnip Arm West				
	Man-made wood stack on beach and harvested woody debris area	0.00	2.22	2.22	↑
Sector	Peace Arm North				
	Man-made wood stack on beach and harvested woody debris area	0.00	0.00	0.00	0.0%
Sector	Peace Arm South				
	Man-made wood stack on beach and harvested woody debris area	0.00	0.00	0.00	0.0%

Table 9-4 Volumes of woody debris (m³) (BM and BH) being removed in 2009 and 2011 in the Sampling cells

Wood Debris Removal Activities		Volume (m ³)		Change	
		2009	2011	m ³	%
Sector	Finlay Arm East				
	Man-made wood stack on beach and harvested woody debris area	0	17 927	17 927	↑
Sector	Finlay Arm West				
	Man-made wood stack on beach and harvested woody debris area	159	11 595	11 436	↑
Sector	Parsnip Arm East				
	Man-made wood stack on beach and harvested woody debris area	50	150	100	200.0%
Sector	Parsnip Arm West				
	Man-made wood stack on beach and harvested woody debris area	0	2 232	2 232	↑
Sector	Peace Arm North				
	Man-made wood stack on beach and harvested woody debris area	0	0	0	0.0%
Sector	Peace Arm South				
	Man-made wood stack on beach and harvested woody debris area	0	0	0	0.0%

