Watershed Analysis Re: Water Yield Increases

Introduction

The need to assess the potential of forest harvesting to increase water flows is identified as an indicator and goal in the recent draft of “Alberta Forest Management Planning Standard” released by Alberta Sustainable Resource Development (ASRD 2005) for public comment. The protection of water and water related resources are identified as a “performance standard” with the objective of limiting the impact of timber harvesting on water yield and water quality. The document states that,

> “The impacts on water yield must be predicted. Watershed modeling and analysis will determine an acceptable target for water yield increase following harvesting for third order watercourses. The ToR (*Terms of Reference*) will describe the models to be used and assessments to be completed.”

Many forest companies are already addressing these issues in their Detailed Forest Management Plans, even though specific models, methods and targets are not fully established. To date such issues are reconciled between forest companies and ASRD on a one-to-one basis.

Objectives

The objective of this document is to describe and provide a scientific basis for the protocol developed by Weyerhaeuser Canada Ltd to identify and analyze watersheds to limit any “negative” effects of forest harvesting on water and water related resources.

Watershed Analysis Protocol

The protocol consists of five steps.

> **Step 1**. All fourth order watersheds in the FMA will be screened to determine if the combined percentage of coniferous stands < 35 years old and deciduous stands < 20 years old equals or exceeds 40% of total watershed area.
>
> **Step 2** If the combined percentage for coniferous and deciduous species exceeds 40%, the ECA-AB model (Silins 2003) which simulates increases in annual water yield and hydrologic recovery as a function of the growth of forest regeneration.
>
> **Step 3** If simulated increases in annual water yield exceed 20%, the harvest plan will be modified, or further analyses will be conducted.
>
> **Step 4** Further analyses would use the Wrenss model (Water Resource Evaluation of Non-Point Silvicultural Sources), which provides a more in depth analysis of potential increases in water yield and peak flows.
>
> **Step 5** If a Wrenss analysis still indicates increases in annual water yield are > 20%, harvest plans will be modified.

Justification for Protocol

The protocol proposes an ECA analysis will only be done for a watershed when 40% of its area contains coniferous and deciduous stands less than 35 years and 20 years in age respectively. Step 1 assumes that significant increases in annual water yield occur when more than 40% of a 3rd - 4th order watershed is cut, and that hydrologic recovery occurs for coniferous and deciduous stands at 35 and 20 years respectively.

The harvest limit of 40% is supported by the following information.

1. The potential to increase annual water yield is proportional to the area harvested in a watershed is well documented in the scientific literature (Bosch and Hewlett 1982). Reported increases in annual water yield vary from 0%-66%, with maximums occurring in climatic zones characterized by high annual precipitation and warm temperatures. Water yield increases documented in Canada are lower (Hetherington 1987), because of cooler temperatures and less precipitation. Increases in water yield usually occur within the first 1-2 years following harvesting, and then steadily decline with the regrowth of forest cover (i.e. hydrologic recovery).

2. A literature review of experimental watershed studies in a paper by Guillemette *et al* (2005) report that harvesting between 40%-50% of a watershed is sufficient to increase 2-year peak flows by 50%, which may result in changes in stream channel morphology and aquatic habitat. The authors in their conclusions stated that more research is needed to confirm the link between increased peak flows and changes in aquatic habitat.

3. Verry (2004) in a retrospective study of the effects of forest cover removal for agricultural development in the Midwestern U. S. also cites increases in the 2-year event as a factor causing changes in stream channel morphology and aquatic habitats. Such changes in stream channel morphology are usually gradual in nature possibly taking 60-100 years to become apparent.

The use of stand ages of 35 years and 20 years for coniferous and deciduous stands as indicators of full hydrologic recovery are based on stand leaf area (i.e. LAI - leaf area index). As LAI increases with growth of forest regeneration so does evapotranspiration and interception leading to a decrease in the volume of extra water generated by forest cover removal. Hydrologic recovery is assumed to be complete at the time of peak LAI for a stand.

1. Research by Lieffers *et al* (2002) in Alberta shows the time to maximum leaf area (LAI) for aspen dominated mixedwood stands varies from 15-25 years for fair to good sites.

2. Recent work by Brabender (2005) shows maximum LAI for lodgepole pine occurs somewhere between 27-35 years.

3. Further work is needed to characterize these relationships for white spruce and black spruce. Given their growth habitats time to maximum leaf area will be greater than that for aspen and pine.

4. Peak LAI for white spruce and black spruce may occur at of 40-50 years and 60-80 years may apply to white spruce and black spruce. These estimates are based on a strong relationship between volume growth and LAI (Brabender 2005).

In Step 3 an increase in simulated annual water yield ≥ 20% is used as a trigger to either modify existing harvest plans or to conduct further analyses. The selection of 20% as a limit was based on an analysis of the natural variability of annual water yield and peak flows (Watertight Solutions, 2005), a regression of simulated increases in annual water yield on percent area of watershed harvested and results from experimental watershed studies.

Natural Variability

1. The analysis of natural variability of flows was done for the Grande Cache-Grande Prairie region. Flow data for 18 watersheds, with a length of record ≥ 10 years, in and adjacent to Weyerhaeuser Canada's FMA were used in the analysis. Natural variability for each watershed was defined as the average annual water yield ± 2 standard deviations. {%NV = ((2 x std/0) x 100)}. This statistical approach was adopted as there are no standards or guidelines regulating the effects of forest harvesting on water flows and definitive data linking changes in flow to aquatic habitat do not exist.

2. Natural variability with respect to increases in annual water yield was defined as (0 + 2 std). This definition includes the full range of variation above the mean flow associated with extreme hydrologic events and natural disturbances such as fire, insect and disease infestations.

3. Natural variability for the 18 watersheds averaged ~100% (27%-145%) (Table 1), which greatly exceeds the potential effects of forest harvesting on water yield. Documented increased water yields following logging in Alberta range from 6% to 27% (Swanson and Hillman 1977; Swanson *et al* 1986).

4. The limits of natural variability for the 18 watersheds were used as a starting point to identify possible limits on increases in water yield. The values for full natural variability for each watershed were systematically reduced into multiples of (0 +1 std), (0 +0.5 std), (0 + 0.33 std), and (0 + 0.25 std). The maximum water yields identified by these reduced limits were then determined and described by their recurrence intervals[1] to identify "acceptable" increases in water yield (Table 1).

5. Recurrence intervals were used to identify "acceptable" increases by magnitude and frequency of occurrence. The effects of forest harvesting on water yield and peak flows are more pronounced for hydrologic events with recurrence intervals of 2-10 years. The effects of forest harvesting on more extreme events (> 10 years) are usually small to nil (i.e. undetectable).

6. Average percent increases for the 18 watersheds were 47% for 0+1 std, 23.6% for 0+0.5 std, 15.6% for 0+0.33 std and 11.80% for 0+0.5 std (Table 1).Recurrence for the same categories were 6.7 years, 4.2 years 3.7 and 3.4 years respectively. The three lower categories are considered most "acceptable" at they target water yields with recurrence intervals of 3-4 years.

Regression Analysis

[1] Recurrence interval or return period expresses the average frequency that an event of given size can be expected to occur. For example, the 2-year peak flow on average will occur once every two years. Another way of expressing this is that in any given year the 2-year peak flow has a 50% change of occurring. In contrast the 25 year peak flow has a 4% chance of occurrence in any given year. On a longer time frame the 2 year event can be expected to occur 50 times in 100 years and the 25 year event only 4 times in 100 years.

An alternative approach to identifying “acceptable” increase in annual water yield was a regression analysis of simulated water yield increases on percent area harvested in a watershed. The simulated water yields were obtained from a history of simulations done for forestry companies by Watertight Solutions Ltd. using WrnsAB2K.

1. The watersheds used in the analysis range in size from very small to large and cover a range of different forest cover types in Alberta (boreal and foothills).

2. Harvesting in most of the simulation runs was less than 40% of watershed area, with water yield increases averaging 6% with minimum and maximum values of 1.4% and 12%.

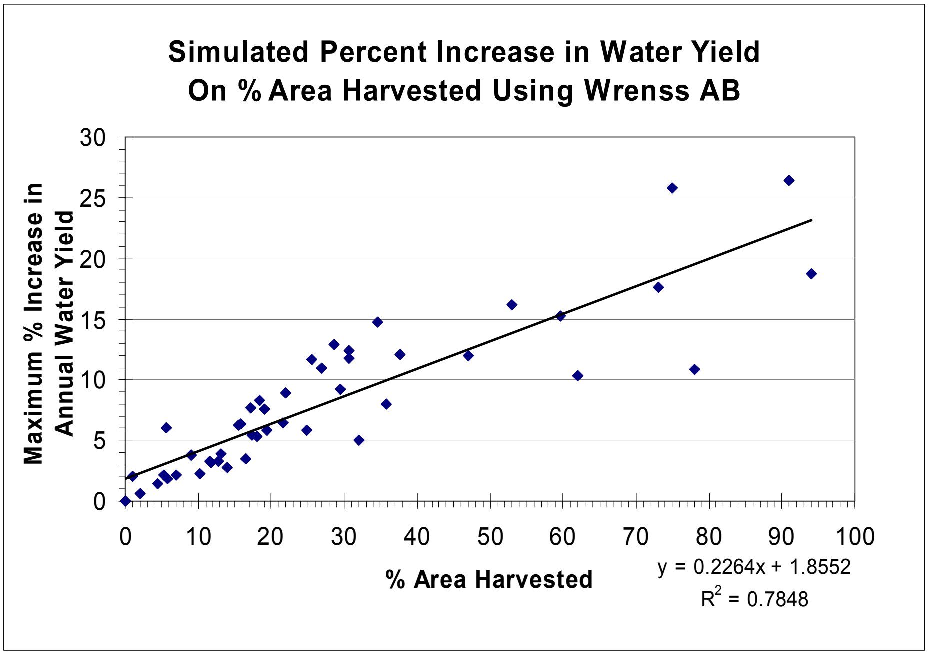
3. The regression curve indicates that harvesting 60%-80% of a watershed could increase maximum annual water yield by 15%-20%. These values should be viewed with some caution as the number of data are less for this part of the curve and the data points were for long term simulations where harvesting was frequent and affected 70-90% of watershed area.

4. Another point to acknowledge is that the regression analysis includes only maximum annual increases in water yield, which does not fully reflect the effects of snow redistribution and the potential for snow scour (i.e. sublimation) on harvest blocks. The inclusion of these effects could increase water yield responses.

Table 1 Natural variability and possible percent increases in annual water yield based on multiples of natural variability (0+2 std) and average recurrence interval for each category (source "Variability of Precipitation and Streamflow, Grande cache-Grande Prairie and Discussion of Guidelines for Water Yield and Peak Flow Increases, Prepared for Weyerhaeuser Canada Ltd., Grande Prairie by Watertight Solutions Ltd. March 2005).

Watersheds	%Natural Variability (0+2 std)	Percent Increases in Annual Water Yield based on Natural Variability			
		0+1 std	0+0.5 std	0+0.33 std	0+0.25 std
Simonette River near Goodwin	71.42	37.71	17.85	11.78	8.93
Smoky river Hells Gate	27.23	13.61	6.81	4.49	3.40
Kakwa River near Grande Prairie	58.25	29.12	14.56	9.61	7.28
Wapiti River near Grande Prairie	59.87	29.94	14.97	9.88	7.48
Red Willow near Beaverlodge	111.56	55.78	27.89	18.41	13.95
Cutbank River near Grande Prairie	73.33	36.67	18.33	12.10	9.17
Muskeg River near Grande Cache	71.30	35.15	17.57	11.60	8.79
Deep Valley near Valleyview	70.10	35.05	17.52	11.57	8.76
Saddle River near Woking	138.01	69.01	34.50	22.77	17.25
Pinto Creek near Grande Prairie	101.46	50.73	25.36	16.74	12.68
Grande Prairie Creek Sexsmith	144.84	72.42	36.21	23.90	18.10
Spring Creek hear Valleyview	135.19	67.59	33.80	22.31	16.90
Little Berland near Grande Cache	78.09	39.04	19.52	12.88	9.76
Upper Spring Creek near Valleyview	127.59	63.79	31.90	21.05	15.95
Bridlebit near Valleyview	133.67	66.84	33.42	22.06	16.71
Rocky Creek near Valleyview	142.52	71.26	35.63	23.52	17.81
Wolverine Creek near Valleyview	98.30	49.15	24.57	16.22	12.29
Horse Creek near Valleyview	117.26	58.63	29.32	19.35	14.66
Average Percents	**97.72**	**47.22**	**23.61**	**15.58**	**11.80**
Average Recurrence Intervals - Years	**18.42**	**6.71**	**4.19**	**3.69**	**3.41**

Figure 1Regression of simulated maximum annual increases in water yield on percent area of watershed harvested. Simulated increases were obtained from a series of simulations done in Alberta for watersheds varying in size from small to large (1 – 350 km^2). The analysis indicates that harvesting 60%-80% of a watershed could increase maximum annual water yield by 15%-20%.



Experimental Watershed Studies

The results from experimental watershed studies report increases in annual water yield ranging from 0% to 66%. The wide range in these results is a reflection of differences in climate (precipitation and energy), forest cover types, soils (i.e. soil water storage) and treatments. These studies are usually conducted on very small watersheds (2.5-7.5 km^2) with treatments that in most cases removed 100% of the forest cover in a short period of time (1 season). The intent of many of these studies was to confirm the effects of forest cover removal and were done to seek the maximum effect.

Direct extrapolation of these results to forest harvesting operations must be done with care. Harvesting planning is usually done at a larger scale (3rd-4th order watersheds) and seldom if ever will a watershed be fully harvested in 1-2 seasons. There are only a few watershed studies where different levels of forest cover removal and long term post harvest evaluations (i.e. cumulative effects) are evaluated.

Conclusions

In conclusion the protocol proposed by Weyerhaeuser Canada should be an effective method for screening harvest plans for 3rd-4th order watersheds to prevent water yield increases above “acceptable“ levels. Using 40% of watershed area with coniferous and deciduous stands of ages ≤ 35 and 20 years in age to trigger an ECA-Alberta analysis should be effective in detecting and preventing water yield increases greater than 20%. The regression analysis shown in Figure 1 indicates that most water yield responses at ≤ 40% harvest level will be less than 12%.

The study of water flows in the Grande Cache-Grande Prairie area show annual water yield increases of 15%-20% fall within the range of natural variability and target annual water yields with recurrence intervals of 3-4 years, which are slightly above “average” conditions represented by the 2-year flows.

Improvements to this protocol and those of other companies undoubtedly will occur as better information and understanding of the hydrology of forested watersheds and hydrologic recovery become available. In particular, the development of “acceptable” flow increases for forest regions within the province (e.g. foothills versus boreal), better leaf area data for white and black spruce cover types, and flow data for headwater 3rd and 4th order watersheds.

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Table 8.6 A: Primary Species Designation of Fourth Order Watersheds as a Percent of Total Forested Land (net of previous cutovers).

Edson DFMP WATERSHED	TOTAL Forested Landbase	Overstory BCGP				Percent of Watershed			Watershed Designation for Watershed Analysis Protocols
		D	DC	CD	C	Primary Deciduous	Primary Coniferous	Total	
Athabasca	1,279.0	544.6	155.1	221.0	358.3	54.7%	45.3%	100.0%	Primary Deciduous
Bear	12,098.3	5,377.9	776.5	753.6	5,190.3	50.9%	49.1%	100.0%	Primary Deciduous
Bigoray	36,209.3	7,006.3	2,687.8	5,280.8	21,234.3	26.8%	73.2%	100.0%	Primary Coniferous
Cairn	1,950.2	209.0	186.9	434.6	1,119.7	20.3%	79.7%	100.0%	Primary Coniferous
Carrot	12,013.3	3,005.6	1,325.8	2,003.5	5,678.4	36.1%	63.9%	100.0%	Primary Coniferous
Carrot Tower	4,136.1	1,500.1	645.6	587.3	1,403.1	51.9%	48.1%	100.0%	Primary Deciduous
Chevron	2,197.5	378.7	192.5	758.9	867.4	26.0%	74.0%	100.0%	Primary Coniferous
Chip	41.7	29.7		0.1	11.9	71.2%	28.8%	100.0%	Primary Deciduous
Coyote	22,847.6	1,051.6	1,346.6	1,962.3	18,487.1	10.5%	89.5%	100.0%	Primary Coniferous
Cricks	6,503.6	2,519.2	1,191.0	870.6	1,922.8	57.0%	43.0%	100.0%	Primary Deciduous
Cynthia	3,884.4	733.2	643.0	1,064.4	1,443.7	35.4%	64.6%	100.0%	Primary Coniferous
Deer Hill	4,256.1	2,166.9	191.1	352.2	1,545.9	55.4%	44.6%	100.0%	Primary Deciduous
East Pembina	18,667.9	7,992.2	1,439.4	1,612.8	7,623.6	50.5%	49.5%	100.0%	Primary Deciduous
Edson	5,414.8	2,243.9	296.2	610.0	2,264.7	46.9%	53.1%	100.0%	Primary Coniferous
Edson North	94.5	66.3	13.8	9.2	5.2	84.8%	15.2%	100.0%	Primary Deciduous
Embarras	1,856.7	290.5	147.3	199.8	1,219.1	23.6%	76.4%	100.0%	Primary Coniferous
Erith	21,033.1	1,158.1	796.7	3,250.3	15,828.0	9.3%	90.7%	100.0%	Primary Coniferous
Fairless	827.4	735.1	49.3	20.3	22.7	94.8%	5.2%	100.0%	Primary Deciduous
Fickle	1,401.3	442.9	201.5	93.4	663.4	46.0%	54.0%	100.0%	Primary Coniferous
Graham	4,277.6	2,527.5	830.7	545.8	373.6	78.5%	21.5%	100.0%	Primary Deciduous
Granada	2,058.9	909.2	784.8	88.6	276.3	82.3%	17.7%	100.0%	Primary Deciduous
Groat	485.7	254.9	132.6	35.5	62.8	79.8%	20.2%	100.0%	Primary Deciduous
Half Moon	17,835.9	483.2	434.0	674.3	16,244.3	5.1%	94.9%	100.0%	Primary Coniferous
Hanlan	58.4				58.4	0.0%	100.0%	100.0%	Primary Coniferous
Hardluck	7,869.3	2,625.6	667.6	834.1	3,742.0	41.8%	58.2%	100.0%	Primary Coniferous
Hinton	691.7	52.7	259.7	102.5	276.8	45.2%	54.8%	100.0%	Primary Coniferous
Kathleen	1,778.4	1,218.7	188.6	168.1	203.1	79.1%	20.9%	100.0%	Primary Deciduous
Ladd	2,032.5	238.1	336.0	379.3	1,079.1	28.2%	71.8%	100.0%	Primary Coniferous
Lobstick	14,186.1	4,276.6	1,286.7	2,196.0	6,426.8	39.2%	60.8%	100.0%	Primary Coniferous
Mason	643.0	617.2	2.0	18.3	5.5	96.3%	3.7%	100.0%	Primary Deciduous
McLeod	30,567.1	7,303.8	2,395.3	3,153.8	17,714.2	31.7%	68.3%	100.0%	Primary Coniferous
Miller	1,169.2	529.0	348.5	184.1	107.6	75.1%	24.9%	100.0%	Primary Deciduous
Minnow	11,921.0	1,020.1	1,248.0	1,498.4	8,154.4	19.0%	81.0%	100.0%	Primary Coniferous
Moose	9,402.6	605.6	185.7	419.8	8,191.5	8.4%	91.6%	100.0%	Primary Coniferous
Obed	9,016.9	1,034.7	441.7	999.8	6,540.8	16.4%	83.6%	100.0%	Primary Coniferous
Oldman	5,284.5	333.2	404.2	668.7	3,878.4	14.0%	86.0%	100.0%	Primary Coniferous
Paddle	1,396.4	585.9	387.6	226.0	196.9	69.7%	30.3%	100.0%	Primary Deciduous
Paddy	19,237.7	4,868.6	774.0	1,270.4	12,324.6	29.3%	70.7%	100.0%	Primary Coniferous
Pembina	11,497.1	1,738.1	720.9	1,176.9	7,861.2	21.4%	78.6%	100.0%	Primary Coniferous
Poison	3,350.2	2,026.4	254.1	458.4	611.3	68.1%	31.9%	100.0%	Primary Deciduous
Rally	1,774.3	944.1	33.0	119.5	677.6	55.1%	44.9%	100.0%	Primary Deciduous
Rat North	28,541.7	3,020.6	1,574.2	1,451.5	22,495.4	16.1%	83.9%	100.0%	Primary Coniferous
Rat South	15,926.6	4,048.6	810.2	1,405.4	9,662.4	30.5%	69.5%	100.0%	Primary Coniferous
Raven	8,996.7	229.3	220.1	515.8	8,031.5	5.0%	95.0%	100.0%	Primary Coniferous
Sang	16,370.9	1,751.7	966.5	1,777.7	11,875.0	16.6%	83.4%	100.0%	Primary Coniferous
Shiningbank	961.1	877.3	27.4	49.6	6.8	94.1%	5.9%	100.0%	Primary Deciduous
Sinkhole	11,825.3	3,974.4	964.8	1,660.7	5,225.4	41.8%	58.2%	100.0%	Primary Coniferous
Slide	2,631.1	1,897.9	128.0	183.8	421.3	77.0%	23.0%	100.0%	Primary Deciduous
Sundance	11,063.9	2,826.4	1,690.3	1,178.3	5,368.9	40.8%	59.2%	100.0%	Primary Coniferous
Swartz	15,678.5	1,194.0	795.6	1,432.2	12,256.7	12.7%	87.3%	100.0%	Primary Coniferous
Tom Hill	4,100.5	1,593.1	693.8	608.3	1,205.4	55.8%	44.2%	100.0%	Primary Deciduous
Trout	902.9	239.1	78.1	65.2	520.6	35.1%	64.9%	100.0%	Primary Coniferous
West Eta	12,025.0	3,360.4	1,254.8	920.2	6,489.4	38.4%	61.6%	100.0%	Primary Coniferous
Whitefish	7,481.9	2,016.3	495.1	1,053.8	3,916.8	33.6%	66.4%	100.0%	Primary Coniferous
Zeta	18,585.6	2,063.7	649.8	1,646.4	14,225.6	14.6%	85.4%	100.0%	Primary Coniferous
Grand Total	**468,338.6**	**100,738.0**	**34,750.6**	**49,252.3**	**283,597.8**	**28.9%**	**71.1%**	**100.0%**	

Table 8.6 B: Total Harvest Area by Fourth Order

Edson DFMP WATERSHED	Watershed Designation for Watershed Analysis Protocols	Effective Harvest Areas for Protocols	Cutovers by 5 year periods						
			2003*-1999	1998-1994	1993-1989	1988-1984	1983-1979	1978-1974	1973-1969
Athabasca	Primary Deciduous	0.0	0.0						
Bear	Primary Deciduous	473.7	231.9	58.5	157.1	26.2	15.0		0.2
Bigoray	Primary Coniferous	5,175.2	2,276.1	1,539.4	987.8	344.0	22.2		5.7
Cairn	Primary Coniferous	121.1				77.5	43.6		
Carrot	Primary Coniferous	1,899.6	637.5	1,020.1	178.5	63.4	0.0		0.0
Carrot Tower	Primary Deciduous	367.8	304.8	15.9	47.1		0.0		
Chevron	Primary Coniferous	506.6	136.5	78.0	284.1	0.0			7.9
Chip	Primary Deciduous	5.1	0.0	5.1		0.0			
Coyote	Primary Coniferous	1,934.6	1,531.7	273.4	42.6	9.5	64.2	13.2	0.0
Cricks	Primary Deciduous	1,066.9	923.1	93.4	50.5		2.7		0.0
Cynthia	Primary Coniferous	520.9	355.0	112.0	32.8	18.9	0.0		2.1
Deer Hill	Primary Deciduous	609.8	293.6	122.7	134.3	59.2	19.9	51.6	32.2
East Pembina	Primary Deciduous	1,160.0	390.5	197.5	556.3	15.7	44.5		0.0
Edson	Primary Coniferous	1,244.3	251.3	461.4	157.9	147.4	106.1	91.8	28.4
Edson North	Primary Deciduous	29.8	0.0	29.8			0.0		
Embarras	Primary Coniferous	57.7	57.6				0.0		
Erith	Primary Coniferous	1,022.8	115.3			376.7	331.5	135.8	63.5
Fairless	Primary Deciduous	0.0	0.0			0.0			0.1
Fickle	Primary Coniferous	271.5	221.6	49.8			0.0		
Graham	Primary Deciduous	959.1	16.8	693.2	119.2	129.9			4.2
Granada	Primary Deciduous	10.5	10.5						
Groat	Primary Deciduous	0.0							
Half Moon	Primary Coniferous	3,052.8	2,450.6	411.0	80.4	27.3	83.5		
Hanlan	Primary Coniferous	0.0							
Hardluck	Primary Coniferous	975.6	211.1	539.3	72.1	53.7	47.8	43.6	7.9
Hinton	Primary Coniferous	0.0							
Kathleen	Primary Deciduous	245.7	84.6	158.1	3.0		0.0		0.1
Ladd	Primary Coniferous	74.8	57.9	8.7	8.3				
Lobstick	Primary Coniferous	1,148.6	469.2	67.7	339.9	173.9	94.7		3.2
Mason	Primary Deciduous	32.2	20.7			11.6			0.1
McLeod	Primary Coniferous	2,405.3	659.9	385.8	238.7	324.6	110.9	270.9	414.6
Miller	Primary Deciduous	79.0	79.0						
Minnow	Primary Coniferous	1,958.1	493.4	416.9	835.3	212.4	0.2		
Moose	Primary Coniferous	312.8	3.0	123.5	120.7	64.4	1.0		
Obed	Primary Coniferous	440.5	38.6	64.5	138.5	181.5	17.1		0.3
Oldman	Primary Coniferous	448.4	380.0	40.4	20.4			7.6	
Paddle	Primary Deciduous	266.8	17.0	216.5	19.6	13.6			42.3
Paddy	Primary Coniferous	1,470.9	323.9	748.2	398.8		0.0		
Pembina	Primary Coniferous	1,260.4	464.5	700.4	75.4	3.6	16.5		0.0
Poison	Primary Deciduous	563.3	65.7	423.3	26.5	47.8	4.5	121.1	60.9
Rally	Primary Deciduous	282.0	123.9	5.0	153.1		2.2	13.6	33.1
Rat North	Primary Coniferous	1,768.5	906.4	447.6	276.1	128.1	10.3		
Rat South	Primary Coniferous	1,376.7	277.3	512.3	513.8	67.6	5.7		
Raven	Primary Coniferous	0.0	0.0						
Sang	Primary Coniferous	1,752.6	235.6	695.6	315.3	325.5	116.2	60.8	3.7
Shiningbank	Primary Deciduous	67.9	63.8			4.1			0.1
Sinkhole	Primary Coniferous	2,003.7	1,010.5	54.5	937.0	0.0	0.2		1.5
Slide	Primary Deciduous	454.4	9.7	188.7	255.9				0.0
Sundance	Primary Coniferous	552.3	44.5	333.3	55.3	12.9	4.6	74.9	26.8
Swartz	Primary Coniferous	805.5	422.2	148.6	81.5	94.0	19.8		39.4
Tom Hill	Primary Deciduous	618.9	217.8	318.2	30.2	52.7	25.4		
Trout	Primary Coniferous	0.0					0.0		
West Eta	Primary Coniferous	430.3	0.0	0.0	430.2				
Whitefish	Primary Coniferous	1,211.2	371.1	118.0	376.8	69.9	0.0	6.3	269.0
Zeta	Primary Coniferous	1,374.0	152.2	1,019.4	149.3	43.5	3.4	6.3	0.0
Total		**44,870.0**	**17,407.9**	**12,895.7**	**8,700.4**	**3,181.2**	**1,214.1**	**897.5**	**1,047.1**

Effective Cutover used in Table 8.6

* 2003 harvest year is between May 1, 2003 and April 30, 2004.

Table 8.6 C: Total Burned Area by Fourth Order Watershed

Edson DFMP WATERSHED	Watershed Designation for Watershed Analysis Protocols	Effective Burned Areas for Protocols	Forest Fires by 5 Year Periods - Hectares						
			2003*-1999	1998-1994	1993-1989	1988-1984	1983-1979	1978-1974	1973-1969
Athabasca	Primary Deciduous	0.0							
Bear	Primary Deciduous	0.0							
Bigoray	Primary Coniferous	8,228.3	152.2	8,001.2		74.8			
Cairn	Primary Coniferous	0.0							
Carrot	Primary Coniferous	0.0							
Carrot Tower	Primary Deciduous	0.0							
Chevron	Primary Coniferous	0.0							
Chip	Primary Deciduous	10.3		10.3					
Coyote	Primary Coniferous	15.4	15.4						
Cricks	Primary Deciduous	0.0							
Cynthia	Primary Coniferous	0.0							
Deer Hill	Primary Deciduous	0.0							
East Pembina	Primary Deciduous	6.7	2.5	4.2					
Edson	Primary Coniferous	0.0							
Edson North	Primary Deciduous	0.0							
Embarras	Primary Coniferous	0.0							
Erith	Primary Coniferous	0.0							
Fairless	Primary Deciduous	0.0							
Fickle	Primary Coniferous	80.3		80.3					
Graham	Primary Deciduous	0.0							
Granada	Primary Deciduous	0.0							
Groat	Primary Deciduous	0.0							
Half Moon	Primary Coniferous	0.0							
Hanlan	Primary Coniferous	0.0							
Hardluck	Primary Coniferous	0.0							
Hinton	Primary Coniferous	0.0							
Kathleen	Primary Deciduous	0.0							
Ladd	Primary Coniferous	0.0							
Lobstick	Primary Coniferous	0.0							
Mason	Primary Deciduous	0.0							
McLeod	Primary Coniferous	0.0							
Miller	Primary Deciduous	0.0							
Minnow	Primary Coniferous	0.0							
Moose	Primary Coniferous	0.0							
Obed	Primary Coniferous	0.0							
Oldman	Primary Coniferous	0.0							
Paddle	Primary Deciduous	0.0							
Paddy	Primary Coniferous	96.9		88.9		8.0			
Pembina	Primary Coniferous	0.0							
Poison	Primary Deciduous	35.7	1.1	34.7					
Rally	Primary Deciduous	0.0							
Rat North	Primary Coniferous	0.0							
Rat South	Primary Coniferous	0.0							
Raven	Primary Coniferous	0.0							
Sang	Primary Coniferous	0.0							
Shiningbank	Primary Deciduous	0.0							
Sinkhole	Primary Coniferous	63.7		63.7					
Slide	Primary Deciduous	0.0							
Sundance	Primary Coniferous	0.0							
Swartz	Primary Coniferous	0.0							
Tom Hill	Primary Deciduous	0.0							
Trout	Primary Coniferous	0.0							
West Eta	Primary Coniferous	1,196.0				1,196.0			
Whitefish	Primary Coniferous	0.0							
Zeta	Primary Coniferous	0.0							
Total		**9,733.2**	**171.2**	**8,283.2**	**0.0**	**1,278.8**	**0.0**	**0.0**	**0.0**

Effective Burn Area used in Table 8.6

* 2003 harvest year is between May 1, 2003 and April 30, 2004.

Table 8.6 D: First decade in the SHS area by Fourth Order Watershed

Edson DFMP WATERSHED	Watershed Designation for Watershed Analysis Protocols	Effective Harvest Areas for Protocols	Planned Harvests	
			2004-2009	2009-2014
Athabasca	Primary Deciduous	7.2		7.2
Bear	Primary Deciduous	2,136.4	877.1	1,259.4
Bigoray	Primary Coniferous	2,523.8	857.3	1,666.5
Cairn	Primary Coniferous	218.5	99.9	118.7
Carrot	Primary Coniferous	918.0	549.6	368.4
Carrot Tower	Primary Deciduous	49.3	36.0	13.3
Chevron	Primary Coniferous	65.4	65.4	
Chip	Primary Deciduous	0.0		
Coyote	Primary Coniferous	1,795.5	318.5	1,477.0
Cricks	Primary Deciduous	552.0	324.8	227.2
Cynthia	Primary Coniferous	377.4	377.4	
Deer Hill	Primary Deciduous	621.7	549.3	72.4
East Pembina	Primary Deciduous	2,071.2	1,723.6	347.7
Edson	Primary Coniferous	216.6	56.2	160.4
Edson North	Primary Deciduous	1.3	1.3	
Embarras	Primary Coniferous	139.1	139.1	
Erith	Primary Coniferous	1,276.8	532.6	744.2
Fairless	Primary Deciduous	160.3	160.3	
Fickle	Primary Coniferous	59.3	59.3	
Graham	Primary Deciduous	958.5	66.1	892.5
Granada	Primary Deciduous	189.3	173.6	15.7
Groat	Primary Deciduous	63.9	63.9	
Half Moon	Primary Coniferous	903.7	446.7	456.9
Hanlan	Primary Coniferous	16.1		16.1
Hardluck	Primary Coniferous	649.4	239.6	409.8
Hinton	Primary Coniferous	0.0		
Kathleen	Primary Deciduous	336.3	134.2	202.1
Ladd	Primary Coniferous	554.3	340.1	214.2
Lobstick	Primary Coniferous	1,795.5	1,560.9	234.6
Mason	Primary Deciduous	44.7	44.7	
McLeod	Primary Coniferous	606.6	202.1	404.6
Miller	Primary Deciduous	213.9	195.8	18.0
Minnow	Primary Coniferous	1,084.8	1,056.2	28.6
Moose	Primary Coniferous	34.0	34.0	
Obed	Primary Coniferous	139.4	32.1	107.3
Oldman	Primary Coniferous	181.6	142.9	38.7
Paddle	Primary Deciduous	187.5	62.6	124.9
Paddy	Primary Coniferous	1,716.0	1,098.0	618.0
Pembina	Primary Coniferous	1,791.2	915.9	875.3
Poison	Primary Deciduous	225.4	14.1	211.3
Rally	Primary Deciduous	220.3	210.2	10.1
Rat North	Primary Coniferous	1,998.4	1,154.3	844.1
Rat South	Primary Coniferous	1,363.9	418.5	945.4
Raven	Primary Coniferous	1,061.7	66.7	995.0
Sang	Primary Coniferous	1,012.5	944.6	67.9
Shiningbank	Primary Deciduous	85.0	85.0	
Sinkhole	Primary Coniferous	544.7	532.2	12.5
Slide	Primary Deciduous	473.1	326.0	147.1
Sundance	Primary Coniferous	54.3		54.3
Swartz	Primary Coniferous	327.4	203.5	123.9
Tom Hill	Primary Deciduous	435.1	95.2	339.8
Trout	Primary Coniferous	122.4	42.3	80.0
West Eta	Primary Coniferous	1,400.4	831.9	568.5
Whitefish	Primary Coniferous	941.0	260.2	680.8
Zeta	Primary Coniferous	2,658.2	2,097.6	560.6
Total		**37,580.4**	**20,819.5**	**16,760.9**

Effective SHS Area used in Table 8.6

NOTE: Includes harvests from Preferred SHS in periods 1 and 2.