Water Yield and Precipitation Inputs for ECA-AB Analysis
Grand Prairie Forest Management Area
Weyerhaeuser Canada Ltd.

Prepared by Watertight Solutions
August 30, 2007

Introduction

The objective of this project was to identify annual water yield and annual precipitation on a watershed basis as inputs for analysis of equivalent clearcut areas and potential increases in water yield with the model ECA-AB in Weyerhaeuser Canada's forest management area (FMA).

Location and Description

The FMA exists as two blocks, one located north of the city of Grande Prairie and the other south of the city. The southern block is 127691 km^2 in area and is drained by the Wapiti River, the Mountain Creeks, Cutbank River and the Kakwa River, which are tributaries of the Smoky River (Figure 1). The northern block is 55979 km^2 in area and its major drainages is the Saddle River which flows eastward to the Smoky River and Pouce Coupe River which flows to the west. Average annual water yield in the region averages 180 mmm with minmum and maximum values of 49 and 466 mm respectively (Table 1). Average annual precipitation for the FMA is 483 mm with minimum and maximum values of 416 and 638 mm (Table 2).

Methods

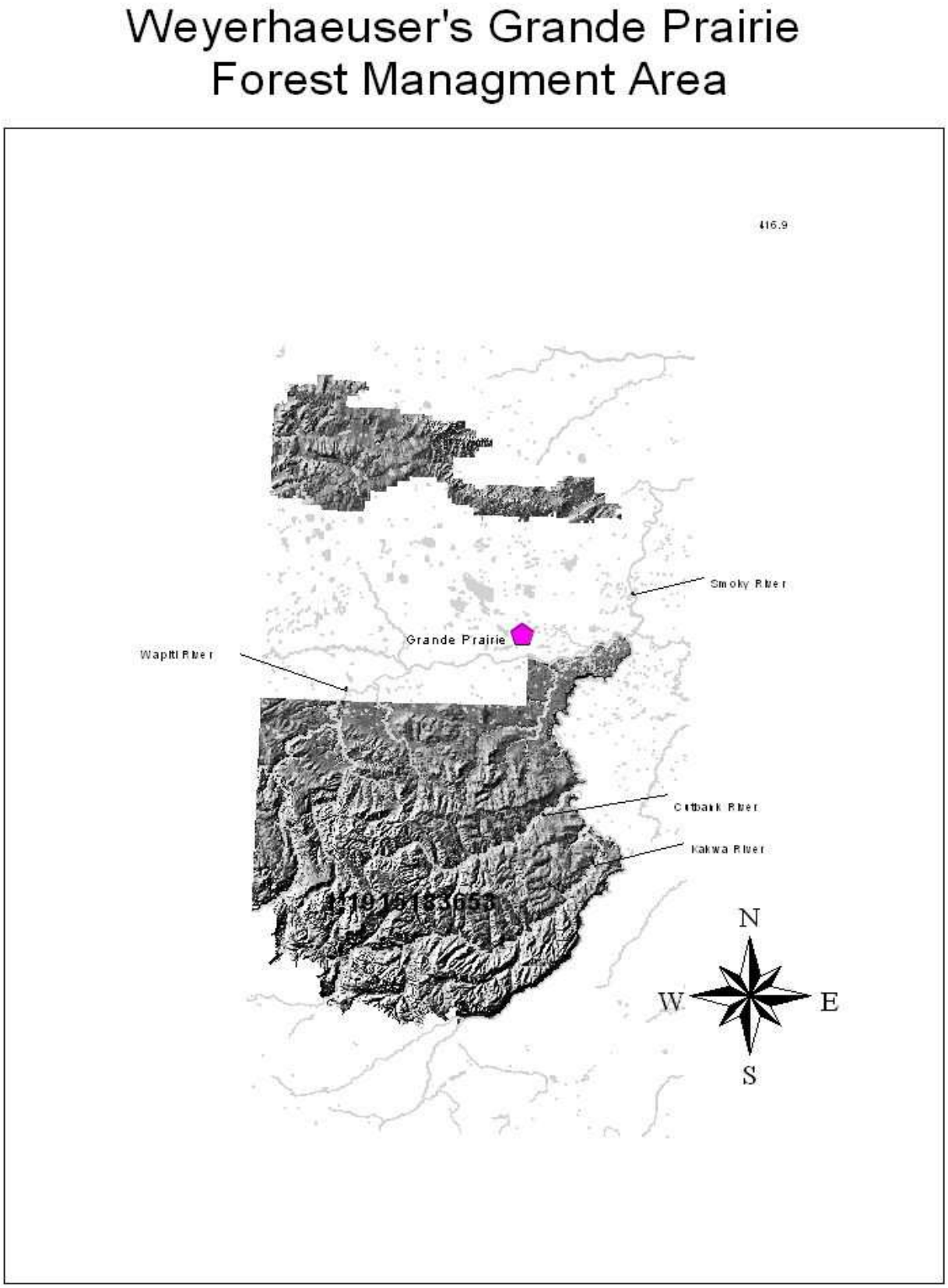
The following steps were followed to allocate annual water yield and annual precipitation to 4^{th} order watersheds in Weyerhaeuser Canada's Grande Prairie forest management area (GP FMA).

1. Isolines of annual precipitation and annual water yield for the GP FMA were derived using existing meteorological stations and hydrometric stations in the region. Isolines were drawn taking into account topographic and elevation features of the FMA.

2. Data for annual precipitation and annual water yield were obtained from Environment Canada (2003). Precipitation was from CD-ROM for the prairie provinces downloaded from the Meteorological Branch of Environment Canada for stations with 12 months of record, which is a data requirement of the ECA-AB model

3. Average water yield was calculated using data from HY-DAT a compendium of daily flows prepared by Water Survey of Canada (Environment Canada 2003). Flow records for many of the stations are for the open water season (March-October), which usually accounts for 90-95% of annual flows. No adjustments were made to the data to account for winter flows.

Figure 1 Location of Weyerhaeuser's Grande Prairie Forest Management Area



DRAFT COPY – HYDROMETRIC INPUTS FOR ECA-AB – GRANDE PRAIRIE FMA

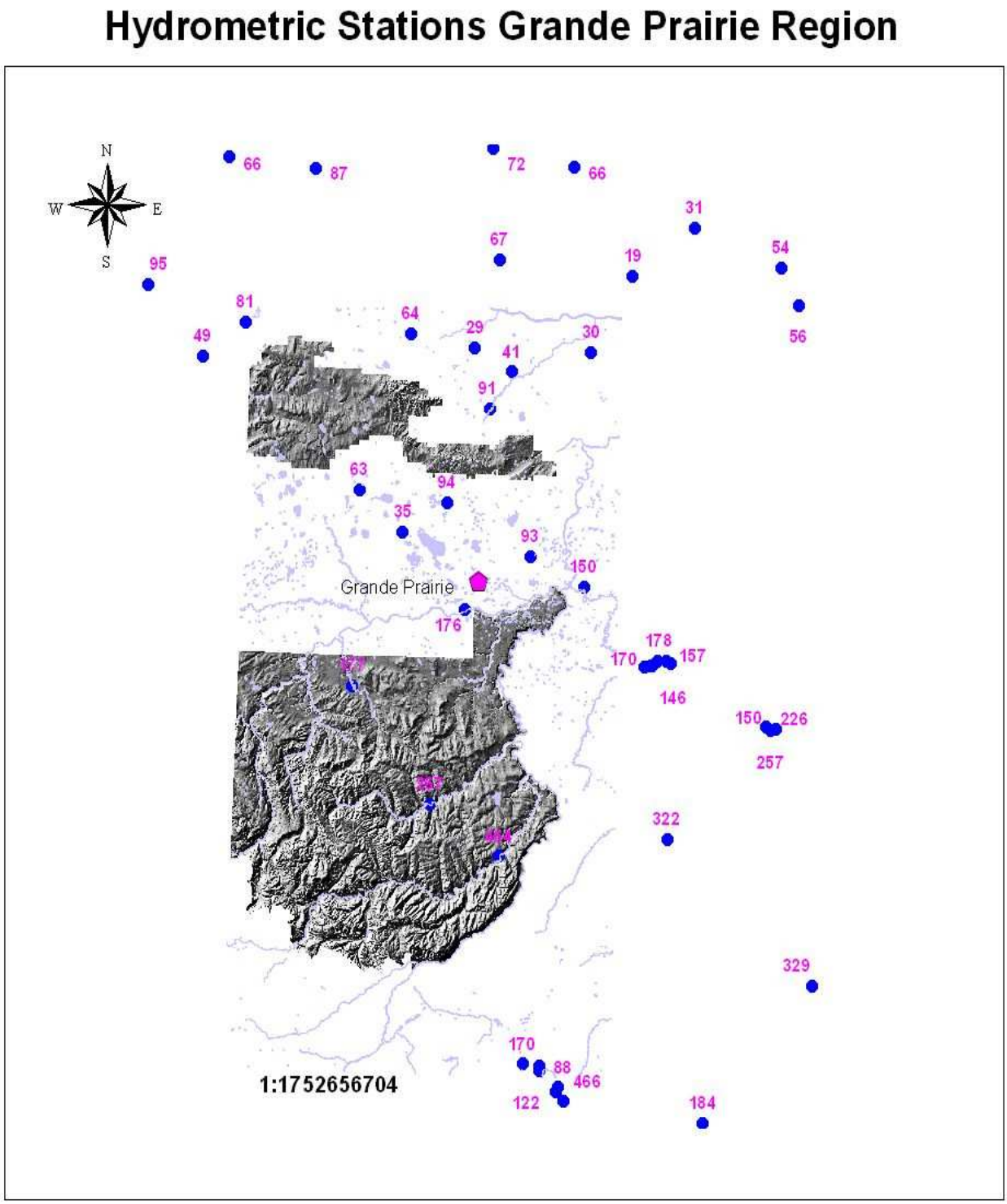
Table 1 Hydrometric Stations in and near Weyerhaeuser's Grande Prairie Forest Management Area (Environment Canada 2003). Regional average flow is 135 mm. Flow stations inside FMA boundaries shown in blue. Average regional water yield is 179.84 mm.

Hydrometric Stations	Longitude	Latitude	Area km^2	Average Annual Flow area mm
LITTLE BERLAND RIVER AT HIGHWAY NO.	118.238611	53.678611	94	466
KAKWA RIVER NEAR GRANDE PRAIRIE	118.594444	54.372222	3300	464
BERLAND RIVER NEAR THE MOUTH	116.963056	54.013056	4740	329
DEEP VALLEY CREEK NEAR VALLEYVIEW	117.719444	54.429444	637	322
CUTBANK RIVER NEAR GRANDE PRAIRIE	118.963056	54.515833	844	267
LITTLE SMOKY RIVER AT LITTLE SMOKY	117.179444	54.740000	3010	257
IOSEGUN RIVER NEAR LITTLE SMOKY	117.151111	54.745278	1950	226
BRIDLEBIT CREEK NEAR VALLEYVIEW	117.733889	54.936111	20	178
PINTO CREEK NEAR GRANDE PRAIRIE	119.389444	54.843056	498	177
WAPITI RIVER NEAR GRANDE PRAIRIE	118.802778	55.072222	11300	176
HORSE CREEK NEAR VALLEYVIEW	117.813056	54.921944	4	170
SPRING CREEK (UPPER) NEAR VALLEYVIEW	117.705556	54.929444	33	157
SIMONETTE RIVER NEAR GOODWIN	118.175000	55.141667	5050	150
WASKAHIGAN RIVER NEAR THE MOUTH	117.205556	54.750833	1040	150
SPRING CREEK NEAR VALLEYVIEW	117.848611	54.918056	112	146
WOLVERINE CREEK NEAR VALLEYVIEW	117.808889	54.921389	11	105
ROCKY CREEK NEAR VALLEYVIEW	117.776389	54.934722	19	103
KISKATINAW RIVER NEAR FARMINGTON	120.562500	55.956944	3570	95
GRANDE PRAIRIE CREEK NEAR SEXSMITH	118.913889	55.374444	152	94
KLESKUN HILLS MAIN DRAIN NEAR GRANDE	118.460278	55.224722	32	93
SADDLE RIVER NEAR WOKING	118.697500	55.644167	538	91
CLEAR RIVER NEAR BEAR CANYON	119.678889	56.308889	2880	87
POUCE COUPE RIVER BELOW HENDERSON CR	120.029444	55.864722	2850	81
BEAR RIVER NEAR VALHALLA CENTRE	119.381389	55.400556	181	63
DAWSON CREEK ABOVE SOUTH DAWSON CREEK	120.250000	55.761944	116	49

Table 2 Average annual precipitation for the Grande Prairie region. Average for all stations 483 mm, with minimum and maximum values of 416 and 638 mm (shown in red). Average regional precipitation – 483.47 mm.

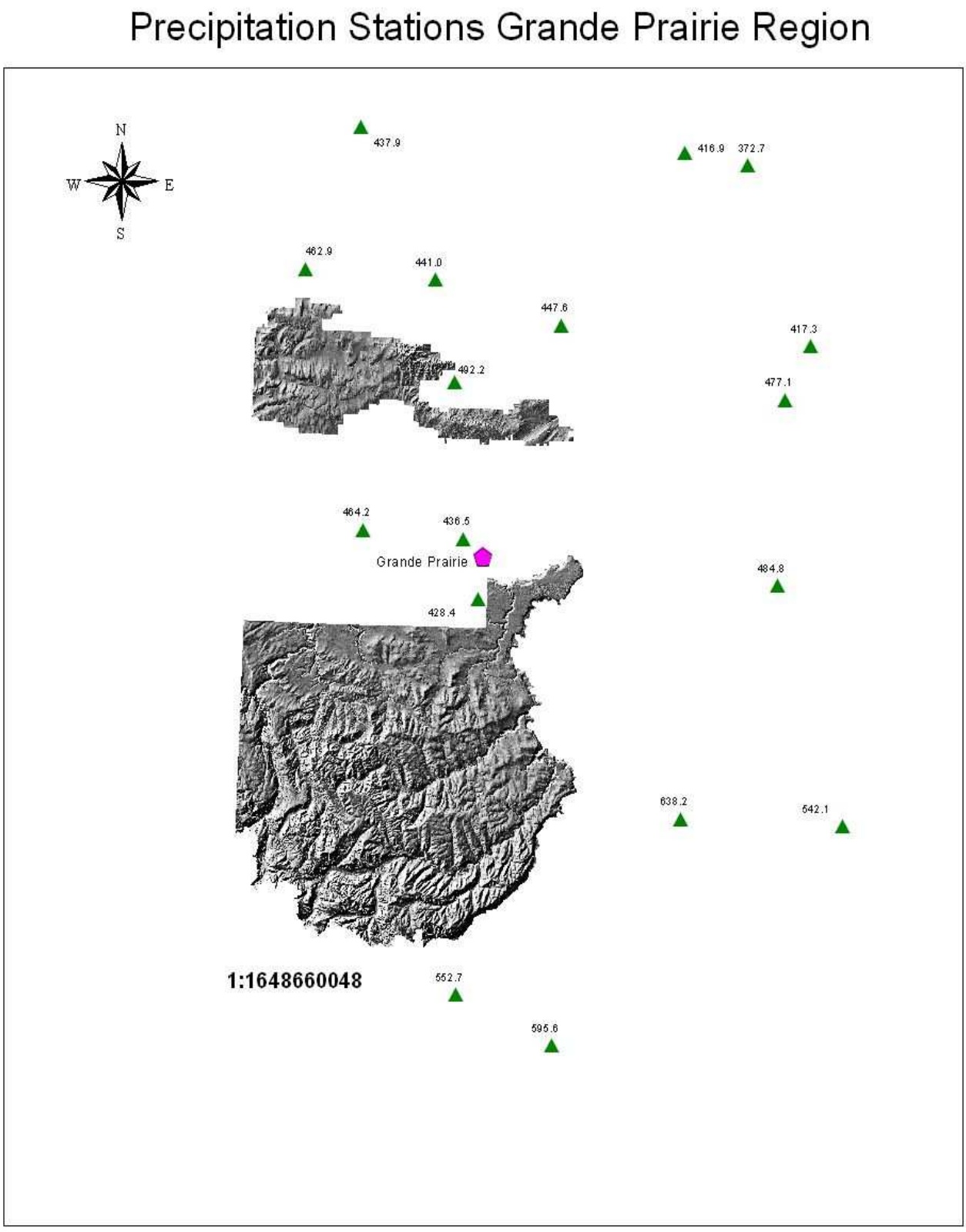
Meteorological Stations	Longitude	Latitude	Elevation m	Length of Record	Average Annual Precipitation mm
BALLATER	117.23333	55.58333	564	1990-1998	477.1
BEAVERLODGE CDA	119.40000	55.20000	745	1913-2003	464.2
CLEARDALE	119.48333	56.31667	643	1964-1998	437.9
DONNELLY	117.10000	55.73333	602	1982-1998	417.3
ELMWORTH CDA EPF	119.75000	55.91667	754	1975-2003	462.9
FOX CREEK RS	116.93333	54.40000	841	1966-1998	542.1
GRANDE CACHE	118.86667	53.91667	1255	1985-2003	552.7
GRANDE PRAIRIE AIRPORT	118.88333	55.18333	669	1942-2003	436.5
GROVEDALE RS	118.80000	55.01667	701	1978-1998	428.4
HENDRICKSON CREEK	118.38333	53.78333	1372	1973-1993	595.6
KSITUAN	119.06667	55.90000	640	1980-1993	441.0
LAC CARDINAL	117.76667	56.26667	649	1989-1996	416.9
SIMONETTE	117.75000	54.41667	884	1973-2003	638.2
VALLEYVIEW RS	117.26667	55.06667	762	1962-2003	484.8
WANHAM CDA	118.40000	55.78333	561	1955-1996	447.6
WOKING CDA (Saddle Hills)	118.95000	55.61667	727	1981-1995	492.2

Figure 2 Distribution of hydrometric stations in the Grande Prairie Region. Units – area mm[1]. Water yields in agricultural areas adjacent to Grande Prairie and north of the Saddle Hills average less than 100 mm. Average water yield for stations in or near forested areas is 179 mm (Table 1).



[1] Area millimeters (area mm) is the total volume annual of runoff (m^3) from a watershed expressed as a uniform depth of water over it surface area (m^2). (depth = m^3/m^2 = m)

Figure 3 Distribution of precipitation stations in the Grande Prairie Region. Units – mm.



4. The small number of hydrometric stations within FMA boundaries (3 stations) made it difficult to derive isolines directly from water yield data. To overcome this difficulty, water yield was estimated by water balance calculations, using annual precipitation isolines and an estimate of evapotranspiration (300 mm) for the region from the Hydrologic Atlas of Canada (Fisheries and Environment Canada 1978).

   Q = P – ET……..where
   P = annual precipitation defined by isolines
   ET = 300 mm

5. The results for estimated precipitation and water yield were assigned to 4th order watersheds defined by Weyerhaeuser Canada. These results were saved in an ArcView project (see attached CD).

Results

1. A hydrologic land base was developed for the FMA based on the watershed coverage provided by Weyerhaeuser Canada (Figure 4). The hydrologic land base for the southern block of the FMA follows the watersheds and confluence areas defined by Weyerhaeuser. Watersheds and confluence areas were identified for each of the major drainages in the FMA (Mountain Creeks, and the Wapiti, Cutbank and Kakwa rivers). Confluence areas contain 1st – 3rd order basins that are exempt from the requirement for water yield prediction, and flood plains and wetlands that cannot be easily identified as watersheds. A review of the boundaries of confluence areas is suggested, as some watersheds (< 4th order) could be considered candidates for estimation of water yield change because of their size.

   A hydrologic land base for the Saddle Hills (north block) was treated differently. The interior of the Saddle Hills is dominated by trellis stream networks, which run parallel to one another with little to no tributaries. Under these conditions few if any of these watersheds will be more than a 1st-2nd order basin. Classification on a 4th order basis would remove a significant part of the Saddle Hills from hydrologic assessment. Therefore individual watersheds were identified within the FMA boundaries.

   There were only two watersheds in the Saddle Hills that are fully within the boundaries of the FMA (Saddle 1 and Saddle 2). Most of the others are headwater zones for streams that flow into the surrounding agricultural areas. It is anticipated that more flow is generated in the headwater zones than in the lower elevation agricultural areas. Because of this, special attention may be needed in harvest planning in these headwater areas to minimize potential downstream impacts on water flows.

2. Analysis of data and drawing of isolines shows annual precipitation in the south block of the FMA increases with elevation from 400-475 mm on the northeastern boundary to 550-600 mm on the southwestern edge of the FMA (Figure 5). Elevation along this gradient ranges from 500-1800 m.

   Average annual precipitation for the south block and north block were estimated at 493 mm. (Table 3). Annual precipitation at Grande Cache and south of the FMA report is 552 up to 600 mm. Precipitation at Grovedale Ranger Station is 428 mm. Annual precipitation to the east of the FMA at the Simonette Fire Tower is 638 mm.

   Precipitation in the Saddle Hills was less than the south block with an average of 488 mm. Precipitation ranged from a maximum of 500 mm at the height of land to 475-400 along its lower slopes. Maximum observed average annual precipitation in the Saddle Hills was 492 mm at the Woking CDA station. Annual precipitation to the north and south of Saddle Hills varies from 441-463 mm at Ksituan and Elmworh to 436 mm at Grande Prairie.

Figure 4 Hydrologic land base for Weyerhaeuser's Grande Prairie Forest Management Area

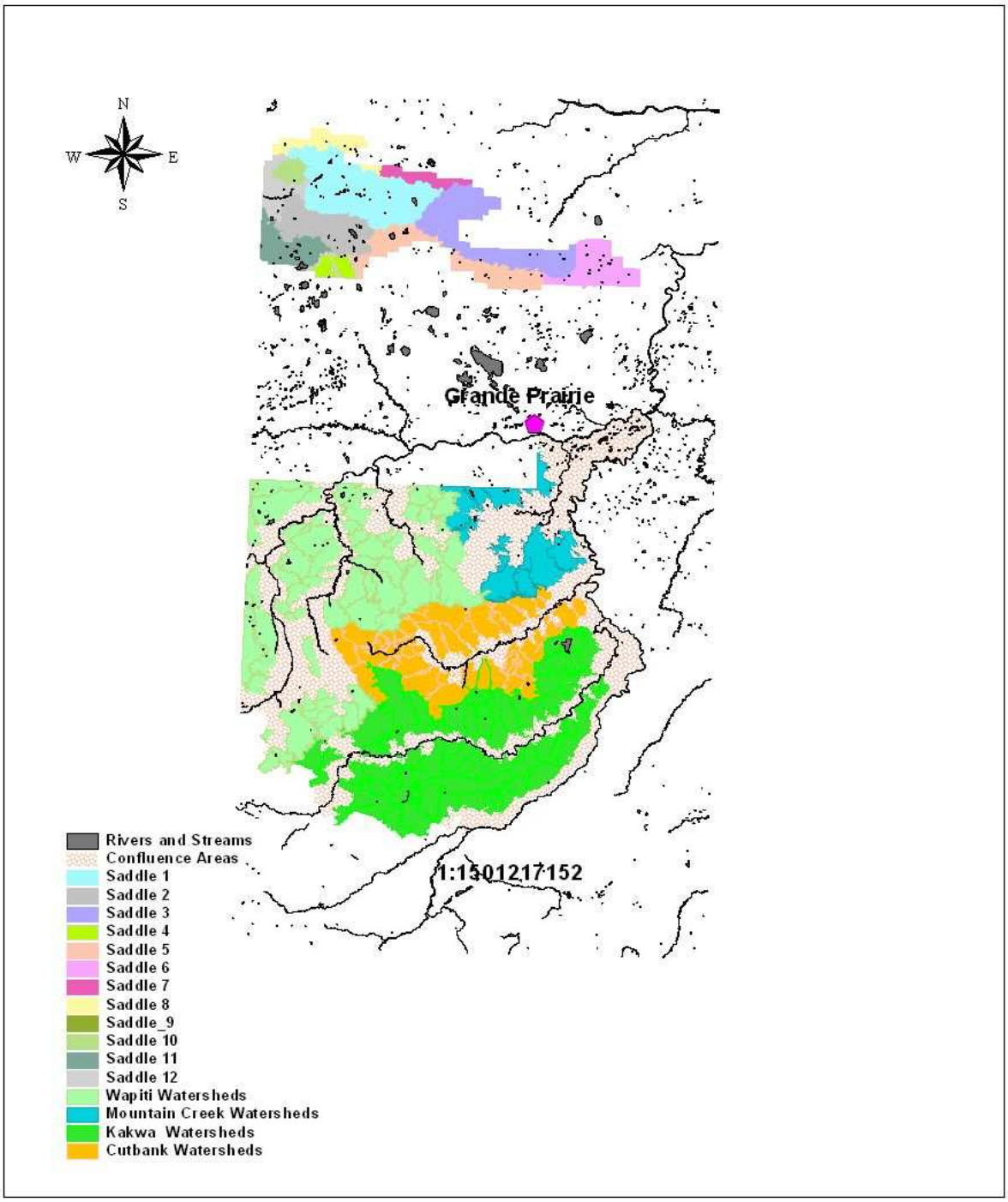
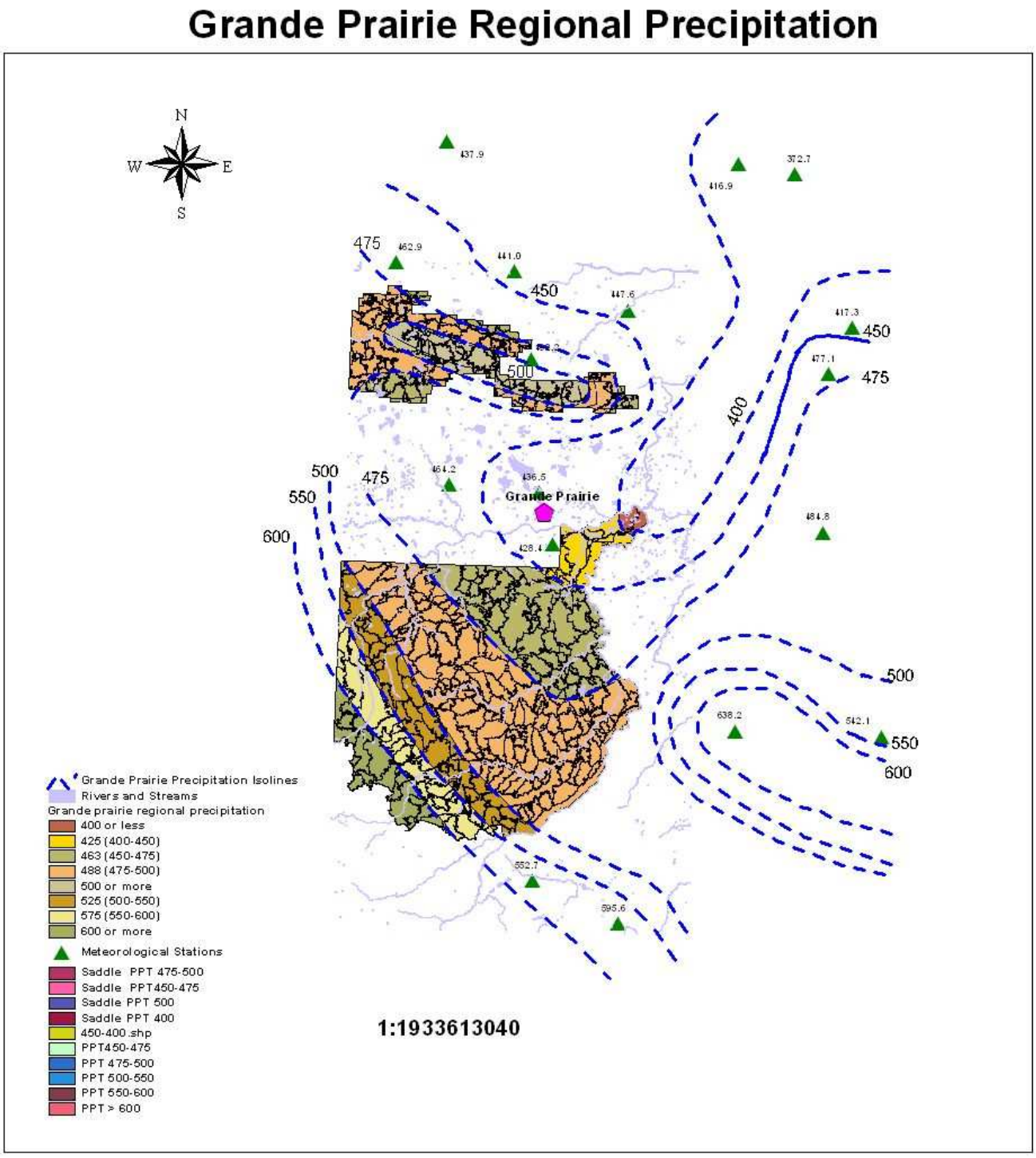


Table 3 Area weighted annual precipitation for the south and north (Saddle Hills) blocks of Weyerhaeuser' Grande Prairie FMA.

South Block of FMA			
Precipitation mm	Median Value	Area ha	Weighted Value
<400	400	25153.69	7.90
400-450	425	97628.21	32.58
450-475	463	272097.31	98.92
475-500	488	492025.13	188.53
500- 550	525	248086.97	102.26
550-600	575	107756.79	48.65
>600	600	34165.16	16.10
		Total Area	**Weighted Average**
		1276913.26	**494.93**
North Block of FMA (Saddle Hills)			
Precipitation mm	Median Value	Area ha	Weighted Value
450-475	463	101470.49	83.97
475-500	488	249497.89	217.61
>500	500	208553.95	186.37
		Total Area	**Weighted Average**
		559522.33	**487.94**

It should be noted that precipitation is highly variable, and at specific locations can be larger or smaller than that indicated by the isolines. Most of the data used in the analysis were at locations adjacent to or outside of FMA boundaries. These data were considered representative of the region, but may underestimate precipitation in the higher elevation zones of the FMA where snow is the dominant form of precipitation. Most of the available precipitation data in the FMA is from fire towers, which are seasonal and do not include winter precipitation.

Figure 5 Annual precipitation for Weyerhaeuser's Grande Prairie Forest Management Area



3. Streamflow data for estimating water yield in the FMA was limited to only three stations (Cutbank River, Kakwa River and Pinto Creek). Annual water yield for these stations varied from 177-464. These data were informative but insufficient by themselves to draw isolines of water yield for the FMA. Observed water yield to the south and east of the FMA varies from 466 mm for the Little Berland River to 178 for Spring Creek. Water yields surrounding the city of Grande Prairie and north of the Saddle Hills in agricultural areas range from 36-95 mm.

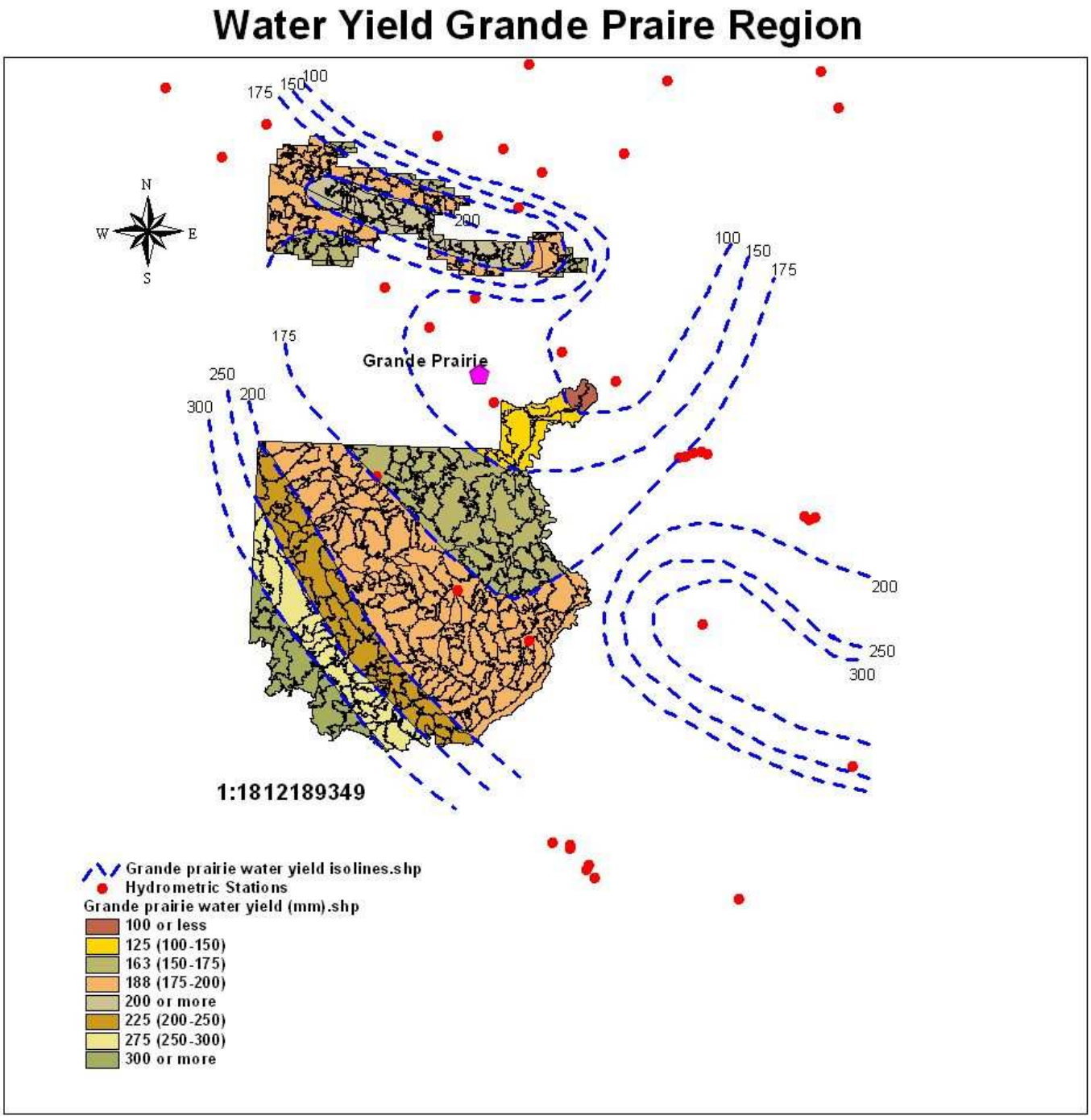
   Given the sparseness and variability of observed streamflow in and adjacent to the FMA water yield was estimated by simple water balance calculations using precipitation from isolines and an assumed evapotranspiration from the Hydrologic Atlas of Canada. The precipitation isolines were considered more reliable estimators as they reflect the effects of elevation on the availability of water for runoff. The ideal situation would be to have flow measurements for a range of different elevation zones across the FMA. The existing flow stations in the FMA include a range of different elevation zones which provide a cumulative measure of water yield, which is not representative of flows in smaller watersheds.

   The isolines in Figure 6 show water yield in the southern block decreases from >300 mm on the southwestern boundary to <100 mm at the extreme northeastern edge of the FMA. Area weighted average water yields for the south and north blocks of the FBA are 193 and 197 mm, which are slightly larger than the regional average of 180 mm for stations in and outside of the FMA. Averages were calculated using the median value for each water yield zone (e.g. 125 for 100-150, Table 4).

Table 4 Calculation of area weighted average water yield for north (Saddle Hills) and south blocks of Weyerhaeuser's Grande Prairie FMA.

South Block of FMA			
Water Yield mm	Median	Area ha	Weighted Values
100+	100.00	25153.69	1.97
100-150	125.00	97628.21	9.56
150-175	163.00	272097.31	34.73
175-200	188.00	492025.13	72.44
200-250	225.00	248086.97	43.71
250-300	275.00	107756.79	23.21
300+	300.00	34165.16	8.03
		Total Area	**Weighted Average**
		1276913.26	**193.50**
North Block of FMA (Saddle Hills)			
Water Yield mm	Median	Area ha	Weighted Values
150-175	163.00	101739.25	29.62
175-200	188.00	249497.89	83.79
200+	225.00	208553.95	83.83
		Total Area	**Weighted Average**
		559791.09	**197.24**

Figure 6 Water yield for Weyerhaeuser's Grande Prairie Forest Management Area



4. The results of these analyses were "rolled up" in to an ArcView project attached to this report along with copies of the isoline maps for precipitation and water yield.

5. This information can be used as inputs into ECA-AB in a number of different ways.

   - Median values for each precipitation and water yield zone were assigned to each watershed in the GIS attribute files. These can be used as inputs for ECA-AB without any modification.
   - Regional average precipitation and water yield values for the north and south blocks of the FMA can also be used as inputs.
   - Inputs for watersheds that are near or straddle precipitation and water yield zones can be averaged or adjusted upwards or downwards depending upon the extent and proportion of harvesting in adjacent zones.

6. The best approach to apply this information would be to do a series of ECA-AB runs to see how sensitive the above suggestions or other approaches affect water yield and ECA outputs.

7. Water yield increases ECA obtained with ECA-AB (or WRENSS) should be viewed as relative estimates of change. ECA values should be considered as a measure of "hydrologic" disturbance and referenced in some way to changes in water yield to be a meaningful index of watershed disturbance.

   Table 5 is a short summary of possible water yield increases and ECA values. The table is based on experience gained from WRENSS assessments and observations and current thinking found in forest hydrology circles. The suggested limits in Table 5 are offered as a base for developing effective operational guidelines to minimize "unacceptable" changes to water flows.

   Water yield increases are characterized as low (<10%), moderate (10-15%, high (15-25%) and unacceptable. These increases are based on the results nine years of WRENSS simulations for a range of different forest types, hydrologic regions and harvesting shown in Figure 7. The scatter in the data points is a reflection of different climate, hydrology used in the simulations. Harvesting in the simulations ranged from single first entries into a watershed to harvest schedules ranging from 20-100 years in length. Water yield increases for first entry into a watershed are usually moderate to low where 20-25% of a watershed is harvested. Subsequent harvesting in a watershed can sustain water yield increase at high levels depending on the frequency of harvesting.

   A harvest limit of no more than 50% of a watershed is suggested to minimize the effects of harvesting on water. Cumulative effects can also be constrained by using %ECA to manage the level of disturbance in a watershed. The numbers in Table 5 are only suggestions, as testing is needed to confirm what is practical and achievable. A maximum annual ECA and an 5-year average ECA are suggested to allow flexibility in planning and harvesting.

   The increases are based on observations from the literature that suggest that increases of ≥ 50% in the 2-year return period for maximum daily flows, over sustained periods of time are sufficient to result in changes in channel morphology (depth, width) which can cause changes in aquatic habitat and fauna. Furthermore, return period events of 2-10 years are more susceptible to change from forest harvesting than larger less frequent events (>10 year).

Table 5 Proposed limits on changes in water yield and peak flows, and ECA values.

Magnitude of Change	Percent Change	Percent of Watershed harvested
Maximum Annual Water Yield Increases		
Low	< 10%	< 20-25%
Moderate	10-15%	<40%
High	15-25%	40-50%
Unacceptable	> 25%	>50%
Maximum allowable annual increase in water yield ~ 25% with a constraint that no more than 50% of a watershed can be taken in a "single" harvest.		
Percent Watershed ECA Maximum annual % ECA of 50% for a duration of no more than 2-3 years Maximum 5-year average ECA of ≤ 20-25%		
Increased Peak Flows. Maximum increase of ≤ 50% in 2-year maximum daily flow		

Figure 7 Simulated increases in water yield obtained with WRENSS for a range of different forest types, hydrologic conditions and harvest patterns in Alberta.