WATER SUPPLY ASSESSMENT FOR THE NORTH SASKATCHEWAN RIVER BASIN

Report submitted to:

North Saskatchewan Watershed Alliance

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EXECUTIVE SUMMARY

In an Agreement dated 22 January 2008, the North Saskatchewan Watershed Alliance (NSWA) contracted Golder Associates Limited (Golder) to assess the water supply and its variability in the North Saskatchewan River Basin (NSRB) under natural hydrologic conditions and present climatic conditions.

The NSRB was divided into seven (7) hydrologic regions to account for the spatial variability in factors influencing water yield. The hydrologic regions were delineated such that the hydrologic responses were essentially similar within each region, but different from region to region. The annual yield for each hydrologic region was estimated as the average of the annual yields of gauged watersheds located completely within the hydrologic region, if available. Thirty-four hydrometric stations within the NSRB were included in the analysis. For the assessment of natural water yield, only those data series or portions thereof that have been collected under natural flow conditions were considered.

A key aspect of the water yield assessment in the NSRB was the estimation of water yield in watersheds with non-contributing areas. The calculation of water yield for each hydrologic region and sub-basins in the NSRB was based on the effective drainage areas of gauged watersheds and on effective drainage areas within each hydrologic region or sub-basin. The non-contributing areas as delineated by the Prairie Farm and Rehabilitation Administration (PFRA) of Agriculture and Agri-Food Canada (AAFC) for the NSRB were used.

Monthly yields were determined by first estimating the average percentage of the annual yield at each station within a hydrologic region, with priority given to stations wholly contained within the hydrologic region and to stations with winter flow records. The average monthly percentage was then used with the annual yield estimated for a hydrologic region to estimate a typical monthly yield for that region. The coefficients of variation and skewness for the annual yield of a hydrologic region were used to estimate the 10^{th}, 25^{th}, 75^{th} and 90^{th} percentiles on the basis that the annual yield series followed a log-normal distribution.

The annual and monthly yields for each sub-basin as defined by NSWA were also estimated from the annual yield of each hydrologic region that is included in each sub-basin and the proportion of each hydrologic region within each sub-basin.

The mean annual natural discharge of the NSR at the Alberta/Saskatchewan boundary is about 7,510 million m^3 (Mm^3), which is equivalent to an annual yield of 179 mm during average hydrologic conditions. The cumulative annual yield (volume) at the same location for the 10^{th}, 25^{th}, 75^{th} and 90^{th} percentile hydrologic conditions are 122, 142, 205 and 248 mm (5,110 Mm^3, 5,930 Mm^3, 8,600 Mm^3, and 10,400 Mm^3), respectively. The headwater hydrologic region, with an area of 4,110 km^2 compared to the NSRB's gross drainage area of 56,860 km^2, contributes almost half (3,600 Mm^3) of the annual cumulative yield of the NSRB at the boundary. The portion of the NSRB downstream of Edmonton contributes less than 300 Mm^3 of flow volume to the annual cumulative volume of the NSRB at the boundary. The mean annual natural discharge of the NSR near Edmonton and at the downstream outlet of the Strawberry sub-basin is 7,080 Mm^3. The cumulative annual discharge at the same location for the 10^{th}, 25^{th}, 75^{th} and 90^{th} percentile hydrologic conditions are 4,990 Mm^3, 5,740 Mm^3, 8,030 Mm^3, and 9,470 Mm^3, respectively.

The most upstream hydrologic region has the highest annual yield at 870 mm, while the easternmost hydrologic regions near the Alberta/Saskatchewan boundary have the lowest annual yields at 35 mm and 25 mm, respectively. These low yields are a reflection of the low precipitation, relatively higher temperature and higher evapotranspiration, and large non-contributing areas in the eastern half of the NSRB. The peak monthly yield from the hydrologic regions in the eastern half of the NSRB occurs in April as a result of snow melt as temperatures begin to increase in spring. In contrast, the peak monthly yield from the hydrologic regions in the western half of the NSRB, particularly those along the eastern slopes of the Rocky Mountains, occur in July because of the gradual rise in temperature during spring and early summer at these high elevations. The peak monthly cumulative yield at the Alberta/Saskatchewan boundary occurs in July and seems to follow the pattern shown by the hydrologic regions in the western half of the NSRB. This is an expected result as the western hydrologic regions generate most of the yield in the NSRB.

The results of an analysis of flow records on the NSR indicate that the approach and results of the water supply assessment for the NSRB as described above are valid.

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1. INTRODUCTION

1.1 Background

During a meeting with the North Saskatchewan Watershed Alliance (NSWA) on December 13, 2007, Golder Associates Limited (Golder) was requested to provide a scope of work to assess water supply and its variability in the North Saskatchewan River Basin (NSRB) under natural hydrologic conditions and present climatic conditions. An additional request was to scope the modeling work required to predict changes in the water yield under potential future climatic conditions. Subsequent to a letter dated January 17, 2008 from Golder outlining the requested scope of work, NSWA authorized Golder in an Agreement dated 22 January 2008 to undertake the water supply assessment. This report presents the results of the analysis for the water supply component of the study.

1.2 Scope of Work

The objective of the water supply component of the study was to provide a basin-wide status of water yield (average conditions) and its variability (quartiles) in the NSRB and its key sub-basins. This component of study would be based on natural flow data series recorded at Environment Canada’s hydrometric stations in the NSRB.

1.3 Approach for Assessment of Water Supply

The North Saskatchewan River Basin (NSRB) exhibits significant spatial variability in temperature and precipitation, both within any given year and from year to year. In the mountains and higher foothills, precipitation tends to be relatively high and evapotranspiration low, resulting in high water yield. In contrast, in the eastern portion of the NSRB, average annual precipitation tends to be less than average annual evapotranspiration, which leads to large moisture-deficit areas, either at certain times of the year or regionally during multi-year droughts. Given the geographic variability in precipitation, evaporation, and other climatic variables, it is critical for an assessment of water yield to consider explicitly the spatial variability of the factors contributing to water yield.

There is considerable flow data for rivers and streams in the NSRB, both on the main stem of the North Saskatchewan River (NSR) and its tributaries. Some of the flow data series include portions that reflect the regulation of flows due to power projects or other activities. For the assessment of natural water yield, it is necessary to consider only those data series or portions thereof that have been collected under natural flow conditions.

The approach for the assessment of water yield in the NSRB consisted of the steps outlined in the following sections.

1.3.1 Hydrologic Regionalization of the North Saskatchewan River Basin

The hydrologic response of a watershed is a function of watershed characteristics including drainage area and slope, precipitation inputs, air temperature at high altitudes and in high latitude regions, evapotranspiration, and infiltration. The NSRB was divided into seven (7) hydrologic regions to account for the spatial variability in water yield between hydrologic regions. The hydrologic regions have been delineated such that the hydrologic response will be essentially similar within each region, but different from region to region. Figure 1 in Appendix I shows the hydrologic regions (HR) for the NSRB, superimposed on the sub-basins delineated by the North Saskatchewan Watershed Alliance (NSWA). Within each hydrologic region, the average water yield was assumed to be essentially spatially uniform. Flow data series within each of these regions were analyzed to obtain average annual water yield, the standard deviation of the annual yields, and the mean monthly yields.

The delineation of the NSRB into seven HRs is based on the hydrologic regionalization work completed for Alberta Environment (AENV) by Golder in 2006 (Golder 2006). As part of that work, the Province of Alberta was classified into hydrologic regions (HR) on the basis of topography, climate, hydrology, drainage, geology, and soils. The classification of the province into hydrologic regions was undertaken in two steps. First, spatial patterns in a number of physiographic, geologic and climatic parameters were identified for the province. The major parameters included physiography, elevation, slope, geology, climate, temperature, precipitation (rainfall and snowfall) and evaporation. The second step in the regionalization process was to assess the similarity of the hydrologic responses of gauged watersheds using relationships between drainage area and mean annual runoff. Watersheds with similar responses were grouped within regions. Other hydrologic response measures such as the 2-year and 10-year flood flows, and mean February flows were also used in the regionalization process. The locations and spatial extents of the gauged watersheds were also considered in the delineation of the regions.

The delineation of the hydrologic regions was determined by comparing the spatial patterns in physiography, geology, climate and hydrologic responses. There were a number of iterations to manually adjust the boundaries of the hydrologic regions to account for the various factors influencing the hydrologic regimes of the various regions. The analysis of the hydrologic response patterns and physiographic-geologic-climate spatial patterns resulted in 20 hydrologic regions for the Province of Alberta that represent a reasonable accounting of the various factors influencing the hydrologic response of a watershed.

1.3.2 Effective and Gross Drainage Areas

A key aspect of the water yield assessment is the estimation of water yield in watersheds with non-contributing areas. This is especially relevant in the east-central and southern watersheds of Alberta. The prairie landscape in the south and eastern part of Alberta is characterized by areas with internal drainages, i.e., areas that do not drain to the main receiving stream, but instead drain to local sloughs or wetlands. The study of prairie hydrology makes a distinction between effective drainage area, which is the area that actually contributes runoff to the main receiving stream during a flood with a return period of two years, and gross drainage area, which is the area that could be contributing runoff only during extremely wet conditions and are delineated based on topography. The Prairie Farm and Rehabilitation Administration (PFRA) of Agriculture and Agri-Food Canada (AAFC) has delineated the non-contributing areas in the NSRB. Figure 2 in Appendix I shows the non-contributing areas in the NSRB. The non-contributing areas do not reflect agricultural drainages systems that may have been constructed to improve local runoff pathways and conditions.

The calculation of water yield for each hydrologic region (HR) in the NSRB was based on the effective drainage areas of gauged watersheds and on effective drainage areas within each hydrologic region (HR).

1.3.3 Data Analysis

The water yield analysis for the NSRB was based on the natural flow records at 34 hydrometric stations within the NSRB. Figure 1 in Appendix I shows the locations of the stations. Except for one headwater station, all other stations were on tributaries to the North Saskatchewan River (NSR) as the records at stations on the main stem of the NSR were generally for regulated flows.

Table 1 in Appendix II lists the stations used, the gross and effective drainage areas at each gauging site, the proportion of the drainage area of each gauged watershed in each hydrologic region it encompasses, the available period of record and the period of record used for the analysis. In several cases, the period of record used for the analysis is shorter than the available record. This results from an attempt to use records spanning approximately the same years for all stations within a hydrologic region so that any bias from using records spanning different wet and/or dry hydrologic cycles is small.

Table 1 in Appendix II indicates whether winter flow records are available at each gauging station. At stations where winter flows were not available for stations within a hydrologic region, the winter monthly yields were filled using a percentage of the mean annual runoff. The percentage used for the winter months was based on an approximate percentage derived for stations with recorded winter flows within the same hydrologic region.

For each station, the mean annual runoff (annual yield) and mean monthly runoff (monthly yield) were estimated from the period of record selected for analysis. Mean annual runoff is calculated as the mean of the annual mean flows (in m^3/s) recorded at a station multiplied by 1000, multiplied by the number of seconds in a year and then divided by the effective drainage area (in m^2). The mean annual runoff is then expressed in millimetres (mm). A similar approach is used for estimating the mean monthly runoff, with the time base being the number of seconds in a month. The standard deviation, coefficient of variation (standard deviation divided by mean) and coefficient of skewness (a measure of how asymmetrical the probability distribution of a variable such as monthly yield is when compared to the symmetrical normal distribution) of the annual yield and monthly yield were also calculated.

Table 1 in Appendix II shows that the annual yield or monthly yield at stations within the same hydrologic region can be different from one another. There are two reasons for the variability in yield between hydrometric stations within the same hydrologic region. One reason is simply that, even though the hydrologic response within a hydrologic region is expected to be similar, slight differences in lengths of record, differences in mean elevations of gauged watersheds even within a hydrologic region, and differences in slopes and geology can lead to slight differences in yield. The other reason is that, even though a gauging station may be located in one hydrologic region, its watershed may extend into two or more hydrologic regions. The yield from a watershed at the gauging site will therefore depend on the proportion of the watershed within each hydrologic region, and this proportion may be different between stations within the same hydrologic region.

The annual yield for each hydrologic region was estimated as the average of the annual yields of gauged watersheds located completely within the hydrologic region, if available. If the gauged watersheds span two or more hydrologic regions, the annual yield estimate for the downstream hydrologic region was estimated from the annual yield of the upstream hydrologic region, the combined yield at the gauging site and the proportion of the watershed in the downstream and upstream hydrologic regions. The annual yield of the most upstream hydrologic region (HR-3) was estimated first because the gauged watersheds in this region will be fully contained within HR-3. The analysis then proceeded to the next downstream hydrologic region (HR-4), using the annual yield of HR-3 where appropriate, and so on for the other downstream hydrologic regions.

The monthly yield distribution was determined by first estimating the average percentage of the annual yield at each station within a hydrologic region, with priority given to stations wholly contained within the hydrologic region and to stations with winter flow records. The average monthly percentage was then used with the annual yield estimated for a hydrologic region to estimate a typical monthly yield for that region.

The coefficients of variation and skewness for the annual yield of a hydrologic region were used to estimate the 10^{th}, 25^{th}, 75^{th} and 90^{th} percentiles on the basis that the annual yield series followed a log-normal distribution. The average monthly percentage derived previously was then used to distribute the annual yield across the twelve months of a year for each percentile.

The annual yield for each sub-basin as defined by NSWA was estimated from the annual yield of each hydrologic region that is included in the sub-basin and the proportion of each hydrologic region within the sub-basin. The annual yield calculations were done using effective drainage areas.

2. SURFACE WATER AVAILABILITY

The objective of this component of the project was to characterize the average water yield condition as well as its spatial and temporal variability in the North Saskatchewan River Basin (NSRB) and its major sub-basins as defined by the NSWA.

The North Saskatchewan River (NSR) begins in the ice fields of Banff and Jasper National Parks and generally flows east toward the Alberta-Saskatchewan boundary. The total area of the NSRB from its headwaters in the glaciers of Jasper and Banff National Parks on the eastern slopes of the Rocky Mountains to the prairie landscape along the Alberta-Saskatchewan boundary is about 57,000 km^2. Within Alberta, the Brazeau, Nordegg, Ram, Clearwater, Sturgeon and Vermilion rivers are the major tributaries to the NSR. The mean annual natural discharge of the NSR at the Alberta/Saskatchewan boundary is about 7,500,000 dam^3. The NSRB is part of the larger Nelson River system, which eventually drains into Hudson Bay.

The following sections provide the results of the data analysis undertaken for the water yield assessment. The approach for the data analysis is described in Section 1.3.

2.1 Hydro-Climatic Characteristics of the Hydrologic Regions of the NSRB

The hydrologic regions (HR) for the NSRB are shown in Figure 1 in Appendix I. The physiographic and hydro-climatic characteristics of the HRs are described in the following paragraphs.

HR-3: Hydrologic Region HR-3 trends northwest to southeast along the eastern slopes of the Rocky Mountains. HR-3 is ecologically classified as generally Alpine in upland areas and as Subalpine along river valleys. Ground elevation in HR-3 generally exceeds 2000 m (amsl), with average ground slope derived from digital elevation maps generally exceeding 2%.

HR-3 has the highest water yield in the NSRB. Mean annual temperature in this region is generally less than -1^oC at very high elevations and between 0 and 2^oC at lower elevations in this region. Mean annual precipitation in this region ranges from 450 to 500 mm along sheltered valley areas to over 600 mm outside of the valleys. Mean annual rainfall is between 250 and 300 mm, while mean annual snowfall can range between 200 and 800 mm. Mean annual evapotranspiration is generally less than 325 mm because of the low year-round temperatures at the high elevations. The high precipitation and low evapotranspiration result in HR-3 having the highest local mean annual water yield for the NSRB and is of the order of 870 mm.

HR-4: Hydrologic Region HR-4 is adjacent to and east of HR-3 with elevations between 1,500 m and 2,500 m (amsl). Average ground slopes derived from digital elevation maps are generally between 1 and 2.5%. HR-4 is ecologically classified as generally Subalpine, with Alpine areas at the higher elevations and Upper Foothills areas at the lower elevations.

HR-4 has the second highest water yield in the NSRB. Mean annual temperature in this region is generally between 0 and 3^{o}C. Mean annual precipitation in this region ranges from 450 to 500 mm along sheltered valley areas to over 600 mm outside of the valleys. Mean annual rainfall is between 300 and 400 mm, while mean annual snowfall can range between 150 and 200 mm, with smaller areas receiving up to 800 mm. Mean annual evapotranspiration is generally between 300 and 350 mm. The high precipitation and moderate evapotranspiration result in HR-4 having the second highest local mean annual water yield for the NSRB and is of the order of 250 mm.

HR-5: Hydrologic Region HR-5 is adjacent to and east of HR-4 with elevations between 1,000 m and 1,500 m (amsl). Average ground slopes derived from digital elevation maps are generally between 0.5 and 2%. HR-5 is ecologically classified as mostly Lower Foothills, with small Upper Foothills areas at the higher elevations.

HR-5 has a moderate to high water yield in the NSRB. Mean annual temperature in this region is generally between 2 and 5^{o}C. Mean annual precipitation in this region is quite high, exceeding 600 mm on most areas. Mean annual rainfall is between 400 and 500 mm, while mean annual snowfall can range between 150 and 200 mm. Mean annual evapotranspiration is generally between 345 and 385 mm. The high precipitation and moderate evapotranspiration result in HR-5 having a moderate to high local mean annual water yield for the NSRB and is of the order of 160 mm.

HR-10: Hydrologic Region HR-10 comprises only a small portion of the NSRB. HR-10 is in central Alberta and encompasses the Swan Hills area. Hydrologic Region HR-10 is ecologically classified as Lower Foothills. Ground elevation in HR-10 ranges from 800 to 1000 m (amsl). Average ground slope derived from digital elevation maps ranges from 0.25% to 1%.

HR-10 is characterized by low to moderate water yield. Mean annual temperature in this region ranges from 3 to 5^{o}C. Mean annual precipitation in this region ranges from 550 to 600 mm, of which mean annual rainfall is between 400 and 500 mm and mean annual snowfall is between 150 and 200 mm. Mean annual evapotranspiration generally ranges from 365 to 385 mm. More than 95% of the area of HR-10 contributes runoff to the NSR during years with average hydrologic conditions. The relatively moderate precipitation, moderate evapotranspiration and almost negligible percentage of non-contributing runoff areas result in HR-10 having a relatively low to moderate mean annual water yield of the order of 85 mm.

HR-8: Hydrologic Region HR-8 is located in central Alberta and encompasses primarily the plains region of the lower Athabasca River watershed. HR-8 also comprises the middle sections of the NSRB and the Red Deer River Basin. Hydrologic Region HR-8 has a range of ecological regions, from the Lower Foothills at higher elevations, Central Mixedwood in the central section of the region, to Dry Mixedwood in the eastern-most section. Ground elevation in HR-8 ranges from 600 to 1000 m (amsl). Average ground slope derived from digital elevation maps ranges from 0.25% to 1%.

HR-8 is characterized by low to moderate water yield. Mean annual temperature in this region ranges from 2 to 5^{o}C. Mean annual precipitation in this region ranges from 500 to 550 mm, of which mean annual rainfall is between 360 and 500 mm and mean annual snowfall is between 100 and 150 mm. Mean annual evapotranspiration generally ranges from 365 to 425 mm. About 95% of the area of HR-8 contributes runoff to the NSR during years with average hydrologic conditions. The relatively moderate precipitation, high evapotranspiration and small percentage of non-contributing runoff areas result in HR-8 having a relatively low to moderate mean annual water yield of the order of 65 mm.

HR-2C: Hydrologic Region HR-2C is ecologically classified as mostly Central Parkland, with some Dry Mixedwood areas. Ground elevation in HR-1C ranges from 600 to 800 m (amsl). Average ground slope derived from digital elevation maps is mild and generally less than 0.25%.

HR-2C is characterized by relatively low water yield. Mean annual temperature in this region ranges from 2 to 5^{o}C. Mean annual precipitation in this region ranges from 450 to 500 mm, of which mean annual rainfall is between 300 and 400 mm and mean annual snowfall is between 100 and 125 mm. Mean annual evapotranspiration generally ranges from 365 to 425 mm. About 65% of the area of HR-2C contributes runoff to the NSR during years with average hydrologic conditions. The low precipitation, high evapotranspiration and moderately high percentage of non-contributing runoff areas result in HR-2C having a relatively low local mean annual water yield of the order of 35 mm.

HR-1C: Hydrologic Region HR-1C is the northern part of HR-1 that encompasses the prairies and lower portions of the South Saskatchewan River, Red Deer River, Battle River and North Saskatchewan River watersheds. The ecological classification of the lower section of HR-1C within the NSRB is Central Parkland, while the upper section is classified as Dry Mixedwood. Ground elevation in HR-1C ranges from 800 m (amsl) along the western edge of the region to about 400 m along the river valley near the Alberta-Saskatchewan boundary. Average ground slope derived from digital elevation maps is mild and generally less than 0.25%.

HR-1C is characterized by very low water yield. Mean annual temperature ranges from 0 to 2^{o}C in the northern section of the region and from 2 to 3^{o}C in the central-western section of the region. Mean annual precipitation in this region ranges from 400 to 450 mm, of which mean annual rainfall is between 300 and 360 mm and mean annual snowfall is between 35 and 125 mm. Mean annual evapotranspiration generally exceeds

400 mm. Less than 50% of the area of HR-1C contributes runoff to the NSR during years with average hydrologic conditions. The low precipitation, high evapotranspiration and high percentage of non-contributing runoff areas result in HR-1C having a very low local mean annual water yield of the order of 25 mm.

2.2 Annual and Monthly Yield and Volumes from Hydrologic Regions

The upper portion of Table 2-1 in Appendix II shows the average annual and monthly yield estimates from each hydrologic region in the NSRB. Table 2-2 in Appendix II shows the same information as annual and monthly flow volumes in units of million cubic metres. Figure 3 in Appendix I shows a map of the mean annual runoff (annual yield) and mean annual volume from each hydrologic region. Hydrologic region HR-3 has the highest annual yield at 870 mm, while the hydrologic regions HR-2C and HR-1C have the lowest annual yields at 35 mm and 25 mm, respectively. These low yields are a reflection of the low precipitation, relatively higher temperature and higher evapotranspiration, and large non-contributing areas in the eastern half of the NSRB. Table 2-1 and Table 2-2 in Appendix II show that most of the water yield or volume in the NSRB is generated from the first two or three hydrologic regions of the NSRB.

The last column of Table 2-1 in Appendix II shows the cumulative annual yield, that is, the amount of runoff that shows up in the main stem of the NSR from the most upstream to the most downstream hydrologic region. The middle portion of Table 2-1 in Appendix II shows the cumulative monthly yield for each month. Table 2-2 in Appendix II provides the same information as cumulative annual and monthly flow volumes in units of million cubic metres.

The figure below Table 2-1 in Appendix II illustrates the monthly yield from each hydrologic region as a percentage of the annual yield. The figure also illustrates the monthly percentage of the cumulative yield in the NSR at the Alberta/Saskatchewan boundary. The figure in Table 2-1 demonstrates that the peak monthly yield from the hydrologic regions in the eastern half of the NSRB occurs in April as a result of snow melt as temperatures begin to increase in spring. In contrast, the peak monthly yield from the hydrologic regions in the western half of the NSRB, particularly those along the eastern slopes of the Rocky Mountains, occur in July because of the gradual rise in temperature during spring and early summer at these high elevations.

The peak monthly cumulative yield at the Alberta/Saskatchewan boundary occurs in July and seems to follow the pattern shown by the hydrologic regions in the western half of the NSRB. This is an expected result as the western hydrologic regions generate most of the yield in the NSRB. Table 2-2 in Appendix II shows that hydrologic region HR-3 contributes almost half (3,600 million m^3) of the annual cumulative yield of the NSRB at the provincial boundary (about 7,510 million m^3). In fact, the portion of the NSRB downstream of Edmonton contributes less than 300 million m^3 of flow volume to the annual cumulative yield of the NSRB at the provincial boundary.

2.3 Annual Yield from Sub-Basins

Figure 1 in Appendix I shows the sub-basins of the NSRB as defined by the NSWA. Some of the sub-basins span more than one hydrologic region. For example, the Ram sub-basin spans hydrologic regions HR-3, HR-4, HR-5, HR-10 and HR-8. The results presented in Section 2.2 can be used to estimate the annual yield from each of these sub-basins individually. The proportion of each sub-basin that falls within the various hydrologic regions that it encompasses is first estimated. The annual yield from the sub-basin is then the area-weighted annual yield of all the hydrologic regions crossed by the sub-basin. Effective areas are used wherever the non-contributing areas are significant. The annual yields from each sub-basin are then cumulated to estimate the cumulative yield at the junction of two or more sub-basins, and further downstream until the Alberta/Saskatchewan boundary. Table 3 in Appendix II shows the results of the annual yield and volume analysis for the sub-basins. The cumulative annual yield or volume at the Alberta/Saskatchewan boundary is 179 mm or about 7,510 million m^3, which is the same as the cumulative annual yield or volume shown in Table 2-1 and Table 2-2 in Appendix II.

The analysis discussed for the sub-basins can be used in the same manner for any watershed within the NSRB.

2.4 Variability in Annual and Monthly Yield from Hydrologic Regions

Table 1 in Appendix I provides the mean annual runoff for each hydrologic region as well as an estimate of the coefficient of variation (CV, which is the standard deviation of the annual yields divided by the mean annual yield) and the coefficient of skewness (CS, which is a measure of the direction and magnitude of the asymmetry of a probability distribution). Table 1 shows that CV and CS tend to increase from hydrologic regions on the western portion of the NSRB to eastern hydrologic regions. CS tends to be positive, that is, the probability distribution of annual yield is skewed to the right. This pattern is a reflection of the relatively much larger variability expected in the hydrologic response of drier areas.

The coefficients of variation and skewness for the annual yield of a hydrologic region were used to estimate the 10^{th}, 25^{th}, 75^{th} and 90^{th} percentiles on the basis that the annual yield series followed a log-normal distribution. The average monthly percentage derived previously was then used to distribute the annual volumes across the twelve months of a year for each percentile. Table 4 in Appendix II shows the average case (same as Table 2-2), 10^{th}, 25^{th}, 75^{th} and 90^{th} percentiles of the annual volumes from each hydrologic region, the cumulative volumes along the NSR and the monthly volumes. Table 5 shows similar results for each sub-basin individually (annual and monthly volumes), and cumulatively (annual volumes).

Table 2-1 in Appendix II indicates that the cumulative annual yield at the Alberta/Saskatchewan boundary is 179 mm for average hydrologic conditions. The cumulative annual yield at the same location for the 10^{th}, 25^{th}, 75^{th} and 90^{th} percentile conditions are 122, 142, 205 and 248 mm, respectively.

2.5 Validation of Yield Estimates

The cumulative annual yield estimates along the NSR that are provided in Table 5 are based on the area-weighted summation of yields from each contributing sub-basin within the hydrologic regions of the NSRB. Recorded flows on the NSR at WSC stations 05DF001 (North Saskatchewan River at Edmonton) and 05EF001 (North Saskatchewan River near Deer Creek) were used to validate the yield estimates.

Station 05DF001 is located close to the downstream outlet of the Strawberry sub-basin. The gross drainage area of the NSRB at 05DF001 is 28,100 km^2, and the effective drainage area is 27,100 km^2. The cumulative gross and effective drainage areas of the NRSB at the outlet of the Strawberry sub-basin are 28,040 and 27,040 km^2, respectively. The flow record at 05DF001 spans from 1911 to 2008, however, flows in the NSR became significantly regulated by power projects and other activities from 1960 onwards. Therefore, the natural flow record for the NSR from 1911 to 1959 only was used for deriving mean annual yield and selected percentiles of the yield. The results indicate that the mean annual yield from the natural flow record at 05DF001 is 255 mm based on effective drainage area. This value compares well with the cumulative mean annual yield of 262 mm estimated at Strawberry. Similarly the 10th, 25th, 75th and 90th percentile annual yields estimated from the natural flow records at 05DF001 (195 mm, 207 mm, 299 mm, 336 mm, respectively) compare well with the cumulative 10th, 25th, 75th and 90th percentile yields derived at Strawberry (191 mm, 219 mm, 306 mm, 360 mm, respectively, from yields of hydrologic regions comprising the NSRB.

Station 05EF001 is located close to Alberta-Saskatchewan boundary and near the downstream outlet of the Monnery sub-basin. The gross drainage area of the NSRB at 05EF001 is 56,818 km^2, and the effective drainage area is 42,700 km^2. The cumulative gross and effective drainage areas of the NRSB at the outlet of the Monnery sub-basin are 56,860 and 41,960 km^2, respectively. The flow record at 05EF001 spans from 1917 to 2006, however, flows in the NSR became significantly regulated by power projects and other activities from 1960 onwards. In addition, only a few sporadic years of natural flow records are available prior to 1960. These were not deemed sufficient for estimate percentiles of annual yield at this station. Instead, the entire flow record was used to estimate the mean annual yield, on the assumption that the effects of regulation due to power projects will not be significant on the total annual flow volumes. The effects of consumptive uses are not known. Nevertheless, an approximate value of the mean annual yield at 05EF001 is estimated to be 173 mm, which again compares well with the cumulative mean annual yield of 179 mm (based on cumulated yield from sub-basins and yield from hydrologic regions) near Monnery at the Alberta-Saskatchewan boundary.

The results of an analysis of flow records on the NSR indicate that the approach and results of the water supply assessment for the NSRB as described above are valid. The validation also suggests that the assumption that the entire NRSB is experiencing similar hydrologic conditions, the assumption on which cumulative yield estimates for selected percentiles are derived, is valid to some degree. The rationale is that the relatively small headwater areas of the NSRB generate almost 90% of the mean annual flow volume and are expected to be similarly affected spatially by dry or wet hydrologic conditions. The relatively insignificant contribution of the areas east of

Edmonton to annual yield suggests that the flows in the NSR downstream of Edmonton will essentially reflect the upstream hydrologic conditions.

2.6 Summary

Natural flow records at gauges within the NSRB have been used to develop tables and maps of natural annual and monthly yields from hydrologic regions contributing runoff to the NSR under average hydrologic conditions. The year-to-year variability in annual yield has been characterized in terms of the coefficient of variation and coefficient of skewness of the annual yield series. The information can be used to estimate the monthly and annual yield from any portion of the NSRB and cumulative annual and monthly yield in the NSR for average hydrologic conditions and for hydrologic conditions that are drier or wetter than average conditions.

3. CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

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Report prepared by:

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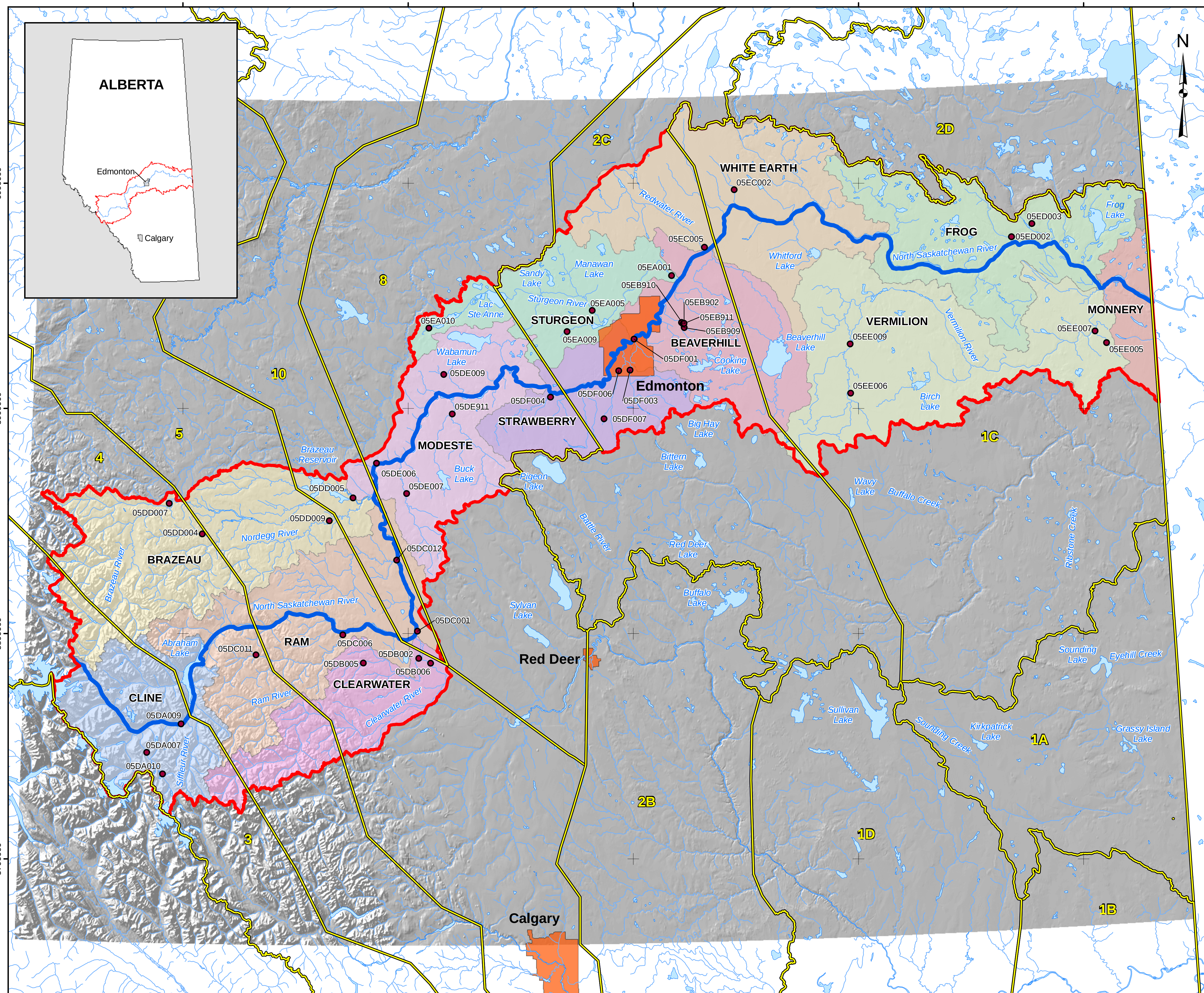
REFERENCES

Golder Associates Ltd. (Golder). 2006. HYDROLOGIC REGIONS OF ALBERTA. Report submitted to Alberta Environment, March 2006.

APPENDIX I

FIGURES - GIS MAPS PRODUCED FOR REPORT



LEGEND

- HYDROMETRIC STATION
- NORTH SASKATCHEWAN RIVER
- WATERCOURSE
- HYDROLOGIC REGION
- WATERSHED
- CITY
- WATERBODY

SUB-BASINS

- BEAVERHILL
- BRAZEAU
- CLEARWATER
- CLINE
- FROG
- MODESTE
- MONNERY
- RAM
- STRAWBERRY
- STURGEON
- VERMILION
- WHITE EARTH

REFERENCE

Digital base data and digital elevation data obtained from Natural Resources Canada. Watersheds obtained from Prairie Farm Rehabilitation Administration, used under license. Hydrometric stations and hydrologic regions obtained from Alberta Environment.
Projection: Alberta 10TM False Easting 500,000 at 115° W. Datum: NAD 83

50 0 50

SCALE 1:1,750,000 KILOMETRES

PROJECT
NORTH SASKATCHEWAN WATERSHED ALLIANCE
WATER SUPPLY ASSESSMENT FOR THE
NORTH SASKATCHEWAN RIVER BASIN

TITLE
HYDROLOGIC REGIONS AND SUB-BASINS OF THE NORTH SASKATCHEWAN RIVER BASIN

Golder Associates
Calgary, Alberta

PROJECT NO. 08-1337-0001			SCALE AS SHOWN	REV. 0
DESIGN	AB	13 Mar. 2008		
GIS	RLP	15 Apr. 2008		
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REVIEW	AB	17 Apr. 2008		

FIGURE: 1

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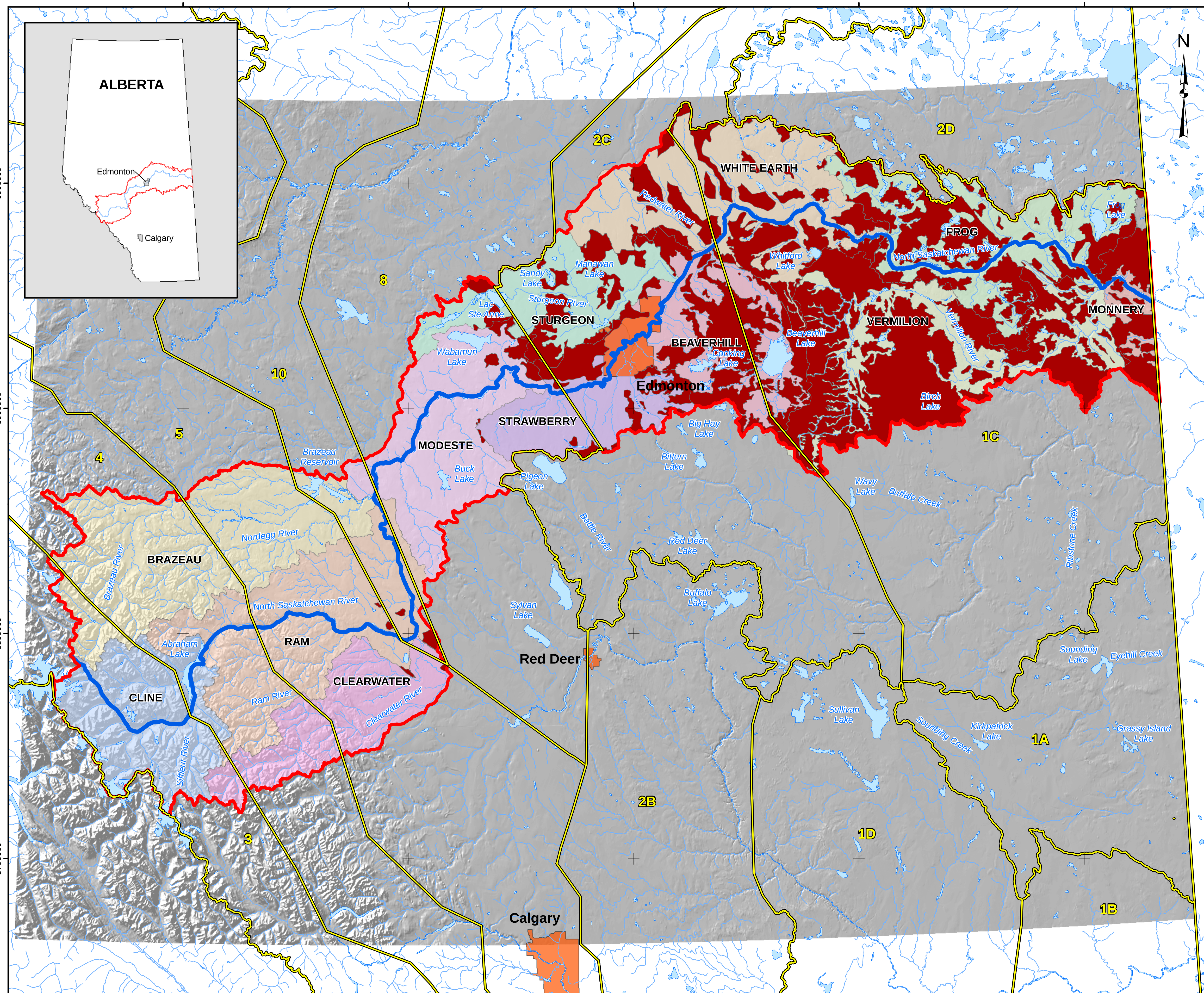

LEGEND

- NORTH SASKATCHEWAN RIVER
- WATERCOURSE
- HYDROLOGIC REGION
- WATERSHED
- NON-CONTRIBUTING AREA
- CITY
- WATERBODY

SUB-BASINS

- BEAVERHILL
- BRAZEAU
- CLEARWATER
- CLINE
- FROG
- MODESTE
- MONNERY
- RAM
- STRAWBERRY
- STURGEON
- VERMILION
- WHITE EARTH

REFERENCE

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50 0 50

SCALE 1:1,750,000 KILOMETRES

PROJECT

NORTH SASKATCHEWAN WATERSHED ALLIANCE
WATER SUPPLY ASSESSMENT FOR THE
NORTH SASKATCHEWAN RIVER BASIN

TITLE

NON-CONTRIBUTING AREAS IN THE NORTH SASKATCHEWAN RIVER BASIN

Golder Associates
Calgary, Alberta

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FIGURE: 2

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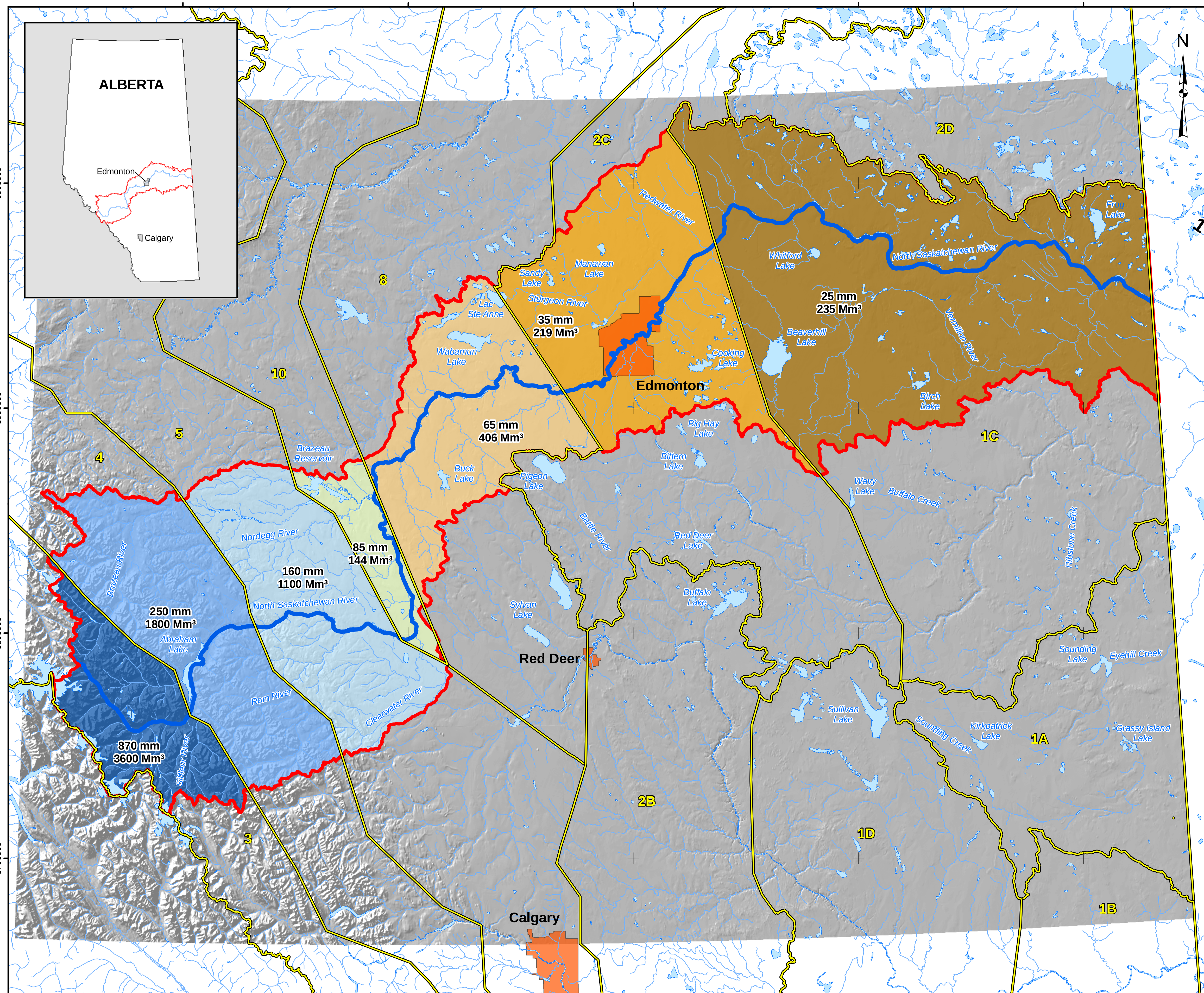

LEGEND

- NORTH SASKATCHEWAN RIVER
- WATERCOURSE
- HYDROLOGIC REGION
- WATERSHED
- CITY
- WATERBODY

HYDROLOGIC REGION MEAN ANNUAL RUNOFF (mm) AND MEAN ANNUAL FLOW (million m³)

- HR - 1C = 25 mm / 235 Mm³
- HR - 2C = 35 mm / 219 Mm³
- HR - 8 = 65 mm / 406 Mm³
- HR - 10 = 85 mm / 144 Mm³
- HR - 5 = 160 mm / 1100 Mm³
- HR - 4 = 250 mm / 1800 Mm³
- HR - 3 = 870mm / 3600 Mm³

REFERENCE

Digital base data and digital elevation data obtained from Natural Resources Canada. Watersheds obtained from Prairie Farm Rehabilitation Administration, used under license. Hydrologic regions obtained from Alberta Environment.
Projection: Alberta 10TM False Easting 500,000 at 115° W. Datum: NAD 83

50 0 50
SCALE 1:1,750,000 KILOMETRES

PROJECT
NORTH SASKATCHEWAN WATERSHED ALLIANCE
WATER SUPPLY ASSESSMENT FOR THE
NORTH SASKATCHEWAN RIVER BASIN

TITLE
NORTH SASKATCHEWAN RIVER BASIN MEAN ANNUAL RUNOFF (mm) AND MEAN ANNUAL FLOW (million m³) FROM HYDROLOGIC REGIONS

Golder Associates
Calgary, Alberta

PROJECT NO. 08-1337-0001			SCALE AS SHOWN	REV. 0
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FIGURE: 3

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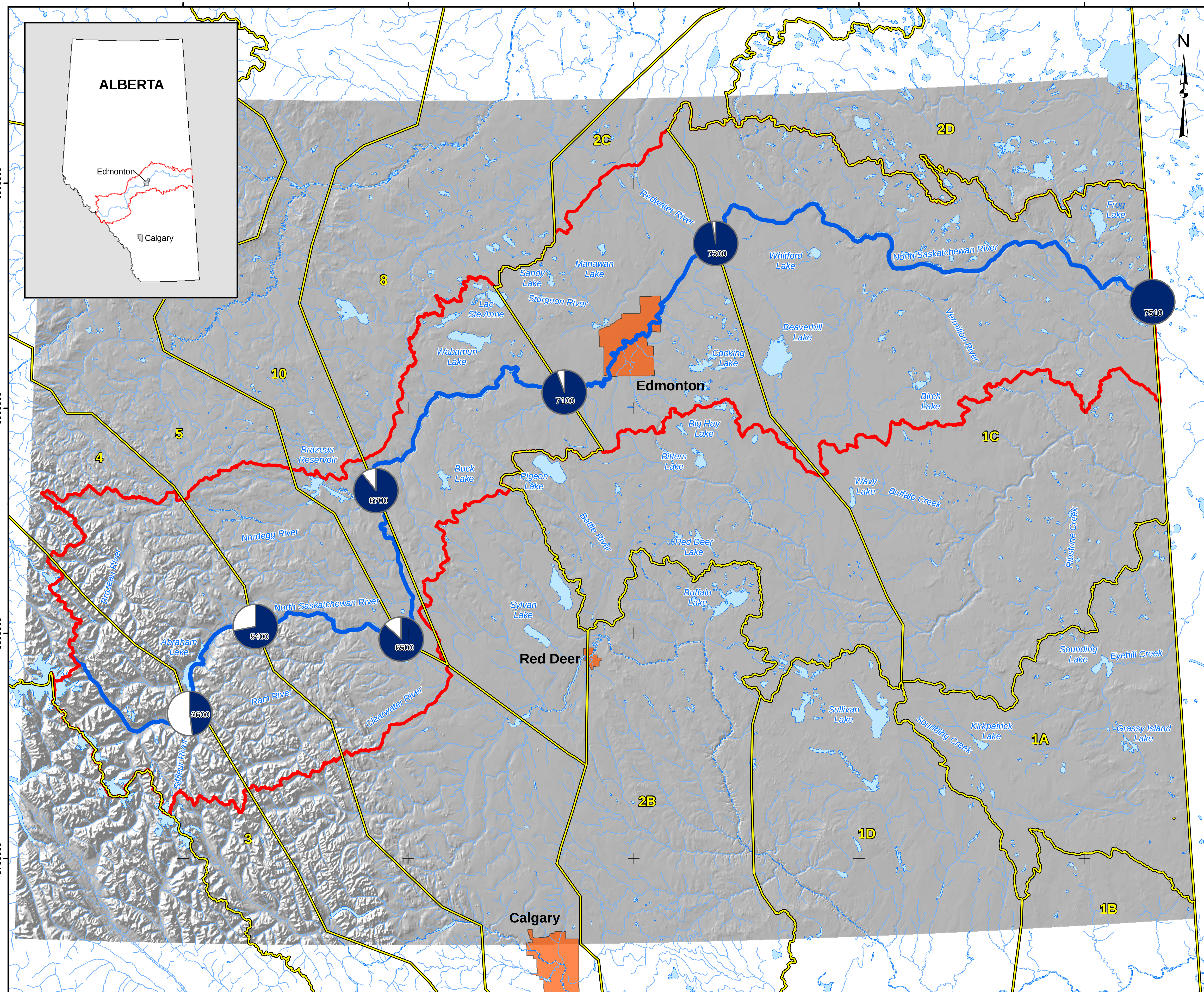

LEGEND

- NORTH SASKATCHEWAN RIVER
- WATERCOURSE
- HYDROLOGIC REGION
- WATERSHED
- CITY
- WATERBODY
- 4600 — PROPORTION OF CUMULATIVE MEAN ANNUAL FLOW (CMAF) COMPARED WITH THAT OF MOST DOWNSTREAM LOCATION (VALUE INDICATES CMAF IN million m³)

REFERENCE

Digital base data and digital elevation data obtained from Natural Resources Canada. Watersheds obtained from Prairie Farm Rehabilitation Administration, used under license. Hydrologic regions obtained from Alberta Environment.
Projection: Alberta 10TM False Easting 500,000 at 115° W. Datum: NAD 83

50 0 50

SCALE 1:1,750,000 KILOMETRES

PROJECT NORTH SASKATCHEWAN WATERSHED ALLIANCE
WATER SUPPLY ASSESSMENT FOR THE
NORTH SASKATCHEWAN RIVER BASIN

TITLE **NORTH SASKATCHEWAN RIVER BASIN**
CUMULATIVE MEAN ANNUAL FLOW (million m³)
FROM HYDROLOGIC REGIONS

Golder Associates
Calgary, Alberta

PROJECT NO. 08-1337-0001			SCALE AS SHOWN	REV. 0
DESIGN	AB	13 Mar. 2008	**FIGURE: 4**	
GIS	RLP	15 Apr. 2008		
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REVIEW	AB	17 Apr. 2008		

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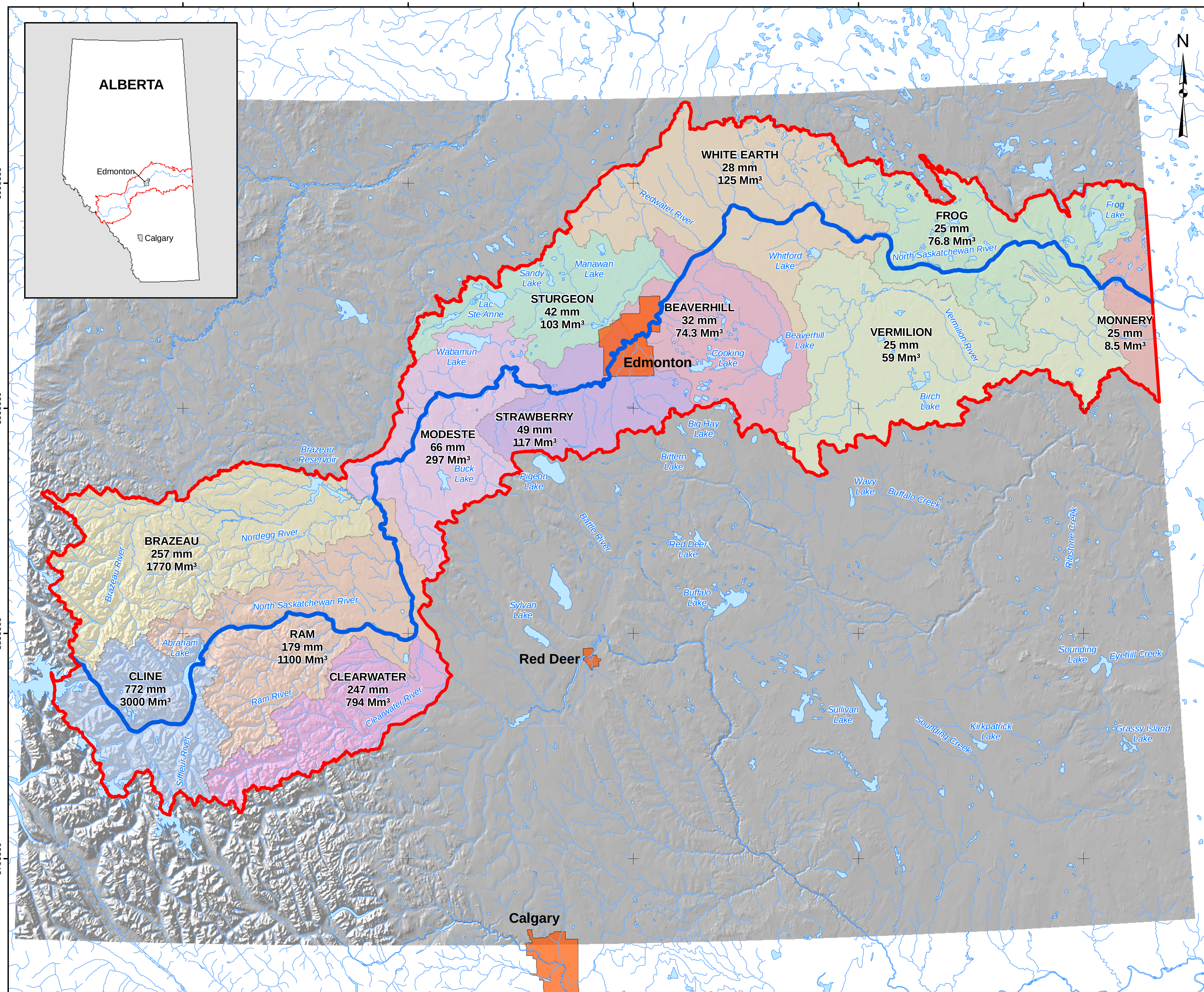

LEGEND

- NORTH SASKATCHEWAN RIVER
- WATERCOURSE
- WATERSHED
- CITY
- WATERBODY

SUB-BASIN MEAN ANNUAL RUNOFF (mm) AND MEAN ANNUAL FLOW (million m³)

- BEAVERHILL = 32 mm / 74.3 Mm³
- BRAZEAU = 257 mm / 1770 Mm³
- CLEARWATER = 247 mm / 794 Mm³
- CLINE = 772 mm / 3000 Mm³
- FROG = 25 mm / 76.8 Mm³
- MODESTE = 66 mm / 297 Mm³
- MONNERY = 25 mm / 8.5 Mm³
- RAM = 179 mm / 1100 Mm³
- STRAWBERRY = 49 mm / 117 Mm³
- STURGEON = 42 mm/103 Mm³
- VERMILION = 25 mm / 59 Mm³
- WHITE EARTH = 28 mm / 125 Mm³

REFERENCE

Digital base data and digital elevation data obtained from Natural Resources Canada. Watersheds obtained from Prairie Farm Rehabilitation Administration, used under license. Hydrologic regions obtained from Alberta Environment. Projection: Alberta 10TM False Easting 500,000 at 115° W. Datum: NAD 83

50 0 50

SCALE 1:1,750,000 KILOMETRES

PROJECT: NORTH SASKATCHEWAN WATERSHED ALLIANCE WATER SUPPLY ASSESSMENT FOR THE NORTH SASKATCHEWAN RIVER BASIN

TITLE: NORTH SASKATCHEWAN RIVER BASIN MEAN ANNUAL RUNOFF (mm) AND MEAN ANNUAL FLOW (million m³) FROM SUB-BASINS

Golder Associates
Calgary, Alberta

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DESIGN	AB	13 Mar. 2008		
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CHECK	LC	17 Apr. 2008		
REVIEW	AB	17 Apr. 2008		

FIGURE: 5

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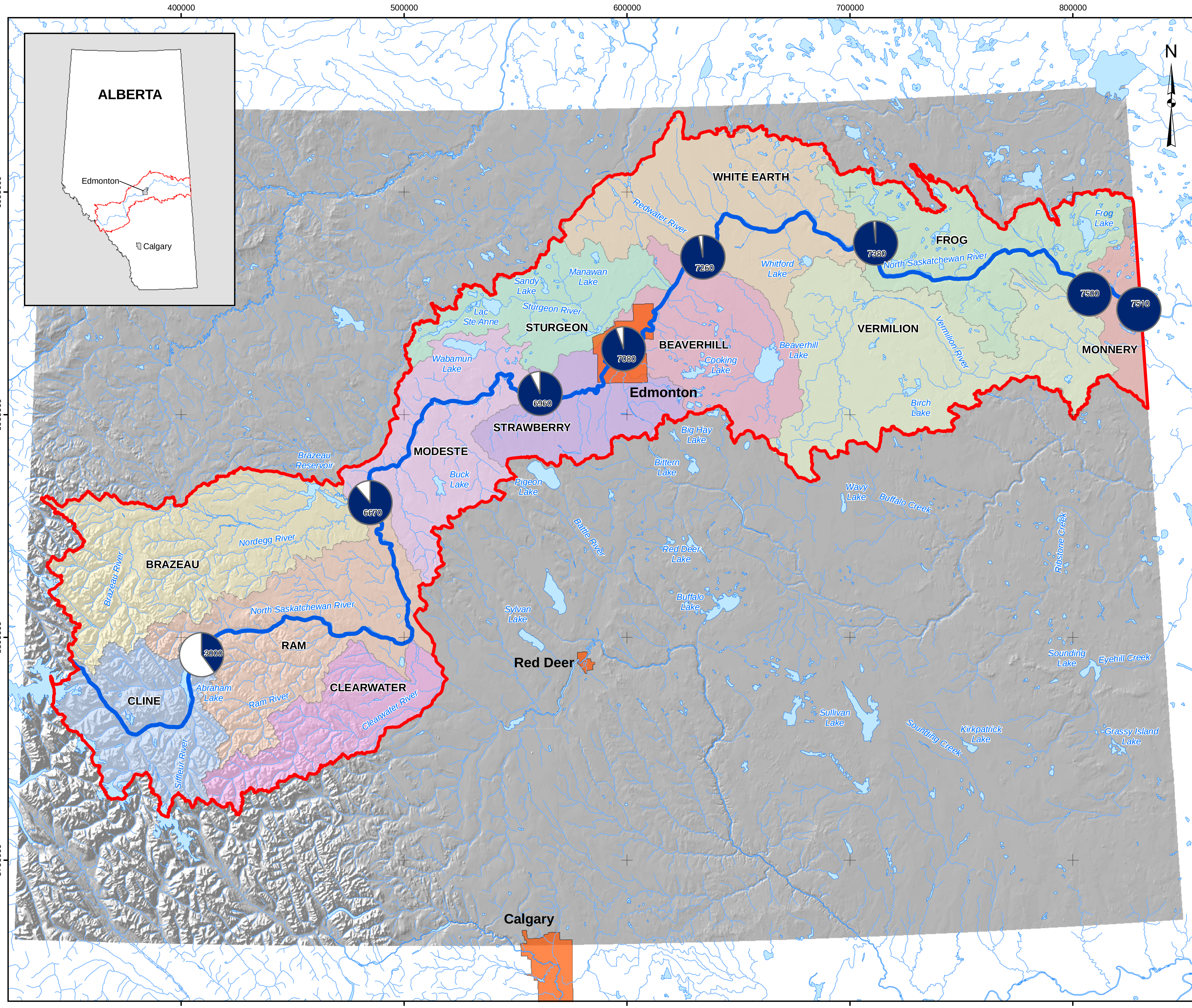

LEGEND

- NORTH SASKATCHEWAN RIVER
- WATERCOURSE
- WATERSHED
- CITY
- WATERBODY

SUB-BASINS

- BEAVERHILL
- BRAZEAU
- CLEARWATER
- CLINE
- FROG
- MODESTE
- MONNERY
- RAM
- STRAWBERRY
- STURGEON
- VERMILION
- WHITE EARTH

4600 — PROPORTION OF CUMULATIVE MEAN ANNUAL FLOW (CMAF) COMPARED WITH THAT OF MOST DOWNSTREAM LOCATION (VALUE INDICATES CMAF IN million m³)

REFERENCE

Digital base data and digital elevation data obtained from Natural Resources Canada. Watersheds obtained from Prairie Farm Rehabilitation Administration, used under license. Hydrologic regions obtained from Alberta Environment. Projection: Alberta 10TM False Easting 500,000 at 115° W. Datum: NAD 83

50 0 50

SCALE 1:1,750,000 KILOMETRES

PROJECT
NORTH SASKATCHEWAN WATERSHED ALLIANCE
WATER SUPPLY ASSESSMENT FOR THE
NORTH SASKATCHEWAN RIVER BASIN

TITLE
NORTH SASKATCHEWAN RIVER BASIN
CUMULATIVE MEAN ANNUAL FLOW (million m³)
FROM SUB-BASINS

Golder Associates
Calgary, Alberta

PROJECT NO. 08-1337-0001			SCALE AS SHOWN	REV. 0
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REVIEW	AB	17 Apr. 2008		

FIGURE: 6

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APPENDIX II

TABLES – HYDROMETRIC STATIONS, HYDROLOGIC REGIONS AND SUB-BASINS, YIELD AND RUNOFF VOLUMES

Table 1 North Saskatchewan River Basin - Runoff Statistics at Hydrometric Stations and Hydrologic Regions - Average Case

Hydrologic Region	Gross Area (km²)	Effective Area (km²)	Hydrometric Station	Station Name	Latitude (ddmmss)	Longitude (ddmmss)	Gross Drainage Area (km²)	Effective Drainage Area (km²)	Percent of Hydrologic Region Contributing to Station (HR-%)	Actual Record Length	Regulation and Period	Is it on the main stem?	Start Year for Analysis	End Year for Analysis	Years with no winter flow	Flow Statistics	Monthly Runoff Statistics Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual (mm)	winter runoff / annual runoff %	Estimated Mean Annual Runoff (mm)	Average Mean Annual Runoff (mm)	Cumulative Mean Annual Runoff (mm)	Average CV & CS for Annual Yield
3	4,110	4,110	05DA009	NORTH SASKATCHEWAN RIVER AT WHIRLPOOL POINT	520006	1162810	1920	1920	3-100	50-06	Natural	Yes	1972	2006	NA	Mean (mm)	7.88	6.50	7.08	11.6	63.0	178	237	204	92.7	36.3	15.0	10.4	869			870	870	0.12
																STD (mm)	1.19	0.86	0.81	3.61	27.3	39.0	34.7	38.7	22.2	10.4	3.38	1.76	83.6					0.28
																CV	0.15	0.13	0.11	0.31	0.43	0.22	0.15	0.19	0.24	0.29	0.23	0.17	0.10					
																CS	-0.34	0.60	0.12	1.34	0.75	0.22	-0.36	0.25	0.45	1.23	0.58	0.48	0.16					
			05DA007	MISTAYA RIVER NEAR SASKATCHEWAN CROSSING	515304	1164117	248	248	3-100	70-06	Natural	No	1972	2006	NA	Mean (mm)	7.92	6.14	6.96	11.9	64.9	167	216	174	84.4	36.7	18.0	11.0	805					
																STD (mm)	1.31	1.18	1.53	4.38	25.2	36.8	28.7	29.4	20.4	10.5	5.09	2.07	67.6					
																CV	0.17	0.19	0.22	0.37	0.39	0.22	0.13	0.17	0.24	0.29	0.28	0.19	0.08					
																CS	-0.03	0.18	-0.12	1.10	0.64	0.02	-0.22	0.17	1.06	2.12	0.68	0.38	-0.17					
			05DA010	SILVERHORN CREEK NEAR THE MOUTH	514800	1163459	21	21	3-100	71-06	Natural	No	1972	2006	NA	Mean (mm)	6.95	5.24	5.30	8.56	62.8	178	192	93.6	50.9	25.6	12.5	8.58	647					
																STD (mm)	2.03	1.32	2.24	4.79	32.5	56.3	72.1	28.8	17.9	9.39	3.80	2.40	109					
																CV	0.29	0.25	0.42	0.56	0.52	0.32	0.38	0.31	0.35	0.37	0.30	0.28	0.17					
																CS	0.40	0.31	1.89	0.92	1.09	0.47	0.75	1.30	1.71	1.18	0.22	0.49	0.84					
																% of annual runoff	1%	1%	1%	1%	7%	20%	27%	24%	11%	4%	2%	1%						
																Monthly runoff (mm)	7.89	6.51	7.09	11.6	63.1	178	237	204	92.8	36.3	15.0	10.4						
4	7,330	7,330	05DD007	BRAZEAU RIVER BELOW CARDINAL RIVER	525250	1163440	2600	2600	4-100	1961-65 / 1971-07	Natural	No	1972	2007	1972-2007	Mean (mm)					39.5	90.4	86.4	63.4	39.5	25.7			413	16%	411	250	473	0.36
																STD (mm)					13.0	29.4	26.6	18.8	10.6	5.29			86.4					0.52
																CV					0.33	0.32	0.31	0.30	0.27	0.21			0.21					
																CS					0.71	0.78	1.07	0.74	0.23	-0.18			0.52					
			05DD004	BROWN CREEK AT FORESTRY ROAD	524540	1162120	219	219	4-100	1915-07	Natural	No	1974	2007	1974-2007	Mean (mm)					39.7	56.4	49.4	30.3	21.5	12.2			248	16%	249			
																STD (mm)					19.7	41.0	45.4	26.9	18.1	6.71			112					
																CV					0.50	0.73	0.92	0.89	0.84	0.55			0.45					
																CS					0.88	2.17	2.22	2.07	1.52	0.88			0.53					
			05DC011	NORTH RAM RIVER AT FORESTRY ROAD	521655	1155930	347	347	4-100	1975-07	Natural	No	1976	2007	1976-2007	Mean (mm)					20.8	49.2	44.6	24.1	19.2	12.9			204	16%	203			
																STD (mm)					14.5	33.1	33.4	12.0	12.3	6.76			84.9					
																CV					0.70	0.67	0.75	0.50	0.64	0.52			0.42					
																CS					1.16	1.37	1.71	0.78	1.38	1.96			0.51					
																% of annual runoff	2%	2%	2%	5%	16%	23%	20%	12%	9%	5%	3%	2%						
																Monthly runoff (mm)	4.98	4.98	4.98	12.4	39.8	56.6	49.6	30.4	21.6	12.2	7.46	4.98						
5	6,980	6,950	05DB002	PRAIRIE CREEK NEAR ROCKY MOUNTAIN HOUSE	521620	1145550	844	844	5-100	22-06	Natural	No	1973	2006	NA	Mean (mm)	5.20	4.42	5.89	11.9	19.2	24.5	28.5	18.4	16.4	12.7	8.41	6.57	162			160	355	0.42
																STD (mm)	1.67	1.13	1.69	5.19	11.5	19.5	24.6	10.1	11.2	6.71	3.50	2.33	64.4					1.12
																CV	0.32	0.26	0.29	0.44	0.60	0.80	0.86	0.55	0.69	0.53	0.42	0.35	0.40					
																CS	1.44	1.27	1.03	1.82	1.41	2.99	1.92	1.28	2.51	2.07	1.50	1.34	1.37					
			05DB005	PRAIRIE CREEK BELOW LICK CREEK	521510	1151730	208	208	5-100	73-07	Natural	No	1973	2007	1973-2007	Mean (mm)			4.63	13.4	32.1	40.6	37.5	22.1	20.1	13.9			218	15%	217			
																STD (mm)			1.70	8.11	21.2	38.0	31.0	12.4	15.3	7.73			96.7					
																CV			0.37	0.61	0.66	0.94	0.83	0.56	0.76	0.56			0.44					
																CS			0.65	2.51	1.00	3.04	1.62	1.26	1.82	1.92			1.24					
			05DB006	CLEARWATER RIVER NEAR DOVERCOURT	521509	1145114	2250	2250	3-10, 4-40, 5-50	75-06	Natural	No	1976	2006	NA	Mean (mm)	5.93	5.50	7.13	11.0	23.2	46.6	46.6	32.6	24.1	17.3	10.6	7.13	238					
																STD (mm)	1.62	1.14	1.92	3.17	10.2	25.8	21.9	11.2	8.90	5.55	2.64	2.22	62.5					
																CV	0.27	0.21	0.27	0.29	0.44	0.55	0.47	0.34	0.37	0.32	0.25	0.31	0.26					
																CS	0.35	0.57	-0.04	2.71	1.27	2.16	1.31	1.26	1.57	1.83	0.87	-0.09	0.99					
			05DC006	RAM RIVER NEAR THE MOUTH	522155	1152533	1850	1850	4-70, 5-30	1967-06	Natural	No	1976	2006	NA	Mean (mm)	4.88	4.10	4.98	10.3	33.7	60.5	50.3	29.3	23.3	16.2	8.66	6.39	252					
																STD (mm)	1.02	0.77	1.34	3.86	17.1	40.4	33.5	13.0	12.9	6.47	2.62	1.54	80.2					
																CV	0.21	0.19	0.27	0.38	0.51	0.67	0.67	0.44	0.56	0.40	0.30	0.24	0.32					
																CS	0.90	0.36	1.14	1.78	0.89	2.14	1.62	0.95	1.55	1.13	0.89	-0.07	0.93					
			05DD009	NORDEGG RIVER AT SUNCHILD ROAD	524913	1153110	876	876	4-10, 5-90	1971-06	Natural	No	1972	2006	NA	Mean (mm)	2.94	2.63	3.27	12.2	29.3	32.8	36.5	18.6	16.3	11.5	5.69	3.95	176					
																STD (mm)	1.19	0.95	1.42	7.11	17.3	24.7	35.7	13.8	12.2	7.72	2.71	1.50	74.7					
																CV	0.41	0.36	0.43	0.58	0.59	0.75	0.98	0.74	0.75	0.67	0.48	0.38	0.43					
																CS	0.48	0.28	1.40	1.22	1.13	1.71	1.87	2.98	1.50	2.58	1.34	0.79	0.73					
																% of annual runoff	3%	3%	4%	7%	12%	15%	18%	11%	10%	8%	5%	4%						
																Monthly runoff (mm)	5.13	4.36	5.82	11.8	19.0	24.1	28.2	18.1	16.2	12.5	8.31	6.49						
10	1,750	1,690	05DC012	BAPTISTE RIVER NEAR THE MOUTH	523951	1150430	1350	1350	5-80, 10-20	1984-06	Natural	No	1984	2006	1984	Mean (mm)	1.74	1.47	3.33	15.8	24.2	28.0	26.8	15.5	13.3	8.45	4.38	2.56	145			85	332	0.44
																STD (mm)	0.93	0.70	2.82	9.67	13.8	20.6	21.5	10.8	11.5	5.04	2.68	1.42	57.8					0.87
																CV	0.54	0.48	0.85	0.61	0.57	0.73	0.80	0.70	0.86	0.60	0.61	0.56	0.40					
																CS	0.70	0.58	2.44	0.62	0.77	1.60	1.65	2.35	1.76	1.16	1.78	1.61	0.98					
																% of annual runoff	1%	1%	2%	11%	17%	19%	18%	11%	9%	6%	3%	2%						
																Monthly runoff (mm)	1.01	0.86	1.94	9.25	14.1	16.4	15.7	9.04	7.76	4.94	2.56	1.49						
8	6,710	6,250	05DE007	ROSE CREEK NEAR ALDER FLATS	525548	1150036	559	559	8-100	1972-07	Natural	No	1972	2007	1972-2007	Mean (mm)			2.54	17.4	23.1	18.7	22.7	7.11	5.46	3.59			108	7%	108	65	269	0.62
																STD (mm)			2.60	15.2	19.6	22.7	25.9	7.46	7.15	3.66			63.0					0.69
																CV			1.02	0.87	0.85	1.21	1.14	1.05	1.31	1.02			0.58					
																CS			1.90	1.54	1.23	2.74	1.46	2.11	2.17	2.12			1.18					
			05DE911	MODESTE CREEK NEAR LINDALE	531453	1144220	1170	1170	8-100	1996-06	Natural	No	1996	2006	1996-2006	Mean (mm)			6.77	22.9	8.49	8.78	16.7	5.69	2.26	1.59			78.8	7%	79			
																STD (mm)			7.19	21.1	6.63	10.9	19.2	6.56	1.88	1.36			44.3					
																CV			1.06	0.92	0.78	1.24	1.15	1.15	0.83	0.85			0.56					
																CS			1.38	0.77	0.62	1.47	1.09	1.23	1.01	1.53			0.40					
			05DE009	TOMAHAWK CREEK NEAR TOMAHAWK	532421	1144541	95.3	95.3	8-100	1984-06	Natural	No	1984	2006	1984-2006	Mean (mm)			6.28	19.1	6.62	8.58	15.0	5.52	1.77	2.05			69.1	7%	70			
																STD (mm)			6.70	21.2	7.69	13.0	20.2	11.0	1.67	2.10			45.1					
																CV			1.07	1.11	1.16	1.52	1.35	1.99	0.94	1.03			0.65					
																CS			1.66	1.29	2.33	2.47	1.51	2.78	0.95	1.67			0.59					
			05DF004	STRAWBERRY CREEK NEAR THE MOUTH	531841	1140302	589	589	8-100	1966-07	Natural	No	1976	2007	1976-2007	Mean (mm)			8.08	15.8	6.96	4.41	10.4	1.31	1.07	0.69			52.7	7%	52			
																STD (mm)			9.24	16.0	11.7	7.48	18.3	1.66	2.25	0.75			36.5					
																CV			1.14	1.01	1.68	1.69	1.75	1.27	2.09	1.08			0.69					
																CS			1.36	1.41	3.61	3.22	2.19	2.22	3.99	2.01			0.59					
																% of annual runoff	2%	2%	9%	26%	14%	12%	21%	6%	3%	2%	2%	1%						
																Monthly runoff (mm)	1.30	1.30	5.75	16.7	8.92	7.99	13.6	3.94	2.03	1.56	1.30	0.63						

Table 1 North Saskatchewan River Basin - Runoff Statistics at Hydrometric Stations and Hydrologic Regions - Average Case

Hydrologic Region	Gross Area (km²)	Effective Area (km²)	Hydrometric Station	Station Name	Latitude (ddmmss)	Longitude (ddmmss)	Gross Drainage Area (km²)	Effective Drainage Area (km²)	Percent of Hydrologic Region Contributing to Station (HR-%)	Actual Record Length	Regulation and Period	Is it on the main stem?	Start Year for Analysis	End Year for Analysis	Years with no winter flow	Flow Statistics	Monthly Runoff Statistics Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual (mm)	winter runoff / annual runoff %	Estimated Mean Annual Runoff (mm)	Average Mean Annual Runoff (mm)	Cumulative Mean Annual Runoff (mm)	Average CV & CS for Annual Yield
2C	9,590	6,250	05DF006	WHITEMUD CREEK NEAR ELLERSLIE	532444	1133530	337	307	2C-100	1969-06	Natural	No	1976	2006	1976-2006	Mean (mm)			6.99	14.1	1.28	1.46	3.60	0.80	1.20	0.37			32.4	7%	32	35	224	0.86
																STD (mm)			8.95	15.7	1.58	2.39	7.21	1.73	3.37	0.65			25.1					1.35
																CV			1.28	1.12	1.23	1.64	2.00	2.16	2.81	1.75			0.77					
																CS			1.31	1.36	2.11	2.66	3.20	4.00	3.81	2.72			0.79					
			05DF007	WEST WHITEMUD CREEK NEAR IRETON	531319	1134144	65.4	53.2	2C-100	1976-07	Natural	No	1976	2007	1976-2007	Mean (mm)			7.45	11.1	2.32	0.98	3.96	0.37	1.03	0.11			28.6	7%	29			
																STD (mm)			9.62	12.9	4.71	1.76	7.84	1.22	3.63	0.40			22.7					
																CV			1.29	1.16	2.03	1.79	1.98	3.26	3.52	3.69			0.79					
																CS			1.76	1.33	3.76	1.84	2.13	4.30	4.50	4.31			0.60					
			05DF003	BLACKMUD CREEK NEAR ELLERSLIE	532450	1133056	643	374	2C-100	1935-07	Natural	No	1976	2007	1976-2007	Mean (mm)			5.93	15.7	4.25	3.15	5.92	1.44	1.40	0.73			40.4	7%	41			
																STD (mm)			6.87	15.4	6.20	6.91	11.5	2.06	3.97	1.79			33.2					
																CV			1.16	0.98	1.46	2.19	1.93	1.44	2.83	2.46			0.82					
																CS			1.35	1.63	2.46	3.33	3.77	2.22	4.91	3.93			1.34					
			05EA001	STURGEON RIVER NEAR FORT SASKATCHEWAN	534714	1131323	3310	2390	2C-95, 8-5	1914-06	Natural	No	1971	2006	1971-2006	Mean (mm)			1.76	12.0	9.08	3.43	4.58	3.11	2.10	2.05			40.8	7%	41			
																STD (mm)			2.59	9.01	11.7	4.47	7.50	4.33	2.11	2.06			38.8					
																CV			1.47	0.75	1.29	1.30	1.64	1.39	1.01	1.00			0.95					
																CS			2.02	1.45	2.87	2.46	2.89	2.75	1.36	1.48			2.66					
			05EA005	STURGEON RIVER NEAR VILLENEUVE	533918	1134542	1910	1570	2C-80, 8-20	1914-15 / 1928-30 / 1968-06	Natural	No	1971	2006	1971	Mean (mm)	0.85	0.75	2.76	13.5	5.27	4.20	5.41	2.34	2.00	1.74	1.38	1.02	39.7					
																STD (mm)	1.00	0.77	3.80	16.0	8.04	6.11	9.34	2.47	2.47	2.46	1.97	1.31	42.1					
																CV	1.18	1.03	1.37	1.19	1.52	1.45	1.73	1.05	1.23	1.41	1.43	1.28	1.06					
																CS	1.63	1.20	2.26	2.20	3.39	2.20	3.40	1.19	1.43	2.03	3.06	2.05	2.35					
			05EA009	ATIM CREEK NEAR SPRUCE GROVE	533420	1135600	315	91.7	2C-100	1979-96	Natural	No	1979	1996	1979-1996	Mean (mm)			8.90	12.8	8.43	6.59	8.88	4.54	3.66	3.98			60.8	7%	62			
																STD (mm)			7.04	6.34	4.31	3.58	7.61	2.51	1.55	1.34			20.0					
																CV			0.79	0.50	0.51	0.54	0.86	0.55	0.42	0.34			0.33					
																CS			0.92	0.47	1.24	0.72	1.78	0.11	1.56	0.48			0.33					
			05EB902	POINTE-AUX-PINS CREEK NEAR ARDROSSAN	533558	1130949	106	106	2C-100	1979-06	Natural	No	1979	2006	1979-2006	Mean (mm)			4.91	11.8	3.49	4.78	4.46	1.71	1.18	0.46			34.9	7%	35			
																STD (mm)			5.55	11.6	4.29	9.34	6.44	4.26	3.63	1.18			29.7					
																CV			1.13	0.99	1.23	1.95	1.44	2.49	3.09	2.56			0.85					
																CS			1.35	1.55	1.56	2.86	1.95	4.21	4.61	3.41			1.26					
			05EB909	POINTE-AUX-PINS TRIBUTARY NO. 1 NEAR ARDROSSAN	533443	1130848	17.8	17.8	2C-100	1981-96	Natural	No	1981	1996	1981-1996	Mean (mm)			5.33	10.7	3.69	5.45	6.03	0.69	0.33	0.24			34.9	7%	35			
																STD (mm)			6.60	9.16	4.48	9.83	8.69	1.23	0.56	0.54			21.0					
																CV			1.24	0.85	1.21	1.81	1.44	1.79	1.69	2.25			0.60					
																CS			1.82	1.04	2.10	2.90	1.17	2.27	1.74	2.72			0.07					
			05EB910	POINTE-AUX-PINS TRIBUTARY NO. 2 NEAR ARDROSSAN	533536	1130913	8.34	8.34	2C-100	1981-06	Natural	No	1981	2006	1981-2006	Mean (mm)			9.04	9.11	1.58	3.74	3.23	0.37	0.27	0.11			29.8	7%	30			
																STD (mm)			10.7	12.0	1.40	10.6	5.56	0.71	0.89	0.18			24.6					
																CV			1.18	1.31	0.89	2.83	1.72	1.93	3.25	1.70			0.83					
																CS			1.55	2.20	1.59	4.09	1.87	2.11	4.63	2.29			1.06					
			05EB911	POINTE-AUX-PINS TRIBUTARY NO. 3 NEAR ARDROSSAN	533544	1130847	3.55	3.55	2C-100	1981-96	Natural	No	1981	1996	1981-1996	Mean (mm)			4.74	7.35	2.76	3.19	2.70	0.47	0.50	0.47			21.7	7%	24			
																STD (mm)			4.68	7.54	3.04	7.87	3.93	0.98	0.97	1.08			15.1					
																CV			0.99	1.02	1.10	2.47	1.45	2.09	1.96	2.33			0.70					
																CS			0.85	1.20	2.79	3.76	1.38	3.38	2.09	3.16			0.95					
			05EC005	REDWATER RIVER NEAR THE MOUTH	535349	1125946	1560	1160	2C-100	1978-06	Natural	No	1978	2006	1978-2006	Mean (mm)			1.19	8.42	3.28	1.41	1.45	0.39	0.35	0.34			18.0	7%	18			
																STD (mm)			2.56	10.4	5.20	2.56	2.75	0.63	0.92	0.77			21.3					
																CV			2.16	1.23	1.58	1.82	1.90	1.60	2.63	2.28			1.18					
																CS			2.89	2.14	2.33	3.84	2.47	1.95	3.98	3.95			2.45					
																% of annual runoff	2%	2%	15%	32%	10%	15%	15%	3%	2%	2%	2%	1%						
																Monthly runoff (mm)	0.53	0.53	5.13	11.3	3.60	5.13	5.26	1.20	0.76	0.70	0.53	0.35						
1C	20,390	9,380	05EC002	WASKATENAU CREEK NEAR WASKATENAU	540723	1124658	312	205	1C-100	1966-06	Natural	No	1978	2006	1978-2006	Mean (mm)			0.70	14.1	2.61	2.37	1.04	0.51	0.77	0.69			25.7	7%	25	25	179	1.15
																STD (mm)			1.78	23.6	6.57	7.44	1.89	1.07	2.28	2.15			45.8					1.59
																CV			2.55	1.68	2.51	3.13	1.81	2.08	2.98	3.10			1.78					
																CS			3.42	2.32	3.93	4.17	2.52	2.43	4.19	3.60			2.68					
			05EE007	VERMILION RIVER NEAR MARWAYNE	532928	1102351	7260	2000	1C-100	1979-06	Natural	No	1979	2006	1979-2006	Mean (mm)			0.73	6.81	3.38	0.84	1.29	0.82	0.19	0.20			15.4	7%	15			
																STD (mm)			1.34	6.60	5.55	1.45	3.58	1.84	0.26	0.30			14.7					
																CV			1.83	0.97	1.64	1.73	2.77	2.24	1.34	1.55			0.96					
																CS			2.55	0.64	4.36	4.18	4.64	3.24	1.54	2.88			1.53					
			05EE006	VERMILION RIVER TRIBUTARY NEAR BRUCE	531742	1120254	46.4	19.9	1C-100	1978-07	Natural	No	1978	2007	1978-2007	Mean (mm)			6.69	27.2	2.35	2.58	4.37	0.77	1.14	0.25			49.8	7%	49			
																STD (mm)			12.4	38.0	5.16	7.74	16.5	3.91	5.67	0.95			57.5					
																CV			1.85	1.40	2.20	3.00	3.78	5.10	4.97	3.80			1.16					
																CS			2.21	2.41	3.60	3.09	4.96	5.47	5.44	3.67			1.75					
			05EE009	VERMILION RIVER AT VEGREVILLE	532928	1120218	1620	367	1C-100	1987-06	Natural	No	1987	2006	1987-2006	Mean (mm)			3.55	16.6	1.24	0.42	0.61	0.22	0.17	0.05			24.7	7%	25			
																STD (mm)			7.36	24.5	3.37	1.36	1.41	0.45	0.45	0.08			35.2					
																CV			2.07	1.48	2.72	3.26	2.30	2.02	2.61	1.53			1.43					
																CS			2.45	2.70	4.20	4.39	2.64	3.32	3.87	2.35			2.48					
			05EE005	STRETTON CREEK NEAR MARWAYNE	532630	1101930	74	56.3	1C-100	1978-06	Natural	No	1978	2006	1978-2006	Mean (mm)			4.47	9.54	0.68	0.31	1.13	0.79	0.18	0.06			18.0	7%	18			
																STD (mm)			6.95	9.71	1.60	0.48	3.36	2.15	0.66	0.28			15.5					
																CV			1.55	1.02	2.35	1.54	2.96	2.72	3.61	4.71			0.86					
																CS			1.52	0.96	4.41	1.92	4.53	3.09	3.60	5.35			0.45					
			05ED002	ATIMOSWE CREEK NEAR ELK POINT	535310	1105510	368	312	1C-100	1975-06	Natural	No	1975	2006	1975-2006	Mean (mm)			0.56	7.91	1.25	0.51	0.43	0.26	0.15	0.20			12.1	7%	12			
																STD (mm)			1.44	8.48	1.76	1.08	0.92	0.45	0.21	0.25			12.2					
																CV			2.60	1.07	1.41	2.11	2.12	1.75	1.44	1.24			1.01					
																CS			4.20	1.09	2.20	3.44	3.77	2.47	1.91	1.78			1.31					
			05ED003	MOOSEHILLS CREEK NEAR ELK POINT	535603	1104636	41	37.7	1C-100	1978-07	Natural	No	1978	2007	1978-07	Mean (mm)			0.79	10.8	5.41	3.14	2.20	0.43	0.23	0.24			24.5	7%	25			
																STD (mm)			1.47	10.1	6.11	5.20	3.22	0.63	0.41	0.44			21.3					
																CV			1.86	0.93	1.13	1.66	1.46	1.47	1.74	1.87			0.87					
																CS			2.34	0.91	1.49	3.34	3.01	2.04	2.91	2.77			0.95					
																% of annual runoff	2%	2%	7%	55%	12%	8%	5%	2%	2%	2%	2%	1%						
																Monthly runoff (mm)	0.38	0.38	1.69	13.8	3.10	1.98	1.29	0.50	0.50	0.50	0.50	0.34						
Total	56,860	41,960																																

NOTES:
[1] The local mean annual runoff (mm) for each hydrologic region (HR) was computed by averaging the mean annual runoff from the local hydrologic stations (i.e., stations recording flows that are originating from within the HR) whenever available, otherwise it was copied from other watersheds in the same hydrologic region or estimated using professional judgement;
[2] If two or more local satations with year round record of streamflow were available, the local mean annual runoff (mm) for each HR was computed from stations with year round record only to avoid the errors introduced by the etimation of winter runoff, which is the case for HR-10, HR-8, and HR-9A. Otherwise all local runoff values were used to compute the mean value;
[3] The cumulative mean annual runoff (mm) on the main stem of the river was obtained by computing the area-weighted-average of consecutive hydrologic regions (HRs) using EFFECTIVE drainage area of each HR;
[4] STD = Standard Deviation; CV = Coefficient of Variation; CS = Coefficient of Skewness

Table 2-1 Annual and Monthly Yields from Hydrologic Regions in the NSRB - Average Case

Hydrologic Region	Cumulative Effective Area (km²)	Effective Area (km²)	Gross Area (km²)	Statistic	Monthly Yield (mm)												Local Annual Yield (mm)	Cumulative Annual Yield (mm)
					Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
3	4,110	4,110	4,110	% of Annual Yield	1%	1%	1%	1%	7%	20%	27%	24%	11%	4%	2%	1%		
				Monthly Yield (mm)	7.89	6.51	7.09	11.6	63.1	178	237	204	92.8	36.3	15.0	10.4	870	870
4	11,440	7,330	7,330	% of Annual Yield	2%	2%	2%	5%	16%	23%	20%	12%	9%	5%	3%	2%		
				Monthly Yield (mm)	4.98	4.98	4.98	12.4	39.8	56.6	49.6	30.4	21.6	12.2	7.46	4.98	250	473
5	18,390	6,950	6,980	% of Annual Yield	3%	3%	4%	7%	12%	15%	18%	11%	10%	8%	5%	4%		
				Monthly Yield (mm)	5.13	4.36	5.82	11.8	19.0	24.1	28.2	18.1	16.2	12.5	8.31	6.49	160	355
10	20,080	1,690	1,750	% of Annual Yield	1%	1%	2%	11%	17%	19%	18%	11%	9%	6%	3%	2%		
				Monthly Yield (mm)	1.01	0.86	1.94	9.25	14.1	16.4	15.7	9.04	7.76	4.94	2.56	1.49	85	332
8	26,330	6,250	6,710	% of Annual Yield	2%	2%	9%	26%	14%	12%	21%	6%	3%	2%	2%	1%		
				Monthly Yield (mm)	1.30	1.30	5.75	16.7	8.92	7.99	13.6	3.94	2.03	1.56	1.30	0.63	65	269
2C	32,580	6,250	9,590	% of Annual Yield	2%	2%	15%	32%	10%	15%	15%	3%	2%	2%	2%	1%		
				Monthly Yield (mm)	0.53	0.53	5.13	11.3	3.60	5.13	5.26	1.20	0.76	0.70	0.53	0.35	35	224
1C	41,960	9,380	20,390	% of Annual Yield	2%	2%	7%	55%	12%	8%	5%	2%	2%	2%	2%	1%		
				Monthly Yield (mm)	0.38	0.38	1.69	13.8	3.10	1.98	1.29	0.50	0.50	0.50	0.50	0.34	25	179
Total		41,960	56,860															

Hydrologic Region		Cumulative Monthly Yield (mm)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3		7.89	6.51	7.09	11.6	63.1	178	237	204	92.8	36.3	15.0	10.4
4		6.02	5.53	5.73	12.1	48.2	100	117	92.9	47.1	20.9	10.2	6.94
5		5.69	5.09	5.77	12.0	37.1	71.4	83.4	64.7	35.4	17.7	9.47	6.77
10		5.29	4.73	5.44	11.8	35.2	66.8	77.7	60.0	33.1	16.6	8.89	6.32
8		4.35	3.92	5.52	12.9	29.0	52.8	62.5	46.7	25.7	13.1	7.09	4.97
2C		3.61	3.27	5.44	12.6	24.1	43.7	51.5	38.0	20.9	10.7	5.83	4.09
1C		2.89	2.62	4.60	12.9	19.4	34.4	40.3	29.6	16.4	8.41	4.64	3.25
	Monthly Distribution of Cumulative Annual Yield at Alberta-Saskatchewan Boundary (NSR@AB/SK)	2%	1%	3%	7%	11%	19%	22%	16%	9%	5%	3%	2%

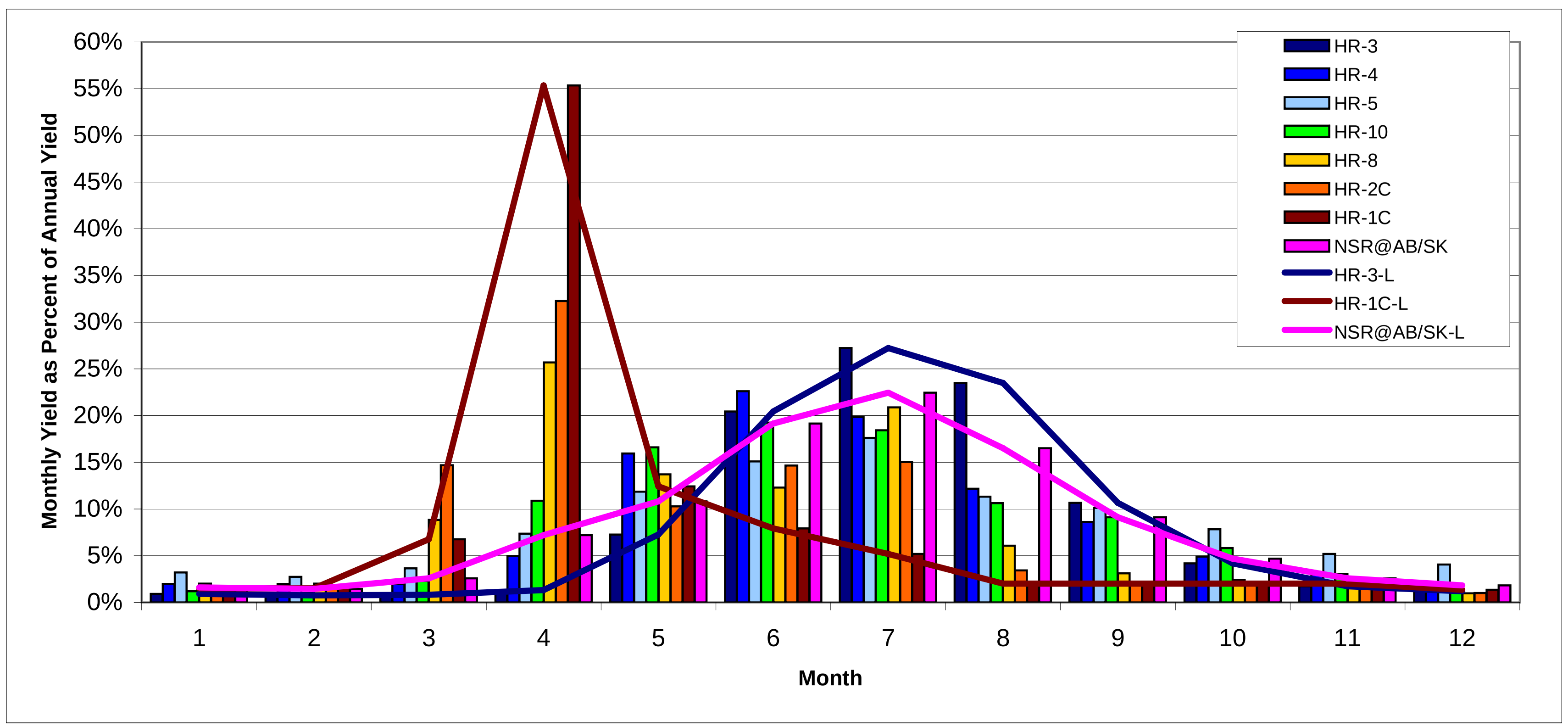

Table 2-2 Annual and Monthly Volumes from Hydrologic Regions in the NSRB - Average Case

Hydrologic Region	Cumulative Effective Area (km²)	Effective Area (km²)	Gross Area (km²)	Statistic	Monthly Volume (Mm³)												Local Annual Volume (Mm³)	Cumulative Annual Volume (Mm³)
					Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
3	4,110	4,110	4,110	% of Annual	1%	1%	1%	1%	7%	20%	27%	24%	11%	4%	2%	1%		
				Volume (Mm³)	32.4	26.7	29.1	47.6	259	731	974	840	381	149	61.8	42.9	3,600	3,600
4	11,440	7,330	7,330	% of Annual	2%	2%	2%	5%	16%	23%	20%	12%	9%	5%	3%	2%		
				Volume (Mm³)	36.5	36.5	36.5	91.2	292	415	364	223	158	89.6	54.7	36.5	1,800	5,400
5	18,390	6,950	6,980	% of Annual	3%	3%	4%	7%	12%	15%	18%	11%	10%	8%	5%	4%		
				Volume (Mm³)	35.7	30.3	40.4	81.7	132	168	196	126	112	87.1	57.7	45.1	1,100	6,500
10	20,080	1,690	1,750	% of Annual	1%	1%	2%	11%	17%	19%	18%	11%	9%	6%	3%	2%		
				Volume (Mm³)	1.71	1.45	3.28	15.6	23.9	27.7	26.5	15.3	13.1	8.35	4.32	2.52	144	6,660
8	26,330	6,250	6,710	% of Annual	2%	2%	9%	26%	14%	12%	21%	6%	3%	2%	2%	1%		
				Volume (Mm³)	8.13	8.13	35.9	104	55.7	49.9	84.9	24.6	12.7	9.75	8.13	3.91	406	7,100
2C	32,580	6,250	9,590	% of Annual	2%	2%	15%	32%	10%	15%	15%	3%	2%	2%	2%	1%		
				Volume (Mm³)	3.28	3.28	32.1	70.5	22.5	32.1	32.9	7.51	4.72	4.38	3.28	2.21	219	7,300
1C	41,960	9,380	20,390	% of Annual	2%	2%	7%	55%	12%	8%	5%	2%	2%	2%	2%	1%		
				Volume (Mm³)	3.52	3.52	15.9	130	29.1	18.6	12.1	4.69	4.69	4.69	4.69	3.20	235	7,510
Total		41,960	56,860		121	110	193	541	814	1,440	1,690	1,240	687	353	195	136	7,510	

Hydrologic Region		Cumulative Monthly Volume (Mm³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3		32	27	29	48	259	731	974	840	381	149	62	43
4		69	63	66	139	551	1,140	1,340	1,060	539	239	116	79
5		105	94	106	220	683	1,310	1,530	1,190	652	326	174	124
10		106	95	109	236	707	1,340	1,560	1,200	665	334	179	127
8		114	103	145	341	763	1,390	1,640	1,230	678	344	187	131
2C		118	106	177	411	785	1,420	1,680	1,240	682	348	190	133
1C		121	110	193	541	814	1,440	1,690	1,240	687	353	195	136
	Monthly Distribution of Cumulative Annual Yield at Alberta-Saskatchewan Boundary (NSR@AB/SK)	2%	1%	3%	7%	11%	19%	22%	16%	9%	5%	3%	2%

NOTE: The numbers shown in the table have been rounded to 3 significant figures; hence, the numbers may not add up exactly as shown in the total columns or rows.

Table 3 Annual Yields from Sub-Basins in the NSRB - Average Case

Sub-Basins of the NSR Basin	Gross Area of Sub-Basin (km²)	Effective Area of Sub-Basin (km²)	% of NSRB		Annual Yield from Hydrological Regions Comprising the NSRB (mm)							Annual Yield from Sub-Basin (mm)	Cumulative Yield (mm)	Annual Volume from Sub-Basins (Mm³)	Cumulative Annual Volume (Mm³)
					HR-3	HR-4	HR-5	HR-10	HR-8	HR-2C	HR-1C				
					870	250	160	85	65	35	25				
CLINE	3,890	3,890	9%	Eff A	3,270	613						772	772	3,000	3,000
				% in HR	84%	16%									
CLEARWATER	3,230	3,220	8%	Eff A	262	1,080	1,820	60				247		794	
				% in HR	8%	33%	57%	2%							
BRAZEAU	6,880	6,880	16%	Eff A	554	3,480	2,330	519				257		1,770	
				% in HR	8%	51%	34%	8%							
RAM	6,210	6,140	15%	Eff A	21	2,160	2,800	933	221			179	331	1,100	6,670
				% in HR	0%	35%	46%	15%	4%						
MODESTE	4,720	4,520	11%	Eff A				178	4,337			66	283	297	6,960
				% in HR				4%	96%						
STRAWBERY	3,110	2,390	6%	Eff A					1,110	1,280		49	262	117	7,080
				% in HR					46%	54%					
STURGEON	3,320	2,430	6%	Eff A					582	1,850		42		103	
				% in HR					24%	76%					
BEAVERHILL	4,410	2,330	6%	Eff A						1,610	724	32	228	74	7,260
				% in HR						69%	31%				
WHITE EARTH	6,520	4,390	10%	Eff A						1,510	2,880	28	204	125	7,380
				% in HR						34%	66%				
VERMILION	7,860	2,360	6%	Eff A						5	2,360	25		59	
				% in HR						0%	100%				
FROG	5,460	3,070	7%	Eff A							3,070	25	181	77	7,500
				% in HR							100%				
MONNERY	1,250	340	1%	Eff A							344	25	179	9	7,510
				% in HR							100%				
Total	56,860	41,960													

Eff A : *Effective Area of Sub-Basin within each Hydrologic Region (HR) in km²;*
% in HR : *Percentage of Effective Sub-Basin Area in each HR*

Table 4 Annual and Monthly Volumes from Hydrologic Regions in the NSRB - Average Case and Selected Percentiles

Hydrologic Region	Cumulative Effective Area (km²)	Effective Area (km²)	Gross Area (km²)	Monthly Volume (Mm³) - Average Case												Average Case			
				Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Yield from Each Hydrologic Region (mm)	Cumulative Annual Yield (mm)	Annual Volume from Each Hydrologic Region (Mm³)	Cumulative Annual Volume (Mm³)
3	4,110	4,110	4,110	32	27	29	48	259	731	974	840	381	149	62	43	870	870	3,600	3,600
4	11,440	7,330	7,330	36	36	36	91	292	415	364	223	158	90	55	36	250	473	1,800	5,400
5	18,390	6,950	6,980	36	30	40	82	132	168	196	126	112	87	58	45	160	355	1,100	6,500
10	20,080	1,690	1,750	2	1	3	16	24	28	26	15	13	8	4	3	85	332	144	6,660
8	26,330	6,250	6,710	8	8	36	104	56	50	85	25	13	10	8	4	65	269	406	7,100
2C	32,580	6,250	9,590	3	3	32	71	23	32	33	8	5	4	3	2	35	224	219	7,300
1C	41,960	9,380	20,390	4	4	16	130	29	19	12	5	5	5	5	3	25	179	235	7,510
Total		41,960	56,860	121	110	193	541	814	1,440	1,690	1,240	687	353	195	136			7,510	

Hydrologic Region	Cumulative Effective Area (km²)	Effective Area (km²)	Gross Area (km²)	Monthly Volume (Mm³) - 10th Percentile												10th Percentile			
				Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Yield from Each Hydrologic Region (mm)	Cumulative Annual Yield (mm)	Local Annual Volume (Mm³)	Cumulative Annual Volume (Mm³)
3	4,110	4,110	4,110	28	23	25	41	222	626	834	720	327	128	53	37	745	745	3,060	3,060
4	11,440	7,330	7,330	22	22	22	55	176	250	219	134	95	54	33	22	151	364	1,100	4,170
5	18,390	6,950	6,980	20	17	22	45	72	92	107	69	62	48	32	25	88	260	610	4,780
10	20,080	1,690	1,750	1	1	2	8	13	15	14	8	7	4	2	1	46	242	77	4,850
8	26,330	6,250	6,710	3	3	15	43	23	20	35	10	5	4	3	2	27	191	166	5,020
2C	32,580	6,250	9,590	1	1	9	21	7	9	10	2	1	1	1	1	10	154	64	5,080
1C	41,960	9,380	20,390	1	1	3	26	6	4	2	1	1	1	1	1	5	122	47	5,110
Total		41,960	56,860	75	67	98	238	518	1,020	1,220	945	498	240	125	88			5,110	

Hydrologic Region	Cumulative Effective Area (km²)	Effective Area (km²)	Gross Area (km²)	Monthly Volume (Mm³) - 25th Percentile												25th Percentile			
				Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Yield from Each Hydrologic Region (mm)	Cumulative Annual Yield (mm)	Local Annual Volume (Mm³)	Cumulative Annual Volume (Mm³)
3	4,110	4,110	4,110	30	25	27	44	238	671	895	772	350	137	57	39	799	799	3,280	3,280
4	11,440	7,330	7,330	27	27	27	68	217	309	271	166	118	67	41	27	186	407	1,360	4,650
5	18,390	6,950	6,980	25	21	28	57	92	118	137	88	79	61	40	32	112	295	780	5,430
10	20,080	1,690	1,750	1	1	2	11	16	19	18	11	9	6	3	2	59	276	99	5,530
8	26,330	6,250	6,710	5	5	21	60	32	29	49	14	7	6	5	2	38	219	234	5,760
2C	32,580	6,250	9,590	2	2	15	33	10	15	15	3	2	2	2	1	16	180	101	5,860
1C	41,960	9,380	20,390	1	1	6	46	10	7	4	2	2	2	2	1	9	142	83	5,930
Total		41,960	56,860	91	81	126	318	617	1,170	1,390	1,060	567	280	149	104			5,930	

Hydrologic Region	Cumulative Effective Area (km²)	Effective Area (km²)	Gross Area (km²)	Monthly Volume (Mm³) - 75th Percentile												75th Percentile			
				Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Yield from Each Hydrologic Region (mm)	Cumulative Annual Yield (mm)	Local Annual Volume (Mm³)	Cumulative Annual Volume (Mm³)
3	4,110	4,110	4,110	35	29	31	51	278	785	1,046	903	409	160	66	46	934	934	3,840	3,840
4	11,440	7,330	7,330	43	43	43	109	348	493	433	265	188	107	65	43	298	527	2,180	6,020
5	18,390	6,950	6,980	43	37	49	99	160	203	237	153	136	105	70	55	194	401	1,350	7,370
10	20,080	1,690	1,750	2	2	4	19	29	34	32	19	16	10	5	3	103	376	175	7,540
8	26,330	6,250	6,710	10	10	45	130	70	62	106	31	16	12	10	5	81	306	507	8,050
2C	32,580	6,250	9,590	4	4	40	88	28	40	41	9	6	5	4	3	44	256	274	8,320
1C	41,960	9,380	20,390	4	4	19	158	35	23	15	6	6	6	6	4	30	205	286	8,600
Total		41,960	56,860	142	129	232	655	948	1,640	1,910	1,380	777	406	227	159			8,600	

Hydrologic Region	Cumulative Effective Area (km²)	Effective Area (km²)	Gross Area (km²)	Monthly Volume (Mm³) - 90th Percentile												90th Percentile			
				Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Yield from Each Hydrologic Region (mm)	Cumulative Annual Yield (mm)	Local Annual Volume (Mm³)	Cumulative Annual Volume (Mm³)
3	4,110	4,110	4,110	37	31	34	55	299	842	1,120	968	439	172	71	49	1,000	1,000	4,120	4,120
4	11,440	7,330	7,330	54	54	54	134	429	609	535	328	232	132	80	54	368	596	2,690	6,810
5	18,390	6,950	6,980	55	47	63	126	204	260	303	195	174	135	89	70	248	464	1,720	8,540
10	20,080	1,690	1,750	3	2	5	24	37	43	41	24	21	13	7	4	133	437	225	8,760
8	26,330	6,250	6,710	14	14	63	185	99	88	150	44	22	17	14	7	115	360	718	9,480
2C	32,580	6,250	9,590	6	6	63	139	44	63	65	15	9	9	6	4	69	304	430	9,910
1C	41,960	9,380	20,390	7	7	34	276	62	40	26	10	10	10	10	7	53	248	499	10,400
Total		41,960	56,860	177	162	315	939	1,170	1,940	2,240	1,580	908	487	279	195			10,400	

NOTE: The numbers shown in the table have been rounded to 3 significant figures; hence, the numbers may not add up exactly as shown in the total columns or rows.

Table 5 Annual and Monthly Volumes from Sub-Basins in the NSRB - Average Case and Selected Percentiles

Sub-Basins	Gross Area (km^2)	Effective Area (km^2)	Monthly Volume (Mm^3) - Average Case												Average Case	
			Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Volume from Each Sub-Basin (Mm^3)	Cumulative Annual Volume (Mm^3)
CLINE	3,890	3,890	29	24	26	46	231	616	805	687	317	126	54	37	3,000	3,000
CLEARWATER	3,230	3,220	17	15	18	38	94	151	167	119	77	46	27	20	794	
BRAZEAU	6,880	6,880	34	31	36	82	225	360	377	265	168	94	55	39	1,770	
RAM	6,210	6,140	26	24	30	73	154	207	204	126	100	67	42	31	1,100	6,670
MODESTE	4,720	4,520	6	6	25	74	41	38	62	19	10	8	6	3	297	6,960
STRAWBERY	3,110	2,390	2	2	13	33	14	15	22	6	3	3	2	1	117	7,080
STURGEON	3,320	2,430	2	2	13	31	12	14	18	5	3	2	2	1	103	
BEAVERHILL	4,410	2,330	1	1	9	28	8	10	9	2	2	1	1	1	74	7,260
WHITE EARTH	6,520	4,390	2	2	13	57	14	13	12	3	3	2	2	2	125	7,380
VERMILION	7,860	2,360	1	1	4	33	7	5	3	1	1	1	1	1	59	
FROG	5,460	3,070	1	1	5	42	10	6	4	2	2	2	2	1	77	7,500
MONNERY	1,250	340	0	0	1	5	1	1	0	0	0	0	0	0	9	7,510
Total	56,860	41,960	121	110	193	541	813	1,440	1,680	1,240	684	352	194	136	7,510	

Sub-Basins	Gross Area (km^2)	Effective Area (km^2)	Monthly Volume (Mm^3) - 10th Percentile												10th Percentile	
			Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Volume from Each Sub-Basin (Mm^3)	Cumulative Annual Volume (Mm^3)
CLINE	3,890	3,890	24	20	22	37	191	519	682	584	268	106	45	31	2,530	2,530
CLEARWATER	3,230	3,220	10	9	11	23	59	100	113	83	51	29	17	12	516	
BRAZEAU	6,880	6,880	21	19	22	49	142	238	256	186	112	60	34	24	1,160	
RAM	6,210	6,140	15	14	17	41	89	119	117	72	57	38	24	17	620	4,830
MODESTE	4,720	4,520	2	2	10	30	17	16	26	8	4	3	3	1	123	4,950
STRAWBERY	3,110	2,390	1	1	5	12	5	6	8	2	1	1	1	0	42	4,990
STURGEON	3,320	2,430	1	1	4	10	4	5	6	2	1	1	1	0	34	
BEAVERHILL	4,410	2,330	0	0	3	7	2	3	3	1	0	0	0	0	20	5,060
WHITE EARTH	6,520	4,390	0	0	3	13	3	3	3	1	1	1	1	0	30	5,090
VERMILION	7,860	2,360	0	0	1	7	1	1	1	0	0	0	0	0	12	
FROG	5,460	3,070	0	0	1	9	2	1	1	0	0	0	0	0	15	5,110
MONNERY	1,250	340	0	0	0	1	0	0	0	0	0	0	0	0	2	5,110
Total	56,860	41,960	75	67	98	238	517	1,010	1,220	939	495	239	125	87	5,110	

Sub-Basins	Gross Area (km^2)	Effective Area (km^2)	Monthly Volume (Mm^3) - 25th Percentile												25th Percentile	
			Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Volume from Each Sub-Basin (Mm^3)	Cumulative Annual Volume (Mm^3)
CLINE	3,890	3,890	26	22	24	41	208	560	735	628	288	115	49	34	2,730	2,730
CLEARWATER	3,230	3,220	12	11	13	28	71	119	132	96	60	35	20	15	613	
BRAZEAU	6,880	6,880	26	24	27	61	171	282	300	215	132	72	41	29	1,380	
RAM	6,210	6,140	19	17	22	51	111	150	147	91	72	48	30	22	780	5,500
MODESTE	4,720	4,520	3	3	15	43	24	22	36	11	6	5	4	2	173	5,670
STRAWBERY	3,110	2,390	1	1	7	17	8	8	12	3	2	1	1	1	62	5,740
STURGEON	3,320	2,430	1	1	6	15	6	7	9	2	1	1	1	1	52	
BEAVERHILL	4,410	2,330	0	0	4	12	3	4	4	1	1	1	1	0	32	5,830
WHITE EARTH	6,520	4,390	1	1	5	22	6	6	5	1	1	1	1	1	50	5,880
VERMILION	7,860	2,360	0	0	1	12	3	2	1	0	0	0	0	0	21	
FROG	5,460	3,070	0	0	2	15	3	2	1	1	1	1	1	0	27	5,930
MONNERY	1,250	340	0	0	0	2	0	0	0	0	0	0	0	0	3	5,930
Total	56,860	41,960	90	81	125	318	616	1,160	1,380	1,050	564	279	148	104	5,930	

Sub-Basins	Gross Area (km^2)	Effective Area (km^2)	Monthly Volume (Mm^3) - 75th Percentile												75th Percentile	
			Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Volume from Each Sub-Basin (Mm^3)	Cumulative Annual Volume (Mm^3)
CLINE	3,890	3,890	31	27	29	50	251	666	869	740	342	136	58	40	3,240	3,240
CLEARWATER	3,230	3,220	20	18	21	46	111	176	192	136	90	54	32	24	919	
BRAZEAU	6,880	6,880	40	37	42	97	265	419	435	304	195	110	65	46	2,060	
RAM	6,210	6,140	32	29	37	87	185	248	245	151	120	80	51	37	1,300	7,520
MODESTE	4,720	4,520	7	7	32	93	51	47	77	23	13	10	8	4	371	7,890
STRAWBERY	3,110	2,390	3	3	16	41	18	19	27	7	4	3	3	1	146	8,030
STURGEON	3,320	2,430	2	2	16	38	15	18	22	6	3	3	2	1	128	
BEAVERHILL	4,410	2,330	1	1	12	35	10	12	12	3	2	2	1	1	93	8,270
WHITE EARTH	6,520	4,390	2	2	16	70	18	17	14	4	3	3	3	2	154	8,420
VERMILION	7,860	2,360	1	1	5	40	9	6	4	1	1	1	1	1	72	
FROG	5,460	3,070	1	1	6	52	12	7	5	2	2	2	2	1	94	8,590
MONNERY	1,250	340	0	0	1	6	1	1	1	0	0	0	0	0	10	8,600
Total	56,860	41,960	142	129	232	655	946	1,640	1,900	1,380	774	405	226	158	8,600	

Sub-Basins	Gross Area (km^2)	Effective Area (km^2)	Monthly Volume (Mm^3) - 90th Percentile												90th Percentile	
			Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Volume from Each Sub-Basin (Mm^3)	Cumulative Annual Volume (Mm^3)
CLINE	3,890	3,890	34	29	31	55	274	721	938	798	369	148	63	44	3,500	3,500
CLEARWATER	3,230	3,220	25	22	27	57	136	211	230	161	108	66	40	29	1,110	
BRAZEAU	6,880	6,880	50	46	52	121	324	503	519	358	234	134	79	56	2,480	
RAM	6,210	6,140	40	37	46	111	233	311	309	190	151	101	64	47	1,640	8,730
MODESTE	4,720	4,520	10	10	45	131	72	66	109	33	18	13	11	5	523	9,260
STRAWBERY	3,110	2,390	4	4	24	61	26	29	40	11	6	5	4	2	215	9,470
STURGEON	3,320	2,430	3	3	25	58	22	27	33	8	5	4	3	2	194	
BEAVERHILL	4,410	2,330	2	2	19	57	16	19	19	5	3	3	2	2	149	9,840
WHITE EARTH	6,520	4,390	4	4	26	118	30	27	23	7	5	5	5	3	257	10,100
VERMILION	7,860	2,360	2	2	9	70	16	10	7	3	3	3	3	2	126	
FROG	5,460	3,070	2	2	11	90	20	13	8	3	3	3	3	2	163	10,400
MONNERY	1,250	340	0	0	1	10	2	1	1	0	0	0	0	0	18	10,400
Total	56,860	41,960	177	162	315	940	1,170	1,940	2,230	1,580	905	486	278	194	10,400	

NOTE: The numbers shown in the table have been rounded to 3 significant figures; hence, the numbers may not add up exactly as shown in the total columns or rows.