CARROT-SASKATCHEWAN RIVER INTEGRATED WATERSHED MANAGEMENT PLAN STATE OF THE WATERSHED REPORT CONTRIBUTION

SURFACE WATER HYDROLOGY REPORT

Disclaimer: The hydrologic conditions presented in this report are estimates to indicate the health of the watersheds as of 2013. They should not be used for licensing or design purposes. The trends are based on historical records and are subject to change as more hydrological information becomes available. Factors such as climate change or land use changes could impact the values in the future. Utilization of this information on a specific case by case basis requires detailed analysis by trained professionals and is intended for demonstration purposes only.

Planning Area:

The Carrot-Saskatchewan River planning area (CSRPA) is separated into distinct areas: 1) area around the urban area of The Pas and 2) Cranberry-Portage area.

1) The Pas area extends from south of Turnberry north towards Medric Bay of Namew Lake. This area's west border rests at the Manitoba-Saskatchewan provincial border and extends east to Lamb Lake. The Pas area covers an area of 4795 km^2.

2) The Cranberry-Portage area is along the east border of Athapapuskow Lake and centers on the community of Cranberry-Portage. The Cranberry-Portage area covers an area of 26 km^2.

The entire CSRPA covers 4,821 km^2 and is shown in Figure 1.

The planning area is made up of a number of individual watersheds. By definition, a watershed is the land area that contributes surface water runoff to a common point. It is separated from adjacent watersheds by a land ridge or divide. Watersheds can vary in size from a few hectares to thousands of square kilometres. A larger watershed can contain many smaller sub-watersheds. On a larger scale, a basin is defined as a collection of watersheds that feed into a common main tributary or large body of water (e.g. the Red River Basin). A sub-basin is a division of a basin and will be made up of multiple watersheds.

Watershed and basin boundaries form a prime ecological unit for:

- Information and knowledge management and analysis, and
- Water and land use planning and management.

Watershed and basin boundaries are defined through the application of the best available science and modified with documented and verifiable local input. Agriculture and Agri-Food Canada through the efforts of the Prairie Farm Rehabilitation Administration (AAFC-PFRA) and Manitoba

<u>Surface Water Management Section</u>

Conservation and Water Stewardship have delineated a system of watershed and basin boundaries for Manitoba. These boundaries have been designed to extend to the mouths of some rivers and streams and along large bodies of water. The CSRPA boundaries were established using this system of watersheds.

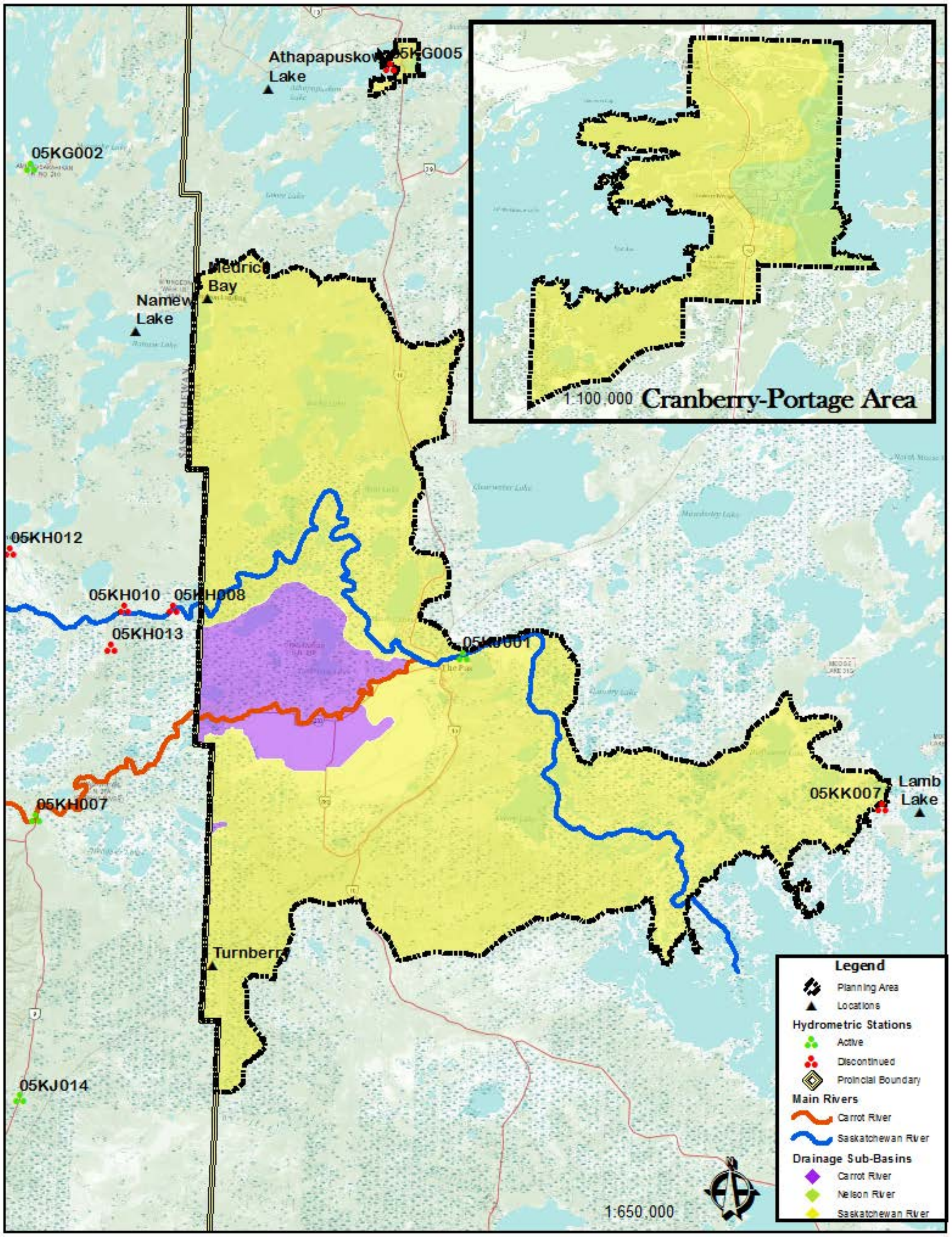

Figure 1: Carrot-Saskatchewan River Planning Area

Surface Water Management Section

Climate and Physiography:

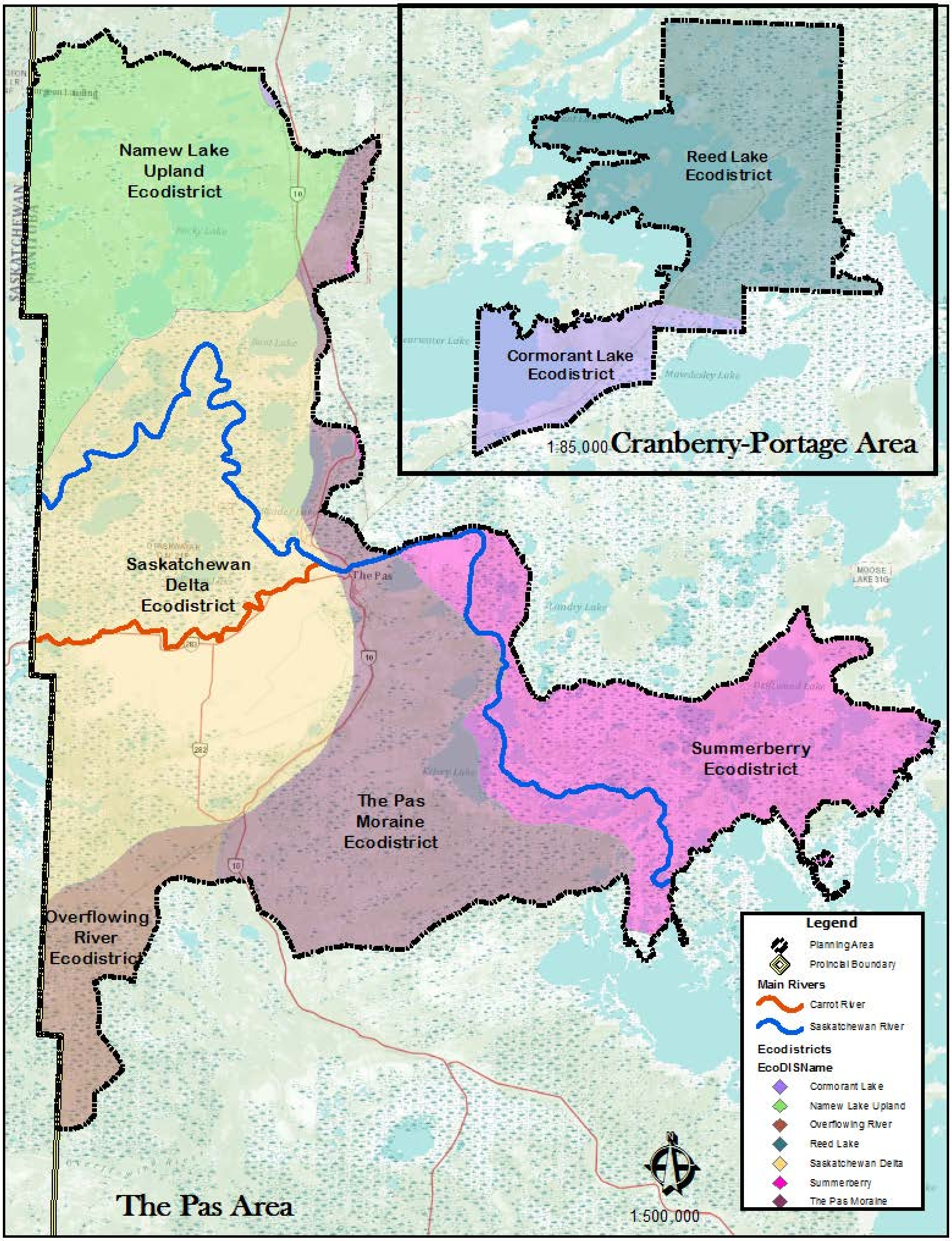

Figure 2: Carrot-Saskatchewan River Planning Area - Ecodistrict

Surface Water Management Section

The CSRPA stretches across two ecozones, two ecoregions and six ecodistricts as shown in Table 1 and Figure 2.

ECOZONE	ECOREGION	ECODISTRICT
Boreal Shield	Churchill River Upland	Reed Lake
Boreal Plains	Mid Boreal Lowlands	Namew Lake Upland
		Saskatchewan Delta
		Overflowing River
		The Pas Moraine
		Cormorant Lake

Table 1: Terrestrial Ecozones, Ecoregions, and Ecodistricts for Carrot-Saskatchewan River Planning Area

Ecozones consist of a distinctive assemblage of physical and biological characteristics and possess environmental characteristics that tend to cohere and endure over the long term. Ecoregions form part of an ecozone and are characterized by a unique combination of landscape physiography and ecoclimate. Ecoregion boundaries are guided by distinctive features of both climate and physiographic. Ecodistricts are subdivisions of an ecoregion and are characterized by relatively homogenous physical landscape and climatic conditions[1].

Boreal Shield Ecozone

This ecozone has a strong continental climate which is characterized by long, cold winters and short, cool summers. The soil climate ranges from humid, cold Cryoboreal in the northwestern half to per humid, moderately cool Boreal in the eastern section[2].

Churchill River Upland Ecoregion

This ecoregion's Manitoba portion extends westward from Grass River to the Saskatchewan border. It has a climate marked by short, cool summers and long, very cold winters[3].

Reed Lake Ecodistrict

This ecodistrict is characterized by short and cool summers and long, cold and snowy winters.[4]. This ecodistrict has no climate station, but the station at Flin Flon Airport is relevant to the ecodistrict (Table 2).

[1] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 11.
[2] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 59.
[3] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 67.
[4] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 88.

	Year	June-Aug	May-Sept	July	Jan
Temperature (°C)	0.2	16.7	13.8	18.2	-19.8
Precip. mm (equiv)	487.6	217.5	322.5	83.1	17.7
Rain/Snow (mm/cm)	355.0/150.2	217.5/0.1	317.4/5.3		

Table 2: Selected Climate Data[5] for Flin Flon Airport

The Reed Lake Ecodistrict is a hummocky to undulating morainal plain. It is thinly covered by stony, sandy morainal veneers and glaciolacustrine blankets. Elevations range from about 335 masl to about 255 masl. Slopes vary from level in peat-filled depressions to about 30 per cent along irregular, hummocky surfaces. Water sources include several large lakes, many smaller lakes and the rivers that flow through the ecodistrict[6].

Boreal Plains Ecozone

The climate of this ecozone is strongly influenced by continental climatic conditions and is typified by cold winters and moderately warm summers. The ecozone has a sub-humid, moderately cold Cryoboreal soil climate[7].

Mid-Boreal Lowland Ecoregion

This ecoregion is marked by short, moderately warm summers and long, cold winters. Precipitation varies greatly from year to year and is highest during the growing season and is characterized by a moderately cold to cold, sub humid to humid, Cryoboreal soil climate[8].

Namew Lake Ecodistrict

This ecodistrict straddles the border with Saskatchewan and is situated in the northwestern corner of the Manitoba portion of the Mid-Boreal Lowland Ecoregion. Climate data for the Flin Flon Airport (Table 2) is relevant to this ecodistrict.

The relief in this ecodistrict is terminated abruptly on the southeast by steep morainic deposits that rise 10 to 15 m above the surrounding area. The ecodistrict slopes gently eastward at the rate of about 1.0 m per km. Elevations range from 300 masl at the Saskatchewan border to 261 masl at Rock Lake near its eastern edge. Local relief within this relatively level to undulating shallow glaciolacustrine plain occurs along river banks and lake shores. Approximately 20 per cent of the ecodistrict is shallow ponds, lakes, rivers and streams, which are the principal source of water. The Goose River and a number of creeks drain several large lakes including Namew and Athapapuskow Lakes[9].

[5] Canadian Climate Normals, 1981-2010. Atmospheric Environment Service, Environment Canada.
[6] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 88-89.
[7] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 139.
[8] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 148
[9] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 152-153.

Cormorant Lake Ecodistrict

This ecodistrict's climate is marked by short, moderately warm summers and long very cold winters. Precipitation varies greatly from year to year, and is highest from late spring through summer. There are no climate stations in this ecodistrict, but climatic data from the Flin Flon Airport has relevance to this area[10].

The Cormorant Lake Ecodistrict borders on the Canadian Shield at Reed Lake on the north and extends south to Clearwater Lake. The ecodistrict is a hummocky morainal plain. Elevations range from about 300 masl in the western sector to about 263 masl along the shore of Hargrave Lake in the east. The ecodistrict slopes gently eastward at the rate of approximately 0.5 m per km.[11].

Summberberry Ecodistrict

The climate in this ecodistrict is characterized by short, moderately warm summers and long very cold winters[12]. Climate data for The Pas airport (Table 3) is relevant to this area.

	Year	June-Aug	May-Sept	July	Jan
Temperature	0.5	16.6	13.8	18.1	-19.1
Precip. mm (equiv)	487.6	217.5	322.5	83.1	17.7
Rain/Snow (mm/cm)	355/150.2	217.8/0.1	317.4/5.3		

Table 3: Selected Climate Data[13] for The Pas Airport

The Summerberry Ecodistrict is nearly level lowland of scrolled, recent alluvial deposits and horizontal fens that extends eastward from The Pas moraine to South Moose and Cedar Lakes. Elevations range from 257 masl to 253 masl. The ecodistrict slopes very gently from west to east at the rate of about 0.1 m per km[14].

The principal source of water is the Saskatchewan River. Water is also available from shallow ponds and lakes that occupy about 5 to 20 per cent of the area.

The Pas Moraine Ecodistrict

The climate in this ecodistrict is characterized by short, moderately warm summers and long cold winters[15]. Climate data for The Pas airport (Table 3) is relevant to this area.

[10] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 154
[11] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 154.
[12] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page158.
[13] Canadian Climate Normals, 1981-2010. Atmospheric Environment Service, Environment Canada.
[14] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page158-159.
[15] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 160.

Surface Water Management Section

The Pas Moraine Ecodistrict consists largely of The Pas Moraine. This feature is a curvi-linear, drumlinized moraine that extends from Long Point on Lake Winnipeg westward between Lake Winnipegosis and Cedar Lake and terminates at The Pas and Rocky Lake on the northwest. The ecodistrict's elevation ranges from 255 masl to 305 masl and is characterized by southwest-northeast oriented drumlin ridges separated by variable-sized swales or depressions. The ecodistrict slopes gently northeast at approximately 1.0 m per km[16].

Saskatchewan Delta Ecodistrict

The climate in this ecodistrict is characterized by short, moderately warm summers and long, very cold winters[17]. Climate data for The Pas airport (Table 3) is relevant to this area.

Topographically, this depressional ecodistrict is terminated abruptly on the east by The Pas Moraine. Elevations in the flood plain range from 264 masl at the Saskatchewan border to 259 masl at its eastern edge, falling at the rate of about 0.3 m per km[18].

Overflowing River Ecodistrict

The climate in this ecodistrict is characterized by short, moderately warm summers and long, very cold winters[19]. Climate data for The Pas airport (Table 3) is relevant to this area.

The Overflowing River Ecodistrict is a smooth, level area bounded by the Pasquia Hills on the northwest and the Porcupine Hills on the south. Elevations range from 305 masl at the Saskatchewan border to about 266 masl along the Overflowing River near Dawson Bay. The land surface slopes gently to the east at the rate of about 1.0 m per km

The principal source of water is the Overflowing River, as well as water from the shallow bays of Lake Winnipegosis[20].

[16] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 160
[17] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 162.
[18] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 162.
[19] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 168.
[20] Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, page 168-169.

Water Courses:

The CSRPA has two main waterways; the Saskatchewan River (160.6 km within the CSRPA) and the Carrot River (46.3 km within the CSRPA). The Saskatchewan River basin is 335, 900 km^2 and through its tributaries, North and South Saskatchewan River, stretches as far west as the Rocky Mountains in Alberta. The Saskatchewan River starts at the confluence of the North and South Saskatchewan Rivers just east of Prince Albert, Saskatchewan and stretches 550 km to empty into Lake Winnipeg.

The Saskatchewan River enters into the CSRPA just south of Barrier Lake and flows in a north easterly direction until it loops around Wanastikwayak Lake. The river continues flowing in a south easterly direction until it passes the Grace Lake Provincial Dam. The river continues to flow in a southerly direction until it exits the CSRPA close to Elbow Lake.

The Saskatchewan River sub-basin is split between the Cranberry Portage and The Pas areas of the CSPRA. The sub-basin in The Pas area has a drainage area of approximately 4,300 km^2 within the CSRPA. The sub-basin includes numerous lakes, the three largest being Rocky Lake, Root Lake and Kelsey Lake. The sub-basin in the Cranberry-Portage area has a drainage area of approximately 20 km^2 within the CSRPA.

The Carrot River watershed covers approximately 13, 200 km^2, of which approximately 520 km^2 is within the CSRPA. The Carrot River enters into the CSRPA just west of Murphy Creek and flows in a westerly direction to where it joins the Saskatchewan River. All tributaries and drains flow north or south into the Carrot River. The sub basin also includes numerous lakes, the three largest being Saskeram Lake, Birch Lake and North Mistuhe Lake.

The Cranberry-Portage portion of the CSRPA rests along the east edge of Athapapuskow Lake. All tributaries within the Saskatchewan River sub-basin flow towards Athapapuskow Lake. Approximately 6 km^2 within the Cranberry-Portage portion of the CSRPA is part of the Nelson River basin and tributaries within this area flow in an easterly direction.

The CSRPA has twelve waterways that have been designated as provincial waterways. A waterway is designated as provincial if it is an artificial or man-made waterway and is a 3rd order drain or higher. Waterways are designated as provincial by an Order-In-Council.

The CSRPA has three provincial dams within its borders: Big Bend Dam, Grace Lake Dam and Knapp (Pasquia Control) Dam.

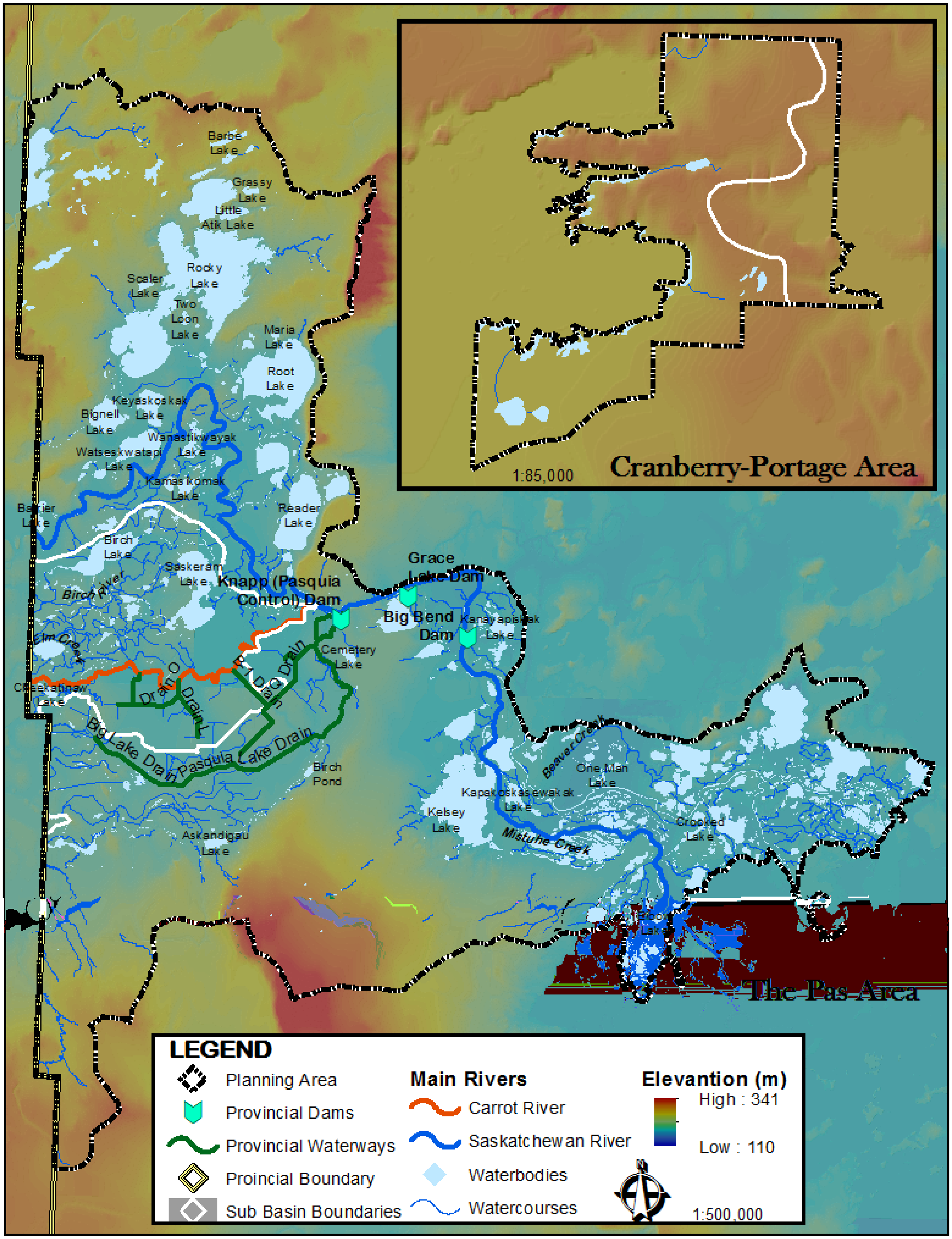

Figure 3: Carrot-Saskatchewan River Planning Area - Hydrography

Hydrometric Data:

The collection of hydrometric data is critical to the understanding of the availability, variability and distribution of water resources and provides the basis for responsible decision making on the management of this resource. Historic hydrometric data provides the basis for understanding the potential extent and limitation of the resource.

Water level and stream flow data collected under the Canada-Manitoba Hydrometric Agreement supports activities such as policy development, operation of water control works, flow forecasting, water rights licensing, water management investigations, hydrologic studies, water quality modeling, ecosystem protection and scientific studies.

Stream flow and level data has been recorded at ten locations within or close to the CSRPA for varying time periods since the late 1910s. The locations of the ten stations are shown in Figure 1. Table 5 provides information related to these ten stations.

Archived and real time hydrometric data can be found at:

Archived - http://www.wsc.ec.gc.ca/applications/H2O/index-eng.cfm or

Real Time - http://www.wateroffice.ec.gc.ca/index_e.html

Streamflow Characteristics:

The gross drainage area boundary is defined as the area at a specific location, enclosed by its drainage divide, which might be expected to entirely contribute runoff to that specific location under extremely wet conditions. The effective drainage area is that portion of a drainage area which might be expected to entirely contribute runoff to the main stem during a median (1:2 year event) runoff year under natural conditions. This area excludes marsh and slough areas and other natural storage areas which would prevent runoff from reaching the main stem in a year of average runoff. The effective to gross drainage area ratio is an indication of how well an area is drained. A perfectly drained area has a ratio of one.

The daily discharges for gauging stations 05KH007 and 05KJ001 (highlighted in yellow in Table 4) were statistically analyzed to determine runoff characteristics of the CSRPA. The results of the analysis are presented as follows:

Table 4: CSRPA Hydrometric Gauging Stations

Station Number	Station Name	Years of Operation	Operational Schedule	Type of Data	Gross Drainage Area in km^2	Real Time Data Available
05KG002	Sturgeon – Weir River at outlet of Amisk Lake	1917-2013	Miscellaneous	Flow	14,600	No
05KG005	Athapapuskow Lake at Cranberry Portage	1948-1997	Continuous	Level	1,990	No
05KH007	Carrot River near Turnberry	1965	Miscellaneous	Flow	12,600	Yes
		1966-2001	Continuous	Flow		
		2002-2013	Continuous	Flow & Level		
05KH008	Saskatchewan River near Manitoba Boundary	1950-1982	Miscellaneous	Flow		No
05KH010	Saskatchewan River below Cumberland House	1954-1956	Seasonal	Flow	328,000	No
05KH012	Tearing River near Cumberland House	1953-1975	Seasonal	Flow		No
05KH013	Birch River near Manitoba Boundary	1979-1984	Continuous	Flow	1340	No
05KJ001	Saskatchewan River at The Pas	1913-1930	Continuous	Flow	347,000	Yes
		1931-1932	Seasonal	Flow		
		1933-1936	Continuous	Flow		
		1937-1940	Seasonal	Flow		
		1941-1961	Continuous	Flow		
		1962-2001	Continuous	Flow		
		2002-2013	Continuous	Flow & Level		
05KJ014	Pasquia River at Hwy. #9	1965-2013	Miscellaneous	Flow	74.3	No
05KK007	Moose River near Moose Lake	1964-1973	Miscellaneous	Flow	9,200	No

A. *Carrot River near Turnberry (05KH007)*

The gross drainage area of station 05KH007 is 15,300 km^2. The station has an effective to gross drainage area ratio equal to 0.7 (PFRA drainage area database).

The mean monthly discharge data for Carrot River near Turnberry is shown in Table 5. Based on available data, the average runoff during the period 1966 to 2012 is equal to 627,800 dam^3 or an equivalent depth of 41.8 mm over the gross drainage area for station 05KH007.

The annual runoff depths for Carrot River from 1966 to 2012 are shown in Figure 4. The values range from a minimum of 5.4 mm in 2002 to a maximum of 110.8 mm in 2010. This figure also illustrates the variability in runoff from year to year, as well as the years above and below the average runoff.

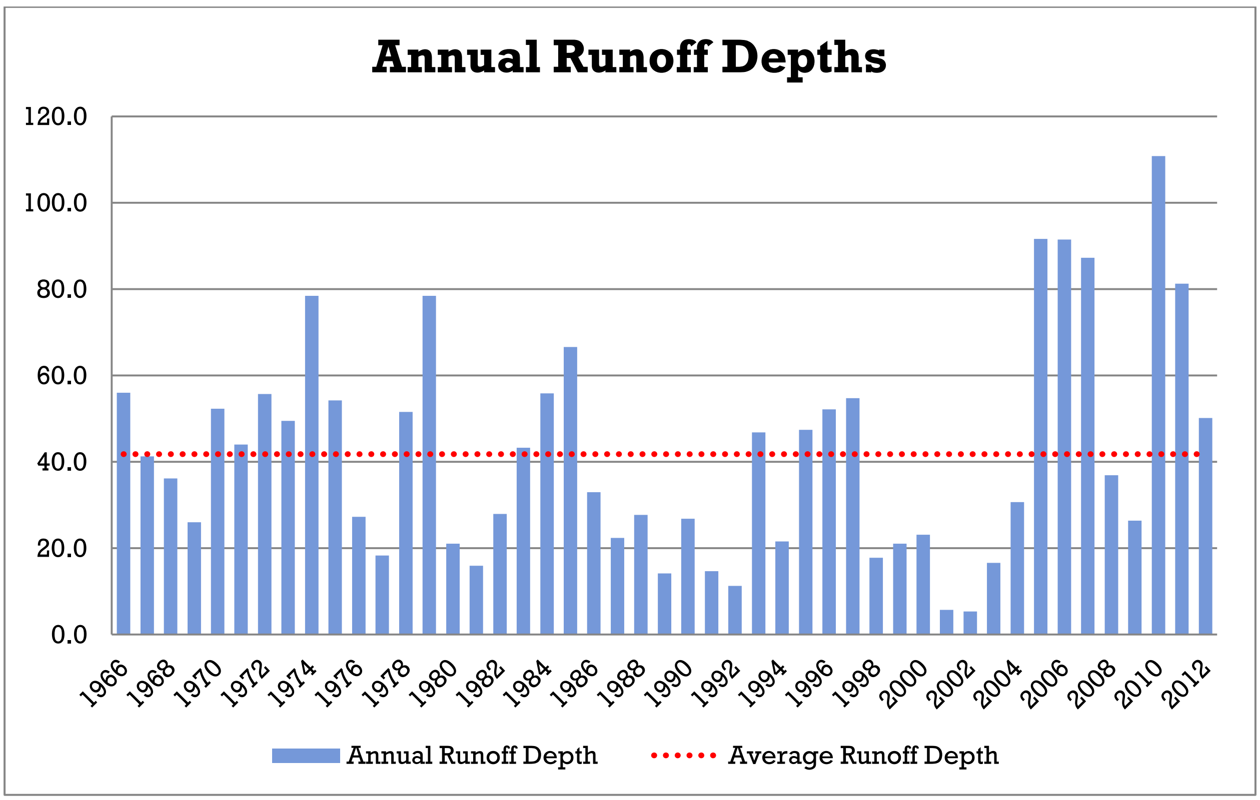

Figure 4: Equivalent Annual Runoff Depth for Carrot River (05KH007)

Table 5: Carrot River near Turnberry (05KH007)

	Monthly Mean Discharge (m^3/s)												Annual Volume dam^3
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	
1966		1.2	1.2	39.0	125.6	72.5	41.0	16.0	10.2	8.0	6.6	3.2	857,500
1967	2.4	2.0	2.0	3.6	112.9	74.0	19.1	11.7	4.7	2.6	2.2	1.5	631,500
1968	1.1	0.9	4.6	33.1	40.6	35.7	41.4	13.1	20.2	9.9	6.1	3.2	553,500
1969	1.6	1.2	1.2	47.1	55.3	13.7	4.4	3.3	2.8	14.2	4.4	1.8	397,800
1970	1.0	0.8	0.8	21.2	128.1	41.8	58.1	15.3	5.4	7.6	16.8	4.7	800,200
1971	1.9	1.2	1.2	53.5	97.8	16.4	12.8	11.2	9.1	25.0	18.4	5.9	673,100
1972	2.8	1.8	1.7	25.9	196.0	53.7	17.3	7.1	5.9	7.0	1.9	0.4	853,000
1973	0.6	0.7	1.3	18.3	36.6	86.2	78.3	30.1	12.2	10.2	7.7	5.0	758,000
1974	3.2	2.6	2.2	33.6	210.9	102.5	28.8	19.1	19.1	18.4	9.5	4.1	1,201,000
1975	2.7	2.1	1.9	19.9	112.8	84.0	43.4	11.7	11.1	15.4	7.2	1.9	830,000
1976	1.3	1.3	1.1	40.6	38.8	28.5	31.9	5.7	3.0	3.1	1.8	1.2	417,300
1977	0.9	0.9	1.6	20.8	20.6	12.9	2.6	10.6	9.8	9.0	13.2	3.4	279,900
1978	1.7	0.9	1.3	26.6	129.2	33.3	9.8	17.0	13.8	38.2	19.9	6.3	789,700
1979	2.3	1.5	1.4	20.9	226.4	137.5	33.9	6.5	6.4	8.3	6.8	2.1	1,200,700
1980	1.1	1.0	1.7	33.9	39.2	5.5	9.2	4.4	8.8	12.3	3.4	1.6	322,100
1981	0.6	0.8	3.1	16.6	19.1	7.5	10.0	5.2	3.0	16.0	8.1	2.3	243,900
1982	0.8	0.4	0.3	21.5	58.8	46.1	11.5	4.2	5.3	9.3	2.3	1.5	427,200
1983	1.6	1.4	1.3	16.2	61.7	66.7	48.8	14.9	15.8	13.0	7.2	2.1	661,900
1984	1.4	1.5	1.7	59.6	84.0	92.2	43.1	7.5	5.1	17.5	7.6	3.4	854,400
1985	2.2	1.8	2.1	70.7	171.8	57.5	24.2	16.7	11.5	18.0	7.5	1.9	1,019,700
1986	2.2	2.0	2.1	54.2	73.1	24.5	6.5	8.1	5.0	9.4	2.2	2.2	505,000
1987	2.1	2.1	2.2	35.4	17.7	12.1	16.4	7.4	6.7	15.9	8.4	3.5	342,200
1988	2.0	1.5	2.1	51.8	77.6	10.3	2.7	2.5	4.5	3.1	1.7	1.3	424,700
1989	0.8	0.7	0.6	12.8	17.7	7.5	8.1	4.7	18.2	5.1	4.1	1.9	216,400
1990	0.9	0.9	1.4	46.9	67.2	19.2	13.1	1.6	1.0	1.4	1.2	1.0	410,500
1991	0.9	0.9	1.0	15.0	20.0	8.3	16.6	5.9	5.0	5.7	3.8	1.9	224,400
1992	1.6	1.1	1.4	15.7	23.4	4.3	3.8	2.3	4.3	4.1	2.0	1.2	172,300
1993	0.8	0.5	3.4	12.9	6.0	14.1	87.0	69.9	35.8	21.7	12.5	5.3	716,600
1994	2.3	1.1	1.3	34.5	32.1	22.3	16.2	7.7	2.4	1.9	2.1	1.6	330,700
1995	1.2	1.1	1.3	19.5	135.2	35.9	9.4	28.8	23.6	9.4	5.5	3.0	726,300
1996	1.6	0.9	0.7	10.3	143.7	73.8	26.4	15.5	6.9	9.5	7.3	4.4	797,700
1997	2.5	1.9	1.9	33.2	170.1	52.9	23.6	6.3	5.2	10.0	6.6	2.0	837,900
1998	1.3	1.8	5.0	36.7	18.5	13.3	13.0	3.5	1.1	3.4	4.4	1.7	271,900
1999	0.7	1.0	2.2	26.3	51.7	12.9	9.1	5.7	2.2	3.1	4.6	2.4	322,500
2000	1.0	0.9	7.5	22.0	16.6	28.1	31.5	15.8	4.4	2.5	2.2	1.6	353,800
2001	1.2	1.0	1.2	5.1	11.2	7.3	3.7	1.0	0.3	0.2	0.4	0.4	87,200
2002	0.3	0.2	0.2	3.3	1.7	5.5	2.3	1.4	6.2	4.2	3.7	2.3	82,500

2003	2.0	1.3	1.1	24.1	35.6	14.9	7.2	2.0	1.7	3.1	2.4	1.1	254,500
2004	0.9	0.8	0.8	0.9	29.2	31.1	25.9	18.9	32.7	22.5	9.7	4.4	469700
2005	3.0	3.0	3.5	111.8	61.2	71.6	53.9	24.2	74.9	77.6	34.8	13.9	1,402,400
2006	8.2	5.8	6.0	90.0	145.8	71.9	39.9	23.8	16.9	50.1	49.3	22.7	1,399,500
2007	12.7	7.1	8.7	76.6	165.3	100.4	67.1	24.1	16.1	12.2	9.1	6.4	1,335,400
2008	3.5	1.5	2.4	33.6	98.2	30.4	18.0	12.5	3.9	3.6	3.8	2.0	565,200
2009	1.1	0.7	0.7	16.5	31.2	18.5	21.1	25.5	15.6	8.7	10.2	2.8	403,700
2010	1.8	1.6	4.0	88.4	100.8	85.2	84.4	70.6	72.7	57.2	48.9	27.3	1,696,100
2011	13.0	10.4	7.9	77.4	167.3	63.6	51.5	40.7	17.2	10.6	6.8	4.3	1,243,800
2012	3.3	2.7	9.8	41.8	56.7	45.2	41.6	37.6	27.9	23.9	24.9	13.3	752,300
Mean	2.3	1.7	2.4	33.8	78.0	40.7	26.5	14.6	12.7	13.7	9.2	4.1	627,800
Max	13.0	10.4	9.8	111.8	226.4	137.5	87.0	70.6	74.9	77.6	49.3	27.3	1,696,100
Min	0.3	0.2	0.2	0.9	1.3	0.5	0.5	0.2	0.3	0.2	0.4	0.4	15,800

Figure 5 illustrates the distribution of annual runoff for Carrot River. On average most of the annual runoff, 33.7 % occurs in May as a result of snowmelt and early spring rains when the watershed is still saturated. The maximum daily discharge of each year, as well as the date it occurred, was reviewed. In 36 of the 47 years of data, maximum daily discharge occurred during the spring runoff, in 8 out of 47 years the peak flow occurred during the summer growing period, and 3 of the 47 years of data, maximum daily discharge occurred during the month of September.

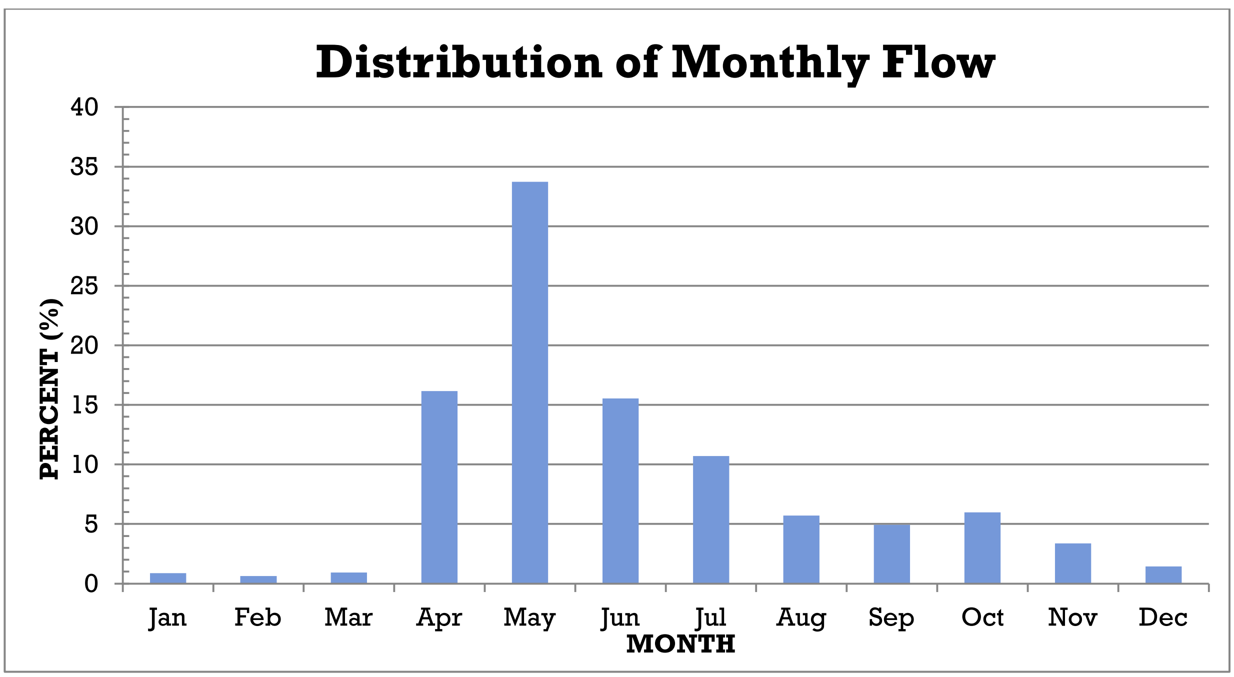

Figure 5: Distribution of Annual Runoff for Carrot River (05KH007)

Table 6 lists the results of frequency analyses of flow data at Carrot River at gauging station 05KH007. The expected annual peak discharge, runoff volume and corresponding unit depth for selected frequencies is given.

Flood Frequency	Return Period (yrs)	Annual Peak Discharge (m^3/s)	Annual Runoff Volume (dam^3)	Unit Runoff Depth (dam^3/km^2)
1%	100	339	29,300	1.9
2%	50	304	26,200	1.7
5%	20	254	21,900	1.4
10%	10	213	18,400	1.2
20%	5	168	14,500	0.9
50%	2	100	8,600	0.6

Table 6: Frequency of Flood Flows for Carrot River (05KH007)

Carrot River's recorded flow hydrographs for year's representative of the 2 %, 5 %, 10 %, and 50 % floods are plotted in Figure 6. The runoff hydrographs show minimal variability from the date the initial peak discharge occurs. In general, the initial peak occurs between April 12 and May 7.

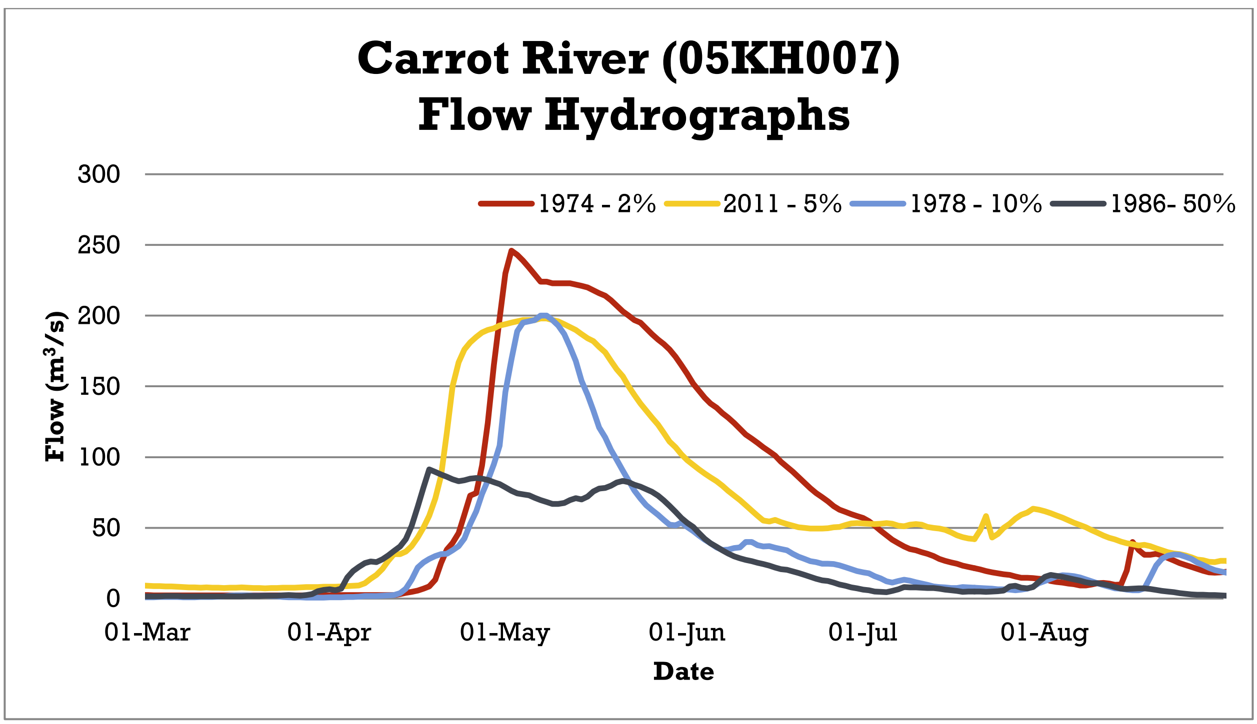

Figure 6: Carrot River near Turnberry (05KH007) - Runoff Hydrographs

B. *Saskatchewan River at The Pas (05KJ001)*

The gross drainage area of station 05KJ001 is 388,800 km^2. The station has an effective to gross drainage area ratio equal to 0.5 (PFRA drainage area database). The Saskatchewan River flows are heavily influenced by upstream regulation, primarily from operation of the Tobin Reservoir and Lake Diefenbaker.

The mean monthly discharge data for Saskatchewan River is shown in Table 7. Based on available data, the average runoff during the period 1913 to 2012 is equal to 19,789,900 dam^3 or an equivalent depth of 506.9 mm over the gross drainage area for station 05KJ001.

Table 8: Saskatchewan River at The Pas (05KJ001) Note: Blanks indicate missing data

	Monthly Mean Discharge (m^3/s)												Annual Volume dam^3
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	
1913	156	156	184	968	1,506	1,427	1,711	1,646	1,269	708	396	227	27,344,300
1914	170	142	127	708	1,259	1,277	1,653	1,144	714	585	476	246	22,457,500
1915	127	146	158	696	710	1,273	2,243	2,681	1,850	966	594	198	30,762,200
1916	152	121	146	953	1,245	1,737	2,654	2,515	1,967	1,419	845	288	37,107,800
1917	182	176	175	507	1,932	2,285	2,399	1,595	900	596	540	204	30,368,000
1918	124	146	179	1,031	846	927	1,414	1,178	832	589	356	150	20,505,900
1919	135	147	126	460	647	842	873	761	664	569	162	89	14,441,400
1920	83	79	83	130	1,726	1,956	1,743	1,495	771	434	254	166	23,600,900
1921	83	79	98	262	1,747	1,691	1,621	1,139	833	560	342	234	22,984,100
1922	177	139	132	430	1,263	1,433	1,394	1,080	985	601	394	176	21,654,200
1923	123	117	112	345	888	1,328	2,276	1,830	1,237	646	262	156	24,659,900
1924	97	92	113	174	949	977	1,237	942	839	478	214	178	16,638,100
1925	136	115	124	696	1,232	1,309	1,555	1,110	1,201	870	462	258	23,945,900
1926	177	154	200	551	999	698	981	725	975	1,282	844	225	20,615,800
1927	215	165	164	493	1,793	1,820	2,149	1,977	1,508	1,349	758	403	33,832,000
1928	303	273	261	763	1,464	1,297	2,183	1,862	880	417	213	111	26,516,200
1929	73	71	90	303	802	1,218	1,138	529	419	242	117	64	13,370,400
1930	55	54	70	634	737	964	1,182	813	529	328	243	132	15,152,700
1931	112	102	118	480	440	503	1,045	815	644	544	320		13,526,000
1932				1,588	1,138	1,498	1,771	1,052	803	507	353	181	23,445,000
1933	170	160	150	510	1,425	1,520	1,511	913	686	421	322	243	21,207,000
1934	172	202	234	676	1,551	1,417	1,608	1,004	657	469	426	295	23,005,600
1935	191	143	213	537	1,054	1,081	1,385	1,252	630	331	155	133	18,781,600
1936	102	91	91	436	1,597	1,258	876	529	487	260	165	87	15,789,700
1937	60	57	64	506	637	624	933	711	388	304	241		11,953,500

1938				1,195	650	1,021	1,357	896	638	425	247		16,954,000
1939				1,274	688	705	1,422	818	462	302	279		15,704,800
1940				1,580	1,252	948	689	603	415	426	189	115	16,381,900
1941	102	76	76	620	388	360	540	470	413	274	267	84	9,666,900
1942	56	62	68	425	539	1,147	1,625	1,507	942	610	318	179	19,770,500
1943	158	134	147	1,029	1,366	1,008	1,422	1,088	631	346	270	122	20,395,000
1944	110	104	103	601	495	880	1,472	1,093	779	437	214	137	16,968,600
1945	99	118	133	512	823	1,208	1,402	876	582	527	298	192	17,878,100
1946	173	169	192	1,004	717	975	1,363	834	569	429	245	120	17,901,100
1947	163	154	173	818	1,459	1,327	1,325	852	678	642	469	283	22,022,800
1948	264	203	180	333	2,255	2,852	2,227	1,454	927	437	197	103	30,188,500
1949	89	76	102	711	502	790	703	713	430	289	322	120	12,758,700
1950	95	121	120	444	954	843	1,392	1,056	606	370	214	150	16,834,600
1951	175	155	158	759	1,509	1,588	1,749	1,613	1,295	1,113	717	395	29654200
1952	212	229	240	1,195	1,839	1,361	1,843	1,486	915	531	381	153	27,421,900
1953	136	128	159	513	1,222	1,630	2,064	1,495	1,019	517	320	145	24,698,100
1954	134	133	187	302	1,267	1,877	2,072	1,699	1,976	1,681	1,150	814	35,106,700
1955	369	346	273	1,159	1,816	1,876	1,622	1,197	604	426	164	145	26,354,800
1956	150	176	185	620	1,955	1,759	1,429	1,069	686	471	307	154	23,669,100
1957	131	97	124	575	1,487	1,366	912	581	515	377	383	206	17,817,200
1958	153	158	196	1,058	1,206	1,203	1,189	904	494	359	224	123	19,165,800
1959	153	141	159	957	655	949	1,428	915	491	475	306	262	18,190,100
1960	207	178	174	1,039	975	1,021	1,060	786	392	271	187	146	16,965,900
1961	135	129	137	526	634	1,119	798	610	368	229	155	89	12,985,500
1962	125	153	179	395	1,125	851	897	752	421	124	104	110	13,835,300
1963	79	78	87	652	817	776	1,107	943	590	412	281	141	15,754,700
1964	163	218	212	518	798	905	1,446	699	477	538	389	158	17,213,000
1965	208	207	225	656	1,390	1,566	2,301	1,836	983	864	575	319	29,431,000
1966	341	225	354	858	1,157	1,225	1,499	1,137	548	338	214	139	21,216,600
1967	230	395	404	304	1,010	1,096	1,038	688	440	334	214	153	16,606,500
1968	425	213	274	580	513	458	544	547	488	355	360	258	13,215,200
1969	413	473	429	932	1,095	688	1,259	954	584	532	327	281	21,000,800
1970	424	522	390	441	1,173	775	1,155	900	501	408	410	333	19,586,700
1971	483	577	534	806	1,194	888	890	817	436	370	436	337	20,429,500
1972	459	403	486	673	1,551	1,078	1,332	1,046	563	536	352	253	23,051,800
1973	472	526	511	648	1,001	1,159	979	582	556	469	306	369	19,930,800
1974	454	537	600	966	2,329	1,860	1,387	946	837	712	546	430	30,580,800
1975	487	627	606	621	1,238	1,156	1,052	595	450	456	443	335	21,206,600
1976	413	541	577	786	513	388	493	498	493	473	284	292	15,097,900
1977	468	520	345	534	477	594	402	365	438	355	250	268	13,140,100
1978	309	338	341	499	1,059	812	799	543	577	679	388	332	17,598,100
1979	451	513	564	543	1,572	1,123	538	388	344	313	295	245	18,116,300

1980	284	497	500	711	587	690	798	438	372	487	398	222	15,704,900
1981	401	464	418	751	558	872	742	1,084	691	512	424	246	18,827,500
1982	378	481	433	588	886	618	689	545	384	412	327	268	15,801,300
1983	417	499	464	535	1,014	671	771	496	397	436	415	276	16,808,100
1984	322	375	352	838	667	689	521	341	357	391	295	266	14,214,700
1985	280	311	363	932	1,350	872	589	427	431	402	309	305	17,304,300
1986	440	399	472	825	815	799	793	991	534	655	483	425	20,106,900
1987	453	578	611	852	639	439	362	398	393	364	300	235	14,745,500
1988	254	331	220	528	587	288	305	265	292	268	175	183	9,702,000
1989	166	292	244	356	555	406	390	461	567	382	237	262	11,353,900
1990	293	357	458	842	885	1,167	1,566	857	498	428	351	269	21,015,000
1991	301	448	457	756	684	696	943	741	593	478	330	322	17,756,800
1992	358	409	428	567	463	379	396	296	242	303	346	192	11,491,000
1993	273	343	272	577	448	422	960	1,297	913	729	480	354	18,634,200
1994	336	476	508	813	796	567	620	511	401	332	272	265	15,492,000
1995	292	361	323	586	803	831	1,068	1,051	870	626	510	447	20,468,600
1996	383	510	520	785	1,525	1,235	955	714	497	558	437	339	22,261,900
1997	457	549	575	928	1,505	1,138	938	511	411	506	470	365	21,978,300
1998	415	527	597	729	507	468	1,181	761	503	384	440	350	18,058,700
1999	319	446	447	934	777	628	698	834	569	496	381	316	17,998,900
2000	286	344	394	726	468	518	601	596	365	296	256	249	13,403,600
2001	314	309	247	560	424	319	338	428	308	219	224	184	10,172,600
2002	178	227	210	202	385	422	514	425	372	321	339	301	10,260,100
2003	263	398	391	729	865	783	663	422	312	266	258	253	14,725,800
2004	236	263	233	595	495	465	559	499	602	553	451	372	14,004,500
2005	314	324	476	1,195	910	1,221	1,909	933	1,192	1,321	985	701	30,264,500
2006	551	544	622	1,367	1,232	1,074	930	622	503	679	626	472	24,245,900
2007	382	420	563	1,244	1,595	1,429	1,237	700	558	473	462	411	24,945,200
2008	388	448	490	622	823	969	900	638	448	435	398	257	17,930,300
2009	331	478	372	670	565	414	431	460	445	381	441	347	13,995,900
2010	339	415	482	795	667	907	1,206	888	797	816	676	487	22,315,000
2011	416	375	523	1,152	1,610	1,859	2,215	1,674	884	670	563	480	32,782,800
2012	437	410	498	894	886	996	1,418	1,310	741	592	547	404	24,084,000
Mean	253	280	291	707	1,032	1,048	1,200	928	667	519	371	253	19,789,900
Max	551	627	622	1,588	2,329	2,852	2,654	2,681	1,976	1,681	1,150	814	37,107,800
Min	55	54	64	130	385	288	305	265	242	124	104	64	9,666,900

The annual runoff depths for the Saskatchewan River at gauging station 05KJ001 from 1913 to 2012 are shown in Figure 7. The values range from a minimum of 248.9 mm in 1941 to a maximum of 955.5 mm in 1916. This figure also illustrates the variability in runoff from year to year, as well as the years above and below the average runoff.

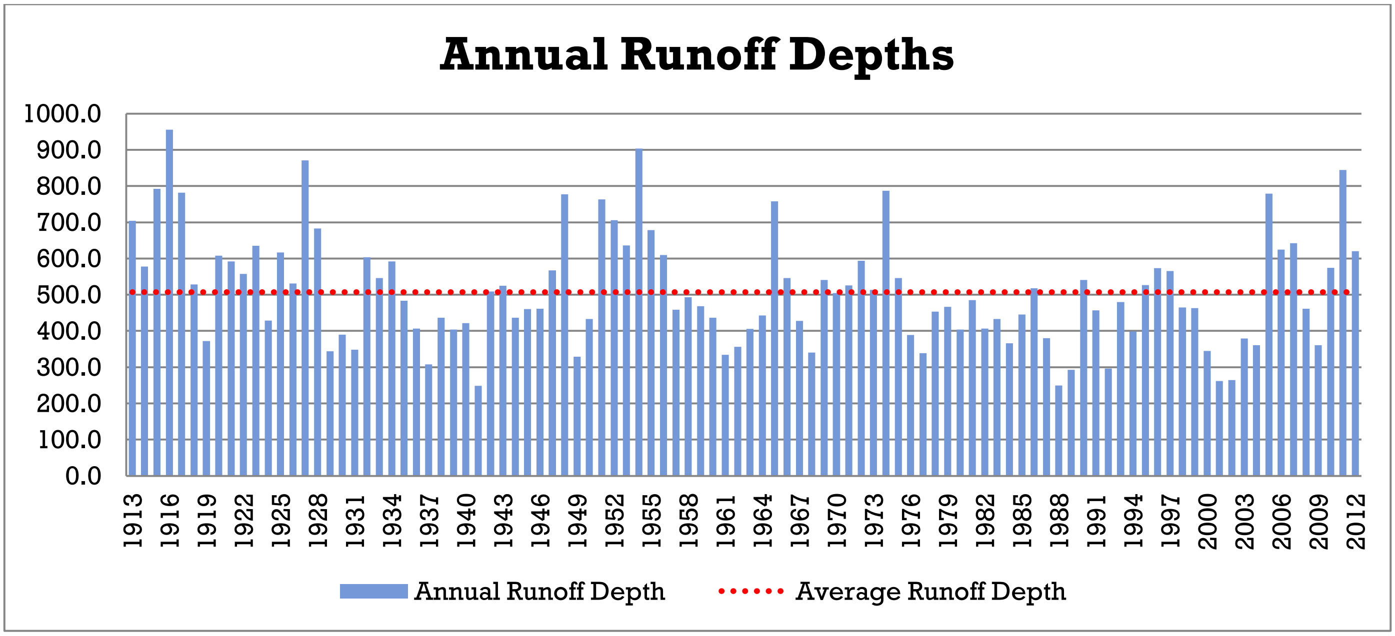

Figure 7: Equivalent Annual Runoff Depths for Saskatchewan River (05KJ001)

Figure 8 illustrates the distribution of annual runoff for Saskatchewan River. On average, the months of April, May, June and July has over 63% of the total annual runoff.

The maximum daily discharge of each year, as well as the date it occurred, was reviewed. In 58 out of 100 years of data, maximum daily discharge occurred during the months of April and May, in 42 out of 100 years the peak flow occurred during the months of June, July and August.

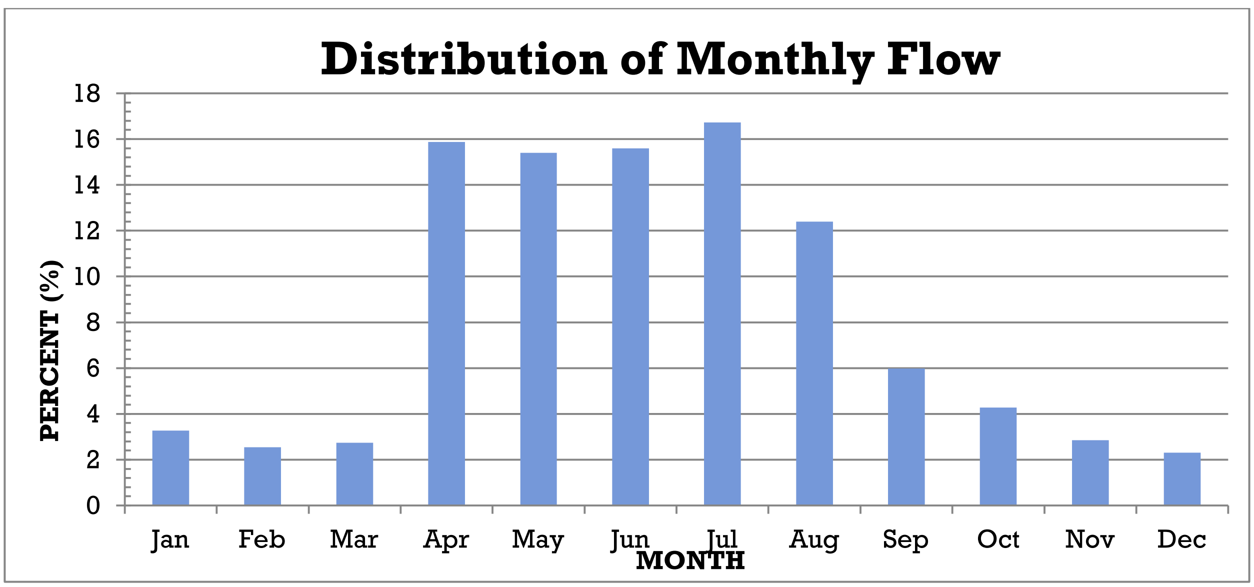

Figure 8: Distribution of Annual Runoff for Saskatchewan River (05KJ001)

Surface Water Management Section

The result of a statistical analysis of Saskatchewan River flows is shown in Table 9. The expected annual peak discharge, runoff volume and corresponding unit depth for selected frequencies is given.

Flood Frequency	Return Period (yrs)	Annual Peak Discharge (m^3/s)	Annual Runoff Volume (dam^3)	Unit Runoff Depth (dam^3/km^2)
1%	100	96,500	8,340,400	21.4
2%	50	89,700	7,752,900	19.9
5%	20	80,400	6,943,300	17.9
10%	10	72,800	6,291,800	16.2
20%	5	64,600	5,579,800	14.4
50%	2	51,200	4,423,800	11.4

Table 9: Frequency of Flood Flows for Saskatchewan River (05KJ001)

Saskatchewan River recorded flow hydrographs for years representative of the 2 %, 5 %, 10 %, and 50 % floods are plotted in Figure 9. The runoff hydrgraphs show some variability from the date the initial peak occurs. In general, the initial peak occurs between April 20 and May 11.

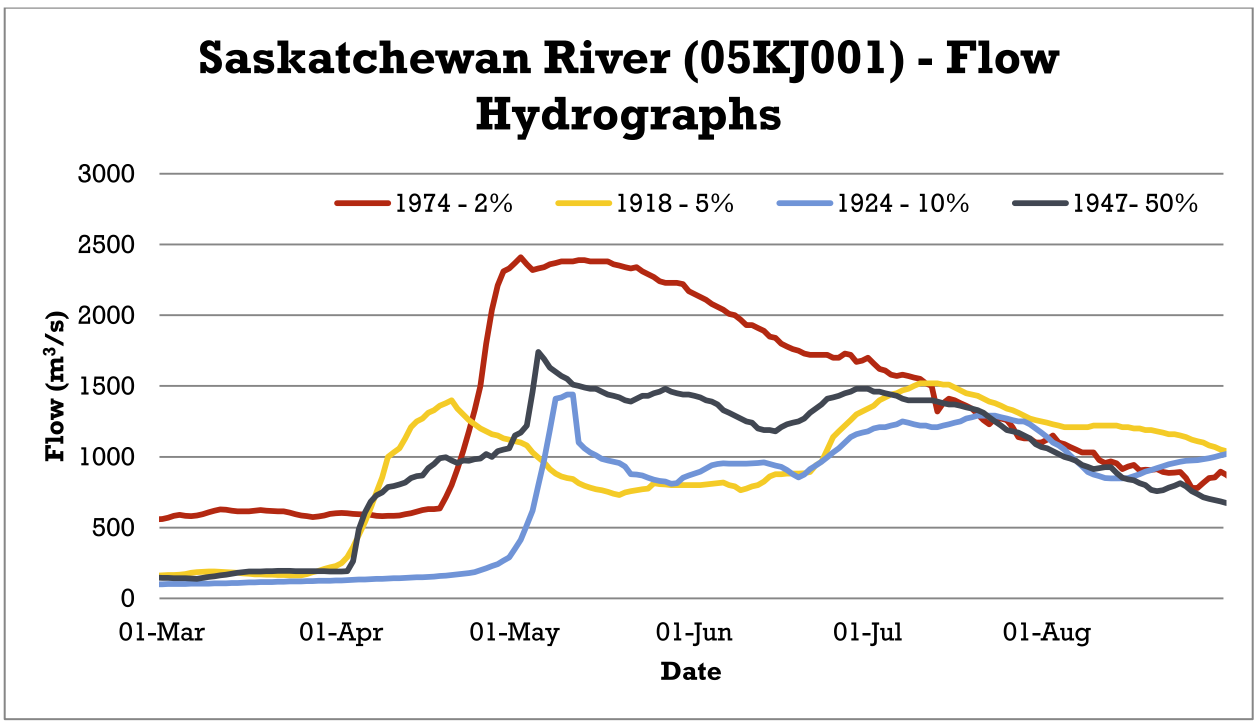

Figure 9: Saskatchewan River at The Pas (05KJ001) - Spring Runoff Hydrographs

C. *Summary of Findings*

Analysis of the available stream flow data in the CSRPA indicates the following:

- Stream flow varies considerably over the months and years.
- Annual stream flow usually peaks between April and May.
- On average, between 60 % and 75 % of the annual runoff volume occurs between March and July of a given year for the Carrot and Saskatchewan Rivers.
- On major watercourses, spring flooding is more significant than flooding from summer precipitation events. Smaller drainage areas (< $30km^2$) are more sensitive to rainfall events. Localized flooding can occur in the smaller poorly drained areas from excessive rainfall events.

Water Allocation:

The issuance of a water use licence requires the determination of the availability of water for human use allocation and the determination of instream flow needs (IFN). The IFN is a specified minimum instantaneous flow that determines when a user may pump from the stream. The allocation procedure depends on whether the stream is considered to be perennial or intermittent.

Intermittent:

The total spring volume (March to May) of water available for allocation on intermittent streams is based on the eight out of ten-year (80 %) risk level based on daily discharge frequency. This would apply to smaller tributary streams.

On intermittent streams, one half of the spring volume of water is available for human use in eight out of ten years. The other half is allocated to IFN for maintenance of stream health and to maintain the ecological integrity of the stream system. Only when the flow in the stream is greater than the IFN can pumping occur.

Perennial:

The Tessman Method has been adopted in Manitoba for determination of the IFN on perennial streams. This method establishes a range of instream flow recommendations for each month based on the following criteria:

1. For months where the average recorded flow for the period of record is less than 40% of the overall mean annual flow, the minimum instream flow is equal to the average monthly flow.

2. If the mean monthly flow is between 40% and 100% of the overall mean annual flow then the minimum instream flow is equal to 40% of the mean annual flow.

3. For months where the mean monthly flow is greater than the mean annual flow, then the minimum instream flow is equal to 40% of that month's overall mean flow.

Under the 80 % risk level, the volume of water available for human use allocation is the 80th percentile value from a duration curve of available volumes after the IFN requirements have been satisfied.

Carrot and Saskatchewan River are both considered to be perennial streams. The Tessman method was applied in determining an allocable volume of water at the two streams respective hydrometric stations, 05KH007 and 05KJ001. The instream flow recommendations on a monthly basis for both streams are shown in Figures 10 and 11.

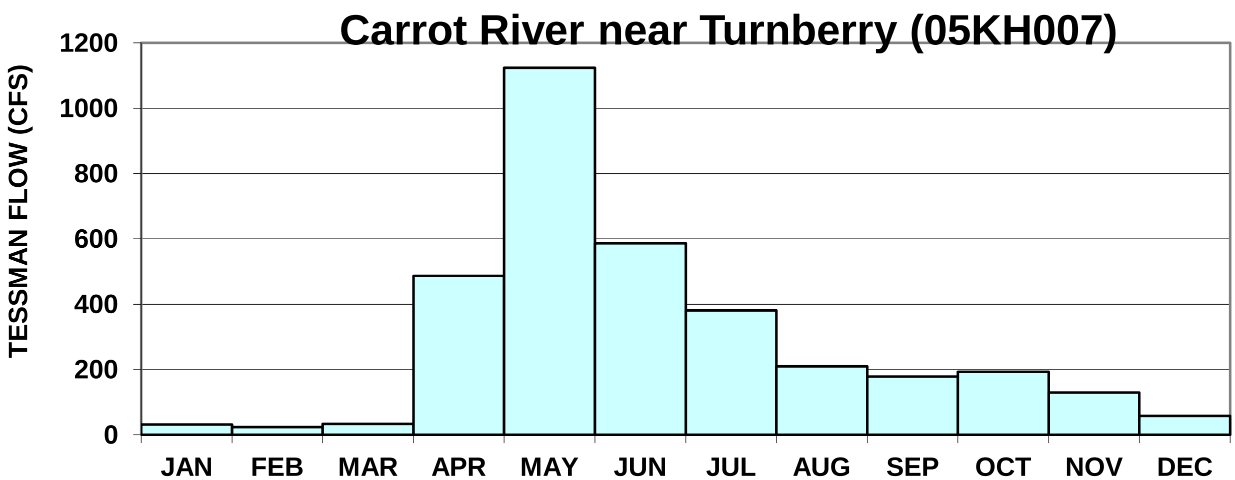

Figure 10: Tessman Flow plots for Carrot River

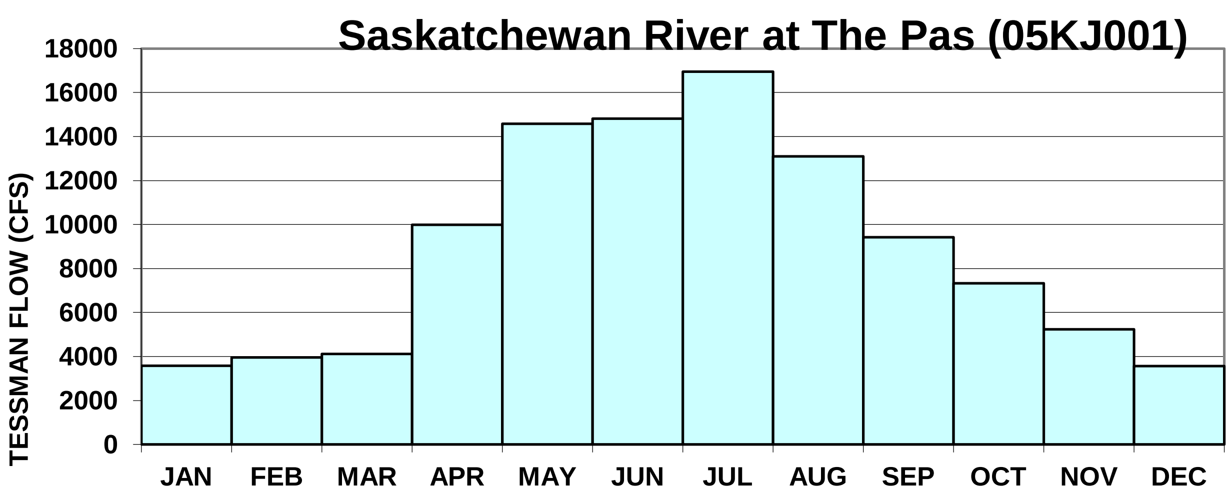

Figure 11: Tessman Flow plots for Saskatchewan River