2016 Fall Conditions Report

Prepared by:

Hydrologic Forecast Centre

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EXECUTIVE SUMMARY

In the Canadian prairies, flooding is most common in the spring as the snowfall accumulated through the winter begins to melt and runoff. Spring flood risk is a combination of a number of different factors some of which are determined in the fall, during the winter, and during the spring period. The fall conditions report describes the state of various factors for which data is available, that affect potential spring runoff and flood risk. The three key factors covered in this report are the soil moisture at the time of freeze-up, base flows on rivers and water levels on lakes prior to spring runoff, and to a lesser extent, long term forecasted winter precipitation as a general indication of probable future weather. A central concept in water management is that water doesn't recognize political boundaries, therefore, as a downstream jurisdiction Manitoba's flood risk in some watersheds is determined in part by the conditions in upstream jurisdictions including Saskatchewan and North Dakota.

One major factor that affects spring runoff potential is the soil moisture at the time of freeze-up. The soil moisture before freeze-up is largely determined by the accumulated summer and fall precipitation. Due to the late freeze-up this year and to capture the effect of late fall precipitation, November rainfall was included in the analyses performed by the Hydrologic Forecast Centre. All river basins in Manitoba have received normal to well above normal precipitation between May and November. The Assiniboine, Qu'Appelle and Souris River watersheds have all received above normal precipitation. The upstream watersheds of the Saskatchewan River and the Lake Winnipegosis basins have received above normal to well above normal precipitation between May and November. The Red River watershed received normal to above normal precipitation between May and November. South-eastern Manitoba, eastern and Interlake regions received normal precipitation during the same period. October and November were particularly very wet compared to historic precipitation records. A Record amount of rain occurred in October across much of Manitoba and Saskatchewan, with precipitation in October was well above normal in all basins except the Red River basin, which has received normal to below normal precipitation during the same period. Precipitation in November was above normal to well above normal throughout the watersheds of the Red, Souris, lower Assiniboine, Saskatchewan River Basins, including the Whiteshell Lakes and Interlake regions.

Due to the fall and summer precipitation patterns, the soil moisture before freeze-up is above normal to well above normal for the Saskatchewan, Assiniboine, Souris and Qu'Appelle Rivers, as well as the watersheds of Lake Winnipegosis and Dauphin Lake. Above normal to well above normal soil moisture indicates the potential for higher risk of spring flooding within these river basins but flooding is still strongly dependent on future weather conditions, including winter and spring precipitation, as well as melt conditions. Soil moisture in these basins is comparable with the soil moisture observed in the fall of 2010, which led to record spring runoff in the spring of 2011. The soil moisture on the Red River basin is normal to above normal. Though the soil moisture in the Red River basin is normal to above normal, it is less than the soil moisture observed in the fall of 2010. The soil moisture in Interlake, Whiteshell lakes and Lake of the Woods regions is generally near normal.

Another major factor that affects the potential spring flood risk is the base flow on rivers and water levels on lakes prior to the spring runoff. Higher base flows and water levels indicate a higher risk of spring flooding as there is more water already in the system before runoff occurs. Base flows on many rivers and water levels on many lakes are above the normal flows and levels for this time of the year. Lake Winnipegosis, Dauphin Lake and Lake of the Prairies (Shellmouth reservoir) are at record high levels for this time of the year exceeding the previous record set in the fall of 2010, which contributed to the flood of 2011. The Shellmouth reservoir was used to store this year's record inflows from the upper Assiniboine River during October and November in order to mitigate downstream flooding of agricultural land and is now being drawn down to create storage space for spring runoff. Lake Winnipeg is above the upper end of the operating range and Lake Manitoba is near the upper end of the operating range. Both lakes have maximum possible outflows. Lake St. Martin is above flood stage.

Most rivers are above the normal flow for this time of the year. The Assiniboine River at most locations downstream of Shellmouth, the Carrot River and the Waterhen River are at record high flows for this time of the year, exceeding the previous record set in the fall of 2010. Flows on the Assiniboine River are high largely because of the release of 1,600 cfs from the Shellmouth reservoir. It is planned to sustain these high outflows throughout most of the winter to achieve the winter drawdown target. There could be a risk of ice jamming on the Assiniboine River similar to what was experienced in the winter of 2010. The Fairford, Dauphin, and Saskatchewan Rivers are at well above normal flows for this time of the year. The Qu'Appelle,

Souris and Red Rivers currently have base flows that are also considered above normal for this time of year.

The forecasted winter precipitation is also another indicator of the potential for spring flooding. Though long term weather forecasts are not very reliable, they provide an indication of potential future weather patterns. Environment Canada's latest long term (December-January-February) precipitation forecast indicates precipitation will be above normal for northern Manitoba including the Lake Winnipegosis watershed. Precipitation is forecasted to be near normal in southern Manitoba including the Red River basin. The US National Weather Service (NWS), however, forecasts above normal precipitation for southern Manitoba and most of the Red river basin, contrary to Environment Canada's forecast. If above normal precipitation within these basins occurs, it will lead to a high risk of major spring flooding. Even with normal precipitation, the basins with high soil moisture could see above normal spring runoff. The Hydrologic Forecast Center of Manitoba Infrastructure works in collaboration with Environment Canada, the National Weather Service, and flood forecasters in neighbouring jurisdictions to regularly monitor the winter precipitation patterns throughout these basins.

For the normal (average) winter weather conditions, the forecasted water levels for major lakes and flows on major rivers throughout the winter on selected lakes and rivers are also given. The Assiniboine River is forecasted to remain at record high flows until the spring runoff. This is mainly due to the sustained release of high flows from the Shellmouth reservoir in order to reduce the level in the reservoir in preparation for spring runoff. The Red River is expected to remain above the upper decile, ninety percentile, flow until the spring runoff. Flows on the Waterhen, Fairford and Dauphin Rivers will remain very high due to the high lakes levels from where these rivers originate. Lake Manitoba is expected to remain near 812.4 to 812.5 ft throughout the winter. Lake Winnipegosis will remain between 833.6 and 833.8 ft throughout the winter. Lake St Martin is expected to reach near 803 ft before the spring runoff.

It is not very practical or feasible to provide a long term flood forecast for spring 2017 as conditions could change significantly during the coming months. However, due to above normal to well above normal soil moisture conditions and high base flow conditions, the Saskatchewan, Assiniboine, Qu'Appelle, Red and Souris Rivers will be closely monitored. Conditions affecting Dauphin Lake, Lake Winnipegosis, Lake Manitoba, and Lake St. Martin will also be closely monitored leading up to the spring. Even with normal winter precipitation, these watersheds could see major flooding if a fast melt rate or heavy spring rainfall were to occur in early spring.

A single major weather storm, similar to the one that occurred in the summer of 2014, could cause major flooding in Manitoba.

The preliminary assessment of the extremely wet soil moisture conditions, the above normal to well above normal base flow and water level conditions and the near normal to above normal future precipitation forecasts in our basins indicate the probable chance of moderate to major flooding at some locations. However, looking back at some of the most significant historic flood events, each flood cause is a combination of unique circumstances. Overestimating or under-estimating the flood potential four month in advance of the spring runoff is very risky. The hydrologic forecast center will continue to monitor the basin conditions closely and will release spring flood outlooks through the winter as required.

BACKGROUND

Runoff potential leading to a possible flood or drought is generally dependent on six major factors: These are listed in the order of significance as:

1. Winter precipitation;
2. Soil moisture at freeze-up;
3. Effective spring rain (April rainfall);
4. Melt rate;
5. Frost index and;
6. Base-flow conditions.

Historically, all of the above factors have effectively contributed to either a major flood or drought. The combination of these factors is generally unique for each specific year and for each specific basin across the province. Generally, the soil moisture at freeze-up, winter precipitation, and base flow conditions are well known before spring melt and give a very strong indication of flood or drought potential.

SUMMER AND FALL PRECIPITATION

Almost all of the major river basins which flow through Manitoba (The Assiniboine River, The Red River, The Saskatchewan River, The Souris River and The Qu'Appelle River) have received normal to above normal precipitation between May and October. The northern part of the province, including the Pas and Lake Winnipegosis basin received well above normal precipitation during this period. Figure 1 shows the comparison of precipitation received during this period with normal conditions. In total, the Red River, the Assiniboine River, Whiteshell Lakes, Upper Saskatchewan River and the Lake Winnipegosis basins received over 450 mm of rain and in some areas over 500 mm of rain between May and October (Figure 2). Most other basins received between 350 to 400 mm of rain during this period.

In particular, the months of October and November were extremely wet and received record amount of precipitation at some locations. All Manitoba river and lake basins, with the exception of the Red River basin, Whiteshell and Lake of the Woods areas, received well above normal precipitation in October (Figure 3). The greatest accumulation of precipitation in October

occurred in the northern part of the province near Lake Winnipegosis and The Pas. These areas have received between 200 to 270 mm of rain, which is about half of the total precipitation amount they would have received in the entire normal year (Figure 4) or about 7 to 8 times the normal precipitation they would have received in the normal October. October precipitation in the Red River basin was normal to below normal.

In November, most basins, including the Red River, the Souris River, the lower Assiniboine River, the Upper Saskatchewan River, Interlake, Whiteshell Lakes, and Lake of the Woods basins received above normal to well above normal precipitation (Figure 5). During this period, the upper Assiniboine River and the Qu'Appelle River basins received near normal precipitation. The Red River basin received between 30 to 60 mm of rain in November (Figure 6). The combined October and November precipitations are above normal to well above normal for all Manitoba basins, except the Red River and the Lake of the Woods basins, which received near normal precipitation (Figure 7). This concentration of high precipitation later in the year will tend to result in higher soil moisture conditions going into the winter, as there is less time for water to infiltrate or evaporate from the soil column.

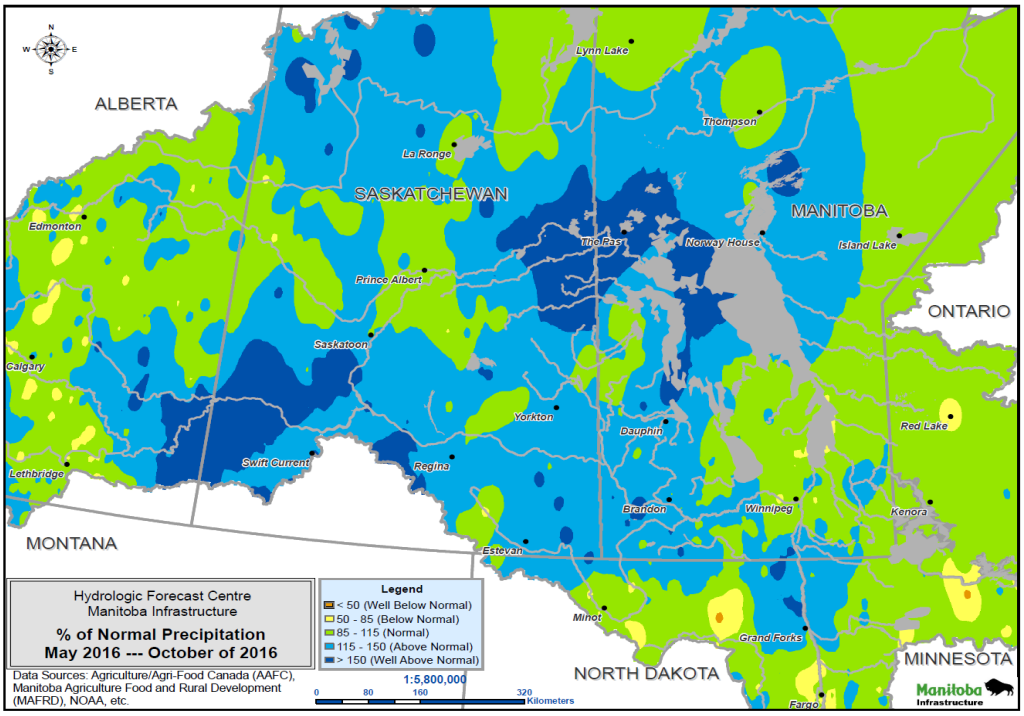


Figure 1. Percent Normal Precipitation (%) from May 1 to Oct 30, 2016.

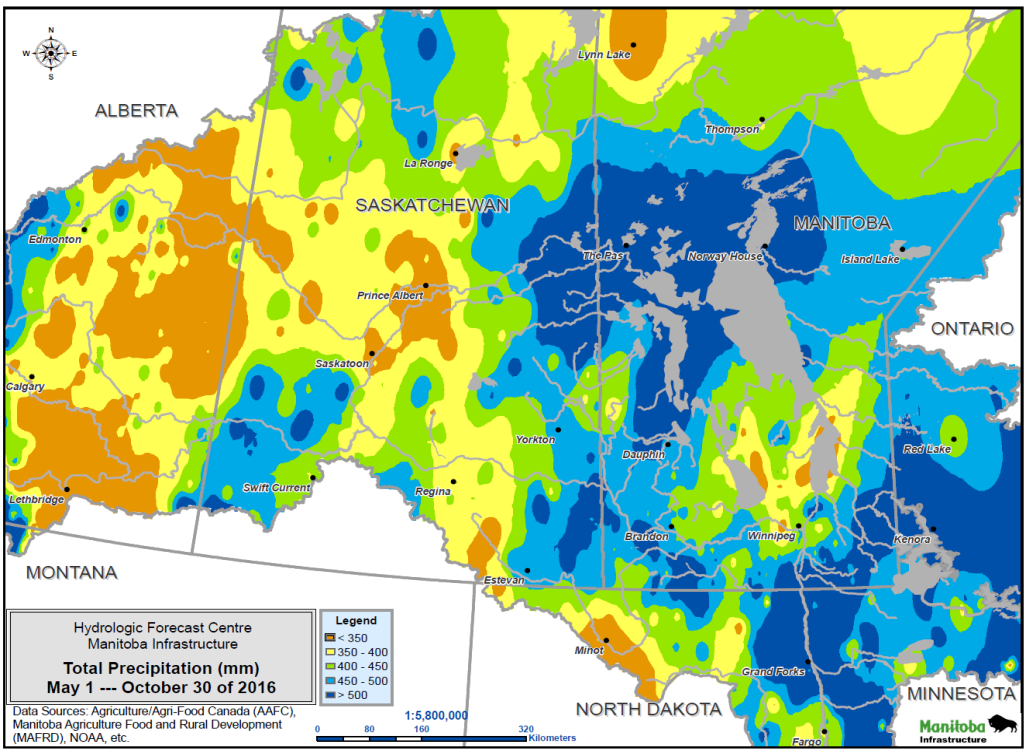


Figure 2. Total Accumulated Precipitation (mm) from May 1 to Oct 30, 2016.

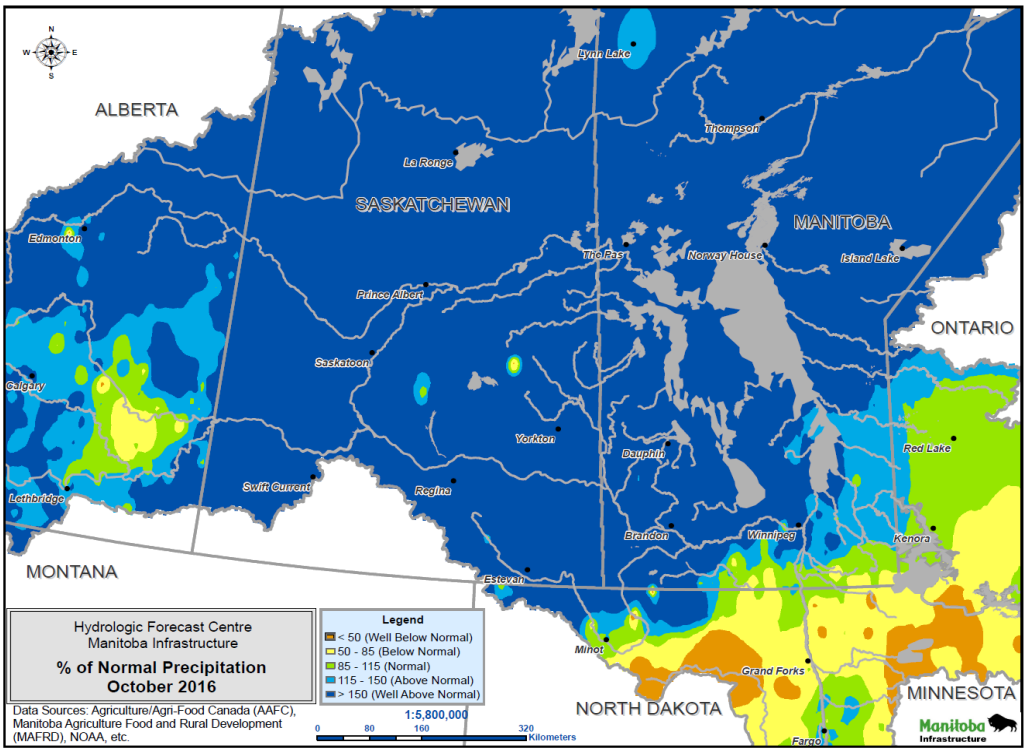


Figure 3. Percent Average Precipitation (%) in October 2016

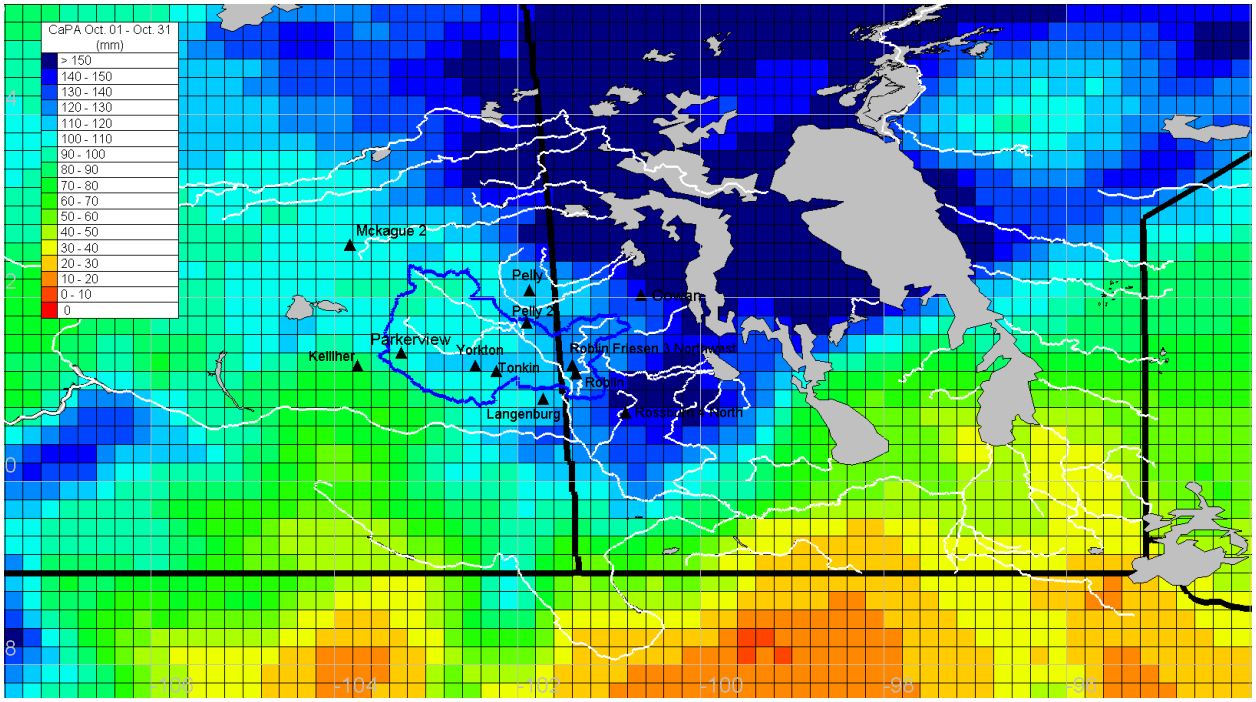


Figure 4. Accumulated Precipitation in October 2016

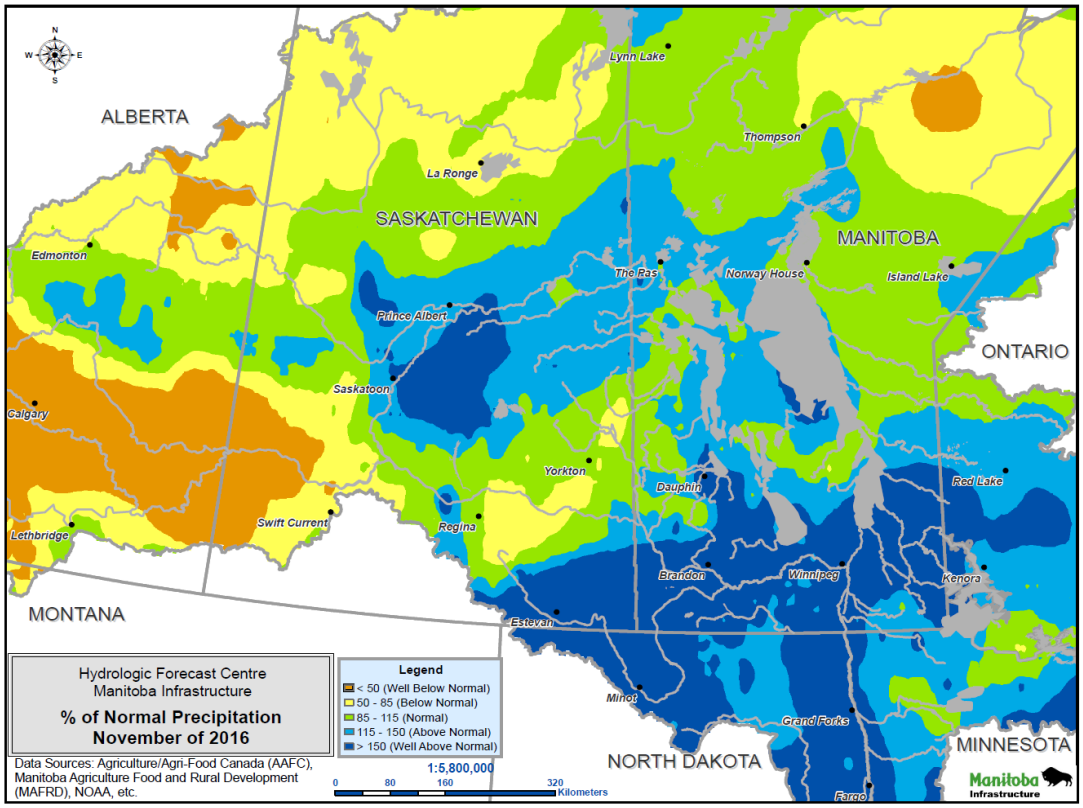


Figure 5. Percent Average Precipitation (%) in November 2016

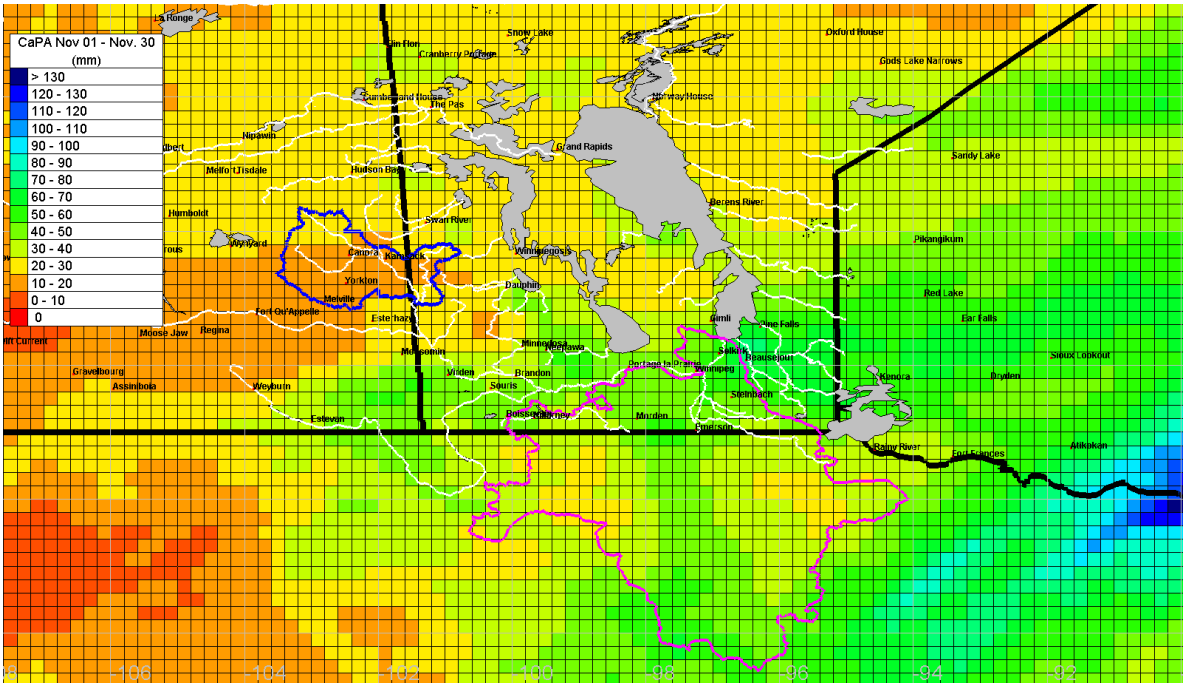


Figure 6. Accumulated Precipitation in November 2016

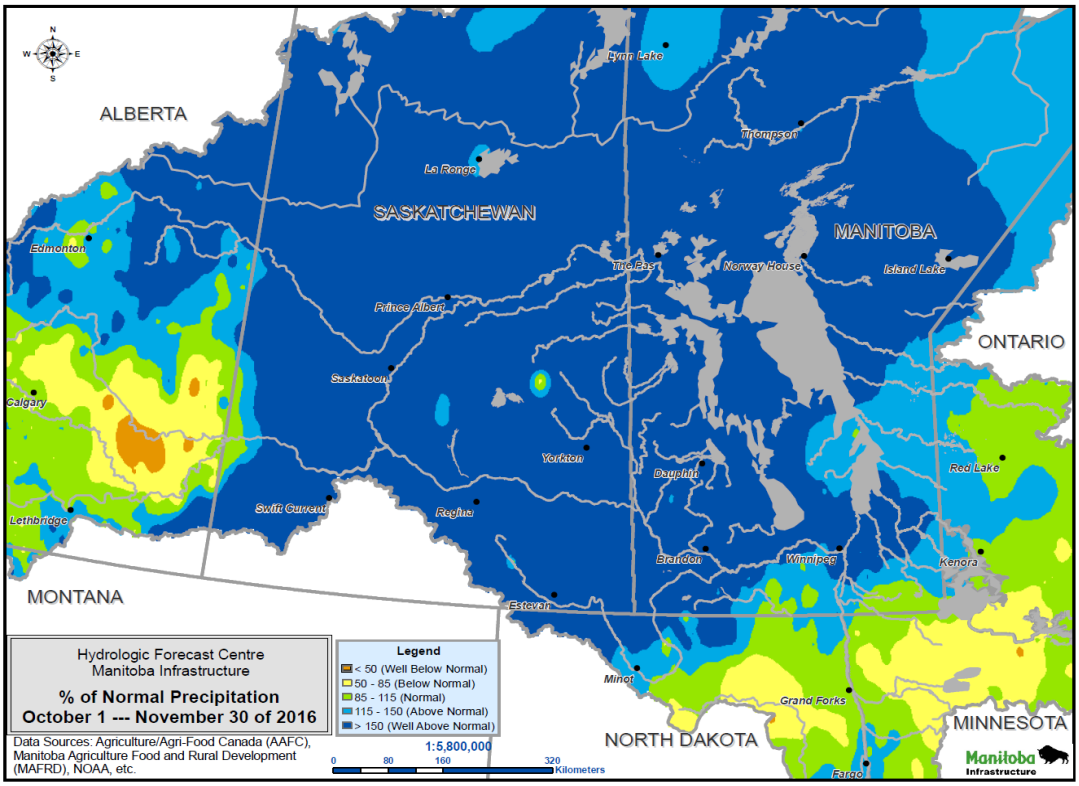


Figure 7. Percent Normal Precipitation (%) in from Oct 1 to Nov 30, 2016.

SOIL MOISTURE CONDITIONS

A number of different tools have been used to determine the soil moisture before freeze-up. The most common method, which has been used for years, is Manitoba's MANAPI model which is expressed by the API (Antecedent Precipitation Index) method. The API index map for the fall of 2016 is shown in Figure 8. Manitoba Agriculture in association with Manitoba Infrastructure also conduct routine surveys physically measuring soil moisture in the root zone across the province. These results, which are usually presented in either percent water holding capacity of the soil or millimetres of water available in the root zone, are presented in Figure 9 to 11. The other common method is the Airborne Gamma Survey, which uses radiation technology from low-flying aircraft to determine the soil moisture within the top 20 cm of soil. The Gamma Survey has been conducted in the southern and south western Manitoba basins and the results are shown on Figure 12.

The API model result indicates that soil moisture is normal to above normal for all of Manitoba basins. The soil moisture is well above normal in the Lake Winnipegosis, Upper Saskatchewan (near the Pas), and middle Assiniboine river basins. The API model indicates the amount of summer and fall rain (May to October or November) that remains in the soil layer and has yet to contribute to runoff. It is a model that indicates the degree of saturation in the soil.

Soil samples collected at the root zone (0 to 120 cm or 0 to 4 ft depth) indicate the soil is extremely saturated (saturation over 95% of water holding capacity) in the south eastern, south western, western and northern regions of the province (Figure 9). This degree of saturation has not been observed in recent years. With in these areas, there is over 300 mm of water stored in the root zone (Figure 10). In other areas, the soil is saturated between 75% and 95% of water holding capacity, with the exception of southern portion of the Interlake, which has less than 65% of saturation. Soil sample testes collected from the upper soil zone (0 to 30 cm or 0 to 1 ft depth) also indicated the same degree of saturation (Figure 11).

The Gamma survey conducted between November 2 and November 8 indicated over 35% saturation in the upper 20 cm of the soil in most southern basin. Saturation is in between 45% and 65% in the Northern Red river basin and south western corner of the province. The moisture content at the top 20 cm is significantly affected by the amount of rain that occurred a

few days prior to the survey. However, the degree of saturation observed by the Gamma survey is not common in recent years.

The US National Weather Service (NWS) in their fall conditions report have also indicated over 70% of saturation, at some areas over 99% of saturation in the Red River basin as of November 22 (Figure 13 to 14). The NWS statement reads “Overall, current soil moisture anomalies are quite high across northern North Dakota, across most of the Red River Basin, and across most of southern Minnesota.”

The soil moisture is relatively high throughout Manitoba and Saskatchewan and is comparable with the soil moisture observed in the fall of 2010. The exception is the Red River watershed and southeastern Manitoba, which have drier soil moisture conditions than the fall of 2010.

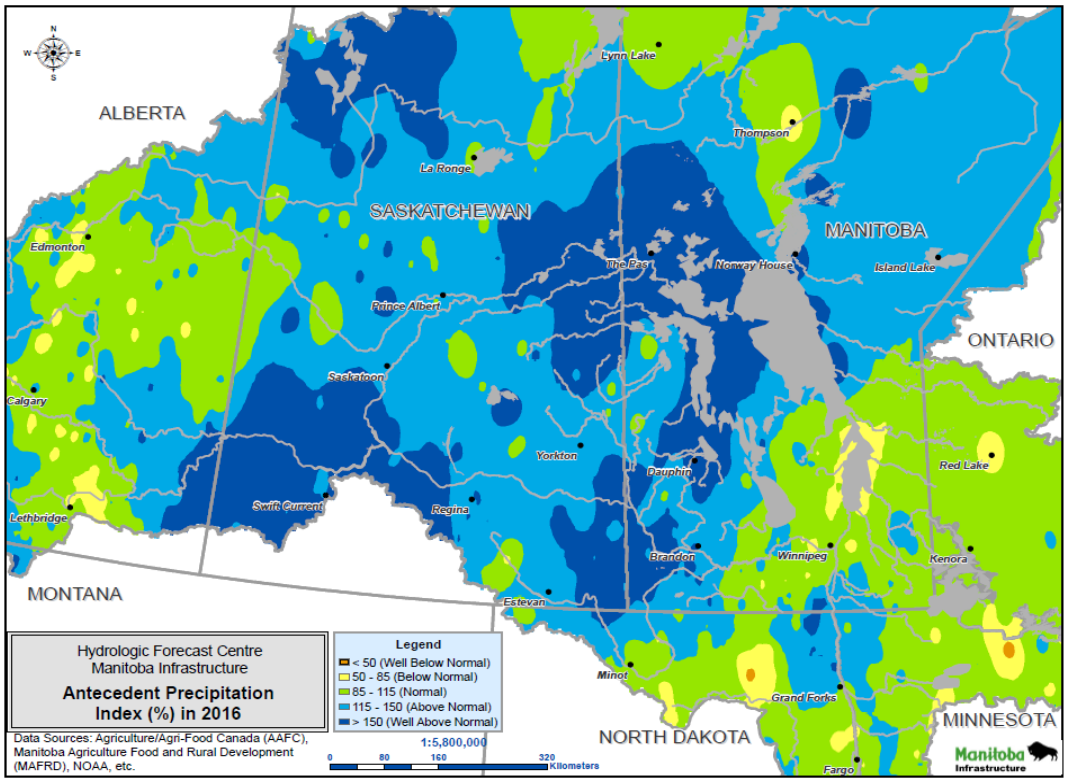


Figure 8. Antecedent Precipitation Index for 2016.

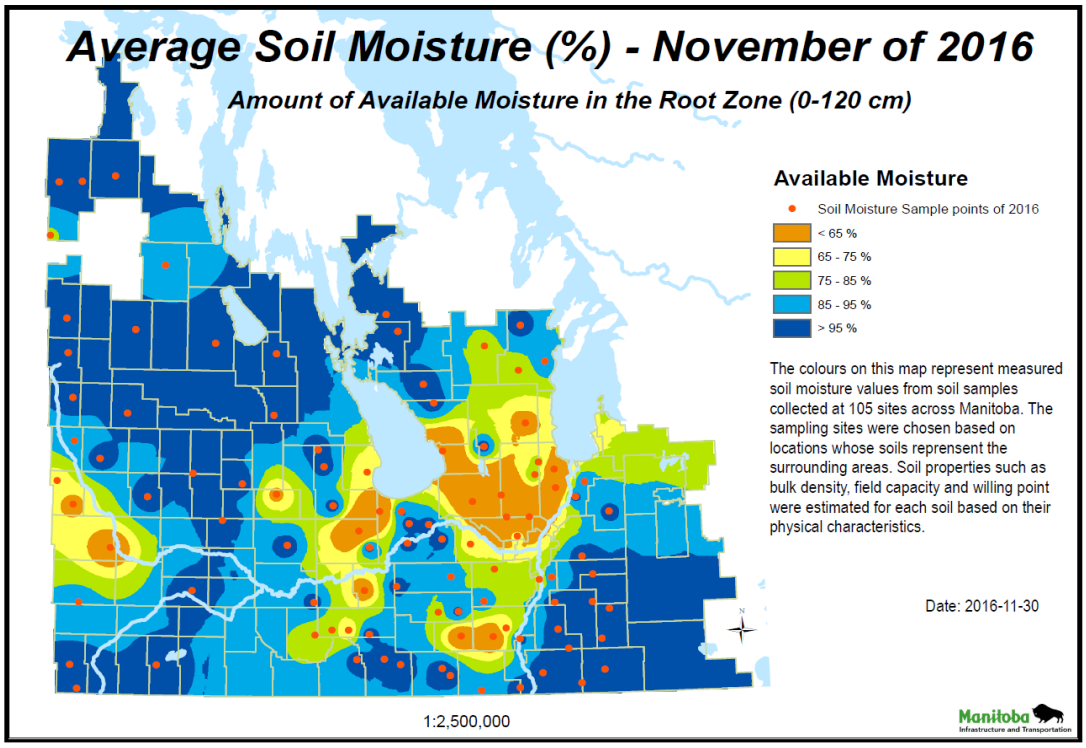


Figure 9. Soil moisture in % in root zone (0 to 120 cm) based on field measurements

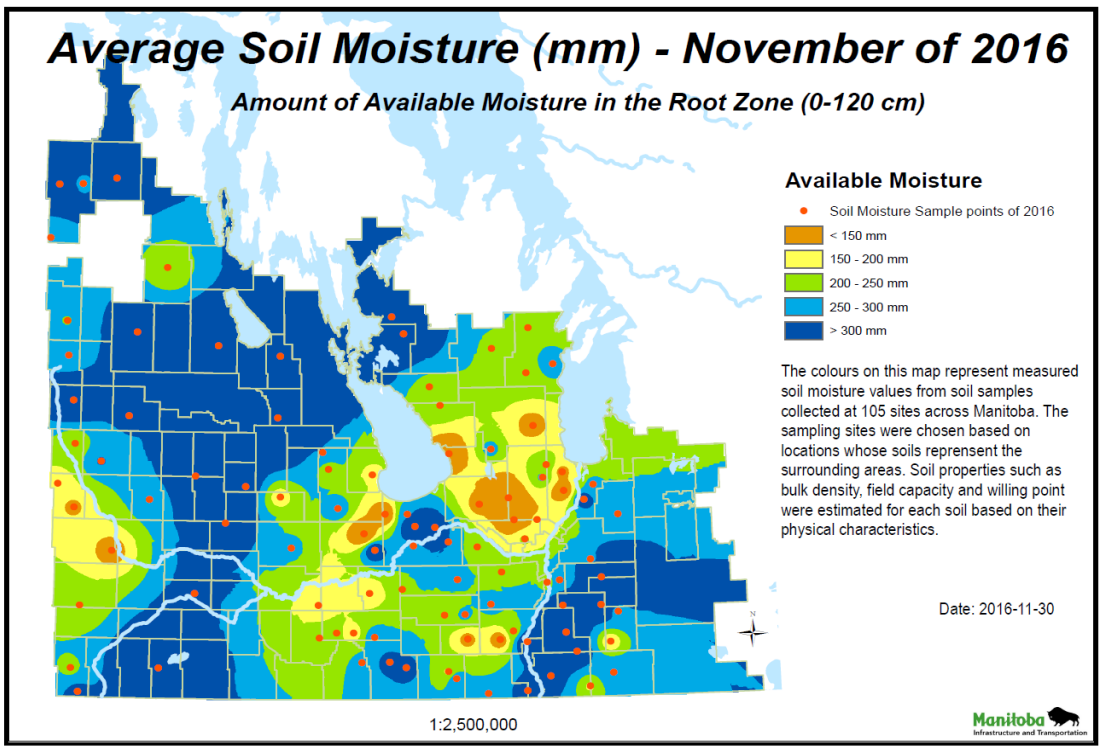


Figure 10. Soil moisture in mm in root zone (0 to 120 cm) based on field measurements

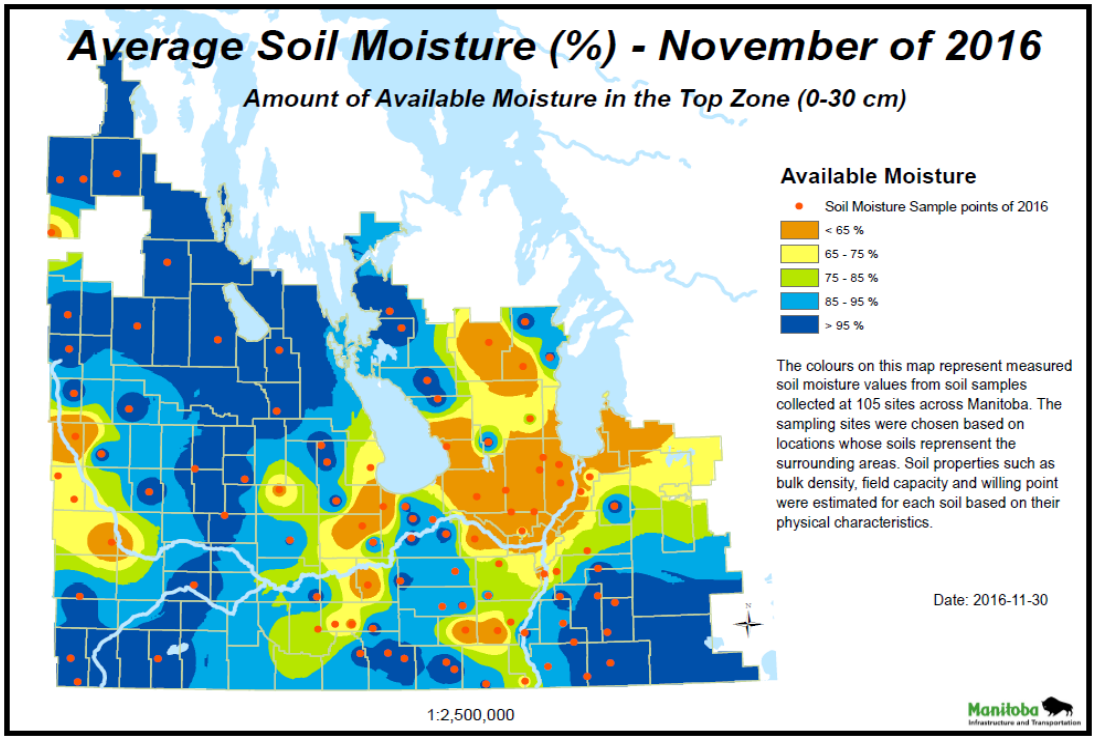


Figure 11. Soil moisture content in % in top zone (0 to 30 cm) based on field measurements

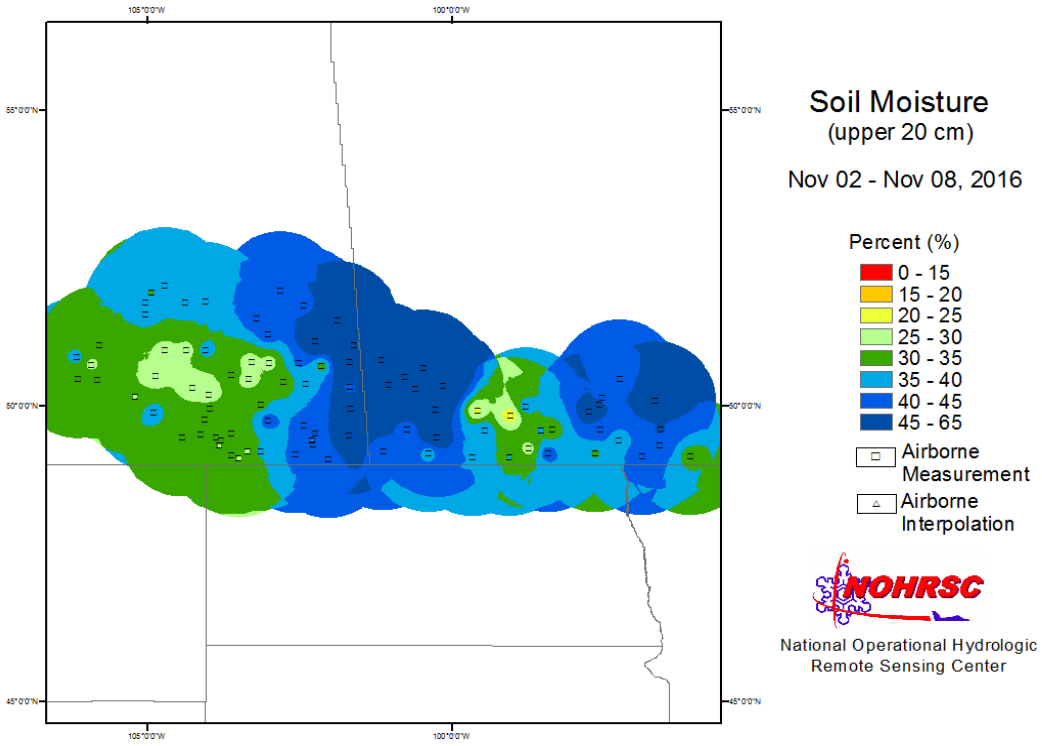
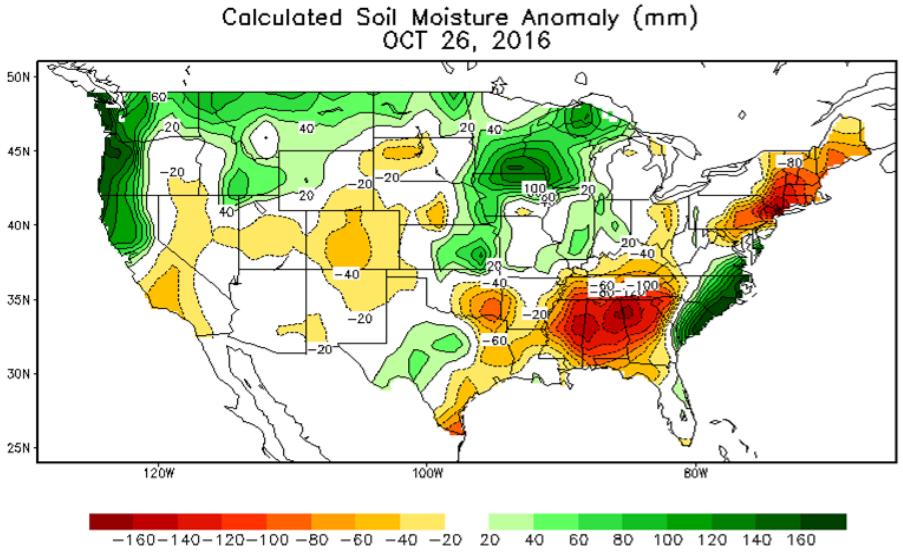


Figure 12. Soil Moisture from Gamma Survey conducted between Nov 02 – Nov 08, 2016



"Overall, **current soil moisture anomalies are quite high across northern North Dakota, across most of the Red River Basin**, and across most of southern Minnesota." NWS

Figure 13. Calculated soil moisture anomaly (mm), from the NWS

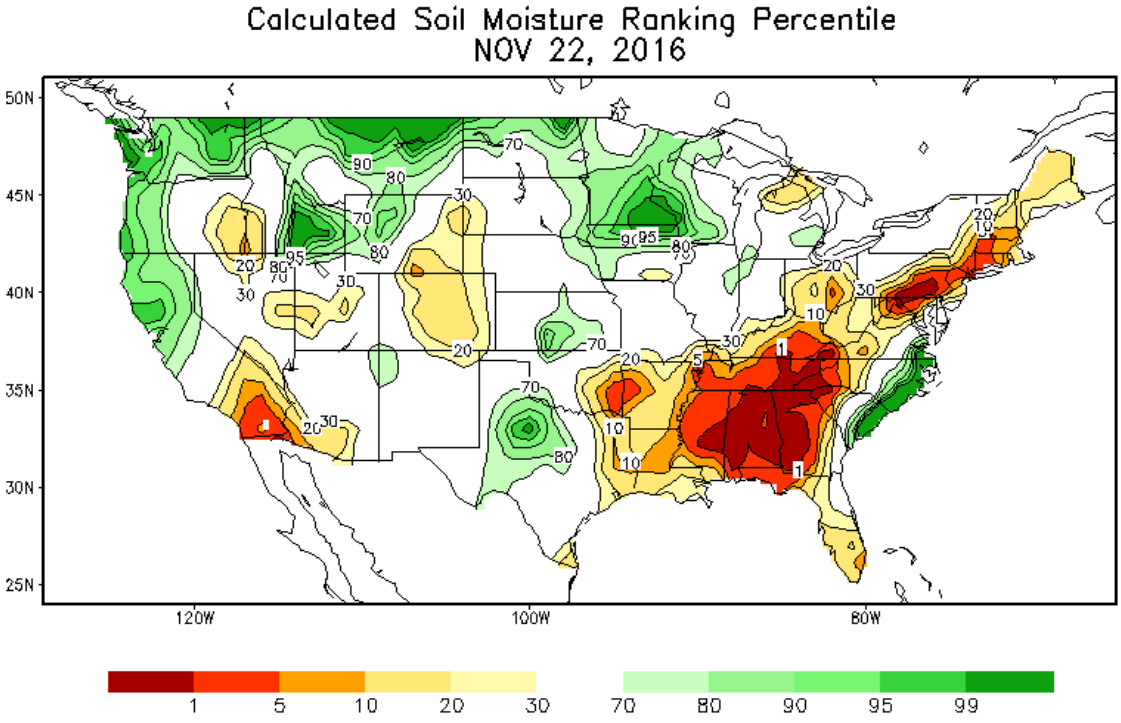


Figure 14. Calculated soil moisture ranking percentile, from the NWS

BASE CONDITIONS

Rivers

Most of the major rivers have above normal flows for this time of year. Flows on the Saskatchewan River, Carrot River, Waterhen River and the Assiniboine River are at or near the record high flows for this time of the year. Recent of the high flows on the Assiniboine River come from the release of the Shellmouth reservoir, which is at a high level for this time of year. The Shellmouth Dam was used to capture the runoff from the upper Assiniboine River this fall in order to mitigate flooding on downstream agricultural land. The reservoir is now being drawn down to prepare spring runoff which will result in high flows on the Assiniboine River throughout the winter. Flows on the Red River, the Qu'Appelle River, the Souris River, the Dauphin River, and the Fairford River are at or above the upper decile conditions. The upper decile indicates that flows are below this level at this time for 90% of the historical record; or flows and levels meet or exceed the upper decile on average once in every 10 years. Hydrographs for the major rivers are shown in Figures 15 to 27. These figures represent the flows on the rivers prior to freeze-up. High base flows and water levels during the spring runoff could increase the potential for spring flooding. Higher base flows also indicate high soil moisture content. Current flows for main rivers at selected locations are listed in Table 1.

Table 1. Flows for main rivers at selected locations as of November 30, 2016

Rivers	Location	Flow (cfs)	Normal Flows in November 30 (cfs)
Red River	Emerson	3,884	2,024
	Ste. Agathe	4,136	1,983
Assiniboine River	Russell	1,595	300
	Miniota	2809	604
	Brandon	3,180	646
	Holland	4,541	853
	Headingley	4,558	729
Shellmouth Dam Release	Shellmouth	1586	
Souris River	Wawanesa	421	52
	Melita	235	44
	Souris	195	50
Qu'Appelle River	Welby	556	240
Fairford River	Near Fairford	7,053	1,712
Dauphin River	Near Dauphin	7,747	1,173
Waterhen River	Near Waterhen	10,541	1,861
Lake St. Martin Emergency Out. Channel	Lake St. Martin	0	

Lakes

All major lakes (Lake Winnipeg, Lake Manitoba, Lake Winnipegosis, Dauphin Lake, Lake St. Martin, and Lake of the Prairies) are above normal for this time of the year. Lake Winnipegosis, Dauphin Lake, and Lake of the Prairies (Shellmouth Reservoir) are at record high levels for this time of the year. Lake Winnipeg is above the upper operating range of 715 ft. Lake Manitoba is near the upper operating range of 812.5 ft. Lake St Martin is at 801.8 ft, above the flood stage of 801.7 ft. Water level hydrographs for these lakes are shown on Figures 28 to 32. The inflows into Lake of the Prairies (Shellmouth Reservoir) and Lake Winnipegosis are at record high levels since October. Lake of the Prairies (Shellmouth Reservoir) is being operated in consultation with the Shellmouth Liaison Committee (SLC). The level is expected to be drawn down to the lowest allowable level of 1386 ft before the spring runoff (Figure 33). If significant spring runoff occurs on top of the already high lake levels, this could induce major flooding around Manitoba's lakes.

FORECASTED LEVELS AND FLOWS OVER THE WINTER PERIOD

Base flows are extremely hard to forecast due to the frozen ground conditions and the effect of ice on flows and levels on rivers and lakes. For the normal (average) conditions, the forecasted levels and flows throughout the winter period on selected lakes and rivers are shown in Figures 25 to 33. The Assiniboine River is forecasted to remain at record high levels until the spring runoff. This is mainly due to the sustained release of high flows from the Shellmouth reservoir in order to reduce the level in the reservoir to 1386 ft in preparation for spring runoff. The target of 1386 ft level is the lowest level the lake can be drawn down to based on the operation guidelines. The Red River is expected to remain above the upper decile, ninety percentile, flow until the spring runoff. The upper decile, ninety percentile, flow indicates historic recorded flows were less than the current flow for 90% of the time; or flow equalled or exceeded the current flow on average once in 10 years. Flows on the Waterhen, Fairford River Dauphin Rivers will remain very high due to the high lake levels.

Lake Manitoba is expected to remain near 812.4 to 812.5 ft throughout the winter. Lake Winnipegosis will remain between 833.6 and 833.8 ft throughout the winter. Lake St Martin is expected to reach near 803 ft before the spring runoff. The current lake levels and the expected level by March 31, 2017 (before the 2017 spring runoff) are given in Table 2.

Table 2. Current lake levels and the expected level by March 30, 2017 (before the 2017 spring runoff)

Lakes	Current Level (ft)	Operating Range or Long Term Average (ft)	Expected Level by March 30, 2017 (ft)
Lake Manitoba	812.58	810.5 – 812.5	812.4 - 812.5
Lake Winnipeg	715.84	711 – 715	
Lake St. Martin	801.8		803
Lake Winnipegosis	834.52	830.5	833.6 - 833.8
Dauphin Lake	856.96	853.0 – 854.8	855.8 - 856.0
Whitewater Lake	1631.6	1628	1631.7-1631.8
Shellmouth	1404.38		1386

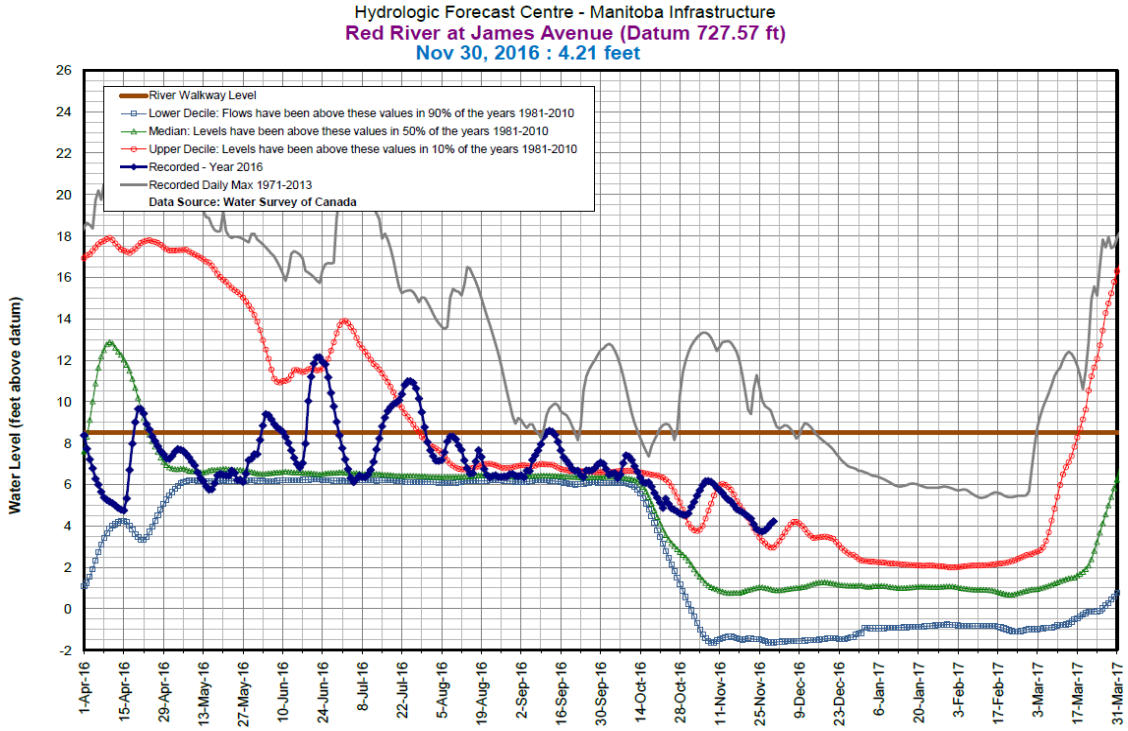


Figure 15. Red River Water Levels at James Avenue

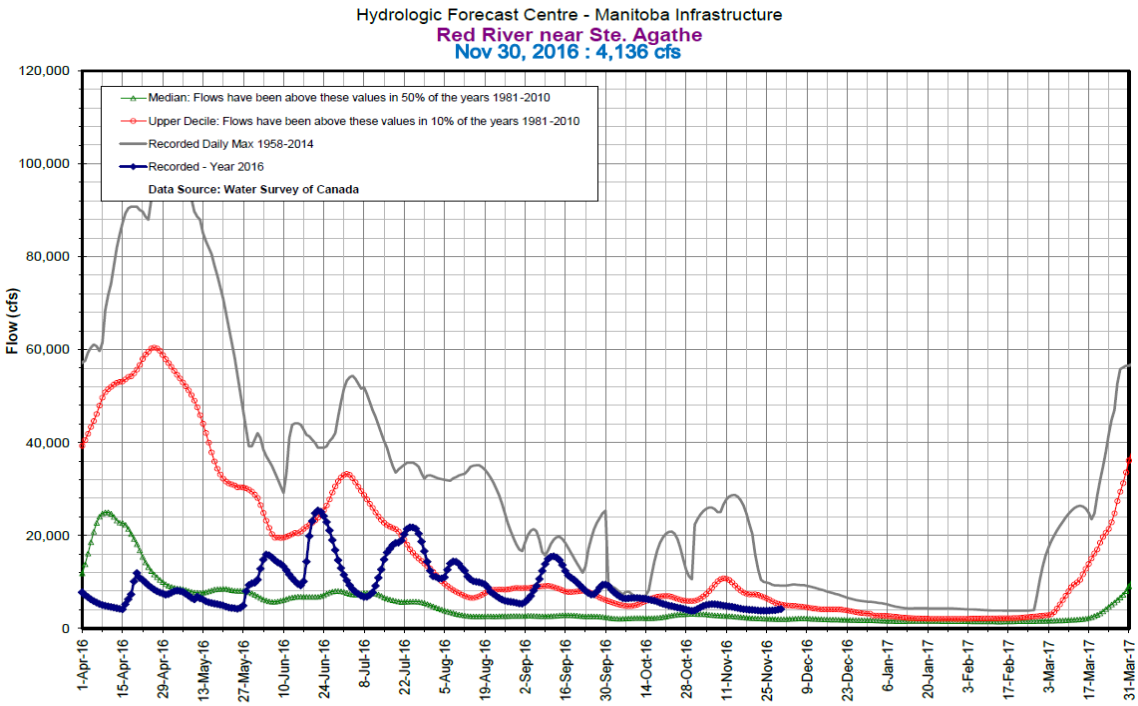


Figure 16. Red River Flows at Ste. Agathe

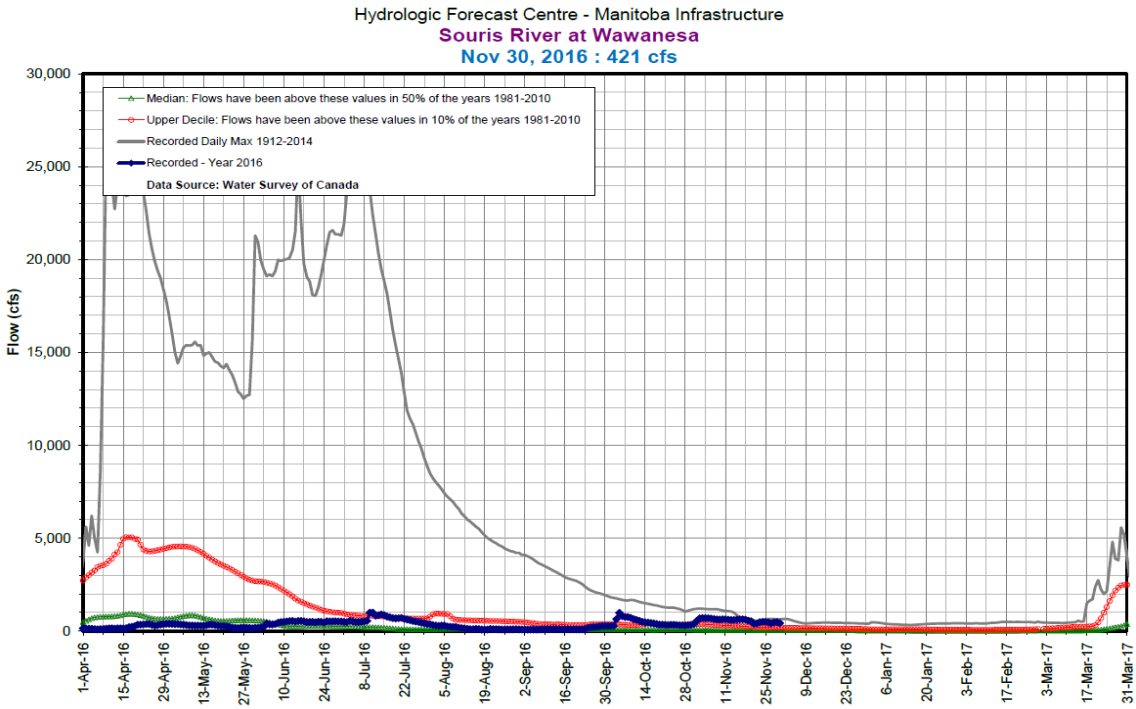


Figure 17. Souris River Flows at Wawanesa

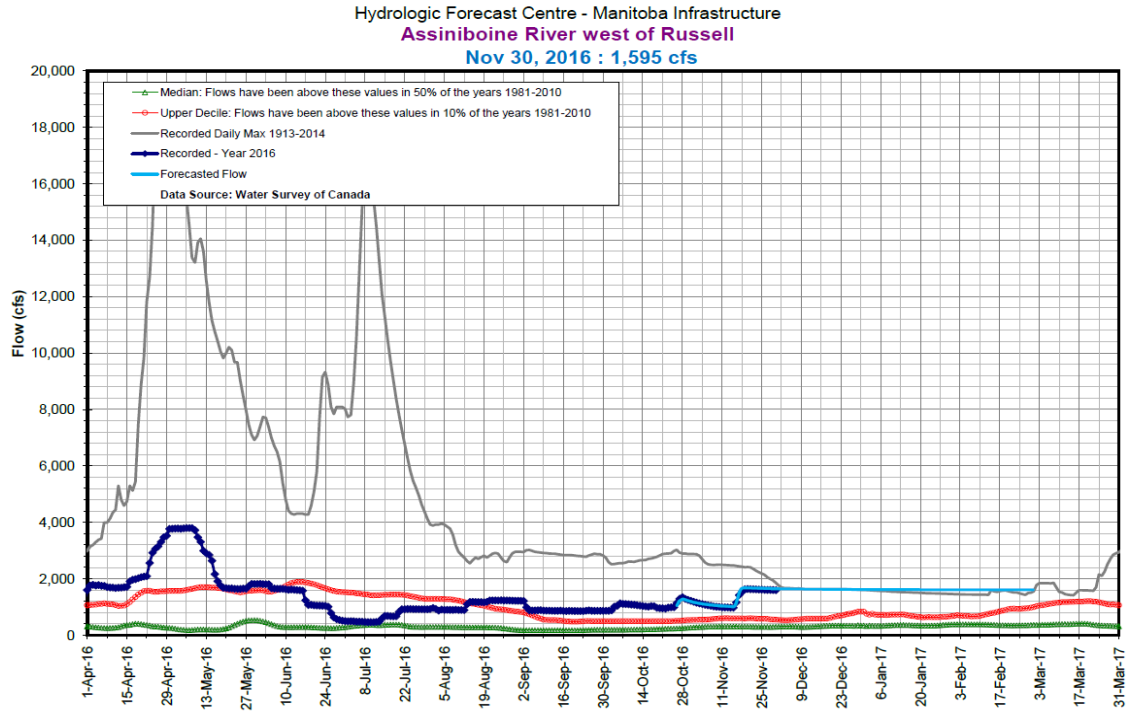


Figure 18. Assiniboine River Flows near Russell

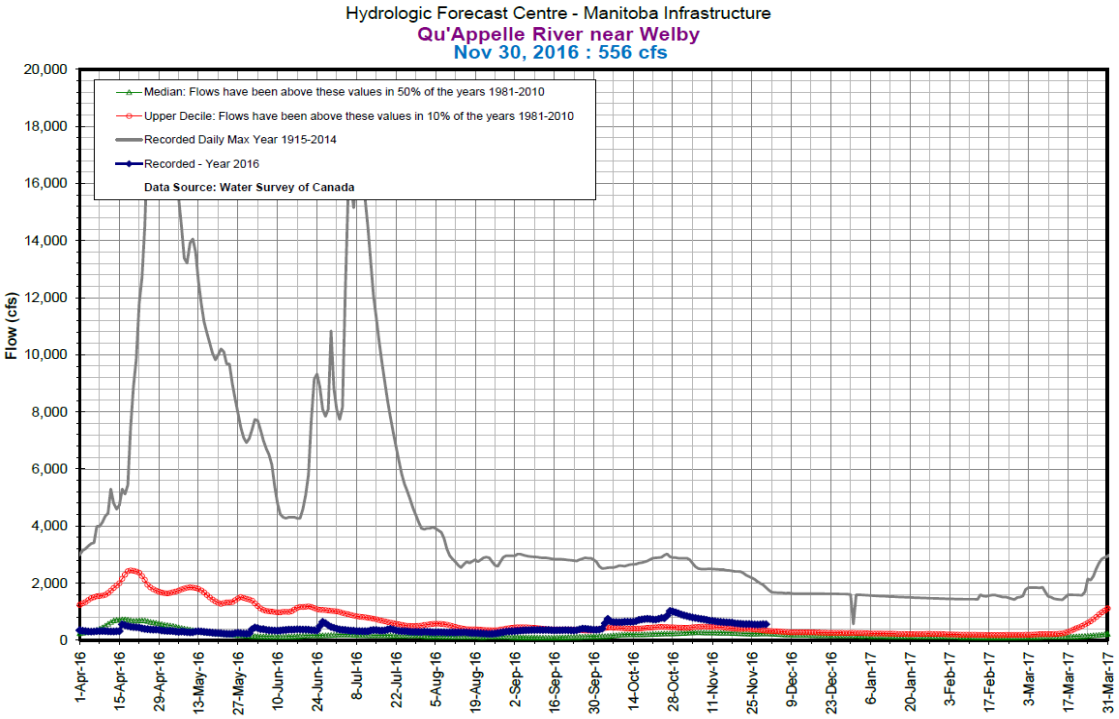


Figure 19. Qu'Appelle River Flows near Welby

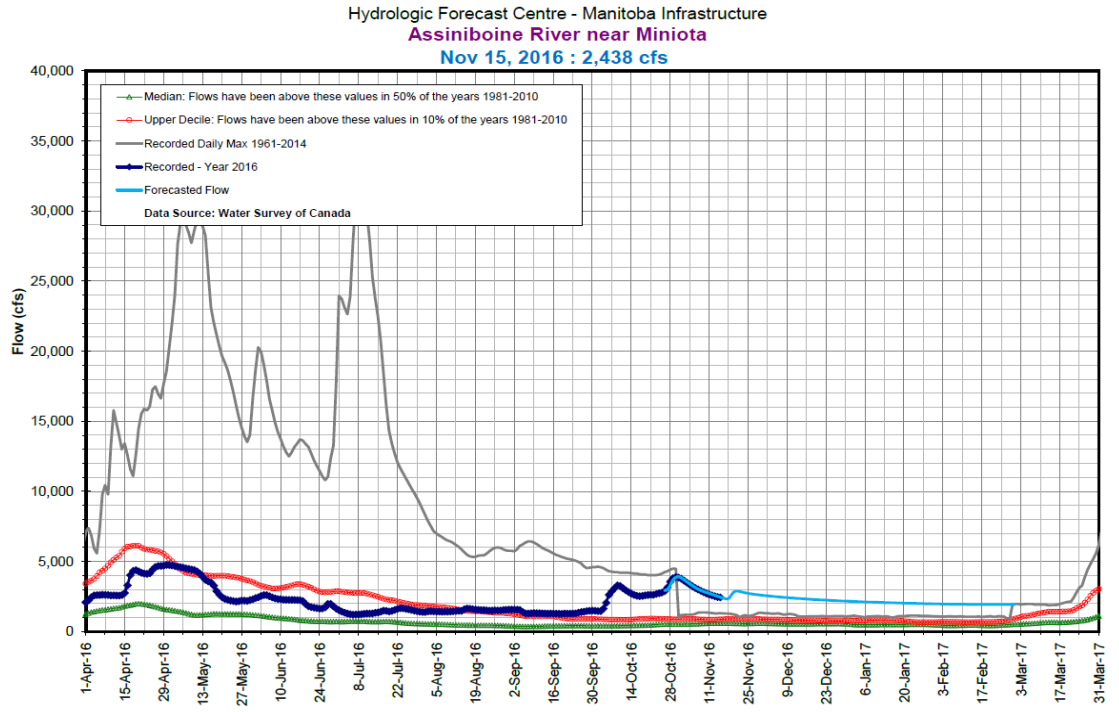


Figure 20. Assiniboine River Flows near Miniota

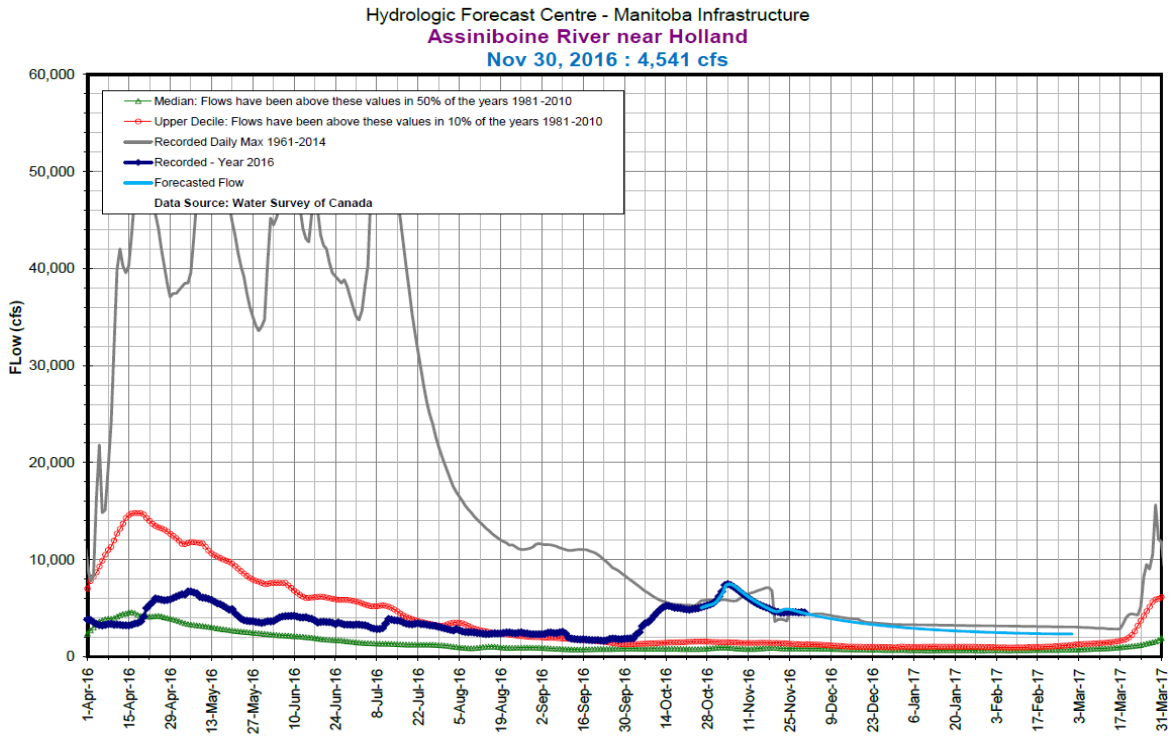


Figure 21. Assiniboine River Flows near Holland

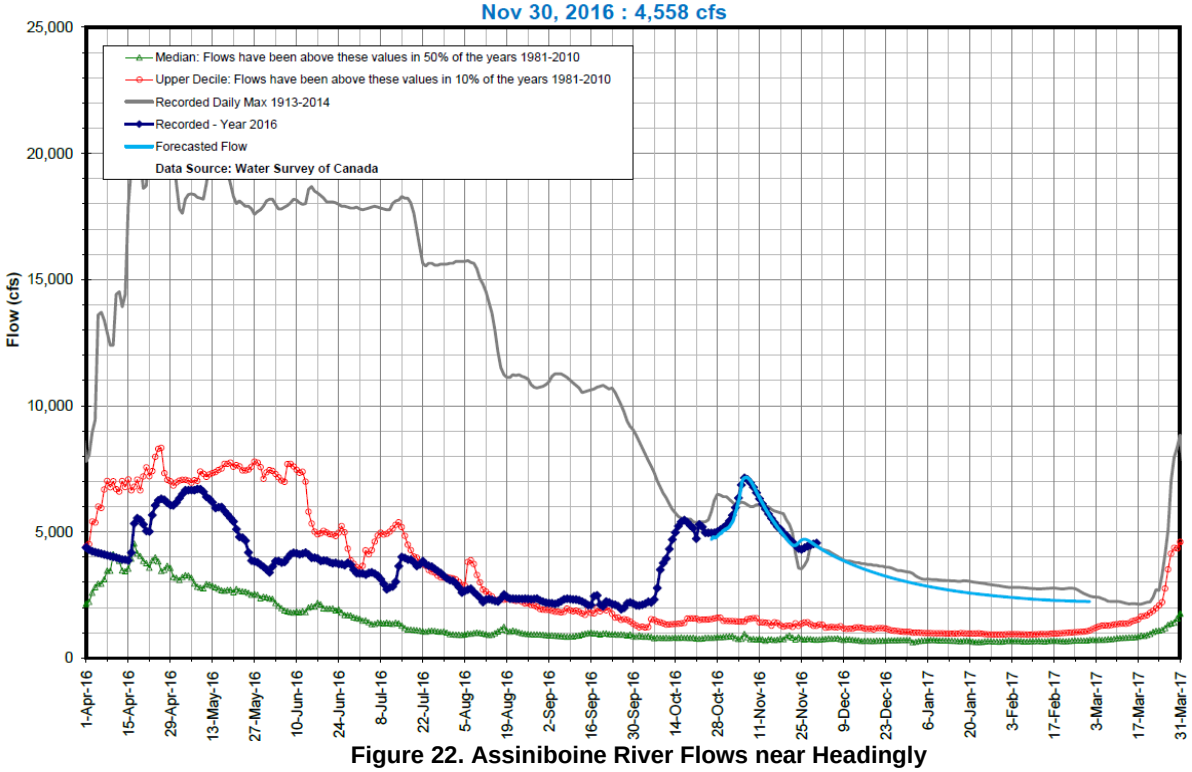


Figure 22. Assiniboine River Flows near Headingly

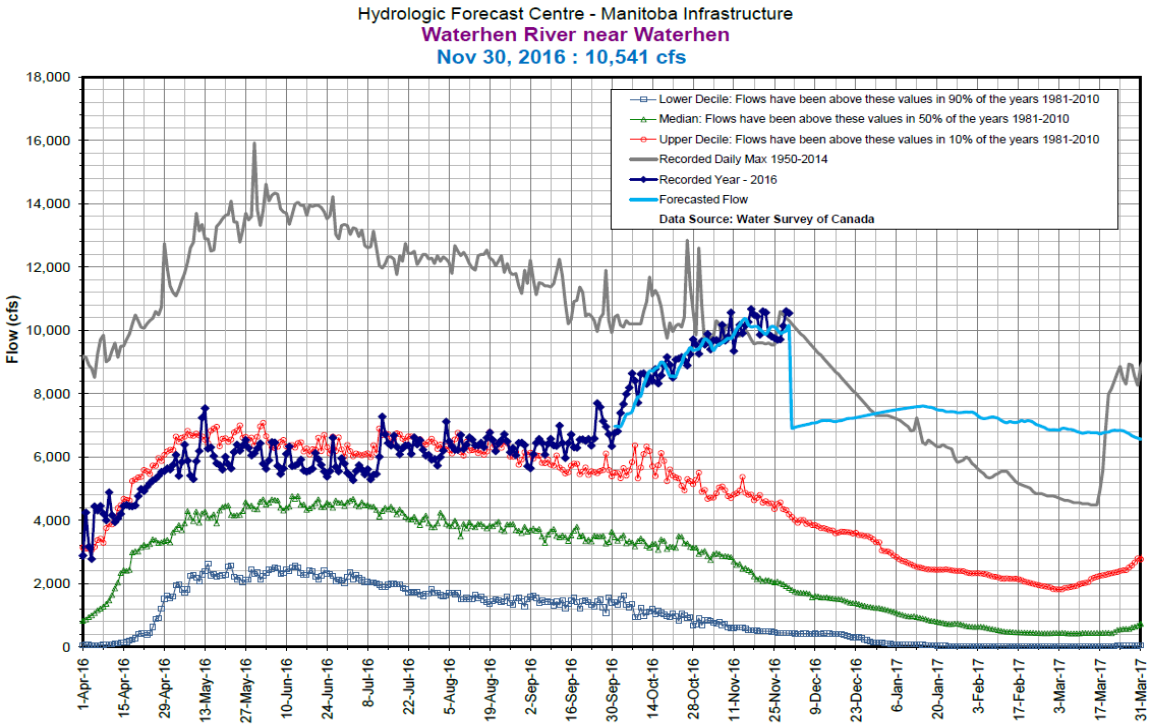


Figure 23. Waterhen River near Waterhen

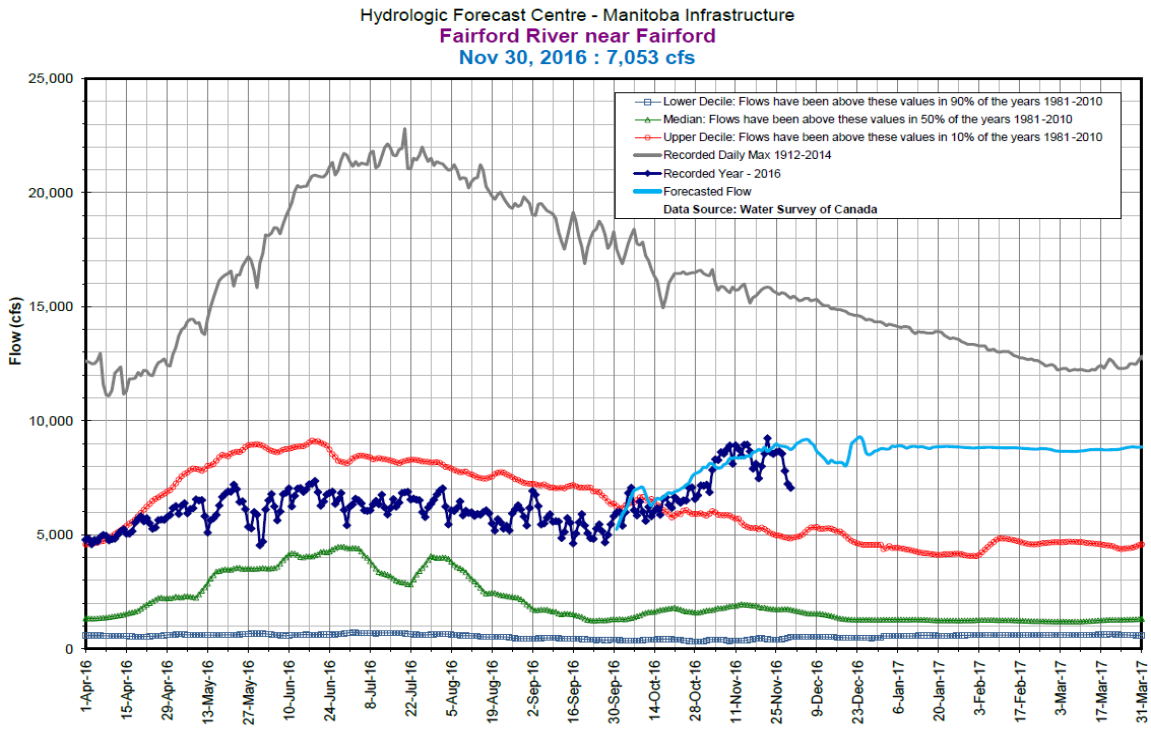


Figure 24. Fairford River near Fairford

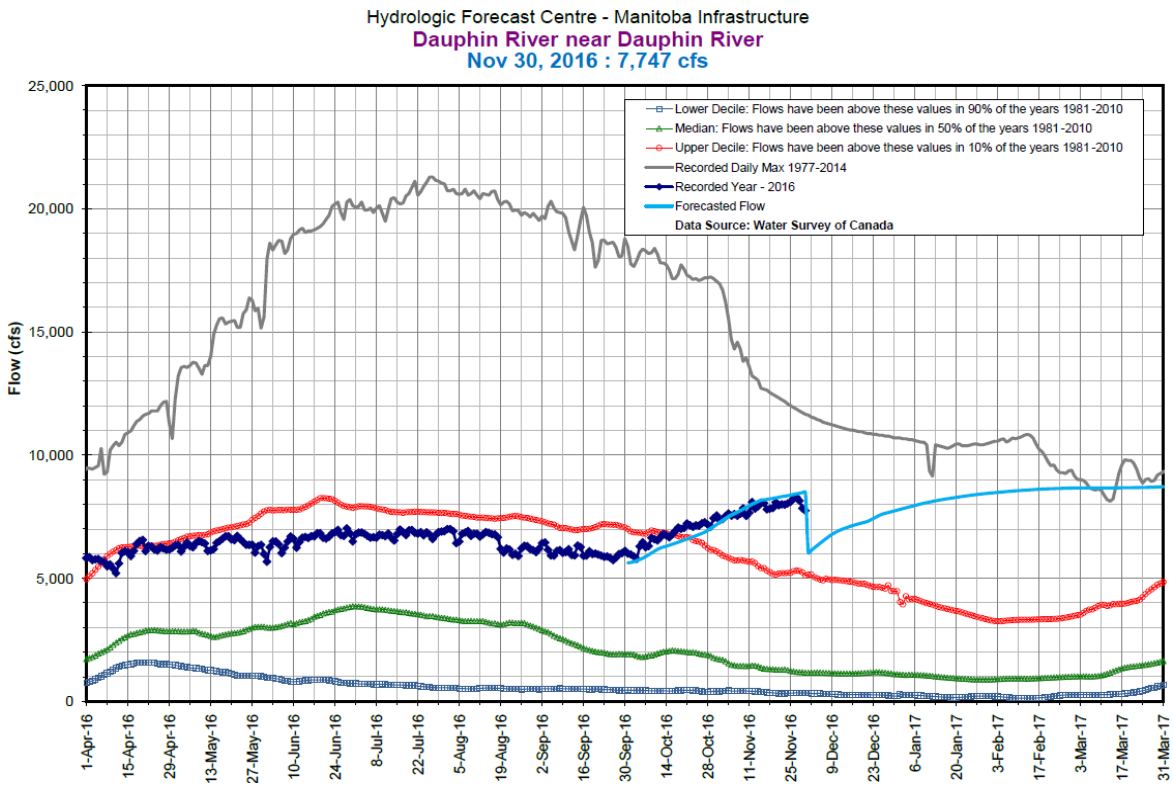


Figure 25. Dauphin River near Dauphin River

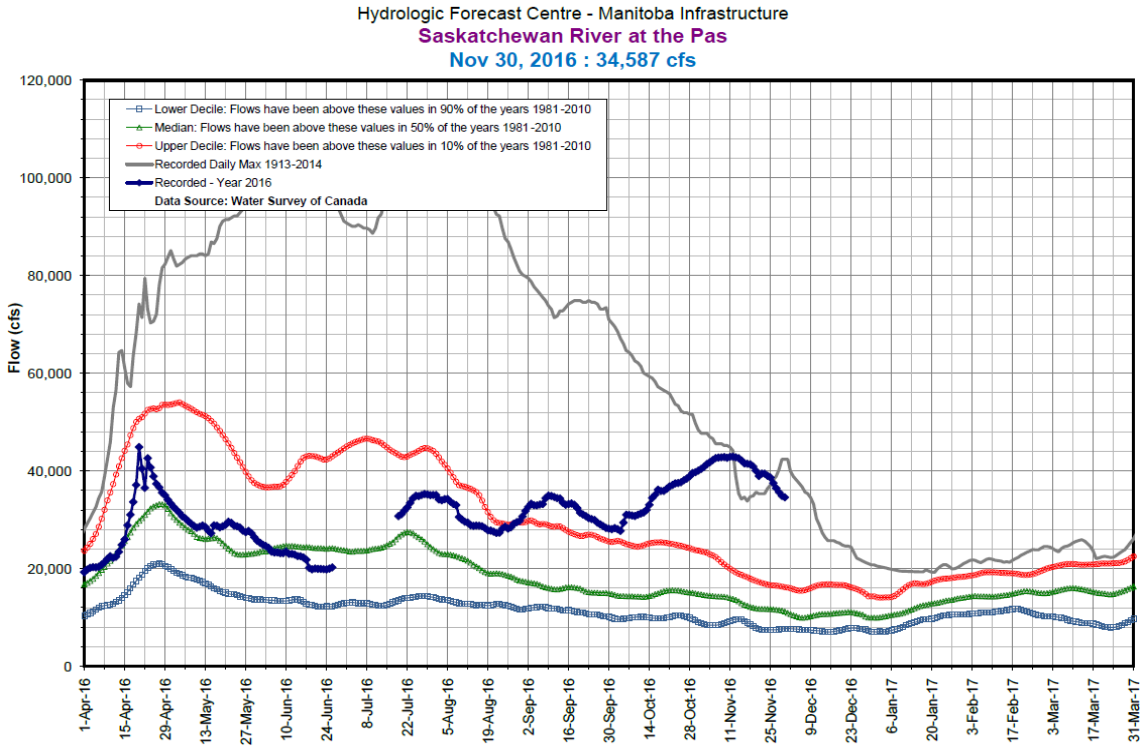


Figure 26: Saskatchewan River Flows at the Pas

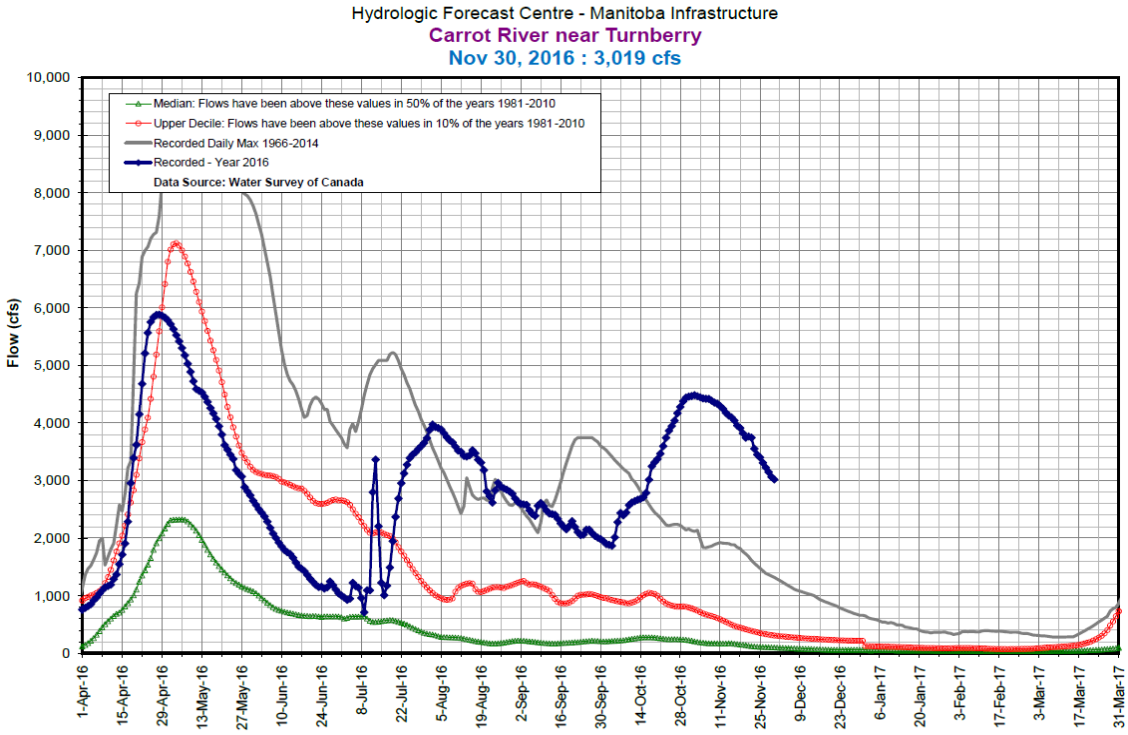


Figure 27. Carrot River near Turnberry

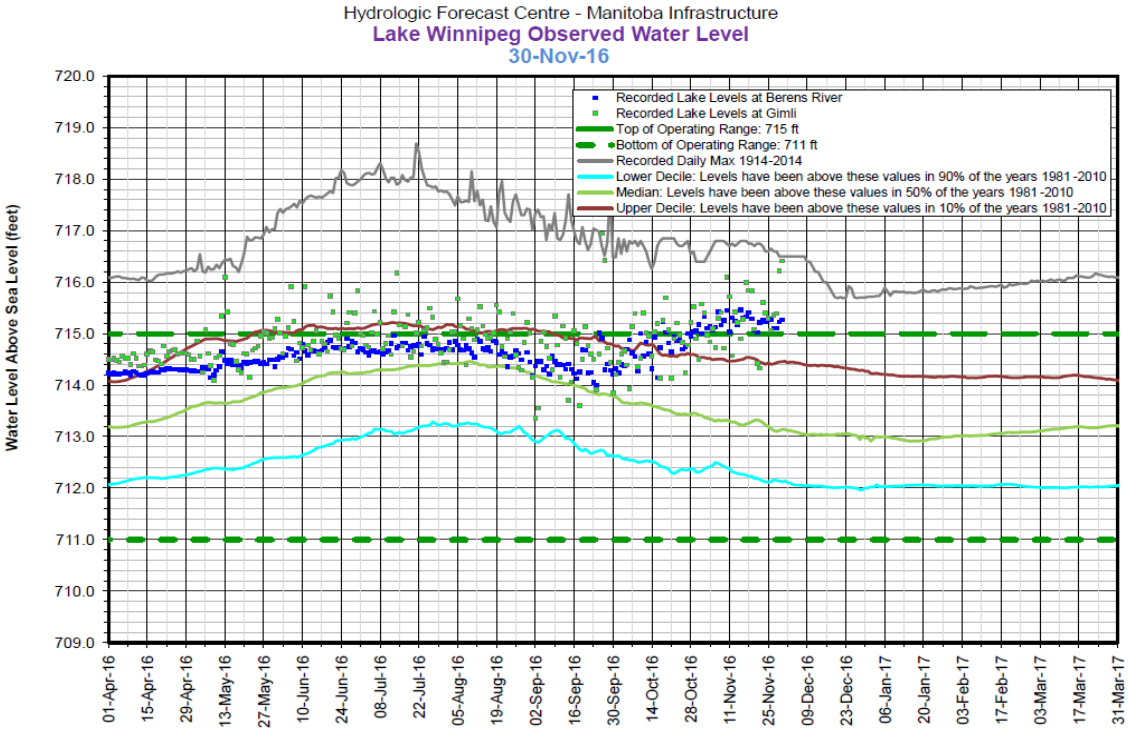


Figure 28. Lake Winnipeg Water Levels

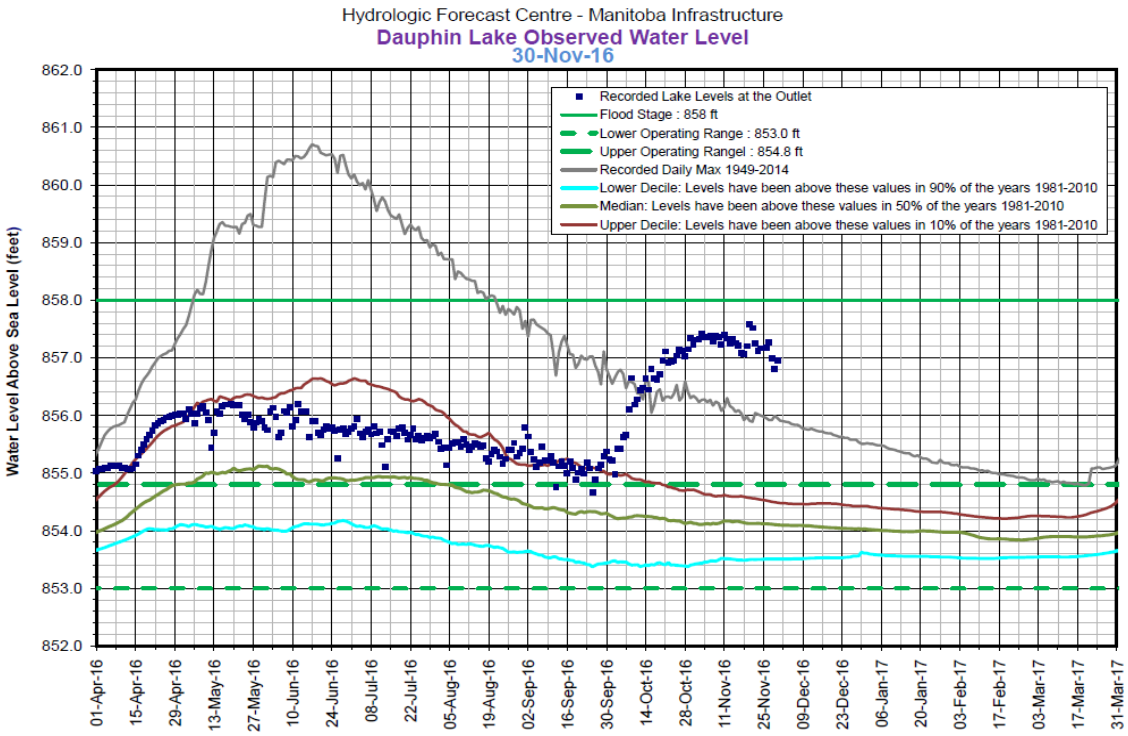


Figure 29. Dauphin Lake Water Levels

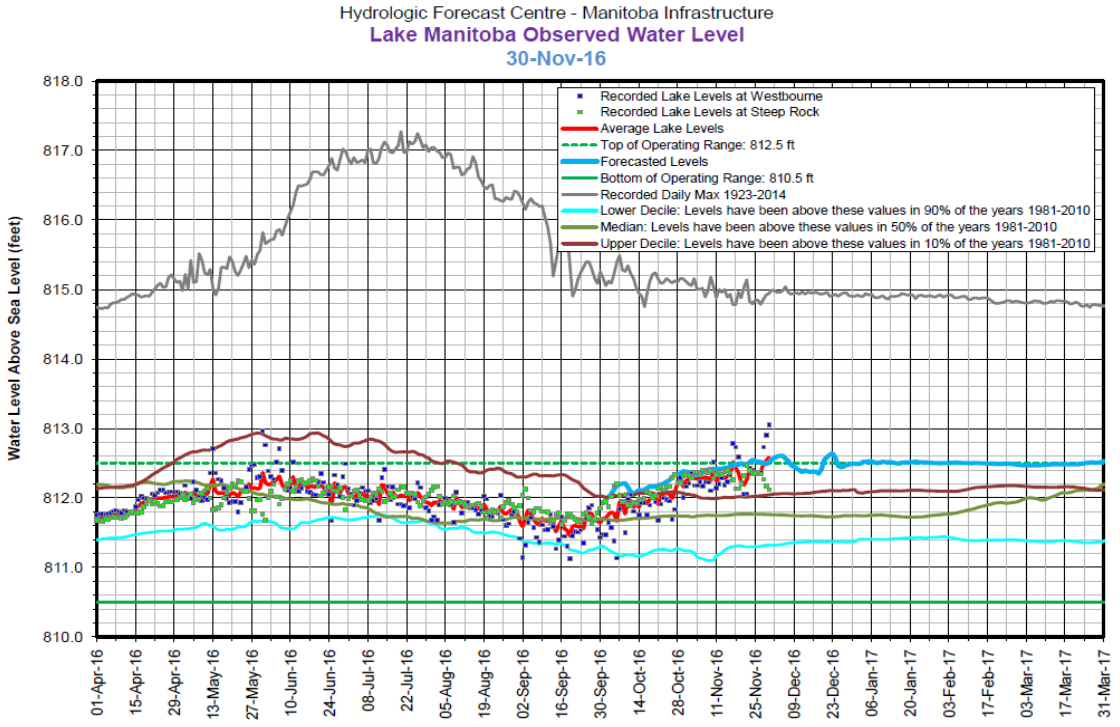


Figure 30. Lake Manitoba Water Levels

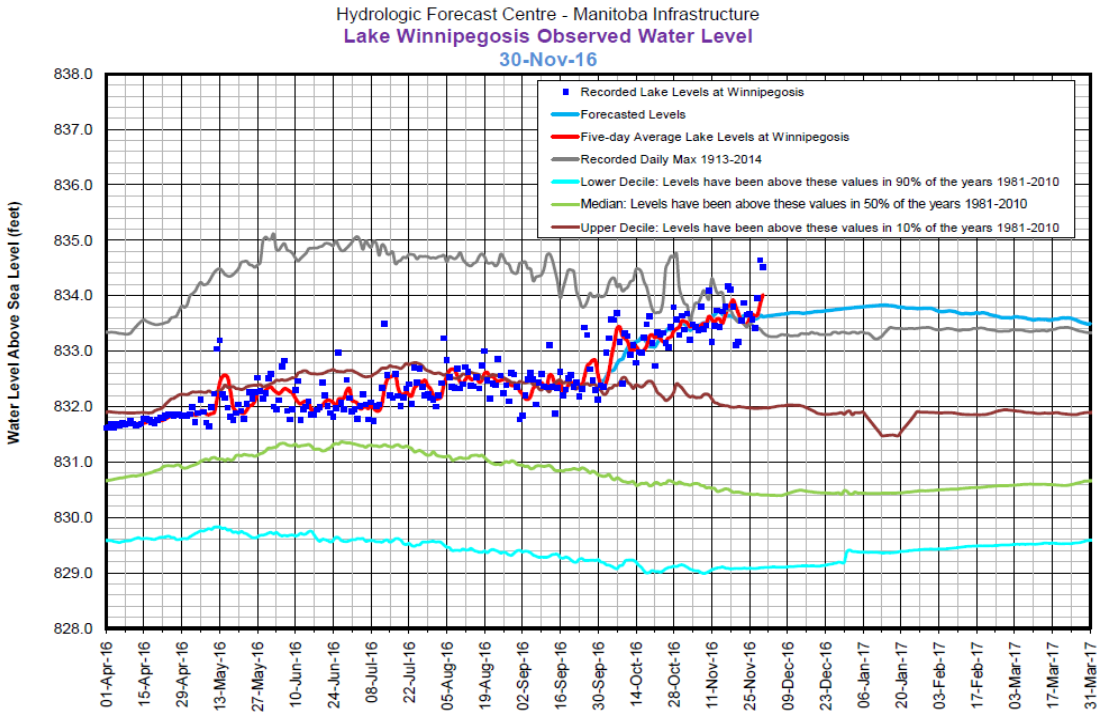


Figure 31. Lake Winnipegosis Water Level

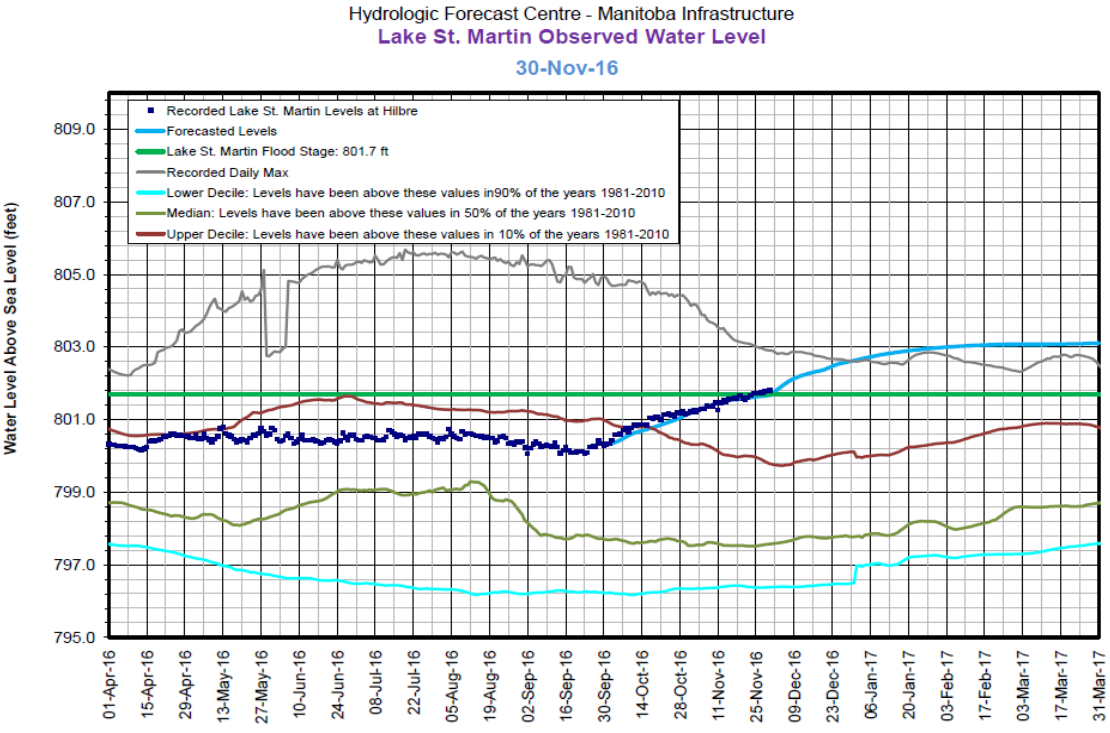


Figure 32. Lake St. Martin Water Levels

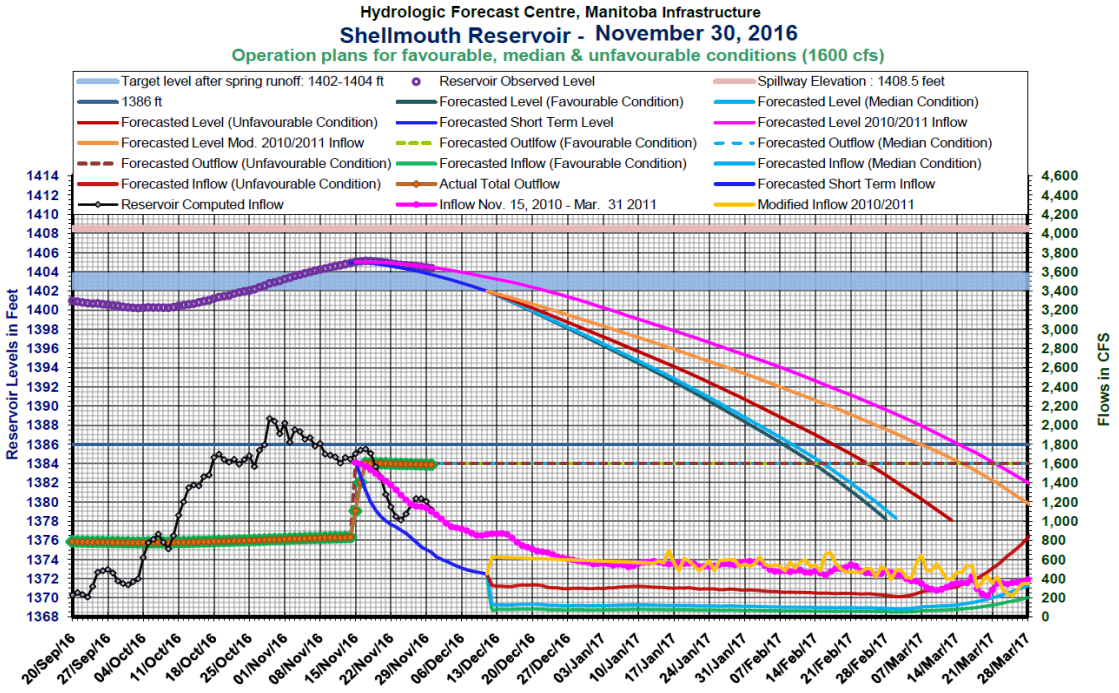


Figure 33. Lake of the Prairies (Shellmouth Reservoir) Water Levels

WINTER PRECIPITATION (LONG TERM PRECIPITATION FORECAST)

Environment Canada recently issued a long term precipitation forecast for the months of December, January and February (Figure 34). Based on the forecast it is expected that the northern part of Manitoba and Saskatchewan will receive above normal winter precipitation. Near normal precipitation is forecasted for the southern part of the province including the Red River basin. Environment Canada's long term forecast for the southern part of the province is inconsistent with the forecast issue by the National Weather Service Climate Prediction Centre. The NWS Climate Prediction Center is forecasting above normal precipitation within the Red River Basin for December, January and February (Figure 35). The NWS Climate Prediction Center also forecasts above normal precipitation within the Red River Basin for January, February, and March (Figure 36). Experience indicates that these long term forecasts are more accurate for the first month of the forecast cycle and conditions start to deviate significantly further into the future. Generally, long term weather forecasts are not as reliable as short term forecasts, and this is partly why the long term precipitation forecasts are not consistent at this time.

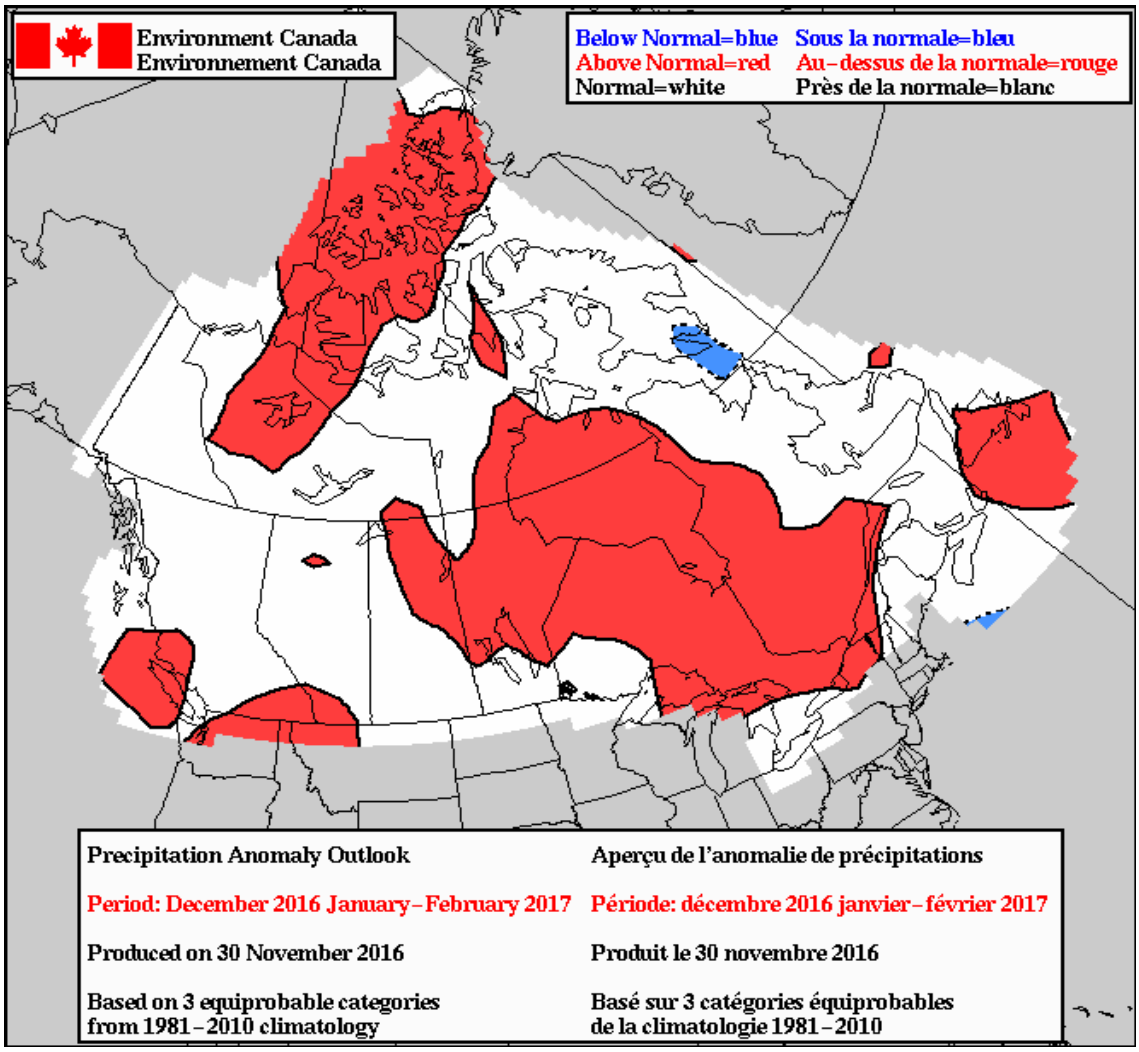


Figure 34. Environment Canada Extended Precipitation Forecast

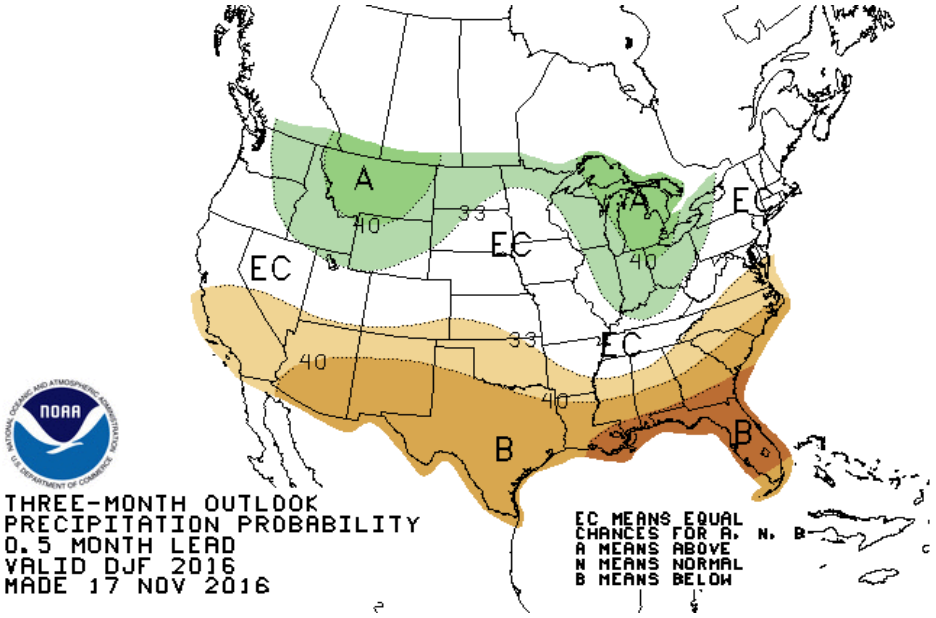


Figure 35. NWS' three month (December, January & February) precipitation outlook, NWS

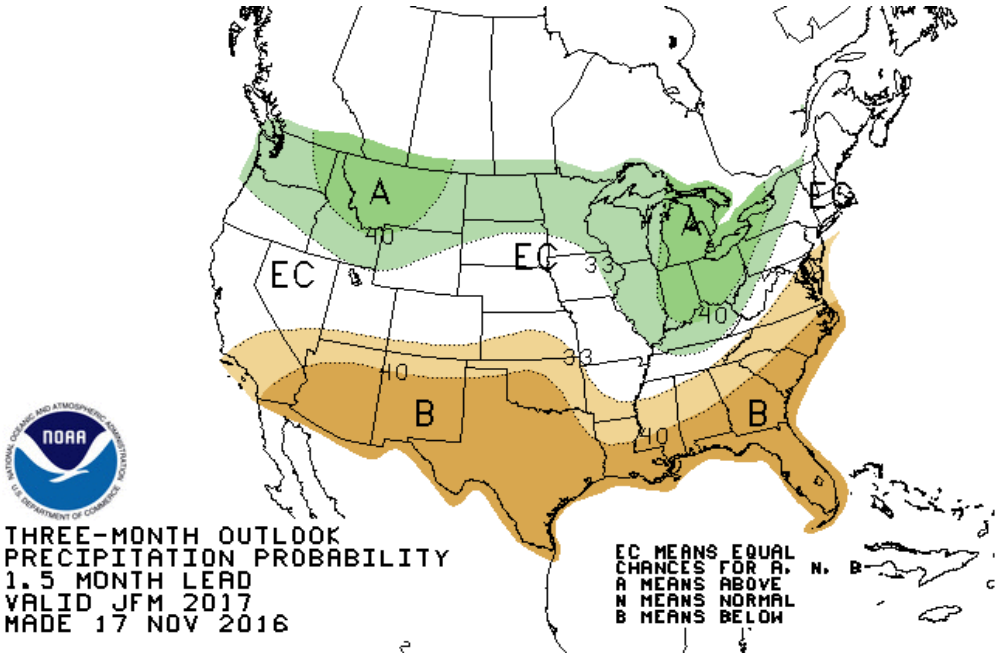


Figure 36. NWS' three month (January, February, & March) precipitation outlook, NWS

HISTORICAL CONTEXT

It is important to note that while the conditions in this report may appear alarming in some areas, it still very early in the season and many things can happen before spring runoff actually occurs. The fall conditions report is the first step taken to prepare for potential spring flooding, and as more data is available as conditions unfold throughout the winter, the accuracy and confidence for flood forecast data will improve. While it is prudent to plan ahead and to prepare, over estimating or under estimating the flood potential four month in advance of the spring runoff is very risky. The Hydrologic Forecast Center of Manitoba Infrastructure will continue to monitor the basin conditions closely and provide spring flood outlooks as required through the winter.

Examining the conditions present during some of the most significant historic flood years, such as the 1995 flood on the Assiniboine River, the 1997 flood on the Red River and the 2011 flood on the Assiniboine, Souris, Qu'Appelle and Red Rivers indicate that the origin of each flood was a combination of some unique circumstances and not necessarily the result of only the conditions which are known at this time of year. The below paragraphs summarize the three major factors: Soil moisture, Winter Precipitation, and spring precipitation, that have contributed to the above mentioned significant flood years. As can be seen in the below paragraphs, early indicators are not always reflective of future conditions.

1995

Leading to the 1995 flood on the Assiniboine River, the soil moisture in the fall of 1994 was near normal on the Assiniboine and Qu'Appelle river basins. The soil moisture was above normal on the Souris and the Red River watersheds (Figure 37). However, the November 1994 to March 1995 winter precipitation was above normal to well above normal on almost all Manitoba basins (Figure 38). A record flood was observed on the Upper Assiniboine and a moderate flood was observed on the Red, the Souris, and the Qu'Appelle Rivers.

1997

Leading to the 1997 flood on the Red River, the soil moisture in the fall of 1996 was near normal on all Manitoba basins (Figure 39). However, the November 1996 to March 1997 winter precipitation was above normal to well above normal on almost all Manitoba basins (Figure 40).

A record flood was observed on the Red River and a moderate flood was observed on the Upper Assiniboine, the Souris, and the Qu'Appelle Rivers. Early April blizzard and timing of the local runoff with the American water was coincident which added to the spring peak of the 1997 flood.

2011

Leading to the 2011 flood on the Assiniboine, the Souris, and the Qu'Appelle Rivers, the soil moisture in the fall of 2010 was above normal to well above normal on all Manitoba basins (Figure 41). The November 2010 to March 2011 winter precipitation was near normal to above normal on the Assiniboine, Qu'Appelle and the Souris River basins. The winter precipitation was below normal to above normal for the Red River basin (Figure 42). A record flood was observed on the on the Assiniboine, the Souris, and the Qu'Appelle Rivers and a moderate flood was observed on the Red River. The Assiniboine, Souris, and Qu'Appelle Rivers also experienced multiple flood peaks, which were significantly influenced by spring and summer precipitation events.

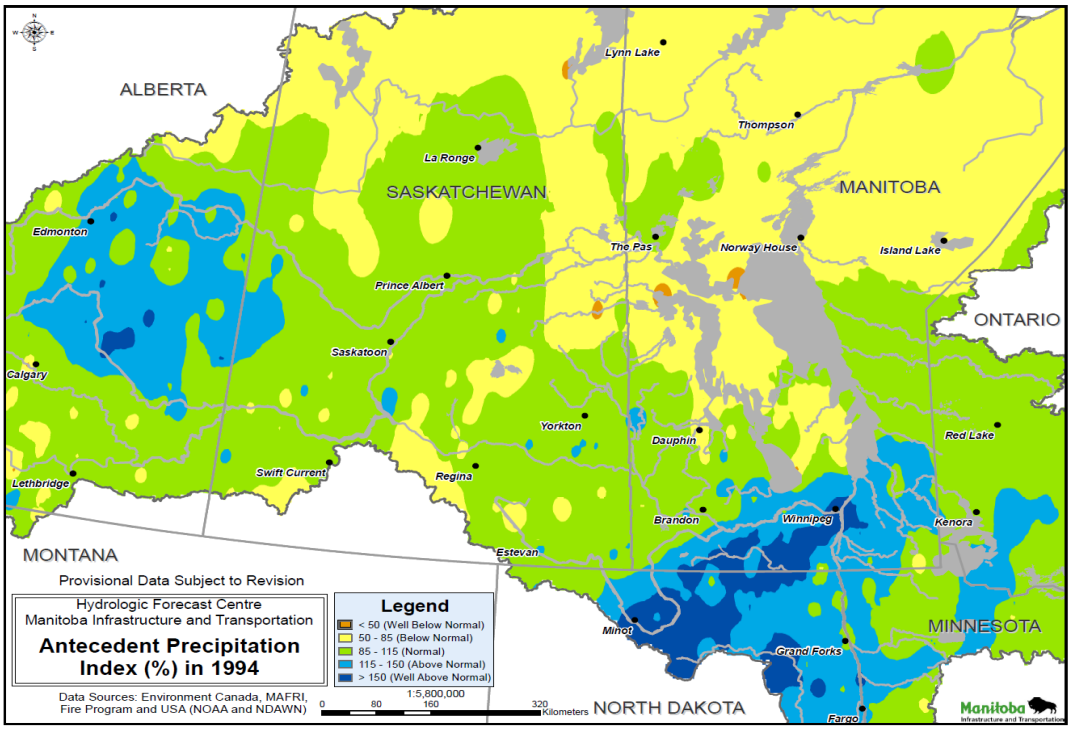


Figure 37. Antecedent Precipitation Index (API) in the fall of 1994

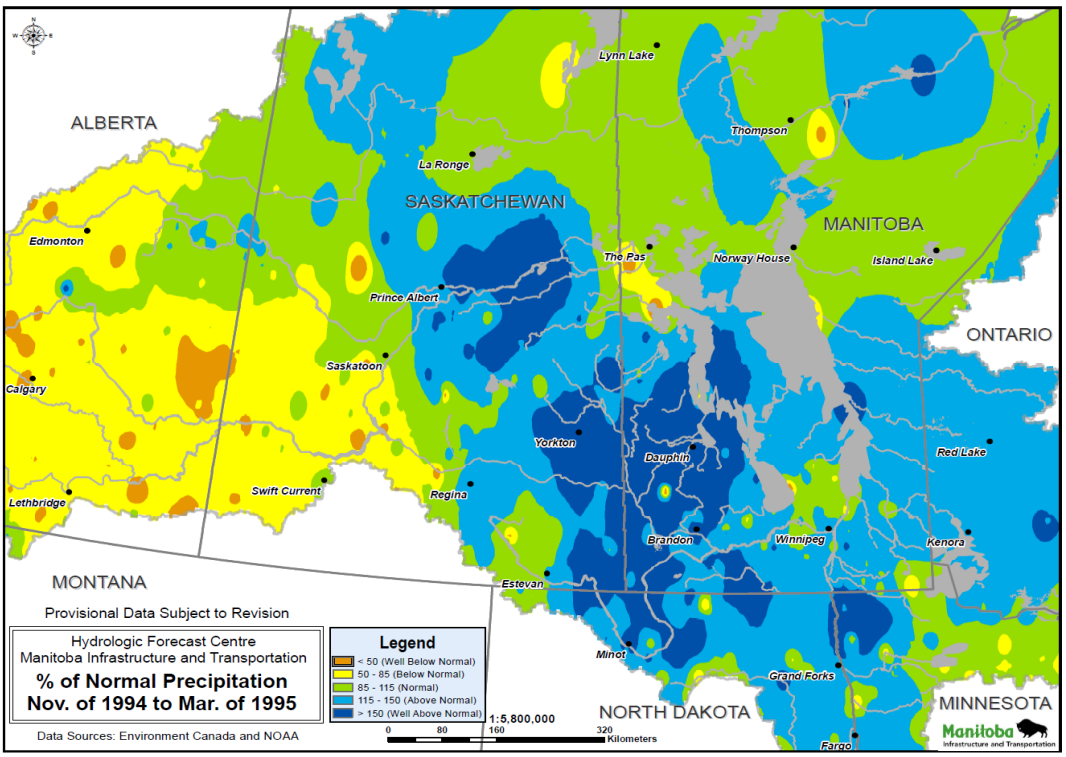


Figure 38. Percent normal winter precipitation prior to the flood of 1995.

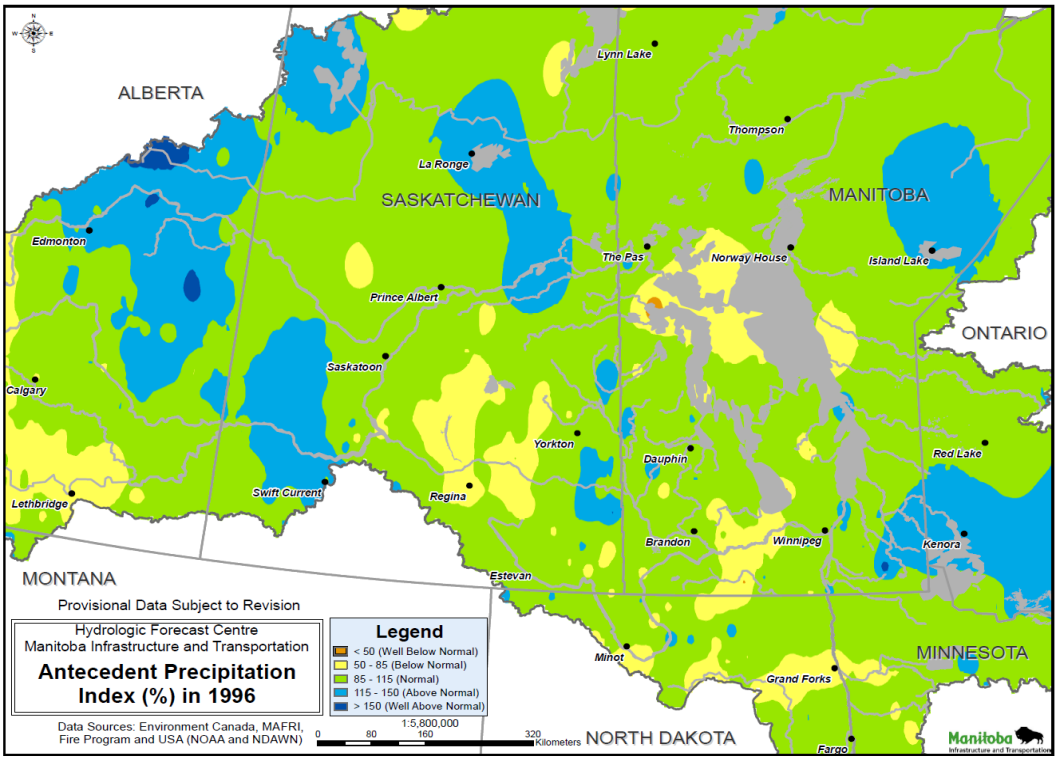


Figure 39. Antecedent Precipitation Index (API) in the fall of 1996

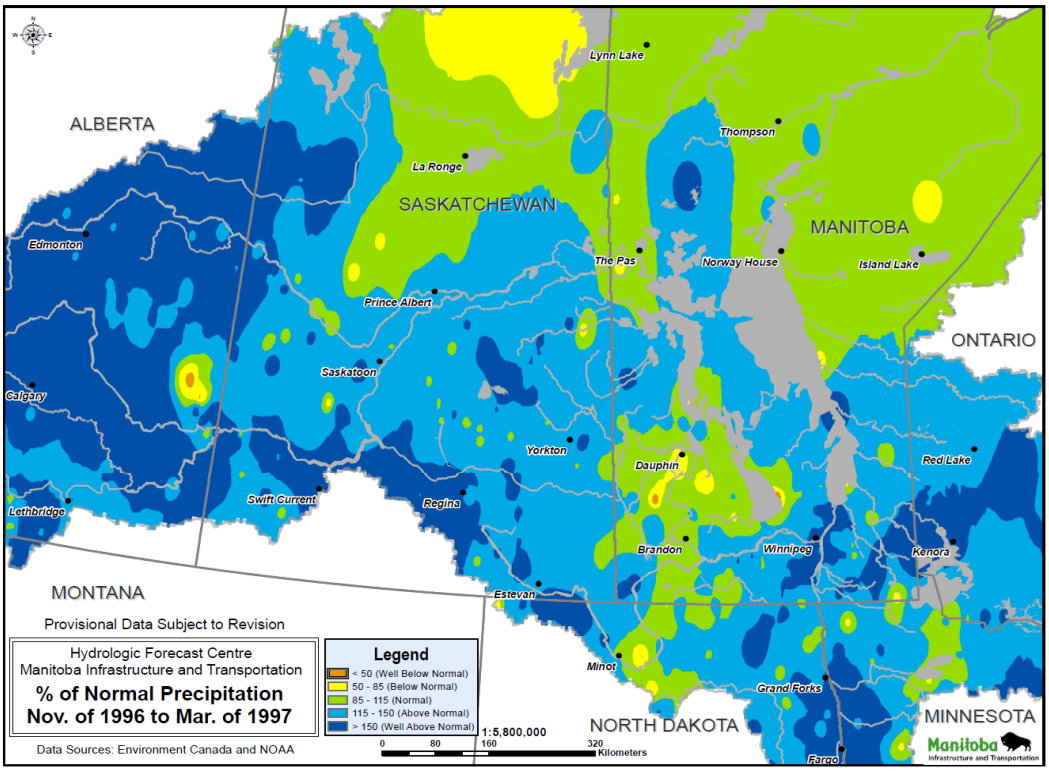


Figure 40. Percent normal winter precipitation prior to the flood of 1997.

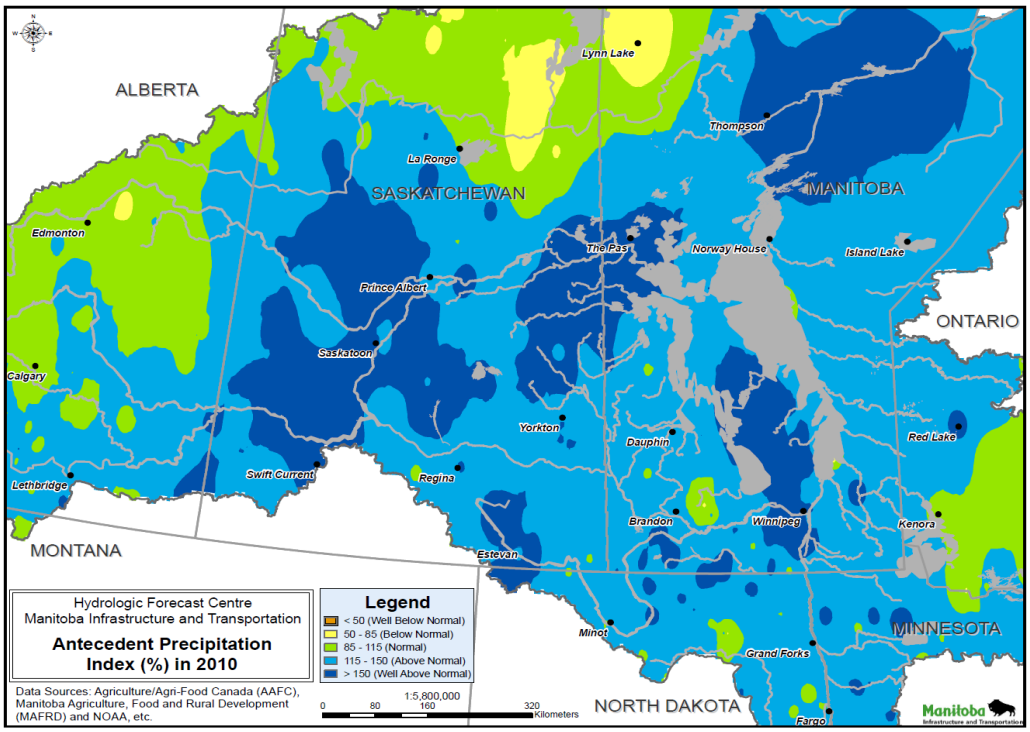


Figure 41. Antecedent Precipitation Index (API) in the fall of 2010

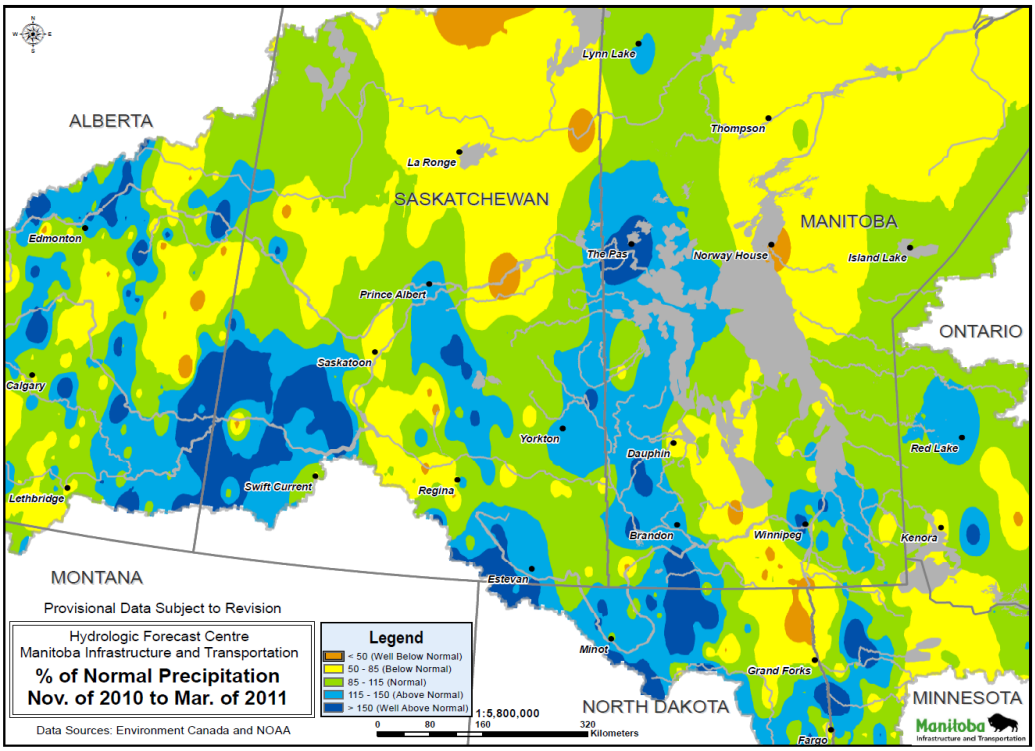


Figure 42. Percent normal winter precipitation prior to the flood of 2011