RED RIVER FLOODWAY OPERATION REPORT

SPRING 2013

Manitoba

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June 28, 2013

Hydrologic Forecasting and Water Management Branch
Water Management and Structures Division
Manitoba Infrastructure and Transportation

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EXECUTIVE SUMMARY

The 2013 Red River spring flood resulted from well above average winter snow fall in the Red River Valley. Early forecasts from the USGS estimated that the peak flow at Emerson could reach the level seen in the 2009 flood. However, compared to recent flood events such as the 2009 and 2011 flood events, the 2013 natural spring flood was a relatively minor event. In comparison, the 2009 peak flow measured along the Red River at Emerson was approximately 88,000 cfs whereas the 2013 peak flow measured at Emerson was approximately 45,000 cfs.

The 2013 Red River spring run-off event occurred later than is typical due to below normal temperatures for most of the month of April. The first ice break-up along the Red River from Emerson to Winnipeg started to occur around April 26th. Red River Floodway gate operations began on April 29th at 6:05 PM and the gates were operated for 40 days ending at 8:10 AM on June 8th. During this period of operation, 44 discrete gate adjustments were made as required at various times throughout any 24 hour period. In the spring of 2013, 450,000 acre-feet of water were diverted around the City of Winnipeg with a peak flow of 15,700 cfs. The Red River Floodway has been operated in 29 of the past 45 years to prevent spring flooding since its first year of operation in 1969.

The Assiniboine River flows in the spring flood of 2013 were also quite manageable when compared to the flows seen in 2011. The natural Assiniboine River contribution at James Avenue peaked at 20,100 cfs on May 25th. The observed flow along the Assiniboine River at Headingley reached a maximum of 8,800 cfs due to operation of the Shellmouth Dam and Portage Diversion.

In spring 2013, operation of the floodway was successful in protecting the City of Winnipeg while minimizing upstream impacts through normal operation in accordance with Rule 1 of the Floodway Rules of Operation. Rule 1 requires that natural levels are maintained on the Red River at the floodway inlet. In concert with operation of the Portage Diversion and Shellmouth Reservoir, operation of the floodway reduced the flood crest in the City of Winnipeg by 6.33 feet at the peak natural flow.

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1.0 INTRODUCTION

On April 20, 2005, *The Red River Floodway Act* was proclaimed in force. Subsection 11(1) of this Act states that:

> "*On or before June 30 of any year in which the government operates the floodway during spring flooding to regulate the river level, the director must provide the minister with a report about the operation containing the information the minister requires.*"

The following report details operation of the Red River Floodway in the spring runoff period of 2013 as required by section 11(1) of *The Red River Floodway Act* and includes the information specified in section 3(1) of The Red River Floodway Regulation.

Within this report, all flows and levels are shown in imperial units. Flows can be converted from cubic feet per second (cfs) to cubic metres per second (m^3/s) by dividing by 35.3148. River levels can be converted from feet to metres by dividing by a factor of 3.28084.

Manitoba Infrastructure and Transportation (MIT) gratefully acknowledges Water Survey Canada (WSC) for providing the provisional flows used in the report.

2.0 2013 SPRING RUNOFF

The 2013 Red River spring flood resulted from well above average winter snow fall in the Red River Valley. Early forecasts from the USGS estimated that the peak flow at Emerson could reach the level seen in the 2009 flood. However, compared to recent flood events such as the 2009 and 2011 flood events, the 2013 natural spring flood was a relatively minor event. In comparison, the 2009 peak flow measured along the Red River at Emerson was approximately 88,000 cfs whereas the 2013 peak flow measured at Emerson was approximately 45,000 cfs.

The 2013 Red River spring run-off event occurred later than is typical due to below normal temperatures for most of the month of April. The first ice break-up along the Red River from Emerson to Winnipeg started to occur around April 26th. Typically, a late thaw can result in rapid melt and high run-off volumes; however the spring thaw was long and drawn out due to favourable weather conditions in April with minimal precipitation. By the time temperatures increased enough to melt snow rapidly, much of the snow had already melted. Additionally, the crests of the water levels in the Manitoba tributaries occurred before the arrival of the crest along the Red River coming from the United States. These factors resulted in favorable conditions along the main stem of the Red River in Manitoba. As a result, measured peaks along the Red River were below forecasted levels. Crests in Manitoba occurred on May 3rd at the floodway inlet and on May 7th at Emerson.

3.0 THE RED RIVER FLOODWAY

Following the historic flood of 1950 in the City of Winnipeg, work began on the design and construction of a series of flood control measures including Shellmouth Reservoir, Portage Diversion, and the Red River Floodway to protect the City from significant flood events. All

were intended to be operated in concert to reduce flood flows and thus, minimize flood damages in the City of Winnipeg.

Operation of the floodway is guided by a set of rules (Appendix A) intended to provide balanced flood protection to the City of Winnipeg without artificially affecting properties south (i.e. upstream) of the inlet. Rule 1 requires that natural levels not be exceeded upstream of the floodway inlet structure as long as water levels within the City of Winnipeg are less than 24.5 ft James Avenue. The natural water level on the Red River at the floodway entrance is defined as the water level that would have occurred at this location in the late 1950s if Shellmouth Reservoir, Portage Diversion, Assiniboine River dikes, Winnipeg dikes, and the Red River Floodway were not in place.

During the 2013 spring floodway operation, the natural water levels upstream of the inlet were calculated with the relationship developed by Acres Manitoba Limited in 2004 [*"Re-Computation of Natural Water Levels at the Floodway Inlet (Final Report)", April 2004*]. This relationship requires two input values: the natural flow in the Red River downstream of the Assiniboine River (at James Avenue) and the natural flow of the Assiniboine River into the Red River. These data along with the natural and actual water levels on the Red River at the floodway inlet are shown for the 2013 spring flood in Appendix B, Table 2. Real-time water level and flow data to guide the operations are obtained at a number of sites including the Red River at James Avenue or Chief Peguis Bridge, above and below the Inlet Control Structure, floodway channel, Assiniboine River at Headingley, Portage Diversion, Sturgeon Creek, and La Salle River along with estimates of un-gauged flow from small streams or overland runoff in the Winnipeg area.

4.0 OPERATION OF THE FLOODWAY IN SPRING 2013

4.1 General Observations

Floodway operation began the evening of April 29th, two days after ice had released upstream of the inlet control structure and floodway inlet areas. On the 29th, water had already begun to spill into the floodway prior to operation of the gates. The Red River Floodway gates were operated in accordance with normal operating procedures to reduce river levels in the City of Winnipeg. Operation of the floodway during open water in 2013 followed normal protocol and was consistent with experience in past spring floods.

The computation of natural water levels at the inlet control structure requires calculation of the natural flow at James Avenue. Natural flow is determined by adjusting the actual flow for the effects of the flood control works. Under open water conditions, the actual flow is determined from the discharge rating curve for the Red River at James Avenue using Water Survey of Canada levels collected at station 05OC015. The City of Winnipeg also operates a gauge at the same location as the Water Survey of Canada gauge for their flood reponse purposes. Early in the 2013 spring flood it was discovered that both the Water Survey of Canada and the City of Winnipeg water level gauges were reading incorrect water levels due to siltation and debris in the gauge well. While efforts were being made to fix the problem with the gauges, the City of Winnipeg was able to provide calculated water levels for James Avenue by adjusting gauge readings taken at the Provencher Bridge. On May 3rd, WSC set up a temporary gauge at

the former site of the Harbour Masters Building (currently a construction site) to be used as the James Avenue water level gauge for the rest of the duration of the spring flood.

James Avenue water levels increased to a peak of 18.78 ft under open water conditions in the morning of May 1st and then decreased for three days as the natural level upstream of the floodway crested at midday on May 4th. The peak natural flow at James Avenue in Winnipeg would have occurred at midday on May 4th and was calculated to be approximately 77,000 cfs. This peak flow would have resulted in a James Avenue level of 23.54 ft. Operation of the floodway, Portage Diversion and Shellmouth Dam lowered the James Avenue water level during the peak natural flow by 6.33 ft to 17.21 ft and prevented millions of dollars of damage. A second crest of 18.21 ft was observed at James Avenue on May 6th as flows along the Assiniboine increased.

Overall, in the spring of 2013, approximately 450,000 acre-feet of water was diverted around the City of Winnipeg with a peak flow of 15,700 cfs. The peak recorded level at the floodway entrance (Water Survey Canada station 05OC026) was 758.05 ft in the morning of May 4th; 0.43 ft lower than the computed natural peak level of 758.48 ft. The recorded river level at the floodway entrance was maintained an average of 0.42 ft below the computed natural level throughout the 40 days of floodway operation.

During operation, the floodway gates were adjusted in small increments to follow the natural rise and drop in water levels. This was done to avoid large gate raises and drops that may have caused sudden changes in water levels above and below the floodway control structure. Table 1 lists the gate operations that occurred during operation of the floodway in the spring of 2013.

Figure 1 shows the recorded and natural water levels for the Red River in Winnipeg at James Avenue during the period of operation. Figure 2 shows the recorded and natural water levels for the Red River upstream of the floodway entrance.

4.2 Public Communication in 2013 Flood

An email database has been developed and maintained in accordance with the recommendations of the 2010 Public Review of the Red River Floodway Rules of Operation. The database includes municipal staff from the City of Winnipeg, Town of Morris, R.M. of East St. Paul, R.M. of West St. Paul, City of Selkirk, R.M. of St. Clements, R.M. of St. Andrews, R.M. of Springfield, R.M. of MacDonald, and the R.M. of Richot. Three notification emails were distributed. The first email was distributed at 10:30 AM, April 29th, providing notice of the planned floodway operation at 6:00 PM, April 29th. The second email was distributed at 7:45 PM, April 29th, confirming the initial operation was completed as planned. The third email was distributed at 3:10 PM, June 8th, informing the stakeholders on the contact list that floodway operations were complete for the Spring 2013 flood.

An information phone line (1-204-284-4550) was also maintained with the most recent information on the operation of the Red River Floodway.

4.3 Ice Conditions in 2013

Ice was present on the Red River until the end of April due to below normal temperatures for most of the month of April. Despite the late spring thaw, ice break-up conditions were favourable along the Red River for the 2013 spring flood. On April 27th the City of Winnipeg reported that ice along the Red River was dissipating in various locations in the city including downstream of the floodway. The City of Winnipeg also reported that ice was starting to pile up one mile upstream of the floodway gates in the evening of the 27th. South of Winnipeg, ice break-up was reported on the 27th along the Red River in regions near Emerson, St. Jean, and Morris. By April 28th ice had cleared out of the city and the ice build-up above the floodway had cleared out during the night of the 27th. South of the city, Emerson and Aubigny were clear of ice on the 27th and flowing ice was observed at Ste. Agathe. North of Winnipeg it was reported that the ice had all cleared out the Red River all the way downstream to Peltz Drive north of Selkirk. On April 29th, all reaches of the Red River were reported to be clear of ice except for at Netley Creek.

Ice jamming was an issue along the Assiniboine River upstream of the Portage Diversion. Attempts were made to direct the ice flows into the diversion with some difficulty on April 30th. It was attempted to maintain the flow on the Assiniboine River at 5,000 cfs to prevent ice jams forming. A surge of water (8,000 cfs peak) was allowed through the bascule gates over a 24 hour period from night of the 30th to alleviate some of the build up of hydraulic head upstream of the Portage Diversion reservoir. Minor ice jamming occurred downstream of Portage la Prairie but did not cause any damages. By May 2nd the ice was flowing freely through the diversion gates and the river was clear of ice from the Portage Diversion reservoir to Holland.

4.4 Assiniboine River Flow Contribution

The Assiniboine River flow volumes that occurred during the spring flood of 2013 were quite manageable when compared to the flows seen in 2011. The natural Assiniboine River contribution at James Avenue peaked at 20,100 cfs on May 25th. The observed flow along the Assiniboine River at Headingley reached a maximum of 8,800 cfs due to operation of the Shellmouth Dam and Portage Diversion.

The highest reductions in flows at James Avenue due to Shellmouth Dam operations occurred on May 25-26th when the Red River flows at James Avenue were reduced by approximately 6,800 cfs.

On May 1st, the Portage Diversion water level gauge (05LL019) was damaged by ice. As a result there are sections in the provisional water level and flow data provided by Water Survey Canada that had to be estimated. Upon review of the estimated provisional data for May 2nd it was found that the flows estimated by Water Survey Canada during this period diverged greatly from the flow rates calculated by the Portage Diversion operators. To resolve this discrepancy, engineers and technicians from Manitoba Infrastructure and Transportation and Water Survey Canada reviewed the real-time data from gauges along the Assiniboine River near Holland and Portage La Prairie (gauges 05MH005 and 05MJ003) in conjunction with information provided by the Portage Diversion operators which included the flow rates calculated using the Portage Diversion gate equation and field observations of ice jamming in the Portage Reservoir and

Portage Diversion. Based on this joint review it was determined that the initial provisional peak flow estimate of 8,500 cfs in the diversion on May 2nd was too low and that the estimated peak flow could be reasonably raised to approximately 12,400 cfs. Increasing the estimate is further supported by the fact the failsafe at the end of the diversion was breached. This typically occurs at flows in excess of 15,000 cfs. The presence of ice in the channel may have created a backwater effect that contributed to the failsafe breach. With all available information considered, a peak flow of 12,400 cfs during this period is considered a reasonable but conservative estimate.

4.5 Floodway Maintenance and Efficiency

In recent years, most notably in 2009 and 2010, the observed floodway conveyance has been slightly lower than the expected design conveyance. The growth of willows in the floodway channel was identified as one possible cause. The willow growth was most significant from the floodway inlet to the Trans Canada Highway, with willows reaching heights of 10 feet in some areas. During the winter of 2012/2013, the Manitoba Floodway Authority mowed all the willows from the floodway inlet to the floodway outlet. The maintenance measures helped to maintain the improvements to flow efficiency that were observed in the floodway during the 2011 flood.

5.0 CONCLUSIONS

In summary:

- During the spring of 2013, the Red River Floodway was operated for 40 days and, in combination with other related flood control measures such as operation of the Portage Diversion and storage of flood waters in Shellmouth Reservoir, reduced the flood crest in the City of Winnipeg by 6.33 feet during the peak natural flow;

- Operation of the Red River Floodway began at 6:05 PM on April 29, 2013, and concluded at 8:10 AM on June 8, 2013. During this period, 44 discrete gate adjustments were made as required;

- Recorded water levels upstream of the inlet were maintained below natural levels throughout floodway operation in the spring of 2013, and on average were 0.42 feet lower than natural levels;

- The crest at the floodway inlet was 758.05 feet; 0.43 feet lower than the computed natural peak level of 758.48 feet;

- Pre-flood willow clearing by the Manitoba Floodway Authority helped to maintain the floodway flow efficiency to the efficiency levels seen in 2011.

- During spring 2013, 450,000 acre-feet of water were diverted around the City of Winnipeg with a peak flow of 15,700 cfs.

Table 1 –2013 Floodway Gate Operations

Date	Time *	Start of Operation	End of Operation	Date	Time *	Start of Operation	End of Operation
April 29, 2013	6:05 PM	728.04	736.05	May 16, 2013	9:20 PM	740.14	739.95
April 30, 2013	1:00 PM	736.05	736.90	May 18, 2013	9:15 AM	739.95	739.76
April 30, 2013	8:30 PM	736.90	738.52	May 19, 2013	9:20 AM	739.76	739.38
May 1, 2013	8:30 AM	738.52	740.14	May 19, 2013	7:15 PM	739.38	738.71
May 1, 2013	3:00 PM	740.14	742.62	May 20, 2013	12:45 PM	738.71	738.23
May 2, 2013	10:45 AM	742.62	743.85	May 20, 2013	9:10 PM	738.23	737.95
May 2, 2013	9:10 PM	743.85	745.16	May 21, 2013	10:25 AM	737.95	737.66
May 3, 2013	2:45 PM	745.16	745.62	May 21, 2013	11:05 PM	737.66	737.38
May 4, 2013	3:15 PM	745.62	745.25	May 22, 2013	8:30 PM	737.38	737.76
May 4, 2013	10:30 PM	745.25	743.85	May 23, 2013	10:20 AM	737.76	738.04
May 5, 2013	11:05 AM	743.85	743.28	May 26, 2013	10:30 PM	738.04	737.85
May 8, 2013	1:00 PM	743.28	743.00	May 27, 2013	11:00 PM	737.85	737.66
May 8, 2013	10:29 PM	743.00	742.81	May 30, 2013	10:05 AM	737.66	737.28
May 9, 2013	10:25 PM	742.81	742.53	June 2, 2013	8:35 PM	737.28	737.76
May 10, 2013	3:20 PM	742.53	742.15	June 4, 2013	10:45 PM	737.76	737.28
May 11, 2013	12:35 AM	742.15	741.96	June 5, 2013	10:40 AM	737.28	736.90
May 11, 2013	11:30 AM	741.96	741.39	June 5, 2013	10:20 PM	736.90	736.52
May 11, 2013	9:30 PM	741.39	741.10	June 6, 2013	1:15 PM	736.52	735.67
May 12, 2013	10:20 AM	741.10	740.62	June 6, 2013	8:40 PM	735.67	734.64
May 13, 2013	2:30 PM	740.62	740.43	June 7, 2013	10:15 AM	734.64	733.43
May 13, 2013	10:25 PM	740.43	740.24	June 7, 2013	4:15 PM	733.43	730.98
May 15, 2013	2:40 PM	740.24	740.14	June 8, 2013	8:10 AM	730.98	728.04

* Time of start of gate operation

Figure 1 – Recorded and Natural River Levels at James Avenue Gauge 2013

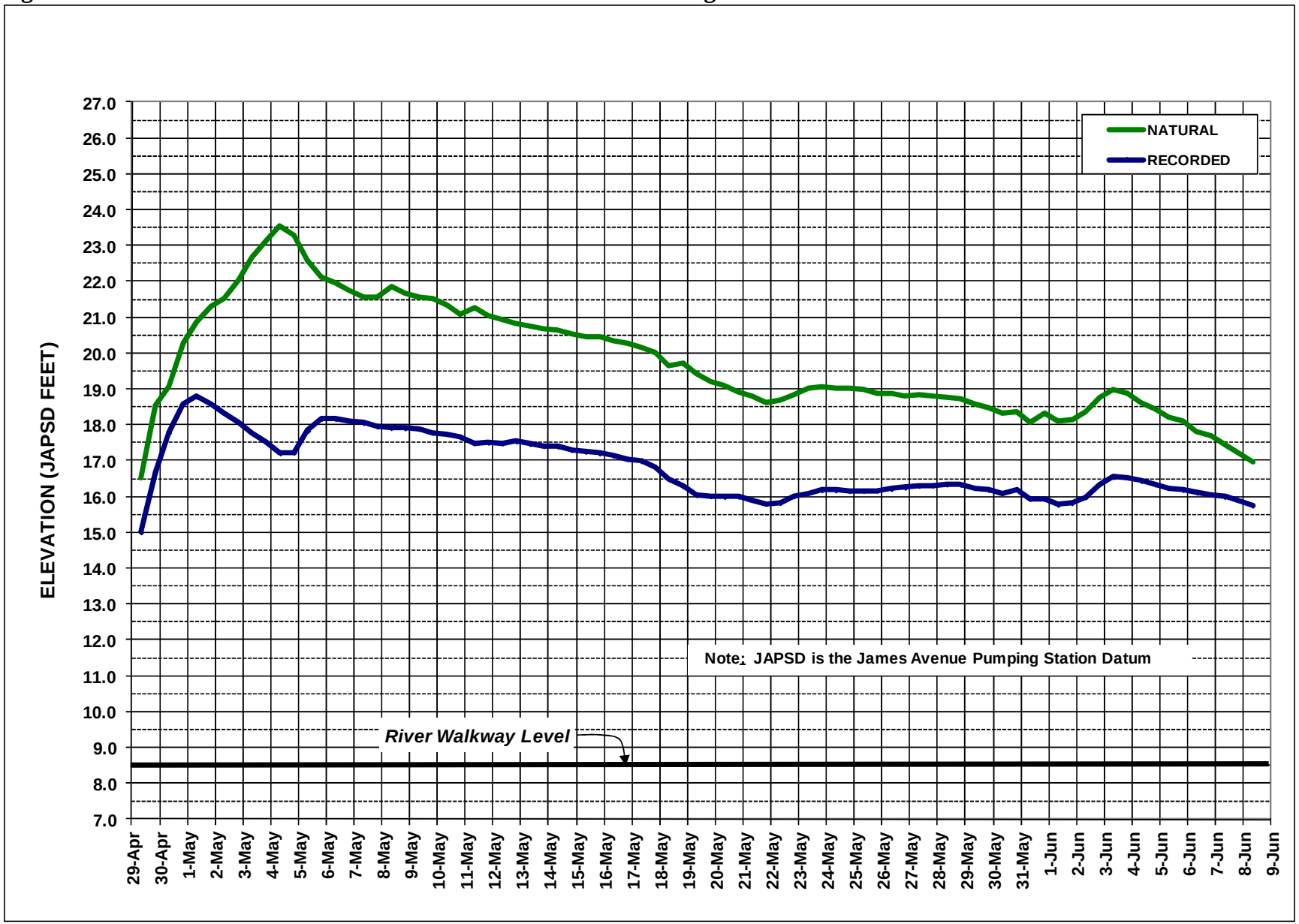
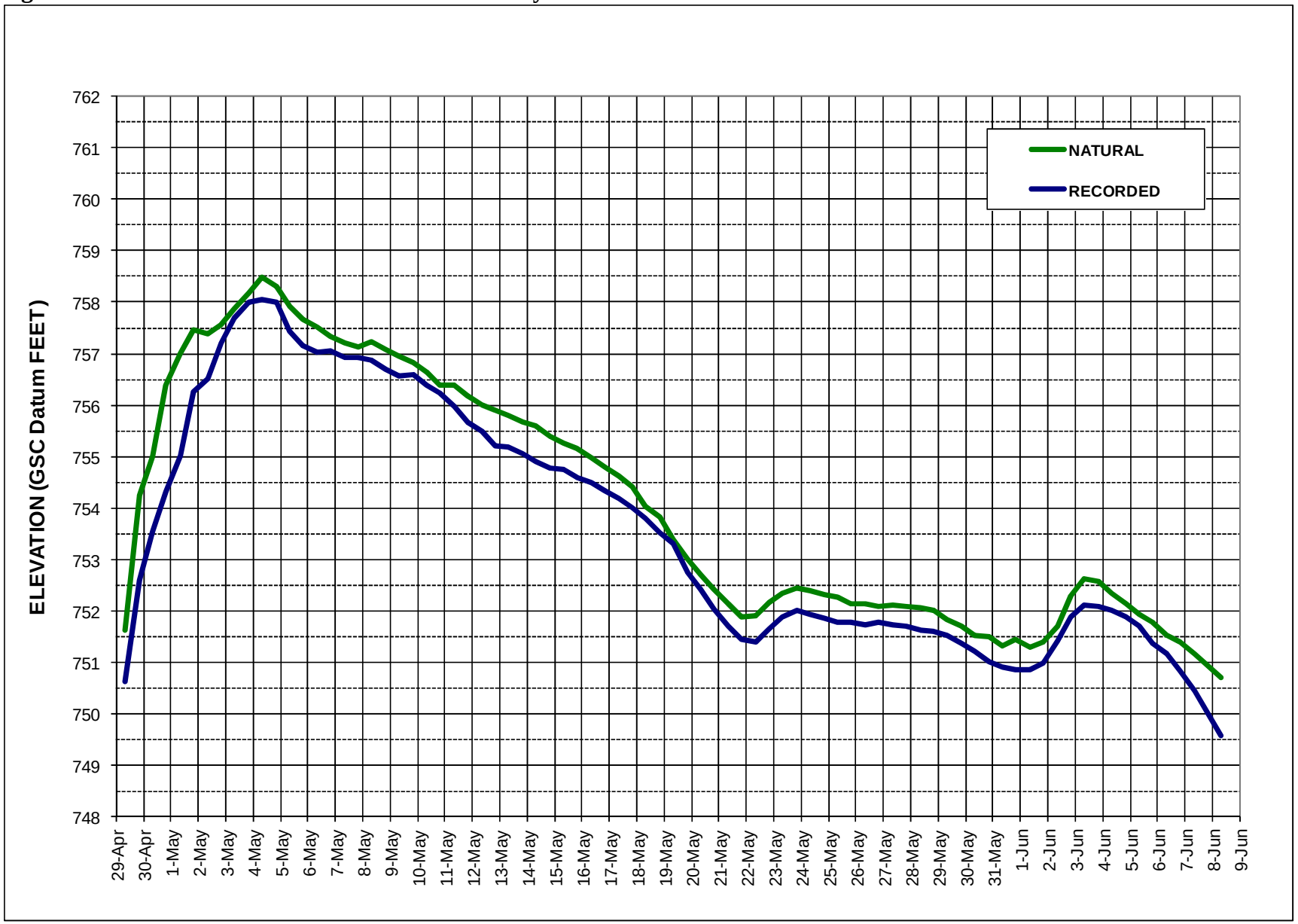


Figure 2 – Recorded and Natural Levels at Floodway Entrance 2013



APPENDIX A

Red River Floodway Rules of Operation

Rules of Operation
Red River Floodway Control Structure

Normal Operation:
1. Maintain natural[1] water levels on the Red River at the entrance to the floodway channel, until the water surface elevation at James Avenue reaches 24.5 feet (7.46 metres), or the river level anywhere along the Red River within the City of Winnipeg reaches two feet below the Flood Protection Level of 27.83 feet (8.48 m).

Major Flood Operation:
2. Once the river levels within Winnipeg reach the limits described in Rule 1, the level in Winnipeg should be held constant while levels south of the control structure continue to rise. Furthermore if forecasts indicate that levels at the entrance to the floodway channel will rise more than two feet (0.6 metres) above natural, the City of Winnipeg must proceed with emergency raising of the dikes and temporary protection measures on the sewer systems in accordance with the flood level forecasts within Winnipeg. The levels in Winnipeg should be permitted to rise as construction proceeds, but not so as to encroach on the freeboard of the dikes or compromise the emergency measures undertaken for protecting the sewer systems. At the same time the Province should consider the possibility of an emergency increase in the height of the floodway embankments and the West Dike. At no time will the water level at the floodway channel's entrance be allowed to rise to a level that infringes on the allowable freeboard on the floodway west embankment (Winnipeg side) and the West Dike.

Extreme Flood Operation:
3. For extreme floods, where the water level at the floodway channel's entrance reaches the maximum level that can be held by the floodway west embankment and the West Dike, the river level must not be permitted to exceed that level. All additional flows must be passed through Winnipeg.

Initial Gate Operation with Ice:
The floodway gates should not be operated until ice on the river is flowing freely, unless flooding in Winnipeg is imminent.

Final drop of Gates:
To minimize bank slumping along the river in Winnipeg and at the same time reduce the probability of sewer backup problems, final gate operations, once the level at the entrance to the floodway channel recedes to elevation 752 feet (229 metres), shall be carried out in consultation with the City of Winnipeg.

Operation of Horn:
The horn at the floodway structure shall only be operated once, before the first gate operation of the year. The horn should be sounded a half-hour before the first gate operation to alert residents that the floodway structure is being put into operation. For ongoing information a 1-800 number should be established that would provide current information of gate operations, potential impacts on water levels, and forecasts for the next few days. The information should also be included on the existing Province of Manitoba internet site.

[1] The term natural refers to the level that would have occurred in the absence of the flood control works, with the level of urban development in place at the time of the construction of these works.

Emergency Operation to Reduce Sewer Backup in Winnipeg

4(1) This rule defines the circumstances under which the Minister of Manitoba Infrastructure and Transportation ("the Minister") may determine that emergency operation of the floodway is necessary to prevent widespread basement flooding and resulting risk to health and damage to property within the City of Winnipeg.

4(2) This rule applies after the spring crest from snowmelt runoff at Winnipeg, whenever high river levels substantially impair the capacity of Winnipeg's combined sewer system.

4(3) As long as the Department of Manitoba Infrastructure and Transportation ("the Department") forecasts that river levels for the next 10 days will be below 14 feet James Avenue Pumping Station Datum (JAPSD), the Department will not operate the floodway control structure.

4(4) When the Department forecasts that river levels for the next 10 days are expected to rise to 14 feet JAPSD or higher, the Department will prepare a report that describes:

(a) The basis of the Department's river level forecasts and its risk assessment;

(b) The risk of basement flooding in Winnipeg, including the following factors:

(i) The predicted peak river level in the next 10 days;

(ii) The length of time the Department forecasts the river level will be at 14 feet JAPSD or higher;

(iii) The risk of an intense rainfall event in Winnipeg in the next 10 days;

(c) The benefits and costs of floodway operation, including:

(i) The extent of basement flooding and damage to property expected from various combinations of intense rainfall events and high river levels;

(ii) The risk to the health of Winnipeg residents from sewer back-up;

(iii) Economic loss and damage caused by artificial flooding south of the inlet control structure;

(iv) Impacts of operation on fish and wildlife and their habitat and on water quality;

(v) The risks and potential costs of riverbank instability that may be caused by artificial river level changes, both upstream and downstream of the inlet control structure;

(vi) During construction of the floodway expansion, costs and risks associated with any resulting delays of that construction, including the potential average annual expected damages associated with an additional period of risk of a flood event that would exceed the current capacity of the floodway;

(vii) Such other benefits and costs of operation of which the Department is aware at the time of the preparation of the report, excluding benefits associated with recreational or tourism activities or facilities; and

(d) measures that may be taken to mitigate the costs and impacts of the operation under consideration, including:

(i) minimizing the rate at which river levels are changed both upstream and downstream of the floodway inlet control structure;
(ii) providing means to assure fish passage.

4(5) The Department will present a draft of the report prepared under rule 4(4) to the Floodway Operation Review Committee and provide an opportunity for the Committee to provide input, before finalizing the report and making recommendations respecting floodway operation.

4(6) The Department will not recommend operation of the floodway unless the expected benefits of doing so clearly and substantially outweigh the expected costs.

4(7) The Department will present its report and recommendations to the Minister, who, subject to rule 4(8), will make a decision respecting floodway operation based on his or her consideration of the report.

4(8) The Department will not operate the floodway control structure under this rule:

(a) to raise river levels immediately upstream of the control structure to an elevation higher than 760 feet above sea level;

(b) to achieve a river level of less than 9 feet JAPSD; or

(c) except in circumstances of extreme urgency, to lower river levels more than one foot per day.

4(9) The Department will issue a news release announcing a decision to operate the floodway at least 24 hours before commencing operation.

4(10) The Department will ensure every reasonable effort is made to personally notify landowners who may be directly affected by flooding due to floodway operation in advance of the operation.

4(11) The Department will sound the horn at the floodway inlet control structure one-half hour before operation commences.

4(12) The Department will maintain a program of compensation for damages suffered by landowners arising from flooding caused by floodway operation under this rule.

APPENDIX B

Computation of Natural Flows and Levels

Computation of Natural Flows and Levels
On the Red and Assiniboine Rivers

Table 2 in the main report lists the natural flows on the Red River below the confluence with the Assiniboine River and on the Assiniboine River at the Forks. This Appendix describes how those flows were determined, and explains how the relationships developed in the Acres 2004 study were applied to compute the natural level at the floodway entrance.

Table B-1 lists the recorded and computed flows and levels for each time step. Columns 1 to 7 list the flows used in computing the natural flows on the Assiniboine River, and columns 8 to 10 list the flows used for computing the natural flows on the Red River.

NATURAL ASSINIBOINE RIVER FLOW

The natural flows on the Assiniboine River are altered by operation of the Shellmouth Dam, the Portage Diversion, and by the presence of dikes along the Assiniboine River.

The Shellmouth Dam can decrease flows below natural levels by adjusting the control gates so that reservoir outflows are lower than the inflows. In this case the reservoir levels rise, and excess water is stored behind the dam.

The Portage Diversion can be used to reduce flows in the lower Assiniboine River by diverting some of the river flow north to Lake Manitoba.

The Assiniboine River dikes were constructed to prevent overflows from the river onto the surrounding lands. Because of the height of the river and the slope of the land much of this overflow did not return to the Assiniboine River. Therefore, the dikes have the effect of increasing flows entering Winnipeg on the Assiniboine River during periods of high flow.

Referring to Table B-1, column 1 lists the flow reductions at Winnipeg resulting from storage behind the Shellmouth Dam. It is important to recognize that these flow changes at the dam take some time to reach Winnipeg. The Department uses the Muskingum routing procedure to compute this flow attenuation.

Column 2 shows the flows diverted to Lake Manitoba via the Portage Diversion. Again the flows are routed to Winnipeg to apply the time delay.

Column 3 shows the recorded flows at the hydrometric station at Headingley. These first three columns are summed to determine the total natural flow before applying the natural breakouts that would have occurred if the dikes were not in place.

Column 4 lists the computed breakouts that would have occurred at those flows if the dikes had not been constructed.

Column 5 lists the computed natural flows at Headingley. These are computed by adding the three adjustments to the recorded flows at Headingley.

There is some additional local inflow entering the Assiniboine River between Headingley and the Forks. Most of this flow is recorded on Sturgeon Creek. In column 6 the recorded flows on Sturgeon Creek are increased to include unmeasured local inflows.

Finally columns 5 and 6 are added together to give the computed natural flows of the Assiniboine River at the Forks, as listed in column 7.

NATURAL RED RIVER FLOW

On the Red River the primary flow adjustment is caused by the Red River Floodway. During periods of extensive flooding there can also be a flow change resulting from changes in the storage of floodwaters on the land, but as long as flood levels at the floodway entrance are held at natural that change would be negligible.

Column 8 lists the recorded flows in the floodway channel, and column 9 shows the recorded flows at James Avenue. Column 10 sums the flows in those two columns and adds the three flow adjustments on the Assiniboine River to give the total natural flow on the Red River at James Avenue, which is downstream of the Forks.

NATURAL RIVER LEVELS AT THE FLOODWAY INLET

Table B-2 is a reproduction of Table 4-7 from the Acres report *"Re-Computation of Natural Water Levels at the Floodway Inlet (Final Report), April 2004*". The table provides natural elevations at the inlet based upon the relative contribution of natural flow at the Forks from the Red and Assiniboine Rivers. The *combined* flow is represented by the values in the left-hand column entitled Red River at James Avenue. The Assiniboine River Contribution amount is shown across the top and is the flow in the Assiniboine River at the Forks.

The natural water level at the inlet can vary by a few feet dependent upon the amount of flow coming from the Assiniboine River (Assiniboine River Contribution). This phenomenon is referred to as a variable backwater effect.

This concept can be illustrated by using the example of 100,000 cfs flow for the Red River at James Avenue in various combinations of Red and Assiniboine River flows. One combination could have 95,000 cfs as Red River flow upstream of the Forks and 5,000 cfs as Assiniboine River Contribution; this combination results in a level at the inlet of 765.6 feet as shown in Table B-2. Similarly, another combination, while still yielding a total James Avenue flow of 100,000 cfs, could be 70,000 cfs as Red River flow upstream of the Forks and 30,000 cfs as Assiniboine River Contribution; the resulting inlet level would be 762.9 feet. The difference in the inlet water elevation between these two flow combinations is 2.7 feet, with the lower elevation occurring when there is relatively more flow on the Assiniboine River.

Natural levels are determined by using the natural Red River flows at James Avenue listed in column 10 of Table B-1, and the natural Assiniboine River flows listed in column 7 of Table B-1 and interpolating between the values listed in Table B-2 to determine the natural levels. These natural levels are listed in column 13 of Table B-1. For comparison, column 14 of Table B-1

lists the recorded levels at the floodway inlet (station 05OC026). Similar levels for James Avenue in Winnipeg are provided in columns 11 and 12.

Table B-1 Spring 2013 Flows and Levels

Column =>	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Assiniboine River Flows							**Red River Flows**						
Date / Time (CDT)	Shellmouth Flow Changes (Routed to Headingley) *Recorded*	Portage Diversion flow (Routed to Headingley) *Recorded*	Actual Assiniboine R. flow at Headingley *Recorded*	Natural breakouts from river *Computed*	Natural Assiniboine River flow at Headingley *=1+2+3-4*	Sturgeon Cr. Flow plus other local inflows *Rec. & Est.*	**Natural Assiniboine R. flow into Red River** *=5+6*	Red River Floodway flow *Recorded*	Red River flow at James Ave. *Recorded*	**Natural Red River flow at James Avenue** *=1+2-4+8+9*	Natural Water Level at James Ave (feet) *Computed*	Recorded Water Level at James Ave (feet) *Recorded*	Natural water level on Red R. at Floodway Inlet (feet) *Computed*	Recorded Water level on Red R. at Floodway Inlet (feet) *Recorded*
29-Apr-2013 8:00 AM	0	0	3,259	0	3,259	2,702	**5,961**	0	47,529	**47,529**	16.51	15.01	751.63	750.63
29-Apr-2013 8:00 PM	0	0	3,744	0	3,744	2,518	**6,262**	2,464	53,139	**55,602**	18.55	16.68	754.24	752.60
30-Apr-2013 8:00 AM	0	0	4,221	0	4,221	1,913	**6,134**	5,519	52,370	**57,890**	19.07	17.78	755.00	753.55
30-Apr-2013 8:00 PM	6	0	4,759	0	4,765	1,915	**6,680**	7,001	55,776	**62,783**	20.29	18.59	756.39	754.30
01-May-2013 8:00 AM	15	0	5,365	0	5,380	2,072	**7,452**	8,644	56,649	**65,308**	20.85	18.78	757.00	755.00
01-May-2013 8:00 PM	33	0	6,049	0	6,082	1,994	**8,076**	11,367	55,782	**67,182**	21.30	18.59	757.46	756.27
02-May-2013 8:00 AM	50	1,275	6,819	0	8,144	1,853	**9,997**	12,076	54,618	**68,019**	21.50	18.32	757.39	756.53
02-May-2013 8:00 PM	68	3,461	7,688	0	11,217	1,606	**12,823**	13,368	53,336	**70,233**	22.05	18.08	757.56	757.21
03-May-2013 8:00 AM	85	6,270	8,668	0	15,033	1,384	**16,417**	14,801	52,142	**73,308**	22.66	17.76	757.87	757.70
03-May-2013 8:00 PM	106	9,317	8,767	566	17,624	1,151	**18,775**	15,461	51,258	**75,577**	23.14	17.53	758.17	758.00
04-May-2013 8:00 AM	122	12,364	7,470	1059	18,897	913	**19,810**	15,658	50,081	**77,166**	23.54	17.21	758.48	758.05
04-May-2013 8:00 PM	140	11,586	7,317	788	18,254	764	**19,018**	15,449	49,759	**76,146**	23.29	17.22	758.30	757.99
05-May-2013 8:00 AM	162	6,583	7,886	0	14,631	671	**15,302**	14,159	52,029	**72,933**	22.59	17.83	757.93	757.43
05-May-2013 8:00 PM	192	3,601	8,397	0	12,189	573	**12,762**	13,492	53,294	**70,579**	22.12	18.17	757.67	757.16
06-May-2013 8:00 AM	213	3,010	8,670	0	11,893	504	**12,397**	13,324	53,266	**69,813**	21.95	18.16	757.51	757.03
06-May-2013 8:00 PM	243	2,498	8,767	0	11,509	398	**11,906**	13,194	53,015	**68,950**	21.74	18.10	757.33	757.04
07-May-2013 8:00 AM	287	1,967	8,803	0	11,057	334	**11,391**	13,108	52,848	**68,210**	21.55	18.05	757.19	756.92
07-May-2013 8:00 PM	347	2,509	8,818	0	11,674	312	**11,985**	12,985	52,463	**68,304**	21.58	17.95	757.12	756.91
08-May-2013 8:00 AM	402	3,833	8,815	0	13,050	291	**13,341**	12,869	52,333	**69,437**	21.86	17.92	757.22	756.87
08-May-2013 8:00 PM	474	3,336	8,807	0	12,616	270	**12,886**	12,582	52,288	**68,679**	21.67	17.90	757.07	756.69
09-May-2013 8:00 AM	576	3,341	8,776	0	12,693	249	**12,942**	12,302	52,083	**68,302**	21.58	17.89	756.94	756.57
09-May-2013 8:00 PM	726	3,648	8,740	0	13,114	226	**13,340**	12,186	51,562	**68,122**	21.53	17.78	756.82	756.60
10-May-2013 8:00 AM	813	3,339	8,705	0	12,857	203	**13,060**	11,809	51,444	**67,405**	21.35	17.75	756.64	756.37
10-May-2013 8:00 PM	958	3,087	8,501	0	12,546	185	**12,731**	11,304	50,997	**66,346**	21.09	17.65	756.38	756.23
11-May-2013 8:00 AM	1100	4,609	8,013	0	13,722	174	**13,896**	10,957	50,369	**67,035**	21.26	17.48	756.38	755.97
11-May-2013 8:00 PM	1263	4,579	7,516	0	13,357	163	**13,521**	10,364	50,001	**66,206**	21.05	17.51	756.19	755.67
12-May-2013 8:00 AM	1425	4,805	7,232	0	13,462	151	**13,613**	9,968	49,473	**65,672**	20.93	17.48	756.01	755.48
12-May-2013 8:00 PM	1595	4,564	7,095	0	13,254	141	**13,395**	9,429	49,636	**65,224**	20.83	17.54	755.91	755.21

Column =>	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Assiniboine River Flows							**Red River Flows**						
Date / Time (CDT)	Shellmouth Flow Changes (Routed to Headingley) *Recorded*	Portage Diversion flow (Routed to Headingley) *Recorded*	Actual Assiniboine R. flow at Headingley *Recorded*	Natural breakouts from river *Computed*	Natural Assiniboine River flow at Headingley *=1+2+3-4*	Sturgeon Cr. Flow plus other local inflows *Rec. & Est.*	**Natural Assiniboine R. flow into Red River** *=5+6*	Red River Floodway flow *Recorded*	Red River flow at James Ave. *Recorded*	**Natural Red River flow at James Avenue** *=1+2-4+8+9*	Natural Water Level at James Ave (feet) *Computed*	Recorded Water Level at James Ave (feet) *Recorded*	Natural water level on Red R. at Floodway Inlet (feet) *Computed*	Recorded Water level on Red R. at Floodway Inlet (feet) *Recorded*
13-May-2013 8:00 AM	1765	4,570	7,071	0	13,406	132	**13,538**	9,243	49,349	**64,927**	20.76	17.46	755.79	755.18
13-May-2013 8:00 PM	1947	4,591	7,041	0	13,579	126	**13,706**	8,932	49,142	**64,612**	20.69	17.41	755.66	755.06
14-May-2013 8:00 AM	2129	4,583	6,997	0	13,708	125	**13,833**	8,634	49,080	**64,427**	20.65	17.40	755.58	754.90
14-May-2013 8:00 PM	2330	4,603	6,952	0	13,886	122	**14,008**	8,272	48,690	**63,896**	20.53	17.30	755.39	754.78
15-May-2013 8:00 AM	2531	4,639	6,903	0	14,073	119	**14,192**	7,958	48,497	**63,625**	20.47	17.25	755.27	754.75
15-May-2013 8:00 PM	2758	4,884	6,827	0	14,468	116	**14,584**	7,519	48,314	**63,475**	20.44	17.20	755.15	754.59
16-May-2013 8:00 AM	2984	4,930	6,856	0	14,770	111	**14,881**	7,134	48,065	**63,113**	20.36	17.14	754.99	754.50
16-May-2013 8:00 PM	3238	4,967	6,866	0	15,075	111	**15,186**	6,760	47,711	**62,680**	20.26	17.05	754.80	754.34
17-May-2013 8:00 AM	3492	5,083	6,825	38	15,361	110	**15,472**	6,288	47,448	**62,273**	20.17	16.99	754.62	754.18
17-May-2013 8:00 PM	3768	5,136	6,224	3	15,125	115	**15,239**	5,830	46,766	**61,496**	20.00	16.82	754.42	754.00
18-May-2013 8:00 AM	4043	5,383	5,574	0	15,000	110	**15,110**	5,306	45,414	**60,147**	19.65	16.48	754.03	753.79
18-May-2013 8:00 PM	4332	6,993	5,400	250	16,474	171	**16,644**	4,685	44,640	**60,399**	19.72	16.28	753.83	753.53
19-May-2013 8:00 AM	4620	7,236	5,390	353	16,893	58	**16,951**	4,097	43,656	**59,255**	19.42	16.04	753.40	753.30
19-May-2013 8:00 PM	4908	7,270	5,582	464	17,295	333	**17,628**	3,193	43,551	**58,457**	19.22	16.01	753.01	752.76
20-May-2013 8:00 AM	5196	7,524	5,851	662	17,909	508	**18,417**	2,429	43,472	**57,959**	19.09	15.99	752.70	752.42
20-May-2013 8:00 PM	5466	7,135	6,097	695	18,003	578	**18,581**	1,796	43,498	**57,200**	18.91	16.00	752.41	752.02
21-May-2013 8:00 AM	5735	7,424	6,298	907	18,551	608	**19,158**	1,340	43,131	**56,723**	18.80	15.91	752.14	751.70
21-May-2013 8:00 PM	5967	7,115	6,498	943	18,637	456	**19,093**	1,116	42,685	**55,939**	18.62	15.80	751.89	751.46
22-May-2013 8:00 AM	6199	7,360	6,710	1159	19,110	304	**19,414**	1,016	42,790	**56,206**	18.68	15.82	751.92	751.41
22-May-2013 8:00 PM	6376	7,078	6,865	1175	19,143	253	**19,397**	1,120	43,538	**56,937**	18.85	16.01	752.17	751.64
23-May-2013 8:00 AM	6552	7,225	7,087	1360	19,504	202	**19,706**	1,334	43,892	**57,644**	19.01	16.10	752.35	751.89
23-May-2013 8:00 PM	6660	6,790	7,281	1314	19,417	151	**19,569**	1,468	44,220	**57,824**	19.06	16.18	752.44	752.00
24-May-2013 8:00 AM	6768	6,702	7,400	1362	19,508	101	**19,609**	1,418	44,194	**57,720**	19.03	16.17	752.40	751.94
24-May-2013 8:00 PM	6802	6,865	7,545	1484	19,728	101	**19,829**	1,320	44,128	**57,631**	19.01	16.16	752.33	751.86
25-May-2013 8:00 AM	6836	7,002	7,787	1637	19,988	101	**20,089**	1,241	44,128	**57,570**	18.99	16.16	752.26	751.79
25-May-2013 8:00 PM	6799	6,309	7,989	1442	19,655	51	**19,706**	1,197	44,168	**57,031**	18.87	16.17	752.15	751.78
26-May-2013 8:00 AM	6762	6,265	8,236	1502	19,760	51	**19,812**	1,172	44,351	**57,047**	18.87	16.21	752.13	751.72
26-May-2013 8:00 PM	6664	5,894	8,432	1404	19,586	51	**19,637**	1,156	44,496	**56,805**	18.82	16.25	752.08	751.79
27-May-2013 8:00 AM	6566	5,802	8,509	1364	19,512	51	**19,564**	1,125	44,692	**56,821**	18.82	16.30	752.10	751.74
27-May-2013 8:00 PM	6419	5,793	8,552	1325	19,439	51	**19,490**	1,104	44,719	**56,709**	18.80	16.30	752.08	751.72

Column =>	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Assiniboine River Flows							**Red River Flows**						
Date / Time (CDT)	Shellmouth Flow Changes (Routed to Headingley) *Recorded*	Portage Diversion flow (Routed to Headingley) *Recorded*	Actual Assiniboine R. flow at Headingley *Recorded*	Natural breakouts from river *Computed*	Natural Assiniboine River flow at Headingley *=1+2+3-4*	Sturgeon Cr. Flow plus other local inflows *Rec. & Est.*	**Natural Assiniboine R. flow into Red River** *=5+6*	Red River Floodway flow *Recorded*	Red River flow at James Ave. *Recorded*	**Natural Red River flow at James Avenue** *=1+2-4+8+9*	Natural Water Level at James Ave (feet) *Computed*	Recorded Water Level at James Ave (feet) *Recorded*	Natural water level on Red R. at Floodway Inlet (feet) *Computed*	Recorded Water level on Red R. at Floodway Inlet (feet) *Recorded*
28-May-2013 8:00 AM	6274	5,660	8,574	1238	19,270	51	**19,321**	1,043	44,863	**56,603**	18.77	16.34	752.07	751.63
28-May-2013 8:00 PM	6091	5,667	8,590	1184	19,163	101	**19,264**	1,005	44,824	**56,402**	18.73	16.33	752.01	751.60
29-May-2013 8:00 AM	5908	5,428	8,611	1056	18,892	51	**18,943**	941	44,456	**55,678**	18.56	16.24	751.83	751.54
29-May-2013 8:00 PM	5700	5,435	8,628	999	18,764	51	**18,815**	865	44,233	**55,235**	18.46	16.18	751.70	751.37
30-May-2013 8:00 AM	5492	5,310	8,638	902	18,538	51	**18,589**	765	43,892	**54,557**	18.31	16.10	751.52	751.22
30-May-2013 8:00 PM	5267	5,308	8,550	812	18,314	735	**19,049**	653	44,325	**54,743**	18.35	16.21	751.49	751.01
31-May-2013 8:00 AM	5043	5,121	7,776	506	17,434	201	**17,635**	548	43,236	**53,442**	18.05	15.93	751.33	750.92
31-May-2013 8:00 PM	4810	6,977	7,393	827	18,354	866	**19,219**	507	43,236	**54,703**	18.34	15.93	751.45	750.87
01-Jun-2013 8:00 AM	4577	6,725	7,398	696	18,005	129	**18,134**	477	42,580	**53,663**	18.11	15.77	751.30	750.86
01-Jun-2013 8:00 PM	4342	6,984	7,393	701	18,018	59	**18,078**	504	42,764	**53,894**	18.16	15.82	751.39	750.99
02-Jun-2013 8:00 AM	4108	7,288	7,325	701	18,020	64	**18,084**	705	43,433	**54,832**	18.37	15.98	751.71	751.42
02-Jun-2013 8:00 PM	3879	7,551	7,310	706	18,033	74	**18,108**	997	44,889	**56,610**	18.77	16.35	752.30	751.88
03-Jun-2013 8:00 AM	3650	7,488	7,330	635	17,833	71	**17,904**	1,268	45,690	**57,461**	18.97	16.55	752.62	752.12
03-Jun-2013 8:00 PM	3433	7,178	7,227	483	17,356	65	**17,421**	1,286	45,637	**57,053**	18.88	16.53	752.58	752.10
04-Jun-2013 8:00 AM	3217	6,562	7,145	288	16,635	61	**16,696**	1,209	45,244	**55,943**	18.62	16.44	752.34	752.02
04-Jun-2013 8:00 PM	3017	6,275	7,068	185	16,175	58	**16,233**	1,103	44,867	**55,077**	18.43	16.34	752.14	751.89
05-Jun-2013 8:00 AM	2818	6,043	6,966	99	15,728	55	**15,783**	927	44,482	**54,172**	18.22	16.25	751.93	751.70
05-Jun-2013 8:00 PM	2639	6,059	6,946	72	15,571	53	**15,625**	747	44,233	**53,606**	18.09	16.18	751.77	751.37
06-Jun-2013 8:00 AM	2460	5,490	6,921	0	14,871	52	**14,923**	590	43,944	**52,485**	17.81	16.11	751.54	751.16
06-Jun-2013 8:00 PM	2302	5,637	6,885	0	14,824	52	**14,876**	397	43,721	**52,057**	17.69	16.06	751.40	750.83
07-Jun-2013 8:00 AM	2144	5,330	6,890	0	14,364	52	**14,417**	144	43,459	**51,077**	17.43	15.99	751.17	750.45
08-Jun-2013 8:00 AM	1869	5,017	6,864	0	13,751	52	**13,802**	0	42,488	**49,374**	16.97	15.75	750.70	749.57

Table B-2 Red River Floodway Inlet Natural Rating Table

RED RIVER AT JAMES AVENUE (cfs)	ASSINIBOINE RIVER CONTRIBUTION (cfs)										
cfs	0	5,000	10,000	15,000	20,000	25,000	30,000	35,000	40,000	45,000	50,000
20,000	742.1	740.4	738.7	737.4							
30,000	746.6	745.2	743.9	742.6	741.5						
40,000	750.4	749.2	748.0	746.9	745.8	744.9					
50,000	753.8	752.7	751.7	750.7	749.7	748.8	747.9				
60,000	756.8	755.9	754.9	754.0	753.1	752.2	751.4				
70,000	759.7	758.8	758.0	757.1	756.3	755.5	754.7				
80,000	762.4	761.6	760.8	760.1	759.3	758.5	757.8				
90,000		763.9	763.2	762.6	761.9	761.2	760.6	759.9			
100,000		765.6	765.3	764.8	764.1	763.5	762.9	762.3			
110,000		766.7	766.3	765.9	765.5	765.2	764.7	764.2			
120,000		767.6	767.5	767.2	766.8	766.5	766.1	765.7	765.4		
130,000		768.5	768.2	768.0	767.7	767.5	767.3	767.0	766.6		
140,000			768.7	768.7	768.6	768.4	768.1	767.9	767.6	767.4	
150,000			769.1	769.0	768.8	768.7	768.6	768.5	768.5	768.3	
160,000			769.6	769.4	769.2	769.1	768.9	768.8	768.7	768.5	768.5
170,000			770.1	769.9	769.8	769.6	769.5	769.3	769.2	769.0	768.8
180,000			770.5	770.4	770.3	770.2	770.0	769.9	769.7	769.5	769.4
190,000				770.5	770.5	770.5	770.5	770.3	770.2	770.1	769.9
200,000				770.7	770.6	770.6	770.5	770.5	770.5	770.5	770.5
210,000				770.9	770.8	770.7	770.7	770.6	770.6	770.5	770.5
220,000				771.1	771.0	770.9	770.8	770.7	770.7	770.6	770.5
230,000				771.2	771.2	771.1	771.0	770.9	770.8	770.7	770.7
240,000					771.5	771.4	771.3	771.2	771.1	771.0	770.9
250,000					771.8	771.7	771.6	771.6	771.5	771.4	771.3
260,000					772.1	772.0	772.0	771.9	771.8	771.7	771.6
270,000					772.4	772.4	772.3	772.2	772.1	772.1	772.0
280,000					772.8	772.7	772.6	772.5	772.5	772.4	772.3
290,000					773.1	773.0	772.9	772.8	772.8	772.7	772.6
300,000					773.3	773.3	773.2	773.1	773.1	773.0	772.9

Note: Open water conditions under steady state (no ice)