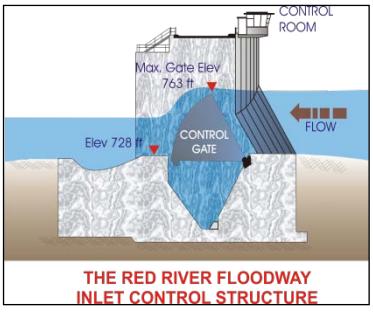
RED RIVER FLOODWAY OPERATION REPORT

SPRING 2011



Manitoba Water Stewardship

Manitoba

RED RIVER FLOODWAY OPERATION REPORT

SPRING 2011

Ecological Services Division
Manitoba Water Stewardship

Printed on Recycled Paper

Manitoba

EXECUTIVE SUMMARY

The Red River spring flood of 2011 was one of the largest floods since record keeping began, with the natural peak in Winnipeg being the 3rd highest since operation of the Red River Floodway first began in 1969. The flood of 2011 was the 6th largest since the year 1826. Larger floods include the recent floods of 1997 and 2009, as well as the historical floods of 1826, 1852, and 1861. Between the completion of the floodway in 1968 and the year 2011, it has been operated in 28 out of the past 43 years to prevent spring flooding.

During the spring of 2011, the Red River Floodway gates were operated for 1303.5 hours over 55 days beginning at 9:00 AM on April 9 and ending at 4:30 PM on June 2. During this period of operation, 55 discrete gate adjustments were made as required at various times throughout any 24 hour period. In the spring of 2011, 2.6 million acre-feet of water were diverted around the City of Winnipeg with a peak flow of 36,700 cfs.

In spring 2011, 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 the Department of Water Stewardship to maintain natural levels 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 11.6 feet.

At the time of preparation of this report, significant and unprecedented flooding was still underway across large parts of Manitoba although the spring 2011 operation of the floodway had ended. As required by *The Red River Floodway Act*, this report must be prepared by June 30th of any year in which spring operation of the Red River Floodway occurred.

RÉSUMÉ

L'inondation de la rivière Rouge qui a eu lieu au printemps 2011 compte parmi les plus fortes jamais enregistrées sur cette rivière. En effet, le débit maximal naturel à Winnipeg était le troisième en importance depuis la mise en service du canal de dérivation de la rivière Rouge en 1969. L'inondation de 2011 était la sixième en importance depuis 1826. Les plus fortes inondations connues comprennent celles de 1997 et de 2009, ainsi que les crues historiques de 1826, de 1852 et de 1861. Au cours des 43 années qui séparent son achèvement en 1968 de l'année 2011, le canal de dérivation a été utilisé 28 fois en vue d'éviter les inondations printanières.

Au cours du printemps de 2011, les vannes du canal de dérivation ont fonctionné pendant 1303,5 h sur une période de 55 jours qui s'est étendue de 9 h le 9 avril à 16 h le 2 juin. Au cours de cette période, 55 ajustements distincts ont été apportés aux vannes selon les besoins à divers moments sur toute période de 24 heures. Au printemps 2011, 2,6 millions d'acres-pieds (3,21 millions de décamètres cubes) d'eau, avec un débit atteignant jusqu'à 1 039,23 m^3/s (36 700 pi^3/s), ont été déviés autour de la ville de Winnipeg.

Au printemps 2011, l'utilisation du canal de dérivation en conformité avec la règle de fonctionnement 1 de l'ouvrage de régularisation des crues a permis de protéger la ville de Winnipeg tout en minimisant les répercussions en amont. La règle de fonctionnement 1 exige que le ministère de la Gestion des ressources hydriques veille à ce que le niveau d'eau de la rivière Rouge à l'entrée de l'ouvrage régulateur soit maintenu au niveau naturel. L'utilisation du canal de dérivation de la rivière Rouge, du canal de dérivation Portage et du réservoir de Shellmouth a eu pour effet de réduire de 3,54 m (11,6 pi) la hauteur de la pointe de crue à Winnipeg.

Au moment de la rédaction de ce rapport, le fonctionnement du canal de dérivation en raison de la crue printanière de 2011 avait cessé, mais de grandes parties du Manitoba connaissaient encore des inondations importantes et sans précédent. En vertu de la *Loi sur le canal de dérivation de la rivière Rouge*, le rapport concernant le fonctionnement du canal doit être remis au plus tard le 30 juin de chaque année au cours de laquelle le gouvernement fait fonctionner le canal de dérivation pendant la crue printanière.

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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 2011 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 Water Stewardship gratefully acknowledges Water Survey of Canada for providing the provisional flows used in the report.

2.0 2011 SPRING RUNOFF

The 2011 natural spring flood on the Red River at James Avenue Winnipeg was the 3rd largest since operation of major flood control works began in 1969 and was only exceeded by the floods of 1997 and 2009 during that period. The peak at Emerson occurred on April 24th at a flow of approximately 83,000 cfs, slightly less than the peak in 2009. The 2011 peak at Emerson was the 5th largest in the last 100 years and has a return period of, on average, once every 26 years.

The 2011 Red River spring flood resulted from well-above average soil moisture at freeze-up in 2010, high winter flows, and snow cover that was generally above average. The soil moisture index at 2010 freeze up was the second highest recorded since 1948 and only slightly lower than the record high measure before the 2009 flood. The flow at James Avenue during the winter was the highest recorded.

Near record or record flooding occurred in many areas across Manitoba in 2011 and indeed, much flooding remained underway at the time of preparation of this report. An unprecedented amount of land was flooded. The Assiniboine River experienced record flows with an approximate return period of, on average, once every 300 years.

Snowmelt runoff began mid-March. Crests from Manitoba tributaries occurred before the arrival of the crest from the United States, resulting in attenuation as the crest moved through Manitoba. Crests in Manitoba occurred on April 24th at Emerson and May 1st at the floodway inlet.

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 or 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 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, and the Red River Floodway were not in place.

During the 2011 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 2011 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 2011

4.1 General Observations

The Red River Floodway gates were first operated at 9:30 AM on Saturday, April 9th, in accordance with normal operating procedures to reduce river levels in the City of Winnipeg. Operation of the floodway during open water in 2011 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 estimated from the discharge rating curve for the Red River at James Avenue using Water Survey of Canada levels collected at station 05OC015.

The Red River at James Avenue crested at 20.78 ft on April 7th due to ice jams downstream of James Avenue. The open water peak occurred during the afternoon of April 9th at a water level of 20.69 ft.

Floodway operation began the morning of April 9th shortly after ice had released upstream of the inlet control structure and floodway inlet areas. James Avenue water levels began decreasing in the evening of April 9th. Excluding the brief peak on April 9th, the peak water level at James Avenue during floodway operation occurred on May 6th at a water level of 19.61 ft. The peak natural flow at Winnipeg was calculated as 116,000 cfs during the May 6th peak, which would have resulted in an estimated peak James Avenue level of 31.2 ft, 0.9 ft higher than the 1950 peak level. Operation of the floodway, Portage Diversion and Shellmouth Dam lowered the James Avenue water level during the peak natural flow by 11.6 ft and prevented billions of dollars of damage.

Overall, in the spring of 2011, 2.6 million acre-feet of water was diverted around the City of Winnipeg with a peak flow of 36,700 cfs. This was the 5th highest peak floodway flow and was only exceeded during the floods of 2009, 1997, 1996, and 1979. The peak recorded level at the floodway entrance (Water Survey of Canada station 05OC026) was 764.09 ft in the early morning of May 1st, 0.68 ft lower than the computed natural peak level of 764.77 ft. The recorded river level at the floodway entrance was maintained an average of 0.52 ft below the computed natural level throughout the 55 days of floodway operation.

During operation, the floodway gates were adjusted in small increments to follow the natural rise in water levels. This was done to avoid large gate raises 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 2011. The average gate adjustment was 0.53 feet during the period of time that floodway flows were affected by gate operation.

Red River recorded and natural levels in Winnipeg at James Avenue during the period of operation are shown on Figure 1 and similar levels at the floodway entrance are plotted in Figure 2.

4.2 Improved Public Communication in 2011 Flood

In the summer of 2010, a public review of the Red River Floodway Rules of Operation was held. As part of the review, municipal governments noted a need for enhanced communication and, in particular, asked that they be notified of the initial operation of the Inlet Control Structure gates, as well as all other major operations on the floodway. To satisfy these requests, an email data base was developed and included 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. Two notification emails were distributed. The first email was distributed at 6 PM, April 8th, providing notice of the planned floodway operation at 9 AM, April 9th. The second email was distributed at 11 AM, April 9th, confirming the initial operation was completed as planned.

4.3 Ice Conditions in 2011

Due to very wet conditions during the summer of 2010 and an extreme storm event at the end of October 2010, flows along the Red River were very high during the freeze-up period in the autumn of 2010. For most of the river, the high flow velocities formed an ice cover with a rough surface made up of consolidated ice floes and frazil ice (white ice). This is in contrast to the ice cover of winter 2009 - 2010 when currents were substantially slower allowing skim ice and a columnar ice cover (black ice) to form over most of the river length. Near the end of winter, a white ice cover maintains its strength until break-up whereas a black ice cover can progressively lose over half of its strength. The predominantly white ice cover on the Red River retained its strength into the break-up period making it very persistent. Ice did not clear from the river upstream of the floodway inlet until April 8th, relatively late compared to recent years.

Ice jamming occurred in the Selkirk area between April 5th and 8th. On April 5th an ice jam occurred in Lockport and then released and jammed near the Selkirk Golf Course. Ice jamming continued in the Selkirk area over the next few days with the most significant ice jam developing in the McIvor Road area north of Selkirk on April 8th. This jam released later in the day and moved down to the Netley Creek area.

Ice and ice jamming were present on the Red River well into April, delaying the operation of the floodway. A large ice pan and ice floe accumulated at the floodway inlet on April 6th and persisted until the morning of April 8th. An accumulation of ice floes and slush also occurred against St. Mary's Road Bridge in the floodway channel (see Figure 1) but was pushed downstream early on April 9th as floodway flow increased.

Figure 1: Ice conditions in the area of the floodway inlet on April 7th, 2011.

Ice jamming also occurred along the Red River within Winnipeg. An ice jam was reported at the Norwood Bridge on April 6th, which released in the evening of that day. The ice then moved downstream to the Disraeli and Redwood Bridges (see Figure 2). This was evident in

the water levels recorded at James Avenue. This ice jam persisted until the morning of April 8th when the ice moved to jam again briefly at Chief Peguis Bridge. The river in Winnipeg was cleared of ice by the late afternoon of April 8th. The ice on the Assiniboine River was more persistent and did not clear from its course in Winnipeg until two days later. Ice cover breakup and ice jamming and flooding were reported at numerous locations along the Assiniboine River upstream from Winnipeg for almost ten days between April 10th and 20th before the Assiniboine River became completely free of ice.

Figure 2: Ice jam between Disraeli and Redwood Bridges on April 7th, 2011.

4.4 Assiniboine River Flow Contribution

The Assiniboine River flows in 2011 during the period covered by this report (that is, April 9 to June 2) were unprecedented in the previous hydrologic record and were substantially higher than any other flood since floodway operation began in the late 1960s. This led to many unique circumstances during floodway operations in 2011.

The highest reductions in flows at James Avenue due to Shellmouth Dam operations coincided closely with the peak natural flow at James Avenue. Red River flows at James Avenue were reduced by 10,800 cfs on May 7-8th. The 2011 reduction in James Avenue flows due to Shellmouth Dam operations was the highest of any major Red River flood. Previously, the highest reduction due to Shellmouth Dam operations during a major Red River flood peak was 6,300 cfs during the flood of 1997.

Portage Diversion saw unprecedented flows in 2011. Portage Diversion flow peaked at approximately 35,000 cfs on May 14th. Prior to 2011, the previous peak Portage Diversion flow was slightly less than 26,000 cfs in 1976. Additionally, prior to 2011, the largest Portage Diversion flow to occur during operation of the floodway was 22,000 cfs in 2009.

The calculation of the natural Assiniboine River contribution considers breakouts from the Assiniboine River that would naturally occur without the flood protection present along the Assiniboine River - Shellmouth Dam, Portage Diversion and the Assiniboine River Dikes between Portage la Prairie and St. Francois Xavier. During high flows, water is assumed to leave the Assiniboine River and remain in storage until flows decrease or overflow south into the La Salle River watershed. Engineering documents from the 1950s and 1960s demonstrate that at high flows, there is also a significant natural overflow to Lake Manitoba near the current location of the Portage Diversion.

Current estimates of natural flow on the Assiniboine River at Headingley do not consider that under sustained high flow, the volume of water entering into storage along the Assiniboine River could decrease as the storage volume is filled. As storage is filled, the natural flow at Headingley, and therefore natural levels at James Avenue and the floodway inlet area, could increase and allow more water to be diverted into the floodway channel. Although the peak flow and duration of the Assiniboine River flood in the spring of 2011 was an unprecedented event, it is recommended that the natural overflows along the Assiniboine River be reviewed. A better understanding of natural overflows into Lake Manitoba, the La Salle River, and into storage adjacent to the Assiniboine River will improve the estimation of natural levels at Headingley, James Avenue, and the floodway inlet.

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 2010/2011, the Manitoba Floodway Authority mowed all the willows from the floodway inlet to Dunning Road as well as 50 % of the willows from Dunning Road to the floodway outlet.

The willow mowing made a noticeable difference in floodway efficiency compared to the spring floods of 2009 and 2010. During the peak inlet levels of 2011, approximately 3500 cfs of additional flow entered the floodway as compared to flow entering the floodway at similar levels in 2009. The difference of 3500 cfs provided a benefit of 0.87 ft at James Avenue.

4.6 Floodway Notch Flow in 2011

During floodway expansion, three notches were constructed in the east dike near the floodway entrance. The spring of 2011 was the first year in which water entered the floodway through any of the notches. In the summer of 2009, the west notch was lowered to allow water to enter at a lower elevation. During the spring of 2011, water began flowing into the west notch at an elevation of approximately 763.5 ft. At the peak inlet elevation of 764.09 ft, the gap flow is estimated to have reached a flow of about 1500 cfs. This additional floodway flow provided a benefit of approximately 0.38 ft to James Avenue. To account for the notch flow, the gauge at

the Trans Canada Highway was used to estimate flow entering the floodway while water was flowing through the notch.

Combining the benefit of the lowered notch and the improved floodway conveyance from willow cutting, an additional 5000 cfs was diverted around the City compared to what would have occurred under the 2009 floodway configuration and willow conditions. This difference in flow equates to a lower water level at James Avenue of approximately 1.25 ft.

Figure 3: Flow through the west notch on May 2nd, 2011.

4.7 Acoustic Velocity Meter Stations and Floodway Operations

An Acoustic Velocity Meter provides estimates of flow in real time with a measured velocity index. This equipment provides advantages compared to using measured levels with rating curves in a number of situations. These situations include: estimating flows under ice conditions where large departures from rating curves are evident, where there are backwater effects, or where there is hysteresis looping of a rating curve. All of these conditions are present at various stations used in floodway operations. For this reason, a number of acoustic velocity meters have recently been installed along the Red River and in the floodway channel.

In the winter of 2009-2010, an acoustic velocity meter was installed in the floodway channel at the Trans Canada Highway. This location is downstream on the gauge on St. Mary's Road Bridge and accounts for the flow through the notches. This meter was calibrated with 2010 data and was operational for the 2011 flood. The acoustic velocity meter was used regularly throughout the 2011 flood as a supplementary data source to estimate floodway flow. As the meter continues to provide reliable flow estimates, it will be relied upon more in future floods.

In the winter of 2010-2011 acoustic velocity meters were installed on the Red River at the South Perimeter and Chief Peguis bridges. Data was collected at the South Perimeter site as planned and it will be operational for 2012. The meter at Chief Peguis had its wiring damaged by ice early in the flood and could not be repaired due to high water. This rendered the Chief Peguis acoustic velocity meter out of use for the remaining duration of the flood and data could not be collected. However, a flow metering program was continued and will provide some data for future calibration.

4.8 Extension of the Red River Floodway Inlet Natural Rating Table

An unprecedented condition developed during the spring of 2011 where the natural Assiniboine River contribution was so large that it required extrapolation of the natural inlet level relationships beyond the existing bounds. Bruce Harding, P. Eng., was contacted to provide additional inlet elevations under larger Assiniboine River flows. Bruce Harding was one of the original authors of the Acres Manitoba Limited report prepared in April 2004. Mr. Harding used the same model and procedure as in 2004 to compute the additional natural inlet levels. These additional values are shown as shaded values in Table B-2 in Appendix B.

5.0 CONCLUSIONS

It can be concluded that:

- During the spring of 2011, the Red River Floodway was operated for 1303.5 hours over 55 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 11.6 feet;
- Operation of the Red River Floodway began at 9:00 AM on April 9, 2011, and concluded at 4:30 PM on June 2, 2011. During this period, 55 discrete gate adjustments were made as required and occurred at various times throughout any 24 hour period;
- Throughout its operation in the spring of 2011, recorded water levels upstream of the inlet were maintained below natural levels and, on average, were 0.50 feet lower than natural levels;
- The crest at the floodway inlet was 764.09 feet, 0.68 feet lower than the computed natural peak level of 764.77 feet;
- Floodway flow was significantly increased due to willow cutting and the lowering of the west notch which resulted in a benefit to James Avenue of 1.25 feet during the May 9th peak;
- During spring 2011, 2.6 million acre-feet of water were diverted around the City of Winnipeg with a peak flow of 36,700 cfs.

Table 1 –2011 Floodway Gate Operations

Date	Time *	Start of Operation	End of Operation	Date	Time *	Start of Operation	End of Operation
April 9, 2011	9:00 AM	728.00	737.00	May 19, 2011	11:00 AM	749.59	749.06
April 9, 2011	2:15 PM	737.00	739.95	May 19, 2011	11:15 PM	749.06	748.71
April 9, 2011	10:15 PM	739.95	742.90	May 21, 2011	2:30 PM	748.71	748.34
April 10, 2011	11:00 AM	742.90	744.04	May 22, 2011	10:30 PM	748.34	747.90
April 10, 2011	9:00 PM	744.04	744.50	May 22, 2011	9:00 PM	747.90	747.27
April 11, 2011	11:00 AM	744.50	745.25	May 23, 2011	10:30 AM	747.27	746.82
April 13, 2011	3:15 PM	745.25	745.62	May 23, 2011	10:45 PM	746.82	746.45
April 15, 2011	11:00 AM	745.62	745.34	May 24, 2011	10:30 AM	746.45	745.99
April 16, 2011	3:00 PM	745.34	746.27	May 24, 2011	8:30 PM	745.99	745.62
April 16, 2011	9:30 PM	746.27	747.18	May 25, 2011	10:30 AM	745.62	745.25
April 17, 2011	1:30 PM	747.18	747.90	May 25, 2011	10:30 PM	745.25	744.97
April 17, 2011	11:30 PM	747.90	748.26	May 26, 2011	10:45 AM	744.97	744.50
April 20, 2011	11:15 PM	748.26	748.44	May 26, 2011	8:45 PM	744.50	743.94
April 24, 2011	1:00 PM	748.44	748.89	May 27, 2011	12:30 PM	743.94	743.47
April 24, 2011	9:00 PM	748.89	749.50	May 27, 2011	10:30 PM	743.47	743.09
April 25, 2011	11:30 AM	749.50	749.86	May 28, 2011	10:15 AM	743.09	742.62
April 28, 2011	9:30 PM	749.86	750.20	May 28, 2011	8:30 PM	742.62	742.24
April 29, 2011	11:30 AM	750.20	750.63	May 29, 2011	10:30 AM	742.24	741.77
April 29, 2011	9:00 PM	750.63	751.06	May 29, 2011	8:45 PM	741.77	741.29
May 1, 2011	7:15 PM	751.06	750.72	May 30, 2011	8:30 AM	741.29	740.91
May 3, 2011	5:00 PM	750.72	750.97	May 30, 2011	6:20 PM	740.91	740.05
May 9, 2011	10:45 PM	750.97	750.81	May 31, 2011	8:30 AM	740.05	738.90
May 11, 2011	12:30 PM	750.81	751.06	May 31, 2011	6:30 PM	738.90	737.57
May 11, 2011	10:45 PM	751.06	751.23	June 1, 2011	8:30 AM	737.57	736.62
May 15, 2011	9:00 PM	751.23	751.89	June 1, 2011	6:30 PM	736.62	735.20
May 16, 2011	12:00 PM	751.89	750.46	June 2, 2011	8:45 AM	735.20	732.42
May 16, 2011	9:00 PM	750.46	750.03	June 2, 2011	4:30 PM	732.42	728.00
May 18, 2011	9:15 PM	750.03	749.59	* Time of start of gate operation			

Figure 4 – Recorded and Natural River Levels at James Avenue Gauge 2011

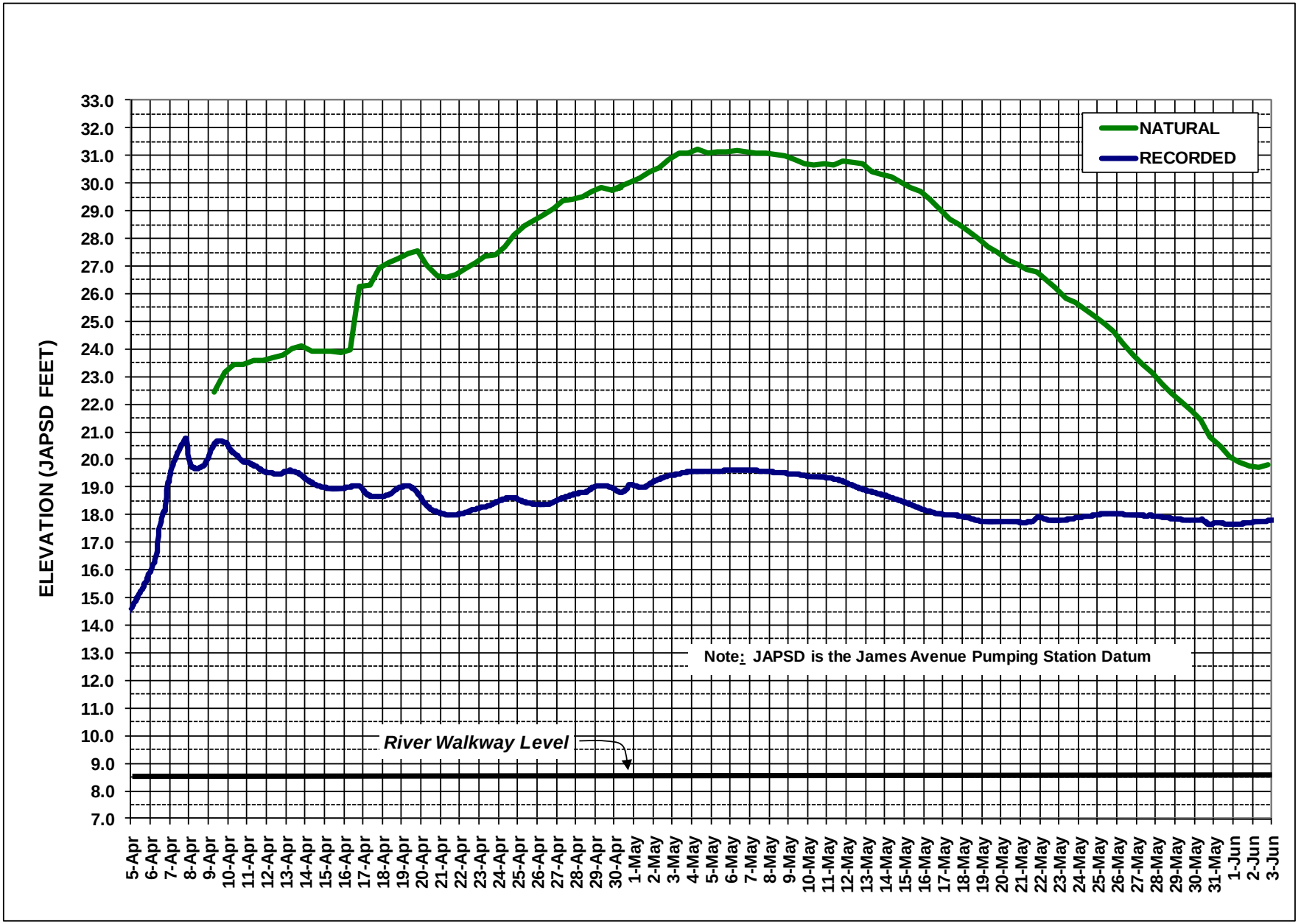
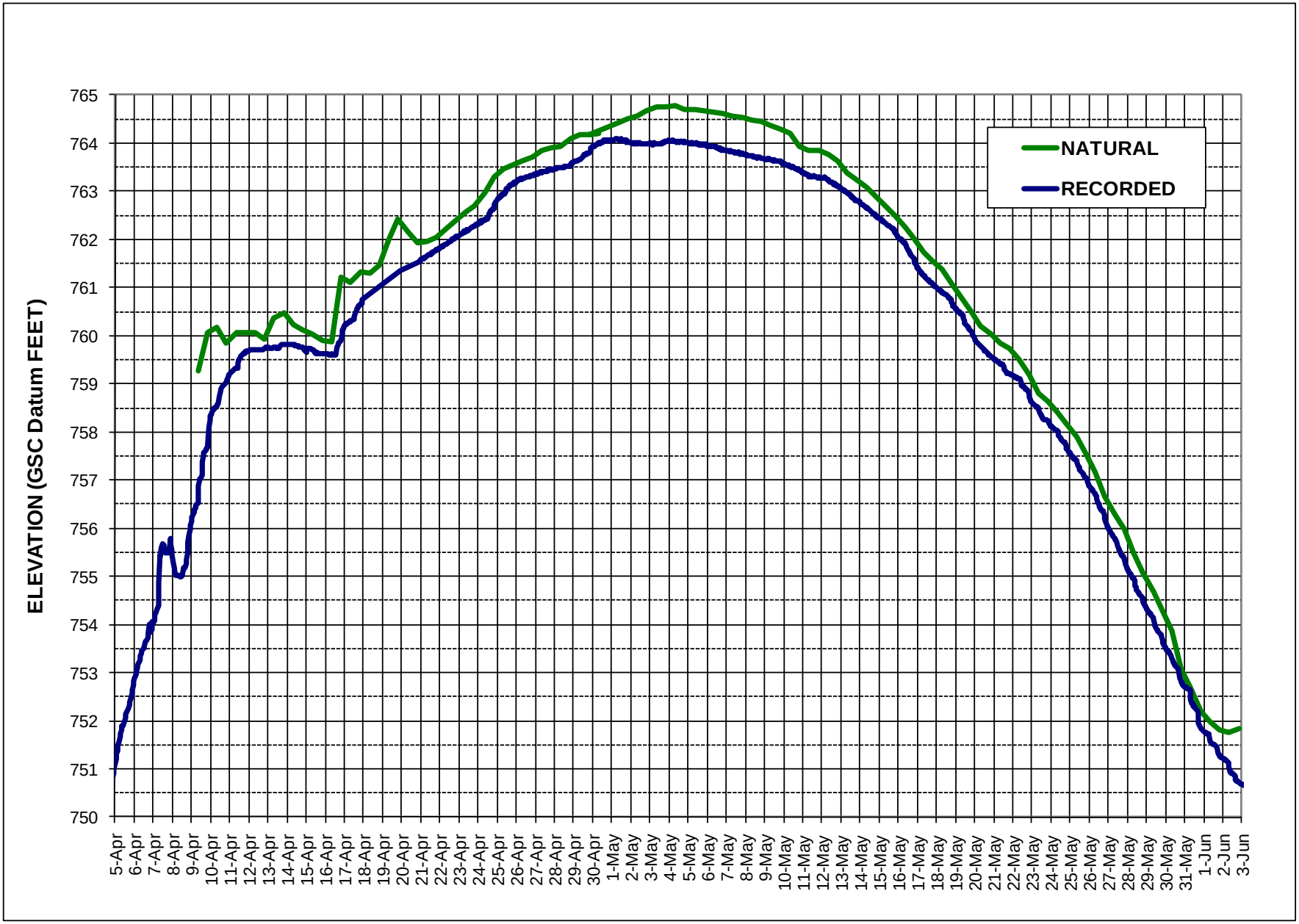


Figure 5 – Recorded and Natural Levels at Floodway Entrance 2011



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 Water Stewardship 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 Water Stewardship ("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 Water Stewardship ("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.

An unprecedented condition developed during the spring of 2011 where the natural Assiniboine River contribution was so large it pushed the calculation of the natural inlet level outside of the bounds of the existing values contained in Table 2. Bruce Harding, P. Eng. was contacted to provide additional inlet elevations for larger Assiniboine River flows. Bruce Harding was one of the original authors of the Acres Manitoba Limited report prepared in April, 2004, and used the same model and procedure as in 2004 to compute the additional natural inlet levels. The additional natural inlet levels calculated in 2011 are shown in Table 2.

Table B-1 Spring 2011 Flows and Levels

Column =>	1	2	3	4	5	6	7	8	9	10			11	12
	Assiniboine River Flows							**Red River Flows**						
Date / Time	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*
09-Apr-2011 8:00 AM	-494	286	4,387	0	4,179	1,811	**5,989**	11,315	61,177	**72,284**	22.46	20.52	759.28	756.50
09-Apr-2011 8:00 PM	-446	368	5,033	0	4,955	2,106	**7,061**	14,192	61,556	**75,669**	23.17	20.61	760.06	757.65
10-Apr-2011 8:00 AM	-398	475	5,830	0	5,907	2,206	**8,113**	16,524	60,128	**76,729**	23.43	20.25	760.19	758.53
10-Apr-2011 8:00 PM	-350	536	7,542	0	7,728	2,515	**10,243**	17,815	58,692	**76,693**	23.42	19.93	759.84	759.01
11-Apr-2011 8:00 AM	-315	706	6,718	0	7,109	2,786	**9,895**	18,698	58,206	**77,294**	23.57	19.81	760.06	759.32
11-Apr-2011 8:00 PM	-280	871	6,575	0	7,167	2,724	**9,891**	19,594	57,154	**77,339**	23.58	19.60	760.07	759.65
12-Apr-2011 8:00 AM	-245	1,557	6,716	0	8,028	2,446	**10,473**	19,827	56,515	**77,655**	23.66	19.50	760.07	759.72
12-Apr-2011 8:00 PM	-216	2,045	8,185	0	10,013	2,326	**12,339**	19,790	56,472	**78,090**	23.77	19.49	759.92	759.72
13-Apr-2011 8:00 AM	-188	2,400	6,616	0	8,828	2,235	**11,063**	19,923	56,891	**79,025**	24.01	19.59	760.37	759.75
13-Apr-2011 8:00 PM	-165	3,479	6,263	0	9,577	2,089	**11,666**	20,105	56,227	**79,646**	24.13	19.44	760.47	759.82
14-Apr-2011 8:00 AM	-142	3,709	5,968	0	9,535	1,949	**11,484**	20,089	55,115	**78,771**	23.94	19.19	760.24	759.81
14-Apr-2011 8:00 PM	-124	4,438	6,068	0	10,382	1,818	**12,200**	19,939	54,422	**78,675**	23.92	19.03	760.11	759.77
15-Apr-2011 8:00 AM	-106	4,986	6,212	0	11,092	1,705	**12,797**	19,777	54,061	**78,719**	23.93	18.95	760.04	759.72
15-Apr-2011 8:00 PM	-91	5,205	6,673	0	11,787	1,597	**13,384**	19,438	54,018	**78,570**	23.89	18.94	759.91	759.61
16-Apr-2011 8:00 AM	-76	5,145	7,599	0	12,668	1,502	**14,170**	19,420	54,321	**78,811**	23.95	19.00	759.86	759.61
16-Apr-2011 8:00 PM	-63	20,017	8,355	4369	23,939	1,420	**25,360**	20,157	54,494	**90,236**	26.38	19.04	761.21	759.88
17-Apr-2011 8:00 AM	-50	20,886	9,445	4838	25,443	1,364	**26,807**	21,521	53,038	**90,557**	26.45	18.71	761.11	760.30
17-Apr-2011 8:00 PM	-37	24,656	11,465	6412	29,672	1,261	**30,933**	22,619	52,880	**93,706**	27.14	18.66	761.33	760.63
18-Apr-2011 8:00 AM	-25	25,048	13,460	7147	31,335	1,154	**32,490**	23,578	53,050	**94,504**	27.32	18.71	761.31	760.74
18-Apr-2011 8:00 PM	-9	24,475	14,490	7298	31,658	1,056	**32,713**	24,072	54,076	**95,316**	27.50	18.95	761.47	760.74
19-Apr-2011 8:00 AM	6	23,594	12,315	6362	29,553	914	**30,468**	24,587	54,480	**96,305**	27.72	19.04	761.99	760.74
19-Apr-2011 8:00 PM	28	23,994	8,447	5398	27,072	796	**27,868**	24,963	53,282	**96,870**	27.84	18.77	762.44	760.74
20-Apr-2011 8:00 AM	50	21,731	7,150	4514	24,418	704	**25,122**	25,317	51,557	**94,142**	27.24	18.31	762.14	761.34
20-Apr-2011 8:00 PM	87	19,501	7,018	3760	22,846	595	**23,441**	25,681	50,768	**92,276**	26.83	18.09	761.93	761.34
21-Apr-2011 8:00 AM	123	18,571	7,060	3385	22,369	482	**22,851**	26,290	50,416	**92,015**	26.77	18.00	761.96	761.66
21-Apr-2011 8:00 PM	185	18,329	7,312	3416	22,409	439	**22,848**	26,771	50,562	**92,430**	26.86	18.00	762.05	761.78
22-Apr-2011 8:00 AM	246	19,325	7,713	4068	23,216	421	**23,636**	27,119	51,033	**93,655**	27.13	18.09	762.22	761.90
22-Apr-2011 8:00 PM	344	19,371	8,192	4278	23,629	421	**24,051**	27,650	51,626	**94,713**	27.37	18.21	762.41	762.05

Column =>	1	2	3	4	5	6	7	8	9	10			11	12
	Assiniboine River Flows							**Red River Flows**						
Date / Time	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*
23-Apr-2011 8:00 AM	442	19,541	8,816	4483	24,316	426	**24,742**	28,097	52,109	**95,707**	27.59	18.30	762.55	762.16
23-Apr-2011 8:00 PM	586	18,587	9,157	4374	23,955	413	**24,368**	28,574	52,762	**96,134**	27.68	18.43	762.69	762.28
24-Apr-2011 8:00 AM	729	18,791	9,299	4487	24,332	383	**24,715**	28,972	53,514	**97,518**	27.99	18.58	762.96	762.40
24-Apr-2011 8:00 PM	920	19,986	9,359	4834	25,430	362	**25,792**	29,796	53,674	**99,541**	28.43	18.61	763.30	762.63
25-Apr-2011 8:00 AM	1110	21,368	9,517	5273	26,722	339	**27,061**	30,951	53,065	**101,221**	28.80	18.46	763.47	762.93
25-Apr-2011 8:00 PM	1347	21,865	9,852	5557	27,507	310	**27,817**	31,791	52,786	**102,232**	29.03	18.39	763.55	763.15
26-Apr-2011 8:00 AM	1584	22,798	10,233	5986	28,628	290	**28,918**	32,223	52,689	**103,307**	29.26	18.36	763.62	763.26
26-Apr-2011 8:00 PM	1868	23,348	10,629	6341	29,503	267	**29,770**	32,526	53,004	**104,405**	29.51	18.45	763.72	763.33
27-Apr-2011 8:00 AM	2152	23,981	11,117	6763	30,486	250	**30,737**	32,746	53,646	**105,761**	29.81	18.60	763.86	763.38
27-Apr-2011 8:00 PM	2494	23,238	11,749	6834	30,647	234	**30,881**	33,027	54,165	**106,090**	29.88	18.72	763.90	763.46
28-Apr-2011 8:00 AM	2835	23,252	12,347	7131	31,302	223	**31,525**	33,166	54,512	**106,633**	30.00	18.80	763.93	763.48
28-Apr-2011 8:00 PM	3256	23,077	12,806	7357	31,782	217	**31,999**	33,674	55,219	**107,869**	30.27	18.96	764.11	763.52
29-Apr-2011 8:00 AM	3676	23,030	13,146	7589	32,262	206	**32,468**	34,227	55,140	**108,484**	30.36	19.04	764.17	763.65
29-Apr-2011 8:00 PM	4190	21,297	13,489	7305	31,672	193	**31,866**	34,858	55,173	**108,214**	30.32	18.99	764.19	763.81
30-Apr-2011 8:00 AM	4704	21,078	13,901	7533	32,149	224	**32,373**	35,687	54,701	**108,636**	30.37	18.82	764.21	764.00
29-Apr-2011 8:00 PM	4190	21,297	13,489	7305	31,672	193	**31,866**	34,858	55,173	**108,214**	30.32	18.99	764.19	763.81
01-May-2011 8:00 AM	5889	20,216	14,930	7984	33,052	898	**33,950**	36,727	56,008	**110,857**	30.63	19.00	764.43	764.08
01-May-2011 8:00 PM	6514	20,548	15,322	8448	33,935	998	**34,933**	36,579	56,792	**111,985**	30.76	19.12	764.50	764.04
02-May-2011 8:00 AM	7138	20,424	15,695	8758	34,500	839	**35,339**	36,233	57,557	**112,595**	30.84	19.29	764.55	763.99
02-May-2011 8:00 PM	7731	21,406	16,031	9342	35,826	749	**36,574**	36,308	58,035	**114,138**	31.02	19.41	764.67	763.98
03-May-2011 8:00 AM	8323	22,132	16,389	9899	36,944	816	**37,760**	36,471	58,304	**115,330**	31.16	19.48	764.75	763.98
03-May-2011 8:00 PM	8828	21,371	16,771	9941	37,028	788	**37,817**	36,570	58,513	**115,340**	31.16	19.55	764.75	764.04
04-May-2011 8:00 AM	9332	21,828	17,225	10415	37,970	666	**38,636**	36,652	58,505	**115,902**	31.22	19.56	764.77	764.04
04-May-2011 8:00 PM	9711	20,785	17,633	10329	37,800	538	**38,338**	36,578	58,522	**115,267**	31.15	19.57	764.69	764.02
05-May-2011 8:00 AM	10090	21,293	17,971	10741	38,613	462	**39,075**	36,542	58,526	**115,711**	31.20	19.59	764.70	764.00
05-May-2011 8:00 PM	10334	21,426	18,189	10941	39,007	397	**39,404**	36,365	58,531	**115,713**	31.20	19.60	764.67	763.97
06-May-2011 8:00 AM	10577	21,663	18,318	11148	39,411	346	**39,757**	36,192	58,509	**115,794**	31.21	19.61	764.66	763.92
06-May-2011 8:00 PM	10689	21,617	18,392	11195	39,503	315	**39,817**	36,018	58,450	**115,579**	31.18	19.60	764.61	763.87
07-May-2011 8:00 AM	10800	21,766	18,433	11297	39,702	292	**39,995**	35,794	58,377	**115,441**	31.17	19.60	764.57	763.82
07-May-2011 8:00 PM	10800	21,995	18,446	11379	39,862	284	**40,146**	35,658	58,241	**115,315**	31.15	19.57	764.53	763.80
08-May-2011 8:00 AM	10800	22,365	18,450	11506	40,109	287	**40,397**	35,495	58,041	**115,195**	31.14	19.53	764.49	763.73

Column =>	1	2	3	4	5	6	7	8	9	10			11	12
	Assiniboine River Flows							**Red River Flows**						
Date / Time	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*
08-May-2011 8:00 PM	10700	22,757	18,442	11603	40,297	293	**40,591**	35,354	57,879	**115,088**	31.13	19.50	764.45	763.69
09-May-2011 8:00 AM	10600	22,111	18,430	11345	39,796	310	**40,107**	35,193	57,794	**114,353**	31.04	19.49	764.36	763.65
09-May-2011 8:00 PM	10425	22,012	18,398	11241	39,594	323	**39,917**	35,173	57,460	**113,828**	30.98	19.42	764.28	763.62
10-May-2011 8:00 AM	10250	22,451	18,380	11325	39,757	350	**40,107**	34,797	57,258	**113,432**	30.93	19.37	764.19	763.52
10-May-2011 8:00 PM	9986	23,857	18,364	11707	40,500	361	**40,861**	33,148	57,186	**112,469**	30.82	19.36	763.94	763.43
11-May-2011 8:00 AM	9722	24,905	18,350	11970	41,007	357	**41,364**	32,596	56,969	**112,223**	30.79	19.31	763.85	763.31
11-May-2011 8:00 PM	9400	27,267	18,356	12671	42,352	339	**42,691**	32,486	56,522	**113,004**	30.88	19.20	763.86	763.29
12-May-2011 8:00 AM	9077	28,404	18,393	12964	42,910	313	**43,223**	32,351	55,872	**112,740**	30.85	19.06	763.76	763.24
12-May-2011 8:00 PM	8718	30,266	18,500	13521	43,962	288	**44,250**	31,796	55,309	**112,567**	30.83	18.93	763.62	763.11
13-May-2011 8:00 AM	8358	29,821	18,593	13274	43,497	264	**43,761**	31,263	54,847	**111,015**	30.65	18.82	763.38	762.96
13-May-2011 8:00 PM	7988	31,308	18,702	13700	44,298	278	**44,576**	30,688	54,443	**110,726**	30.62	18.73	763.24	762.81
14-May-2011 8:00 AM	7617	32,422	18,756	13978	44,818	251	**45,069**	30,087	53,938	**110,087**	30.54	18.62	763.07	762.66
14-May-2011 8:00 PM	7251	33,383	18,765	14188	45,210	232	**45,442**	29,405	53,418	**109,268**	30.45	18.50	762.88	762.50
15-May-2011 8:00 AM	6885	33,819	18,754	14209	45,249	214	**45,464**	28,857	52,898	**108,250**	30.33	18.37	762.68	762.33
15-May-2011 8:00 PM	6528	34,642	18,726	14362	45,533	195	**45,728**	28,251	52,376	**107,434**	30.17	18.23	762.50	762.16
16-May-2011 8:00 AM	6170	34,714	18,621	14225	45,279	186	**45,464**	27,381	51,951	**105,990**	29.86	18.11	762.26	761.92
16-May-2011 8:00 PM	5818	34,804	18,498	14091	45,029	178	**45,207**	26,289	51,635	**104,456**	29.52	18.03	762.00	761.60
17-May-2011 8:00 AM	5466	34,197	18,402	13723	44,342	169	**44,511**	25,081	51,550	**102,571**	29.10	18.00	761.72	761.25
17-May-2011 8:00 PM	5115	34,090	18,339	13542	44,002	161	**44,163**	24,391	51,393	**101,447**	28.85	17.96	761.55	761.06
18-May-2011 8:00 AM	4764	34,017	18,291	13379	43,694	155	**43,848**	23,816	51,101	**100,320**	28.60	17.88	761.38	760.90
18-May-2011 8:00 PM	4417	33,829	18,265	13184	43,327	153	**43,480**	23,009	50,737	**98,808**	28.27	17.78	761.06	760.66
19-May-2011 8:00 AM	4069	33,716	18,235	13015	43,006	152	**43,158**	22,220	50,603	**97,594**	28.00	17.75	760.79	760.44
19-May-2011 8:00 PM	3732	33,999	18,239	12997	42,973	152	**43,125**	21,081	50,591	**96,406**	27.74	17.74	760.49	760.08
20-May-2011 8:00 AM	3395	33,865	18,243	12836	42,666	150	**42,816**	20,094	50,628	**95,146**	27.46	17.75	760.21	759.78
20-May-2011 8:00 PM	3079	34,000	18,246	12775	42,550	159	**42,709**	19,511	50,603	**94,419**	27.30	17.75	760.04	759.58
21-May-2011 8:00 AM	2762	33,593	18,250	12527	42,078	228	**42,306**	19,073	50,506	**93,407**	27.08	17.72	759.83	759.42
21-May-2011 8:00 PM	2474	33,052	18,267	12249	41,545	425	**41,970**	18,443	51,138	**92,858**	26.96	17.89	759.74	759.20
22-May-2011 8:00 AM	2186	32,151	18,352	11871	40,818	254	**41,072**	18,172	50,943	**91,581**	26.67	17.84	759.52	759.11
22-May-2011 8:00 PM	1929	31,817	18,345	11667	40,423	242	**40,665**	17,284	50,737	**90,100**	26.35	17.78	759.20	758.77
23-May-2011 8:00 AM	1672	30,186	18,338	11025	39,171	239	**39,410**	16,465	50,858	**88,156**	25.92	17.82	758.80	758.49
23-May-2011 8:00 PM	1447	29,855	18,293	10822	38,773	232	**39,005**	15,805	51,089	**87,374**	25.74	17.88	758.63	758.23

Column =>	1	2	3	4	5	6	7	8	9	10			11	12
	Assiniboine River Flows							**Red River Flows**						
Date / Time	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*
24-May-2011 8:00 AM	1222	28,810	18,240	10377	37,895	221	**38,116**	15,273	51,271	**86,199**	25.49	17.93	758.42	758.02
24-May-2011 8:00 PM	1024	28,265	18,182	10109	37,362	206	**37,567**	14,390	51,465	**85,035**	25.23	17.98	758.16	757.66
25-May-2011 8:00 AM	825	27,242	18,126	9683	36,511	191	**36,702**	13,675	51,623	**83,683**	24.94	18.02	757.89	757.40
25-May-2011 8:00 PM	650	26,236	18,098	9281	35,702	181	**35,883**	12,842	51,635	**82,082**	24.62	18.03	757.55	757.05
26-May-2011 8:00 AM	476	24,812	18,085	8799	34,574	175	**34,749**	12,052	51,599	**80,140**	24.23	18.02	757.16	756.70
26-May-2011 8:00 PM	320	23,857	18,066	8399	33,844	168	**34,012**	10,887	51,490	**78,155**	23.79	17.99	756.66	756.18
27-May-2011 8:00 AM	164	23,247	18,039	8125	33,325	161	**33,487**	10,013	51,429	**76,728**	23.43	17.97	756.29	755.79
27-May-2011 8:00 PM	25	23,098	18,024	8022	33,125	211	**33,337**	9,090	51,417	**75,608**	23.15	17.97	755.97	755.36
28-May-2011 8:00 AM	-114	21,817	18,020	7547	32,176	186	**32,362**	8,239	51,235	**73,630**	22.73	17.92	755.49	754.95
28-May-2011 8:00 PM	-236	21,165	18,029	7299	31,660	177	**31,836**	7,367	51,053	**72,050**	22.41	17.87	755.08	754.47
29-May-2011 8:00 AM	-358	20,184	18,082	6966	30,941	171	**31,113**	6,735	50,895	**70,489**	22.10	17.83	754.70	754.14
29-May-2011 8:00 PM	-464	19,521	18,126	6743	30,441	526	**30,967**	6,005	50,798	**69,117**	21.78	17.80	754.27	753.67
30-May-2011 8:00 AM	-570	18,568	18,147	6430	29,715	728	**30,443**	5,217	50,858	**67,644**	21.41	17.82	753.86	753.28
30-May-2011 8:00 PM	-660	17,769	18,180	6179	29,110	941	**30,051**	3,967	50,215	**65,112**	20.80	17.64	753.08	752.80
31-May-2011 8:00 AM	-749	16,876	18,248	5919	28,457	980	**29,436**	2,938	50,458	**63,605**	20.47	17.71	752.68	752.43
31-May-2011 8:00 PM	-825	16,645	18,248	5833	28,236	970	**29,206**	1,758	50,276	**62,022**	20.12	17.66	752.19	751.84
01-Jun-2011 8:00 AM	-900	16,103	18,248	5662	27,789	1,030	**28,819**	1,252	50,336	**61,129**	19.90	17.68	751.96	751.57
01-Jun-2011 8:00 PM	-961	15,551	18,574	5584	27,580	1,013	**28,593**	1,072	50,458	**60,536**	19.75	17.71	751.80	751.27
02-Jun-2011 8:00 AM	-1022	15,665	18,574	5598	27,619	943	**28,562**	772	50,603	**60,420**	19.72	17.75	751.77	751.03
02-Jun-2011 8:00 PM	-1080	16,458	18,568	5798	28,147	844	**28,992**	527	50,725	**60,831**	19.83	17.78	751.84	750.72

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	747.3			
60,000	756.8	755.9	754.9	754.0	753.1	752.2	751.4	750.8			
70,000	759.7	758.8	758.0	757.1	756.3	755.5	754.7	754.0	753.3		
80,000	762.4	761.6	760.8	760.1	759.3	758.5	757.8	757.1	756.4	755.7	755.2
90,000		763.9	763.2	762.6	761.9	761.2	760.6	759.9	759.3	758.7	758.1
100,000		765.6	765.3	764.8	764.1	763.5	762.9	762.3	761.8	761.2	760.6
110,000		766.7	766.3	765.9	765.5	765.2	764.7	764.2	763.6	763.1	762.5
120,000		767.6	767.5	767.2	766.8	766.5	766.1	765.7	765.4	765.0	764.6
130,000		768.5	768.2	768.0	767.7	767.5	767.3	767.0	766.6	766.2	765.9
140,000			768.7	768.7	768.6	768.4	768.1	767.9	767.6	767.4	767.1
150,000			769.1	769.0	768.8	768.7	768.6	768.5	768.5	768.3	768.0
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)
Shaded values provided by Bruce Harding, P. Eng., May, 2011