

Manitoba Water Stewardship Water Branch



Re-Computation of Natural Water Levels at the Floodway Inlet

EXECUTIVE SUMMARY

APRIL 2004

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Acres Manitoba Limited



Executive Summary

INTRODUCTION

After the 1997 flood, the Manitoba Government reconvened the Manitoba Water Commission (MWC) and tasked the Commission to review the operation of the Red River Floodway during the 1997 flood. One of the many issues for the MWC was review of the Floodway's Program of Operation and the determination of what "natural" water levels would have been for the 1997 flood as discussed in their report (Manitoba Water Commission, 1998). One of the many recommendations from the MWC was that the Floodway's Program of Operation should be reviewed by the Province in full consultation with the federal government, the City of Winnipeg and residents in the Valley.

Both the Manitoba Water Commission and the Floodway Operation Review Committee recommend that the procedure for determining "natural" levels be recomputed.

Subsequent to the MWC report, a Floodway Operation Review Committee was formed, with a report being issued in December 1999. One of the recommendations of the Red River Floodway Operation Review Committee (1999) was that:

"the 'natural' water level relationship be recomputed. To assure that the relationships receive broad acceptance, the computation should be done under the supervision of a technical working group of representatives from the provincial and federal governments, from the City of Winnipeg, and from the valley south of the Floodway Control Structure"

In December 2002, Acres Manitoba was awarded the study by Manitoba Water Branch (MWB) to carry out a study to re-compute the "natural" water levels at the Floodway Inlet for a full range of Red River and Assiniboine river flows. In keeping with the recommendations of the Floodway Operation Review Committee report, the Minister set up a Steering Committee, supported by a Technical Sub-committee (TSC). The majority of the members on the TSC were senior technical water resource engineers from either government or the University.

Terms of Reference for Acres study

The primary deliverables for the study were:

- 1) A table of "natural" water levels at the Floodway Channel Inlet for a combination of Red River (downstream of the confluence with the Assiniboine River) flows and Assiniboine River flows.
- 2) The hydraulic model used to calculate the "natural" water levels noted in the above paragraph. At the end of the study, the final hydraulic model will be given to the Manitoba Water Branch, and

Branch staff will be trained to run the model in its entirety.

- 3) A report which will include a discussion of the methodology used, of all inputs to the hydraulic model, of the calibration effort, of all assumptions made, of problems encountered during the development and completion of the deliverables, of the limitations of the hydraulic model, and of any other relevant issues. This report will be presented and explained to the entire Steering Committee and as such must be conducted in non-technical language. This presentation shall be held at 200 Saulteaux Crescent, Winnipeg or, by mutual agreement only, at any other facility including the Contractor's offices.

NATURAL LEVELS

The determination of "natural" levels at the Floodway Inlet is fundamental to the operation of the Floodway. Under the current operating rules the Floodway is to operate to ensure that:

- the water surface elevation at the entrance of the Red River Floodway channel does not rise above "natural", unless the water surface elevation at James Avenue reaches 24.5 ft or the water level along the Red River within the City of Winnipeg reaches two feet below the Flood Protection Level of 27.83 ft (Rule 1); and,
- once the river levels within the City of Winnipeg reach the limits described in Rule 1, the levels in Winnipeg would be held constant and levels upstream of the Floodway would be allowed to rise above natural. If levels are forecast to rise more than 2 ft above natural, the City of Winnipeg must proceed with emergency raising of the dykes and other temporary protection measures (e.g., further closure of their sewer systems from high river levels). The water levels within the City should be permitted to rise as construction proceeds on raising the dykes (Rule 2).

Definition of "natural"

The "natural flow" is the flow that would have occurred if flood proofing projects such as Shellmouth, Portage Diversion, Assiniboine Dykes and Floodway had not been built

The "natural level" is defined as the level that would have occurred in the absence of flood control works and level of urban development in place at time of construction of flood control works.

A rating curve is used to relate the natural flow at James Avenue in downtown Winnipeg to the natural level at the Floodway Inlet in St. Norbert. Backwater analysis was used to determine this relationship.

NUMERICAL BACKWATER ANALYSIS

A numerical backwater study is a common engineering technique for computing water levels within a river reach for a given a flow. The computations start from a downstream location and progress upstream. The inherent assumptions are:

- flow is assumed to be one-directional
- flow through a cross-section can be considered averaged
- flow is assumed to be constant or gradually varied

While some of the preliminary backwater analysis had been carried out by the Red River Basin Investigation (RRBI) in the 1951 to 1953 timeframe, the majority of the detailed hydraulic calculations were made by the Province following the release of the report of the 1958 Royal Commission on Flood Cost-Benefit which recommended construction of a 60,000 cfs capacity floodway around the City of Winnipeg. In the spring of 1959, field investigations were carried out to relocate the Floodway Inlet from a point near the South Perimeter Highway (a recommendation of the Royal Commission) to a point upstream of the Town of St. Norbert, a distance of about 8 kilometres. The final location of the inlet was approved in 1960. Subsequent to this, detailed hydraulic investigations were carried out to determine "natural" conditions at the Floodway Inlet for a range of Red and Assiniboine River flows.

In 1965, the Floodway Inlet Rating Curve was finalized and documented in a 1970 report. The 1965 rating Curve required classifying the Assiniboine River contribution as minimum, average or maximum and then consulting the rating curve to determine what the natural level at the Floodway should be. Based on recommendations of the Manitoba Water Commission in 1980, the above-described 1965 multiple-plot rating curve was converted into a numerical formula and documented in a 1984 MWB report.

*Differences
between the
early 1960's
analysis and the
Acres analysis*

Some of the differences between the Province's early 60's analysis and the current Acres analysis are as follows:

- back in the early 1960's the backwater calculation would have been done by hand using lookup tables and slide rules. At that time the number of scenarios tested would have been limited. For this re-computation analysis the US Army Corps of Engineers River Analysis System, HEC-RAS model (version 3.1.1) was used. This model allows a multitude of scenarios to be tested;
- in the early 1960's, model calibration was solely based on data

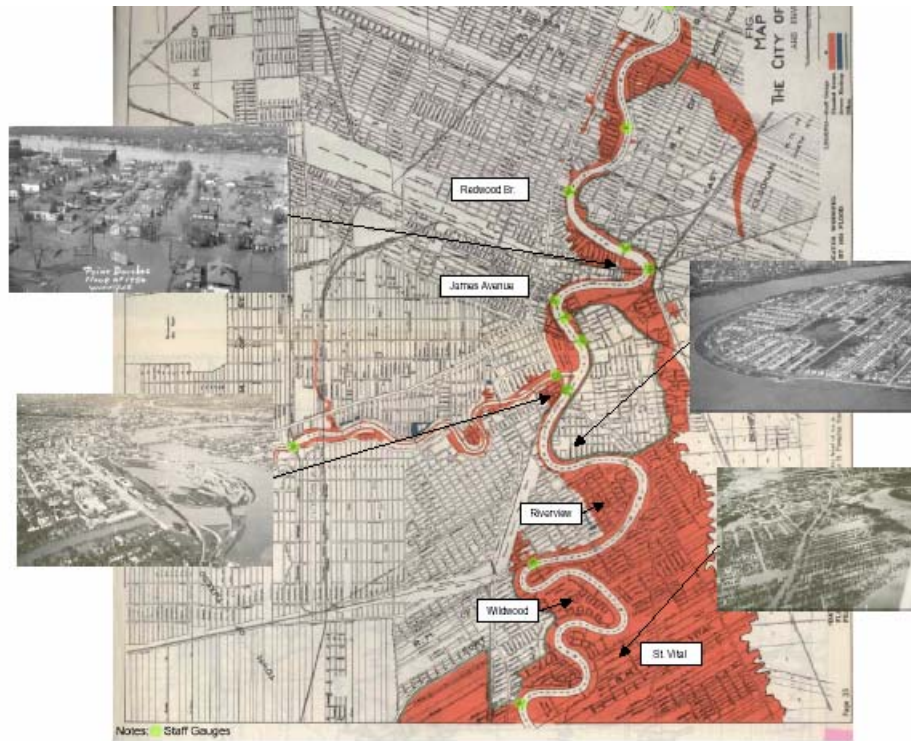
collected from the 1950 flood. For the current re-computation, data from both the 1950 and 1966 flood was used. Prior to using the 1950 and 1966 data, Acres performed a quality control (QC) review of the data. As outlined in the main report there are QC problems with the 1950 data that were not known at the time of the earlier study;

- the modelling done in the early 1960's was based on the available topographical information of the time to define overbank elevation. In the Acres study, detailed topographical information has been generated from a variety of sources to better define the area;
- in this study topographical and backwater modelling was linked to a geographic information system (GIS) to allow the graphical visualization of model construction and results; this type of technology was not available when the original study was done.

REVIEW OF HISTORIC FLOOD DATA

1950 flood

The floods of 1950 and 1966 represent the largest "pre-Floodway" Winnipeg floods in recent record with water levels at the James Ave

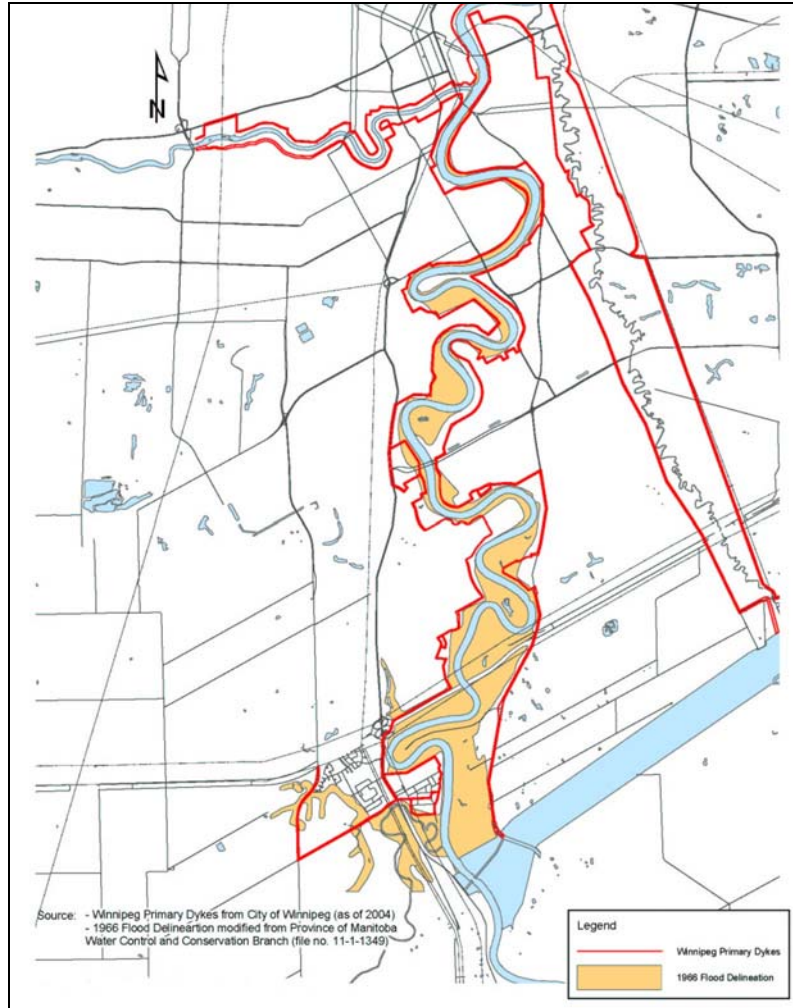


1950 Flooded Area – James Ave. 30.3 ft.

Pumping Station in the City of Winnipeg reaching 30.3 ft and 26.2 ft

above James Avenue datum (JAD) respectively. Zero for JAD is normal winter ice level or elevation 727.57 ft.. Normal summer water level is 6.5 ft JAD or elevation 734.0 ft. In the summer when the St. Andrews Lock and Dam is in operation water levels in the City are kept relatively constant. Normal flood stage for Winnipeg is generally considered around 18.0 ft. JAD.

1966 flood



1966 flooded Area – James Ave. 26.2 ft.

The 1950 and 1966 flood years also represent years where a significant amount of additional hydraulic information was collected along the rivers, which is why these years were chosen as the focus of this review. With the opening of the Red River Floodway in 1969, spring flood stages typically would only reach a maximum stage of 18 to 20 ft JAD. While the 1997 flood represents the Flood of the Century for the Red River, the diversion of approximately 65,000 cfs around the City via the Red River Floodway saved Winnipeg from significant flooding. In 1997, the river only reached 24.5 ft JAD. However the

slope of the river increased going northward to an equivalent water level of 25.0 ft JAD as a result of water backing up from the floodway outlet. Because of the backwater effects in 1997 that year was not used for model calibration.

As discussed in the main report, analysis of the 1950 and 1966 noted several uncertainties in the 1950 flow estimates. Discrepancies were also noted in some in the recorded water level data at select sites. Modelling was used to address these uncertainties.

In 1966, primary dykes protected the City from flooding. In 1950, only temporary dykes existed and many of these failed except for the Lyndale Dyke that protected the St. Boniface area.

BRIDGES AND STRUCTURES

Bridges included in the study

Bridges and structures located along the Red River circa 1950 were also incorporated into the backwater model. The structures may act as constrictions, reducing the flow capacity of the river and creating a drop in water levels from upstream to downstream or a hydraulic loss. This reduction in conveyance area can be due to pier layout (size, shape or number), low bridge decks or loss of cross section area in the abutment region which will result in a measurable head loss under high flow conditions. The bridges included in the analysis are:

- **Elm Park Bridge** - multi-span open truss type structure with minor approaches and minimal constriction on flow;
- **Norwood Bridge (pre 1997)** - multi-span plate girder structure with lift section for boat traffic. Minor approaches with minimal constriction of flow;
- **Provencher Bridge (pre 2003)** - multi-span plate girder structure with lift section for boat traffic. Lower bottom girder relative to other bridges will create losses under higher flows. Minor approaches with minimal constriction of flow;
- **Canadian National Railways - Redditt Subdivision Bridge** - multi-span open truss type structure. The eastern railway embankment is elevated well above prairie level; however a lower section further east can potentially convey flows under larger flood events. The western railway embankment, although high at the bridge, slopes down to prairie level and turns parallel to the river permitting overland flow to pass west of the bridge through downtown Winnipeg during larger flood events;
- **Canadian Pacific Railways - Keewatin Subdivision Bridge** - multi-span open truss type structure with elevated railway embankments which constrict discharge through the bridge opening up to moderate flood events. The railway embankment is

- overtopped during large flood events;
- **Louise Bridge** - multi-span open truss type structure with minimal constriction of flow;
- **Redwood Bridge** - multi-span open truss type structure with minimal constriction of flow;
- **Canadian Pacific Railways - Bergen Cutoff Bridge** - multi-span open truss type structure with elevated railway embankments which constrict discharge through bridge opening only during small floods. During large flood events, overland flow can occur beyond the western railway embankment;
- **St Andrews Lock and Dam** - a unique water control structure comprised of multiple spillway bays controlled by removable wooden "curtains". The curtains are used only during low flow open water periods to control water levels upstream through the City of Winnipeg. The curtains are removed during the passage of a flood; and,
- **PR 204 Highway Bridge - Selkirk** - multi-span open truss structure with lift section for boat traffic. Minor approaches with minimal constriction of flow.

RESULTS

1966 Calibration Results

*Calibration for
1966 flows*

The model was initially calibrated to the spring flood of 1966, the second highest flood on record for the City of Winnipeg. The 1966 flood was modelled using a HEC-RAS dataset which included the primary dykes as they existed in 1966. For correct modelling of the flood in the Kingston Row area, i.e., preventing overland flow across the meander bend the secondary dyke in this area was raised. The dykes used in the HEC-RAS are modelled as levees and elevations were chosen to prevent overtopping of the dykes. From the 1966 observed flood dataset, 7 days were chosen where there was certainty in the recorded flows on the Red River both upstream and downstream of the confluence of the Assiniboine River.

The 1966 dataset covers a flow range from 44,000 to 87,000 cfs (at Redwood Bridge). The overall error in calibration between observed and computed levels is in the range of 0.02 to 0.10 ft for the observed data near the peak (April 15 to April 21). April 24 had the largest calibration error with an overall difference of 0.48 ft.

1950 Calibration Results

Calibration for

The flood of 1950 was the highest flood in recent history for the City of Winnipeg. In 1950, there was substantial overbank flooding in the

1950 flows

south end of the City. During the 1950 flood temporary dyking in Riverview, Wildwood and Crescent Drive areas was overtopped, large areas of St. Vital were flooded as the Red River and Seine River joined. Temporary dyking around Lyndale Crescent and west of the Seine River protected the St. Boniface area from significant flooding. Downstream of the confluence of the Assiniboine the majority of the flow was contained within the river for the most part, except for some overbank flooding along Scotia Street and back flooding into Bunn's Creek.

The physical basis for the 1950 HEC-RAS model was the "natural" model without primary dykes except for the Lyndale Dyke and the raising of the west approach to Provencher Bridge to shunt flows through the bridge cross-section and not across the rail yards.

Model used to compute 1950 flows

The first step in the 1950 calibration involved matching for the flow on May 29 (that was similar in levels to the April 15, 1966 peak). Solving for a range of flows from 87,000 to 91,000 cfs it was determined that a flow of 88,000 cfs provided the smallest overall difference in water levels between observed and simulated in the SALD to Norwood Br. section of the river. The adjusted increase in the May 29 flow was 3,400 cfs or about 4%.

The second step in the model calibration was to calibrate for the peak flow from the 1950 flood and to solve for the floodplain n value in the areas in the south part of the city.

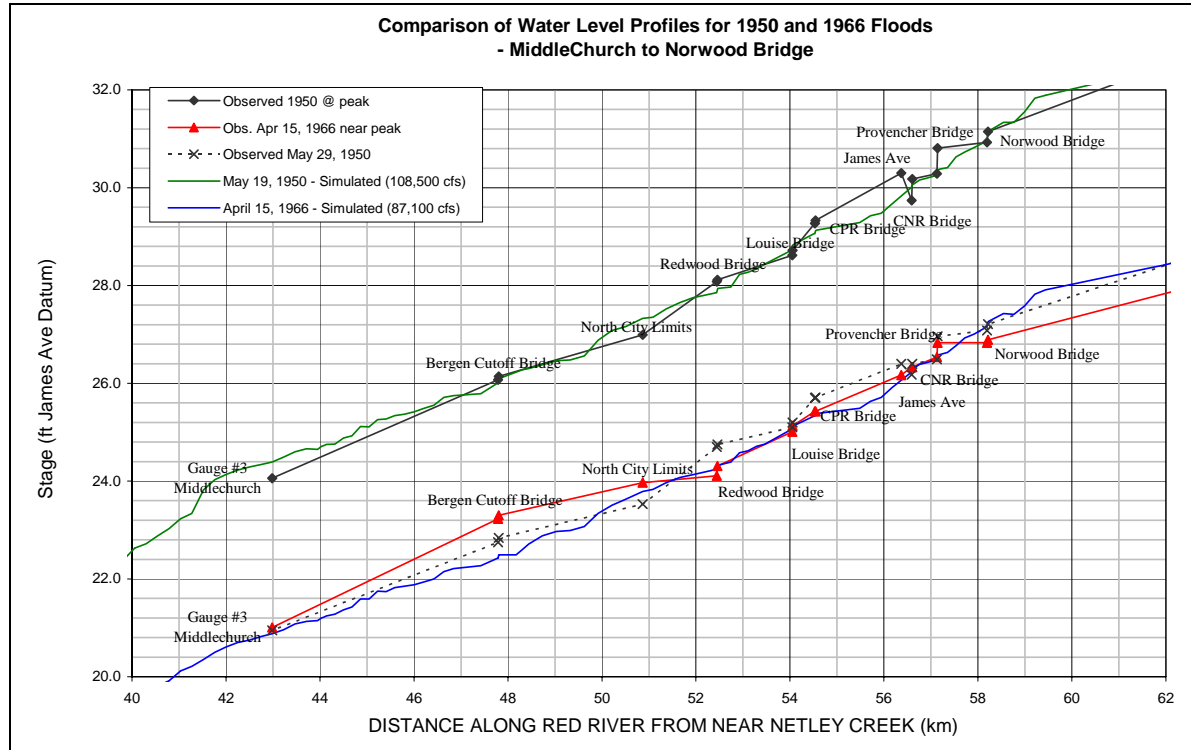
The overall difference in observed versus model calibration is 0.01 feet at the peak.

The following plot shows the modelled versus observed profile in the Middle Church to Norwood section of the river for 1950 and 1966 flows. Examination of the figure yields the following observations:

Assessment of calibration for 1966 and 1950

- The irregularity in the profile line is a result of plotting the "hydraulic" grade line. Inclusion of the variable velocity head component would smooth out the line.
- The 1950 peak simulated profile matches the observed profile reasonably well except in the James Avenue, CNR and Provencher Bridge section of the river. As discussed in the main report there are some anomalies with certain bridges and that the observed losses for these bridges are too high.
- In 1950 at the peak the James Avenue level is high relative to the upstream gauges. Based on modelling this level is incorrect, or

alternatively all other stage data are too low and flows need to be increased to match the James Avenue data. To match the other stage data this study has computed a flow of 108,500 cfs, to match the higher James Avenue stage of 30.3 ft JAD would require a flow in the range of 112,000 cfs.



- For the lower-flow profiles, the simulated profile plotted represents the best fit plot for the 1966 data, except for Bergen Cutoff. In 1966, the gauge height for Bergen Cutoff appears to be in error with the level being too high. Long and Wagner (1970) also felt that Bergen Cutoff data was in error based on review of other low flow profiles for 1966. For example as shown in the main report, at the lower flows there is practically no slope on the river in the Bergen to North City limits reach of the river for the May 7 and May 12 profile which would not be expected. To match the 1950 lower-flow profile a slightly higher discharge would be required.

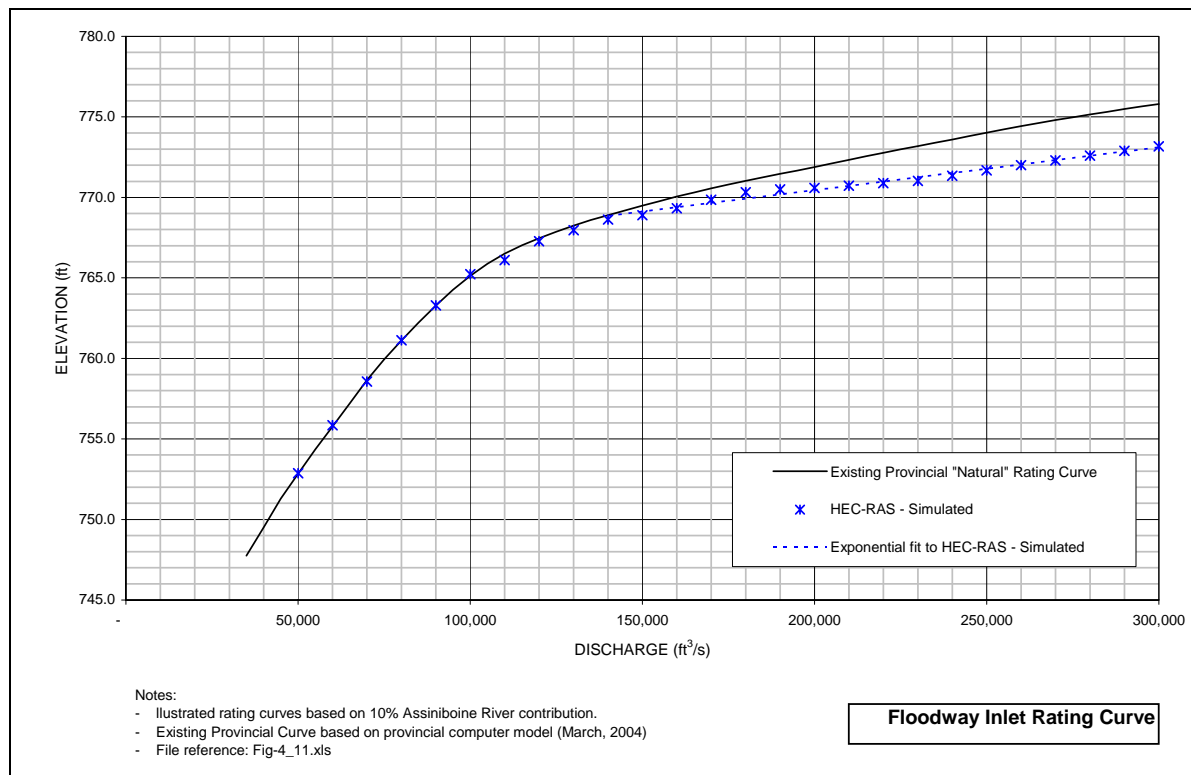
Impact of Dyking on Water Surface Profile and Flooded Area

An assessment of the effect of the primary dykes on water surface profiles was conducted. The primary dykes are for the most part located upstream of the Assiniboine River confluence, therefore the difference in water surface profiles in this reach are the greatest. The maximum difference between the water surface profiles under 1966

flood conditions is 0.10 ft. An additional assessment of the effect of the Lyndale Drive dyke during the peak of the 1950 flood was also conducted. The computed water surface profiles at the peak of the 1950 flood (May 19) is about 0.2 ft.

Floodway Inlet Rating Curve

As discussed in the Introduction the purpose of this study was to derive a new “natural” rating curve(s)/table of water levels at the Floodway inlet. The rating table is not a single relationship, due to the variable nature of Assiniboine River contributions. As such, a two-dimensional matrix of Red and Assiniboine River discharge was required. The matrix of Red River and Assiniboine River discharges was simulated using the calibrated backwater model, with the exception that the Lyndale Drive dike (which existed during the 1950 flood) was removed to reflect pre-1950 flood “natural” conditions. The calculated rating table is presented in the following table and as a stage-discharge rating curve based on 10% flow contribution from the Assiniboine River is shown in the figure below. Note that the Red River discharge corresponds to the combined Red and Assiniboine River discharge at James Avenue.



		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
RED RIVER DOWNSTREAM OF ASSINIBOINE RIVER CONFLUENCE (cfs)	20,000	742.4	740.6	738.9	737.5							
	30,000	746.8	745.4	744.0	742.7	741.6						
	40,000	750.6	749.4	748.2	747.1	746.0	745.0					
	50,000	753.9	752.9	751.8	750.8	749.8	748.9	748.0				
	60,000	757.0	756.0	755.1	754.2	753.2	752.4	751.5				
	70,000	759.8	758.9	758.1	757.2	756.4	755.6	754.8				
	80,000	762.3	761.6	760.8	760.1	759.3	758.6	757.8				
	90,000		763.8	763.2	762.5	761.9	761.2	760.6	759.9			
	100,000		765.5	765.2	764.7	764.1	763.5	762.9	762.3			
	110,000		766.6	766.2	765.8	765.4	765.1	764.6	764.1			
	120,000		767.5	767.4	767.1	766.7	766.4	766.0	765.6	765.3		
	130,000		768.4	768.1	767.9	767.6	767.4	767.2	766.9	766.5		
	140,000			768.7	768.6	768.6	768.3	768.0	767.8	767.5	767.3	
	150,000			769.0	768.9	768.8	768.7	768.5	768.5	768.4	768.3	
	160,000			769.5	769.4	769.2	769.0	768.9	768.7	768.6	768.5	768.4
	170,000			770.1	769.9	769.8	769.6	769.4	769.3	769.1	769.0	768.8
	180,000			770.5	770.4	770.3	770.1	770.0	769.8	769.7	769.5	769.4
	190,000				770.5	770.5	770.5	770.5	770.3	770.2	770.0	769.9
	200,000				770.7	770.6	770.5	770.5	770.5	770.5	770.5	770.4
	210,000				770.8	770.8	770.7	770.6	770.5	770.5	770.5	770.5
	220,000				771.0	770.9	770.8	770.7	770.7	770.6	770.5	770.5
	230,000				771.2	771.1	771.0	770.9	770.8	770.8	770.7	770.6
	240,000					771.4	771.3	771.3	771.2	771.1	771.0	770.9
	250,000					771.8	771.7	771.6	771.5	771.4	771.4	771.3
260,000					772.1	772.0	771.9	771.9	771.8	771.7	771.6	
270,000					772.4	772.3	772.3	772.2	772.1	772.0	771.9	
280,000					772.7	772.6	772.6	772.5	772.4	772.4	772.3	
290,000					773.0	772.9	772.9	772.8	772.7	772.7	772.6	
300,000					773.3	773.2	773.2	773.1	773.0	773.0	772.9	

Floodway Inlet "Natural" Rating Table

The simulated rating curve begins to diverge from the existing Floodway Inlet curve at about 150,000 cfs.

The rating curve plot shows that the simulated curve begins to diverge from the existing Floodway Inlet curve at about 150,000 cfs and this divergence grows to about a foot lower at 200,000 cfs, and about two feet lower at 250,000 cfs.

Based on this study Acres computes the natural level for the 1997 flood (for a flow of 162,000 cfs) as 769.3 ft. This level is comparable to Klohn-Crippen study using the Mike11 model (Manitoba Water Commission, 1998) that computed a water level of 769.5 ft for natural conditions for 1997. The Acres level is somewhat lower than the Manitoba Water Stewardship estimate of natural water levels at the Floodway Inlet of 770.1 ft. The MWS estimate of Inlet water levels is based on current procedures in applying the Floodway Inlet Rating Curve. During the 1997 flood, water levels at the Inlet reached 771.5 on May 3, 1997. As discussed in the Manitoba Water Commission (1998) report water levels were raised above natural to keep water levels at James Ave to 24.5 ft JAD.

Sensitivity Analysis and Data Uncertainty

The largest “natural” flood, with corresponding observed water levels, for which the model could be calibrated, was the 1950 flood. The peak discharge during this event (estimated to be 108,500 cfs) was much less than the maximum discharge presented in the rating table. The estimation of water levels well beyond observed conditions can introduce uncertainty with respect to the levels. Determining the uncertainty in the estimated water levels through statistical means is not practical however the uncertainty can be estimated through sensitivity analyses of some of the key hydraulic parameters.

There is some uncertainty in the hydraulic roughness in the overbank areas as limited data exists for calibration

The sensitivity analysis involved the adjustment of the hydraulic roughness in the overbank region of the cross-section, within a reasonable range. The following table shows the values used in the calibration simulations as well as values for the hydraulic roughness within what is considered to be a reasonable range.

Overbank Hydraulic Roughness for a Reasonable Range of Manning “n” Values

Hydraulic Roughness	Residential/ Commercial Developments	Flood Plain - Undeveloped
Calibrated Values	0.20	0.05
Lower Limit	0.15	0.04
Upper Limit	0.25	0.06

The results of the sensitivity analysis for varying overbank roughness are presented for a range of Red River flows in the following table.

Sensitivity of Computed Floodway Inlet Water Levels to Overbank Hydraulic Roughness

Sensitivity analysis used to address uncertainty in overbank roughness

Scenario	100,000 cfs¹	200,000 cfs¹	300,000 cfs¹
Calibrated Values	765.23 ft	770.59 ft	773.18 ft
Lower Limit	765.16 ft (- 0.07 ft)	770.46 ft (-0.13 ft)	772.21 ft (-0.97 ft)
Upper Limit	765.27ft (+0.04 ft)	770.92 ft (0.33 ft)	773.98 ft (0.80 ft)

¹ Corresponds to Red River Discharge at James Avenue with 10% cfs contribution from the Assiniboine River as illustrated in Floodway Inlet Rating Curve plot.

As shown in the above table the overall uncertainty in the estimated “natural” water levels at the Floodway Inlet varies depending on the discharge. The sensitivity to roughness has been limited to the floodplain/overbank areas, which have a greater influence on computed water levels as the discharge increases and more area is inundated.

- For flood events less than 100,000 cfs, the effect on the estimated “natural” water level at the Floodway Inlet is minimal, with virtually no difference in estimated water levels at the Inlet.
- For larger floods, the estimated uncertainty increases to approximately -0.1 to +0.3 ft at 200,000 cfs, and to -1.0 to +0.8 ft at 300,000 cfs.

The uncertainty in the estimated water levels, although not negligible at the extreme flood discharges is typical of the uncertainty that would be expected in extending any rating curve well beyond metered values. The relative insensitivity of water levels to overbank roughness is due primarily to the flow split between the main channel and the overbank. The approximate flow split between the main channel and the overbank under flows greater than 200,000 cfs, when the overbank is inundated, is approximately 80% and 20% respectively indicating that the dominant conveyance area is still within the main channel.

While the above discussion has focused on the uncertainty of roughness values (Manning’s n values) the other uncertainty in modelling is whether the actual physical data used in model calibration is reasonably accurate and representative, this includes: channel cross-sections, flow estimates and recorded water levels at various sites. As discussed in the main report a great deal of attention was spent on ensuring that the flow

estimates and water level data were reasonably accurate and where there are anomalies steps have been taken in this study to resolve those differences.

Other uncertainties include accuracy of channel cross-sections and differences in flow meterings during the 1997 flood

Two areas where there is uncertainty in the physical data are in the area of channel cross-section data and metering discrepancies in the 1997 flow data.

- For this study it was assumed that the channel cross-sections surveyed in 1950 by the RRBI have remained relatively the same allowing comparison of water level profiles from various flood years, i.e., 1966 and 1997. As described in the main report, a limited number of RRBI cross-sections have been re-surveyed and no significant changes noted. While it is not expected that the channel cross-sections would change given that morphologically the Red River is relatively stable, there has been a reduction in channel maintenance floods through the City with the construction of the Red River Floodway. Re-surveying of additional RRBI cross-sections on a systematic basis would assess whether there has been any changes in the channel cross-sections.
- The other area of model uncertainty is in the differences in meterings between WSC and the Province during the 1997 flood at the peak. While metering were done at different locations, WSC metering at the Redwood Bridge (a less than ideal site for meterings) and the Provincial meterings at Chief Peguis Bridge just downstream of the Redwood site, the differences in metering of 5,000 cfs represents about a foot on the James Ave rating curve. As discussed in the main report this study has used the WSC metering as the assumed “correct” metering, however it is possible that the Provincial meterings may be more representative of the actual flows. If this is the case then it would reflect on the overall model calibration to 1966 data and adjustments would need to be made. To address this uncertainty it is recommended that a comprehensive data collection program be carried out during the next significant flood which results in James Ave levels exceeding 22 to 23 ft JAD.

MODEL LIMITATIONS

Low Flows

Model not calibrated for flows below 40,000 cfs.

The backwater model has been developed to simulate the Red River under high discharge (>40,000 cfs) conditions and not necessarily to model low flow scenarios. If it is required that water level be accurately predicted for water levels below 40,000 cfs, which reflects “in-channel” conditions, then it is recommended that a separate model that includes

all the channel cross-sections be set up and calibrated for this flow range.

During extreme floods the hydraulic conveyance area may change

Extreme Floods

During the passage of an extreme flood, i.e., greater than 200,000 cfs it can be difficult to determine the true extent of flooding, the corresponding flow patterns, or the possibility of overflow/breakout through other depressions and waterways. Two areas of note, which could result in overflow to other waterways through depressions within the topography, are:

- Overflow/breakout from the Red River south of Winnipeg into the Assiniboine River watershed.
- Overflow/breakout from the Red River northwest of Winnipeg into the Netley/Wavey Creek watershed.

Both of these overflows could have the potential for diverting a significant portion of flow outside of the Red River Floodplain under very large flow events. However, based on a review of the water surface profiles and the available topography, neither of these overflows was determined to occur under Red River discharges less than 250,000 cfs. These overflows have therefore not been included in the model, and therefore the upper limit of discharge for the model should not exceed the 300,000 cfs as presented in the rating table. If larger flows are to be simulated in the future, the model may require some modification.

Study does not include effects of ice

Ice Conditions

The backwater model has been developed to simulate the Red River under open water conditions without the presence of an ice cover.

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