ASSINIBOINE RIVER & LAKE MANITOBA BASINS
FLOOD MITIGATION STUDY
LAKE MANITOBA & LAKE ST. MARTIN OUTLET CHANNELS
CONCEPTUAL DESIGN - STAGE 1 - DELIVERABLE NO: LMB-01

Manitoba
INFRASTRUCTURE AND TRANSPORTATION

KGS GROUP REPORT
12-0300-011

February 2014

Kontzamanis | Graumann | Smith | MacMillan | Inc.

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INFRASTRUCTURE AND TRANSPORTATION

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EXECUTIVE SUMMARY

Kontzamanis Graumann Smith MacMillan Inc. (KGS Group) was retained by Manitoba Infrastructure and Transportation (MIT) to develop a two-stage process to advance the Lake Manitoba & Lake St. Martin Outlet Channels Conceptual Design Study. The current Stage 1 study scope was similar to what was originally included in the Assiniboine River & Lake Manitoba Basins Flood Mitigation Study. However, it included additional effort to expedite this portion of the work and increase the level of detail.

The scope of work and methodology for Stage 1 included:

- Identify Outlet Options for Lake Manitoba & Lake St. Martin.
- Develop Screening Level Designs and Cost Estimates.
- Economic Assessment.
- Stage/Damage Relationships.
- Summary Report.
- Public Consultation in the Spring of 2014.

For this conceptual study, six Lake Manitoba outlet channel options (Option A to Option F) and two Lake St. Martin outlet channel options (R123-JB and R123-WP) were developed:

- Option A – Twinning the Fairford River.
- Option B – Channel south of Pinaymootang First Nation.
- Option C – Channel slightly less south of Pinaymootang First Nation.
- Option D – Channel following Birch Creek.
- Option E – Bypass channel north of the FRWCS.
- Option F – Expansion of the Fairford River and FRWCS.
- Option R123-JB – Reach 1, Reach 2 and Reach 3 to Johnson Beach.
- Option R123-WP - Reach 1, Reach 2 and Reach 3 east of Willow Point.

Outlet channel capacities from zero (do nothing) to 425 cms (15,000 cfs) have been considered for Lake Manitoba. Outlet channel capacities from 113 cms (4000 cfs) to 540 cms (19,000 cfs) have been considered for Lake St. Martin. A description of the different channel options and a plan showing their conceptual alignment has been included in the report.

Based on recommendations from the Lake Manitoba and Lake St. Martin Regulation Review Committee and the Manitoba 2011 Flood Review Task Force, the governing principal for the design of the Lake Manitoba and Lake St. Martin channel was that there should be no net increase in flow to Lake St. Martin above the base condition of the existing Reach 1 channel, which has a capacity of 113 cms (4,000 cfs).

A Monte Carlo analysis was conducted to generate combined flood volumes for the Assiniboine River and local Lake Manitoba inflow, given the limited record of flows and limited information on the correlation between floods on the two basins. A flood routing model was also developed to determine peak water levels on Lake Manitoba and Lake St. Martin, with and without outlet channels, for different combinations of flood volume. For the 200-year event and based on the results of the flood routing model and the Montel Carlo analysis, the peak still water level on Lake Manitoba without an outlet channel was determined to be approximately 248.9 m

(816.6 ft). For the 200-year event, a 142 cms (5,000 cfs) and a 283 cms (10,000 cfs) outlet channel would reduce the peak Lake Manitoba level by 0.24 m (0.8 ft) and 0.43 m (1.4 ft), respectively. On Lake St. Martin, the peak still water level without an outlet channel was determined to be approximately 245.5 m (805.4 ft) for a 200-year event and the outlet channel would reduce the peak water level by 0.8 m (2.7 ft).

A cost estimate was conducted for each of the alternatives investigated. The Lake Manitoba outlet channel option with the lowest cost was Option E ($16M for 3750 cfs); however, its hydraulic capacity is limited, and it increases downstream water levels locally. Costs for Lake Manitoba outlet channels that considered greater hydraulic capacities ranged from $86 M (Option A for 5000 cfs) to $431 M (Option B for 15,000 cfs). Costs for Lake St. Martin outlet channels ranged from $87 M (Option R123-JB for 4000 cfs) to $283 M (Option R123-WP for 19,000 cfs).

Each Lake Manitoba and Lake St. Martin outlet channel option is viable from a constructability perspective. However, an outlet channel capacity sufficient to avoid flooding due to a 2011-sized event would be greater than 15,000 cfs and is, therefore, not justifiable due to the high cost.

Each of the Lake Manitoba outlet channel options, as well as the inlet to Reach 1 of each of the Lake St. Martin options, should incorporate a control structure to regulate flows. Also, all Lake St. Martin outlet channel options should incorporate a permanent access road to facilitate construction, maintenance and operation.

A description of the general environmental concerns is provided in the report along with a relative ranking of the channel options from best to worst. For all options, utilizing the lower portion of Buffalo Creek on a permanent basis is not recommended due to environmental impacts, increased potential for flooding of the Dauphin River communities and opposition from stakeholders. Also for all options, since fish passage is not feasible within the outlet channels because they will not be continuously operated, improvement of fish passage directly at the Fairford River Water Control Structure should be considered.

On Lake Manitoba, the combined biophysical and social environment rankings of the options were the lowest for Option A (61 out of 120) and the highest for Option C (91 out of 120). It was concluded that Options A and F should not be considered further due to the significant environmental and social concerns. On Lake St. Martin, the combined biophysical and social environment rankings of the options were equivalent for both Option R123-JB and Option R123-WP (average of 90 out of 120). On this basis, the social perspective that the Reach 3 outlet be located east of Willow Point versus Johnson Beach is not consistent with the preliminary biophysical environment rankings.

An economic analysis was conducted to determine the benefit / cost (B/C) ratio of the different outlet channel options. It was determined that none of the options investigated have B/C ratios that would support an economic justification to proceed based on economics alone. However, a 5,000 cfs outlet channel on Lake Manitoba, combined with 9,000 cfs Lake St. Martin outlet channels is the most attractive alternative from an economic perspective, as it has a higher B/C ratio than the larger channel options. Furthermore, Option D on Lake Manitoba is the most attractive alternative from an economic perspective as it has the highest B/C ratio due to its lower cost, followed by Option C. On Lake St. Martin, Option R123-JB is the most attractive alternative, as it has a higher B/C ratio than Option R123-WP. These conclusions were not affected by changing the economic parameters or the several assumptions in hydraulic conditions analyzed for sensitivity. Qualitative consideration should also be given to the relative effects of intangible aspects such as stress and anxiety by acknowledging the numbers of people affected, the duration of stress imposed and generally comparing the event to other catastrophes.

Based on the concept designs, the estimated costs and environmental assessment, the following recommendations have been developed:

Lake Manitoba

- Options C and D should be considered for further review as part of Conceptual Design Stage 2 – Detailed Review of Preferred Alternatives.
- Channel capacities in the range of 142 to 283 cms (5,000 to 10,000 cfs) should be considered for further review since lesser capacities will not adequately reduce lake levels and greater capacities are not justifiable due to the high cost.
- Option E should be considered for further review to supplement the capacity of one of the other Lake Manitoba outlet options (i.e. only use during extreme flood events).

Lake St. Martin

- The Lake St. Martin Emergency Outlet Channel should be made permanent with a base capacity of 113 cms (4000 cfs) to control Lake St. Martin levels.
- Additional capacity in the range of 142 to 283 cms (5,000 to 10,000 cfs) should be considered for further review to match a Lake Manitoba outlet channel to ensure that flooding will not be aggravated on Lake St. Martin.
- Options for the Reach 3 outlet at Johnson Beach and east of Willow point have similar rankings and, therefore, both should proceed to Stage 2 for further review.

A proposed scope for the Conceptual Design Stage 2 – Detailed Review of Preferred Alternatives has been included in the report. The focus of Stage 2 will be to complete the conceptual design of the preferred alternatives. This would enable the next phase of design to proceed to the detailed design stage.

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1.0 INTRODUCTION

Kontzamanis Graumann Smith MacMillan Inc. (KGS Group) was retained by Manitoba Infrastructure and Transportation (MIT) to develop a two stage process to advance the Lake Manitoba & Lake St. Martin Outlet Channels Conceptual Design Study. The Scope of services and methodology used to complete Stage 1 (Refine Alternatives) were based on discussions with MIT on June 4, 2013 and on July 29, 2013. It is anticipated that the Stage 2 scope will be refined and authorized once Stage 1 of the Conceptual Design Study is nearing completion.

The scope of Stage 1 study was similar to the scope that was originally included in the Assiniboine River & Lake Manitoba Basins Flood Mitigation Study. However, additional effort was required to expedite this portion of the work, increase the level of detail due to the number of outlet options considered, prepare an interim report, and expand the public consultation process. The focus of Stage 1 was to reduce the number of preferred alternatives to a minimum, with the goal of selecting two preferred alternatives, if possible.

The scope of work and methodology for Stage 1 is summarized as follows:

- **Identify Outlet Options for Lake Manitoba & Lake St. Martin** – Review key previous reports in detail to understand issues and options addressed previously. Discuss options and develop a short list for further analysis. The options should be coupled with schemes to permit appropriate simultaneous control of Lake Manitoba and Lake St. Martin. The Lake Manitoba Outlet Options study will focus primarily on an outlet capacity that will be capable of maintaining Lake Manitoba levels within the target range set by the designers of the Fairford River Water Control Structure (FRWCS) in all years except 2011. However, given the large public interest in this concept, KGS Group will also undertake the necessary conceptual engineering studies and cost estimates for a larger-scale outlet to satisfy public concerns. In general it has been assumed that expanding the Lake St. Martin outlet will be required to offset any additional inflows from Lake Manitoba on the principle of no net addition to Lake St. Martin. However, since the additional capacity provided by a permanent outlet from Lake St. Martin reduces the operational constraints on both the FRWCS and the proposed additional Lake Manitoba outlet, increased flows could potentially pass through the FRWCS throughout the year and contribute towards reduced levels on Lake Manitoba while still achieving desired lake levels on Lake St. Martin.

- **Develop Screening Level Designs & Cost Estimates for Lake Manitoba & Lake St. Martin Outlets** – Develop general basis of design for the outlet options identified. Estimate hydraulic characteristics, primarily the new rating curve compared to the existing rating curve of outlet discharge versus water level on Lake Manitoba and Lake St. Martin. Develop screening level designs for each option to a level of detail appropriate to define the channel hydraulics and costs. Estimate costs of each alternative. The key hydraulic capabilities of each option will be defined graphically, with emphasis on the stage-discharge relationship for the outlet from Lake Manitoba and Lake St. Martin. Key tasks completed as part of the study include:

- Review of existing geotechnical field investigations
- Review of existing GIS data
- Hydrodynamic modeling and review of ice impacts
- Assessment of costs and constructability for each of the alternatives
- Review of environmental impacts based on available existing data
- Review of aquatic impacts based on available existing data
- Preparation of an estimate of mitigation and compensation costs for the identified environmental and aquatic impacts
- Review of social impacts including First Nations

- **Economic Assessment** – Estimate the economic viability of increasing the discharge capacity from Lake Manitoba and Lake St. Martin by applying accepted principles of estimating benefit-cost ratios and net benefits for the options defined. For comparison the economic assessment will also evaluate other options such as buyouts, individual flood protection (dikes, raising of buildings, etc.), doing nothing, etc. The rationale used to arrive at the economic indicators for the options of improving the outlet discharge capacity of Lake Manitoba and Lake St. Martin will be in accordance with the Guidelines for Economic Analysis of Flood Protection Options that has been developed as part of the original project scope and is included in Appendix A.

- **Stage/Damage Relationships** – Estimate stage-damage relationships for Lake Manitoba. This will require a detailed breakdown of actual damages from 2011 from MIT and other organizations, including costs for temporary preemptive works and a list of any mitigation measures that have since been implemented (permanent dikes, relocations, buyouts, raised buildings, etc.).

- **Stage 1 Summary Report** – Prepare a summary report, separate from the overall report scheduled for completion in early 2014, describing the options, their hydraulic performance characteristics, estimated costs, constructability, potential environmental impacts and recommendations (i.e. identify preferred alternatives for further refinement in Stage 2).

- **Stage 1 Public Consultation** – A key stakeholder meeting and public open house will be held at a single location in the Interlake Region in addition to the key stakeholder meetings and public open houses in Dauphin, Brandon and Portage La Prairie as part of the original scope of work. Additional presentation materials (maximum of 15 storyboards) will be developed for the Lake Manitoba and Lake St. Martin Outlet Channels to reflect the increased emphasis being placed on these mitigation options.

2.0 BACKGROUND

In 2011, record, widespread flooding occurred across much of southern Manitoba resulting in unprecedented high inflows into Lake Manitoba through the Waterhen River, Whitemud River, Portage Diversion, and from saturated groundwater storage and from local ungauged contributing drainage area. These high flows extended well into the summer and overwhelmed the capacity of the existing regulatory system. The result was that Lake Manitoba crested at 249.1 m (817.2 ft), which was 1.43 m (4.7 ft) above the desirable range of 247.0 to 247.7 m (810.5 ft to 812.5 ft). Flooding around Lake Manitoba caused significant damage to hundreds of properties around the lake, particularly during a storm in late May when winds reached over 100 km/h (62 mi/h); wind set-up raised the lake up to 1.5 m (5 ft), and waves as high as 2.1 m (7 ft).

The inflow to Lake St. Martin from Lake Manitoba was greater than the natural outflow capacity, causing Lake St. Martin to crest at 245.6 m (805.5 ft), which was 1.68 m (5.5 ft) above the desirable operating range of 242.9 to 243.8 m (797.0 to 800.0 ft). Flooding on Lake St. Martin prompted the emergency construction of dikes up to 2.4 m (8 ft) high with a top elevation of 246.6 m (809 ft). Road access was severely limited to several communities and widespread long-term evacuation from the four First Nations around Lake St. Martin and the Dauphin River was required.

In June 2011, the Province of Manitoba commissioned KGS Group and AECOM (the "2011 team") to urgently explore options to bring the levels of Lake St. Martin and Lake Manitoba down to the desirable range on an emergency basis. The Province sought a broad review of potential options to achieve this objective in a timely and cost-effective manner while also minimizing the potential impact on other areas of the Province (Figure 1). The scope of services performed in 2011 included:

- Identification and screening level assessment of over 11 diversion channel options and 4 historic mitigation options (e.g. Holland Dam).
- Geotechnical field investigations (peat probes, test pits, boreholes and geo-seismic) to estimate rock and overburden excavation quantities.
- Acquisition and processing of GIS data (survey, LiDAR, air photos, and sonar).

- Hydrodynamic and ice modeling to assess the potential effects of ice on the performance of the various channel options.
- Preliminary assessment of costs and constructability for each of the alternatives.

A report was prepared summarizing the results of the investigation titled, "Analysis of Options for Emergency Reduction of Lake Manitoba and Lake St. Martin Levels", which identified the Dauphin River as the hydraulic restriction in the system, and on July 22, 2011 the team recommended the following:

- Begin immediate construction of a 140 cms (5,000 cfs) emergency outlet channel from Lake St. Martin to Buffalo Lake and Creek, en route to Lake Winnipeg to address the hydraulic flow restrictions out of Lake St. Martin and to accommodate additional Lake Manitoba outflows over the winter.
- Allow unrestricted outflow of water from Lake Manitoba through the FRWCS during the winter of 2011/2012, allowing several times more outflow than past winters.

Subject to the successful implementation of the above recommendation, the team also conditionally recommended that the Province of Manitoba consider:

- Construction of a 70 cms (2,500 cfs) bypass channel around the north side of the FRWCS to allow additional outflow from Lake Manitoba.
- Expansion of the emergency outlet channel from Lake St. Martin by 70 cms (2,500 cfs) to offset the additional inflows from Lake Manitoba on the principle of no net additional flow to Lake St. Martin.

The construction of Reach 1 of the Lake St. Martin Emergency Outlet Channel (LSMEOC) was completed on November 1, 2011; but due to time constraints and construction challenges, the original design channel base width was reduced, resulting in a design capacity of approximately 106 cms (3,750 cfs; actual capacity was 113 cms (4,000 cfs) based on hydrometric data collected during operation of the LSMEOC in 2011 and 2012). The proposed 70 cms (2,500 cfs) FRWCS bypass channel was not constructed, as an expansion of the LSMEOC by 70 cms (2,500 cfs) to offset the additional flow was not feasible in 2011. Now that the 2011 emergency has passed the conditional recommendations noted above must be re-evaluated.

During operation, the water from the LSMEOC flowed into a bog area around Big Buffalo Lake before flowing into Buffalo Creek and finally discharging into the lower Dauphin River, upstream of Sturgeon Bay (Lake Winnipeg). During the early stages of the project, there was concern that the hydraulic restriction at the upstream end of Buffalo Creek would result in extensive flooding of the bog area during operation of Reach 1. The concern was that the water would potentially spillover and move overland towards the Dauphin River and lower portions of Buffalo Creek. To eliminate this potential flow restriction, an option was considered which involved excavating a natural segment of the upstream end of Buffalo Creek (Reach 2); however, it was later determined that the natural creek section could convey the peak flow in 2011, without requiring any modifications.

As the Reach 1 project developed, hydraulic modeling of potential water levels at the mouth of the Dauphin River indicated that there was a significant risk of major flooding of the Dauphin River communities in the spring of 2012 due to ice jam formations. This was largely due to the unprecedented winter flows with the FRWCS running at full capacity all winter. Therefore, it was determined that construction of the Reach 3 Emergency Channel (Reach 3) would be required to divert flows away from the Dauphin River prior to spring break up. The Reach 3 channel, in combination with dikes being constructed along the banks of the Dauphin River, would significantly reduce the risk of flooding for the Dauphin River communities. KGS Group was directed by MIT to proceed with the development of an appropriate design for Reach 3 in August 2011. The Reach 3 Emergency Channel was partially constructed between January and March 2012. However, with extremely mild winter conditions, ice jams on the Dauphin River did not develop as predicted. This ultimately precluded the need for Reach 3 to be operated in the spring of 2012. The Reach 3 Emergency Channel currently remains in an incomplete condition particularly with respect to some hydraulic structures.

The Reach 1 Emergency Outlet Channel was operated beginning in November 2011 and closed in November 2012, as required under the federal government terms and conditions for emergency operations. A longer-term environmental monitoring program is being implemented to ensure the full impacts of the emergency channel are documented and mitigation requirements identified. Unless required again for emergency operation, the channel will not be re-opened until it complies with the normal approval and licensing requirements under *The Environment Act*.

As a follow-up to the 2011 emergency flood mitigation activities for the Assiniboine River and Lake Manitoba Basins, the Province of Manitoba commissioned two independent review groups;

The Lake Manitoba and Lake St. Martin Regulation Review Committee (the Committee) chaired by Harold Westdal and The Manitoba 2011 Flood Review Task Force (the Task Force) chaired by David Farlinger.

The Committee made the following recommendations with respect to the LMB and LSM Outlet Channels:

> *"The Committee recommends that the Lake St. Martin Emergency Channel be made permanent.*
>
> - *The capacity should be sufficient such that Lake St. Martin can be maintained within the desirable range of 242.9 to 243.8 m (797 to 800 ft) at least 90 percent of the time;*
> - *Consideration should be given to the inclusion of a control structure at the mouth of the permanent outlet channel to limit outflow at times of low lake levels; and*
> - *The current Reach 3 should be redirected so that the channel outlets south of Willow Point on Lake Winnipeg.*
>
> *The Committee recommends that a second channel be constructed between Lake Manitoba and Lake St. Martin that would provide the total outlet capacity to meet the original design criteria for the Fairford Control Structure. If the Province builds a new outlet to Lake Manitoba as recommended, it should take that opportunity to design the new outlet in such a way as to provide unrestricted fish passage between Lake Manitoba and Lake St. Martin."*

The Task Force chaired by David Farlinger made the following recommendations with respect to LMB & LSM Outlet Channels:

> *"Adopt the recommendations of the Lake Manitoba and Lake St. Martin Regulation Review Committee regarding additional outlet capacity requirements for Lake Manitoba and Lake St. Martin, with due consideration for the engineering studies that are being conducted."*

3.0 DATA AVAILABLE

Stage 1 of the current Conceptual Design Study is primarily a desktop review based on existing available data described in the following paragraphs (no new field programs were included in the scope).

The key previous reports that were reviewed in detail to understand issues and options addressed previously include the following:

- Analysis of Options for Emergency Reduction of Lake Manitoba and Lake St. Martin Levels Report by KGS Group and AECOM (2014 Full Report, 2011 Executive Summary).
- Lake Manitoba and Lake St. Martin Regulation Review Committee Report (2013).
- The Manitoba 2011 Flood Review Task Force Report (2013).
- Flood Mitigation Study for First Nations along Fairford River, Lake St. Martin, and Lake Pineimuta (2012).
- Regulation of Water Levels on Lake Manitoba and along the Fairford River, Pineimuta Lake, Lake St. Martin, and Dauphin River and Related Issues (2003).
- Lake St. Martin and Pineimuta Lake Regulation (1978).
- Lake Manitoba Regulation (1972 to 1984).
- Lake Manitoba Regulation - Volume 1 and 2 (1973).
- Lake Manitoba Regulation Operating Rules of the Fairford River Dam (1961).
- Report on Measures for the Control of the Waters of Lake Winnipeg and Manitoba - Supplementary Volume II (1958).
- Investigation of Means of Lowering Lake Manitoba - Report on Auxiliary Channel Scheme No. 2 on Fairford River (1954).

As part of the overall assessment of channel options a geotechnical investigation was completed in 2011 along most of the proposed emergency channel routes to supplement existing data available from the Province of Manitoba, Conservation and Water Stewardship, Water Well Records (GWDrill). The primary focus of the 2011 geotechnical investigation program was to collect subsurface information in the vicinity of the proposed routes to allow the preliminary channel designs to be refined with the development of subsurface profiles to identify major design constraints such as excessive bedrock excavation requirements. The geotechnical investigation consisted of test pits, boreholes, monitoring wells, peat probes, lake bottom soundings, and laboratory testing and geo-seismic surveys. The data obtained from the 2011 geotechnical investigations is documented in an appendix within the Analysis of Options for Emergency Reduction of Lake Manitoba and Lake St. Martin Levels Report and includes the following:

- Detailed test pit logs, to determine the depth to bedrock to refine cost estimates for proposed channel construction.
- Detailed overburden and bedrock core logs to classify the materials (stratigraphy) and depth to bedrock along the proposed channel routes.
- Piezometric elevations in the bedrock to interpret groundwater conditions along the proposed channel routes.
- Summary table of peat depths and consistency of materials beneath the peat along sections of proposed routes that traverse peat bogs.
- Summary table of approximate depth of water and lake bottom sediments on lakes within bog areas situated on and adjacent to proposed channel routes.
- Seismic refraction surveys to provide an estimate of the bedrock surface elevation in select areas where test pitting was insufficient to confirm the depth to bedrock, and where drill access was problematic.

The primary GIS data used for the project consisted of terrestrial and bathymetry surveys collected by KGS Group, the Province of Manitoba and other consultants, as well as data from LiDAR and aerial and satellite imagery. Large area terrain models from Natural Resource Canada (NRCAN) and Shuttle Radar Topography Mission (SRTM) were used initially to develop project wide contour datasets at larger scales. The data and information collected during the 2011 emergency work program was also used in the current Stage 1 phase of the Conceptual Design Study for the evaluation of outlet channel options. ATLIS Geomatics acquired and classified LiDAR point cloud data for approximately, 1960 square kilometres during July 2011. The LiDAR data provided key information for all of the potential channel options and surrounding area including Birch and Buffalo Creeks, Fairford and Dauphin Rivers, as well as Lake Pineimuta and Lake St. Martin. The LiDAR data was processed by KGS Group to produce a bare earth DEM and contours at a 0.25 m vertical interval.

4.0 DESCRIPTION OF ALTERNATIVES AND HYDRAULIC DESIGNS

It is clear from presentations made to the Lake Manitoba/Lake St. Martin Regulation Review Committee, comments from the public, and survey responses that there is an overwhelming interest and demand for an additional outlet from Lake Manitoba. To ensure that flooding would not be aggravated on Lake St. Martin, a similarly-sized channel would be required from Lake St. Martin to Lake Winnipeg. Many have suggested that additional outlet capacity must be sufficient to avoid the flooding that would be experienced in a repeat of a 2011-sized flood. However, it will be difficult to justify the addition of a second outlet from Lake Manitoba sized to accommodate such a rare event. Regardless the Review Committee encouraged the Province to undertake the necessary engineering studies and to develop cost estimates to provide the information necessary to address the public concerns. A preliminary analysis suggested that an increase of about 35 percent in the FRWCS capacity would be required to maintain Lake Manitoba levels within the target range set by the designers of the FRWCS in all years except 2011. Therefore, the Committee recommended that a second channel be constructed between Lake Manitoba and Lake St. Martin to provide the total outlet capacity required to meet the original design criteria for the FRWCS.

As part of the Analysis of Options for Emergency Reduction of Lake Manitoba and Lake St. Martin Levels study, five emergency outlet channel routes (and several variations in capacity for each) were investigated to bypass the FRWCS and convey additional discharge to Lake St. Martin. The alignment of these channel options (A through E; Figure 1) have not changed significantly from those considered in 2011. For the current study, the level of design was advanced for each of the routes, a new route (Option F) was added and additional capacities were evaluated that were not previously considered (Table 1). The current study also examined various capacities and options for the Lake St. Martin outlet channels to achieve no net additional inflow into Lake St. Martin meeting additional requirements that were suggested by the Lake Manitoba/Lake St. Martin Regulation Review Committee. The channels are expected to operate over a range of water levels on Lake Manitoba and Lake St. Martin. However, for purposes of the design, the nominal channel capacities have been established for lake levels of 248.1 m (814 ft) on Lake Manitoba and 244.1 m (801 ft) on Lake St. Martin.

Profiles for each of the Lake Manitoba and Lake St. Martin channel options showing the existing ground surface, channel invert, water surface profile and bedrock surface, where applicable, are provided in Appendix B.

4.1 LAKE MANITOBA OUTLET CHANNELS

The Lake Manitoba outlet channel options include the five alignments previously examined along with one new channel option (F), which MIT requested be included. These are shown on Figure 2 and described as follows;

- Option A – Twinning the Fairford River.
- Option B – Channel south of Pinaymootang First Nation.
- Option C – Channel slightly less south of Pinaymootang First Nation.
- Option D – Channel following Birch Creek.
- Option E – Bypass channel north of the FRWCS.
- Option F – Expansion of the Fairford River and FRWCS (including dredging of the inlet channel).

The assessment of options included evaluation of additional channel capacities that were not previously considered for several of the original alignments (Table 1). Except for Option E, a conceptual design was completed for each option for a capacity of 140 cms (5,000 cfs) at a Lake Manitoba elevation of 248.1 m (814 ft). Additionally a conceptual design was completed for Options A, B, C and D for a capacity of 283 cms (10,000 cfs) and 424 cms (15,000 cfs). For Option E a conceptual design was completed for capacities of 70 cms (2,500 cfs) and 106 cms (3,750 cfs) at Lake Manitoba elevation 248.1 m (814 ft). These additional channel capacities for each outlet channel option have been designated numerically (e.g. A1, A2, A3, B1, etc.).

The channels were designed with a trapezoidal cross section with 4:1 side slopes in overburden (till) and near vertical 1:4 side slopes in bedrock. The channel slope for most options was 0.013%; although it was 0.032% for Option A and 0.030% for Option E. The channel roughness used for all options was 0.028 in till and 0.032 in bedrock, except for Option F which ranged from 0.025 to 0.031 (till). The depth of flow was 3.4 m for Options B and C, 3.5 m for Options A and E, 4.0 m for Option D and varied for Option F. The base width and average top width for each option varied depending on the material and design flow as described in the following sections for each option. The design maximum flow velocity for the channels was generally 5.0 ft/s (1.5 m/s) in till. For Option A, the average flow velocities ranged from 3.6 to 3.9 ft/s (1.1

to 1.2 m/s all in till), and for Option D, they ranged from 1.6 to 2.3 ft/s (0.5 to 0.7 m/s all in till), whereas for Option E the velocities were 3.0 ft/s (0.9 m/s in till). The flow velocities in the various channel alternatives varied due to the available hydraulic gradient from the downstream end of the channel to the upstream lake and from channel hydraulic efficiencies due to different width to depth ratios.

Excavation volumes for each option were estimated using the design channel geometry, the ground surface based on Shuttle Radar Topography Mission (SRTM) data and LiDAR data, and the bedrock surface based on well drilling data base (GWDrill), geophysical exploration and test-hole data.

The following sections provide a description of each of the Lake Manitoba outlet channel alternatives and the basis for the development of the associated excavation volumes. The calculated hydraulic impact of the outlet channels for the various capacities is provided in Section 5.0, while cost estimates for each of the options are provided in Section 6.0.

4.1.1 Option A

The Option A outlet channel, which is comprised of the twinning of the existing Fairford River from just upstream of the FRWCS to Lake St. Martin, crosses through the Fairford River at two locations as shown in Figure 3. One of the design criterion for this option included increasing the capacity of the Fairford River without increasing the surface level elevation at any location in the river. The proposed route is approximately 12.5 km long and located primarily within the Pinaymootang First Nation, with a portion on privately held lands. This option would require construction of two new control structures; one incorporated into a new bridge where the channel crosses Provincial Trunk Highway #6 (PTH 6). This upstream control structure would regulate discharges from Lake Manitoba for the purpose of maintaining target levels on the Lake (i.e. supplement the FRWCS when lake levels are high). The second control structure would be located downstream of Lake Pineimuta and would be incorporated into a new bridge where the channel crosses the municipal road. This downstream control structure is required to maintain Lake Pineimuta levels. Without the second control structure, Lake Pineimuta levels would be reduced in an uncontrolled manner during periods in which the channel was not required to be operated. The Option A channel crosses another three municipal roads, with new bridges proposed to be constructed at two of these locations to minimize disruption of road access. It may be possible to reduce the number of new bridge crossings required by localized realignment of roads.

The excavation for Option A is assumed to be primarily in till. The bedrock surface elevation is assumed to lie below the level of the channel invert based on GWDrill data and from bedrock surface elevation DEM maps compiled by Natural Resources Canada. The channel lengths, widths and estimated excavation volumes are summarized in Table 2.

TABLE 2:
OPTION A EXCAVATION VOLUME ESTIMATES

Design Option	Design Flow (cfs)	Material	Channel Length (m)	Base Width (m)	Channel Side Slopes	Average Top Width (m)	Average Depth of Excavation (m)	Overall Excavation Quantity (Mil.Cu.m)
A1	5000	Till	12300	26	4:1	64	4.7	2.63
A2	10000			64		83		4.83
A3	15000			112		131		7.61

4.1.2 Option B

The Option B outlet channel south of Pinaymootang First Nation was considered to bypass First Nation land and to improve construction conditions by going through an area that is not impacted by flooding. This route also bypassed Lake Pineimuta, which was seen as an advantage since flooding on this lake affects First Nation communities and agricultural land. As well, bypassing Lake Pineimuta eliminates the need for a downstream control structure. Option B would connect Portage Bay on Lake Manitoba to Lake St. Martin, south of the Pinaymootang First Nation as shown in Figure 3. The proposed route is approximately 11.5 km long and situated on privately held lands and crown leased lands.

This option would require construction of new bridge crossings for one municipal road and for PTH 6. The bridge at PTH 6 will be incorporated into construction of a new control structure and drop structure (Figure 3). The control, drop and bridge structures have all been combined into one structure to reduce construction costs. The control structure was located near the mid-point of the channel length to allow for a narrower and less costly structure than if it was located at the upstream municipal road near Lake Manitoba. However, this will result in a significant length of upstream channel that will be continuously wet, as it will be linked directly to Lake Manitoba.

Option B would require excavation of a significant bedrock ridge in the first half of the channel and that the channel would have rock at its base for roughly half of the total length. The channel lengths, widths and estimated excavation volumes are summarized in Table 3.

TABLE 3:
OPTION B EXCAVATION VOLUME ESTIMATES

Design Option	Design Flow (cfs)	Material	Channel Length (m)	Base Width (m)	Channel Side Slopes	Average Top Width (m)	Average Depth of Excavation (m)	Overall Excavation Quantity (Mil.Cu.m)
B1	5000	Till	5760	31	4:1	82	8.5	4.13
		Rock	5740	47	1:4			1.98
B2	10000	Till	5760	72	4:1	125		6.85
		Rock	5740	92	1:4			3.77
B3	15000	Till	5760	113	4:1	167		9.58
		Rock	5740	136	1:4			5.56

4.1.3 Option C

The first half of the Option C outlet channel is situated slightly north of Route B and just south of Pinaymootang First Nation. This alignment was chosen to reduce the amount of rock excavation required in comparison to Option B, while still bypassing First Nation land. Option C would connect Portage Bay on Lake Manitoba with Lake St. Martin, as shown in Figure 3. The proposed route is approximately 11.6 km long and situated on privately held lands and crown leased lands.

Similar to Option B, this option would require construction of new bridge crossings at two municipal roads and at one PTH 6, with the bridge at PTH 6 combined with a new control structure and drop structure (Figure 3). The control, drop and bridge structures have all been combined into one structure to reduce construction costs. The control structure was located near the mid-point of the channel length to allow for a narrower and less costly structure than if it was located at the upstream municipal road near Lake Manitoba. However, this will result in a significant length of upstream channel that will be continuously wet as it will be linked directly to Lake Manitoba.

The Geophysical exploration found that a significant bedrock ridge must still be excavated in the first half of the channel and that the channel would have rock at its base for over half of the total length. However, estimated rock and till construction volumes were slightly lower than Option B. The channel lengths, widths and estimated excavation volumes are summarized in Table 4.

TABLE 4:
OPTION C EXCAVATION VOLUME ESTIMATES

Design Option	Design Flow (cfs)	Material	Channel Length (m)	Base Width (m)	Channel Side Slopes	Average Top Width (m)	Average Depth of Excavation (m)	Overall Excavation Quantity (Mil.Cu.m)
C1	5000	Till	5470	31	4:1	79	7.9	3.47
		Rock	6090	47	1:4			1.74
C2	10000	Till	5470	72	4:1	122		5.84
		Rock	6090	92	1:4			3.32
C3	15000	Till	5470	113	4:1	165		8.18
		Rock	6090	136	1:4			4.90

4.1.4 Option D

The Option D outlet channel route connects Watchorn Bay on Lake Manitoba to the outlet of Birch Creek on Lake St. Martin as shown in Figure 4. This proposed route alignment is adjacent to low-lying terrain between Lake Manitoba and Lake St. Martin along which numerous marshes and small lakes exist. The proposed route is approximately 22.8 km long and situated on privately held lands and crown leased lands.

This option would require construction of new bridge crossings at three municipal roads, Provincial Road (PR) 239 and PTH 6. The bridge at PTH 6 would be combined with a new control structure and drop structure (Figure 4). The control, drop and bridge structures have all been combined into one structure to reduce construction costs. The control structure was located at PTH 6, which is near the mid-point of the channel length to allow for a narrower and less costly structure than if it was located at the upstream municipal road near Lake Manitoba. However, this will result in a significant length of upstream channel that will be continuously wet as it will be linked directly to Lake Manitoba. Local land drainage from the west may be impeded along the upstream half of the channel. This issue can be addressed by the construction of an outside drain with the flow directed into the channel downstream of the control structure at PTH 6. Land drainage along the downstream portion may be improved as it can be redirected directly into the new channel. Similarly, land drainage along the upstream half could be improved by constructing an outside drain along the channel and directing the flow downstream of PTH 6 to Lake St. Martin.

While the channel crosses a fourth municipal road just south of Lake St. Martin a minor road realignment would be constructed rather than constructing another bridge crossing. It may be possible to further reduce the number of new bridge crossings required by localized realignment of roads, in particular PR 239 may be re-routed north to avoid crossing the new channel alignment.

While Option D is longer than Options B and C, the excavation depths and total volume of excavation required is less. Information from GWDrill and from preliminary test hole data also showed that by shifting the channel alignment to the north side of the Birch Creek, costly bedrock excavation would likely be avoided. Locating the channel north of the existing marshes and lakes would also avoid wet conditions and improve the constructability; however, the route may still be impacted by flooding during construction if lake levels are high. The channel lengths, widths and estimated excavation volumes are summarized in Table 5.

TABLE 5:
OPTION D EXCAVATION VOLUME ESTIMATES

Design Criteria For Lake Manitoba Outlet Channels								
Design Option	**Design Flow (cfs)**	**Material**	**Channel Length (m)**	**Base Width (m)**	**Channel Side Slopes**	**Average Top Width (m)**	**Average Depth of Excavation (m)**	**Overall Excavation Quantity (Mil.Cu.m)**
D1	5000	Till	22800	27	4:1	72	5.53	6.29
D2	10000			64		108		10.86
D3	15000			100		144		15.37

4.1.5 Option E

The Option E outlet channel was considered as a short bypass of the FRWCS to add additional outlet capacity to Lake Manitoba. The channel alignment is similar to the beginning portion of Option A, bypassing the FRWCS to the north and then merging with the Fairford River a short distance downstream of the existing outlet from Lake Manitoba as shown on Figure 3. However, unlike Option A, the increased capacity from this outlet will result in increases in the surface elevations in the downstream reaches of the Fairford River. As previously noted, two capacities were evaluated for this option 70 cms (2,500 cfs; Option E1) and 106 cms (3,750 cfs; Option E2). The capacity for this option is limited as it does not consider channel twinning for the full length of the Fairford River. The proposed route is approximately 2.2 km long and situated on privately held lands. This option would require construction of one new bridge and control structure at PTH 6, with the bridge incorporated into construction of a new control structure (Figure 3).

The excavation for Option E is assumed to be primarily in till. The bedrock surface elevation is assumed to lie below the level of the channel invert based on GWDrill data and previous geotechnical investigations. The channel lengths, widths and estimated excavation volumes are summarized in Table 6.

**TABLE 6:
OPTION E EXCAVATION VOLUME ESTIMATES**

Design Option	Design Flow (cfs)	Material	Channel Length (m)	Base Width (m)	Channel Side Slopes	Average Top Width (m)	Average Depth of Excavation (m)	Overall Excavation Quantity (Mil.Cu.m)
E1	2500	Till	2150	9	4:1	54	5.4	0.37
E2	3750			21		65		0.50

4.1.6 Option F

Option F was included in this study at the request of MIT and is comprised of the widening of the Fairford River and FRWCS (including dredging of the inlet channel). A stipulation for the design criteria of Option F was to increase capacity without increasing the surface elevation in the river at any location. Widening of the Fairford River to increase the capacity would require removal of the abandoned railway bridge. Construction of two additional 5.84 m wide bays would be required at the FRWCS and a new control structure/bridge would need to be constructed downstream of Lake Pineimuta to replace the existing municipal road bridge. The downstream control structure is required to maintain, Lake Pineimuta levels. Without the second control structure Lake Pineimuta levels would be reduced in an uncontrolled manner during periods in which the channel is not required to be operated.

To facilitate construction, it has been assumed that Option F will require temporary fill for machinery access parallel to the river and staging areas to excavate the existing river channel to the invert. The fill volume required for construction along the river reaches would be removed as the below water excavation proceeds. There would also be an above water cut volume required to excavate the existing riverbank. The temporary fill, below water and the above water excavation material would be deposited in a spoil pile offset a safe distance from the top of the riverbank.

The excavation for Option F is assumed to be primarily in till. The bedrock surface elevation is assumed to lie below the level of the channel invert based on GWDrill data and previous geotechnical investigations. The channel lengths, widths and estimated excavation volumes are summarized in Table 7.

TABLE 7:
OPTION F EXCAVATION VOLUME ESTIMATES

Design Criteria For Lake Manitoba Outlet Channels								
Design Option	**Design Flow (cfs)**	**Material**	**Channel Length (m)**	**Base Width (m)**	**Channel Side Slopes**	**Average Top Width (m)**	**Average Depth of Excavation (m)**	**Overall Excavation Quantity (Mil.Cu.m)**
F1	18500	Till	18700	95	4:1	n/a	3.0	4.88

4.2 LAKE ST. MARTIN OUTLET CHANNELS

All water that exits Lake Manitoba ends up in Lake St. Martin. The only natural outlet from Lake St. Martin is the Dauphin River that flows into Sturgeon Bay (Lake Winnipeg). The development of the FRWCS and associated channel works in 1961 has resulted in the Fairford River having a greater capacity than the Dauphin River with Lake St. Martin at normal levels. As such, the Dauphin River is the critical restriction of flow between Lake Manitoba and Lake St. Martin, particularly during winter months, due to frazil ice formations further reducing the capacity of the Dauphin River. In addition, the storage capacity of Lake St. Martin is significantly less than that of Lake Manitoba. As a result, Lake St. Martin often rises to a level above its flood stage to balance inflows and maximize natural outflows. The outlet capacity of Lake St. Martin must be increased to allow maximum outflows from Lake Manitoba through the FRWCS without causing any additional flooding on Lake St. Martin and regional water bodies.

The Lake St. Martin Emergency Outlet Channel (LSMEOC) was divided into three separate sections (Reach 1, Reach 2, and Reach 3) when it was originally developed (Figure 5). As previously discussed, Reach 1 was constructed and operated from November 2011 through to November 2012. Reach 2 was not designed or constructed as it was determined in the early stages of the project that it was not required for the 2011/2012 flows. Reach 3 was only partially constructed as extremely mild winter conditions limited ice staging on Lake St. Martin and ultimately precluded the need for Reach 3 to be operated in the spring of 2012. Since Reach 3 was not operated in 2011/2012, flows from operation of Reach 1 followed the entire length of Buffalo Creek and discharged into the lower Dauphin River. However, utilizing the lower portion of Buffalo Creek on a permanent basis is not recommended due to environmental impacts, increased potential for flooding of the Dauphin River communities and opposition from stakeholders. Therefore, for the current study it has been assumed that all Lake St. Martin outlet channels would include Reach 3 and that only riparian flow would be permitted in Buffalo Creek.

During construction, the Dauphin River First Nation community noted a preference to have the Reach 3 outlet located on the east side of Willow point rather than the designed alignment which ended at Johnson Beach. While this was not feasible during the time restrictions in 2011, the east of Willow Point option was re-examined as a part of this Stage 1 study. The Willow Point route was also recommended by the recent Lake Manitoba/Lake St. Martin Regulation Review based on feedback received from First Nations.

The Lake St. Martin outlet channel options being evaluated include a combination of the following reaches:

- Reach 1 (R1) – Re-opening and/or expansion of Reach 1.
- Reach 2 (R2) – Expansion of Buffalo Creek (Reach 2) downstream of Buffalo Lake.

- Reach 3 (R3-JB) – Completion and/or expansion of Reach 3 to Lake Winnipeg at Johnson Beach.
- Reach 3 (R3-WP) – Completion and/or expansion of Reach 3 to Lake Winnipeg east of Willow Point.

Note that unlike the Lake Manitoba outlet channel options, R1, R2 and R3 are separate reaches that are downstream of each other and therefore combinations of the reaches are required to form a complete Lake St. Martin outlet channel system (i.e. they cannot be implemented independently). Therefore, since only one route was considered for both Reach 1 and Reach 2, the two possible Lake St. Martin outlet channel options being evaluated include the following:

- Option R123-JB – Reach 1, Reach 2 and Reach 3 to Johnson Beach.
- Option R123-WP - Reach 1, Reach 2 and Reach 3 east of Willow Point.

Reach 1 had been originally designed in 2011 for a discharge of approximately 140 cms (5,000 cfs) at a Lake St. Martin elevation of 244.1 m (801 ft); however, due to construction delays, the channel was constructed to approximately 75% of the design flow, and currently has a capacity of approximately 113 cms (4,000 cfs). The original design capacity for Reach 3 was 120 cms (4,250 cfs). However, as the role of the Reach 3 channel is to divert the added flows in Buffalo Creek from Reach 1 away from the lower Dauphin River, it is required to support flow capacities equivalent to Reach 1. Likewise to convey flows from Reach 1, the capacity of Reach 2 also needs to be equivalent to Reach 1. As such, the existing (base) capacity for Reach 1, 2 and 3 is listed as 113 cms (4,000 cfs).

As outlined in Section 2.0, the Lake Manitoba and Lake St. Martin Regulation Review Committee, and The Manitoba 2011 Flood Review Task Force recommended that the Lake St. Martin Emergency Channel be made permanent. KGS Group adopted this recommendation and therefore the existing capacity for Reach 1, 2 and 3 of 113 cms (4,000 cfs) formed the base condition for this study. Furthermore, as also outlined in Section 2.0 and recommended in the report "Analysis of Options for Emergency Reduction of Lake Manitoba and Lake St. Martin Levels", the governing principal for the design of the Lake Manitoba and Lake St. Martin channel is that there should be no net increase in flow to Lake St. Martin above the base condition of the existing Reach 1 channel. On this basis, the current assessment included evaluation of increased capacities, in addition to the base capacity of 113 cms (4,000 cfs), to account for increased flows from the Lake Manitoba outlet channel options of 140 cms (5,000 cfs), 283 cms

(10,000 cfs) and 424 cms (15,000 cfs). This would result in additional Lake St. Martin outlet channel alternatives with capacities of 255 cms (9,000 cfs), 396 cms (14,000 cfs), and 538 cms (19,000 cfs), respectively, at a Lake St. Martin elevation of 244.1 m (801 ft).

Alternatives to handle the additional capacities corresponding to the Lake Manitoba channel Option E (increased capacity by 70 cms (2,500 cfs) or 106 cms (3,750 cfs) were not assessed because on their own they would not provide the flood protection required to meet the goals of the project (Table 1).

The outlet channels were designed as a trapezoidal cross section with near vertical 1:4 side slopes in bedrock (Reach 3 only) and 3:1 side slopes in overburden (till). The Lake St. Martin outlet channels were designed with 3:1 side slopes, to match the conditions of the existing constructed channels rather than the 4:1 side slopes used to develop the Lake Manitoba options. Future detailed design may consider 4:1 side slopes to provide more acceptable conditions for re-vegetation of the channel. The channel roughness used was 0.028 in till and 0.032 in bedrock. The average flow velocity, channel slope, depth of flow, base width and average top width varied depending on the Reach, material and design flow, as described in the following sections.

During the consideration of emergency channel measures in 2011, the flow through the Buffalo Lake Bog was considered to be a potential problem resulting from organic material dislodging and floating to the surface thus restricting downstream flow passage. Downstream of the bog where Buffalo Creek begins, the available cross section area was also a concern in that it would not have capacity to discharge the flow from the Reach 1 channel, which would result in a backwater effect in Reach 1. Additional field surveys conducted in 2011 and, from experience gained during the operation of the Reach 1 channel in 2011-12, aided in determining that these concerns were not a problem for the limited flow capacity of Reach 1 and the corresponding relatively low discharges that occurred. As a result, it has been concluded that Reach 2 channel excavation would not be required for lower design discharge similar to the existing capacity of Reach 1 channel.

The need for channel improvement for Reach 2 was reexamined for the enlarged channel alternative being examined in this study. Detailed backwater model runs with design discharge greater than approximately 280 cms (10,000 cfs) resulted in water levels in the bog that would result in water escaping from the bog and overflowing to the Dauphin River. The corresponding high levels would also result in backwater to Reach 1, which would reduce flows in Reach 1 and require increased excavation to offset the backwater effects.

Excavation volumes were generally estimated using the design channel geometry, the ground surface based on Shuttle Radar Topography Mission (SRTM) data and LiDAR data, and the bedrock surface based on well drilling data base (GWDrill), geophysical exploration and test-hole data.

The following sections provide a description of the various reaches of a Lake St. Martin outlet channel together with the associated excavation volumes. The predicted hydraulic impact of the outlet channels for the various capacities is provided in Section 5.0. Cost estimates for each of the options are provided in Section 6.0.

4.2.1 Reach 1

Reach 1 of the Lake St. Martin outlet channel connects Lake St. Martin to the bog complex surrounding Big Buffalo Lake and is approximately 6 km in length as shown in Figure 5. The route is located entirely on crown land.

When the LSMEOC was initially opened, an earth plug was removed at the inlet which was replaced with an earth fill cofferdam when the channel was subsequently closed. This method of operation is not recommended for a permanent channel, as it is not practical in the long-term. As well, it has environmental concerns with respect to erosion and sedimentation. As such, two concepts, an overflow weir and a control structure, were considered for a permanent inlet to Reach 1.

An overflow weir would operate in an uncontrolled manner as lake levels fluctuate. Therefore, it would have to be constructed at an elevation near the upper limit of the desirable operating range for Lake St. Martin because a lower weir elevation would draw down Lake St. Martin excessively during dry periods. To achieve the required discharge capacity, the overflow weir would have to be significantly wider than the outlet channel. In comparison, a control structure could be operated strategically in response to actual conditions, which would make the outlet channel more efficient, particularly at lower lake levels. Making inlet improvements and adding a control structure would also increase the existing outlet channel capacity. A control structure could also possibly be strategically operated to help deal with ice formation issues within the outlet channel and the Dauphin River.

Based on the above, all Lake St. Martin outlet channel design capacities considered in this report incorporate an inlet control structure at Reach 1, rather than an overflow weir. The control structure is envisaged to be a simple sluiceway structure with stoplogs similar to the FRWCS. It would have a horizontal apron slab at an elevation of 241.0 m with no overflow crest (no elevation drop downstream). The structure would have piers spaced at approximately 6 m, and a bridge deck complete with hoisting structure from which the stoplogs could be removed manually when required to release flow into Reach 1 of the outlet channel. The bridge deck would also be used as a crossing for maintenance access to the other side of the outlet channel.

The excavation for Reach 1 is assumed to be primarily in till. The design was based on a channel slope of 0.020% with an average depth of flow of 2.8 m and a design average flow velocity of 0.9 m/s (3.0 ft/s). The channel lengths, widths and estimated excavation volumes are summarized in Table 8.

TABLE 8:
LAKE ST. MARTIN OUTLET CHANNEL – REACH 1 EXCAVATION VOLUME ESTIMATES

Design Option	Design Flow (cfs)	Material	Channel Length (m)	Base Width (m)	Channel Side Slopes	Average Top Width (m)	Average Depth of Excavation (m)	Overall Excavation Quantity (Mil.Cu.m)
R1 Base	4000	Till	6000	45	3:1	70	4.2	0.55
R1+5000	9000			81		106		1.46
R1+10000	14000			128		153		2.68
R1+15000	19000			176		201		3.90

4.2.2 Reach 2

Reach 2 of the Lake St. Martin outlet channel is located along Buffalo Creek beginning at the edge of the bog complex surrounding Big Buffalo Lake and is approximately 2.9 km in length as shown in Figure 5. The route is located entirely on crown land.

Reach 2 involves the widening and deepening of a natural segment of the upstream end of Buffalo Creek to increase the capacity and ensure water levels on Buffalo Lake are contained by the surrounding topography and to reduce backwater effect to Reach 1 channel. The concern is that the water could potentially spillover from Buffalo Lake and travel overland towards the Dauphin River and lower portions of Buffalo Creek in an uncontrolled manner. Reach 2 is also required to ensure water levels on Buffalo Lake at the exit of Reach 1 are low enough not to reduce the capacity of Reach 1 due to backwater effects.

The excavation for Reach 2 is assumed to be primarily in till. Some of the excavation material will be used to construct containment dikes along the creek, and the rest will be deposited in spoil piles. The channel was designed with a slope of 0.013% with an average depth of flow of 7 m and a design average flow velocity of 0.5 m/s (1.6 ft/s). The channel lengths, widths and estimated excavation volumes are summarized in Table 9.

TABLE 9:
LAKE ST. MARTIN OUTLET CHANNEL – REACH 2 EXCAVATION VOLUME ESTIMATES

Design Criteria For Lake St. Martin Outlet Channels								
Design Option	**Design Flow (cfs)**	**Material**	**Channel Length (m)**	**Base Width (m)**	**Channel Side Slopes**	**Average Top Width (m)**	**Average Depth of Excavation (m)**	**Overall Excavation Quantity (Mil.Cu.m)**
R2 Base	4000	Till	2900	0	3:1	n/a	5.0	0.00
R2+5000	9000			10		35		0.10
R2+10000	14000			80		105		0.75
R2+15000	19000			140		165		1.30

4.2.3 Reach 3

Reach 3 of the Lake St. Martin outlet channel would divert flood flows from Buffalo Creek directly to Lake Winnipeg, rather than following the natural drainage path along lower Buffalo Creek to the Dauphin River and then Lake Winnipeg as shown in Figure 5. An earth dam structure would be constructed across Buffalo Creek to divert the flood flows into Reach 3. The earth dam would include culverts so that riparian flow in Buffalo Creek due to local runoff would be allowed to remain in the creek and continue downstream of Reach 3.

In addition to evaluating different capacities for Reach 3, the evaluation considers two alternative locations where Reach 3 outlets to Lake Winnipeg; including the Johnson Beach location and the east side of Willow Point location. The total length of Reach 3 is approximately 9.7 km for the Johnson Beach outlet location and approximately 11.4 km for the Willow Point outlet. Both routes are located entirely on crown land and both currently only have winter road access. Aside from at the proposed new Reach 1 inlet control structure, bridge crossings would not be necessary as there are no existing permanent roads in this area.

To reduce the gradient and flow velocities in the channel, multiple rock fill drop structures would be required. As shown in Figure 5, the Johnson Beach outlet option requires 11 drop structures and the Willow Point outlet option requires 12 drop structures. For both outlet options, three of the drop structures would be located within the portion of the Reach 3 channel that was partially constructed in 2012.

The excavation for Reach 3 is primarily in till with a portion in bedrock. Some of the excavation material will be used to construct containment dikes along the creek, and the remainder will be deposited in spoil piles. The design channel slope is 0.034 % in till and 0.074% in bedrock. The average depth of flow is 3.5 m in till and 2.0 m in bedrock with average flow velocities of 1.1 m/s (3.6 ft/s) and 1.6 m/s (5.2 ft/s), respectively. The channel lengths, widths and estimated excavation volumes are summarized in Table 10.

TABLE 10:
LAKE ST. MARTIN OUTLET CHANNEL – REACH 3 EXCAVATION VOLUME ESTIMATES

Design Option	Design Flow (cfs)	Material	Channel Length (m)	Base Width (m)	Channel Side Slopes	Average Top Width (m)	Average Depth of Excavation (m)	Overall Excavation Quantity (Mil.Cu.m)
R(JB) Base	4000	Till	8040	21	3:1	39	3.0	0.36
		Rock	1660		1:4			0.00
R3(JB) +5000	9000	Till	8040	52	3:1	70	3.0	1.47
		Rock	1660		1:4			0.03
R3(JB) +10000	14000	Till	8040	82	3:1	101	3.0	2.35
		Rock	1660		1:4			0.06
R3(JB) +15000	19000	Till	8040	113	3:1	131	3.0	3.22
		Rock	1660		1:4			0.09
R3(WP) Base	4000	Till	9760	21	3:1	41	3.4	0.69
		Rock	1660		1:4			0.00
R3(WP) +5000	9000	Till	9760	52	3:1	72	3.4	2.11
		Rock	1660		1:4			0.03
R3(WP) +10000	14000	Till	9760	82	3:1	103	3.4	3.27
		Rock	1660		1:4			0.07
R3(WP) +15000	19000	Till	9760	113	3:1	133	3.4	4.43
		Rock	1660		1:4			0.08

5.0 EFFECTS OF CHANNELS ON WATER LEVELS

5.1 CHARACTERISTICS OF THE DRAINAGE BASINS OF LAKE MANITOBA AND ASSINIBOINE RIVER

Lake Manitoba has a drainage area of approximately 79,800 km^2, which includes the surface area of the lake at approximately 4,500 km^2. Under normal conditions, the dominant source of inflow to Lake Manitoba is from local runoff from the surrounding watershed. The largest tributary to Lake Manitoba is the Waterhen River, which has a drainage area of approximately 55,100 km^2, including the surface area of Lake Winnipegosis (over 5,300 km^2). However, during periods of floods in the adjacent Assiniboine River watershed, the Portage Diversion Channel (PDC) may transfer water from the Assiniboine River and thereby contribute inflow to Lake Manitoba. The Assiniboine River has a drainage area of about 161,000 km^2 at Portage la Prairie. When necessary, the PDC diverts excess flow at Portage la Prairie away from the communities located downstream on the Assiniboine River, including Winnipeg.

For the purpose of this study, inflow to Lake Manitoba was separated between the two sources:

1. Local inflow from the watershed surrounding Lake Manitoba; and
2. Inflow from the Portage Diversion.

The volumes of the Assiniboine River flood were computed in this study by summing the daily reported river flows at the Water Survey of Canada Station observed flows at the Assiniboine River near Holland (Hydrometric Station 05MH005), for the period from April 1st to October 31st each year. This is a typical time period when the PDC may be in operation. Calculation of the volumes of inflows to Lake Manitoba was based on the traditional method of computing "Inflow Available Outflow" (IAO) and implicitly included the components of precipitation and evaporation. After July, inflows to Lake Manitoba diminish sharply with significant increases in evaporation. The time period of April 1st to July 31st was, therefore, chosen to calculate the total volumes of those inflows for purposes of developing annual inflow hydrographs. A description and discussion on the analysis of IAO is provided in Section 5.3.2.

Floods on the Lake Manitoba and Assiniboine River watersheds are often, although not always, coincident. Figure 6 shows the recorded data of flood volumes from 1961 to 2011, inclusive. In most wet years, a relatively high runoff occurs in both catchments. Nevertheless, there are some years where the coincidence is less apparent. When all years are compared, the correlation coefficient for these datasets is approximately 0.86, which suggests a reasonably strong statistical correlation between the datasets

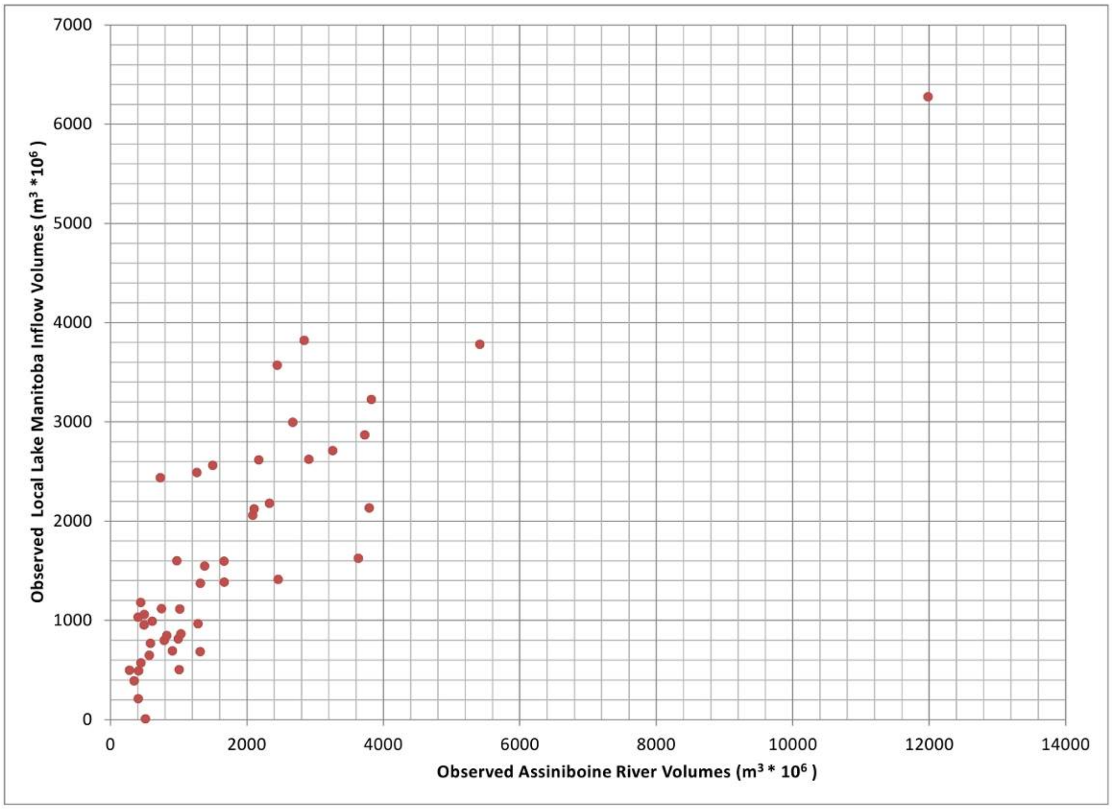


Figure 6 – Observed Assiniboine River and Local Lake Manitoba Inflow Volumes

5.2 TECHNIQUE FOR ANALYSIS OF HYDRAULIC AND ECONOMIC PERFORMANCE OF FLOOD MITIGATION OPTIONS

One of the most respected and experienced authorities in the world on analysis and planning of flood protection systems is the U.S. Army Corps of Engineers (USACE).

It has become standard policy of the USACE to examine the effects of risk and uncertainty in evaluation of the performance of potential flood mitigation works. The usual approach by the USACE is to apply the HEC-FDA ("Hydrologic Engineering Center – Flood Damage Analysis") software package. That package incorporates the concept of uncertainty into the estimation of hydraulic performance and the "expected annual damages" (EAD) that form the cornerstone of the economic analysis.

The FDA software uses a "Monte Carlo" procedure to generate a large representative dataset of river flows that leads to the estimation of the EAD. This is a technique wherein large numbers of synthetic years of flood events are generated using the statistical characteristics of flood magnitude, and the relationship between flood flow and water levels, and ultimately the impact on flood damages. Thousands of years of flood events, water levels, and potential flood damages are typically generated by the numerical model so as to develop an average that is truly representative of the diversity of river conditions that could be expected to occur. This process develops a realistic representation of the frequency of flood damages for large floods that improves upon the limitations of estimating directly from the observed record alone.

The technique incorporated in FDA was used in the studies and planning of the expansion of the Red River Floodway in 1999-2000, by KGS Group (KGS Group, 2000). It was viewed by KGS Group as a rigorous, comprehensive technique that would be well suited and justified in evaluation of flood protection options for Lake Manitoba as well. A difficulty in applying this technique, however, is that the flooding of Lake Manitoba is caused by two separate sources, as explained in Section 5.1 above. This issue of dual sources of flood waters does not lend itself well to the direct application of the standard FDA software.

Adding to the complexity of the dual source of flood waters and its impact on Lake Manitoba is the influence of wind on the peak water levels at specific locations around the lake. Due to the large surface area of the lake and it's relatively shallow depth (average of 4.2 m (14 ft) when the water level is at 247.2 m (811 ft)), a rise in lake levels of 0.5 m to 1.0 m from wind setup alone is not uncommon during wind storms in some locations around the lake. The combination of a wind event that coincides with high lake levels can exacerbate the damages that occur around the lake and affect each and every region of the lake differently. This additional dimension of wind effects that is required for the analysis of damages on Lake Manitoba also does not lend itself well to the direct application of the FDA software.

Given the importance of the flood protection measures, it was concluded that development of a technique that could emulate the principles of the USACE's FDA was justified. That technique is described in the sections that follow, and in general terms, complies with the principles promoted by the USACE.

5.3 FLOOD ROUTING

The Monte Carlo approach that was adopted and is described in subsequent sections of this report is used to generate thousands of synthetic annual flood volumes for the Assiniboine and Lake Manitoba drainage basins. These volumes must, in turn, be analyzed to develop the peak still water levels (wind effects eliminated) for Lake Manitoba that would contribute to governing the extent of flood damage for each event. The conversion from synthetically generated flood volumes to peak annual still water levels was done with a flood routing model as described below.

5.3.1 Description of Flood Routing Model

KGS Group developed a spreadsheet flood routing model to undertake the flood routing analyses to compute water levels on Lake Manitoba and Lake St. Martin and outflows from these lakes. The model calculates daily changes in still water levels and outflows based on predetermined stage-discharge relationships at the outlet channels from the lakes and the available storage volume as a function of lake level. The model had as input the net inflow to Lake Manitoba based on flood hydrographs that were developed for local Lake Manitoba inflow. A discussion on the flood hygrographs is given in Section 5.3.2.

Stage-storage relationships used in the model were developed from measured surface areas of the lakes. The stage-storage relationships for Lake Manitoba and Lake St. Martin are provided on Figures 7 and 8 respectively.

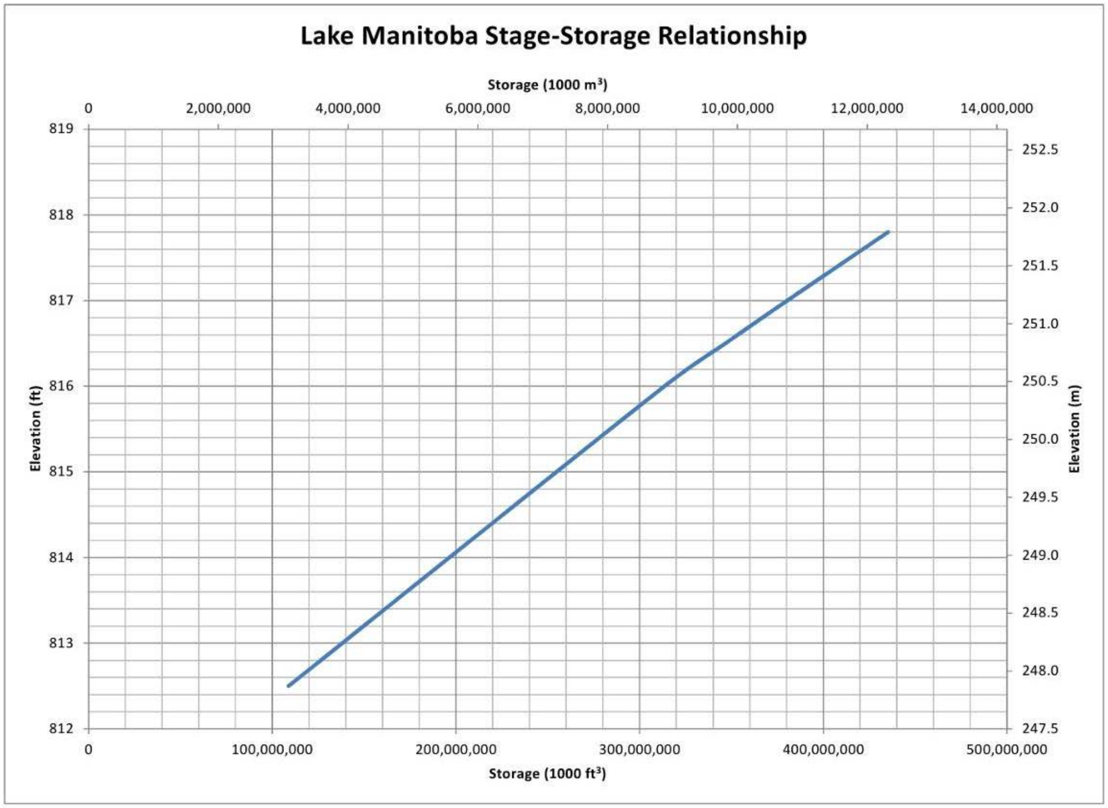


Figure 7 – Lake Manitoba Stage-Storage Relationship

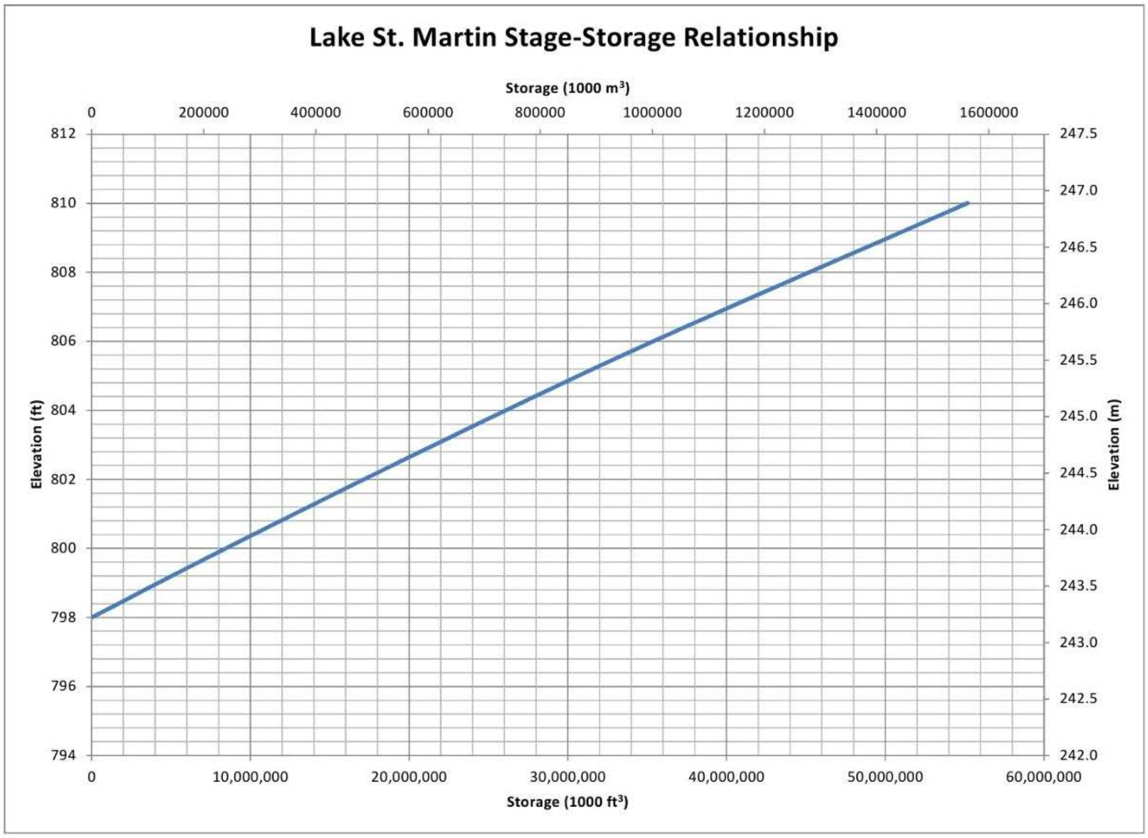


Figure 8 – Lake St. Martin Stage-Storage Relationship

The existing stage-discharge relationship for outflow from Lake Manitoba was based on historical water levels and flow data from Water Survey of Canada (WSC) records and augmented by results from a backwater model analysis of the Fairford River. The model assumed that the FRWCS would be fully open. The stage-discharge relationship for Lake Manitoba is provided on Figure 9.

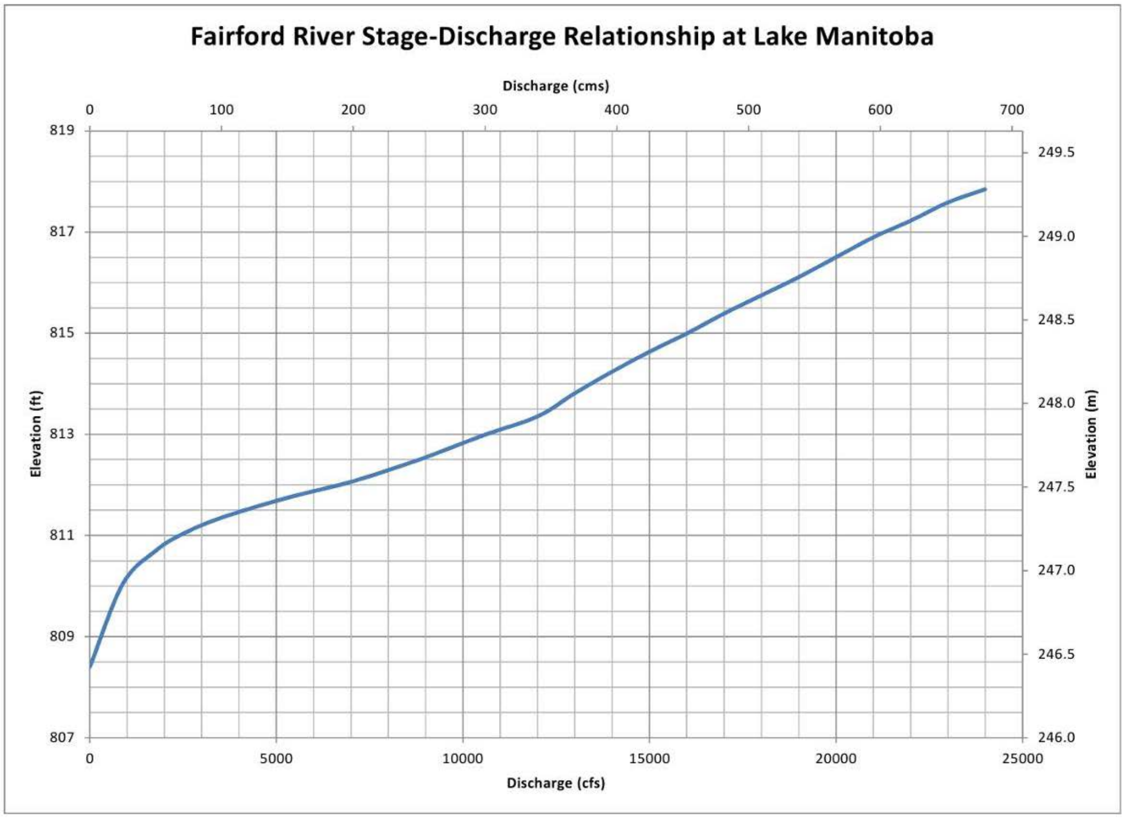


Figure 9 – Fairford River Stage-Discharge Relationship at Lake Manitoba

The stage-discharge relationship for outflow from Lake St. Martin for open water conditions in the Dauphin River was based on historical lake levels recorded by WSC on Lake St. Martin (Station 05LM005), and flow data recorded by WSC on the Dauphin River (Station 05LM006). The stage-discharge relationship for winter ice conditions was based on results from numerical models and ice staging observations in the Dauphin River conducted by KGS Group for the Emergency Reduction of Lake Manitoba and Lake St. Martin Water Levels Project. The existing stage-discharge relationships for Lake St. Martin are provided on Figure 10.

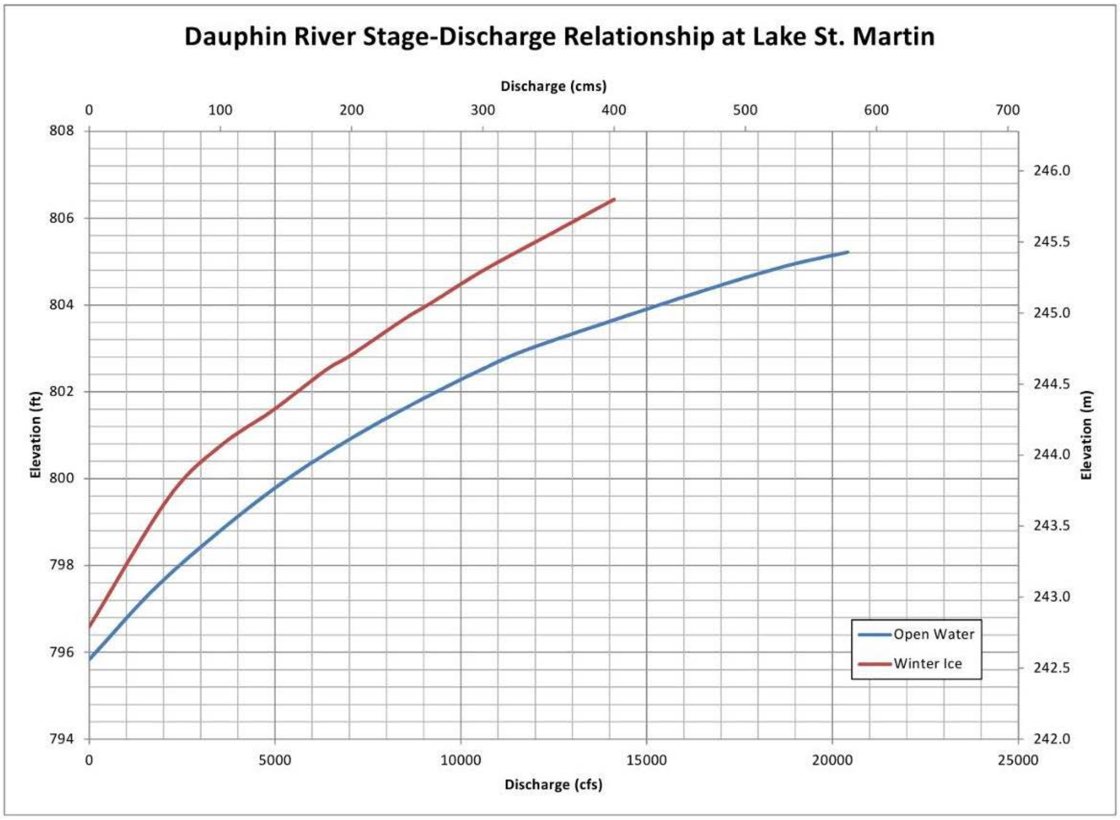


Figure 10 –Dauphin River Stage-Discharge Relationship at Lake St. Martin

Stage-discharge relationships for the Lake Manitoba and Lake St. Martin outlet channels were also developed for the routing model. The stage-discharge relationships for the Lake Manitoba Outlet channels are provided on Figure 11 and were developed based on the results of a backwater models of the channels. Only one representative stage-discharge curve was used for the different outlet channel options. The justification for this simplification is that the basis of design for all channels required that the design discharge be provided at a Lake Manitoba elevation of 814 ft (248.107 m), which resulted in similar rating curves for all channels. It was recognized that the stage-discharge curves could vary slightly depending on the route option selected due to differences in channel geometry and conditions at the channel inlet. Nevertheless, for this concept phase study, the curves shown on Figure 11 were considered representative of the increase in outflow from Lake Manitoba for all of the alternatives.

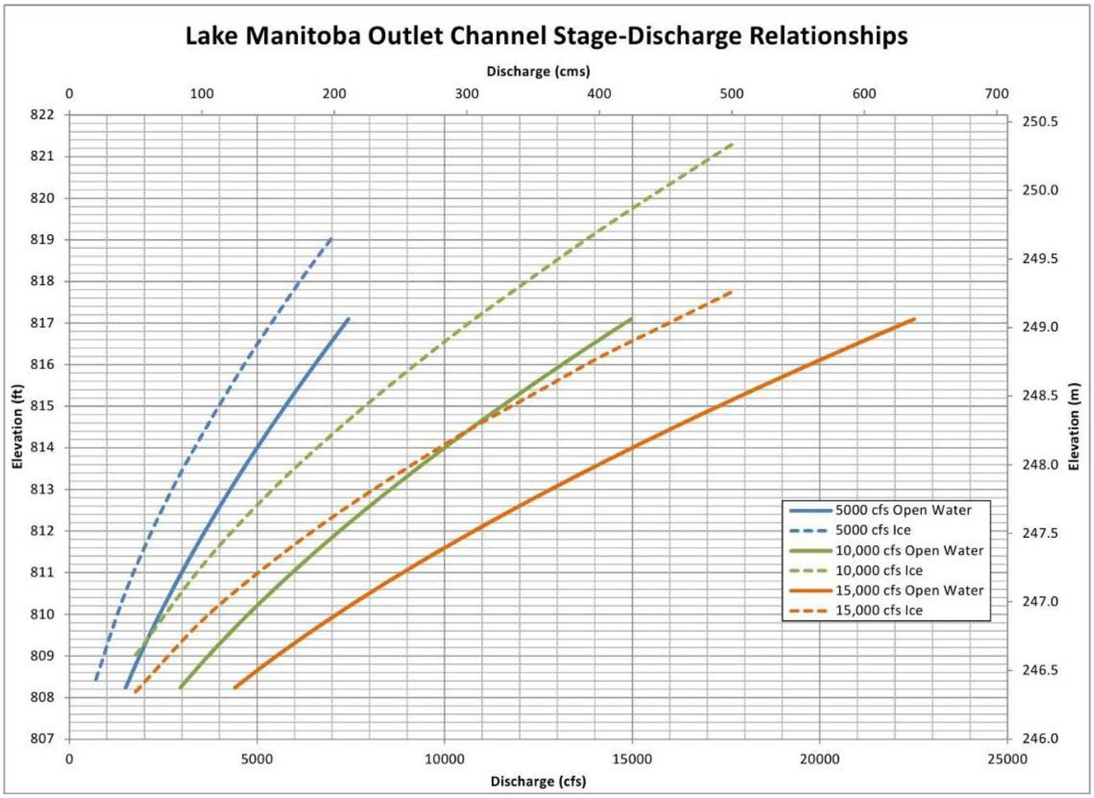


Figure 11 – Lake Manitoba Outlet Channel Stage-Discharge Relationships

The stage-discharge relationship for the Lake St. Martin Outlet Channel, which has a design flow of 113 cms (4,000 cfs), is provided on Figure 12. Its derivation was based on the hydrometric data collected in Reach 1 during operation of the Lake St. Martin Emergency Outlet Channel in 2011 and 2012. For larger channels, the stage-discharge curves were based on the results of backwater models of the channels and are provided on Figure 13.

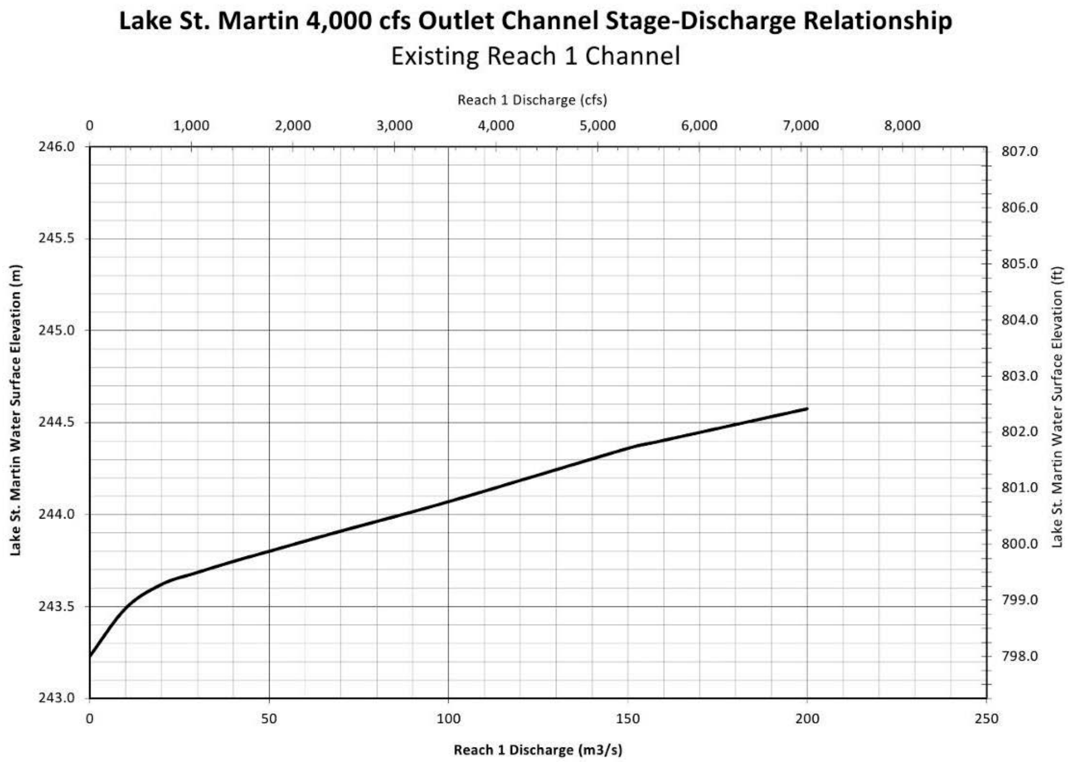


Figure 12 – Lake St. Martin 4,000 cfs Outlet Channel Stage-Discharge Relationship

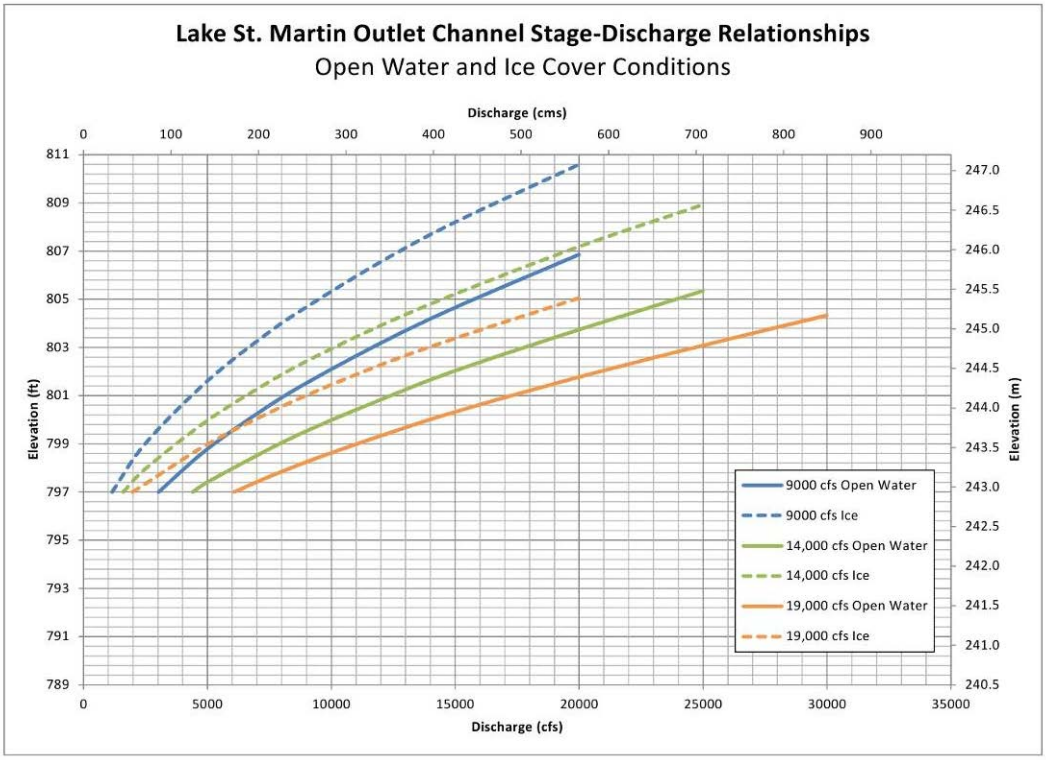


Figure 13 – Lake St. Martin Outlet Channels Stage-Discharge Relationships

A 15-month simulation period was selected for the flood routing modeling, with the first day of simulation starting on January 1 and the last day ending on March 31 in the following year. This simulation "window" of time was selected such that two winter periods were included in the model.

As depicted by the stage-discharge curves for Lake St. Martin and the different outlet channel alternatives, the formation of an ice cover in the channels or in the river can reduce the outflow capacity from Lakes Manitoba and St. Martin. For this analysis, ice restrictions in the Dauphin River at the outlet of Lake St. Martin were assumed from past experience to occur between December 15 and March 31. Based on experience from the 2011 flood, it was assumed that ice would not form in the Lake Manitoba and Lake St. Martin outlet channels. Rating curves were also prepared for the outlet channels assuming that a worse case ice cover would form early in the winter with a maximum ice cover thickness of 0.6 m (2 ft). A sensitivity analysis was conducted to determine the effects to the computed lake levels of a change to the ice conditions in the model and is documented in Section 5.3.4.

By selecting the first day of simulation to be January 1 in the routing model, it was also assumed that the outlet channels would be operated starting on that date. A sensitivity analysis was conducted to determine the effects to the computed lake levels of a change to the first day of simulation in the model and is documented in Section 5.3.4.

A starting water level of 247.65 m (812.5 ft) was assumed for Lake Manitoba and 244.15 m (801 ft) was assumed for Lake St. Martin for the baseline conditions without the outlet channels. By selecting those water levels, it was assumed that the two lakes were already at the upper limits of their operating ranges prior to the flood. With the outlet channels in place, a starting water level of 247.5 m (812.0 ft) was assumed for Lake Manitoba and 243.84 m (800 ft) was assumed for Lake St. Martin. In this case, it was assumed that the outlet channels were effective in maintaining the lake levels below the upper limit of the operating range before the start of the flood. A sensitivity analysis was conducted to determine the effects to the computed lake levels of a change to the starting water level and is documented in Section 5.3.4.

5.3.2 Flood Hydrographs

Flood hydrographs were developed for the releases from the PDC and for local Lake Manitoba inflow to forecast water levels on Lake Manitoba and Lake St. Martin and discharges from these lakes. Flood hydrographs for flow through the PDC were based on the flood hydrographs that were developed for the Assiniboine River near Holland as documented in Deliverable No. UA-02 titled, "Summary of Method to Develop Design Hydrographs" and attached in Appendix C. The diverted portions of the Assiniboine River hydrographs through the PDC were estimated based on the best estimate of the modes of operation of the PDC. The assumptions that constitute that best estimate are listed in Deliverable No. PD-01 titled, "Elimination of the Portage Diversion Failsafe" and attached herewith in Appendix D. Those assumptions were based on knowledge of the current operation guidelines and experience with the operation of the PDC in the past. However, as per the terms of reference for this study, it was assumed that the maximum discharge capacity of the Portage Diversion was 963 cms (34,000 cfs). The flood hydrographs for the Portage Diversion are provided on Figure 14.

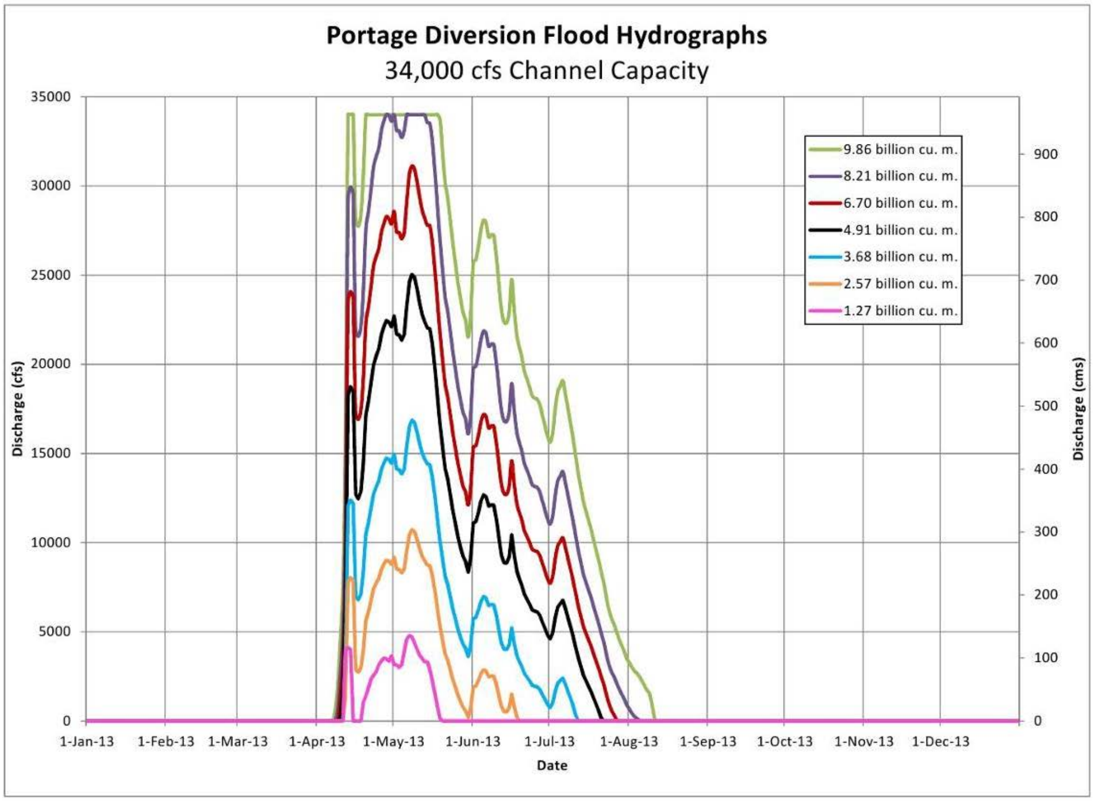


Figure 14 – Portage Diversion Flood Hydrographs

To check the validity of the assumptions made for the PDC, the historic record of Assiniboine River flows near Holland from WSC hydrometric station 05MH005 was analysed to determine the computed amounts of diverted flow. The computed amounts of diverted flow would then be compared with the actual recorded amounts of diverted flow. For this comparison, a maximum discharge capacity of 708 cms (25,000 cfs) was adopted for the PDC for the period of record of 1970 to 2012, with the exception of 2011 where a maximum capacity of 963 cms (34,000 cfs) was assumed. The resultant yearly volume of water diverted by the PDC was compared to the actual volume of water recorded by WSC station 05LL019 (Portage Diversion near Portage La Prairie) and is provided on Figure 15. As shown on the figure, the computed volumes based on flows near Holland agreed reasonably well on average with the observed volumes passing through the PDC. On this basis, it was determined that the assumptions made for estimating the operation of the PDC were valid for the purpose of routing flood volumes on Lake Manitoba and Lake St. Martin, and to forecast water levels and discharges from these lakes.

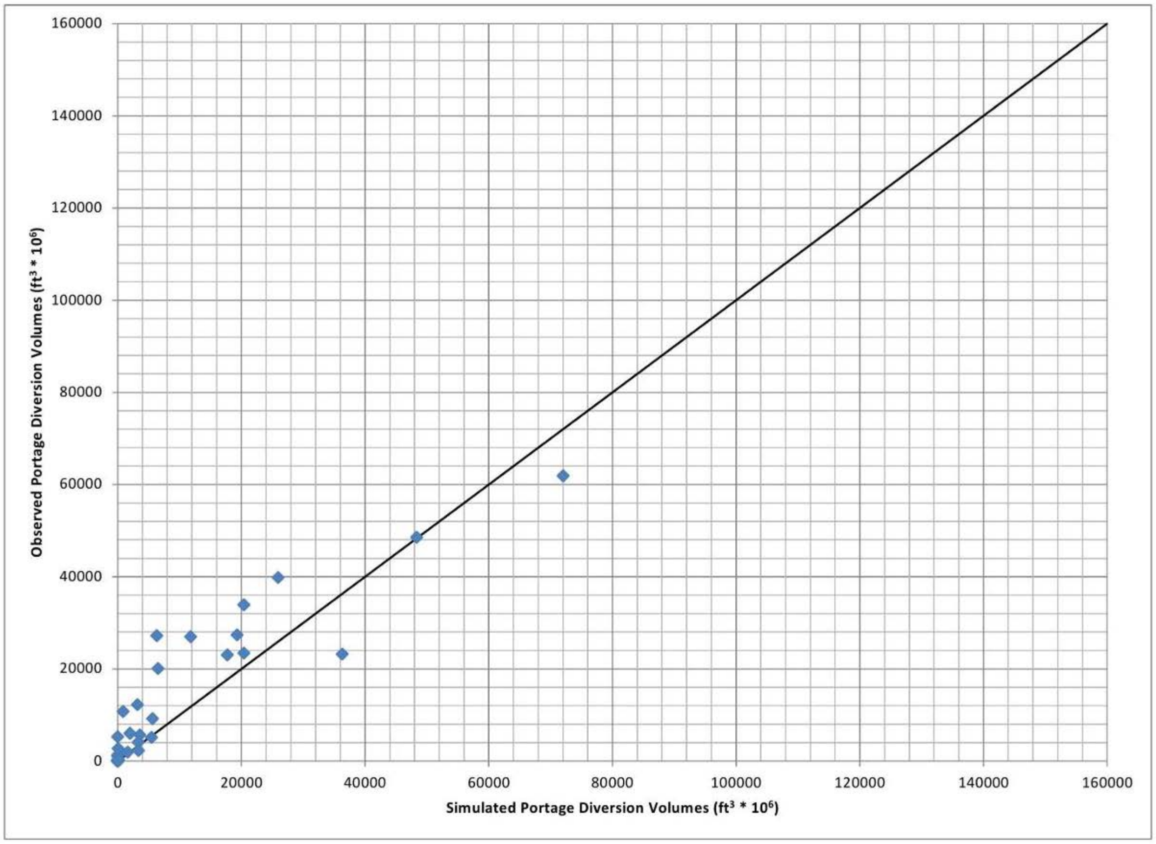


Figure 15 – Portage Diversion Volume Comparison

The flood hydrographs for Lake Manitoba were developed based partly on an analysis of the Inflow Available for Outflow (IAO) for Lake Manitoba. The IAO method is based on a simple water balance model which solves for inflow during a time period when the rate of change in storage and the outflow during the same period are known (i.e. Inflow = Change in Storage + Outflow). The rate of change in storage is determined from observed water levels on the lake and a stage-storage relationship for the lake. The outflow is determined from recorded outflows through the outlet river. This method indirectly accounts for all sources of inflow including precipitation, evaporation, gauged and ungauged surface inflows, and other miscellaneous inputs such as seepage and groundwater inflow. All these inputs are included in the change in the volume of the lake as measured by the water level.

For this analysis, observed Lake Manitoba water levels were based on historic records at WSC station 05LK002 (Lake Manitoba at Steep Rock) and station 05LL012 (Lake Manitoba near Westbourne), and the outflows were based on recorded flows in the Fairford River near Fairford at WSC station 05LM001, between 1961 to 2012. The stage–storage relationship for Lake Manitoba is provided in Section 5.3.1.

Since the IAO consists of a record of all sources of inflow to the lake, the inflow portion from the PDC as recorded by WSC at station 05LL019 was subtracted from the results to obtain a continuous record of local inflows to Lake Manitoba.

The annual IAO volumes were input to the FFA flood frequency curve program to produce a frequency curve of flood volumes. The results of these frequency analyses were used to estimate a range in possible IAO volumes from a 1:500 year to 1:2 year return periods. Eight hydrographs were developed covering the range in flood volumes 1.18 x 10^9 to 9.23 x10^9 m^3. The IAO hydrograph shape for 2011 was used as a guide to determine the shape of the runoff hydrographs for large floods, with volumes above approximately 5 x 10^9 m^3. The start of runoff was assumed to begin on April 1 with 86% of the peak occurring by May 1 and the peak inflow on June 14. The recession of the flood occurred by July 1. As a comparison, the 2011 flood had a volume of approximately 6.3 x10^9 m^3. For lesser flood magnitudes, less than approximately 5 x 10^9 m^3, the hydrograph shape was based on the 2009 inflow flood. This hydrograph had the start of the hydrograph on April 1 with the peak occurring on May 1. Baseline flows during the winter period prior to and after the flood were based on a statistical analysis of average Waterhen River flows in the winter. For the summer and fall period after the recession of the hydrograph, the baseline flows were based on a statistical analysis of the IAO for that period. The flood hydrographs for Local Lake Manitoba inflow are provided on Figure 16.

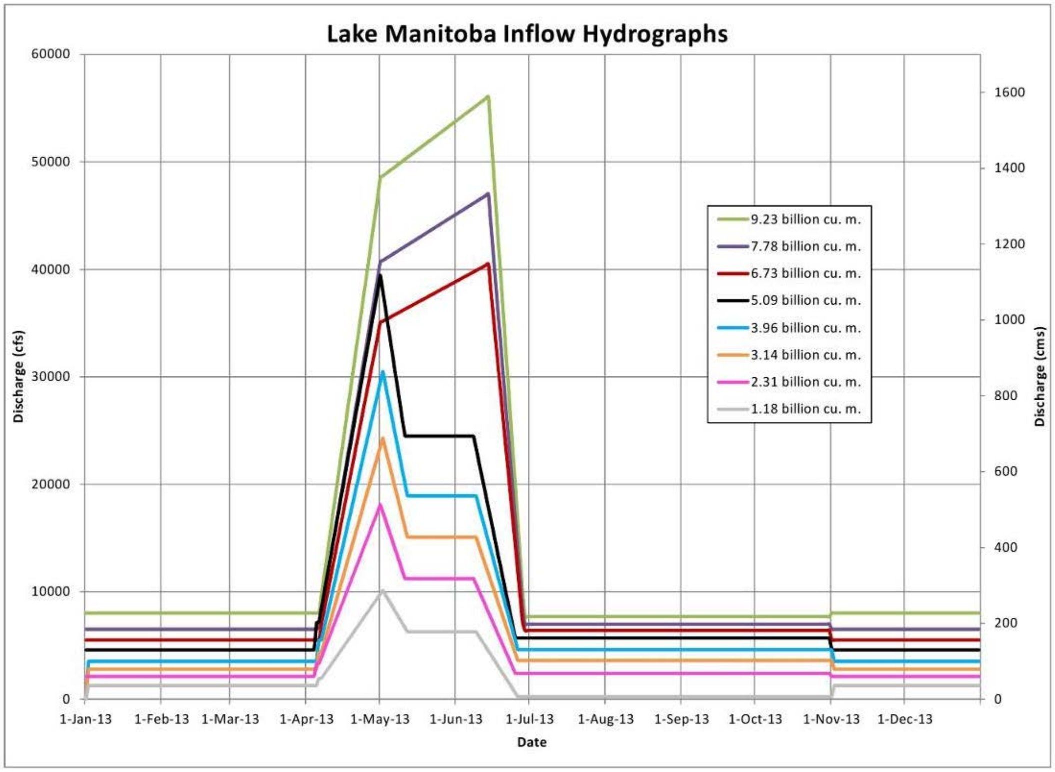


Figure 16 – Local Lake Manitoba Inflow Hydrographs

5.3.3 Modeling Results

Over 25 different combinations of PDC inflow hydrographs and local Lake Manitoba IAO hydrographs, covering the full range of possible flows, were routed numerically through the model of Lake Manitoba and Lake St. Martin. Each scenario was for the baseline condition (i.e. maximum capacity of Portage Diversion is 963 cms (34,000 cfs) and assumes no new outlet channel in place on Lake Manitoba) as well as for conditions with the proposed outlet channels.

Resultant hydrographs for Lake Manitoba and Lake St. Martin for a scenario which results in a peak water level of approximately 249.1 m (817.3 ft) on Lake Manitoba and of approximately 245.8 (806.5 ft) on Lake St. Martin without new outlet channels are provided in Figures 17 and 18. Resultant hydrographs with outlet channels in operation are also shown on the Figures. The computed return period of peak water levels on Lake Manitoba (discussed in Section 5.4.2) has been included on Figure 17 as reference.

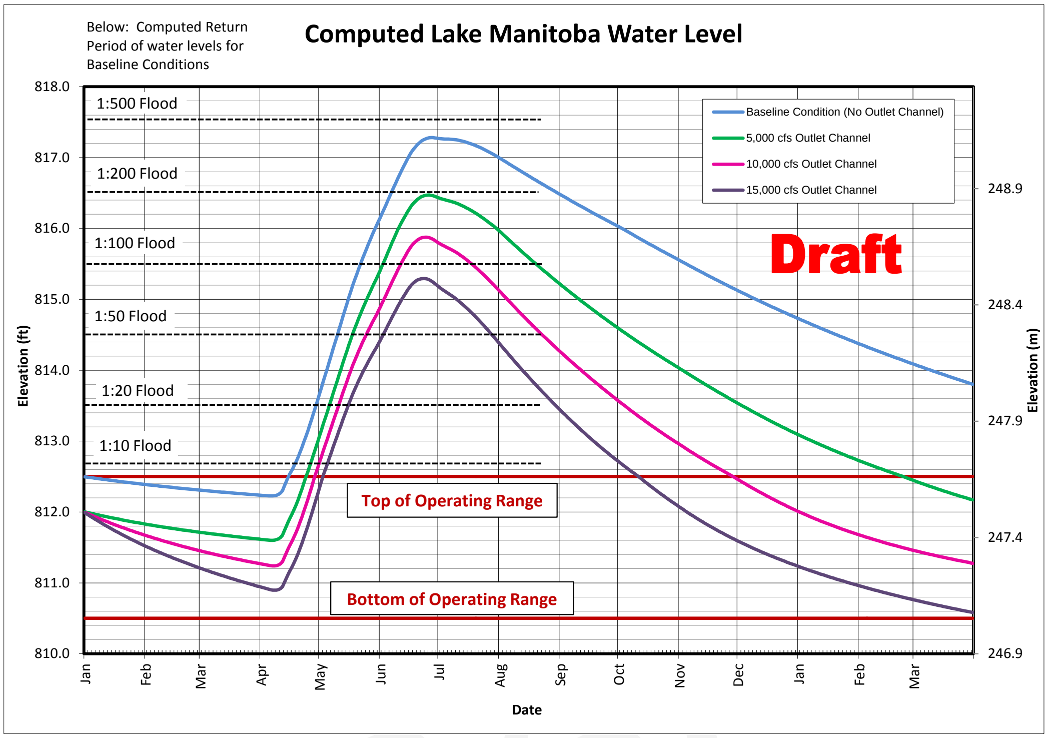


Figure 17 – Computed Lake Manitoba Water Level Hydrographs

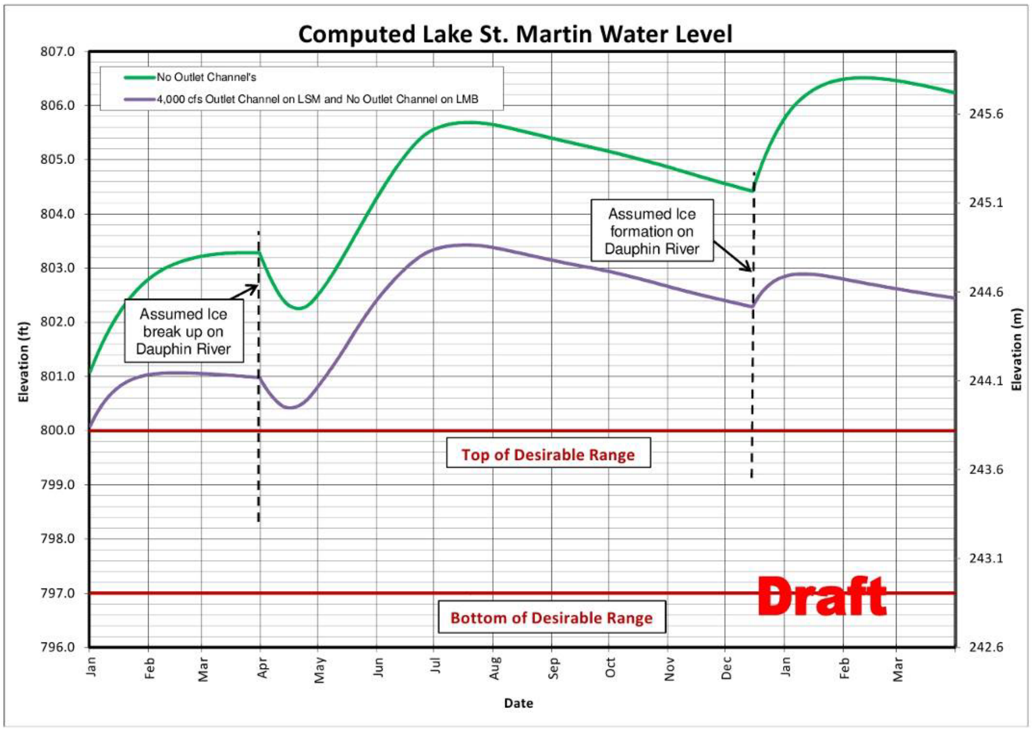


Figure 18 – Computed Lake St. Martin Water Level Hydrographs

The results of the flood routing were used to generate a relationship of Assiniboine River flood volume, local Lake Manitoba inflow and peak Lake Manitoba water level, as shown on Figure 19. By interpolating between lines on the figure, an estimated peak water level on Lake Manitoba can be obtained for any combination of flood volume from any of the two basins.

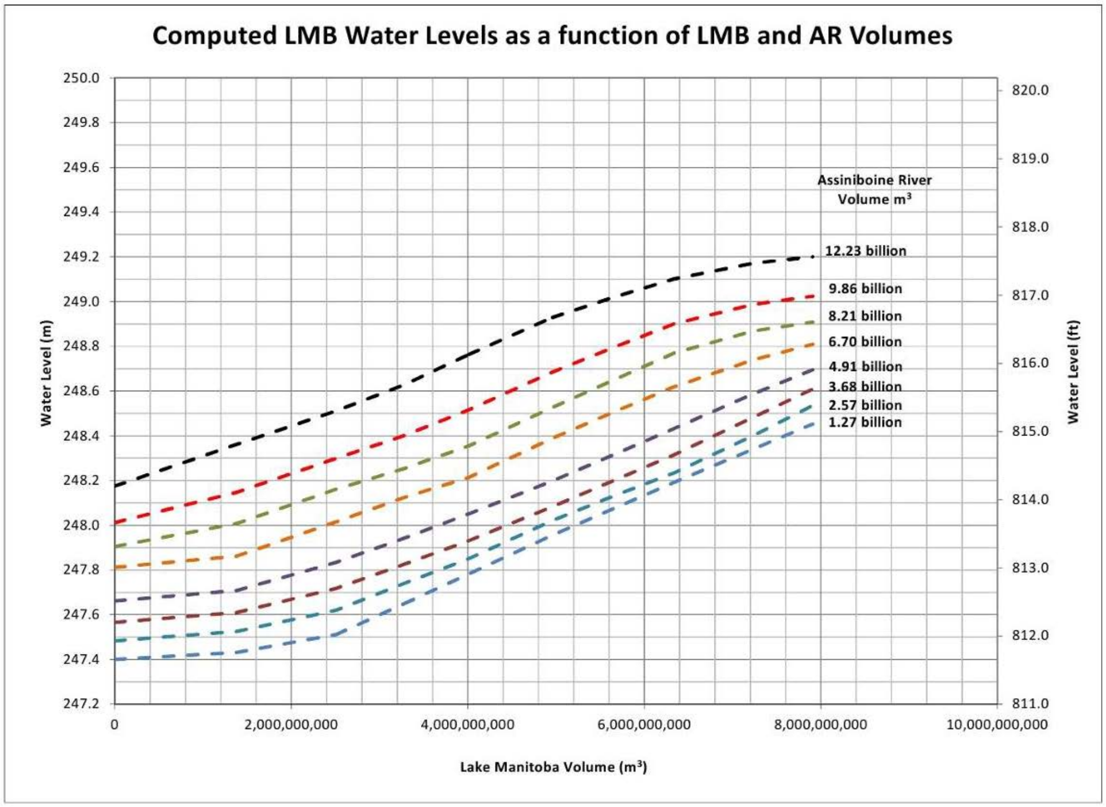


Figure 19 – Computed Lake Manitoba Water Levels

A relationship was also developed to determine the reduction in water levels on Lake Manitoba due to operation of an outlet channel as shown on Figure 20. By interpolating between lines on the figure, the reduction in Lake Manitoba water levels can be obtained for any size of outlet channel, and for any peak water level for the base case condition.

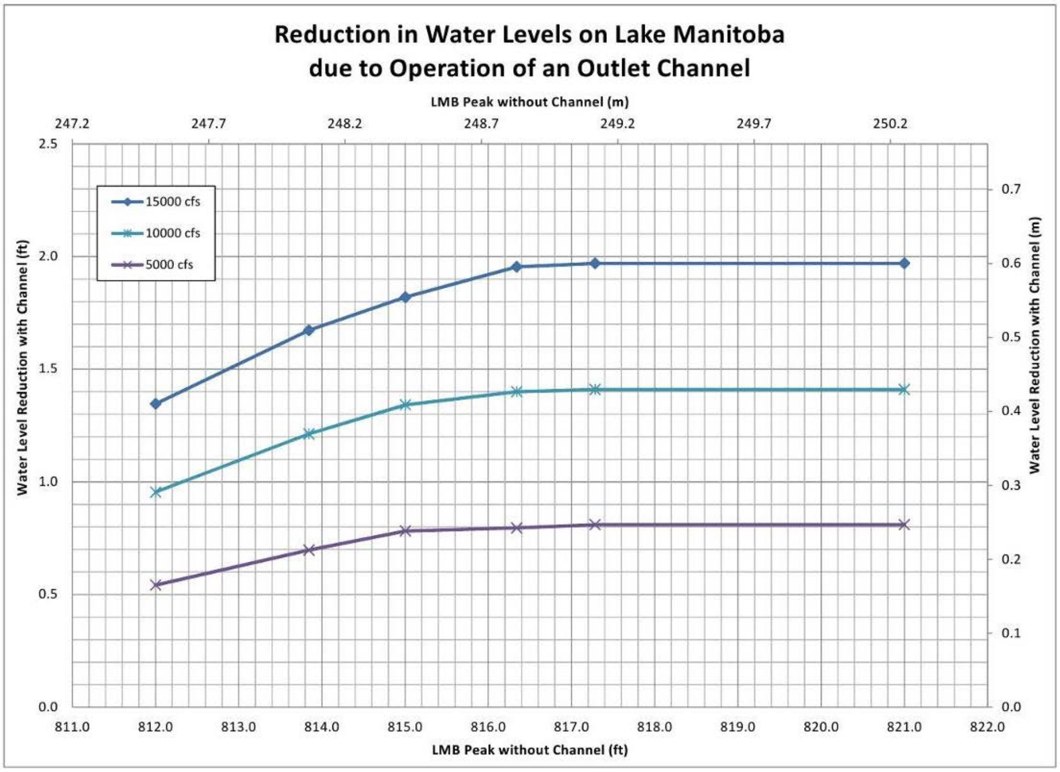


Figure 20 – Reduction in Water Levels on Lake Manitoba due to Operation of an Outlet Channel

A relationship was developed between Lake Manitoba and Lake St. Martin to determine the peak water levels on Lake St. Martin with and without the base case for the permanent Reach 1 channel with a design flow of 113 cms (4,000 cfs). This is shown on Figure 21. Without the Reach 1 channel, the peak water level on Lake St. Martin was computed to occur in the summer for small flood events. However for large floods, the peak water level was computed to occur in the winter due to discharge restrictions caused by ice in the Dauphin River. By contrast, with a permanent Reach 1 channel in operation, the peak water level on Lake St. Martin was computed to always occur in the summer, regardless of whether a discharge restriction due to ice was assumed in Reach 1. A sensitivity analysis of assumed ice conditions is provided in Section 5.3.4.

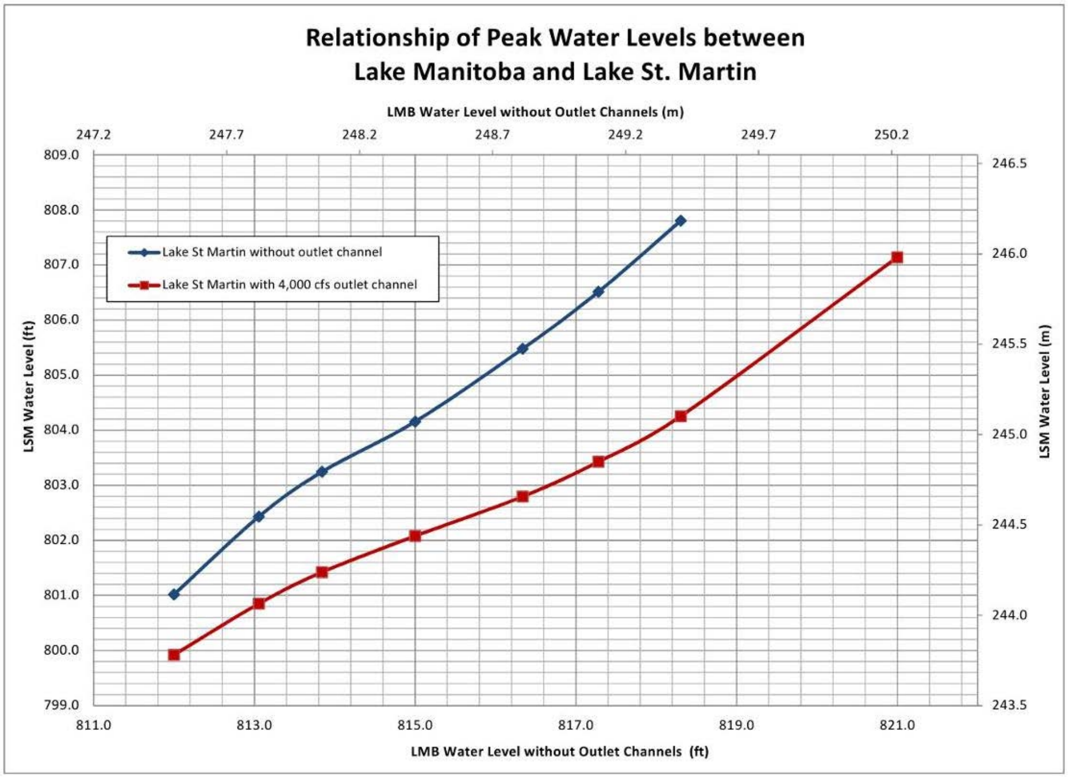


Figure 21 – Relationship between Peak Water Levels on Lake Manitoba and Lake St. Martin

As discussed in Section 4.2, the governing principal for the design of the Lake Manitoba / Lake St. Martin channel is that there should be no net increase in flow to Lake St. Martin above the base condition of the existing Reach 1 channel. All Lake St. Martin outlet channel alternatives, therefore, assumed the design flows were in addition to the outflow capacity of the existing Reach 1 of 113 cms (4,000 cfs). For this reason, the relationship developed with a permanent Reach 1 channel was also used for the other Lake St. Martin outlet channel alternatives. It is recognised that due to the routing effects through Lake St. Martin, and the reduced peak water level on the lakes from operating the outlet channels, the actual relationship between Lake Manitoba and Lake St. Martin would vary between alternatives; however, at this concept phase of study, the computed relationship for Reach 1 which has a design flow of 113 cms (4,000 cfs) was considered representative.

As discussed in Section 5.3.2, a maximum discharge capacity for the Portage Diversion was assumed to be 963 cms (34,000 cfs) for this analysis. This is more than the original design capacity of the Portage Diversion, which is 708 cms (25,000 cfs). To determine the effects of assuming a 963 cms (34,000 cfs) Portage Diversion Capacity instead of the existing 708 cms (25,000 cfs) capacity, Portage Diversion hydrographs were developed for the existing 708 cms (25,000 cfs) capacity based on the methodology outlined in Section 3.3.2 and were routed through Lake Manitoba.

It was determined that peak water level on Lake Manitoba with the existing 708 cms (25,000 cfs) Portage Diversion capacity was approximately 0.03 m to 0.12 m (0.1 ft to 0.4 ft) less than with an assumed 963 cms (34,000 cfs) capacity. On Lake St. Martin, the corresponding peak water level was at most 0.06 m (0.2 ft) less.

5.3.4 Sensitivity Analysis

Sensitivity analyses on the computed peak water level on Lake Manitoba and Lake St. Martin were assessed for the following hydraulic assumptions:

- Ice effects in the channels.
- Starting water level.
- First day of simulation.

The results of the sensitivity analyses on the computed peak water levels are discussed below. From an economic perspective, the effects of changing any of the hydraulic assumptions discussed below were found not to change the conclusions of the economic analysis. This is discussed in Section 9.4.2 of this report.

Sensitivity to Ice Effects

As discussed in Section 5.3.2, it was assumed for the base conditions that ice would not form in the outlet channels. This assumption was based on experience from the 2011 flood. The effects of an ice cover on the Lake Manitoba and Lake St Martin outlet channels to peak water levels was determined using a stage-discharge relationship representing the best estimate of the worst case ice conditions. The stage-discharge relationships of the different channel alternatives are provided in Section 5.3.1. Discharge restrictions due to ice were assumed to occur between January 1 and March 31.

For Lake Manitoba, if ice were to be assumed to form on the outlet channel, this was computed to cause an increase of approximately 0.03 m (0.1 ft) to the peak water level of the lake. Conversely, on Lake St. Martin, assumption of formation of ice on the outlet channel was shown to cause an increase of approximately 0.3 to 0.6 m (1 to 2 ft) to the peak winter water level of the lake. However, the computed peak winter level did not exceed the computed peak summer level. As discussed in Section 5.3.3, with a permanent Lake St. Martin Outlet Channel, the peak water level on Lake St. Martin was computed to always occur in the summer.

Sensitivity to Starting Water Level

As discussed in Section 5.3.2, the assumed baseline condition for the starting water level on Lake Manitoba was 247.65 m (812.5 ft) on January 1, without the outlet channels. The exact water level at the start of a flood event, however, varies depending on timing of the flood and antecedent conditions. To understand how the starting water level on January 1 affect the peak lake level during a flood, flood hydrographs were also routed based on starting water levels of 247.2 m (811.0 ft) and also 247.8 m (813.0 ft). The computed peak Lake Manitoba levels were shown to decrease by approximately 0.12 m (0.4 ft) when starting at an elevation of 247.2 m (811.0 ft) and increased by approximately 0.06 m (0.2 ft) when starting at an elevation of 247.8 m (813.0 ft).

Sensitivity to the First Day of Simulation

To understand how the first day of simulation affects the peak Lake Manitoba level during a flood, flood hydrographs were also routed using April 1 as the first day of simulation. The computed peak water level on Lake Manitoba was shown to increase by approximately 0.12 m (0.4 ft) when starting at 247.7 m (812.5 ft) on April 1. If starting at a different water level than the baseline condition on April 1, the computed peak water level on Lake Manitoba was shown to decrease by approximately 0.15 m (0.5 ft) when starting at 247.2 m (811.0 ft) and increased by 0.15 m (0.5 ft) when starting at 247.8 m (813.0 ft).

5.4 WIND SETUP ANALYSIS

The Monte Carlo approach that was adopted and is described in subsequent sections of this report generated thousands of wind setup events on Lake Manitoba at different locations around the lake. The magnitude of rise of the Lake Manitoba water level for each event was determined based on the wind setup analysis as described below.

5.4.1 Estimation of Wind Setup

A wind setup computer program developed by the Province of Manitoba was used for the analysis. The methodology used in the program follows the procedures in the USACE Shore Protection Manual, 1977 edition (USACE 1977). The program is a one-dimensional model, which computes wind setup along a user-defined axis at different time increments associated with a given wind speed. The model utilized a finite difference approach of the differential equations of wind setup rather than using the explicit solution (e.g. the Zuider Zee formula). Specifically, the program solves Equations 3-103, 3-104, and 3-105 in the Shore Protection Manual. Wind data was provided by the Province of Manitoba.

Wind setup around Lake Manitoba is variable as determined by the variation in wind speed by direction and the variability of the shoreline due to the irregular shape of the Lake. To account for this variability, wind setup was computed at 32 locations around the lake. The variability of the wind speed by direction was determined from wind frequency by directional charts (wind roses) developed for the South Basin of Lake Manitoba by Custom Climate Services and provided by Manitoba Infrastructure and Transportation. Due to the relatively large size of the lake, it was estimated that a minimum duration of six (6) hours would be required to fully setup the water level.

Due to the constriction in the width of the Lake at the Narrows, the North and South pools of Lake Manitoba were assumed to be independent and separate wind setup analyses were conducted for each pool. Major and minor axes directions were defined for each pool. The major axis was defined along the longest length of the lake with the minor axis defined perpendicular to the major axis. Lake cross sections were defined for each pool perpendicular to the axis direction. Winds were applied to the axis if the angle between the directions of the wind and the axis was less than 90 degrees (clockwise and counter clockwise). To compute setups for the four cardinal and four ordinal directions, two axes were used for each pool.

For the north pool, the two axes were North-South and West-East which consisted of four cardinal directions, namely north, south, west and east. For the south pool, the two axes were the cardinal directions of NW-SE and NE-SW axis. Cross sections were defined and were evenly placed orthogonally to the axes. Figures 22 and 23 illustrate the cross section locations for the south and north pools, respectively.

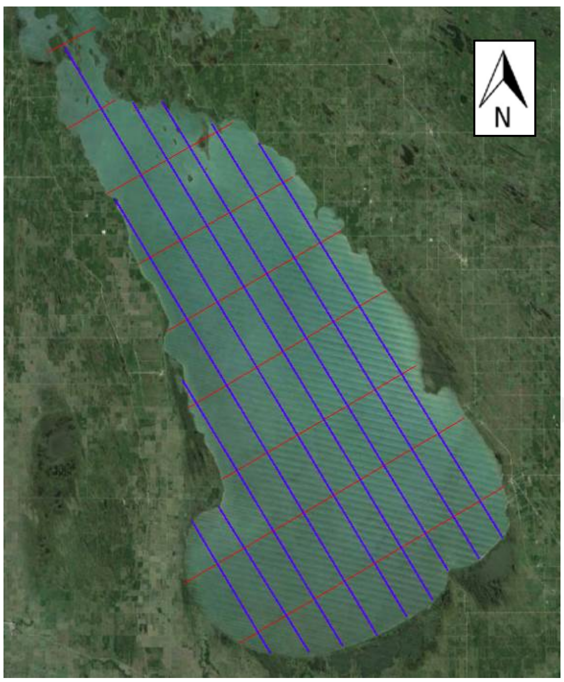


Figure 22 – Cross Sections on South Pool

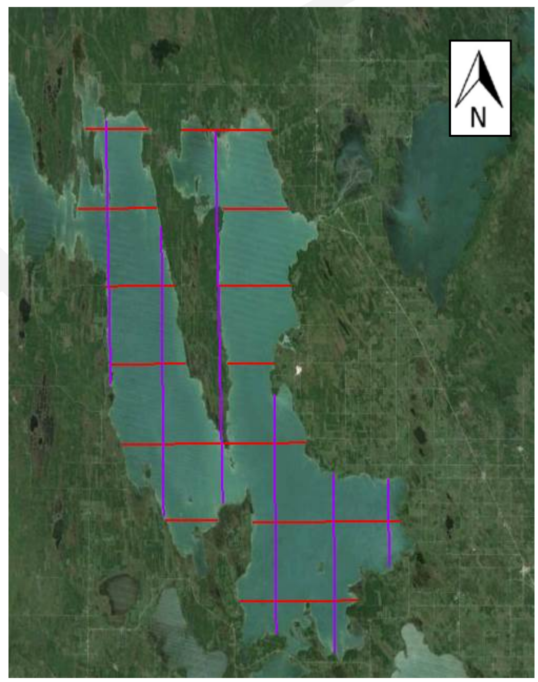
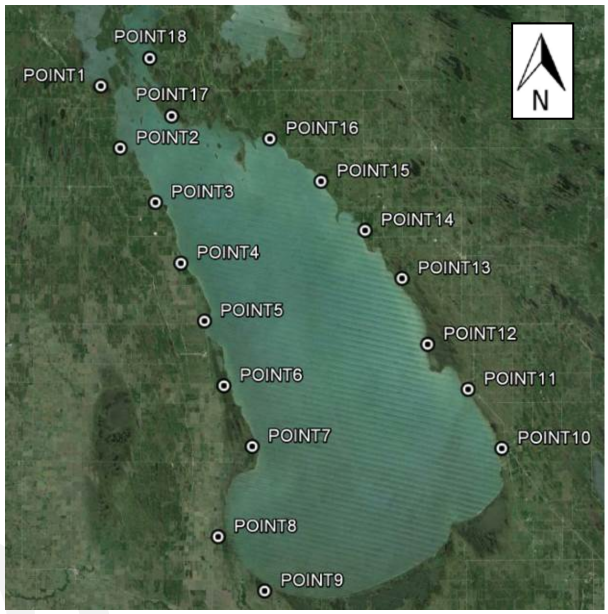


Figure 23 – Cross Sections on North Pool

Rectangular cross sections were assumed with the width and depth obtained from the hydrographic maps published by the Canadian Hydrographic Service. Other inputs to the model include: number of cross sections, cross section spacing, computational time step, magnitude of the wind speed for the return period, the still water level and the angle between the wind directions and the axis.

The computed setup at each cross section was assumed to apply equally at all locations along the section. The setups at the opposite shore were, therefore, computed equally for the wind direction that was applied. The maximum setup for the chosen return period at each point along the shoreline was similarly computed for all wind directions, and the maximum value was selected for the setup.

Figures 24 and 25 show points along the lake shore where the setups were computed.



Figures 24 – Computation Points on South Pool

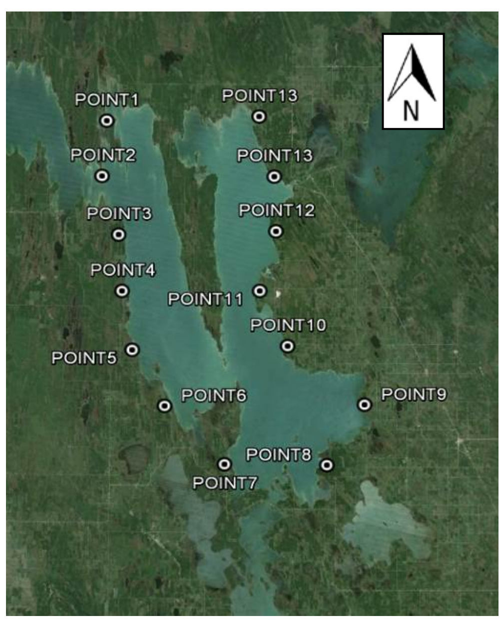


Figure 25 – Computation Points on North Pool

Wind setup typically varies inversely proportionally to the depth of the lake. However, results of the numerical model showed that the variation in possible Lake Manitoba depths did not appreciably affect the computed setup. The wind setup was shown to be much more sensitive to the wind speed and lake geometry rather than to water depth. It was therefore assumed for this study that the maximum wind setup is independent of still water level (SWL). A constant SWL of 247m (810.2 ft) was selected for all setup computations. For an assumed constant SWL of 249.0 m (816.9 ft) the wind setup was determined to decrease by approximately 0.10 to 0.15 m (0.3 to 0.5 ft), depending on location around the lake, during a wind event with an average 6h wind speed of 75 km/h (47 miles/h). This decrease in water level would be even less for a more frequent wind event with lower wind speeds. On this basis, it was determined that using the SWL of 247 m (810.2 ft) to determine wind setup was a conservative assumption.

5.4.2 Results

At each chosen point (see Figures 24 and 25), wind setups under all possible combinations of wind speeds and angles between axis and wind were computed. The maximum among the combinations was taken as the maximum wind setup at a given location. Each maximum wind setup is associated with a return period that is the same as the return period of the wind speed, thus the wind setup is fully dependent on wind speed. Figures 26 to 29 summarize the results of modeled wind setup at each point along the west shore of north pool, east shore of north pool, west shore of south pool and east shore of south pool, respectively.

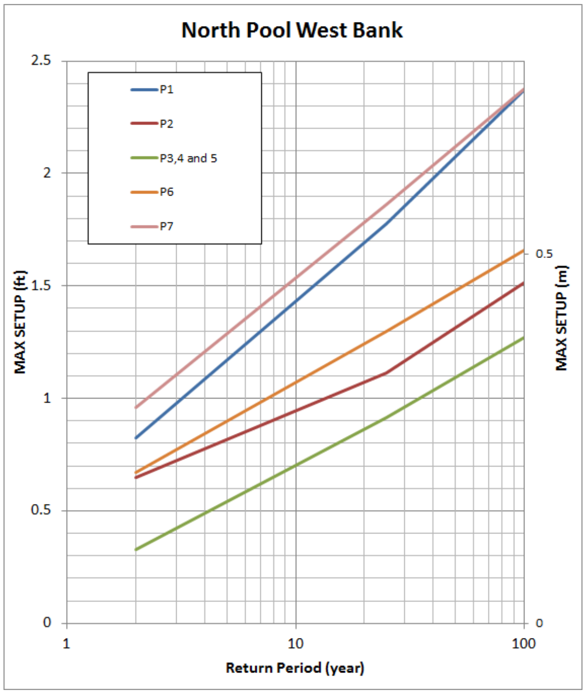


Figure 26 – Wind Setup on West Shore of North Pool

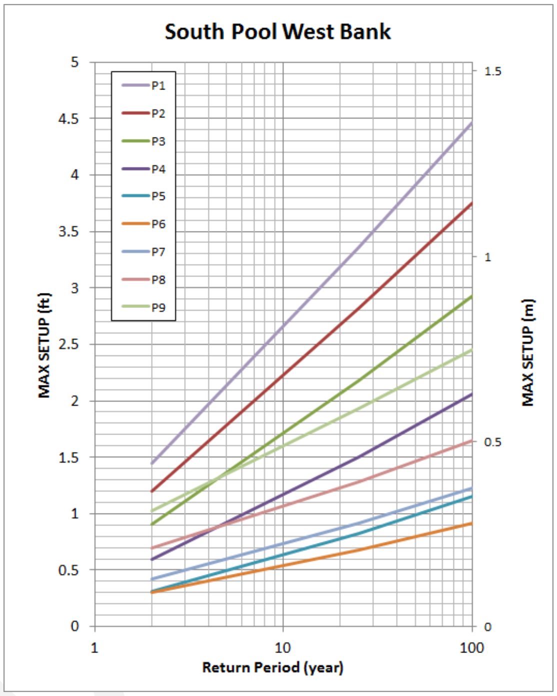


Figure 28 – Wind Setup on West Shore of South Pool

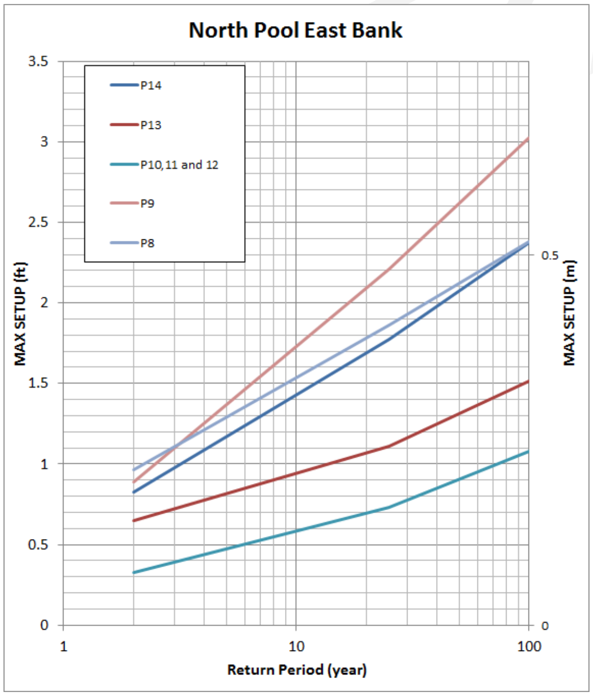


Figure 27 – Wind Setup on East Shore of North Pool

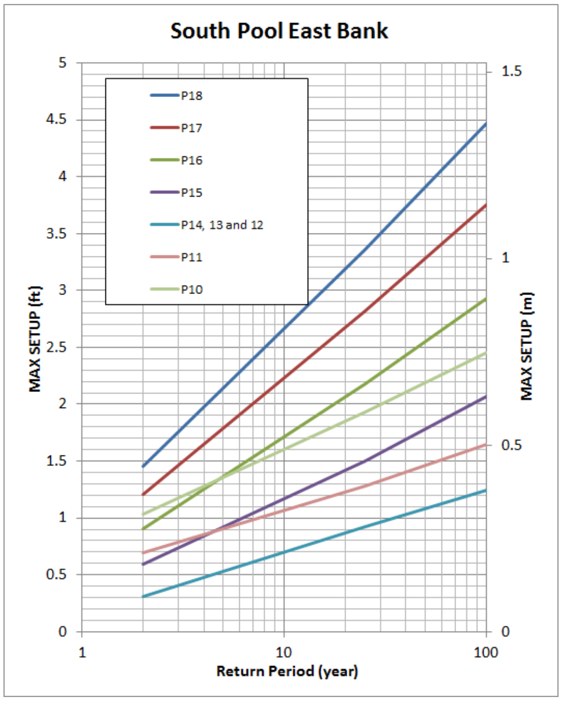


Figure 29 – Wind Setup on East Shore of South Pool

The results of the model simulations were compared to the recorded setup data on Lake Manitoba at the WSC stations at Westbourne and Steep Rock. The location of the two WSC stations and the closest points of the 1-D model are shown on Figures 30 and 31.

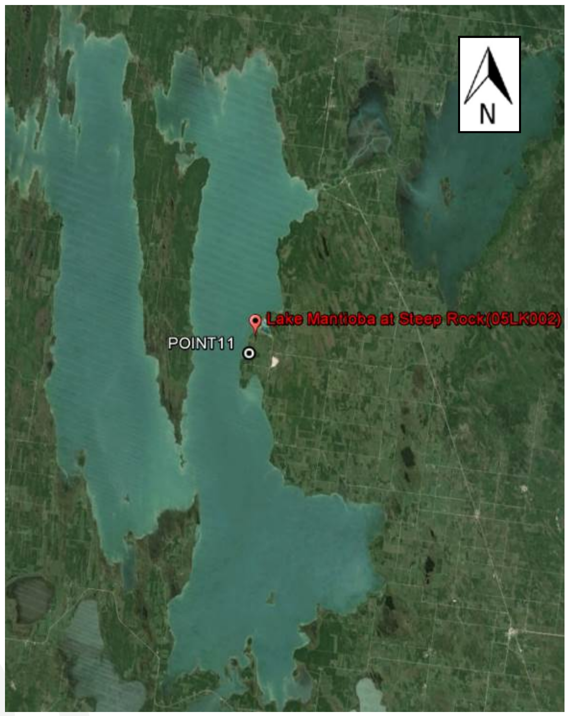


Figure 30 – Location of Steep Rock and Point 11 of 1-D Model

Figure 31 – Location of Westbourne and Point 9 in 1-D Model

The recorded wind setup was estimated at the two stations by subtracting the recorded average daily lake levels from the normalized lake level. This method of calculating wind setup is an approximation as it uses average daily levels instead of instantaneous levels. A frequency analysis was then computed on the recorded wind setup. Table 11 summarizes the results of the frequency analysis and the computed wind setup using the 1-D model.

TABLE 11: COMPARISON OF MODELLED AND RECORDED WIND SETUP AT STEEP ROCK AND WESTBOURNE

North Pool Wind Setup (m)			
	2 year	25 year	100 year
Steep Rock	0.10	0.17	0.21
1-D model(Point 11)	0.08	0.22	0.32
South Pool Wind Setup (m)			
Westbourne	0.33	0.64	0.81
1-D model(Point 9)	0.33	0.59	0.75

As shown on Table 11, the computed wind setup values compared reasonably well to the wind setup calculated from recorded water levels, considering that both methods are only approximations of what the actual wind setup could be under a series of assumed conditions. In addition, the results of the frequency analysis showed that the computed wind setup values fitted a lognormal distribution. A one sample KS test used to test this assumption passed with high p values equal to 0.91 and 0.88, respectively.

5.4.3 Wave Uprush

The magnitude of wave uprush on a structure depends on numerous variables such as shoreline conditions, distance from the shoreline, steepness of slope, depth of water and slope roughness, which are all unique to the shoreline location. In addition this data is not available for every single structure at risk of flooding around Lake Manitoba. Simplistic assumptions and approximations were therefore required for the estimation of wave uprush to be used for the combined wind and wave effects water level for use in the damage assessment in this study.

A single value for the wave uprush was used to represent the wave uprush around the lake, regardless of the location. A number of wave uprush conditions were determined for different wave conditions on Lake Manitoba. The wave characteristics were determined based on methods outlined in the USACE 1984 Shore Protection Manual (USACE 1984). Wave uprush was determined based on the USACE momentum flux equation. The results showed that, on average, the magnitude of wave uprush was approximately equal to the magnitude of wind setup (i.e. 0.5 m of setup translated also to 0.5 m of wave uprush). It was determined that the average contribution of wind setup to the combined water level (all events included) ranged between 0.6 m to 0.75 m (2 to 2.5 ft). A conservative wave uprush value of 0.7 m (2.25 ft) was selected. The application of wind setup in the Lake Manitoba damage model is discussed in in Section 9.1.

For comparison purposes, the computed wave uprush values were compared with wave uprush values determined by the Province of Manitoba for the calculation of the Flood Protection Level on Lake Manitoba as outlined in the February 16, 2012 memorandum entitled, “Flood Protection Level Determination – Lake Manitoba South Pool” (MC&WS-1 2012) and in the February 21, 2012 memorandum entitled “Flood Protection Level Determination - Lake Manitoba North Pool”

(MC&WS-2 2012). The average wave uprush was determined to be 0.65 m (2.14 ft) in the memorandum for the South pool. These results concur with the 0.7 m (2.25 ft) wave uprush value selected for this study. Furthermore, the results of the Province of Manitoba memorandum for the North pool showed that the average wave uprush on the North pool on Lake Manitoba was less than on the South pool. The assumption of 0.7 m for the wind uprush for both north and south pools is considered to be conservative.

5.5 MONTE CARLO ANALYSIS

5.5.1 Description of Model to Generate Still Water Levels of Lake Manitoba

As discussed in Section 5.2, a Monte Carlo analysis was used to generate a large number of combined flood volumes of the Assiniboine River local Lake Manitoba inflows. This formed the stochastic dataset of flood events in each basin. The random flood volumes for the two basins were generated based on the statistical distribution and correlations of the observed volumes in the historical record.

The calculation of the Assiniboine River flood volumes and the observed volumes of local Lake Manitoba inflow was discussed in Section 5.3.2. The statistical distributions of observed Assiniboine River and local Lake Manitoba inflow volumes were selected as lognormal and Gumbel distributions, respectively, based on a visual comparison of the "goodness of fit" of the theoretical distribution to the actual recorded data. Comparisons of the theoretical distributions with the empirical distributions of the observed volumes are shown in Figures 32 and 33.

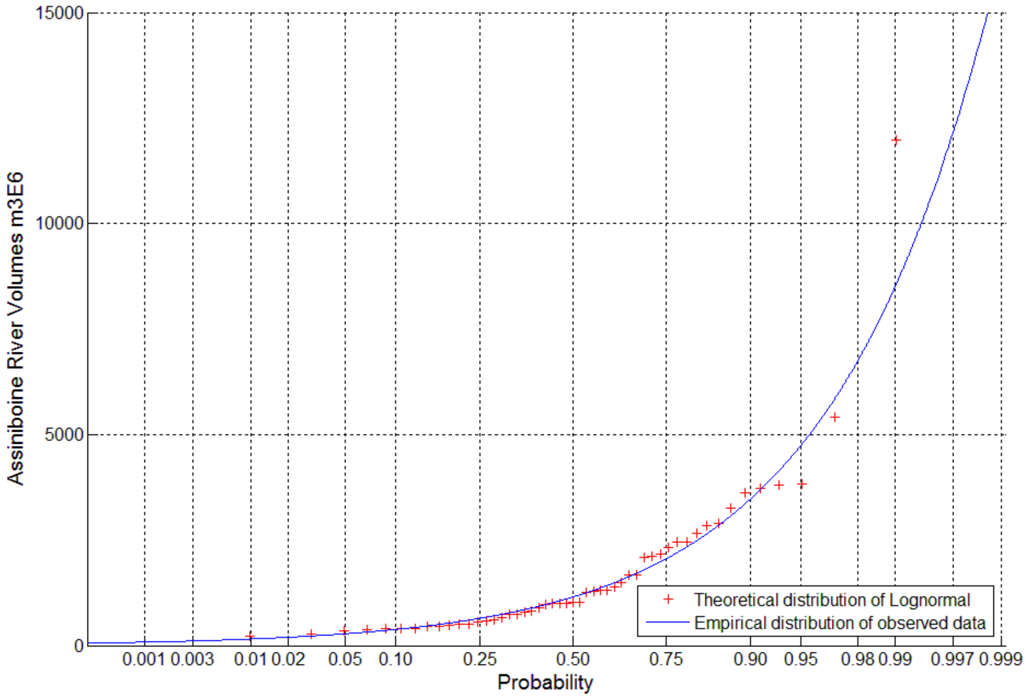


Figure 32 – Statistical Distribution of Assiniboine River Volumes

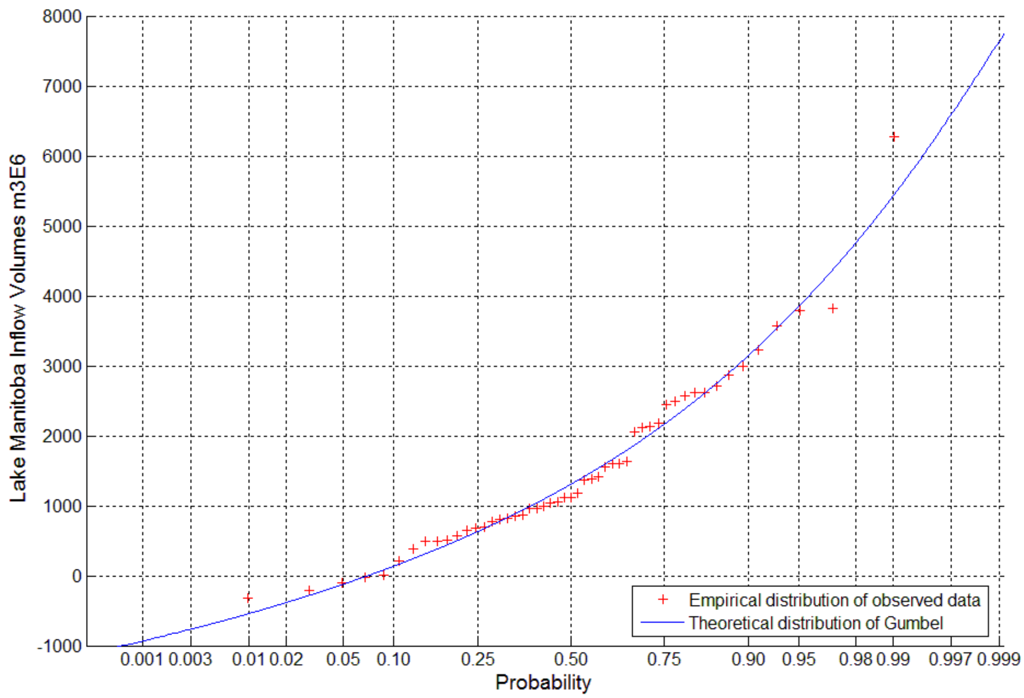


Figure 33 – Statistical Distribution of local Lake Manitoba Inflow Volumes

The generation of the 5,000 synthetic combined flood volumes was done using the MATLAB™ software.

For each synthetically generated flood event, the peak Lake Manitoba water level was determined based on the results of the routing model discussed in Section 5.3.3 using the relationship between Lake Manitoba water level and volumes of the Assiniboine River and of local Lake Manitoba inflows shown on Figure 19. A frequency curve of the computed peak water level was then generated to obtain the probability of exceedance of still water levels (SWL) on Lake Manitoba.

5.5.2 Description of Model to Generate Wind Setup on Lake Manitoba

A Monte Carlo analysis was also used to generate wind setup events that coincide with the 5000 synthetically generated flood events that were described in Section 5.5.1. Stochastic simulation of wind setup with a Monte Carlo approach requires knowledge of the distribution of the wind setup data. KGS Group assumed a lognormal distribution based on results of the Wind Setup Analysis discussed in Section 5.4.2. Parameters of lognormal distribution were then calculated for the previously computed wind setup at each of the 32 point locations (see Figures 24 and 25). These parameters were then used to populate stochastic wind setups at each location.

The “Combined Water Level” (CWL) was then calculated at each of the 32 point locations for the synthetically generated flood events. As discussed in Section 5.4.1, changes in SWL do not cause significant changes in wind setup. The SWL and wind setup were, therefore, assumed to be statistically independent events. This assumption allowed the generation of SWL and wind setup with independent random generation techniques, and the summation of the generated values to determine the CWL for a particular synthetic event.

5.5.3 Results

A comparison of volumes generated from the Monte Carlo model and the observed historic volumes in the two basins is shown on Figure 34. The Figure shows that the observed and stochastic volumes follow a similar trend, as depicted by the polynomial fit of the two different data series.

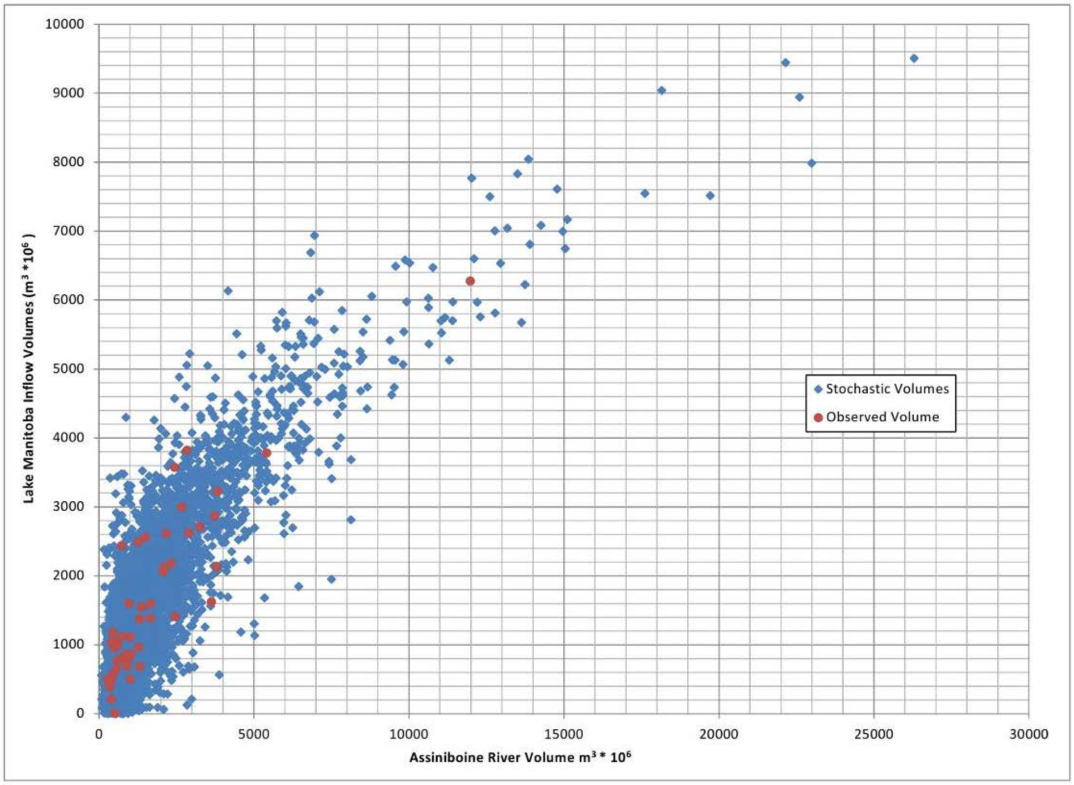


Figure 34 – Comparison between Stochastic Volumes and Observed Volumes

Based on the results of the flood routing model discussed in Section 5.3.3, a peak Lake Manitoba water level was determined for each of the stochastic flood events generated. These formed the basis of a frequency curve of the stochastic peak annual water levels on Lake Manitoba for Still Water Level (SWL) conditions.

In addition, for comparative purposes, and to examine how the synthetic water levels compare with other assumptions, KGS Group also developed other frequency curves. These represent the SWL of Lake Manitoba for the following separate hypothetical scenarios:

- Lake Manitoba inflow volumes and Assiniboine River flood volumes exactly as recorded from 1961 to 2011. Only 51 data points are available.
- Lake Manitoba inflow volumes and Assiniboine River flood volumes are assumed to be fully statistically dependent (e.g. an event with a Lake Manitoba flood volume with an

annual probability of being equal or greater than X% will always combine with an Assiniboine River Flood Volume with an annual probability of being equal or greater than X%).

- Lake Manitoba inflow volumes and Assiniboine River volumes are fully statistically independent (i.e. no statistical correlation whatsoever between flood volumes in each basin exists).

The frequency curves of the stochastic SWLs compared to the SWLs interpolated from observed volumes are shown on Figure 35.

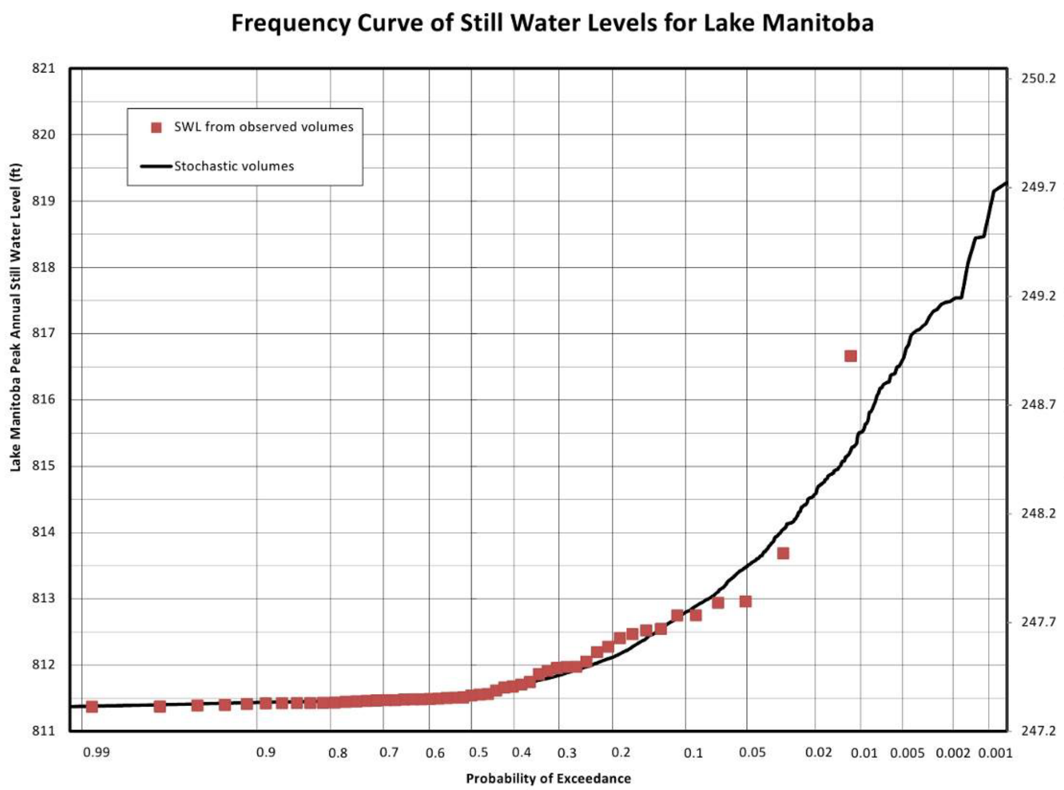


Figure 35 – Computed Frequency Curve of Still Water Levels on Lake Manitoba Compared to Levels from Observed Values

The frequency curves of the stochastic SWLs compared to the hypothetical SWLs under conditions of statistical dependency and statistical independency are shown for comparative purposes only on Figure 36.

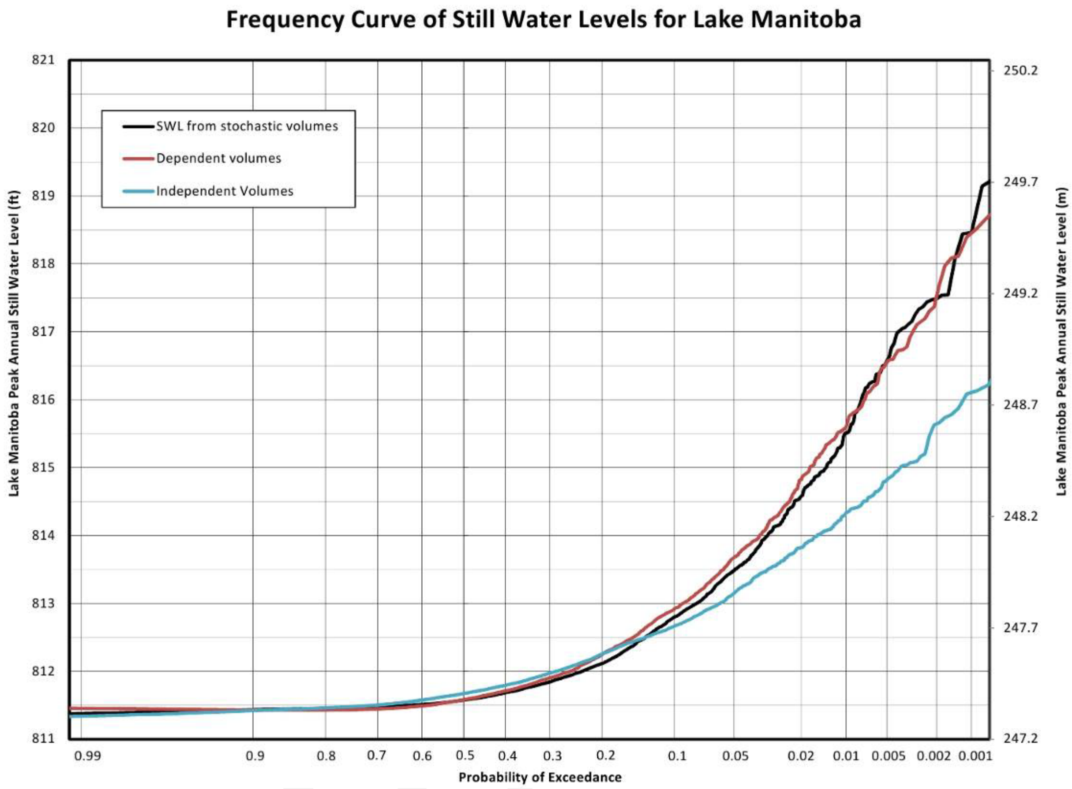


Figure 36 – Computed Frequency Curve of Still Water Levels for Lake Manitoba Compared to Conditions of Statistical Dependency and Independency

The frequency curve of Lake Manitoba SWL with the different outlet channel alternatives was determined by adjusting the stochastic SWLs based on the relationships developed between peak Lake Manitoba water levels and reduction in water levels due to operation of an outlet channel provided in Figure 20 and discussed in Section 5.3.3. The frequency curves are shown on Figure 37.

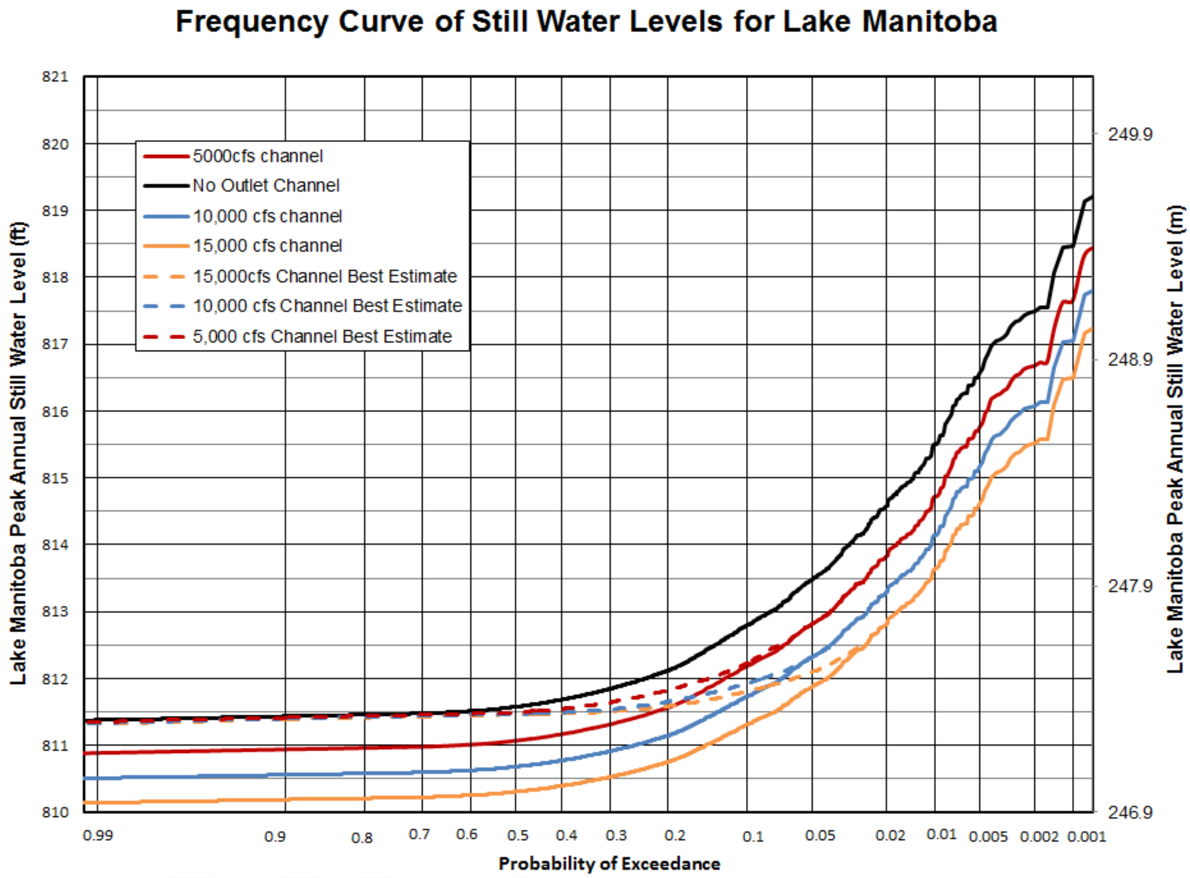


Figure 37 – Frequency Curves of Still Water Level on Lake Manitoba with an Outlet Channel

Since the flood routing scenarios from which the relationships were developed do not consider changes in gate operation at the FRWCS or closure of the Lake Manitoba outlet channel when Lake Manitoba levels are within the normal operating range of 247.04 m and 247.65 m (810.5 ft to 812.5 ft), the frequency curves for high frequency events (i.e. events where the peak water level is below 247.65 m or 812.5 ft) are conservatively high. In all likelihood, the FRWCS and Lake Manitoba outlet channel would be operated to control the lake level within its normal operating range during such routine flood events. A best estimate of what the actual frequency curve at the lower range would be has been included on Figure 37. A sensitivity analysis of a change to the frequency curve at high frequencies to the results of the benefit-cost analysis has been included in the section of this report that describes the economic analysis.

The frequency curves of Lake St. Martin SWL, with and without a 113 cms (4,000 cfs) Reach 1 outlet channel were determined using the frequency curve of Lake Manitoba SWLs and the relationships developed between Lake Manitoba peak water levels and Lake St. Martin peak water levels provided in Figure 21 and discussed in Section 5.3.3. The resultant frequency curves are provided in Figure 38.

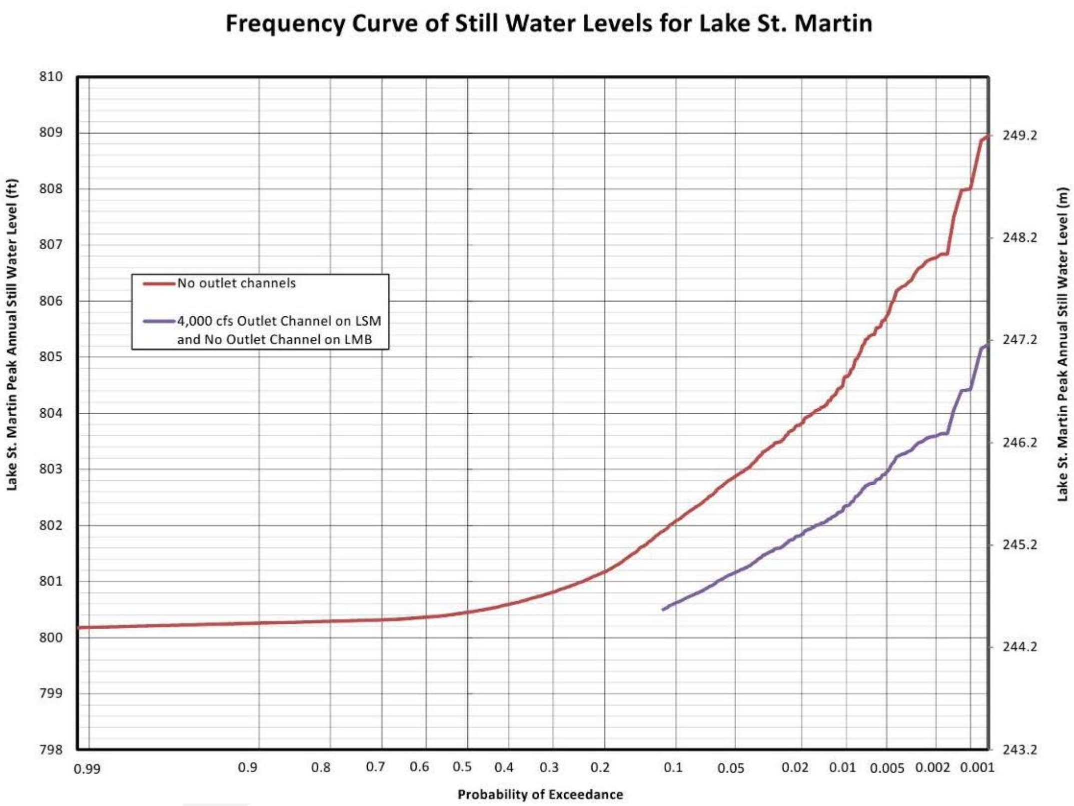


Figure 38 – Frequency Curve of Still Water Levels for Lake St. Martin

Frequency plots were also developed based on stochastic CWL at the north and south pools respectively with and without outlet channel alternatives. Representative frequency curves at 3-point locations on the north and south pools are shown in Figures 39 and 40 for conditions without an outlet channel on Lake Manitoba. The CWL frequency curves show that the CWL on Lake Manitoba varies around the lake due to the varying contribution of the wind setup for a given return period.

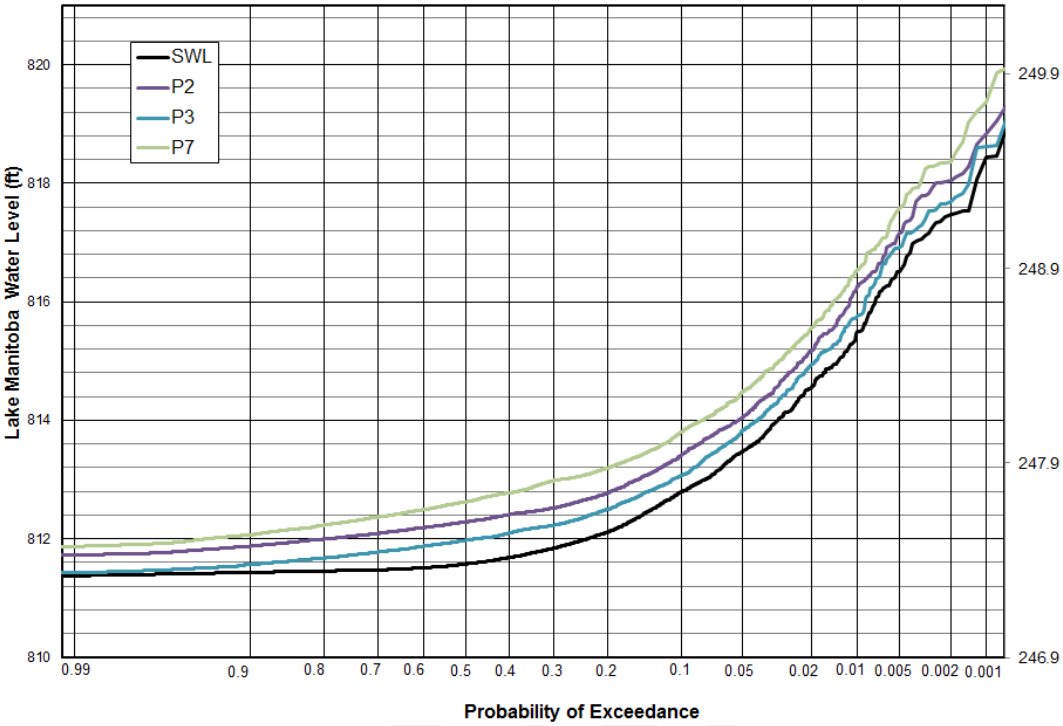


Figure 39 – Frequency Curve of CWL at North Pool

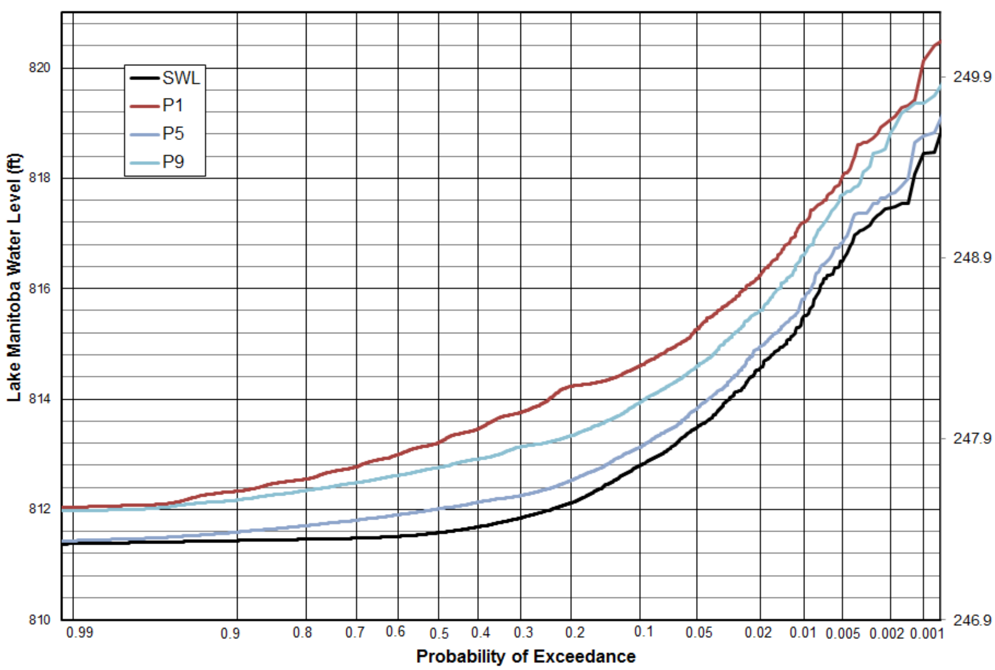


Figure 40 – Frequency Curve of CWL at South Pool

6.0 COST ESTIMATES

An integral element in selecting a preferred alternative is a definition of the project components and the subsequent funding that would be required to develop each channel option. The following section describes the basis for the costing and provides a breakdown of the major items in the cost estimate for each of the proposed outlet channel options for Lake Manitoba and Lake St. Martin. The project requires a combination of one Lake Manitoba option and one Lake St. Martin option (Reach 1, Reach 2, and Reach 3) to effectively mitigate flooding on the two lakes. However, at this time summary costs are not provided for combinations of the more probable channel options.

6.1 BASIS OF ESTIMATES

The cost estimates proposed in the following section are based, in part, on the preliminary estimates included in the Analysis of Options for Emergency Reduction of Lake Manitoba and Lake St. Martin Levels (KGS Group and AECOM 2014). The cost estimates include many of the same components previously defined in the Analysis of Options report including control structures, bridges, excavation volumes and land acquisition. The standard widths of control structures as well as PTH and municipal bridges were assumed to be the same as those defined in the Analysis of Options report (14 m, 12 m, and 10.8 m, respectively). However, the dimensions of the channels and corresponding excavation volumes and structure lengths have been substantially updated in this report based on the more advanced hydraulic assessment of each option. Additional project components included in the current cost estimate table that were not previously examined in detail include rock riprap, permanent access roads, rail bridge removal, construction camp, re-vegetation and mitigation costs.

The basis for the unit measures and prices for preliminary use in this study was previously issued in a memorandum titled, “Draft Guidelines for Economic Analysis of Flood Protection Options, Rev B”, and has been appended to this report (Appendix A). The unit measure/prices established in the memorandum to estimate costs at a conceptual level of study are consistent with cost estimates used for the evaluation of other Assiniboine River and Lake Manitoba Basin alternatives and included the following:

- Unclassified earth excavation ($10/cubic metre).

- Excavation in the wet – for option F ($25/cubic metre).
- Rock excavation ($25/cubic metre).
- Control structure construction ($9,200/square metre – footprint area).
- PTH Bridge ($5,200/square metre – area of deck).
- Municipal Road Bridge ($2,500/square metre – area of deck).
- Land acquisition/buyouts ($5,000/hectare).
- Acquisition/buyouts of residences, farms, etc. (100-150% of assessed value).
- Contingency (30% of the direct and indirect costs).

The above unit measures and prices include mobilization/demobilization, but do not account for indirect costs such as engineering fees, construction administration, or approvals. As such, a 20% increase (of construction cost) was added to the total construction cost estimate for each channel option in the current study to account for these elements. The following section describes how the costs for each component were developed for the various options and includes unit measures and pricing for updated project components that were not discussed in previous studies.

6.2 COST ESTIMATE DESCRIPTION

The estimated construction costs for the Lake Manitoba and Lake St. Martin outlet channel options are provided in Table 12. These were calculated based on the unit pricing and the quantities for each channel option as previously described in Sections 4.1 and 4.2. Details and clarifications for calculating quantities and/or unit pricing that were not previously described are provided in the following sections.

Excavation

Earth and rock excavation costs were calculated by multiplying the estimated volumes by the unit pricing. Option A was unique in that a premium was added to the unit pricing for earth excavation to account for the two locations where the alignment crosses the Fairford River as this will require excavation in the wet and localized modification of the riverbanks. As such a blended rate of $12/m^3$ was used for this option.

Option F was also unique in that it requires fill for machinery access to excavate the existing river channel down to the invert level. The fill volume required for construction was estimated to be 1,200,000 m^3 at $25/$m^3$. The cut volume below the water was estimated to be 1,800,000 m^3, plus an additional 1,200,000 m^3 to remove the temporary fill, at a unit price of $25/$m^3$. The cut volume above the water was estimated to be 680,000 m^3 at $10/$m^3$. The costs for the fill volume, and the cut volume above and below the water level for Option F were combined and input as a single entry into the cost table (Table 12) within the excavation category.

Rock Riprap

Rock riprap is required to armour the downstream side of concrete control structures and bridges. It will also be used for construction of rock fill gradient control drop structures along Reach 3, as previously described in Section 4.0. The cost for riprap armouring has been incorporated as part of the cost estimate for each concrete structure. Whereas the cost estimate for the rock fill gradient control drop structures is based on an estimated quantity of 11 gradient control structures for Willow Point and 12 structures for Johnson Beach and the footprint area of each structure.

The unit rate for the rock riprap cost estimate was based on the upper end of known costs for developing the East Side Road, an all-season road being constructed on the east side of Lake Winnipeg (estimated at approximately $60/cubic metre). This was done to account for the potential requirement of hauling rock riprap from existing off-site quarries, with the assumption that the bedrock at site is not suitable for use as riprap. This assumption was based on analysis of bedrock samples collected from the rock ridge at the Reach 3 site in 2012. The bedrock samples were submitted to MIT testing laboratories for LA abrasion, sulphate soundness, and specific gravity and absorption testing. The bedrock was found to be highly susceptible to mechanical breakdown (56% losses in the LA abrasion test) and freeze-thaw action (45% to 46% losses in the sulphate soundness test). The limestone had a specific gravity that ranged from 2.55 to 2.59, and was also found to be highly absorptive (3.0% to 3.4%). The results of the testing indicated that the local bedrock did not meet MIT riprap Standard Specification 1297 and would only be considered for temporary erosion protection (5 years or less) and emergency usage. It is possible that other sources of bedrock in proximity to the Lake St. Martin and Lake Manitoba channel options may be discovered and developed into quarries. However, a conservative value for the unit price of rip rap was used to account for the uncertainty in terms of bedrock quality.

Control Structures

The estimated concrete control structure costs for each option were calculated based on the footprint area of each structure and the number of structures required. This was estimated using the lengths calculated by KGS Group to provide the required capacity and a standardized 14 m width, which is based on the dimensions of the FRWCS. The control structure would have piers spaced at approximately 6 m and a bridge deck complete with hoisting structure from which the stoplogs could be removed manually when required to release flows. While the height and subsequent width of the control structure for the Reach 1 options may not be required to be as wide as the Lake Manitoba options, there is an unknown in terms of the footing requirements (will be built on till rather than bedrock). Therefore, a conservative value was considered more appropriate at this time.

Option F is unique in that it requires the addition of two bays to the existing FRWCS, which will require a cofferdam, temporary traffic control, and relocation of the existing abutment and approach. Therefore the actual footprint area of the additional two bays was increased for this option to account for the associated extra costs.

Bridges

The estimated bridge costs for each option were calculated based on the footprint area of each bridge and the number of PTH and municipal road bridges required. The footprint area was estimated using the lengths of the PTH bridges and the municipal bridges, which were calculated by KGS Group, and a standard width of 12 m, and 10.8 m, respectively. Because the PTH bridges will be built over the proposed control structures, the bridge lengths were based on the length of the control structures, whereas, the lengths for the municipal bridges were based on the average top width of the channel (in till sections). The standard widths of the bridges were based on the information developed for the Analysis of Options report. While Option D crosses PR 239, for the purposes of the cost estimate it was treated as a municipal road. As previously noted, it may be possible to reduce the number of new bridge crossings required for some options by localized realignment of roads.

Option F would require removal of the abandoned railway bridge to increase the capacity of the Fairford River. A lump sum allowance of $1.0 M was assumed, which includes the salvage value of the steel superstructure.

Land Acquisition

The area of land acquisition required for each channel option was estimated by multiplying the channel length by the width of an appropriate Right of Way (ROW). The ROW for each channel option was estimated by adding 140 m to the channel base width, which is comparable to distances used in the design of Reach 1 and Reach 3. The ROW represents the area of the channel top width, berms, spoil piles, drainage ditching and a buffer zone. The calculation of estimated land acquisition required for the Lake Manitoba Options is summarized in Table 13.

TABLE 13:
ESTIMATED LAND ACQUISITION

Option	Base Width (m)	ROW (m)	Channel Length (m)	Land Acquisition (ha)
A1	26	166	12300	204
A2	64	204	12300	251
A3	112	252	12300	310
B1	31	171	11500	197
B2	72	212	11500	244
B3	113	253	11500	291
C1	31	171	11600	198
C2	72	212	11600	246
C3	113	253	11600	294
D1	27	167	22800	381
D2	64	204	22800	464
D3	100	240	22800	546
E1	9	149	2150	32
E2	21	161	2150	35
F	95	180	18700	336

Permanent Access Roads

The Lake Manitoba outlet channel options will not require significant development of permanent roads for construction purposes, and access to the control structures for operation will be via PTH 6. The Lake St. Martin outlet channel options could be accessed along winter road systems for construction purposes; however, this would restrict all construction activities to winter months (late December to mid-March). The cost estimate assumes that an all-season road will be required to permit year round access to the project site for construction and also in the future for the purpose of operating the control structure, maintaining re-vegetation components of the project, and general maintenance to the structure and channel. All-season access to Reach 2 and Reach 3 would be required only if access to Reach 1 was already established, therefore the cost estimates for Reach 2 and 3 include only the incremental cost to extend access from Reach 1.

There is an existing forestry road approximately 61 km in length extending from Spearhill Manitoba that was used for access during the construction of Reach 3 in 2012. At the end of the forestry road, a winter road was developed extending the remaining distance to the Reach 1 inlet and Reach 3 project site. The Reach 1 winter road access is approximately 19 km. The winter road access to Reach 2 and 3 from the Reach 1 access road would require an additional 16 km road to Reach 3 and a further 3.7 km to Reach 2. It is estimated that upgrading the current 61 km forestry road to a single-lane gravel road would cost approximately $100,000/km for a total of $6.1 million. It is estimated that upgrading the current winter road access to a single-lane gravel road would cost approximately $750,000/km. Therefore access to Reach 1 would cost a total of $20.35 million ($6.1 million to upgrade forestry road plus $14.25 million to upgrade winter road). The estimated incremental cost to upgrade the winter road to Reach 3 would be $12.0 million with a further incremental cost to Reach 2 of $2.78 million.

Construction Camp

The construction camp estimates are based on the size of the construction camp used for the development of Reach 3 in 2012. A daily cost per person was estimated at $102/person to cover food and lodging for onsite staff. A mobilization and demobilization fee was included, which covers the costs of provincial permits (permit for storage and handling of petroleum products, explosive magazine permits, and an onsite wastewater management systems permit), and the installation and removal of trailers for lodging, washhouses, dining area and office space ($2,800/unit). These prices assume that the camp equipment/infrastructure is owned by the contractor that will be administering the camp rather than renting this required infrastructure from an outside source.

The estimated construction camp costs vary based on the maximum number of staff proposed to be in the camp at one time, which is a function of the project magnitude and construction schedule. A construction camp cost for the Lake St. Martin Reach 3 outlet channel to Johnson Beach, with an increased capacity of 140 cms (5,000 cfs; R3-JB +5000), was estimated and assumed a base requirement of 50 staff for a period of 270 days (nine months) and 14 units. This option was deemed to be the most comparable to the construction camp operated during the development of Reach 3 in 2012, which was used as a basis for the cost estimate. The construction camp costs for the remaining options were estimated by prorating the cost relative to the estimate for R3-JB +5000, based on the subtotal of all direct costs (excluding the construction camp). The prorated value is intended to reflect the appropriate construction schedules and size of the construction camp relative to the size of each option and the complexity due to additional structures, rock excavation, or underwater excavation.

Revegetation

The estimated cost to provide appropriate weed control and a vegetation cover for any of the outlet channel options at Lake Manitoba or Lake St. Martin is based on costs for conducting similar work along the East Side Road, which was developed and administered by Scatliff Millar Murray Inc. For the East Side Road, revegetation costs ranged from approximately $8,000/ha to $15,000/ha. For this study, the average value of $11,500/ha was assumed. This price assumed:

- Specifications will be developed prior to construction activities to allow for appropriate stockpiling of overburden and site/seed bed preparation (slopes, organic cover, mechanically preparing soils, etc.).
- All shaping of embankments and site/seed bed preparation is included in the construction costs.
- Appropriate site access is available for all options.
- Appropriate site conditions for seeding requirements.

- No significant delays or hindrances to revegetation work.

Total revegetation costs were calculated based on the total hectares estimated for the land acquisition (ha) multiplied by the unit price / ha. This estimate is likely conservative, since revegetation will not be required over the length of the rock sections that are included in the total area. This will require further discussions prior to developing the specifications for weed control and vegetation cover.

Mitigation Costs

Costs associated with proposed best practices to mitigate effects during construction, such as control of surface water and groundwater (dewatering, ditching, silt fences and settling ponds) have been included in the construction cost estimate as part of the unit price for excavation. Design measures such as riprap to mitigate effects of erosion and the use of control structures to reduce velocities during operation have been incorporated in the channel design and the costs included as part of the cost estimate for structures. Likewise the costs associated with land acquisition to compensate people for land required as part of the channels has been included, as previously described.

Mitigation and compensation costs that have not been accounted for in the cost estimate include costs for long-term monitoring, groundwater mitigation costs wells affected by the project (Lake Manitoba routes), compensation for damage to fish habitat, compensation to fishermen or any additional mitigation and compensation measures that may come from Regulator requirements determined during the advancement of the licensing and permitting process for the channel. These costs have been estimated as a percentage of the direct project costs with the percentage relative to the potential environmental effects as described in Section 7.0. The percentages used in the cost estimate for each option is as follows:

- Option A - 10%.
- Option B - 5%.
- Option C - 5%.
- Option D - 7%.
- Option E - 8%.

- Option F - 10%.
- Option R1 - 5%.
- Option R2 - 4%.
- Option R3 (JB) - 6%.
- Option R3 (WP) - 6%.

6.3 COST SUMMARY OF OUTLET CHANNEL OPTIONS

The total costs for each of the Lake Manitoba and Lake St. Martin outlet channel options, for the various capacities assessed are summarized in Table 14. This cost summary is based on the project components for each option as described in Sections 4.1 and 4.2, the unit pricing and the basis for the costing described in Sections 6.1 and 6.2, as well as the 30% contingency and 20% fees for engineering, administration and environmental approvals.

TABLE 14:
COST SUMMARY OF OUTLET CHANNEL OPTIONS

Design Alternatives	Total Cost ($Mil CAD) by Capacity (cfs)				
Lake Manitoba Channels	**2,500**	**3,750**	**5,000**	**10,000**	**15,000**
Option A – Twinning the Fairford River	-	-	86.0	149.5	228.3
Option B – Channel South of Pinaymootang FN	-	-	169.2	300.1	431.1
Option C – Channel Slightly Less South of Pinaymootang FN	-	-	151.2	269.1	386.5
Option D – Channel Following Birch Creek	-	-	141.3	236.8	332.4
Option E – Bypass Channel North of FRWCS	11.7	16.3	-	-	-
Option F – Expansion of Fairford River / FRWCS	-	-	239.3	-	-
Lake St. Martin Channels		**4,000**	**9,000**	**14,000**	**19,000**
Reach 1		56.4	80.1	111.4	139.5
Reach 2		0.0	7.0	18.5	28.2
Reach 3 to Johnson Beach		30.7	54.5	74.0	93.5
Reach 3 east of Willow Point		37.0	66.0	91.3	115.2
Option R123-JB – Reach 1, 2 and 3 to Johnson Beach		87.1	141.6	204.0	261.1
Option R123-WP – Reach 1, 2 and 3 east of Willow Point		93.4	153.1	221.2	282.8

Notes: "-" indicates alternative was not assessed for this capacity.

Option E with a 2,500 cfs capacity was the lowest estimated cost for the Lake Manitoba outlet channel options as shown in Table 14. For the outlet channels that considered larger capacities, Option A was nearly half the cost compared to the other options. The remaining options from least expensive to most were Options D, C, B and F.

For the Lake St. Martin outlet channels, the Reach 3 to Johnson Beach option was approximately 7 to 8% lower in cost compared to the Reach 3 east of Willow Point option as shown in Table 14.

7.0 POTENTIAL ENVIRONMENTAL CONCERNS

The proposed construction and future operation of an outlet channel between Lake Manitoba and Lake St. Martin and the subsequent modifications to the existing outlet channel system between Lake St. Martin and Lake Winnipeg will provide a large scale positive effect by helping to alleviate flooding in the region. However they will also likely result in a number of environmental concerns. Biophysical attributes that may be affected include, but are not limited to surface water quality, groundwater, terrestrial environment, aquatic environment and fish resources. Social attributes and concerns that could affect the project include land use and ownership, access, and unresolved First Nation litigation claims. While these and other potential environmental concerns will be examined in detail during the development of future licensing and permitting for the proposed project, this report acknowledges the likelihood of particular environmental concerns from a general perspective and focuses on the localized effects along each of the individual outlet channel options to better assess the relative difference between them.

A description of the general environmental concerns is provided in the following sections along with a relative ranking of the channel options from best to worst (on a scale from 1 to 10 with 10 being the best indicating the smallest effect). The relative ranking is qualitative and the criteria have not been weighted based on the potential level of effect for this preliminary assessment. For example criteria that may be assigned more importance could include erosion / sedimentation, fish resources, land use / ownership and First Nation litigation; however, this was beyond the scope of this conceptual study. The ranking is based on what is known about a project of this nature and the existing information about the current proposed locations for the outlet channels, as well as our understanding of certain environmental impacts that are likely to occur. The information herein will be used to gauge the extent of potential impacts for each of the outlet channel alignments, with the rankings summarized in Table 15 in Section 7.7 so as to aide in the selection of preferred options, with the expectation that an environmental assessment will follow.

7.1 SURFACE WATER QUALITY

Based on examination of monitoring data for the Reach 1 Emergency Outlet Channel in 2011 through 2012 (KGS Group 2013; NSC 2013), there would likely be varying levels of impact to surface water quality during construction, initial operation and continued operation of the proposed outlet channels. Water quality in direct proximity to the project activities and the downstream receiving waters can be affected through several physical effects pathways associated with the proposed Lake Manitoba and Lake St. Martin channels including:

- Alteration in the rate and seasonality of flow discharged into downstream water bodies within the project study area.
- Effects of flooding along the outlet channel routes.
- Potential for erosion and/or mobilization of sediment due to the diversion.

Many of the details described in the following sub-sections were previously developed as a part of the base of examination for the 2011-2012 monitoring program for the construction and operation of the Reach 1 Emergency Outlet Channel (NSC 2013).

7.1.1 Alterations in Rate and Seasonality of Flow Discharges

The proposed project will result in an increased rate of discharge from Lake Manitoba through Lake St. Martin and into Lake Winnipeg. These water bodies typically drain into one another in this sequence; however, the outlet channel systems will alter the timing and volume of the discharge. The concern is that these alterations could lead to changes in the water quality within the downstream water bodies. Preliminary review of routine water quality variables indicated that water quality in the Fairford and Dauphin Rivers exhibit seasonal differences, which may in turn affect conditions in Lake Winnipeg (NSC 2013).

The outlet channel would be operated when needed in response to flood conditions, regardless of which option is selected, so there would be little to no difference between any of the options in relation to changes in timing of discharge. In comparison, the change in rate of discharge is directly related to the increased volume or capacities of the proposed outlet channels and the volume of the downstream receiving water body. As such, each reach of the Lake St. Martin outlet channel options was ranked the same because they all have the same potential increase in capacity, while they ranked better than the Lake Manitoba outlet channels because they will have less effect given the larger volume of Lake Winnipeg. Option E was ranked the best of the Lake Manitoba channels, as it had the lowest increase in capacity followed by Option F; whereas Options A, B, C and D were all equally ranked the worst, as they all have the largest potential capacity increases.

7.1.2 Effects of Flooding Along the Outlet Channel Routes

Flooding of terrestrial habitat may affect water quality through leaching and decomposition of organic materials, which may in turn consume dissolved oxygen (DO), decrease pH, and increase the concentration of various nutrients and metals in the surface water. Flooding of terrestrial habitat may also mobilize mercury and increase the methylation of mercury leading to increased concentrations downstream and potential bioaccumulation within aquatic biota. This could in turn be affected by factors such as the total area flooded, differences in terrestrial habitat that is inundated (mass of organic material), and changes in water residence times and thermal regimes.

All of the proposed channels will provide a benefit to some extent as they are designed to decrease flooding within the drainage basins and the associated adverse effects. Of the Lake Manitoba channels, Options B and C were ranked the best as they will relieve the flooding on Lake Manitoba with no new flooding along channel. Option D was next best as only minor flooding will likely occur in the small lakes, creeks and wetland complex along the route. Whereas Options A, F and E would increase potential flooding on Lake Pineimuta, with Option E being the worst as it provides the least reduction in flood relief on Lake Manitoba, while potentially flooding Lake Pineimuta.

While each reach of the Lake St. Martin channel options has equal capacities to reduce the flooding on Lake St. Martin, Reach 1 results in the potential for flooding of Buffalo Lake and the surrounding bog. Whereas, Reach 2 and Reach 3 have containment dikes to prevent flooding of the surrounding land. Both the Johnson Beach and Willow Point Reach 3 options were ranked the same because they both divert the flood waters directly to Lake Winnipeg without flooding the surrounding land.

7.1.3 Erosion and Sediment Mobilization

The construction, initial operation, and continued operation of the outlet channels have the potential to increase shoreline, lake bed, and creek bed erosion, which can cause increases in the concentrations of Total Suspended Solids (TSS)/turbidity and related variables in downstream receiving waters. The impacts to water quality parameters such as TSS can have lethal and sub-lethal adverse effects on fish and other aquatic biota.

Construction activities such as excavation of shorelines or in proximity to shorelines, dredging within waterways or water bodies, or dewatering project sites in direct proximity to surface water bodies or watercourses can result in localized plumes of suspended sediment. To mitigate the effects of these activities, use of appropriate sediment control measures such as silt fences, turbidity curtains, and cofferdams (to allow the activities to proceed under dry conditions) would be required. In situations where dewatering is required, dissipation mats and or the use of sumps/settling ponds can reduce the extent of turbidity.

During initial operation of any channel option, it is expected that an immediate increase in TSS concentrations will be observed. This spike in the concentration of TSS could be from a combination of any of the following:

- Mobilization of loose earth material within the outlet channels.
- Eroding of the channel banks.
- Release of materials from the upstream water body being re-suspended as the inlet structure is operated.
- Movement of materials from within water bodies or wetland along the channel route.

While it is probable that the increase in concentrations during the initial operation will be well above typical conditions for the downstream receiving waters, these effects are expected to be short-term in duration. The effects from prolonged operation of the emergency channels have the potential to continue to provide increased TSS/ turbidity loading into Lake St. Martin and Lake Winnipeg; although, this would be in much lower concentrations as the channels have been designed so that average flow velocities are below the threshold to cause erosion. Periodic monitoring of the water quality throughout the project study area is advised in order to ensure that concentrations of routine water quality parameters are not exceeding conditions, which will have detrimental impacts on fish and other aquatic biota.

All the proposed channel options will require construction of an inlet and outlet requiring work in or adjacent water. However, based on the above discussion, the options that require additional construction activities within or immediately adjacent to water would be worse than channels through dry land. Additionally, channel options that are longer, and in particular through till sections, would have more materials exposed for potential erosion during initial operation. As such, Option F was ranked the worst and much lower than the other Lake Manitoba options as it requires excavating the river bank and dredging the river bottom to increase the capacity as well as other in water work to expand the existing FRWCS, construction of a new downstream control structure and to decommission a rail bridge. Additionally, Option F is one of the longest channels and constructed entirely within till that could continue to erode during long-term operation. Option A was ranked second worst as the route crosses the Fairford River twice requiring substantial in water work and is also one of the longer routes also constructed entirely in till. Option D was ranked third worst as the channel is in close proximity to several small lakes and wetlands along Birch Creek and is the longest route, constructed entirely within till. In comparison, Options B, C and E would mostly be constructed in the dry, with Option B and C ranked the same, as they have similar lengths of channel in till, and Option E ranked the best as it is the shortest.

All three reaches of the Lake St. Martin outlet channel will likely require work immediately adjacent to water or some in water work. Reach 1 will require construction of the control structure at the inlet and dredging to improve the existing inlet. Reach 2 will require bank excavation along Buffalo Creek. Both Reach 3 options will require shoreline excavation and construction of the outlet to Lake Winnipeg. The effects associated with initial and long-term operation are directly related to the length of each Reach, with greater effects for longer channels. An additional consideration was that Reach 1 will input sediment into Buffalo Lake and that both Reach 3 options will input sediment into Lake Winnipeg. Based on these considerations the Reach 3 channel to Johnson Beach was ranked slightly better compared to the channel to Willow Point as it is approximately 1.7 km shorter.

7.2 GROUNDWATER

Excavation of the proposed channels into the till and in particular bedrock sections will likely result in constant seepage of groundwater into the channel that will lower the water table and may affect groundwater wells in the vicinity of the channel. Likewise, flood waters in the channel could lead to potential infiltration, especially in areas where the channel intersects bedrock. When the flood waters are from developed or agricultural land, there is the potential for the infiltration to cause aquifer contamination. Additional construction related impacts include the potential for contamination of groundwater resulting from leaks and accidental spills of fuel or other hazardous substances. These potential groundwater issues are more of a concern for the Lake Manitoba options as there are groundwater wells in the bedrock aquifer that are used as a source for potable water. Mitigation of wells affected by the project along Lake Manitoba routes would include deepening or drilling new wells. Mitigation to prevent leaks, spills, and releases include providing secondary containment for fuel and hazardous material storage, requiring drip trays for equipment, providing spill clean-up equipment and materials, and providing an emergency (spill) response plan.

Construction of the Lake St. Martin outlet channel may adversely affect the groundwater regime or cause potential contamination during construction, as noted above; however, because the groundwater in this area is not used as a potable water supply each of the reaches would likely not have a significant effect. Options E and F were ranked the best of the Lake Manitoba channels. There are very few wells in the vicinity of Option E, and it is the shortest channel and constructed entirely in till; whereas because Option F is expanding the existing river, it should have minimal changes to the groundwater regime. Options D was ranked the next best because, again, there are few wells in the vicinity; and the channel will be constructed entirely in till, although it is the longest of the routes. Options A and B were ranked next best, while Option C was ranked the worst. While Option A is constructed entirely in till, there are many domestic wells in the vicinity of the channel that may be affected. In comparison, Option B has very few wells in the vicinity, however, there is a portion excavated through the bedrock so it may have a more direct effect on the groundwater. Option C was ranked the worst, as there are several wells in the vicinity; and a portion of the channel is excavated through bedrock.

7.3 TERRESTRIAL ENVIRONMENT

The key components of the terrestrial environment that may potentially be impacted by this project include vegetation associated with clearing for the channel ROW and the associated impacts to wildlife through physical disturbance and loss of habitat.

7.3.1 Vegetation

Vegetation will be lost during the site preparation and construction activities such as clearing, excavation, and blasting. Secondary impacts of construction activities include introduction of weedy species and the production of fugitive dust which can settle on vegetation surrounding the project site and impair growth and development. For most channel options, extent of impacts to vegetation is a function of alignment length as the entire right of way will be cleared in order to develop the channel. A qualifier for determining the extent of impact is the quality of vegetation being cleared; agriculture fields or heavily disturbed areas may be viewed as lower quality compared to relatively undisturbed vegetation. Mitigation to prevent these effects may include ensuring equipment is clean to avoid transfer of weedy species as well as taking measures to control dust such as dust suppressants, covering loads when hauling materials and restricting activities during high wind events, minimizing clearings to the extent absolutely required to complete the tasks, whenever possible use previously disturbed areas, and re-vegetate disturbed and reclaimed areas after construction.

Operation of several outlet channels (Options A, F, D and Reach 1) will result in higher flows along natural waterways and could result in losses in vegetation either from inundation, or from high velocity of the water eroding and flushing the substrate material downstream. No mitigation measures are proposed for this effect.

Option E was ranked the best of the Lake Manitoba channel options because it would require the smallest area of disturbance, and most of the vegetation is lower quality consisting of already disturbed agricultural land. Options C was ranked the next best because it also consists of mostly disturbed agricultural land and would require a similar area of disturbance to many of the other options. Options A, B and F were ranked the next best with Option A and B requiring a similar area of disturbance as Option C, however, the route would require clearing more undisturbed forested land. While Option F would require less area of disturbance than Options A and B it was ranked similarly because there was less previously disturbed vegetation, with a large portion of the vegetation being riparian wetland vegetation considered important for wildlife. Option D was ranked the worst as it would disturb at least twice as much area as most of the other Options, and the vegetation that would be impacted is a mix of previously disturbed agricultural land and wetland vegetation.

Reach 1 of the Lake St. Martin outlet channel was previously cleared when the channel was originally constructed in 2011 and will, therefore, have minimal further impacts. In comparison the vegetation around Reach 2 is largely undisturbed and will need to be cleared; however, this area of disturbance is relatively small. The Johnson Beach option for Reach 3 is ranked better than the Willow Point option because it requires a smaller area of disturbance and more of this route has been cleared previously.

7.3.2 Wildlife/Habitat

The vegetation clearing during site preparation and construction activities will result in a direct loss of wildlife habitat used for breeding and foraging and may have an indirect effect through construction noise that may disturb wildlife during nesting and rearing. Habitat may also be disturbed or lost through modification of natural conditions through inundation or drainage associated with construction and operation of the outlet channels. Mitigation to reduce the adversity of these effects may include cataloging and avoiding, when feasible, sensitive areas or areas that contain species of interest, in particular, during critical nesting and rearing periods (typically spring and early summer).

Construction activities such as transporting materials during construction and increased vehicle traffic along highways and access roads will increase risk of vehicle-wildlife interactions and potential for disturbance, injury or mortality. Mitigation may include operating transport trucks during daylight hours, providing wildlife awareness information to drivers and adhering to set speed limits.

Project effects to wildlife and wildlife habitat, as noted, are directly related to the amount and quality of vegetation disturbed. As such, the ranks assigned to each of the outlet channels reflect the ranks previously assigned under vegetation. The rank assigned to each reach of the

Lake St. Martin outlet channels was lowered relative to the Lake Manitoba outlet channels because the area has less human disturbance and, therefore, provides better habitat and more wildlife is likely present that may be affected by these channels.

7.4 FISH HABITAT

The proposed project has the potential to result in the alteration and loss of fish biota habitat. Habitat loss would occur from the construction footprint of structures within water bodies, while habitat alteration would occur from shoreline excavation, increased or altered flow patterns, flooding, and water quality changes from erosion and sedimentation. The habitat alteration and loss on its own is not likely to result in serious harm to the fishery, although some effort should be made to assess the quality of the habitat that will be affected for the preferred option.

Option F will require the construction of a control structure in the Fairford River downstream of Lake Pineimuta, which will result in the loss of fish habitat. Construction of the inlet and outlet for each of the Lake Manitoba and Lake St. Martin channels, as well as other in water work such as shoreline excavation and dredging, will result in alteration of fish habitat. However, this alteration of fish habitat may be offset by the creation of fish habitat in the channels. Upstream of the control structures the channels will typically contain water and provide fish habitat, except during low water years when the upstream lake levels are lower than the inlet. Downstream of the control structure the channels will only provide temporary fish habitat during operation until the flows are ended.

Several options for the Lake Manitoba outlet channels (Options A, E, and F) and Lake St. Martin outlet channel will involve increased flows or altered flow patterns along existing water ways including the Fairford River and the upper Buffalo Creek. Within the Fairford River, habitat changes could occur from increasing water levels and velocities altering the existing erosion and sedimentation patterns. Similar to what was observed in 2011-2012, the operation of Reach 1 will result in increased water levels in Big Buffalo Lake and flooding of the surrounding bog and wetland areas. This will provide additional usable habitat for fish during operation and for some time after closure as the water recedes. However, the inclusion of flow from Reach 1 and subsequent increased flow out of the Big Buffalo Lake have the potential to alter the habitat type towards a more riverine environment, which could reduce the residency time for fish within the lake. As water continues along the upper portion of Buffalo Creek, the increase in flow and potential for scour could alter channel geometry, and certainly impact the riparian and in-stream vegetation and fine-grained sediment.

The downstream end of all channel options could be used as temporary fish habitat, if fish are able to access the downstream end, except Option F and Reach 2, which are part of a natural water body. After closure of the channel control structures, the water would recede and, for most options, the channel will be inaccessible to fish. For channel options that connect directly to existing waterways (Fairford River and Buffalo Creek), the reduction in flow could result in exposure of spawning habitat and a reduced littoral zone in the natural waterways. This could result in exposure of egg incubation and early larval rearing habitat in these waterways.

Option F was ranked the worst of the Lake Manitoba options because it will result in habitat loss and likely the greatest amount of and most destructive habitat alterations associated with the downstream control structure, excavating the river bank and dredging the river bottom, as noted above. Option A and E were ranked the next worst. Option A will result in substantial habitat alterations at the two locations where the channel crosses the Fairford River and will result in flow alterations by twinning the river. While Option E will only have minor habitat alterations at the inlet and outlet because it is the shortest channel, there will be relatively little fish habitat created to offset the alterations made. Option D was ranked next worst as the channel is in close proximity to Birch Creek and may require in water work to tie the channel into the creek near the downstream end, although route optimization may eliminate the in water work. In comparison, Options B and C were ranked the best as they would mostly be constructed in the dry, except the habitat alterations at the inlet and outlet, which would be compensated for by the similar lengths of channel providing new fish habitat.

All three reaches of the Lake St. Martin outlet channel will require alteration of fish habitat. Reach 1 will require dredging to improve the existing inlet; Reach 2 will require bank excavation along Buffalo Creek; and both Reach 3 options will require shoreline excavation and construction of the outlet to Lake Winnipeg. While Reach 2 will result in the alteration of the largest area of fish habitat, this will be offset by the creation of a substantial area of new habitat within the widened portion of Buffalo Creek. Both the Johnson Beach and Willow Point Reach 3 options were ranked the same because they are mostly in the dry, except the minor area of habitat alterations at the outlet.

7.5 FISH RESOURCES

Three aspects of the project that could impact fish resources in the study area include habitat change, disruption of access to habitat and re-distribution of fish species from changes in flow patterns.

7.5.1 Habitat Change from Alterations in Flow Patterns

Within the Fairford River, Buffalo Lake, upper Buffalo Creek and Birch Creek, increase in flows can result in flooding and erosion of aquatic and terrestrial vegetation. This could affect the availability and distribution of spawning habitat and potentially affect spawning behavior and timing. Erosion of substrate composition can also affect both egg distribution and incubation success rates. Similarly, increased depth, sedimentation, and turbidity from increased flow could impact the littoral zone habitat used by many species of fish for rearing and feeding and could result in a temporary redistribution of fish to other areas within the watershed or to adjacent, unaffected watersheds. Other indirect effects include transportation and redistribution of invertebrates which serve as prey items for the fish and may result in movement of fish to locations further downstream.

Option B and C were ranked best of the Lake Manitoba channels because they are not connected to any other natural water body along the route in which flow patterns or water levels would be altered. Option D was ranked next best as the proposed route could be optimized so that it would not have any connection to Birch Creek, although currently the channel is shown connected at the downstream end which could change fish habitat. Option A, E and F were ranked much lower because these options are directly connected to the Fairford River and Lake Pineimuta with potential to change water levels and flow patterns causing the associated effects described above. Option E was ranked the worst because it would result in an increased flow capacity without increasing the capacity of the Fairford River further downstream to prevent water level increases on the river or Lake Pineimuta.

Reach 1 of the Lake St. Martin outlet channel would result in an increased flow to Buffalo Lake and the associated effects described above. Similarly Reach 2 will have increased flows to upper Buffalo Creek, however, widening Buffalo Creek will mitigate these effects. Reach 3 to both Willow Point and Johnson Beach were ranked the same because both options would result in an increased flow to Lake Winnipeg and the associated effects related to sedimentation.

7.5.2 Change in Species Composition and Distribution

Increased flows and changes in flow pattern may result in velocity barriers to certain species of fish that are adapted to lower flow conditions (e.g. yellow perch, northern pike, etc.), which may limit the amount of available habitat for these species during operation. Conversely, fish that are more adapted to higher water velocity conditions may become more prevalent during operation of the outlet channels. Depending on the timing, higher flows may negatively impact egg and larval fish distribution. Eggs may be flushed downstream into habitat unsuitable for incubation and drifting larval fish may be transported to areas further downstream that are unsuitable or have increased numbers of potential predators. Both scenarios can lead to increased mortality rates.

Alternative flows and/or increased flows may act as attractants to certain fish species during fall and spring spawning runs; affecting the timing and distribution of spawning activity. This could occur at the downstream end of all the Lake Manitoba channel options (excluding Option F) and at the downstream end of either alignment option for Reach 3. Fish that would normally migrate up the Fairford or Dauphin Rivers may alternatively ascend the corresponding channel. Closure of the channels following operation may result in stranding of fish as the water recedes. Consideration should be given to the operation and closure of the channels so as to reduce the effect on spring and fall spawning runs. Further, consideration should be given to installing drop structures at the downstream end of all Lake Manitoba options (except Option F) and for Reach 3, to prevent fish from ascending the channels during migration. Alternative options will have to be considered for Reach 1, as a drop structure will not be feasible at the downstream end of that reach.

Option B and C were ranked best of the Lake Manitoba channels because they are not connected to any other natural water body along the route in which flow patterns or water levels would be altered and, therefore, only have the potential concern of fish stranding. Option D was ranked next best as the proposed route could be optimized so that it would not have any connection to Birch Creek, although currently the channel is shown connected at the downstream end, which could change flow patterns and velocity in addition to the concern of fish stranding. Options A, E and F were ranked lower because these options are directly connected to the Fairford River and Lake Pineimuta with potential to change water levels and flow patterns affecting fish composition to a greater extent. Option F was ranked better than Option A because there is no concern for fish stranding in the Fairford River expansion. Option E was ranked the worst because it would result in an increased flow capacity without increasing the capacity of the Fairford River further downstream resulting in the greatest potential for water level increases and flow pattern changes.

Reach 1 of the Lake St. Martin outlet channel has a large potential to change flow patterns and water levels on Buffalo Lake and is a demonstrated concern for fish stranding. Reach 2 consists of widening Buffalo Creek to increase the capacity to ensure water levels on Buffalo Lake are contained and there is no concern for fish stranding in Buffalo Creek. Reach 3 to both Willow Point and Johnson Beach were ranked the same because both options will act as an attractant to certain species with the increased flows at the outlet and may be a concern for fish stranding.

7.5.3 Fish Passage

The Lake Manitoba and Lake St. Martin Regulation Review Committee recommended that "if the Province builds a new outlet to Lake Manitoba it should take that opportunity to design the new outlet in such a way as to provide unrestricted fish passage between Lake Manitoba and Lake St. Martin". However, with the exception of Option F, none of the channel options will be operated year round; therefore, none of the Lake Manitoba Channel options are appropriate for providing unrestricted fish passage between the two lakes. As indicated in the previous section, fish access to the channels during operation could hinder rather than help the fish populations by altering migration patterns during spawning. An option that may be more valuable in accomplishing the goal of unrestricted fish passage would be including the improvement for fish passage at the current FRWCS as part of the proposed project, regardless of the Lake Manitoba outlet channel that is selected.

Because none of the Lake Manitoba outlet channel options are appropriate for providing unrestricted fish passage between the two lakes, as noted above, and because the review committee did not require fish passage for the Lake St. Martin outlet channels, the options were not ranked based on this criteria.

7.6 SOCIAL ENVIRONMENT

Certain options may be viewed as more or less favorable by the First Nation communities and other stakeholders. While the project as a whole provides a direct benefit to the communities on the drainage basin, by mitigating future flooding issues and subsequent environmental and social impacts, the individual components may not be viewed as such. The most likely First Nation and public concerns associated with this project includes land use and ownership, access, and unresolved First Nation litigation claims. This is based on our knowledge of the area and experiences associated with this project to date. The following sections contain a brief overview of these issues and the public engagement process that is proposed to advance the project.

7.6.1 Land Use/Ownership

The Lake St. Martin outlet channel is located entirely within crown land while the Lake Manitoba outlet channel options are routed through a mix of private and crown land with Options A and F also located within the Pinaymootang First Nation Land. The land consists of a mix of undeveloped natural forest and wetland vegetation, agricultural fields and residential development. Acquiring the required land for the channels will take these areas away from the current land use while some of the channels may also affect the adjacent land use.

Lake Manitoba channel options A, E and F that are directly associated with the Fairford River will likely be faced with strong resistance. There are long-term unresolved issues over the operation of the FRWCS and how changes in flow conditions on the Fairford River have caused flooding along the river and in Lake Pineimuta and Lake St. Martin. This flooding has impacted land use and activities including fishing, muskrat trapping, waterfowl hunting, agriculture hay fields, and a multitude of infrastructure (roads, houses, etc.).