DATE: 2019-06-14

TO: Christine Baljko
Environmental Coordinator
Manitoba Infrastructure
280 Broadway

FROM: Chris Propp
Hydrologic Services Engineer
Manitoba Infrastructure
280 Broadway

SUBJECT: Lake Manitoba and Lake St. Martin Outlet Channels Impacts on Lake Manitoba and Lake St. Martin

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This technical memorandum summarizes the hydrologic analysis and modelling conducted by the Hydrologic Operations Section to evaluate the impact of the proposed Lake Manitoba and Lake St. Martin Outlet Channels on Lake Manitoba and Lake St. Martin.

BACKGROUND

Lake Manitoba and Lake St. Martin Regulation

Lake Manitoba is currently regulated by the Fairford River Water Control Structure. The structure, completed in 1961, was built to reduce flooding on Lake Manitoba by allowing additional water to flow down the Fairford River and to maintain lake levels during periods of low inflow by reducing outflow into the Fairford River. In the past 20 years, two Committees (one for each lake) have been formed to develop recommendations for an operating regime that would balance the impacts of the structure to Lake Manitoba and downstream Lake St. Martin.

Construction of new Outlet Channels is proposed for Lake Manitoba and Lake St. Martin to enhance flood protection on both lakes. Operating guidelines for the channels and Fairford River Water Control Structure are included below. Background information on how these guidelines were developed and the rationale for each guideline can be found in an internal memo written by Chris Propp for Eugene Kozera entitled “Development of Operating Rules for Lake Manitoba and Lake St. Martin Outlet Channels with Recommended Revisions” (February 7, 2019).

Fairford River Water Control Structure Operating Guidelines

The current operating guidelines are based on the recommendations of the 2003 Lake Manitoba Regulation Review Advisory Committee and the 2013 Lake Manitoba, Lake St. Martin Regulation Review Committee. The guidelines allow for a more natural fluctuation of lake levels when the lake is within the desire regulation range.

1. The desired operating range on Lake Manitoba is 812.5 fasl to 810.5 fasl. The desired operating range on Lake St. Martin is 797.0 fasl to 800.0 fasl.

2. During recovery from flood conditions on Lake Manitoba, the Fairford Control Structure is kept wide open until Lake Manitoba recedes to the middle of the range after which is should be cut back [*meaning partially closed using stop log adjustment*s] to a normal outflow setting (50-60% capacity).

3. During recovery from drought, the Fairford Control Structure is kept at 800 cfs until Lake Manitoba levels increase to middle of the desired operating range after which point the structure will be operated to achieve normal outflow (50-60% capacity).

4. Under normal operating conditions, once outflow reaches normal (50-60% capacity), there are no further stop-log adjustments, as long as Lake Manitoba remains within the range.

5. Any variances in the lake levels outside of the range shall be shared between Lake Manitoba and Lake St. Martin insofar as this may be reasonably possible.

6. The minimum flow on the Fairford River should be 800 cfs with a desirable flow of 1,000 cfs as often as possible.

Proposed Lake Manitoba Outlet Channel Operating Guidelines

The proposed Lake Manitoba Outlet Channel Operating Guidelines were developed to compliment the operating guidelines for the Fairford River Water Control Structure allowing for natural fluctuation of lake levels when Lake Manitoba and Lake St. Martin are within desired regulation range, i.e. the proposed Lake Manitoba Outlet Channel is not to be operated when Lake Manitoba water levels are, or are forecast to be, within the desirable range.

1. The Lake Manitoba Outlet Channel will be opened to maximum capacity when Lake Manitoba is above the top of the regulation range (812.5 ft),

2. The Lake Manitoba Outlet Channel may be opened pro-actively (when the water level is below 812.5 ft) if the water level on Lake Manitoba is forecasted to be above 813 ft in the same season.

3. The outflow from the Lake Manitoba Outlet Channel will be reduced when the water level on Lake Manitoba recedes to the middle of the regulation range (811.5 ft), so that the combined outflow from the Fairford River Water Control Structure and the Lake Manitoba Outlet Channel, insofar as possible, matches the inflow into Lake Manitoba.

4. The Lake Manitoba Outlet Channel will be closed once the Lake Manitoba water level recedes below 811.5 ft and the outflow from the Fairford River Water Control Structure is greater than the total inflow into Lake Manitoba. During Outlet Channel shutdown, consideration will be given to ensuring that the drawdown rate within the Outlet Channel does not compromise channel embankment stability.

5. Initial operation of the outlet control structure will not be initiated during the period in which there is solid ice cover in the channel (typically from Dec 1 – April 30th). However, operation may be considered if severe flooding is forecasted for the following spring.

Proposed Lake St. Martin Outlet Channel Operating Guidelines

1. The target regulation range for Lake St. Martin is 797-800 ft.

2. The Lake St. Martin Outlet Channel will be operated to full capacity:
    a. when the Lake St. Martin water level rises above 800 ft

or,

b. when the Lake Manitoba Outlet is opened for initial operation, Lake St. Martin is above 797 ft, and Lake St. Martin is forecasted to go above 800 ft without operation of the Lake St. Martin Outlet Channel.

Consideration may be given to opening the Lake St. Martin Outlet Channel to less than full capacity if Lake St. Martin is only forecasted to go slightly above 800 ft.

3. The outflow from the Lake St. Martin Outlet Channel will be reduced when the lake level decreases below 800 ft, to the greater of the following:
   a. 25% of channel capacity,
   b. the outflow required to ensure total outflow from the Dauphin River and the Lake St. Martin Outlet Channel matches the total inflow into Lake St. Martin at the time of the Outlet Channel gate setting adjustment.
4. The outflow from the Lake St. Martin Outlet Channel will be further reduced when the water level on Lake St. Martin recedes below 798 ft, so that the outflow from the Dauphin River and the Lake St. Martin Outlet Channel, insofar as possible, matches the inflow into Lake St. Martin.
5. The Lake St. Martin Outlet Channel will be closed fully when Lake St. Martin drops below 798 ft and the outflow from the Dauphin River is equal to or greater than the total inflow into Lake St. Martin from the period when ice cover has cleared out of the channel in the spring to October 31st (under open water conditions). During channel shutdown consideration will be given to ensuring that the drawdown rate within the Outlet Channel does not compromise channel embankment stability.
6. If the Lake Manitoba Outlet is in operation in November, the Lake St. Martin Outlet Channel should be operated throughout the winter so that the outflow from the Dauphin River and the Lake St. Martin Outlet Channel, insofar as possible, matches the inflow into Lake St. Martin.
7. Notwithstanding the above guidelines, the Lake St. Martin Outlet Channel will be operated during the spring freshet if the Lake Manitoba Outlet Channel has been in operation over the winter will continue to be operated into the spring, so that the outflow from the Dauphin River and the Lake St. Martin Outlet Channel, insofar as possible, matches the inflow into Lake St. Martin.
8. Initial operation of the outlet control structure will not be initiated during the period in which there is solid ice cover in the channel (typically from Dec 1 – April 30th). An exception to this guideline may be considered if severe flooding is forecasted for the following spring.

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HYDROLOGIC MODELLING

Manitoba Infrastructure's Hydrologic Operations group uses two water balance models to evaluate the impact of water control structure operations on the Lake Manitoba to Lake Winnipeg drainage system. Water balance models use inflow, precipitation, evaporation data, and stage storage curves to calculate changes in lake level, and rating curves to determine lake outflow, based on the following equations:

$$Q_{in} + Precip - Evap - Q_{out} = \Delta_{storage}$$

$$\Delta_{storage} \xrightarrow{Stage\ Storage\ Curve} \Delta_{lake\ level}$$

$$Lake\ Level \xrightarrow{Discharge\ Rating\ Curve} Q_{out}'$$

Where:
Q = Water Flow
Precip = Precipitation (including both rain and snow)
Evap = Evaporation
Δ = Change
Stage Storage Curve = The relationship between lake level and lake volume
Discharge Rating Curve = The relationship between lake level and lake outflow rate

Not all inflow sources into a lake are gauged. However, the total inflow available as outflow (IAO) can be calculated based on the gauged outflows and observed historical stage data collected by Environment and Climate Change Canada (ECCC) for the lake.

Water Balance Models

The Lake Manitoba Water Balance model is used to evaluate the impacts of water control structure on Lake Manitoba and Lake St. Martin. This tool incorporates the operation of the Fairford River Water Control Structure and the proposed Lake Manitoba and Lake St. Martin outlet channels to simulate water levels and outflows on Lake Manitoba and Lake St. Martin under various operational strategies, using the data and relationships described above.

Data

1. IAO data for the model was produced back to 1915. This was done using a combination of recorded data and reconstructed data based on established relationships.

2. Precipitation amounts for the model were based on numerical averages of rain and snow gauge information around the lake.

3. Snow water equivalent was assumed to be 10% of measured snow depths and was applied to the lake surface directly.

4. Historical evaporation data was produced by the Prairie Farm Rehabilitation Association (PFRA).

5. Historical flow and water level data was available from Environment and Climate Change Canada for the following water bodies:

   a. Lake Manitoba 1914 - present
   b. Lake St. Martin 1966 - present

c. Fairford River 1912 – 1920, 1955 - present
d. Dauphin River 1977 – present
e. Portage Diversion 1970 - present
f. Assiniboine River 1913 – present

6. The 1914 data for Lake Manitoba was not used because it was only captured for part of the year.

7. Fairford River outflows for 1921 – 1954 were reconstructed using a the Lake Manitoba/Fairford River stage-discharge relationship based on available data prior to the construction of the Fairford River Water Control Structure.

8. Lake St. Martin levels prior to 1966 and Dauphin River flows prior to 1977 were estimated by routing Fairford River flows through Lake St. Martin, using the established stage-discharge relationship for Dauphin River and the stage-surface area relationship for Lake St. Martin.

9. Portage Diversion flows were estimated prior to 1970 (prior to construction) to develop consistent operating regime scenarios. The flows were estimated by applying the Portage Diversion operating guidelines in years prior to construction based on published Assiniboine River flows, City of Winnipeg river levels, and Lake Manitoba water levels

10. The surface area of Lake Manitoba and Lake St. Martin as a function of water level was based on LiDAR data and historic bathymetric data.

Lake Manitoba / Lake St. Martin Model Calibration

The model was calibrated to a 10-year period from 2006-2015. This period was selected because the operating regime utilized during this period most closely follows the operating guidelines currently utilized for the operation of the Fairford River Water Control structure. The results of the calibration are shown in the figure below.

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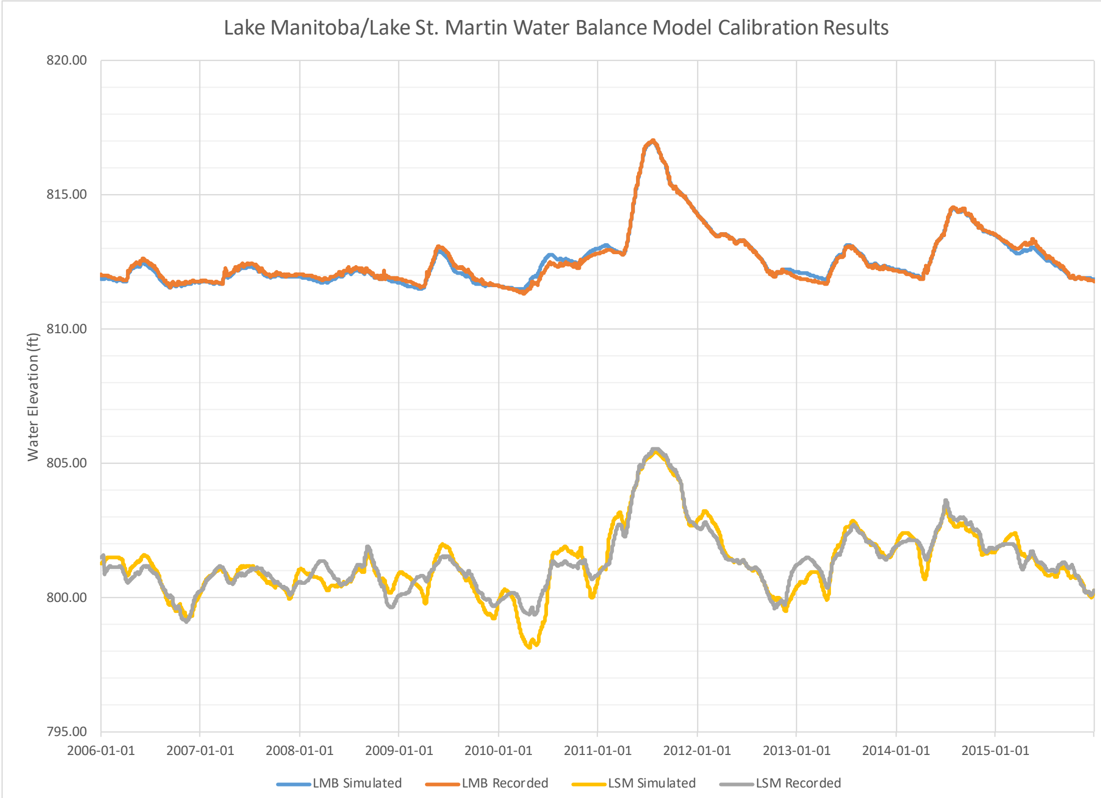


Figure 1: Lake Manitoba/Lake St. Martin Calibration Results

As can be seen in the chart above, the simulated results for Lake Manitoba are in very close agreement with the recorded water levels. The simulated Lake St. Martin water levels deviate more from the recorded values but appear to match the annual peak water levels well. Since Lake St. Martin is a much smaller lake, small differences in flow rates have a more noticeable effect on the lake level. In years where a larger difference between recorded peaks and simulated peaks is observed, the model tends to predict higher peaks and hence more conservative values. This is desirable where flooding is the primary concern.

Potential Sources of Error in Model

1. Adherence to operating guidelines - The model strictly adheres to the operating guidelines of the Fairford River Water Control Structure through use of logic statements whereas in reality operation of the structure may deviate from the guidelines for a period of time due to extenuating circumstances, such as delay in operation to accommodate maintenance or construction activities, or reducing the flow rate through the Fairford River Water Control Structure to manage frazil ice on the Dauphin River.

2. Rating curves – Two sets of rating curves (water level – discharged relationships) are used within the model: open water rating curves and winter rating curves. These relationships are relatively rigid within the model, however in reality there is a degree of natural fluctuation from the rating curves that is not captured by the model. During winter the relationship between water level and discharge changes over time due to ice formation and ice erosion.

3. Stage storage curves – Stage storage curves were developed using the best available topographical and bathymetric data. In some areas, there is a gap between the bathymetry and the topographical data that has to be interpolated. The elevation data also represents a snapshot in time whereas the lake bed and shoreline changes over time.

4. Hydrometric data – Published flow data is not 100% accurate and there is an approximate 5% margin of error on flow measurements.

5. Meteorological data – Evapotranspiration data is calculated using an algorithm rather than directly measured.

Simulation Scenarios

The Lake Manitoba Water Balance model was run to produce lake levels and outflows for over 100 years using inflow and precipitation data for over 100 years from 1915-present. The model was run under two scenarios: "Current Operation" and "Future Operation". The Current Operation scenario assumes that the Fairford River Water Control Structure is operated under the current operating guidelines for the entire period of record (1915-2017) and omits the operation of the Lake St. Martin Emergency Outlet Channel entirely. The Future Operation scenario assumes that Lake Manitoba and Lake St. Martin have been regulated with the proposed outlet channels according to the proposed operating guidelines for the entire period of record and omits any operation of the Lake St. Martin Emergency Outlet Channel.

Results

Lake level hydrographs have been included in Appendix A to demonstrate the impact of the new outlets' operation on Lake Manitoba and Lake St. Martin. Specific years of interest have their own plots for clarity; these include the plots for 1954-1955, 2001-2003, and 2010-2012. In 1954-1955, the Lake Manitoba recorded level was above its operating range for an extended period. In 2001, operation of the outlets drops Lake Manitoba below its desired range. The 2011 flood is the flood event of record. The hydrographs show Lake Manitoba and Lake St. Martin levels over time for both simulations and the simulated flow through the Lake St. Martin Outlet Channel. It should be noted that all water levels given are static water levels and do not incorporate wind and wave effects. A typical windstorm event can cause water Lake Manitoba level increases in the range 2.0 ft to 2.5 ft and Lake St. Martin level increases in the range of 1.0 ft to 2.5 ft depending on shoreline location, wind direction, and wind speed.

Operation of the new flood outlets will have an effect on the range of water levels on the lakes. Based on the model results, operation of the new outlets will dramatically decrease the peak water levels in high flood years, and reduce peak levels in almost all years, increasing the amount of time the lake is within its desired operating range. Table 1 below summarizes the model results. See Appendix B for a table of statistics for all years.

Table 1: Average Decrease in Peak Water Levels with Operation of Outlet Channels

Flood Level on Lake Manitoba	LMB Average Decrease	LSM Average Decrease
Non Flood (LMB < 812.5fasl)	-0.08 ft	-0.26 ft
Minor Flood (812.5 fasl < LMB < 813.5 fasl)	-0.28 ft	-1.59 ft
Major Flood (LMB > 813.5 fasl)	-1.27 ft	-2.45 ft

There is also a decrease in minimum water level on the lakes. The decrease primarily effects high water years, where this is a desirable outcome, but it also effects low water years. This is because any additional volume conveyed by the Outlets during a flood event is lost to Lake Winnipeg, and cannot be returned to the system in future low water years. Table 2 summarizes the model results.

Table 2: Average Decrease in Minimum Lake Levels with Outlet Channels

Water Level Regime	Lake Manitoba		Lake St. Martin	
	Level Range	Avg Decrease	Level Range	Avg Decrease
Low Water	< 810.5 fasl	-0.08 ft	< 797 fasl	-0.02 ft
Average	> 810.5 fasl < 812.5 fasl	-0.17 ft	> 797 fasl < 800 fasl	-0.11 ft
High Water	> 812.5 fasl	-0.48 ft	> 800 fasl	-0.85 ft

Duration curves were produced to show the percentage of time that the lakes are below given water levels under the current operating regime and proposed operating regime (see Appendix C). Under the current operating conditions, Lake Manitoba is below the top of its desired operating range 91.6% of the time. With the new outlets it is below the top of its desired operating range 97.2% of the time. There is also a 1.4% increase in the amount of time the lake is below its range. Table 3 summarizes the duration curve results for Lake Manitoba.

Under the current operating conditions, Lake St. Martin is within its desired operating range 50.5% of the time. With the new outlets, it is within its desired operating range 68.4% of the time. This represents a dramatic improvement in flood protection. However, there is an increase in the amount of time the lake is below its range. Under the current regime, Lake St. Martin is below its desired range 25.1% of the time. With the proposed Outlet Channels, this increases by 1.3%. Table 4 summarizes the duration curve results for Lake St. Martin

Table 3: Lake Manitoba Duration Curve Summary

Lake Manitoba Level (fasl)	% of Time Lake is Below Indicated Level		
	Without New Outlets	With New Outlets	Change
815	99.6%	99.9%	0.3%
812.5	91.6%	97.2%	5.6%
810.5	16.7%	18.1%	1.4%
810	7.7%	8.9%	1.2%

Table 4: Lake St. Martin Duration Curve Summary

Lake St. Martin Level (fasl)	% of Time Lake is Below Indicated Level		
	Without New Outlets	With New Outlets	Change
803	97.6%	99.9%	2.3%
800	75.6%	94.8%	19.2%
797	25.1%	26.4%	1.3%
796	3.8%	3.8%	0.0%

The Outlet Channels are operated in 34% of the years simulated (35 years out of 103 years).

DISCUSSION

Impacts to Lake Manitoba

Operation of the new flood outlets will have an effect on the range of water levels on Lake Manitoba. In High Flood years the peak Lake Manitoba is significantly reduced as demonstrated on the 1954-1955 and 2010-2012 detailed hydrographs. In 1955 the peak level is reduced by 1.0 ft, and in 2011 the peak level is reduced by 1.5 ft (see Appendix A). Operation with the new outlets also lowers the minimum water level in Lake Manitoba which, in some years, may drive the level below the lower end of the desired operating range sooner that would otherwise have gone. An example of this is the operation in 2001, which causes the lake level below the lower end of the desired operating range in the fall of 2002. Operation in 2001 affects the timing and magnitude of the lower level, but does not change the fact that the lake would have gone out of range in the following years. Based on the model results, operation of the new outlets will significantly decrease the peak water levels in high flood years, and reduce peak levels in almost all years, increasing the amount of time the lake is within its desired operating range.

There are some years (1956, 1974, and 1996) where operation of the Lake Manitoba creates higher peaks in the subsequent years; these hydrographs have been provided for reference. Operations in these years lower the Lake Manitoba level below 811.5 ft, triggering discharge at the Fairford River Water Control Structure to be reduced to 60% of full capacity. Without the new outlets, the Lake Manitoba level would have stayed above 811.5 ft, and flow at Fairford would have been 100% of full capacity. The reduced capacity in these three years would have allowed Lake Manitoba levels to creep up over the winter, and resulted in higher peaks in the following years. This phenomenon is observed in only 3% of simulation years.

Positive impacts of the proposed Lake Manitoba outlet channel include reduction in peak flood levels, reduced flood inundation areas, and an increase in the amount of time that the lake is within the regulated range.

For the 2011 flood event, the calculated decrease in the peak water level on Lake Manitoba is 1.5 ft. This represents a decrease in flooded area of 754.1 km^2. An inundation map of the 2011 conditions has been included in Appendix D for reference.

As highlighted previously, regulation of Lake Manitoba with the new outlet channel will increase the amount of time that the lake is below the top of its desired regulation range (812.5 ft) by 5.6%. This represents an improvement in flood protection around the lake.

The regulation of the lake under the future operation scenario also slightly increases the amount of time that the lake is below the lower end of its desired operating range (810.5 ft) by 1.4%. While this is not a large amount, it is still an undesirable effect.

Impacts to Lake St Martin

Positive impacts of the proposed Lake St. Martin outlet channel operation include reduction in peak flood levels, reduced flood inundation areas, and a substantial increase in the amount of time that the lake is within the regulated range.

For the 2011 flood event (high flood event), the calculated decrease in the peak water level on Lake St. Martin is 2.5 ft (see Appendix A for hydrograph). This represents a decrease in flooded area of 27.5 km^2. For all years in which Lake St. Martin is in flood stage, the average decrease in water level is 1.7 ft. This represents an average decrease in flooded area of 21.4 km^2. In years where neither Lake Manitoba nor Lake St. Martin are in flood stage, there will be no operation of the new outlets. Inundation maps of both conditions have been included in Appendix D for reference.

As noted above, regulation of Lake St. Martin with the new outlet channel will increase the amount of time that the lake is within the desired regulation range (797 fasl – 800 fasl) by 18%. This represents a large improvement in flood protection around the lake.

The regulation of the lake under the future operation scenario will also slightly increase the amount of time that the lake is below 797 fasl by 1.3%. While this is not a large amount, it is still an undesirable effect.

The only year in which the new operating regime caused Lake St. Martin to drop below the desired regulation range (below 797 fasl), where it would not otherwise have, is 1977. A hydrograph for this year is included in Appendix A. With operation of the Outlet Channels in 1976, the large spring operation would have lowered Lake Manitoba to the bottom of its operating range and Lake St. Martin would have remained in the middle of its range. Carrying over to the following year (1977), the runoff event would not have raised the level of Lake Manitoba significantly, and there would not have been enough flow on the Fairford River to maintain the level on Lake St. Martin, which would have dropped below its desired range later that year. Occasional deviations from the desired operating range are considered acceptable under the operating guidelines in place for the Fairford River Water Control structure.

<original signed by>

<original signed by>

Prepared by:
Peter Johnston, P. Eng.
Senior Hydrologic Operations Engineer

Submitted by:
Chris Propp, P. Eng.
Hydrologic Services Engineer

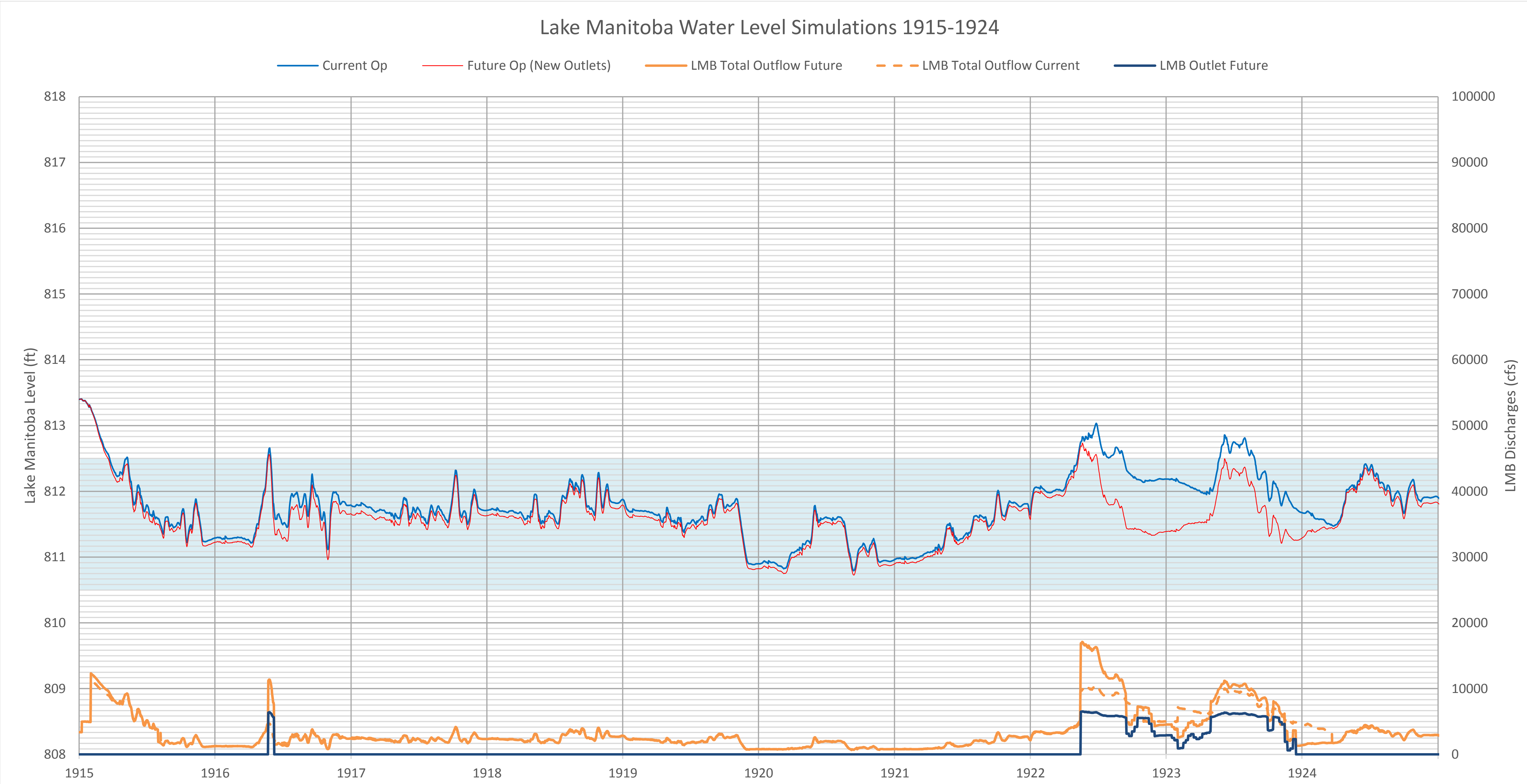
c: Eugene Kozera
Scott Johnstone

Manitoba
Infrastructure

Jeremy Fiebelkorn
Jared Baldwin

Manitoba
Infrastructure

Appendix A:
Lake Level Hydrographs


Lake Manitoba Water Level Simulations 1915-1924
Current Op
Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
818
817
816
815
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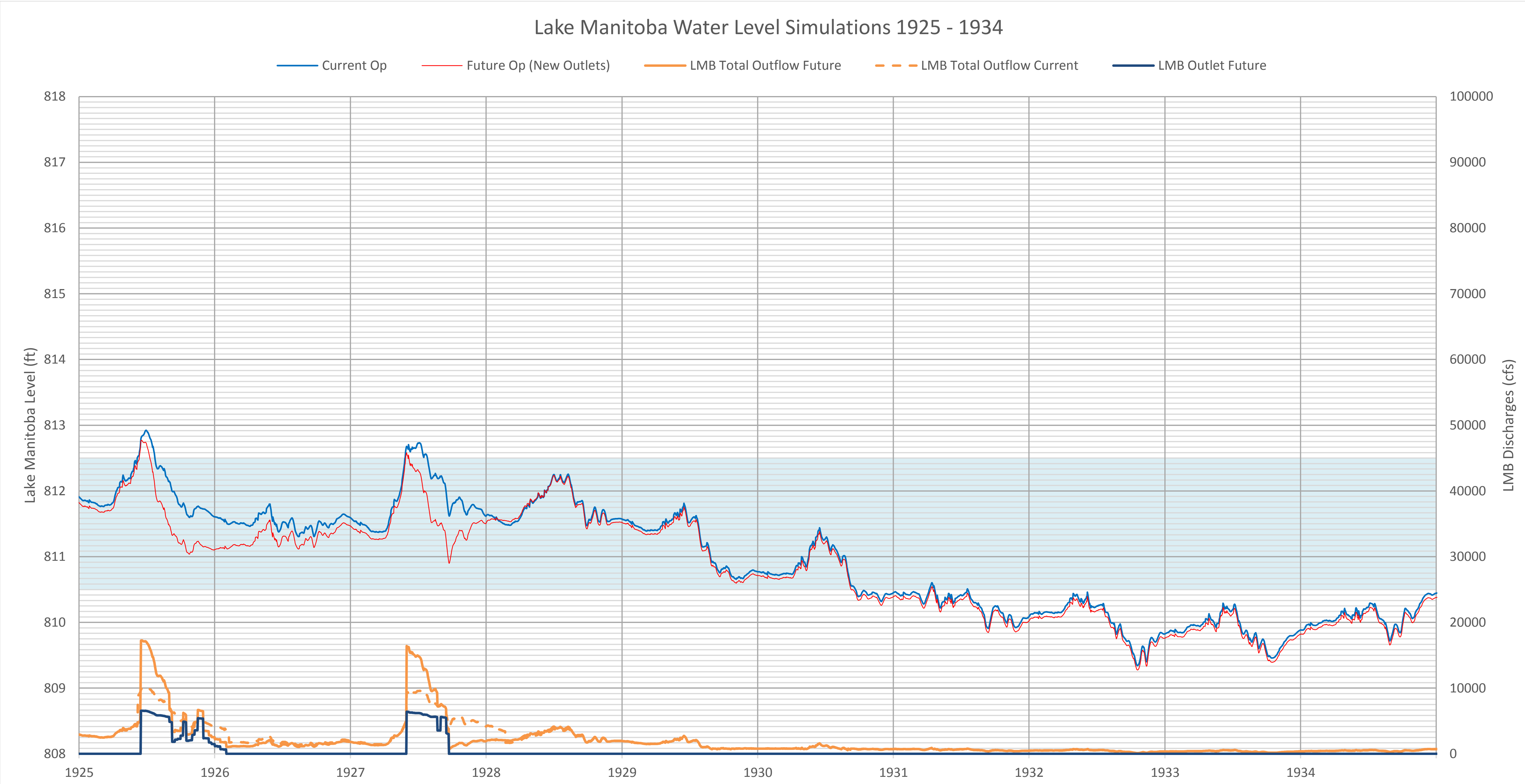
Lake Manitoba Water Level Simulations 1925 - 1934
Current Op
Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
818
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816
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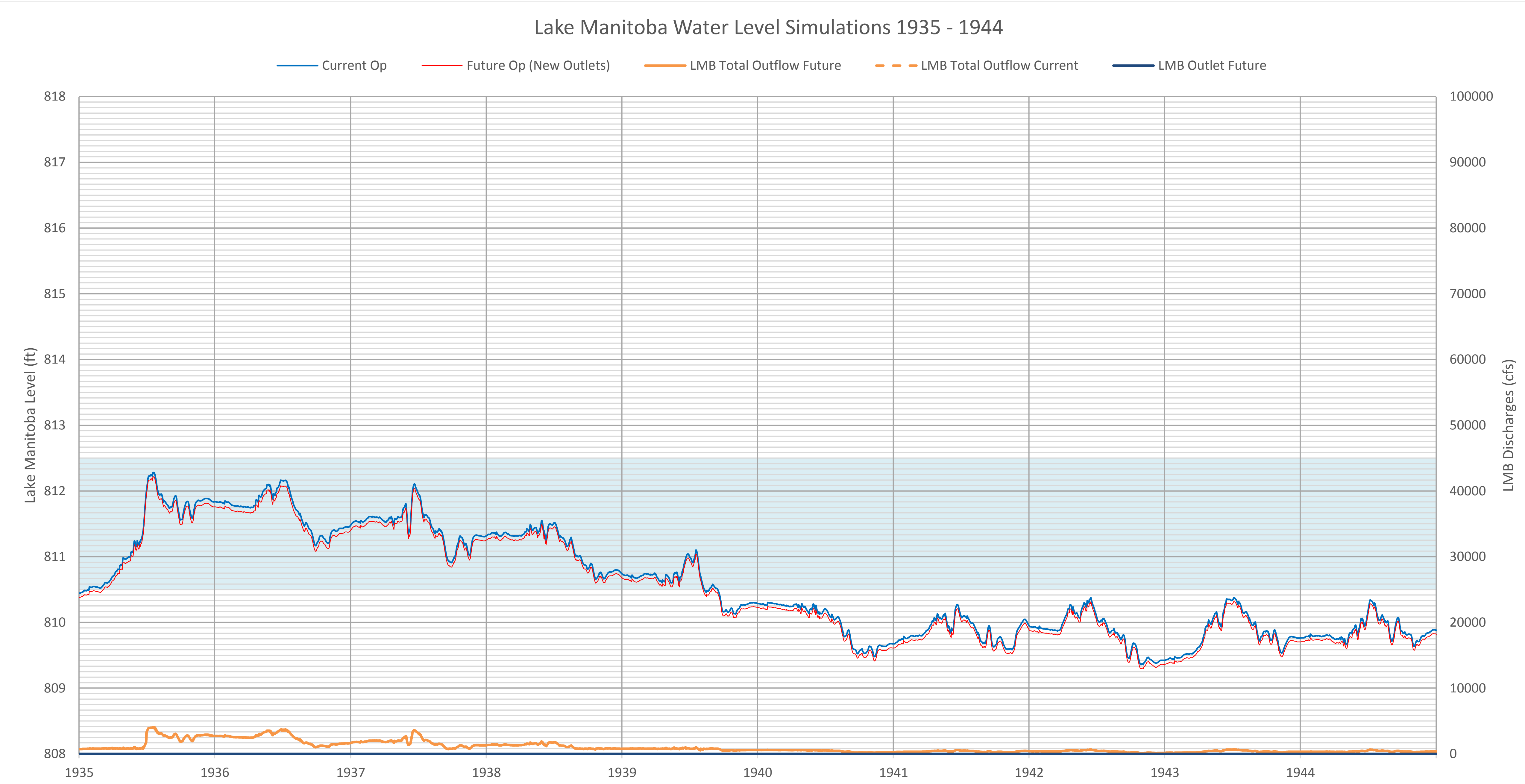

Lake Manitoba Water Level Simulations 1935 - 1944
Current Op
Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
818
817
816
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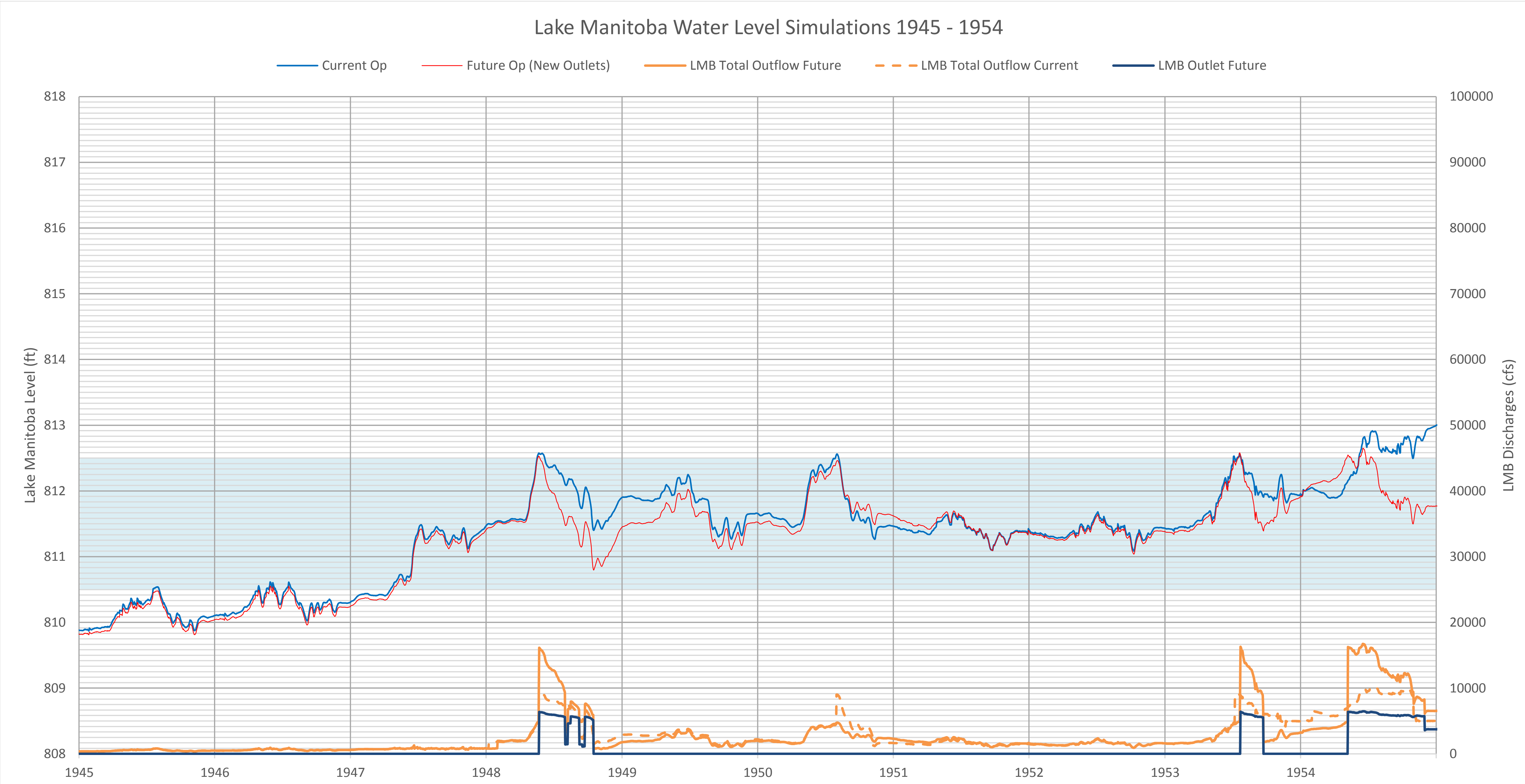

Lake Manitoba Water Level Simulations 1945 - 1954
Current Op
Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
818
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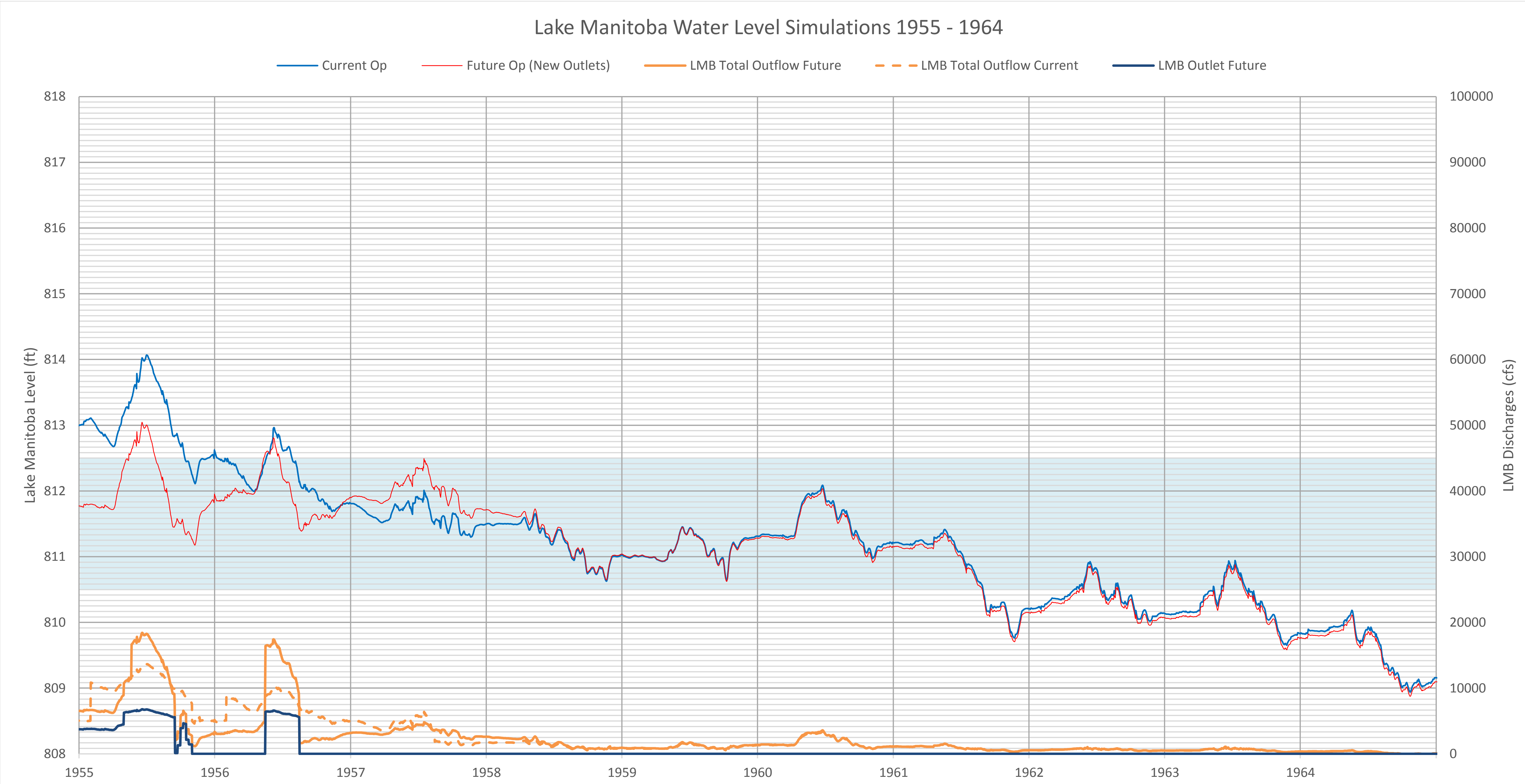

Lake Manitoba Water Level Simulations 1955 - 1964
Current Op
Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
818
817
816
815
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812
811
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809
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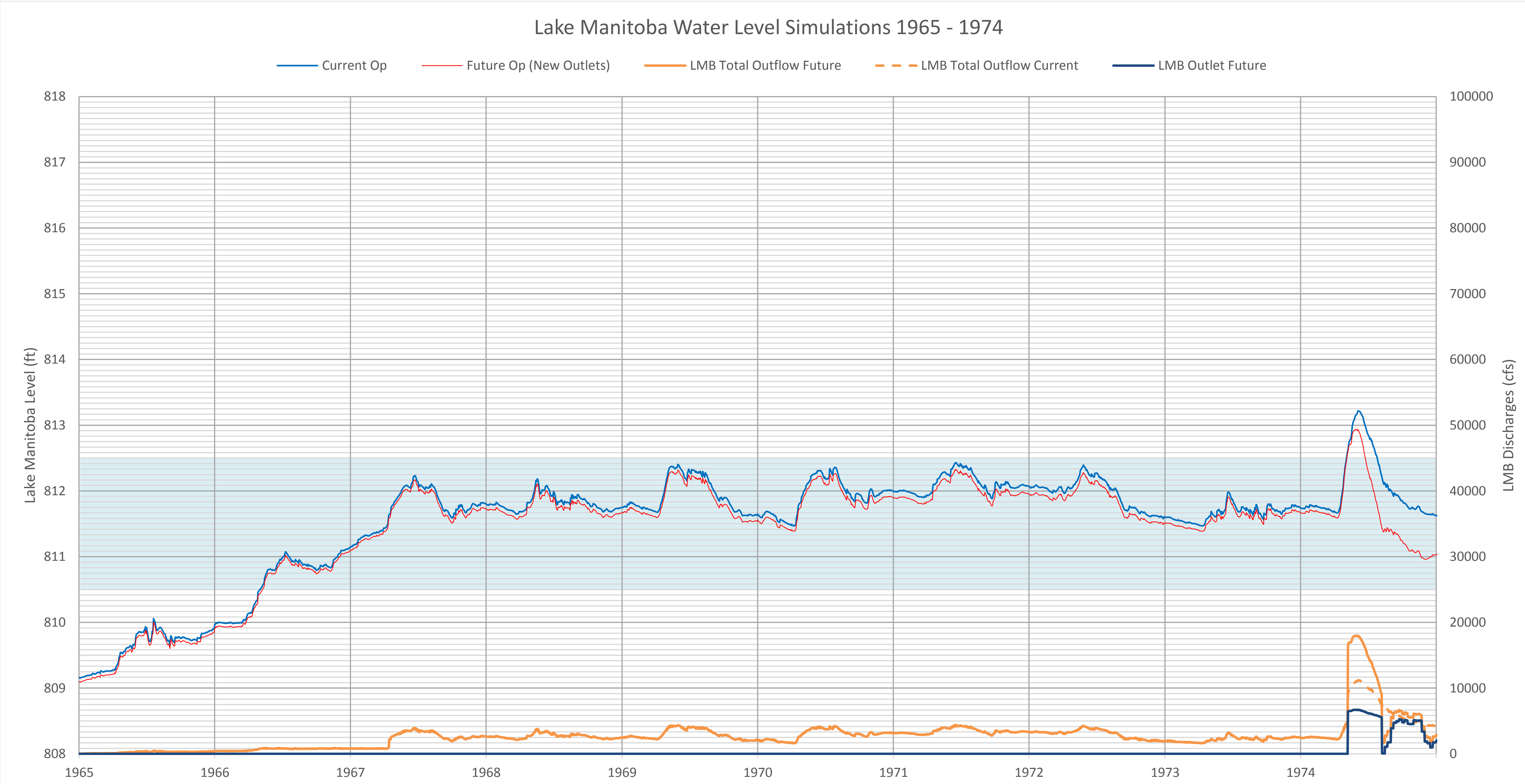
Lake Manitoba Water Level Simulations 1965 - 1974
Current Op
Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
818
817
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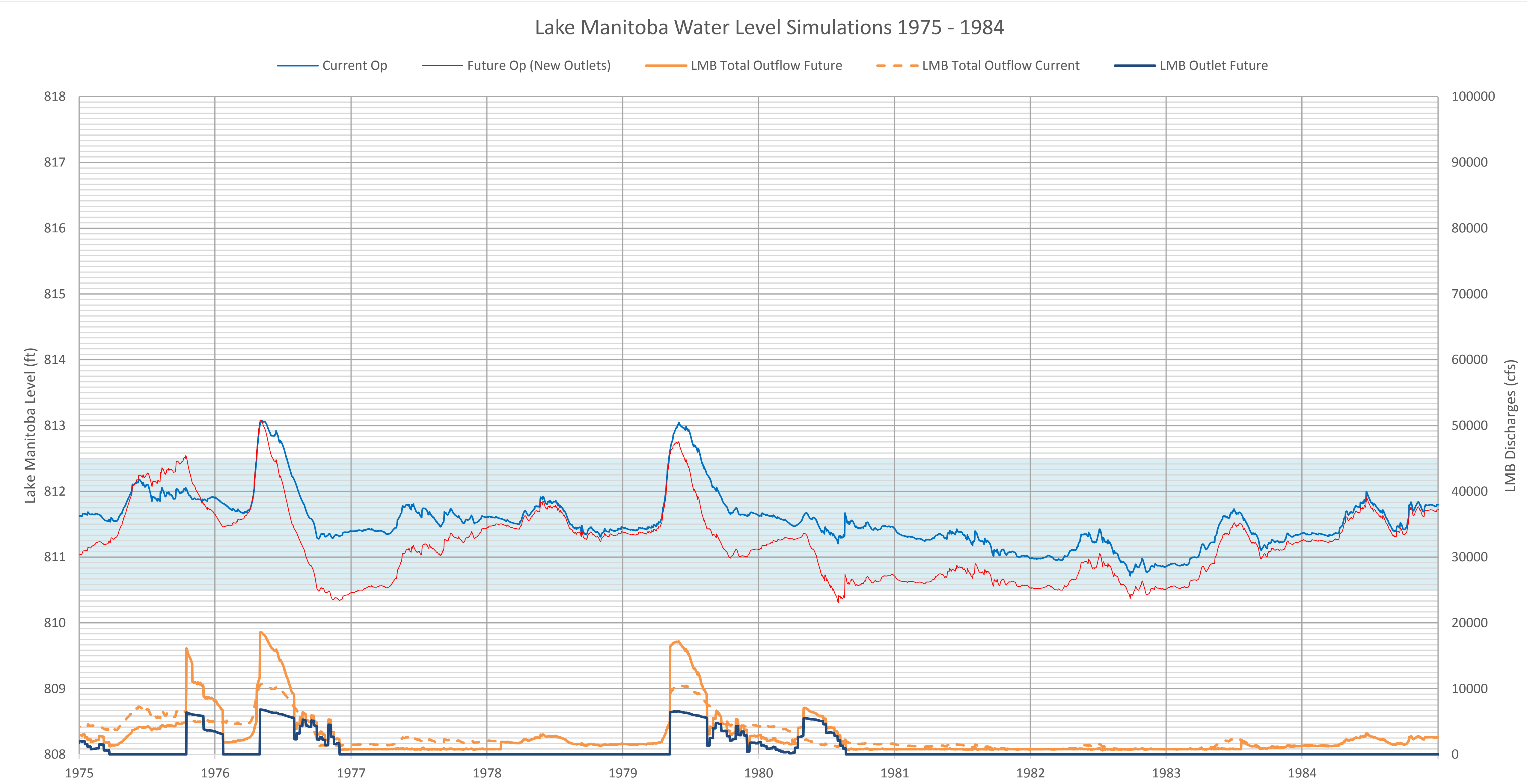

Lake Manitoba Water Level Simulations 1975 - 1984
Current Op
Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
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817
816
815
814
813
812
811
810
809
808
100000
90000
80000
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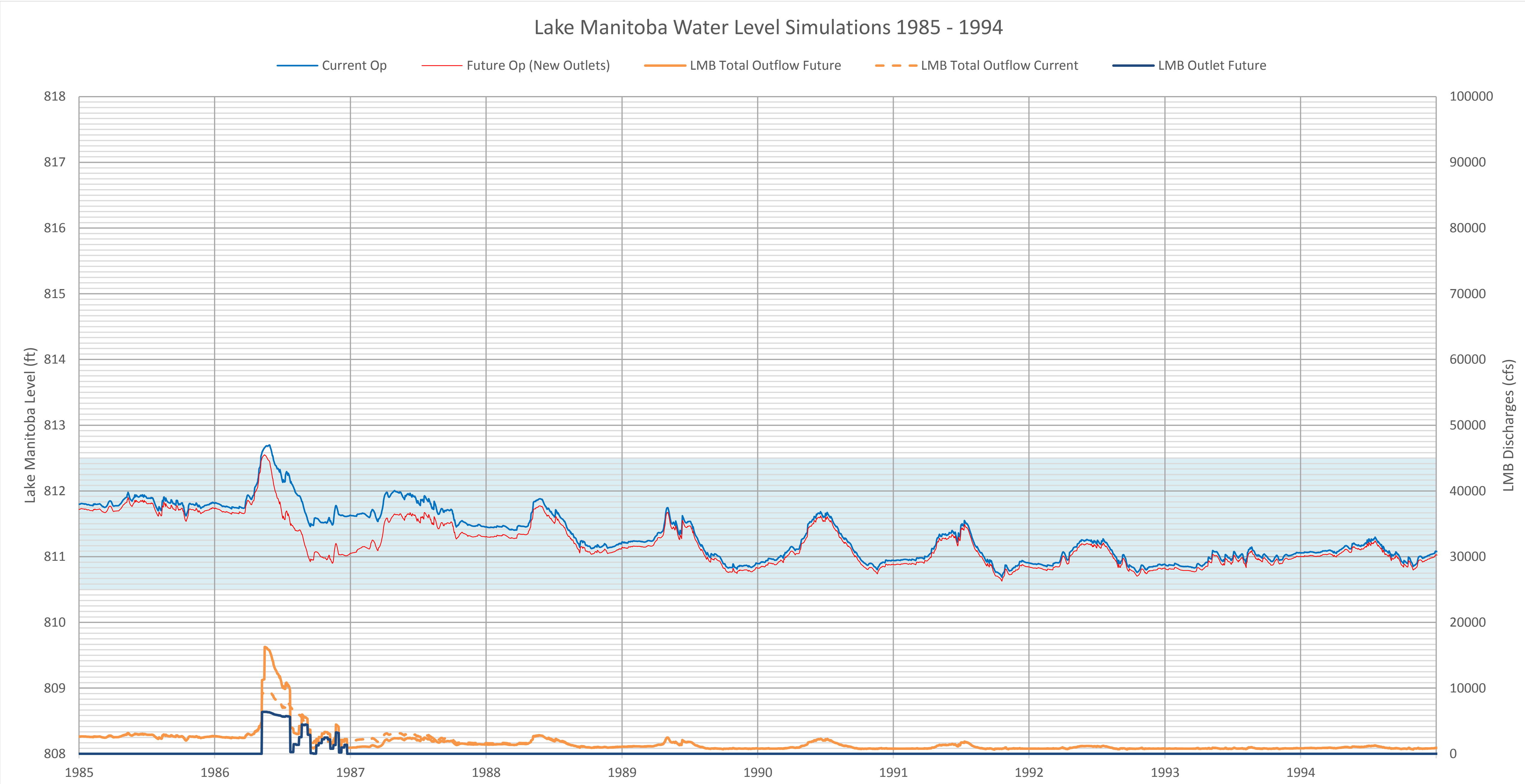
Lake Manitoba Water Level Simulations 1985 - 1994
Current Op
Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
818
817
816
815
814
813
812
811
810
809
808
100000
90000
80000
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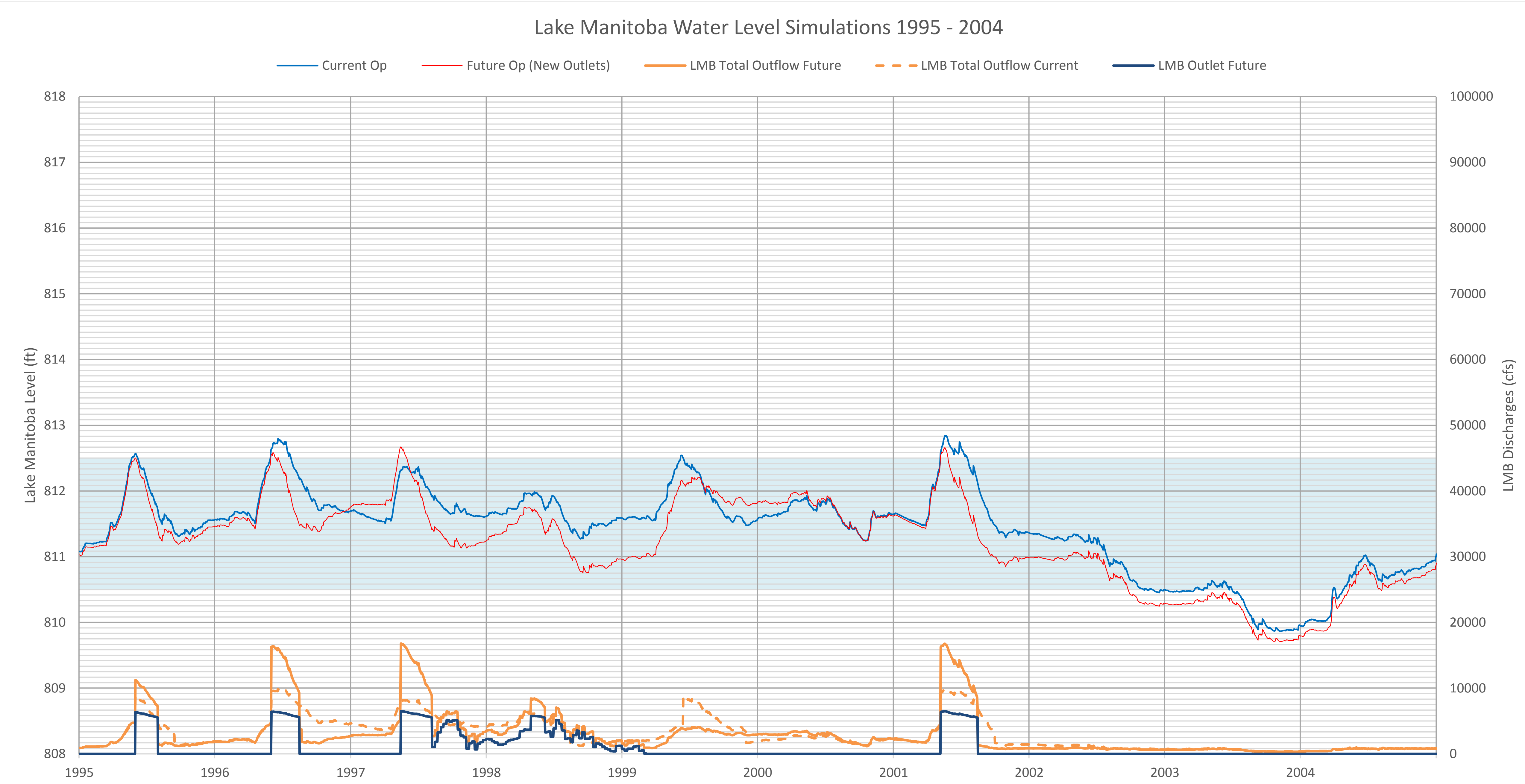
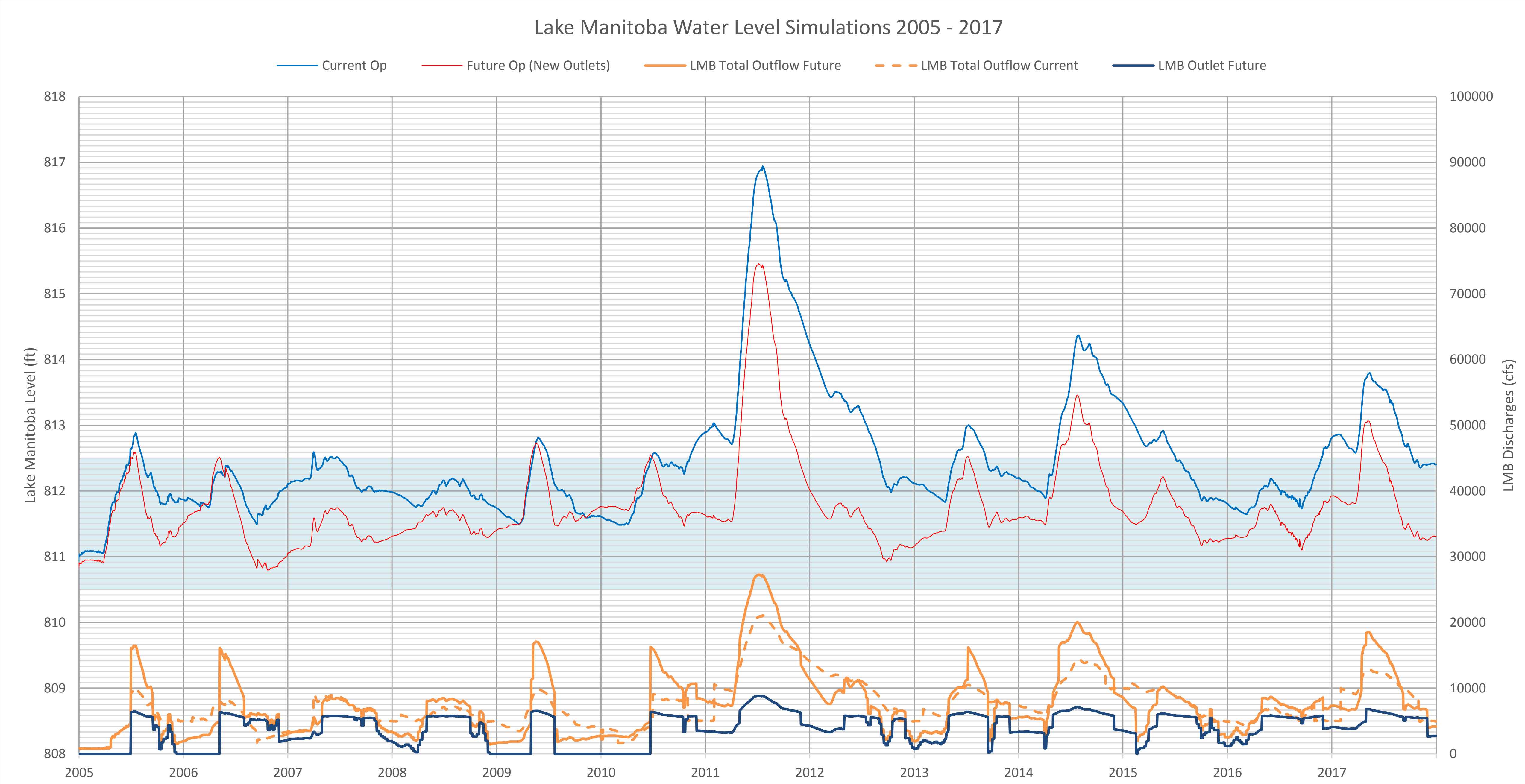
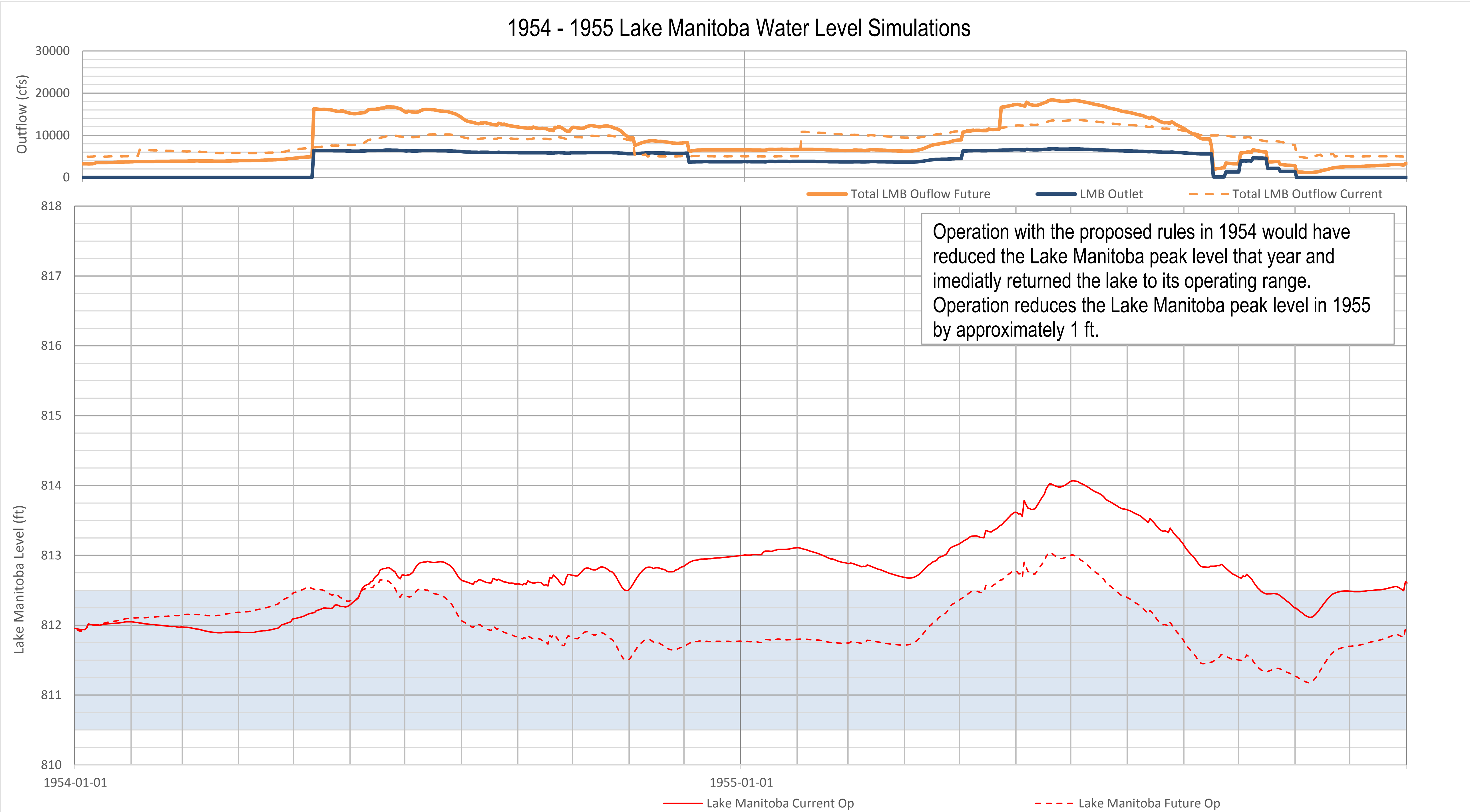
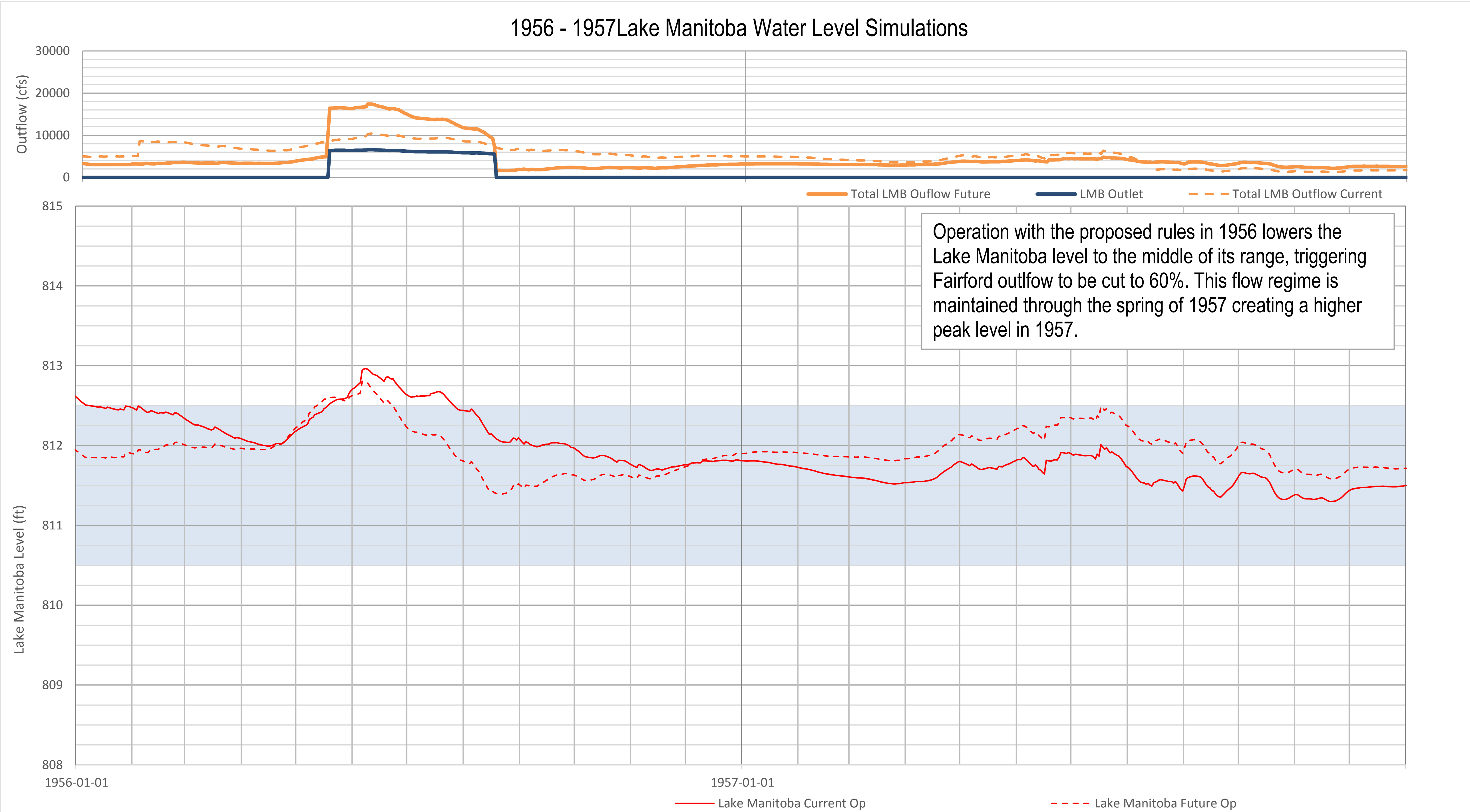
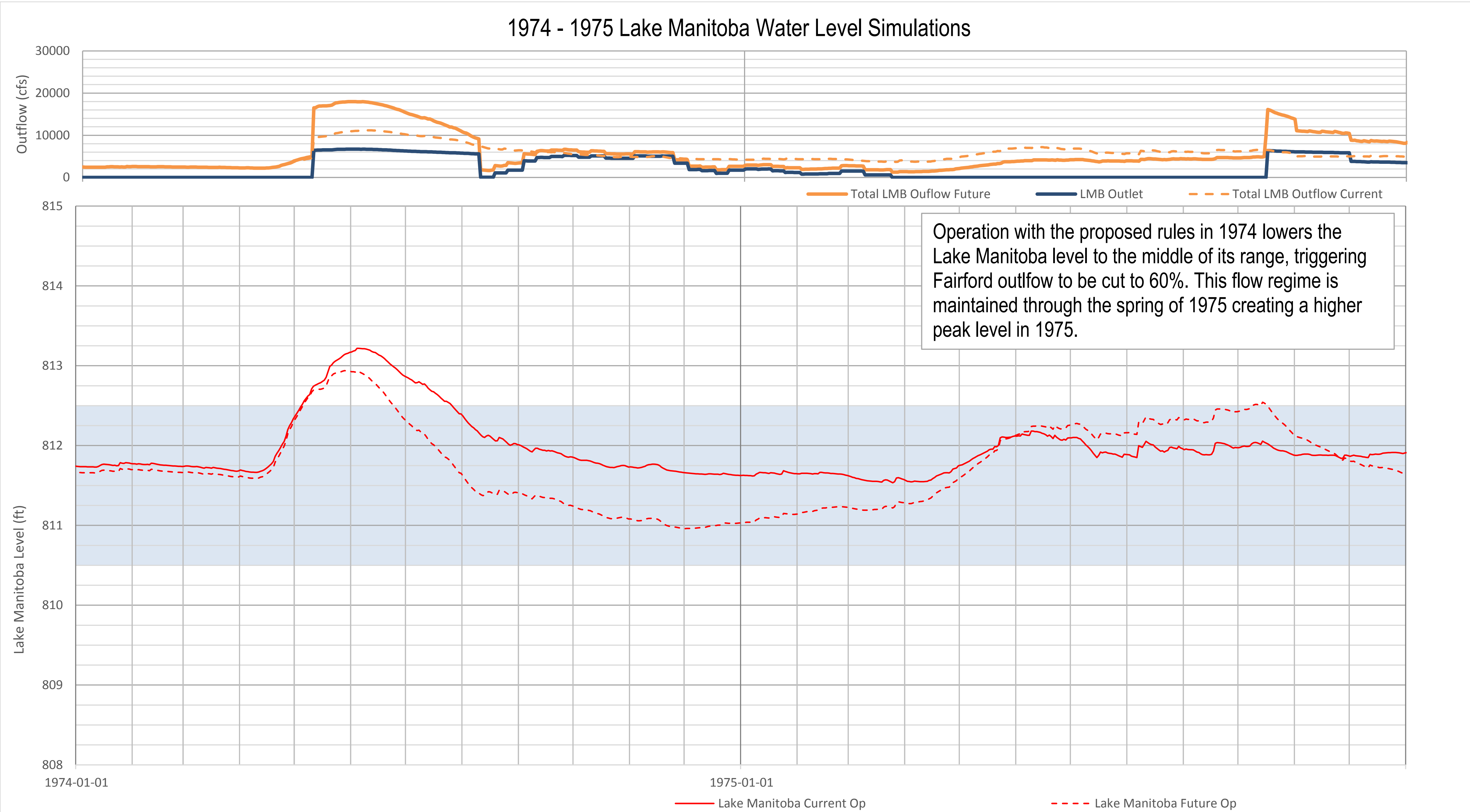
1993
1994


Lake Manitoba Water Level Simulations 1995 - 2004
Current Op
Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
818
817
816
815
814
813
812
811
810
809
808
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004

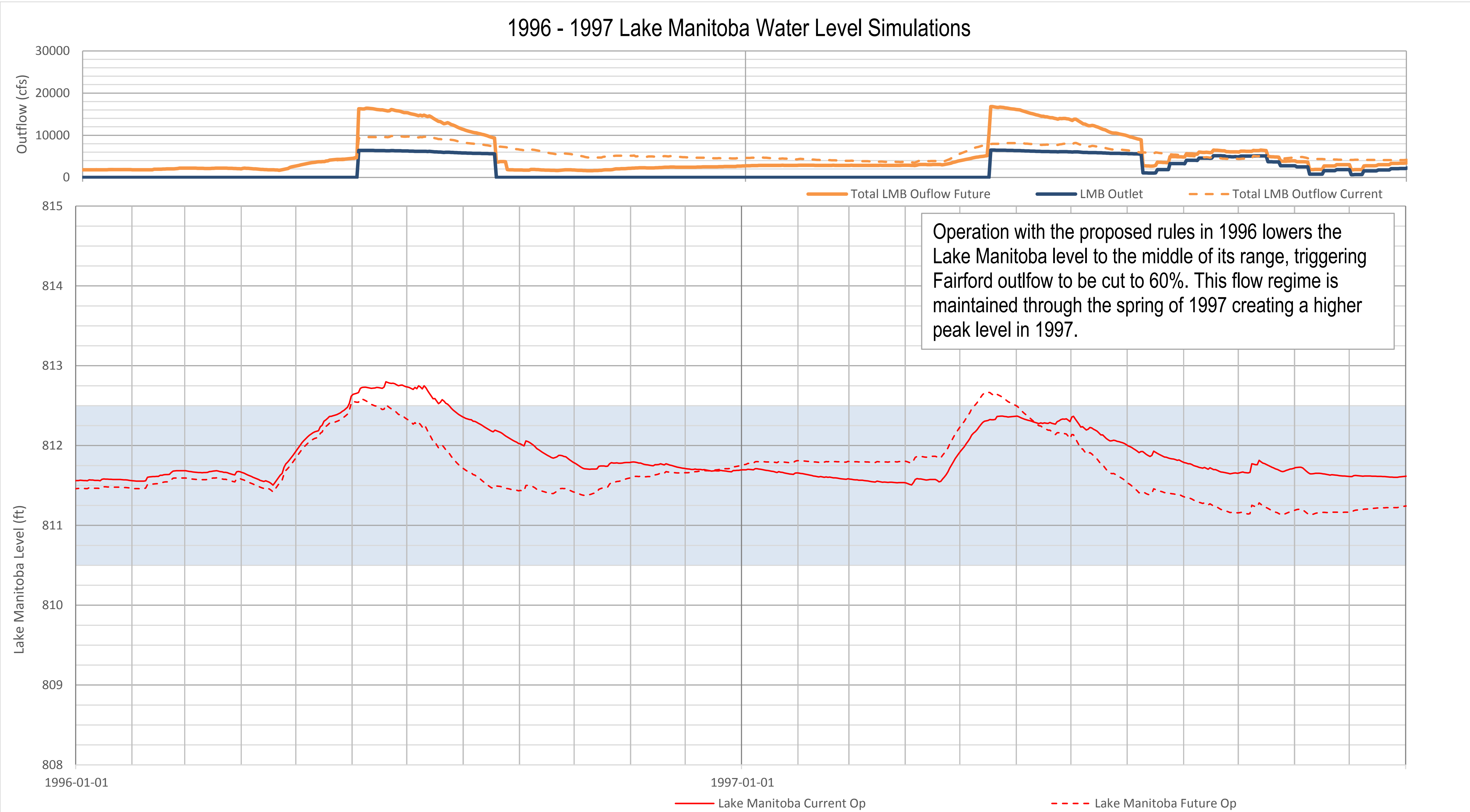

Lake Manitoba Water Level Simulations 2005 - 2017
Current Op
Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
818
817
816
815
814
813
812
811
810
809
808
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

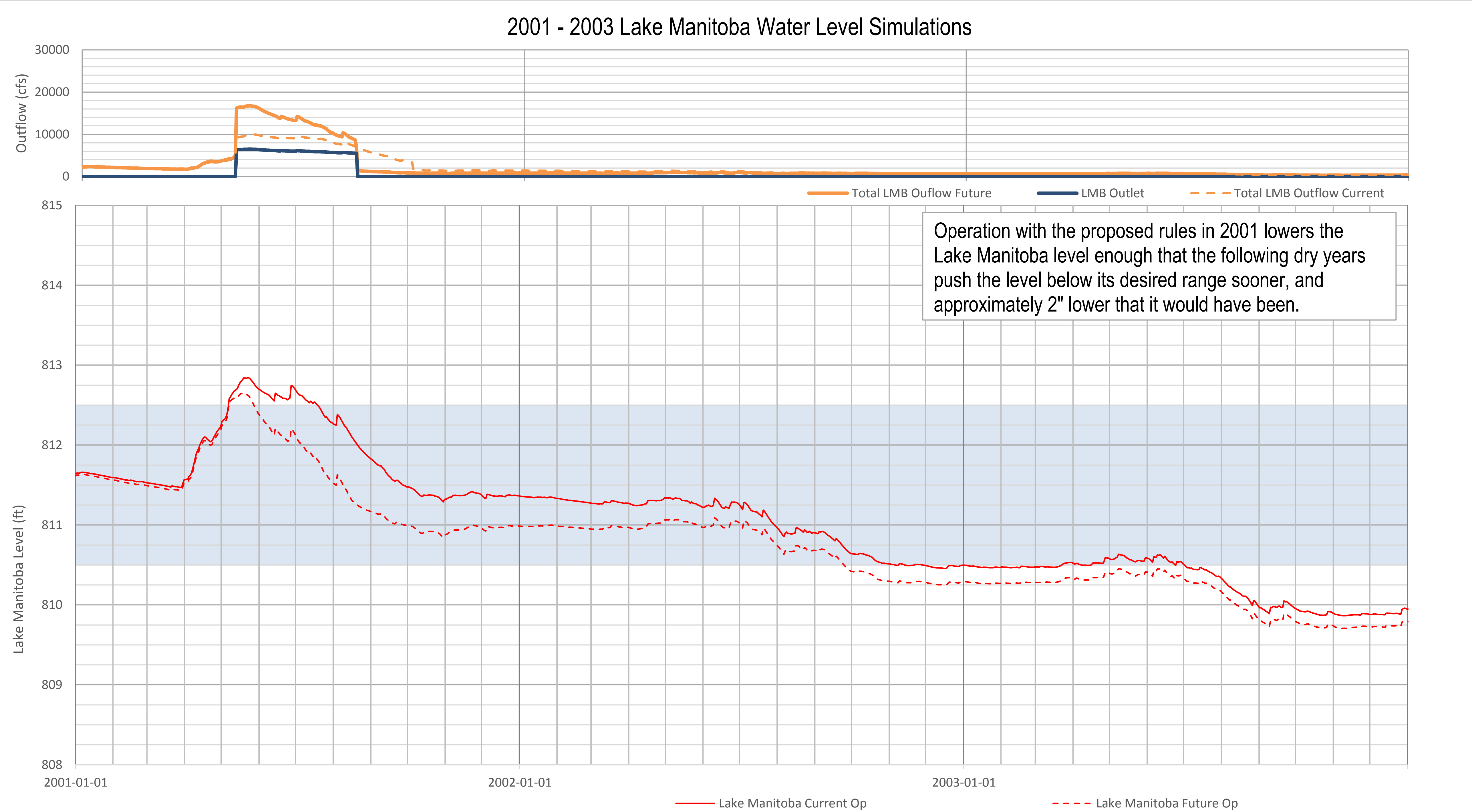

1954 - 1955 Lake Manitoba Water Level Simulations
Outflow (cfs)
30000
20000
10000
0
Total LMB Ouflow Future
LMB Outlet
Total LMB Outflow Current
Lake Manitoba Level (ft)
818
817
816
815
814
813
812
811
810
1954-01-01
1955-01-01
Operation with the proposed rules in 1954 would have reduced the Lake Manitoba peak level that year and imediatly returned the lake to its operating range. Operation reduces the Lake Manitoba peak level in 1955 by approximately 1 ft.
Lake Manitoba Current Op
Lake Manitoba Future Op

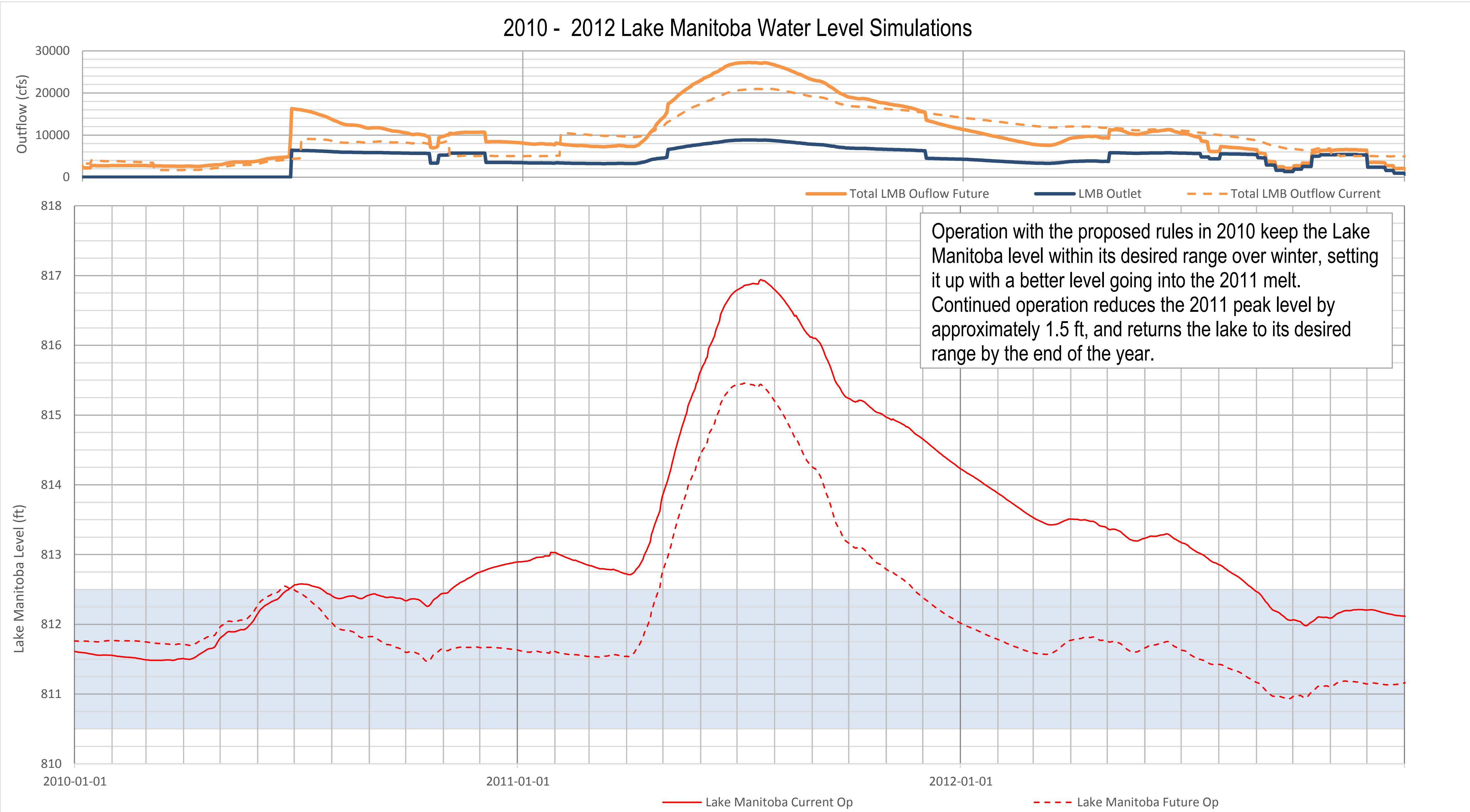

1956 - 1957Lake Manitoba Water Level Simulations
Outflow (cfs)
30000
20000
10000
0
Total LMB Ouflow Future
LMB Outlet
Total LMB Outflow Current
Lake Manitoba Level (ft)
815
814
813
812
811
810
809
808
1956-01-01
1957-01-01
Operation with the proposed rules in 1956 lowers the Lake Manitoba level to the middle of its range, triggering Fairford outlfow to be cut to 60%. This flow regime is maintained through the spring of 1957 creating a higher peak level in 1957.
Lake Manitoba Current Op
Lake Manitoba Future Op



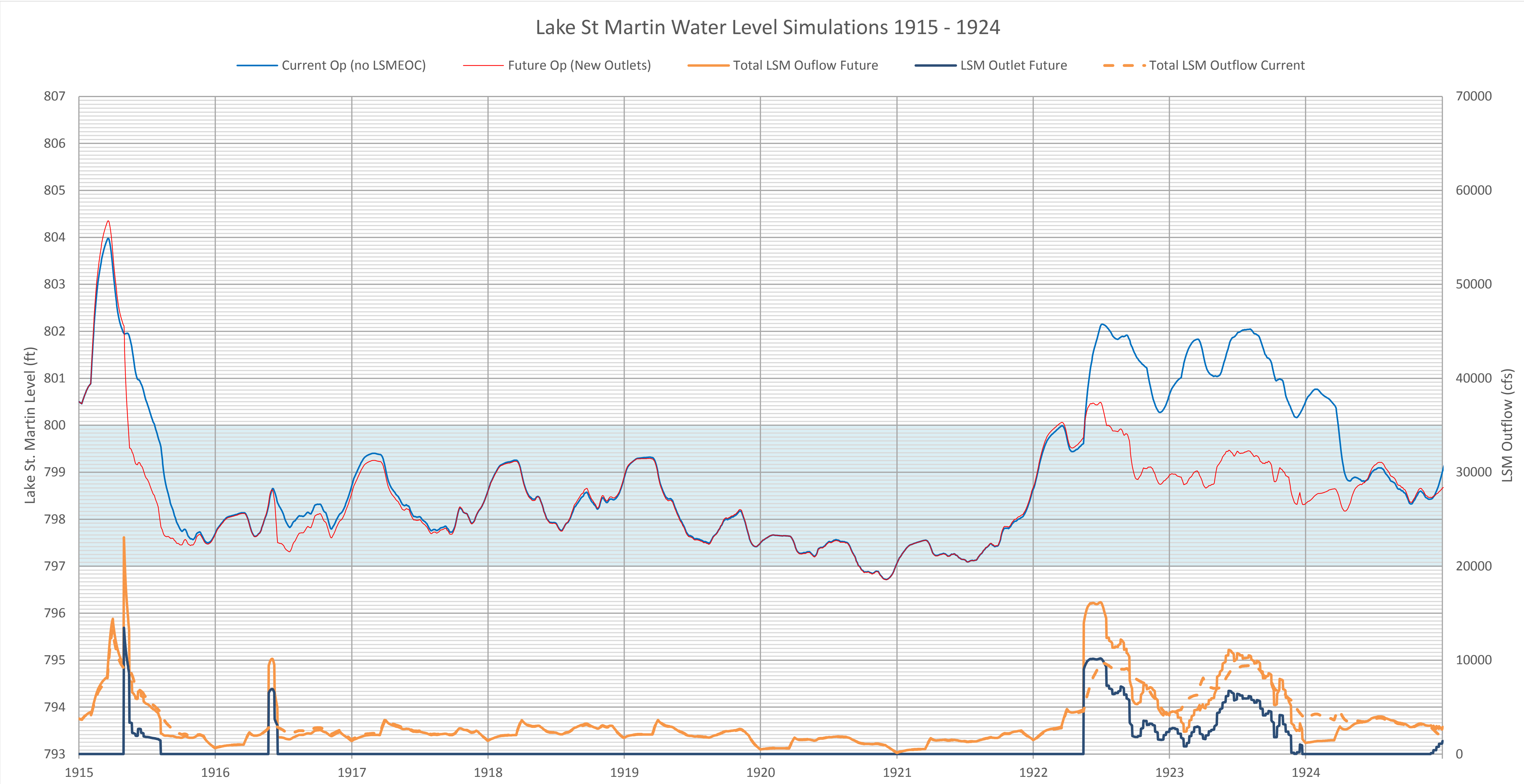
1974 - 1975 Lake Manitoba Water Level Simulations
Outflow (cfs)
30000
20000
10000
0
Total LMB Ouflow Future
LMB Outlet
Total LMB Outflow Current
Lake Manitoba Level (ft)
815
814
813
812
811
810
809
808
1974-01-01
1975-01-01
Operation with the proposed rules in 1974 lowers the Lake Manitoba level to the middle of its range, triggering Fairford outlfow to be cut to 60%. This flow regime is maintained through the spring of 1975 creating a higher peak level in 1975.
Lake Manitoba Current Op
Lake Manitoba Future Op


1996 - 1997 Lake Manitoba Water Level Simulations
Outflow (cfs)
30000
20000
10000
0
Total LMB Ouflow Future
LMB Outlet
Total LMB Outflow Current
Lake Manitoba Level (ft)
815
814
813
812
811
810
809
808
Operation with the proposed rules in 1996 lowers the Lake Manitoba level to the middle of its range, triggering Fairford outlfow to be cut to 60%. This flow regime is maintained through the spring of 1997 creating a higher peak level in 1997.
1996-01-01
1997-01-01
Lake Manitoba Current Op
Lake Manitoba Future Op

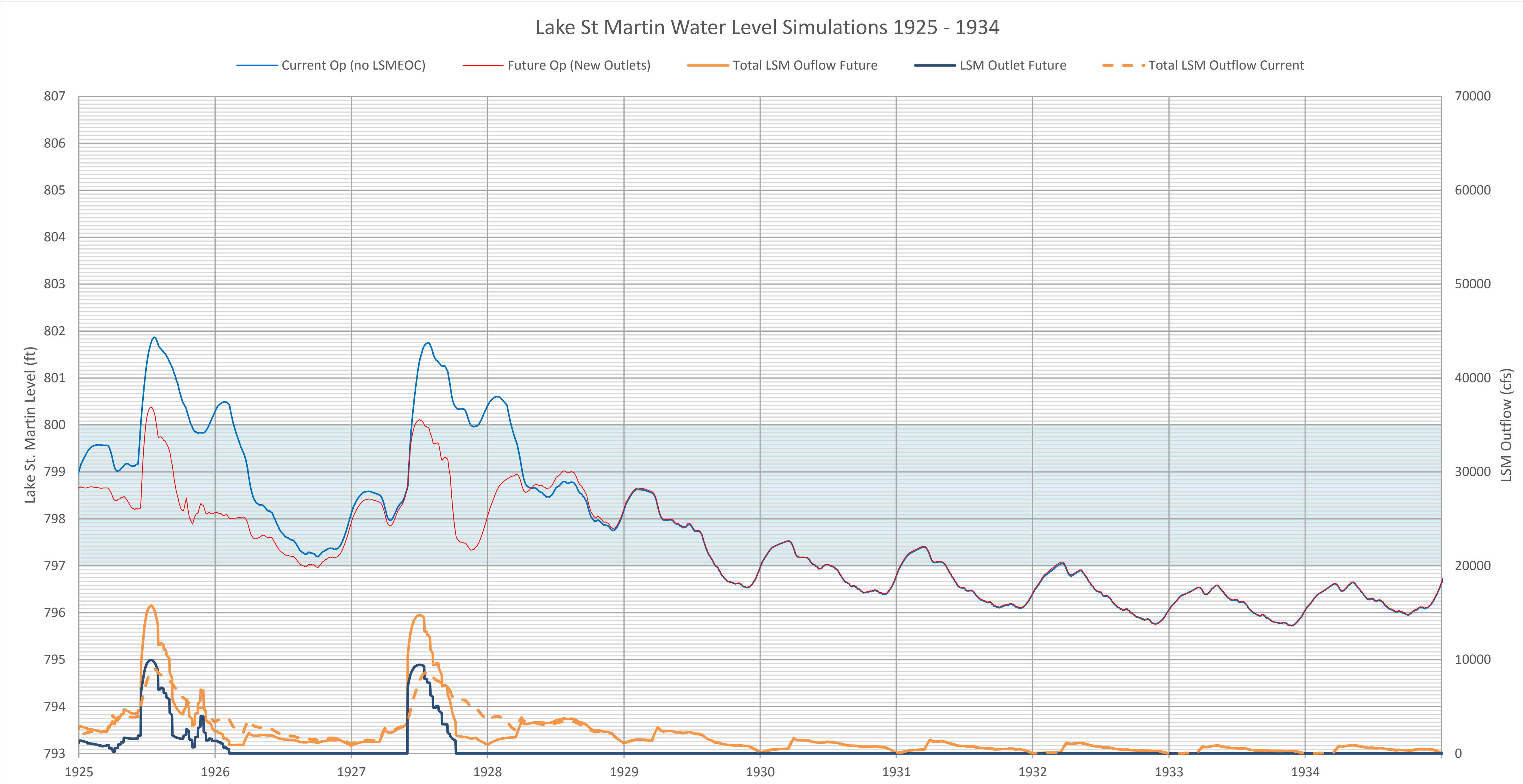

2001 - 2003 Lake Manitoba Water Level Simulations
30000
20000
10000
0
Outflow (cfs)
Total LMB Ouflow Future
LMB Outlet
Total LMB Outflow Current
815
814
813
812
811
810
809
808
Lake Manitoba Level (ft)
Operation with the proposed rules in 2001 lowers the Lake Manitoba level enough that the following dry years push the level below its desired range sooner, and approximately 2" lower that it would have been.
2001-01-01
2002-01-01
2003-01-01
Lake Manitoba Current Op
Lake Manitoba Future Op



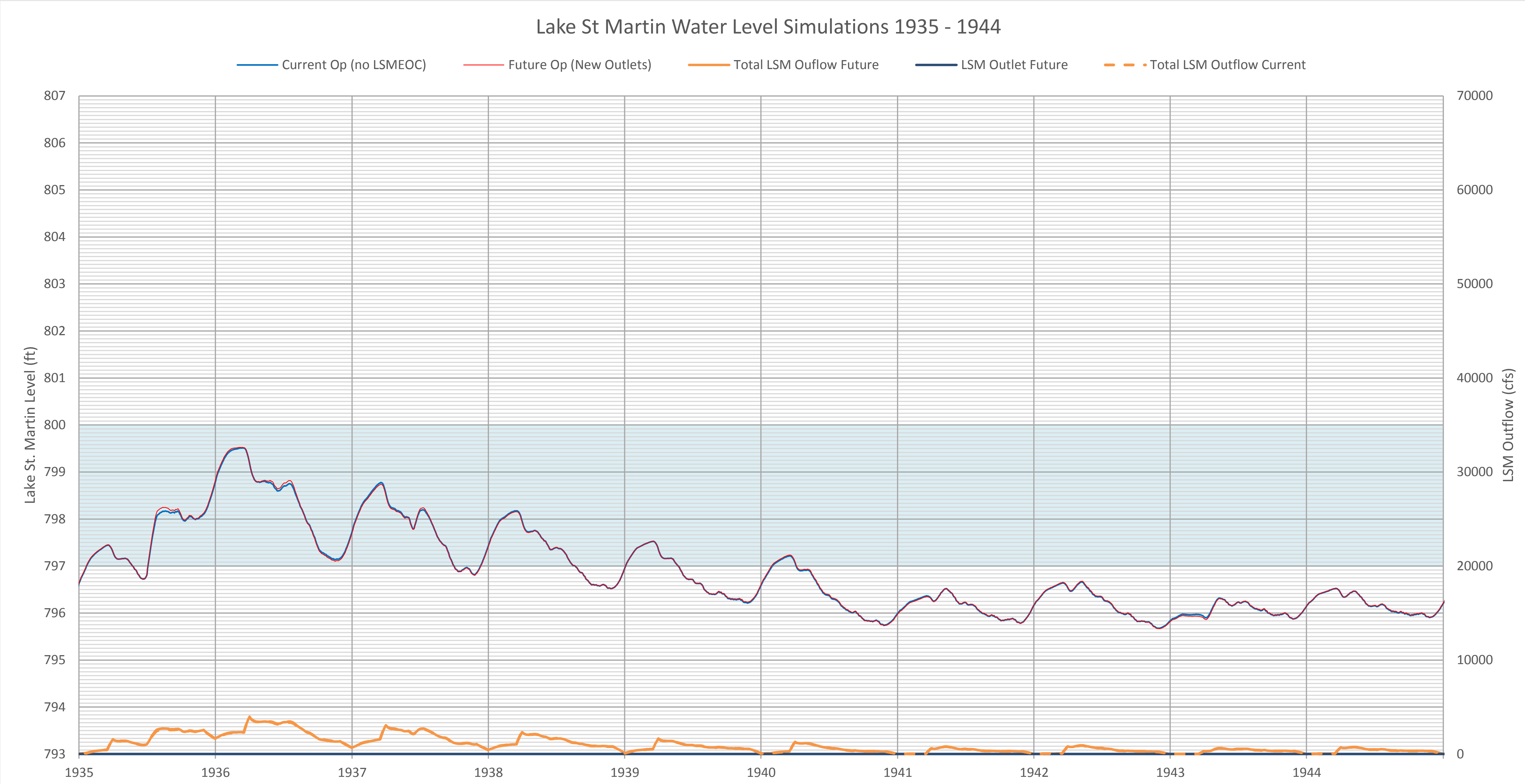
2010 - 2012 Lake Manitoba Water Level Simulations
Outflow (cfs)
30000
20000
10000
0
Total LMB Ouflow Future
LMB Outlet
Total LMB Outflow Current
818
817
816
815
814
813
812
811
810
Lake Manitoba Level (ft)
Operation with the proposed rules in 2010 keep the Lake Manitoba level within its desired range over winter, setting it up with a better level going into the 2011 melt. Continued operation reduces the 2011 peak level by approximately 1.5 ft, and returns the lake to its desired range by the end of the year.
2010-01-01
2011-01-01
2012-01-01
Lake Manitoba Current Op
Lake Manitoba Future Op



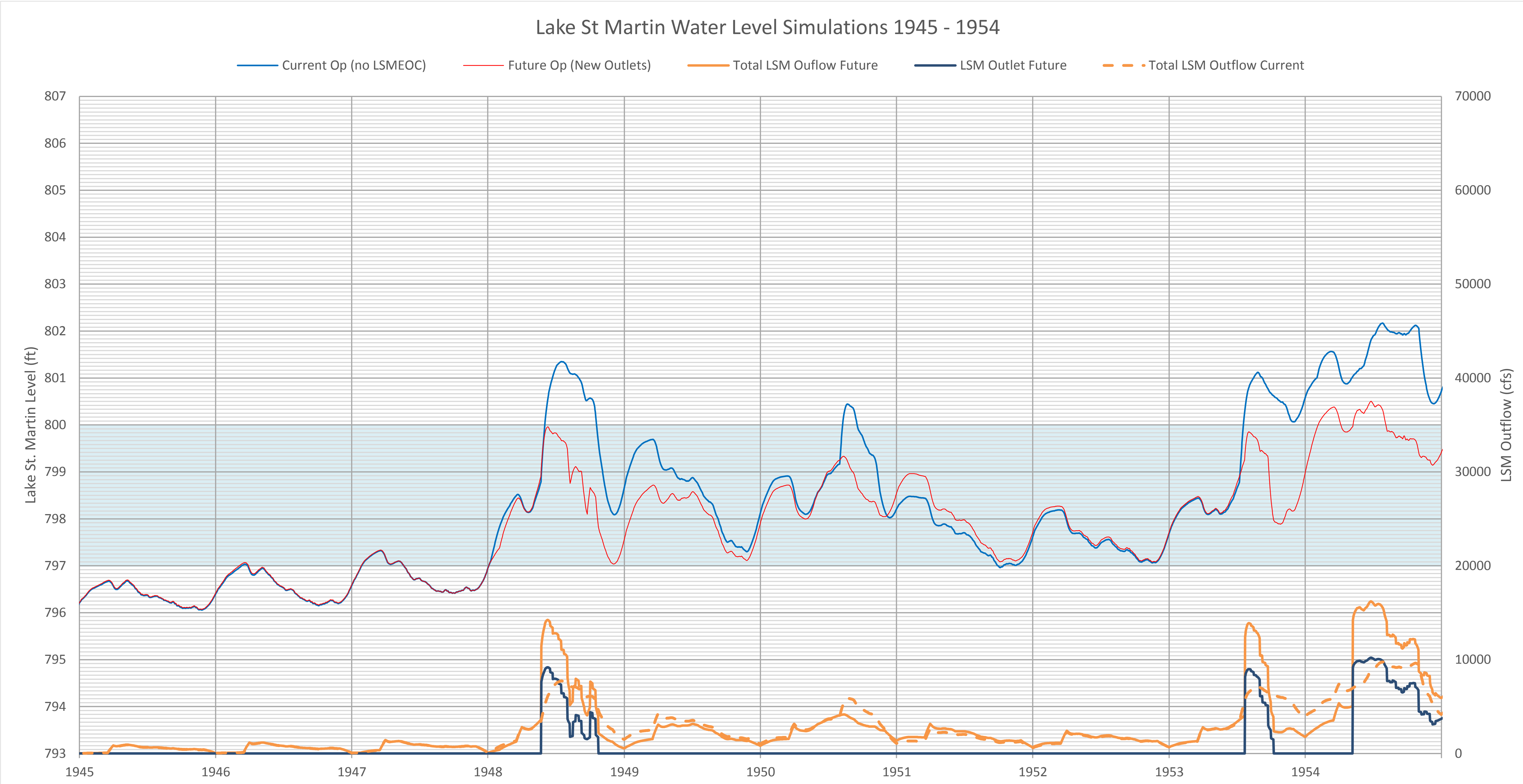
Lake St Martin Water Level Simulations 1915 - 1924
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
807
806
805
804
803
802
801
800
799
798
797
796
795
794
793
70000
60000
50000
40000
30000
20000
10000
0
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924

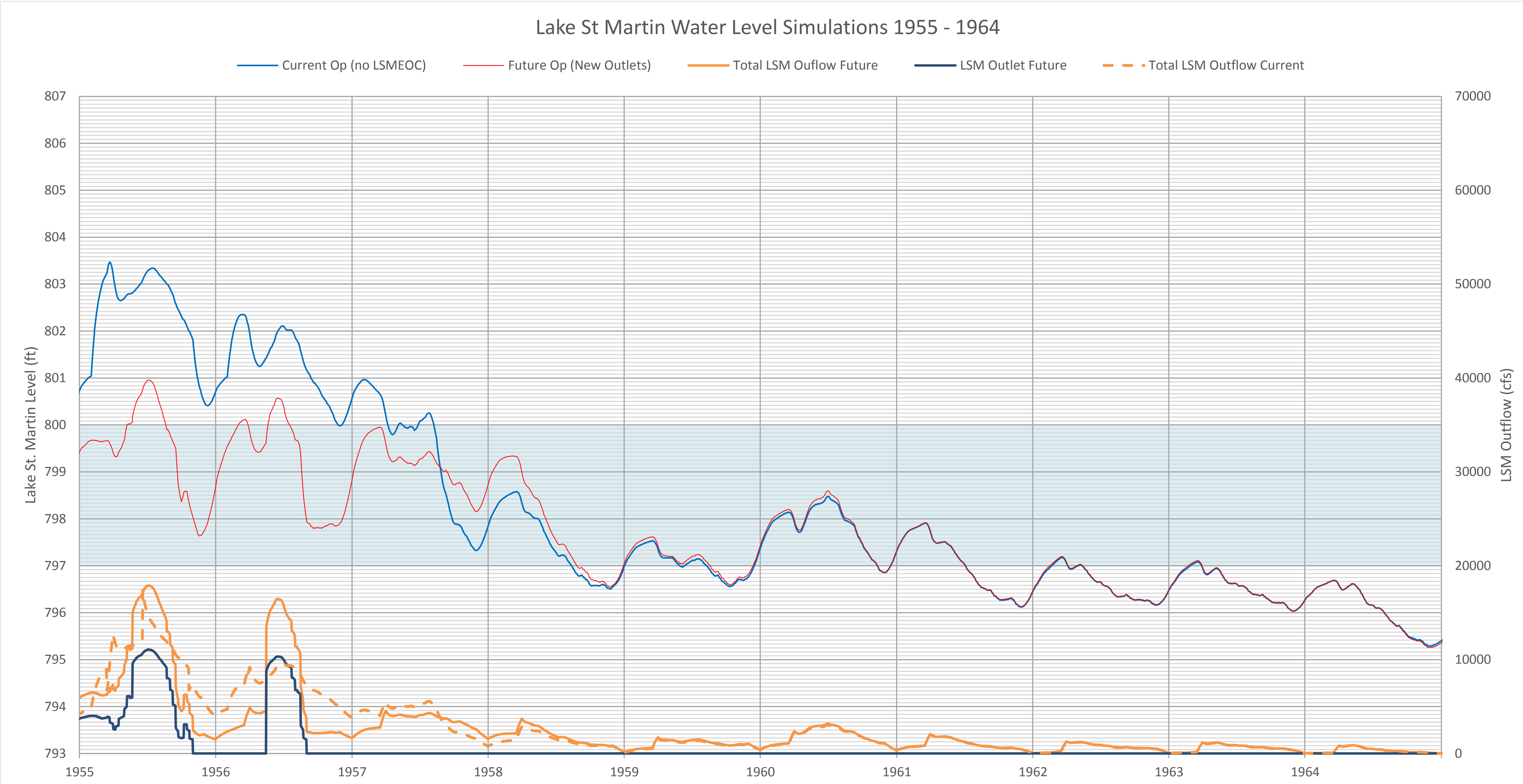


Lake St Martin Water Level Simulations 1925 - 1934
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
807
806
805
804
803
802
801
800
799
798
797
796
795
794
793
70000
60000
50000
40000
30000
20000
10000
0
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934

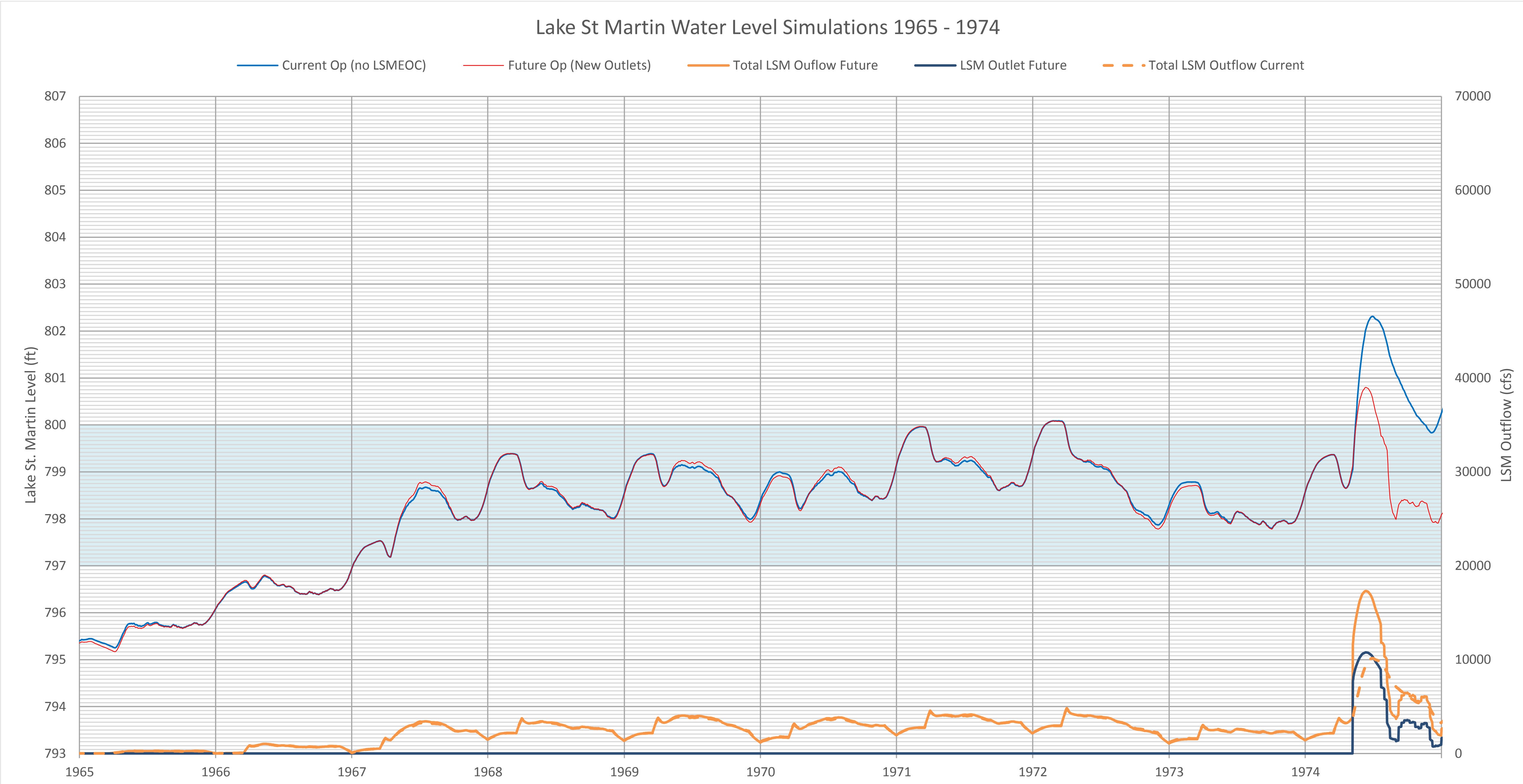


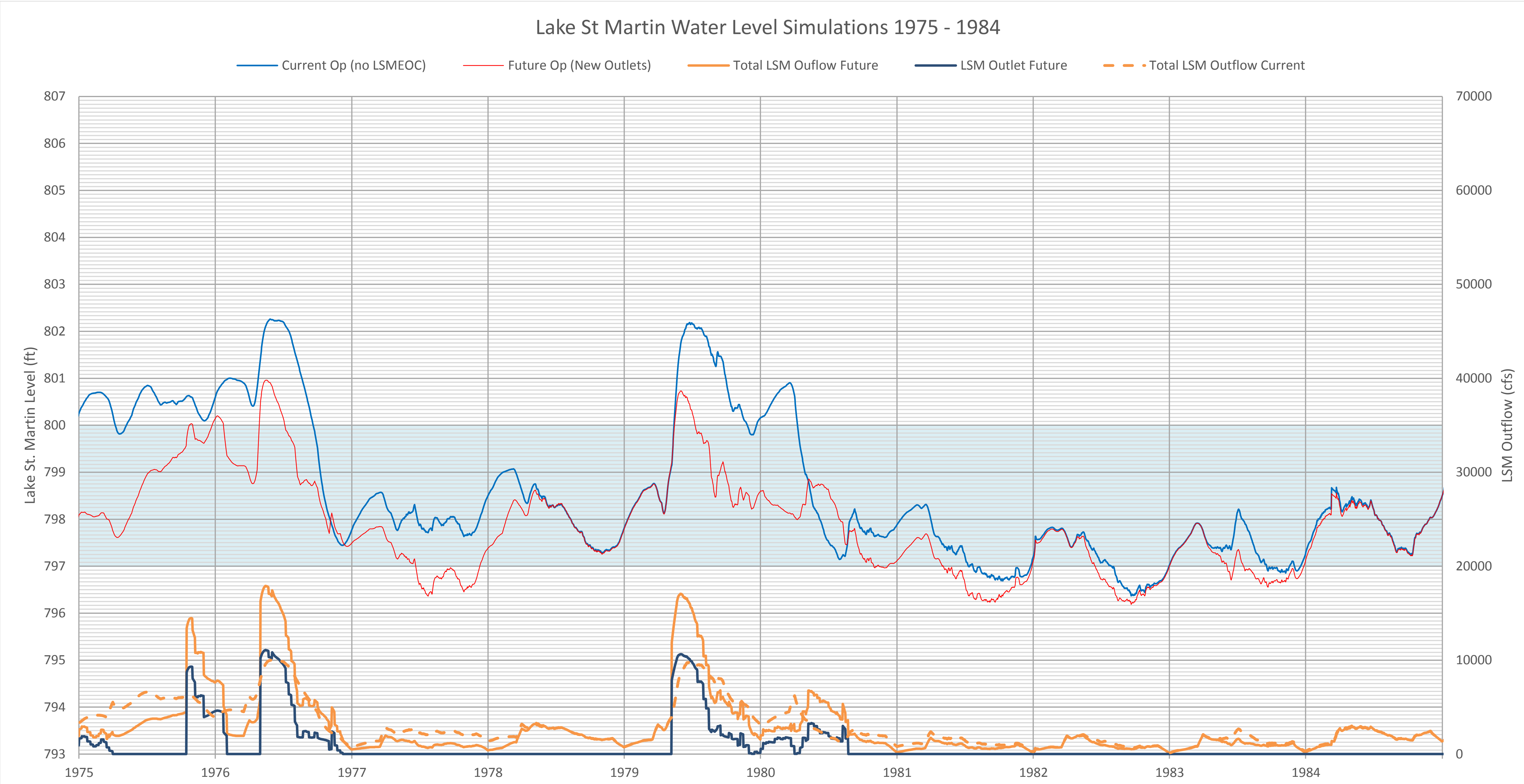
Lake St Martin Water Level Simulations 1935 - 1944
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
807
806
805
804
803
802
801
800
799
798
797
796
795
794
793
70000
60000
50000
40000
30000
20000
10000
0
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944

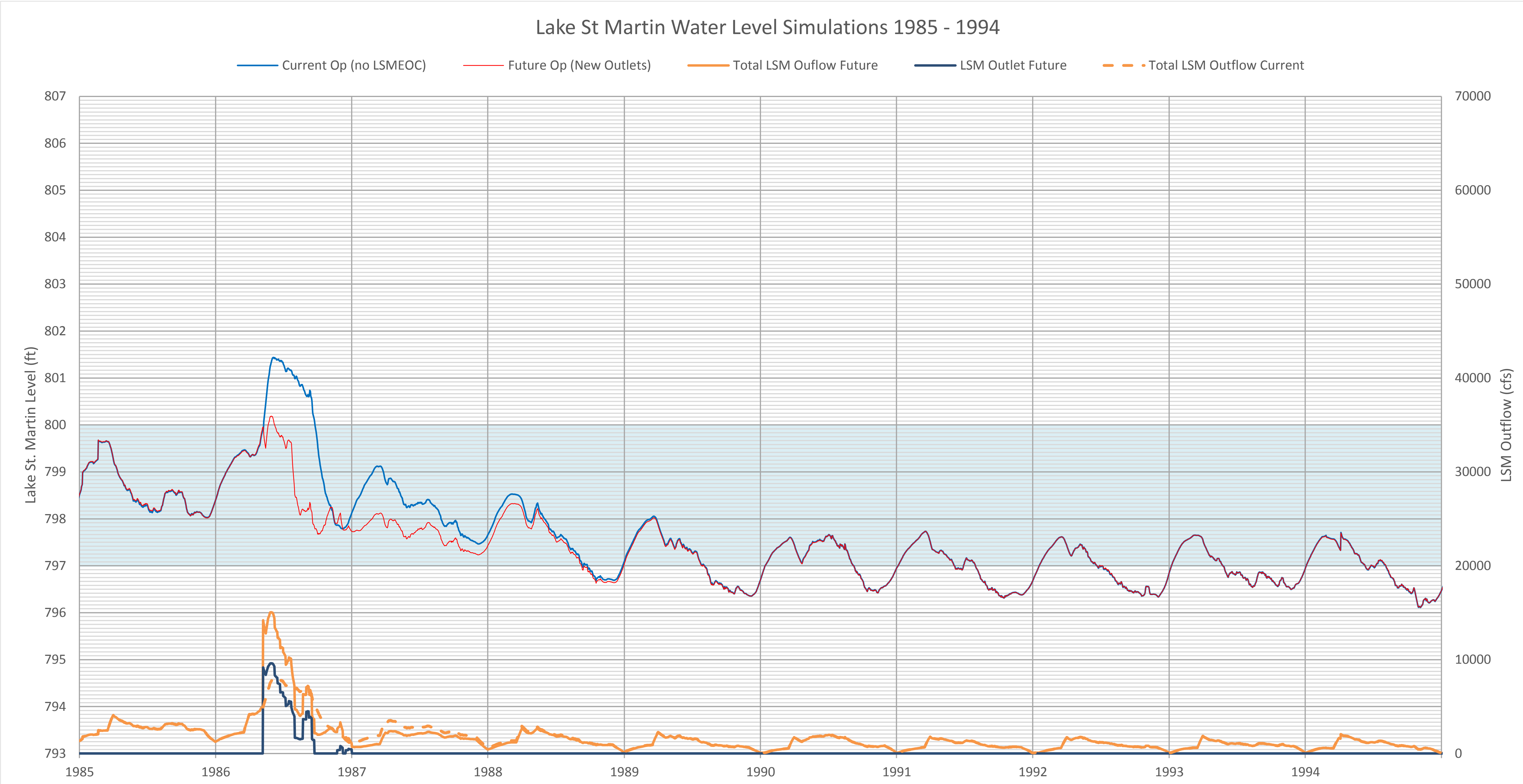

Lake St Martin Water Level Simulations 1945 - 1954
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
807
806
805
804
803
802
801
800
799
798
797
796
795
794
793
70000
60000
50000
40000
30000
20000
10000
0
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954

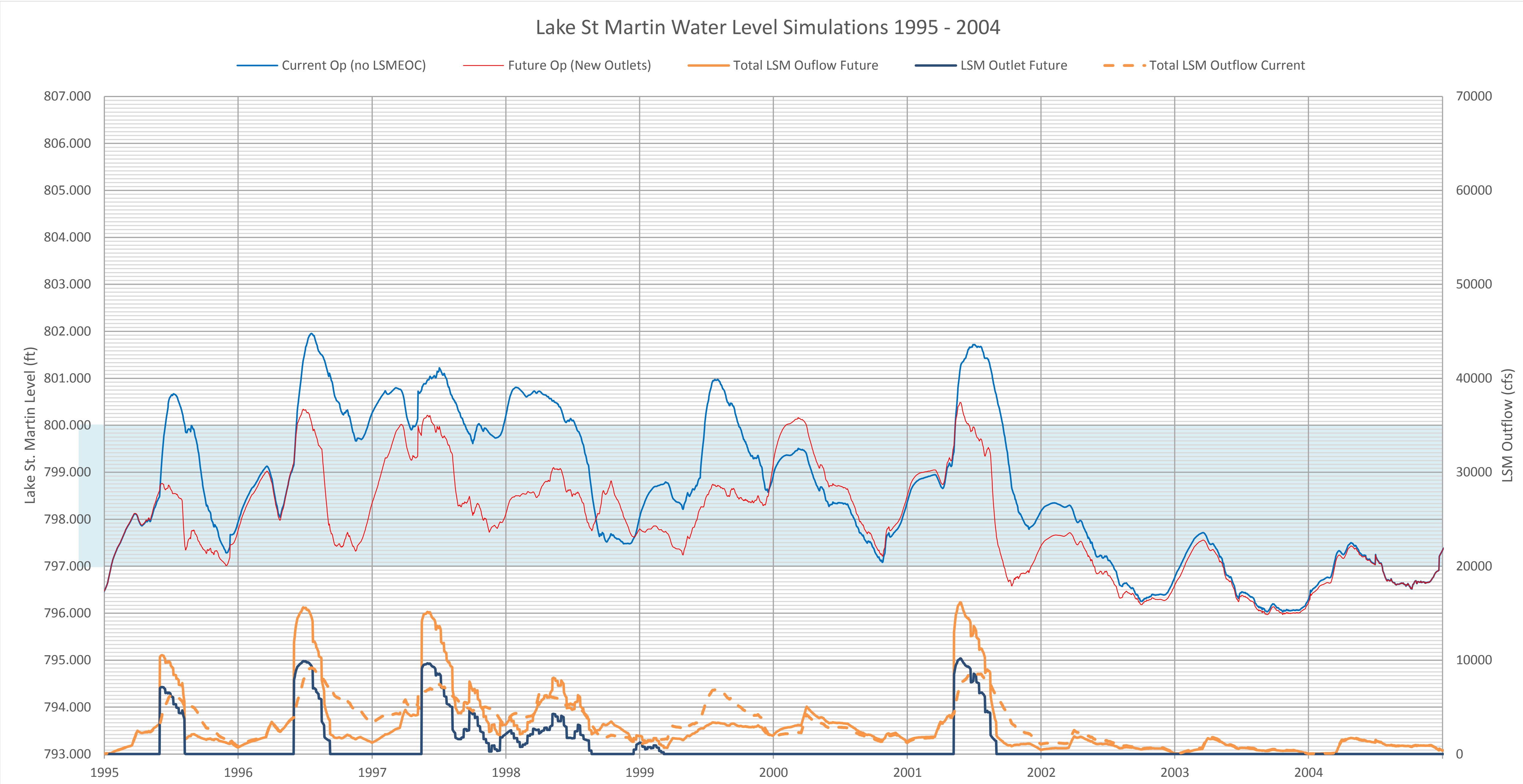


Lake St Martin Water Level Simulations 1955 - 1964
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
807
806
805
804
803
802
801
800
799
798
797
796
795
794
793
70000
60000
50000
40000
30000
20000
10000
0
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964

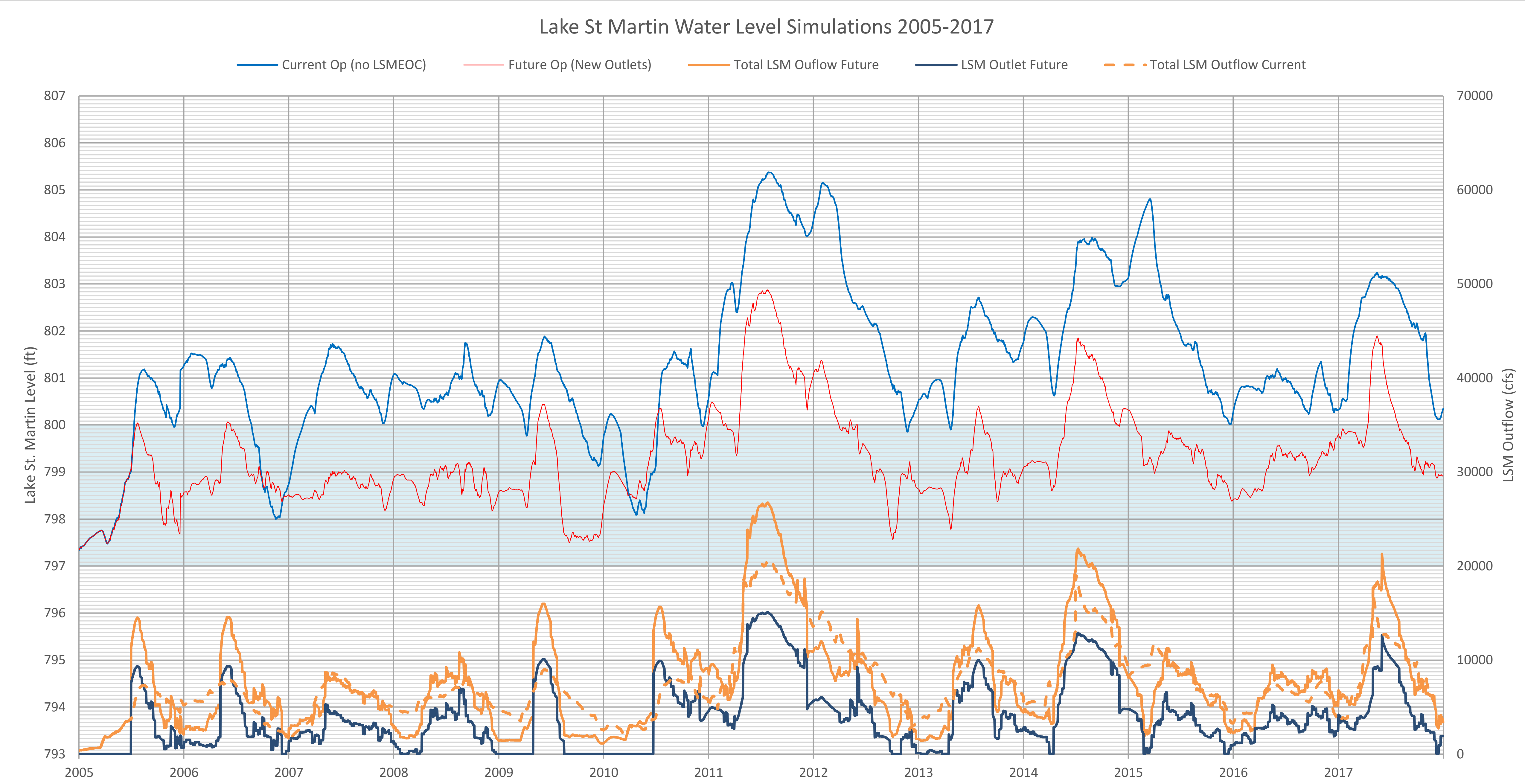

Lake St Martin Water Level Simulations 1965 - 1974
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
807
806
805
804
803
802
801
800
799
798
797
796
795
794
793
70000
60000
50000
40000
30000
20000
10000
0
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974

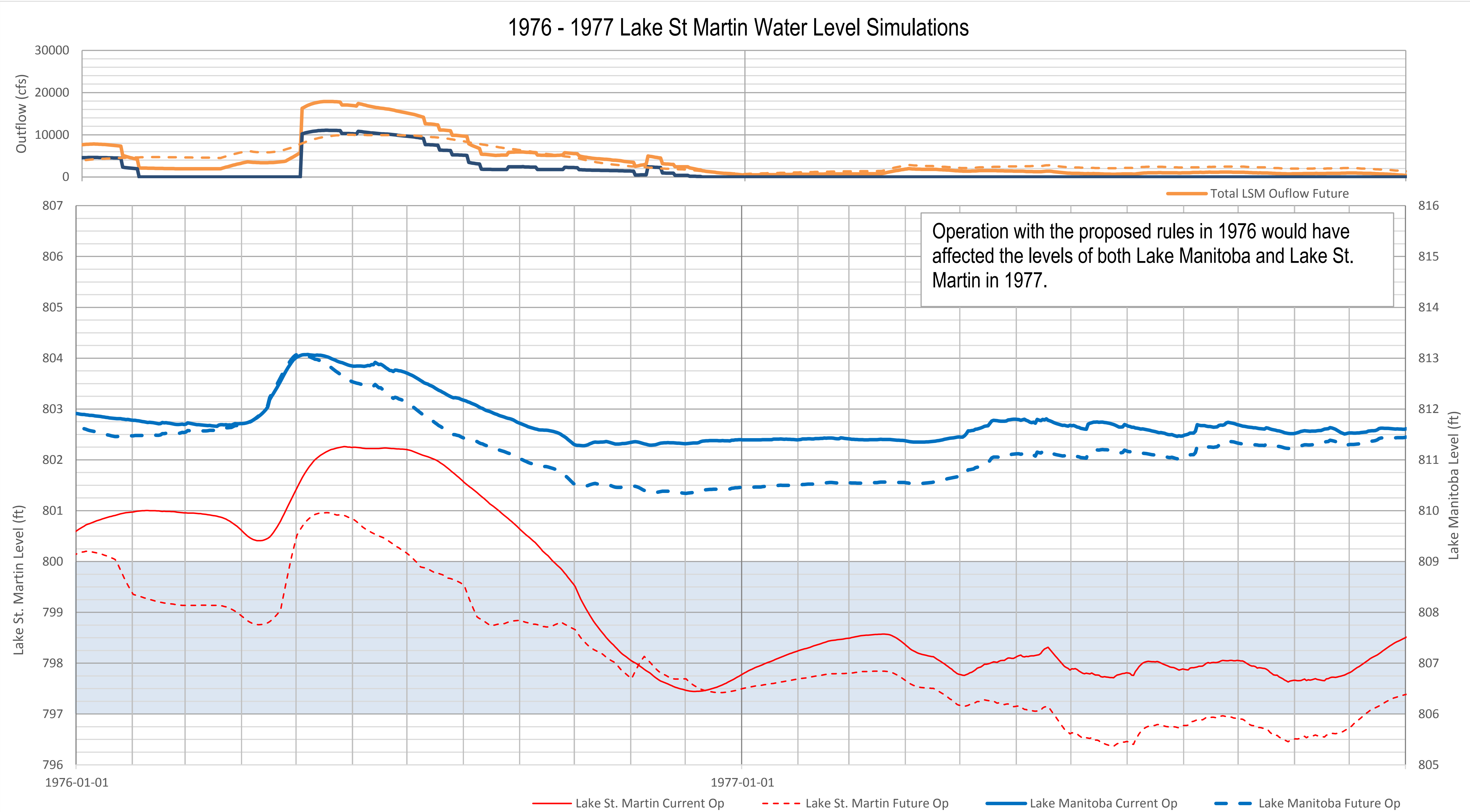

Lake St Martin Water Level Simulations 1975 - 1984
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
807
806
805
804
803
802
801
800
799
798
797
796
795
794
793
70000
60000
50000
40000
30000
20000
10000
0
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984

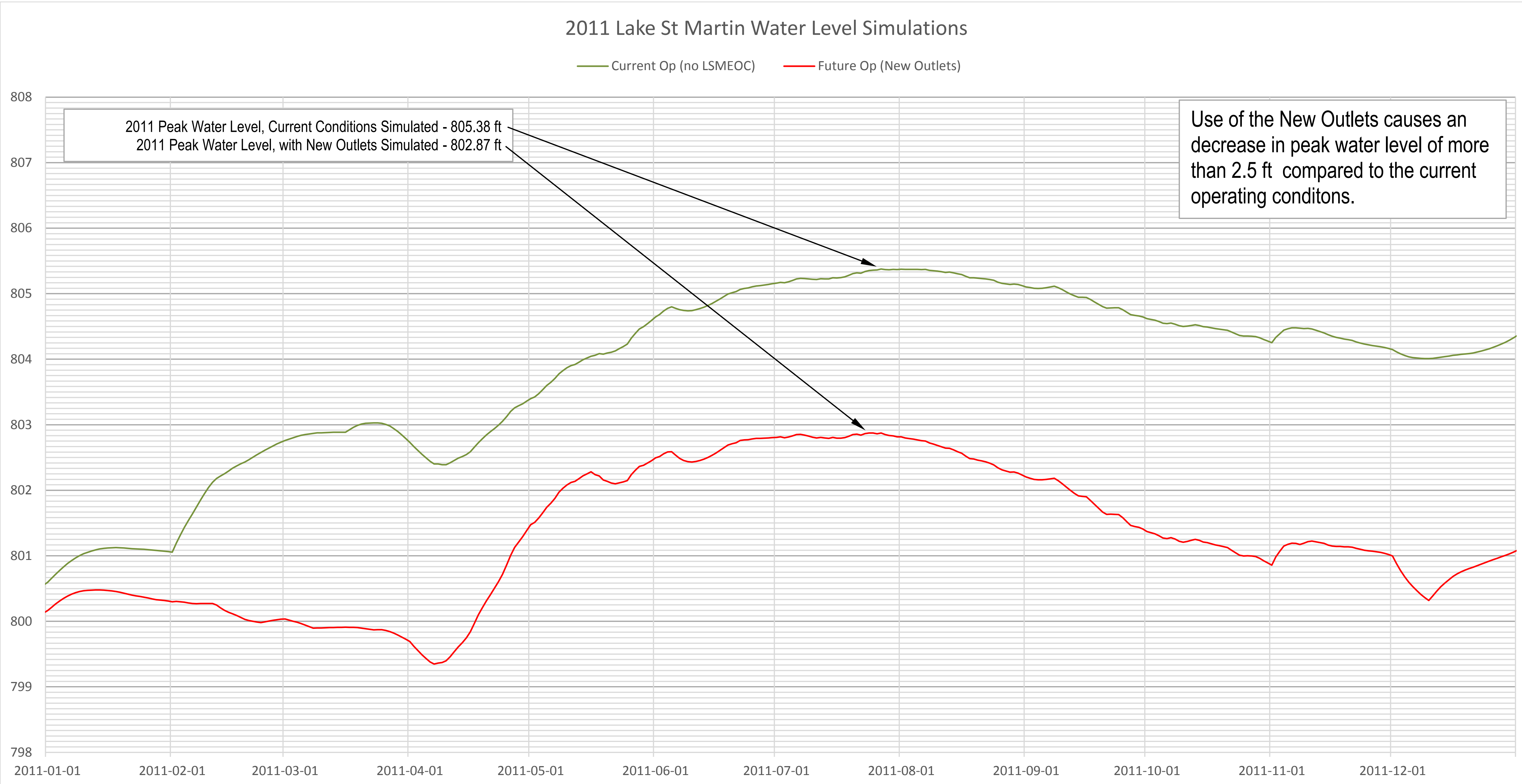

Lake St Martin Water Level Simulations 1985 - 1994
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
807
806
805
804
803
802
801
800
799
798
797
796
795
794
793
70000
60000
50000
40000
30000
20000
10000
0
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994



Lake St Martin Water Level Simulations 1995 - 2004
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
807.000
806.000
805.000
804.000
803.000
802.000
801.000
800.000
799.000
798.000
797.000
796.000
795.000
794.000
793.000
70000
60000
50000
40000
30000
20000
10000
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004


Lake St Martin Water Level Simulations 2005-2017
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
807
806
805
804
803
802
801
800
799
798
797
796
795
794
793
70000
60000
50000
40000
30000
20000
10000
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017


1976 - 1977 Lake St Martin Water Level Simulations
Outflow (cfs)
30000
20000
10000
0
Total LSM Ouflow Future
Operation with the proposed rules in 1976 would have affected the levels of both Lake Manitoba and Lake St. Martin in 1977.
Lake St. Martin Level (ft)
807
806
805
804
803
802
801
800
799
798
797
796
Lake Manitoba Level (ft)
816
815
814
813
812
811
810
809
808
807
806
805
1976-01-01
1977-01-01
Lake St. Martin Current Op
Lake St. Martin Future Op
Lake Manitoba Current Op
Lake Manitoba Future Op


2011 Lake St Martin Water Level Simulations
Current Op (no LSMEOC)
Future Op (New Outlets)
2011 Peak Water Level, Current Conditions Simulated - 805.38 ft
2011 Peak Water Level, with New Outlets Simulated - 802.87 ft
Use of the New Outlets causes an decrease in peak water level of more than 2.5 ft compared to the current operating conditons.
808
807
806
805
804
803
802
801
800
799
798
2011-01-01
2011-02-01
2011-03-01
2011-04-01
2011-05-01
2011-06-01
2011-07-01
2011-08-01
2011-09-01
2011-10-01
2011-11-01
2011-12-01

Manitoba
Infrastructure

Appendix B:
Table of Statistics

Statistics for Lake Manitoba

	Minimum Water Level (ft)			Maximum Water Level (ft)			Water Level Range (ft)			Days Above Operating Range		
Year	Current Operation	Future Operation With LMB Outlet	Change	Current Operation	Future Operation With LMB Outlet	Change	Current Operation	Future Operation With LMB Outlet	Change	Current Operation	Future Operation With LMB Outlet	Change
1915	811.22	811.16	-0.06	813.40	813.40	0.00	2.18	2.25	0.06	98	87	-11
1916	811.11	810.96	-0.15	812.66	812.56	-0.10	1.54	1.60	0.06	11	9	-2
1917	811.50	811.42	-0.08	812.32	812.24	-0.08	0.82	0.83	0.00	0	0	0
1918	811.50	811.43	-0.07	812.28	812.21	-0.08	0.78	0.77	-0.01	0	0	0
1919	810.89	810.81	-0.08	811.96	811.89	-0.07	1.07	1.08	0.01	0	0	0
1920	810.79	810.73	-0.07	811.78	811.71	-0.07	0.99	0.99	0.00	0	0	0
1921	810.96	810.90	-0.06	812.02	811.96	-0.06	1.05	1.06	0.01	0	0	0
1922	811.64	811.33	-0.31	813.03	812.73	-0.30	1.39	1.40	0.01	132	55	-77
1923	811.68	811.21	-0.47	812.86	812.49	-0.36	1.18	1.29	0.10	102	8	-94
1924	811.47	811.29	-0.18	812.42	812.36	-0.06	0.94	1.07	0.12	7	0	-7
1925	811.60	811.04	-0.56	812.92	812.77	-0.15	1.33	1.73	0.41	59	39	-20
1926	811.31	811.11	-0.20	811.80	811.56	-0.24	0.50	0.45	-0.04	0	0	0
1927	811.37	810.90	-0.47	812.73	812.58	-0.15	1.36	1.68	0.32	65	16	-49
1928	811.47	811.42	-0.05	812.26	812.24	-0.02	0.78	0.81	0.03	0	0	0
1929	810.66	810.60	-0.06	811.81	811.76	-0.06	1.16	1.16	0.00	0	0	0
1930	810.32	810.26	-0.06	811.44	811.38	-0.06	1.12	1.13	0.00	0	0	0
1931	809.91	809.85	-0.06	810.61	810.54	-0.06	0.70	0.70	0.00	0	0	0
1932	809.34	809.28	-0.07	810.46	810.39	-0.07	1.12	1.12	0.00	0	0	0
1933	809.46	809.39	-0.07	810.29	810.23	-0.07	0.84	0.83	0.00	0	0	0
1934	809.72	809.65	-0.07	810.44	810.38	-0.07	0.73	0.73	0.00	0	0	0
1935	810.44	810.38	-0.07	812.28	812.22	-0.06	1.84	1.84	0.00	0	0	0
1936	811.17	811.08	-0.08	812.17	812.08	-0.08	1.00	1.00	0.00	0	0	0
1937	810.91	810.84	-0.07	812.11	812.04	-0.07	1.20	1.20	0.00	0	0	0
1938	810.66	810.60	-0.06	811.55	811.49	-0.06	0.89	0.89	0.00	0	0	0
1939	810.13	810.07	-0.06	811.10	811.04	-0.06	0.97	0.97	0.00	0	0	0
1940	809.48	809.41	-0.07	810.31	810.24	-0.06	0.83	0.83	0.00	0	0	0
1941	809.58	809.52	-0.06	810.27	810.21	-0.06	0.69	0.69	0.00	0	0	0
1942	809.36	809.29	-0.06	810.38	810.32	-0.06	1.02	1.02	0.00	0	0	0
1943	809.42	809.36	-0.06	810.38	810.32	-0.06	0.95	0.96	0.00	0	0	0
1944	809.64	809.58	-0.06	810.34	810.28	-0.06	0.70	0.71	0.00	0	0	0
1945	809.87	809.81	-0.06	810.54	810.48	-0.06	0.67	0.67	0.00	0	0	0
1946	810.02	809.96	-0.06	810.62	810.55	-0.06	0.59	0.59	0.00	0	0	0
1947	810.31	810.25	-0.07	811.49	811.42	-0.06	1.18	1.18	0.00	0	0	0
1948	811.40	810.80	-0.61	812.58	812.53	-0.04	1.17	1.74	0.56	28	18	-10
1949	811.27	811.11	-0.16	812.25	812.03	-0.22	0.98	0.92	-0.06	0	0	0
1950	811.27	811.34	0.08	812.56	812.46	-0.10	1.30	1.12	-0.17	27	10	-17
1951	811.10	811.09	0.00	811.66	811.70	0.03	0.57	0.60	0.04	0	0	0
1952	811.09	811.04	-0.05	811.68	811.64	-0.04	0.60	0.60	0.01	0	0	0
1953	811.39	811.34	-0.05	812.57	812.58	0.01	1.18	1.24	0.07	28	24	-4
1954	811.89	811.50	-0.39	813.00	812.65	-0.35	1.11	1.15	0.05	209	74	-135
1955	812.11	811.18	-0.93	814.07	813.05	-1.02	1.96	1.87	-0.09	339	90	-249
1956	811.69	811.39	-0.30	812.97	812.81	-0.16	1.28	1.42	0.14	141	49	-92
1957	811.30	811.58	0.29	812.01	812.49	0.48	0.71	0.91	0.20	0	8	8
1958	810.63	810.65	0.02	811.66	811.73	0.07	1.03	1.08	0.05	0	0	0
1959	810.64	810.62	-0.02	811.45	811.45	0.00	0.81	0.83	0.02	0	0	0
1960	810.97	810.91	-0.06	812.09	812.04	-0.05	1.12	1.13	0.01	0	0	0
1961	809.77	809.71	-0.06	811.41	811.36	-0.06	1.65	1.65	0.00	0	0	0
1962	810.02	809.96	-0.06	810.92	810.86	-0.06	0.90	0.91	0.00	0	0	0
1963	809.65	809.58	-0.07	810.94	810.88	-0.07	1.29	1.29	0.00	0	0	0
1964	808.94	808.87	-0.06	810.18	810.11	-0.07	1.24	1.24	0.00	0	0	0
1965	809.15	809.09	-0.06	810.06	810.00	-0.06	0.90	0.91	0.01	0	0	0
1966	809.97	809.91	-0.06	811.14	811.09	-0.05	1.17	1.18	0.00	0	0	0
1967	811.15	811.09	-0.05	812.23	812.17	-0.06	1.09	1.08	-0.01	0	0	0
1968	811.65	811.57	-0.08	812.18	812.11	-0.08	0.54	0.54	0.00	0	0	0
1969	811.62	811.53	-0.09	812.40	812.32	-0.09	0.78	0.79	0.01	1	0	-1
1970	811.47	811.39	-0.08	812.36	812.27	-0.09	0.89	0.88	-0.01	0	0	0
1971	811.88	811.77	-0.11	812.43	812.33	-0.11	0.55	0.55	0.01	10	0	-10
1972	811.58	811.49	-0.09	812.39	812.28	-0.11	0.82	0.80	-0.02	0	0	0
1973	811.47	811.39	-0.08	811.98	811.91	-0.08	0.51	0.52	0.01	0	0	0
1974	811.63	810.96	-0.67	813.22	812.94	-0.28	1.59	1.98	0.39	89	56	-33
1975	811.54	811.03	-0.50	812.18	812.54	0.36	0.65	1.51	0.86	0	32	32
1976	811.28	810.34	-0.94	813.07	813.08	0.01	1.79	2.74	0.95	88	59	-29
1977	811.35	810.46	-0.89	811.81	811.44	-0.37	0.46	0.98	0.52	0	0	0
1978	811.31	811.24	-0.07	811.92	811.85	-0.07	0.61	0.61	0.00	0	0	0
1979	811.40	810.98	-0.42	813.05	812.75	-0.30	1.64	1.77	0.12	94	51	-43
1980	811.20	810.30	-0.90	811.67	811.36	-0.31	0.47	1.06	0.59	0	0	0
1981	810.98	810.53	-0.45	811.43	810.90	-0.53	0.45	0.38	-0.07	0	0	0

Statistics for Lake Manitoba

	Minimum Water Level (ft)			Maximum Water Level (ft)			Water Level Range (ft)			Days Above Operating Range		
Year	Current Operation	Future Operation With LMB Outlet	Change	Current Operation	Future Operation With LMB Outlet	Change	Current Operation	Future Operation With LMB Outlet	Change	Current Operation	Future Operation With LMB Outlet	Change
1982	810.71	810.37	-0.34	811.43	811.05	-0.37	0.71	0.68	-0.03	0	0	0
1983	810.86	810.51	-0.34	811.73	811.53	-0.21	0.87	1.01	0.14	0	0	0
1984	811.31	811.22	-0.10	812.00	811.91	-0.08	0.68	0.70	0.01	0	0	0
1985	811.62	811.54	-0.08	811.98	811.90	-0.08	0.36	0.36	0.00	0	0	0
1986	811.46	810.90	-0.56	812.70	812.55	-0.15	1.24	1.65	0.41	39	25	-14
1987	811.45	811.05	-0.40	812.01	811.67	-0.33	0.55	0.62	0.07	0	0	0
1988	811.12	811.04	-0.09	811.88	811.77	-0.11	0.76	0.74	-0.02	0	0	0
1989	810.81	810.74	-0.07	811.75	811.67	-0.07	0.93	0.93	0.00	0	0	0
1990	810.80	810.74	-0.06	811.68	811.62	-0.06	0.88	0.88	0.00	0	0	0
1991	810.69	810.63	-0.06	811.55	811.49	-0.06	0.86	0.86	0.00	0	0	0
1992	810.76	810.70	-0.06	811.27	811.21	-0.06	0.51	0.51	0.00	0	0	0
1993	810.83	810.77	-0.06	811.15	811.09	-0.06	0.32	0.32	0.00	0	0	0
1994	810.85	810.80	-0.06	811.30	811.24	-0.05	0.45	0.45	0.00	0	0	0
1995	811.08	811.02	-0.06	812.57	812.50	-0.07	1.49	1.48	-0.01	27	18	-9
1996	811.51	811.38	-0.13	812.80	812.58	-0.22	1.29	1.21	-0.09	65	27	-38
1997	811.51	811.13	-0.37	812.37	812.67	0.30	0.86	1.54	0.67	0	31	31
1998	811.27	810.75	-0.52	811.98	811.75	-0.23	0.71	1.00	0.29	0	0	0
1999	811.48	810.94	-0.53	812.54	812.21	-0.33	1.06	1.27	0.20	27	0	-27
2000	811.24	811.24	0.00	811.93	812.01	0.08	0.69	0.77	0.08	0	0	0
2001	811.29	810.84	-0.44	812.84	812.66	-0.18	1.55	1.82	0.26	78	24	-54
2002	810.45	810.25	-0.21	811.36	811.09	-0.27	0.91	0.84	-0.06	0	0	0
2003	809.87	809.71	-0.16	810.63	810.46	-0.18	0.77	0.75	-0.02	0	0	0
2004	809.94	809.79	-0.15	811.02	810.89	-0.14	1.08	1.10	0.02	0	0	0
2005	811.02	810.89	-0.13	812.89	812.59	-0.30	1.86	1.70	-0.16	55	25	-30
2006	811.49	810.80	-0.70	812.38	812.51	0.13	0.89	1.72	0.83	0	23	23
2007	811.98	811.05	-0.94	812.59	811.75	-0.85	0.61	0.70	0.09	86	0	-86
2008	811.74	811.29	-0.45	812.19	811.75	-0.45	0.45	0.46	0.01	0	0	0
2009	811.50	811.41	-0.09	812.81	812.73	-0.08	1.31	1.32	0.01	63	46	-17
2010	811.48	811.46	-0.02	812.89	812.55	-0.34	1.41	1.08	-0.33	128	31	-97
2011	812.71	811.53	-1.18	816.94	815.46	-1.48	4.23	3.93	-0.30	365	218	-147
2012	811.98	810.93	-1.05	814.23	812.02	-2.21	2.25	1.09	-1.16	249	0	-249
2013	811.83	811.16	-0.67	813.00	812.53	-0.48	1.17	1.36	0.19	121	21	-100
2014	811.89	811.49	-0.40	814.37	813.46	-0.91	2.48	1.97	-0.51	241	147	-94
2015	811.81	811.17	-0.64	813.33	812.22	-1.11	1.52	1.05	-0.47	209	0	-209
2016	811.64	811.10	-0.54	812.80	811.92	-0.88	1.16	0.82	-0.34	43	0	-43
2017	812.35	811.25	-1.11	813.80	813.07	-0.73	1.44	1.82	0.38	341	86	-255

- non-flood year
- minor flood year
-major flood year

Statistics for Lake St. Martin

Year	Minimum Water Level (ft) Current Operation	Minimum Water Level (ft) With LSM Outlet	Minimum Water Level (ft) Change	Maximum Water Level (ft) Current Operation	Maximum Water Level (ft) With LSM Outlet	Maximum Water Level (ft) Change	Water Level Range (ft) Current Operation	Water Level Range (ft) With LSM Outlet	Water Level Range (ft) Change	Days Above Operating Range Current Operation	Days Above Operating Range With LSM Outlet	Days Above Operating Range Change
1915	797.50	797.44	-0.06	803.98	804.35	0.37	6.48	6.91	0.43	203	132	-71
1916	797.64	797.31	-0.33	798.70	798.63	-0.08	1.07	1.32	0.25	0	0	0
1917	797.72	797.68	-0.04	799.40	799.25	-0.15	1.68	1.57	-0.11	0	0	0
1918	797.76	797.75	-0.02	799.26	799.23	-0.02	1.50	1.49	-0.01	0	0	0
1919	797.41	797.42	0.00	799.32	799.29	-0.03	1.91	1.87	-0.03	0	0	0
1920	796.72	796.71	-0.01	797.66	797.67	0.00	0.95	0.96	0.01	0	0	0
1921	797.07	797.07	0.00	798.62	798.67	0.04	1.55	1.60	0.05	0	0	0
1922	798.64	798.69	0.04	802.15	800.49	-1.66	3.51	1.80	-1.71	227	80	-147
1923	800.16	798.31	-1.85	802.05	799.47	-2.58	1.88	1.16	-0.73	365	0	-365
1924	798.33	798.17	-0.15	800.77	799.21	-1.56	2.44	1.04	-1.40	87	0	-87
1925	799.02	797.89	-1.13	801.87	800.38	-1.49	2.85	2.49	-0.36	151	29	-122
1926	797.19	796.96	-0.23	800.49	798.14	-2.35	3.30	1.18	-2.12	50	0	-50
1927	797.97	797.33	-0.63	801.75	800.11	-1.64	3.79	2.78	-1.01	183	25	-158
1928	797.75	797.79	0.04	800.61	799.02	-1.58	2.86	1.23	-1.63	64	0	-64
1929	796.53	796.53	0.00	798.62	798.65	0.03	2.09	2.12	0.03	0	0	0
1930	796.39	796.41	0.01	797.53	797.53	0.00	1.13	1.12	-0.01	0	0	0
1931	796.10	796.11	0.02	797.40	797.42	0.02	1.30	1.30	0.00	0	0	0
1932	795.76	795.75	-0.01	797.05	797.08	0.03	1.29	1.33	0.04	0	0	0
1933	795.72	795.71	-0.01	796.58	796.59	0.01	0.86	0.88	0.02	0	0	0
1934	795.95	795.96	0.01	796.64	796.66	0.02	0.70	0.70	0.01	0	0	0
1935	796.63	796.65	0.02	798.78	798.81	0.04	2.14	2.16	0.02	0	0	0
1936	797.14	797.10	-0.03	799.51	799.53	0.01	2.38	2.42	0.05	0	0	0
1937	796.81	796.80	-0.01	798.78	798.74	-0.04	1.96	1.94	-0.02	0	0	0
1938	796.52	796.52	0.00	798.18	798.16	-0.02	1.66	1.64	-0.02	0	0	0
1939	796.21	796.23	0.02	797.53	797.52	0.00	1.31	1.29	-0.02	0	0	0
1940	795.74	795.73	-0.01	797.21	797.24	0.02	1.47	1.51	0.03	0	0	0
1941	795.78	795.78	0.00	796.52	796.52	0.00	0.74	0.74	0.01	0	0	0
1942	795.68	795.67	-0.01	796.66	796.68	0.02	0.98	1.01	0.03	0	0	0
1943	795.84	795.82	-0.02	796.32	796.31	-0.01	0.48	0.49	0.01	0	0	0
1944	795.90	795.91	0.01	796.52	796.53	0.01	0.62	0.62	0.00	0	0	0
1945	796.06	796.07	0.01	796.68	796.70	0.02	0.62	0.63	0.01	0	0	0
1946	796.15	796.16	0.02	797.03	797.07	0.03	0.88	0.90	0.02	0	0	0
1947	796.41	796.41	0.00	797.33	797.34	0.01	0.91	0.92	0.01	0	0	0
1948	796.95	796.95	0.00	801.35	799.96	-1.39	4.40	3.01	-1.39	139	0	-139
1949	797.30	797.11	-0.19	799.69	798.72	-0.97	2.39	1.61	-0.79	0	0	0
1950	798.02	797.93	-0.10	800.44	799.33	-1.11	2.42	1.41	-1.01	39	0	-39
1951	796.96	797.08	0.12	798.48	798.96	0.49	1.52	1.88	0.36	0	0	0
1952	797.06	797.08	0.02	798.19	798.27	0.08	1.13	1.19	0.06	0	0	0
1953	797.70	797.73	0.03	801.12	799.85	-1.27	3.42	2.12	-1.30	166	0	-166
1954	800.45	799.00	-1.45	802.17	800.51	-1.66	1.72	1.51	-0.21	365	149	-216
1955	800.41	797.64	-2.78	803.47	800.96	-2.51	3.06	3.32	0.27	365	104	-261
1956	799.98	797.80	-2.19	802.35	800.57	-1.79	2.37	2.77	0.40	356	86	-270
1957	797.33	798.15	0.83	800.97	799.95	-1.02	3.64	1.80	-1.84	149	0	-149
1958	796.51	796.54	0.04	798.58	799.34	0.76	2.07	2.79	0.72	0	0	0
1959	796.55	796.59	0.04	797.53	797.62	0.09	0.98	1.02	0.04	0	0	0
1960	796.86	796.86	0.00	798.48	798.60	0.12	1.62	1.74	0.12	0	0	0
1961	796.12	796.13	0.01	797.91	797.92	0.01	1.79	1.79	0.00	0	0	0
1962	796.16	796.18	0.01	797.18	797.20	0.02	1.02	1.02	0.01	0	0	0
1963	796.04	796.04	0.00	797.08	797.11	0.03	1.05	1.08	0.03	0	0	0
1964	795.29	795.26	-0.03	796.69	796.69	0.00	1.40	1.43	0.03	0	0	0
1965	795.25	795.17	-0.08	796.08	796.08	0.01	0.82	0.91	0.09	0	0	0
1966	796.09	796.10	0.01	796.92	796.92	0.00	0.84	0.83	-0.01	0	0	0
1967	796.95	796.95	0.00	798.67	798.79	0.11	1.73	1.84	0.11	0	0	0
1968	798.01	797.99	-0.02	799.39	799.39	0.00	1.37	1.40	0.03	0	0	0
1969	797.99	797.93	-0.06	799.39	799.37	-0.02	1.40	1.44	0.05	0	0	0
1970	798.22	798.17	-0.04	799.13	799.15	0.02	0.91	0.97	0.06	0	0	0
1971	798.60	798.60	0.00	799.96	799.97	0.01	1.36	1.37	0.01	0	0	0
1972	797.87	797.78	-0.09	800.09	800.08	-0.01	2.22	2.30	0.08	52	52	0
1973	797.80	797.78	-0.01	798.79	798.71	-0.08	0.99	0.93	-0.06	0	0	0
1974	798.59	797.91	-0.68	802.31	800.80	-1.51	3.73	2.89	-0.84	198	62	-136
1975	799.82	797.61	-2.21	800.85	800.14	-0.71	1.03	2.53	1.49	335	17	-318
1976	797.44	797.42	-0.02	802.26	800.96	-1.30	4.82	3.54	-1.28	262	91	-171
1977	797.63	796.36	-1.27	798.57	797.84	-0.73	0.94	1.48	0.54	0	0	0
1978	797.27	797.25	-0.02	799.07	798.62	-0.45	1.80	1.37	-0.43	0	0	0
1979	797.82	797.81	-0.02	802.19	800.73	-1.46	4.36	2.93	-1.44	207	55	-152
1980	797.14	796.96	-0.18	800.91	798.85	-2.05	3.76	1.89	-1.87	99	0	-99
1981	796.69	796.23	-0.46	798.31	797.69	-0.62	1.62	1.46	-0.16	0	0	0
1982	796.37	796.19	-0.18	797.83	797.79	-0.03	1.46	1.60	0.15	0	0	0
1983	796.86	796.55	-0.30	798.22	797.91	-0.30	1.36	1.36	0.00	0	0	0

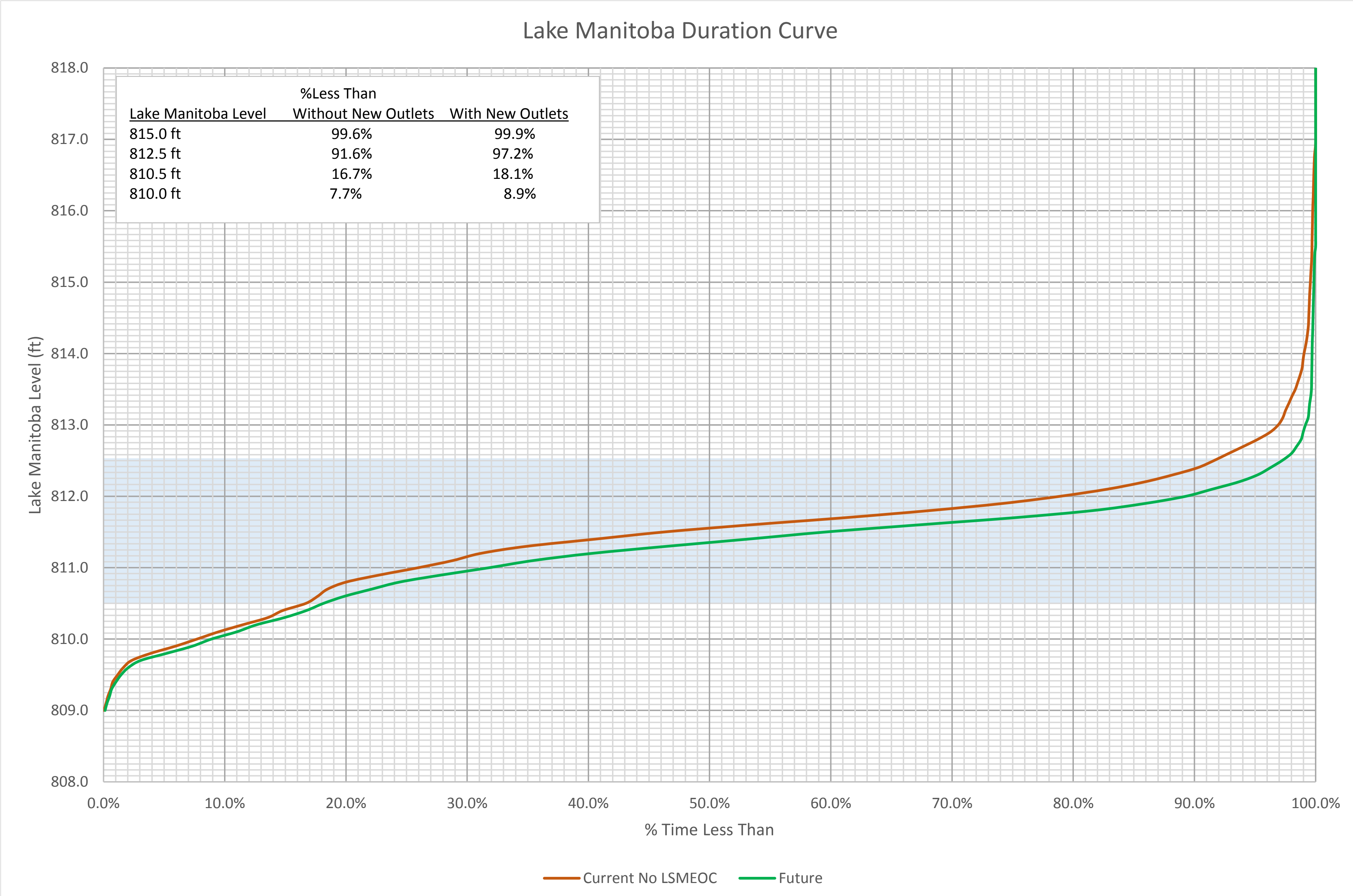
Statistics for Lake St. Martin

	Minimum Water Level (ft)			Maximum Water Level (ft)			Water Level Range (ft)			Days Above Operating Range		
Year	Current Operation	With LSM Outlet	Change	Current Operation	With LSM Outlet	Change	Current Operation	With LSM Outlet	Change	Current Operation	With LSM Outlet	Change
1984	797.25	797.14	-0.11	798.68	798.56	-0.12	1.43	1.42	-0.01	0	0	0
1985	798.03	798.02	-0.01	799.67	799.68	0.01	1.65	1.66	0.02	0	0	0
1986	797.79	797.67	-0.12	801.44	800.19	-1.25	3.65	2.52	-1.13	137	17	-120
1987	797.47	797.23	-0.23	799.12	798.12	-1.00	1.66	0.89	-0.76	0	0	0
1988	796.69	796.63	-0.06	798.53	798.32	-0.20	1.84	1.70	-0.14	0	0	0
1989	796.36	796.35	0.00	798.06	798.02	-0.03	1.70	1.67	-0.03	0	0	0
1990	796.42	796.42	0.00	797.67	797.66	0.00	1.24	1.24	0.00	0	0	0
1991	796.31	796.31	0.00	797.73	797.73	0.00	1.42	1.42	0.00	0	0	0
1992	796.33	796.33	0.00	797.62	797.62	0.00	1.28	1.28	0.00	0	0	0
1993	796.50	796.50	0.00	797.65	797.65	0.00	1.16	1.16	0.00	0	0	0
1994	796.11	796.11	0.00	797.71	797.70	-0.01	1.60	1.59	-0.01	0	0	0
1995	796.48	796.48	0.00	800.67	798.77	-1.90	4.19	2.28	-1.90	53	0	-53
1996	797.95	797.32	-0.63	801.95	800.34	-1.61	4.00	3.02	-0.98	161	41	-120
1997	799.61	797.72	-1.89	801.22	800.21	-1.01	1.61	2.49	0.88	250	40	-210
1998	797.48	797.62	0.14	800.81	799.10	-1.71	3.33	1.48	-1.85	189	0	-189
1999	798.05	797.24	-0.82	800.98	799.16	-1.81	2.92	1.92	-1.00	93	0	-93
2000	797.08	797.21	0.13	799.51	800.16	0.66	2.42	2.95	0.52	0	56	56
2001	797.79	796.58	-1.21	801.72	800.49	-1.23	3.93	3.91	-0.02	130	37	-93
2002	796.25	796.18	-0.07	798.35	797.71	-0.64	2.10	1.53	-0.57	0	0	0
2003	796.03	795.97	-0.06	797.71	797.56	-0.16	1.68	1.59	-0.10	0	0	0
2004	796.30	796.23	-0.07	797.50	797.43	-0.07	1.20	1.20	0.00	0	0	0
2005	797.35	797.35	0.00	801.26	800.05	-1.21	3.91	2.70	-1.21	165	7	-158
2006	798.00	798.36	0.36	801.52	800.07	-1.46	3.52	1.70	-1.82	236	14	-222
2007	798.76	798.18	-0.57	801.73	799.04	-2.69	2.97	0.86	-2.11	316	0	-316
2008	800.18	798.18	-2.01	801.74	799.20	-2.54	1.56	1.03	-0.53	366	0	-366
2009	799.12	797.50	-1.63	801.89	800.44	-1.44	2.76	2.95	0.19	271	41	-230
2010	798.09	798.30	0.21	801.62	800.36	-1.27	3.53	2.05	-1.48	210	34	-176
2011	800.59	799.35	-1.24	805.38	802.87	-2.50	4.79	3.53	-1.26	365	317	-48
2012	799.86	797.55	-2.30	805.15	801.38	-3.77	5.30	3.83	-1.47	355	101	-254
2013	799.90	797.78	-2.12	802.72	800.39	-2.32	2.82	2.61	-0.20	357	28	-329
2014	800.62	798.60	-2.02	803.98	801.85	-2.13	3.36	3.25	-0.11	365	214	-151
2015	800.01	798.38	-1.63	804.81	800.32	-4.49	4.80	1.94	-2.86	365	25	-340
2016	800.23	798.41	-1.82	801.34	799.79	-1.55	1.11	1.39	0.27	366	0	-366
2017	800.12	798.87	-1.25	803.24	801.90	-1.34	3.12	3.02	-0.10	365	107	-258

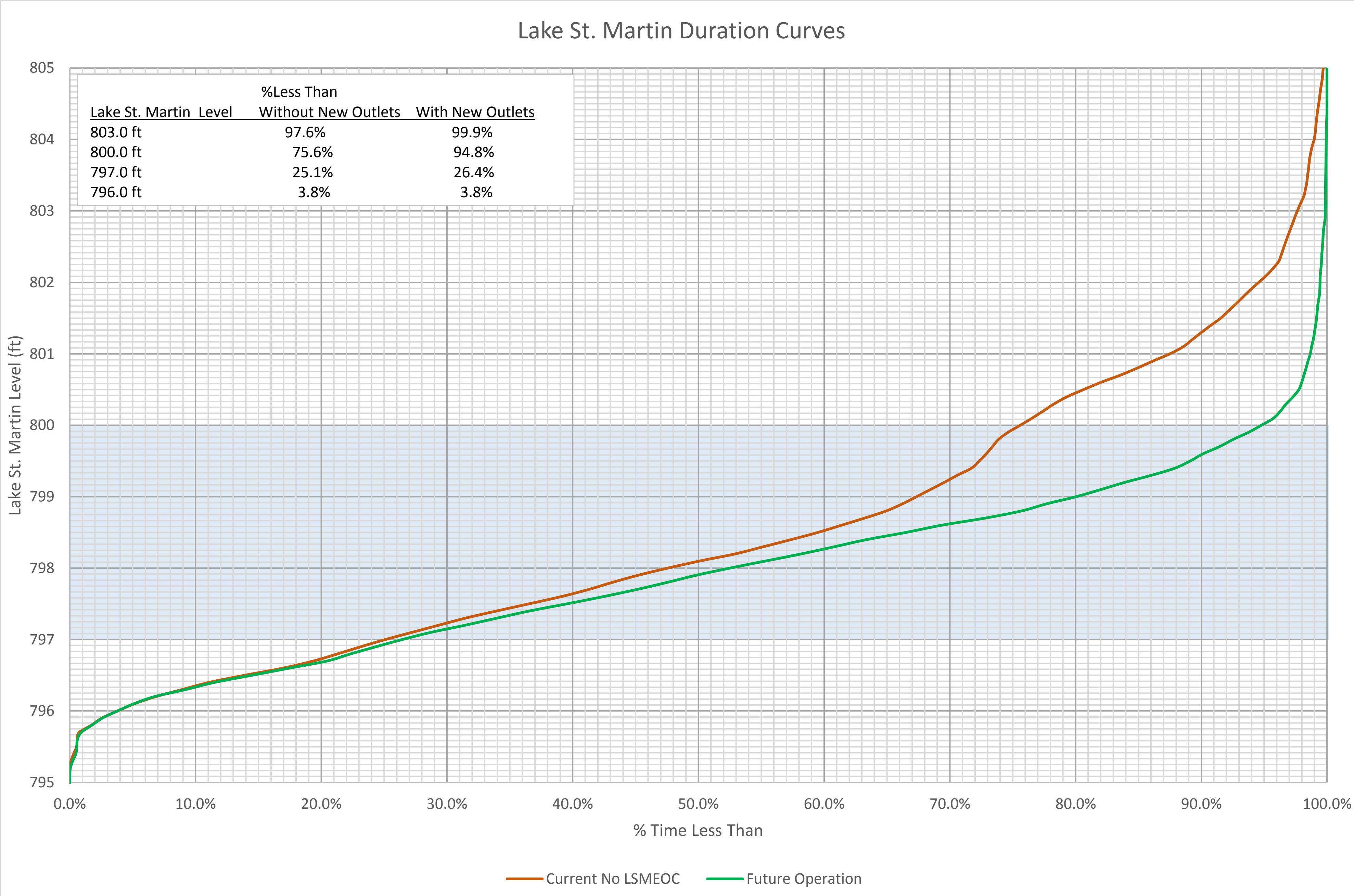
- non-flood year
- minor flood year
-major flood year

Manitoba Infrastructure

Appendix C:
Duration Curves

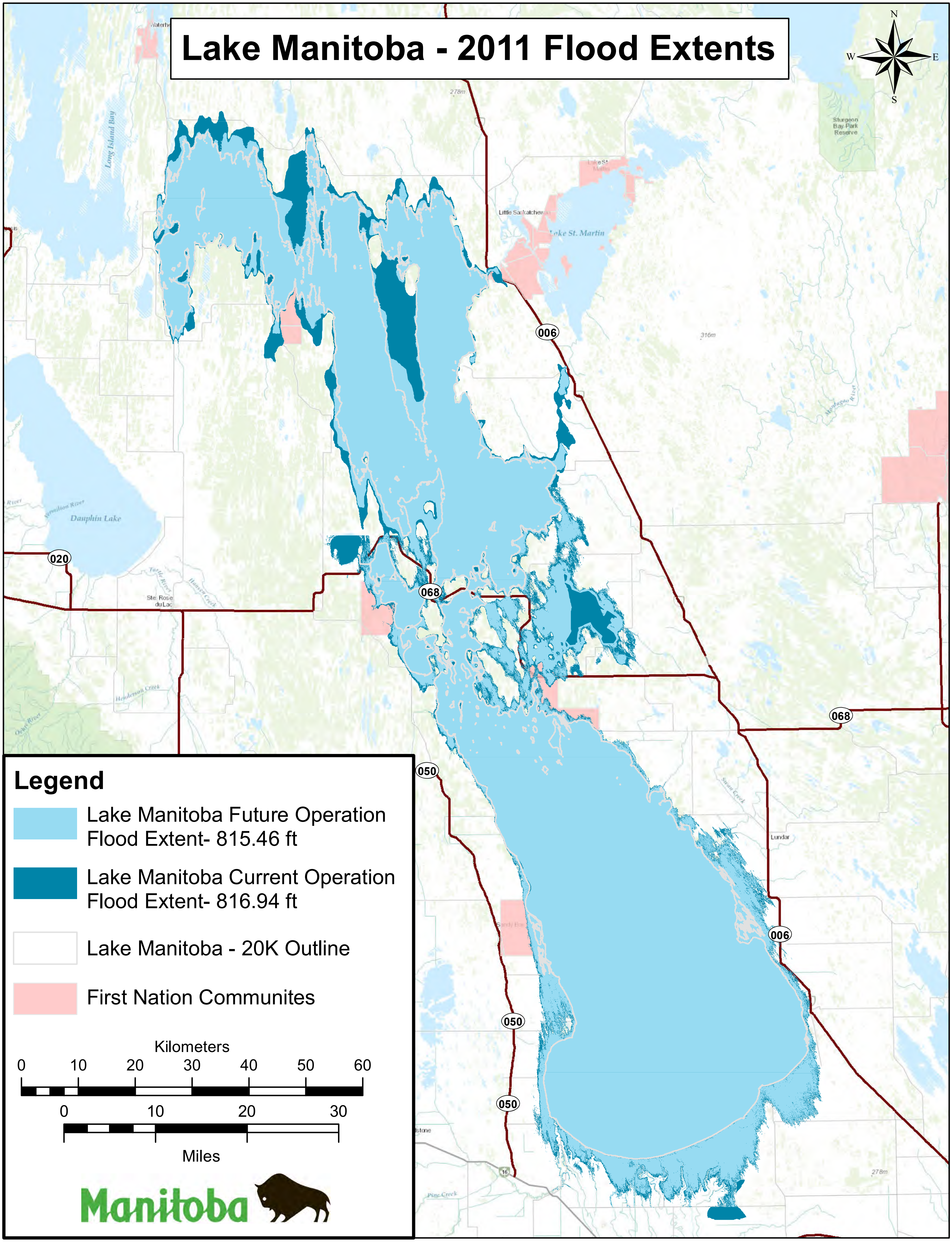


Lake Manitoba Duration Curve
%Less Than
Lake Manitoba Level | Without New Outlets | With New Outlets
815.0 ft | 99.6% | 99.9%
812.5 ft | 91.6% | 97.2%
810.5 ft | 16.7% | 18.1%
810.0 ft | 7.7% | 8.9%
Lake Manitoba Level (ft)
818.0
817.0
816.0
815.0
814.0
813.0
812.0
811.0
810.0
809.0
808.0
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%
70.0%
80.0%
90.0%
100.0%
% Time Less Than
Current No LSMEOC
Future

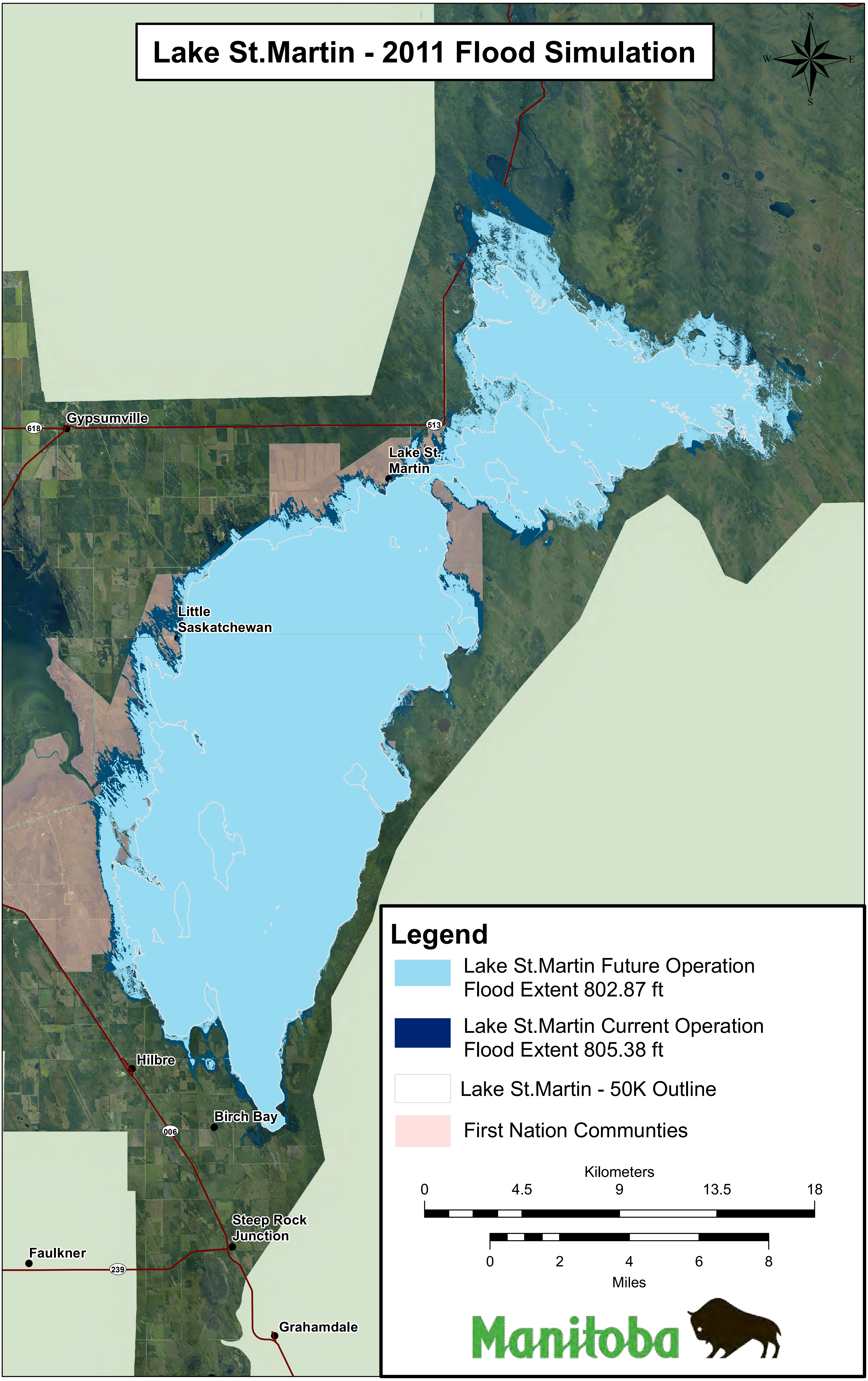

Lake St. Martin Duration Curves
%Less Than
Lake St. Martin Level | Without New Outlets | With New Outlets
803.0 ft | 97.6% | 99.9%
800.0 ft | 75.6% | 94.8%
797.0 ft | 25.1% | 26.4%
796.0 ft | 3.8% | 3.8%
Lake St. Martin Level (ft)
805
804
803
802
801
800
799
798
797
796
795
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%
70.0%
80.0%
90.0%
100.0%
% Time Less Than
Current No LSMEOC
Future Operation

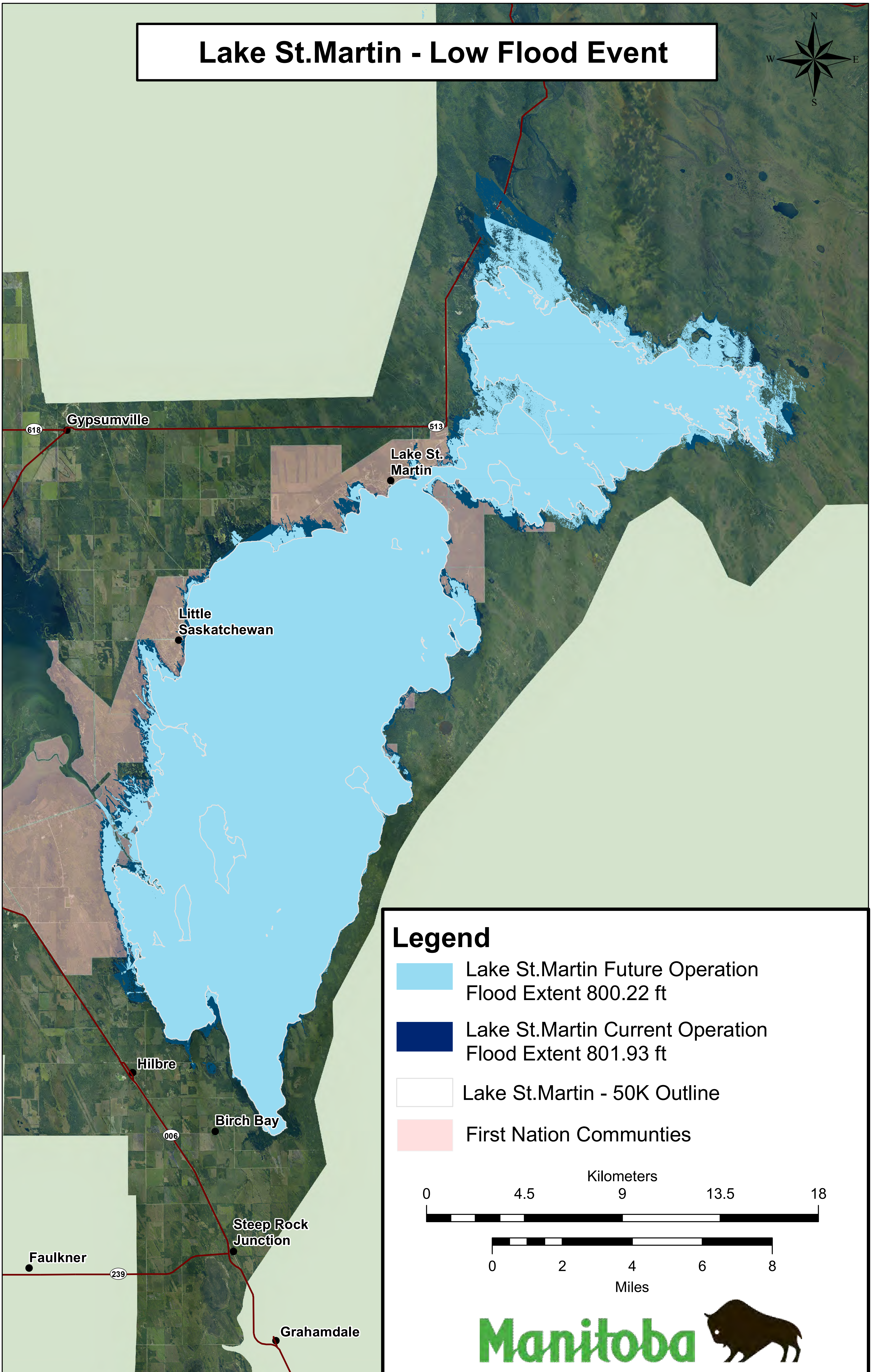
Manitoba Infrastructure

Appendix D:
Flood Inundation Maps



Lake Manitoba - 2011 Flood Extents
N
W
E
S
Sturgeon Bay Park Reserve
Long Island Bay
Little Saskatchewan
Lake St. Martin
006
316m
278m
Dauphin Lake
020
068
Ste. Rose du Lac
050
Lundar
Legend
Lake Manitoba Future Operation Flood Extent- 815.46 ft
Lake Manitoba Current Operation Flood Extent- 816.94 ft
Lake Manitoba - 20K Outline
First Nation Communites
Kilometers
0 10 20 30 40 50 60
0 10 20 30
Miles
Manitoba


Lake St.Martin - 2011 Flood Simulation
N
W
E
S
Gypsumville
618
513
Lake St.
Martin
Little
Saskatchewan
Hilbre
Birch Bay
006
Steep Rock
Junction
Faulkner
239
Grahamdale
Legend
Lake St.Martin Future Operation
Flood Extent 802.87 ft
Lake St.Martin Current Operation
Flood Extent 805.38 ft
Lake St.Martin - 50K Outline
First Nation Communties
Kilometers
0
4.5
9
13.5
18
0
2
4
6
8
Miles
Manitoba



Lake St.Martin - Low Flood Event
N
W
E
S
Gypsumville
618
513
Lake St.
Martin
Little
Saskatchewan
Hilbre
Birch Bay
006
Steep Rock
Junction
Faulkner
239
Grahamdale
Legend
Lake St.Martin Future Operation
Flood Extent 800.22 ft
Lake St.Martin Current Operation
Flood Extent 801.93 ft
Lake St.Martin - 50K Outline
First Nation Communties
Kilometers
0
4.5
9
13.5
18
0
2
4
6
8
Miles
Manitoba