2011 Report on Artificial Flooding due to Operation of the Shellmouth Dam

Manitoba Infrastructure and Transportation

1/28/2013

This report was prepared in fulfillment of the requirements of s. 12.7(1) of The Water Resources Administration Act, and s. 3(1) of the Shellmouth Dam Regulation.

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Introduction

Legislative Background

In 2008, the Government of Manitoba amended *The Water Resources Administration Act* to establish compensation for damages due to artificial flooding caused by the operation of designated water control works. More specifically, the amendments establish the Shellmouth Dam as a designated water control work, define “artificial flooding” and other key terms, establish a requirement for Manitoba to report on artificial flooding which causes damages, and establish eligibility for compensation. Regulations under the Act stipulate the information that must be included in the artificial flood report and outline how compensation is to be administered. The amended Act came into force in February, 2011.

The following definitions from the Act are pertinent to this report:

"artificial flooding", in relation to a given event, means flooding of a water body
- (a) that is caused by the operation of a designated water control work, or the operation of a designated water control work and one or more other water control works, and
- (b) whereby the water body exceeds its unregulated level at the time of the event;

"designated water control work" means
- (a) the Shellmouth Dam, or
- (b) any other water control work designated in the regulations for the purpose of this definition, not including the "floodway" as defined in *The Red River Floodway Act* insofar as it relates to "spring flooding" as defined in that Act;

"unregulated level", in relation to artificial flooding, means the scientifically demonstrable level that would be expected in the water body at a given time
- (a) in the absence of the designated water control work, or
- (b) if specified by regulation in respect of the water body, in the absence of the designated water control work and one or more other specified water control works;

Put more simply, artificial flooding in the Assiniboine River valley downstream of the Shellmouth Dam occurs when the regulated water level is above flood stage and is higher than the unregulated water level. Unregulated water levels are those that would have occurred if the Shellmouth Dam did not exist. Regulated water levels are those that did occur, and which were influenced by the operation of the Shellmouth Dam.

The Water Resources Administration Act stipulates that once it is determined that damage to eligible property or economic loss has occurred as a result of an artificial flooding event on the Assiniboine River caused by the operation of the Shellmouth Dam, a report must be prepared on the artificial flooding. The report must include:

- A statement of the period reported on
- A statement that the Minister responsible for *The Water Resources Administration Act* has determined that damages due to the artificial flooding have occurred
- For the regulated and the unregulated conditions, charts of the discharges from the Shellmouth Dam and river water levels at relevant hydrometric monitoring stations
- Charts showing the dates that artificial flooding began and ended
- A description of how the regulated and unregulated levels were determined
- A description of all Dam operations and any technical issues that arose
- A description of how the operation did or did not conform to the operating guidelines
- A tabulation of the Dam gate adjustments, including the dates and times of the adjustments, the reservoir levels and volume stored at each adjustment, and the flows resulting from each adjustment

Within this report, all flows and levels are shown in imperial units. Flows can be converted from cubic feet per second (cfs) to cubic metres per second (m^3/s) by dividing by 35.3148. River levels can be converted from feet to metres by dividing by a factor of 3.28084. All data in this report is real-time data with quality control provided by the Hydrologic Forecasting and Water Management Branch of Manitoba Infrastructure and Transportation.

Benefits of Shellmouth Dam Operation and the Nature of Artificial Flooding

Operation of the Shellmouth Dam provides a significant flood reduction benefit to communities, agricultural producers and other interests downstream of the Dam. Operation of the Dam results in a reduction in the peak flows downstream on the Assiniboine River, and therefore the extent and height of flooding experienced, and it generally provides a reduction in the net length of flooding. In some years, operation of the Shellmouth Dam does not completely eliminate flooding downstream of the Dam but it does reduce the height of flood waters (usually by a significant amount) and often reduces the total duration of flooding. The conceptual hydrograph in Figure 1 illustrates the reduction in peak flow (A), the duration of flooding under unregulated flow conditions (B), the duration of flooding under regulated flow conditions (C), and the reduction in the duration of flooding (difference in the lengths of lines B & C).

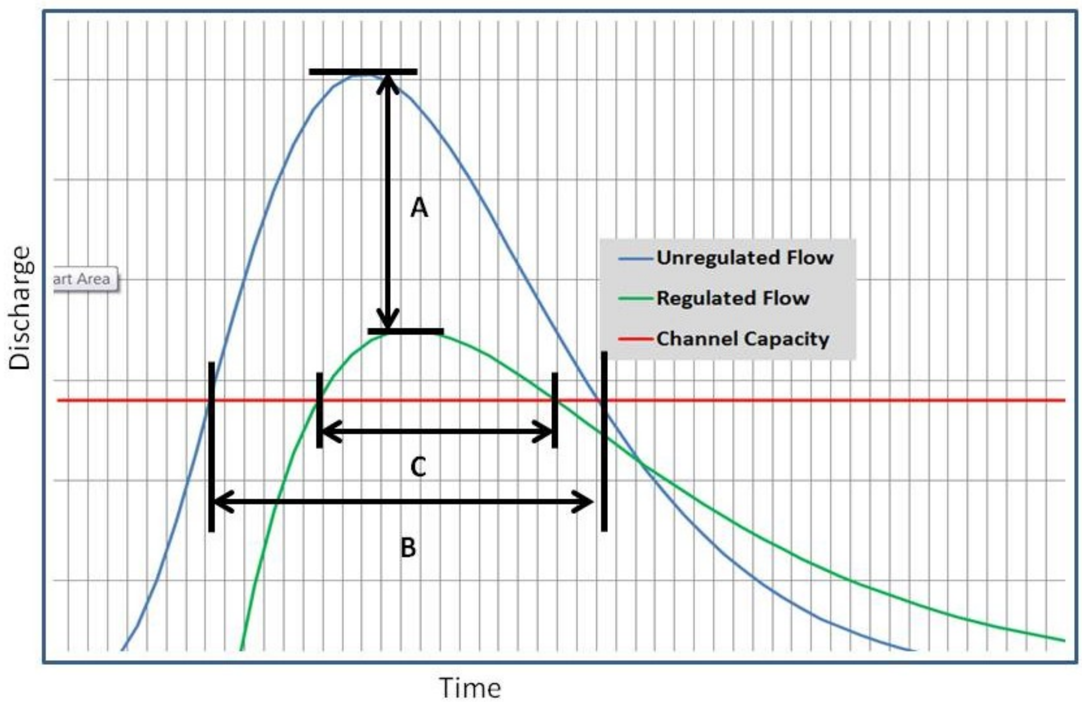

Figure 1: Conceptual hydrograph showing the reduction in peak flow (A) and reduction in duration of flooding (B-C)

Unfortunately, the Shellmouth Dam and Reservoir have a finite water storage capacity and in some years the inflows to the Reservoir can cause the water level to rise above spillway elevation, resulting in uncontrolled flows over the spillway that increase as the level of the Reservoir rises. Reservoir levels generally only rise above spillway elevation as a result of significant snowmelt runoff and/or rainfall events which cause high reservoir inflows. The Reservoir level will only begin to fall when total outflows exceed inflows, and it is under these conditions that artificial flooding may occur. Once inflows to the reservoir begin to fall, uncontrolled flows over the spillway will continue until the reservoir water level falls below spillway elevation. This can result in a situation where regulated outflows from the reservoir (over the spillway) exceed the unregulated flows that would have occurred in the absence of the dam (the inflows to the reservoir), resulting in artificially high flows downstream of the dam. If these artificially high flows exceed the channel capacity of the river, which is approximately 1,600 cfs immediately below the dam, then artificial flooding is deemed to have occurred.

Artificial flooding caused by operation of the Shellmouth Dam will typically occur after the regulated and unregulated flood peaks have occurred (see Figure 2). Following the peak of a flood event, as the flows on the river are decreasing and the flood waters recede towards the river channel, in cases where artificial flooding occurs the regulated water level will be higher than the unregulated water level (due to the influence of the spillway flows explained in the previous paragraph). Thus it can be useful to visualize artificial flooding caused by the operation of the Shellmouth Dam as a delay in the recession of flood waters or as a delay in the overall timing of a flood event that would have otherwise occurred under unregulated conditions. Since artificial flooding does not begin until a flood event begins to recede, it can be difficult to differentiate artificial flooding from flooding that would have occurred under unregulated flows. It is also important to note that flooding that occurs in the Assiniboine River Valley downstream of the Shellmouth Dam is not always artificial flooding. Only in the circumstances described above, at times where regulated flows exceed unregulated flows, does artificial flooding occur.

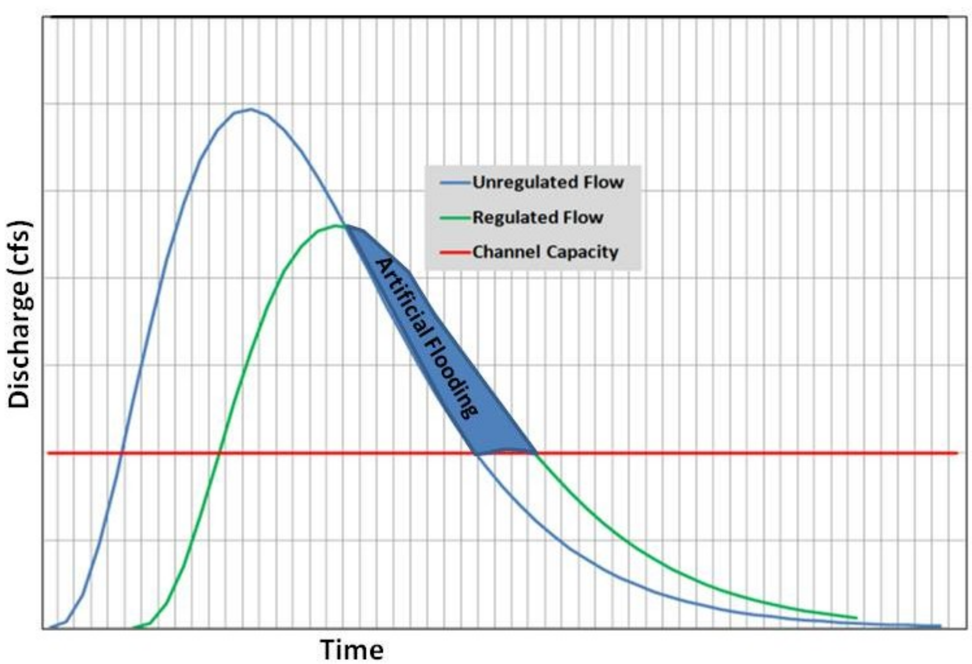

Figure 2: Hydrograph illustrating a conceptual example of artificial flooding

The duration of artificial flooding at an elevation of land can be determined by comparing the date when the regulated hydrograph crosses the elevation of that land versus the date when the unregulated hydrograph crosses the same elevation (on a horizontal line); see line A in Figure 3. Similarly, the incremental height of artificial flood waters at a given time can be observed by comparing the water level on the unregulated hydrograph versus the regulated hydrograph (along a vertical line); see line B in Figure 3.

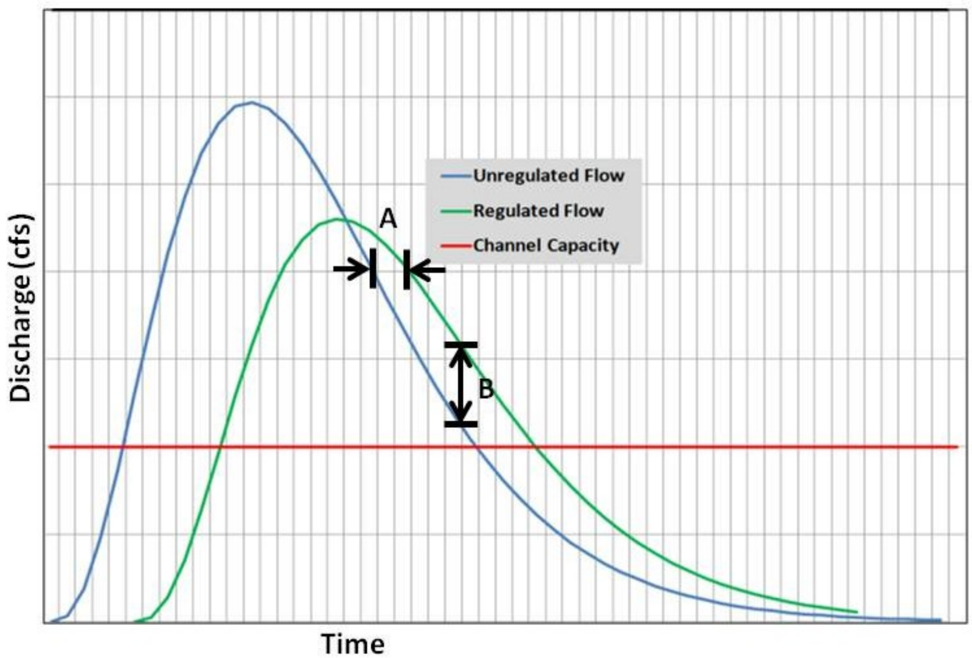

Figure 3: Conceptual hydrograph illustrating how to determine the duration (A) and extent (B) of artificial flooding

Artificial Flooding in 2011

This report covers two periods of artificial flooding that occurred in 2011 and which are described below. As was announced on November 16, 2012 Manitoba Infrastructure and Transportation, the department responsible for *The Water Resources Administration Act,* has determined that damages due to artificial flooding did occur in 2011.

2011 was an exceptional year which saw record high flows and in which most locations on the Upper Assiniboine River experienced two distinct periods of artificial flooding. The first period of artificial flooding was generally shorter, occurring on the recession of the flood peak. The first period of artificial flooding generally lasted for one to 12 days depending on elevation, starting as early as May 13 in the upstream reaches and ending as late as July 2 in further downstream reaches. The second period of artificial flooding occurred later in the year, following significant precipitation and a spike in peak inflows which caused the reservoir level to rise above spillway elevation for a second time. The second period of artificial flooding lasted for up to 23 days at some lower elevations, starting as early as July 8 in upstream reaches and ending as late as Aug 7 further downstream.

In the upstream reaches immediately below the Dam, the first period of artificial flooding occurred as early as May 13 at the higher elevations of the flooded area and ended as late as June 24 in lower areas closer to the Assiniboine River channel. Depending on the elevation of land, artificial flooding in this reach of the valley lasted between one and nine days, areas at higher elevation were affected for one to three days, while land at lower elevations were affected for longer periods of up to nine days. The second period of artificial flooding occurred in the upstream reaches as early as July 8 at the higher elevations of the flooded area, and ended as late as August 2 in lower areas closer to the Assiniboine River channel. The second period of artificial flooding affected only those lands which are at lower elevations and the duration of artificial flooding was approximately three weeks.

In general, moving downstream from the Dam the extent and duration of artificial flooding decreased, and the artificial flooding occurred later and for a shorter period of time. This is due to the increasing influence of tributaries and other inflows to the Assiniboine River as the river moves downstream. It is significant to note that from St. Lazare downstream there were a number of smaller unregulated peaks that occurred while the flows on the Assiniboine River were receding. This means that some parcels of land would have been artificially flooded, then flooded under unregulated conditions, and then subsequently artificially flooded as the secondary or tertiary peak receded. An example can be seen in Figure 6, land near Russell at elevation of approximately 1345 ft would have been artificially flooded in both the first and second periods of artificial flooding, however, the intervening unregulated peak that occurred on July 1 would probably negate any impact that the first period of artificial flooding may have caused. In the development of a compensation program, it is expected that for any given parcel of land which is subject to more than one period of artificial flooding, that only the damages due to the most recent period of artificial will be included. In general, damages cannot be caused by artificial flooding twice for the same parcel of land.

It is also significant to note that in some locations, lands at specific elevations may not have been affected by artificial flooding in 2011; even though lands at both higher and lower elevations may have experienced artificial flooding. For example, examination of Figure 15 reveals that land near Griswold which is at an elevation of approximately 1200 ft was not affected by artificial flooding, although land at elevation 1198 ft and 1202 ft were affected by artificial flooding.

In the downstream reaches of the River near Brandon, the first period of artificial flooding occurred as early as May 20 at the higher elevation of the flooded area and ended as late as July 2 in lower areas closer to the Assiniboine River channel. Depending on the elevation of land, artificial flooding in this reach of the valley lasted between one and four days, areas in the valley at higher elevations were affected for one to three days, while lower elevations were generally affected for longer periods up to four days. The second period of artificial flooding occurred as early as July 15 at the higher elevation land in the flooded area and lasted for one to three days, while for the lower elevation land below approximately 1184.5 ft, artificial flooding started on July 21 and ended as late as August 7, lasting for up to 13 days at any given elevation.

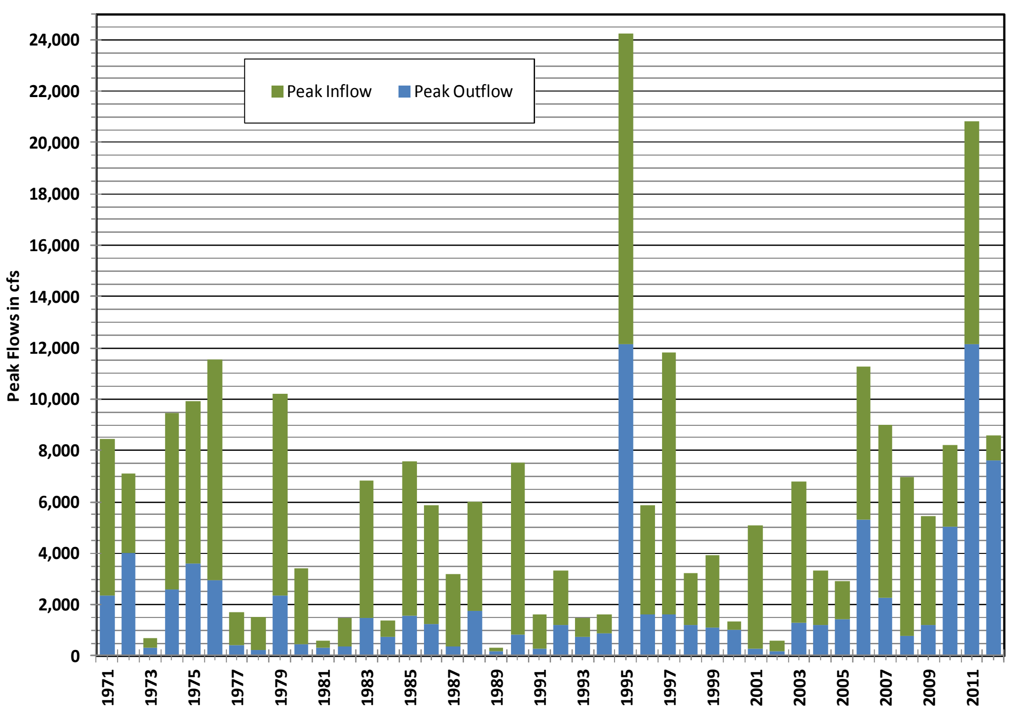

Figure 4: Shellmouth Reservoir annual peak inflows and outflows

In summary, operation of the Dam in 2011 caused two periods of artificial flooding as the flood waters receded from the larger, first peak flow and from a secondary, rain caused peak that occurred in early July. Operation of the Shellmouth Dam in 2011 reduced the flood peak (see Figure 4) but actually increased the maximum total duration of flooding on some lower elevation land in the Assiniboine River Valley. The prolonged total duration of flooding on lower elevation lands was largely due to the secondary peak and secondary period of artificial flooding. In general, land at an elevation that was above the secondary flood peak saw a reduction in the maximum total duration of flooding. Depending on location and elevation, some parcels of land did not experience any artificial flooding in 2011, although lands at higher and lower elevations may have been affected by artificial flooding. The duration, peak flows and peak stages for the regulated and unregulated flood events are summarized in

Tables 1 and 2 below. Table 3 presents a summary of the effect of Shellmouth Dam operation and Table 4 presents a summary of artificial flooding.

Table 1: Summary of flooding under unregulated flows

	Channel Capacity (cfs)	Unregulated Flows				
		Start of Flooding	End of Flooding	Length of flooding (days)	Peak Flow (cfs)	Peak Stage (ft)
Shellmouth	1600	13-Apr-11	16-Jul-11	95	20,845	
Russell	3000	13-Apr-11	10-Jul-11	89	19,364	1356.23
St. Lazare	5000	13-Apr-11	25-Jul-11	104	32,273	1291.59
Miniota	5250	14-Apr-11	25-Jul-11	103	34,354	1247.62
Virden	5400	13-Apr-11	26-Jul-11	105	35,478	1222.07
Griswold	5900	13-Apr-11	23-Jul-11	102	36,282	1203.63
Grand Valley near Brandon	5800	13-Apr-11	27-Jul-11	106	39,434	1193.39

Table 2: Summary of flooding under regulated flows

	Channel Capacity (cfs)	Regulated Flows				
		Start of Flooding	End of Flooding	Length of flooding (days)	Peak Flow (cfs)	Peak Stage (ft)
Shellmouth	1600	21-Apr-11	02-Aug-11	104	12,124	
Russell	3000	22-Apr-11	31-Jul-11	96	13,689	1352.88
St. Lazare	5000	13-Apr-11	05-Aug-11	115	29,474	1291.21
Miniota	5250	14-Apr-11	06-Aug-11	115	30,825	1247.39
Virden	5400	13-Apr-11	06-Aug-11	116	31,872	1221.99
Griswold	5900	14-Apr-11	06-Aug-11	115	32,894	1203.56
Grand Valley near Brandon	5800	13-Apr-11	07-Aug-11	117	36,323	1192.89

Note: At Russell, there was a five day period from July 2–6 where the regulated flows dropped below flood stage, these five days have been subtracted from the total length of flooding.

Table 3: Summary of the effect of Shellmouth Dam operation

	Change in Peak Flow (cfs)	Change in Peak Stage (ft)	Net Change in Length of flooding (days)
Shellmouth	-8,721		9
Russell	-5,675	-3.35	12
St. Lazare	-2,799	-0.38	11
Miniota	-3,529	-0.23	12
Virden	-3,606	-0.08	11
Griswold	-3,387	-0.07	13
Grand Valley near Brandon	-3,111	-0.50	11

Table 4: Summary of artificial flooding

	First Period of Artificial Flooding			Second Period of Artificial Flooding		
	First Day with some Artificial Flooding	Day when all Artificial Flooding Ended	Approximate Maximum duration of Artificial Flooding (days)	First Day with some Artificial Flooding	Day when all Artificial Flooding Ended	Approximate Maximum duration of Artificial Flooding (days)
Shellmouth	13-May-11	24-Jun-11	9	08-Jul-11	02-Aug-11	21
Russell	13-May-11	25-Jun-11	12	09-Jul-11	31-Jul-11	23
St. Lazare	17-May-11	29-Jun-11	6	11-Jul-11	05-Aug-11	18
Miniota	18-May-11	30-Jun-11	6	12-Jul-11	06-Aug-11	16
Virden	19-May-11	01-Jul-11	6	13-Jul-11	05-Aug-11	14
Griswold	20-May-11	01-Jul-11	5	17-Jul-11	05-Aug-11	13
Grand Valley near Brandon	20-May-11	02-Jul-11	4	15-Jul-11	07-Aug-11	13

Note: The effect of artificial flooding is site specific based on the location of the land within the river valley and the elevation of the land in question.

Regulated levels are the water levels that actually occurred. At Shellmouth, Russell and Brandon, these levels were observed/measured by hydrometric gauging on the river. At St. Lazare, Miniota, Virden and Griswold, the water levels and flows were computed using Muskingum routing, a modelling technique used to predict the movement of water down the river. Manual measurements of water levels were taken during the 2011 flood event to verify that the model provided accurate predictions at each of these four locations.

Unregulated levels and flows must be computed at each site since the operation of the Dam means that only regulated levels are available to be measured. The unregulated levels and flows at the Shellmouth Dam site are computed based on the actual inflows into the Shellmouth Reservoir, including over reservoir precipitation. The rationale for this approach is that if the Dam was not in place, the flows that would be observed on the river at this location would be made up of the Assiniboine River flows plus the flows that tributaries would have provided to the river. The unregulated levels and flows at each of the sites downstream of the Shellmouth Dam were computed by using Muskingum routing to model the movement of the inflows downstream from the Shellmouth site, while incorporating the addition of tributary runoff.

In Figure 5, the regulated discharges from the Shellmouth Dam are labelled as “Total Outflow”. The unregulated discharges are labelled as “Total Inflows Including Over-Reservoir Precipitation”. A number of other relevant parameters, including reservoir level and spillway elevation, are also shown in this figure.

Figures 6 to 17 are hydrographs that show the unregulated and regulated water levels and flows at six locations downstream of the Shellmouth Dam. On some of the graphs the recorded cumulative precipitation and the monthly normal cumulative precipitation from nearby or upstream weather stations are shown in order to show the relative magnitude of the precipitation that occurred during this time, and to illustrate the effect that the precipitation had on flows.

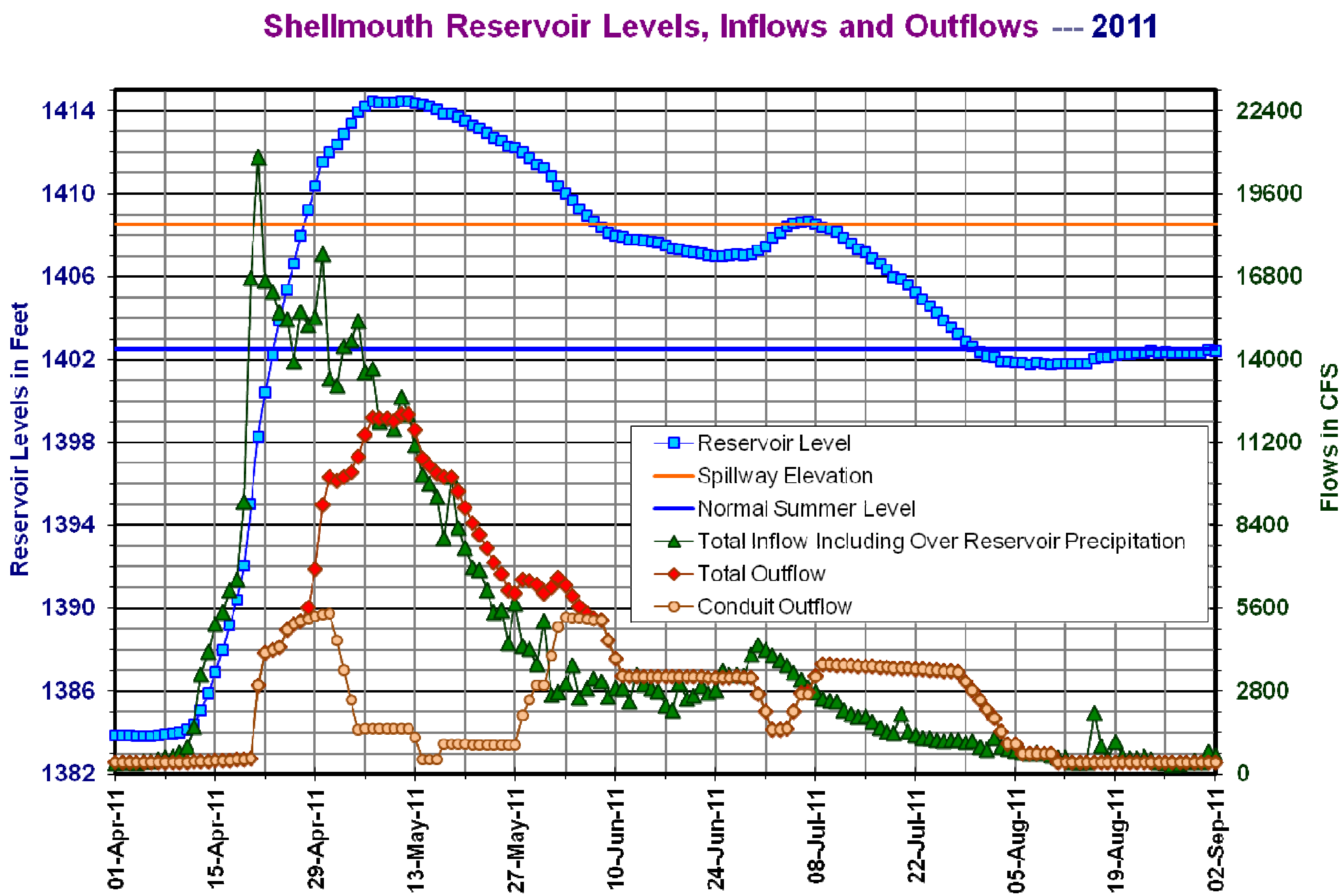

Figure 5: Hydrograph showing 2011 Reservoir levels, inflows and outflows at the Shellmouth Dam

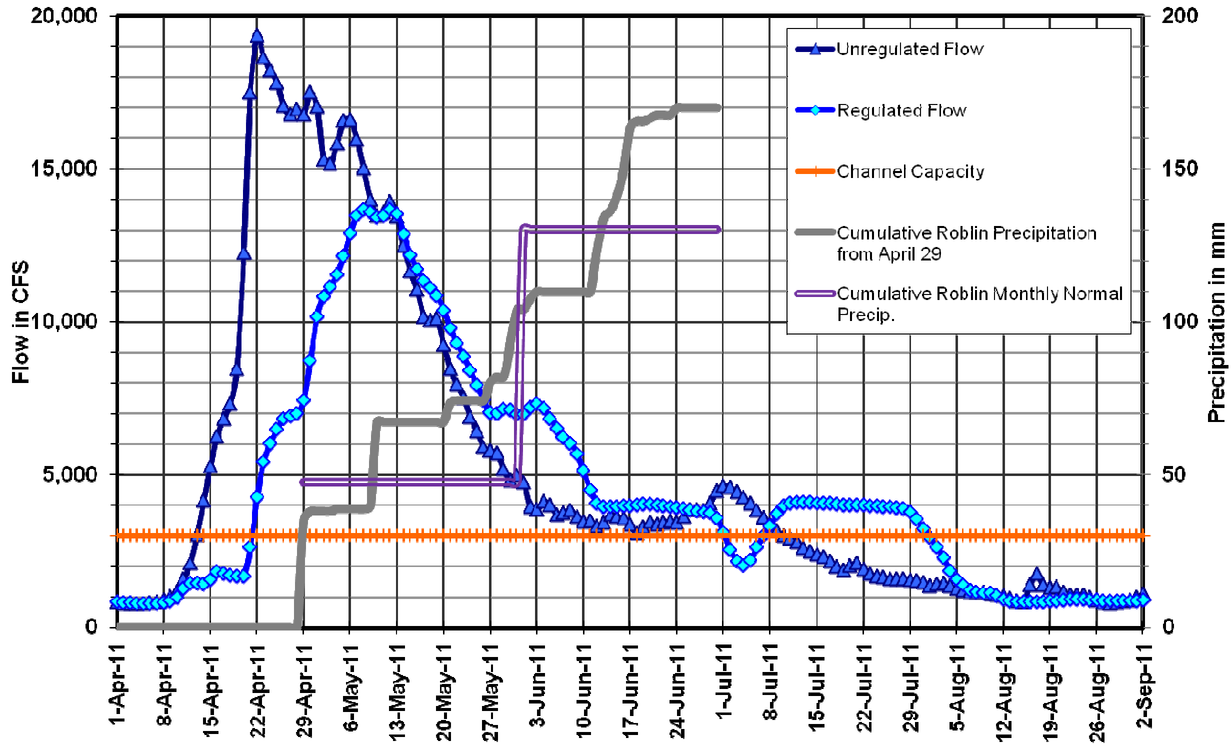

Figure 6: Hydrograph showing regulated and unregulated discharge at Russell, and recorded and monthly normal cumulative precipitation

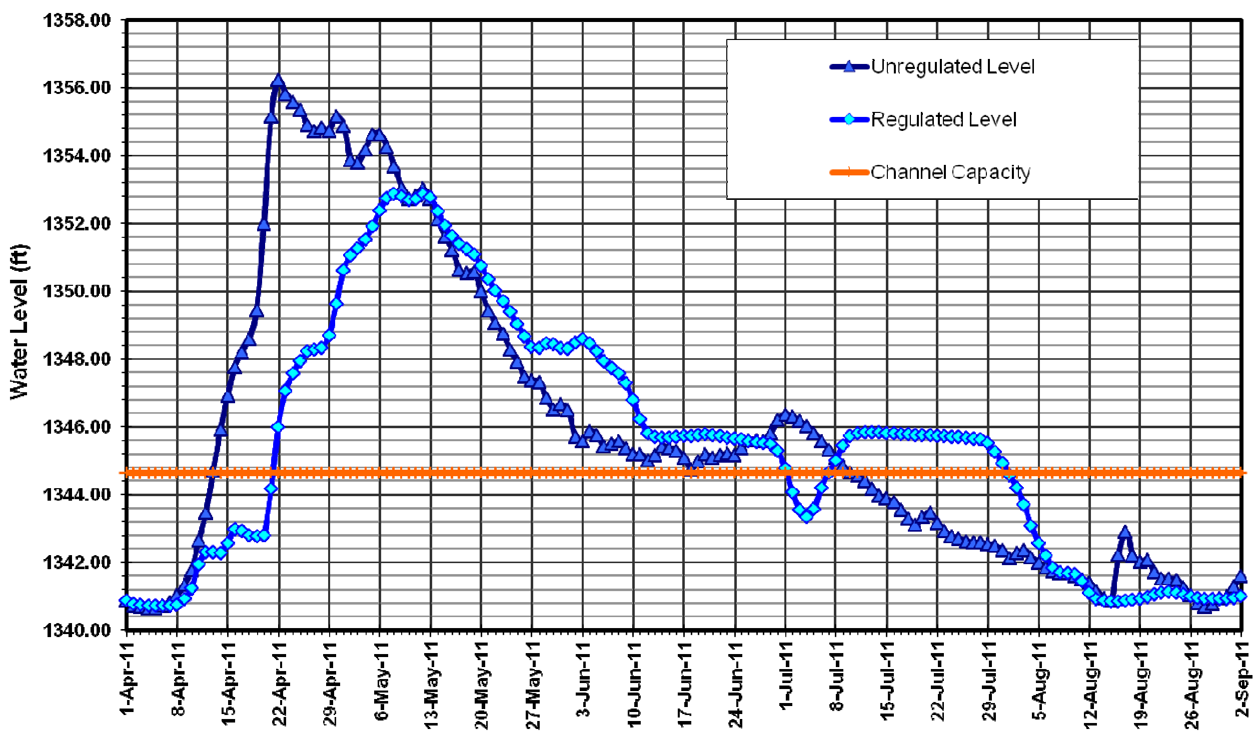

Figure 7: Hydrograph showing regulated and unregulated water level at Russell

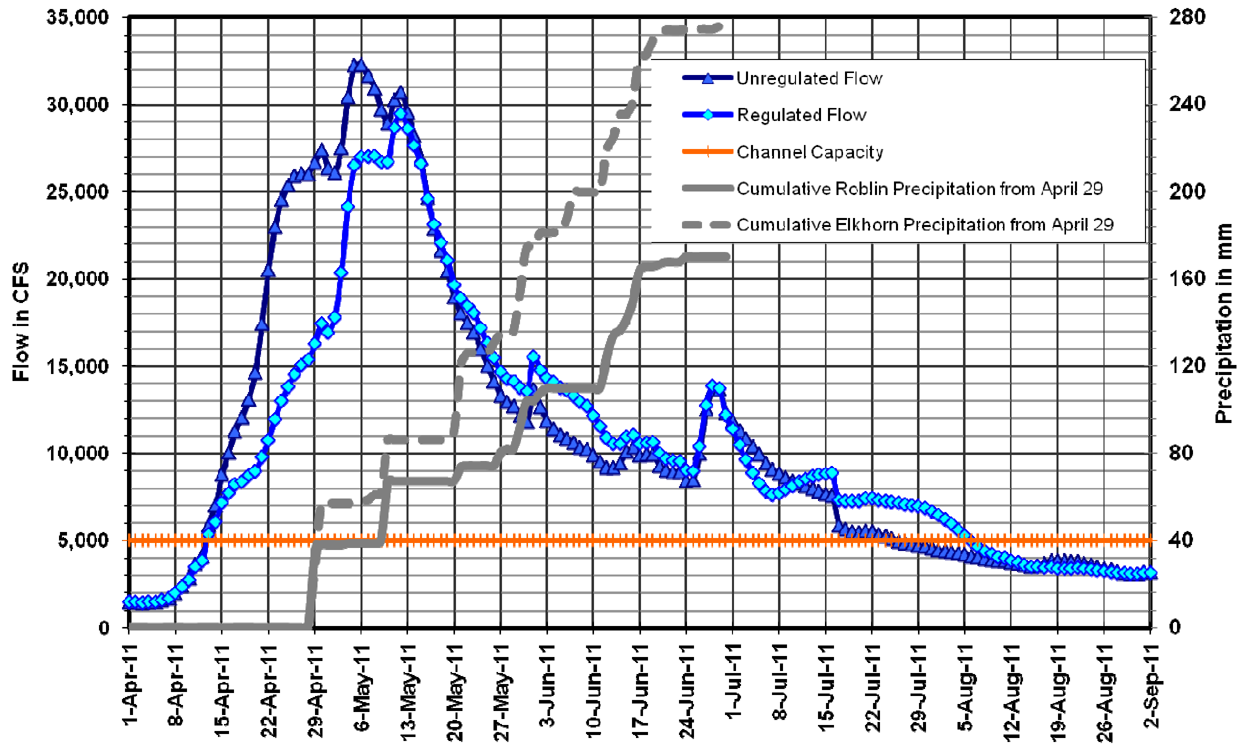

Figure 8: Hydrograph showing regulated and unregulated discharge at St. Lazare, and recorded cumulative precipitation

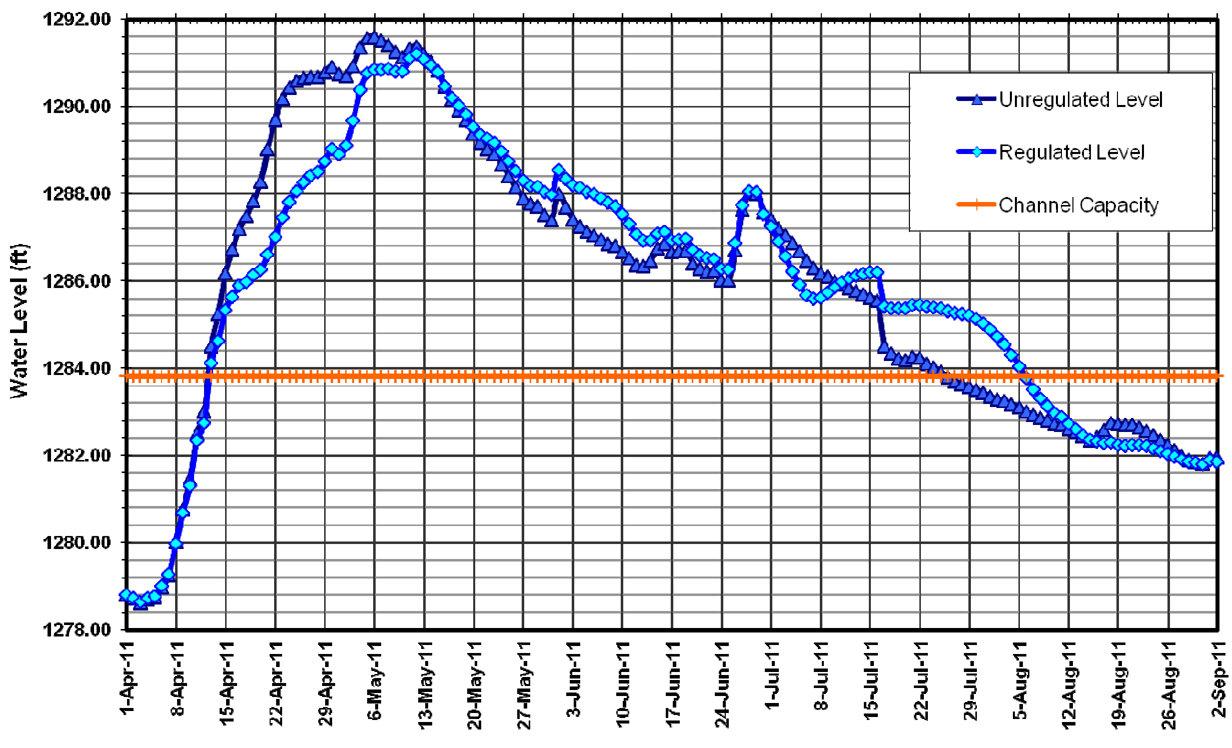

Figure 9: Hydrograph showing regulated and unregulated water level at St. Lazare

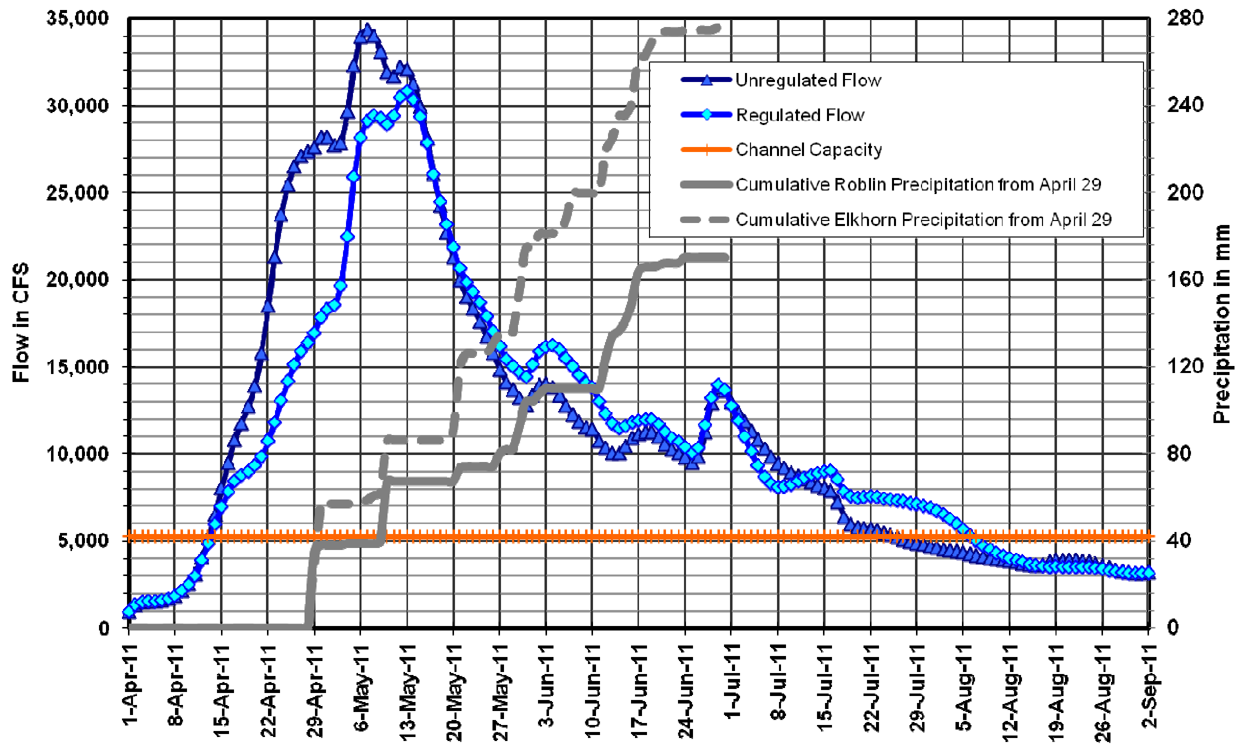

Figure 10: Hydrograph showing regulated and unregulated discharge at Miniota, and recorded cumulative precipitation

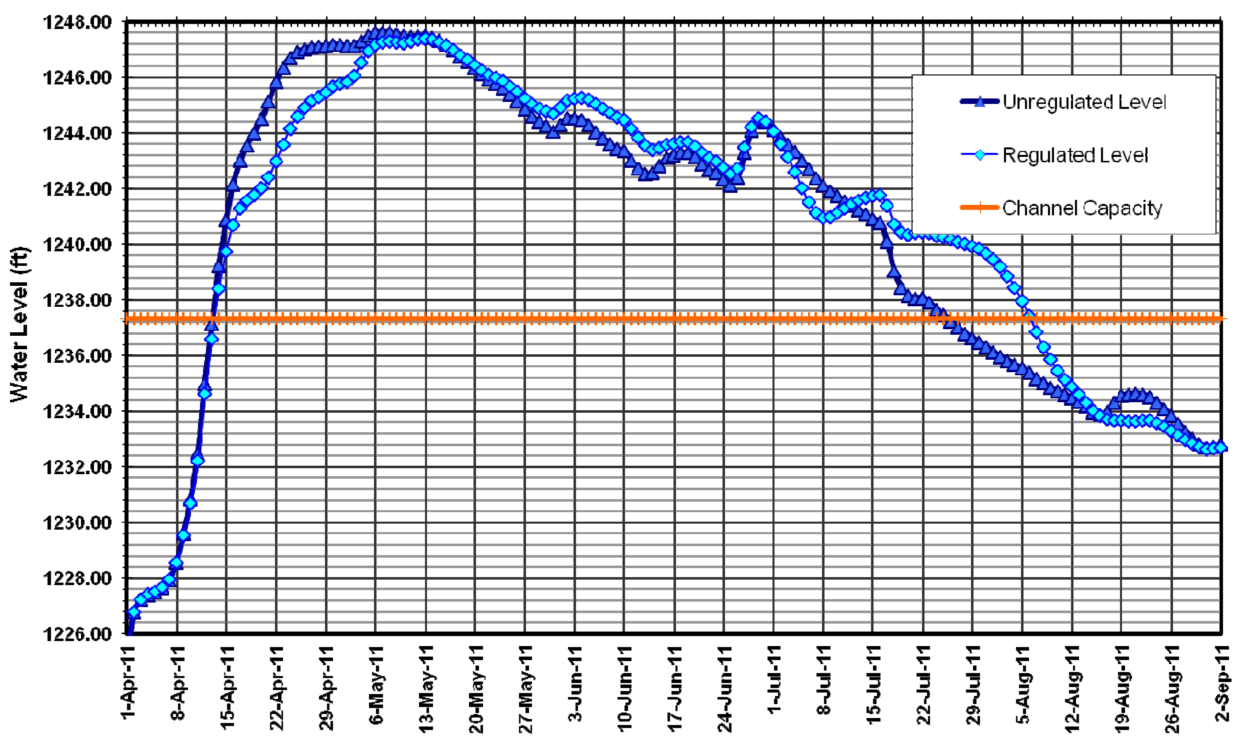

Figure 11: Hydrograph showing regulated and unregulated water level at Miniota

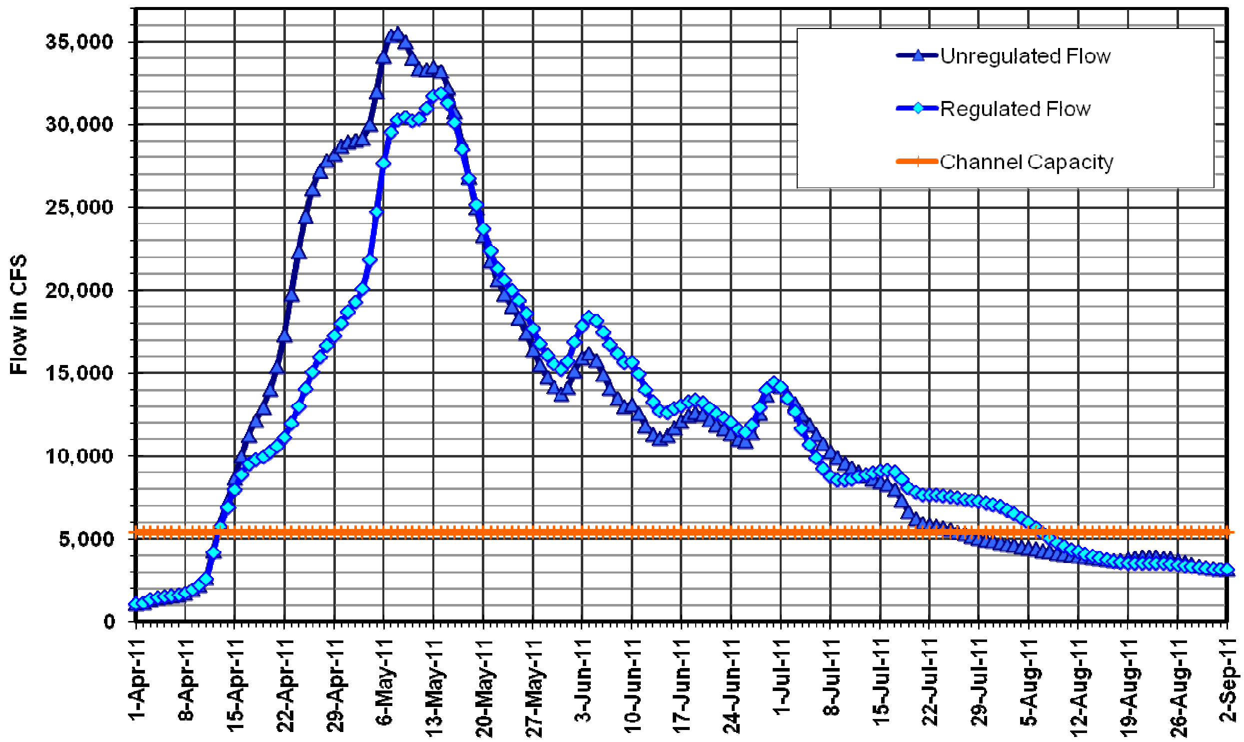

Figure 12: Hydrograph showing regulated and unregulated discharge at Virden

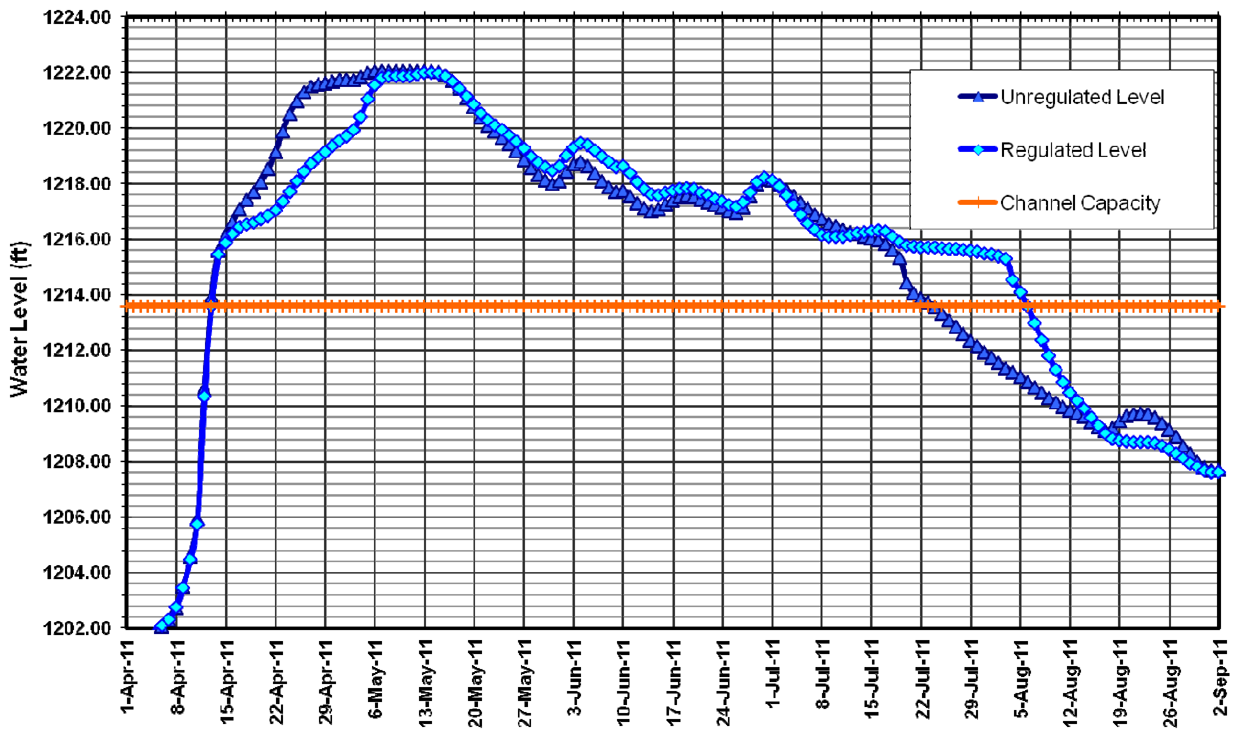

Figure 13: Hydrograph showing regulated and unregulated water level at Virden

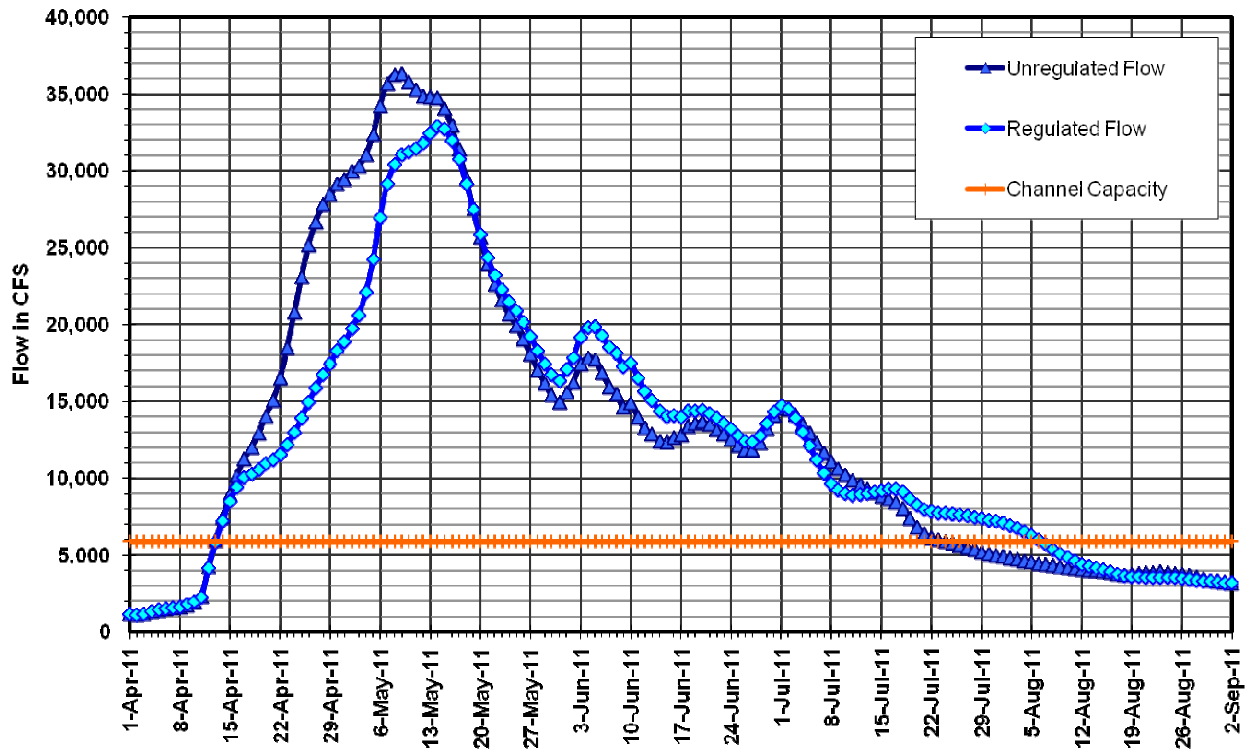

Figure 14: Hydrograph showing regulated and unregulated discharge at Griswold

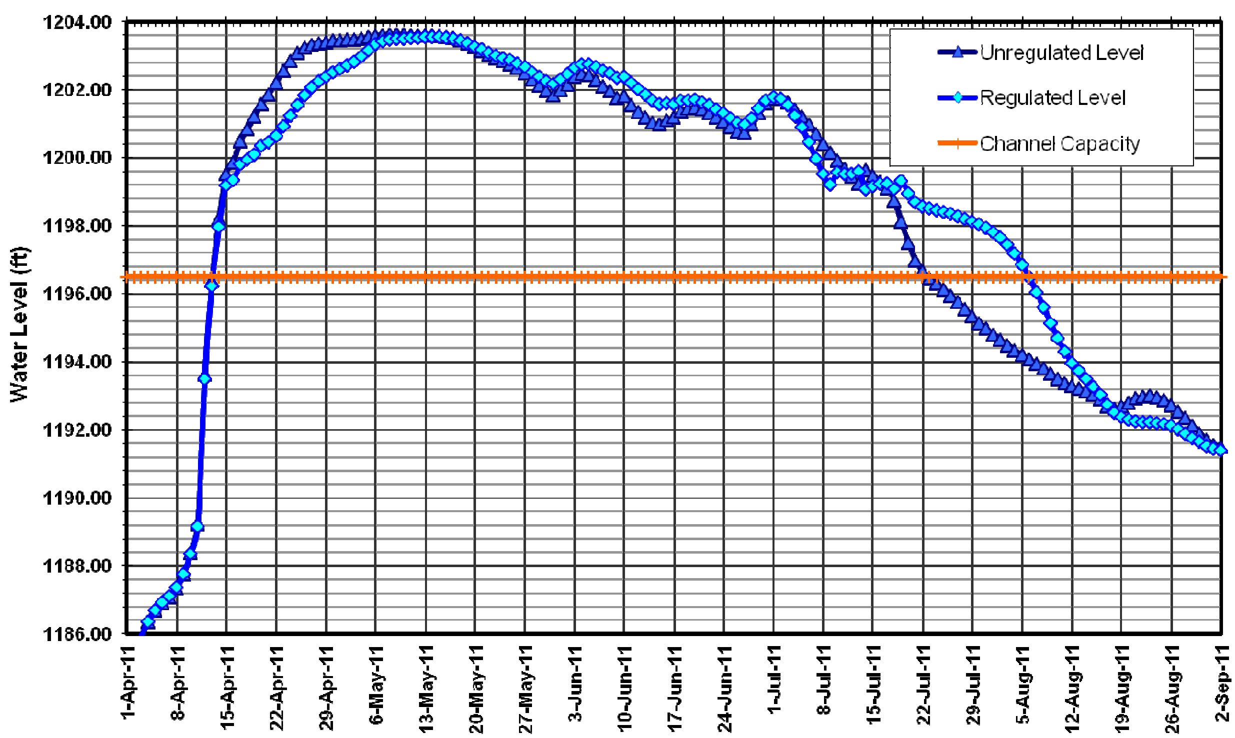

Figure 15: Hydrograph showing regulated and unregulated water level at Griswold

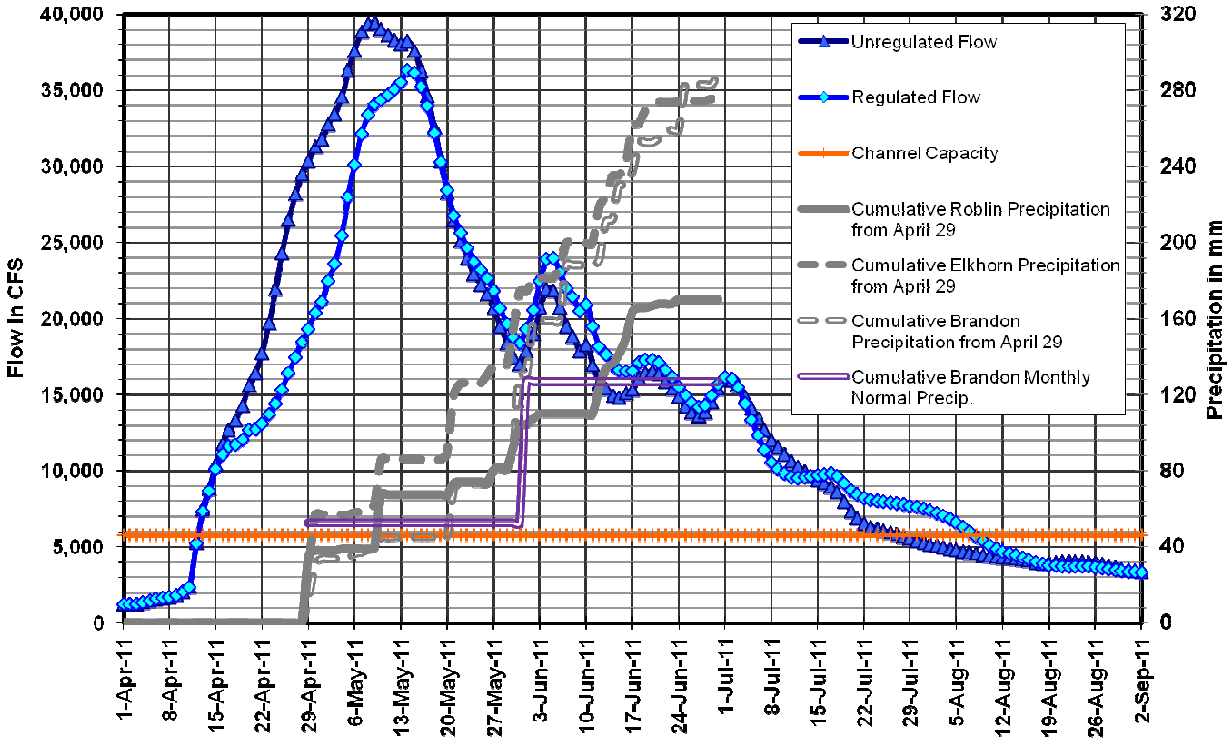

Figure 16: Hydrograph showing regulated and unregulated discharge at Brandon, and recorded and monthly normal cumulative precipitation

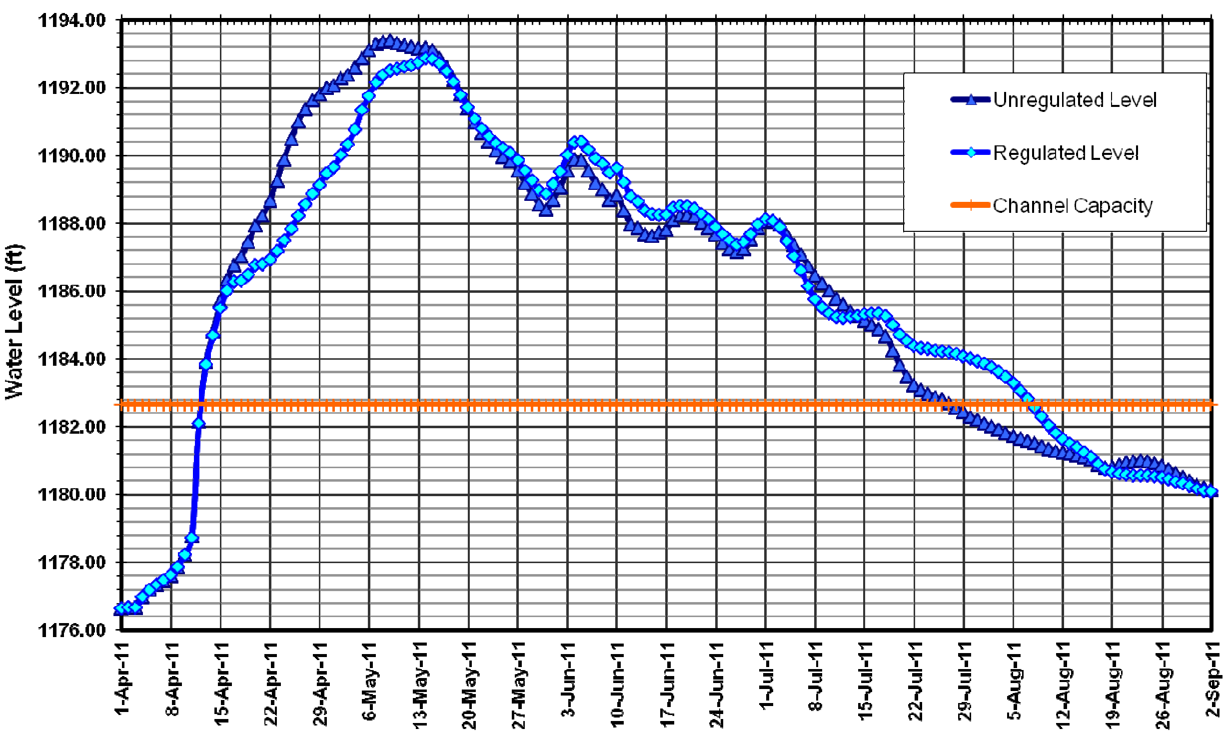

Figure 17: Hydrograph showing regulated and unregulated water level at Brandon

2011 Shellmouth Dam Operations

In 2011 Manitoba experienced widespread and severe flooding across a large number of basins. The Assiniboine River in particular experienced significant flooding and record flows at many locations on the river.

Precipitation during the summer and autumn of 2010 was well above normal across most of Manitoba, and central and southern Saskatchewan, including the Upper Assiniboine River Basin (see Figure 18). In many areas of the province, this led to high water levels on lakes and high flows on many streams prior to freeze-up in the fall of 2010. The wet conditions in 2010 also produced high soil moisture levels in many basins, including the Upper Assiniboine River Basin (see Figure 19). The soil moisture index at freeze-up in 2010 was the second highest on record and above the levels that were recorded prior to the 1997 flood. An aerial soil moisture survey conducted between November 2 and 11, 2010 showed that moisture in the top 7.9 inches (20 centimetres) of soil was well above average in much of southern Manitoba. Finally, the precipitation from November 2010 to March 2011 in the form of snow for the Assiniboine River basin was up to 170 percent of normal (see Figure 20). The high flows and levels on many lakes and streams, high soil moisture content, and above average snow pack accumulations resulted in spring run-off potential for the upper and lower portions of the Assiniboine River that was well above average. In anticipation of high spring run-off, and in communication with the Shellmouth Dam Liaison Committee, the water level in the Shellmouth Reservoir was drawn down to 1,383.83 feet (421.78 metres) by the end of March 2011, a historic low for pre-spring levels.

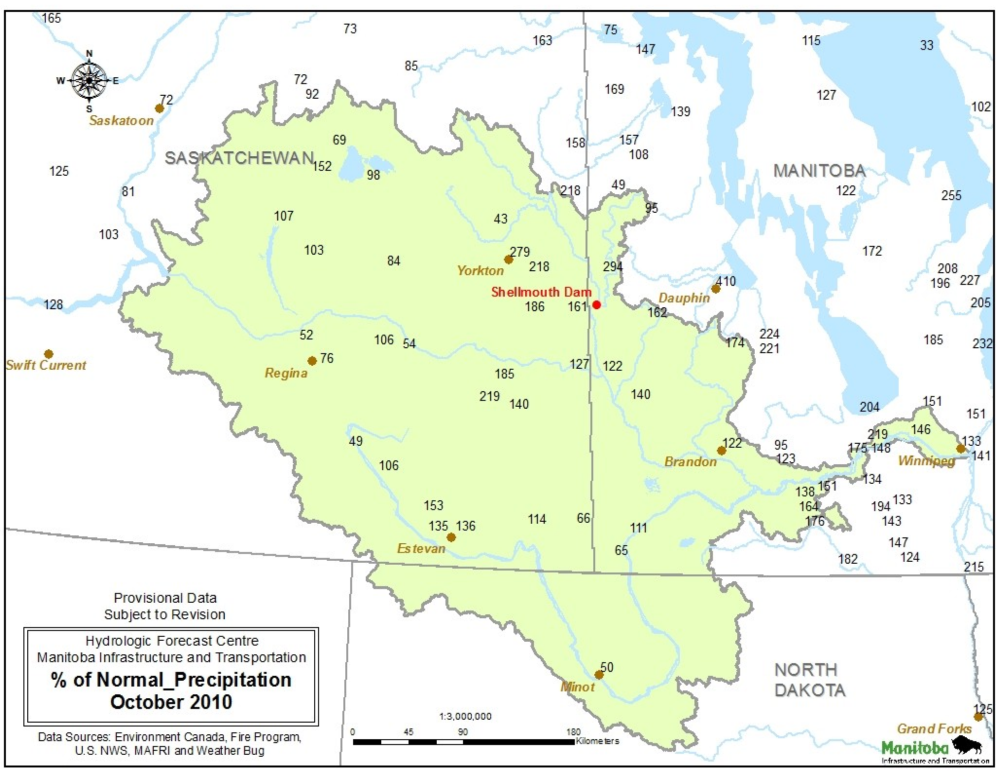

Figure 18: Percent of normal precipitation, October 2010

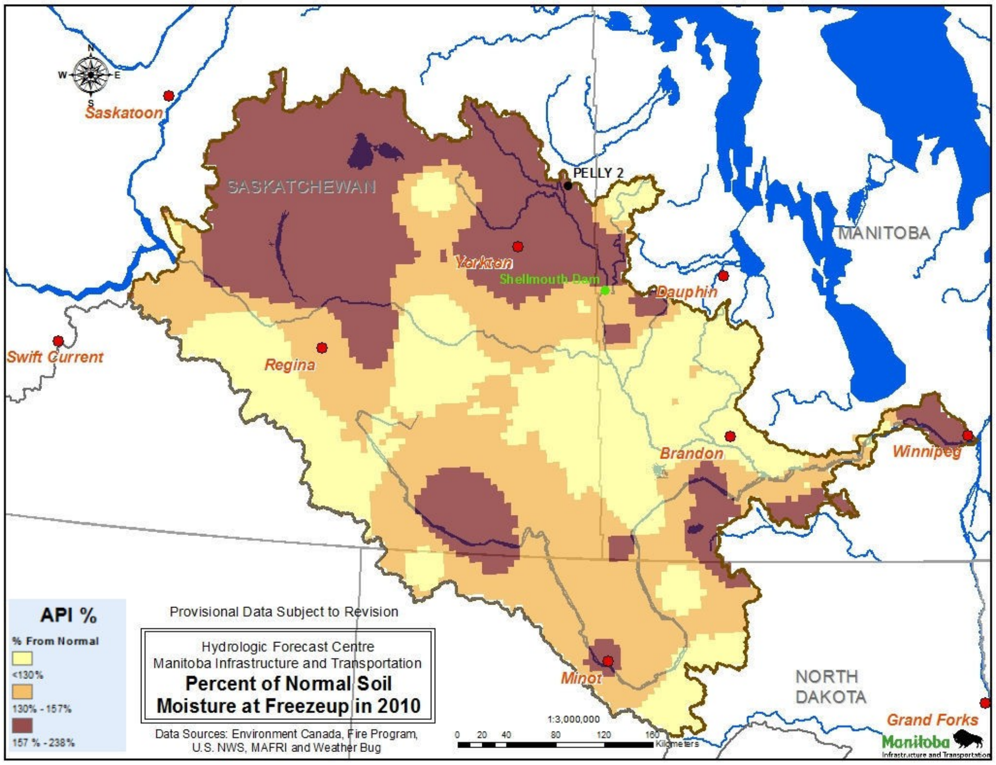

Figure 19: Percent of normal soil moisture at freeze-up, fall 2010

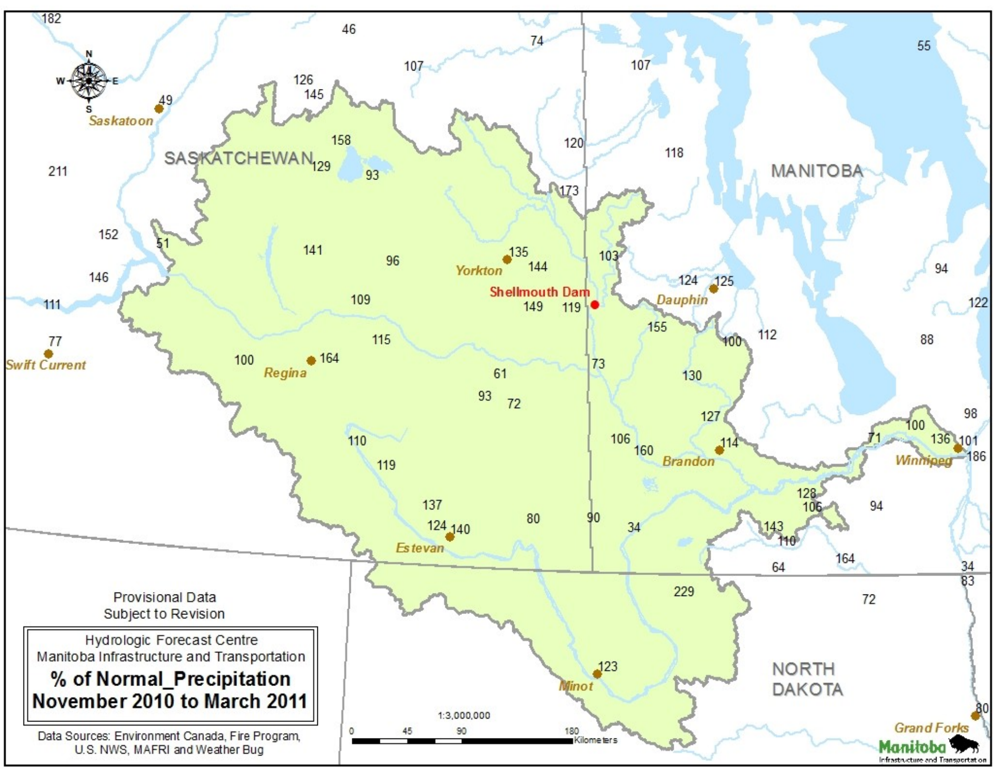

Figure 20: Percent of normal precipitation, November 2010 to March 22, 2011

As the spring runoff began the inflows to the reservoir increased quickly (see Figure 5) from 5,000 cfs on April 15 to peak at 20,800 cfs on April 21. The inflows to the reservoir were very high for a prolonged period, remaining above 10,000 cfs for the period from April 20 to May 14. Total outflows were held to below 500 cfs until April 21 when the conduit outflows were increased up to 4,000 cfs, and subsequently raised to 5,000 cfs on April 25, the maximum possible outflow at that reservoir level. In spite of the maximum possible conduit outflows, the reservoir reached spillway elevation on April 28 and continued to rise as the inflows still far exceeded the total outflows.

Between May 1 and May 13 conduit outflows were reduced in increments of 500 cfs while the reservoir level, and resultant spillway flows, continued to increase. Operating in this manner is known as peak shaving and is done in order to limit the total outflow from the reservoir and thereby maximize the flood protection benefit that the dam provides downstream.

Reservoir levels peaked on May 12 at 1414.47 ft with corresponding peak total outflow of 12,124 cfs made up of 10,600 cfs over the spillway and 1,520 cfs through the conduit. As the inflows began to decrease the reservoir level began to drop starting on May 13. On May 16, conduit outflow was increased to 1,000 cfs as the spillway flows decreased with the falling reservoir levels. From May 27 to June 2 the conduit flows were increased in increments of 500 cfs in order to maintain a total outflow of approximately 7,000 cfs. The 7,000 cfs total outflow was maintained in order to help bring the reservoir levels down below spillway elevation as quickly as possible, minimizing the risk of damage to the structure due to very high levels and creating additional room in the reservoir for forecasted future precipitation.

Spillway flows ceased on June 8 when the reservoir fell below the spillway elevation of 1408.5 ft. Starting on June 8 the conduit outflows were decreased in increments of 600 cfs, reaching 3,300 cfs on June 10. In late June, owing largely to significant precipitation, the inflows to the reservoir began increasing leading to the reservoir level rising. Beginning on June 29, conduit outflow was again reduced by increments of 600 cfs, reaching as low as 1,500 cfs on July 1. This reduction of outflows in late June and early July while the reservoir level was rising was a second period of peak shaving, undertaken to help reduce the peak flow downstream, particularly in the Portage la Prairie area, to help offset very high flows on the Souris River. Starting on July 4, conduit outflow was increased in increments of 600 cfs until reaching 3,700 cfs on July 8, in order to offset the increased inflow and to try to prevent the reservoir from reaching spillway elevation.

On July 5 the reservoir rose above spillway elevation for the second time in 2011 and remained above spillway elevation until July 8. During this second peak in reservoir levels, the reservoir was only slightly above spillway elevation and the spillway flows peaked at less than 100 cfs. Once the reservoir levels dropped below the spillway on July 8, conduit outflow was maintained at approximately 3,700 cfs until July 28 in order to bring the reservoir levels down to the summer target range more quickly. From July 28 onwards, conduit outflows were decreased in increments of 300 cfs until reaching 400 cfs outflow on August 10. On August 3, the total outflow from the Dam dropped below 1,600 cfs, ending the second period of artificial flooding. A tabulation of the gate adjustments is contained in Table 6.

The Reservoir holding capacity when its water level is at the top of the spillway is 387,000 acre-feet. In a normal year the annual volume of flow on the Assiniboine River at Russell is about 385,000 acre-feet. In 2011, the volume of water that flowed into the Reservoir for the four month period of April through July was 1.33 million acre-feet. Of this, 1.2 million acre-feet flowed into the Reservoir during the three month period of April through June. Put simply, the Shellmouth Dam and Reservoir provided a significant flood reduction benefit downstream in the Assiniboine River Valley, but was simply not large enough to store the volume of water that would have been required to fully mitigate the 2011 flood event.

Operating Guidelines

In 2011, the Shellmouth Dam was operated in a manner consistent with most of the approved operating guidelines, which are shown in Table 5. The operations were not consistent with three of the summer operation guidelines.

First, the third guideline for summer operation states that if the spillway is overtopped peak shaving is to be used to try to maintain the total outflow at 1,600 cfs. During the first period where the reservoir level was above the spillway, the spillway flows were greater than 1,600 cfs. During the second period of over-spillway flows the spillway was only overtopped by a small amount, approximately 0.25 ft resulting in approximately 70 cfs of spillway flow. During this second period of spillway flows it may have been possible to remain at or below 1,600 cfs total outflow. There are a number of reasons why the Dam was not operated in this manner. With lower total outflows the reservoir level would have dropped much slower and may have continued to rise (inflows to the reservoir remained above 1,600 cfs until July 16), this would have led to high reservoir levels and prolonged spillway flows late into the summer and fall of 2011, making it more difficult to lower the reservoir and create storage space in time for spring 2012 runoff.

Second, the fourth summer operating guideline calls for total outflows to be increased once the reservoir level exceeds 1410.5 ft in order to prevent the reservoir from rising higher. In 2011, the reservoir level peaked at nearly 1414.5 ft on May 12, however, peak shaving was undertaken at this time so as to help reduce peak flows in communities downstream, including Brandon and at the Portage Reservoir. If the Dam was managed to comply with this guideline, it would have meant increasing total outflow by increasing the conduit flow. Operating to increase outflow at this time would have reduced the flood protection afforded by the Dam to downstream communities at a critical period of time.

Finally, after the spillway was overtopped, and while on the recession limb of the hydrograph, the fifth guideline for summer operation states that at this point the Dam should be operated to maintain 1,200 cfs outflow until the reservoir reaches a level of 1406.5 ft. Attempting to restrict total outflows to 1,200 cfs would have been extremely difficult in 2011 since the inflows to the reservoir did not drop below 1,200 cfs until July 25. This means that if the dam was operated consistent with this guideline after either the first or second period of over-spillway flows, that the reservoir level would have remained stationary or been increasing up until July 25.

In the years 2010, 2011, and 2012, the upper Assiniboine River basin experienced periods of extraordinary wet conditions, which resulted in summertime spillway flows and artificial flooding in each of these three years. In light of this, it may be advisable to review the Shellmouth Dam Operation Guidelines to ensure that they continue to meet the best water management interests of Manitoba.

Table 5: Shellmouth Reservoir seasonal operation guidelines

Guidelines for Spring	Guidelines for Summer	Guidelines for Winter
• Outflow below 500 cfs if possible until Assiniboine crest has passed Miniota. • Keep outflows from exceeding 1600 cfs but not if this raises reservoir above 1407 feet • Outflows must meet downstream requirements with a minimum of 25 cfs. • If forecast based on observed rain and streamflow indicates reservoir level may rise to 1406.5 feet, keep outflow below 1600 cfs. • If forecast based on observed rain and streamflow indicates reservoir level may rise to spillway, set April outflow as high as required to keep level below 1407 feet. During May or June, if valley crops have been seeded, use peak shaving if necessary to prevent total outflows from exceeding 2000 cfs.	• Summer target range 1400-1404. • Operate to meet downstream needs if possible. Minimum needs are 100 cfs at Brandon and 200 cfs at Headingley. Minimum outflow of 50 cfs and maximum of 1000 cfs while in summer target range. • If serious summer flood develops, adjust outflows up to 1600 cfs to prevent spillway overtopping. If spillway is overtopped anyway, use peak shaving to try to maintain 1600 cfs outflow. • If reservoir level exceeds 1410.5 feet, increase outflows as required to prevent further rises. • On falling limb after spillway overtopped, operate to maintain 1200 cfs until reservoir down to 1406.5. • Operate to prevent decline of more than 0.3 feet per day at bridge downstream of Shellmouth. • When reservoir declines below 1400 feet, set outflow at minimum of 25 cfs. • During severe drought, meet downstream requirements to a level of 1390 feet. At lower levels, outflows to be approved at ministerial level following discussions with stakeholders.	• Minimum drawdown level of 1386 feet. • Target 1404 level after spring runoff. • Try to avoid large fluctuations in outflow. • Be in a position to get down to 1386, without exceeding 1500 cfs outflow, when upper decile forecast indicates a spring level near spillway. • November and December outflows based on lower decile inflow forecast. • January and February outflows based on lower quartile inflow forecast. • March outflow based on upper quartile inflow forecast.

Table 6: Tabulation of 2011 conduit operations

	Date	Time	Reservoir Level (metres)	Reservoir Level (feet)	Storage Volume (acre feet)	Gate Setting (ft)	Conduit Flow (cfs)	Spillway Flow (cfs)	Total Outflow (cfs)
1	6-Jan-11	13:00	427.46	1402.42	298978	8.4	1650	0	1650
2	19-Jan-11	14:30	426.48	1399.21	259439	8.81	1670	0	1670
3	27-Jan-11	15:00	426.04	1397.78	241750	9.72	1800	0	1800
4	31-Jan-11	12:30	425.79	1396.95	231542	10.97	2000	0	2000
5	24-Mar-11	15:00	421.79	1383.82	94391	11.7	1480	0	1480
6	24-Mar-11	15:30	421.79	1383.82	94391	7.47	1000	0	1000
7	25-Mar-11	12:30	421.75	1383.69	93275	5.26	700	0	700
8	26-Mar-11	12:15	421.72	1383.61	92597	3.01	400	0	400
9	21-Apr-11	11:20	426.20	1398.31	248297	10.71	2000	0	2000
10	21-Apr-11	22:00	426.46	1399.16	258819	21.12	4000	0	4000
11	25-Apr-11	13:00	428.41	1405.55	334765	24	5000	0	5000
12	1-May-11	20:45	430.43	1412.18	447770	22.1	5000	4978	9978
13	1-May-11	21:45	430.43	1412.18	447770	19.89	4500	4978	9478
14	2-May-11	12:50	430.51	1412.43	451776	17.63	4000	5535	9535
15	2-May-11	15:00	430.51	1412.43	451776	15.43	3500	5535	9035
16	3-May-11	11:00	430.65	1412.89	459360	13.16	3000	6548	9548
17	3-May-11		430.65	1412.89	459360	10.96	2500	6548	9048
18	4-May-11	11:20	430.80	1413.38	467719	8.72	2000	7680	9680
19	4-May-11	13:20	430.80	1413.38	467719	6.54	1500	7680	9180
20	4-May-11	19:30	430.80	1413.38	467719	6.54	1500	7680	9180
21	4-May-11	20:30	430.80	1413.38	467719	8.72	1500	7680	9180
22	13-May-11	12:30	431.10	1414.37	485386	4.31	1000	10353	11353
23	13-May-11	15:30	431.10	1414.37	485386	2.16	500	10353	10853
24	16-May-11	14:10	430.98	1413.98	478311	4.33	1000	9334	10334
25	27-May-11	14:00	430.45	1412.25	448883	6.63	1500	5133	6633
26	27-May-11	15:05	430.45	1412.25	448883	8.82	2000	5133	7133
27	28-May-11	12:30	430.37	1411.98	444626	11.07	2500	4550	7050
28	29-May-11	13:20	430.29	1411.71	440437	13.32	3000	4009	7009
29	31-May-11	12:01	430.16	1411.29	433732	15.63	3500	3161	6661
30	31-May-11	14:00	430.16	1411.29	433732	17.88	4000	3161	7161
31	1-Jun-11	14:30	430.00	1410.75	424298	20.23	4500	2173	6673
32	1-Jun-11	16:30	430.00	1410.75	424298	22.48	4500	2173	6673
33	2-Jun-11	13:10	429.88	1410.37	417788	24	5300	1601	6901
34	8-Jun-11	16:50	429.18	1408.08	376941	22.29	4800	0	4800
35	8-Jun-11	18:50	429.18	1408.08	376941	20.9	4500	0	4500
36	9-Jun-11	12:30	429.17	1408.03	375826	19.52	4200	0	4200
37	9-Jun-11	15:30	429.17	1408.03	375826	18.13	3900	0	3900
38	10-Jun-11	13:15	429.13	1407.91	373207	16.74	3600	0	3600
39	10-Jun-11	16:15	429.13	1407.91	373207	15.36	3300	0	3300
40	29-Jun-11	12:30	428.90	1407.15	358372	14.11	3000	0	3000

41	29-Jun-11	14:30	428.90	1407.15	358372	12.69	2700	0	2700
42	30-Jun-11	13:30	428.94	1407.28	360710	11.25	2400	0	2400
43	30-Jun-11	15:30	428.94	1407.28	360710	9.85	2100	0	2100
44	1-Jul-11	11:00	429.00	1407.48	364461	8.42	1800	0	1800
45	1-Jul-11	13:00	429.00	1407.48	364461	7.02	1500	0	1500
46	4-Jul-11	13:30	429.28	1408.41	384674	8.33	1800	0	1800
47	4-Jul-11	15:30	429.28	1408.41	384674	9.71	2100	0	2100
48	5-Jul-11	13:15	429.33	1408.57	388661	11.08	2400	30	2430
49	5-Jul-11	14:15	429.33	1408.57	388661	12.46	2700	30	2730
50	7-Jul-11	12:30	429.36	1408.66	390914	13.83	3000	72	3072
51	7-Jul-11	13:30	429.36	1408.66	390914	15.22	3300	72	3372
52	8-Jul-11	14:00	429.32	1408.53	387653	16.16	3500	12	3512
53	8-Jul-11	14:30	428.41	1405.53	387653	17.09	3700	12	3712
54	28-Jul-11	13:30	427.70	1403.22	308499	16.37	3300	0	3300
55	28-Jul-11	16:30	427.70	1403.22	308499	15.62	3150	0	3150
56	29-Jul-11		427.60	1402.88	304535	14.85	2980	0	2980
57	29-Jul-11	15:45	427.60	1402.88	304535	14.1	2830	0	2830
58	30-Jul-11	10:35	427.52	1402.62	301408	13.36	2670	0	2670
59	30-Jul-11	13:55	427.52	1402.62	301408	12.61	2520	0	2520
60	31-Jul-11	10:00	427.44	1402.37	298370	11.83	2355	0	2355
61	31-Jul-11	13:00	427.44	1402.37	298370	11.05	2200	0	2200
62	1-Aug-11	12:10	427.38	1402.15	295688	10.3	2045	0	2045
63	1-Aug-11	16:15	427.38	1402.15	295688	9.57	1900	0	1900
64	2-Aug-11	12:30	427.36	1402.10	295078	8.82	1750	0	1750
65	2-Aug-11	14:00	427.36	1402.10	295078	8.07	1600	0	1600
66	2-Aug-11	16:00	427.36	1402.10	295078	7.31	1450	0	1450
67	3-Aug-11	11:20	427.30	1401.90	292633	6.57	1300	0	1300
68	3-Aug-11		427.30	1401.90	292633	5.82	1150	0	1150
69	3-Aug-11	15:20	427.30	1401.90	292633	5.06	1000	0	1000
70	5-Aug-11	12:20	427.28	1401.84	291899	4.3	850	0	850
71	5-Aug-11	15:20	427.28	1401.84	291899	3.54	700	0	700
72	10-Aug-11	14:30	427.26	1401.77	291042	2.79	550	0	550
73	10-Aug-11	17:30	427.26	1401.77	291042	2.03	400	0	400

Note: the reservoir levels in the table are based on a single daily value, reservoir levels may have been affected by wind set-up or set-down